The quantification of perceptual and behavioural variation in commercial fishing logbooks

by

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GENERAL ABSTRACT

Reliable data are vital to the successful management of a fishery. Commercial fishing logbooks are a valuable source of data, yet may be inaccurate due to data collection methodology or fishing strategy. As a result, these data are currently under-used in research and in management.

Potential biases in the logbook data need to be identified and quantified so that these data can be analysed with greater confidence. I examined the records of catches of cod, haddock, and pollock in commercial logbooks from offshore bottom trawlers on the Scotian Shelf for inaccuracies due to both the perception of a haul and the effect of the presence of an observer.

Typically, a captain underestimated the catch and frequently did not report small catches of all three species, but particularly cod and haddock. The probability that a captain reported these smaller quantities of cod and haddock could be predicted by the amount of that species and the amount of the other two species in the catch. A comparison of observed and unobserved trips on the same vessels revealed that captains tended to fish at different positions or depths when monitored. In addition, hauls containing cod were recorded more frequently but hauls containing pollock were less commonly recorded on trips that were not observed. The resultant total landings from unobserved trips were more valuable. I was unable to distinguish between targeting and high-grading as the mechanism to increase the proportion of desired species in the catch.

CHAPTER 1: GENERAL INTRODUCTION

Fisheries have traditionally been managed without direct consideration of the fishers themselves (Hillborn 1985). More recently the study of fishers' behaviour has been recognised as an important part of fisheries science. This area includes aspects of economics (Lane 1988, Sampson 1994) and anthropology (Andersen 1973, McCay 1978, Berkes and Pocock 1987) in addition to more classical fisheries analyses. Fishers affect the outcome of a fishery through what they catch and also in how they catch it. They are faced with many decisions while fishing including where and when to fish and what portions of the resulting catch to keep. Management decisions should be based not only on the species of interest and their interactions with the natural environment, but they should also take into account any effect of the fishers behaviour on the system, including how their catch data are collected. The examination of fisheries from this broader perspective can result in improved interpretation of fisheries data and better management of a fishery.

In commercial fisheries there are several sources of data, each with it's own advantages and drawbacks. Of all the data sources, the logbooks are the most comprehensive because they document many trips, in some cases all trips, in a fishery. They provide records of fishing activities at a high degree of spatial and temporal resolution, often to the level of a single setting of the nets or lines. Other data sources are considered more reliable but either only cover a portion of the fishery or else lack the spatial and temporal detail of the logbooks.

Logbook data, which are found in many fisheries (Tyler et al. 1984, Almeida et al. 1988, Abrahams and Healy 1990, Richards and Fargo 1994, Béné 1996, Fox and Starr 1996), are not collected with the same rigour as data in a scientific study. For this reason, they are commonly thought to be inaccurate or even biased and so are under-used in research (Hanke 1993, Angel et al. 1994, Fox and Starr 1996).

Effective management decisions depend on reliable data. A failure to recognise potential biases could lead to poor management decisions and ultimately the collapse of a stock. Apart from a few studies (see Richards and Fargo 1994, Fox and Starr 1996), there is a paucity of research into quantitative methodologies that assess inaccuracies introduced by fishers' behaviour in commercial fishing logbooks. No previous study has quantitatively examined the influence of captains' perceptions of a haul on the data they collect and the effects of the presence of an observer on fishing practices.

Any potential inaccuracies do not necessarily render logbook data unusable. Instead, these data should be applied with caution. A methodology to identify and quantify these inaccuracies would be beneficial. The quantification of inaccuracies in the logbooks could increase their utility in management and thus provide a relatively inexpensive yet comprehensive data source to supplement data obtained from other sources such as scientific surveys. This thesis initiates the development of such methods.

I examined the influence of the perception of a haul by a captain on data recording and also the effects of the presence of an observer on fishing strategy.

These two factors were examined separately because of their potential to influence the data in different manners. I have developed quantitative procedures for contrasting simultaneously collected data from alternative sources to examine perceptual and behavioural variation in the logbooks from an Atlantic trawl fishery.

CHAPTER 2: THE QUANTIFICATION OF DATA COLLECTION PATTERNS IN A COMMERCIAL FISHERY ON THE SCOTIAN SHELF.

ABSTRACT

This study examined commercial data collection practices evident in the catch records of offshore trawlers fishing for cod, haddock, and pollock on the Scotian Shelf. Captains and observers differed in their interpretations of the same hauls, though their data sets were highly correlated. A typical captain reported a lower catch and fewer species in a haul than did an observer on the same vessel. Small amounts of cod and haddock present in the observer reports were not present in the corresponding captains' logbook records. Generally, a minimum amount of cod and haddock had to be caught before a captain recorded them. This minimum amount varied with both the amount of that species caught and its proportion in the catch. Despite the discrepancies in the description of catch, I also found that the catch estimates in captains' logbooks and observers' records were correlated at the resolution of haul and were highly correlated at the resolution of trip. Finally, a comparison of total landings in the purchase slips and the logbooks of monitored and unmonitored trips revealed no demonstrable effect on data collection practices due to the presence of an observer.

INTRODUCTION

This study focuses on the perception of groundfish hauls and the resulting data collection practices. Commercial fishing records from three sources are compared: captains' logbooks, observer reports and final landings in the form of purchase slips. The fishing data used were obtained from the Canadian Department of Fisheries and Oceans, Marine Fish Division, Bedford Institute of Oceanography, Nova Scotia.

In the Marine Fish Division, a combination of the logbooks and the purchase slips currently is being used in stock assessments. In the assessments, the logbook data are prorated based on the final landings recorded in the purchase slip data (P. Comeau, Marine Fish Division, Department of Fisheries and Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, personal communication). Although these corrections result in a more accurate measure of catch from the logbooks, they only account for underestimations of catch and not for species that are unreported. Therefore the corrected logbooks may not provide a good description of a particular haul.

There are many advantages to using logbook data in research. Logbook data are useful for many types of studies because of the detailed haul by haul description of fishing activities that they provide. They are extensive because they are collected throughout the entire fishing season. The same comprehensive coverage of a fishery would be difficult to obtain through research surveys because it would be both time consuming and costly. Logbook data are collected with a minimum amount of involvement in the fishery on the part of the researcher and so take relatively little time to acquire. This also eliminates the risk of the researcher inadvertently influencing fishing or data collection practices. In addition, information regarding commercial fishing strategies, such as the targeting of desired species, cannot be inferred from survey data alone. A possible disadvantage however, is that the recording of commercial data lacks the rigour of scientific methodology, hence there is the risk of unquantified inaccuracies (Hanke 1993; Angel et al. 1994; Burke et al. 1996; Fox and Starr 1996).

Researchers have used logbook data to describe various aspects of fisheries. Tyler et al. (1984) described the distribution of commercial fishing effort off the northwestern United States based on logbooks. Abrahams and Healy (1990) applied ideal free distribution theory to examine the effect of catch rates on the spatial distribution of vessels with varying competitive abilities in the British Columbia salmon troll fleet. Béné (1996) used commercial logbooks to describe the spatial distribution of fishing effort in the French Guyana shrimp fishery in an attempt to identify a link between fleet dynamics and particular fishing strategies. Fox and Starr (1996) compared catch rates, distribution, and biomass estimates for five species of groundfish calculated from logbook and survey data from a commercial fishery in Oregon to assess the logbooks as a data source supplementary to the survey data.

Previous examinations of commercial fishing data sources found that the logbook records correspond closely to other more reliable data sources. Fox and Starr (1996) compared logbooks to research survey data and reported that the two sources agreed in their description of catch rates, distribution and biomass estimates of fish. However, they only analysed approximately 50% of the hauls in the fishery after eliminating any that were incomplete, illegible, or that they considered not to correspond closely to the landings records. Richards and Fargo (1994) found that reported species compositions in a haul agreed in their comparison of observer records to captains' logbooks and sales records in a British Columbia groundfish trawl fishery. They also noted that observers consistently reported a lower total catch and higher effort than did captains. These studies assessed the utility of commercial fishing data but did not address the data collection methodology that determined their quality.

In this paper, my objective was to assess inaccuracies in logbook data due to differences in perception of catch composition in hauls. Any inaccuracies in the logbook data should be quantified before these data are used in research and stock assessment. The identification and quantification of the relationships between commercial fishing data from logbooks, observer reports, and purchase slips could reveal patterns of data collection and thus allow a more rigorous assessment of catch estimates in the logbooks. This would enable scientists to use these data with greater confidence in fisheries management and in research.

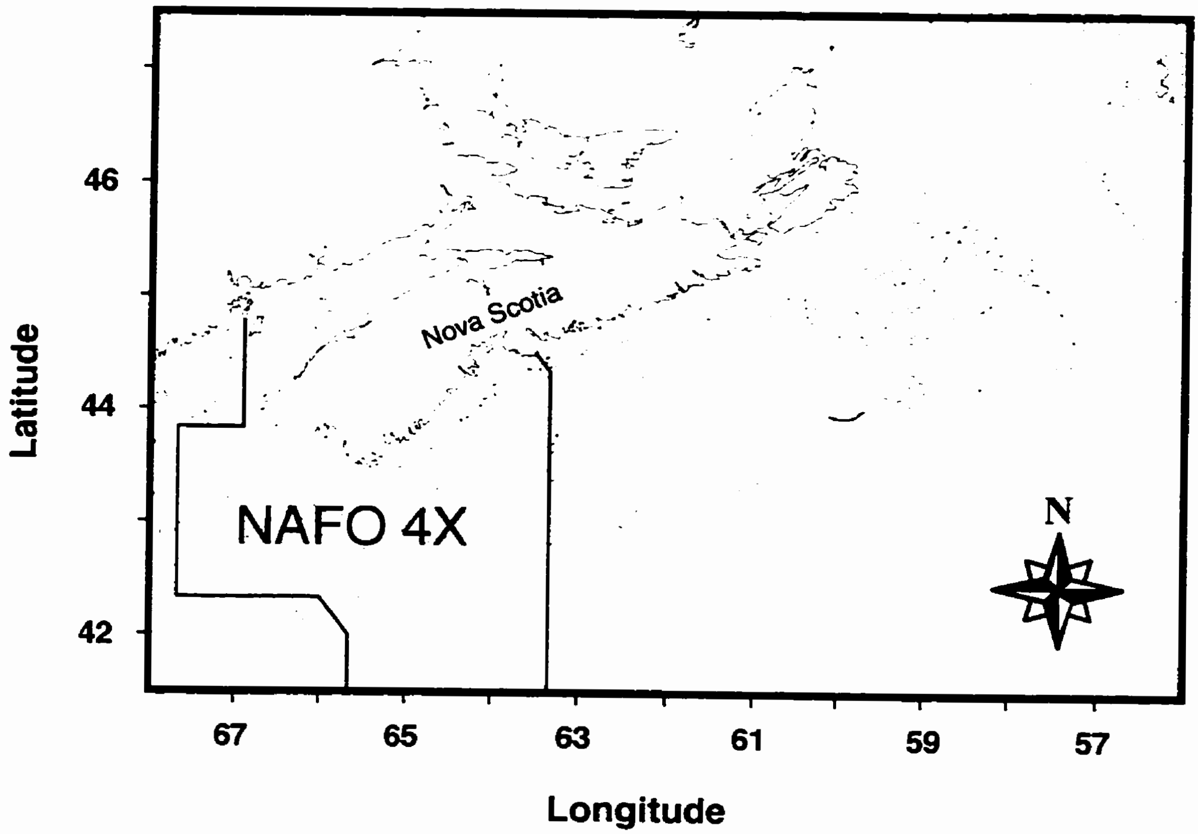
My study contrasts the reported catches of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and pollock (*Pollachius virens*) from North Atlantic Fisheries Organisation (NAFO) Division 4X among the 1993 captains' logbooks, records from independent observers, and the purchase slips completed by the buyer or dockside monitor. Divergence among the three data sets is used to develop a methodology to quantify relationships among data sources and to examine factors influencing a captain's perception of a haul as reflected in the data.

METHODS AND MATERIALS

Data Sources

The commercial fishing database maintained by the Marine Fish Division is large and varied. To limit confounding variables in the analyses, I concentrated on hauls made by similar vessels under the same regulatory regime. Regulatory regimes are based on the overall length of the vessel, type of gear, fishing area, and species sought. I selected catches of cod, haddock, and pollock because they were three of the most heavily exploited species on the Scotian Shelf (Simon and Comeau 1994; O'Boyle and Neilson 1994) and they tended to co-occur in a haul. My data were collected in NAFO division 4X during (Figure 2.1) 1993, where there was a directed fishery for both cod and pollock; haddock was landed as by-catch. This also was the year that the mandatory landing provision was implemented that dictated that all cod, haddock, and pollock (as well as most other species of groundfish) must be landed regardless of their size. The selected records represented catches made by Canadian otter trawlers in tonnage classes 4 and 5 (offshore fleet greater than 100 feet in length overall and less than 1000 gross registered tons in capacity) and comprised 436 hauls from 45 trips. This sector of the Scotian Shelf groundfish fishery was

Figure 2.1. Chart of the Scotian Shelf indicating the location of North Atlantic Fisheries Organization Division 4X.



46
44
42
Latitude
67
65
63
61
59
57
Longitude
Nova Scotia
NAFO 4X
N

documented by records from the logbook, observer, and purchase slip databases.

In the Logbook Program, every commercial fishing vessel's captain is required to complete a logbook describing each fishing trip as part of the fishing license conditions. Information collected includes the type of gear, time, location, and depth of every haul. The catch is listed by species or species group (for example 'flatfishes' is sometimes used to designate all pleuronectiformes in a catch) with estimates of the weight of fish landed and also of those discarded. The logbooks contain an abundance of data and cover the entire fishery. However, these data are considered to be collected in a biased, non-random manner (Hanke 1993; Angel et al. 1994; Burke et al. 1996, Fox and Starr 1996) and so they are currently used in stock assessments and research with reservation.

Contracted observers are assigned to fishing trips by the Department of Fisheries and Oceans (DFO) to collect data for the International Observer Program. They collect much of the same data as seen in the logbooks and their reports are considered more reliable but are less comprehensive because only a fraction of the total number of trips carry an observer. In addition to estimating the landings and discards, observers sample the catch for biological information such as weight, sex, and maturity of individual fish. Each haul description includes the vessel's size, the gear used, and the time, location, and depth of the haul. Finally, additional comments are noted in the trip narrative which recounts the fishing strategy and data collection methods as well as identifying any irregularities in fishing practices. In 1993, 37% of the trips fished by vessels in tonnage classes 4 and 5 landing cod, haddock, and pollock in NAFO division 4X were monitored.

My third source of data was the purchase slips, also called weighout or sales slips, which were collected by the DFO as a part of their Logbook Program. Upon landing, the commercially important fishes (such as those in my study) were sorted by species and weighed by the dockside monitor and/or the buyer's weighmaster. This information was recorded on the purchase slip that was completed for each trip. Since actual weights rather than estimates were recorded, these data are considered accurate and have been used to calculate the landings from the fishery (McMillan and O'Boyle 1986). As with the logbooks, the purchase slips covered 100% of the fishery and so were extensive as well as being accurate. A shortcoming of these data was that they lacked the spatial and temporal depth of the logbook or observer data sets since only the final landings of the entire trip were recorded. Rather than the haul by haul detail seen in the previous two data sets, a purchase slip record included only catch from an entire trip, the dates sailed, and landed and the NAFO division where most fishing occurred.

The logbook, observer, and purchase slip data differed in format. In order to make comparisons, I matched haul estimates by assigning a common code for each haul, according to vessel number, date, time, and position. This allowed the comparison between the different sets of records for the same haul, thus the same catch.

Analyses

The goal of the analyses was to quantify the divergence among records from the three data collection programs due to differing perceptions of haul composition between captains and observers. The results of these quantified relationships were then used to propose methods for the detection and estimation of potential biases in the logbooks.

I investigated which factors affected a fisher's decision to report a species in the logbook by examining the probability of occurrence of a species in the haul. I also contrasted logbook and observer records of the same hauls to examine qualitative and quantitative differences in catch estimates at the resolution of haul, and then of trip. The comparisons between logbooks and observer reports were limited to hauls monitored by an observer and so may not be representative of hauls from unmonitored trips. To test if fishers altered their reporting behaviour in the presence of an observer, I compared catch estimates from trips with an observer to those without, as recorded in the logbooks and in the purchase slips. This tested for any change in reporting behaviour manifested as a change in the relationship between actual landings and those estimated in the logbook records.

Analyses by haul

I first investigated potential differences between the catch in a haul as reflected in the logbooks and in the observer reports. By comparing records for the same haul from the two sources, I could contrast the perceptions of catch of captains and observers while controlling for actual catch composition. That is, any differences detected would be in how the data were recorded rather than in the catch. I began with a qualitative analysis of species composition in a haul.

A chi-square statistic was used to determine if the species mixes reported in the logbooks were different from those reported in the observer data. Hauls in both the logbooks and the observer reports were classified as belonging to one of seven categories according to their reported species content: CHP, CH, CP, HP, C, H, or P where C=cod, H=haddock, and P=pollock. The hauls were then sorted into a 7 x 2 contingency table according to their membership among the seven classes of haul content and the two classes of data source.

As is common with fisheries data (Pennington 1983; Gillis et al. 1995b; Fox and Starr 1996), the relationships between the observer records and the logbooks were dichotomous (Figure 2.2). Most species were estimated both in the logbook and the observer records, but there were also hauls where the captain made no catch estimate for one or more species when catch was reported by the observer. Using a logistic regression, I modelled the probability that a species will be reported by a captain based on the quantity of that species caught and the amount of other species in the catch, as reported by the observers. A binomial variable indicated the presence of a species in a logbook record (1 = some amount reported and 0 = none reported). I concentrated on cod and haddock because these were the two species most commonly unreported; most hauls included some estimate of pollock.

A logistic regression is used to estimate the probability that an event, in this case that a captain will report the catch, would occur. The model can be written as:

Equation 2.1 $$\text{probability of event} = \frac{e^{z}}{1+e^{z}}$$

where

Equation 2.2 $$Z = B_0 + B_1X_1 + B_2X_2 + \ldots + B_pX_p$$

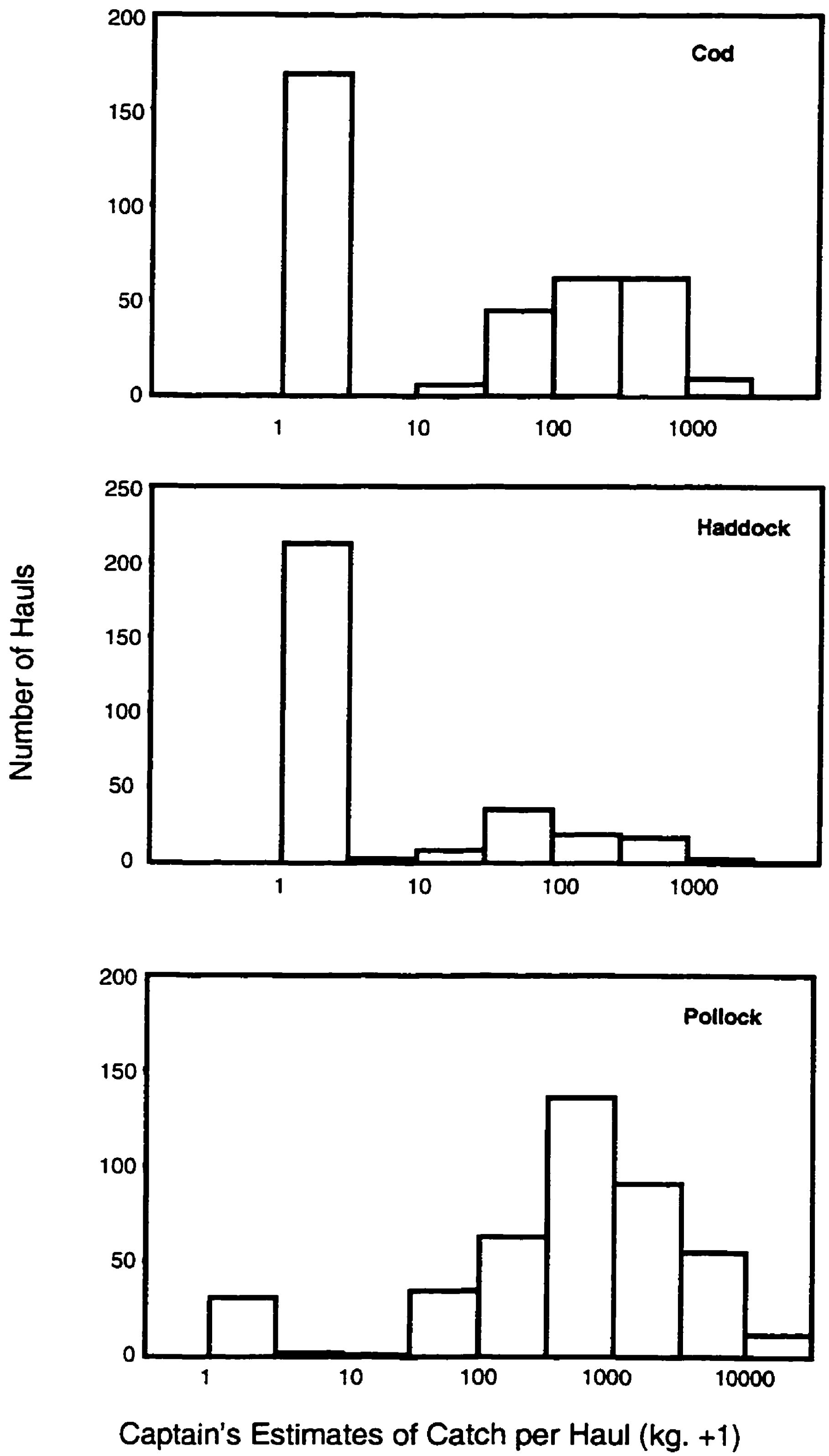
This model was fitted by maximum likelihood by forcing all variables into the regression equation on the first step. Variables which did not contribute significantly to the fit of the equation were then eliminated (Norusis 1997).

The predictor variables were the weight of the three species in the haul as recorded by the observers. For example, when examining the reporting of cod in the logbooks, the three independent variables tested were the estimates of cod, of haddock, and of pollock in the observer's record of the haul.

I compared the estimates of cod, haddock, and pollock caught via linear regressions of the logbook records on the observer records. The data were log-transformed so that their distribution would meet the assumptions of the test (Zar 1974). One analysis was performed for each of the three species.

These tests included data where both the captain and the observer made an estimate. One of the assumptions of the least squares regression is that the *x* variable not be subject to error. Both variables in this case were estimates and so, as with most real data, they were subject to error. However the least squares regression can provide reliable results if the magnitude of the error in

Figure 2.2. Histograms illustrating the captains' estimates of catch for hauls where observers have reported the presence of that species.


Number of Hauls
Cod
200
150
100
50
0
1
10
100
1000
Haddock
250
200
150
100
50
0
1
10
100
1000
Pollock
200
150
100
50
0
1
10
100
1000
10000
Captain's Estimates of Catch per Haul (kg. +1)

the *y* variable is much greater than that in the *x* variable (McArdle 1988), as it is in this case. The observers' estimates are considered accurate relative to the captains since not only are observers trained to accurately estimate catch, but also they can focus on this task as this is their primary function.

In addition, I plotted the location of catch estimates in the logbooks and observer reports to visually examine the frequency of unreported catch in the logbooks. This plot also demonstrates how biases in the estimation of species range from logbooks could be caused by a failure to report catches.

Analyses by trip

I aggregated the catches by trip and compared the captains' and the observers' estimates of catch to examine correlation between the data sets at a broader level. Next, I examined the influence of the presence of observers on data collection though a comparison of the relationship between the landings in the logbooks and the purchase slips. A change in this relationship coincident with the presence of an observer would indicate a change in data collection practices. The results of this study could only be extrapolated to include those trips that did not carry an observer if the patterns in captains' data collection were unaltered when an observer was absent. My final analysis was a comparison of the proportions of each species in the final landings of monitored and unmonitored trips.

I regressed the logbook records on the observer records for cod, haddock, and pollock, excluding trips where the species did not occur, to examine patterns at the resolution of trip. Estimates of landings for each species were log-transformed so that their distribution would meet the assumptions of a least squares regression (Zar 1974).

I then compared the catches in the purchase slips to the landed logbook catches via multiple regressions to see if the presence of an observer influenced the reporting pattern. A dummy variable indicated whether trips carried an observer. Only non-zero catches were included because I was interested in behaviour when fish were reported in both data sets.

The purchase slip data, which I used for the multiple regressions, were recorded by sub-trip or for an entire trip rather than divided into individual hauls. As a result, the hauls in NAFO division 4X could no longer be isolated. When aggregating the logbook records for these analyses all the hauls within a single trip for each vessel were combined, including any outside of NAFO division 4X. Vessels that had at least one observed trip partially in 4X during 1993 were included in the analysis. Any vessels that were never monitored that year were omitted in the event that their behaviour differed from the vessels that did carry an observer at some time.

Finally, I examined the logbook records using Mann-Whitney U tests to compare the proportions of a species in the catch between monitored and unmonitored trips as reported by the captain.

RESULTS

Overall I found that captains and observers differed in their estimations of haul contents but also that their estimates were correlated. Captains reported catch differently than observers, both qualitatively and quantitatively. The observers reported more species in a haul than did the fishers and they also reported more frequent, higher catches of each species. Captains often did not report small catches of cod and haddock. Despite these differences, at the resolution of trip, logbook and observer records corresponded closely. Although a typical logbook had a lower estimate of catch in a trip, the estimates from the two sources were highly correlated. No change in captains' reporting behaviour in the presence of an observer was evident.

Analyses by haul

The two patterns I found when I contrasted hauls in the logbooks and observer reports were: captains tended to make smaller estimates of catch and captains tended not to report a species when only a small quantity is caught. The analysis of the contingency table showed that haul records from the observer data were qualitatively different from those in the logbooks. The observer haul records were more mixed than the logbook hauls, that is, there were a higher number of hauls with more than one species recorded as present (Table 2.1. n=872, chi-square = 286.16, $p<0.001$). These differences were due to data collection practices, since the comparison was between corresponding records for the same hauls, hence the same catch. The 'CHP' hauls were most common in the observer data; in contrast, 'P' hauls were most common in the logbook records. 40% of the observers' 'CHP' hauls were reported as 'P' in the logbooks. These hauls typically contained some relatively small amount of cod and/or haddock (Table 2.1), suggesting that captains commonly did not report very small catches of these species.

The results from the logistic regression indicated that observer estimates of cod and of pollock could be used to assess the probability that small quantities of cod would be reported by a captain (Table 2.2). When an observer reported greater quantities of cod, the probability that a captain also reported it increased. The inverse relationship was seen with the amount of pollock reported. The goodness of fit test (Hosmer and Lemeshow test, $p<0.05$) (see Agresti 1996 p.113) indicated there was some lack of fit of the resulting model to the data. Although a trend was detected, the predictive power was low.

The analysis of the probability for reporting of haddock revealed that the estimates of cod, haddock, and pollock contributed to the fit of the logistic model (Table 2.2) (Hosmer and Lemeshow test, $p>0.25$). As more pollock was reported, it was less likely that catches of haddock would be reported. Conversely, the probability of reporting haddock increased with the amount of cod and haddock caught.

The linear regressions of hauls revealed that there was a positive correlation between the non-zero catch estimates in the logbook and the observer records (Figure 2.3, Table 2.3). The figure illustrates that observer records did not serve as a strong predictor of the catch reported in the logbooks at the level of haul, although the linear relationships were significant.

Table 2.1. Tabulation of hauls classified according to the observers' and the captains' perceptions of haul contents. Observers report more species than do captains in the corresponding records of the same haul

Captains' classifications

Observers' classifications

	CHP	CH	CP	HP	C	H	P	Σ
CHP	44	5	62	15	10	9	95	240
CH	1	0	0	0	4	4	0	9
CP	6	1	49	2	2	0	43	103
HP	0	0	1	7	2	1	38	49
C	0	0	0	0	0	0	1	1
H	0	0	0	0	0	0	0	0
P	0	0	4	0	0	1	29	34
Σ	51	6	116	24	18	15	206	436

Table 2.2. Results of logistic regressions predicting the probability that cod and haddock will be reported by a captain. Parameters are based on observers' estimates of catch in a haul. The probability of cod being reported is positively correlated with the amount of cod reported by the observer and negatively correlated to the amount of pollock reported. The probability of haddock being reported is positively correlated to the amount of cod and haddock reported by an observer and negatively correlated to the amount of pollock reported.

	n	parameter	coefficient	p
Cod	436	cod	1.90	0.00
		pollock	-0.43	0.00
		constant	-2.14	0.00
Haddock	436	cod	0.32	0.03
		haddock	1.24	0.00
		pollock	-0.44	0.00
		constant	-2.26	0.00

The frequency of unreported catches of cod and haddock in the logbooks can be deduced from the geographical plots in Figure 2.4. The disparity between the captains' and observers' reporting is depicted by the more frequently reported catches of both species by an observer. The plots reveal that the apparent spatial extent of cod and of haddock catches was greater when unreported catches were included.

Analyses by trip

When I aggregated the data by trip, I found that the captains' and observers' catch estimates from cod, haddock, and pollock were highly correlated, with observer estimates being higher than logbook estimates for the same catch (Figure 2.5, Table 2.4). These relationships indicated that, at the level of trip, captains' estimates are consistently biased from the observers'. However, when data sets are so highly correlated, a consistent bias such as this could be eliminated with a correction based on the regression equation.

The analysis of observer effects on catch composition was not statistically significant. The Mann-Whitney U tests comparing the proportions of a species in the catch between monitored and unmonitored trips provided no evidence of an observer effect (n=41; cod p=0.36; haddock p=0.71; pollock p=0.29).

Figure 2.3. Linear regressions of captains' estimates on observers' estimates of catch per haul for cod, haddock, and pollock.

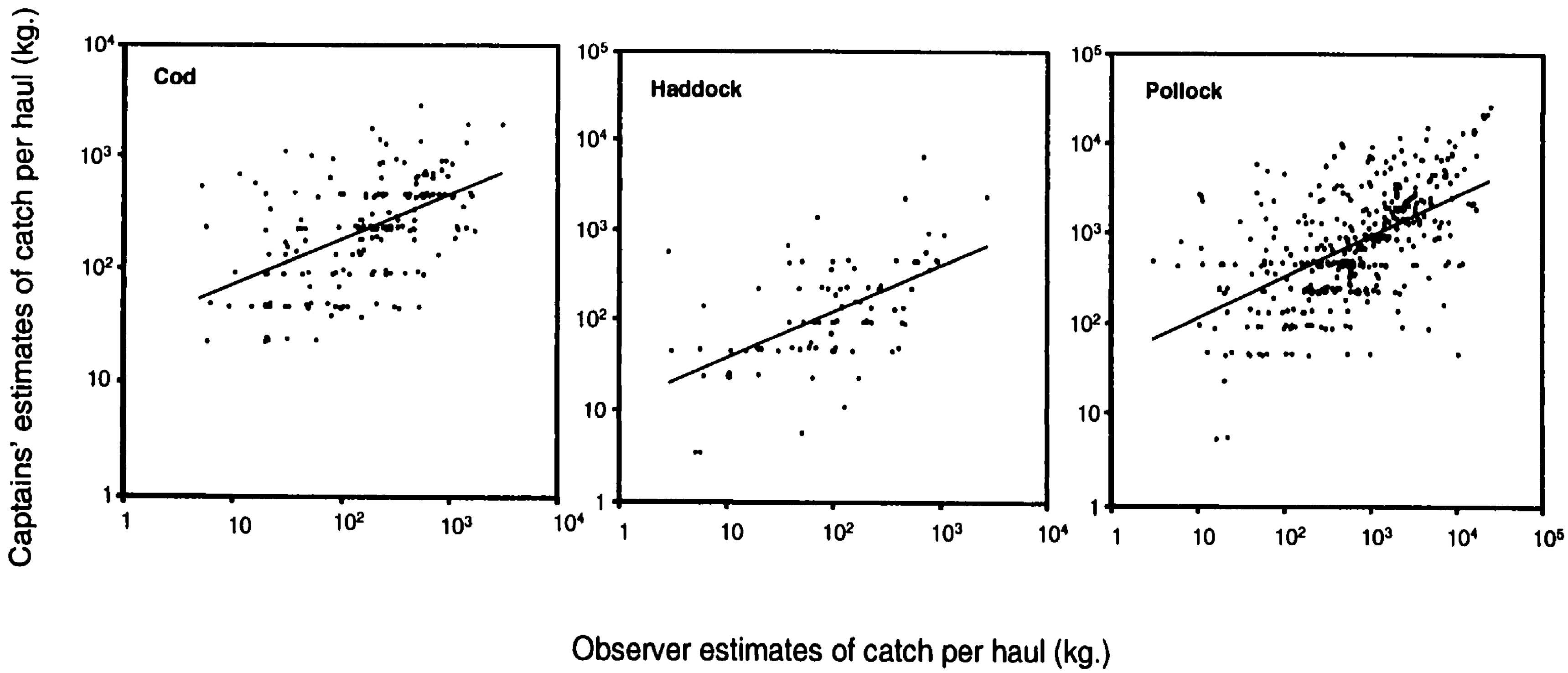
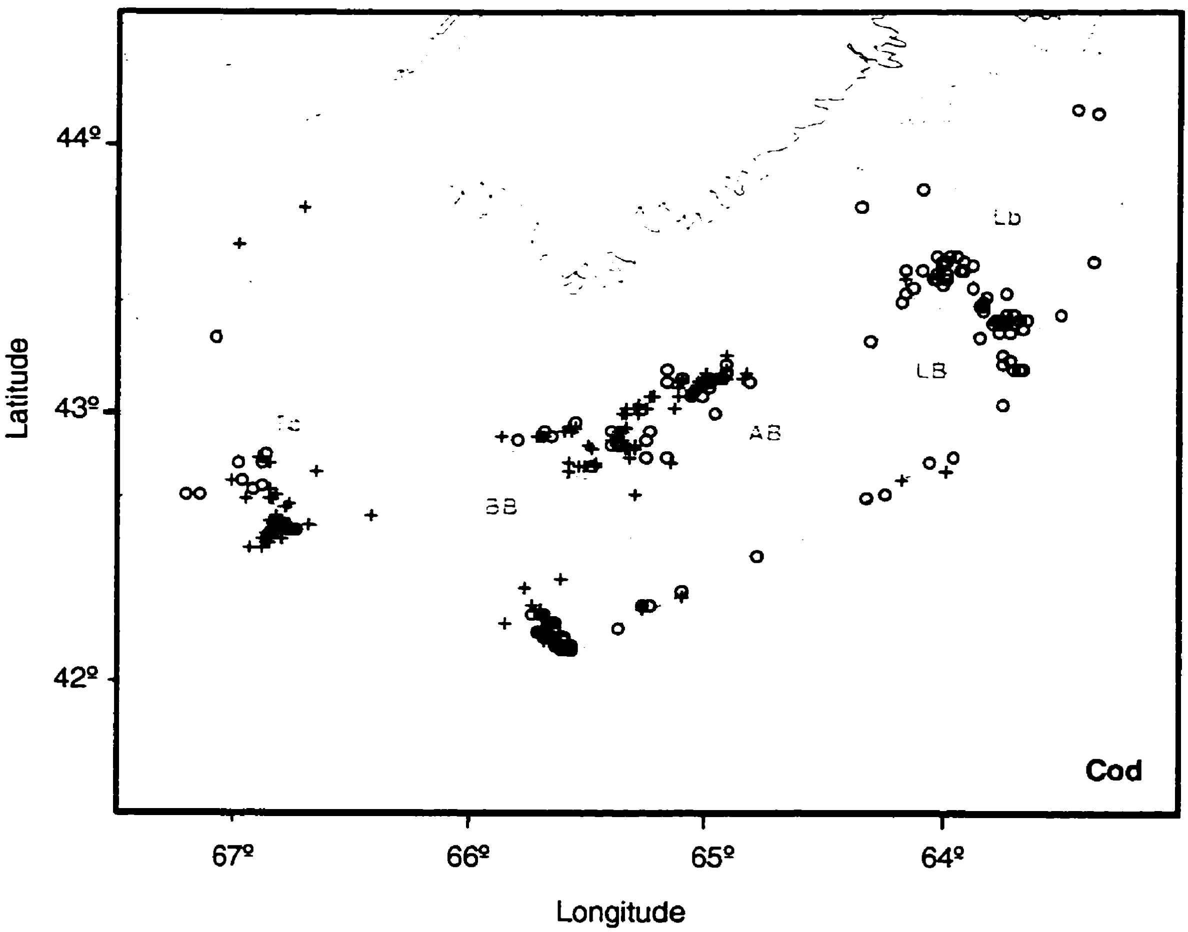

Cod
Haddock
Pollock
Captains' estimates of catch per haul (kg.)
Observer estimates of catch per haul (kg.)
1
10
10²
10³
10⁴
10⁵

Table 2.3. Results from linear regressions of logbook estimates on observer estimates of catch per haul for cod, haddock, and pollock. The relationships are significant but the low R^2 values emphasise the variability in the perceptions of haul contents between captains and observers. An asterisk beside the probability value indicates significance at $\alpha = 0.05$.

	slope					intercept								
	coeff.	**lower 95% C.I.**	**upper 95% C.I.**	***t-tests***	**p**	**coeff.**	**lower 95% C.I.**	**upper 95% C.I.**	***t-tests***	**p**	**R^2**	**F**	**p**	**resid. sum of squares**
Cod														
n=184	0.40	0.30	0.50	8.11	0.00*	1.45	1.23	1.67	12.81	0.00*	0.27	65.79	0.00*	28.05
Haddock														
n=86	0.52	0.35	0.68	6.26	0.00*	1.04	0.70	1.38	6.06	0.00*	0.32	39.13	0.00*	20.45
Pollock														
n=395	1.16	1.41	1.80	16.33	0.00*	0.45	0.39	0.52	13.41	0.00*	0.31	179.86	0.00*	102.74

Figure 2.4a and b. Location of catches of cod and haddock that were reported by both the captain and the observer and those that were only reported by the observer. In both cases, the observed spatial range of the species is increased by including the catches that were not reported by the captain but did appear in the corresponding observer report.

a) Cod

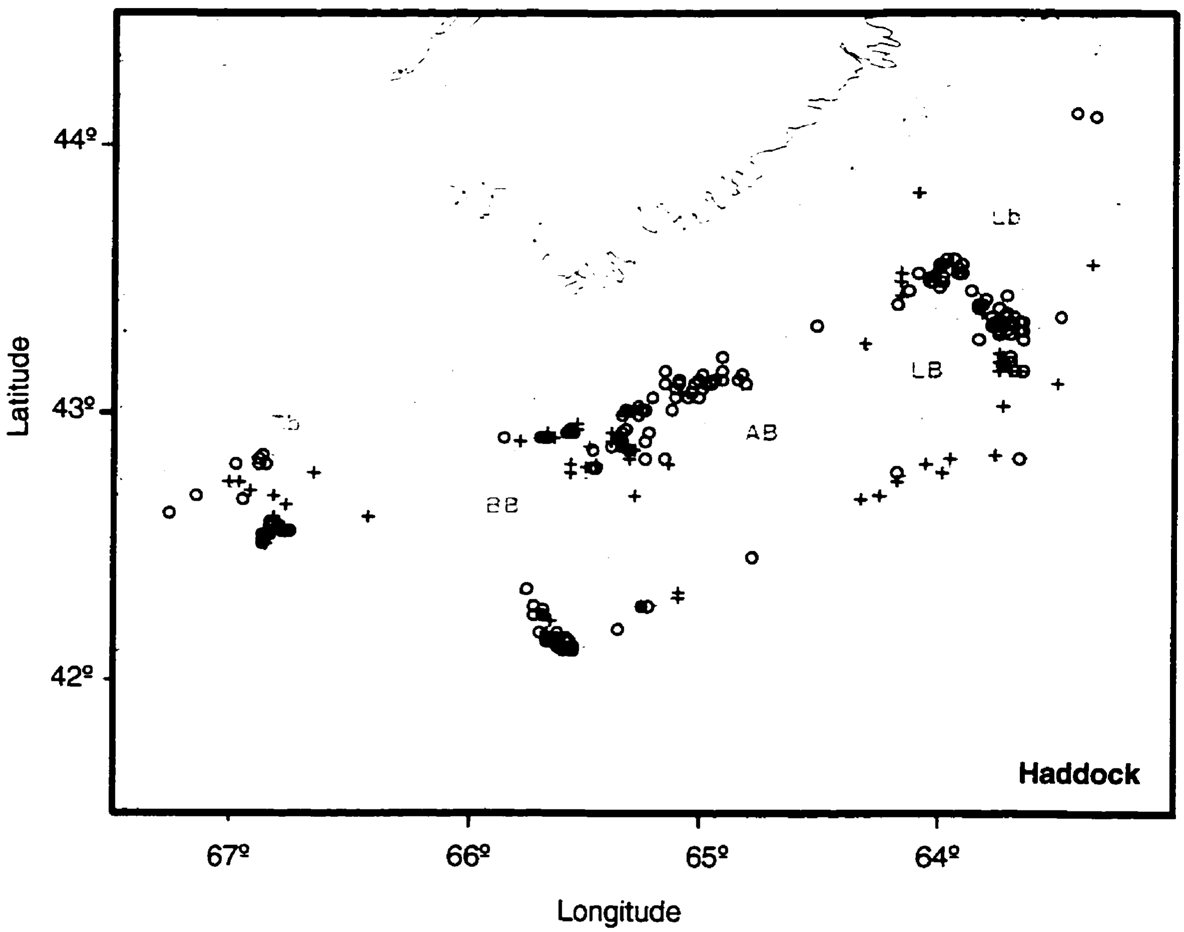


AB Baccaro Bank
BB Browns Bank
LB LaHave Bank
Lb LaHave Basin
Tb Tusket Basin

o Reported by observer only
\+ Reported by observer and captain

---------100 metres
_____200 metres

b) Haddock



AB Baccaro Bank
BB Browns Bank
LB LaHave Bank
Lb LaHave Basin
Tb Tusket Basin

o Reported by observer only
+ Reported by observer and captain

---------100 metres
_____ 200 metres

Figure 2.5. Linear regressions of captains' estimates on observers' estimates of catch for monitored trips.

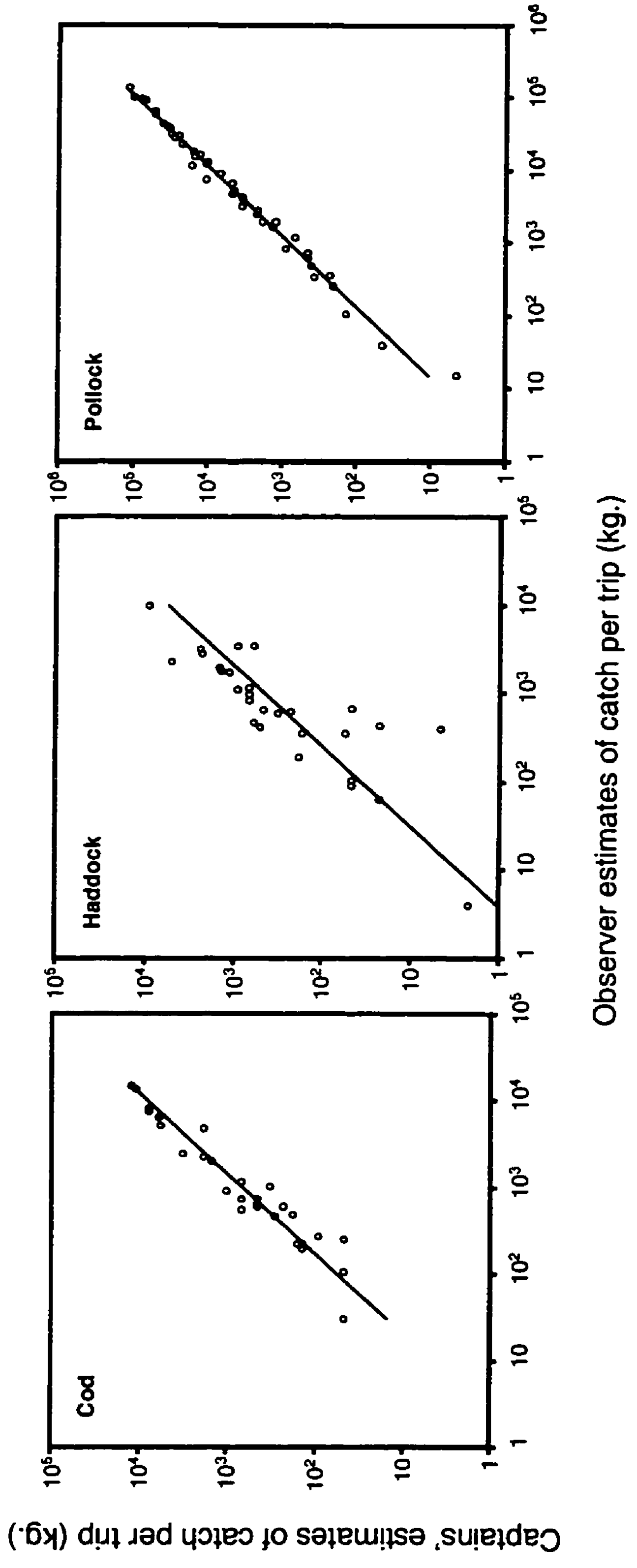

Cod
Haddock
Pollock
Observer estimates of catch per trip (kg.)
Captains' estimates of catch per trip (kg.)

Table 2.4. Results from linear regressions of logbooks on observer estimates of catch per trip for cod, haddock, and pollock. The data sets were highly correlated but the captains consistently underestimated catch. An asterisk beside the probability value indicates significance at $\alpha = 0.05$.

	slope					intercept								
	coeff.	lower 95% C.I.	upper 95% C.I.	*t-tests*	p	coeff.	lower 95% C.I.	upper 95% C.I.	*t-tests*	p	R^2	F	p	resid. sum of squares
Cod n=29	1.08	0.96	1.21	18.40	0.00*	-0.40	-0.80	-0.05	-2.31	0.03*	0.93	338.43	0.00*	1.19
Haddock n=28	1.09	0.81	1.38	7.94	0.00*	-0.61	-1.43	0.20	-1.55	0.13	0.71	63.00	0.00*	6.02
Pollock n=43	1.03	0.99	1.07	57.90	0.00*	-0.18	-0.32	-0.04	-2.67	0.01*	0.99	3351.90	0.00*	0.49

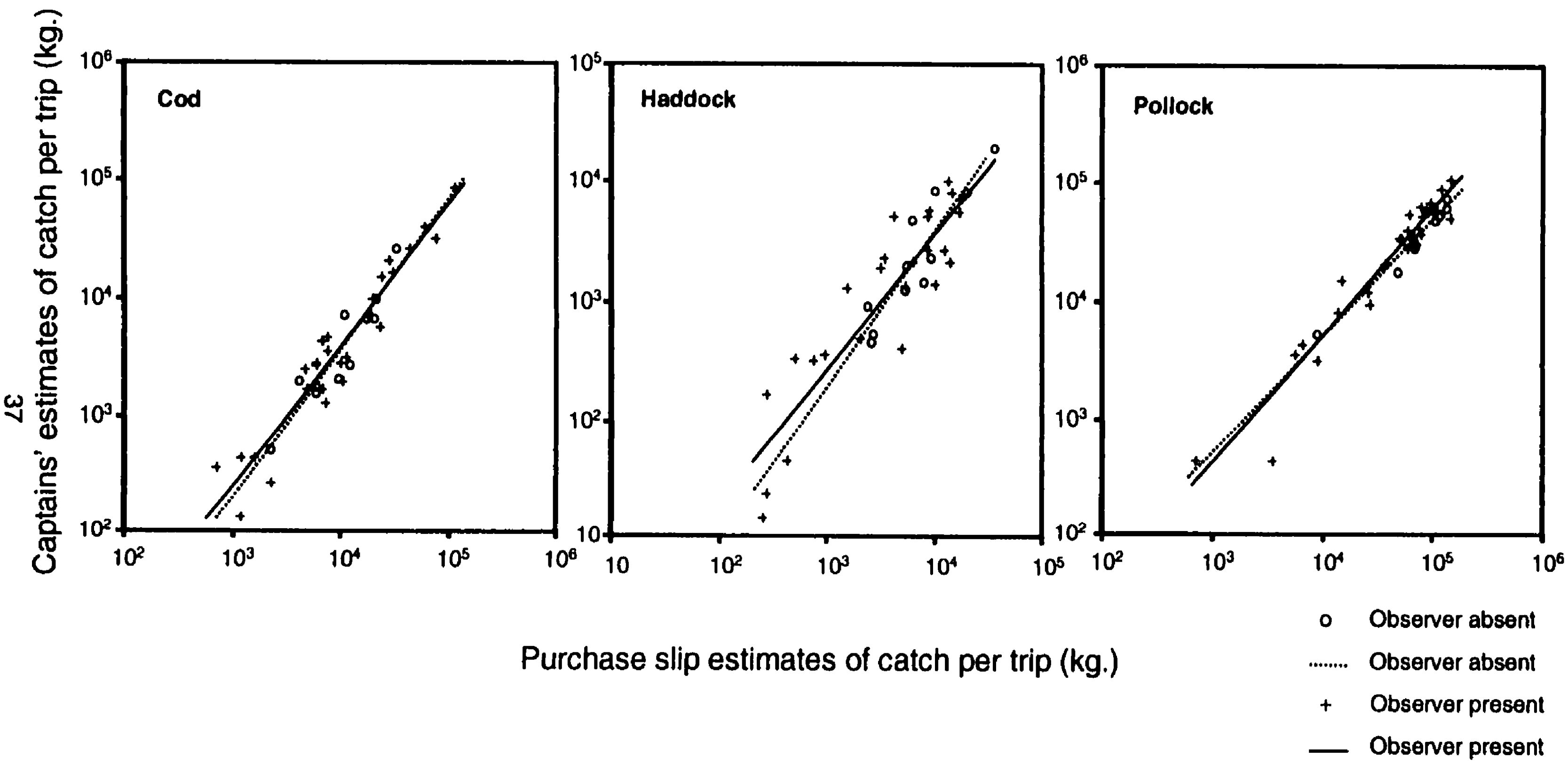
DISCUSSION

This study revealed that the perceptual differences in reporting between the observers and the fishers could be quantified. The methodology I described in this study for examining the logbook data employs other, more reliable sources of commercial data (the observer reports and the purchase slips). The advantage to using observer and purchase slip data over survey data for comparison purposes is that they are from the commercial fishery and therefore provide an accurate reflection of fishing patterns that would be seen in the logbooks. That is, they are collected from the same vessels as the logbook data, under the same regulatory regime and fishing conditions thus reducing the risk of confounding effects due to these variables.

I do not suggest that the relationships I found are representative of other fisheries. These relationships may change with regulatory regime, gear type, directed species, as well as other factors specific to the fishery examined. However, the methodology developed in this study can be applied to other fisheries when evaluating their logbooks. The systematic quantification of the patterns in the logbook data provides an objective evaluation of catch estimates, increasing the utility of the logbook data in the management of a fishery and in research.

The qualitative analyses generated the initial evidence that fishers and observers differed in their reporting. The tabulation of haul types made it apparent that observers were reporting more species than were the captains for

Figure 2.6. Multiple regressions of captains' estimates on purchase slip estimates comparing trips carrying an observer to those that were not. There was no significant change in the relationship between the two data sets due to the presence of an observer.



Captains' estimates of catch per trip (kg.)
Cod
Haddock
Pollock
10
10²
10³
10⁴
10⁵
10⁶
Purchase slip estimates of catch per trip (kg.)
o Observer absent
······· Observer absent
+ Observer present
—— Observer present

Table 2.5. Results of the multiple regressions of logbook estimates on purchase slip estimates of catch per trip. The presence of an observer did not have a significant effect on the relationship between the two data sources for any of the species. An asterisk beside the probability value indicates significance at $\alpha = 0.05$.

	n	R^2	parameter	coefficient	p
Cod	39	0.91	purchase slip	1.20	0.00*
			observer presence	0.02	0.62
			purchase slip * observer presence	0.05	0.33
			constant	-1.21	0.00*
Haddock	38	0.82	purchase slip	1.13	0.00*
			observer presence	0.01	0.87
			purchase slip * observer presence	0.08	0.28
			constant	-0.97	0.01*
Pollock	41	0.93	purchase slip	1.04	0.00*
			observer presence	0.04	0.32
			purchase slip * observer presence	0.06	0.15
			constant	-0.48	0.03*

the same catch. Hauls that contained pollock and small quantities of cod and haddock (according to the observers' reports) were frequently described as containing only pollock by captains. The distribution of logbook estimates of haul contents with corresponding non-zero estimates in the observer data also supported the hypothesis that there were unreported species in the captains' haul records. Figure 2.2 illustrated that the logbook data for cod and haddock are dichotomous with many estimates of zero representing unreported catches.

In their written reports, several observers noted that small catches of a species, ranging from 10 kilograms to 100 kilograms, often went unreported. Weights were often recorded in tons and so small quantities were omitted due to rounding. Also, some fishing companies had a policy allowing the crew to take home a certain amount of fish. In these instances the fish taken by the crew, typically haddock, were often not reported. Another explanation for unreported species is that captains might be including very small quantities of a species from one tow in the estimate of the following tow to simplify their record keeping. My analysis of the probability of a species being reported revealed that there is not a fixed minimum amount to be caught for a species to be reported. The amount of other species as well as which species are caught influences the reporting of fish.

The relationships between the quantities of cod, haddock, and pollock caught can be used to estimate the probability of a species being reported by a captain. This model does not address biases due to discarding of fish, but it does describe inaccuracies due to unreported catch. In my study the models for estimating the probability that a species will be reported differed between haddock and cod. Predictor variables will vary among, or even within, fisheries and so it is important to choose and test predictor variables appropriate for the fishery being studied.

I found that the probability of haddock being reported was positively correlated to the amount of cod and the amount of haddock caught. As the reported amount of pollock increased, the likelihood that catches of haddock were reported decreased. This result was not surprising since large amounts of pollock will obscure other species in the catch. By contrast, the probability of reporting haddock increased with the amount of haddock and cod caught. Cod and haddock habitat preferences are more similar to each other than to pollock's (Scott 1982) and so it is expected that when cod is caught, haddock will be as well. However, the effect of the amount of haddock caught has been statistically separated from cod abundance in this analysis by including it as a separate variable in the model. This pattern suggests that cod may have acted as an indicator of haddock in the catch. The crew may then have sorted the fish with the expectation of finding some haddock.

The probability of cod being reported is negatively correlated to the amount of pollock reported, which was the most abundant species in this fishery sector. As the amount of pollock documented increases, the probability that cod will be reported decreases. This is the same relationship observed for the reporting of haddock. The amount of haddock caught did not affect the reporting of cod. The reason that haddock did not act as an indicator for the presence of cod could stem from the relative proportions of these two species. Cod catches were greater and more frequent than haddock catches in 1993 and so an indicator for the presence of cod would not be required. However if the relative proportions of these fish were to change, this relationship may reverse. That is, if cod were to become more rare than haddock, haddock might act as a cue to the presence of cod.

The unreported catches of cod and haddock must be taken into account when analysing the logbook data to avoid biasing results. For example, if one were to prorate the logbook estimates for each haul based on the weights recorded in the purchase slip data, catches of cod and haddock would be omitted if the captain made no estimate, even when these fish were actually caught. This unreported amount would then be distributed among hauls where these species were reported, inflating the estimates for those haul positions. Though final landings would be the same, the distribution of the catch among hauls would be incorrect. Reported catches would be overestimated and unreported catches would be neglected. These catches of cod and haddock which captains tended not to report were small relative to the rest of the haul. Individually they may not seem important, however the effects are cumulative. Ignoring unreported catches would produce misleading results if logbook data were used in addressing certain research questions, particularly where the spatial distribution of catches becomes important such as the study of migration or of the geographic range of a stock.

The plots of the geographic location of hauls illustrated that unreported catches were frequent for both cod and haddock. The inclusion of unreported catches on the charts produces a geographically more extensive estimate of the fishery. MacCall (1990), Swain and Sinclair (1994), and Hutchings (1996) have demonstrated the importance of stock area in stock assessments. They noted that catchability could increase when stocks are declining due to a density-dependent reduction in stock area. This means there will not be a decrease in catch per unit effort when a stock begins to decline. A reduction in species or stock range can be an important cue in alerting a researcher to a dwindling population. Unreported catches should be considered for a more accurate representation of the range in which a particular species is caught.

Overall, I found that, despite differences in the perception of a haul by a typical captain and a typical observer, their two data sets were correlated. This correlation was strongest at the level of trip. The logbooks provide a valuable source of data however caution should be exercised in their use because captains tended to omit estimates of small catches. When the captains' estimates were aggregated by trip, these estimates were lower than the observers' estimates. This underestimation was slight and can be attributed, in part, to the captains' tendency to not report small catches of each species. As for the applicability of my results to unmonitored trips as well as monitored trips, I found no evidence of an observer effect on data collection practices when comparing the trip records from the logbooks to the sales slips. Almeida et al. (1988) and Richards and Fargo (1994) also found that, in a comparison of trips with observers to those without observers, there were no significant changes in catch. Because of the seemingly consistent biases in data collection methodology practised by captains, adjustment methods can be extended to include trips that did not carry an observer for a more accurate reflection of the fishery, but only with caution.

This chapter focused on inaccuracies in logbook data stemming from the captains' perceptions of hauls. It did not address the issues of discarding or variation in fishing strategies. However, both in the logbooks and in the observer reports, there were few estimates of discarding. In a cursory examination of the logbook data I compared the proportions of a species in the catch between monitored and unmonitored trips, but found no evidence of an observer effect on the landings composition. In the observers' narratives the discarding of cod, haddock, and pollock was not prevalent. This apparent lack of discarding may be due to effective targeting of species by captains, to the implementation of the mandatory landing provision, or to the presence of observers. The comparison of monitored and unmonitored trips provided no indication of observer effects on landings patterns. The following chapter provides a more in-depth analysis of observer effects and the possibility of unreported discarding and variation in fishing strategies in this fishery.

CHAPTER 3: OBSERVER EFFECTS ON THE DISTRIBUTION OF FISHING EFFORT, CATCH COMPOSITION, AND REMUNERATION OF THE CATCH

ABSTRACT

Observer programs in commercial fisheries collect data offering a comprehensive and detailed view of the fishing activities of observed vessels. However, the observers themselves may influence fishing practices and so their data may not be representative of the fishery in general. I examined fishing patterns evident in the logbook records from offshore commercial trawlers catching cod, haddock, and pollock on the Scotian Shelf for effects due to the presence of these observers. My data suggested that, in general, vessels tended to fish in different locations when monitored. These differences were both in geographic position and in depth of hauls. A change in depth, however, was not necessarily indicative of a change in geographic location. A categorical analysis revealed that this observer effect influenced catch content as well suggesting a change in discarding or targeting of species. Hauls containing pollock were more frequent and hauls containing cod were less frequent when an observer was on board. Unmonitored trips tended to produce a more valuable catch. There was no statistically significant observer effect on the price obtained for individual species.

INTRODUCTION

The International Observer Program (IOP) on Canada's East Coast is a valuable source of data from the commercial groundfish fishery. As part of their license conditions, large offshore groundfish trawlers must carry an IOP observer for the duration of the trip when assigned by the Canadian Department of Fisheries and Oceans (DFO). The IOP serves two functions: the collection of biological data and the enforcement of regulations (Kulka and Waldron 1983). The data these observers collect includes catch estimates and haul descriptions for every haul observed. Observers also sample the catch to gather biological data such as length and weight of individual fish, sex, age, and stage of maturity on species of interest. Although these data are collected only for a portion of the total fishery, much information about the fishery can be gained from the IOP, particularly if the data are also representative of unmonitored trips. Conclusions about a fishery on a broader scale can be made only if captains did not change their fishing behaviour while an observer was on board.

A fisher may change fishing practices while monitored because of the nature of the data collected by the observers. Observers are responsible for describing the catch but they must also describe fishing practices performed by the captain and crew, including any irregularities. Because the observer records when and where fish were caught, captains may change fishing patterns in order to conceal a favoured fishing location from an observer. Captains might also change behaviour while observed if they normally use irregular or illegal practices. I examined Logbook Program records of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and pollock (*Pollachius virens*) catches for evidence of changes in fishing patterns during monitored trips that I will refer to as an 'observer effect'.

A more valuable catch may be determined by which species and size of fish are landed. Of the three species I am studying, haddock commands the highest price and pollock is the least valuable. Larger size classes also command a higher price while very small fish are considered 'junk' and are used in meal or other processing. Market sized fish landed by the vessels in this study ranged from 21 to 63 cents per kilogram for cod, from 30 to 77 cents per kilogram for haddock, and from 15 to 41 cents per kilogram for pollock. Fish classified as junk, based on size and/or quality ranged from 1 to 11 cents per kilogram. Observers may affect the value of landed catch through their influence on targeting or high-grading. Both attempt to increase the proportion of more valuable species or size classes in a catch. Targeting refers to a change in fishing location, depth, or other aspect of gear deployment, to improve the probability that a particular type of fish will be caught. High-grading is the selective discarding of fish. In the year of my study (1993), high-grading of cod, haddock, and pollock was illegal. If discarding did occur, regulations provided an incentive to conceal it from observers.

Early in 1993, the mandatory landing provision was implemented. This regulation increased the motivation for fishers to target rather than high-grade by dictating that all cod, haddock, and pollock (as well as most other groundfish) were to be landed regardless of size. If fishers had complied with this regulation, then high-grading would not have occurred. Nevertheless, there was still a disincentive to land undersized fish. To keep landings of small fish to a minimum while not unduly penalising the fishers, the undersized catch could be sold for meal or other processing; the price obtained for these fish was much lower than for the market-sized fish. Also, if a large proportion of fish landed were undersized, the Department of Fisheries and Oceans' policy was to close that area to the fishery. Obviously it was to the fishers' advantage to land the least amount of small fish possible. This could have been accomplished by effectively targeting the larger fish or by surreptitiously discarding the undersized portion of the catch.

Cod, haddock, and pollock often co-occur, however, they do not mix uniformly by species or by size. There is segregation that would enable a fisher to target a specific catch. Scott (1982) found that during surveys of the Scotian Shelf, pollock generally occurred higher in the water column than did cod or haddock. Sinclair (1992) examined survey data and reported that cod segregated by age allowing for year-class targeting of older cod in colder, deeper water. In addition to seasonal shifts in distribution, Wigley and Serchuk (1992) found that older juvenile cod from the New England fishery tended to be in deeper water. Michalsen et al. (1996) reported that, during the day, there was a decrease in the proportion of smaller cod in bottom-trawl survey data. Engås and Soldal (1992) found the same pattern for both smaller cod and smaller haddock; they also noted that the proportion of haddock in the total catch was greater during daylight. Wigley and Serchuk (1992) found that cod distribution varied throughout a year and Wroblewski et al. (1995) reported seasonal changes in spatial distribution of pre-spawning and spawning cod which they suggested reflected migratory patterns. These studies have linked segregation in distribution by species and size classes to depth, temperature, time of day, and season, all of which illustrate that targeting is possible.

Fishing practices themselves can alter the catch composition. During research surveys, proportionately more large cod were caught when longer sweep lines (the cables that connect the trawl net to the trawl door) were used (Engås and Godø 1989). The authors suggested this was due to larger fish being more sensitive to herding effects caused by the trawl doors.

A captain with knowledge of these and other patterns of fish distribution could target a specific catch. Gabriel (1993) found evidence for targeting in the otter-trawl fisheries of the Mid-Atlantic Bight. The author reported a close correspondence between species sought by a captain and the catch composition in a haul, particularly for cod and summer flounder. This could be due to a change in the captains' expectation of species caught during a trip but it could also indicate that captains can alter the composition of landings by changing fishing tactics. Sinclair (1992) found that long-liners and trawlers concentrated fishing effort in areas characterised by different age-group assemblages, which suggests that targeting occurred.

Effective targeting could increase the proportion of valuable fish caught and reduce the incentive to discard fish. It would also save time required to sort the fish, as less or no culling would be necessary. If targeting rather than discarding is the dominant practice, fishing mortality estimates reported in landings data would be representative of the actual values.

Unreported discarding to high-grade a catch has long caused concern among fisheries scientists. It is difficult to quantify, though various techniques for doing so have been suggested (see Hillis 1981, Tallman 1991, McBride and Fotland 1996, and Allard and Chouinard 1997 for examples). Unreported portions of a catch result in an underestimation of fishing mortality that could lead to the depletion of a stock. Discarding has been documented in many fisheries. Angel et al. (1994) collected qualitative evidence of unreported discarding of cod, haddock, and pollock among other species on the Scotian Shelf by domestic and foreign fishers. Stevenson (1981, 1983) found significant discarding of undersized American plaice and Tallman (1991) also stated that discarding of this species was a serious problem. Kulka (1986) reported that the discarding rates of commercial and non-commercial species in Newfoundland increased from 1981 to 1985 and that, of the commercially important species, this increase was mostly due to the discarding of cod and haddock. He listed the capture of undersized fish, the capture of less desirable species, and catches that were too large to handle as the three major causes of discarding. Murawski (1993) found that discard rates on otter trawlers varied with year, area, month, and target species and that the rates for flounder were highest. Gillis et al. (1995a) modelled discarding behaviour based upon the actions of fishers in an Oregon trawl fishery and predicted that highest discard rates would occur when effort limits are high and quotas are low. Successful targeting of desired size classes or species results in a more desirable landed catch but so does high-grading and so the two practices are difficult to distinguish in data from commercial fisheries.

My study examines the logbooks and purchase slips from bottom trawlers catching cod, haddock, and pollock in NAFO division 4X in 1993 for evidence of observer effect on fishing activities, such as discarding and targeting. I examined the catch records for effects manifested in a change in fishing location, catch composition, and in catch value. I also attempted to discriminate between targeting and high-grading based on the data available.

METHODS AND MATERIALS

Data Sources

All data were obtained from the Marine Fish Division, Bedford Institute of Oceanography, Department of Fisheries and Oceans, in Dartmouth, Nova Scotia. As in Chapter 1, I selected records of catches of cod, haddock, and pollock made by large offshore bottom trawlers in NAFO division 4X in 1993. I restricted my analyses to vessels that had the same captain for all trips because I did not want a captain's personal preference of fishing location or catch composition to influence my comparisons within a single vessel. This resulted in the analysis of 41 trips made by 6 vessels. Records from the captains' logbooks, the purchase slips, and the observer reports were used for the subsequent analyses.

In the DFO's Logbook Program, each fishing vessel's captain must complete a log detailing each tow in a fishing trip as part of the fishing license conditions. Information collected includes the gear, time, location, and depth for each haul. Both the landed and discarded portions of the catch are listed with estimates of weight for each species. The purchase slips (also referred to as weighout or sales slips) are also collected by the DFO in their Logbook Program. Upon landing, the commercially important fishes (such as those in my study) are sorted and weighed according to species by the dockside monitor and/or the buyer's weighmaster to complete the purchase slip for that trip. The price obtained and the total landed value for each species is also recorded. These data are only recorded for an entire trip rather than for each haul. Unlike the logbooks, the quantity of discarded fish is not documented in the purchase slips; only the landed portion of the catch is reported.

Though I did not use data collected by observers for my analyses, I did use their records to identify trips where an observer was present. I identified corresponding trips in the logbooks by vessel number, position, date, and time to create a binomial variable distinguishing between the trips monitored by an observer and those that were not.

Analyses

I first examined the logbook data for evidence of an observer effect on fishing location. Latitude and longitude, and then depth were used in the analyses of the location of hauls. I also examined the data for evidence of an observer effect on the species composition in a haul and on the monetary value of total trip landings as well as individual species.

I performed statistical tests for data from the six vessels individually since the number of hauls was not evenly distributed among vessels. This precluded any one vessel that made many hauls in 1993 from dominating the analyses. In addition, captains may differ in their preference for fishing areas or catch composition due to personal experience. If one of these vessels were frequently monitored while the other was rarely monitored, an analysis including all vessels might detect these preferences and falsely give significant results. This pattern would not be the result of the observer effects that I was investigating.

I performed spatial analyses in the form of Mantel tests (Hubert 1985, Smouse et al. 1986, Manly 1991) to test for changes in geographic location. These tested the position of hauls as recorded by a vessel's captain in the logbook. A Mantel test is a randomisation test that examines the relationship between two distance matrices. Each distance matrix is an array measuring the degree of dissimilarity between objects. The first matrix measured the similarity of location based on plane sailing distances calculated from the latitude and longitude of hauls (Great Britain, Minister of Defence (Navy) 1960). The second matrix described the monitoring of trips, measuring the degree of dissimilarity between 'observer present' and 'observer absent' based on the binomial code previously assigned to hauls. If the haul geographic location matrix is completely unrelated to the observer matrix, the observed correlation would not appear different from 95% of the distribution of correlations obtained after randomising the observer matrix. The Mantel test involves this randomisation to create a null distribution of correlation to which the correlation measure from the original data is compared to test for significance.

I combined the probabilities from the six analyses in a meta-analysis. This is done by summing the natural logarithm of each of the six probabilities and multiplied this value by negative two. This value is compared to the chi-square (degrees of freedom are twice the number of probabilities) since if all the null hypotheses were true, this quantity would have a chi-square distribution (Sokal and Rohlf 1981). Implicitly, this procedure gives equal weight to the results of each vessel in the meta-analysis.

I was also interested in observer effects on the depth of hauls that may co-occur with a change in geographic position (latitude and longitude). I used Mann-Whitney U tests to examine the depth of hauls in the logbooks made by each of the six vessels and then combined the results in a meta-analysis in the same manner as for the Mantel tests.

If there is an observer effect on fishing location, one might expect to see a corresponding change in catch. Fisher's exact tests, using the algorithms of Pagano and Halvorsen (1981), were used on data from each of the six vessels to determine if there was an observer effect on catch composition as recorded in the logbook by the captain. I selected Fisher's exact test because there were frequent low counts for certain categories, making a chi-square inappropriate (Agresti 1996 p. 194). Observed and unobserved hauls were classified as belonging to one of seven categories according to their reported species contents in the logbooks: CHP, CH, CP, HP, C, H, or P where C=cod, H=haddock, and P=pollock. The Fisher's exact tests were performed on the resulting 7 x 2 contingency tables.

A change in catch would likely be reflected in the amount paid to the fisher for the landings. To test for a difference in value, I examined the monetary value of catch per trip as recorded in the purchase slips in two manners. First, I compared the value of total combined landings for cod, haddock, and pollock to indicate if captains obtained a more valuable catch when no observer was present. Second, I compared the price per kilogram for each of the three species between monitored and unmonitored trips. Here, an increase in price per unit would imply a more valuable catch based on the size classes of the species in the catch. I used paired *t*-tests to examine both the value of a trip and the price per kilogram obtained for individual species. For each vessel I selected two trips from the same time period, one monitored and one not. Each pair of trips had starting dates within a 32-day period except for one pair where the difference in starting dates was two months. The price per kilogram for each species obtained by the large offshore trawlers does not vary to the extent of that for the smaller, operator-owned vessels (J. Kane, Statistics Branch, Department of Fisheries and Oceans, Maritime Centre, 1505 Barrington St., Halifax, Nova Scotia, B3J 3K5, personal communication) and so the difference in time should not influence the results. These analyses were performed on the amount paid for landings per trip and the price per kilogram recorded in the purchase slips.

RESULTS

The spatial analyses revealed that some vessels fished in a different location when an observer was present (Table 3.1, Figure 3.1). The results were significant when the probabilities from the tests for six vessels were combined in a meta-analysis indicating the general trend was a change in position. The Mann-Whitney U tests revealed that 2 of 6 vessels changed fishing depth when an observer was on board (Table 3.1). This was not true for all vessels, however the meta-analysis indicated that this was also a general, statistically significant pattern. I contrasted the mean depths fished by vessels that showed a significant observer effect and found no consistent pattern. Some vessels fished at greater depths while monitored while others preferred a shallower location. Vessels that manifested a change in geographical location did not show a corresponding change in depth. This means that depth, which is statistically easier to analyse, cannot serve as an indicator of a change in location. When examining the distribution of effort, both depth and position should be considered.

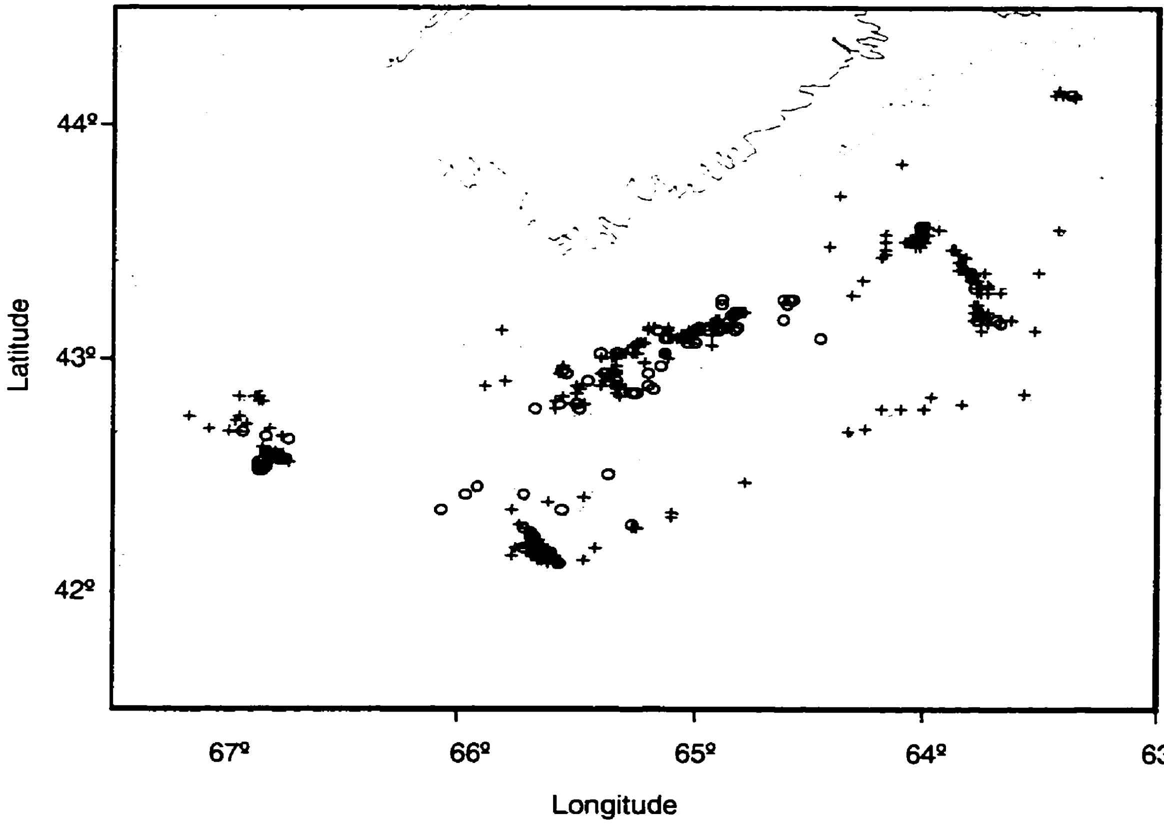
The Fisher's exact tests revealed there was an observer effect on catch composition (Table 3.1). Two main trends were seen: hauls that contained cod (C, CH, CP, and CHP) tended to be more frequent in trips that were not observed (Figure 3.2). Hauls containing pollock only (P) were always more numerous when an observer was present. Unlike the changes in fishing location, the observer effect on catch composition was evident for all six vessels.

The trip-wise analysis of the combined value of cod, haddock, and pollock landings revealed there was an observer effect on total monetary value of landings (Table 3.2, $n=6$, $p>0.03$). The total landings from trips that were monitored by an observer were less valuable than landings from trips that were not monitored.

Table 3.1. Comparisons of haul location and contents for the six vessels. Position represents the probability values from the Mantel tests. Depth represents the probability values from the Mann-Whitney U tests. The last line in the table represents the results from the meta-analysis as described by Sokal and Rohlf (1981). Catch composition represents the probability values from the Fisher's exact tests. There was an observer effect on position, depth, and catch composition. Vessels that changed position did not exhibit a corresponding change in depth. Significance at $\alpha = 0.05$ is indicated by an asterisk.

Vessel	n_{absent}	$n_{present}$	Position (p)	Depth (p)	Catch Composition (p)
1	10	54	0.136	0.011*	0.001*
2	73	187	0.270	0.140	0.006*
3	6	8	0.720	0.027*	0.479
4	5	16	0.001*	0.320	0.007*
5	6	12	0.059	0.203	0.017*
6	39	66	0.990	0.863	0.000*
all vessels			<0.050	<0.025	

Figure 3.1. Location of hauls from monitored and unmonitored trips. There is much overlap but some segregation is apparent. There are few unmonitored hauls in the areas north of LaHave basin, south of LaHave Bank and east of Tusket Basin. In general, hauls are concentrated in areas characterised by a steep slope. This could explain how a change in depth does not always result in a change in position.



AB Baccaro Bank
BB Browns Bank
LB LaHave Bank
Lb LaHave Basin
Tb Tusket Basin

o Observer absent
\+ Observer present
------ 100 metres
—— 200 metres

Figure 3.2. Classification of hauls when an observer was absent and when an observer was present for the six vessels. Hauls containing cod (CHP, CH, CP, and C) are more frequent and hauls containing only pollock (P) are less frequent when an observer is on board.

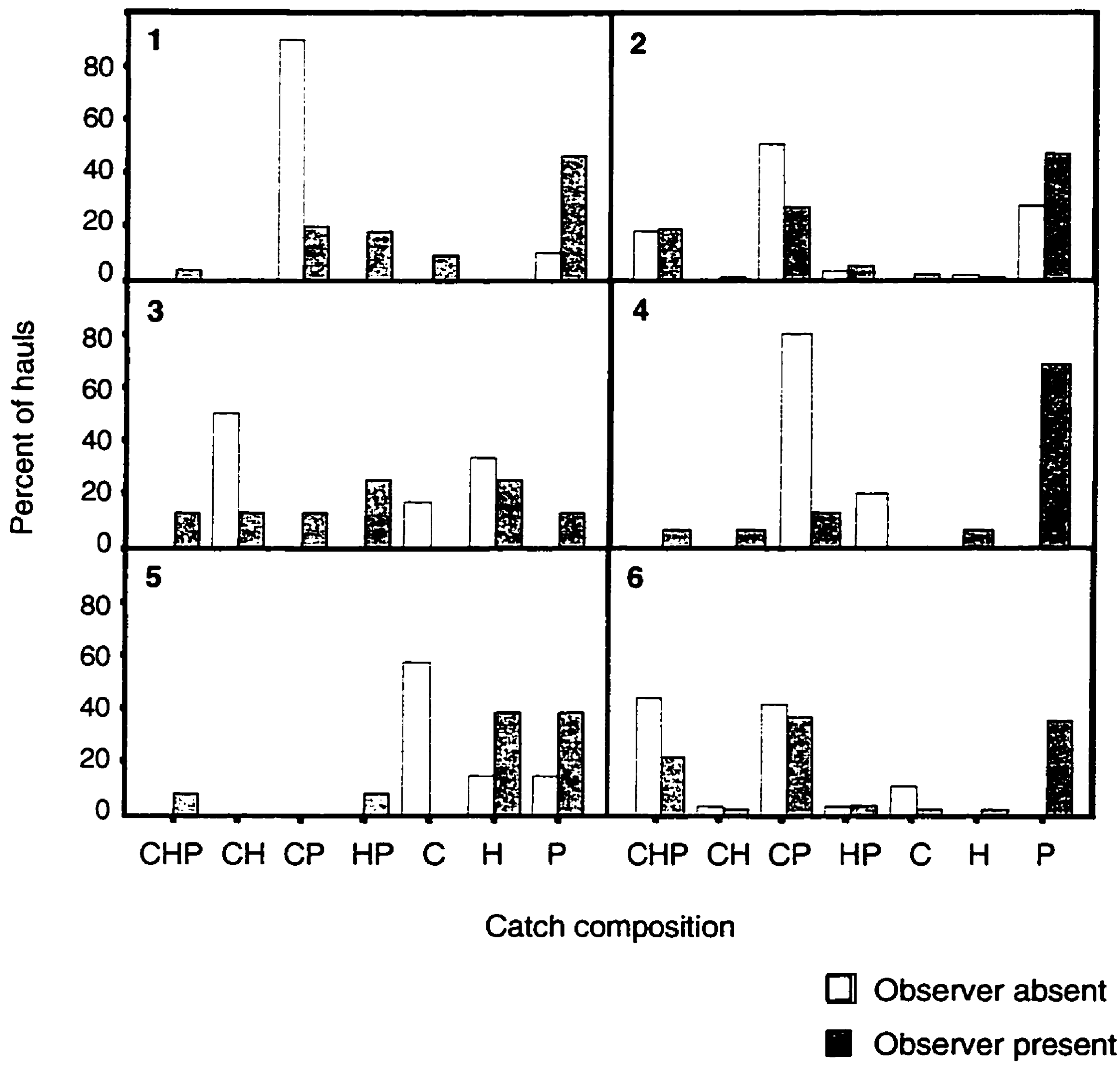

1
2
3
4
5
6
80
60
40
20
0
Percent of hauls
CHP CH CP HP C H P
CHP CH CP HP C H P
Catch composition
Observer absent
Observer present

Table 3.2. Results of paired *t*-tests on the monetary value of landings for the six vessels. Mean values are for total combined landings in a trip (sum of cod, haddock, and pollock) and the price per kilogram for each species from trips where an observer was present and those where one was not. Catches tended to be more valuable when no observer was present. However, this effect was only statistically significant for total combined landings. AN asterisk beside the probability value indicates significance at $\alpha = 0.05$. Power is indicated for non-significant results.

	Mean value		**p**	**power (%)**
	Observer absent	Observer present		
Value of landings ($)	42175.33	30336.73	0.023*	
Cod $/kg.	0.41	0.37	0.064	28
Haddock $/kg.	0.50	0.42	0.076	31
Pollock $/kg.	0.20	0.19	0.333	13

The analyses of price per kilogram obtained for each of the three species individually revealed no observer effect. Although there were differences in the prices obtained, these were not statistically significant (Table 3.2).

DISCUSSION

My examination of the logbook data revealed there were observer effects on haul locations, catch content, and on catch value. Though not all vessels changed their fishing location, the overall pattern supported the hypothesis of an observer effect. I also found that all vessels caught a different species mix when no observer was present. The value of total landings was greater with no observer on board.

The change in vessel location was indicated by a change in geographical position or by a change in depth. Vessels that fished in a different location when an observer was on board were not those that indicated a change in depth. A change in location that does not result in a change in depth can be easily explained. The bathymetry of the Scotian Shelf is variable and there are many geographically distinct areas that have the same bottom depth. However one would assume that a change in depth would indicate a change in position. This counterintuitive pattern can be better understood if the areas where fishing occurred are considered (Figure 3.1). Many of the hauls were made in areas characterised by a relatively steep incline such as the areas between LaHave Bank and LaHave Basin, north of Browns Bank and Baccaro Bank, near Tusket Basin, and along the outer edge of the Scotian Shelf. One could change location and fish at a position that is only slightly different geographically yet is quite different in depth. It is unfortunate that changes in geographic location were not accompanied by changes in depth since this means that depth alone cannot be used to test for changes in fishing patterns; geographical patterns must also be examined.

Further support for observer effects on fishing patterns was evident in the changes in catch composition. The most valuable fish in my study were haddock and the least valuable were pollock. Larger individuals of all three species commanded a higher price. If fishers were maximising the value of landings one would expect to see more frequent catches of the higher priced fish. If fishers are changing fishing behaviour when observed, and I have already demonstrated changes in fishing location, I would expect that this would also be reflected in the catch composition. I found that hauls from unmonitored trips contained cod more often and pollock less frequently than trips which were not monitored. No general pattern for haddock was revealed which may be due to the fact that haddock catches were relatively small and could only be landed as by-catch. It is unlikely that haddock was discarded because of its high value, even if discarding of other species took place.

The increase in value of combined landings supported the hypothesis that fishers changed behaviour when not observed, as did the analysis of catch composition. A similar trend was apparent on the price obtained for individual species. Cod obtained almost 4 cents more per kilogram, haddock obtained over 7 cents more, and pollock obtained 1 cent more when caught in the absence of an observer. This was suggestive of an observer effect as seen on the combined landings, but it was not statistically significant. The power of the *t*-tests to detect a difference in price was low (Table 3.2) and so it may be that there was an effect (particularly on cod and haddock) but that the tests were unable to detect it. The difference in combined value of trip landings could therefore be explained by the increase in catches of the more valuable species (as seen in the qualitative analysis of catch composition) and possibly by the increase in proportion of more valuable cod and haddock being landed.

I have examined catches in several manners, however the patterns revealed could be the result of changes in either discarding or in targeting practices; no one test I have presented can distinguish between these two phenomena. It is also possible that both tactics are practised simultaneously where a fisher targeted a preferred catch and then discarded the less desirable portion of that catch. I have found changes in fishing location (both in position and in depth associated with the presence of an observer). These changes in location are more consistent with the hypothesis of targeting than high-grading. The qualitative differences in catch composition could be due to either phenomenon.

The large offshore trawlers I studied have less incentive to discard because they are managed by enterprise allocations. This means that a company is given an annual quota for a particular stock and trip limits do not apply. The motive to discard fish increases as trip limits decrease. The absence of trip limits would reduce the pressure to high-grade the catch (Gillis et al. 1995a). However, the incentive to target more valuable fish, when practical, would still be present. The trends found did not allow the distinction between the two practices but they did strengthen the argument for targeting.

I also looked at the observers' narratives for evidence in support of either targeting or high-grading. Many observers documented targeting to obtain desirable species or to avoid undersized fish. Discarding of cod, haddock, and pollock was recorded, but not prevalent, in the observers' reports. Some observers stated that discarding was less of a problem in 1993 that it had been in the past. These reports, however, may not be representative of unmonitored trips.

A fisher could increase fishing income by better targeting regardless of observer presence. If the patterns I found are evidence of a change in targeting, one might ask why a fisher would not always target a more valuable catch. I suggest two possible factors that could influence this behaviour: captains may wish to conceal preferred fishing locations or captains may not be strictly complying with quotas. A captain may wish to conceal a consistently more lucrative fishing location. Observers are randomly assigned to vessels and so will work with several fishers throughout a year. Concealing preferred fishing locations from observers could reduce a perceived risk of other captains learning of them. It also is possible that captains may not strictly adhere to quota regulations. In NAFO division 4X in 1993 there was no directed fishery for haddock, though it could be landed as by-catch. A captain could target more haddock to increase the value of the catch and legally land these fish as by-catch. If this were the case, captains would be more likely to do this during unmonitored trips for fear of reprisal.

Fishers may also maximise the value of landings by increasing catch rates rather than value of fish, but I did not examine this factor. The large offshore trawlers I examined depend on large catches for a trip to be profitable. Smaller fish are generally more abundant and so catch rates are higher than for larger fish. Fishing where high abundances of smaller fish occur could increase the profitability of a trip by reducing the amount of time the vessel and its crew were at sea. There would be an incentive to target larger fish while monitored. The mandatory landing provision dictates that all cod, haddock, and pollock must be landed and so small fish cannot be legally culled. These small fish would devalue the landings and might induce the closure of that sector of the fishery if the proportion of undersized fish is large.

Overall I found evidence for an observer effect on fishing patterns but was not able to distinguish between targeting and discarding as the cause. The detail that the logbooks provide is a useful source of information on fishing activities but generalisations encompassing both monitored and unmonitored trips should be made with caution due to the presence of observer effects.

CHAPTER 4: GENERAL CONCLUSIONS

In this thesis, I have shown that fishers differ from trained observers in their estimation of haul contents and that fishing practices differ when an observer is aboard a vessel. A comparison of the catch estimates for cod, haddock, and pollock in logbooks to those in the observer reports revealed that the two data sources are correlated. They correspond closely at the level of trip but captains tend to slightly underestimate the catch. This indicates that the logbooks offer a fairly reliable description of the catch during trips monitored by an observer. The consistent underestimation of the captains could be corrected based on the correlation between the estimates of catch in the logbooks and the observer reports.

There was a tendency for captains not to report small quantities of both cod and haddock. The probability that a captain would report cod was negatively correlated to the amount of pollock reported by an observer and positively correlated to the amount cod reported by an observer. This suggests that as the proportion of cod in the total catch increases, so does the likelihood that a captain will see it and report it. The probability of haddock being reported is also negatively correlated to the amount of pollock in the catch and is positively correlated to the amounts of both cod and haddock caught. The positive correlation between the amount of cod and the chance that haddock would be reported was counterintuitive. One would expect that with higher catches of other species, there would be a decrease in the likelihood that haddock would be seen and reported. I have suggested that the relative abundances of these species may explain these patterns. Of the three species studied, haddock was caught in the smallest numbers in the fishery sector of this study. Cod and haddock are found in similar habitats, and so it could be that captains and crew are using that presence of cod as an indicator of the potential presence of haddock. If the relative abundances of these two species were to change, haddock might appear as an indicator of the presence of cod.

The unreported catches in logbooks become important when examining a fishery at the resolution of a haul. The effect of ignoring them would be an underestimate catch at those haul locations. This could put a stock at risk by underestimating fishing mortality in the local area, such as a single bank. Ignoring the unreported catches in this study would also result in an estimate of an observed species range that would be biased downward. The range of a stock is important because of its relationship with abundance. MacCall (1990), Swain and Sinclair (1994), and Hutchings (1996) have all noted that in certain fisheries, catch rate is not a good indicator of fish abundance and that the range of the stock can often act as a more sensitive indicator of abundance.

I also examined the logbooks for evidence of an effect associated with the presence of an observer on fishing patterns as manifested in the logbooks. Fishers changed their fishing position and the depth of hauls when they were monitored. There was also a qualitative difference in species composition in hauls; hauls containing cod were more frequent and hauls containing only pollock were less frequent when an observer was on board. An observer effect was also seen on the value of landings. Landings from unmonitored trips were more valuable and cod landed obtained a higher price per kilogram. These findings suggest that fishers are changing their fishing practices when monitored.

The logbook data can provide a reasonable depiction of the fishery, however, caution should be taken because of the sources of bias I have identified. The data collected by the captains when observers are on board are closely correlated to those in the observer reports. However, small catches of cod and haddock were often omitted from the logbook estimates of catch. Also, in the presence of observers, there was a demonstrable change in fishing activities. This change was apparent in haul location, catch composition, and catch value of the landings. It was not possible to determine if these observer effects were caused by discarding, targeting, or a combination of the two tactics with the available data. Further research to distinguish between discarding and targeting would enhance the usefulness of the logbooks in research and increase the body of knowledge needed to make informed management decisions.

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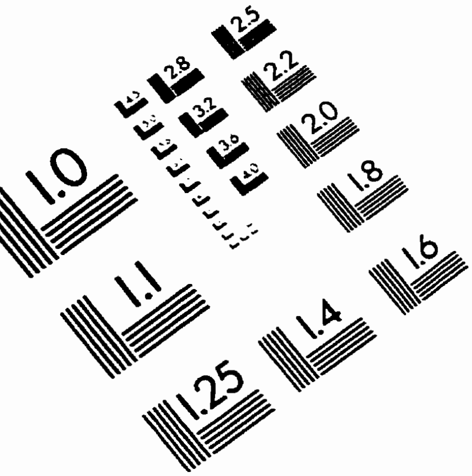
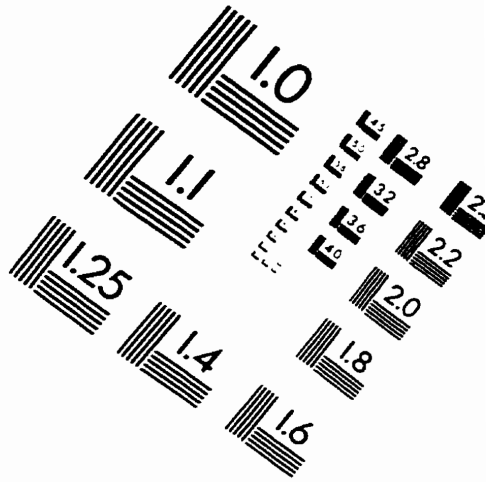
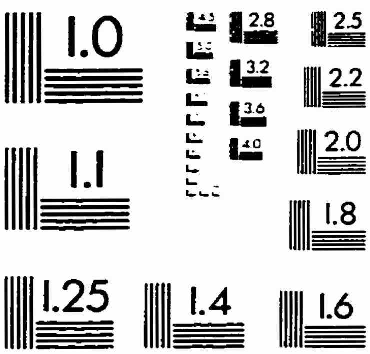
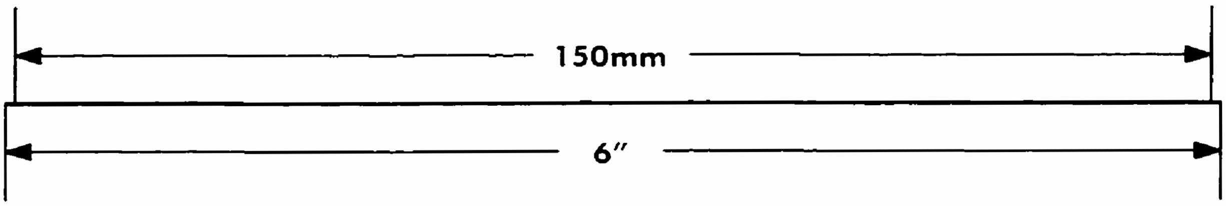
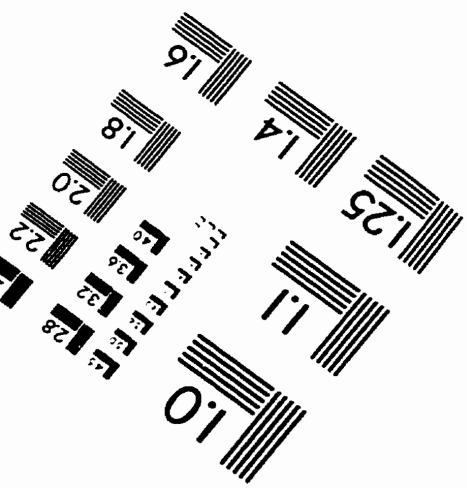
IMAGE EVALUATION TEST TARGET (QA-3)

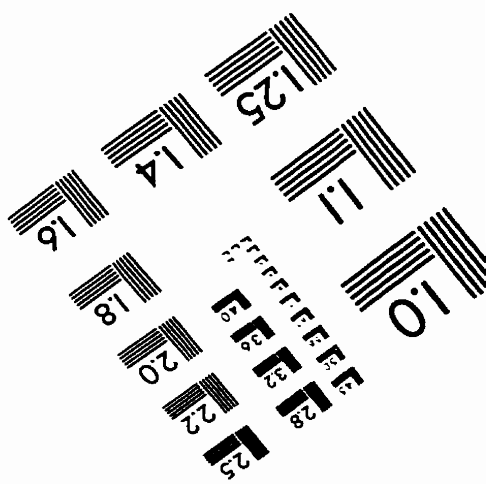












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