HERRING FISHERMEN AND BIOLOGISTS: THEIR ROLES IN STOCK ASSESSMENT

Herring Workshop
Held at the Gulf Fisheries Centre in
Moncton, New Brunswick
February 25-26, 1987

E.M.P. Chadwick, Editor

Marine and Anadromous Fish Division
Science Branch, Gulf Region
Department of Fisheries and Oceans
P.O. Box 5030, Moncton, N.B. E1C 9B6

February 1988

Canadian Industry Report of Fisheries and Acquatic Sciences No. 183

Canada

Canadian Industry Report of Fisheries and Aquatic Sciences

Industry reports contain the results of research and development useful to industry for either immediate or future application. They are directed primarily toward individuals in the primary and secondary sectors of the fishing and marine industries. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Industry reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-91 in this series were issued as Project Reports of the Industrial Development Branch, Technical Reports of the Industrial Development Branch, and Technical Reports of the Fisherman's Service Branch. Numbers 92 110 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Industry Reports. The current series name was changed with report number 111.

Industry reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport canadien à l'industrie sur les sciences halieutiques et aquatiques

Les rapports à l'industrie contiennent les résultats des activités de recherche et de développement qui peuvent être utiles à l'industrie pour des applications immédiates ou futures. Ils sont surtout destinés aux membres des secteurs primaire et secondaire de l'industrie des pêches et de la mer. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports à l'industrie peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports à l'industrie sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 91 de cette série ont été publiés à titre de rapports sur les travaux de la Direction du développement industriel, de rapports techniques de la Direction du développement industriel, et de rapports techniques de la Direction des services aux pêcheurs. Les numéros 92 à 110 sont parus à titre de rapports à l'industrie du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 111.

Les rapports à l'industrie sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Industry Report of
Fisheries and Aquatic Sciences 183

February 1988

HERRING FISHERMEN AND BIOLOGISTS: THEIR ROLES IN STOCK ASSESSMENT

Herring Workshop
Held at the Gulf Fisheries Centre in Moncton, New Brunswick
February 25-26, 1987

by

E.M.P. Chadwick, Editor

Marine and Anadromous Fish Division
Science Branch, Gulf Region
Department of Fisheries and Oceans
P.O. Box 5030, Moncton, NB E1C 9B6

Cat. No. Fs97-14/183E ISSN 0704-3694

Correct citation for this publication:

Chadwick, E.M.P. 1988. Herring Fishermen and Biologists: Their Roles in Stock Assessment. Can. Ind. Rep. Fish. Aquat. Sci. 183: viii + 131 p.

CONTENTS

ABSTRACT

Chadwick, E.M.P. 1988. Herring Fishermen and Biologists: Their Roles in Stock Assessment. Can. Ind. Rep. Fish. Aquat. Sci. 183: viii + 131 p.

In February 1987, a workshop was held with representatives from the herring fishery in southern Gulf of St. Lawrence (NAFO Division 4T) and herring biologists from Gulf, Scotia-Fundy, Newfoundland, Pacific, and Ottawa regions. The objective of the workshop was to review the basic ingredients of a stock assessment and to explore ways that industry could contribute to the annual stock assessment of 4T herring.

RÉSUMÉ

Chadwick, E.M.P. 1988. Pêcheurs de hareng et biologistes: leurs rôles dans l'évaluation des stocks. Rapp. can. ind. sci. halieut. aquat. 183: viii + 144 p.

En février 1987, il y eut un atelier sur le hareng regroupant des représentants de l'industrie du hareng du sud du Golfe du Saint-Laurent et des biologistes du hareng des régions du Golfe, de Scotia-Fundy, de Terre-Neuve, du Pacifique et d'Ottawa. L'atelier avait pour but d'examiner les éléments de base requis dans l'évaluation d'un stock et d'identifier de quelles façons l'industrie pourrait contribuer à l'évaluation annuelle du hareng 4T.

1. INTRODUCTION

Denis Rivard, Chairman
Fisheries and Biological Sciences Directorate
Fisheries Research Branch
200 Kent Street
Ottawa, Ontario
Canada K1A 0E6

The objective of this workshop is to bring fishermen, the industry and biologists together to discuss how they can collectively and cooperatively generate the data essential for a good stock assessment. This workshop was originally proposed by Mr. Peter Dysart, from the New Brunswick Fish Packers Association. The workshop was jointly planned by the New Brunswick Fish Packers Association, the Prince Edward Island Fishermen Asociation, the Maritimes Fisheries Union and the Department of Fisheries and Oceans, Gulf Region. It must be clear that the workshop is not being held to review past assessments, nor to conduct one for 1987 or thereafter. Rather, this workshop is an attempt to bring all sides of a very controversial fishery together to facilitate understanding of the components of the 4T assessment, will promote a better appreciation of the biological assessment and will perhaps forge a cooperative approach to data collection.

The agenda is structured according to the two basic components of a stock assessment. The first component is the analysis of research data that lead to the estimation of the current stock size or stock conditions. The presentations and the discussions will focus on the basic ingredients of an assessment, including stock identity, catch data, sampling data, and abundance indices. The second component is a forecast of stock size and of catch levels for upcoming years. The presentations will also include an outline of the management of herring on the Canadian Pacific Coast, as well as an overview of a cooperative project in the Bay of Fundy. The last session of the workshop will take the form of an open discussion on future cooperation. We are looking for well defined ways by which fishermen can contribute their knowledge to stock assessments.

I trust that this workshop will contribute to a better understanding of a number of technical aspects of biological assessments, will serve to reiterate the importance of a sound data base, and will provide a number of useful recommendations for future cooperation.

2. ESTIMATE OF POPULATION SIZE

How many herring are in the Gulf of St. Lawrence is the foremost question in the minds of fishermen and biologist. In this section, it will be seen that an understanding of stock identity is an important first step. Next we deal with the landings and sampling that is necessary to calculate the ages of all herring caught in the Gulf of St. Lawrence. This part is followed by presentations on six types of abundance index. The final part on virtual population analysis shows us how the abundance index can be used to estimate the proportion of catch to total population size.

Please note that after each presentation there is a summary of questions and comments raised during the workshop.

2.1 HERRING STOCKS - ARE THEY REAL?

Derrick Iles
Science Branch
Scotia-Fundy Region
Biological Station
St. Andrews, N.B.

There are two kinds of fishes, the cartilaginous fishes, the sharks, skates and rays, and the bony fishes, called "teleosts" by fisheries biologists. It is the teleosts that make up most of the worlds fish catch. The herring-like fishes are bony, teleost fishes, and there are about 360 different kinds of them, almost one for each day of the year. Even so they make up only a small fraction of the teleosts that as a whole, inlcude about 30,000 different kinds or species. On the other hand, the herring-like fishes have been around a lot longer than most bony fishes, and are thought to be about 150 million years old; the only older bony fishes are the eels! When it is realized that the Atlantic ocean is itself only a bit more than 100 million years old, and that as recently as 15,000 years ago this part of the world, including where we now catch herring, was under ice cover, it is not surprising that herring have learned a thing or two that we are still trying to work out!

Herring are found also in the Pacific and in the Arctic, but this is a different kind of herring with another name, and considered to be a different species. It is now believed by some that when the Atlantic ocean began to open up from the huge land mass that included what is now Europe, Africa, and North and South America, the herring-like fishes were the first to take advantage of the new opportunities for aquatic animals.

Herring feed on plankton for the whole of their life history, and are thus able to tap the most abundant food resource in the oceans, which accounts for their large numbers, and for the fact that they support such large fisheries. Herring are important prey for larger fishes, which pass on the production in forms that we exploit. It is not surprising that herring became the basis for the earliest large scale fisheries undertaken by man.

These historical fisheries have been talked about or documented for well over a thousand years, and were so important economically that whole countries and civilizations developed and became dependent on them. The Hanseatic League was the dominant economic power in Europe in the 12th and 13th centuries and this power was founded on herring. The "hanse" towns, which included Hamburg and Lubec, protected this power by stringent regulations on every detail of the fishery and the marketing of its products. The town of Lubec in what is now Germany, and which has a "sister" town in our part of the world, had its own executioner who enforced the licensing and reporting regulations at the end of a rope! Heaven help you if you did not fill in your log-book! There are many people in the

Canadian industry who think that things have not improved much since! On the other hand there are some managers who look back on the "good old days" with regret and longing!

In North America the indigenous weir fishery for small herring predated colonization, but the earliest settlers on the continent also relied on the herring for food and trade. In this particular part of the world, eastern Canada, it is still important overall and crucial to the well being of many communities. This brings me to my first point, that fishermen have had a much more direct involvement with herring over a much longer period of time than have fisheries biologists. They have been earning a living from them, and have been able to do so only because they have learned so much about them. It has been said that the average herring is smarter than the average fisheries biologist - and is almost as smart as the average fisherman!

One main reason for the existence of large herring fisheries is that to the fishermen, herring was so predictable. One could go to the same place at the same time every year and find the herring there, almost to the day and the mile, even in the open sea. Inshore herring fisheries were even more predictable, which accounts for the existence of the New Brunswick "sardine" industry, at one time the most important industry in the area. It is this predictability and regularity in the behaviour of herring that is recognized by both fishermen and scientists, or most of them at least, as demonstrating that there are "different kinds of herring". We refer to these as "stocks", and it is the identification and separation of the different stocks of herring that is the real (herring) problem for the herring biologist - he dreams that he can solve the stock problem in his area and has nightmares that this will turn out to be impossible!

To give some indication of the nature of this problem it is necessary only to list names of some of the best known stocks. For example the East Anglian herring, the Norwegian herring, Grand Manan, Georges Bank, Minas Basin, Magdalene Island, Icelandic Spring, Icelandic Summer, Whitby, Dogger Bank, Buchan herring, Isle of Man herring, Zuider Zee, Clyde, Faroes - the list could go on and on and would contain at least a hundred names and possibly two hundred, if we took into account both sides of the Atlantic. Each "stock" has its own particular spawning area and spawns at its own particular time of year; the problem is that they all look very much alike, all are obviously herring and differ only in minor ways.

To complicate the problem herring are great wanderers; outside the spawning period they migrate apparently in all directions and are known to mix while feeding or overwintering. This became obvious when biologists first began to put "tags" on them, for then individuals could be recognized uniquely by this artificial label put on by the biologist; untagged fish only too often looked the same as any other herring!

Why was this so important? There is a song which maintains that only God can make a tree, and it is equally true that only a herring can make a herring. This question is whether only a Magdalene Island herring can make another Magdalene Island herring. If this is so, the proper management of herring has to be based on the protection of individual "stocks" identified at the spawning ground and period, and then followed and given equivalent protection wherever they may wander thereafter.

To bring this point home we can look at the stock picture for the west Atlantic, which happens to be taken from a report that was prepared as the biological basis for the very first agreement on quotas for herring, made at ICNAF (International Commission for Northwest Atlantic Fisheries) in 1972. It can be pointed out that this agreement, which involved Canada, the United States and the foreign countries that were exploiting herring off our east coast, was considered to be absolutely essential by Canadian industry and was a necessary part of the process that led to the establishment of the Canadian 200 mile management zone. At that time management was not a dirty word!

This example is important because it illustrates the way in which the stock question becomes a vital practical one. ICNAF was the only organization with the authority to agree to management measures, and although the convention area covered the whole of the northwest Atlantic north of Cape Cod, this was subdivided into smaller areas, as it was completely impractical to apply catch regulations to the whole convention area. This would make as much sense as having a Total Allowable Catch (TAC) for the whole of eastern Canada!

While Canada and the U.S.A. both wanted the foreigners out in the long term, in the early 1970's we were both bound by the rules set out in the ICNAF Treaty and would be until such time as we achieved exclusive management rights for ourselves. For Canada the position was more complicated because we had recently declared the Bay of Fundy and the Gulf of St. Lawrence areas to be exclusively for the use of Canadian fishermen. This creation of "exclusive fishing zones" was part of our general policy to gain management control of the whole 200 mile zone, but there was no certainty that it would be accepted internationally, particularly if it conflicted with the management mandate of ICNAF.

There was a way out as far as the Gulf herring were concerned, for if we could show that certain herring stocks were confined to these areas of obvious Canadian "content" we could maintain that they could safely be left to us to manage. This would be all the more acceptable for fisheries in which we were the only participants, as was the case for the Gulf of St. Lawrence stocks and those of Newfoundland.

As the result of a lot of hard work and thought on the part of the relatively small group of herring scientists that were available in the late 1960's and early 1970's in eastern Canada, this was achieved. It was shown that there was little movement of herring caught within the Gulf into areas accessible to the foreign fleet. Tagging experiments and other studies proved that herring migrated along distances from the Gulf in the fall and winter, but this movement was towards the Newfoundland coast and was mainly well within the 12 mile "territorial sea" zone we had already established.

However this still left the Scotian Shelf, the Bay of Fundy including the big fishery off southwest Nova Scotia, and the Gulf of Maine and Georges Bank. Outside Canada's 12 mile limit, all of these areas were infested by foreign herring fishermen! If we wanted to persuade them to leave the herring to us it was necessary to show that they were, indeed, our herring, that the fish they were catching offshore belonged to the same "stocks" as those we were exploiting.

To put all this into its proper perspective it must be appreciated that only Canada and the U.S.A. were really interested in preserving the fish in the ICNAF area, and that all of the initiatives for "conservation" came from Canada and the U.S.A. The scientists of the other countries co-operated in getting at the scientific facts, and played a vital part in supporting the management case but it was up to the "coastal states" to initiate the proposals at the political level and to organize their debate and acceptance at ICNAF at the management level.

The major problem was to demonstrate that management was feasible within the administrative context of the treaty that had established ICNAF in the first place. Some countries would have been glad to have an excuse not to accept management controls even though it was difficult for them to deny that management was a good thing and highly desirable - after all ICNAF was set up to achieve management; they would not wish to appear greedy and irresponsible.

From the outcome, it was possible to demonstrate that each of the three administrative areas of ICNAF that were being considered contained a single major herring stock. This meant that three separate proposals could be put forward; one for each area. It is important to appreciate that the key biological issue that was both appreciated and indeed insisted upon at the "management" level was that the stocks were "reproductively isolated". This implied that if one stock was overfished, would it not be replaced by others, which is what was meant by "reproductive isolation". On a more practical level, this meant that IF agreement on the way that each TAC was shared by the competing countries was reached, and IF the scientific work on which the TAC was based was sound, and IF there was no cheating in the reporting of catches, a countries share was "money in the bank"! Within the overall TAC, ownership of the individual allocation was assured, and each country could make its own plans as to how it would make the most of its share.

Fortunately, the members of ICNAF, who made up a pretty mixed bunch politically with less in common than say a seiner skipper and a gill-netter in the Gulf, did finally agree in January 1972 on TAC's and allocations for each of the major stocks. The three stocks (Figure 1) were those spawning off southwest Nova Scotia (A in Figure 1) and, on Georges Bank (C), in the inshore Gulf of Maine (B). In addition, regulations were introduced to control the Canadian and U.S.A. inshore fisheries for juveniles, while conceding that these inshore "sardine" fisheries of Maine and New Brunswick would then be our own business. In return we promised to follow accepted management guidelines and to report all of our catches in the inshore region.

This agreement for herring at ICNAF was the first of its kind for any fishery anywhere in the world but it was quickly followed by agreement for virtually all the stocks for all species in the whole of the ICNAF area.

The question arises, however, whether the assumptions about the separateness and integrity of the different herring stocks made at that rather special time were justified, and whether the principles involved could be applied more generally.

It can be claimed that at least as far as this part of the world is concerned there is not much doubt. Figure 2 shows a map of the area with circles indicating how far herring tagged by Canadian scientists were found to travel. As can be seen, the average distance travelled by herring that were at large for any reasonable length of time is far greater than the distance between the spawning grounds in the Gulf of Maine and adjacent parts. Figure 3 shows the subsequent history of two of the largest stocks, the Georges Bank stock and the Nova Scotia stock.

The Nova Scotia stock was under relatively strict Canadian control from 1972 onwards. In early 1972, Canada set up the "Atlantic Herring Management Committee" which was a forum at which the provincial governments and industry could interact directly in all management matters. This committee regularly reviewed all relevent information and proposals, and was largely responsible for the general acceptance of the need for management within the Canadian herring industry, and to a degree that is unique anywhere in the world. While there was considerable argument about "internal management", that the resource needed protection from uncontrolled fishing effort as much after as before Canada had taken over responsibility, the extension of jurisdiction was never in question.

The other stock was subject to international regulation but it proved to be too little too late, and in addition the regulations were themselves difficult to enforce. There is no prize for guessing which is which in the figure, but it can be claimed, and quite legitimately, that the Canadian management of the last 15 years has been worth many hundreds of millions of dollars to the Canadian economy, and has saved a whole lot of public money and provided a lot of employment. And as far as the reality of stocks is concerned, if they are not really "separate", then the vacant Georges Bank spawning area, which was the biggest in the eastern Atlantic, would surely have been colonized by one or other of the many other spawning groups in the immediate area.

The reality of herring stocks has recently been challenged by foreign scientists on the grounds that certain kinds of genetic evidence does not show the differences that might be expected from classical genetic theory. It is true that in many, indeed most cases, obvious physical differences that can be easily described and can be applied under any circumstances at any place and any time of year are difficult or impossible to find. But the real question to be answered is whether what we see as "stocks" behave differently in the crucial way of reproducing "their own kind" in "their own place" and up to now the evidence for this is pretty solid. It is also precisely the sort of evidence that has been the good herring fisherman's stock in trade for hundreds of years.

This does not mean that we have all the answers, but it does indicate that the same set of accurate facts can carry the same weight for both the scientist and the fisherman if there is an opportunity to discuss the evidence frankly and in a reasonably objective atmosphere. One thing is worth stating, and that is that both fisherman and scientist earns his living from the same animal and needs to know as much about it as possible. Under these circumstances it is not very sensible, surely, to completely ignore what the other is saying!

2.1.1 Questions and Comments

Question:

Has the maintenance of herring yields from the Bay of Fundy stocks, in contrast to the crash in yields from the Georges Bank stock, been a result of good fortune, or the consequence of management quotas?

Response:

Initially the Fundy stocks were fished less intensively because of their inshore nature. Quotas were introduced at the time of the start of the decline of the Georges Bank fishery, preventing excessive effort on the Fundy stocks. Of note is that despite the close proximity of the two stocks, and the continued relatively high levels of the Fundy stock, it has not led to a recovery of the Georges Bank stock by cross-over from one area to the other. This is also found elsewhere, e.g., the Whitby herring population in the North Sea, maintained its population levels while the more easily fished Dogger Bank population 60 miles away, was fished-out.

Response:

The Magdalene herring stock, which collapsed in the 1970's offers another example of a herring stock which crashed while nearby populations were able to maintain their stock sizes, and no apparent "cross-over" occurred.

Question:

Must quotas be stock specific for efficient utilization of the resource?

Response:

Generally yes, but historical reasons made it essential that global quotas be adopted; further, these had been effective in preventing stock collapse. Management using stock-by-stock quotas would have failed. This may not be the situation today.

Question:

Do local stocks show homing tendencies? In a tagging study of 4,000 gaspereau in which 400 fish were recaptured, only 2 were caught from a different water shed, doesn't this example indicate that management must be on a stock basis.

Response:

Herring have good knowledge of where they are with respect to season, time of day, etc., and also have good directional sense.

Comment:

There are at least two herring stocks in the Gulf and such management may require further stock separation studies.

Comment:

Different stocks may vary enormously in size from a few hundred tons (Minas Basin) to more than 10 million tons (Icelandic-Norwegian stocks). There may be large differences in scale of migrations which are undertaken; some move hardly at all, others move large distances.

Comment:

Newfoundland studies found more than 75% of tag returns were from the same area.

Comment:

In B.C. a large percentage of tagged herring returned to the same grounds on which they were tagged.

Comment:

CAFSAC documents had not indicated support for management on a stock basis.

Comment:

Though stocks may be separated at some times, at other times, when a fishery is occurring, they are all mixed together, it then becomes very difficult to manage.

Comment:

Noted that fishing of mixed stocks may be done by seiners, fishing in different areas.

Question:

Given the separateness of stocks, what would be the required level of effort, type of gear, etc., that should be used in their explotation?

Response:

It is more a question of the quantity of resource removed than the type of gear that is used.

Comment:

How do the mesh size, depth, amount of net, etc. contribute to providing adequate escapement?

Comment:

A benefit of gillnets is that they are selective and do not catch small fish.

Fig. 1: 1972 herring management units as depicted in the ICNAF Herring Working Group Report (Redbook, Part 1, 1972, p. 62, Fig. 1): "Herring stock structure in the ICNAF Area (double lines indicate stock boundaries and the solid black areas indicate the general spawning grounds)." Note the dashed lines isolating 4Wa and 4Xb.

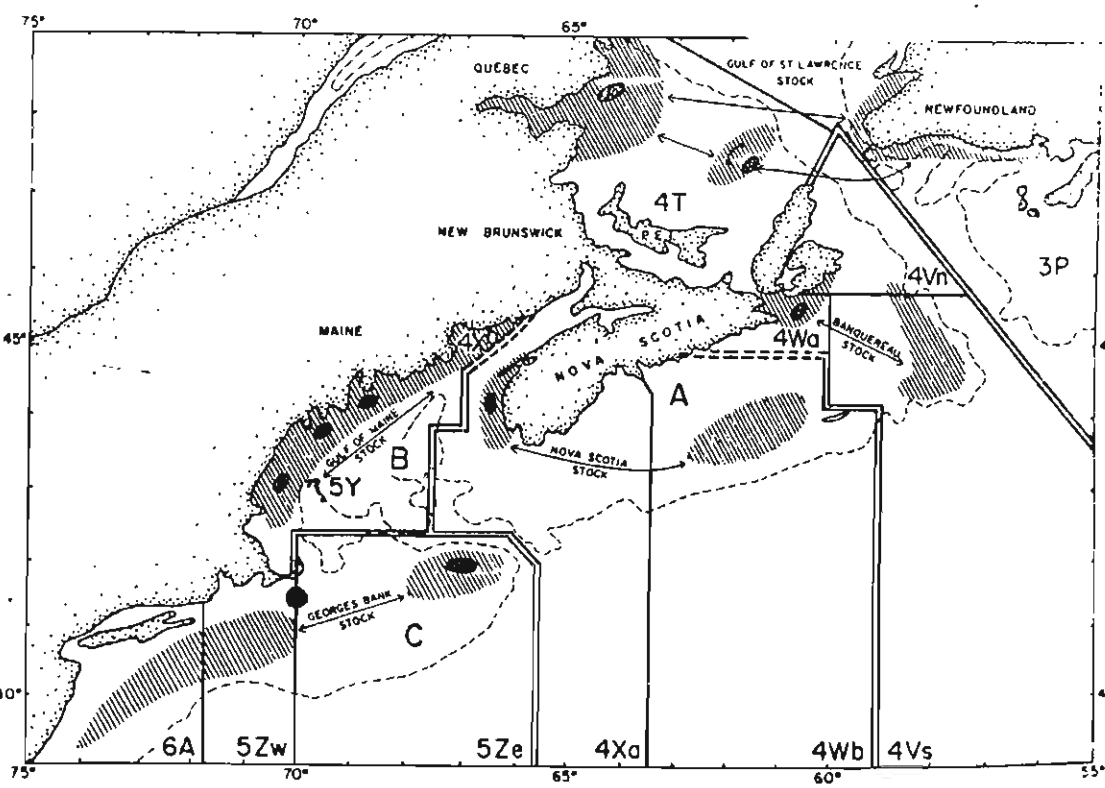


Fig. 2: Spawning grounds of Gulf of Maine Herring and average migration distance of tagged herring. All grounds are well within the range of all other grounds and yet no overexploited stock has been replaced by another.

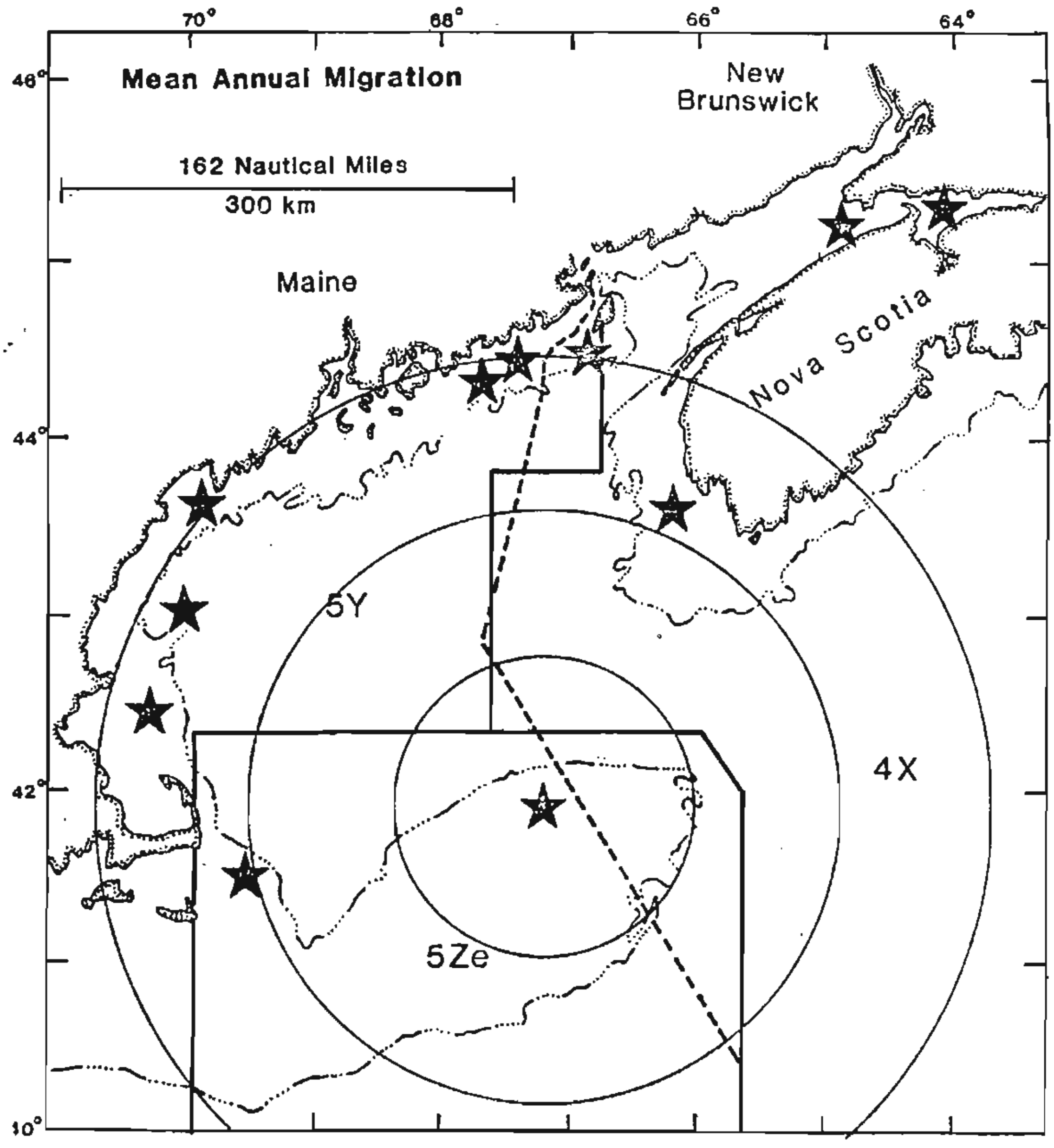
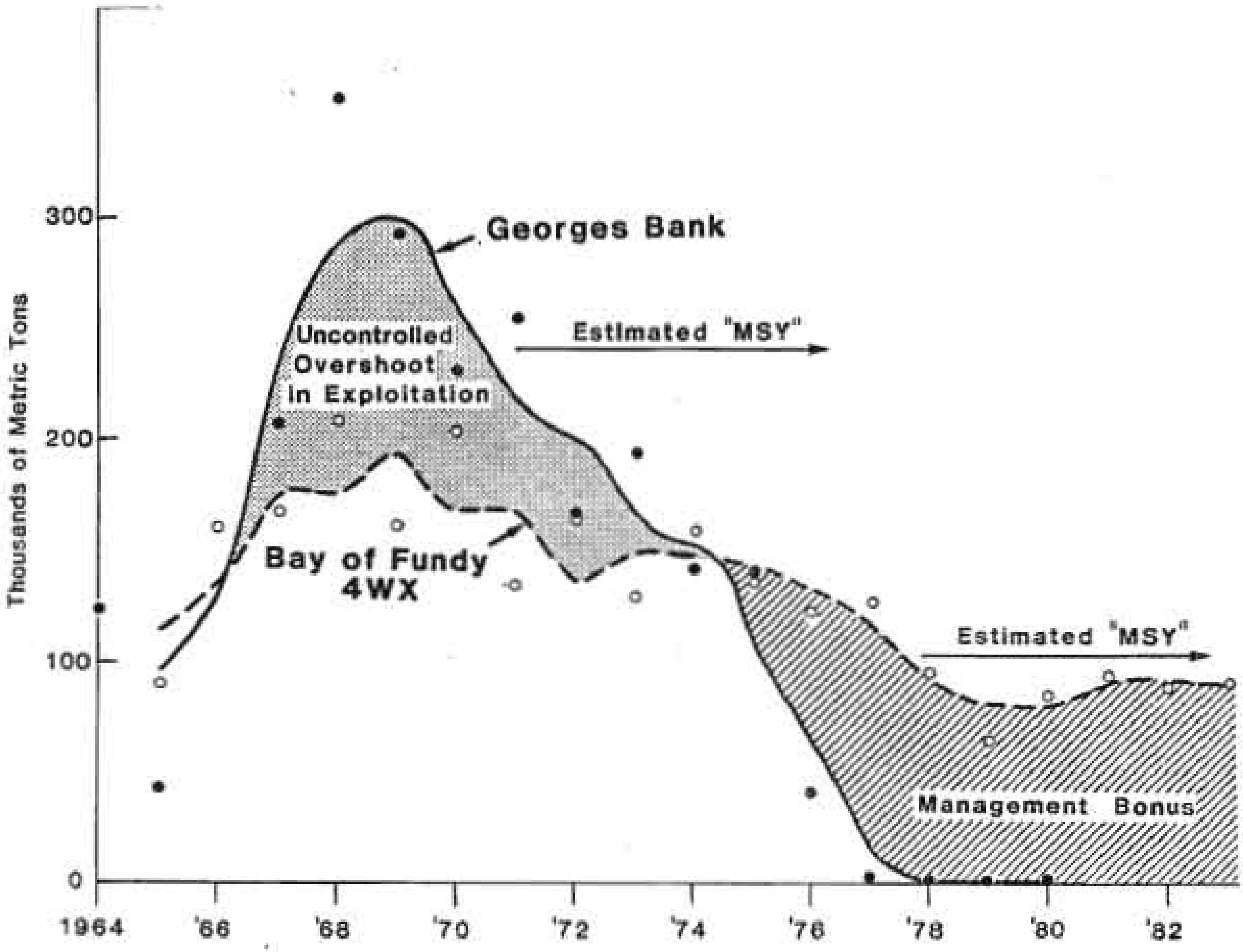


Fig. 3: The tale of two Herring stocks: Georges Bank stock overshoot in exploitation and stock collapse; and Bay of Fundy stock the benefits of Resource Management



2.2 CATCH DATA: THEIR IMPORTANCE AND COMPLEXITIES

Robert L. Stephenson
Science Branch, Scotia-Fundy Region
Biological Station
St. Andrews, New Brunswick

Catch data are the single most important piece of information used for assessment. The analytical models commonly used in the Gulf of St. Lawrence and other east coast stock assessments are based upon information from the commercial fishery. This section deals, in general terms, with how catch data are used in assessment, and addresses some of the complexities involved in the collection and interpretation of catch information. It uses, for the most part, examples from the Bay of Fundy herring stock (NAFO subarea 4WX), with which the author is most familiar.

2.2.1 The Place and Importance of Catch Data

4T herring and most other CAFSAC stock assessments are based upon sequential population analysis (SPA; see section 2.5). In SPA, information from commercial catch is used to construct a "catch table" (tonnes of fish caught at each age) which is then used to estimate present population size and to make future projections. The process is shown schematically in Figure 1. Two pieces of catch information are essential for construction of the catch table:

1) Total catch. This is the most important piece of information. It is obtained most commonly from purchase slips, but may also be obtained from hails or log records.

2) Biological characteristics. The catch table is partitioned by age. Age, as well as related biological characteristics (length and weight) are obtained from biological subsamples of the commercial catch (see section 2.3). This is the second essential piece of catch information.

The use of catch information is summarized in Figure 2. Total catch (from purchase slips) plus age structure of the catch (from biological samples) are combined in a catch-at-age table. The catch-at-age table is added to that of previous years in a historical table (see for example Figure 3). The catch-at-age table is then used as the basis for sequential population analysis.

2.2.2 Complexities of Catch Data

Construction of the catch-at-age table is complicated by a number of factors. Differences in location, timing, gear types and market, to name a few, can result in differences in catch-at-age characteristics. This section documents the major complicating factors in the 4WX herring fishery and shows how a time/area/gear type breakdown is used in construction of the catch-at-age matrix.

Figures 4 and 5 show the over space and time distribution of the various gear types in the 4WX fishery. Fishing takes place almost throughout the year but using different gear types and in different areas at different times of the year. This diversity has significant implications for sampling (see section 2-3) and for construction of the catch-at-age table because the characteristics of fish taken in the various segments of the fishery differ. Figure 6 shows, for example, that in 1985 the 4Xa weirs caught predominantly 2-yr-old fish, whereas the nearby 4X gillnets took predominantly 4-yr-olds. Differences in selectivity occur, as might be expected, from gear type (e.g. gillnet vs weirs), location (southwest Nova Scotia vs Chedabucto Bay, Cape Breton) and season (summer or winter). However, differences can also occur in catches from a single gear type in the same general area at one time. Figure 7 shows the difference in numbers at age of purse seine catches for 2 months from two adjacent areas (10 minute squares) off southwest Nova Scotia. Catches on Trinity Ledge, a traditional spawning ground, were dominated by 4- and 5-yr-old fish (used for the roe market). However, catches from nearby McDormands Patch had a much higher proportion of 2- and 3-yr-old fish (taken for the sardine market).

The result of this complexity is the need to consider catch information by gear, by area and by time period (such as month). This requires, in addition to total catch, knowledge of where exactly the catch was made, what gear was used and when. There are a variety of ways of getting this information, but the best is probably log records (see also sections 2.4.5). Figure 8 shows the distribution from logbooks of catch by 10' square in the summer of 1985 4X purse seine fishery.

2.2.3 Matching Catch and Biological Information to Create the Catch Matrix

When a sufficiently complete set of catch information from the fishery, catch records, biological samples and logbook information (location, gear type, etc.) has been obtained, they can be matched to construct a more accurate catch-at-age matrix based upon the characteristics for each month, areas and gear segment, as shown in Figure 9. During the matching process, total catch is allocated among areas on the basis of logbook reports and matched with the closest available biological sample as in Figure 10. The result is a number of month/gear/area matches for the fishery (as shown in Figure 11) which are ultimately combined in the final catch-at-age matrix.

2.2.4 Conclusion

This section has shown the importance of catch data in creation of the catch-at-age matrix which is the basis of the analytical assessment, catch is the most important information required for the assessment. Figure 12 summarizes the relative advantages and disadvantages of various sources of catch data.

2.2.5 References

Chadwick, E.M.P., and G.A. Nielsen. 1986. Assessment of Atlantic herring in NAFO Division 4T, 1985. CAFSAC Res. Doc. 86/38

Stephenson, R.L., M.J. Power, and T.D. Iles. 1986. Assessment of the 1985 4WX herring fishery. CAFSAC Res. Doc. 86/43.

Stephenson, R.L., M.J. Power, T.D. Iles, and P.M. Mace. 1985. Assessment of the 1984 4WX herring fishery. CAFSAC Res. Doc. 85/78.

2.2.6 Questions and Comments

It was questioned whether hails are accurate. The consensus was that they were.

Question:

Are hails used in 4T and does the information show in logbooks?

Response:

Hails are used for quota closures. Purchase slips, logbooks and hails are then compared to determine total catch. For example, in P.E.I. in 1985 the fishery was closed by hails and the quota was overrun by only 1.1%

Comment:

It was noted by Cleary (1983) that logbook data from seiners are unreliable and that good information is provided only when the quota has not been obtained.

Comment:

It was suggested that due to better enforcement in recent years, catch information from hails may be better than in the past.

Question:

Are there two sets of logbooks as for groundfish?

Response:

There was one standard logbook; a research logbook was not allowed.

Comment:

A lack of coordination by DFO in the past has led to many mistakes. Without cooperation between fishermen and DFO, no real-time management could occur.

Comment:

Catch data are the basic ingredients of stock assessments, accurate catches, not necessarily landings, are critical. Serious implications arise if this information is not available.

Fig. 1: Schematic overview of the assessment process.

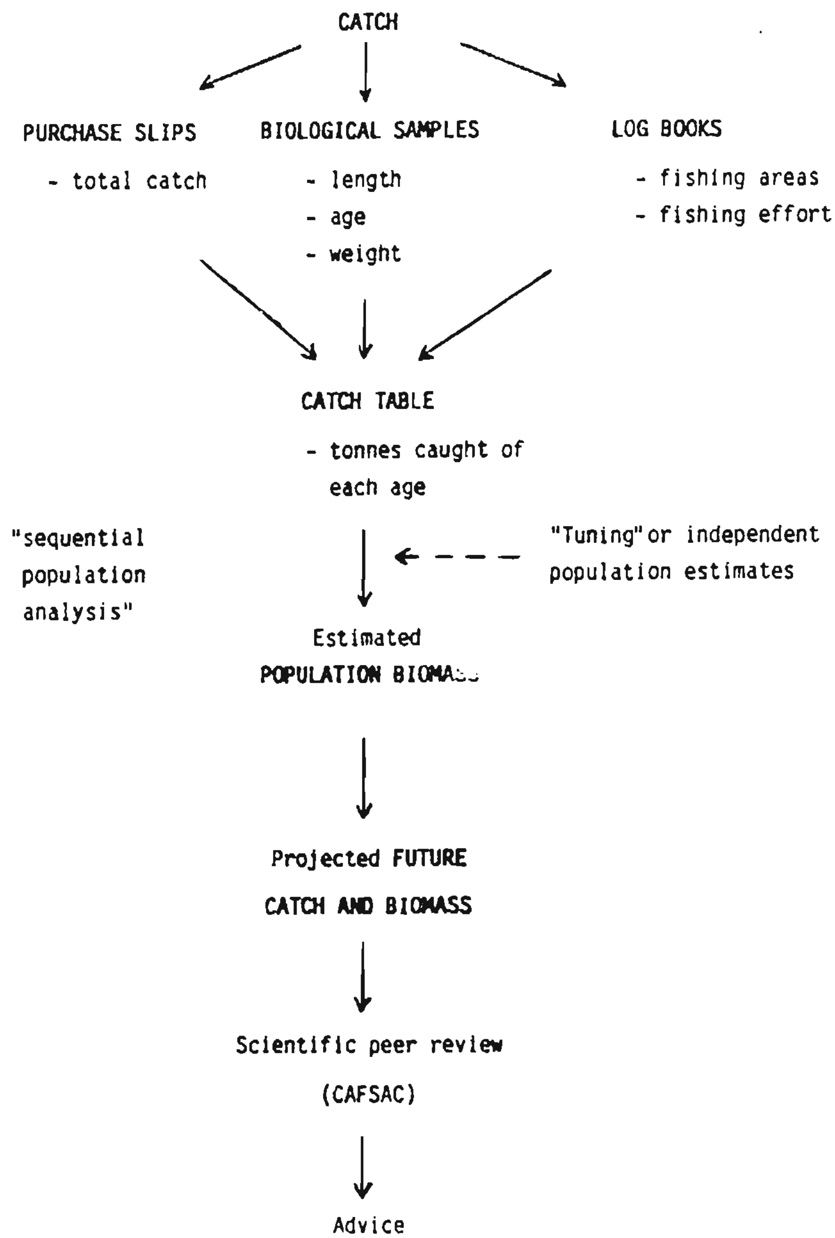


Fig. 2: Summary of the use of catch information in assessment.

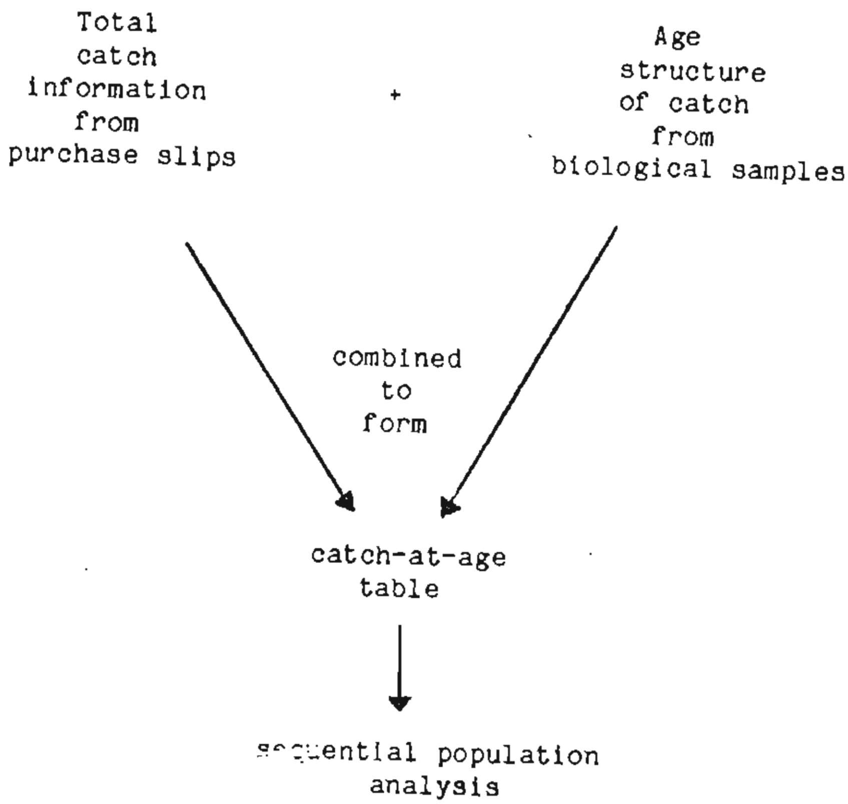


Fig. 3: Example of a historical catch-at-age table (from the fall spawning component of the 4T gillnet fishery - Chadwick and Nielsen 1986). Note the appearance of relatively strong (e.g. 1977; circled) and weak year-classes.

FALL GILLNET CATCH 5/ 1/87

I	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
2 I	1	1	1	1	5	1	25	1	1	1	0	0
3 I	125	1	39	122	351	128	7254	6851	3542	792	931	1638
4 I	4258	1602	276	1879	4389	7809	3293	28863	18645	21648	26518	15901
5 I	1765	8163	1455	340	3104	3821	4027	5537	23280	10465	14918	22616
6 I	515	1227	5839	253	593	1883	929	2471	5308	12544	12214	11093
7 I	1876	742	465	3215	614	402	836	974	2250	2223	6236	6417
8 I	180	616	243	133	3440	484	185	830	960	1782	1308	3050
9 I	2070	403	419	81	83	694	210	104	491	589	446	317
10 I	730	315	50	468	178	11	139	53	131	81	154	289
11+ I	4813	1800	2143	1162	1785	1418	620	866	61	260	171	154

Fig. 4: Geographical distribution of gear components of the 1985 4VWX herring fishery. Resolution = 10' square. From Stephenson et al. 1986.

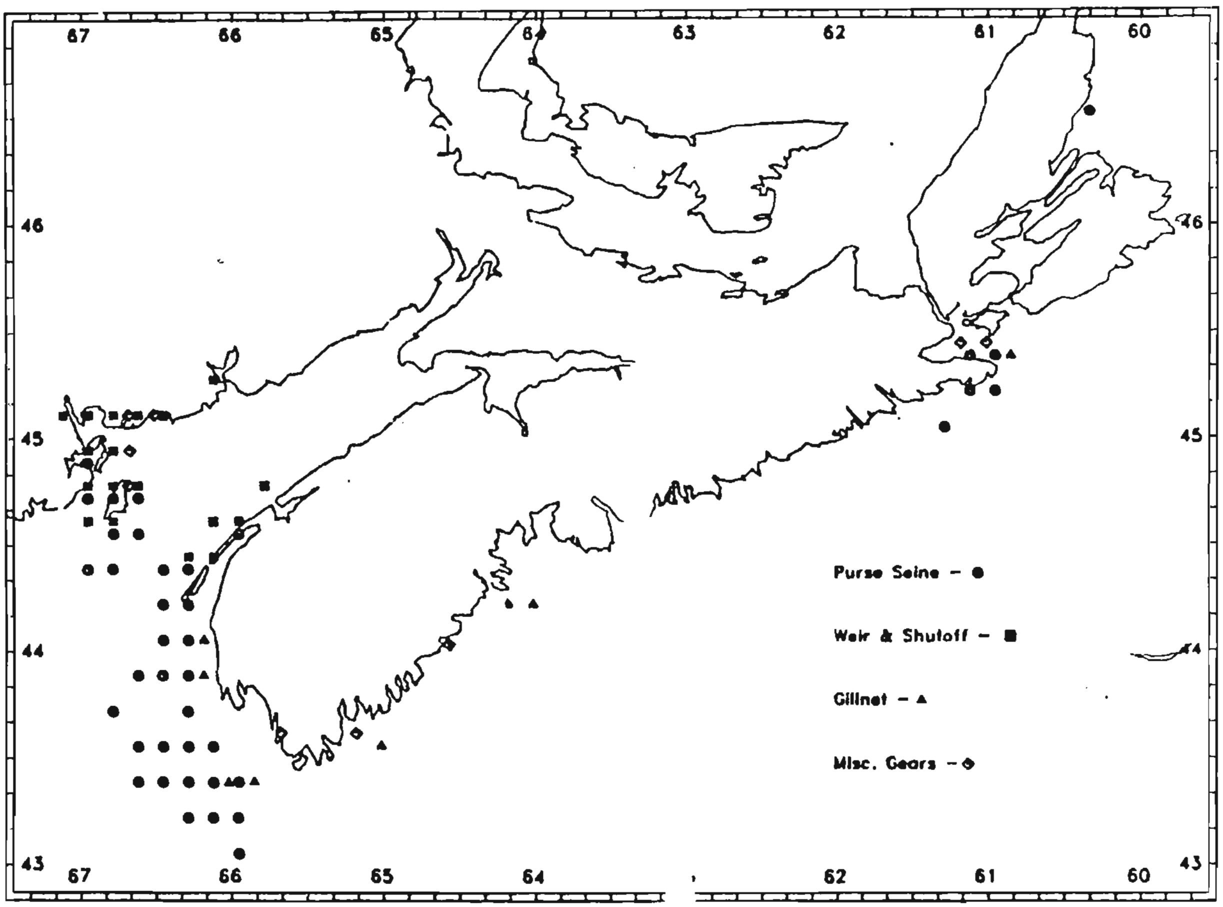


Fig. 5: Seasonal distribution of activity by gear component of the 1985 4WX herring fishery. From Stephenson et al. 1986.

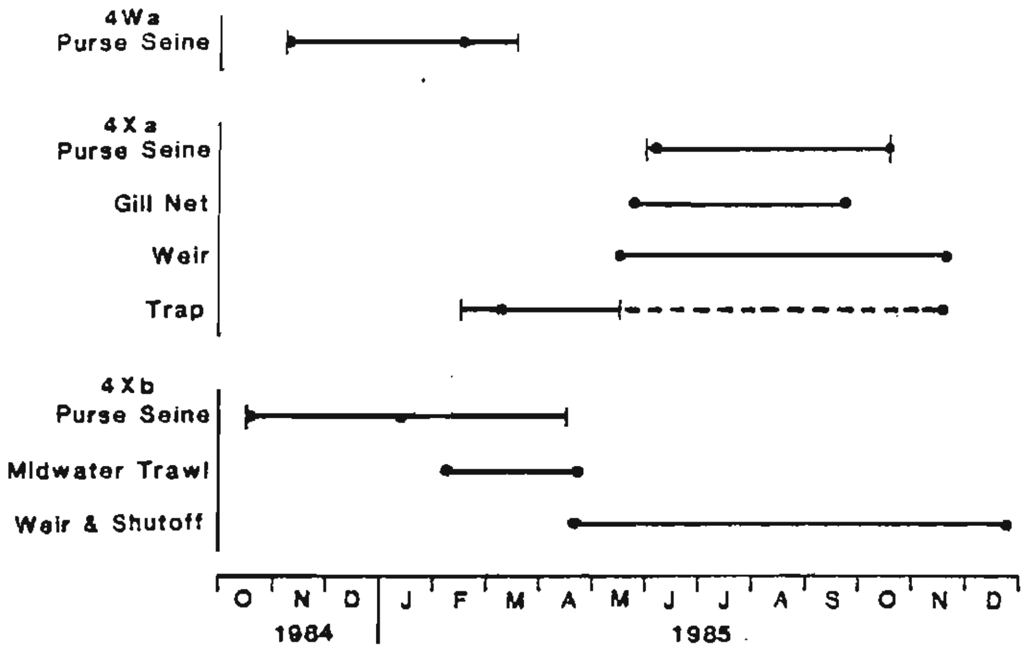


Fig. 6: Catch at age by different segments of the 4WX herring fishery. From Stephenson et al. 1986.

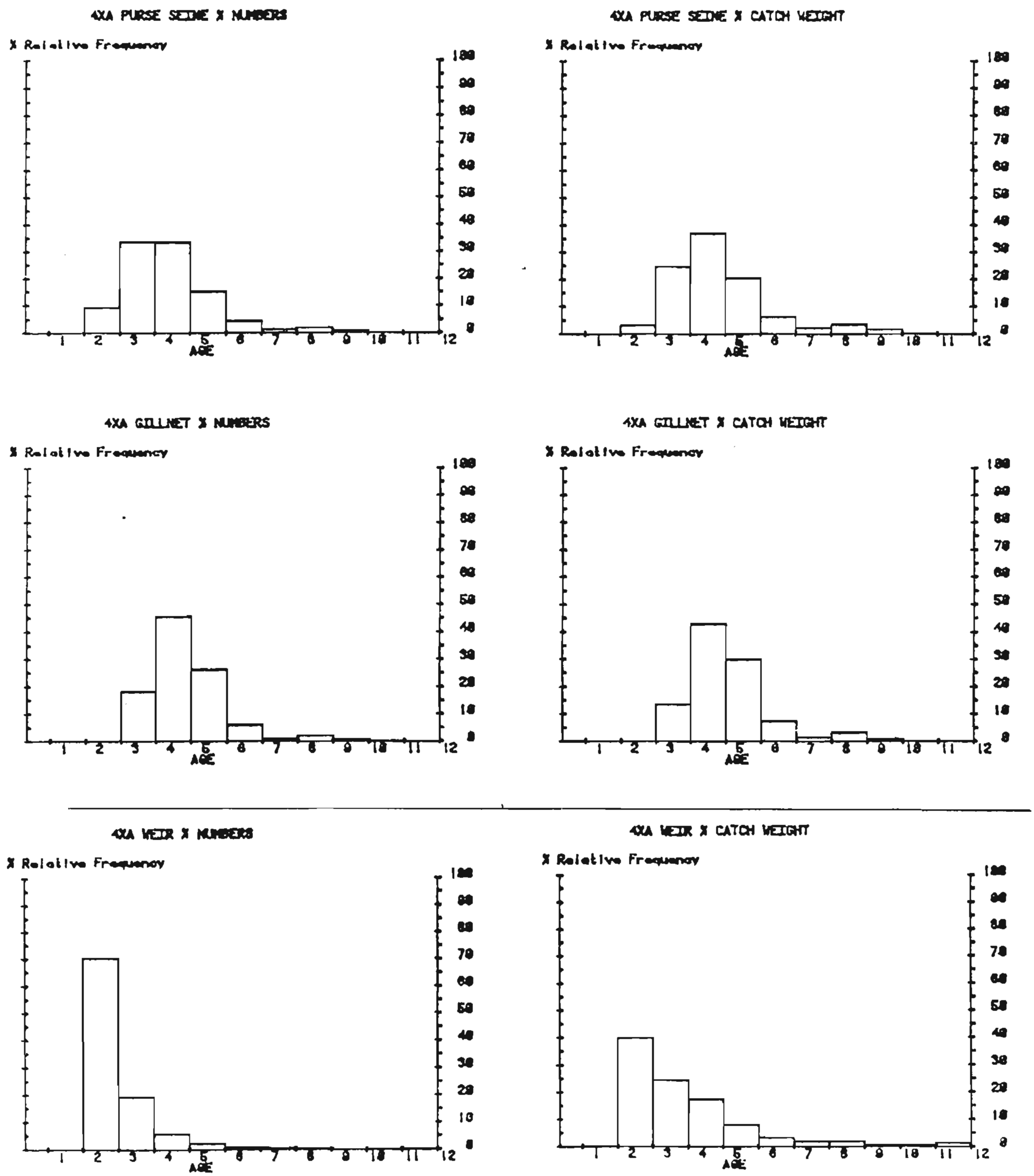


Fig. 7: Number at age for two adjacent 10' squares of the 4Xa purse seine fishery, calculated using individual length frequencies but the same age composition and catch weight (assumed to be 100 t). Trinity = square 440-661 and 435661; McDormand Patch square = 440662.

Diff (%) calculated as:

$$[(\text{Trinity} - \text{McDormands})/\frac{(\text{Trinity} - \text{McDormands})}{2}] \times 100.$$

		2	3	4	5	6	7	8	9	10	11+	Total
Aug.	Trinity	9	58	214	112	22	17	23	5	1	2	461
	McDormands	123	256	202	61	11	5	6	1	0	0	664
	% diff.	173	126	6	59	67	109	117	133	200	200	36
Sept.	Trinity	2	74	222	120	6	10	22	9	2	3	471
	McDormands	491	144	129	58	3	6	16	6	1	4	860
	% diff.	198	64	53	70	67	50	32	40	67	29	58

Fig. 8: Summary of catch by 10' square in the 1985 4X purse seine fishery from logbook information. From Power and Stephenson 1985.

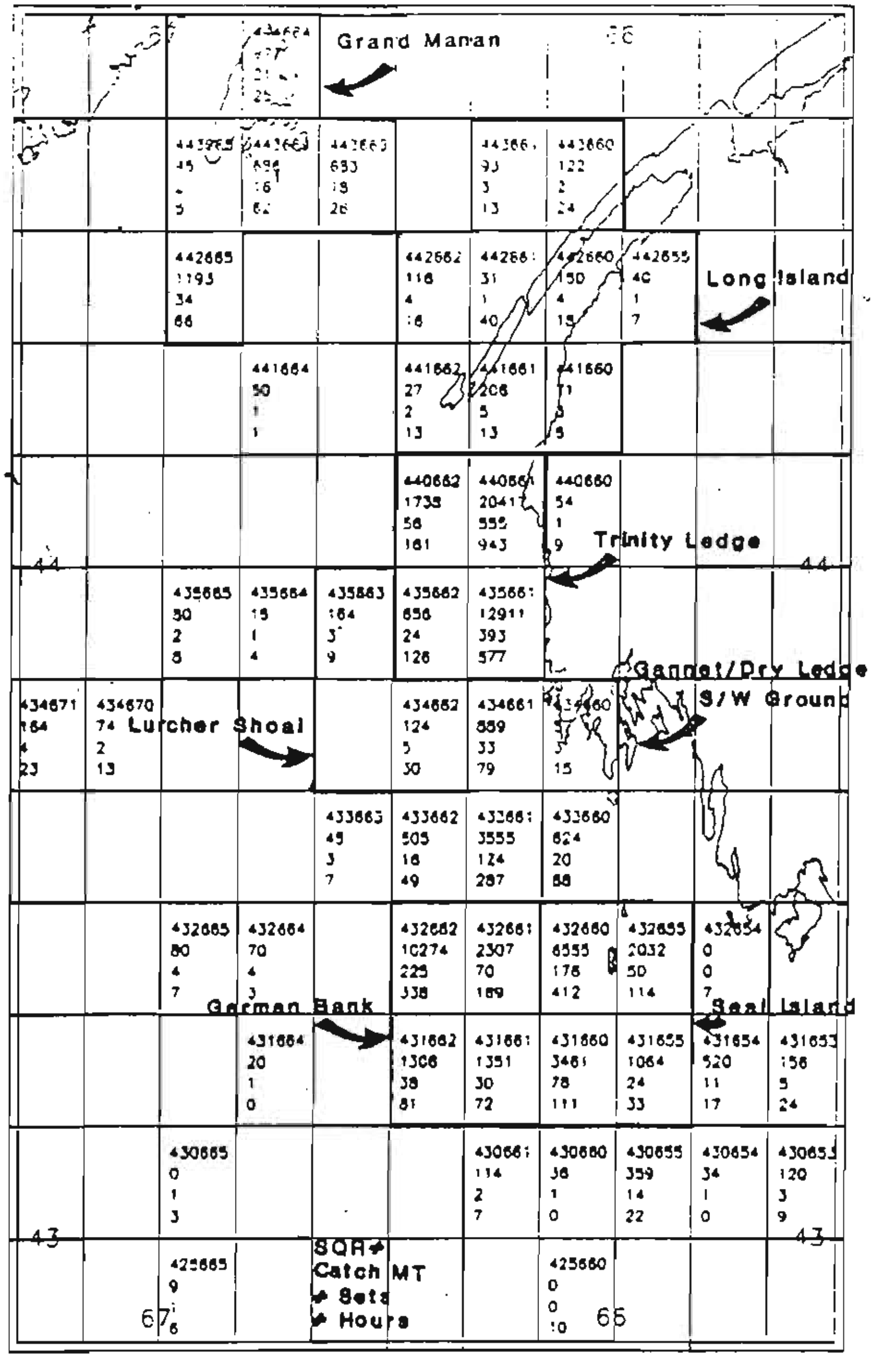


Fig. 9: Schematic representation for the matching of catch, biological and logbook information to create catch at age by month, area and gear segment.

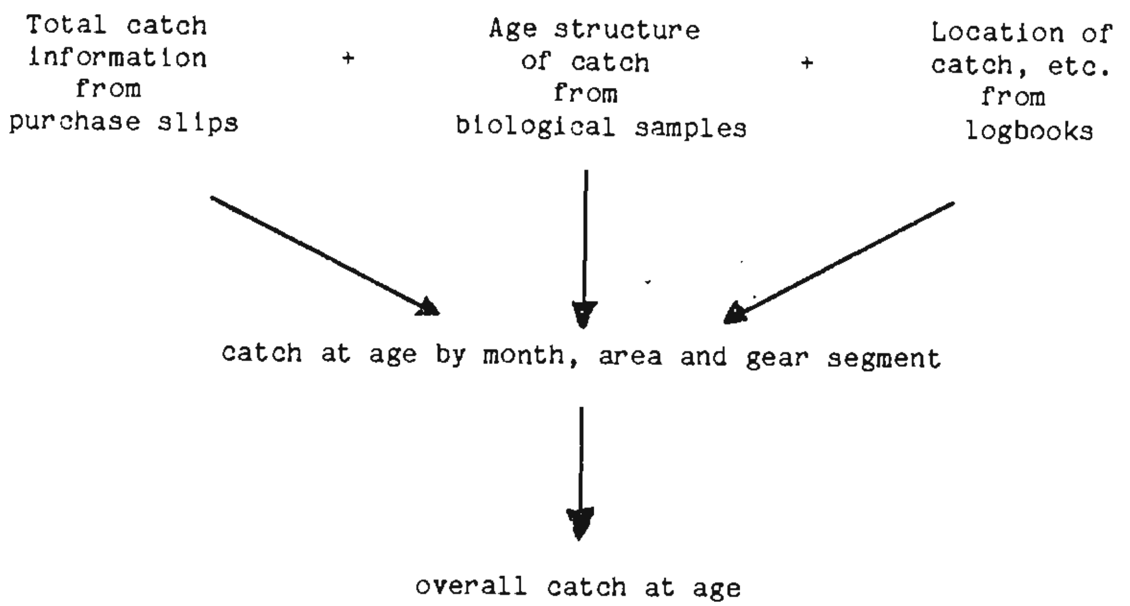


Fig. 10: Hypothetical example of catch/sample matching as used in the 4WX herring assessment.

EXAMPLE OF SAMPLE MATCHING IN 4WX HERRING FISHERY

LANDINGS MONTHLY	LOGBOOK SQUARE	LOGBOOK CATCH	LOGBOOK ADJUSTED	LEN FREQ NO. MEAS	DETAIL NO. FISH		CATCHES AGE 1	BY AGE 2	AGE AGE 3	TOTAL	
	A	50	111.10	0	0	} combined					} A+B
1000	B	100	222.20	300	50		30	200	103	333	
	C	300	666.70	400	150	separate	67	400	200	667	C
TOTALS		450	1000	700	200		97	600	303	1000	

Fig. 11: Distribution of catch and of biological samples from the 1985 4WX herring fishery. From Stephenson et al. 1986.

Distribution of biological samples from the 1985 4WX commercial herring fishery; detail fish = number of fish take for detail analysis including ageing, LF samples = number of length-frequency samples, LF fish = number of fish measured.

Gear component		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
4Wa purse seine	- detail fish		737	366	701	*										
	- LF fish		4445	2765	7381											
	- LF samples		22	14	37											
	- catch (t)		2379	2517	3452	403										
4Xa purse seine	- detail fish									86*	1080	1467	1085	467[b]		
	- LF fish									1708	22990	21841	6824	2986		
	- LF samples									8	110	110	42	19		
	- catch (t)									290	12393	30646	37133	6705		
4Xb purse seine	- detail fish	698[c]	230		100*											
	- LF fish	3286	1728		705											
	- LF samples	28	11		4											
	- catch (t)	2431	1892		1096											
4Xa gillnet (4XOQR)	- detail fish								*	*	*	265	217			
	- LF fish									180		4302	6111			
	- LF samples									1		22	28			
	- catch (t)								88	86	60	1944	3406			
4Xa NS weir (4XR)	- detail fish								134*	455	936	285				
	- LF fish								995	3770	5696	1383				
	- LF samples								5	20	34	8				
	- catch (t)								378	1803	1381	489			11	
4Xa NS trap (4XMOQ)	- detail fish								139*	102*	*	*				
	- LF fish								714	290						
	- LF samples								3	2						
	- catch (t)								190	446	406	201	47	13	1	
4Xb mid trawl	- detail fish				18*		166	40								
	- LF fish				142		2066	374								
	- LF samples				1		10	2								
	- catch (t)				52		6	40								
4Xb weirs	- detail fish								94	45*	1082	1129	761	706	134*	*
	- LF fish								1054	476	9796	9085	4898	4351	929	
	- LF samples								6	3	64	60	30	28	6	
	- catch (t)								23	84	4214	8451	6910	4825	2079	138
4Xb shutoff	- detail fish										*	14*	70*	122*	*	
	- LF fish											132	285	1245		
	- LF samples											1	2	8		
	- catch (t)							36			73	184	208	288	306	44
4WX misc.	- detail fish								139[a]	102[a]	87[a]	299[a]	217[a]			
	- LF fish								861	470	924	4520	5764			
	- LF samples								4	3	9	24	26			
	- catch (t)					12		25	277	210	871	192	21	4		

*Cells undersampled according to criteria of 200 detail fish per gear type per month with >50 t catch.
[a]Combined monthly detail and LF information used (4X gillnet, 4X trap = 4W gillnet);
[b]Oct. 1-14; [c]Oct. 15-31.

Fig. 12: Relative advantages and disadvantages of potential sources of catch data.

Source	Advantages	Disadvantages
Purchase slip	- should represent total landed (measured)	- no record of releases - often discounted - may represent mixture from several areas
Hail	- accurate location and vessel info.	- estimate rather than measure
Logbook	- complete record of catch and location info.	- estimate rather than measure
Product weight	- usually well documented	- rough estimate only

2.3 SAMPLING OF THE HERRING FISHERIES IN SOUTHERN GULF OF ST. LAWRENCE

Michael Chadwick
Science Branch
Gulf Region
Gulf Fisheries Centre
Moncton, N.B.

2.3.1 Objective

The objective of the sampling program is to estimate the average size and age structure of the fish caught by all herring fisheries. The age structure is the proportion of fish caught at each age. As will be explained later, the age structure is multiplied by the landings to get the number of fish caught at each age.

In southern Gulf of St. Lawrence, there is not just one herring fishery; herring are fished with many types of gear, in many areas, and at different times of the year. Each gear type, area and season represents a different fishery which may select towards a particular size or type of herring. All of these fisheries must be adequately sampled.

2.3.2 Background

It is important to distinguish between the terms catch and stock. Catch is the part of the stock captured by the fishery and because fisheries are often selective, the type of fish in the catch may be different from the average type in the stock. Thus, the sampling program is directed towards only the catch. Later, we will see how this information is used to estimate the stock's structure, that is, what the stock really looks like.

In fact, in the Gulf of St. Lawrence there is not just one stock, but several. Currently our assessments assume that there are two stocks: herring which spawn in the spring, between April and July; and fall spawners which spawn between July and October. Therefore the biological sampling program must consider not only the age and size of fish caught, but their spawning group as well.

Because the sampling must be representative of the catch, it might be useful to examine selectivity of the various fisheries. The two major gear types are gillnets and purse seines. Gillnets can range in mesh size from 1 5/8" to 3 1/4". Generally, the smaller mesh gears catch smaller herring. This phenomenon can be seen in Figure 1.

Purse seines can also be selective. Depending on markets, seiner captains can avoid schools of small herring.

The size of fish can also vary with season. For example, in the spring fishery, which occurs from April to June, generally smaller herring are caught than in the fall fishery, which occurs from July to November. Samples must be representative of both fisheries.

Finally, the size of fish can change with location of fishing grounds. It can be seen in Figure 2 that the size of herring from Chaleur Bay is different from herring taken in Pictou, despite the fact that samples were taken with the same gear and during the same season in both areas.

2.3.3 Length-Frequency Samples

The first step in a sampling program is to collect length-frequency samples from all the various fisheries throughout the fishery season. A length-frequency sample consists of 200 or more fish which have been randomly collected from a fishermen's catch. Each fish is measured to the nearest 1/2 centimeter, from the nose to the tip of the tail, and each length is tallied on a sheet. When all fish in the sample are measured we know the number of fish at each 1/2 centimeter of length and this final tally is called a length-frequency sample (Figure 3).

It is very important that the fish to be measured are collected randomly, in other words, the sample must represent the catch on board the fishing vessel. Usually a bucket is filled by plunging it into the catch and this is felt to be a representative sample because there is no selection for smaller or larger individuals.

In each area, length-frequencies are collected daily throughout the fishing season. At the end of the season all length-frequencies are added together and the length-frequency distribution, or the percentage of fish caught at each length, is calculated for all major sampling areas.

There are four major sampling areas: Magdalen Islands, Northumberland Strait (including the coasts of New Brunswick, PEI and Nova Scotia which border on the strait), Miramichi Bay (Pokemouche south to Buctouche) and Northwest PEI, and finally the Chaleur Bay and Gaspé areas. It is felt that the stocks in each of these areas may be different and therefore length-frequencies are treated separately for each area.

2.3.4 Detail Samples

In addition to length, some fish are also measured for weight, sex, maturity stage and age. Because it is expensive and time consuming to age herring, detail samples are collected less frequently than length-frequency samples. A detail sample consists of two fish for each 1/2 cm of length that are collected from the same bucket of fish that is used for the length-frequency sample. Generally it will include about 50 fish which are frozen and brought to the laboratory in Moncton.

Detail samples are used to estimate spawning group, age and average weight of the catch in each area. The maturity stage of gonads is used to determine spawning group. Fish with mature gonads are assumed to spawn at the time of sampling. The spawning group of immature or spawned-out fish is validated with otoliths. Otoliths, or ear bones, are removed from the head of herring and stored in plastic trays. Herring which spawn in the fall tend to have otoliths with a more square shape and with larger centers than the otoliths of spring spawners.

Age is determined by counting annual rings on otoliths. It is assumed that all herring have their birthday on January 1st each year, consequently one extra ring or year is added to otoliths from fall spawners.

Ultimately detail samples are used to calculate average weight, proportion spawning group and percentage of ages at each 1/2 cm of length from the combined length-frequency samples.

2.3.5 Catch-at-age

The catch at age is simply the numbers of fish caught at each age group and for each major sampling area. It is estimated separately for spring and fall spawners. There are three basic steps to follow. First, the numbers of fish caught must be estimated which also involves three steps: 1) the average weight at each length is weighted or adjusted by the length-frequency distribution to calculate an overall mean weight; 2) the total weight of landings in each sampling area is divided by the overall mean weight to get the total number of fish caught; and 3) the length-frequency distribution is multiplied by the total numbers of fish caught to get the catch in numbers of fish at each length, or catch-at-length.

The second step is to estimate the number of fish in each spawning group. This number is calculated by multiplying the catch-at-length by the appropriate spawning group-length key. This key is the proportion of spring and fall spawners at each length.

Third, the catch-at-age is calculated by multiplying the catch-at-length by age-length keys. An age-length key is simply the percentage of ages at each length (Figure 4); they are calculated separately for spring and fall spawners and for each major sampling area.

2.3.6 Weight-at-age

The average weight at each age is calculated from the combined detailed samples which have been weighted by the catches in each major sampling area.

If the sampling is done properly, the total weight of landings should equal the average weight-at-age times the catch-at-age- summed for all ages and both spawning groups. This last test is routinely used to double check the calculations.

2.3.7 Questions and Comments

The presentation dealt with three points:

1) Objectives of sampling
   - to determine i) tons of fish taken at each age
     ii) average weight of fish at each age
   - to document catch (not population)
   - in 4T it is complicated by division into spring and fall spawning components

2) Sampling without bias
   - sampling is complicated by differences as a result of fishing gear, mesh size, seasons and location
   - a sampling must take this complexity into account
   - two phase sampling:
     - lengths are easy to get - measure thousands
     - age & spawning samples (biological detail) are harder - limited to 5,000 per year
     - these must be representative of diversity of fishery

3) Conversion of tons of fish to numbers of fish at age
   - steps ii) - age/length key allows length info to be partitioned by age
     ii) - catch is weighted according to age
     ii) - catch at age (in number) by gear, area, etc.
     ii) - division into spring and fall components

Question:

How can DFO avoid missing samples?

Response:

This results from lack of communication, particularly around the start of spring fishery. Fishermen willing to cooperate. Processors willing to freeze samples.

Question:

Does sampling account for variations in mesh size?

Question:

Why are mesh sizes in Escuminac and Val Comeau different?

Response:

The spring Escuminac fishery supplies a bloater market, so would rather have 10-11" rather than 12" fish. Small fish in Escuminac landings may reflect market preference rather than size of fish on spawning grounds, although herring in Escuminac are generally not as large.

Comment:

Is there a circular argument in the case of areas not fished? No quota means no landings and therefore the impression of no fish?

Comment:

Lack of sampling in some areas does not lead to lower quota; quotas are based on overall health of stock

Comment:

Lack of feedback regarding biological studies (e.g. 1984 Fisherman's Bank study).

Fig. 1: The length frequency distribution of herring compared for gillnets of three different mesh sizes:

top - 2 3/8 inches, middle - 2 1/2 inches, and bottom 2 5/8 inches.

The herring were sampled from the Caraquet fall fishery in 1986.

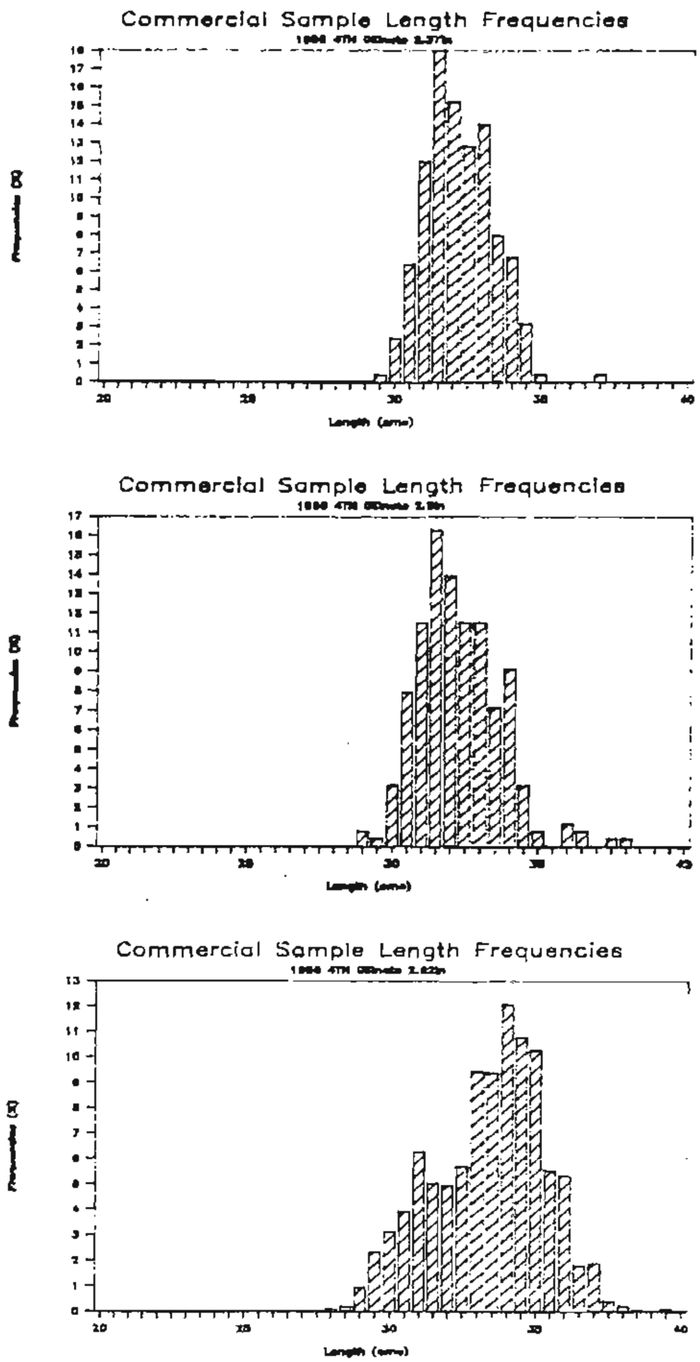
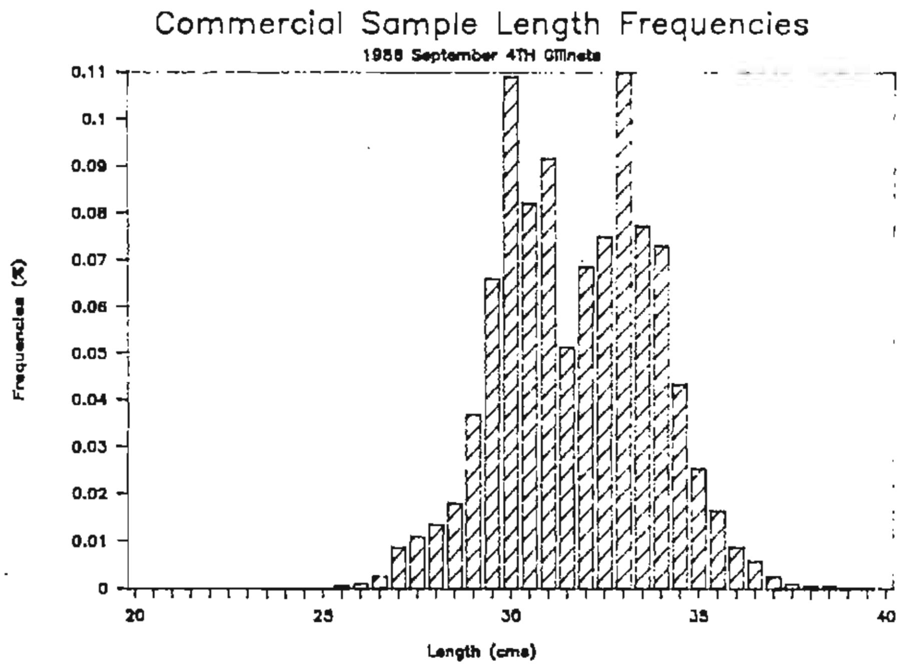


Fig. 2: The length frequency distribution of herring captured in 2 5/8" gillnets during the fall fishery of 1986 compared in two areas: top - Pictou, N.S.; bottom - Caraquet, N.B.



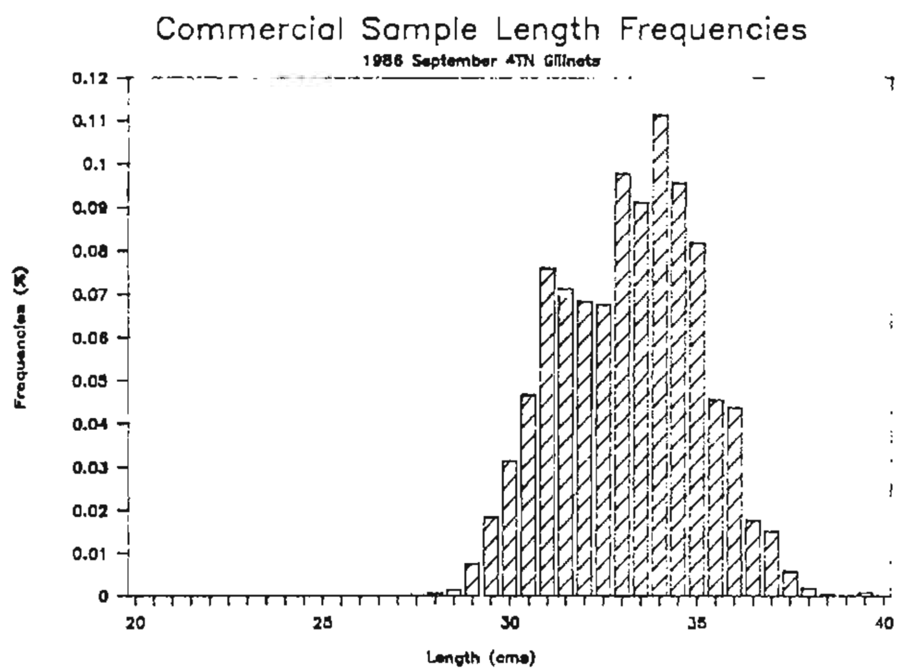


Fig. 3: An example of a length frequency tally sheet used for collecting samples in the commercial fishery.

ECHANTILLONNAGE COMMERCIAL SAMPLING

TYPE CD. 9 | DIST. 265 | Set No. 081 | L.PECH./F.LOC. 4TN | DATE 131066

TYPE EXP. 96 | ENGIN/GEAR P51 | MAILLE/MESH (po./in) 125 | PROF. EN./GEAR DEPTH (fm.) 013 | BATEAU L.H.T./SHIP L.O.A. (Pi./ft.) 098

SET INFORMATION — DEBUT/START

SET WEIGHT (lbs.) 250000 | LAT./LORAN-C 48°28'12

SET RELEASED | LONG./LORAN-C 64°16'29

SET KEPT ✓ | HEURE/TIME 2043

CODE SP. 0060 | Pd.ECH./SAMPL.WT. (Lbs.) 185

Sample # 23

Sonar on 18:00 hrs
Set Finished 22:20 hrs
315 fish measured

LEN. INT. LONG. (1=1, 2=.5)	DECOMPT./TALLY (1=cm, 2=mm)	TOT.	LEN. INT. LONG. (1=1, 2=.5)	DECOMPT./TALLY (1=cm, 2=mm)	TOT.
20.0			0.0		
0.5			0.5		
1.0			1.0		
1.5			1.5		
2.0			2.0		
2.5	|	01	2.5		
3.0			3.0		
3.5			3.5		
4.0			4.0		
4.5			4.5		
25.0			5.0		
5.5	|	01	5.5		
6.0			6.0		
6.5			6.5		
7.0			7.0		
7.5	|	01	7.5		
8.0	|	01	8.0		
8.5	|||	03	8.5		
9.0	||	02	9.0		
9.5		06	9.5		
30.0		08	0.0		
0.5		11	0.5		
1.0		09	1.0		
1.5		24	1.5		
2.0		32	2.0		
2.5		37	2.5		
3.0		40	3.0		
3.5		37	3.5		
4.0		30	4.0		
4.5		24	4.5		
35.0		18	5.0		
5.5		10	5.5		
6.0		06	6.0		
6.5		08	6.5		
7.0		05	7.0		
7.5			7.5		
8.0	|	01	8.0		
8.5			8.5		
9.0			9.0		
9.5			9.5		

Fig. 4: An example of an age-length key used to convert lengths of herring into ages.

AGE LENGTH KEY

LENGTH	AGE 1	2	3	4	5	6	7	8	9	10	11	TOTAL
21.5	0	0	0	1	0	0	0	0	0	0	0	1
27.0	0	0	1	1	0	0	0	0	0	0	0	2
27.5	0	0	1	1	0	0	0	0	0	0	0	2
28.0	0	0	7	1	0	0	0	0	0	0	0	8
28.5	0	0	2	4	0	0	0	0	0	0	0	6
29.0	0	0	1	19	0	0	0	0	0	0	0	20
29.5	0	0	0	27	3	0	0	0	0	0	0	30
30.0	0	0	0	64	8	0	0	0	0	0	0	72
30.5	0	0	0	53	14	1	0	0	0	0	0	68
31.0	0	0	0	76	28	4	0	0	0	0	0	108
31.5	0	0	0	56	43	11	0	1	0	0	0	111
32.0	0	0	0	28	47	14	4	0	0	0	0	93
32.5	0	0	0	7	48	18	2	0	0	0	0	75
33.0	0	0	0	0	36	21	0	4	1	0	0	62
33.5	0	0	0	0	17	16	3	5	1	0	0	42
34.0	0	0	0	0	5	10	10	6	3	0	0	34
34.5	0	0	0	0	6	7	11	7	3	0	0	34
35.0	0	0	0	0	1	7	10	13	7	1	0	39
35.5	0	0	0	0	1	0	2	5	1	0	0	9
36.0	0	0	0	0	0	0	0	13	5	0	2	20
36.5	0	0	0	0	0	0	3	10	1	1	0	15
37.0	0	0	0	0	0	0	0	3	2	0	1	6
37.5	0	0	0	0	0	0	0	1	0	0	1	2
38.0	0	0	0	0	0	0	0	0	0	1	2	3
39.0	0	0	0	0	0	0	0	0	1	0	0	1
TOTAL	0	0	12	343	263	109	45	72	26	3	6	
LEN	0.0	0.0	28.0	30.6	32.1	32.9	34.3	35.2	35.3	36.5	37.1	
DEV	0.0	0.0	0.5	1.6	2.1	1.1	1.1	3.7	3.2	1.3	0.9	

2.4 ABUNDANCE INDICES

Because abundance indices are so important to our understanding of the size of the herring resource, it was decided to devote one presentation to each of six types of abundance index which would be potentially useful in the Gulf of St. Lawrence.

2.4.1 Index Fishermen: A Summary of the Herring Research Gillnet Program In Newfoundland Region

John P. Wheeler
Science Branch
Department of Fisheries and Oceans
Northwest Atlantic Fisheries Centre
St. John's, Newfoundland

A research gillnet program, in which selected commercial fishermen are contracted to fish experimental herring gillnets, has been in effect in the Newfoundland Region since 1980.

There are presently 23 fishermen along the northeast and southeast coasts of Newfoundland (Figure 1) who fish five herring nets each for a period of one month annually. The nets are fished in the same location at the same time each year. The fishermen are responsible for recording daily catch rates and for the provision of herring samples from these nets.

The primary purpose of the program is to provide annual stock abundance indices from a source independent of the commercial fishery. This assumes that annual changes in catch rates of these nets reflect changes in stock abundance. Herring samples from the program provide biological information on growth rates, stock age compositions, and percentage of spawning types within the populations. The program also provides a stock recruitment index for juvenile herring prior to the recruitment of these fish to the commercial fishery.

2.4.1.1 Methodology

Each fisherman is provided with the following gear:

1) five commercial herring nets (18 fathoms long x 200 meshes deep), mesh sizes 2", 2-1/4", 2-1/2", 2-3/4", and 3".
2) four grapnels
3) 15-20 30" net buoys
4) 200-400 fathoms 1/2" polypropylene rope
5) mending twine
6) five plastic fish baskets
7) logbook and waterproof notebook
8) sampling bags and tags
9) deep freezer (if necessary)

The contract requires that the fisherman set the nets in a predetermined area in two fleets, with the 2" and 2-1/4" mesh nets together and the 2-1/2", 2-3/4", and 3" nets together. The nets are not set as a single fleet due to the excessive strain that this would create. The nets cannot be relocated from the predetermined area anytime during the agreement and should be removed from the water only for cleaning or in case of damage and should be replaced in the water as quickly as possible.

Weather permitting, the nets are hauled once every day, except Sundays. The herring caught in each mesh size net are separated in the fish baskets. The catch from each net is recorded in the waterproof notebook as the nets are hauled. Information is subsequently transferred from the notebook to the logbook.

Each page of the logbook (Figure 2) has space to record the information for one day only. An entry is made for each day, Sundays included, regardless of whether the nets are hauled or any herring are caught. The following information is recorded each day:

1) date
2) time nets are hauled
3) headrope depth
4) wind direction and speed
5) air temperature
6) was a sample taken?
7) which nets were fished?
8) which nets were hauled?
9) number of herring caught in each net
10) bycatch, by species, for all nets combined

A remarks section is provided for incidental observations and sightings.

The fisherman is required to collect two samples of herring per week for a minimum of eight samples during the month. A sample consists of 100 herring, 20 fish chosen randomly from each of the five nets. The herring from each net are placed in separate plastic bags and a label is affixed to the bag indicating mesh size. These five smaller bags are placed in a large bag, a label is affixed indicating the sample number and date, and the sample is frozen for later analysis.

As remuneration, the fisherman can sell all herring in excess of those required for samples. In addition, the fisherman is paid $600 upon completion of the contract for compiling the log record and collecting and freezing the research samples.

2.4.1.2 Analysis

All logbook information, with the exception of the remarks section, is coded and computerized. The total catch, by mesh size, is tabulated for each fisherman. The number of days that each mesh size net is fished and hauled is then tabulated in order to calculate catch per days fished and catch per days hauled for each net. This information can then be combined to determine the overall catch rate of the five nets. Catch rates of several fishermen within a stock area can then be combined to give a stock abundance index (Figure 3).

The fishermen collect samples (100 fish per sample) at approximately four-day intervals. The biological information derived from a sample is applied to the fish caught during the interval immediately prior to when the sample was taken. The catch for each mesh size net is tabulated for the interval and the proportions of fish caught by each net are then calculated. Detailed biological measurements are made on a subsample of 50 fish; these fish are chosen from each net using the same proportions as the catch for that net. These measurements include length, weight, sex, age, spawning type, maturity stage and gonad weight.

The age compositions of the research gillnet catches are calculated by applying age distributions of samples taken during the month, normally at four-day intervals, to catches during that interval and then combining these age distributions to obtain one for the entire month. Stock age distributions are obtained by combining the results for all fishermen within the stock area (Figure. 4). As well as providing information on dominant year-classes, these distributions indicate the percentage of spawning types within the population, information critical to the management of herring stocks. Recruitment indices for juvenile fish (ages 2 and 3) are also provided before these fish are recruited to the commercial gillnet fishery at ages 4 and 5.

2.4.1.3 Pros and Cons

The research gillnet program provides abundance and recruitment indices, stock age compositions, and spawning type percentages which are critical components in fish stock assessments. However, as with most fisheries research, the program has both its advantages and disadvantages.

Its primary advantage is that the information provided is independent of the commercial fishery and hence not subject to the biases associated with such a data source. Also, information can be collected at any time regardless if a commercial fishery exists or not. The program has been designed so that comparisons can be made both between areas and between years. Locations and timing do not vary from year to year and gear, data collection, and sampling regimes are standardized between areas. Learning factors are not considered to be a problem as experienced commercial herring fishermen are chosen to conduct the work. The liaison between biologist and fisherman is one further advantage of the program. The fisherman gains better insights into the role of fisheries biologists and the biologist learns more about fish behavior and the problems encountered by the fisherman while pursuing his livelihood. Additional environmental and by-catch data provided by the fishermen are also very useful in studying other relationships such as that between environmental conditions and gillnet catch rates or the interaction between herring and other species.

The program also has its sources of error, the greatest of which is the high variability in catch rates between areas. This is due mostly to the schooling behavior of herring and their clumped rather than random distribution patterns. The variability in results could be reduced by increasing the number of contract fishermen in each area, a process that has gradually implemented since the inception of the program in 1980. There are also human sources of error, including individual differences in the way nets are set and hauled and the way data and samples are collected. Market conditions play a role in the results of the program as fishermen tend to be more conscientious in tending the gear when markets are good.

The research gillnet program has proven very effective in providing abundance estimates for Newfoundland herring stocks. However, it is only one component in the assessment procedure and must be considered in relation to information from the commercial fishery and other research activities. A single abundance index is not sufficient. The program is constantly evolving; more fishermen are required and more detailed data analysis must be done. The future success of the program depends upon the cooperation and support provided by the contracted fishermen.

2.4.1.4 Questions and Comments

Question:

How does indexing (catch rates) compare with overall abundance assessments?

Response:

They tend to follow the same trends as the overall assessment trends.

Question:

How long and where do they fish?

Response:

They fish for one month, depending on the area and time of year.

Question:

Looks good on paper but does it exist in the Gulf?

Response:

A program was implemented in the Gulf this year, but we don't supply the nets so we don't get to evaluate the abundance of young herring. Also we move our nets, they don't in Newfoundland.

Comment:

Not enough communication with the fishermen involved from the Caraquet area. There was agreement from the Department on this; we will try to work on that problem.

Comment:

Varied mesh size surveys are very useful but they could also be used to estimate percentage of male/female, roe yield, and percent spent. These characteristics may vary from mesh size to mesh size.

Comment:

Because our fishery is so different from Newfoundland, we could not carry on such a program in the same way. We need to move our nets and require more fishermen to cover the large area of the Gulf.

Fig. 1: Newfoundland herring stock areas and research gillnet locations.

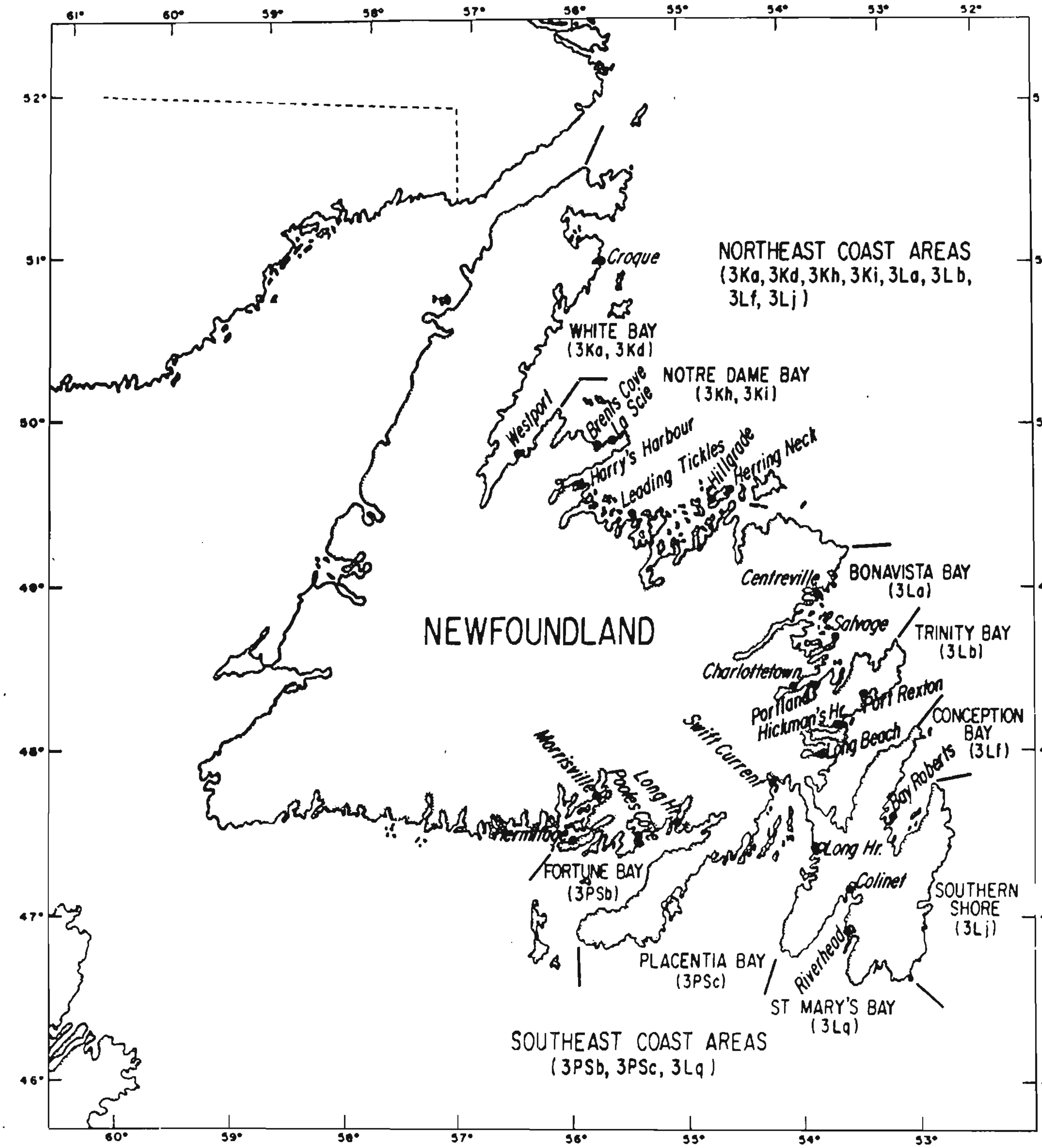


Fig. 2: Sample page from the research gillnet program logbook.

FIELD				CODES
FISHERMAN			1 – 3	
AREA			4 – 6	
LOCATION			7	
YEAR			8 – 9	
MONTH			10 – 11	
DAY			12 – 13	
TIME NETS HAULED			–	
BOTTOM DEPTH			14 – 16	
HEADROPE DEPTH			17 – 19	
NET TYPE	DEEP	SHALLOW	20	
WIND DIRECTION			21	
WIND SPEED			22	
AIR TEMPERATURE			23 – 26	
SAMPLE TAKEN	YES	NO		
SAMPLE NUMBER			27 – 29	
GEAR FISHED – 2"	YES	NO	30	
– 2 1/4"	YES	NO	31	
– 2 1/2"	YES	NO	32	
– 2 3/4"	YES	NO	33	
– 3"	YES	NO	34	
GEAR HAULED – 2"	YES	NO	35	
– 2 1/4"	YES	NO	36	
– 2 1/2"	YES	NO	37	
– 2 3/4"	YES	NO	38	
– 3"	YES	NO	39	

SPECIES	MESH	SPECIES	MESH	CATCH (NUMBERS)	
HERRING	2"	150	22		
"	2 1/4"	150	23		
"	2 1/2"	150	24		
"	2 3/4"	150	25		
"	3"	150	26		
"	MIXED	150	28		

REMARKS: ______________________________

____

____

____

____

Fig. 3: Individual catch rates and stock abundance index for Placentia - St. Mary's research gillnet fishermen, 1982-85.

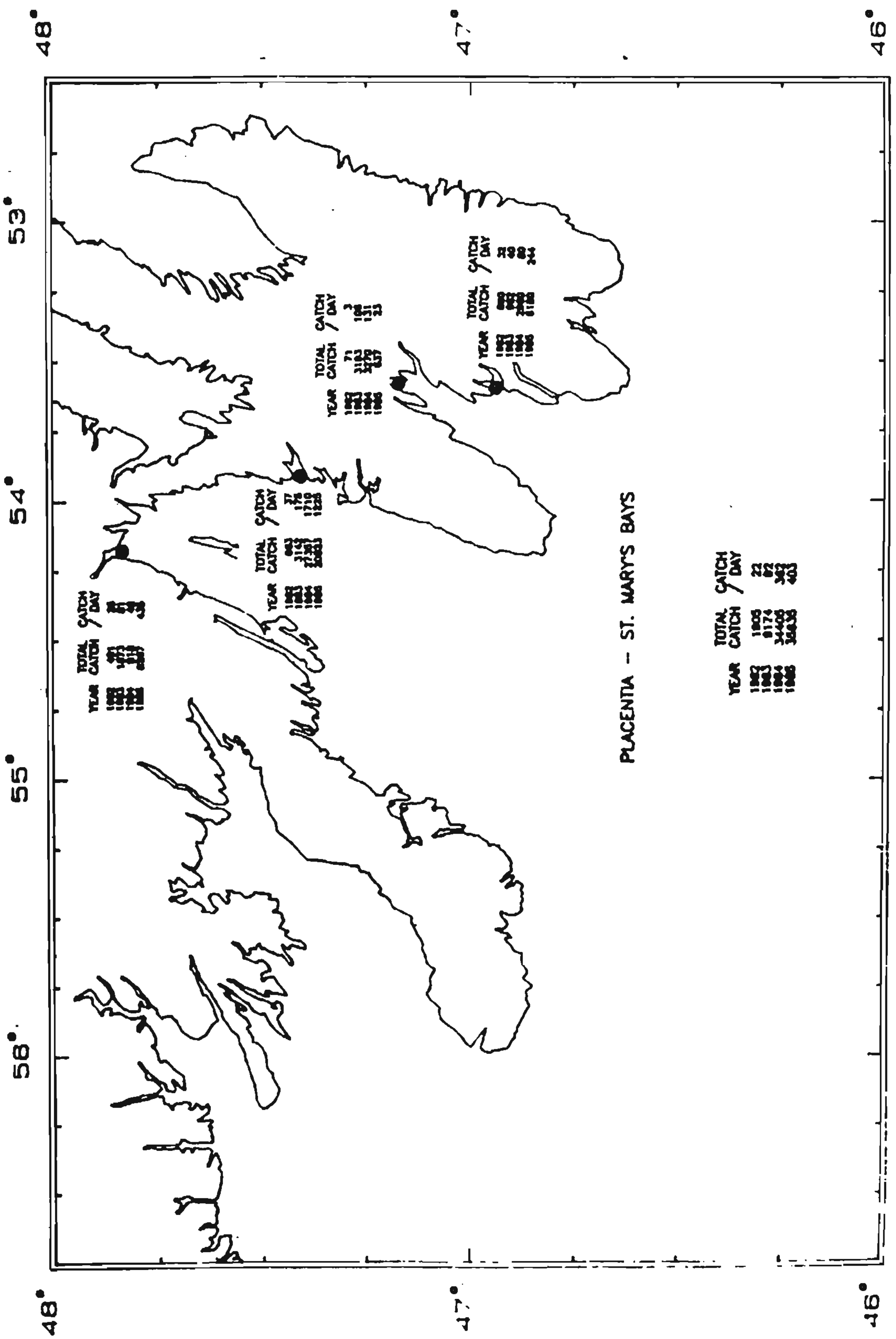
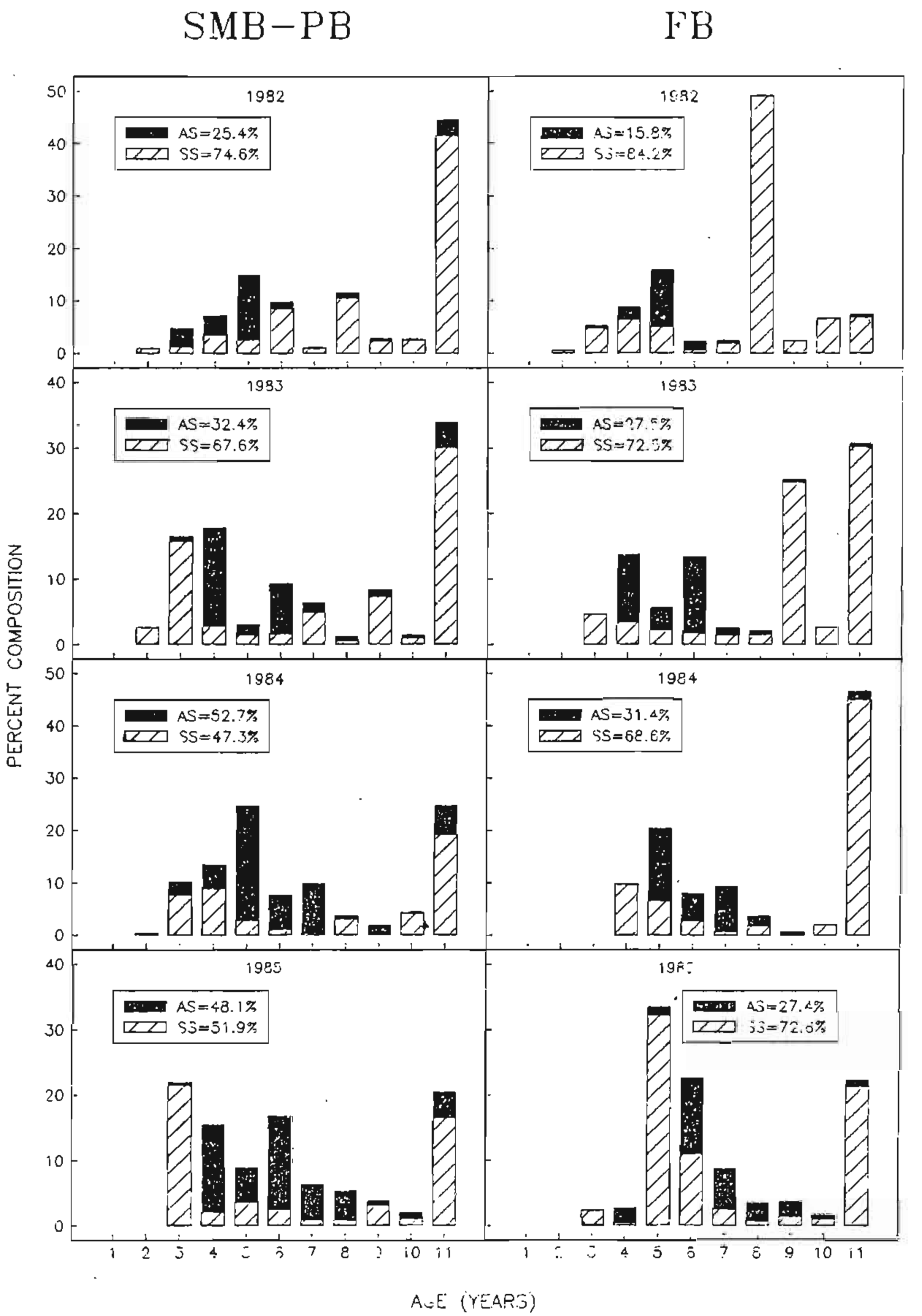


Fig. 4: Age compositions and percentages of spawning types from research gillnet catches, St. Mary's Bay - Placentia Bay, 1982-85.



2.4.2 Acoustic Surveys for Estimating Size of Herring Populations

Ross Shotton
Economics Branch
Scotia-Fundy Region
Department of Fisheries & Oceans
Halifax, N.S.

An acoustic survey is a technique that provides a means of rapidly and directly determining the size of a fish stock at the time the survey is undertaken. Thus for example, the size of a population may be determined acoustically at the start of a fishery, and sometime later when the fishery closes. Estimates of fish stock size obtained from acoustic estimates may be used to formulate advice on what catch quotas should be permitted for a particular fishery given the estimated size of the stock.

There are several requirements essential to undertake an acoustic stock assessment:

(1) The necessary acoustic equipment and a survey vessel,

(2) a fish stock whose behavior and distribution makes it possible to survey it acoustically, and

(3) certain information necessary for interpreting the echo data that are collected in teams.

In the following sections these requirements will be examined in relation to how they affect acoustic assessment of herring stocks in the southern Gulf of St. Lawrence.

2.4.2.1 The Physics of Sound Involved in the Acoustic Technique

Herring fishermen will not put to sea if their fish finding gear, in particular their sonar, is not working. The sonar can indicate not only the presence of herring but, to the skilled operator, the size and density of the herring school. The manner of operation of an acoustic system used for estimating stock abundance is essentially the same as those systems used for finding fish.

A transmitter is used to activate a transducer which results in a pulse of sound radiating out from the transducer. Fish, or anything else whose density (or its acoustic impedance) varies from that of the surrounding seawater will result in an echo, which if its intensity is not too weak, will be detected by the transducer. The transducer converts the sound pulse into an electrical pulse, just as a telephone mouth piece does. The voltage of the induced pulse is proportional to the intensity of the echo pulse arriving at the transducer.

Because the speed of sound in water is well known (it depends in a complicated way on the temperature, salinity and depth), by measuring the time from when the transmitted pulse left the transducer to when the echo was received, the distance of a fish can be determined,

$$\text{i.e.,} \quad \text{range} = \frac{vt}{2}$$

where: v = speed of sound in seawater (1500 m/sec)
t = time

The right hand side of the equation is divided by two as the distance travelled by the sound is twice the range, i.e., there and back.

The acoustic system uses a clock which measures with an accuracy of 100 &secs, i.e., 1/10 000 of a second; hence it can measure the range of a fish from the transducer, with a resolution of 7.5 cm!

With a commercial sonar, the more dense the fish, the brighter the response on the screen, or the darker the mark on the paper recorder. For doing accurate assessments, a scientific system must be able to measure the intensity of the echo, independently of how much gain is being used on the screen or paper recorder. To do this a piece of electronic equipment known as an analogue-digital converter is used: it converts the voltage into a number which can be stored in a computer for later analyses.

While the principal components of a scientific acoustic system are the same as a commercial system, and the physics of how they work is the same, there are some differences in how the equipment is configured. For acoustic surveys the transducer is placed inside a streamlined body so that it can be towed beneath the ship. This reduces the effect of rolling and pitching of the ship on the position of the transducer and reduces the noise from the propeller and waves which would tend to mask the echo of small fishes, particularly when they are at great range from the transducer.

To tow the transducer an expensive coaxial cable must be used, containing wires for conveying the transmit pulse and the echo pulse between the transducer and the acoustic system. As mentioned earlier, a device to measure the "echo voltage" is needed. These values are stored on magnetic tape; all of these operations are controlled by a computer which is the heart of the scientific system.

Because it is important that the results obtained in one year be consistent with those obtained in other years, the acoustic system must work in an identical manner each time it is used. To ensure this, the acoustic system is calibrated at frequent intervals by using a standard target or a standard hydrophone. Should the response of the acoustic system vary, then an adjustment (of the gain) ensures that a fish of the same size produces a voltage of the same level each time the acoustic system is used.

2.4.2.2 Estimation of Fish Density

The first step in determining the amount of fish in a particular area is to relate the intensity of the echoes that are received to the number of fish which are causing them. The echo intensity received at the transducer face is determined by a mathematical relation:

$$I_r = \frac{I_o \, p \, \bar{\sigma}_b \, \Omega_o \, \frac{c\tau}{2}}{R^2 \, e^{2\beta R}}$$

where I_r = intensity of an echo measured at the transducer

I_o = intensity of the transmitted pulse 1 m from the transducer. This is often called the "source level".

p = density of fish, i.e., number per cubic metre

$\bar{\sigma}_b$ = average backscattering cross section of a fish.

Ω_o = equivalent beam angle

$c\tau$ = pulse width of the sonified volume

R = range of the sonified volume

β = attenuation coefficient of sound in seawater

I_o is sometimes called the source level when it is measured in decibel units. It is the intensity of the sound that is transmitted, 1 m from the transducer on the acoustic axis. $\bar{\sigma}_b$ is described as baskscattering because it refers to the sound echoed back to the transducer. It is called a cross-section area because a fish can be considered in terms of the area it represents in scattering sound: it measures the amount of sound which is intercepted by the fish; a bigger fish will intercept more sound than a smaller fish and thus will have a larger cross-section area. The bar tells us we must use the average value for all the fish in the sound beam, i.e., those fish "sonified" by the acoustic pulse. The equivalent beam angle measures the width of the transducer beam. A transducer with a wide beam will have a larger equivalent beam angle than a fish with a narrow beam angle. The term $\frac{c\tau}{2}$ measures the width, or thickness of the transmitted pulse. This distance depends on the speed of sound, C, and the time the transmitter is turned on to generate the pulse, τ . It is divided by two because the sound has to go and return, so the "opponent" pulse width, i.e., that volume from which echoes are retained at the same time, is only half its actual value. The R^2 term in the denominator accounts for the dimunition of the sound intensity as the pulse spreads out as the range increases. The term, $e^{2\beta R}$, describes the decrease in the intensity of the transmitted pulse caused by absorption of sound by the seawater.

If a good estimate for $\bar{\sigma}_b$ exists then the density of fish can be obtained by rearranging the model so that,

$$P = \frac{I_r R^2 e^{2\beta R}}{I_o \Omega_o \frac{c\lambda}{2} \bar{\sigma}_b}$$

Because the density, P, can be determined from the transducer to the seafloor, the number of fish in a column of seawater will be the sum of each P measurement.

$$N = P_1 + P_2 + \ldots + P_d$$

If the survey area is A square meters, then the total number of fish will be:

$$N_{total} = AN$$

2.4.2.3 The Effect of Herring Behavior on Acoustic Surveys

Unfortunately, there is more to undertaking a successful acoustic survey of herring than installing the equipment on a survey vessel and heading to sea. One of the critical elements of a herring survey is knowing well the behavior of the herring. The location of the herring must be known before the start of the survey because usually there is insufficient time to steam all over the Southern Gulf of St. Lawrence to locate the herring before the survey can be started. Fortunately, herring are very regular in their seasonal movements from one year to the next so that in designing the survey a reasonable level of confidence exists as to where herring will be located.

In the Southern Gulf, at the time of the annual survey in November, the major concentration occurs along the coast from Grande Rivière to Newport with small aggregations being encountered further along the coast towards Shigawake. Some schools are also usually found in La Malbaie, about Bonaventure Isle and Gaspé Bay. Our surveys have shown that some, but not many, isolated schools occur about Miscou Island. Scattered schools occur along the northern coast of eastern Prince Edward Island, and along the western coast of the northern part of Cape Breton Island.

In the Sydney Bight another major concentration of herring occurs, though in this relatively small area two separate populations appear to exist along the east side of the Bight. Herring occur from Neil Harbor to south of Ingonish, in some years as far as St. Anne's Bay, but otherwise not south of Wreck Point. These herring have distinct day and night behaviors. At night they move close inshore and disperse forming a band from ½ to 1½ km wide which can extend along the whole coast. During the day these herring form into schools and move offshore. Along the southern part of the Bight, many relatively small schools occur, mainly off New Waterford, but extending along the coast to Flint Island, though with decreasing abundance.

Of course herring don't stop there, and some initial work shows that herring can continue to be found south of Flint Island, in Gabarus Bay and possibly down into Chedabucto Bay.

The planning of acoustic surveys must take account of the migratory behavior of herring. For example, herring move from Chaleur Bay to Sydney Bight. The survey design must ensure that the same herring must not be counted twice. By the same token, the timing of the survey should ensure that all, or as much of the existing stock as possible is surveyed at least once. Because knowledge about the migratory behavior of herring is not perfect, the possibility of either failing to survey part of the population, or counting them twice, must also be kept in mind in designing surveys and interpreting the results.

Migratory behavior of herring can raise another difficulty because different stocks of herring spend some part of the year mixed with herring from different stocks. Herring may be mixed together in spawning areas, and move to different feeding areas. They may spawn in different areas and mix with other stocks in feeding areas. In Chaleur Bay, herring move north to Anticosti Island and to Sydney Bight. In Sydney Bight, herring can be present from the Gulf of St. Lawrence and from southwest Nova Scotia. In these areas, it is not sufficient to simply do an acoustic survey without paying careful attention to reporting the acoustic results from different stocks occurring in the same area, if this is possible!

The most important aspect of a herring's behavior is that the herring must be accessible to the acoustic survey. If the herring, or an important part of the stock, occur near the surface (at least at the time of the survey) then those fish cannot be sonified, and it is not possible to survey them acoustically. If herring move close inshore where it is not possible to safely navigate with the survey boat, then such fish will not be able to be surveyed. Another possible type of behavior by herring has been suggested. Some believe that at times herring spread out along the bottom. If this type of behavior occurs, then such herring will not be distinguishable from the seafloor. These types of behavior emphasize the requirement that if the herring can't be located, either because their location is unknown, or they occur in an area which is inaccessible to the survey vessel, or even if the herring simply avoid the survey vessel as it steams along its survey transects, then all these types of behavior will contribute to error in the final estimates of herring abundance.

2.4.2.4 Relation of Backscattering Cross Section and Herring Aspect

The nature of herring behavior can be important even when the herring can be sonified by the acoustic system. From the mathematical model explained above, it is apparent that the estimate of the amount of herring present in an area depends on $\bar{\sigma}_b$. This value is often expressed in terms of a kg of herring. However, if this value changes, then the estimate that is obtained will be in error. The backscattering cross section will depend on the size of the herring, but more importantly, it will depend on the average aspect of the herring in the sea. If herring always swam in a horizontal mode, then the scattering area they show to the transducer will be the same. However, underwater photographs show that herring swim at all angles, sometimes pointing directly upwards or downwards. In these cases, the cross section aspect in relation to the transducer will be smaller, and if a $\bar{\sigma}_b$ value is used based on observations on herring which swam horizontally, then the amount of herring estimated would be too low. This would be an extreme case. However changes in the variance of the pitch angle, as well as the mean pitch angle, will require that appropriate values be used in estimating the amount of fish from the echo intensity that is measured.

Another aspect of the biology of herring that is important in affecting the backscattering cross section of herring is the state of inflation of the herring's swimbladder. Because the swimbladder is the organ of the fish which contributes the main part of the echo, then the state of inflation of the swimbladder will be an important determinant in how strong the intensity of an echo is from a single herring. If the swimbladder is empty, i.e., if it contains no gas, then the echo intensity from such a herring will be only 10% that of a herring whose swimbladder is full. Thus knowledge of the state of inflation of the swimbladders of the sonified herring will be important in the proper interpretation of the echo intensities that are obtained. At present, this remains a problem to be further researched.

2.4.2.5 Survey Design Requirements

It is not sufficient simply to install the acoustic system on the vessel and head off where the herring are expected to be, and then steam around from one school to another. There must be a pre-designed survey based on rigorous statistical principles. The reason for adopting such a procedure is to ensure that the results from one year must be comparable with the results obtained in other years. To do this, the estimate of the population total must be unbiased, i.e., the expected value of the sample results should be the same as the actual number of herring that occur in the population. Second, the survey should be designed in such a manner so that the precision or variance of the population estimate can be determined. The variance of the estimate gives an indication of the possible error in the population estimate. The variance of the population estimate can only be determined if the survey transects are randomized in a proper manner.

Estimates of the herring population total will vary depending on how the transects are placed in the survey area so it is important to know how confidently one can decide that two population totals are different, say from surveys in two successive years. While two estimates may vary, the difference may be due only to sampling variation, and not because there is an actual difference in the successive population sizes.

Negative bias in a population estimate will occur if part of the population cannot be covered by the survey. For example, if some of the herring occur in very shallow areas, or in some area that is not covered by the survey, then no matter how much survey effort is expended, the final population estimate will be too low. If the bias from this cause is constant from year to year then the population estimate will still provide a good index of population abundance. However, if the fraction of the stock which is inaccessible varies from one year to another, then the population estimate obtained by the acoustic survey may merely reflect changes in availability of the herring population to the acoustic survey, rather than actual changes in the actual size of the population itself. Likewise, changes in the availability of the population may magnify changes in population abundance indicated by the acoustic survey.

Obviously, the more precise an estimate of the total population is, the better. It also seems obvious that an estimate based on one week's sampling effort will be better than an estimate based on only one day's surveying: as the amount of survey effort increases, the better the result will be. How true this is depends on the nature of the distribution of the herring. If the herring are distributed in a highly clumped manner, then the addition of an extra transect may radically change the population estimate if it should pass through the centre of a large aggregation. If the herring were fairly uniformly dispersed, then the population estimate will not change very much as the sampling effort is increased. Yet a further consideration is that surveying is expensive, each day at sea can cost about $3,000. While this value stays constant with time, the improvement in the precision of the estimate will constantly decrease with time. Thus at some point it will not be worthwhile to continue sampling because of the diminishing return in "value" for the sampling effort.

When to stop sampling, or more realistically, how much sampling time is necessary to get a "good" population estimate? This question is still to be researched, despite the self-evident importance of this question. There may even be limitations on how much sampling effort should be expended that depend on the possibility of increasing bias, rather than increasing precision. For example, if sampling continues for an extended period, then the herring may move out of the survey area while sampling continues. Thus the population estimate will be negatively biased - it will be too low.

Solutions to these problems are not simple. However, neither are they so complex that judgement, based on a good understanding of the nature of the fishery and the biology of the herring, cannot provide a good basis for designing a survey that provides useful results. Research should be continued to improve understanding of the nature of these relations.

2.4.2.6 Requirements for Biological Information

Acoustic surveys cannot restrict their activities to steaming acoustic transects. Some of the time spent at sea must be used to collect biological information about the target stock. Directly relevant to the acoustic survey are the sizes of the herring. This is important because the value of the backscattering cross section of the herring depends on the size of the herring: smaller herring have a larger backscattering cross section per kg than do larger herring. But other biological data are important also: it is important to know what fraction of the surveyed population is sexually ripe, or has just spawned. This information is used to estimate the proportion of spring and fall spawners when they occur in the same area at the time of an acoustic survey. Herring that are sampled for sexual condition can also be measured and bones taken for age determination.

Collecting biological information, while necessary, compromises the precision of the population estimates as time must be set aside to take trawl samples; how many trawl samples should be taken is also a matter for further research.

2.4.2.7 Future Possible Innovations in Acoustic Survey Techniques

Acoustic surveys have many attributes as a method used in management of pelagic fisheries. However using research vessels is expensive, because of their size they may be unable to survey in areas where significant amounts of herring are known to occur, and they can only be in one place at a time. This last constraint is important if a rapid survey is essential to ensure that herring are not counted twice by their movement from one part of the survey area to another.

One possible solution to these constraints is for the herring fleet themselves to undertake this survey. In this way a number of vessels can be deployed at once, each allocated a part of the geographical range of the herring to survey. Such an acoustic survey technique has been done in Peru in the anchoveta fisheries where a qualitative survey was termed a "Eureka" survey, i.e., the estimate for the whole population was obtained in one day.

For such surveys to be of use, considerable attention must be paid to the planning and execution of survey transects by the vessels, to ensure that the results obtained by the different vessels were compatible. Each vessel must be equipped with identical equipment, carefully calibrated to ensure that they produce consistent results.

Equipping a fleet of vessels with suitable acoustic systems is not a trivial task. An acceptable acoustic system could cost $20,000 per set. Thus before vigorously advocating a Eureka survey approach, careful cost-benefit analyses are necessary to ensure that the survey costs are not excessive in relation to the benefits of a rapidly obtained survey result.

2.4.2.8 Questions and Comments

Comment:

Acoustic surveys are a direct rather than an indirect method of measuring abundance. There are three necessary components to a good survey:

adequate technology, and idea of where and when to go, and a method of designing the acoustic survey so that results are "good" and comparable from one year to the next.

Acoustic technology and its application must take into consideration the physics of the pulse, the electronics on the boat and the echo that is reflected from the fish. There are a number of factors which must be considered. These are the tilt or position of the fish relative to the sounder, the location of the fish or school relative to the seafloor and thickness of the school, backscattering effects and size of the fish.

Question:

What is the rationale for using transects rather than only targetting on large concentrations of herring?

Response:

To obtain an estimate of biomass a preconceived search pattern and/or survey design approach has to be followed. The autumn acoustic survey in Chaleur Bay was successful in locating and quantifying the herring which were present. Gulf Region Science Branch intends to continue these surveys.

Comment:

There should be acoustic surveys at other times of year, for example Fisherman's Bank in September.

Comment:

Acoustic surveys are not the only source of information on biomass; they have serious limitations.

Comment:

The length of the survey should reflect the precision required by resource managers. The biomass survey of Chaleur Bay should be more intensive. Industry can provide intelligence as to where herring are located.

2.4.3 Spawning Bed Surveys in the Southern Gulf of St. Lawrence

Shoukry N. Messieh
Science Branch, Gulf Region
Fisheries and Oceans
P.O. Box 5030
Moncton, N.B.
Canada E1C 9B6

Surveys of Pacific herring spawning beds on the coast of British Columbia have been carried out on a yearly basis since 1937 with the aim of providing an index of stock abundance. On the Atlantic coast, it was not until 1980 when scuba surveys were initiated in the Miramichi Bay to provide an index of herring abundance for assessment purposes. The aims of this project were to locate and survey the spawning beds, and to obtain data on spawning intensity and spawning stock biomass. Prior to 1980, only one scuba survey of a herring spawning bed (Tibbo et al. 1973) had been carried out in the Bay of Chaleur. This survey, however, was more qualitative than quantitative in nature.

Scuba-diving surveys of herring spawning beds were carried out in the springs of 1980, 1981, 1983, and 1984 and in the autumns of 1985 and 1986 (Messieh et al. 1983; 1984, 1985; Pottle et al. 1981). The spring surveys were conducted on a major spawning ground at Escuminac in Miramichi Bay, N.B., and the autumn surveys were carried out on Fishermans Bank off southeastern P.E.I. (Figure 1). These locations were chosen because they are the centers of major herring fisheries in the southern Gulf of St. Lawrence. These surveys provided information on substrate characteristics and allowed estimation of the sizes of spawning beds and intensities of egg deposition.

2.4.3.1 Locating the Spawning Beds

On the basis of information from local fishermen, gillnet distribution and maturity stages of the herring catch, the biologist identifies the general area of the spawn. Scuba divers then carry out dives at regular intervals along a search grid. Each dive is of 3-5 minutes duration and consists of a quick descent to the bottom along the anchor cable and a search of the substrate within a radius of 4-5 m. Data on depth, substrate type, algal species present, and percent cover are recorded at each station.

Once the spawn is located, the spawning bed boundary is determined by divers swimming in transects from the central area of the bed. When no more eggs are found on the substrate, the divers continue on for a few more meters, then surface and obtain a buoy from the tender. The buoy is placed at the last location in which eggs are found. The locations of the boundary marker buoys are determined by LORAN C. In 1986, an underwater video camera was used to assist divers in the search for spawning beds. This technique drastically reduced the searching time. Delineation of the perimeter of the spawning beds by the video camera was much faster than "bounce" diving. Moreover, instant pictures of the spawn received on the monitor on board of the vessel were readily available for review and replay.

2.4.3.2 Description of Spawning Beds

The substrate of the spring spawning bed at Escuminac can be described generally as rocky with sandy patches covered with seaweeds. Irish moss was the dominant macrophyte in the area, followed by rockweeds and leafweeds. Eggs were found mostly on algae, but also on exposed bedrock. Herring eggs were distributed over a depth range of 0.8 - 5.0 m, with the largest concentrations in 1.5 - 4.0 m. The lack of eggs deeper than 5 m was probably due to the sandy bottom and lack of vegetation. The attachment of a high proportion of the eggs to Irish moss was probably due to the widespread distribution of that seaweed rather than to a preference for it by herring.

The substrate of the autumn spawning bed on Fishermans Bank consists mostly of bedrock mixed with cobble. The algal cover is negligible and mainly composed of filamentous red algae. Herring eggs were distributed over a depth range of 10-25 m, and unlike the spring spawning, the eggs were evenly distributed in the form of a thick carpet.

2.4.3.3 Egg Density

After mapping the perimeter, a sampling grid is plotted on the spawning bed with stations about 200 m apart. Some stations are taken outside the bed as a check on the accuracy of boundary determination. At each station the diver collects a random sample (0.25 m^2) of the herring deposit, using an airlift operated by compressed air from the diver's tank. The airlift propells loose material and eggs scraped from the substrate into special bags. In case of heavy egg deposition, the airlift is not used, and the samples are cut out of the egg sheet within the quadrat. Sample bags are labelled and preserved for laboratory examination. Some fresh egg batch samples are incubated in a recirculated sea water system for further observation of their development.

Estimates of egg counts are made from dried samples. Eggs are thoroughly cleaned from gravel and then placed in an oven (60°C) to dry for about 16 h to a constant weight. Subsamples of eggs are accurately weighed and counted to estimate the total number of eggs per quadrat. Two to three counts are usually taken for validation, and differences in count do not exceed 1%. Egg density is expressed as number of eggs per m^2.

The size of the spawning beds and the density of egg deposition varied greatly (Table 1). In 1980, the spring-spawning areas in Huckleberry Island, Miramichi Bay was 87,500 m^2 and egg density was 8,600 eggs/m^2. In 1981, the spring-spawning area in Escuminac was only 42,500 m^2 and egg density was very low at 1,760 eggs/m^2. In 1983, the single spawning bed was 20 times larger than in 1981 and egg density was also much higher at 24,700 eggs/m2. In 1984, spawning was distributed over three beds (Figure 2) with a total area exceeding 2,000,000 m2, and mean egg density (80,000 eggs/m2) was more than 3 times higher than in 1983.

Egg density was much higher in the autumn-spawning beds on Fishermans Bank (Table 1). In 1985, egg density was extremely variable among the four autumn-spawning beds, but, nevertheless, egg deposition was very high with the average intensity being 3,560,000 eggs/m2. Total area off the four spawning beds (Figure 2) was 1,821,000 m2. In 1986, the single spawning bed was 1,100,000 m2, which was about 60% of that in 1985. Egg density was slightly higher at 3,800,000 eggs/m2. In the two years of observation, egg densities were much higher than had been observed on the spring-spawning grounds.

2.4.3.4 Estimating Number of Spawners

From estimates of size of spawning beds and egg densities, the number of spawners are estimated. This requires the knowledge of fish fecundity, proportion of males and females in the population, catch composition and mean weight-at-age of herring. Estimates of the number of spawners in spring- spawning population in Escuminac (Table 2) showed a sharp decrease in number of spawners in 1981. This could be attributed to the dredging of the Miramichi shipping channel which began near the spawning bed in late April 1981, and the possibility of interfering with the movement of herring schools. In 1984, number of spawners were about 8 times higher than those in 1983.

In the two years of observation, number of spawners of autumn-spawning population was much higher than those of spring-spawning population (Table 2). The highest value was in autumn 1985 when an estimated 89.5 million spawners deposited their eggs on Fishermans Bank spawning bed.

2.4.3.5 Incubation Period

In all 4 years of observation, spring spawning at Escuminac occurred during the first 3 weeks of May, and egg deposition varied from scattered eggs to patches which were 1-5 layers thick. The incubation period varied from 14 to 19 days, depending on water temperature which ranged from 3.3°C to 9.7°C during the spring surveys.

In the two years of observation, autumn spawning on Fishermans Bank occurred in waves during September 4-26. Herring eggs were distributed evenly like a thick carpet. The incubation period lasted from 7-10 days, depending on water temperature which ranged from 14.0° to 17.0°C during the autumn surveys.

2.4.3.6 Egg Mortalities

Mortalities of herring eggs are caused by natural causes, i.e. egg development failure, and by fish predation. Samples of herring eggs for examination of developmental stages were collected prior to and during the quadrat sampling. After deposition on substrate, herring eggs pass through 5 stages of development until they hatch. Examination of egg developmental stages showed a difference in egg moralities between spring-spawned and autumn-spawned herring. In the 4 years of observation in Escuminac the natural mortalities of eggs did not exceed 10%. In contrast, natural mortalities on Fishermans Bank in 1985 exceeded 90%. The high egg mortalities were attributed to high density of egg deposition (up to 30 layers of eggs; 4.5 cm thick).

Fish predation on herring eggs contributes to high rate of egg mortalities on the spawning bed. Analysis of stomach contents revealed that various fishes feed on herring eggs. These are winter flounder, sculpins, Atlantic cod, cunner and for the first time recorded, Atlantic mackerel. In spring, winter flounder was the major predator. The mean number of herring eggs per stomach was 1,530, 3,500 and 6,500 in 1981, 1983 and 1984, respectively. Estimates of egg mortalities due to predation ranged from 30% to 69% of the total egg deposition in the three years of observation. In fall, winter flounder and Atlantic mackerel were the major predators of herring eggs. Mean number of herring eggs per stomach was 7,600 and 3,900 for the two species, respectively. Minimum total predation on herring eggs was estimated at 30% of egg deposition.

2.4.3.7 Questions and Comments

Question:

What factors determine location of beds?

Response:

Most important is geographic location and depth.

Comment:

No. of eggs cannot predict recruitment but are useful for estimating size of spawning stock.

Comment:

Egg layers thicker than 1/2" - 3/4" result in heavy mortality of eggs.

Question:

Where was heaviest concentration of spawn?

Response:

At 45' depth on west shore of Fisherman's Bank.

Question:

Spawning bed survey in Chaleur Bay when will DFO look in this area?

Response:

We intend to start in 1988.

Comment:

Activities of fishing fleet may affect spawning behaviour of herring and result in heavy concentrations of herring spawn. This aspect is not known.

Comment:

Spawning bed survey, focussing on thickness of egg layers could be used as an index of recruitment.

Comment:

More activities should be focussed on Chaleur Bay spring and fall spawning beds.

Question:

Why does milt remain well defined in the water column for such a long time, up to several days?

Response:

We do not know.

Table 1. Size of herring spawning beds and intensity of egg deposition in major spring and autumn spawning locations surveyed by SCUBA diving in the southern Gulf of St. Lawrence, 1981-86.

Season	Year	Location of Spawning Beds	Spawning Area (10^3 m2)	Egg Intensity (NX10^3 m2)
Spring	1980	Huckleberry Is.	87.5	8.6
	1981	Escuminac (1)	30.0	2.0
		Escuminac (2)	12.5	1.2
	1983	Escuminac	880.0	24.7
	1984	Escuminac (1)	560.0	85.9
		Escuminac (2)	445.0	34.2
		Escuminac (3)	1,100.0	95.8
Autumn	1985	Fishermans Bank (1)	286.0	2,590.0
		Fishermans Bank (2)	489.0	250.0
		Fishermans Bank (3)	239.0	4.7
		Fishermans Bank (4)	807.0	6,960.0
	1986	Fishermans Bank	1,100.0	3,800.0

Table 2. Mean number of spawners in spring-spawning population in Escuminac, and autumn-spawning population in Fishermans Bank.

Year	Season	Number of Spawners
1980	Spring	29,400
1981*	Spring	3,500
1982	no survey	---
1983	Spring	930,000
1984	Spring	7,650,000
1985	Autumn	89,500,000
1986	Autumn	58,200,000

* Miramichi Bay dredging operation.

Fig. 1: Spring and autumn spawning grounds in the southern Gulf of St. Lawrence. Locations of spawning bed surveys are circled.

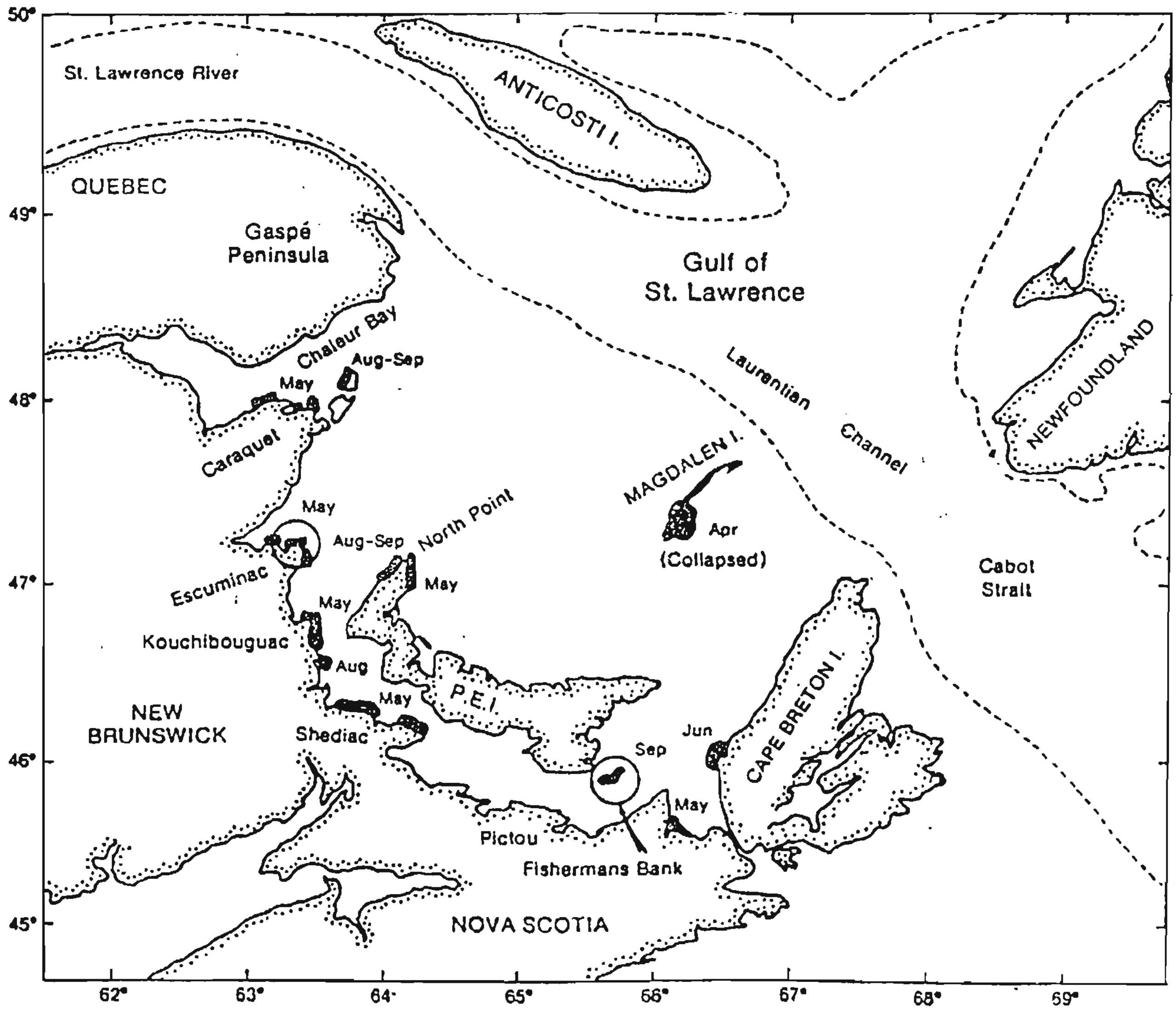
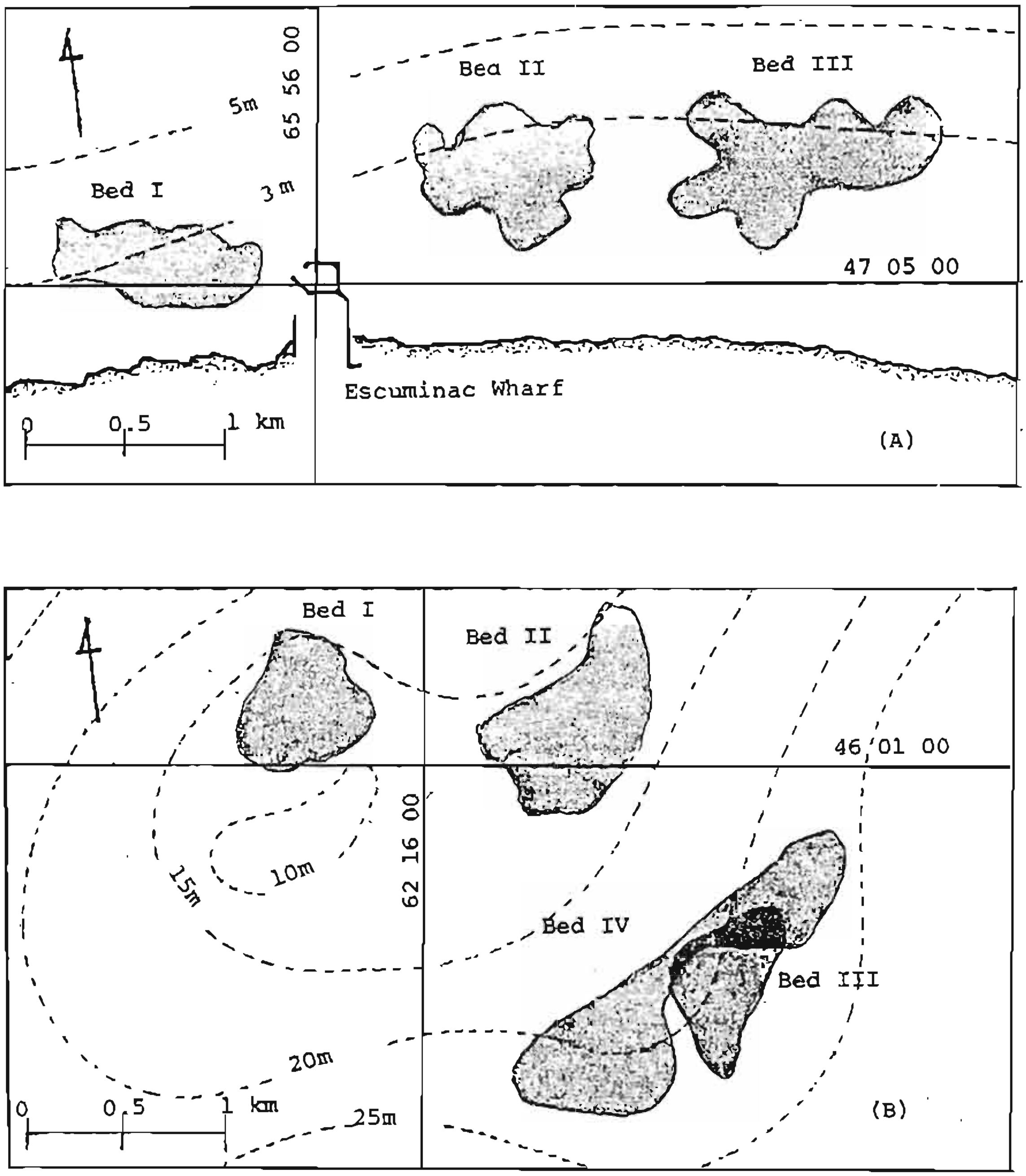


Fig. 2: Herring spawning beds surveyed by Scuba divers:
(A) Escuminac, spring 1984;
(B) Fishermans Bank, autumn 1985



2.4.4 Larval Surveys as Potential Indices of Abundance

Robert L. Stephenson
Science Branch, Scotia-Fundy Region
Department of Fisheries & Oceans
Biological Station
St. Andrews, New Brunswick EOG 2XO

2.4.4.1 Introduction

Herring lay demersal eggs (on the bottom) which hatch after about a week into larvae approximately 5 mm in length. Larvae are planktonic (floating or swimming) for several months before assuming their herring-like appearance and becoming "brit". During the planktonic, larval phase, herring are easily captured using fine-mesh (0.5-mm) nets. A standard oblique tow for 10 min at a speed of 3.5 knots samples herring larvae in the entire water column.

Herring are assumed to home to particular spawning areas. The larval distributions correspond to spawning areas and appear to remain aggregated in these areas for some time. These features, when combined with the fact that larvae are easily sampled, have attracted considerable attention to the larval stage as a potential indicator of stock size.

Two general approaches have been taken: larval abundance has been used both to forecast future recruitment and to hindcast parent stock size. The steps involved in both approaches are outlined in Figure 1. The forecast approach projects from larval numbers to the resulting juvenile and adult fish in the future. The hindcast method works back from larval numbers, through estimates of egg numbers to spawning stock size. In both cases, the result may be an actual number of spawners or of recruits or a relative index which may then be used to "tune" or otherwise validate analytical stock assessments.

The two approaches have different assumptions and require sampling during different times of the larval phase (Figure 2). Recruitment forecasting assumes that year-class strength has already been determined, or that subsequent mortality factors are constant from year to year. It requires that a larval survey is done late in the larval stage. Hindcasting spawning stock size from larval abundance assumes constant hatching rates from deposited spawn and constant early larval mortality rates. It requires that a larval survey is done early in the larval stage.

2.4.4.2 Methods

A larval herring survey has been carried out in the Bay of Fundy and eastern Gulf of Maine (Figure 3) each year since 1969, and with standardized procedures since 1972. Since 1981, a larval abundance index from this survey has been used in the hindcast approach to tune cohort analysis for the 4WX herring assessment.

The standard survey of 112 stations is undertaken during late October and early November each year. An oblique tow using paired 61-cm bongo nets (.505 mm mesh) equipped with digital flow meters is made to within 5 m of the bottom at each site. Larval herring are picked from preserved plankton samples, identified, counted and measured. Larval numbers are expressed volumetrically on the basis of the measured volume of water filtered by the net in each tow as the number of larvae per cubic meter and are converted to the numbers beneath a square meter of ocean surface based on the depth at each station. The resulting map of distribution (e.g. Figure 4) shows a consistent aggregation of larvae each year off southwest Nova Scotia in the vicinity of the major spawning grounds.

An abundance index is calculated as the geometric mean of larval density (number m-2) for the standard set of stations. The historical series of larval abundance values is plotted against estimated spawning stock size (as in Figure 5) during the assessment tuning process (see Section 2.5).

2.4.4.3 Questions and Comments

Question:

Have there been larval surveys in Gulf?

Response:

There is a 10 year data set 1965-75, but this time series was designed to look at cod larvae and therefore is not suitable as an abundance index of herring.

Comment:

Navicula has collected herring larva in St. Géorges Bay. This study was very restricted and only a short time span.

Question:

Are larval surveys a useful direction for 4T herring?

Response:

Because they are only useful for predicting the size of spawning stock, they would duplicate our work on spawning surveys, therefore, they would appear to be less useful in the Gulf.

Fig. 1: Potential estimates of abundance from larval herring abundance surveys.

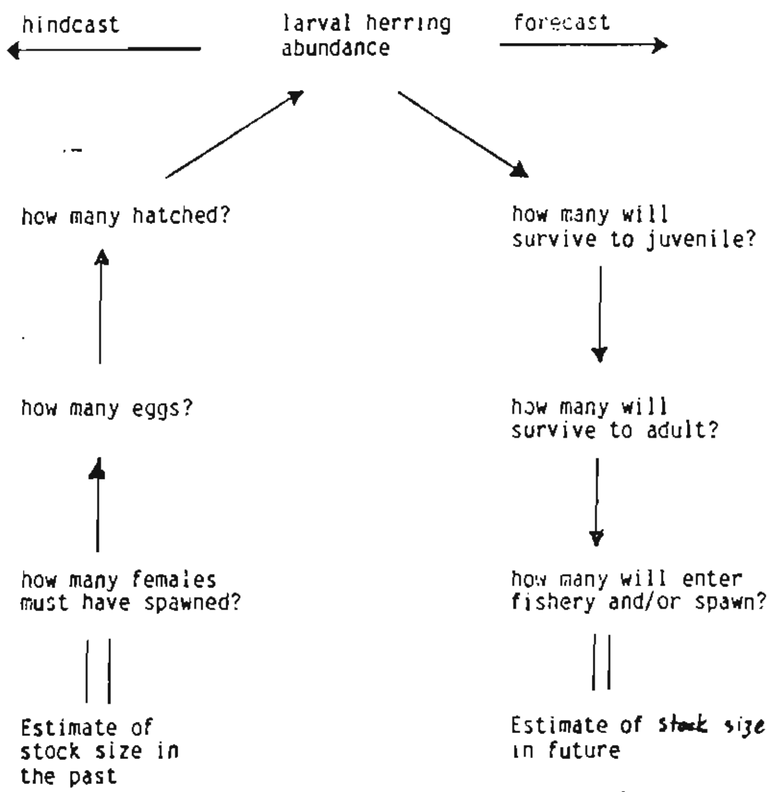


Fig. 2: Schematic representation of the effect of larval survey timing on relative ability to hindcast spawning stock size and to forecast recruitment to the fishery.

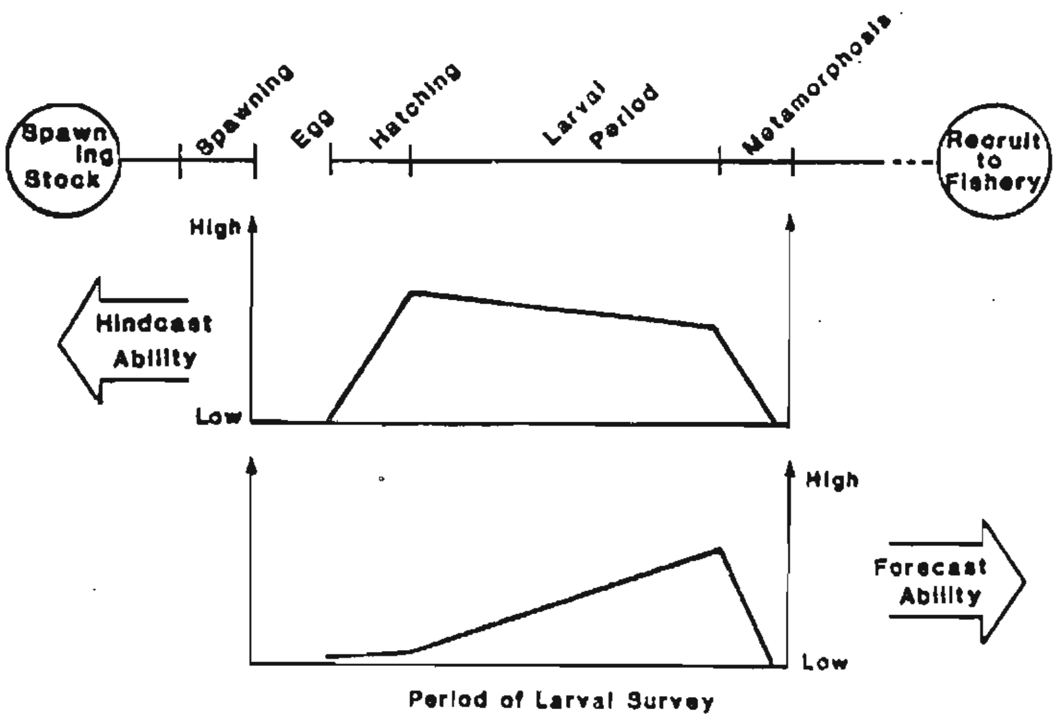


Fig. 3: Station coverage, Bay of Fundy larval herring survey, 1972-85.

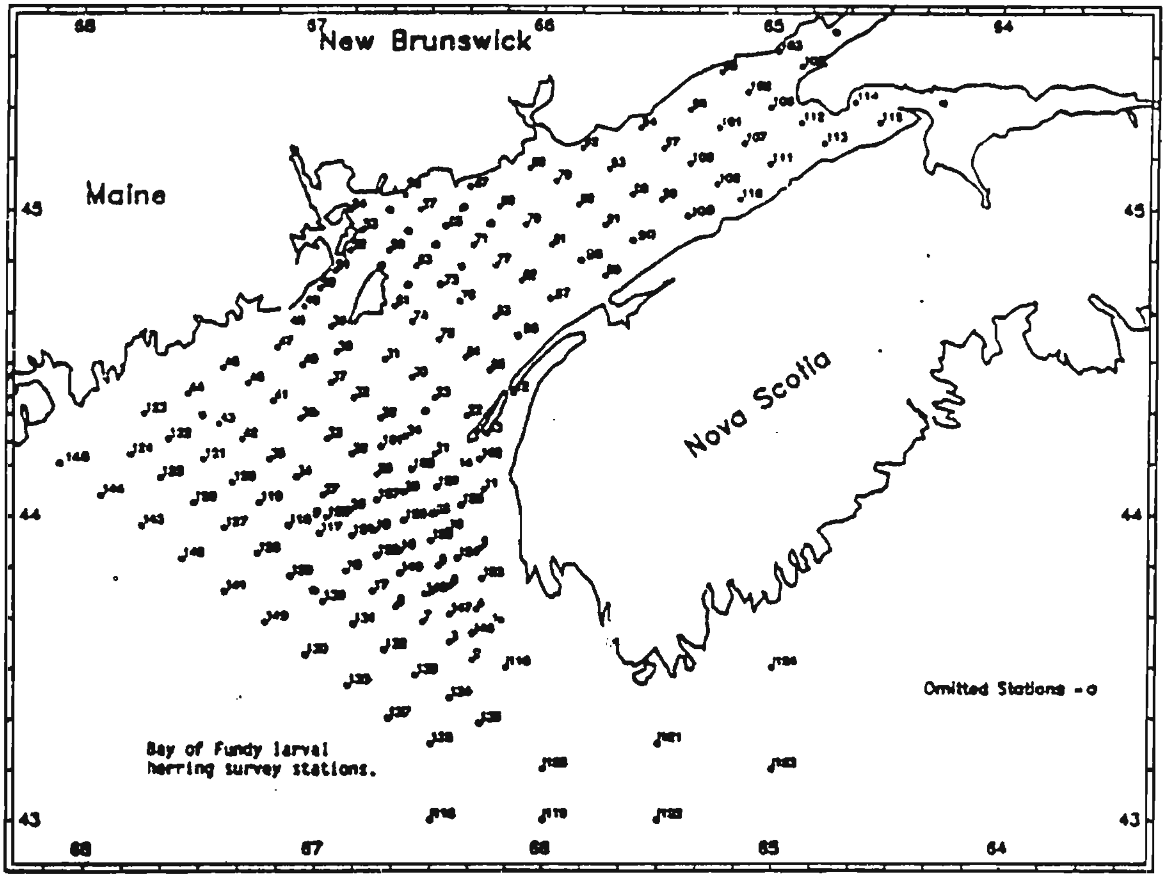


Fig. 4: Distribution of larval herring density (number per m2 to bottom) from 1985 Bay of Fundy larval herring survey.

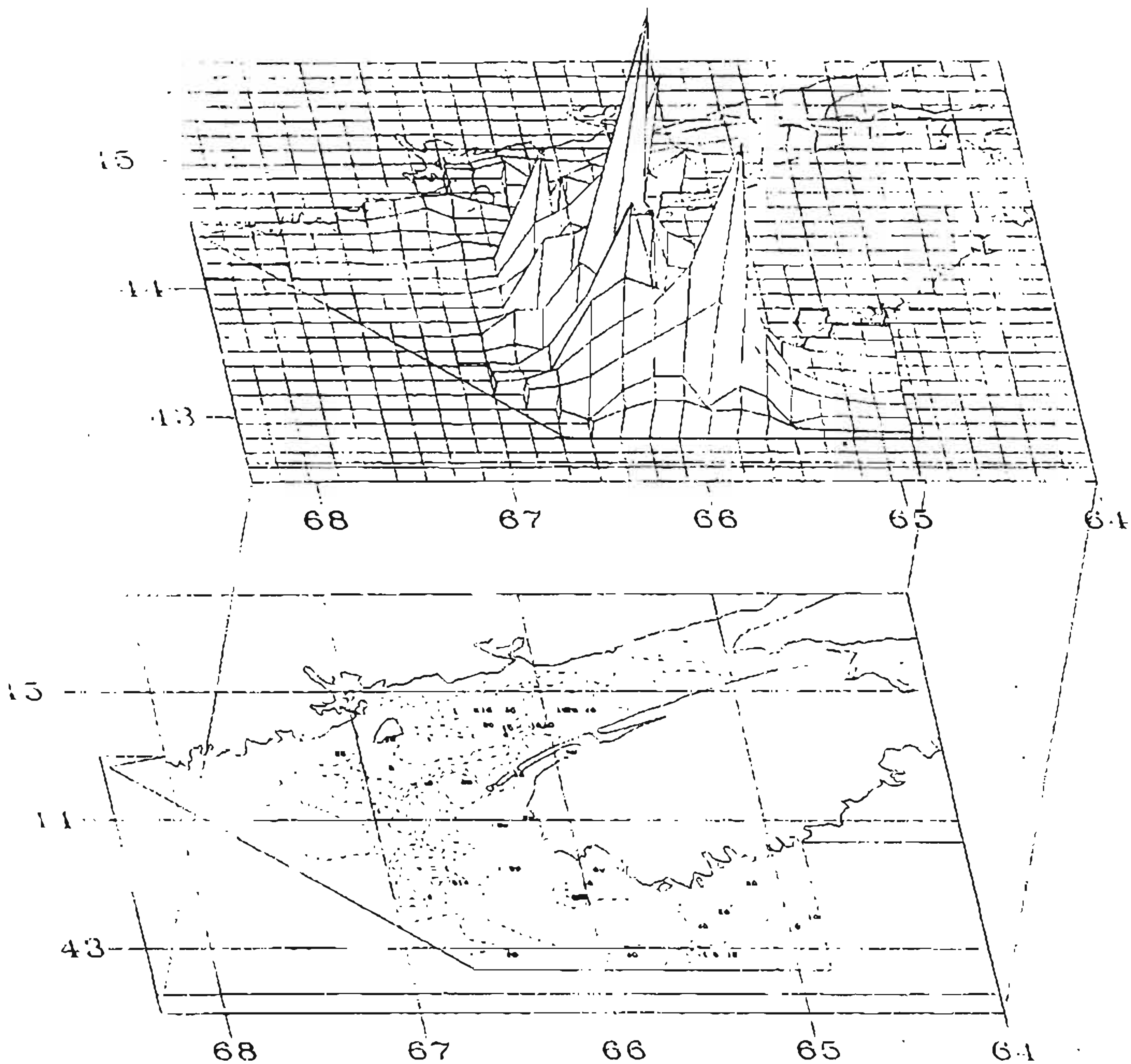
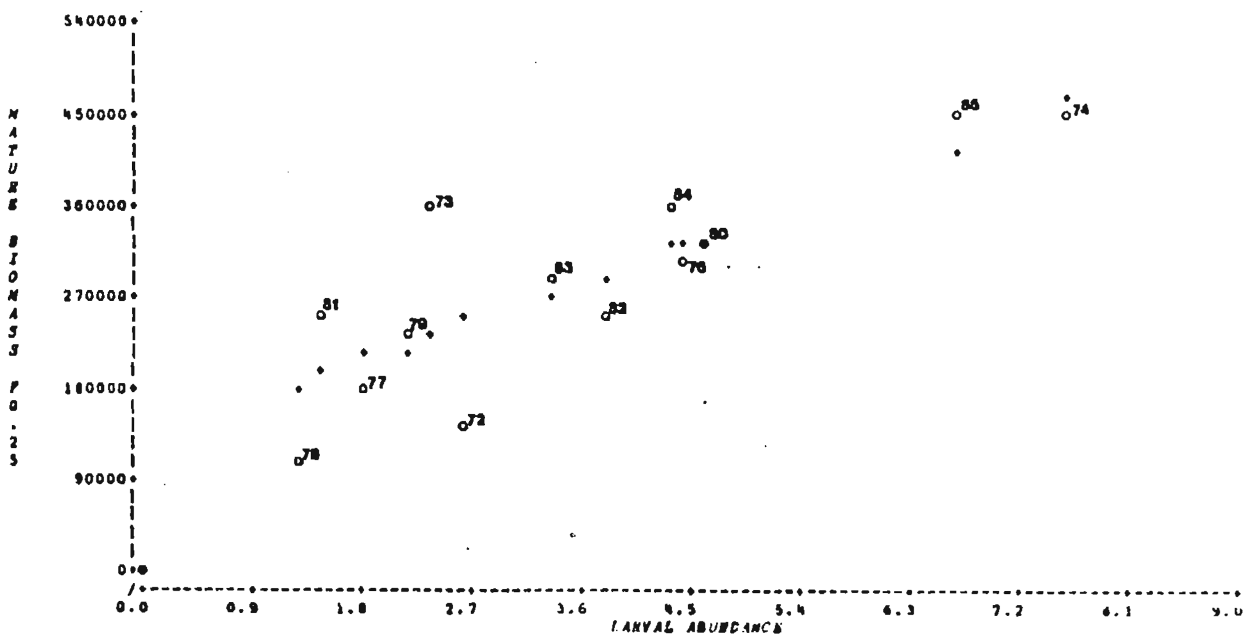


Fig. 5: "Tuning" plot of 4WX herring biomass vs larval abundance 1972-85.



2.4.5 Logbooks in Bay of Fundy

Michael J. Power and Robert L. Stephenson
Science Branch, Scotia-Fundy Region
Department of Fisheries & Oceans
Biological Station
St. Andrews, New Brunswick
EOG 2X0

2.4.5.1 Introduction

Previous sections have stressed the importance of accurate commercial fishery information to the stock assessment process. Fishing vessel logbooks are potentially one of the most valuable sources of such information. Logbooks, if properly designed and completed, can provide a complete and detailed description of the fishery, including amount caught, location and effort expended. The importance and use of logbook in compiling catch information are discussed in Section 2.2 and will not be dealt with here, except to point out that logs are potentially valuable in documenting "total" as opposed to "landed" catch (i.e. documentation of fish released), and in allocating or splitting up catch among smaller unit areas.

Another potential use of logbook information in assessment is through abundance indices based upon catch and effort (i.e. search time) information, or catch per unit effort (CPUE). Based upon the premise that fish should be easier to catch when they are more abundant, the catch rate (or catch per unit of fishing effort) should vary in response to changes in abundance.

In this section we discuss aspects of a new logbook introduced recently into the 4WX fishery purse sein fishery, including a variety of potential CPUE indices.

2.4.5.2 Development of the 4WX Purse Seine Logbook

Purse seiners dominate the large 4WX herring fishery. For several years the fleet has been allocated 80% of the TAC and, in 1985, the 41 active vessels recorded total landings of 101,337 t - 90% of the 4WX stock catch (Stephenson et al. 1986). The potential of this segment of the fishery to affect the stock structure and parameters used in assessment (particularly CPUE indices) is obvious.

While a considerable amount of data had been collected routinely from the 4WX purse seine fishery, the quality and quantity of this information had not always been adequate. As part of an effort to improve the quality of biological information, a new purse seine logbook was designed (Figure 1) and implemented for the 1985 4X summer fishery. Several logbook formats had been in use in the 4WX fishery prior to 1985, but these formats lacked places for information on a number of important activities for the herring purse seiners, especially searching time. The revised log had several improvements, including fields for search time, markets sought and specific details on sets. All of this information was laid out on one page for each trip or fishing night. At the same time, several operational initiatives were put into effect, including submission of logs on a weekly basis as a condition of license, which reduced misreporting and improved logbook return. All logs were interpreted and coded by Fisheries and Oceans personnel familiar with the herring fishery. The result was a significant improvement in the amount of catch information from the purse seine fishery (further details of logbook development and analysis are available in Power and Stephenson 1986).

Log coverage for the first year (1985) was excellent; 1,802 logs (nights) were received from all 41 active vessels, representing 2,295 sets and accounting for 96% of the landed weight of fish. Logs were generally complete and decipherable. The new form was completed well for location (96%) and catch (84%).

After initial analysis of the 1985 data, feedback was provided to the participating skippers, including: 1) a summary of their particular log data, and 2) a summary of performance by the entire fleet.

2.4.5.3 CPUE Analysis

The 1985 log information allowed the calculation of several indices of CPUE expressed per set (i.e. catch per set), per hour and per day. Values from a single year are of no use as an abundance index. To be of use, comparable statistics for a series of years are required. Even with a series, there is evidence that purse seine CPUE indices are suspect because of variable catchability of pelagic fishes with changing school size and because of the impact of fleet dynamics on catch rates. However, we believe that a useful CPUE series may be possible, and are continuing to gather logbook information for a time series. In addition, the detailed logbook documentation of spatial aspects of the fishery has proven to be critical in the formation of the catch table for the 4WX herring fishery assessment process. The energy required for collection and analysis of the logbooks is worthwhile for this reason alone.

Contribution of logbook information is a means by which members of a fishery can contribute significantly to the assessment process. Logs, as has been discussed, are potentially very valuable. However, the logbook data set is only as good as the quality of the logbook information provided. Its use requires the cooperation of the fishery.

2.4.5.4 References

Power, M.J., and R.L. Stephenson. 1986. An analysis of logs from the 1985 4Xa summer herring purse seine fishery. CAFSAC Res. Doc. 86/44: 35p.

Stephenson, R.L., M.J. Power, and T.D. Iles. 1986. Assessment of the 1985 4WX herring fishery. CAFSAC Res. Doc. 86/43: 46p.

2.4.5.5 Questions and Comments

Question:

What is the value of recording set time and sonar time in log books?

Response:

To establish actual fishing or searching time, set time is subtracted from sonar time.

Question:

Is it true that seiners in southwest Nova Scotia under-reported in the early part of the season and then over reported late in the season so that they would achieve their quota.

Response:

We do not know.

Question:

Will misreporting affect usefulness of logs?

Response:

Yes. One solution would be select logs from reliable fishermen.

Comment:

Seiners log books are not used by Statistics Branch to monitor quotas or to calculate total landings. The log books are sent directly to the biologist.

Question:

Is there observer coverage on sieners in southwest Nova Scotia?

Response:

Not today, but there was several years ago.

Comment:

We should discuss the possibility of observers onboard seiners in 4T.

Fig. 1: Revised 4WX logbook as introduced for the 1985 4Xa summer purse seine fishery.

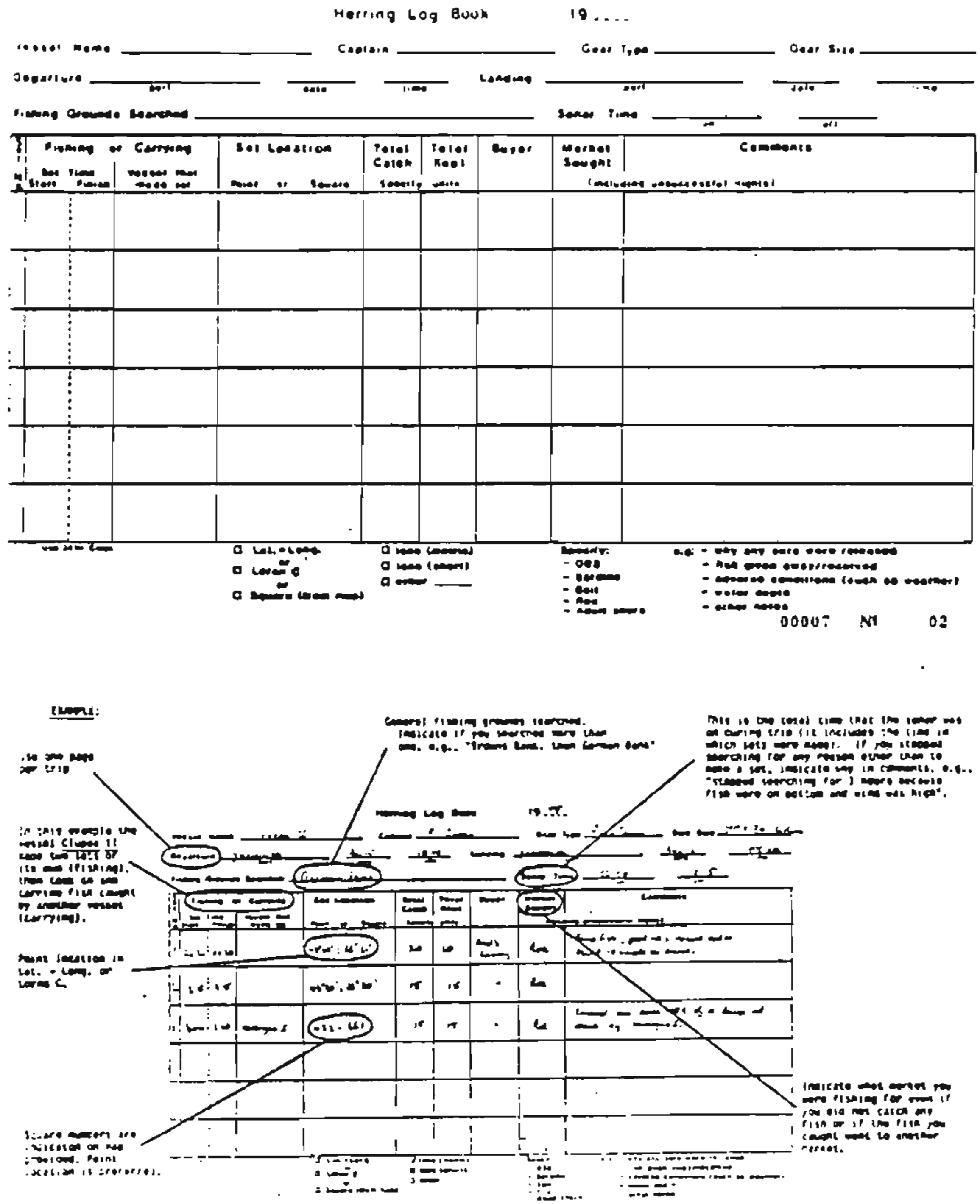


Fig. 2: General statistics on CPUE variables for the 1985 4Xa summer purse seine fishery.

Fig. 2. General statistics on CPUE variables for the 1985 4Xa summer purse seine fishery.

Variable name	Number of observations	Mean	Standard deviation	Minimum	Maximum
Total catch (mt) per trip	1802	46.2	38.1	0	562.5
Kept catch (mt) per trip	1802	44.6	35.0	0	224.0
Released catch (mt) per trip	1802	1.6	14.7	0	471.7
Total trip hours per trip	1494	12.2	3.9	1.0	36.0
Total search hours per trip	1177	4.4	2.8	0.1	14.5
Catch per hour (mt)	994	26.6	41.8	0.2	590.0*
Catch per set (mt)	1539	41.2	25.1	0.9	187.5
Release per hour (mt)	44	13.0	18.6	0.3	113.4
Release per set (mt)	68	26.3	25.6	0.6	157.2
Kept per hour (mt)	980	26.4	41.8	0.2	590.0*
Kept per set (mt)	1519	40.6	24.4	0.9	164.2
Sets per hour	1054	0.6	0.7	0.1	10.0

*Result of one set with 0.1 h searching and a catch of 59.0 mt.

2.4.6 Fishermen Surveys: Gillnetters in the Gulf of St. Lawrence

Gloria Nielsen
Science Branch, Gulf Region
Department of Fisheries and Oceans
Moncton, N.B.

2.4.6.1 Historical Index of Abundance

For the gillnet herring fishery in the southern Gulf of St. Lawrence, the index of abundance that has been used in the assessment process since 1981 is catch per net. This is composed of two parts: catch per trip from the purchase slip information, and the number of nets per trip from surveys of gillnetters. One set per trip is assumed; one trip per day is assumed; and only information for those gillnetters selling at least 50% of their catch to processors is included. In addition, the index for the fall fishery includes only the Acadian Penninsula, while the spring index includes all of New Brunswick, as well as most of the gillnetters from western Prince Edward Island.

2.4.6.2 History of the Gillnetters Survey

In 1978 and 1979, Bob O'Boyle and Lynn Cleary intensively surveyed the herring gillnetters in the Atlantic provinces to determine background information on the southern Gulf of St. Lawrence fishery. Information was collected both from dockside interviews of gillnetters, and from mailed questionnaires sent to all licenced gillnetters in the three provinces. A total of 174 gillnetters were interviewed, and 888 questionnaires out of 3,339 were returned. Information was collected for the period 1970-1979 and included the spatial and temporal distribution of the fishery; characteristics of the gear used in the fishery; number of days spent fishing, and number of nets used; use of the catch; and some characteristics of the herring population. The historic abundance index for the gillnet fishery was developed from this survey.

In 1982, Cleary again sent questionnaires to all licenced gillnetters in the Atlantic provinces to determine the same kinds of information for the period 1980 to 1982, concentrating on the distribution and intensity of fishing effort. More than 3,600 interviews were sent out, and 1,055 completed forms were returned. The data were summarized using different areal breakdowns of the information, making direct comparisons of this survey with the previous one difficult.

Martin Ahrens, in 1983, surveyed 162 gillnetters for information about the sizes of mesh used in the fishery and the distribution of these mesh sizes. From information of this survey, and informal discussions with the gillnetters over the next couple of years, he determined that the distribution of mesh sizes and the number of nets fished did not vary significantly in the period 1982 to 1985.

In 1985, however, the herring gillnetters in the 4T area asserted that the number of nets they fished had changed from that in the early 1980's, and that the constant effort that we were using for assessment purposes caused a serious underestimation of the herring population sizes. The Marine Finfish Division, therefore, designed a survey to test this out.

There were several objectives of the survey:

1. Determine the distribution and intensity of fishing effort for herring during 1983 to 1985.
2. Determine, for 1985, the sizes and distribution of mesh used.
3. Calculate the percentage of herring catch that was accounted for by purchase slips in 1985.

A systemmatic random sample of active licensed herring gillnetters from the Maritime provinces plus Quebec was chosen, and these gillnetters were interviewed in person. In total, 310 gillnetters were interviewed. The results were summarized by the eight areas which had been identified as "major" fishing areas (Figure 1), and then combined to produce an overall picture for 4T. The summary areas did not correspond to any used in previous surveys, making comparisons difficult. The data were recombined, however, to update the historical abundance index. This did in fact verify the assertions of less effort in recent years.

2.4.6.3 The 1986 Gillnetters Survey

A survey similar to that in 1985 was carried out in 1986, with a few modifications: the interviews were held by telephone; nobody from the Magdalen Islands was interviewed; and the sample was chosen in a somewhat different manner. The general objectives of the survey were the same as those in 1985, with information being collected only for th 1986 fishing season.

To choose an unbiased representative sample of all gillnetters fishing for herring in the southern gulf, we first compiled a list of all the licensed gillnetters. There were four times as many licensed gillnetters as there were fishermen who actually fished in 1986 (Table 1), so, for the Maritime provinces, we got a list of the CFV numbers of all the boats for which purchase slips had been submitted. This list, which was sorted by home port, was used to choose a systematic random sample of more than 400 gillnetters. The CFV numbers were cross-referenced with the list of licenced gillnetters to get the telephone numbers and addresses of the selected sample. For Quebec, we chose a random sample from the list of licensed gillnetters. In total, 342 interviews from gillnetters actively fishing in 1986 were completed. The summary of the sample size by area is shown in Table 2.

2.4.6.4 Results of the 1986 Survey

Comparisons of the fishing effort for 1984-1986 are shown in Figures 2 to 7. Since 1984, the number of nets fished in the spring fishery has increased in Escuminac and southeast New Brunswick, and decreased in Quebec and west P.E.I. In the fall fishery, the number of nets fished has decreased in Nova Scotia and all of P.E.I. The number of days fished has generally decreased in the spring fishery except in southeast New Brunswick and west P.E.I. The number of days fished in the peak of the fishery in the fall has generally decreased, but the number of days in the non-peak has not shown a trend since 1984.

Three indices of effort were calculated and compared to those from the 1985 survey:

1. The average number of net-hauls per gillnetter.
2. The average number of net-hauls per trip.
3. The average number of net-hauls in each fishing area.

In the spring fishery, the three indices are consistent for the Acadian Penninsula, southeast New Brunswick, Nova Scotia, and west P.E.I. for the three year period (Fig. 6). In Quebec, Escuminac, and east P.E.I., the indices do not show similar trends. An overall Gulf index for the spring fishery does not show a clear trend. (Quebec is not included in the overall Gulf index).

In the fall fishery, east and west P.E.I. are the only areas with internal consistency in the three effort indices (Fig. 7). But again, the number of net-hauls per gillnetter and the number of net-hauls per trip generally show the same trends by area. The overall Gulf indices do not show a clear trend.

The historic abundance index shown in Figure 8 shows no change in either the spring or the fall since 1984.

Questions about the percentage of the catch kept for personal use, sold to processors, or dumped, reveal significant differences from 1985. In the spring, a higher proportion of the catch was sold to processors in the New Brunswick fishing areas. In the fall, much more of the catch was sold throughout the Gulf of St. Lawrence, and the high "kept" percentages in Escuminac and west P.E.I. decreased from 1985 to 1986. (See Figures 9 and 10).

Table 3 summarizes the mesh size composition of the fisheries. Most nets used in the spring had a mesh size between 2.25 and 2.50 inches, with perhaps a higher percentage of 2.63, and 2.75 inches in 1986. There is a large number of mesh sizes used in the spring fishery. In the fall, fewer mesh sizes are used, and they are generally larger than in the spring, with most of the nets having a mesh size between 2.38 and 2.75 inches.

2.4.6.5 Questions and Comments

Comment:

There was confusion over what is peak and non-peak fishing periods during 1985 the interviews.

Comment:

Some fishermen don't wish to be interviewed any more; do we return results of survey to fishermen?

Comment:

Catch rate information requires information on number of nets per trip, number of trips and total catch. The telephone interview gathers information on the number of nets per trip.

Comment:

Gillnet abundance index should be reviewed by industry before it is used in the assessment.

Comment:

Is there an attempt to separate fishermen with daily boat quotas from other fishermen?

Comment:

Fleets are reducing their holding capacity, by how much is this taken into account?

Comment:

Was the 1985 survey reliable, because fishermen were aware that these responses would affect the abundance index.

Comment:

Fishermen were advised in southeastern Nova Scotia to under-report the number of nets to try and artificially increase the gillnet catch rate.

Comment:

Number of net hauls affects the catch rate: two nets hauled four times will catch more than six nets hauled once.

Comment:

How do interceptory fisheries affect catch rates? If abundance index doesn't fall along the migration route does this indicate that only a small proportion of the stock is being fished?

Comment:

What does industry think that the catch rate would be? Could the fishermen develop their own historical catch rate indices?

Comment:

It appears that during 1982 and 1983 CAFSAC underestimated the population and therefore there was a loss of potential yield. Therefore it is important that our catch rate indices are correct.

Table 1. Summary of the 1986 telephone survey.

AREA	# LICENCES	# CFVN"S
Que	1224	
Ac Pen	623	301
Esc	331	158
SeNB	264	112
NS	436	116
E PEI	383	86
W PEI	484	114
TOTAL	3745	887

Table 1. The number of herring gillnetters in each fishing area in 1986

AREA	NUMBER OF NAMES	NUMBER OF REPORTS	PHONE. ADDRESS PROBLEMS	UNABLE TO CONTACT	UNCO-OP-ERATIVE	NOT FISHING
QUE	51	21	6	16	1	7
Ac PEN	129	111	15	1	1	1
ESC	67	57	8	1	1	0
SeNB	49	33	9	4	2	1
NS	51	38	9	1	2	1
E PEI	37	28	4	4	0	1
W PEI	71	54	5	9	1	2
TOTAL	455	342	56	36	8	13

Table 2: Percentage of each mesh size used in the 4T herring gillnet fishery.

1985 SPRING

Area	<=2"	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	>=3"
Que	7.8	5.8		48.9		6.0	9.5	11.0	6.3	1.0	3.5
A Pen	3.3			14.7		40.6	26.5	13.7	1.2		
Esc		0.6		72.1		17.5	9.8				
SeNB				89.3		6.9	3.7				
NS	2.6			5.1		21.7	48.0	22.6			
E PEI				15.2		46.2	21.7	7.1	4.9	3.9	
W PEI	0.3			55.2	4.2	23.4	10.1	1.1	4.0	1.0	

1986 SPRING

Area	<=2"	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	>=3"
Que		4.0		25.0		2.6	21.0	36.8	9.2		1.3
A Pen				10.0	1.8	33.8	37.0	12.0	2.7	2.7	
Esc	3.0	0.8	3.3	77.8	4.9	5.7	3.6	2.3	2.0		
SeNB		1.0		85.8		7.0			3.0		
NS				10.0		28.0	32.0	30.0			
E PEI				66.7		4.2	4.2	16.7		8.3	
W PEI	5.9	6.2	2.7	50.2	4.2	17.5		3.9	1.2	8.2	0.2

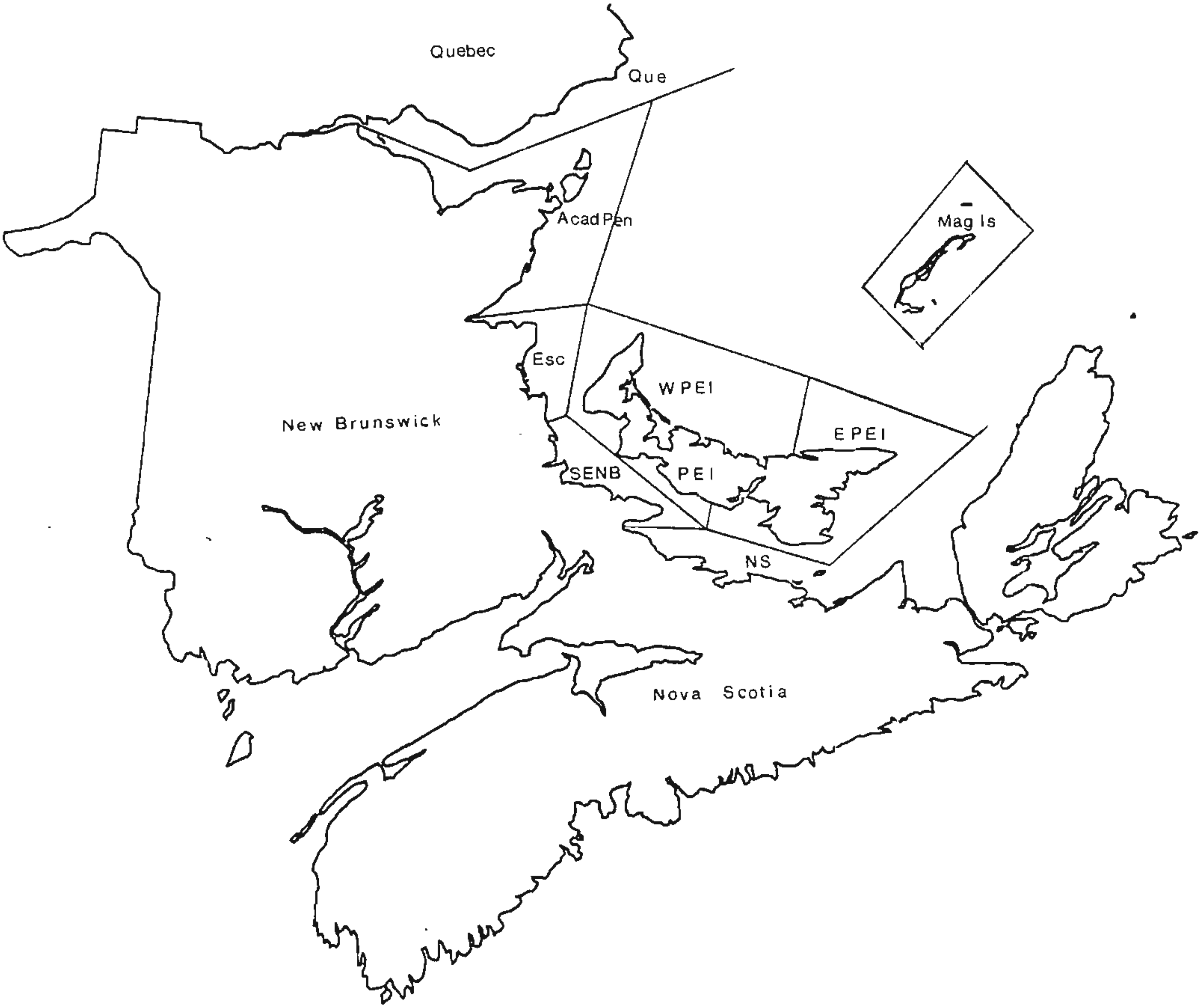
1985 FALL

Area	<=2"	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	>=3"
Que	10.4	6.0		0.5		5.1	18.8	18.5	27.3	5.1	8.1
A Pen							1.0	79.7	16.6	2.5	0.3
Esc									100.0		
SeNB											
NS						2.5	3.7	93.8			
E PEI								98.6	1.4		
W PEI				3.3	0.9	3.7	2.7	40.1	30.1	19.2	

1986 FALL

Area	<=2"	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	>=3"
Que				3.6		3.6	27.3	65.5			
A Pen	0.4					1.0		73.4	13.7	8.2	3.3
Esc								85.7	7.1	7.1	
SeNB											
NS						3.6	8.9	83.5	3.2	0.8	
E PEI	13.2						1.9	85.1			
W PEI						4.0	43.0	40.0		13.0	

Fig. 1: Geographic Division of the Southern Gulf of St. Lawrence used in the 1985 Herring Gillnet Survey.



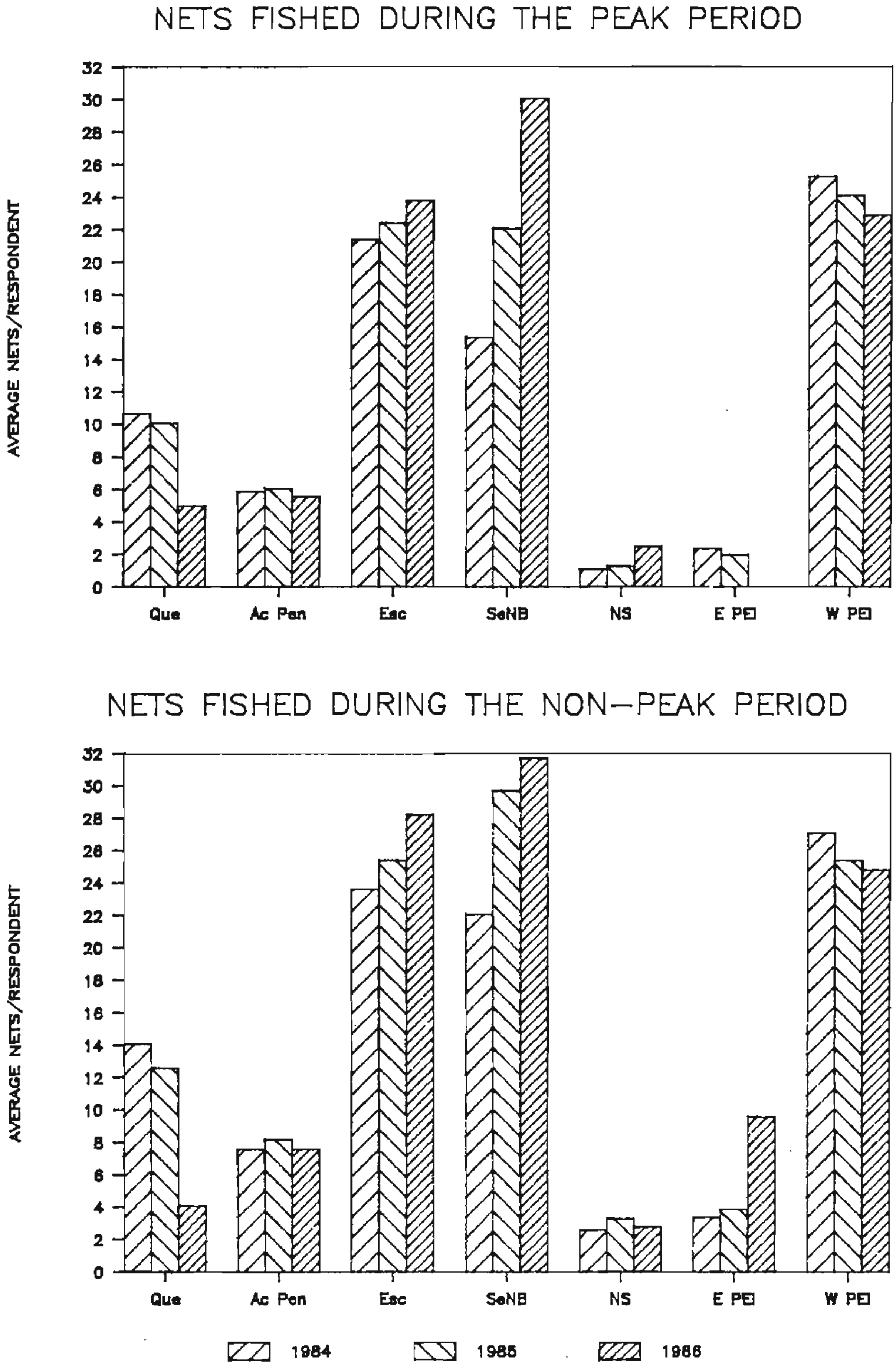
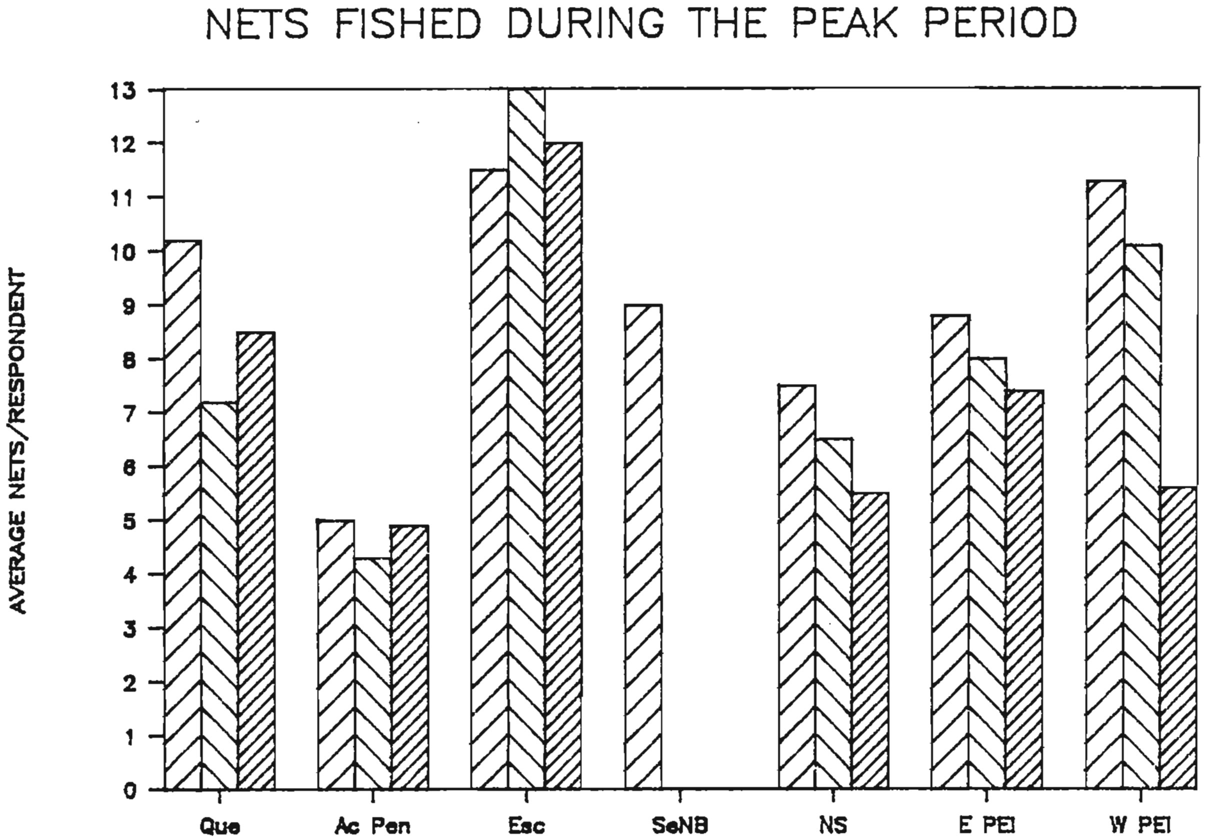


Figure 2. Average Number of Nets Fished in the 4T Spring Gillnet Fishery



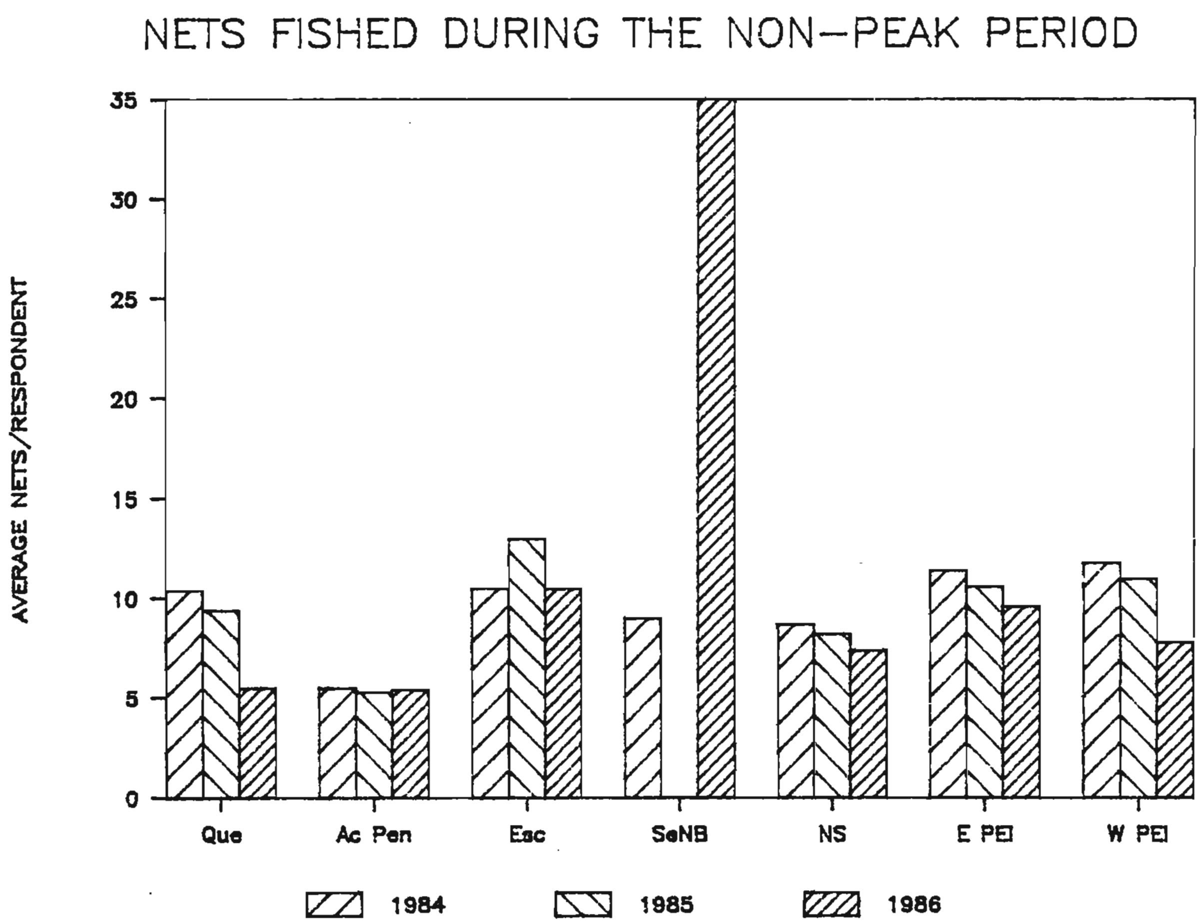


Figure 3. Average Number of Nets Fished in the 4T Fall Gillnet Fishery

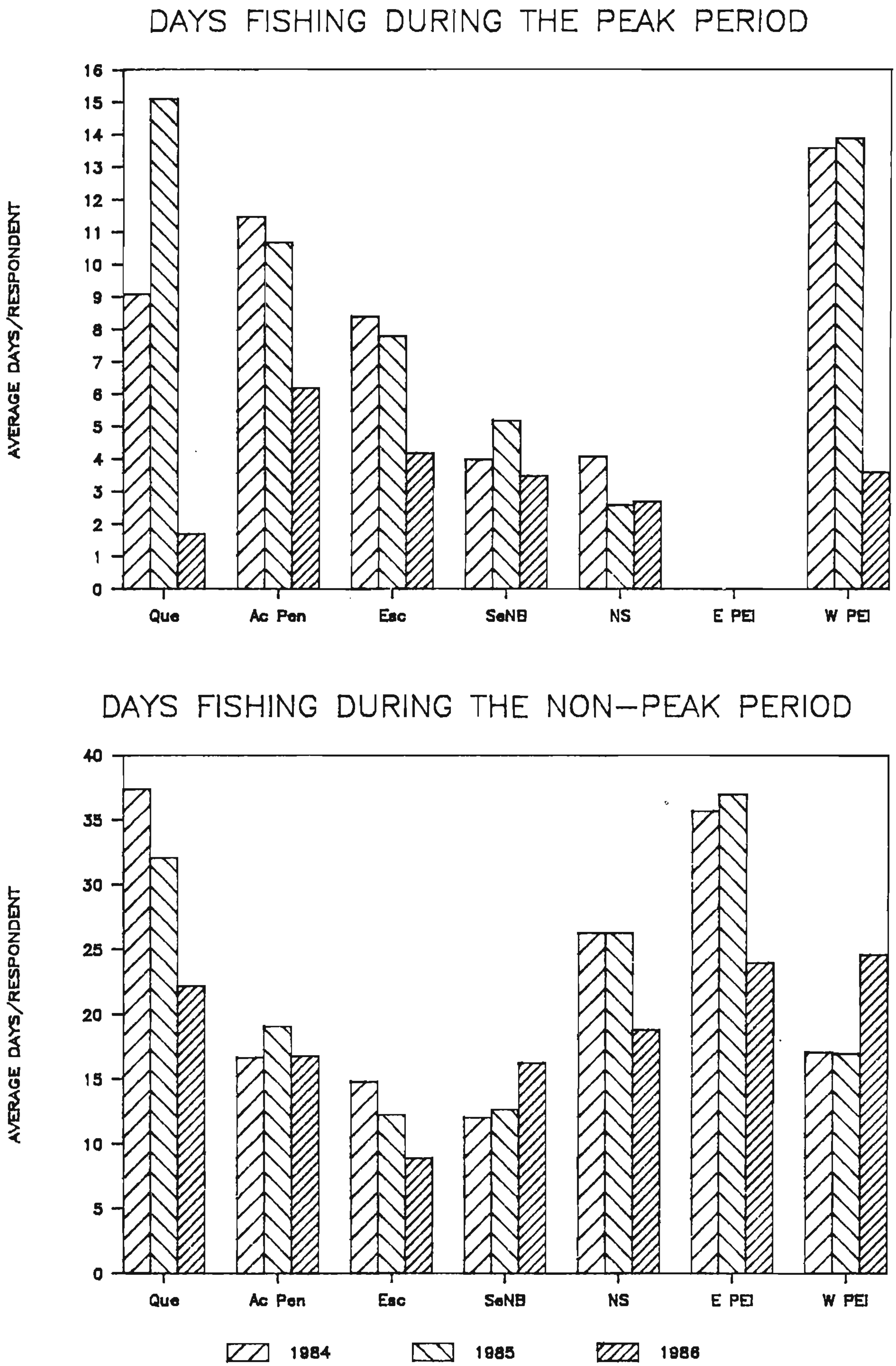
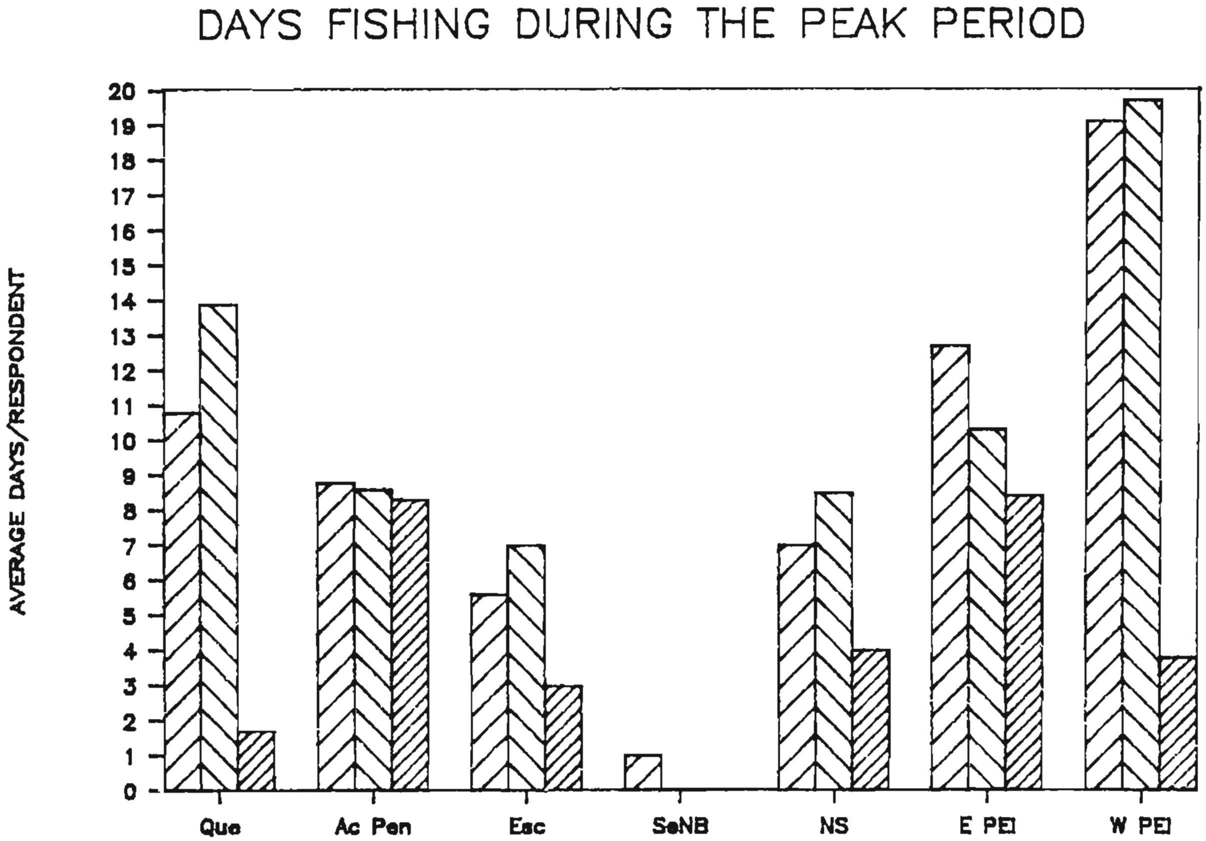


Figure 4. Average Number of Days Fished in the 4T Spring Gillnet Fishery



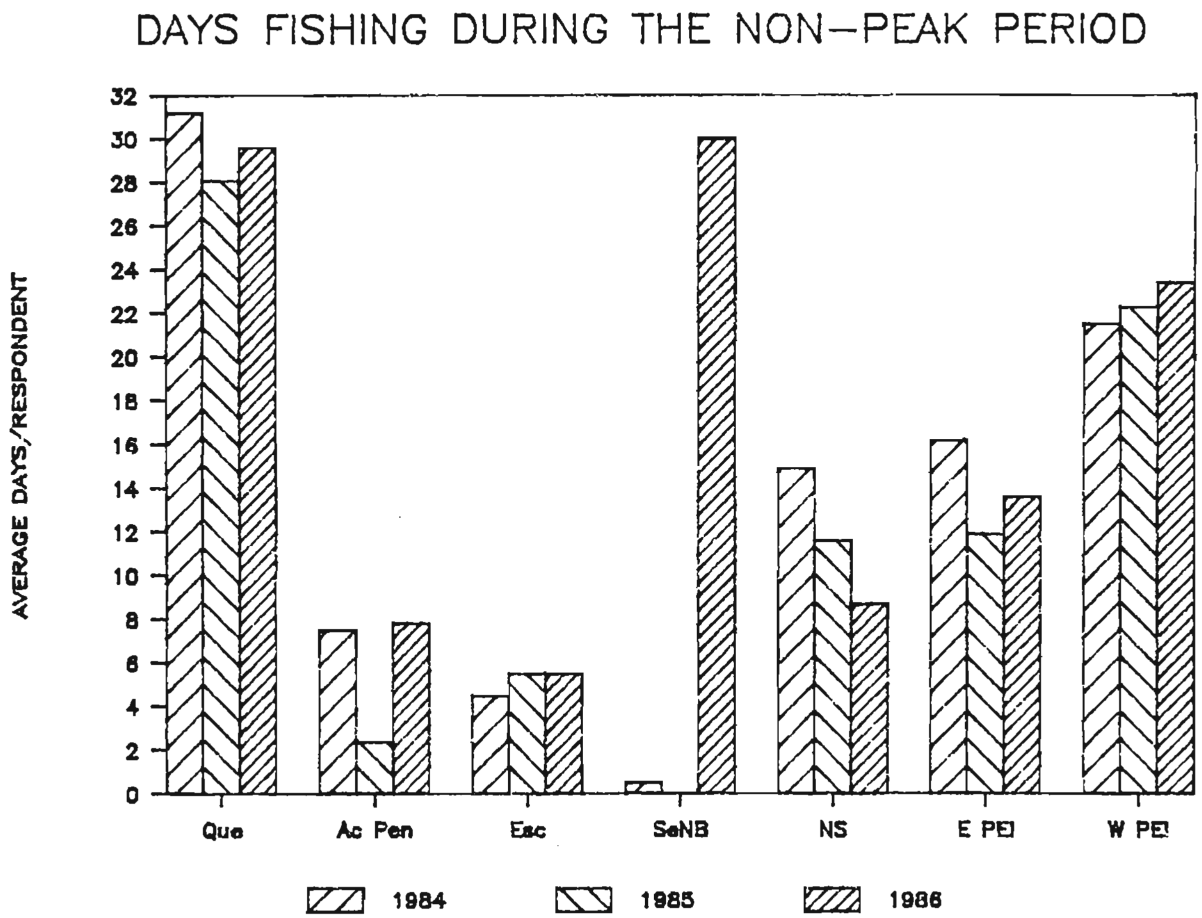


Figure 5. Average Number of Days Fished in the 4T Fall Gillnet Fishery

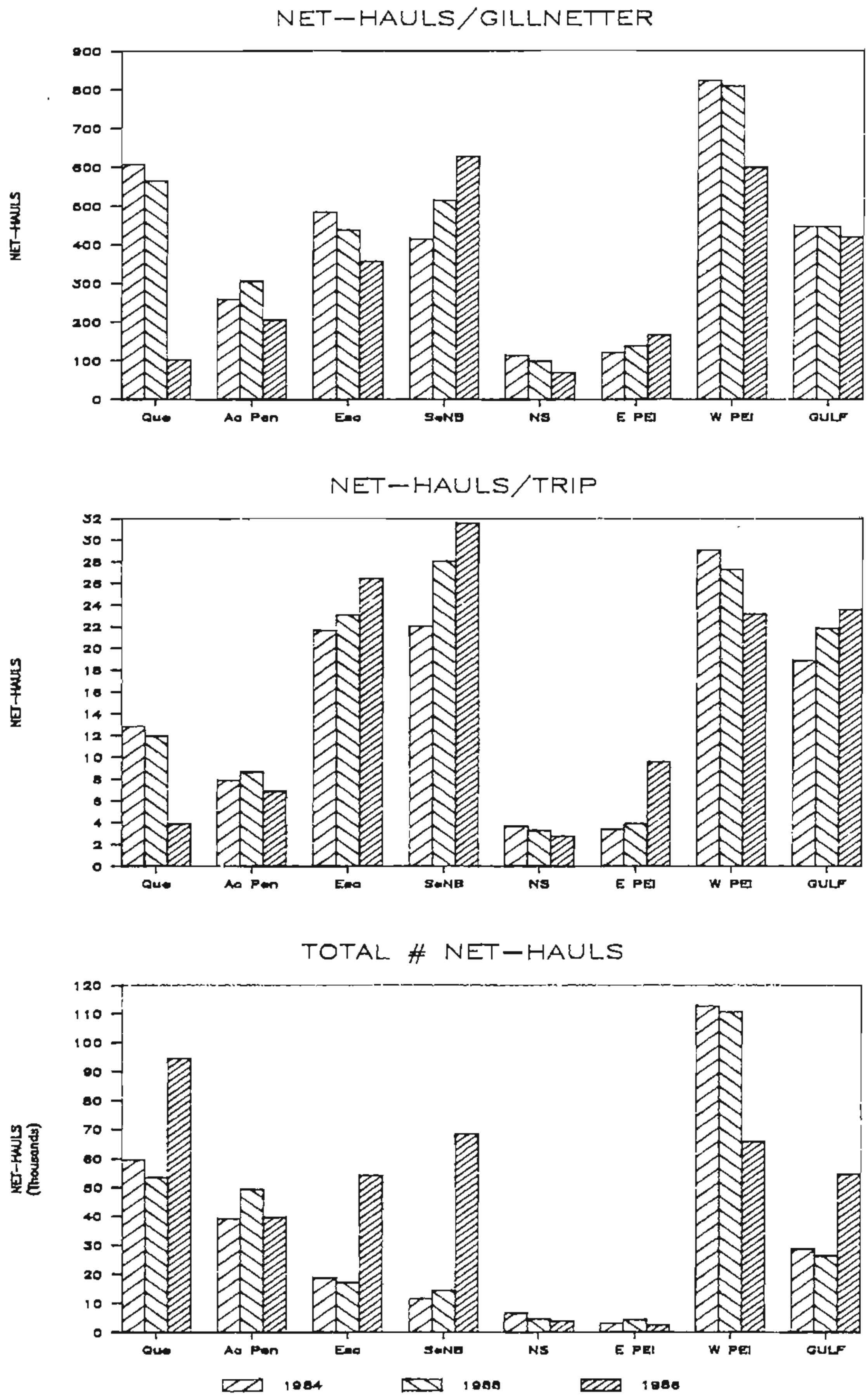


Figure 6. Derived Effort Indices for the 4T Spring Gillnet Fishery

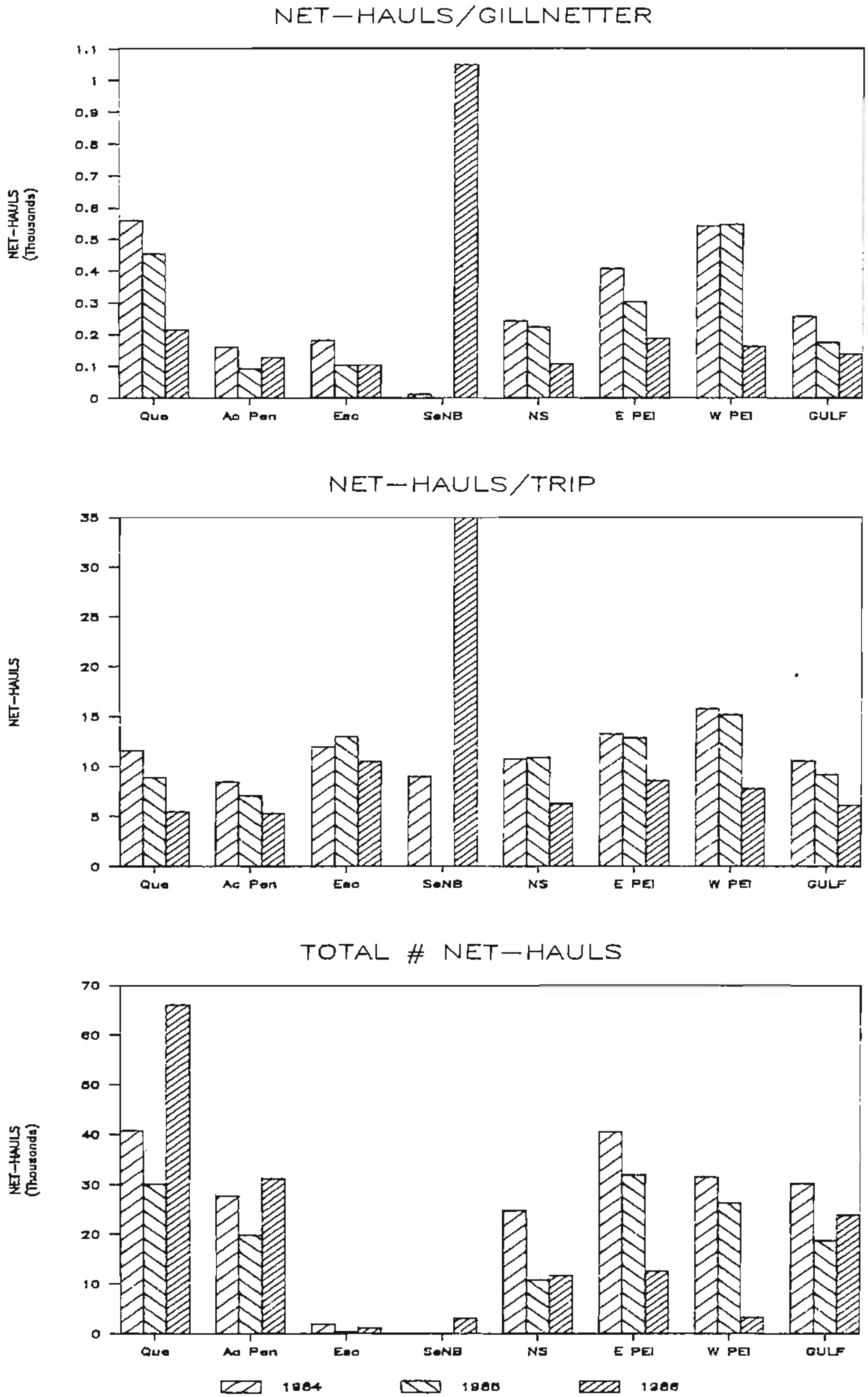


Figure 7. Derived Effort Indices for the 4T Fall Gillnet Fishery

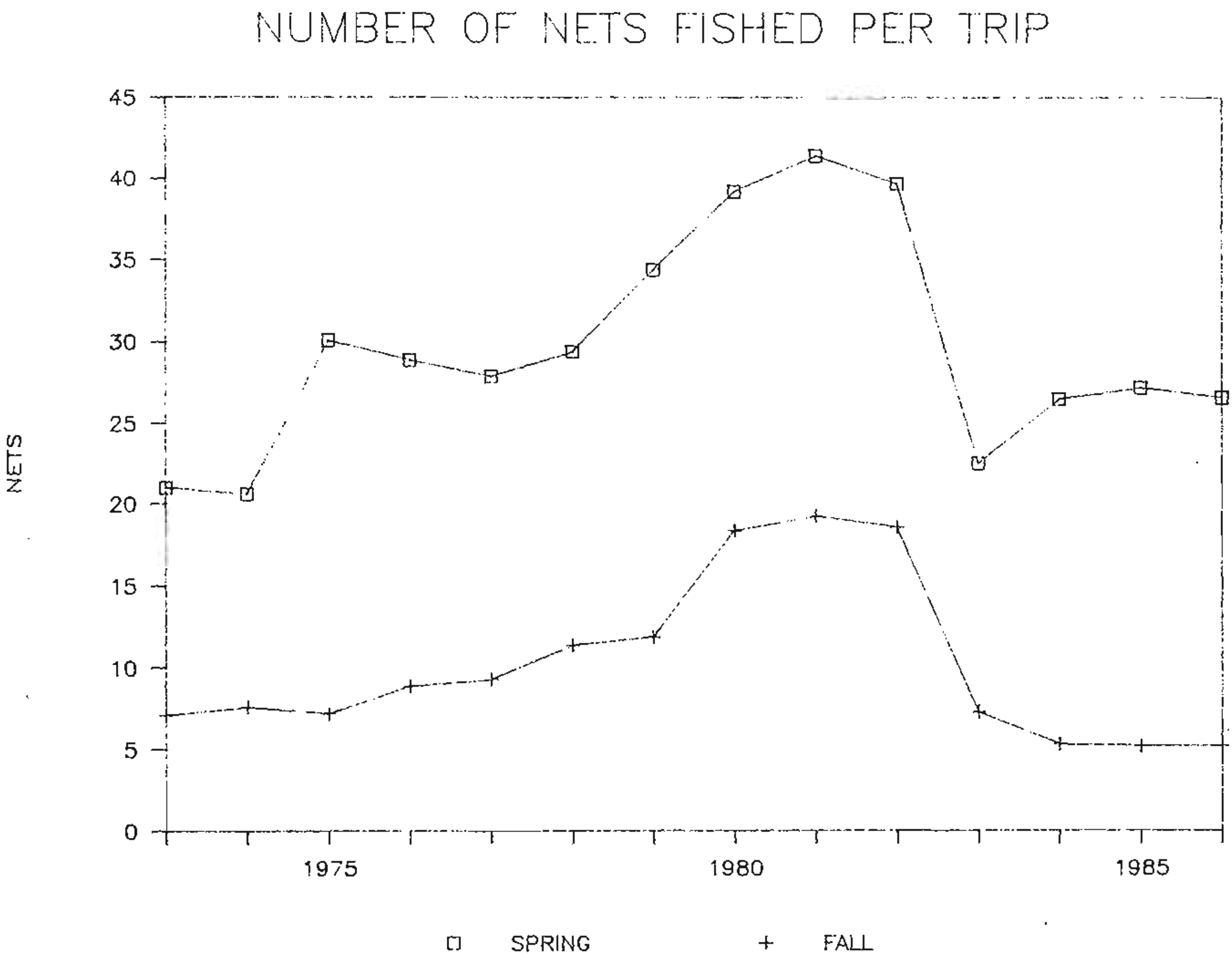


Figure 8. 4T Herring Historical Effort Index

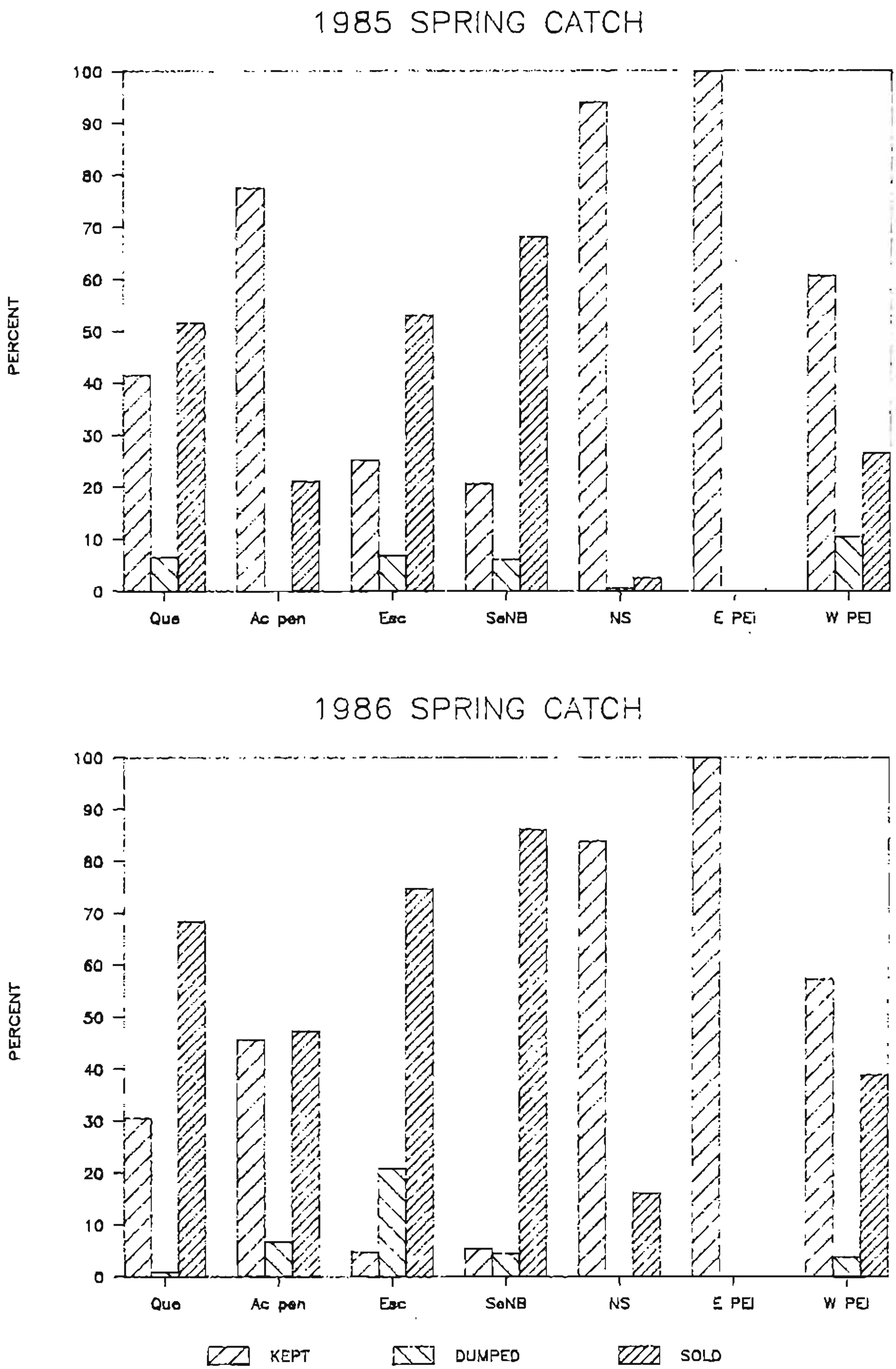


Figure 9. Disposition of the 4T Herring Spring Catch

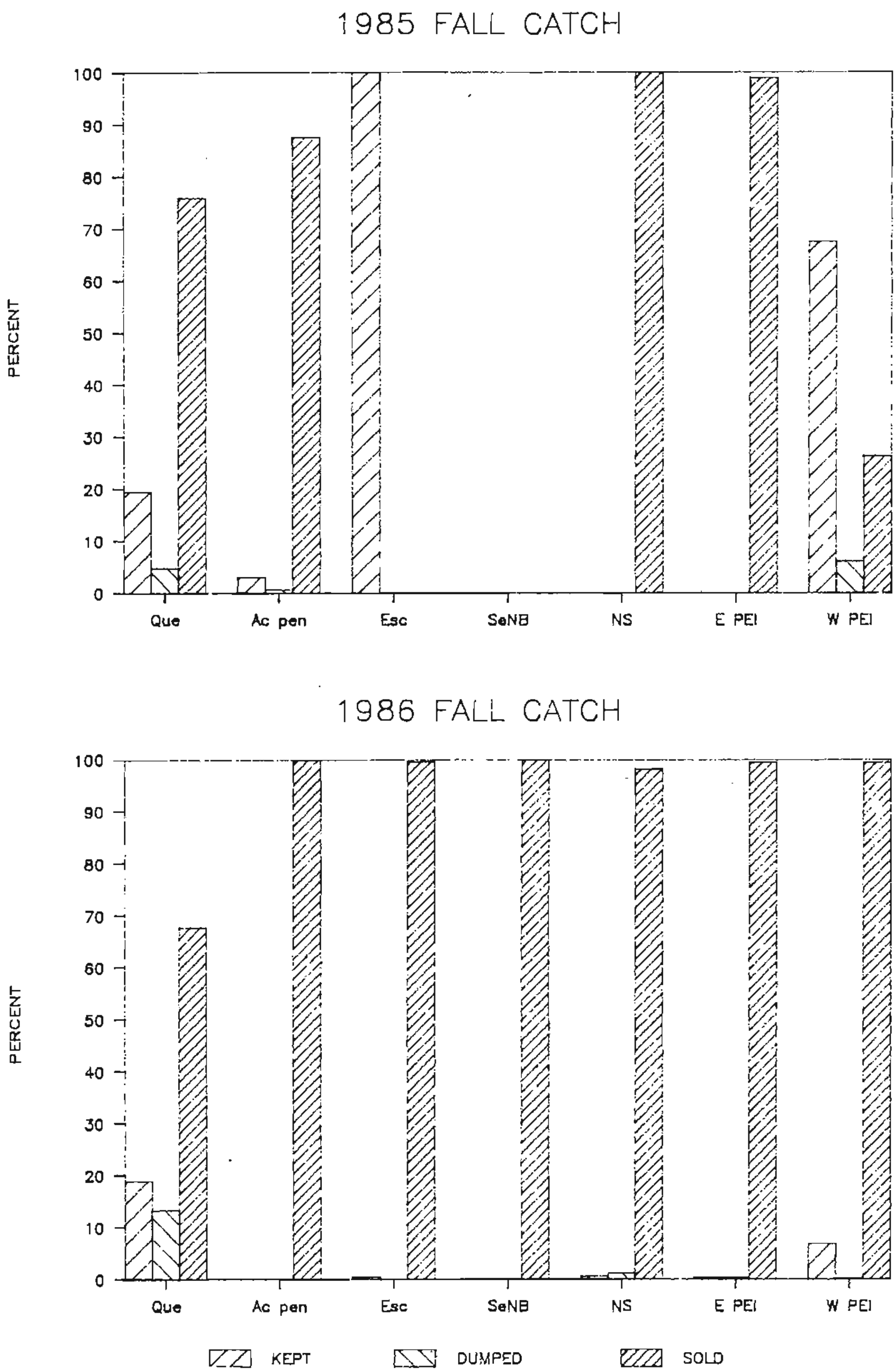


Figure 10. Disposition of the 4T Herring Fall Catch

2.5 VIRTUAL POPULATION ANALYSIS

Robert O'Boyle
Science Branch, Scotia-Fundy Region
Bedford Institute of Oceanography
Dartmouth, N.S.

Virtual Population Analysis or VPA for short is a mathematical technique which uses catch data and abundance indices to determine population numbers for each year of a fishery. In fact, VPA is a special form of Sequential Population Analysis (SPA) of which the commonly used Cohort Analysis (CA), which is closely related to VPA, is also a member.

These techniques rely heavily upon the fishery data to determine population size. In essence, the fishery is considered a very large "sampling" tool. The landed catch is assumed to be a fraction of the total population. The analysis attempts to discover just what the size of that fraction is and consequently allow estimation of total population size.

An overview of the stock assessment process (Figure 1) shows how central VPA is to population size and thus quota estimation. Input data such as catch and abundance indices are compiled by VPA to generate a set of population numbers at age for each year of the fishery. The most current numbers are then used to project next year's catch at a chosen effort level, such as $F_{0.1}$.

This chapter reviews the fundamentals of VPA. from the input data to the calibration of VPA.

2.5.1 The Input Data

VPA requires two sets of input data. Both have been discussed more fully in previous chapters but will be quickly reviewed here.
A long time series of an abundance index is an essential requirement of VPA. Catch rates, be they research survey or commercial, are considered to be an index of abundance. In other words, when the stock increases in numbers so too do the catch rates; when abundance falls, again so too do the catch rates. Given a catch rate and a constant of proportionality, commonly referred to as q, the catchability, one can calculate the corresponding abundance. The main assumption is that q does not change over the data series. As was discussed in earlier chapters, the abundance index data sets have to be carefully analysed to meet this assumption. It is preferable if these indices describe abundance trends separately by age group.

The second major data set is the catch numbers at age. This describes the annual catch of fish in a stock broken down across the age groups or year classes. By putting the data for all years together in one table, one can follow the progression of a year class through the history of a fishery. For instance, the exploitation history of the 1975 year class is outlined in Figure 2. In 1979, 3,056 individuals of this year class or cohort were caught. In 1980, the catch was 1,406. By 1985, the numbers of this cohort that had been caught was reduced to 31.

The construction of the catch-at-age matrix requires the careful combination of the catch statistics, collected by the purchase slips/log book system, and the sampling data. Indeed a significant part of the assessment process is the decision making in conducting this phase of the analysis. Once the input data is available, one is then ready to conduct a VPA.

2.5.2 Some Fundamentals of VPA

Although VPA involves calculating the strength of all year classes simultaneously in a fishery, the computations are in fact conducted independently for each year class. Thus, the best way to describe VPA is to consider the calculations as they relate to one year class in isolation of the others. This is equivalent to extracting only the 1975 data from the table presented in Figure 2.

Let's consider the fate of 1,000 hypothetical fish that enter a population. In addition, for illustrative purposes only, let us consider that the only way that these fish can die is by being caught by the fishing fleets. Thus, if fishing effort is nonexistant or low, these fish would be able to live a very, very long time. Needless to say, this does not occur but the assumption will not dramaticaly affect the description of the overall philosophy behind VPA.

As a further assumption, let us assume that the "availability" of the year class to the fleet changes with age. In our example, at age one, availability is 0 while at age 2 it is only 1 percent. At age three, this increases to 20%. In other words, only 20 of 100 fish are accessible to fishing - not caught but accessible. How many are actually caught depends on the combination of availability and fishing effort. By age 5, all fish in the cohort are available to fishing activity. The availability at age is more commonly referred to as the partial recruitment. Its determination is a very critical step in the VPA process. Due to the complexity of the calculations, it will not be fully discussed in this document.

We will assume that four out of every 10 fully available fish (ages 5-10) or 40% are caught by fishing activity.

The results of these assumptions are shown in Figure 3. Since no or almost no fish at ages 1 and 2 are available and there is no natural morality, virtually all 1,000 fish survive to age 3. At this age, catch starts to increase and the population starts to fall. With increasing availability and fishing effort, this trend continues so that by age 5 the maximum catch is recorded. Now because the population abundance is still dropping, catch subsequent to age 5 drops off and is very small indeed by age 10.

What can this catch tell us about the size of the population? Since there is no natural mortality in this hypothetical population, then the catch itself will, given enough years, tell us how many fish were in the ocean. If for instance, all the fish were caught in three years, then all one would have to do is to add the catch of the three years together to determine what the population size was. In our hypothetical population, the catch occurs over a 10 year period. In the first year, 0 fish were caught so we have no estimate of population size. At age 2, five fish were caught, so that we know that at least 5 existed in the population. At age 3, 97 fish were caught. thus this number plus those that were caught at age 5, or 102, is now our estimate of initial population size. At age 4, 237 fish were caught so that we know that at least this many exist at this age. Now, the year before 97 age 3 were caught. We know that the 237 that we caught this year existed last year (common sense) so that our estimate of the number of age 3 fish that existed is now 237 + 97 = 334. This logic applied to age 2 fish gives 334 + 5 = 339. As one can see, as catch is accumulated, the age- specific estimates of population size slowly approach the truth (Figures 4 and 5).

This property of VPA is called "Convergence" and is fundamental to the analysis success. Basically, the more one catches of a population,the better will be the estimate of its size.

Assuming that natural mortality is greater than zero does not qualitatively change this picture. If it is assumed constant across all age groups, only the height of the bars in Figure 5 is increased. In essence, the catch is adjusted upward to compensate for natural mortality before it is accumulated back along the cohort.

So far we have restricted our discussion to just one cohort. VPA is conducted simultaneously for a number in parallel. How it does this is now described.

2.5.3 How Does a VPA Work?

The catch at age, as discussed above, is one of the key inputs to VPA. It is a table of numbers describing the catch of fish at each age in each year of the fishery. Suppose in our hypothetical fishery that the catch in each year was identical. Then Figure 6 would result. Figure 7 presents the population size estimates using the accumulation technique described in the previous section. Note that this accumulation goes up a cohort and thus up a diagonal rather than along a row or column. A comparison of this table with the true numbers provided in Figure 2 will show clearly the property of convergence.

Now it is also evident that the population estimates in the most recent year, 1986, are the most inaccurate. Indeed, all the numbers delimited by the triangle indicated on Figure 7 are significantly below the true values. Catch projections are conducted using the most recent numbers. Thus, without other sources of information, this particular VPA is not much good in providing reliable current year population size estimates suitable for projection. These are provided through the process of calibration.

2.5.4 Calibration

Calibration is the process whereby relationships between independently derived abundance indices and historical VPA population numbers are used to obtain estimates of numbers in the most recent year of the analysis. It thus matches the VPA data from the converged part of the population table with abundance indices such as survey or commercial catch rates.

This matching is done statistically with a graphical presentation of the two commonest relationships given in Figure 8. Both are widely used in CAFSAC and NAFO. The first is straightforward. The second requires some explanation. The abundance index is really catch divided by effort or C/E. K is the inverse of the catchability, q. Thus, catch rate is the catchability times the mean population size:

$$C/E = q\,\overline{N} \tag{1}$$

or

$$C = qE\,\overline{N}$$

Now catch is really the part of the population caught, the size of which is determined by the fishing mortality, F.

$$C = F\overline{N} \tag{2}$$

A quick comparison of equations 1 and 2 will show that the fishing mortality, F, is equal to the catchability, q, times the effort, E.

$$F = qE \tag{3}$$

This is the second relationship shown in Figure 8. Why go through all these calculations? Sometimes only effort data is available from a fishery in which case this relationship is used.

Here is how these relationships are used in VPA. A VPA is run using "guestimates" of the population size in the most recent year. Through the convergence process these are adjusted to better reflect historical population size. A converged part of the population table is identified (by a process not discussed here) and is used to develop the so-called tuning relationships (Figure 8 and 9). Ideally, there should be a relationship for each age in the population. For instance, the one for age 3 is shown in Figure 9. Note that only the 1977 to 1982 data were used to determine the solid line. The 1983-86 points are examined in relation to this line. The 1986 estimate of population numbers is, based on the relationship, too high. There are more fish there than the abundance index is saying there is. Thus the input population number "guestimate" is adjusted down to compensate for this and the VPA rerun. A second age 3 relationship is determined in a like manner to the above and the position of the 1986 point in relation to the historically derived VPA numbers - abundance index line once again examined. This process is repeated until all the 1983-86 points lie close to the historical line.

The above process is conducted for each age of the VPA. Since the relationships are along rows or ages whereas the VPA is conducted along diagonals or cohorts, the age-specific calculations are very interrelated. A great deal of the discussion in CAFSAC and NAFO is devoted to these interrelationships, the influence of spurious data points, the reliability of the abundance index and so on. There are a number of very sophisticated mathematical processes that do the above but all do essentially what is described here - find the optimal relationship between the VPA derived population numbers and the abundance index. No matter what the level of sophistication, all are critically dependent on the reliability of the catch at age and the abundance indices.

2.5.5 Summary

Virtual Population Analysis (VPA) is the main computations vehicle used by CAFSAC and NAFO to calculate the size of the population in the most recent year. It uses catch-at-age data derived from landings statistics and sampling data along with abundance indices based on research survey and commercial fishing activity. The analysis has the property of convergence in which historical population estimates become more accurate as years of catch are added to the data set. This characteristic is used to advantage in that statistical relationships between historical VPA population estimates and abundance indices are developed and used, in a process called calibration, to provide more accurate estimates of population size in the most recent year. It is these that are used as the basis for catch projections for the upcoming year.

2.5.6 Questions and Comments

Sequential population analysis determines the fraction of the total population that is caught.

The input data consists of abundance indices and a catch-at-age matrix. The SPA works on cohorts or year-classes. Estimates of year-class strengths are obtained from the catch information.

Estimates of the current year's population at age is extremely poor for the year-classes for which little information is known. Calibration is the process whereby relationships between abundance indices and historical SPA numbers are used to obtain estimates of numbers in the current year. Success of calibration depends on the reliability of the indices of abundance, and the appropriateness of catch between SPA numbers and indices.

Comment:

The term virtual population analysis used by the person who developed it using a population with complete census; complete catch data are absolutely important for its use.

Catchability is the slope of the line of the relationship between F and effort. We do try to adjust our data to account for any systematic trends in catchability over time. In general we look at catch rates which are adjusted for differences between fishing components.

Fishing power changes can be separate from catchability. Example - in the purse seine fishery catch rates can remain very high until the end of the fishery. For this reason, we do not use purse seine catch rates for assessments.

Question:

Don't get a very good feeling for the year-class strength until it is several years old.

Response:

Catch rates broken down by age groups and independent surveys with small mesh gear and acoustic surveys can help to estimate recruitment to the fishery.

Question:

Trend to go to larger mesh sizes because the fish are big. Does this have an affect on our estimation of younger fish.

Response:

Yes.

Fig. 1:

A flowchart of an Analytical Assessment

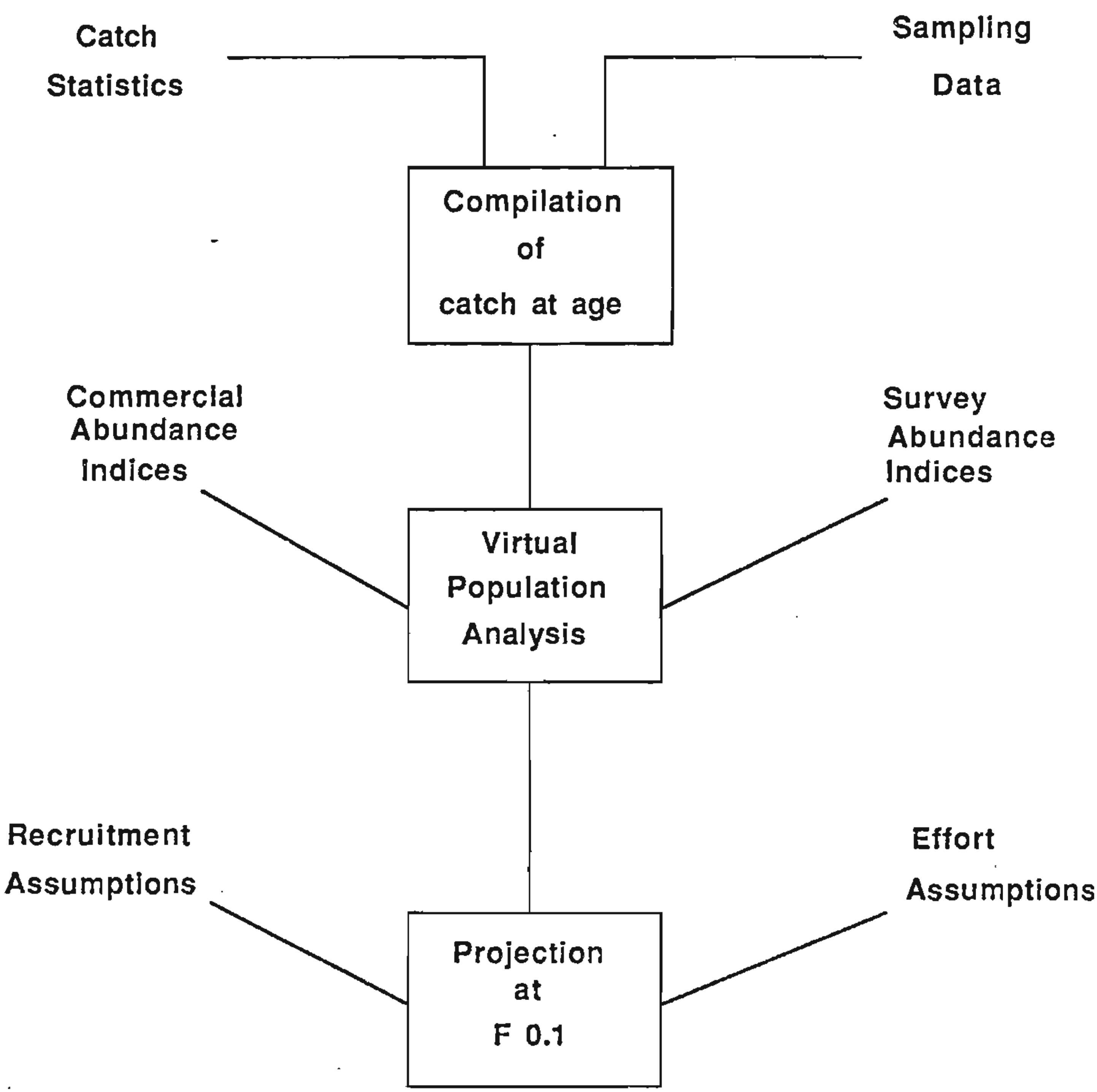


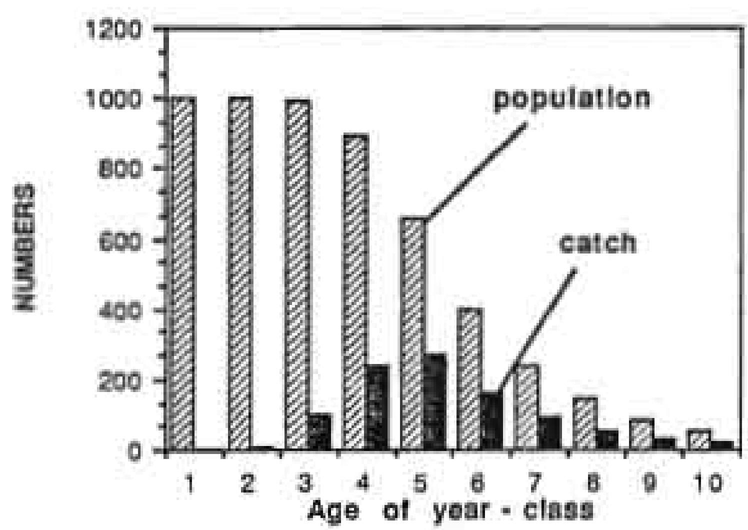
Fig. 2: The catch numbers-at-age table for 4T (spring) herring showing the 1975 year class.

Year

Age	1979	1980	1981	1982	1983	1984	1985
2	55	541	45	68	1	13	11
3	7667	22219	13031	32597	5160	1877	4565
4	3056	3567	7527	6047	29194	7932	8440
5	20895	1406	1270	1475	3646	11970	9483
6	556	9528	785	326	1019	1195	6487
7	1404	216	3197	177	36	52	1904
8	110	1074	79	332	1	0	396
9	63	104	285	113	1	0	271
10	362	140	38	1	1	0	31
11+	1672	2134	1009	109	1	0	121

1975 year class

Fig. 3: The exploitation path of a hypothetical year class showing the population catch and availability with age.



Availability - at - age (%)	0	1	20	60	100	100	100	100	100	100

Fig. 4: An illustration of convergence.

		True No.	Population estimate after indicated number of years in fishery									
			1	2	3	4	5	6	7	8	9	10
	1	1000	0	5	102	339	603	762	857	914	948	969
	2	1000		5	102	339	603	762	857	914	948	969
	3	995			97	334	598	757	852	909	943	964
	4	898				237	501	660	755	812	846	867
Age	5	661					264	423	518	575	609	630
	6	397						159	254	311	345	366
	7	238							95	152	186	207
	8	143								57	91	112
	9	86									34	55
	10	52										21

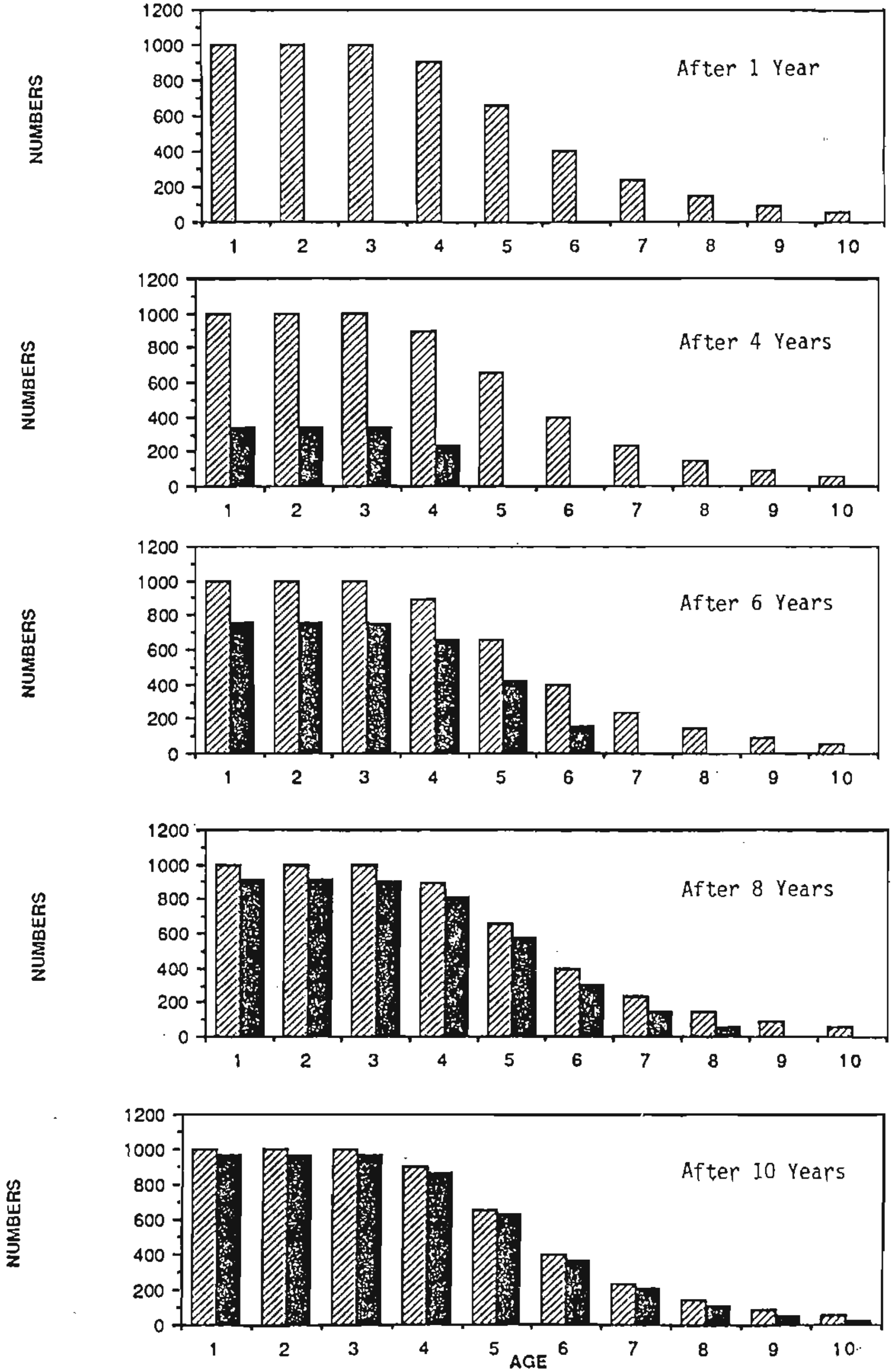


Figure 5. How catch accumulates with increasing years of data.

▨ - True population numbers

■ - Population numbers based on catch

Fig. 6: The catch numbers at age for a hypothetical fishery.

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0	0	0	0	0	0	0	0	0	0
2	5	5	5	5	5	5	5	5	5	5
3	97	97	97	97	97	97	97	97	97	97
4	237	237	237	237	237	237	237	237	237	237
5	264	264	264	264	264	264	264	264	264	264
6	159	159	159	159	159	159	159	159	159	159
7	95	95	95	95	95	95	95	95	95	95
8	57	57	57	57	57	57	57	57	57	57
9	34	34	34	34	34	34	34	34	34	34
10	21	21	21	21	21	21	21	21	21	21

Fig. 7: The population numbers at age derived from the catch at age for a hypothetical fishery.

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	969	948	914	857	762	603	339	102	5	0
2	969	969	948	914	857	762	603	339	102	5
3	964	964	964	943	909	852	757	598	334	97
4	867	867	867	867	846	812	755	660	501	237
5	630	630	630	630	630	609	575	518	423	264
6	366	366	366	366	366	366	345	311	254	159
7	207	207	207	207	207	207	207	186	152	95
8	112	112	112	112	112	112	112	112	91	57
9	55	55	55	55	55	55	55	55	55	34
10	21	21	21	21	21	21	21	21	21	21

Fig. 8: Two of the commonest forms of tuning relationships used in calibration.

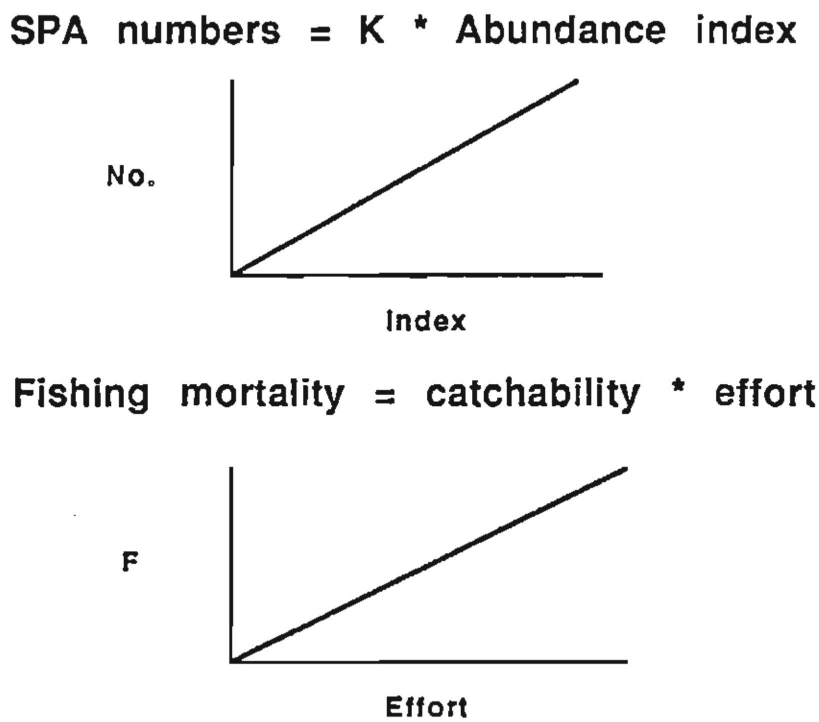
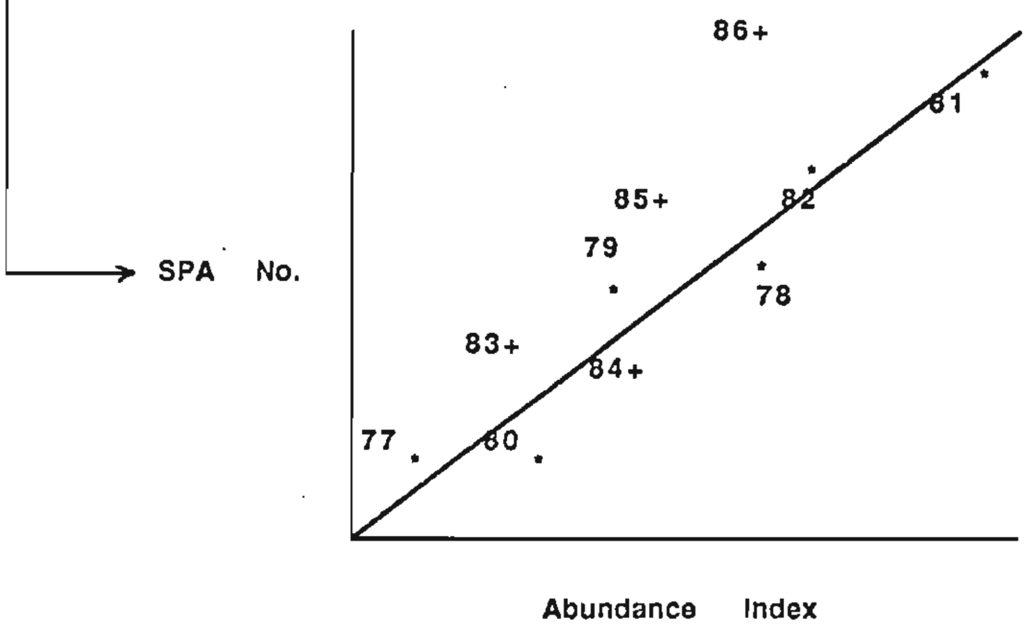


Fig. 9: An illustration of calibration using the VPA or SPA population numbers at age 3 from the hypothetical fishery and an independently-derived abundance index.

YEAR

AGE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	969	948	914	857	762	603	339	102	5	0
2	969	969	948	914	857	762	603	339	102	5
3	964	964	964	943	909	852	757	598	334	97
4	867	867	867	867	846	812	755	660	501	237
5	630	630	630	630	630	609	575	518	423	264
6	366	366	366	366	366	366	345	311	254	159
7	207	207	207	207	207	207	207	186	152	95
8	112	112	112	112	112	112	112	112	91	57
9	55	55	55	55	55	55	55	55	55	34
10	21	21	21	21	21	21	21	21	21	21



3. FORECAST

In this section the current approach to forecasting the abundance of herring stocks in Atlantic Canada is briefly compared to the method used for Pacific Herring.

3.1 FORECAST OF HERRING CATCHES IN GULF OF ST. LAWRENCE

Michael Chadwick
Science Branch, Gulf Region
Fisheries & Oceans
P.O. Box 5030
Moncton, N.B.
Canada E1C 9B6

3.1.1 Objective

The three objectives of a forecast are: 1) to estimate the optimal or best rate of fishing, 2) to estimate the future contribution of age groups currently in the fishery, and 3) to estimate recruitment, or the future contribution of new age groups. Generally, forecasts are made one to two years ahead of the current fishery. As we shall see, longer term forecasts for herring stocks are not very reliable.

3.1.2 Optimal Rate of Fishing

The terms, rate of fishing, exploitation rate and fishing mortality (F) all mean the same thing. The optimal rate of fishing, usually called $F_{0.1}$, is designed to maximize profit to the fishermen and to ensure against poor recruitment. $F_{0.1}$ is calculated as the rate of fishing where marginal yield is 10% of the initial catch per unit of effort. Essentially, when fishing becomes ten times more difficult in comparison to when a fishery first starts, it is felt that the rate of fishing should not be increased anymore. This target level of fishing is called the $F_{0.1}$.

To calculate $F_{0.1}$, yield is measured for different rates of fishing. Yield is the number of fish at each age group multiplied by their average weight. For herring, $F_{0.1}$ is assumed to be 0.3, which, over a one year period, amounts to about 25% of the fishable population is available for exploitation.

3.1.3 Projected Population

The projected population is an estimate of how big the current population will be in one, two or more years. The current population is the numbers of herring at each age which are alive in the southern Gulf of St. Lawrence. The technique for calculating the size of the current population using virtual population analysis was described in detail in Section 2.4. In the forecast the numbers of herring in the current population are projected forwards.

In order to estimate the number of fish that will continue to live for several years in the future, we need to know how many will die from natural causes (natural mortality), how many will be caught by the fishery in the intervening years (fishing mortality), how much the fish will grow, what proportion will be available to the fishery (partial recruitment), and finally how many young fish will be entering the fishery (recruitment).

Natural mortality of herring is assumed to be fairly constant after they are two years old. Usually, it is assumed that 18% of herring die or are eaten each year, that is, the annual survival rate is 82%. The assumption that large herring have a constant and high survival is consistent with observations of other fish species of similar size. Therefore, if our estimate of the number of three year old herring is fairly accurate, then our estimate of their numbers when they are five years old should also be fairly accurate.

By contrast, the natural mortality of eggs, larvae, and very young juveniles is high and unpredictable. Thus if it were possible to make an accurate estimate of the number of eggs or larvae, it would be unlikely that they would be useful for predicting the number of adults.

A forecast for 1988 is made using information collected in the 1986 fishery. The forecast assumes that catches in 1987 will be at the $F_{0.1}$ level as calculated in the previous assessment. Sometimes the recommended catch or quota is different from that at $F_{0.1}$, if so the best estimate of what the 1987 catch will be is used in the projection for 1988.

It is not possible to predict the average size or weight of fish at each age group in the projection because growth rates can change greatly from one year to the next. Instead, either average weights over several years or the weights at age from the most recent fishery are used in the projection. Because the growth of adult herring is small in comparison with other fish such as salmon or cod, this potential source of error in the projection is considered to be relatively minor.

Partial recruitment is the proportion of an age group which is available to the fishery. When an age group is fully available to a fishery, it is said to be fully recruited. In the gillnet fishery spring spawners are believed to be fully recruited at age 4 and fall spawners at age 5. In gillnet fisheries, older and larger herring may not be completely available to the fishery and would therefore be only partially recruited. This type of phenomenon is sometimes attributed to the purse seine fishery when it is felt that purse seiners are following large year-classes and releasing sets which contain individuals from smaller year-classes. In this situation, individuals from the smaller year-classes would be only partially recruited. Partial recruitment of younger age groups is also difficult to predict and will be discussed below.

3.1.4 Recruitment

An important part of the projection is to predict the size of new year-classes which are currently not recruited to the fishery. For example in 1985, age 1 and age 2 herring were not captured in the fishery but in 1987 they will become age 3 and 4 herring; and age 3 herring which were only partially recruited in 1985 will become age 5 herring in 1987. In the spring fishery more than 50% of the forecasted catch for 1987 was based on ages which were not fully recruited in 1985. Unfortunately, there is no satisfactory method to predict recruitment. As mentionned in Sections 2.4.3 and 2.4.4, egg and larval surveys are useful for estimating the number of spawners, but not for predicting recruitment. We can only estimate recruitment in hindsight, that is once the young age groups have grown into the fishery. For example only in 1989 will we have a good idea of how many age 2 herring there was in 1985; in 1989 these fish will be six years old and will have spent about three years in the fishery.

The current method to estimate recruitment is to assume that the number of age 2 and 3 herring will be the same as the average over the past ten years. This method may be objective but it is not very accurate; we can see in Figure 1 that the number of age 2 herring can vary greatly from one year to the next. By saying that recruitment in 1987 will be average, we are ignoring large fluctuations in abundance. It is clear in Figure 2 that very good recruitment, as was seen in the 1974 year-class (Figure 1), would result in a projection several times higher than a projection based upon average recruitment. In contrast, very poor recruitment would result in a very low projection for spring spawners. Because there is no reliable way of predicting recruitment, it is safest to base projections on average values.

3.1.5 Summary

The forecast is based on three estimates: the optimal or best rate of fishing, the contribution of age groups currently in the fishery, and the contribution of new age groups or recruitment. The two most important questions are: how can we estimate recruitment or the numbers of young herring and how can we measure partial recruitment in the fishery?

3.1.6 Questions and Comments

Question:

What happens to the age 11+ groups?

Response:

At present, these are few in abundance but the analysis does include as many age groups as possible. The reason for the lack of age 11+ animals is due to both natural and fishing mortality.

Comment:

However, in Chaleur Bay there are herring greater than 16 inches long, blue in colour, perhaps old fish.

Comment:

It was noted that 50% of the 1987 spring quota was based on age groups partially recruited to the 1985 fishery (age groups 1, 2 and 3). These partial recruitment estimates are based on historical averages and are susceptible to annual variation. In relation to this, the question was raised as to the efficiency of quota advice given the uncertainities in the size of incoming year classes.

The derivation of $F_{0.1}$ was also briefly discussed. It was produced primarily as a practical measure - a quick and easy method to produce a value. However, this is not to infer that another fishing mortality is not appropriate.

Comment:

The main objective should be the maintenance of spawning potential and not necessarily $F_{0.1}$. This could be obtained by mesh size and limited weekly effort regulations (fishing 3-4 days/week only). However, the opinion was raised that consideration should be given to the effect gillnet fishing has on not only the amount of spawning biomass but also the interruption of the organized spawning behaviour.

Comment:

There was discussion on the issue of gillnet fishing disruptions of spawning behaviour. Some industry representatives disputed this. It is certainly not clear whether or not there is a cause-effect relationship. This would require more study. The point was raised in that the gillnet fisheries are and always have been fisheries directed at spawning fish.

Fig. 1: Annual variation in the estimated numbers of two year old herring in the spring and fall populations.

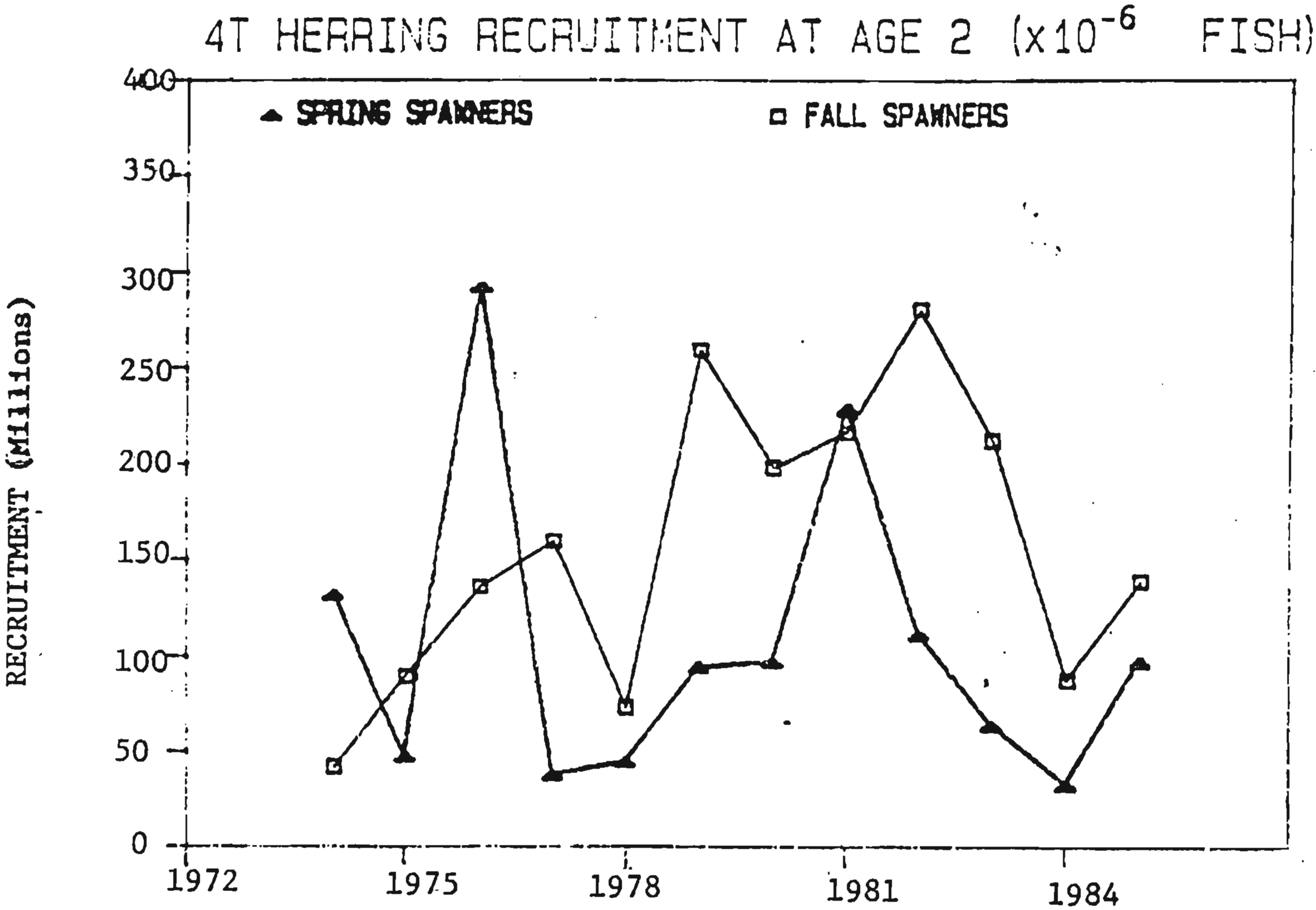
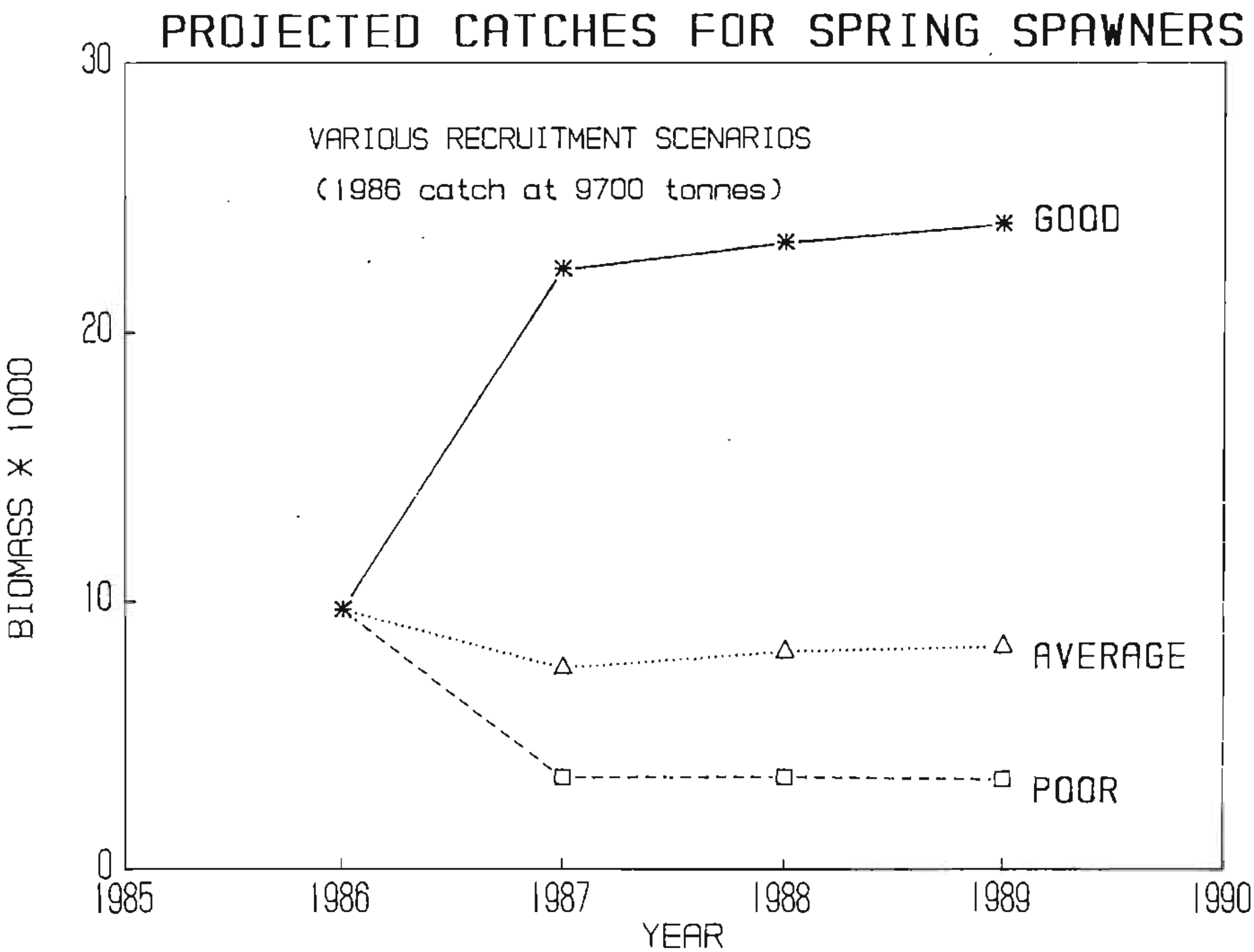


Fig. 2: Three projections of $F_{0.1}$ catches for spring sawning herring based on poor average and good recruitment of age 2+ fish (taken from Fig. 1).



3.2 BIOLOGICAL ADVICE FOR BRITISH COLUMBIA HERRING

by
Max Stocker
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, B.C. V9R 5K6

Pacific herring (Clupea harengus pallasi) range from southern California to Arctic Alaska in the north western Pacific, and from Korea to Kamchatka in the north eastern Pacific. Herring are pelagic planktivores, and schooling is standard behaviour. Herring migrate onshore to spawn inter- and sub-tidally during the months of March and April. They lay demersal eggs, which adhere to vegetation. The larvae hatch after 6-18 days, and juveniles recruit at ages 2-5. Maximum age is 20-yr old, and they are found up to age 10 in the fishery. In British Columbia, currently 7 stocks are recognized (Haist, Schweigert, and Stocker 1986).

The first commercial catch of Pacific herring was recorded in 1877. There was a fishery for the dry salted herring market in the Orient from 1904-1934 with up to 77,000 t of annual catch. A reduction fishery by purse seine followed from 1935-1967. Fish were taken during their inshore spawning migration from November through March. Large catches up to 240,000 t were taken. High catches in combination with poor recruitment led to a collapse of the fishery and subsequent closure in 1968.

Cessation of the intense reduction fishery led to stock recovery and commencement of the roe herring fishery. The seine and gillnet fishery catches herring on or near the spawning grounds to supply the lucrative Japanese Kazunoko market. The fishery is short and intense and the fleet has excess capacity and is difficult to manage. Other herring fisheries include roe-on-kelp and food and bait.

3.2.1 Herring Management Structure

The herring fishery management objective in B.C. is based on a fixed harvest rate of 20% in conjunction with a predetermined CUTOFF (Stocker 1985) level. There are two criteria fundamental to this management system:

(1) The stock assessment has to be consistent with all available information.

(2) There has to be a management structure for planning and implementing fisheries (Fig. 1).

These objectives are affected through:
Stock Assessment Committee
Herring Management Working Group
Herring Industry Advisory Board
In season Management Teams

The process was formalized in 1982 and is overseen by the herring co-ordinator of the Fisheries Branch. The key to the process is that "concensus" of status is sought from many perspectives.

The stock assessment committee establishes relative stock trends in biological characteristics and field observations used to establish harvestable surplus. The herring management working group takes the information to draw up fishing plans. The herring industry advisory board reviews fisheries, reviews proposed management plans, and provides input for the final fishing plans.

The in-season management varies somewhat from area to area. Soundings are undertaken, roe test sets are made from chartered vessels, enforcement is carried out, fishing to quota occurs, and the season is reviewed with industry.

A significant contribution to this "consensus" system of management is the recording of planning and decision making. Minutes of meetings are produced as well as in-season records of management strategies are kept.

The record of roe catch (1000 t) for the total B.C. coast vs roe quotas (1000 t) indicates good correspondence.

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
ROE CATCH	73.6	63.1	37.3	14.4	26.3	27.5	38.9	32.6	24.4	15.1
ROE QUOTA	72.6	74.6	53.8	31.7	27.3	31.8	28.0	31.3	18.9	12.5

3.2.2 Methods of Stock Assessment and Forecasting

In fisheries management we want to predict what will occur in a fishery in the future. Forecasting the potential catch that can be removed from stocks requires assessing the status and determining which factors affect stock dynamics. We are currently using 2 methods in our analytical assessment system: 1) Age-structured model analysis, and 2) an escapement based method. These models provide simple descriptions of the dynamics of real herring populations.

For the escapement based method current population size estimates depend heavily on spawn deposition information. Relative importance of spawn can be adjusted in the age-structured model depending on degree of belief in the accuracy of the spawn information. In addition to the analytical stock assessment methods other criteria used for determining biological quotas for B.C. herring include:

- Stock trends
- Recruitment forecasting methods
- CUTOFF's (minimum stock level below which no harvesting occurs).

Forecasting recruitment is an important component of the stock assessment system. Herring has experienced strong fluctuations in recruitment success associated with changes in oceanographic conditions (Fig. 2). We use environmentally dependent stock recruitment models to forecast recruitment to the fishery. With changing environmental conditions from year to year, there exists a family of stock recruitment curves. From a fisheries perspective, accurate forecasts of recruitment success has great benefits to the commercial fishing industry.

3.2.3 Summary

1 - A quota system based on fixed harvest rate of 20% of forecast run in conjunction with a CUTOFF is used to manage B.C. herring.

2 - The employed management system is a "consensus" system. It makes extensive use of the consultative process.

3 The system is well documented.

4 - The analytical stock assessment gives us a reasonable understanding of past performance of B.C. herring populations. We are continuously refining these methods. With these refinements we hope to avoid pitfalls that lead to severe stock declines.

5 - Finally, in B.C. fishermen share the responsibility of annual assessment through:
   a) vessel charter program (collection of biological samples).
   b) participating in seine and gillnet openings to provide catch samples.
   c) sending representatives as observers to the stock assessment meeting.
   d) sending representatives to participate in the herring industry advisory board meeting with DFO.

3.2.4 References

Farlinger, S. 1986. Herring management in British Columbia. p. 11-19 in Haegele, C. W. (ed). 1986. Proceedings of the fifth Pacific coast herring workshop, October 29-30, 1985. Can. MS Rep. Fish. Aquat. Sci. 1871: 164 p.

Haist, V., M. Stocker, and J. F. Schweigert. 1985. Stock assessments for British Columbia herring in 1984 and forecasts of the potential catch in 1985. Can. Tech. Rep. Fish. Aquat. Sci. 1365: 53 p.

Haist, V., J. F. Schweigert, and M. Stocker. 1986. Stock assessments for British Columbia herring in 1985 and forecasts of the potential catch in 1986. Can. MS Rep. Fish. Aquat. Sci. 1889: 48 p.

Stocker, M. 1985. Estimates of equilibrium biomass in the absence of fishing and corresponding CUTOFF levels for B.C. herring. 6 p. Presented to annual meeting of the Herring Stock Assessment Committee, Cowichan Bay, Sept. 4-5, 1985.

3.2.5 Questions and Comments

The herring management system on Canada's west coast uses a quota system with a fixed rate (20%) of exploitation, modified by a defined "cutoff". The administration of the system is similar to that in place on the east coast. The industry participates in the assessment process by sending representatives to both the adivsory committees and the stock assessment committees.

Question:

How is the minimum cutoff level derived?

Response:

It is based on the stock-recruitment relationship. It is 25% of the unfished equilibrium, based on the experience with peruvian anchovies. it is an attempt to define a minimum spawning stock biomass.

Comment:

There are two approaches to harvesting roe on kelp - impoundment, and open pounding. The major fishery on roe is however a pre-spawning one with purse seines and gillnetters involved.

Comment:

It was stated that there is a difference between the east and west coast as regards to the amount of resources spent on herring research. It was the perception that it was higher on the west coast. No figures were presented to confirm this.

Question:

How sensitive is the catch prediction to the environmental information used in the described stock-recruitment (S/R) relationship.

Response:

River discharge sea surface temperature and sea surface water transport are involved. Warm water is generally unfavourable for recruitment. It appears that pacific hake and mackerel from the U.S.A. come further north in warm years and may predate on young herring. About 50% of the variability in the S/R relationship can be described by the environment. Thus recruitment using it can be described as only poor, average or strong. For this reason, net surveys for age 2 herring are being initiated.

Comment:

Roe price is initially set (generally low) prior to the fishery but is adjusted upward subsequent to harvesting. It is about $2,000 per ton for gillnetters and $1,500 for purse seiners. Gillnet or girth net mesh sizes are 2-1/4", designed to catch fully ripe fish.

Comment:

Because openings and closures are by small areas, sometimes bays, the assessments are conducted on small areas, using the spawning escapement information.

Fig. 1: Structure of herring management in British Columbia (from Farlinger 1986).

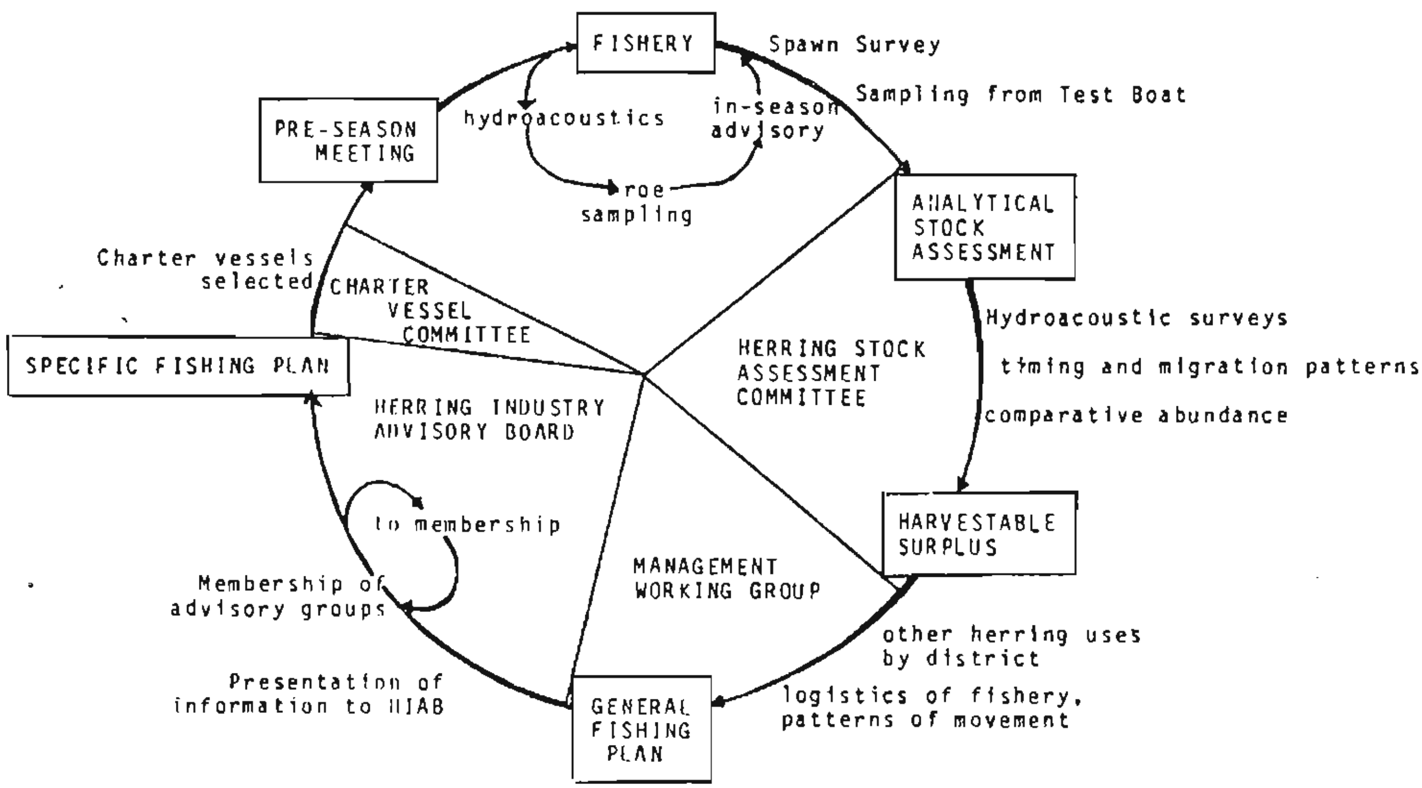
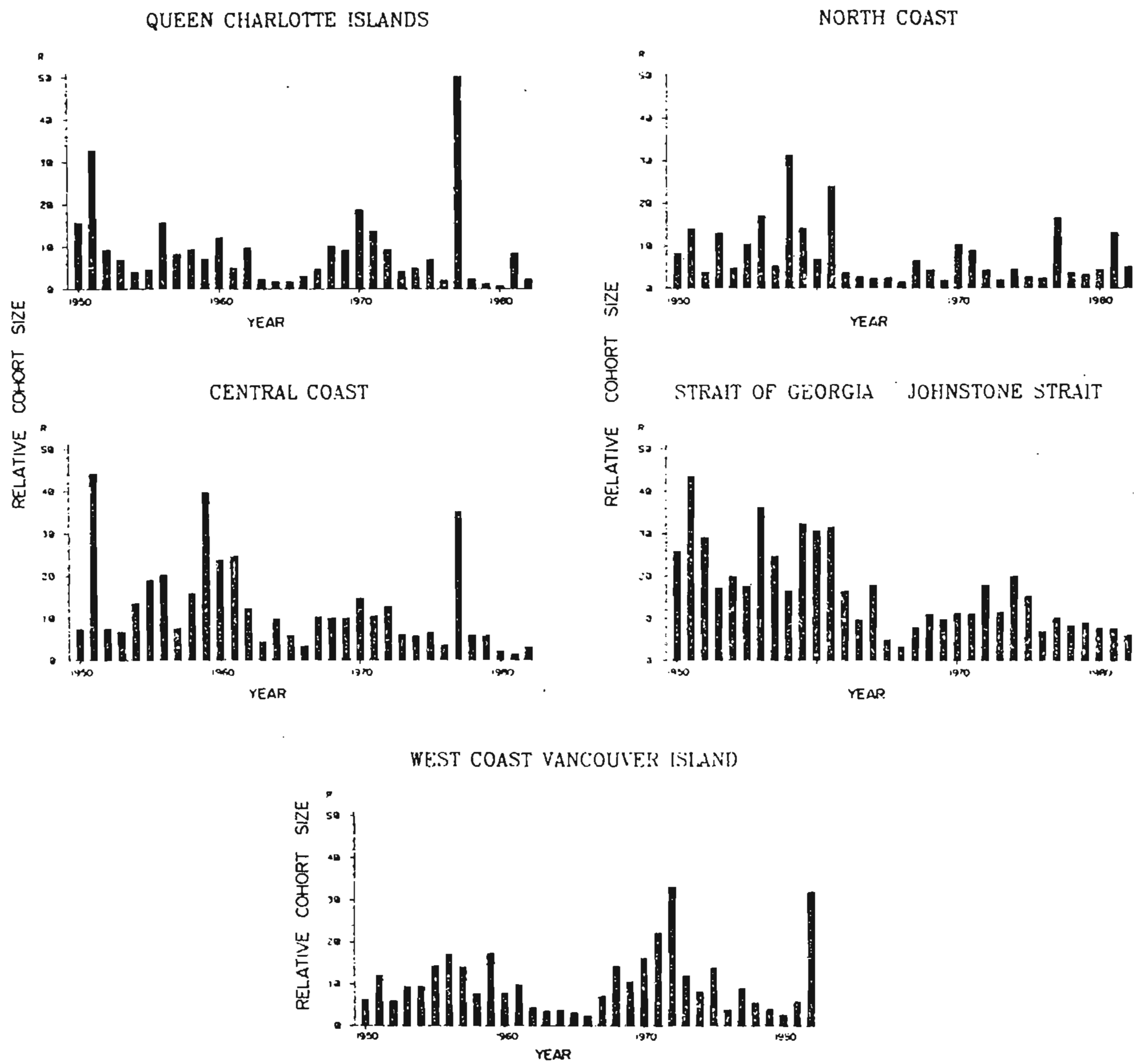


Fig. 2: Relative cohort strengths from age-structured model analysis, 1950-1982 (from Haist et al. 1985).



4. FUTURE COOPERATION

This final section was initiated with a review of a cooperative project between biologists and fishermen in the Bay of Fundy. Next, we ask if a formal mechanism is needed to ensure cooperation between fishermen and biologists in the assessment of Gulf of St. Lawrence herring stocks. Finally, we provide a summary of the major questions and issues which arose from the workshop.

4.1 BAY OF FUNDY: AN EXAMPLE OF COOPERATION BETWEEN SCIENTISTS AND INDUSTRY

Derrick Iles
Science Branch
Scotia Fundy Region
Biological Station
St. Andrews, New Brunswick

There is considerable confusion in some places as to what is meant by "management". Those who deal with management theory on the biological side, and without first hand involvement in a fishery, tend to deal only with the question of advice on catch regulation and related matters. Economists go a little further than that, but even so, tend to use the same approach and deal largely with the primary side of industry - things get so complicated if you want to look at all aspects of a major fishery that it becomes impossible to deal with the subject as a theoretical exercise. Indeed there are some fishery biologists who believe that theoretical "management" makes about as much sense as does theoretical brain surgery or theoretical piano playing - there is only one way and that is to be involved in the fishery as closely as is possible.

To indicate what is involved in fisheries management and to suggest how complicated the process as a whole can be - and usually is - one can set out the kinds of questions that are asked of a fishery; there are four of them, so:

1) How much (or many) fish - this can be referred to as the biological question.
2) How many dollars - the economic question.
3) How many jobs - the social question.
4) How many votes - the political question.

Everyone with any first hand experience in dealing with real fisheries problems will recognize that these are genuine questions that always arise, and which must be born in mind when considering ones own particular interest or responsibility, but it is worthwhile to follow it up by putting them in the context of the Canadian management situation. The point to emphasize is that the Canadian "management situation" is nothing less than the impact or influence of the Canadian economic and social history and of the political system that is the result of this history. It is unique to Canada and to the particular part of Canada that is affected. The assumption by Canada of managment responsibility of her marine fisheries introduced new factors, compared with the "old" system, that are still being appreciated, and hopefully, by meetings of this kind, sorted out!

Canada is fortunate that the "biological" question is the responsibility of a single authority, the Federal Department of Fisheries and Oceans, and specifically the Minister of this department. This arrangement reflects the particular kind of federal system that Canada adopted from the very beginning and it has important, and in this instance favourable implications. This is because any system in which this resource control authority is fragmented is amost certain to be ineffective. The kind of federal government enjoyed by our neighbours to the south where the States have entrenched rights in the old "three-mile zone" creates boundary disputes with each "coastal State" and with no possibility of their being resolved by a higher authority. There is none unless the Deity can be involved! In my view this has contributed greatly to their difficulties in reaching accord on management problems, and particularly in the herring fisheries of the eastern United States. The same can be said for the eastern Atlantic where management requires the agreement between all of the interested countries which is about 20 of them, even at the biological level. In practice, any difficult question at the "higher" levels of management tend to be avoided, which is easily done by maintaining that the biologists have not done their job properly and that definite and incontravertible proof has not been provided that would justify their raising sensitive issues.

However, the Canadian system makes it all the more important that those responsible for the scientific advice should not have access to, or responsibility for, the "higher levels" of management. Their advice on management affects their fellow Canadians and should be discussed and presented as objectively as possible. The CAFSAC organization was set up to ensure that this is so although there is sometimes confusion on this point. For example it is often said, but it is completely incorrect, that the TAC is "fixed by the scientists". This is not their responsibility and although they should be required at any time to justify any advice they produce that is referred to in the management process, they should not be asked to, or accused of going beyond their scientific mandate. This is not to say that scientists should be blissfully ignorant of the "facts of life" related to fisheries for which they have assessment responsibility!

In fact, given good information from the fishery, the scientists job is the easiest of all; the rules are much more clear-cut and the objectives usually defined in standard ways that are independent of those other management issues; the ones that involve special interests and require decisions that have to be made on subjective rather than objective grounds. Indeed a very reasonable definition of management at the higher levels of involvement is "the quantitative resolution of conflicts of interest", and an excellent example of the complexity of a real situation that required precisely this is given by what became known at the Bay of Fundy Project.

Henry Ford once said that "history is bunk" but the current situation that exists in east coast Canadian fisheries was molded by the recent historical processes that resulted in our assumption of complete management responsibility; anyone who does not appreciate this should think for a moment of St. Pierre and Miquelon! This particular story involving the herring industry of the Bay of Fundy began with the agreement at ICNAF discussed earlier, that was reached in early 1972, and which was immediately quite rigorously enforced by Canada. This "holier than thou" attitude on our part was resented by some Canadian fishermen but it was essential if we were to demonstrate to the world at large our managment determination and competence. Remember that we were far from being able to claim exclusive management responsibility at that time, and were bound to work within INCAF, the only authority that existed at that time. Our fishermen and industry were not easily convinced of its necessity at the time because of persistent reports of evasion of quota limits by other countries, and, to coin a phrase, "it wasn't easy"!

Two points can be made that have to be born in mind in relation to what happened subsequently. The ICNAF agreement depended critically on the ability to allocate "national shares" to the interested individual governments; without this it was impossible to expect agreement on an annual quota amongst countries with different market interests and different fishing seasons; the country that had a fishery that coincided with the beginning of the quota year would have scooped the pool! Secondly, as an interesting sidelight, it was in this agreement that the famous criterion of "$F_{0.1}$" was first used. Oddly enough, it was not used as a basis to set catch levels but to counter an argument by the foreigners that maintained that catch limitations were unnecessary, a fact that is not widely appreciated. That it has been accepted as a fundamental management aim on both sides of the Atlantic is a somewhat surprising fact to those few who were involved in its introduction as a theoretical argument applied specifically to herring fisheries!

The almost immediate result of Canada's inforcement of the catch limit represented by her ICNAF "quota" on her own fishermen was a drastic reduction in the length of the fishing season off southwest Nova Scotia in the summer fishery there. After only two seasons this was cut to about six weeks from the several months that was enjoyed before catch limitations were imposed. Within Canada there was a mad scramble for quota amongst the 50 or so seiners operating in the area; each wanted to get a lions share before it all ran out, and fishermen dreaded the possibility of boat breakdown or gear loss that could spell disaster rather than inconvenience.

In the early years this did not have too great an overall economic effect because the fishermen's price for their herring, which was used almost entirely for meal, was relatively high. A world wide slump in meal prices took place by 1975 and this precipitated a crisis to the fishermen; the total value of the proposed 1976 Canadian quota from ICNAF was completely inadequate to sustain even half of the fleet, even at subsistence levels.

The fishermen approached the Minister who responded by inviting them to get together to analyze the situation and, with help from his advisors, propose solutions. To this end a committee was set up, that unlike most committees, acutally did something useful!

The analysis of the situation was quite simple: it had to be assumed that the amount of herring available was fixed by the international allocation of the overall quota and could not be increased by Canada because it was set by international treaty. A reduction of the size of the fleet by more than 50% was clearly unacceptable to the fishermen even if it could be limited to that degree. Therefore they had to get more money for the same amount of fish; therefore they had to find or create another market at a much higher price.

Now there was such a market in Europe, in West Germany particularly, for butterfly fillets, but there were no facilities to produce food herring of the high quality demanded by this market at anything like the levels that were needed. The meal market would take practically any kind of herring, of any size and of almost any quality, and the whole industry was organized technically and economically very largely around this single product.

At this stage it became obvious that the whole fishery had to be transformed from a low-grade to a high grade produce, which both highlighted quality as a crucial aim and, certainly to the "outsiders" involved in the project, drew attention to the single most important issue for any fishery and indeed any economic operation - MARKET. The adage that people fish for dollars and not fish was strikingly confirmed.

It was also made clear that such a major change must involve both sides of industry, the fishermen and the processors, and a new factor emerged. It was quite impractical for the processors to invest in a food industry for a six to eight week season, which was the inevitable result of the imposition of Canadian quota. The difficulties caused by an unallocated quota at the international level were being found to apply at the national level. It became clear that a major, even miraculous improvement in the way fish were handled and transported to the plants had to be achieved. The only herring used for food until then were those most recently caught and "on top of the load", and under the best of conditions this was no more than about 10% of the total.

The fishermen's part in this was to control the rate at which the quota was taken by the fleet as a whole so as to spread it over a much longer season and this in turn could be achieved only if there could be agreement on individual boat quotas and on limits to catch to match the available current market. The real problem was to agree on a system of boat quotas, an agreement that had to apply to all the boats in the fleet, to include both those owned by fishermen and those owned by plants. When it is realized that the range of catch by individual boats in 1975 was from nearly 4,000 tons, for the high liners, down to less than 100 tons, to the "also-rans", the scope of the problem became evident. That the fishermen agreed to an allocation scheme that guaranteed at least a fighting chance to all boats in the fleet represented an attitude of good will that was remarkable for its time. The boat quota allocation was based on size of boat and crew, and the boat performance for the most recent period, with the proviso that special cases of hardship would be given a second look. At the same time agreement was reached on how the catch of the fleet as a whole would be spread out to match the available market, and this led to the acceptance of weekly boat quotas.

All of this required an organization both to link the fleet to the market and to ensure the proper enforcement of all the agreed measures as well as conformation to the Canadian quota for the fishery that had been fixed at ICNAF, and could not be modified to give the industry more elbow room.

Two other aspects of the operation must be mentioned. To emphasize that the attempt to restructure the fishery was genuine, and to make a committment to the success of the project, the Minister invoked the section of the Fisheries Act, that had been put in abeyance, that forbade the use of herring for meal production; to give some financial incentive and a glimpse at least of what might develop, "over the side sales" to the Poles at very respectable "food herring" prices were arranged - the first of its kind. Although towards the end of the first year of the project it became clear that all of the quota could not be put into food and it was necessary to relax the meal moratorium at the end of the season, by the second year less than 5% of the total catch was used for meal, and the transformation was virtually complete. This confounded critics of the project who were convinced that it was impossible to make such radical changes so quickly.

The operation of the project depended critically on the setting up of a fair and honest reporting system so that no one cheated on his quota. Fishermen are no more or less honest than anyone else, and the rules of the game until the Bay of Fundy Project came along was "devil take the hindmost". This not only had to be efficient but had to be seen to be efficient and in practice the only people with the detailed knowledge of what was going on NOW were the fishermen themselves, and of course, the plants that accepted the catch. It was necessary to set up a recording and analytical system at the St. Andrews biological station that was the centre for the reception of reports from all sources, that kept the books and that "blew the whistle" when necessary. To ensure that things not only were fair but were seen to be fair, a weekly newsletter was circulated that presented a detailed breakdown of the previous weeks fishery. This gave the details of catches by individual boat, by the day of the week and area of catch, together with landing point and a breakdown of product use. This system was extended to include the Bay of Fundy weir fishery as well, and reported and analyzed the weeks catches by the Tuesday of the next week. The system set up then is still the basis for catch reporting for the Nova Scotia stock although there have been some changes, and you would be lucky to get such rapid service.

The fishery was transformed and its economic value to all participants increased many fold within three or four years; there have been less favourable developments since and the original market for fillets has long been lost, but the first several years were, and are, considered to represent a revolutionary success that stimulated both the acceptance of fishermen's organizations and the realization that a fishery, to be successful, must be made up of individual components that are prepared to address common problems jointly even if they differ in their individual aims. The important thing is to identify the common problems to agree on common aims and to anticipate any major changes that could affect the fishery as a whole. What if the Japanese roe fishery collapsed?

It is worthwhile to identify some of the aspects of the organization of the project that were thought to be responsible for its success at the time. The first, and perhaps the most important was that all problems were discussed in detail by the people who were most directly involved and who were the most informed and expert in the relevant fields. In this particular case this meant that they proposed the solutions too! The crucial decision involved the agreement on sub-allocation amongst the boat skippers, which, it must be stressed, was arrived at by the fishermen themselves; they set out the criteria and supplied the accurate information needed to put it into effect. The most desirable characteristic of the organization was its flexibility to meet the demands of a rapidly changing and often unpredictable market and resource situation. This was achieved by the delegation of "real time" management to a small group of departmental employees who had the power to make the relevant decisions, or proposals provided that they came within the guide lines established by senior management. This in turn was possible only if a constant stream of up-to-date and accurate information came from the fishery itself and although there had to be a competent point of collection analysis and dissemination of facts, the information could come only from industry. This meant that people with quite different and even conflicting interests had to cooperate in aspects of the project that were essential to its working at all.

This cooperation became formalized by setting up a post mortem process after each season, attended and enthusiastically supported by all interested parties. This took place throughout the closed season and resulted, finally, in the drawing up of proposals to address problems that had arisen during the fishery season itself that could not be dealt with then. These were then presented to the Department for acceptance, and/or modification and were promulgated in time for the next year's fishery. This was one time and one fishery where the operational plan was worked out by industry and "local" departmental staff and presented to the departmental higher management for approval, rather than the other way around, but such a system is possible if and only if the will to agree is present - or forced on everyone by the possibility of catastrophe and/or by the other difficulty of the management situation. No question was ever avoided, frank and even brutal discussion was common, but over a period of time people began to appreciate the point of view of those who were their competitors or traditional antagonists so that, at the very least, it was possible to identify what was possible from what was impossible. If interaction of this kind does not take place, any problem becomes labelled as impossible even before it can be analysed objectively, and difficult but manageable questions are not tackled.

The kind of meeting instigated here has many of the features familiar to those who were involved in the Bay of Fundy Project, and there is little doubt in my mind that significant results could be achieved!

4.2 DO WE NEED A FORMAL MECHANISM?

The most obvious formal mechanism would be to renew this workshop on an annual basis. There was general agreement that this should be done. The objective would be to allow biologist and fishermen to decide which abundance index is most representative of the fishery before the calculations for the stock assessment are initiated.

Several points were raised. First, participants at the workshop should be members of a technical working group which in turn would be part of the Gulf of St. Lawrence small pelagic advisory committee. This working group would ensure that there would be fair representation of all interest groups. Second, this working group should meet at least twice each year: before the assessment is done to review abundance indices and other features of the fishery; and, after the assessment has been approved by CAFSAC

4.3 SUMMARY OF MAJOR ISSUES

4.3.1 Stock Identity

- Without good management stocks can be destroyed.
- There is no evidence that another stock can assist the recovery of another.
- More work is needed on stock structure.
- A review of historical tagging data base is recommended.
- Acoustic surveys may be useful for identifying herring stocks.

4.3.2 Index Fishermen

- There is great potential to have index fishermen fishing smaller and larger mesh sizes than normally used in the fishery.

4.3.3 Acoustic Surveys

- Intensive surveys should be initiated in Chaleur Bay, the current expenditure is inadequate.

- The November survey is not useful for estimating the biomass of specific stocks, therefore the entire Gulf of St. Lawrence must be covered.

- Acoustic surveys should be done in spawning aggregations in specific areas.

- Good surveys require a long term investment of resources.

4.3.4 Spawning Bed Survey

- Diving surveys should be done to measure possible detrimental affects of fishing on spawning beds.

- Spawning bed surveys should be initiated in Chaleur Bay.

4.3.5 Larval Surveys

- The mackerel egg surveys may contain some information on herring larvae; at least they may be useful for identifying discrete distributions of larvae.

4.3.6 Log Books

- Log books can easily be used in the gillnet fishery, but making them mandatory would not work. Misreporting is done because fishermen perceive the stock to be much larger.

4.3.7 Forecasts

- Projections should be made using a variety of fishing strategies other than $F_{0.1}$.

- Need to know the advice much sooner.

5. LIST OF PARTICIPANTS

Name	Affiliation	Location
Stuart Beaton	Maritime Fishermen's Union	North Bay, N.S.
Fernand Bourgeois	Sec. Treas. Union des Pêcheurs des Maritimes	Shediac Bridge, N.B.
Walter Bruce	Eastcoast Fishermen's Federation	P.E.I.
Scott Campbell	Dept. of Fisheries & Oceans	Moncton, N.B.
René Castilloux	Pres. Assoc. des Pêcheurs Côtiers	Newport, P.Q.
Michael Chadwick	Dept. of Fisheries & Oceans	Moncton, N.B.
Réginald Comeau	Union des Pêcheurs des Maritimes	Sheila, N.B.
Bernie Conway	Maritime Fishermen's Union	P.E.I.
Maxime Cormier	N.B. Fish Packers Assoc.	Moncton, N.B.
André Doiron	Union des Pêcheurs des Maritimes	Caraquet, N.B.
Peter Dysart	N.B. Fish Packers Assoc.	Moncton, N.B.
Fernand Friolet	Gulf Seiner Association	Bas Caraquet, N.B.
Derrick Iles	Dept. of Fisheries & Oceans	St. Andrews, N.B.
Bob MacClure	SPANS	Shelburne, N.S.
Paul-Aimé Maillet	Union des Pêcheurs des Maritimes	LeGoulet, N.B.
Shoukry Messieh	Dept. of Fisheries & Oceans	Moncton, N.B.
Marcel Muise	Union des Pêcheurs des Maritimes	Baie Ste-Anne, N.B.
Gloria Nielsen	Dept. of Fisheries & Oceans	Moncton, N.B.
Eugene Niles	Dept. of Fisheries & Oceans	Moncton, N.B.
Bob O'Boyle	Bedford Institute of Oceanography	Dartmouth, N.S.
Louis Poirier	L'Association de Pêcheurs Propriétaires des Iles de la Madeleine	Cap aux Meules, P.Q.
Edouard Richard	Union des Pêcheurs des Maritimes	Richibouctou, N.B.
Arthur Rioux	N.B. Fish Packers Assoc.	Shippagan, N.B.
Denis Rivard	Dept. of Fisheries & Oceans	Ottawa, Ont.
Ross Shotton	Dept. of Fisheries & Oceans	Halifax, N.S.
Rob Stephenson	Dept. of Fisheries & Oceans	St. Andrews, N.B.
Max Stocker	Pacific Biological Station	Nanaimo, B.C.
Cliff Thomson	PEI Fishermen's Association	Charlottetown, P.E.I.
Rhéal Vienneau	Dept. of Fisheries & Oceans	Moncton, N.B.
John Wheeler	Northwest Atlantic Fisheries Ctre.	St. John's, Nfld.