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Quantitative acoustic surveys of 4WX herring in 1997

By

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Abstract

An automated acoustic logging system installed aboard two commercial herring seiners was used to document the abundance and the distribution of herring in NAFO Division 4WX during the 1996/97 fishing season. The data were collected during standard fishing operations and structured surveys. The former were used to document the general distribution of fish throughout the season, while the latter followed standard acoustic survey protocol for quantitative assessment. Biomass estimates were determined for several major spawning components within the 4WX stock complex. Prior to the fishing season it was estimated that 7-10 days must elapse between spawning surveys to ensure a new wave of fish had occupied the spawning grounds and to avoid double counting. Unfortunately, large and presumably new schools of fish were observed and surveyed by the fishing industry in Scots Bay and on German Bank with only 6 days between surveys. Examination of length frequencies, gonad stages and distribution of catches did not provide conclusive evidence that the observations were made on a new and/or different group of fish. To avoid double counting the estimate from the second survey was discounted by the percent of stage 5 pre-spawning herring observed in the first. Total biomass estimate for a spawning component was determined by summing the surveys after discounting. Based on this approach the German Bank spawning component was estimate to be 370,356t between September 18 and October and the Scots Bay component 160,168t between July 29 and August 18.

Résumé

Un système d'enregistrement acoustique automatisé installé à bord de deux senneurs harenguiers commerciaux a été utilisé pour déterminer l'abondance et la distribution du hareng dans les divisions 4WX de l'OPANO pendant la saison de pêche de 1996-1997. Les données ont été obtenues pendant des opérations de pêche normales et des relevés structurés. Les premières ont été appliquées à l'examen de la distribution générale du poisson tout au long de la saison et les deuxièmes, conformes au protocole standard des relevés acoustiques, ont servi à l'évaluation quantitative. La biomasse de plusieurs importantes composantes de frai du complexe de stocks de 4WX a été estimée. Il a été évalué, avant la saison de pêche, qu'une période de 7 à 10 jours devait séparer chaque relevé des géniteurs afin de s'assurer que la nouvelle vague de géniteurs ait occupé les frayères et d'éviter les doubles dénombrements. Malheureusement, des bancs de poissons importants et sans doute nouveaux ont été observés et dénombrés par les pêcheurs dans la baie Scots et sur le banc German à seulement six jours d'intervalle. L'examen des fréquences de longueurs, du développement des gonades et de la répartition des prises n'a pas permis de montrer de façon certaine que les observations portaient sur un groupe de poissons nouveau ou différent. Afin d'éviter le double dénombrement, l'estimation du deuxième relevé a été réduite du pourcentage de pré-géniteurs de stade 5 observé antérieurement. La biomasse totale estimée de la composante de géniteurs était déterminée en additionnant les résultats des relevés après réduction. On trouve, en procédant de cette façon, que la composante de frai du banc German s'élevait à 370 356 t entre le 18 septembre et octobre et que celle de la baie Scots s'élevait à 160 168 t entre le 29 juillet et le 18 août.

Introduction:

Over the past two years DFO, in conjunction with the private sector and the fishing industry, has developed an automated sounder/sonar logging system for deployment aboard commercial fishing vessels. The purpose for developing this system was to integrate acoustic biomass estimates and the fishing industry's input into the stock assessment process. During 1996 the Hydroacoustic Data Processing Software (HDPS) logging module (DFO standard in Scotia-Fundy) was enhanced to simultaneously log output from off-the-shelf commercial sounders, single and multi-beam sonars with a video output, and location (i.e. GPS/DGPS). The system was designed for simple operation and required only the push of a single button to activate, allowing operation of the system at the captain's discretion. Each vessel's transducer was also calibrated to provide a quantitative estimate from the ship's sounder.

Under a voluntary program with industry, two systems were installed aboard commercial seiners and operated throughout the fall of 1996 for testing and evaluation. The first quantitative survey using this equipment was undertaken in January of 1997 on a non-spawning aggregation of herring off Halifax. Details of the system's development are reported in the 1997 NHP Report " Automated Acoustic Recording System" (Melvin, 1997, DFO internal report).

A critical factor in estimating total spawning biomass for a given spawning ground is the elapsed time between surveys. Unfortunately, factors that initiate migration, homing to the spawning grounds and time on spawning grounds are not well known (Haegele and Schweigert 1985). There are conflicting reports in the literature with regard to the behaviour of Atlantic herring prior to, during and after spawning. Direct observations of spawning behaviour tend to be made on fish in captivity or do not include observations of the behaviour of fish immediately after spawning. Furthermore, many of the observations date back more than fifty years.

For Atlantic herring Ewart (1884, in Haegele and Schweigert 1985) suggests that females spawn over three days whilst males take about six days. Towards the end of spawning males are dominant on the spawning ground. Runnstrom (1941a)states that herring move onto the spawning grounds at night and spawn over several weeks with the oldest fish spawning first, followed by a second wave of recruit spawners. The idea of waves of spawning is widely reported (Lambert 1984,1987, Hay 1985, Runnstrøm 1941 in Haegele and Schweigert 1985), but according to Blaxter (1985) it is more common for spawning to occur over a period of a few weeks on any given spawning ground. Bradford (1991) found that within individual populations, spawning is a continuous process throughout the spawning season but there may be single or multiple waves. Lambert (1987) reports that spent fish tend to leave the spawning area soon after spawning but no evidence is given to support this claim. Herring fishers in southwest Nova Scotia report similar behaviour.

According to Haegele and Schweigert (1985) adult Pacific herring congregate near the spawning grounds several weeks to months in advance of spawning, move on to the spawning grounds for spawning, then leave immediately - although some herring remain near their spawning grounds throughout the year. They also noted that most major spawning events continue for several days. Hay (1985) reports that spawning can occur two or more times at some locations. These spawnings are separated by roughly 10 to 15 days and the later spawners tend to be smaller and younger. He also reports that during the second wave of spawning there are substantial numbers of spent fish from the first wave still present on the spawning grounds. Hay (1985) also points out that the differences in the age and size compositions of the spawning waves are important since most roe fisheries operate on the first wave (the larger, older fish) and thus, samples taken from the commercial fishery do not necessarily accurately reflect the total spawning population.

Given the uncertainties expressed in the literature, the absence of spent herring in samples from fisheries on spawning grounds and the pattern of abundance and distribution on spawning grounds observed in the Southwest Nova Scotia fishery a working model was established prior to the 1997 survey season. Assuming that spent herring disperse quickly from the spawning area then 7 to 10 days should be sufficient for a complete turnover of fish on spawning grounds once spawning has begun.

This report summarizes the acoustic biomass estimates obtained during standard fishing operations and from structured surveys using both the automated logging systems and a DFO research vessel. We also discuss how the data were partitioned to provide a biomass estimate when two surveys were conducted with less than the minimum established elapsed time between surveys. During the 1997 spawning season only six days had elapsed between surveys in Scots Bay and on German Bank.

Methods:

In 1997, the two HDPS systems were installed, calibrated and operated aboard the purse seiners *Margaret Elizabeth* and the *Island Pride* for most of the fishing season. Data were collected during regular fishing excursions and structured surveys in NAFO Division 4WX (Figure 1). Although fishing operations have been primarily used to test the system's reliability and the systems have typically been activated during the search phase of the night's fishing, there have been a number of occasions when an estimate of observed biomass could be obtained. Biomass estimates from the structured surveys and a selection of fishing recordings from important spawning areas are presented in Table 1 along with target strength and mean length data. During the past fishing season (1997) in excess 1000 hours of these data were collected.

Fishing Operations:

Data logging during a standard fishing operation do not follow any standardized survey design, although captain's are increasingly running parallel lines when documenting aggregations. When coverage of the search area was significant an estimate of observed biomass could be obtained by selecting segments of the vessel's track (transects), computing the average area backscatter (Sa), estimating the mean weight of fish/m^2 under the vessel (target strength equation, Foote, 1987) and multiplying by the area covered. Target strength estimates were based on herring sample lengths and associated weights collected from several commercial vessels fishing in the area of interest as follows:

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

To utilize the data from fishing operations the vessel track was divided into a series of non-intersecting transects. Portions of the vessel track where the vessel has looped back to take a second look at a group of fish were also removed to prevent overweighting of areas of heavy concentrations. The average Sa was then computed for a fixed navigation interval (usually 20 navigational fixes) and weighted by the distance traveled during that interval. The average Sa values, weighted for distance, were then used to compute the mean Sa (dB m^{-2}) for the transect. Biomass density per transect (sample unit) was computed as follows:

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

In the case of fishing operations, where coverage area was generally small, all segments or transects are representative of a single stratum. The mean Sa for each transect was used to estimate the mean weighted area backscatter for the stratum, where the data are weighted for the length of the transect. Biomass density per stratum in kg m^{-2} was computed as above.

Area covered by the vessel was determined by fitting a rectangle or polygon over the vessel track and estimating the area. Sonar data were used to determine the boundaries of the fish schools. The area was then multiplied by the biomass density/stratum to determine the biomass in the area covered by the fishing vessel. Figure 2 provides an example of an actual vessel track and the segments used to estimate biomass. Standard Error (S.E.) was estimated from the standard deviation of the transect biomass density, where n is the number of transects. To determine the SE of the overall biomass estimate the SE was multiplied by the area of coverage.

Structured Surveys:

The automated logging system also provides a means to undertake industry based acoustic surveys throughout the fishing season. The standard operating procedure for such a survey involves the presence of DFO scientific staff onboard one or more of the vessels to direct the activities. Typically, a standard random transect protocol was employed in the area of interest with a two phase survey design (i.e. search then survey). Once the aggregation was located each vessel involved in the survey was assigned a series of transects which are then executed. Biomass estimates are made using the procedure described above for standard fishing operations, except that the transects are usually of similar length and selected at random within the area of interest. Transect estimates were again weighted for the length of each transect.

Results:

During 1997 data were collected and analyzed from NAFO Division 4WX to obtain biomass estimates of both spawning and non-spawning aggregations of herring within the Maritime Region (Figure 1). These included fishing operations, structured acoustic surveys, and an integrated survey which combined the efforts of the R.V. *Teleost*, the *Island Pride* and the *Margaret Elizabeth*. Each of these surveys will be discussed in the following section.

Scotian Shelf:

Several nights of acoustic recording were made on the Scotian Shelf during the spring fishery. Unfortunately, in many cases the fish were observed in the basins and were too deep to be detected with the sounder (200kHz) connected to the automated logging system aboard the *Margaret Elizabeth*. This was an unforeseen limitation of the system previously used in waters less than 150 meters. The only reasonable coverage occurred on the night of July 7 when herring were observed near the surface. The biomass estimate for this single aggregation was 40,651 t in an area of 11.89 km^2 (Table 1). It is important to note that the commercial vessels were scattered over a wide area of the shelf and the observed biomass reflects only the fish encountered by the Margaret Elizebeth. Herring sampled from the two vessels fishing on the observed aggregation ranged from 26 to 35 cm with a mean of 30.3 cm (Figure 3).

Long Island Shore:

Each year the purse seine fleet is active along the Long Island Shore of Nova Scotia from June through September. The area is known to contain a mixture of juvenile and adult fish (likely destined for Scots Bay) throughout this period. On July 11th, 1997 the *Margaret Elizabeth*, while fishing in the area, activated it's automated acoustic logging system to record the occurrence of fish. Based on the logged data the vessel covered an area of approximately 15.86 km^2 (9.52 km by 1.66 km) in which the biomass was estimate to be 104,992t (Table 1). The fish were found to be mixed in size, ranging from 16.5 to 34.5 cm with a mean of 25.2 cm (Figure 4).

Grand Manan:

During the summer of 1997 industry reported a large aggregation of herring off Grand Manan just south of North Head. To obtain an estimate of these fish, the *Margaret Elizabeth* volunteered to survey the area with its automated logging system. On the night of July 21 the vessel covered an area of 18.29 km^2 (19.5 km x 0.93 km). The biomass estimate for this area was 101,786 t of predominately juvenile fish. The mean length of sampled fish was 23.6 with a range from 16.5 to 27.0 cm (Figure 5).

Scots Bay:

In recent years the second largest spawning component within the 4WX stock complex has occurred in Scots Bay (Stephenson et al.,1998). This component represents the earliest spawning group with a roe fishery beginning in the second half of July. Traditionally, the fishery continued until quota or target levels were reached. The first dataset analyzed from Scots Bay was August 5 when the *Island Pride* covered an area of 540 km^2. Several transects were extracted from the vessel track (Figure 2) and were used to estimate biomass. The total biomass for the search area was estimated to be 44,428 t (Table 1) for fish ranging from 22.5 to 31.0 cm (Figure 6). Mean fork length was 27.7 cm. Another recording was analyzed for August 6 when the vessel recorded only the small group of fish it was working on. The biomass estimate for the 1.23 km^2 covered was 1,188 t. This estimate serves to illustrate the limited coverage of many fishing nights for which recordings are available, but not included in this report..

On the night of August 18, 1997 both the *Margaret Elizabeth* and the *Island Pride* activated their automated acoustic logging systems while fishing in Scots Bay. The area covered by both vessels is shown in Figure 7. The extent of overlap is 2.18 km^2. Two analyses were undertaken to estimate biomass. In the first case each vessel was considered to have undertaken an independent survey and the overlap was not removed from the estimate. The *Island Pride* observed 56,517 t in 9.15 km^2 compared with 35,041 t in 10.54 km^2 for the *Margaret Elizabeth*. At first glance it might appear that the former estimate is high. However, examination of the backscatter distribution shows that the densest group of fish occurred in the southwestern area covered only by the Island Pride and accounts for the difference in biomass estimates. In the second analysis the data from both vessels were combined for a total coverage area of 17.31 km^2. The biomass estimate was 85,718 t (Table 1). Given that the two vessels were recording at approximately the same time, did not cover the same area and that overlap area was removed, the best estimate of biomass for August 18 is assumed to be 85,718 t. Herring sampled from the *Island Pride's* catch had a mean length of 27.5 cm and ranged from 24.0 to 31.5 cm (Figure 8).

German Bank:

German Bank supports the largest spawning component in the 4WX stock complex with spawning aggregations occurring on the bank from early September to mid-October. As such, accurate information of the status of this component is critical to the overall 4WX assessment. During the fall of 1997 several surveys were conducted on the bank to document the distribution and abundance of spawning herring. The first survey occurred on September 18th and reflects the combined the efforts of the Canadian research vessel *Teleost* and the two commercial vessels equipped with automated logging systems. The survey area was divided into two strata; the active fishing area and the boundary waters.

The total coverage (5nm x 5nm) was 85.74 km^2, 69.06 by the *Teleost* and 16.68 km^2 for commercial vessels including a buffer zone around the fleet (Figure 9). The data were downloaded from the commercial vessels on the morning of the 19th and a biomass estimate made available before 16:00h the same day.

The purpose of the integrated survey was to demonstrate that research and commercial vessels can complement each other during a survey to provide an overall estimate of fish biomass in the area. That is, the commercial vessels can operate amongst the fleet where a research vessel cannot due to clearance restrictions. Furthermore, the results of the survey when coordinated can be made available in near real time to provide guidance for harvest levels on individual spawning components.

On September 21/22 an extensive survey (Lurcher to Southern German Bank) was undertaken by the *Teleost* using ten randomly selected transects and covering an area of 1,028 km^2. The observed biomass was 33,078 t $\pm$ 6,065 t (Table 1) of mixed sized fish. Juvenile fish were found primarily in the upper water column and adults near the bottom. It was also interesting to note that the only significant concentration of herring occurred in the area were the fleet was active on the night of September 18.

The first industry survey on German Bank was conducted on a spawning aggregation of herring during the night of October 3. Three vessels, two with automated logging systems, participated in the survey. A two phase design (search then survey) was employed. Once the aggregation was located transects were assigned each vessel (Figure 10). The biomass estimate for this survey was 215,800 t $\pm$ 37,284 in 10.3 km^2. Mean length of the sampled fish was 27.1 cm with a range of 23.0 to 32 cm (Figure 11). The length frequency is based only on the catches of the two vessels participating in the survey. It is important to note that the survey transects were directed through the fishing fleet which was active in the area. This would not have been possible using a research vessel as it requires a 1 n.m clearance from active fishing gear.

The second important survey occurred on the night of October 9 and represents a major milestone in our efforts to establish industry based surveys. After finishing fishing for the evening, the *Island Pride* encountered a large school of spawning herring on German Bank, on its homeward journey. The captain independently (without DFO input) established a series of transects to cover the area (Figure 12) and conducted the survey before returning to port. The morning of Oct 10th we were notified of the survey and immediately deployed a technician to download the data. The biomass estimate for this aggregation of fish was 194,100t $\pm$ 33,000 in 14.95 km^2. These fish seemed to be different in size when compared with the fish sampled on the night of October 3rd. The fish ranged in size from 23.0 to 34.5 cm with a mean length of 28.5 cm (Figure 13).

Timing Between Surveys:

For most of the surveys conducted during 1997 sufficient time had past to assume that the spawning ground being surveyed for a second or third time was occupied by a new group of fish (i.e. a minimum of 7-10 days had elapsed between surveys). Unfortunately two opportunistic surveys were conducted by industry in Scots Bay and on German Bank with only 6 days from a previous survey. The key question to be addressed regarding the status of the 4WX herring stock is "Are these the same fish or two distinct aggregations given the time between first and second surveys and their location?". The acoustic biomass estimate for German Bank was 194,100t on October 3rd and 215,000t on October 9th. If the two groups surveyed in October were different fish then the estimated tonnage for German Bank would be 427,545t, however if the second survey was of the same group then the estimate falls to 233,400t.

Seiner captain's who were fishing on German Bank reported that the fish of October 3 were different in size and roe content from those of October 9. To investigate their supposition, length frequency and maturity data from samples taken during the fishery and catch/set locations were examined for the period October 3 -9 inclusive. Twenty-one length frequency and 5 detailed samples were available from purse seine catches for the period. This represents 2,897 fish measured and 182 fish sexed and staged.

Although the length frequencies of fish collected from October 3 to 9 suggest a slight shift to larger fish as time progresses they do not show any significant differences ($P<0.05$)over time (Figure 14). The results are inconclusive with respect to a new group of fish having moved in between the two surveys. Length frequency samples collected from Scots Bay between August 12th and 19th show similar results in that there is no discernible shift in fish size (Figure 15).

The distributions of German Bank maturity stages (sexes combined) in the detailed samples taken on October 3, 4 and 9 show a decrease in the percentage of stage 5 fish (from 26.5% on October 3 to 12.5% on October 9) and an increase in the percentage of stage 6 fish (from 73.5% on October 3 to 82.5% on October 9) (Figure 15). This would support the assumption of an influx of new fish for the period in question. Only one spent female (Stage 8) from October 3rd and two spent males were observed in the October 9th samples, indicating that herring move off the spawning grounds shortly after spawning.

In Scots Bay there were also only 6 days between the surveys on August 12 and 18. Maturity data from the detailed sample collected on August 12 showed 57% stage 4 and 5 fish (Figure 17). No detailed samples were available for August 18 from Scots Bay.

The distribution of purse seine daily catches from the DFO Statistics database was examined relative to the survey area for German Bank. These data show some geographical differences in the location of fishing catches from October 3 to 9 (Figure 18). The fleet activity was separated by approximately 5 miles between the two dates. A similar distance separated the two surveyed aggregations. Such a short distance is considered to be inconclusive with respect to determining whether or not the two surveys should be pooled. However, on both occasions fishing activity (i.e. catches) occurred outside the actual area surveyed. This would indicate that additional fish were present outside the survey area on both dates.

Discussion

Several important factors regarding the use of acoustic to estimated fish biomass were identified during our 1997 activities. The first observation was that survey timing of spawning aggregations is critical to the observed biomass estimate. The September 18 -26 Teleost survey timing was selected from the bank's historical performance and covered most of the area where spawning herring should have been present. Based on this survey only 33,000t of herring were observed. Yet, less than two weeks later an industry survey under DFO supervision, documented approximately 194,100 t in a much smaller area on German Bank. The ability to undertake a survey when the fish are present is critical for accurately estimating biomass. This can only be achieved through industry based surveys. Research vessel scheduling does not allow the flexibility to react on short notice.

Standard survey design requires the running of transects which may or may not intercept the area of commercial fishing activity. The former situation is particularly true when an aggregation of fish is being surveyed by a research vessel. The research vessel, due to a navigational restriction (1-2 mile clearance request by the captain), was unable to survey the area where the commercial vessels were operating (likely the greatest concentration of fish). Commercial vessels do not have the same clearance restriction and can continue transects through the fleet, thereby providing complete coverage of the area.

Groundtruthing of targets has always been a problem during acoustic research surveys in that adequate samples were difficult to obtain. Working with the commercial fleet provides a means to collect samples from several vessels working on the aggregation of fish being surveyed.

As a result of observations from Industry and Science, a survey protocol that there be 7 to 10 days between surveys was established prior to the fishing season to prevent the possibility of double counting. For most of the surveys conducted during the 1998 fishing season sufficient time had elapsed to minimize the probability of this event occurring . Consequently the number of herring observed acoustically on an individual spawning ground can be considered cumulative. However, in the two cases where the surveys were only 6 days apart it was necessary to examine biological characteristics of samples collected during the survey intervals and the distribution of the fishing fleet to determine if the same fish were surveyed on both occasions. For German Bank it was even more important given that combining the two surveys would increase the 4WX biomass estimate by more than 50%. Unfortunately, length frequency samples between the two surveys did not show any marked shift is size, nor was there a large distance separating the surveyed fish. Fish were however observed and captured by the fleet outside the survey area on both nights. The results were inconclusive in determining whether or not the fish were the same or a different group.

Maturity stages provide an estimate of gonad development and whether or not fish have spawned. Herring are classified as stage 6 only when there is evidence that spawning has started. Stage 7 represents spent fish. Thus, assuming that stage 6 fish from the early survey are unlikely to be present on the spawning ground during the second survey, it is possible to estimate the portion of the fish which might be double counted (i.e., Stage 4 and Stage 5). It was therefore proposed to discount the second survey by the amount of Stage 4 and 5 fish observed during the second survey.

During the October 3 German Bank survey 215,797t of herring were estimated acoustically with 26.5% stage 5 fish in the detailed sample. Using the above approach the 194,145t of fish observed on the second survey was discounted by 57,186t (amount of stage 5 fish from October 3). This results in an overall estimate of 370,356t for German Bank for the period of September 18 to October 9, 1997.

Surveys were conducted on July 29, August 5, August 12 and August 18 in Scots Bay. A similar approach was used for the October 12th and 18th surveys. The estimated tonnage of 85,718t recorded on the August 18 survey was discounted by 19,950t (57% of the 35,000t observed on August 12). Thus the cumulative estimate for the Scots Bay spawning component during the period of July 29 to August 18 was 160,168t

Summary

Acoustic surveys conducted by DFO and the fishing industry during the 1997 fishing season provided biomass estimates for the major spawning components within the 4WX stock complex. This information, in conjunction with the annual larval survey and ad hoc surveys, provided the bases for the 1998 stock assessment. A protocol of 7-10 days between surveys was established prior to the fishing season to ensure that a new group or wave of spawning fish had occupied the spawning ground. In Scots Bay and on German Bank, the fishing industry observed what appeared to be a new group of spawning fish and undertook an acoustical survey using the automated logging systems. Unfortunately, only 6 days had elapsed since the previous survey. Given that the length frequency samples did not show a marked shift in size and that the distance between survey areas was minimal, the biomass estimated for the second surveys were discounted for the proportion of maturity stage 4 and 5 observed in the first survey. Total biomass estimate for a spawning component was determined by summing the surveys after discounting. Based on this approach the German Bank spawning component was estimate to be 370,356t between September 18 and October and the Scots Bay component 160,168t between July 29 and August 18.

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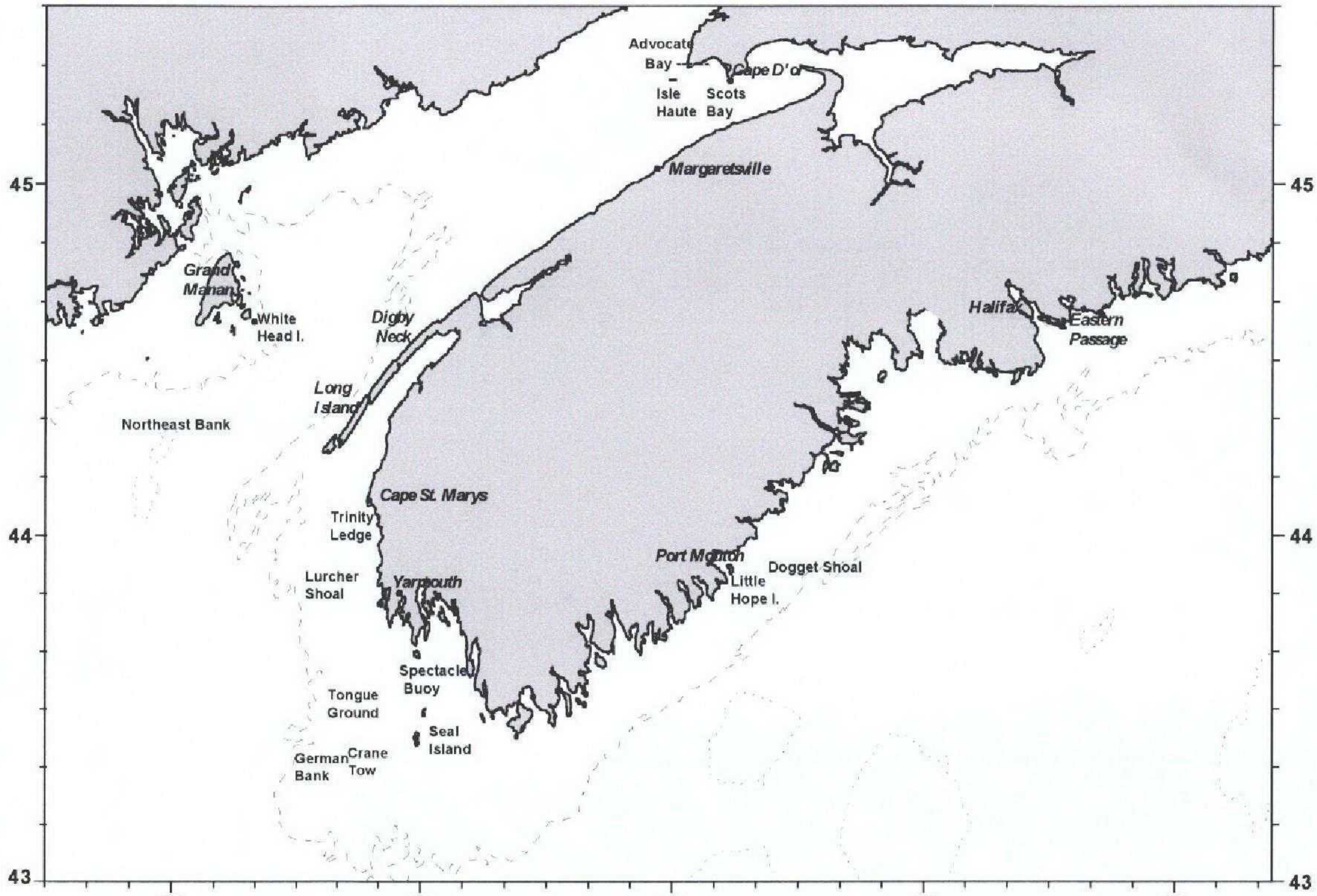
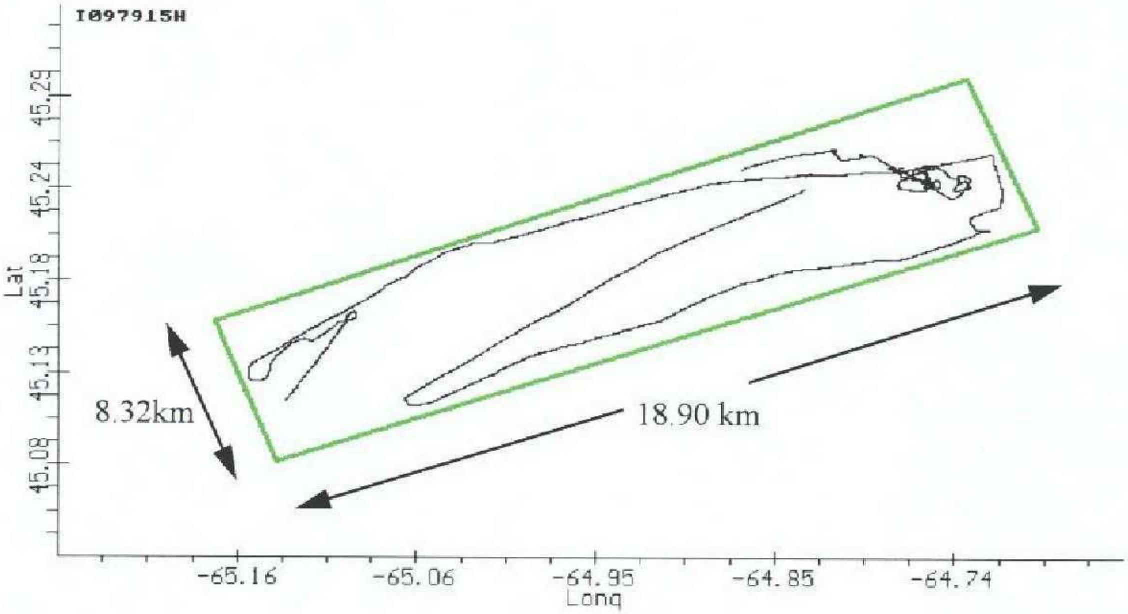


Figure 1. Herring fishing locations in the Bay of Fundy, Southwest and Coastal Nova Scotia.



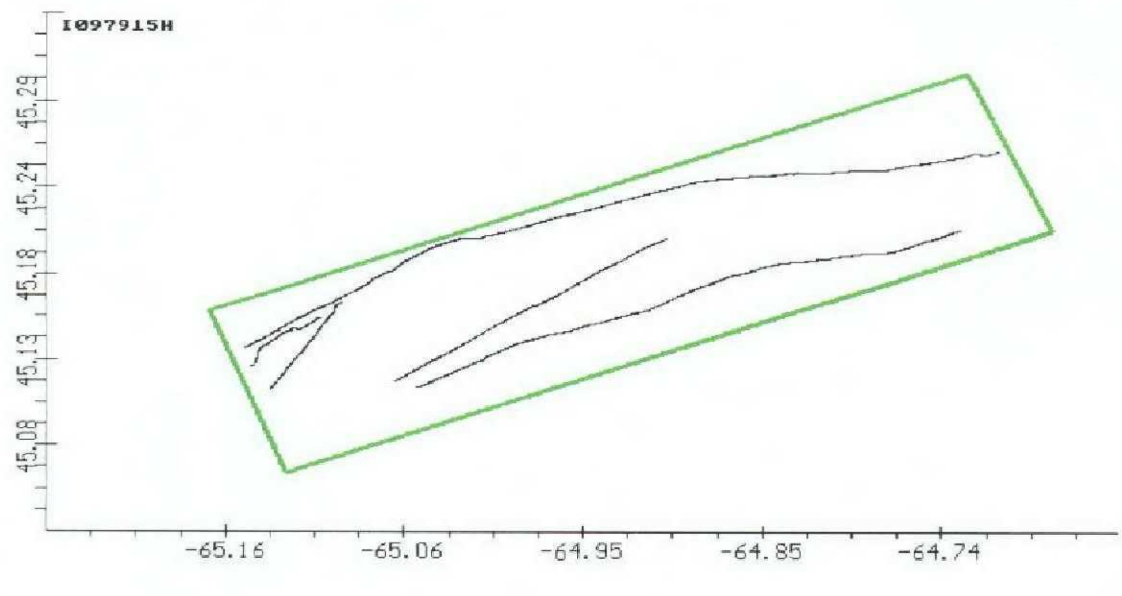


Figure 2. An example of a search phase undertaken by the Island Pride in Scots Bay during a night's fishing and the track segments used to estimate the biomass/m^2 within the search area.

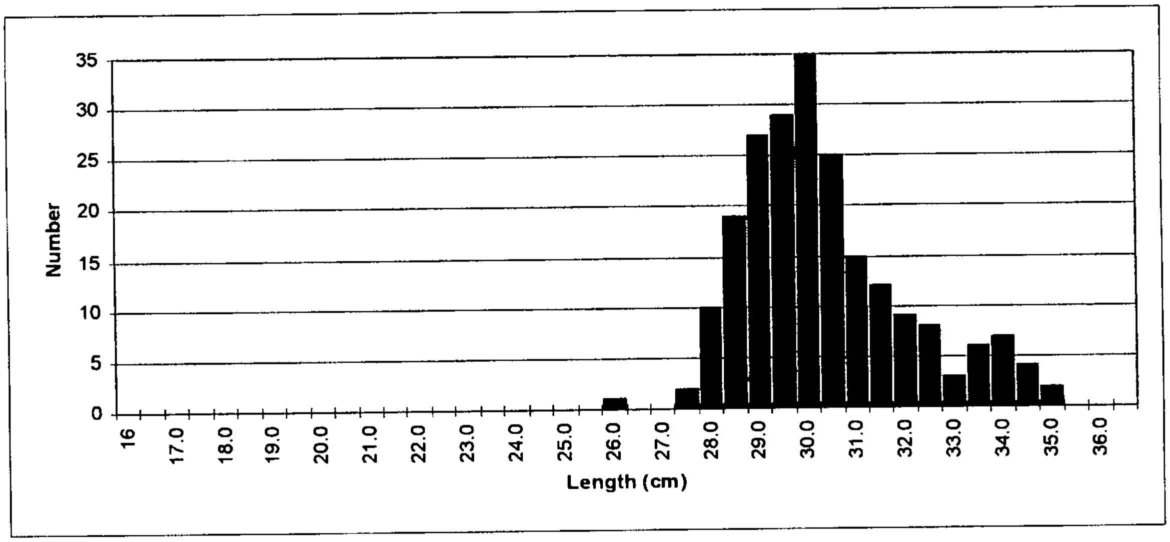


Figure 3. Length frequency of herring sampled from the Dual Venture and the Margaret Elizabeth on July 7,1997 on the Scotian Shelf near the McKenzie Spot. The number of fish sampled equals 214.

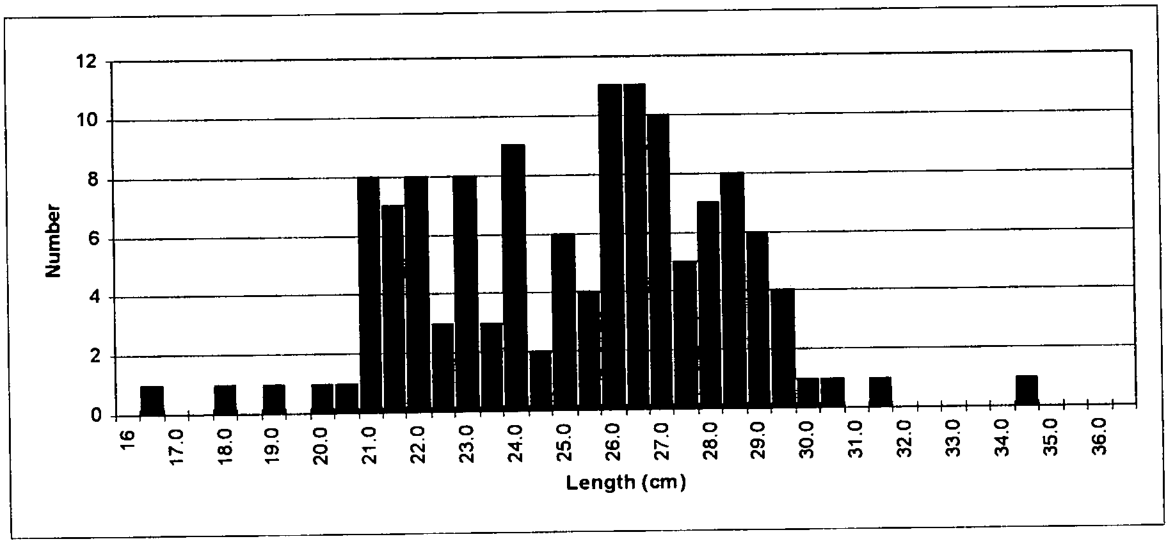


Figure 4. Length frequency of herring sampled from the Atlantic Mariner on July 11,1997 on Long Island Shore, N.S.. The number of fish sampled equals 129.

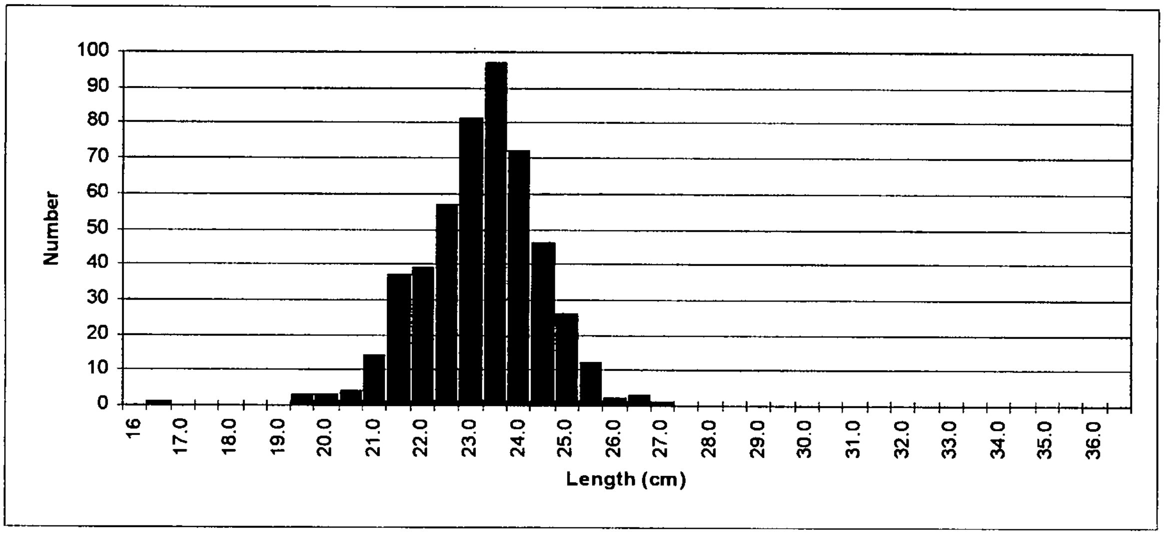


Figure 5. Length frequency of herring sampled from the Canada 100, Margaret Elizabeth, Polly B and Aaron & Kate on July 21,1997 off Grand Manan.. The number of fish sampled equals 498.

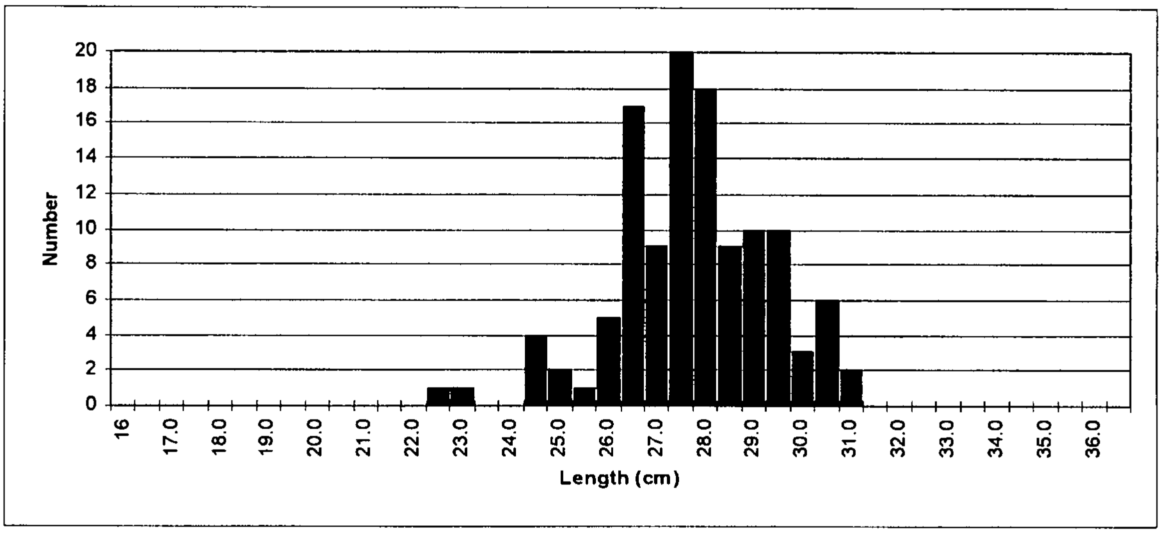


Figure 6 . Length frequency of herring sampled from the Island Pride on August 5,1997 in Scots Bay. The number of fish sampled equals 118.

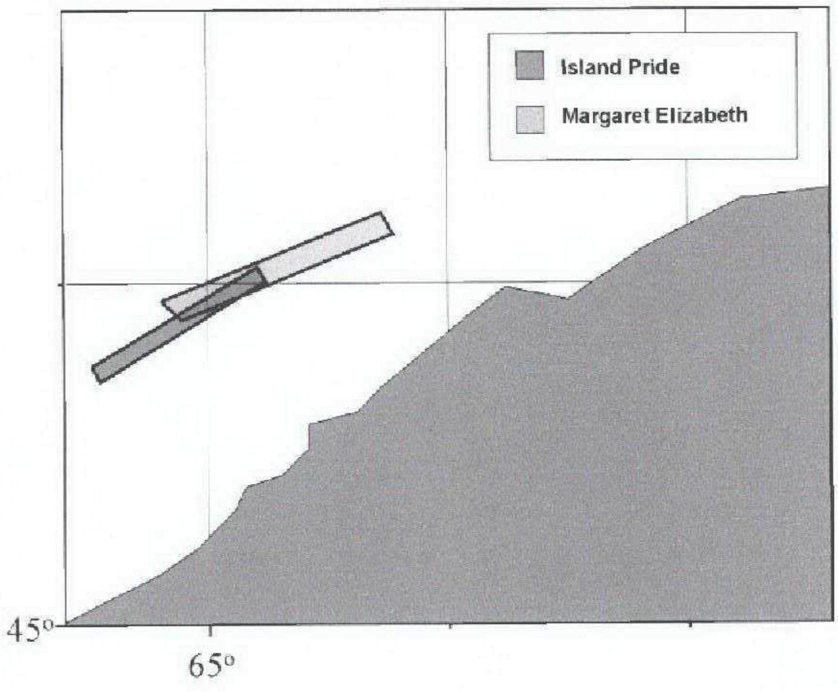


Figure 7. Coverage area for the Island Pride and the Margaret Elizabeth in Scots Bay on the night of August 18, 1997.

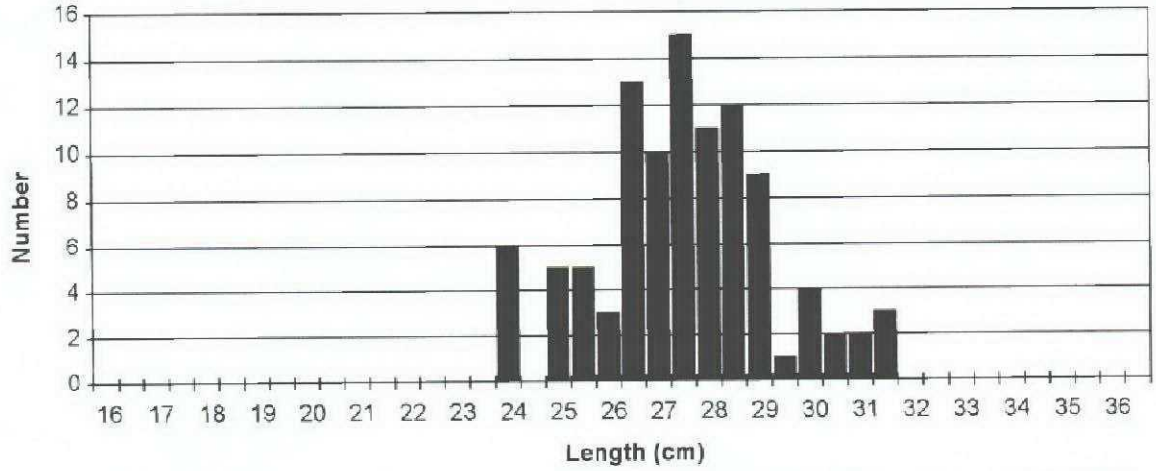


Figure 8. Length frequency of herring sampled from the Island Pride on August 18,1997 in Scots Bay. The number of fish sampled equals 101.

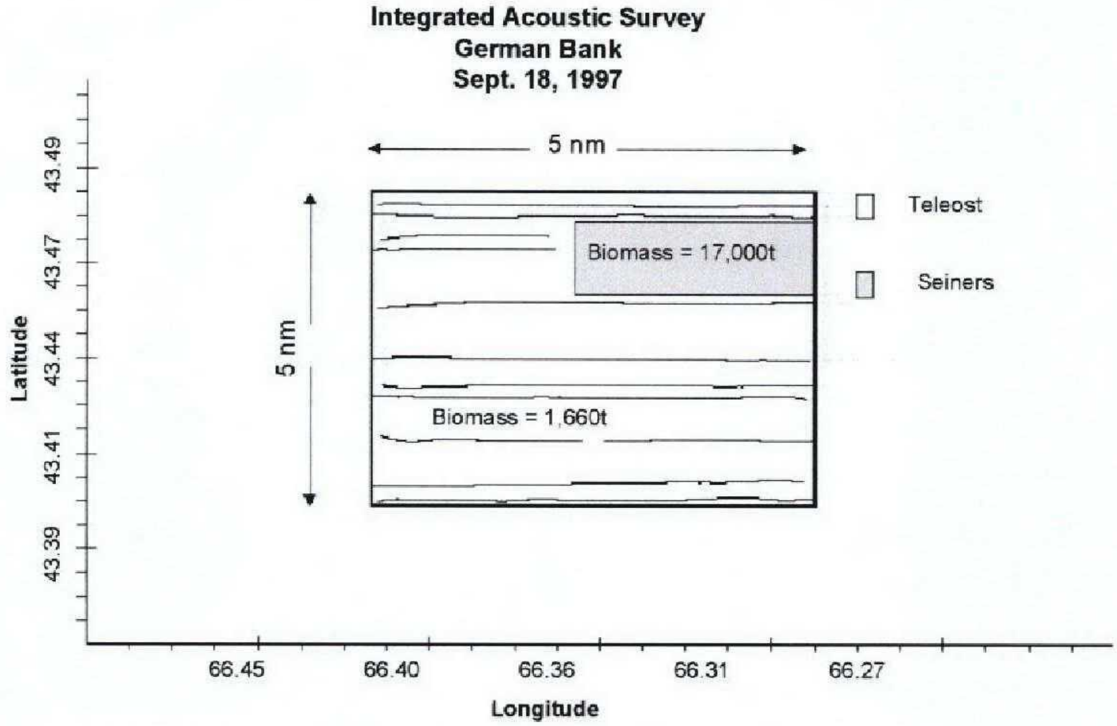


Figure 9. Detailed acoustic transects of the research vessel Teleost and the operational area for the commercial fishing vessels during the Integrated Survey. The total biomass was estimated by combining the data from the two commercial and the research vessels.

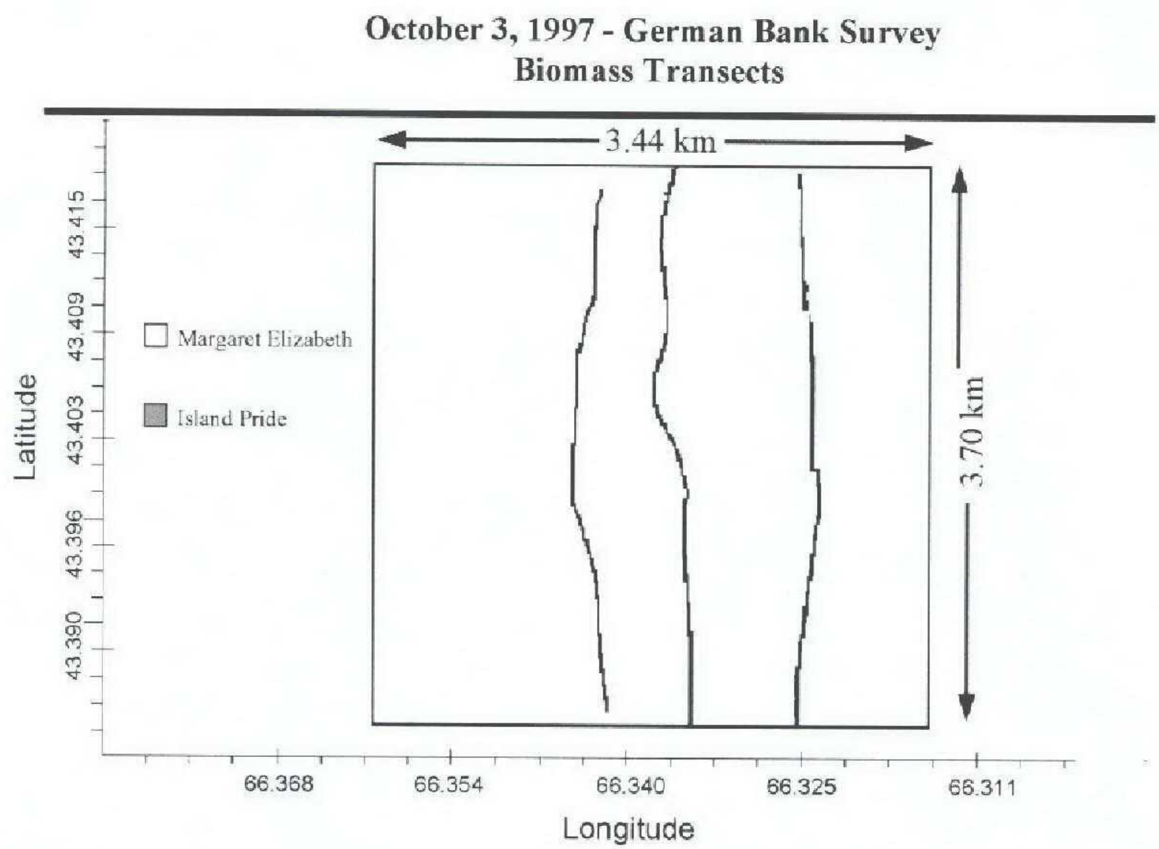


Figure 10. Survey transects for each vessel with an automated acoustic logging system during the October 3, 1997 industry survey.

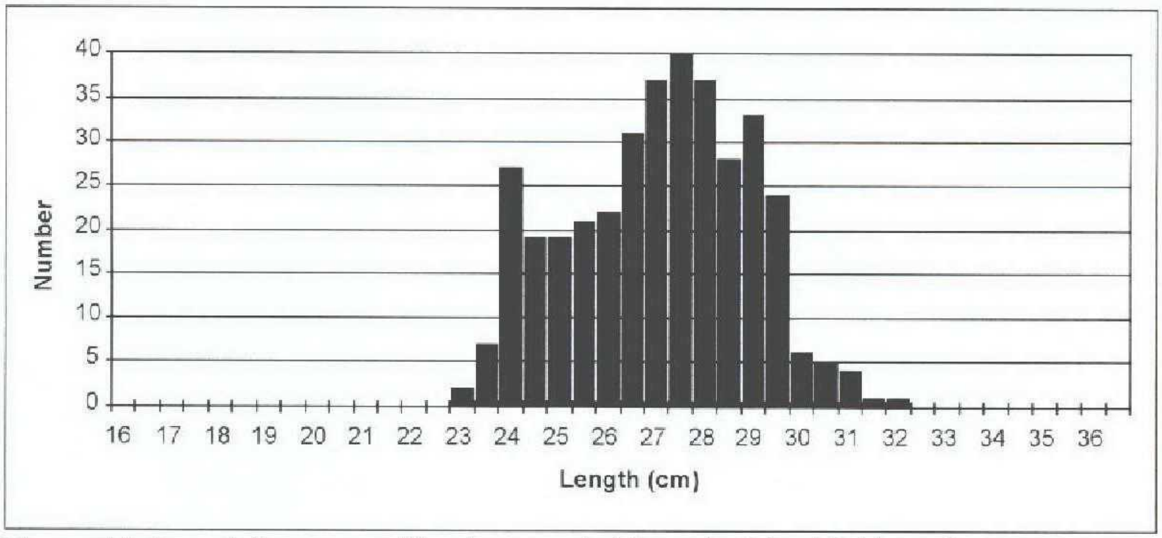


Figure 11. Length frequency of herring sampled from the Island Pride and Margaret Elizabeth on October 3,1997 for German Bank. The number of fish sampled equals 364.

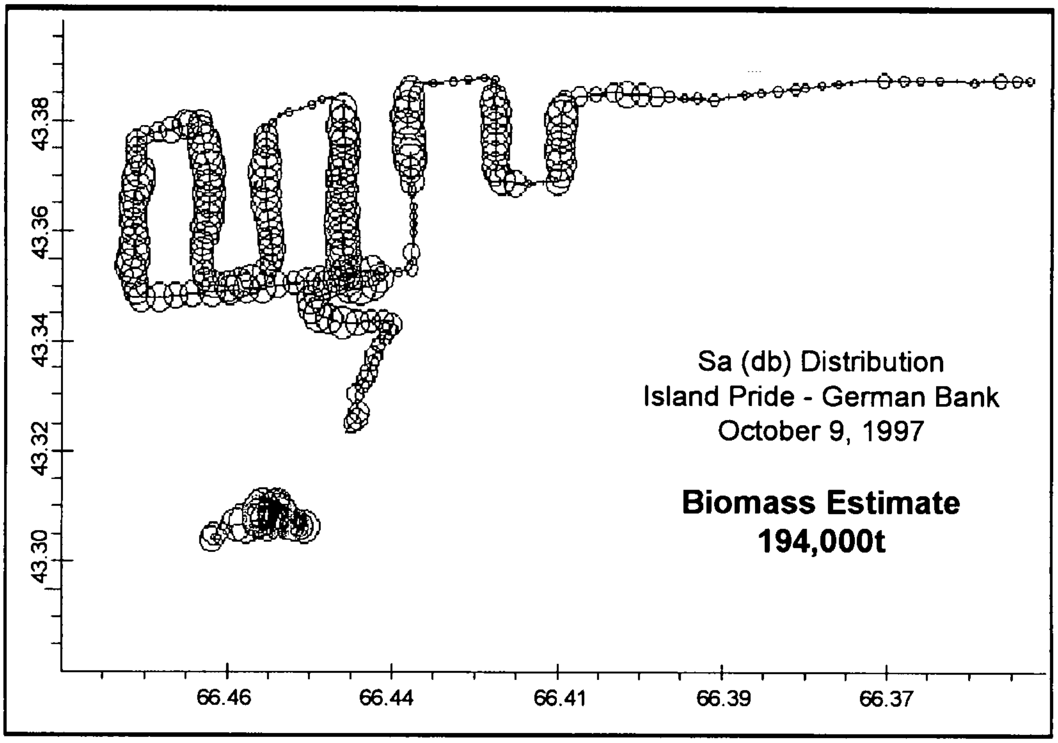


Figure 12. Vessel track and acoustic backscatter distribution for the October 9, 1997 industry survey of herring on German Bank. The clumped circles in the lower left hand corner shows where the vessel made a set prior to surveying the large concentration of fish.

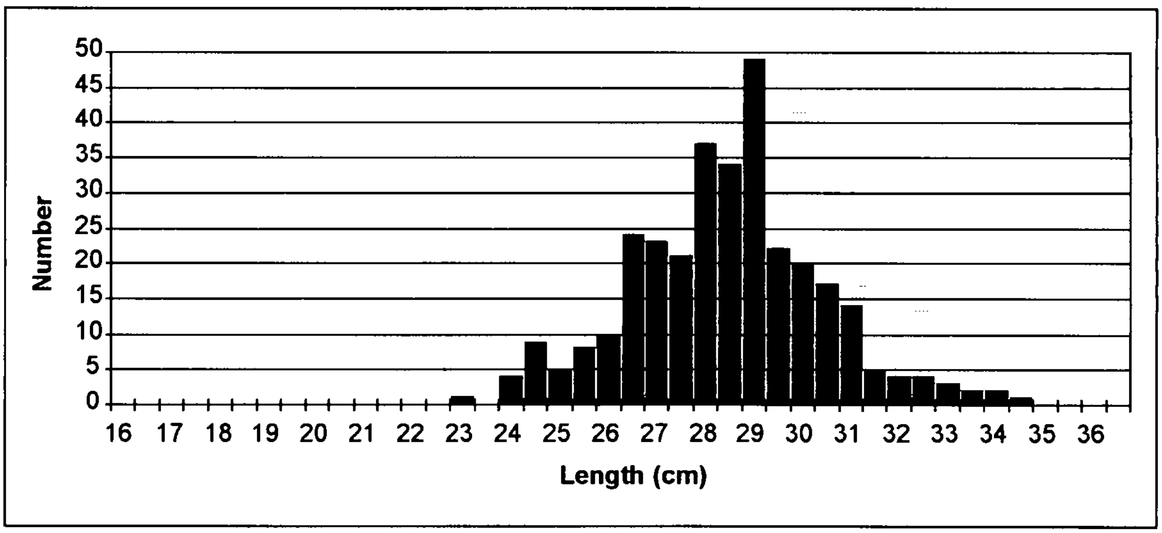


Figure 13. Length frequency of herring sampled from the Island Pride and Tasha Marie on October 9,1997 for German Bank. The number of fish sampled equals 319.

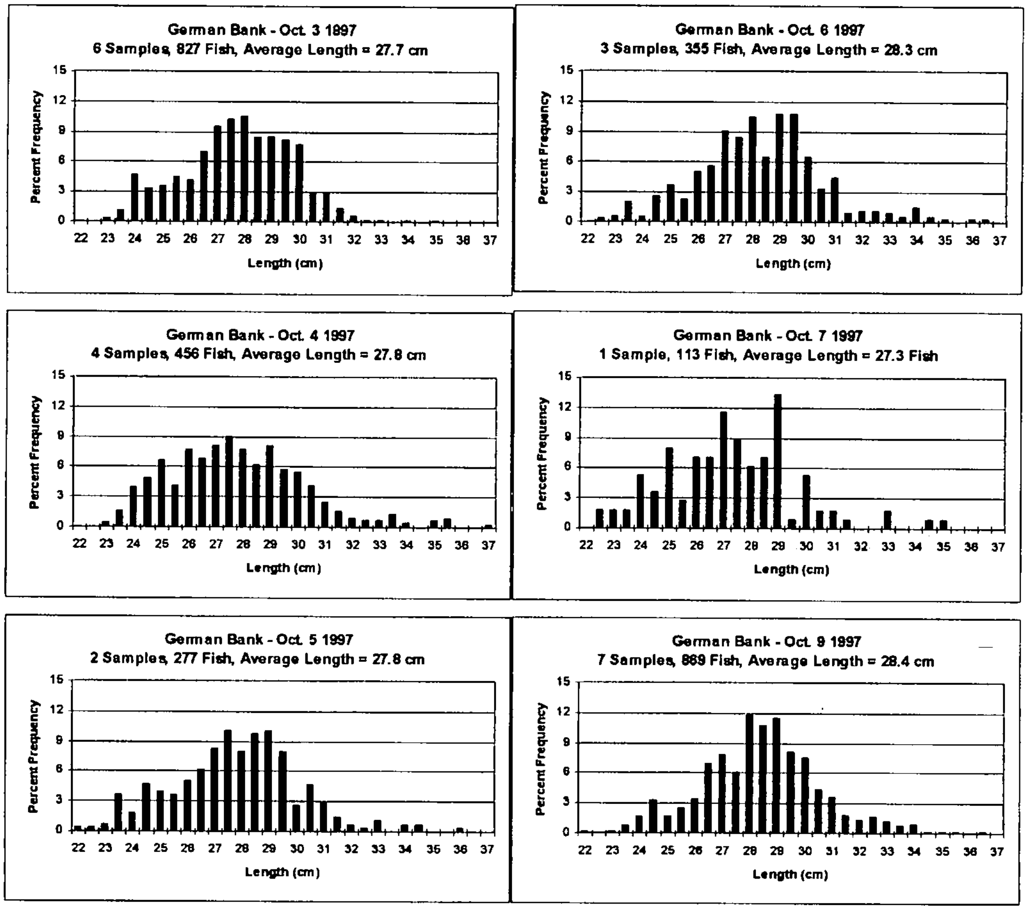


Figure 14. Length frequency of herring collected from the German Bank commercial fishery, October 3 - 9, 1997.

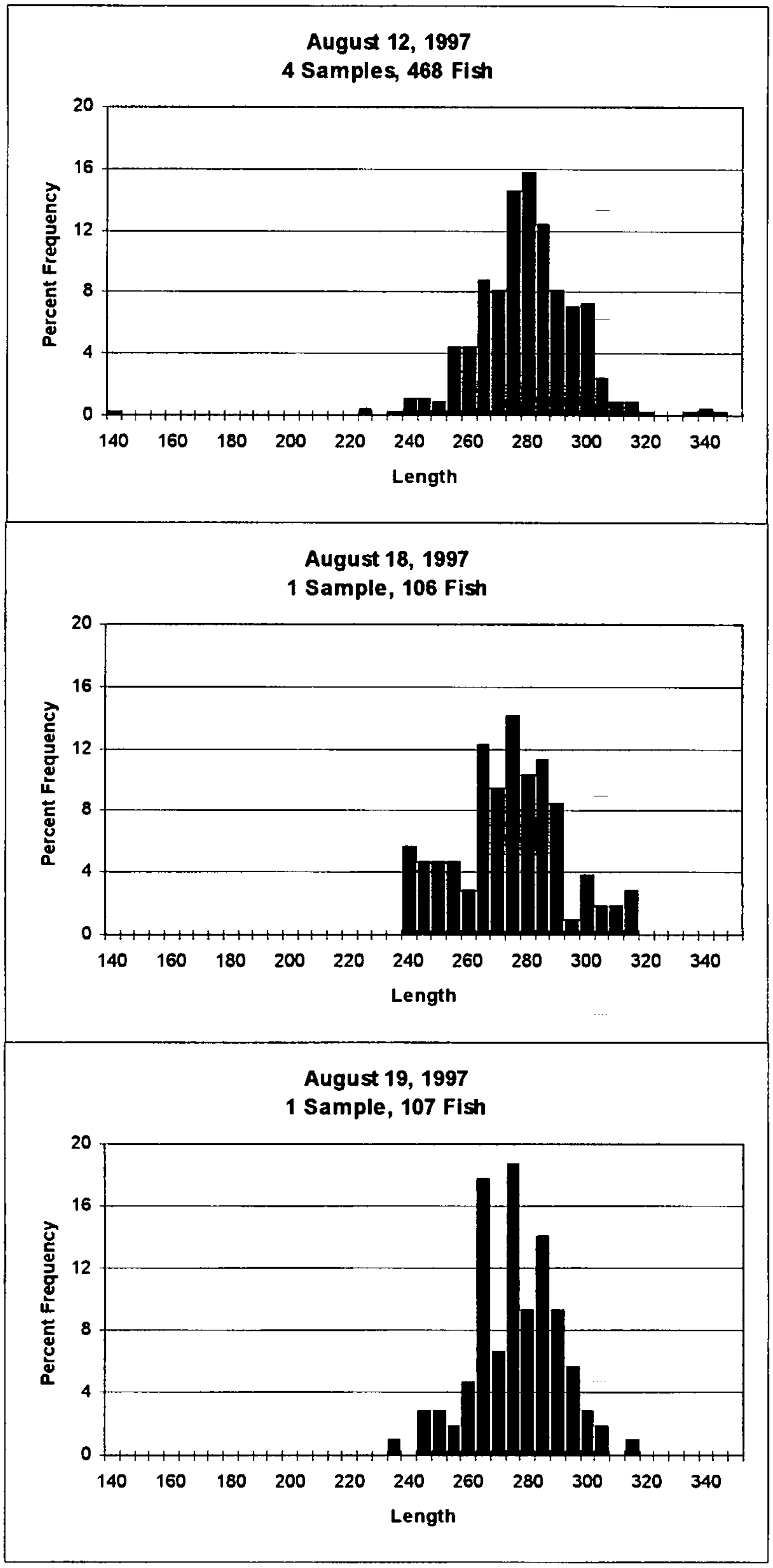


Figure 15. Length frequency of herring collected from the Scots Bay commercial fishery, August 12-19, 1997.

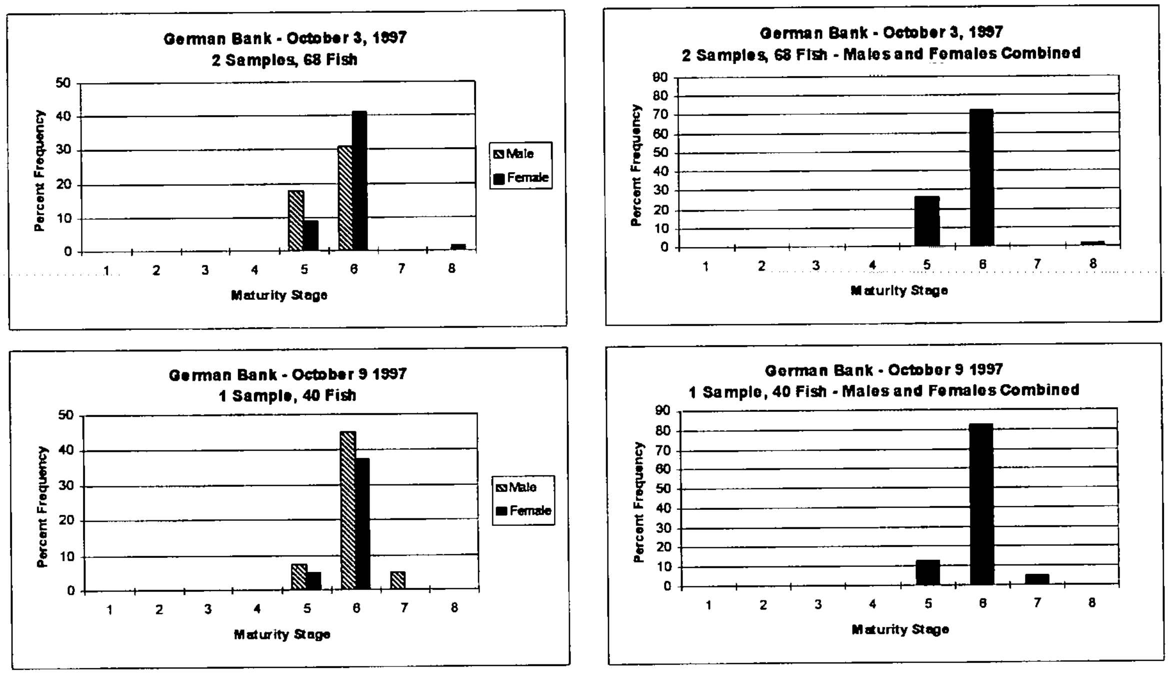


Figure 16. Maturity distribution of herring collected from the German Bank commercial fishery, October 3 and 9, 1997.

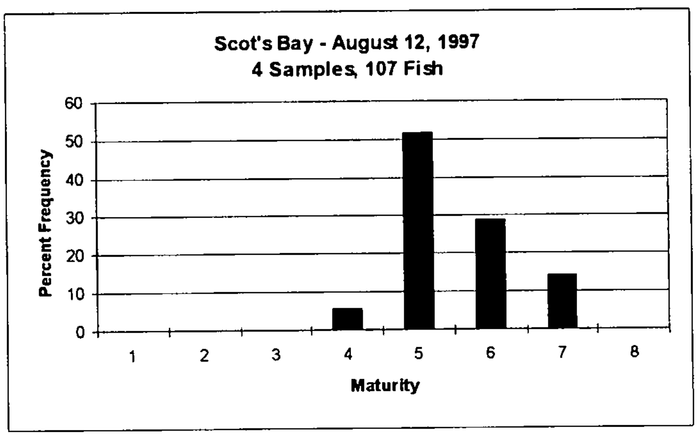


Figure 17. Maturity distribution of herring collected from the Scots Bay commercial fishery, August 12, 1997.

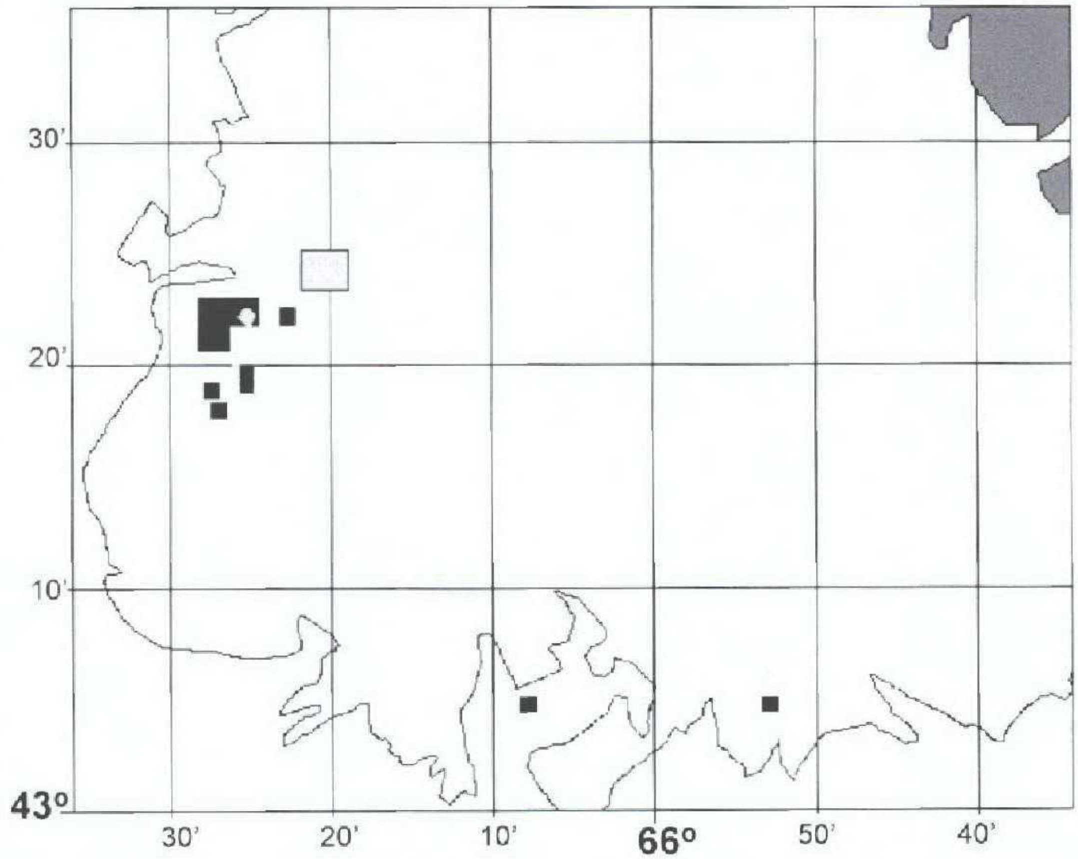


Figure 18. Acoustic surveys conducted on German Bank on the nights of October 3 (square) and October 9 (L-shape). The circles represent the locations of the seiner fishing fleet catches on October 3, whilst the squares represent catch locations on October 9.

Table 1. Summary of acoustic surveys undertaken in 1997

Scotian Shelf - East of McKenzie Spot

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
July 7,1997	Margaret E	11.89	-36.1	30.33	242.15	40,651	10,576

Long Island Shore

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
July 11,1997	Margaret E	15.86	-35.03	25.15	130	104,992	38,175

Grand Manan - North Head

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
July 21,1997	Margaret E	18.29	-34.6	23.56	103.8	101,786	38,250

Scots Bay

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
Aug 5,1997	Island Pride	540	-35.58	27.74	179.73	44,428	30,817
Aug 6,1997	Island Pride	1.23	-35.50			1,188	380
Aug 18,1997	Island Pride	9.15	-35.54	27.52	175.07	56,517	12,110
Aug 18,1997	Margaret E	10.54	-35.54	27.52	175.07	35,041	9,728
Aug 18,1997	IP&ME	17.31	-35.5	27.52	175.07	85,718	14,939

German Bank

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
Oct 3,1997	IP & ME	10.29	-35.49	27.05	165.28	215,797	37,284
Oct 6,1997	Island Pride	0.44	-35.7	28.35	193.3	7,855	1,838
Oct 8,1997	Island Pride	37.93	-35.7	28.36	193.6	82,749	11,132
Oct 9,1997	Island Pride	14.95	-35.73	28.45	195.5	194,145	33,005

German Bank - Teleost

Date	Vessel	Area (km2)	TS	Mean Length (cm)	Mean Weight (gm)	Biomass (t)	Std Err (t)
Sept 18,1997	Teleost	85.74	-35.5			1,660	327
	IP/ME	0.41	-35.5			17,624	1,434
Sept 21,1997	Teleost	1028.97	-35.48	27.20	168.6	33,078	6,065
Sept 23,1997	Teleost	124.5	-35.5			8,031	2,921