Fisheries and Oceans Canada — Pêches et Océans Canada
Science — Sciences

C S A S — **S C C S**

Canadian Science Advisory Secretariat — **Secrétariat canadien de consultation scientifique**

Research Document 2004/031 — **Document de recherche 2004/031**

Not to be cited without
Permission of the authors *

Ne pas citer sans
autorisation des auteurs *

Summary of the 2003 Herring acoustic surveys in NAFO Divisions 4VWX

Résumé des relevés acoustiques du hareng effectués en 2003 dans les divisions 4VWX de l'OPANO

G.D. Melvin[1], M.J. Power[1], L. M. Annis[2], K.J. Clark[1],
F.J. Fife[1] and R.L. Stephenson[1].

Marine Fish Division [1]
Department of Fisheries and Oceans
Biological Station
531 Brandy Cove Road
St. Andrews, N.B.
Canada E5B 2L9

Herring Science Council [2]
35 Hawthorne St
Yarmouth, Nova Scotia, B5A 4B4

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1499-3848 (Printed / Imprimé)
© Her Majesty the Queen in Right of Canada, 2004
© Sa majesté la Reine, Chef du Canada, 2004

Canada

ABSTRACT

Automated acoustic recording systems deployed on commercial fishing vessels were used to document the distribution and abundance of Atlantic herring in NAFO Division 4VWX from industry vessel surveys and fishing excursions. Regularly scheduled surveys, at approximately 2-week intervals, were conducted on the main spawning components and the spawning stock biomass (SSB) for each component was estimated by summing these results.

In 2003, three surveys were conducted in Scots Bay, three on Trinity Ledge and five on German Bank following established protocol, and provided good coverage of these spawning areas consistent with previous years. Additional data from fishing nights in Scots Bay and German Bank were examined. On German Bank, a 22 day gap between surveys, as well as equipment failure during the documentation of a large spawning aggregation, may have led to an underestimate of total SSB. There were also equipment problems during the first Scots Bay survey which resulted in the loss of data from transects containing dense areas of fish. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 133,900t, 14,500t, and 343,500t for a total SSB of 493,300t in the traditional survey areas. A single fishing night recording near Seal Island observed 12,200t and 1,400t of spawning fish were documented in the spring near Spectacle Buoy. The total estimated SSB for the Bay of Fundy/SW Nova Scotia component of the 4WX herring complex in 2003 spawning season was 505,500t. While this represents a slight decrease, it is not considered significantly different from 2002.

Biomass estimates from surveys of the coastal Nova Scotia spawning components were higher in 2003 with large increases in estimated spawning biomass for the Little Hope/Port Mouton, Eastern Shore and Glace Bay areas. For the offshore Scotian Shelf there were no large aggregations of herring observed and no acoustic surveys were conducted. There was no acoustic survey effort in the Bras d'Or lakes.

RÉSUMÉ

Des systèmes d'enregistrement acoustique automatisé installés à bord de bateaux de pêche commerciale ont servi à déterminer la répartition et l'abondance du hareng atlantique dans les divisions 4VWX de l'OPANO, dans le cadre de relevés effectués par l'industrie et d'excursions de pêche. Des relevés des principaux groupes de reproducteurs ont été effectués environ aux deux semaines selon le programme prévu, et la biomasse du stock reproducteur (BSR) a été estimée pour chaque groupe en faisant la somme des résultats.

En 2003, trois relevés ont été effectués selon le protocole établi dans la baie Scots, trois sur le récif de la Trinité et cinq sur le banc German, ce qui a donné une bonne couverture des zones de fraie, comme lors des années précédentes. D'autres données, recueillies lors de nuits de pêche dans la baie Scots et sur le banc German, ont été examinées. Sur le banc German, un intervalle de 22 jours entre deux relevés et la défectuosité de l'équipement pendant le relevé d'un grand banc de reproducteurs pourraient avoir entraîné la sous-estimation de la BSR totale. Il y a aussi eu des problèmes d'équipement lors du premier relevé dans la baie Scots, ce qui causé la perte de données sur des transects à forte densité de harengs. Les biomasses dans la baie Scots, sur le récif de la Trinité et sur le banc German ont été estimées à environ 133 900 t, 14 500 t et 343 500 t, respectivement, pour une BSR totale de 493 300 t dans les secteurs de relevé habituels. Durant une seule nuit de pêche près de l'île Seal, l'enregistrement acoustique a détecté 12 200 t, tandis que 1 400 t de harengs reproducteurs ont été relevées au printemps près de la bouée Spectacle. La BSR totale de la composante baie de Fundy et sud-ouest de la Nouvelle-Écosse du complexe de hareng de 4WX a été estimée à 505 500 t pour la période de fraie de 2003. Bien que légèrement en baisse, cette valeur n'est pas considérée comme significativement différente de celle de 2002.

Les estimations de biomasse obtenues lors des relevés de groupes de reproducteurs des eaux côtières de la Nouvelle-Écosse étaient en hausse en 2003, présentant de fortes augmentations dans les secteurs de Little Hope/Port Mouton, de la côte est et de Glace Bay. Aucun grand banc de harengs n'a été observé dans les eaux hauturières du plateau néo-écossais, et aucun relevé acoustique n'y a été effectué, ni dans le lac Bras d'Or.

INTRODUCTION:

Since 1998 the spawning stock biomass (SSB) of 4WX herring has been estimated using acoustic surveys conducted by the fishing industry (Melvin *et al.*, 1998; Stephenson *et al.*, 1998). Each year commercial fishing vessels equipped with calibrated acoustic logging systems undertake both scheduled and unscheduled surveys of herring aggregations on the spawning grounds. The data collected during these surveys serve two purposes. First, when necessary the data can be analyzed in near real-time, and used as input for the "survey, assess, then fish" protocol, to apportion fishing effort on individual spawning grounds. Secondly, the estimates for individual spawning areas can be summed, under specific assumptions about elapsed time between surveys, to provide an estimate of the SSB for the annual assessment process. The development and implementation of the automatic acoustic systems represents a major improvement in quantifying fish biomass. Pre-1998 estimates are considered qualitative only and relied on the experience of the observer to estimate the amount of fish from mapping surveys (Melvin *et al.*, 2002b).

The use of commercial fishing vessels to survey and to estimate spawning stock biomass (SSB) was initially developed to provide additional protection of individual spawning components within a global TAC during a period (1994-95) of declining biomass. The original qualitative approach, commonly referred to as the "survey, assess, then fish" protocol, continues today, but now uses a quantitative acoustic methodology with a standard survey design (DFO, 1997; Melvin and Power, 1999; Melvin *et al.*, 2003; Power *et al.*, 2003) to estimate biomass.

Several major improvements to our approach have been made in the areas of survey design and in the standardization of survey coverage to a point where they can be considered comparable from year to year (Melvin and Power, 1999; Melvin *et al.*, 2003; Power *et al.*, 2003). The most recent improvement, to be discussed in this report, is the introduction of a calibration factor for echo integration.

The purpose of this document is to report and to summarize the 4VWX stock assessment related survey data collected during the 2003 fishing and survey season.

METHODS:

Acoustic and mapping surveys using commercial fishing vessels have been employed to estimate the spawning stock biomass of individual components within the stock complex for the past 6 years. The methods and procedures are well established and described in previous research documents (Melvin *et al.*, 2000; 2001; 2002a; 2003). This section provides only a general overview of the approach. A detailed description of the methodology and analytical approach is presented in Appendix A.

Data collected and used to estimate the spawning stock biomass (SSB) during the 2003 fishing season were obtained during both standard fishing operations and structured (i.e. organized) surveys. Structured surveys were either acoustic or mapping surveys (Melvin *et. al.,* 2001). In 2003 no major changes from previous years were made to the established protocol for either acoustic or mapping surveys. The sixteen surveys scheduled for 2003 were completed on or near the tentative dates scheduled and three additional surveys were initiated by industry to enhance coverage. Table 1 summarizes the number of structured surveys undertaken for each area and the locations of these areas are shown in Figure 1.

In general, surveys were conducted in accordance with the protocol established in Melvin and Power (1999). There was an improvement in the survey design in situations when only a single aggregation of fish was surveyed. In most cases, vessel captains established a series of parallel transects to document the fish, rather than the unorganized search pattern common in fishing operations. The trend of moving away from mapping surveys toward standardized and scheduled acoustic surveys continued. When structured surveys were undertaken participating vessels tend to follow standard protocol and there was a vast improvement in the coverage of the survey area.

<u>Equipment Problems: Summer 2003</u>

Over the summer of 2003, several computer mishaps resulted in the loss of important acoustic information. One newly installed system had a problem with the computer not booting up properly. Another recording system was dismantled to repair a separate piece of equipment, but when the system was put back in place it was not properly reconnected. In addition, one recording system required the threshold level to be adjusted, after excessive file sizes of acoustic data were noted.

Problems were also noticed with the new windows logging software after the second Scot's Bay survey, when it appeared from the data files that some boats did not finish their lines. It was found that when systems with the new software were turned off the current file was being saved but contained no data. Since data files are automatically saved and a new one created hourly, this meant that up to one hour of information could potentially be lost. All captains were notified of the problem and asked in the future to leave their systems recording at least one hour after the end of their last transect.

The above problems resulted in the loss of data from Scot's Bay and German Bank over the season. In the first Scot's Bay survey, the recordings of two vessels were completely lost due to the various problems. On other Scot's Bay surveys, up to the last 45 minutes of the survey were lost from the last transect. In three of five German Bank surveys only parts of the final lines were completed due to the problem with files being saved with no data when the system was turned off.

Length/Weight Relationship:

Prior to 2001, the fish weight variable in the target strength (TS) equation (Appendix A) was estimated using a length/weight relationship developed from monthly data for each area. A correction factor of 1.02 was applied to each fish to account for the shrinkage of fish due to freezing, prior to calculating the length/weight relationship (Hunt *et al.*, 1986). This relationship was then used to estimate the weight of a fish for a given length.

Since 2001, the time window applied for data has changed only slightly to provide a more representative estimate of mean fish weight for each spawning area and for each survey. Recent initiatives and continued collaboration with the processing plants, have greatly improved sampling such that it is now possible to obtain a significant number of detailed samples (length/weight data) within a 9 -day window (4 days either side each of the surveys). These data are used to develop a weight/length relationship specific to each acoustic survey (Table 2). The mean length of herring sampled during the night of the survey (or from landings of the previous night) and the calculated mean weight is then used to estimate TS specific to each survey period.

Integration Calibration Factor:

In 2003, an option to account for the non-square waveform observed in a ball calibration was incorporated into the HDPS software. Theoretically, the return signal from a calibration ball or target should be square, however in actuality it often takes on a variety of shapes similar to, but not exactly, a square due to transmitter/transducer mismatching and echo-sounder/acoustic path filtering. Figure 2 illustrates the difference between the ideal shape and one measured during an actual calibration. Although alike, the real observation depicts a peak signal return that in the past was used to calibrate a system. A more accurate approach would be to average the return within the wave envelope. This approach is used by several acoustic manufacturers when calibrating their echo sounder. The effect of including an integration calibration factor to estimate backscatter in the integration process varies depending on the vessel's acoustic hardware. The multiplier for the factor typically lies between a positive and negative 0.6 and 1.0, with 1.0 equivalent to an ideal square wave.

Given that the inclusion of the calibration is deemed to provide a more accurate estimate of biomass, it is recommended that all future analysis utilize the calibration factor to calculate actual biomass. However, when comparing observations from year to year it is recommended that the comparison be made between the biomass estimate that excludes the adjustment until a time series has been established with the calibration factor included. After several years only the biomass estimate with the calibration factor will be needed.

Table 3 summarizes the biomass estimates for all surveys by spawning component both without the integration factor (previous method) and with the proposed integration factor. Overall for the Bay of Fundy/Southwest Nova Scotia stock complex the estimated biomass was reduced by 2% if the calibration factor was included in the calculations. The biomass estimate was reduced by 9% for Scots Bay but increased slightly (2%) for German Bank depending upon the mixture of fishing vessels undertaking the survey. When single boats are used for a survey the differences can be extremely variable depending on the vessel's calibration factor. The calibration factor significantly decreased the biomass estimate for Little Hope and Trinity Ledge (15%) and increased it for Eastern Shore (41%).

Acoustic Systems:

In 2003, as in previous years, acoustic data were collected using automated logging systems aboard commercial fishing vessels during both standard fishing excursions and structured surveys. The systems, which were activated whenever the captain wished to document observations, automatically saved all data to the system's hard drive. The data were downloaded at regular intervals to either a removable hard-drive or tape prior to archiving and analysis. Eight automated acoustic logging systems were deployed on commercial fishing vessels in 2003. Systems were installed and calibrated aboard the purse seine vessels *Margaret Elizabeth, Island Pride, Lady Melissa, Dual Venture, Leroy & Barry* and *Secord* and on the inshore gillnet boats, *Bradley K* and *Attaboy*.

Structured Surveys:

Structured surveys are defined as those surveys that follow the standard protocol described by Melvin and Power (1999). Under this protocol, commercial vessels follow a series of randomly selected transects within a pre-defined area. The number of transects depends upon the number of vessels involved. Acoustic recording vessels are distributed throughout the survey area to provide representative coverage. The surveys which are conducted at regular intervals throughout the spawning season and are generally scheduled at two-week intervals, play an important role in our understanding and perception of the 4WX herring stock. Sufficient flexibility was built into the process to allow for schedule changes, which increased the number of surveys, and allowed for investigation of areas of interest or uncertainty. Structured surveys were conducted on each of the major, and several of the minor, spawning grounds within 4WX, as well as non-spawning aggregations (Figure 1).

Fishing Excursions:

Fishing nights are defined as those occasions when acoustic data are collected by fishing vessels equipped with automated acoustic logging systems during the search phase of a fishing excursion. These data, which do not follow any formal survey design, provide information on the distribution and abundance of herring during non-survey nights. The data have also been used to document large spawning aggregations not included in a survey and/or as a substitute for a survey in the event no other information is available. The approach to the activation of the systems has changed since start of the program. During the early stages fishing captains would turn their system on when they reached the fishing ground and off once they deployed their fishing gear. For the last few years, the majority of vessels have activated their systems only when they believed there was something worth recording. This has greatly reduced the amount of time required for archiving, editing and analyzing. Analyses of acoustic data from non-survey nights increased due to the provision of technical support for the program in 2002 and 2003. Data from fishing nights were examined for Trinity, Scots Bay and German Bank SSB in 2003. Only one fishing night from the Scots Bay area on Sept. 6 was used to fill in for missing data not covered by a traditional survey. All other estimates were found to be lower than the nearest survey estimate for that area and time period.

RESULTS:

The spawning biomass for individual components of the 4WX herring stock complex in 2003 was estimated from industry collected data using multiple structured acoustic and mapping surveys on major spawning grounds. These surveys, when summed, provide an estimate of SSB and form the foundation for evaluation of the stock status. In the absence of a structured survey, acoustic data from fishing excursions were used to estimate component SSB for a given night, assuming sufficient elapsed time had evolved between surveying and fishing events. The following text provides a summary of the 2003 observations and SSB estimates for each of the main spawning components within the stock complex. The number of surveys scheduled, the number actually completed and the number of fishing nights used in the biomass estimate are summarized in Table 1 for each of the main spawning areas.

Bay of Fundy/SWNS Spawning Component:

Biological Sampling for Maturity:

The timing of surveys in relation to the residence time of spawning groups on the spawning grounds is an issue discussed at length each year. The current hypothesis for surveys on individual spawning grounds assumes that there is continuous spawning on each ground over the season with individual spawning groups or waves continuously arriving, spawning and then leaving within 10 to 12 days (or less). Evidence from tagging of ripe and running (spawning) herring showed that the residence time for most fish on the same grounds was less than

7-10 days. However 25% of the returns were captured on the same grounds after 10 days at large (Paul, 1999). Sampling data for maturity supports the view of continuous spawning with high proportions of ripe and running or spawning (stage 6) fish observed over an extended period (Figure 3, 4). The 10 to 12 day window also assumes that there will be no double counting and that the maturing (hard) stage 5 fish in the samples will have spawned and left before the next survey. The proportion of maturing fish appeared to be less on German Bank than in Scots Bay. It is also worth pointing out that spent fish are rarely found even with the intensive sampling that is done. This is substantiated by fishermen's reports of the fish leaving very quickly after spawning and rarely being caught. In 2003, there were only two cases of large proportions of spent fish; once in Scots Bay on Sept. 4 with 100% in spent condition and once on German Bank on Oct. 10 with 53% spent. These data show unequivocal evidence of an actual turnover in progress. It is also interesting to note the high proportion of spawning fish in the samples from the days before or after these two events.

In 2003, herring maturity data were again obtained from two primary sources: 'Roe Analysis Data Sheets' from the Scotia Garden Seafoods processing plant quality control group and from the standard biological sampling program conducted by staff at the St. Andrews Biological Station (SABS). The 'Roe Analysis Sheets' from industry were supplied as available, usually on a daily basis during the spawning period, often with multiple samples from different boats. These are random samples of 50 to 100 fish with the males and females separated and the individual gonads weighed into categories for use by the processing plant. From these data the overall percent weight of mature, immature and spent females as well as percent weight of the male gonads were determined. The plant classification system must not be confused with the standardized ICES scientific scale of 1 to 7 (Parrish & Saville, 1965) but the roe data can be compared with SABS data based on knowledge of the two methods.

The SABS biological samples provide data on individual fish for length, weight, sex, maturity stage, gonad weight and age. For comparison with the industry categorization, data by maturity stages were grouped such that stages 1-2 were called 'immature', stages 4 and 5 (mature/hard roe) were combined as 'maturing', stage 6 (ripe and running) were designated as 'spawning' and stages 7 (spent) and 8 (recovering) were combined as 'spent'. A modification to the SABS lab procedure to weigh all gonad stages was implemented in 2003 in order to make more exact comparison with industry maturity samples. SABS samples were combined for female fish by day and percent numbers by the categories determined.

'Roe Analysis Sheets' from 21 Scots Bay samples were provided by Scotia Garden Seafoods from July 23 to Sept. 6, 2003, while SABS maturity data were available for 25 samples (1,137 fish) from July 6 to Sept. 6. The combined data from both sources averaged by day showed that spawning roe fish were present in the samples throughout the entire period and the percent of female roe to overall roe weight often exceeded 50%. There were peaks in the percent spawning fish above 70% on July 30, Aug. 7, 20 and Sept. 6, each of which corresponded to within a few days of a survey (Figure 3). The sample of spent fish on Sept. 4, followed by a sample with a high proportion of spawning fish on Sept. 6, suggested a turnover of herring just as the last fishing survey took place.

Scotia Garden Seafoods provided ‘Roe Analysis Sheets’ for 33 German Bank samples over a 25 day period from Aug. 26 to Oct. 10, 2003. SABS maturity data were available for 27 samples (1,071 fish) from June 5 to Oct. 26. The combined data averaged by day showed that there were adult spawning fish on German Bank throughout the period with the percent of roe to overall roe weight exceeding 60% for most days (Figure 4). There were also more days with total spawning fish of over 80% than seen in Scots Bay. The survey timing appeared adequate to allow for complete turnover between surveys. The gap in sampling and surveys from Sept. 26 to Oct. 5 is unfortunate, as there was likely continued spawning over this period which cannot be accounted for.

Samples were provided for the Little Hope/Port Mouton fishery by Scotia Garden Seafoods for four days (Oct. 4 to 8, 2003). SABS maturity data were available from one sample (59 fish) on Oct. 1 when a survey also took place. The combined data averaged by day from this spawning area showed a high proportion of spawning fish (over 70%) for most days and evidence of a turnover with spent fish in the samples on Oct. 6 (Figure 5). No sample data were available for the survey nights of Sept. 14, 16 or 18, 2003.

<u>Scots Bay</u>:

Four surveys were conducted during the 2003 spawning season in Scots Bay between July 31 and Sept. 6 (Table 4). The surveys began slightly later than in 2002 and continued much longer than most years in the series (the first survey was on July 16 in 2001). The last survey was completed approximately 2 weeks later than normal. This is consistent with the general observation that fish were observed to be 1-2 weeks late arriving on the spawning grounds. Fish samples collected indicated that mature spawning herring dominated samples collected on or near the date of the first three surveys (100% stages 5 & 6). Herring samples collected on Sept. 6 showed that 97% were stage 5/6 and 3% stage 4. No immature herring were collected in Scots Bay during the survey period. Overall the Scots Bays surveys were well conducted and provided good coverage of the spawning area. However, a number technical problems with acoustic equipment (as described in Equipment Problems: Summer 2003) diminished the number of transects available to estimate biomass. Data from several fishing nights in Scots Bay were analyzed, but only Sept. 6 was used in the final overall estimate of SSB (Table 5).

The first survey in Scots Bay was undertaken on the night of July 31, 2003 and involved 10 commercial purse seiners, including with 4 acoustic logging systems. As is the tradition, the vessels met off Margaretsville just after sunset. Each vessel was assigned pre-defined northeast transects which extended approximately 35 km up the bay (Figure 6). The ten transects were all conducted south of the Isle de Haute. The survey provided good coverage of the spawning ground and it is assumed to reflect the distribution of spawning herring. However, technical problems were encountered on two of the recording vessels, *Secord* and *Island Pride*, and the data from these vessels were lost for that night. This resulted in a higher than usual error estimate as only two acoustic transects were available to estimate SSB. Survey participants reported that some of the more dense areas of fish were not recorded due to the lost data. Boundaries for the survey area were determined using information from all vessels. Total coverage for the first survey was 475 km^2. The mean length (28.4 cm) estimated from herring sampled during the survey night and the length-weight relationship of detailed samples collected from Scots Bay during the survey period (Table 2), resulted in a TS estimate of –35.35 dB/kg. Length frequency data used for estimation of target strength are presented in Figure 7 and indicated adult fish sizes only. Analysis of the gonads from detailed samples showed that 100% of the herring were ripe or ripe/running fish (Stage 5-6), consistent with fish within 1 week of spawning. Estimates of fish density, based on distance weighted mean area backscattering (Sa) of the individual transects, ranged from 0.005 to 0.036 kg/m^2. The SSB observed in Scots Bay on the night of July 31, 2003 was estimated to be 9,163t (Table 4).

The second survey in Scots Bay was conducted on the night of Aug. 10, 2003 by 13 purse seiners, with 4 acoustic recording systems. No technical problems were encountered and all transect data were used to estimate biomass. The survey encompassed an area of 400 km^2 of the spawning grounds and provided excellent coverage of the fish distribution (Figure 8). The majority of herring were distributed from the middle to the southern portion of the survey grid, close to the Nova Scotia shore. The mean length of herring was virtually unchanged from last year (27.5 cm in 2002 vs. 27.4 cm in 2003). The target strength of –35.21 dB/kg was estimated from the mean length of herring sampled in Scots Bay on the night of the survey and the weight/length relation described in Table 2. The size distribution was consistent with adult fish (Figure 9). Again, examination of the gonads from samples confirmed the presence of only adult fish with the majority of herring in stage 5 or 6. Only a single spent fish was found in the samples. Fish densities were higher than in the first survey and ranged from 0.06 to 0.4258 kg/m^2. Based on four transects with a distance weighted mean Sa of –42.22 dB/m^2, the observed spawning biomass in Scots Bay on Aug. 10 was 79,598t (Table 4).

The third survey in Scots Bay occurred on the night of Aug. 24 and involved 6 vessels, two of which had acoustic recording systems. This survey covered a relatively large area (415 km^2) concentrated closer to the Nova Scotia shore than the two previous surveys. Herring were observed in one large aggregation about mid-bay and near the shore (Figure 10). Based on distribution information from previous fishing nights, herring were assumed to be absent from the northern portion of the survey area. The length frequency of herring collected on the night of the survey indicated a slight shift toward smaller size with a mean length of 26.8

cm. (Figure 11). The mean length and the weight-length relationship from (Table 2) were used to calculate target strength of -35.06 dB/kg. Again, all herring sampled were observed to be in the adult size range and 92% of the detailed samples contained fish with gonads in an advanced stage (stages 5 and 6) of development or spent (stage 7). The remaining fish were adult but were in earlier stages of development (stages 3 and 4). Fish concentrations between transects ranged from 0.043 to 0.17 kg/m^2 and when weighted for transect length resulted in a Sa of –45.98 dB/m^2. The estimated SSB for Aug. 24 was 33,633t (Table 4).

The final estimate of SSB for Scots Bay in 2003 occurred on the night of Sept. 6 with the *Margaret Elizabeth* recording two schools of herring during standard search and fishing operations. Although the area (3.33 km^2) was relatively small (Figure 12), the density of fish surveyed was high. Examination of the gonads from detailed samples collected on the night of Sept. 6 indicated that all fish were in mature spawning condition (stage 6) with no spent fish found. However, samples from the previous day in the same area were 100% spent, indicating that a turnover with a new group of spawning fish had taken place. The length frequency from biological samples showed a size distribution consistent with adult fish (Figure 13). The mean length of 26.1 cm, the smallest observed in 2003 from Scots Bay surveys, resulted in a TS estimate of -35.06 dB/kg (Table 2). The combined biomass for the two fish schools based on transects excised from the vessel track was 11,468t (Table 5).

The 2003, Scots Bay SSB, estimated from three structured surveys and the one fishing night, was 133,900t (Table 4). Although, the SSB is slightly lower than the 2002 estimate of 141,000t, it is well above the 1997-2001 average of 108,700t. It should also be noted that equipment failure during the first survey resulted in the loss of several key transects which are known to have contained dense concentrations of herring.

<u>Trinity Ledge:</u>

The surveying of spawning herring on Trinity Ledge continued to be less than optimal in 2003 and it is unlikely that biomass estimates reflect the abundance of fish. Prior to 2001, surveys used multiple vessels (10-20) and the portable acoustic logging system to cover most of the potential spawning area (Melvin and Power, 1999). Regrettably, since the deployment of an automated acoustic logging system aboard a single vessel in 2001 there has been a tendency to concentrate on a relatively small area where the fish are known to aggregate. Structured multi-vessel surveys covering the entire spawning area of 200 km^2 seem to have been abandoned. Even mapping surveys undertaken by multiple vessels concentrate their effort in a small area. Improvements to the survey approach and adherence to the design protocols are required if the data are to reflect trends in abundance. The area covered by the 2003 surveys on Trinity Ledge ranged from 0.62 km^2 to 18.0 km^2 in a potential spawning area of 200 km^2.

A number of surveys or recording events to estimate biomass on Trinity Ledge were undertaken in 2003 without consideration of the 10-14 day elapsed time required between surveys. The sampling of fish to determine length frequency improved because of the use of a multi-panel (variable mesh size) gillnet on survey nights. There was however a problem associated with the labeling of samples from each net size and for several samples there is uncertainty as to the completeness of the sample. As such, the only sample considered valid and representative of the fish present was collected on Aug. 24 (Figure 14). Partitioning the catch into the size distribution for the 2½" and 2-7/8" mesh sizes used by the fishery clearly illustrates the selectively between nets and why a multi-panel net is required to obtain a representative sample of all fish surveyed acoustically. The overall mean length for this multi-panel sample was 28.3 cm which is only slightly larger than the default value of 28.0 cm currently used when sample data are unavailable. All biomass estimates for the period Aug. 21 to Sept. 6 were based on the TS estimate of –35.71 dB/kg from the Aug. 24 sample adjusted for a frequency of 120 kHz (Table 2). The survey of Sept. 14 used the TS estimate for a 28 cm herring (standard size), the length/weight equation from the Aug. 24 sample and the echo sounder frequency correction for 120 kHz to obtain a TS of -35.65 dB/kg.

Data related to the abundance of herring on Trinity ledge in 2003 covered the entire traditional spawning period of Aug. 15 to Sept. 15, but surveyed only a very small proportion of the spawning area on any given night (Figures 15-17). Although data from 5 survey nights were examined (Table 6) the biomass estimates from three nights, Aug. 21 (572t), Sept. 2 (2,674t) and Sept. 14 (11,266t), were used to estimate the overall 2003 SSB. Estimates for Aug. 24 and Sept. 6 were not considered in the total as insufficient time had elapsed between surveys for a turnover to have occurred and limited information on changes in gonad development were available from the biological samples. The overall total SSB estimate for Trinity Ledge spawning component in 2003 was 14,500t (Table 6).

<u>German Bank:</u>

The spawning stock biomass for German Bank in 2003 was estimated from five structured surveys (Table 7) extending from Aug. 29 to Oct. 20. Data from a number of fishing nights were analyzed, but none of this information was used in the final estimate of total SSB (Table 8-9). In 2003 the number of structured surveys on German Bank increased from three in 2002 to five and this resulted in improved coverage of this spawning area.

The time required for herring to spawn, leave the area, and a new wave of fish to arrive (turnover time) has always been a concern of both the fishing industry and DFO. Based on detailed analysis of available gonad maturity data and the elapsed time between surveys (>10days), all dates selected for inclusion of the 2003 SSB estimate were considered independent (Figure 4). It should also be noted that several technical problems were encountered during the 2003 survey season resulting in the loss of some acoustic data from German Bank.

The first survey of German Bank occurred on Aug. 29, 2003, and involved 6 fishing vessels, 3 with recording systems. Length frequency samples collected from several vessels on Aug. 29 indicated the presence of a significant number of small and likely immature herring in the catch from the northern portion of the survey area (Figure 18). Examinations of the detailed samples confirmed that although the majority of herring above 20.0 cm length were mature, those less than 20.0 cm were immature. Subsequently, the total acoustic backscatter (Sa) was partitioned into 0.5 cm length intervals and the signal returns from the immature fish (i.e., those fish <20 cm) removed from the biomass estimate. The survey encompassed an area of 490 km^2 and the coverage of spawning ground by both recording and mapping vessels was excellent (Figure 19). Five transects were used to estimate the mean density of herring in the survey area. One transect was lost due a software error and could not be used in the final analysis. The mean length including the immature herring was 26 cm. In this analysis the target strength for each size interval was estimated and the number weighted Sa for only the mature size intervals summed to obtain the SSB. Target strength (weight) ranged from -33.57 dB/kg for a 20 cm fish to –36.61 dB/kg for a 36 cm herring. Density estimates for the size internals ranged from 0.0005 to 0.0292 kg/m^2. The SSB estimate for German Bank on the night of Aug. 29, 2003 was 101,182t (Table 7).

The second structured survey of German Bank occurred on Sept. 8, 2003 and involved 10 vessels, including four with acoustic logging systems. The elapsed time between the first and second survey was 10 days. The vessels provided excellent coverage of the spawning grounds, surveying an area of 365 km^2 (Figure 20). Six transects were used in the estimation of biomass with one duplicate transect removed from the analysis. In addition, a persistent software problem rendered the data from a large portion of one transect unusable. Length measurements were obtained from six samples (817 fish) which demonstrated a bimodal distribution with a mean length of 27 cm, and no fish smaller than 23 cm (Figure 21). Examination of the gonad stages from the detailed sample showed that almost all herring were mature with 92% in spawning condition (Figure 4). A single herring was found to be in the recovering stage 8 but no adjustment was made for this observation. The SSB was estimated based on a TS of –35.17 dB/kg for the 50 kHz systems and –35.44 dB/kg for the 75 kHz system using the sample mean length and calculated weight (Table 2). Mean transect density ranged from 0.00 to 1.224 kg/m^2 from the acoustic recordings after weighting for transect length. The estimated SSB for Sept. 8, 2003 was 97,926t (Table 7).

A third survey was conducted on German Bank on Sept. 18, 2003 and involved 8 purse seiners, 4 with acoustic recorders. Ten days had elapsed between this and the previous survey. Again the survey provided excellent coverage of the spawning area and the transects were followed as directed. The total area surveyed was 300 km^2 (Figure 22). Of the 8 transects completed, 7 were used in the final analysis.

One transect, which cut diagonally across 3 other transects and violated the transect independent assumption, was removed. Length frequency samples indicated the presence of adult size fish with a mean length 26.5 cm. A single herring less than 23 cm was observed in the samples (Figure 23). The biological samples showed the gonads from all herring to be in development stage 5 (5%) or stage 6 (92%) confirming that all fish were mature (Figure 4). Based on a TS of -35.00 dB/kg (50 kHz), -35.27 dB/kg (75 kHz) and a weighted mean acoustic backscatter (Sa) of -42.65 dB/m^2, the SSB was estimated to be 52,599t (Table 7). Transect densities ranged from 0.079 to 0.3161 kg/m^2.

On Oct. 7, 2003 the *Island Pride* documented what was considered to be a very large aggregation of spawning herring during a fishing excursion. Unfortunately, they suffered equipment failure and all acoustic data were lost for that night. The captain, however, provided a detailed summary of the fish area (18.75 km^2), density and distribution. Based on this information, the standard mapping approach estimated this school of fish at 64,000t (Table 8). Fishing night data for the next night of Oct. 8 by the *Dual Venture* and *Leroy & Barry* gave a biomass estimate of 42,000t for a school area of only 3.1 km^2 (Table 9). Neither of these estimates were used as the survey estimate from Oct. 10 provided a higher total SSB.

The fourth survey of German Bank occurred on Oct. 10, 2003 with an elapsed time of 22 days since the previous survey. This is a relatively long period of time between surveys given that spawning was still occurring. As in the previous surveys the vessels provided good coverage of the spawning grounds with 10 vessels, 5 of which had acoustic recorders (Figure 24). The overall survey, however, was less organized and the vessels with recorders tended to concentrate on areas with herring, did not follow the defined survey lines, and extended further south than in previous surveys to document spawn fish. Consequently, the survey area was divided into 3 sub-regions with a total area of 710 km^2 for analysis. The biomass estimates for each area were summed to determine the SSB for the evening. Target strength was estimated for a mean length of 24.9 cm using the length/weight equation described for Oct. 10 in Table 2. Based on a TS of –35.55 dB/kg (50kHz) and –35.81 dB/kg (75 kHz), the SSB for this survey was 70,011t.

Although no fishing took place after the survey, there were 6 samples available from landings between Oct. 9 to Oct. 10 (Figure 25). The length samples from these two nights, while all were adult spawning size, appeared to be different with a smaller mean size and size range on Oct. 10. Maturity samples on Oct. 9 indicated spawning fish with over 90% mature, while samples from Oct. 10 observed only 26% mature with a large portion of spent (53%) and immature (21%) stages (Figure 26). These data indicate that a turnover of fish was starting to take place on the spawning ground after the night of Oct. 9, before this survey took place.

The fifth and final survey for 2003 on German Bank was conducted on the night of Oct. 20 using 3 vessels, 2 with recording systems. Although the survey covered a reasonable area (260 km^2) on the spawning grounds, it occurred late in the season (Figure 27). Furthermore, no fishing was undertaken to collect either length frequency or biological samples on the survey night (due to weather). There is no information about the development stage of the gonads or on the size of the acoustically observed fish. Normally, data from the night before or the night after a survey can be substituted to represent fish size and development stage for the survey night. In this case, biological samples were only available for Oct. 9 and Oct. 26 on German Bank and the former data were previously used in the Oct. 10 survey. The length frequency distribution of the Oct. 26 sample indicated that all fish were of adult size (Figure 28). This detail sample indicated that the majority (65%) of these herring were in a recovering stage suggesting they had spawned several weeks prior or they were immature (Figure 4, 29). If this sample was assumed representative of the survey night only 36% of the observed herring could be considered in the SSB estimate. Alternatively, if this sample is not considered valid and no discounting for maturity stage was applied, based on TS of –34.67 dB/kg (Table 7) the overall SSB would be 21,765t.

Fishing data for German Bank were examined for nights where sufficient data for estimation of biomass were collected (Table 9). Biomass estimates from eight fishing nights between Aug. 31 to Oct. 8 were analyzed with SSB's ranging from 5,400t to 42,000t. None of these estimates were used in the final SSB for German Bank as they overlapped survey nights in the ten day spawning timing window and were lower in total SSB than the formal surveys.

In summary, the total spawning stock biomass observed on German Bank in 2003 was estimated to be 343,500t (Table 7). The SSB is based on estimates of biomass from 5 structured surveys undertaken on Aug. 29, Sept. 8, Sept. 18, Oct. 10 and Oct. 20, 2003. One survey was downgraded to account for the presence of immature/juvenile herring. The elapsed time between all surveys was within the 10-14 day guideline and turnover of spawners was assumed to be 100%. One concern in 2003 was the absence of a survey for 22 days in the middle of the spawning season (Sept. 18 to Oct. 10) in part due to a major hurricane (Juan). This is likely to have resulted in the missing of an unknown portion of the SSB. Another concern was the timing of the Oct. 10 survey which took place just as a turnover of fish was occurring and the loss of crucial fishing night data from just before this survey. A final concern was the absence of a representative sample for the final survey on Oct. 20.

The purse seine fleet is to be commended for the number of surveys and level of effort put into the 2003 survey season. It is a vast improvement over the 2002 season where the majority of biomass estimates originated from fishing night data.

Seal Island:

Historically, the spawning areas around Seal Island made a significant contribution to the biomass of the Bay of Fundy/SW Nova stock complex. In recent years the abundance of herring and the documentation of spawning fish in this area have been intermittent. In 2002, approximately 1,200t of herring were observed during the spawning season.

In 2003 data on the distribution and abundance of spawning herring were collected during a single fishing night of Sept. 15. A relatively dense 1.85 km^2 aggregation of fish was observed in an area southeast of Seal Island (Figure 30). The vessel track was sectioned into 7 transects, considered to be representative of the area surveyed, for biomass estimation. No detailed samples of these fish were available to calculate target strength. Given the proximity of Seal Island to German Bank the biological data from the latter were used in the estimation of SSB (Table 2). Based on this information it was estimated that the vessel observed 12,156t of herring, a marked increase from previous years (Table 10).

Browns Bank :

No surveys were undertaken on Brown's Bank in 2003. A single report by the Morning Star on Oct. 10, 2003 identified the presence of several kilometers of herring while traveling over the ground. Insufficient data were provided to make a biomass estimate.

Spectacle Buoy:

The spring gillnet fishery for roe occurs each year for a short period in June in the vicinity of Spectacle Buoy located just southwest of Yarmouth, N. S. The fishery is dependent upon the availability of fish and to some extent market conditions, and may or may not occur in any given year.

In 2003, spawning herring were caught during early June and several acoustic recordings were made to document the distribution and abundance of this small spawning component. Data were available for the nights of June 2, 4, 6 and 8 (organized survey involving 10 vessels). Data analysis was restricted to the nights of June 2 and June 4 because the latter two nights observed so few fish that detailed quantification of the acoustic recordings was not warranted. A single sample of 35 fish collect by commercial gillnet had a mean length of 30 cm, but was not used to estimate mean length due to the selective nature of the net (Figure 31). Biomass estimates were made for both nights using the TS of a 28 cm herring and the mean weight from the single sample (Table 2). The SSB of 1,416t observed on June 2 was considered to reflect the amount of herring present on the spawning ground during the first week of June (Table 11, Figure 32). Insufficient time had elapsed between data collections to sum the estimates from other fishing nights.

Bay of Fundy/SW Nova Summary:

Over the past 7 years biomass estimates determined from acoustic surveys have been used to evaluate the status of the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex. During this time the approach for estimating SSB has evolved from a heavy reliance on distribution and abundance estimates from fishing excursions with a 10 day minimum elapsed time, to structured surveys scheduled at two week intervals. In the absence of survey data fishing excursion data were substituted. Regular monitoring of herring gonad development throughout the season from both industry and DFO sampling provided evidence that the fish surveyed were mature spawners and that a turnover of spawning fish had occurred between each survey (and that at least 10 days had elapsed between surveys). The total observed biomass for the complex was obtained by summing the SSB estimate for each spawning ground.

In 2003, the total SSB for the Bay of Fundy/Southwest Nova Scotia spawning complex was estimated to be 493,300t, a decrease of 9% from the previous year (Table 12). The SSB for Scots Bay was down by 5% but about the same as in recent years and is not of concern. German Bank was down by 13% and this is attributed more to survey timing and equipment issues than a real decline. The estimates of spawning biomass on Trinity Ledge and Seal Island (areas of concern in recent years) increased substantially from 2002. Although some fish were observed on Browns Bank they are not included in the overall estimate.

The 2003 length frequency samples generally indicated a broad bimodal size distribution with a large component of smaller spawning adults due to the strength of the strong recruiting 2000 year class. As a result, a smaller mean length and weight were observed when compared to a standard 28 cm herring used for standard target strength. When the TS estimated from these data are applied to the acoustic backscatter (Sa) it results in an increase in the number of fish but a decrease in the overall SSB due to the presence of small fish.

A few final points regarding the precision of acoustic biomass results should also be made. The estimation of biomass from acoustic backscatter relies on the relationship of TS to length measured under a variety of conditions (Foote, 1987). The size and weight of herring from appropriate sample data have been applied but there can still be considerable variance. Studies in controlled conditions in herring weirs (Melvin *et al*., 2000, 2001) resulted in absolute differences of 7 to 12% of the known biomass removed. Finally the variance in individual survey estimates as provided in the 2003 tables (SE or standard error) ranged from 9 to 68% and depended on both survey design and the actual variance in Sa observed by transect. Thus the small differences between areas from year to year are likely not to be detectable.

Nova Scotia Coastal Spawning Component:

The shallow inshore waters of the bays and inlets along the Atlantic coast of Nova Scotia support a number of herring spawning populations. Several documents describe reports of coastal spawning in 4VWX (Clark et al., 1999; Crawford, 1979). Our direct knowledge of these relatively small coastal populations is limited to a few areas where there are active commercial fisheries for roe on spawning grounds. The traditional bait fishery occurs in the spring and summer of the year. In 2003, commercial roe fisheries were conducted in three areas of the Nova Scotia coastal stock component: Port Mouton/Little Hope, Jeddore/Eastern Shore and Glace Bay. Surveys of the spawning grounds were undertaken using both the mapping and the structured acoustic survey approach, and the approach varied depending upon the area and the availability of a recording vessel. The results for each spawning area are presented below.

Little Hope:

Adherence to survey protocol for the spawning grounds near Little Hope/Port Mouton improved in 2002, but was variable in 2003. The surveys were coordinated through the Little Hope Management Committee which represents the gillnet fleet in this area. The actual organization of the surveys required a great deal of effort and there was only limited coverage of the spawning grounds using acoustic recorders. In addition, there was a lack of attention to the required 10 to 14 day elapsed time window between surveys. A vessel with an acoustic recording system was not available until the fourth and final survey on Oct. 1, 2003.

The first survey which took place on Sept. 14, 2003 involved 17 gillnet vessels and covered area of 120 km^2 from the approaches to Lockeport, eastward as far as Liverpool with herring observed in small to large bunches over much of the survey area (Figure 33). This was a mapping survey with data recorded at 5-minute intervals on standard deck sheets (Appendix A). A contoured biomass estimate of 6,200t was made based on these observations for the two main areas of fish both east and west of Port Mouton (Table 13). No biological samples were available from either this survey night or recent fishery landings.

The second survey on Sept. 16, 2003, only 2 days after the first survey involved 8 vessels, again none with acoustic recording equipment. Observations were over a much smaller area (15 km^2) and recorded two additional groups of fish not seen in the first survey on Sept. 14 (Figure 33). One group was found just east of Port Medway and a second group located just southwest of Lunenburg. The total contoured biomass of these groups was estimated at 3,600t (Table 13). No biological samples were available.

A third survey took place on Sept. 18, again only 2 days after the previous survey and again none of the 10 vessels involved had acoustic recording equipment. This survey concentrated on the spawning grounds just off Port Mouton where most of the fishery has taken place in recent years. The total survey area was about 75 km^2 with fish recorded in an area of about 10.5 km^2 (Figure 33). The contoured biomass estimate of about 6,400t is based on fish density estimates from the deck sheets and a maximum distance of 1.5 miles between valid observations (Table 13).

Mapping surveys are subjective by design and are used only to provide a preliminary estimate of herring biomass. This information is normally subject to validation using an acoustic recording system. For these surveys there were no acoustic data, as there were no vessels present with a recording system. In addition, it should be noted that the third survey was only separated by 4 days from the first survey of this area on Sept. 14, and only provided a slightly higher estimate of the same group of fish previously observed. Standard accepted protocol for herring surveys has a minimum 10-day separation between surveys and/or detailed biological samples for maturity to show that fish were in spawning condition or that there had been a documented turnover of a group of fish. None of these criteria were met for the first 3 surveys in the Port Mouton/Little Hope area.

A fourth and final survey took place on Oct. 1 with 21 gillnet vessels, including one boat with an acoustic recording system. The survey covered an area of about 200 km^2 near the approaches to Port Mouton with herring observed over much of the survey area (Figure 34).

Fishing took place after the survey and there was a biological sample collected and frozen for later analysis. Samples from fishing nights after the survey using 2½ " mesh gillnet showed herring from 25 to 33.5 cm with a mean of 30 cm and a mode at 30.5 cm. A multi-panel gillnet with various mesh sizes was also set in order to provide a sample of the complete size range of fish but was unsuccessful in catching herring. As a result, the biomass estimate was based on the standard 28 cm herring with target strength of –35.96 dB adjusted for sounder frequency (Table 2). The acoustic survey vessel covered much of the same survey area covered by the mapping boats (Figure 34) with a concentration of survey effort on two main groups or schools. The acoustic data were analyzed with the available transects divided into two schools and the outlying areas examined separately. The final SSB estimated from this survey was 56,109t (Table 13).

The final total 2003 SSB estimate for the Little Hope area based on the Sept. 18 mapping and Oct. 1 acoustic surveys was 62,500t.

<u>Eastern Shore:</u>

In 2003, acoustic and mapping surveys in the Eastern Shore/Jeddore area were coordinated by the Eastern Shore Fishermen's Protective Association. This group did an excellent job in following established survey protocols and design and providing the raw acoustic data on a timely basis.

The first survey on the night of Sept. 18, 2003 involved 15 gillnet vessels including one boat with an acoustic recording system. The fleet covered an area of about 185 km^2 from the approaches to Halifax Harbour east as far as Owl's Head off Ship Harbour, N.S. (Figure 35). The acoustic recording boat followed behind the mapping boats and documented fish along the entire survey track. There were also three areas or schools of fish that received additional survey effort by the recording and mapping boats. Acoustic biomass estimates were determined for each of the three schools (dense aggregations of fish) as well as the area outside. The large amount of herring outside the schools was difficult to estimate using only a single transect recorded while following the mapping survey boats. Using an estimated area of 15 km^2 for the schools and 64 km^2 for fish outside the schools the biomass was estimated to be 52,472t (Table 14). There was no multi-panel gillnet with various mesh sizes available to provide a sample of the complete size range of fish. The biomass is based on a standard target strength estimate for a 28 cm herring corrected for the sounder frequency (-35.96 dB).

The second survey took place on Oct. 14 in a small area of 2 km^2 near the mouth of Halifax Harbor (Figure 36). Dense groups of herring were observed in the water column and near bottom. Biomass estimates were made separately for transects running in both north/south and east/west directions on this single school of fish (Figure 37). These two estimates were within 200t and the final biomass was estimated to be 23,979t with a standard error of 21% (Table 14). This biomass is based on a standard target strength estimate (-35.96 dB) for a 28 cm herring with adjustment for the sounder frequency (Table 2).

Fishery samples using standard 2 3/4" mesh gillnet are selective for size, biased, and do not represent the size or weight distribution of herring observed by the acoustic signal returns. One sample was available on the survey night and had a length range of 27 to 33 cm with a mean and modal length of 30 cm. This sample was used to confirm that the herring were all in spawning condition.

The final 2003 SSB estimate for the Eastern Shore/Jeddore area based on the Sept. 18 and Oct. 14 acoustic surveys was 76,451t (Table 14).

Glace Bay:

In 2003 there were three mapping surveys in the Glace Bay area coordinated by the gillnet fleet in consultation with DFO staff at St. Andrews. There were no boats with acoustic recording system but efforts are under way to acquire a suitable system for the 2004 season.

The first survey on Sept. 7 involved 9 gillnet vessels divided into two groups . The area covered about 100 km^2 northeast and southwest of the approaches to Glace Bay (Figure 38). A contoured biomass estimate of 6,500t is based on fish density estimates from the deck sheets and a maximum distance of 1.5 miles between valid observations. A single set was made using a 2¾" gillnet and a sample of mature spawning herring was collected. The fish size ranged from 28.5 to 35 cm with a mode and mean of 31 cm.

A second survey on Sept. 13 involved six gillnet vessels divided into two areas, northeast on the Red Grounds and in the approaches to Glace Bay. Fish were observed in both general areas (Figure 39). The total survey area was about 50 km^2 with fish occurring in an area of about 40 km^2. The contoured biomass estimate of 11,500t is based on fish density reported from the deck sheets and a maximum distance of 1.5 miles between valid observations (Table 15). Samples collected on subsequent fishing nights of Sept. 15 and Sept. 17 indicated all fish were in spawning condition with mean lengths of 32 and 32.5 cm respectively.

A third and final survey on Sept. 27, 2003 involved 25 gillnet vessels allocated to the various areas around the approaches to Glace Bay. Each boat provided observations of herring distribution on the fishing grounds as seen on their sounders. The survey covered a total area of 250 km^2 including the Red Grounds, the approaches to Glace Bay and The Big Shoal. Fish were reported over an area of about 50 km^2 (Figure 40) in two main groups. Herring were also documented in several outlying areas. The contoured biomass estimate of 20,000t is based on fish density estimates from the deck sheets and a maximum distance of 1.0 miles between valid observations.

These mapping estimates are considered to have a large amount of uncertainty surrounding the biomass estimates. The final 2003 SSB estimate for the Glace Bay area based on the Sept. 13 and Sept. 27 mapping surveys was 31,500t (Table 15).

<u>Bras d'Or Lakes:</u>

In 2003 no surveys were conducted to document the abundance of spawning herring in the Bras d'Or Lakes. The last mapping survey was conducted in 2000 and documented only 70t. Biological data were collected and are reported separately for this area (Power et al., 2004).

Offshore Scotian Shelf Component:

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf continued to decrease in 2003. Acoustic recorders were activated on a few occasions but insufficient quantities of fish were observed to warrant analysis. Consequently, no acoustic biomass estimates were available from the Scotian Shelf. There was also no fall herring research survey on the Scotian Shelf due to a fire on the research vessel CCGS *Alfred Needler*.

Chebucto Head (January 2003):

Since 1998, DFO and the herring industry have undertaken acoustic surveys of a large over-wintering aggregation of herring just off Chebucto Head, N.S. The purpose of the acoustic survey has been to estimate the abundance of herring and to investigate the movement of these mixed spawning origin fish through tagging. On January 20, 2003 a single vessel undertook an exploratory survey of the area. The vessel found only a small group of herring just off Chebucto Head but no sampling or tagging occurred. The biomass of this school of herring was estimated (using a standard TS) to be only 794t (Table 16). No other herring were observed in the area. It has been suggested that the winter aggregation was in the area earlier and may have been present in December 2002.

There was no exploratory survey activity in the Chebucto Head area in January 2004.

DISCUSSION:

In 2003, as in previous years, the spawning stock biomass for the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex was determined primarily from industry based surveys of the three major spawning components: Scots Bay, Trinity Ledge, and German Bank. No structured surveys were conducted outside the main spawning areas, except around Seal Island where about 12,000t were observed. No spawning aggregations of herring were documented in the vicinity of Browns Bank due to the absence of fleet activity in the area. A small amount of spawning fish (1,400t) was documented in the Spectacle Buoy area in June.

This is the seventh season of surveying in which biomass estimates from industry based surveys have played a significant role in the evaluation of the 4WX herring stock abundance. As in any year, there is a possibility that spawning fish were outside the coverage area for any given survey. There is also the potential for the series of scheduled surveys to miss a wave(s) of spawners using a 10-14 day interval between surveys on any given spawning ground. Consequently, the results must be considered an estimate of minimum observed SSB. Increased effort was also put into the documentation of spawning waves through the monitoring of changes in composition of mature herring.

For 2003 the majority of acoustic surveys in the Bay of Fundy/Southwest Nova Scotia areas were well organized and provided good coverage of the spawning grounds. The survey vessels generally completed the assigned transects and automated recording systems were distributed throughout the fleet on survey nights. The main deficiency in 2003 was the absence of structured surveys during late September to early October on German Bank with a 22 day gap between structured surveys. Coverage of Trinity Ledge was less than optimal and the spawning stock biomass is unlikely to be representative of the amount of fish spawning in the area. There was also an absence of surveys, and consequently biomass estimates, from Browns Bank.

The observed SSB for Scots Bay in 2003 decreased slightly from the previous year. Sufficient time (10-14 days) had elapsed between surveys and coverage was good but equipment problems may have compromised some of the survey estimates. Spawning fish were again observed later in the season, into early September. The biomass observed on the four survey nights and one fishing night was added to provide an SSB of 133,900t for the component.

There were problems with the surveying of Trinity Ledge again this year and it is unlikely that biomass estimates reflect the abundance of fish. There has been a tendency for the survey vessels to concentrate on a relatively small area where the fish are known to aggregate. Structured multi-vessel surveys covering the entire spawning area of 200 km^2 seem to have been abandoned. Improvements to the survey approach and adherence to the design protocols are required if the data are to reflect trends in abundance. Trinity Ledge once supported a large spawning component within the 4WX stock complex. As such, given the fact that the observed biomass is still reduced, any fishing on Trinity Ledge must strictly adhere to the "survey, assess, then fish" protocol during the upcoming spawning season. This means that no fishing should occur until sufficient quantities of herring are observed to allow for removals. Alternatively, given the slow rate of recovery consideration should also be given to complete closure until a significant increase in spawning biomass is observed.

In 2003, the total spawning stock biomass observed on German Bank was estimated to be 343,500t (Table 7). The SSB is based on estimates of biomass from 5 structured surveys undertaken from Aug. 29 to Oct. 20. One survey was downgraded to account for the presence of immature/juvenile herring. The elapsed time between all surveys was within the 10-14 day guideline and turnover of spawners was assumed to be 100%. The absence of a survey for 22 days in the middle of the spawning season (Sept. 18 to Oct. 10 including a major hurricane [Juan]) was a concern. As a result an unknown portion of the SSB may have been missed. Other concerns include the timing of the Oct. 10 survey as a turnover of fish was taking place and the loss of crucial fishing night data on Oct 7.

Biomass estimates for the Nova Scotia coastal spawning component of the 4WX stock complex included acoustic and mapping survey data from Little Hope/Port Mouton, Halifax/Eastern Shore and Glace Bay areas. In all three areas there was a substantial increase in the observed SSB and in the amount of fishing effort (Table 17). No biomass estimates were made for the Bras d'Or Lakes or for the offshore Scotian Shelf banks. The large winter aggregation off Chebucto Head was not found in 2003 or in 2004. There continues to be a need to improve knowledge of all coastal Nova Scotia herring spawning areas.

ACKNOWLEDGEMENTS

The authors would like to thank the following for their invaluable contributions to the provision of survey data and other assistance in the preparation of this report: Allen Clay, FEMTO Electronics; Atlantic Herring Co-Op; Comeau's Sea Foods Ltd.; Connors Bros. Ltd.; Herring Science Council; Eastern Shore Fishermen's Protective Association; Glace Bay herring gillnet group; Little Hope Management Committee; Scotia Garden Seafood Inc. and South-West Seiners.

REFERENCES:

Black, G. 2000. ACON Data Visualization Software Version 8.29. Department of Fisheries and Oceans, Dartmouth, N.S. www.mar.dfo-mpo,gc.ca/science/acon.

Clark, K.J., D. Rogers, H. Boyd and R.L. Stephenson. 1999. Questionnaire survey of the coastal Nova Scotia herring fishery, 1998. DFO Canadian Stock Assessment Secretariat Res. Doc. 99/137: 54p.

Crawford, R.H. 1979. A biological survey of the Nova Scotia herring fishery, 1978. N.S. Dept. of Fish. Tech. Rep. 79-05: 66p.

DFO. 1997. In-season management in the 4WX herring fishery. DFO Science Fisheries Status Report 97/2E: 5p.

Foote, K. G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

Hunt, J.J., G. Martin and G.A. Chouinard. 1986. The effect of freezer storage on herring length and maturity stage determination. Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 86/89: 13 p.

Melvin, G.D., Y. Li, L.A. Mayer and A. Clay. 1998. The development of an automated sounder/sonar acoustic logging system for deployment on commercial fishing vessels. ICES Visualization of Spatial Data CM 1998/S:14, 14p.

Melvin, G.D. and M.J. Power. 1999. A proposed acoustic survey design for the 4WX herring spawning components. DFO Canadian Stock Assessment Secretariat Res. Doc. 99/63: 15p.

Melvin, G.D., T. Scheidl, F.J. Fife, M.J. Power, K.J. Clark, R.L. Stephenson, C.L. Waters and S.D. Arsenault. 2000. Summary of 1999 herring acoustic surveys in NAFO Divisions 4WX. DFO Canadian Stock Assessment Secretariat Res. Doc. 2000/66: 40p.

Melvin, G.D., M.J. Power, F.J. Fife, K.J. Clark, and R.L. Stephenson. 2001. Summary of 2000 herring acoustic surveys in NAFO Divisions 4WX. DFO Canadian Stock Assessment Secretariat Res. Doc. 2001/56: 41p.

Melvin, G.D., L.M. Annis, M.J. Power, F.J. Fife, K.J. Clark and R.L. Stephenson. 2002a. Herring acoustic surveys for 2001 in NAFO Divisions 4VWX. DFO Canadian Science Advisory Secretariat Res. Doc. 2002/044: 50p.

Melvin, G.D. Y. Li, L.A. Mayer, and A. Clay. 2002b. Commercial fishing vessels, automatic acoustic logging systems and 3-D data visualization. ICES Journal of Marine Science 59.179-190.

Melvin, G.D., L.M. Annis, M.J. Power, K.J. Clark, F.J. Fife and R.L. Stephenson. 2003. Herring acoustic surveys for 2002 in NAFO Divisions 4WX. DFO Canadian Science Advisory Secretariat Res. Doc. 2003/034: 46p.

Parrish, B.B. and R.E. Saville. 1965. The biology of the northeast Atlantic herring populations. Oceanogr. Mar. Biol. Annu. Rev. 3:323-373.

Paul, S.D. 1999. Report of the 1998-1999 4VWX herring and mackerel tagging program and plans for 1999-2001. DFO Canadian Stock Assessment Secretariat Res. Doc. 99/138: 25p.

Power, M.J., R.L. Stephenson, L.M. Annis, F.J. Fife, K.J. Clark and G.D. Melvin. 2002. 2002 Evaluation of 4VWX herring. DFO Canadian Stock Assessment Secretariat Res. Doc. 2002/45: 103p.

Power, M.J., R.L. Stephenson, L.M. Annis, K.J. Clark, F.J. Fife and G.D. Melvin. 2003. 2003 Evaluation of 4VWX herring. DFO Canadian Science Advisory Secretariat Res. Doc. 2003/035.

Power, M.J., R.L. Stephenson, L.M. Annis, K.J. Clark, F.J. Fife and G.D. Melvin. 2004. 2004 Evaluation of 4VWX herring. DFO Canadian Science Advisory Secretariat Res. Doc. 2004/030 (in press).

Stephenson, R.L., M.J. Power, K.J. Clark, G.D. Melvin, F.J. Fife and S.D.Paul. 1998. 1998 Evaluation of the 4WX herring fishery. DFO Atl. Fish. Res. Doc. 98/52. 58p.

Table 1. Summary of the number of scheduled herring spawning ground surveys for 2003, the number of surveys undertaken and the number of fishing nights examined in the estimation of spawning stock biomass in the 4VWX stock complex. The number in brackets refers to the number of fishing nights for which data were analyzed.

Spawning Ground	Surveys Scheduled	Surveys Completed	Fishing Nights
Scots Bay	3	3	1(3)
Trinity Ledge	3	5	0 (3)
German Bank	4	5	0 (8)
Eastern Shore	2	2	
Little Hope	2	2	
Glace Bay	2	2	
Total	16	19	1(14)

Table 2. Summary of fish sampled, length/weight relationship, target strength estimate of samples, and target strength estimate for a 28 cm herring using the length/weight equation by date and location.

Date	Location	Number Samples	Number Detail Fish	Mean Len (cm)	Mean Weight (gm)	Slope	Intercept	Target Strength dB/kg	Wt 28 cm Fish (gm)	TS 28 cm Fish dB/kg
31-Jul	Scots Bay	3	715	28.40	178.6	3.23	-5.64	-35.35	170.6	-35.28
10-Aug	Scots Bay	7	965	27.40	161.3	3.18	-5.51	-35.21	172.3	-35.32
24-Aug	Scots Bay	5	592	26.80	149.1	3.31	-5.84	-35.06	171.8	-35.31
06-Sep	Scots Bay	1	83	26.06	140.5	3.13	-5.38	-35.06	175.9	-35.41
24-Aug	Trinity Ledge[2]	1	68	28.30	173.4	3.15	-5.49	-35.71[1]	167.7	-35.65[1]
02-Sep	Trinity Ledge[2]	1	68	28.30	173.4	3.15	-5.49	-35.71[1]	167.7	-35.65[1]
14-Sep	Trinity Ledge[2]			28		3.15	-5.49	-35.65[1]	167.7	-35.65[1]
02-Jun	Spec Buoy			28		2.68	-4.33	-35.83[1]	174.6	-35.83[1]
04-Jun	Spec Buoy	1	35	28		2.68	-4.33	-35.83[1]	174.6	-35.83[1]
29-Aug	German Bank	6	947	26.11	137.9	3.23	-5.66	-34.96	175.5	-35.40
08-Sep	German Bank	5	269	26.96	154.0	3.10	-5.43	-35.17	174.1	-35.36
18-Sep	German Bank	4	264	26.46	139.0	3.27	-5.78	-34.87	167.1	-35.19
10-Oct	German Bank	3	400	24.91	114.0	3.28	-5.80	-34.55	167.9	-35.21
20-Oct	German Bank	1	96	25.94	127.0	3.01	-5.15	-34.67	160.0	-35.00
01-Oct	Little Hope	1	59	28				-35.96[1]		-35.96[1]
18-Sep	East. Passage	1	72	28				-35.96[1]		-35.96[1]
14-Oct	East. Passage	1	55	28				-35.96[1]		-35.96[1]

[1] TS adjust by -0.46 dB to account for difference in acoustic signal from 120 kHz system.
[2] TS estimated for 28 cm herring using length/weight relationship from August 24 multi-mesh sample.

Table 3. Summary of the changes in biomass resulting from the use of the integration calibration factor by survey and spawning ground for all acoustic surveys in 2003. Note that totals are for all surveys completed and do not represent the final SSB by area.

Location/Survey	Date	Biomass without Integration Calibration Factor	Biomass with Integration Calibration Factor	Proportion With Factor / Without Factor
4WX Stock Component Surveys				
Scots Bay 1	30-Jul	9,163	8,759	
Scots Bay 2	10-Aug	79,598	73,311	
Scots Bay 3	24-Aug	33,633	30,351	
Scots Bay 4	25-Aug	31,954	28,439	
Scots Bay 5	06-Sep	11,468	10,564	
Scots Bay	Subtotal	165,816	151,424	91%
Trinity 1	20-Aug	572	504	
Trinity 2	24-Aug	571	475	
Trinity 3	02-Sep	2,674	2,228	
Trinity 4	06-Sep	3,343	2,785	
Trinity 5	14-Sep	11,266	9,385	
Trinity	Subtotal	18,426	15,377	83%
Spectacle Bouy 1	02-Jun	1,416	1,180	
Spectacle Bouy 2	04-Jun	1,252	1,043	
Spectacle Buoy	Subtotal	2,668	2,223	83%
Seal Island 1	15-Sep-03	12,156	11,866	98%
German Bank 1	29-Aug	101,182	107,204	
German Bank 2	08-Sep	97,926	101,447	
German Bank 3	18-Sep	52,599	52,765	
German Bank 4	10-Oct	70,011	66,781	
German Bank 5	20-Oct	21,768	20,579	
German Bank	Subtotal	343,486	348,776	102%
4WX Stock Total (all surveys included)		542,552	529,666	98%
Coastal Nova Scotia surveys				
Little Hope	01-Oct	56,109	47,755	85%
Eastern Shore 1	18-Sep	52,472	72,249	
Eastern Shore 2	14-Oct	23,979	33,742	
Eastern Shore	Subtotal	76,451	105,991	141%

Table 4. Summary of the 2003 Scots Bay spawning ground acoustic survey data and associated biomass estimates. The total SSB for the spawning component is obtained by summing the biomass estimates.

Location/ Type	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Scots Bay									
Survey	31-Jul	475	-52.746	0.019	28.40	-35.35	9,163	4,066	44
Survey	10-Aug	400	-42.225	0.199	27.42	-35.21	79,598	35,023	44
Survey	24-Aug	415	-45.977	0.081	26.83	-35.06	33,633	7,590	23
Fishing	06-Sep	3.33	-28.688	1.238	26.06	-35.06	11,468	2,651	23
Overall							**133,862**	**36,163**	**27**

Table 5. Summary of acoustic biomass estimates of SSB in Scots Bay from selected fishing nights.

Location/ Type	Date	Vessel	Area (km^2)	Target Strength	Mean Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)
Scots Bay							
Fishing	06-Aug	LB/SC	16.00	-35.50	-38.59	0.49	8,057
Fishing	25-Aug	SC,ME,DV	11.25	-35.50	-30.82	2.84	31,954
Fishing	26-Aug	ME,DV,SC	3.00	-35.50	-31.52	5.79	16,218
Fishing	06-Sep	ME	3.33	-35.06	-28.69	1.24	11,468

Table 6. Summary of the 2003 Trinity Ledge acoustic surveys and SSB biomass estimate. Total SSB estimated from biomass on Aug. 21, Sept. 2 and Sept. 14 surveys.

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Trinity Ledge									
	21-Aug	**1.13**	**-39.81**	**0.389**	**-**	**-35.71**	**572***	**169**	**30**
	24-Aug	0.62	-36.07	0.921	28.3	-35.71	571	204	36
	02-Sep	**18.00**	**-43.99**	**0.149**		**-35.71**	**2,674***	**917**	**34**
	04-Sep	4.40	-36.89	0.761	-	-35.71	3,343	980	29
	14-Sep	**1.90**	**-27.92**	**5.930**	**28.0**	**-35.65**	**11,266***	**2,055**	**18**
Overall							**14,512**	**2,257**	**16**

* Used to estimate total SSB for 2003

Table 7. Summary of the 2003 German Bank spawning ground acoustic survey results and SSB biomass estimates from surveys.

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
German Bank									
Survey	29-Aug	490	-41.70	0.21	26.12	-34.96	101,182	44,614	44
Survey	08-Sep	365	-40.89	0.26	26.96	-35.17	97,926	54,569	56
Survey	18-Sep	300	-42.65	0.18	26.46	-35.00	52,599	9,578	18
Survey	10-Oct	710	-44.82	0.09	24.91	-34.56	70,011	29,122	42
Survey	20-Oct	260	-45.82	0.08	26.79	-34.67	21,768	13,535	62
Overall							**343,486**	**78,046**	**23**

Table 8. Summary of biomass estimation for a spawning school surveyed by the Island Pride on Oct. 7, 2003. Equipment problems resulted in loss of all acoustic data and these estimates were calculated using standard assumptions for density as used for mapping survey estimation (Table A1, Appendix 1).

Estimation of School	Length	Width	Area
School size (naut miles)	2.6	2.1	5.46 sq. mi.
School size (km)	4.82	3.89	18.75 sq. km.

Area	80% Very Dense	20% Moderate	Total Area
School size (sq naut mi)	4.37	1.09	5.46
School size (sq km)	15.00	3.75	18.75
Biomass Conversion	@4,000/sqkm	@1000/sqkm	Total Biomass (t)
Biomass (t)	59,992	3,750	63,742

Table 9. Summary of the 2003 herring biomass estimates observed during fishing nights on German Bank. The vessel names are Dual Venture (DV), Island Pride II (IP), Lady Melissa (LM), Leroy & Barry (LB) and Secord (SC). None of these estimates from were used in the final 2003 German Bank SSB.

Location	Vessel	Date	Area (km2)	Weighted Sa (dB/m2)	Density (kg/m2)	Target Strength (dB/kg)	Biomass (t)	SE (%)
German Bank	DV,LM, LB	31-Aug-03	4.00	-27.610	6.152	-35.5	24,607	35
German Bank	IP	06-Sep-03	2.20	-25.252	10.589	-35.5	23,295	35
German Bank	SC	14-Sep-03	1.15	-19.801	37.149	-35.5	42,721	25
German Bank	DV	21-Sep-03	0.25	-22.147	21.644	-35.5	5,411	17
German Bank	LM	21-Sep-03	0.70	-25.739	9.464	-35.5	6,625	38
	Total	21-Sep-03	0.95				12,036	
German Bank	DV	22-Sep-03	0.20	-22.029	22.238	-35.5	4,448	9
German Bank	DV	23-Sep-03	1.25	-27.513	6.291	-35.5	7,864	20
German Bank	DV	24-Sep-03	1.05	-26.216	8.481	-35.5	8,905	18
German Bank	DV/LB	08-Oct-03	3.10	-24.180	13.551	-35.5	42,009	28

Table 10. Summary of the 2003 Seal Island acoustic results and SSB biomass estimate for the single fishing night.

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	SE (t)	SE (%)
Seal Island	15-Sep	1.85	-26.82	6.571	24.5	-35.00	12,156	2,608	21

Table 11. Summary of the 2003 Spectacle Buoy acoustic results and SSB biomass estimate.

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	SE (t)	SE (%)
Spec Buoy	**02-Jun**	**0.50**	**-31.129**	**2.832**		**-35.65**	**1,416***	**620**	**44**
	04-Jun	0.58	-32.308	2.159	30.3	-35.65	1,252	857	68
Overall							**1,416**	**620**	**44**

* Used to estimate total SSB for 2003

Table 12. Summary of the minimum observed spawning stock biomass for each of the surveyed spawning grounds in the Bay of Fundy/SW Nova component of the 4WX stock complex. Total SSB is rounded to nearest 100t.

Location/Year	1997	1998	1999	2000	2001	2002	2003
Scots Bay	160,200	72,500	41,000	106,300	163,900	141,000	133,900
Trinity Ledge	23,000	6,800	3,900	600	14,800	8,100	14,500
German Bank	370,400	440,700	460,800	356,400	190,500	393,100	343,500
Spectacle Buoy							
- Spring	15,000	1,300	0	0	1,100		1,400
- Fall					87,500		
Sub-Total	568,600	521,300	505,700	463,300	457,800	542,200	493,300
Seal Island					3,300	1,200	12,200
Browns Bank					45,800		
Overall SSB	568,600	521,300	505,700	463,300	506,900	543,400	505,500
Overall SE %	n/a	n/a	19	14	10	9	17

Table 13. Summary of the 2003 Little Hope/Port Mouton acoustic survey results and SSB biomass estimates. Note the standard TS was corrected to account for the frequency of the echo sounder (120 kHz).

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	SE (t)	SE (%)
Little Hope									
Mapping	14-Sep	120					6,200		
Mapping	16-Sep	15					3,600		
Mapping	**18-Sep**	**75**					**6,400***		
Survey	**01-Oct**	**200**	**-41.480**	**0.2805**	**28.00**	**-35.96**	**56,109***	**31,512**	**56**
Overall							**62,500**	**31,512**	**56**

* Used to estimate total SSB for 2003

Table 14. Summary of the 2003 Eastern Passage acoustic survey results and SSB biomass estimates.

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	SE (t)	SE (%)
Eastern Shore									
Survey	18-Sep	79.0	-32.37	0.59	28	-35.96	52,472	13,413	35
Survey	14-Oct	1.8	-24.71	13.68	28	-35.96	23,979	5,064	21
Overall							**76,451**	**14,337**	**19**

Table 15. Summary of mapping surveys undertaken in the vicinity of Glace Bay. The estimates for Sept. 13 and Sept. 27 were pooled for the SSB. Total SSB is rounded to nearest 100t.

Location	Date	Area (m^2)	Mean Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)
Glace Bay								
Mapping	07-Sep	100					6,500	n/a
Mapping	**13-Sep**	**50**					**11,500***	n/a
Mapping	**27-Sep**	**250**					**20,000***	n/a
Overall							**31,500**	n/a

* Used to estimate total SSB for 2003

Table 16. Summary of the 2003 winter acoustic surveys conducted off Chebucto Head, N.S. on the night of January 20, 2003 (as reported previously in Melvin et al., 2003).

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)
Chebucto Head								
ME & Portable	Jan 20	0.36	-32.06	2.21	24.91	-35.5	794	-

Table 17. Summary of the estimated biomass for locations outside the Bay of Fundy/Southwest Nova Scotia quota area. All areas except the Scotian Shelf are for individual spawning grounds and are estimates of SSB rounded to the nearest 100t.

Location	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Little Hope/Port Mouton	14,100	15,800	5,200	21,300	56,000	62,500
Halifax/Eastern Shore	8,300	20,200	10,900	16,700	41,500	76,500
Glace Bay		2,000		21,200	7,700	31,500
Bras d'Or Lakes		530	70			

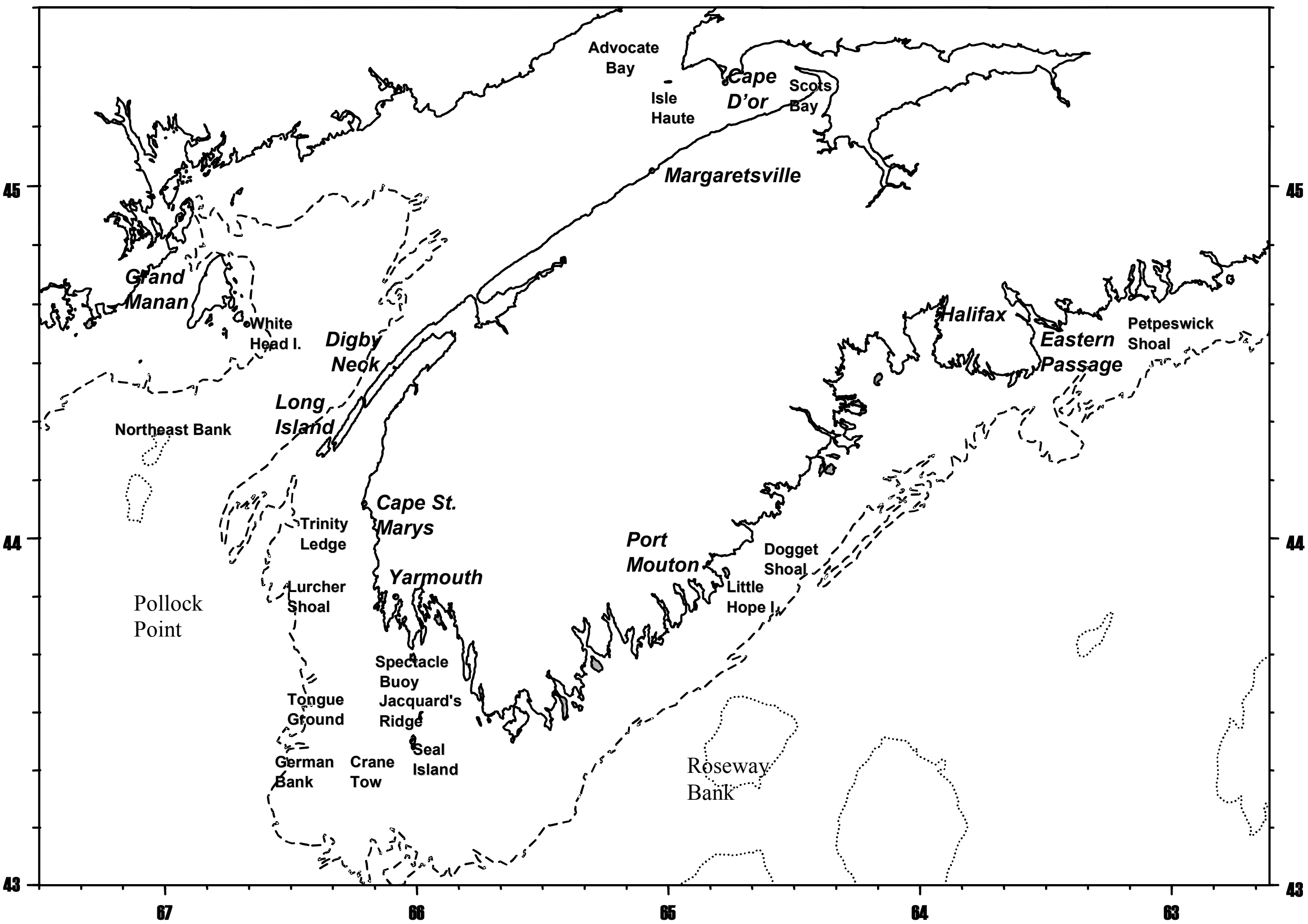


Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

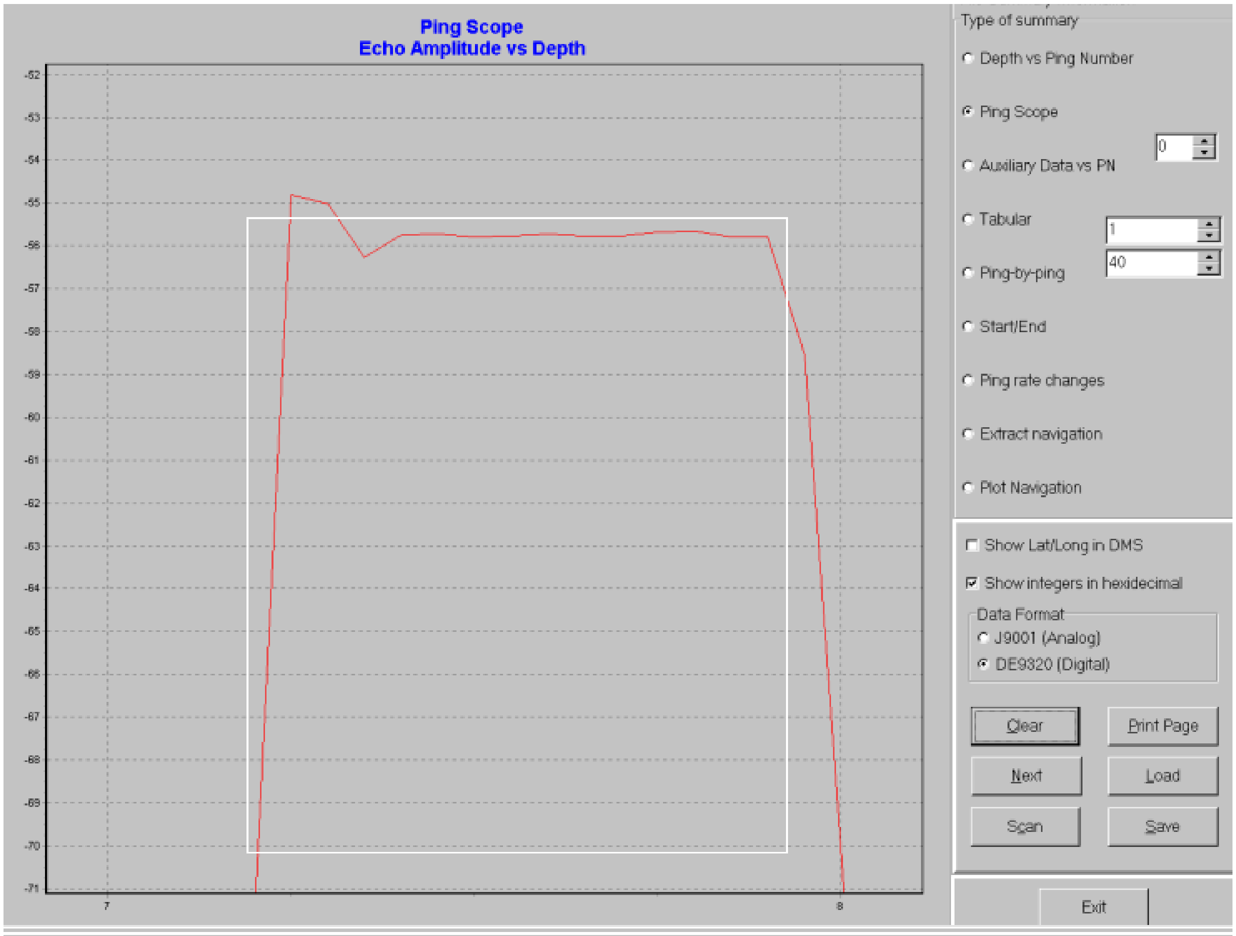


Figure 2. Illustration of an actual measured calibration ball verses an ideal wave form.

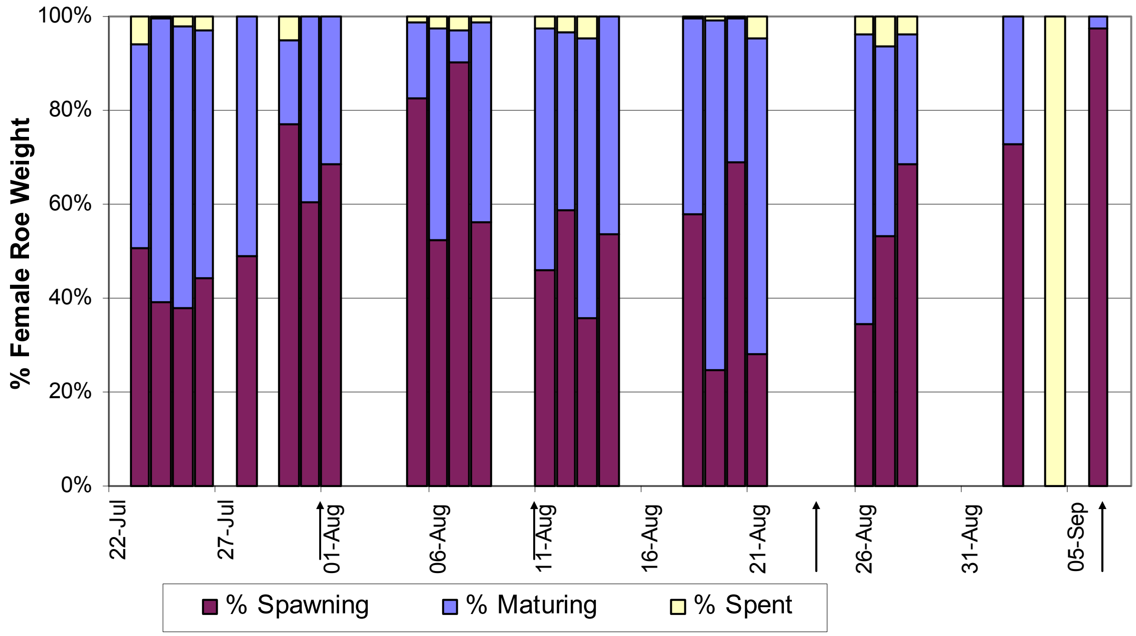


Figure 3. Daily herring female gonad maturity samples (% roe weight) for Scots Bay in 2003. Data combined by day from industry and SABS/DFO sources with arrows showing timing of major surveys. Arrows indicate dates of acoustic surveys.

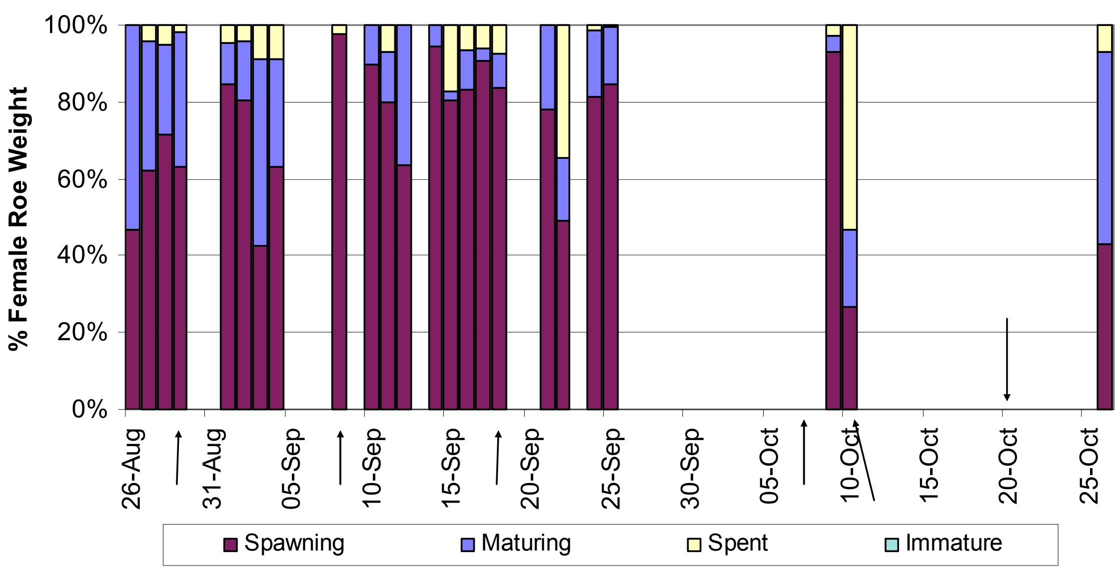


Figure 4. Daily herring female gonad maturity samples (% roe weight) for German Bank in 2003. Data combined by day from industry and SABS/DFO sources with arrows showing timing of major surveys. Arrows indicate dates of acoustic surveys.

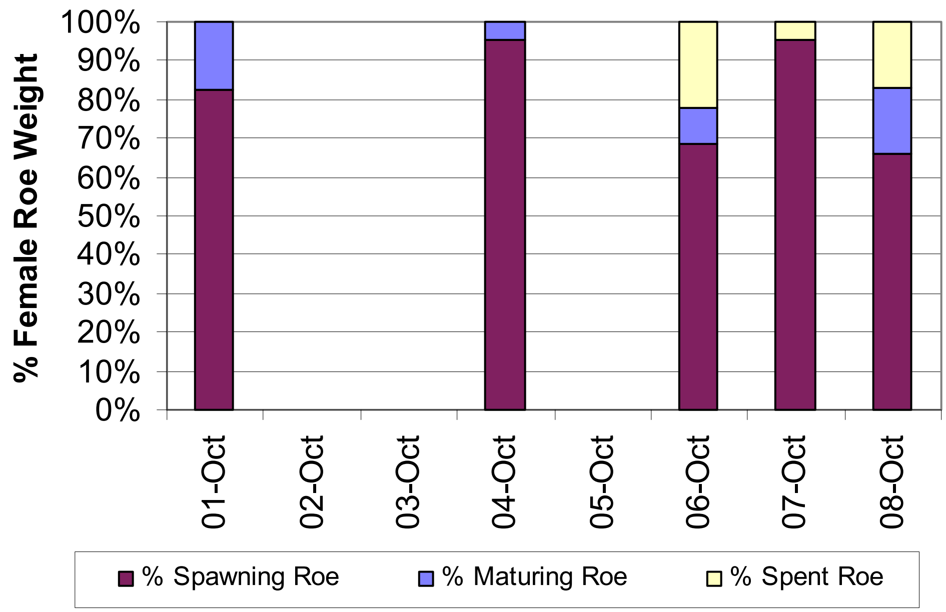


Figure 5. Daily herring female gonad maturity samples (% roe weight) for Little Hope/Port Mouton in 2003. Data combined by day from industry and SABS/DFO sources.

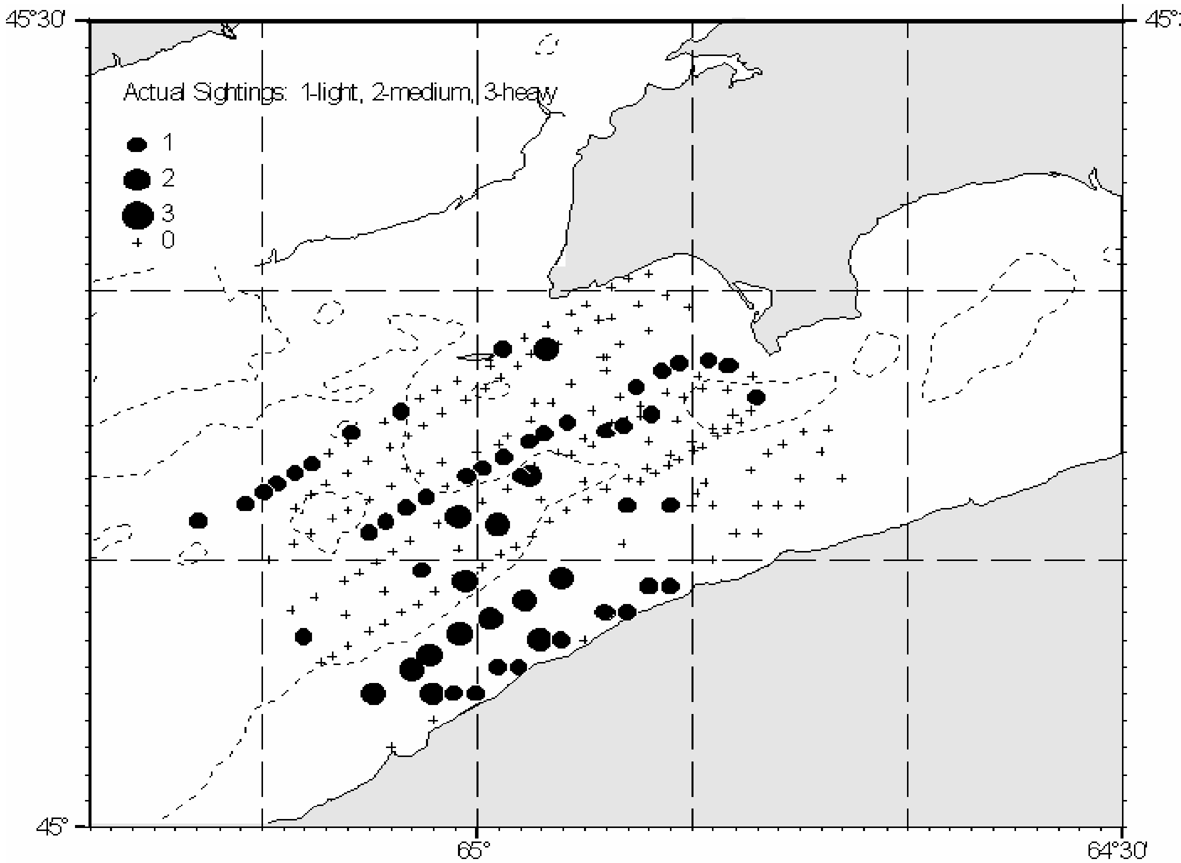


Figure 6. Summary of the Scots Bay July 31, 2003 spawning ground survey transects and the observed distribution of herring.

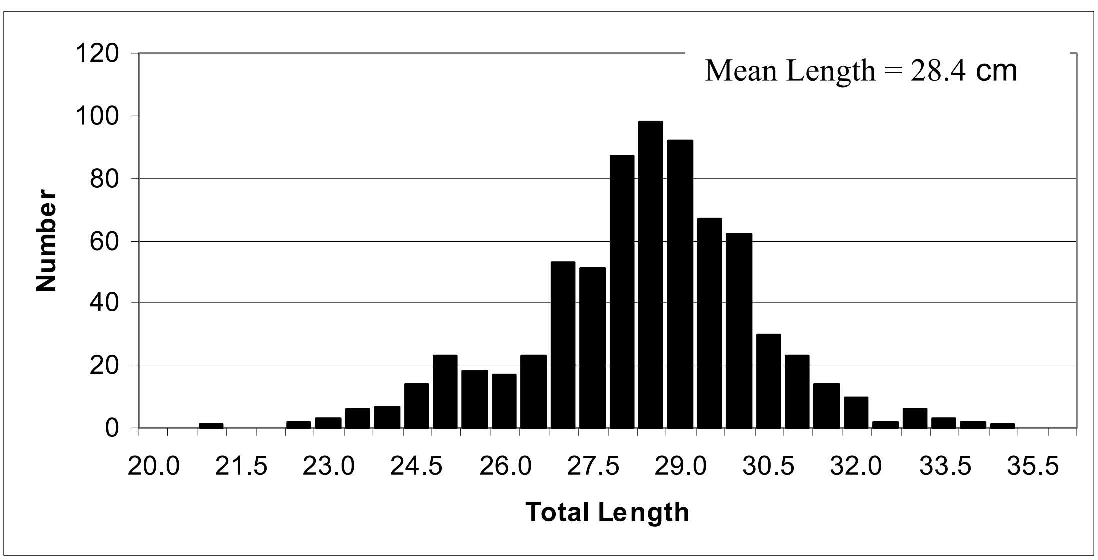


Figure 7. Length frequency of herring samples collected in Scots Bay on the nights of July 31, 2003.

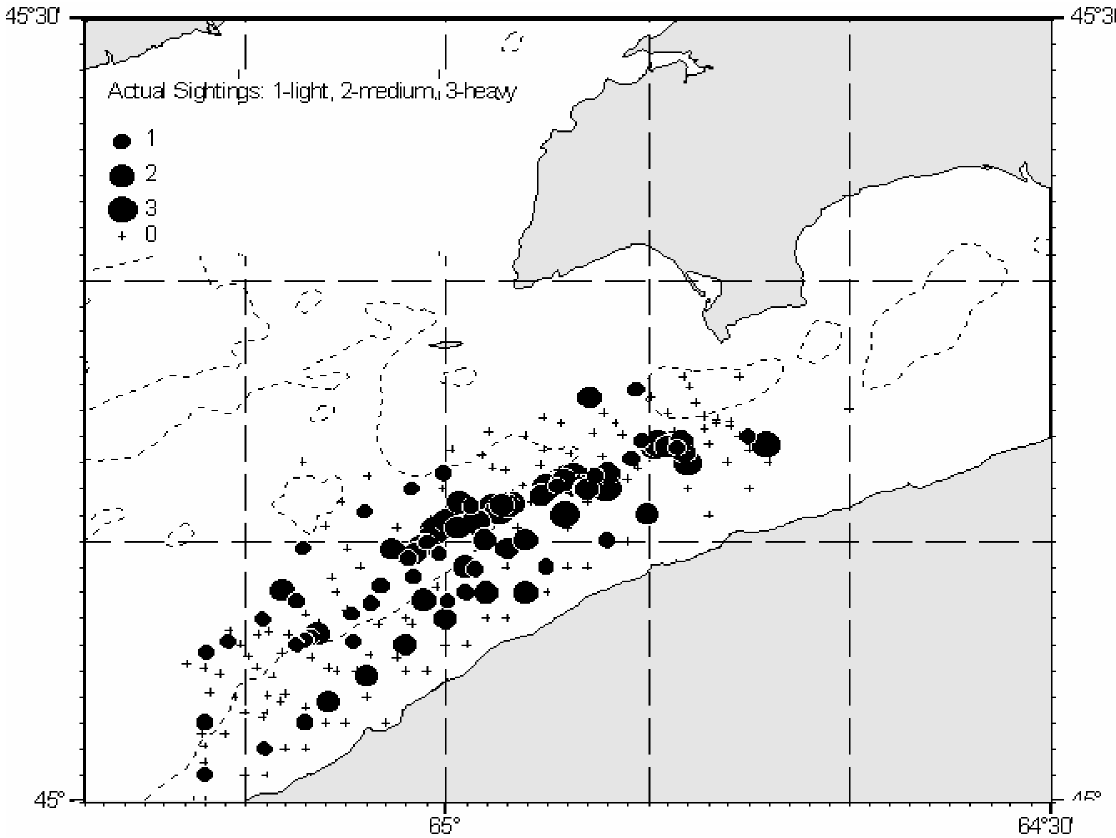


Figure 8. Summary of the Scots Bay August 10, 2003 spawning ground survey transects and the observed distribution of herring. Data for both recording and non-recording vessels are presented.

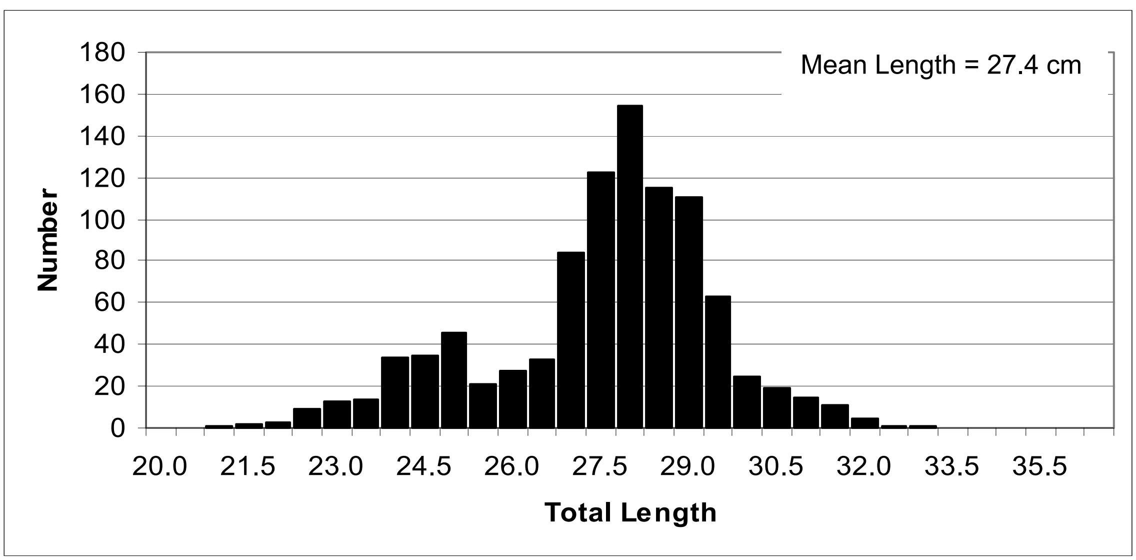


Figure 9. Length frequency of herring samples collected in Scots Bay on the nights of August 10/11, 2003.

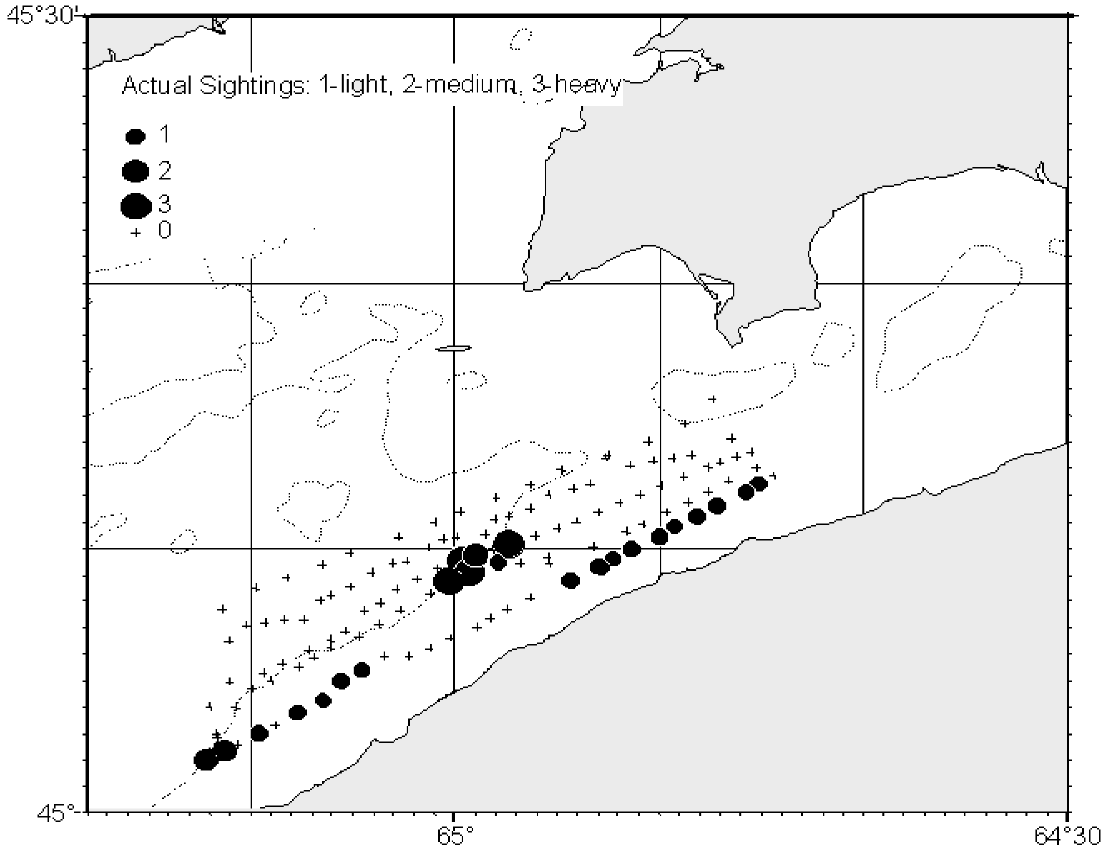


Figure 10. Summary of the Scots Bay August 24, 2003 spawning ground survey transects and the observed distribution of herring. Data for both recording and non-recording vessels are presented.

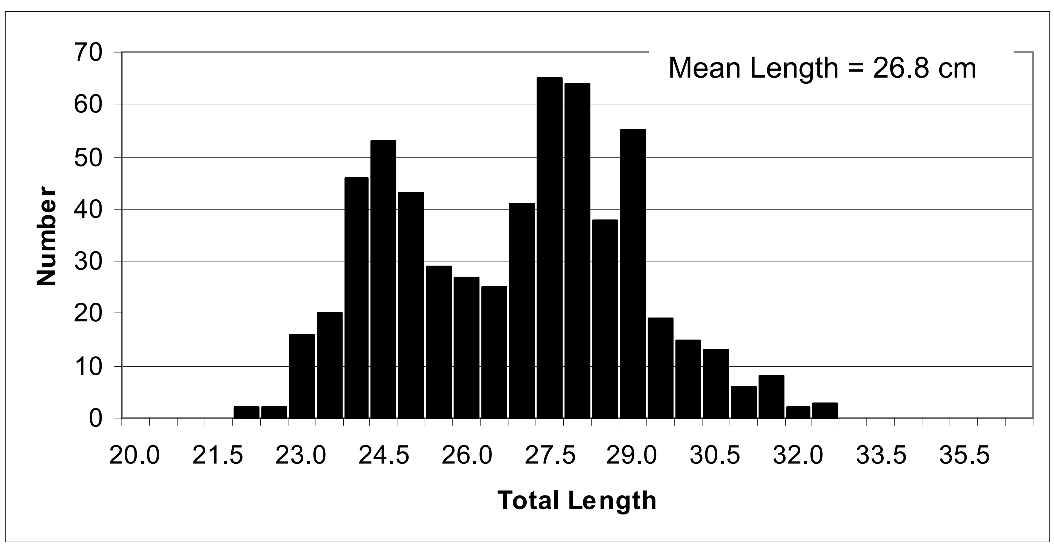


Figure 11. Length frequency of herring samples collected in Scots Bay on the nights of August 24/25, 2003.

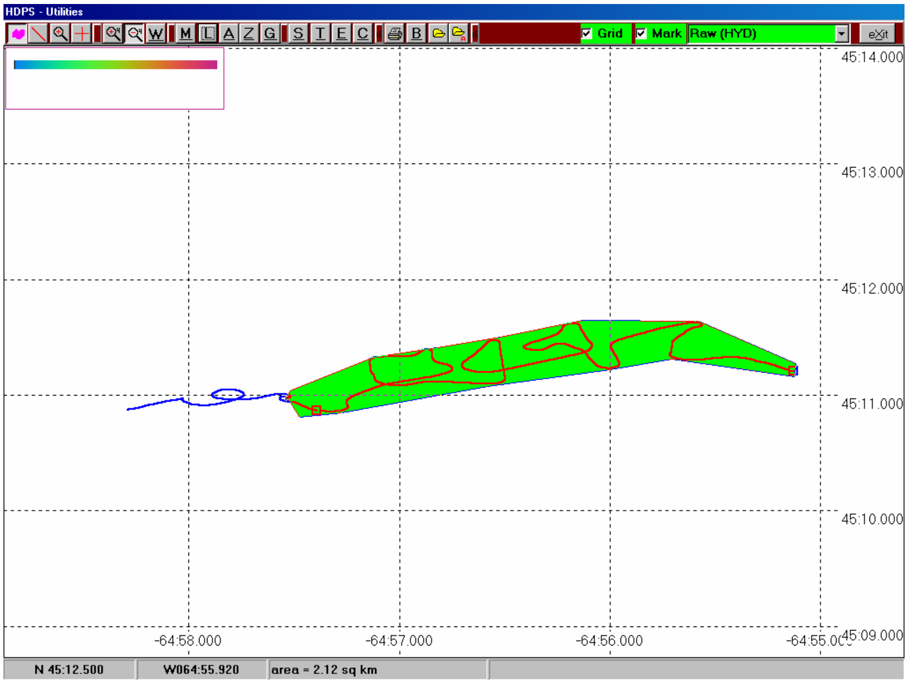


Figure 12. Summary of the vessel track in Scots Bay on the fishing night of September 6, 2003. Although two schools of fish were documented only one is shown here.

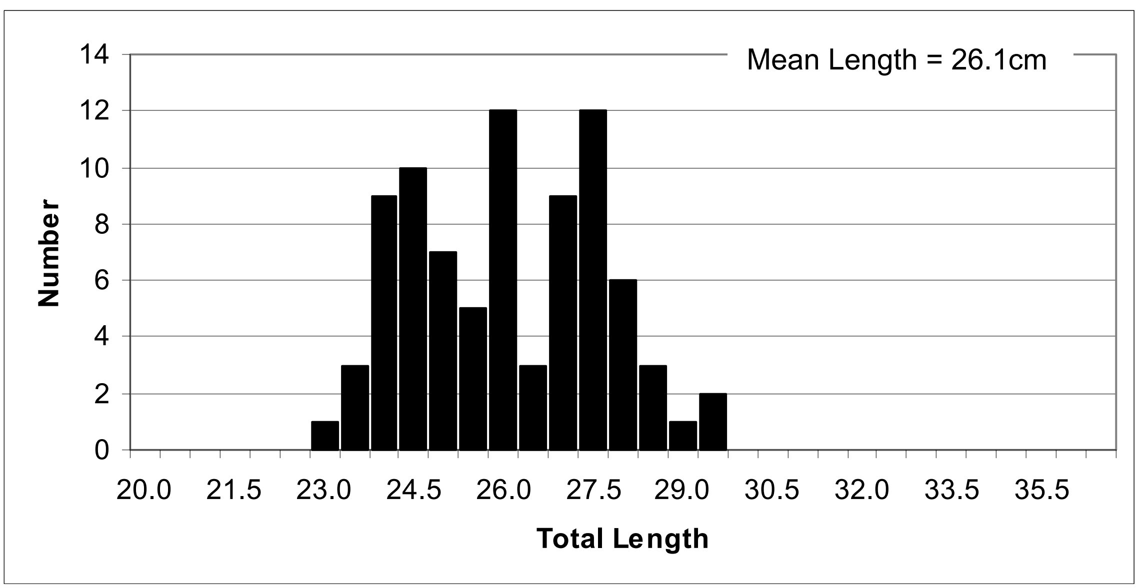


Figure 13. Length frequency of herring samples collected in Scots Bay on the nights of September 6, 2003.

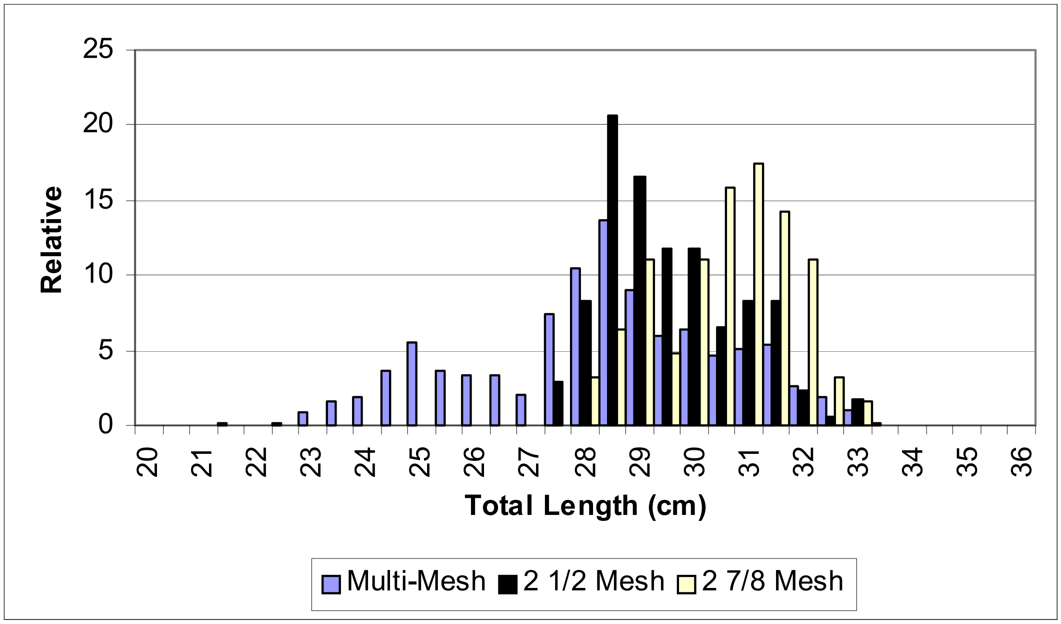


Figure 14. Length frequency distribution of herring collected on Trinity Ledge August 24, 2003 from a multi-mesh gillnet (1½", 2", 2½" and 2-7/8" mesh panel sizes) compared with 2½" and 2-7/8" mesh nets from the same sample.

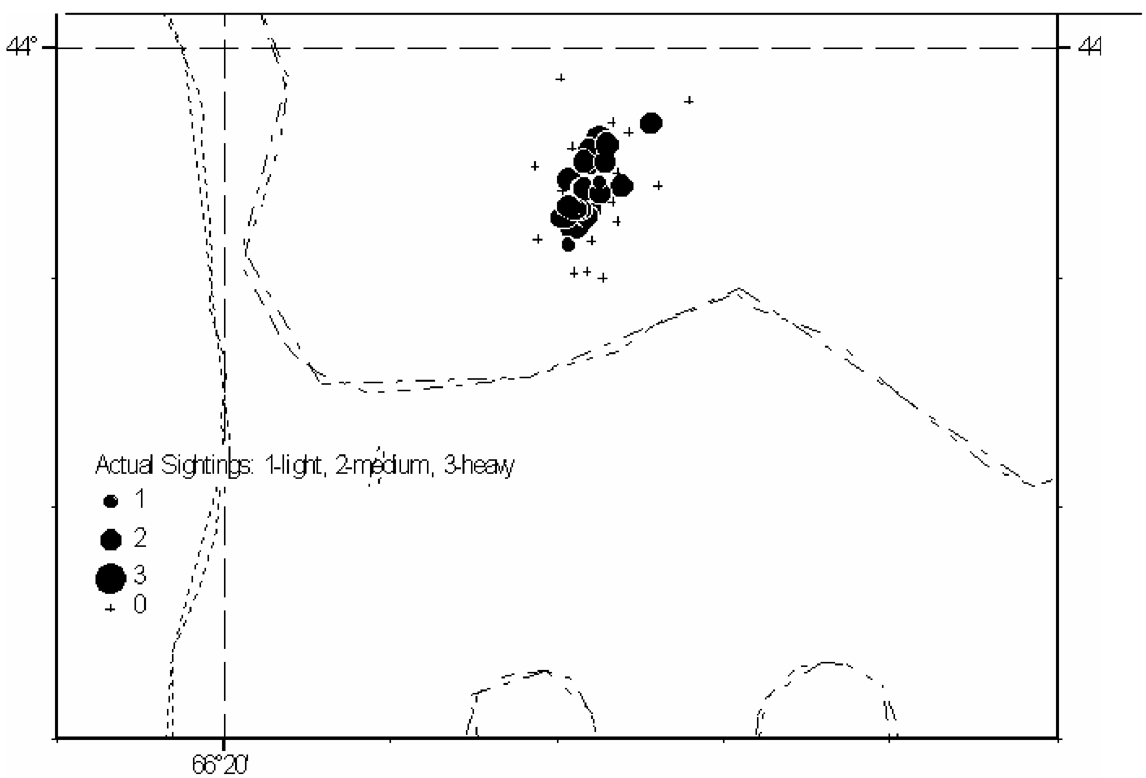


Figure 15. Summary of the Trinity Ledge August 21, 2003 spawning ground survey and the observed distribution of herring. Data for both recording and non-recording vessels are presented. Total coverage area is approximately 1 km^2.

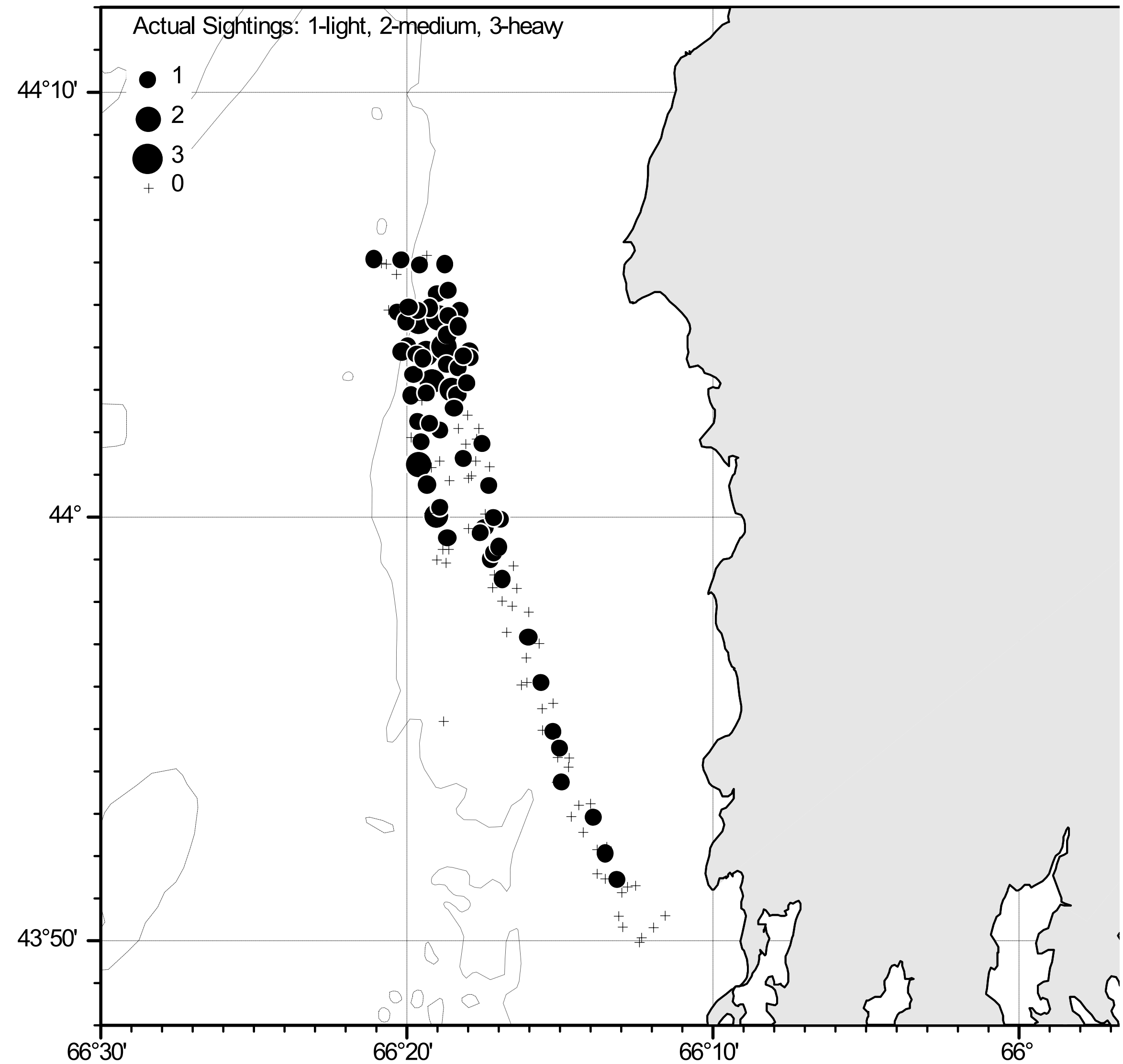


Figure 16. Summary of the Trinity Ledge September 2, 2003 spawning ground survey and the observed distribution of herring. Data for both recording and non-recording vessels are presented. Total coverage area is approximately 18 km^2.

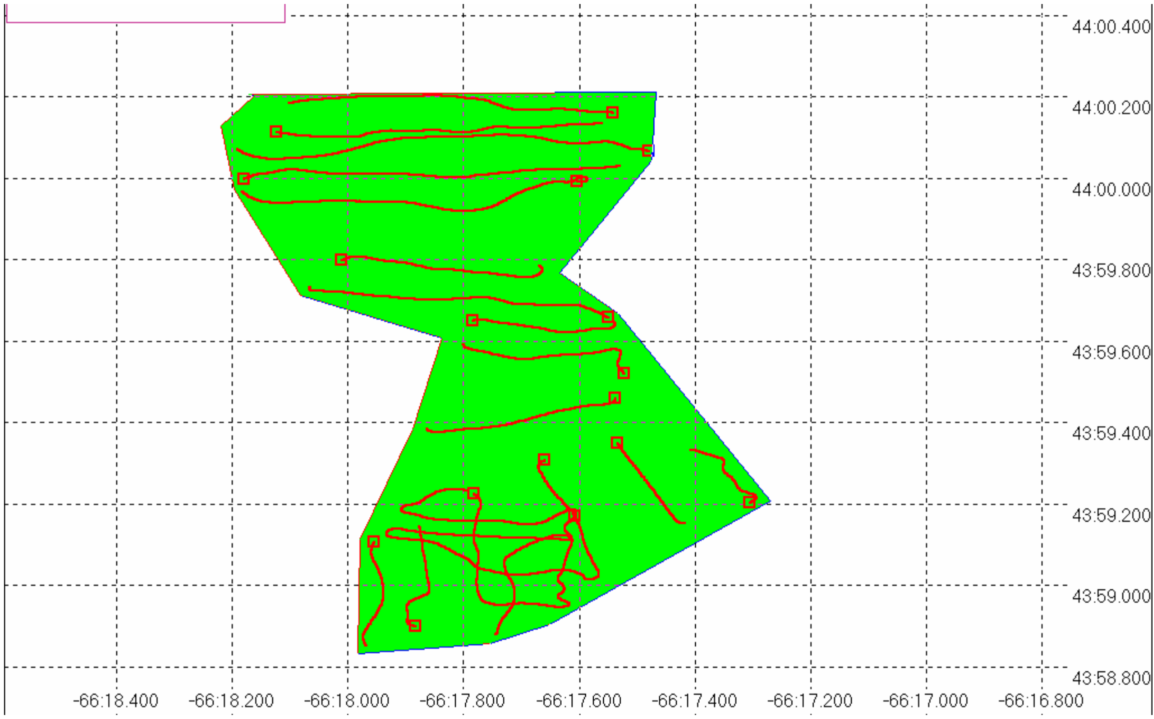


Figure 17. Summary of the September 14, 2003 fishing coverage on Trinity Ledge spawning ground and the observed distribution of herring. Data presented are from the recording vessel as no other vessels participated in the survey. Total coverage area is approximately 1.9 km^2.

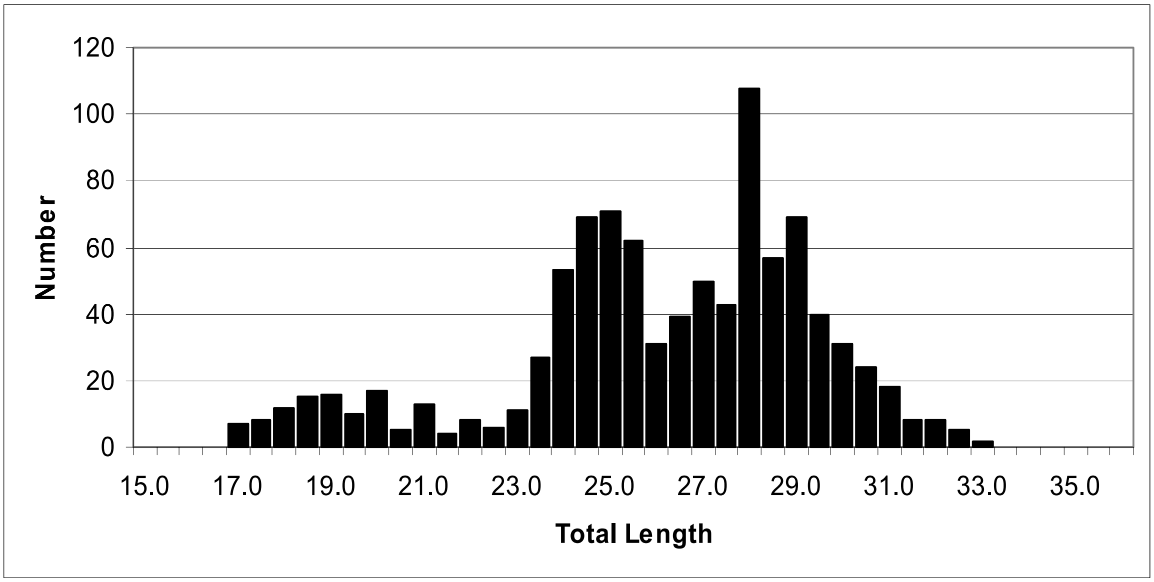


Figure 18. Length frequency of herring samples collected from German Bank on the nights of August 29, 2003. Mean Length = 26.1 cm.

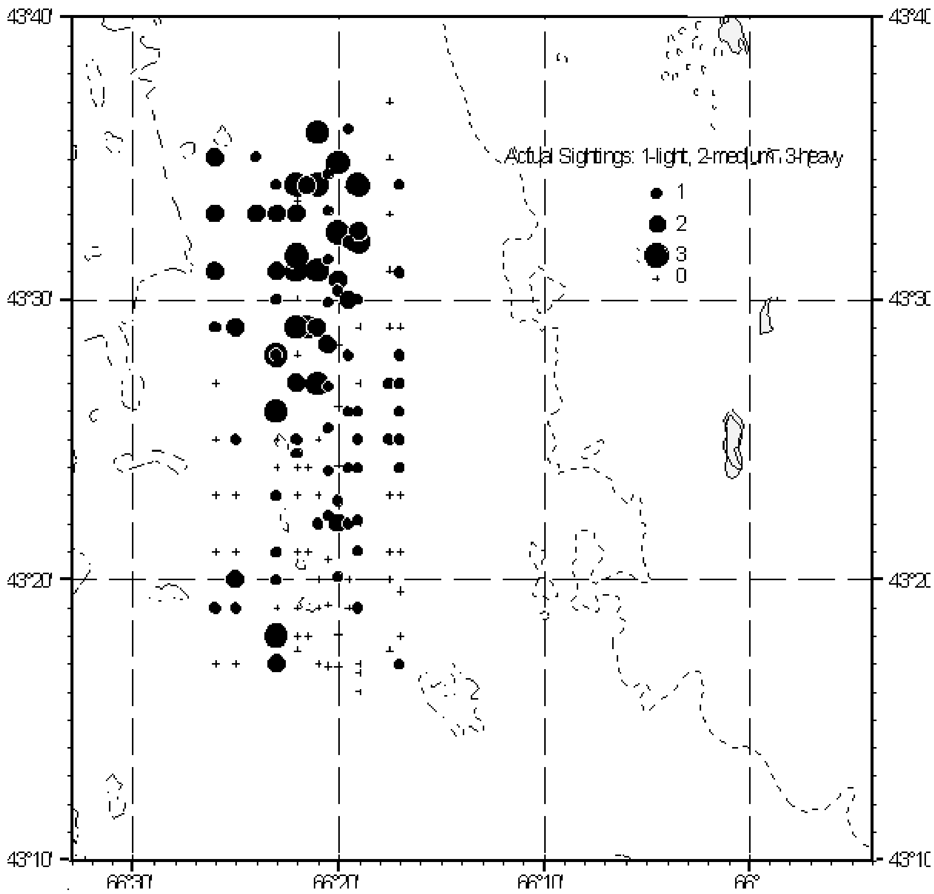


Figure 19. Distribution of herring during the August 29, 2003 survey of the German Bank spawning grounds. Area surveyed was 490 km^2 on German Bank.

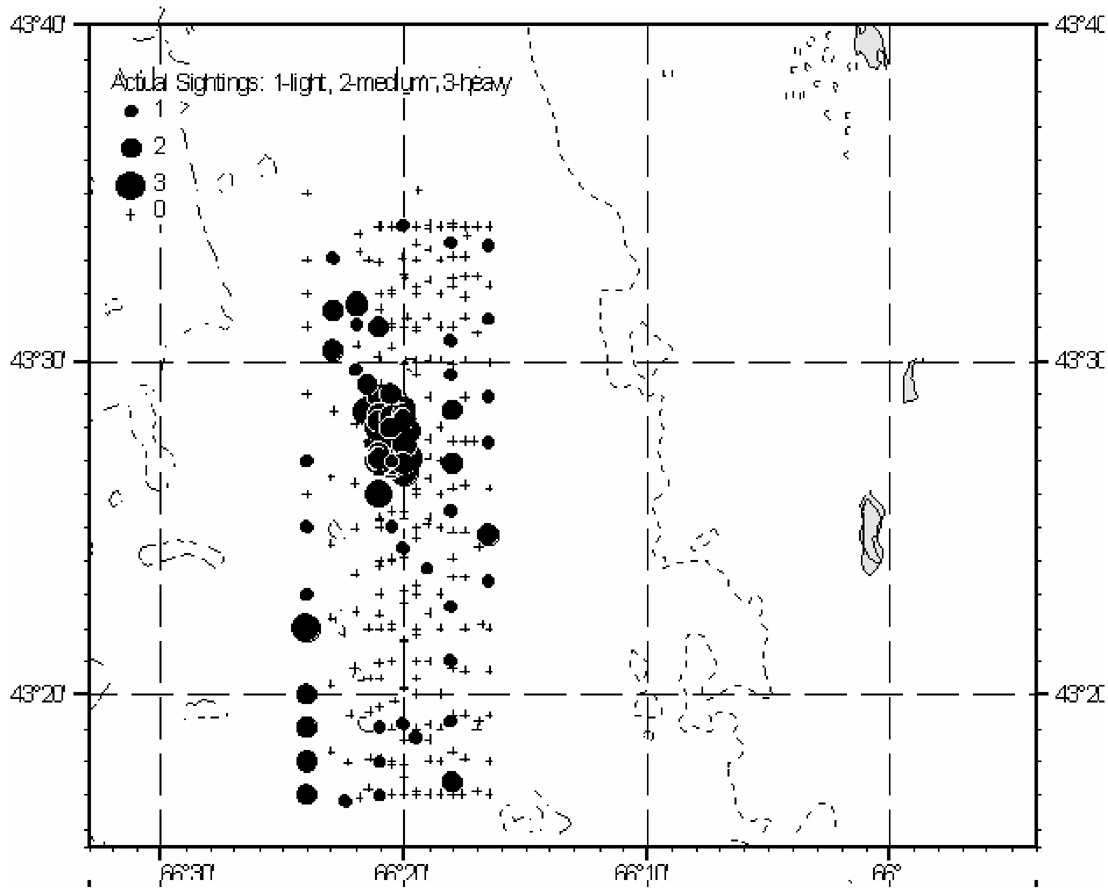


Figure 20. Distribution of herring during the September 8, 2003 survey of the German Bank spawning grounds. Area surveyed was 365 km^2.

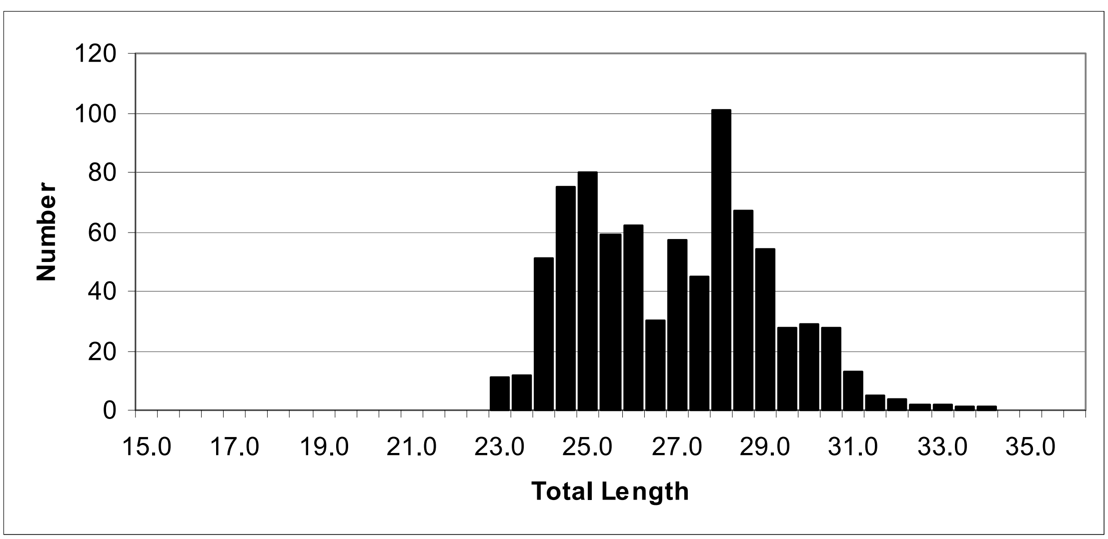


Figure 21. Length frequency distribution of herring sampled from purse seine catches on German Bank on September 8, 2003.

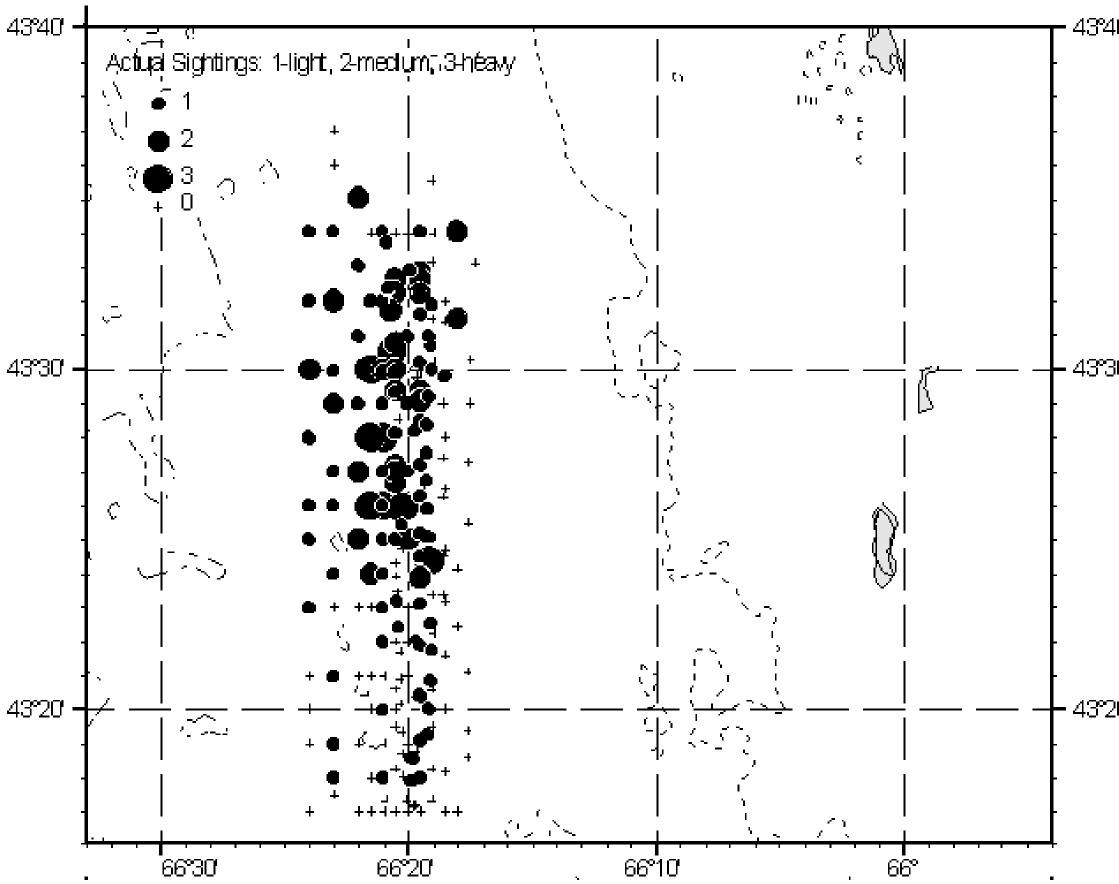


Figure 22. Distribution of herring during the September 18, 2003 survey of the German Bank. The survey area was 300 km^2.

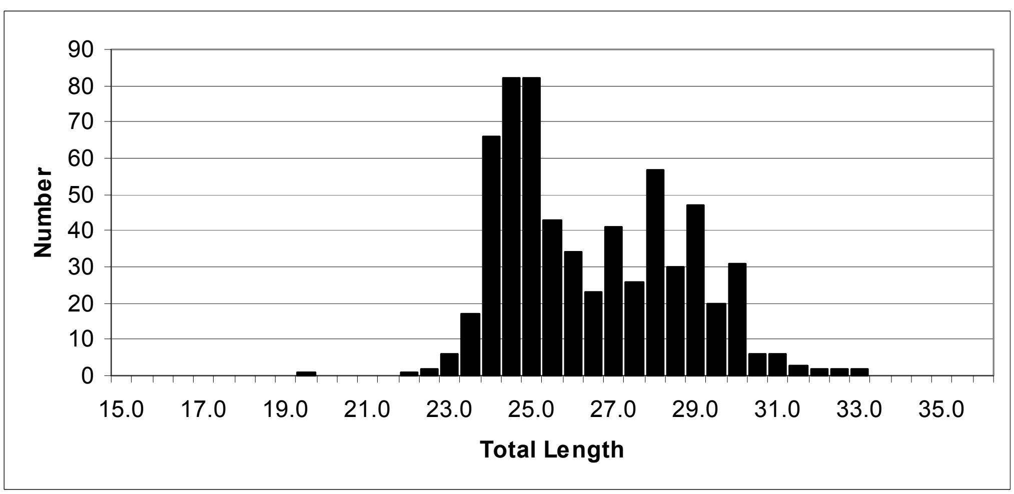


Figure 23. Length frequency distribution of herring sampled from purse seine catches on German Bank on September 18, 2003. Mean length equals 26.5 cm.

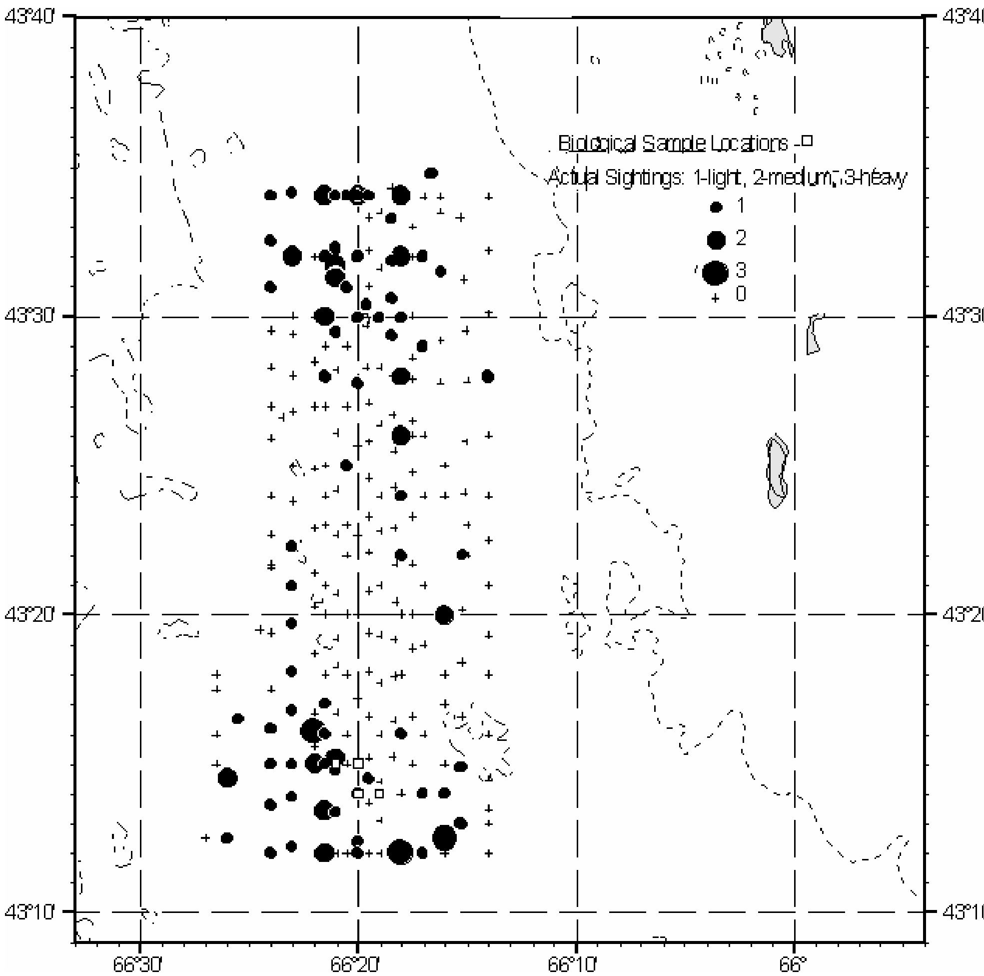


Figure 24. Distribution of herring during the October 10, 2003 survey of German Bank. The survey area was 710 km^2.

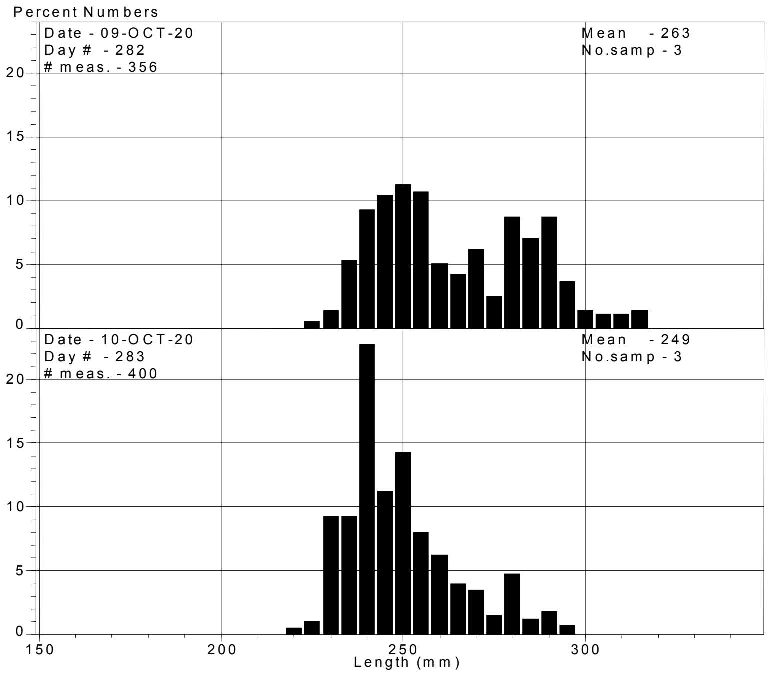


Figure 25. Herring size distribution for purse seine samples collected from German Bank landings for Oct. 9 (top panel) and Oct.10, 2003 (bottom panel).

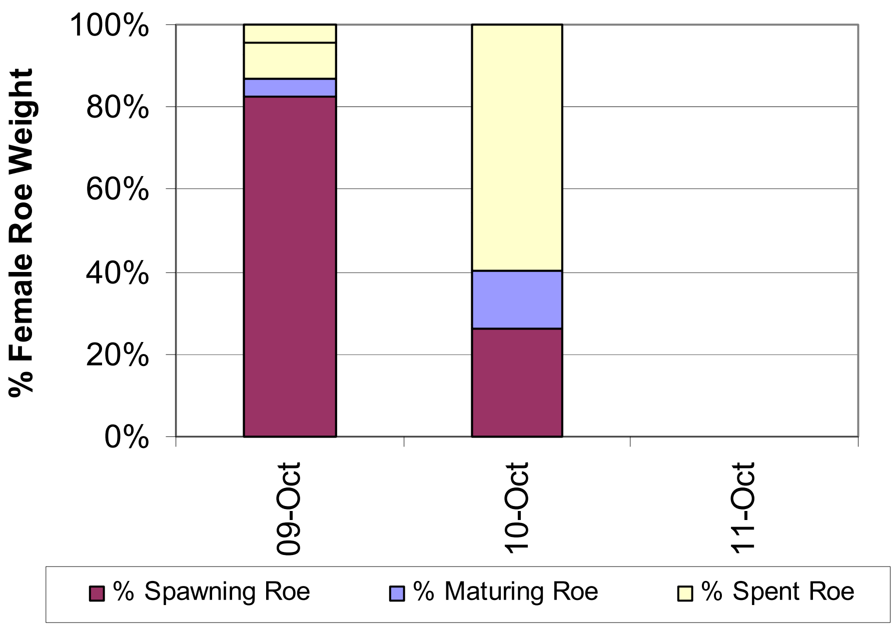


Figure 26. Herring female gonad proportions by development stage for samples collected from German Bank landings for Oct. 9-10, 2003.

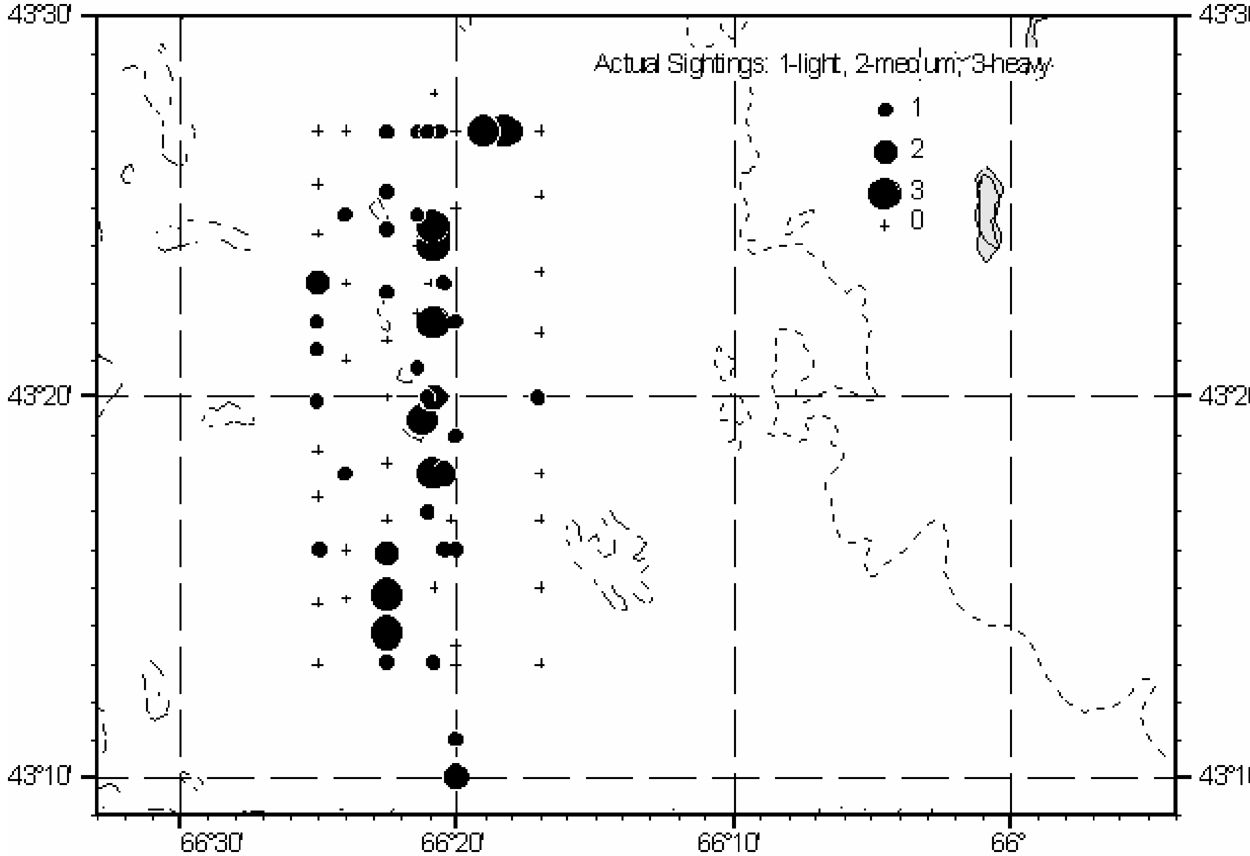


Figure 27. Distribution of herring during the October 20, 2003 German Bank spawning ground survey. Total area surveyed was 260 km^2.

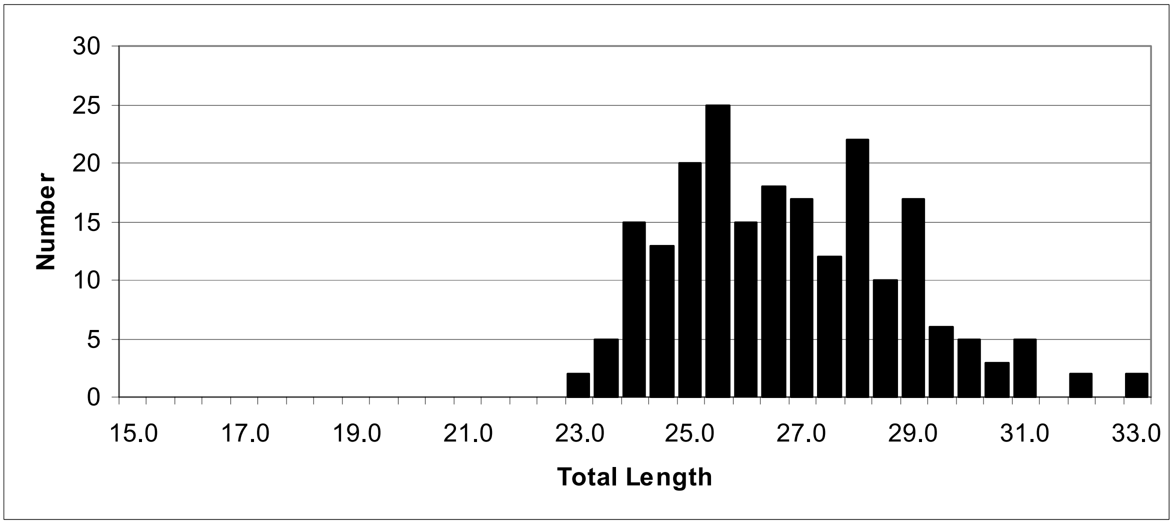


Figure 28. Length frequency distribution of herring sampled from purse seine catches from German Bank on October 26, 2003. The mean length of fish was 26.8 cm.

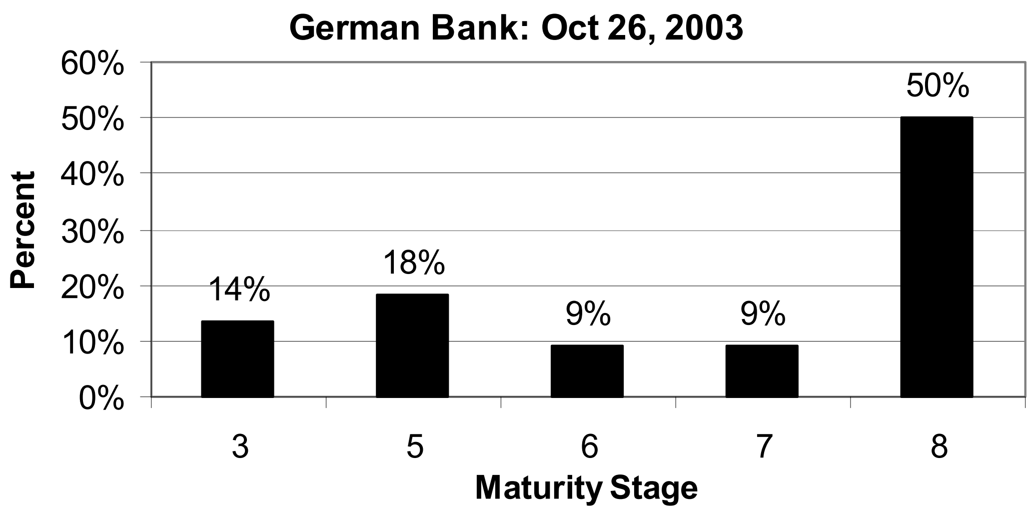


Figure 29. Maturity stage distribution (% number) of herring sampled from German Bank on October 26, 2003.

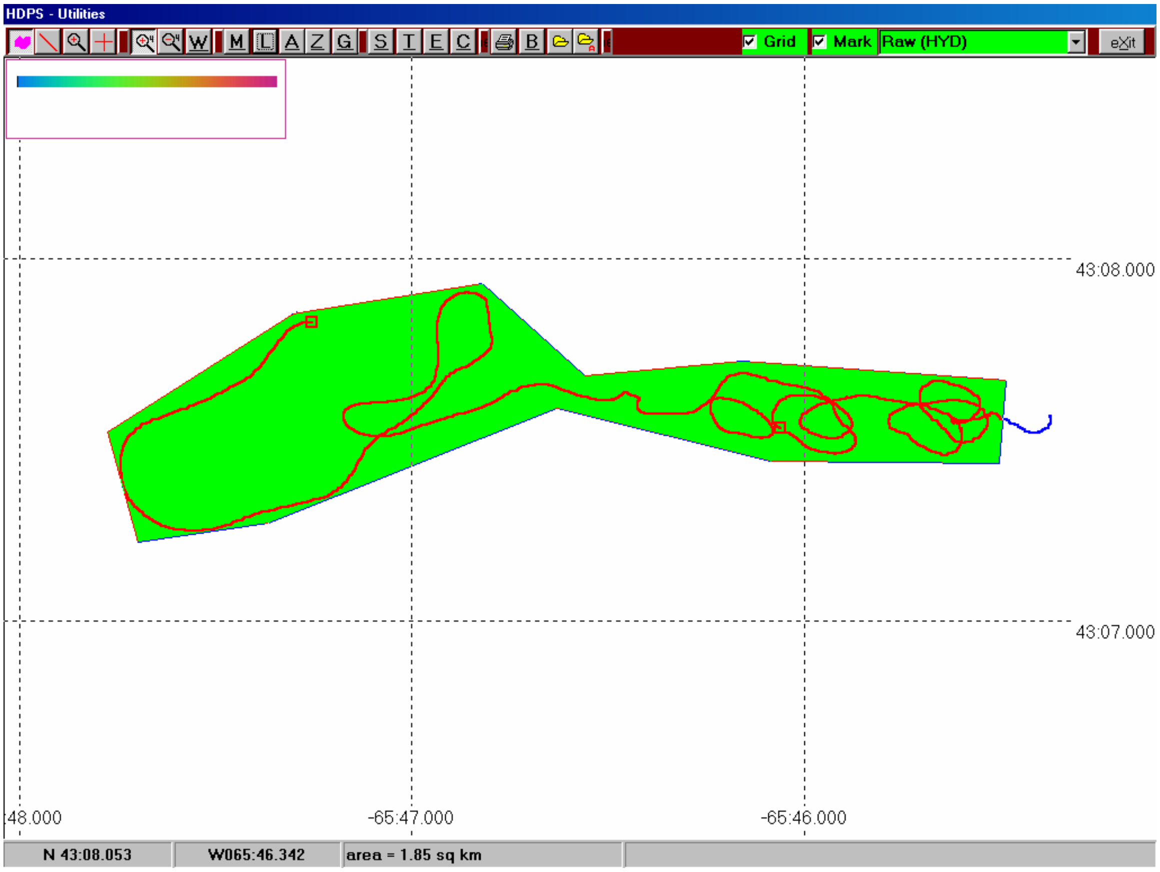


Figure 30. Vessel track of the *Island Pride* near Seal Island on the fishing night of September 15, 2003. Total area covered was 1.85 km^2.

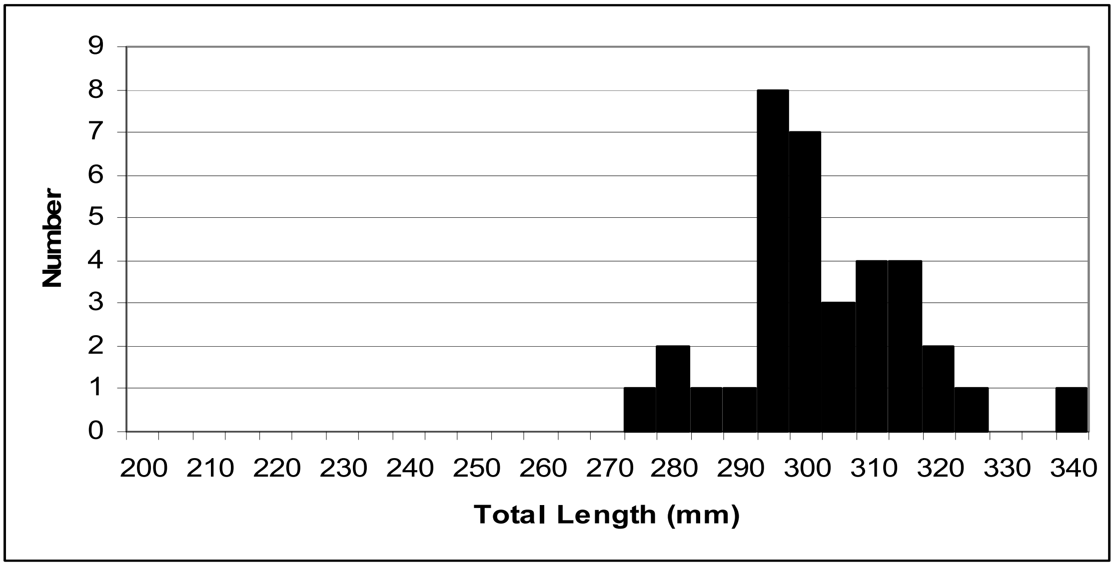


Figure 31. Length frequency of herring samples collected from a gillnet fishery sample near Spectacle Buoy on June 5, 2003. The mean length was 30.3 cm.

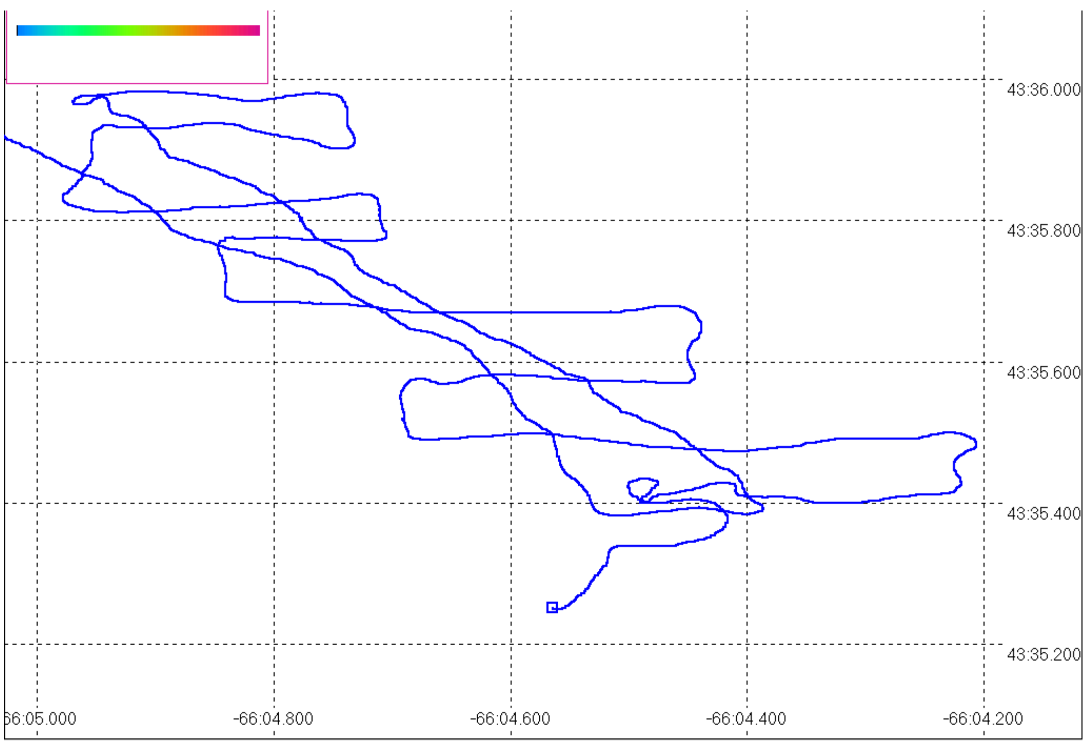


Figure 32. Summary of the June 2, 2003 vessel track in the vicinity of Spectacle Buoy spawning ground. Data presented are from the fishing vessel "Attaboy" . Total coverage area is approximately 0.5 km^2.

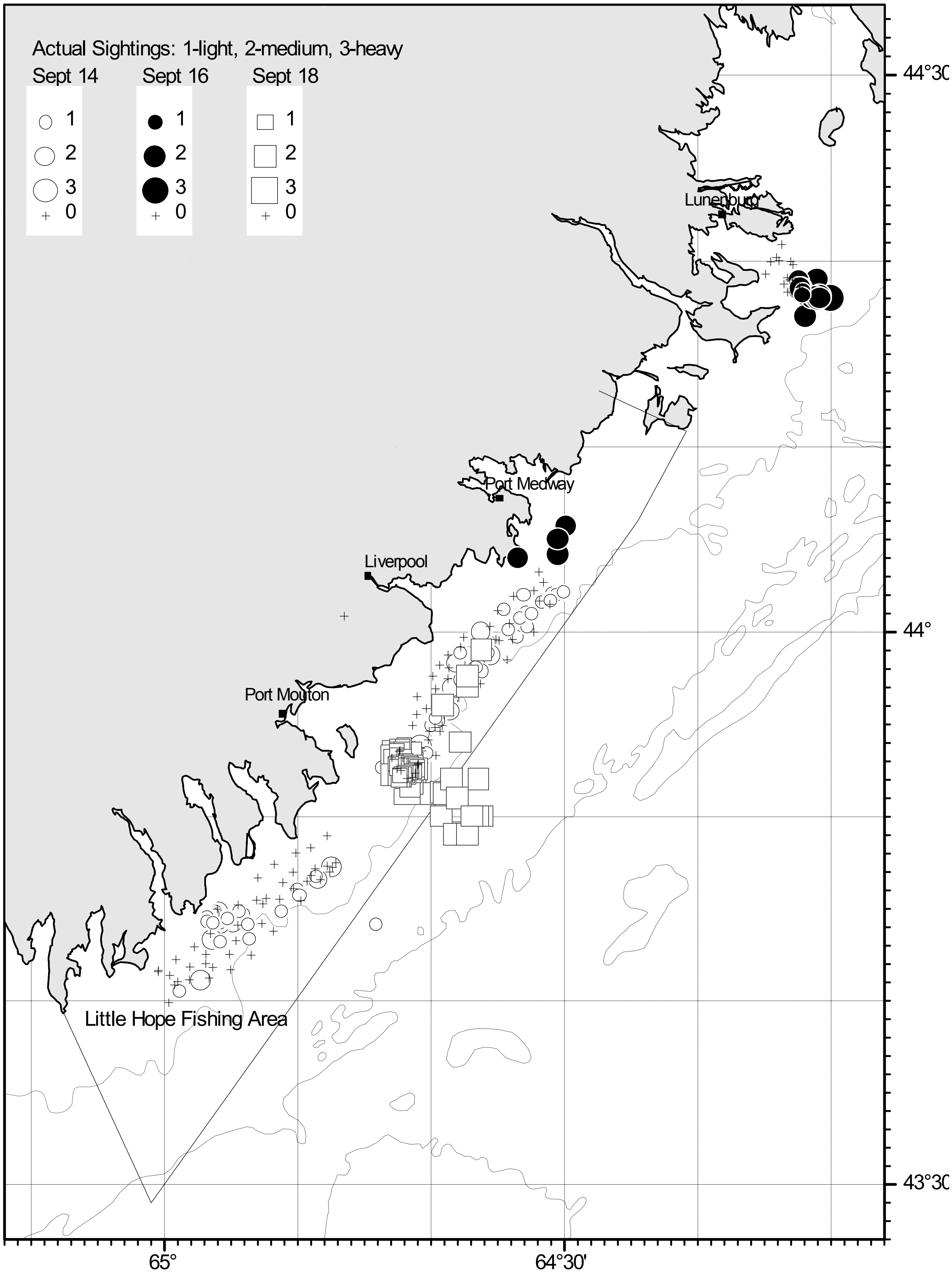


Figure 33. Survey coverage and the distribution of herring during the September 14, 16 and 18, 2003 surveys of the Little Hope/Port Mouton spawning grounds.

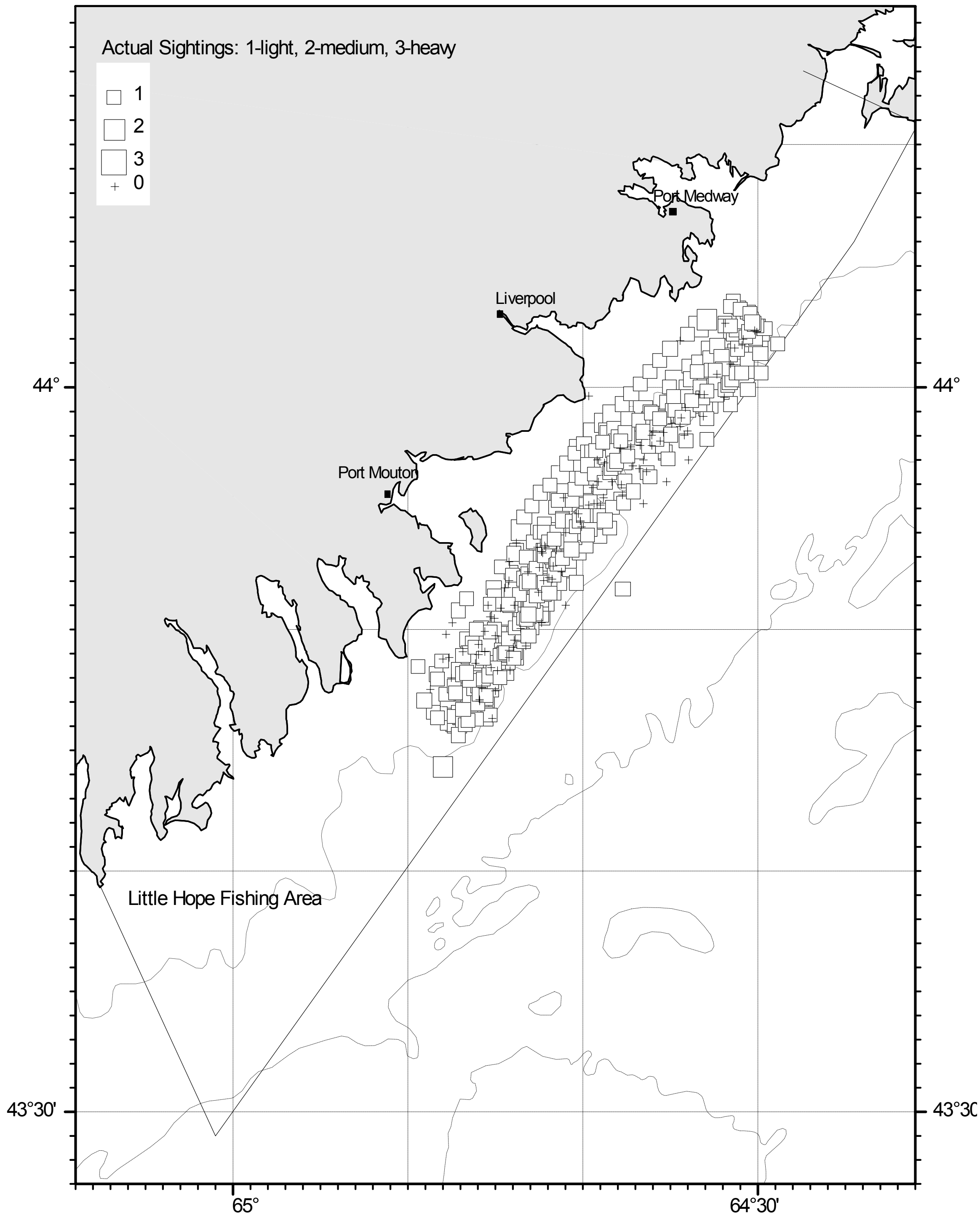


Figure 34. Survey coverage and the distribution of herring during the October 1, 2003 survey of the Little Hope/Port Mouton spawning grounds.

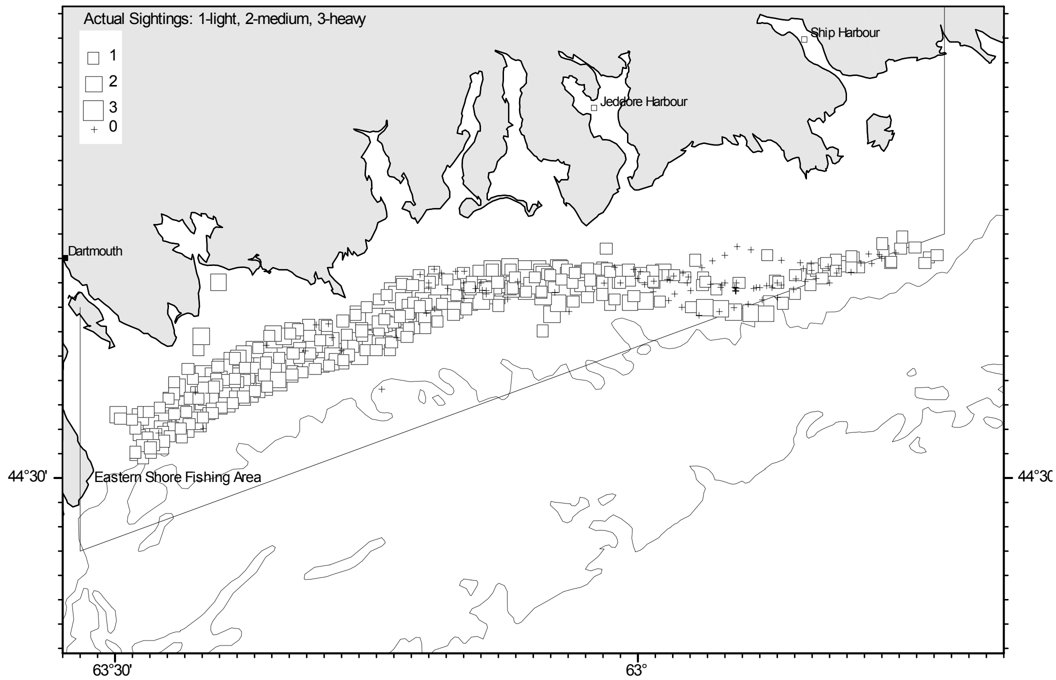


Figure 35. Survey coverage and the distribution of herring during the September 18, 2003 survey of the Eastern Passage spawning area.

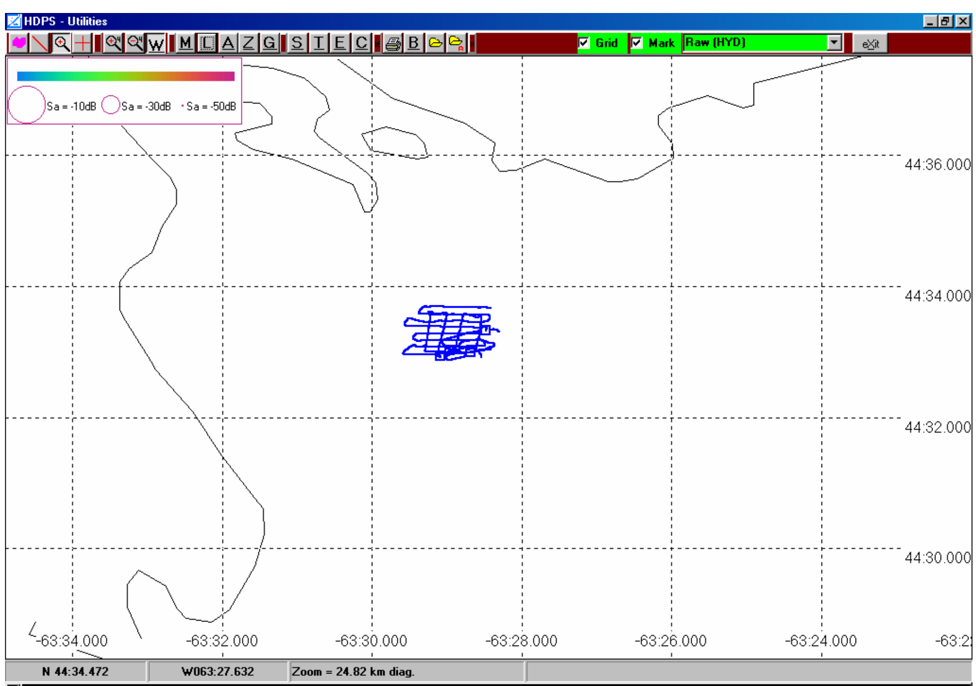


Figure 36. Survey coverage during the October 14, 2003 survey of the Eastern Passage spawning grounds.

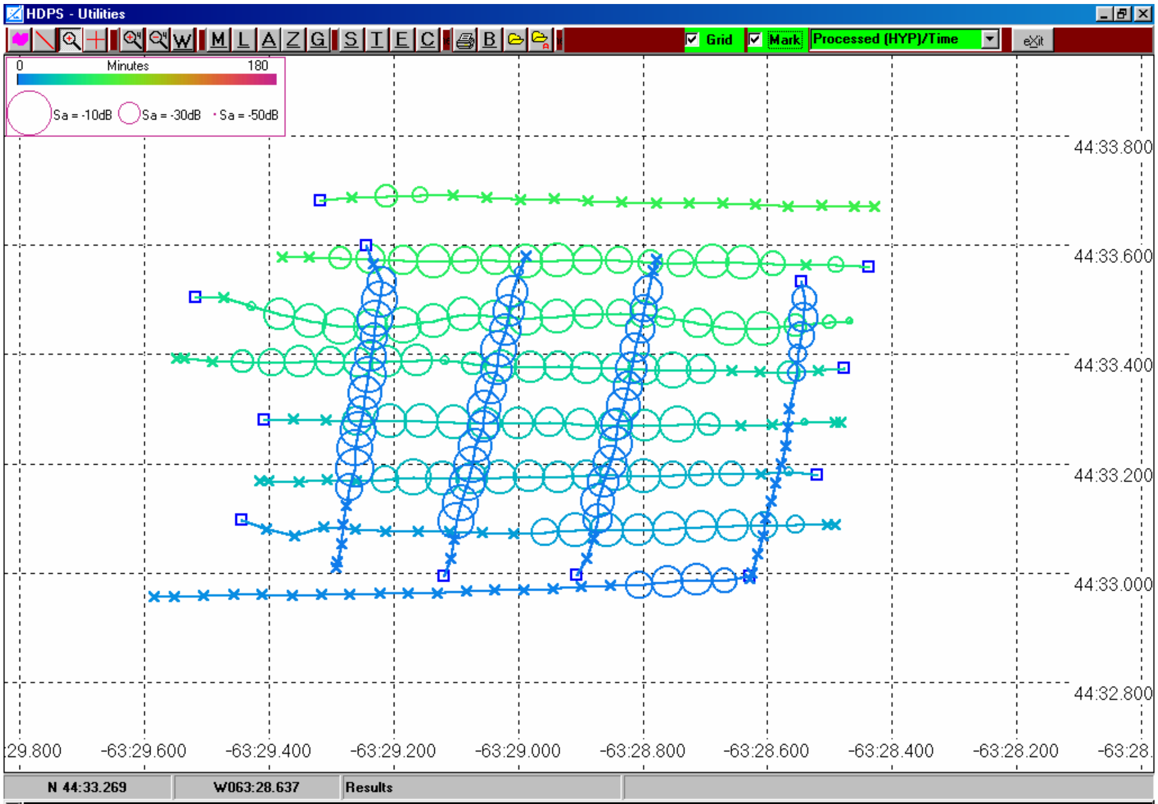


Figure 37. Eastern Passage (October 14, 2003) survey lines with fish locations and density shown as expanding circles.

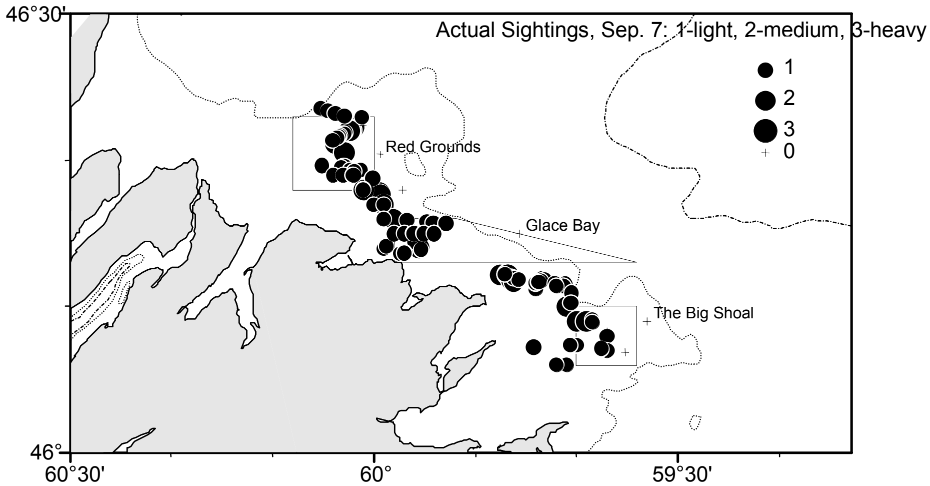


Figure 38. Survey coverage during the September 7, 2003 survey of the Glace Bay area spawning grounds.

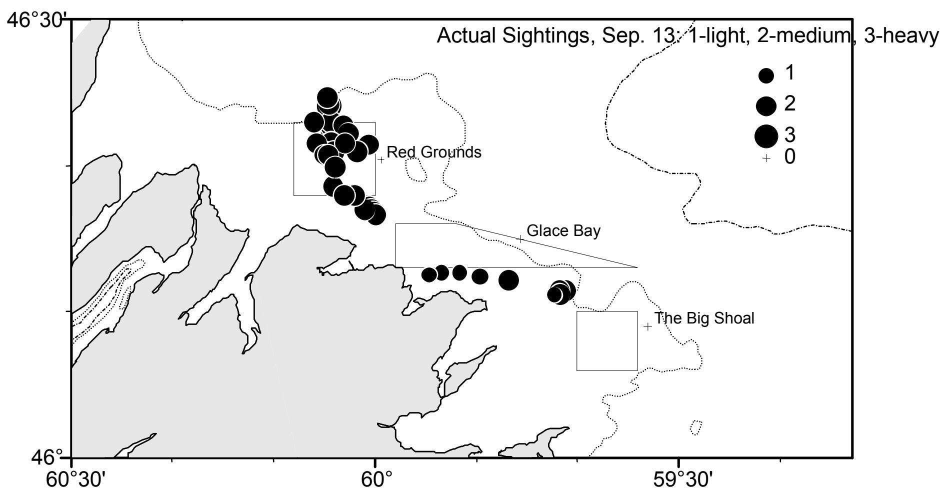


Figure 39. Survey coverage during the September 13, 2003 survey of the Glace Bay area spawning grounds.

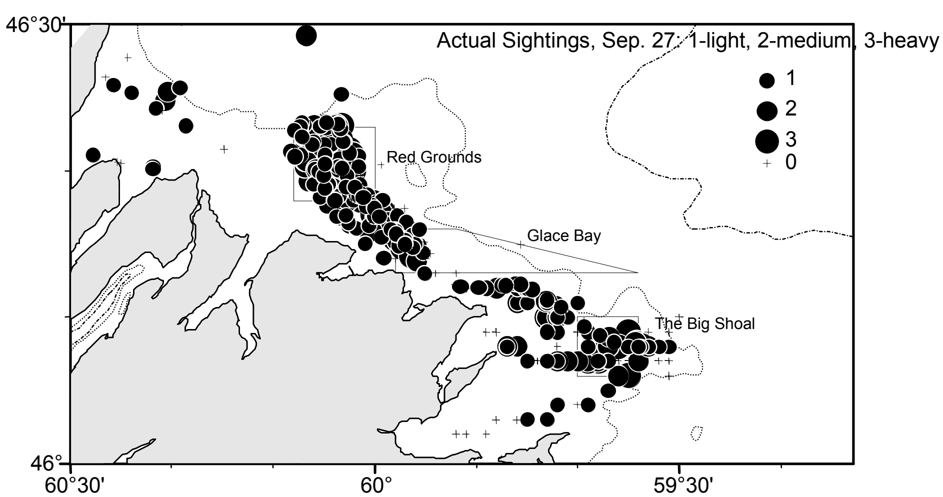


Figure 40. Survey coverage during the September 27, 2003 survey of the Glace Bay area spawning grounds.

Acoustic Survey Protocols and Analytical Procedures:

Introduction:

The following provides a general description of the types of surveys, survey protocol and the analytical procedure used to estimate biomass from the acoustic data collected by scientific and commercial fishing vessels. Prior to 1999, surveys were undertaken on an *ad hoc* basis and usually at the request of the fishing industry. This resulted in some uncertainty as to the turnover time between spawning waves and the potential for double counting of fish. In 1998 a procedure was established to estimate the percent of herring remaining on the spawning ground between surveys when the time between surveys was less than 10 days (Melvin et. al., 1999). To avoid potential problems associated with an elapsed time of less than 10 days between surveys, a survey schedule was established for the main spawning area at approximately two-week intervals during the spawning season since 1999. Additional research has also been undertaken to investigate turnover time on German Bank (Power et al., 2002)

Surveys:

Surveys undertaken by the fishing industry fall into two broad categories – mapping surveys which do not involve quantitative acoustic data, and quantitative surveys which depend heavily on acoustic data to estimate biomass. Most scheduled surveys involve a combination of both types.

Mapping Surveys:

In recent years, surveys that relied solely on the mapping approach, used in the early years of industry based surveying, were few. Most surveys included a combination of both mapping and acoustic data collection. Mapping data (log sheets) were collected on each survey by all vessels participating in the survey to establish the outer bounds and distribution of herring in the survey area. Biomass estimates were also made from the mapping type data to provide a quick approximation of fish numbers and to use as input for the “survey, assess, then fish” protocol. The procedure involved recording information on fish abundance and distribution observed from the sounders and sonars of vessels without acoustic recording systems. Survey protocol required that parallel transects were run with vessel spacing varying from 1/8 mile to ½ mile, depending on the availability of sonar, to ensure that no large schools were missed. Observations were recorded at every 5 to 10 minutes on standardized data sheets. The observations were later categorized into the 3 density values (light, medium or heavy) and biomass estimated using the area and a relative density category (Table 1A) (Melvin *et. al*, 2000; Stephenson *et. al*, 1998). In most of the surveys for the current year at least one automated acoustic system was available to collect quantitative data.

Mapping data were contoured and plotted using the ACON Data Visualization package and the triangular contour method (Black, 2000). Blanking distance was set to the maximum distance between valid data recordings and varied between 1 and 3 miles depending on the survey. Interpolation between data points was undertaken using the inverse distance weighting gradient approach to compute the density at any given point. Once the area of the three contour levels was estimated, the areas (km^2) were multiplied by the appropriate fish density in accordance with the previously defined scale and summed to get the total biomass within the survey coverage area. However, final biomass estimates were based on acoustic density estimates whenever available.

Quantitative Surveys:

Industry based structured surveys were used throughout the current spawning season to document the distribution and abundance of herring on individual spawning grounds. Standard operating procedure for surveying involved the presence of DFO scientific staff onboard one or more of the vessels to direct the activities, assign transects, determine coverage (with fishing captains), sample fish and download/collect the data upon completion of the survey. Most of the data is now downloaded by an industry (Herring Science Council) technician. Typically, a series of randomly selected transects were provided to the participating vessels for the area of interest and a two-phase survey design (i.e. search then survey) implemented. The initial phase involved the search for fish on the spawning grounds along the pre-defined transects using vessels equipped with and without acoustic logging systems. Fishing vessels without a recording system would document their observations as if they were undertaking a mapping survey. Once the entire area was covered and the distribution of fish identified, each vessel involved in the survey was assigned a series of transects to execute in the area containing the higher concentration of fish. Biomass estimates were made using the procedure described below for fishing operations, except that transects were usually of similar length and selected at random within the pre-defined area of interest. Transect estimates were weighted for length (i.e. distance traveled) and the mean transect backscatter (converted to kg/m^2 using the Foote equation) extrapolated for the survey area to estimate the minimum observed biomass.

Analytical Procedures:

The computational procedures for analyzing data collected from standard fishing operations and structured surveys are similar. However, given that the vessel track from standard fishing operations does not follow any standardized survey design, some assumptions have to be made about the area covered and the representative nature of the data. Occasionally, there are some recording nights when the data are simply too convoluted or too sparse relative to the area covered or the area covered is too small to be incorporated into the SSB for the stock. In recent years boat captains have attempted to structure their ad hoc recordings by running parallel lines when documenting aggregations of fish as recommended

(Melvin and Power, 1999). Furthermore, when the area covered in search of fish is of sufficient size and representative lines (equivalent to transects) can be extracted, an estimate of observed biomass can be obtained.

For structured surveys, transects are usually predefined and represent randomly distributed parallel lines within the survey area. Transects for fishing operations are extracted from the vessel track by dividing the track into a series of non-intersecting segments. Portions of the vessel track where the vessel looped back to take a second look at a group of fish are always removed to prevent over-weighting of areas of heavy fish concentrations.

Fish biomass is estimated by selecting segments of the vessel's track (transects), computing the distance weighted average area backscatter (Sa), estimating the mean weight of fish/m^2 under the vessel using the Foote target strength equation (Foote, 1987) and multiplying by the area covered. Target strength estimates are based on herring length frequency samples and associated weights collected from several commercial vessels fishing in the area of interest as follows:

TS (target strength) = (20 Log(length cm) - 71.9) - 10 Log(weight kg) in dB kg^{-1}.

Length frequency data are normally obtained from the survey vessel or vessels fishing in the survey area for TS calculation and target verification. The weight component of the TS equation is computed from recent data on the weight/length relationship for the mean size of fish observed. In the event length frequency and weight/length data are unavailable, standard TS of –35.5 is used for calculating biomass. Such events occur when gillnet samples are collected (selective for larger size) or no fishing is undertaken. The standard target strength corresponds to the TS of a 28.0 cm herring in September. This represents the lower end of the observed mean spawning lengths and generally translates into smaller biomass estimate.

The area backscattering coefficient (Sa) is initially computed by averaging the return signal for a specific navigational interval (usually 20 navigational fixes) along the transect and weighted by the distance traveled during that interval. The average Sa values, weighted for distance, are then used to compute the mean Sa (dB m^{-2}) for the transect. Average biomass density per transect (sample unit) was computed from the estimated Sa and TS as follows:

Biomass density/transect = 10 $^{\wedge((\text{mean Sa - Target strength})/10)}$ in kg m^{-2}

The area covered by the vessel is determined by fitting a rectangle or polygon over the vessel tracks and estimating the area. When available, sonar data are used to determine the boundaries of the fish schools. The area is then multiplied by the biomass density/stratum to determine the biomass in the area covered by the fishing vessel. Standard Error (S.E.) is estimated from the standard deviation of the transect biomass density, where n is the number of transects. The overall biomass for the area is then multiplied by the standard error (%) to determine the SE of the biomass estimate.

Table A1. Summary of weightings for each category used in mapping surveys. The tonnes/set is based on the fishermen's estimate of their catch if they set on the school of fish, converted to km^2. The acoustic values are the range of tonnages estimated from acoustic recordings and categorized by the observers.

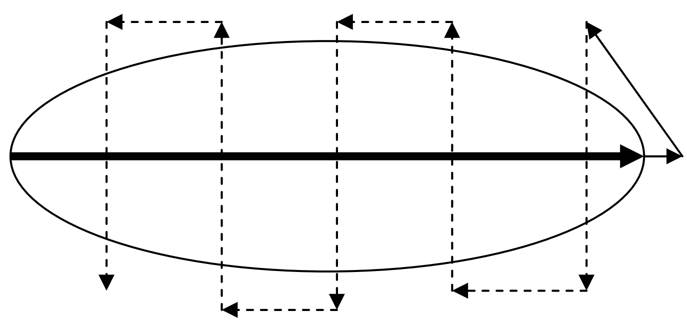
Category	Tonnes/Set	Tonnes/km^2	Acoustic (tonnes/km^2)
No Fish	0	0	0
Light	5	200	230 - 250
	10	400	
Moderate	25	1000	600 - 1300
	50	2,000	
Heavy	100	4,000	2,000 – 11,000
	200	8,000	
Very Heavy	250	10,000	20,000+
	500	21,000	

General Instructions for surveying a school (or schools) of fish:

Once a school of fish has been observed and the captain decides the aggregation is large enough to document or record, the following survey design should be implemented to determine the distribution and shape of the school or schools of fish. Two situations, commonly encountered during fishing, and the approaches to surveying are presented. The captain should write down the date, time and fishing area when they activate the automated logging system.

If a logging system is not available then the alternative is to use the attached Herring Survey Search Log sheet to record the data on paper. If the data sheet is used then detailed observations should be recorded at least every 5 minutes as well as when encountering and/or leaving a school as recorded by the bottom sounder.

1) In the first scenario a single large school of herring is encountered during a typical fishing night.

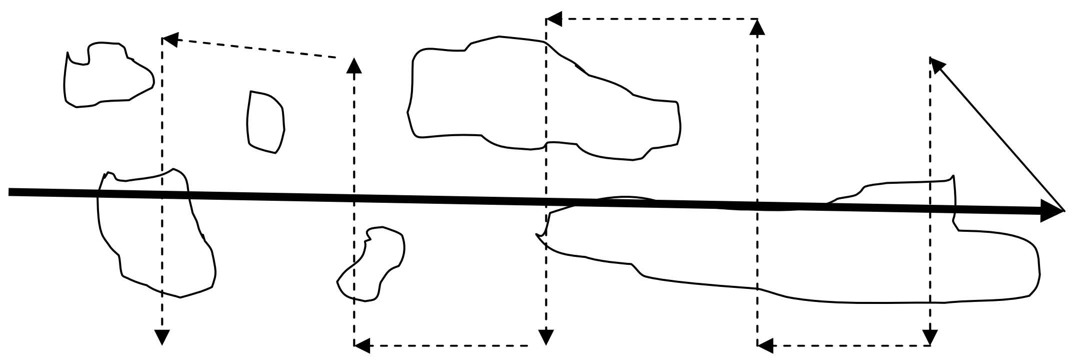


The first step to surveying the school of fish is to determine the long axis of the school as indicated above by the thick black solid line. Thereafter, a series of line transects should be run perpendicular to the long axis of the fish (dashed lines). The number of transects will be restricted to the amount of time the captain's has available to survey, but should not be less than three (3). If time is available, 5 transects should be run. The distance between transects will depend upon the size of the school and the time available, however as a general rule the transects should be separated at a minimum by one quarter (1/4) of a nautical mile. When running a transect the captain should try to continue along the line until he/she runs out of fish. This will not be possible when the fish are near shore.

Either before the survey or after the survey, a set should be made to confirm the fish are herring and to collect information on their size and maturity. If no set is made then the captain should note other vessels fishing in the area from which a biological sample could be obtained.

2) In the second case, the captain encounters an area where several schools of fish which are worth recording occur. The same procedure as for a single school of fish is to be followed except that the outer bounds of the survey area is determined by the distribution of the schools.

As above the first step is to determine the size of the area to be surveyed by running a line along the long axis of the school (thick black line). Once this has been done the vessel should proceed to undertake a series of transects (minimum of 3) perpendicular to the long axis (dashed lines) with up to five or more transects if time is available. Again the distance between transects will depend upon the size of the school and the time available, however as a general rule the transects should be separated at a minimum by one quarter (1/4) of a nautical mile. Once a distance between transects is selected it should not be changed through the survey. For example if the captains decides to set the distance at ¼ n.m. then this distance must not be changed even if fish are seen in the sonar. When running a transect the captain should try to continue along the line until he/she runs out of fish.



It is important to note that if more than one vessel with an automated logging system is working in the area the vessels should try to split up the transects to be surveyed amongst the boats. This way time and fuel will be saved.

Samples of fish should also be collected if possible. Once the vessel arrives at port it should notify DFO that a survey has been undertaken and arrangements made to download the data or to fax the survey sheets to St. Andrews (506-529-5862).

Herring Survey Search Log

Vessel: ________________ Captain: ______________________
Date: ___________________ Observer: _____________________

- record every 5-10 minutes or more frequently when encountering/leaving fish
- give estimates of school size and depth
- all depths in ftm. unless otherwise noted

#	Time	Latitude	Longitude	Speed	Heading	Depth	School Size,Depth, Notes	Water Temp C
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								