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Summary of the 2005 Herring Acoustic Surveys in NAFO Divisions 4VWX

Résumé des relevés acoustiques du hareng effectués en 2005 dans les divisions 4VWX de l'OPANO

M.J. Power[1], G.D. Melvin[1], F.J. Fife[1], D. Knox[1] and L. M. Annis[2]

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

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ABSTRACT

Automated acoustic recording systems deployed on commercial fishing vessels have been used since 1997 to document the distribution and relative abundance of Atlantic herring in NAFO Division 4VWX from industry vessel surveys and fishing excursions. In 2005 regularly scheduled surveys, at approximately 2-week intervals, were conducted on the main spawning components and the spawning stock biomass for each component was estimated by summing these results. Three structured surveys were conducted in Scots Bay, one on Trinity Ledge and three on German Bank following the established protocol. This provided good coverage of these spawning areas consistent with previous years. Additional data from fishing nights in Scots Bay and German Bank were examined. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 16,800t, 5,100t, and 211,000t for an estimated total SSB of 233,200t in the traditional survey areas, which is a substantial decrease from previous years.

Biomass estimates from surveys of the coastal Nova Scotia spawning components for the Little Hope/Port Mouton and Eastern Shore areas were also examined and showed increases from the previous year. A survey with an acoustic recorder was completed for the first time in the Glace Bay area (previous estimates were based on mapping surveys). There was again no acoustic survey effort in the Bras d'Or lakes. There were no large aggregations of herring observed and no acoustic surveys were conducted for the offshore Scotian Shelf.

RÉSUMÉ

Depuis 1997, des systèmes d'enregistrement acoustiques automatiques installés sur des bateaux de pêche commerciale servent à documenter la répartition et l'abondance relative du hareng dans les divisions 4VWX de l'OPANO, dans le cadre de relevés de l'industrie et de sorties de pêche. En 2005, on a effectué, à environ deux semaines d'intervalle, des relevés des principales composantes de reproducteurs; on a ensuite évalué la biomasse génitrice de chaque composante en additionnant les résultats obtenus. Trois relevés structurés ont été réalisés dans la baie Scots, un sur le récif de la Trinité et trois sur le banc German, selon le protocole établi. Ces relevés ont assuré une couverture satisfaisante des frayères, comparable à celle des années précédentes. Des données additionnelles recueillies durant des nuits de pêche dans la baie Scots et sur le banc German ont été examinées. Les estimations de la biomasse pour la baie Scots, le récif de la Trinité et le banc German sont de 16 800 t, de 5 100 t et de 211 000 t environ, pour une biomasse génitrice totale estimée à 233 200 t dans les zones de relevé habituelles, ce qui représente une baisse substantielle par rapport aux années précédentes.

Les estimations de la biomasse dérivées des relevés des composantes de géniteurs des côtes de la Nouvelle-Écosse pour les secteurs de Little Hope/Port Mouton et de la côte ont aussi été examinées et se sont révélées supérieures à celles de l'année précédente. Un relevé au moyen d'un enregistreur acoustique a été réalisé pour la première fois dans la région de Glace Bay (les estimations antérieures étaient basées sur des relevés par contours). Encore une fois, aucun relevé acoustique n'a été réalisé dans le lac Bras d'Or. Au large de la plate-forme Néo-Écossaise, on n'a pas observé de grandes agrégations de harengs, et aucun relevé acoustique n'a été effectué.

INTRODUCTION:

Since 1997 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 have been summed, under specific assumptions about elapsed time between surveys, to provide an annual index of the SSB for the assessment process. The development and implementation of the automatic acoustic systems represents a major improvement in quantifying fish biomass. Pre-1997 estimates relied on the experience of the observer to estimate the amount of fish from mapping surveys and are considered qualitative only (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.*, 2004; Power *et al.*, 2004, 2005a) to provide an index of spawning 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, 2004; Power *et al.*, 2003, 2004, 2005b). 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 2005 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 since 1999. The methods and procedures are well established and described in more detail in previous research documents (Melvin *et al.*, 2004, Power *et al.*, 2005b).

Data from the 2005 fishing season were obtained during both standard fishing operations and regularly scheduled structured surveys. Structured surveys were either acoustic or mapping surveys (Melvin *et. al.,* 2001). In 2005 no major changes from previous years were made to the established protocol for either acoustic or mapping surveys. The fourteen surveys scheduled for 2004 were completed on or near the tentative dates scheduled and an additional 25 fishing night surveys were examined in order 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, structured surveys were conducted in accordance with the protocol established in Melvin and Power (1999). In cases of fishing night surveys, there was improvement in the survey design with vessel captains establishing a series of parallel transects to document the fish, rather than the unorganized search pattern common in fishing operations. In addition, the trend of moving away from mapping surveys toward standardized acoustic surveys continued with mapping vessels (without acoustic recording systems) used mainly to enhance the survey coverage area. When structured surveys were undertaken, participating vessels tended to follow standard protocol and there was usually good coverage of the defined spawning survey area.

A few exceptions to the normal protocols of survey design did take place and these are explained below. Additional details for each survey situation where this took place are described with the individual surveys.

<u>Data quality issues:</u>

There were three main areas of concern with the 2005 data, surveying protocols, provision and verification of the raw data and editing, and issues of noise and interference.

There is a well defined survey protocol for structured surveys and fishing night school documentation. The 2005 structured surveys in BOF/SWNS were well executed and generally followed the established protocol. However, the coastal NS and fishing night recordings did not always follow the proscribed design. Fishing night data is typically a semi-random fishing pattern of loops and turns which is difficult to analyse. In addition it is very time consuming to extract a representative series of transects. Biomass estimates are likely biased positively and are difficult to defend scientifically. It is important to follow the protocol for surveying an aggregation of fish. Protocols for surveying schools or aggregations of fish described in Appendix A. Data collections inconsistent with established protocols were given a low priority for analysis.

A major portion of time is required to download, backup and edit the raw acoustic survey data files and in previous years DFO staff completed this task and received all “original” raw data files (unedited). More recently these tasks have been split between the Herring Science Council (HSC) and DFO with the complete raw data received at the end of the season. In 2005, all raw data was again received and compared with the edited results before the final analysis was completed. The main reason for these comparisons is to check for target uncertainty, distinguish fish from bottom and to examine interference/noise patterns. As a result of these examinations, some serious noise/interference problems were found with some vessels. In a few cases the bottom was not completely removed and some non-herring species were apparent. In the future all raw data files will be made available on a more regular basis for review prior to finalizing the acoustic biomass estimates.

Vessel noise/interference was apparent for some of the raw data files examined. The amount of noise generated by a vessel typically increases with speed and the amount and frequency of noise varies between vessels. In previous years, surveys were conducted at speeds of 5-6 knots but now they are run at up to 8-10 knots. As a result noise is becoming a problem for some boats to a point where the data are unusable. Acoustic interference or noise on a fishing vessel can come from the propeller, hydraulics, engine, other echo-sounder / sonars and general electrical systems onboard. Some serious effects of vessel speed, noise and interference may be going unnoticed in the absence of access to raw/original data files. A bias which may be positive or negative may be introduced into the biomass estimates due to this interference.

Noise levels on one vessel, the Leroy & Barry, were so extreme that the data from this vessel was excluded from most analysis. Problems were also observed with data from the purse seiners *Morning Star*, *Secord*, *Lady Melissa* and a couple of the inshore gillnet vessels. The solution for future analysis is to have raw data files made available and examined at regular intervals and at the first sign of problem the source be determined and corrected if possible. In addition, the operational vessel speed should be determined for each vessel and surveying speed limited to this. Any data files that include high levels of noise/interference should not be edited nor included in the analysis due to the time required for editing and uncertainty of bias.

Length/Weight Relationship:

Prior to 2001, the fish weight variable in the target strength (TS) equation (Table 2) 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.

The time window used to select data appropriate for individual surveys has changed slightly in recent years to provide a more representative estimate of mean fish weight. 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 prior to or after 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. 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 integration calibration factor (ICF) is deemed to provide a more accurate estimate of biomass, it was recommended that all future analyses utilize the ICF to calculate absolute biomass (Melvin et al 2004). However, when comparing observations from year to year it was recommended that the comparisons be made between biomass estimates that exclude the adjustment until a time series has been established with the ICF included. After several years only the biomass estimate with the ICF will be needed.

The following analysis presents results using both methods of calculation (with and without the ICF). Comparisons between years are made only with data calculated without the ICF since it has not yet been possible to recalculate the estimates for all years using the ICF.

Acoustic Systems:

In 2005, 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. Thirteen automated acoustic logging systems were deployed on commercial fishing vessels in 2005. Systems were installed and calibrated aboard the purse seine vessels, *Dual Venture, Island Pride, Lady Melissa, Leroy & Barry, Margaret Elizabeth, Morning Star* and *Secord* and on the inshore gillnet vessels, *Bradley K, Knot Paid For, Miss Owl's Head, Natasha Lee*, and *Sea Quiz.*

One system was also installed and tested on the herring carrier *Strathaven* based in southwest New Brunswick in Sept. 2004. This system was used in the 2005 fishing season to conduct surveys near fishing weirs in southwest New Brunswick and also participated in two of the Scots Bay surveys.

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 conducted periodically throughout the spawning season are generally scheduled at two-week intervals. These surveys play an important role in the understanding and perception of the 4WX herring stock. Sufficient flexibility is built into the process to allow for schedule changes and 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, and additional recordings were made of both spawning and non-spawning aggregations during fishing night operations.

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 in the past to document large spawning aggregations not included in a survey and/or as a substitute for a survey in the event that no other information is available. The approach to the activation of the systems has changed since the 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 from the Herring Science Council since 2002. Data from fishing nights were examined for Scots Bay, German Bank and Eastern Shore areas in 2005. All fishing night estimates were found to be lower than the nearest survey estimate for that spawning area and time period and were not used further.

RESULTS:

The spawning biomass for individual components of the 4WX herring stock complex in 2005 was estimated from industry collected data using multiple structured acoustic and mapping surveys on major spawning grounds. These surveys, when summed, provided an index of SSB and formed the foundation for evaluation of the stock status. The following text provides a summary of the 2005 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 examined are summarized for each of the main spawning areas in Table 1.

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 continues to be an issue of major concern. The current hypothesis for surveys on individual spawning grounds assumes that there is constant 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).

Sampling data for maturity supports the view of continuous spawning with high proportions of ripe and running (spawning/stage 6) fish observed over an extended period. The 10 to 12 day window also assumes that there will be no double counting and that the maturing (hard/stage 5) as well as the spawning (stage 6) fish in the samples will also have spawned and left before the next survey. The proportion of maturing (hard/stage 5) fish appeared to be less on German Bank than in Scots Bay. It is also noteworthy that spent fish are rarely captured even with the intensive daily sampling that is done. This is substantiated by fishermen's reports of the spent fish leaving the spawning grounds very quickly after spawning and rarely being caught.

In 2005, herring maturity data were again obtained from two primary sources: 'Roe Analysis Data Sheets' from the Scotia Garden Seafood 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 weights 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 8

(Parrish & Saville, 1965) but the roe data can be compared with SABS data based on knowledge of the two comparative methods (Table 3).

The SABS biological samples provide data on individual fish for length, weight, sex, maturity stage, gonad weight and age. These samples are collected from various sources including research surveys, tagging trips and acoustic surveys and from landings at various plants. For comparison with the industry categorization, data by maturity stages were grouped such that stages 1-3 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 which are based on gonad weight. SABS samples were combined for female fish by day and percent numbers and percent weight by the categories determined.

'Roe Analysis Sheets' from 4 Scots Bay samples were provided by Scotia Garden Seafood from Aug. 22 to Aug 25, 2005 (Figure 2), while SABS maturity data were available for 24 samples from July 28 to Sept. 9 (Figure 3). Fish were confirmed to be in mature condition for all samples throughout this period but the proportion of spawning fish (stage 6) was quite variable from day to day ranging from about 10 to 100%. This is a typical pattern for the Scots Bay spawning area and has been seen in previous years (Melvin et al, 2004).

Scotia Garden Seafood also provided 'Roe Analysis Sheets' for 9 German Bank samples over a 36 day period from Aug. 30 to Oct. 5, 2005 (Figure 4). SABS maturity data were available from this area for 14 samples from Aug. 7 to Oct. 11 (Figure 5). The samples again confirmed the absence of immature/non-spawning fish with the proportion of spawning fish (stage 6) at about 90% which is typical for the German Bank area during the spawning fishery (Melvin et al, 2004).

Spawning ground turnover rates

The current acoustic survey method on spawning grounds is dependent on the assumption of periodic turnover of spawning fish on the spawning grounds. Acoustic surveys are required to be separated by at least 10 to 14 days to allow for turnover and to prevent double counting (Power et al. 2002). This aspect of the assessment method was the subject of investigation in 2001 and of intensive sampling for maturity stage since that fishing season. The results and application to the acoustic surveys are summarized by Melvin et al. (2002a, 2003, 2004, Power et al. 2005a) and were used to assist in the evaluation of turnover timing and the inclusion or exclusion of specific acoustic surveys.

From 1998 to 2002, the Pelagics Research Council/Herring Science Council, in partnership with Fisheries and Oceans Canada, tagged herring on spawning grounds and on the major Nova Scotia over-wintering grounds. Although this project has concluded, tags continue to be returned. The information on tags returned from this study has been summarized by Waters and Clark (2005). Evidence from tagging experiments conducted in 1998 of ripe and running (spawning) herring showed that the residence time for most returns on the same grounds was less than 7-10 days, however 25% of returns were captured on the same grounds after more than 10 days at large (Paul, 1999). In contrast, a similar experiment in September 2001 on German Bank showed no recaptures after nine days on the same grounds during the same spawning season (Power et al. 2002). This latter result was complicated by a large decrease in fishing effort (and thus returns) during the second week after tagging.

In response to a recommendation from the 2005 RAP, tags were applied to herring on the spawning grounds of Scots Bay and German Bank (Clark, 2006). The results from the tag returns indicated that some tagged herring remained on the spawning grounds for at least 3 weeks after tagging, and in some cases, up to five to six weeks after tagging. Thus, acoustic surveys that were spaced at 2 week intervals were surveying some of the same fish twice or possibly even 3 times.

These results have serious implications in how the acoustic surveys are evaluated and used to determine stock status. Some preliminary analysis has been completed comparing three different approaches for the interpretation of the acoustic biomass estimates in an absolute sense (Appendix B). The results showed that caution is warranted when employing the cumulative biomass estimates as absolute in any of the survey areas. How these results are interpreted and what approach future assessments utilize will be addressed at the framework assessment meeting scheduled for January 2007. In the interim, the current practice of summing all survey biomass estimates which are separated by 10-14 days will be used for this report.

Scots Bay:

The Scots Bay herring purse seine fishery is an important component of the summer fishery with catches since 1987 ranging from 1,000 to 24,400t during the period of early July to late August-early September (Table 4, Figure 6). The 2004 fishery was unusual in several aspects, with the highest recorded catch of 24,388t and the longest season thus far extending to Sept. 16. The distribution of catches in 2004 was also more widespread extending both north and east of the innermost strata survey area (Figure 7). In 2005 the overall catch was reduced to only 5,870t and was limited to areas more to the north and east of the main survey area. The fishing season also started later and was of shorter duration than in previous years (Figure 8).

Three structured surveys were conducted during the 2005 spawning season in Scots Bay between July 31 and Sept. 11 (Table 5). The surveys which began slightly later than in recent years, were separated by three week intervals and continued later into September (the first survey was on July 16 in 2001). In addition to the acoustic recordings, visual observations from the sounder were recorded at

5 to 10 minute intervals on deck sheets during each survey. Fish samples collected indicated that mature spawning herring dominated samples collected on or near the dates of the three surveys (Figure 2, 3), while very few immature herring were collected from Scots Bay spawning grounds during the survey period. Overall, the Scots Bays surveys generally followed the protocol and provided good coverage of the spawning area on the survey nights that were completed. Data from four fishing nights in Scots Bay were also analyzed, but none were used in the final overall estimate of SSB (Table 6).

The fishery in Scots Bay was complicated by the unavailability of the Digby Wharf to offload herring in 2005. This difficulty resulted in fewer vessels being active in Scots Bay and therefore there was less information about Scots Bay spawning aggregations. In addition there were not as many vessels involved in the first and third surveys. The seiners first fished in Scots Bay on the week of July 24, one week later than the previous three years and two weeks later than the year before that. The main reason for the delay was good fishing in other areas, and also a lack of incentive to steam to Scots Bay due to the Digby Wharf situation. Thus the first normally documented early spawning wave may have been missed. It was noted by industry that if a two week survey schedule had been maintained a fourth survey could have also occurred.

Scots Bay survey #1: July 31, 2005

The first herring acoustic survey in the Scots Bay area for 2005 took place on July 31 with a total of four vessels including three purse seiners and one herring carrier equipped with an acoustic recording system. Lines were selected randomly and started about 1.5 miles off of the Nova Scotian shore. Observations were recorded on deck sheets at 10 minute intervals or when entering and exiting a school of fish (Figure 9). The acoustic transects were well done with six transects covering the survey area (Figure 10).

The general consensus from the survey captains was that there was not much fish around because a turnover of spawning herring had just occurred. Recent gonad maturity samples (Figure 3) support this view showing considerable variability with a high proportion of stage 7 (65% spent) on July 28, a mixture of stage 5 and stage 6 (45% hard, 42% spawning) on July 29 and a large proportion (74%) in spawning condition on August 2. The lack of any successful sets after the survey was due to several factors including the late time when the survey finished, one vessel with a lack of full crew, and fish not available for setting. Samples from fishing sets before and after the survey were used in the calculation of target strength (Figure 11).

Several files were re-edited to remove obvious interference and general background individual targets. Some vessels had excessive noise and interference and were very difficult and time consuming to edit. Other vessels had generally good acoustic recordings with little noise. The final biomass estimate for this first survey was 9,430t (without the ICF).

Scots Bay survey #2: August 21, 2005

The second herring acoustic survey of Scots Bay in 2005 took place on the evening of August 21 with twelve vessels participating (Figure 12). There were eleven vessels given lines and a "floater boat" assigned to document larger schools and areas of fish not covered by the main survey. The data was downloaded from the six boats with acoustic recorders and was edited with removal of bottom and of non-herring targets. The acoustic data for the main survey vessels was then cut into transects and showed an aerial coverage of 740 km^2 (Figure 13). The five acoustic transects provided excellent coverage but the speed was likely too fast. On re-analysis of the data the removal of a small section of bottom as well as some small weak unknown targets resulted in a significant reduction in backscatter or signal return. Data from the 'floater boat' was analyzed separately with a school of fish found between the survey lines (Figure 14). The survey estimate for the overall area including the school between lines was 6,332t with a standard error of 35% (Table 5).

Gonad maturity samples available from SABS (Figure 3) and industry sources (Figure 2) show a mixture of stage 5 (hard) and stage 6 (spawning) with slightly declining trends for stage 6 (spawning) for the period from Aug 15 to Aug 25. There was no significant maturity change (i.e. possible evidence of turnover) as seen in the previous survey period near July 31. Daily length frequency samples showed an increase of larger fish (300mm and up) between August 19-21 as well as a mean size increase from 257mm to 273mm. Length samples from landings on August 21-22 were used for the overall survey mean length and in the calculation of target strength (Figure 15). Length-weight data for the period Aug. 15-24 provided sufficient numbers for regression analysis used in the calculation of target strength.

Scots Bay survey #3: September 11, 2005

A total of five vessels participated in the survey including one purse seiner and one herring carrier each equipped with a recording computer. Due to the small number of boats participating in the survey, it was necessary for each boat to run two lines. However, weather conditions deteriorated as the night went on and it was unsafe for all boats to finish their 2nd line, as winds increased to 35kts from the southwest. The survey ended at approximately midnight after covering an area of about 450 km^2 (Figure 16). The lack of any successful sets after the survey was due to very poor weather conditions.

The data was downloaded from the two boats with acoustic recorders. After editing to remove bottom and non-herring targets the acoustic data was cut into transects showing a smaller aerial coverage of 315 km2 than that of all boats combined (Figure 17). There were only thin scattered small bunches of herring recorded, mostly on the western end of the lines. The survey estimate using the overall area of 450 km^2 calculated ‘without’ the calibration integration factor was 1,083t with a standard error of 50% (Table 5).

Daily length frequency samples since the date of the previous survey (August 21) showed little trend in the recent period with a similar size range and mean size around 260mm. Since there were no biological samples available from this area on the survey night, data was selected from September 8-9 for the analysis (Figure 18). Length-weight data from Scots Bay for the period August 15-24 were used in the calculation of target strength.

Fishing night acoustic data from Scots Bay were examined for four nights where sufficient data for estimation of biomass was collected (Table 6). Biomass estimates from five fishing nights between July 26 and August 24 were analyzed with preliminary biomass estimates ranging from 490t to 2,000t. All of these estimates overlapped survey nights in the ten day spawning timing window and were lower in total SSB than the formal surveys.

In summary, the 2005 Scots Bay acoustic survey SSB estimated from the three structured surveys using the calibration integration factor was 21,200t (Table 5b). The 2005 SSB estimate of 16,800t without the integration factor can be compared to data calculated in a similar manner for previous years (Table 5a). The SSB follows a continued decline since the high of 2001 and it is well below the 1999-2005 average of 101,500t.

German Bank:

The German Bank herring purse seine fishery is usually the major component of the summer fishery with catches since 1985 ranging from 9,000 to 36,000t during the entire fishery period of early May to late October (Table 7). Catches during the spawning period defined from August 15 to October 31 have been near 20,000t since 1995 but the 2004 and 2005 catches only amounted to 12,000t for the main strata survey area (Figure 19). Daily catches in 2004 were also reduced compared to previous recent years with a shorter period of sustained activity than is normally seen from mid-August to the end of the quota year (Figure 20). The amount of catch in the spawning period has remained around 60 to 70% of the overall German Bank catch (Table 7, Figure 21).

Three surveys were conducted during the 2005 spawning season on German Bank between September 7 and October 4 (Table 8). The first survey began about 1 week later than in previous years and the last survey took place about 1 week before the end of the fishing season on October 15. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets. Fish samples, while limited in early September, indicated that mature spawning herring dominated samples collected on or near the dates of the three surveys (Figure 4, 5). Overall the German Bank surveys were well conducted and provided good spatial coverage of the spawning area but were again limited in temporal coverage at the beginning and end of the expected spawning period.

Fishing night acoustic data for German Bank were examined for fourteen nights between August 28 and October 11 where sufficient data for estimation of biomass were collected (Table 9). Biomass estimates from these fishing nights ranged from 2,370t to 45,780t. An additional mapping survey report was analyzed and estimated at 62,000t. 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.

German Bank Survey #1: September 7, 2005

The first survey of German Bank was conducted on September 7, 2005 with ten herring purse seiners participating including 5 with acoustic data recorders. All vessels completed two lines and following the designated survey plan. Several good areas of abundance were noted during this survey with fish observed close to bottom and of medium to high density. The vessel on the 66° 20.5 line of longitude (*Lady Melissa*) noted that fish were seen by vessels on either side on the way down the line. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets and later coded to represent these observations (Figure 22).

The data were downloaded from the 5 boats with acoustic recorders. The acoustic data from the *Leroy and Barry* was found to be unsuitable due to the large amount of interference and these transects were removed from the analysis. After editing to remove bottom and non-herring targets the acoustic data was then cut into transects and showed an aerial coverage of 710 km^2 (Figure 23). Herring were recorded acoustically primarily along 3 of the 8 available transects, mostly in the central to northern portion of the survey area (Figure 24). Length samples from landings on September 7-8 were used for the overall survey mean length and in the calculation of target strength (Figure 25). Industry supplied length-weight data from September 7-8 provided sufficient numbers for regression analysis used in the calculation of target strength. Gonad maturity samples available from industry sources showed a high proportion (98%) of stage 6 (spawning) for herring landed on Sept. 8 confirming that spawning was occurring (Figure 4, 5). The survey estimate calculated 'without' the calibration integration factor (comparable to previous years) was 74,900t with a standard error of 55% (Table 8a).

Silver Harvester deck sheet: September 14, 2005

On September 14, 2005 the *Silver Harvester* documented a large area of fish in the German Bank area with positions to record the overall extent of the aggregation. There were detailed observations including the comments:

> *'Fish inside the area described were anywhere from 2 fathoms thick from bottom up (medium thickness) to 15 fathoms thick from bottom up (heavy thickness). As far as we could tell, the fish were unbroken in their coverage of bottom.*

A lot of fish are very ripe. This bunch of fish came in this week and I don't think they will stay until the survey next week. The fish may have reached further but were in this area for sure.'

Since there is no record of an acoustic recording of this area of fish the only alternative to estimate the amount of herring is to use the standard mapping approach. The data was plotted and contoured using three estimates for the data provided a) all points were considered low density (biomass of 200t/km^2), b) all points were considered medium density (biomass of 1000t/km^2) or c) all points were considered high density (biomass of 4000t/km^2) as shown in Figures 26. The area of fish aggregation was estimated as 62.1 km^2 and includes recent catches both inside and outside this area. These analyses gave a range of biomass values of 12,410t, 62,000t and 248,200t respectively. Without further confirmation using acoustics it will be difficult to support replacing biomass estimates already recorded for the structured surveys on September 7 and September 21. Fishing night acoustic data for the nights of September 13-14 were examined and had biomass estimates near 40,000t which was less than the adjacent surveys (Table 9).

German Bank Survey #2: September 21, 2005

Eleven herring purse seiners including seven vessels with acoustic recording units participated with Jay Lugar from the HSC attending. The survey started around 8:30pm at the 43° 34 line of latitude, with the boats lining up about 0.50 to 0.75 nautical miles apart. All the vessels completed two lines following the designated survey plan. In addition to acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets and later coded to represent these observations. The deck sheets showed herring schools were observed in abundance in the north central as well as in the northwest corner of the survey area (Figure 27).

The data were downloaded from the seven boats with acoustic recorders. There was a problem with the data from the *Margaret Elizabeth* which was missing GPS location data but this was adjusted using the deck sheet record of location. After editing to remove bottom and non-herring targets the acoustic data was then cut into transects and showed an aerial coverage of 600 km^2 (Figure 28). The acoustic data from the *Leroy and Barry* was again found to be unsuitable due to the large amount of interference and these transects were removed from the analysis. Herring were recorded with densities of greater than 0.2 kg/m^2 along 4 of the 12 remaining transects in the north-central and north-western parts of the survey area. Length samples from landings on September 20-22 were used for the overall survey mean length of 27.2cm and in the calculation of target strength (Figure 29). Industry supplied length-weight data from September 20-22 provided sufficient numbers for regression analysis used in the calculation of target strength. A gonad maturity sample available from industry showed a high proportion (100%) of stage

6 (spawning) for herring landed on September 22 confirming that spawning was occurring.

The survey biomass estimate with all available transects given equal weighting and calculated ‘without’ the calibration integration factor (CIF) for comparison to previous years was 99,520 with a standard error of 43% (Table 8).

It is noteworthy that the intensity of coverage and number of recording boats in this survey was the most complete and highest yet completed on German Bank over the nine year history of surveying since 1997.

<u>German Bank Survey #3: October 4, 2005</u>

The third survey of German Bank in 2005 was conducted with eight herring purse seiners including five vessels with acoustic recording units and with the captains organizing the survey on the water. The survey started around 8:00pm at the 43° 34 line of latitude, with the boats lining up about 0.75 nautical miles apart. All the vessels completed two lines following the designated survey plan. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets and later coded to represent these observations (Figure 30).

The data were downloaded from four of the five boats with acoustic recorders. There was a problem with the recording system on the *Morning Star* and no data was available from this boat due to a mouse/GPS program conflict. The acoustic data from the *Leroy and Barry* were again found to be unsuitable due to the large amount of interference and these transects were removed from the analysis. After editing to remove bottom and non-herring targets the acoustic data was then cut into transects showing an aerial coverage of 500 km^2 (Figure 31). Herring were recorded with densities of greater than 0.1 kg/m^2 along two of the eight available transects with fish recorded in the north-central and south-central parts of the survey area.

Daily length frequency samples since September 20 showed a consistent range and mean size in the recent period. Length samples from landings on Oct. 4-5, with an overall survey mean length of 27.4cm, were used in the calculation of target strength (Figure 32). Industry supplied length-weight data from Oct. 4-5 provided sufficient numbers for regression analysis used in the calculation of target strength. A gonad maturity sample available from industry showed a high proportion (100%) of stage 6 (spawning) for herring landed on Oct. 5 confirming that spawning was occurring.

The resulting survey biomass estimate with all available transects weighted by distance covered and calculated ‘without’ the calibration integration factor (CIF) (for comparison to previous years) was 36,500t with a standard error of 71% (Table 8).

In summary, the overall spawning stock biomass (without the integration factor) for German Bank in 2005 was estimated as 211,000t from three structured surveys (Table 8) extending from September 7 to October 4. The elapsed time between all surveys was greater than the 10-14 day guideline and in this analysis the turnover of spawning fish was assumed to be 100%. One concern was the lack of a structured survey after October 4 when fishing activity took place and for which there were also good indications of spawning fish from sampling for maturity.

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 2004, no fishery took place and no spawning herring were caught during May and June. In 2005, a single survey of the Spectacle Buoy area was undertaken on June 6. The survey tracks for the *Sea Quiz* in June 2005 for files recorded near the Spectacle Buoy area are shown in Figure 33. The acoustic survey data were edited and cut into transects and had an estimated total survey area of 0.57 km^2 (Figure 34). The survey biomass result was 292t with a standard error of 33% without the CIF or 616t with the CIF (Table 10).

Trinity Ledge:

As in previous years, the surveying of spawning herring in 2005 on Trinity Ledge continued to be less than optimal and it is unlikely that biomass estimates accurately reflect the abundance of fish in this 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 2005 surveys on Trinity Ledge ranged from 0.7 km^2 to 6.0 km^2 in a potential spawning area of 200 km^2.

The only structured survey of Trinity Ledge was carried out on September 6, 2005 by eight herring gillnet vessels including one with an acoustic recording system (*Sea Quiz*). The herring survey deck sheet observations for September 6, 2005 with results from 8 boats showed as small area of coverage (Figure 35). Acoustic survey transects and estimated total survey area of 0.82 km^2 for Trinity Ledge on September 6, 2005 by *Sea Quiz* are shown in Figure 36. One herring gonad maturity sample available from September 7, 2005 (% by stage for sexes combined) and showed 83% in ripe and running condition and 17% in pre-spawning hard stages (Figure 37).

The overall SSB estimate for Trinity Ledge spawning component in 2005 was 5,070t without and 10,700t with the use of the calibration integration factor (Table 11).

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 on September 15 and it was estimated that the vessel observed 12,150t of herring, a marked increase from previous years. In 2004 there were no surveys or fishing night analyses. It was suggested that some effort should take place in this area in future years in order to document spawning occupation on these grounds. There were no surveys or fishing night analysis undertaken for Seal Island in 2005.

Browns Bank :

No surveys or fishing night analysis were undertaken for Brown's Bank in 2005.

BAY OF FUNDY/SW NOVA SUMMARY:

These results are considered to provide a reasonable estimate of herring present at the time of surveying when conducted according to the survey design. A major source of uncertainty continues to be the assumption that the surveys are simply additive. If herring do not move on to and off of the spawning grounds in waves, the estimate of total SSB will be significantly biased upward due to double counting. The issue of turn-over time and potential overlap (repeat counting) is to be evaluated further at the next Regional Advisory Process (RAP) meeting scheduled for March 2006.

Since 1997, 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 1999 spawning areas were defined and survey protocols were established to make the estimates more representative of the actual SSB rather than a minimum observed value. This was accomplished by undertaking a series of surveys that covered most of the spawning area on each of the spawning grounds during the defined spawning season.

In the absence of survey data fishing excursion data may be substituted as appropriate. 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. Given the changes that have occurred over time the estimated SSB prior to 1999 should not be compared with those reported since that year.

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% between the acoustic estimate and the biomass removed from the weir by seining. Finally the variance in individual survey estimates as provided in the 2005 tables (SE or standard error) ranged from 16 to 70% and depended on both survey design and the actual variance in Sa observed by transect. Thus differences observed between areas from year to year are often not statistically significant (Figure 38).

In 2005, the total SSB for the Bay of Fundy/Southwest Nova Scotia spawning complex was estimated to be 233,200t, a large decrease from the previous year (Table 12, Figure 38, 39). The SSB for Scots Bay was down substantially and is of major concern, especially in light of the increased effort and landings for this area in recent years. German Bank also had a large decrease with only three structured surveys over a limited time period. Estimates of spawning biomass on Spectacle Buoy, Trinity Ledge and Seal Island were low partly due to lack of survey effort.

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 the fall 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, 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 has been variable since 1999 but improved in 2005 with two well conducted surveys. One deficiency was the lack of a multi-panel gillnet sample using a variety of mesh sizes to provide a good estimate of the overall size distribution of all herring surveyed.

Little Hope/Port Mouton herring survey #1: October 4 , 2005

The first herring survey of the Little Hope/Port Mouton area for the 2005 season was conducted on October 4. Eleven herring gillnet vessels participated, including one vessel with an acoustic recording unit. The survey started around 9:45pm with the boats lining up about 0.25 to 0.50 nautical mile apart and ended around 2:00am after all vessels completed lines for the designated survey plan. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets and later coded to represent these observations (Figure 40). The deck sheets had a total aerial coverage of about 200 km^2 and showed herring in abundance mainly for one school south of Little Hope Island.

The data were downloaded from the fishing vessel, *Knot Paid For*, with the acoustic recording system. After editing to remove bottom and non-herring targets the acoustic data were cut into transects for the main area of fish (Figure 41). Surveys of the one major school of fish were done with a series of equally spaced parallel lines in either north to south or east to west directions with separate analysis for each direction. Additional survey lines were also completed to the north and south of this school but few fish were observed in these areas. These lines were used for estimation of herring outside of the main school area. The total biomass was calculated from the largest of the three separate passes on the main school added to the biomass for the rest of the survey area.

Industry samples for maturity reported all herring in ‘ripe and running’ spawning condition (Figure 42). Length samples available from the herring gillnet fishery for October 4-7 had a mean size of about 30cm and a range from 26 to 34cm (Figure 43). These were not suitable for calculation of target strength because of the limited size selection using a single mesh size. A multi-panel gillnet using various mesh sizes to sample for length was planned but this data was not collected.

The survey estimate calculated ‘without’ the calibration integration factor, which is comparable to analysis done in previous years, was 19,600t with a standard error of 34% (Table 13a). The survey estimate calculated ‘with’ the calibration integration factor (used in the most recent three years) was 22,220t with the same standard error (Table 13b).

Little Hope/Port Mouton herring survey #2: October 19 , 2005

The second herring survey of the Little Hope/Port Mouton area for the 2005 season was conducted on the night of October 19. Twelve herring gillnet vessels participated, including one vessel with an acoustic recording unit. The deck sheets had a total aerial coverage of about 135 km^2 and showed herring in abundance mainly for one school south of Little Hope Island (Figure 44). Industry samples for maturity reported most (78%) herring in 'ripe and running' spawning condition but also had some hard (16%) and spent roe (6%) (Figure 45). Length samples available from the herring gillnet fishery for October 4-21 had a mean size of about 30cm and a range from 26 to 34cm (Figure 43). These fishery length data were not suitable for calculation of target strength because of the limited size selection using a single mesh size. A multi-panel gillnet sample for length was planned during the survey but was not taken and thus standard target strength for a 28cm herring was used for this analysis.

The data were downloaded from the fishing vessel, *Knot Paid For*, with the acoustic recording system (Figure 46). After editing to remove bottom and non-herring targets the acoustic data were cut into transects for the main area of fish (Figure 47). Survey lines completed to the northeast in the area of the previous survey on October 4 were estimated separately with an area of 7.48 km^2 and showed a biomass of only 324t. Lines completed outside of the main school of fish were used to estimate the biomass in the outer areas using the overall area from the mapping results. Very little fish were seen acoustically in these outer regions with a biomass estimate of only 41t in an area of 125 km^2.

Surveys of the one major school of fish in the southwest were done with a series of equally spaced parallel lines in either north to south or east to west directions with separate analysis for each direction (Figure 47). The total biomass was calculated from the larger of the two separate passes on the main school added to the biomass for the northeast area plus biomass for the rest of the outer survey area. The overall survey estimate calculated 'without' the calibration integration factor, which is comparable to analysis done in previous years, was 19,850t with a standard error of 28% (Table 13a).

The final total 2005 SSB estimate (using the ICF) for the Little Hope area based on the mapping and acoustic surveys was 44,700t from the sum of the October 4 and October 19 surveys combined.

Eastern Shore: September 28-29, 2005

Herring catches for the Halifax/Eastern Shore area for the period September 19 to November 16, 2005 showed a wide distribution with 3 main areas of fishing (Figure 48). The first survey of the Halifax/Eastern shore area was done on September 28, 2005 with survey deck sheet observations showing widely distributed fish (Figure 49). Search tracks by acoustic survey vessels *Bradley K* (blue upper line) and *Miss*

Owls Head (green bottom line) for September 28-29 survey night showed fish only in a few areas (Figure 50). The overall biomass estimate for the night of September 28 was 16,300t (with the ICF).

Eastern Shore: October 3 , 2005

Subsequent to the September 28 survey a better abundance of spawning herring was observed on October 3 with an acoustic survey completed by the two vessels with systems. Surveys of two major schools of fish, one off Halifax Harbour and one south of Jeddore, were done with a series of equally spaced parallel lines (Figure 51) in either north to south or east to west directions. After editing to remove bottom and non-herring targets the acoustic data was then cut into transects. The excellent pattern of lines on the schools of fish allowed for easier and more accurate estimation of biomass (Figure 52).

A multipanel gillnet herring sample using 4 different mesh sizes from 1.5” to 2 5/8” taken on September 30 from the same area of the survey was used for the calculation of target strength (Figure 53). Maturity samples from September 30 to October 5 showed a change to a large proportion at the ripe and running stage (Figure 54, 55) but this is not significant in the analysis due to the large difference in time and space between the surveys used for the overall biomass.

The survey estimate calculated ‘without’ the calibration integration factor (comparable to previous years) was 25,160t with a standard error of 18% (Table 14a). The survey estimate calculated ‘with’ the calibration integration factor (used in the most recent two years) was 33,240t with a standard error of 18% (Table 14b). These estimates are based on the multi-panel sample for target strength with adjustment for sounder frequency.

Eastern Shore: October 31 , 2005

Between October 4 and the end of the season there were a number of surveys and fishing operations completed but none were of major significance until the last few nights (Table 14). These data for October 30-31 were analyzed from start to finish independently by both M. Power (DFO) and by Allen Clay (FEMTO electronics). The data for the night of October 31 for a school of herring south of Owls Head was found to be of higher biomass and was used in the overall estimate. Survey tracks were completed in both a north/south and east/west directions (Figure 56, 57).

The initial analysis was completed by A. Clay (FEMTO electronics) and a revised analysis by M. Power (DFO) including a complete re-edit, re-cut of all transects re-calculation of the areas and new biomass estimates which follow (Table 14). The new biomass for Oct. 31 using DFO edits was 3,710t. The original result by Clay was 4,461t which is a decrease of 17%. In comparing the two analyses it is found that the areas and transects used were very similar (within 0.01 km^2) so this was not the obvious cause of the difference. It was found, however, that Clay's edits were less conservative near bottom with some bits of dense returns at the lower margins. Clay's transects were re-edited for high intensity returns and a final adjustment was made by applying the remove low noise (-75db) and noise filter on Clay's lines. This new estimate of 3,702t was virtually identical to the DFO estimate. The intent was not to get identical results but have comparable analysis by different experienced people on the same set of data. These results show the difficulty in editing schools which are continuous with the bottom. The data need to be carefully examined and the final results qualified as a minimum estimate with a range of error as described.

The final 2005 SSB estimate (using the ICF) for the Eastern Shore/Jeddore area based on the October 3 and October 31 acoustic surveys was 36,950t (Table 14).

<u>Glace Bay:</u>

In September 2004 an acoustic recording system was installed on the herring gillnet vessel *Natasha Lee* based out of Glace Bay, N.S. Initial test recordings were completed but problems were encountered with the system power supply which resulted in fragmented data files. These difficulties were not resolved in time for the spawning fishery which took place during October 2004 with a total of 1,480t of spawning fish landed. As a result of the lack of mapping or acoustic survey data there was no estimate of spawning stock biomass for the Glace Bay area in 2004.

<u>Glace Bay herring acoustic survey #1: September 20, 2005</u>

This was the first herring acoustic survey of Glace Bay in 2005 with one survey vessel (*Natasha Lee*) with an acoustic recording system participating. There were also other herring gillnet vessels fishing and searching in the same area which helped to define the search area northwest of Glace Bay.

There were no suitable length samples available from landings for the overall survey mean length and in the calculation of target strength. In any case, a sample from a multi-panel net with various mesh sizes would be required to properly estimate the total size range of herring surveyed. As a result the standard target strength value for a 28cm herring was used with an adjustment for the sounder frequency.

The data was downloaded from the *Natasha Lee* and then edited with removal of bottom and of non-herring targets. There were some problems in processing the raw data due to numerous errors in the navigation fixes. These were removed using the interactive routines in the HDPS acoustic software. The survey was also difficult to analyze due to the various loops and turns made while searching for herring. In the future the analysis and results would be easier if a grid pattern of straight and parallel lines in two directions were completed (Appendix A)

The acoustic data was then cut into transects and showed an aerial coverage of 0.35 km2 (Figure 58). The survey estimate calculated 'without' the calibration integration factor (comparable to previous years) was 2,067t with a standard error of 15% (Table 15).

Glace Bay herring acoustic survey #2: October 6, 2005

The second herring acoustic survey near Glace Bay took place on Oct. 6, 2005 with one survey vessel *Natasha Lee* (Figure 59). There were no length samples available from landings for the overall survey mean length and in the calculation of target strength. The data showed an aggregation of herring in an area northeast of the previous survey on September 20 including good indications along a track to the southeast with density of higher values than seen in the school area. However, there were no lines across this group to indicate overall area and it was difficult to analyze and was not used in the total. The overall estimate for this night was 1,110t with a standard error of 26% (Table 15b).

The final 2005 SSB estimate (using the ICF) for the Glace Bay area based on the September 26 and October 6 acoustic surveys was 3,180t (Table 15b). The results without the integration factor are also presented for the record (Table 15a).

Bras d'Or Lakes:

In 2005 no surveys were conducted to document the abundance of spawning herring and no biological data were collected in the Bras d'Or Lakes. The last mapping survey was conducted in 2000 and documented only 70t.

OFFSHORE SCOTIAN SHELF COMPONENT:

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf have varied between 1,000 and 20,000t since 1996 with landings of 5,263t in 2005. 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 again no fall herring research survey on the Scotian Shelf using the research vessel CCGS *Alfred Needler*.

SOUTHWEST NEW BRUNSWICK ACOUSTIC SURVEYS

On September 9, 2004, FEMTO Electronics Ltd. installed the HDPS Model DE9320 SN 24100 acoustics system on the herring carrier vessel, *Strathaven*. The system was calibrated and tested. The *Strathaven* used this system to record preliminary observations of herring schools while on its regular runs to pick up fish from herring weirs between September 10 to October 3, 2004.

The system was recalibrated in the summer of 2005 and the *Strathaven* continued to collect acoustic information. The collected data files were downloaded from the system aboard the *Strathaven* and analyzed using HDPS software by Fundy Weir Fishermen Association (FWFA) personnel in partnership with DFO Science.

In 2005, weir landings declined significantly, decreasing from 20,686t in 2004 to 12,639t. An extremely poor fishery in the Grand Manan area accounted for much of the decline. Correspondingly in 2005 there were few reports of aggregations of fish outside the weirs. Since the purpose of this project was to assess the size of schools of fish in the vicinity of the weirs, the lack of fish made this difficult.

During 2005 the acoustic equipment onboard the *Strathaven* was used to collect information on herring distribution on nine different occasions. A total of 61 hours of sounder recordings covering a distance of 808 kilometers were analyzed. Data was collected during regular fishing operations around the weirs on five occasions and twice during survey operations in the Scots Bay area.

The acoustic system provided valuable data from the structured survey on Scots Bay. With the continued funding of this project in 2006 it is hoped that more structured surveys can be conducted using the standard survey protocol of Melvin and Power (1999), primarily around the weirs. Weir fishers were consulted in 2005 to identify important areas where herring are known to congregate and these areas were mapped. In 2006 it is proposed that two surveys be conducted in each of the areas. The technician hired by this project will be present on the *Strathaven* during each of the surveys to ensure adherence to the survey protocol. In addition, if other schools of herring are encountered during normal fishing operations the vessel can be used to survey these aggregations.

DISCUSSION:

In 2005, 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, either around Seal Island or in the vicinity of Browns Bank, due to the absence of fleet activity in the area. There was limited activity in the Spectacle Buoy area in June with one survey of that area.

This is the ninth 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. For 2005 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 2005 was the absence of structured surveys during mid August or late October on German Bank. 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. The set of surveys are considered to be comparable to others in the series since 1999.

The observed SSB for Scots Bay in 2005 decreased dramatically 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 estimates of herring observed on the three survey nights were added to provide an SSB of only 16,800t which is the lowest recorded 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 2005, the total spawning stock biomass observed on German Bank was estimated to be 211,000t which is a decrease of 150,000t and well below the average (Table 12). The SSB is based on estimates of biomass from only 3 structured surveys undertaken from Sept. 7 to Oct. 4. The elapsed time between all surveys was within the 10-14 day guideline and turnover of spawners was assumed to be 100% for this analysis. An alternative treatment of the acoustic data based on recent tagging experiments on the spawning grounds is shown in Appendix A.

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, the Halifax/Eastern Shore and Glace Bay areas. Trends in catches and survey biomass for these areas is shown in Table 16 and Figure 60.

No biomass estimates were made for the Bras d'Or Lakes or for the offshore Scotian Shelf banks. Large winter aggregations of herring off Chebucto Head have not been documented since January 2002.

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Table 1. Summary of the number of scheduled herring spawning ground surveys for 2005, the number of surveys undertaken and the number of fishing nights examined in the estimation of spawning stock biomass in the 4VWX stock complex.

Spawning Ground	Surveys Scheduled	Surveys Completed	Fishing Nights
Scots Bay	3	3	4
Trinity Ledge	1	1	0
German Bank	3	3	13
Spectacle Buoy	1	1	0
Little Hope	2	2	0
Eastern Shore	2	2	8
Glace Bay	2	2	0
Total	14	14	25

Table 2. Summary of fish sampled, length/weight relationship, target strength estimated from available samples, and target strength estimate for a 'standard' 28 cm herring by survey date and location for the 2005 herring fishery.

Date of Survey	Location of survey	Interval (days)	Number Samples	Number Measured Fish	Number Len/Wt Fish	Mean Length (mm)	Mean Weight (gm)	Slope (log vs log regression)	Intercept (log vs log regression)	Target Strength dB/kg	Wt 28 cm Fish (gm)	TS 28 cm Fish dB/kg
31-Jul	Scots Bay	0	5	692	167	275	163	3.46	-6.23	-35.24	174	-35.36
21-Aug	Scots Bay	21	4	407	104	264	135	3.31	-5.89	-34.78	164	-35.11
11-Sep	Scots Bay	20	3	329	65	263	140	3.22	-5.63	-34.98	172	-35.31
05-Sep	Trinity Ledge[1]	0				280						-35.96
08-Jun	Spectacle Buoy[1]	0				280						-35.96
07-Sep	German Bank	0	12	1402	375	271	154	3.38	-6.03	-35.12	172	-35.30
21-Sep	German Bank	14	8	1144	362	273	157	3.29	-5.82	-35.14	171	-35.29
04-Oct	German Bank	13	5	689	451	274	157	3.25	-5.73	-35.10	168	-35.36
04-Oct	Little Hope[1]	0				280						-35.96
19-Oct	Little Hope[1]	15				280						-35.96
03-Oct	Eastern Shore [1,2]	0	2	152	144	292	203	2.83	-4.68	-36.12	180	-35.96
31-Oct	Eastern Shore [1,2]	28				292				-36.12		-35.96
20-Sep	Glace Bay[1]	0				280						-35.96
06-Oct	Glace Bay[1]	16				280						-35.96

[1] TS adjust by -0.446 dB to account for difference in acoustic signal for 120 kHz system.

[2] TS estimated using length/weight relationship from Eastern Shore Sept 30 multi-panel sample.

Table 3. Maturity staging for fresh herring as applied by the St. Andrews Biological Station herring investigation in comparison to Scotia Garden Seafood plant maturity stages and with estimated time to spawn.

Stage	SABS Stage Name	Industry Stage Name	Time to Spawning	Female Herring Gonad Definition (from Parrish and Saville, 1965)
1	Immature 1		Year or more	Virgin herring. Ovaries very small 1-3mm broad, wine-red or pinkish color.
2	Immature 2		Year or more	Virgin herring with small sexual organs. Width of ovaries about 3-8mm, eggs not visible to naked eye but can be seen with magnifying glass, oval in cross-section, wine-red or pinkish.
3	Ripening 1		This season, months to go	Ovaries about half the length of body cavity. Width between 1-2 cm, distal end is torpedo shaped, eggs small but can be distinguished with naked eye, overall color is orange.
4	Ripening 2		Months or Weeks	Ovaries almost as long as body cavity. Eggs larger, varying in size, eggs opaque. Overall color is orange or pale yellow.
5	Ripe / Hard	Immature / Hard	Weeks or Days	Ovaries fill body cavity. Yellowish in color. Eggs large, round; some transparent but do not flow with pressure.
6	Spawning	Mature (small, bloody, white)	0 days, Now	Ovaries ripe. Eggs transparent and flowing freely.
7	Spent	Spent	Spawned days or weeks previously	Spent herring. Ovaries baggy and bloodshot, empty or containing only a few residual eggs.
8	Recovering / Resting		1 year	Recovering spent. Ovaries firm and larger than virgin herring at stage 2. Eggs not visible to naked eye. Walls of ovary striated, blood vessels prominent, dark wine-red in color. (This stage passes into Stage 3)
0	Undetermined			Unable to determine stage.

Table 4. Summary of 1987 to 2005 Scots Bay herring purse seine catches.

Year	Min. Date	Max. Date	No. Days	Catch t	No. Slips	Catch/Day	Catch/Slip
1987	08-Jul-87	06-Aug-87	30	3,398	91	113.25	37.34
1988	20-Jul-88	29-Jul-88	10	3,780	65	377.99	58.15
1989	19-Jul-89	13-Sep-89	57	6,021	164	105.64	36.72
1990	22-Jul-90	14-Aug-90	24	8,088	108	336.98	74.89
1991	05-Jul-91	14-Aug-91	41	7,365	163	179.63	45.18
1992	25-Jul-92	11-Aug-92	18	7,960	189	442.22	42.12
1993	25-Jul-93	01-Sep-93	39	5,228	100	134.04	52.28
1994	10-Jul-94	25-Aug-94	47	10,610	286	225.74	37.10
1995	24-Jul-95	26-Jul-95	3	907	33	302.33	27.48
1996	25-Jul-96	20-Aug-96	27	8,939	151	331.06	59.20
1997	30-Jul-97	27-Aug-97	29	4,847	91	167.14	53.26
1998	20-Jul-98	10-Sep-98	53	7,880	163	148.68	48.34
1999	19-Jul-99	17-Aug-99	30	1,789	40	59.63	44.73
2000	25-Jul-00	30-Aug-00	37	10,853	171	293.34	63.47
2001	10-Jul-01	21-Aug-01	43	10,739	176	249.74	61.02
2002	22-Jul-02	09-Sep-02	50	7,994	160	159.88	49.96
2003	21-Jul-03	05-Sep-03	47	19,196	237	408.43	81.00
2004	19-Jul-04	16-Sep-04	60	24,388	330	406.47	73.90
2005	26-Jul-05	09-Sep-05	46	5,872	96	127.65	61.17

Table 5. Summary of the 2005 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.

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (mm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Scots Bay									
Survey*	31-Jul-05	264	-34.8	614	-52.93	0.015	9,431	6,745	72%
Survey*	21-Aug-05	275	-35.2	743.6	-56.02	0.009	6,332	2,214	35%
Survey*	11-Sep-05	263	-35.0	450	-61.20	0.002	1,083	546	50%
* multi-frequency transducers							16,846	7,120	42%

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (mm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Scots Bay									
Survey*	31-Jul-05	264	-34.8	614	-51.74	0.020	12,404	8,934	72%
Survey*	21-Aug-05	275	-35.2	743.6	-55.21	0.010	7,618	2,708	36%
Survey*	11-Sep-05	263	-35.0	450	-60.74	0.003	1,206	586	49%
* multi-frequency transducers							21,228	9,354	44%

Table 6. Summary of the 2005 herring biomass estimates observed during fishing nights in Scots Bay. The vessel names are *Leroy & Barry* (LB) and *Secord* (SC).

Location	Vessel	Date	Area (km2)	Weighted Sa (db/m2)	Density (kg/m2)	Target Strength	Biomass (t)	Standard Error (%)
Scots Bay	SC	26-Jul-05	0.40	-33.77	1.26	-34.8	491	25
Scots Bay	LB	14-Aug-05	0.20	-26.21	8.01	-35.2	1,602	12
Scots Bay	LB	23-Aug-05	0.34	-31.60	2.31	-35.2	787	107
Scots Bay	LB	24-Aug-05	0.58	-29.86	3.45	-35.2	2,004	43

Table 7. Summary of 1985 to 2005 German Bank herring purse seine catches.

Year	Start Date	End Date	No. Days	No. Slips	Pre-spawn Catch Before Aug 15	Spawn Catch After Aug 14	Total Catch t	Percent Catch After Aug 14
1985	22-Jun-85	08-Oct-85	109	428	8,856	14,228	23,084	62%
1986	18-Jun-86	01-Oct-86	106	349	2,349	13,542	15,892	85%
1987	26-May-87	14-Oct-87	142	403	5,138	13,218	18,357	72%
1988	29-May-88	06-Oct-88	131	610	14,776	18,348	33,125	55%
1989	28-May-89	15-Oct-89	141	313	2,061	12,087	14,148	85%
1990	23-May-90	23-Oct-90	154	428	1,220	23,647	24,867	95%
1991	02-Jun-91	15-Oct-91	136	621	11,800	18,328	30,127	61%
1992	31-May-92	04-Oct-92	127	556	13,175	10,985	24,160	45%
1993	24-May-93	29-Sep-93	129	192	7,912	1,092	9,003	12%
1994	05-May-94	28-Sep-94	147	252	1,186	11,454	12,641	91%
1995	05-Jun-95	06-Oct-95	124	301	434	21,339	21,773	98%
1996	20-Jun-96	27-Oct-96	130	260	2,229	16,091	18,320	88%
1997	11-Jul-97	14-Oct-97	96	327	2,009	17,110	19,119	89%
1998	10-Jun-98	14-Oct-98	127	516	3,231	21,489	24,720	87%
1999	20-Apr-99	20-Oct-99	184	666	18,508	16,401	34,909	47%
2000	18-Apr-00	26-Oct-00	192	598	9,806	26,171	35,977	73%
2001	22-May-01	20-Oct-01	152	521	5,312	22,156	27,468	81%
2002	18-Apr-02	12-Oct-02	178	643	10,871	19,935	30,806	65%
2003	05-May-03	15-Oct-03	164	392	8,900	20,070	28,970	69%
2004	10-May-04	15-Oct-04	159	238	5,680	12,345	18,025	68%
2005	16-May-05	13-Oct-05	151	364	8,069	12,039	20,107	60%

Table 8. Summary of the 2005 German Bank spawning ground acoustic survey results and SSB biomass estimates.

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (mm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
German Bank									
Survey*	7-Sep-05	271	-35.3	710	-45.02	0.106	74,924	41,271	55%
Survey*	21-Sep-05	273	-35.1	600	-42.95	0.166	99,520	42,481	43%
Survey*	4-Oct-05	274	-35.2	500	-46.54	0.073	36,515	25,773	71%
* multi-frequency transducers							210,959	64,592	31%

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
German Bank									
Survey*	7-Sep-05	271	-35.2	710	-44.14	0.129	91,701	48,920	53%
Survey*	21-Sep-05	273	-35.1	600	-41.83	0.215	128,825	55,594	43%
Survey*	4-Oct-05	274	-35.2	500	-45.34	0.096	48,084	35,315	73%
* multi-frequency transducers							268,610	82,043	31%

Table 9. Summary of the 2005 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), *Morning Star* (MS) and *Silver Harvester* (SH). None of these results were used in the overall 2005 German Bank SSB as all adjacent surveys within 10 days had higher biomass estimates.

Location	Vessel	Date	Area (km2)	Weighted Sa (db/m2)	Density (kg/m2)	Target Strength	Biomass (t)	Standard Error (%)
German Bank	LM/LB	28-Aug-05	9.20	-31.98	2.09	-35.3	19,241	57
German Bank	LM/LB	29-Aug-05	10.00	-36.26	0.84	-35.5	8,396	64
German Bank	DV/LB	30-Aug-05	7.00	-34.35	1.30	-35.5	9,124	34
German Bank	LB	08-Sep-05	7.00	-28.31	5.24	-35.5	36,687	36
German Bank	MS/LM	13-Sep-05	14.00	-30.50	2.98	-35.2	41,780	37
German Bank	DV/LB	14-Sep-05	9.00	-27.16	6.83	-35.5	39,433	64
German Bank	SH -map	14-Sep-05	62.10				62,000	
German Bank	IP/DV/LM	15-Sep-05	6.00	-31.22	2.68	-35.5	14,735	72
German Bank	MS/LB	01-Oct-05	9.00	-34.13	1.37	-35.5	12,341	45
German Bank	DV	07-Oct-05	1.00	-31.23	2.67	-35.5	1,336	17
German Bank	DV	02-Oct-05	1.00	-26.91	7.24	-35.5	4,341	8
German Bank	LB	06-Oct-05	2.00	-33.79	1.48	-35.5	2,372	21
German Bank	MS/DV	03-Oct-05	2.50	-27.96	5.18	-35.1	12,947	27
German Bank	LB	11-Oct-05	0.90	-27.58	5.65	-35.1	5,087	44

Table 10. Summary of the 2005 Spectacle Buoy acoustic surveys and SSB biomass estimates.

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %	SE ^2
Spectacle Buoy										
	8-Jun-05	28.0	-36	0.57	-38.87	0.512	292	95	33%	9025
	10-Jun-05			no nav	n/a	n/a	n/a	n/a		
	12-Jun-05			no nav	n/a	n/a	n/a	n/a		
note - using standard TS adjusted for frequency of sounder							292	95	33%	9025

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %	SE ^2
Spectacle Buoy										
	8-Jun-05	28.0	-36	0.57	-35.63	1.080	616	200	32%	40000
	10-Jun-05			no nav	n/a	n/a	n/a	n/a		
	12-Jun-05			no nav	n/a	n/a	n/a	n/a		
note - using standard TS adjusted for frequency of sounder							616	200	32%	40000

Table 11. Summary of the 2005 Trinity Ledge acoustic surveys and SSB biomass estimates.

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Trinity Ledge									
	5-Sep-05	28.0	-36	0.8	-27.94	6.339	5,071	819	16%
	6-Sep-05			no nav	n/a	n/a	n/a	n/a	
note - using standard TS adjusted for frequency of sounder							5,071	819	16%

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Trinity Ledge									
	5-Sep-05	28.0	-36	0.8	-24.70	13.376	10,701	1,729	16%
	6-Sep-05			no nav	n/a	n/a	n/a	n/a	
note - using standard TS adjusted for frequency of sounder							10,701	1,729	16%

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 and all data was calculated without the use of the integration calibration factor.

Location/Year	1997*	1998*	1999	2000	2001	2002	2003	2004	2005	Average 1999-2005
Scots Bay	160,200	72,500	41,000	106,300	163,900	141,000	133,900	107,600	16,800	101,500
Trinity Ledge	23,000	6,800	3,900	600	14,800	8,100	14,500	6,500	5,100	7,643
German Bank	370,400	440,700	460,800	356,400	190,500	393,100	343,500	367,600	211,000	331,843
Spectacle Buoy										
- Spring	15,000	1,300	0	0	1,100		1,400	n/s	300	560
- Fall					87,500					87,500
Sub-Total	568,600	521,300	505,700	463,300	457,800	542,200	493,300	481,700	233,200	453,886
Seal Island					3,300	1,200	12,200			5,567
Browns Bank					45,800					45,800
Total	568,600	521,300	505,700	463,300	506,900	543,400	505,400	481,700	233,200	462,800
Overall SE t	n/a	n/a	94,600	64,900	50,800	49,500	86,100	74,200	64,900	69,286
Overall SE %	n/a	n/a	19	14	10	9	17	15	28	16

*Biomass estimates prior to 1999 are not considered comparable due to variation in the coverage area.

Table 13. Summary of the 2005 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). Highlighted surveys in bold were used to estimate total SSB for 2005

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Survey	4-Oct-05	28.0	-36	100.8	-43.07	0.195	19,605	6,584	34%
Survey	19-Oct-05	28.0	-36	136.2	-44.32	0.146	19,850	5,465	28%
note - using standard TS adjusted for frequency of sounder							39,455	8,557	22%

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Survey	4-Oct-05	28.0	-36	100.8	-42.53	0.221	22,222	7,463	34%
Survey	19-Oct-05	28.0	-36	136.2	-43.78	0.165	22,500	6,194	28%
note - using standard TS adjusted for frequency of sounder							44,722	9,699	22%

Table 14a. Summary of the 2005 Eastern Passage acoustic survey results and SSB estimates calculated without the calibration integration factor.

a - without integration factor; as presented since 1997

Survey Date	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Sept 20_BK	-36.1	0.1	-27.2	7.9	471	84	18
Sept 20_MOH	-36.1	0.5	-29.9	4.2	1,894	589	31
Sept 25	-36.1	0.2	-23.0	20.6	3,706	1,275	34
Sept 26_Halifax	-36.1	0.7	-27.5	7.3	5,108	1,263	25
Sept 28_outer	-36.1	20.0	-39.9	0.4	8,469	4,088	48
Sept 28_nw	-36.1	0.6	-28.5	5.8	3,497	1,104	32
Sept 28_se	-36.1	0.5	-36.6	0.9	452	107	24
Sept 28 overall (sum)	-36.1	21.1	-38.4	0.6	12,418	4,236	34
Oct 3_a_ns	-36.1	1.5	-26.1	10.0	14,748	3,895	26
Oct 3_b	-36.1	1.5	-27.8	6.8	10,414	2,317	22
Oct 3 overall (sum)	**-36.1**	**3.0**	**-26.9**	**8.4**	**25,162**	**4,532**	**18**
Oct 4	-36.1	1.0	-33.8	1.7	1,662	463	28
Oct 5	-36.1	0.7	-29.0	5.1	3,650	1,181	32
Oct 6	-36.1	1.8	-28.6	5.7	10,383	4,061	39
Oct 8	-36.1	4.4	-45.5	0.1	511	1,196	234
Oct 9	-36.1	0.7	-32.4	2.4	1,589	911	57
Oct 11 am	-36.1	0.8	-34.1	1.6	1,342	644	48
Oct 11 pm	-36.1	0.8	-43.9	0.2	139	317	227
Oct 12	-36.1	1.5	-38.0	0.6	997	398	40
Oct 13	-36.1	5.8	-54.2	0.0	90	73	81
Oct 30_west_group	-36.1	0.5	-29.4	4.7	2,207	658	30
Oct 30_east_group	-36.1	0.1	-32.9	2.1	167	77	46
Oct 30 overall (sum)	-36.1	0.6	-29.8	4.3	2,374	662	28
Oct 31 east_west	**-36.1**	**0.7**	**-29.6**	**4.5**	**2,940**	**880**	**30**
Totals/Overall	**-36.1**	**3.7**			**28,102**	**4,617**	**16**

Table 14b. Summary of the 2005 Eastern Passage acoustic survey results and SSB estimates calculated with the calibration integration factor.

b - with integration factor as introduced in 2004 assessment

Survey Date	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Sept 20_BK	-36.1	0.1	-25.7	11.1	666	118	18
Sept 20_MOH	-36.1	0.5	-28.4	5.9	2,652	825	31
Sept 25	-36.1	0.2	-22.0	25.8	4,646	1,613	35
Sept 26_Halifax	-36.1	0.7	-26.4	9.3	6,512	1,605	25
Sept 28_outer	-36.1	20.0	-38.8	0.5	10,814	5,144	48
Sept 28_nw	-36.1	0.6	-27.0	8.2	4,913	1,551	32
Sept 28_se	-36.1	0.5	-35.5	1.1	571	136	24
Sept 28 overall (sum)	-36.1	21.1	-37.2	0.8	16,298	5,374	34
Oct 3_a_ns	-36.1	1.5	-25.1	12.7	18,612	4,916	26
Oct 3_b	-36.1	1.5	-26.3	9.5	14,631	3,255	22
Oct 3 overall (sum)	**-36.1**	**3.0**	**-25.7**	**11.0**	**33,243**	**5,896**	**18**
Oct 4	-36.1	1.0	-32.3	2.4	2,335	651	28
Oct 5	-36.1	0.7	-27.5	7.2	5,128	1,660	32
Oct 6	-36.1	1.8	-27.1	8.0	14,586	5,706	39
Oct 8	-36.1	4.4	-44.0	0.2	717	1,680	234
Oct 9	-36.1	0.7	-30.9	3.3	2,232	1,280	57
Oct 11 am	-36.1	0.8	-32.6	2.2	1,885	905	48
Oct 11 pm	-36.1	0.8	-42.4	0.2	196	445	227
Oct 12	-36.1	1.5	-36.5	0.9	1,400	560	40
Oct 13	-36.1	5.8	-52.7	0.0	127	103	81
Oct 30_west_group	-36.1	0.5	-28.4	5.9	2,785	831	30
Oct 30_east_group	-36.1	0.1	-31.9	2.6	211	98	46
Oct 30 overall (sum)	-36.1	0.6	-28.8	5.4	2,996	837	28
Oct 31 east_west	**-36.1**	**0.7**	**-28.6**	**5.6**	**3,710**	**1,111**	**30**
Totals/Overall	**-36.1**	**3.7**			**36,953**	**6,000**	**16**

Table 15. Summary of the 2005 Glace Bay acoustic survey results and SSB estimates. Note that the estimate for travel lines on Oct. 6 was not included in the overall total.

a - without integration factor; as presented since 1997

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Glace Bay									
Survey	20-Sep-05	28.0	-36	0.34	-29.76	4.169	1,418	211	15%
Survey	6-Oct-05	28.0	-36	0.1	-27.14	7.630	763	195	26%
Lines*	6-Oct-05	28.0	-36	0.1	-24.23	14.881	1,488	352	24%
							2,181	287	13%

b - with integration factor as introduced in 2004 assessment

Location/ Type	Date	Mean Length (cm)	Target Strength (dB/kg)	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Biomass (t)	Standard Error (t)	SE %
Glace Bay									
Survey	20-Sep-05	28.0	-36	0.34	-28.12	6.081	2,067	307	15%
Survey	6-Oct-05	28.0	-36	0.1	-25.50	11.129	1,113	285	26%
Lines*	6-Oct-05	28.0	-36	0.1	-22.60	21.703	2,170	513	24%
							3,180	419	13%

- using standard TS adjusted for frequency of sounder

* Lines on Oct. 6 not included in total

Table 16. Summary of the catch and estimated biomass for locations outside the Bay of Fundy/Southwest Nova Scotia quota area from 1996 to 2005. All areas are for individual spawning grounds and are estimates of SSB rounded to the nearest 100t.

a - Landings for spawning components along coastal Nova Scotia with 5 year and overall averages

Landings (t)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average Catch Last 5 yr.	Average Catch All Years
Little Hope/Port Mouton		490	1,170	2,919	2,043	2,904	3,982	4,526	1,267	2,239	2,984	2,393
Halifax/Eastern Shore	1,280	1,520	1,100	1,628	1,350	1,898	3,334	2,727	4,176	3,446	3,116	2,246
Glace Bay		170	1,730	1,040	834	1,204	3,058	1,905	1,481	626	1,655	1,339
Bras d'Or Lakes	170	160	120	31	56	0	1	4	0	0	1	54
Total	1,450	2,340	4,120	5,618	4,283	6,006	10,375	9,162	6,924	6,311	7,756	5,659

b - Acoustic survey estimates for spawning components along coastal Nova Scotia with 5 year and overall averages

Survey SSB (t)	1998	1999	2000	2001	2002	2003	2004	2005	10% SSB Average Last 5 yr	10% SSB Average All years
Little Hope/Port Mouton	14,100	15,800	5,200	21,300	56,000	**62,500**	15,600	39,500	3,898	2,875
Halifax/Eastern Shore	8,300	20,200	**10,900**	16,700	**41,500**	76,500	18,200	28,100	3,620	2,755
Glace Bay		2,000		21,200	7,700	31,500	0	2,200	1,252	1,077
Bras d'Or Lakes		530	70						0	30

Note: shaded cells include mapping surveys; bold cells include mapping and acoustic surveys.

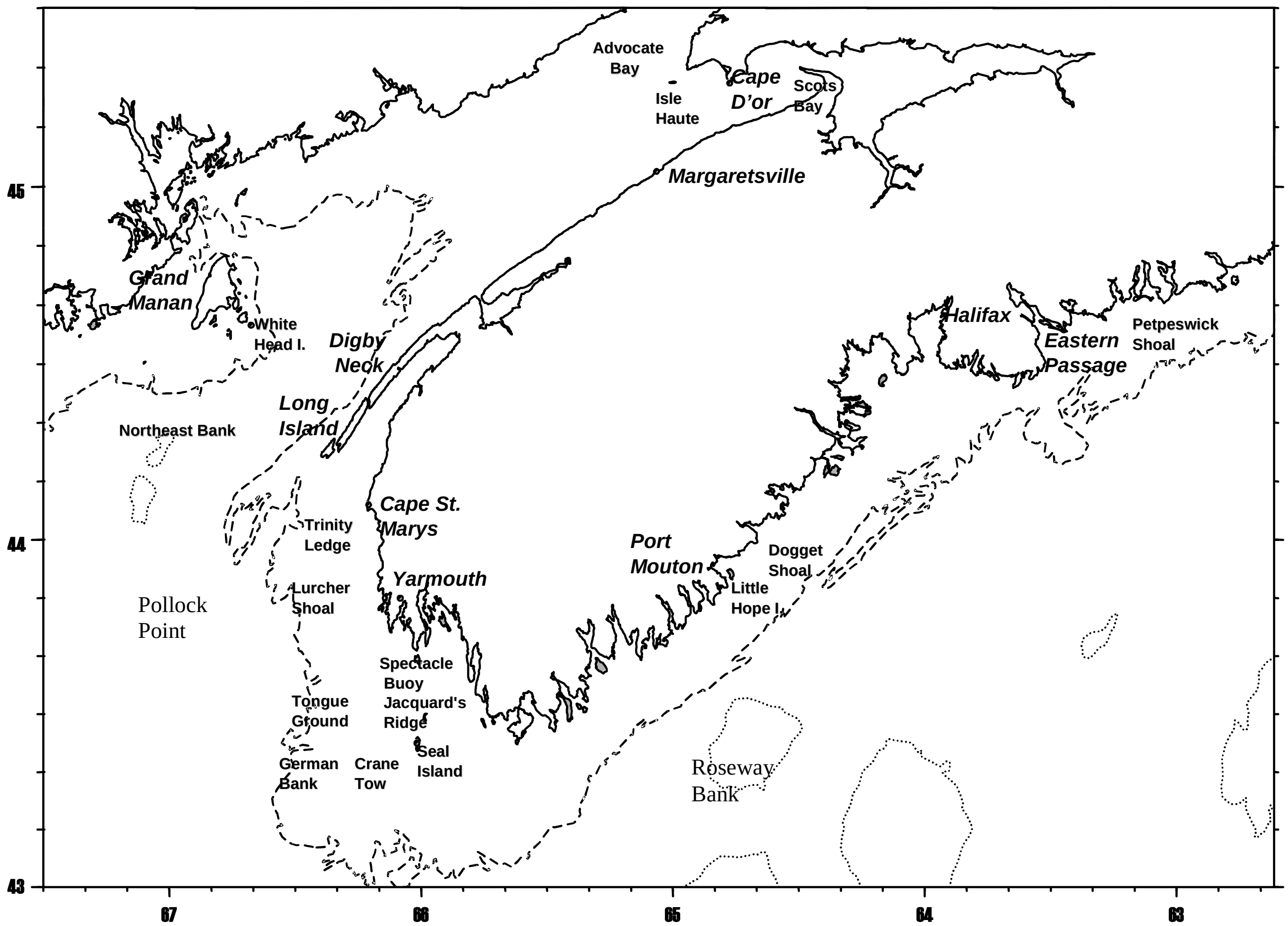


Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

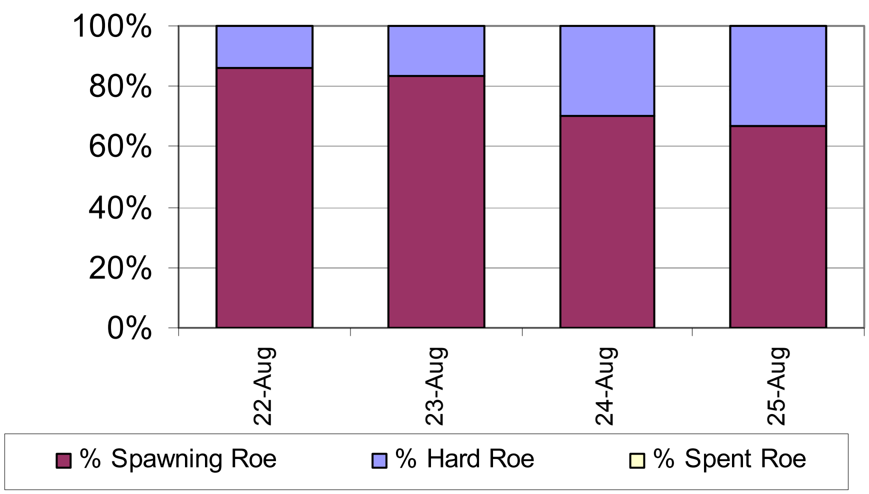


Figure 2. Daily herring female gonad maturity samples (% roe weight) for 2005 Scots Bay from industry supplied data.

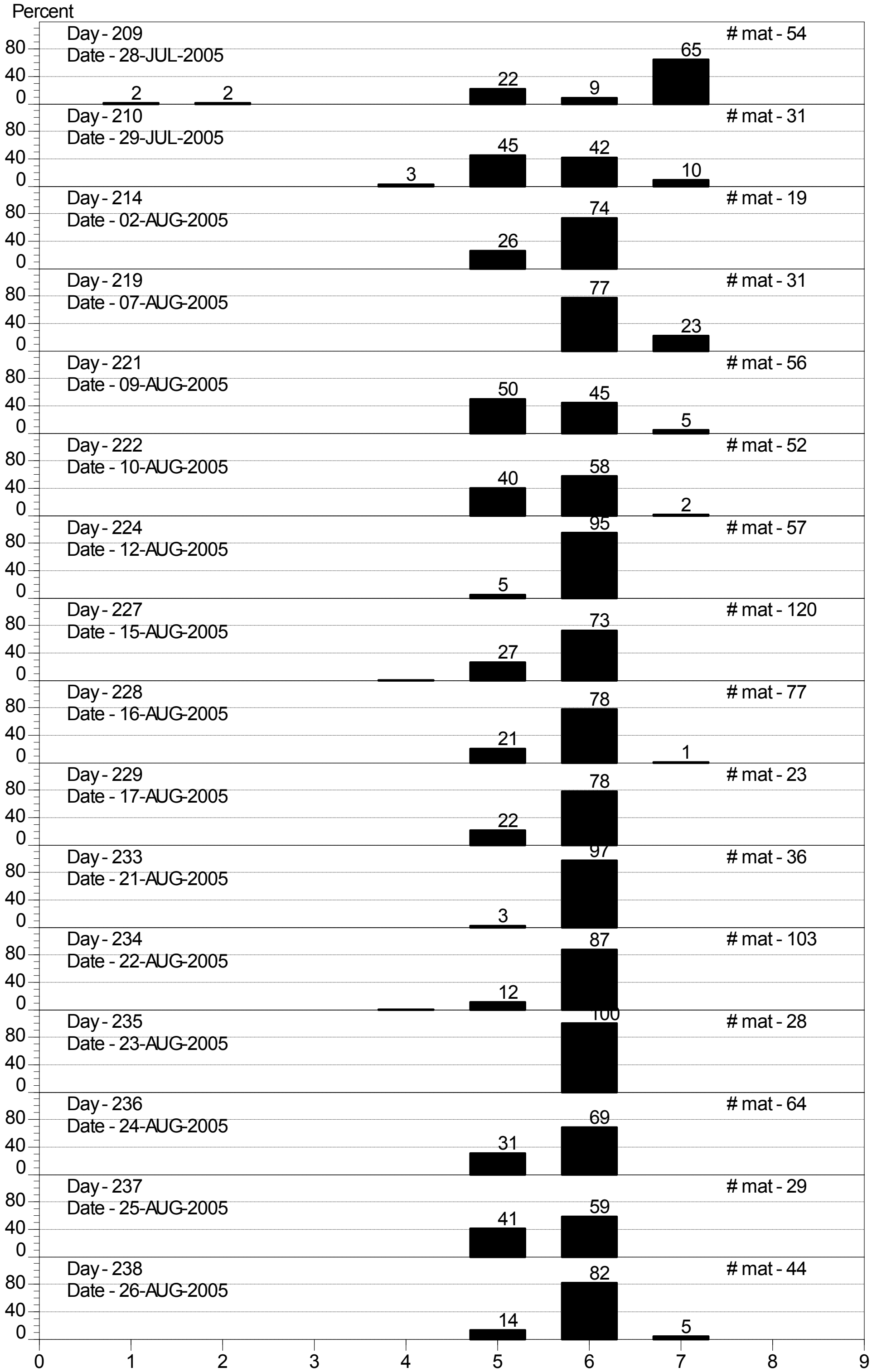


Figure 3. Daily herring gonad maturity samples (% by stage for sexes combined) from the Scots Bay area in 2005.

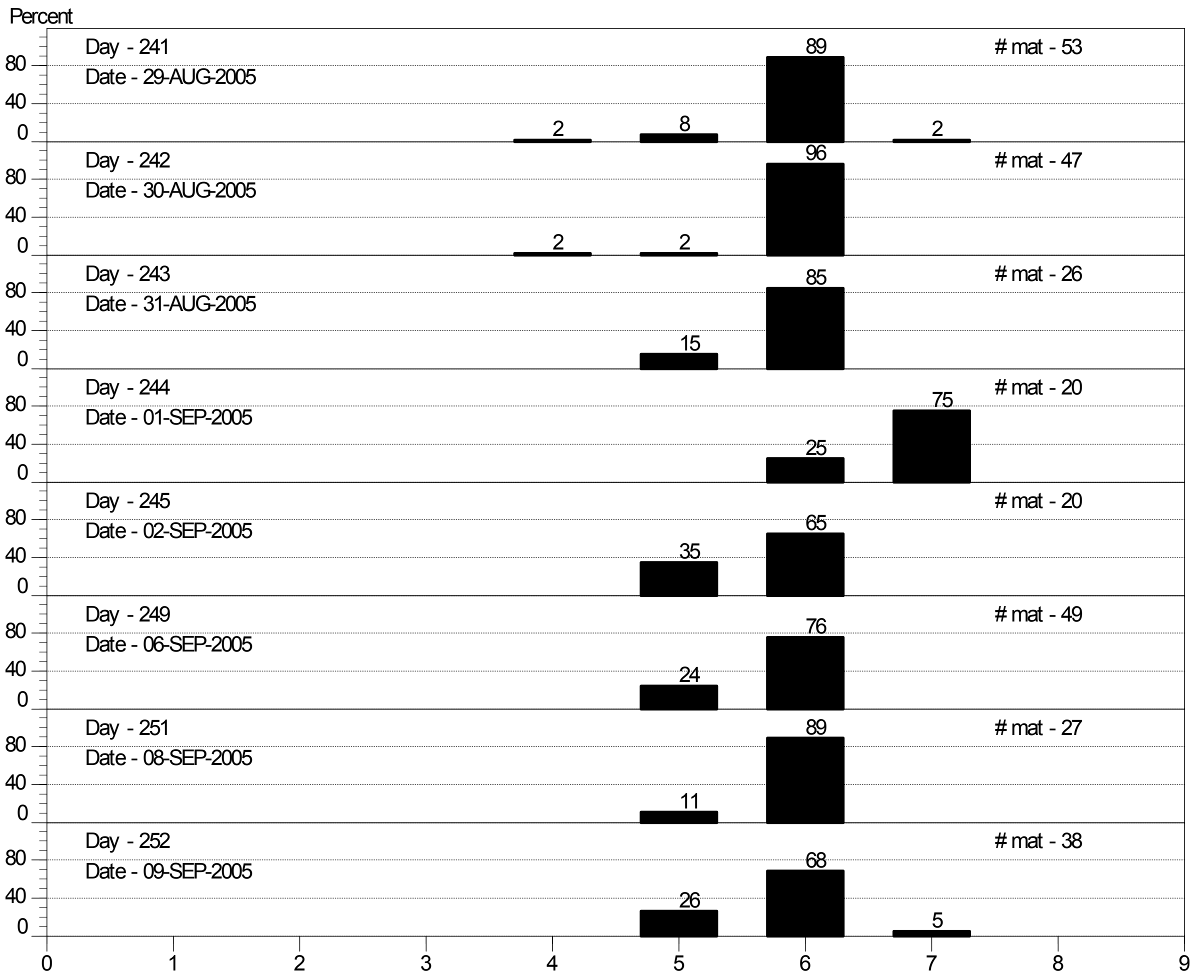


Figure 3 (continued). Daily herring gonad maturity samples (% by stage for sexes combined) from the Scots Bay area in 2005.

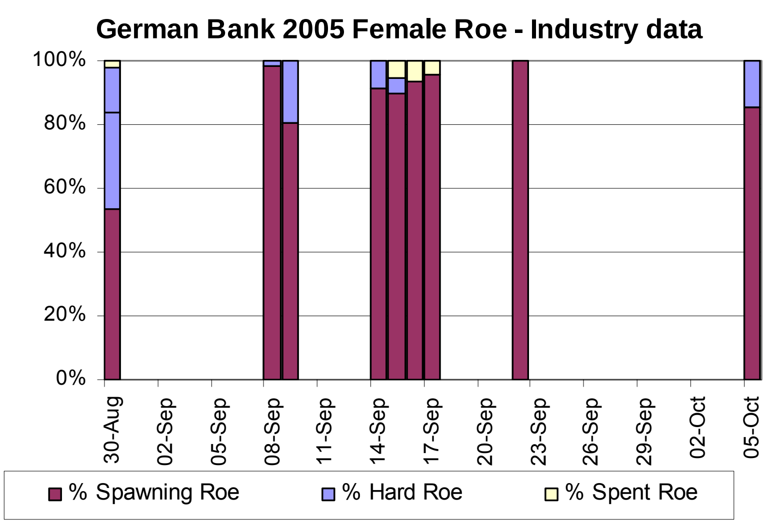


Figure 4. Daily herring female gonad maturity samples (% roe weight) for German Bank in 2005 for Industry supplied data.

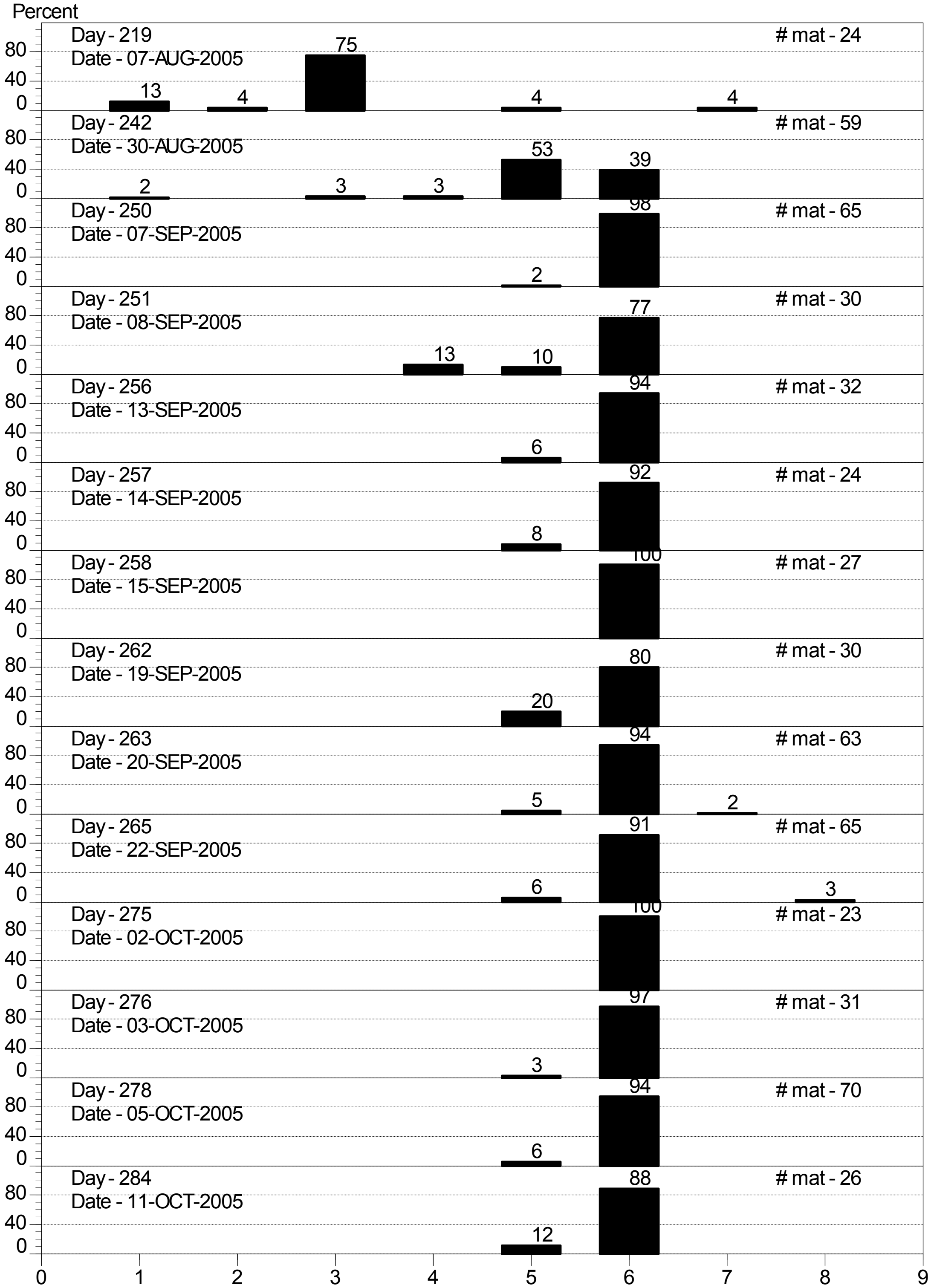


Figure 5. Daily herring gonad maturity samples (% by stage for sexes combined) from the German Bank survey box area in 2005.

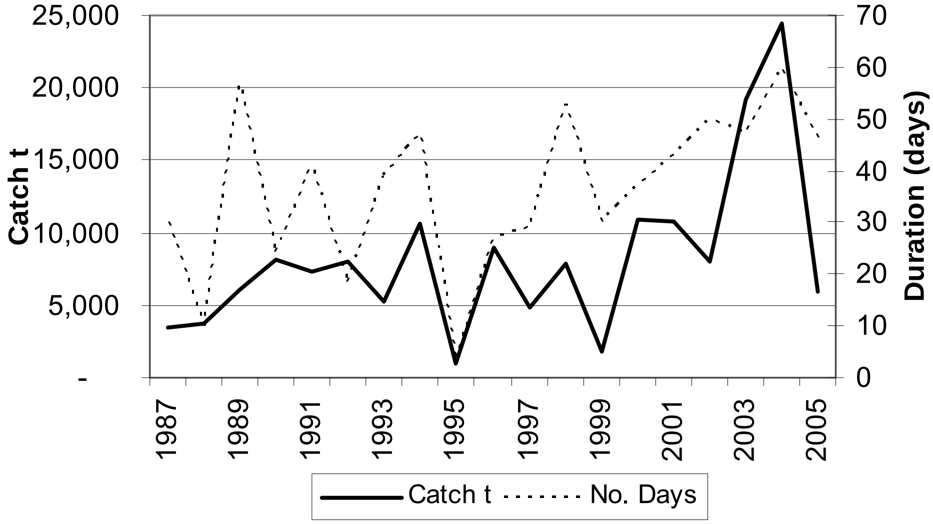


Figure 6. Annual herring purse seine catches for the Scots Bay area from 1987-2005 with duration of fishery in days (start date to end date).

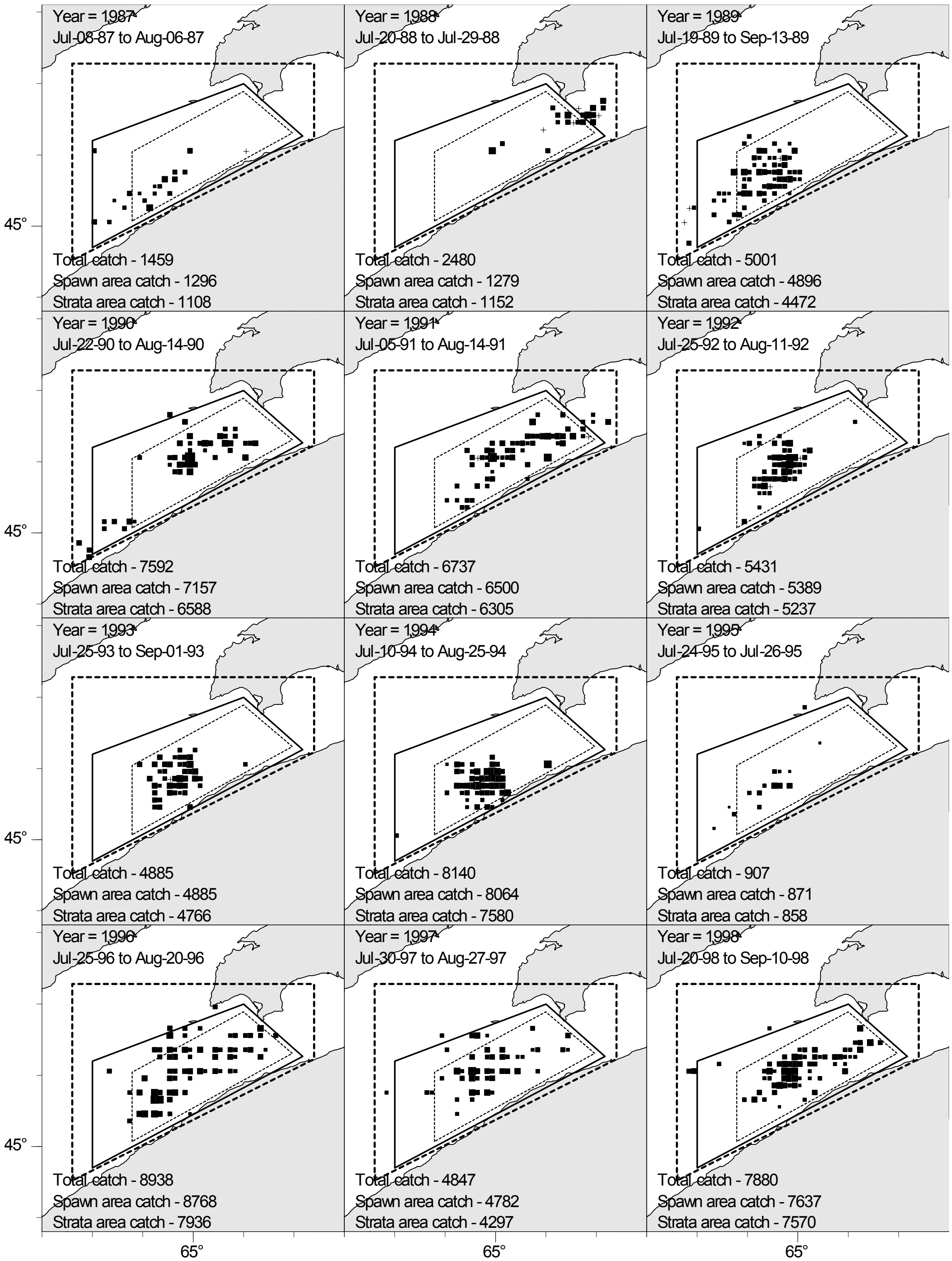


Figure 7. Herring purse seine catches for the Scots Bay area from 1987-1998 with catch totals for the overall area, the middle ‘Spawning’ area and the inner ‘Strata’ area which was used as the primary search area in acoustic surveys.

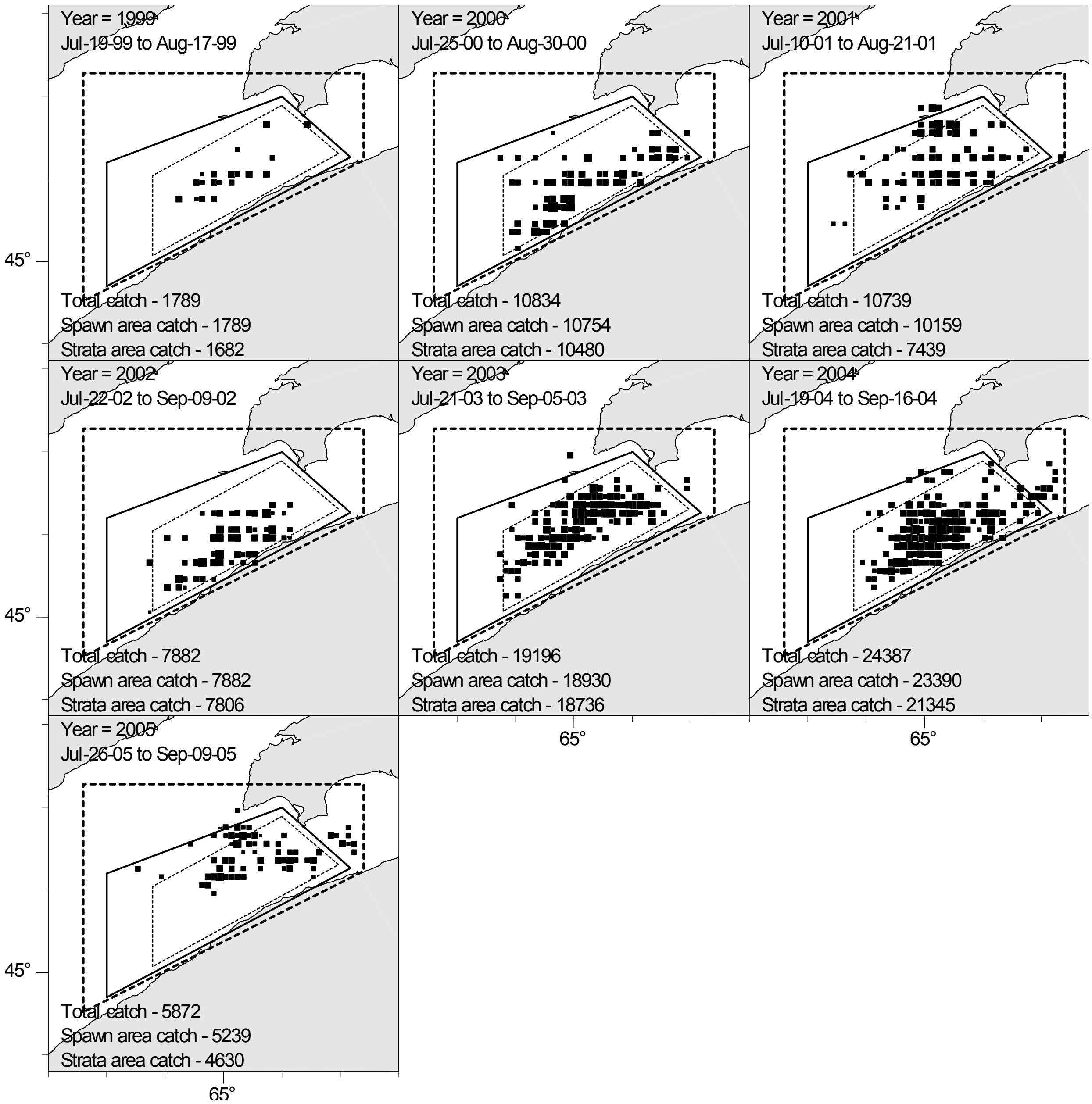


Figure 7 (continued). Herring purse seine catches for the Scots Bay area from 1999-2005 with catch totals for the overall area, the middle 'Spawning' area and the inner 'Strata' area which was used as the primary search area in acoustic surveys.

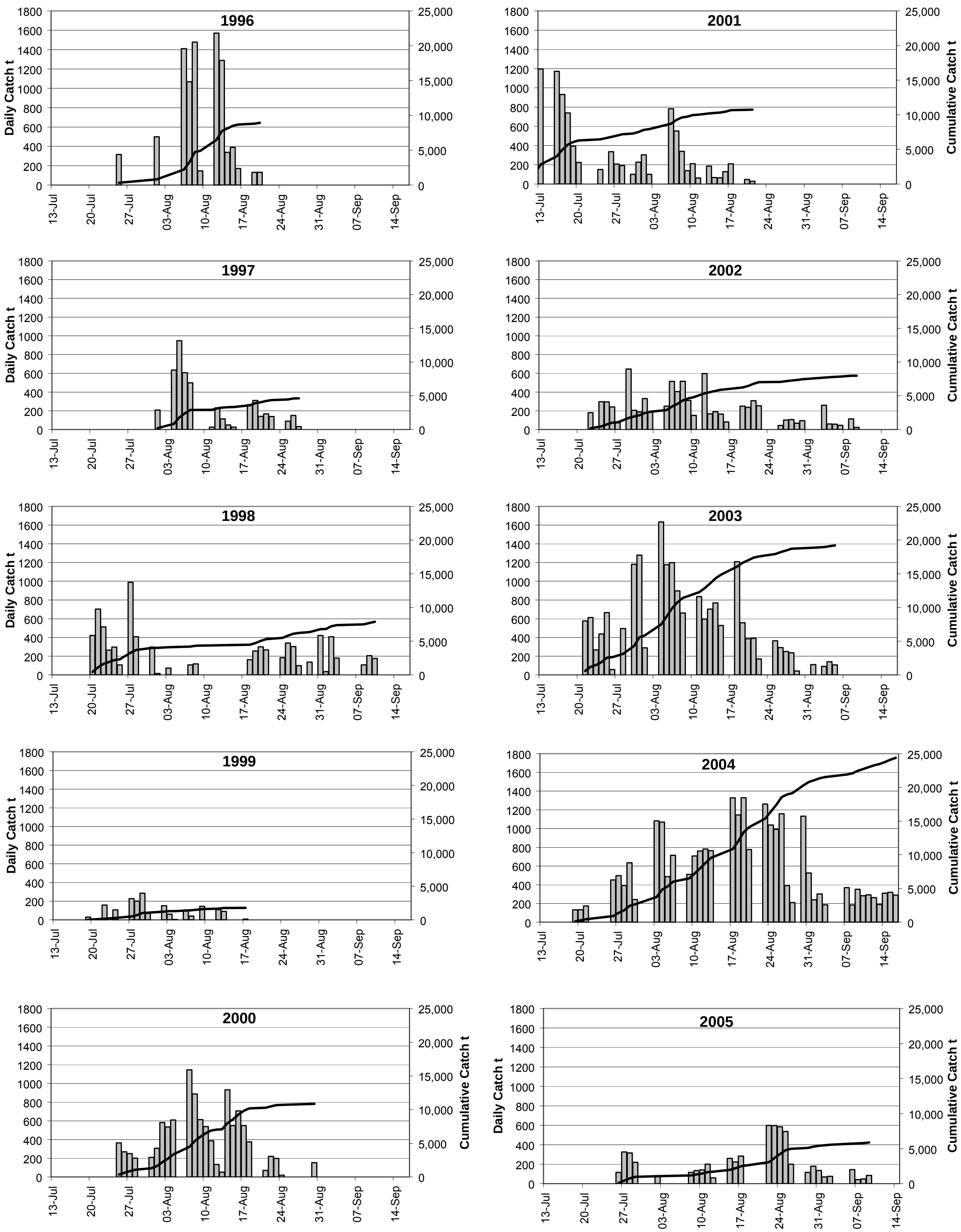


Figure 8. 1996 to 2005 daily purse seine herring catches in tonnes (bars) for Scots Bay with the cumulative total catch (solid line) over the entire fishing season.

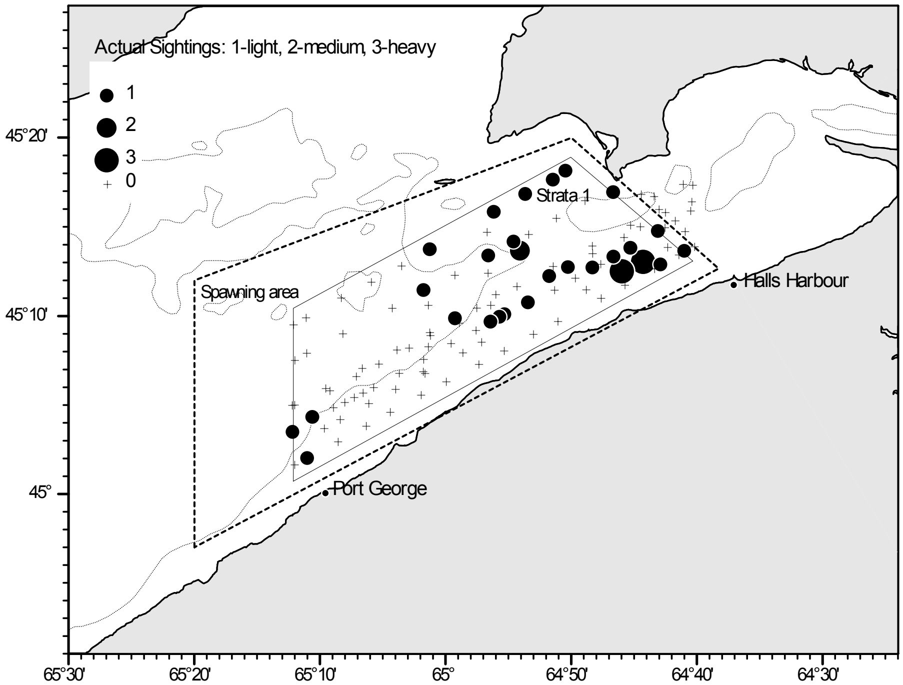


Figure 9. Scots Bay herring survey deck sheet observations for July 31, 2005 with overall defined spawning area (dashed line, outer box) and standard survey area or Strata 1 (solid line, inner box).

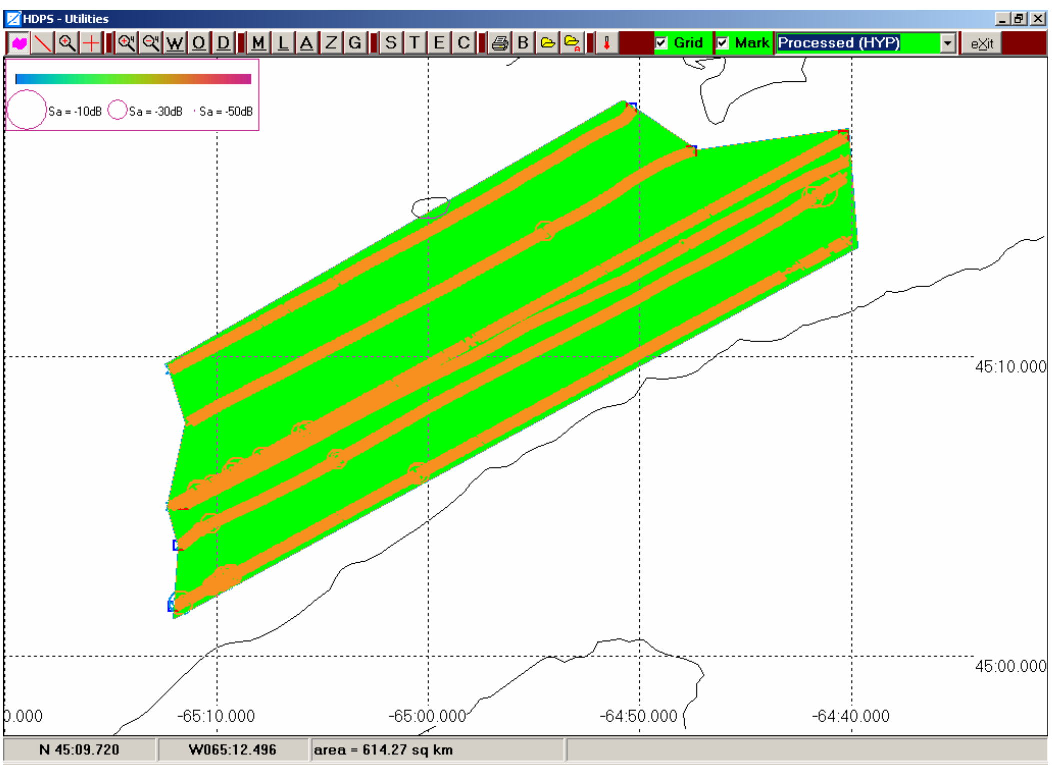


Figure 10. Scots Bay survey on July 31, 2005 with acoustic transects showing location of targets and estimated total survey area of 614 km^2.

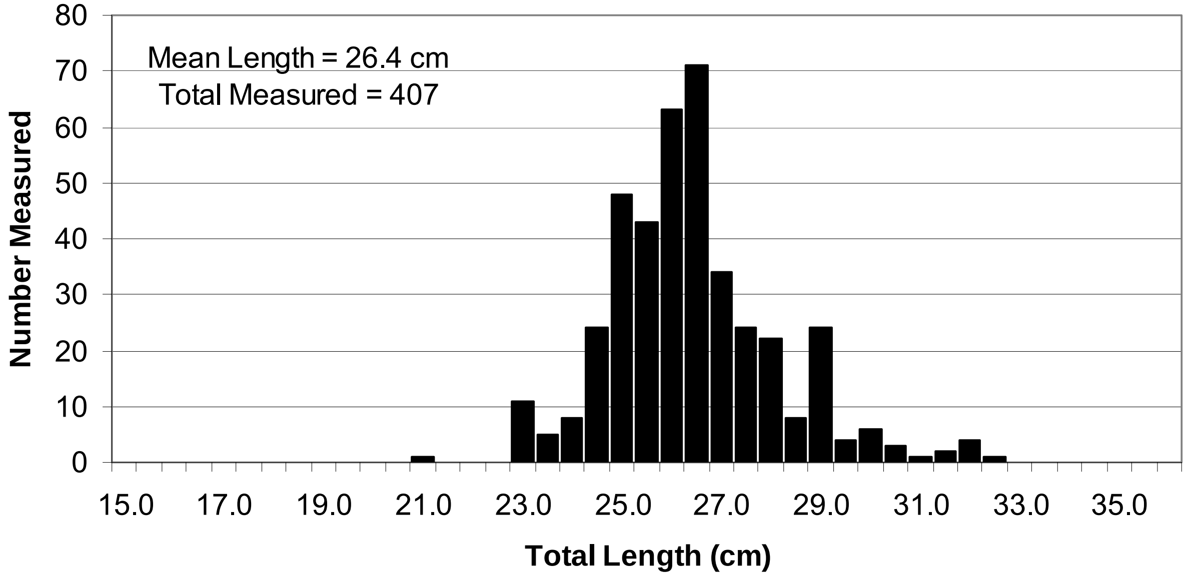


Figure 11. Size distribution of Scots Bay herring purse seine landings used in calculation of target strength from four samples collected from July 29 to Aug. 2, 2005.

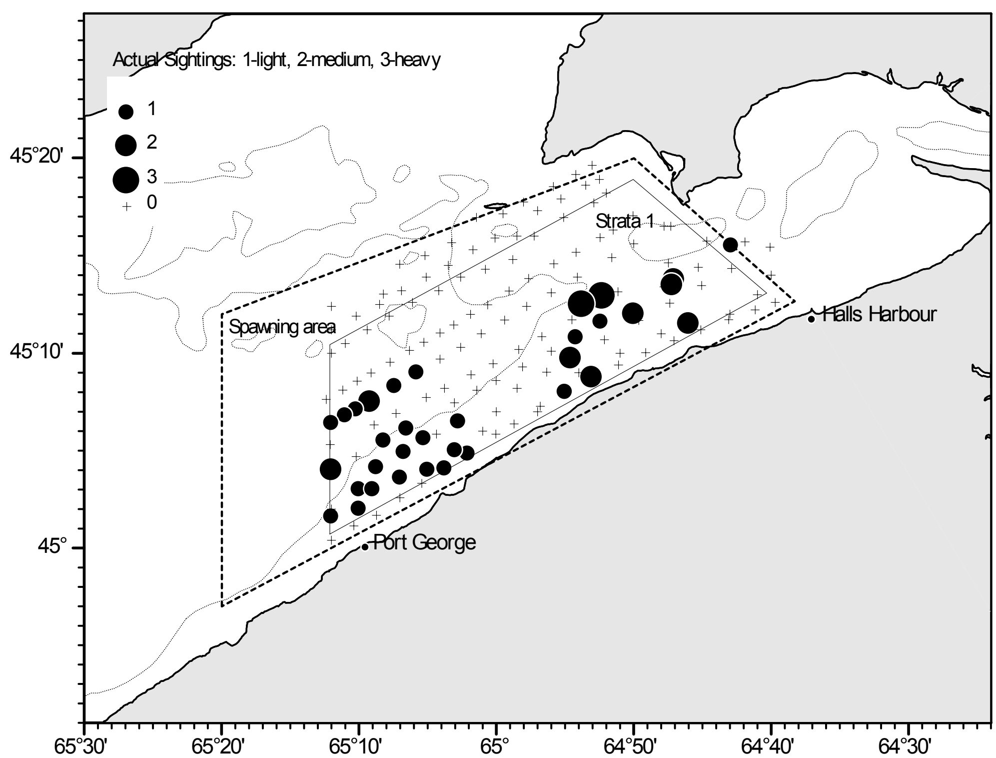


Figure 12. Scots Bay herring survey deck sheet observations for Aug. 21, 2005 with overall defined spawning area (dashed line, outer box) and standard survey area or Strata 1 (solid line, inner box).

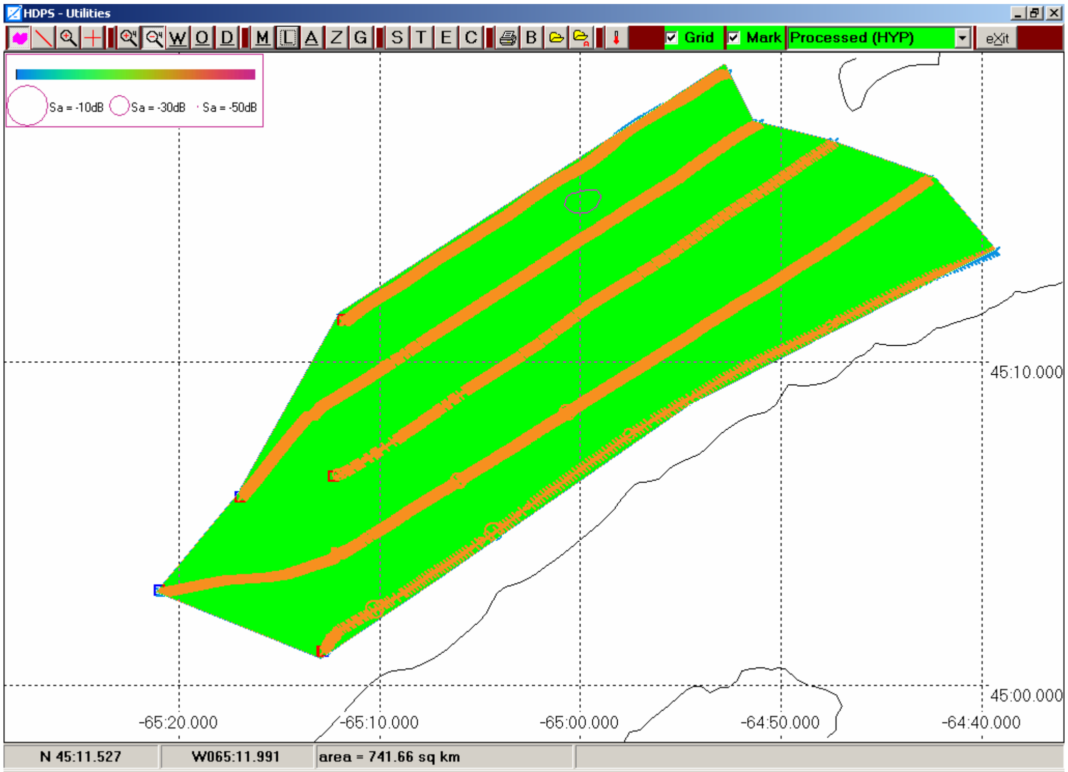


Figure 13. Acoustic transects showing total backscatter (Sa) as expanding circles and estimated total survey area of 740 km^2 from Scots Bay survey on Aug. 21, 2005.

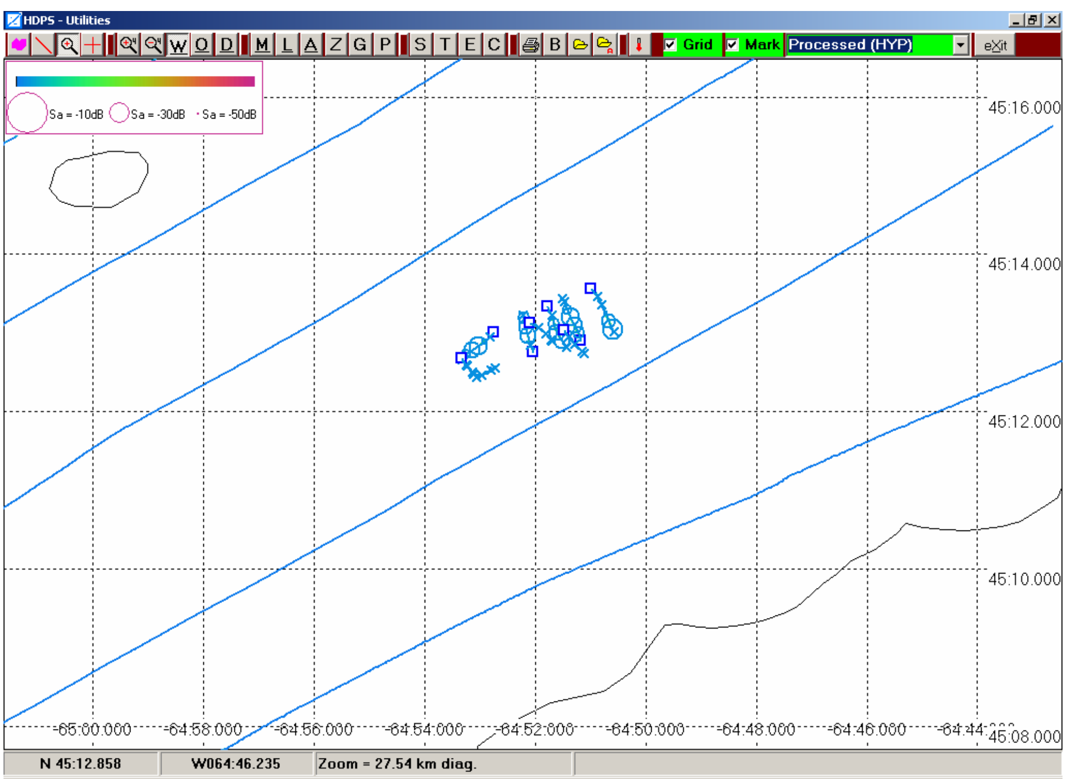


Figure 14. Acoustic transects by Lady Melissa between main survey transects showing total backscatter (Sa) as expanding circles for Scots Bay survey on Aug. 21, 2005.

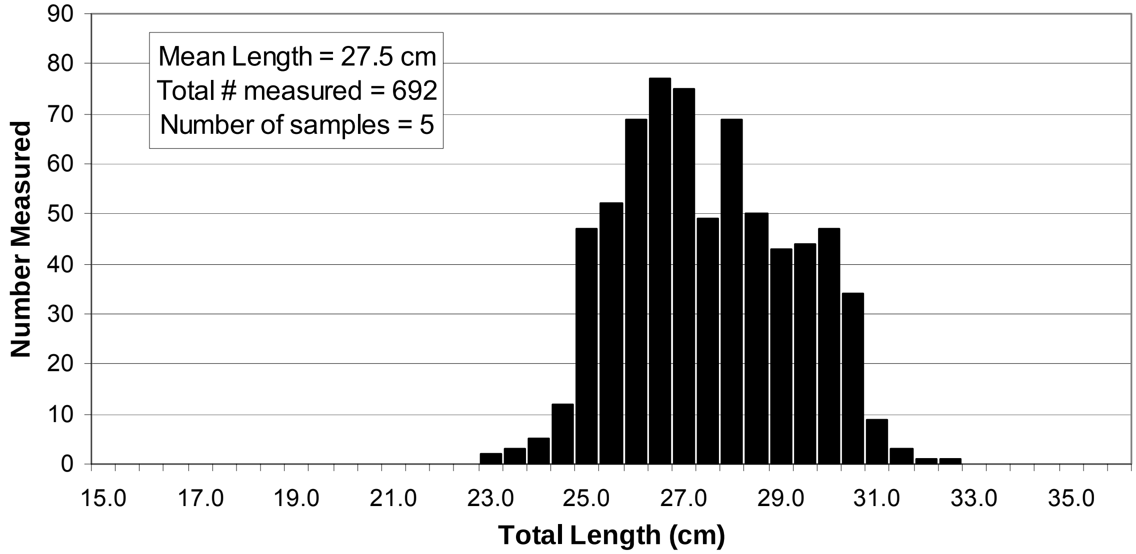


Figure 15. Herring size distribution used for calculation of target strength from Scots Bay samples landed from Aug. 21-22, 2005.

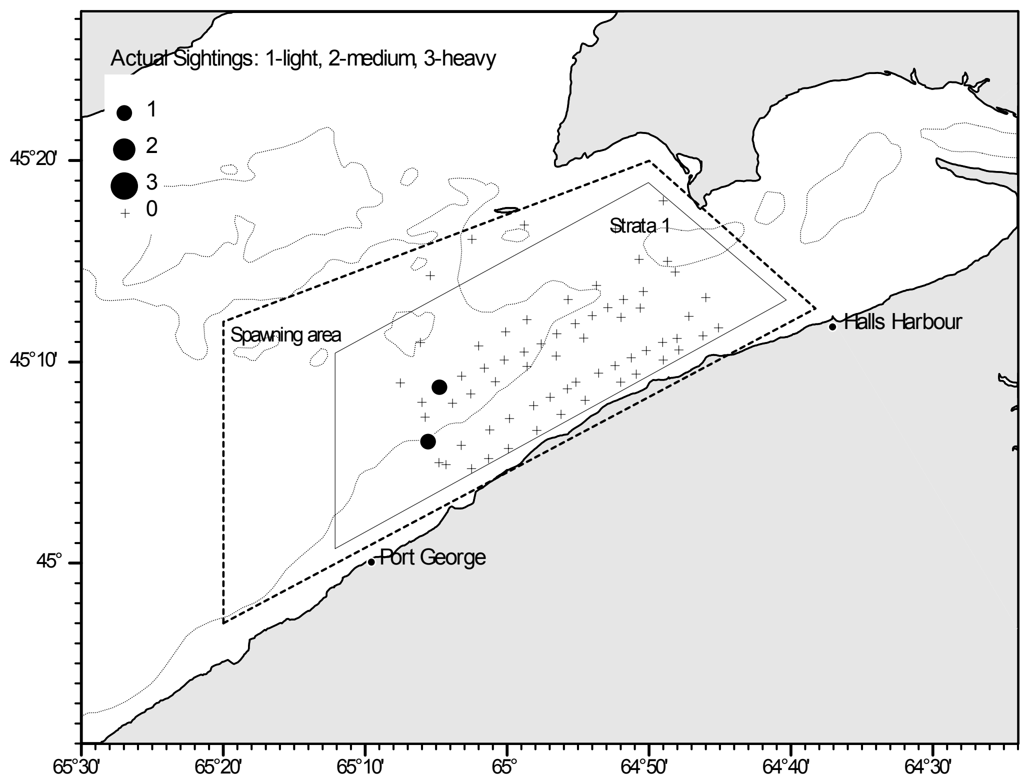


Figure 16. Scots Bay herring survey deck sheet observations for Sept. 11, 2005 with overall defined spawning area (dashed line, outer box) and standard survey area or Strata 1 (solid line, inner box).

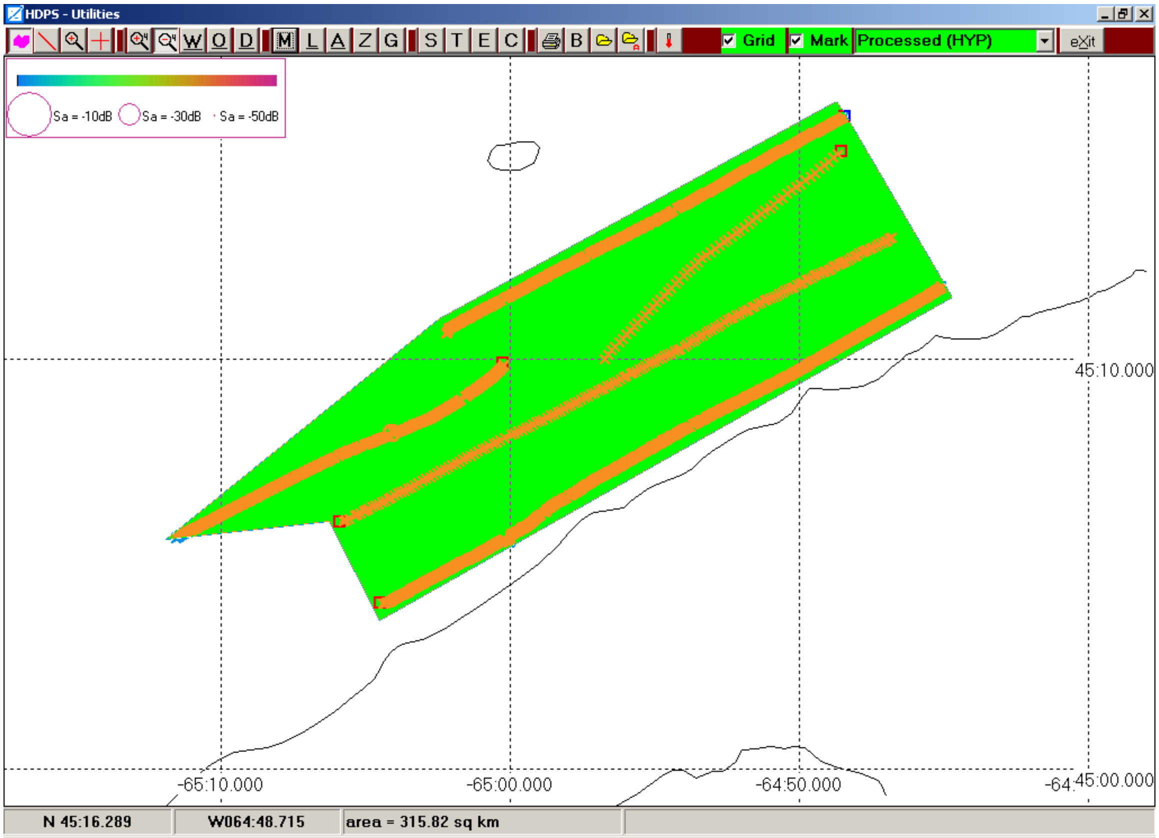


Figure 17. Acoustic survey transects and estimated area of 315 km^2 based on these lines for Scots Bay on Sept. 11, 2005.

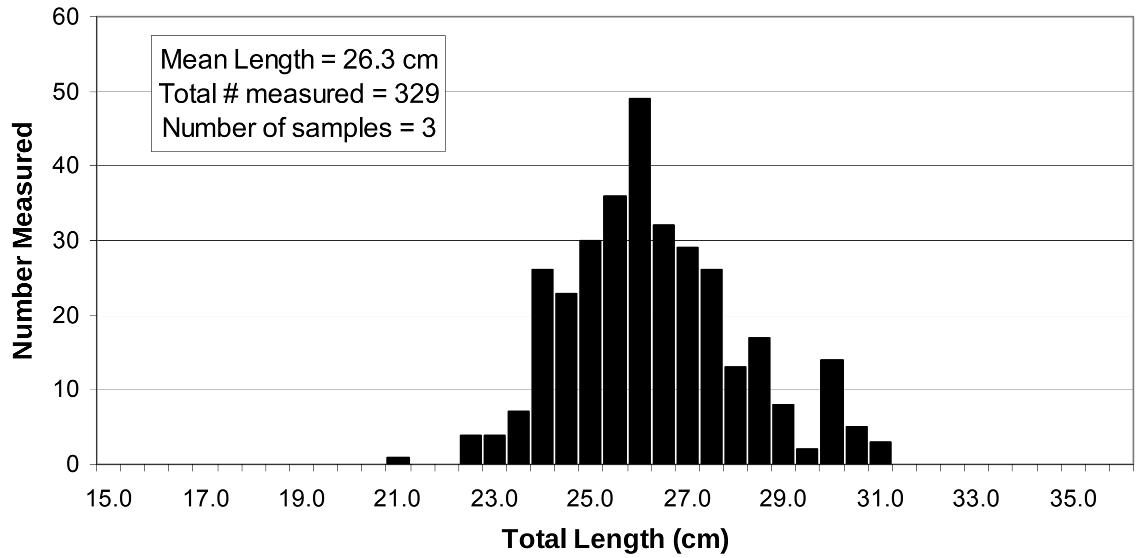


Figure 18. Length size distribution from Scots Bay for Sept. 8-9, 2005 used for the calculation of target strength from a total of three samples available.

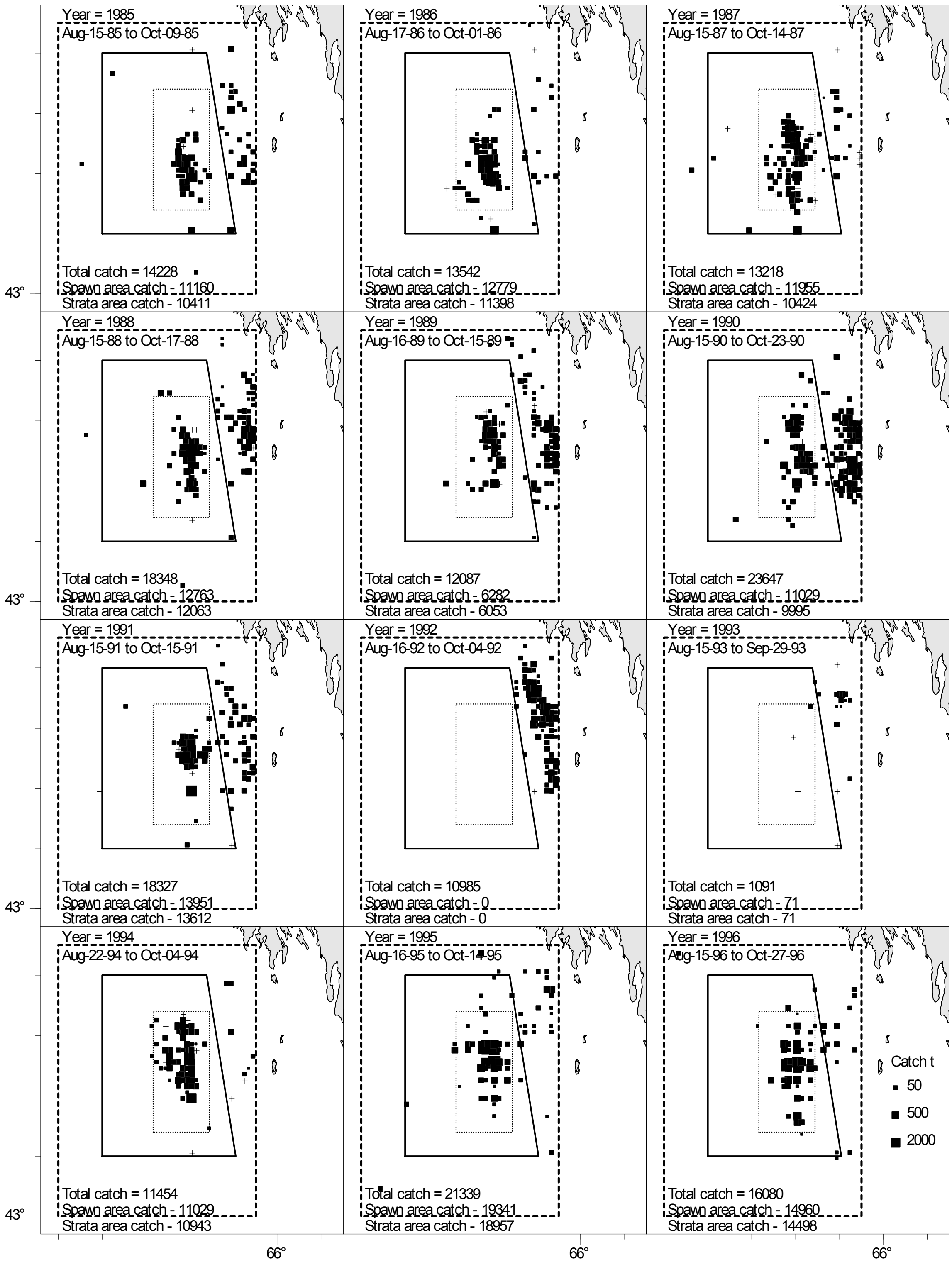


Figure 19. Herring purse seine spawning period catches (Aug. 15 to Oct. 31) for German Bank from 1985-1996 with catch totals for the overall area, the middle 'Spawn Box' and the inner 'Strata Box' which was used as the primary search area in acoustic surveys.

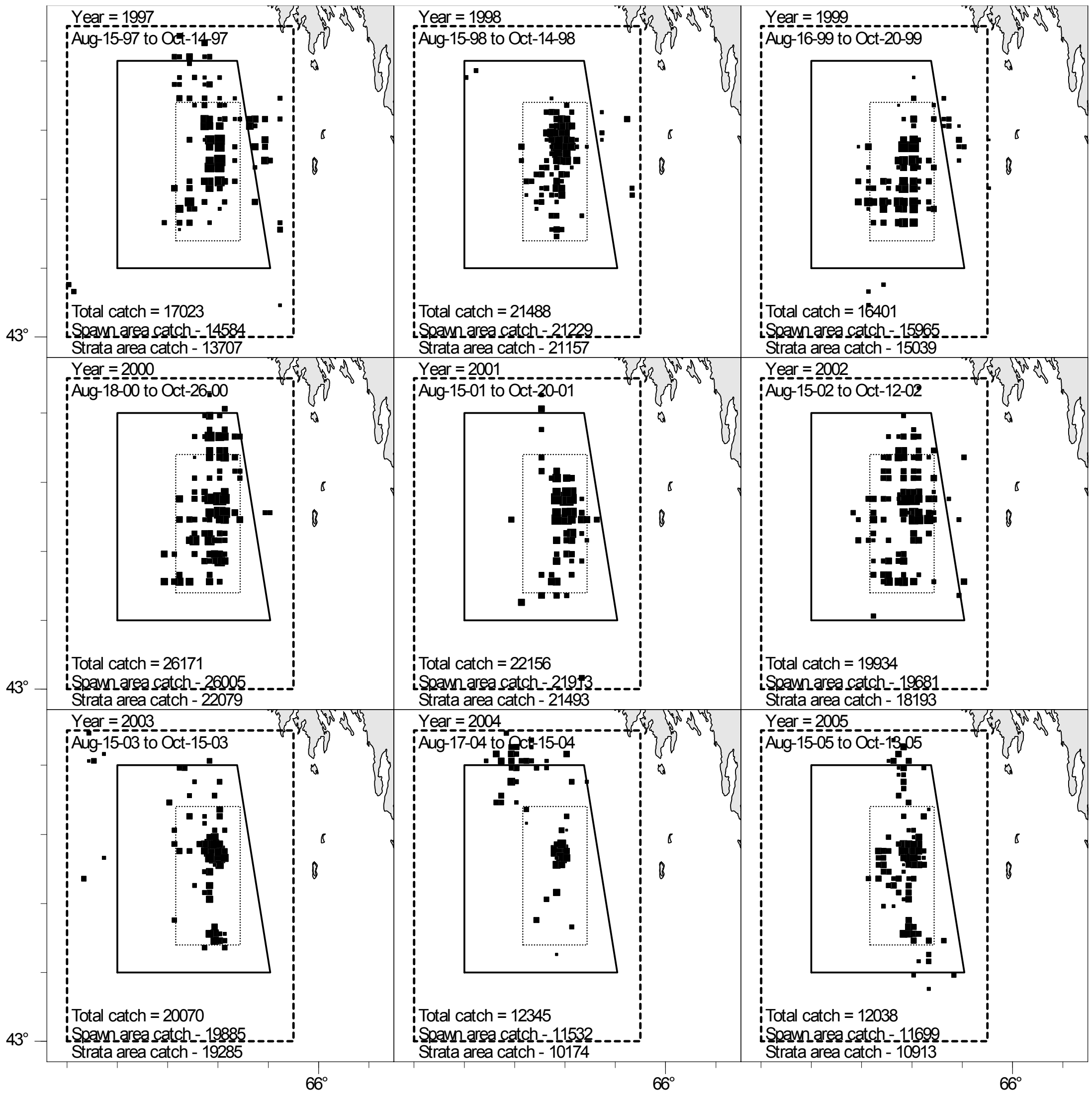


Figure 19 (continued). Herring purse seine spawning period catches (Aug. 15 to Oct. 31) for German Bank from 1997-2005 with catch totals for the overall area, the middle ‘Spawn Box’ and the inner ‘Strata Box’ which was used as the primary search area in acoustic surveys.

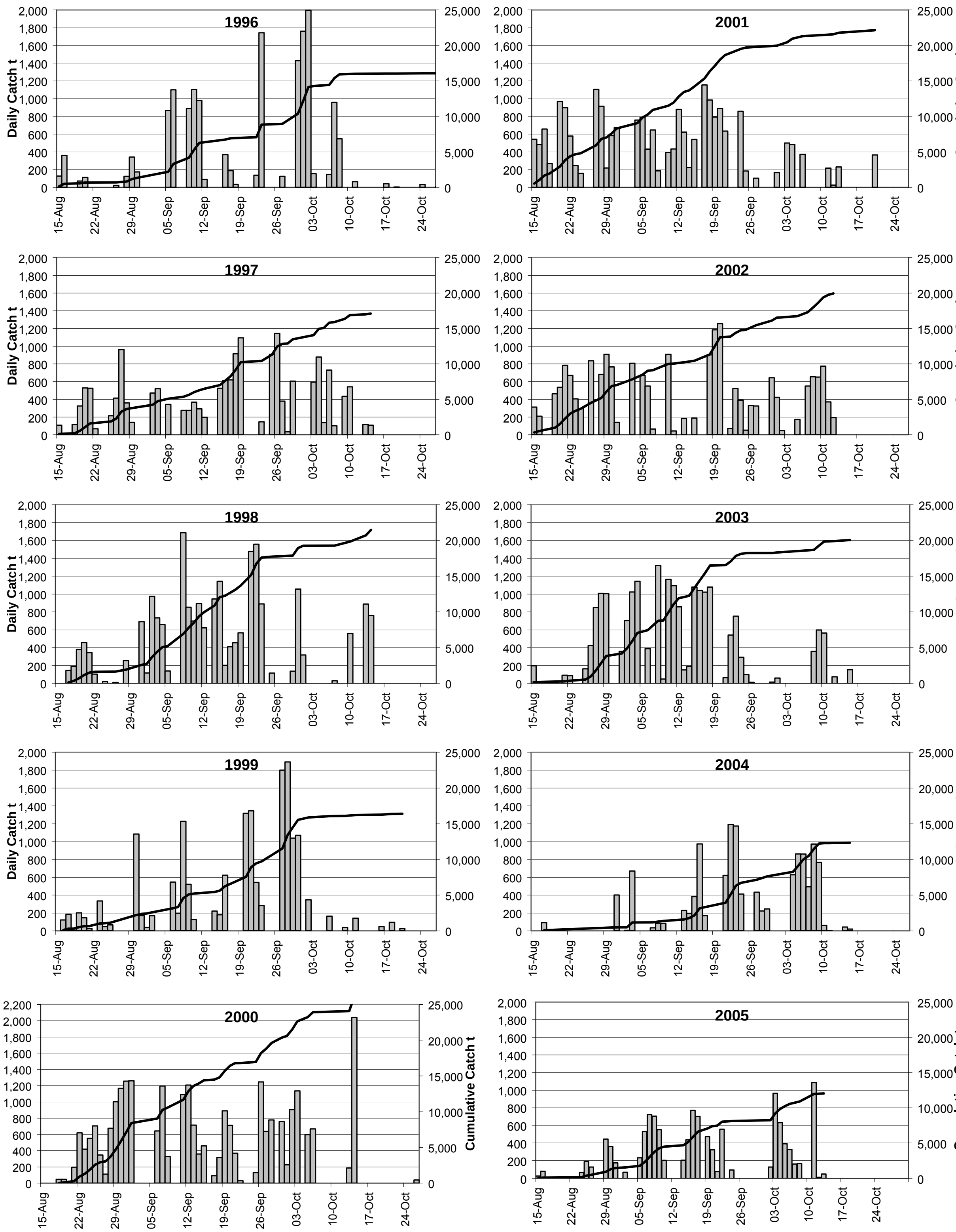


Figure 20. 1996 to 2005 daily purse seine herring catches in tonnes (bars) for German Bank with the cumulative total catch (solid line) over the defined spawning season from Aug. 15 to Oct. 30.

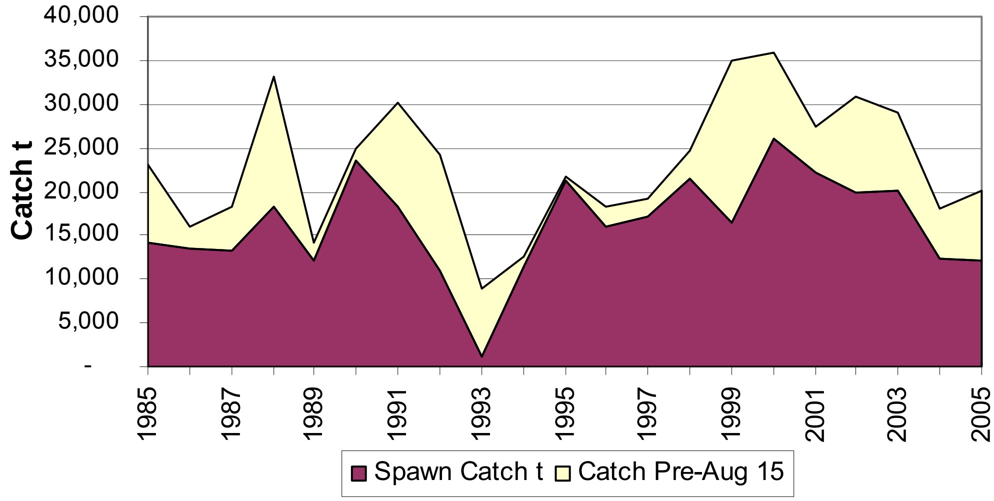


Figure 21. Annual herring purse seine catches for the German Bank area from 1985-2005 with pre-spawning and spawning period catches based on Aug. 15 start date.

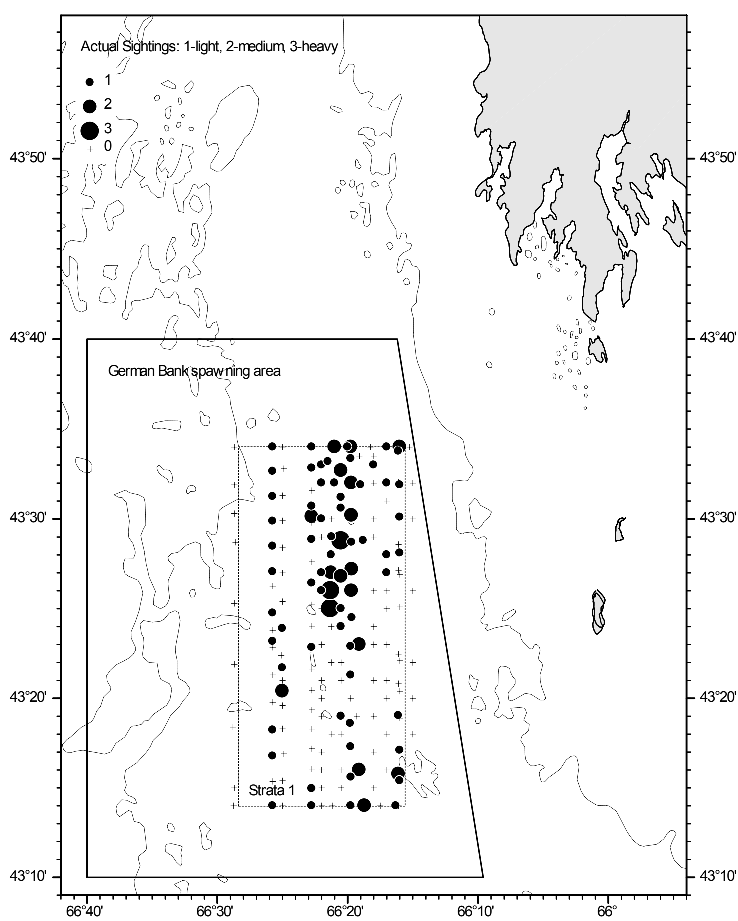


Figure 22. German Bank herring survey deck sheet observations for Sept. 7, 2005 with overall defined spawning area (outer box) and standard survey area or Strata 1 (inner box).

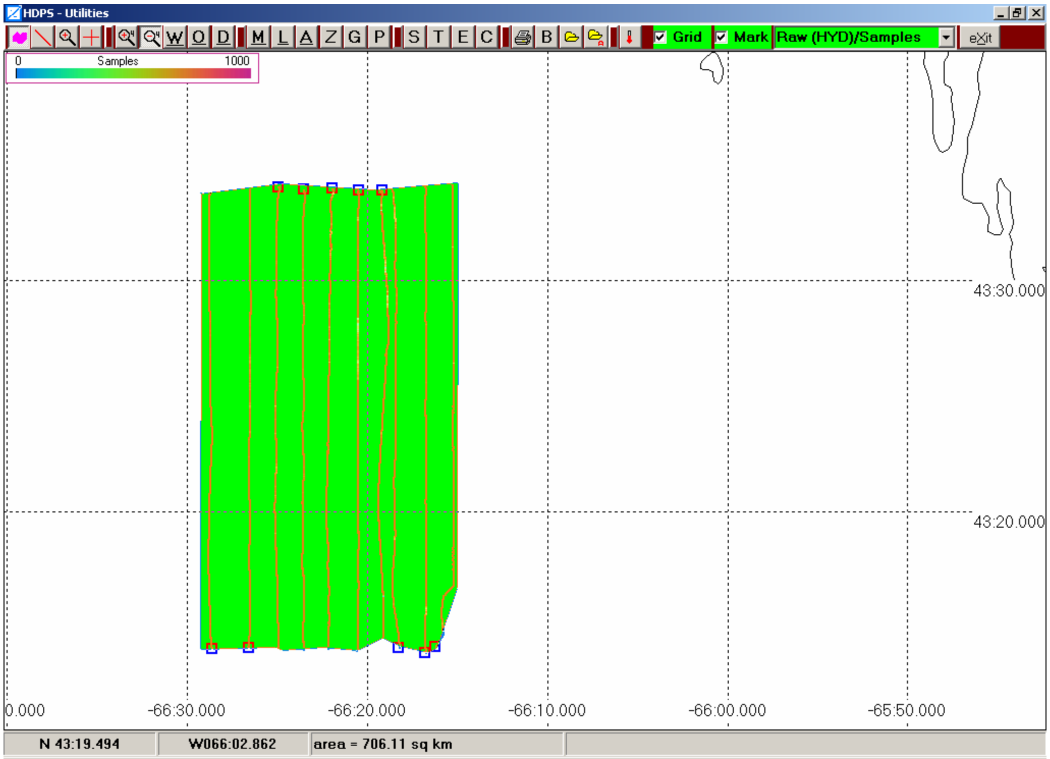


Figure 23. Acoustic survey transects and estimated total survey area of 706 km^2 for German Bank on Sept. 7, 2005.

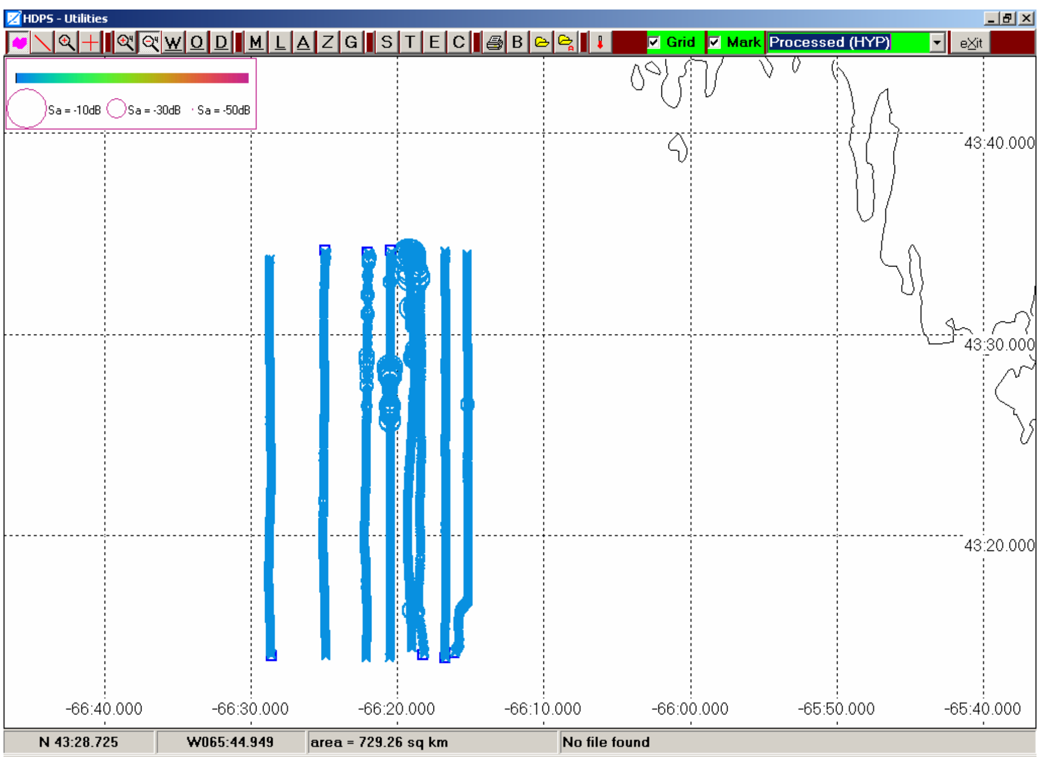


Figure 24. Herring acoustic transects showing total backscatter (Sa) for German Bank survey on Sept. 7, 2005.

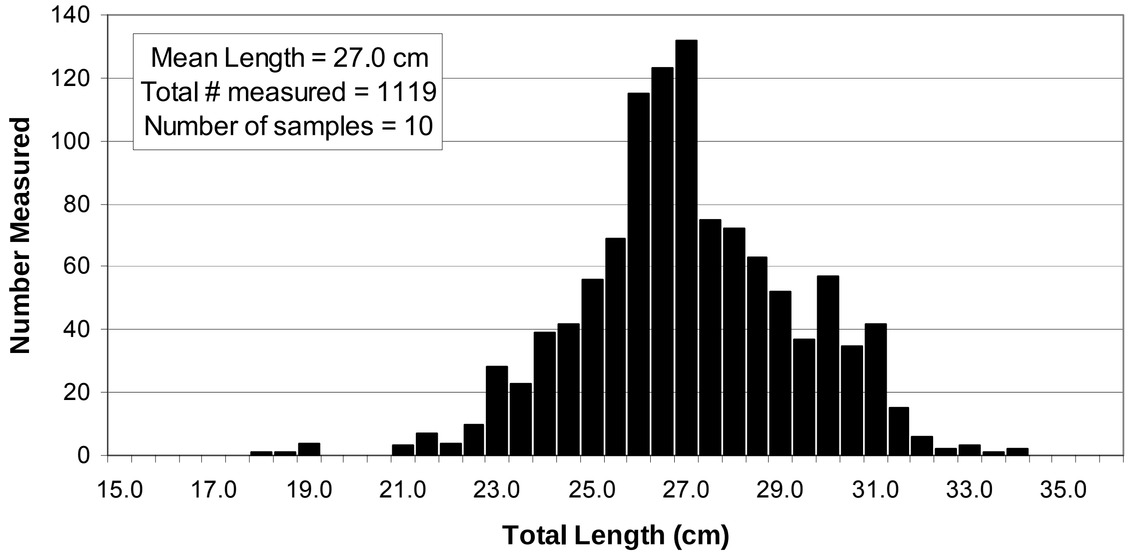


Figure 25. Length sample frequency distribution from German Bank for Sept. 7-8, 2005 used in the calculation of target strength (TS).

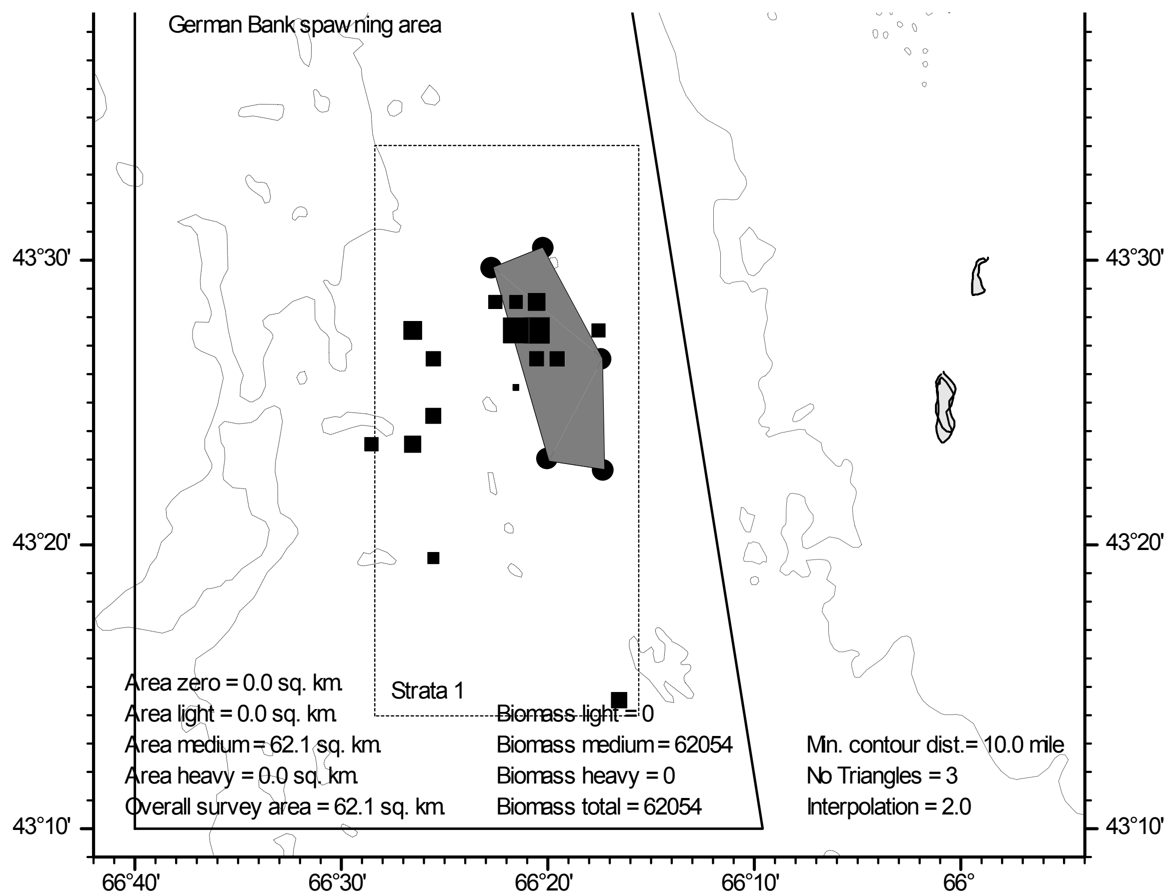


Figure 26. Observations on German Bank for Sept. 14, 2005 for area estimated as medium density of $1000t/km^2$ with catches in survey box for Sept. 7 to Sept. 14.

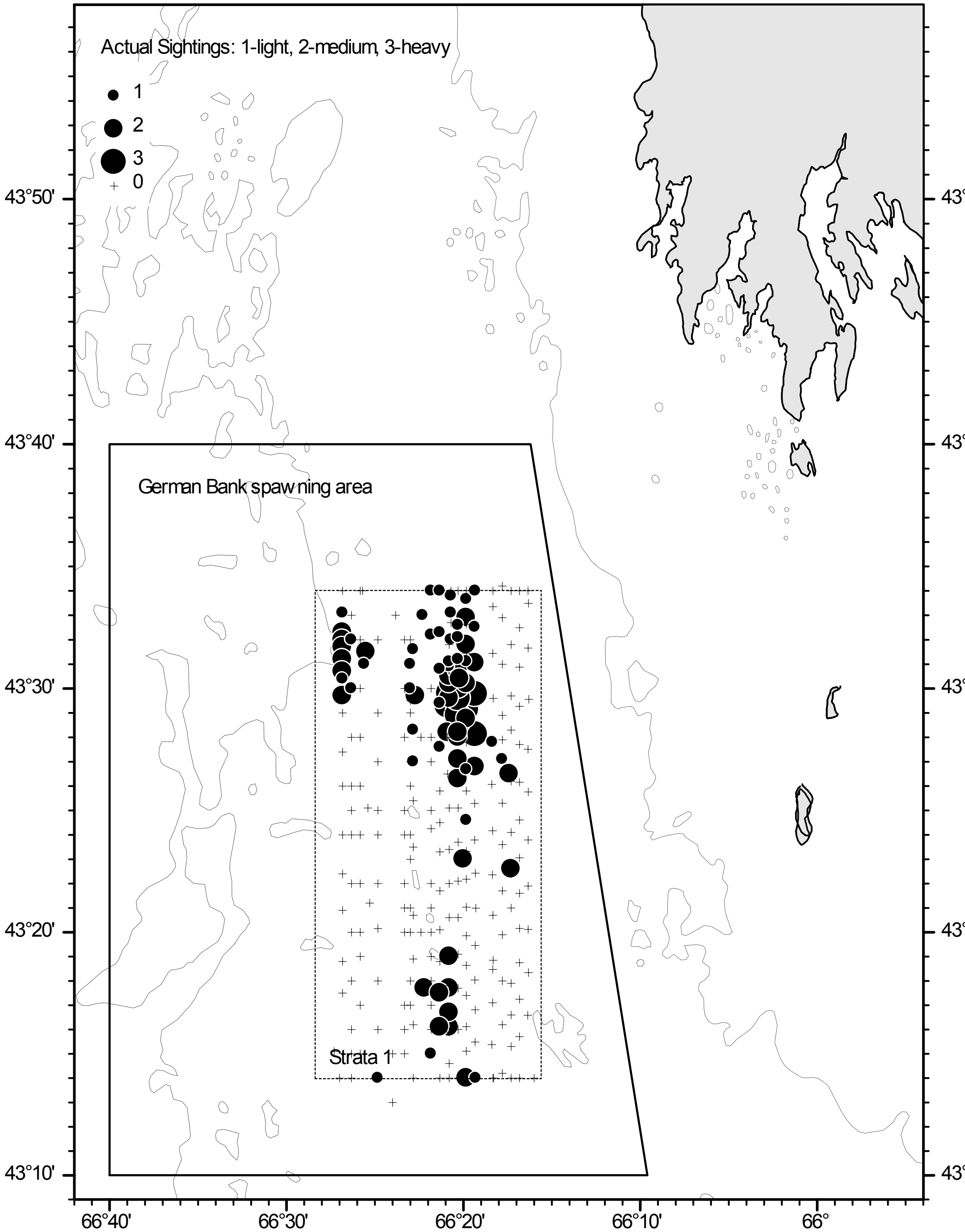


Figure 27. German Bank herring survey deck sheet observations for Sept. 21, 2005 with overall defined spawning area (outer box) and standard survey area or Strata 1 (inner box).

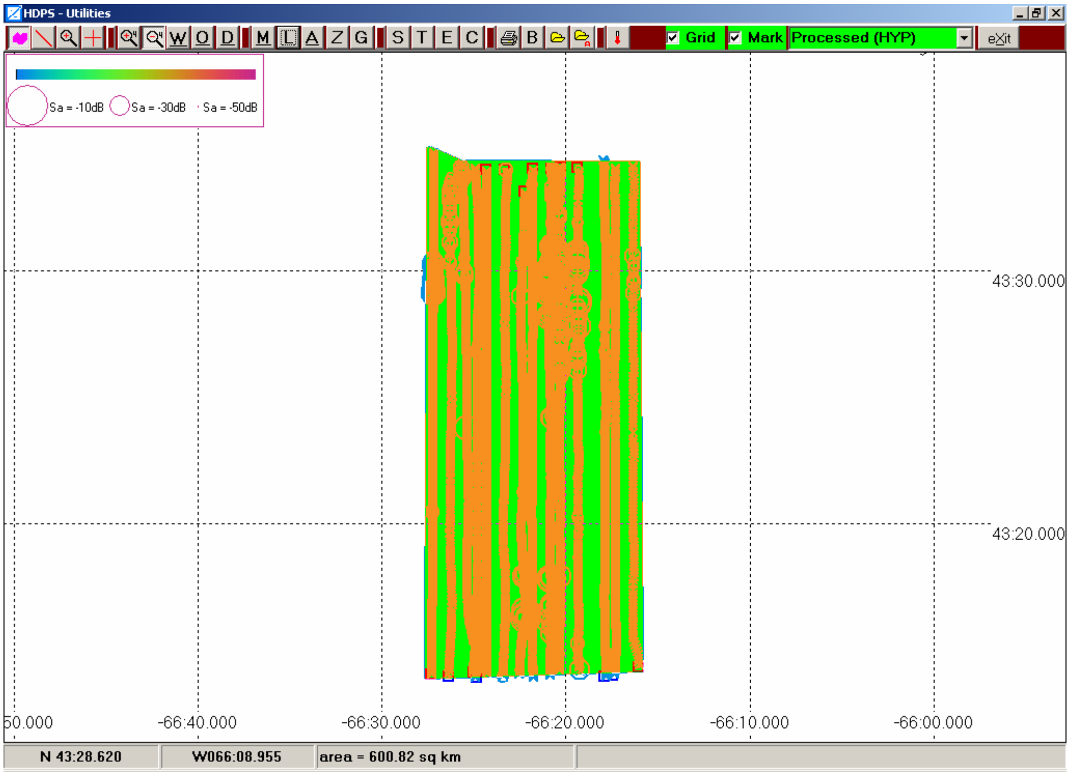


Figure 28. Acoustic survey transects and estimated total survey area of 600 km^2 for German Bank on Sept. 21, 2005 (map in Mercator projection).

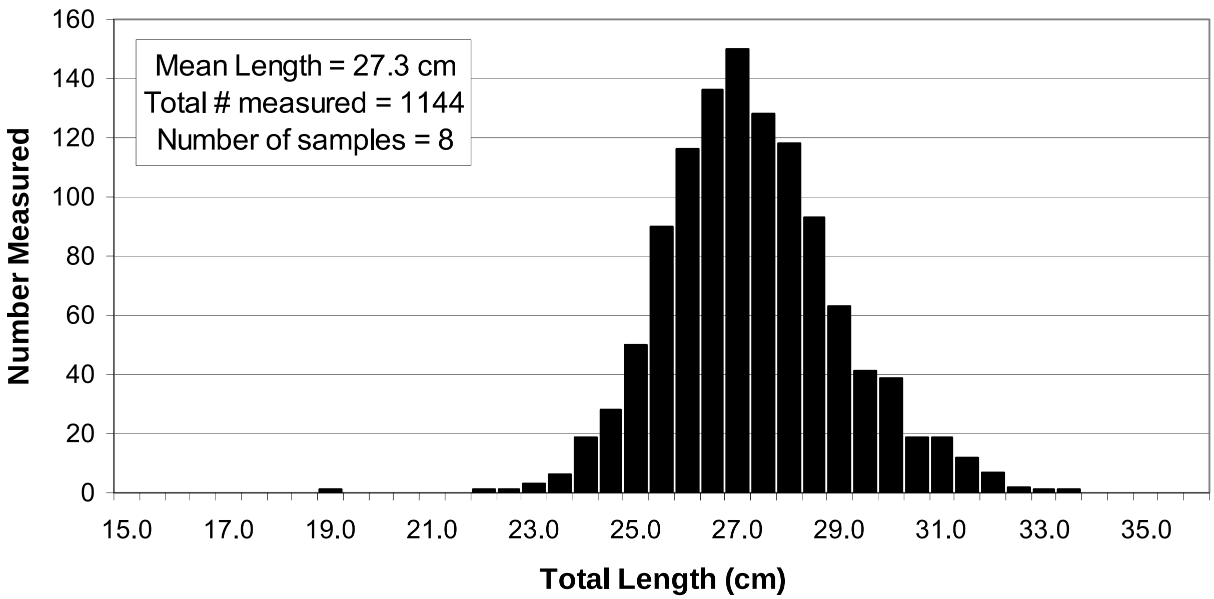


Figure 29. Length sample frequency distribution from German Bank for Sept. 20-22, 2005 used in the calculation of target strength (TS).

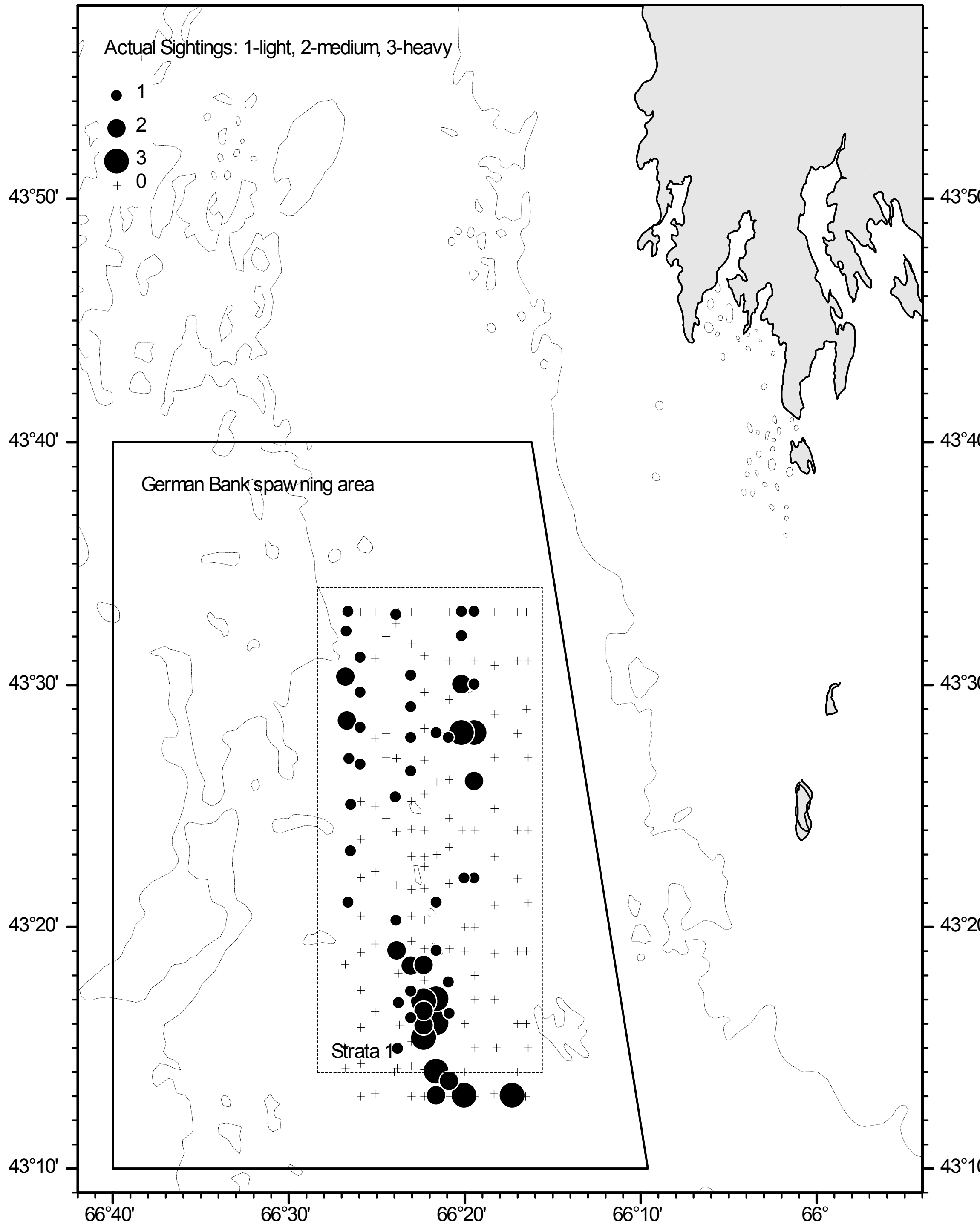


Figure 30. German Bank herring survey deck sheet observations for Oct. 4, 2005 with overall defined spawning area (outer box) and standard survey area or Strata 1 (inner box).

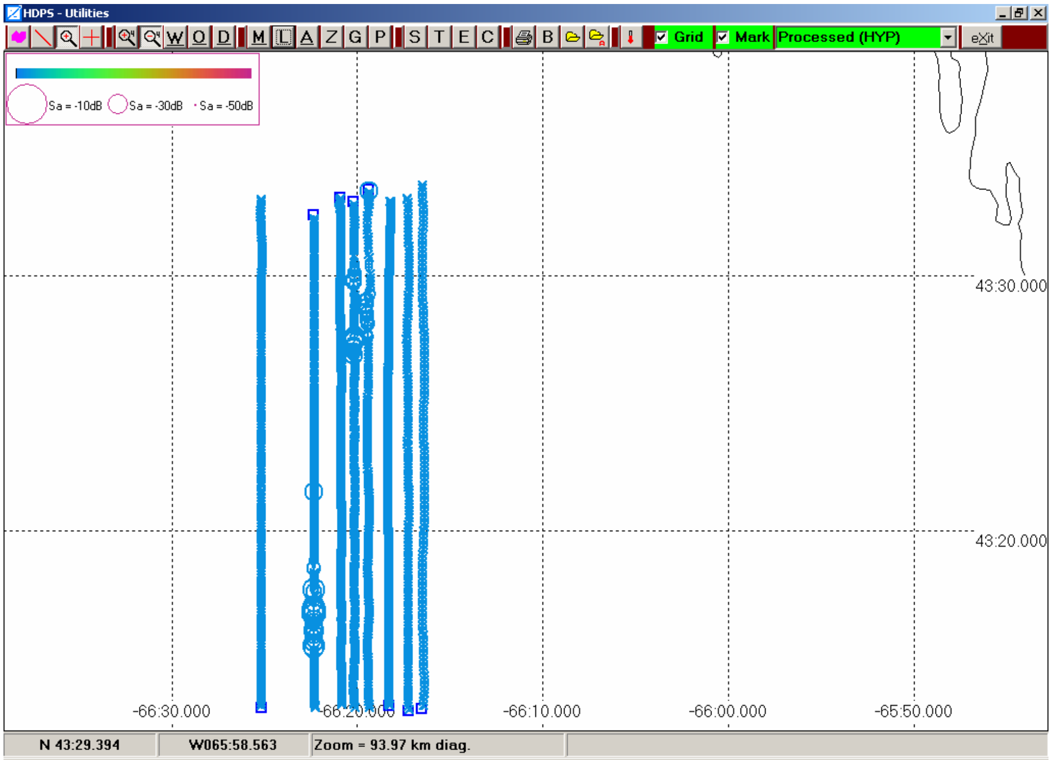


Figure 31. Acoustic survey transects with estimated total survey area of 500 km^2 for German Bank on Oct. 4, 2005.

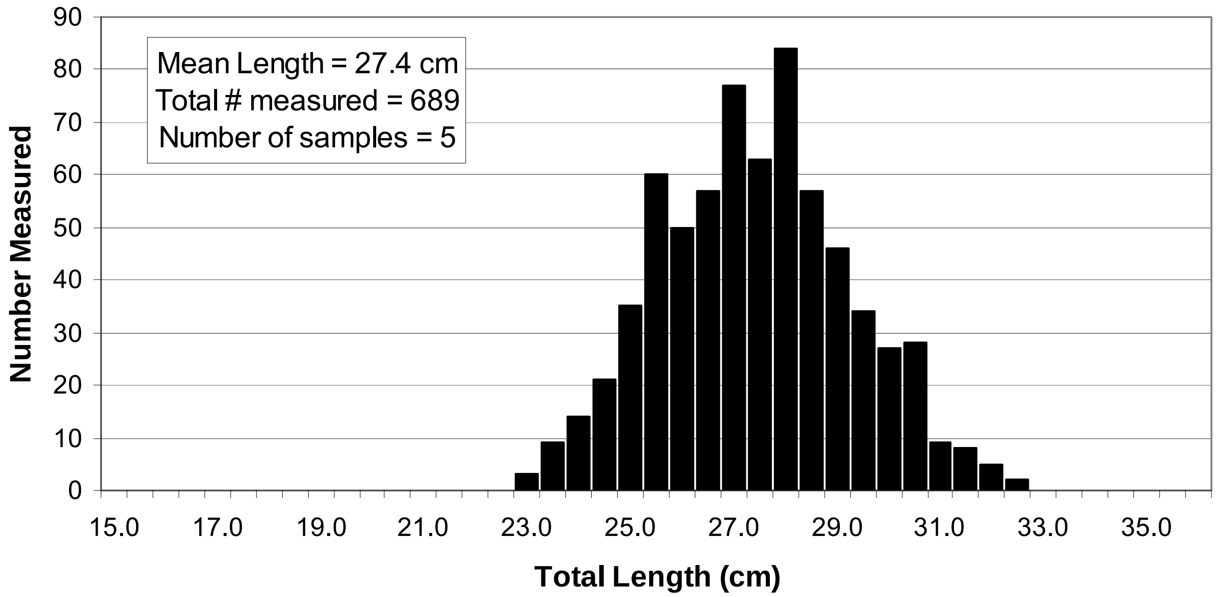


Figure 32. Length sample frequency distribution from German Bank for Oct. 4-5, 2005 used in the calculation of target strength (TS).

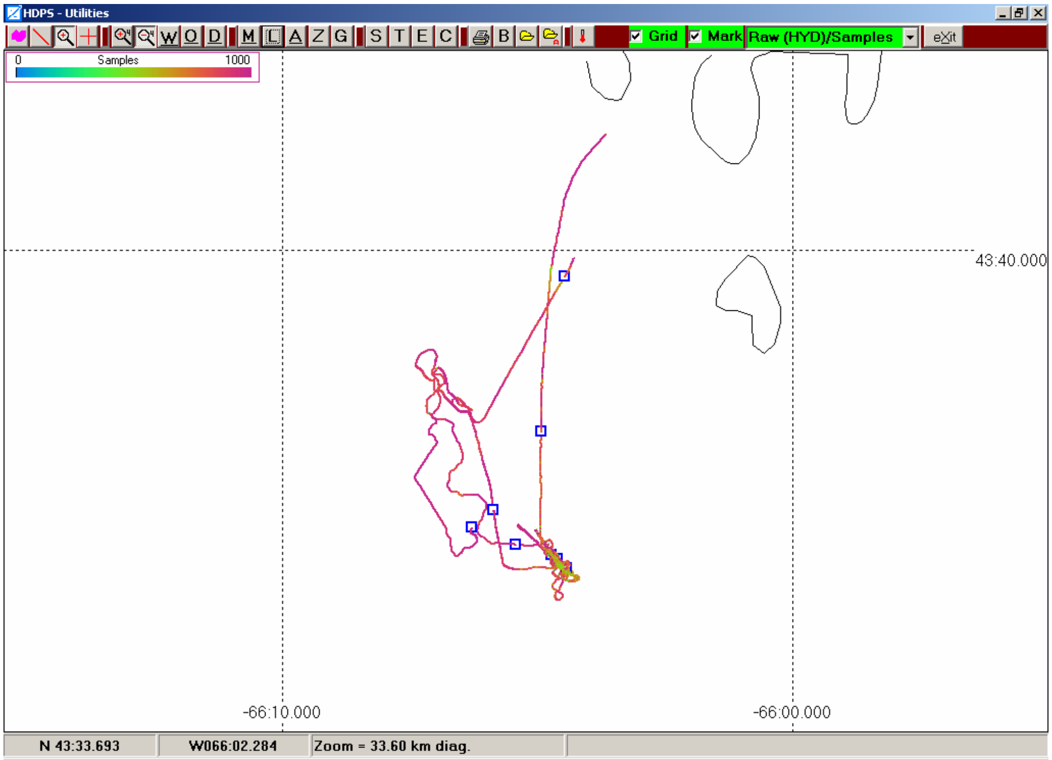


Figure 33. Survey tracks for the *Sea Quiz* in June 2005 for files recorded near the Spectacle Buoy area.

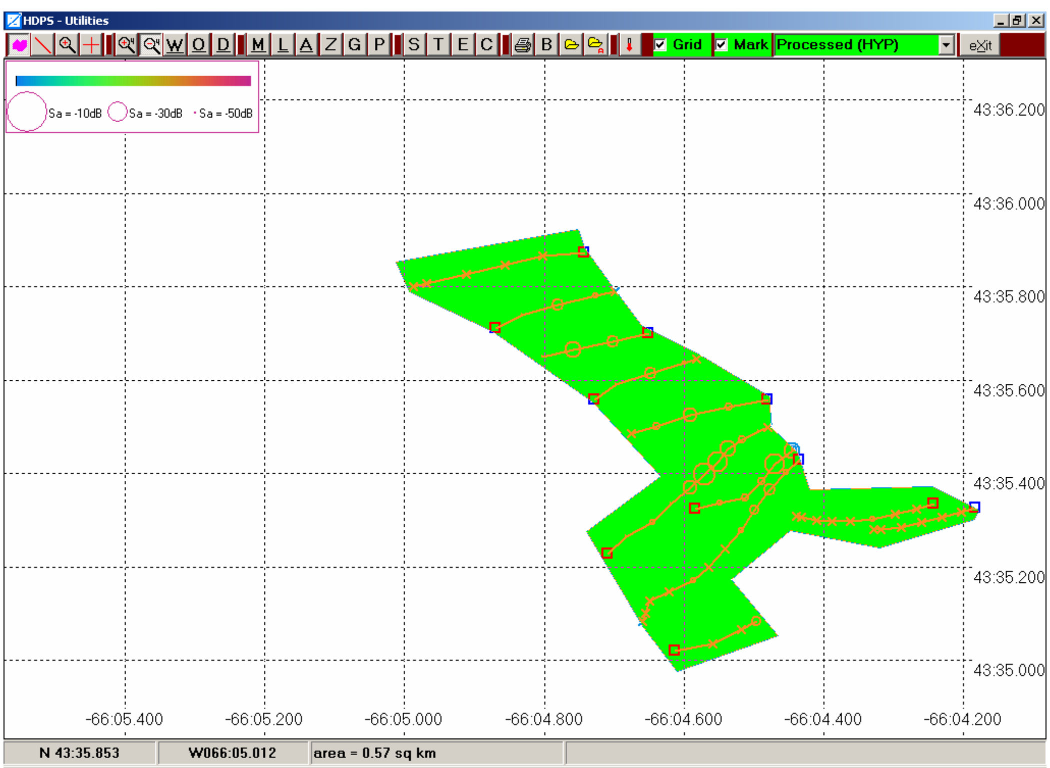


Figure 34. Acoustic survey transects and estimated total survey area of 0.57 km^2 for the Spectacle Bouy area on June 6, 2005.

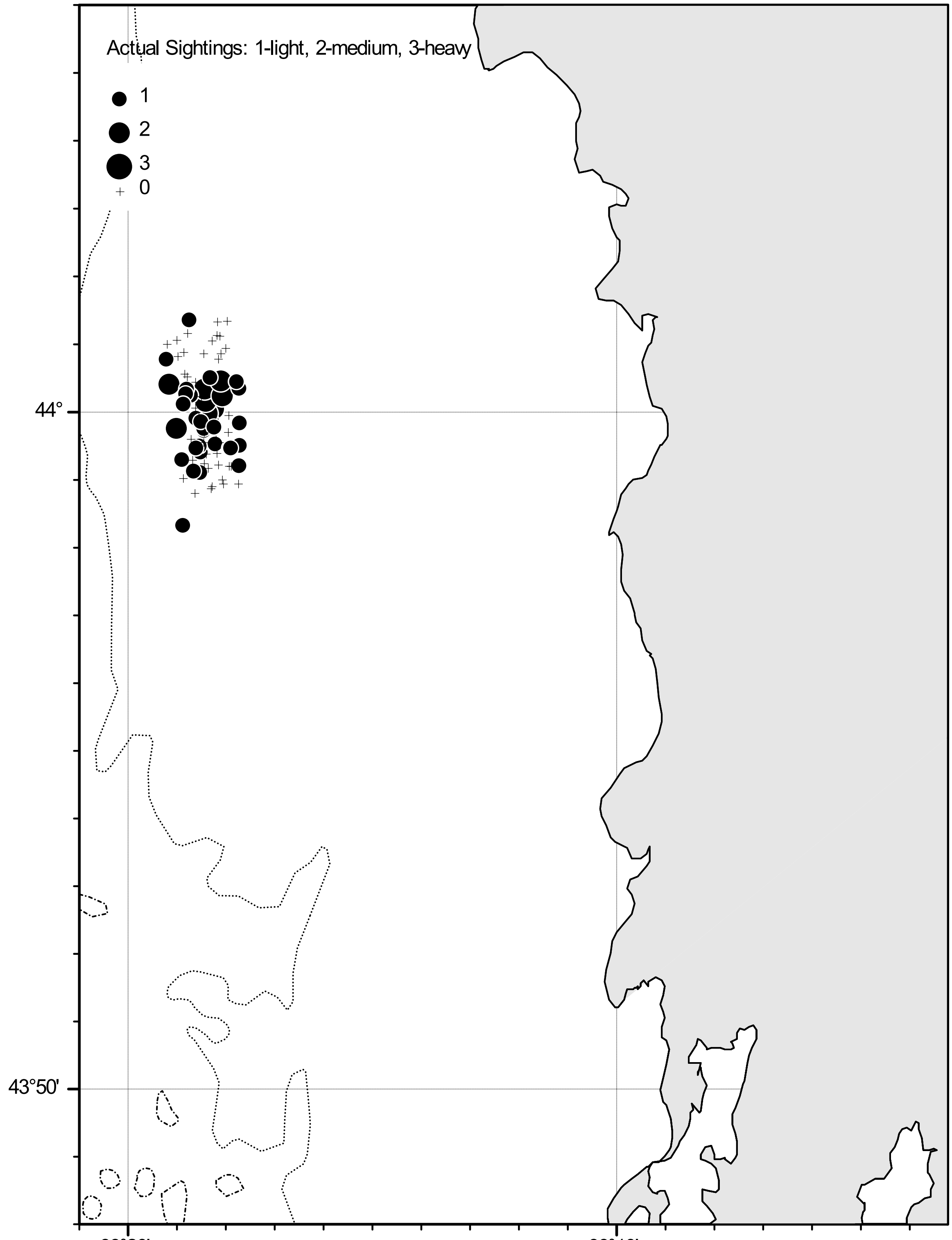


Figure 35. Trinity Ledge herring survey deck sheet observations for Sept 6, 2005 with results from 8 boats.

Figure 36. Acoustic survey transects and estimated total survey area of 0.82 km^2 for Trinity Ledge on Sept. 6, 2005 by the *Sea Quiz*.

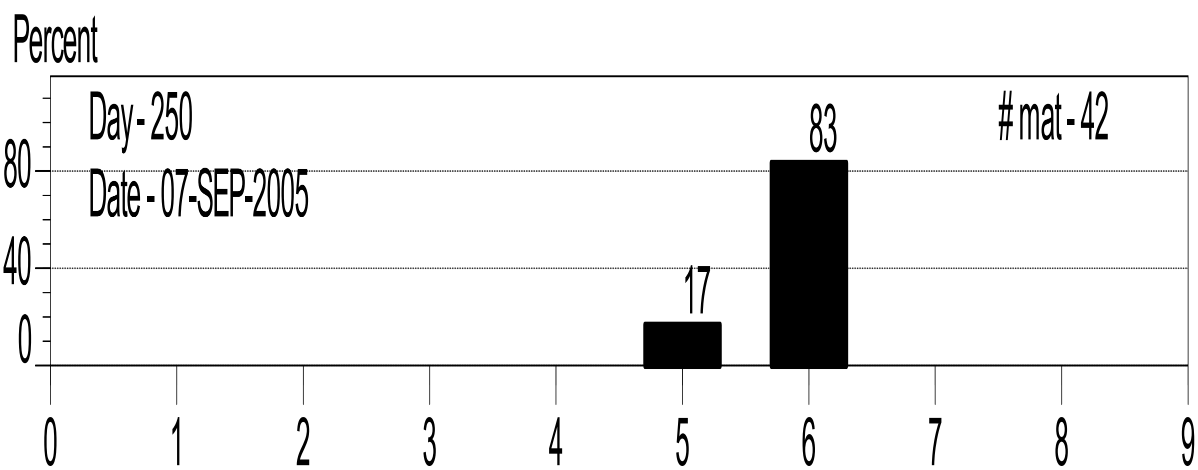


Figure 37. Trinity Ledge herring gonad maturity sample for Sept. 7, 2005 (% by stage for sexes combined).

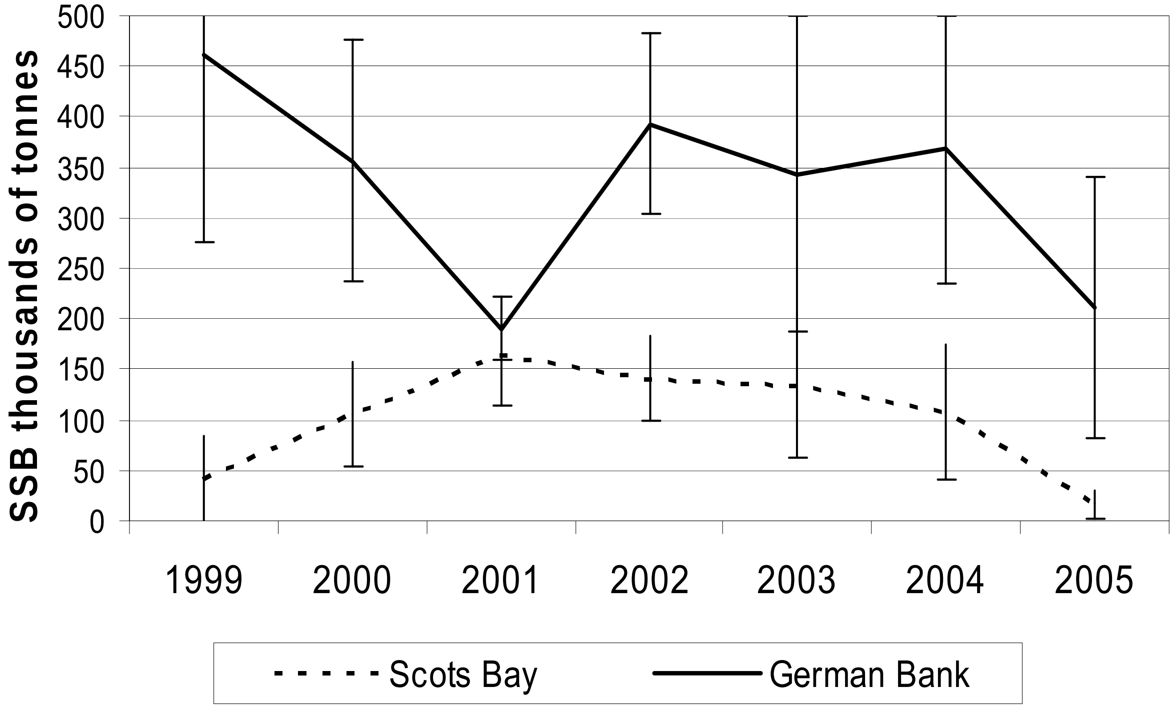


Figure 38. Trends in herring spawning stock biomass from acoustic surveys in Scots Bay and German Bank areas with 95% confidence intervals (equivalent to 2 times SE).

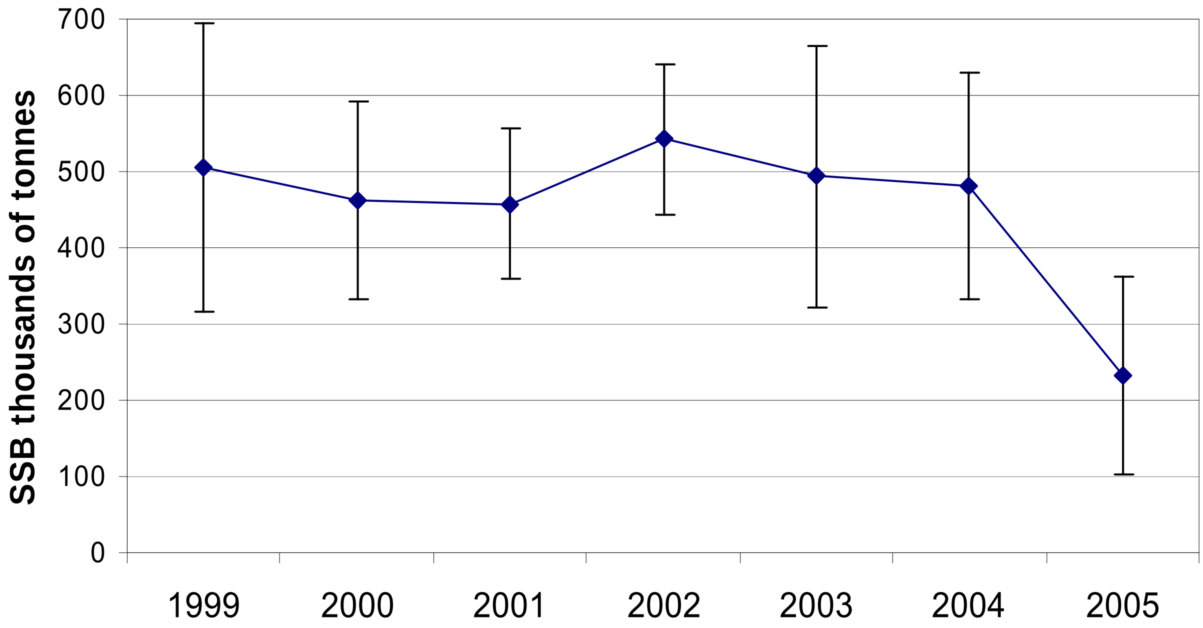


Figure 39. Trends in herring spawning stock biomass from acoustic surveys for the combined southwest Nova Scotia areas with 95% confidence intervals (equivalent to 2 times SE).

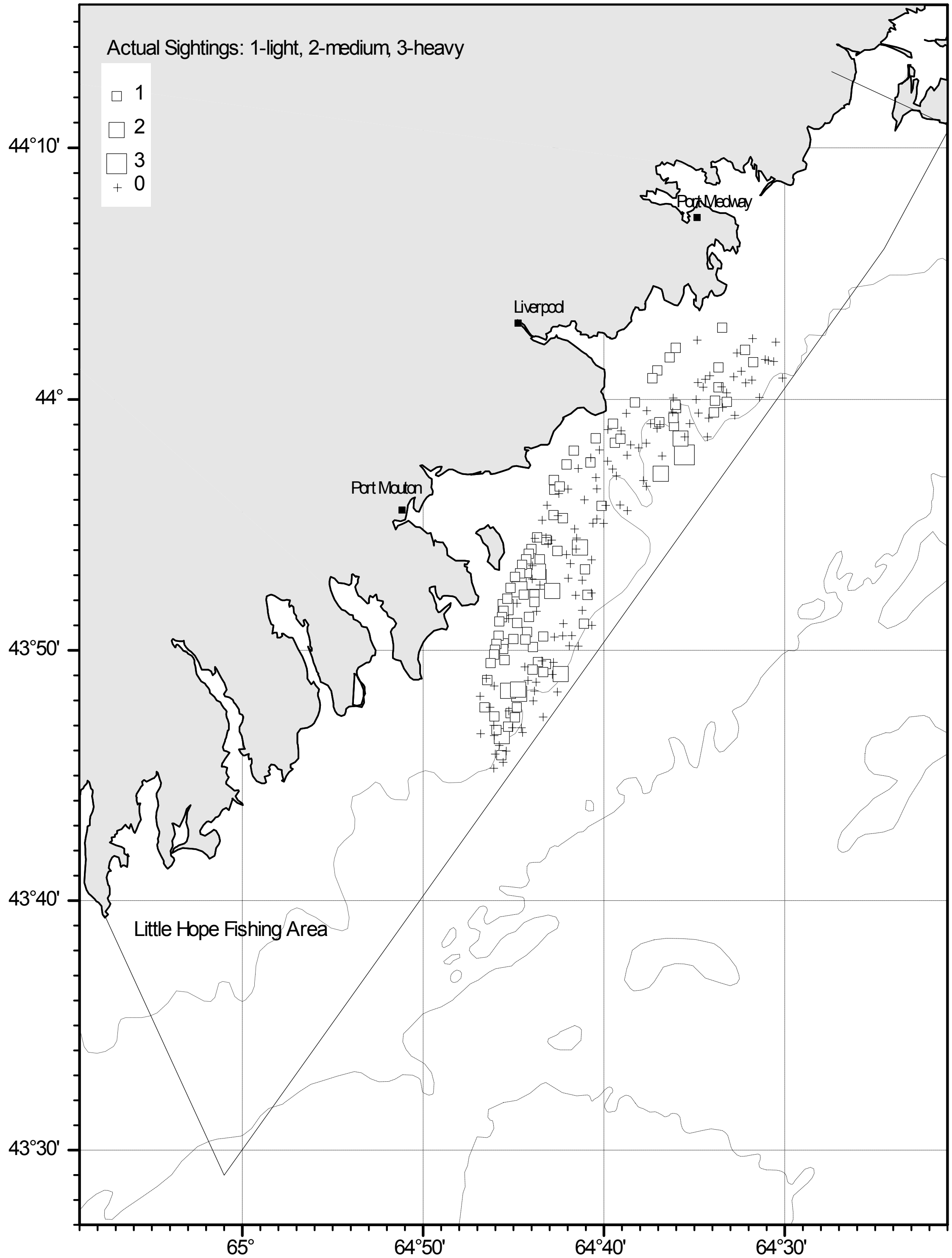


Figure 40. Little Hope herring mapping survey for Oct. 4, 2005 with marker size corresponding to density of fish sightings encountered. The defined Little Hope fishing area is also shown.

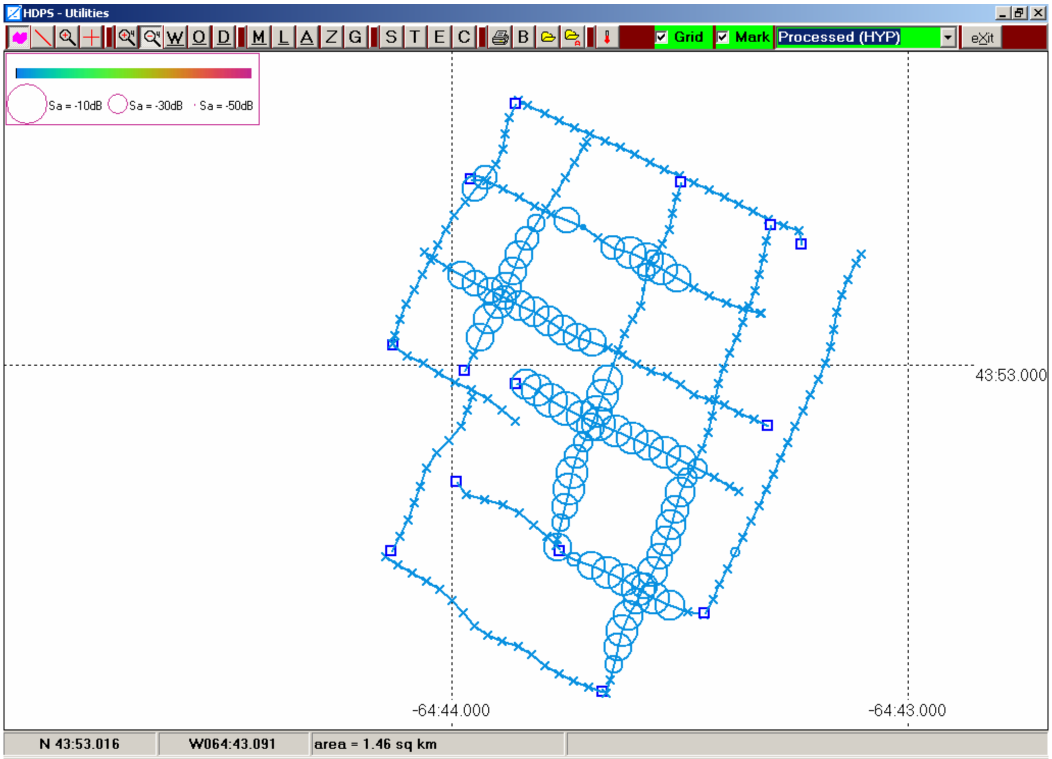


Figure 41. Acoustic lines showing total backscatter (Sa) on a herring school south of Little Hope Island on Oct. 4, 2005 by survey vessel *Knot Paid For*.

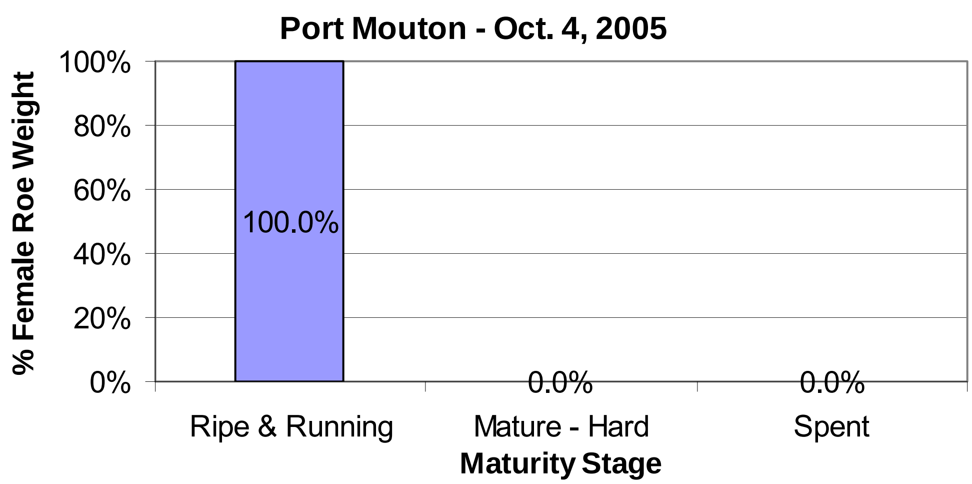


Figure 42. Industry maturity sample from Port Mouton on Oct. 4, 2005 for female herring roe by percent weight.

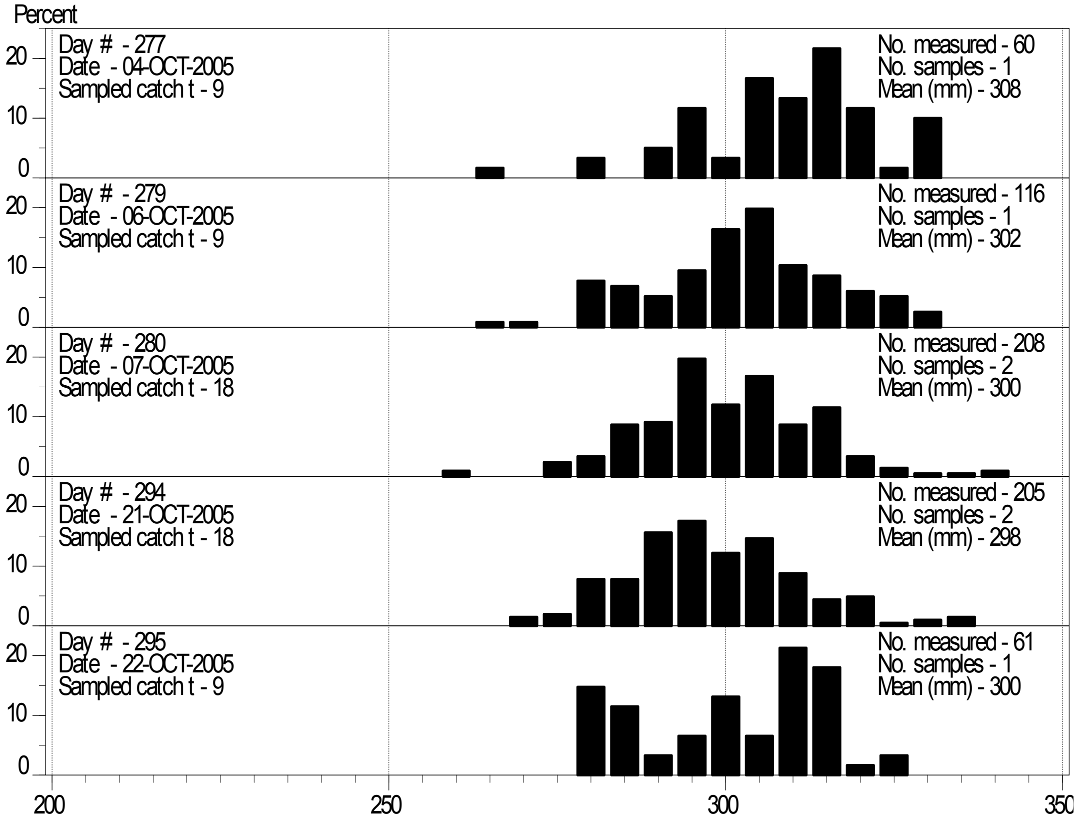


Figure 43. Herring length distributions for gillnet fishery samples from the Little Hope/Port Mouton area for Oct. 4-22, 2005.

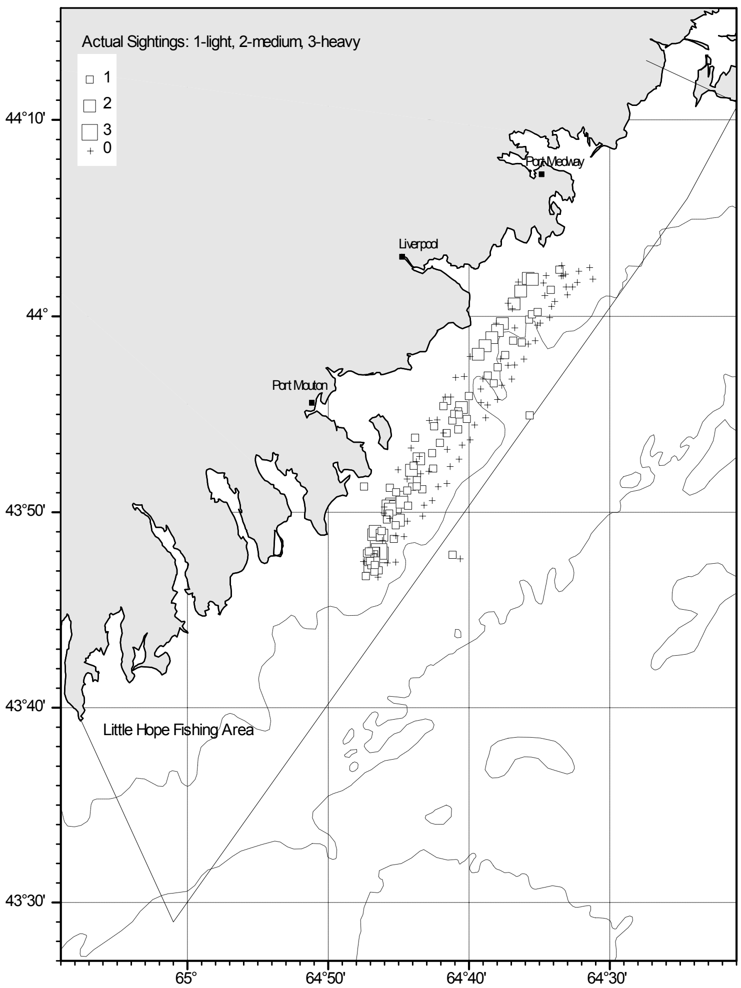


Figure 44. Little Hope/Port Mouton herring survey deck sheet observations for Oct. 19, 2005 with the defined fishing area.

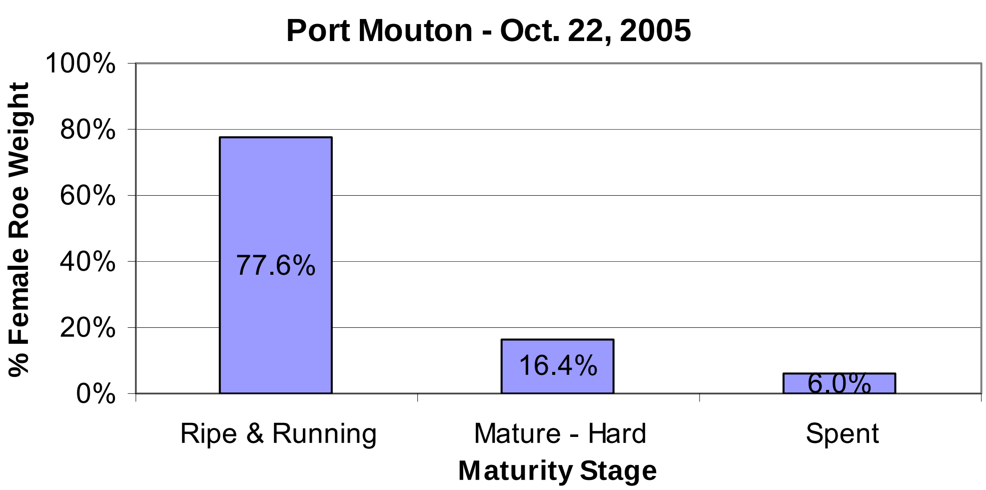


Figure 45. Industry maturity sample from Port Mouton on Oct. 19, 2005 for female herring roe by percent weight.

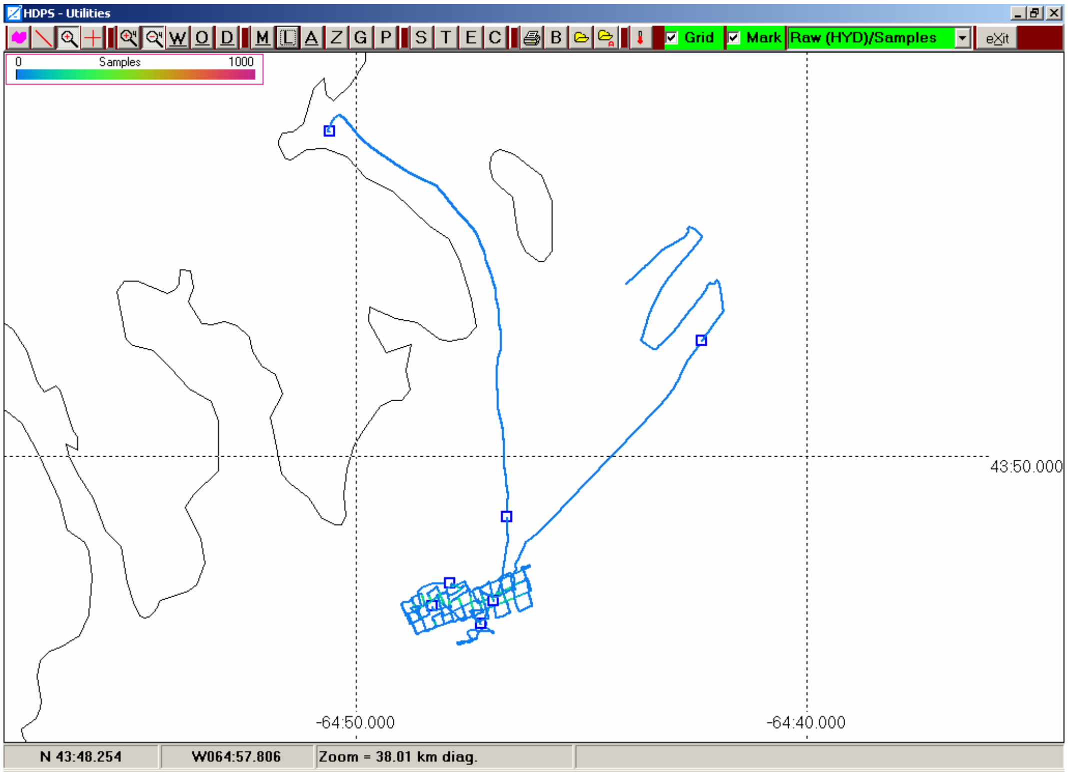


Figure 46. Acoustic survey tracks off Little Hope/Port Mouton, N.S. on Oct. 19-20, 2005.

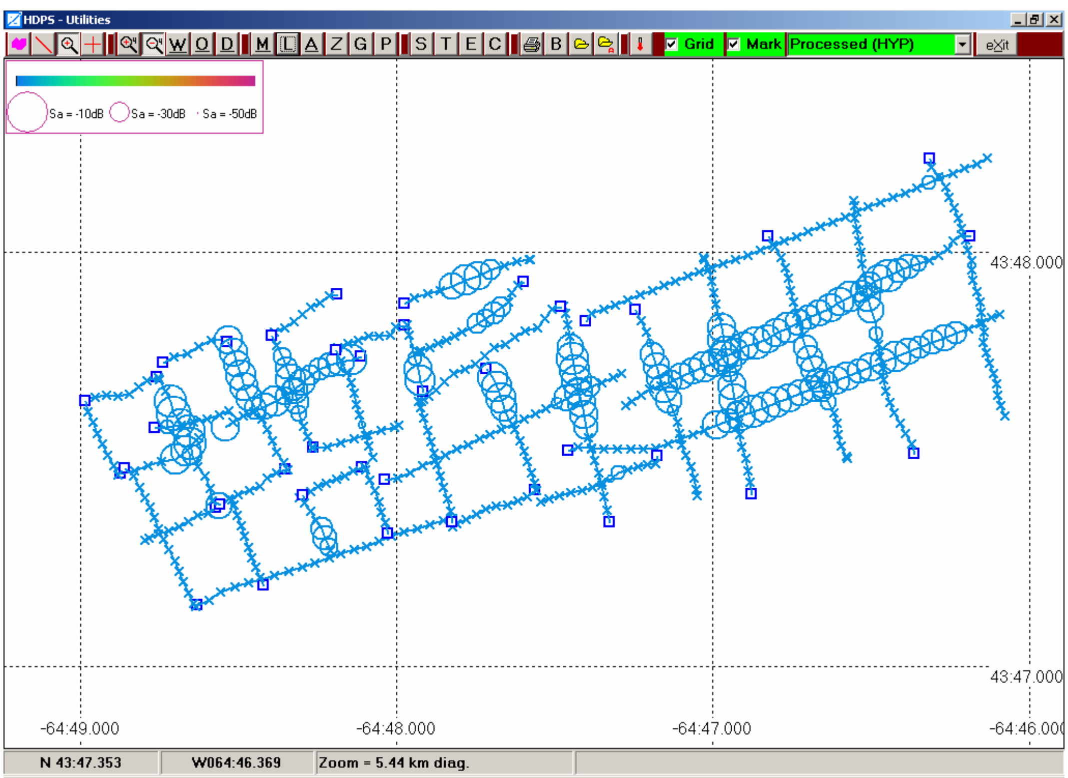


Figure 47. Acoustic lines showing total backscatter (Sa) on a herring school south of Little Hope Island on Oct. 19-20, 2005 by survey vessel *Knot Paid For*.

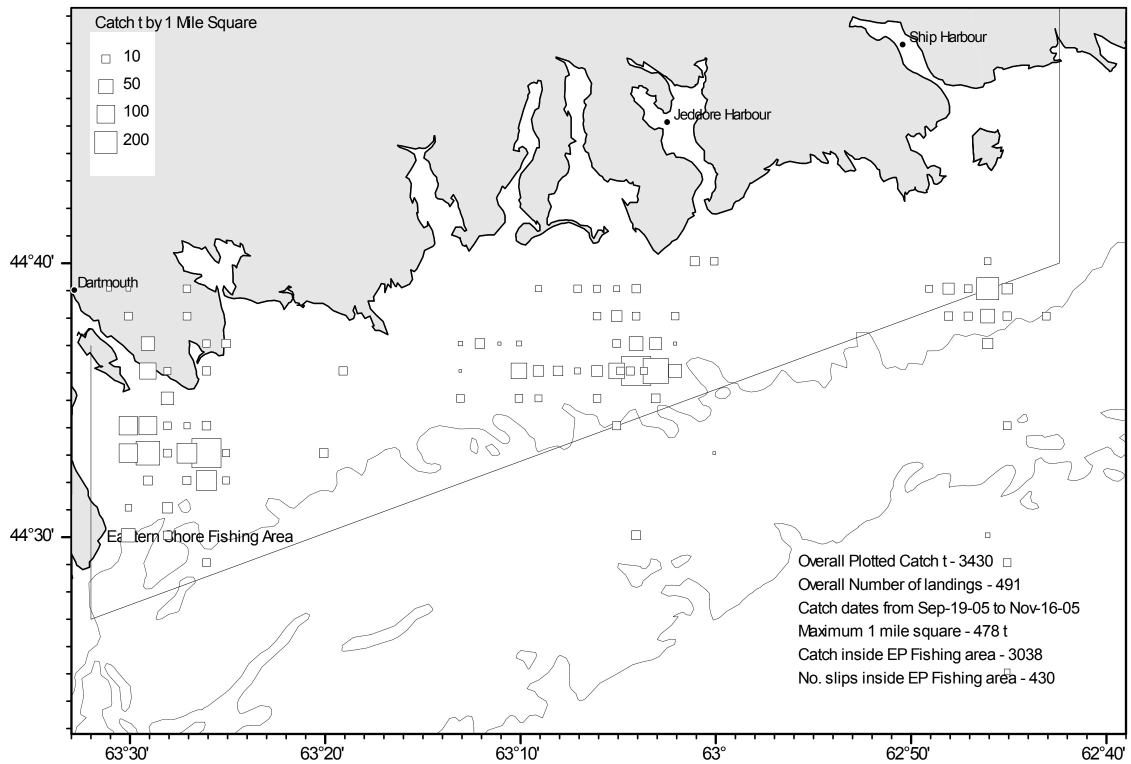


Figure 48. Herring catches for the Halifax/Eastern Shore area for the period Sept. 19 to Nov. 16, 2005.

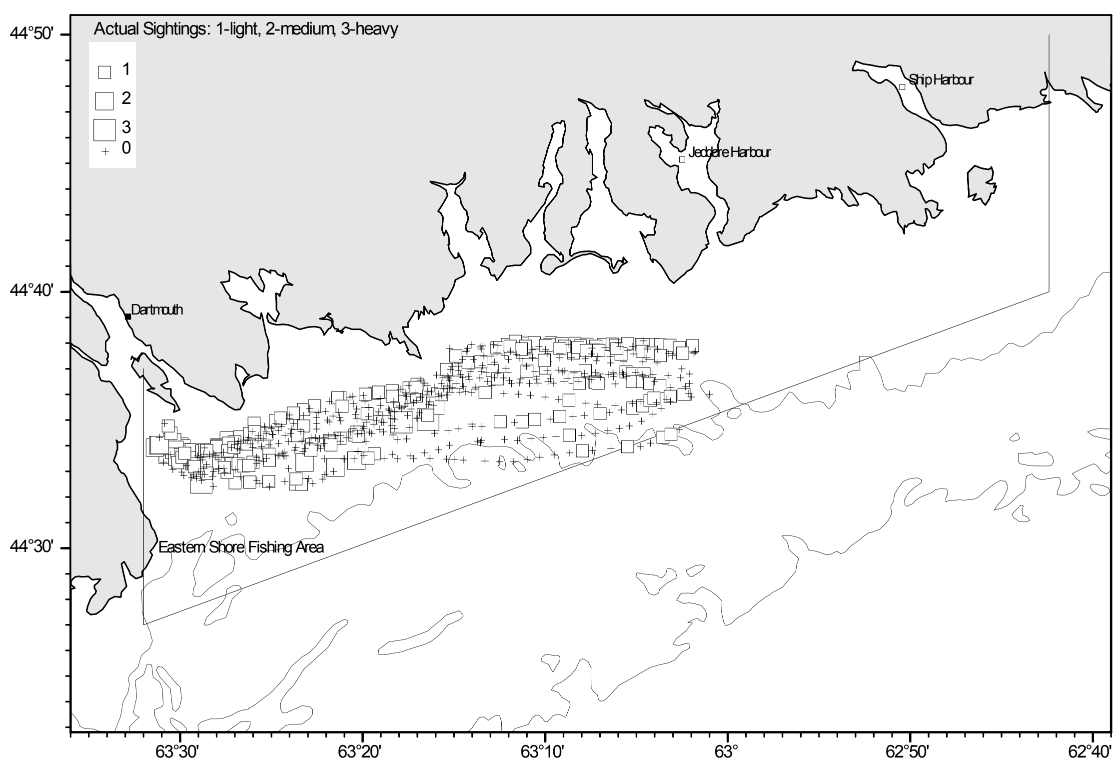


Figure 49. Halifax/Eastern Shore herring survey deck sheet observations for Sept. 29, 2005 with the defined Eastern Shore fishing area.

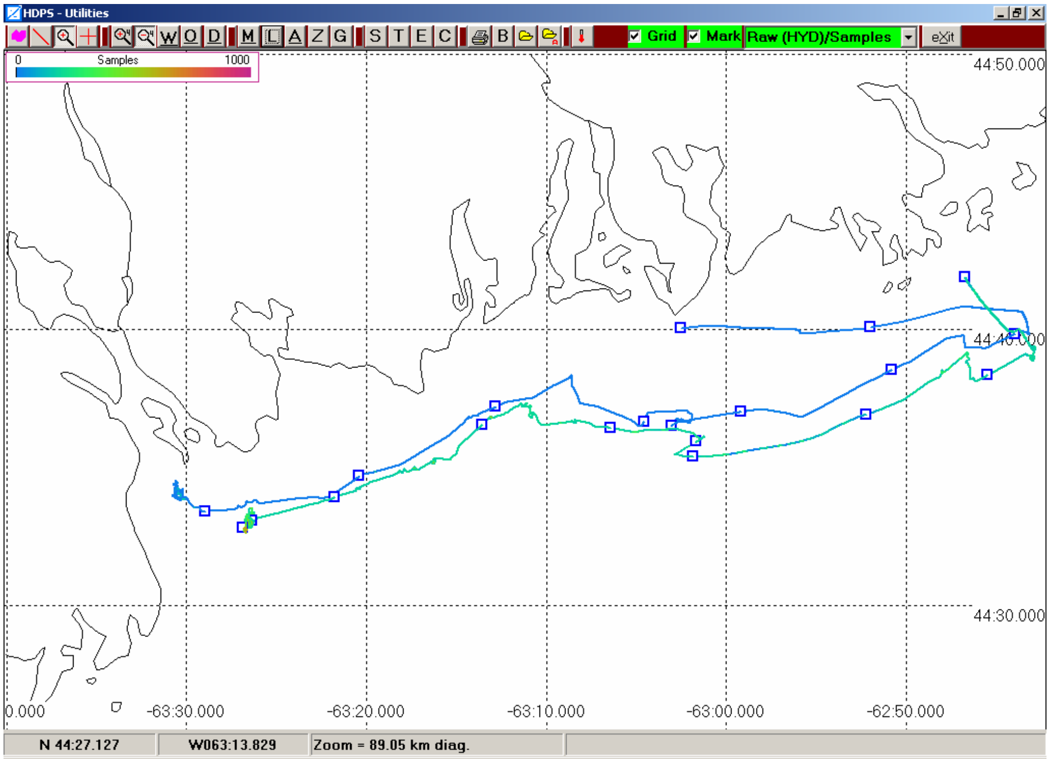


Figure 50. Search tracks by acoustic survey vessels *Bradley K* (blue upper line) and *Miss Owls Head* (green bottom line) for Sept 28-29, 2005 survey night.

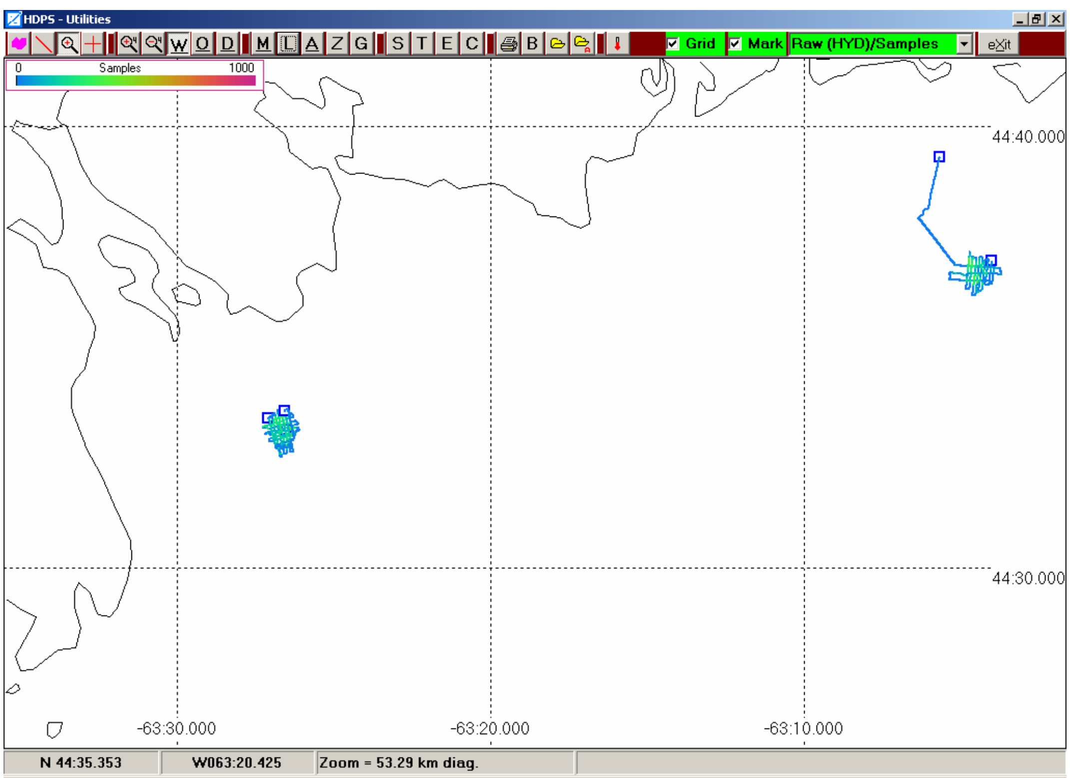


Figure 51. Survey tracks by the *Miss Owls Head* off Halifax harbour and by the *Bradley K* near Jeddore on Oct. 3, 2005.

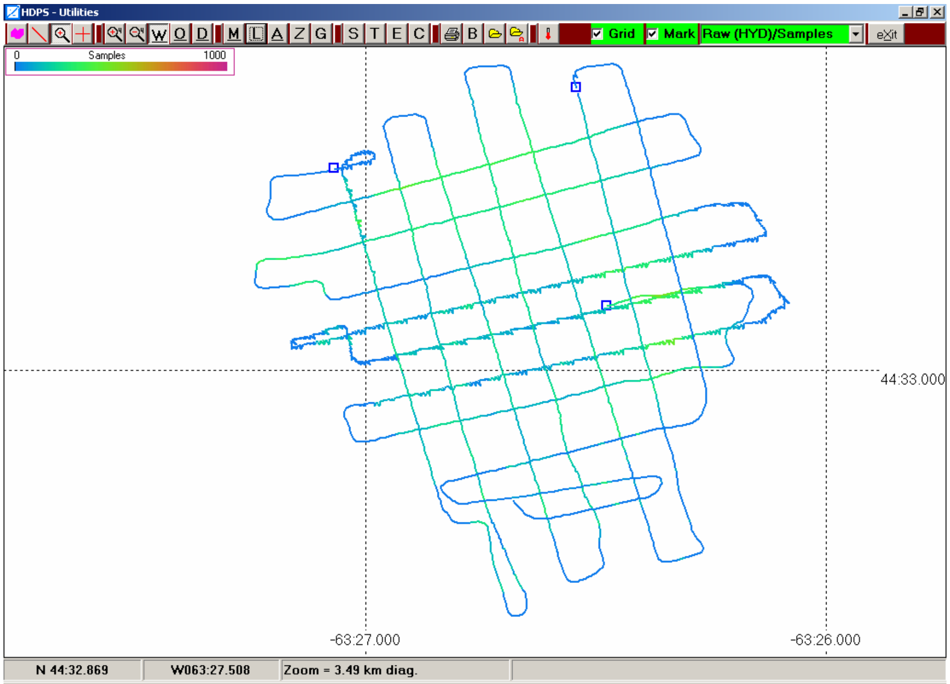


Figure 52. Survey Tracks by *Miss Owls Head* on Oct 3, 2005 off Halifax harbour.

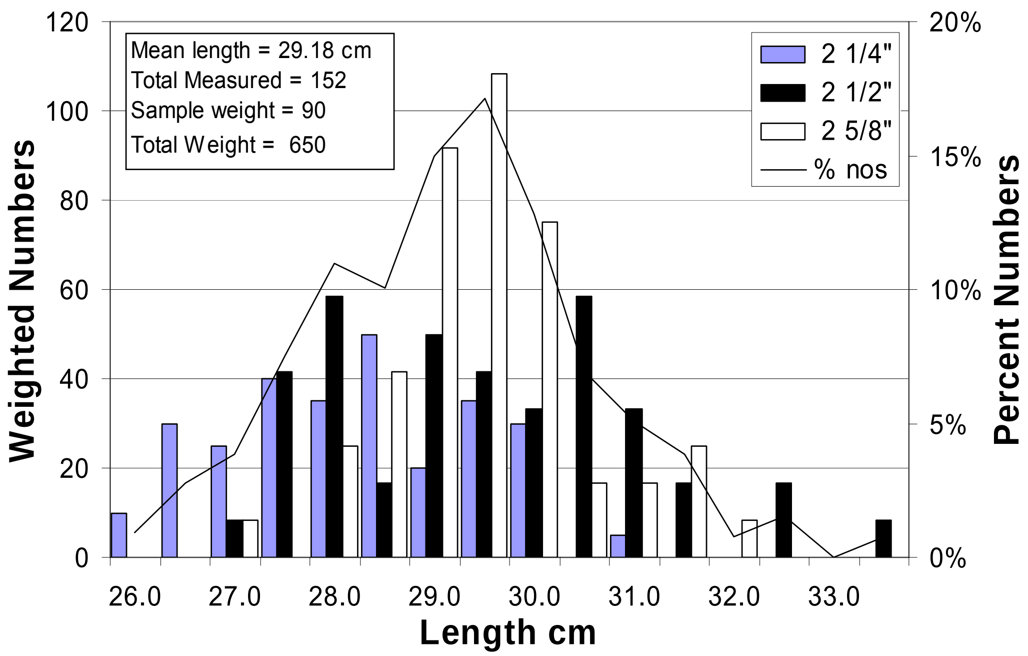


Figure 53. Multipanel gillnet sample from Eastern Shore/Halifax area collected on Sept. 30, 2005 (note - an additional panel with 1.5" mesh caught no fish).

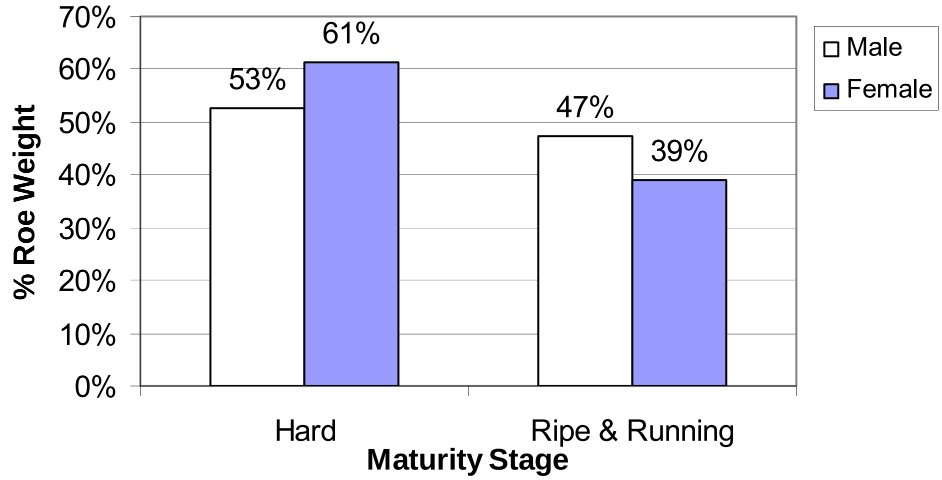


Figure 54. Maturity stages for male and female roe by % roe weight for a multipanel gillnet sample from Halifax/Eastern Shore on Sept. 30, 2005.

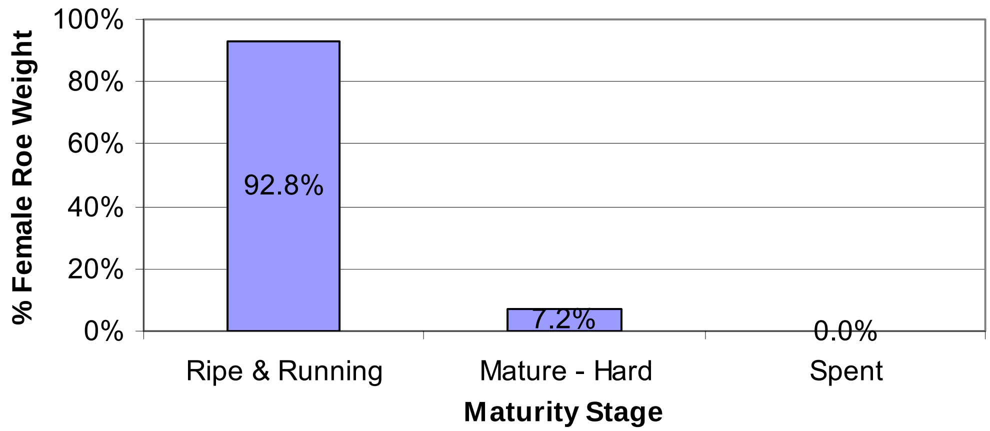


Figure 55. Herring female gonad maturity samples (% female roe weight) from the Halifax/Eastern shore fishery collected by industry on Oct. 5, 2005.

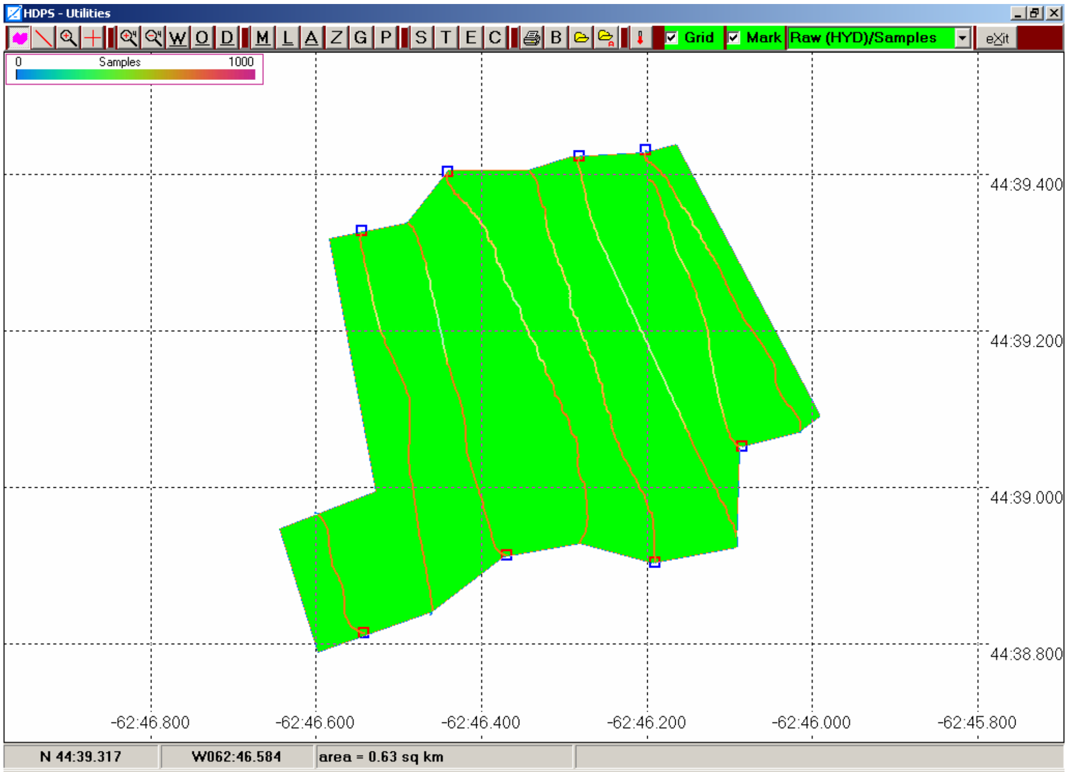


Figure 56. Survey tracks running north to south on Oct. 31, 2005 by the *Miss Owls Head* on the Eastern Shore southeast of Owls Head.

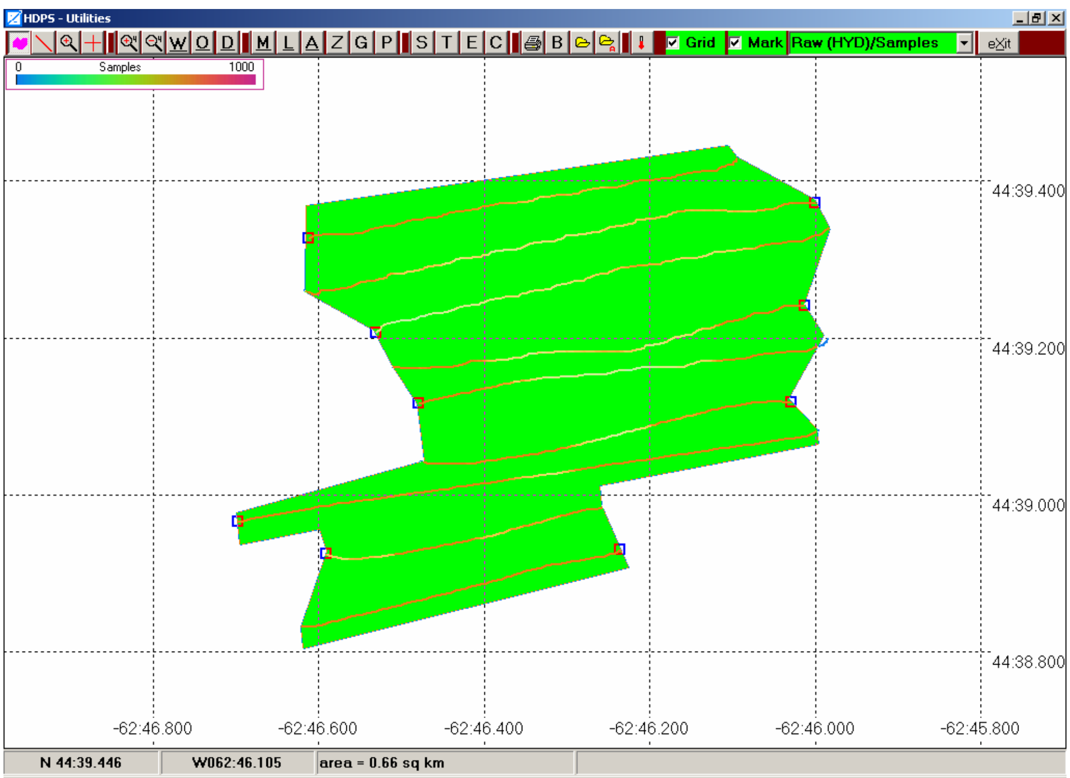


Figure 57. Survey tracks running east to west on Oct. 31, 2005 by the *Miss Owls Head* on the Eastern Shore southeast of Owls Head.

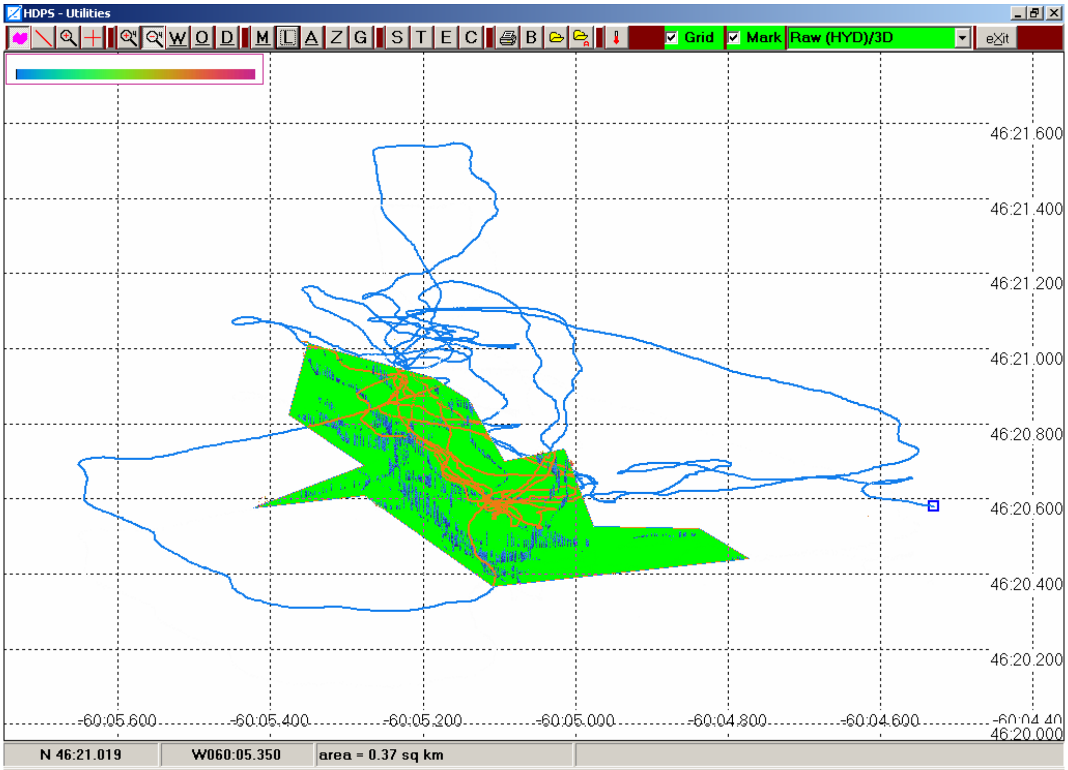


Figure 58. Glace Bay acoustic survey on Sept 20, 2005 with 3d track and school area.

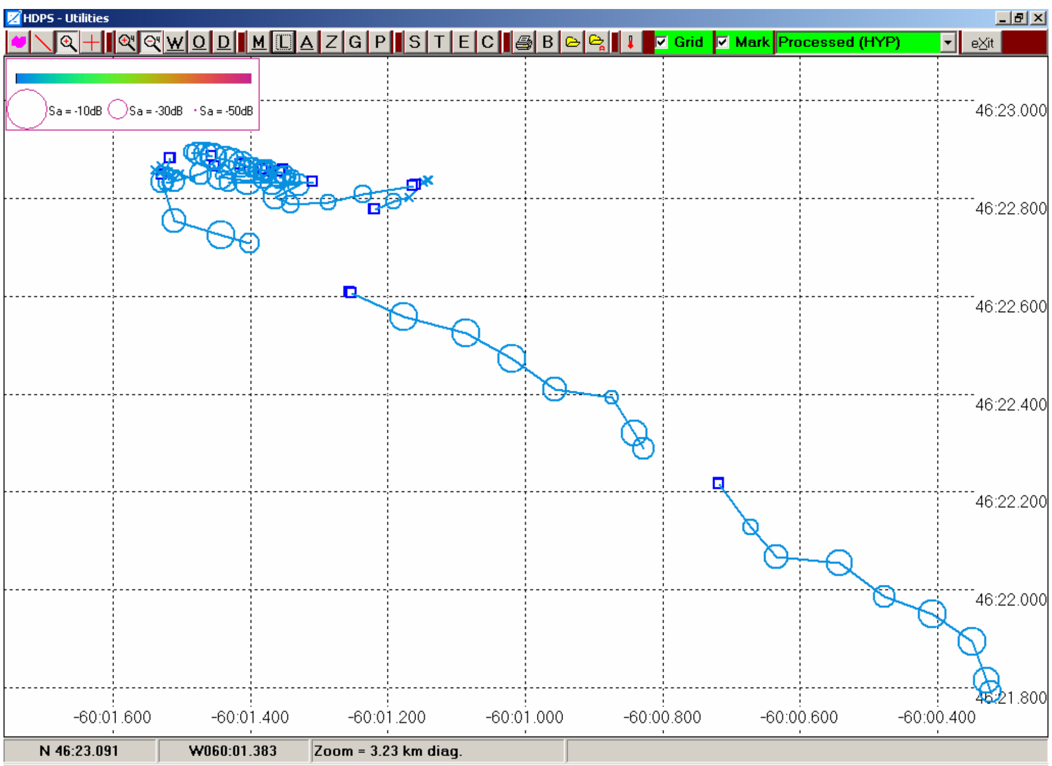


Figure 59. Glace Bay acoustic survey on Oct. 6, 2005 with backscatter/fish shown as expanding circles along the survey lines.

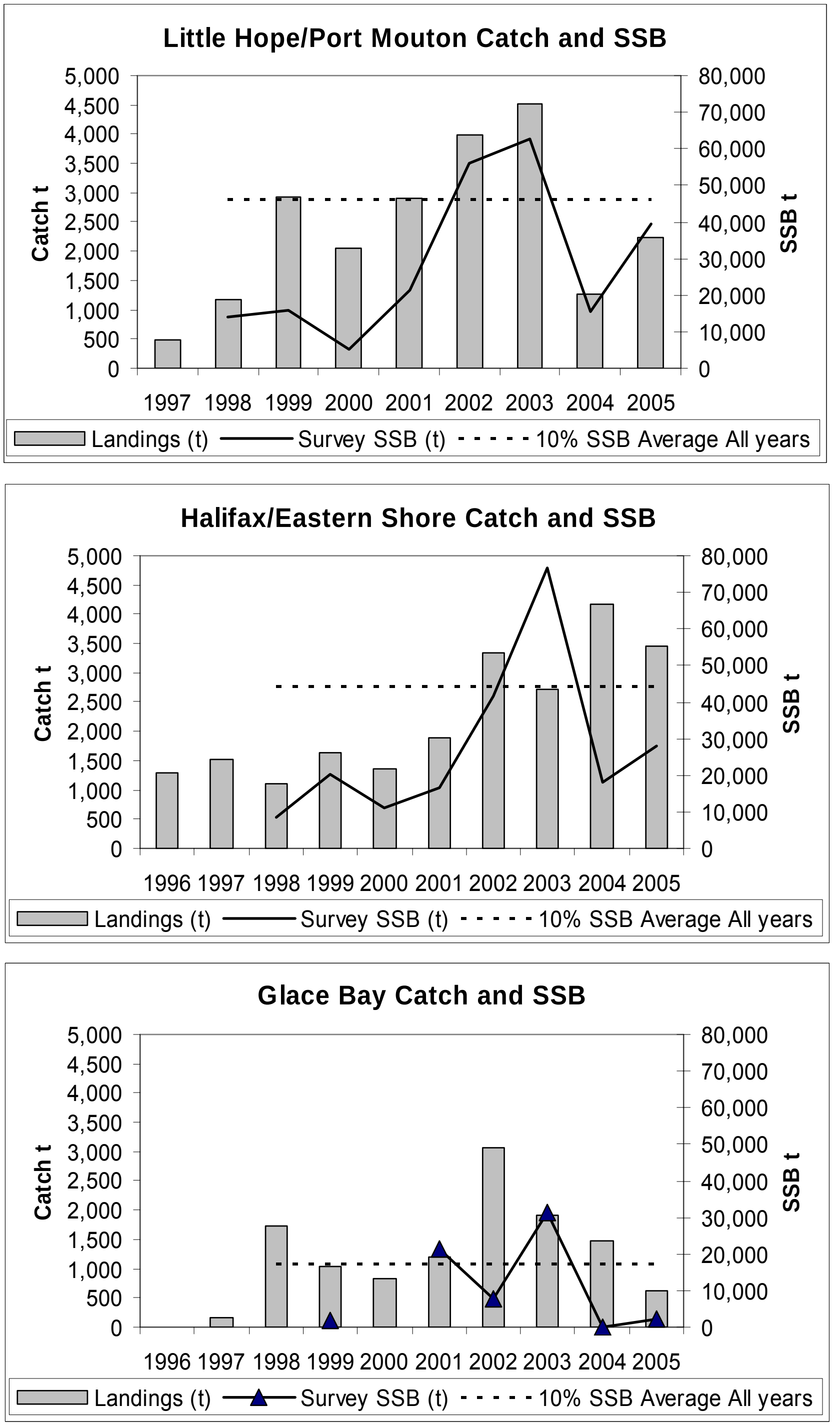


Figure 60. Summary of landings (bars), surveyed biomass (solid line), 10% of average SSB (dashed line) for the coastal Nova Scotia herring spawning areas near Little Hope/Port Mouton, Halifax/Eastern shore and Glace Bay.

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., 1998). 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 ⅛ to ½ nautical 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:

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

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.

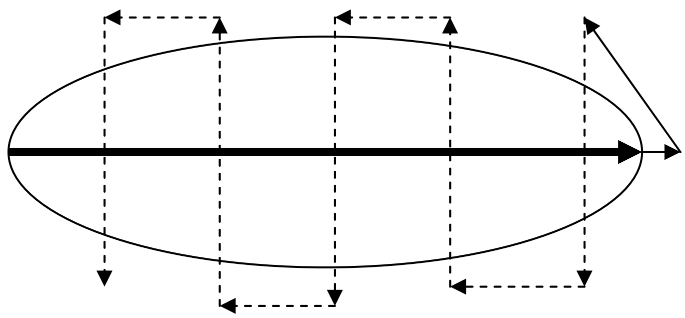
Category	Tonnes/Set	Tonnes/km^2	Acoustic (tonnes/km^2)
No Fish	0	0	0
Light	5	200	230 - 250
	10	400	
Moderate	25	1000	600 - 1300
	50	2,000	
Heavy	100	4,000	2,000 – 11,000
	200	8,000	
Very Heavy	250	10,000	20,000+
	500	21,000	

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.

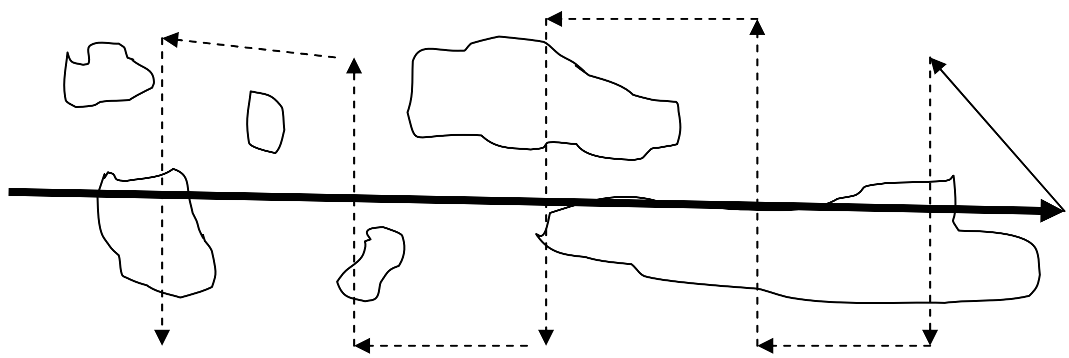


The first step to surveying the school of fish is to determine the long axis of the school as indicated above by the thick black solid line. Thereafter, a series of line transects should be run perpendicular to the long axis of the fish (dashed lines). The number of transects will be restricted to the 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 (¼) 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 (¼) 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 the St. Andrews Biological Station (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								
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Acoustic biomass adjustment for turnover time.

Introduction:

Over the past ten years the spawning stock biomass (SSB) on individual spawning grounds, such as Scots Bay and German Bank, has been determined by the addition of acoustic biomass estimates from multiple surveys undertaken during the spawning season. The surveys, spaced at 10-14 day intervals, were assumed to allow sufficient elapsed time for the herring present at the time of one survey to spawn and departed the spawning grounds before the next survey, thereby minimizing the likelihood of double counting. The assumption of multiple spawning events on individual spawning grounds was based on observations by fishers and scientific knowledge that mature fish moved on to, and off of, the grounds in waves during the spawning season. However, the length of time individual fish or groups of fish actually spent on the spawning grounds has been, and continues to be, a real uncertainty and a subject of debate at almost every assessment meeting since acoustic biomass estimates were introduced into the herring assessment process.

A number of analysis and reports have examined the available data to determine if there were any clues or indicators within the standard biological data collected to determine when and if a turnover of fish had occurred. Unfortunately, none of the data sets provided a definitive mechanism to identify when, or if, a wave of fish had passed through the spawning grounds. Examination of changes in gonad stages from sampling day to sampling day indicate that a portion of herring were moving into the spawning area, spawning and leaving (near absence of spent fish) at irregular intervals. Significant changes in the composition of stages 5 through 7 were observed in Scots Bay at intervals of about two weeks, yet on German Bank the variability was less distinct and the percent of stage 6 fish remained high for almost the entire spawning season. In addition, a single tagging study conducted late in the 2001 spawning season suggested that the majority of tagged herring were gone from the spawning grounds in less than 10 days. Thus, justifying the use of a 10-14 day window between surveys in previous years to minimize the potential for double counting.

In (2005) the acoustic estimates of absolute biomass were introduced as a tuning index for relative abundance in a VPA. Unfortunately, there were large discrepancies between the estimated biomass from the VPA, which is heavily dependent upon the catch-at-age data, and the cumulative acoustic surveys. Biomass estimates were 2-3 times higher for the acoustic approach. This lead to a number of questions/concerns regarding, in particular, turnover time amongst spawning events, potential double counting, and the time between surveys. If it is assumed that the acoustic surveys provide a reasonable estimate (absolute) of the fish present at the time of surveying, then a large portion of the discrepancy between the two methods is likely a function of how we interpret or combine the biomass estimates from the individual surveys to determine the total SSB. This analysis compares three different approaches for the interpretation of the acoustic biomass estimates in an absolute sense. It should be noted that for an index of relative abundance, it is only important that trends in the index reflect changes in abundance, not the overall numbers. The three approaches examined and compared in this report are:

1) the current practice of summing all survey biomass estimates which are separated by 10-14 days
2) the maximum biomass estimate for a single survey as the total SSB
3) adjustment of SSB to reflect the recent observed decaying turnover time from tagging results for a period of 4 weeks or more

Methods:

The data for approach 1 and 2 are provided in the annual research documents summarizing the acoustic surveys. However the third approach needs some explanation. In the summer/fall of 2005 a tagging experiment was undertaken to address the issue of time herring remain on the spawning grounds after tagging. Tagging was conducted throughout the spawning season in Scots Bay and on German Bank and the tag returns analyzed in the context of turnover time. Details of the study are presented in Clark (WP 2006/03).

The information provided in Table 11 of Clark (2006) clearly depicts a gradual decline over 4 weeks in the proportion of tagged herring remaining on the Scots Bay spawning ground. Regression analysis of these data indicates a significant ($r = 0.91$, $P<0.05$) relationship between the proportion of spawning fish remaining on the grounds and elapsed time (Figure 1). Although the confidence interval of this relationship is broad there is a strong indication that the proportion of herring remaining on the spawning ground wanes with time. However, the time interval for a complete turnover may be as long 4 weeks or more, not the 10-14 days assumed in the past. A similar analysis for German Bank could not be undertaken due the limited number of tag returns.

To investigate the implications of the uncertainty in turnover time and the new observations, the regression equation was used to estimate the biomass of herring still on the spawning grounds from previous surveys at the time of surveying. The number of days between surveys was used to estimate the biomass of fish remaining. The results of this accounting approach are presented in Table 1 for Scots Bay in 2004. For this exercise the biomass estimates without the calibration integration factor (CIF) were used so the effects could be compared back to 1999. The practice of using the CIF for biomass estimates was adopted by RAP in 2005. Biomass estimates using the CIF are typically 10-15% higher and depend upon the vessels participating in the surveys.

Results:

Biomass adjustments based on the new information from tagging indicate a significant change in our perception of stock status and absolute biomass. For example, the August 3, 2004 Scots Bay survey estimated a biomass of 16,774t of herring, but assuming the tagging observations of 2005 are representative of past turnover times then 361t of herring from the July 19th survey were still on the grounds 2.1 weeks later

(Table 1). This reduces the biomass estimate from 16,774t to 16,413t for the August 3 survey. The decline in estimated biomass is even more dramatic from August 16 through September 12 where the third survey is reduced from 60,437t to 52,843t and to 0t for the last two surveys as it is estimated that more fish from the previous surveys should be present then were observed (Table1). Using this approach for the entire year reduces the overall biomass in Scots Bay from 107,624t to 70,178t in 2004.

Adjusting the biomass estimates for a decaying turnover of the proportion of herring remaining on the spawning ground with time shows a large decline in biomass in every year for the Scots Bay spawning component (Table 2). The percent reduction ranged from 18-37% with an average of 30% over the last years. The greatest changes occurred for the later surveys as a significant proportion of the estimated biomass was found to originate from earlier surveys. Figure 2 illustrates the changes in absolute biomass for Scots Bay for the reported, adjusted, and maximum survey estimates from 1999 to 2005. Immediately apparent from the figure is the dramatic drop in absolute abundance levels from our current approach of summing all surveys, separated by 10-14 days, to the adjusted estimate and the even further decline if only the maximum survey estimate is used. Instead of dealing with an absolute biomass well above 100,000t between 2001 and 2004 in Scots Bay, we could be dealing with one substantially lower. Adjusting the biomass for a different turnover rate (decaying) has a serious effect on our view stock status which may actually be more in line with the VPA results However, even more disturbing is the fact that 2 of the three approaches indicate a strong declining trend since 2001, the third since 2003 and that all three have converged at an extremely low level for 2005. The 2005 survey results indicate a major decline in the Scots Bay spawning component after two years of unusually high catches in 2003 (19,196t) and 2004 (24,388t). The absolute biomass estimate for Scots Bay in 2005 was only 10,000 to 15,000t. If this is the true situation then there is real concern for the Scots Bay spawning component. Similar estimates could not be undertaken for German Bank because of the low number tag returns.

Summary:

In summary this analysis indicates that, even excluding the sources of uncertainty associated with converting acoustic backscatter to biomass, the estimate of absolute biomass is extremely sensitive to how the data are pooled from multiple surveys. The perceived biomass can decline substantially depending upon how the multiple survey estimates are combined. In the case of Scots Bay applying the results of the 2005 tagging study to determine how long and what proportion of herring remain on the spawning ground after tagging, indicates that some fish can remain on the grounds for 4 weeks or more and that the SSB may be much lower than expected using our current approach. In light of this information caution is warranted when employing the cumulative biomass estimates as absolute in any of the survey areas. How these results are interpreted and what approach future assessments utilize will be addressed at the framework assessment meeting scheduled for the fall of 2006.

Table 1. Summary of the 2004 Scots Bay adjusted biomass estimates assuming the 2006 observations as representative of the turnover time. The diagonal numbers are the reported biomass estimates before adjusting for elapsed time. Above the diagonal are the estimates of biomass from previous surveys and below the diagonal are the weeks between the surveys. The highlighted biomass is the tonnage before adjustment and the un-highlighted after adjustment for elapsed time.

Date	Survey					Biomass (t)
	1	2	3	4	5	
19/07/2004	922	361	0	0	0	
03/08/2004	2.1	16774	7594	896	0	
16/08/2004	4.0	1.9	60437	27361	1373	
29/08/2004	5.9	3.7	1.86	23673	9990	
12/09/2004	7.9	5.7	3.86	2.0	5818	
Sub-Total	922	16413	52843	0	0	70178
						107624

Table 2. Current, adjusted, and maximum single survey estimated biomass for the Scots Bay herring spawning grounds from 1999 to 2005.

Spawning Ground	Year						
	1999	2000	2001	2002	2003	2004	2005
Scots Bay							
Current	40972	106316	163898	140495	133862	107624	16846
Adjusted	27491	73951	110201	107794	83768	70178	12221
Maximum	22307	45284	78458	79938	79598	60437	9431

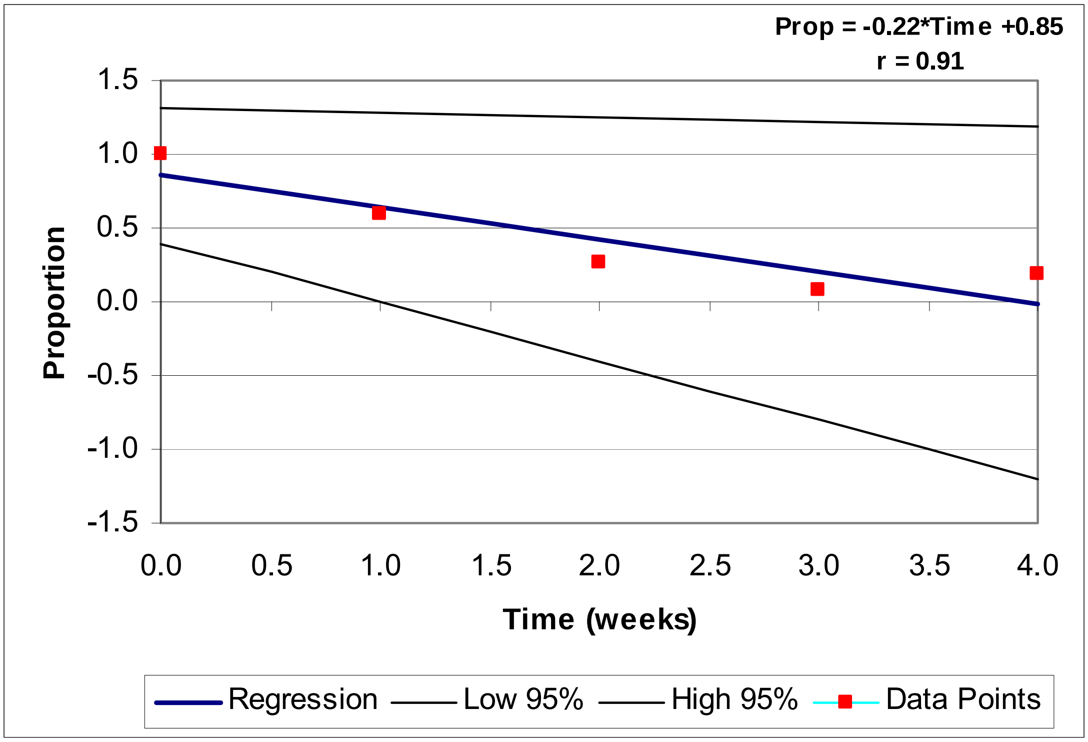

Figure 1. Regression of the proportion of tagged herring remaining on the spawning grounds with elapsed time between tagging and recovery. The 95% confidence interval is represented by the upper and lower lines. Observed data points are presented as boxes

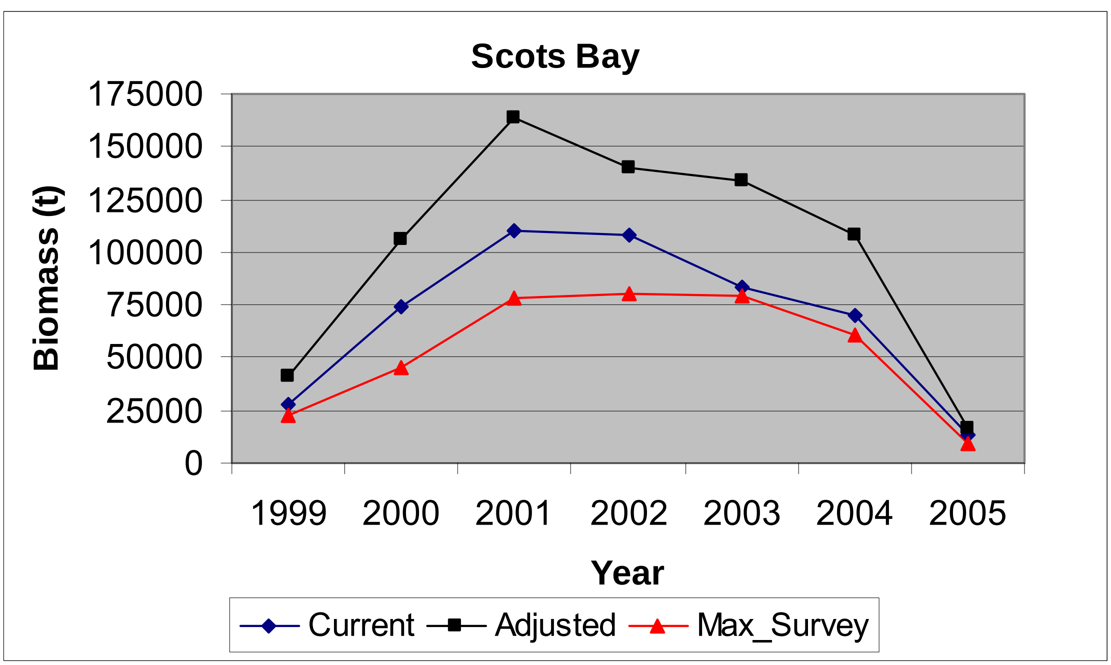

Figure 2. Comparison of the estimated biomass from 1999 to 2005 using the current approach, adjusted for turnover time, and the maximum single survey estimate for Scots Bay.