AN ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF DROUGHT ON WATERFOWL IN AGRO-MANITOBA AND RECOMMENDATIONS FOR MITIGATION MEASURES

By

Ben Semchuk

A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree,
Master of Natural Resources Management

Natural Resources Institute
The University of Manitoba
Winnipeg, Manitoba, Canada
August, 1982

ABSTRACT

Drought is a recurring climatic phenomenon of the northern Great Plains which include most of Agro-Manitoba. Historical and archeological evidence indicates that cyclical dry periods have been ocurring since ancient times and will continue into the future. Droughts generally have an adverse impact on wildlife and wildlife habitat. In the case of waterfowl, cyclical droughts have both positive and negative environmental impacts. Prairie dry cycles have the effect of rejuvenating wetlands and improving them as waterfowl habitat. Waterfowl have developed an equilibrium with alternating wet and dry prairie cycles, after thousands of years of evolution. Stable waters in the northern latitudes provide a place for resident and drought-displaced waterfowl to await the return of wet conditions on the prairies. Waterfowl can explosively reproduce their numbers on the fertile prairies during a wet cycle. On the negative side, droughts cause the decline of the continental populations of waterfowl because of adverse nesting conditions. Reduced populations result in reduced harvest opportunities and an economic loss. The equilibrium of waterfowl with alternating wet and dry prairie cycles has been altered by the introduction of large-scale agriculture on the prairies. Agricultural activities are responsible for the progressive elimination of wetlands which are vital for waterfowl to repopulate themselves during

wet cycles. The federal grain quota is the chief policy acting against wetlands preservation. It is only recently that the true economic valuation of wildlife has been appreciated. Economists have determined methods of placing monetary valuations on wildlife. The indirect travel cost method is applicable to waterfowl at specific sites in Agro-Manitoba. Mitigation measures for the negative environmental impacts of drought on waterfowl depend upon government policies that support wetlands preservation. There are a multitude of ways to preserve and enhance wetlands. Agricultural practices can be modified and adapted to achieve wetlands preservation.

ACKNOWLEDGEMENTS

Many people and organizations have contributed to this practicum. I would like to thank the members of my practicum committee: Dr. Rick Riewe, who throughout the course was not only an inspiration to myself, but to all the NRI students of my year, to Pat Rakowski, of the Canadian Wildlife Service, who generously gave of his time and much valuable material from his personal library, to Dr. Terry Neraasen, of Ducks Unlimited, who also gave generously of his time and valuable material, Dr. Bob Jones, of the Manitoba Department of Natural Resources, who also gave generously of his time and valuable material. To Professors Rick Baydack and Thomas Henley who read drafts and offered encouragement throughout the whole process. To Pat Martin, who thoughtfully kept an eye out for additional material for me while she was doing her own research. To Dr. W. Henson for his support and assistance throughout.

I am grateful to the Prairie Farm Rehabilitation Administration for the financial assistance they provided in support of this practicum.

A very special thank you goes to Emilie Novotny and Marie Klaus for the excellent typing of the draft and for the thoughtful help and assistance I received from them during my entire stay at NRI.

To Liz and Sherry whose support made the whole thing possible.

LIST OF FIGURES

FIGURE		PAGE
1	Area of reference of drought-displaced ducks	12
2	Dabbling duck breeding population index as derived from serial surveys on prairies, N.W.T., and Alaska	12
3	Map of southwestern Manitoba showing locations of Priority I and II soils. . .	16
4	Airflow in the American west.	21
5	Entrenched high over Texas -- Sumer 1980 .	46
6	Priority duck production habitat in Manitoba	58

TABLE OF CONTENTS

PAGE

ABSTRACT i

ACKNOWLEDGEMENTS iii

LIST OF FIGURES viii

LIST OF TABLES ix

CHAPTER I: INTRODUCTION

1.1 Background 1

1.1.1 Canada-Manitoba Drought Proofing Agreement 2

1.2 Problem Statement 2
1.3 Research Objectives 3
1.4 Methods 4
1.5 Limitations 5

CHAPTER II: LITERATURE REVIEW

2.1 Historical Perspective 7
2.2 General Effects of Drought on Wildlife 9

2.2.1 Habitat Losses 10
2.2.2 Population Reductions 10
2.2.3 Reproductive Losses 10
2.2.4 Diseases 11

2.3 Valuation of Wildlife Losses 11

2.3.1 Consumptive Values 14
2.3.2 Non-Consumptive Values 14
2.3.3 Other Valuations 15

2.4 Environmental Damage 17

CHAPTER III: EFFECTS OF PRAIRIE DROUGHT ON WILDLIFE AND HABITAT

3.1 Climactic History of the Great Plains 18
3.2 Recorded Effects of Prairie Drought on Wildlife and Habitat 27

3.2.1 Drought Displacement of Northern Great Plains Waterfowl .. 31
3.2.2 Habitat Fundamentals 40

CHAPTER IV: DROUGHT IMPACT ON AGRO-MANITOBA DURING 1980 AND 1981

4.1 Drought History of Agro-Manitoba 42
4.2 The Droughts of 1980 and 1981 in Agro-Manitoba 45

4.2.1 Conditions Necessary for Surface Water in Prairie Potholes 47
4.2.2 Discussion of Canadian Wildlife Service Spring 1981 Transect Results 48
4.2.3 1981 Spring Waterfowl Forecast ... 52

CHAPTER V: CURRENT STATUS OF WATERFOWL MANAGEMENT IN AGRO-MANITOBA

5.1 General Comments on Waterfowl Management 55
5.2 Status of Waterfowl Habitat in Agro-Manitoba 57

CHAPTER VI: ECONOMIC VALUATIONS OF WILDLIFE, WATERFOWL AND HABITAT

6.1 Introduction 61
6.2 Attempts at Wildlife Evaluation by Using Gross Dollar Values 63
6.3 Ecological, Economic and Legislative Factors Affecting Wetlands 67
6.4 A Review of Attempts to Determine Wildlife Valuations 71

6.4.1 Gross Dollar Estimates 71
6.4.2 Shooting Preserve Values 72
6.4.3 Legal Values 72
6.4.4 Input-Output Analysis 72
6.4.5 Benefit-Cost Analysis 73
6.4.6 Resource Production Base 73
6.4.7 Non-Consumptive Values 74
6.4.8 Natural Resource Econometrics ... 74

6.5 Benchmark Valuation Methods 75

6.5.1 Bioeconomic Evaluation 75
6.5.2 Colorado Wildlife Division Values 78
6.5.3 Canadian Wildlife Service Approach 82

6.6 Conclusion 82

CHAPTER VII: BIOLOGICAL IMPACT OF DROUGHT ON WATERFOWL

7.1 Effects of Drought on Waterfowl Reproduction 84
7.2 Drought and Botulism 87
7.3 Waterfowl and Drought in Australia ... 88

CHAPTER VIII: DROUGHT-INDUCED CONFLICTS BETWEEN WATERFOWL AND AGRICULTURE

8.1 Crop Depredation 90
8.2 Saskeram Marsh -- 1980 Drought Induced Conflict 91

8.2.1 General 91
8.2.2 Facts Discovered by Provincial Government Investigation 92
8.2.3 Ducks Unlimited Viewpoint 93
8.2.4 Discussion 94

CHAPTER IX: MITIGATION MEASURES

9.1 General 96
9.2 Government Policies 97

9.2.1 Grain Delivery Quotas 99
9.2.2 Government Support of Conservation Agencies 100
9.2.3 Policy Requirements 101

9.3 Agricultural Practices 101

9.3.1 General 101
9.3.2 Zero Tillage 102
9.3.3 Stubble Mulching 105
9.3.4 Rotational Grazing and Controlled Burning 105

9.3.4.1 General 105
9.3.4.2 Rotational Grazing 106
9.3.4.3 Controlled Burning 106

9.3.5 Improvements for Wetlands 107

9.3.5.1 General 107
9.3.5.2 Protection of Natural Wetland Cover 108
9.3.5.3 Alteration and Creation of Wetlands 108

9.3.6 Enhancement of Natural Environment 109

9.3.6.1 Artificial Nesting Islands 109
9.3.6.2 Artificial Nesting Structures 110
9.3.6.3 Stock Ponds 110
9.3.6.4 Artificial Propagation .. 112

CHAPTER X: SUMMARY AND CONCLUSIONS 113

10.1 Summary 113

10.1.1 Historical Overview of Cyclical Prairie Droughts 113
10.1.2 Environmental Effects of Cyclical Prairie Droughts on Wildlife and Waterfowl 114
10.1.3 Economic Valuation of Drought Damage to the Waterfowl Resource 118
10.1.4 Recommendations for Mitigation Measures 121

10.2 Conclusions 122

LITERATURE CITED 124

PERSONAL COMMUNICATIONS 131

LIST OF TABLES

TABLE		PAGE
1	Five Driest and Wettest Crop Years	43
2	Duck breeding populations and pond counts for the prairie provinces, May 1981	49
3	Agricultural impacts on potential wetlands in southwestern Manitoba and southeastern Saskatchewan	51
4	Description of priority duck production habitat in Manitoba	59
5	Colorado Product List	80

LIST OF FIGURES

FIGURE		PAGE
1	Area of reference of drought-displaced ducks	12
2	Dabbling duck breeding population index as derived from aerial surveys in prairies, N.W.T., and Alaska	12
3	Map of southwestern Manitoba showing locations of Priority I and II soils	16
4	Airflow in the American West	21
5	Entrenched high over Texas - Summer 1980	46
6	Priority duck production habitat in Manitoba	58

CHAPTER I

INTRODUCTION

1.1 Background

A stable high-pressure weather system over Western Canada caused dry weather and drought conditions over the prairies during the summer of 1980. The drought conditions focused attention on the economic importance of a water development plan to mitigate water shortage effects. Recurring moisture shortages are one of the features of prairie weather. These shortages can be measured in terms of deviation from ideal soil moisture conditions for crop production and/or lack of adequate water supplies. During drought periods, the adverse economic effects of water shortages impact heavily upon the provincial agricultural sector. However, drought also affects the environment in general, and there is the added negative economic effect of environmental damage.

Droughts of a severe nature have been documented on the prairies since the 19th century (Tyrchniewicz, et al., 1979). There were at least 20 droughts in Western Canada in the 19th century, the worst of which occurred in the late 1880's and early 1890's. In the 20th century, the pattern of periodic droughts has persisted. Drought was experienced on the prairies in 1910, 1914, in the period between 1917 and 1920, in 1924 and 1929, and during the 1930's. In more recent times, droughts occurred in 1961 and 1977. A high-pressure ridge was located over Western Canada during the winter of 1980/81 which again caused a dry spring in 1981.

1.1.1 *Canada-Manitoba Drought Proofing Agreement*

The Canada-Manitoba interim subsidiary agreement on Water Development for Regional Economic Expansion and Drought Proofing was formalized on 30 May 1980. The purpose of this agreement is to improve the potential for economic and socio-economic development in Manitoba by alleviating the constraints imposed on economic performance by recurrent water shortages and droughts. The agreement will develop a strategy to improve the effectiveness of future water management activities; to analyse the availability and requirements for water in selected areas; and the construction of water supply and delivery schemes consistent with the strategy. The Canadian Federation of Agriculture supports the two levels of government designing joint and permanent drought policies (Greenspon, 1981). Therefore, one of the main thrusts of the agreement is to develop policies for adopting drought resistant economic activities to the Agro-Manitoba sector. The environmental losses also constitute an economic loss attributable to drought and have an effect on economic activity.

1.2 Problem Statement

Environmental damage can occur from the effects of drought as discussed in the foregoing sections. Vegetation dies and potholes and marshes dry up, reducing the wildlife habitat and, in turn, reducing wildlife populations. Waterfowl do not have sufficient wetlands for annual breeding and there is reduced reproduction from the breeding pairs that do find nesting areas. One of the decisions which the Management Group in charge of the Canada-Manitoba Drought Proofing Agreement are to make is, "should the study be concerned with the environmental impact of drought, i.e. fish, wildlife, reduced water quality along with possible mitigation measures?" The author will outline a study of this problem and identify the data required to address the question.

1.3 Research Objectives

The main purpose of this study was to investigate the environmental impact of prairie droughts on waterfowl in Agro-Manitoba and to determine possible mitigation measures that could be undertaken. The main objectives of this study included the following:

a. An historical overview of the phenomenon of cyclical prairie droughts.

b. An examination of the environmental effects that cyclical prairie droughts have on wildlife in general, and waterfowl in particular.

c. An economic valuation of the damage to the waterfowl resource that results from cyclical prairie droughts.

d. Recommendations outlining feasible mitigation measures that could be implemented to reduce the negative environmental impacts of drought on waterfowl.

All of the above findings are intended to provide environmental impact information that could be coordinated within the framework of the Canada-Manitoba Drought Proofing Agreement.

1.4 Methods

The proposed environmental study of drought impacts on waterfowl was interdisciplinary in approach. To assist with the question of whether the Agreement should be concerned with environmental impact of drought on waterfowl, both positive and negative impacts were examined. The general environmental effects and the mitigation measures to lessen waterfowl losses that could be undertaken within the overall development strategy were considered. Several aspects of potential wildlife losses were considered, however, the assessment concentrated on the environmental impact of drought on waterfowl. The findings of this study can be advanced to the Management Group to assist in determining if the Agreement should be concerned with the environmental impact of drought on wildlife and waterfowl in particular.

A related literature review was undertaken to obtain an historical overview and to identify other related sectors for detailed study. The study focused on the following:

- a determination of the environmental impact on waterfowl as recorded in biological research papers.

- valuation of drought-affected wildlife, especially waterfowl.
- vulnerability of waterfowl to drought on short-term (one season) and long-term bases.
- mitigation measures which are feasible to deal with the negative environmental impacts.
- interface with the agricultural sector on some aspects of drought-induced waterfowl problems.

An assessment of the environmental impacts was prepared combining all data and information obtained. Mitigation recommendations were made based on the data obtained.

1.5 Limitations

The study was time-limited from spring 1981 to winter 1982. Data collected was largely limited to existing data and information sources. Mitigation measures are restricted to those which fall within practical limits and existing political policy. The study area was limited primarily to Agro-Manitoba as far as possible.

The study of wildlife and waterfowl economic valuations was combined with data for other game animals was well as waterfowl. Some economic studies did deal exclusively with waterfowl, but the final result would have been incomplete unless it was coordinated with key studies which approached wildlife valuations on a broad sphere. The best literature in most cases didn't segregate between waterfowl valuation methods and game animal valuations because the recreation day concept proved to be the final approach towards solving the problem. This, however, was in keeping with one of the original aims of this paper which was to provide lead-ins for future studies of the impacts of drought on other wildlife besides waterfowl.

The subject area dealing with mitigation measures was large enough for an independent study. The points covered are considered those which have the most visibility and potential ease of implementation.

CHAPTER II

LITERATURE REVIEW

2.1 Historical Perspective

Bryson (1980) described the climatic cycles of weather changes on the Great Plains of North America as the interactions of massive air flows across the continent. The main air flows are westerlies from the Pacific; cold arctic air flowing southward down the eastern half of North America; and warm, moist tropical air flowing northward. Between the two extremes of air from north and south, Pacific westerlies drive their own air mass eastward, acting like a giant wedge.

Climatic changes are determined by the variation in length of time the various airstreams dominate in a given area. Bryson has found archaeological and fossil evidence of climatic changes and resultant precipitation changes on the Great Plains dating back to 1200 A.D. Scientific observation of weather data has pointed out that the most recent long term wet climatic cycle occurred on the Great Plains in the period between the 1850's and 1930-1960, This period was characterized by a 20 to 30 percent increase in precipitation from the present level of precipitation we now have on the Great Plains. However, segments of air masses involved in climatic changes tend to locate in a preferential pattern over certain geographical areas, which results in strong west-east contrasts of climate.

Recurring moisture shortages are a regular feature of prairie weather and can be detected almost every year.

(Tyrchniewicz, et al., 1979). These shortages vary greatly in magnitude and impact and are measured in terms of deviation from ideal soil moisture conditions for the production of crops and/or inadequate water supplies for domestic and livestock purposes. Twenty severe droughts were recorded in Western Canada in the 19th century and at least nine droughts have occurred in the 20th century. The last Prairie droughts were recorded in 1961, 1977, 1980 and 1981. The drought of 1961 was not considered severe since it was preceded and followed by years of normal precipitation. The spring drought of 1977 saw prairie crops saved by May rains but dugouts, reservoirs, and shallow aquifers were not recharged in certain instances, and grass growth failed to fully recover, causing reduced pasturage and fodder supplies. A general drought-induced environmental deterioration was observed. Marshes and sloughs dried up, there was a die-out of native trees and shelterbelts, and major streams recorded historically low water levels. Had the 1961 and 1977 droughts continued into a second or third year, the impacts would have escalated sharply.

In 1980, a stable and persistent high-pressure system over Western Canada diverted the Pacific westerlies far north of their normal course and caused that summer's dry weather (Adler, 1981). Meterologists could not adequately explain this phenomenon. During the winter of 1980/81, the same phenomenon repeated itself and once again, raised concern about a potential dry summer for 1981. However, in Manitoba rains ended the early spring drought conditions that developed and the Prairie Provinces harvested the best grain crop in history. But these same rains that saved the agricultural scene, came too late for spring-nesting prairie waterfowl.

2.2 General Effects of Drought on Wildlife

The carrying capacity of wildlife habitat determines wildlife populations. The carrying capacity in turn, is determined by habitat quantity and quality which is relatively stable, since habitat changes are usually gradual. The exception to this orderliness can be a climatic catastrophe such as drought. Lauckhart (1962) states that carrying capacity can be determined by the yearly low point in population graphs, as they represent levels to which the wildlife population is depressed by habitat limitations. Therefore, maintenance of proper habitat is basic to all wildlife abundance. With many species, food without cover is as useless as cover without food, and a lack of water can cancel the value of both. Wade (1938), in a study of effects of the 1936 drought on game management areas in Wisconsin, noted a marked reduction in wildlife populations which coincided with severely damaged native flora and agricultural crops. Boyd (1981a) stated that the numbers of prairie ducks found in the farmland parts of Western Canada in the 1990's should remain approximately the same as the numbers that are counted in the 1980's, unless a sustained drought as severe as that of the 1930's should occur.

2.2.1 *Habitat Losses*

Drought reduces water availability resulting in the drying of potholes and marshes and death of native trees and shelterbelts. Marshes and woodlands represent high-quality wildlife habitat which furnish protection, nesting sites, succulent foods, and water supply to many wildlife species. The possibility of fire is increased, which can cause still further deterioration of habitat. Drought also diminishes the supply and nutritional value of wildlife food plants.

2.2.2 *Population Reductions*

Bossenmaier (1978) notes that the drought of the 1930's decimated the prairie duck population. Similarly, Wade (1938) observed a general shrinkage in almost all resident game species as a result of the 1936 drought in Wisconsin. Wildlife populations, which are ecologically tied to the carrying capacity of their habitat, decrease as drought deteriorates the habitat. Aerial surveys of duck populations have proven that the number of prairie ducks rise and fall with wetness and dryness of the prairies (Boyd, 1981a).

2.2.3 *Reproductive Losses*

Salyer (1962) reported that drought conditions decreased reproductive success of prairie nesting ducks because of a loss of suitable nesting sites. Diving duck populations also responded directly with water levels. Yeager and Swope (1956) compared duck production between wet and dry years and discovered that drought conditions could reduce reproduction in the order of 40 percent. Hansen and McKnight

(1964) observed that prairie ducks spend their summers on northern waters when drought dries out their normal breeding areas. Little reproduction occurs during these conditions (Fig. 1, Fig. 2). It is well known that eggs of various upland game bird species spoil during periods of drought-induced heat (Wade, 1938).

2.2.4 *Diseases*

Drought can lower water levels in marshes and expose lethal bacteria in exposed mud. Botulism toxin is created and ingested by aquatic invertebrates which are in turn, eaten by ducks. These conditions occurred at Oak Lake, Manitoba in August 1980, and resulted in the death of at least 10,000 ducks (Blicq, 1980). Avian botulism has been the cause of the most massive losses from disease known to occur in waterfowl (Kalmbach, 1968). Friend (1981), has pointed out that habitat quantity and quality are very important factors in modern day control of waterfowl diseases. Poor quality habitat has been demonstrated to accelerate the disease process of waterfowl.

Drought conditions cause disease problems for wildlife dependent on the food supply of a deteriorating habitat. Leopold and Ball (1931) suggested that drought conditions induced diseases in wildlife because of the reduced quality of food supply.

2.3 Valuation of Wildlife Losses

Because of law and tradition, activities made possible by wildlife are available without market transactions,

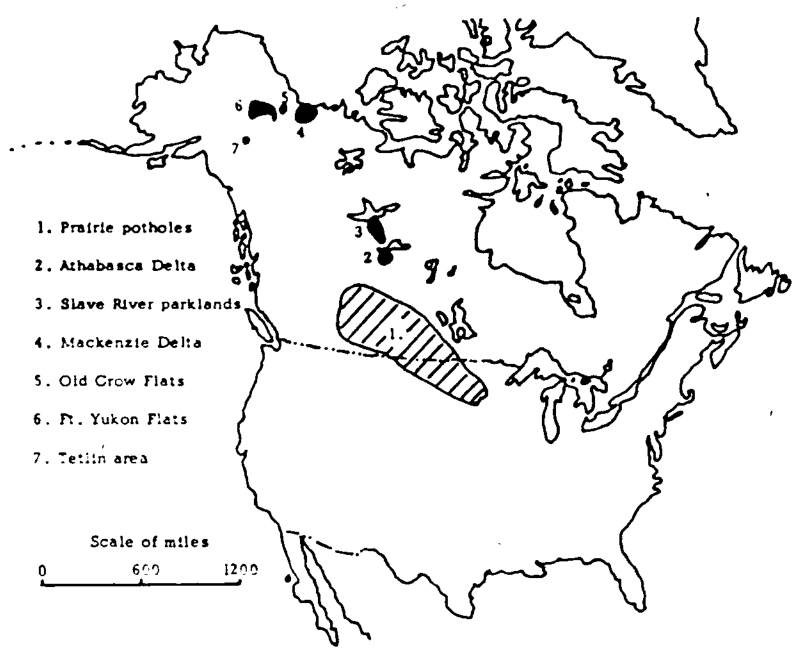


Figure 1. Area of Reference of Drought-Displaced Ducks

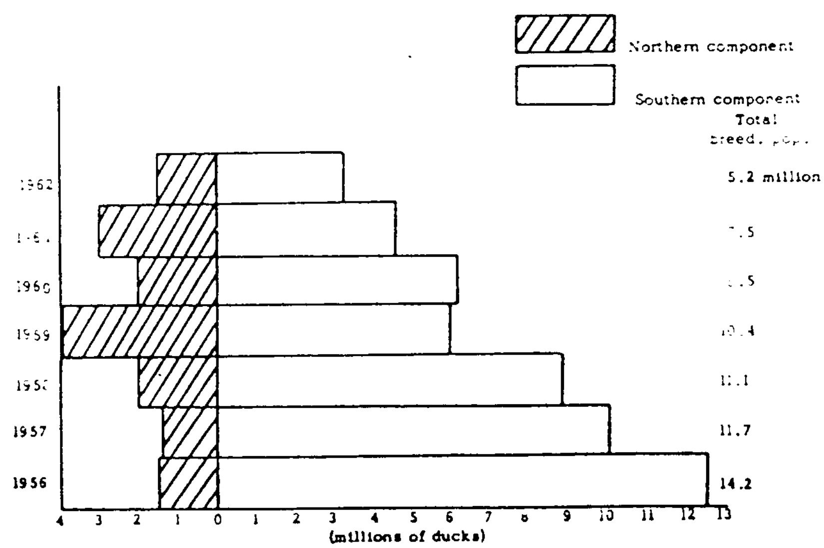


Figure 2. Dabbling Duck Breeding Population Index as Derived from Aerial Surveys on Prairies, NWT and Alaska.

Source: Hansen and McKnight, 29th N.A. Wildlife Conf., 1964.

and consequently there are no directly acceptable ways of placing unit values on wildlife expressed in dollars. The problem of wildlife valuation has been the subject of research efforts for almost the last 30 years (Hoover, 1976). Environmental managers have long recognized the need to express wildlife values in terms of dollars since most negotiations involving land use involve economics. The evaluation of a wildlife resource by an economist, can hold more importance than evaluations presented by wildlife managers or biologists. A cost/benefit analysis is often the deciding factor in resolving a land-use problem. The most basic wildlife management problem, is to determine optimum population levels of wildlife species. Resolution of this basic problem and related decisions, such as wildlife mitigation measures, require information on the value of the wildlife and its sustaining habitat (Davis and Seneca, 1971). For many years, the gross expenditure method of evaluating a wildlife resource has been used. Since the 1960's, most economists have rejected this method as conceptually unsound (Langford and Cocheba, 1978). Gross expenditures understate the value of a wildlife resource. However, these valuations (Horvath, 1974) are still used today in certain applications. Current valuations strive to define and quantify wildlife resources in terms of consumptive and non-consumptive uses (Langford and Cocheba, 1978, Norman _et al_., 1975).

2.3.1 *Consumptive Values*

As a source of direct consumer benefits, wildlife resources can be defined in terms of the product of commercial hunting and fishing; the value of a product such as meat or fur; as input into research processes; and as a pool of genetic material. The primary valuation of a wildlife resource is now determined in terms of recreation days provided (Langford and Cocheba, 1978). The Colorado Division of Wildlife has determined valuations that give dollar values for individual animals, habitat required to sustain them, and recreation days obtainable (Norman et al., 1975). However, these values are derived in part, by use of gross expenditures. With these dollar valuations, the Colorado Division of Wildlife determines the cost of mitigating measures to replace wildlife habitat that is given up for other land uses. Langford and Cocheba (1978) have recommended use of travel-cost and direct consumer surplus techniques as useful methods for valuation problems. The input-output method determines the economic contribution wildlife values make to a certain area and has the advantage of providing a multiplier effect, or how many times a wildlife dollar turns over (Hoover, 1976). Once the consumptive values have been determined, they must be added to the non-consumptive values in order to obtain the true costs involved in a cost/benefit analysis of a mitigation project.

2.3.2 *Non-Consumptive Values*

Several valuations have been determined, based on considerations of recreational, aesthetic, educational, biological and social values. A dollar valuation on wildlife based on these elements is difficult to determine (Chapman, 1973). Langford and Cocheba (1978) note that wildlife is of central importance to certain non-hunting recreational activities. They identified these activities as wildlife-based, such as wildlife photography; wildlife-related, such as hiking where wildlife is one of the recreation inputs; endemic wildlife, such as wildlife-based activities in the vicinity of a participant's residence; and recording-based wildlife activities, such as watching wildlife films. There is also contemplative wildlife activity such as contributing time and money for the preservation of a wildlife species. They state that a dollar value can be determined on these non-hunting benefits by using a direct-question approach. Norman et al. (1975) derived a non-consumptive dollar value for wildlife by applying a conversion factor to consumptive values obtained.

2.3.3 *Other Valuations*

There is much evidence that ducks prefer breeding marshes in areas of high soil fertility (Rose and Morgan, 1964). Loss of duck habitat on good agricultural soils pushes birds to wetlands on soils of lesser fertility. In times of high duck populations and/or reduced water areas, displaced birds will find no unoccupied prairie waters. Drought damage to fertile potholes reduces the shootable duck surplus produced on the prairies. Figure 3 is a graphical representation of

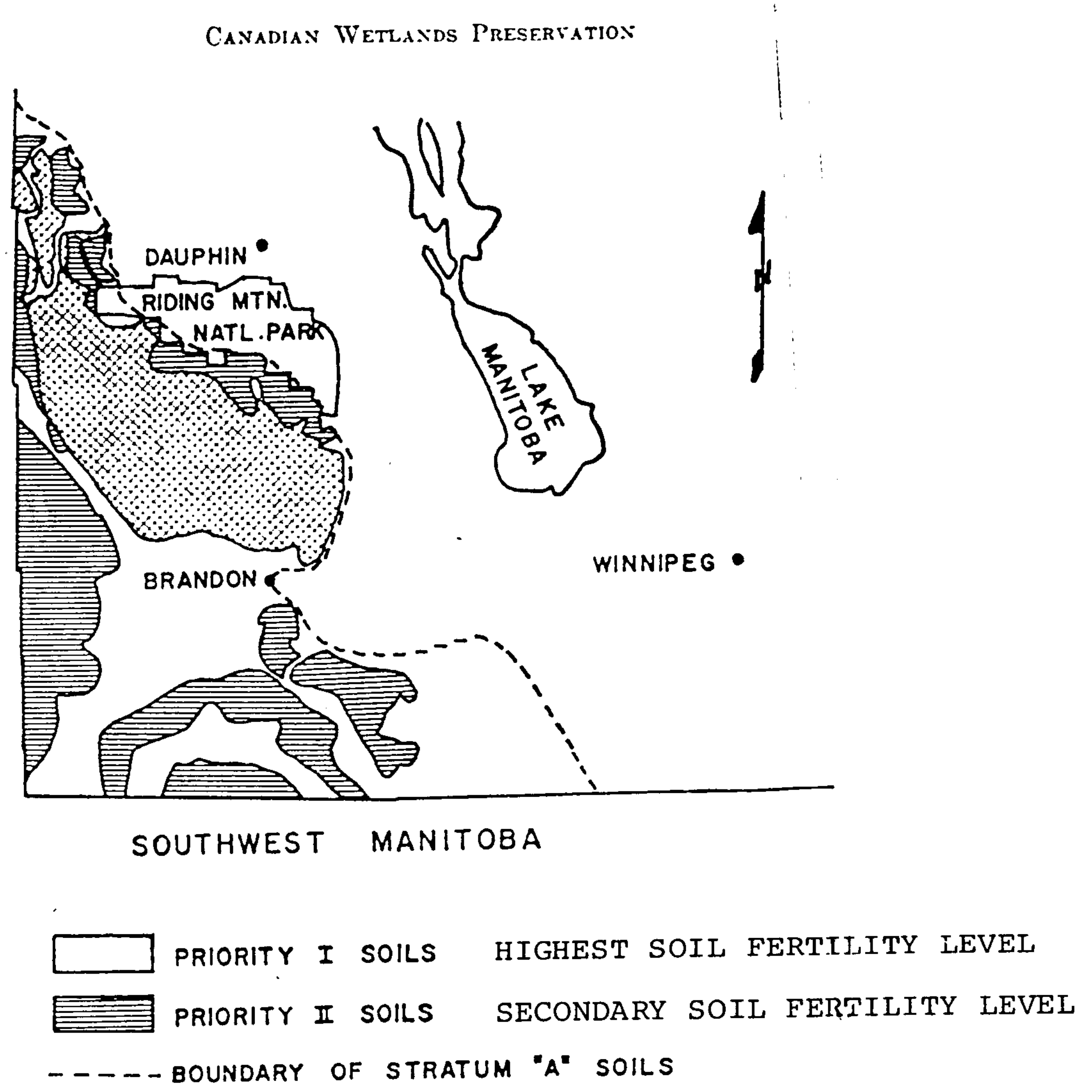


Figure 3. Map of southwestern Manitoba showing locations of Priority I and II soils.

NOTE: Stippled area was not included in this study.

SOURCE: Rose and Morgan, 29th N.A. Wildlife Conf., 1964.

priorized soil areas where potholes have the most productive value. Drought mitigation measures for waterfowl can be maximized in dollar value by employing this map as a decision-making tool.

2.4 Environmental Damage

When wetlands are dried out by drought, a series of corollary adverse environmental effects are set in motion (Larson, 1980). Wetlands function as basins in the watershed that retain and detain water at various flood stages. It is known that anaerobic soils of wetlands remove nitrogen from water, and during the growing season, plant uptake of nitrogen and phosphorous removes these nutrients from water in and passing through wetlands. This latter function is really a form of pollution filtration. Wetlands can also reduce the sediment load transported in streams. Because of the complex ecological role performed by wetlands, the loss of wetlands causes a succession of ensuing environmental damage.

CHAPTER III

EFFECTS OF PRAIRIE DROUGHT ON WILDLIFE AND HABITAT

3.1 Climactic History of the Great Plains

During the drought conditions which prevailed over western North America in the summer of 1980, the public was abruptly made aware that cyclical drought is a constant factor in the climatic make-up of the Great Plains despite long intervals without the occurrence of drought. The spectre of the drought conditions of the "dirty thirties" seemed to be reappearing. Public concern was roused by the media, who compared the 1980 situation with the drought of the "Thirties". Adler *et al*. (1981) reviewed the water shortage problem on a continental scale and traced through the entire background of political, cultural and geological history of water utilization in the United States. They provided a background to why drought-induced water shortages have an immediate and dramatic effect. They concluded that the original water supplies of the U.S.A. which existed before the coming of European settlers, were being expended at an alarming rate, faster than could be replaced by natural precipitation.

Bryson (1980) described the complex climatic history of the Great Plains including the drought effects that have occurred over the last centuries. The historical outline of North American climatic changes that he described, is important because it provides an overview of the climatic changes

that can occur on the Great Plains over the very long run. The climate of western North America is best described in terms of special topographic features. The Great Plains are primarily a high plateau. The Cordillera Mountain ranges on the west, modify the flow of air across this plateau. The air flow consists of mid-latitude westerlies blowing almost at right angles to the mountains. This air flow dominates the climate of most of North America. The western mountains are too high for most of the most low-level air coming from the West Coast to cross. The kinetic energy of the west winds is usually insufficient to enable the air to rise from near sea level along the Pacific coast, to the crests of the western mountains. Much more air leaves the east side of the Cordilleras near the ground than arrives at the west coast near the ocean. The excess comes from atmospheric levels near the height of the plateau, about 4000 to 5000 feet (1219 to 1524 metres). Because of the location of the various mountain ranges and the character of the air, there are three dominant routes by which this mid-level Pacific air moves eastward to the Great Plains. These three Pacific air streams undergo warming and drying as they descend to the Great Plains and cause a chinook effect.
The northernmost air route, which flows across the Canadian Rockies is the most interesting for purposes of this paper. However, the ensuing climactic effects created by all three air flows will be seen to affect the climate of western North America, including the northern Great Plains in western

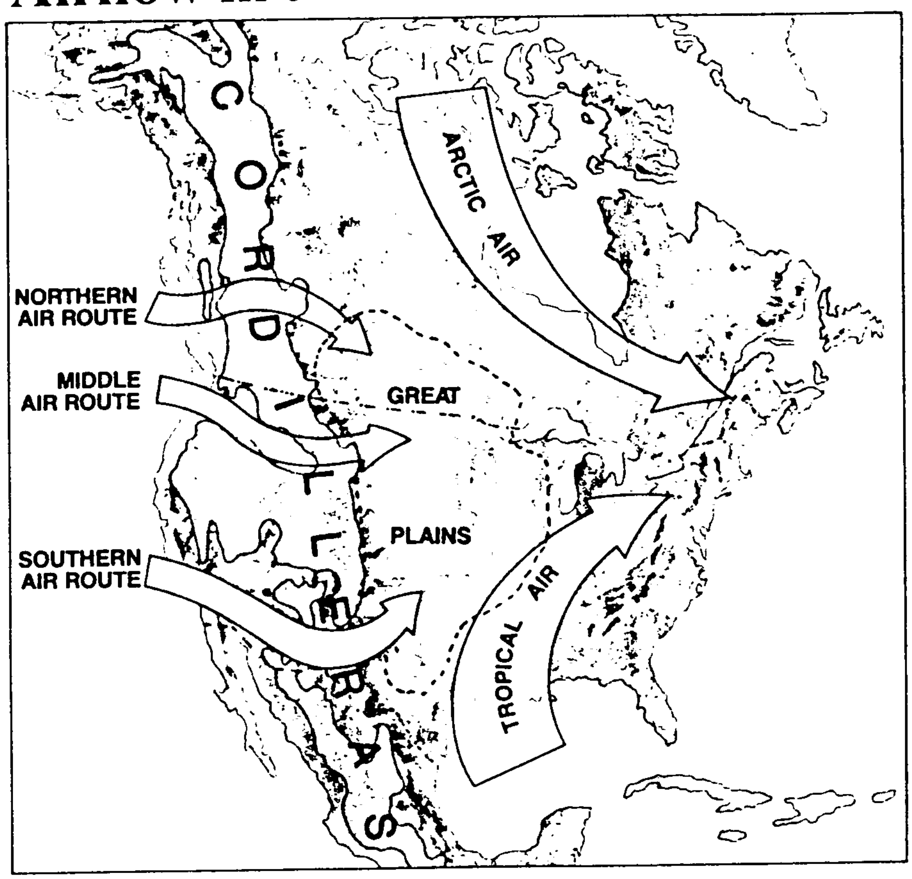
Canada. The southern and middle air flows tend to travel through a series of mountain passes, however the northern air flow has no broad system of passes but flows because of the relative ease of vertical movement of the Pacific air at Canadian latitudes, combined with the strength of the westerlies. This rather low-level Pacific air is able to cross the mountains and is mild for its latitude, and dry.

The eastern half of North America, with its broad Hudson Bay-Mississippi Valley system of lowlands is open to the unimpeded flow of cold arctic air southward and of warm, moist tropical air northward. Between these two extreme types of air, the west winds drive a wedge composed of the three modified varieties of Pacific air (Figure 4). It is important to note that the seasonal dominance and interplay of all five of these air types defines the climatic regions of North America and puts controls on the distribution of plant and animal life. The variation in length of time the various airstreams dominate in a given area is at the heart of climatic regions of North America and also puts controls on the distribution of plant and animal life. The variation in length of time the various airstreams dominate in a given area, is the main reason for climatic change.

In early summer, west winds of the mid-latitudes shift northward and contract into a smaller vortex around the North Pole. With this change, moist tropical air more readily penetrates northward over the Great Plains. This event raises the humidity and provides midsummer showers in the northern regions of the Great Plains. At the same time,

Figure 4:

Airflow in the American West



Source: Bryson, Natural History, Jun. 1980.

the northward shift of the westerlies moves the warm chinook zone northward to flow across the Canadian spruce forests. In winter, a shallow layer of cold air pours southward from the Arctic, filling the central lowlands and the plains up to about a 2,500 foot (762 metres) elevation on average, along the edge of the northern plains. During winter, the westerlies are further south than in summer and more dry air moves eastward across the southern Great Plains. During relatively cool and more winterlike periods in earth's history, arctic air reached further south in summer and the westerlies were further south and stronger. In warmer periods, the arctic air occupied a more restricted region, the westerly wedge of chinook climates was farther north, and so was the rain derived from tropical air streaming northward.

The above description (Bryson, 1980) of the climactic forces operating in western North America sets the stage for a discussion of the climatic changes that have been recorded in the northern Great Plains. Historical records show that there was a medieval warm period from about 900 to 1200 AD. Archeological evidence has shown that the prehistoric Indians of the northern Great Plains during this period, lived in villages scattered across the region and grew rain-fed corn and hunted deer and bison. Radiocarbon soil dating has indicated that after about 1200 AD these villages were abandoned and became covered with windblown dust. Various evidence shows that hemispheric cooling occurred from the thirteenth to the twentieth centuries. This period is sometimes referred to as the "Little Ice Age". This hemispheric cooling occurred in two steps. The first step occurred at the beginning of the thirteenth century and the second step was largely completed prior to 1600. During this period, Arctic ice expanded and glaciers in the northern hemisphere grew. The climate in western North America was changed. Certain features of this new climatic situation are fairly certain because the climatic changes continued into the period of scientific observation, the early 1800's, and did not end until about the beginning of the twentieth century.

The northern Canadian treeline is bounded by year-round cold arctic air and the southern treeline by the warmth and dryness of year-round chinook-dominated air. The shifting of the air streams from one century to another have made dramatic changes in the tundra and northern forest. Bryson, in the 1960's, explored fossil soils in Manitoba. He discovered soils that recorded north-south movements of about 200 miles (322 km) of the northern forest border along the line from Churchill, Manitoba, to Great Bear Lake in the Northwest Territories. The soil evidence showed that 3,600 years ago, the forest was far north of its present limit. It subsequently retreated abruptly southward to its approximate present position 2000 years ago. By the late twelfth century, it had again advanced 50-60 miles (80-97 km). A second, abrupt southward shift of the forest border in about 1200, indicated an expansion of the realm of Arctic air that brought a change in the pattern of the westerlies further south. Data from various other sources corroborated the evidence of the fossil soils. The extent of sea ice and cold-induced famine years in Iceland, written records from Europe, and pollen data from the North American mid-west, all record the occurrence of cooling at the high latitudes and a southward shift of the westerlies about the year 1200. Bryson used modern data and reconstructed past summer rainfall changes in North America that should have accompanied the increased strength of the summer westerlies in mid-latitudes. His reconstruction indicated that a slight expansion of the Arctic area, combined with a slight increase of the westerlies in the latitutdes of the United States, produced a dramatic decrease in midsummer rainfall in the northern and central regions of the Great Plains. His study concluded that the twelfth century marked the beginning of a two-century-long period of frequent, severe drought in the northern regions of the Great Plains. This drought terminated the lifestyle of the prehistoric Indian tribes on the high parts of the plains where agriculture was most marginal.

To understand the climatic changes that occurred during the Little Ice Age, it is necessary to examine atmospheric behaviour during the development of the north-south meandering of the high altitude westerly winds. When the Northern Hemisphere chills, most of the cooling takes place in the Arctic and sub-Arctic. This cooling is associated with a southern expansion of the west winds toward the equator, similar to the expansion of 1200. Additional southward movement of air masses, with further cooling, extends the west winds far enough into the tropics to produce a phenomenon called dynamic instability in which the upper-level west winds, instead of flowing eastward with gentle north-south undulations, frequently break into great loops. These loops may carry tropical air far north into the arctic and arctic air far south into the tropics. The most important climatic effect of these big loops of air is that they are slow-moving. Meteorologists refer to their effects as "blocking". Scientific evidence shows that such weather situations were far more common during the Little Ice Age than in the twentieth century. These blocking loops tend to be preferentially located in certain geographical areas. An unusually persistent upper-atmospheric block discouraged precipitation and warmed temperatures in the Canadian prairies from April 1980 until May 1981, except for a brief break near the end of the summer of 1980. This same block created weather conditions that parched the Southeast, Northeast, and large parts of the Midwest of the United States. Meteorologists couldn't accurately describe why this pattern developed. Bryson pointed out that the rainfall pattern since July 1974 has had a strong similarity to the pattern of the thirteenth century. The question he raises is whether we are at the beginning of a very long period of drought or at the end of a short period.

The wave of European immigrants who reached the Great Plains in the nineteenth century, found conditions that had changed from the drought that characterized the thirteenth and fourteenth centuries. The climate was changing to the immediate post Little Ice Age. Instead of the drought that had terminated corn agriculture over a wide area seven centuries earlier, the Great Plains had up to 30 percent more rainfall than in the modern era. There has been a 20 to 30 percent decrease of precipitation in the Great Plains between the 1850's and the 1930-1960 period. It is estimated that 1883 marked the end of the wetter period on the Great Plains. However, this wet period experienced weather with sluggish behaviour because of atmospheric instability and of blocking. It is known that such periods in the Great Plains are characterized by both weeks of intense drought and weeks of heavy rain. Data show that our perception of the western Great Plains as a sea of grass supporting enormous herds of grazing animals during the settlement of the west was only a snapshot of the transient climatic history of the prairies. Bryson (1980) believes the widely held theory that climate does not change or changes so slowly that humans can always adjust, is incorrect. He states that the facts are clear that western climate changes significantly, sometimes rapidly, and may stay changed long enough to change the character of human cultures. He cautions that our technology is not invincible and that our dams and irrigation works may not prevail against the extremes of drought which could occur on the Great Plains. He also notes that climatic variations will become more critical as the carrying capacity of the land is extended for food production for future populations.

3.2 Recorded Effects of Prairie Drought on Wildlife and Habitat

Aldo Leopold is acknowledged as being in the forefront of environmentalists and conservationists who perceived the inter-relationships between the flora and fauna of the environment. In his classic book, Game Management, published in 1933, he noted many of the adverse effects on wildlife and wildlife habitat that drought created. His observations are still quoted in present day literature. He attempted to sort the myriad effects of drought on wildlife, as observed by himself and other researchers, into an orderly interpretation of the facts. The effects of drought on the environment are complex because many of the initial adverse effects, in turn, result in further adverse effects so that there is a chain reaction or ripple effect of environmental damage. In the case of extreme drought, environmental damage of this ripple effect can be devastating.

Leopold (1933) defined four sources of water for wildlife. These sources are:

1. Surface water
2. Dew water which condenses on vegetation
3. Succulence, which means the water contained in plants having a high moisture content, and
4. Metabolic water which is internally manufactured by certain species such as some rodents and insects.

The requirements of wildlife for water-sources could be divided into two types which Leopold described as: (1) optimum, for wildlife productivity under various conditions, and (2) minimum, for survival under various conditions. While all game animals utilize surface water for drinking when it is available, this doesn't indicate whether or not an individual game species is dependent on this water-source. In broad general terms, the following requirements have been noted: most upland game birds can subsist on succulence and dew alone, many game animals and rodents can subsist on succulence except white-tailed deer, moose and caribou, which require drinking water. These classifications break down, however, during extreme drought when there is no longer a supply of succulence and dew. This description doesn't include the animals that are dependent on an aquatic medium for life such as muskrat and beaver.

During extreme drought conditions, the adverse effects of water deficiency are also accentuated and obscured by two additional sources of wildlife mortality. These are:

1. Food shortages, and
2. Drying out or undue heating of eggs

Wade (1938) observed that a prolonged drought in 1936 in Wisconsin severely damaged native flora and agricultural crops, and coincided with a marked reduction in wildlife populations. Leopold (1933) noted that our understanding of wildlife physiology is limited and most of the available knowledge is empirical in nature. Therefore, the relationship between wildlife and the plants which constitute wildlife food is subject to this unavoidable limitation. For example, it is known that most wildlife species eat a tremendous variety of food plants, and that the number of important food plants for an individual wildlife species can number in the hundreds. These plant food requirements are governed by their availability, palatability and special physiological needs of the individual wildlife species. Leopold 1933) noted that quail produced in a drought year had substantially reduced body weight compared to a normal year. It was felt that decreased weight and vigor in these birds was a result of curtailment of their food supply as a result of the drought. Droughts also can cause extraordinary food habits in animals. Mice caused substantial girdling losses to willow and dogwood trees located in moist areas during the summer drought of 1936 in Wisconsin (Wade, 1938). Normally, this type of damage by mice occurs in the winter. Leopold (1933) observed that drought was one of the basic causes of agricultural crop depredation by wildlife because droughts create a seasonal scarcity of natural foods and water.

It is well known that eggs lose moisture during incubation and that this moisture loss must not exceed a certain amount, otherwise the chick becomes too weak to accomplish its release from the egg. Incubating hens that are disturbed by the intense heat of a drought may let the sun overheat their eggs. The intense heat of droughts also unduly dries the eggs out. The combination of temperature and humidity tolerances of eggs varies for different game bird species. Salyer (1962) observed that drought was responsible for decreased duck egg viability during his study of nesting ducks in North Dakota in the drought years of 1959 and 1961. He found that the per cent of dead embryos left in the nests doubled in 1960 over 1961, a wet year. Nests found on high ground in both years held most of the dead embryos. The eggs in nests in slough bottoms were more successful, probably attributable to the more humid conditions there. Nests in 1961, the drought year, were farther away from water which also reduced the moisture normally carried to the eggs by the hen's feathers.

The ripple effects can continue and cause more adverse effects, such as fire and overgrazing. These disruptions from the norm can in turn, induce wildlife into unusual movements, actions and migration patterns. Wade (1938) reporting on the effects of the 1936 drought in Wisconsin, noted many wildlife species were driven into unusual movement patterns, presumably because of the lack of succulent foods and water supply, and also, in part, to nesting and rearing difficulties. Leopold (1933) noted that as the number of watering places are reduced for wildlife, the success ratio of predator species rises, because predators can concentrate their activities around the reduced number of water-sources. Gabrielson (in Wade, 1938) observed that on the Lower Souris Refuge in North Dakota, 30.6 percent of the damage to duck nests was caused by skunks forced into the lowlands by drought.

Leopold (1933) observed that local ducks in Mexico would not breed during drought years and did not breed until rains came.

The northern Great Plains in Canada are the spring breeding ground for a large proportion of the waterfowl population of North America. These waterfowl depend on the cyclical supply of surface water in this region for successful reproduction. When cyclical droughts occur, the reproductive cycle and continental populations of these waterfowl are subjected to a series of stresses and set-backs because of the adverse effects of drought. Studies by Salyer (1962) and Yeager and Swope (1956) detail some of the environmental stresses that occur to breeding water-fowl that are attributable to prairie droughts. The effects of drought on the edges of shallow wetlands can lead to an outbreak of botulism poisoning among waterfowl. Such an event creates considerable media coverage. All of the above aspects of drought effects on waterfowl are discussed in more detail in Chapter 8, which deals with the biological impacts of drought on waterfowl.

3.2.1 *Drought Displacement of Northern Great Plains Waterfowl*

The northern Great Plains of Canada are the principal breeding grounds for North American waterfowl. The surface water in this region is one of the basic requirements for successful breeding. But historically, it has been seen that these waters are in precarious supply from year to year and can change dramatically within a year or even within a breeding season. Pond numbers of a wet year may be reduced by more than 90% during drought periods (Macaulay, 1978). On a broad scale, the U.S. Fish and Wildlife Service survey records show that spring ponds on the Great Plains fluctuated between a maximum of 7.3 million in 1955 to a minimum of 1.5 million in 1961. The 1980 and 1981 pond counts were lower than the 1961 count. During the summer, pond numbers progressively decline as shallower ponds dry out from evaporation and seepage. Fish and Wildlife data shows that the overall attrition of ponds between May and July averages 50% and as high as 65% in very dry years.

The question arises as to what happens to the breeding waterfowl when a drought occurs. The number of returning waterfowl which remain to breed on the prairies is correlated with the number of ponds present in the spring. During years when the breeding population moves north in the spring and finds the number of potholes reduced by drought, there is a tendency for a significant portion of the population to over-fly in a generally north-westerly direction. The bulk of these birds spend the summer in northern Alberta and the western portion of the Northwest Territories (Crissey, 1969) (Figures 1 and 2). This fact has been repeatedly documented for both dabbling and diving ducks (Salyer, 1962; Rogers, 1964). Salyer reported a 40% decline in total breeding birds in a North Dakota study during the dry spring in 1961. Rogers (1964) reported a 63% decline in scaup populations during the second spring of a dry period in his research near

Erickson, Manitoba. Smith (1969) observed ducks of several species apparently loafing away the summer on a choice pond in the Lousana Waterfowl Study Area of Alberta during the dry year of 1959. He theorized that these waterfowl could have been the young of the previous year who found that their natal ponds had disappeared in the dry spring, or perhaps they were waterfowl in a state of physiological "shock" who had difficulty coping with the absence of spring nesting sites. Stoudt (1969) noted that at the Redvers, Saskatchewan Waterfowl Study Area, the populations of breeding pairs have fluctuated from 600 during a year of optimum water levels to 52 during a year of drought. Drewien and Springer (1969) found blue-winged teal breeding densities to be largely influenced by water conditions from 1950 to 1966, at the Waubway Study Area in South Dakota. They noted that the period of pond availability was important and that pairing increased if there were enough suitable ponds during the period the ducks were selecting nest sites. They speculated that in wet years "pioneer" breeding ducks as opposed to "homing" ducks could be short-stopped in the southern prairies during their northward migration. Sowls (1955) also noted this pioneering behaviour of waterfowl.

Hansen and McKnight (1964) were able to demonstrate from aerial surveys that when the populations of dabbling ducks decreased on the prairies in drought years, that this decrease corresponded with increased northern populations. Their results represented statistical evidence since the numbers of drought-displaced ducks did not coincide exactly.

The population of northern displaced ducks was somewhat less than the displaced southern population which could have been due to a second "wave" of late northern arrivals. Cooch (1969) estimated that there were 5.63 and 6.84 million drought-displaced mallards in 1959 and 1961 respectively. Smith (1970) studied the response of pintail breeding populations to drought and noted that this duck is a harbinger species since it is known to nest north of the Arctic circle as well as on the prairies. He found that there existed an inverse relationship between the number of prairie potholes and the proportion of the pintail population moving to northern areas. This indicates that varying proportions of the pintail population continue to move northward, depending upon the abundance of prairie ponds. Bellrose (1976) also noted this inverse relationship between northern duck populations and prairie droughts.

It has been observed that the drought-displaced waterfowl in the north have a reduced capacity to reproduce which is confirmed by the low ratio of immature ducks compared to adult ducks returning in the fall flight (Crissy, 1969; Smith, 1970; Hansen and McKnight, 1964; Macaulay, 1978; Calverly and Boag, 1977; Nudds, 1978). It was observed that although northern habitat seems fully capable of supporting adults during the summer, this habitat is no substitute for potholes in producing young of most important waterfowl species. Drought-displaced prairie waterfowl may arrive in the north past their physiological primeness and too dissipated by the added travel to successfully rear a brood. The displaced prairie waterfowl in the north appear instead, to be a reservoir of breeding birds waiting for the drought in the south to recede so that they can again reproduce in the more fertile ponds on the prairies.

Calverley and Boag (1977) studied the nesting success of mallards and pintails in the parkland area in comparison to the northern areas. The parkland area is the transitional zone between the Great Plains and the northern spruce forests and is a region of rolling terrain and ponds interspersed with meadows and aspen. They found that reproductive effort for northern nesting ducks of these species was not as great as that for the same species in the parklands. Nudds (1978) challenged this hypothesis and instead postulated that northern latitudes hold a population of waterfowl that produce smaller clutch sizes as a result of an evolutionary process. Hochbaum and Brace (in press) studied the dramatic increase in mallard population levels in southern Manitoba during the spring of 1976. Spring habitat conditions during May 1976 had 15 per-cent more waterbodies than the previous ten year average. But water conditions in North and South Dakota were more arid than usual. Southern Manitoba's spring mallard population increased from 348,000 in 1975 to 536,100 in 1976, a 54% increase (Hochbaum and Brace, 1976).

In North and South Dakota, all species of ducks showed sharp declines in response to the unfavourable habitat conditions. The calculated 1976 mallard breeding population in southern Manitoba was 400,311, substantially below the observed 536,100 mallards. Hochbaum and Brace concluded that the additional mallards might have been attributable to an immigration of birds from less favourable areas. This would be similar to the response of drought-displaced waterfowl flying to the north but at a lower latitude. A July 1976 production survey showed a brood index similar to 1975 and it was concluded that the displaced mallards were not contributing to production. Supporting evidence was obtained when a significantly higher number than normal of moulted mallard hens were caught during mid-summer banding activities. Usually, adult female mallards moult from mid-August to mid-September after their broods are reared. It appeared that the immigrant birds were at a competitive disadvantage on an unfamiliar range and instead chose to abandon nesting that season which in turn, would lead to increased long-term fitness for them in preparation for the following spring nesting season. If the harvest quota was set based on observation of the spring pair abundance, then a large depletion of adult ducks could arise. Smith (1970) noted that protection is paramount for drought-displaced prairie ducks who fly north because of the large number of adult birds that return in the autumn. These older ducks have a significantly greater reproductive potential than young-of-the-year ducks. Crissey (1969) observed that southern Manitoba mallard populations have not rejuvenated since droughts caused a low level in 1962, and it is suspected that the annual harvests are exceeding annual reproduction. Manitoba hunting regulations have been adjusted since that time to a later opening of the waterfowl season in order to allow an increased number of the resident mallard population the opportunity to migrate southward in advance of the annual harvest.

Fluctuations in prairie water conditions can be seen to have a significant impact on our waterfowl populations. However, these alternating wet and dry periods should more correctly be regarded as a mixed blessing. In the short term, droughts reduce population levels but in the long term, it is these same dry periods which ensure basin fertility and the diversity of aquatic plants and animals which make the prairie habitat capable of sustaining high levels of waterfowl production in good (wet) years. Drought is a calamity to ducks only in a short-sighted view because prairie ducks have evolved a breeding system over the last 10,000 years which is designed to cope with these conditions. Hochbaum in a 1981 preface to his classic book, The Canvasback on a Prairie Marsh, first published in 1944, provides an excellent summary of the relationship between prairie waterfowl and cyclical droughts. He states that waterfowl banding returns indicate that duck species such as mallards, pintails, and canvasbacks have the potential for a long lifespan of more than 20 years, or perhaps a potential age limit of 20 to 30 years. These same banding returns however, also reveal that few female mallards or canvasbacks or other game ducks live to reach their fourth nesting season. Yearling ducks are not as productive as adults. They nest later in the season and cannot have the renesting persistence of older hens. Leopold (1933) observed that renesting persistence was one of the keys to successful waterfowl reproduction. Most long-lived animals do not reach peak productivity until after their second year. There may be a "burning-off" of our breeding stock by hunting before it becomes prime. The long life span in ducks is related to the wet and dry cycles natural to their nesting environment. In dry years, many ducks simply do not attempt nesting. Nesting under such circumstances subjects them to higher nest predation rates than normal (Salyer, 1962; Rogers, 1964; Stoudt, 1969) and higher brood mortality resulting from increased overland movement from one pond to another. Stoudt (1969) noted that predation is probably the single most important cause of nest-loss to waterfowl. Instead of nesting, waterfowl abandon their untenable home ranges in dry years to spend the summers on permanent waters of lakes or large marshes. Some displaced birds shift to nest in northern parkland or taiga, but for most, a drought is a period of waiting out, a natural time for living through to nest again when the cycle swings around to wet. This response to drought is of high survival value. Hens are not exposed to the nesting-time hazards of a substandard dry environment. They protect themselves by shifting to large permanent waters where, in groups, they conserve their energies and grow fat. Many remain with their mates during this rest period, which becomes another energy-saving pattern of survival. They are not encumbered by the production of young that might only die when brought to life on a parched prairie. Drought is part and parcel of the marshy world to which ducks are adapted. Marshes which are held at stable water levels eventually become "dead", gradually losing their attractiveness not only to ducks but to other species of marsh life such as muskrats. Through the natural alternation of wet and dry periods, sloughs and potholes are periodically reborn, thoroughly regenerated, regaining their rich floral and faunal endowments essential to the well-being of waterfowl and other aquatic life. Drying out establishes the continuity of rich production as long as marshland basins, small and large, remain to play their fundamental roles in the complicated pattern of prairie ecology. This cycle of events was dramatically illustrated during the drought of the "dirty thirties". Laws were passed to protect the ducks remaining during the dry years. When a wet cycle returned to the prairies, pairs of ducks that had waited out the bad years spread themselves everywhere over the newly wet prairies. Like most ground-nesting birds, ducks are opportunistic reproducers and take advantage of favourable nesting circumstances to create a rapid population expansion. With the advance of the first wet summer after the drought, came an explosion of broods and by September of 1938, the large marshes and lakes, traditional staging places, were crowded with ducks. There was a massive reproductive success during 1938 and 1939 because conservation practices had ensured sufficient numbers of experienced breeders were available to nest with the end of the drought. Macaulay (1978) sees the basic threat to waterfowl not as drought, but as the progressive long-term drainage of potholes and marshes which reduces the nucleus of breeding birds for following years. Long-term pothole drainage represents permanent drought.

3.2.2 *Habitat Fundamentals*

Lauckhart (1962) has proposed a concept that wildlife reproduction doesn't really attempt to replace losses. He believes that wildlife losses ensue because wildlife reproduction is designed to ensure sufficient numbers of wildlife to fill the carrying capacity of the habitat. The losses are simply wildlife produced which is beyond the carrying capacity of the habitat. Carrying capacity can be defined as the maximum number of individual animals that can live through the greatest stress each year; therefore, a capacity population is the number reaching the next breeding season. The yearly low points in population graphs are all important because they represent the levels to which a wildlife population is depressed by habitat limitations. Capacity is determined by habitat quantity and quality. Food could be the most important capacity-limiting factor controlling wildlife populations. The most fertile soils produce the best plant foods for wildlife (Leopold, 1933). Therefore, habitat on fertile soils represents the most valuable classes of wildlife habitat available. Rose and Morgan (1964) have developed a classification system which identifies and classifies the wetlands habitat of southwestern Manitoba in relation to the fertility of the soil. This classification system can be used to priorize the conservation of wetlands in this region in order of their fertility and hence, carrying capacities.

Carrying capacity of habitat is relatively stable since habitat changes are usually gradual. The exceptions are climatic catastrophes such as droughts. In the case of wetlands, the problem is exacerbated because the great majority of wetlands are found on private lands. Farmers under the squeeze for cash in difficult economic times, convert wet lands to crops to keep pace with the cost of living. Droughts provide the opportunity for them to more conveniently plough, drain, and level wetlands. This loss of waterfowl habitat that occurs during a drought is the genuine fundamental hazard to the continental populations of waterfowl, rather than the physical effects of the drought itself.

CHAPTER IV

DROUGHT IMPACT ON AGRO-MANITOBA DURING 1980 and 1981

4.1 Drought History of Agro-Manitoba

Kiel *et al.* (1972), investigated the early weather records of southern Manitoba. The weather pattern that emerged was one of interspersed dry, wet, cold, and warm years. The periods 1837-48, 1861-68, 1905-19, and the 1930's were exceptionally dry. During the 1870's, the early 1900's (to 1905) and the mid 1950's, the prairies were unusually wet. The summer of 1806 was probably the wettest ever. The worst recorded flood of the Red River was in 1826 when it reached an elevation of 765.5 feet (233.3 metres).

The first western Canadian weather stations began operating in the late 1800's and official precipitation levels are kept on a calendar year basis. However, agricultural weather analysts use a crop year approach beginning on August 1 and ending on July 31 of the following year. Duck habitat conditions for any given year are better reflected by crop year than by calendar year precipitation. The Searle Grain Co. Ltd. has kept a precipitation study starting from the beginning of rainfall record keeping, which includes weighted reports from 600 rain gauges evenly distributed through the cultivated regions of the Prairie Provinces. The five dryest and wettest crop years are shown in Table 1.

A period of two decades of drought was ending when settlers arrived at the turn of the century. A rain deluge

Table I Five Driest and Wettest Crop Years

The five driest and wettest crop years*, according to the Searle Grain Company tables.

Alberta		Saskatchewan		Manitoba		Prairie provinces	
Year	Rainfall (in inches)	Year	Rainfall (in inches)	Year	Rainfall (in inches)	Year	Rainfall (in inches)
driest							
1910	6.86	1961	6.68	1931	7.94	1961	7.83
1889	7.67	1937	6.97	1929	8.32	1929	7.96
1949	7.80	1929	7.07	1886	8.50	1889	8.43
1886	7.86	1924	7.77	1889	8.61	1924	8.91
1892	8.03	1894	8.06	1910	8.72	1918	8.95
wettest							
1900	19.30	1901	17.63	1901	21.93	1901	21.06
1915	19.22	1955	16.81	1927	19.83	1927	16.64
1927	18.40	1891	15.60	1963	19.43	1955	16.63
1901	17.86	1927	15.29	1885	18.89	1899	16.59
1902	16.66	1963	14.94	1891	18.75	1902	15.34

*Crop year is the previous fall plus the following crop growing period. Winter precipitation is excluded. These are weighted averages.

Source: Kiel, et al., 1972.

started in 1901 in Manitoba and surface water conditions reached impressive levels by 1904. A bad drought hit in 1910 but soon subsided. A severe 3-year drought lasted from 1917 through 1919. The 1920's saw a drought in 1924, two wet years in 1927 and 1928, and in 1929 the beginning of the great drought of the 1930's. Surface water conditions were mediocre in the early 1920's and excellent just before dwindling to almost nothing in the 1930's, as the second greatest drought, since settlement descended over the land, occurred.

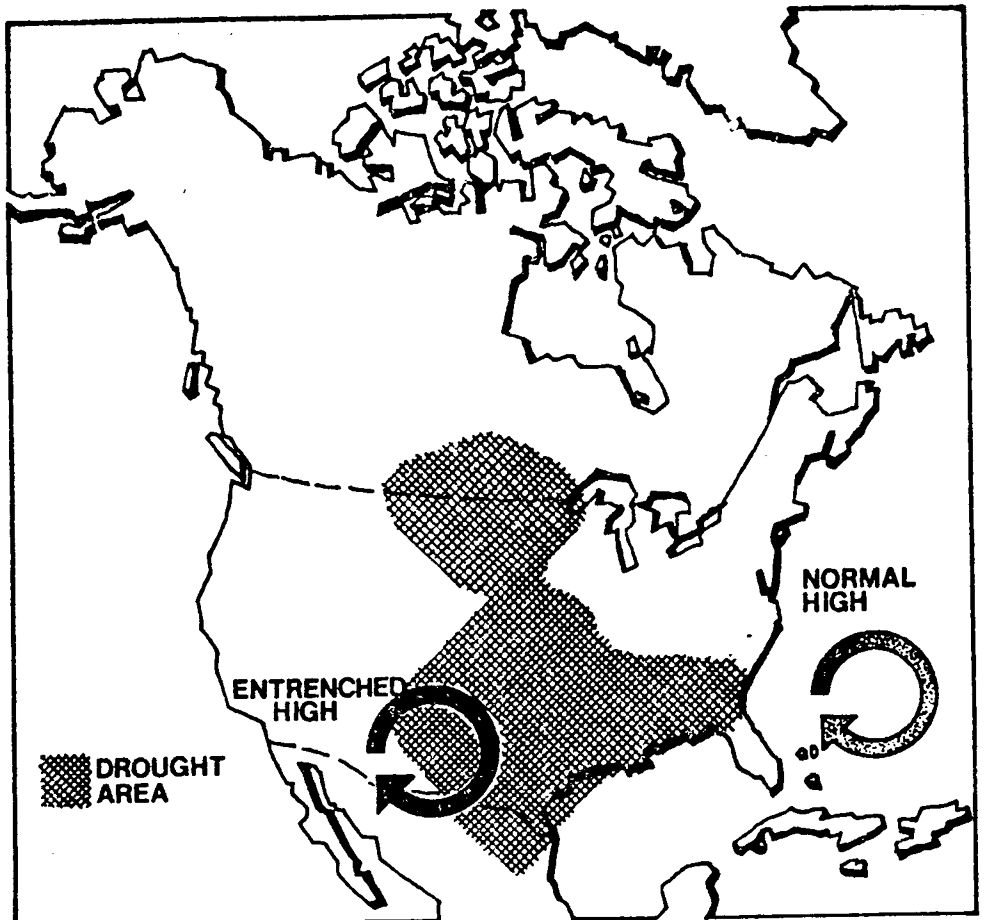
The 1940's and early 1950's included some good and bad years for duck ponds, but since wet and dry periods were interspersed, fairly stable conditions resulted.

In the mid 1950's, a major wet period filled most prairie ponds to capacity. Pond counts had begun by this time. The number of ponds increased about 50% from the early to mid-1950's, during May, from about four million to six million. Then a drought developed and the pond count declined to a low of about 1.5 million in 1961, after a one-year recovery in 1960 to near the levels of the early 1950's. Gradually, the rains and snows of the mid-1960's refilled ponds until over all habitat conditions were approaching those of the stable years in the 1940's and early 1950's. Drought in 1967 caused a severe setback in pond numbers and quality, but that decade ended with most ponds again full and ducks staging a remarkable comeback.

4.2 The Droughts of 1980 and 1981 in Agro-Manitoba

The droughts of 1980 and 1981 have been selected for case studies because they are the most recent and, the effects of these droughts were severe on the waterfowl population which nests in this area. The media coverage of the environmental forces in operation focused the problem in the public's eye. The nesting ducks suffered a setback because of these droughts but paradoxically, the summer rains in 1981 enabled the agricultural sector of Manitoba to harvest the largest grain crop recorded in the province. Saskatchewan and Alberta also harvested record grain crops that year. These droughts serve as a convenient example to illustrate the adverse effects of drought on waterfowl and coordinate the scope of this study.

During the summer of 1980, Manitoba (as well as Saskatchewan and parts of Alberta) fell victim to what meteorologists call an Omega Block. A high pressure system centered over Texas became locked in place, sending horseshoe or omega-shaped ridges of high pressure over most of central North America. This in turn held low-pressure systems in place to the west and east, causing above average precipitation in British Columbia, parts of Alberta and most of eastern Canada and depriving the central region of its usual sources of moisture. Although blocking actions of this kind are not uncommon, it was unusual for the length of time that it persisted (Fig. 5). As a result, official government weather-watchers issued figures that showed



The entrenched high over Texas during the summer months was one of the principle factors for the drought (shaded area of map)

Figure 5 Entrenched High Over Texas - Summer 1980

SOURCE: Environment Canada, Land, Vol. 1 No.2 1980.

water levels in Manitoba were too low and the worst since 1955 (Radimer, 1980). Another unusually persistent upper-atmospheric block, centered over Saskatchewan, discouraged precipitation and warmed temperatures on the prairies during the spring of 1981. This block covered most of the grain growing regions.

4.2.1 *Conditions Necessary for Surface Water in Prairie Potholes*

The northern Great Plains are in an area of low annual precipitation which ranges from 12" - 24" (30.48-60.96 cm.), 50-75% falling as rain during the summer. Wind and warm summer temperatures combine to create high evaporation losses during the summer (24" - 36") (60.96-91.44 cm.), resulting in a net evaporation loss of 12" - 24" (30.48-60.96 cm.) annually. The hydrology of a prairie pond usually involves additional water loss due to seepage. This seepage may account for a further 12" - 18" (30.48-45.72 cm.) loss of water. If this water deficit is to be made up, it must occur from basin inflow, or runoff, from the drainage area surrounding the pond. The basic factor influencing the volume of basin inflow is the permeability of the soil surface. Dry porous soils are capable of absorbing several inches of water per hour, but soil already saturated with water or in a frozen state is almost impermeable. When considering basin inflow from snowmelt and its effect on spring pond conditions, the maximum runoff will occur when fall rains moistened the soil prior to freeze-up. This creates an impermeable "frost seal" and promotes maximum runoff.

Winter snowfall exceeding 50" (127 cm.) usually has a measureable effect on surface water conditions the following spring. Brush and tall emergent vegetation surrounding ponds serve as natural snow fences causing snow to pile up in drifts which melt directly into the pond. If snowmelt occurs quickly in the spring before the soil has thawed, and average snowfall has occurred, good pond conditions are assured. Conversely, if snowmelt is slow and the soil is dry, heavy snowpack is required to produce any runoff at all. The timing is almost as important as the amount. When considering replenishment of ponds from summer rains, the intensity of rainfall and the moisture content of the soil are of primary importance. Thus a 2" (5.08 cm.) rainfall occurring in one hour could cause potholes to flood, whereas the same amount of precipitation occurring in showers over a two-week period would have a negligible effect on water levels. Prairie ponds depend on basin inflow for replenishment, and it is the chance combination of factors influencing basin inflow which will ultimately determine the spring surface water condition of the prairies (Macaulay, 1978).

4.2.2 *Discussion of Canadian Wildlife Service Spring 1981 Transect Results*

Brace and Caswell (1982) noted that waterfowl breeding habitat had declined since 1979, due to the loss of wetlands associated with the drought then in progress (Table 2) and the destruction of wetlands associated with agricultural

Table 2 Duck breeding populations and pond counts for the prairie provinces, May 1981.

Area	MALLARDS			TOTAL DUCKS			PONDS		
	1981*	% Change 1980	% Change Average	1981*	% Change 1980	% Change Average	1981*	% Change 1980	% Change Average
S. Man.	352.0	+ 6.1	+ 4.8	1,558.3	+ .2	- 9.4	261.8	- 8.7	-68.9
S. Sask.	1,504.9	-30	-40	5,231.3	-34	-44	611.3	-56	-74
S. Alta.	901.4	- 7.6	-33	4,724.7	- 5	-18.6	569.3	+23	-34
Totals	2,758.3	-20	-34.3	11,514.3	-20.4	-32	1,442.4	-33	-65
N. Man. & Sask.	1,034.4	+ 4	+13	5,424.9	+ 8	+31			
N. Alta. NWT & BC	1,078.1	-24	-10	10,336.2	-11	- 2			
TOTAL N.	2,112.5	-12	- 2.3	15,761.1	- 5	+ 7.2			
GRAND TOTAL	4,870.8	-16.7	-23.5	27,275.4	-12.2	-13.8			

*Nos. in thousands.

SOURCE: Brace and Caswell, C.W.S., 1982.

processes (Table 3). The rate of agricultural impact on potential wetlands had increased during the drought and resulted in 50% of the wetlands in southwestern Manitoba and southeastern Saskatchewan being affected by some type of agricultural practice in 1981. The numbers of July ponds found within the southern portion of the three prairie provinces remained 1/3 to 2/3 below the average values (Table 3). The 1980 fall flight was 25% smaller than the 1979 value. Canada produces up to 80% of North America's mallards, the principle duck of interest to hunters. There was a decline in mallards which represented a real loss as opposed to a redistribution of ducks from unsuitable breeding areas to more permanent staging areas. The continental mallard population has declined by 20% (from 8.4 million in 1979 to 6.7 million in 1981).

The prediction for waterfowl production in 1981 was unfavourable due to low breeding populations, redistribution and probably non-breeding by displaced mallards, poor habitat conditions as reflected by low pond values in May and July, low brood counts and low late nesting indices on the more important production areas.

Gage (1981) reported that in southern Manitoba, there was a 20-year low in the number of duck breeding ponds. However, it was felt that this hadn't seriously affected the first waterfowl hatch. There was concern about ducklings produced by renesting waterfowl surviving during the summer because of fewer ponds. Ducks nest up to one kilometre from

Table 3: Agricultural impacts on potential wetlands in southwestern Manitoba and southeastern Saskatchewan.

Impact	Basins			Margins		
	1980*	1981*	Level of Significance	1980*	1981*	Level of Significance
Cultivated	20.7	26.5	.01	19.5	28.9	.01
Hayed	4.3	6.3	.01	6.6	8.1	.05
Grazed	5.1	6.4	.01	9.4	11.7	.01
Burned	5.5	4.8	.01	7.3	7.3	N.S.
Filled	7.0	7.2	N.S.	.8	1.5	.01
Cleared	.4	.3	N.S.	1.5	2.4	.05
Total Affected	41.2	49.8	.01	44.2	57.7	.01
Potential Wetlands	3834	3897				

*Percent

SOURCE: Brace and Caswell, C.W.S., 1982.

water, but if ducklings don't reach water within 24 hours after leaving the nest, they dehydrate and die. There was also concern about mud rings around ponds which form barriers to ducklings.

Canadian Wildlife Service counted 261,800 ponds in southern Manitoba in the spring of 1981. This was 68.9% lower than the 10-year average and the lowest number on record since 1961 when the surveys started.

There was also concern about total production because drakes and hens were not getting together for renesting. However, the spring nesting for mallards and pintails had been good because agricultural activity hadn't gotten underway.

An estimated 350,000 mallards were counted in the aerial and ground survey in southern Manitoba. This level was 6% above the 1980 count and 5% higher than the 10-year average. This 10-year average didn't include the high levels in the 1950's and 1960's. The total duck population was set at 1.5 million, slightly off the 10-year average. The waterfowl problem didn't affect Canada geese which nest in the northern lake country.

4.2.3 *1981 Spring Waterfowl Forecast*

Robinson (1981) annually reports the waterfowl hunting outlook based on the results of his spring survey of the breeding areas in the prairie provinces. In his forecast for the fall flight of 1981 he stated that upon arrival in Manitoba in mid-May, he found conditions in the southern part of the province dismal. He quoted Peter Ward, the director of the Delta Waterfowl Research Station as stating:

> Most of us who lived through the 1930's are apprehensive about drought. We saw what it did to ducks -- and fear its return. Last year's drought was the worst in 100 years, followed by a winter with less than normal snowfall. There hasn't been such a winter in Manitoba since 1877. Field water on which waterfowl normally rest and feed was virtually non-existent.

During the latter part of May and June, most of Manitoba experienced heavy rains, but it came too late and the ducks over-flew to the north where they never do as well. Farther north through the parklands, nesting areas were greatly improved. This region had a good production of waterfowl. It was estimated that waterfowl production would be down on the 8500-acre Oak Hammock, but production would be good in the Interlake. The Netley Marsh, south of Lake Winnipeg, had the lowest water in years (Robinson, 1981). This marsh, however, is usually only a marginal producer of waterfowl since it experiences large fluctuations in water levels caused by northerly winds coming across Lake Winnipeg. The Minnedosa pothole country had fewer potholes than the previous year and very few canvasback broods and non-breeders. An inspection of hundreds of potholes in this area showed the lowest number of waterfowl in many years. There was 50% fewer potholes in this region than 20 years earlier. The area would produce very few ducks this spring but the heavy June rains over most of the pothole area were already improving the habitat. The C.W.S. in southern Manitoba indicated a 9% decrease in the breeding population of all ducks in the area and a 9% decrease in counts of breeding ponds.

Ducks Unlimited reported persistent water shortages in the southwest of Manitoba throughout most of the summer (Macaulay, 1981). The USFWS reported:

> A badly deteriorated breeding habitat in southern Manitoba resulted in a poor hatch. Rivers, lakes and artificial ponds gained new importance for breeding waterfowl, as all but the deepest, most persistent natural ponds disappeared from the prairies. Pintails, American wigeon and blue-winged teal were down, but other species fared well.

CHAPTER VI

CURRENT STATUS OF WATERFOWL MANAGEMENT IN AGRO-MANITOBA

5.1 General Comments on Waterfowl Management

Hochbaum (1981) pointed out that potentially, ducks are the most successful, the most aggressively reproductive, and the most manageable of all North American gamebirds. They spread themselves widely over the breeding range so that no local catastrophe can overtake large segments of their numbers. They have large clutches, averaging 8 to 12 eggs. They are persistent renesters capable of laying a second or even a third clutch if the first or second is lost to a predator or agricultural practices. Most of the game ducks nest in middle latitudes where the breeding season generally is long enough to allow several renestings. They are highly adaptable and will nest right up to the edges of human habitation. Leitch (1975) also commented on how remarkably well equipped ducks are to exploit the unpredictable prairie environment and how their breeding biology has evolved in response to it. Most species, particularly those utilizing the shallow prairie ponds rather than the semi-permanent marshes, mature at one year and are relatively long-lived. Their populations are continually augmented by some northern production. Their high reproductive potential can result in a tremendous increase in population after a cyclical drought period. However, both agreed that the effects of agricultural encroachment on their prairie habitat causes the peak population of a wet period to be below that of the previous one. Leitch noted that an estimated 70% of the continental waterfowl population nest in the prairies and parkland habitat of western Canada and that this is the only source of ducks that can maintain the sport of waterfowling.

Buller (1975) pointed out that various activities of man are changing the ancient habitats of prairie waterfowl. These are the introduction of cultivated grains to the prairies and the construction of water storage structures. Opportunistic species such as mallards, quickly adapt to these new conditions.

Boyd (1981a) pointed out that perhaps agricultural impacts are not as important in the very long run as thought to be by most waterfowl managers. He based this view on the fact that aerial surveys indicate that the 7 principle dabbling ducks of northwestern North America have shown great variability in regional abundance over the last quarter of a century, as can be expected from highly mobile animals attuned to living in a fluctuating environment. He felt that waterfowl numbers in 1990 would parallel those of 1980 unless a severe drought developed.

Boyd (1981b) has noted that in an attempt to define the principles, objectives and goals of waterfowl management in Canada, the C.W.S. has drafted a Waterfowl Management Plan for Canada. Two of the main objectives of that plan are:

1. To maintain or attain waterfowl populations at desired levels and ensure that no waterfowl species becomes threatened or endangered as the result of human actions.

2. To determine the major environmental factors regulating populations and levels of sport and subsistence harvest which can be maintained and which will ensure sustained populations.

5.2 Status of Waterfowl Habitat in Agro-Manitoba

The primary production habitat for ducks in Manitoba is located in the grassland and aspen parkland of southwestern Manitoba (Rakowski, et al. 1976) and comprises an area of approximately 1,976,773 acres (800 thousand hectares). Sixty per cent of all ducks breeding in Manitoba, breed in this region. The key to the maintenance of present waterfowl population levels is considered to be the maintenance of this high quality production habitat. Seven high priority areas of production habitat in the grassland and aspen parkland zone are shown in Figure 6 and Table 4.

Rakowski et al. (1976) undertook an inventory to determine the quantitative and qualitative areas of waterfowl habitat in southwestern Manitoba that were owned by the province. This was in response to a general belief that waterfowl habitat on private land has decreased in quantity and quality through drainage and removal of trees and other vegetation on pond edges.

Canada Land Inventory Capability Maps were used to determine the percentage of habitat owned by the province of Manitoba. For the entire southwest, the province owned merely 0.02 percent or 640 acres (259 ha) out of 206,701 acres (83,652 ha) of Class 1 waterfowl habitat. For Class 2, provincial ownership consisted of 1.2 percent or 12,931 acres

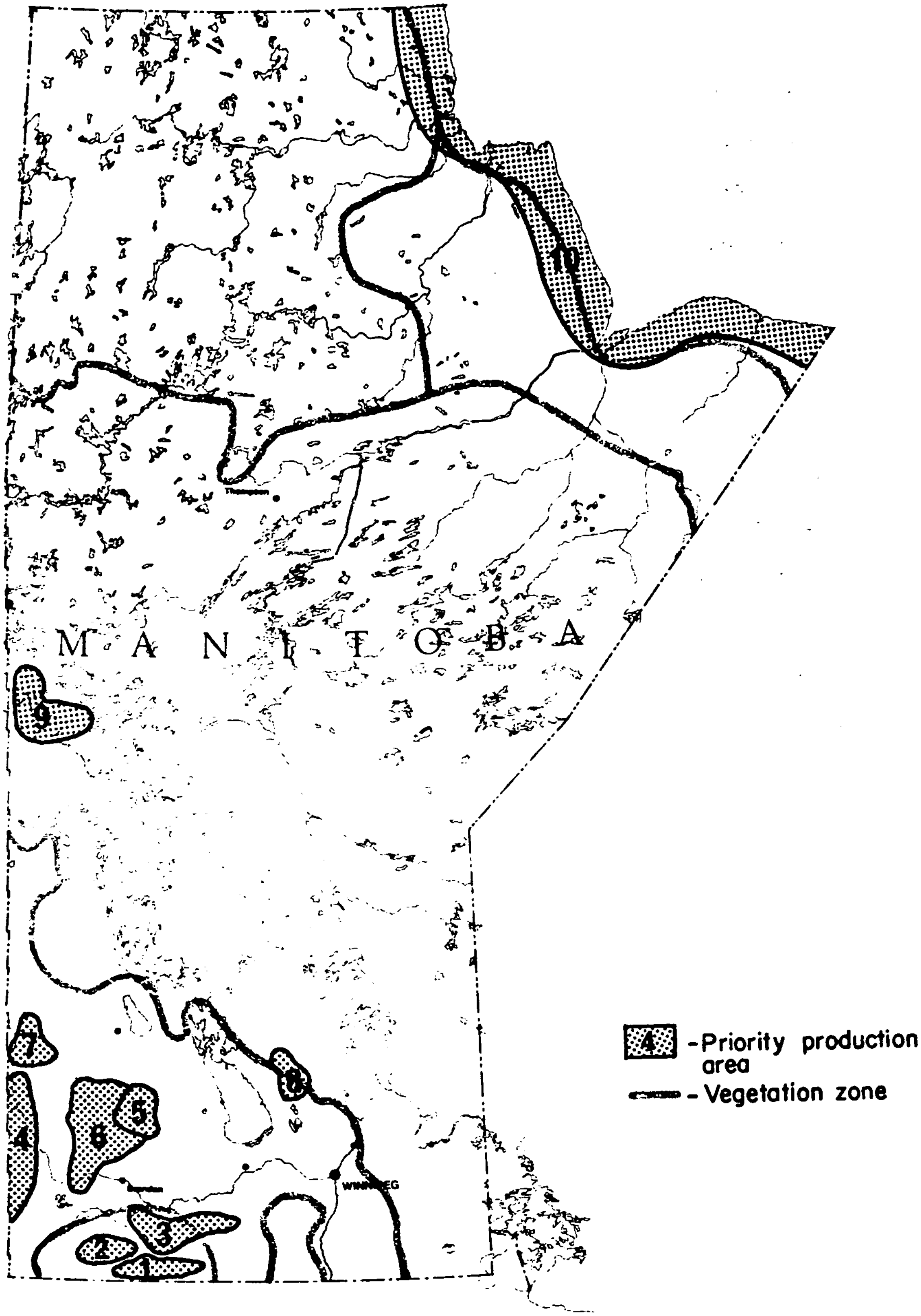


Figure 6 **Priority duck production habitat in Manitoba.**

SOURCE: Migratory Bird Habitat Priorities; Prairie Provinces, C.W.S., 1979.

Table 4 Description of Priority Duck Production Habitat in Manitoba

Area No.	Name	Priority	Vegetation Zone	Size (hectares)
1	Killarney	High	Grassland	96,000
2	Boissevain	High	Grassland	92,000
3	Baldur	High	Aspen Parkland	84,320
4	Reston	High	Aspen Parkland	16,000
5	Minnedosa	High	Aspen Parkland	16,000
6	Hamiota	High	Aspen Parkland	211,968
7	Roblin	High	Aspen Parkland	31,200
8	Interlake	Medium	Aspen Parkland	2,000
9	The Pas	High	Boreal Forest	40,000
10	Hudson's Bay Coast	High	Tundra	2,000,000
		Grassland total		188,000
		Aspen Parkland total		361,488
		Boreal Forest total		40,000
		Tundra total		2,000,000
		Grand total		2,589,488

SOURCE: Migratory Bird Habitat Priorities; Prairie Provinces; C.W.S., 1979.

(5233 ha) out of an available 1,077,576 acres (436,095 ha); for Class 3, 4.6 percent or 83,029 acres (33,602 ha) out of 1,804,991 acres (730,480 ha). Taking Classes 1 to 3 together, the province holds 96,600 acres (39,094 ha) of an available 3,089,268 acres (1,250,227 ha). Classes 1 to 3 are considered prime waterfowl habitat since these 3 classes have high production potential (in descending order from 1 to 3).

Class 4 and 5 lands were included in the study. These latter classes have limited capability for waterfowl production. Of 2,522,750 acres (1,020,957 ha) of Class 4 lands, 1.9 percent or 47,932 (19,398 ha) are owned by the province; of 4,270,752 acres (1,728,373 ha) of Class 5, 4.3 percent or 183,642 acres (743,199 ha) belong to Manitoba. The results showed that the province owned mainly low quality waterfowl production habitat in southwestern Manitoba.

The 4,100 square mile (10,618 square km) Minnedosa pothole region was used to determine agricultural disturbances on potholes on private land. This region is regarded as one of the best duck producing areas in North America (Kiel *et al.*, 1972). Information on land use trends was updated from the 1928 to 1964 period up to 1974 by using the transect study areas devised by Kiel *et al.*, (1972). The result showed a significantly steady decline in the total area of wetlands because of the cultivation and clearing activities of farming operations.

CHAPTER VI

ECONOMIC VALUATIONS OF WILDLIFE, WATERFOWL AND HABITAT

6.1 Introduction

The problem faced by wildlife managers, biologists, and conservationists for the past 30 years has been to place a realistic dollar valuation on wildlife resources so that this resource can compete on the same terms with other demands for the available land supply. The difficulty in obtaining monetary values has been complicated because wildlife has for many years been considered publicly owned "free goods" rather than the public wildlife industry that it really is (Oliver, 1979). Because the resource base producing these "goods" is at a severe competitive disadvantage with all the other land use demands, a considerable effort has been undertaken by economic researchers to determine the real worth of the wildlife resource. Armed with practical valuations of wildlife, conservationists are attempting to stem the rapid loss of wildlife habitat to developers. Environmental impact statements can now be written in terms of lost revenue associated with potential wildlife losses and can compete dollar for dollar with land developers, and if unsuccessful, can at least indicate the costs of mitigation.

The related literature which describes the progress leading up to present day wildlife values is both voluminous and convoluted and a comprehensive study would be a monumental task beyond the scope of this paper. This paper will instead discuss the most relevant developments over recent years which have led to acceptable economic valuations today. The benchmark economic techniques that represent current state of the art will be discussed in detail. To bring the situation into present day focus, individual wildlife values, in dollar terms, will be used as examples throughout the paper.

Wildlife resource agencies have experienced considerable difficulties in obtaining monetary values on wildlife for the last three decades (Norman, et al., 1975). Oliver (1979) in his appraisal of wildlife value systems, noted that values of wildlife have been consistently underestimated in public decisions that involved choices between alternative uses of natural resources. This situation developed because of failure for a long time to develop acceptable ways of placing unit values, expressed in dollars, on wildlife. Because wildlife has both direct consumptive uses and indirect non-consumptive uses, there was the additional problem of identifying and placing values on these dual uses. Federal, provincial, and private wildlife agencies realized for a long time, the need to express wildlife values in terms of dollars as they saw developers consistently claim the wildlife resource base (land) for "higher value" projects. The problem of determining wildlife values was one they struggled with over the years. Wildlife agencies discovered that when it came to a real battle over the economics of a controversial land use decision, it was far better to have an economist voicing the position of wildlife interests, than a wildlife manager or biologist (Hoover, 1976). Nearly every wildlife agency has conducted some form of economic research project to determine the dollar value of recreational hunting. Many approaches have been tried but no one technique has become universally accepted as unquestionably superior to all other approaches. Recent years, however, have seen the development of generally acceptable methods based on fundamental economic theories. These methods have provided dollar values for wildlife and wildlife habitat that have been successfully used to defend the position of the wildlife resource in competition for land uses.

6.2 Attempts at Wildlife Evaluation by Using Gross Dollar Values

To set the discussion in perspective, it is worthwhile to review some early gross dollar valuation methods and the reasons these values are unrealistic. More than 19 years ago, Crutchfield (1962) rejected the gross expenditure method as an approach to valuating wildlife. He pointed out that the activities which are made possible by wildlife are available to us unpriced because law and tradition provide these activities without market transaction data. He saw that new or modified market models would be necessary for wildlife valuation problems. Other economic researchers who have followed him have consistently supported this position (Langford and Cocheba, 1978). However, even today the gross expenditure method has limited use in economic valuations because gross expenditure values provide an entry value for modern economic models (Norman, *et al*., 1975; Horvath, 1974). The assumption is an application of this kind is that these entry values will become refined with time and experience. The Colorado Wildlife Division's wildlife valuation models represent sophisticated benchmark progress in obtaining realistic economic values. These models used gross dollar expenditure for recreation days as determined by Ashton, *et al*. (1974) as first approximations in order to develop value scales for wildlife products and wildlife habitat.

For years gross dollar expenditures for a recreation day have been the statistic of choice for wildlife valuations despite the incompleteness they represent. Since 1955, the U.S. Fish and Wildlife Service, using the expertise of the Bureau of Census, has conducted national surveys at 5 year intervals to determine the total expenditures made by hunters and fishermen. In these surveys, the numbers of sportsmen participating in various hunting and fishing activities, together with their dollar expenditures incurred for each activity, are reported regionally and nationally. However, economic researchers have found these data too gross and cumbersome to be of value in land use planning at either the state or regional level (Hoover, 1976). These survey figures can provide only a basis for comparison against similar data obtained for smaller geographical areas.

For several years a nominal dollar valuation, which was more of a rule of thumb, was used to determine wildlife values. For example, in 1965, New York State placed the value of a duck at $5, because that was the average shooting preserve price at that time (Benson, 1965). A similar type of waterfowl valuation was made in Manitoba. Ducks at Delta Marsh were valued at $5 each in a 1968 study and geese at $10 each at Plum Lakes in a 1973 study. These latter prices conformed approximately to shooting preserve prices at those times. For comparison purposes, these latter waterfowl values if compounded to a 1981 present value at a 10 percent discount rate, result in the Delta Marsh duck having a value of $17.26 and the Plum Lake's goose having a value of $34.52. The federal government uses a 10 percent discount rate in benefit-cost analysis for public projects, therefore, these present values are realistic. These values are in real terms since no inflation factor is considered.

In many gross dollar estimates of wildlife, the overall dollar value is determined by simply totalling the costs of hunting licences purchased, estimated daily expenditures of the average hunter, and the direct commercial market value of the harvested wildlife. A variety of gross dollar valuations can be obtained depending on the hunting activity under consideration and what wildlife products are recorded (Grower, 1977). For example, in 1973, Delta Marsh was estimated to have provided 6,000 user days of hunting. The non-resident hunters, within these user hunting days, spent an estimated $250,000 on their hunting activities. Another gross estimate study in 1978 reported that over $160,000 was spent in that year by the 10,000 visitors to Ontario's Long Point Marsh. Other examples of gross dollar valuations of wildlife are as follows. The combined value of provincial and federal duck hunting licences for southern Manitoba in 1975 was $511,866. The wild duck down that was processed in the Portage area that same year had an estimated worth of $80,000. The direct commercial meat value of the ducks and geese harvested in 1975 in southern Manitoba was $978,000 (based on 334,000 ducks plus 83,000 geese valued at 96¢ per pound, the retail price at that time). It was estimated that waterfowl hunting in Manitoba in 1975 provided 299,700 recreation days which were valued by the province at approximately $5,020,000 based on $16.75/day. This latter figure was indexed from 1961 = $9.07 per hunter-day. It can be seen from the foregoing examples that non-standardized gross dollar valuations of wildlife are difficult to convert into meaningful economic terms which accurately describe the true worth of the wildlife resource generating the wildlife harvest.

For several years the literature on wildlife valuations from across North America has quoted gross dollar valuations similar to the above examples. Several difficulties arise in attempting to relate these gross valuations to the real underlying value of wildlife. The direct commercial value of wildlife products produced from wildlife habitat can be arbitrarily grouped and a dollar value estimation of these products can be made in a wide variety of ways. There is no standardized way of determining what a recreation day for outdoor sportsmen consists of, and therefore, there is wide interpretation from place to place. There are both consumptive and non-consumptive uses for wildlife. Many of the non-consumptive uses are very difficult upon which to place a dollar value. The fundamental problem is that gross valuations are obtained without a free market mechanism and cannot be measured by the economic models developed for market transactions.

It will be demonstrated further in this paper that the true value of wildlife to consumptive users can be best approximated by determining the price hunters are willing to pay for the hunting experience. This method of determining a value will define what economists identify as a measure of consumer surplus. Gross dollar estimates should be recognized as representing considerably less than the total underlying monetary value of a wildlife resource.

6.3 Ecological, Economic and Legislative Factors Affecting Wetlands

Wetlands represent special areas of wildlife habitat because they are among the most valuable ecological units in the environment. Considerable research has been conducted into determining the multiple values of wetlands and as a consequence, there exists a large collection of literature and data on this subject. Some of the vital ecological functions fulfilled by wetlands are:

1. provision of spawning and nursery areas for both commercial and sports fishes
2. natural breakdown and treatment of air-borne and waterborne pollutants
3. recharging of ground water supplies
4. natural absorbtion of excess water flows arising from storms and floods
5. provision of a high-quality food source for aquatic animals
6. provision of important pollution filtering systems for lakes and streams
7. provision of essential nesting and wintering areas for waterfowl

Canada's wetlands comprise a total area of 170 million hectares (Canada Land Inventory, 1967). Prior to 1963, the term wetlands was used by wildlife biologists to describe land where water was a dominating factor. Technically, wetlands affect the nature of soil development and the plant and animal communities within their environs. The term wetlands has now become a household word routinely used by resource managers, lawyers, real estate developers, engineers, ecologists, public health officials, and the media. Wide useage of the word wetlands was popularized after 1978 when 13 states passed legislation specifically designed to regulate wetlands. In 1977, President Carter issued an Executive Order which made it mandatory, for federal agencies carrying out land use programs, not to alter wetlands except as a last resort. Because of the multiple ecological benefits that wetlands provide, the National Wildlife Federation in

1976 estimated than an acre (0.4047 ha) of wetlands was valued at between 50 and 80 thousand dollars (Sullivan, 1976).

Studies are in progress to determine the value of wetlands as producers of wildlife. Studies of this type are a departure from the traditional methods of simply estimating direct dollar values of wildlife produced (Larson, 1980). For example, in Massachusetts the U.S. Soil Conservation Service employs a value scale for the purchase of wetlands for wildlife preservation. This scale was derived from an economic study which determined public willingness to pay to have wetlands preserved. The U.S. Fish and Wildlife Service is in the process of developing a habitat valuation system called Habitat Evaluation Procedure (HEP) which is applicable to wetlands and is based on habitat requirements for specific species of wildlife. This procedure generates a measurement called Habitat Units (Schamberger, et al., 1979). However, the procedure is relatively untested at present because it requires detailed informaton on of habitat requirements for each specific species. Application on this procedure can increase only at the rate at which the necessary habitat information is accumulated.

In the past, wildlife has also been evaluated on the basis of being an alternate crop of agricultural land instead of conventional crops. This evaluation was made in 1964 when the U.S. Department of the Interior studied the feasibility of preserving waterfowl habitat by paying incentives to landowners to maintain wetlands on private land in a natural state. This program envisioned the designation of demonstration farms where quality hunting could be sold to the public by the landowner similar to the way that other farm crops were marketed.

In 1979, the state of Minnesota brought out new legislation designed to preserve their wetlands (Mueller, 1979). This legislation has the following features:

1. It establishes a tax credit for each acre of wetlands owned by a farmer so that he can reduce his total taxes payable.

2. It provides for direct payment to counties, in lieu of taxes, for wetlands administered by the Department of Natural Resources.

3. It establishes a State Water Bank Program whereby farmers would find it more financially advantageous to place wetlands on their property into the Water Bank rather than drain these wetlands for cropland.

Studies at the Natural Resources Institute of the University of Manitoba have also made recommendations that incentives be paid to landowners to encourage them not to drain wetlands on their property. Colpitts (1974) investigated the economic feasibility of making payments to private landowners in Manitoba's Minnedosa Pothole Country to induce them to maintain the wetlands on their property as wildlife habitat. Osborne (1979) classified the sloughs in the same area of Manitoba for their potential use as wildlife habitat. Zittlau (1979) assessed the implications of current farming practices as they affected waterfowl habitat management.

The Manitoba Provincial Land Use Conference, held in March 1980, considered methods of encouraging farmers to stop draining wetlands and breaking marginal land for additional cropland simply as a means of enlarging their overall grain shipment quota.

6.4 A Review of Attempts to Determine Wildlife Valuations

Aldo Leopold stated that ideally, there should not have to be a requirement to find economic values for wildlife in order to ensure their continued existence (Gibbons, 1981). He hoped that some time in the future, man's conscience would preclude allowing his environment and the wildlife within it from being badly managed. This ideal state is still on the distant horizon and wildlife managers have no choice but to obtain the economic values of wildlife at this point in time in order to ensure its preservation for the future when wildlife can be enjoyed on purely ethical grounds. A listing of various approaches that have been used to measure values accruing to users of wildlife follows. The difficulties of measurement associated with these approaches have been also noted.

6.4.1 *Gross Dollar Estimates*

As previously discussed, one of the earliest approaches was simply to total the amounts of money recreationists spent in pursuing their outdoor activities. This approach results in an arbitrary valuation of a portion of the wildlife harvest and doesn't determine the true underlying value of wildlife resources.

6.4.2 *Shooting Preserve Values*

These valuations are localized and exclude the values of non-consumptive uses and the value of the wildlife habitat producing the wildlife resource.

6.4.3 *Legal Values*

The courts have established arbitrary units of value for wildlife which are used in determining fines and penalties. For example, North Dakota law sets a value of $25 as the penalty or "liquidation damage" for illegal waterfowl destruction. Such a valuation bears no relationship to the costs of production from the resource base.

6.4.4 *Input-Output Analysis*

The input-output analysis method estimates the value of wildlife as the increase in the economy of a geographically defined area as a result of the wildlife in the area. The monetary value of the wildlife is considered to be the net dollars brought into the defined area by recreationists attracted by the wildlife. A serious drawback of these surveys is that they are expensive to conduct. The principal advantage of this method is that it measures the multiplier effect, or how many times a dollar turns over before leaving the economy of the geographically defined area. In Colorado, these multiplier values have been found to nearly match the economic value of agriculture and to sometimes exceed the values of timbering and mining (Hoover, 1976). Another drawback to this method is that it excludes the consumer's surplus value of the recreationists.

6.4.5 *Benefit-Cost Analysis*

Treasury Board of the federal government uses its publication, Benefit-Cost Analysis Guide (first published in 1976, reprinted 1976) as its basic evaluation tool when considering the feasibility of public projects, which includes wildlife projects. Treasury Board is emphatic that public projects have a minimum one to one ratio in a benefit-cost analysis before federal funding can be considered. Economists regard this provision as being designed more for the purpose of screening out marginal projects, rather than establishing the monetary valuation of a resource (Freshwater, 1981, personal communication). The U.S. Park Service used the benefit-cost analysis method for water projects and assumed the recreational benefits generated were equal to the development costs. They have subsequently rejected this system of valuation.

6.4.6 *Resource Production Base*

Hedlin (1969) proposed that a wildlife product, such as a duck, be considered a free good and that economic research be solely directed at cataloguing wildlife habitat in terms of its productivity. He further recommended that productive wildlife habitat, located on agricultural land, be put into a wildlife resource base. The landowners would then be paid a fair market valuation by the public sector for the use of this land for the production of public goods. An earlier study in this direction was conducted by Rose and Morgan (1964). They evolved a rating system for wetlands in southwestern Manitoba which determined the most productive waterfowl habitat based on soil fertility. This information led to a priority system which showed the key waterfowl habitat that should first be acquired for any resource base. This proposal recognized the economic value of wildlife but gave only an indirect valuation of the resource.

6.4.7 *Non-Consumptive Values*

More (1979) predicted that outdoor recreation, based on non-consumptive use of wildlife, would be the dominant form of wildlife-related recreation by the year 2000. He noted that the dollar value of wildlife would be substantial in economic terms but difficult to measure directly.

6.4.8 *Natural Resource Econometrics*

Hammack and Brown (1974) have devised a series of econometric models which use the number of ponds located on the North American prairies as a factor of production in estimating annual mallard duck production. There is insufficient baseline data presently available to obtain satisfactory predictions from their models. Krutilla and Fisher (1975) in a critique of the models, have noted that if accurate data could be obtained in the future, it would be possible to predict the total duck production for North America on an annual basis from a knowledge of the availability of ponds on the summer prairie breeding grounds. This would provide a direct valuation of breeding ponds to the annual duck production.

6.5 Benchmark Valuation Methods

The following is a detailed discussion of economically derived wildlife valuations that have become accepted to represent wildlife in benefit-cost analysis, environmental impact statements, and to negotiate wildlife mitigation.

6.5.1 *Bioeconomic Evaluation*

Oliver (1979) advocates that the wildlife industry be placed on the same economic basis as other industries. He conducted research on wildlife economics for the Washington State Game Department and developed economic values for wildlife to show its significance in competition for land use. Washington State's bioeconomic evaluation process assumes the value of any piece of land to the wildlife industry is limited by: (1) the land's capacity to produce wildlife, and (2) wildlife's capacity to produce recreation. Each animal is assumed to produce a given number of consumptive and non-consumptive recreation man-days. The bioeconomic evaluation process then applies wildlife oriented recreation dollar values to wildlife. Wildlife is assumed to be the incentive for that portion of the recreation industry that needs and uses wildlife.

To assign wildlife values to any species population the following information must be obtained.

- rate of harvest - which is determined as a percentage of the wildlife population
- recreation standards - the man-days of consumptive recreation produced
- average expenditures - the economic value of harvested game animals as determined from information on the cash flow of sportsmen expenditures pursuing the consumptive recreation
- non-consumptive relationships - this value is determined as a coefficient of the consumptive recreation produced and is measured over a long time period in managed hunting areas of the state
- annual recreation values - the sum of the consumptive and non-consumptive values
- perennial wildlife values - this is obtained by capitalizing the annual recreation value so as to measure the value of the wildlife in perpetuity.

The system can be illustrated by determining the value of a piece of land that supports a deer herd of 100 animals. A harvest rate of 30 percent (30 animals) can reasonably be expected. Washington State has determined that it takes 32 mandays of hunting to harvest a deer in their state. The average hunter spent $28.18 per day trying to do this in 1975. Thus, 960 man-days of hunting was yielded by the herd. The annual consumptive value of the 30 deer harvested was $27,053 in 1975. It was estimated that 1.15 man-days of non-consumptive recreation for every man-day of consumptive recreation occurred on game lands in 1975. By this ratio, 37 man-days of non-consumptive recreation took place for every deer harvested; therefore, the 100 deer also produced 1,104 mandays of non-consumptive recreation. These people spent $9.54 per man-day in 1975. This added $10,532 to the annual value of the deer herd. Adding hunting and non-hunting values yielded $37,585 as being spent on food, lodging, equipment, gas and other items because 100 deer exist. The value was $1,252 per deer killed.

In business terms the harvest of the 30 deer and the cash flow of $37,585 produced by related recreation, represents gross income. The remaining 70 animals represent "capital investment". A portion of this is lost to depreciation (natural mortality) and the remainder represents "production machinery" necessary to sustain the productive capacity of the herd.

In this illustration, to return $37,585 annually at six percent simple interest, a capital investment of $626,417 would be needed. Therefore, a huntable population of 100 deer is worth $626,417. If all animals had an equal probability of being harvested, the 1975 value of each animal would be $6,264. If the breeding stock (70 animals) could be segregated, they would be worth $8,412 each. The high capitalized value of deer is realistic because a certain portion of the herd is harvested, and there is a high demand to hunt deer.

The Washington State bioeconomic evaluation can be seen to function only after basic wildlife resource data has been compiled and analysed.

6.5.2 *Colorado Wildlife Division Values*

This wildlife valuation approach was developed by the Colorado Division of Wildlife when it found that wildlife habitat was disappearing at an alarming rate because of explorations for oil shale and coal. Wildlife valuations derived could be used to obtain mitigation from the mining developers to offset the heavy losses of wildlife that were occuring. The valuation is quite similar to the Washington State bio-economic method.

Norman et al. (1975) have used the economic research findings of Colorado State University's Economics Department to determine a dollar value for individual wildlife species and also the dollar value per acre of lost wildlife habitat. It was assumed that wildlife populations declined in direct proportion to losses of wildlife habitat, and that the real value of wildlife was equal to the value of land required to replace lost wildlife habitat. Representative wildlife management areas were selected for special study and a determination was made of the long-term amounts of each wildlife species that was produced in these management areas. The initial dollar values of the wildlife were made by determining the amount of consumptive recreation man-days that were generated by the wildlife and the gross expenditures of sportsmen using these recreation man-days (Ashton et al., 1974).

The area of wildlife habitat (including both summer and winter ranges) required for individual wildlife species was determined from the wildlife management areas under study. Wildlife habitat under consideration in a benefit-cost analysis is valued as the produce of the area times the dollar value of the wildlife species found in that habitat. The non-consumptive value was determined in a similar method to that used by the Washington State Game Department. A study was made of the number of non-consumptive wildlife recreation days expressed as a proportion of the consumptive wildlife recreation days (Horvath, 1974).

The wildlife valuation figures are expected to become more refined with time and experience. Using the wildlife valuations determined by this method, the Colorado Wildlife Division can compete for land uses with developers. These valuations also provide mitigation costs for wildlife habitat that is lost to development.

Table 5, giving individual wildlife species dollar values called a product list by the Colorado Game Division, is attached for reference purposes. From this Table it is seen that a duck was valued at $20.79 (U.S.) in 1975. For comparison purposes, the present value of the same duck in Canada in 1981 at the Colorado rate, and at a 10 percent discount rate and a 15 percent currency conversion rate, would be worth $42.36 (Can.) in real terms.

TABLE 5

COLORADO PRODUCT LIST

UNIT OF PRODUCT MEASURE LIST

AND

VALUE PER UNIT OF PRODUCT MEASURE LIST

PRODUCT LIST	UNIT OF PRODUCT MEASURE	UNIT OF PRODUCT MEASURE VALUE
Antelope	Harvest	$ 234.00
Bighorn Sheep	Harvest	11,200.00
Black Bear	Harvest	6,400.00
Deer	Harvest	709.00
Elk	Harvest	5,639.00
Mountain Goat	Harvest	1,480.00
Mountain Lion	Harvest	1,600.00
Ducks	Harvest	20.79
Geese	Harvest	68.72
Blue Grouse	Harvest	19.10
Sage Grouse	Harvest	20.38
Sharp-tailed Grouse	Harvest	33.34
Ptarmigan	Harvest	24.08
Chukar Partridge	Harvest	16.67
Pheasant	Harvest	22.20
Dove	Harvest	5.13
Band-tailed Pigeon	Harvest	12.15
Bob White Quail	Harvest	16.21
Gambel's Quail	Harvest	12.15
Scaled Quail	Harvest	9.26
Cottontail Rabbit	Harvest	13.66
Snowshoe Hare	Harvest	21.07
Fox Squirrel	Harvest	17.17
Turkey	Harvest	341.69
Beaver	Harvest	11.63
Martin	Harvest	8.68
Mink	Harvest	27.62
Muskrat	Harvest	1.21
Ringtail Cat	Harvest	8.88
Badger	Harvest	7.11
Gray Fox	Harvest	12.11
Kit Fox	Harvest	6.42
Oppossum	Harvest	1.33
Skunk	Harvest	2.02

Table 5. ..continued

PRODUCT LIST	UNIT OF PRODUCT MEASURE	UNIT OF PRODUCT MEASURE VALUE
Coyote	Harvest	31.30
Jack Rabbit	Harvest	1.51
Raccoon	Harvest	6.79
Red Fox	Harvest	13.81
Bobcat	Harvest	24.23
Marmot	Harvest	1.51
Porcupine	Harvest	1.51
Greater Sandhill Crane	Population Size	350.00
Greater Prairie Chicken	Population Size	500.00
Lesser Prairie Chicken	Population Size	500.00
Peregrine Falcon Nests	Population Size	20,000.00
White Pelican Nesting Area	Population Size	350.00
Bald Eagle Nests	Population Size	350.00
Golden Eagle Nests	Population Size	200.00
Grizzly Bear	Population Size	20,000.00
River Otter	Population Size	2,000.00
Black-footed Ferret	Population Size	50,000.00
Gray Wolf	Population Size	10,000.00
Wolverine	Population Size	10,000.00
Lynx	Population Size	10,000.00
Swift Fox	Population Size	10,000.00
Coldwater Stream Fish	Acres of Habitat	2,793.00[1]
Coldwater Lake Fish	Acres of Habitat	1,241.00[1]
Coolwater Fish (Pike & Walleye)	Acres of Habitat	616.00[1]
Warmwater Predator Fish	Acres of Habitat	1,019.00[1]
Pan Fish	Acres of Habitat	520.00[1]
Colorado River Squawfish	Acres of Habitat	5,000.00
Greenback Cutthroat Trout	Acres of Habitat	10,000.00
Humpback Chub	Acres of Habitat	5,000.00
Humpback Sucker	Acres of Habitat	5,000.00
Rio Grande Cutthroat Trout	Acres of Habitat	10,000.00
Colorado River Cutthroat Trout	Acres of Habitat	10,000.00
Bony-tailed Chub	Acres of Habitat	5,000.00

[1]The values per acre given for sport game fish are average per rate values and should be adjusted by a water quality rating factor to obtain values for water above or below the average.

Source: Norman et al., 1975.

6.5.3 *Canadian Wildlife Service Approach*

An economic analysis of wildlife valuations was conducted in 1978 by Langford and Cocheba (1978) for the Canadian Wildlife Service. After reviewing the economic literature on this subject, they conclude that a very accurate valuation would result if demand curves could be obtained for wildlife users, both consumptive and non-consumptive. The area under the demand curves would represent the total expenditure of the recreationists plus their consumer's surplus or willingness to pay. One method of obtaining the information would be to utilize travel cost data, however, this method is limited because it is site specific. They speculated that a questionnaire could be devised to determine how much a recreationist is willing to pay (or alternately how much he would take to forego) for his activity. The questionnaire questions would have to be worded so as to disguise the true intent of the survey and avoid biased answers. Such a study would doubtlessly yield valuable information on the dollar value of wildlife to outdoor recreationists.

6.6 Conclusion

Wildlife managers have been handicapped for a long time by a lack of dollar valuations for wildlife which could be used in competition for dwindling land resources. Wildlife resources must be evaluated on the basis of consumptive uses, non-consumptive uses, and the value of the wildlife habitat generating the wildlife. Recent studies based on economic theories have succeeded in providing wildlife valuations that are acceptable in benefit-cost analyses, environmental impact statements, and mitigation. There is room and opportunity to define wildlife valuations even closer than at present.

CHAPTER VII

BIOLOGICAL IMPACT OF DROUGHT ON WATERFOWL

7.1 Effects of Drought on Waterfowl Reproduction

Rogers (1964), in a study conducted from 1957 to 1959 at Erickson, Manitoba in the Minnedosa pothole country, observed the effects of drought on the reproduction of lesser scaup. The period 1957 to 1959 marked the transition in southwestern Manitoba, from a period of water abundance to a drought period. Lesser scaup are late nesters and usually do not attempt renesting if the initial nest is lost. Rogers observed a dramatic reduction in reproduction from 1957, a year of water abundance, to 1959, a drought year. The drought conditions were observed to negatively influence scaup production in several ways. The adverse water levels created a deterioration of nesting habitat. Scaup nest in cover close to the water's edge. The lowered water levels created large mud flats and increased the distance between edge cover and the water. Female scaup were observed to show greatly reduced interest in searching out nest sites during the adverse water conditions. Rogers also found that the ovarian growth in females was reduced under the drought conditions. The reproductive cycle became depressed. Many pairs of mated birds were observed to lose interest in breeding under the poor nesting conditions, and instead formed large concentrations on lakes. These pairs simply abandoned the reproductive effort for the year.

The ducks that succeeded in nesting produced smaller broods than average. The principal cause was predation of nests, chiefly by skunks. Rogers concluded that droughts created deteriorated nesting habitat which, in turn, diminished the nesting efforts of the ducks. Predators took a heavy toll of the nests that were attempted. Nest predation was very often total. Stoudt (1969) and others have also cited nest predation as the main cause for nest losses during drought years.

The drought conditions enabled predators to maintain a steady pressure on brood reduction even after hatching. Broods were exposed to additional predation because of the increased distances when travelling between ponds.

Salyer (1962) studied the effects of drought on dabbling duck reproduction. His research was conducted on the Lostwood National Wildlife Refuge in northwestern North Dakota during the period 1959-1961. During this period water conditions ranged between: 1959 - fair; 1960 - good; and 1961 - poor. He observed the reasons for a sharp decline in reproductive success of the ducks from the wet years to the drought year. The reduced water levels caused a lack of safe nest sites for the ducks. There was a high rate of nest predation, again chiefly by skunks. The high temperatures and lack of humid nest sites caused a reduction in egg viability and resulted in high embryo mortality. During 1960, all the study nests were within 125 yards of water. During 1961, the water levels kept receding during the nesting period so that hatched broods had to travel from ¼ to

1½ miles (1.2 to 2.4 km) to get to water. The added travel distance and the extended mud flats around the ponds, exposed the broods to additional predation. Leitch (1975) commented on the fact that drought periods expand predator opportunities. Farmers use dry periods to increase their hay cutting. This results in narrow strips of vegetative cover left around pond edges and fence rows. These strips provide predator paths and seriously reduce the number of safe nesting sites for waterfowl.

Salyer (1962) concluded that breeding pair populations tended to fluctuate with the number of available water areas. The number of suitable breeding territories was reduced during drought conditions and the nesting population declined. There was no decline in the nesting effort or in the clutch size among pairs finding territories. (Rogers (1964) found no difference in the clutch size in scaup between wet and dry years.) The success of the reproductive efforts of breeding birds was very low in the drought year because of increased predation and embryo mortality. The size and number of the broods were also much lower, probably due to the greater distance from nest to water.

Yeager and Swope (1956) studied the effects of habitat changes on nesting waterfowl in Colorado between a wet season (1949) and a drought season (1955). They found a reduction of suitable nesting habitat of 62% and a production decline of 75%.

7.2 Drought and Botulism

Botulism outbreaks are annual events (Macaulay, 1980) but low-water levels and high temperatures intensified the threat in Manitoba during 1980. Blicq (1980) reported the loss of at least 10,000 ducks to botulism at Oak Lake, Manitoba in August 1980 because of the drought condition experienced there. Bohuslawsky (1981) reported the loss of 4,100 ducks to botulism at Oak Hammock Marsh, Manitoba in August 1981 after the spring drought of 1981.

Botulism (Kalmbach, 1968) is caused by toxins or poisons produced by bacterial action on decaying animal matter which accumulates on marsh bottoms. The toxins develop as the water recedes, exposing the mud to heat and air. Ducks and other birds ingest food or water contaminated with the toxin and die. Then, as birds ingest maggots from botulism-infected carcasses, the outbreak spreads quickly. The poison slowly paralyzes the birds until they are unable to fly, walk or hold up their heads. They often drown as their heads droop below water.

Resource Agencies (D.U., C.W.S., Dept. Nat. Res.) have adopted the following control measures: diseased carcasses are collected and disposed of; and, sick birds are collected and exposed to fresh, clean water. Many of the infected birds can recover within days if given the clean water.

Avian botulism has been the cause of the most massive losses from disease known to occur in waterfowl Kalmback (1968).

Botulism receives considerable media coverage whenever outbreaks occur. It is probably the most dramatic and best recorded side effect of drought upon waterfowl.

7.3 Waterfowl and Drought in Australia

Australia is one of the world's driest continents. Its location, topography, and shape all contribute to a highly variable rainfall. More than half of its surface receives less than 20" (50.8 cm) of rain annually. High temperatures and tropical high pressure systems combine in a way that causes two-thirds of the continent to have an annual evaporation that exceeds annual rainfall. This dry climate has probably been responsible for the fact that Australia has a much smaller waterfowl population than that of North America (19 species compared to 42 in North America).

The rivers and their flood plains are the main habitat for waterfowl in Australia. Most Australian waterfowl have regular seasonal breeding patterns in coastal locations where seasonal precipitation regularly occurs. But floods on an irregular basis, often occur in the Australian interior river systems. Two inland nesting species have evolved (Braithwaite, 1975) that nest in the arid interior in conjunction with these irregular floods. These are the grey teal and the pink-eared duck. These species are of interest because they represent the next evolutionary step from North American ducks. They have evolved a specialized response system in their internal physiology which differs in the ways in which different environmental variables are interpreted.

Floods are essential to these waterfowl because they create a temporary but dynamic ecological succession of insect and plant foods (Lavery, 1972). These inland waterfowl species have no fixed pattern of movements; they follow the floods, arriving and breeding as floodwaters are formed, and then dispersing widely across the continent. Frith (1959) has shown that the principal factor initiating the breeding cycle is increasing water level. When water is low the gonads of these birds remain small and inactive and no sexual behaviour is evident. With a sufficient rise in water level the gonads immediately begin to enlarge, followed by breeding. But, if the increase in water is too small or too brief, sexual display may begin but soon ceases and no breeding occurs. Since rainfall sufficient to fill the pools and streams is of irregular occurrence, the breeding cycle of these ducks is also irregular and may occur at any season of the year.

CHAPTER VIII

DROUGHT-INDUCED CONFLICTS BETWEEN WATERFOWL AND AGRICULTURE

8.1 Crop Depredation

Leopold (1933) in his classic book, Game Management, listed droughts as one of the basic causes of crop depredation by waterfowl. Sugden and Driver (1979) examined the problem of mallard crop damage and drew the following conclusions:

1. Preservation of wetlands that attract mallards would be useful in terms of crop damage protection because wetland foods buffered the impact of crop damage. The ducks probably would eat more grain if forced to concentrate on fewer wetlands.

2. Mallards would start field feeding sooner if a field adjacent to their wetland was swathed. Mallards preferred fields closest to their resting lakes early in the season. This behaviour could be exploited if a lure crop was being considered. However, farmers should leave fields adjacent to wetlands until last, to reduce the impact of local flocks on crop damage.

3. Any disturbances around wetlands early in the crop damage season, plus association with other flocks, were important in starting up mallard field feeding.

Compensation is paid to farmers for crop damage by a joint Province of Manitoba/Federal fund.

8.2 Saskeram Marsh -- 1980 Drought-Induced Conflict

8.2.1 *General*

The Saskeram Marsh Wildlife Management Area comprises 138,000 acres (55,849 ha) located within the Saskeram Wildlife Management Area in an area known as the Carrot River Triangle. It is bounded by the Saskatchewan River on the north and the Carrot River on the south. The rivers converge just west of The Pas and the area of the marsh extends westward to the Manitoba-Saskatchewan border. The Squaw Rapids generating plant upstream in Saskatchewan and the Grand Rapids generating station downstream have adversely affected the natural flushing-out and drawing-down that was vital to keep the wildlife habitat in a healthy state. In 1962, Ducks Unlimited was invited in by the province and given a long term lease in order to construct wetland enhancement structures. During the drought of 1980, farm organizations advocated a lowering of the water level of Saskeram Marsh by one foot (from 851.8 feet to 850.8 feet ie. 259.6 to 259.3 metres) in order to make sedge meadows along the south shore of the marsh available for haying. At that time the marsh was already more than a foot below the 853.0 (270 metres) regulated level. Ducks Unlimited were concerned about the reduction of wetlands that would be left available for drought-displaced waterfowl when the water level was lowered (from 12,000 acres to 5,000 acres ie. 4856 to 2024 ha). Local natives were concerned because a water level drop would affect the muskrat population in the marsh. Muskrat trapping formed a substantial portion of their annual income. The provincial government allowed the one-foot drop in water level as part of their program to make additional hayland available for cattle owners suffering hardship from the effects of the drought on regular hayland. The situation received wide attention because the farm organizations used the media extensively to state their position.

8.2.2 *Facts Discovered by Provincial Government Investigation*

The provincial report on the situation showed the following facts:

1. The Saskeram Marsh had been used for emergency haying purposes during the drought of 1960. Farm organization spokesmen used various figures for the perceived hay potential in their statements. Some of their estimates claimed a potential 30-40 thousand acres of hayland that could yield two and one-half tons per acre and result in more than one million bales of hay.

2. Agricultural specialists who surveyed the area estimated that there was a potential 10,000 acres which could yield one ton per acre. Of this 10,000 potential hayland acreage, 3,000 acres were available during the summer of 1980, and 7,000 were under water. Provincial resources during that summer had located 2,720 acres of sedge that would be available for haying. The sedge meadows along the south shore of the marsh were perceived by the farmers as representing a very large area suitable for haying. Old haying areas were now covered by willows or used for cattle grazing.

3. Farm organization spokesmen had stated that there was wide-spread interest in the Saskeram hay potential by other farm groups. Summer precipitation made it possible for farmers to use traditional haying areas. Nine local farmers used the Saskeram area for haying purposes during 1980. They cut hay on 673 acres and obtained 1,086 tons. Only 176 acres of the 3,000 potential Saskeram Marsh acreage was utilized of which only 50 acres were below the 853 foot level. Samples of the sedge showed that it yielded 9.03% crude protein and 32.6% crude fiber content.

8.2.3 *Ducks Unlimited Viewpoint*

Radimer (1980) stated that The Pas area farmers' group took advantage of the drought to pressure the government to order Ducks Unlimited to drawdown valuable wetlands within the Saskeram Marshes. The farmers' group claimed the area could produce up to 1.2 million bales of hay. The farmers presented their case through the local media and culminated their campaign by illegally opening control gates in advance of any government decision. Ducks Unlimited eventually lowered the marshes' water levels by one foot, in compliance with a government order; this reduced the useable area for waterfowl on the marshes form 12,000 to 5,000 acres (4856-2024 ha) and left no area over 18 inches (45.7 cm) deep. Ducks Unlimited concluded that the hay supplies in drawdown areas would be of marginal quality and extremely difficult to harvest. Ducks Unlimited also pointed out the detrimental effects the action would have on waterfowl and muskrat numbers. Analysis of hay gathered from the marsh substantiated the claim that the hay was of marginal quality. The farmers' performance in harvesting the material substantiated concerns that the area was inaccessible. By September 1, the day the government authorized reflooding of the area, only a minimum of hay had been harvested. Almost all of it came out of upland areas, from where Ducks Unlimited had said at the outset, emergency supplies could be taken. The farmers' organization continues to pressure government to implement permanent agricultural development on the marshes. Ducks Unlimited is maintaining an intensive public relations program to underline the value of these wetlands for waterfowl and muskrat production.

8.2.4 *Discussion*

The facts indicate that the reduction of the water level on Saskeram Marsh during the summer of 1980 proved of little value for emergency hay production. There was an impression left that The Pas farmers' organization was using the drought emergency as a means of gaining long-term access to the Saskeram Marsh for agricultural activities.

Total hay production for the Saskeram area during 1980 was 1,086 tons (985,200 kg) cut on 673 acres (272.4 ha) which represents a yield of 1.61 tons/acre (1461 kg/0.4047 ha) of sedge hay. The 1981 Field Crop Recommendations for Manitoba estimates that an alfalfa field yields 3 tons/acre

/season (2722 kg/0.4047 ha/season) of high quality hay. It can be seen that the Saskeram sedge meadows compare unfavourably in both productivity and quality with commercial hay fields. Furthermore, the gross hay production taken from the area did not justify the controversy that it engendered. During the duress of the 1980 drought, only 176 acres (71.2 ha) of the potential 3,000 Saskeram Marsh acreage (1214 ha) was cut, of which only 50 acres (20.2 ha) were below the 853 foot (25,999 cm) level. Assuming the yield of 1.61 tons/acre (1461/0.4047 ha) as representative for the area, then 7,000 acres (2,833 ha) of wetlands was sacrificed in order to provide less than 81 tons (73,482 kg) of sedge hay. At this same yield, the entire estimated 3,000 potential Saskeram Marsh acreage (1214 ha) could only have provided a maximum of 4,830 tons (4,381,679 kg) of sedge hay. Therefore, Saskeram Marsh does not offer any significant mitigation as an emergency haying area. Other alternatives to Saskeram Marsh should be considered in the event of future drought-inflicted livestock feed problems in The Pas area. One alternative would be to stockpile a contingency store of livestock feed in the area to provide for emergency hay demands that occur in the future.

CHAPTER IX

MITIGATION MEASURES

9.1 General

The complex mechanisms of drought when it appears are very profound and pervasive. To attempt to adequately deal with mitigation measures in depth would involve an undertaking beyond the scope of this study and would probably best be managed as a separate study. This chapter proposes instead, to deal with the most visible aspects of drought as it affects waterfowl and waterfowl habitat. Mitigation measures are already built into our society in the form of government departments and agencies who are mandated to deal with specific drought-induced environmental problems. An excellent example of the implementation of governmental mitigation measures is found in the inter-agency cooperation between P.F.R.A. and the C.W.S. The latter agency provides the biological expertise to deal with drought-effected waterfowl and the former agency makes available its land resources where these mitigation measures can be put into effect. These two government agencies have entered into a cooperative agreement so that waterfowl and wildlife habitat on selected P.F.R.A. pastures in Manitoba (and Saskatchewan) can be improved for long term benefits to both agencies. Alongside these organizations are research institutes such as universities and private organizations as for example, the Delta Waterfowl Research Station. The following is a discussion of the general terms of reference affecting mitigation measures and current hands-on methods that can be directly applied as mitigation measures when faced with the prospect of drought conditions. A very effective approach is to incorporate drought mitigation techniques into activities that are currently underway. Leopold (1933) summarized this idea when he stated:

> The fact is that game is not usually a separate product, demanding a separate investment of time or money, with returns proportionate to the separate investment. It is rather a by-product, often demanding only skillful consideration of its needs in conjunction with outlays of time or money that are going to be made in any event, for purposes of agriculture, forestry, animal husbandry or other economic activities.

Wade (1938), when commenting on methods of mitigating the effects of drought, added,

> To preserve and to restore more marshes and ungrazed wood lots is to take out insurance against the destructive effects of droughts that will surely come again.

9.2 Government Policies

The ultimate success or failure of drought mitigation measures are predicated upon whether governments have policies in place that offer long-term survival of wetlands for waterfowl. In Manitoba, this progressive step has been taken by implementation of Provincial Land Use Policies, November 1980, which forms Manitoba Regulation 217/80 under The Planning Act of Manitoba. The key policy here is Policy No. 10. Under Part B, Policy Application, paragraph one, sub-paragraphs (c) and (d), specific direction is given that prime wetlands are to be protected within the framework of future land use plans. Although all lands potentially could fall to agriculture, this policy ensures at least a core of wetlands habitat for waterfowl during the extreme stresses imposed by drought conditions. At present, most of the prime waterfowl habitat in southwestern Manitoba is on private lands (Rakowski et al., 1976). Federal land use policy has also taken wetlands preservation into account within the general provision of the Federal Policy on Land Use. Policy Statement 5 states that the Federal government will identify, appropriate, and protect lands of particular value to the nation for ecological and recreational importance. The Ontario government, in September 1981, published a Discussion Paper as a preliminary towards a wetlands policy for Ontario. This document takes cognizance of the many-faceted ecological and economical values associated with wetlands protection. Proposals are made on the best ways and means of setting up administrative machinery to safeguard the future of the wetlands resource. The U.S.A., under the Carter administration, implemented a wetlands conservation policy. Under this policy, federal agencies are banned from using wetlands for federal projects (except as a last resort). The State of Minnesota recently passed legislation that enables farmers to place wetlands on their land into a

Water Bank system. The economics of the legislation provide a better monetary return to the farmer for safeguarding his wetlands than draining and filling them for crop production. Since wetlands are a continental resource, this type of legislation is required across the jurisdictions of North America to safeguard the prime wetlands habitat against the coming of the next cyclical dry period.

9.2.1 *Grain Delivery Quotas*

Discussions at the Manitoba Land Use Conference in March, 1981, repeatedly made the point that the present structure of the federal grain quota system is having an adverse effect on wildlife habitat. The grain quota system, as it now stands, sets a grain delivery quota for farmers that is based on the acreage a farmer has under cultivation. Farmers,caught in a cash squeeze by current economics, are induced to break and clear marginal land and drain wetlands in order to expand their cultivated acreage. This marginal farmland is the prime habitat of many wildlife species. During dry periods, farmers take the opportunity to move heavy earth-moving equipment onto their wetlands for drainage and leveling operations. The net result is a large reduction of wetlands available for waterfowl when the next wet cycle arrives. Hatch (1981b) observed that "a change in the grain quota system would take much unproductive land out of agricultural use and could provide an incentive to safeguard wildlife lands."

The Manitoba Land Use Conference (1981) proceedings emphasized that the present structure of the grain quota system was the direct cause for the current rapid elimination of wildlife habitat that is situated on marginal agricultural land.

9.2.2 *Government Support of Conservation Agencies*

Several private conservation agencies are involved in wetlands preservation. One example is Ducks Unlimited. This organization was born out of the drought of the "dirty thirties" and is funded by private sportsmen. Since 1938, Ducks Unlimited has spent 150 million dollars in the Prairie Provinces to restore and develop wetlands for duck production. Governments assist these projects by making available 3 million acres (1,214,100 ha) crown lands for wetlands projects. Simply stated private agencies and government policy together appear to provide the empetus and administration to ensure the perpetuation of prime wetlands, which is the ultimate drought mitigation policy framework. The proposed Ontario wetlands policy discussion paper stresses (p. 19) that the participation of private interest groups is fundamental to any successful wetlands program. Coordination of government policies and private interest appear to be the most efficient and effective way of combining effors for drought mitigation.

9.2.3 *Policy Requirements*

Hatch (1981a), commenting on the 1981 spring drought in Manitoba, listed the following policy requirements that should be addressed in order to provide drough mitigation:

1. The need for greatly improved land-use practices.
2. The value of permanent managed and unmanaged waterbodies across the country.
3. The serious plight that faces waterfowl and essentially all associated wildlife.
4. The alarming economic position facing many farmers -- most ducks and big game animals are produced on farmers' property and the farmers receive no tax incentive for preserving habitat.
5. The tremendous contribution made by Ducks Unlimited in preserving wetlands and as a conservation voice.

9.3 Agricultural Practices

9.3.1 *General*

The subject of agricultural practices that can be utilized to mitigate the effects of drought is one where enough literature exists to make this the subject of a separate study. The following methods were chosen because of their current high public awareness and because the drought mitigation potential that could result from their general implementation would be enormous. No effort is made to delve into the cost effectiveness or production efficiency of these methods, except in a general way.

9.3.2 *Zero Tillage*

Stobbe (1981) stated that conventional tilling practices have reduced the organic matter in prairie soils from an initial high of 8 to 12% down to 4 to 6%. High organic matter in the soil increases its moisture retention abilities. Conventional tilling leaves no stubble on the cultivated prairie fields, snow entrapment is reduced and less moisture is available for the crop in the following spring. Because in most years, the Canadian prairies have a severe water deficit, winter precipitation accumulation can play a key role in successful crop production. To overcome the water deficit problem of prairie crop production, farmers summer fallow half of the acreage each year to accumulate additional soil moisture. Approximately 20% of the precipitation that falls during the summerfallow year is accumulated in the soil, the rest is lost by evaporation and downward percolation. Studies at the University of Manitoba plant science department (Stobbe, 1981) have shown that crops on the Candian prairie can successfully be grown under zero tillage. By this method, the stubble from the previous crop is allowed to remain and the seed is planted with specialized drills to minimize soil and stubble disturbance. Under zero tillage, soil erosion is almost eliminated. On zero tillage fields, the winter precipitation accumulation can often eliminate the necessity of summerfallowing. Spring tillage exposes the soil and rapid moisture loss occurs in the tillage zone. In areas where continuous cropping is practiced, the zero tillage fields have substantially more available water in spring, which can improve germination and early seedling growth, especially in dry springs. With zero tillage, weed control is accomplished with environmentally safe herbicides. There are still agronomical problems to be solved. Seeding on poorly drained soils is difficult and not all crops respond equally well to zero tillage. Zero tillage has opened the way to planting winter wheat on the prairies. Winter wheat seeded into stubble is less likely to winterkill, since the stubble traps the snow, giving winter wheat a protective blanket from severe winter temperatures.

Macaulay (1981) advises that zero tillage has several positive aspects from the point of view of waterfowl production. Returning spring waterfowl cannot nest on black summerfallow fields, but mallards and pintails find standing stubble reasonably attractive, probably because it resembles the short grass prairie from which these waterfowl evolve. Under zero tillage, these ducks would have many fields in which to distribute themselves for nesting. If spring seeding disrupted duck nests, the ducks could simply renest if their initial nests were disturbed. With summerfallowed fields, the ducks have fewer fields in which to nest. Ducks are confined to remnant cover (roadside ditches, uncultivated fence lines) when conventional spring seeding disrupts the first nest. Ducks nesting in remnant cover are extremely vulnerable to mammalian predation (Leitch, 1975; Stoudt, 1969) and nesting success can be reduced to 10-20% from an optimum 50-70% (Macaulay, 1981). Comparisons of waterfowl production under the traditional cultivation system with spring seeded crops and zero tillage with spring seeded crops indicates a 10-fold increase in waterfowl production is possible from agricultural lands under zero tillage in prime pothole prairie. If winter wheat was planted, then there would be no spring disturbance to nesting waterfowl of significance and the success ratio could be further improved.

Zero tillage appears to offer solutions to some of the problems that waterfowl experience when nesting under drought conditions. The number of safe nest sites would be significantly increased. Salyer (1962) and Rogers (1964) both found that nest predation was the most serious handicap to nesting success for waterfowl under drought conditions. Increased soil moisture retention could help alleviate the shrinking water levels of ponds which inhibit nesting of divers (Rogers, 1964) and increased brood predation for dabblers (Salyer, 1962) because of the increased distances from nest to water. Increased moisture retention in the soil could provide the humid conditions for nests that can preserve egg viability from scorching drought-induced temperature (Salyer, 1962).

Wind-blown soil erosion off summerfallowed fields is pervasive during drought conditions (Alder, *et al.*, 1981).

Zero tillage could prevent the filling-in of pothole basins with drifting soil and reduce the loss of ponds during severe droughts.

9.3.3 *Stubble Mulching*

Stubble mulching has been known since the 1930's but is only now gaining more widespread attention. It could provide moisture retention, erosion protection and weed control at the same time. The technique involves the use of a tillage implement equipped with a series of two foot wide sweeping blades that skim two or three inches (5-7.6 cm) under the soil surface, severing weed roots but leaving the stubble upright to retain moisture, protect the soil surface, and provide cover for nesting waterfowl. The process appears to work best when soil conditions are not too wet. Farmers in North Dakota are experiencing success using stubble mulching. Trials using the stubble mulching technique are currently in progress in southern Manitoba under the sponsorship of Ducks Unlimited. If the method proves successful and becomes widely adopted, then the same waterfowl drought mitigation advantages as zero tillage would accrue.

9.3.4 *Rotational Grazing and Controlled Burning*

9.3.4.1 General

Rotational grazing and controlled burning are discussed because they are representative of many direct hands-on techniques that can sustain wetlands habitat for waterfowl nesting when drought periods occur.

9.3.4.2 Rotational Grazing

The C.W.S. handbook on Wildlife Habitat issued in 1981, describes one form of grazing rotation for pastures (pp. 27-29). The concept involves dividing grazing range into several parts and then adopting a program of rest-rotation grazing. Tall grasses on a pasture in the rest cycle adjacent to wetlands would provide additional safe nest sites for waterfowl nesting during drought conditions (Salyer, 1962).

9.3.4.3 Controlled Burning

Controlled burning can have more negative effects than positive effects if improperly carried out. It is discussed because fire has become such a popular, but often misused tool for controlling vegetation, including tree and shrub invasions. The use of burning is economical and involves little manual labour. Any burning in and around wetlands should only be done in late fall or early winter when there are not waterfowl nests to be destroyed.

Controlled burning can be effectively used to convert overgrown wetlands and create a marsh edge that waterfowl pairs and broods prefer. The goal of this type of controlled burning is to break up a continuous blanket of sedge, cattail or bulrush. Even emergent vegetation over water or very wet soil can be burned if stems are brittle and closely spaced. It is desirable to achieve a burn hot enought to actually kill some of the vegetation. If the roots of some plants are killed, revegetation will occur slowly, and the wetland should not have to be burned again for many years. Rogers (1964) observed that the availability of suitable edge growth was one of the nesting problems for divers during drought conditions. Fires set simply to get rid of old growth, without regard to season or site, can produce adverse side effects such as loss of soil moisture and loss of snow-trapping vegetation. Frequent burning destroys nutrients and breaks down the soil.

9.3.5 *Improvements for Wetlands*

9.3.5.1 General

Besides the immense value of wetlands as waterfowl and wildlife habitat, the sloughs, marshes, temporary ponds, potholes and lakes act as a huge natural reservoir or sponge that absorbs runoff and then slowly discharges water back into the surroundings during dry periods. Wetlands also are known to act as inlets for underground aquifer that store soil moisture. Improvements to wetlands by all interested parties are important for encouraging drought mitigation. Macaulay (1980) pointed out that only 10% of all Ducks Unlimited projects in western Canada went waterless during the peak of the 1980 drought. The following techniques which are described are more suitable for individual landowners, concerned about the environment and wetlands enhancement.

9.3.5.2 Protection of Natural Wetland Cover

When cultivating around wetlands, some marshy cover can be left around each edge, preferably in strips 25 to 50 feet. A 50 foot strip completely around the edge is unnecessary, just in a few places where cultivation could be difficult anyway, because of wet ground if there is a problem in manoeuvering machinery. Livestock should not be permitted to overgraze wetland fringes. Some grazing helps create openings along shore and keeps backshore vegetation from becoming too thick and weedy. Late summer and fall are the best times for grazing around wetlands as far as waterfowl are concerned. Grazing of fringe areas should not be done every year in order to improve waterfowl nesting cover. Livestock should be kept away from badly trampled and overgrazed wetland fringes until emergent and backshore vegetation has recovered. Nests and young birds are endangered if haying of wetland grasses and sedges is conducted in late spring or early summer (June to mid-July). Many ponds and potholes are ringed by trees and shrubs which can provide almost as good cover as grasses and forbs. Also, woody growth keeps shoreline soils from eroding.

9.3.5.3 Alteration and Creation of Wetlands

Pits can be excavated or blasted near the center of a wetland when it is dry. One pit for every 1 or 2 acres of wetland is recommended. The recommended dimensions of such pits are three to six feet deep, 15 to 20 feet across and shaped in a crescent or "L" shape. Excavated overburden should be used to form small flat islands about two feet high and 10 to 15 feet across. These pits can provide permanent water and emergency habitat for duck broods in times of drought.

Wetlands with a single narrow outlet can be dammed or sandbagged to a height of approximately two or three feet to create new open water and shoreline habitat. Simply blasting an existing marsh or natural depression can be used to form a pothole.

9.3.6 *Enhancement of Natural Environment*

9.3.6.1 Artificial Nesting Islands

Giroux (1981) studied the utilization of artificial islands by nesting waterfowl during a drought period in southern Alberta. He found that nesting waterfowl increased their use of suitable artificial nesting islands by 100% during the drought in comparison to the utilization rate of these islands during wet years. The nesting success for both wet and dry years was approximately 50%, in comparison to the normal 40% (Bellrose, 1976). The increase in nesting success was attributed to increased nest security from mammalian predation afforded by the artificial islands.

In an inversion of the above method, Coulter and Miller (1968) introduced artificial nesting cover into natural islands where the nesting habitat was suitable except for a lack of safe rest sites. Nesting black ducks and mallards readily accepted the man-made nesting cover which allowed them to gain the added security of an island nest location.

9.3.6.2 Artificial Nesting Structures

Mallards and cavity-nesting ducks will utilize man-made nesting structures if they are provided (Oetting, 1973). The C.W.S. handbook on Wildlife Habitat and the Manitoba Government publication Manitoba's Wildlife Heritage are two publications, of many available, that illustrate suitable artificial waterfowl nests. The lack of secure nest sites is the principal problem faced by nesting waterfowl during droughts (Salyer, 1962). On a large enough scale, artificial structures could provide safe nests for part of a homing population seeking to nest on their natal marsh during a drought. This would insure at least some resident ducks being available to take advantage of favourable conditions again when a wet cycle appeared.

9.3.6.3 Stock Ponds

Rumble and Flake (1982) have just concluded a study in central South Dakota to identify habitat variables important to the use of stock ponds by waterfowl broods. These recommendations are as follows:

1. Build larger ponds whenever possible ((1.5 acres (0.61 ha) acres was a minimum size)).

2. Maximize the amount of shallow water area and shallow inlets for the production of submersed and emersed vegetation.

3. Fence shorelines if necessary, to provide suitable vegetation conditions.

4. Leave grain stubble left in fields for fallow until after the peak nesting period to provide good nesting cover.

5. Do not drain natural pond basins in adjacent areas.

The C.W.S. handbook on Wildlife Habitat, issued in 1981, describes and illustrates the construction (pp. 20-23) of stock ponds which incorporate features making them attractive to waterfowl. Many of the recommended construction features of Rumble and Flake are included in the C.W.S. design.

Mack and Flake (1980) conducted a study to determine the most critical design features that made stock ponds attractive to nesting waterfowl. They discovered that the total length of shoreline was more important than pond size, for brood occurrence.

Oetting (1973) noted that,

> During drought periods, stock ponds may be effective in keeping waterfowl in an area. Ponds about two acres in size with at least a third of the shoreline rimmed with brush or trees are preferred. Ponds in hay meadows or pastures are used more often by waterfowl than ponds in cultivated land.

Giroux (1981) commented as follows regarding the 1977 drought in Alberta,

> The increase of nesting ducks during the dry conditions of 1977 indicates that the overall

impact of drought on waterfowl in an area with artificial impoundments may be less detrimental than in areas without them. They provided suitable nesting habitat for homing waterfowl and apparently attracted displaced ducks. If creation of artificial impoundments is promoted on the prairies to minimize the impact of drought on waterfowl production, the new habitat should be suitable for waterfowl until the young have fledged.

9.3.6.4. Artificial Propogation

Burger (1975) reviewed the history of introducing man-reared waterfowl into the wild in order to replace depleted natural ducks or in an attempt to start a new colony. He reviewed the 21-year data on the release of hand-reared ducks from wild-gathered eggs at Delta Marsh and concluded that the great vulnerability to hunting of such birds and the production costs involved, made stocking impractical. Several American states have experimented intermittently with releasing pen-reared waterfowl, but with usually unsuccessful long-term results. These ducks have not been able to successfully re-colonize depleted habitat. There is also a genuine risk of gene pool problems by introducing pen-reared stock. Therefore, restocking of drought-damaged areas by artificial propogation appears impractical.

CHAPTER X

SUMMARY AND CONCLUSIONS

10.1 Summary

The research objectives of this paper were basically accomplished. One shortfall, however, was the attempt to determine an economic valuation that measured the damage to the waterfowl resource which results from the negative impacts of a drought. The economic literature revealed that this state of the art has not been achieved to date. However, an acceptable procedure that would lead to this result has been identified and is discussed below.

10.1.1 *Historical Overview of Cyclical Prairie Droughts*

Droughts are naturally occurring climatic events on the prairies of the northern Great Plains which includes most of Agro-Manitoba. Historical records and archeological evidence indicates that cyclical droughts have been occurring since ancient times. Persistent high altitude weather blocks over western North America during 1980 and 1981, created the climatic conditions for heat, dry weather and resulted in droughts during both those years. The drought of the "dirty thirties" drastically reduced the prairie population of waterfowl and the numbers of potholes vital to the waterfowl reproductive cycle. That drought was the impetus that launched our modern day concern with waterfowl conservation. It is disconcerting to note that the archeological evidence indicates that drought cycles still in our future may exceed the severity of those recorded since the settlement of western North America.

10.1.2 *Environmental Effects of Cyclical Prairie Droughts on Wildlife and Waterfowl*

In general, droughts have an adverse impact on both wildlife and wildlife habitat. The lack of water and high temperatures associated with drought conditions, reduces the food supply and vegetative coverts of wildlife. Disease and overcrowding follow these conditions and many wildlife populations decline. Summer drought creates the conditions for avian botulism on certain wetlands. The carrying capacity of wildlife habitat is relatively stable despite a variety of natural stresses, but drought conditions create a disaster for wildlife habitat and cause a rapid decline in its capacity to carry wildlife populations.

Droughts have both positive and negative environmental impacts on waterfowl. The positive environmental impacts are as follows: Prairie wetlands utilize alternating wet and dry cycles to rejuvenate their productivity and vegetative growth which is important in maintaining their value as waterfowl habitat. Waterfowl are well adapted to survive during cyclical prairie drought conditions after thousands of years of evolution. A discrete, stable, summer resident population of waterfowl exists in northland waters. This population serves as a reservoir of prime breeding waterfowl which can take advantage of the return of wet conditions to the prairies. During drought conditions, many returning spring waterfowl overfly the prairies and continue in a northwesterly direction to the stable waters of the northern latitudes. These drought-displaced waterfowl comprise another population of waterfowl that is superimposed on the resident northern waterfowl. These drought-displaced waterfowl do not engage significantly in reproduction but rather build up into huge concentrations of waterfowl that simply wait out the drought conditions on the prairies. This behaviour increases the fitness and survivability of these waterfowl and enhances their chance of reproductive success when wet conditions again return to the prairies. Waterfowl are a long-lived species and opportunistic breeders and can explosively expand their population with the arrival of wet conditions on the fertile prairie potholes. However, this evolutionary process has made waterfowl dependent on sufficient prairie wetlands being available to them during wet cycles in order to reach a maximum continental population. This ancient equilibrium of waterfowl with cyclical droughts has been altered since the introduction of large scale agriculture by settlers who have come to the northern Great Plains.

The negative environmental impacts are as follows: Drought conditions reduce the ability of waterfowl to successfully reproduce. Waterfowl nesting on the prairies during a drought experience low success, chiefly because of nest predation. Some prairie waterfowl find the drought conditions too adverse for nesting and abandon the attempt to reproduce during a drought year. The reduced reproductive success of waterfowl during a prairie drought results in a decline in the continental populations of waterfowl and the harvestable quantity of waterfowl is reduced. There is a significant economic loss associated with a reduction in the continental population of waterfowl through reduced hunting opportunities. There is also the economic loss associated with non-consumptive uses of the waterfowl population. Drought conditions concentrate waterfowl on the available wetlands, and create conditions for increased crop depredation and conflicts with the agricultural sector.

Most of Agro-Manitoba is located within the well-known "duck factory" of the prairie provinces where the majority of North American waterfowl are produced. The southwest corner of Manitoba contains the province's best waterfowl production habitat, including the famous Minnedosa pothole country. Almost all of the most productive waterfowl habitat in southwestern Manitoba is located on private land.

Man-made factors have entered into the picture and have upset the ancient equilibrium that waterfowl have had with cyclical prairie droughts. These man-made factors are resulting in the progressively permanent reduction of the total amount of wetlands. The provisions of the federal grain quota are set up so as to give the agricultural sector a strong incentive to modify or eliminate wetlands for agricultural purposes. Drought conditions hasten the permanent reduction of wetlands because the dry conditions provide farmers with the conditions to move heavy machinery onto wetlands for drainage and levelling purposes. As the total number of wetlands are reduced by these actions, the successive waterfowl population peaks that follow wet periods, can only trend downwards. Unless these man-made policies and activities are altered, the negative environmental impacts of drought on waterfowl will continue and gradually reduce the continental waterfowl populations to succeeding lower and lower numbers. This study has pointed out that the amount of wetlands in Agro-Manitoba is steadily declining due to draining and levelling resulting from intensified agricultural crop production activities.

Drought conditions increase the demand for hay for livestock feed while simultaneously exposing the sedge meadows in wetlands for additional haying opportunities. A case study at Saskeram Marsh during the 1980 drought was analysed. The facts of this case study clearly showed that valuable wetlands were sacrificed for a marginal amount of hay which could have been better provided from a contingency livestock feed supply.

The 1981 C.W.S. spring transect showed that drought conditions during the transect had substantially reduced the amount of wetlands and that waterfowl reproduction was adversely impacted. Large concentrations of non-breeding waterfowl were recorded. Paradoxically, summer rains broke the 1981 drought and a record grain crop was harvested in Agro-Manitoba. However, this rainfall came too late for the nesting waterfowl.

10.1.3 *Economic Valuation of Drought Damage to the Waterfowl Resource*

Economic literature describing methods of evaluating wildlife resources is relatively new. The literature, in general, has pointed out the following: until recently, monetary valuations of the value of wildlife have tended to be cursory and grossly underestimated. During the last decade, economists have undertaken studies to more accurately determine the value of these resources. Their investigations have indicated that the wildlife resource is best evaluated on a consumptive and non-consumptive basis. Both of these latter evaluations have led to a determination of how the resource is utilized and this utilization, in turn, is usually expressed in terms of the value of recreation days produced. All the economic valuation studies reviewed consistently supported the fact that wildlife are a very valuable resource base that fully deserves to take an important place in our economy with other natural resource bases.

The current economic literature on wildlife valuations documented examples of how firm wildlife valuations had been achieved in other regions, but, the methods employed could not be translated to waterfowl in Agro-Manitoba. In fact the state of the art does not, at this point in time, give definitive figures that can be generally applied to this or any other study. Fortunately, the literature does identify widely accepted methods that can be employed to the case of waterfowl in Agro-Manitoba. The following reviews the reasons why the results of previous studies do not give the desired results and then outlines the general method that could be followed for Agro-Manitoba waterfowl. The bioeconomic evaluation developed by the Washington State Game Department was derived using land-based mammals for benchmark purposes, in this case white-tailed deer. The system determined the recreational value of each animal in terms of its harvest value and the land base that supported the herd. This method would not conveniently adopt itself to migratory species such as waterfowl. The Colorado Division of Wildlife developed an approach that equated wildlife values to the value of the land containing the habitat of the wildlife. This method was evolved to obtain land compensation for wildlife purposes from oil shale developers. This method also would not adopt itself conveniently to waterfowl in Agro-Manitoba. Langford and Cocheba (1978) described a valuation method for the Canadian Wildlife Service that was feasible. This method is the indirect travel cost method often called the Hotelling Clawson Knetch (HCK) method for the economists who developed the concept. The procedure takes the form of developing a questionnaire that can be used to interview the hunters and visitors that use a specific outdoor recreation area. The answers to the questions in the questionnaire, combined with the distances the interviewees had travelled and their travelling expenses, could be converted into a monetary valuation of the recreation area. Economists call this type of valuation a measure of the consumer surplus or the real value the recreation area represents to the people using it. For example, such a survey could be undertaken for the public shooting grounds at Delta Marsh or for Oak Hammock Marsh. The next data required would be biological information which measured the productivity of the surveyed area in terms of quantity by species of waterfowl produced. By using the HCK data and biological productivity data a monetary valuation could be determined for the waterfowl produced at a specific site under study. The reduction from optimum production that occurred at the study site as a result of drought conditions would provide a measure of the drought-inflicted monetary damage to the waterfowl. The method outlined above would be an informative study to consider undertaking and would undoubtedly provide valuable management information for all agencies involved in waterfowl management.

10.1.4 *Recommendations for Mitigation Measures*

Mitigation of the negative environmental impacts of drought on waterfowl begins and depends upon enlightened governmental policies which are designed to safeguard, preserve, and enhance the wetlands. For mitigation measures to succeed they must have the support of government policies that provide the administrative framework for wetlands preservation programs. Within the framework of government support, concerned private organizations and individuals can optimistically pursue programs for wetlands preservation and enhancement.

In Agro-Manitoba the promulgation of the Provincial Land Use Policies of November 1980 have provided government policy support for wetlands preservation. The federal government has voiced support for wetlands preservation within the provisions of the Federal Policy on Land Use. An excellent example of policy in action is the inter-agency cooperation between the C.W.S. and P.F.R.A. in a program of wetlands enhancement on community pastures. The present structure of the federal grain quota system works in direct opposition to wetlands preservation. It provides an economic incentive to farmers to convert wetlands into agricultural land. Almost all the prime wetlands in Agro-Manitoba are on private land. Farmers faced with difficult economic times and the provisions of the federal grain quota system, are rapidly eliminating the prime wetlands in southwestern Agro-Manitoba.

Government support of private conservation agencies, such as Ducks Unlimited, is a positive method of ensuring the perpetuation of key wetlands. Concerned private individuals can also play a role either directly or by supporting private conservation agencies. Existing wetlands can be enhanced for waterfowl and additional wetlands can even be created. Stockponds can be designed so that they are attractive to waterfowl. Agricultural practices such as rotational grazing, delayed summer haying, and controlled burning are useful in protecting and improving natural wetland cover. Methods such as zero tillage and stubble mulching, if they are adopted on a large scale, hold the promise of mitigating a great deal of the negative impacts of drought on breeding waterfowl. In general, mitigation measures can be summarized as all those measures which are directed at preserving and enhancing wetlands.

10.2 Conclusions

The following conclusions may be drawn from the results of this study:

1. Waterfowl were in an equilibrium with cyclical prairie droughts until relatively recent large-scale agricultural development took over the northern Great Plains. Agricultural practices are reducing the amount of wetlands in Agro-Manitoba and across the prairies at a rapid rate. Continental waterfowl population peaks will likely trend downward after each prairie dry cycle because there will be progressively less wetlands available to waterfowl during wet cycles for the ducks to rebuild their populations.

2. Waterfowl are a very valuable wildlife resource that has tended to be undervalued until recent times. A method exists for determining the economic value of waterfowl in Agro-Manitoba at specific sites. If this valuation is determined, then drought-inflicted waterfowl losses could be directly measured in monetary terms at specific sites.

3. During the 1980 drought at Saskeram Marsh, lowering of the water level did not provide any significant additional hay. The potential 3,000 acres (1214 ha) of sedge meadows on Saskeram Marsh do not represent a significant source of emergency hay for livestock in the area. A contingency stockpile of emergency livestock feed located in the area would be an effective way of dealing with future drought-inflicted livestock feed problems.

4. The present structure of the federal grain quota system is responsible for accelerating the drainage and levelling of wetlands in Agro-Manitoba. In its present form, this quota encourages farmers to put marginal land to agricultural use as a means of increasing the total amount of grain that can be delivered. This policy works against wetlands preservation and if continued, will result in the serious reduction of waterfowl and other wildlife.

5. Mitigation of the negative environmental impacts of drought on waterfowl requires government policies that endorse wetlands preservation. There are a multitude of ways and means of preserving and enhancing wetlands that can be undertaken by organizations and concerned individuals. Agricultural practices can be adopted to assist in the preservation of wetlands.

LITERATURE CITED

Adler, J., 1981 Editor. The Browning of America. Newsweek. Feb. 23, 1981. pp. 26-30, 35-37.

Ashton, P. M., R. A. Wykstra and K. D. Nobe. 1974. Optimum supplies of recreation days under conditions of uncertainty: A Case study application to wildlife resources. Dept. Econ., Colo. State Univ., Ft. Collins, Co.

Bellrose, F. C. 1976. Ducks, Geese, and Swans of North America. Stackpole Books. Harrisburg, Pa.

Benson, D. 1965. An Acre of Marsh is Worth. N. Y. State Conservationist. June-July 1965.

Blicq, A. 1980. Poison kills 10,000 ducks. Wpg. Free Press. Aug. 16, 1980. p. 1.

Boeker, H. M. 1964. Alternate Methods of Waterfowl Habitat Preservation in the Prairie Pothole Region of the United States. Dept. of the Int. Fish and Wildl. Suc.

Bohuslawsky, M. 1981. Thousands of ducks killed by botulism at Oak Hammock. Wpg. Free Press. 13 Aug. 1981.

Bossenmaier, E. F. 1978. 100 Plus Years of Wildlife Protection and Development in Manitoba. Man. Dept. Renewable Resources and Trans. Services. Wpg., Man.

Boyd, H. 1981a. A Fair Future for Prairie Ducks: Cloudy Further North. Trans. 46th N.A. Wildl. Conf. 1981.

______. 1981b. Prairie Dabbling Ducks, 1941-1990. C.W.S. Rep. 119. Jan. 1981.

Brace, R. K. and F. D. Caswell. 1982. Prairie Waterfowl Status Report: A briefing document. C.W.S paper.

Braithwaite, L. W. 1975. Waterfowl on a Dry Continent. Natural History. May 1975.

Bryson, R. A. 1980. Ancient Climes on the Great Plains. Natural History. 89(6). Jun. 80. pp. 65-73.

Buller, R. J. 1975. Redistribution of Waterfowl: Influence of Water, Protection and Feed. First Int. Waterfowl Symposium. St. Louis.

Burger, G. V. 1975. The Role of Artificial Propagation in Waterfowl Management. First Int. Waterfowl Symposium, St. Louis.

Chapman, D. W. 1973. Sport Fishery Economics. U. of Idaho.

Colpitts, L. K. 1974. The Cost and Feasibility of Wildlife Habitat Maintenance on Private Lands in the Minnedosa Pothole Country. Nat. Res. Inst., U. of Man., Wpg., Man.

Calverly, B. C. and D. A. Boag. 1977. Reproductive potential in parkland - and arctic-nesting populations of mallards and pintails (Anatidae). Can. J. Zool. 55(8):1242-1251.

Canada Land Inventory - Land Capability for Waterfowl; Environment Canada. 1:250,000 maps.

Canadian Wildlife Service. 1981. Wildlife Habitat. Supply and Services Canada. Cat. No. CW66-51/1981E.

______. 1979. Migratory Bird Habitat Priorities: Prairie Provinces. C.W.S. Report.

Cooch, F. G. 1969. Waterfowl production habitat requirements. Saskatoon Wetlands Seminar, C.W.S. Rep. Ser. 6:5-10.

Coulter, M. W. and W. R.Miller. 1968. Nesting Biology of Black Ducks and Mallards in Northern New England. Vermont Fish and Game. Bulletin No. 68-2.

Crissey, W. F. 1969. Prairie potholes from a continental viewpoint. C.W.S. Rep. Ser. 6:161-171.

Cross, D. 1982. Use of Saskeram Wildlife Management Area for Emergency Hay Extraction, 1980. Province of Manitoba internal report.

Crutchfield, J. A. 1962. Valuation of a Fishery. University of Washington, Seattle, Washington, p. 1-11.

Davis, R.K. and J.J. Seneca. 1971. An evaluation of techniques for demand analysis in state fish and game planning. Nat. Res. Policy Centre, Geo. Wash. Univ., Rep. U.S. Bur. Sport Fish. Wildl. July. Cited in Langford and Cocheba (1978).

Drewien, R.C. and P.F. Springer. 1969. Ecological relationships of breeding blue-winged teal to prairie potholes. Saskatoon Wetlands Seminar, C.W.S. Rep. Ser. 6:102-115.

Ducks Unlimited. 1981. Stubble Mulching: Sensible summerfallowing. Conservator. Vol. 2, No. 3. Fall, 1981.

_______________ 1980. New Crop for the Canadian Provinces? Conservator. Vol. 1. No. 1. Winter, 1980.

Environment Canada. 1980. The Year of the Drought. Land. Vol. 1, No. 2, 1980.

Friend, M. 1981. Waterfowl Management and Waterfowl Disease--Independent or Cause and Effect Relationships. Trans. 46th N.A. Wildl. Conf. 1981.

Frith, H.J. 1959. The ecology of wild ducks in inland New South Wales. Commonwealth Sci. and Effect Relationships. Trans. 46th N.A. Wildl. Conf. 1981.

Gabrielson, I.N. 1973. Report of the Chief of the Bureau of Biological Survey, 1937. 15 Sept. 1937. Washington, D.C.

Gage, R. 1981. Duck Ponds Scarce. Winnipeg Free Press. Fri. June 5, 1981.

Gibbons, B. 1981. Aldo Leopold: A Durable Scale of Values. Nat. Geographic. Vol. 160, No. 5, Nov. 1981.

Giroux, J.F. 1981. Ducks Nesting on Artificial Islands During Drought. J. Wildl. Manage. 45(3):783-785.

Government of Canada. 1981. Federal Policy on Land Use. Supply and Services. Cat.No. EN72-9/1981E.

____________________ 1976. Benefit-Cost Analysis Guide. Supply and Services. Cat. No. BT 35-2-1976.

Greenspon, E. 1981. Drought hangs over the Prairies. The Fin. Post Western Business. McLean Hunter. Mar. 7, 1981.

Grower, D. 1977. The Value of Wetlands. Dept. Renewable Res. and Trans. Svcs. Man. Govt. Wpg.

Hammack, J. and G. M. Brown. 1974. Waterfowl and Wetlands: Toward Bioeconomic Analysis. John Hopkins Press, Baltimore. Cited in Krutilla, J. V. and A. C. Fisher. 1975. The Economics of Natural Environments. John Hopkins Press. Baltimore.

Hansen, H. A. and D. E. McKnight. 1964. Emigration of Drought-Displaced Ducks to the Arctic. Trans. 29th N.A. Wildl. Conf. pp. 119-127.

Hatch, D. 1981a. Chickadee Notes, Wpg. Free Press. May 15, 1981.

Hatch, D. 1981b. Chicadee Notes, Wpg. Free Press. Oct. 16, 1981.

Hedlin. R. 1969. Economic values of small wetlands. C.W.S. Rep. Ser. No. 6.

Hochbaum, H. A. 1944. The Canvasback on a Prairie Marsh. 1981 Edition. University of Nebraska Press. Lincoln, Neb.

Hochbaum, G. S. and R. K. Brace. In Press. Do Displaced Mallards Breed? C.W.S. Paper.

Hoover, F. L. 1976. Incorporating Fish and Wildlife Values in Land Use Planning. Trans. 41st N.A. Wildl. Conf. pp. 279-289.

Horvath, J. C. 1974. Economic survey of southeastern wildlife and wildlife oriented recreation. 39th Am. Wildl. and Nat. Res. Conf. Techn. Session No. 1. Denver, Co. 13 pp.

Kalmbach, E. R. 1968. Type C Botulism among wild birds - an historical sketch. Bur. of Sports Fish and Wild. Spec. Scie. Rep. Wildl. No. 110. Wash. pp. 8 cited in Friend (1981).

Kiel, W. H., A. S. Hawkins, and N. G. Perret. 1972. Waterfowl habitat trends in the aspen parkland of Manitoba. C.W.S. Rep. Ser. 18.

Krutilla, J. V. and A. C. Fisher. 1975. The Economics of Natural Environments. Chapter 9. pp. 219-233. John Hopkins Univ. Press. Baltimore, Maryland.

Langford, W. A. and D. J. Cocheba. 1978. The Wildlife Valuation Problem: A critical review of economic approaches. Can. Wildl. Svc. Occasional Paper No. 37. Fisheries and Envir. Canada. Ottawa.

Larson, J. S. 1980. Wetland Value Assessment -- State of the Art. Int. Wetlands Conf. Indian Nat. Science Academy. India. Sept. 1980.

Lavery, H. J. 1972. Studies of Waterfowl (Anatidae) in North Queensland. Fauna Conservation Branch Bulletin No. 6.

Lauckhart, J. B. 1962. Wildlife Population Fundamentals. Trans. 27th N.A. Wildl. Conf. pp. 233-242.

Leitch, W. G. 1975. Waterfowl Habitat and Management in Western Canada. First Int. Waterfowl Symposium. St. Louis.

Leopold, A. 1933. Game Management. Charles Scribner's Sons, N.Y.

______ and J. W. Ball. 1931. The Quail Shortage of 1930. Outdoor Life, Apr. 1931.

Lowery, B. 1981. Saskeram. Wpg. Free Press. Mon., Mar. 9, 1981. p. 2.

Macaulay, A. J. 1978. Northern prairie water cycles and their impact on waterfowl production. Trans. Third International Waterfowl Symposium. New Orleans. p. 10-13.

______. 1980. Weathering the Drought. Ducks Unlimited. Vol. XLIV No. 6, Nov./Dec. 1980. cited in Radimer (1980).

______. 1981. Zero Tillage Winter Wheat ... And Ducks. Trans. 4th International Waterfowl Symposium. pp. 240-241.

Mack, G. D. and L. D. Flake. 1980. Habitat Relationships of Waterfowl Broods on South Dakota Stock Ponds. J. Wildl. Manage. 44(3):1980. 695-699

Manitoba Land Use Conference. 1981. Proceedings. Steering Committee. Wpg. Man.

Manitoba Government. 1981. Field Crop Recommendations for Manitoba. Govt. of Man.

Manitoba Provincial Land Use Policies. 1980. Prov. Land Use Committee of Cabinet. Govt. Man. Wpg.

More, T. A. 1979. The Demand for Non-Consumptive Wildlife Uses. Forest Ser. Gen. Techn. Rep. NE-52. Broomall, Pa.

Mueller, M. 1979. $ for Wetlands. The Minnesota Volunteer. Sept. - Oct. 1979.

Norman, R. L., L. A. Roper and P. O. Olson. 1975. Using Wildlife Values in Benefit/Cost Analysis and Mitigation of Wildlife Losses. Colo. Div. Wildl. Denver, Colo.

Nudds, T. D. 1978. Comments on Calverley and Boag's (1977) hypothesis on displaced ducks and an evolutionary alternative. Can. J. Zool. 56, 2239-2241.

Oetting, R. B. 1973. Editor. Manitoba's Wildlife Heritage. Man. Dept. Mines, Resources, and Environmental Management.

Oliver, W. H. 1979. Economics as a Wildlife Management Tool. Washington State Game Department. Informational Report No. 11.

Osborne, A. E. 1979. Classification and Potential Land Use of Prairie Sloughs in the Minnedosa Area of Manitoba. Nat. Res. Inst. U. of M., Wpg.

Radimer, C. 1980. Weathering the Drought. Ducks Unlimited. Vol. XLIV, No. 6. Nov./Dec. 1980.

Rakowski, P. R., W. Nero, and R. C. Hutchison. 1976. Present status of waterfowl habitat in the prime duck production area of Manitoba. C.W.S. paper.

Robinson, J. 1981. Jimmy Robinson's Waterfowl Forecast. Sports Afield. Oct. 1981. Vol. 186, No. 4.

Rogers, J. P. 1964. Effect of drought on reproduction of the lesser scaup. J. Wildl. Manage. 28(2):213-222.

Rose, B. J. and H. R. Morgan. 1964. A Priority Rating System for Canadian Wetlands Preservation. Trans. 29th N.A. Wildl. Conf. pp. 249-258.

Rumble, M.A. and L.D. Flake. 1982. Management Considerations to Enhance Use of Stock Ponds by Waterfowl Broods. U.S. Dept. of Agriculture. Unpublished.

Salyer, J.W. 1962. Effects of Drought and Land Use on Prairie Nesting Ducks. Trans. 27th N.A. Wildl. Conf. pp. 69-79.

Schamberger, M.L., C. Short and A. Farmer. 1979. Evaluation of Wetlands as Wildlife Habitat. Wetland Functions and Values: The State of our Understanding. Amer. Water Resources Assn. Minneapolis, Minn. pp. 74-83.

Smith, A.G. 1969. Waterfowl-habitat relationships on the Lousana, Alberta Waterfowl Study Area. Saskatoon Wetlands Seminar, C.W.S. Rep. Ser. 6:116-122.

Smith, R.I. 1970. Response of pintail breeding populations to drought. J. Wild. Manage. 34(4): 943:946.

Sowls, L.K. 1955. Prairie Ducks. The Wildlife Management Institute. Washington, D.C.

Stobbe, E.H. 1981. Zero Tillage. Trans. 4th International Waterfowl Symposium. pp. 237-239.

Stoudt, J.H. 1969. Relationships between waterfowl and water areas on the Redvers Waterfowl Study Area. Saskatoon Wetland Seminar. C.W.S. Rep. Ser. 6:123-131.

Sugden, L.G. and E.A. Driver. 1979. Mallard use of small wetlands during the crop damage season. C.W.S. Progress Notes. No. 100.

Sullivan, P. 1976. Versatile Wetlands -- An Endangered Resource. Conservation News. Oct. 1976. Nat. Wildl. Fed. Wash., D.C.

Tyrchniewicz, E.W., C.F. Framingham, and D. Freshwater. 1979. Proposal for Drought Sensitivity Analysis of Agro-Manitoba. Dept. of Agricul. Econ., U. of Man., Wpg.

Wade, D.E. 1938. Drought Intensity Measurements and the Effects of the 1936 Drought on Wildlife. Trans. 3rd N.A. Wildl. Conf. pp. 558-569.

Yeager, L. E. and H. M. Swope. 1956. Waterfowl Production during Wet and Dry Years in North-Central Colorado. J. Wildl. Manage. 20(4). Oct. 1956.

Zittlau, W. T. 1979. An Environmental Assessment of Agricultural Practises and Policies: Implications for Waterfowl Habitat Management. Nat. Res. Inst. U. of Man., Wpg.

PERSONAL COMMUNICATIONS

Dr. B. Batt, Asst.Director, Delta Waterfowl Research Station.

Dr. W. Cowan, Biologist, Ducks Unlimited, Wpg.

Dr. D. Freshwater, Faculty of Agricultural Economics.

Mr. G. H. MacKay, P. Eng., Director, Manitoba Affairs, P.F.R.A.

Mr. N. Mudry, P. Eng, Director of Planning, Water Resources Division, Manitoba, Wpg.