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1998 EVALUATION OF 4VWX HERRING

BY

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ABSTRACT

Spawning stock biomass (SSB) of the southwest (SW) Nova Scotia spawning component is estimated from acoustic surveys of spawning grounds to exceed 500,000t. Age composition has improved, but contains a relatively small fraction of fish older than the 1992 year-class. Large amounts of spawning fish were documented on German Bank and in Scots Bay, but spawning was again absent or below historical levels on some traditional grounds. The 1998 catch should be less than 100,000t.

Catches from the second year of a reactivated Scotian Shelf banks fishery almost doubled in 1997 to approximately 20,000t. Age composition from both the fishery and research survey showed a dominant 1992 year-class and a rather narrow age distribution. There is little quantitative information on which to evaluate the status of this stock.

With a few exceptions, the fisheries and stock status of spawning groups along the coast of Nova Scotia remain undocumented. The lack of information precludes evaluation of stock status. Improved documentation of these spawning areas and fisheries is essential.

The Bras D'Or lakes spawning component exhibits a continuing trend of decline. In 1997 there was a further decrease in spawning locations, an absence of fish in several traditional fishing areas, low levels of larvae, and an intensification of effort in the few, very small remaining areas of herring spawning distribution. From a biological perspective, no fishing should take place on this spawning component in 1998.

RÉSUMÉ

Des relevés acoustiques des fonds de frai ont permis d'estimer à plus 500 000 t la biomasse du stock de géniteurs de la composante de frai du sud-ouest de la Nouvelle-Écosse. La composition par groupes d'âge s'est améliorée, mais on dénote un pourcentage relativement faible de poissons antérieurs à la classe d'âge de 1992. Des quantités importantes de géniteurs ont été décelées sur le banc German et dans la baie Scots mais, sur certaines frayères, il n'y a toujours pas eu de frai, ou celui-ci a été inférieur aux niveaux historiques. Les captures de 1998 devraient être inférieures à 100 000 t.

Les prises d'une pêche sur le plateau néo-écossais, réouverte pour la deuxième année, ont presque doublé en 1997 pour atteindre 20 000 t environ. La composition des âges, tant des captures de la pêche que de celles des relevés de recherche, indiquait une dominance par la classe d'âge de 1992 et une distribution des âges relativement étroite. Nous disposons de peu de renseignements quantitatifs permettant d'évaluer l'état de ce stock.

À quelques exceptions près, nous possédons peu de renseignements sur la pêche et l'état des groupes de géniteurs de la côte de la Nouvelle-Écosse et cela nous interdit de procéder à une évaluation de l'état du stock. Il est essentiel d'obtenir de meilleurs renseignements sur ces zones de frai et les pêches qui y sont effectuées.

La composante de frai des lacs Bras D'Or présente une allure à la baisse continue. En 1997, nous avons noté une autre baisse du nombre de fonds de frai, l'absence de poissons dans plusieurs zones de pêche traditionnelles, des concentrations de larves réduites et une intensification de l'effort dans les zones restantes, peu nombreuses et très petites, de la répartition du hareng. Dans une telle perspective biologique, cette composante de frai ne devrait faire l'objet d'aucune pêche en 1998.

Evaluation of 4VWX Herring

1) Background and Context

1.1 Stock structure and management units

The 4VWX management unit is known to contain a number of spawning areas separated to various degrees in space and time. Spawning units in close proximity, with similar spawning times, and which share a larval distribution area (e.g. Trinity Ledge and Seal Island in SW Nova Scotia) are considered to be part of the same complex and undoubtedly have much closer affinity than spawning units which are widely separated in space or time, and do not share a common larval distribution. Some spawning areas are large and offshore, whereas others are small, and more localised, sometimes very near shore or in small embayments. The situation is complicated further by the fact that herring tend to migrate long distances, and mix outside the spawning period with members of other spawning groups. Some spawning areas are known from fishery sampling, tagging, etc. to have formed the basis for major historical fisheries while others have not. For the purposes of evaluation and management the 4VWX herring fisheries are divided into four components (Fig. 1):

1) SW Nova Scotia/Bay of Fundy spawning component
2) Offshore Scotian Shelf spawning component
3) Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component; and
4) SW New Brunswick migrant juveniles.

Further details on these components are provided in the 1997 Stock Status Report (Anon 1997a).

Recognizing that each component has several spawning areas (Fig. 1), and that there is mixing of fish from more than one component at certain times of the year, industry and management have explored means of managing the complexity within each component. These include distributing fishing effort among spawning areas according to their relative size and taking appropriate account of interaction among components such as restrictions on some areas of mixing.

1.2 Recent workshops

Several workshops of relevance to these herring assessments took place in 1997:

A) Maritimes Region Herring Workshop; Feb. 1997 (Sinclair 1997)

This workshop which involved a broad spectrum of industry, government and interested parties, reviewed several aspects of the scientific basis of herring management in the Maritimes Region, with the view to reaching consensus on principles by which management decisions are made. The workshop addressed five issues: conservation objectives, strategic targets corresponding to conservation objectives, management unit definition, issues surrounding fisheries in various seasons (winter, summer and spawning periods), and the form and approach of management. The workshop involved plenary presentations of background material, working group discussions of the issues, and plenary presentation of working group

responses. The report summarizes the degree to which consensus was achieved on these issues, and lists recommendations which were to be presented to appropriate advisory committees.

The following aspects were of particular relevance to the 4VWX fisheries and assessments.

Precautionary approach: Although there were some concerns relative to the application of the precautionary approach to herring management, it was accepted that this approach should be incorporated into management planning in a common sense way.

Conservation objectives: There was general agreement on the following three objectives:

1) To maintain the reproductive capacity of herring in each management unit;
2) To prevent growth overfishing; and
3) To maintain ecosystem integrity/ecological relationships ("ecosystem balance").

Strategic targets: Working groups agreed that the following targets should be accepted for the first conservation objective (maintaining reproductive capacity):

- persistence of all spawning components in the management unit;
- maintain biomass of each spawning component above a minimum threshold;
- maintain a broad age composition for each spawning component; and
- maintain a long spawning period for each spawning component.

It was accepted that $F^{0.1}$ continues to be the fishing mortality target to achieve the second objective (above). Although the third conservation objective (above) was accepted, there was insufficient information available on which to base targets, and it was concluded that the issue required further attention.

The list of recommendations from the workshop is appended (Appendix I).

B) Atlantic Zonal Herring Workshop; March 1997 (Rice 1997)

The 1997 Zonal Herring Workshop reviewed stock status information and the methodological approaches being used for assessment and management of herring in this and other areas. Among the conclusions of that workshop were the following:

Management Units: The overall management area and assessment were disaggregated into the four units described above (formalizing something which had been evolving for several years) .

Survey-assess-fish protocol: Several portions of the 4WX herring fishery have been managed according to a protocol whereby industry, scientists and managers worked together using industry vessels to evaluate the size of individual aggregations prior to harvesting. On spawning grounds, only a portion (commonly 20%) of what was surveyed was allocated to the fishery. In this way effort within the established TAC was distributed among the spawning components according to their relative size and only after documentation of sufficient quantities of herring in the area. The workshop supported this approach noting, however, that greater

quantitative rigor was required. It was particularly suitable for use on the spawning grounds to distribute effort within an overall TAC (as was being done in SW Nova Scotia). It should not be used as a tool in setting overall harvest levels until a higher level of rigor has been achieved. Outside of the spawning period, the method was seen as having value in preventing depletion of a single aggregation, but is not adequate to ensure conservation of all stock components. This issue was described in a Regional Fisheries Status Report (Anon 1997c).

Coastal Nova Scotia spawning components: There is little information of the status of stocks within the coastal component, aside from a recent study in the Bras D'Or Lakes. There is an immediate concern about new fisheries developing in these coastal areas. All participants agreed that all herring fisheries need to be managed in ways which prevent targeting on these small and possibly discrete units, whether during spawning or when they mix with other components at other seasons.

The full results of the workshop are documented in the Proceedings (Rice 1997), in the 1997 Stock Status Report for 4VWX herring (Anon 1997a), and in a report on in-season management in the 4WX herring fishery (Anon 1997c).

C) Workshop on Ecosystem Considerations for Krill and Other Forage Fisheries; April 1997 (Head et al. 1997)

This workshop proposed the following set of conservation objectives for fisheries on species which are important as forage:

- maintain ecological relationships/ecosystem integrity
- minimize risk of irreversible decline
- maintain ecosystems and constituent species within the bounds of natural fluctuation
- maintain full recruitment potential including genetic diversity
- allow fisheries which meet conservation objectives and maximize knowledge returns

The results of the workshop are of particular relevance to further definition of the issue of maintaining ecosystem integrity (conservation objective 3 above), and discussions took place regarding how to begin to meet these objectives in the 4VWX herring fisheries. Further details of the workshop are available in Head et al. (1997).

D) Herring Stock Assessment and Research priorities Workshop; Dec. 1997 (Mooney-Seus et al. 1998)

A workshop involving 86 people from six countries, and representing diverse interests, was held in December 1997 at the New England Aquarium to discuss methods, programs, and approaches to herring stock assessment employed throughout the North Atlantic and North East Pacific. The report of this meeting (Mooney-Seus et al. 1998) summarizes presentations and discussions and presents a comprehensive list of potential research issues raised during the meeting. This workshop confirmed the importance of improved understanding of stock structure and attention to individual spawning components as major research priorities in the 4VWX area

1.3 Pelagics Research Council

The Pelagics Research Council (PRC) is an organization created by the herring and mackerel fishing industry in 1996 to sponsor and promote research projects which will increase the state of knowledge of these species thereby improving fisheries management. The PRC envisaged building on the collaborative approach to surveys which had evolved in the herring industry and to obtain funding to improve, extend and fill some gaps in current research programs. In 1997 the PRC and DFO co-sponsored an intern (under the Science & Technology Internship Program) which resulted in improved documentation of fleet activity and sampling during the fishery (see Paul 1998). Late in 1997 the PRC received funding from Human Resources Development Canada (HRDC) to undertake a set of research projects in collaboration with DFO and the Nova Scotia Dept. of Fisheries and Aquaculture. The following eight projects are included in this program:

- Technical orientation (training in sampling, survey data recording and tagging) of approximately 40 members of the purse seine and inshore herring and mackerel fleets;
- Improved resource documentation (primarily acoustic and larval surveys) of Georges Bank herring and mackerel;
- Improved resource documentation (primarily acoustic and larval surveys) of Scotian Shelf herring and mackerel;
- Improved resource documentation of herring and mackerel occupying coastal waters of Nova Scotia and the Bay of Fundy;
- A new comprehensive tagging program addressing questions of herring and mackerel stock structure;
- Improved acoustic survey methodology, documentation and implementation;
- Investigation of hydro-acoustic survey methodology and offshore fishing practices used elsewhere; and
- Promotion of studies of ecology and feeding relationships of herring and mackerel as part of the coastal ecosystem.

1.4 Management Plan and Objectives

The 1997 Scotia-Fundy herring integrated fisheries management plan (Anon 1997b) set out principles, conditions, and management measures for the 4VWX fisheries.

The main principle stated in the plan was "the conservation of the 4WX stock and the preservation of all of its spawning components". A TAC of 57,000t was established for the southwest Nova Scotia spawning component with 45,144t (80%) allocated to the mobile gear sector and 11,286t (20%) to the fixed gear sector.

An "in-season" management process, first implemented in the southwest Nova Scotia fishery during 1995 (Stephenson et al. 1996, 1997) was extended to other areas and fisheries. The approach encouraged surveying using the fishing fleet under scientific direction and control prior to fishing to ensure that fishing was distributed appropriately among various components of the stock (particularly among spawning components) according to the relative size and current state of each component. It improved data collection and enabled modifications to management decisions to be made with the involvement of participants and on the basis of up-

to-date information. The 1997 management plan extended the Dockside Monitoring Program (DMP) to include some components of the fixed gear sector for the first time.

2) SW Nova Scotia/Bay of Fundy Spawning Component

2.1 The 1997 Fishery

The TAC for this component was set at 57,000t. This was the same as had been allocated in 1996 and represents the lowest allocation in the history of this fishery. The low quota and sector allocation formula resulted in a further reduction in landings by the purse seine sector (45,042t), but an increase in landings by the gillnet (6,818t) and Nova Scotia weir (4,019t) sectors (Table 1). Total quota landings of 56,117t (Table 2, Fig. 2) were the lowest in over three decades (Table 3).

Continuation of the in-season management approach resulted in continued improvement in sampling and in ongoing discussion and review of the fishery. Again, fishing on spawning aggregations operated under a "survey, assess then fish" protocol, in which spawning aggregations were surveyed and predefined conditions had to be met before that part of the fishery was allowed to take place. There was a deterioration in 1997, compared with 1996 (Stephenson et al. 1997), in the number of surveys and quantitative estimates made by the purse seine and gillnet fleets. The installation of two acoustic recording devices allowed for the collection of quantitative records from two purse seiners during the 1997 season.

The distribution of herring as reflected by the fishery (Fig. 3) during the summer feeding and pre-spawning period were consistent with historical patterns (Paul 1998). Surveys and fishing confirmed the presence of large amounts of herring on German Bank and Scots Bay. However, there continued to be an absence of spawning at Seal Island and although there has been an improvement in the amount of spawning herring on Trinity Ledge, it remains below historical levels. Large aggregations (>100,000t) which included substantial amounts of pre-spawning and juvenile herring were documented off Long Island, Nova Scotia and off Grand Manan, New Brunswick (Melvin et al. 1998).

2.2 Resource Status

Catch at age

Biological sampling continued to improve with additional processing plants taking length frequencies on a regular basis, and with increased sampling aboard vessels. Table 4 shows the distribution of length frequency and detail samples including numbers aged from the 1997 fishery.

The 1992 yearclass (age 5) dominated this fishery component both in number and weight (Table 5, Fig. 4). The 1994 and 1993 year-classes at ages 3 and 4 followed in importance. The 1991 and earlier year-classes (ages 6+) made up only a small fraction of the catch (7% by number; 15% by weight). The age composition also contained fewer age 6+ fish than the average of the previous decade (Fig. 4). The age composition for the major gear sectors of the

1997 SW Nova Scotia spawning component are presented in Table 6. The average lengths and weights at age for 1997 (Table 7) and the historical fishery (Table 8) are similar to previous years showing large differences among geartypes reflecting the size and age selectivity of gears.

Larval Abundance

The Bay of Fundy larval herring survey was undertaken between October 29 and November 12, 1997 (Fife 1998 MS). The larval abundance index or 23.3 larvae m^2 was higher (Fig. 5; Table 9) and the area of larval distribution was greater than it has been the past three years (Fig. 6). The larval index was just below the average of 25.5, but above the median, of the 26 year time series. The sudden, large drop in larval abundance index in 1994 is difficult to explain.

Acoustic surveys

Building on developments since 1995, acoustic surveys were undertaken of major spawning areas and some of the major fishing areas using the acoustic equipment on commercial vessels and a research vessel. Sonars and sounders of the purse seine fleet, and sounders of the gillnet fleet were used to document the number, location and approximate size of herring schools. In a major improvement over the previous year, two purse seiners were equipped with quantitative recording devices which automatically logged survey results for later analysis (Melvin et al. 1998). Although the total number of survey hours was reduced compared to 1996, there was adequate surveying of key spawning areas and increased quantification for some of these due to the use of automated recorders. Surveys with automated recorders were edited as described by Melvin et al. (1998) using standard quantitative acoustics methods. Biomass estimates were made using standard target strength relationships.

Mapping surveys (vessels without quantitative recorders) were quantified using area and a density category (light, medium, heavy) as developed in 1995 and 1996 (Paul 1998).

The protocol for surveying spawning areas which has been used in the past two years required a 7-10 day interval between surveys to avoid the possibility of double counting. Fifteen quantitative estimates of various spawning aggregations are available (Table 10). These surveys are known to have missed some spawning events and areas. Applying the conservative 10-day interval between surveys eliminates eight estimates as too close together and results in a total Spawning Stock Biomass (SSB) of 400,500 t. Applying the minimum 7-day interval is complicated by two cases (Scots Bay and German Bank) where a second survey was undertaken after only six days but with the thought at the time that there had been a replacement of fish in the area. Since these surveys there has been considerable discussion regarding whether it is possible to demonstrate the turnover of the spawning aggregations between surveys (see discussion in Melvin et al. (1998) and Denny et al. (1998)). The suggested approach to these cases is to discount the results of the second survey by the amount of ripe (stage 5) fish which were present in the first survey, and which therefore might have been still present in the second survey. The sum of the 11 valid estimates, treated in this way, is 568,500 t.

Assessment

The same analytical assessment (Sequential Population Analysis (SPA)) model used in recent years, which uses larval abundance as an index of spawning stock abundance, was attempted (Appendix II). Larval abundance, which is considered to represent spawning stock biomass near the end of the fishery was related to spawning stock biomass (SSB) (population x weight at age x maturity at age) at the beginning of the year following the November larval survey. The analysis showed a weak relationship between the larval abundance index and SSB, poor model resolution, and a strong retrospective pattern, and was not considered to give valid estimates of recent stock size.

Major sources of uncertainty

There remains the need for a more reliable indicator of abundance for this stock. There have been difficulties using the larval abundance index, and there is no other time series. The sudden, large drop in larval abundance index in 1994, and the relatively low values of the past three years, are difficult to explain. The introduction of recording devices has improved quantification in the acoustics surveys, but there is need for improved survey coverage (spatial and temporal) and investigation of the duration of the spawning stages.

2.3 Ecosystem considerations

Herring is a prominent species in the diets of many other fish, birds and marine mammals, and should be managed with these interactions in mind. At present, a natural mortality rate of 0.2 is assumed to account for these interactions. Low fat content and poor condition of herring observed in 1994, thought to be related to an environmental anomaly, have not been observed since, and the 1997 distributions, growth rate and fat content were considered normal.

2.4 Outlook

The 1997 Stock Status Report (SSR) (Anon 1997a) stated:

> *"Although the analysis* [analytical assessment] *suggests a SSB of about 300,000t, there is large uncertainty in parameter estimates due to weak fit to the tuning index, especially in the last three years, and the predicted population estimate was considered to be too high. The analytical assessment (considered to be an overestimate), and the 190,000t documented in survey (considered a minimum) were thought to bracket the actual SSB."*
>
> *"the fishery continues to rely primarily upon a single year-class (1992). Recruiting year-classes (1993 and 1994) may be relatively weak. There is need to rebuild spawning stock biomass and to broaden age structure in the population; therefore, it is appropriate to fish below F0.1 level for several years. A fishery at the status quo catch (57,000t) is considered unlikely to exceed F0.1 reference levels, but may result in a decrease in biomass if recruitment is poor."*

The spawning ground surveys indicated an SSB in 1997 of 568,500t, and there is known to have been spawning outside of the survey areas and times from data on the distribution of

fishing activity. Modification of the acoustic estimate to account for fishing which took place after the surveys (not more than half of the total catch; 26,000t) results in an end of year SSB that is likely over 500,000t. Substantial areas of prespawning fish were also documented during 1997.

The age composition of the catch for this component has improved, but is still narrow, with few fish older than the 1992 year-class. Spawning is occurring in most traditional areas, and large numbers of spawners were documented on German Bank and Scots Bay in 1997. There remains concern that there was no spawning observed in the traditional Seal Island area, and that the Trinity Ledge spawning component has not fully recovered.

The substantial reductions implemented in the past three years have had a positive impact on the rebuilding of this component. The population appears to be increasing from the low experienced in 1994. Application of the exploitation rate previously used as a guideline for this resource (approx. 20%), with the best estimate of spawning stock biomass of over 500,000t would imply a catch of over 100,000t. In light of the narrow age structure and lack of full occupation of traditional spawning grounds, and since this is only the second year of reliance on the acoustic survey method, the 1998 catch should remain below 100,000t. Conditions should continue to be monitored in 1998 using the in-season management approach.

2.5 Management considerations

The previous assessment of this component suggested that fishing mortality should remain below $F^{0.1}$ for a number of years in order to rebuild spawning stock biomass and improve age composition. Since the current age composition remains narrow, and a new approach has been used for determination of biomass, fishing below $F^{0.1}$ would again be prudent.

The in-season management approach, which spreads the effort in the fishery spatially and temporally among spawning components, is seen as beneficial in achieving the objectives related to maintaining spawning potential. The portion of surveyed spawning biomass taken on the spawning grounds under the "survey, assess then fish" protocol should be reduced (below 20%) to reflect what amount of that spawning group has been taken previously in other areas.

Acoustic surveys have become critical to stock status evaluation. They have helped protect individual spawning areas and have improved documentation and sampling from the fishery. The increased communication and discussion during the fishery as a result of in-season management and spawning ground surveys before and during the fisheries on individual spawning components has helped insure that the situation was not worse than assumed.

The decrease in surveying in 1997, although partially compensated for by quantitative acoustic devices, was detrimental to evaluation of stock status. It is important that adequate surveying take place in 1998 and future years and it is important that there be continued improvement in coverage and survey design and attention to developing year-to-year consistency in these surveys. Additional surveys and biological studies are planned for 1998 in collaboration with the Pelagics Research Council.

3) Offshore Scotian Shelf Banks Spawning Component

Herring taken on the offshore Scotian Shelf by foreign fisheries prior to the extension of jurisdiction, were presumed to be part of an overall 4VWX stock. A foreign fishery is estimated to have removed as much as 60,000 tons in a year from the offshore Scotian Shelf banks during the period 1963-1974 (Stephenson et al. 1987). There had been little effort or herring catch after the extension of jurisdiction until 1996 when a fishery was initiated by the 4WX purse seine fleet and 11,745 tons was taken. Evidence of increasing presence of herring (e.g. in research vessel surveys) and of spawning offshore from research surveys and occasional fishing excursions within the past decade has suggested that there is a discrete offshore spawning component. The presence of spawning herring in catches in 1986 and of larvae in scientific surveys (1991-93), the consistent presence of large herring on the Scotian Shelf in summer trawl surveys and broad age distribution of the catch during the 1996 fishery are all consistent with the treatment of the offshore banks as a separate management.

3.1 The 1997 fishery

This was the second year since a fishery was reestablished on the offshore Scotian Shelf banks. Exploration started in mid-April, but fishing began on May 19 and continued until July 15 (Fig. 3). Total landings were 20,261t (Table 3). The weekly distribution of landings and the distribution of fleet activity is documented by Paul (1998).

Unlike 1996 when activity was concentrated in the vicinity of "The Patch", the 1997 fishery took place on several banks. Fish were seen on and between all of the banks and catches were widely distributed. On most nights, the fleet was distributed on several banks, spanning a distance of 30 to 220 nautical miles. At times, fish size and condition differed on and between the banks; fat content was very high, greater than 20% at times.

The majority of the fish stayed too deep in the water column to be caught by purse seine. Several nights where characterized by good sightings of fish, but few catches. Many comments such as "we have been seeing a lot of bunches of fish over a 3 - 4 mile area, but they won't come up enough to be caught" were made by fishers throughout the fishery.

Several quantitative observations from various banks were made and submitted by fishers, documenting abundance on twelve fishing nights (Paul 1998).

3.2 Catch at age

Sampling was extensive for this fishery (Table 4, 4W Purse Seine, May to July) with 94 samples taken including 11,214 fish measured and 413 fish aged. The catch in 1997 was composed mostly of two year-classes. Age 5 (1992 year-class) made up almost 60% in both number and weight while age 4 (1993 year-class) contributed approximately 30% (Table 11, Fig. 7). All other ages combined contributed about 10%. A similar age structure was seen in samples from the July bottom trawl survey of the Scotian Shelf (Fig. 8).

3.3 Research survey data

A larval herring survey was conducted in November 1997 in collaboration with Dalhousie University (Power 1997a MS). This was the first broad scale directed larval survey for herring on the offshore Scotian Shelf since the Scotian Shelf Ichthyoplankton (SSIP) surveys ended in 1982. Although the complete results from this survey will not be available until May of this year, maps of the distribution and abundance of herring larvae from samples analyzed to date are presented in Fig. 9 and Fig. 10 (C. Reiss and C. Taggart, Dalhousie University, unpublished data). These confirm the presence of small herring larvae offshore (Fig. 10), presumed to originate from spawning on the offshore banks in addition to small larvae near-shore from coastal spawning groups. This survey also encountered a sampling problem with the Alfred Needler (Power 1997a MS; Appendix III). The bongo was observed 'back-flushing' with substantial loss of plankton from the net mouth during final haul-back in sea-swell conditions that resulted in substantial pitching motion of the ship. Modifications are required to the towing method or another vessel should be used for future larval surveys.

Results from the summer bottom trawl survey (Table 9, Appendix IV) showed few herring on the Scotian Shelf during the 1970's, but increasing amounts during the 1980's and a relatively widespread distribution recently (Fig. 11). There has been a decrease in the mean numbers taken by this survey in the past three years (Fig. 12).

3.4 Resource Status and Outlook

There is insufficient information on which to base an evaluation of stock status. Industry records show that herring were widely distributed on Scotian Shelf banks in May and June of 1997. Although a considerable amount of herring was seen, there was little quantitative information from the fishery. The decrease in numbers of herring taken in the July bottom trawl survey, and the narrow age composition in the catch are considered to be negative signals. The catch should be reduced unless there is information during the season which demonstrates that these concerns are unfounded.

3.5 Management Considerations

It has been previously recommended that a strategy for assessment and exploration of the Scotian Shelf component be developed. Industry and DFO have reviewed results of the Regional Herring Workshop (Sinclair 1997) and the Workshop on Ecosystem Considerations for Krill and Other Forage Fisheries (Head et al. 1997) and have established a committee to investigate the range of possible approaches to the management of the Offshore Scotian Shelf herring fishery.

Projects to be initiated by the Pelagics Research Council in 1998 will focus on improving the information base on which to evaluate resource status for the next assessment. Of particular interest will be an acoustic survey in the autumn of 1998 to document the abundance of spawning aggregations on the offshore banks.

Industry and Management have proposed a two-step approach for this year;

> "The management approach for 1998 will be generally as follows. An initial catch limit will be established following review by RAP, probably in the range between the previous two years catch i.e. 12,000 - 20,000t.
>
> After the fish have aggregated sufficiently to survey and prior to the initial catch level being caught, a detailed survey utilizing the recording acoustic equipment will be undertaken by the industry to determine the relative stock abundance. Changes as considered appropriate and in line with the recommendations by RAP, will be made to the initial catch level."

The caution expressed in the Resource Status and Outlook (section 3.4 above), suggests that the initial catch limit should be low.

Foreign fisheries took relatively large amounts (as much as 60,000t per year) from the offshore Scotian Shelf banks during the period 1963-1973. These fisheries did not sustain large catches over a number of years and the average recorded catch for the 1970 - 1973 period was 30,000t. Industry, science and management are encouraged to work together to develop a medium term strategy (i.e. over the next few years) for assessment and exploitation of the herring on the Scotian Shelf outer banks.

4) Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia Spawning Component

Historical spawning areas have been documented for coastal Nova Scotia (Crawford 1979, Sameoto 1971). Active spawning in several of these areas has been confirmed in recent years by the data from the 1996 and 1997 fishery. Much of the inshore fishery, particularly the bait fishery, remains undocumented and thus it is likely that other inshore spawning areas exist but are not recorded. There is an urgent need to document the current status of all spawning grounds within this component. Background information and further details are recorded in Denny et al. (1998).

4.1 1997 Fishery

The fishery operates throughout the coastal waters of 4VWX, but information is very limited. This year there has been some improvement in the available information from two areas, Eastern Passage and Little Hope, and a continued improvement in the information from the Bras d'Or Lakes and Glace Bay areas. Since most of the coastal fishery is for bait, a considerable proportion of the catch is unrecorded or poorly documented.

There has been a considerable increase in the number of active gillnet licenses in recent years. This was the second year of the fishery on spawning fish east of Halifax and the first gillnet roe fishery off Little Hope in recent years. There was no winter purse seine fishery off Halifax this year although 234t were caught during experimental surveys.

Recorded landings by gillnet along the coast of Nova Scotia totaled 2,965t in 1997 (Table 1). This included landings of 1,518t from the Eastern Passage Area, 170t from the Glace Bay Area,

164t from the Bras d'Or Lakes and 485t from Little Hope. The overall total is considered to be an underestimate of landings.

4.2 East of Halifax

Fishery

Recorded landings are from the October roe fishery. This gillnet fishery, lasting from October 4 to October 20, landed 1,518t.

Surveys

One mapping survey involving 13 vessels was held in the Eastern Passage area on October 9. Ten gillnet vessels ran two transects from Petpeswick Shoal to east of Three Fathom Harbour and one from south of Three Fathom Harbour towards Eastern Passage where they met up with an additional three boats that were surveying the Eastern Passage area. A very dense group of fish covering about 3 km^2 inside a larger group of medium density, about 5 km by 2 km, was observed during the first and third transect. The three boats from Eastern Passage reported a group of fish, 1.5 km by 7 km, of medium density on the bottom. The overall estimate of the amount of herring seen was 15,000t.

Sampling

Two length frequency and detailed samples were obtained from the October fishery (Fig. 13). Two hundred and fifty five fish were measured and 82 fish were examined in detail for age, sex and maturity. The combined length frequency showed a mode at about 30 cm and a large number of larger fish (>33 cm). The mature fish were all ripe or ripe and running (maturity stage 5 and 6) with a male:female ratio of 2:1. All females were ripe and running (maturity stage 6).

Catch at Age

Catches in this component had a broad age distribution dominated by the age 5 (1992) year-class (Table 12, Fig 14).

4.3 Little Hope

Fishery

The fishery occurred in the Little Hope area, southwest of Liverpool, N. S., from October 7 to 18, 1997. A total of 485t was landed by gillnet fishers.

Surveys

There were two surveys of Little Hope, one on October 14 and the other on October 23. The first survey was of Dogget Shoal; ten gillnet vessels participated. The first transect was from north to south and it passed over a large school of moderate density, 1-12 fathoms thick and

1.5 miles long. The second transect, from east to west, showed the school to be about 0.5 miles wide and 1-5 fathoms thick. The school was estimated to be between 3,000 and 4,000t. While the gillnet vessels surveyed Dogget Shoal, a purse seine vessel surveyed Little Hope and found nothing. Following this, the purse seiner surveyed Dogget Shoal and found a large, dense school of fish, 3.8 fathoms thick and 1.5 miles long. The gillnetters simultaneously surveyed Little Hope and found nothing. No samples were taken during this survey.

The second survey, on October 23, involved twelve gillnet vessels. They surveyed from the buoy off Port Mouton to the Little Hope Light and back. Fish were seen in the area around the buoy and 2 sets were made. The catch was 100% mackerel.

Sampling Data

Although a small gillnet fishery was conducted in this area prior to October 10, no samples were collected. During the October 14 survey there was no fishing and on the October 23 survey only mackerel were caught.

4.4 Bras d'Or Lakes and 4Vn

Fishery

The fixed gear gillnet fishers landed 164t of herring in the Bras d'Or Lakes during April and May. The fishery began later and was shorter than in recent years. In 1997 there was a shift in effort to the Baddeck Bay area from other traditional areas. There was a reduction in the number of locations at which herring were caught, an increase in the overall fishing effort and a concentration of catches at a single location. Herring did not appear in the usual fishing locations and there was a shift in effort to the Baddeck Bay area (Denny et al. 1998).

Gillnet fishers landed 170t of herring from the Glace Bay area of 4Vn during the fall fishery.

Surveys

Two larval surveys of the Bras d'Or Lakes were conducted in 1997 using the research vessel Navicula. The first survey (Wilson 1997 MS) conducted in mid May, was too early in the season as no larval herring were caught. The second survey (Power 1997b MS) conducted from June 20 to 26 caught herring larvae in very small numbers at only 16 out of 53 sampling locations (Fig. 15). Larvae were generally restricted to the northern portion of the lakes. Few larvae were taken in the south (Big Lake), where occasional sampling in the past 20 years had documented substantial numbers of larvae (Crawford pers. comm.).

Sampling

Bras d'Or Lakes
The Bras d'Or Lakes were sampled extensively during the 1997 fishing season. In April and May, 22 gillnet length frequency samples (3,749 fish) (Fig. 16) and 13 detailed samples (317 fish aged) were collected. The combined length frequency was unimodal with a peak at around 33 cm. The majority of fish were ripe or ripe and running (maturity stage 5 and 6), although some spent and recovering (maturity stage 7 and 8) condition fish were also present. The

proportions of spent and recovering fish were higher in May than in April. The Bras d'Or Lakes spring fishery was dominated by ages 7 and 8 (1990 and 1989 year-classes) while ages 4-6 were less prevalent (Table 13, Fig. 17).

A small bait fishery was also conducted in September 1997 and one length frequency and one detailed sample was collected. The length frequency shows a mode at 32 to 32.5 cm (Fig. 18). The majority of the fish in the detailed sample were ripe (stage 5) but one recovering (stage 8) fish was also present.

Glace Bay

Five gillnet length frequency samples (1,078 fish) and 4 detailed samples (146 fish) were collected from the September/October Glace Bay gillnet fishery. The length frequency was unimodal with a peak at 30.5 cm and a moderate percentage (29%) of larger fish (33+ cm) (Fig. 19). The majority of fish were ripe and running (67%) although spent fish were also quite common (23%).

4.5 Biological Evaluation

Spawning Areas

Historical spawning areas have been documented for coastal Nova Scotia by Sameoto 1971, Crawford 1979 and Crawford et al. 1982. Active spawning in several of these areas has been confirmed in recent years by the data from the 1996 and 1997 fishery and with the information collected in 1996 from fishers in the Bras d'Or Lakes by Shelley Denny of the Eskasoni Fish and Wildlife Commission (Fig. 20,21). However, much of the inshore fishery remains undocumented, particularly the bait fishery, and thus it is likely that many other inshore spawning areas exist but are not recorded. There is an urgent need to document activity in all spawning grounds within this component.

Of particular concern in the 1997 fishery is the further decrease in the number of spawning areas in the Bras d'Or Lakes. In 1996 it was reported that spawning was restricted to only a few of the traditional spawning grounds (Anon 1997a) and in 1997 spawning was observed at even fewer locations (Fig. 21).

4.6 Issues and Recommendations

The coastal Nova Scotia spawning component fisheries are still largely undocumented. The lack of information from these fisheries precludes evaluation. Landings for bait may be considerable, from relatively small spawning groups. Without complete landings information and surveys, no evaluation of stock status is possible.

Recommendation: Improve documentation of the fishery and spawning groups by conducting a questionnaire survey of gillnet fishers. Improve monitoring of existing fisheries.

There is increasing pressure to develop fisheries (especially for roe). These new fisheries are being proposed in the absence of knowledge of the current level of fishing pressure or estimates of spawning group status.

Recommendation: As in the 1997 Stock Status Report (Anon 1997a), it is recommended that "no coastal spawning area should have a large effort increase until much more information is available on the state of that spawning group. There should be no new fisheries developed when there is uncertainty regarding stock composition and degree of mixing."

It was noted in 1997 that the status of herring in the Bras d'Or Lakes was cause for concern. This year with the further decrease in spawning locations, low levels of larvae and the increase in fishing effort, the situation appears to be worse.

Recommendation: Given continued deterioration in signals from the Bras d'Or Lakes fishery it is preferable, from a biological perspective, that no fishing take place on this spawning component.

The draft management plan developed recently for 1998 (Denny et al. 1998) includes spawning area closures and effort restrictions which are major steps forward in this regard. If fishing is to take place in the Bras d'Or Lakes, the following recommendations should be considered:

1. Reduce overall effort and prevent concentration of effort at one or two locations.
2. Improve the collection of landings statistics.
3. Prevent the complete occlusion of spawning grounds and major fishways.
4. Enlarge the proposed closed spawning areas.

5) SW New Brunswick migrant juveniles

5.1 Management context

The southwest New Brunswick weir and shutoff fishery has relied, for over a century, on the aggregation of large numbers of juvenile (ages 1-3) herring near shore at the mouth of the Bay of Fundy. These have traditionally been considered to be a mixture of juveniles dominated by fish originating from Subarea 5 spawning components, and have therefore been excluded from the 4WX quota. Mature herring (ages 4+) taken in this fishery would be considered to be of 4WX origin.

5.2 The fishery

The number of active weirs and distribution of weirs has decreased over the past decade, due in part, to the conversion of sites to aquaculture (Fig 22). The 1997 catch (20,552t) was higher than the previous two years, but below the average (about 26,000t) from this fishery in the past 35 years (Table 3, Fig 23).

Sampling of this fishery was extensive due to increased sampling at the major herring plants in the area using plant personnel to sample all landings. As a result a total of 642 samples were taken in the N. B. Weirs and Shut-off (Table 4) with over 73,000 fish measured and 1,179 detail fish aged. The 1997 catch was, as usual, dominated by age 2 (61% by number; 43% by weight), followed by age 3 (Fig 24). Only a small proportion (4% by number, 12% by weight) were ages 4+.

5.3 Management considerations

Landings of juvenile herring from this fishery are included in the U.S. "coastal complex" which is considered to be at high abundance. No separate evaluation of this fishery was made.

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Table 1. 4VWX herring fishery landings (t) by month, gear sector and management unit for 1997 (calendar year).

			Month											
	Area	**Gear**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
Coastal Nova Scotia														
(South Shore,	4Vn	Trap					15	153	17			11	20	216
Eastern Shore,	4Vn	Gillnet				50	105		1		94	111		361
Cape Breton)	4W	Gillnet				3	2	9	3		1	1,532		1,550
	4X	Trap					7	10						17
	4X	Gillnet					1	6	160	52	68	534		821
Coastal Nova Scotia Total						53	130	178	181	52	163	2,188	3,598	2,965
Offshore Scotian Shelf	4W	Offshore P. Seine					2,695	12,219	3,708					18,622
	4X	Offshore P. Seine					55	501	271					827
	4X	Bottom Trawl												0
Offshore Scotian Shelf Total							2,750	12,720	3,979					19,449
Southwest Nova Scotia	4W	Fall/Winter P. Seine	234										1,405	1,639
	4X	Fall/Winter P. Seine	285									952	199	1,436
	4X	Summer P. Seine						740	8,458	11,447	11,695	8,017		40,357
	4X	Gillnet "Stock"						2,760	544	969	2,543			6,816
	4X	N.B. Midwater Trawl	129	100	9	2								240
	4X	N.S. Weirs					70	1,874	1,739	271	65			4,019
Southwest Nova Scotia Total			648	100	9	2	70	5,374	10,741	12,687	14,303	8,969	1,604	54,507
Migrant	4X	N.B. Weirs				8	153	1,017	6,526	7,396	5,316			20,416
Juveniles	4X	N.B. Shutoff							1	13	122			136
Migrant Juvenile Total						8	153	1,017	6,527	7,409	5,438			20,552
Overall Total			648	100	9	63	3,103	19,289	21,428	20,148	19,904	11,157	5,202	101,051

Table 2. South West Nova Scotia component quota landings (t) for October 1996 to October 1997 quota year.

4WX (SW Nova Scotia)	Period during Quota Year	Landings
4W Purse Seine	Oct. 16, 1996 to Dec. 31, 1996	1,759
4X Fall/Winter P. Seine	Oct. 16, 1996 to Feb 1, 1997	2,926
4X Summer P. Seine	May to Oct. 15, 1997	40,357
4X Summer Gillnet (stock[1])	May to Oct. 15, 1997	6,816
N.B. Midwater Trawl	Jan. to Apr., 1997	240
N.S. Weirs	May to Oct., 1997	4,019
Total Against Quota		**56,117**
Age 4+ from N.B. Weirs	May to Oct., 1997	2,467
Overall Total		**58,584**

[1] 4X Gillnet (stock) is defined as gillnet landings, west of Baccaro Point, in statistical districts 32 to 40.

Table 3. Historical series of nominal and adjusted annual landings (t) by major gear components and seasons of the 4WX herring fishery, 1963-1997

Year^	4W Winter Purse Seine	4Xs Fall&Winter Purse Seine	4Xqr Summer Purse Seine	4X Summer Gillnet	4Xr Summer Weir	4WX Stock Nominal Landings	4WX Stock Adjusted Landings*	4WX Stock TAC	Non-Stock 4Xs Weir and Shutoff	Offshore Scotian Shelf Banks	Total 4WX Adjusted Landings
1963		6,871	15,093	2,955	5,345	30,264	30,264		29,366	3,000	62,630
1964		15991	24,894	4,053	12,458	57,396	57,396		29,432	2,000	88,828
1965		15,755	54,527	4,091	12,021	86,394	86,394		33,346	6,000	125,740
1966		25,645	112,457	4,413	7,711	150,226	150,226		35,805	2,000	188,031
1967		20,888	117,382	5,398	12,475	156,143	156,741		30,032	1,000	187,773
1968		42,223	133,267	5,884	12,571	193,945	196,362		33,145	18,000	247,507
1969	25,112	13,202	84,525	3,474	10,744	137,057	150,462		26,539	121,000	298,001
1970	27,107	14,749	74,849	5,019	11,706	133,430	190,382		15,840	87,000	293,222
1971	52,535	4,868	35,071	4,607	8,081	105,162	129,101		12,660	28,000	169,761
1972	25,656	32,174	61,158	3,789	6,766	129,543	153,449		32,699	21,000	207,148
1973	8,348	27,322	36,618	5,205	12,492	89,985	122,687		19,935	14,000	156,622
1974	27,044	10,563	76,859	4,285	6,436	125,187	149,670		20,602		170,272
1975	27,030	1,152	79,605	4,995	7,404	120,186	143,897		30,819		174,716
1976	37,196	746	58,395	8,322	5,959	110,618	115,178		29,206		144,384
1977	23,251	1,236	68,538	18,523	5,213	116,761	117,171	109,000	23,487		140,658
1978	17,274	6,519	57,973	6,059	8,057	95,882	114,000	110,000	38,842		152,842
1979	14,073	3,839	25,265	4,363	9,307	56,847	77,500	99,000	37,828		115,328
1980	8,958	1,443	44,986	19,804	2,383	77,574	107,000	65,000	13,525		120,525
1981	18,588	1,368	53,799	11,985	1,966	87,706	137,000	100,000	19,080		156,080
1982	12,275	103	64,344	6,799	1,212	84,733	105,800	80,200	25,963		131,763
1983	8,226	2,157	63,379	8,762	918	83,442	117,400	82,000	11,383		128,783
1984	6,336	5,683	58,354	4,490	2,684	77,547	135,900	80,000	8,698		144,598
1985	8,751	5,419	87,167	5,584	4,062	110,983	165,000	125,000	27,863		192,863
1986	8,414	3,365	56,139	3,533	1,958	73,409	100,000	97,600	27,883		127,883
1987	8,780	5,139	77,706	2,289	6,786	100,700	147,100	126,500	27,320		174,420
1988	8,503	7,876	98,371	695	7,518	124,653	199,600	151,200	33,421		233,021
1989	6,169	5,896	68,089	95	3,308	83,557	97,500	151,200	44,112		141,612
1990	8,316	10,705	77,945	243	4,049	102,627	172,900	151,200	38,778		211,678
1991	17,878	2,024	73,619	538	1,498	97,010	130,800	151,200	24,576		155,376
1992	14,310	1,298	80,807	395	2,227	100,227	136,000	125,000	31,967		167,967
1993	10,731	2,376	81,478	556	2,662	98,464	105,089	151,200	31,573		136,662
1994	9,872	3,174	64,509	339	2,045	80,099	80,099	151,200	22,241		102,340
1995	3,191	7,235	48,481	302	3,049	62,499	62,499	80,000	18,248		80,747
1996	2,049	3,305	42,708	6,340	3,476	58,068	58,068	57,000	15,913	11,745	85,726
1997	1,759	2,926	40,357	6,816	4,019	56,117	56,117	57,000	20,552	20,261	96,930

^Annual landings by purse seiners are defined for the annual plan period from October 15 of the preceding year to October 14 of the current year.
All landings by other gear types are for the calendar year.
*Adjusted totals includes misreporting adjustments for 1978-1984 (Mace 1985).

Table 4. Summary of biological samples (by fishery and month) taken in the 1997 4VWX herring fisheries.

		Month											
Gearname	Data	1	2	3	4	5	6	7	8	9	10	11	Grand Total
4Vn Purse Seine	Sum of NO_LF											8	8
	Sum of NO_MEAS											2,631	2,631
	Sum of Aged												
4W Purse Seine	Sum of NO_LF	5				9	61	24				10	109
	Sum of NO_MEAS	641				1,171	7,300	2,743				1,225	13,080
	Sum of Aged	117				45	263	105				191	721
5Y Purse Seine	Sum of NO_LF						8	18	3				29
	Sum of NO_MEAS						880	2,098	318				3,296
	Sum of Aged							58	28				86
5Y USA Purse Seine	Sum of NO_LF						2	1				1	4
	Sum of NO_MEAS						227	139					366
	Sum of Aged						25						25
5Z CAN Purse Seine	Sum of NO_LF										1		1
	Sum of NO_MEAS										40		40
	Sum of Aged										18		18
5Z USA Purse Seine	Sum of NO_LF	55	42										97
	Sum of NO_MEAS	6,565	4,841										11,406
	Sum of Aged												
Gillnet	Sum of NO_LF				8	15	7		3	7	4		44
	Sum of NO_MEAS				1,283	2,666	1,022		534	1,209	622		7,336
	Sum of Aged				143	165	193		64	140	155		860
Midwater Trawl	Sum of NO_LF	13	7				1						21
	Sum of NO_MEAS	1,699	817				112						2,628
	Sum of Aged		18				27						45
N.B. Midwater Trawl	Sum of NO_LF	4	3										7
	Sum of NO_MEAS	225	264										489
	Sum of Aged	67	62										129
N.B. Purse Seine	Sum of NO_LF	3					17	56	10	39	70	2	197
	Sum of NO_MEAS	444					2,015	6,359	1,099	4,865	8,245		23,027
	Sum of Aged						55	108	30	147	179	34	553
N.B. Shut-off	Sum of NO_LF						1			2		1	4
	Sum of NO_MEAS						116			260		100	476
	Sum of Aged											16	16
N.B. Weirs	Sum of NO_LF					6	33	224	224	121	21	9	638
	Sum of NO_MEAS					771	3,710	25,317	25,310	14,069	2,190	1,075	72,442
	Sum of Aged					78	130	253	215	225	160	100	1,161
N.S. Purse Seine	Sum of NO_LF	1					13	68	95	64	26		267
	Sum of NO_MEAS	252					1,539	7,823	12,061	8,060	3,379		33,114
	Sum of Aged	34					128	261	430	222	107		1,182
N.S. Weirs	Sum of NO_LF				1	3	37	36	7	1			85
	Sum of NO_MEAS				177	601	4,099	4,093	841	110			9,921
	Sum of Aged					36	113	121	106	38			414
Resrch. MW Trawl	Sum of NO_LF									3	1		4
	Sum of NO_MEAS									517			517
	Sum of Aged									80	12		92
Resrch. Otter Trawl	Sum of NO_LF		12	36				42		1	17		108
	Sum of NO_MEAS			300						265			565
	Sum of Aged		166	284				260		31	127		868
Weir	Sum of NO_LF						2		2	4	3		11
	Sum of NO_MEAS						232		266	466	295		1,259
	Sum of Aged						11			42			53
Total Sum of NO_LF		81	64	36	9	33	182	469	344	242	143	31	1,634
Total Sum of NO_MEAS		9,826	5,922	300	1,460	5,209	21,252	48,572	40,429	29,821	14,771	5,031	182,593
Total Sum of Aged		218	246	284	143	324	945	1,166	873	925	758	341	6,223

Table 5. Herring catch at age for the purse seine, weir and gillnet fishery conducted on the southwest Nova Scotia spawning component (4WX stock) in numbers caught (thousands), % numbers, weight caught (t), % weight and average weight per fish (g) by age.

SW Nova Scotia Spawning Component - Catch at age (number and weight). 1997												
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
Number	356	56,561	87,395	78,098	131,062	18,917	5,131	3,636	894	620	874	383,544
% number	0	15	23	20	34	5	1	1	0	0	0	100
Catch wt	7	1,947	7,034	12,548	24,964	4,507	1,457	1,141	320	233	347	54,505
% catch wt	0	4	13	23	46	8	3	2	1	0	1	100
Avg. Wt (g)	19	34	80	161	190	238	284	314	358	376	397	142

Table 6. Catch at age by gear sector in numbers (thousands), percent numbers, weight (t.) and percent weight for the SW Nova Scotia component of the 4WX fishery.

Catch Numbers (000's)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
4W Purse Seine	22	337	3,263	3,247	4,151	569	47	27	15	36	70	11,784
4X N.S. Purse Seine	-	13,744	39,911	64,757	107,572	14,604	2,766	2,174	300	222	249	246,299
4X N.S. Weir	78	11,294	34,727	2,217	4,503	800	231	73	7	8	40	53,978
4X N.B. Purse Seine	256	15,999	8,401	632	269	24	5	-	-	-	-	25,586
4X Midwater Trawl	-	15,187	998	-	-	-	-	-	-	-	-	16,185
4X Gillnet	-	-	95	7,245	14,567	2,920	2,082	1,362	572	354	515	29,712
Total Numbers by Age	356	56,561	87,395	78,098	131,062	18,917	5,131	3,636	894	620	874	383,544
Percent Numbers	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**	**Age 11**	**Total**
4W Purse Seine	0	3	28	28	35	5	0	0	0	0	1	100
4X N.S. Purse Seine		6	16	26	44	6	1	1	0	0	0	100
4X N.S. Weir	0	21	64	4	8	1	0	0	0	0	0	100
4X N.B. Purse Seine	1	63	33	2	1	0	0					100
4X Midwater Trawl		94	6									100
4X Gillnet			0	24	49	10	7	5	2	1	2	100
Percent Numbers by Age	0	15	23	20	34	5	1	1	0	0	0	100
Catch Weight (t.)	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**	**Age 11**	**Total**
4W Purse Seine	1	22	244	450	733	124	12	8	5	13	26	1,638
4X N.S. Purse Seine	-	635	3,926	10,348	20,306	3,417	766	670	107	83	96	40,356
4X N.S. Weir	1	337	2,240	327	821	186	64	22	2	3	17	4,019
4X N.B. Purse Seine	5	745	581	66	34	4	1	-	-	-	-	1,436
4X Midwater Trawl	-	208	32	-	-	-	-	-	-	-	-	240
4X Gillnet	-	-	11	1,357	3,070	775	614	440	206	134	208	6,816
Total Weight t. by Age	7	1,947	7,034	12,548	24,964	4,507	1,457	1,141	320	233	347	54,505
Percent Weight	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**	**Age 11**	**Total**
4W Purse Seine	0	1	15	27	45	8	1	0	0	1	2	100
4X N.S. Purse Seine		2	10	26	50	8	2	2	0	0	0	100
4X N.S. Weir	0	8	56	8	20	5	2	1	0	0	0	100
4X N.B. Purse Seine	0	52	40	5	2	0	0					100
4X Midwater Trawl		87	13									100
4X Gillnet			0	20	45	11	9	6	3	2	3	100
Percent Weight by Age	0	4	13	23	46	8	3	2	1	0	1	100

Table 7. Average weight (g) and length (cm) by gear sector for the SW Nova Scotia component of the 4WX herring fishery.

Average Weight (g.)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11
4W Purse Seine	53	41	81	123	147	190	219	298	329	363	373
4X N.S. Purse Seine		51	94	156	190	235	274	312	363	376	392
4X N.S. Weir	14	35	72	145	177	231	262	277	293	386	416
4X N.B. Purse Seine	20	34	67	112	146	185	184		0	0	0
4X Midwater Trawl	0	14	32	0	0	0	0		0	0	0
4X Gillnet	0	0	123	188	212	263	296	324	359	377	395
Average Length (cm.)	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**	**Age 7**	**Age 8**	**Age 9**	**Age 10**	**Age 11**
4W Purse Seine	20.6	17.7	22.9	26.1	27.6	30.0	31.1	33.8	34.8	35.8	36.1
4X N.S. Purse Seine		18.9	22.9	26.9	28.5	30.5	32.0	33.3	34.9	35.3	35.8
4X N.S. Weir	8.7	17.1	21.2	26.4	28.0	30.4	31.6	32.1	32.6	35.3	36.1
4X N.B. Purse Seine	7.3	16.8	21.3	25.1	27.3	29.5	29.5				
4X Midwater Trawl	0.0	13.6	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4X Gillnet			24.8	28.3	29.4	31.5	32.7	33.7	34.8	35.4	35.9

Table 8. Average weights at age (g) for the SW Nova Scotia component of the 4WX herring fishery (weighted by fishery) for 1965-1997.

Fishery_Weights	1	2	3	4	5	6	7	8	9	10
1965	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1966	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1967	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1968	0.010	0.033	0.112	0.148	0.185	0.244	0.276	0.399	0.338	0.410
1969	0.010	0.037	0.105	0.162	0.207	0.242	0.282	0.306	0.334	0.390
1970	0.010	0.032	0.119	0.169	0.211	0.257	0.292	0.332	0.369	0.389
1971	0.010	0.066	0.143	0.199	0.230	0.254	0.293	0.329	0.362	0.388
1972	0.010	0.044	0.138	0.192	0.224	0.262	0.292	0.322	0.345	0.380
1973	0.010	0.029	0.106	0.143	0.225	0.252	0.279	0.331	0.360	0.389
1974	0.010	0.048	0.110	0.175	0.206	0.240	0.277	0.322	0.342	0.352
1975	0.010	0.021	0.094	0.179	0.216	0.240	0.268	0.333	0.358	0.379
1976	0.010	0.033	0.114	0.159	0.233	0.249	0.277	0.317	0.382	0.404
1977	0.010	0.065	0.113	0.174	0.214	0.274	0.293	0.325	0.328	0.416
1978	0.010	0.028	0.112	0.181	0.229	0.259	0.302	0.330	0.351	0.397
1979	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1980	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1981	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1982	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1983	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389
1984	0.010	0.038	0.132	0.191	0.229	0.259	0.280	0.296	0.309	0.364
1985	0.010	0.053	0.118	0.204	0.249	0.278	0.315	0.334	0.344	0.440
1986	0.010	0.055	0.124	0.182	0.239	0.271	0.306	0.329	0.360	0.400
1987	0.012	0.050	0.098	0.153	0.199	0.245	0.274	0.290	0.318	0.350
1988	0.013	0.021	0.088	0.154	0.196	0.242	0.281	0.304	0.327	0.341
1989	0.007	0.033	0.079	0.162	0.207	0.238	0.274	0.303	0.324	0.353
1990	0.010	0.031	0.092	0.161	0.200	0.234	0.255	0.287	0.319	0.336
1991	0.010	0.048	0.100	0.147	0.186	0.217	0.251	0.270	0.303	0.322
1992	0.009	0.025	0.100	0.148	0.181	0.216	0.252	0.275	0.295	0.313
1993	0.018	0.029	0.108	0.153	0.188	0.215	0.251	0.279	0.302	0.324
1994	0.012	0.037	0.079	0.131	0.175	0.203	0.223	0.253	0.289	0.304
1995	0.015	0.042	0.076	0.136	0.187	0.223	0.247	0.293	0.300	0.326
1996	0.010	0.033	0.098	0.137	0.168	0.228	0.266	0.308	0.332	0.355
1997	0.019	0.034	0.080	0.161	0.190	0.238	0.284	0.314	0.358	0.376

Table 9. Herring abundance indices; larval abundance index (average number of larvae per m2 from 79 index stations), and herring by-catch (stratified numbers per tow) from July groundfish survey.

Larval Herring Bongo Survey No.per m2 to bottom					Summer groundfish by-catch (mean nos per tow for herring)									
					4WX area combined				4W Only		4X Only		Offshore Banks	
Year	Cruise	Mean	SE	N	Cruise	Mean#	SE	N	Mean#	SE	Mean#	SE	Mean#	SE
70					A175/176	4.1	1.5	95	4.9	2.4	1.6	0.6	8.4	4.0
71					A188/189	4.0	1.9	86	2.6	1.2	3.6	2.6	4.9	2.4
72	P109	9.4	1.8		A200/201	1.4	0.6	105	1.7	1.0	0.5	0.1	2.9	1.5
73	P127	6.6	1.3		A212/213	0.9	0.3	96	0.4	0.3	1.0	0.4	7.7	7.1
74	P147	49.5	10.9		A225/226	0.7	0.3	102	0.2	0.0	1.0	0.4	0.2	0.1
75	P160	11.7	1.5	58	A236/237	0.9	0.4	104	0.8	0.4	0.7	0.4	1.3	0.8
76	P175	13.5	2.9		A250/251	0.4	0.2	103	0.1	0.1	0.5	0.3	0.1	0.1
77	P190	6.3	1.0		A265/266	0.5	0.3	106	0.0	0.0	0.8	0.5	0.6	0.5
78	P207	4.5	0.5	77	A279/280	0.3	0.3	103	0.5	0.5	0.1	0.0	0.3	0.3
79	P232	7.1	2.1		A292/293	0.6	0.5	106	0.0	0.0	1.0	0.7	0.1	0.1
80	P246	26.2	6.7		A306/307	0.5	0.5	105	0.0	0.0	0.8	0.8	0.0	0.0
81	P263	2.7	0.3	78	A321/322	1.5	1.4	104	0.0	0.0	2.3	2.1	0.0	0.0
82	P280	10.6	1.2	77	H080/081	1.5	0.9	108	0.5	0.3	1.9	1.4	1.2	0.8
83	P298	13.9	1.6	74	N012/013	2.4	0.8	106	2.6	1.2	2.2	1.0	1.3	0.6
84	P315	12.7	1.4	78	N031/032	7.0	3.5	102	3.3	1.2	10.5	6.8	6.7	3.4
85	P329	40.8	4.6	79	N048/049	3.4	1.8	111	6.6	3.8	0.3	0.1	3.1	1.7
86	P344	18.9	2.1	78	N065/066	23.2	14.9	118	30.8	26.7	16.0	14.3	14.4	12.3
87	P361	27.9	3.2	78	N85/86/87	10.4	5.6	135	17.0	11.3	4.0	1.8	51.5	34.1
88	P377	100.7	11.5	76	N105/106	2.1	0.6	127	2.7	1.2	1.5	0.5	1.3	0.5
89	P391	54.5	6.1	79	N123/124	8.4	1.8	124	11.8	3.4	4.5	1.2	7.3	2.0
90	P408	27.2	3.1	79	N139/140	5.6	1.9	156	7.4	3.6	3.4	1.0	4.2	1.8
91	P422	48.2	5.5	78	N154/H231	10.6	5.8	137	13.0	8.8	5.0	1.8	12.4	6.6
92	P437	57.0	6.4	79	N173/174	16.5	4.9	136	16.2	6.6	40.8	15.7	14.4	4.5
93	P451	55.0	6.2	78	N189/190	18.7	4.5	137	6.3	2.5	30.4	8.5	9.5	2.8
94	N211	5.4	0.7	77	N221/222	76.4	30.2	140	108.4	58.9	45.9	18.4	64.9	28.6
95	N232	20.3	4.6	78	N226/227	63.5	24.2	140	100.5	47.9	28.4	12.8	59.3	23
96	N252	9.5	1.6	77	N246/247	40.2	14.2	135	53.2	24.5	27.1	14.1	27.85	16.7
97	N765	23.3	2.7	77	N726/734	31.8	15.3	137	34.6	10.1	51.3	39.3	18.44	4.8

Table 10. Quantitative estimates from industry surveys in 1997 of herring spawning aggregations in the southwest Nova Scotia spawning component (4WX stock) used to estimate spawning stock biomass (SSB).

Spawning Area	Date	Survey Type	Estimated Biomass	Amount Attributed to SSB Total (min 10 day interval between surveys)	Amount Attributed to SSB Total (min 6-7 day interval between surveys)
Spectacle Buoy	Jun 12	A	15,000	15,000	15,000
Scot's Bay	Jul 29	B	15,000		15,000
	Aug 05	B,C	44,428	44,428	44,400
	Aug 06	C	1,188		
	Aug 11	B	1,700		
	Aug 12	B	35,000		35,000
	Aug 18	C	85,718	85,700	65,768[1]
Trinity Ledge	Sep 01	A,B	15,000	15,000	15,000
	Sep 09	A,B	1,000		1,000
	Sep 16	A	7,000	7,000	7,000
German Bank	Sep 18	C	17,600	17,600	17,600
	Oct 03	B,C	215,797	215,800	215,800
	Oct 06	C	7,855		
	Oct 08	C	82,749		
	Oct 09	C	194,145		136,959[1]
				400,528	568,527

A = gillnet mapping survey

B = purse seine mapping survey

C = purse seine quantitative acoustic records

[1] = This survey discounted by the amount of stage 5 fish in previous survey

Table 11. Catch at age for the 1997 offshore Scotian Shelf Banks herring purse seine fishery in numbers caught (thousands), % numbers, weight caught (t), % weight and average weight per fish (g) by age.

Offshore Scotian Shelf Banks Spawning Component - Catch at age (number and weight). 1997												
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
Number	0	0	3,156	33,160	64,091	5,519	3,329	1,109	318	169	215	111,066
% number	0	0	3	30	58	5	3	1	0	0	0	100
Catch wt	0	0	378	5,057	11,348	1,208	882	333	104	59	80	19,449
% catch wt	0	0	2	26	58	6	5	2	1	0	0	100
Avg. Wt (g	0	0	120	153	177	219	265	300	328	347	373	175

Table 12. Catch at age for the 1997 coastal Nova Scotia fisheries (excluding Bras d'Or Lakes) in numbers caught (thousands), % numbers, weight caught (t), % weight and average weight per fish (g) by age.

Coastal Nova Scotia Spawning Component(except Bras D'Or Lakes) - Catch at age (number and weight). 1997												
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
Number	0	446	611	4,171	10,616	4,948	1,684	1,505	845	1,026	1,533	27,385
% number	0	2	2	15	39	18	6	5	3	4	6	100
Catch wt	0	14	54	761	2,162	1,195	476	458	282	375	598	6,375
% catch wt	0	0	1	12	34	19	7	7	4	6	9	100
Avg. Wt (g	0	0	88	182	204	242	283	304	334	366	390	233

Table 13. Catch at age for the 1997 Bras d'Or Lakes gillnet fishery in numbers caught (thousands), % numbers, weight caught (t), % weight and average weight per fish (g) by age.

Bras D'Or Lakes Spring Fishery - Catch at age (number and weight). 1997												
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
Number	0	0	0	11	42	105	167	162	62	34	30	613
% number	0	0	0	2	7	17	27	26	10	6	5	100
Catch wt	0	0	0	2	9	26	45	46	19	11	10	168
% catch wt	0	0	0	1	6	16	27	28	11	6	6	100
Avg. Wt (g	0	0	0	197	223	249	269	286	300	311	326	274

Table 14. Catch at age for the 1997 New Brunswick coastal weir and shutoff fisheries in numbers caught (thousands), % numbers, weight caught (t), % weight and average weight per fish (g) by age.

NB weir and shutoff fishery - Catch at age (number and weight). 1997												
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Total
Number	9,309	216,159	113,197	11,333	3,597	523	206	95	11	0	0	354,430
% number	3	61	32	3	1	0	0	0	0	0	0	100
Catch wt	153	8,742	9,189	1,554	695	128	59	29	2	0	0	20,552
% catch wt	1	43	45	8	3	1	0	0	0	0	0	100
Avg. Wt (g	16	40	81	137	193	245	286	310	213	0	0	58

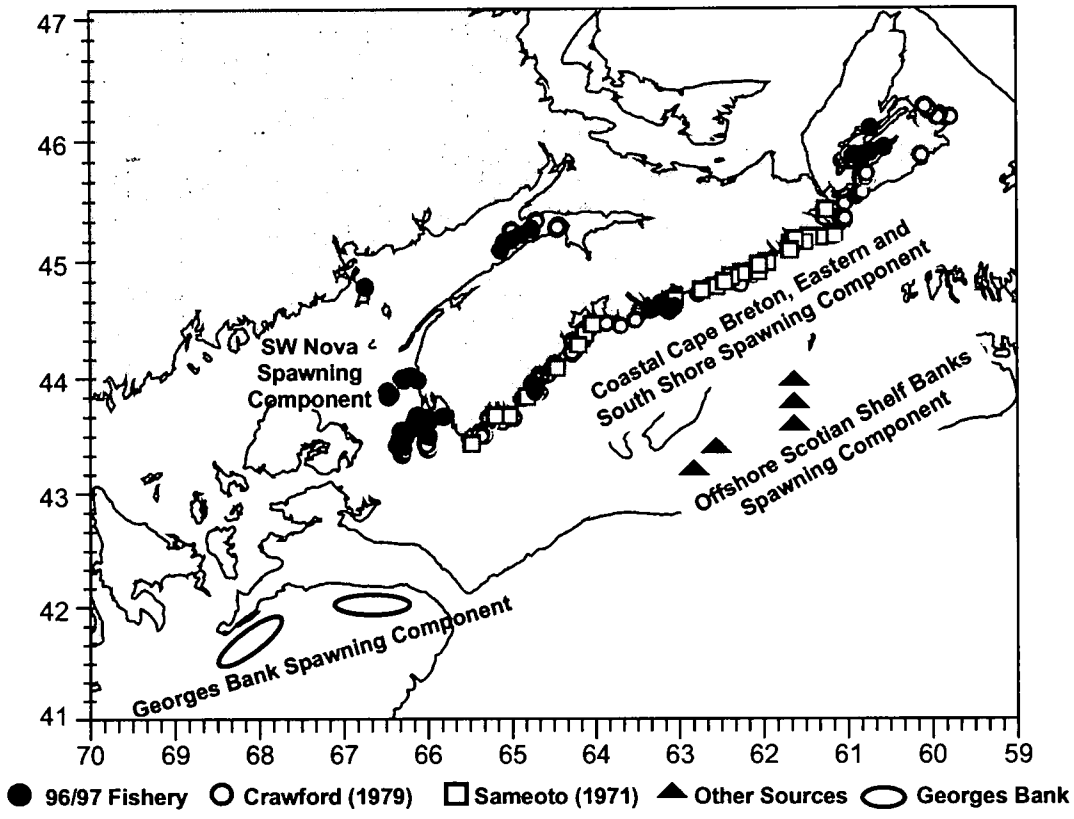


Fig 1. Management units for herring in areas 4VWX and 5 showing locations of known current (solid) and historical (open) spawning locations.

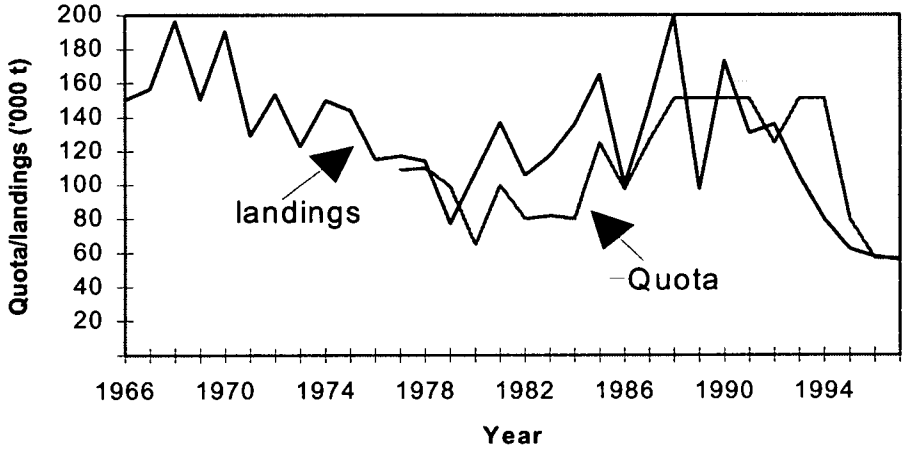


Fig 2. Annual herring landings and TAC (quota) for the southwest Nova Scotia spawning component (4WX stock).

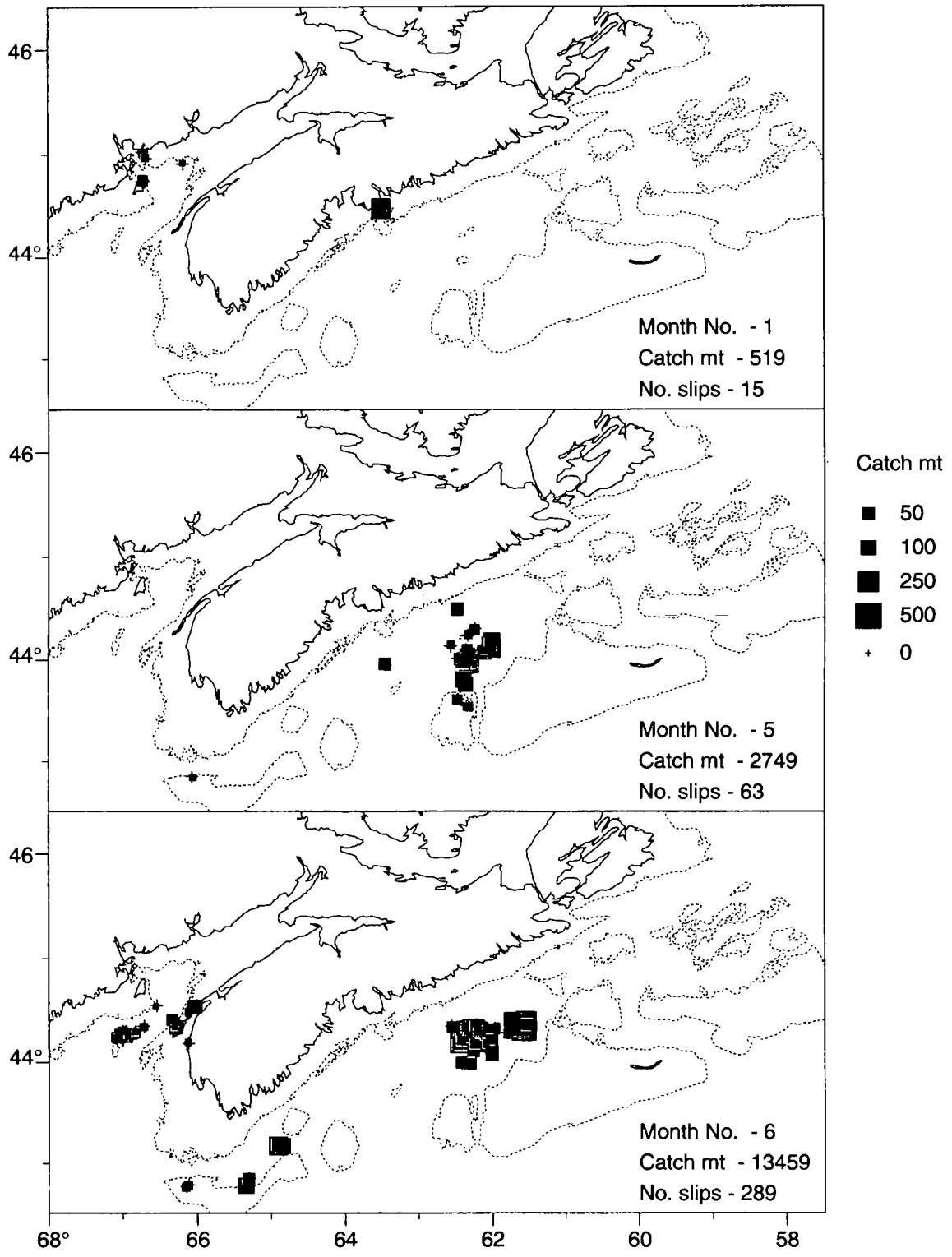


Fig. 3. 1997 4VWX herring purse seine catches by month for all fishing components with total monthly catch and number of slips (landings).

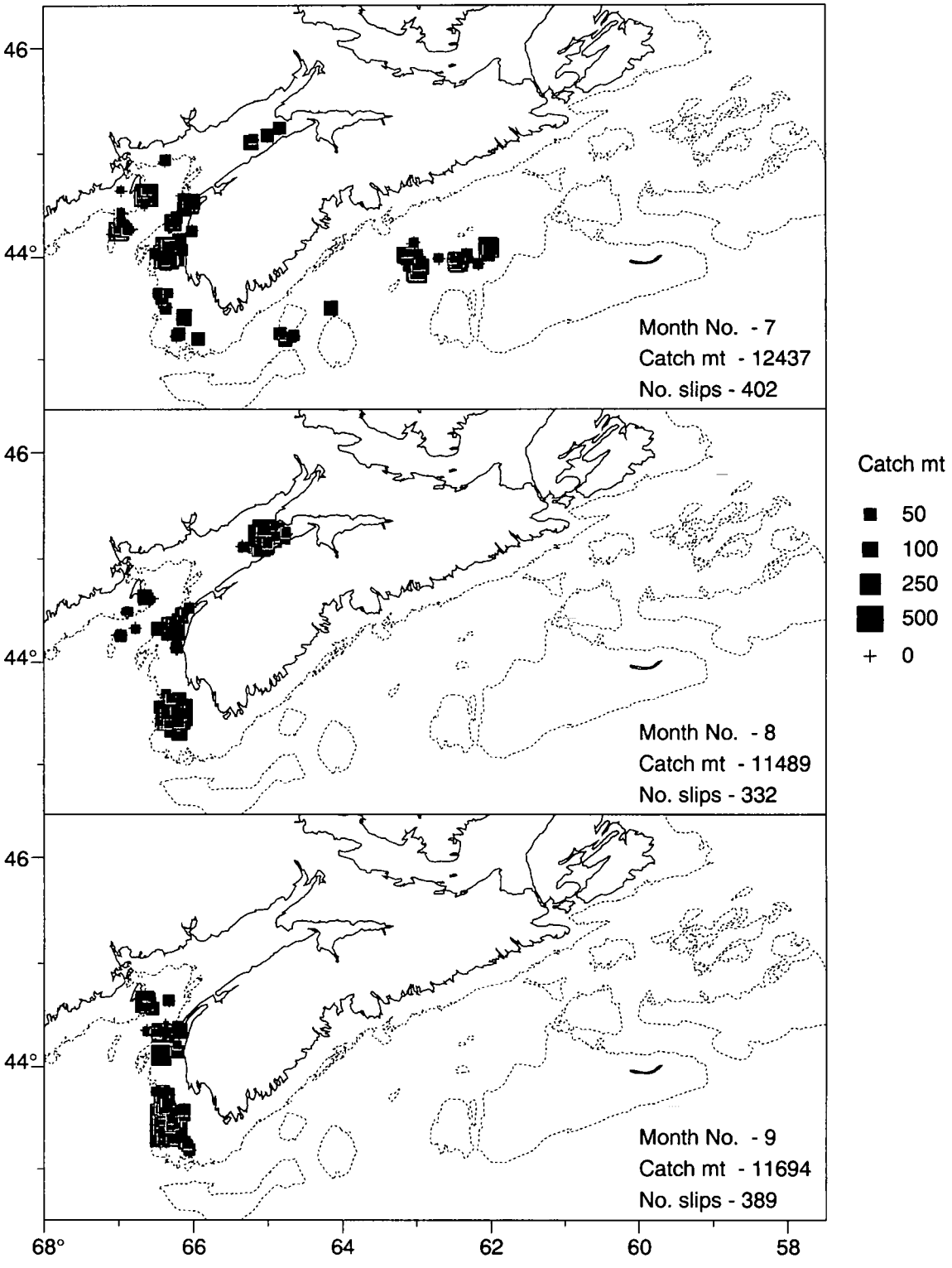


Fig 3. (continued)

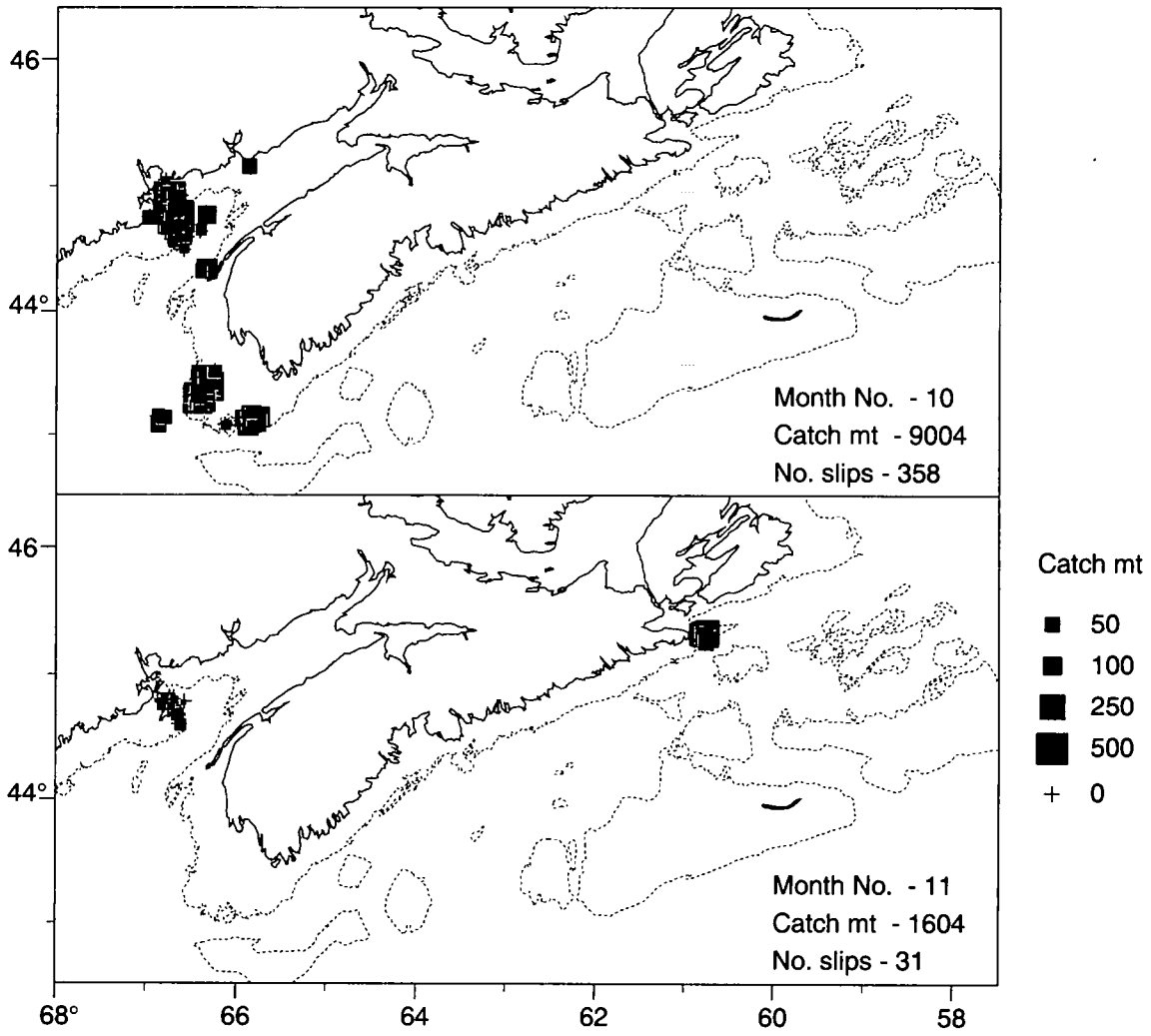


Fig 3. (continued)

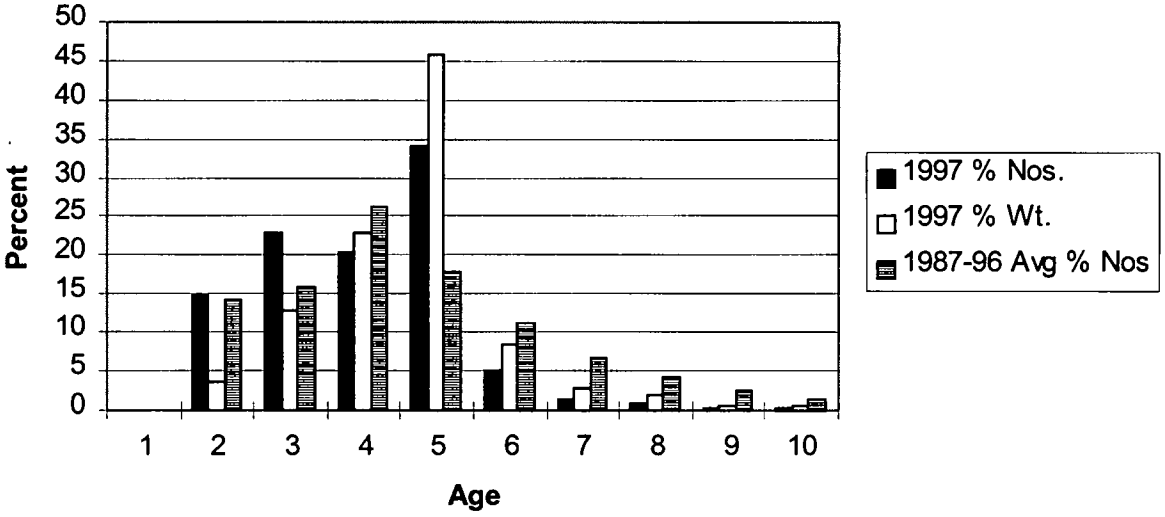


Fig. 4. Catch at age in 1997 for the southwest Nova Scotia spawning component (% numbers and % weight) and average catch at age (% numbers) for 1987 to 1996.

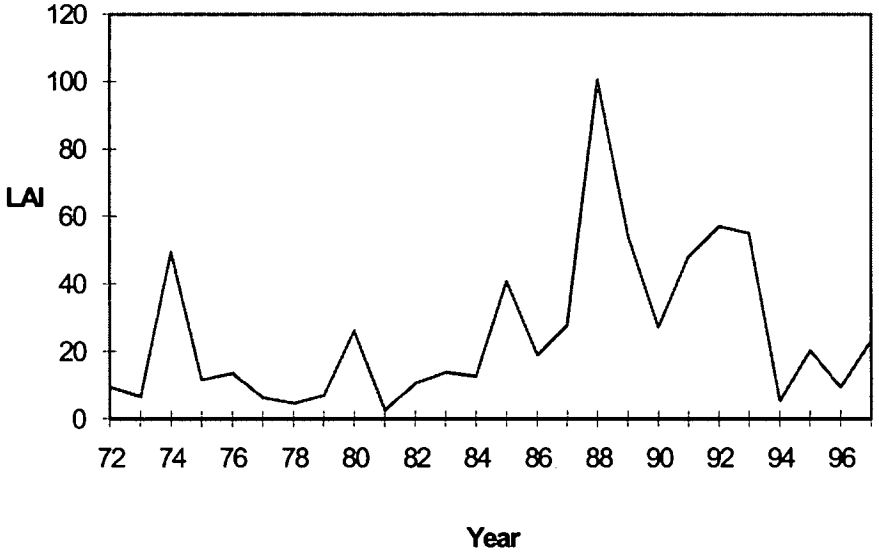


Fig. 5. Abundance of herring larvae (number per m^2 to bottom) in Bay of Fundy autumn ichthyoplankton surveys 1972-1997.

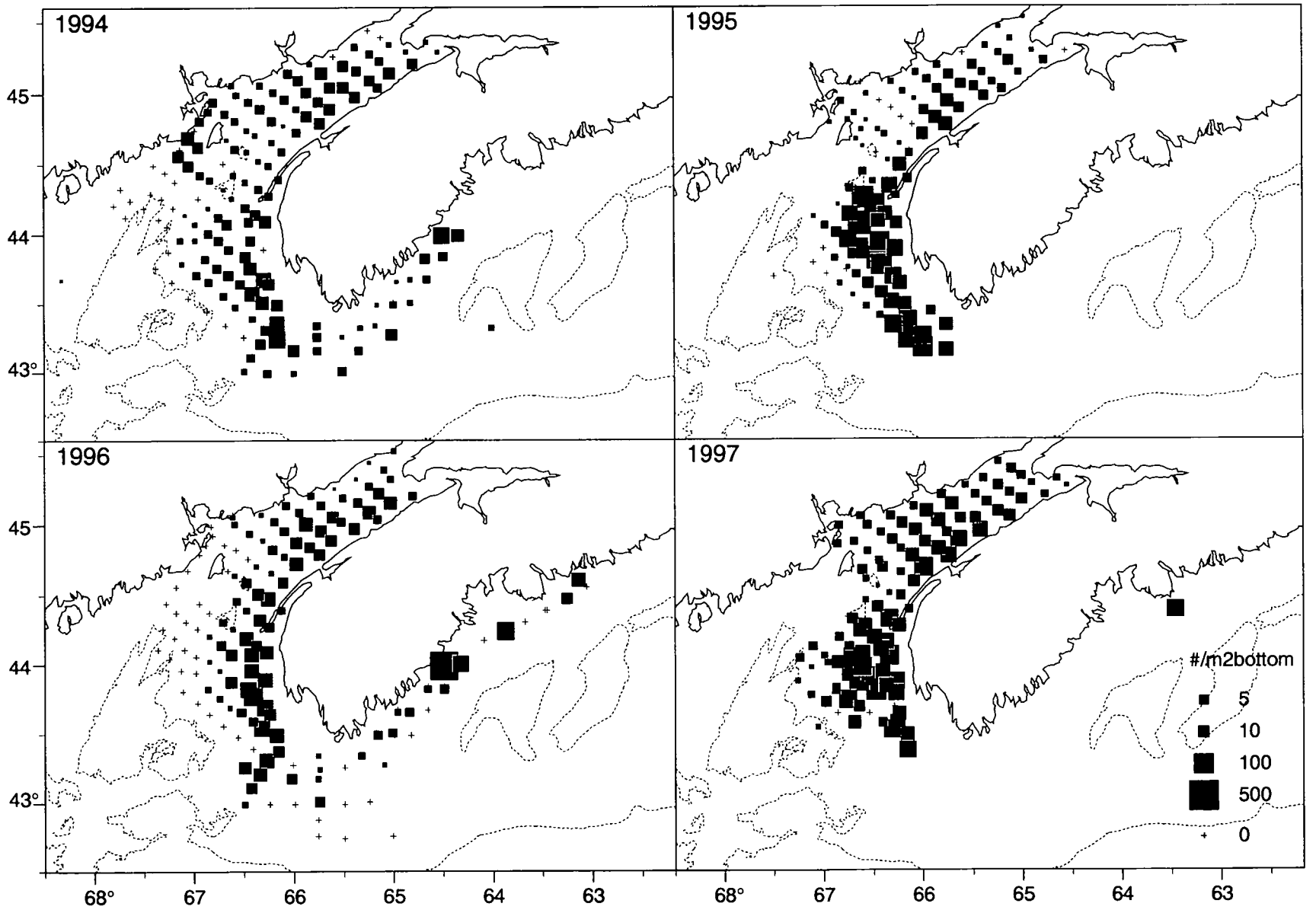


Fig 6. Distribution and abundance of herring larvae from the November 1994 -1997 Bay of Fundy larval surveys.

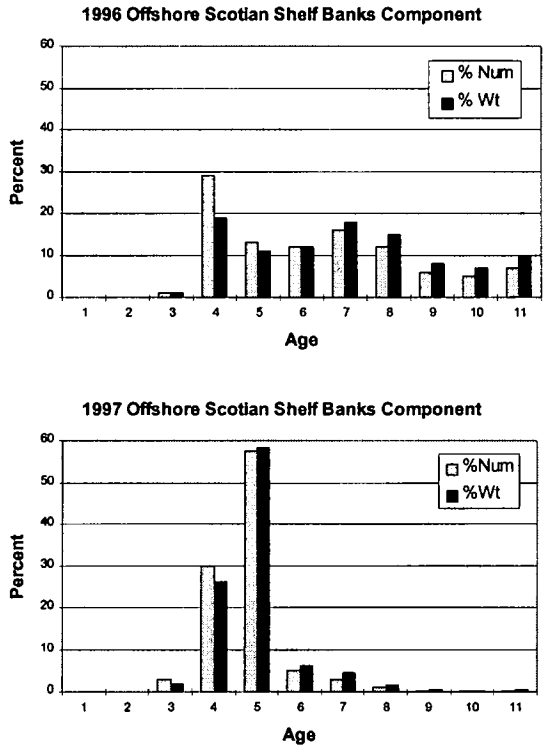


Fig. 7. Catch at age for the herring purse seine fishery on the offshore Scotian Shelf Banks component in % numbers and % weight for 1996 (top) and 1997 (bottom).

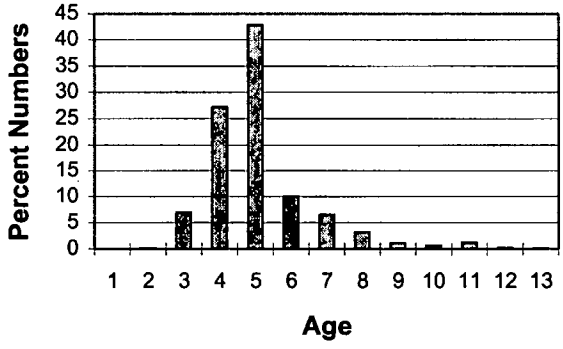


Fig. 8. Herring catch at age from the July 1997 research bottom trawl survey on the Scotian Shelf (strata 40 to 78).

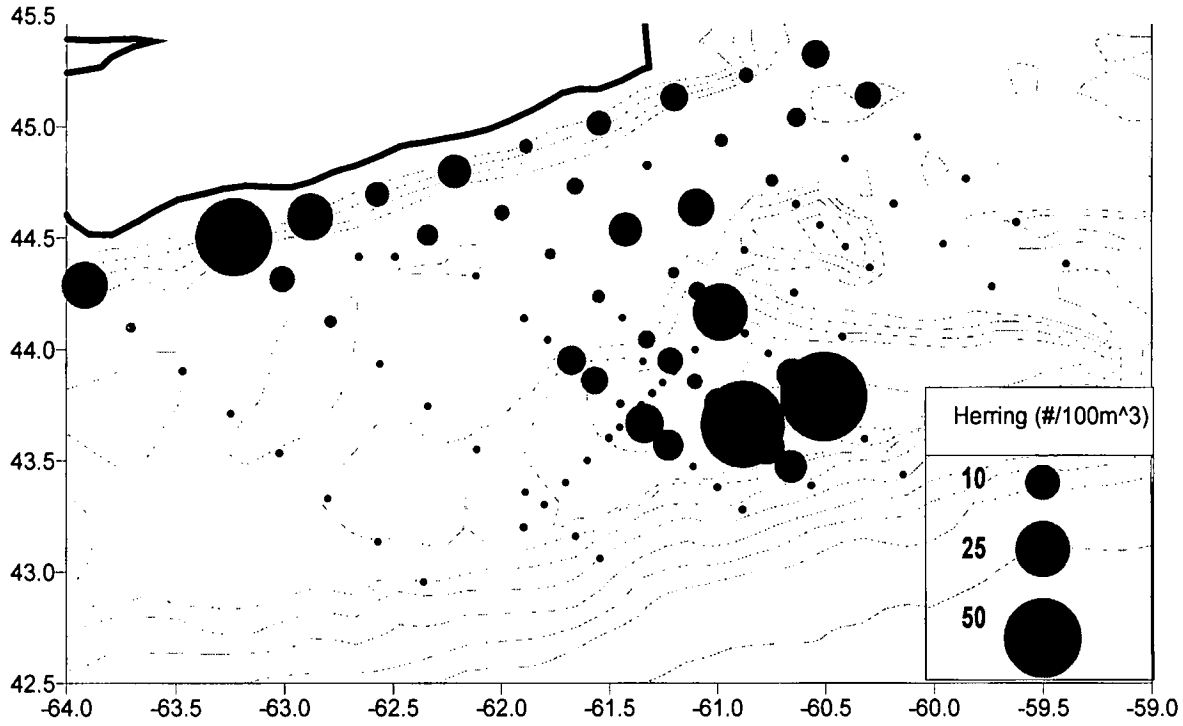


Fig. 9. Preliminary distribution of herring larvae on offshore Scotian Shelf Banks from the November 1997 larval survey (C. Reiss and C. Taggart, Dalhousie Univ. , unpublished data).

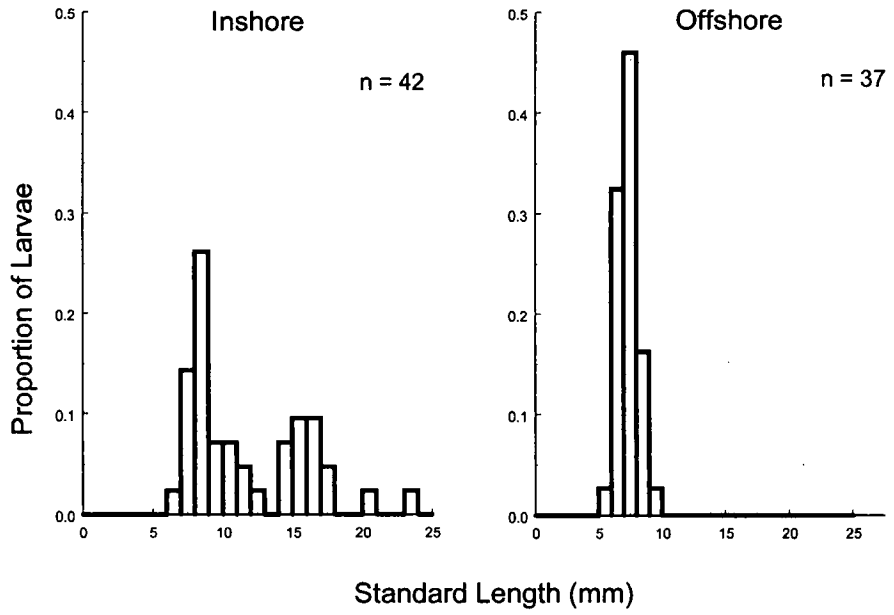


Fig. 10. Larval herring length frequency distribution from near shore and offshore Scotian Shelf Banks from the November 1997 larval survey. (C. Reiss and C. Taggart, Dalhousie Univ., unpublished data).

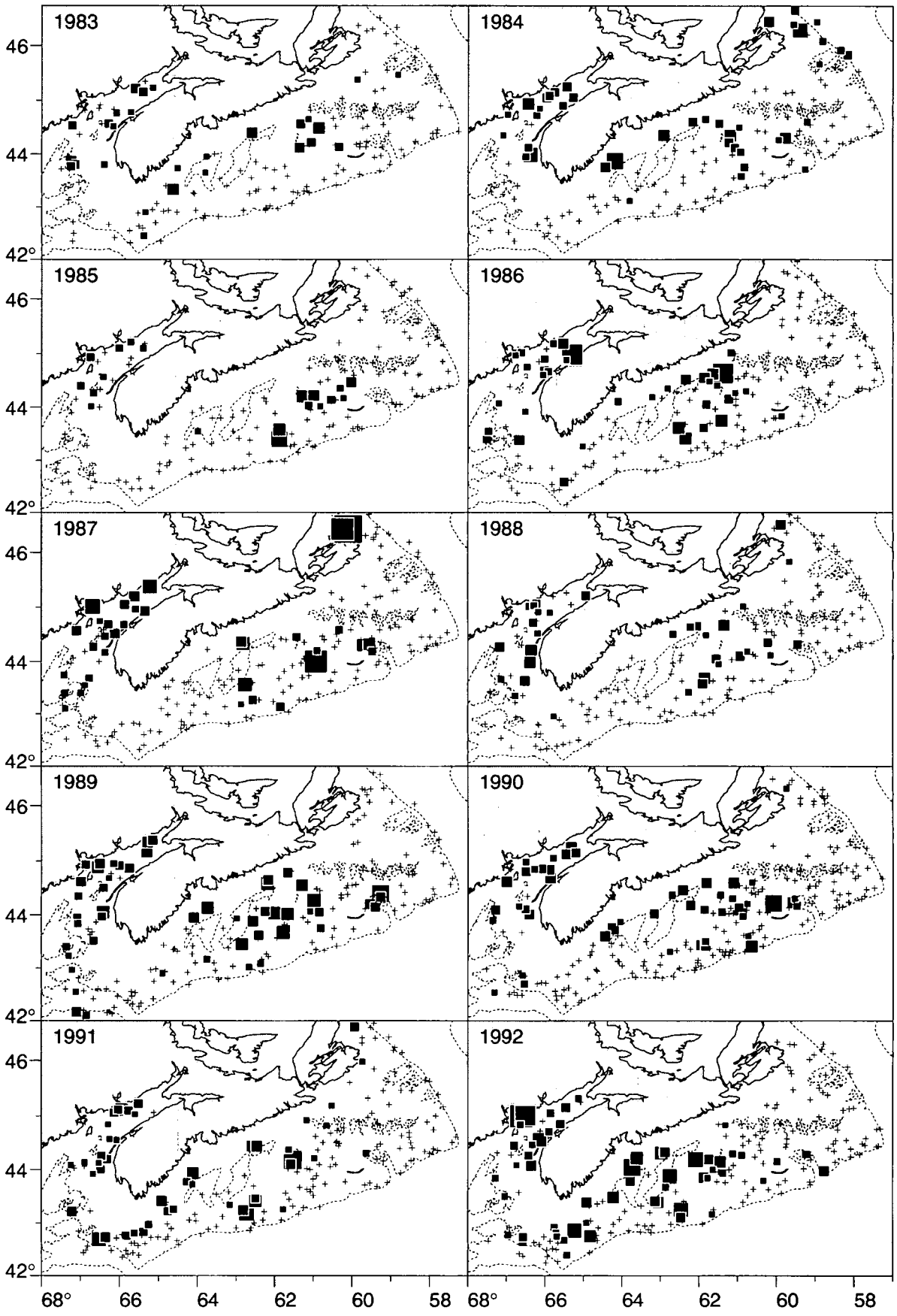


Fig 11. Distribution of herring catches from July research bottom trawl surveys, 1983-97.

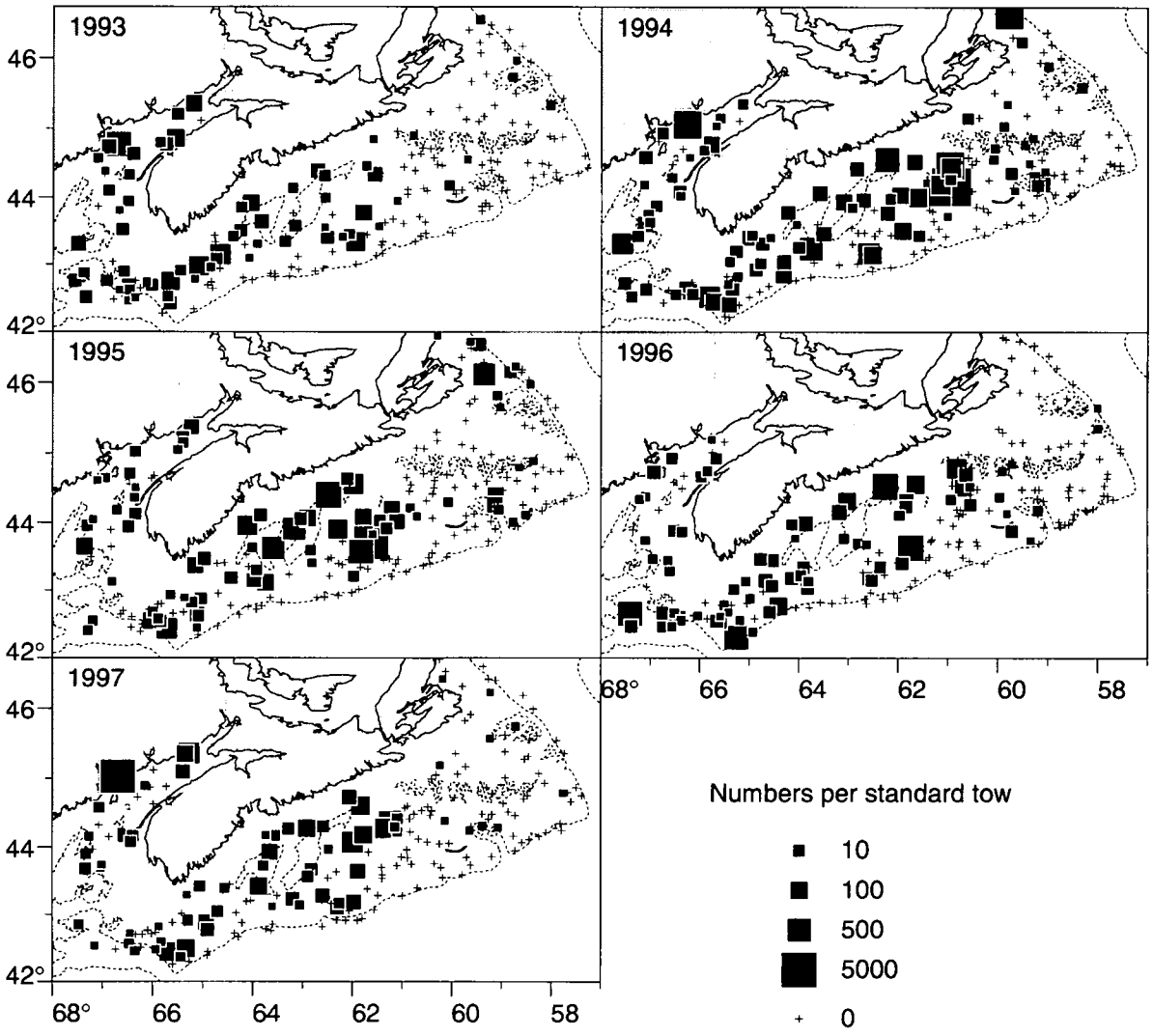


Fig 11. (continued)

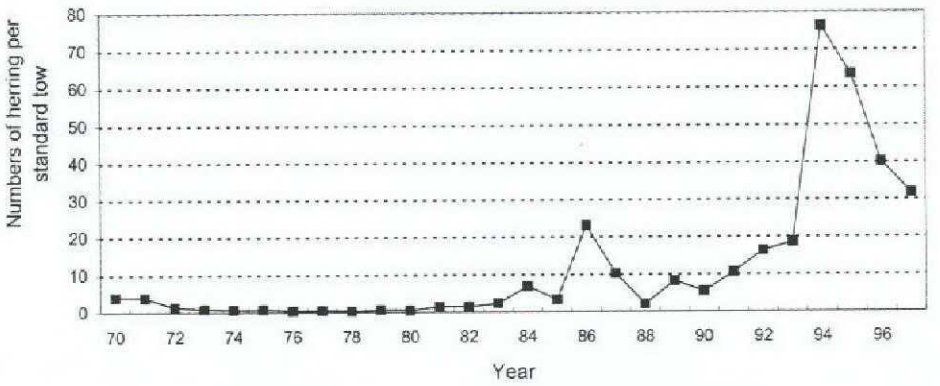


Fig 12. Abundance of herring (numbers per standard tow) from July research bottom trawl surveys on the Scotian Shelf (strata 40 to 78).

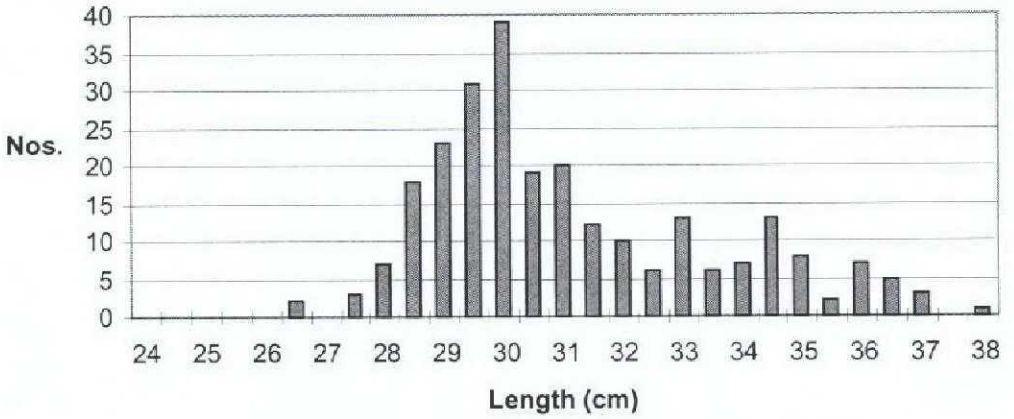


Figure 13. Length frequency for two herring samples collected from area 457, east of Halifax, for the October 1997 gillnet fishery.

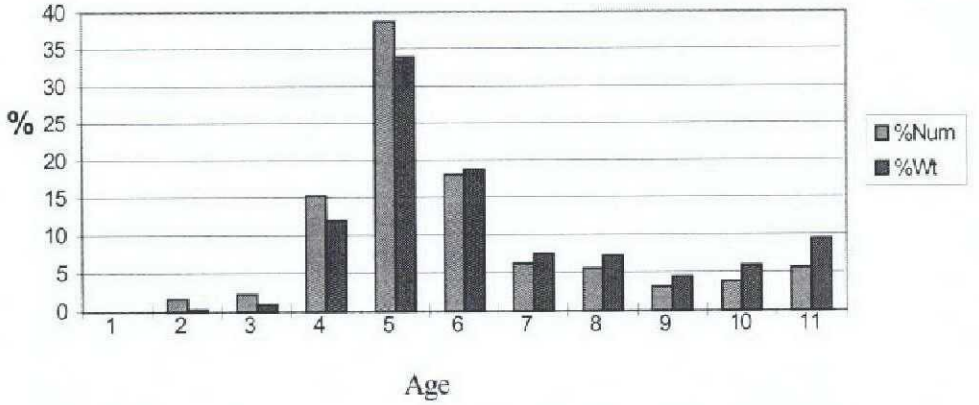


Fig. 14. Catch at age (% numbers and % weight) for the 1997 gillnet fishery on the coastal Nova Scotia spawning component (except Bras d'Or Lakes).

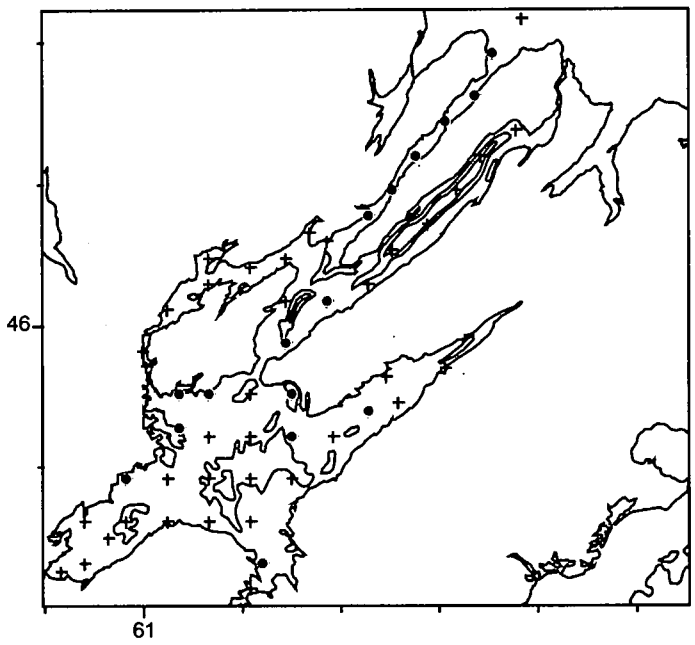


Figure 15. Bras d'Or Lake larval herring sampling and catch locations during the June 20-26 R. V. Navicula survey. (Solid dots represent locations at which larvae were found; crosses indicate locations at which no larvae were found.)

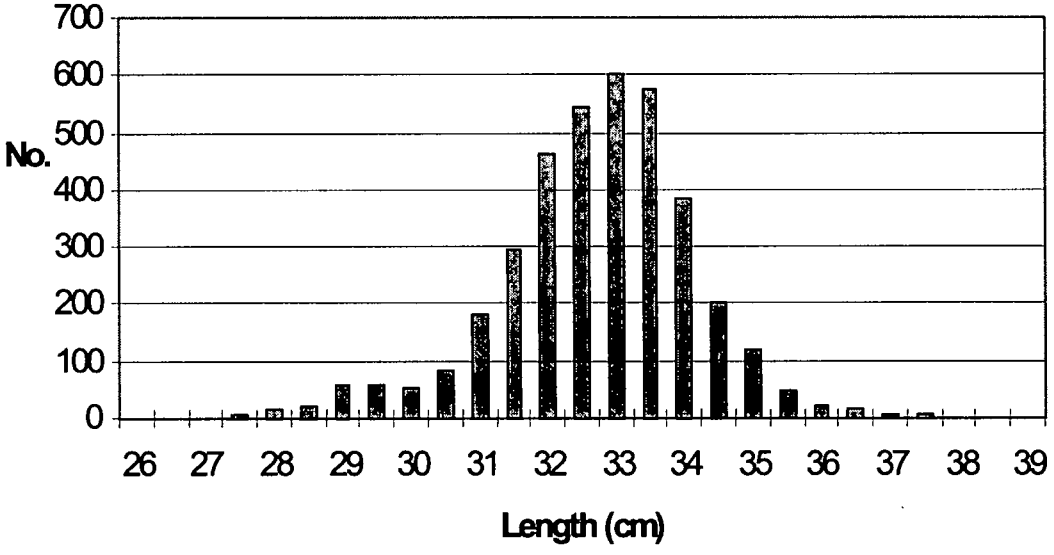


Figure 16. Length frequency for 22 herring samples collected (3749 fish measured) from the 1997 spring gillnet fishery in the Bras d'Or Lakes.

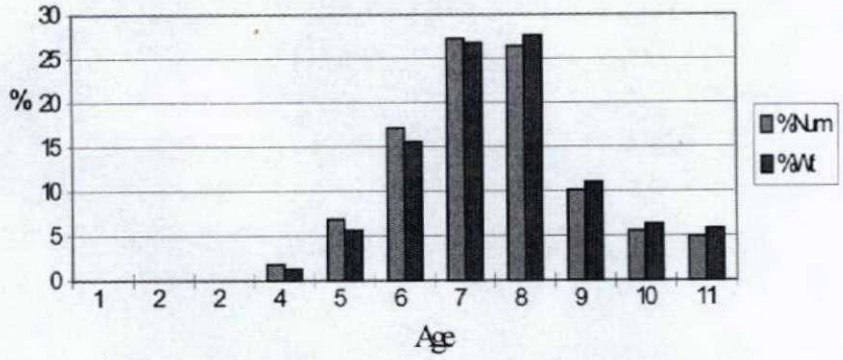


Fig. 17. Catch at age for the spring gillnet herring fishery on the Bras d'Or Lakes spawning component in percent numbers and percent weight.

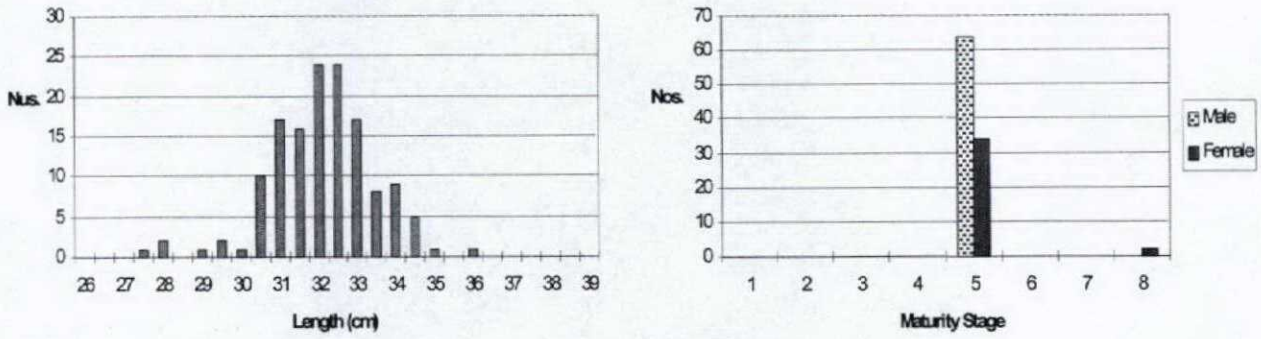


Figure 18. Length frequency and maturity for herring samples collected from the fall gillnet bait fishery in the Bras d'Or Lakes, N.S.

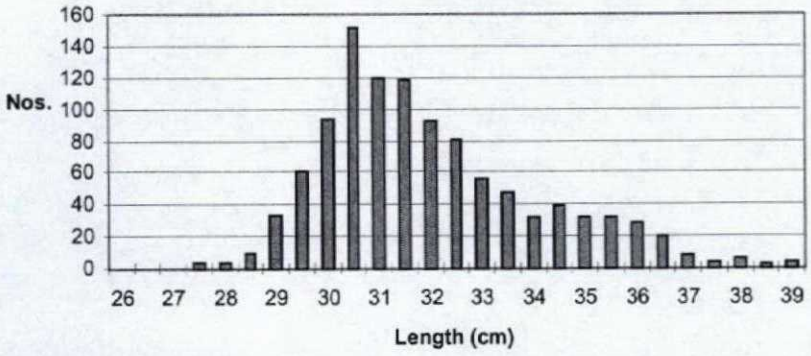


Figure 19. Length frequency for the 1997 fall herring gillnet fishery off Glace Bay, N. S. (5 samples, 1078 fish measured).

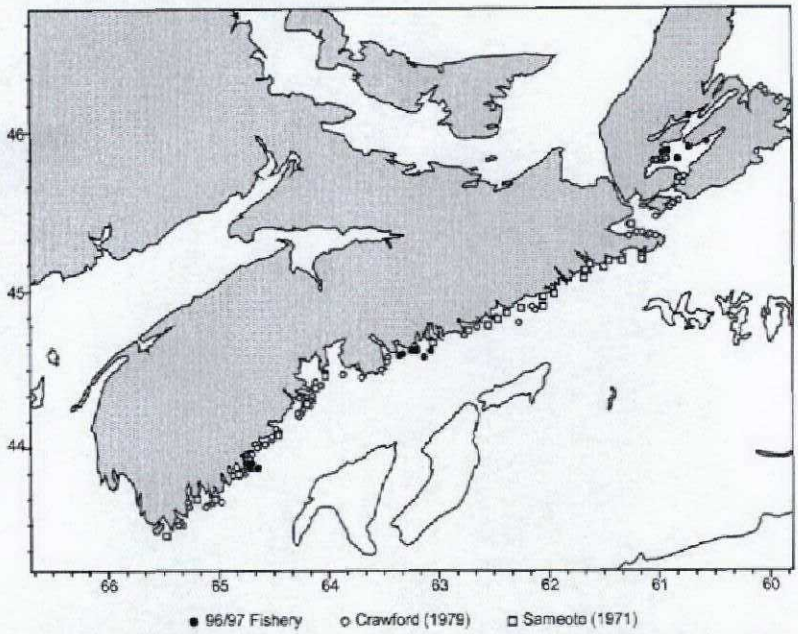


Figure 20. Active herring spawning areas for coastal Nova Scotia (closed circles) from 1997 and historical spawning areas (open circles and squares) from the literature.

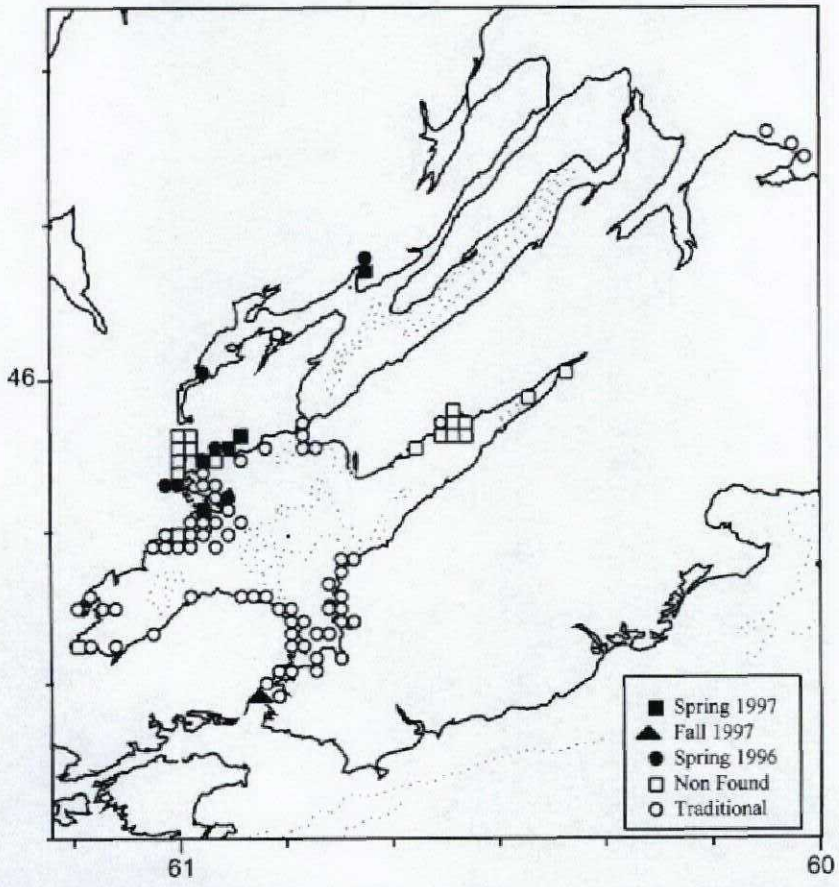


Figure 21. Historical and active herring spawning areas in the Bras d'Or Lakes.

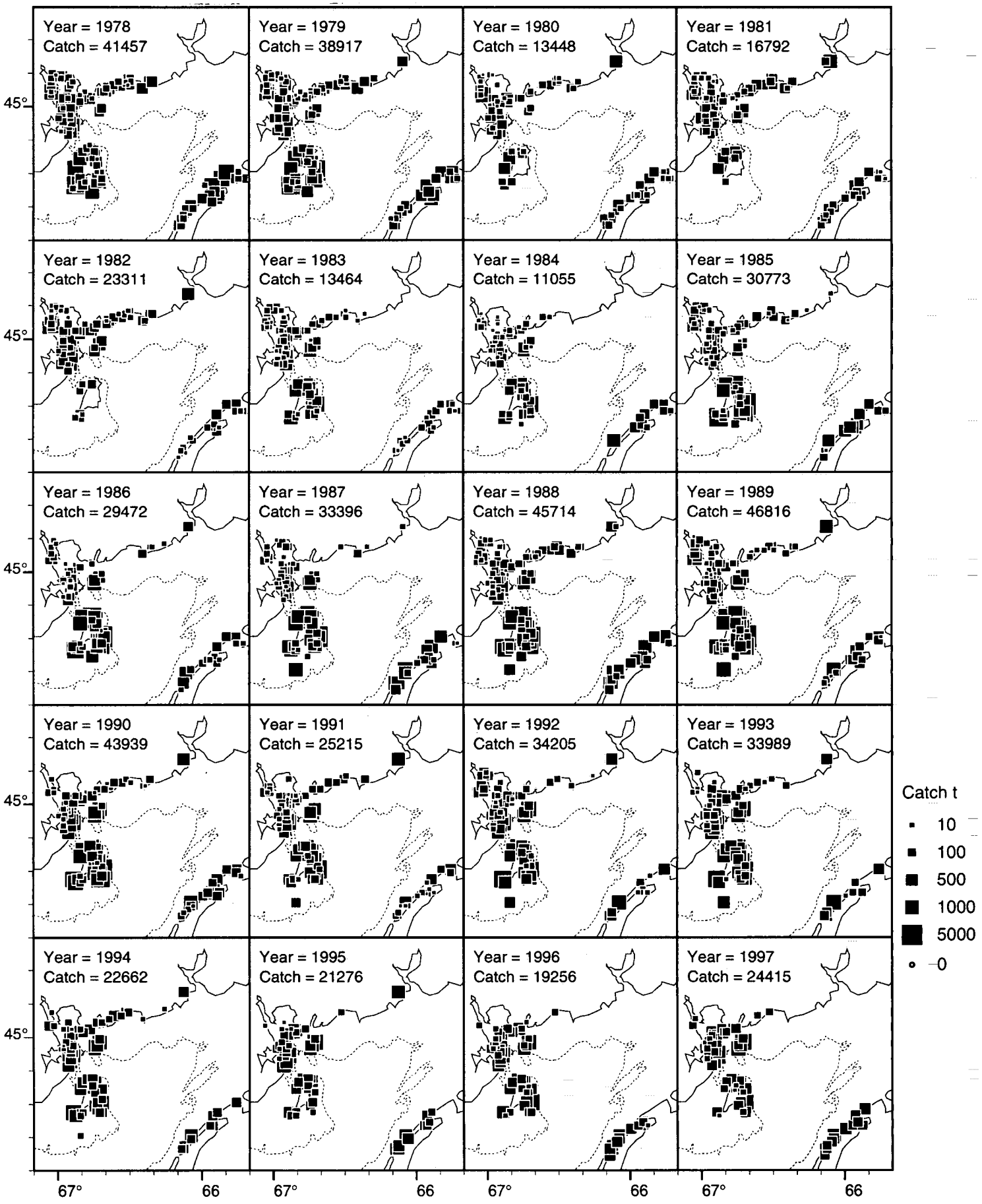


Fig 22. New Brunswick and Nova Scotia weir catches from 1978-97.

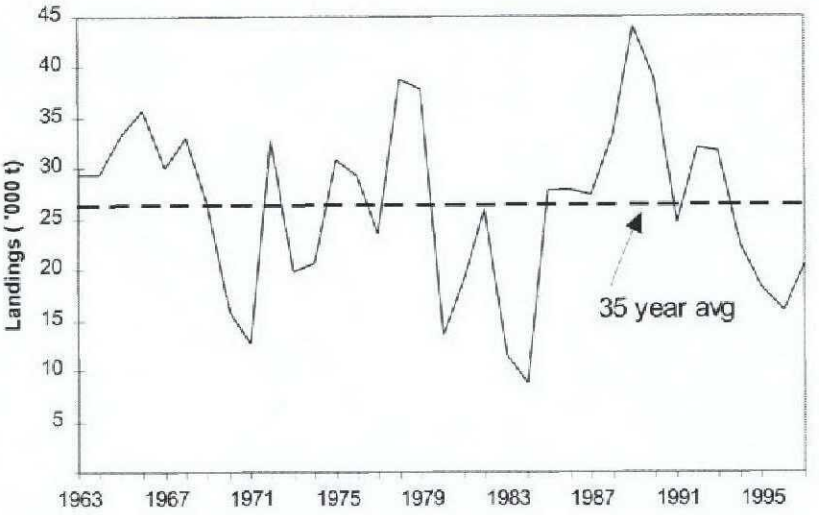


Fig. 23. Herring landings from the southwest New Brunswick weir and shutoff fishery, 1963-1997.

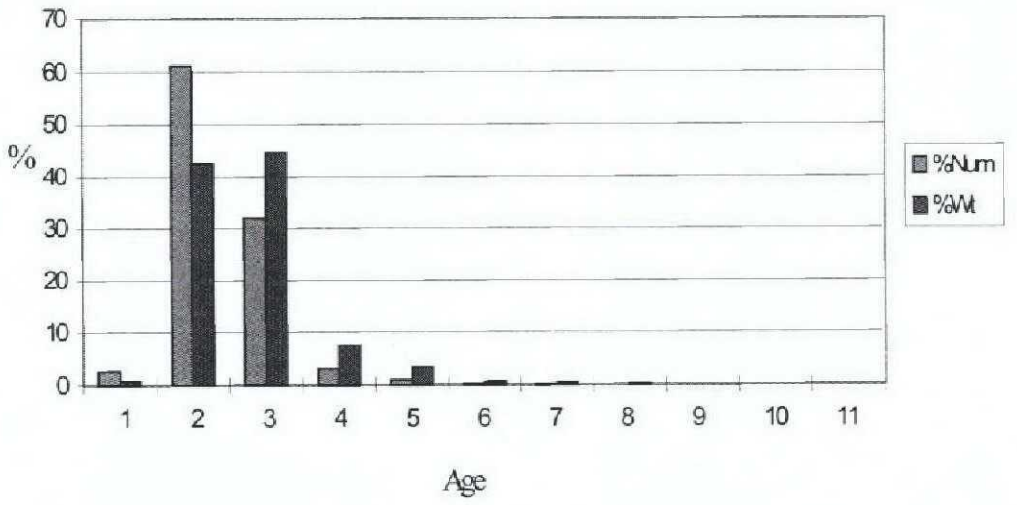


Fig 24. Herring age composition (% numbers and % weight) for the 1997 southwest New Brunswick weir and shutoff fisheries.

Appendix I - Recommendations from Maritimes Region Herring Workshop; Feb. 18-19, 1997 (Sinclair 1997)

Recommendations

1. It is **recommended** that 7 management units be used for herring in the Maritimes Region. These are:

i. Southern Gulf of St. Lawrence spring spawning components;
ii. Southern Gulf of St. Lawrence autumn spawning components;
iii. Southwest Nova Scotia/Bay of Fundy spawning components;
iv. Coastal Nova Scotia spawning components (South Shore, Eastern Shore, Cape Breton);
v. Offshore (greater than 25 miles) Scotian Shelf banks spawning components;
vi. Southwest New Brunswick migrant juveniles; and
vii. Georges Bank spawning component.

2. It was **recommended** that the three conservation objectives and the precautionary approach be incorporated into the respective management plans.

3. It is **recommended** that the stated targets for the first two conservation objectives be included in the management plans, as well as identification of actions to be taken if targets have been exceeded by the fishery.

4. It is **recommended** that operational targets be defined for the third conservation objective (i.e. maintenance of ecosystem balance).

5. It is **recommended** that science evaluate the percentage of each spawning group that can be safely taken in the Southwest Nova Scotia/Bay of Fundy area, taking into account fishing mortality on this spawning complex at other times of the year.

6. It is **recommended** that a model be developed to subdivide the southern Gulf of St. Lawrence gillnet quotas amongst spawning areas that takes into account differences in abundance trends between areas.

7. It is **recommended** that there be no expansion of fisheries on coastal spawning groups in 4VWX without prior research on the abundance levels for the stocks.

8. It is **recommended** that decision rules be developed for the purse seine fisheries on overwintering herring that incorporate the precautionary approach and that take into consideration by-catch of herring which are not part of the target quota.

9. It is **recommended** that management/science/industry prepare a strategy for the management of the offshore Scotian Shelf banks spawning component in 4VWX that takes into account forage issues.

10. It is **recommended** that RAP evaluate the degree to which industry/science acoustics surveys can be used to set quotas.

Appendix II - Details and results of ADAPT Formulation for SW Nova Scotia herring

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the larval index survey results using the following data :

$C_{a,y}$ = catch
for ages *a* = 1 to 10 and for years *y* = 1965 to 1997 and

I_y = larval abundance index
for years *y* = 1972 to 1997;

The larval survey abundance results for year y were compared to beginning-of-year spawning population biomass in year y + 1. The model formulation employed assumed that the error in the catch at age was negligible. Further, it is assumed that any error in the observed weight at age, $w_{a,y}$, proportion mature, $m_{a,y}$, or average partial recruitment to the fishery, pr_a, is also negligible. The error in the larval survey abundance index was assumed to be independent and identically distributed after taking natural logarithms of the values. Natural mortality, *M*, was assumed constant and equal to 0.2 and fishing mortality, *F*, for age 10 was assumed equal to the arithmetic average for ages 6 to 8.

Following Gavaris (1993), a model formulation using as parameters the ln population abundance at the beginning of the year following the terminal year for which catch at age is available was considered. The following model parameters were defined:

$\theta, a, 1998$ = ln population abundance
for *a* = 5 at the beginning of the year 1998,

κ = ln calibration constant for the larval index

ADAPT was used to solve for the parameters by minimizing the sum of squared differences between the ln observed larval abundance index and the ln spawning population biomass adjusted for catchability. The objective function for minimization was defined as

$$\Psi(\theta,\kappa) = \sum_y \left(\ln I_y - \kappa + \sum_a \ln m_{a,y} w_{a,y} \bar{N}_{a,y}(\theta) \right)^2$$

For convenience, the mid- year population abundance $\bar{N}_{a,y}(\theta)$ is abbreviated to $\bar{N}_{a,y}$. For year y = 1998, the beginning of year population abundance was obtained directly from the parameter estimate, $N_{a,1998} = e^{\theta_{a,1998}}$ for age 5. For ages 1 and 2, $N_{1,1998}$ and $N_{2,1998}$, their abundance was assigned a fixed value of 1 million. For ages 3, 4 and 6 to 10, their abundance was derived using partial recruitment to the fishery as follows:

solve for $F_{3,1997}$ in the following catch equation using a Newton-Raphson algorithm

$$N_{4,1998} = \frac{C_{3,1997}\left(F_{3,1997} + M\right)}{F_{3,1997}\left(e^{\left(F_{3,1997}+M\right)} - 1\right)}$$

compute the fishing mortality rate in 1997 for other ages using partial recruitment to the fishery

$$F_{a,1997} = F_{3,1997} pr_a$$

then compute population abundance for other ages using the catch equation

$$N_{a+1,1998} = \frac{C_{a,1997}\left(F_{a,1997} + M\right)}{F_{a,1997}\left(e^{\left(F_{a,1997}+M\right)} - 1\right)}$$

In all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality M is assumed and the fishing mortality $F_{a,y}$, for ages a = 1 to 9, is obtained by solving the catch equation using a Newton-Raphson algorithm

$$N_{a,y} = \frac{C_{a,y}\left(F_{a,y} + M\right)}{F_{a,y}\left(1 - e^{-\left(F_{a,y}+M\right)}\right)}$$

The fishing mortality rate for age 10 was assumed equal to the average for ages 6 to 8.

$$F_{10,y} = \sum_{a=4}^{7} F_{a,y} \Big/ 4$$

The mid-year population abundance was obtained by applying the annual fishing mortality rate at age for a time period of 0.5 years to the beginning of year population abundance in each year

$$\overline{N}_{a,y} = N_{a,y} e^{-(F_{a,y}+M)0.5}$$

Following is the listing from the ADAPT run selected:

Input parameters:

```
Ages for which abundance will be estimated
5
Initial values
10000
Ages for which abundance will be calculated using PR
3 4 6 7 8 9 10
PR for these yearclasses in the previous time period
0.3 0.6 1 1 1 1 1
Estimated ages used in the PR calculations
5
PR for these estimated yearclasses in the previous time period
1
Ages assigned a fixed value
1 2
Assigned abundance for these ages
1000000 1000000
Ages being averaged for oldest age F
6 7 8
PR multiplier for oldest age F
1
Unweighted oldest age F
```

Appendix II - Details and results of ADAPT Formulation for SW Nova Scotia herring

Catch (thousands)

	1	2	3	4	5	6	7	8	9	10
1965	270378	1084719	34835	234383	49925	10592	1693	561	54	37
1966	154323	914093	448940	73382	321857	45916	13970	7722	1690	215
1967	722208	613970	153626	266454	110051	159203	57948	4497	409	296
1968	164703	2389061	224956	83109	290285	73087	90617	31977	15441	5668
1969	108875	290329	531812	132319	162439	112631	62506	22595	6345	2693
1970	699720	576896	76532	286278	201215	120280	111937	41257	21271	7039
1971	87570	404224	183896	106630	113566	75593	93620	50022	36618	7536
1972	0	649254	71984	148516	77207	75384	49065	48700	26055	13792
1973	1018	167454	781061	130851	40128	30334	22046	20249	23871	11630
1974	18411	766064	93606	803651	68276	19093	10232	6565	12786	7102
1975	3199	317641	239827	124599	514605	66302	12298	4409	4778	3847
1976	240	55596	206535	153782	68804	268839	21460	5571	3951	2059
1977	1170	153921	31572	218478	119234	51173	177247	13977	3170	1415
1978	35381	383611	40887	12906	122108	68410	31088	108975	11082	2425
1979	342	183982	250393	54620	5430	23142	18255	11836	41389	4527
1980	2339	12503	80518	474091	27930	4373	4692	6560	2985	10641
1981	0	103051	50883	102743	451482	32978	2418	2767	1917	538
1982	3589	102133	150764	22640	98206	211043	14627	2080	1354	1250
1983	5488	191682	150328	244007	24483	60678	89982	10352	1728	642
1984	0	88433	243542	224354	146096	22716	21654	28299	9515	2183
1985	9022	216740	337591	302782	147670	42404	14075	18178	7997	1201
1986	63	125300	275903	292792	56937	31599	10770	4320	2942	1356
1987	2300	82940	126436	527443	242597	45933	19481	7292	3361	3120
1988	151	148399	113208	195096	434192	236089	42533	21208	4186	3797
1989	8	101788	114095	61842	79451	169023	76684	18303	8270	3814
1990	0	178532	130176	171560	89922	101066	201901	116788	31466	10572
1991	0	96960	179463	183647	88431	41352	50380	80732	45516	18291
1992	9	168561	132642	286923	126510	75473	34458	35369	59136	34558
1993	166	76405	43766	194198	130713	67708	33820	21481	21893	20684
1994	151	103885	142260	53700	118015	72512	36059	14889	8706	10447
1995	1831	113457	219777	112245	36784	36402	22127	6474	4217	2957
1996	0	37496	37715	256063	54534	16862	9151	3300	1782	1310
1997	356	56561	87395	78098	131062	18917	5131	3636	894	620
1998										

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.000451

MEAN SQUARE RESIDUALS 0.674477

Estimates for index catchability parameters

PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
-9.513E0	1.784E-1	-1.875E-2	-3.043E-3	3.199E-4

Terminal year-class abundance

PAR. Age Yr	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
1 1998	1000000	0	0.00	0	0.00
2 1998	1000000	0	0.00	0	0.00
3 1998	1379205	751203	0.54	186153	0.13
4 1998	1045537	580148	0.55	143877	0.14
5 1998	546511	310792	0.57	77219	0.14
6 1998	917139	521563	0.57	129587	0.14
7 1998	132376	75281	0.57	18704	0.14

Appendix II - Details and results of ADAPT Formulation for SW Nova Scotia herring

PAR. Age Yr	PAR. EST.	STD. ERR.	REL. ERR.	BIAS	REL. BIAS
8 1998	35905	20419	0.57	5073	0.14
9 1998	25444	14470	0.57	3595	0.14
10 1998	6256	3558	0.57	884	0.14
11 1998	4339	2467	0.57	613	0.14
11 1997	4005	2014	0.50	500	0.12
11 1996	3127	1200	0.38	291	0.09
11 1995	6448	1382	0.21	331	0.05
11 1994	18444	1906	0.10	461	0.02
11 1993	41519	2155	0.05	518	0.01
11 1992	33621	890	0.03	212	0.01
11 1991	14591	260	0.02	62	0.00
11 1990	15567	166	0.01	40	0.00
11 1989	9227	89	0.01	21	0.00
11 1988	14055	103	0.01	24	0.00
11 1987	5950	34	0.01	8	0.00
11 1986	2161	11	0.01	3	0.00
11 1985	3140	9	0.00	2	0.00
11 1984	672	1	0.00	0	0.00
11 1983	2051	1	0.00	0	0.00
11 1982	1036	1	0.00	0	0.00
11 1981	18154	7	0.00	2	0.00
11 1980	2764	0	0.00	0	0.00
11 1979	1587	0	0.00	0	0.00
11 1978	1848	0	0.00	0	0.00
11 1977	3647	0	0.00	0	0.00
11 1976	5584	0	0.00	0	0.00
11 1975	12621	0	0.00	0	0.00
11 1974	13123	0	0.00	0	0.00
11 1973	13095	0	0.00	0	0.00
11 1972	10341	0	0.00	0	0.00
11 1971	11490	0	0.00	0	0.00
11 1970	6191	0	0.00	0	0.00
11 1969	7619	0	0.00	0	0.00
11 1968	549	0	0.00	0	0.00
11 1967	626	0	0.00	0	0.00
11 1966	282	0	0.00	0	0.00
11 1965	0	0	1.00	0	1.00

Population Numbers (thousands)

	1	2	3	4	5	6	7	8	9	10	11
1965	3519813	3855302	997927	1315177	349389	91813	41148	4346	1282	385	0
1966	2744236	2637898	2182572	785586	865817	241085	65624	32161	3052	1001	282
1967	6079237	2107534	1340493	1383120	577015	420626	156068	41164	19391	995	626
1968	1286748	4326385	1174412	959039	892656	373395	201831	75881	29649	15506	549
1969	1753791	905094	1416146	759114	710245	470528	239954	84291	33532	10516	7619
1970	2301347	1337648	480639	683223	502405	435466	284006	140308	48719	21745	6191
1971	7465175	1256337	579488	324601	303370	231291	248525	132346	77846	20877	11490
1972	1138732	6032880	666073	309497	170148	146680	121579	119645	63566	31046	10341
1973	2344088	932315	4354043	480446	120859	70342	52905	55642	54390	28736	13095
1974	1626238	1918257	612601	2861804	275848	62972	30476	23598	27417	23198	13123
1975	247027	1314823	885052	417256	1621503	164493	34425	15779	13426	11032	12621
1976	723650	199360	791015	509240	229804	865995	75355	17167	8960	6711	5584
1977	4143587	592258	113303	462101	278937	126403	467834	42430	9059	3805	3647
1978	1344248	3391425	346630	64417	183317	121778	57708	224327	22206	4576	1848
1979	455861	1068632	2430902	246948	41130	42025	38851	19567	86435	8298	1587

Appendix II - Details and results of ADAPT Formulation for SW Nova Scotia herring

	1	2	3	4	5	6	7	8	9	10	11
1980	1590761	372919	709304	1764519	153071	28782	13812	15512	5512	33830	2764
1981	1673550	1300292	294033	508156	1018879	100188	19626	7102	6834	1855	18153
1982	2318157	1370187	971642	194931	323619	430768	52457	13890	3338	3874	1036
1983	4140247	1894704	1029686	659746	139191	176837	164418	29815	9499	1522	2051
1984	5043902	3384790	1378440	707634	321617	91922	90395	54523	15133	6222	672
1985	1844239	4129598	2691386	909361	378124	132824	54847	54547	19423	3952	3138
1986	1071463	1501786	3185435	1899317	473056	177409	70715	32260	28362	8749	2158
1987	1417355	877183	1116553	2359197	1291357	335994	116809	48197	22520	20568	5942
1988	1425804	1158355	643391	800195	1457316	838969	233708	78096	32893	15411	14030
1989	1768821	1167213	814666	424865	479817	803493	474925	153065	44894	23159	9205
1990	1287406	1448181	863840	564213	292148	321310	505826	319789	108824	29314	15527
1991	688745	1054039	1024787	590014	308001	158513	172407	233470	157209	60853	14529
1992	1127700	563897	775543	677486	318311	172786	92634	95936	118794	87856	33408
1993	3476178	923275	310412	515555	298133	147402	74013	44983	46867	44522	41001
1994	1415869	2845904	687004	214719	248209	127275	60216	30391	17657	18826	17983
1995	1839108	1159079	2236251	434514	127546	97883	39725	17278	11600	6691	6117
1996	1855993	1504080	846679	1632734	254915	71407	47540	12837	8349	5720	2836
1997	1221796	1519558	1197581	659162	1106187	159663	43307	30688	7546	5233	3505
1998	1000000	1000000	1193052	901660	469291	787552	113672	30832	21849	5372	3726

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10
1965	0.088	0.369	0.039	0.218	0.171	0.136	0.046	0.153	0.048	0.112
1966	0.064	0.477	0.256	0.109	0.522	0.235	0.266	0.306	0.921	0.269
1967	0.140	0.385	0.135	0.238	0.235	0.534	0.521	0.128	0.024	0.395
1968	0.152	0.917	0.236	0.100	0.440	0.242	0.673	0.617	0.837	0.511
1969	0.071	0.433	0.529	0.213	0.289	0.305	0.337	0.348	0.233	0.330
1970	0.405	0.637	0.193	0.612	0.576	0.361	0.564	0.389	0.647	0.438
1971	0.013	0.435	0.427	0.446	0.527	0.443	0.531	0.533	0.719	0.502
1972	0.000	0.126	0.127	0.740	0.683	0.820	0.582	0.588	0.594	0.663
1973	0.000	0.220	0.220	0.355	0.452	0.636	0.607	0.508	0.652	0.584
1974	0.013	0.574	0.184	0.368	0.317	0.404	0.458	0.364	0.710	0.409
1975	0.014	0.308	0.353	0.396	0.427	0.581	0.496	0.366	0.493	0.481
1976	0.000	0.365	0.338	0.402	0.398	0.416	0.374	0.439	0.656	0.410
1977	0.000	0.336	0.365	0.725	0.629	0.584	0.535	0.447	0.483	0.522
1978	0.029	0.133	0.139	0.249	1.273	0.942	0.882	0.754	0.784	0.859
1979	0.001	0.210	0.120	0.278	0.157	0.913	0.718	1.067	0.738	0.899
1980	0.002	0.038	0.133	0.349	0.224	0.183	0.465	0.620	0.889	0.423
1981	0.000	0.091	0.211	0.251	0.661	0.447	0.146	0.555	0.368	0.383
1982	0.002	0.086	0.187	0.137	0.404	0.763	0.365	0.180	0.586	0.436
1983	0.001	0.118	0.175	0.518	0.215	0.471	0.904	0.478	0.223	0.618
1984	0.000	0.029	0.216	0.427	0.684	0.316	0.305	0.832	1.143	0.485
1985	0.005	0.060	0.149	0.454	0.557	0.430	0.331	0.454	0.597	0.405
1986	0.000	0.096	0.100	0.186	0.142	0.218	0.183	0.159	0.121	0.187
1987	0.002	0.110	0.133	0.282	0.231	0.163	0.203	0.182	0.179	0.183
1988	0.000	0.152	0.215	0.311	0.395	0.369	0.223	0.354	0.151	0.315
1989	0.000	0.101	0.167	0.175	0.201	0.263	0.195	0.141	0.226	0.200
1990	0.000	0.146	0.181	0.405	0.411	0.423	0.573	0.510	0.381	0.502
1991	0.000	0.107	0.214	0.417	0.378	0.337	0.386	0.476	0.382	0.400
1992	0.000	0.397	0.208	0.621	0.570	0.648	0.522	0.516	0.781	0.562
1993	0.000	0.096	0.169	0.531	0.651	0.695	0.690	0.735	0.712	0.707
1994	0.000	0.041	0.258	0.321	0.730	0.964	1.048	0.763	0.770	0.924
1995	0.001	0.114	0.115	0.333	0.380	0.522	0.930	0.527	0.507	0.658
1996	0.000	0.028	0.050	0.189	0.268	0.300	0.238	0.331	0.267	0.290
1997	0.000	0.042	0.084	0.140	0.140	0.140	0.140	0.140	0.140	0.140

Appendix II - Details and results of ADAPT Formulation for SW Nova Scotia herring

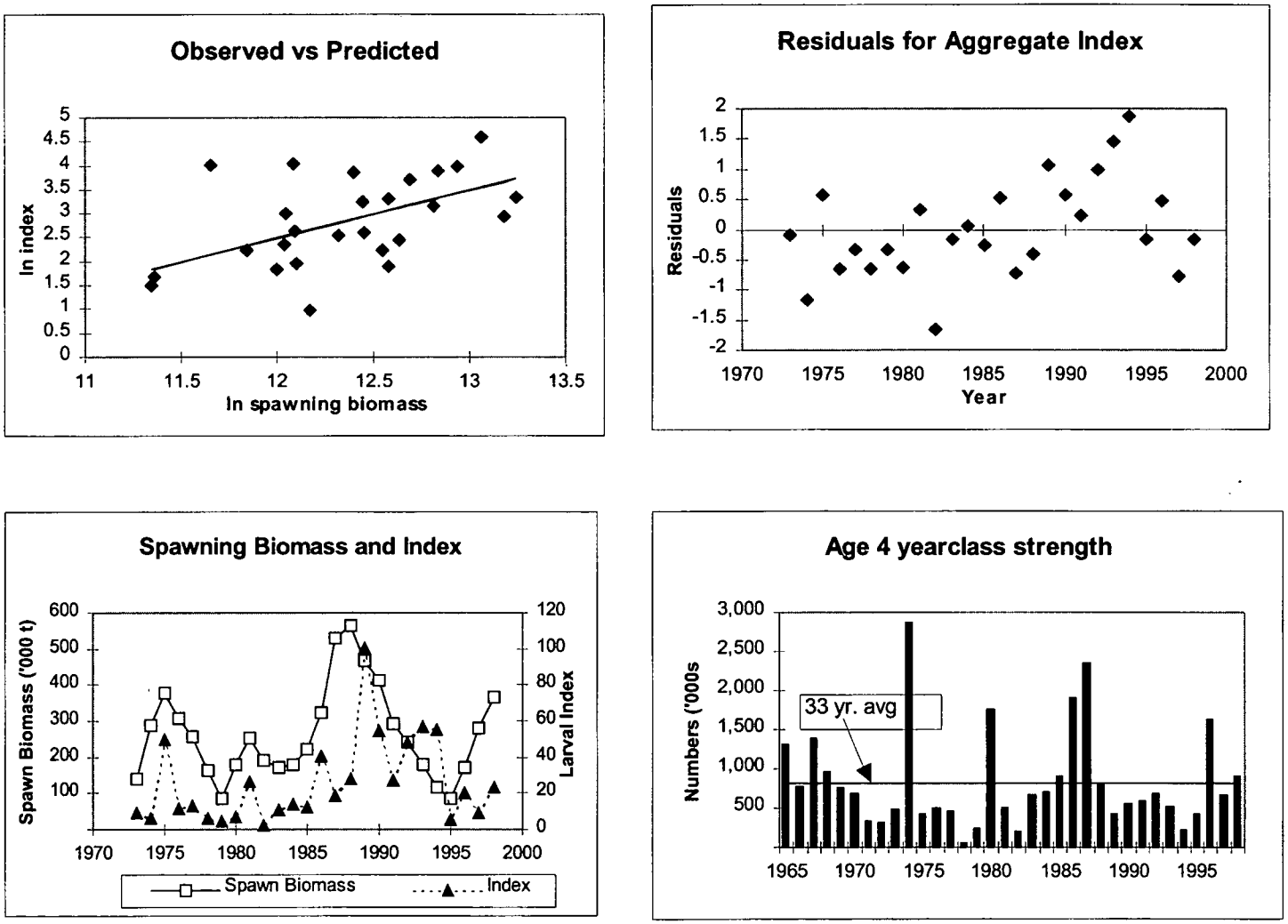


Figure A2. Diagnostic plots from ADAPT formulation for SW Nova Scotia herring; observed vs. predicted spawning biomass (top left), residuals for relationship (top right), spawning biomass and larval abundance index for 1972-1997 (bottom right) and age 4 yearclass size from ADAPT with age 4 long term average (bottom right).

Appendix III - Selected sections from mission report: Alfred Needler 97-070 (Scotian Shelf, Nov. 18-Dec. 5, 1997)

Mission Report 97-070

VESSEL/MISSION: Alfred Needler (97-070)

DEPARTURE PORT: Dartmouth, N. S. DATE: November 18, 1997

ARRIVAL PORT: Dartmouth, N. S. DATE: December 5, 1997

AREA OF OPERATIONS: eastern Scotian Shelf with special focus on the Western Bank area

OBJECTIVES:

1. Survey the eastern Scotian Shelf to determine the large-scale distribution and abundance of ichthyoplankton (especially larval herring and cod) and other zooplankton.

2. Conduct meso-scale and fine-scale physical/biological surveys in the vicinity of Western Bank as part of the GLOBEC Canada Western Bank Group research project.

METHODS:

The spatial distribution of herring larvae was sampled using bongo gear and a fixed grid station design. The initial emphasis was to complete the 88 large-scale stations followed by more intensive sampling of Western Bank (Fig. 1).

PROBLEMS ENCOUNTERED:

A- Back-flushing of bongo gear - The above described method of bongo hauls down the trawl ramp of the Alfred Needler has been employed since the decommissioning of the E. E. Prince in 1994. The cruise report for N211 (Nov. 1-15, 1994) noted the following:

"The annual Bay of Fundy fall larval herring survey is on-going since 1972 and has been done exclusively using the E.E. Prince until this year. The results of this survey form an essential ingredient in the 4WX herring assessment and there has been concern that the potential impact of spawning time and/or cruise timing would bias the results. The ship change this year has resulted in a number of similarities and unavoidable differences, which must be noted.

Similarities
- *61 cm bongo frame with 250 lb. depressor*
- *deployed off stern*
- *calibrated digital General Oceanic or TSK flowmeters*

Differences
- *draft: Prince = 3.7 m, Needler = 4.9 m which affects all bottom depth data which is relative to bottom of hull*
- *length overall: Prince = 39.6 m, Needler = 47.2 m which affects the extend of pitching motion to the gear, especially in a large swell*
- *ship speed: Prince = 3.5 kt, Needler = 3.0 kt to compensate for meter block slippage*
- *prop-wash effects: Prince = ?, Needler design pushes gear away from stern*
- *wire and winch: Prince used ship trawl winch and 3/4" wire with 25 fathom marks or a 1/2" wire with a meter block system when available; Needler used 3/8" electro-mechanical wire on a Swann slip-ring winch and meter block system*

Appendix III - Selected sections from mission report: Alfred Needler 97-070 (Scotian Shelf, Nov. 18-Dec. 5, 1997)

- depth monitoring: Prince = Vemco telemeter with 6 second depth and temperature updates; Needler with Netminder II gear monitoring system with 1 second updates of depth, temperature, flow rate and pitch "

There is another difference with the E. E. Prince not noted above. On the Prince, the bongo was deployed over a square stern using a pivoting A-frame while on the Needler it is deployed down the stern trawl ramp from a fixed in-board meter block position above top of trawl ramp.

Unfortunately, the differences noted above due to 'length overall' and 'prop-wash effects' may be more critical than first thought in 1994. During the current survey, the bongo was observed 'back-flushing' with substantial loss of plankton from the net mouth. It is believed that this only occurred (on occasion) during sea-swell conditions that resulted in a substantial pitching motion of the ship. At the end of the tow, as the gear was brought up close to the base of the trawl ramp, the bongo often remained in that position (at the base of the ramp) for several seconds before retrieval out of the water and up the ramp. The pitching motion of the ship (due to the prevalent sea-state) together with the prop wash apparently resulted in an upwelling from the base of the bongo net through the mouth causing serious loss of plankton. This may not be a problem when the sea-state is calm and will be further investigated by reviewing historical data that includes sea-state and wind observations by set.

After this problem was noted, attempts were made to correct/minimize the possibility of 'back-flushing' as follows. The gear was carefully observed after surfacing at the end of the tow and with the ship propeller pitch set to neutral, the haulback rate was increased to 30-40 m/min to bring it more quickly out of the water. This change of procedure only began after set 72 on Nov. 26.

Back-flushing tests - A series of seven bongo tows were done at station 4-2 to test for loss of plankton or 'back-flushing'. All deployment and retrieval procedures were kept as constant as possible in the prevailing 'poor' weather conditions. The control variables introduced were ship tow direction either into or away from the current swell direction and retrieval rates (at the end of the tow after the bongo came to the surface) either at 20 m/min or 40 m/min.

B- Deployment problems while using the EPSONDE - Despite the high level of competence and extremely helpful attitude of the crew, Captain, and officers, the Needler proved to be a difficult ship from which to deploy EPSONDE for several reasons. These are (1.) high freeboard, (2.) tendency to drift off the wind very slowly while on station, (3.) inability to de-clutch the propeller while on station, (4.) underwater hull protrusions, and (5.) lack of a bow thruster.

1. Extension of the Foc'sle deck along both sides of the ship created about 5 m freeboard from the rail to the waterline. The high freeboard combined with the tendency for the ship to roll heavily, making it difficult to deploy the instrument without it contacting the side of the ship and damaging the sensors.

2. EPSONDE is a tethered free-falling instrument, which means that the line must be spooled out loosely into the water while the instrument drops through it's measurement zone. The ship drifts off the wind somewhat slowly (perhaps because of her draft of nearly 5 m), such that the surface layer of water is often blown downwind faster than the ship and is then drawn under the ship. The consequence is that the EPSONDE and/or its line tend to be drawn under the ship under a wide variety of conditions.

3. The ship has a single, variable-pitch propeller, which cannot be de-clutched and stopped from turning while on station. The rotating propeller, combined with the tendency for the line to go under the ship, creates a serious risk of the line becoming tangled in the propeller and consequent loss of the

instrument. The propeller also creates a large amount of prop-wash, which may seriously degrade the measurements in the top 10 m. of the water.

4. The hull has at least one underwater protrusion, which has the ability to snag the instrument cable. During the Basin inter-comparison test on Dec. 4, the cable snagged on one such protrusion. The launch IBIS was used to retrieve EPSONDE by hand and to de-tangle the cable. Without the help of the launch, it is possible that loss of the instrument could have occurred.

5. The lack of a bow-thruster and the fact that the ship has a single screw seriously limits the maneuverability of the ship while on station or while moving slowly.

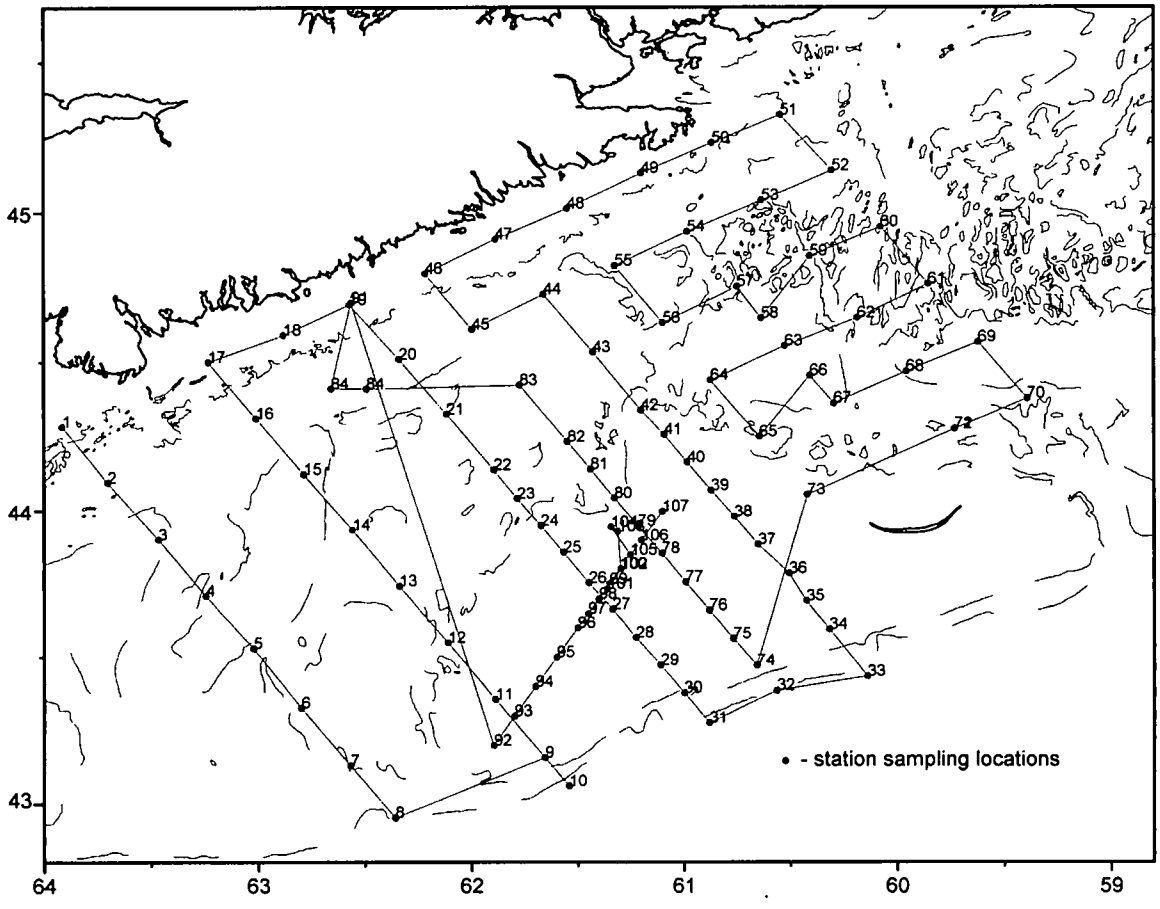
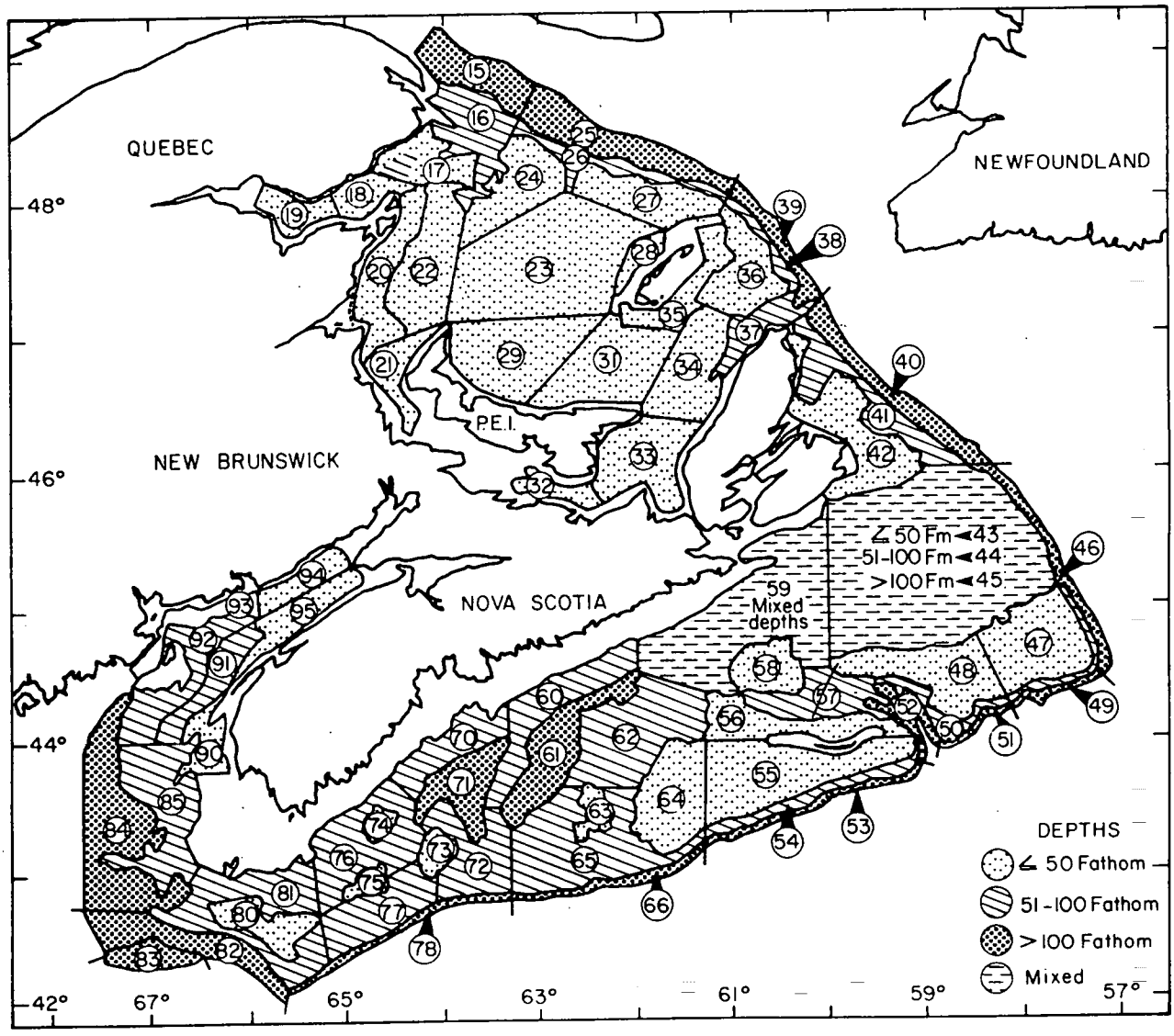


Figure 1. Alfred Needler (97-070) survey track of stations completed.

Appendix IV.1 - Strata in NAFO Divisions 4T, 4V, 4W and 4X (from Doubleday 1981). Strata areas are given in Appendix IV.2.



Appendix IV.2 - Depth interval, area (nautical miles squared) and number of fishing units for strata in NAFO Divisions 4T, 4V, 4W and 4X (from Doubleday 1981).

Div.	Stratum No.	Depth interval	Area (n. mi²)	No. of units	Div.	Stratum No.	Depth interval	Area (n. mi²)	No. of units
4T	15	101–150 fath	764	227	4T	27	11–50 fath	951	299
	16	51–100	1,067	296		28	11–50	202	57
	17	11–50	525	158		29	11–50	1,696	486
	18	11–50	394	113		31	11–50	1,419	412
	19	11–50	443	127		32	11–50	301	78
	20	11–50	773	202		33	11–50	1,188	334
	21	11–50	329	100		34	11–50	1,211	344
	22	11–50	1,244	359		35	11–50	639	173
	23	11–50	3,211	952		36	11–50	958	294
	24	11–50	1,050	318		37	51–100	495	132
	25	101–150	630	176		38	51–100	168	30
	26	51–100	388	95		39	101–150	353	85
4V	40	101–200 fath	924	263	4V	47	11–50 fath	1,616	452
	41	51–100	1,000	301		48	11–50	1,449	484
	42	11–50	1,437	403		49	51–100	144	35
	43	11–50	1,318			50	51–100	383	102
	44	51–100	3,925	1,778		51	101–150	147	40
	45	101–150	1,023			52	101–150	345	89
	46	101–200	491	124					
4W	53	101–150 fath	259	65	4W	60	51–100 fath	1,344	368
	54	51–100	499	137		61	101–150	1,154	283
	55	11–50	2,122	581		62	51–100	2,116	577
	56	11–50	955	264		63	11–50	302	80
	57	51–100	811	222		64	11–50	1,297	360
	58	11–50	658	181		65	51–100	2,383	640
	59	(variable)	3,148	881		66	101–150	226	51
4X	70	51–100 fath	920	232	4X	82	101–150 fath	1,042	270
	71	101–150	1,004	256		83	101–150	532	141
	72	51–100	1,249	337		84	101–150	2,264	598
	73	11–50	265	69		85	51–100	1,582	422
	74	11–50	161	41		90	11–50	601	153
	75	11–50	156	41		91	51–100	687	185
	76	51–100	1,478	400		92	51–100	1,086	300
	77	51–100	1,232	322		93	11–50	533	147
	78	101–150	233	50		94	11–50	417	116
	80	11–50	655	174		95	11–50	584	170
	81	51–100	1,875	395					