

The jump-yip display, vigilance, and foraging behaviour of the black-tailed prairie dog

(*Cynomys ludovicianus*).

by

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**ABSTRACT**

The contagious nature of the black-tailed prairie dog (*Cynomys ludovicianus*) jump-yip display may provide information to signalers and receivers regarding the vigilance of neighbours. Videotaping jump-yip bouts and the behaviour of both bout initiators and respondents within those bouts provided evidence that: 1) individuals became vigilant immediately following jump-yip production, but exhibited minimal changes in their immediate post-jump-yip behaviour with changes in the characteristics of the preceding bout, 2) bout initiators spent more time actively foraging and exhibited vigilance behaviours less frequently with greater levels of response in the preceding jump-yip bout, 3) respondents spent more time actively foraging and less time vigilant following bouts with greater response. These results suggest that black-tailed prairie dogs base behavioural decisions at least in part on the characteristics of their jump-yip bouts and thus the jump-yip display may provide information about the vigilance of group members.

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## TABLE OF CONTENTS

ABSTRACT .....	i
ACKNOWLEDGEMENTS .....	ii
TABLE OF CONTENTS.....	iii
LIST OF TABLES .....	viii
LIST OF FIGURES .....	xi
INTRODUCTION .....	1
Literature cited.....	18
METHODS .....	27
Study animals.....	27
Apparatus .....	31
Initial data collection.....	32
Quality control of jump-yip bouts.....	34
Identification of subject individual .....	35
The response characteristics of a jump-yip bout.....	36
Identification of independent jump-yip bouts.....	40
Jump-yip related behaviour.....	41
Time scales for behaviour recording.....	41
Recorded behaviours.....	44
Immediate post-jump-yip behaviour.....	45
One minute post-jump-yip behaviour and post-jump-yip changes in behaviour.....	47
Secondary effects .....	48
Aboveground population size (a social variable).....	48

“Secondary” vocalizations .....	50
Physical factors .....	52
Temporal variables.....	53
Environmental variables .....	54
Data analysis .....	56
Characteristics of jump-yip bouts and the behaviour of jump-yipping individuals.....	58
Secondary effects and the behaviour of jump-yipping individuals .....	59
Autocorrelations.....	60
Literature cited.....	61
RESULTS .....	64
Effects of jump-yip bout characteristics on the behaviour of bout initiators.....	64
Immediate post-jump-yip behaviour.....	64
One-minute post-jump-yip behaviour.....	64
Changes in behaviour following jump-yip production .....	65
Effects of jump-yip bout characteristics on the behaviour of respondents .....	70
Immediate post-jump-yip behaviour.....	70
One-minute post-jump-yip behaviour.....	70
Changes in behaviour following jump-yip production .....	82
Aboveground population size and the behaviour of black-tailed prairie dogs .....	97
Time of first post-subject, non-subject vocalization and the behaviour of black-tailed prairie dogs.....	100
Extraneous vocalizations and the behaviour of bout initiators .....	100

Immediate post-jump behaviour .....	100
One-minute post-jump-yip behaviour.....	103
Changes in behaviour following jump-yip production .....	109
Extraneous vocalizations and the behaviour of respondents .....	114
Immediate post-jump-yip behaviour.....	114
One-minute post-jump-yip behaviour.....	116
Changes in behaviour following jump-yip production .....	119
Abiotic factors and the behaviour of bout initiators .....	124
Immediate post-jump-yip behaviour.....	124
One-minute post-jump-yip behaviour.....	126
Changes in behaviour following jump-yip production .....	131
Abiotic factors and the behaviour of respondents.....	137
Immediate post-jump-yip behaviour.....	137
One-minute post-jump-yip behaviour.....	139
Changes in behaviour following jump-yip production .....	139
Other variables of interest.....	145
DISCUSSION .....	149
Immediate post-jump-yip behaviour – presence of vigilance.....	152
Characteristics of jump-yip bouts recorded in this study.....	154
Immediate post-jump-yip behaviour.....	158
Level and duration of vigilance .....	158
The behaviour of individuals over extended periods of time .....	164
Expected results .....	164

Results inconsistent with the expected decrease in vigilance/increase in foraging with increases in the magnitude of response in the associated jump-yip bouts .....	167
Interpretation of unexpected results.....	171
The absence of strong inverse relationships between foraging and vigilance .....	171
Non-linear relationships between response and behaviour – does jump-yipping indicate fitness?.....	176
Predominance of significant differences in behaviour only across large differences in response magnitude.....	179
Are highly-alert behaviours really indicative of changes in social state?.....	181
Effects of response latency on behaviour. ....	183
Effects of social variables on black-tailed prairie dog behaviour.....	186
Aboveground population size .....	186
Secondary vocalizations.....	188
Effects of abiotic variables on black-tailed prairie dog behaviour .....	197
Alternative hypotheses.....	205
Future studies .....	207
Conclusions.....	217
Literature cited.....	218
APPENDIX A: Glossary of terms and abbreviations.....	226
General terms .....	226
Independent variables .....	226
Dependent variables.....	229

Social variables .....	233
Abiotic variables .....	235
APPENDIX B: Complete results for the effects of the response characteristics of a subject jump-yip bout on the behaviour of a caller (initial or response) in that bout .....	237
APPENDIX C: Autocorrelations of the characteristics of the subject jump-yip bouts ...	265
APPENDIX D: Autocorrelations of the behaviour of subject individuals .....	274
APPENDIX E: Autocorrelations of the social variables present at the time of the subject jump-yip bout and their relationships to the characteristics of the bout.....	291
APPENDIX F: Autocorrelations of the abiotic factors present at the time of the subject jump-yip bout and their relationships to the characteristics of that bout and the social variables present at that time.....	366



## LIST OF TABLES

Table 1: The geographical locations of black-tailed prairie dog populations observed in this study.....	29
Table 2: Relationships between the aboveground population size present at the time of a jump-yip bout and the behaviour of the initial caller in the jump-yip bout over three temporal scales.^.....	98
Table 3: Relationships between the aboveground population size present at the time of a jump-yip bout and the behaviour of a respondent in the jump-yip bout over three temporal scales.^.....	99
Table 4: Relationships between the time at which the first post-subject-bout, non-subject-bout vocalization occurred and the behaviour of the initial caller in the subject jump-yip bout over three temporal scales.^.....	101
Table 5: Relationships between the time at which the first post-subject-bout, non-subject-bout vocalization occurred and the behaviour of a respondent in the subject jump-yip bout over three temporal scales.^.....	102
Table 6: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the immediate post-jump-yip behaviour of the initial caller in the subject jump-yip bout (n = 26).^.....	104
Table 7: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the immediate post-jump-yip behaviour of the initial caller in the subject jump-yip bout (n = 26).^.....	105

Table 8: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the behaviour of the initial caller in that bout over the minute following jump-yip production (n = 42).^ .....	106
Table 9: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the behaviour of the initial caller in that bout over the minute following jump-yip production (n = 42).^ .....	108
Table 10: Correlations between characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the post-jump-yip change in the behaviour of the initial caller in that bout (n = 24).^ .....	111
Table 11: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the post-jump-yip change in the behaviour of the initial caller in that bout (n = 24).^ .....	113
Table 12: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the immediate post-jump-yip behaviour of a respondent in that bout (n = 22).^ .....	115
Table 13: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the immediate post-jump-yip behaviour of a respondent in the subject jump-yip bout (n = 22).^ .....	117

Table 14: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the behaviour of a respondent in that bout over the minute following jump-yip production (n = 26).^ .....	118
Table 15: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the behaviour of a respondent in that bout over the minute following jump-yip production (n = 26).^ .....	120
Table 16: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the post-jump-yip change in the behaviour of a respondent in that bout (n = 18).^ .....	121
Table 17: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the post-jump-yip change in the behaviour of a respondent in that bout (n = 18).^ .....	123
Table 18: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the immediate post-jump-yip behaviour of the initial caller in that bout.^ .....	125
Table 19: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts under different levels of cloud cover.^ .....	126
Table 20: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts under different wind intensities.^ .....	127
Table 21: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts occurring in different habitats.^ .....	128

Table 22: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the behaviour of the initial caller in that bout over one minute following jump-yip production (n = 42). <sup>^</sup> .....	129
Table 23: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring under different levels of cloud cover. <sup>^</sup> .....	130
Table 24: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring under different wind intensities. <sup>^</sup> .....	131
Table 25: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring in different habitats. <sup>^</sup> .....	133
Table 26: Correlations between the time of day and the time of year at which a jump-yip bout occurred and the change in the behaviour of the initial caller in that bout between the minute preceding and the minute following the jump-yip production (n = 24). <sup>^</sup> .....	134
Table 27: The effects of cloud cover on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts. <sup>^</sup> .....	135
Table 28: The effects of wind intensity on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts. <sup>^</sup> .....	136
Table 29: The effects of habitat on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts. <sup>^</sup> .....	138
Table 30: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the behaviour of a respondent in that bout immediately following jump-yip production (n = 22). <sup>^</sup> .....	140

Table 31: Differences in the immediate post-jump-yip behaviour of respondents in jump-yip bouts occurring under different levels of cloud cover.^	141
Table 32: Differences in the immediate post-jump-yip behaviour of respondents in jump-yip bouts occurring under different wind intensities.^	141
Table 33: Correlations between time of day and time of year and the post-jump-yip behaviour of a respondent in the subject jump-yip bout over one minute following jump-yip production (n = 26).^	142
Table 34: Differences in the behaviour of respondents in jump-yip bouts over the minute following jump-yip production under different levels of cloud cover.^	143
Table 35: Differences in the behaviour of respondents in jump-yip bouts over the minute following jump-yip production under different wind intensities.^	144
Table 36: Correlations between time of day and time of year and the change in the pre- and post-jump-yip behaviour of a respondent in the subject jump-yip bout (n = 18).^	145
Table 37: The effects of cloud cover on differences in the pre- and post-jump-yip behaviour of respondents in jump-yip bouts.^	147
Table 38: The effects of wind intensity on differences in the pre- and post-jump-yip behaviour of respondents in jump-yip bouts.^	148
Table B.1: Correlations of the response characteristics of a jump-yip bout and the behaviour of the initial caller in that bout immediately following jump-yip production (n = 26).^	237

Table B.2: The effect of the number of responses in a jump-yip bout on the behaviour of the initial caller in that bout immediately following jump-yip production.^.....	238
Table B.2: Continued^ .....	238
Table B.3: The effect of the duration of a jump-yip bout on the behaviour of the initial caller in that bout immediately following jump-yip production.^.....	239
Table B.4: Correlations of the response characteristics of a jump-yip bout and the behaviour of the initial caller in that bout over one minute following jump-yip production (n = 42).^.....	239
Table B.5: The effect of the number of responses in a jump-yip bout on the behaviour of the initial caller in that bout over one minute following jump-yip production.^.....	240
Table B.5: Continued^ .....	241
Table B.6: The effect of the duration of a jump-yip bout on the behaviour of the initial caller in that bout over one minute following jump-yip production.^.....	242
Table B.6: Continued^ .....	243
Table B.7: Correlations of the response characteristics of a jump-yip bout and the difference in the behaviour of the initial caller in that bout between the minute preceding and the minute following jump-yip production (n = 24).^.....	244
Table B.8: The effect of the number of responses in a jump-yip bout on the change in the behaviour of the initial caller in that bout from the minute preceding to the minute following jump-yip production.^.....	245
Table B.8: Continued^ .....	246

Table B.9: The effect of the duration of a jump-yip bout on the change in the behaviour of the initial caller in that bout between the minute preceding and the minute following jump-yip production.^ .....	247
Table B.9: Continued^ .....	248
Table B.10: Correlations of the response characteristics of a jump-yip bout and the behaviour of respondent within that bout immediately following jump-yip production (n = 22).^ .....	249
Table B.11: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the behaviour of that respondent immediately following jump-yip production.^ .....	250
Table B.11: Continued^ .....	250
Table B.12: The effects of the duration of a subsection of a jump-yip bout beginning with the subject respondent's jump-yip on the behaviour of that respondent immediately following jump-yip production.^ .....	251
Table B.13: The effect of the number of responses in an entire jump-yip bout on the behaviour of a respondent in that bout immediately following jump-yip production.^ .....	251
Table B.14: The effect of the duration of an entire jump-yip bout on the behaviour of a respondent within that bout immediately following jump-yip production.^ .....	252
Table B.15: Correlations of the response characteristics of a jump-yip bout and the behaviour of a respondent in that bout over one minute following jump-yip production (n = 26).^ .....	253

Table B.16: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the behaviour of that respondent over one minute following jump-yip production.^ .....	254
Table B.16: Continued^ .....	255
Table B.17: The effect of the duration of a section of a jump-yip bout beginning with the subject respondent's jump-yip on the behaviour of that respondent over one minute following jump-yip production.^ .....	256
Table B.18: The effect of the number of responses in an entire jump-yip bout on the behaviour of a respondent in that bout over one minute following jump-yip production.^ .....	257
Table B.19: The effect of the duration of an entire jump-yip bout on the behaviour of a respondent in that bout over one minute following jump-yip production.^ .....	258
Table B.20: Correlations of the response characteristics of a jump-yip bout and changes in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production (n = 18).^ .....	259
Table B.21: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the change in the behaviour of that respondent from the minute preceding to the minute following jump-yip production.^ .....	260
Table B.21: Continued^ .....	261
Table B.22: The effect of the duration of a section of a jump-yip bout beginning with the subject respondent's jump-yip on the changes in the behaviour of	



that respondent from the minute preceding to the minute following jump-yip production.^ .....	262
Table B.23: The effect of the number of responses in an entire jump-yip bout on the changes in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production.^ .....	263
Table B.24: The effect of the duration of an entire jump-yip bout on the change in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production.^ .....	264
Table C.1: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the immediate post-jump-yip behaviours of the initial callers in the bouts were analyzed (n = 26).^ .....	266
Table C.2: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the behaviours of the initial callers in the bouts over the minute following jump-yip production were analyzed (n = 42).^ .....	266
Table C.3: Autocorrelation of the response characteristics of the subject jump-yip bouts in which post-jump-yip changes in the behaviours of the initial callers in the bouts were analyzed (n = 24).^ .....	267
Table C.4: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the immediate post-jump-yip behaviours of respondents in the bouts were analyzed (n = 22).^ .....	268
Table C.5: Autocorrelation of the response characteristics of the subject jump-yip bouts in trials where the post-jump-yip behaviours of respondents in the bouts were analyzed (n = 26).....	269

Table C.6: Autocorrelation of the response characteristics of the subject jump-yip bouts in trials where the post-jump-yip changes in the behaviours of respondents in the bouts were analyzed (n = 18).^	270
Table D.1: Autocorrelations of the immediate post-jump-yip behaviours exhibited by the subject initial caller in a jump-yip bout (n = 26).^	275
Table D.2: Autocorrelations of the immediate post-jump-yip behaviours exhibited by the subject respondent in a jump-yip bout (n = 22).^	275
Table D.3: Correlations between the behaviours exhibited by the subject initial caller in a jump-yip bout over one minute following jump-yip production (n = 42).^	277
Table D.3: Continued^	278
Table D.4: Correlations of the behaviours exhibited by a subject respondent in a jump-yip bout over the minute following jump-yip production (n = 26).^	279
Table D.4: Continued^	280
Table D.5: Correlations of the post-jump-yip changes in the behaviours exhibited by the subject initial caller in a jump-yip bout (n = 24).^	281
Table D.5: Continued^	282
Table D.6: Correlations of the post-jump-yip changes in the behaviours exhibited by a subject respondent in a jump-yip bout (n = 18).^	283
Table D.6: Continued^	284
Table E.1: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). ....	292

Table E.2: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42). .....	292
Table E.3: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24). .....	293
Table E.4: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22). .....	293
Table E.5: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials where the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26). .....	294
Table E.6: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18). .....	294
Table E.7: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). ^.....	295

Table E.8: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).^	296
Table E.9: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).^	297
Table E.10: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).^	298
Table E.11: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).^	300
Table E.12: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).^	301

Table E.13: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of bout initiators was analyzed (n = 26).....	302
Table E.14: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the behaviour of bout initiators over one minute following jump-yip production was analyzed (n = 42).....	302
Table E.15: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of bout initiators were analyzed (n = 24). .....	303
Table E.16: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).....	303
Table E.17: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of a respondent in the subject bout over one minute following jump-yip production was analyzed (n = 26).....	304
Table E.18: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of a respondent in the	

subject bout between the minute preceding and the minute following jump-yip production were analyzed (n = 18). .....	305
Table E.19: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of bout initiators was analyzed (n = 26).^ .....	307
Table E.20: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of bout initiators over one minute following jump-yip production was analyzed (n = 42).^ .....	308
Table E.21: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of bout initiators between the minute preceding and the minute following jump-yip production were analyzed (n = 24). .....	309
Table E.22: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).^ .....	311
Table E.23: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of a respondent in the subject bout over one minute following jump-yip production was analyzed (n = 26).^ .....	312

Table E.24: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of a respondent in the subject bout between the minute preceding and the minute following jump-yip production were analyzed (n = 18).^ .....	313
Table E.25: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual in which its immediate post-jump-yip behaviour was analyzed (n = 26).^ .....	314
Table E.25: Continued^ .....	315
Table E.26: The relationships between vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual in which its behaviour over one minute was analyzed (n = 42).^ ...	317
Table E.26: Continued^ .....	318
Table E.27: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual for trials in which the post-jump-yip changes in its behaviour were analyzed (n = 24).^ .....	319
Table E.27: Continued^ .....	320
Table E.28: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent in trials where its immediate post-jump-yip behaviour was analyzed (n = 22).^ .....	321

Table E.28: Continued^ .....	322
Table E.29: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent in trials where its behaviour over one minute following jump-yip production was analyzed (n = 26).^ .....	323
Table E.29: Continued^ .....	324
Table E.30: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent and in trials where the post-jump-yip changes in its behaviour were analyzed (n = 18).^ .....	325
Table E.30: Continued^ .....	326
Table E.31: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the immediate post jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).^ .....	327
Table E.32: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42).^ .....	328
Table E.33: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24).^ .....	329



Table E.34: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22). <sup>^</sup> .....	330
Table E.35: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the behaviour of a respondent in the subject bout over the minute following jump-yip production was analyzed (n = 26). <sup>^</sup> .....	331
Table E.36: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18). <sup>^</sup> .....	332
Table E.37: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). <sup>^</sup> .....	333
Table E.38: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42). <sup>^</sup> .....	334
Table E.39: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the	

post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24). <sup>^</sup> .....	335
Table E.40: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22). <sup>^</sup> .....	336
Table E.41: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the behaviour of a respondent in the bout over the minute following jump-yip production was analyzed (n = 26). <sup>^</sup> .....	337
Table E.42: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18). <sup>^</sup> .....	338
Table E.43: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). <sup>^</sup> .....	339
Table E.44: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42). <sup>^</sup> .....	340

Table E.45: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24). <sup>^</sup> .....	341
Table E.46: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22). <sup>^</sup> .....	342
Table E.47: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the behaviour of a respondent in the subject bout over the minute following jump-yip production was analyzed (n = 26). <sup>^</sup> .....	343
Table E.48: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18). <sup>^</sup> .....	344
Table F.1: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).....	367
Table F.2: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31). .....	367

Table F.3: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17). .....	368
Table F.4: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18). .....	368
Table F.5: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21). .....	369
Table F.6: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16). .....	369
Table F.7: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).^ .....	370
Table F.8: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31).^ .....	371

Table F.9: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17). <sup>^</sup> .....	372
Table F.10: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18). <sup>^</sup> .....	373
Table F.11: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21). <sup>^</sup> .....	374
Table F.12: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16). <sup>^</sup> .....	375
Table F.13: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). .....	377
Table F.14: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of the	

initial caller in the bout over one minute following jump-yip production was analyzed (n = 42). .....	377
Table F.15: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24). .....	378
Table F.16: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22). .....	378
Table F.17: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26). .....	379
Table F.18: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18). .....	379
Table F.19: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). ^ .....	381
Table F.20: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the	

behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42). <sup>^</sup> .....	382
Table F.21: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24). <sup>^</sup> .....	383
Table F.22: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22). <sup>^</sup> .....	385
Table F.23: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26). <sup>^</sup> .....	386
Table F.24: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18). <sup>^</sup> .....	387
Table F.25: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in the subject jump-yip bouts. <sup>^</sup> .....	389

Table F.26: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in the subject jump-yip bouts over one minute following jump-yip production.^ .....	390
Table F.27: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of initial callers in the subject jump-yip bouts.^ .....	391
Table F.28: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of respondents in the subject jump-yip bouts.^ .....	393
Table F.29: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of respondents in the subject jump-yip bouts over the minute following jump-yip production.^ .....	394
Table F.30: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the changes in the post-jump-yip changes in the behaviour of respondents in the subject jump-yip bouts.^ .....	395
Table F.31: The effect of cloud cover on the social variables present at the time of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.^ .....	396
Table F.32: The effect of cloud cover on the social variables present during the subject jump-yip bout for trials where the behaviours of bout initiators in the minute following jump-yip production were analyzed.^ .....	397



Table F.33: The effect of cloud cover on the social variables present at the time of the subject jump-yip bout for trials where the post-jump-yip changes in the behaviours of bout initiators were analyzed.^ .....	398
Table F.34: The effect of cloud cover on the social variables present at the time of subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in those bouts were analyzed.^ .....	400
Table F.35: The effect of cloud cover on the social variables present during subject jump-yip bouts for trials where the behaviours of respondents in those bouts in the minute following their jump-yip were analyzed.^ .....	402
Table F.36: The effect of cloud cover on the social variables present during the subject jump-yip bouts for trials where post-jump-yip changes in the behaviours of respondents in those bouts were analyzed.^ .....	403
Table F.37: The effect of wind intensity on the response characteristics of subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in those jump-yip bouts.^ .....	405
Table F.38: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in those jump-yip bouts over the minute following jump-yip production.^ .....	406
Table F.39: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of post-jump-yip changes in the behaviour of initial callers in those jump-yip bouts.^ .....	407

Table F.40: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of respondents in those jump-yip bouts.^ .....	408
Table F.41: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of respondents in those jump-yip bouts over the minute following jump-yip production.^ .....	409
Table F.42: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of respondents in those jump-yip bouts.^ .....	410
Table F.43: The effect of wind intensity on the social variables present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.^ .....	412
Table F.44: The effect of wind intensity on the social variables present during the subject jump-yip bouts for trials where the behaviours of bout initiators in the minute following their jump-yip were analyzed.^ .....	413
Table F.45: The effect of wind intensity on the social variables present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.^ .....	414
Table F.46: The effect of wind intensity on the social variables present during the subject jump-yip bouts for trials where the immediate post-jump-yip behaviours of respondents in those bouts were analyzed.^ .....	416

Table F.47: The effect of wind intensity on the social variables present during subject jump-yip bouts for trials where the behaviours of respondents in those bouts in the minute after their jump-yip were analyzed.^	417
Table F.48: The effect of wind intensity on the social variables present during subject jump-yip bouts for trials where post-jump-yip changes in the behaviours of respondents in those bouts were analyzed.^	418
Table F.49: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in those jump-yip bouts.^	420
Table F.50: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in the subject jump-yip bouts over the minute following jump-yip production.^	421
Table F.51: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of initial callers in those jump-yip bouts.^	422
Table F.52: The effect of habitat type on the social variables present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.^	423
Table F.53: The effect of habitat type on the social variables present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.^	424

Table F.54: The effect of habitat type on the social variables present at the time of the subject jump-yip bouts for trials where the post-jump-yip changes in the behaviours of bout initiators were analyzed.^ .....	425
Table F.55: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).^ .....	428
Table F.56: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31).^ .....	428
Table F.57: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17).^ .....	429
Table F.58: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18).^ .....	429
Table F.59: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21).^ .....	430

Table F.60: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16). <sup>^</sup> .....	430
Table F.61: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26). <sup>^</sup> .....	431
Table F.62: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42). <sup>^</sup> .....	431
Table F.63: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24). <sup>^</sup> .....	432
Table F.64: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22). <sup>^</sup> .....	432
Table F.65: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the	

behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).^	433
Table F.66: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).^	433
Table F.67: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post jump-yip behaviours of bout initiators were analyzed.^	435
Table F.68: The effect of cloud cover on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.^	435
Table F.69: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.^	436
Table F.70: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in the subject bouts were analyzed.^	438
Table F.71: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the behaviours of respondents in the subject bouts over the minute following jump-yip production were analyzed.^	439

Table F.72: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of respondents in the subject bouts were analyzed.^.....	440
Table F.73: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.^ .....	441
Table F.74: The effect of wind intensity on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.^ .....	441
Table F.75: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.^ .....	442
Table F.76: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in the subject bouts were analyzed.^ .....	443
Table F.77: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the behaviours of respondents in the subject bouts over the minute following jump-yip production were analyzed.^ .....	444
Table F.78: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of respondents in the subject bouts were analyzed.^ .....	445

Table F.79: The effect of habitat type on the abiotic factors present during the subject jump-yip bouts for trials where the immediate post-jump-yip behaviours of bout initiators were analyzed.^ .....	446
Table F.80: The effect of habitat type on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators in the minute following jump-yip production were analyzed.^ .....	446
Table F.81: The effect of habitat type on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.^ .....	447



## LIST OF FIGURES

- Figure 1: Effect of the number of responses in a jump-yip bout on the proportion of time the initial caller in the jump-yip bout spent actively foraging in the minute following jump-yip production ( $\bar{x} + SE$ ) (\* denotes significant difference at  $\alpha = 0.10$ ).....66
- Figure 2: Effect of the number of responses in a jump-yip bout on the proportion of time the initial caller in the jump-yip bout spent foraging in the minute following jump-yip production ( $\bar{x} + SE$ ) (\* denotes significant difference at  $\alpha = 0.10$ ).....67
- Figure 3: Effect of the duration of a jump-yip bout on the proportion of post-jump-yip time the initial caller in the jump-yip bout spent in the bipedal-alert posture ( $\bar{x} + SE$ ).....68
- Figure 4: Effect of the duration of a jump-yip bout on the difference in the number of head lifts per minute ( $\bar{x} +$  or  $- SE$ ) performed by the initial caller in the bout before and after jump-yip production (\* denotes significant difference at  $\alpha = 0.10$ ).....69
- Figure 5: Relationship between the number of post-subject respondents in a jump-yip bout and the adjusted level of vigilance of the subject respondent in the bout immediately following its jump-yip ( $n = 14$ ) (# indicates number of overlapping data points).....71
- Figure 6: Relationship between the number of post-subject responses in a jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent

in a bipedal-alert posture (n = 26) (# indicates number of overlapping data points).....	73
Figure 7: Relationship between the post-subject jump-yip bout duration and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).....	74
Figure 8: Relationship between the number of responses in an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).....	75
Figure 9: Relationship between the duration of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-slouched posture (n = 26). ....	76
Figure 10: Relationship between the duration of an entire jump-yip bout and the proportion of post jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).....	77
Figure 11: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent quadrupedal with its head up (n = 26). ....	78
Figure 12: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent vigilant (n = 26). ....	79
Figure 13: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent foraging (n = 26). ....	80

Figure 14: Effect of the duration of an entire jump-yip bout on the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-slouched posture ( $\bar{x} + SE$ ). .....	81
Figure 15: Relationship between the number of post-subject responses in a jump-yip bout and the difference in the proportion of post-jump-yip time a respondent in the bout spent actively foraging before and after jump-yip production (n = 18).....	83
Figure 16: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the proportion of time a respondent in the bout spent actively foraging before and after jump-yip production (n = 10).....	84
Figure 17: Relationship between the post-subject jump-yip bout duration and the difference in the proportion time a respondent in the bout spent actively foraging before and after jump-yip production (n = 18).....	85
Figure 18: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the rate at which a respondent in the bout lifted its head before and after jump-yip production (n = 10).....	86
Figure 19: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the rate at which a respondent in the bout increased its level of vigilance before and after jump-yip production (n = 10).....	87
Figure 20: Relationship between the post-subject response latency (latency between the subject's jump-yip and the subsequent jump-yip) of the subject bout and the post-jump-yip change in the proportion of time the subject spent foraging (n = 11).....	88

- Figure 21: Effect of the number of responses in the section of a jump-yip bout following a respondent's display on the post-jump-yip change in the time that respondent spent vigilant ( $\bar{x} +$  or  $-$  SE) (\* denotes statistical significance at  $\alpha = 0.10$ ).....90
- Figure 22: Effect of the number of post-subject responses in a jump-yip bout on the post-jump-yip changes in the proportion of time that subject respondent spent actively foraging ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.05$ ). .....91
- Figure 23: Effect of the number of post-subject responses in a jump-yip bout on the post-jump-yip change in the total proportion of time the subject respondent spent foraging ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.10$ ).....93
- Figure 25: Effect of the post-subject duration of a jump-yip bout on the difference in the proportion of time a respondent in the bout spent actively foraging before and after jump-yip production ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.05$ ).....95
- Figure 26: Effect of the post-subject duration of a jump-yip bout on the difference in the proportion of time a respondent spent foraging before and after jump-yip production ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.10$ ). .....96

## INTRODUCTION

Behavioural decisions made by animals reflect the finite world in which they live. Performing a particular behaviour requires the investment of time and energy, both of which are limited (Cuthill and Houston 1997). The performance of any given behaviour may also preclude the performance of other behaviours, where those behaviours are mutually exclusive, while behaviours which occur simultaneously may be performed less efficiently, and thus reduce their benefits to the individual (Futuyama and Moreno 1988; Leigh 1990; Cuthill and Houston 1997). An animal making a behavioural decision must assess not only the benefits of performing a given behaviour, but also the costs associated with that behaviour. The relative costs and benefits of these “trade-offs” (performing one behaviour at the expense of another) – which may be influenced by internal (physical, cognitive) and external (environmental, social) factors – shape the way in which animals allocate time and energy to particular behaviours (Maynard Smith 1984; Houston et al. 1993; Cuthill and Houston 1997).

Attempts to understand the expression of behaviour often employ optimality models to describe the behavioural choices made by animals (e.g. Emlen 1966; Pyke et al. 1977; Maynard Smith 1984; Krebs et al. 1981; Pulliam et al. 1982; Houston et al. 1993). In optimality models, animals make behavioural decisions which maximize their fitness – their probability of survival (Pulliam et al. 1982; Houston et al. 1993) – or, more commonly, the number and/or quality of offspring (and thus the genetic contribution) they will produce in their lifetime (current and future reproductive success) (Maynard Smith 1978, 1984). But while maximizing fitness is recognized as the driving force behind the evolution of behaviour (e.g. Pulliam et al. 1982; Maynard Smith 1984),

its long-term nature and complexity – which requires measuring variables such as fecundity and survival not only at the time of a behavioural choice, but also into the future – has necessitated the use of easily-quantifiable, short-term variables in cost/benefit analyses of behavioural decisions (McNamara and Houston 1986; also see Parker and Maynard Smith 1990 for review of the general structure of optimality models).

The foraging behaviour of animals is often explained using optimality models (Emlen 1966; Pyke et al. 1977; Krebs et al. 1981; Stephens and Krebs 1986). Though fitness considerations ultimately dictate an animal's foraging behaviour, many optimality models use the more readily quantifiable "rate of energy gain" (the energy gained from performing a behaviour minus the energetic cost of performing the behaviour) as the primary variable which individuals maximize, since the energy gained from foraging is necessary for survival (Emlen 1966; Schoener 1971; Pyke et al. 1977; Stephens and Krebs 1986; Cuthill and Houston 1997). To maximize energy intake, animals may forage more intensely or for longer periods of time (Pyke et al. 1977). As with other behaviours, however, foraging animals incur energetic costs associated with the collection and processing of food (moving to food, chewing, digesting) as well as temporal costs associated with being unable to perform other behaviours while feeding (Schoener 1971; Cuthill and Houston 1997). Thus, while prolonged feeding may provide the greatest rate of energy intake, its benefits are ultimately offset by costs which may ultimately decrease lifetime reproductive success (Pyke et al. 1977; McNamara and Houston 1986; Lima and Dill 1990; Cuthill and Houston 1997).

Among the greatest costs experienced by foraging animals is predation. High future reproductive success is predicated on survival – a dead or severely injured animal can no longer reproduce (or care for immature offspring) (e.g. Pulliam et al. 1982). Because the death or debilitating injury which result from a successful or near-successful predator attack imposes a severe and often terminal cost on presumptive prey, the risk of predation experienced by an animal is a major determinant of its behaviour (Lima and Dill 1990).

A common method by which animals avoid predation is to identify a predator early enough to reduce the risk of predation (Alcock 1993; Roberts 1996). This antipredator vigilance, which involves the orientation of one or more sensory organs (typically the eyes, but also other sensory organs) towards sources of potential risk, by its very nature, occurs at the expense of foraging (Pulliam 1973; Elgar 1989; Lima and Dill 1990). In many avian species, for example, scanning behaviours, which involve frequent head lifts while foraging, are recognizable because they interrupt feeding bouts with stereotypical behaviour (Pulliam 1973; Elgar and Catterall 1981; Sullivan 1984). In other vertebrate species, and particularly in mammals, vigilance behaviours may be less distinct, but generally involve raising the sensory organs above the horizon at the expense of efficient foraging (Elgar 1989; Lima and Dill 1990).

The tradeoff between foraging and vigilance has been studied in a number of species of birds and mammals (reviewed in Elgar 1989; Lima and Dill 1990). Because vigilance is costly (e.g. Treves 2000), its benefits must also be weighed against its costs when considering whether to forage or be vigilant (Lima and Dill 1990). Ideally, an animal is able to maximize the benefits of both foraging and vigilance while minimizing

their costs – i.e. once a certain level of energetic intake is reached, the animal can devote its remaining time and energy to being vigilant (Schoener 1971; Pyke et al. 1977; Lima and Dill 1990). Conversely, if an animal is able to maintain a certain “safe” level of vigilance when utilizing a certain proportion of its time scanning for predators, the remaining time is available for foraging. If an animal was capable of devoting less time to vigilance while retaining a “safe” level of predator detection, the amount of time it could devote to foraging would increase. The ability of group-living animals to do exactly this is commonly regarded as a primary selective pressure promoting the evolution and maintenance of sociality (e.g. Pulliam 1973; Alexander 1974; Hoogland 1979, 1981; Hare and Murie 2007).

Solitary individuals must rely on their own senses to detect a predator. As the perceived risk of predation increases, the solitary individual must increase its level of vigilance accordingly – either by exhibiting vigilance more frequently or for longer periods of time – and consequently devote less time to other beneficial behaviours, most notably foraging, but also grooming, sleeping, moving, and mating (e.g. Lima and Dill 1990; Roberts 1996; Cuthill and Houston 1997). As part of a social group, however, an animal may forage (or perform any number of non-vigilant behaviours) in close proximity to several other individuals, each remaining vigilant long enough to avoid predation (Pulliam 1973). Providing that individuals near one another are capable of quickly and accurately communicating the presence of a predatory threat (e.g. through the production of an alarm signal), all members of the group benefit from the vigilance behaviour of any one individual (Roberts 1996). When one or more individuals in the



group are scanning for predators, the entire social group achieves a level of vigilance that can be termed collective (or group) vigilance (Treves 2000).

If individuals exhibit vigilant behaviours independently – that is without basing their behaviour on that of their neighbours (a basic tenet of Pulliam's (1973) group vigilance hypothesis (also see Bednekoff and Lima 1998)) – it is also reasonable to assume that multiple individuals may be vigilant simultaneously and may be able to be vigilant over a greater area by scanning in different directions (Da Silva and Terhune 1988). Experimental evidence, in fact, suggests that some social groups may detect predators earlier than solitary individuals (Pulliam 1973; Hoogland 1979; Elgar 1989). This improved method of predator detection and avoidance by social animals has been called both the “many-eyes effect” (Powell 1974) and the “group-vigilance hypothesis” (Roberts 1996).

The level of vigilance achieved by a group will ultimately be determined by the same selective pressures acting on individuals – collective vigilance will remain at the lowest possible level which provides a maximum level of predator avoidance (Roberts 1996). With all other factors remaining equal, this “safe” level of vigilance will remain constant as more individuals join a social group. These new individuals, however, can also contribute vigilance behaviour to the group. Resident individuals can therefore lower their individual level of vigilance while still retaining the “safe” level of vigilance enjoyed by the group as a whole (Pulliam 1973; Roberts 1996). This inverse relationship between individual vigilance and group size may also be observed when comparing groups of different sizes. Individuals living in smaller groups will be more vigilant than those living in larger groups (Pulliam 1973; Elgar and Catterall 1981; Roberts 1996).

This “group-size effect” allows an individual to spend more time on other behaviours, including foraging, as well as mating, courting, and other beneficial activities (Pulliam 1973; Roberts 1996).

Group-size effects on vigilance have been observed in more than 50 species of birds and mammals (Elgar 1989). Group-size effects have been documented in marsupials (Quokkas, *Setonix brachyurus*) under minimal predation risk (Blumstein et al. 2001), in terrestrial ungulates such as the Nxai Pan Springbok (*Antidorcas marsupialis*) (Bednekoff and Ritter 1994), and in domesticated fowl (Newberry et al. 2001). Group size effects are also observed in mammalian species which display only transient, seasonal groups, such as harbour seals (*Phoca vitulina*) (Da Silva and Terhune 1988) and capybaras (McDonald 1981; Yáber and Herrera 1994). Despite the relatively large number of studies focusing on the group-size effect, however, very little is actually known concerning the mechanisms underlying population-size-induced changes in behaviour (Barbosa 2003).

While much of the work on social vigilance is based on the assumption that animals are capable of measuring group size in some way, empirical evidence of a specific mechanism by which animals can measure group size is lacking (Beauchamp 2003). Moreover, despite the cooperative nature of Pulliam’s (1973) group-vigilance model, in which the vigilance behaviours of individuals provide the entire group with a better chance of detecting and surviving a predator attack, it is based on individuals acting (scanning) independently (Pulliam 1973; Bednekoff and Lima 1998). There is even evidence that “selfish” behaviours by social individuals, in which individual fitness rather than group fitness shapes behaviour, produce the group-size

effects predicted by Pulliam's (1973) model (Pulliam et al. 1982; McNamara and Houston 1992; Bednekoff and Lima 1998). While independent scanning is prevalent among the species studied to date, such scanning does not provide the ideal mechanism by which to enjoy the benefits of group vigilance (Bednekoff and Lima 1998). Instead, social animals would enjoy a greater benefit of social vigilance by adjusting their behaviour relative to the behaviour of their neighbours, decreasing their level of vigilance as they detect more of their neighbours becoming vigilant or increasing their level of vigilance when more of their neighbours are non-vigilant, such as when they are foraging (e.g. Bednekoff and Lima 1998).

Several studies have postulated that social animals may monitor their neighbours for clues concerning their "state," including their level of vigilance or their perceived level of threat, basing their behaviour on this socially-acquired information (Verdolin and Slobodchikoff 2002; Dall et al. 2005). Wild boars (*Sus scrofa*) have shown evidence of monitoring and mimicking the foraging behaviour of neighbours (Quenette and Gerard 1992), while the direct monitoring of neighbouring individuals is seen in species which use sentinels for predator detection (Bednekoff 1997; Bednekoff and Lima 1998). In this case, the scanning behaviour of the sentinels can be easily monitored by non-sentinel individuals, and the vigilance of the group can be coordinated (Bednekoff 1997; Bednekoff and Lima 1998). In light of these findings, my thesis research attempted to identify a mechanism by which individuals of a social rodent species, the black-tailed prairie dog (*Cynomys ludovicianus*), could assess the vigilance levels of their neighbours and subsequently adjust their own vigilance levels to better suit the collective vigilance level of their groups.

Black-tailed prairie dogs are one of the most social non-primate mammalian species, living in family groups (coterie) of up to 26 individuals (Hoogland 1995). The demographics of their coterie (1 breeding male, 3-4 reproductively-mature adult females, and multiple male and female yearlings and juveniles in each coterie) approach the social complexity of some primate species (Eisenberg et al. 1972; Smith et al. 1976; Hoogland 1995). While each coterie generally extends over no more than approximately 1/3 of a hectare, multiple coterie lie adjacent to one another, forming large colonies (towns) which may contain thousands of individuals over several kilometres (Hoogland 1995).

Being of small size and inhabiting an open prairie ecosystem, black-tailed prairie dogs are at risk of predation from a number of species, including: terrestrial reptiles such as bull snakes (*Pituophis melanoleucus*) and rattlesnakes (*Crotalus viridis*; *C. atrox*), terrestrial mammals such as American badgers (*Taxidea taxus*), bobcats (*Felis rufus*), and coyotes (*Canis latrans*), and avian species such as golden eagles (*Aquila chrysaetos*), several species of hawk including red-tailed hawks (*Buteo jamaicensis*), and several species of falcon (Hoogland 1995). Consequently, individual black-tailed prairie dogs spend a large proportion of their time engaged in vigilance, though as in other social species, individuals may reduce their level of vigilance in large groups (Hoogland 1979, 1995; Kildaw 1995). Improved predator detection and a reduction in the proportion of time devoted to vigilance, in fact, has been suggested as a primary selective pressure favouring sociality in black-tailed prairie dogs (Hoogland 1981).

Group-size effects are not limited to black-tailed prairie dogs. Individuals of both white-tailed and Gunnison's prairie dogs (*Cynomys gunnisoni*) increase their vigilance

when in smaller groups (Hoogland 1979; Verdolin and Slobodchikoff 2002 respectively), though the group size effect in white-tailed prairie dogs is not as pronounced as it is in black-tailed prairie dogs (Hoogland 1979), and Gunnison's prairie dogs are only significantly more vigilant in very small groups (Verdolin and Slobochikoff 2002). Group-size effects are also observed between species, with white-tailed prairie dogs, which live in smaller colonies with correspondingly lower population densities than the black-tailed species, spending proportionately more time vigilant (Hoogland 1979).

The group-size effects exhibited by black-tailed prairie dogs are evident not only between colonies of different sizes, but also in response to transient changes in population size and/or density, with individuals decreasing their level of vigilance as: 1) (vigilant) juveniles first emerge from their burrows following early development, 2) individuals emerge from their burrows each morning, and/or, 3) individuals move from the edge of a coterie/colony to the centre, where population density is generally higher (Hoogland 1979). Similarly, black-tailed prairie dogs forage less when individuals are temporarily removed from a colony, with individuals reducing their number of foraging bouts, increasing the number of times they interrupt foraging to scan for predators, and decreasing the total amount of time they spend foraging in direct proportion to the number of individuals that are removed (Kildaw 1995). When previously removed individuals are replaced, the resident (unremoved) individuals decrease their vigilance correspondingly, though not completely back to original levels (Kildaw 1995).

The presence of a threat in the environment is communicated through a prairie dog colony by a high-pitched, 1-2 syllable alarm call referred to as a "repetitious bark" (Waring 1970). When an individual produces this call, surrounding individuals become

alert and scan their environment for the origin of the threat (Waring 1970). Individuals may then flee if the threat is detected or if neighbours are observed fleeing (Tileston and Leichleitner 1966; Waring 1970; Smith et al. 1976). It is this sharing of information between members of a colony which allows black-tailed prairie dogs to utilize the collective vigilance of their social group to avoid predation.

The repetitious bark is but one call in a rich vocal repertoire possessed by black-tailed prairie dogs (Waring 1970; Smith et al. 1976; Grady and Hoogland 1986; Hoogland 1995). Waring (1970) identified nine distinct sounds produced by black-tailed prairie dogs. Though many of these vocalizations were modified barks, black-tailed prairie dogs were also seen to produce a unique vocalization called a “wee-oo” (Waring 1970). This call, also known as a yelp (Jillson 1871), a cry (Wilder 1872), a song (Seton 1926), or most commonly, a jump-yip (Smith et al. 1976; Halpin 1983; Owings and Loughry 1985; Hoogland 1995), consists of an auditory component – two syllables of different frequency, the “wee” and the “oo” as described by Waring (1970) – and a visual component in the form of stereotypical behaviour – the first syllable is emitted as the caller extends its head up and back and rises up onto its hind legs while the second syllable is emitted as the caller is lowering itself back onto its four legs (Waring 1970). A jump-yip is produced in response to a number of environmental stimuli, including during territorial disputes and chases (King 1955; Smith et al. 1976), when an individual is confronted with a “less dangerous” predator such as a non-poisonous snake (Halpin 1983; Owings and Loughry 1985), and following the retreat of a threat – i.e. as an “all-clear” call (Anthony 1955; Waring 1970; Hoogland 1995).

While the jump-yip is often considered to serve as an “all-clear” signal, where individuals jump-yip when they are “at ease” (e.g. King 1955; Hoogland 1995), empirical evidence for this (or any) function is minimal. In some cases, such as during and after a territorial dispute or chase, or in the presence of a non-threatening predator, jump-yips are produced by individuals who are “agitated” (Waring 1970). Furthermore, jump-yips may be produced during simple pauses in feeding (Waring 1970) or even in the absence of any apparent extrinsic stimuli (Waring 1970; Smith et al. 1976). It is possible, then, that the jump-yip may serve an as yet undetermined function in black-tailed prairie dog sociality.

As in the case of the “repetitious bark,” the production of a jump-yip by a black-tailed prairie dog often elicits an immediate behavioural response from nearby individuals. Instead of stimulating secondary behaviours (e.g. alertness and predator-scanning following repetitious bark production), however, a jump-yip produced by one individual often causes other individuals to produce their own jump-yip display. A jump-yip can therefore be considered a “contagious” vocalization or display (e.g. Waring 1970; Provine 1996), consisting of an initial jump-yip and “responses” to that display (e.g. Smith et al. 1976).

Contagious behaviours, though not common, are observed throughout the animal kingdom. In humans and other primates, both yawning (Platek et al. 2003; Anderson et al. 2004) and laughing (Provine 1996) are behaviours which, when performed by one individual, may spread within a group. To date, there is little consensus concerning the significance of the contagious nature of these behaviours, though researchers such as

Platek et al. (2003) believe the contagious nature of yawning may provide information concerning the “mental state” of nearby individuals.

Contagious behaviours may also play a major role in social learning and the transfer of information between individuals. In mimicking the evasive behaviours of neighbours, group-living insects may be able to avoid an unseen predator, a situation termed the “Trafalgar effect” (Treherne and Foster 1981). Schooling fish may also mimic the behaviours of their neighbours to evade predators they had not encountered previously (Brown and Laland 2003). In this way, behavioural information and mimicry can also be used in social learning, in which naïve individuals obtain information concerning an object or stimulus from other (nearby) individuals (Brown and Laland 2003). Correspondingly, colonies may serve as “information centres” concerning the location of food in an environment, allowing individuals not previously aware of a particular resource patch to locate food and forage more efficiently (Ward and Zahavi 1973; Krebs 1974; Brown 1984). Birds and mammals, through observation and mimicry, may also obtain cultural information and acquire innovations from others in a manner akin to the transmission of a contagion (Cavalli-Sforza and Feldman 1981; Lefebvre and Giraldeau 1994).

Black-tailed prairie dogs are also not alone among prairie dog species in exhibiting contagious behaviours. White-tailed and Gunnison’s prairie dogs produce contagious vocalizations, though they are generally produced only in peaceful environments (Waring 1970). The contagious vocalizations of these two species are single-syllable calls with limited associated stereotypical behaviour – though the contagious call is always produced with the head outstretched and the mouth extended



forward and up, the caller may assume any number of postures, including standing, sitting hunched, or even slowly running while producing the call (Waring 1970). Thus, while as many as 15 individuals may participate in a contagious call bout, neither white-tailed nor Gunnison's prairie dogs produce a call which approaches the vocal or behavioural complexity of the black-tailed prairie dog jump-yip.

Additionally, while the stereotypical black-tailed prairie dog jump-yip behaviour is rapid, often occurring in less than one second, and despite the fact that the responses within the jump-yip bout may begin before the completion of the entire previous vocalization, an entire jump-yip bout may last several seconds with as many as 40-50 individuals responding (Hoogland 1995). In these bouts, where respondents may span hundreds of metres in the wild, this can result in a "wave of sound and movement traveling across the prairie" (Hoogland 1995).

The object of my research was to determine whether the contagious nature of the black-tailed prairie dog jump-yip vocalizations could provide individuals with information concerning the vigilance of neighbours and thus the level of collective vigilance of their colony. More specifically, could callers who initiate a jump-yip bout use the response characteristics of the bout – the number of responses per bout, the number of respondents per bout, the duration of the bout, and/or the response latency (the duration between the initial call in the bout and the first response) of the bout – to assess the vigilance level of their neighbours and adjust their behaviour accordingly?

While evidence for this type of complex assessment in animals is sparse, it is not unheard of. Marine insects may detect approaching predators via information gleaned from other members of their flotilla (social group) (Treherne and Foster 1981), as do

schooling fish (Treherne and Foster 1981; Brown and Laland 2003). Lima and Dill (1990) provided evidence that animals may be able to assess many different environmental variables (e.g. group density, location in group, and distance to safety) in determining instantaneous predation risk. Pygmy marmosets (*Cebuella pygmaea*) have been observed using bouts of calling and response (“conversations”), which may provide information concerning the presence and location of group-mates when the act of foraging moves them out of visual range (Snowdon and Cleveland 1984). Individuals may also use the sampling behaviour of nearby individuals – “public information” – to assess the quality of an environment or a resource (Valone and Templeton 2002). While public information is often exploited by individuals attempting to assess the quality of forage patches (Valone 1989; Templeton and Giraldeau 1996; Giraldeau et al. 2002), public information may also function to assess the quality of other resources and/or environments, including breeding habitat, opponents, and mate quality (Valone and Templeton 2002).

Numerical abilities are thought to underlie the ability of individuals to assess the costs and benefits of certain behaviours, such as in the determination of the amount of food in a particular food patch (e.g. Hauser 2000), while animals exhibiting group-size effects (including prairie dogs) are presumed to possess some numerical ability, given that they can adjust their behaviour according to changes in population size. While there is no direct evidence of “true” counting ability in black-tailed prairie dogs, measuring the magnitude of response (e.g. the number of responses) could be done using simpler forms of numerical competency such as subitizing, in which patterns of stimuli are recognized and classed ordinally, rather than assigning each stimulus a numeral (Davis and Pérusse

1988; Hauser 2000). Sloan's (2005) recent demonstration that adult Richardson's ground squirrels (*Spermophilus richardsonii*) count the number of individual callers contributing to an alarm chorus, suggests that ground squirrels possess at least rudimentary numerical abilities.

Furthermore, the quantification of jump-yip displays may be aided by the characteristics of the display itself. The multiple sensory components may facilitate quantification by promoting the accurate counting of the display (by providing information to multiple senses, in the event one sensory system is compromised by internal or external factors). Most jump-yips in a bout occur sequentially (i.e. with limited overlap between jump-yips), while the stereotypical length of each jump-yip display – approximately one second in length (Smith et al. 1976) – and their rhythmical nature (two syllables and two postural changes) may aid in quantification through subitizing (Davis and Pérusse 1988).

Whether producing a jump-yip in response to particular environmental stimuli, or producing one in the absence of a stimulus, an individual initiating a jump-yip bout is likely to be vigilant. In order for response characteristics to provide information to individuals concerning the vigilance of their neighbours, the responders in the bout must be vigilant and their responses must be relatively "honest." Honest signaling, in which individuals do not mislead conspecifics concerning information they possess, is a defining characteristic of evolutionarily stable signals (signals that have been retained by species through their evolution) since their high costs prevent the signals from being deceitful (Zahavi 1975; Zahavi 1977; Grafen 1990; Zahavi 1991; Johnstone 1998; Fischer et al. 2004). There are several characteristics of the jump-yip vocalization which

fit these criteria. First, a jump-yip involves both auditory and visual signals – both of which could be used to determine the number of responding individuals. This is especially relevant as it reduces the probability that a severe “miscount” could occur – if environmental conditions reduce the acuity of auditory signals (e.g. if it is windy), visual signals are still available; if respondents are located outside an observer’s visual field, auditory cues are still present (e.g. Hebets and Papaj 2005). The multimodal nature of these signals may also aid in their processing by receivers (Rowe 1999).

Second, by their very nature, jump-yips are highly compelling signals – more often than not, the production of a jump-yip by one individual will elicit responses from nearby individuals, including additional jump-yips (Waring 1970; Smith et al. 1976) or changes in their postures and spatial positions (Smith et al. 1976; Owings and Owings 1979; Halpin 1983; Owings and Loughry 1985). This increases the probability of nearby individuals detecting and responding to the initial jump-yip, making most, if not all, of the responses “honest” and improving the estimation of the number of vigilant individuals. Jump-yips are especially compelling given the distinct visual component of the jump-yip. Prairie dogs possess acute vision and respond strongly to visual cues, such as the retreat of an alarm caller or nearby individuals from a predatory threat (Tileston and Leichleitner 1966; Waring 1970; Smith et al. 1976).

Third, the costs of producing a jump-yip – the energetic cost of both producing the vocalization and jumping, the temporal cost required to produce the display, and possible predation costs (in increased visibility and noisiness) associated with the production of the display – also likely contribute to the honesty of the signal. They impose a relatively high cost to individuals who do not contribute “correct” information

concerning their state and therefore ensure that only individuals correctly “describing” their vigilance (and thus contributing to an accurate representation of the collective vigilance of their group) perform a jump-yip display (Zahavi 1975; Zahavi 1977; Grafen 1990; Zahavi 1991). Producing such a complex, multimodal signal may also make it difficult for dishonest individuals to accurately mimic the entire display, further ensuring honest signalling (Rohwer and Rohwer 1978).

The final benefit to using a jump-yip to assess the vigilance of neighbours is that the call is often associated with the departure of threatening stimuli – after a jump-yip is emitted, the performing individual is less likely to flee (Smith et al. 1976). In cases when it is produced in response to a predator, that predator is not highly dangerous and the call may in fact stimulate congregation or mobbing (Halpin 1983; Owings and Loughry 1985). When calls are associated with strongly negative stimuli, such as the presence of a potentially fatal predator, and are produced frequently without being associated with an actual threat, they may eventually be ignored, as in the case for unreliable alarm callers in Richardson’s ground squirrels (Hare and Atkins 2001). The fact that jump-yips are not associated with immediate danger would allow them to be used repeatedly as an assessment tool, without exhausting the responsiveness of neighbours.

The complexity and uniqueness of the jump-yip display, coupled with the relatively complex social structure of black-tailed prairie dogs, make it possible that jump-yips aid black-tailed prairie dogs in making behavioural decisions based on the social environment present at the time the jump-yipping occurs. I observed jump-yipping prairie dogs in wild and captive habitats to determine whether they adjusted their vigilance behaviour according to the response characteristics of the jump-yip bout in

which they were a participant – either as the initial caller in the bout or as a responding individual within the bout. If the level of response in a jump-yip bout was indicative of the vigilance of neighbouring individuals, a bout initiator should become less vigilant as the level of responsiveness in their jump-yip bout (number of responses and responding individuals in the jump-yip bout; the duration of the jump-yip bout; inverse of response latency) increases.

Though several studies have examined the jump-yip display of black-tailed prairie dogs, there is still uncertainty concerning the exact function of the jump-yip. If the response characteristics of a jump-yip bout shape the behaviour of the participants in those bouts, it would provide evidence of an unconsidered aspect of cognitive processing in this highly social species.

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## **METHODS**

This study examined both the frequency and duration of vigilance behaviours (as well as the opposing foraging behaviours) exhibited by jump-yip bout initiators immediately after and over one minute following jump-yip production, as well as changes in behaviour from the minute preceding to the minute following jump-yip production, as the level of response in the initiator's jump-yip bout varied. Because individuals may also passively gain information about the vigilance of neighbours by "listening" to a previously-initiated jump-yip bout, the behaviour of respondents in a jump-yip bout relative to the level of response in their jump-yip bout was also examined. Furthermore, the possible effects of jump-yip bouts which did not involve the studied individual, as well as population size and abiotic factors (including meteorological, temporal, and habitat variables) were also examined with respect to changes in the behaviour of a previously jump-yipping individual.

### **Study animals**

Behavioural data were collected from each of six black-tailed prairie dog populations throughout Manitoba (MB), North Dakota (ND), and South Dakota (SD) over a period of approximately 10 months. Sampling occurred at Theodore Roosevelt National Park (TRNP), Medora, ND from 10-14 November, 2003, Bramble Park Zoo (BPZ), Watertown, SD from 15-19 November, 2003, Wind Cave National Park (WCNP), Hot Springs, SD from 21-26 May, 2004, Dakota Zoo (DZ), Bismarck, ND from 27-28 May, 2004, Assiniboine Park Zoo (APZ), Winnipeg, MB on 8 August and 1 September,

2004, and Fort Whyte Centre (FWC), Winnipeg, MB on 3, 9, and 22 September, 2004 (Table 1).

These populations were classified according to their level of captivity (for subsequent examinations of the relationship between habitat type, black-tailed prairie dog behaviour, the characteristics of vocalizations, and the abiotic factors present at the time of each observational session). The black-tailed prairie dog populations in the national parks (TRNP, WCNP) were considered “wild” populations, where there were no artificial boundaries to movement or colony expansion (i.e. fences) and food was not provided. The populations at BPZ and FWC were considered “intermediate” populations, because while all food was natural (grasses and other vegetation), both populations were enclosed by fences. The populations at DZ and APZ were considered “captive” populations, because nearly all the food available was artificially provided (by zookeepers or zoo visitors) and both populations were within artificial barriers to expansion.

Due to the observational nature of this study, subject animals in this experiment were not trapped, marked, or handled in any way. This reduced the investment of time at any one location, permitting the replication of the experiment at several different populations. Additionally, leaving the experimental animals unmarked limited the experiment’s visibility to the public, increased the ease with which research permits could be obtained, and reduced the stress placed on the study animals. As a consequence of leaving individuals unmarked, however, the identification of more than 4-6 (verifiably) independent jump-yipping individuals in any given area was impossible. When possible, the movement of individuals was tracked or, failing that, unique markings (fur colouration, scars) were used to identify individuals.



Table 1: The geographical locations of black-tailed prairie dog populations observed in this study.

Location	GPS Coordinates
Theodore Roosevelt National Park <sup>^</sup>	46°55.875'N 103°30.850'W 46°57.216'N 103°30.535'W 46°58.706'N 103°29.515'W
Bramble Park Zoo	44°54.608'N 097°07.749'W
Assiniboine Park Zoo	49°52.425'N 097°14.337'W
Fort Whyte Centre	49°49.276'N 097°13.547'W
Dakota Zoo	46°47.931'N 100°48.382'W
Wind Cave National Park <sup>^</sup>	43°32.399'N 103°29.568'W 43°32.548'N 103°29.048'W 43°32.548'N 103°29.048'W 43°32.992'N 103°29.548'W 43°34.511'N 103°29.409'W 43°37.295'N 103°29.509'W 43°37.515'N 103°29.426'W 43°38.377'N 103°28.044'W 43°32.697'N 103°28.845'W

<sup>^</sup> locations with multiple coordinates were those large enough to permit multiple observations to be collected in the same geographical area.

In instances when the independence of jump-yipping individuals (subjects) was ambiguous (when movements could not reliably be tracked or when no unique markings were evident), the behaviours of those individuals were not included in subsequent analyses. Consequently, in smaller populations (DZ, APZ, FWC) where only a single sampling site was available, the number of calls used per site was limited to a maximum of four to limit pseudoreplication (including the behaviours of one individual multiple times within the dataset). The larger sizes of the remaining populations (TRNP, BPZ, and WCNP) allowed sampling from multiple subpopulations, which, in the national parks, were separated by as many as several kilometers (Table 1).

Subpopulations in these colonies were often large enough to be further divided into smaller sites which were generally separated by at least 100 m. Owings and Loughry (1985) utilized inter-site distances of approximately 33 m (22-47 m) to minimize the repetitive sampling of individuals during behavioural experiments. However, because black-tailed prairie dog coterie in WCNP can range in area from 0.005 hectares to 1.01 hectares (1 hectare = 10000 m<sup>2</sup>) (Hoogland 1995), a larger inter-site distance – approximately equivalent to the maximum coterie length observed by Hoogland (1995) – was utilized in this study. While the movement of individual black-tailed prairie dogs may span more than 100 metres during the course of one day (King 1955), it is generally limited to their own coterie (King 1955; Hoogland 1995), reducing the likelihood of repeatedly sampling a single individual between two distant sites. Excursions by an individual (generally the dominant male) outside a coterie are typically met with aggressive territorial interactions (King 1955; Hoogland 1995) which would result in the exclusion of any simultaneous jump-yips from subsequent analyses

(since observational sessions were not conducted in the presence of “major” extraneous events, such as a fight or prolonged chase). While long-distance emigration may be occurring at WCNP at the time observational studies occurred (mid-late May; see Hoogland 1995), immigrants are greeted with the same aggression as transient intruders (Hoogland 1995), making it highly unlikely that their behaviour would be included in any analyses. Thus, by leaving a relatively large “buffer” between adjacent observational sites, it was possible to generate a relatively large sample size with little risk of pseudoreplication.

### **Apparatus**

Black-tailed prairie dog behaviour was recorded using a digital video camera (SONY DCR-TRV110 or DCR-TRV120) at designated viewing areas (e.g. walkways at zoos, roadside stops, and enlarged hard shoulders in national parks) at all sites. Though no blind or camouflage was used, by situating the recording equipment in locations frequented by humans (and vehicles in the national parks), the prairie dogs used in the study were well-acclimated to the presence of humans and vehicles and thus were unlikely to have modified their behaviour in response to the observer. In the national parks, where the presence of people may be more sporadic (especially during the months in which these “wild” populations were sampled), the camera was set up in close proximity to a vehicle which provided some cover. A previous study by King (1955) indicated that when a vehicle was driven into the midst of a previously undisturbed colony and subsequently used as a blind, black-tailed prairie dogs quickly habituated to its presence. While the visual requirements in this study (needing a large visual field to

maximize the probability of recording jump-yips) precluded using the vehicle as a true blind, by recording near the vehicle, the visibility of the camera, tripod, and experimenter was reduced. To further ensure that human presence did not affect the behaviour of the subject animals, observation sessions in which one or more individuals appeared to be responding to the presence of the vehicle or researcher (by continuously orienting towards the camera or producing a continuous alarm call for the duration of a trial) were either stopped before completion of the entire session (and thus were not analyzed) or were removed from subsequent analyses (see “Quality control of jump-yip bouts” below). Any non-perceptible effects of the presence of the researcher on the vigilance behaviour of nearby individuals should be relatively constant across habitats, or at least be the same within habitats, and thus not affect the collection and subsequent analysis of the jump-yip-dependent behaviour of black-tailed prairie dogs.

### **Initial data collection**

Black-tailed prairie dog behaviour was continuously recorded for at least one hour at each observation site, though sites were observed for more than one hour if there were more than approximately 20 individuals covering an area of approximately 400 m<sup>2</sup> or more and/or when there was more than one observation area (e.g. at the intersection of two roads) at a large site. The duration of single-site recording was also prolonged if jump-yip production occurred sporadically relative to the population density or size of the site being recorded (i.e. if only two jump-yips were recorded for a site containing more than 20 individuals). This was an attempt to maximize the number of independent samples collected at any one site and thus maximize the total sample size in the study.

An observational session began with the tentative identification of the initial caller (subject) in a jump-yip bout (subject jump-yip bout; Appendix A) and the response characteristics of the jump-yip bout. This included both the magnitude of response in the bout – the number of responses in the bout, the number of respondents (unique responding individuals) in the bout, and the duration of the bout – and the response latency (the period of time elapsing between the initial jump-yip in a jump-yip bout and the first response in the bout) of that bout (Appendix A). Initially, the visual field of the video camera was kept as large as possible to increase the probability of visually identifying the initiation of a jump-yip bout, while also permitting the recording of the behaviour of a jump-yipping individual prior to jump-yip production. The use of a wide field also permitted the visual identification of responses/respondents in the subject bout, which improved the accuracy with which the level of response in the subject bout was measured (see below).

Upon the initiation of a jump-yip bout, the visual field of the camera was shifted to focus on the behaviour of the subject individual in the bout (either the initial caller or a respondent). The behaviour of a subject was isolated within 2-10 s of jump-yip production though it was recorded immediately following jump-yip production providing the subject was on-screen and in sufficient focus to distinguish individual behaviours at the time of jump-yip production ( $n = 48$ ).

The behaviour of each subject was recorded continuously for three minutes following jump-yip production, though it was subsequently determined that because relatively little is known about the effects of jump-yips, or for that matter, the effects of other vocalizations such as alarm calls and chirps (as defined by Waring 1970) on the

behaviour of black-tailed prairie dogs, only behaviour recorded over one minute following jump-yip production, and thus most closely associated with the jump-yip, would be analyzed. Given the acoustic complexity (the number of extraneous sounds) of most environments, including those used in this study, a short experimental duration which limits the number of extraneous factors that may alter focal behaviour is most appropriate (Hare and Atkins 2001).

### **Quality control of jump-yip bouts**

A total of 173 jump-yips (including associated vigilance behaviour of the tentatively identified initial caller in the bout) were recorded onto digital video tape following observational sessions run at the six sites listed above. Upon review of the videotaped calls, however, it became evident that, for several reasons, many of the jump-yip bouts recorded could not be used for subsequent analyses. Because individuals were unmarked in this experiment, it was impossible to remove, during taping, any observational sessions in which an individual that had previously initiated a jump-yip bout started another bout. Consequently, 48 of the 173 total calls recorded were removed because their independence could not be verified. Furthermore (as described previously), calls in which the behaviour of subject individuals appeared to be affected by the presence of the camera/tripod or researcher, traffic (pedestrian or vehicular), predators, conspecifics, or other variables (including non-predatory animals, physical variables), as demonstrated by continuous alarm calling or persistent stimulus-directed behaviours (including vigilance or locomotion), were also removed from analysis (16 of 173) as were bouts in which other nearby vocalizations (vocalizations occurring within ~100 m of the

subject individual and not produced by the subject) were persistent in the environment throughout the observational trial (11 of 173). Some observational sessions also had a questionable identification of the initial caller (or any caller as described below) in a jump-yip bout (7 of 173) or had poor audio and/or video which affected the accuracy with which: 1) the magnitude of response in the subject jump-yip bout, and/or, 2) the social variables (i.e. other vocalizations) in the environment, and/or, 3) the behaviour of the subject individual was recorded (18 of 173). These calls were thus removed from analysis, resulting in 72 jump-yip bouts available for analysis.

### **Identification of subject individual**

Post-hoc examination of each subject jump-yip bout showed that not all subject individuals were bout initiators. In some cases, particularly in the larger populations found in both TRNP and WCNP, the tentatively-identified bout initiator was actually a respondent within a larger jump-yip bout (Appendix A).

While this study was intended to examine only whether individuals initiate jump-yip bouts to “test” their neighbours’ vigilance, studying the jump-yip-related behaviour of respondents could provide additional evidence for individuals passively detecting and using jump-yips to gather information about their environment. Based on their participation in a jump-yip bout, respondents are obviously attuned to events in the environment. Thus, it stands to reason that they may be able to utilize bouts which they did not initiate to assess the vigilance of neighbours, effectively allowing them to “eavesdrop” on the displays of others. In fact, given the abundance of jump-yips which occur in the natural (wild) environments (approximately 4 bouts/min., 15 jump-yips/min.

in wild habitats vs. 1 bout/min., 2 jump-yips/min. in intermediate habitats, and < 1 bout/min. and < 1 jump-yip/min. in captive habitats), individuals that monitor the jump yips initiated by other individuals may be able to continually modify their behaviour with changes in the characteristics of jump-yip bouts occurring in the environment.

Thus, in this study, the behaviours of two groups of individuals – bout initiators and respondents within a jump-yip bout – were examined. The vigilant and non-vigilant behaviours measured in this study were identical for both groups, as were the “potentially-confounding variables” described below. While all the response characteristics of the jump-yip bouts used in the analysis of the behaviour of bout initiators were also recorded for the jump-yip bouts of respondents (the number of responses and respondents, the duration, and the response latency – see below), because respondents were part of a larger jump-yip bout, two levels of response in the jump-yip bout were examined. Thus, the response characteristics of the subject jump-yip bout were examined both after the respondent’s jump-yip (i.e. as if that individual initiated a section of its bout; Appendix A) and over the entire jump-yip bout.

### **The response characteristics of a jump-yip bout**

The independent variables of interest in this study included four aspects of the response characteristics within a jump-yip bout: the magnitude of response in the jump-yip bout – the number of responses in the bout, the number of respondents (unique responding individuals) in the bout, and the duration of the bout – as well as the response latency (the amount of time passing between the production of the initial vocalization in a



jump-yip bout and the onset of the first response in the bout) in the subject bout (Appendix A). For trials in which the subject individual was a respondent in a jump-yip bout, the four response characteristics indicated above were measured for the subsection of the subject bout beginning with the subject's (respondent's) jump-yip (i.e. as if the subject was the initiator of the latter part of the larger jump-yip bout; Appendix A). Responses which occur after an individual's jump-yip may be particularly relevant to that individual, and indeed even deterministic of its subsequent behaviour, because those responses occur after the individual has demonstrated its "awareness" by participating in the jump-yip bout. Since the respondent was also part of a larger jump-yip bout, however, its behaviour was also examined with respect to the number of responses in, the duration of, and the response latency of the larger bout (Appendix A). The subject's response latency (the response latency of the subject respondent's jump-yip to the previous jump-yip in the bout; Appendix A) was also compared to the vigilance of the subject to assess directly whether response latency is actually indicative of vigilance.

A combination of visual and auditory identification methods was used to count the number of responses in each jump-yip bout. While visual counts were highly accurate within the captive habitats (owing to their relatively small areas which permitted most of the, if not the entire, population to be recorded at one time), auditory cues were used to identify at least a portion of the total responses in a jump-yip bout for nearly all observational sessions occurring in wild habitats. In these locations, the large number of individuals comprising each population, coupled with the massive area the populations occupied, required the acoustic identification of jump-yip responses. To make response counts as accurate as possible, noise-canceling, hi-fi headphones (Jensen JHF400) were

used in conjunction with multiple viewings of each jump-yip (at different, often high, volume levels).

In describing the social interactions between individuals of adjacent wards or subcolonies, Hoogland (1995) recognized that individuals inhabiting different wards typically hear and see residents of other wards, but described communication between wards as rare. If this is true – and responses occurring outside the ward of the subject individual do not carry relevant vigilance information and thus do not contribute to the behavioural decisions made by the subject – it is possible that the magnitude of response is overestimated for bouts in which responses are identified acoustically. Given the observational nature of this study, however, wards could not be precisely delineated to exclude “unimportant” distant jump-yips, and even if ward borders were defined, the inability of the video camera to simultaneously record an entire ward (which in wild habitats could necessitate recording in 360°) would still render visual response counts effectively impossible. Furthermore, jump-yip bouts regularly propagate several hundred metres (Hoogland 1995; pers. obs.) and thus likely include members of different wards. While black-tailed prairie dogs are often described as having a well-developed sense of hearing, comparatively little is known about the physiological limits of the black-tailed prairie dog auditory system. Heffner et al. (1994), for example, described the auditory thresholds of black-tailed prairie dogs, but said little concerning the limits of the auditory system in nature. Consequently, within the parameters of this study, it was impossible to eliminate calls on the basis of non-detectability. Thus it was decided that all responses in the subject bout which were detectable on camera would be included in subsequent analyses.

Counts of the number of respondents (the number of individuals responding) in a jump-yip bout required the visual identification of most, if not all, of the responses in the bout. Acoustic counts of the number of respondents were only performed if one (or more) of the three following conditions were met: only one acoustically-identified call was off-screen (ensuring the independence of respondents), if multiple off-screen, acoustically-identified calls occurred concurrently (again ensuring the independence of respondents), or if the differing position of two or more acoustically-identified off-screen calls could be inferred using obvious, large-scale pitch and intensity differences captured on the video recording. Smith et al. (1976) found little evidence that an individual's jump-yip changed appreciably when produced multiple times, and independence was only inferred in this study when the differences in pitch or intensity were large (i.e. one call was very loud, one call was very soft, and there were no other variables, such as wind, which could have produced the differences). In the event these conditions were not met (i.e. a count of respondents could not be reliably performed) but the rest of the bout characteristics (number of responses, duration, response latency) could be determined, the bout was removed from analyses involving the number of respondents but was still used for analyses involving the remaining bout characteristics.

Temporal measures of the level of response in a jump-yip bout (e.g. the duration of jump-yip bout, the response latency of the jump-yip bout) were obtained by taking the arithmetic mean of two measures obtained using a stopwatch. When recording both the duration of the jump-yip bout and the response latency, timing began as the subject produced the second syllable in the jump yip (theoretically the time at which the individual could begin monitoring the environment, as its head is no longer pointed

skyward and the loudest part of the jump-yip is completed). When recording bout duration, timing was stopped at the end of the second syllable of the final jump-yip in the bout. When recording response latency (both the response latency of the subject bout, as well as the response latency of subject respondents), timing was stopped when the first syllable of the second jump-yip in the bout was completed. It is at this point at which an individual can; 1) identify the multisyllabic nature of the call, 2) assess the frequency characteristics of the first and beginning of the second syllable of the call, and, 3) assess the duration of the first syllable of the call, which, when considered together, likely identify the call as a jump-yip (see Waring 1970; Smith et al. 1976, 1977 for the acoustic characteristics of the vocalizations of black-tailed prairie dogs).

#### Identification of independent jump-yip bouts

To ensure that only the response characteristics of a single jump-yip bout were considered, a criterion was needed to distinguish between one or more independent jump-yip bouts. This was necessary given the complex acoustic environments (which contained frequent jump-yips, alarm calls, and chirps) present for some observational sessions (particularly those occurring in TRNP and WCNP) which obscured the true end of a particular jump-yip bout.

Smith et al. (1976) defined a jump-yip bout as being discrete if more than five seconds elapsed between the end of the bout and the beginning of a second bout. For the purpose of this study, bouts were considered discrete if they were separated by four or more seconds. This slight decrease in interbout interval accounted for two observational sessions in which the subject bout occurred between four and five seconds prior to the

subsequent bout. Because less than 2% of the jump-yip bouts used in this study had average response rates greater than two responses per second, a four second interbout interval should be sufficient to differentiate the end of one bout and the start of another, thereby avoiding overestimating the level of response in the subject jump-yip bout.

### **Jump-yip related behaviour**

#### Time scales for behaviour recording

To assess the relationship between the levels of response in jump-yip bouts and the behaviour of initial callers and respondents in the bouts, three aspects of jump-yip related behaviour were examined for both subject groups: 1) the behaviour of the subject immediately following jump-yip production, 2) the behaviour of the subject over one minute following jump-yip production, and, 3) the changes in the behaviour of the subject from the minute preceding jump-yip production to the minute following jump-yip production. Utilizing three scales of behaviour accounts for the uncertainty regarding what aspects of behaviour may be affected by differences in the response characteristics of the associated jump-yip bout.

The examination of the immediate post-jump-yip behaviour of the subject tests whether a jump-yip bout acts almost instantaneously to determine behaviour. The behaviours exhibited by the subject immediately following jump-yip production are also less likely to be influenced by external factors such as other vocalizations, meteorological factors such as wind, or the presence of other species (including humans) (Hare and Atkins 2001).

The examination of the behaviour of a subject over one minute following jump-yip production examines whether the effects of the subject's jump-yip bout persist and may play a role in (relatively) long-term behavioural decisions. Examining behaviour over a larger scale also addresses whether jump-yip-related behavioural decisions are insensitive to transient environmental or social factors which occur between jump-yip production and the end of the observational period.

This study assumed that individuals exhibit jump-yip-related changes in behaviour regardless of the majority of environmental stimuli present in the environment at the time – i.e. any effects of the signal should supersede, however briefly, other stimuli in the environment, in much the same way alarm calls elicit vigilance regardless of the need to forage at the time (e.g. Waring 1970). They may, however, exhibit certain behavioural tendencies or be sensitive to environmental stimuli which could affect their post-jump-yip behaviour (manifested as artificially low or high levels of vigilance or foraging or a greater propensity to interrupt feeding with vigilance or vice versa, even after a jump-yip bout occurs). By incorporating the behaviour of a subject preceding jump-yip production (i.e. adjusting post-jump-yip behaviours to account for pre-jump-yip tendencies), the examination of post-jump-yip changes in the subject's behaviour accounts for the subject's previous "baseline" behaviour (such as the propensity of an individual to be alert, for example) which may influence the relationships found between the characteristics of the subject's bout and the subject's post-jump-yip behaviour. Incorporating the pre-jump-yip behaviours of the subject also accounts for any persistent confounding effects in the environment (such as distant alarm calls, the nearby presence of conspecifics, cloud cover, mean wind intensities) that could influence the behaviour of

the subject. Because their effects should be relatively constant throughout the trial, they are negated by looking only at the post-jump-yip changes in behaviour, which should only be affected by the characteristics of the jump-yip bout.

The quality of the behaviour recorded (i.e. the duration of continuous recording, the proximity of the onset of behaviour recording to the jump-yip being recorded) determined into which group defined above the observation sessions were included. Immediate post-jump-yip behaviour could only be analyzed if the subject was in focus and close enough to distinguish individual behaviours at the time of its jump-yip. This resulted in the sample sizes of 26 bout initiators and 22 respondents when the immediate post-jump-yip behaviour of subjects was analyzed.

The analysis of subject behaviour over one minute following jump-yip production and measurements of the difference in behaviour exhibited in the minute preceding and the minute following jump-yip production required at least 30 seconds of reliable behaviour identification (differentiation of behaviours and measurements of their durations). The 30 (or more) seconds of behaviour were then standardized to one minute. Of the 173 total jump-yip bouts recorded, 42 were used in the analysis of the behaviour of bout initiators over one minute following jump-yip production, 24 were used in the analysis of post-jump-yip changes in the behaviour of bout initiators, 26 were used in the analysis of the behaviour of respondents over one minute following jump-yip production and 18 were used in the analysis of post-jump-yip changes in behaviour of respondents. By obtaining at least 30 seconds of continuous behaviour, it is less likely that the frequency or duration of certain behaviours would be over-estimated. Furthermore, behaviours were only standardized in 35% of the trials (25/72), with behaviour recorded

for less than 50 seconds in less than 10% of analyzed trials (6/72) so any effect of standardizing behavioural variables should be minimal.

### Recorded behaviours

Four general postures were recorded for the subject individual during each trial (before and after jump-yip production): standing on all four legs (or lying down) with its head below horizontal (S4D), standing on all four legs (or lying down) with its head at or above horizontal (S4U), standing on two legs in a “slouched” position with back curved and neck compressed (BS), and standing on two legs with back straight and neck extended (BA) (Appendix A; see Owings and Virginia 1978; MacWhirter 1992; Hare 1998 for similar classifications of behaviour). For statistical analyses, each recorded behaviour was assigned an ordinal value associated with the level of vigilance incorporated in the behaviour: S4D = 0, S4U = 1, BS = 2, BA = 3. Secondary behaviours, including foraging (grazing, chewing), digging, grooming (self or others), and moving were also noted, and if occurring, caused the subject to assume what I call “occupied” postures (S4Dx, S4Ux, BSx, BAx), which could imply a reduced level of vigilance (Appendix A; Futuyama and Moreno 1988; Leigh 1990; Cuthill and Houston 1997). When an individual was “occupied,” the ordinal “vigilance” value assigned to its behaviour was accordingly decreased by 0.5 to represent this reduction in vigilance.

Each posture was then analyzed alone (i.e. which posture/behaviour is assumed by the subject prairie dog, what proportion of time the individual devotes to each posture) or grouped into two categories – non-vigilant (S4Dx, S4D) and vigilant (S4Ux, S4U, BSx, BS, BAx, BA) – and then analyzed with respect to the frequency with which



vigilant postures were assumed (how often the subject changed its posture to increase its level of vigilance) and the proportion of time the subject spent vigilant (Appendix A).

The frequency of vigilance behaviour exhibited by the subject prairie dog was defined as the number of “head ups” or head lifts (S4D → S4U) per minute (to ensure accurate comparisons could be made between observational sessions, both frequency and proportion-of-time measures were standardized to one minute as described previously) and the number of times the subject increased its vigilance level (S4D → S4U; S4D → BS; S4D → BA; S4U → BS; S4U → BA; BS → BA) per minute (Appendix A).

Because of the established trade-off between foraging and vigilance (Elgar 1989; Lima and Dill 1990), the proportion of time spent foraging was obtained for the subject individual in each recorded jump-yip bout. Foraging time was analyzed both with respect to the distinct components of foraging – active foraging (pulling out grass, feeding on grass/food held in forepaws) and passive foraging (chewing food after it was collected) – and as a whole (time spent foraging by any method or “total” or “general” foraging). When actively foraging, animals devote at least some of their attention to the act of gathering food, including looking down to identify food items and assuming postures suited to food intake (Pulliam 1973; Elgar 1989; Lima and Dill 1990). Passive foraging, on the other hand, can be done with the head raised (pers. obs.), requiring limited attention and allowing the chewing individual to devote some of its senses to vigilant behaviours.

#### Immediate post-jump-yip behaviour

The presence or absence of vigilance behaviour (of any kind) immediately following jump-yip production was tested for both bout initiators and respondents in a

jump-yip bout. Immediate post-jump-yip vigilance might indicate the subject is actively measuring (or is at least more likely to detect) the level of response in their jump-yip bout. To determine whether individuals alter their immediate post-jump-yip vigilance in response to the level of response in their jump-yip bout, their general level of vigilance (S4U, BS, BA, regardless of secondary behaviours) and adjusted level of vigilance (incorporating the 0.5 unit decrease in vigilance when secondary behaviours occur with vigilance; i.e. is the individual in the S4U posture alone or is the subject “occupied”) were both measured immediately following jump-yip production (Appendix A).

Because it is possible that individuals would alter not only their level of vigilance, but also the amount of time they devoted to vigilance in response to the vigilance of neighbours, the amount of time the subject spent vigilant immediately following jump-yip production (which included individuals which may alter their precise behaviour, but still remain vigilant following the production of a jump-yip) was measured (Appendix A). Furthermore, to assess whether certain levels of response in a jump-yip bout could cause individuals to become more prone to changing their behaviour (i.e. become vigilant more quickly despite their initial lack of vigilance), the duration of the subject’s immediate post-jump-yip behaviour (regardless of whether the individual was vigilant or not) was also measured (Appendix A).

These values provide some indication of the immediate effects of a jump-yip bout on the post-jump-yip behaviour of an individual, including how long a vigilant (or non-vigilant) behaviour persists following jump-yip production and whether the effect of a jump-yip bout is immediate or whether it requires some collection and processing time before it has an effect. This is especially true if an individual continually collects

information concerning the jump-yip bout it initiated as it first begins to exhibit post-jump-yip behaviour. By measuring the duration of immediate post-jump-yip behaviours, it is also possible to assess whether individuals base their behaviour on the presence of jump-yips in the environment (i.e. do individuals remain vigilant only as long as their jump-yip bout continues).

#### One minute post-jump-yip behaviour and post-jump-yip changes in behaviour

The same behaviours were measured over the minute preceding and the minute following jump-yip production. This standardized the behavioural measures and allowed the examination of the behaviour of individuals over one minute following jump-yip production as well as the examination of changes in behaviour following jump-yip production.

Individuals alter their vigilance both by devoting more time to vigilance behaviour (e.g. Hoogland 1979) or by interrupting non-vigilant behaviours with vigilant behaviours more often – i.e. by increasing the rate at which they exhibit vigilant behaviours (e.g. Hoogland 1979; Kildaw 1995). Consequently, both the frequency with which each subject performed vigilant behaviours – the number of head lifts per minute and the number of increases in vigilance per minute – and the proportion of time the subject spent vigilant were recorded and examined with respect to the level of response in the subject's jump-yip bout (Appendix A). As described previously, the proportion of time each subject spent actively, passively, and generally (actively and passively combined) foraging in the minute following jump-yip production were also compared to the response characteristics of the subject's jump-yip bout to look for both the expected

inverse relationship between foraging and individual vigilance and the direct relationship between foraging and collective vigilance (Appendix A).

To further determine how individuals may alter the time they devote to specific vigilance behaviours, the proportion of time each subject devoted to each of the individual vigilant behaviours (S4Ux, S4U, BSx, BS, BAx, and BA) was recorded (Appendix A). Separating the overall behaviour of subjects into their constituent behaviours allowed for the examination of the levels of vigilance assumed by each subject, including the lower vigilance levels of “occupied” behaviours and the high levels of vigilance of the bipedal postures.

### **Secondary effects**

While the main focus of this study was to determine whether black-tailed prairie dogs base their vigilance behaviour on information carried by the response characteristics of jump-yip bouts in which they participate, they are also subject to numerous variables in the environment which may also alter their behaviour. Therefore, several “secondary” variables were also measured to examine their relationships with the jump-yip-associated behaviour of black-tailed prairie dogs.

#### Aboveground population size (a social variable)

As aboveground population size is generally identified as the primary affecter of social vigilance (in black-tailed prairie dogs: Hoogland 1979, Kildaw 1995; general review: Elgar 1989), this study attempted to identify effects of the number of neighbouring individuals on the behaviour of subject individuals (Appendix A). Various

methods of defining aboveground population size have been used in studies of vigilance in prairie dogs. Researchers such as King (1955) and Hoogland (1979, 1995) have used prolonged observations of marked individuals to determine the size and social structure of coterie themselves. Given the fact that individuals in this study were unmarked and were only observed for short periods of time, estimating precise coterie size and boundaries was impossible.

Studies specifically dealing with group vigilance in black-tailed prairie dogs have used wards – portions of colonies which are divided from the rest of the colony by natural barriers such as streams or trees – or other isolated groups and peripheral fragments of larger colonies for estimates of functional/relevant population size (King 1955; Kildaw 1995). For the natural populations used in this study, individuals were considered to be a part of a given aboveground population if they resided within borders defined by low population or burrow density. In most cases, this resulted in the population occurring over approximately a 25-30 metre radius. While this estimate of population size is significantly smaller than the total population at any site, I believe this definition of aboveground population size is appropriate as it is consistent with the work of Kildaw (1995), who utilized both isolated colonies (more than two kilometres from nearest individuals) and “peripheral fragments” of larger colonies that were “spatially separated and visually isolated” from the remainder of the larger colonies. Individuals within these borders are also more likely to be identified by an individual as part of the population (less likely to be obstructed or be beyond visual identification) and are more likely to be detected, especially visually, as respondents in a jump-yip bout. Population size estimates

based on this criterion are also reliably obtainable and allow a test of the prairie dogs' responses to variation in local group size.

The “intermediate” population at BPZ was large enough in area to be split into subgroups for population size estimates. Similar to the criteria of Hoogland (1979), each area was delineated by barriers (e.g. deadfall, viewing platform) which pose obstacles to free movement and limit visual (and potentially auditory) cues. FWC and the two “captive” populations (APZ, DZ) were too small in area to divide into subpopulations, so complete aboveground population counts were used.

While defining aboveground population size as above is reasonable (and allows population size to be measured and used as a variable), because response counts in the subject bouts were not limited to individuals in close proximity to the subject, comparisons of the effects of aboveground population size and the level of response in the subject bout are limited in their relevance (since they occur on two different scales). It may be possible, however, to identify the confounding (but not jump-yip-related) effects of local aboveground population size.

#### “Secondary” vocalizations

In all habitats, and particularly in wild habitats, black-tailed prairie dogs experience a highly complex acoustic environment in which auditory information occurs in the form of noises produced by humans (including the sounds of passing vehicles), the vocalizations of other species, and the vocalizations of conspecifics, including alarm calls and jump-yips (Waring 1970; Smith et al. 1977; Hoogland 1995). Of particular importance are the vocalizations of conspecifics (“secondary vocalizations”) which

occurred before or after a subject jump-yip bout, since information encoded in the calls of nearby individuals could be detected by “eavesdropping” individuals and used to determine their subsequent behaviour. Because of their importance in this study, the vocalizations of conspecifics and their relationships with the behaviour of the subject were examined (Appendix A).

The presence of secondary vocalizations in an environment could provide novel information to a listening individual, resulting in that individual altering its behaviour accordingly. If such a vocalization occurred after a jump-yip bout, the behaviour-determining effects of that bout could be affected, depending upon how much time had elapsed between the jump-yip bout and the subsequent vocalization. Consequently, in this experiment, the time at which the first post-subject-bout vocalization (jump-yip, alarm call, chirp) that was not part of the subject bout (the first post-subject, non-subject vocalization; Appendix A) occurred in the environment was recorded and analyzed with respect to the behaviour of the subject individual. As the time between the subject bout and the subsequent vocalization increased, the confounding effects of the subsequent vocalization on the behaviour of the subject individual should decrease.

All black-tailed prairie dog vocalizations were recorded in the minute preceding and the minute following the onset of the subject jump-yip bout. Secondary jump-yip bouts were counted and their response characteristics recorded in the manner described above for measuring the response characteristics of the subject jump-yip bout, with two exceptions. First, because the secondary jump-yip bouts occurred off camera, the responses in the bouts were counted acoustically. Second, because responses were

counted acoustically, counts of respondents could not be performed, since there was no way to determine the identity and independence of callers in the bouts. The duration of the bouts and their response latencies, however, were measured as they were in the subject jump-yip bouts. Ultimately, the number of jump-yip bouts and the total number of jump-yips were measured for both the minute preceding (“pre-subject”) and the minute following (“post-subject”) the subject jump-yip bout, as were the average number of responses in, the average duration of, and the average response latency of the pre- and post-subject bouts (Appendix A).

As the prevalence of “threatened” vocalizations – alarm calls and chirps (single syllable vocalizations thought to be akin to barks) (Waring 1970; Smith et al. 1977; Hoogland 1995) – present in the environment increases, surrounding individuals should become more vigilant. While the focus of this study on the jump-yip precluded studying the characteristics of these vocalizations in depth, simple measures of the presence of these vocalizations were obtainable. Thus, the amount of time alarm calls were present in the environment in both the minute preceding and the minute following the subject jump-yip bout were also recorded for all subjects, as was the number of single chirps occurring before and after the subject bout (Appendix A). These variables may provide some information concerning the “threat level” of the subject’s colony, and thus the subject’s propensity to become vigilant.

### Physical factors

Black-tailed prairie dog behaviour may also be affected by physical factors, including temporal and environmental variation present in this study. While physical



factors were not explicitly measured when the observational sessions occurred, several variables, including two temporal variables – time of year (month and day) and time of day – and three environmental variables – cloud cover, wind (intensity/regularity), and habitat type, were quantifiable following the analysis of the recorded jump-yip bouts.

### *Temporal variables*

Seasonal and daily variability in the behaviour of not only the black-tailed prairie dogs studied in the experiment, but also their predators and other species inhabiting the same locations, necessitated the inclusion of time of year and time of day as variables in this experiment. The time of year at which each observational session occurred was defined as the day (Julian date) on which the subject jump-yip occurred (Appendix A). Behavioural differences associated with breeding season, day length, and other seasonal effects (foraging differences, age distribution within colonies), may be evident when time of year is considered.

While most observational sessions occurred 2-3 hours after dawn or 2-3 hours before dusk, differences in black-tailed prairie dog activity associated with the time of day at which the subject jump-yip occurred may have affected the results of this study (e.g. King 1955). The time of day was recorded at the time of each subject jump-yip bout (defined as the fraction of the hour at which the subject bout occurred; Appendix A). For the observational sessions which occurred at TRNP and BPZ, however, time of day was not recorded by the experimenter, nor was it available from the time stamp on the videotape. Thus, the sample sizes used in the analyses of the effects of time of day on behaviour were reduced accordingly (initial caller:  $n = 19$  for immediate post-jump-yip

behaviour, n = 31 for one-minute post-jump-yip behaviour, n = 17 for post-jump-yip change in behaviour; respondent: n = 19 for immediate post-jump-yip behaviour, n = 23 for one-minute post-jump-yip behaviour, n = 16 for post-jump-yip change in behaviour).

### *Environmental variables*

Efforts were made to ensure that observation sessions occurred under agreeable environmental conditions. Observational sessions occurred throughout the year, but were confined to months in which the daytime temperature (i.e. the temperature during the trial) never dropped below 0°C. While precise temperature measurements were not taken at all sites, temperatures ranged from approximately 1-2°C at Theodore Roosevelt National Park in November to approximately 15-18°C at Assiniboine Park Zoo and Fort Whyte Centre in August and September, values lying well within the range of temperatures at which black-tailed prairie dogs are active (Hoogland 1995). Because temperature effects are generally associated with month (especially in this experiment), effects of temperature should be apparent when time of year is considered as a variable.

Precipitation levels during all observational sessions were zero, with no sessions occurring within three hours following rain/sleet/snow. Therefore, precipitation was not considered as an environmental variable. At TRNP, where observational sessions occurred later in year (and at higher latitudes than those in BPZ), some snow cover was present, though it was minimal (0-5 cm) and not expected to have had a major effect on behaviour, as black-tailed prairie dogs are active throughout the winter months (Hoogland 1995).

In the absence of a precise means to measure weather data at each site, variation in cloud cover and wind intensity were assigned ordinal values based on estimates made using visual and audio evidence from the behavioural recordings (Appendix A). With respect to cloud cover, a value of 0 represented a clear sky or wispy, thin clouds, a value of 1 represented a partly cloudy (thick clouds) or hazy sky, while a value of 2 represented a completely cloudy sky.

With respect to wind, a value of 0 represented a calm day, a value of 1 represented an intermittent breeze (between 5 and 10s of constant wind with interspersed calm periods of approximately 30 or more seconds) accompanied by some movement of trees (if present), a value of 2 represented either a regular breeze which was relatively constant (calm periods of no more than 5-10 seconds) or strong gusts of wind lasting 10-15 seconds (with intermittent periods of calm) which sounded very loud on camera or caused extensive tree/grass movement, and a value of 3 represented constant (loud) wind and periods of calm lasting no more than approximately 5 seconds with constant tree movement.

As described previously, the six locations at which behavioural data were obtained were subdivided into three major habitat types: “wild” habitats, where prairie dogs feed off natural vegetation and have no artificial boundaries to movement and expansion (TRNP, WCNP), “captive” habitats, where prairie dogs are enclosed by a wall or fence and are fed by humans (DZ, APZ), and “intermediate” habitats, where prairie dogs live in a fenced enclosure, but feed on natural vegetation (BPZ, FWC). For statistical analyses, these populations were assigned ordinal values based on the level of “captivity” of each habitat: “wild” habitats = 0, “intermediate” habitats = 1, and “captive”

habitats = 2 (Appendix A). Though all habitat types were exposed to the unregulated presence of humans during the observational sessions, black-tailed prairie dog behaviour (including jump-yip structure and associated behaviour) is well conserved in captive populations (Smith et al. 1976) and is minimally affected by the presence of people (Smith et al. 1973). Furthermore, efforts were made to limit observational sessions to times in which the effects of nearby humans were minimal (e.g. during non-peak hours at zoos, before and after typical vacation times at national parks), rendering human-related disturbances relatively equal and thus not biased toward any one habitat type. Because the different habitat types impose different predatory and nutritional pressures (i.e. captive populations may be provided extensive food and experience very little risk of predation), contain different numbers of individuals as well as different population densities, and despite all efforts, may experience different levels of human interference, habitat type was explicitly considered as a potentially-confounding variable.

### **Data analysis**

All data (response characteristics of jump-yip bouts, behaviour of subject individuals, aboveground population size, social variables, and physical factors) were tabulated using Excel spreadsheet software (Microsoft Corp., Redmond, Wash.). Statistical analysis was performed using SPSS statistical software (SPSS Inc., Chicago, Ill.). Statistical significance for all tests was defined at  $\alpha = 0.05$ . In this study, however, statistical results achieving  $P = 0.10$  were also identified as relationships/differences of interest since they could become statistically significant if confounding factors were more rigorously controlled.

A post hoc examination of the data obtained revealed that certain groups of data (e.g. Table 27 – the effect of wind intensity on the immediate post-jump-yip behaviour of bout initiators, among others) consisted of only three or four data points, while many of the statistical tests were performed on data sets of highly variable size (e.g. Table 19 – the effect of cloud cover on the immediate post-jump-yip behaviour of bout initiators, among others). In cases such as this, where the sample sizes of data sets are highly variable and where data are sparse in certain groups, “typical” asymptotically-derived *p*-values may be inaccurate (Mehta and Patel 1996). Instead, exact tests, based on Fisher’s exact test for 2×2 contingency tables (Zar 1984; Mehta and Patel 1996), were therefore used to obtain more accurate *P*-values.

Exact tests eliminate the assumption of asymptotic tests that a particular dataset is representative of a population by calculating every possible distribution of data in a population and determining the probability (the “exact *P*-value”) that the observed dataset and any “more extreme” datasets occur in the population (Mehta and Patel 1996). Because exact tests do not rely on any assumptions about a particular dataset, the resultant *P*-value is 100% accurate regardless of the distribution or sparseness of a particular set of data (Mehta and Patel 1996). Owing to the complexity of the permutations required to determine the exact *P*-values of particular datasets, however, even computer programs may have difficulty in performing the necessary calculations – SPSS may take hours to perform exact tests on particularly large data tables and in some cases may simply be unable to determine exact *P*-values (Mehta and Patel 1996). Consequently, in this experiment, Monte Carlo tests were performed on each Mann-Whitney and Kruskal-Wallis test run to obtain more accurate *P*-values.

Rather than calculating every possible distribution of data in a population, the Monte Carlo test calculates a random subset of all datasets which could be obtained from a population, providing a more accurate estimate of the exact *P*-value of a population than obtained through the asymptotic method (Mehta and Patel 1996). Though not 100% accurate like the exact tests, Monte Carlo tests are approximately 99% accurate when run in the SPSS statistical program, and their reduced running time permitted the use of Monte Carlo tests in each non-parametric test performed in this study (Mehta and Patel 1996).

#### Characteristics of jump-yip bouts and the behaviour of jump-yipping individuals

A chi-square goodness-of-fit test was used to determine if a greater than expected number of individuals assumed vigilance postures following jump-yip production (in the absence of an effect of jump-yipping on black-tailed prairie dog vigilance, we would expect to see an equal number of individuals being vigilant and non-vigilant immediately following jump-yip production). Two-sided, non-parametric Spearman's rank correlations, corrected for ties, were used to look for relationships between the response characteristics of the subject jump-yip bout and the behaviour of both bout initiators and respondents in a bout for all three temporal scales: immediately following jump-yip production, over one minute following jump-yip production, and the changes in behaviour following jump-yip production (Seigel 1956; Zar 1984).

The number of responses in the subject jump-yip bout and the duration of the subject jump-yip bout were also considered as discrete variables (rather than on a continuum) for certain analyses. While the number of responses in the subject bout were

inherently discrete, the durations of the subject bouts were rounded to the nearest whole second (calls less than 0.5 s were rounded to 0 s, calls between 0.5 s and 1.5 s were rounded to 1 s, etc.). The behaviour of each subject was compared between bouts containing each of five levels of response (response/duration) – 0 responses/seconds, 1 response/second, 2 responses/seconds, 3 responses/seconds, and 4 or more responses/seconds – and between low (0 responses/seconds and/or 1 response/second, depending on whether the groups were large enough to be tested statistically) and high (4+ responses/seconds) levels of response. Kruskal-Wallis tests were used to test for differences in behaviour between all five response categories, while Mann-Whitney tests were used to look for differences in behaviour between the low (0 responses/seconds and/or 1 response/seconds, as above) and high (4+ responses/seconds) response groups (and were also used in the multiple levels of response test if only two groups were large enough to test) (Zar 1984).

#### Secondary effects and the behaviour of jump-yipping individuals

Two-sided, non-parametric Spearman's rank correlations were used to examine relationships between both aboveground population size and all social variables (time of first post-subject, non-subject vocalization; measures of secondary jump-yips; secondary alarm calls and chirps) and the behaviour of the subject individual for all three temporal scales. They were also used to examine the relationships between the temporal variables measured in this study (time of year, time of day) and the behaviour of the subject individuals (Seigel 1956; Zar 1984).

The effects of cloud cover, wind, and habitat on the behaviour of subject individuals was analyzed using either Mann-Whitney (two groups) or Kruskal-Wallis (three or more groups) tests, depending on the number of testable groups present for each variable (Zar 1984). Thus, if the sample sizes of each of the three levels of cloud cover measured are large enough to allow statistical tests to occur, a Kruskal-Wallis test was used. If only two levels of cloud cover could be statistically tested (due to insufficient sample sizes under other levels of cloud cover), a Mann-Whitney test was used.

### Autocorrelations

For each of the six study groups in this experiment (the behaviour of bout initiators over three temporal scales and that of respondents over three temporal scales), two-sided, non-parametric Spearman's rank correlations were used to test for relationships within (i.e. autocorrelations) each of the groups of variables measured in this experiment – the response characteristics of the subject bouts, the behaviour of subject individuals, social variables, and temporal variables. They were also used to test for relationships between the response characteristics of the subject bout and: 1) aboveground population size, 2) social variables, and, 3) temporal variables; and between aboveground population size and: 1) social variables, and, 2) temporal variables; and between social variables and temporal variables.

For each of the six study groups in this experiment, Mann-Whitney and/or Kruskal-Wallis tests were used to examine differences in: 1) the response characteristics of the subject bout, 2) aboveground population size, 3) social variables, and, 4) physical variables when subject bouts occurred under: 1) different levels of cloud cover,



2) different wind intensities, and, 3) in different habitats. As was the case for the tests on the effects of environmental factors on the behaviour of subject individuals, whether a Mann-Whitney test or a Kruskal-Wallis test was utilized depended upon the number of testable groups for each environmental variable.

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## RESULTS

### Effects of jump-yip bout characteristics on the behaviour of bout initiators

#### Immediate post-jump-yip behaviour

Individuals who initiated a jump-yip bout were significantly more likely to assume vigilant postures immediately following jump-yip production ( $n = 26$ ,  $\chi^2 = 15.385$ ,  $P < 0.001$ ). No relationships were evident, however, between the response characteristics of a jump-yip bout and the immediate post-jump-yip behaviour of the initial caller in the bout (Appendix B; Table B.1). Likewise, no significant differences in the immediate post-jump-yip behaviour of the initial caller in a jump-yip bout were found between bouts consisting of different numbers of responses (Appendix B; Table B.2) or of different durations (Appendix B; Table B.3), regardless of whether comparisons of behaviour were made following all recorded levels of response (e.g. no response, one response, two responses, etc.) or just between bouts with high and low levels of response (e.g. one response and four or more responses; Appendix B; Table B.2, B.3).

#### One-minute post-jump-yip behaviour

No relationships (at  $\alpha = 0.05$  or  $0.10$ ) were found between the response characteristics of a jump-yip bout and the behaviour of the initial caller in that bout over one minute following jump-yip production (Appendix B; Table B.4). The post-jump-yip behaviour of the initial caller in a jump-yip bout was also not significantly different between bouts with different numbers of responses, whether all responses or just high and low numbers of response were considered (Appendix B; Table B.5). Initial callers in

jump-yip bouts did, however, spend more time actively foraging (Fig. 1;  $U = 30.5$ ,  $P = 0.082$ ) and generally foraging (Fig. 2;  $U = 31.5$ ;  $P = 0.095$ ) when there were four or more responses in the subject bout compared to when there was only one response in the bout, though the differences were only statistically significant at  $\alpha = 0.10$  (Appendix B; Table B.5). Bout initiators also spent significantly more time in a bipedal-alert posture following bouts of longer duration (Fig. 3;  $\chi^2 = 12.721$ ,  $P = 0.022$ ), though no difference in post-jump-yip behaviour were observed following bouts of short (zero and one seconds) and long (four or more seconds) duration (Appendix B; Table B.6).

#### Changes in behaviour following jump-yip production

No relationships (at  $\alpha = 0.05$  or  $0.10$ ) were found between the response characteristics of a jump-yip bout and the change in behaviour of the initial caller in that bout from the period prior to jump-yip production to the minute following jump-yip production (Appendix B; Table B.7). Post-jump-yip changes in the behaviour of bout initiators following jump-yip production also did not differ significantly when the jump-yip bouts they initiated contained different numbers of responses (Appendix B; Table B.8). When jump-yip bouts lasting approximately one second and those lasting approximately four or more seconds were compared, however, bout initiators increased their rate of head lifting after bouts of approximately one second and decreased their rate of head lifting following bouts lasting four or more seconds ( $U = 4.0$ ,  $P = 0.092$ ; Fig. 4, Appendix B; Table B.9) Post-jump-yip changes in the behaviour of jump-yip bout initiators did not differ significantly between bouts of different duration when bouts of all recorded durations were considered (Appendix B; Table B.9).

Figure 1: Effect of the number of responses in a jump-yip bout on the proportion of time the initial caller in the jump-yip bout spent actively foraging in the minute following jump-yip production ( $\bar{x} + SE$ ) (\* denotes significant difference at  $\alpha = 0.10$ ).

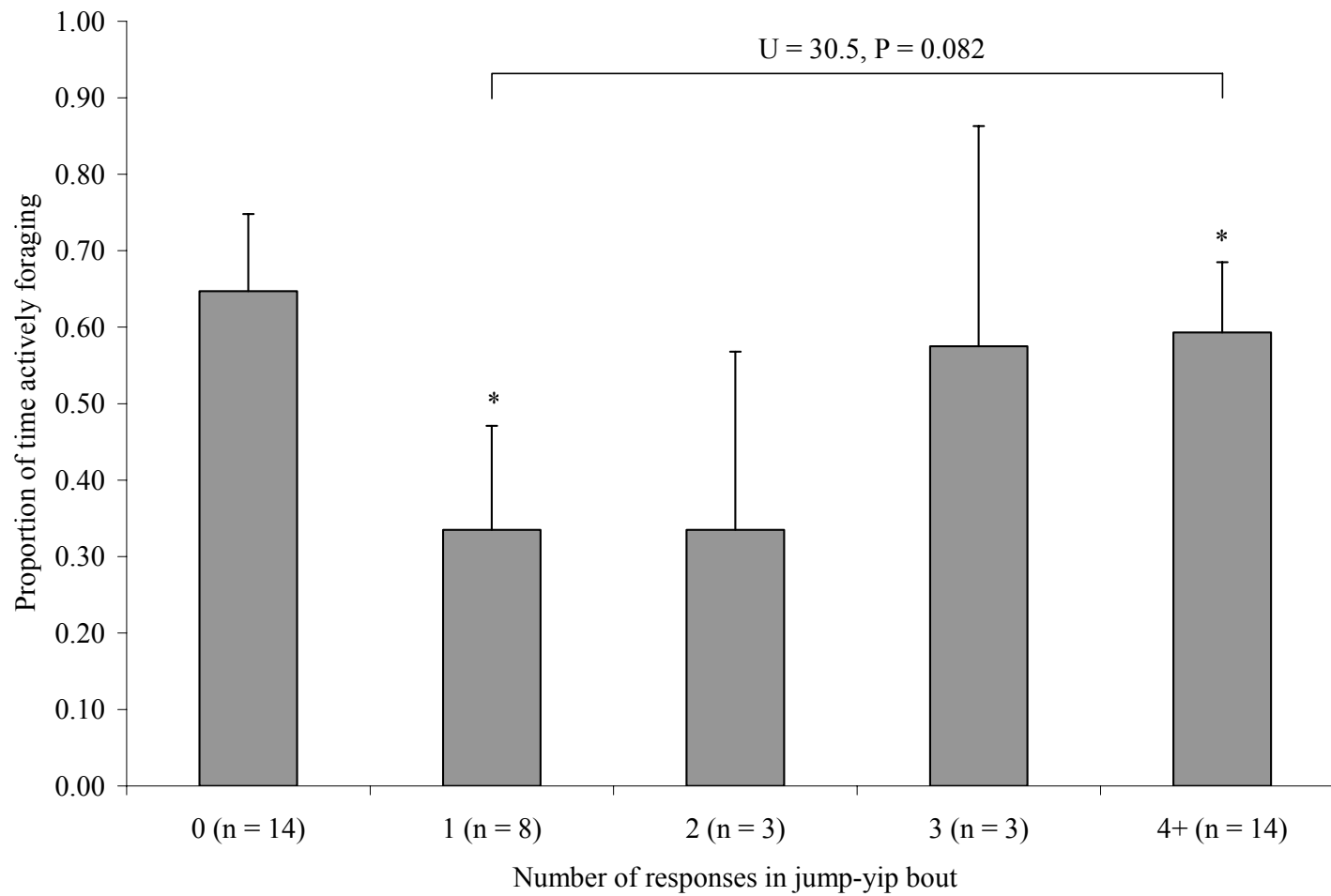


Figure 2: Effect of the number of responses in a jump-yip bout on the proportion of time the initial caller in the jump-yip bout spent foraging in the minute following jump-yip production ( $\bar{x} + SE$ ) (\* denotes significant difference at  $\alpha = 0.10$ ).

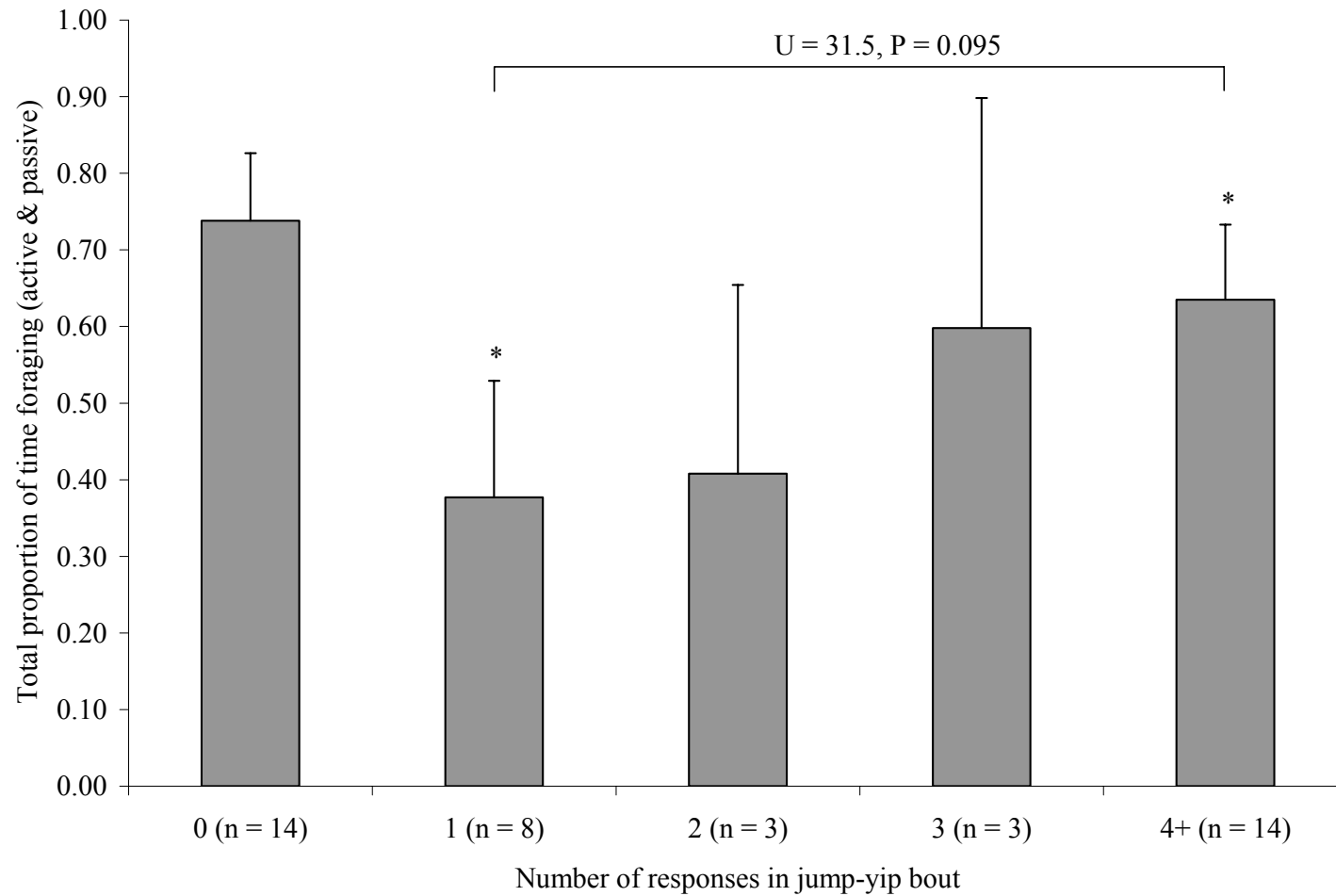


Figure 3: Effect of the duration of a jump-yip bout on the proportion of post-jump-yip time the initial caller in the jump-yip bout spent in the bipedal-alert posture ( $\bar{x} + SE$ ).

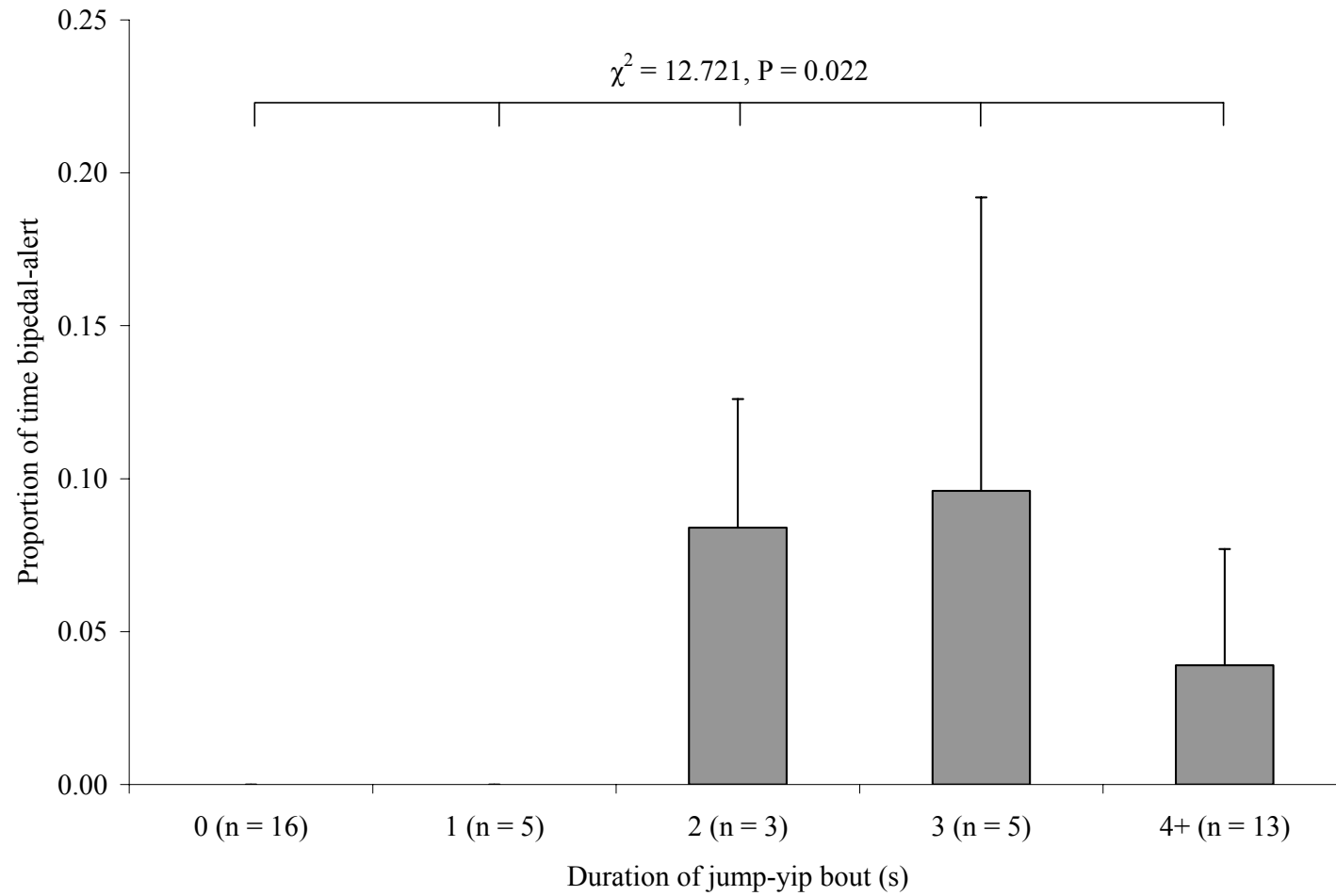
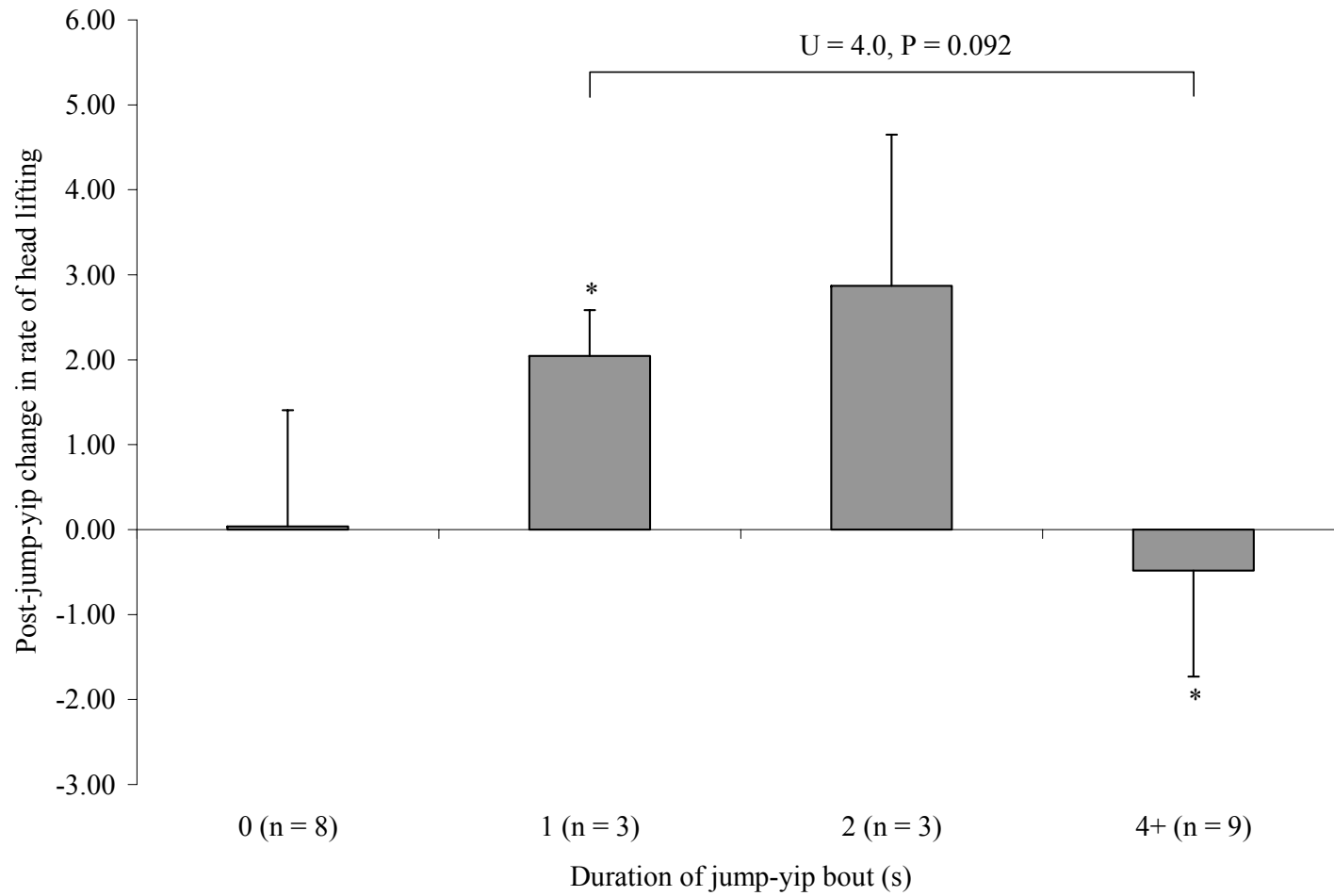




Figure 4: Effect of the duration of a jump-yip bout on the difference in the number of head lifts per minute ( $\bar{x} \pm$  or  $-$  SE) performed by the initial caller in the bout before and after jump-yip production (\* denotes significant difference at  $\alpha = 0.10$ ).



## **Effects of jump-yip bout characteristics on the behaviour of respondents**

### Immediate post-jump-yip behaviour

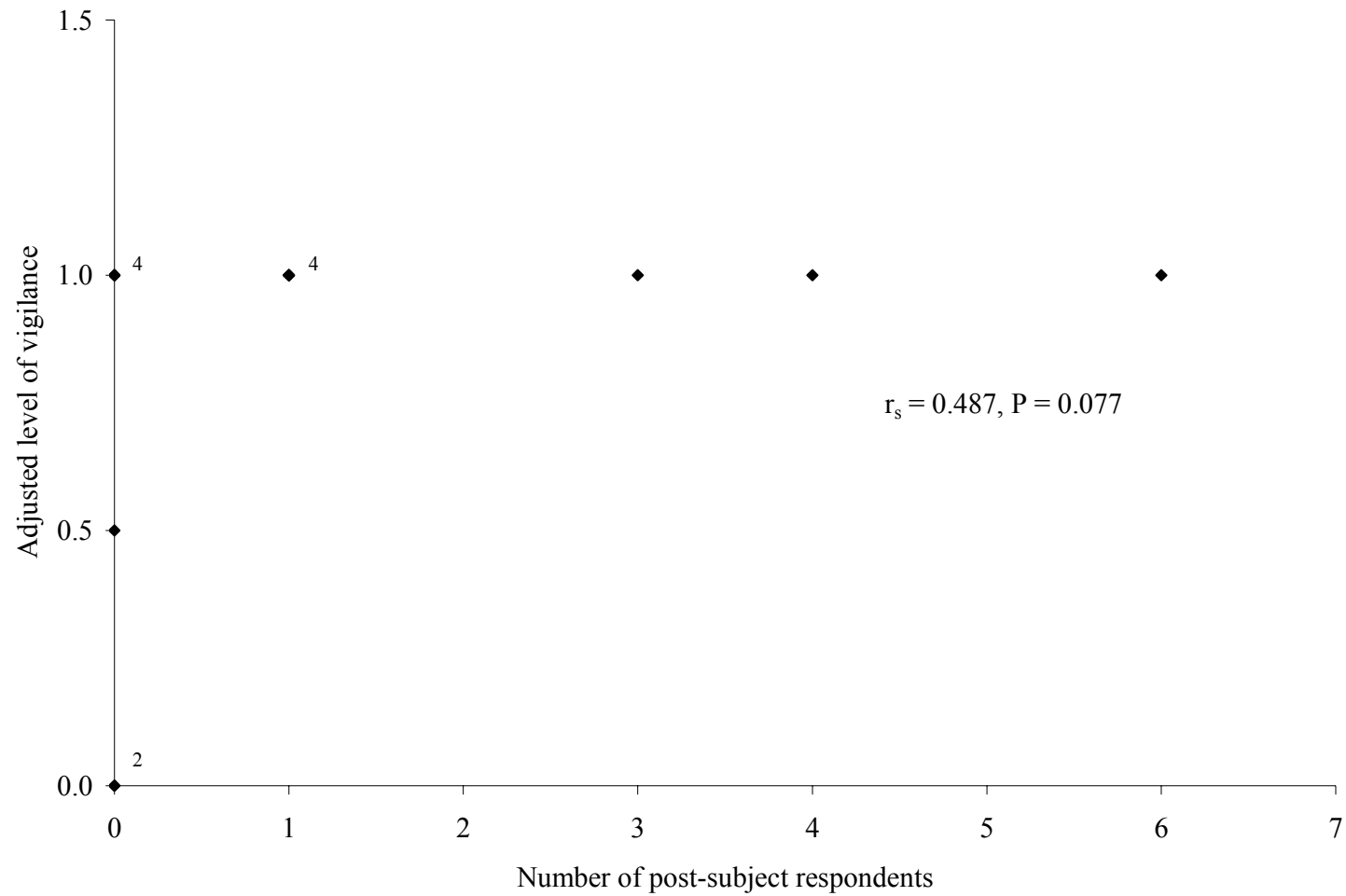
Individuals who responded to a jump-yip (were part of a jump-yip bout) were significantly more likely to assume vigilant postures immediately following jump-yip production than to be non-vigilant immediately following jump-yip production ( $n = 22$ ,  $\chi^2 = 11.636$ ,  $P = 0.001$ ). These individuals, however, only increased their adjusted level of immediate post-jump-yip vigilance with increases in the number of respondents found after their own jump-yip (“post-subject respondents;” Fig. 5;  $n = 14$ ,  $r_s = 0.487$ ,  $P = 0.077$ ). They did not vary their immediate post-jump-yip behaviour with changes in the duration or response latency of the subsection of the subject jump-yip bout beginning with their jump-yip, nor did they vary their immediate post-jump-yip behaviour with changes in the characteristics of their entire jump-yip bout (Appendix B; Table B.10).

Respondents did not exhibit significantly different immediate post-jump-yip behaviour when the section of the subject bout beginning with their jump-yip contained different numbers of responses (Appendix B; Table B.11) or lasted for different durations (Appendix B; Table B.12). Respondents also did not exhibit different immediate post-jump-yip behaviour when the bouts in which they were respondents contained different numbers of responses (Appendix B; Table B.13) or persisted for different durations (Appendix B; Table B.14).

### One-minute post-jump-yip behaviour

Respondents in a jump-yip bout decreased the proportion of time they spent bipedally-alert in the minute following jump-yip production with increases in both the

Figure 5: Relationship between the number of post-subject respondents in a jump-yip bout and the adjusted level of vigilance of the subject respondent in the bout immediately following its jump-yip (n = 14) (# indicates number of overlapping data points).



number of responses in (Fig. 6;  $n = 26$ ,  $r_s = -0.352$ ,  $P = 0.078$ ) and the duration of (Fig. 7;  $n = 26$ ,  $r_s = -0.351$ ,  $P = 0.079$ ) the section of the subject jump-yip bout beginning with their vocalization (“post-subject” characteristics; Appendix B; Table B.15). Respondents also reduced the proportion of post-jump-yip time they spent bipedally-alert as the number of responses in their entire jump-yip bout increased (Fig. 8;  $n = 26$ ,  $r_s = -0.393$ ,  $P = 0.047$ ), and decreased the proportion of time they spent both in a bipedal-slouched posture (Fig. 9;  $n = 26$ ,  $r_s = -0.345$ ,  $P = 0.084$ ) and in a bipedal-alert posture (Fig. 10;  $n = 26$ ,  $r_s = -0.342$ ,  $P = 0.087$ ) as the duration of their entire jump-yip bout increased. As the response latency of the entire subject bout increased, respondents increased the proportion of time they spent both quadrupedal with their head up (Fig. 11;  $n = 26$ ,  $r_s = 0.419$ ,  $P = 0.033$ ) and generally vigilant (Fig 12;  $n = 26$ ,  $r_s = 0.377$ ,  $P = 0.058$ ), while decreasing the total proportion of time they devoted to foraging (Fig. 13;  $n = 26$ ,  $r_s = -0.430$ ,  $P = 0.028$ ) in the minute following jump-yip production.

Respondents did not exhibit significantly different behaviour in the minute following jump-yip production when the section of their bout that began with their jump-yip contained different numbers of responses (Appendix B; Table B.16) or persisted for different durations (Appendix B; Table B.17). The behaviour of respondents over the minute following jump-yip production also did not differ significantly when their entire jump-yip bout contained different numbers of responses (Appendix B; Table B.18). They did, however, spend significantly more post-jump-yip time in a bipedal-slouched posture when their entire jump-yip bout lasted approximately two seconds than when it lasted approximately one second or four or more seconds (Fig. 14;  $\chi^2 = 10.189$ ,  $P = 0.040$ ). There was no difference in the proportion of

Figure 6: Relationship between the number of post-subject responses in a jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26) (# indicates number of overlapping data points).

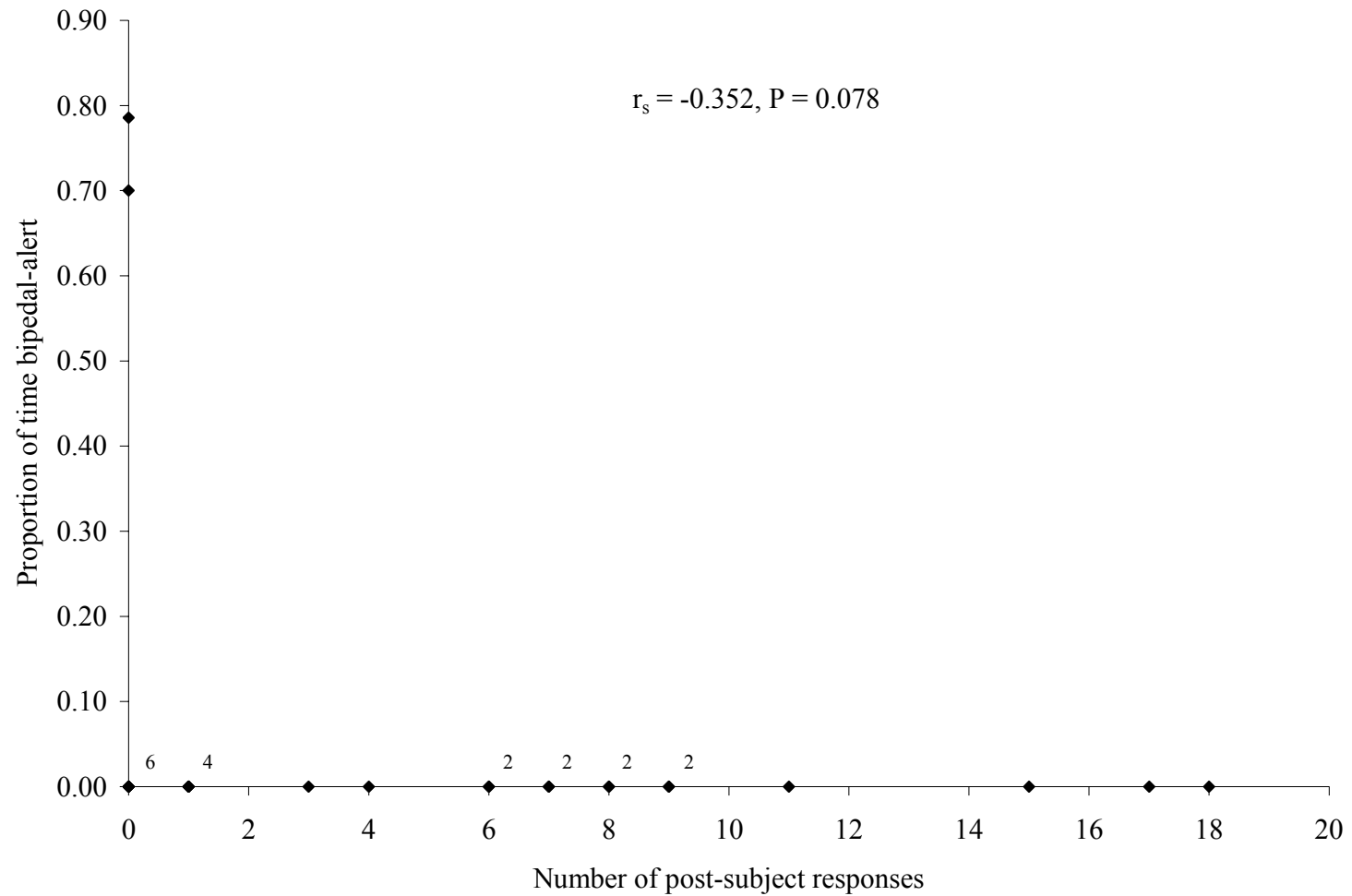


Figure 7: Relationship between the post-subject jump-yip bout duration and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).

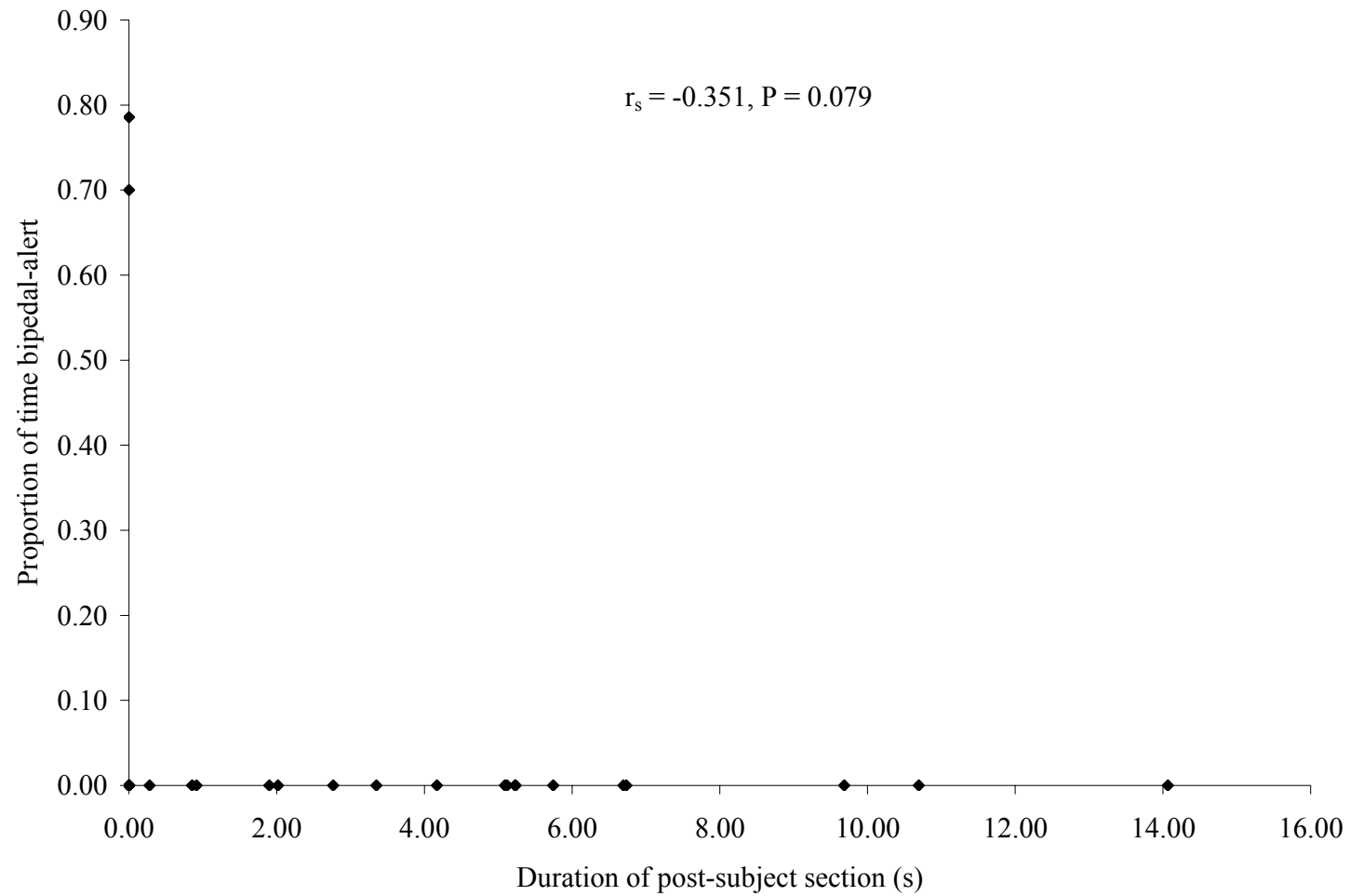


Figure 8: Relationship between the number of responses in an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).

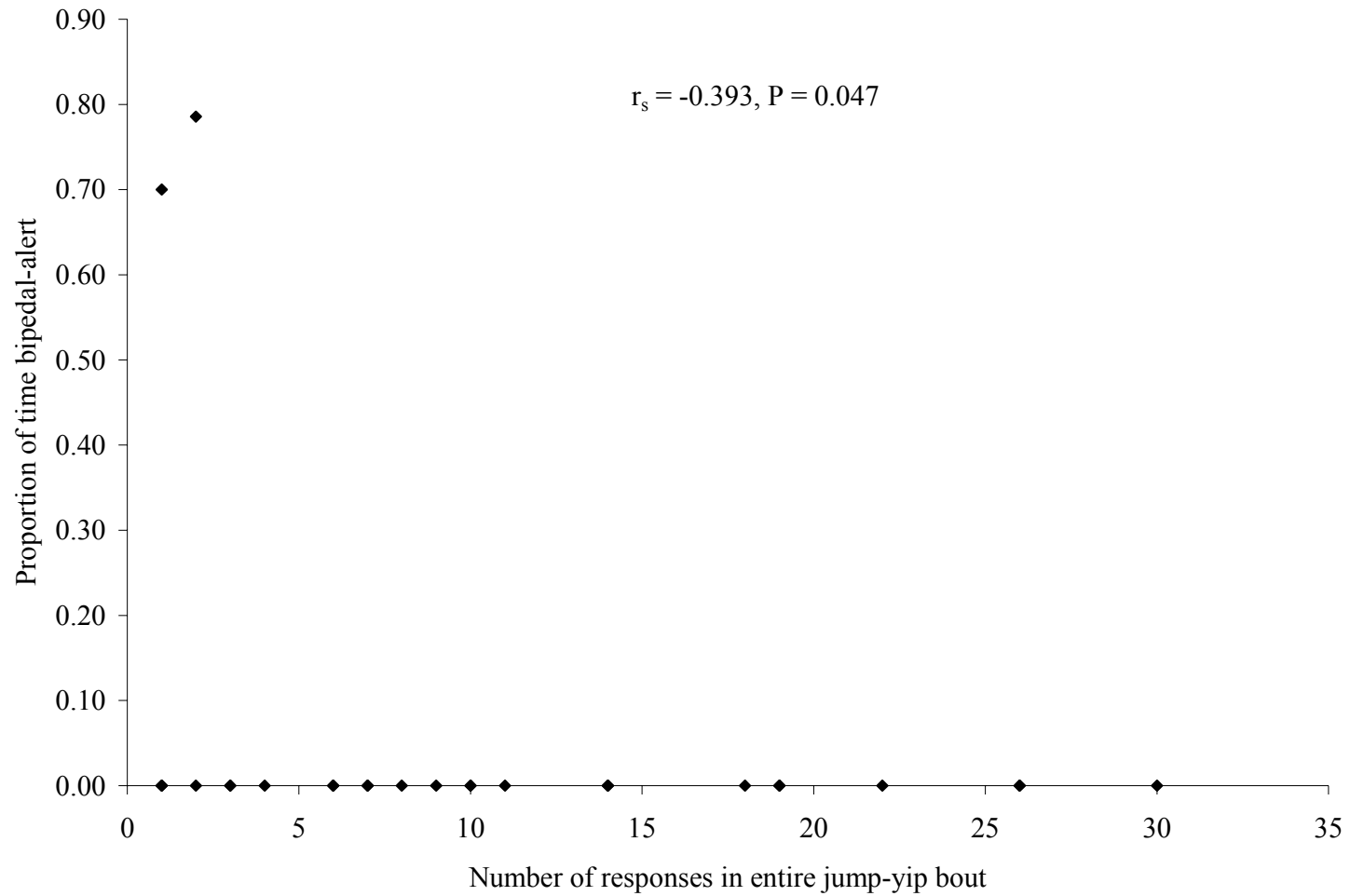


Figure 9: Relationship between the duration of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-slouched posture (n = 26).

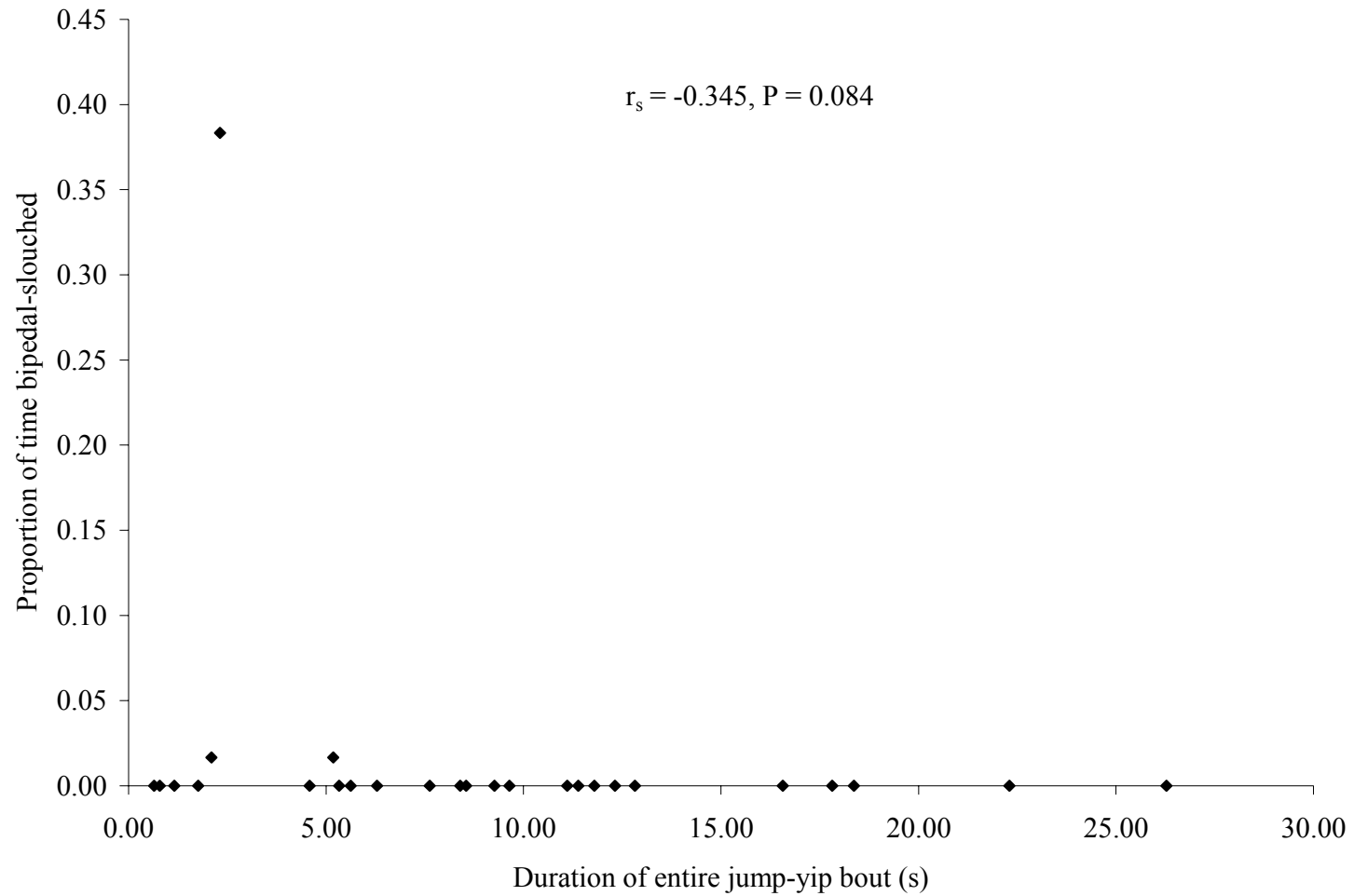




Figure 10: Relationship between the duration of an entire jump-yip bout and the proportion of post jump-yip time a respondent in the bout spent in a bipedal-alert posture (n = 26).

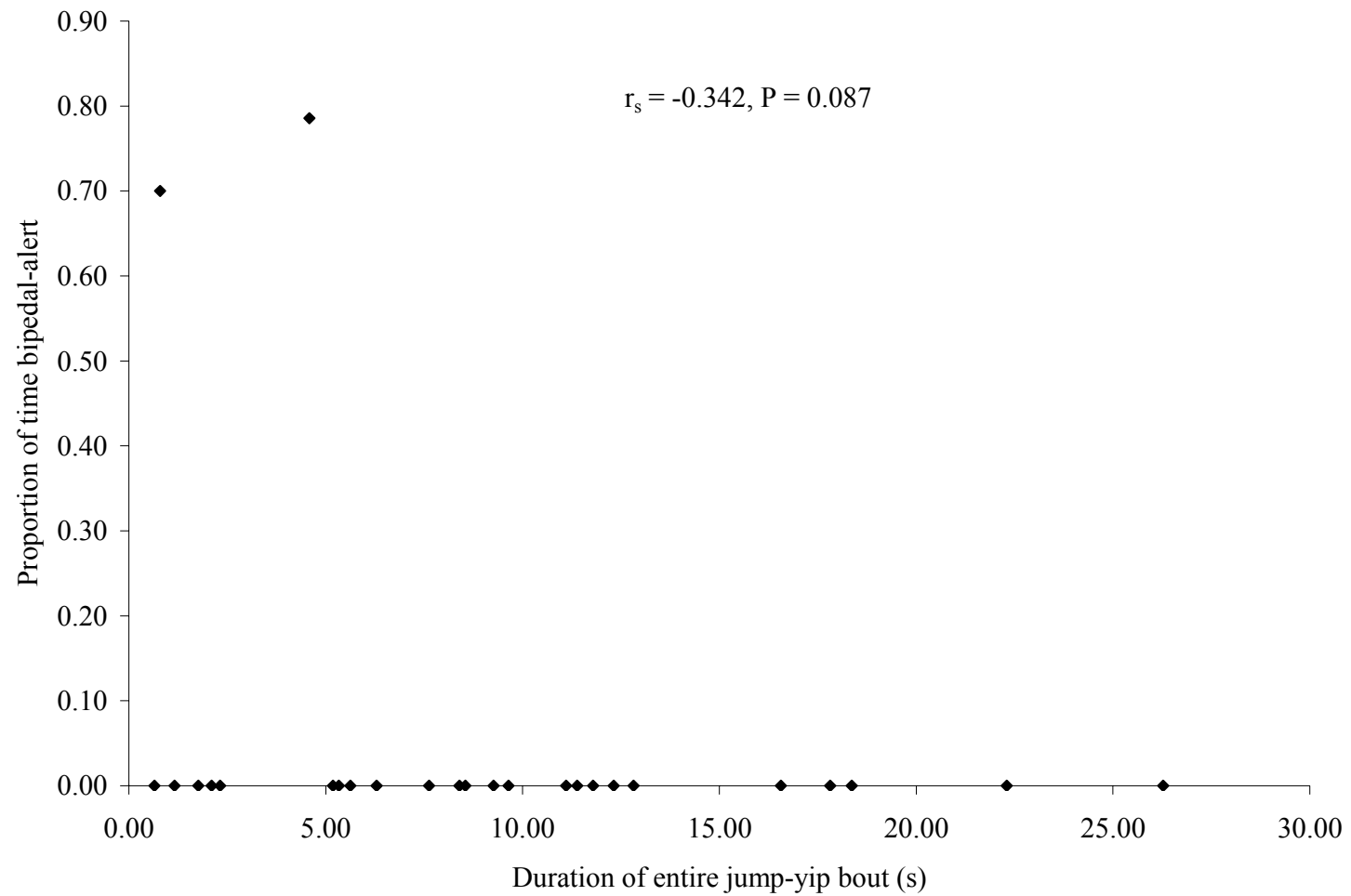


Figure 11: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent quadrupedal with its head up (n = 26).

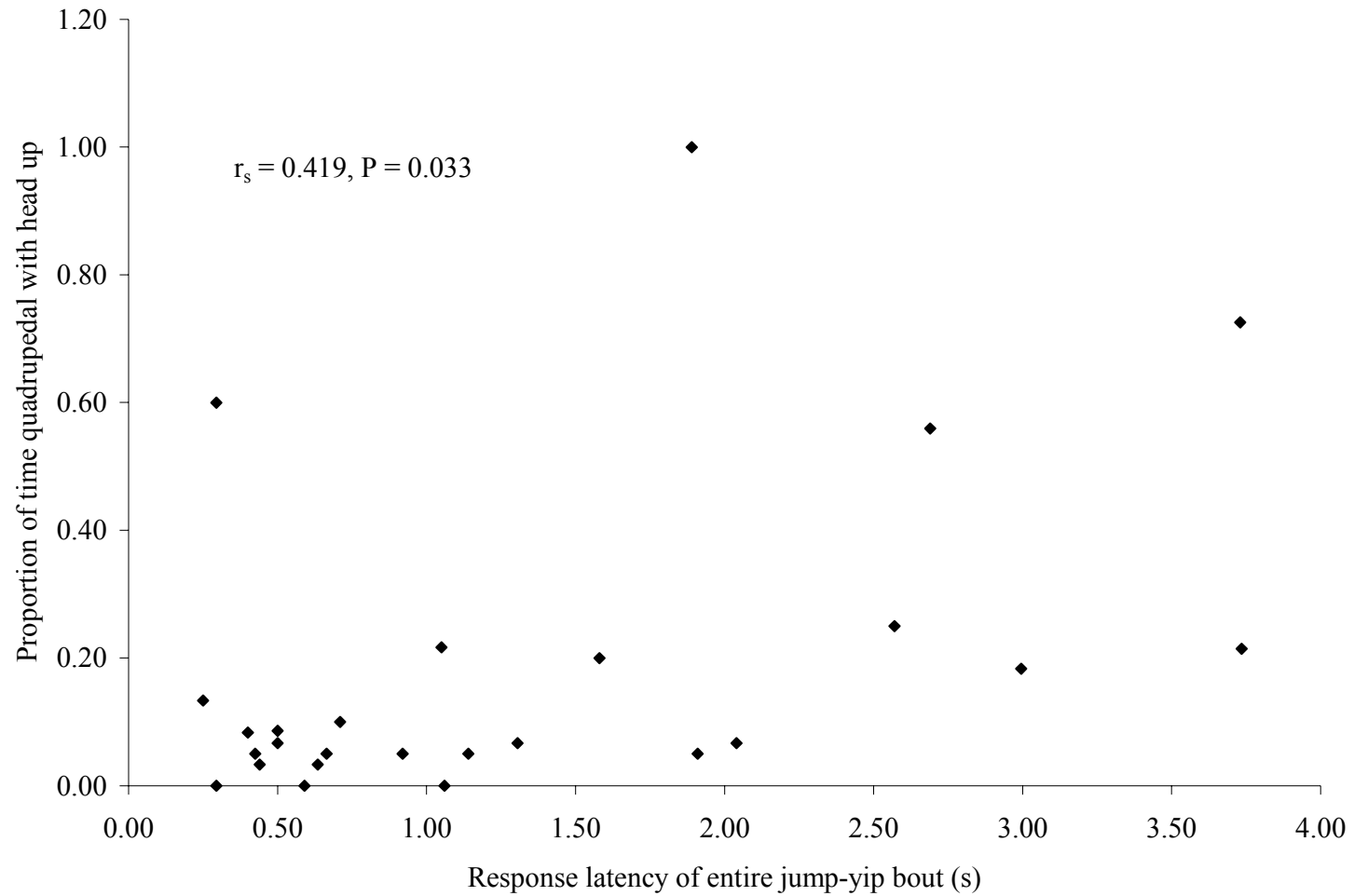


Figure 12: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent vigilant (n = 26).

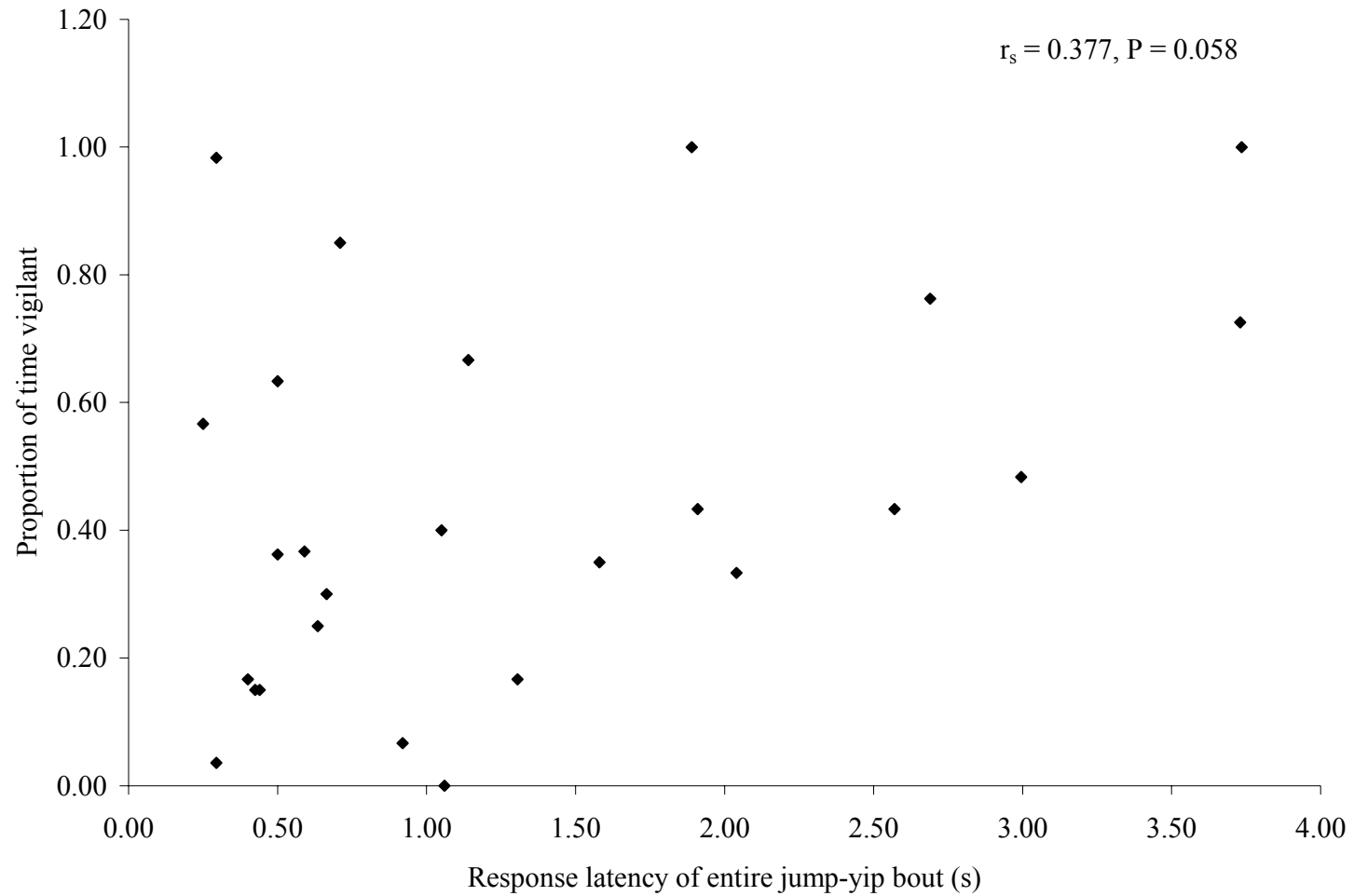


Figure 13: Relationship between the response latency of an entire jump-yip bout and the proportion of post-jump-yip time a respondent in the bout spent foraging (n = 26).

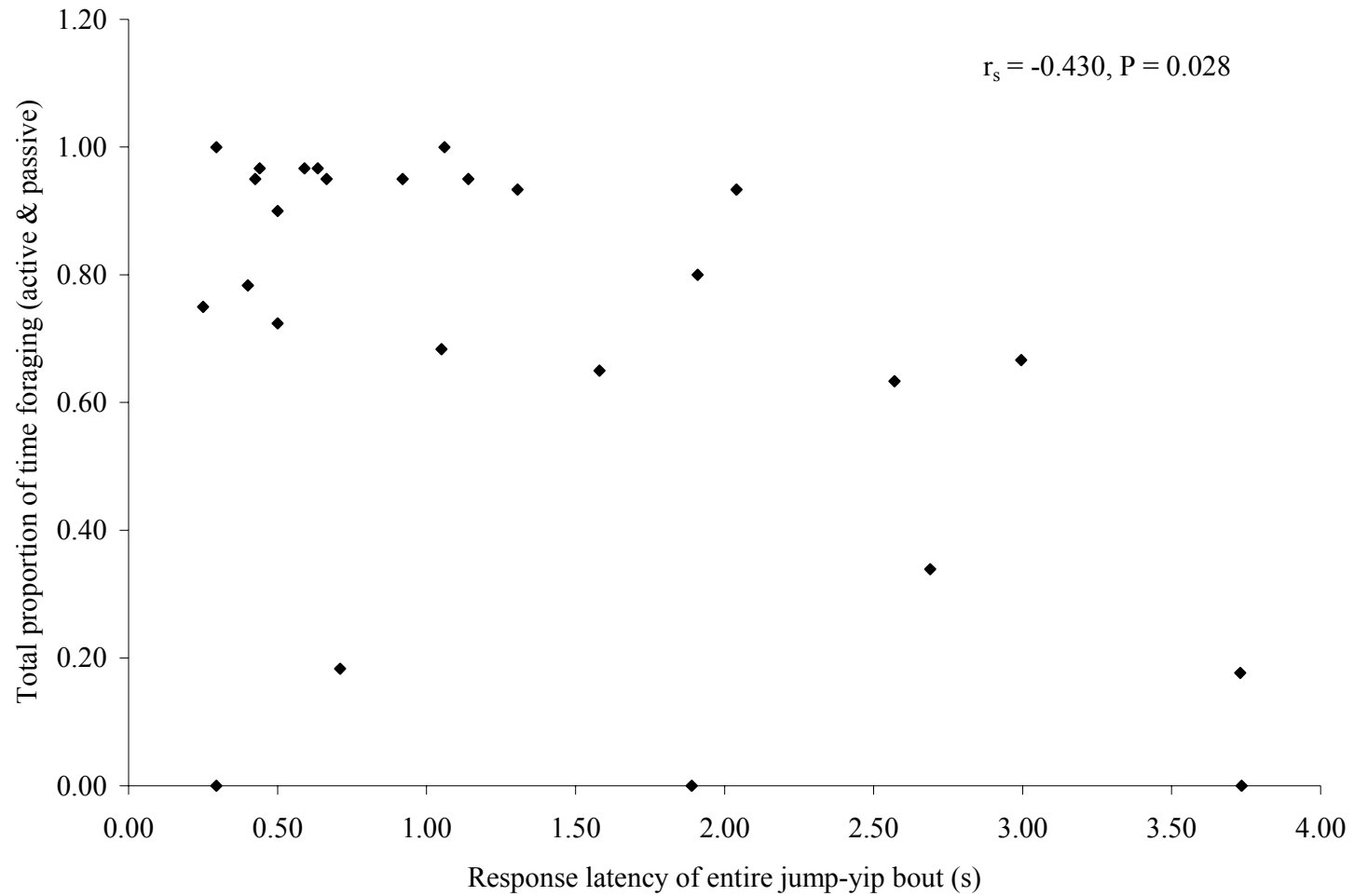
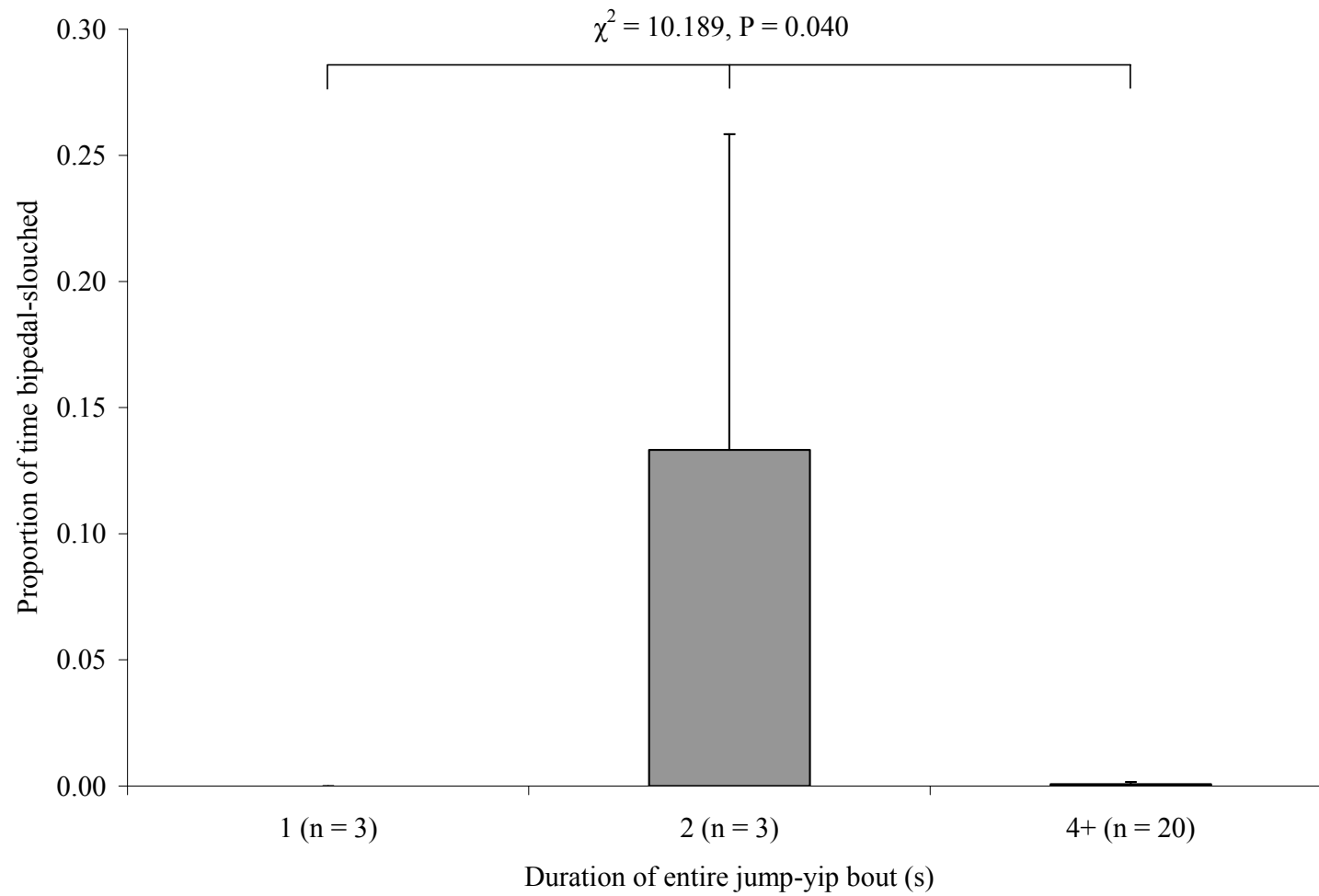


Figure 14: Effect of the duration of an entire jump-yip bout on the proportion of post-jump-yip time a respondent in the bout spent in a bipedal-slouched posture ( $\bar{x} + SE$ ).



post-jump-yip time respondents devoted to bipedal-slouched postures between short (1 s) and long (4+ s) bouts (Appendix B; Table B.19).

#### Changes in behaviour following jump-yip production

Respondents in a jump-yip bout exhibited greater post-jump-yip increases in the proportion of time they spent actively foraging between the minute preceding and the minute following jump-yip production as: 1) the number of responses in (Fig. 15;  $n = 18$ ,  $r_s = 0.445$ ,  $P = 0.064$ ), 2) the number of respondents in (Fig. 16;  $n = 10$ ,  $r_s = 0.686$ ,  $P = 0.029$ ), and, 3) the duration of (Fig. 17;  $n = 18$ ,  $r_s = 0.478$ ,  $P = 0.045$ ) the section of their jump-yip bout which began with their jump-yip increased (Appendix B; Table B.20). Respondents also exhibited greater post-jump-yip increases in the rate they lifted their head (Fig. 18;  $n = 10$ ,  $r_s = 0.572$ ,  $P = 0.084$ ) and increased their level of vigilance (Fig. 19;  $n = 10$ ,  $r_s = 0.573$ ,  $P = 0.083$ ) as the number of respondents following their jump-yip increased, though both correlations only achieved statistical significance at  $\alpha = 0.10$  (Appendix B; Table B.20). An increase in the latency of response between the subject respondent's jump-yip and the subsequent call in their jump-yip bout was associated with a decrease in the post-jump-yip change in the total proportion of time the respondents spent generally (actively and passively) foraging (Fig. 20;  $n = 11$ ,  $r_s = -0.592$ ,  $P = 0.055$ ), though the correlation was only statistically significant at  $\alpha = 0.10$  (Table B.20; and upon removal of the apparent outlier at latency = 2.67s, the correlation became non-significant even at  $P = 0.10$ :  $r_s = -0.468$ ,  $P = 0.172$ ). Respondents did not vary their post-jump-yip changes in behaviour with changes in the characteristics of their entire jump-yip bout (Appendix B; Table B.20).

Figure 15: Relationship between the number of post-subject responses in a jump-yip bout and the difference in the proportion of post-jump-yip time a respondent in the bout spent actively foraging before and after jump-yip production (n = 18).

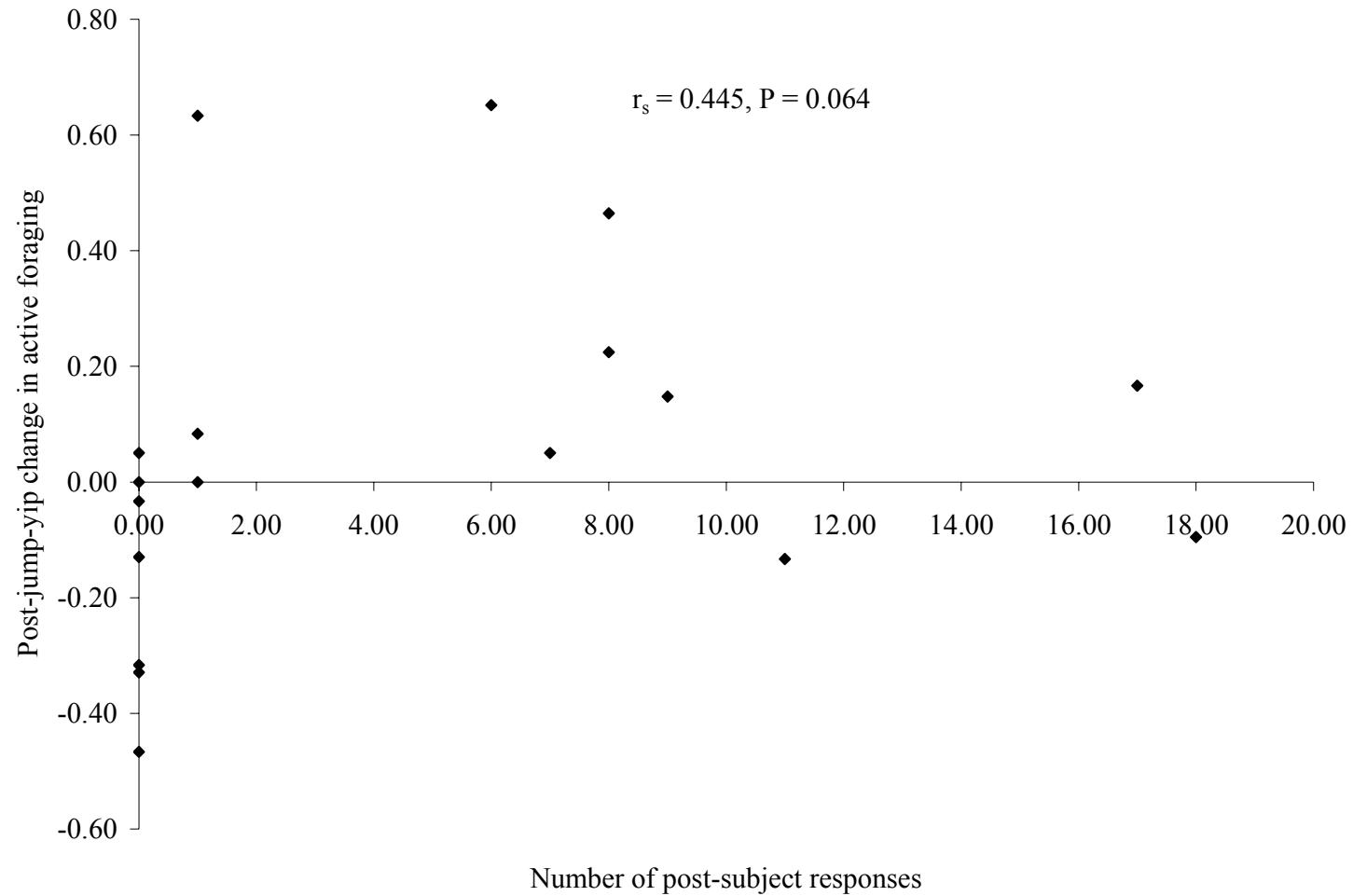


Figure 16: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the proportion of time a respondent in the bout spent actively foraging before and after jump-yip production (n = 10).

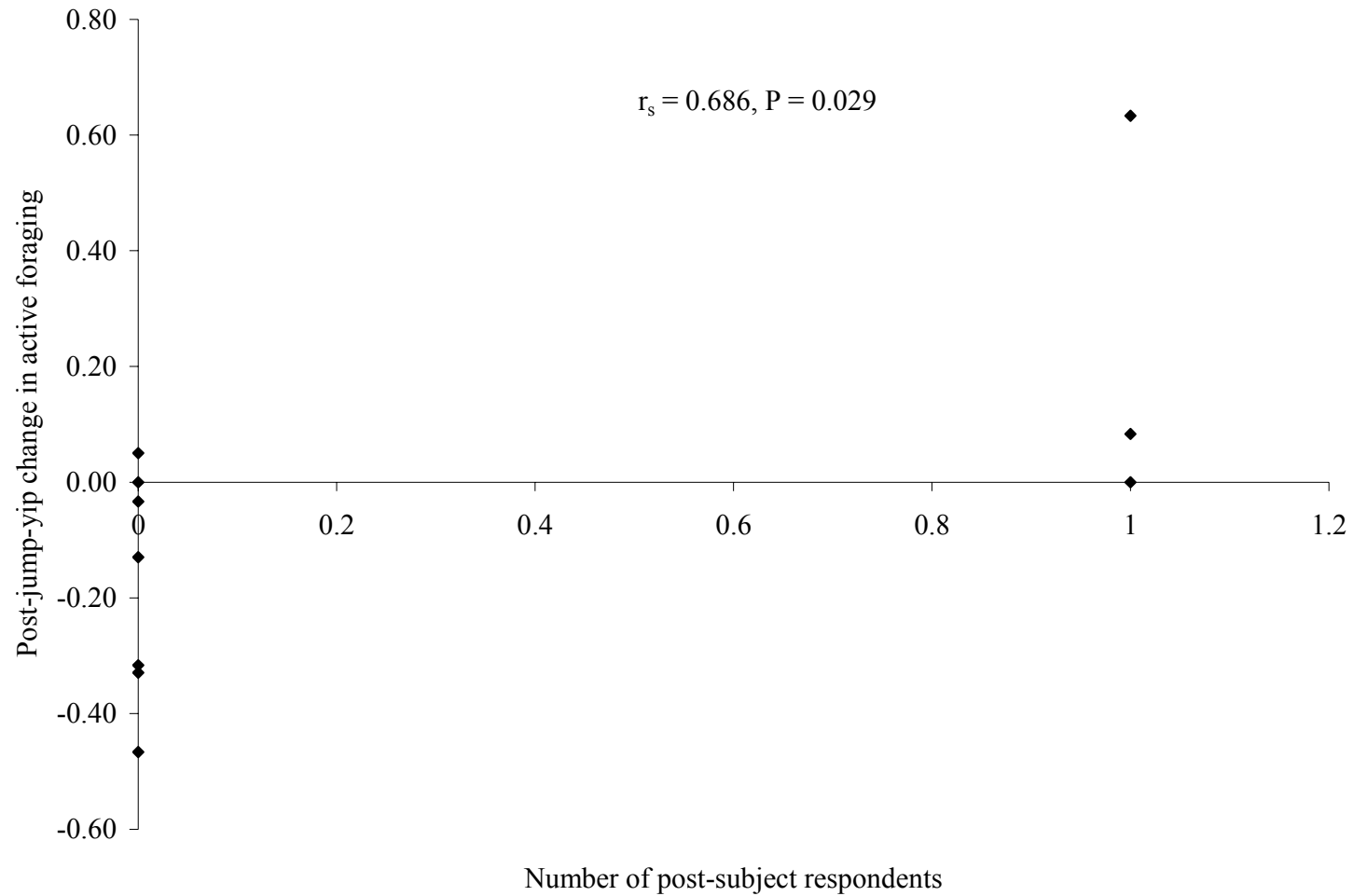




Figure 17: Relationship between the post-subject jump-yip bout duration and the difference in the proportion time a respondent in the bout spent actively foraging before and after jump-yip production (n = 18).

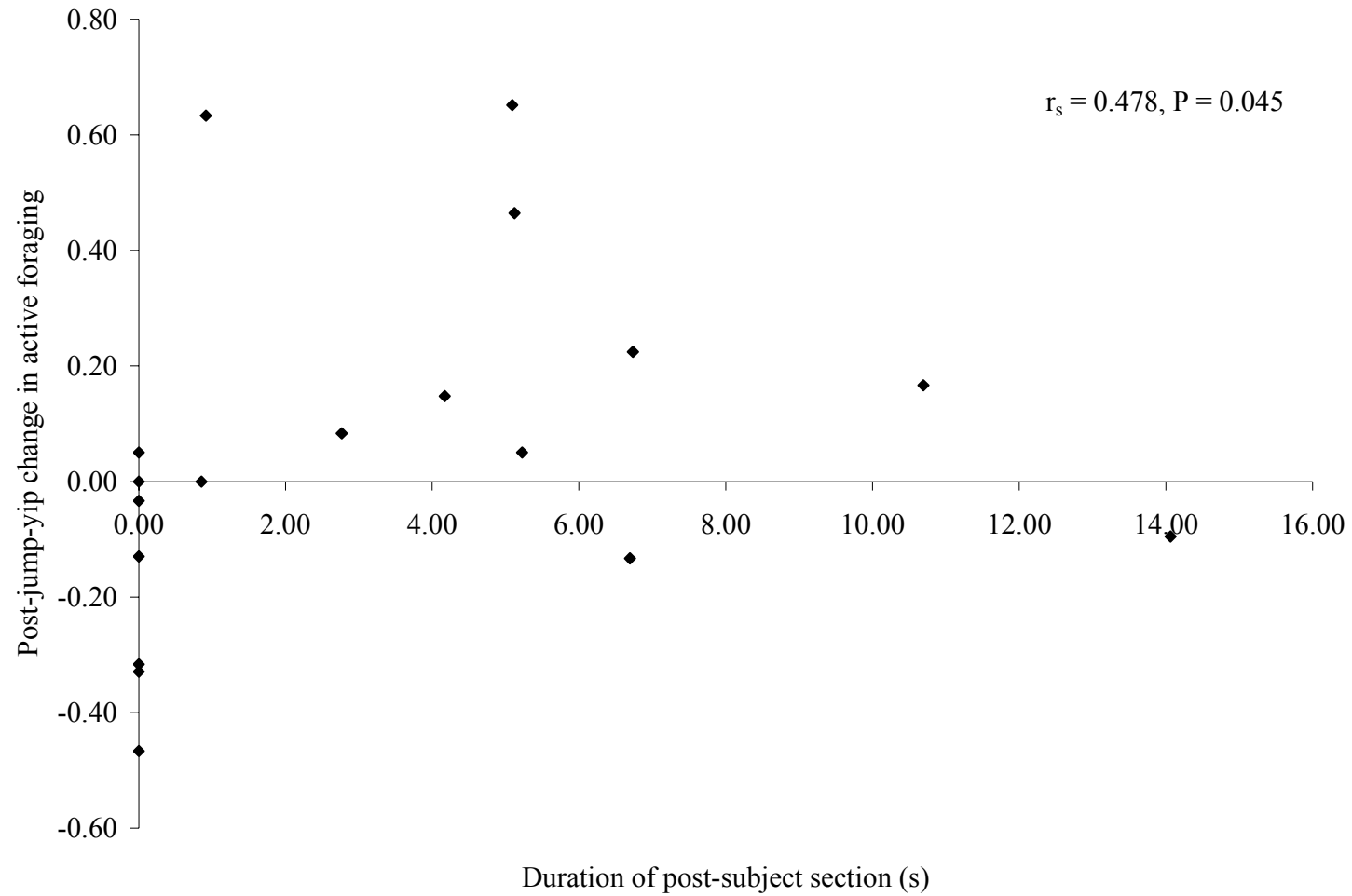


Figure 18: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the rate at which a respondent in the bout lifted its head before and after jump-yip production (n = 10).

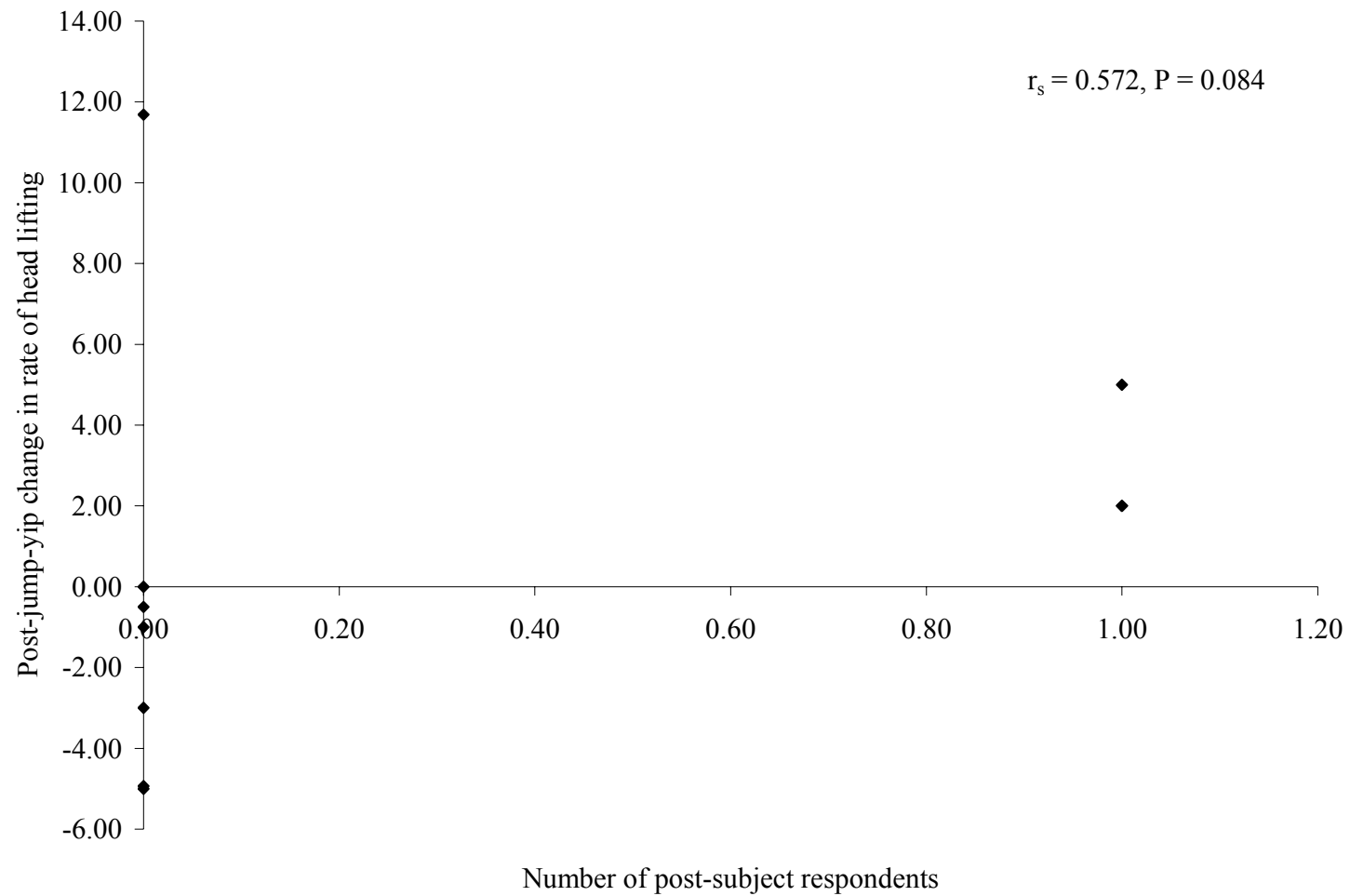


Figure 19: Relationship between the number of post-subject respondents in a jump-yip bout and the difference in the rate at which a respondent in the bout increased its level of vigilance before and after jump-yip production (n = 10).

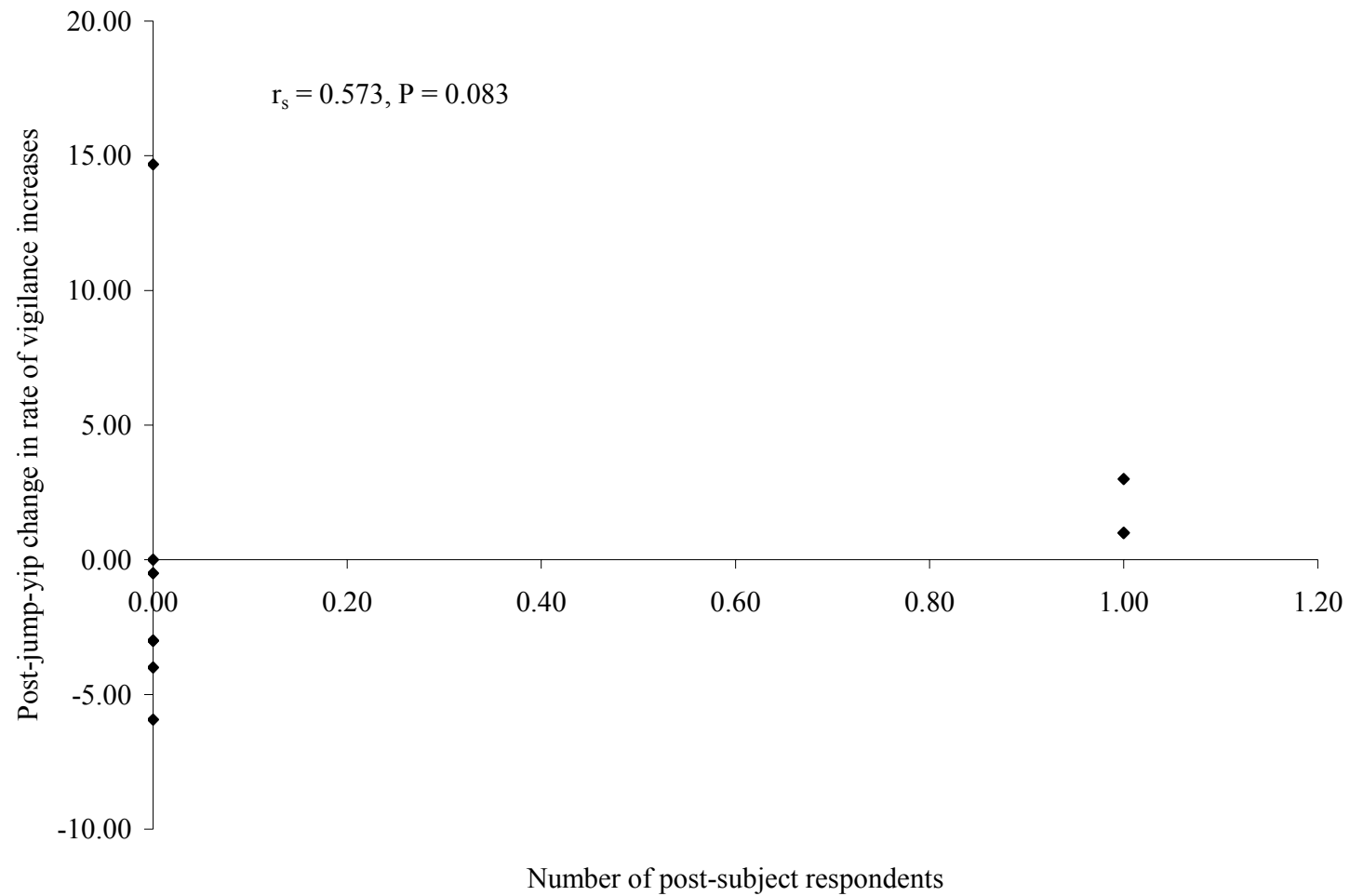
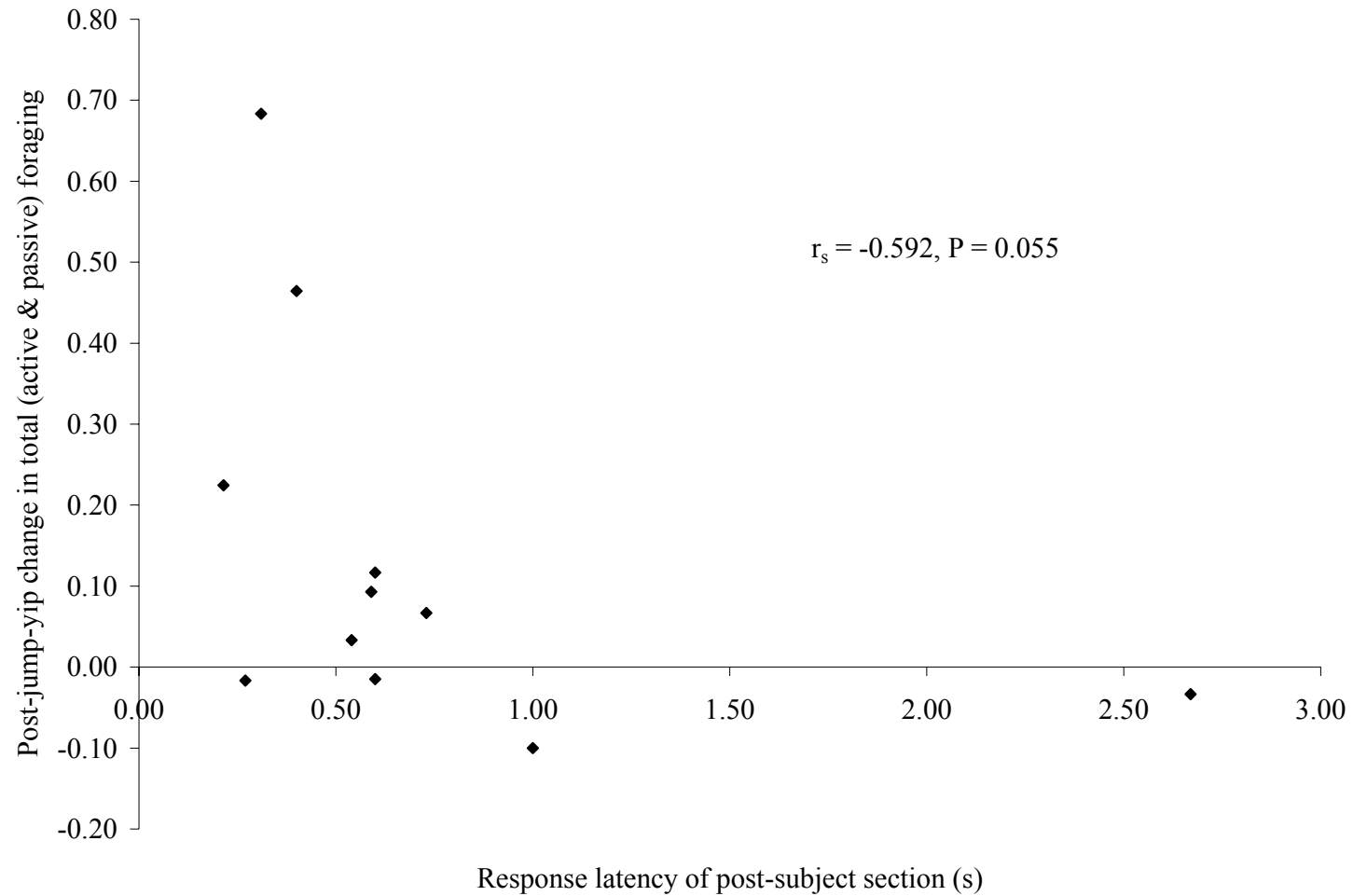


Figure 20: Relationship between the post-subject response latency (latency between the subject's jump-yip and the subsequent jump-yip) of the subject bout and the post-jump-yip change in the proportion of time the subject spent foraging (n = 11).



Respondents exhibited post-jump-yip increases in the proportion of time they devoted to vigilant behaviours when their jump-yip was followed by no more responses (i.e. they were the last jump-yip in their bout) and when there was one response in the section of their bout beginning with their jump-yip, but exhibited post-jump-yip decreases in the time they devoted to vigilance when there were four or more responses in their section of the jump-yip bout (Appendix B; Table B.21). The difference in vigilant behaviour was only significant, however, between sections of jump-yip bouts containing no responses (low response) and those containing four or more responses (high response) (Fig. 21;  $U = 12.5$ ,  $P = 0.072$ ). Conversely, respondents decreased the proportion of time they spent actively foraging after jump-yip bouts in which their jump-yip was followed by no responses while they increased the proportion of time they spent actively foraging after bouts in which their jump-yip was followed by both one or four or more jump-yips (Appendix B; Table 21). These post-jump-yip changes in behaviour were significantly different when each bout type (zero, one, and four or more responses) were considered ( $\chi^2 = 7.168$ ,  $P = 0.017$ ) and when only bouts with zero responses and four or more responses ( $U = 7.5$ ,  $P = 0.011$ ) were compared (Fig 22; Appendix B; Table B.21). Respondents also decreased the total proportion of time they spent foraging after jump-yip bouts in which they were the final vocalization and increased the proportion of time they spent foraging following bouts in which there were one or four or more responses after their jump-yip (Appendix B; Table B.21). In this case, only the difference in post-jump-yip changes in the total proportion of time respondents spent foraging between bouts containing zero post-subject responses and

Figure 21: Effect of the number of responses in the section of a jump-yip bout following a respondent's display on the post-jump-yip change in the time that respondent spent vigilant ( $\bar{x} +$  or  $-$  SE) (\* denotes statistical significance at  $\alpha = 0.10$ ).

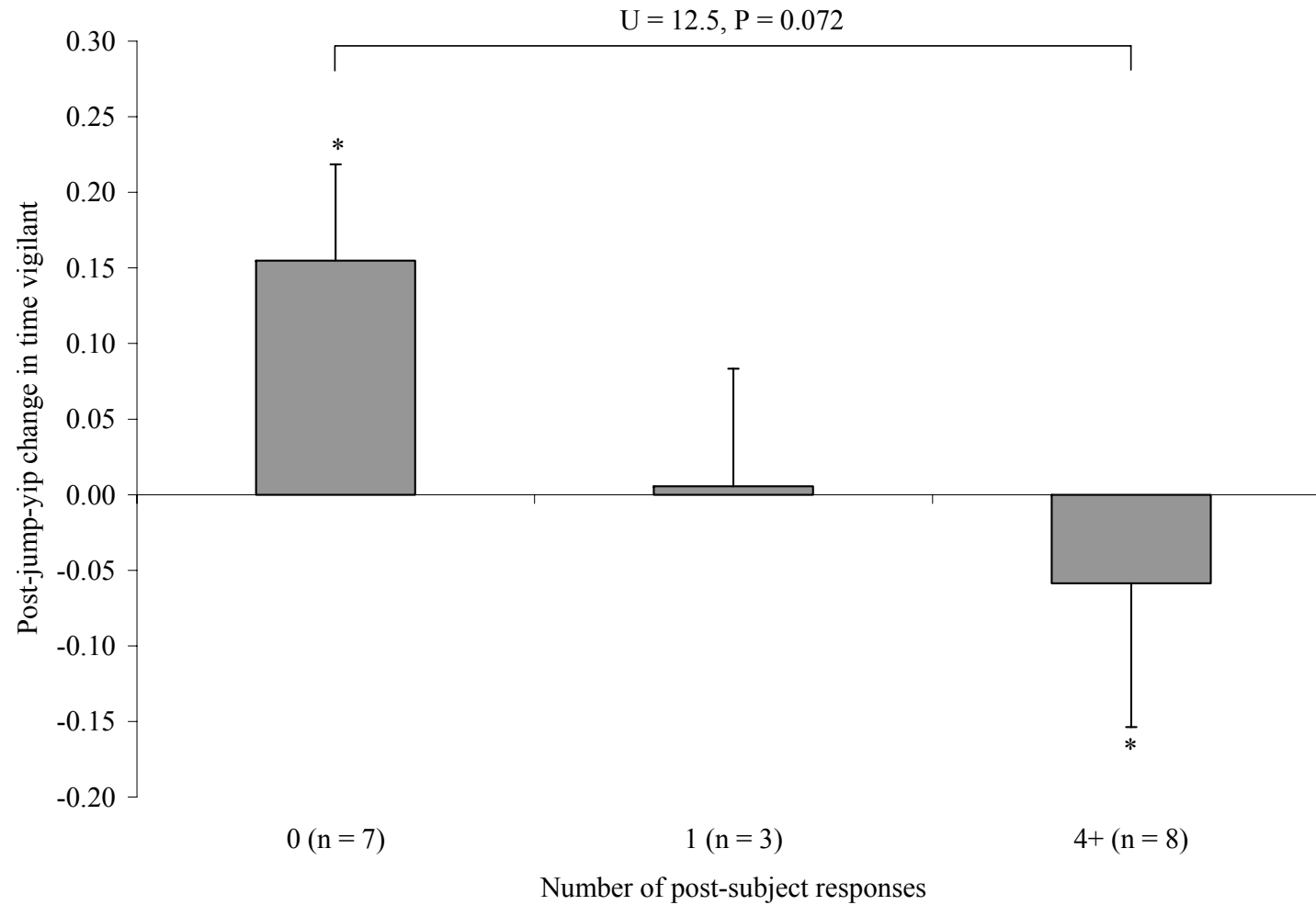
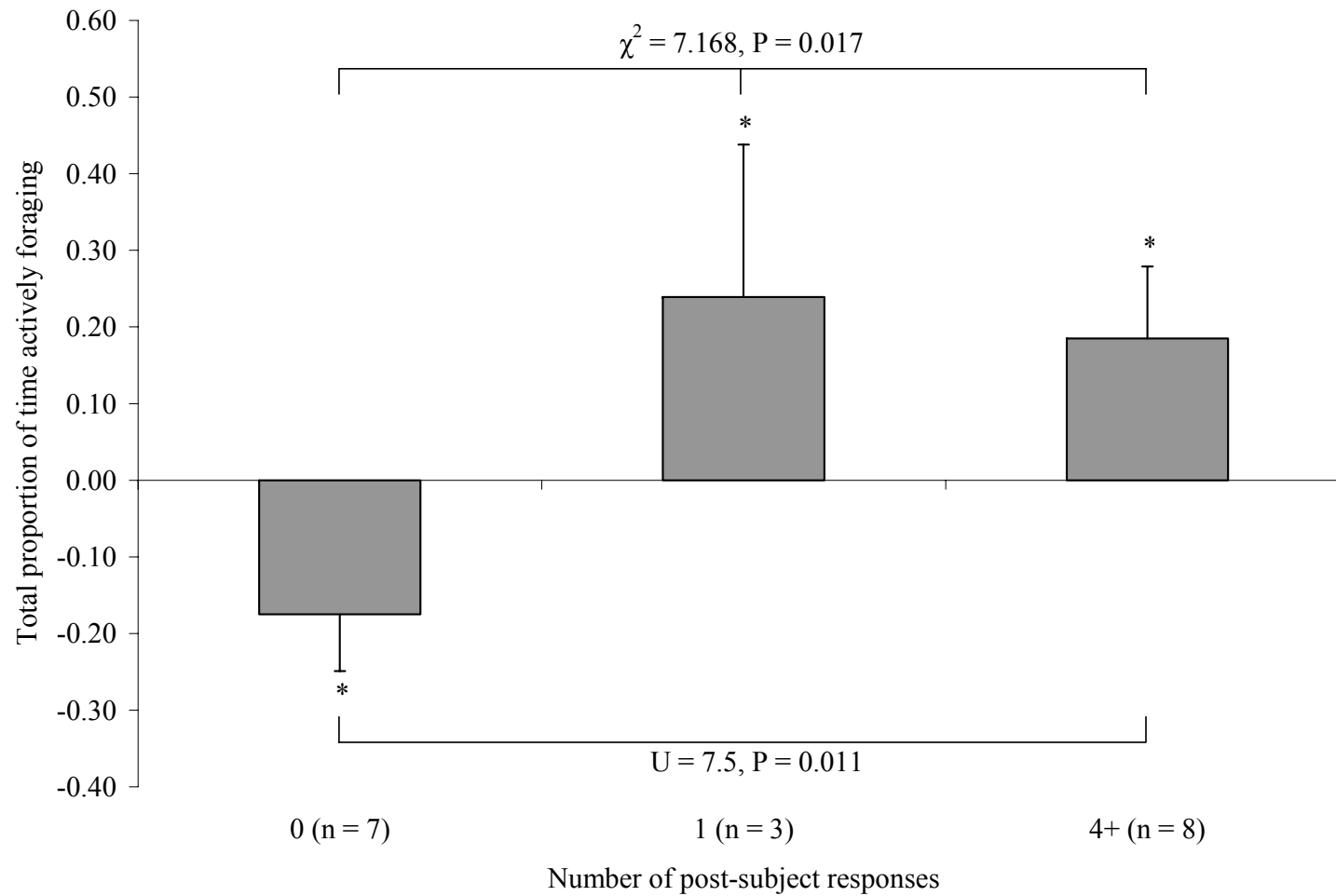


Figure 22: Effect of the number of post-subject responses in a jump-yip bout on the post-jump-yip changes in the proportion of time that subject respondent spent actively foraging ( $\bar{x} \pm$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.05$ ).



bouts containing four or more post-subject responses approached, but did not achieve, statistical significance at  $\alpha = 0.05$  (Fig. 23;  $U = 11.5$ ,  $P = 0.056$ ).

Respondents exhibited significantly different ( $\alpha = 0.10$ ) post-jump-yip changes in the proportion of time they spent vigilant when the section of their jump-yip bout which they initiated were of different durations (Fig. 24;  $U = 12.5$ ,  $P = 0.072$ ), increasing the time they spent vigilant when their section lasted less than 0.5 seconds while decreasing the time they spent vigilant when their sections lasted approximately four or more seconds (Appendix B; Table B.22). Conversely, respondents exhibited the opposite trends in their post-jump-yip changes in the proportion of time they spent actively (Fig. 25;  $U = 7.5$ ,  $P = 0.017$ ) and generally (actively and passively) (Fig 26;  $U = 11.5$ ,  $P = 0.057$ ) foraging, decreasing the proportion of time they spent both actively and generally foraging when their section lasted less than 0.5 seconds and increasing the time they devoted to foraging when their section lasted approximately four or more seconds, with only the difference in the time respondents devoted to active foraging significant at  $\alpha = 0.05$  (Appendix B; Table B.22). Respondents did not, however, exhibit significantly different changes in behaviour between the minute preceding and the minute following jump-yip production when their entire jump-yip bouts contained different numbers of responses (Appendix B; Table B.23) or were of different durations (Appendix B; Table B.24).



Figure 23: Effect of the number of post-subject responses in a jump-yip bout on the post-jump-yip change in the total proportion of time the subject respondent spent foraging ( $\bar{x} \pm$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.10$ ).

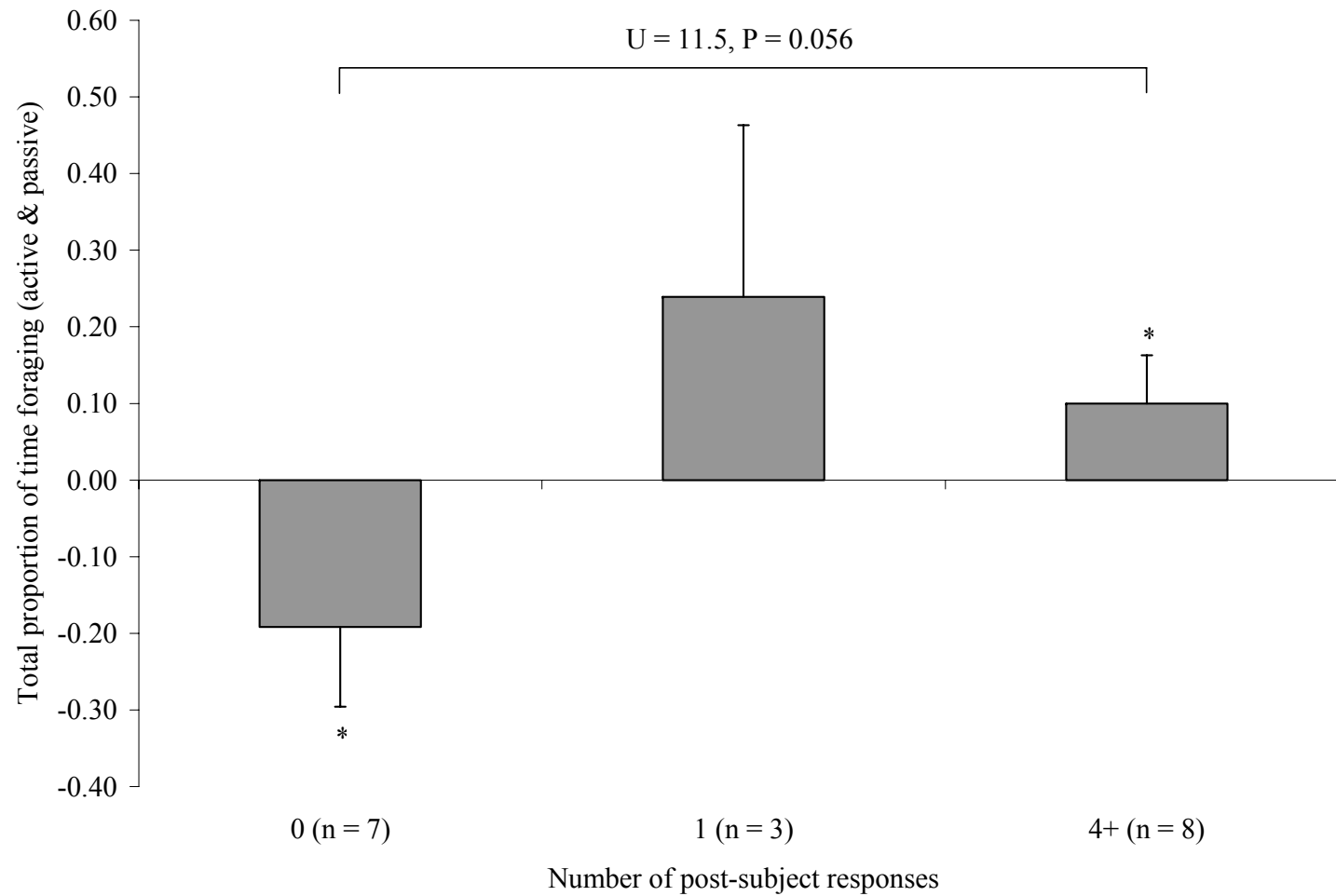


Figure 24: Effect of the post-subject duration of a jump-yip bout on the difference in the proportion of time a respondent in the bout spent vigilant before and after jump-yip production ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.10$ ).

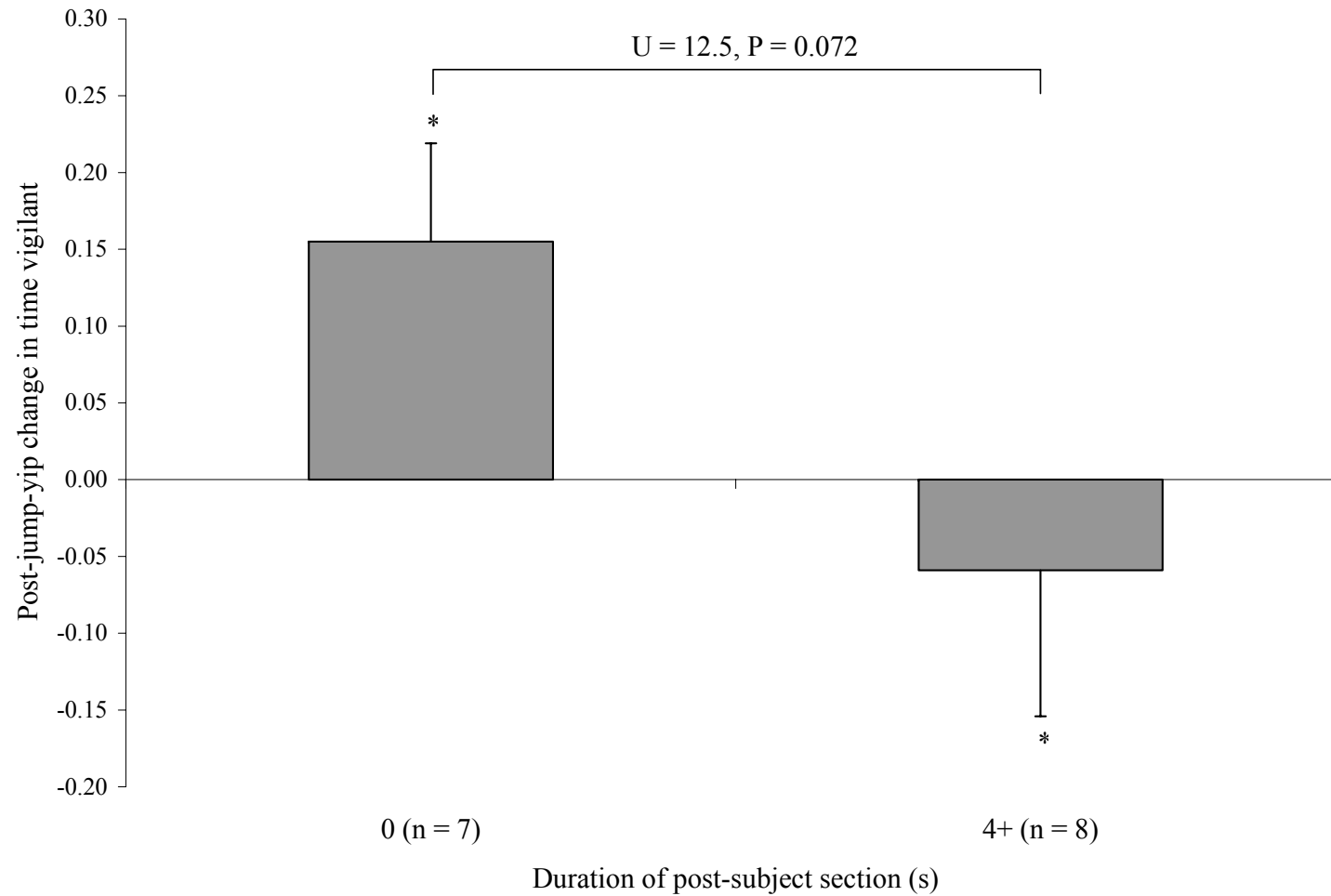


Figure 25: Effect of the post-subject duration of a jump-yip bout on the difference in the proportion of time a respondent in the bout spent actively foraging before and after jump-yip production ( $\bar{x} \pm$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.05$ ).

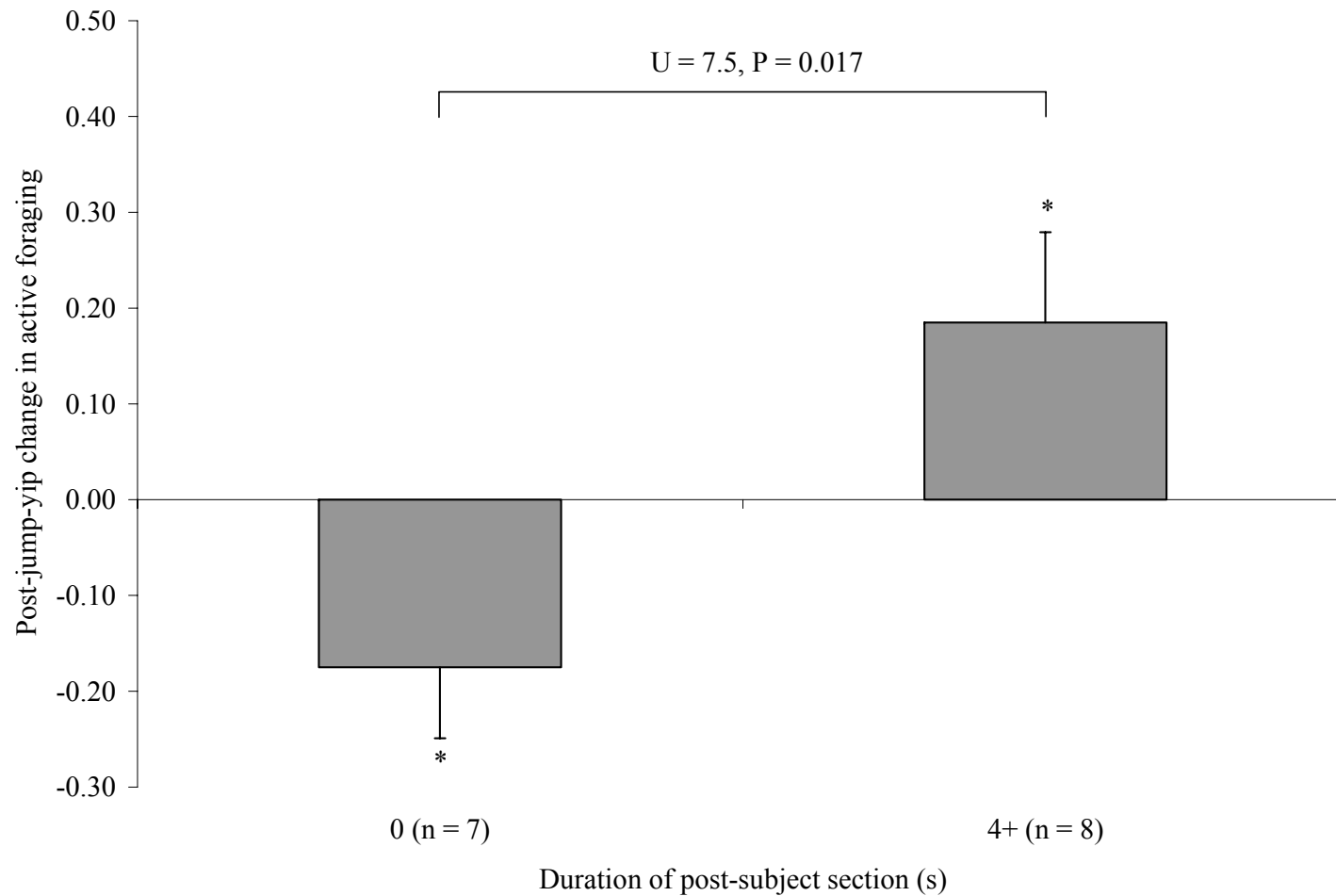
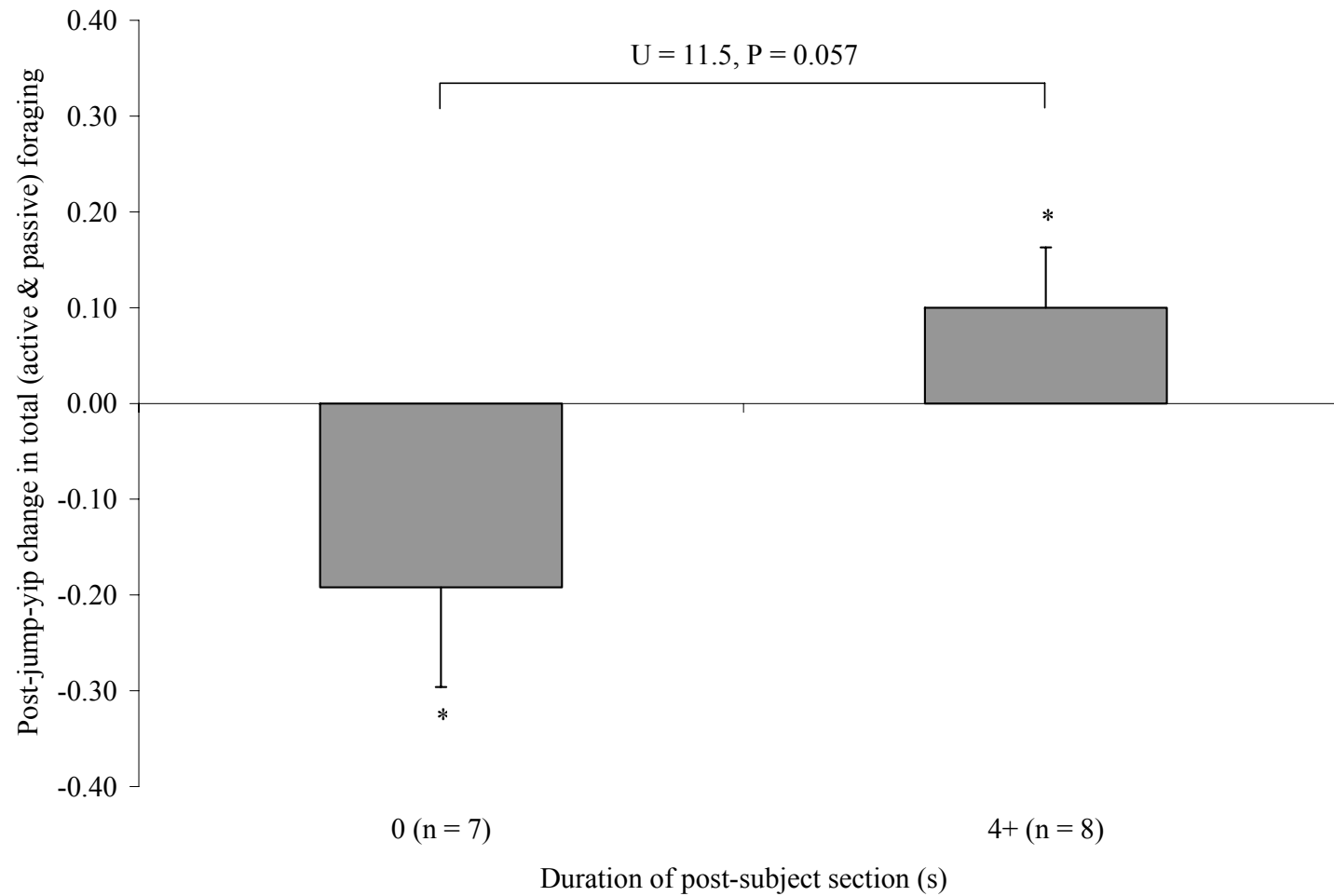


Figure 26: Effect of the post-subject duration of a jump-yip bout on the difference in the proportion of time a respondent spent foraging before and after jump-yip production ( $\bar{x} +$  or  $-$  SE) (\* denotes significant difference at  $\alpha = 0.10$ ).



### **Aboveground population size and the behaviour of black-tailed prairie dogs**

Bout initiators did not vary their immediate post-jump-yip behaviour with changes in aboveground population size at the time of their jump-yip (Table 2). They did, however, spend more time in a bipedal-alert posture over the minute following jump-yip production as aboveground population size increased ( $n = 42$ ,  $r_s = 0.330$ ,  $P = 0.033$ ; Table 2). As aboveground population size increased, bout initiators also exhibited smaller post-jump-yip increases in the proportion of time they spent vigilant ( $n = 24$ ,  $r_s = -0.386$ ,  $P = 0.063$ ) though the relationship was only statistically significant at  $\alpha = 0.10$  (Table 2).

Respondents in a jump-yip bout significantly increased the duration of their immediate post-jump-yip vigilance as the aboveground population size present at the time of their jump-yip increased ( $n = 22$ ,  $r_s = 0.430$ ,  $P = 0.046$ ; Table 3). However, respondents significantly decreased the frequency with which they both lifted their head ( $n = 26$ ,  $r_s = -0.390$ ,  $P = 0.049$ ) and increased their level of vigilance ( $n = 26$ ,  $r_s = -0.423$ ,  $P = 0.031$ ) in the minute following jump-yip production as aboveground population size increased (Table 3). Respondents also exhibited smaller post-jump-yip increases in the proportion of time they spent both quadrupedal with their head up ( $n = 18$ ,  $r_s = -0.428$ ,  $P = 0.077$ ) and bipedally-slouched ( $n = 18$ ,  $r_s = -0.463$ ,  $P = 0.053$ ) as aboveground population size increased (Table 3).

Table 2: Relationships between the aboveground population size present at the time of a jump-yip bout and the behaviour of the initial caller in the jump-yip bout over three temporal scales.<sup>^</sup>

	F-I (n = 26)	F-P (n = 42)	F-PP (n = 24)
INITVIG	-0.204	-	-
ADJINITVIG	-0.053	-	-
DURINITBHV†	0.174	-	-
DURINITVIG†	0.133	-	-
HL / MIN	-	-0.160	0.168
INCVIG / MIN	-	-0.100	0.198
TVIG	-	-0.041	<b>-0.386*</b>
ACTFOR	-	0.012	0.226
PASSFOR	-	-0.254	0.074
TOTFOR	-	-0.059	0.038
S4Ux	-	-0.192	0.138
S4U	-	-0.013	-0.117
BSx	-	-0.042	-0.088
BS	-	0.181	0.072
BAx	-	0.098	0.357
BA	-	<b>0.330**</b>	-0.246

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 25

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 3: Relationships between the aboveground population size present at the time of a jump-yip bout and the behaviour of a respondent in the jump-yip bout over three temporal scales.<sup>^</sup>

	R-I (n = 22)	R-P (n = 26)	R-PP (n = 18)
INITVIG	-0.023	-	-
ADJINITVIG	0.038	-	-
DURINITBHV	<b>0.430**</b>	-	-
DURINITVIG	0.049	-	-
HL / MIN	-	<b>-0.390**</b>	-0.379
INCVIG / MIN	-	<b>-0.423**</b>	-0.265
TVIG	-	-0.153	-0.338
ACTFOR	-	0.144	0.221
PASSFOR	-	-0.103	0.058
TOTFOR	-	0.166	0.396
S4Ux	-	-0.160	-0.249
S4U	-	-0.121	<b>-0.428*</b>
BSx	-	0.057	0.163
BS	-	0.050	<b>-0.463*</b>
BAx	-	-0.282	0.306
BA	-	-0.235	-0.081

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

## **Time of first post-subject, non-subject vocalization and the behaviour of black-tailed prairie dogs**

The time at which the first post-subject, non-subject vocalization occurred did not have any relationships with the immediate post-jump-yip behaviour nor the post-jump-yip changes in the behaviour of bout initiators (Table 4). Bout initiators did, however, spend less time in a bipedal-alert posture as the time at which the first post-subject, non-subject vocalization occurred increased, though the correlation was only statistically significant at  $\alpha = 0.10$  ( $n = 42$ ,  $r_s = -0.271$ ,  $P = 0.082$ ; Table 4).

Respondents reduced their adjusted level of vigilance immediately following jump-yip production ( $n = 18$ ,  $r_s = -0.382$ ,  $P = 0.080$ ) and maintained their immediate post-jump-yip vigilance for shorter periods of time ( $n = 18$ ,  $r_s = -0.364$ ,  $P = 0.096$ ) as the first post-subject, non-subject vocalization in the environment occurred at a later time (Table 5). Their behaviour over the minute following jump-yip production and their post-jump-yip changes in behaviour, however, did not vary with changes in the timing of the first post-subject, non-subject vocalization (Table 5).

## **Extraneous vocalizations and the behaviour of bout initiators**

### Immediate post-jump behaviour

The immediate post-jump-yip behaviour of bout initiators was not related to the frequency of jump-yipping (both bouts and total jump-yips) in the environment in the minute preceding their jump-yip (“pre-subject”). The average number of responses in the jump-yip bouts occurring in the environment in the minute preceding the subject jump-yip bout, however, was significantly positively correlated with the initial level of



Table 4: Relationships between the time at which the first post-subject-bout, non-subject-bout vocalization occurred and the behaviour of the initial caller in the subject jump-yip bout over three temporal scales.<sup>^</sup>

	F-I	F-P	F-PP
	(n = 26)	(n = 42)	(n = 24)
INITVIG	0.067	-	-
ADJINITVIG	0.033	-	-
DURINITBHV†	0.053	-	-
DURINITVIG†	-0.055	-	-
HL / MIN	-	0.071	0.123
INCVIG / MIN	-	-0.016	0.065
TVIG	-	0.187	0.076
ACTFOR	-	-0.091	-0.095
PASSFOR	-	0.037	0.237
TOTFOR	-	-0.057	0.090
S4Ux	-	0.210	0.180
S4U	-	0.165	-0.048
BSx	-	-0.074	-0.009
BS	-	-0.097	-0.188
BAx	-	0.139	-0.085
BA	-	<b>-0.271*</b>	0.267

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 25

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 5: Relationships between the time at which the first post-subject-bout, non-subject-bout vocalization occurred and the behaviour of a respondent in the subject jump-yip bout over three temporal scales.^

	R-I	R-P	R-PP
	(n = 22)	(n = 26)	(n = 18)
INITVIG	-0.266	-	-
ADJINITVIG	<b>-0.382*</b>	-	-
DURINITBHV	0.025	-	-
DURINITVIG	<b>-0.364*</b>	-	-
HL / MIN	-	0.217	0.279
INCVIG / MIN	-	0.242	0.190
TVIG	-	0.099	0.089
ACTFOR	-	-0.130	-0.039
PASSFOR	-	-0.067	0.188
TOTFOR	-	-0.100	-0.055
S4Ux	-	-0.059	0.299
S4U	-	0.038	0.120
BSx	-	0.282	0.164
BS	-	-0.083	0.383
BAx	-	-0.232	0.278
BA	-	0.100	-0.335

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

vigilance of the initiator of the subject bout ( $n = 20$ ,  $r_s = 0.448$ ,  $P = 0.048$ ; Table 6), while a positive correlation was found between the average duration of the pre-subject jump-yip bouts and the immediate post-jump-yip level of vigilance exhibited by the subject jump-yip bout initiator ( $n = 20$ ,  $r_s = 0.421$ ,  $P = 0.064$ ; Table 6). The characteristics of the extraneous jump-yip bouts occurring in the minute following the subject jump-yip bout (“post-subject”) were not related to any measures of the immediate post-jump-yip behaviour of the subject bout initiator nor was the number of “post-subject” chirps (Table 7). Subject bout initiators did, however, assume a lower level of immediate post-jump-yip vigilance ( $n = 26$ ,  $r_s = -0.562$ ,  $P = 0.003$ ), a lower adjusted level of immediate post-jump-yip vigilance ( $n = 26$ ,  $r_s = -0.456$ ,  $P = 0.019$ ), and spent a reduced amount of time performing their first post-jump behaviour ( $n = 26$ ,  $r_s = -0.403$ ,  $P = 0.046$ ) as the amount of time alarm calls were present in the minute following the subject jump-yip bout increased (Table 7).

#### One-minute post-jump-yip behaviour

Bout initiators spent a greater proportion of their post-jump-yip time actively foraging when there were a greater number of extraneous jump-yip bouts in the minute preceding the subject jump-yip bout ( $n = 42$ ,  $r_s = 0.258$ ,  $P = 0.100$ ; Table 8). Increases in the number of pre-subject jump-yip bouts were also associated with bout initiators spending less post-jump-yip time vigilant ( $n = 42$ ,  $r_s = -0.269$ ,  $P = 0.085$ ) and in a quadrupedal head-up posture ( $n = 42$ ,  $r_s = -0.303$ ,  $P = 0.051$ ), though both relationships were only statistically significant at  $\alpha = 0.10$  (Table 8). Bout initiators also spent less post-jump-yip time vigilant as the total number of pre-subject jump-yips increased

Table 6: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the immediate post-jump-yip behaviour of the initial caller in the subject jump-yip bout (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
INITVIG	-0.030	0.157	<b>0.448**</b>	<b>0.421*</b>	0.370	-0.322	0.077
ADJINITVIG	0.004	0.146	0.348	0.296	0.316	-0.248	0.128
DURINITBHV <sup>‡</sup>	-0.049	0.038	0.120	0.046	-0.091	-0.207	-0.136
DURINITVIG <sup>‡</sup>	0.069	0.147	0.264	0.291	0.198	-0.319	-0.214

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 20, except DURINITVIG and DURINITBHV (n = 19)

<sup>‡</sup> n = 25, except PRERESP, PREDUR, and PRELAT (n = 19)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 7: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the immediate post-jump-yip behaviour of the initial caller in the subject jump-yip bout (n = 26).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
INITVIG	-0.034	-0.039	0.190	0.156	0.096	0.077	<b>-0.562**</b>
ADJINITVIG	-0.082	-0.043	0.269	0.230	0.125	0.130	<b>-0.456**</b>
DURINITBHV <sup>‡</sup>	0.115	0.150	0.309	0.274	0.243	-0.074	0.000
DURINITVIG <sup>‡</sup>	0.158	0.104	0.096	0.092	0.092	-0.066	<b>-0.403**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>‡</sup> n = 17, except DURINITVIG and DURINITBHV (n = 16)

<sup>‡</sup> n = 25, except PRERESP, PREDUR, and PRELAT (n = 16)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 8: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the behaviour of the initial caller in that bout over the minute following jump-yip production (n = 42).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
HL / MIN	-0.213	-0.113	0.163	0.136	-0.018	<b>-0.259*</b>	0.060
INCVIG / MIN	-0.227	-0.152	0.115	0.108	-0.017	<b>-0.286*</b>	-0.019
TVIG	<b>-0.269*</b>	<b>-0.262*</b>	-0.048	-0.149	-0.134	<b>-0.314**</b>	-0.257
ACTFOR	<b>0.258*</b>	0.223	-0.088	-0.025	-0.152	0.153	0.190
PASSFOR	-0.043	0.027	0.160	0.224	0.107	-0.029	0.115
TOTFOR	0.221	0.208	-0.042	0.052	-0.062	0.162	0.227
S4Ux	-0.038	0.022	0.114	0.090	-0.175	-0.213	0.133
S4U	<b>-0.303*</b>	-0.249	0.050	-0.080	-0.082	-0.189	-0.192
BSx	-0.114	-0.091	-0.139	-0.096	-0.168	-0.131	-0.065
BS	0.013	-0.077	-0.197	-0.111	-0.081	-0.108	-0.192
BAx	-0.216	-0.214	-	-	-	-0.035	-0.097
BA	-0.160	-0.201	0.021	-0.079	0.120	-0.072	-0.201

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

( $n = 42$ ,  $r_s = -0.262$ ,  $P = 0.094$ ; Table 8). No relationships were found, however, between the characteristics of the pre-subject jump-yip bouts (number of responses, duration, and response latency) and the behaviour of the subject bout initiator over one minute post-jump-yip (Table 8).

As the number of chirps occurring in the minute preceding the subject jump-yip bout increased, bout initiators significantly decreased: 1) their rate of head lifting in the minute following jump-yip production ( $n = 42$ ,  $r_s = -0.259$ ,  $P = 0.098$ ), 2) the rate at which their level of vigilance increased in the minute following the jump-yip ( $n = 42$ ,  $r_s = -0.286$ ,  $P = 0.066$ ), and, 3) the proportion of post-jump-yip time they spent vigilant ( $n = 42$ ,  $r_s = -0.314$ ,  $P = 0.043$ ; Table 8). Their post-jump-yip behaviour did not vary, however, with changes in the amount of pre-subject alarm calling.

As the number of jump-yip bouts in the minute following the subject jump-yip bout increased, bout initiators decreased the rate at which they lifted their head ( $n = 42$ ,  $r_s = -0.273$ ,  $P = 0.081$ ) and the rate at which they increased their level of vigilance ( $n = 42$ ,  $r_s = -0.281$ ,  $P = 0.071$ ), though neither relationship was statistically significant at  $\alpha = 0.05$  (Table 9). Similar decreases in the rate of head lifting ( $n = 42$ ,  $r_s = -0.264$ ,  $P = 0.091$ ) and the rate of increasing vigilance ( $n = 42$ ,  $r_s = -0.294$ ,  $P = 0.059$ ) performed by the subject bout initiator in the minute following jump-yip production were found as the number of post-subject jump-yips increased (Table 9). Bout initiators also reduced the proportion of time they spent quadrupedal with their heads up in the minute following jump-yip production as the total number of post-subject jump-yips increased ( $n = 42$ ,  $r_s = -0.284$ ,  $P = 0.068$ ), though the relationship was only statistically significant at  $\alpha = 0.10$ . Jump-yip bout initiators did, however, significantly (at  $\alpha = 0.05$ ) decrease the

Table 9: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the behaviour of the initial caller in that bout over the minute following jump-yip production (n = 42).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
HL / MIN	<b>-0.273*</b>	<b>-0.264*</b>	-0.032	-0.027	0.009	-0.155	-0.050
INCVIG / MIN	<b>-0.281*</b>	<b>-0.294*</b>	-0.156	-0.093	-0.004	-0.104	-0.044
TVIG	-0.182	<b>-0.328**</b>	<b>-0.382**</b>	-0.230	-0.173	-0.186	-0.251
ACTFOR	0.190	<b>0.313**</b>	<b>0.307*</b>	0.136	0.065	0.216	0.062
PASSFOR	-0.086	-0.045	0.076	0.067	0.017	-0.057	0.198
TOTFOR	0.153	<b>0.302**</b>	<b>0.370**</b>	0.222	0.113	0.173	0.036
S4Ux	-0.131	-0.134	-0.014	-0.032	-0.028	-0.166	-0.035
S4U	-0.135	<b>-0.284*</b>	<b>-0.308*</b>	-0.158	-0.004	-0.117	-0.113
BSx	-0.167	-0.170	-0.114	-0.020	0.067	-0.048	0.052
BS	-0.120	-0.151	-0.207	-0.053	0.120	-0.025	-0.116
BAx	-0.098	-0.123	-0.252	-0.251	-0.251	-0.057	-0.081
BA	0.052	0.002	-0.197	-0.046	-0.044	<b>0.346**</b>	0.012

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



proportion of post-jump-yip time they spent vigilant as the number of post-subject jump-yips increased ( $n = 42$ ,  $r_s = -0.328$ ,  $P = 0.028$ ; Table 9).

Increases in the number of post-subject jump-yips were also associated with significant increases in both the proportion of post-jump-yip time bout initiators spent actively foraging ( $n = 42$ ,  $r_s = 0.313$ ,  $P = 0.043$ ) and generally foraging ( $n = 42$ ,  $r_s = 0.302$ ,  $P = 0.052$ ; Table 9). As the average number of responses in the post-subject bouts increased, bout initiators significantly decreased the proportion of post-jump-yip time they spent vigilant ( $n = 33$ ,  $r_s = -0.382$ ,  $P = 0.028$ ; Table 9). They also decreased the proportion of post-jump-yip time they spent quadrupedal with their head up, though the decrease was only significant at  $\alpha = 0.10$  ( $n = 33$ ,  $r_s = -0.308$ ,  $P = 0.081$ ; Table 9). Bout initiators also increased the proportions of post-jump-yip time they spent actively foraging ( $n = 33$ ,  $r_s = 0.307$ ,  $P = 0.082$ ; Table 9) and generally foraging ( $n = 33$ ,  $r_s = 0.370$ ,  $P = 0.034$ ) with increases in the average number of responses in the post-subject bouts, though only the change in general foraging was statistically significant at  $\alpha = 0.05$ .

Bout initiators significantly increased the proportion of post-jump-yip time they spent bipedally-alert as the number of post-subject chirps increased ( $n = 42$ ,  $r_s = 0.346$ ,  $P = 0.025$ ; Table 9). This was, however, the only change in bout initiator behaviour observed with changes in the characteristics of the non-jump-yip vocalizations (chirps, alarm calls) present in the environment.

#### Changes in behaviour following jump-yip production

As the number of jump-yip bouts occurring in the minute preceding the subject bout increased, jump-yip bout initiators exhibited smaller post-jump-yip increases in the

proportion of time they spent in the quadrupedal head-up posture, though the decrease was only significant at  $\alpha = 0.10$  ( $n = 24$ ,  $r_s = -0.350$ ,  $P = 0.094$ ; Table 10). Bout initiators also exhibited significantly smaller post-jump-yip increases in the proportion of time they spent quadrupedal with their head up after jump-yip production as the number of pre-subject jump-yips increased ( $n = 24$ ,  $r_s = -0.461$ ,  $P = 0.023$ ; Table 10). An increase in the number of pre-subject jump-yips was also associated with greater post-jump-yip increases in the proportion of time bout initiators spent actively foraging after jump-yip production, though the correlation was only statistically significant at  $\alpha = 0.10$  ( $n = 24$ ,  $r_s = 0.371$ ,  $P = 0.074$ ; Table 10). Jump-yip bout initiators also exhibited smaller post-jump-yip increases in the proportion of time they spent vigilant as: 1) the average number of responses in the pre-subject bouts increased ( $n = 19$ ,  $r_s = -0.399$ ,  $P = 0.091$ ), 2) the average duration of the pre-subject bouts increased ( $n = 19$ ,  $r_s = -0.489$ ,  $P = 0.034$ ), and, 3) the average response latency of the pre-subject bouts increased ( $n = 19$ ,  $r_s = -0.448$ ,  $P = 0.055$ ; Table 10). Additionally, bout initiators exhibited significantly smaller post-jump-yip increases in the proportion of time they spent in “occupied” bipedal-slouched postures as the average response latency of the pre-subject bouts increased ( $n = 19$ ,  $r_s = -0.468$ ,  $P = 0.043$ ; Table 10). Increases in the average number of responses in the jump-yip bouts occurring in the minute preceding the subject bout were associated with greater post-jump-yip increases in the proportion of time bout initiators spent bipedally-alert ( $n = 19$ ,  $r_s = 0.400$ ,  $P = 0.089$ ; Table 10). Bout initiators also exhibited greater post-jump-yip increases in the proportion of time they spent generally foraging as the number of pre-subject chirps increased ( $n = 24$ ,  $r_s = 0.370$ ,  $P = 0.075$ ; Table 10).

Table 10: Correlations between characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the post-jump-yip change in the behaviour of the initial caller in that bout (n = 24).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
HL / MIN	-0.185	-0.230	0.009	-0.027	-0.164	-0.055	-0.264
INCVIG / MIN	-0.103	-0.088	0.054	-0.008	-0.248	-0.011	-0.167
TVIG	0.212	0.061	<b>-0.399*</b>	<b>-0.489**</b>	<b>-0.448*</b>	-0.131	-0.173
ACTFOR	0.334	<b>0.371*</b>	0.309	0.280	0.057	0.305	0.328
PASSFOR	-0.231	-0.206	0.044	0.117	0.265	0.113	0.022
TOTFOR	0.156	0.184	0.261	0.226	0.070	<b>0.370*</b>	0.278
S4Ux	-0.106	-0.123	-0.012	0.041	-0.041	0.011	-0.098
S4U	<b>-0.350*</b>	<b>-0.461**</b>	-0.370	-0.324	-0.053	-0.262	-0.296
BSx	0.322	0.276	-0.270	-0.334	<b>-0.468**</b>	0.092	0.174
BS	0.184	0.078	-0.186	-0.084	-0.068	0.025	-0.112
BAx	0.000	0.000	-	-	-	-	-
BA	-0.097	0.136	<b>0.400*</b>	0.191	0.039	-0.245	0.006

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Neither the number of jump-yip bouts in the minute following the subject jump-yip nor the number of post-subject jump-yips was associated with changes in the difference in pre- and post-jump-yip behaviour of bout initiators (Table 11). Bout initiators did, however, show significantly greater post-jump-yip increases in the rate they increased their level of vigilance after jump-yip production as the average duration of the post-subject bouts increased ( $n = 17$ ,  $r_s = 0.522$ ,  $P = 0.031$ ), but did not modify their behaviour with changes in the average number of responses in the post-subject bouts (Table 11). As the average response latency of the post-subject bouts increased, bout initiators exhibited significantly greater post-jump-yip increases in the rate at which they increased their level of vigilance ( $n = 17$ ,  $r_s = 0.554$ ,  $P = 0.021$ ) and greater post-jump-yip increases in the proportion of time they spent in the bipedal-slouched posture ( $n = 17$ ,  $r_s = 0.502$ ,  $P = 0.040$ ; Table 11). As the average response latency of the post-subject bouts increased, bout initiators also exhibited significantly greater post-jump-yip increases in the rate at which they lifted their head, though the correlation was only significant at  $\alpha = 0.10$  ( $n = 17$ ,  $r_s = 0.425$ ,  $P = 0.089$ ; Table 11). Bout initiators also exhibited smaller post-jump-yip increases in the proportion of time they spent in “occupied” quadrupedal head-up postures as the average response latency of the post-subject bouts increased, though again the correlation was only statistically significant at  $\alpha = 0.10$  ( $n = 17$ ,  $r_s = -0.463$ ,  $P = 0.061$ ; Table 11).

An increase in the number of post-subject chirps was associated with smaller post-jump-yip increases in the proportion of time bout initiators spent vigilant, though the correlation was only significant at  $\alpha = 0.10$  ( $n = 24$ ,  $r_s = -0.354$ ,  $P = 0.090$ ; Table 11). Conversely, an increase in the amount of time alarm calls were present in the

Table 11: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the post-jump-yip change in the behaviour of the initial caller in that bout (n = 24).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
HL / MIN	-0.103	-0.034	0.199	0.366	<b>0.425*</b>	-0.187	-0.168
INCVIG / MIN	-0.008	0.090	0.359	<b>0.522**</b>	<b>0.554**</b>	-0.042	-0.211
TVIG	0.173	0.054	-0.240	-0.352	-0.216	<b>-0.354*</b>	-0.111
ACTFOR	0.282	0.303	0.027	-0.013	-0.255	0.079	-0.015
PASSFOR	-0.138	-0.112	-0.097	-0.039	-0.266	-0.255	-0.147
TOTFOR	0.129	0.151	0.001	-0.011	-0.249	-0.005	-0.023
S4Ux	-0.028	-0.031	-0.240	-0.223	<b>-0.463*</b>	-0.201	-0.299
S4U	-0.193	-0.268	-0.348	-0.318	-0.034	-0.156	0.074
BSx	0.302	0.283	-0.026	-0.255	-0.408	-0.134	-0.166
BS	0.095	0.051	0.100	0.279	<b>0.502**</b>	0.173	-0.160
BAx	0.107	0.085	-0.386	-0.383	-0.383	0.000	0.000
BA	-0.022	0.066	0.246	0.092	-0.063	-0.331	<b>0.349*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

environment in the minute following the subject jump-yip bout was associated with greater post jump-yip increases in the proportion of time bout initiators spent in the bipedal-alert posture, though again the correlation was only statistically significant at  $\alpha = 0.10$  ( $n = 24$ ,  $r_s = 0.349$ ,  $P = 0.094$ ; Table 11).

## **Extraneous vocalizations and the behaviour of respondents**

### Immediate post-jump-yip behaviour

Respondents in a jump-yip bout increased their level of immediate post-jump-yip vigilance with increases in the number of jump-yip bouts occurring in the minute preceding their jump-yip bouts ( $n = 26$ ,  $r_s = 0.377$ ,  $P = 0.084$ ) and assumed vigilance postures for greater periods of time with increases in the number of pre-subject bouts ( $n = 21$ ,  $r_s = 0.553$ ,  $P = 0.008$ ), though only the change in the duration of the immediate vigilance behaviour was statistically significant at  $\alpha = 0.05$  (Table 12). Increases in the number of pre-subject jump-yip bouts were also associated with increases in the duration of the immediate post-jump-yip behaviour (vigilant or non-vigilant), though again the correlation was only statistically significant at  $\alpha = 0.10$  ( $n = 21$ ,  $r_s = 0.363$ ,  $P = 0.097$ ; Table 12). Respondents also increased the duration of their immediate post-jump-yip vigilance (though only at  $\alpha = 0.10$ ) as the average response latency of the jump-yip bouts occurring in the minute preceding the subject bout increased ( $n = 21$ ,  $r_s = 0.410$ ,  $P = 0.058$ ; Table 12), but significantly (at  $\alpha = 0.05$ ) decreased the duration of their immediate post-jump-yip vigilance as the number of pre-subject chirps increased ( $n = 26$ ,  $r_s = -0.518$ ,  $P = 0.013$ ; Table 12).

Table 12: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the immediate post-jump-yip behaviour of a respondent in that bout (n = 22).<sup>^</sup>

	PREBOUT	PREJY	PRERESP	PREDUR	PRELAT	PRECHIRP	PREAC
INITVIG	<b>0.377*</b>	0.190	0.055	0.093	0.132	0.093	0.028
ADJINITVIG	0.250	0.038	-0.059	0.003	0.009	0.189	0.025
DURINITBHV	<b>0.363*</b>	-0.128	-0.219	-0.086	<b>0.410*</b>	<b>-0.518**</b>	-0.085
DURINITVIG	<b>0.553**</b>	0.016	-0.200	-0.091	0.230	-0.069	0.163

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

The immediate post-jump-yip behaviour of respondents did not vary with changes in the number or characteristics of the jump-yips occurring in the minute following jump-yip production (Table 13). Respondents did, however, increase both their level of immediate post-jump-yip vigilance ( $n = 26$ ,  $r_s = 0.374$ ,  $P = 0.086$ ) and their adjusted level of immediate post-jump-yip vigilance ( $n = 26$ ,  $r_s = 0.383$ ,  $P = 0.079$ ) as the number of chirps in the minute following the subject bout increased, though both correlations were only statistically significant at  $\alpha = 0.10$  (Table 13).

#### One-minute post-jump-yip behaviour

The behaviour of respondents over the minute following jump-yip production did not vary with changes in the number of jump-yip bouts occurring in the minute preceding their jump-yip bout (Table 14). They did, however, increase the proportion of time they spent passively foraging ( $n = 26$ ,  $r_s = 0.391$ ,  $P = 0.048$ ) and decrease the proportion of time they spent in a bipedal-alert posture ( $n = 26$ ,  $r_s = -0.387$ ,  $P = 0.051$ ) with increases in the number of jump-yips occurring in the minute preceding their jump-yip bout, though only the correlation with passive foraging was statistically significant at  $\alpha = 0.05$  (Table 14). As the average number of responses in the pre-subject jump-yip bouts increased, respondents increased the proportion of post-jump-yip time they spent both actively ( $n = 26$ ,  $r_s = 0.338$ ,  $P = 0.092$ ) and generally foraging ( $n = 26$ ,  $r_s = 0.359$ ,  $P = 0.071$ ), though both correlations only achieved statistical significance at  $\alpha = 0.10$  (Table 14). Conversely, as the average number of responses in the pre-subject bouts increased, respondents decreased the proportion of post-jump-yip time they devoted to vigilant behaviours ( $n = 25$ ,  $r_s = -0.347$ ,  $P = 0.083$ ) and to bipedal-alert postures ( $n = 26$ ,



Table 13: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the immediate post-jump-yip behaviour of a respondent in the subject jump-yip bout (n = 22).<sup>^</sup>

	POSTBOUT <sup>†</sup>	POSTJY <sup>†</sup>	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
INITVIG	0.279	0.206	0.124	0.041	0.224	<b>0.374*</b>	-0.039
ADJINITVIG	0.279	-0.036	-0.101	-0.165	0.065	<b>0.383*</b>	-0.076
DURINITBHV	0.072	0.212	0.192	0.121	0.030	-0.178	0.131
DURINITVIG	0.289	0.184	0.143	0.039	0.244	-0.050	0.082

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 21

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 14: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject

jump-yip bout and the behaviour of a respondent in that bout over the minute following jump-yip production (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
HL / MIN	-0.097	0.140	0.135	0.114	0.012	0.134	0.062
INCVIG / MIN	-0.060	0.030	-0.017	-0.020	-0.097	0.199	0.114
TVIG	0.059	-0.302	<b>-0.347*</b>	-0.321	-0.196	-0.102	0.046
ACTFOR	-0.120	0.279	<b>0.338*</b>	0.312	0.181	-0.035	-0.094
PASSFOR	-0.070	<b>0.391**</b>	0.306	0.334	0.240	0.135	0.164
TOTFOR	-0.079	0.327	<b>0.359*</b>	0.325	0.226	-0.004	0.000
S4Ux	-0.032	0.289	0.252	0.234	0.327	-0.119	0.117
S4U	0.059	-0.249	-0.251	-0.212	-0.099	-0.085	-0.032
BSx	0.008	0.058	-0.036	0.079	0.063	-0.235	0.077
BS	0.037	-0.271	-0.284	-0.259	-0.145	-0.130	-0.064
BAx	0.014	-0.227	-0.307	-0.307	-0.307	<b>0.553**</b>	0.282
BA	-0.113	<b>-0.387*</b>	<b>-0.462**</b>	<b>-0.462**</b>	<b>-0.462**</b>	0.329	0.073

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 25

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

$r_s = -0.462, P = 0.017$ ), though only the correlation with the time they spent in a bipedal-alert posture was statistically significant at  $\alpha = 0.05$  (Table 14). Similarly, respondents spent less time bipedally-alert in the minute following jump-yip production with increases in both the average duration of ( $n = 26, r_s = -0.462, P = 0.017$ ) and the average response latency ( $n = 26, r_s = -0.462, P = 0.017$ ) of the pre-subject bouts (Table 14). Respondents also significantly increased the proportion of post-jump-yip time they spent in “occupied” bipedal-alert postures as the number of chirps occurring in the minute preceding the subject jump-yip bout increased ( $n = 26, r_s = 0.553, P = 0.003$ ; Table 14).

Increases in the number of jump-yips occurring in the minute following a jump-yip bout were associated with increases in the proportion of post-jump-yip time respondents in the bout spent in a bipedal-alert posture ( $n = 26, r_s = -0.360, P = 0.071$ ) though the correlation was statistically significant only at  $\alpha = 0.10$ . The post-jump-yip behaviour of respondents did not vary, however, with changes in the characteristics of the post-subject jump-yip bouts, nor did it vary with changes in the chirps or alarm calls occurring in the environment over the minute following the subject jump-yip bout (Table 15).

#### Changes in behaviour following jump-yip production

Respondents exhibited greater post-jump-yip increases in the proportion of time they spent actively foraging as the number of jump-yip bouts occurring in the minute preceding their jump-yip bout increased ( $n = 18, r_s = 0.411, P = 0.091$ ), though the correlation was only statistically significant at  $\alpha = 0.10$  (Table 16). Respondents did not, however, exhibit different post-jump-yip changes in either vigilant or foraging behaviour

Table 15: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the behaviour of a respondent in that bout over the minute following jump-yip production (n = 26).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
HL / MIN	-0.220	-0.104	-0.062	-0.082	-0.028	-0.088	-0.171
INCVIG / MIN	-0.184	-0.130	-0.078	-0.106	-0.065	-0.082	-0.225
TVIG	-0.024	-0.103	0.010	-0.060	-0.168	-0.114	0.027
ACTFOR	0.013	0.277	0.095	0.183	-0.139	0.138	0.036
PASSFOR	0.141	0.125	0.099	0.123	0.297	-0.216	0.237
TOTFOR	0.108	0.243	0.044	0.119	-0.031	0.085	0.123
S4Ux	0.066	0.280	0.128	0.037	-0.092	-0.175	0.201
S4U	-0.139	-0.208	-0.017	-0.079	0.061	-0.106	-0.024
BSx	0.065	0.299	0.284	0.227	0.083	-0.037	0.054
BS	0.181	-0.223	-0.266	-0.245	-0.025	-0.153	0.201
BAx	0.109	-0.174	-0.226	-0.226	-0.015	-0.085	-0.163
BA	-0.170	<b>-0.360*</b>	-0.226	-0.226	-0.015	-0.123	-0.235

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 16: Correlations between the characteristics of the extraneous vocalizations present in the minute preceding the subject jump-yip bout and the post-jump-yip change in the behaviour of a respondent in that bout (n = 18).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
HL / MIN	0.071	0.289	0.252	0.221	0.024	-0.072	-0.015
INCVIG / MIN	0.189	0.227	0.127	0.107	0.086	-0.096	-0.010
TVIG	-0.324	0.032	0.007	-0.008	-0.129	-0.014	0.162
ACTFOR	<b>0.411*</b>	-0.018	-0.021	0.026	0.119	-0.037	0.007
PASSFOR	0.027	0.030	-0.040	-0.094	0.169	<b>-0.481**</b>	0.120
TOTFOR	0.316	0.039	0.022	-0.014	0.380	<b>-0.453*</b>	0.323
S4Ux	0.009	0.235	0.144	0.134	0.152	-0.392	0.184
S4U	-0.139	-0.059	-0.070	0.000	-0.221	0.336	-0.373
BSx	0.239	-0.128	-0.204	-0.181	0.084	<b>-0.467*</b>	0.311
BS	-0.162	-0.125	-0.167	-0.208	-0.295	0.204	<b>-0.554**</b>
BAx	0.049	0.351	0.398	0.397	0.397	<b>-0.540**</b>	-0.334
BA	0.074	-0.102	-0.108	-0.135	-0.244	<b>0.416*</b>	0.136

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

with changes in the characteristics of the pre-subject jump-yip bouts (Table 16). As the number of chirps occurring in the minute preceding the subject bouts increased, respondents exhibited greater post-jump-yip increases in the proportion of time they spent bipedally-alert ( $n = 18$ ,  $r_s = 0.416$ ,  $P = 0.086$ ), though again the correlation was only statistically significant at  $\alpha = 0.10$  (Table 16). They also exhibited smaller post-jump-yip increases in the proportion of time they spent both passively foraging ( $n = 18$ ,  $r_s = -0.481$ ,  $P = 0.043$ ) and generally foraging ( $n = 18$ ,  $r_s = -0.453$ ,  $P = 0.059$ ) as the number of pre-subject chirps increased, though only the correlation with passive foraging was statistically significant at  $\alpha = 0.05$  (Table 16). They also exhibited smaller post-jump-yip increases in the proportion of time they spent both in “occupied” bipedal-slouched postures ( $n = 18$ ,  $r_s = -0.467$ ,  $P = 0.051$ ) and in “occupied” bipedal-alert postures ( $n = 18$ ,  $r_s = -0.540$ ,  $P = 0.021$ ), though again, the correlation with “occupied” bipedal-slouched postures was significant only at  $\alpha = 0.10$  (Table 16). Increases in the amount of time alarm calls were present in the environment in the minute preceding the subject bout were associated with significantly smaller post-jump-yip increases in the proportion of time respondents in the bout spent in a bipedal-slouched posture ( $n = 18$ ,  $r_s = -0.554$ ,  $P = 0.017$ ; Table 16).

Respondents exhibited smaller post-jump-yip increases in the proportion of time they spent in “occupied” quadrupedal head-up postures as the number of jump-yip bouts occurring in the minute following the subject bout increased ( $n = 18$ ,  $r_s = -0.417$ ,  $P = 0.085$ ), while exhibiting greater post-jump-yip increases in the proportion of time they spent in a bipedal-alert posture ( $n = 18$ ,  $r_s = 0.465$ ,  $P = 0.052$ ; Table 17), though both correlations were only statistically significant at  $\alpha = 0.10$ . Respondents did not, however,

Table 17: Correlations between the characteristics of the extraneous vocalizations present in the minute following the subject jump-yip bout and the post-jump-yip change in the behaviour of a respondent in that bout (n = 18).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
HL / MIN	-0.255	0.151	0.194	0.198	0.141	-0.011	-0.088
INCVIG / MIN	-0.054	0.268	0.244	0.183	0.113	0.023	-0.103
TVIG	-0.148	-0.039	0.030	-0.007	-0.125	-0.388	-0.036
ACTFOR	0.167	0.217	0.108	0.108	-0.010	<b>0.404*</b>	0.108
PASSFOR	-0.361	-0.228	0.063	0.064	0.180	<b>-0.470**</b>	0.149
TOTFOR	0.017	0.068	0.061	0.088	0.027	-0.062	<b>0.405*</b>
S4Ux	<b>-0.417*</b>	0.164	0.375	0.342	0.093	-0.329	0.179
S4U	-0.090	-0.007	0.074	0.077	0.007	-0.002	-0.399
BSx	0.066	0.334	0.217	0.143	-0.158	0.027	0.055
BS	-0.275	-0.181	0.035	0.102	-0.062	0.205	<b>-0.606**</b>
BAx	-0.145	0.257	0.357	0.357	0.000	0.108	0.205
BA	<b>0.465*</b>	0.156	-0.181	-0.296	0.049	0.163	0.039

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

exhibit variation in their post-jump-yip changes in behaviour with variation in the characteristics of the jump-yip bouts which occurred in the minute following their jump-yip bout.

As the number of chirps occurring in the minute following the subject jump-yip bout increased, respondents in the bouts exhibited greater post-jump-yip increases in the proportion of time they spent actively foraging ( $n = 18$ ,  $r_s = 0.404$ ,  $P = 0.096$ ) and smaller post-jump-yip increases in the proportion of time they spent passively foraging ( $n = 18$ ,  $r_s = -0.470$ ,  $P = 0.049$ ), though only the negative correlation with passive foraging was statistically significant at  $\alpha = 0.05$ . Respondents also exhibited greater post-jump-yip increases in the proportion of time they spent generally foraging as the amount of time alarm calls were present in the minute following the subject bout increased ( $n = 18$ ,  $r_s = 0.405$ ,  $P = 0.095$ ), though the correlation was only statistically significant at  $\alpha = 0.10$  (Table 17). Conversely, as the amount of post-jump-yip time alarm calls were present in the environment increased, respondents significantly reduced their post-jump-yip change in the proportion of time spent bipedally-slouched ( $n = 18$ ,  $r_s = -0.606$ ,  $P = 0.008$ ; Table 17).

## **Abiotic factors and the behaviour of bout initiators**

### Immediate post-jump-yip behaviour

The immediate post-jump-yip behaviour of jump-yip bout initiators was unrelated to the time of day at which the subject bout occurred (Table 18). Bout initiators, however, assumed lower levels of vigilance immediately following jump-yip production ( $n = 25$ ,  $r_s = -0.358$ ,  $P = 0.073$ ) and maintained their immediate post-jump-yip behaviour



Table 18: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the immediate post-jump-yip behaviour of the initial caller in that bout.<sup>^</sup>

	TIME <sup>†</sup>	DATE <sup>‡</sup>
INITVIG	-0.118	<b>-0.358*</b>
ADJINITVIG	-0.338	-0.254
DURINITBHV	-0.323	-0.144
DURINITVIG	-0.158	<b>-0.383*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19, except DURINITVIG and DURINITBHV, where n = 18

<sup>‡</sup> n = 25, except DURINITVIG and DURINITBHV, where n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

for less time ( $n = 18$ ,  $r_s = -0.383$ ,  $P = 0.059$ ) following jump-yip bouts occurring later in the year, though both relationships were only significant at  $\alpha = 0.10$  (Table 18).

No significant differences in the immediate post-jump-yip behaviour of bout initiators were found between bouts occurring under different levels of cloud cover (Table 19) or different wind intensities (Table 20), but the individuals did assume vigilant behaviours for different durations in different habitats – exhibiting the shortest immediate post-jump-yip vigilance in intermediate-captivity habitats – though the difference was only statistically significant at  $\alpha = 0.10$  ( $\chi^2 = 4.585$ ,  $P = 0.090$ ; Table 21).

#### One-minute post-jump-yip behaviour

Jump-yip bout initiators spent a greater proportion of time passively foraging in the minute following jump-yip production when bouts occurred later in the day ( $n = 31$ ,  $r_s = 0.308$ ,  $P = 0.092$ ), though the correlation was only statistically significant at  $\alpha = 0.10$  (Table 22). The post-jump-yip behaviour of bout initiators did not vary, however, when the bouts they initiated occurred at different times of the year (Table 22).

Bout initiators had different rates of head lifting ( $\chi^2 = 4.640$ ,  $P = 0.096$ ) and spent significantly different proportions of post-jump-yip time in “occupied” bipedal-slouched postures ( $\chi^2 = 12.305$ ,  $P = 0.003$ ), in both cases being more vigilant following bouts occurring under greater levels of cloud cover, though only the difference in “occupied” bipedal-slouched behaviour was statistically significant at  $\alpha = 0.10$  (Table 23). When a jump-yip bout occurred during greater wind intensities, jump-yip bout initiators spent significantly more time in a quadrupedal head-up posture in the minute following the subject bout ( $\chi^2 = 7.086$ ,  $P = 0.061$ ), though the correlation was only

Table 19: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts under different levels of cloud cover.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 20)	Cloudy (n = 5)	U	Sig.
INITVIG	0.900 ± 0.100	1.000 ± 0.000	45.0	0.927
ADJINITVIG	0.825 ± 0.091	1.000 ± 0.000	40.0	0.507
DURINITBHV†	7.368 ± 3.143	4.600 ± 1.503	41.5	0.686
DURINITVIG†	9.421 ± 3.659	5.200 ± 2.059	41.0	0.668

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 19, Cloudy: n = 5

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 20: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts under different wind intensities.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 13)	Moderate (n = 8)	High (n = 3)	$\chi^2$	Sig.
INITVIG	0.846 ± 0.104	0.875 ± 0.125	1.000 ± 0.000	0.505	1.000
ADJINITVIG	0.808 ± 0.107	0.813 ± 0.132	1.000 ± 0.000	0.857	0.745
DURINITBHV	9.462 ± 4.469	3.125 ± 0.479	1.667 ± 0.667	3.349	0.191
DURINITVIG	9.692 ± 4.545	2.875 ± 0.611	15.333 ± 13.346	0.224	0.900

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 21: Differences in the immediate post-jump-yip behaviour of initial callers in jump-yip bouts occurring in different habitats.^

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 9)	Captive (n = 4)	$\chi^2$	Sig.
INITVIG	1.000 ± 0.113	0.778 ± 0.147	1.000 ± 0.000	1.892	0.397
ADJINITVIG	0.923 ± 0.096	0.778 ± 0.147	0.875 ± 0.125	0.702	0.754
DURINITBHV†	8.667 ± 4.773	2.889 ± 0.611	9.250 ± 4.328	2.176	0.337
DURINITVIG†	<b>12.500 ± 5.453</b>	<b>2.111 ± 0.588</b>	<b>10.000 ± 4.435</b>	<b>4.585*</b>	<b>0.090</b>

^ See Appendix A for abbreviations and definitions

† Wild: n = 12, Intermediate: n = 9; Captive: n = 4

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 22: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the behaviour of the initial caller in that bout over one minute following jump-yip production (n = 42).<sup>^</sup>

	TIME <sup>†</sup>	DATE
HL / MIN	-0.084	0.136
INCVIG / MIN	-0.154	0.068
TVIG	-0.059	0.067
ACTFOR	0.033	-0.077
PASSFOR	<b>0.308*</b>	-0.046
TOTFOR	0.103	-0.124
S4Ux	0.112	0.015
S4U	-0.144	0.212
BSx	-0.177	0.159
BS	-0.124	-0.145
BAx	-	0.188
BA	-0.026	-0.112

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 31

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 23: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring under different levels of cloud cover.^

	Extent of Cloud Cover			Statistical Results	
	Clear (n = 29)	Partly Cloudy (n = 7)	Cloudy (n = 6)	$\chi^2$	Sig
HL / MIN	6.116 ± 0.689	7.691 ± 1.351	7.498 ± 1.174	2.584	0.282
INCVIG / MIN	<b>6.821 ± 0.788</b>	<b>8.716 ± 1.645</b>	<b>9.282 ± 1.200</b>	<b>4.640*</b>	<b>0.096</b>
TVIG	0.414 ± 0.059	0.265 ± 0.061	0.607 ± 0.104	4.015	0.129
ACTFOR	0.521 ± 0.074	0.714 ± 0.097	0.444 ± 0.161	2.119	0.350
PASSFOR	0.064 ± 0.027	0.079 ± 0.029	0.014 ± 0.009	3.120	0.218
TOTFOR	0.585 ± 0.076	0.793 ± 0.077	0.457 ± 0.168	2.151	0.351
S4Ux	0.123 ± 0.031	0.133 ± 0.033	0.088 ± 0.025	1.370	0.515
S4U	0.215 ± 0.048	0.090 ± 0.032	0.266 ± 0.094	2.934	0.233
BSx	<b>0.014 ± 0.011</b>	<b>0.032 ± 0.014</b>	<b>0.210 ± 0.104</b>	<b>12.305**</b>	<b>0.003</b>
BS	0.023 ± 0.014	0.010 ± 0.008	0.023 ± 0.017	1.123	0.621
BAx	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	0.448	1.000
BA	0.038 ± 0.024	0.000 ± 0.000	0.020 ± 0.020	0.994	0.624

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

statistically-significant at  $\alpha = 0.10$  (Table 24). Bout initiators also spent significantly more post-jump-yip time vigilant in different habitats, being more vigilant in captive habitats ( $\chi^2 = 9.274$ ,  $P = 0.007$ ; Table 25).

#### Changes in behaviour following jump-yip production

Jump-yip bout initiators did not vary the magnitude of their behavioural changes between the minute preceding their jump-yip and the minute following jump-yip production when their bout occurred at different times of day or at different times of the year (Table 26). Bout initiators did, however, exhibit smaller increases in the proportion of time they spent actively ( $U = 21.5$ ,  $P = 0.088$ ) and generally foraging ( $U = 19.5$ ,  $P = 0.061$ ) following jump-yip bouts which occurred under greater levels of cloud cover, though both differences were only significant at  $\alpha = 0.10$  (Table 27).

Bout initiators also exhibited significantly different post-jump-yip changes in the time they spent actively foraging under different wind intensities ( $\chi^2 = 5.070$ ,  $P = 0.077$ ), decreasing the amount of time they spent actively foraging in calm conditions and increasing their active foraging under low wind conditions (Table 28). Similarly, after jump-yipping under calm conditions, bout initiators increased the amount of time they spent in a quadrupedal head-up posture, while they decreased the amount of time they spent in a quadrupedal head-up posture under low wind conditions ( $\chi^2 = 9.027$ ,  $P = 0.004$ ; Table 28). Despite the differences in behaviour under different wind conditions, however, no consistent trends in behaviour were evident (under high winds, they exhibited an intermediate level of foraging and vigilance; Table 28).

Table 24: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring under different wind intensities.^

	Wind Intensity				Statistical Results	
	Calm (n = 19)	Low (n = 12)	Moderate (n = 3)	High (n = 8)	$\chi^2$	Sig.
HL / MIN	6.524 ± 0.844	5.972 ± 1.107	4.786 ± 1.752	8.275 ± 1.061	3.339	0.352
INCVIG / MIN	7.861 ± 1.067	6.055 ± 1.137	6.470 ± 2.598	9.134 ± 0.953	3.370	0.345
TVIG	0.534 ± 0.071	0.286 ± 0.062	0.388 ± 0.227	0.346 ± 0.103	5.056	0.169
ACTFOR	0.456 ± 0.090	0.610 ± 0.108	0.376 ± 0.273	0.706 ± 0.110	2.810	0.443
PASSFOR	0.076 ± 0.041	0.024 ± 0.009	0.051 ± 0.051	0.077 ± 0.026	2.836	0.442
TOTFOR	0.532 ± 0.092	0.634 ± 0.110	0.427 ± 0.263	0.782 ± 0.117	3.967	0.273
S4Ux	0.125 ± 0.042	0.116 ± 0.039	0.040 ± 0.031	0.142 ± 0.026	4.822	0.187
S4U	<b>0.285 ± 0.066</b>	<b>0.169 ± 0.058</b>	<b>0.153 ± 0.091</b>	<b>0.073 ± 0.028</b>	<b>7.086*</b>	<b>0.061</b>
BSx	0.087 ± 0.040	0.001 ± 0.001	0.023 ± 0.023	0.017 ± 0.012	3.704	0.293
BS	0.023 ± 0.010	0.000 ± 0.000	0.006 ± 0.006	0.054 ± 0.046	3.807	0.272
BAx	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	1.211	1.000
BA	0.013 ± 0.009	0.000 ± 0.000	0.167 ± 0.167	0.060 ± 0.060	3.655	0.266

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table 25: Differences in the post-jump-yip behaviour of initial callers in jump-yip bouts occurring in different habitats.^

	Habitat Type			Statistical Results	
	Wild (n = 23)	Intermediate (n = 13)	Captive (n = 6)	$\chi^2$	Sig.
HL / MIN	5.853 ± 0.754	7.345 ± 0.881	7.680 ± 1.715	2.310	0.325
INCVIG / MIN	6.470 ± 0.825	8.053 ± 0.892	10.165 ± 2.338	2.455	0.297
TVIG	<b>0.351 ± 0.062</b>	<b>0.363 ± 0.064</b>	<b>0.786 ± 0.058</b>	<b>9.274**</b>	<b>0.007</b>
ACTFOR	0.598 ± 0.080	0.570 ± 0.103	0.266 ± 0.130	4.101	0.132
PASSFOR	0.042 ± 0.012	0.055 ± 0.023	0.139 ± 0.123	0.631	0.741
TOTFOR	0.639 ± 0.082	0.625 ± 0.107	0.405 ± 0.145	3.404	0.176
S4Ux	0.103 ± 0.023	0.107 ± 0.022	0.209 ± 0.123	0.431	0.806
S4U	0.170 ± 0.051	0.208 ± 0.059	0.311 ± 0.112	4.535	0.103
BSx	0.010 ± 0.005	0.033 ± 0.024	0.206 ± 0.105	4.131	0.117
BS	0.026 ± 0.017	0.004 ± 0.004	0.040 ± 0.020	4.606	0.101
BAx	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	2.231	0.450
BA	0.043 ± 0.029	0.010 ± 0.010	0.020 ± 0.020	0.304	0.973

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 26: Correlations between the time of day and the time of year at which a jump-yip bout occurred and the change in the behaviour of the initial caller in that bout between the minute preceding and the minute following the jump-yip production (n = 24).<sup>^</sup>

	TIME <sup>†</sup>	DATE
HL / MIN	0.226	0.274
INCVIG / MIN	-0.036	0.181
TVIG	0.333	0.015
ACTFOR	0.180	0.035
PASSFOR	0.111	0.303
TOTFOR	0.331	0.054
S4U <sub>x</sub>	0.039	0.294
S4U	0.114	0.092
BS <sub>x</sub>	0.140	-0.030
BS	-0.093	-0.121
BA <sub>x</sub>	-0.408	0.168
BA	0.242	0.010

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 27: The effects of cloud cover on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts.^

	Extent of Cloud Cover		Statistical Results	
	Clear (n = 18)	Cloudy (n = 5)	U	Sig.
HL / MIN	0.461 ± 0.664	1.122 ± 2.497	35.5	0.504
INCVIG / MIN	-0.356 ± 0.822	1.264 ± 3.307	36.0	0.522
TVIG	0.054 ± 0.046	-0.004 ± 0.110	41.0	0.796
ACTFOR	<b>-0.030 ± 0.077</b>	<b>-0.197 ± 0.099</b>	<b>21.5*</b>	<b>0.088</b>
PASSFOR	0.060 ± 0.042	0.012 ± 0.009	39.0	0.668
TOTFOR	<b>0.030 ± 0.077</b>	<b>-0.185 ± 0.102</b>	<b>19.5*</b>	<b>0.061</b>
S4Ux	0.079 ± 0.046	0.008 ± 0.012	35.5	0.510
S4U	0.045 ± 0.040	0.118 ± 0.048	31.0	0.315
BSx	-0.026 ± 0.019	-0.134 ± 0.133	39.0	0.568
BS	-0.026 ± 0.045	0.008 ± 0.008	35.0	0.439
BAx	-0.013 ± 0.014	0.000 ± 0.000	45.0	1.000
BA	-0.005 ± 0.028	-0.003 ± 0.003	43.0	1.000

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 28: The effects of wind intensity on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts.^

	Wind Intensity			Statistical Results	
	Calm (n = 12)	Low (n = 7)	High (n = 3)	$\chi^2$	Sig
HL / MIN	0.802 ± 1.125	1.064 ± 1.193	0.188 ± 0.607	0.653	0.742
INCVIG / MIN	0.375 ± 1.459	0.911 ± 1.259	-1.143 ± 1.280	0.889	0.665
TVIG	0.047 ± 0.076	0.014 ± 0.049	0.003 ± 0.054	0.626	0.759
ACTFOR	<b>-0.159 ± 0.097</b>	<b>0.114 ± 0.103</b>	<b>0.001 ± 0.050</b>	<b>5.070*</b>	<b>0.077</b>
PASSFOR	0.077 ± 0.062	0.020 ± 0.015	0.028 ± 0.055	0.123	0.943
TOTFOR	-0.082 ± 0.101	0.133 ± 0.100	0.029 ± 0.089	2.409	0.318
S4Ux	0.074 ± 0.052	0.101 ± 0.062	0.037 ± 0.059	0.259	0.889
S4U	<b>0.129 ± 0.042</b>	<b>-0.058 ± 0.033</b>	<b>-0.039 ± 0.091</b>	<b>9.027**</b>	<b>0.004</b>
BSx	-0.081 ± 0.059	-0.024 ± 0.024	0.000 ± 0.000	0.443	0.825
BS	-0.052 ± 0.057	0.000 ± 0.000	0.125 ± 0.125	1.208	0.645
BAx	-0.019 ± 0.021	0.000 ± 0.000	0.000 ± 0.000	0.000	1.000
BA	-0.004 ± 0.003	-0.005 ± 0.005	-0.120 ± 0.120	0.854	0.856

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Similarly, bout initiators exhibited different pre- to post-jump-yip changes in both the rate at which they lifted their heads ( $\chi^2 = 4.988$ ,  $P = 0.078$ ) and the proportion of time they spent in “occupied” bipedal alert postures ( $\chi^2 = 5.271$ ,  $P = 0.086$ ) when they resided in different habitats, but again, no trends were evident for either behaviour (Table 29). In captive habitats, they exhibited the greatest post-jump-yip increase in the rate at which they raised their head and the greatest post-jump-yip decrease in the time they spent in “occupied” bipedal-alert postures (Table 29). Bout initiators did, however, exhibit significantly greater decreases (negative trend) in the proportion of time they spent in “occupied” bipedal-slouched postures as their habitats became more “captive” ( $\chi^2 = 6.720$ ,  $P = 0.018$ ; Table 29).

### **Abiotic factors and the behaviour of respondents**

Misidentification of the initial caller in a jump-yip bout, which provided the impetus to perform analyses on the behaviour of respondents in the bout, was generally confined to wild habitats, where a large number of individuals were spread across a large area. Consequently, because only one non-wild “respondent” trial was obtained, the effects of habitat on the behaviour of respondents could not be tested, leaving the temporal variables (time of day, time of year), cloud cover, and wind intensity at the time of the subject jump-yip bout as the only examinable abiotic factors.

### Immediate post-jump-yip behaviour

Neither the time of day nor the time of year when the subject jump-yip bout occurred were correlated (significantly or near-significantly) with the immediate

Table 29: The effects of habitat on differences in the pre- and post-jump-yip behaviour of initial callers in jump-yip bouts.^

	Habitat Type			Statistical Results	
	Wild (n = 13)	Intermediate (n = 8)	Captive (n = 3)	$\chi^2$	Sig.
HL / MIN	<b>0.166</b> ± <b>0.814</b>	<b>-0.347</b> ± <b>1.461</b>	<b>3.961</b> ± <b>0.961</b>	<b>4.988*</b>	<b>0.078</b>
INCVIG / MIN	-0.503 ± 1.010	-0.972 ± 1.802	3.863 ± 2.769	2.529	0.295
TVIG	0.063 ± 0.037	0.019 ± 0.100	-0.032 ± 0.147	0.536	0.781
ACTFOR	-0.016 ± 0.087	-0.014 ± 0.086	-0.374 ± 0.187	3.572	0.171
PASSFOR	0.005 ± 0.013	0.037 ± 0.014	0.250 ± 0.250	3.046	0.225
TOTFOR	-0.011 ± 0.091	0.023 ± 0.096	-0.124 ± 0.232	0.625	0.745
S4Ux	0.032 ± 0.044	0.047 ± 0.021	0.218 ± 0.208	1.669	0.461
S4U	0.014 ± 0.041	0.096 ± 0.066	0.133 ± 0.042	3.467	0.182
BSx	<b>0.000</b> ± <b>0.000</b>	<b>-0.033</b> ± <b>0.049</b>	<b>-0.291</b> ± <b>0.165</b>	<b>6.720**</b>	<b>0.018</b>
BS	0.021 ± 0.032	-0.088 ± 0.081	-0.004 ± 0.075	1.597	0.434
BAx	<b>0.000</b> ± <b>0.000</b>	<b>0.002</b> ± <b>0.002</b>	<b>-0.083</b> ± <b>0.083</b>	<b>5.271*</b>	<b>0.086</b>
BA	-0.004 ± 0.040	-0.005 ± 0.004	-0.005 ± 0.005	0.492	0.802

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

post-jump-yip behaviour of respondents in the bout (Table 30). Furthermore, the immediate post-jump-yip behaviour of respondents was not significantly different between bouts occurring under different levels of cloud cover (Table 31) and under different wind intensities (Table 32).

#### One-minute post-jump-yip behaviour

Respondents spent more post-jump-yip time passively foraging as bouts occurred later in the day ( $n = 21$ ,  $r_s = 0.406$ ,  $P = 0.068$ ), though the correlation was only statistically significant at  $\alpha = 0.10$  (Table 33). The time of year at which the subject jump-yip bout occurred, however, was not related to the behaviour of respondents in the bout over the minute following jump-yip production (Table 33).

Respondents did not exhibit different post-jump-yip behaviours following bouts which occurred under different levels of cloud cover (Table 34). They did, however, spend significantly different proportions of their post-jump-yip time passively foraging when the jump-yip bouts in which they participated occurred under different wind intensities ( $\chi^2 = 7.679$ ,  $P = 0.017$ ), spending the most post-jump-yip time passively foraging under low wind conditions and the least time under calm conditions (Table 35). No trend in foraging, however, was observed across different wind intensities (Table 35).

#### Changes in behaviour following jump-yip production

Respondents in jump-yip bouts decreased the magnitude of their change in the proportion of time they spent actively foraging after jump-yip production as their jump-yip bout occurred later in the day ( $n = 16$ ,  $r_s = -0.434$ ,  $P = 0.093$ ), though the

Table 30: Correlations of the time of day and the time of year at which a jump-yip bout occurred and the behaviour of a respondent in that bout immediately following jump-yip production (n = 22).<sup>^</sup>

	TIME <sup>†</sup>	DATE
INITVIG	-0.243	-0.073
ADJINITVIG	-0.300	-0.055
DURINITBHV	-0.161	0.195
DURINITVIG	-0.229	-0.102

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table 31: Differences in the immediate post-jump-yip behaviour of respondents in jump-yip bouts occurring under different levels of cloud cover.^

	Extent of Cloud Cover		Statistical Results	
	Clear (n = 12)	Cloudy (n = 8)	U	Sig.
INITVIG	0.917 ± 0.083	1.000 ± 0.189	44.5	1.000
ADJINITVIG	0.875 ± 0.090	0.813 ± 0.162	43.5	0.673
DURINITBHV	12.667 ± 5.083	8.125 ± 2.767	39.0	0.506
DURINITVIG	17.417 ± 6.293	7.500 ± 3.333	31.0	0.204

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 32: Differences in the immediate post-jump-yip behaviour of respondents in jump-yip bouts occurring under different wind intensities.^

	Wind Intensity			Statistical Results	
	Calm (n = 6)	Moderate (n = 8)	High (n = 8)	$\chi^2$	Sig.
INITVIG	0.833 ± 0.307	1.000 ± 0.000	0.875 ± 0.125	0.728	0.599
ADJINITVIG	0.667 ± 0.247	0.938 ± 0.063	0.813 ± 0.132	1.114	0.619
DURINITBHV	20.667 ± 8.269	8.625 ± 4.114	10.750 ± 7.091	4.505	0.108
DURINITVIG	10.833 ± 4.490	11.875 ± 7.034	13.875 ± 7.553	0.022	0.991

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 33: Correlations between time of day and time of year and the post-jump-yip behaviour of a respondent in the subject jump-yip bout over one minute following jump-yip production (n = 26).<sup>^</sup>

	TIME <sup>†</sup>	DATE
HL / MIN	0.312	-0.215
INCVIG / MIN	0.161	-0.274
TVIG	-0.217	-0.055
ACTFOR	0.004	0.049
PASSFOR	<b>0.406*</b>	-0.221
TOTFOR	0.218	0.034
S4U <sub>x</sub>	0.185	0.124
S4U	-0.134	0.033
BS <sub>x</sub>	-0.243	-0.020
BS	-0.095	0.091
BA <sub>x</sub>	-0.222	-0.219
BA	-0.013	-0.316

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 21

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 34: Differences in the behaviour of respondents in jump-yip bouts over the minute following jump-yip production under different levels of cloud cover.^

	Extent of Cloud Cover			Statistical Results	
	Clear (n = 13)	Partly Cloudy (n = 10)	Cloudy (n = 3)	$\chi^2$	Sig.
HL / MIN	5.852 ± 1.190	6.645 ± 1.494	5.177 ± 3.561	0.476	0.804
INCVIG / MIN	6.863 ± 1.326	7.748 ± 1.714	5.177 ± 3.561	0.677	0.736
TVIG	0.515 ± 0.092	0.373 ± 0.079	0.403 ± 0.213	0.854	0.677
ACTFOR	0.537 ± 0.102	0.791 ± 0.071	0.614 ± 0.239	4.265	0.119
PASSFOR	0.050 ± 0.015	0.047 ± 0.017	0.000 ± 0.000	3.953	0.155
TOTFOR	0.587 ± 0.110	0.838 ± 0.063	0.614 ± 0.239	3.470	0.182
S4Ux	0.099 ± 0.025	0.148 ± 0.033	0.100 ± 0.100	1.734	0.438
S4U	0.229 ± 0.077	0.098 ± 0.052	0.303 ± 0.218	4.211	0.125
BSx	0.039 ± 0.025	0.127 ± 0.057	0.000 ± 0.000	3.843	0.118
BS	0.032 ± 0.029	0.000 ± 0.000	0.000 ± 0.000	3.250	0.235
BAx	0.003 ± 0.003	0.000 ± 0.000	0.000 ± 0.000	1.000	1.000
BA	0.114 ± 0.078	0.000 ± 0.000	0.000 ± 0.000	2.080	0.597

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 35: Differences in the behaviour of respondents in jump-yip bouts over the minute following jump-yip production under different wind intensities.<sup>^</sup>

	Wind Intensity			Statistical Results	
	Calm (n = 7)	Low (n = 9)	High (n = 10)	$\chi^2$	Sig.
HL / MIN	3.790 ± 0.987	6.257 ± 1.151	7.521 ± 1.856	2.526	0.292
INCVIG / MIN	4.790 ± 1.252	6.705 ± 1.169	8.835 ± 2.101	1.826	0.413
TVIG	0.423 ± 0.104	0.361 ± 0.093	0.543 ± 0.108	2.048	0.367
ACTFOR	0.770 ± 0.108	0.684 ± 0.094	0.519 ± 0.123	2.725	0.261
PASSFOR	<b>0.005 ± 0.003</b>	<b>0.069 ± 0.019</b>	<b>0.047 ± 0.018</b>	<b>7.679**</b>	<b>0.017</b>
TOTFOR	0.775 ± 0.109	0.753 ± 0.102	0.566 ± 0.128	1.422	0.504
S4Ux	0.110 ± 0.047	0.114 ± 0.024	0.127 ± 0.038	0.428	0.818
S4U	0.163 ± 0.097	0.143 ± 0.060	0.244 ± 0.099	1.003	0.625
BSx	0.150 ± 0.080	0.060 ± 0.036	0.018 ± 0.012	2.047	0.353
BS	0.000 ± 0.000	0.044 ± 0.042	0.002 ± 0.002	1.953	0.433
BAx	0.000 ± 0.000	0.000 ± 0.000	0.003 ± 0.003	1.600	1.000
BA	0.000 ± 0.000	0.000 ± 0.000	0.149 ± 0.099	3.328	0.313

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

correlation was only statistically significant at  $\alpha = 0.10$  (Table 36). Conversely, they significantly increased the change in the proportion of time they spent passively foraging following jump-yip production as the bout in which they were a participant occurred later in the day ( $n = 16$ ,  $r_s = 0.790$ ,  $P < 0.001$ ; Table 36). Respondents also exhibited greater (at  $\alpha = 0.10$ ) post-jump-yip increases in the time they spent in “occupied” quadrupedal head-up postures later in the day ( $n = 16$ ,  $r_s = 0.477$ ,  $P = 0.062$ ; Table 36). As jump-yip bouts occurred later in the year, respondents in the bouts showed smaller increases in the proportion of time they spent bipedally-slouched between the minute preceding and the minute following jump-yip production ( $n = 18$ ,  $r_s = -0.440$ ,  $P = 0.068$ ; Table 36).

Respondents in jump-yip bouts exhibited significantly different post-jump-yip changes in the proportion of time they spent passively foraging when their jump-yip bouts occurred under different levels of cloud cover ( $U = 13.0$ ,  $P = 0.027$ ), decreasing the amount of time they spent processing food when cloud cover was greater (Table 37). Respondents did not, however, exhibit significantly different changes in behaviour between the minute preceding and the minute following jump-yip production when the jump-yip bouts in which they were participants occurred under different wind intensities (Table 38).

### **Other variables of interest**

Though the focus of this study was on the effects of jump-yip bout characteristics (as well as social and abiotic factors) on the behaviour of black-tailed prairie dogs, the interrelationships between non-behaviour variables must also be considered. To that end,

Table 36: Correlations between time of day and time of year and the change in the pre- and post-jump-yip behaviour of a respondent in the subject jump-yip bout (n = 18).<sup>^</sup>

	TIME <sup>†</sup>	DATE
HL / MIN	0.233	-0.092
INCVIG / MIN	0.127	-0.093
TVIG	0.253	-0.325
ACTFOR	<b>-0.434*</b>	0.376
PASSFOR	<b>0.790**</b>	-0.211
TOTFOR	0.286	0.271
S4U <sub>x</sub>	<b>0.477*</b>	-0.096
S4U	-0.418	-0.267
BS <sub>x</sub>	0.005	0.025
BS	-0.014	<b>-0.440*</b>
BA <sub>x</sub>	0.196	0.243
BA	-0.329	0.220

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 37: The effects of cloud cover on differences in the pre- and post-jump-yip behaviour of respondents in jump-yip bouts.^

	Extent of Cloud Cover		Statistical Results	
	Clear (n = 8)	Partly Cloudy (n = 9)	U	Sig.
HL / MIN	1.063 ± 1.182	0.641 ± 1.779	33.0	0.795
INCVIG / MIN	0.313 ± 0.986	0.286 ± 2.297	33.5	0.834
TVIG	0.101 ± 0.057	-0.014 ± 0.094	26.5	0.376
ACTFOR	-0.033 ± 0.114	0.132 ± 0.100	22.0	0.198
PASSFOR	<b>0.040</b> ± <b>0.030</b>	<b>-0.123</b> ± <b>0.077</b>	<b>13.0**</b>	<b>0.027</b>
TOTFOR	0.006 ± 0.127	0.008 ± 0.090	34.5	0.913
S4Ux	0.063 ± 0.028	-0.052 ± 0.096	24.5	0.293
S4U	0.020 ± 0.027	0.050 ± 0.065	31.5	0.697
BSx	0.010 ± 0.013	0.034 ± 0.049	33.0	0.796
BS	-0.021 ± 0.021	-0.037 ± 0.020	30.0	0.580
BAx	-0.017 ± 0.017	0.000 ± 0.000	31.5	0.478
BA	0.046 ± 0.073	-0.009 ± 0.009	31.0	0.537

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table 38: The effects of wind intensity on differences in the pre- and post-jump-yip behaviour of respondents in jump-yip bouts.^

	Wind Intensity			Statistical Results	
	Calm (n = 5)	Low (n = 6)	High (n = 7)	$\chi^2$	Sig.
HL / MIN	-0.525 ± 1.443	2.500 ± 0.719	-0.158 ± 2.348	3.512	0.179
INCVIG / MIN	-0.107 ± 1.494	1.500 ± 0.671	-0.913 ± 2.957	2.707	0.269
TVIG	-0.008 ± 0.119	0.000 ± 0.059	0.096 ± 0.104	1.977	0.387
ACTFOR	0.196 ± 0.126	0.119 ± 0.111	-0.104 ± 0.118	3.870	0.149
PASSFOR	-0.145 ± 0.131	0.000 ± 0.052	-0.010 ± 0.047	2.102	0.366
TOTFOR	0.051 ± 0.054	0.119 ± 0.114	-0.114 ± 0.142	0.802	0.695
S4Ux	-0.059 ± 0.171	0.058 ± 0.041	-0.003 ± 0.047	0.880	0.669
S4U	-0.007 ± 0.030	-0.003 ± 0.018	0.087 ± 0.084	1.097	0.599
BSx	0.101 ± 0.061	-0.019 ± 0.040	0.000 ± 0.020	4.239	0.117
BS	-0.028 ± 0.027	-0.031 ± 0.027	-0.025 ± 0.021	0.317	0.866
BAx	0.000 ± 0.000	0.000 ± 0.000	-0.019 ± 0.019	1.571	1.000
BA	-0.016 ± 0.016	-0.006 ± 0.006	0.057 ± 0.083	0.065	0.930

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



the relationships between bout characteristics, social variables, and abiotic variables have been examined as a series of appendices. These relationships include: the autocorrelations between the characteristics of the subject bouts (Appendix C), the autocorrelations between the recorded behaviours of black-tailed prairie dogs (Appendix D), the relationships between the social variables present at the time of the subject bouts and the characteristics of those bouts and the autocorrelations of the social variables (Appendix E), and the relationships between: 1) the abiotic factors present at the time of the subject bouts and the characteristics of those bouts, 2) the abiotic factors present at the time of the subject bouts and the social factors present at that time, and, 3) the autocorrelations of the abiotic factors (Appendix F).

## DISCUSSION

This study examined the jump-yip-associated behaviour of black-tailed prairie dogs to assess whether individuals varied their behaviour with differences in the characteristics of jump-yip bouts in which they participated (either as the initial caller in the bout or as a respondent in the bout). Central to this hypothesis was the assumption that the response of an individual to a jump-yip display (i.e. the participation of an individual in a jump-yip bout) itself provides information concerning the state of that respondent – i.e. that the responding individual is aware of the preceding jump-yip (consequently responding in kind) and is therefore vigilant to events in the environment. The characteristics of jump-yip bouts which contain multiple responses and/or respondents (magnitude of response, timing of responses), when taken together, may then provide information concerning the vigilance of the social group as a whole (since it is representative of the individuals in the group who are vigilant).

The black-tailed prairie dogs observed in this study became vigilant immediately following jump-yip production, but there was little evidence that the immediate post-jump-yip behaviour of individuals varied with the characteristics of the preceding jump-yip bout. Over longer periods of time following jump-yip production, and when pre-jump-yip behaviours were considered, however, black-tailed prairie dogs exhibited reductions in vigilance and increases in foraging in association with jump-yip bouts containing greater levels of response, consistent with the hypothesis that individuals derive information regarding the vigilance of local conspecifics from jump-yip bouts. A series of unexpected results were also observed – including non-linear changes in foraging and highly vigilant behaviour with changes in the characteristics of

preceding jump-yip bouts, as well as relationships that appear to run counter to those predicted under the extraction of information regarding group vigilance from jump-yip bouts – however, these unexpected findings may be attributable to extraneous variables (e.g. social factors such as population size and extraneous vocalizations and abiotic factors such as the time of the observational session and meteorological variables) that affected information reception, processing, and the responses of individual prairie dogs.

This discussion examined bout initiator and respondent behaviour immediately following jump-yip production (regardless of the characteristics of the associated jump-yip bout) as well as the characteristics of the associated jump-yip bouts. The characteristics of the bouts were then related to the behaviours of both types of jump-yipping individual over the three timeframes examined in this study – immediately following jump-yip production, over the minute following jump-yip production, and as it changed following jump-yip production – examining both results which were consistent with the hypothesis of this experiment – that the characteristics of a jump-yip bout provide information concerning the vigilance of a social group – and those which were not. For those which were inconsistent with the expectations of this study, potential causes were examined. Relationships between black-tailed prairie dog behaviour and both social and abiotic variables were examined in detail, as were some pertinent relationships between the extraneous variables. Finally, alternatives to the central hypothesis of this study were examined, as were potential future studies which may expand on the findings of this study. Finally, the conclusions drawn from this study were summarized.

**Immediate post-jump-yip behaviour – presence of vigilance**

Among black-tailed prairie dogs observed in this study, a significant proportion of both initial callers and respondents in jump-yip bouts assumed vigilant postures immediately following jump-yip production, consistent with the results of Smith et al. (1976). The impetus for immediate post-jump-yip vigilance may arise from the complex nature of the jump-yip display, for while jump-yips are often considered to occur following the cessation of a predatory threat (e.g. Hoogland 1995), it is reasonable to assume that some residual risk exists owing to the potential presence of unseen predators. This predation risk may be even greater if, as postulated (and observed), individuals jump-yip regardless of preceding stimuli – i.e. in the absence of diminishing threat (e.g. Waring 1970). Any pre-existing risk of predation could further be exacerbated by the highly visible nature of the jump-yip display, which may advertise the location of individuals to nearby predators. A period of vigilance immediately following the display could serve to ameliorate some (or perhaps all) of this risk.

Individuals may also need to assume vigilant postures immediately after jump-yip production owing to the complexity of the display. The movements which comprise the jump-yip – particularly the “jump,” where the head is rapidly oriented toward the sky – may degrade vision, while the production of the relatively high amplitude vocal signals during the “yip” may degrade hearing ability. Movement, like that seen in the “jump” of the jump-yip display, can blur the visual field and produce noise which inhibits the auditory system, reducing the acuity of visual and auditory senses and limiting the amount and quality of information that can be collected (McAdam and Kramer 1998; Kramer and McLaughlin 2001). These sensory deficits also prevent an individual from

focusing its attention on a particular object or event in the environment (Kramer and McLaughlin 2001) and this combined with the direction of attention to the performance of a complex display such as the jump-yip, may result in a brief, but substantial, informational null, in which individuals are incapable of acquiring “high-quality” (accurate, non-degraded) information from the environment.

Pauses in locomotion (or during other movements or behaviours) stabilize the senses and provide an individual with time to scan the environment, and if necessary, focus on a particular stimulus such as the presence of a predator (Avery et al. 1987; McAdam and Kramer 1998; Kramer and McLaughlin 2001; Trouilloud et al. 2004). In fact, pauses in feeding behaviour – which allow a foraging animal to orient its sensory organs away from the ground and toward its surroundings – play a major role in the foraging-vigilance tradeoff (e.g. Pulliam 1973; Elgar 1989; Lima and Dill 1990).

Individuals exhibiting vigilant behaviours immediately following jump-yip production may also prolong their vigilance owing to subsequent responses in their jump-yip bout. Many animals use vigilant behaviours to assess novel stimuli in their environment. Birds, for example, exhibit brief vigilance behaviours following the departure of individuals from a flock (i.e. changes in aboveground population size), ostensibly to assess changes in social state and collective vigilance (Roberts 1995; Broom and Ruxton 1998), while fish, rats, and several primate species will approach and examine novel potential threats (e.g. fish: Pitcher et al. 1986; rats and primates: MacDonald and Pinel 1991). If each jump-yip bout contains novel information concerning the collective vigilance of the prairie dog’s social group, the characteristics of

the bout may be analogous to the detection of changes in the flock size of birds, and may thus elicit a similar (temporary) vigilance response.

The significance of the immediate post-jump-yip vigilance of both bout initiators and respondents within a jump-yip bout is two-fold. First, an individual exhibiting vigilant behaviour (regardless of the cause of said behaviour) is ideally suited to detect and assess/quantify any subsequent jump-yips, particularly those which occur immediately after the onset of vigilance (i.e. those which are part of its jump-yip bout). Consequently, it is reasonable to assume that individuals who produce jump-yips are able to glean information concerning the response of neighbours to their jump-yip. Second, this demonstrates that individuals who jump-yip are, at least briefly, vigilant members of their social group and thus contribute to the collective vigilance of a black-tailed prairie dog colony. If individuals are able to characterize the responses of individuals within a jump-yip bout, it should provide an accurate representation of the vigilance of their colony, at least over a short period of time (and potentially longer, depending upon the persistence of the immediate post-jump-yip vigilance behaviour).

### **Characteristics of jump-yip bouts recorded in this study**

The mean number of jump-yips in all bouts recorded in this study ( $4.20 \pm 0.29$ ) was higher than that observed by Owings and Owings in 1979 (1.93). These results indicate that, on average, there are 2-4 responses per jump-yip bout. This might appear to make the classification of four or more responses in a jump-yip bout as the representative value for “high” levels of response (in comparisons of behaviour following bouts with high and low – zero or one response – responses) inconsistent with the range of

jump-yips present in most (if not all) environments (since it is not that much higher than the average number of responses per bout). However, in light of the fact that in some cases, there were extremely high levels of response in the recorded jump-yip bouts (i.e. > 20 responses), which could significantly skew the observed average response counts, as well as previously published results demonstrating lower average response counts, defining “high” response as four or more responses and/or seconds is not unreasonable. This is particularly true since many of the “high” response subject bouts (19 of 27) contained at least six responses (and lasted longer than six seconds).

The measures of response magnitude in the subject jump-yip bouts – number of responses, number of respondents, and duration – were positively correlated with one another in sessions examining the behaviour of both bout initiators and respondents (Appendix C). In the case of “respondent” subject bouts, the positive correlations between responses, respondents, and duration were observed both with respect to the section of the subject bout beginning with the subject’s jump-yip and the entire subject bout. In some cases, positive correlations were also observed between the magnitude of response in the subject-initiated section of the subject bout and the magnitude of response in the entire bout, though this likely represents the fact that most respondents examined in this study were individuals who jump-yipped early in the subject bout, rather than any relevant positive relationships between the characteristics of entire jump-yip bouts and subsets of those bouts (Appendix C).

The positive correlations between the number of responses and respondents in a subject jump-yip bout and the duration of that bout were expected, given that more responses/respondents should take more time. The strong positive correlation between

responses and respondents further suggests that, generally, few individuals jump-yip more than once in a given bout. Though instances in which single individuals repeated their jump-yip display were observed, it appears generally to be limited to a single individual in a given bout and is not prevalent among multiple bouts. The close relationships between the number of responses and respondents in and the duration of the subject bouts also demonstrates that jump-yip bout receivers (listeners) have the potential to obtain consistent quantitative (number of responses/respondents) and temporal (duration) information concerning the level of response in a jump-yip bout. This may allow individuals to use one form of information preferentially or to reinforce the information contained in the bout using both quantitative and temporal measurements.

The positive correlations between both the number of responses and the number of respondents in a jump-yip bout and the duration of the bout also indicate that differences in rate between bouts are relatively small (since rate differences should result in no correlations being observed between the number of responses/respondents and the duration of the bout). Consequently, differences in the rate at which jump-yips occur in a bout likely play a minimal role in providing semantic information to receivers, as compared to other modes of communication, such as alarm calling, where rate may convey important information (e.g. Leger et al. 1980; Evans et al. 1993; Randall and Rogovin 2002; Warkentin et al. 2001; Sloan and Hare 2004). While an individual producing an alarm call can directly adjust the rate at which it calls, the multiple individuals participating in a jump-yip bout likely exert little effect on the entire rate of the call (i.e. any “rapid” response of one individual may be overwhelmed by differences in the rate of calling of other individuals).



If an individual were to convey information in a jump-yip bout by varying the rate at which they responded to a preceding jump-yip (i.e. responding slowly or quickly to the preceding jump-yip), the information would only be evident if the individual was the first respondent in the bout (i.e. as the response latency of the bout). This value, however, should provide little information concerning the “state” of a social group, since the calling characteristics of subsequent respondents are effectively irrelevant.

Correspondingly, in the three data groups in which the behaviour of bout initiators was examined, the response latency of a jump-yip bout was not correlated with any measures of the magnitude of response in the bout. In these groups, any information carried by the response latency of the subject jump-yip bouts must act independently of the other components/characteristics of the bout. In certain groups of data in which the behaviour of respondents was examined, however, increases in the number of responses in and the duration of the subject’s section of the subject bout were associated with decreases in the response latency of both the section and the entire bout (an expected inverse relationship, given that higher response magnitudes and shorter response latencies should both demonstrate greater vigilance). In these cases, and in conjunction with the other bout characteristics, response latency may provide supplemental information concerning the magnitude of response in a jump-yip bout and is thus considered as a potential contributing factor to behavioural changes in black-tailed prairie dogs, even though the lack of universal correlations (correlations in all six data groups) would seem to indicate that response latency is not a reliable source of social information. The relationship between jump-yip-related behaviour and the response latency of the jump-yip bout, and

the resultant evidence concerning the effects of response latency on the behaviour of black-tailed prairie dogs is discussed below.

### **Immediate post-jump-yip behaviour**

#### Level and duration of vigilance

Though black-tailed prairie dogs reliably exhibited vigilant behaviours immediately following jump-yip production regardless of the characteristics of the preceding bout, it was expected that the characteristics of this immediate post-jump-yip vigilance (and other immediate post-jump-yip behaviours) would vary with respect to the characteristics of the bouts – i.e. individuals would be more vigilant for longer periods of time following short bouts than following long bouts. In fact, it was expected that the strongest correlations between jump-yip bout characteristics and black-tailed prairie dog behaviour would be observed in the short period of time immediately following jump-yip production, given the relatively transient nature of information contained in rapid displays or vocalizations which cannot be repeatedly accessed by receivers (as opposed to social signals such as population size which persist in the environment as described by Hoogland (1979) and Kildaw (1995)). Such short-term behavioural responses to social signals are actually observed in black-tailed prairie dogs when alarm calls are present in the environment. Upon hearing an alarm call, black-tailed prairie dogs will (almost) immediately become vigilant. This vigilance persists, however, only if the cause of the alarm call (i.e. the threat) is identified (e.g. Hoogland 1995).

Among the immediate post-jump-yip behaviours themselves, increases in the level of vigilance assumed by both bout initiators and respondents immediately following

jump-yip production were associated with increases in the “adjusted” level of vigilance assumed by both types of jump-yipping individuals immediately following jump-yip production, a result that is not surprising given the simple 0.5 unit “adjustment” for secondary behaviours (Appendix D). Increases in the immediate-post-jump-yip level of vigilance, both unadjusted and adjusted, were associated with increases in the duration of the immediate post-jump-yip vigilance for both bout initiators and respondents. This would indicate that increases in black-tailed prairie dog vigilance are reflected both in the type of vigilance behaviour exhibited and the amount of time the vigilance persists. The duration of the immediate-post-jump-yip period of vigilance was also positively correlated with the duration of the initial behaviour for both bout initiators and respondents, results consistent with the observation that the immediate post-jump-yip behaviour was often a vigilant behaviour.

There was little evidence, however, of any relationship between the immediate post-jump-yip behaviour of black-tailed prairie dogs and the characteristics of the preceding jump-yip bout. The immediate post-jump-yip vigilance behaviour (as well as general behaviour) of bout initiators did not vary with changes in the characteristics of their jump-yip bout. Respondents did assume higher levels of vigilance (adjusted for secondary behaviours) immediately following jump-yip production as the number of respondents occurring after their jump-yip increased, but this correlation was only statistically significant at  $\alpha = 0.10$  (Appendix D). The potential relevance of the correlation is further minimized when the precise post-jump-yip levels of vigilance of prairie dogs are considered. Respondents never assumed vigilant behaviours beyond lifting their heads while remaining quadrupedal and only assumed “head-down” postures

when they (the subjects) were the final jump-yip in their entire jump-yip bout. Thus, they effectively became vigilant under almost all conditions – i.e. the previously described tendency for individuals to become vigilant immediate following jump-yipping – and exhibited no graded response to differing levels of response in their jump-yip bout.

Furthermore, neither bout initiators nor respondents exhibited significantly different behaviours following bouts containing different levels of response, regardless of whether comparisons were performed for all levels of response or just high and low levels of response. This indicates that the lack of graded response to small changes in the characteristics of jump-yip bouts (e.g. a difference of one response/respondent/second between bouts) does not simply arise from the inability of individuals to detect such small differences, nor does it appear to result from individuals “ignoring” such small differences in response, since they likewise do not adjust their behaviour for larger differences in response.

It would appear then, that the immediate post-jump-yip behaviour of black-tailed prairie dogs occurs independently from information contained in the preceding social display. While it was expected that behavioural responses to variation in the response characteristics of jump-yip bouts would occur rapidly following the completion of a jump-yip bout (as described above), the nature of the jump-yip bout as well as physiological limits on information-processing and response may make rapid (instantaneous) behavioural changes in response to variation in the characteristics of jump-yip bouts unlikely, if not impossible. For instantaneous changes in behaviour to be manifested by black-tailed prairie dogs, individuals must be capable of rapidly collecting information concerning the response characteristics of their jump-yip bout and then

processing the information to a level appropriate for making behavioural decisions (e.g. calculating the level of response in the bout, comparing that level of response to some preset level of response or to previously measured levels of response in other jump-yip bouts). The lack of relationships between immediate post-jump-yip behaviour and the response characteristics of the preceding jump-yip bouts may represent a deficit in one of these processes.

The simplest explanation for a lack of correlation between the immediate post-jump-yip behaviour of a jump-yipping prairie dog and the response characteristics of the preceding jump-yip bout is that behavioural decisions only occur once a complete assessment (or at least a “sufficient” assessment) of the characteristics of a jump-yip bout is performed. This “receiving delay” (i.e. the time required to receive the information contained in the jump-yip bout) could be manifested in one of two ways. First, individuals could remain vigilant as long as there are jump-yips occurring in the environment (i.e. they remain vigilant for information as long as it is present). As described previously, black-tailed prairie dogs remain vigilant as long as predators are nearby (where the presence of predator is the information) (e.g. Hoogland 1995), while other species such as California ground squirrels (Loughry and McDonough 1988) and Columbian ground squirrels (Harris et al. 1983) exhibit variation in vigilance behaviour with variation in the characteristics of alarm vocalizations (i.e. show evidence of maintaining vigilance as long as signals are present in the environment). If this were the case, however, differences in vigilant behaviour should still be observed following bouts of different duration, particularly with respect to comparisons of behaviours occurring after bouts of long ( $> 4$  s) and short ( $< 1$  s) duration. As described previously, no

significant differences in vigilant behaviour were observed for either bout initiators or respondents following bouts of different duration – results consistent with studies that show no evidence of prolonged signals stimulating prolonged vigilance (e.g. Sloan and Hare 2004). Second, individuals may remain vigilant only until a set level of response is achieved (or until sufficient information can be gleaned about the response characteristics of the bout), and then perform other behaviours, including searching for and identifying potential food sources (i.e. a receiver has determined the collective vigilance of its social group is high enough to allow it to assume non-vigilant behaviours). In this case, any relationships between the duration of a jump-yip bout and the immediate vigilance behaviour of a jump-yipping individual (initiator or respondent) may only be evident for low levels of response (where the “set-point” has not been achieved).

Though there is little direct evidence for a “set-point” level of collective vigilance which promotes subsequent non-vigilant behaviour in group members, much of the modeling of the effects on sociality posits an asymptotic relationship between group size (collective vigilance) and the non-vigilant behaviour of group members. Indeed, there are diminishing returns in antipredator benefits with increasing group size until the benefit of additional members is relatively small (e.g. Pulliam 1973; Jarman 1987, Dehn 1990, Blumstein et al. 1999). It is this point – at which further group size increases do not appreciably improve group vigilance – which could correspond to the hypothetical “set-point.” Again, however, there is little evidence of any difference in immediate post-jump-yip behaviour even when bouts containing low levels of response (short duration) are compared to bouts containing high levels of response (long duration).

Individuals may also face a “processing delay” in exhibiting changes in behaviour in response to changes in the characteristics of their jump-yip bout, arising from the time required to either assess the characteristics of the bout – including counting the number of responses in the bout and/or assessing the duration and response latency of the bout and providing these measures some form of quantitative label (e.g. Davis and Pérusse 1988) – or performing one or more calculations involving the characteristics of the bout – comparing the characteristics of the bout against previously detected and measured bouts or against set levels of response associated with the vigilance of the group. These processing delays may be similar to the cognitive delays described initially in humans by Stroop (1935) and reviewed by MacLeod (1991), and while complex calculations or quantitative comparisons are not ubiquitous throughout the animal kingdom (e.g. Davis and Pérusse 1988, Hauser 2000), this “processing delay” could be particularly relevant if individuals perform any calculations involving sequential comparisons of multiple jump-yip bouts – i.e. where individuals would become more or less vigilant as the response levels of successive bouts change in magnitude (see “Social effects on behaviour” discussed below).

It is also possible that individuals exhibit a stereotypical progression from vigilant to non-vigilant behaviours regardless of the level of response in their jump-yip bout, devoting a relatively standard period of time to vigilance postures immediately following jump-yip production, independent of the characteristics of the preceding bout. It is only after this period of vigilance that the response characteristics of jump-yip bouts would exert an effect on behaviour, stimulating either more vigilance (with low levels of response) or non-vigilant behaviours such as foraging (with high levels of response).

Because this period of vigilance would occur regardless of the level of response in the preceding jump-yip bout, no correlations would be observed between the characteristics of jump-yip bouts and the immediate post-jump-yip behaviour of displaying individuals. Likewise, the immediate post-jump-yip behaviour of displaying individuals would not differ significantly following bouts with large differences in the magnitude of response (e.g. 1 vs. 4 responses). Any changes in behaviour with changes in the characteristics of jump-yip bouts would instead occur (and be observed) over longer periods of time following jump-yip production (in this study, over one minute following jump-yip production and as differences in behaviour between the minute preceding and the minute following jump-yip production).

### **The behaviour of individuals over extended periods of time**

#### Expected results

Bout initiators devoted more time to active and total foraging (both passively and actively foraging) when their bout contained four or more responses than when their bout contained only a single response. Their behaviour did not, however, vary with changes in the response characteristics of the preceding jump-yip bout (as was the case for immediate post-jump-yip behaviour). Correspondingly, individuals did not exhibit graded differences in behaviour when the preceding jump-yip bout contained different numbers of responses or lasted for different durations (i.e. the post-jump-yip behaviour of bout initiators did not differ when bouts containing 0, 1, 2, 3, and 4 or more responses were all contrasted).



The foraging behaviour of respondents over the minute following jump-yip production did not vary with changes in the characteristics of the preceding jump-yip bouts. Respondents did, however, decrease the amount of time they spent in a bipedal-alert posture as the magnitude of response (number of responses, duration) in both the section of their jump-yip which they initiated and their entire jump-yip bout increased, with the strongest negative correlation observed between bipedal-alert behaviour and the number of responses in the entire jump-yip bout. They also spent less time in a bipedal-slouched posture as the number of responses in their entire jump-yip bout increased. These reductions in highly vigilant behaviour with increases in the magnitude of response in the preceding jump-yip bout were consistent with the hypothesis that individuals would exhibit less vigilance with increases in the level of response in associated jump-yip bouts. Respondents did not, however, assume highly vigilant postures for significantly different periods of time following bouts (sections or entire) containing different numbers of responses or lasting for different durations, regardless of whether all levels of response or just low and high levels of response were considered.

When pre-jump-yip behaviours were considered, bout initiators exhibited lower rates of head lifting (i.e. how often they interrupted head-down behaviours, particularly foraging, with vigilance behaviours) following jump-yip bouts lasting four or more seconds compared to the increases in the rate of head lifting they exhibited following bouts which lasted only one second. In fact, they actually exhibited a post-jump-yip reduction in the rate at which they lifted their head following jump-yip bouts lasting four or more seconds.

Respondents in jump-yip bouts exhibited greater post-jump-yip increases in the amount of time they spent actively foraging as the magnitude of response (responses, respondents, and duration) in their section of the jump-yip bout increased. They also decreased the proportion of time they spent vigilant after jump-yip bouts which contained four or more responses in their section of their jump-yip bout, while increasing the proportion of time they spent vigilant following bouts in which there were no responses in their section of the bout (i.e. when they were the final response in the bout). Correspondingly, they exhibited post-jump-yip increases in the proportion of time they spent actively and totally foraging when there were four or more responses in their section of their bout, while decreasing the proportion of time spent actively and totally foraging when their response was the final response in the bout. The same relationships were observed when the respondents' sections of their jump-yip bout lasted different durations, decreasing the amount of time they spent vigilant and increasing the amount of time they spent actively and totally foraging when their section of their jump-yip bout lasted four or more seconds and increasing their time spent vigilant and decreasing their time spent actively and totally foraging following jump-yip bouts lasting less than 0.5 seconds (i.e. where duration was effectively zero).

These results support the hypothesis that black-tailed prairie dogs participating in jump-yip bouts with high levels of response (represented by either increases in/greater numbers of responses, respondents, and/or duration) should exhibit less vigilance and more foraging than individuals participating in bouts with low levels of response. However, while several expected behavioural changes were observed, there were several relationships between the characteristics of response in the preceding jump-yip bout and

the behaviour of bout initiators and respondents which were not consistent with the hypotheses underlying this study.

Results inconsistent with the expected decrease in vigilance/increase in foraging with increases in the magnitude of response in the associated jump-yip bouts

Bout initiators devoted a high proportion of their post-jump-yip time to foraging when their jump-yip bout contained no responses (i.e. they produced a solitary jump-yip), particularly when compared to bouts of low response (i.e. one response). This non-linear relationship (bout initiators also spent large amounts of time foraging following jump-yip bouts containing four or more responses) between the magnitude of response in a preceding jump-yip bout and the foraging behaviour of the bout initiator underlies the lack of variation/gradation in foraging behaviour across all measured levels of response (i.e. the lack of significant correlations between the amount of time bout initiators spent foraging and the number of responses in the associated jump-yip bout, even though there was a significant difference in the time spent foraging between high and low response) and runs counter to the expectation that individuals producing a solitary jump-yip should become more vigilant (or even the most vigilant, given the complete lack of response) and thus forage less because there are fewer vigilant individuals in the environment.

Similarly, bout initiators spent more post-jump-yip time in a bipedal-alert posture when their jump-yip bouts lasted two or three seconds compared to when they lasted less than one second, one second, or four or more seconds (with no difference found between bouts of short – zero and one second – and long – four or more seconds – duration). This non-linear relationship, while consistent with the significant decrease in foraging

described above, is not consistent with the expectation that vigilance should decline with increases in the duration of the preceding jump-yip bout.

Respondents also exhibited a non-linear relationship between their post-jump-yip vigilance and the duration of their jump-yip bout, spending significantly more time in bipedal-slouched postures (a relatively high level of alertness— Owings and Virginia 1978; MacWhirter 1992; Hare 1998) following entire bouts lasting approximately two seconds than they did following entire bouts lasting approximately one second or four or more seconds. As was the case for bout initiators, however, no differences in post-jump-yip bipedal-slouched behaviour were observed between short (1 s) and long (4+ s) duration bouts.

This greater foraging/reduced vigilance following jump-yip bouts containing little to no response may reflect pre-jump-yip behavioural tendencies which persist following jump-yip production. An individual producing a solitary jump-yip may face ambiguity with respect to the cause of the low response. It may, for example, stem from a low level of collective vigilance, or it may result from nearby individuals not detecting the signal at all (unlike the case of jump-yip bouts which contain a single response and are thus detectible). Rather than vary their behaviour (and risk making incorrect behavioural decisions), individuals detecting no response to their jump-yip bout may instead maintain their pre-jump-yip behaviours, which themselves were based on previously (presumably reliable) information concerning the state of the environment. Individuals may also exhibit a tendency to forage in the absence of other behaviour-determining information (such as alarm calls), since energy acquisition plays such a major role in determining an

individual's behaviour (Emlen 1966; Schoener 1971; Pyke et al. 1977; Stephens and Krebs 1986; Cuthill and Houston 1997).

The effect of previous tendencies to perform certain behaviours (either vigilance or foraging) is borne out by the lack of non-linear relationships in foraging and highly vigilant behaviour in both bout initiators and respondents when pre-jump-yip behaviours are factored into the analysis (Appendix B). In fact, many of the significant relationships between the behaviour of black-tailed prairie dogs in the minute following jump-yip production and the characteristics of their jump-yip bout – such as the greater foraging and less time in bipedal-alert postures following bouts of greater response/duration – were not found when pre-jump-yip behaviours were considered. Other (expected) relationships between foraging and vigilance and the characteristics of the associated jump-yip bout were, however, observed, though some changes/differences in behaviour were not as universal as expected (e.g. bout initiators only exhibited less frequent vigilance behaviour following long duration bouts, while only the foraging behaviour of respondents varied as expected).

When pre-jump-yip behaviours were factored into the analyses, bout initiators were not found to exhibit any graded post-jump-yip changes in behaviour (i.e. correlations) with changes in the characteristics of their jump-yip bout, nor did they exhibit significantly different post-jump-yip changes in behaviour following jump-yip bouts containing different numbers of responses. Non-linear relationships between bout initiator vigilance and the response magnitude of their jump-yip bout also persisted, as they exhibited the greatest post-jump-yip increase in the rate of head lifting when their jump-yip bout lasted approximately one or two seconds, while barely

adjusting their rate of head lifting when their jump-yip occurred alone (when there were no responses in their bout) and decreasing their rate of head lifting when their jump-yip bout was prolonged (lasting four or more seconds). As described below, this may indicate that non-linear relationships between vigilance and the jump-yip characteristics of a social group represent more than simply an unusual change in behaviour, but instead a significant behavioural response by individuals to information concerning the state of members of their coterie/colony.

Respondents, as described previously spent more time vigilant and less time actively and generally foraging when their jump-yip was the final jump-yip in their bout (i.e. there were no responses in the section of their bout beginning with their jump-yip), results consistent with the expected decreases in foraging and increases in vigilance in association with “low response” jump-yip bouts. At the same time, however, respondents also exhibited greater post-jump-yip increases in the rate at which they both lifted their heads and increased their level of vigilance (including postural changes to bipedal positions) as the number of respondents in their section of the jump-yip bout increased, opposing both the expected decrease in vigilance with increasing response in a jump-yip bout and the observed increase in foraging. Furthermore, they did not exhibit graded post-jump-yip changes in foraging or vigilance with changes in the number of responses in, or the duration of, their entire jump-yip bout. This was consistent with their behaviour over the minute following their jump-yip bout (where no changes/differences in behaviour were found), but did not correspond to the observed changes in respondent behaviour with changes in the characteristics of “their” section of the subject bout (i.e. the section of the bout beginning with their jump-yip).

The lack of any variation and/or difference in behaviour with changes in the characteristics of entire jump-yip bouts may indicate that individuals are demonstrating their awareness of the environment by jump-yipping, as it would appear those jump-yips preceding their own display exerted limited effects on their behaviour. Before drawing this conclusion, however, a more direct examination of the effects, or lack thereof, of preceding jump-yips in a bout needs to be performed (see “Future studies”). Furthermore, the inconsistent relationships between the post-jump-yip changes in the time respondents spent foraging and the post-jump-yip changes in the rate at which they assumed vigilance postures may be explained if they simply interrupt periods of active foraging with increasingly greater number of head lifts and postural changes, a possibility discussed below.

It also does little to explain why several of the observed changes/differences in the behaviour of bout initiators and respondents are non-linear, results which, while not fully contradicting the expectations of this study, do not support the contention that vigilance should decrease and foraging increase as the amount of response in a jump-yip bout increases. Instead, they may point to a secondary role of the jump-yip in the social interactions of black-tailed prairie dogs, indicating to receivers that potentially threatening conspecifics are nearby (described in “non-linear relationships between response and behaviour – does jump-yipping indicate fitness” below).

### **Interpretation of unexpected results**

#### The absence of strong inverse relationships between foraging and vigilance

Chief among the unexpected results of this study is the lack of inverse relationships between foraging and vigilance, even for results which conform to the

hypotheses of this study (e.g. the greater proportion of time bout initiators spent actively and generally foraging after jump-yip bouts containing four or more responses was not accompanied by a smaller proportion of time spent vigilant). This does not conform to previously-described vigilance-foraging trade-offs (Pulliam 1973; Elgar 1989; Lima and Dill 1990), but may reflect the methodology of this experiment and/or the way black-tailed prairie dogs devote time to non-vigilant behaviours other than foraging.

An examination of the behaviour of subject individuals in this study independent of the characteristics of associated jump-yip bouts (Appendix D) demonstrated expected positive correlations within the measures of vigilance and foraging (i.e. in the absence of any group size effects). The strong positive correlations observed between the number of head lifts per minute and the number of increases in vigilance per minute exhibited by both bout initiators and respondents, for example, reflect the (expected) significant contribution of head lifts to the total number of increases in vigilance performed by the individual. Increases in the total time spent vigilant were also associated with increases in the time spent in a quadrupedal head-up posture (all groups) and in the time spent bipedal-slouched and bipedal-alert in most groups, each positive correlation reflecting the contribution of individual vigilant behaviours to the total time spent vigilant. Not surprisingly, “occupied” vigilant behaviours also contributed significantly to the time individuals spent vigilant, though the positive correlations were not as universal amongst study groups.

Interestingly, there were relatively few correlations between the “occupied” form of a behaviour and the “unoccupied” form of the behaviour. Only in the case of respondents performing “occupied” bipedal-alert and “unoccupied” bipedal-alert postures



did there appear to be a correlation between occupied and unoccupied behaviours. Consequently, there is no evidence of a progression in behaviour from occupied to unoccupied behaviours (with individuals spending approximately equivalent time in the occupied and unoccupied forms of the behaviour) and the specific levels of vigilance recorded in this study can be considered independently.

Similar expected positive correlations were observed between active foraging and general foraging in all groups, demonstrating the strong contribution of active foraging to general foraging. Time spent passively foraging was also positively correlated with time spent totally foraging, but as was the case for the contribution of “occupied” vigilant behaviours to total time vigilant, the correlation was not seen for all study groups (it was observed in three of the four study groups).

Most importantly, increases in the total time both bout initiators and respondents spent vigilant were associated with decreases in the time they spent actively and generally foraging (except for subjects used in the examination of post-jump-yip changes in bout initiator behaviour, where those changes were only associated with decreases in the time they spent passively foraging). Therefore, the lack of observed inverse relationships between foraging and vigilance behaviour when the effects of the characteristics of the associated jump-yip bout are taken into account does not result from an underlying lack of a general foraging-vigilance trade-off, but instead from the lack of concurrent increases in foraging and decreases in vigilance with increases in the magnitude of response in the associated subject bout.

With no readily-evident cause for the lack of inverse relationships between the time spent foraging and the time spent vigilant, it is possible that some secondary effects,

not directly examined in this study, underlie the unexpected changes in behaviour. For example, an individual needing to replenish energy reserves may spend significantly more time foraging as the magnitude of response in the preceding bout increases, but not at the expense of vigilance (possibly altering the amount of time devoted to non-vigilant behaviours such as movement, social interactions, grooming, etc.). Conversely, individuals who have recently experienced a nearby threat, or have been exposed to social indicators of such an event (i.e. alarm calling, neighbours fleeing the source of the threat), may devote more time to vigilance in association with jump-yip bouts containing low response but continue to forage at a rate consistent with their energy needs (and decreasing the time they devote to other behaviours such as movement and social interactions).

Indeed, the observed exaggeration of post-jump-yip increases in both the time respondents devoted to active foraging and the rate at which they lifted their heads and increased their level of vigilance with increases in the number of post-subject responses in the associated jump-yip bout demonstrate that foraging and vigilant behaviours need not be mutually exclusive. In this study, the frequency at which vigilant behaviours were exhibited was not associated with increases in the time spent vigilant or with decreases in the time spent actively or generally foraging. In several species, increases in vigilance are observed to occur with decreases in aboveground population size, with feeding bouts being more frequently interrupted by vigilant behaviours (e.g. Hoogland 1979; Kildaw 1995). Rather than devoting prolonged periods to vigilance behaviours (in which there may be no risk of predation), these individuals instead rely on more frequent (though briefer) periods of vigilance to assess the risk at any given time. This may be particularly

relevant for species in which individuals in a social group warn others of approaching predators (reducing the need for individuals to identify predators themselves).

In this study, there was also evidence that among instances where active foraging is interrupted, foraging does not necessarily stop. The rates of head lifting of both bout initiators and respondents were associated with increases in the proportion of time they spent passively foraging (i.e. chewing) and in “occupied” quadrupedal head-up postures (behaviours which themselves were positively correlated, reflecting the significant role passive foraging plays in any “occupied” behaviour). Thus, while individuals may lift their head from the ground and consequently be unable to take in new forage, they use their time to process what they have already taken in, maximizing their foraging time while not suffering a significant decrease in vigilance. Other studies have not examined the time devoted to the specific forms of vigilance (specific postures) examined in this study (e.g. Hoogland 1979; Kildaw 1995) or did not consider vigilance to begin prior to the cessation of chewing (e.g. Hoogland 1979) and thus may have obtained different fundamental measures of foraging behaviour. I believe, however, that failing to delineate these different types of vigilance discounts what is likely an important component of vigilance and foraging.

Finally, there is evidence that vigilance and foraging are not mutually exclusive behaviours and may in fact work in concert in certain species (Lima and Bednekoff 1999). This may occur particularly in those species in which social cues (alarm calling, fleeing of neighbouring individuals) may be used to assess threat at any given time (as in black-tailed prairie dogs), and may further contribute to occasions in which inverse relationships between vigilance and foraging were not strong or observed.

Non-linear relationships between response and behaviour – does jump-yipping indicate fitness?

As described previously, some of the observed changes in the behaviour of both bout initiators and respondents were not linearly related to the changes in the characteristics of the associated jump-yip bouts. While it was hypothesized that these unusual changes in behaviour could reflect pre-jump-yip tendencies to perform certain behaviours, the cost of performing a jump-yip bout may also contribute to the observed pattern of behavioural change.

Signals or displays produced by animals require an investment of time and energy (e.g. Zahavi and Zahavi 1997). As the complexity of a signal or display increases, so too does the investment of the signaler in performing that behaviour, with individuals performing these costly signals advertising their high level of fitness (e.g. Zahavi and Zahavi 1997; Rivero et al. 2000). With its relatively intricate vocal and behavioural components, the jump-yip is a complex signal. Though often produced singly (as opposed to repeated signals such as alarm calls), they require time and, likely more importantly, considerable energy to perform. The rhythmic nature of the display, requiring at least some level of coordination and concentration, may also impart an increased cost to performing the signal (Lambrechts and Dhandt 1986; Zahavi and Zahavi 1997).

The acoustic components and postural changes associated with jump-yip production may also make callers more visible to predators in the environment, imparting further cost on producing the display (e.g. Zahavi and Zahavi 1997). Even though the irregular nature of response(s) in a jump-yip bout may ameliorate this cost by confusing a potential predator (e.g. Humphries and Driver 1970), a displaying individual must be

willing to accept a potential increase in predation risk. In doing so, it advertises its ability to “cope” with this cost and thus its level of fitness (Zahavi and Zahavi 1997).

If a certain level of fitness is required before an individual can jump-yip, then jump-yipping individuals may be advertising their relatively high fitness. With responses in a jump-yip bout often occurring in close proximity to other participants in the bout, increasing numbers of jump-yipping individuals may indicate that “fit” individuals are nearby and represent a possible threat. Though black-tailed prairie dogs are an extremely social species (e.g. Smith et al 1976; Hoogland 1995), territorial and other conflicts over resources occur regularly (e.g. King 1955; Waring 1970; Smith et al. 1976, 1977; Hoogland 1979; Hoogland 1995).

If a jump-yip display serves two functions – as an indicator of vigilance/awareness and as an indicator of fitness – it may explain the non-linear relationship between vigilance/foraging and the level of response in a jump-yip bout. Initially, as the magnitude of response in a jump-yip bout increases, bout initiators and respondents perceive that there are more vigilant individuals in their social group and consequently become less vigilant and forage more. However, as the magnitude of response further increases, the risk of conflict and/or competition with nearby individuals overcomes the reduced risk of predation and causes increases in vigilance and/or reductions in foraging. Increases in vigilance could arise from individuals attempting to avoid conflict, while the presence of nearby individuals of high fitness could lead individuals to immediately forage more to avoid competition with these fit individuals.

If jump-yipping indicated the fitness of individuals, it may also underlie the greater post-jump-yip increases in head lifting and vigilance increases exhibited by

respondents in association with jump-yip bouts containing greater levels of response. As the level of response in a jump-yip bout increases, individuals may be exposed to a simultaneous decrease in predatory threat due to a greater level of social vigilance and an increase in conspecific threat (e.g. territorial incursion, foraging competition). To mitigate and take advantage of the relative costs and benefits, they may forage at a greater rate (to take advantage of the greater social vigilance) while exhibiting frequent short periods of vigilance to identify the number and location of potential intraspecific competitors (e.g. Cresswell 1997; Beauchamp 2001). Brief periods of vigilance may be particularly appropriate since the actual threat to the life or health of an individual is relatively minor among even fighting black-tailed prairie dogs, so conspecific vigilance need not be as thorough as antipredator vigilance.

Though recognizing that studies of the “true” fitness of jump-yipping individuals would be required to test this hypothesis – and also acknowledging that while conflict is not rare among black-tailed prairie dogs, it rarely results in serious injury to either combatant and individuals rarely come into direct competition with one another – the prevalence of non-linear relationships in this study make this an interesting avenue for future research. Any future studies addressing this possibility should also ensure that all levels (incorporating a broad range) of response (whether number of responses in a bout or bout duration) in a jump-yip bout are represented, thereby circumventing a problem present in this study in which bouts with certain response characteristics (and the associated behaviour of participants in the bout) were not recorded or analyzed. This would allow for an assessment of the magnitude of response where foraging and/or vigilance is greatest and how the behaviours vary with response magnitude.

Predominance of significant differences in behaviour only across large differences in response magnitude.

Most of the statistically significant changes in behaviour documented in this study were observed with large-scale differences in the response characteristics of the associated jump-yip bouts. The absence of a large number of significant correlations may arise from the inability of individuals to detect or assess small differences in response magnitude (i.e. differences of one response and/or one second). Indeed, while the characteristics of the jump-yip bout, including its multimodal (multi-sensory) form and its rhythmic structure may aid in the quantification of response (e.g. Davis and Pérusse 1988; Hauser 2000), it does not ensure that black-tailed prairie dogs possess the physiological or behavioural ability to make behavioural decisions based on the measurable or quantifiable characteristics of their jump-yip bout.

The duration of a jump-yipping individual's immediate post-jump-yip vigilance is independent of the response characteristics of the jump-yip bout in which that individual is a participant, indicating that the presence of jump-yips in the environment does not predict vigilance in a recently jump-yipping individual (i.e. individuals do not remain vigilant as long as there are jump-yips occurring in the environment). It is possible that the response characteristics of, and particularly the number of responses in, a jump-yip bout are not directly enumerated, but instead are measured in terms of meeting a threshold of response. If black-tailed prairie dogs are incapable of "counting" (or are even incapable of any form of numerical competency; Davis and Pérusse 1988; Hauser 2000), the use of thresholds may be the only mechanism by which individuals can make quantitative comparisons.

It is also possible that certain thresholds represent the level of response at which there is no further benefit to remaining vigilant (i.e. there becomes a point at which any further response in a jump-yip bout does not represent an appreciable or significant increase in the collective vigilance of a social group, and consequently the need to remain aware of further response in the jump-yip bout becomes unnecessary). Therefore, graded responses to different levels of response in a jump-yip bout are not required or even beneficial, resulting in fewer relationships between the magnitude of response in a jump-yip bout and the immediate post-jump-yip vigilance of a calling individual – results which were observed in this study. Further studies addressing the specific levels at which increasing group size and thus collective vigilance (both directly measured and as represented by the level of response in a jump-yip bout) no longer provide appreciable reductions in the predation risk experienced by individuals are thus warranted. These thresholds could then be manipulated to assess the effects on the behaviour of individuals in the social group.

There is also the possibility that the subject jump-yip bouts recorded in this study did not possess characteristics consistent with other bouts present in the environment. As described previously, while the mean ( $\pm$  standard error) number of jump-yips in the bouts recorded in this study ( $4.20 \pm 0.29$ ) was higher than a previously recorded mean number of jump-yips per bout (1.93: Owings and Owings 1979), the subject bouts generally contained a greater level of response, ranging from 3-10 jump-yips/bout. Consequently, using four or more responses (or durations of more than four seconds) as a representative “high” level of response, while not necessarily inaccurate, may not reflect the apparent predominance of bouts containing lower levels of response (less than two



responses/seconds), and may underlie the lack of correlations in many of the study groups. In this case, vigilance or foraging behaviours would plateau following jump-yip bouts of two/three or more responses. Any analysis of behavioural changes for bouts with more response would result in no significant correlations since the behaviour would not change appreciably. The presence of significant differences in subject behaviour following jump-yip bouts with two responses/seconds indicate that individuals may, in fact, vary their behaviour in response to graded changes in the magnitude of response in associated jump-yip bouts (even if not all of the differences are expected). Likewise, a qualitative examination of the correlations obtained in this study show little evidence of asymptotic changes in behaviour with changes in the characteristics of associated jump-yip bouts. Future studies may be required, however, to precisely determine at what point individuals no longer vary their behaviour with changes in the level of response in associated jump-yip bouts.

Are highly-alert behaviours really indicative of changes in social state?

Decreases in the time both bout initiators and respondents spent in highly-vigilant behaviour (bipedal-alert and bipedal-slouched postures) over the minute following jump-yip production were commonly observed with increases in the response magnitude of the preceding jump-yip bouts. These noticeable changes in behaviour were not present, however, when the behaviour of those individuals preceding jump-yip production were considered. This would seem to indicate that individuals who assumed highly-vigilant postures following jump-yip production were influenced by factors (including prior environmental stimuli, behavioural tendencies, or other unknown factors) other than the

response characteristics of their jump-yip bout, since the highly-vigilant behaviours began well before jump-yip production and persisted over a relatively long period of time following jump-yip production.

These results call into question whether high levels of vigilance – bipedal stances and particularly bipedal-alert postures – change (or should be expected to change) in response to the transient changes in predation risk (collective vigilance) conveyed by the characteristics of the jump-yip bout. Generally, assuming a bipedal stance prevents an individual from performing certain additional behaviours (such as actively taking in food) since the head is moved well away from the ground and its associated vegetation, though some chewing or feeding on items held by the forelimbs may occur with a raised head. Furthermore, a bipedal-posture may make an individual more conspicuous as they move away from the camouflage provided by the ground and surrounding vegetation. Thus, while a posturally-alert individual benefits from increased predator-detection capabilities arising from moving its sensory organs above obstacles in the environment (including vegetation, rocks and other geological structures), the costs experienced by the alert individual – in the form of energy costs, time lost to performing other beneficial behaviours, and an increase in conspicuousness to predators – may prove too great to allow the behaviours to occur except under periods of great predation risk. These periods may include when a predator has been sighted nearby or when alarm calling indicates impending danger (e.g. King 1955). If this is the case, the social-vigilance information provided by jump-yip bouts, which may be somewhat ambiguous and relatively short-term, may not be sufficient to promote maximal postural vigilance in receivers.

Interestingly, the observed (and expected) decreases in the vigilance of black-tailed prairie dogs with increases in population size in the studies of Hoogland (1979) and Kildaw (1995) did not extend to highly-vigilant behaviours. Likewise, neither the amount of time nor the frequency with which highly alert postures were assumed differed significantly with changes in aboveground population size (Hoogland 1979; Kildaw 1995). With aboveground population size being a relatively persistent signal of the collective vigilance of a social group, but still not affecting the highly vigilant behaviours of black-tailed prairie dogs, it is not surprising that highly vigilant behaviours would not differ appreciably with changes in the characteristics of jump-yip bouts.

Effects of response latency on behaviour.

As described at length in the examination of the immediate post-jump-yip behaviour of bout initiators and respondents, the response latency of any jump-yip bout is unlikely to contain much, if any, information concerning the collective vigilance of a particular group. Even as an indication of the vigilance level of the first respondent, response latencies (and the differences in response latency between multiple bouts) are generally quite short (in this study, response latencies averaged  $0.89 \pm 0.13$  (mean  $\pm$  SE) seconds in bout initiator bouts,  $0.71 \pm 0.15$  seconds in the respondent-initiated sections of the subject bouts, and  $1.32 \pm 0.21$  seconds in the respondents' entire bouts). For response latency to convey information, a receiver must accurately identify the first respondent in the bout (which itself may be difficult, particularly if the response occurs during the production of the initial jump-yip) and then correctly process and/or quantify differences in latency of fractions of a second (regardless of whether multiple bouts are compared to

each other or if the latency of a single bout is compared to a “set-point” equivalent to some level of vigilance).

Ground-dwelling squirrels have demonstrated the ability to differentiate seemingly small temporal differences in the patterns of alarm calling (e.g. Sloan and Hare 2004), but in many cases those temporal properties are repeated several times, allowing a receiver to continually assess and refine their estimation of that signal parameter, likely making it easier to process the information contained therein (e.g. Bradbury and Vehrencamp 1998). The response latency of any given jump-yip bout, on the other hand, occurs only once and must therefore be accurately detected and analyzed with no opportunity to “confirm” any initial assessment. Furthermore, while omitting a response from a count of the responses in a bout may result in relatively small differences in the perceived magnitude of response (especially for larger/longer bouts), incorrectly identifying a later response in the bout as the second response could result in the perceived latency of the bout being several times longer than it truly is. Thus, processing errors may be much more severe in measuring latency, as opposed to other characteristics of response, rendering latency an unreliable characteristic on which to base one’s vigilance.

Similarly, the response latency of a bout cannot continue indefinitely. At some point, any further response could be considered the onset of a second bout, imparting an additional potential confound upon any comparisons of response latency (i.e. an individual comparing the response latencies of two bouts occurring at two different times must also ensure that the response latency they are processing does not actually denote the onset of a second distinct bout). This would be a much more difficult and potentially

costly (time and attention) process than identifying differences in discrete measures, such as the number of responses in a jump-yip bout, casting even more doubt as to whether response latency is functionally indicative of the collective vigilance of a social group.

The expected absence of relationships between the response latency of a subject jump-yip bout and the behaviour of individuals participating in the bout was borne out in the case of bout initiators, whose behaviour over the minute following jump-yip production, and as it changed following jump-yip production, did not vary with the response latency of their bout. The behaviour of respondents, however, did vary with changes in the response latency of the associated jump-yip bouts.

The observed increases in the time respondents spent vigilant and in quadrupedal head-up postures over the minute following jump-yip production with increases in the response latency of their entire jump-yip bout are expected if longer latencies are consistent with a low collective vigilance. This increase in vigilance was also accompanied by the expected decrease in the total time they spent foraging (active and passive) in the minute following jump-yip production. Similarly, when pre-jump-yip behaviours were considered, respondents exhibited (expected) smaller post jump-yip increases in the total time they spent foraging as the latency of their section of their jump-yip bout increased (as opposed to the latency of their entire jump-yip bout). The observed increases in vigilance and decreases in foraging seen with increases in the response latency of the entire jump-yip bout, however, were no longer observed when pre-jump-yip behaviours were considered, indicating that (as was the case for highly alert behaviours described above) behavioural tendencies toward foraging or being vigilant

may be present before jump-yip production, minimizing the apparent role of response latency in determining receiver behaviour.

Furthermore, there was no evidence that the behaviour of respondents was correlated with their latency of response to the previous jump-yip in their bout. Increases in the response latencies of subject respondents were not associated with corresponding increases in vigilance (either in general or with respect to individual vigilant behaviours). While this may be due to the influence of the subject jump-yip bout itself (which could promote changes in foraging and vigilance inconsistent with the subject's response latency), it provides further evidence that response latency in a jump-yip bout (or even for a single individual) may be a poor indicator of social state.

When a larger sample of jump-yip bouts were examined (i.e. in the examination of the characteristics of extraneous bouts; Appendix E), response latency was no longer correlated with the magnitude of response of the jump-yip bouts (latency and level of response were positively, rather than negatively, correlated, as it was for the subject jump-yip bouts; Appendix C). Consequently, if individuals glean information concerning the collective vigilance of their social group from the characteristics of jump-yip bouts in which they are both an active participant and a passive receiver, response latency may play even less of a role in determining behaviour, since the information it provides may be contradictory even over short periods of time.

### **Effects of social variables on black-tailed prairie dog behaviour**

#### Aboveground population size

As described previously, aboveground population size is among the most commonly cited social affecters of both vigilance and foraging behaviour (e.g. Pulliam

1973; Alexander 1974; Hoogland 1979, 1981; Kildaw 1995; Hare and Murie 2007). In this study, however, the estimated population sizes at the time subject jump-yip bouts occurred were not associated with consistent changes in the behaviour of either bout initiators or respondents (Appendix E). Only respondents exhibited a reduction in vigilance with greater population size (and even then, only for select vigilance behaviours).

When considered independently, these results cast doubt upon the effect of population size on the behaviour of black-tailed prairie dogs. The estimated aboveground population size recorded in this study, however, shared few expected relationships with any variables (including the characteristics of recorded jump-yip bouts and social variables) recorded in this study (Appendix E). Increases in aboveground population size were not associated with any changes in the characteristics of the subject bout recorded for either bout initiators or respondents, and were not associated with any consistent changes in the social variables present at the time observational data were collected. The relationships that were observed – increases in the frequency of jump-yip bouts and total jump-yips in the environment, the magnitude of response in certain environmental jump-yip bouts, the response latency of the environmental bouts, the amount of alarm calling in the environment, and decreases in the number of chirps in the environment with increases in the aboveground population size – were only limited to certain data sets (Appendix E).

In light of these results, it is possible that the frequency of jump-yipping in any environment is not associated with changes in the size of the population in the environment. This would provide support for the idea that the frequency of response in

a jump-yip is indicative of the state of individuals in the environment, rather than just an indication of the number of individuals in the environment (“Alternative hypotheses” below). A more likely scenario, however, is that the estimations of aboveground population size made in this study are not accurate representations of the actual population size. Incorporating refined measures of population size, where marked individuals allow direct measures of both colony and coterie size, would aid in resolving the sources of the observed relationships (or lack thereof) between population size, the behaviour of individuals in the population, and the characteristics of jump-yip bouts in the population (see “Future studies” below).

#### Secondary vocalizations

The extent to which vocalizations in the environment should affect the behaviour of subject individuals in this study is unclear. The premise of this study was that individuals performing jump-yips, particularly those individuals responding to preceding jump-yips, are demonstrating their awareness (vigilance) of events in their environment and thus contribute to the collective vigilance of their social group. Regardless of the size of their particular colony or coterie, however, black-tailed prairie dogs are exposed to numerous vocal signals, including jump-yips, barks, and alarm calls. If a single jump-yip bout contains information concerning the state of a particular colony/coterie, it stands to reason that repeated exposure to jump-yip bouts in the environment, even those in which an individual does not participate, may provide similar information (particularly if the characteristics of the bouts are relatively consistent, and thus available for repeated sampling). Likewise, the effects of barks and alarm calls on the behaviour of



black-tailed prairie dogs are well established (e.g. Waring 1970; Smith et al. 1976; Hoogland 1995) and are expected to affect the behaviour of receivers.

At the simplest level, any vocalizations (be they jump-yips or alarm calls) may exert an effect on the behaviours of individuals recorded in this study through their timing – vocalizations occurring early in a recording session should exert a greater effect on the behaviour of a subject individual than those occurring later in the bout (simply because their influence may be present for the immediate post-jump-yip behaviour of subject, though in this study this was rare, and is present for a greater proportion of the one minute post-jump-yip behaviour recording period). However, while bout initiators spent less time bipedally-alert in the minute following jump-yip production and respondents were less vigilant immediately following jump-yip production as secondary vocalizations occurred later in the observational session, observed changes in the behaviour of both bout initiators and respondents with changes in the timing of the first post-subject (non-subject) vocalization were limited. Because behavioural responses to vocalizations (or other displays) are highly dependent upon the type of signal being detected, it is quite possible that the rarity of relationships between the timing of secondary vocalizations in the environment and the behaviour of receivers arises because the type of vocalization was not considered (i.e. more alarm calling immediately after the subject jump-yip bout would be expected to provoke different behavioural changes than if jump-yips occurred in the same manner).

There was some evidence that as the first post-subject, non-subject vocalization occurred later, the subject jump-yip bouts contained fewer responses and respondents, and were of a shorter duration (Appendix E), indicating that the characteristics of

vocal activity in a particular environment may be consistent between different measures of said activity (i.e. a reduction in the number of calls is associated with more temporally-dispersed calling, resulting in secondary vocalizations occurring later in a recording session). These correlations were present, however, only for those data groups examining bout initiator behaviour. Likewise, reductions in the amount of pre-subject vocal activity (bouts, jump-yips, responses, duration, and response latency) and the number of post-subject jump-yip bouts, jump-yips, and chirps were observed for all bout initiator data groups when the first post-subject, non-subject vocalization occurred later in the recording session. This demonstrates that a decrease in vocal activity in the environment may be directly associated with a later time of post-subject vocalization (a result which is not unexpected). These changes, however, did not persist in the respondent data sets, where only a reduction in the number of post-subject jump-yip bouts (and some evidence of a decrease in the amount of post-subject alarm calling) was observed with later times at which the first post-subject, non-subject vocalization occurred.

This result casts doubt on whether the timing and the characteristics of the vocalizations in the environment are consistent, particularly in wild habitats, where there are many potential callers and consequently greater variability in the characteristics of their calls. Furthermore, any information contained by the timing of the first non-subject vocalization may be limited by the solitary nature of the signal – i.e. the first post-subject vocalization occurs only once, leaving only one opportunity for listeners to acquire and correctly process the information contained therein. The type and characteristics of

vocalizations in the environment may instead provide better information, particularly if they are consistent over at least short periods of time.

Alarm calls should produce the most recognizable behavioural changes in black-tailed prairie dogs, stimulating vigilance in receivers. In this study, however, variation in the amount of alarm calling in the environment at the time of the recording sessions was not generally associated with changes in the behaviour of either bout initiators or respondents (there was some evidence of increased initial vigilance and more highly vigilant behaviour in bout initiators and more foraging/less highly vigilant behaviour in respondents, but it was only present for certain sets of data) (Appendix E). This unexpected result may arise from the predominance of only prolonged and distant alarm calling during the recording sessions (because trials were not run or analyzed if there was significant nearby alarm calling at the time). Distant alarm calling may not produce the same response in receivers as local alarm calling, since the apparent threat is not as imminent if it is farther away. Likewise, alarm calling may lose its effectiveness as a signal (resulting in an unexpectedly low amount of vigilance in listeners) the longer it persists in an environment as individuals become habituated to its presence, particularly if it is not associated with a recognized threat (e.g. Hare and Atkins 2001).

Variation in the amount of alarm calling in the environment was also minimally associated with changes in the characteristics of the subject jump-yip bouts (for both bout initiator and respondent groups) (Appendix E). While increases or decreases in jump-yipping may be expected with increases in the amount of alarm calling in the environment (increases if jump-yipping is directly associated with the cessation of alarm calling during the observational session or is indicative of the individuals “made vigilant”

by the alarm calling; decreases if it is associated with a “safe” environment), this lack of any relationship is consistent with the methodology of this study which emphasized eliminating trials from analysis in which significant confounding events (such as nearby alarm calls) occurred.

Single syllable vocalizations which were not readily identifiable as jump-yips or alarm calls (barks) were also recorded in this study and were called “chirps.” Initially, it was thought that these vocalizations were akin to alarm calls – owing to their single syllable, monofrequency structure – and should therefore elicit vigilance in listening individuals. However, as was the case for alarm calling in the environment, the number of “chirps” in the environment was not associated with consistent variation in the behaviour of either bout initiators or respondents (Appendix E). The frequency of their occurrence in the environment was also not consistent with the frequency or characteristics of other environmental vocalizations. Consequently, they should exert little confounding effect on the results of this study. The ambiguous nature of even defining the characteristics of the “chirps” recorded in this study, as well as its surface similarities to other vocalizations such as alarm barks or the developing jump-yips of recently-emerged young (Owings and Loughry 1985), make further studies of “chirps” necessary to identify their function (see “Future studies”).

Jump-yips occur frequently in any black-tailed prairie dog population, and while information contained therein is likely exploited best by individuals who have demonstrated awareness to events in the environment (i.e. individuals who have jump-yipped), it is still present for any individuals who happen to passively receive information contained within the jump-yips. Interestingly, both bout initiators and

respondents exhibited greater vigilance immediately following jump-yip production with increases in the magnitude of response in (bout initiators) and the frequency of jump-yip bouts in (respondents) the minute preceding the subject bout. This could indicate that individuals exposed to more jump-yipping in their environment “expect” responses in their jump-yip bout and consequently assume vigilant postures to allow them to accurately receive these responses. Secondary jump-yips in the minute following the subject bout, however, were associated with no changes in black-tailed prairie dog behaviour immediately following jump-yip production, likely reflecting their limited effects on the brief post-jump-yip behaviours (when most, if not all, post-jump-yip vocalizations have yet to occur).

Bout initiators were generally less vigilant with increases in the frequency of jump-yipping (bouts and total jump-yip) in the minutes before and after their jump-yip and were less vigilant and foraged more when there were more responses in the post-subject bouts. Likewise, bout initiators exhibited smaller post-jump-yip increases in the time they spent vigilant and greater post-jump-yip increases in the time they spent foraging with increases in the number of pre-subject bouts and total jump-yips, and exhibited greater post-jump-yip increases in the time they spent vigilant with increases in the magnitude of response in the pre-subject bouts – results which conform to the expectations of increasing foraging and decreasing vigilance with increases in the amount of jump-yipping (whether in a bout or simply overall) – as well as with increases in the response latency of the pre-subject bouts (the significance of which are discussed below). There was also evidence of larger post-jump-yip increases in the time bout initiators spent highly vigilant with increases in the magnitude of response in the

pre-subject bouts – a result which opposes the expected decrease in vigilant behaviour with increases in the magnitude of response in a jump-yip bout. This may demonstrate, however, the previously described influences on highly vigilant behaviour, though it is more likely that highly vigilant behaviour is exhibited in response to perceived danger, rather than the characteristics of jump-yipping in the environment. Also opposing the expected effects of the characteristics of secondary jump-yip bouts on the behaviour of subjects were the observed greater post-jump-yip increases in the rate at which vigilant behaviours were exhibited with increases in the duration and latency of the post-subject jump-yip bouts (as well as an increase in the rate of head lifting and the time spent bipedal-slouched with increases in the response latency). In addition to casting even more doubt upon the relevance of latency as an information-carrying characteristic, this finding also indicates that the effects of secondary jump-yip bouts on the behaviour of black-tailed prairie dogs may be more complex than initially assumed.

The effects of extraneous jump-yip bouts on the behaviour of black-tailed prairie dogs are borne out in the changes in behaviour exhibited by respondents with changes in the characteristics of secondary jump-yipping in their environment. As expected, they spent more time foraging and less time vigilant with increases in the number of pre-subject jump-yips and the number of responses in the pre-subject bouts, while there was also (limited) evidence of less bipedal-alert behaviour. Similarly, increases in the number of post-subject jump-yips were also associated with decreases in the time respondents spent bipedal-alert. Conversely, however, while respondents spent more time foraging with increases in the number of jump-yip bouts in the minute preceding their own jump-yip, and less time vigilant with increases in the number of post-subject bouts,

they exhibited increases in the rate at which they increased their level of vigilance with increases in the number of post-subject bouts. Though positive correlations between the time spent foraging and the rate of vigilance are not necessarily unexpected, there are relatively few expected changes in the behaviour of respondents with changes in the characteristics of jump-yipping in the environment, especially when compared to the behaviour of bout initiators. This may reflect the environment of respondents, where there are more jump-yip bouts (as well as more general vocal activity) over any given time scale. With such a large amount of information present, it stands to reason that individuals may face some difficulty in processing (and then using) the information.

Interestingly, increases in the frequency of jump-yipping in the minute preceding and the minute following the subject bouts used in the examination of bout initiator and respondent behaviour were associated with increases in the magnitude of response (responses, respondents, duration) in the subject bouts (in the case of respondent subject bouts, with the magnitude of response in the subject's section of and the entire bout), though the correlations with the characteristics of the "respondent" subject bout were not as strong or consistent (Appendix E). Furthermore, increases in the response magnitude of the pre-subject bouts were associated with increases in the magnitude of response in the jump-yip bouts of bout initiators and respondents (where the strongest correlations were with the magnitude of response in the entire subject bout). Increases in the magnitude of response in post-subject bouts were not associated with changes in the characteristics of the "bout initiator" subject bouts, but were associated with increases in the magnitude of response in both the subjects' sections of, and the entire "respondent" subject bouts.

These results demonstrate a consistency in the characteristics of jump-yipping which is also seen among all jump-yips recorded in this study. The number of jump-yip bouts in the environment was consistent across each recording session and was, in many instances, positively correlated with the frequency of total jump-yipping in the environment (Appendix E). There was also some evidence of correlation between the frequency of jump-yip bouts in the environment and the magnitude of response in the constituent bouts. Likewise, increases in the frequency of total jump-yipping in the environment were associated with greater magnitudes of response in the associated jump-yip bouts (a result that is not surprising given that the jump-yips which make up each jump-yip bout also make up the total number of jump-yips in the environment). These results demonstrate that increases in jump-yipping in an environment are manifested as both general increases in the frequency of jump-yipping as well as increases in the magnitude of response in the jump-yip bouts in the environment. Additionally, the magnitudes of response in the environmental bouts are generally consistent, with positive correlations found between the responses in the environmental bouts and their durations (Appendix E). Furthermore, many of these correlations are found across the minute preceding and the minute following the subject bouts, providing even more evidence that environmental jump-yips provide generally consistent information, at least across the observational periods used in this study. Passive receivers in the environment are therefore potentially able to glean information concerning the state of their social group through not only actively assessing the state of their neighbours, but also through sampling the characteristics of the vocalizations occurring in their environment. Because this social information is available from multiple sources, it



provides the opportunity for continuous or periodic (repeated) sampling of the vocalizations in the environment, potentially allowing individuals to more accurately access the information contained within the jump-yip bouts.

### **Effects of abiotic variables on black-tailed prairie dog behaviour**

Unlike the social variables recorded and assessed in this study, each of which can provide additional evidence concerning the role of jump-yip bouts in determining black-tailed prairie dog behaviour, the effects of abiotic factors (including meteorological and temporal factors) on the behaviour of subject individuals are primarily confounding in nature. Their effects, however, cannot be ignored. The behaviour of any animal is dependent upon the conditions of its environment (e.g. Elgar 1989; Houston et al. 1993). Studies of black-tailed prairie dogs have shown that wind direction and intensity may alter an individual's vigilance and foraging behaviour by affecting the social information available to individuals (MacDonald 1998). Other variables such as the time of day at which the behaviour is observed may affect physiological factors, such as the need to replenish energy reserves (Loughry 1993) or may alter social variables such as the number of emerged individuals (Hoogland 1979) which could affect an individual's behaviour.

Temporal variables, however, appeared to exert minimal effects on the results of this study. Both bout initiators and respondents spent more time passive foraging later in the day, but respondents exhibited smaller post-jump-yip increases in the time they spent actively foraging later in the day. When recording sessions occurred later in the year, subject behaviour (for both bout initiators and respondents) changed little. What few

changes there were (decreases in the immediate post-jump-yip vigilance of bout initiators and the magnitude of post-jump-yip increases in the time respondents spent in a bipedal-slouched posture later in the year) were inconsistent across recording periods and between the two types of jump-yipping individuals observed in this study.

Because temporal effects are constant across the short periods during which individual behaviour was recorded, their influence on the effects of jump-yips on black-tailed prairie dog behaviour should be limited. More prolonged behaviours, such as mating, territory expansion, and the care of young, occur at different times of year (e.g. Hoogland 1995) and could therefore be observed during select recording sessions of this study. In particular, the recording sessions at Wind Cave National Park occurred soon after the first emergence of juveniles, a period which could stimulate increased vigilance. It is possible that these events were not associated with appreciable changes in black-tailed prairie dog behaviour because they do not change linearly over the day/year (with their effects instead focused on specific short periods of time, resulting in no observable correlations) or because they simply did not exert any significant effects on the vigilance and foraging behaviours of the subjects in this experiment.

The characteristics of jump-yipping in the environment during the recording sessions varied as expected with changes in the timing of the recording bout (Appendix F). Though correlations were far from consistent for all data groups, subject jump-yip bouts occurring later in the day contained fewer responses and increased response latency, both of which could be indicative of the expected increase in foraging (and thus the decrease in vigilance and the decrease in response). There was also some evidence of decreasing magnitude of response (responses, respondents, and duration) in

the subject bouts later in the year, though again the results were not consistent for all data groups (mostly for bout initiator bouts), as well as a corresponding decrease in jump-yipping (frequency of bouts and total jump-yips and the magnitude of response in the bouts) later in the year. This may be indicative of fewer aboveground individuals at the time of the recording sessions (correspondingly reducing the number of available vigilant individuals in the environment) which occurred in November, though as described previously, there is limited evidence that the number of jump-yips or the magnitude of response in a jump-yip bout are directly indicative of aboveground population size. Individuals observed later in the year, however, may be expected to forage more to account for the greater energetic requirements of being active during the winter or may have to forage more to find and consume sparse vegetation, which could account for the reduction in the level of response in the subject bouts later in the year.

Meteorological factors may affect the behaviour of black-tailed prairie dogs directly, by altering an individual's physiological or energetic requirements, and also indirectly by affecting the behaviour of predators or conspecifics. Under cloudier skies, black-tailed prairie dogs spent more time vigilant and less time foraging, possibly reflecting a reduction in the ability of individuals to distinguish approaching predators (particularly avian predators) under reduced sunlight and thus a need for individuals to increase their vigilance. Whether this is in fact the underlying cause for these changes in behaviour, however, is questionable. Greater levels of response were observed in subject bouts occurring under clear skies (Appendix F), which would appear to indicate that collective vigilance is higher under clear skies than under cloudy skies, though under

clear skies there was less response in the jump-yip bouts occurring in the environment. These differences, however, were only observed in certain data groups, and these results, in association with the observation that the greatest level of response is observed under partly cloudy skies, demonstrate that further study is required before conclusions can be drawn concerning the effects of cloud cover on the behaviour of black-tailed prairie dogs and the characteristics of their displays.

With greater levels of wind present in the environment, black-tailed prairie dogs spent less time vigilant and more time foraging than under calm conditions. This opposed the increase in vigilance with increases in wind intensity expected when high winds detrimentally affect the quality of threat-indicating chemical and acoustic signals (including alarm signals) present in the environment (e.g. MacDonald 1998), but may reflect the influence of wind direction – a variable not examined in this study – on the behaviour of black-tailed prairie dogs. Coterie position (which affects population density and thus the predation risk experienced by individuals) plays a major role in determining black-tailed prairie dog behaviour and MacDonald (1998) demonstrated that wind direction, more so than wind intensity, is the major affecter of behaviour, since it differentially affects the signals received by individuals situated at different positions in the environment (e.g. MacDonald 1998). The observed greater vigilance under calm conditions may arise from other variables persisting in the environment, rather than the wind intensity itself, or may arise from the somewhat subjective classification of wind intensity from recorded visual and auditory cues (which itself is likely affected by the direction of the blowing wind).

Wind intensity had minimal effects on the characteristics of “bout initiator” subject bouts (Appendix F). “Respondent” bouts did, however, have a greater magnitude of response under calm conditions (compared to low or high wind conditions) and greater response latencies under high winds. Though this conformed to the expected inverse relationship between magnitude of response and response latency, it opposes the expected increase in vigilance (and thus increase in jump-yipping demonstrating vigilance) with increases in wind intensity. Furthermore, while these results were consistent with observed low vocal activity in “respondent” groups under high wind conditions (Appendix F), it opposes the observed increases in vocal activity (more jump-yips, jump-yip bouts, and magnitude of response in the bouts) in the environment under high wind conditions in “bout initiator” groups, though these correlations were only present in a few instances. These unusual, and in some cases opposite, results may be due to the unmeasured direction of wind, or could be due to interactions with other environmental factors.

Differences in the habitat types where observational sessions were performed incorporate differences in multiple variables, including population size and density, predation risk, food availability, and meteorological effects (since in both captive and intermediate habitats, such effects are reduced), making the interplay between the effects of captivity/habitat type and the variables measured in this study complex. Individuals in wild habitats, for example, are generally part of larger colonies that extend over much greater areas (though the population density of captive habitats may be significantly higher) and thus may enjoy a greater social vigilance. They are, however, more exposed to predators and consequently may have to compensate with greater vigilance. They may

also have to forage more intensely than individuals in captive habitats, since captive individuals are generally provided with abundant food (both artificial and natural), some of which (such as vegetables) may be manipulated by the forelimbs while the individual retains bipedal (vigilant) postures, allowing them to forage and be vigilant simultaneously.

Bout initiators inhabiting captive habitats (all but one respondent were found in wild habitats) were more vigilant both immediately and over one minute following jump-yip production than bout initiators in “wilder” habitats, though there were smaller post-jump-yip increases in highly vigilant behaviour in captive habitats. This contradicts the higher expected vigilance among individuals in wild habitats who face greater predatory threat. Captive individuals, however, were observed to perform alarm calls and alert behaviours in response to the presence of certain stimuli, including crows and approaching humans. Therefore, their perceived predatory threat may not be substantially different between wild and captive habitats. Instead, the difference in foraging pressure (i.e. the need to forage more in wild habitats, where food is less plentiful and more dispersed) between captive and wild habitats may allow individuals in captive habitats to be more vigilant without incurring a significant energetic cost. Even though there were no significant differences in passive foraging behaviour between individuals in different habitats, the ability of individuals in captive habitats to forage and be vigilant simultaneously may also influence the observed greater vigilance of individuals in captive habitats.

Though the effects of habitat on subject bout characteristics could not be tested for “respondent” bouts, “bout initiator” bouts contained the greatest magnitude of

response in wild habitats (though there was some variability in the magnitude of response between bouts occurring in captive and “intermediate” habitats) (Appendix F). This likely reflects the significantly greater population/colony sizes in wild habitats than in captive and intermediate habitats (whose population sizes did not differ extensively). The reduced population sizes in intermediate and captive habitats may also underlie the observed later first post-subject, non-subject vocalizations in those habitats if there is a simple reduction in the number of callers/rate of calling in the environment (though if a constant level of collective vigilance is maintained though an increase in the number of vigilant individuals in the social group and calling is consistent over at least a period of a few minutes, the timing of the vocalizations in the environment should not fluctuate).

There was more vocal activity in wild habitats with more jump-yip bouts and jump-yips in the minute preceding the subject jump-yip bouts and greater magnitudes of response in those bouts, again likely reflecting the greater number of available callers in wild habitats (Appendix F). Interestingly, the response latency of certain environmental bouts (those bouts occurring in the minute preceding the subject bout) also increased in wild habitats, opposing the expected decrease in latency with greater numbers of vigilant individuals. This again casts doubt upon the relevance of response latency as an indicator of social state. There was also some evidence of greater amounts of alarm calling in wild habitats, possibly reflecting an increased risk of predation in the observed non-captive habitats.

These results suggest that differences in habitat type may promote differences not only directly on the behaviour of individuals in those habitats, but also indirectly by altering other behaviour-determining factors (such as the availability of vigilant

individuals). While this study (and others: e.g. Smith et al. 1976) have assumed that black-tailed prairie dogs exhibit the same general behaviours in captive and wild habitats, future studies may be best served by limiting the scope of the study to individuals in one habitat type (ideally, wild habitats). This would provide the best opportunity to study individuals exposed to most or all of the potentially-confounding variables in any environment.

The majority of inter-relationships between the abiotic variables themselves were reflective not of biologically-relevant interactions, but instead the method by which recording sessions were scheduled and performed. Subject bouts which occurred later in the day generally occurred later in the year (Appendix F). This reflected the limiting of observation trials until late-morning/early-afternoon in colder months to enjoy the greatest heat benefits of the midday sun – heat which may stimulate aboveground activity in black-tailed prairie dogs. Bouts occurring later in the day generally occurred under less cloud cover but more wind, while bouts occurring later in the year occurred under the opposite conditions (more cloud, less wind). The inverse relationship between cloud cover and wind intensity was also consistent for most of the data groups.

Though these results could indicate that cloud cover is inversely proportional to wind, more likely it reflects the habitat types in which the observational sessions occurred. Later in the year, trials took place in more captive habitats (a result which simply occurred due to the times at which the populations could be observed, rather than for any biological reason) (Appendix F). While recording sessions in wild habitats were limited to times in which meteorological variables were most favourable to observing black-tailed prairie dog behaviour (ideally when there was the least amount of cloud and



wind), in captive habitats, trials were simply run when there was no precipitation. Thus, cloud cover could be relatively high. Furthermore, because many of the captive populations were at least partially shielded from the wind by the construction of the habitats, the wind intensity at the time was less than in many of the wild populations observed in this study. Correspondingly, wind intensity was generally greatest in wild habitats, where populations inhabit large expanses of open prairie with limited protection from wind (Appendix F). In cases such as this, additional studies which better quantify abiotic factors may be required to assess the biological relevance of temporal and meteorological variables.

### **Alternative hypotheses**

Previous studies of black-tailed prairie dog behaviour have focused on an “all-clear” function of the jump-yip display, in which individuals jump-yip once a threat has been removed from the environment (e.g. King 1955; Hoogland 1995). If individuals do assess risk through the detection of jump-yips produced by neighbouring individuals, then the resultant behaviour should actually be similar to that predicted in this study – increased jump-yipping should provide strong information that the environment is safe from imminent threats and thus should stimulate a reduction in receiver vigilance. This explanation, however, does not account for the presence of jump-yips when there is no apparent cessation of threat. More generally, jump-yipping individuals may indicate through jump-yipping that they are less likely to perform escape behaviours than before jump-yipping (Smith et al. 1976, 1977). Unlike the “all-clear” hypothesis, this explanation does not discount the use of jump-yips in aggressive

conspecific interactions (Waring 1970; Smith et al. 1976, 1977) and in interactions with minimally-threatening predators (Smith et al. 1976; Owings and Owings 1979; Halpin 1983; Owings and Loughry 1985) since in both situations individuals generally do not perform evasive behaviours.

It would then stand to reason that individuals would have no need to devote time and energy to vigilance behaviours once they have determined they do not need to flee (since predation risk is evidently minimal). The results of this study, as well as those of Smith et al. (1976), however, found that individuals did become vigilant immediately following jump-yip production. Though Smith et al. (1976) described this vigilance as an “artifact behaviour” which occurs before the “true” reduction in the probability of escape (and the associated reduction in vigilance), it may be reasonable to assume that individuals become vigilant (however briefly) due to the role of jump-yipping in alerting colony members (and eliciting vigilance) to the presence of snakes in the environment, which in attracting conspecifics and promoting mobbing behaviour (Owings and Owings 1979; Halpin 1983; Owings and Loughry 1985). The presence of prolonged vigilance, however, may indicate that the immediate post-jump-yip vigilance is not an artifact, but instead allows individuals to assess the collective vigilance of their social group.

Even if individuals are less likely to perform escape behaviours following jump-yip production (regardless of whether the jump-yip contains high or low levels of response), it may be because they obtain real-time information about the (vigilance) state of their colony, and thus the probability of predation at the time. Barring sudden environmental stimuli which promote escape behaviours, such as the attack of a previously undetected predator, individuals could modify their vigilance and foraging

behaviours to allow them to remain aboveground and in close proximity to resources including food and mates while reducing the risk that they will be depredated. These behavioural decisions would occur over some period of time following jump-yip production, with the information used to make these behavioural decisions provided by the response characteristics of the individual's jump-yip bout.

Other possible functions of the jump-yip display have been discussed previously, including conveying information concerning the fitness of signalers (i.e. demonstrating jump-yipper fitness) or simply acting as a mechanism by which aboveground population size is assessed. Both of these hypotheses are plausible, though the evidence for the enumeration function of the jump-yip, in this study in particular, is sparse (and may necessitate further examination in more refined studies described below).

### **Future studies**

The results of this study provide evidence that jump-yip displays provide information concerning the state of a social group. It is clear, however, that more research is required to determine the precise mechanisms by which jump-yips provide information and subsequently how that information is used by receivers. An approach which establishes the physiological limitations to jump-yip detection (as well as general detection thresholds), limits or controls potentially-confounding factors, and further examines the changes in behaviour associated with signal detection should provide the best method to establish the role of the jump-yip vocalization in determining black-tailed prairie dog behaviour.

In the wild, black-tailed prairie dogs may be exposed to numerous jump-yip bouts in a relatively short period of time, originating from individuals both near and far. Given their relatively well-developed senses of hearing and sight, this study made no assumptions concerning which jump-yips (if any) are not detected and/or not processed by the subject individuals. In reality, however, it is possible that jump-yips that occur far from a given receiver may not be detected or may be effectively ignored since they do not represent the state of nearby individuals. Indeed, anecdotal evidence of individuals in one coterie “ignoring” vocalizations/displays in other coterie does exist (e.g. King 1955; Hoogland 1995). Previous research has provided the acoustic characteristics of the jump-yip display of black-tailed prairie dogs, including frequency spectra, duration, and amplitude (Smith et al. 1976), while the hearing abilities of black-tailed prairie dogs has been examined in a separate study (Heffner et al. 1994). The work of Smith et al. (1976) could be supplemented by cataloguing variation in the acoustic components of jump-yip displays – including frequency spectra and signal amplitude. This would allow the examination of the propagation characteristics of the auditory component of the jump-yip display, which could then be used to calculate the effective range of the acoustic components of the black-tailed prairie dog jump-yip. Laboratory studies which examine general auditory and visual thresholds, coupled with laboratory and field studies which examine both the levels of attenuation of the jump-yip vocalizations over various distances and in the presence of the effects of wind (direction and intensity), vegetation, and other meteorological effects, as well as distances at which visual signals deteriorate beyond identification/usability, may provide a basis for limiting counts of response magnitude to those jump-yips which are capable of being detected by individuals. These

figures could then be tested directly using playbacks of recorded jump-yip bouts at different distances from a subject individual, a protocol which could also allow for an examination of how detection limits are affected by changes in the environment and individual variation in the characteristics of jump-yips. Once detection ranges are established, they could be used in the field to identify individuals that “should” respond to nearby jump-yip displays.

Assessing the visual limits of individuals may be more difficult, but generally could be performed in much the same way. Conditioning experiments could be used to assess detection limits of both stationary and moving objects, via serially-presented video clips and/or solid objects, either in a lab or in the wild. The visual detection of jump-yips may be tested directly through the presentation of muted video clips of actual jump-yips at different distances (and the observation of subsequent changes in subject’s attention level and/or direction or, ideally, the jump-yipping of the subject individuals). A more complex test could involve the development of robotic black-tailed prairie dogs which ideally would produce lifelike jump-yips that could be manipulated as necessary (e.g. Michelsen et al. 1992; Patricelli et al. 2002). Testing jump-yips at different distances could/should also involve the incorporation of naturally-occurring obstacles to visual signals, including moving and stationary vegetation, geographic variability (hills, valleys), and natural visual impediments (other black-tailed prairie dogs, prairie dog mounds). If “artificial” jump-yips can be produced reliably, this could also allow for studies in which only the auditory or visual components of a jump-yip display are presented to receivers. This would permit the study of the contributions of both the

auditory and visual components of the jump-yip display to both the “contagiousness” of the display, as well as any other changes in receiver behaviour.

Accurate recording and cataloguing of all vocalizations occurring during behaviour recording sessions, including jump-yips, alarm calls, and “chirps” would also serve to improve the results obtained. Spectrographic analyses of any recorded vocalizations would aid in the identification of jump-yip vocalizations (compared to “unusual” barks or other vocalizations) and consequently provide a better count of responses. Analyses of the auditory characteristics of jump-yip vocalizations produced by separate individuals may also be used to determine whether differences in call characteristics could be used to identify unique individuals (e.g. Hare 1998). The complex characteristics of jump-yip vocalizations in general, incorporating two syllables of different frequencies and amplitudes (in addition to the broadband frequencies of each individual syllable), provide multiple avenues by which variation can be imparted to a single vocalization, while not appreciably altering the fundamental characteristics of the vocalization itself (i.e. retaining the characteristics which identify the vocalization as a jump-yip). Variation in jump-yips produced by single individuals could identify changes in jump-yip characteristics with changes in the state of the caller, similar to the changes in alarm call structure (faster alarm calling) with increasing threat (e.g. Leger et al. 1980; Evans et al. 1993; Randall and Rogovin 2002; Warkentin et al. 2001; Sloan and Hare 2004). If these differences are observed, playback experiments could be used to determine whether the behaviour of receivers varied with the identity of the caller (e.g. differential response to close family members compared to members of other coteries) or with structurally different jump-yips produced by the same individual

(e.g. less vigilance with slower, longer, or lower-frequency jump-yips – King 1955; Hoogland 1995). Finally, spectrographic analyses of “chirps” could either identify these “unknown” vocalizations as consistent components of the black-tailed prairie dog vocal repertoire, or eliminate it from further consideration by determining its “true” call type (i.e. an incomplete jump-yip or modified bark).

Playback experiments may also be used to control the response characteristics of a jump-yip bout and thus obtain direct relationships between the characteristics of a jump-yip bout and the behaviour of a receiver. This would eliminate much of the variability that could confound natural experiments, but would make testing the jump-yip-related behaviour of bout initiators difficult (since the initial jump-yip would be produced artificially). Tamed black-tailed prairie dogs may be stimulated to produce jump-yip vocalizations (Hoogland 1995), however studies that look for contextual differences in jump-yip characteristics (as described previously) may be required before undertaking studies in which jump-yips are stimulated from tamed individuals (to ensure that these stimulated jump-yips are consistent with those produced in the natural environment, particularly those environmental jump-yips which appear to occur in the absence of stimuli – i.e. those testing the vigilance of neighbours).

Once the limits of detection and/or attention are established, implementing Cartesian coordinate systems in each study population would allow for the focus of the study to remain on those jump-yips which influence the behaviour of subjects. Furthermore, such a coordinate system would allow improved categorization of potentially-confounding variables. Population density, for example, affects black-tailed prairie dog behaviour in much the same way as general population size (Hoogland 1979;

Kildaw 1995), with individuals who forage away from their neighbours experiencing a greater risk of predation and consequently spending more time vigilant. If jump-yips are perceived and/or counted only when they occur within a short distance from a receiver (or any subject individual), this may even be a more relevant measure of sociality or social vigilance than gross population size. With a coordinate system, the position of subject individuals relative to the centre of the coterie/colony (where population density is generally greatest) can be assessed and examined both independently and with respect to the jump-yip-related behaviours of subject individuals.

Assessing the position of subjects within a coterie/colony can be supplemented through a thorough examination of the population dynamics of the coterie/colony being examined. Though time constraints and financial costs precluded trapping and marking subject individuals in this study, any subsequent studies of jump-yip-related changes in black-tailed prairie dog behaviour would benefit from marking all individuals inhabiting a given population. This would prevent pseudoreplication on an individual level and could allow for a greater study sample size by identifying each jump-yipping individual (though this would not preclude pseudoreplication on a coterie or colony level). The movement of marked individuals could also be used to determine the members of each coterie/colony, allowing for more accurate population size assessments. This information could also be used in conjunction with the previously defined spatial limits to jump-yip detection and/or attention to determine which jump-yips are particularly relevant to the behaviours of subjects.

Once trapped, the age, sex, and even genetic relatedness of each individual could be determined. The effect of age or sex could be seen in individual display behaviour, as



in the case among toque macaques (*Macaca sinica*) which call/display differently depending on their sex or age (Dittus 1988), or baboons (*Papio cynocephalus ursinus*) where vocalizations change with age (Fischer et al. 2004). As described previously, there is evidence that black-tailed prairie dog vocalizations vary with age (e.g. Waring 1970; Owings and Loughry 1985); jump-yips in particular change, with juveniles often producing “bark-yips” (calls intermediate between alarm barks and jump-yips) in response to predators which, though not a threat to adults, do pose a danger to younger individuals (Owings and Loughry 1985). By identifying juveniles, instances in which they produce these “incomplete” vocalizations can be removed from analysis, or the relationships between these vocalizations and the behaviours of receivers can be determined (i.e. do individuals respond to bark-yips the same way as they respond to jump-yips or alarm barks?). Correlations between the number of young/juvenile individuals in a coterie (or larger population) and the vigilance behaviour of coterie (or population) members could also provide evidence concerning the apparent reliability of young individuals at identifying threats in the environment (i.e. do individuals become less vigilant with more juveniles or does their vigilance remain unchanged?).

The identification of members of particular coterie, assessments of their genetic relatedness, and the subsequent examination of changes in their behaviour following jump-yips both inside and outside their coterie, could provide evidence for a role of the jump-yip in nepotistic interactions (e.g. alarm calls in ground-dwelling sciurids; Sherman 1985). This information could be used to assess whether individuals jump-yip more in the presence of related individuals – similar to the increase in alarm calling by vervet monkeys (*Cercopithecus aethiops*) when in the presence of related young (Cheney and

Seyfarth 1985) and cockerels (*Gallus domesticus*) exhibiting differential calling in the presence of familiar versus unfamiliar individuals (Marler et al. 1986) or in the presence/absence of nearby individuals (Gyger et al. 1986) (reviewed in Marler and Mitani 1988). If they do, it may point to a beneficial role of the jump-yip display in social interactions.

Utilizing prolonged recording periods (as opposed to the short periods used in this study) of both subject individuals as well as entire coterie could also provide information concerning the utility of jump-yip production. With long recording periods, call profiles may be constructed, identifying which individuals, if any, jump-yip, how often they jump-yip, and under what environmental conditions they jump-yip. In some species, including meerkats (*Suricata suricata*), vervet monkeys (*Cercopithecus aethiops*), and dwarf mongoose (*Helogale undulata rufula*), certain individuals (sentinels) scan for predators at a greater rate than other individuals in their population (Moran 1984; Rasa 1986; Baldellou and Henzi 1992; Hoogland 1995; Bednekoff 1997), in effect assuming the responsibility of imparting the benefits of the antipredator behaviour to their social group. To our knowledge, black-tailed prairie dog colonies do not contain individuals who act as sentinels, but males are most often involved in territorial challenges, acting as the protectors of their particular social group (e.g. King 1955; Hoogland 1995). There is also some evidence that dominant (reproductive) males are more vigilant than other coterie members (Loughry 1993; Hoogland 1995). In this case, their active role in protecting a territory may be associated with more frequent jump-yipping.

Extending observational periods to hours or even days would also permit the recording of hundreds of jump-yip bouts. Ideally, this would result in the recording of significant numbers of jump-yip bouts with the same response characteristics (number of responses and/or respondents, duration, response latency), allowing for comparisons of signaler/receiver behaviour both between jump-yip bouts with the different characteristics (with each jump-yip being considered individually, or with behaviours at each response “level” being averaged) and within a set of jump-yip bouts with the same response characteristics. With a much larger number of jump-yip bouts to analyze, it would also permit a greater level of specificity in the examination of graded behavioural responses to jump-yip bouts with different characteristics (i.e. eliminate the need to define “high” levels of response as four or more responses/seconds), though as described previously, it is possible that “high” responses actually involve a limited number of responses (or have relatively short durations).

A more rigorous examination of abiotic factors measured in this study (as well as some factors not examined in this project), including direct measures of meteorological variables including wind intensity and direction and air temperature at the site at which the observational session is occurring (as opposed to classifying meteorological variables as in this study or obtaining measures from a weather station some distance away) may permit a more accurate determination of how environmental variables affect black-tailed prairie dog behaviour (particularly those behaviours associated with jump-yip production). For example (and as described previously), wind direction and intensity may significantly alter the vigilance and foraging behaviour of black-tailed prairie dogs (e.g. MacDonald 1998). I also did not record ambient temperatures at the time of

recording sessions, which when extreme, could result in behavioural changes associated with thermoregulation – including retreating underground, assuming postural changes to conserve or radiate heat (in black-tailed prairie dogs: MacDonald 1998; in other species: Scholander et al. 1950; Stelzner and Hausfater 1986), and increasing foraging to account for metabolic costs associated with heat production (e.g. King 1955) – and thus confound jump-yip-associated behavioural changes. Observational sessions could also be limited to time periods in which meteorological variables are relatively constant, though this could impose severe constraints on the number of sessions that could be run.

Doing so would also effectively ignore the environmental variability present in any habitat – variability which in any case should be superseded by any signals that play significant roles in determining behaviour (as in black-tailed prairie dogs that become vigilant upon detecting alarm calling in their coterie: e.g. Smith et al. 1977; Hoogland 1995) and which, based on individuals in this study regularly assuming vigilant postures following jump-yip production, appears to be superseded.

The complexity of both the jump-yip display and the environment in which those displays occur require complex methodologies for a complete understanding of the relationships between the displays and the behaviour of black-tailed prairie dogs. The modification of procedures used in the experiment, coupled with the addition of further studies in field and laboratory settings, would serve to expand on my findings and provide a more complete understanding of the role of the jump-yip display plays in modifying black-tailed prairie dog behaviour.

## Conclusions

The results of this study provide evidence that jump-yip displays provide information concerning the state of a black-tailed prairie dog social group. The immediate post-jump-yip vigilance of both bout initiators and respondents in a bout provide both an opportunity for individuals to assess the characteristics of response in their own jump-yip bout, and evidence that individuals who jump-yip are, in fact, vigilant individuals (at least over the short-term). Though there was little evidence that individuals varied their immediate post-jump-yip vigilance with variation in the characteristics of their jump-yip bout, when longer periods of time were considered, black-tailed prairie dogs reduced their vigilance and increased foraging in association with jump-yip bouts containing greater levels of response. Higher resolution methodology and analyses may help to explain some of the unexpected results obtained, including non-linear changes in the amount of time individuals spent foraging and highly vigilant, as well as examining any effects of jump-yips (and other vocalizations) in the environment on the behaviour of coterie and colony members. The core findings of this study, however, provide a framework around which these studies may be designed and conducted.

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## **APPENDIX A: Glossary of terms and abbreviations**

### **General terms**

Subject jump-yip bout (subject bout): The jump-yip bout which is recorded/analyzed for each observational trial – contains the subject as either the initial caller in the bout or as a respondent.

Subject (subject individual): The jump-yipping individual whose behaviour is recorded/analyzed for each observational trial. May either be the initial caller or a respondent in the subject bout.

Initial caller (bout initiator): The individual producing the first jump-yip in a jump-yip bout.

Responding caller (respondent): An individual producing a jump-yip which occurs in “response” to a previous jump-yip.

### **Independent variables**

Number of responses (RESPS): When the subject is the initial caller in the subject bout, the number of “non-subject” jump-yips occurring in a subject bout. When the subject is a respondent, the number of responses may be considered as either:

Number of post-subject responses (SUBRESP): The number of responses occurring following the production of a jump-yip by the subject, when the subject is a respondent; excludes all preceding jump-yips.

Total number of responses (TOTRESP): The number of responses, including the subject's response, in the entire subject jump-yip bout, when the subject is a respondent.

Number of respondents (RPDTS): When the subject is the initial caller in the subject bout, the number of "non-subject" jump-yipping individuals in a subject bout. Unlike number of responses, number of respondents excludes multiple jump-yips produced by a single caller.

Number of post-subject respondent (SUBRPDT): The number of respondents jump-yipping following the jump-yip of the subject respondent, when the subject is a respondent. In this case, the "total number of respondents" was not considered as the determination of independence was impossible.

Duration of jump-yip bout (DUR): The duration of the subject jump-yip bout, beginning at the end of the initial call in the bout and ending upon completion of the final jump-yip in the bout.

Duration of post-subject section of jump-yip bout (SUBDUR): The duration of the section of the subject jump-yip beginning with the completion of the subject's jump-yip and ending upon completion of the final jump-yip in the bout, when the subject is a respondent.

Duration of entire jump-yip bout (TOTDUR): The duration of the entire subject jump-yip bout in which the subject individual is a respondent, beginning with the completion of the initial jump-yip in the bout and ending with the completion of the final jump-yip in the bout.

Response latency (LAT): The amount of time passing between the production of the initial vocalization in the subject jump-yip bout and the onset of the first response in the bout.

Subject's response latency (OWNLAT): The amount of time passing between the completion of the jump-yip previous to the subject's jump-yip and the onset of the subject's jump-yip, when the subject is a respondent.

Post-subject response latency (SUBLAT): The amount of time passing between the completion of the subject's jump-yip and the subsequent jump-yip in the subject bout, when the subject is a respondent (i.e. the response latency of the first post-subject call)..



Initial response latency (INITLAT): The amount of time passing between the completion of the initial jump-yip in the subject bout and the onset of the next jump-yip in the bout (does not necessarily involve the subject's jump-yip), when the subject in the bout is a respondent.

### **Dependent variables**

#### Immediate post-jump-yip behaviour of bout initiators (F-I) and respondents (R-I)

Level of initial vigilance (INITVIG): The level of vigilance assumed by the subject immediately upon jump-yip completion, ranked on an ordinal scale ranging from 0 (head down/non-vigilant) to 3 (bipedal, head up, back straight). Does not account for any secondary behaviours (e.g. chewing with head up is considered simply head up).

Adjusted level of initial vigilance (ADJINITVIG): The level of vigilance assumed by the subject immediately upon jump-yip completion, ranked on an ordinal scale ranging from 0 (head down/non vigilant) to 3 (bipedal, head up, back straight), with secondary behaviours (chewing, eating, grooming) resulting in the ordinal ranking of behaviour being reduced by 0.5.

Duration of initial vigilance (DURINITVIG): The amount of time the initial vigilant behaviour (if present) of the subject is maintained without any postural changes or additions of secondary behaviours.

Duration of initial behaviour (DURINITBHV): The amount of time the initial behaviour (vigilant or non-vigilant) is maintained without any postural changes or additions of secondary behaviours.

The behaviour of individuals over the minute following jump-yip production – bout initiators (F-P) and respondents (R-P) – and post-jump-yip changes in behaviour – bout initiators (F-PP) and respondents (R-PP)

The following behavioural measures were either standardized to the number of events per minute (when the frequency of behavioural events was considered) or are expressed as a proportion of the time in which behaviour was analyzed. Trials in which less than a continuous minute of behaviour is available for analysis were standardized to one minute providing at least 20 s of recorded behaviour was available.

Number of head lifts per minute (HL/MIN): The number of times in the minute before and/or after the subject jump-yip bout the subject individuals raise their heads from below horizontal to a position equal to or above horizontal.

Number of increases in vigilance per minute (INCVIG/MIN): The number of times in the minute before and/or after the subject jump-yip bout the subject individuals increase their level of vigilance in any way (including head lifts/min as well as increases from head down and head up postures to bipedal postures and increases from slouched bipedal postures to alert bipedal postures).

Proportion of time spent vigilant (TVIG): The proportion of time the subject individuals spent in any vigilance postures in the minute before and/or the minute after jump-yip production.

Proportion of time spent actively foraging (ACTFOR): The proportion of time the subject individuals spent looking for food, grazing, or manipulating food items in the minute before and/or after jump-yip production.

Proportion of time spent passively foraging (PASSFOR): The proportion of time the subject individuals spent chewing in the minute before and/or after jump-yip production.

Proportion of time spent foraging (TOTFOR): The proportion of time the subject individuals spent passively and actively foraging in the minute before and/or after jump-yip production (also called time spent generally foraging).

Proportion of time spent in “occupied quadrupedal head-up” postures (S4Ux): The proportion of time before and/or after jump-yip production the subject individuals spent with their four legs on ground and their heads at or above horizontal while engaging in some form of secondary behaviour (chewing, eating, grooming, intraspecific interactions).

Proportion of time spent in “quadrupedal head up” posture (S4U): The proportion of time before and/or after jump-yip production the subject individuals spent with their four legs

on the ground and their heads at or above horizontal while not engaging in any secondary behaviours.

Proportion of time spent in “occupied bipedal slouched” postures (BSx): The proportion of time before and/or after jump-yip production the subject individuals spent sitting on their hind legs with their spines curved (i.e. slouched) while engaging in some form of secondary behaviour (see definition of S4Ux).

Proportion of time spent in “bipedal slouched” postures (BS): The proportion of time before and/or after jump-yip production the subject individuals spent sitting on their hind legs with their spines curved while not engaging in any secondary behaviours.

Proportion of time spent in “occupied bipedal alert” postures (BAx): The proportion of time before and/or after jump-yip production the subject individuals spent sitting on their hind legs with their spines straight while engaging in some form of secondary behaviour (see definition of S4Ux).

Proportion of time spent in “bipedal alert” posture (BA): The proportion of time before and/or after jump-yip production the subject individuals spent sitting on their hind legs with their spines straight while not engaging in any form secondary behaviours.

**Social variables**

Aboveground population (AGPOP): Number of individuals present aboveground within borders defined by natural barriers or low population or burrow densities at the time of subject jump-yip production.

Time of second vocalization (T2VOC): Also called the time of the first post-subject, non-subject vocalization – the time at which the first vocalization following the production/completion of the subject jump-yip bout occurred (measured in 10 s of seconds).

Number of “pre-subject” jump-yip bouts (PREBOUT): The number of jump-yip bouts which occurred in the minute preceding the subject jump-yip bout.

Number of “pre-subject” jump-yips (PREJY): The total number of jump-yips which occurred in the minute preceding the subject jump-yip bout.

Mean number of “pre-subject” responses (PRERESP): The average number of responses in the jump-yip bouts which occurred in the minute preceding the subject jump-yip bout.

Mean “pre-subject” jump-yip bout durations (PREDUR): The average duration of the jump-yip bouts which occurred in the minute preceding the subject jump-yip bout.

Mean “pre-subject” jump-yip response latencies (PRELAT): The average response latencies of the jump-yip bouts which occurred in the minute preceding the subject jump-yip bout.

Number of “pre-subject” chirps (PRECHIRP): The number of “chirps” (single, high frequency, brief duration barks) which occurred in the minute preceding the subject jump-yip bout.

Duration of “pre-subject” alarm call (continuous barking) bouts (PREAC): The total duration of alarm call (continuous barking) bouts which occurred in the minute preceding the subject jump-yip bout.

Number of “post-subject” jump-yip bouts (POSTBOUT): The number of jump-yip bouts which occurred in the minute following the subject jump-yip bout.

Number of “post-subject” jump-yips (POSTJY): The total number of jump-yips which occurred in the minute following the subject jump-yip bout.

Mean number of “post-subject” responses (POSTRESP): The average number of responses in the jump-yip bouts which occurred in the minute following the subject jump-yip bout.

Mean “post-subject” jump-yip bout durations (POSTDUR): The average duration of the jump-yip bouts which occurred in the minute following the subject jump-yip bout.

Mean “post-subject” jump-yip response latencies (POSTLAT): The average response latencies of the jump-yip bouts which occurred in the minute following the subject jump-yip bout.

Number of “post-subject” chirps (POSTCHIRP): The number of “chirps” (single, high frequency, brief duration barks) which occurred in the minute following the subject jump-yip bout.

Duration of “post-subject” alarm call (continuous barking) bouts (POSTAC): The total duration of alarm call (continuous barking) bouts which occurred in the minute following the subject jump-yip bout.

### **Abiotic variables**

Extent of cloud cover (CLOUD): A qualitative measure of the average amount of cloud cover present during each observational bout (from one minute prior to the initiation of the subject jump-yip bout to one minute following the subject jump-yip bout). Cloud cover was ranked on an ordinal scale ranging from 0 (no cloud) to 2 (complete cloud cover).

Average wind intensity (WIND): A qualitative measure of the average intensity of wind present during each observational bout (from one minute prior to the initiation of the subject jump-yip bout to one minute following the subject jump-yip bout). Wind intensity was ranked on an ordinal scale ranging from 0 (no wind) to 3 (continuous gusting wind).

Habitat type (HABITAT): A qualitative measure of the relative “naturalness” of the habitat in which a subject jump-yip bout was recorded. Habitat was ranked on an ordinal scale ranging from 0 (wild habitat/no captivity) to 2 (man-made boundaries with food artificially provided).

Time of day (TIME): The time of day, measured to the minute (Julian date), at which the subject jump-yip bout was initiated.

Time of year (DATE): The time of year, measured to the day (percentage of the month), at which the subject jump-yip bout was initiated.



**APPENDIX B: Complete results for the effects of the response characteristics of a subject jump-yip bout on the behaviour of a caller (initial or response) in that bout**

Table B.1: Correlations of the response characteristics of a jump-yip bout and the behaviour of the initial caller in that bout immediately following jump-yip production (n = 26).<sup>^</sup>

	RESPS	RPDTS <sup>†</sup>	DUR	LAT <sup>‡</sup>
INITVIG	0.017	0.009	0.048	-0.323
ADJINITVIG	0.024	-0.017	0.083	-0.283
DURINITBHV	0.197	0.150	0.139	-0.270
DURINITVIG <sup>#</sup>	0.113	0.072	0.122	-0.156

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 24, except "DURINITVIG" and "DURINITBHV" (n = 23)

<sup>‡</sup> n = 15

<sup>#</sup> n = 25, except RPDTS (n = 23) and LAT (n = 15)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.2: The effect of the number of responses in a jump-yip bout on the behaviour of the initial caller in that bout immediately following jump-yip production.<sup>^</sup>

	Number of responses		
	0 (n = 11)	1 (n = 5)	4+ (n = 6)
INITVIG	0.909 ± 0.091	1.000 ± 0.000	1.000 ± 0.000
ADJINITVIG	0.864 ± 0.097	1.000 ± 0.000	1.000 ± 0.000
DURINITBHV†	4.900 ± 1.997	14.200 ± 11.470	3.670 ± 0.560
DURINITVIG†	5.000 ± 2.145	22.400 ± 12.030	4.830 ± 1.660

<sup>^</sup> See Appendix A for abbreviations and definitions

† 0: n = 10, 1: n = 5; 2: n = 6

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.2: Continued<sup>^</sup>

	All Variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
INITVIG	1.000	1.000	30.0	1.000	15.0	1.000
ADJINITVIG	2.095	0.471	27.0	0.515	15.0	1.000
DURINITBHV†	0.655	0.737	23.5	0.501	13.5	0.816
DURINITVIG†	2.770	0.251	22.5	0.424	10.5	0.430

<sup>^</sup> See Appendix A for abbreviations and definitions

† 0: n = 10, 1: n = 5; 2: n = 6

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.3: The effect of the duration of a jump-yip bout on the behaviour of the initial caller in that bout immediately following jump-yip production.<sup>^</sup>

	Duration (s)		Test Statistics	
	0 (n = 13)	4+ (n = 8)	U	Sig.
INITVIG	0.923 ± 0.077	1.000 ± 0.189	48.5	1.000
ADJINITVIG	0.885 ± 0.083	0.938 ± 0.148	45.5	0.624
DURINTBHV†	9.250 ± 4.905	4.625 ± 1.438	42.0	0.684
DURINITVIG†	9.333 ± 4.941	5.375 ± 1.832	42.5	0.689

<sup>^</sup> See Appendix A for abbreviations and definitions

† 0: n = 12, 1: n = 8

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.4: Correlations of the response characteristics of a jump-yip bout and the behaviour of the initial caller in that bout over one minute following jump-yip production (n = 42).<sup>^</sup>

	RESPS	RPDTS†	DUR	LAT‡
HL / MIN	0.024	-0.106	0.055	0.206
INCVIG / MIN	0.062	-0.060	0.078	0.137
TVIG	0.038	0.026	0.045	-0.157
ACTFOR	-0.033	-0.008	-0.069	-0.090
PASSFOR	0.056	-0.127	0.070	0.047
TOTFOR	-0.049	-0.089	-0.067	-0.118
S4U <sub>x</sub>	0.144	-0.092	0.166	0.016
S4U	0.038	0.090	0.007	-0.160
BS <sub>x</sub>	-0.119	-0.081	-0.153	0.132
BS	0.088	-0.022	0.089	0.070
BA <sub>x</sub>	-0.040	0.009	-0.059	-0.090
BA	0.174	0.203	0.113	-0.184

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 35

‡ n = 29

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.5: The effect of the number of responses in a jump-yip bout on the behaviour of the initial caller in that bout over one minute following jump-yip production.<sup>^</sup>

	Number of responses				
	0 (n = 14)	1 (n = 8)	2 (n = 3)	3 (n = 3)	4+ (n = 14)
HL / MIN	6.521 ± 0.962	6.832 ± 1.726	7.712 ± 1.459	4.019 ± 0.502	6.788 ± 0.907
INCVIG / MIN	7.103 ± 1.037	8.461 ± 2.101	9.062 ± 2.032	4.019 ± 0.502	7.724 ± 0.995
TVIG	0.371 ± 0.091	0.585 ± 0.122	0.412 ± 0.145	0.374 ± 0.205	0.377 ± 0.060
ACTFOR	<b>0.647 ± 0.101</b>	<b>0.335 ± 0.136</b>	<b>0.335 ± 0.233</b>	<b>0.575 ± 0.288</b>	<b>0.593 ± 0.092</b>
PASSFOR	0.091 ± 0.055	0.043 ± 0.016	0.073 ± 0.044	0.023 ± 0.011	0.043 ± 0.017
TOTFOR	<b>0.738 ± 0.088</b>	<b>0.377 ± 0.152</b>	<b>0.408 ± 0.246</b>	<b>0.598 ± 0.300</b>	<b>0.635 ± 0.098</b>
S4Ux	0.135 ± 0.056	0.102 ± 0.030	0.095 ± 0.034	0.053 ± 0.026	0.134 ± 0.034
S4U	0.150 ± 0.049	0.323 ± 0.130	0.284 ± 0.193	0.321 ± 0.218	0.141 ± 0.029
BSx	0.075 ± 0.048	0.039 ± 0.039	0.028 ± 0.020	0.000 ± 0.000	0.031 ± 0.021
BS	0.011 ± 0.008	0.059 ± 0.047	0.006 ± 0.006	0.000 ± 0.000	0.017 ± 0.011
BAx	0.000 ± 0.000	0.002 ± 0.002	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
BA	0.000 ± 0.000	0.060 ± 0.060	0.000 ± 0.000	0.000 ± 0.000	0.054 ± 0.036

<sup>^</sup> See Appendix A for abbreviations and definitions

Table B.5: Continued<sup>^</sup>

	All variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	2.476	0.672	94.5	0.882	55.0	0.960
INCVIG / MIN	4.455	0.367	85.5	0.572	54.0	0.908
TVIG	3.534	0.499	88.5	0.675	36.0	0.180
ACTFOR	5.337	0.270	86.0	0.595	<b>30.5*</b>	<b>0.082</b>
PASSFOR	0.804	0.946	97.5	0.990	54.0	0.918
TOTFOR	5.315	0.273	81.5	0.455	<b>31.5*</b>	<b>0.095</b>
S4Ux	1.267	0.882	86.5	0.615	48.0	0.612
S4U	2.583	0.656	85.0	0.561	39.0	0.258
BSx	3.976	0.423	84.5	0.504	52.5	1.000
BS	1.409	0.912	92.0	0.872	52.0	0.685
BAx	4.250	0.326	98.0	1.000 <sup>c</sup>	49.0	0.358
BA	4.323	0.308	77.0	0.230	51.5	0.846

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>c</sup> Exact test

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.6: The effect of the duration of a jump-yip bout on the behaviour of the initial caller in that bout over one minute following jump-yip production.<sup>^</sup>

	Duration (s)				
	0 (n = 16)	1 (n = 5)	2 (n = 3)	3 (n = 5)	4+ (n = 13)
HL / MIN	6.268 ± 0.913	8.632 ± 2.196	4.680 ± 0.803	6.183 ± 1.594	6.752 ± 0.941
INCVIG / MIN	6.777 ± 0.984	10.487 ± 2.880	6.915 ± 2.145	7.957 ± 1.851	7.162 ± 0.989
TVIG	0.397 ± 0.090	0.511 ± 0.120	0.455 ± 0.128	0.477 ± 0.170	0.374 ± 0.065
ACTFOR	0.620 ± 0.098	0.363 ± 0.161	0.556 ± 0.153	0.393 ± 0.200	0.569 ± 0.106
PASSFOR	0.085 ± 0.048	0.051 ± 0.022	0.017 ± 0.010	0.037 ± 0.030	0.050 ± 0.018
TOTFOR	0.705 ± 0.091	0.414 ± 0.183	0.574 ± 0.163	0.430 ± 0.200	0.618 ± 0.114
S4U <sub>x</sub>	0.125 ± 0.049	0.135 ± 0.039	0.069 ± 0.026	0.071 ± 0.025	0.138 ± 0.036
S4U	0.196 ± 0.069	0.290 ± 0.134	0.191 ± 0.025	0.208 ± 0.137	0.174 ± 0.051
BS <sub>x</sub>	0.066 ± 0.043	0.062 ± 0.062	0.098 ± 0.098	0.024 ± 0.015	0.008 ± 0.007
BS	0.010 ± 0.007	0.020 ± 0.020	0.013 ± 0.013	0.078 ± 0.074	0.016 ± 0.012
BA <sub>x</sub>	0.000 ± 0.000	0.003 ± 0.003	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
BA	<b>0.000 ± 0.000</b>	<b>0.000 ± 0.000</b>	<b>0.084 ± 0.042</b>	<b>0.096 ± 0.096</b>	<b>0.039 ± 0.038</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

Table B.6: Continued<sup>^</sup>

	All variables		1 vs. 4+		0 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	1.840	0.788	97.0	0.773	23.0	0.362
INCVIG / MIN	1.521	0.841	93.5	0.658	23.5	0.403
TVIG	1.928	0.772	97.5	0.793	21.0	0.283
ACTFOR	3.105	0.559	93.0	0.643	19.5	0.215
PASSFOR	0.730	0.957	97.0	0.756	29.5	0.788
TOTFOR	4.554	0.345	93.5	0.652	18.0	0.166
S4Ux	2.151	0.734	87.5	0.476	32.5	1.000
S4U	3.258	0.532	97.0	0.781	19.5	0.215
BSx	1.674	0.833	86.0	0.270	30.0	0.677
BS	2.077	0.785	101.0	0.873	31.0	0.836
BAx	7.400	0.314	104.0	1.000 <sup>c</sup>	26.0	0.280
BA	<b>12.721**</b>	<b>0.022</b>	96.0	0.451	30.0	1.000 <sup>c</sup>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>c</sup> Exact test

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.7: Correlations of the response characteristics of a jump-yip bout and the difference in the behaviour of the initial caller in that bout between the minute preceding and the minute following jump-yip production (n = 24).<sup>^</sup>

	RESPS	RPDTS <sup>†</sup>	DUR	LAT <sup>‡</sup>
HL / MIN	-0.081	-0.083	-0.128	-0.077
INCVIG / MIN	0.120	0.106	0.015	-0.125
TVIG	0.069	0.018	0.234	0.014
ACTFOR	0.059	0.214	0.064	-0.042
PASSFOR	-0.264	-0.120	-0.240	-0.247
TOTFOR	-0.113	0.051	-0.117	-0.183
S4U <sub>x</sub>	-0.076	0.145	-0.038	-0.230
S4U	-0.115	-0.224	-0.064	0.252
BS <sub>x</sub>	0.078	0.033	0.171	-0.105
BS	0.269	0.245	0.247	-0.161
BA <sub>x</sub>	0.127	0.184	0.116	-0.023
BA	-0.027	-0.257	-0.039	0.222

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19

<sup>‡</sup> n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table B.8: The effect of the number of responses in a jump-yip bout on the change in the behaviour of the initial caller in that bout from the minute preceding to the minute following jump-yip production.<sup>^</sup>

	Number of responses		
	0 (n = 6)	1 (n = 6)	4+ (n = 9)
HL / MIN	0.159 ± 1.834	1.010 ± 0.638	0.614 ± 1.339
INCVIG / MIN	-1.008 ± 2.207	0.178 ± 1.154	0.503 ± 1.724
TVIG	0.029 ± 0.068	-0.053 ± 0.087	0.038 ± 0.067
ACTFOR	-0.043 ± 0.153	0.048 ± 0.106	-0.138 ± 0.115
PASSFOR	0.130 ± 0.124	0.040 ± 0.019	0.003 ± 0.019
TOTFOR	0.087 ± 0.116	0.087 ± 0.120	-0.136 ± 0.123
S4Ux	0.107 ± 0.106	0.055 ± 0.027	0.033 ± 0.065
S4U	0.066 ± 0.042	0.013 ± 0.032	0.035 ± 0.063
BSx	-0.067 ± 0.077	-0.028 ± 0.028	-0.064 ± 0.064
BS	-0.036 ± 0.025	-0.029 ± 0.138	0.001 ± 0.018
BAx	-0.042 ± 0.042	0.003 ± 0.003	0.000 ± 0.000
BA	0.000 ± 0.000	-0.066 ± 0.059	0.032 ± 0.039

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.8: Continued<sup>^</sup>

	All variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	0.241	0.886	25.5	0.886	22.0	0.604
INCVIG / MIN	0.393	0.827	22.5	0.636	26.0	0.954
TVIG	0.897	0.648	25.5	0.882	20.0	0.435
ACTFOR	0.371	0.835	23.5	0.711	25.0	0.840
PASSFOR	3.142	0.216	17.5	0.266	14.0	0.129
TOTFOR	0.285	0.870	24.0	0.754	22.0	0.584
S4U <sub>x</sub>	0.757	0.693	22.5	0.626	20.0	0.446
S4U	0.583	0.759	24.0	0.752	26.0	0.934
BS <sub>x</sub>	0.071	0.944	26.0	0.905	26.0	1.000
BS	2.096	0.420	17.0	0.167	24.0	0.733
BA <sub>x</sub>	3.333	0.165	22.5	0.405	22.5	0.407
BA	2.021	0.370	24.0	0.897	20.0	0.387

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.9: The effect of the duration of a jump-yip bout on the change in the behaviour of the initial caller in that bout between the minute preceding and the minute following jump-yip production.<sup>^</sup>

	Duration (s)			
	0 (n = 8)	1 (n = 3)	2 (n = 3)	4+ (n = 9)
HL / MIN	<b>0.039</b> ± <b>1.367</b>	<b>2.046</b> ± <b>0.538</b>	<b>2.871</b> ± <b>1.777</b>	<b>-0.484</b> ± <b>1.246</b>
INCVIG / MIN	-0.970 ± 1.653	2.069 ± 1.096	3.773 ± 2.586	-1.007 ± 1.483
TVIG	0.011 ± 0.052	-0.114 ± 0.176	-0.033 ± 0.141	0.124 ± 0.066
ACTFOR	-0.009 ± 0.116	0.065 ± 0.222	-0.239 ± 0.167	-0.084 ± 0.102
PASSFOR	0.108 ± 0.092	0.051 ± 0.030	0.023 ± 0.011	0.003 ± 0.019
TOTFOR	0.099 ± 0.089	0.116 ± 0.242	-0.216 ± 0.178	-0.081 ± 0.110
S4Ux	0.086 ± 0.079	0.090 ± 0.045	0.053 ± 0.027	0.035 ± 0.065
S4U	0.038 ± 0.037	0.029 ± 0.048	0.097 ± 0.060	0.065 ± 0.079
BSx	-0.050 ± 0.057	-0.056 ± 0.056	-0.191 ± 0.191	0.000 ± 0.000
BS	-0.027 ± 0.019	-0.183 ± 0.235	0.013 ± 0.013	-0.009 ± 0.018
BAx	-0.031 ± 0.031	0.006 ± 0.006	0.000 ± 0.000	0.000 ± 0.000
BA	-0.005 ± 0.004	0.000 ± 0.000	-0.005 ± 0.005	0.034 ± 0.038

<sup>^</sup> See Appendix A for abbreviations and definitions

Table B.9: Continued<sup>^</sup>

	All variables		1 vs. 4+		0 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	4.467	0.216	<b>4.0*</b>	<b>0.092</b>	28.5	0.497
INCVIG / MIN	4.619	0.205	6.0	0.200	35.5	0.984
TVIG	3.011	0.407	5.0	0.136	24.0	0.260
ACTFOR	2.104	0.576	13.0	1.000	32.0	0.734
PASSFOR	3.838	0.283	6.0	0.209	22.0	0.177
TOTFOR	2.715	0.458	12.0	0.864	31.0	0.655
S4U <sub>x</sub>	2.035	0.588	8.5	0.407	31.0	0.665
S4U	0.732	0.877	13.0	0.971	35.5	0.980
BS <sub>x</sub>	2.083	0.536	9.0	0.256	31.5	0.494
BS	1.763	0.681	13.0	1.000	31.0	0.539
BA <sub>x</sub>	5.042	0.222	9.0	0.256	31.5	0.468
BA	1.416	0.806	13.5	1.000	31.5	0.494

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.10: Correlations of the response characteristics of a jump-yip bout and the behaviour of respondent within that bout immediately following jump-yip production (n = 22).<sup>^</sup>

	SUBRESP	SUBRPDT <sup>†</sup>	SUBDUR	SUBLAT <sup>‡</sup>
INITVIG	0.220	0.383	0.190	0.360
ADJINITVIG	0.048	<b>0.487*</b>	0.027	0.170
DURINITBHV	0.068	0.004	0.068	-0.185
DURINITVIG	0.114	0.234	0.064	0.025

	OWNLAT	TOTRESP	TOTDUR	TOTLAT
INITVIG	-0.274	0.214	0.144	-0.117
ADJINITVIG	0.001	0.160	0.146	0.032
DURINITBHV	0.049	0.012	0.058	0.189
DURINITVIG	-0.278	0.099	0.063	-0.045

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 14

<sup>‡</sup> n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.11: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the behaviour of that respondent immediately following jump-yip production.^

	Number of responses					
	0 (n = 7)		1 (n = 4)		4+ (n = 10)	
INITVIG	0.714	± 0.184	1.000	± 0.000	1.000	± 0.149
ADJINITVIG	0.643	± 0.180	1.000	± 0.000	0.850	± 0.130
DURINITBHV	20.000	± 10.374	4.500	± 2.533	11.300	± 3.461
DURINITVIG	15.000	± 8.647	5.000	± 3.028	13.800	± 5.821

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.11: Continued^

	All variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
INITVIG	2.013	0.413	26.0	0.344	20.0	1.000
ADJINITVIG	2.028	0.353	27.0	0.435	16.0	0.508
DURINITBHV	2.073	0.371	32.5	0.835	9.0	0.130
DURINITVIG	1.103	0.604	29.5	0.614	11.5	0.264

^ See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.12: The effects of the duration of a subsection of a jump-yip bout beginning with the subject respondent's jump-yip on the behaviour of that respondent immediately following jump-yip production.<sup>^</sup>

	Duration (s)				Test statistics	
	0 (n = 8)		4+ (n = 8)		U	Sig.
INITVIG	0.750	± 0.164	1.000	± 0.189	25.0	0.627
ADJINITVIG	0.688	± 0.162	0.813	± 0.162	28.0	0.773
DURINITBHV	17.750	± 9.262	9.125	± 2.594	27.0	0.622
DURINITVIG	13.375	± 7.662	9.250	± 3.416	27.5	0.668

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.13: The effect of the number of responses in an entire jump-yip bout on the behaviour of a respondent in that bout immediately following jump-yip production.<sup>^</sup>

	Number of responses				Test statistics	
	1 (n = 3)		4+ (n = 16)		U	Sig.
INITVIG	0.667	± 0.333	1.000	± 0.063	16.5	0.391
ADJINITVIG	0.500	± 0.289	0.906	± 0.091	11.5	0.190
DURINITBHV	21.000	± 19.502	12.875	± 3.874	17.5	0.516
DURINITVIG	11.000	± 10.504	14.563	± 4.792	16.0	0.403

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.14: The effect of the duration of an entire jump-yip bout on the behaviour of a respondent within that bout immediately following jump-yip production.<sup>^</sup>

	Duration (s)						All variables		1 vs. 4+	
	1 (n = 3)		2 (n = 3)		4 (n = 16)		$\chi^2$	Sig.	U	Sig.
INITVIG	0.667	± 0.333	1.000	± 0.000	0.938	± 0.111	1.211	0.678	18.0	0.490
ADJINITVIG	0.500	± 0.289	1.000	± 0.000	0.844	± 0.099	2.854	0.317	13.5	0.244
DURINITBHV	21.000	± 19.502	15.667	± 10.269	10.563	± 3.616	0.740	0.724	18.0	0.546
DURINITVIG	11.000	± 10.504	23.667	± 18.224	10.438	± 3.820	1.401	0.522	18.5	0.574

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table B.15: Correlations of the response characteristics of a jump-yip bout and the behaviour of a respondent in that bout over one minute following jump-yip production (n = 26).<sup>^</sup>

	SUBRESP	SUBRPDT <sup>†</sup>	SUBDUR	SUBLAT <sup>‡</sup>
HL / MIN	0.127	0.096	0.098	0.046
INCVIG / MIN	0.075	0.061	0.060	-0.016
TVIG	-0.248	-0.082	-0.205	-0.171
ACTFOR	0.277	0.142	0.276	0.116
PASSFOR	-0.032	-0.052	-0.051	-0.035
TOTFOR	0.213	0.081	0.206	0.101
S4U <sub>x</sub>	0.294	0.330	0.260	0.135
S4U	-0.172	0.035	-0.167	-0.127
BS <sub>x</sub>	0.174	0.083	0.224	-0.093
BS	-0.140	0.345	-0.173	-0.370
BA <sub>x</sub>	-0.244	-0.237	-0.244	-
BA	<b>-0.352*</b>	-0.347	<b>-0.351*</b>	-
	OWNLAT	TOTRESP	TOTDUR	TOTLAT
HL / MIN	0.130	-0.025	-0.015	-0.013
INCVIG / MIN	0.139	-0.167	-0.158	-0.005
TVIG	0.041	-0.228	-0.120	<b>0.377*</b>
ACTFOR	0.004	0.239	0.144	-0.313
PASSFOR	-0.240	0.146	0.088	-0.291
TOTFOR	-0.140	0.139	0.011	<b>-0.430**</b>
S4U <sub>x</sub>	0.013	0.244	0.249	-0.069
S4U	0.192	-0.040	0.108	<b>0.419**</b>
BS <sub>x</sub>	0.000	-0.067	-0.101	-0.168
BS	-0.210	-0.262	<b>-0.345*</b>	-0.252
BA <sub>x</sub>	-0.013	-0.307	-0.307	-0.040
BA	-0.139	<b>-0.393**</b>	<b>-0.342*</b>	0.222

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 15

<sup>‡</sup> n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.16: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the behaviour of that respondent over one minute following jump-yip production.<sup>^</sup>

	Number of responses		
	0 (n = 8)	1 (n = 4)	4+ (n = 13)
HL / MIN	5.892 ± 2.283	8.250 ± 1.887	5.686 ± 0.961
INCVIG / MIN	7.535 ± 2.731	8.500 ± 2.021	6.380 ± 0.959
TVIG	0.560 ± 0.142	0.333 ± 0.072	0.404 ± 0.076
ACTFOR	0.459 ± 0.147	0.771 ± 0.072	0.718 ± 0.084
PASSFOR	0.050 ± 0.022	0.046 ± 0.021	0.034 ± 0.015
TOTFOR	0.509 ± 0.153	0.817 ± 0.082	0.751 ± 0.087
S4U <sub>x</sub>	0.073 ± 0.037	0.188 ± 0.040	0.125 ± 0.030
S4U	0.272 ± 0.123	0.121 ± 0.046	0.160 ± 0.064
BS <sub>x</sub>	0.023 ± 0.015	0.025 ± 0.025	0.090 ± 0.046
BS	0.002 ± 0.002	0.000 ± 0.000	0.030 ± 0.029
BA <sub>x</sub>	0.004 ± 0.004	0.000 ± 0.000	0.000 ± 0.000
BA	0.186 ± 0.122	0.000 ± 0.000	0.000 ± 0.000

<sup>^</sup> See Appendix A for abbreviations and definitions

c Exact value

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.16: Continued<sup>^</sup>

	All variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	1.837	0.418	45.0	0.632	14.5	0.213
INCVIG / MIN	0.947	0.636	49.0	0.851	17.0	0.332
TVIG	1.472	0.497	36.5	0.272	23.5	0.806
ACTFOR	1.814	0.421	35.5	0.245	23.5	0.800
PASSFOR	0.887	0.662	43.5	0.543	18.5	0.404
TOTFOR	1.063	0.601	41.0	0.450	24.5	0.889
S4U <sub>x</sub>	4.308	0.114	33.5	0.182	13.5	0.171
S4U	0.415	0.826	43.5	0.553	26.0	1.000
BS <sub>x</sub>	0.523	0.765	45.0	0.555	22.5	0.625
BS	0.500	1.000	50.0	1.000	24.0	1.000
BA <sub>x</sub>	2.125	0.477	45.5	0.381	26.0	1.000 <sup>c</sup>
BA	4.427	0.116	39.0	0.138	26.0	1.000 <sup>c</sup>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>c</sup> Exact value

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.17: The effect of the duration of a section of a jump-yip bout beginning with the subject respondent's jump-yip on the behaviour of that respondent over one minute following jump-yip production.<sup>^</sup>

	Duration (s)		Test statistics	
	0 (n = 9)	4+ (n = 11)	U	Sig.
HL / MIN	6.571 ± 2.125	5.628 ± 0.924	47.5	0.899
INCVIG / MIN	8.031 ± 2.459	6.359 ± 0.967	48.0	0.924
TVIG	0.551 ± 0.125	0.358 ± 0.070	31.5	0.180
ACTFOR	0.482 ± 0.132	0.765 ± 0.069	29.5	0.137
PASSFOR	0.045 ± 0.020	0.038 ± 0.017	47.0	0.870
TOTFOR	0.527 ± 0.136	0.803 ± 0.071	33.0	0.226
S4Ux	0.099 ± 0.041	0.123 ± 0.030	36.5	0.333
S4U	0.262 ± 0.109	0.128 ± 0.062	35.5	0.300
BSx	0.020 ± 0.014	0.106 ± 0.053	38.5	0.337
BS	0.002 ± 0.002	0.000 ± 0.000	44.0	0.457
BAx	0.004 ± 0.004	0.000 ± 0.000	44.0	0.457
BA	0.165 ± 0.109	0.000 ± 0.000	38.5	0.186

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.18: The effect of the number of responses in an entire jump-yip bout on the behaviour of a respondent in that bout over one minute following jump-yip production.<sup>^</sup>

	Number of responses		Test statistics	
	1 (n = 3)	4+ (n = 19)	U	Sig.
HL / MIN	8.333 ± 5.239	5.052 ± 0.709	24.5	0.735
INCVIG / MIN	11.333 ± 6.119	5.580 ± 0.731	19.0	0.391
TVIG	0.406 ± 0.246	0.432 ± 0.068	27.0	0.911
ACTFOR	0.650 ± 0.257	0.670 ± 0.075	26.0	0.846
PASSFOR	0.067 ± 0.051	0.039 ± 0.011	24.0	0.695
TOTFOR	0.717 ± 0.267	0.708 ± 0.076	18.5	0.379
S4Ux	0.094 ± 0.086	0.118 ± 0.022	22.5	0.608
S4U	0.033 ± 0.033	0.214 ± 0.066	13.0	0.141
BSx	0.033 ± 0.033	0.078 ± 0.035	28.0	1.000
BS	0.000 ± 0.000	0.021 ± 0.020	25.5	1.000
BAx	0.011 ± 0.011	0.000 ± 0.000	19.0	0.129
BA	0.233 ± 0.233	0.000 ± 0.000	19.0	0.129

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.19: The effect of the duration of an entire jump-yip bout on the behaviour of a respondent in that bout over one minute following jump-yip production.<sup>^</sup>

	Duration (s)			All variables		1 vs. 4+	
	1 (n = 3)	2 (n = 3)	4+ (n = 20)	$\chi^2$	Sig.	U	Sig.
HL / MIN	8.333 ± 5.239	5.333 ± 2.963	5.853 ± 0.841	0.198	0.913	27.5	0.846
INCVIG / MIN	11.333 ± 6.119	6.333 ± 2.963	6.461 ± 0.873	0.716	0.720	21.0	0.439
TVIG	0.406 ± 0.246	0.617 ± 0.199	0.429 ± 0.065	0.741	0.711	28.0	0.878
ACTFOR	0.650 ± 0.257	0.500 ± 0.257	0.664 ± 0.071	0.844	0.679	27.0	0.821
PASSFOR	0.067 ± 0.051	0.067 ± 0.033	0.036 ± 0.011	1.009	0.631	24.5	0.625
TOTFOR	0.717 ± 0.267	0.567 ± 0.289	0.700 ± 0.072	1.282	0.555	19.5	0.375
S4Ux	0.094 ± 0.086	0.083 ± 0.044	0.126 ± 0.023	0.689	0.731	22.5	0.536
S4U	0.033 ± 0.033	0.261 ± 0.171	0.199 ± 0.059	2.959	0.246	13.0	0.127
BSx	0.033 ± 0.033	0.139 ± 0.093	0.063 ± 0.031	1.897	0.396	29.0	0.922
BS	<b>0.000 ± 0.000</b>	<b>0.133 ± 0.125</b>	<b>0.001 ± 0.001</b>	<b>10.189**</b>	<b>0.040</b>	28.5	1.000
BAx	0.011 ± 0.011	0.000 ± 0.000	0.000 ± 0.000	7.667	0.230	20.0	0.125
BA	0.233 ± 0.233	0.000 ± 0.000	0.039 ± 0.039	2.816	0.412	22.0	0.247

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.20: Correlations of the response characteristics of a jump-yip bout and changes in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production (n = 18).<sup>^</sup>

	SUBRESP	SUBRPDT <sup>†</sup>	SUBDUR	SUBLAT <sup>‡</sup>
HL / MIN	0.297	<b>0.572*</b>	0.352	0.440
INCVIG / MIN	0.284	<b>0.573*</b>	0.347	0.507
TVIG	-0.321	-0.494	-0.313	0.368
ACTFOR	<b>0.445*</b>	<b>0.686**</b>	<b>0.478**</b>	-0.478
PASSFOR	-0.119	0.114	-0.124	-0.085
TOTFOR	0.332	0.494	0.319	<b>-0.592*</b>
S4U <sub>x</sub>	0.244	0.270	0.223	0.123
S4U	-0.226	-0.418	-0.138	0.372
BS <sub>x</sub>	0.138	0.122	0.176	0.086
BS	-0.147	-0.514	-0.172	0.485
BA <sub>x</sub>	0.266	0.218	0.265	-
BA	-0.140	-0.234	-0.235	0.049

	OWNLAT	TOTRESP	TOTDUR	TOTLAT
HL / MIN	-0.307	0.098	0.118	-0.190
INCVIG / MIN	-0.257	-0.013	-0.004	-0.123
TVIG	-0.109	-0.060	-0.090	0.204
ACTFOR	0.133	0.018	0.110	-0.209
PASSFOR	0.044	-0.274	-0.281	0.029
TOTFOR	0.142	-0.154	-0.106	-0.181
S4U <sub>x</sub>	-0.065	-0.076	-0.021	-0.136
S4U	-0.039	0.271	0.272	0.396
BS <sub>x</sub>	0.176	-0.351	-0.317	0.046
BS	-0.082	-0.049	-0.181	0.074
BA <sub>x</sub>	-0.023	0.352	0.351	0.023
BA	-0.286	-0.138	-0.121	-0.338

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 10

<sup>‡</sup> n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.21: The effect of the number of responses occurring after the subject respondent's jump-yip in a jump-yip bout on the change in the behaviour of that respondent from the minute preceding to the minute following jump-yip production.<sup>^</sup>

	Number of responses		
	0 (n = 7)	1 (n = 3)	4+ (n = 8)
HL / MIN	-0.393 ± 2.155	3.000 ± 1.000	0.627 ± 1.306
INCVIG / MIN	-0.250 ± 2.603	1.667 ± 0.667	-0.147 ± 1.629
TVIG	<b>0.155 ± 0.064</b>	<b>0.006 ± 0.078</b>	<b>-0.059 ± 0.095</b>
ACTFOR	<b>-0.175 ± 0.074</b>	<b>0.239 ± 0.199</b>	<b>0.185 ± 0.094</b>
PASSFOR	-0.017 ± 0.045	0.000 ± 0.059	-0.085 ± 0.090
TOTFOR	<b>-0.192 ± 0.104</b>	<b>0.239 ± 0.224</b>	<b>0.100 ± 0.063</b>
S4Ux	0.002 ± 0.043	0.067 ± 0.050	-0.023 ± 0.109
S4U	0.107 ± 0.075	-0.017 ± 0.029	-0.018 ± 0.029
BSx	0.000 ± 0.020	0.028 ± 0.036	0.038 ± 0.053
BS	-0.005 ± 0.008	-0.061 ± 0.053	-0.035 ± 0.023
BAx	-0.019 ± 0.019	0.000 ± 0.000	0.000 ± 0.000
BA	0.069 ± 0.081	-0.011 ± 0.011	-0.020 ± 0.013

<sup>^</sup> See Appendix A for abbreviations and definitions

c Exact value



Table B.21: Continued<sup>^</sup>

	All variables		0 vs. 4+		1 vs. 4+	
	$\chi^2$	Sig.	U	Sig.	U	Sig.
HL / MIN	3.279	0.205	19.0	0.316	7.0	0.363
INCVIG / MIN	2.646	0.285	19.0	0.322	10.0	0.739
TVIG	3.994	0.141	<b>12.5*</b>	<b>0.072</b>	10.5	0.810
ACTFOR	<b>7.168**</b>	<b>0.017</b>	<b>7.5**</b>	<b>0.011</b>	12.0	1.000
PASSFOR	0.501	0.792	23.0	0.613	9.5	0.666
TOTFOR	4.368	0.112	<b>11.5*</b>	<b>0.056</b>	11.0	0.922
S4Ux	0.933	0.643	22.5	0.557	9.0	0.583
S4U	2.270	0.335	17.5	0.252	10.0	0.731
BSx	1.023	0.628	20.0	0.385	10.0	0.765
BS	3.235	0.216	21.0	0.327	7.0	0.406
BAx	1.571	0.553	24.0	0.462	12.0	1.000 <sup>c</sup>
BA	1.186	0.531	21.0	0.327	12.0	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>c</sup> Exact value

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.22: The effect of the duration of a section of a jump-yip bout beginning with the subject respondent's jump-yip on the changes in the behaviour of that respondent from the minute preceding to the minute following jump-yip production.<sup>^</sup>

	Duration (s)		Test statistics	
	0 (n = 7)	4+ (n = 8)	U	Sig.
HL / MIN	-0.393 ± 2.155	0.627 ± 1.306	19.0	0.317
INCVIG / MIN	-0.250 ± 2.603	-0.147 ± 1.629	19.0	0.320
TVIG	<b>0.155 ± 0.064</b>	<b>-0.059 ± 0.095</b>	<b>12.5*</b>	<b>0.072</b>
ACTFOR	<b>-0.175 ± 0.074</b>	<b>0.185 ± 0.094</b>	<b>7.5**</b>	<b>0.017</b>
PASSFOR	-0.017 ± 0.045	-0.085 ± 0.090	23.0	0.592
TOTFOR	<b>-0.192 ± 0.104</b>	<b>0.100 ± 0.063</b>	<b>11.5*</b>	<b>0.057</b>
S4Ux	0.002 ± 0.043	-0.023 ± 0.109	22.5	0.556
S4U	0.107 ± 0.075	-0.018 ± 0.029	17.5	0.241
BSx	0.000 ± 0.020	0.038 ± 0.053	20.0	0.376
BS	-0.005 ± 0.008	-0.035 ± 0.023	21.0	0.420
BAx	-0.019 ± 0.019	0.000 ± 0.000	24.0	0.475
BA	0.069 ± 0.081	-0.020 ± 0.013	21.0	0.420

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.23: The effect of the number of responses in an entire jump-yip bout on the changes in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production.<sup>^</sup>

	Number of responses		Test statistics	
	1 (n = 3)	4+ (n = 13)	U	Sig.
HL / MIN	1.228 ± 5.260	0.276 ± 0.914	17.0	0.787
INCVIG / MIN	2.895 ± 5.895	-0.431 ± 1.085	19.0	0.960
TVIG	0.221 ± 0.140	-0.027 ± 0.061	9.0	0.183
ACTFOR	-0.182 ± 0.151	0.141 ± 0.081	7.5	0.116
PASSFOR	-0.001 ± 0.076	-0.072 ± 0.057	16.5	0.727
TOTFOR	-0.183 ± 0.209	0.068 ± 0.080	15.0	0.592
S4Ux	0.049 ± 0.075	-0.022 ± 0.067	18.5	0.915
S4U	0.000 ± 0.029	0.030 ± 0.046	18.5	0.924
BSx	0.033 ± 0.033	0.016 ± 0.033	15.0	0.589
BS	0.000 ± 0.000	-0.038 ± 0.018	13.5	0.523
BAx	-0.044 ± 0.044	0.000 ± 0.000	13.0	0.185
BA	0.183 ± 0.183	-0.012 ± 0.008	11.0	0.164

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table B.24: The effect of the duration of an entire jump-yip bout on the change in the behaviour of a respondent in that bout from the minute preceding to the minute following jump-yip production.<sup>^</sup>

	Duration (s)		Test statistics	
	0 (n = 3)	4+ (n = 14)	U	Sig.
HL / MIN	1.228 ± 5.260	0.185 ± 0.851	18.0	0.757
INCVIG / MIN	2.895 ± 5.895	-0.686 ± 1.037	20.0	0.928
TVIG	0.221 ± 0.140	-0.013 ± 0.058	10.0	0.181
ACTFOR	-0.182 ± 0.151	0.108 ± 0.082	9.5	0.163
PASSFOR	-0.001 ± 0.077	-0.061 ± 0.054	18.5	0.782
TOTFOR	-0.183 ± 0.209	0.047 ± 0.077	17.0	0.663
S4Ux	0.049 ± 0.075	-0.017 ± 0.062	20.5	0.968
S4U	0.000 ± 0.029	0.041 ± 0.044	18.5	0.783
BSx	0.033 ± 0.033	0.014 ± 0.031	15.0	0.466
BS	0.000 ± 0.000	-0.034 ± 0.017	16.5	0.656
BAx	-0.044 ± 0.044	0.000 ± 0.000	14.0	0.181
BA	0.183 ± 0.183	-0.016 ± 0.009	11.0	0.174

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

### APPENDIX C: Autocorrelations of the characteristics of the subject jump-yip bouts

In all three bout initiator groups (in which their behaviour was examined immediately after jump-yip production (F-I), over one minute following jump-yip production (F-P), and as it changed following jump-yip production (F-PP)), increases in the number of responses in the subject jump-yip bouts were associated with increases in the number of respondents in (F-I:  $n = 24$ ,  $r_s = 0.999$ ,  $P < 0.001$ ; F-P:  $n = 35$ ,  $r_s = 0.994$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.997$ ,  $P < 0.001$ ) and the duration of (F-I:  $n = 26$ ,  $r_s = 0.970$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = 0.956$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.931$ ,  $P < 0.001$ ) the subject bout (Tables C.1, C.2, C.3). Increases in the number of respondents in the subject bouts were also associated with increases in the duration of the subject bouts (F-I:  $n = 24$ ,  $r_s = 0.965$ ,  $P < 0.001$ ; F-P:  $n = 35$ ,  $r_s = 0.951$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.932$ ,  $P < 0.001$ ) in all three groups (Tables C.1, C.2, C.3).

In all three respondent groups (immediate post-jump-yip behaviour (R-I), one-minute post-jump-yip behaviour (R-P), and post-jump-yip changes in behaviour (R-PP)), increases in the number of responses in the section of the subject jump-yip bout which followed the subject respondent's jump-yip (post-subject responses) were associated with increases in the number of post-subject respondents in the subject bout (R-I:  $n = 14$ ,  $r_s = 1.000$ ,  $P < 0.001$ ; R-P:  $n = 15$ ,  $r_s = 1.000$ ,  $P < 0.001$ ; R-PP:  $n = 10$ ,  $r_s = 1.000$ ,  $P < 0.001$ ) and the duration of the subject-initiated section of their jump-yip bout (R-I:  $n = 22$ ,  $r_s = 0.975$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.974$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.967$ ,  $P < 0.001$ ) (Tables C.4, C.5, C.6). The number of post-subject respondents in the subject bout was also positively correlated with the duration of the post-subject section of the subject bout (R-I:  $n = 14$ ,  $r_s = 0.957$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.964$ ,

Table C.1: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the immediate post-jump-yip behaviours of the initial callers in the bouts were analyzed (n = 26).<sup>^</sup>

	RESPS	RPDTS <sup>†</sup>	DUR	LAT <sup>‡</sup>
RESPS	1.000			
RPDTS <sup>†</sup>	<b>0.999**</b>	1.000		
DUR	<b>0.970**</b>	<b>0.965**</b>	1.000	
LAT <sup>‡</sup>	-0.078	-0.007	0.071	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 24, except RPDTS (n = 13)

<sup>‡</sup> n = 15, except RPDTS (n = 13)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table C.2: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the behaviours of the initial callers in the bouts over the minute following jump-yip production were analyzed (n = 42).<sup>^</sup>

	RESPS	RPDTS <sup>†</sup>	DUR	LAT <sup>‡</sup>
RESPS	1.000			
RPDTS <sup>†</sup>	<b>0.994**</b>	1.000		
DUR	<b>0.956**</b>	<b>0.951**</b>	1.000	
LAT <sup>‡</sup>	-0.163	-0.174	0.034	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 35, except RPDTS (n = 22)

<sup>‡</sup> n = 29, except RPDTS (n = 22)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table C.3: Autocorrelation of the response characteristics of the subject jump-yip bouts in which post-jump-yip changes in the behaviours of the initial callers in the bouts were analyzed (n = 24).<sup>^</sup>

	RESPS	RPDTS <sup>†</sup>	DUR	LAT <sup>‡</sup>
RESPS	1.000			
RPDTS <sup>†</sup>	<b>0.997**</b>	1.000		
DUR	<b>0.931**</b>	<b>0.932**</b>	1.000	
LAT <sup>‡</sup>	-0.156	-0.058	0.067	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19, except RPDTS (n = 13)

<sup>‡</sup> n = 18, except RPDTS (n = 13)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table C.4: Autocorrelation of the response characteristics of the subject jump-yip bouts in which the immediate post-jump-yip behaviours of respondents in the bouts were analyzed (n = 22).<sup>^</sup>

	SUBRESP	SUBRPDT <sup>†</sup>	SUBDUR	OWNLAT	SUBLAT <sup>‡</sup>	TOTRESP	TOTDUR	INITLAT
SUBRESP	1.000							
SUBRPDT <sup>†</sup>	<b>1.000**</b>	1.000						
SUBDUR	<b>0.975**</b>	<b>0.957**</b>	1.000					
OWNLAT	-0.216	-0.177	-0.202	1.000				
SUBLAT <sup>‡</sup>	-0.030	<b>-0.768**</b>	0.023	-0.218	1.000			
TOTRESP	<b>0.466**</b>	0.157	<b>0.510**</b>	-0.200	0.276	1.000		
TOTDUR	0.319	0.021	<b>0.379*</b>	0.002	0.254	<b>0.925**</b>	1.000	
INITLAT	-0.322	-0.316	-0.290	<b>0.706**</b>	0.186	-0.039	0.083	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 14, except SUBRPDT (n = 7)

<sup>‡</sup> n = 15, except SUBRPDT (n = 7)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table C.5: Autocorrelation of the response characteristics of the subject jump-yip bouts in trials where the post-jump-yip behaviours of respondents in the bouts were analyzed (n = 26).

	SUBRESP	SUBRPDT†	SUBDUR	OWNLAT	SUBLAT‡	TOTRESP	TOTDUR	INITLAT
SUBRESP	1.000							
SUBRPDT†	<b>1.000**</b>	1.000						
SUBDUR	<b>0.974**</b>	<b>0.964**</b>	1.000					
OWNLAT	-0.111	-0.144	-0.080	1.000				
SUBLAT‡	-0.107	<b>-0.768**</b>	-0.041	-0.011	1.000			
TOTRESP	<b>0.547**</b>	0.228	<b>0.573**</b>	-0.122	0.146	1.000		
TOTDUR	<b>0.368*</b>	0.031	<b>0.421**</b>	0.094	0.191	<b>0.911**</b>	1.000	
INITLAT	<b>-0.387*</b>	-0.380	-0.320	<b>0.647**</b>	0.328	-0.169	0.040	1.000

^ See Appendix A for abbreviations and definitions

† n = 15, except SUBRPDT (n = 7)

‡ n = 18, except SUBRPDT (n = 7)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table C.6: Autocorrelation of the response characteristics of the subject jump-yip bouts in trials where the post-jump-yip changes in the behaviours of respondents in the bouts were analyzed (n = 18).<sup>^</sup>

	SUBRESP	SUBRPDT†	SUBDUR	OWNLAT	SUBLAT‡	TOTRESP	TOTDUR	INITLAT
SUBRESP	1.000							
SUBRPDT†	<b>1.000**</b>	1.000						
SUBDUR	<b>0.967**</b>	<b>0.981**</b>	1.000					
OWNLAT	-0.372	-0.190	-0.349	1.000				
SUBLAT‡	-0.249	#	-0.282	-0.466	1.000			
TOTRESP	<b>0.445*</b>	0.154	<b>0.473**</b>	-0.306	0.300	1.000		
TOTDUR	0.309	0.190	0.358	-0.090	0.196	<b>0.915**</b>	1.000	
INITLAT	<b>-0.545**</b>	-0.494	<b>-0.431*</b>	<b>0.644**</b>	0.068	-0.073	0.075	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 10

‡ n = 11

# Insufficient sample size to perform statistical analysis

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

$P < 0.001$ ; R-PP:  $n = 10$ ,  $r_s = 0.981$ ,  $P < 0.001$ ) in all three groups (Tables C.4, C.5, C.6). Similarly, in all three respondent groups, the number of responses in the entire subject jump-yip bout was significantly positively correlated with the duration of the entire subject bout (R-I:  $n = 22$ ,  $r_s = 0.925$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.911$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.915$ ,  $P < 0.001$ ; Table C.4, C.5, C.6).

These correlations for both “bout initiator” and “respondent” bouts were generally quite strong (with  $P$ -values often being less than 0.001). This demonstrates that the different measures of response magnitude in a jump-yip bout are generally highly related – not surprising given the contributions of the number of responses and/or respondents in a jump-yip bout to the duration of the bout. The strong correlation between the number of responses and respondents in a bout is likely indicative of the relatively rare instances of a single individual repeatedly producing a jump-yip, at least within a single bout, while the correlations between response and duration demonstrate that the rate of jump-yips in a bout varies little between different bouts, making it unlikely rate plays a major role in providing semantic information to receivers. These results also demonstrate that individuals are presented with consistent information (including quantitative and temporal measures of response) concerning the level of response in a jump-yip bout across several modalities. This may provide individuals with the opportunity to use either both modalities simultaneously or one preferentially over the other to obtain information from the jump-yip bouts.

In all three respondent groups, the number of post-subject responses in the subject jump-yip bout was positively correlated with the number of responses in the entire subject bout (R-I:  $n = 22$ ,  $r_s = 0.466$ ,  $P = 0.029$ ; R-P:  $n = 26$ ,  $r_s = 0.547$ ,  $P = 0.004$ ;

R-PP:  $n = 18$ ,  $r_s = 0.445$ ,  $P = 0.064$ ; Tables C.4, C.5, C.6). Positive correlations were also observed between the number of post-subject responses and the duration of the entire bout (R-P:  $n = 26$ ,  $r_s = 0.368$ ,  $P = 0.064$ ), while negative correlations were found between the number of post-subject responses and the response latency of the entire subject bout (R-P:  $n = 26$ ,  $r_s = -0.387$ ,  $P = 0.051$ ; R-PP:  $n = 18$ ,  $r_s = -0.545$ ,  $P = 0.019$ ), though in both cases, the correlations were not consistent across all respondent groups (Tables C.4, C.5, C.6). The duration of the section of the subject bout beginning with the subject's (respondent's) jump-yip was also positively correlated with the number of responses in the entire subject bout for all three respondent groups (R-I:  $n = 22$ ,  $r_s = 0.510$ ,  $P = 0.015$ ; R-P:  $n = 26$ ,  $r_s = 0.573$ ,  $P = 0.002$ ; R-PP:  $n = 18$ ,  $r_s = 0.473$ ,  $P = 0.048$ ) and with the duration of the entire bout in two of the respondent groups (R-I:  $n = 22$ ,  $r_s = 0.379$ ,  $P = 0.082$ ; R-P:  $n = 26$ ,  $r_s = 0.421$ ,  $P = 0.032$ ; Table C.4, C.5, C.6).

These correlations suggest that the variables representing response magnitude in jump-yip bouts are consistent for both an entire bout and the respondent-initiated section of a bout. More than likely, however, these correlations are a function of the respondents studied than true relationships between the sections and entire bouts examined. Because respondents were not specifically chosen (i.e. respondents were initially misidentified as initial callers) their jump-yip generally occurred early in their jump-yip bout. Consequently, the section of their bout and the entire bout generally differed by only a couple of responses and/or seconds and therefore the measured characteristics should be similar. This is supported by observed positive correlations between the response latencies of the respondents studied in this experiment – the time it took for the subject respondent to respond to the previous jump-yip in the bout – and the

response latencies of their entire jump-yip bout. The number of post-subject respondents was significantly correlated with the response latency of the first post-subject response in the subject jump-yip bout (R-I:  $n = 7$ ,  $r_s = -0.768$ ,  $P = 0.044$ ; R-P:  $n = 18$ ,  $r_s = -0.768$ ,  $P = 0.044$ ), though the correlation was not consistent across all respondent groups. Similarly, in one group (R-PP), the duration of the subject-initiated section of its jump-yip bout was negatively correlated with the response latency of the entire bout ( $n = 18$ ,  $r_s = -0.431$ ,  $P = 0.074$ ; Table C.6). Finally, the response latency of the subject's (respondent's) jump-yip to the previous jump-yip in its bout (i.e. the latency of the subject's response) was significantly positively correlated with the response latency of the entire subject bout (R-I:  $n = 22$ ,  $r_s = 0.706$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.647$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.644$ ,  $P = 0.004$ ). Though these results could be seen as an indication of similar latencies for multiple callers (i.e. the latency of the subject respondent was similar to the latency of the second caller in the bout), more likely it is indicative of the fact that the subject respondent was often the second caller in the bout.

## APPENDIX D: Autocorrelations of the behaviour of subject individuals

The level of vigilance exhibited by both bout initiators and respondents immediately following jump-yip production was significantly positively correlated with their “adjusted” level of immediate post-jump-yip vigilance (bout initiators:  $n = 26$ ,  $r_s = 0.850$ ,  $P < 0.001$ ; respondents:  $n = 22$ ,  $r_s = 0.814$ ,  $P < 0.001$ ; Table D.1, Table D.2). This result reflects the simple 0.5 unit adjustment to “unadjusted” vigilance – an adjustment that while not universal (since vigilance was often performed in the absence of other behaviours), was consistent across all adjustments. For bout initiators and respondents, the level of immediate post-jump-yip vigilance was also associated with the duration of their immediate post-jump-yip vigilance (bout initiators:  $n = 25$ ,  $r_s = 0.602$ ,  $P = 0.001$ ; Table D.1; respondents:  $n = 22$ ,  $r_s = 0.627$ ,  $P = 0.002$ ; Table D.2). The adjusted level of immediate post-jump-yip vigilance of both bout initiators and respondents was also positively correlated with the duration of the immediate post jump-yip vigilance (bout initiators:  $n = 25$ ,  $r_s = 0.402$ ,  $P = 0.047$ ; respondents:  $n = 22$ ,  $r_s = 0.547$ ,  $P = 0.008$ ). The positive correlations between the level of immediate post-jump-yip vigilance (unadjusted and adjusted) and the duration of the initial behaviour indicate that post-jump-yip vigilance may be represented by changes in both the type of vigilance exhibited, as well as the amount of time the vigilant behaviour lasts. The duration of the immediate post-jump-yip vigilance of bout initiators and respondents was also positively correlated with the duration of their immediate post-jump-yip behaviour (bout initiators:  $n = 25$ ,  $r_s = 0.678$ ,  $P < 0.001$ ; Table D.1;  $n = 22$ ,  $r_s = 0.449$ ,  $P = 0.036$ ; Table D.2), likely reflecting that the majority of immediate post-jump-yip behaviours were vigilant behaviours.

Table D.1: Autocorrelations of the immediate post-jump-yip behaviours exhibited by the subject initial caller in a jump-yip

bout (n = 26).<sup>^</sup>

	INITVIG	ADJINITVIG	DURINITBHV	DURINITVIG
INITVIG	1.000			
ADJINITVIG	<b>0.850**</b>	1.000		
DURINITBHV <sup>†</sup>	0.237	0.051	1.000	
DURINITVIG <sup>†</sup>	<b>0.602**</b>	<b>0.402**</b>	<b>0.678**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions<sup>†</sup> n = 25\* Significant at  $\alpha = 0.10$ \*\* Significant at  $\alpha = 0.05$ 

Table D.2: Autocorrelations of the immediate post-jump-yip behaviours exhibited by the subject respondent in a jump-yip

bout (n = 22).<sup>^</sup>

	INITVIG	ADJINITVIG	DURINITBHV	DURINITVIG
INITVIG	1.000			
ADJINITVIG	<b>0.814**</b>	1.000		
DURINITBHV	-0.144	-0.116	1.000	
DURINITVIG	<b>0.627**</b>	<b>0.547**</b>	<b>0.449**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions\* Significant at  $\alpha = 0.10$ \*\* Significant at  $\alpha = 0.05$

Increases in the rate at which both bout initiators and respondents raised their heads were associated with increases in the rate at which they increased their level of vigilance, both in the minute following the subject bout (bout initiators:  $n = 42$ ,  $r_s = 0.943$ ,  $P < 0.001$ , Table D.3; respondents:  $n = 26$ ,  $r_s = 0.949$ ,  $P < 0.001$ ; Table D.4) and as it changed following jump-yip production (bout initiators:  $n = 24$ ,  $r_s = 0.915$ ,  $P < 0.001$ ; Table D.5; respondents:  $n = 18$ ,  $r_s = 0.916$ ,  $P < 0.001$ ; Table D.6), reflecting the fact that head lifts comprised a major component of general increases in the level of vigilance exhibited by black-tailed prairie dogs.

Greater rates of head lifting were also associated with more time spent passively foraging (F-P:  $n = 42$ ,  $r_s = 0.370$ ,  $P = 0.016$ ; R-P:  $n = 26$ ,  $r_s = 0.661$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.482$ ,  $P = 0.043$ ), more time spent in “occupied” quadrupedal head-up postures (F-P:  $n = 42$ ,  $r_s = 0.595$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.726$ ,  $P < 0.001$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = 0.723$ ,  $P = 0.001$ ; Table D.6), and more time spent in “occupied” bipedal-slouched postures (F-P:  $n = 42$ ,  $r_s = 0.412$ ,  $P = 0.007$ ; Table D.3), though the correlations were not consistent across all groups. These correlations reflect both the transition from head-down to head-up feeding (the correlation between head lifts and passive foraging) and the major contribution of passive foraging to the “occupied” behaviours exhibited by black-tailed prairie dogs. They also demonstrate that individuals performing vigilant behaviours may not do so at the expense of foraging, but instead perform both behaviours simultaneously (though potentially performing the behaviours at lower efficiencies than would occur if either behaviour was performed individually). Likewise, increases in the rate at which individuals increased their level of vigilance were associated with increases in the time they spent passively foraging (F-P:  $n = 42$ ,



Table D.3: Correlations between the behaviours exhibited by the subject initial caller in a jump-yip bout over one minute following jump-yip production (n = 42).<sup>^</sup>

	HL / MIN	INCVIG / MIN	TVIG	ACTFOR	PASSFOR	TOTFOR
HL / MIN	1.000					
INCVIG / MIN	<b>0.943**</b>	1.000				
TVIG	0.119	0.222	1.000			
ACTFOR	-0.151	-0.222	<b>-0.808**</b>	1.000		
PASSFOR	<b>0.370**</b>	<b>0.336**</b>	-0.157	0.191	1.000	
TOTFOR	-0.093	-0.172	<b>-0.766**</b>	<b>0.949**</b>	<b>0.393**</b>	1.000
S4Ux	<b>0.595**</b>	<b>0.519**</b>	0.167	0.010	<b>0.625**</b>	0.121
S4U	0.092	0.094	<b>0.735**</b>	<b>-0.835**</b>	<b>-0.363**</b>	<b>-0.883**</b>
BSx	<b>0.412**</b>	<b>0.567**</b>	0.140	0.059	0.246	0.058
BS	0.042	0.255	<b>0.411**</b>	<b>-0.341**</b>	-0.037	<b>-0.314**</b>
BAx	-0.097	-0.045	-0.071	0.097	0.198	0.123
BA	-0.198	0.016	<b>0.339**</b>	<b>-0.308**</b>	-0.239	<b>-0.334**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table D.3: Continued<sup>^</sup>

	S4Ux	S4U	BSx	BS	BAx	BA
HL / MIN						
INCVIG / MIN						
TVIG						
ACTFOR						
PASSFOR						
TOTFOR						
S4Ux	1.000					
S4U	-0.098	1.000				
BSx	0.171	-0.135	1.000			
BS	-0.022	0.095	<b>0.379**</b>	1.000		
BAx	0.097	-0.097	-0.092	-0.075	1.000	
BA	<b>-0.261*</b>	0.204	-0.006	0.256	-0.051	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table D.4: Correlations of the behaviours exhibited by a subject respondent in a jump-yip bout over the minute following jump-yip production (n = 26).<sup>^</sup>

	HL / MIN	INCVIG / MIN	TVIG	ACTFOR	PASSFOR	TOTFOR
HL / MIN	1.000					
INCVIG / MIN	<b>0.949**</b>	1.000				
TVIG	-0.138	0.011	1.000			
ACTFOR	0.056	-0.006	<b>-0.777**</b>	1.000		
PASSFOR	<b>0.661**</b>	<b>0.579**</b>	-0.176	-0.045	1.000	
TOTFOR	0.175	0.097	<b>-0.815**</b>	<b>0.918**</b>	0.214	1.000
S4Ux	<b>0.726**</b>	<b>0.593**</b>	-0.156	0.207	<b>0.536**</b>	0.274
S4U	-0.158	-0.152	<b>0.734**</b>	<b>-0.864**</b>	-0.147	<b>-0.955**</b>
BSx	0.256	<b>0.387*</b>	0.188	0.147	0.216	0.153
BS	-0.059	-0.009	0.282	<b>-0.345*</b>	0.104	-0.323
BAx	0.080	0.281	0.254	-0.254	0.055	-0.227
BA	-0.124	0.064	<b>0.416**</b>	<b>-0.406**</b>	-0.127	<b>-0.388**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table D.4: Continued<sup>^</sup>

	S4Ux	S4U	BSx	BS	BAx	BA
HL / MIN						
INCVIG / MIN						
TVIG						
ACTFOR						
PASSFOR						
TOTFOR						
S4Ux	1.000					
S4U	-0.193	1.000				
BSx	0.224	-0.192	1.000			
BS	-0.213	<b>0.368*</b>	0.227	1.000		
BAx	-0.188	0.067	-0.131	-0.072	1.000	
BA	<b>-0.341*</b>	0.177	-0.188	-0.104	<b>0.663**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table D.5: Correlations of the post-jump-yip changes in the behaviours exhibited by the subject initial caller in a jump-yip

bout (n = 24).<sup>^</sup>

	HL / MIN	INCVIG / MIN	TVIG	ACTFOR	PASSFOR	TOTFOR
HL / MIN	1.000					
INCVIG / MIN	<b>0.915**</b>	1.000				
TVIG	-0.102	-0.108	1.000			
ACTFOR	-0.057	0.093	-0.292	1.000		
PASSFOR	0.140	-0.014	<b>-0.429**</b>	0.113	1.000	
TOTFOR	0.075	0.076	-0.318	<b>0.854**</b>	<b>0.412**</b>	1.000
S4Ux	0.230	0.117	-0.235	0.127	<b>0.835**</b>	<b>0.387*</b>
S4U	-0.016	-0.201	<b>0.426**</b>	<b>-0.675**</b>	-0.258	<b>-0.602**</b>
BSx	-0.155	0.016	<b>0.484**</b>	<b>0.467**</b>	<b>-0.383*</b>	0.217
BS	0.275	<b>0.364*</b>	0.077	-0.171	-0.254	-0.340
BAx	-0.104	0.052	-0.250	<b>0.417**</b>	-0.043	0.073
BA	-0.037	0.018	0.299	-0.062	-0.303	-0.098

<sup>^</sup> See Appendix A for abbreviations and definitions\* Significant at  $\alpha = 0.10$ \*\* Significant at  $\alpha = 0.05$

Table D.5: Continued<sup>^</sup>

	S4Ux	S4U	BSx	BS	BAx	BA
HL / MIN						
INCVIG / MIN						
TVIG						
ACTFOR						
PASSFOR						
TOTFOR						
S4Ux	1.000					
S4U	-0.312	1.000				
BSx	-0.309	-0.162	1.000			
BS	-0.265	-0.047	0.014	1.000		
BAx	-0.063	-0.063	<b>0.352*</b>	-0.024	1.000	
BA	-0.276	0.171	0.131	<b>-0.480**</b>	0.000	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table D.6: Correlations of the post-jump-yip changes in the behaviours exhibited by a subject respondent in a jump-yip

bout (n = 18).<sup>^</sup>

	HL / MIN	INCVIG / MIN	TVIG	ACTFOR	PASSFOR	TOTFOR
HL / MIN	1.000					
INCVIG / MIN	<b>0.916**</b>	1.000				
TVIG	0.218	0.227	1.000			
ACTFOR	-0.010	0.013	<b>-0.895**</b>	1.000		
PASSFOR	<b>0.482**</b>	0.375	0.238	-0.241	1.000	
TOTFOR	0.157	0.121	<b>-0.557**</b>	<b>0.658**</b>	<b>0.405*</b>	1.000
S4Ux	<b>0.723**</b>	<b>0.633**</b>	<b>0.415*</b>	-0.202	<b>0.739**</b>	0.314
S4U	-0.016	-0.017	<b>0.469**</b>	<b>-0.475**</b>	<b>-0.413*</b>	<b>-0.886**</b>
BSx	0.350	<b>0.554**</b>	0.077	0.234	0.190	0.384
BS	0.068	0.091	0.253	<b>-0.410*</b>	0.072	<b>-0.552**</b>
BAx	0.352	0.187	-0.398	0.398	0.259	0.398
BA	-0.344	-0.152	0.067	-0.157	<b>-0.461*</b>	-0.380

<sup>^</sup> See Appendix A for abbreviations and definitions\* Significant at  $\alpha = 0.10$ \*\* Significant at  $\alpha = 0.05$

Table D.6: Continued<sup>^</sup>

	S4U <sub>x</sub>	S4U	BS <sub>x</sub>	BS	BA <sub>x</sub>	BA
HL / MIN						
INCVIG / MIN						
TVIG						
ACTFOR						
PASSFOR						
TOTFOR						
S4U <sub>x</sub>	1.000					
S4U	-0.278	1.000				
BS <sub>x</sub>	0.381	-0.281	1.000			
BS	0.032	<b>0.439*</b>	-0.199	1.000		
BA <sub>x</sub>	0.234	-0.211	0.025	-0.111	1.000	
BA	-0.363	0.075	-0.168	0.050	<b>-0.503**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



$r_s = 0.336$ ,  $P = 0.029$ ; R-P:  $n = 26$ ,  $r_s = 0.579$ ,  $P = 0.002$ ), the time they spent in “occupied” quadrupedal head-up postures (F-P:  $n = 42$ ,  $r_s = 0.519$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.593$ ,  $P = 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.633$ ,  $P = 0.005$ ) and “occupied” bipedal-slouched postures (F-P:  $n = 42$ ,  $r_s = 0.567$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.387$ ,  $P = 0.051$ ; R-PP:  $n = 18$ ,  $r_s = 0.554$ ,  $P = 0.017$ ), and the time they spent in an “unoccupied” bipedal-slouched posture (F-PP:  $n = 24$ ,  $r_s = 0.364$ ,  $P = 0.080$ ), likely reflecting the positive correlation between head lifts and general increases in vigilance, which would result in the observed positive correlations between the rate at which individuals increased their level of vigilance and the time they devoted to “occupied” behaviours.

Interestingly, increases in the rate at which vigilance behaviours were exhibited were not positively correlated with the proportion of time individuals spent vigilant, nor with the proportion of time they spent in any of the specific vigilant postures. This indicated that the propensity of individuals to exhibit vigilant behaviours was not directly related with the amount of time they then spent performing the vigilant behaviours. Correspondingly, increases in the rate at which vigilant behaviours were performed by both bout initiators and respondents were not accompanied with decreases in the proportion of time they spent actively foraging. In fact, individuals spent more time passively foraging when exhibiting more frequent vigilant behaviours. The expected inverse relationships between foraging and vigilance were therefore not observed when the frequency of vigilance was compared to the time spent foraging, particularly when passive foraging was considered. When the amounts of time spent foraging and vigilant were compared, however, increases in the total time individuals spent vigilant

were associated with decreases in the proportion of time they spent actively (F-P:  $n = 42$ ,  $r_s = -0.808$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = -0.777$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = -0.895$ ,  $P < 0.001$ ) and generally (F-P:  $n = 42$ ,  $r_s = -0.766$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = -0.557$ ,  $P = 0.016$ ) foraging and with decreases in the time they spent passively foraging (F-PP:  $n = 24$ ,  $r_s = -0.429$ ,  $P = 0.036$ ; R-P:  $n = 26$ ,  $r_s = -0.815$ ,  $P < 0.001$ ). This reflected the expected inverse relationship between the time individuals spend foraging and the time they spend vigilant. Consequently, any “unusual” relationships observed between the time black-tailed prairie dogs devote to foraging and vigilance when the characteristics of the associated jump-yip bouts are included in the analyses do not arise from an underlying lack of a foraging-vigilance tradeoff.

Increases in the total time black-tailed prairie dogs spent vigilant were also associated with increases in the time they spent in “unoccupied” quadrupedal head-up (F-P:  $n = 42$ ,  $r_s = 0.735$ ,  $P < 0.001$ ; Table D.3; F-PP:  $n = 24$ ,  $r_s = 0.426$ ,  $P = 0.038$ ; Table D.5; R-P:  $n = 26$ ,  $r_s = 0.734$ ,  $P < 0.001$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = 0.469$ ,  $P = 0.050$ ; Table D.6), “unoccupied” bipedal-slouched (F-P:  $n = 42$ ,  $r_s = 0.411$ ,  $P = 0.007$ ), and “unoccupied” bipedal-alert (F-P:  $n = 42$ ,  $r_s = 0.339$ ,  $P = 0.028$ ; R-P:  $n = 26$ ,  $r_s = 0.416$ ,  $P = 0.035$ ) postures, and with increases in the time they spent in “occupied” quadrupedal head-up (R-PP:  $n = 18$ ,  $r_s = 0.415$ ,  $P = 0.087$ ) and “occupied” bipedal-slouched postures (F-PP:  $n = 24$ ,  $r_s = 0.484$ ,  $P = 0.017$ ). These correlations demonstrate that all of the individual “unoccupied” vigilant behaviours, as well as some of the “occupied” vigilant behaviours contributed to the overall vigilance of black-tailed prairie dogs, though their contributions were not universal across all data groups. Highly vigilant (bipedal-slouched and bipedal-alert) behaviours, in particular, contributed

significantly to general vigilance in only a couple of data groups, indicating that any differences in their exhibition may result from factors other than merely a general need to increase vigilance, such as the presence of an imminent threat, such as a predator.

Increases in the amount of time black-tailed prairie dogs spent actively foraging were associated with increases in the time they spent generally foraging (F-P:  $n = 42$ ,  $r_s = 0.949$ ,  $P < 0.001$ ; Table D.3; F-PP:  $n = 24$ ,  $r_s = 0.854$ ,  $P < 0.001$ ; Table D.5; R-P:  $n = 26$ ,  $r_s = 0.918$ ,  $P < 0.001$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = 0.658$ ,  $P = 0.003$ ; Table D.6) and decreases in the amount of time they spent in “unoccupied” quadrupedal head-up (F-P:  $n = 42$ ,  $r_s = -0.835$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.675$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = -0.864$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = -0.475$ ,  $P = 0.046$ ), “unoccupied” bipedal-slouched (F-P:  $n = 42$ ,  $r_s = -0.341$ ,  $P = 0.027$ ; R-P:  $n = 26$ ,  $r_s = -0.345$ ,  $P = 0.084$ ; R-PP:  $n = 18$ ,  $r_s = -0.410$ ,  $P = 0.091$ ), and “unoccupied” bipedal-alert (F-P:  $n = 42$ ,  $r_s = -0.308$ ,  $P = 0.047$ ; R-P:  $n = 26$ ,  $r_s = -0.406$ ,  $P = 0.040$ ) postures. These results demonstrate that active foraging comprised a great proportion of the total time black-tailed prairie dogs spent foraging, as well as demonstrating that the inverse relationship between vigilance and foraging was strong for all recorded vigilant behaviours and active foraging, conforming to the underlying expectations of this study. Increases in active foraging were also associated with increases in the time individuals spent in “occupied” bipedal-slouched (F-PP:  $n = 24$ ,  $r_s = 0.467$ ,  $P = 0.021$ ) and “occupied” bipedal-alert (F-PP:  $n = 24$ ,  $r_s = 0.417$ ,  $P = 0.043$ ) postures. Though it may be expected that individuals engaging in active foraging are unable to assume highly vigilant postures, in certain situations (particularly in zoos, where much of the food is comprised of vegetables) the food being consumed by the black-tailed prairie dogs is highly

manipulatable, allowing for individuals to hold it in their forelimbs and eat while in bipedal postures.

Increases in the amount of time individuals spent passively foraging was also associated with increases in the amount of time they spent generally foraging (F-P:  $n = 42$ ,  $r_s = 0.393$ ,  $P = 0.010$ ; Table D.3; F-PP:  $n = 24$ ,  $r_s = 0.412$ ,  $P = 0.045$ ; Table D.5; R-PP:  $n = 18$ ,  $r_s = 0.405$ ,  $P = 0.095$ ; Table D.6), also indicating that passive foraging contributes to total foraging, though the correlations were not universal across all groups, indicating that passive foraging may not play as great a role in general foraging as active foraging. Increases in passive foraging were also associated with increases in the amount of time individuals spent in “occupied” quadrupedal head-up postures (F-P:  $n = 42$ ,  $r_s = 0.625$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.835$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.536$ ,  $P = 0.005$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = -0.739$ ,  $P < 0.001$ ), demonstrating the major contribution of foraging to “occupied” behaviours, particularly head-up postures (where the head may be lifted during foraging to provide brief periods of vigilance at a minimal cost to foraging). Increases in passive foraging were also associated with decreases in the amount of time individuals spent in “unoccupied” quadrupedal head-up (F-P:  $n = 42$ ,  $r_s = -0.363$ ,  $P = 0.018$ ; R-PP:  $n = 18$ ,  $r_s = -0.413$ ,  $P = 0.089$ ) and bipedal-alert postures (R-PP:  $n = 18$ ,  $r_s = -0.461$ ,  $P = 0.054$ ), potentially demonstrating that passive foraging may in some cases be associated with an increase in general foraging (i.e. as an intermediate behaviour from active foraging to pure vigilance) and thus a decline in vigilance, and with decreases in the amount of time individuals devoted to “occupied” bipedal-slouched postures (F-PP:  $n = 24$ ,  $r_s = -0.383$ ,  $P = 0.065$ ), a result which is somewhat unexpected given the extent to which passive foraging

contributed to “occupied” behaviours, but may simply be an artifact of certain environmental or extraneous factors in certain recording sessions, given that the negative correlation was limited to one group.

Increases in the amount of time individuals spent generally foraging were associated with decreases in the amount of time they spent in “unoccupied” quadrupedal head-up (F-P:  $n = 42$ ,  $r_s = -0.883$ ,  $P < 0.001$ ; Table D.3; F-PP:  $n = 24$ ,  $r_s = -0.602$ ,  $P = 0.002$ ; Table D.5; R-P:  $n = 26$ ,  $r_s = -0.955$ ,  $P < 0.001$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = -0.886$ ,  $P < 0.001$ ; Table D.6), bipedal-slouched (F-P:  $n = 42$ ,  $r_s = -0.314$ ,  $P = 0.043$ ; R-PP:  $n = 18$ ,  $r_s = -0.552$ ,  $P = 0.017$ ), and bipedal-alert (F-P:  $n = 42$ ,  $r_s = -0.334$ ,  $P = 0.031$ ; R-P:  $n = 26$ ,  $r_s = -0.388$ ,  $P = 0.050$ ) postures, reflecting the expected foraging-vigilance tradeoff. It was also associated with an increase in the amount of time they spent in “occupied” quadrupedal head-up postures (F-PP:  $n = 24$ ,  $r_s = 0.387$ ,  $P = 0.062$ ), which is somewhat unexpected, but may reflect a relatively greater proportion of time bout initiators spent passive foraging in the F-PP group (which would lead to increases in both the time spent foraging and the time bout initiators spent in “occupied” quadrupedal head-up postures).

Relationships between individual vigilant behaviours, though present, were generally less universal (and in many cases, of lower statistical strength) than expected, and consequently may provide little practical information concerning the behaviour of black-tailed prairie dogs. Increases in the amount of time individuals spent in “occupied” quadrupedal head-up postures were associated with decreases in the amount of time they spent in an “unoccupied” bipedal-alert posture (F-P:  $n = 42$ ,  $r_s = -0.261$ ,  $P = 0.095$ ; R-P:  $n = 26$ ,  $r_s = -0.341$ ,  $P = 0.088$ ), which may reflect an increase in vigilance with a

reduction in even passive foraging (as represented by the inverse relationship between “occupied” and “unoccupied” behaviours), though the evidence for this relationship is sparse. Increases in the amount of time individuals spent in “unoccupied” quadrupedal head-up postures were associated with decreases in the amount of time they spent in an “unoccupied” bipedal-slouched posture (R-P:  $n = 26$ ,  $r_s = 0.368$ ,  $P = 0.064$ ; Table D.4; R-PP:  $n = 18$ ,  $r_s = 0.439$ ,  $P = 0.069$ ; Table D.6), demonstrating the lack of a continuum in vigilant behaviours (i.e. individuals who assume quadrupedal postures did not necessarily progress to bipedal postures – and may have, in some cases, become less vigilant). The observed increases in the amount of time individuals spent in “occupied” bipedal-slouched postures were associated with increases in the amount of time they spent in an “unoccupied” bipedal-slouched posture (F-P:  $n = 42$ ,  $r_s = 0.379$ ,  $P = 0.013$ ; Table D.3) and in “occupied” bipedal-alert postures (F-PP:  $n = 24$ ,  $r_s = 0.352$ ,  $P = 0.091$ ; Table D.5) did provide some evidence that individuals exhibited a progression in behaviour as their vigilance increased. Increases in the amount of time they spent in an “unoccupied” bipedal-slouched posture were associated, however, with decreases in the amount of time they spent in an “unoccupied” bipedal-alert posture (F-PP:  $n = 24$ ,  $r_s = -0.480$ ,  $P = 0.018$ ), while increases the amount of time they spent in “occupied” bipedal-alert postures were associated with both increases in (R-P:  $n = 26$ ,  $r_s = 0.663$ ,  $P < 0.001$ ) and decreases in (R-PP:  $n = 18$ ,  $r_s = -0.503$ ,  $P = 0.033$ ) the amount of time they spent in an “unoccupied” bipedal-alert posture, demonstrating that a linear progression in increasing vigilance was far from consistent for all individuals in all situations, and may require further study.

**APPENDIX E: Autocorrelations of the social variables present at the time of the subject jump-yip bout and their relationships to the characteristics of the bout**

Increases in the aboveground population size present at the time of the recording sessions were associated with increases in the response latency of the subject bout (F-I:  $n = 15$ ,  $r_s = 0.512$ ,  $P = 0.051$ ; Table E.1), but only for the one data group indicated, a result which opposes the expected decrease in response latency with increasing population size, if greater population size provided more respondents (and thus a reduction in the time it would take for the first individual to respond). Similarly, increases in aboveground population size were also associated with increases in the response latency of the pre-subject bouts observed in some “respondent” groups (R-I:  $n = 21$ ,  $r_s = 0.384$ ,  $P = 0.078$ ; Table E.4; R-PP:  $n = 17$ ,  $r_s = 0.457$ ,  $P = 0.042$ ; Table E.6). In bout initiator groups, however, increases in aboveground population size were associated with increases in the number of responses in (F-PP:  $n = 19$ ,  $r_s = 0.390$ ,  $P = 0.099$ ; Table E.9) and the duration of (F-PP:  $n = 19$ ,  $r_s = 0.390$ ,  $P = 0.099$ ) the pre-subject jump-yip bouts, as well as with increases in the number of post-subject jump-yip bouts (F-PP:  $n = 24$ ,  $r_s = 0.388$ ,  $P = 0.061$ ) and jump-yips (F-PP:  $n = 24$ ,  $r_s = 0.513$ ,  $P = 0.010$ ), though the correlations were not universal across all groups. These correlations may demonstrate that an increase in population size provided more potential respondents (or jump-yipping individuals in general) and therefore more vigilant individuals – a finding consistent with previously observed group-size effects. Increases in aboveground population size were also associated with increases in the number of post-subject bouts in certain “respondent” groups (R-I:  $n = 22$ ,  $r_s = 0.391$ ,  $P = 0.080$ ; Table E.10), though none of the correlations were consistent throughout all groups. There was no observed variation in the

Table E.1: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).

	Aboveground population size
Number of responses	0.126
Number of respondents†	0.199
Duration of bout	0.117
Response latency‡	<b>0.512*</b>

† n = 24

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.2: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).

	Aboveground population size
Number of responses	0.092
Number of respondents†	0.035
Duration of bout	0.033
Response latency‡	0.032

† n = 35

‡ n = 29

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.3: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).

	Aboveground population size
Number of responses	0.290
Number of respondents†	0.387
Duration of bout	0.237
Response latency‡	0.236

† n = 19

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.4: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).

	Aboveground population size
Number of post-subject responses	-0.068
Number of post-subject respondents†	0.189
Duration of post-subject subsection	-0.084
Response latency of subject‡	0.178
Response latency of first post-subject call	-0.260
Total number of responses	-0.032
Duration of entire bout	-0.115
Response latency of entire bout	0.199

† n = 14

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.5: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials where the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).

	Aboveground population size
Number of post-subject responses	0.075
Number of post-subject respondents†	0.191
Duration of post-subject subsection	0.069
Response latency of subject‡	0.183
Response latency of first post-subject call	-0.161
Total number of responses	0.054
Duration of entire bout	-0.077
Response latency of entire bout	0.071

† n = 15

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.6: Correlation of the aboveground population size at the time of a jump-yip bout and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).

	Aboveground population size
Number of post-subject responses	-0.105
Number of post-subject respondents†	-0.077
Duration of post-subject subsection	-0.122
Response latency of subject‡	0.354
Response latency of first post-subject call	-0.323
Total number of responses	-0.044
Duration of entire bout	-0.079
Response latency of entire bout	0.247

† n = 10

‡ n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.7: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	Aboveground population size
T2VOC	-0.055
PREBOUT	0.006
PREJY	-0.031
PRERESP†	-0.017
PREDUR†	-0.032
PRELAT†	-0.154
PRECHIRP	-0.077
PREAC	-0.105
POSTBOUT	0.166
POSTJY	0.185
POSTRESP‡	-0.241
POSTDUR‡	-0.305
POSTLAT‡	-0.391
POSTCHIRP	-0.095
POSTAC	0.081

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20

‡ n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.8: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	Aboveground population size
T2VOC	-0.065
PREBOUT	-0.088
PREJY	-0.073
PRERESP†	-0.054
PREDUR†	-0.102
PRELAT†	-0.105
PRECHIRP	-0.126
PREAC	-0.149
POSTBOUT	0.096
POSTJY	0.183
POSTRESP‡	0.052
POSTDUR‡	0.139
POSTLAT‡	-0.025
POSTCHIRP	0.131
POSTAC	-0.140

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 33

‡ n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.9: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).<sup>^</sup>

	Aboveground population size
T2VOC	-0.304
PREBOUT	0.083
PREJY	0.185
PRERESP <sup>†</sup>	<b>0.390*</b>
PREDUR <sup>†</sup>	<b>0.390*</b>
PRELAT <sup>†</sup>	0.241
PRECHIRP	-0.110
PREAC	-0.027
POSTBOUT	<b>0.388*</b>
POSTJY	<b>0.513**</b>
POSTRESP <sup>‡</sup>	0.212
POSTDUR <sup>‡</sup>	0.300
POSTLAT <sup>‡</sup>	0.099
POSTCHIRP	0.059
POSTAC	-0.088

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19

<sup>‡</sup> n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.10: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).<sup>^</sup>

	Aboveground population size
T2VOC	-0.326
PREBOUT	-0.060
PREJY	-0.031
PRERESP†	-0.048
PREDUR†	-0.027
PRELAT†	<b>0.384*</b>
PRECHIRP	<b>-0.531**</b>
PREAC	-0.011
POSTBOUT	<b>0.391*</b>
POSTJY	0.127
POSTRESP‡	-0.046
POSTDUR‡	-0.126
POSTLAT‡	-0.085
POSTCHIRP	0.011
POSTAC	<b>0.452**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 21

‡ n = 20

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

characteristics of the environmental jump-yip bouts in any of the “respondent” groups with changes in aboveground population size, which indicates that over longer periods of time (rather than just for the solitary subject jump-yip bout), population size does not directly influence the characteristics of jump-yip bouts.

Increases in aboveground population size were associated with decreases in the number of pre-subject chirps in all three “respondent” groups (R-I:  $n = 22$ ,  $r_s = -0.531$ ,  $P = 0.011$ ; Table E.10; R-P:  $n = 26$ ,  $r_s = -0.504$ ,  $P = 0.009$ ; Table E.11; R-PP:  $n = 18$ ,  $r_s = -0.570$ ,  $P = 0.013$ ; Table E.12) and with increases in the amount of post-subject alarm calling (R-I:  $n = 22$ ,  $r_s = 0.452$ ,  $P = 0.035$ ; R-PP:  $n = 18$ ,  $r_s = 0.485$ ,  $P = 0.041$ ). The lack of consistent variation in secondary vocalizations with changes in population size likely reflects the nature of the two vocalizations recorded – alarm calls should only occur in the presence of a threatening stimulus, regardless of population size, while chirps are of an unknown function, and thus should not necessarily be expected to vary with population size.

For “bout initiator” groups, when the first post-subject, non-subject vocalization occurred later, the subject jump-yip bout contained fewer responses (F-I:  $n = 26$ ,  $r_s = -0.537$ ,  $P = 0.005$ ; Table E.13; F-P:  $n = 42$ ,  $r_s = -0.486$ ,  $P = 0.001$ ; Table E.14; F-PP:  $n = 24$ ,  $r_s = -0.503$ ,  $P = 0.012$ ; Table E.15) and respondents (F-I:  $n = 24$ ,  $r_s = -0.552$ ,  $P = 0.005$ ; F-P:  $n = 35$ ,  $r_s = -0.509$ ,  $P = 0.002$ ; F-PP:  $n = 19$ ,  $r_s = -0.537$ ,  $P = 0.018$ ) and were of shorter duration (F-I:  $n = 26$ ,  $r_s = -0.585$ ,  $P = 0.002$ ; F-P:  $n = 42$ ,  $r_s = -0.510$ ,  $P = 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.538$ ,  $P = 0.007$ ). And while the characteristics of “respondent” subject bouts did not vary with changes in the timing of the first post-subject, non-subject vocalization (Tables E.16, E.17, E.18), the negative correlations

Table E.11: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	Aboveground population size
T2VOC	-0.197
PREBOUT	-0.114
PREJY	0.002
PRERESP <sup>†</sup>	0.087
PREDUR <sup>†</sup>	0.082
PRELAT <sup>†</sup>	0.284
PRECHIRP	<b>-0.504**</b>
PREAC	0.023
POSTBOUT	0.326
POSTJY	0.128
POSTRESP <sup>‡</sup>	-0.071
POSTDUR <sup>‡</sup>	-0.132
POSTLAT <sup>‡</sup>	0.114
POSTCHIRP	0.085
POSTAC	0.324

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 25

<sup>‡</sup> n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.12: Correlation of the aboveground population size at the time of a jump-yip bout and the social variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).<sup>^</sup>

	Aboveground population size
T2VOC	-0.248
PREBOUT	-0.054
PREJY	0.058
PRERESP†	0.092
PREDUR†	0.074
PRELAT†	<b>0.457*</b>
PRECHIRP	<b>-0.570**</b>
PREAC	0.078
POSTBOUT	0.322
POSTJY	0.109
POSTRESP‡	-0.048
POSTDUR‡	-0.123
POSTLAT‡	-0.080
POSTCHIRP	0.003
POSTAC	<b>0.485**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

‡ n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.13: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of bout initiators was analyzed (n = 26).

	Time of first post-subject, non-subject vocalization
Number of responses	<b>-0.537**</b>
Number of respondents†	<b>-0.552**</b>
Duration of bout	<b>-0.585**</b>
Response latency‡	-0.430

† n = 24

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.14: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the behaviour of bout initiators over one minute following jump-yip production was analyzed (n = 42).

	Time of first post-subject, non-subject vocalization
Number of responses	<b>-0.486**</b>
Number of respondents†	<b>-0.509**</b>
Duration of bout	<b>-0.510**</b>
Response latency‡	-0.204

† n = 35

‡ n = 29

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.15: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of bout initiators were analyzed (n = 24).

	Time of first post-subject, non-subject vocalization
Number of responses	<b>-0.503**</b>
Number of respondents†	<b>-0.537**</b>
Duration of bout	<b>-0.538**</b>
Response latency‡	-0.288

† n = 19

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.16: Correlation of the time at which the first post-subject, non-subject vocalization occurred and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).

	Time of first post-subject, non-subject vocalization
Number of post-subject responses	0.251
Number of post-subject respondents†	-0.203
Duration of post-subject subsection	0.185
Response latency of subject‡	-0.041
Response latency of first post-subject call	0.288
Total number of responses	-0.110
Duration of entire bout	-0.146
Response latency of entire bout	-0.014

† n = 14

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.17: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of a respondent in the subject bout over one minute following jump-yip production was analyzed (n = 26).

	Time of first post-subject, non-subject vocalization
Number of post-subject responses	0.212
Number of post-subject respondents†	-0.276
Duration of post-subject subsection	0.175
Response latency of subject‡	0.034
Response latency of first post-subject call	0.277
Total number of responses	-0.121
Duration of entire bout	-0.128
Response latency of entire bout	0.160

† n = 15

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.18: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of a respondent in the subject bout between the minute preceding and the minute following jump-yip production were analyzed (n = 18).

	Time of first post-subject, non-subject vocalization
Number of post-subject responses	0.338
Number of post-subject respondents†	-0.077
Duration of post-subject subsection	0.239
Response latency of subject‡	-0.210
Response latency of first post-subject call	0.087
Total number of responses	-0.129
Duration of entire bout	-0.286
Response latency of entire bout	-0.247

† n = 10

‡ n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

for bout initiator subject bouts may demonstrate that the frequency of jump-yipping (or even general calling) in an environment is consistent for single bouts and over longer periods of time.

Indeed, when the first post-subject, non-subject vocalization occurred later following “bout initiator” subject bouts, there were fewer jump-yip bouts (F-I:  $n = 26$ ,  $r_s = -0.702$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = -0.597$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.571$ ,  $P = 0.004$ ) and total jump-yips (F-I:  $n = 26$ ,  $r_s = -0.694$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = -0.563$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.513$ ,  $P = 0.010$ ) in the minute preceding the subject bout, with the bouts also having shorter response latencies (F-I:  $n = 20$ ,  $r_s = -0.570$ ,  $P = 0.009$ ; Table E.19; F-P:  $n = 33$ ,  $r_s = -0.476$ ,  $P = 0.005$ ; Table E.20; F-PP:  $n = 19$ ,  $r_s = -0.450$ ,  $P = 0.053$ ; Table E.21) in all three “bout initiator” groups. It was also associated with decreases in the number of jump-yip bouts (F-I:  $n = 26$ ,  $r_s = -0.728$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = -0.628$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.631$ ,  $P = 0.001$ ) and total jump-yips (F-I:  $n = 26$ ,  $r_s = -0.679$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = -0.557$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.537$ ,  $P = 0.007$ ) in the minute following the subject bout. These (expected) results indicate that the frequency of jump-yipping in an environment is consistent with respect to both the amount of jump-yipping and in the timing of the displays. In addition, when the first post-subject, non-subject occurred later, pre-subject jump-yip bouts contained fewer responses ( $n = 33$ ,  $r_s = -0.322$ ,  $P = 0.068$ ) and were of a longer duration ( $n = 33$ ,  $r_s = -0.446$ ,  $P = 0.009$ ), but only for those bouts used in the examination of bout initiator behaviour over the minute following jump-yip production. Similarly, though only a single result was observed for “respondent” subject

Table E.19: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of bout initiators was analyzed (n = 26).<sup>^</sup>

	Time of first post-subject, non-subject vocalization
PREBOUT	<b>-0.702**</b>
PREJY	<b>-0.694**</b>
PRERESP <sup>†</sup>	-0.253
PREDUR <sup>†</sup>	-0.343
PRELAT <sup>†</sup>	<b>-0.570**</b>
PRECHIRP	-0.254
PREAC	-0.260
POSTBOUT	<b>-0.728**</b>
POSTJY	<b>-0.679**</b>
POSTRESP <sup>‡</sup>	-0.068
POSTDUR <sup>‡</sup>	-0.111
POSTLAT <sup>‡</sup>	-0.247
POSTCHIRP	<b>-0.418**</b>
POSTAC	-0.101

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 20

<sup>‡</sup> n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.20: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of bout initiators over one minute following jump-yip production was analyzed ( $n = 42$ ).<sup>^</sup>

	Time of first post-subject, non-subject vocalization
PREBOUT	<b>-0.597**</b>
PREJY	<b>-0.563**</b>
PRERESP <sup>†</sup>	<b>-0.322*</b>
PREDUR <sup>†</sup>	<b>-0.446**</b>
PRELAT <sup>†</sup>	<b>-0.476**</b>
PRECHIRP	-0.148
PREAC	<b>-0.283*</b>
POSTBOUT	<b>-0.628**</b>
POSTJY	<b>-0.557**</b>
POSTRESP <sup>‡</sup>	0.050
POSTDUR <sup>‡</sup>	-0.012
POSTLAT <sup>‡</sup>	-0.058
POSTCHIRP	<b>-0.396**</b>
POSTAC	-0.240

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup>  $n = 33$

<sup>‡</sup>  $n = 33$

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.21: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of bout initiators between the minute preceding and the minute following jump-yip production were analyzed (n = 24).

	Time of first post-subject, non-subject vocalization
PREBOUT	<b>-0.571**</b>
PREJY	<b>-0.513**</b>
PRERESP†	-0.080
PREDUR†	-0.251
PRELAT†	<b>-0.450*</b>
PRECHIRP	-0.253
PREAC	-0.117
POSTBOUT	<b>-0.631**</b>
POSTJY	<b>-0.537**</b>
POSTRESP‡	0.098
POSTDUR‡	0.025
POSTLAT‡	-0.114
POSTCHIRP	<b>-0.526**</b>
POSTAC	-0.015

^ See Appendix A for abbreviations and definitions

† n = 19

‡ n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

bouts, with fewer post-subject jump-yip bouts (R-I:  $n = 22$ ,  $r_s = -0.604$ ,  $P = 0.004$ ; Table E.22; R-P:  $n = 26$ ,  $r_s = -0.686$ ,  $P < 0.001$ ; Table E.23; R-PP:  $n = 18$ ,  $r_s = -0.618$ ,  $P = 0.006$ ; Table E.24) the first post-subject, non-subject vocalization occurred later following the subject bout.

When the first post-subject, non-subject vocalization occurred later, there were also fewer post-subject chirps (F-I:  $n = 26$ ,  $r_s = -0.418$ ,  $P = 0.034$ ; Table E.19; F-P:  $n = 42$ ,  $r_s = -0.396$ ,  $P = 0.010$ ; Table E.20; F-PP:  $n = 24$ ,  $r_s = -0.526$ ,  $P = 0.008$ ; Table E.21), though only for “bout initiator” groups, and with less pre-subject (F-P:  $n = 42$ ,  $r_s = -0.283$ ,  $P = 0.070$ ) and post-subject (R-P:  $n = 26$ ,  $r_s = -0.420$ ,  $P = 0.033$ ) alarm calling, though only in select “bout initiator” and “respondent” groups. These results are consistent with the expectation that a reduction in general vocal activity in the environment is associated with less frequent calling (and thus a later first post-subject, non-subject vocalization).

As secondary vocalization, chirps and alarm calls represented unique stimuli to behavioural changes. Chirps are an unknown vocalization, which may be alarm-type vocalizations or even underdeveloped/incomplete jump-yips. Consequently, their effects on black-tailed prairie dog behaviour may be unusual or unexpected. Alarm calling occurs only in the presence of nearby threats, but could be associated with increases in general vocal activity, or if jump-yips are associated with a cessation of a threat, potential increases in the amount of jump-yipping (if threats leave the environment during a recordings session). In all three “bout initiator” data groups, increases in the number of chirps in the minute following the subject bouts were associated with increases in the number of responses (F-I:  $n = 26$ ,  $r_s = 0.519$ ,  $P = 0.007$ ; Table E.25; F-P:  $n = 42$ ,

Table E.22: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).<sup>^</sup>

	Time of first post-subject, non-subject vocalization
PREBOUT	0.014
PREJY	-0.095
PRERESP <sup>†</sup>	-0.048
PREDUR <sup>†</sup>	-0.010
PRELAT <sup>†</sup>	0.053
PRECHIRP	-0.070
PREAC	-0.212
POSTBOUT	<b>-0.604**</b>
POSTJY	-0.076
POSTRESP <sup>‡</sup>	0.089
POSTDUR <sup>‡</sup>	0.169
POSTLAT <sup>‡</sup>	0.161
POSTCHIRP	-0.001
POSTAC	-0.336

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 21

<sup>‡</sup> n = 20

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.23: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the behaviour of a respondent in the subject bout over one minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	Time of first post-subject, non-subject vocalization
PREBOUT	-0.166
PREJY	-0.157
PRERESP <sup>†</sup>	-0.057
PREDUR <sup>†</sup>	-0.036
PRELAT <sup>†</sup>	-0.141
PRECHIRP	-0.101
PREAC	-0.238
POSTBOUT	<b>-0.686**</b>
POSTJY	-0.302
POSTRESP <sup>‡</sup>	0.097
POSTDUR <sup>‡</sup>	0.112
POSTLAT <sup>‡</sup>	0.266
POSTCHIRP	0.064
POSTAC	<b>-0.420**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 25

<sup>‡</sup> n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.24: Correlation of the time at which the first post-subject, non-subject vocalization occurs and the response characteristics of the subject jump-yip bout for trials in which the changes in the behaviour of a respondent in the subject bout between the minute preceding and the minute following jump-yip production were analyzed (n = 18).<sup>^</sup>

	Time of first post-subject, non-subject vocalization
PREBOUT	0.138
PREJY	-0.114
PRERESP <sup>†</sup>	-0.092
PREDUR <sup>†</sup>	-0.074
PRELAT <sup>†</sup>	-0.037
PRECHIRP	-0.112
PREAC	-0.217
POSTBOUT	<b>-0.618**</b>
POSTJY	-0.234
POSTRESP <sup>‡</sup>	0.042
POSTDUR <sup>‡</sup>	0.188
POSTLAT <sup>‡</sup>	0.116
POSTCHIRP	-0.030
POSTAC	-0.322

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17

<sup>‡</sup> n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.25: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual in which its immediate post-jump-yip behaviour was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
RESPS	<b>0.540**</b>	<b>0.540**</b>	0.188	0.161	-0.035	0.030	-0.033
RPDTS <sup>‡</sup>	<b>0.538**</b>	<b>0.556**</b>	0.313	0.276	0.175	0.081	-0.105
DUR	<b>0.556**</b>	<b>0.501**</b>	0.107	0.063	-0.002	0.060	0.033
LAT <sup>#</sup>	-0.071	-0.014	-0.044	0.109	0.193	-0.341	0.009

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 20, except RPDTS (n = 18) AND LAT (n = 12)

<sup>‡</sup> n = 24, except PRERESP, PREDUR, and PRELAT (n = 18)

<sup>#</sup> n = 15, except PRERESP, PREDUR, and PRELAT (n = 12)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.25: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
RESPS	<b>0.562**</b>	<b>0.543**</b>	0.279	0.140	0.289	<b>0.519**</b>	-0.168
RPDTS <sup>‡</sup>	<b>0.649**</b>	<b>0.598**</b>	0.251	0.084	0.146	<b>0.493**</b>	-0.163
DUR	<b>0.519**</b>	<b>0.478**</b>	0.123	-0.001	0.174	<b>0.466**</b>	-0.190
LAT <sup>#</sup>	0.011	0.014	-0.058	-0.176	-0.251	0.040	0.124

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 20 except RPDTS (n = 15) and LAT (n = 13)

<sup>‡</sup> n = 24, except POSTRESP, POSTDUR, and POSTLAT (n = 15)

<sup>#</sup> n = 15, except POSTRESP, POSTDUR, and POSTLAT (n = 13)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

$r_s = 0.393$ ,  $P = 0.010$ ; Table E.26; F-PP:  $n = 24$ ,  $r_s = 0.526$ ,  $P = 0.008$ ; Table E.27) and respondents (F-I:  $n = 24$ ,  $r_s = 0.493$ ,  $P = 0.014$ ; F-P:  $n = 35$ ,  $r_s = 0.472$ ,  $P = 0.004$ ; F-PP:  $n = 19$ ,  $r_s = 0.598$ ,  $P = 0.007$ ) in and the duration of (F-I:  $n = 26$ ,  $r_s = 0.466$ ,  $P = 0.017$ ; F-P:  $n = 42$ ,  $r_s = 0.292$ ,  $P = 0.061$ ; F-PP:  $n = 24$ ,  $r_s = 0.394$ ,  $P = 0.057$ ) the subject bout, which could indicate a general increase in vocal activity, or could point to the majority of chirps being forms of jump-yips. Increases in the number of post-subject chirps were, however, only associated with an increase in the response latency of the subject-initiated section of the subject bout, and then only in one “respondent” group (R-P:  $n = 26$ ,  $r_s = 0.557$ ,  $P = 0.016$ ; Table E.29) – a result which opposes the expected decrease in response latency with increases in vocal activity in the environment, particularly if chirps are a form of jump-yip.

Increases in the number of chirps in the minute preceding the subject bouts in “bout initiator” groups were associated with increases in the amount of pre-subject alarm calling (F-I:  $n = 20$ ,  $r_s = 0.495$ ,  $P = 0.010$ ; Table E.31; F-PP:  $n = 24$ ,  $r_s = 0.458$ ,  $P = 0.024$ ; Table E.33) as well as with increases in the number of chirps (F-I:  $n = 26$ ,  $r_s = 0.347$ ,  $P = 0.083$ ; E.43; F-P:  $n = 42$ ,  $r_s = 0.271$ ,  $P = 0.083$ ; Table E.44) and the amount of alarm calling (F-I:  $n = 26$ ,  $r_s = 0.381$ ,  $P = 0.055$ ; F-PP:  $n = 24$ ,  $r_s = 0.379$ ,  $P = 0.068$ ; Table E.45) in the minute following the “bout initiator” subject bouts. Changes in the amount of chirps in the environment were not associated, however, with changes in the social environment present in the minute preceding and the minute following the subject bouts in all the “respondent” groups (Tables E.34, E.35, E.36, E.40, E.41, E.42, E.46, E.47, E.48). The irregular associations between the chirps in the environment and alarm calling and jump-yipping further indicate that chirps must be



Table E.26: The relationships between vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual in which its behaviour over one minute was analyzed (n = 42).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
RESPS	<b>0.375**</b>	<b>0.484**</b>	<b>0.446**</b>	<b>0.375**</b>	0.086	-0.019	0.160
RPDTS <sup>‡</sup>	<b>0.309*</b>	<b>0.381**</b>	<b>0.476**</b>	<b>0.408**</b>	0.141	0.057	-0.014
DUR	<b>0.451**</b>	<b>0.526**</b>	<b>0.380**</b>	<b>0.310*</b>	0.060	0.014	0.190
LAT <sup>#</sup>	0.119	0.123	0.047	0.144	<b>0.408*</b>	-0.260	0.106

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 33, except RPDTS (n = 26) AND LAT (n = 22)

<sup>‡</sup> n = 35, except PRERESP, PREDUR, and PRELAT (n = 26)

<sup>#</sup> n = 29, except PRERESP, PREDUR, and PRELAT (n = 22)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.26: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
RESPS	<b>0.465**</b>	<b>0.461**</b>	0.142	0.211	0.239	<b>0.393**</b>	0.045
RPDTS <sup>‡</sup>	<b>0.487**</b>	<b>0.410**</b>	-0.023	0.016	0.074	<b>0.472**</b>	-0.082
DUR	<b>0.467**</b>	<b>0.452**</b>	0.098	0.107	0.127	<b>0.292*</b>	0.073
LAT#	0.051	0.063	0.140	-0.105	-0.192	-0.230	0.240

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 33, except RPDTS (n = 26) AND LAT (n = 25)

<sup>‡</sup> n = 35, except PRERESP, PREDUR, and PRELAT (n = 26)

# n = 29, except POSTRESP, POSTDUR, and POSTLAT (n = 25)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.27: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout initiated by that individual for trials in which the post-jump-yip changes in its behaviour were analyzed (n = 24).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
RESPS	0.296	<b>0.441**</b>	0.360	0.279	0.028	-0.055	-0.034
RPDTS <sup>‡</sup>	0.346	<b>0.431*</b>	0.422	0.393	0.265	0.032	-0.343
DUR	<b>0.423**</b>	<b>0.469**</b>	0.196	0.142	0.000	-0.011	0.001
LAT <sup>#</sup>	-0.045	0.002	0.095	0.253	0.319	-0.328	-0.056

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19, except RPDTS and LAT (n = 14)

<sup>‡</sup> n = 19, except PRERESP, PREDUR, and PRELAT (n = 14)

<sup>#</sup> n = 18, except PRERESP, PREDUR, and PRELAT (n = 14)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.27: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
RESPS	<b>0.494**</b>	<b>0.552**</b>	0.379	0.377	0.387	<b>0.526**</b>	-0.279
RPDTS <sup>‡</sup>	<b>0.597**</b>	<b>0.581**</b>	0.345	0.316	0.255	<b>0.598**</b>	<b>-0.420*</b>
DUR	<b>0.512**</b>	<b>0.518**</b>	0.157	0.054	0.036	<b>0.394*</b>	-0.284
LAT <sup>#</sup>	-0.043	-0.116	-0.190	-0.270	-0.362	0.039	0.070

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17, except RPDTS (n = 12) and LAT (n = 15)

<sup>‡</sup> n = 19, except PRERESP, PREDUR, and PRELAT (n = 12)

<sup>#</sup> n = 18, except PRERESP, PREDUR, and PRELAT (n = 15)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.28: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent in trials where its immediate post-jump-yip behaviour was analyzed (n = 22).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
SUBRESP	<b>0.384*</b>	0.284	0.202	0.203	0.269	0.022	-0.112
SUBRPDT <sup>‡</sup>	0.093	-0.077	0.036	-0.086	-0.071	-0.103	-0.079
SUBDUR	<b>0.379*</b>	0.323	0.236	0.252	0.261	0.089	-0.144
OWNLAT	-0.021	-0.215	-0.214	-0.167	0.039	-0.268	0.136
SUBLAT <sup>#</sup>	-0.151	0.234	0.214	0.315	0.313	0.054	-0.036
TOTRESP	0.038	<b>0.777**</b>	<b>0.731**</b>	<b>0.757**</b>	<b>0.377*</b>	0.060	-0.324
TOTDUR	0.019	<b>0.746**</b>	<b>0.702**</b>	<b>0.755**</b>	<b>0.366*</b>	0.027	-0.262
INITLAT	-0.019	-0.248	-0.255	-0.216	0.291	-0.347	-0.154

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 21, except SUBRPDT (n = 13) and SUBLAT (n = 15)

<sup>‡</sup> n = 14, except PRERESP, PREDUR, and PRELAT (n = 13)

<sup>#</sup> n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.28: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP <sup>†</sup>	POSTDUR <sup>†</sup>	POSTLAT <sup>†</sup>	POSTCHIRP	POSTAC
SUBRESP	-0.269	0.296	<b>0.424*</b>	<b>0.479**</b>	0.344	0.156	0.039
SUBRPDT <sup>‡</sup>	0.112	-0.232	-0.330	-0.373	-0.298	0.149	0.078
SUBDUR	-0.243	0.323	<b>0.450**</b>	<b>0.506**</b>	0.317	0.196	0.001
OWNLAT	-0.140	0.040	0.053	-0.076	-0.335	0.020	0.018
SUBLAT <sup>#</sup>	-0.047	0.220	0.134	0.071	0.068	0.430	<b>-0.446*</b>
TOTRESP	-0.111	<b>0.558**</b>	<b>0.626**</b>	<b>0.694**</b>	0.313	0.219	0.109
TOTDUR	-0.158	<b>0.595**</b>	<b>0.666**</b>	<b>0.684**</b>	0.303	0.168	0.146
INITLAT	-0.188	-0.132	-0.073	-0.157	-0.302	-0.168	-0.228

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 20, except SUBRPDT (n = 12) and SUBLAT (n = 15)

<sup>‡</sup> n = 13, except PRERESP, PREDUR, and PRELAT (n = 12)

<sup>#</sup> n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.29: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent in trials where its behaviour over one minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
SUBRESP	0.269	<b>0.380*</b>	<b>0.369*</b>	<b>0.364*</b>	0.251	0.010	0.004
SUBRPDT <sup>‡</sup>	0.118	0.028	0.139	0.033	0.041	-0.069	-0.020
SUBDUR	0.240	<b>0.392**</b>	<b>0.390**</b>	<b>0.393**</b>	0.225	0.063	-0.049
OWNLAT	-0.113	-0.107	-0.047	-0.018	0.067	-0.278	0.073
SUBLAT <sup>#</sup>	-0.196	-0.005	0.160	0.192	0.224	0.040	-0.175
TOTRESP	0.032	<b>0.789**</b>	<b>0.769**</b>	<b>0.787**</b>	<b>0.367*</b>	0.046	-0.203
TOTDUR	-0.026	<b>0.739**</b>	<b>0.715**</b>	<b>0.759**</b>	0.314	0.036	-0.217
INITLAT	-0.164	<b>-0.356*</b>	-0.300	-0.287	0.049	-0.299	-0.277

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 25, except SUBRPDT (n = 14) and SUBLAT (n = 18)

<sup>‡</sup> n = 15, except PRERESP, PREDUR, and PRELAT (n = 14)

<sup>#</sup> n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.29: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
SUBRESP	-0.039	<b>0.381*</b>	<b>0.419**</b>	<b>0.455**</b>	<b>0.447**</b>	0.149	0.036
SUBRPDT‡	0.284	0.032	-0.330	-0.373	-0.298	0.170	0.121
SUBDUR	-0.050	<b>0.381*</b>	<b>0.436**</b>	<b>0.462**</b>	<b>0.434**</b>	0.188	-0.020
OWNLAT	-0.253	-0.006	0.141	-0.024	-0.212	0.190	-0.031
SUBLAT#	-0.152	0.082	0.089	-0.017	-0.040	<b>0.557**</b>	-0.391
TOTRESP	0.087	<b>0.624**</b>	<b>0.627**</b>	<b>0.691**</b>	<b>0.357*</b>	0.154	0.106
TOTDUR	-0.034	<b>0.623**</b>	<b>0.682**</b>	<b>0.683**</b>	0.269	0.179	0.080
INITLAT	<b>-0.443**</b>	-0.308	-0.017	-0.106	-0.298	0.035	-0.300

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 23, except SUBRPDT (n = 12) and SUBLAT (n = 18)

‡ n = 15, except POSTRESP, POSTDUR, and POSTLAT (n = 12)

# n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.30: The relationships between the vocalizations experienced by a jump-yipping individual and the response characteristics of the jump-yip bout in which that individual was a respondent and in trials where the post-jump-yip changes in its behaviour were analyzed (n = 18).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
SUBRESP	0.369	0.385	0.345	0.344	0.240	0.071	-0.151
SUBRPDT <sup>‡</sup>	0.118	0.419	0.457	0.494	0.190	0.163	0.203
SUBDUR	0.356	0.348	0.311	0.305	0.201	0.097	-0.216
OWNLAT	-0.018	-0.155	-0.281	-0.159	0.087	-0.339	0.199
SUBLAT <sup>#</sup>	-0.487	0.355	0.428	0.501	-0.009	0.014	-0.323
TOTRESP	-0.174	<b>0.787**</b>	<b>0.806**</b>	<b>0.793**</b>	0.280	0.024	<b>-0.457*</b>
TOTDUR	-0.150	<b>0.745**</b>	<b>0.720**</b>	<b>0.771**</b>	0.259	-0.021	-0.357
INITLAT	-0.026	-0.173	-0.299	-0.203	0.337	-0.392	-0.189

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17, except SUBRPDT (n = 9) and SUBLAT (n = 11)

<sup>‡</sup> n = 10, except PRERESP, PREDUR, and PRELAT (n = 9)

<sup>#</sup> n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.30: Continued<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
SUBRESP	-0.234	0.360	<b>0.438*</b>	<b>0.593**</b>	<b>0.460*</b>	0.179	0.053
SUBRPDT‡	0.078	0.152	0.046	-0.091	0.091	0.509	0.043
SUBDUR	-0.234	0.338	<b>0.432*</b>	<b>0.596**</b>	<b>0.428*</b>	0.128	0.000
OWNLAT	0.005	0.098	0.239	0.079	-0.247	0.021	0.310
SUBLAT#	0.110	0.096	-0.187	-0.228	-0.328	0.465	<b>-0.661**</b>
TOTRESP	-0.020	<b>0.521**</b>	<b>0.522**</b>	<b>0.609**</b>	0.272	0.146	0.122
TOTDUR	-0.017	<b>0.597**</b>	<b>0.606**</b>	<b>0.591**</b>	0.230	0.089	0.207
INITLAT	-0.009	-0.066	0.105	-0.010	-0.262	-0.175	-0.022

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 16, except SUBRPDT (n = 8) and SUBLAT (n = 11)

‡ n = 10, except POSTRESP, POSTDUR, and POSTLAT (n = 8)

# n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.31: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the immediate post jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	<b>0.899**</b>	1.000					
PRERESP†	0.252	<b>0.755**</b>	1.000				
PREDUR†	0.224	<b>0.690**</b>	<b>0.937**</b>	1.000			
PRELAT†	0.110	<b>0.467**</b>	<b>0.741**</b>	<b>0.778**</b>	1.000		
PRECHIRP	<b>0.351*</b>	0.155	-0.203	-0.261	-0.058	1.000	
PREAC	<b>0.390**</b>	0.293	-0.006	-0.083	-0.059	<b>0.495**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.32: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	<b>0.878**</b>	1.000					
PRERESP†	0.278	<b>0.791**</b>	1.000				
PREDUR†	<b>0.353**</b>	<b>0.793**</b>	<b>0.926**</b>	1.000			
PRELAT†	0.242	<b>0.475**</b>	<b>0.648**</b>	<b>0.737**</b>	1.000		
PRECHIRP	<b>0.267*</b>	0.060	-0.241	-0.254	-0.133	1.000	
PREAC	<b>0.509**</b>	<b>0.510**</b>	0.225	0.230	-0.009	0.295	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.33: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	<b>0.855**</b>	1.000					
PRERESP†	0.140	<b>0.724**</b>	1.000				
PREDUR†	0.202	<b>0.742**</b>	<b>0.940**</b>	1.000			
PRELAT†	0.066	<b>0.444*</b>	<b>0.664**</b>	<b>0.716**</b>	1.000		
PRECHIRP	<b>0.353*</b>	0.132	-0.267	-0.313	-0.094	1.000	
PREAC	<b>0.351*</b>	0.336	0.011	-0.003	-0.148	<b>0.458**</b>	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 19

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.34: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	0.078	1.000					
PRERESP†	-0.198	<b>0.923**</b>	1.000				
PREDUR†	-0.035	<b>0.962**</b>	<b>0.941**</b>	1.000			
PRELAT†	<b>0.420*</b>	<b>0.397*</b>	0.216	<b>0.360*</b>	1.000		
PRECHIRP	-0.048	0.005	0.014	-0.009	<b>-0.516**</b>	1.000	
PREAC	0.271	-0.037	-0.090	-0.074	0.092	-0.035	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 21

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.35: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the behaviour of a respondent in the subject bout over the minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	0.106	1.000					
PRERESP†	-0.212	<b>0.899**</b>	1.000				
PREDUR†	-0.074	<b>0.946**</b>	<b>0.957**</b>	1.000			
PRELAT†	<b>0.501**</b>	<b>0.386*</b>	0.199	<b>0.332*</b>	1.000		
PRECHIRP	-0.012	0.022	0.012	-0.006	<b>-0.429**</b>	1.000	
PREAC	0.293	0.097	0.001	0.035	0.145	-0.027	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 25

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.36: Autocorrelations of the characteristics of the vocalizations occurring in the environment before the subject jump-yip for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
PREBOUT	1.000						
PREJY	-0.182	1.000					
PRERESP†	<b>-0.416*</b>	<b>0.930**</b>	1.000				
PREDUR†	-0.317	<b>0.949**</b>	<b>0.955**</b>	1.000			
PRELAT†	0.385	0.327	0.170	0.232	1.000		
PRECHIRP	-0.080	-0.113	-0.043	-0.075	<b>-0.621**</b>	1.000	
PREAC	0.067	-0.206	-0.164	-0.170	-0.035	-0.047	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.37: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	<b>0.962**</b>	1.000					
POSTRESP†	<b>0.417*</b>	<b>0.774**</b>	1.000				
POSTDUR†	<b>0.458*</b>	<b>0.748**</b>	<b>0.916**</b>	1.000			
POSTLAT†	0.364	<b>0.522**</b>	<b>0.681**</b>	<b>0.872**</b>	1.000		
POSTCHIRP	0.167	0.237	0.262	0.120	0.190	1.000	
POSTAC	-0.046	-0.025	-0.049	0.079	0.237	-0.130	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.38: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	<b>0.928**</b>	1.000					
POSTRESP†	<b>0.434**</b>	<b>0.796**</b>	1.000				
POSTDUR†	<b>0.374**</b>	<b>0.713**</b>	<b>0.914**</b>	1.000			
POSTLAT†	0.289	<b>0.464**</b>	<b>0.660**</b>	<b>0.797**</b>	1.000		
POSTCHIRP	0.023	0.080	-0.025	0.084	0.102	1.000	
POSTAC	0.176	0.152	0.021	-0.029	0.149	-0.190	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.39: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	<b>0.912**</b>	1.000					
POSTRESP†	0.158	<b>0.716**</b>	1.000				
POSTDUR†	0.129	<b>0.633**</b>	<b>0.917**</b>	1.000			
POSTLAT†	0.001	0.255	<b>0.565**</b>	<b>0.779**</b>	1.000		
POSTCHIRP	0.097	0.133	0.104	0.139	0.310	1.000	
POSTAC	-0.121	-0.150	-0.141	-0.035	0.158	-0.168	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.40: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	0.244	1.000					
POSTRESP†	-0.086	<b>0.911**</b>	1.000				
POSTDUR†	-0.201	<b>0.800**</b>	<b>0.945**</b>	1.000			
POSTLAT†	-0.221	<b>0.377*</b>	<b>0.553**</b>	<b>0.587**</b>	1.000		
POSTCHIRP	<b>0.387*</b>	0.332	0.161	0.094	-0.261	1.000	
POSTAC	<b>0.503**</b>	<b>0.495**</b>	0.345	0.248	0.145	-0.092	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.41: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the behaviour of a respondent in the bout over the minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	<b>0.449**</b>	1.000					
POSTRESP†	-0.064	<b>0.904**</b>	1.000				
POSTDUR†	-0.159	<b>0.796**</b>	<b>0.932**</b>	1.000			
POSTLAT†	-0.210	0.288	<b>0.471**</b>	<b>0.512**</b>	1.000		
POSTCHIRP	0.196	0.215	0.128	0.020	-0.158	1.000	
POSTAC	<b>0.544**</b>	<b>0.519**</b>	0.302	0.258	0.067	-0.143	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.42: Autocorrelations of the characteristics of the vocalizations occurring in the environment after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18).<sup>^</sup>

	POSTBOUT	POSTJY	POSTRESP†	POSTDUR†	POSTLAT†	POSTCHIRP	POSTAC
POSTBOUT	1.000						
POSTJY	0.311	1.000					
POSTRESP†	-0.188	<b>0.900**</b>	1.000				
POSTDUR†	-0.374	<b>0.746**</b>	<b>0.933**</b>	1.000			
POSTLAT†	<b>-0.510**</b>	0.059	0.289	0.400	1.000		
POSTCHIRP	<b>0.509**</b>	0.338	0.084	-0.028	<b>-0.428*</b>	1.000	
POSTAC	<b>0.417*</b>	<b>0.484**</b>	0.358	0.236	-0.058	-0.095	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.43: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP†	PREDUR†	PRELAT†	PRECHIRP	PREAC
POSTBOUT	<b>0.724**</b>	<b>0.768**</b>	<b>0.472**</b>	<b>0.583**</b>	<b>0.440*</b>	0.119	0.017
POSTJY	<b>0.692**</b>	<b>0.777**</b>	<b>0.545**</b>	<b>0.650**</b>	0.378	0.089	0.093
POSTRESP‡	0.189	<b>0.542**</b>	<b>0.625**</b>	<b>0.631**</b>	0.291	-0.150	0.090
POSTDUR‡	0.110	<b>0.486**</b>	<b>0.654**</b>	<b>0.631**</b>	0.420	0.037	0.114
POSTLAT‡	0.089	0.346	<b>0.475*</b>	<b>0.428*</b>	0.356	0.262	0.152
POSTCHIRP	<b>0.338*</b>	<b>0.344*</b>	0.074	0.087	-0.007	<b>0.347*</b>	0.313
POSTAC	0.082	-0.024	-0.226	-0.242	-0.068	<b>0.381*</b>	0.144

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20, except POSTRESP, POSTDUR, POSTLAT n = 16

‡ n = 17, except PRERESP, PREDUR, PRELAT n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.44: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject

jump-yip bout for trials in which the behaviour of the initial caller in the bout over the minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
POSTBOUT	<b>0.672**</b>	<b>0.754**</b>	<b>0.610**</b>	<b>0.650**</b>	<b>0.437**</b>	0.037	<b>0.309**</b>
POSTJY	<b>0.623**</b>	<b>0.781**</b>	<b>0.689**</b>	<b>0.722**</b>	<b>0.457**</b>	0.000	<b>0.361**</b>
POSTRESP <sup>‡</sup>	0.182	<b>0.513**</b>	<b>0.527**</b>	<b>0.527**</b>	<b>0.360*</b>	-0.188	<b>0.298*</b>
POSTDUR <sup>‡</sup>	0.037	<b>0.393**</b>	<b>0.532**</b>	<b>0.545**</b>	<b>0.355*</b>	-0.120	0.173
POSTLAT <sup>‡</sup>	0.166	<b>0.298*</b>	0.260	0.260	0.107	0.147	0.185
POSTCHIRP	0.000	-0.040	-0.019	0.009	-0.088	<b>0.271*</b>	0.063
POSTAC	<b>0.267*</b>	<b>0.261*</b>	0.086	0.051	0.082	0.154	<b>0.320**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 33, except POSTRESP, POSTDUR, POSTLAT (n = 29)

<sup>‡</sup> n = 33, except PRERESP, PREDUR, PRELAT (n = 29)

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table E.45: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject

jump-yip bout for trials in which the post-jump-yip changes in the behaviour of the initial caller in the bout were analyzed (n = 24).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
POSTBOUT	<b>0.758**</b>	<b>0.820**</b>	<b>0.493**</b>	<b>0.526**</b>	<b>0.416*</b>	0.145	0.030
POSTJY	<b>0.660**</b>	<b>0.822**</b>	<b>0.573**</b>	<b>0.560**</b>	0.318	0.066	0.171
POSTRESP <sup>‡</sup>	-0.058	<b>0.466*</b>	<b>0.544**</b>	<b>0.445*</b>	0.190	-0.244	0.231
POSTDUR <sup>‡</sup>	-0.168	0.353	<b>0.523**</b>	0.407	0.243	-0.075	0.176
POSTLAT <sup>‡</sup>	-0.186	-0.004	0.140	0.039	0.011	0.186	-0.070
POSTCHIRP	0.159	0.145	0.003	0.054	-0.025	0.285	0.217
POSTAC	-0.020	-0.005	0.070	-0.040	0.246	<b>0.379*</b>	0.108

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19, except POSTRESP, POSTDUR, POSTLAT n = 15

<sup>‡</sup> n = 17, except PRERESP, PREDUR, PRELAT n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.46: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the immediate post-jump-yip behaviour of a respondent in the subject bout was analyzed (n = 22).<sup>^</sup>

	PREBOUT	PREJY	PRERESP#	PREDUR#	PRELAT#	PRECHIRP	PREAC
POSTBOUT†	0.101	-0.056	-0.104	-0.061	0.077	-0.011	0.353
POSTJY†	0.251	<b>0.620**</b>	<b>0.447**</b>	<b>0.588**</b>	<b>0.423*</b>	-0.258	0.099
POSTRESP‡	<b>0.371*</b>	<b>0.687**</b>	<b>0.476**</b>	<b>0.611**</b>	<b>0.477**</b>	-0.220	0.001
POSTDUR‡	0.310	<b>0.705**</b>	<b>0.533**</b>	<b>0.625**</b>	<b>0.410*</b>	-0.117	-0.129
POSTLAT‡	0.367	0.293	0.074	0.188	0.247	0.106	-0.054
POSTCHIRP	0.006	0.293	0.259	0.338	0.074	0.224	-0.092
POSTAC	0.068	0.252	0.198	0.202	0.297	-0.341	<b>0.518**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 21, except POSTRESP, POSTDUR, POSTLAT n = 29

‡ n = 20, except PRERESP, PREDUR, PRELAT n = 29

# n = 20, except POSTCHIRP, POSTAC n = 21

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.47: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject

jump-yip bout for trials in which the behaviour of a respondent in the subject bout over the minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
POSTBOUT	0.189	0.197	0.102	0.098	0.201	0.059	<b>0.449**</b>
POSTJY	0.255	<b>0.695**</b>	<b>0.534**</b>	<b>0.622**</b>	<b>0.451**</b>	-0.168	0.217
POSTRESP <sup>‡</sup>	0.301	<b>0.673**</b>	<b>0.481**</b>	<b>0.608**</b>	<b>0.436**</b>	-0.214	0.006
POSTDUR <sup>‡</sup>	<b>0.345*</b>	<b>0.661**</b>	<b>0.473**</b>	<b>0.577**</b>	<b>0.440**</b>	-0.120	-0.120
POSTLAT <sup>‡</sup>	0.213	0.287	0.209	0.275	0.111	0.059	-0.078
POSTCHIRP	-0.123	0.146	0.265	0.279	0.000	0.177	-0.158
POSTAC	0.229	0.226	0.137	0.154	<b>0.371*</b>	-0.294	<b>0.508**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 25, except PRERESP, PREDUR, PRELAT n = 23

<sup>‡</sup> n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table E.48: Correlations of the characteristics of the vocalizations occurring in the environment before and after the subject jump-yip bout for trials in which the post-jump-yip changes in the behaviour of a respondent in the subject bout were analyzed (n = 18).<sup>^</sup>

	PREBOUT	PREJY	PRERESP <sup>†</sup>	PREDUR <sup>†</sup>	PRELAT <sup>†</sup>	PRECHIRP	PREAC
POSTBOUT	-0.025	0.041	0.096	0.036	0.152	0.059	0.375
POSTJY	0.089	<b>0.646**</b>	<b>0.539**</b>	<b>0.587**</b>	0.269	-0.301	0.011
POSTRESP <sup>‡</sup>	0.212	<b>0.649**</b>	<b>0.453*</b>	<b>0.522**</b>	0.303	-0.386	-0.228
POSTDUR <sup>‡</sup>	0.212	<b>0.603**</b>	<b>0.462*</b>	<b>0.471*</b>	0.230	-0.287	-0.324
POSTLAT <sup>‡</sup>	<b>0.464*</b>	0.210	0.075	0.093	0.113	0.059	-0.218
POSTCHIRP	-0.038	0.248	0.243	0.297	0.041	0.193	-0.125
POSTAC	0.048	0.343	0.329	0.300	0.366	-0.377	<b>0.565**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17, except PRERESP, PREDUR, PRELAT n = 16

<sup>‡</sup> n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

studied in greater detail to define their function as well as their associations with other vocalizations in the environment.

Increases in the amount of alarm calling in the minute preceding “bout initiator” subject bouts were not associated with changes in the characteristics of the subject bouts, though increases in the amount of pre-subject alarm calling were associated with decreases in the number of responses in the “respondent” subject bouts, but only for one data group (R-PP:  $n = 18$ ,  $r_s = -0.457$ ,  $P = 0.083$ ; Table E.30). Increases in the amount of post-subject alarm calling were associated with decreases in the number of respondents in “bout initiator” subject bouts (F-PP:  $n = 19$ ,  $r_s = -0.420$ ,  $P = 0.073$ ; Table E.27) and with decreases in the response latency of the subject-initiated sections of “respondent” subject bouts (R-I:  $n = 22$ ,  $r_s = -0.446$ ,  $P = 0.095$ ; Table E.28; R-PP:  $n = 11$ ,  $r_s = -0.661$ ,  $P = 0.027$ ; Table E.30), though in both cases the correlations were not universal. These results suggest that increases in alarm calling in the environment may be associated with decreases in the level of response in jump-yip bouts, and consequently decreases in the vigilance of the social group. Conversely, increases in the amount of alarm calling in the minute preceding “bout initiator” subject bouts were associated with increases in the number of post-subject jump-yip bouts (F-P:  $n = 42$ ,  $r_s = 0.309$ ,  $P = 0.046$ ) and total jump-yips (F-P:  $n = 42$ ,  $r_s = 0.361$ ,  $P = 0.019$ ), as well as with increases in the number of responses in the post-subject bouts (F-P:  $n = 33$ ,  $r_s = 0.298$ ,  $P = 0.092$ ; Table E.44). It was also associated with increases in the number of post-subject jump-yip bouts in one “respondent” group (R-P:  $n = 26$ ,  $r_s = 0.449$ ,  $P = 0.021$ ; Table E.47). In light of these results being limited to relatively few data groups (in both “bout initiator” and “respondent” groups), however, conclusions regarding the association between alarm

calling and jump-yipping in the environment cannot be made. Increases in the amount of pre-subject alarm calling were also associated with increases in the amount of post-subject alarm calling in one “bout initiator” group (F-P:  $n = 22$ ,  $r_s = 0.518$ ,  $P = 0.013$ ; Table E.44) and all three “respondent” groups (R-I:  $n = 42$ ,  $r_s = 0.320$ ,  $P = 0.039$ ; Table E.46; R-P:  $n = 26$ ,  $r_s = 0.508$ ,  $P = 0.008$ ; Table E.47; R-PP:  $n = 18$ ,  $r_s = 0.565$ ,  $P = 0.015$ ; Table E.48) indicating that alarm calling, if present, was relatively constant throughout the recordings sessions. This reflects the methodology of this study, in which recording sessions were stopped if nearby alarm calling began during the session or appeared to alter the behaviour of subject individuals.

While the focus of this study was on the relationship between a single jump-yip bout and the behaviour of participants in the bout, the prevalence of jump-yipping in the environment at any given time may provide extensive information to any receivers in the social group. This may be particularly true if the characteristics of jump-yipping in an environment remain relatively constant, at least over relatively short periods of time. This would allow receivers to repeatedly sample the characteristics of environmental jump-yips to make subsequent behavioural decisions.

Increases in the number of jump-yip bouts occurring in the minute preceding “bout initiator” subject bouts were associated with increases in the number of responses (F-I:  $n = 26$ ,  $r_s = 0.540$ ,  $P = 0.004$ ; F-P:  $n = 42$ ,  $r_s = 0.375$ ,  $P = 0.015$ ) and respondents (F-I:  $n = 24$ ,  $r_s = 0.538$ ,  $P = 0.007$ ; F-P:  $n = 35$ ,  $r_s = 0.309$ ,  $P = 0.071$ ) in and the duration of (F-I:  $n = 26$ ,  $r_s = 0.556$ ,  $P = 0.003$ ; Table E.25; F-P:  $n = 42$ ,  $r_s = 0.451$ ,  $P = 0.003$ ; Table E.26; F-PP:  $n = 24$ ,  $r_s = 0.423$ ,  $P = 0.039$ ; Table E.27) the subject bouts. Likewise, increases in the number of jump-yip bouts occurring in the minute preceding

“respondent” subject bouts were associated with increases in the number of responses in (R-I:  $n = 22$ ,  $r_s = 0.384$ ,  $P = 0.078$ ) and the duration of (R-I:  $n = 22$ ,  $r_s = 0.379$ ,  $P = 0.082$ ; Table E.28) the subject-initiated sections of the subject bouts, though only for select “respondent” data sets. There were no relationships between the number of pre-subject bouts and the characteristics of the entire “respondent” subject bouts.

Increases in the total number of pre-subject jump-yips were associated with increases in the number of responses (F-I:  $n = 26$ ,  $r_s = 0.540$ ,  $P = 0.004$ ; F-P:  $n = 42$ ,  $r_s = 0.484$ ,  $P = 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.441$ ,  $P = 0.031$ ) and respondents in (F-I:  $n = 24$ ,  $r_s = 0.556$ ,  $P = 0.005$ ; F-P:  $n = 42$ ,  $r_s = 0.526$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.431$ ,  $P = 0.066$ ) and the duration of (F-I:  $n = 26$ ,  $r_s = 0.501$ ,  $P = 0.009$ ; Table E.25; F-P:  $n = 35$ ,  $r_s = 0.381$ ,  $P = 0.024$ ; Table E.26; F-PP:  $n = 24$ ,  $r_s = 0.469$ ,  $P = 0.021$ ; Table E.27) the “bout initiator” subject bouts. Likewise, increases in the total number of pre-subject jump-yip bouts were associated with increases in the number of responses in (R-I:  $n = 22$ ,  $r_s = 0.777$ ,  $P < 0.001$ ; R-P:  $n = 26$ ,  $r_s = 0.789$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.787$ ,  $P < 0.001$ ) and the duration of (R-I:  $n = 22$ ,  $r_s = 0.746$ ,  $P < 0.001$ ; Table E.28; R-P:  $n = 26$ ,  $r_s = 0.739$ ,  $P < 0.001$ ; Table E.29; R-PP:  $n = 18$ ,  $r_s = 0.745$ ,  $P < 0.001$ ; Table E.30) the entire “respondent” subject bouts. There were also increases in the number of responses in (R-P:  $n = 26$ ,  $r_s = 0.380$ ,  $P = 0.055$ ) and the duration of (R-P:  $n = 26$ ,  $r_s = 0.392$ ,  $P = 0.048$ ) the subject-initiated sections of the “respondent” jump-yip bouts, and decreases in the response latencies of the entire “respondent” subject bouts (R-P:  $n = 26$ ,  $r_s = -0.356$ ,  $P = 0.074$ ).

The positive correlations between the number of jump-yips and bouts in the environment and the magnitude of response in the subject bouts demonstrate that

increases in the frequency of jump-yipping in the environment preceding a jump-yip bout were associated with increases in the jump-yipping in that bout. In many cases, these correlations were consistent throughout all groups (for both bout initiators and respondents) and were quite strong. Consequently, the information contained in the response characteristics of a single bout and the general characteristics of jump-yipping in the environment was relatively consistent.

Correlations between the characteristics of the pre-subject jump-yip bouts and the characteristics of the “bout initiator” subject bouts were less universal, with increases in the number of responses in the pre-subject bouts associated with increases in the number of responses (F-P:  $n = 33$ ,  $r_s = 0.446$ ,  $P = 0.009$ ) and respondents in (F-P:  $n = 26$ ,  $r_s = 0.476$ ,  $P = 0.014$ ) and the duration of (F-P:  $n = 33$ ,  $r_s = 0.380$ ,  $P = 0.029$ ; Table E.26) “bout initiator” subject bouts, but only in one data group. Likewise, increases in the duration of the pre-subject bouts were associated with increases in the number of responses (F-P:  $n = 42$ ,  $r_s = 0.375$ ,  $P = 0.032$ ) and respondents in (F-P:  $n = 26$ ,  $r_s = 0.408$ ,  $P = 0.038$ ) and the duration of (F-P:  $n = 33$ ,  $r_s = 0.310$ ,  $P = 0.079$ ) “bout initiator” subject bouts, but again only in one data group. Increases in the response latencies of the pre-subject bouts were associated with increases in the response latency of the “bout initiator” subject bouts, but again only in one data group (F-P:  $n = 22$ ,  $r_s = 0.408$ ,  $P = 0.060$ ).

Increases in the number of responses in the pre-subject jump-yip bouts in the “respondent” data groups were associated with increases in the number of responses in (R-I:  $n = 21$ ,  $r_s = 0.731$ ,  $P < 0.001$ ; R-P:  $n = 25$ ,  $r_s = 0.769$ ,  $P < 0.001$ ; R-PP:  $n = 17$ ,  $r_s = 0.806$ ,  $P < 0.001$ ) and the duration of (R-I:  $n = 21$ ,  $r_s = 0.702$ ,  $P < 0.001$ ; Table E.28;



R-P:  $n = 25$ ,  $r_s = 0.715$ ,  $P < 0.001$ ; Table E.29; R-PP:  $n = 17$ ,  $r_s = 0.720$ ,  $P = 0.001$ ; Table E.30) the entire subject bouts for all “respondent” data groups. It was also associated with increases in the number of responses in (R-I:  $n = 25$ ,  $r_s = 0.369$ ,  $P = 0.063$ ) and the duration of (R-I:  $n = 25$ ,  $r_s = 0.390$ ,  $P = 0.049$ ) the subject-initiated section of the “respondent” subject bouts, but only for one data group. Likewise, increases in the duration of the pre-subject jump-yip bouts in the “respondent” data groups were associated with increases in the number of responses in (R-I:  $n = 21$ ,  $r_s = 0.757$ ,  $P < 0.001$ ; R-P:  $n = 25$ ,  $r_s = 0.787$ ,  $P < 0.001$ ; R-PP:  $n = 17$ ,  $r_s = 0.793$ ,  $P < 0.001$ ) and the duration of (R-I:  $n = 21$ ,  $r_s = 0.755$ ,  $P < 0.001$ ; R-P:  $n = 25$ ,  $r_s = 0.759$ ,  $P < 0.001$ ; R-PP:  $n = 17$ ,  $r_s = 0.771$ ,  $P < 0.001$ ) the entire subject bouts for all “respondent” data groups. It was also associated with increases in the number of responses in (R-I:  $n = 25$ ,  $r_s = 0.364$ ,  $P = 0.067$ ) and the duration of (R-I:  $n = 25$ ,  $r_s = 0.393$ ,  $P = 0.047$ ) the subject-initiated section of the “respondent” subject bouts, but again only for one data group. The positive correlations between the magnitude of response in the pre-subject bouts and the characteristics of the subject bouts, coupled with the positive correlations between the frequency of jump-yipping and the magnitude of response in the subject bouts, advance the idea that the information content of jump-yip bouts in the environment are relatively constant, at least over a relatively short period of time.

Increases in the response latencies of the pre-subject bouts were associated with increases in the number of responses in (R-I:  $n = 21$ ,  $r_s = 0.377$ ,  $P = 0.084$ ; Table E.28; R-P:  $n = 25$ ,  $r_s = 0.367$ ,  $P = 0.065$ ; Table E.29) and the duration of (R-I:  $n = 21$ ,  $r_s = 0.366$ ,  $P = 0.093$ ) the entire “respondent” subject bouts, but only for

select data groups. This opposes the expected inverse relationship between the magnitude of response in a jump-yip bout (or multiple jump-yip bouts) and the response latencies of the bout/bouts, and may further point to the potential problems of using response latency as an information-carrying component of a jump-yip bout.

As was the case for jump-yips which occurred in the minute preceding subject jump-yip bouts, increases in the number of jump-yip bouts occurring in the minute following “bout initiator” subject jump-yip bouts were associated with increases in the number of responses (F-I:  $n = 26$ ,  $r_s = 0.562$ ,  $P = 0.003$ ; F-P:  $n = 42$ ,  $r_s = 0.465$ ,  $P = 0.002$ ; F-PP:  $n = 24$ ,  $r_s = 0.494$ ,  $P = 0.014$ ) and respondents in (F-I:  $n = 24$ ,  $r_s = 0.649$ ,  $P = 0.001$ ; F-P:  $n = 35$ ,  $r_s = 0.487$ ,  $P = 0.003$ ; F-PP:  $n = 19$ ,  $r_s = 0.597$ ,  $P = 0.007$ ) and the duration of (F-I:  $n = 26$ ,  $r_s = 0.519$ ,  $P = 0.007$ ; Table E.25; F-P:  $n = 42$ ,  $r_s = 0.467$ ,  $P = 0.002$ ; Table E.26; F-PP:  $n = 24$ ,  $r_s = 0.512$ ,  $P = 0.011$ ; Table E.27) the subject bouts. Increases in the number of post-subject bouts were only associated with decreases in the response latency of the entire “respondent” jump-yip bouts, and then only for one data group (R-P:  $n = 26$ ,  $r_s = -0.443$ ,  $P = 0.023$ ; Table E.29).

Increases in the total number of jump-yips in the minute following “bout initiator” subject bouts were associated with increases in the number of responses (F-I:  $n = 26$ ,  $r_s = 0.543$ ,  $P = 0.004$ ; F-P:  $n = 42$ ,  $r_s = 0.461$ ,  $P = 0.002$ ; F-PP:  $n = 24$ ,  $r_s = 0.552$ ,  $P = 0.005$ ) and respondents in (F-I:  $n = 24$ ,  $r_s = 0.598$ ,  $P = 0.002$ ; F-P:  $n = 35$ ,  $r_s = 0.410$ ,  $P = 0.014$ ; F-PP:  $n = 19$ ,  $r_s = 0.581$ ,  $P = 0.009$ ) and the duration of (F-I:  $n = 26$ ,  $r_s = 0.478$ ,  $P = 0.014$ ; Table E.25; F-P:  $n = 42$ ,  $r_s = 0.452$ ,  $P = 0.452$ ; Table E.26; F-PP:  $n = 24$ ,  $r_s = 0.518$ ,  $P = 0.009$ ; Table E.27) the subject bouts. Increases in the total number of jump-yips in the minute following “respondent” subject bouts were also

associated with increases in number of responses in (R-I:  $n = 22$ ,  $r_s = 0.558$ ,  $P = 0.009$ ; R-P:  $n = 26$ ,  $r_s = 0.624$ ,  $P = 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.521$ ,  $P = 0.027$ ) and the duration of (R-I:  $n = 22$ ,  $r_s = 0.595$ ,  $P = 0.004$ ; Table E.28; R-P:  $n = 26$ ,  $r_s = 0.623$ ,  $P = 0.001$ ; Table E.29; R-PP:  $n = 18$ ,  $r_s = 0.597$ ,  $P = 0.009$ ; Table E.30) the entire subject bouts, and with increases in the number of responses in (R-I:  $n = 26$ ,  $r_s = 0.381$ ,  $P = 0.055$ ) and the duration of (R-I:  $n = 26$ ,  $r_s = 0.381$ ,  $P = 0.055$ ) the subject-initiated section of the subject bout, but only for one data set. These results were relatively consistent with the correlations observed between the characteristics of the subject bouts and the frequency of pre-subject jump-yipping, and may further demonstrate the similarities in jump-yip characteristics over a short period of time.

Interestingly, in “bout initiator” data groups, changes in the characteristics of the post-subject jump-yip bouts were not associated with changes in the characteristics of the subject bouts themselves. This result is somewhat unexpected, but may reflect unobserved and/or unrecorded environmental factors which affected the vigilance behaviours of individuals in the environment. Increases in the number of responses in post-subject jump-yip bouts were, however, associated with increases in the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.424$ ,  $P = 0.055$ ; R-P:  $n = 23$ ,  $r_s = 0.419$ ,  $P = 0.042$ ; R-PP:  $n = 16$ ,  $r_s = 0.438$ ,  $P = 0.078$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.450$ ,  $P = 0.041$ ; R-P:  $n = 23$ ,  $r_s = 0.436$ ,  $P = 0.033$ ; R-PP:  $n = 16$ ,  $r_s = 0.432$ ,  $P = 0.083$ ) the subject-initiated sections of the “respondent” subject bouts, and the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.626$ ,  $P = 0.002$ ; R-P:  $n = 23$ ,  $r_s = 0.627$ ,  $P = 0.001$ ; R-PP:  $n = 16$ ,  $r_s = 0.522$ ,  $P = 0.032$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.666$ ,  $P = 0.001$ ; Table E.28; R-P:  $n = 23$ ,  $r_s = 0.682$ ,  $P < 0.001$ ; Table E.29; R-PP:  $n = 16$ ,

$r_s = 0.606$ ,  $P = 0.010$ ; Table E.30) the entire “respondent” subject jump-yip bouts in all three data groups. Similarly, increases in the duration of the post-subject bouts were associated with increases in the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.479$ ,  $P = 0.028$ ; R-P:  $n = 23$ ,  $r_s = 0.455$ ,  $P = 0.026$ ; R-PP:  $n = 16$ ,  $r_s = 0.593$ ,  $P = 0.012$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.506$ ,  $P = 0.019$ ; R-P:  $n = 23$ ,  $r_s = 0.462$ ,  $P = 0.023$ ; R-PP:  $n = 16$ ,  $r_s = 0.596$ ,  $P = 0.012$ ) the subject-initiated sections of the “respondent” subject bouts, and the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.694$ ,  $P < 0.001$ ; R-P:  $n = 23$ ,  $r_s = 0.691$ ,  $P < 0.001$ ; R-PP:  $n = 16$ ,  $r_s = 0.609$ ,  $P = 0.009$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.684$ ,  $P = 0.001$ ; Table E.28; R-P:  $n = 23$ ,  $r_s = 0.683$ ,  $P < 0.001$ ; Table E.29; R-PP:  $n = 16$ ,  $r_s = 0.591$ ,  $P = 0.013$ ; Table E.30) the entire “respondent” subject jump-yip bouts in all three data groups. These results are consistent with the correlations between the characteristics of the subject bouts and the characteristics of the pre-subject environmental jump-yips, and may again reflect general similarities in the characteristics of jump-yips occurring in an environment. It may also serve to indicate that the unexpected results (i.e. lack of correlations) in the “bout initiator” groups are more reflective of extraneous factors rather than any variation in the environmental jump-yips.

Increases in the response latencies of the post-subject bouts were also associated with increases in the number of responses in (R-P:  $n = 23$ ,  $r_s = 0.447$ ,  $P = 0.029$ ; R-PP:  $n = 16$ ,  $r_s = 0.460$ ,  $P = 0.063$ ) and the duration of (R-P:  $n = 23$ ,  $r_s = 0.434$ ,  $P = 0.034$ ; R-PP:  $n = 16$ ,  $r_s = 0.428$ ,  $P = 0.086$ ) the subject-initiated section of the “respondent” subject bouts and the number of responses in (R-P:  $n = 23$ ,  $r_s = 0.357$ ,  $P = 0.087$ ; Table E.29) the entire “respondent” subject bouts, though the correlations

were not present for all data groups. The sparse nature of these correlations among the “respondent” groups (and their absence in “bout initiator” groups) again reflects the relatively poor information-carrying capabilities of response latency as a component of the jump-yip bout. Furthermore, the positive correlations between response latency and magnitude of response contradict the expected inverse relationship between the variables, again casting doubt upon a role of response latency in conveying information to receivers.

Relatively consistent correlations between the characteristics of environmental jump-yip bouts and the subject bouts persist in comparisons of only the environmental jump-yip bouts, though in some cases these correlations are not as strong or as numerous. Increases in the number of pre-subject jump-yip bouts were associated with increases in the total number of pre-subject jump-yips (F-I:  $n = 26$ ,  $r_s = 0.899$ ,  $P < 0.001$ ; Table E.31; F-P:  $n = 42$ ,  $r_s = 0.878$ ,  $P < 0.001$ ; Table E.32; F-PP:  $n = 24$ ,  $r_s = 0.855$ ,  $P < 0.001$ ; E.33), indicating that the frequency of bouts and general jump-yipping are relatively consistent (not surprising, since the total jump-yips in the environment make up the environmental jump-yip bouts). Increases in pre-subject bouts were also associated with increases in the amount of pre-subject chirping (F-I:  $n = 26$ ,  $r_s = 0.351$ ,  $P = 0.078$ ; F-P:  $n = 42$ ,  $r_s = 0.267$ ,  $P = 0.087$ ; F-PP:  $n = 24$ ,  $r_s = 0.353$ ,  $P = 0.091$ ) and alarm calling (F-I:  $n = 26$ ,  $r_s = 0.390$ ,  $P = 0.049$ ; F-P:  $n = 42$ ,  $r_s = 0.509$ ,  $P = 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.351$ ,  $P = 0.093$ ). The significance of these results is in some question (particularly given the unknown function of chirps), but could signify that many of the recorded “chirps” are in fact a form of jump-yip. The positive correlations with alarm calling could reflect an increase in social vigilance (or a greater rate of vigilance testing) with an increase in perceived threat in the

environment. Increases in the number of pre-subject bouts were also associated with increases in the duration of the pre-subject bouts (F-P:  $n = 33$ ,  $r_s = 0.353$ ,  $P = 0.044$ ), but only in one “bout initiator” group. For subject bouts in which the behaviour of respondents was examined, increases in the number of pre-subject bouts were only associated with increases in the response latency of the pre-subject bouts (R-I:  $n = 21$ ,  $r_s = 0.420$ ,  $P = 0.051$ ; Table E.34; R-P:  $n = 25$ ,  $r_s = 0.501$ ,  $P = 0.009$ ; Table E.35) and the number of responses in the pre-subject bouts (R-PP:  $n = 17$ ,  $r_s = -0.416$ ,  $P = 0.086$ ; Table E.36). These results indicate that while there is some evidence of greater magnitude of response with greater numbers of jump-yip bouts in the environment, the correlations are far from universal when multiple environmental bouts are considered. It is therefore possible that general similarities are present only for a small subset of all environmental jump-yips. Over longer periods of time, variation in the characteristics of the bouts becomes greater than those characteristics which remain constant.

Correlations between the total number of jump-yips in the environment in the minute preceding the subject bout and the characteristics of the bouts during the same time period were stronger, possibly reflecting the contribution of all the environmental jump-yips to the characteristics of each environmental bout. Increases in the total number of pre-subject jump-yips were associated with increases in the number of responses in (F-I:  $n = 20$ ,  $r_s = 0.755$ ,  $P < 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.791$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ;  $r_s = 0.724$ ,  $P < 0.001$ ), the duration of (F-I:  $n = 20$ ,  $r_s = 0.690$ ,  $P = 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.793$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.742$ ,  $P < 0.001$ ), and the response latency of (F-I:  $n = 20$ ,  $r_s = 0.467$ ,  $P = 0.038$ ; Table E.31; F-P:  $n = 33$ ,  $r_s = 0.475$ ,  $P = 0.005$ ; Table E.32; F-PP:  $n = 19$ ,  $r_s = 0.444$ ,  $P = 0.057$ ; Table E.33) the pre-subject bouts.

Likewise, increases in the total number of jump-yips in the minute preceding “respondent” subject bouts were associated with increases in the number of responses in (R-I:  $n = 21$ ,  $r_s = 0.923$ ,  $P < 0.001$ ; Table E.34; R-P:  $n = 25$ ,  $r_s = 0.899$ ,  $P < 0.001$ ; Table E.35; R-PP:  $n = 17$ ,  $r_s = 0.930$ ,  $P < 0.001$ ; Table E.36), the duration of (R-I:  $n = 21$ ,  $r_s = 0.962$ ,  $P < 0.001$ ; R-P:  $n = 25$ ,  $r_s = 0.946$ ,  $P < 0.001$ ; R-PP:  $n = 17$ ,  $r_s = 0.949$ ,  $P < 0.001$ ), and the response latency of (R-I:  $n = 21$ ,  $r_s = 0.397$ ,  $P = 0.067$ ; R-P:  $n = 25$ ,  $r_s = 0.386$ ,  $P = 0.052$ ) the pre-subject bouts. Increases in the total number of pre-subject jump-yips were also associated with increases in the amount of pre-subject alarm calling (F-P:  $n = 42$ ,  $r_s = 0.510$ ,  $P = 0.001$ ; Table E.32), but only for one “bout initiator” group. This result may further demonstrate that individuals jump-yip more often in the presence of increased alarm calling – either upon the cessation of alarm calling (i.e. the all-clear hypothesis) or due to an increased need to assess group vigilance under the threat of predation. The fact that this positive correlation is only observed in a single group, however, indicates that further study of this potential relationship is required.

Increases in the number of responses in the pre-subject bouts were associated with increases in the duration of (F-I:  $n = 20$ ,  $r_s = 0.937$ ,  $P < 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.926$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.940$ ,  $P < 0.001$ ) and response latency of (F-I:  $n = 20$ ,  $r_s = 0.741$ ,  $P < 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.648$ ,  $P < 0.001$ ; F-PP:  $n = 19$ ,  $r_s = 0.664$ ,  $P = 0.002$ ) the pre-subject bouts, while increases in the duration of the pre-subject bouts were also associated with increases in the response latency of the pre-subject bouts (F-I:  $n = 20$ ,  $r_s = 0.778$ ,  $P < 0.001$ ; Table E.31; F-P:  $n = 33$ ,  $r_s = 0.737$ ,  $P < 0.001$ ; Table E.32; F-PP:  $n = 24$ ,  $r_s = 0.716$ ,  $P = 0.001$ ; Table E.33). Increases in the number of responses in the pre-subject bouts in all three “respondent” groups were associated with

increases in the duration of the pre-subject bouts (R-I:  $n = 21$ ,  $r_s = 0.941$ ,  $P < 0.001$ ; Table E.34; R-P:  $n = 25$ ,  $r_s = 0.957$ ,  $P < 0.001$ ; Table E.35; R-PP:  $n = 17$ ,  $r_s = 0.955$ ,  $P < 0.001$ ; Table E.36). Increases in the duration of the pre-subject bouts were associated with increases in the response latency of the pre-subject bouts (R-I:  $n = 21$ ,  $r_s = 0.360$ ,  $P = 0.100$ ; R-P:  $n = 25$ ,  $r_s = 0.332$ ,  $P = 0.097$ ). These results demonstrate the expected positive correlations between the number of responses in and the duration of jump-yip bouts in the environment, further indicating that receivers may be able to glean relatively consistent information concerning the vigilance of their social group from multiple jump-yip bouts (including those in which they were not a participant). They also further demonstrate, however, that response latency of a jump-yip bout is not necessarily inversely correlated with the magnitude of response in the bout, and may consequently be a poor information-carrying component of a jump-yip bout. Increases in the response latency of the pre-subject bouts were also associated with decreases in the number of pre-subject chirps (R-I:  $n = 21$ ,  $r_s = -0.516$ ,  $P = 0.014$ ; Table E.34; R-P:  $n = 25$ ,  $r_s = -0.429$ ,  $P = 0.029$ ; Table E.35; R-PP:  $n = 17$ ,  $r_s = -0.621$ ,  $P = 0.006$ ; Table E.36), which could be considered expected if chirps are a form of jump-yip (increasing “jump-yipping” associated with decreasing response latency), however, this conclusion cannot be drawn without further study of chirps and their association with black-tailed prairie dog behaviour.

Increases in the number of jump-yip bouts in the minute following “bout initiator” subject bouts were associated with increases in the total number of post-subject jump-yips (F-I:  $n = 26$ ,  $r_s = 0.962$ ,  $P < 0.001$ ; Table E.37; F-P:  $n = 42$ ,  $r_s = 0.928$ ,  $P < 0.001$ ; Table E.38; F-PP:  $n = 24$ ,  $r_s = 0.912$ ,  $P < 0.001$ ; Table E.39) and increases in



the number of responses in (F-I:  $n = 20$ ,  $r_s = 0.417$ ,  $P = 0.096$ ; F-P:  $n = 33$ ,  $r_s = 0.434$ ,  $P = 0.012$ ) and the duration of (F-I:  $n = 20$ ,  $r_s = 0.458$ ,  $P = 0.065$ ; F-P:  $n = 33$ ,  $r_s = 0.374$ ,  $P = 0.032$ ) the post-subject bouts, though only the correlation with the total number of post-subject jump-yips was present for all “bout initiator” groups. Increases in the number of post-subject jump-yip bouts in “respondent” groups were associated with increases in the total number of post-subject jump-yips (R-P:  $n = 26$ ,  $r_s = 0.449$ ,  $P = 0.021$ ; Table E.41) and decreases in the response latency of the post-subject bouts (R-PP:  $n = 16$ ,  $r_s = -0.510$ ,  $P = 0.036$ ; Table E.42). These results were consistent with the correlations observed between the frequency of pre-subject bouts in the environment and the characteristics of the pre-subject bouts (though more numerous, particularly in “bout initiator” bouts), with increases in the number of bouts being associated with increases in the magnitude of response in the bouts. As was the case for pre-subject bouts, however, the correlations are not universal among “bout initiator” and “respondent” groups.

Increases in the number of post-subject bouts were also associated with increases in the number of post-subject chirps (R-I:  $n = 22$ ,  $r_s = 0.387$ ,  $P = 0.083$ ; R-PP:  $n = 18$ ,  $r_s = 0.509$ ,  $P = 0.031$ ) and the amount of post-subject alarm calling (R-I:  $n = 22$ ,  $r_s = 0.503$ ,  $P = 0.020$ ; Table E.40; R-P:  $n = 26$ ,  $r_s = 0.544$ ,  $P = 0.004$ ; Table E.41; R-PP:  $n = 18$ ,  $r_s = 0.417$ ,  $P = 0.085$ ; Table E.42), though only the variation in post-subject alarm calling was present for all “respondent” groups. The positive correlation with chirps may again demonstrate that chirps are a form of jump-yip (at least in the “respondent” groups), while the increase in alarm calling may again reflect either an increase in “all-clear” jump-yips, or a greater need to test collective vigilance in the

presence of predatory threats. In both cases, however, more study is required before these conclusions can be drawn.

As was the case for pre-subject vocalizations, increases in the total number of post-subject jump-yips were associated with greater increases in the magnitude of response in the post-subject bouts. Increases in the total number of post-subject jump-yips were associated with increases in the number of responses in (F-I:  $n = 20$ ,  $r_s = 0.774$ ,  $P < 0.001$ ; Table E.37; F-P:  $n = 33$ ,  $r_s = 0.796$ ,  $P < 0.001$ ; Table E.38; F-PP:  $n = 17$ ,  $r_s = 0.716$ ,  $P = 0.001$ ; Table E.39), the duration of (F-I:  $n = 20$ ,  $r_s = 0.748$ ,  $P = 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.713$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.633$ ,  $P = 0.006$ ), and the response latency of (F-I:  $n = 20$ ,  $r_s = 0.522$ ,  $P = 0.032$ ; F-P:  $n = 33$ ,  $r_s = 0.464$ ,  $P = 0.006$ ) the post-subject bouts, though only the correlations with responses and duration were present for all “bout initiator” groups. Increases in the number of jump-yips in the minute following “respondent” subject bouts were also associated with increases in the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.911$ ,  $P < 0.001$ ; Table E.40; R-P:  $n = 23$ ,  $r_s = 0.904$ ,  $P < 0.001$ ; Table E.41; R-PP:  $n = 16$ ,  $r_s = 0.900$ ,  $P < 0.001$ ; Table E.42), the duration of (R-I:  $n = 20$ ,  $r_s = 0.800$ ,  $P < 0.001$ ; R-P:  $n = 23$ ,  $r_s = 0.796$ ,  $P < 0.001$ ; R-PP:  $n = 16$ ,  $r_s = 0.746$ ,  $P = 0.001$ ), and the response latency of (R-I:  $n = 20$ ,  $r_s = 0.377$ ,  $P = 0.090$ ) the post-subject bouts. The positive correlations with magnitude of response are consistent with the expectation that general increases in jump-yipping in an environment are associated with greater levels of response in the bouts occurring during that time (particularly since the total jump-yips comprise the magnitude of response in the bouts). The positive correlation with response latency opposes the expected inverse relationship between the amount of jump-yipping in the environment and the response

latency of the bouts in the environment, and again may demonstrate that response latency is a poor indicator of group vigilance. Increases in the total number of post-subject bouts were also associated with increases in the amount of post-subject alarm calling (R-I:  $n = 22$ ,  $r_s = 0.495$ ,  $P = 0.022$ ; Table E.40; R-P:  $n = 26$ ,  $r_s = 0.519$ ,  $P = 0.007$ ; Table E.41; R-PP:  $n = 18$ ,  $r_s = 0.484$ ,  $P = 0.042$ ; Table E.42) which may again demonstrate that jump-yips occur more frequently with increases in environmental alarm calling, either to indicate the cessation of alarm calling (i.e. the “all-clear” function) or because there is a greater need to assess the collective vigilance of the social group under the threat of predation.

Increases in the number of responses in the post-subject bouts were associated with increases in the duration of (F-I:  $n = 20$ ,  $r_s = 0.916$ ,  $P < 0.001$ ; F-P:  $n = 33$ ,  $r_s = 0.914$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.917$ ,  $P < 0.001$ ) and the response latency of (F-I:  $n = 20$ ,  $r_s = 0.681$ ,  $P = 0.003$ ; Table E.37; F-P:  $n = 33$ ,  $r_s = 0.660$ ,  $P < 0.001$ ; Table E.38; F-PP:  $n = 17$ ,  $r_s = 0.565$ ,  $P = 0.018$ ; Table E.39) the post-subject bouts. Increases in the number of responses in the jump-yip bouts occurring in the minute following the “respondent” subject bouts were also associated with increases in the duration of (R-I:  $n = 20$ ,  $r_s = 0.945$ ,  $P < 0.001$ ; Table E.40; R-P:  $n = 23$ ,  $r_s = 0.932$ ,  $P < 0.001$ ; Table E.41; R-PP:  $n = 16$ ,  $r_s = 0.933$ ,  $P < 0.001$ ; Table E.42) and response latency of (R-I:  $n = 20$ ,  $r_s = 0.553$ ,  $P = 0.009$ ; R-P:  $n = 23$ ,  $r_s = 0.471$ ,  $P = 0.020$ ) the post-subject bouts, though only the correlation with duration was present for all three “respondent” groups. These results were consistent for those observed in pre-subject bouts. The positive correlation between responses and duration are expected given the role the number of responses in a bout play in determining the duration of the bout. The

positive correlation between the number of responses and latency is unexpected, but again may demonstrate the problems with using response latency as an information-carrying component of a social signal.

Similarly, increases in the duration of the post-subject bouts were associated with increases in the response latency of the bouts for both “bout initiator” (F-I:  $n = 20$ ,  $r_s = 0.872$ ,  $P < 0.001$ ; Table E.37; F-P:  $n = 33$ ,  $r_s = 0.797$ ,  $P < 0.001$ ; Table E.38; F-PP:  $n = 17$ ,  $r_s = 0.779$ ,  $P < 0.001$ ; Table E.39) and “respondent” (R-I:  $n = 20$ ,  $r_s = 0.587$ ,  $P = 0.005$ ; Table E.40; R-P:  $n = 23$ ,  $r_s = 0.512$ ,  $P = 0.010$ ; Table E.41) groups, further demonstrating that response latency does not vary as expected with changes in the magnitude of response in a jump-yip bout. Increases in the response latency of the post-subject bouts were associated with decreases in the number of post-subject chirps, but only for one “respondent” group (R-PP:  $n = 16$ ,  $r_s = -0.428$ ,  $P = 0.087$ ; Table E.42). This result could be considered expected, if chirps are akin to jump-yips. However, in light of the limited knowledge of the function of the chirp as a signal and the unexpected correlations observed between the number of jump-yips in an environmental bout and the response latency of the bout, this conclusion cannot be drawn (and is, in fact, far from supported).

These correlations, for the most part, show that the characteristics of jump-yipping in the environment are relatively constant, at least over a short period of time (in the above cases, over approximately one minute), and thus present consistent information to any receivers of the signals (even if those receivers do not participate in the bout). The results of this study also suggest, however, that these expected correlations

persist over double that time (the minute preceding and the minute following the subject bout), and could conceivably persist even longer.

Increases in the number of pre-subject jump-yip bouts were associated with increases in the number of post-subject bouts (F-I:  $n = 26$ ,  $r_s = 0.724$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = 0.672$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.758$ ,  $P < 0.001$ ) and total post-subject jump-yips (F-I:  $n = 26$ ,  $r_s = 0.692$ ,  $P < 0.001$ ; Table E.43; F-P:  $n = 42$ ,  $r_s = 0.623$ ,  $P < 0.001$ ; Table E.44; F-PP:  $n = 24$ ,  $r_s = 0.660$ ,  $P < 0.001$ ; Table E.45), indicating that the frequency of bouts is consistent over a longer period of time. It was also associated with increases in the number of post-subject chirps (F-I:  $n = 26$ ,  $r_s = 0.338$ ,  $P = 0.091$ ) and the amount of post-subject alarm calling (F-P:  $n = 42$ ,  $r_s = 0.267$ ,  $P = 0.088$ ), though neither correlation was universal for all three “bout initiator” groups. As before, these results are too sparse to draw any conclusions concerning the positive relationships between the different types of vocalizations in the environment, but could point to both a similarity between jump-yips and chirps as well as the need to either mark the end of alarm calls with jump-yips or to repeatedly test the collective vigilance of a social group in the presence of nearby threat. Increases in the number of pre-subject bouts observed in “respondent” groups were also associated with increases in the total number of post-subject jump-yips (R-P:  $n = 26$ ,  $r_s = 0.345$ ,  $P = 0.099$ ; Table E.47), the number of responses in the post-subject bouts (R-I:  $n = 21$ ,  $r_s = 0.371$ ,  $P = 0.097$ ; Table E.46), and the response latency of the post-subject bouts (R-PP:  $n = 16$ ,  $r_s = 0.464$ ,  $P = 0.061$ ; Table E.48). Though these correlations are far from consistent in all “respondent” groups, they again point to a general consistency in

jump-yipping (both in frequency and in the magnitude of response in bouts) over a longer period of time.

Increases in the total number of pre-subject jump-yips were also associated with increases in the number of post-subject bouts (F-I:  $n = 26$ ,  $r_s = 0.768$ ,  $P < 0.001$ ; Table E.43; F-P:  $n = 42$ ,  $r_s = 0.754$ ,  $P < 0.001$ ; Table E.44; F-PP:  $n = 24$ ,  $r_s = 0.820$ ,  $P < 0.001$ ; Table E.45) and total number of post-subject jump-yips (F-I:  $n = 26$ ,  $r_s = 0.777$ ,  $P < 0.001$ ; F-P:  $n = 42$ ,  $r_s = 0.781$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = 0.822$ ,  $P < 0.001$ ) and were associated with increases in the number of responses in (F-I:  $n = 17$ ,  $r_s = 0.542$ ,  $P = 0.024$ ; F-P:  $n = 33$ ,  $r_s = 0.513$ ,  $P = 0.002$ ; F-PP:  $n = 17$ ,  $r_s = 0.466$ ,  $P = 0.059$ ), the duration of (F-I:  $n = 17$ ,  $r_s = 0.486$ ,  $P = 0.048$ ; F-P:  $n = 33$ ,  $r_s = 0.393$ ,  $P = 0.024$ ), and the response latency of (F-P:  $n = 33$ ,  $r_s = 0.298$ ,  $P = 0.092$ ) the post-subject bouts. Increases in the total number of jump-yips occurring in the minute preceding the “respondent” subject bouts were associated with increases in the total number of post-subject jump-yips (R-I:  $n = 21$ ,  $r_s = 0.620$ ,  $P = 0.003$ ; R-P:  $n = 26$ ,  $r_s = 0.695$ ,  $P < 0.001$ ; R-PP:  $n = 18$ ,  $r_s = 0.646$ ,  $P = 0.004$ ) and the number of responses in (R-I:  $n = 20$ ,  $r_s = 0.687$ ,  $P = 0.001$ ; R-P:  $n = 23$ ,  $r_s = 0.673$ ,  $P < 0.001$ ; R-PP:  $n = 16$ ,  $r_s = 0.649$ ,  $P = 0.005$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.705$ ,  $P = 0.001$ ; Table E.46; R-P:  $n = 23$ ,  $r_s = 0.661$ ,  $P = 0.001$ ; Table E.47; R-PP:  $n = 16$ ,  $r_s = 0.603$ ,  $P = 0.010$ ; Table E.48) the post-subject bouts. Again, these results demonstrate a general consistency in the amount of jump-yipping in an environment, even over longer periods of time.

Increases in the total number of pre-subject bouts were also associated with increases in the number of post-subject chirps (F-I:  $n = 26$ ,  $r_s = 0.344$ ,  $P = 0.085$ ; Table E.43) and the amount of post-subject alarm calling (F-P:  $n = 42$ ,  $r_s = 0.261$ ,  $P = 0.094$ ; Table E.44). As

discussed above, however, the scarcity of these correlations make drawing conclusions concerning the significance of these correlations impossible.

Increases in the number of responses in the pre-subject bouts were associated with increases in the number of post-subject bouts (F-I:  $n = 20$ ,  $r_s = 0.472$ ,  $P = 0.036$ ; F-P:  $n = 33$ ,  $r_s = 0.610$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.493$ ,  $P = 0.032$ ) and the total number of post-subject jump-yips (F-I:  $n = 20$ ,  $r_s = 0.545$ ,  $P = 0.013$ ; F-P:  $n = 33$ ,  $r_s = 0.689$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.573$ ,  $P = 0.010$ ), and with increases in the number of responses in (F-I:  $n = 17$ ,  $r_s = 0.625$ ,  $P = 0.010$ ; F-P:  $n = 29$ ,  $r_s = 0.527$ ,  $P = 0.003$ ; F-PP:  $n = 15$ ,  $r_s = 0.544$ ,  $P = 0.036$ ), the duration of (F-I:  $n = 17$ ,  $r_s = 0.654$ ,  $P = 0.006$ ; Table E.43; F-P:  $n = 33$ ,  $r_s = 0.532$ ,  $P = 0.003$ ; Table E.44; F-PP:  $n = 15$ ,  $r_s = 0.523$ ,  $P = 0.045$ ; Table E.45), and the response latency of (F-I:  $n = 16$ ,  $r_s = 0.475$ ,  $P = 0.063$ ) the post-subject bouts. Increases in the total number of pre-subject jump-yips were associated with increases in the total number of post-subject jump-yips (R-I:  $n = 20$ ,  $r_s = 0.447$ ,  $P = 0.042$ ; R-P:  $n = 25$ ,  $r_s = 0.534$ ,  $P = 0.005$ ; R-PP:  $n = 17$ ,  $r_s = 0.539$ ,  $P = 0.021$ ) and the number of responses in (R-I:  $n = 19$ ,  $r_s = 0.476$ ,  $P = 0.029$ ; R-P:  $n = 23$ ,  $r_s = 0.481$ ,  $P = 0.017$ ; R-PP:  $n = 16$ ,  $r_s = 0.453$ ,  $P = 0.068$ ) and the duration of (R-I:  $n = 19$ ,  $r_s = 0.533$ ,  $P = 0.013$ ; Table E.46; R-P:  $n = 23$ ,  $r_s = 0.473$ ,  $P = 0.019$ ; Table E.47; R-PP:  $n = 16$ ,  $r_s = 0.462$ ,  $P = 0.062$ ; Table E.48) the jump-yips occurring in the minute following the “respondent” subject bouts (for all three groups). These results further demonstrate the close relationships between the frequency of jump-yipping and the characteristics of jump-yip bouts in the environment – results which persist when the duration of pre-subject bouts are considered.

Increases in the duration of the pre-subject jump-yip bouts were associated with increases in the number of post-subject bouts (F-I:  $n = 20$ ,  $r_s = 0.583$ ,  $P = 0.007$ ; F-P:  $n = 33$ ,  $r_s = 0.650$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.526$ ,  $P = 0.021$ ) and total number of post-subject jump-yips (F-I:  $n = 20$ ,  $r_s = 0.650$ ,  $P = 0.002$ ; F-P:  $n = 33$ ,  $r_s = 0.722$ ,  $P < 0.001$ ; F-PP:  $n = 17$ ,  $r_s = 0.560$ ,  $P = 0.013$ ), and with increases in the number of responses in (F-I:  $n = 17$ ,  $r_s = 0.631$ ,  $P = 0.009$ ; Table E.43; F-P:  $n = 29$ ,  $r_s = 0.527$ ,  $P = 0.003$ ; Table E.44; F-PP:  $n = 15$ ,  $r_s = 0.445$ ,  $P = 0.097$ ; Table E.45), the duration of (F-I:  $n = 17$ ,  $r_s = 0.631$ ,  $P = 0.009$ ; F-P:  $n = 29$ ,  $r_s = 0.545$ ,  $P = 0.002$ ), and the response latency of (F-I:  $n = 17$ ,  $r_s = 0.428$ ,  $P = 0.098$ ) the post-subject bouts. Increases in the duration of the jump-yip bouts occurring in the minute following the “respondent” subject bouts were associated with increases in the total number of post-subject jump-yips (R-I:  $n = 20$ ,  $r_s = 0.588$ ,  $P = 0.005$ ; R-P:  $n = 26$ ,  $r_s = 0.622$ ,  $P = 0.001$ ; R-PP:  $n = 17$ ,  $r_s = 0.587$ ,  $P = 0.010$ ) and the number of responses in (R-I:  $n = 19$ ,  $r_s = 0.611$ ,  $P = 0.003$ ; R-P:  $n = 23$ ,  $r_s = 0.608$ ,  $P = 0.002$ ; R-PP:  $n = 16$ ,  $r_s = 0.522$ ,  $P = 0.031$ ) and the duration of (R-I:  $n = 19$ ,  $r_s = 0.625$ ,  $P = 0.002$ ; Table E.46; R-P:  $n = 23$ ,  $r_s = 0.577$ ,  $P = 0.003$ ; Table E.47; R-PP:  $n = 16$ ,  $r_s = 0.471$ ,  $P = 0.057$ ; Table E.48) the post-subject bouts. Again, these results demonstrate the strong associations between the frequency of jump-yipping in the environment and the characteristics of response in those bouts. Consequently, any receiver repeatedly sampling jump-yip bouts in an environment should acquire relatively consistent information concerning the state of their social group.

Increases in the response latency of the pre-subject jump-yip bouts were associated with increases in the number of post-subject jump-yip bouts (F-I:  $n = 20$ ,



$r_s = 0.440$ ,  $P = 0.052$ ; Table E.43; F-P:  $n = 33$ ,  $r_s = 0.437$ ,  $P = 0.011$ ; Table E.44; F-PP:  $n = 17$ ,  $r_s = 0.416$ ,  $P = 0.076$ ; Table E.45), the total number of post-subject jump-yips (F-P:  $n = 33$ ,  $r_s = 0.457$ ,  $P = 0.008$ ), the number of responses in the post-subject bouts (F-P:  $n = 29$ ,  $r_s = 0.360$ ,  $P = 0.055$ ), and the duration of the post-subject bouts (F-P:  $n = 29$ ,  $r_s = 0.355$ ,  $P = 0.059$ ) in certain “bout initiator” groups. Increases in the response latency of the pre-subject jump-yip bouts in the “respondent” groups were associated with increases in the total number of post-subject jump-yips (R-I:  $n = 20$ ,  $r_s = 0.423$ ,  $P = 0.056$ ; R-P:  $n = 25$ ,  $r_s = 0.451$ ,  $P = 0.021$ ) and the number of responses in (R-I:  $n = 19$ ,  $r_s = 0.477$ ,  $P = 0.029$ ; R-P:  $n = 23$ ,  $r_s = 0.436$ ,  $P = 0.033$ ) and the duration of (R-I:  $n = 20$ ,  $r_s = 0.410$ ,  $P = 0.065$ ; Table E.46; R-P:  $n = 23$ ,  $r_s = 0.440$ ,  $P = 0.032$ ; Table E.47) the post-subject bouts. These results, while inconsistent with the expected inverse relationship between jump-yipping in an environment (and the magnitude of response in those bouts) and the response latency of those bouts, are consistent with the correlations in social variables described previously. Increases in the response latency of the pre-subject bouts were also associated with increases in the amount of post-subject alarm calling (R-P:  $n = 25$ ,  $r_s = 0.371$ ,  $P = 0.062$ ), but only for one “respondent” group. Though this positive correlation could demonstrate that individuals exposed to greater alarm calling respond less rapidly to jump-yips in the environment, individuals should actually respond quicker if their level of vigilance is higher (owing to the alarm calling in the environment). With the correlation only being observed in one “respondent” group, however, this idea requires further study.

**APPENDIX F: Autocorrelations of the abiotic factors present at the time of the subject jump-yip bout and their relationships to the characteristics of that bout and the social variables present at that time**

When “bout initiator” jump-yip bouts occurred later in the day, they contained fewer responses (F-PP:  $n = 13$ ,  $r_s = -0.501$ ,  $P = 0.081$ ) and had longer response latencies (F-I:  $n = 17$ ,  $r_s = 0.815$ ,  $P = 0.002$ ; Table F.1; F-P:  $n = 24$ ,  $r_s = 0.414$ ,  $P = 0.044$ ; Table F.2; F-PP:  $n = 14$ ,  $r_s = 0.597$ ,  $P = 0.024$ ; Table F.3). The inverse relationships between the number of responses and the response latency in the bout is consistent with the expectations of the study (that longer response latencies and lower levels of response indicate a reduction in group vigilance), while the decrease in the magnitude of response later in the day may reflect an increased need to forage as the day progresses (to both replenish energy used during the day as well as to prepare energy stores for the upcoming night), resulting in a reduction in collective vigilance and a reduction in the level of response in the subject bouts. When “respondent” jump-yip bouts occurred later in the day, however, there were no differences in the characteristics of the subject bouts (Tables F.4, F.5, F.6), which may indicate that the observed variation in the characteristics of the subject bouts recorded in this study may be related to other (unmeasured) factors. In fact, post-subject jump-yip bouts had shorter response latencies later in the day (F-PP:  $n = 13$ ,  $r_s = -0.511$ ,  $P = 0.074$ ; Table F.9) – a result opposite that observed in the response latencies of the subject bouts – while the characteristics of the environmental jump-yip bouts did not vary in many of the other groups (Tables F.7, F.8, F.10, F.11, F.12), results which demonstrate the necessity of further study of the effects of time of day on the characteristics of jump-yipping in the environment.

Table F.1: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).

	Time of day
Number of responses	-0.060
Number of respondents†	-0.030
Duration of bout	-0.017
Response latency‡	<b>0.815**</b>

† n = 17

‡ n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.2: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31).

	Time of day
Number of responses	-0.034
Number of respondents†	-0.207
Duration of bout	0.050
Response latency†	<b>0.414**</b>

† n = 24

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.3: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17).

	Time of day
Number of responses	-0.333
Number of respondents†	<b>-0.501*</b>
Duration of bout	-0.140
Response latency‡	<b>0.597**</b>

† n = 13

‡ n = 14

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.4: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18).

	Time of day
Number of post-subject responses	-0.233
Number of post-subject respondents†	-0.258
Duration of post-subject subsection	-0.317
Response latency of subject‡	0.160
Response latency of first post-subject call	-0.130
Total number of responses	-0.044
Duration of entire bout	-0.088
Response latency of entire bout	0.278

† n = 11

‡ n = 12

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.5: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21).

	Time of day
Number of post-subject responses	-0.258
Number of post-subject respondents†	-0.305
Duration of post-subject subsection	-0.311
Response latency of subject‡	0.247
Response latency of first post-subject call	-0.066
Total number of responses	-0.064
Duration of entire bout	-0.088
Response latency of entire bout	0.342

† n = 12

‡ n = 14

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.6: Correlation of the time of day at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16).

	Time of day
Number of post-subject responses	-0.230
Number of post-subject respondents†	-0.126
Duration of post-subject subsection	-0.290
Response latency of subject‡	0.150
Response latency of first post-subject call	-0.146
Total number of responses	-0.012
Duration of entire bout	-0.109
Response latency of entire bout	0.165

† n = 8

‡ n = 10

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.7: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).<sup>^</sup>

	Time of day
AGPOP	-0.200
T2VOC	-0.126
PREBOUT	0.224
PREJY	0.203
PRERESP†	0.319
PREDUR†	0.134
PRELAT†	0.244
PRECHIRP	-0.031
PREAC	0.170
POSTBOUT	0.089
POSTJY	0.054
POSTRESP‡	-0.066
POSTDUR‡	-0.110
POSTLAT‡	-0.005
POSTCHIRP	-0.068
POSTAC	0.258

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 14

‡ n = 13

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.8: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31).<sup>^</sup>

	Time of day
AGPOP	-0.156
T2VOC	-0.053
PREBOUT	0.132
PREJY	0.142
PRERESP <sup>†</sup>	0.104
PREDUR <sup>†</sup>	0.112
PRELAT <sup>†</sup>	0.248
PRECHIRP	-0.088
PREAC	0.169
POSTBOUT	0.124
POSTJY	0.220
POSTRESP <sup>‡</sup>	0.199
POSTDUR <sup>‡</sup>	0.036
POSTLAT <sup>‡</sup>	-0.137
POSTCHIRP	-0.256
POSTAC	<b>0.324*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 24

<sup>‡</sup> n = 25

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.9: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17).<sup>^</sup>

	Time of day
AGPOP	-0.078
T2VOC	0.264
PREBOUT	-0.035
PREJY	-0.015
PRERESP†	0.176
PREDUR†	0.126
PRELAT†	0.198
PRECHIRP	-0.112
PREAC	0.141
POSTBOUT	-0.092
POSTJY	-0.068
POSTRESP†	-0.072
POSTDUR†	-0.225
POSTLAT†	<b>-0.511**</b>
POSTCHIRP	-0.389
POSTAC	0.193

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 13

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.10: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18).<sup>^</sup>

	Time of day
AGPOP	0.252
T2VOC	0.075
PREBOUT	-0.112
PREJY	0.269
PRERESP†	0.228
PREDUR†	0.146
PRELAT†	0.317
PRECHIRP	<b>-0.526**</b>
PREAC	0.126
POSTBOUT†	-0.229
POSTJY†	-0.095
POSTRESP‡	0.039
POSTDUR‡	0.061
POSTLAT‡	0.123
POSTCHIRP	<b>-0.455*</b>
POSTAC	0.194

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

‡ n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.11: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21).<sup>^</sup>

	Time of day
AGPOP	0.201
T2VOC	0.142
PREBOUT	-0.172
PREJY	0.166
PRERESP†	0.148
PREDUR†	0.083
PRELAT†	0.201
PRECHIRP	<b>-0.513**</b>
PREAC	0.080
POSTBOUT	-0.334
POSTJY	-0.183
POSTRESP‡	0.026
POSTDUR‡	0.042
POSTLAT‡	0.146
POSTCHIRP	<b>-0.434**</b>
POSTAC	0.127

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.12: Correlation of the time of day at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16).<sup>^</sup>

	Time of day
AGPOP	0.361
T2VOC	0.068
PREBOUT	-0.203
PREJY	0.289
PRERESP†	0.226
PREDUR†	0.147
PRELAT†	0.309
PRECHIRP	<b>-0.531**</b>
PREAC	0.143
POSTBOUT	-0.238
POSTJY	-0.109
POSTRESP‡	0.063
POSTDUR‡	0.107
POSTLAT‡	0.254
POSTCHIRP	<b>-0.480*</b>
POSTAC	0.344

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 15

‡ n = 14

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Among other social variables measured in this study, there was also more post-subject alarm calling later in the day (F-P:  $n = 31$ ,  $r_s = 0.324$ ,  $P = 0.075$ ; Table F.8), indicating that there may be more frequent threats perceived/detected later in the day. The relative paucity of correlations, however, makes further study necessary before this conclusion can be drawn. There were also greater numbers of chirps in the minute preceding (R-I:  $n = 18$ ,  $r_s = -0.526$ ,  $P = 0.025$ ; Table F.10; R-P:  $n = 21$ ,  $r_s = -0.513$ ,  $P = 0.017$ ; Table F.11; R-PP:  $n = 16$ ,  $r_s = -0.531$ ,  $P = 0.034$ ; Table F.12) and the minute following (R-I:  $n = 18$ ,  $r_s = -0.455$ ,  $P = 0.058$ ; Table F.10; R-P:  $n = 21$ ,  $r_s = -0.434$ ,  $P = 0.049$ ; Table F.11; R-PP:  $n = 16$ ,  $r_s = -0.480$ ,  $P = 0.060$ ; Table F.12) the subject bout later in the day. These results demonstrate that chirps in the environment do not vary directly with jump-yips in the environment and therefore may be a different type of vocalization. The unknown function of chirps, however, makes any conclusions concerning their variation with time of day impossible to draw without further study.

When “bout initiator” jump-yip bouts occurred later in the year, they contained fewer responses (F-P:  $n = 42$ ,  $r_s = -0.444$ ,  $P = 0.003$ ; Table F.14; F-PP:  $n = 24$ ,  $r_s = -0.544$ ,  $P = 0.006$ ; Table F.15) and respondents (F-PP:  $n = 19$ ,  $r_s = -0.405$ ,  $P = 0.085$ ; Table F.15) and were of shorter durations (F-P:  $n = 42$ ,  $r_s = -0.432$ ,  $P = 0.004$ ; Table F.14; F-PP:  $n = 24$ ,  $r_s = -0.485$ ,  $P = 0.016$ ; Table F.15), though the correlations were not present for all groups, and were not present in the “respondent” groups (see below and Tables F.16, F.17, F.18). These results may reflect a reduction in the number of individuals present aboveground during those trials which occurred later in the year (in November). This is consistent with the observation that the first post-subject, non-subject vocalization occurred later in the recording session (F-I:  $n = 26$ ,  $r_s = 0.392$ ,  $P = 0.048$ ;

Table F.13: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).

	Time of year
Number of responses	-0.327
Number of respondents†	-0.183
Duration of bout	-0.288
Response latency‡	0.252

† n = 24

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.14: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).

	Time of year
Number of responses	<b>-0.444**</b>
Number of respondents†	-0.250
Duration of bout	<b>-0.432**</b>
Response latency‡	0.070

† n = 35

‡ n = 29

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.15: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).

	Time of year
Number of responses	<b>-0.544**</b>
Number of respondents†	<b>-0.405*</b>
Duration of bout	<b>-0.485**</b>
Response latency‡	0.089

† n = 19

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.16: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).

	Time of year
Number of post-subject responses	0.029
Number of post-subject respondents†	0.198
Duration of post-subject subsection	0.008
Response latency of subject‡	0.064
Response latency of first post-subject call	-0.090
Total number of responses	-0.233
Duration of entire bout	-0.134
Response latency of entire bout	-0.101

† n = 14

‡ n = 15

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.17: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).

	Time of year
Number of post-subject responses	0.106
Number of post-subject respondents†	0.253
Duration of post-subject subsection	0.098
Response latency of subject‡	0.104
Response latency of first post-subject call	0.016
Total number of responses	-0.163
Duration of entire bout	-0.111
Response latency of entire bout	-0.109

† n = 15

‡ n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.18: Correlation of the time of year at which a jump-yip bout occurred and the characteristics of that bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).

	Time of year
Number of post-subject responses	0.043
Number of post-subject respondents†	0.157
Duration of post-subject subsection	0.039
Response latency of subject‡	0.012
Response latency of first post-subject call	-0.364
Total number of responses	-0.114
Duration of entire bout	-0.013
Response latency of entire bout	-0.195

† n = 10

‡ n = 11

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.19; F-P:  $n = 42$ ,  $r_s = 0.387$ ,  $P = 0.011$ ; Table F.20; F-PP:  $n = 24$ ,  $r_s = 0.353$ ,  $P = 0.091$ ; Table F.21), as well as with decreases in the number of pre-subject jump-yip bouts (F-P:  $n = 42$ ,  $r_s = -0.394$ ,  $P = 0.010$ ; Table F.20) and the total number of pre-subject jump-yips (F-I:  $n = 26$ ,  $r_s = -0.398$ ,  $P = 0.044$ ; F-P:  $n = 42$ ,  $r_s = -0.480$ ,  $P = 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.436$ ,  $P = 0.033$ ) and with pre-subject bouts which contained fewer responses (F-I:  $n = 20$ ,  $r_s = -0.428$ ,  $P = 0.059$ ; F-P:  $n = 33$ ,  $r_s = -0.494$ ,  $P = 0.004$ ; F-PP:  $n = 19$ ,  $r_s = -0.493$ ,  $P = 0.032$ ) and were of shorter durations (F-I:  $n = 20$ ,  $r_s = -0.541$ ,  $P = 0.014$ ; Table F.19; F-P:  $n = 33$ ,  $r_s = -0.516$ ,  $P = 0.002$ ; Table F.20; F-PP:  $n = 19$ ,  $r_s = -0.462$ ,  $P = 0.046$ ; Table F.21). The pre-subject bouts also had shorter response latencies (F-P:  $n = 33$ ,  $r_s = -0.350$ ,  $P = 0.046$ ; Table F.20), though this may reflect the unexpected variation in response latency discussed previously (Appendix E) and may again point to the relatively poor nature of response latency as an information-carrying component in jump-yip bouts. Likewise, “bout initiator” subject bouts occurring later in the year were also associated with fewer post-subject jump-yip bouts (F-I:  $n = 26$ ,  $r_s = -0.455$ ,  $P = 0.020$ ; F-P:  $n = 42$ ,  $r_s = -0.465$ ,  $P = 0.002$ ; F-PP:  $n = 24$ ,  $r_s = -0.433$ ,  $P = 0.035$ ) and the total number of post-subject jump-yips (F-I:  $n = 26$ ,  $r_s = -0.489$ ,  $P = 0.011$ ; Table F.19; F-P:  $n = 42$ ,  $r_s = -0.487$ ,  $P = 0.001$ ; Table F.20; F-PP:  $n = 24$ ,  $r_s = -0.413$ ,  $P = 0.045$ ; Table F.21) and with post-subject bouts which contained fewer responses (F-I:  $n = 17$ ,  $r_s = -0.507$ ,  $P = 0.038$ ), had shorter durations (F-I:  $n = 17$ ,  $r_s = -0.512$ ,  $P = 0.036$ ), and had shorter response latencies (F-I:  $n = 17$ ,  $r_s = -0.520$ ,  $P = 0.032$ ; Table F.19). Later in the year, there were also fewer post-subject chirps (F-I:  $n = 26$ ,  $r_s = -0.500$ ,  $P = 0.009$ ; Table F.19; F-PP:  $n = 24$ ,  $r_s = -0.459$ ,  $P = 0.024$ ; Table F.21), which could demonstrate the similarity between



Table F.19: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	Time of year
AGPOP	0.076
T2VOC	<b>0.392**</b>
PREBOUT	-0.290
PREJY	<b>-0.398**</b>
PRERESP†	<b>-0.428*</b>
PREDUR†	<b>-0.541**</b>
PRELAT†	-0.274
PRECHIRP	-0.068
PREAC	-0.143
POSTBOUT	<b>-0.455**</b>
POSTJY	<b>-0.489**</b>
POSTRESP‡	<b>-0.507**</b>
POSTDUR‡	<b>-0.512**</b>
POSTLAT‡	<b>-0.520**</b>
POSTCHIRP	<b>-0.500**</b>
POSTAC	<b>0.398**</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 20

‡ n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.20: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	Time of year
AGPOP	0.188
T2VOC	<b>0.387**</b>
PREBOUT	<b>-0.394**</b>
PREJY	<b>-0.480**</b>
PRERESP†	<b>-0.494**</b>
PREDUR†	<b>-0.516**</b>
PRELAT†	<b>-0.350**</b>
PRECHIRP	-0.065
PREAC	-0.247
POSTBOUT	<b>-0.465**</b>
POSTJY	<b>-0.487**</b>
POSTRESP‡	-0.283
POSTDUR‡	-0.255
POSTLAT‡	-0.280
POSTCHIRP	-0.221
POSTAC	-0.039

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 33

‡ n = 33

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.21: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).<sup>^</sup>

	Time of year
AGPOP	-0.060
T2VOC	<b>0.353*</b>
PREBOUT	-0.284
PREJY	<b>-0.436**</b>
PRERESP†	<b>-0.493**</b>
PREDUR†	<b>-0.462**</b>
PRELAT†	-0.234
PRECHIRP	-0.077
PREAC	-0.167
POSTBOUT	<b>-0.433**</b>
POSTJY	<b>-0.413**</b>
POSTRESP‡	-0.250
POSTDUR‡	-0.184
POSTLAT‡	-0.253
POSTCHIRP	<b>-0.459**</b>
POSTAC	0.078

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 19

‡ n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

chirps and jump-yips, though more study is required. There was also more post-subject alarm calling later in the year (F-I:  $n = 26$ ,  $r_s = 0.398$ ,  $P = 0.044$ ; Table F.19), which could signify a greater predation risk in the colder months. We might expect the opposite to be true, however, if predator activity decreases in the winter months. It is more likely that the observed correlations with both chirps and alarm calls arise not from the effects of time of year on the social environment, but instead from unmeasured extraneous variables.

The lack of variation in the “respondent” subject bouts at different times of year (Tables F.16, F.17, F.18), again casts doubt upon whether the correlations observed in the “bout initiator” groups demonstrate an effect of the time of year on bout characteristics, or whether the changes in subject bout characteristics are due to other factors. Fewer total pre-subject jump-yips were observed later in the year (R-I:  $n = 22$ ,  $r_s = -0.376$ ,  $P = 0.084$ ; Table F.22), matching the decrease in environmental jump-yipping observed in “bout initiator” groups, though the inverse relationships were only present for a single “respondent” group. Likewise, post-subject bouts were of shorter durations later in the year (R-P:  $n = 26$ ,  $r_s = -0.379$ ,  $P = 0.068$ ; Table F.23), again corresponding to the results observed in “bout initiator” groups, however, post-subject jump-yip bouts occurred more frequently later in the year (R-P:  $n = 26$ ,  $r_s = 0.349$ ,  $P = 0.081$ ; Table F.23; R-PP:  $n = 18$ ,  $r_s = 0.465$ ,  $P = 0.052$ ; Table F.24), opposing the observed variation in jump-yip bout frequency in the “bout initiator” groups. In both cases, however, the correlations were not universal among “respondent” groups, meaning that further study may be required to fully assess how jump-yipping varies at different times of year. As was the case in “bout initiator” groups, there was more post-subject

Table F.22: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).<sup>^</sup>

	Time of year
AGPOP	0.252
T2VOC	-0.123
PREBOUT	-0.173
PREJY	<b>-0.376*</b>
PRERESP†	-0.215
PREDUR†	-0.306
PRELAT†	-0.102
PRECHIRP	-0.139
PREAC	0.308
POSTBOUT	0.319
POSTJY	-0.036
POSTRESP‡	-0.248
POSTDUR‡	-0.365
POSTLAT‡	-0.213
POSTCHIRP	0.000
POSTAC	<b>0.415*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 21

‡ n = 20

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.23: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	Time of year
AGPOP	0.319
T2VOC	-0.138
PREBOUT	-0.169
PREJY	-0.305
PRERESP†	-0.099
PREDUR†	-0.187
PRELAT†	-0.035
PRECHIRP	-0.148
PREAC	0.281
POSTBOUT	<b>0.349*</b>
POSTJY	0.078
POSTRESP‡	-0.262
POSTDUR‡	<b>-0.379*</b>
POSTLAT‡	-0.150
POSTCHIRP	0.112
POSTAC	<b>0.383*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 25

‡ n = 23

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.24: Correlation of the time of year at which a jump-yip bout occurred and the social variables present at the time of the bout trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).<sup>^</sup>

	Time of year
AGPOP	0.368
T2VOC	-0.199
PREBOUT	-0.142
PREJY	-0.215
PRERESP†	-0.018
PREDUR†	-0.099
PRELAT†	0.006
PRECHIRP	-0.089
PREAC	0.338
POSTBOUT	<b>0.465*</b>
POSTJY	0.137
POSTRESP‡	-0.206
POSTDUR‡	-0.297
POSTLAT‡	-0.328
POSTCHIRP	0.089
POSTAC	<b>0.457*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† n = 17

‡ n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

alarm calling later in the year (R-I:  $n = 22$ ,  $r_s = 0.415$ ,  $P = 0.055$ ; Table F.22; R-P:  $n = 26$ ,  $r_s = 0.383$ ,  $P = 0.053$ ; Table F.23; R-PP:  $n = 18$ ,  $r_s = 0.457$ ,  $P = 0.057$ ; Table F.24), which could indicate that predation risk (real or perceived) is higher later in the year. It is also possible however, that alarm calls were simply more prevalent in the observational sessions which occurred later in the year, meaning direct studies of predatory events are required before such conclusions can be drawn.

Though not typically a focus of studies on the effects of the abiotic environment on animal behaviour, cloud cover may present visual impediments to predator identification, either by limiting the ambient light available to potential prey or by providing camouflage to approaching predators (particularly avian predators). These effects could alter the perceived predation risk of black-tailed prairie dogs, altering the characteristics of their displays (both jump-yips and other predation-related behaviours). Effects on available light could also alter the detectibility of jump-yips occurring in the environment, which could alter the characteristics of the resulting jump-yip bouts. When subject bouts occurred under clear skies, they contained significantly more responses (F-I:  $U = 15.0$ ,  $P = 0.014$ ) and respondents (F-I:  $U = 15.0$ ,  $P = 0.021$ ) and were of a longer duration (F-I:  $U = 15.0$ ,  $P = 0.016$ ; Table F.25) than under cloudy skies, but only for those bouts used in the examination of bout initiator behaviour immediately following jump-yip production. There was also some evidence of subject bouts having longer response latencies under clear skies (F-PP:  $U = 21.5$ ,  $P = 0.084$ ; Table F.27), which opposes the observed increases in the response magnitude in the subject bouts, but is consistent with the previous findings that response latency is positively correlated with response magnitude when jump-yip bouts are compared over longer periods of time



Table F.25: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in the subject jump-yip bouts.<sup>^</sup>

	Extent of cloud cover				Test statistics	
	Clear (n = 20)		Cloudy (n = 5)		U	Sig.
RESPS	<b>2.400</b>	$\pm$ <b>0.701</b>	<b>0.000</b>	$\pm$ <b>0.000</b>	<b>15.0**</b>	<b>0.014</b>
RPDTS <sup>†</sup>	<b>1.556</b>	$\pm$ <b>0.398</b>	<b>0.000</b>	$\pm$ <b>0.000</b>	<b>15.0**</b>	<b>0.021</b>
DUR	<b>2.701</b>	$\pm$ <b>0.696</b>	<b>0.000</b>	$\pm$ <b>0.000</b>	<b>15.0**</b>	<b>0.016</b>
LAT <sup>‡</sup>	0.708	$\pm$ 0.148	-	$\pm$ -	n/a	n/a

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> Clear: n = 18; Cloudy: n = 5

<sup>‡</sup> Clear: n = 14; Cloudy: n = 0

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.26: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in the subject jump-yip bouts over one minute following jump-yip production.<sup>^</sup>

	Extent of cloud cover			Test statistics	
	Clear (n = 29)	Partly cloudy (n = 7)	Cloudy (n = 6)	$\chi^2$	Sig.
RESPS	<b>2.517</b> ± <b>0.547</b>	<b>4.286</b> ± <b>1.128</b>	<b>0.833</b> ± <b>0.833</b>	<b>7.025**</b>	<b>0.027</b>
RPDTS†	<b>1.417</b> ± <b>0.318</b>	<b>3.000</b> ± <b>1.095</b>	<b>0.667</b> ± <b>0.667</b>	<b>5.373*</b>	<b>0.068</b>
DUR	<b>2.679</b> ± <b>0.572</b>	<b>3.969</b> ± <b>1.018</b>	<b>0.284</b> ± <b>0.284</b>	<b>8.199**</b>	<b>0.011</b>
LAT‡	0.760 ± 0.120	1.346 ± 0.375	0.400 ± -	47.0#	0.296#

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Clear: n = 24; Partly Cloudy: n = 5; Cloudy: n = 6

‡ Clear: n = 21; Partly Cloudy: n = 7; Cloudy: n = 1

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.27: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of initial callers in the subject jump-yip bouts.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 18)	Cloudy (n = 5)	U	Sig.
RESPS	3.000 ± 0.767	1.600 ± 1.030	29.0	0.239
RPDTS <sup>†</sup>	1.786 ± 0.471	1.000 ± 1.000	16.0	0.241
DUR	<b>3.281 ± 0.778</b>	<b>0.760 ± 0.469</b>	<b>21.5*</b>	<b>0.084</b>
LAT <sup>‡</sup>	0.695 ± 0.141	0.395 ± 0.005	n/a	n/a

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> Clear: n = 14; Cloudy: n = 4

<sup>‡</sup> Clear: n = 15; Cloudy: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

(Appendix E). Also, since contrasting the presence of an aerial predator against clear skies should be easier, we might expect there to be more response under cloudy skies (where the risk of predation is higher, collective vigilance could be expected to increase).

Furthermore, in some “bout initiator” sessions, subject bouts simply contained different number of responses (F-P:  $\chi^2 = 7.025$ ,  $P = 0.027$ ) and respondents (F-P:  $\chi^2 = 5.373$ ,  $P = 0.068$ ) and were of different durations (F-P:  $\chi^2 = 8.199$ ,  $P = 0.011$ ; Table F.26) under different levels of cloud, without any obvious trends, while in a “respondent” group, there were more responses in the entire subject bouts occurring under partly cloudy skies than under clear skies (R-I:  $U = 26.5$ ,  $P = 0.098$ ; Table F.28). Likewise, the entire subject bouts used in examining the behaviour of respondents over the minute following jump-yip production contained different numbers of responses (R-P:  $\chi^2 = 6.323$ ,  $P = 0.029$ ) and had different response latencies (R-P:  $\chi^2 = 5.344$ ,  $P = 0.057$ ; Table F.29) under different levels of cloud cover, though no trends were apparent (the most responses and shortest latencies were found under partly cloudy skies). Consequently, it would appear that the level of cloud cover in an environment does not strongly affect the characteristics of single black-tailed prairie dog jump-yip bouts.

When the jump-yip bouts occurring over a longer period of time (i.e. environmental jump-yip bouts) are examined, similar differences are observed. “Bout initiator” subject bouts occurring under cloudy skies were associated with the latest first post-subject, non-subject vocalizations (F-I:  $U = 24.5$ ,  $P = 0.071$ ; Table F.31; F-P:  $\chi^2 = 10.580$ ,  $P = 0.003$ ; Table F.32), while under clear skies, pre-subject bouts contained more responses (F-I:  $U = 9.5$ ,  $P = 0.040$ ; F-PP:  $U = 7.5$ ,  $P = 0.028$ ; Table F.33)

Table F.28: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of respondents in the subject jump-yip bouts.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 12)	Partly cloudy (n = 8)	U	Sig.
SUBRESP	3.500 ± 1.125	7.375 ± 2.535	34.0	0.280
SUBRPDT <sup>†</sup>	1.667 ± 0.726	0.333 ± 0.333	9.0	0.473
SUBDUR	2.225 ± 0.708	5.440 ± 1.751	30.0	0.164
OWNLAT	1.094 ± 0.227	1.088 ± 0.324	45.5	0.867
SUBLAT <sup>‡</sup>	0.544 ± 0.121	0.891 ± 0.374	20.5	0.683
TOTRESP	<b>8.917 ± 2.151</b>	<b>15.750 ± 3.390</b>	<b>26.5*</b>	<b>0.098</b>
TOTDUR	7.723 ± 1.729	13.461 ± 2.875	29.0	0.159
INITLAT	1.159 ± 0.211	1.012 ± 0.303	39.0	0.523

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> Clear: n = 9; Partly cloudy: n = 3

<sup>‡</sup> Clear: n = 8; Partly cloudy: n = 6

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.29: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of respondents in the subject jump-yip bouts over the minute following jump-yip production.<sup>^</sup>

	Extent of cloud cover			Test statistics	
	Clear (n = 13)	Partly cloudy (n = 10)	Cloudy (n = 3)	$\chi^2$	Sig.
SUBRESP	3.231 ± 1.069	8.200 ± 2.139	2.667 ± 2.186	3.635	0.152
SUBRPDT <sup>†</sup>	1.500 ± 0.671	0.333 ± 0.333	0.500 ± 0.500	11.0#	0.639
SUBDUR	2.054 ± 0.673	5.833 ± 1.447	1.838 ± 1.700	3.915	0.132
OWNLAT	1.059 ± 0.210	1.057 ± 0.273	2.393 ± 0.771	3.995	0.127
SUBLAT <sup>‡</sup>	0.544 ± 0.121	0.756 ± 0.288	1.158 ± 0.603	31.5#	0.983
TOTRESP	<b>8.385 ± 2.049</b>	<b>15.800 ± 2.820</b>	<b>4.000 ± 2.082</b>	<b>6.323**</b>	<b>0.029</b>
TOTDUR	7.496 ± 1.612	12.584 ± 2.408	5.570 ± 2.366	3.574	0.161
INITLAT	<b>1.357 ± 0.277</b>	<b>0.889 ± 0.253</b>	<b>2.595 ± 0.796</b>	<b>5.344*</b>	<b>0.057</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

<sup>†</sup> Clear: n = 10; Partly Cloudy: n = 3; Cloudy: n = 2

<sup>‡</sup> Clear: n = 8; Partly Cloudy: n = 8; Cloudy: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.30: The effect of cloud cover on the response characteristics of the subject jump-yip bouts used in the analysis of the changes in the post-jump-yip changes in the behaviour of respondents in the subject jump-yip bouts.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 8)	Partly cloudy (n = 9)	U	Sig.
SUBRESP	2.500 ± 1.476	7.444 ± 2.237	20.0	0.124
SUBRPDT <sup>†</sup>	0.333 ± 0.211	0.333 ± 0.333	9.0	1.000
SUBDUR	1.711 ± 0.947	5.404 ± 1.545	20.0	0.127
OWNLAT	1.148 ± 0.265	1.001 ± 0.299	25.0	0.304
SUBLAT <sup>‡</sup>	0.545 ± 0.088	0.821 ± 0.324	13.5	0.971
TOTRESP	10.000 ± 3.174	15.111 ± 3.057	24.0	0.266
TOTDUR	9.281 ± 2.351	12.558 ± 2.692	29.0	0.539
INITLAT	1.218 ± 0.243	0.932 ± 0.278	20.0	0.141

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> Clear: n = 6; Cloudy: n = 3

<sup>‡</sup> Clear: n = 4; Cloudy: n = 7

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.31: The effect of cloud cover on the social variables present at the time of the subject jump-yip bout for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 20)	Cloudy (n = 5)	U	Sig.
AGPOP	8.950 ± 0.766	10.600 ± 3.842	46.0	0.809
T2VOC	27.200 ± 4.667	43.200 ± 10.365	28.0	0.138
PREBOUT	2.750 ± 0.491	1.200 ± 0.374	30.5	0.186
PREJY	7.000 ± 1.458	1.800 ± 0.735	28.0	0.138
PRERESP†	<b>1.583 ± 0.285</b>	<b>0.375 ± 0.239</b>	<b>9.5**</b>	<b>0.040</b>
PREDUR†	<b>1.866 ± 0.398</b>	<b>0.404 ± 0.298</b>	<b>10.0*</b>	<b>0.055</b>
PRELAT†	0.554 ± 0.116	0.344 ± 0.268	18.0	0.267
PRECHIRP	0.100 ± 0.069	0.000 ± 0.000	45.0	1.000
PREAC	5.000 ± 2.454	2.600 ± 2.600	46.5	0.781
POSTBOUT	<b>2.350 ± 0.443</b>	<b>0.200 ± 0.200</b>	<b>16.0**</b>	<b>0.019</b>
POSTJY	<b>4.650 ± 1.024</b>	<b>0.200 ± 0.200</b>	<b>15.5**</b>	<b>0.013</b>
POSTRESP‡	0.909 ± 0.184	0.000 ± -	n/a	n/a
POSTDUR‡	1.041 ± 0.216	0.000 ± -	n/a	n/a
POSTLAT‡	0.443 ± 0.104	0.000 ± -	n/a	n/a
POSTCHIRP	0.250 ± 0.176	0.000 ± 0.000	45.0	1.000
POSTAC	2.350 ± 1.854	2.400 ± 2.400	45.0	0.863

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 15; Cloudy: n = 4

‡ Clear: n = 15; Cloudy: n = 1

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.32: The effect of cloud cover on the social variables present during the subject jump-yip bout for trials where the behaviours of bout initiators in the minute following jump-yip production were analyzed.<sup>^</sup>

	Extent of cloud cover			Test statistics	
	Clear (n = 29)	Partly cloudy (n = 7)	Cloudy (n = 6)	$\chi^2$	Sig.
AGPOP	10.103 ± 0.692	8.143 ± 1.370	14.667 ± 5.136	0.807	0.677
T2VOC	<b>25.897 ± 3.413</b>	<b>9.571 ± 0.948</b>	<b>37.500 ± 10.204</b>	<b>10.580**</b>	<b>0.003</b>
PREBOUT	<b>2.414 ± 0.376</b>	<b>4.429 ± 0.481</b>	<b>1.000 ± 0.365</b>	<b>9.710**</b>	<b>0.005</b>
PREJY	<b>7.035 ± 1.464</b>	<b>20.143 ± 3.074</b>	<b>1.500 ± 0.671</b>	<b>14.181**</b>	<b>&lt;0.001</b>
PRERESP†	<b>1.909 ± 0.456</b>	<b>3.869 ± 0.981</b>	<b>0.375 ± 0.239</b>	<b>10.207**</b>	<b>0.003</b>
PREDUR†	<b>2.180 ± 0.527</b>	<b>4.825 ± 1.189</b>	<b>0.404 ± 0.298</b>	<b>10.802**</b>	<b>0.002</b>
PRELAT†	0.537 ± 0.096	0.754 ± 0.138	0.344 ± 0.268	3.476	0.179
PRECHIRP	0.069 ± 0.048	0.000 ± 0.000	0.000 ± 0.000	0.919	1.000
PREAC	<b>4.724 ± 2.233</b>	<b>26.143 ± 10.771</b>	<b>2.167 ± 2.167</b>	<b>8.570**</b>	<b>0.010</b>
POSTBOUT	<b>2.448 ± 0.360</b>	<b>4.143 ± 0.634</b>	<b>0.333 ± 0.211</b>	<b>12.487**</b>	<b>&lt;0.001</b>
POSTJY	<b>6.552 ± 1.373</b>	<b>12.429 ± 2.298</b>	<b>0.500 ± 0.342</b>	<b>12.111**</b>	<b>0.001</b>
POSTRESP‡	1.539 ± 0.396	1.845 ± 0.463	0.500 ± 0.500	61.0#	0.286
POSTDUR‡	1.715 ± 0.432	2.102 ± 0.586	1.580 ± 1.580	67.0#	0.442
POSTLAT‡	0.501 ± 0.106	0.754 ± 0.192	1.525 ± 1.525	53.0#	0.148
POSTCHIRP	0.241 ± 0.137	0.143 ± 0.143	0.167 ± 0.167	0.114	1.000
POSTAC	<b>1.931 ± 1.301</b>	<b>31.857 ± 11.352</b>	<b>2.000 ± 2.000</b>	<b>8.675**</b>	<b>0.013</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Clear: n = 22; Partly Cloudy: n = 7; Cloudy: n = 4

‡ Clear: n = 24; Partly Cloudy: n = 7; Cloudy: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.33: The effect of cloud cover on the social variables present at the time of the subject jump-yip bout for trials where the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 18)	Cloudy (n = 5)	U	Sig.
AGPOP	9.167 ± 0.746	12.200 ± 5.945	38.0	0.618
T2VOC	26.833 ± 4.704	33.600 ± 11.084	37.5	0.603
PREBOUT	2.944 ± 0.521	1.400 ± 0.400	26.5	0.177
PREJY	8.889 ± 2.119	2.200 ± 0.735	22.5	0.100
PRERESP†	<b>2.219 ± 0.677</b>	<b>0.500 ± 0.204</b>	<b>7.5**</b>	<b>0.028</b>
PREDUR†	<b>2.322 ± 0.751</b>	<b>0.446 ± 0.281</b>	<b>8.0**</b>	<b>0.036</b>
PRELAT†	0.505 ± 0.093	0.369 ± 0.258	18.0	0.328
PRECHIRP	0.111 ± 0.076	0.000 ± 0.000	40.0	1.000
PREAC	7.056 ± 3.478	2.600 ± 2.600	40.5	0.788
POSTBOUT	<b>2.333 ± 0.464</b>	<b>0.600 ± 0.400</b>	<b>19.5*</b>	<b>0.057</b>
POSTJY	5.833 ± 1.799	3.000 ± 2.530	28.0	0.208
POSTRESP‡	1.450 ± 0.632	3.250 ± 2.250	n/a	n/a
POSTDUR‡	1.579 ± 0.691	3.980 ± 0.820	n/a	n/a
POSTLAT‡	0.432 ± 0.111	2.104 ± 0.946	n/a	n/a
POSTCHIRP	0.278 ± 0.195	0.200 ± 0.200	42.0	1.000
POSTAC	2.444 ± 2.023	2.400 ± 2.400	41.0	0.851

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 14; Cloudy: n = 4

‡ Clear: n = 14; Cloudy: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

and were of longer durations (F-I:  $U = 10.0$ ,  $P = 0.055$ ; F-PP:  $U = 8.0$ ,  $P = 0.036$ ). Post-subject jump-yip bouts (F-I:  $U = 16.0$ ,  $P = 0.019$ ; F-PP:  $U = 19.5$ ,  $P = 0.057$ ) and the total number of post-subject jump-yips (F-I:  $U = 15.5$ ,  $P = 0.013$ ) were also more plentiful under clear skies. But again, as in the case of subject bouts used to examine the behaviour of bout initiators over the minute following jump-yip production, the greatest number of pre-subject bouts (F-P:  $\chi^2 = 9.710$ ,  $P = 0.005$ ) and total number of pre-subject jump-yips (F-P:  $\chi^2 = 14.181$ ,  $P < 0.001$ ), the greatest number of responses in (F-P:  $\chi^2 = 10.207$ ,  $P = 0.003$ ) and the longest durations of (F-P:  $\chi^2 = 10.802$ ,  $P = 0.002$ ) the pre-subject bouts, as well as the greatest number of post-subject bouts (F-P:  $\chi^2 = 12.487$ ,  $P = <0.001$ ) and total number of post-subject jump-yips (F-P:  $\chi^2 = 12.111$ ,  $P = 0.001$ ; Table F.32), were observed under partly cloudy skies. These results further demonstrate that cloud cover exhibited little directed effect on the characteristics of jump-yipping in the environment (i.e. there were no increases or decreases in response under increasing levels of cloud cover). Similarly, the most pre-subject alarm calling (F-P:  $\chi^2 = 8.570$ ,  $P = 0.010$ ), and the most post-subject alarm calling (F-P:  $\chi^2 = 8.675$ ,  $P = 0.013$ ; Table F.32) were all found under partly cloudy skies, further demonstrating the lack of directed effects of cloud cover on the characteristics of vocalizations (or the risk of predation), though more study is required before conclusions can be drawn on the effect of cloud cover on perceived predation risk.

Similarly, “respondent” subject bouts occurring under clear skies were associated with pre-subject bouts that contained the greatest number of responses (R-I:  $U = 24.5$ ,  $P = 0.075$ ) and were of the longest duration (R-I:  $U = 26.0$ ,  $P = 0.098$ ; Table F.34) as well as with the greatest number of total post-subject jump-yips (R-I:  $U = 21.5$ ,

Table F.34: The effect of cloud cover on the social variables present at the time of subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in those bouts were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 12)	Partly cloudy (n = 8)	U	Sig.
AGPOP	7.750 ± 0.719	7.250 ± 1.656	41.0	0.612
T2VOC	13.750 ± 4.486	12.875 ± 2.039	35.5	0.352
PREBOUT	4.500 ± 0.314	4.125 ± 0.515	39.0	0.514
PREJY	18.167 ± 3.072	24.875 ± 2.580	30.5	0.186
PRERESP†	<b>3.229 ± 0.887</b>	<b>6.249 ± 1.692</b>	<b>24.5*</b>	<b>0.075</b>
PREDUR†	<b>3.239 ± 0.782</b>	<b>6.030 ± 1.423</b>	<b>26.0*</b>	<b>0.098</b>
PRELAT†	0.723 ± 0.110	0.706 ± 0.130	45.0	0.853
PRECHIRP	0.167 ± 0.167	0.500 ± 0.378	40.0	0.432
PREAC	14.000 ± 5.487	11.250 ± 7.466	48.0	1.000
POSTBOUT†	3.636 ± 0.378	3.875 ± 0.479	38.0	0.620
POSTJY†	<b>16.273 ± 2.660</b>	<b>24.875 ± 2.991</b>	<b>21.5*</b>	<b>0.068</b>
POSTRESP‡	3.667 ± 0.829	6.288 ± 1.581	30.0	0.274
POSTDUR‡	4.244 ± 0.853	7.297 ± 1.711	27.0	0.182
POSTLAT‡	1.175 ± 0.173	0.827 ± 0.209	30.0	0.276
POSTCHIRP	<b>0.000 ± 0.000</b>	<b>0.500 ± 0.267</b>	<b>30.0**</b>	<b>0.050</b>
POSTAC	12.417 ± 5.803	17.125 ± 6.898	43.0	0.695

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 11; partly cloudy: n = 8

‡ Clear: n = 10; partly cloudy: n = 8

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

$P = 0.068$ ). These results were consistent with those previously discussed in the “bout initiator” groups, though not as numerous. There were also more post-subject chirps under clear skies (R-I:  $U = 30.0$ ,  $P = 0.050$ ; Table F.34), which could demonstrate a similarity between chirps and jump-yips, though again more study is required before this conclusion can be drawn. There were also non-linear differences in the characteristics of environmental jump-yip bouts with differences in cloud cover for certain “respondent” sessions. There were more pre-subject bouts under clear skies compared to under cloudy skies (R-P:  $\chi^2 = 8.007$ ,  $P = 0.010$ ), however, the greatest number of total pre-subject jump-yips were found under partly cloudy skies (R-P:  $\chi^2 = 7.995$ ,  $P = 0.010$ ; Table F.35). Similarly, pre-subject bouts contained more responses (R-P:  $\chi^2 = 5.271$ ,  $P = 0.066$ ) and were of longer durations (R-P:  $\chi^2 = 6.081$ ,  $P = 0.039$ ; Table F.35) under partly cloudy skies. There were also more total post-subject jump-yips under partly cloudy skies (R-P:  $\chi^2 = 8.449$ ,  $P = 0.007$ ), while the post-subject bouts also contained more responses (R-P:  $\chi^2 = 4.964$ ,  $P = 0.081$ ) and were of longer duration (R-P:  $\chi^2 = 6.370$ ,  $P = 0.030$ ) under cloudy skies. These results were consistent with those seen in “bout initiator” groups, and again point to cloud cover as not exerting major directed effects (or any effects; R-PP – Table F.36) on the characteristics of environmental vocalizations. The smallest number of post-subject chirps were observed under clear skies (R-P:  $\chi^2 = 4.589$ ,  $P = 0.078$ ; Table F.35), which opposes the increase in jump-yips observed and further indicates the need to establish the form and function of the chirp as a vocalization.

Changes in wind intensity may affect both the propagation characteristics of the acoustic portion of the jump-yip display, as well as any acoustic indications of predator approach. Strong winds may also produce movement in the flora which make up the

Table F.35: The effect of cloud cover on the social variables present during subject jump-yip bouts for trials where the behaviours of respondents in those bouts in the minute following their jump-yip were analyzed.<sup>^</sup>

	Extent of cloud cover			Test statistics	
	Clear (n = 13)	Partly cloudy (n = 10)	Cloudy (n = 3)	$\chi^2$	Sig.
AGPOP	7.769 ± 0.662	8.800 ± 1.724	10.000 ± 3.055	0.894	0.654
T2VOC	17.308 ± 5.448	12.900 ± 1.670	15.667 ± 2.906	1.646	0.453
PREBOUT	<b>4.385 ± 0.311</b>	<b>4.000 ± 0.471</b>	<b>1.333 ± 0.333</b>	<b>8.007**</b>	<b>0.010</b>
PREJY	<b>17.000 ± 3.057</b>	<b>27.000 ± 3.599</b>	<b>6.000 ± 3.000</b>	<b>7.995**</b>	<b>0.010</b>
PRERESP†	<b>2.981 ± 0.853</b>	<b>7.809 ± 2.403</b>	<b>3.000 ± 1.000</b>	<b>5.271*</b>	<b>0.066</b>
PREDUR†	<b>2.990 ± 0.761</b>	<b>7.334 ± 2.032</b>	<b>1.560 ± 1.038</b>	<b>6.081**</b>	<b>0.039</b>
PRELAT†	0.668 ± 0.116	0.687 ± 0.106	0.373 ± 0.098	2.217	0.338
PRECHIRP	0.154 ± 0.154	0.400 ± 0.306	0.000 ± 0.000	1.226	0.599
PREAC	12.923 ± 5.161	10.800 ± 5.964	0.000 ± 0.000	2.343	0.332
POSTBOUT	3.077 ± 0.473	3.900 ± 0.379	2.333 ± 0.333	4.101	0.129
POSTJY	<b>13.769 ± 2.804</b>	<b>23.300 ± 2.688</b>	<b>5.333 ± 1.856</b>	<b>8.449**</b>	<b>0.007</b>
POSTRESP‡	<b>3.667 ± 0.829</b>	<b>5.680 ± 1.324</b>	<b>1.444 ± 1.029</b>	<b>4.964*</b>	<b>0.081</b>
POSTDUR‡	<b>4.244 ± 0.853</b>	<b>6.721 ± 1.405</b>	<b>1.396 ± 1.171</b>	<b>6.172**</b>	<b>0.040</b>
POSTLAT‡	1.175 ± 0.173	0.963 ± 0.188	0.591 ± 0.424	1.486	0.488
POSTCHIRP	<b>0.000 ± 0.000</b>	<b>0.400 ± 0.221</b>	<b>0.667 ± 0.667</b>	<b>4.589*</b>	<b>0.078</b>
POSTAC	11.462 ± 5.423	13.900 ± 5.853	0.000 ± 0.000	2.297	0.345

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 12; Partly Cloudy: n = 10; Cloudy: n = 3

‡ Clear: n = 10; Partly Cloudy: n = 10; Cloudy: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.36: The effect of cloud cover on the social variables present during the subject jump-yip bouts for trials where post-jump-yip changes in the behaviours of respondents in those bouts were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 8)	Partly cloudy (n = 9)	U	Sig.
AGPOP	6.750 ± 0.861	8.444 ± 1.886	32.0	0.719
T2VOC	16.500 ± 6.609	12.556 ± 1.827	31.0	0.659
PREBOUT	4.500 ± 0.378	4.222 ± 0.465	31.5	0.689
PREJY	21.375 ± 3.973	24.111 ± 2.400	34.5	0.913
PRERESP†	4.067 ± 1.217	5.843 ± 1.546	25.5	0.339
PREDUR†	4.186 ± 1.014	5.672 ± 1.305	29.0	0.539
PRELAT†	0.789 ± 0.155	0.712 ± 0.115	31.0	0.667
PRECHIRP	0.250 ± 0.250	0.444 ± 0.338	32.5	0.859
PREAC	13.625 ± 7.265	10.333 ± 6.648	34.0	0.879
POSTBOUT	2.750 ± 0.453	3.889 ± 0.423	19.0	0.108
POSTJY	15.250 ± 3.881	23.444 ± 3.001	20.5	0.149
POSTRESP‡	4.512 ± 1.120	5.811 ± 1.474	30.0	0.895
POSTDUR‡	5.245 ± 1.082	6.926 ± 1.554	28.0	0.753
POSTLAT‡	1.385 ± 0.132	0.901 ± 0.198	18.0	0.173
POSTCHIRP	0.000 ± 0.000	0.444 ± 0.242	24.0	0.209
POSTAC	10.000 ± 7.514	15.444 ± 6.312	28.0	0.450

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 7; Cloudy: n = 9

‡ Clear: n = 6; Cloudy: n = 9

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

prairie dogs' environment, adversely affecting the quality of even the visual component of the jump-yip display. Consequently, the vigilance of black-tailed prairie dogs may be greater under higher levels of wind, while increases in the rate of jump-yipping (and the level of response in jump-yip bouts) may also increase owing to the need for the social group to be more vigilant. The majority of characteristics of "bout initiator" subject bouts, however, did not vary with changes in the level of wind at the time of the bouts (Tables F.37, F.39) – the subject bouts did have longer latencies under high winds (F-P:  $\chi^2 = 4.905$ ,  $P = 0.078$ ; Table F.38) which opposes the expected decrease in latency (and therefore increase in collective vigilance) under higher wind conditions (and which again may show that latency is not an ideal information-carrying component of a vocal signal), but only in one "bout initiator" group. The subject-initiated sections of the "respondent" subject bouts did vary significantly under different levels of wind, but they contained more responses (R-I:  $\chi^2 = 5.960$ ,  $P = 0.047$ ; R-P:  $\chi^2 = 6.447$ ;  $P = 0.034$ ), more respondents (R-P:  $U = 11.5$ ,  $P = 0.082$ ; R-PP:  $U = 2.5$ ,  $P = 0.051$ ; Table F.42) and were of longer duration (R-I:  $\chi^2 = 6.243$ ,  $P = 0.040$ ; Table F.40; R-P:  $\chi^2 = 7.009$ ,  $P = 0.025$ ; Table F.41) under calm conditions, a result which opposed the expected increased vigilance (and therefore increased response) under windy conditions. The response latency of the entire subject bout was also significantly different under different levels of wind, though no trends were apparent (R-I:  $\chi^2 = 9.508$ ,  $P = 0.004$ ; Table F.40; R-P:  $\chi^2 = 8.396$ ,  $P = 0.011$ ; Table F.41). Subject-initiated sections of "respondent" subject bouts also contained different numbers of respondents under different wind conditions (R-PP:  $\chi^2 = 5.786$ ,  $P = 0.036$ ; Table F.42), though again no trends were apparent. As was the case for the effects of cloud cover, the characteristics of the subject



Table F.37: The effect of wind intensity on the response characteristics of subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in those jump-yip bouts.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 13)	Low (n = 8)	High (n = 3)	$\chi^2$	Sig.
RESPS	1.923 ± 1.016	2.500 ± 0.824	2.333 ± 1.856	1.500	0.510
RPDTS <sup>†</sup>	0.917 ± 0.434	2.500 ± 0.824	0.500 ± 0.500	27.5#	0.102
DUR	1.970 ± 0.927	2.116 ± 0.774	3.693 ± 2.317	1.215	0.561
LAT <sup>‡</sup>	0.625 ± 0.301	0.688 ± 0.168	1.115 ± 0.115	12.0#	0.367

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

<sup>†</sup> Calm: n = 12; Low: n = 8; High: n = 2

<sup>‡</sup> Calm: n = 6; Low: n = 6; High: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.38: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in those jump-yip bouts over the minute following jump-yip production.<sup>^</sup>

	Wind intensity				Test statistics	
	Calm (n = 19)	Low (n = 12)	Moderate (n = 3)	High (n = 8)	$\chi^2$	Sig.
RESPS	1.895 ± 0.733	2.750 ± 0.676	2.000 ± 1.155	4.125 ± 1.156	4.867	0.183
RPDTS†	1.056 ± 0.347	2.364 ± 0.607	1.000 ± 1.000	1.500 ± 1.190	3.758	0.150
DUR	1.622 ± 0.647	2.766 ± 0.724	2.045 ± 1.057	4.628 ± 1.238	5.772	0.118
LAT‡	<b>0.561 ± 0.182</b>	<b>0.865 ± 0.165</b>	<b>1.540 ± 0.940</b>	<b>1.207 ± 0.317</b>	<b>4.905*</b>	<b>0.078</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 18; Low: n = 11; Moderate: n = 2; High: n = 4

‡ Calm: n = 10; Low: n = 10; Moderate: n = 2; High: n = 7

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.39: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of post-jump-yip changes in the behaviour of initial callers in those jump-yip bouts.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 12)	Low (n = 7)	High (n = 3)	$\chi^2$	Sig.
RESPS	2.583 ± 1.083	2.857 ± 0.857	4.333 ± 1.667	2.436	0.313
RPDTS†	1.400 ± 0.562	2.857 ± 0.857	1.000 ± -	21.0#	0.167
DUR	2.224 ± 0.960	2.461 ± 0.811	6.332 ± 1.608	4.335	0.120
LAT‡	0.550 ± 0.221	0.717 ± 0.179	0.877 ± 0.247	2.448	0.315

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Calm: n = 10; Low: n = 7; High: n = 1

‡ Calm: n = 8; Low: n = 6; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.40: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of respondents in those jump-yip bouts.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 6)	Moderate (n = 8)	High (n = 8)	$\chi^2$	Sig.
SUBRESP	<b>8.333</b> ± <b>2.376</b>	<b>4.750</b> ± <b>2.144</b>	<b>1.750</b> ± <b>1.048</b>	<b>5.960**</b>	<b>0.047</b>
SUBRPDT <sup>†</sup>	0.000 ± -	1.667 ± 0.615	1.000 ± 0.845	11.0#	0.144
SUBDUR	<b>5.968</b> ± <b>1.878</b>	<b>3.230</b> ± <b>1.286</b>	<b>1.107</b> ± <b>0.717</b>	<b>6.243**</b>	<b>0.040</b>
OWNLAT	1.536 ± 0.343	0.769 ± 0.274	1.239 ± 0.282	3.684	0.165
SUBLAT <sup>‡</sup>	0.735 ± 0.183	0.731 ± 0.330	0.485 ± 0.093	1.112	0.606
TOTRESP	11.500 ± 3.413	11.000 ± 2.557	10.000 ± 4.066	0.687	0.725
TOTDUR	10.328 ± 2.829	9.198 ± 2.342	9.034 ± 3.125	0.564	0.769
INITLAT	<b>1.103</b> ± <b>0.238</b>	<b>0.582</b> ± <b>0.103</b>	<b>1.849</b> ± <b>0.321</b>	<b>9.508**</b>	<b>0.004</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

<sup>†</sup> Calm: n = 1; Moderate: n = 6; High: n = 7

<sup>‡</sup> Calm: n = 5; Moderate: n = 7; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.41: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of respondents in those jump-yip bouts over the minute following jump-yip production.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 7)	Low (n = 9)	High (n = 10)	$\chi^2$	Sig.
SUBRESP	<b>8.143</b> ± <b>2.017</b>	<b>5.889</b> ± <b>2.208</b>	<b>2.200</b> ± <b>1.062</b>	<b>6.447**</b>	<b>0.034</b>
SUBRPDT <sup>†</sup>	<b>0.000</b> ± -	<b>1.667</b> ± <b>0.615</b>	<b>0.875</b> ± <b>0.743</b>	<b>11.5*#</b>	<b>0.082</b>
SUBDUR	<b>5.863</b> ± <b>1.591</b>	<b>3.947</b> ± <b>1.342</b>	<b>1.398</b> ± <b>0.709</b>	<b>7.009**</b>	<b>0.025</b>
OWNLAT	1.849 ± 0.427	0.877 ± 0.252	1.067 ± 0.251	3.644	0.160
SUBLAT <sup>‡</sup>	0.906 ± 0.227	0.678 ± 0.291	0.464 ± 0.069	2.448	0.308
TOTRESP	11.000 ± 2.928	12.222 ± 2.565	9.200 ± 3.306	1.370	0.520
TOTDUR	10.176 ± 2.396	9.620 ± 2.107	8.219 ± 2.525	1.350	0.523
INITLAT	<b>1.478</b> ± <b>0.426</b>	<b>0.573</b> ± <b>0.091</b>	<b>1.882</b> ± <b>0.361</b>	<b>8.396**</b>	<b>0.011</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney test

<sup>†</sup> Calm: n = 1; Low: n = 6; High: n = 8

<sup>‡</sup> Calm: n = 6; Low: n = 8; High: n = 4

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.42: The effect of wind intensity on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of respondents in those jump-yip bouts.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 5)	Low (n = 6)	High (n = 7)	$\chi^2$	Sig.
SUBRESP	8.200 ± 2.905	5.167 ± 2.903	2.143 ± 1.388	4.133	0.126
SUBRPDT <sup>†</sup>	<b>0.000</b> ± -	<b>0.750</b> ± <b>0.250</b>	<b>0.000</b> ± <b>0.000</b>	<b>2.5*#</b>	<b>0.051</b>
SUBDUR	6.012 ± 2.300	3.654 ± 1.716	1.478 ± 0.954	3.604	0.170
OWNLAT	1.527 ± 0.420	0.973 ± 0.330	0.826 ± 0.228	1.303	0.542
SUBLAT <sup>‡</sup>	0.601 ± 0.160	0.904 ± 0.449	0.500 ± 0.100	10.0#	1.000
TOTRESP	11.800 ± 4.164	13.000 ± 2.989	11.429 ± 4.509	0.432	0.814
TOTDUR	10.715 ± 3.433	11.528 ± 2.427	9.384 ± 3.588	1.139	0.579
INITLAT	1.007 ± 0.268	0.685 ± 0.105	1.436 ± 0.366	2.245	0.354

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

<sup>†</sup> Calm: n = 1; Low: n = 4; High: n = 5

<sup>‡</sup> Calm: n = 4; Low: n = 5; High: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

bouts did not differ linearly with increases or decreases in wind intensity, and may indicate that wind intensity does not exert a major effect on the characteristics of jump-yip bouts.

These results were consistent with the variation in environmental jump-yipping observed under different wind intensities. Pre-subject jump-yip bouts under low wind conditions contained the most responses (F-I:  $\chi^2 = 5.759$ ,  $P = 0.045$ ) and were of the longest duration (F-I:  $\chi^2 = 5.786$ ,  $P = 0.043$ ; Table F.43). The social variables present at the time of “bout initiator” subject bouts did not, however, vary linearly with changes in wind intensity. The greatest number of pre-subject bouts (F-P:  $\chi^2 = 12.613$ ,  $P = 0.002$ ) and total number of pre-subject jump-yips (F-P:  $\chi^2 = 16.831$ ,  $P < 0.001$ ; Table F.44; F-PP:  $\chi^2 = 6.540$ ,  $P = 0.028$ ; Table F.45) were found under high and low wind conditions (the fewest pre-subject jump-yips were found under calm conditions). Similarly, pre subject bouts contained the fewest responses (F-P:  $\chi^2 = 15.509$ ,  $P < 0.001$ ; Table F.44; F-PP:  $\chi^2 = 6.812$ ,  $P = 0.023$ ; Table F.45), were of the shortest duration (F-P:  $\chi^2 = 16.557$ ,  $P = <0.001$ ; F-PP:  $\chi^2 = 6.268$ ,  $P = 0.037$ ), and contained the shortest response latencies (F-P:  $\chi^2 = 7.533$ ,  $P = 0.042$ ) under calm conditions (though, again, in sessions examining bout initiator behaviour over the minute following jump-yip production, the magnitude of response in the subject jump-yip bouts were greatest in both low and high wind conditions). In addition to these results further demonstrating the lack of linear differences in the characteristics of environmental jump-yipping, they again demonstrate the lack of inverse relationship between the magnitude of response in a bout and the response latency of the bout – more evidence that response latency may be a poor information-carrying component of a jump-yip display.

Table F.43: The effect of wind intensity on the social variables present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 13)	Low (n = 8)	High (n = 3)	$\chi^2$	Sig.
AGPOP	8.846 ± 1.636	10.500 ± 0.500	8.000 ± 3.606	1.930	0.396
T2VOC	33.846 ± 6.266	33.375 ± 8.155	12.333 ± 3.333	2.866	0.248
PREBOUT	1.846 ± 0.478	2.875 ± 0.934	3.333 ± 1.202	1.619	0.462
PREJY	3.615 ± 1.180	11.125 ± 3.957	6.333 ± 1.667	2.005	0.383
PRERESP†	<b>0.892 ± 0.347</b>	<b>3.328 ± 1.404</b>	<b>1.200 ± 0.416</b>	<b>5.759**</b>	<b>0.045</b>
PREDUR†	<b>0.882 ± 0.354</b>	<b>4.022 ± 1.924</b>	<b>2.151 ± 1.235</b>	<b>5.786**</b>	<b>0.043</b>
PRELAT†	0.415 ± 0.139	0.584 ± 0.186	0.632 ± 0.279	1.798	0.428
PRECHIRP	0.077 ± 0.077	0.125 ± 0.125	0.000 ± 0.000	0.442	1.000
PREAC	1.231 ± 1.007	2.875 ± 2.875	4.333 ± 4.333	0.651	0.955
POSTBOUT	1.308 ± 0.444	2.625 ± 0.925	3.000 ± 1.000	2.813	0.252
POSTJY	2.385 ± 0.991	6.625 ± 2.738	6.333 ± 2.963	2.877	0.243
POSTRESP‡	0.581 ± 0.220	1.531 ± 0.704	1.083 ± 0.507	1.525	0.487
POSTDUR‡	0.752 ± 0.319	1.822 ± 0.857	1.161 ± 0.791	1.552	0.479
POSTLAT‡	0.408 ± 0.209	0.666 ± 0.242	0.365 ± 0.101	1.105	0.590
POSTCHIRP	0.154 ± 0.154	0.125 ± 0.125	1.000 ± 1.000	1.727	0.526
POSTAC	1.769 ± 1.199	4.500 ± 4.500	0.000 ± 0.000	0.473	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 10; Low: n = 5; High: n = 3

‡ Calm: n = 7; Low: n = 5; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.44: The effect of wind intensity on the social variables present during the subject jump-yip bouts for trials where the behaviours of bout initiators in the minute following their jump-yip were analyzed.<sup>^</sup>

	Wind intensity				Test statistics	
	Calm (n = 19)	Low (n = 12)	Moderate (n = 3)	High (n = 8)	$\chi^2$	Sig.
AGPOP	11.263 ± 1.840	10.500 ± 0.622	9.000 ± 2.082	8.875 ± 1.540	0.435	0.939
T2VOC	30.158 ± 4.815	26.583 ± 6.082	19.000 ± 6.807	11.750 ± 1.398	5.641	0.129
PREBOUT	<b>1.421 ± 0.369</b>	<b>3.167 ± 0.588</b>	<b>3.000 ± 1.000</b>	<b>4.125 ± 0.611</b>	<b>12.613**</b>	<b>0.002</b>
PREJY	<b>2.632 ± 0.873</b>	<b>12.333 ± 2.715</b>	<b>8.667 ± 2.333</b>	<b>16.250 ± 3.963</b>	<b>16.831**</b>	<b>&lt;0.001</b>
PRERESP†	<b>0.660 ± 0.222</b>	<b>3.056 ± 0.731</b>	<b>2.167 ± 0.417</b>	<b>3.200 ± 1.136</b>	<b>15.509**</b>	<b>&lt;0.001</b>
PREDUR†	<b>0.644 ± 0.270</b>	<b>3.619 ± 0.945</b>	<b>2.457 ± 0.704</b>	<b>4.007 ± 1.207</b>	<b>16.557**</b>	<b>&lt;0.001</b>
PRELAT†	<b>0.331 ± 0.115</b>	<b>0.680 ± 0.154</b>	<b>0.569 ± 0.220</b>	<b>0.751 ± 0.142</b>	<b>7.533**</b>	<b>0.042</b>
PRECHIRP	0.053 ± 0.053	0.083 ± 0.083	0.000 ± 0.000	0.000 ± 0.000	0.877	1.000
PREAC	<b>0.842 ± 0.694</b>	<b>7.750 ± 5.155</b>	<b>13.667 ± 13.667</b>	<b>22.875 ± 8.711</b>	<b>11.930**</b>	<b>0.005</b>
POSTBOUT	<b>1.316 ± 0.316</b>	<b>3.500 ± 0.723</b>	<b>1.667 ± 0.333</b>	<b>3.750 ± 0.491</b>	<b>11.935**</b>	<b>0.004</b>
POSTJY	<b>2.474 ± 0.698</b>	<b>10.167 ± 2.348</b>	<b>3.667 ± 1.453</b>	<b>12.500 ± 3.076</b>	<b>12.524**</b>	<b>0.003</b>
POSTRESP‡	<b>0.826 ± 0.253</b>	<b>1.921 ± 0.442</b>	<b>1.000 ± 0.577</b>	<b>2.479 ± 1.009</b>	<b>6.745*</b>	<b>0.068</b>
POSTDUR‡	1.181 ± 0.335	2.240 ± 0.507	0.877 ± 0.480	2.613 ± 1.130	4.588	0.206
POSTLAT‡	0.673 ± 0.272	0.763 ± 0.156	0.227 ± 0.123	0.507 ± 0.086	4.166	0.249
POSTCHIRP	0.263 ± 0.150	0.083 ± 0.083	0.000 ± 0.000	0.375 ± 0.375	0.859	0.830
POSTAC	1.211 ± 0.833	8.083 ± 5.582	20.667 ± 16.826	13.625 ± 8.980	4.976	0.177

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 12; Low: n = 10; Moderate: n = 3; High: n = 8

‡ Calm: n = 13; Low: n = 9; Moderate: n = 3; High: n = 8

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.45: The effect of wind intensity on the social variables present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 12)	Low (n = 7)	High (n = 3)	$\chi^2$	Sig.
AGPOP	9.083 ± 2.527	10.571 ± 0.571	11.000 ± 2.646	3.954	0.143
T2VOC	30.917 ± 6.588	29.571 ± 8.329	11.333 ± 2.333	2.003	0.386
PREBOUT	1.833 ± 0.534	3.429 ± 0.896	4.000 ± 0.577	4.603	0.101
PREJY	<b>3.583 ± 1.294</b>	<b>13.143 ± 3.985</b>	<b>16.667 ± 8.667</b>	<b>6.540**</b>	<b>0.028</b>
PRERESP†	<b>0.802 ± 0.295</b>	<b>3.106 ± 1.167</b>	<b>3.978 ± 3.180</b>	<b>6.812**</b>	<b>0.023</b>
PREDUR†	<b>0.842 ± 0.385</b>	<b>3.679 ± 1.608</b>	<b>4.286 ± 3.370</b>	<b>6.268**</b>	<b>0.037</b>
PRELAT†	0.435 ± 0.156	0.573 ± 0.152	0.537 ± 0.198	1.333	0.542
PRECHIRP	0.083 ± 0.083	0.143 ± 0.143	0.000 ± 0.000	0.513	1.000
PREAC	1.333 ± 1.089	3.286 ± 3.286	20.000 ± 14.012	4.352	0.112
POSTBOUT	1.333 ± 0.449	3.000 ± 0.976	2.667 ± 0.882	3.088	0.225
POSTJY	3.250 ± 1.338	7.571 ± 2.967	12.667 ± 9.207	3.112	0.221
POSTRESP‡	1.367 ± 0.717	1.531 ± 0.704	3.528 ± 2.911	0.243	0.897
POSTDUR‡	1.771 ± 0.666	1.822 ± 0.857	3.654 ± 3.283	0.069	0.973
POSTLAT‡	0.961 ± 0.410	0.666 ± 0.242	0.306 ± 0.044	1.037	0.625
POSTCHIRP	0.250 ± 0.179	0.143 ± 0.143	1.000 ± 1.000	0.886	0.845
POSTAC	1.000 ± 1.000	5.143 ± 5.143	0.000 ± 0.000	0.579	0.820

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 8; Low: n = 6; High: n = 3

‡ Calm: n = 7; Low: n = 5; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Interestingly, the least number of post-subject bouts (F-P:  $\chi^2 = 11.935$ ,  $P = 0.004$ ) and total post-subject jump-yips (F-P:  $\chi^2 = 12.524$ ,  $P = 0.003$ ; Table F.44) were found under calm conditions (compared to low and high wind conditions), while the post-subject bouts also contained the fewest responses under calm conditions (F-P:  $\chi^2 = 6.745$ ,  $P = 0.068$ ). These results are consistent with the expectations outlined previously (decreased responsiveness under calm conditions, where the risk of predation is lowest and the quality of information transfer is greatest), and may be further supported by the observation that the least amount of pre-subject alarm calling was observed under calm conditions (F-P:  $\chi^2 = 11.930$ ,  $P = 0.005$ ). The relatively sparse nature of these expected correlations, however, indicate that further study is required to confirm that underlying secondary variables are not responsible for the observed changes in bout characteristics.

For the most part, differences in the characteristics of jump-yip bouts occurring during “respondent” sessions were consistent with those in “bout initiator” sessions. The most total pre-subject jump-yips were observed under low wind conditions (R-P:  $\chi^2 = 5.389$ ,  $P = 0.065$ ; Table F.47), while pre-subject bouts were also of the longest duration under low winds (R-P:  $\chi^2 = 5.295$ ,  $P = 0.069$ ). The most total post-subject jump-yips were found under calm conditions (R-I:  $\chi^2 = 4.956$ ,  $P = 0.078$ ; Table F.46; R-P:  $\chi^2 = 6.304$ ,  $P = 0.038$ ), though only in the case of “R-P” group was there a trend towards decreasing numbers of post-subject jump-yips under greater levels of wind (there was no effect in R-PP; Table F.48). Likewise, the most post-subject chirps were found under calm conditions (R-P:  $\chi^2 = 5.385$ ,  $P = 0.054$ ; Table F.47) with the number of chirps decreasing with increases in the wind intensity. As was the case for previous changes in

Table F.46: The effect of wind intensity on the social variables present during the subject jump-yip bouts for trials where the immediate post-jump-yip behaviours of respondents in those bouts were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 6)	Moderate (n = 8)	High (n = 8)	$\chi^2$	Sig.
AGPOP	9.000 ± 1.673	7.625 ± 1.085	6.750 ± 1.398	1.464	0.499
T2VOC	12.667 ± 1.476	11.625 ± 2.783	15.625 ± 6.456	0.917	0.651
PREBOUT	4.333 ± 0.843	4.125 ± 0.479	3.750 ± 0.491	0.623	0.745
PREJY	19.167 ± 4.423	24.000 ± 3.937	14.500 ± 3.268	2.823	0.251
PRERESP†	3.693 ± 1.048	5.823 ± 1.898	3.000 ± 0.944	2.153	0.354
PREDUR†	3.921 ± 1.257	5.443 ± 1.521	2.640 ± 0.941	3.007	0.231
PRELAT†	0.769 ± 0.061	0.629 ± 0.155	0.677 ± 0.152	1.295	0.541
PRECHIRP	0.000 ± 0.000	0.500 ± 0.378	0.250 ± 0.250	1.739	0.662
PREAC	11.167 ± 6.400	12.500 ± 6.985	11.375 ± 7.867	0.109	0.949
POSTBOUT†	3.500 ± 0.428	3.750 ± 0.526	3.571 ± 0.429	0.075	0.970
POSTJY†	<b>25.333 ± 4.645</b>	<b>18.125 ± 3.254</b>	<b>12.571 ± 2.852</b>	<b>4.956*</b>	<b>0.078</b>
POSTRESP‡	6.964 ± 2.162	4.156 ± 1.013	2.348 ± 0.588	4.072	0.131
POSTDUR‡	7.550 ± 2.466	4.698 ± 0.988	3.233 ± 0.970	2.745	0.266
POSTLAT‡	0.861 ± 0.199	1.269 ± 0.247	0.652 ± 0.192	4.104	0.128
POSTCHIRP	0.333 ± 0.211	0.250 ± 0.250	0.000 ± 0.000	2.800	0.246
POSTAC	11.500 ± 6.397	17.875 ± 8.132	9.250 ± 6.466	1.451	0.499

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 6; Moderate: n = 8; High: n = 7

‡ Calm: n = 6; Moderate: n = 8; High: n = 6

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.47: The effect of wind intensity on the social variables present during subject jump-yip bouts for trials where the behaviours of respondents in those bouts in the minute after their jump-yip were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 7)	Low (n = 9)	High (n = 10)	$\chi^2$	Sig.
AGPOP	9.429 ± 1.478	8.111 ± 1.073	8.000 ± 1.571	1.257	0.549
T2VOC	13.857 ± 1.724	12.111 ± 2.502	19.500 ± 6.819	0.826	0.682
PREBOUT	4.000 ± 0.787	3.889 ± 0.484	3.800 ± 0.416	0.054	0.978
PREJY	<b>18.143 ± 3.876</b>	<b>27.222 ± 4.737</b>	<b>13.700 ± 2.860</b>	<b>5.389*</b>	<b>0.065</b>
PRERESP†	3.879 ± 0.905	8.009 ± 2.753	2.660 ± 0.802	4.235	0.120
PREDUR†	<b>3.876 ± 1.064</b>	<b>7.316 ± 2.304</b>	<b>2.392 ± 0.789</b>	<b>5.295*</b>	<b>0.069</b>
PRELAT†	0.713 ± 0.076	0.610 ± 0.138	0.618 ± 0.139	1.073	0.606
PRECHIRP	0.000 ± 0.000	0.444 ± 0.338	0.200 ± 0.200	1.860	0.474
PREAC	9.571 ± 5.639	12.778 ± 6.166	9.400 ± 6.348	0.101	0.953
POSTBOUT	3.286 ± 0.421	3.778 ± 0.465	2.900 ± 0.567	0.963	0.640
POSTJY	<b>23.000 ± 4.567</b>	<b>18.556 ± 2.902</b>	<b>10.000 ± 2.565</b>	<b>6.304**</b>	<b>0.038</b>
POSTRESP‡	6.469 ± 1.893	4.194 ± 0.895	2.304 ± 0.511	4.581	0.101
POSTDUR‡	7.005 ± 2.154	4.718 ± 0.872	3.323 ± 0.845	2.310	0.335
POSTLAT‡	0.943 ± 0.187	1.298 ± 0.220	0.756 ± 0.196	4.347	0.116
POSTCHIRP	<b>0.571 ± 0.297</b>	<b>0.222 ± 0.222</b>	<b>0.000 ± 0.000</b>	<b>5.385*</b>	<b>0.054</b>
POSTAC	9.857 ± 5.650	15.889 ± 7.441	7.600 ± 5.220	1.107	0.591

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 7; Low: n = 9; High: n = 9

‡ Calm: n = 7; Low: n = 9; High: n = 7

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.48: The effect of wind intensity on the social variables present during subject jump-yip bouts for trials where post-jump-yip changes in the behaviours of respondents in those bouts were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 5)	Low (n = 6)	High (n = 7)	$\chi^2$	Sig.
AGPOP	9.000 ± 2.049	6.833 ± 1.276	8.286 ± 2.190	0.565	0.768
T2VOC	13.000 ± 1.761	13.167 ± 3.458	16.000 ± 7.410	0.682	0.731
PREBOUT	4.000 ± 0.949	4.167 ± 0.601	4.286 ± 0.360	0.097	0.959
PREJY	20.800 ± 5.034	28.167 ± 3.361	16.857 ± 3.225	4.219	0.124
PRERESP†	4.264 ± 1.075	7.242 ± 2.239	3.193 ± 1.072	3.093	0.223
PREDUR†	4.508 ± 1.362	6.803 ± 1.672	3.142 ± 0.991	4.247	0.123
PRELAT†	0.742 ± 0.067	0.701 ± 0.202	0.765 ± 0.156	0.223	0.902
PRECHIRP	0.000 ± 0.000	0.667 ± 0.494	0.286 ± 0.286	2.084	0.420
PREAC	5.800 ± 4.271	13.167 ± 9.130	13.429 ± 8.794	0.495	0.792
POSTBOUT	3.400 ± 0.510	3.167 ± 0.477	3.429 ± 0.649	0.607	0.753
POSTJY	26.200 ± 5.589	19.000 ± 4.219	13.143 ± 2.882	4.098	0.131
POSTRESP‡	7.507 ± 2.563	4.903 ± 1.180	2.878 ± 0.473	2.940	0.238
POSTDUR‡	8.173 ± 2.922	5.422 ± 1.130	4.321 ± 0.732	2.071	0.374
POSTLAT‡	0.747 ± 0.200	1.408 ± 0.267	0.971 ± 0.187	3.319	0.196
POSTCHIRP	0.400 ± 0.245	0.333 ± 0.333	0.000 ± 0.000	2.831	0.207
POSTAC	12.600 ± 7.718	13.333 ± 9.824	10.857 ± 7.245	0.029	0.985

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 5; Low: n = 6; High: n = 6

‡ Calm: n = 5; Low: n = 6; High: n = 5

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

the frequency of chirping in the environment, this could demonstrate that chirps are akin to jump-yips (owing to the similar changes in their exhibition in the environment), however, more study is required before this conclusion can be drawn.

Differences in the habitats in which the observational sessions were run could also impose an effect on the variables recorded in the study, as population size and density, predation risk, food availability, and the effects of weather could be altered based on the environment in which the subjects inhabit. In wild habitats, subject bouts contained more responses (F-I:  $\chi^2 = 8.280$ ,  $P = 0.008$ ; Table F.49; F-P:  $\chi^2 = 8.929$ ,  $P = 0.009$ ; Table F.50; F-PP:  $\chi^2 = 5.540$ ,  $P = 0.055$ ; Table F.51) and respondents (F-I:  $\chi^2 = 6.768$ ,  $P = 0.029$ ) and were of a longer duration (F-I:  $\chi^2 = 7.996$ ,  $P = 0.012$  F-P:  $\chi^2 = 10.158$ ,  $P = 0.004$ ; F-PP:  $\chi^2 = 5.875$ ,  $P = 0.045$ ) than those occurring in intermediate or captive habitats, though only the difference in duration exhibited a trend to becoming shorter as captivity increased. This is not surprising, given the general trend toward larger populations (and thus more potentially-vigilant individuals and more responses and/or respondents) in wild habitats. The lack of decreases in the magnitude of response in the subject jump-yip bouts with decreases in population size, however, may demonstrate that (as hypothesized in this study) population size is not the only determinant of response in jump-yip bouts.

Similarly, in wild habitats, the first post-subject, non-subject bouts occurred earliest in the recording sessions (F-I:  $\chi^2 = 11.519$ ,  $P = 0.001$ ; Table F.52; F-P:  $\chi^2 = 11.837$ ,  $P = 0.001$ ; Table F.53; F-PP:  $\chi^2 = 5.325$ ,  $P = 0.069$ ; Table F.54), likely reflecting the greater number of potential respondents in the wild habitats. In wild habitats, there were also the most pre-subject bouts (F-I:  $\chi^2 = 17.080$ ,  $P < 0.001$ ; F-P:  $\chi^2 = 28.494$ ,  $P < 0.001$ ; F-PP:  $\chi^2 = 16.245$ ,  $P < 0.001$ ) and total number of

Table F.49: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the immediate post-jump-yip behaviour of initial callers in those jump-yip bouts.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 9)	Captive (n = 4)	$\chi^2$	Sig.
RESPS	<b>3.539</b> ± <b>1.010</b>	<b>0.889</b> ± <b>0.351</b>	<b>0.000</b> ± <b>0.000</b>	<b>8.280**</b>	<b>0.008</b>
RPDTS†	<b>2.455</b> ± <b>0.679</b>	<b>0.778</b> ± <b>0.278</b>	<b>0.000</b> ± <b>0.000</b>	<b>6.768**</b>	<b>0.029</b>
DUR	<b>3.731</b> ± <b>0.926</b>	<b>1.010</b> ± <b>0.514</b>	<b>0.000</b> ± <b>0.000</b>	<b>7.996**</b>	<b>0.012</b>
LAT‡	0.615 ± 0.142	0.896 ± 0.310	- ± -	19.0#	0.491#

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Wild: n = 11; Intermediate: n = 9; Captive: n = 4

‡ Wild: n = 10; Intermediate: n = 5; Captive: n = 0

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.50: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the behaviour of initial callers in the subject jump-yip bouts over the minute following jump-yip production.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 23)	Intermediate (n = 13)	Captive (n = 6)	$\chi^2$	Sig.
RESPS	<b>3.826</b> ± <b>0.685</b>	<b>1.000</b> ± <b>0.358</b>	<b>1.167</b> ± <b>0.792</b>	<b>8.929**</b>	<b>0.009</b>
RPDTS†	2.313 ± 0.538	0.769 ± 0.231	1.000 ± 0.632	4.006	0.136
DUR	<b>3.984</b> ± <b>0.670</b>	<b>0.965</b> ± <b>0.380</b>	<b>0.499</b> ± <b>0.274</b>	<b>10.158**</b>	<b>0.004</b>
LAT‡	0.965 ± 0.180	0.819 ± 0.244	0.573 ± 0.090	0.333	0.854

<sup>^</sup> See Appendix A for abbreviations and definitions

† Wild: n = 16; Intermediate: n = 13; Captive: n = 6

‡ Wild: n = 19; Intermediate: n = 7; Captive: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.51: The effect of habitat type on the response characteristics of the subject jump-yip bouts used in the analysis of the post-jump-yip changes in the behaviour of initial callers in those jump-yip bouts.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 8)	Captive (n = 3)	$\chi^2$	Sig.
RESPS	<b>4.154</b> ± <b>0.966</b>	<b>1.000</b> ± <b>0.378</b>	<b>2.000</b> ± <b>1.528</b>	<b>5.540*</b>	<b>0.055</b>
RPDTS†	2.778 ± 0.778	0.714 ± 0.286	1.667 ± 1.202	3.010	0.231
DUR	<b>4.305</b> ± <b>0.923</b>	<b>1.016</b> ± <b>0.495</b>	<b>0.780</b> ± <b>0.498</b>	<b>5.875**</b>	<b>0.045</b>
LAT‡	0.603 ± 0.130	0.840 ± 0.332	0.550 ± 0.150	23.0#	0.645

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Wild: n = 9; Intermediate: n = 7; Captive: n = 3

‡ Wild: n = 11; Intermediate: n = 5; Captive: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.52: The effect of habitat type on the social variables present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 9)	Captive (n = 4)	$\chi^2$	Sig.
AGPOP	8.769 ± 0.968	9.000 ± 1.236	12.250 ± 4.479	0.185	0.919
T2VOC	<b>14.769 ± 2.042</b>	<b>42.000 ± 7.500</b>	<b>50.500 ± 9.500</b>	<b>11.519**</b>	<b>0.001</b>
PREBOUT	<b>4.077 ± 0.415</b>	<b>1.000 ± 0.333</b>	<b>0.500 ± 0.289</b>	<b>17.080**</b>	<b>&lt;0.001</b>
PREJY	<b>12.308 ± 2.011</b>	<b>1.444 ± 0.530</b>	<b>1.250 ± 0.946</b>	<b>17.728**</b>	<b>&lt;0.001</b>
PRERESP†	<b>2.223 ± 0.600</b>	<b>0.400 ± 0.187</b>	<b>1.500 ± 1.500</b>	<b>5.5**#</b>	<b>0.004</b>
PREDUR†	<b>2.798 ± 0.811</b>	<b>0.421 ± 0.231</b>	<b>1.130 ± 1.130</b>	<b>7.0**#</b>	<b>0.009</b>
PRELAT†	0.607 ± 0.126	0.362 ± 0.208	0.385 ± 0.385	20.0#	0.227
PRECHIRP	0.154 ± 0.104	0.000 ± 0.000	0.000 ± 0.000	2.083	0.638
PREAC	7.692 ± 3.597	1.444 ± 1.444	0.000 ± 0.000	3.672	0.168
POSTBOUT	<b>3.462 ± 0.447</b>	<b>0.667 ± 0.373</b>	<b>0.250 ± 0.250</b>	<b>15.943**</b>	<b>&lt;0.001</b>
POSTJY	<b>8.000 ± 1.515</b>	<b>1.000 ± 0.667</b>	<b>0.250 ± 0.250</b>	<b>16.289**</b>	<b>&lt;0.001</b>
POSTRESP‡	1.280 ± 0.291	0.333 ± 0.333	0.000 ± -	7.0**#	0.107
POSTDUR‡	<b>1.524 ± 0.362</b>	<b>0.276 ± 0.276</b>	<b>0.000 ± -</b>	<b>5.0*#</b>	<b>0.055</b>
POSTLAT‡	<b>0.592 ± 0.126</b>	<b>0.114 ± 0.114</b>	<b>0.000 ± -</b>	<b>5.0*#</b>	<b>0.055</b>
POSTCHIRP	0.462 ± 0.268	0.000 ± 0.000	0.000 ± 0.000	3.246	0.242
POSTAC	2.769 ± 2.769	2.556 ± 1.692	0.000 ± 0.000	1.444	0.550

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Wild: n = 13; Intermediate: n = 5; Captive: n = 2

‡ Wild: n = 13; Intermediate: n = 3; Captive: n = 1

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.53: The effect of habitat type on the social variables present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.<sup>^</sup>

	Habitat type						Test statistics	
	Wild (n = 23)		Intermediate (n = 13)		Captive (n = 6)		$\chi^2$	Sig.
AGPOP	9.044	± 0.715	10.846	± 1.170	14.833	± 5.069	0.876	0.664
T2VOC	<b>14.348</b>	± <b>1.414</b>	<b>37.077</b>	± <b>6.079</b>	<b>38.500</b>	± <b>9.784</b>	<b>11.837**</b>	<b>0.001</b>
PREBOUT	<b>4.000</b>	± <b>0.308</b>	<b>1.077</b>	± <b>0.239</b>	<b>0.167</b>	± <b>0.167</b>	<b>28.494**</b>	<b>&lt;0.001</b>
PREJY	<b>14.348</b>	± <b>1.798</b>	<b>1.769</b>	± <b>0.426</b>	<b>0.167</b>	± <b>0.167</b>	<b>30.667**</b>	<b>&lt;0.001</b>
PRERESP†	<b>2.807</b>	± <b>0.514</b>	<b>0.667</b>	± <b>0.220</b>	<b>0.000</b>	± -	<b>26.0**#</b>	<b>0.001</b>
PREDUR†	<b>3.396</b>	± <b>0.605</b>	<b>0.581</b>	± <b>0.219</b>	<b>0.000</b>	± -	<b>19.0**#</b>	<b>0.001</b>
PRELAT†	<b>0.677</b>	± <b>0.091</b>	<b>0.324</b>	± <b>0.120</b>	<b>0.000</b>	± -	<b>52.0**#</b>	<b>0.030</b>
PRECHIRP	0.087	± 0.060	0.000	± 0.000	0.000	± 0.000	1.693	0.655
PREAC	<b>13.913</b>	± <b>4.424</b>	<b>1.000</b>	± <b>1.000</b>	<b>0.000</b>	± <b>0.000</b>	<b>8.980**</b>	<b>0.010</b>
POSTBOUT	<b>3.783</b>	± <b>0.344</b>	<b>0.923</b>	± <b>0.309</b>	<b>0.500</b>	± <b>0.224</b>	<b>24.552**</b>	<b>&lt;0.001</b>
POSTJY	<b>11.044</b>	± <b>1.528</b>	<b>1.692</b>	± <b>0.593</b>	<b>0.667</b>	± <b>0.333</b>	<b>24.162**</b>	<b>&lt;0.001</b>
POSTRESP‡	<b>1.878</b>	± <b>0.400</b>	<b>0.952</b>	± <b>0.439</b>	<b>0.333</b>	± <b>0.333</b>	<b>5.774**</b>	<b>0.046</b>
POSTDUR‡	2.093	± 0.445	1.108	± 0.477	1.053	± 1.053	2.814	0.248
POSTLAT‡	0.614	± 0.088	0.455	± 0.299	1.017	± 1.017	2.942	0.233
POSTCHIRP	0.261	± 0.157	0.154	± 0.154	0.167	± 0.167	0.305	0.971
POSTAC	11.652	± 4.610	1.769	± 1.199	0.000	± 0.000	3.158	0.188

<sup>^</sup> See Appendix A for abbreviations and definitions

† Wild: n = 23; Intermediate: n = 9; Captive: n = 1

‡ Wild: n = 23; Intermediate: n = 7; Captive: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.54: The effect of habitat type on the social variables present at the time of the subject jump-yip bouts for trials where the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 8)	Captive (n = 3)	$\chi^2$	Sig.
AGPOP	9.539 ± 0.867	8.750 ± 1.333	14.667 ± 10.171	0.736	0.708
T2VOC	<b>16.308 ± 2.161</b>	<b>40.250 ± 7.961</b>	<b>43.000 ± 17.000</b>	<b>5.352*</b>	<b>0.069</b>
PREBOUT	<b>4.077 ± 0.415</b>	<b>1.250 ± 0.313</b>	<b>0.000 ± 0.000</b>	<b>16.245**</b>	<b>&lt;0.001</b>
PREJY	<b>14.077 ± 2.586</b>	<b>2.125 ± 0.549</b>	<b>0.000 ± 0.000</b>	<b>17.936**</b>	<b>&lt;0.001</b>
PRERESP†	<b>2.865 ± 0.864</b>	<b>0.750 ± 0.281</b>	- ± -	<b>13.0**#</b>	<b>0.019</b>
PREDUR†	<b>3.169 ± 1.037</b>	<b>0.705 ± 0.308</b>	- ± -	<b>15.0**#</b>	<b>0.035</b>
PRELAT†	0.532 ± 0.102	0.404 ± 0.165	- ± -	30.0#	0.473
PRECHIRP	0.154 ± 0.104	0.000 ± 0.000	0.000 ± 0.000	1.769	0.631
PREAC	9.769 ± 4.638	1.625 ± 1.625	0.000 ± 0.000	2.952	0.264
POSTBOUT	<b>3.308 ± 0.458</b>	<b>0.625 ± 0.324</b>	<b>0.333 ± 0.333</b>	<b>14.687**</b>	<b>&lt;0.001</b>
POSTJY	<b>9.385 ± 2.338</b>	<b>2.000 ± 1.592</b>	<b>0.667 ± 0.667</b>	<b>12.728**</b>	<b>&lt;0.001</b>
POSTRESP‡	1.869 ± 0.683	1.833 ± 1.833	1.000 ± -	12.0#	0.337
POSTDUR‡	2.088 ± 0.762	1.600 ± 1.600	3.160 ± -	11.0#	0.288
POSTLAT‡	0.573 ± 0.128	0.386 ± 0.386	3.050 ± -	11.0#	0.288
POSTCHIRP	0.462 ± 0.268	0.000 ± 0.000	0.333 ± 0.333	2.357	0.305
POSTAC	3.385 ± 2.786	1.500 ± 1.500	0.000 ± 0.000	0.503	0.898

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney test

† Wild: n = 13; Intermediate: n = 6; Captive: n = 0

‡ Wild: n = 13; Intermediate: n = 3; Captive: n = 1

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

pre-subject jump-yips (F-I:  $\chi^2 = 17.728$ ,  $P < 0.001$ ; F-P:  $\chi^2 = 30.667$ ,  $P < 0.001$ ; F-PP:  $\chi^2 = 17.936$ ,  $P < 0.001$ ), and pre-subject bouts with the greatest number of responses (F-I:  $U = 5.5$ ,  $P = 0.046$ ; F-P:  $U = 26.0$ ,  $P = 0.001$ ; F-PP:  $U = 13.0$ ,  $P = 0.019$ ) and the longest durations (F-I:  $U = 7.0$ ,  $P = 0.009$ ; F-P:  $U = 19.0$ ,  $P = 0.001$ ; F-PP:  $U = 15.0$ ,  $P = 0.035$ ), results which again demonstrate the effects of greater numbers of potential jump-yipping individuals in the wild habitats. In wild habitats, the pre-subject bouts also had the longest response latencies (F-P:  $U = 52.0$ ,  $P = 0.030$ ), which is somewhat unexpected, but as previously described, likely demonstrates the drawbacks of using response latency as an indicator of social state. The most post-subject bouts (F-I:  $\chi^2 = 15.943$ ,  $P < 0.001$ ; F-P:  $\chi^2 = 24.552$ ,  $P < 0.001$ ; F-PP:  $\chi^2 = 14.687$ ,  $P < 0.001$ ) and total number of post-subject jump-yips (F-I:  $\chi^2 = 16.289$ ,  $P < 0.001$ ; F-P:  $\chi^2 = 24.162$ ,  $P < 0.001$ ; F-PP:  $\chi^2 = 12.728$ ,  $P < 0.001$ ), and post-subject bouts with the greatest number of responses (F-P:  $\chi^2 = 5.774$ ,  $P = 0.046$ ), the longest durations (F-I:  $U = 5.0$ ,  $P = 0.055$ ), were all observed in wild habitats (meeting expectations), while again, the longest response latencies in the post-subject bouts were found in wild habitats (F-I:  $U = 5.0$ ,  $P = 0.055$ ), further demonstrating the potential drawbacks of response latency as an information-carrying component of the jump-yip bout.

The most pre-subject alarm calling was also observed in wild habitats (F-P:  $\chi^2 = 8.980$ ,  $P = 0.010$ ; Table F.53). This may indicate that predation risk is greater in wild habitats, where predators have relatively free access to large areas of potential prey (as opposed to captive habitats such as zoos). It may also indicate, however, that there are simply more individuals with lower thresholds to alarm call in wild habitats, where there should be greater differences in the risk perceived by individuals than in

captive habitats (with their smaller population sizes). Owing to the methodology of this study, however, this difference in alarm calling must be further examined before such conclusions can be drawn.

Many of the interrelationships observed between abiotic variables recorded in this study are reflective not of biologically-relevant interactions, but instead by the method by which recording sessions were scheduled and performed. “Bout initiator” subject bouts which occurred later in the day occurred under less cloud cover (F-I:  $n = 19$ ,  $r_s = -0.470$ ,  $P = 0.042$ ; Table F.55; F-P:  $n = 31$ ,  $r_s = -0.360$ ,  $P = 0.047$ ; Table F.56), while “respondent” subject bouts which occurred later in the day occurred earlier in the year (R-I:  $n = 18$ ,  $r_s = -0.400$ ,  $P = 0.100$ ; Table F.58; R-P:  $n = 21$ ,  $r_s = -0.390$ ,  $P = 0.081$ ; Table F.59), under less cloud cover (R-I:  $n = 18$ ,  $r_s = -0.517$ ,  $P = 0.028$ ; R-P:  $n = 21$ ,  $r_s = -0.472$ ,  $P = 0.031$ ; R-PP:  $n = 16$ ,  $r_s = -0.588$ ,  $P = 0.017$ ; Table F.60), and under more intense wind (R-P:  $n = 21$ ,  $r_s = 0.390$ ,  $P = 0.080$ ; Table L.8). “Bout initiator” subject bouts which occurred later in the year occurred in greater levels of captivity (F-I:  $n = 26$ ,  $r_s = 0.506$ ,  $P = 0.008$ ; Table F.61; F-P:  $n = 42$ ,  $r_s = 0.609$ ,  $P < 0.001$ ; Table F.62; F-PP:  $n = 24$ ,  $r_s = 0.570$ ,  $P = 0.004$ ; Table F.63), under more cloud (F-I:  $n = 26$ ,  $r_s = 0.333$ ,  $P = 0.097$ ; F-PP:  $n = 24$ ,  $r_s = 0.481$ ,  $P = 0.017$ ), and under less intense wind (F-I:  $n = 26$ ,  $r_s = -0.444$ ,  $P = 0.023$ ; F-P:  $n = 42$ ,  $r_s = -0.588$ ,  $P < 0.001$ ; F-PP:  $n = 24$ ,  $r_s = -0.469$ ,  $P = 0.021$ ). “Respondent” bouts which occurred later in the year occurred under greater cloud cover (R-I:  $n = 22$ ,  $r_s = 0.490$ ,  $P = 0.021$ ; Table F.64; R-P:  $n = 26$ ,  $r_s = 0.538$ ,  $P = 0.005$ ; Table F.65; R-PP:  $n = 26$ ,  $r_s = 0.738$ ,  $P < 0.001$ ; Table F.66), in greater levels of captivity (R-I:  $n = 22$ ,  $r_s = 0.372$ ,  $P = 0.089$ ; R-P:  $n = 26$ ,  $r_s = 0.342$ ,  $P = 0.087$ ; R-PP:  $n = 26$ ,  $r_s = 0.413$ ,  $P = 0.089$ ), under less intense wind (R-P:  $n = 26$ ,

Table F.55: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 19).<sup>^</sup>

	Time of day
CLOUD	<b>-0.470**</b>
WIND	0.388
HABITAT	-0.138
TIME	1.000
DAY	0.076

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.56: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 31).<sup>^</sup>

	Time of day
CLOUD	<b>-0.360**</b>
WIND	0.256
HABITAT	-0.150
TIME	1.000
DAY	0.048

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.57: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 17).<sup>^</sup>

	Time of day
CLOUD	-0.385
WIND	0.387
HABITAT	0.053
TIME	1.000
DAY	0.158

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.58: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 18).<sup>^</sup>

	Time of day
CLOUD	<b>-0.517**</b>
WIND	0.387
HABITAT	-
TIME	1.000
DATE	<b>-0.400*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.59: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 21).<sup>^</sup>

	Time of day
CLOUD	<b>-0.472**</b>
WIND	<b>0.390*</b>
HABITAT	-
TIME	1.000
DATE	<b>-0.390*</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.60: Correlation of the time of day at which a jump-yip bout occurred and the abiotic factors present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 16).<sup>^</sup>

	Time of day
CLOUD	<b>-0.588**</b>
WIND	0.321
HABITAT	-
TIME	1.000
DATE	-0.312

<sup>^</sup> See Appendix A for abbreviations and definitions

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.61: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of the initial caller in the bout was analyzed (n = 26).<sup>^</sup>

	Time of year
CLOUD	<b>0.333*</b>
WIND	<b>-0.444**</b>
HABITAT	<b>0.506**</b>
TIME	0.076
DAY	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 19

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.62: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the behaviour of the initial caller in the bout over one minute following jump-yip production was analyzed (n = 42).<sup>^</sup>

	Time of year
CLOUD	0.088
WIND	<b>-0.588**</b>
HABITAT	<b>0.609**</b>
TIME	0.048
DAY	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 31

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.63: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the changes in the behaviour of the initial caller in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 24).<sup>^</sup>

	Time of year
CLOUD	<b>0.481**</b>
WIND	<b>-0.469**</b>
HABITAT	<b>0.570**</b>
TIME	0.158
DAY	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 17

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.64: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the immediate post-jump-yip behaviour of a respondent in the bout was analyzed (n = 22).<sup>^</sup>

	Time of year
CLOUD	<b>0.490**</b>
WIND	-0.352
HABITAT	<b>0.372*</b>
TIME	<b>-0.400*</b>
DATE	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 18

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.65: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the behaviour of a respondent in the bout over one minute following jump-yip production was analyzed (n = 26).<sup>^</sup>

	Time of year
CLOUD	<b>0.538**</b>
WIND	<b>-0.370*</b>
HABITAT	<b>0.342*</b>
TIME	<b>-0.390*</b>
DATE	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 21

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.66: Correlation of the time of year at which a jump-yip bout occurred and the abiotic variables present at the time of the bout for trials in which the changes in the behaviour of a respondent in the bout from the minute preceding to the minute following jump-yip production were analyzed (n = 18).<sup>^</sup>

	Time of year
CLOUD	<b>0.738**</b>
WIND	-0.260
HABITAT	<b>0.413*</b>
TIME	-0.312
DATE	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

<sup>†</sup> n = 16

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

$r_s = -0.370$ ,  $P = 0.062$ ), and earlier in the day (R-I:  $n = 22$ ,  $r_s = -0.400$ ,  $P = 0.100$ ; R-P:  $n = 26$ ,  $r_s = -0.390$ ,  $P = 0.081$ ).

Observational sessions were generally limited to late-morning/early-afternoon in the colder (later) months to enjoy the greatest heat benefits of the midday sun which may stimulate aboveground activity in black-tailed prairie dogs. Owing to the smaller population sizes during the colder months, however, the number of observational sessions run was limited (since there were limited numbers of individuals to observe). In warmer months, several observational sessions were run per day, often extending later in the day. This may underlie the observed inverse relationships between the time of day and the time of year at which the observational sessions occurred.

Bouts which occurred later in the day generally occurred under less cloud cover but more wind, while bouts which occurred later in the year occurred under the opposite conditions (more cloud, less wind), not surprising given the inverse relationships observed between time of day and time of year. The inverse relationship between cloud cover and wind intensity was actually consistent for most of the data groups, while the correlations observed for time of day and time of year and the meteorological variables were also present as significant differences in the temporal variables under different levels of cloud cover and wind.

“Bout initiator” subject bouts occurring under greater levels of cloud cover occurred under significantly less intense wind (F-I:  $U = 20.0$ ,  $P = 0.038$ ; Table F.67; F-PP:  $U = 17.5$ ,  $P = 0.033$ ; Table F.69), occurred significantly earlier in the day (F-I:  $U = 0.0$ ,  $P = 0.013$ ; F-P:  $\chi^2 = 7.960$ ,  $P = 0.013$ ; Table F.68) and later in the year (F-I:  $U = 18.0$ ,  $P = 0.029$ ; F-PP:  $U = 7.0$ ,  $P = 0.002$ ), and occurred in significantly more

Table F.67: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Extent of cloud cover				Test statistics	
	Clear (n = 20)		Cloudy (n = 5)		U	Sig.
WIND	<b>1.000</b>	<b>± 0.241</b>	<b>0.000</b>	<b>± 0.000</b>	<b>20.0**</b>	<b>0.038</b>
TIME†	<b>13.265</b>	<b>± 0.636</b>	<b>9.792</b>	<b>± 0.025</b>	<b>0.0**</b>	<b>0.013</b>
DATE	<b>7.996</b>	<b>± 0.584</b>	<b>10.203</b>	<b>± 0.794</b>	<b>18.0**</b>	<b>0.029</b>
HABITAT	<b>0.500</b>	<b>± 0.154</b>	<b>1.400</b>	<b>± 0.245</b>	<b>17.0**</b>	<b>0.012</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 16; Cloudy: n = 2

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.68: The effect of cloud cover on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.<sup>^</sup>

	Extent of cloud cover						Test statistics	
	Clear (n = 29)		Partly cloudy (n = 7)		Cloudy (n = 6)		$\chi^2$	Sig.
WIND	<b>0.897</b>	<b>± 0.194</b>	<b>2.286</b>	<b>± 0.360</b>	<b>0.000</b>	<b>± 0.000</b>	<b>14.383**</b>	<b>&lt;0.001</b>
TIME†	<b>14.164</b>	<b>± 0.598</b>	<b>13.364</b>	<b>± 0.573</b>	<b>9.845</b>	<b>± 0.055</b>	<b>7.960**</b>	<b>0.013</b>
DATE	<b>8.284</b>	<b>± 0.504</b>	<b>5.783</b>	<b>± 0.013</b>	<b>9.879</b>	<b>± 0.725</b>	<b>9.027**</b>	<b>0.007</b>
HABITAT	<b>0.552</b>	<b>± 0.127</b>	<b>0.000</b>	<b>± 0.000</b>	<b>1.500</b>	<b>± 0.224</b>	<b>13.980**</b>	<b>&lt;0.001</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 21; Partly Cloudy: n = 7; Cloudy: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.69: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 18)	Cloudy (n = 5)	U	Sig.
WIND	<b>1.056</b> ± <b>0.262</b>	<b>0.000</b> ± <b>0.000</b>	<b>17.5**</b>	<b>0.033</b>
TIME†	13.809 ± 0.677	9.950 ± -	n/a	n/a
DATE	<b>7.729</b> ± <b>0.612</b>	<b>10.852</b> ± <b>0.648</b>	<b>7.0**</b>	<b>0.002</b>
HABITAT	<b>0.444</b> ± <b>0.166</b>	<b>1.200</b> ± <b>0.200</b>	<b>17.0**</b>	<b>0.015</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 15; Cloudy: n = 1

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



captive habitats (F-I:  $U = 17.0$ ,  $P = 0.012$ ; F-P:  $\chi^2 = 13.980$ ,  $P < 0.001$ ; F-PP:  $U = 17.0$ ,  $P = 0.015$ ). “Bout initiator” subject bouts occurred under the greatest level of wind (F-P:  $\chi^2 = 14.383$ ,  $P < 0.001$ ) and occurred earliest in the year (F-P:  $\chi^2 = 9.027$ ,  $P = 0.007$ ) under partly cloudy skies rather than under clear skies. “Respondent” subject bouts occurring under clear skies occurred later in the day (R-I:  $U = 16.0$ ,  $P = 0.035$ ; Table F.70; R-P:  $U = 25.0$ ,  $P = 0.039$ ; Table F.71; R-PP:  $U = 10.0$ ,  $P = 0.026$ ; Table F.72). There was also some evidence that the “respondent” subject bouts occurred latest in the year under cloudy skies (R-P:  $\chi^2 = 8.678$ ,  $P = 0.008$ ), though in the “R-PP” group, where there was insufficient sample size to examine abiotic factors under cloudy skies, the subject bouts occurred latest under clear skies ( $U = 9.0$ ,  $P = 0.005$ ).

“Bout initiator” subject bouts occurring under less wind occurred in more captive habitats (F-I:  $\chi^2 = 7.542$ ,  $P = 0.017$ ; Table F.73; F-P:  $\chi^2 = 22.463$ ,  $P < 0.001$ ; Table F.74; F-PP:  $\chi^2 = 7.265$ ,  $P = 0.019$ ; Table F.75) and occurred latest in the year under calm and low wind conditions (F-I:  $\chi^2 = 5.983$ ,  $P = 0.044$ ; F-P:  $\chi^2 = 15.624$ ,  $P < 0.001$ ).

“Respondent” subject bouts which occurred under calm conditions occurred under the greatest level of cloud cover (R-P:  $\chi^2 = 5.643$ ,  $P = 0.056$ ; Table F.77; R-PP:  $\chi^2 = 6.325$ ,  $P = 0.037$ ; Table F.78), though in neither case was there evidence of decreasing cloud with increases in wind intensity.

Though these results could indicate that cloud cover is inversely proportional to wind, more likely it reflects the habitat types in which the observational sessions occurred. “Bout initiator” subject bouts which occurred in wild habitats occurred under greater levels of wind (F-I:  $\chi^2 = 9.427$ ,  $P = 0.005$ ; Table F.79; F-P:  $\chi^2 = 21.932$ ,  $P < 0.001$ ; Table F.80; F-PP:  $\chi^2 = 9.022$ ,  $P = 0.005$ ; Table F.81). Subject bouts in

Table F.70: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in the subject bouts were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 12)	Partly cloudy (n = 8)	U	Sig.
WIND	1.750 ± 0.329	1.000 ± 0.463	29.0	0.149
TIME†	<b>14.725 ± 0.932</b>	<b>12.190 ± 0.416</b>	<b>16.0**</b>	<b>0.035</b>
DATE	6.663 ± 0.648	5.730 ± 0.013	31.0	0.178
HABITAT	0.000 ± 0.000	0.000 ± 0.000	48.0	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 10; Partly cloudy: n = 8

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.71: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the behaviours of respondents in the subject bouts over the minute following jump-yip production were analyzed.<sup>^</sup>

	Extent of cloud cover			Test statistics	
	Clear (n = 13)	Partly cloudy (n = 10)	Cloudy (n = 3)	$\chi^2$	Sig.
WIND	1.846 ± 0.317	1.200 ± 0.416	1.000 ± 1.000	2.738	0.276
TIME†	<b>14.674 ± 0.845</b>	<b>12.182 ± 0.328</b>	- ± -	<b>25.0***#</b>	<b>0.039</b>
DATE	<b>6.587 ± 0.601</b>	<b>5.732 ± 0.012</b>	<b>11.445 ± 0.040</b>	<b>8.678**</b>	<b>0.008</b>
HABITAT	0.000 ± 0.000	0.000 ± 0.000	0.333 ± 0.333	7.667	0.119

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U test

† Clear: n = 11; Partly cloudy: n = 10; Cloudy: n = 0

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.72: The effect of cloud cover on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of respondents in the subject bouts were analyzed.<sup>^</sup>

	Extent of cloud cover		Test statistics	
	Clear (n = 8)	Partly cloudy (n = 9)	U	Sig.
WIND	2.000 ± 0.378	1.222 ± 0.465	22.0	0.231
TIME†	<b>15.702 ± 1.132</b>	<b>12.170 ± 0.367</b>	<b>10.0**</b>	<b>0.026</b>
DATE	<b>6.400 ± 0.724</b>	<b>5.735 ± 0.013</b>	<b>9.0**</b>	<b>0.005</b>
HABITAT	0.000 ± 0.000	0.000 ± 0.000	36.0	1.000

<sup>^</sup> See Appendix A for abbreviations and definitions

† Clear: n = 7; Cloudy: n = 9

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.73: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 13)	Low (n = 8)	High (n = 3)	$\chi^2$	Sig.
CLOUD	0.769 ± 0.281	0.125 ± 0.125	0.000 ± 0.000	3.360	0.231
TIME†	12.650 ± 1.405	12.524 ± 0.510	14.461 ± 1.613	2.521	0.296
DATE	<b>8.799 ± 0.755</b>	<b>9.189 ± 0.822</b>	<b>5.709 ± 0.032</b>	<b>5.983**</b>	<b>0.044</b>
HABITAT	<b>1.077 ± 0.211</b>	<b>0.375 ± 0.183</b>	<b>0.000 ± 0.000</b>	<b>7.542**</b>	<b>0.017</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 7; Low: n = 7; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.74: The effect of wind intensity on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators over the minute following jump-yip production were analyzed.<sup>^</sup>

	Wind intensity				Test statistics	
	Calm (n = 19)	Low (n = 12)	Moderate (n = 3)	High (n = 8)	$\chi^2$	Sig.
CLOUD	0.632 ± 0.219	0.167 ± 0.112	0.333 ± 0.333	0.500 ± 0.189	2.271	0.537
TIME†	12.883 ± 1.251	13.730 ± 0.684	13.283 ± 0.682	14.212 ± 0.826	2.519	0.495
DATE	<b>9.178 ± 0.601</b>	<b>8.522 ± 0.736</b>	<b>5.763 ± 0.043</b>	<b>5.758 ± 0.018</b>	<b>15.624**</b>	<b>&lt;0.001</b>
HABITAT	<b>1.158 ± 0.158</b>	<b>0.250 ± 0.131</b>	<b>0.000 ± 0.000</b>	<b>0.000 ± 0.000</b>	<b>22.463**</b>	<b>&lt;0.001</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 9; Low: n = 11; Moderate: n = 3; High: n = 8

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.75: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 12)	Low (n = 7)	High (n = 3)	$\chi^2$	Sig.
CLOUD	0.833 ± 0.297	0.143 ± 0.143	0.000 ± 0.000	3.445	0.172
TIME†	13.056 ± 1.493	12.700 ± 0.565	16.278 ± 0.973	2.350	0.347
DATE	8.847 ± 0.821	9.174 ± 0.949	5.742 ± 0.032	4.240	0.122
HABITAT	<b>1.000 ± 0.213</b>	<b>0.286 ± 0.184</b>	<b>0.000 ± 0.000</b>	<b>7.265**</b>	<b>0.019</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 6; Low: n = 6; High: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.76: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the immediate post-jump-yip behaviours of respondents in the subject bouts were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 6)	Moderate (n = 8)	High (n = 8)	$\chi^2$	Sig.
CLOUD	1.000 ± 0.258	0.250 ± 0.164	0.500 ± 0.267	4.719	0.103
TIME†	11.750 ± 0.130	14.474 ± 1.315	13.779 ± 0.762	3.090	0.222
DATE	7.635 ± 1.217	6.441 ± 0.718	6.428 ± 0.720	2.645	0.278
HABITAT	0.167 ± 0.167	0.000 ± 0.000	0.000 ± 0.000	2.667	0.277

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 4; Moderate: n = 7; High: n = 7

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.77: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the behaviours of respondents in the subject bouts over the minute following jump-yip production were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 7)	Low (n = 9)	High (n = 10)	$\chi^2$	Sig.
CLOUD	<b>1.143</b> ± <b>0.261</b>	<b>0.333</b> ± <b>0.167</b>	<b>0.500</b> ± <b>0.224</b>	<b>5.643*</b>	<b>0.056</b>
TIME†	11.750 ± 0.130	14.200 ± 1.171	13.626 ± 0.617	3.828	0.155
DATE	8.168 ± 1.159	6.360 ± 0.639	6.287 ± 0.576	3.609	0.166
HABITAT	0.143 ± 0.143	0.000 ± 0.000	0.000 ± 0.000	2.714	0.268

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 4; Low: n = 8; High: n = 9

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$



Table F.78: The effect of wind intensity on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of respondents in the subject bouts were analyzed.<sup>^</sup>

	Wind intensity			Test statistics	
	Calm (n = 5)	Low (n = 6)	High (n = 7)	$\chi^2$	Sig.
CLOUD	<b>1.200 ± 0.200</b>	<b>0.333 ± 0.211</b>	<b>0.429 ± 0.202</b>	<b>6.325**</b>	<b>0.037</b>
TIME†	11.750 ± 0.130	15.523 ± 1.633	13.548 ± 0.803	2.924	0.243
DATE	6.868 ± 1.158	6.653 ± 0.963	5.722 ± 0.023	1.639	0.466
HABITAT	0.200 ± 0.200	0.000 ± 0.000	0.000 ± 0.000	2.600	0.279

<sup>^</sup> See Appendix A for abbreviations and definitions

† Calm: n = 4; Low: n = 5; High: n = 7

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.79: The effect of habitat type on the abiotic factors present during the subject jump-yip bouts for trials where the immediate post-jump-yip behaviours of bout initiators were analyzed.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 9)	Captive (n = 4)	$\chi^2$	Sig.
CLOUD	<b>0.077</b> ± <b>0.077</b>	<b>0.667</b> ± <b>0.333</b>	<b>1.000</b> ± <b>0.577</b>	<b>4.412*</b>	<b>0.072</b>
WIND	<b>1.385</b> ± <b>0.311</b>	<b>0.333</b> ± <b>0.167</b>	<b>0.000</b> ± <b>0.000</b>	<b>9.427**</b>	<b>0.005</b>
TIME†	12.800 ± 0.562	11.506 ± 0.096	13.909 ± 2.377	1.066	0.606
DATE	<b>7.045</b> ± <b>0.683</b>	<b>10.756</b> ± <b>0.364</b>	<b>7.065</b> ± <b>0.689</b>	<b>14.140**</b>	<b>&lt;0.001</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Wild: n = 12; Intermediate: n = 3; Captive: n = 4

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.80: The effect of habitat type on the abiotic factors present during the subject jump-yip bouts for trials where the behaviours of bout initiators in the minute following jump-yip production were analyzed.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 23)	Intermediate (n = 13)	Captive (n = 6)	$\chi^2$	Sig.
CLOUD	0.304 ± 0.098	0.462 ± 0.243	1.000 ± 0.447	2.320	0.320
WIND	<b>1.696</b> ± <b>0.230</b>	<b>0.231</b> ± <b>0.122</b>	<b>0.000</b> ± <b>0.000</b>	<b>21.932**</b>	<b>&lt;0.001</b>
TIME†	13.779 ± 0.471	11.456 ± 0.093	13.839 ± 1.789	2.078	0.374
DATE	<b>6.737</b> ± <b>0.452</b>	<b>10.975</b> ± <b>0.265</b>	<b>7.065</b> ± <b>0.534</b>	<b>25.959**</b>	<b>&lt;0.001</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

† Wild: n = 22; Intermediate: n = 3; Captive: n = 6

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

Table F.81: The effect of habitat type on the abiotic factors present at the time of the subject jump-yip bouts for trials in which the post-jump-yip changes in the behaviours of bout initiators were analyzed.<sup>^</sup>

	Habitat type			Test statistics	
	Wild (n = 13)	Intermediate (n = 8)	Captive (n = 3)	$\chi^2$	Sig.
CLOUD	<b>0.077</b> ± <b>0.077</b>	<b>1.000</b> ± <b>0.378</b>	<b>0.667</b> ± <b>0.667</b>	<b>5.457*</b>	<b>0.051</b>
WIND	<b>1.385</b> ± <b>0.311</b>	<b>0.250</b> ± <b>0.164</b>	<b>0.000</b> ± <b>0.000</b>	<b>9.022**</b>	<b>0.005</b>
TIME†	13.379 ± 0.652	11.525 ± 0.108	15.139 ± 2.600	12.0#	0.452
DATE	<b>7.042</b> ± <b>0.684</b>	<b>10.942</b> ± <b>0.358</b>	<b>6.667</b> ± <b>0.796</b>	<b>13.459**</b>	<b>&lt;0.001</b>

<sup>^</sup> See Appendix A for abbreviations and definitions

# Mann-Whitney U Test

† Wild: n = 12; Intermediate: n = 2; Captive: n = 3

\* Significant at  $\alpha = 0.10$

\*\* Significant at  $\alpha = 0.05$

intermediate habitats also occurred latest in the year (F-I:  $\chi^2 = 14.140$ ,  $P < 0.001$ ; F-P:  $\chi^2 = 25.959$ ,  $P < 0.001$ ; F-PP:  $\chi^2 = 13.459$ ,  $P < 0.001$ ), while the greatest level of cloud cover was found in intermediate and captive habitats (F-I:  $\chi^2 = 4.412$ ,  $P = 0.072$ ; F-PP:  $\chi^2 = 5.457$ ,  $P = 0.046$ ).

Later in the year, trials took place in more captive habitats (a result which simply occurred due to the times at which the populations could be observed, rather than for any biological reason). While recording sessions in wild habitats were limited to times in which meteorological variables were most favourable to observing black-tailed prairie dog behaviour (ideally when there was the least amount of cloud and wind), in captive habitats trials were simply run when there was no precipitation. Thus, cloud cover could be relatively high. Furthermore, because many of the captive populations were at least partially shielded from the wind by the construction of the habitats (where some of the habitat was at least partially below ground – APZ – or was shielded by surrounding structures – DZ), the wind intensity at the time was less than in many of the wild populations observed in this study. Correspondingly, wind intensity was generally greatest in wild habitats, where populations inhabit large expanses of open prairie (with limited protection from wind). In cases such as this, additional studies which better quantify abiotic factors may be required to assess the biological relevance of temporal and meteorological variables.