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Summary of the 2006 Herring Acoustic Surveys in NAFO Divisions 4VWX

Résumé des relevés acoustiques sur le hareng effectués en 2006 dans les divisions 4VWX de l'OPANO

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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 2006 regularly scheduled surveys, at approximately 2-week intervals, were again 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, five on Trinity Ledge and four on German Bank with most following the established protocol. Except for the Trinity Ledge area these surveys provided good coverage of the spawning areas consistent with previous years. Additional data from fishing or survey nights in Scots Bay, German Bank, Browns Bank, Seal Island and Spectacle Buoy areas were also examined. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 28,600t, 8,500t, and 245,500t for an estimated total SSB of 282,600t in the traditional survey areas, which is an increase from 2005 but still a substantial decrease from previous years. An additional 18,300 t was surveyed outside of the standard survey areas.

Biomass estimates from surveys of the coastal Nova Scotia spawning components for the Little Hope/Port Mouton and Eastern Shore areas were also examined. There was a relatively large decrease in the Little Hope area while the Eastern Shore area saw a substantial increase from the previous year. A survey with an acoustic recorder had been completed in 2005 for the Glace Bay area but was not repeated in 2006. There was again no acoustic survey effort in the Bras d'Or lakes. There were some large aggregations of herring observed and reported but no acoustic surveys were completed for the offshore Scotian Shelf.

RÉSUMÉ

Depuis 1997, on utilise, dans le cadre de relevés de l'industrie et de sorties de pêche, des systèmes d'enregistrement acoustiques automatiques installés sur des bateaux de pêche commerciale pour documenter la répartition et l'abondance relative du hareng dans les divisions 4VWX de l'OPANO. En 2006, on a de nouveau effectué des relevés des principales composantes des reproducteurs à environ deux semaines d'intervalle. 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, cinq sur le récif de la Trinité et quatre sur le banc German, la plupart selon un protocole établi. À l'exception de celui du secteur du récif de la Trinité, ces relevés ont assuré une bonne couverture des frayères, comparable à celle des années précédentes. D'autres données recueillies durant les nuits de pêche et de relevés dans les secteurs de la baie Scots, du banc German, du banc Browns, de l'île Seal et de la bouée Spectacle ont également été examinées. Les estimations de la biomasse pour la baie Scots, le récif de la Trinité et le banc German étaient d'approximativement 28 600, 8 500 et 245 500 t, pour une biomasse génitrice totale estimée de 282 600 t dans ces trois zones de relevés standard, ce qui représente une augmentation par rapport à 2005, mais qui demeure néanmoins une diminution substantielle par rapport aux années précédentes. Par ailleurs, les relevés effectués à l'extérieur des zones de relevés standard ont révélé une biomasse supplémentaire de 18 300 t.

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 est ont également été examinées. On a observé une diminution relativement importante dans le secteur de Little Hope, tandis que le secteur de la côte présentait une augmentation substantielle par rapport à l'année précédente. En 2005, on a effectué un relevé effectué au moyen d'un enregistreur acoustique dans le secteur de Glace Bay, mais on n'a pas répété l'exercice en 2006. Encore une fois, aucun relevé acoustique n'a été réalisé dans le lac Bras d'Or. Au large du plateau néo-écossais, certaines grandes agrégations de harengs ont été observées et signalées, mais 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.*, 1998a; 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, 2006b) 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 purpose of this document is to report and to summarize the 4VWX stock assessment related survey data collected during the 2006 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.*, 2005a, 2006b).

Data from the 2006 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 2006 no major changes from previous years were made to the established protocol for either

acoustic or mapping surveys. The sixteen surveys scheduled for 2006 were completed on or near the tentative dates scheduled and an additional 17 fishing night surveys were examined in order to enhance coverage (Table 1, Figure 1). Additional surveys were completed in order to either enhance coverage or to ensure that newly observed groups of fish were recorded bringing the total number of structured surveys to 22. For example a 4th structured survey was undertaken for German Bank on Oct. 15, 2006 which conformed to the minimum 10 day window between surveys. The total number of survey boat nights completed was 98 with 45 of these from vessels with acoustic recording systems (Table 2).

In general, structured surveys were conducted in accordance with the protocol established in Melvin and Power (1999). 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 in more detail where they occur below.

Data quality issues:

In the previous analysis of the 2005 season data there were three main areas of concern with the data including surveying protocols, provision and verification of the raw data and editing, and issues of noise and interference (Power *et al.*, 2006a). In the 2006 season some of these issues have been resolved but others continue to be a problem.

There is a well defined survey protocol for structured surveys and fishing night school documentation but these are not always being followed and remain an issue. In cases of fishing night surveys by purse seine vessels, there was very poor adherence to survey design with vessel captains rarely establishing a series of parallel transects to document the fish. Rather the data provided was usually one of an unorganized search pattern common in fishing operations and was very difficult to analyze. It is important to follow the protocol (of a series of stepped parallel lines) for surveying an aggregation or school of fish. Protocols for surveying schools or aggregations of fish described in Appendix A. Data collections inconsistent with established protocols were again given a low priority for analysis or were not processed.

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 the previous review, it was recommended that all raw data files be made available on a regular basis for review prior to finalizing the acoustic biomass estimates. In 2006, all raw data was 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 data problems were found and resolved with some vessels and for specific surveys. In a few cases the bottom was not completely removed and some non-herring species were apparent.

In the previous year, vessel noise/interference was apparent for some of the raw data files examined. 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 is determined and corrected if possible. In addition, the operational vessel speed should be determined for each vessel and surveying speed limited to this. In 2006 noise tests were completed for each vessel as part of the calibration process and recommended speed or vessel RPM levels were made. As a result of these efforts the resulting raw data collected was found to have less background noise and was useable from all survey vessels.

Length/Weight Relationship:

Prior to 2001, the fish weight variable in the target strength (TS) equation (Table 3) was estimated using a length/weight relationship developed from monthly data for each area. A correction factor of 1.02 was also applied to each length measurement 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 since 2001 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 3). 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 (Melvin, et al 2004). This approach is used by several acoustic manufacturers when calibrating their echo sounders. 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 which is applied to the standard calibration typically lies between 0.4 and 1.6, with 1.0 equivalent to an ideal square wave and thus no adjustment.

Given that the inclusion of the integration calibration factor (ICF or CIF) is deemed to provide a more accurate estimate of biomass, it was recommended that all future analyses utilize the CIF 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 CIF included. After several years only the biomass estimate with the CIF will be needed.

The following analysis presents results using both methods of calculation (with and without the CIF). Comparisons between years are made only with data calculated without the CIF since it has not yet been possible to recalculate the estimates for all earlier years using the CIF. Unless otherwise noted in the text, only biomass estimates without the CIF will be referred to when summarizing the data results. The reader may refer to the appropriate tables to see the estimates calculated in both ways.

Acoustic Systems:

In 2006, 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 2006. Systems were installed and/or re-calibrated aboard the eight purse seine vessels*, Brunswick Provider, Dual Venture, Island Pride, Lady Melissa, Leroy & Barry, Margaret Elizabeth, Morning Star* and *Secord.* There were four systems on the inshore gillnet vessels, *Bradley K, Knot Paid For, Miss Owl's Head* and the *Sea Quiz.* A new system was installed in 2006 on the purse seine vessel *Brunswick Provider* while the existing system on the gillnet vessel *Natasha Lee* based in Glace Bay, N.S. was not calibrated or activated. One final system installed in 2004 on the herring carrier *Strathaven* based in southwest New Brunswick was again used in the 2006 fishing season to conduct surveys near fishing weirs in southwest New Brunswick.

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 has 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, Seal Island and Browns Bank areas in 2006 (Table 4). All fishing night estimates for the Scots Bay and German Bank areas were found to be lower than the nearest survey estimate for that spawning area and time period and were not used further. However, fishing night data from the Browns Bank and Seal Island areas were used as these were the only source of acoustic information for these two areas.

RESULTS:

The spawning biomass for individual components of the 4WX herring stock complex in 2006 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 2006 observations and SSB estimates for each of the main spawning components within the stock complex.

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.

In 2006, herring maturity data were again obtained from two primary sources: 'Herring Roe Analysis Sheet' data from the Scotia Garden Seafood processing plant quality control group and samples 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 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 a modification to the SABS lab procedure to weigh all gonad stages was implemented in 2003. SABS samples were combined for female fish by day and percent numbers and percent weight by the categories determined. The plant classification system of maturity must not be confused with the standardized ICES scientific scale of 1 to 8 (Parrish & Saville, 1965) but the industry roe data can be compared with SABS data based on knowledge of the two methods. Analysis of the roe maturities was completed for the data available on an individual survey basis and is presented with the details for each survey completed.

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, 2006b) 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 (Power et al, 2006b). The results showed that caution is warranted when employing the cumulative biomass estimates as absolute in any of the survey areas. The results also indicated that some proportion of herring remain in the survey area even three weeks or longer.

A framework assessment meeting in January 2007 determined that double counting does occur but the extent has not been well determined (DFO, 2007). However, it was still recommended to continue to do surveys at 10-14 day intervals to avoid double sampling. The timing/turnover issue was considered to be of highest importance for further study which should include work on the duration of the maturation process, further tagging with more frequent intervals to estimate turnover rates and increased survey frequency to reflect maturity stage duration.

Scots Bay:

The Scots Bay herring purse seine fishery (Figure 1) has been 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 (Power et al, in press).

The 2006 fishery was similar in overall duration to the previous year with catches scattered within the defined spawning area but there was a reduction in overall activity. Several external factors contributed to a decrease in fishing activity and survey effort including a reduced roe market, lack of access to the Digby wharf to offload herring, re-introduction of Herring Fishing Area 22 (HFA-22) line closures and distance to market. The duration of the spawning fishery period in Scots Bay was the same as in 2005 but there was no observed spawning or catches of spawners in the spawning box in the middle of the period during early August. This difficulty resulted in fewer vessels being active in Scots Bay and the surveys and therefore there was less information about Scots Bay spawning aggregations.

Three structured surveys were conducted during the 2006 spawning season in Scots Bay, a reduction of one survey over the previous two years. (Table 5). The surveys which began about the same time as in recent years were separated by 13 to 14 day intervals. 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. Overall, the Scots Bay surveys generally followed the protocol and provided good coverage of the spawning area on the survey nights that were completed. Data from three fishing nights in Scots Bay were also analyzed, but none were used in the final overall estimate of SSB (Table 4).

Scots Bay survey #1: July 22, 2006

The first survey of Scots Bay in 2006 took place on the evening of July 22 with 3 purse seine vessels participating including 2 with recording systems. The vessels met at the south-western edge of the survey box and were positioned randomly for the run north-eastward to the edge of the survey box. All of the 8 assigned lines were covered. *Brunswick Provider* and *Canada 100* each covered 3 lines while the *Margaret Elizabeth* covered 2 lines and then documented areas of fish which were missed by random lines but seen to one side or other of the survey lines by sonar (Figure 2).

Six length frequency samples were collected and showed modes between 27 and 28.5 cm. The mean size was 27 cm with a range from 21 to 31 cm (Figure 3). The maturities from these samples were mixed from immature to spent and the sex ratio was unequal with 60% male and 40% female (Figure 4).

Two vessels with recorders completed 5 randomly selected lines but virtually no fish were encountered along the lines (Figure 5). The biomass estimate without the

calibration integration factor (CIF) was only 635t (Table 5). Schools of herring were identified and surveyed both between and very close to the central random lines by the Margaret Elizabeth (Figure 6). Two main areas or schools were surveyed and are identified as 'west' and 'east' in the analysis. Surveying also took place within a few miles of the school area on the following night. Estimation of the schools was difficult since lines were not parallel and due to problems in area estimation. Biomass estimates for the eastern school was 3,200t, while that for the western school were 17,300t. Additional data from the evening after the survey recorded a smaller area and biomass. The overall estimate for the 1st Scots Bay survey including the random lines and the eastern and western schools amounted to 21,100t (Table 5).

A significant noise problem was identified with the Brunswick Provider and was found to be a function of the recording unit and the method of calibration. It has been determined that the data results are of good quality as long as estimates which use the CIF are applied.

Scots Bay survey #2: August 6, 2006

The second survey of Scots Bay in 2006 took place on the evening of Aug. 6, 2006 with 5 purse seine vessels participating including 4 with recording systems.
The survey started at 2100hr and lasted until 0230 hr on Aug. 7 with each boat completing two lines in the survey area (Figure 7). Afterward the vessels continued searching for fish but no substantial aggregations of herring were encountered. During the survey there was little fish seen with only a few comments of 'specks' or 'spikes' observed on the sounders. There was also a very bright moon (almost full) and the weather conditions were windy on the night of the survey.

No fishing was undertaken on the night before on the night of or following the survey due to the lack of fish in the area and consequently no samples were available for the survey night. The closest length samples were collected from landings on Aug. 4 and 11th which straddle the survey dates and show an increase in mean size (Figure 8). In addition there were no maturity samples available except for landings after Aug. 12 which showed most herring in hard (stage 5) or spawning (stage 6) condition.

The data were downloaded from three boats with acoustic recorders and analyzed but no data was available from the *Brunswick Provider* on the night of the survey as the system was not turned on except to conduct noise/speed tests when departing port. The 3 vessels with working recorders completed 6 randomly selected lines but virtually no fish were encountered along the lines (Table 5, Figure 9). Searching which took place after the survey completed between the assigned survey lines found no fish. The biomass estimate without the calibration integration factor (CIF) based on standard target strength (-35.5 for a 28cm average size herring) and with adjustments for sounder frequency was only 500t

Scots Bay survey #3: August 19, 2006

The third survey of Scots Bay in 2006 took place on the evening of Aug. 19, 2006 with 6 purse seine vessels participating including 4 with recording systems. The vessels met off Port George at 2100 hr and were positioned randomly for the run north-eastward to the edge of the pre-defined Strata 1 survey box as well as additional lines north-east of Halls Harbour near Scots Bay. The survey lasted until 0300 hr on Aug. 20 with each boat completing at least two lines in the survey area (Figure 10).

During the survey there was little fish seen along the survey lines but there were comments of several 'bunches' observed on the sonar off the lines and some of these schools were documented by briefly deviating from the survey lines. Afterward the vessels also continued searching for fish and additional aggregations of herring were encountered and surveyed as individual schools which have been estimated separately from the random survey lines. One of these bunches was identified as very dense on the sonar but the fish were on the surface and would spread out as they attempted to document them with the sounders. Some fish were also observed to appear better on a higher 200 KHz frequency than with the 50 KHz sounders, which is typically a sign of the presence of smaller size fish.

No fishing took place on the night of the survey but on the night following the survey, fishing and tagging did take place. Six length frequency samples collected from Aug. 20-21 showed a mean size of 27.2 cm and a mode of 28 cm (Figure 11). Length samples since the previous survey in this area showed similar mean and modal sizes. The maturities from the samples on Aug. 20-21 showed a mixture of maturity stages from immature to spent with the largest proportion either in spawning or hard condition on successive days (Figure 12).

Four vessels with recorders completed 8 randomly selected lines on the evening of August 19 but as in previous surveys of Scots Bay in 2006, very few fish were encountered along the lines (Figure 13, Table 5). The biomass estimate without the calibration integration factor (CIF) was 1,500t. Schools of herring were identified and surveyed both between and very close to the random lines by both the *Margaret Elizabeth* and *Secord*. Two separate areas or schools were surveyed by each vessel and estimates of biomass were then calculated. The estimation of the biomass for the schools was problematic since the survey design was non-standard with the lines not parallel due to difficulty in area estimation (Figure 14). Biomass estimates for the four schools summed together was 5,400t (without the CIF).

In summary, the 2006 Scots Bay acoustic survey SSB estimated from the three structured surveys was 28,600t (without the CIF)(Table 5a). This is an improvement of 11,800t from the 2005 SSB estimate of 16,800t and can be compared to data calculated in a similar manner for previous years. The SSB

remains low since the high of 2001 and it is well below the 1999-2005 average of 92,400t.

German Bank:

The German Bank herring purse seine fishery (Figure 1) is usually one of the major components of the summer fishery with catches since 1985 ranging from 9,000 to 36,000t during the overall fishery period of early May to late October (Power et al, in press). Catches during the spawning period in 2006 were very similar to those of 2005 with two localized groups of presumed spawning herring seen within the Strata area and more scattered groups seen north of the survey box which are usually shown to be pre-spawning or juvenile sized herring.

Four acoustic surveys were conducted on German Bank during the 2006 season between August 25 and October 15 covering the entire spawning period (Table 2). The time interval between surveys ranged from 14 to 20 days and a total of 33 vessel nights of surveying were completed. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets for vessels without acoustic systems. Fish samples for maturity, while limited from industry sources, indicated that mature spawning herring dominated samples collected (Figure 15). There were some indications of immature fish within the spawning box area earlier in the season from SABS samples on Aug. 29 and Sept. 11 (Figure 16). Length sampling was very extensive for this fishery with fish sampled from within the survey box found to be mostly larger than 23cm, which is the approximate size of first spawning for this stock (Figure 17). There were a few occasions where smaller pre-spawning herring of less than 23cm were sampled in the survey area but this was generally infrequent in 2006.

Fishing night acoustic data for German Bank were examined for eleven nights between August 17 and October 8 where sufficient data for estimation of biomass were collected (Table 4). Biomass estimates from these fishing nights ranged from 2,560t to 28,160t. 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 four structured surveys.

German Bank Survey #1: August 25, 2006

The first herring acoustic survey of German Bank in 2006 was conducted on Aug. 25, 2006. Nine purse seiner vessels participated following the designated survey plan. Each vessel completed two lines of about 37 km each in length. Survey speed was determined from previously completed noise tests and was based on maximum RPM assigned to boats with recorders. The actual speed varied between 7 and 10 knots depending on the vessel and the direction of the tide in relation to transect direction. The deck sheet observations of the sounder recordings showed herring mostly in the eastern and northern part of the survey area (Figure 18).

Catch and length sample information collected within 5 days of the survey, from Aug. 21 to Aug 30, showed catches concentrated in the mid-central area of the survey box and contained a high proportion (99%) of adult size fish (>= 23 cm) (Figure 19). Daily length frequency samples available from Aug. 21-30 had a modal size of 28cm and a mean size which varied from 26cm to 28cm with significant daily changes in the overall size range (Figure 17).

Length samples from landings on Aug. 25 (the day of the survey) were used for estimating the survey mean length and in the calculation of target strength (Figure 20). Five length samples were collected with 677 fish measured, a mean length of 27cm and a mode at 28cm. Industry supplied length-weight data from Aug. 25 which provided 312 fish for regression analysis used to calculate mean weight and target strength.

Gonad maturity samples were available in the form of 'Roe Analysis' reports from industry sources and from samples processed at the St. Andrews Biological Station but were collected 3-4 days before or after the survey (Figure 15, 16). The three samples showed a trend of increasing proportion of immature or hard roe from a low of 6% on Aug. 21 to a high of 46% on Aug. 29. The samples suggest that spawning was occurring but the proportion of spawning/ripe and running females was highly variable (54-94%).

The data were downloaded from the 5 boats with acoustic recorders and after editing to remove bottom and non-herring targets the files were merged into transects (Figure 21). Problems were encountered with the *Island Pride* computer which produced errors and kept freezing up during the survey. This required numerous restarts and resulted in short data file recordings with gaps in transects ranging from 30 seconds to 3 minutes. These data were analyzed as separate short segments and then combined together with the missing segments assigned as zero. The estimated length of the missing segments was calculated as 1682m and 203m for the two transects. There was also a partial loss of navigation for one transect by the *Leroy and Barry* but this was restored during the analysis with a software utility. Herring were observed acoustically primarily along the 5 western transects of the 10 available transects, in the central to north-western portion of the survey area (Figure 21). It was noted, that prior to the survey, some schools of herring were also found and recorded north of the survey box but these are not included in this analysis because these lines were incomplete.

As recommended at the RAP herring Framework meetings (January 2007) the use of a standard survey area of 646 km^2 was applied. This standard box area was used for transects completed within the survey box. One transect along the innermost eastern longitude line at 66°15' was outside of the standard area by 0.6 miles and was calculated separately as 'outbox'. The survey biomass calculated 'without' the calibration integration factor (CIF) using the standard survey box and transects within the survey area (inbox) was 94,640t with a standard error of 34%

(Table 6a). The survey estimate calculated 'with' the CIF and transects within the survey area was 114,060t with a standard error of 35% (Table 6b). The biomass estimate for the one transect outside the standard survey area (outbox) was essentially zero (only 8t and 9t for the without and with CIF calculations respectively).

German Bank Survey #2: September 15, 2006

The second herring acoustic survey on German Bank in 2006 was conducted Sept. 15, twenty days after the initial survey. Eleven herring purse seiner vessels participated each completing two transects approximately 37 km in length and 1-2 km apart following the designated survey plan for the German Bank area. Survey speed was determined from previously completed noise tests and was based on maximum RPM assigned to boats with recorders. Additional surveying was completed before and after the primary German Bank survey in areas just outside of the survey box to the north and south. One line was also completed in transit to the east back towards Seal Island with some fish encountered. Additional survey effort occurred on Dry Ledge, Trinity Ledge, Spectacle Buoy and Seal Island areas with data collected on several aggregations of fish. The deck sheets of the sounder observations showed herring in medium to high abundance in the north-central part of the survey box , in an area just north and south of the survey box as well as on Trinity Ledge. Small amounts were also reported around Spectacle Buoy and Seal Island (Figure 22).

Catch and length sample information collected within 5 days of the survey, for the period from Sept. 10-20, showed catches concentrated in the mid-central to southern portion of the survey box. All fish within the German Bank area were of adult size fish (>= 23 cm) (Figure 23). Maturity samples collected within 5 days of the survey confirmed that most herring caught within the 'German Bank Spawning Area' were adults either maturing or in spawning condition, while samples above the 'German Bank Spawning Area' were found to be mostly of mixed or immature spawning stages. There were no 'Roe Analysis' reports available from industry for this period. The samples within the survey box were mostly in either hard (stage 5) or spawning condition (stage 6) and the proportion of spawning fish was highly variable (38-100%) (Figure 16).

Length samples collected to the north of the survey box in the Dry Ledge area and around Lurcher Shoal showed a mixture of adult juveniles indicating non-spawning fish. There were no biological samples available for the Trinity Ledge, Seal Island or the Spectacle Buoy areas. Daily length frequency samples from within the German Bank survey box for Sept 10-20 showed a modal size of 28cm, a mean size which varied from 27.7cm to 28.3cm and an overall size range mostly greater than 25cm signifying adult fish (Figure 17). Samples from outside the survey box on the other hand were generally smaller than 25cm signifying mostly juvenile herring catches but there were some days with a bi-modal mixture of both large and small sizes . Length samples from within the survey box from landings on

Sept. 13 and Sept. 18 (+/- 3 days of the survey) were used in the calculation of mean length for target strength estimation since there were no samples closer to the survey night from within the survey box. Six length samples were collected with 725 fish measured, mean length of 27.9 cm and mode at 28cm (Figure 24).

Length samples from outside the survey box area were available for landings on Sept. 14-15 (+/- 1 days of the survey). These were used for the calculation of target strength for fish encountered outside of the survey box which were found to be of different size and maturity. Eight length samples were collected with 958 fish measured, a mean length of 22.2 cm and modes at 20 and 23.5cm (Figure 25).

Industry supplied length-weight information and SABS sampling data from Sept. 13-20 provided sufficient numbers (396 fish and 229 fish) for regression analysis used in the calculation of target strength for fish encountered both inside and outside of the German Bank survey box. The resulting target strength (TS) estimates for various sounder frequencies are shown in Table 7 along with the default standard TS of -35.5 dB/kg for a 28cm herring which is used when no samples are available. The results for within the survey box area estimated TS for a 50 kHz sounder at -35.49 dB/kg which is close to the default of -35.5 dB/kg. Using samples from outside of the survey area with a smaller mean length results in TS of -34.244 dB/kg for a 50 kHz sounder, which is significantly different from the standard and illustrates the requirement for good sampling to go along with acoustic surveying.

The data were downloaded from the 5 boats with acoustic recorders. After editing to remove bottom and non-herring targets the acoustic files were cut/merged into transects (Figures 26 and 27). Problems were again encountered on the *Island Pride* recording system which resulted in a loss of information for some data files. These data were analyzed as separate segments. The 8.5 km of lost recordings were assigned a value of zero based on observations from the deck sheets. There was also a partial loss of data by the *Leroy and Barry* due to the system being shut off before the survey and then turned on part way along the first transect. Herring were observed acoustically primarily in the northern half of the box, with an additional school found just south of the survey area (Figure 26).

As recommended at the RAP herring Framework meeting (January 2007) the survey area was standardized to a predefined size. The standard box which has a total area of 646 km2 was applied to the nine transects completed within the survey box (Figure 27). One transect along the longitude line 66°15' was outside of the standard area by 0.6 miles and was calculated separately with 'GB#2-outbox-north'. The survey estimate 'without' the calibration integration factor (CIF) using the standard survey area and transects within the survey box (GB#2-inbox) was 88,100t with a standard error of 33% (Table 6a). The biomass estimate 'with' the CIF using the standard survey box area and transects within the survey area (GB#2-inbox) was 102,700t with a standard error of 34% (Table 6b).

Additional schools of herring were found and recorded outside of the survey box (Figure 26). One school was continuous from the southern edge of the survey and is included in this analysis as GB#2-outbox south. Sampling confirmed this group as spawning fish and a biomass estimate of 2,940t (without CIF) was made based on an area of 10km^2 using the two available lines.

Other schools of herring were recorded just to the north and east of the survey box as well as around Seal Island (GB#2-outbox-north) (Figure 26). These were reported to be mostly thin scattered groups on the deck sheets and this was confirmed in the acoustic record. The available samples indicate that these fish were mostly juvenile herring but with some adult sized fish mixed in. It was difficult to determine the area of coverage because of the non-systematic search pattern used. Consequently, the area was estimated using the total transect length multiplied by a width of 250m. The estimate of 1,170t (without CIF) was based on an area of 45 km^2 for the selected line segments; including the most eastern transect which was excluded from the main survey estimate.

The Trinity Ledge area was also surveyed by 2 vessels with acoustic recorders and found only a small dense area of spawning herring. These were confirmed as spawning fish from the active gillnet fishery that was taking place around the time of the survey. No samples were available so standard target strength for a 28cm herring was used. Due to the non-systematic survey pattern it was difficult to determine the area of coverage. Transects were cut from the data using segments containing fish only and these were used to calculate an area of 0.3km^2. The biomass estimate for this group was estimated to be 4,900t (without CIF) with a standard error of 35%.

<u>German Bank Survey #3: October 1, 2006</u>

The third herring acoustic survey of German Bank in 2006 was conducted on Oct. 1, 2006. Six herring purse seiner vessels participated and each of the vessels completing two transects of about 37 km each in length and followed the designated survey plan for the German Bank area. No additional surveying was undertaken outside of the German Bank survey box. Survey speed was determined from previously completed noise tests and was based on maximum RPM assigned to boats with recorders. Herring were observed from sounder recording to be in medium to high abundance in the central and north-western parts of the survey box area (Figure 28).

Catch and length samples for the period from Sept. 21 to Oct. 6, (since the previous survey) showed catches concentrated in the central and southern portions of the survey box with samples within the survey box of mostly adult size fish (>= 23 cm) (Figure 29). Length samples collected to the north of the survey area near Dry Ledge and around Lurcher Shoal had a mixture of adult and juveniles indicating non-spawning fish.

Gonad maturity data are available from samples processed at the St. Andrews Biological Station and 'Roe Analysis' reports from industry sources. There was only one sample available, on Oct. 4, for the period within 5 days of the survey (Figure 16). This sample was in ripe and running spawning condition (87% by number) with a small proportion hard (13%). There were no industry roe samples available within the 5 day window of the survey date.

Daily length frequency samples from within the German Bank survey box from Sept 21 to the end of the season showed variable mean size and overall size range. The samples from Oct. 4, closest to the survey, were larger than 23cm signifying adult fish (Figure 17). Samples from outside the survey box, on the other hand, were mostly smaller than 23cm signifying juvenile herring catches but there were some days with a bi-modal mixture of both large and small sizes.

Length samples from within the survey box for landings on Oct. 4 (+/- 3 days of the survey) were used in the calculation of target strength since there were no other samples from within the survey box area (Figure 30). Five length samples were collected with 697 fish measured, a mean length of 27.4cm and modes at 27-28cm. Industry supplied length-weight information and SABS sampling data from the Oct. 4 samples provided 303 fish for the calculation of herring target strength inside the German Bank survey box.

The data were downloaded from the four boats with acoustic recorders. After editing to remove bottom and non-herring targets the acoustic files were cut into transects. There were no significant problems encountered with the acoustic systems or in the data analysis resulting in a total of eight good transects completed. Herring were observed acoustically primarily in the north-central and north-western part of the box (Figure 31).

As recommended at the RAP herring Framework meetings (January 2007) the use of a standard survey area of 646 km^2 was applied. Eight transects were completed within the survey box (Figure 31). The survey estimate 'without' the calibration integration factor (CIF) using the standard survey box area and transects within the survey box was 44,500t with a standard error of 25% (Table 6a). The survey estimate 'with' the CIF using the standard survey box area and transects within the survey box was 50,900t with a standard error of 26% (Table 6b).

<u>German Bank Survey #4: October 15, 2006</u>

The fourth acoustic survey on German Bank in 2006 was conducted on Oct. 15, 2006. Seven herring purse seine vessels participated with each completing two transects of about 37 km each in length and following the designated survey plan. No additional surveying was undertaken outside of the German Bank survey box. Survey speed for each vessel was determined from previously completed noise tests and was based on maximum RPM assigned to boats with recorders. Herring were observed infrequently and in low to medium abundance in the central and

northern part of the survey box area (Figure 32).

Catch and length sample information since the last survey, from Oct. 7 to Oct. 16, showed catches concentrated mainly in the central portion and consisted of adult size fish (>= 23 cm) (Figure 33). Length frequency samples collected to the north of the survey area near Dry Ledge and around Lurcher Shoal showed a mixture of adult and juveniles indicating non-spawning fish.

Gonad maturity data were available from samples processed at the St. Andrews Biological Station and the 'Roe Analysis' reports from industry sources. The three biological samples from within the survey area available from Oct. 4-10 were mostly in ripe and running spawning condition (87-100% by number) with a small proportion (3-13%) in hard roe condition (Figure 16). Industry roe samples available since Oct. 1 were also mostly in spawning condition but with a variable mixture (5-40%) of hard and spent stages (Figure 15).

Daily length frequency samples from within the German Bank survey box from Oct. 4 to the end of the season showed variable mean size and a broad size range. The samples from Oct. 14, closest to the survey, were all larger than 23cm signifying adult fish (Figure 17). Samples from outside the survey box area were mixed in size with larger fish sampled on Oct. 7 and smaller sizes recorded after the survey on Oct. 23-24.

Length samples from within the survey box for landings on Oct. 14 (+/- 1 days of the survey) were used in the calculation of target strength (Figure 34). Two length samples were collected with 234 fish measured, a mean length of 27.7 cm and modes at 27.5-28.5 cm. Industry and science length-weight data from the Oct. 10-16 samples provided 153 fish for the calculation of herring target strength.

The data were downloaded from the four boats with acoustic recorders. After editing to remove bottom and non-herring targets the acoustic files were cut/merged into transects. There were no significant problems encountered with the acoustic recordings or in the data analysis with a total of eight good transects completed. Herring were observed acoustically mainly in the north-central portion of the box with a wide range of acoustic biomass density for individual transects (Figure 35). For example, transects by the *Lady Melissa* along longitude lines only 3 miles apart at 66°17' and 66°20' ranged from 0.0002 kg/m^2 to 0.1651 kg/m^2 which is a range of over 800 times.

As recommended at the RAP herring Framework meeting (January 2007) the use of a standard survey area was applied. The German Bank survey box area of 646 km2 was applied to the eight transects completed within the survey box (Figure 35). The biomass estimate 'without' the calibration integration factor (CIF) using the standard survey box area and transects within the survey box was 18,200t with a large standard error of 70% (Table 6a). The survey estimate 'with' the CIF using the standard survey box area and transects within the survey box was 22,800t with

a standard error of 71% (Table 6b).

German Bank summary

In summary, the overall spawning stock biomass (without the integration factor) for German Bank in 2006 was estimated as 245,450t from four structured surveys extending from Aug. 25 to October 15, which was about 3 weeks longer than the survey period in 2005 (Table 6). 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%.

As recommended at the RAP herring Framework meeting (January 2007) the use of a standard survey area was applied. This SSB estimate reflects only biomass estimated from within the survey box and may be used in inter-year comparisons for trends. The 2006 estimate of 245,450t represents a 34,450t or 16% increase from that observed in 2005. It may be argued that a portion of this increase may be attributed to the increased number of surveys which has not always been constant over time. A biomass of 4,100t was observed during the 2006 German Bank surveys in areas outside of the standard survey box. No adjustments were made for possible double counting documented by tagging studies.

Trinity Ledge:

In previous years, the surveying of spawning herring on Trinity Ledge (Figure 1) has been considered to be less than optimal and it unlikely that biomass estimates accurately reflect the abundance of fish in this area (Power et al 2006b). Improvements to the survey approach and adherence to the design protocols are required if the data are to reflect trends in abundance. The only structured survey of Trinity Ledge in 2005 was carried out on September 6 by eight herring gillnet vessels including the *Sea Quiz* with an acoustic recording system. The overall survey area in 2005 was 0.82 km^2 and the biomass was estimated as 5,070t without the CIF and 10,700t with the use of the CIF.

In 2006, the herring gillnet fishery in the Trinity Ledge and Spectacle Buoy fishing area took place between June 3 and Sept. 21, 2006 with landings of 719 t (Power et al, in press). On Trinity Ledge catches began around Sept. 7 with less than 50t/day until Sept 14, and then increased to about 100t/day until Sept 21 (Figure 36). Acoustic surveys were completed in the Trinity Ledge fishing area on Sept. 3, 7, 8 and Sept. 20 (Figures 37 and 38). There was also a survey completed in the Spectacle Buoy area on Sept. 10 (Figure 39). The data were downloaded from the single boat with an acoustic recorder, the *Sea Quiz,* and after editing to remove bottom and non-herring targets the acoustic files were cut into transects for each survey. These surveys were organized by the Yarmouth Herring Management Committee and were conducted entirely by the fishing captain of the acoustic survey boat. Additional surveying was completed near Trinity Ledge by two purse

seine vessels on Sept 15 as part of a larger survey including German Bank (Figure 26). A summary of each survey is provided below.

Acoustic survey of Trinity Ledge on Sept. 3, 2006

The acoustic survey boat *Sea Quiz* covered a small area with 3 groups/schools of herring encountered. There was no sampling data available from any of the surveys in this area so standard values for target strength were used with adjustment for sounder frequency (Table 8). A multi-panel gillnet sample was necessary to provide the complete size distribution of herring surveyed for target strength and biomass estimation but was not available.

There was some difficulty in editing the acoustic data because of the very uneven bottom and the location of fish very close to the bottom in some data files. The completed data collection was ad hoc and poor with a random fishing pattern resulting difficulties with the analysis when extracting relevant unbiased transects that covered the herring distribution.

Biomass estimates without the calibration integration factor (CIF) ranged from 15t to 70t for the schools surveyed (Table 8a). Biomass estimates with the calibration integration factor (CIF) ranged from 30t to 130t for the schools surveyed (Table 8b). The large difference in the biomass estimates both with and without the calibration integration factor was noted in 2005 for this vessel and is due to poor transducer matching and less than ideal calibration conditions. Using the integration factor provides a superior estimate of the biomass because the entire wave envelope of the wave echo is incorporated. However, the calculation without the CIF is required for comparison with earlier years and is used for the overall acoustic index.

Acoustic survey of Trinity Ledge on Sept 7, 2006

Four days had elapsed since the previous survey on Sept. 3. Surveying by the single acoustic boat located two aggregations that were about 100m by 200m in overall area about 1 km south of that seen in the previous survey with a total area of only 0.06km^2. A series of random lines were completed and transects were extracted with some difficulty for the schools surveyed. Biomass estimates were 480t and 560t for the two schools using standard target strength values and without the CIF (Table 8a).

Acoustic survey of Trinity Ledge on Sept 8, 2006

This survey occurred one night after the previous survey but with better coverage of the main spawning area around Trinity Ledge. Surveying by the single acoustic boat located four aggregations both north and south of the ledge with areas ranging from 0.1 to 0.5km^2. A series of parallel lines were completed over most of the identified schools which allowed for easier selection of transects for analysis.

Biomass estimates ranged from 890t to 2,230t for the individual schools with a total of 5,800t for all four schools combined using standard target strength values and without the CIF (Table 8a).

Acoustic survey of Trinity Ledge on Sept 15, 2006 by two purse seine vessels

The Trinity Ledge area was surveyed by two purse seine vessels with acoustic recorders and found only a small dense area of spawning herring (Figure 26). These were confirmed as spawning fish from the active gillnet fishery that was taking place. No samples were available and so standard target strength for a 28cm herring was used (Table 8). Due to the non-systematic survey pattern it was difficult to determine the area of coverage and the survey area. Transects were cut from the data using segments containing fish only and these were used to calculate an area of 0.3km^2. The biomass estimate for this group was 4,930t (without CIF) with a standard error of 35% (Table 8a).

Acoustic survey of Trinity Ledge on Sept 20, 2006

This survey was completed 5 days after the purse seine vessel excursions on Sept. 15 and 12 days after the more complete coverage that occurred on Sept. 8 by the *Sea Quiz.* Surveying by the single acoustic boat located one larger aggregation east of the previously surveyed area with an area of 0.45km^2. Survey lines were also completed for a few kilometres to the north of the school area but found few fish. A series of parallel lines were completed over the main school which allowed for easier selection of transects for the analysis. The biomass estimate for the individual school and area to the north combined was 2,650t using standard target strength values and without the CIF (Table 8a).

Spectacle Buoy:

The spring gillnet fishery for roe has occurred in recent years for a short period in June in the vicinity of Spectacle Buoy (Figure 1) 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 which estimated a total survey biomass of only 292t in an area of 0.57 km^2.

Landings were minimal in the Spectacle Buoy area in June 2006 with less than 10t reported and no surveying completed. A single acoustic survey of Spectacle Buoy was completed on Sept 10, 2006 during the fall spawning season. Purse seine vessels also explored the area on Sept. 15 during one of the German Bank surveys but documented no herring. Two lines were completed during a transit down and back through the expected spawning area located southwest of Big Tusket Island (Figure 39). The estimated area of coverage was about 4.0 km^2 with

virtually no herring seen. The estimate of 16t is based on standard target strength values without the CIF (Table 8a).

Summary of 2006 Trinity Ledge/Spectacle Buoy Survey Results

A total of 6 acoustic surveys were completed from Sept. 3-20 with 11 schools surveyed on various occasions. The area between schools was also surveyed in most cases. Standard protocol for surveys of spawning herring is to allow 10-14 days between surveys in order to avoid double counting of fish that still remain from previous surveys. The independence of the various schools is based on their separation in time and space. The schools surveyed around Trinity Ledge in 2006 were very close in space with less than a few kilometers separating the entire surveyed area and the total area of all the school areas combined was only 3.1 km^2. Summing the maximum of the biomass estimates for all schools surveyed on the nights of Sept. 8 and Sept. 20 results in a total of 8,490t calculated without the CIF (Table 8a). There were little or no herring seen in the Spectacle Buoy area and the final biomass is zero for this area in 2006 (16t rounded down to nearest 100t).

While surveying was improved in 2006 as far as the number of surveys completed, the area of coverage remained a very small portion of the defined survey area. There is also a need to use the multi-panel net more frequently to document the complete size distribution and to provide a more accurate estimation of target strength. Once again, it is recommended that improvements be made in the survey design with coverage of the entire area using a combination of mapping and acoustic boats.

Browns Bank :

The Browns Bank area has seen only occasional acoustic survey effort with no surveys or fishing night analysis undertaken in 2005. In 2006, some recordings were made on Brown's Bank by the *Lady Melissa* and *Leroy & Barry* on the night of Sept. 5. Catches from this area for the period Sept. 1-10 reported 2 landings with 24t catch but there were no biological samples available. The survey pattern, while not an ideal series of parallel lines mapping the fish area, did allow extraction of several lines used for biomass estimation (Figure 40). These lines ranged from 250m to 2.9 km in length and had average density estimates from 0.1 to 2.5 kg/m^2. Using a survey area of 17 km^2 the biomass estimate was 6,070t for this single survey on Browns Bank (calculated without the CIF) (Table 9a).

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 addition, little fishing has occurred in these shallow grounds

partly as a result of the deep purse seines that are now being employed which are unsuitable for fishing these areas.

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.

In 2006 fish were reported in the Seal Island area on several occasions and acoustic recordings were made of a few aggregations encountered. There was a report of some fish in the area on July 12 but the raw data has not been located and in any case would likely be non-spawning herring based on historical records for the area with the normal spawning season in the month of Sept.

On Sept. 15, 2006 a recording was made along a long narrow strip of fish approximately 9 km in length with mean densities of less than 135 g/m^2 (Figure 41). It is difficult to estimate survey area from a single strip recording but using a survey area of 2.5 km^2 the total estimate for this night was only 220t due to the low average density and small area. Four days later, on Sept. 19, 2006 a series of recordings were made over a more substantial aggregation west of Seal Island (Figure 42). The captain reported that the fish were in shallow water of about 20ftm (36m) where the purse seiners cannot set and that they were behaving like roe fish (tightly aggregated and close to bottom). A series of 5 transects were selected from the recordings which provided density estimates from 0.5 to 16.7 kg/m^2. To put this in perspective, a density of 16.7 kg/m^2 works out to a reasonable 2.5 fish per m^3 using assumptions of an average weight of 179 grams per fish and a depth of 36m. The total biomass estimate was 8,050t for an area of 1.5 km^2 (calculated without the CIF) (Table 10a).

BAY OF FUNDY/SW NOVA SUMMARY:

The 2006 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 and off the spawning grounds in waves with a short period of time (days) between the 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) was evaluated at the Regional Advisory Process (RAP) Framework review meetings in 2006/2007 (DFO, 2007) and the 10-14 day time period between surveys was considered reasonable but required further investigations.

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.

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 11, Figure 43, 44). The SSB for Scots Bay was down substantially in 2005 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 in 2005 but 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.

In 2006, the total SSB for the Bay of Fundy/Southwest Nova Scotia spawning complex was estimated to be 282,600t representing a modest increase from the previous year but still well below the average of the 8 year series (Table 11, Figure 43). The SSB for Scots Bay improved to 28,600t but is very low compared with the mean. The SSB on German Bank also saw an improvement in 2006 but is below the 8 year average. Finally the variance in individual survey estimates as provided in the 2006 tables (SE or standard error) ranged from 25 to 70% and depending on the survey and the actual variance in Sa observed by transect. Differences observed between areas from year to year are often not statistically significant with overlap in the 95% confidence interval between years (Figure 43, 44).

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. A traditional fishery for lobster bait 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 has improved in recent years. In 2005 two well conducted surveys were completed with a total SSB estimate of 44,700t (using the CIF) based on the mapping and acoustic data collected. 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.

In 2006, the herring gillnet fishery in the Little Hope/Port Mouton fishing area took place primarily between Sept. 28 and Oct. 28 with daily landings of up to 300t/day and total landings of 3,133t (Figure 45). Acoustic surveys were completed in each of the primary fishing areas near Little Hope/Port Mouton on Oct. 7, 17, 19, 22 and Oct. 25 (Figure 46). The data were downloaded from the single boat with an acoustic recorder, the *Knot Paid For,* and after editing to remove bottom and non-herring targets the acoustic files were cut into transects for each survey. Additional

data were available from deck sheet recordings on Oct. 7 and Oct. 22 with 12 vessels participating each night.

Acoustic survey on Oct. 7-8, 2006

The first survey of Little Hope Fishing Area in 2006 by 12 mapping vessels observed mostly light density targets except off Little Hope Island where a larger more dense group was found (Figure 47). The acoustic survey boat covered a similar overall area as the mapping boats. The main area of fish of about 4 km^2 was surveyed in two directions with eight equally spaced lines to provide separate biomass estimates (Figure 48).

A multi-panel sample with mesh sizes from 1 inch to 3 inches was used to capture all available sizes and to provide target strength for the acoustic analysis. The mean size was 30.9 cm with a range from 25 to 35 cm (Figure 49) Daily fishery length samples from Oct. 4 to 6 had a mean length from 29.4 to 30.7cm, similar to that of the multi-panel sample (Figure 50). Maturity condition was 97% spawning (ripe and running) from the SABS processed multi-panel gillnet sample on Oct. 7 (Figure 51). Industry supplied roe maturity reports for the same time period showed primarily spawning roe with a mixture of about 10-20% spent (Figure 52).

There was some difficulty in editing the acoustic data because of the very uneven bottom and the location of fish very close to the bottom. Biomass estimate ranged from 5,900t to 8,500 for the two passes on the main school area with an additional 150t found along transects outside of the school (Table 12b). This survey was organized by the Little Hope Herring Management Committee and was conducted entirely by the fishing captains. The completed survey design and execution of two sets of lines over the school was excellent, providing for good estimation of biomass.

Acoustic survey on Oct. 17, 2006

Ten days had elapsed since the previous survey on Oct. 7. Surveying was completed by a single acoustic boat which located an aggregation with an area of 1km^2 about 4 km north of that seen in the previous survey (Figure 46). Another small group was also surveyed about 7 km to the north-east of this school. Transects were completed along two axes for the southern school (Figure 53). No multi-panel gillnet sample was taken but the size remained large in fishery samples (Figure 50). Target strength was estimated using the multi-panel sample from the previous survey (Figure 49). Industry supplied roe maturity reports for the same time period showed about 60% spawning roe with a mixture of about 10% hard and 30% spent (Figure 52).

Biomass estimates ranged from 780t to 1,100t for two passes on the southern school with an additional 110t found along transects outside of the school (Table 12b). Very few fish were seen in the north-eastern school with an estimate of only

36t for the single pass. This survey was organized by the Little Hope Herring Management Committee and was conducted entirely by the fishing captain. The completed survey design and execution of two sets of lines over the main school encountered was again excellent.

Acoustic survey on Oct. 19-20, 2006

Only 2 days had elapsed since the previous survey on Oct. 17. The survey by the single acoustic boat had a similar area of coverage as the previous survey but a larger group was encountered in the northern area (Figure 46). The two school areas were well surveyed and multiple passes were made on both groups (Figure 54, 55). Target strength was again estimated using the multi-panel sample from the first survey (Figure 49). Size remained large in the fishery samples (Figure 50). Industry supplied roe maturity reports on Oct. 20, showed a large proportion (about 60%) spent females (Figure 52).

The biomass estimate for the northern school with an area of 1.6 km^2 ranged from 3,100t to 4,000t while that for the 4 passes on the southern school with an area of coverage of 0.5 to 1.2 km^2 ranged from 560t to 1,290t (Table 12b). Very little acoustic backscatter considered to be herring was seen between the schools. This survey was organized by the Little Hope Herring Management Committee and was conducted entirely by the fishing captain. The completed survey design and execution of multiple sets of lines over the two main schools encountered was again excellent.

Acoustic survey on Oct. 22-23, 2006

Only three days had elapsed since the previous survey on Oct. 19. A survey of a large portion of the Little Hope Fishing Area was also completed by 12 mapping vessels which observed mostly light to medium density herring along the outer edge of the fishing area but had uneven coverage in the center of the surveyed area. The acoustic survey boat covered a similar overall area as the mapping boats but with more extensive lines on the three herring schools encountered (Figure 46). The southern school was about 1.5 km north of the group surveyed on Oct. 19, while the central and northern schools located 20-25 km to the northeast were new. The three school areas were well surveyed and multiple passes were made on each group (Figure 56).

Target strength was estimated using the multi-panel sample from the first survey while fish size in fishery samples on Oct. 23 showed a mixture of smaller fish less than about 28cm (Figure 50). Maturity condition from a fishery sample collected on Oct. 23 was 96% spawning (ripe and running) and 4% spent (Figure 51). Industry supplied roe maturity reports for Oct. 23 showed a similar result (Figure 52).

The biomass estimates for the north-eastern school ranged from 2,500t to 7,500t, for the middle school from 1,600t to 2,100t and for the south-western school from

2,750t to 4,070t (Table 12b). As in previous surveys very little acoustic backscatter (about 70t) considered to be herring was seen between the schools. This survey was organized by the Little Hope Herring Management Committee and was conducted entirely by the fishing captains. The completed survey design and execution of multiple sets of lines over the three main schools encountered was excellent. There was considerable variation in some of the repeated estimates on single schools due to the orientation of the lines in relation to the school and the highly variable transect densities where fish were encountered.

Acoustic survey on Oct. 25, 2006

Only three days had elapsed since the previous survey on Oct. 22. This survey was by the single acoustic boat with coverage of the middle and upper areas where fish were encountered in the previous survey (Figure 46). Only one school was located and this was about 2 km northeast of an area previously surveyed on Oct. 22. The single school was well surveyed and multiple passes were made (Figure 57).

Target strength was estimated using the multi-panel sample from the first survey with size of fish remaining large in the fishery samples (Figure 50). Industry supplied roe maturity reports for Oct. 25, showed a large proportion (about 70%) of females in spawning condition with a mixture of hard and spent maturity stages (Figure 52). The biomass estimates for the single school ranged from 2,600t to 3,300t and about 300t was estimated for outside of the school area (Table 12b). This survey was organized by the Little Hope Herring Management Committee and was conducted entirely by the fishing captain. The completed survey design and execution of two sets of lines over the main school encountered was again excellent.

Summary of Little Hope/Port Mouton Survey Results

A total of 5 acoustic surveys were completed from Oct. 7 to Oct. 25 with at least 5 separate schools surveyed. The area between schools was also surveyed. Standard protocol for surveys of spawning herring is to allow 10 days between surveys in order to avoid double counting of fish that still remain from previous surveys. The various surveys completed in the Little Hope area provided evidence for coverage of at least 5 different spawning schools, several of which were visited and well surveyed on multiple days. The independence of the various schools is based on their separation in time and space with evidence from survey coverage over several nights. For example, a school area in the southwest surveyed on both Oct. 17 and Oct 19 was found in the exact same location, orientation and size. In contrast a school found on Oct. 22 in the northeast of the Little Hope Fishing Area appeared to have shifted a few kilometres to the northeast when found on Oct. 25 but remained of similar size and area.

Summing the maximum of the biomass estimates for all schools surveyed on the nights of Oct. 7 and Oct. 22 results in a total of 24,100t (Table 12b). Also included in the estimate is an additional southwest school surveyed on the nights of Oct. 17 and 19th. The inclusion of these fish assumes that the spawning groups were independent of each other and there was no double counting on subsequent surveys. The remaining data for Oct. 17 and 25th are not included in the total biomass as they were surveyed within the 10 to 14 day window around Oct 22.

The results although preliminary, are considered to provide a reasonable estimate of herring present at the time of surveying. A major concern or source of uncertainty continues to be the assumption that the surveys are simply cumulative. If herring do not move 'on' and 'off' the spawning grounds in waves the estimate of total SSB will be significantly biased upward due to double counting. There is also a need to use the multi-panel net more frequently to document the complete size distribution and to provide a more accurate estimation of target strength.

Eastern Shore:

The 2006 herring gillnet fishery in the Eastern Shore fishing area took place between Sept. 18 and Oct. 17 2006 with total landings of 3,348t. Daily landings were less than 100t/day until Oct. 1, and then increased to about 300t/day until Oct. 10 (Figure 58). Surveys were completed in each of the primary fishing areas along the Eastern Shore from Halifax Harbour to near Ship Harbour, N.S. on Sept. 26, Oct. 6 and Oct. 15 (Figure 59). The data were downloaded from the two boats with acoustic recorders, *Bradley K* and *Miss Owls Head* and after editing to remove bottom and non-herring targets the acoustic files were cut into transects for individual survey. Additional data were available from deck sheet recordings on Oct. 6 with 14 vessels participating.

Acoustic survey on Sept 26, 2006

The first survey in the Eastern Shore area in 2006 covered one school of herring found southwest of Jeddore Head with duplicate coverage was made with nearly identical lines by the two vessels with recorders (Figure 60). Eight approximately equally spaced lines were made through the school by each boat with separate biomass estimates made for each vessel. Daily length samples which include fishery samples had mean lengths ranging from 30.8 to 31.1cm (Figure 61). Final biomass estimates were based on target strength determined from a multi-panel gillnet sample taken after the survey (Figure 62). Maturity condition was 100% spawning (ripe and running) from the multi-panel gillnet sample on Sept. 27 (Figure 63). Biomass estimates ranged from 24,400t to 25,800 with a mean of 25,100t and a 6% difference between boats (Table 13).

This was a superb survey conducted entirely by the fishing captains of the *Miss Owl's Head* (Clark Stevens) and the *Bradley K* (Donald Kent). The data provided an opportunity to compare the observations from two vessels using the same

FEMTO equipment and the overall estimate of school biomass. In addition, separate data analysis was completed by two independent parties which provided very comparable results. The final survey estimate using the average of the two estimates by boat and calculated 'with' the calibration integration factor was 25,100t with a standard error of 40% (Table 16).

Acoustic survey on Oct. 6-7, 2006

Ten days had elapsed since the previous survey on Sept. 26. Industry supplied roe maturity reports for the same time period showed primarily spawning roe with a mixture of about 20% spent (Figure 64). This was an extensive survey from the approaches to Halifax Harbour to Jeddore Head with 14 gillnet vessels participating including two vessels with acoustic recorders. Data from deck sheet sounder observations described mostly low density fish with a total aerial coverage of 170 km^2 (Figure 65). There was no multi-panel gillnet sample collected but the size remained large from industry samples from the fishery which typically uses 2 ¾" mesh (Figure 61). The multi-panel sample from the earlier survey on Sept. 26 was used for target strength estimation (Figure 62). Acoustic survey boats completed transects on 2 separate schools near Halifax Harbour approaches and southwest of Jeddore Head as well as the area between the schools. The school near Jeddore Head was about 4km away from the area previously surveyed on Sept. 26 (Figure 59). A total of 5 transects were completed for the Halifax school and 7 transects for the Jeddore school provided good delineation of the spawning aggregations for biomass estimation (Figure 66, 67). Estimates were made for each of the surveyed schools and for the estimated overall area between the schools which was covered by all participating survey vessels.

This was another excellent survey conducted entirely by the fourteen fishing vessels involved. The area of coverage was good, reflecting where recent gillnet catches had occurred, and transects on the schools by the acoustic survey boats were well defined allowing for accurate biomass estimation. One small deficiency in the survey was the lack of a multi-panel gillnet sample for target strength estimation. The final survey estimate using the sum of the two school estimates and the overall survey area between schools was calculated 'with' the calibration integration factor for a total biomass of 37,700t with a standard error of 16% (Table 13).

Acoustic survey on Oct. 15, 2006

Nine days had elapsed since the previous survey on Oct. 6. This was a single vessel survey on a single herring school located south of Ship Harbour. This school was approximately 20 km east of the last area surveyed south of Jeddore Head on Oct. 6. Maturity condition was 96% spawning (ripe and running) from the multi-panel gillnet sample taken after the survey (Figure 63). Industry supplied roe maturity reports for the same period showed primarily spawning roe with a mixture of about 20% spent and 10% hard roe (Figure 64). The acoustic survey boat, *Miss*

Owls Head, completed 8 transects with 4 in each direction providing good delineation of the spawning school for biomass estimation (Figure 68, 69). Target strength was based on a multi-panel gillnet sample taken two days after the survey on Oct. 17 (Figure 70).

This was a well conducted survey by a single acoustic survey vessel, *Miss Owls Head* and provided accurate biomass estimation. A multi-panel gillnet sample was provided which allowed for more accurate target strength estimation. The Oct. 15 survey estimate using the average of the two school estimates was calculated 'with' the calibration integration factor for a biomass of 6,100t with a standard error of 32% (Table 13).

Summary of Eastern Shore Survey Results

A total of 3 acoustic surveys were completed from Sept. 26 to Oct. 15 with 4 separate schools being surveyed as well as the area between schools for the Oct. 6 survey. Summing of the biomass estimates for the 3 surveys gives a total of 68,900t as calculated 'with' the CIF and assumes that the spawning groups were independent of each other and there was no double counting on subsequent surveys. There is a possibility that fish surveyed on Sept. 26 were also seen during the Oct. 6 survey which was conducted 10 days later with a large aggregation found about 4 km to the east. The independence of the schools and the time interval between surveys remains an issue with all acoustic surveys when used in this manner.

The results are considered to provide a reasonable estimate of herring present at the time of surveying. A major concern or source of uncertainty is the assumption that the surveys are simply cumulative. 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.

Glace Bay:

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.

In 2005 there were two acoustic surveys for herring in the Glace Bay area with one survey vessel (*Natasha Lee*) with an acoustic recording system in operation. 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. 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.

In 2006 there was very little herring gillnet activity due to poor roe prices with only 85t of catch reported for the year and no acoustic survey work undertaken.

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.

Summary for Nova Scotia Coastal component:

The recorded landings of 6,600t in 2006 in the four major gillnet fisheries along the coast of Nova Scotia were higher for Little Hope/Port Mouton area, about the same for the Eastern Shore area, minimal for Glace Bay and the Bras d'Or Lakes fishery remained closed (Table 14a, Figure 71).

In 2006 there was a large increase in surveyed acoustic biomass from 28,100t to 51,100t in the Halifax/Eastern Shore area, while the Little Hope area saw a large decline from 39,500t to 21,700t (Table 14b, Figure 71). A survey with an acoustic recorder had been completed for the first time in the Glace Bay area 2005 but there was no survey effort in 2006.

As indicated for the SW Nova Scotia / Bay of Fundy component, summing of multiple surveys may result in overestimates of SSB due to double counting. However, the majority of surveys of the Coastal Nova Scotia spawning component were undertaken on spatially separated aggregations of fish.

OFFSHORE SCOTIAN SHELF COMPONENT:

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf has 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*.

Acoustic records were made by the *Julianne* III a purse seine/midwater trawl vessel during operations in the offshore. A large aggregation was reported and recordings were made in an area east of Sable Island along the shelf edge during Nov.- Dec. 2006. The acoustic system, which is a Simrad 200kHz ES60, has yet to be calibrated and so the data has not been analyzed.

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 at that time. 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.

In 2006, it was hoped that more structured surveys would be conducted using the standard survey protocol of Melvin and Power (1999), primarily around the weirs. Weir fishers were consulted to identify important areas where herring are known to congregate and these areas were mapped. It was planned to have two surveys conducted in each of the areas with a technician hired by this project present on the *Strathaven* to ensure adherence to the survey protocol. In addition other schools of herring encountered during normal fishing operations were intended to be surveyed using the vessel's acoustic system.

Acoustic survey results and analysis for 2006 in SW New Brunswick are incomplete. The vessel *Strathaven* made a number of recordings and completed a total of 42 hours of recordings over seven nights of operations (Table 15, Figure 72). Surveys were completed in the Grand Manan area, around the Wolves Islands and near Campobello and Deer Island. The average density of the survey lines completed was generally low, except for the survey around Grand Manan on the night of Sept. 13 (Table 15, Figure 73).

DISCUSSION:

In 2006 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. While no structured surveys were conducted outside the main spawning areas, around Seal Island or in the vicinity of Browns Bank there was some fishing night data collected on aggregations found in these areas. There was limited activity in the Spectacle Buoy area in June with very little catch and no survey effort but there was some surveying in the fall which found little fish.

This is the tenth 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 2006 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 2006 was the absence of survey protocols when attempting to document schools of fish on non-survey (or fishing) nights. These methods are well described (Appendix 1) and provide a quick way to document a group of fish acoustically that is efficient with time and also much easier to analyze and produce reliable biomass estimates with a good estimate of the total area of coverage. The set of surveys for the overall areas are considered to be comparable to others in the series since 1999.

In 2005, the observed SSB for Scots Bay decreased dramatically to only 16,800t which was the lowest recorded for the component. In 2006, the Scots Bay acoustic survey SSB estimated from the three structured surveys was 28,600t. While, this is an improvement from 2005, the SSB remains low and it is well below the 1999-2005 average of 92,400t.

Coverage of Trinity Ledge in 2006 was much improved over that of 2005 with an increased number of surveys completed but the area of coverage remained small and the survey patterns did not always follow the described protocols (Appendix 1). 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. 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. Until complete surveys of the entire Trinity Ledge survey area are completed, the coverage remains less than optimal and the spawning stock biomass is unlikely to be representative of the total amount of fish spawning in the area.

In 2005, the total spawning stock biomass observed on German Bank was estimated to be 211,000t which was a decrease of 150,000t from 2004 and well below the average (Table 11). The SSB in 2005 was based on estimates of biomass from only 3 structured surveys undertaken from Sept. 7 to Oct. 4.

In 2006 the overall spawning stock biomass for German Bank was estimated at 245,500t from four structured surveys (Table 6) extending from Aug. 25 to October 15, which was about 3 weeks longer than the survey period in 2005. The 2006 estimate of 245,450t represents a 34,450t or 16% increase from that observed in 2005. A survey biomass of 4,100t was also observed in areas outside of the standard survey box. The elapsed time between all surveys was within the 10-14 day guideline and turnover of spawning herring was assumed to be 100% for this analysis.

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. In 2006 there was a large increase in surveyed acoustic biomass from 28,100t to 51,100t in the Halifax/Eastern Shore area, while the Little Hope area saw a large decline from 39,500t to 21,700t (Table 14b, Figure 71). A survey with an acoustic recorder had been completed for the first time in the Glace Bay area 2005 but there was no survey effort in 2006.

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.

Acoustic survey results and analysis for 2006 in SW New Brunswick are incomplete. The vessel *Strathaven* made a number of recordings and completed a total of 42 hours of recordings over seven nights of operations with surveys completed in the Grand Manan area, around the Wolves Islands and near Campobello and Deer Island.

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Table 1. Summary of the number of scheduled herring spawning ground surveys for 2006, 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	3
Trinity Ledge	2	5	0
German Bank	3	4	11
Spectacle Buoy	1	1	0
Browns Bank	0	0	1
Seal Island	1	1	2
Little Hope	2	5	0
Eastern Shore	2	3	0
Glace Bay	2	0	0
Total	16	22	17

Table 2. Summary of completed herring acoustic surveys undertaken in 2006 with interval (days) between surveys on the same grounds, number of boats with acoustic systems and the number of mapping boats (without acoustic systems using deck sheets only).

Survey Date	Location of survey	Interval (days)	Acoutic Boats	Mapping Boats	Total No. Boats
22-Jul	Scots Bay #1	0	2	1	3
06-Aug	Scots Bay #2	14	4	1	5
19-Aug	Scots Bay #3	13	4	2	6
25-Aug	German Bank #1	0	5	4	9
15-Sep	German Bank #2 *	20	5	6	11
01-Oct	German Bank #3	16	4	2	6
15-Oct	German Bank #4	14	4	3	7
03-Sep	Trinity Ledge #1	0	1		1
07-Sep	Trinity Ledge #2	4	1		1
08-Sep	Trinity Ledge #3	1	1		1
15-Sep	Trinity Ledge #4	7	2		2
20-Sep	Trinity Ledge #5	5	1		1
10-Sep	Spectacle Buoy	0	1		1
07-Oct	Little Hope #1	0	1	11	12
17-Oct	Little Hope #2	10	1		1
19-Oct	Little Hope #3	2	1		1
22-Oct	Little Hope #4	3	1	11	12
25-Oct	Little Hope #5	3	1		1
26-Sep	Eastern Shore #1	0	2		2
06-Oct	Eastern Shore #2	10	2	12	14
15-Oct	Eastern Shore #3	9	1		1
none	Glace Bay		0	0	0
Total number of survey boat nights			45	53	98

* included searching and surveying around Seal Island, Spectacle Buoy and Trinity Ledge

Table 3. Summary by survey date and location for the 2006 herring acoustic surveys with sampling numbers, mean length, mean weight, target strength estimated from samples, and target strength estimate for a 'standard length' 28 cm herring.

Date of Survey	Location of survey	Interval (days)	Number Samples	Number Measured Fish	Number Len/Wt Fish	Mean Length (mm)	Mean Weight (gm)	Target Strength dB/kg	Wt 28 cm Fish (gm)	TS 28 cm Fish dB/kg
22-Jul	Scots Bay #1	0	6	962	118	270	157	-35.23	177	-35.44
06-Aug	Scots Bay #2	14	0			280				-35.50
19-Aug	Scots Bay #3	13	6	818	28	272	168	-35.45	187	-35.66
25-Aug	German Bank #1	0	5	677	312	270	164	-35.41	184	-35.61
15-Sep	German Bank #2 (inbox)	20	6	725	396	279	179	-35.49	179	-35.49
15-Sep	German Bank #2 (outbox)		8	958	229	222	85	-34.24	177	-35.43
01-Oct	German Bank #3	16	5	697	303	274	167	-35.37	179	-35.49
15-Oct	German Bank #4	14	2	234	153	277	168	-35.31	175	-35.38
03-Sep	Trinity Ledge[1]					280				-35.96
10-Sep	Spectacle Buoy[1]					280				-35.96
07-Oct	Little Hope[1,2]		1	128	119	309	242	-36.39	182	-35.96
27-Sep	Eastern Shore [1,3]		1	131	98	300	228	-36.39	192	-35.96
17-Oct	Eastern Shore [1,4]		1	93	89	293	207	-36.18	182	-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 Little Hope multi-panel sample.on Oct.7

[3] TS estimated using length/weight relationship from Eastern Shore multi-panel sample.on Sept. 26

[4] TS estimated using length/weight relationship from Eastern Shore multi-panel sample.on Oct.17

Table 4. Summary of the 2006 herring biomass estimates observed during fishing nights for various grounds off southwest Nova Scotia and the Bay of Fundy. Standard target strength and calculation without the CIF were used. Shaded rows indicate nights included in the overall SSB for the Bay of Fundy/SW Nova component

No	Date	Vessels	Ground	Total Area (km2)	TS	Mean Density (kg/m2)	Mean of strata Sa (dB re /mý)	Strata Biomass (tons)
1	13/08/2006	LM, MS	Scots	17.00	-35.5	0.3939	-39.546	6,662
2	14/08/2006	MS	Scots	0.25	-35.5	2.9897	-30.744	747
3	15/08/2006	MS	Scots	0.10	-35.5	5.5724	-28.040	557
4	17/08/2006	DV, LM	German	7.00	-35.5	0.7386	-36.816	5,318
5	18/08/2006	LM	German	10.00	-35.5	0.3879	-39.613	3,879
6	20/08/2006	LM	German	3.00	-35.5	4.5168	-28.952	11,292
7	21/08/2006	DV, LB, LM	German	27.00	-35.5	0.4753	-38.731	12,832
8	19/09/2006	IP, LM	German	3.00	-35.5	5.0050	-28.506	15,015
9	20/09/2006	DV, LM	German	20.00	-35.5	1.2690	-34.465	25,381
10	21/09/2006	LM	German	10.00	-35.5	1.7328	-33.112	17,328
11	22/09/2006	DV	German	8.00	-35.5	3.5641	-29.980	28,157
12	05/10/2006	IP, LB	German	6.00	-35.5	3.4105	-30.172	18,758
13	07/10/2006	LB	German	3.00	-35.5	0.9317	-35.807	2,562
14	08/10/2006	LB	German	6.00	-35.5	0.9282	-35.824	5,569
15	05/09/2006	LB, LM	Browns	17.00	-35.5	0.3570	-39.974	6,068
16	15/09/2006	IP	Seal Isl	3.00	-35.5	0.0893	-45.992	223
17	19/09/2006	IP	Seal Isl	2.00	-35.5	5.3668	-28.203	8,050

Table 5. Summary of the 2006 Scots Bay spawning ground acoustic survey data and associated biomass estimates. The total SSB for the spawning component was 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									
#1-Survey lines	22-Jul-06	270	-35.5	530	-64.71	0.001	635	394	62%
#1-school west	22-Jul-06	270	-35.2	1.4	-24.31	12.340	17,275	4,759	28%
#1-school east	22-Jul-06	270	-35.2	1.61	-32.21	2.002	3,224	2,049	64%
#2 Survey*	6-Aug-06	280	-35.6	600	-66.47	0.001	494	115	23%
#3-Survey lines	19-Aug-06	272	-35.5	650	-61.74	0.002	1,528	577	38%
#3-schools	19-Aug-06	272	-35.5	1.98	-31.09	2.730	5,405	1,347	25%
Scots Bay total							28,561	5,400	19%

* multi-frequency transducers

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									
#1-Survey lines	22-Jul-06	270	-35.5	530	-68.58	0.001	260	156	60%
#1-school west	22-Jul-06	270	-35.2	1.4	-24.08	13.018	18,225	5,021	28%
#1-school east	22-Jul-06	270	-35.2	1.61	-31.98	2.112	3,401	2,162	64%
#2 Survey*	6-Aug-06	280	-35.6	600	-65.74	0.001	586	144	25%
#3-Survey lines	19-Aug-06	272	-35.5	650	-60.65	0.003	1,966	660	34%
#3-schools	19-Aug-06	272	-35.5	1.98	-29.87	3.625	7,178	1,885	26%
Scots Bay total							31,616	5,824	18%

* multi-frequency transducers

Table 6. Summary of the 2006 German Bank spawning ground acoustic survey results and SSB biomass estimates.

a - without integration calibration factor; as presented since 1997

Location	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 - inbox									
GB#1-inbox *	25-Aug-06	270	-35.5	646	-43.80	0.147	94,642	32,531	34%
Gb#2-inbox *	15-Sep-06	279	-35.5	646	-44.17	0.136	88,144	29,288	33%
Gb#3-inbox *	1-Oct-06	274	-35.4	646	-47.05	0.069	44,486	10,963	25%
Gb#4-inbox *	15-Oct-06	277	-35.5	646	-51.00	0.028	18,180	12,792	70%
German Bank - inbox total (comparable to previous assessments)							245,452	46,903	19%
German Bank - outbox									
GB#1-outbox	25-Aug-06	270	-35.4	60	-74.28	0.000	8	0	0%
Gb#2-outbox-north*	15-Sep-06	222	-35.3	45	-51.15	0.026	1,170	429	37%
Gb#2-outbox-south	15-Sep-06	279	-35.5	10	-40.81	0.294	2,940	994	34%
GB-outbox total							4,118	1,083	26%
German Bank overall total							249,570	46,915	19%

* multi-frequency transducers

b - with integration calibration factor; as introduced in 2004 assesment

Location	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 - inbox									
GB#1-inbox *	25-Aug-06	270	-35.5	646	-42.99	0.177	114,060	40,271	35%
Gb#2-inbox *	15-Sep-06	279	-35.5	646	-43.51	0.159	102,727	34,731	34%
Gb#3-inbox *	1-Oct-06	274	-35.4	646	-46.47	0.079	50,893	13,032	26%
Gb#4-inbox *	15-Oct-06	277	-35.5	646	-50.02	0.035	22,787	16,195	71%
GB-inbox total							290,467	57,097	20%
German Bank - outbox									
GB#1-outbox	25-Aug-06	270	-35.4	60	-73.45	0.000	9	0	0%
Gb#2-outbox-south	15-Sep-06	279	-35.5	10	-39.97	0.356	3,561	1,204	34%
Gb#2-outbox-north*	15-Sep-06	222	-35.3	45	-50.53	0.030	1,353	487	36%
GB-outbox total							4,923	1,299	26%
GB overall total							295,390	57,112	19%

Table 7. Target strength (TS) estimates used for the Sept. 15, 2006 survey according to sample availability and location; a) no samples available for area surveyed, b) samples within the German Bank survey box and c) samples outside the German Bank survey box.

a- TS if no samples available

Based on 28cm std only (no samples)	
Standard TS for 28cm (50Khz)	-35.500
Standard TS for 28cm (75Khz)	-35.766
Standard TS for 28cm (120Khz)	-35.949

b- TS using samples within the German Bank box for the Sept. 15, 2006 survey.

Mean length (mm)	279.986	L28cm weight (kg) calculated	0.179
Mean weight (kg)	0.179	TS for 28cm & calculated wt	
Target Strength (50kHz) =	-35.490	TS for 28cm (50Khz)	-35.490
Target Strength (75kHz) =	-35.755	TS for 28cm (75Khz)	-35.756
Target Strength (120kHz) =	-35.939	TS for 28cm (120Khz)	-35.939

c- TS using samples 'outside' the German Bank box for the Sept. 15, 2006 survey.

Mean length (mm)	222.118	L28cm weight (kg) calculated	0.177
Mean weight (kg)	0.085	TS for 28cm & calculated wt	
Target Strength (50kHz) =	-34.244	TS for 28cm (50Khz)	-35.435
Target Strength (75kHz) =	-34.510	TS for 28cm (75Khz)	-35.701
Target Strength (120kHz) =	-34.693	TS for 28cm (120Khz)	-35.884

Table 8. Biomass estimation for the 2006 Trinity Ledge/Spectacle Buoy acoustic surveys. The shaded boxes represent the biomass estimates summed for the overall SSB based on the 10-14 day time window between surveys.

a) Final runs with summary by school including the seiner survey (without CIF)

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)	Total by day
Trinity_sep3_s1	-35.9	0.06	-41.95	0.251	15	11	73	
Trinity_sep3_s2	-35.9	0.16	-46.34	0.091	15	12	82	
Trinity_sep3_s3	-35.9	0.05	-34.57	1.374	69	29	42	99
Trinity_sep7_s1	-35.9	0.04	-24.52	13.911	556	250	45	
Trinity_sep7_s2	-35.9	0.03	-23.88	16.090	483	222	46	1,039
Trinity_sep8_s1	-35.9	0.11	-24.54	13.833	1,522	502	33	
Trinity_sep8_s2	-35.9	0.26	-26.62	8.577	2,230	1,128	51	
Trinity_sep8_s3	-35.9	0.53	-32.46	2.233	1,183	536	45	
Trinity_sep8_s4	-35.9	0.12	-27.26	7.404	888	485	55	5,823
Spec_Buoy_Sep10	-35.9	4.00	-59.98	0.004	16	2	13	16
Trinity_sep15_seiner	-35.5	0.30	-23.34	16.442	4,933	1,717	35	4,933
Trinity_sep20_outside	-35.9	1.00	-55.34	0.012	11	6	49	
Trinity_sep20_school	-35.9	0.45	-28.25	5.894	2,652	612	23	2,663
Selected total								8,486

b) Final runs with summary by school including the seiner survey (with CIF)

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)	Total by day
Trinity_sep3_s1	-35.9	0.06	-39.17	0.476	29	21	73	
Trinity_sep3_s2	-35.9	0.16	-43.57	0.173	28	23	82	
Trinity_sep3_s3	-35.9	0.05	-31.80	2.602	130	55	42	187
Trinity_sep7_s1	-35.9	0.04	-21.74	26.347	1,054	474	45	
Trinity_sep7_s2	-35.9	0.03	-21.11	30.475	914	420	46	1,968
Trinity_sep8_s1	-35.9	0.11	-21.77	26.200	2,882	952	33	
Trinity_sep8_s2	-35.9	0.26	-23.84	16.245	4,224	2,136	51	
Trinity_sep8_s3	-35.9	0.53	-29.69	4.229	2,241	1,015	45	
Trinity_sep8_s4	-35.9	0.12	-24.48	14.022	1,683	919	55	11,030
Spec_Buoy_Sep10	-35.9	4.00	-57.20	0.008	30	4	13	30
Trinity_sep15_seiner	-35.5	0.30	-22.58	19.602	5,881	2,130	36	5,881
Trinity_sep20_outside	-35.9	1.00	-52.57	0.022	22	11	49	
Trinity_sep20_school	-35.9	0.45	-25.47	11.164	5,024	1,160	23	5,046
Selected totals								16,076

Table 9. Biomass estimation for a fishing night survey completed on Browns Bank by the *Lady Melissa* on Sept. 5, 2006.

a - without integration calibration factor; as presented since 1997

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Browns Bank Sep5	-35.5	17	-39.974	0.357	6068	3579	59

b - with integration calibration factor; as introduced in 2004 assesment

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Browns Bank Sep5	-35.5	17	-38.954	0.4515	7675	4527	59

Table 10. Biomass estimation for a fishing night survey completed near Seal Island by the *Island Pride* on Sept. 19, 2006.

a - without integration calibration factor; as presented since 1997

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Seal_Isl_Sep19	-35.5	1.5	-28.203	5.3668	8050	4947	61

b - with integration calibration factor; as introduced in 2004 assesment

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)
Seal_Isl_Sep19	-35.5	1.5	-27.27	6.6521	9978	6132	61

Table 11. 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	1999	2000	2001	2002	2003	2004	2005	2006	Average 1999-2006
Scots: lines	41,000	106,300	163,900	141,000	133,900	107,600	15,000	2,660	88,920
Scots:schools							1,800	25,900	13,850
Scots Bay total	41,000	106,300	163,900	141,000	133,900	107,600	16,800	28,560	92,383
German Bank	460,800	356,400	190,500	393,100	343,500	367,600	211,000	245,500	321,050
Trinity Ledge	3,900	600	14,800	8,100	14,500	6,500	5,100	8,500	7,750
Spec Buoy - Spring	0	0	1,100		1,400	n/s	300	n/s	560
Spec Buoy - Fall			87,500					0	43,750
Sub-Total	505,700	463,300	457,800	542,200	493,300	481,700	233,200	282,560	432,470
German (outside box)								4,100	4,100
Seal Island			3,300	1,200	12,200			8,100	6,200
Browns Bank			45,800					6,100	25,950
Total	505,700	463,300	506,900	543,400	505,400	481,700	233,200	300,860	442,558
Overall SE t	94,600	64,900	50,800	49,500	86,100	74,200	64,900	47,251	66,531
Overall SE %	19	14	10	9	17	15	28	16	16

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

Table 12a. Biomass estimation for the 2006 Little Hope/Port Mouton acoustic surveys calculated without the calibration integration factor (CIF). The shaded boxes represent the biomass estimates summed for the overall SSB based on the 10-14 day time window and evidence for separation in time and location.

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)	Min	Max	Avg
Oct.7_outer_area	-36.4	8.1	-54.20	0.017	134	68	51	134	134	134
Oct.7_run1	-36.4	4.6	-35.75	1.157	5,323	1,396	26	5,323		
Oct.7_run2	-36.4	4.0	-33.55	1.921	7,682	2,680	35		7,682	6,503
								5,457	7,816	6,637
Oct.17_outer	-36.4	2.2	-49.69	0.047	103	38	37	103	103	103
Oct.17_ne	-36.4	1.0	-51.32	0.032	32	17	53	32	32	32
Oct.17_sw_run1	-36.4	1.1	-36.51	0.973	1,021	424	42		1,021	
Oct.17_sw_run2	-36.4	1.1	-38.12	0.670	704	362	51	704		863
								839	1,156	998
Oct.19_outer	-36.4	2.5	-57.56	0.008	19	11	56	19	19	19
Oct.19_ne_run1	-36.4	1.6	-32.85	2.258	3,612	887	25		3,612	
Oct.19_ne_run2	-36.4	1.7	-34.15	1.673	2,760	1,201	44	2,760		3,186
Oct.19_sw_run1	-36.4	1.0	-36.48	0.980	980	660	67			
Oct.19_sw_run2	-36.4	1.2	-36.54	0.965	1,158	581	50		1,158	
Oct.19_sw_run3	-36.4	0.5	-36.37	1.005	502	336	67	502		
Oct.19_sw_run4	-36.4	0.5	-34.51	1.541	786	289	37			1,237
								3,281	4,789	4,442
Oct.22_outer	-36.4	6.3	-56.28	0.010	65	19	29	65	65	65
Oct.22_ne_run1	-36.4	2.3	-36.34	1.012	2,276	604	27	2,276		
Oct.22_ne_run2	-36.4	1.5	-29.63	4.740	7,109	2,620	37		7,109	4,693
Oct.22_mid_run1	-36.4	1.1	-33.92	1.765	1,853	1,280	69		1,853	
Oct.22_mid_run2	-36.4	1.0	-34.94	1.397	1,453	1,133	78	1,453		1,653
Oct.22_sw_run1	-36.4	1.7	-32.95	2.204	3,659	1,022	28		3,659	
Oct.22_sw_run2	-36.4	1.4	-33.91	1.769	2,476	1,535	62	2,476		3,068
								6,270	12,686	9,478
Oct.25_outer	-36.4	5.8	-49.64	0.047	274	230	84	274	274	274
Oct.25_run1	-36.4	1.9	-34.37	1.590	2,941	1,360	46		2,941	
Oct.25_run2	-36.4	1.9	-35.31	1.282	2,372	1,102	46	2,372		2,657
							Subtotal	2,646	3,215	2,931
Overall							Totals	18,493	29,662	24,485
Select maximum for 5 schools and outer area								Total SSB	21,660	

Table 12b. Biomass estimation for the 2006 Little Hope/Port Mouton acoustic surveys calculated with the calibration integration factor (CIF). The shaded boxes represent the biomass estimates summed for the overall SSB based on the 10-14 day time window and evidence for separation in time and location.

Stratum Layer 1	Average TS (dB/kg)	Stratum Area (km2)	Weighted Mean Sa (/m2)	Biomass Density (kg/m2)	Strata Biomass (tons)	Standard Error (tons)	Standard Error (%)	Min	Max	Avg
Oct.7_outer_area	-36.4	8.1	-53.74	0.018	149	76	51	149	149	149
Oct.7_run1	-36.4	4.6	-35.29	1.287	5,919	1,553	26	5,919		
Oct.7_run2	-36.4	4.0	-33.09	2.136	8,542	2,980	35		8,542	7,231
							Subtotal	6,068	8,691	7,380
Oct.17_outer	-36.4	2.2	-49.22	0.052	114	42	37	114	114	114
Oct.17_ne	-36.4	1.0	-50.86	0.036	36	19	53	36	36	36
Oct.17_sw_run1	-36.4	1.1	-36.05	1.082	1,136	472	42		1,136	
Oct.17_sw_run2	-36.4	1.1	-37.66	0.745	783	402	51	783		960
							Subtotal	933	1,286	1,110
Oct.19_outer	-36.4	2.5	-57.10	0.009	21	12	56	21	21	21
Oct.19_ne_run1	-36.4	1.6	-32.39	2.511	4,017	986	25		4,017	
Oct.19_ne_run2	-36.4	1.7	-33.69	1.860	3,069	1,336	44	3,069		3,543
Oct.19_sw_run1	-36.4	1.0	-36.02	1.089	1,089	734	67			
Oct.19_sw_run2	-36.4	1.2	-36.08	1.073	1,288	646	50		1,288	
Oct.19_sw_run3	-36.4	0.5	-35.91	1.117	559	373	67	559		
Oct.19_sw_run4	-36.4	0.5	-34.05	1.714	874	322	37			1,376
							Subtotal	3,649	5,326	4,940
Oct.22_outer	-36.4	6.3	-55.81	0.011	72	21	29	72	72	72
Oct.22_ne_run1	-36.4	2.3	-35.88	1.125	2,531	672	27	2,531		
Oct.22_ne_run2	-36.4	1.5	-29.17	5.270	7,905	2,913	37		7,905	5,218
Oct.22_mid_run1	-36.4	1.1	-33.46	1.963	2,061	1,423	69		2,061	
Oct.22_mid_run2	-36.4	1.0	-34.47	1.553	1,616	1,260	78	1,616		1,839
Oct.22_sw_run1	-36.4	1.7	-32.49	2.451	4,069	1,136	28		4,069	
Oct.22_sw_run2	-36.4	1.4	-33.45	1.967	2,754	1,706	62	2,754		3,412
							Subtotal	6,973	14,107	10,540
Oct.25_outer	-36.4	5.8	-49.18	0.053	305	256	84	305	305	305
Oct.25_run1	-36.4	1.9	-33.91	1.768	3,270	1,512	46		3,270	
Oct.25_run2	-36.4	1.9	-34.85	1.426	2,637	1,226	46	2,637		2,954
							Subtotal	2,942	3,575	3,259
Overall							Totals	20,565	32,985	27,227
Select maximum for 5 schools and outer area								Total SSB	24,086	

Table 13. Summary of the 2006 Halifax/Eastern Shore acoustic surveys with biomass results calculated both without the calibration integration factor (CIF) and with the CIF.

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 %
Eastern Shore	26-Sep-06	300	-36.4	3.1	-28.6	6.037	18,652	7,524	40%
	1-Oct-06	300	-36.4	168.9	-44.2	0.165	27,800	4,504	16%
	15-Oct-06	293	-36.2	1.1	-29.8	4.306	4,612	1,466	32%
Eastern Shore total							51,064	8,890	17%

b - with integration factor (as calculated since 2003)

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 %
Eastern Shore	26-Sep-06	300	-36.4	3.1	-27.3	8.124	25,108	10,149	40%
	1-Oct-06	300	-36.4	168.9	-42.9	0.223	37,703	6,051	16%
	15-Oct-06	293	-36.2	1.1	-28.6	5.711	6,117	1,944	32%
Eastern Shore total							68,927	11,975	17%

Table 14. Summary of landings (t) and acoustic survey biomass (t) for the Nova Scotia coastal spawning component spawning areas from 1996 to 2006. Acoustic survey estimates of SSB are rounded to the nearest 100t.

a - Landings by spawning area along coastal Nova Scotia with 5 year and overall averages

Landings (t)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	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	3,133	3,029	2,467
Halifax/Eastern Shore	1,280	1,520	1,100	1,628	1,350	1,898	3,334	2,727	4,176	3,446	3,348	3,406	2,346
Glace Bay		170	1,730	1,040	834	1,204	3,058	1,905	1,481	626	85	1,431	1,213
Bras d'Or Lakes	170	160	120	31	56	0	1	4	0	0	0	1	49
Total	1,450	2,340	4,120	5,618	4,283	6,006	10,375	9,162	6,924	6,311	6,566	7,868	5,741

b - Acoustic survey biomass by spawning area along coastal Nova Scotia with 5 year and overall averages (without CIF)

Survey SSB (t) w/o CIF	1998	1999	2000	2001	2002	2003	2004	2005	2006	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	21,700	3,906	2,797
Halifax/Eastern Shore	8,300	20,200	**10,900**	16,700	**41,500**	67,602	18,200	28,100	51,100	4,130	2,918
Glace Bay		2,000		21,200	7,700	31,500		2,200	n/s	1,380	1,292
Bras d'Or Lakes		530	70	n/s	n/s	n/s	n/s	n/s	n/s	n/s	30

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

c - Acoustic survey biomass by spawning area along coastal Nova Scotia with recent 4 year average (with CIF since 2003)

Survey SSB (t) with CIF	1998	1999	2000	2001	2002	2003	2004	2005	2006	10% SSB Average Last 4 yr	10% SSB Average All years
Little Hope/Port Mouton						**53,100**	22,500	44,700	24,100	3,610	3,610
Halifax/Eastern Shore						92,600	28,400	36,950	68,900	5,671	5,671
Glace Bay						31,500		3,180	n/s	1,734	1,734
Bras d'Or Lakes						n/s	n/s	n/s	n/s	n/s	n/a

Note 1: shaded cells include mapping surveys; bold cells include mapping and acoustic surveys.

Note 2: data prior to 2003 calculated with the Calibration Integration Factor (CIF) are not available.

Table 15. Summary by day of Strathaven acoustic data with number of hours of recording, distance traveled, average backscatter (Sa) and average density along combined daily transects.

Date	Transect	Transect Time (hours)	Transect Length (km)	Average Sa (/m2)	Biomass Density (kg/m2)	Biomass Tonnes per km2
1-Jul-06	S216500H	2.3	38.5	-52.028	0.0247	24.7
3-Aug-06	S216510H	8.0	140.6	-47.027	0.0782	78.2
12-Sep-06	S216520H	5.9	108.6	-50.243	0.0373	37.3
13-Sep-06	S216530H	3.6	65.8	-44.764	0.1317	131.7
19-Sep-06	S216540H	10.8	73.8	-55.623	0.0108	10.8
20-Sep-06	S216550H	7.0	126.3	-46.541	0.0875	87.5
21-Sep-06	S216560H	4.3	75.1	-49.688	0.0424	42.4
Totals		41.8	628.6			
Average (distance weighted)				-47.957	0.0631	63.1

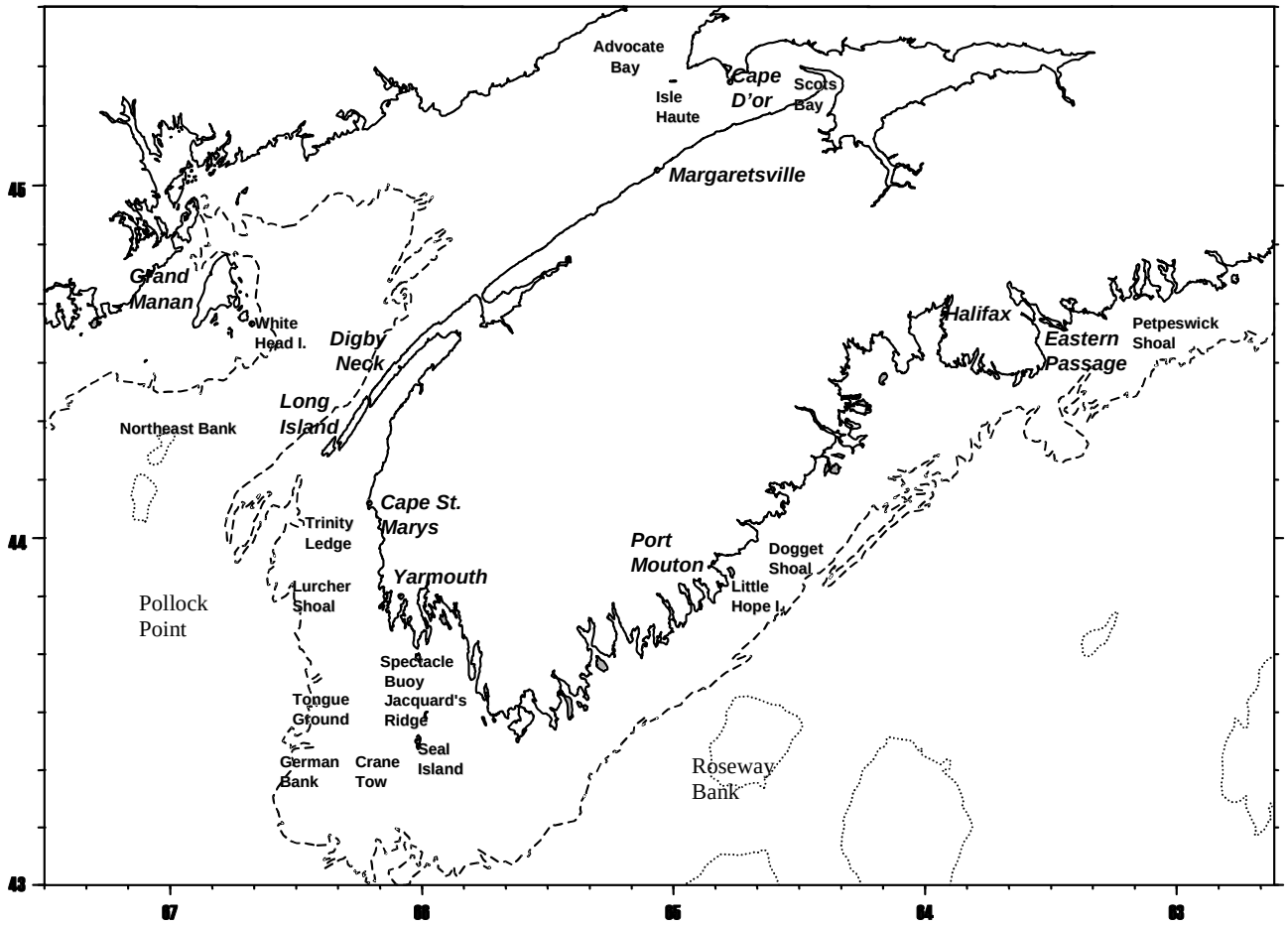

Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

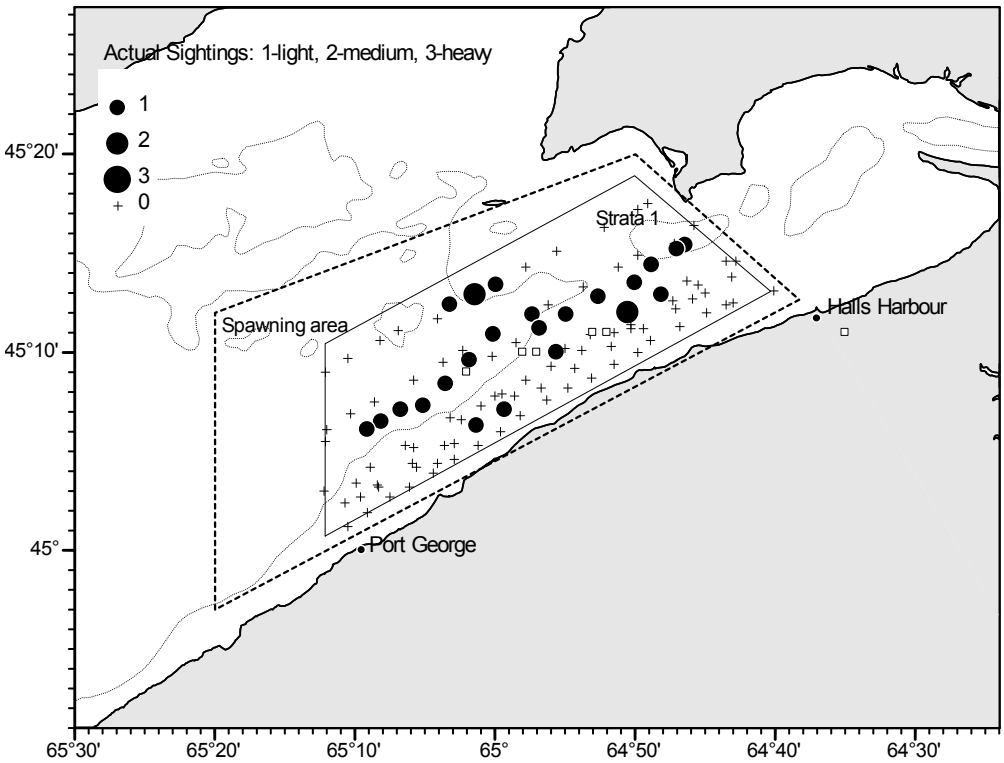

Figure 2. Survey deck sheet observations from herring acoustic survey in Scots Bay on July 22, 2006.

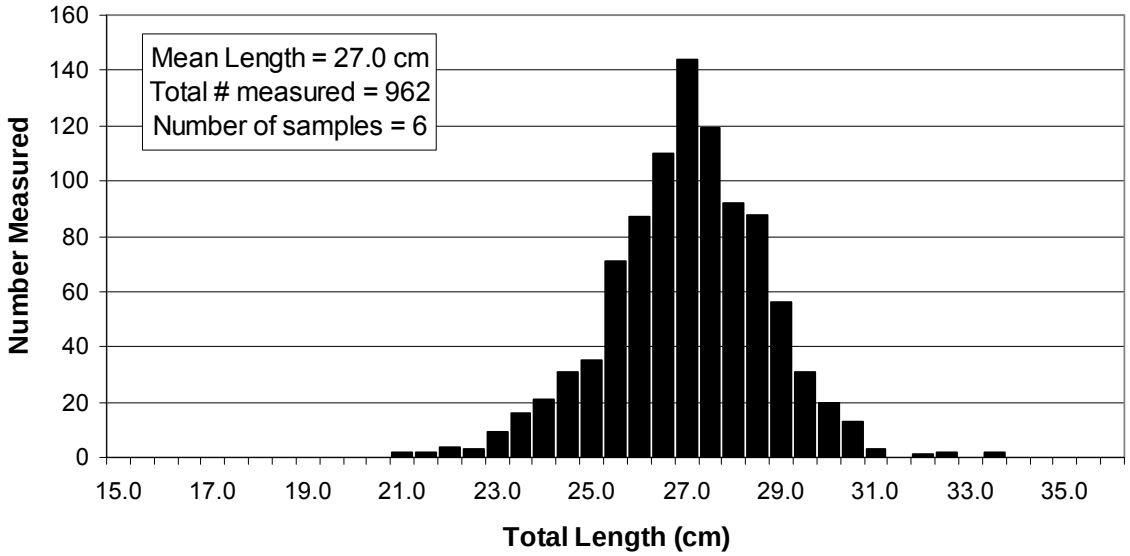

Figure 3. Length distribution for Scots Bay herring samples collected from landings on July 23-24, 2006.

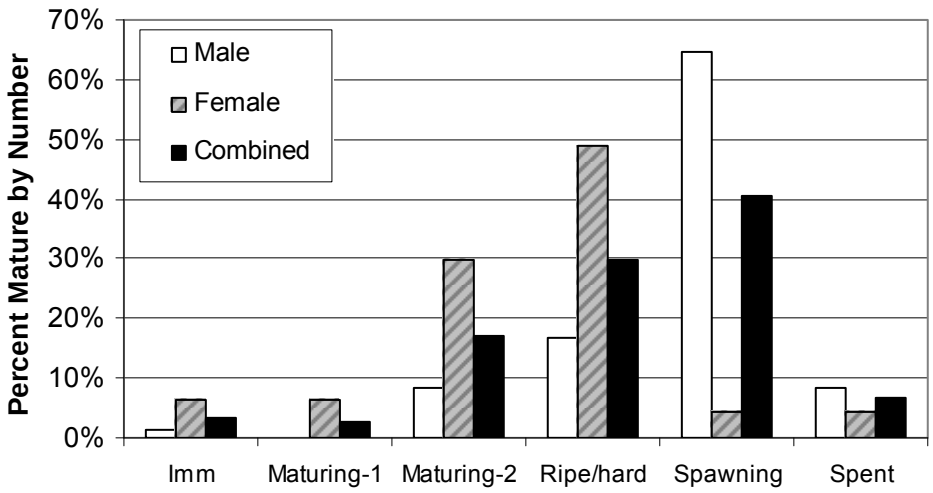

Figure 4. Herring maturity stages for Scots Bay herring samples collected from landings on July 23-24, 2006.

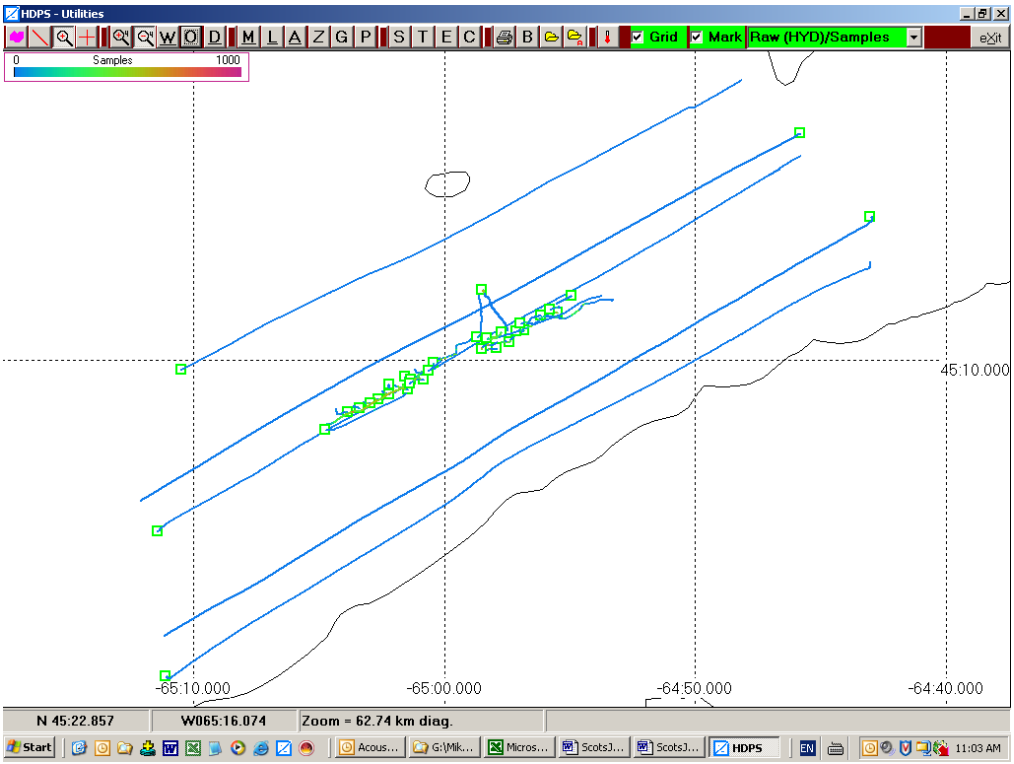

Figure 5. Scots Bay survey on July 22-23, 2006 with survey lines and lines for fish schools outside the random survey transects.

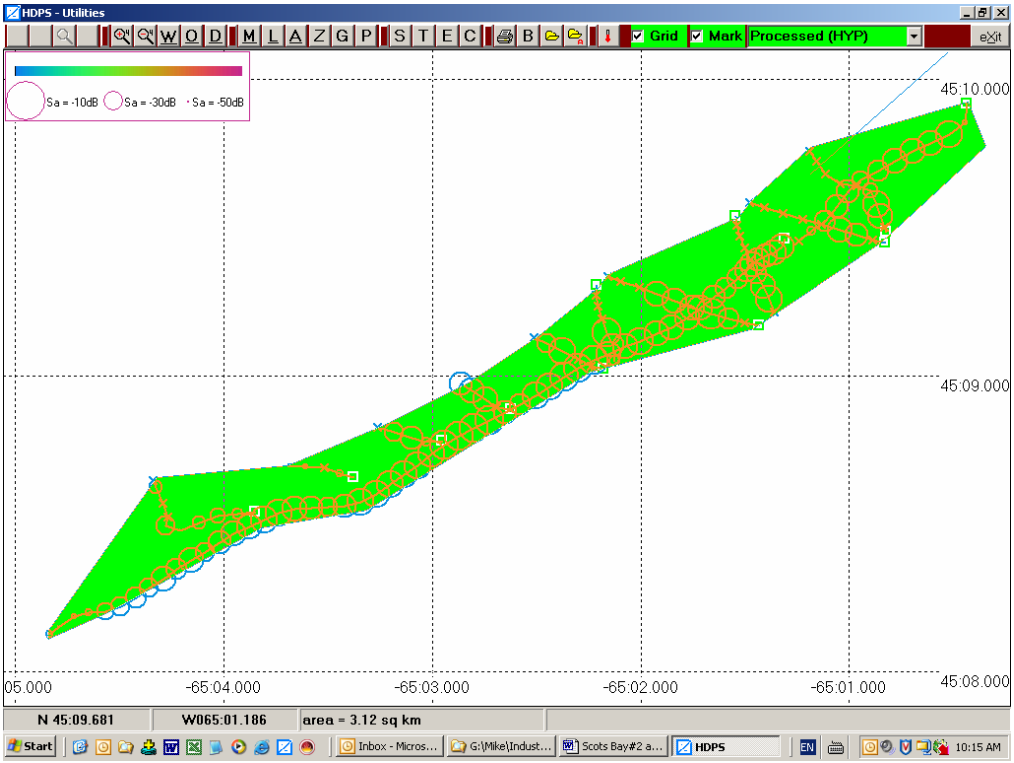

Figure 6. Scots Bay survey on July 22, 2006 for western school with area estimate of 3.1 km^2.

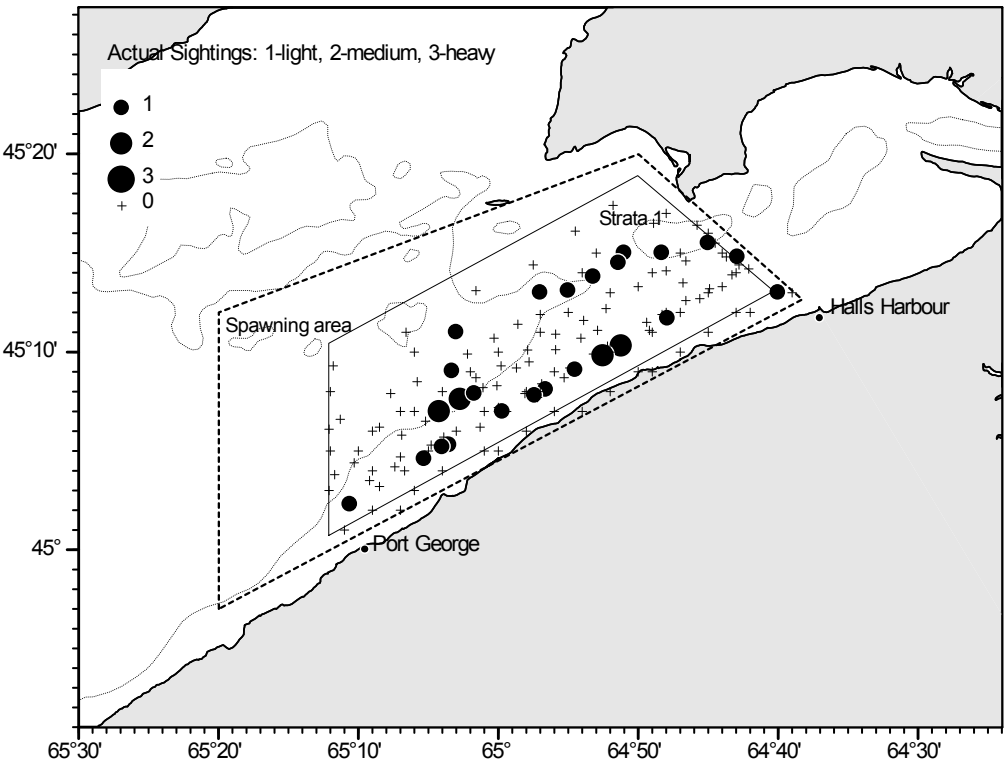

Figure 7. Survey deck sheet observations from the herring acoustic survey in Scots Bay on Aug. 6-7, 2006.

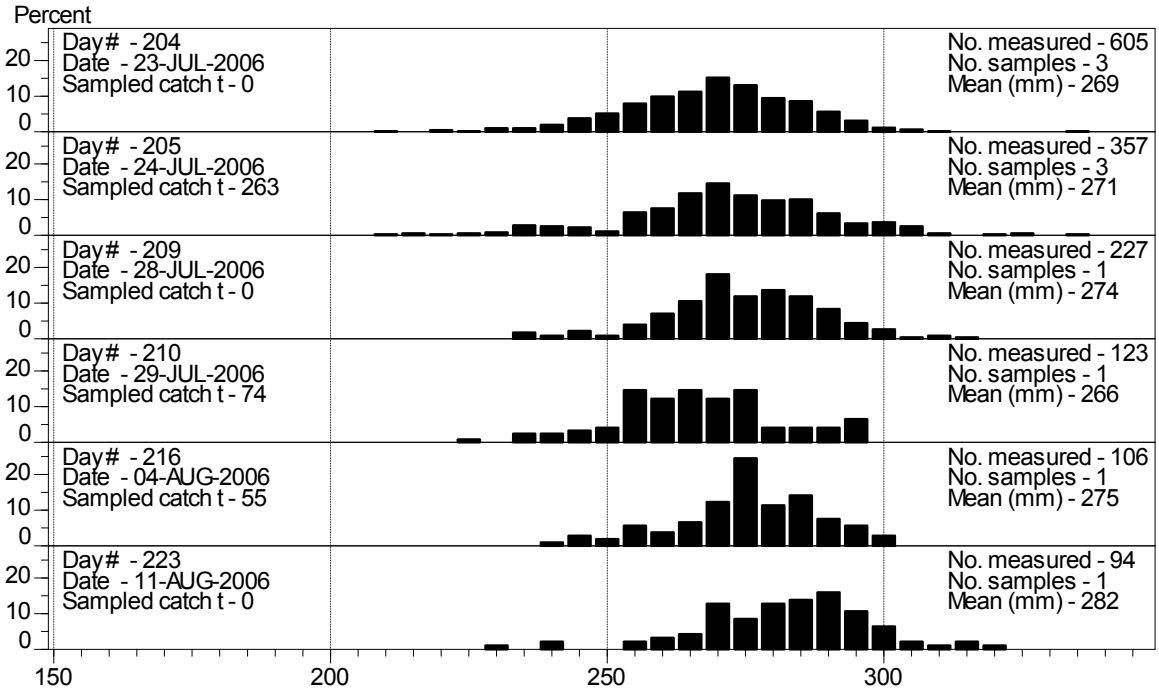

Figure 8. Length distribution for Scots Bay herring samples collected from landings for July 23 to Aug. 11, 2006.

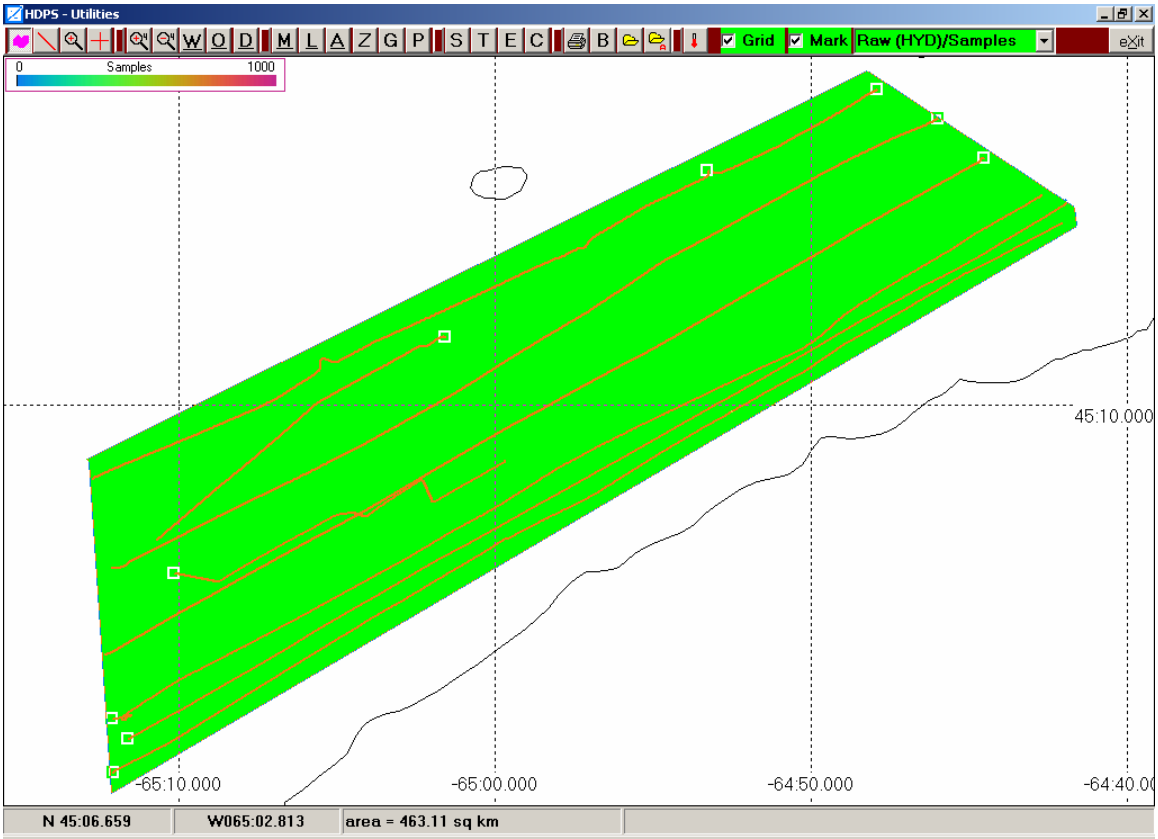

Figure 9. Random survey lines and additional post-survey lines for herring acoustic survey in Scots Bay on Aug. 6-7, 2006 with area estimation of 460 km^2.

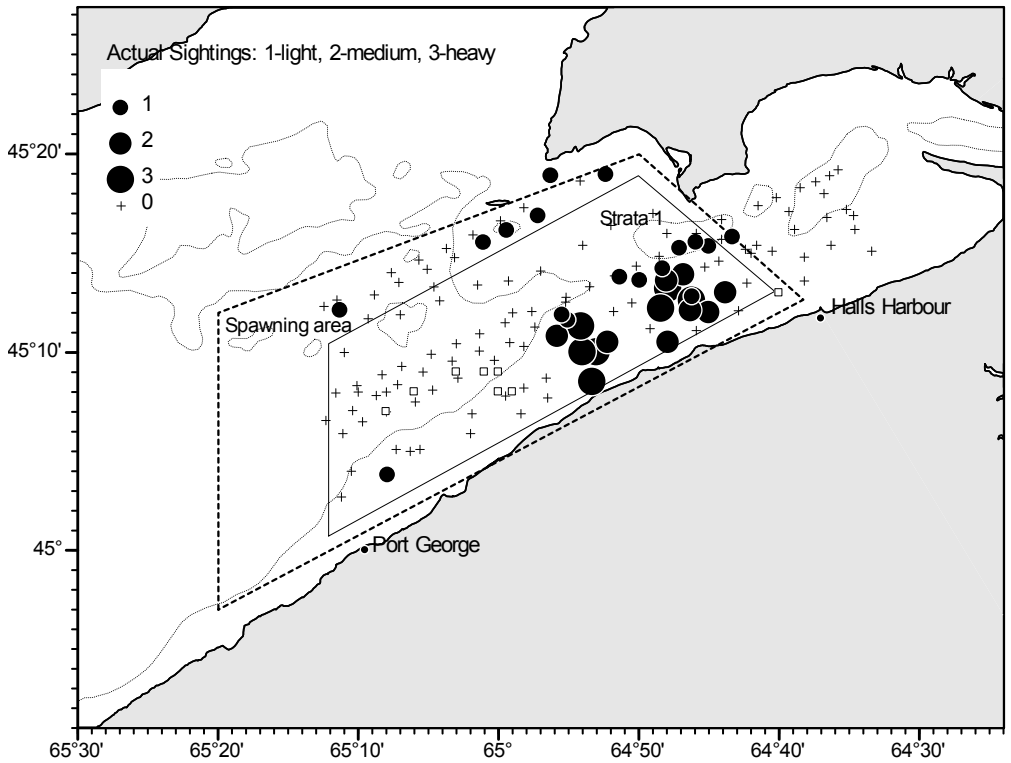

Figure 10. Survey deck sheet observations from herring acoustic survey in Scots Bay on Aug. 19, 2006.

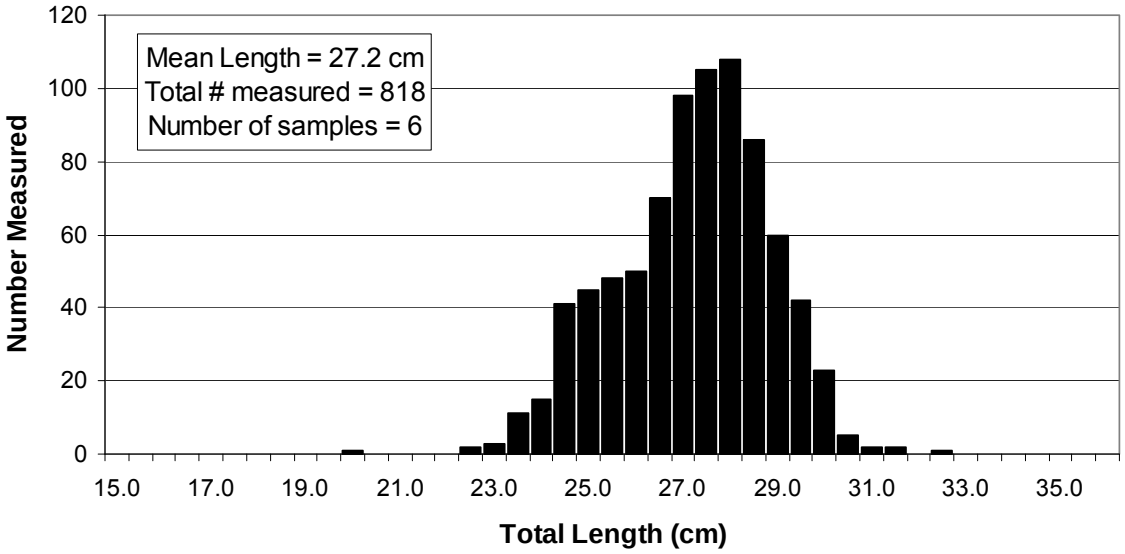

Figure 11. Combined length distribution for Scots Bay herring samples collected from landings on Aug. 20 to Aug. 21, 2006 used for calculation of target strength.

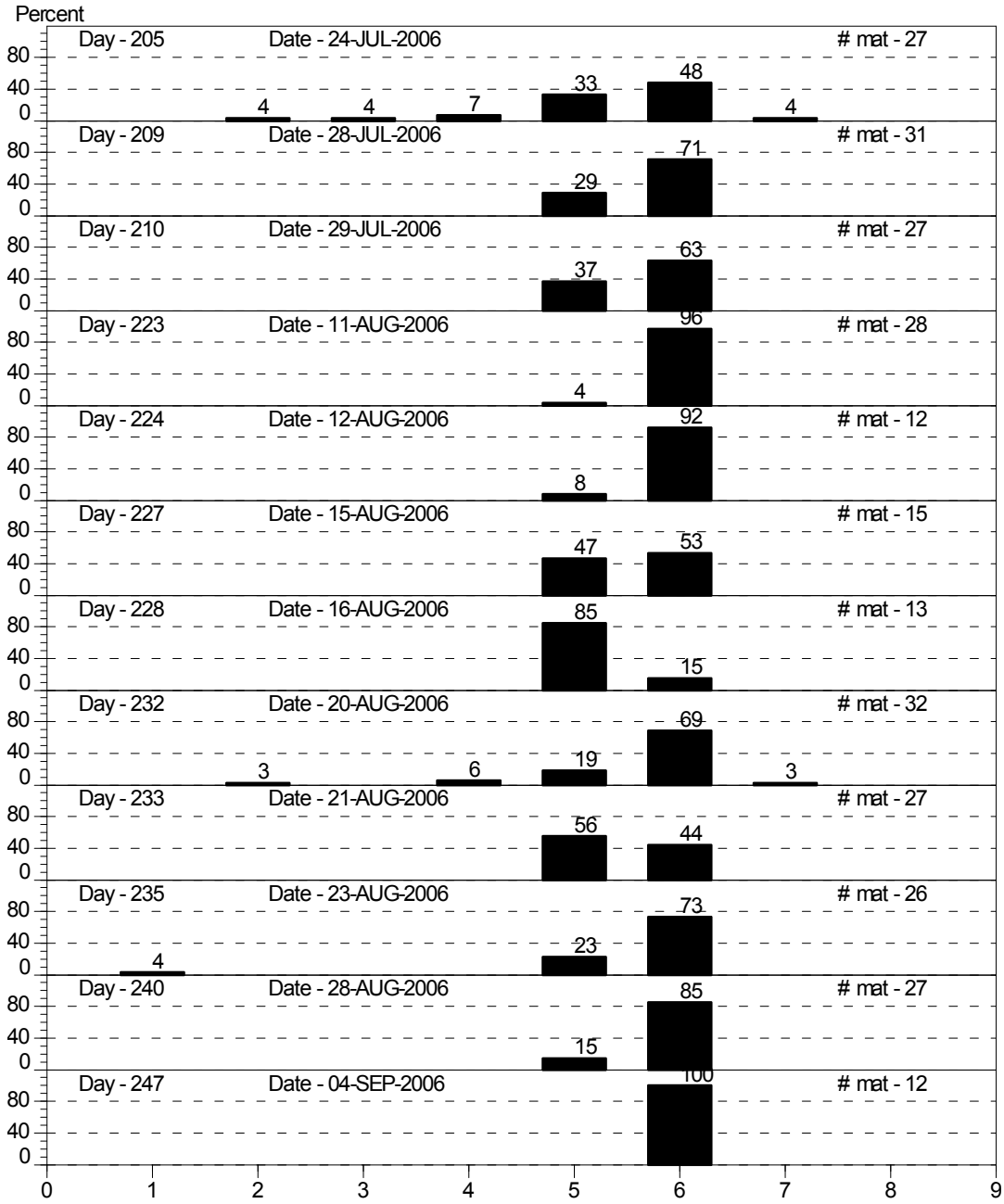

Figure 12. Daily herring maturity samples as processed by SABS by maturity stage for Scots Bay herring collected from landings for July 24 to Sept. 4, 2006. (Stage codes are 1-2=immature, 3-4=developing, 5=hard, 6=spawning, 7=spent, 8=recovering).

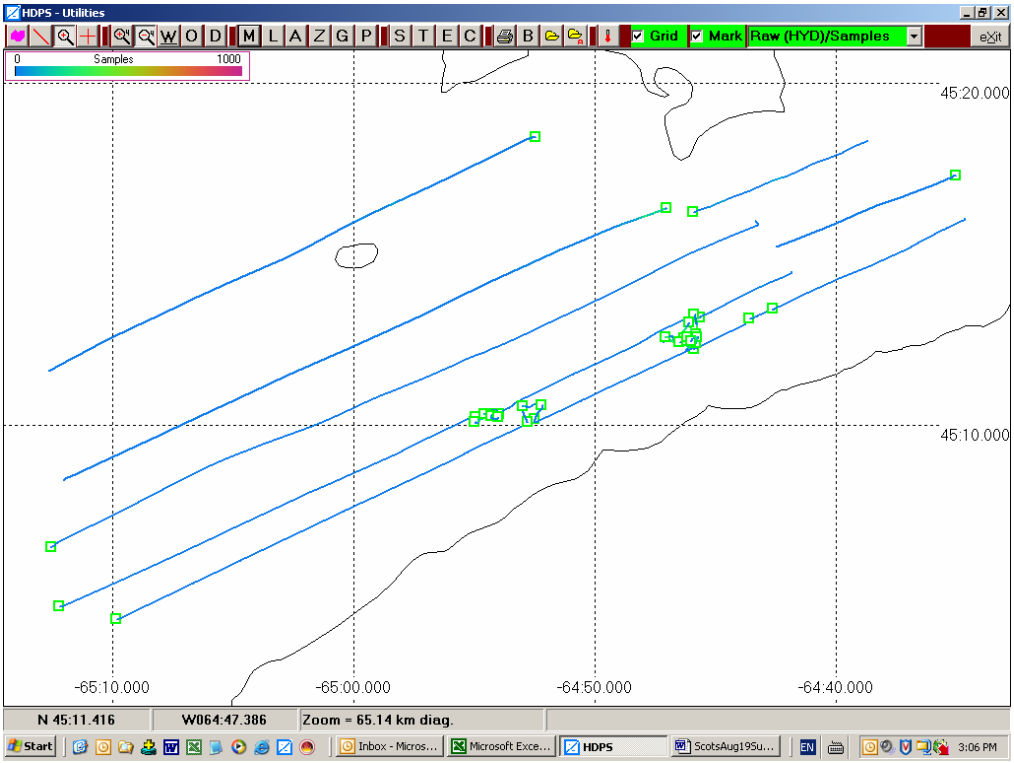

Figure 13. Random survey lines and additional school transects between lines for herring acoustic survey in Scots Bay on Aug. 19-20, 2006.

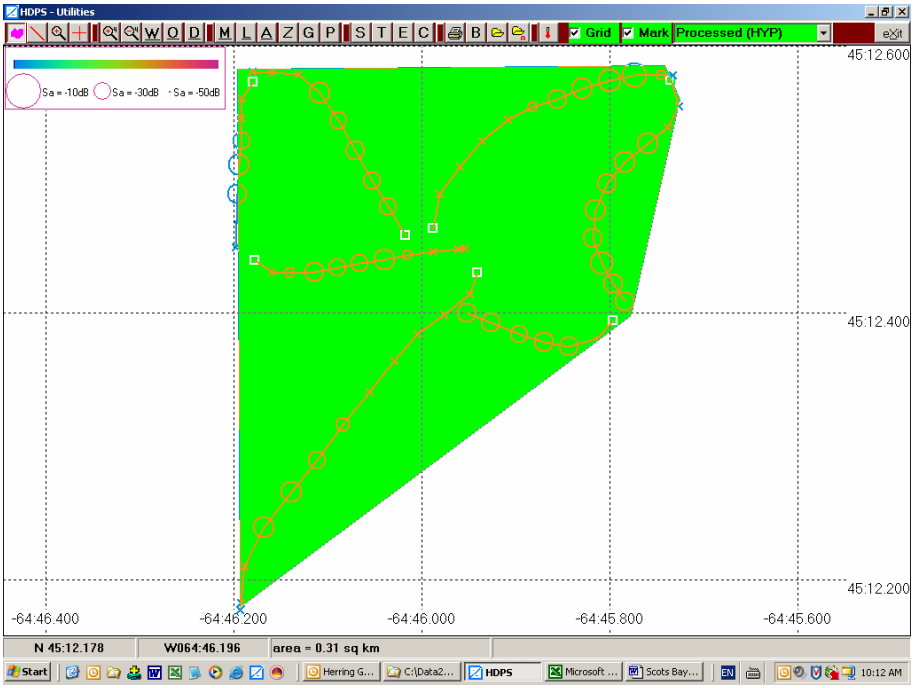

Figure 14. Scots Bay survey lines by *Margaret Elizabeth* on Aug. 19, 2006 for fish school #2 as completed after the survey between the random survey transects.

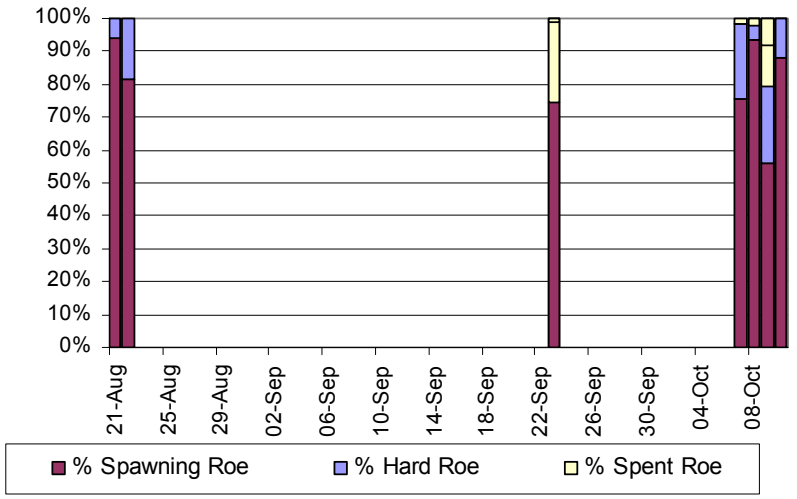

Figure 15. Daily female roe maturity samples (% roe weight) for German Bank in 2006 from industry supplied data reports.

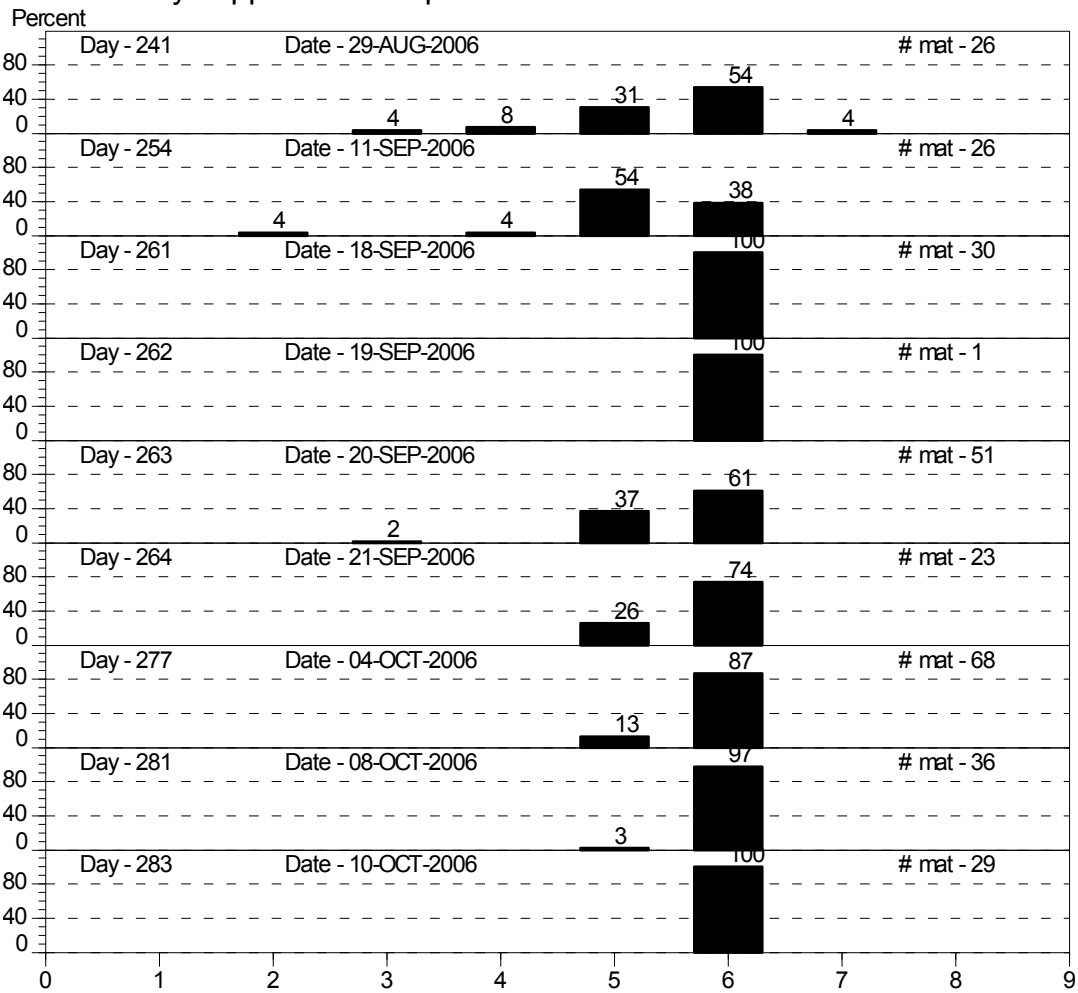

Figure 16. Daily herring maturity samples as processed by SABS by maturity stage for 2006 German Bank landings from August to October within the Strata box area. (Stage codes are 1-2=immature, 3-4=developing, 5=hard, 6=spawning, 7=spent, 8=recovering)

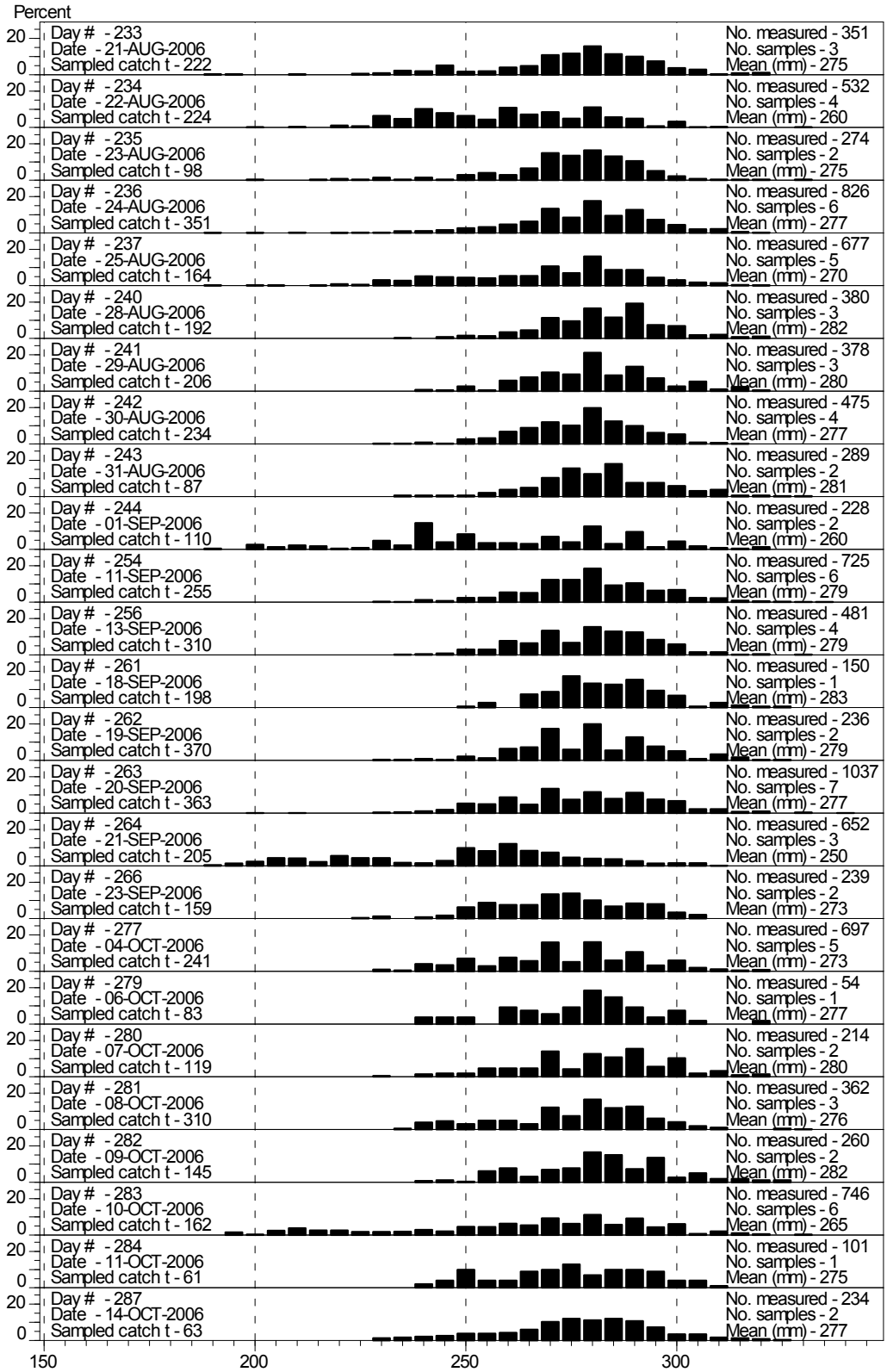

Figure 17. Combined daily length frequency samples from within the German Bank survey box (Strata) area from Aug. 20 to Oct.15, 2006 with sampled catch, number measured, number of samples and mean length (mm).

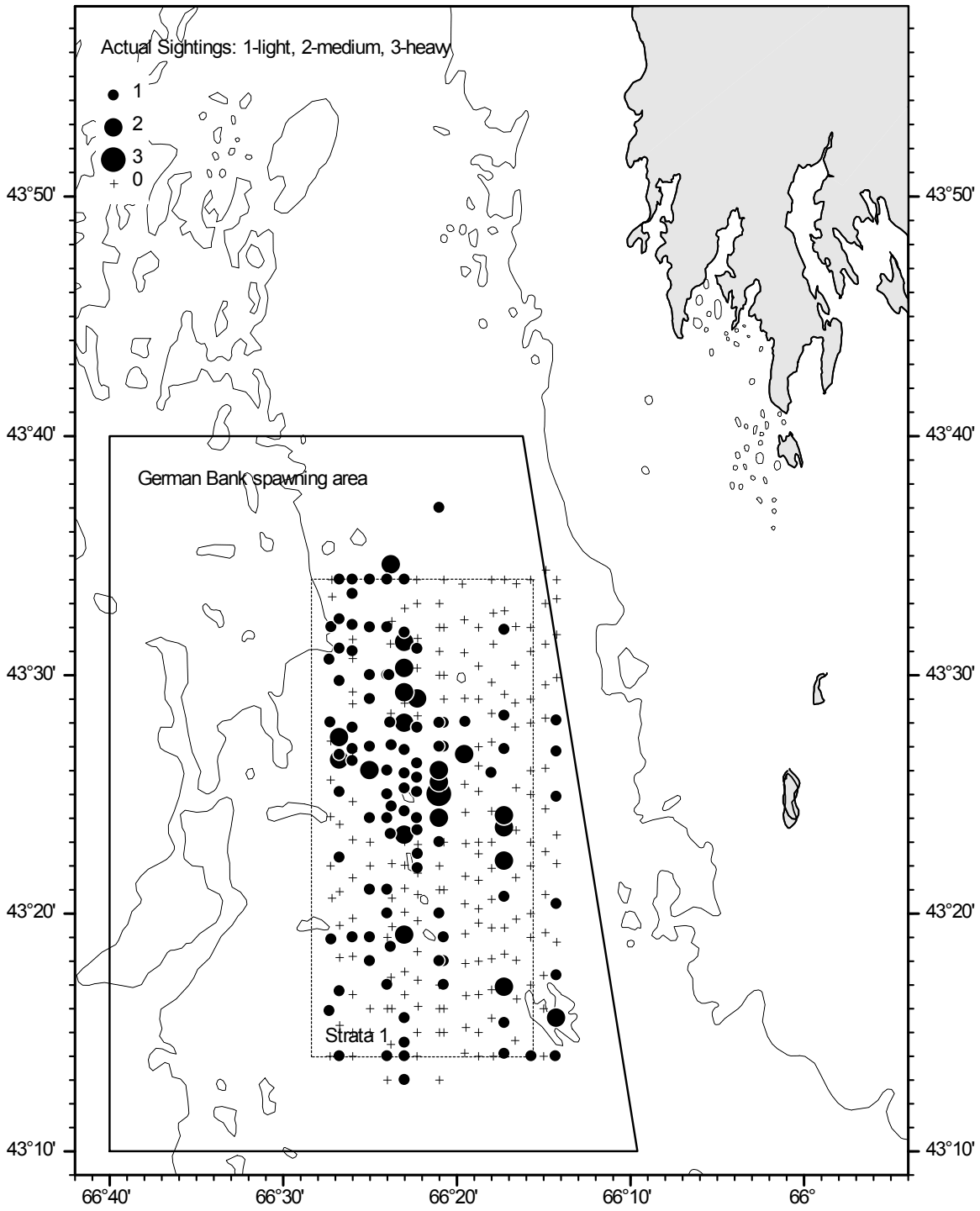

Figure 18. German Bank herring survey deck sheet observations for Aug. 25, 2006 with overall defined spawning area (solid line, outer box) and standard survey area or Strata 1 (dashed line, inner box).

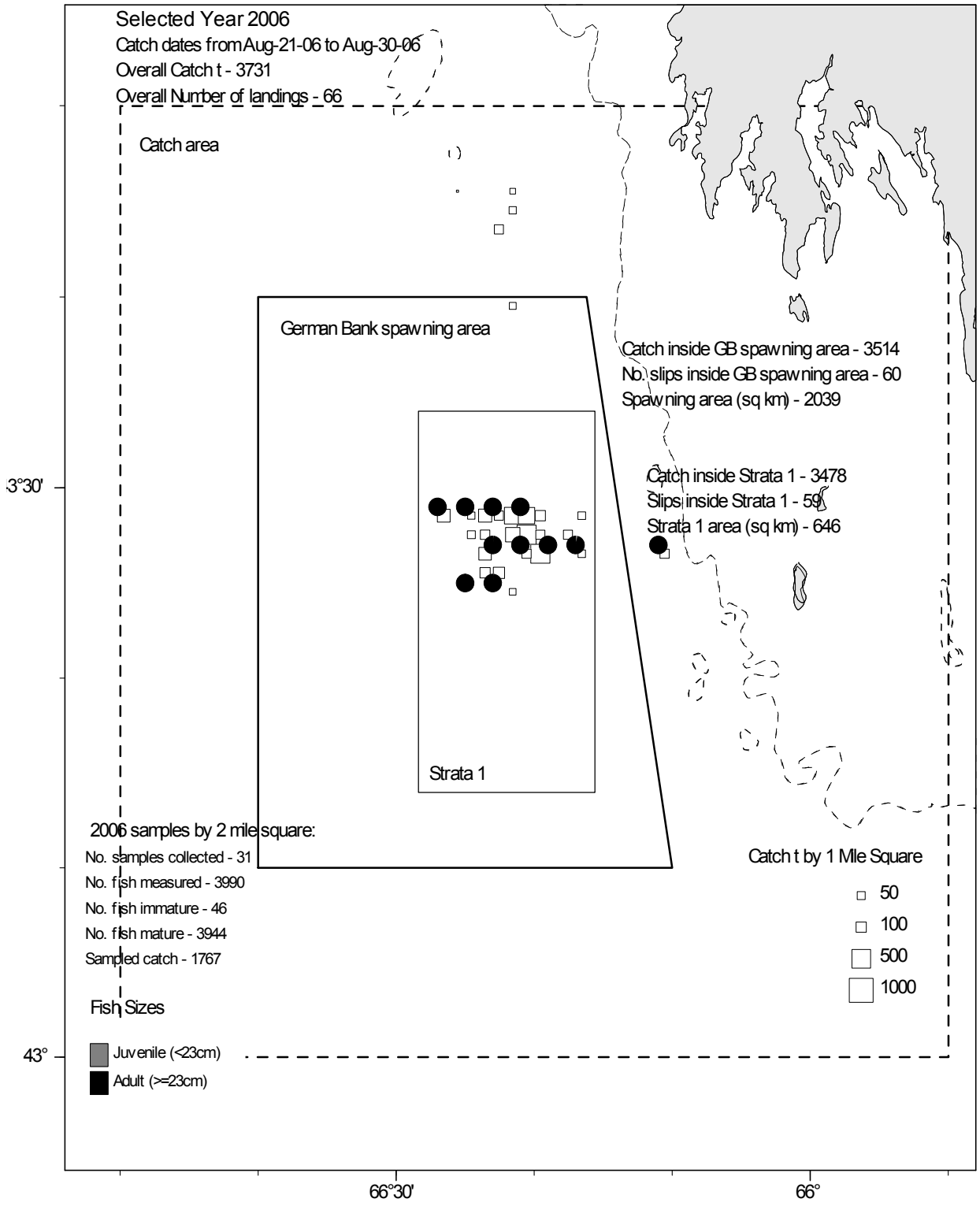

Figure 19. German Bank herring catches and samples for the period from Aug. 21 to Aug. 30, 2006 (5 day window around survey). Open rectangles represent catches by 1 mile aggregation and shaded circles show sampling by size with pies showing adult (>=23cm) in black and juvenile (<23cm) in grey.

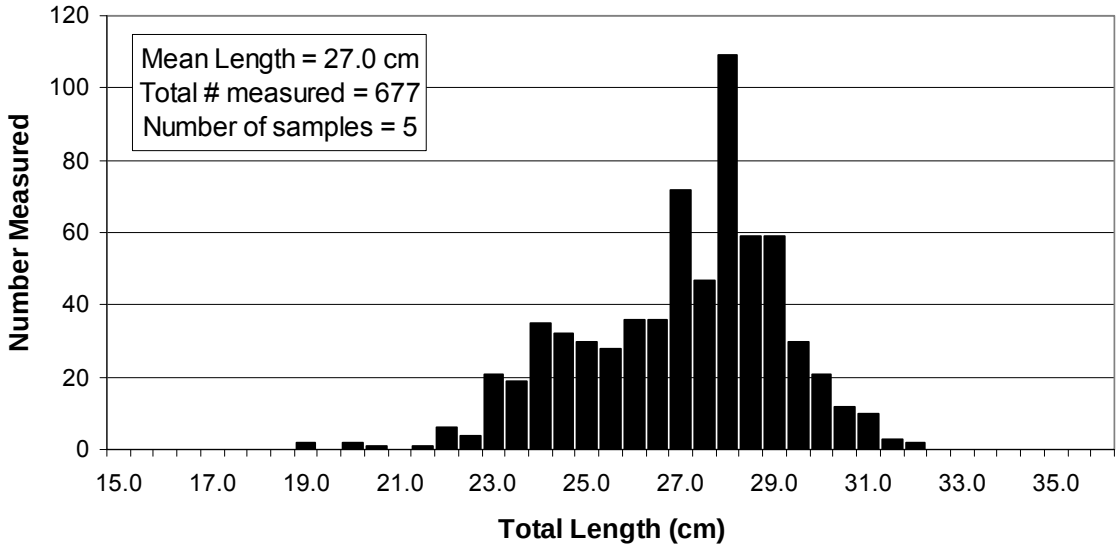

Figure 20. Length sample frequency distribution from German Bank for Aug. 25, 2006 used in the calculation of target strength (TS).

Figure 21. Acoustic transects showing total backscatter (Sa) and estimated area of 645 km^2 for German Bank survey on Aug. 25, 2006. The single eastern transect outside the standard survey box area was calculated separately from the remainder.

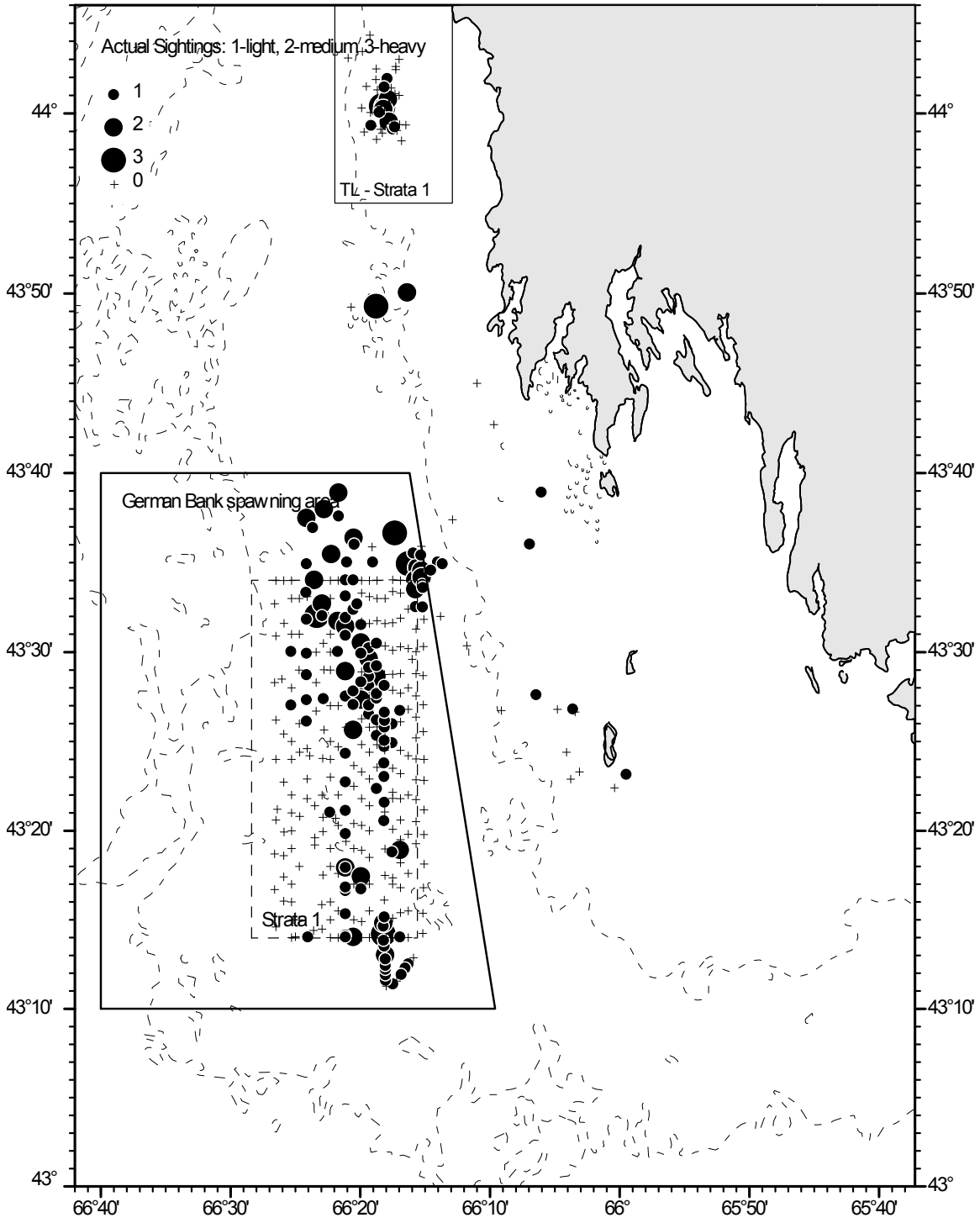

Figure 22. Herring survey deck sheet observations for Sept. 15, 2006 within the defined spawning area (solid line, outer box) and the standard survey area or Strata 1 (dashed line, inner box).

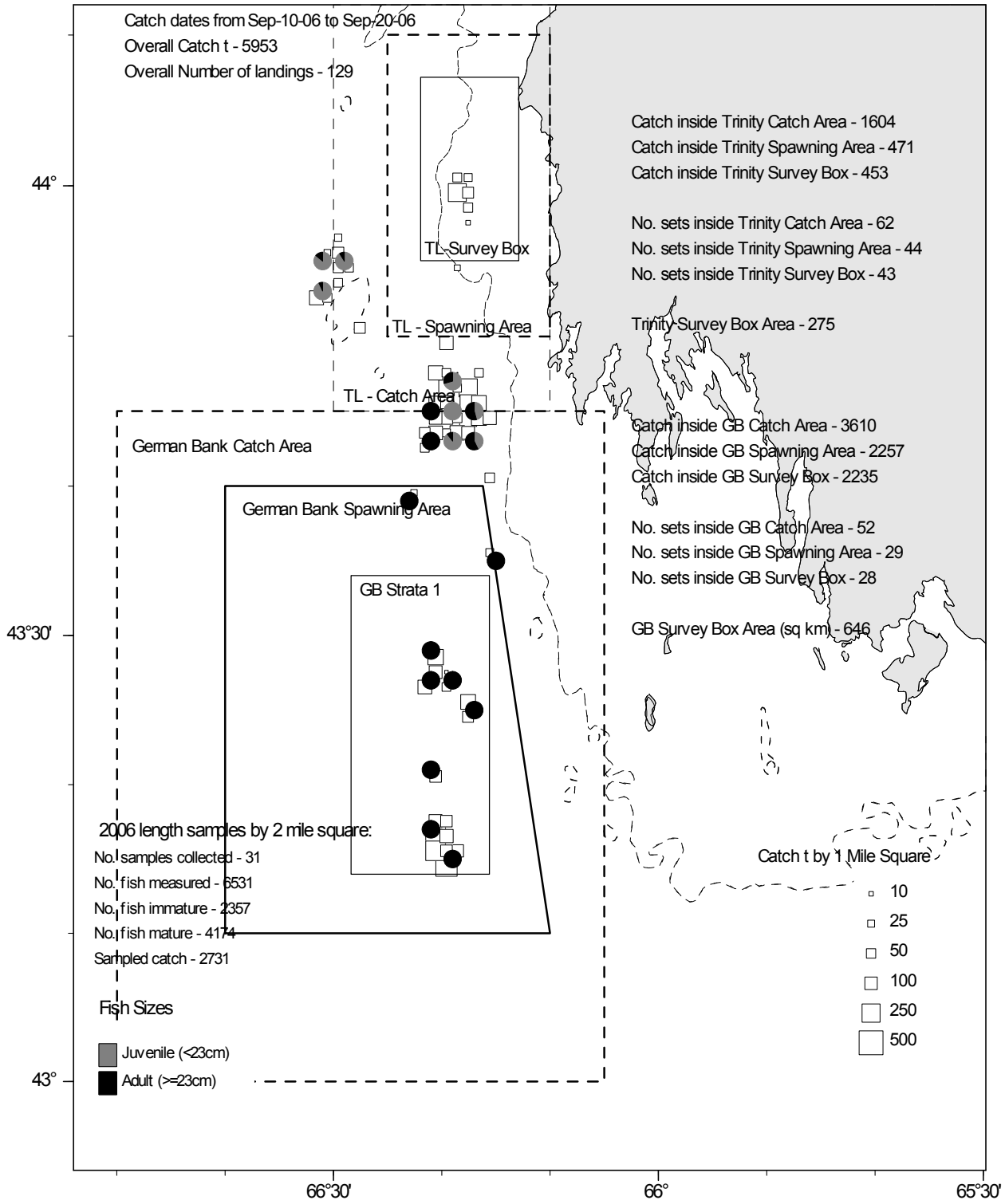

Figure 23. German Bank and Trinity Ledge area herring catches and length samples from all gear types for the period from Sept. 10 to Sept. 20, 2006 (5 day window around survey). Open rectangles represent catches by 1 mile aggregation and colored circles show length sampling by size with pies showing adult (>=23cm) in black and juvenile (<23cm) in grey.

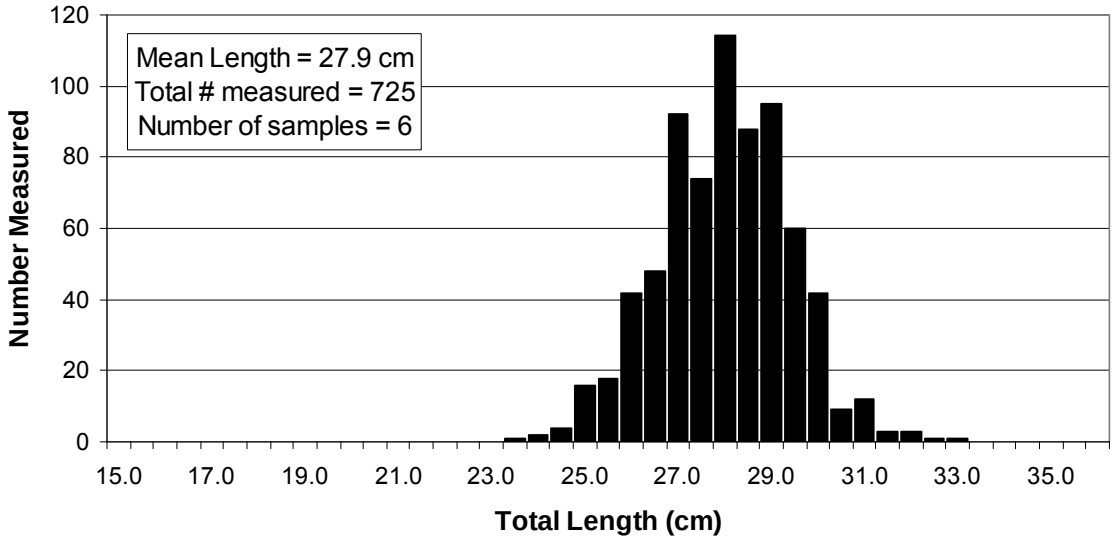

Figure 24. Length frequency distribution from samples within German Bank survey box collected on Sept. 13 and Sept. 18, 2006 and used in the calculation of target strength (TS).

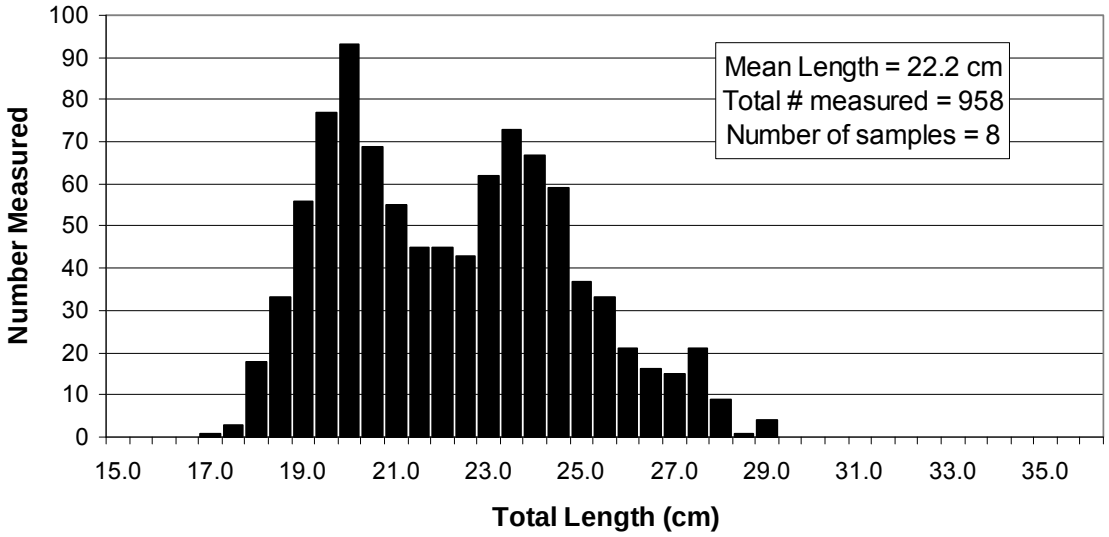

Figure 25. Length frequency distribution from samples located outside of German Bank survey box from Sept. 14-15, 2006 and used for calculation of target strength with the grouping GB#2-outbox-north.

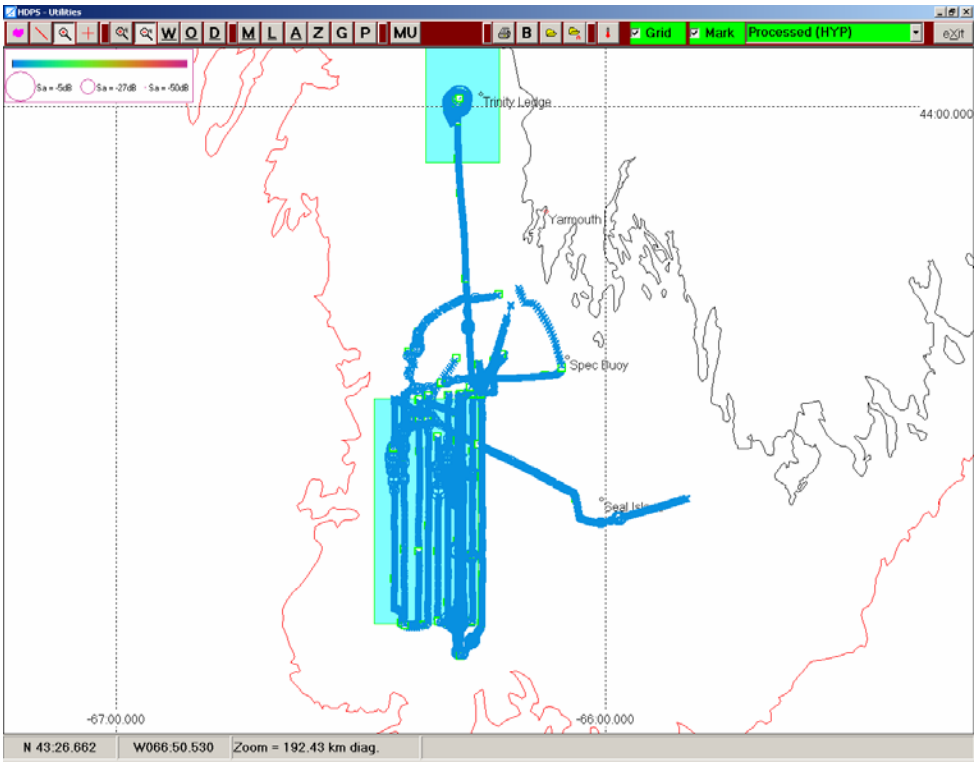

Figure 26. Acoustic lines showing total backscatter (Sa) and survey box areas for all lines completed during survey on Sept. 15, 2006.

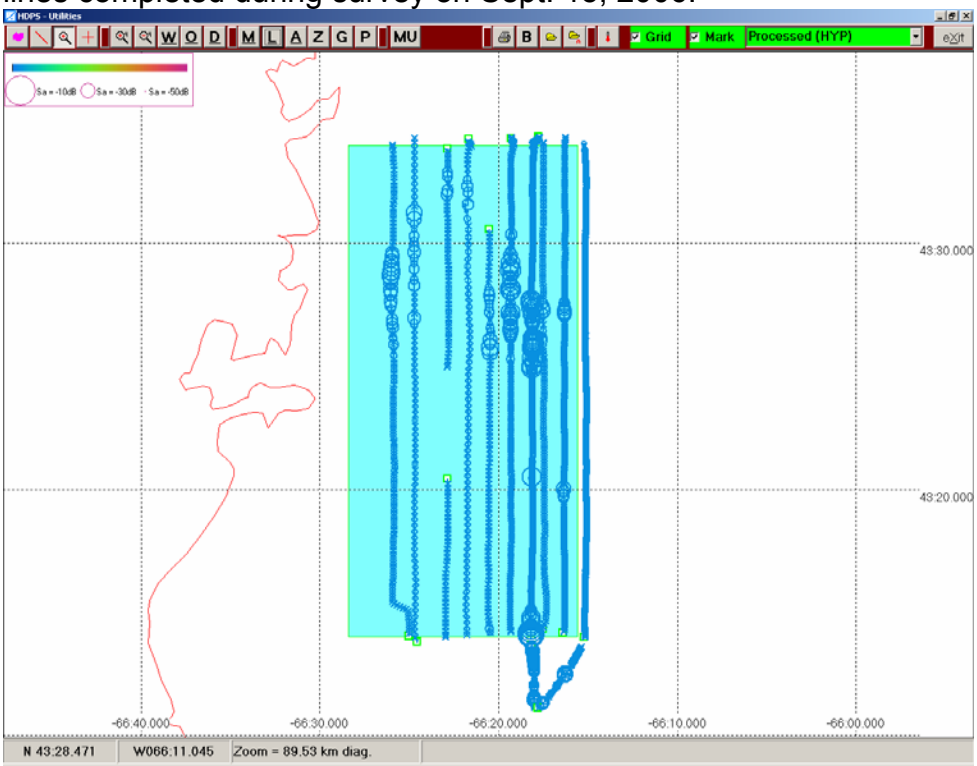

Figure 27. Acoustic transects showing total backscatter (Sa) and survey box area of 646 km^2 for German Bank survey on Sept. 15, 2006. Lines south and east of the survey box area were calculated separately from the remainder.

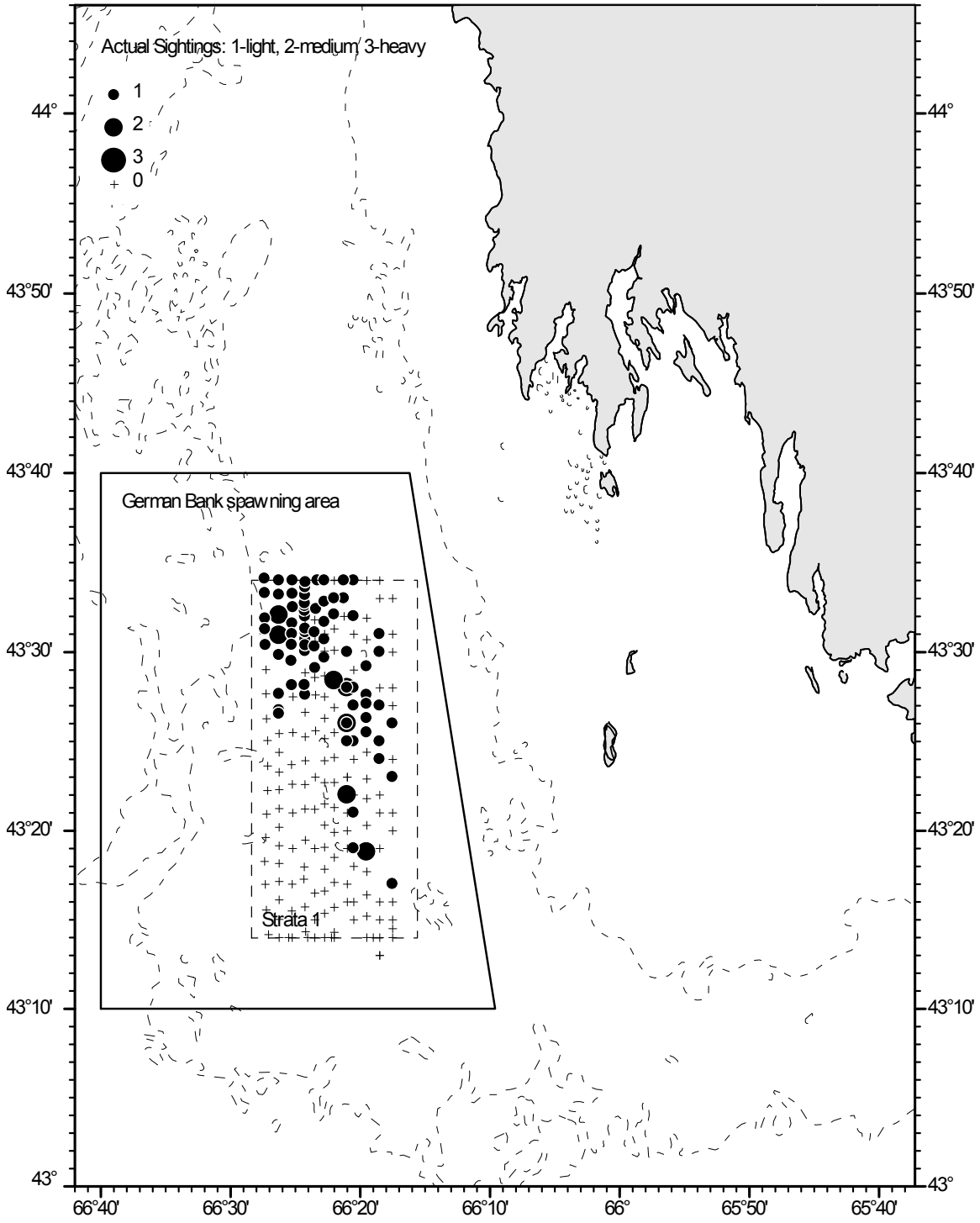

Figure 28. Herring survey deck sheet observations for Oct. 1, 2006 within the defined German Bank spawning area (solid line, outer box) and the standard survey area or Strata 1 (dashed line, inner box).

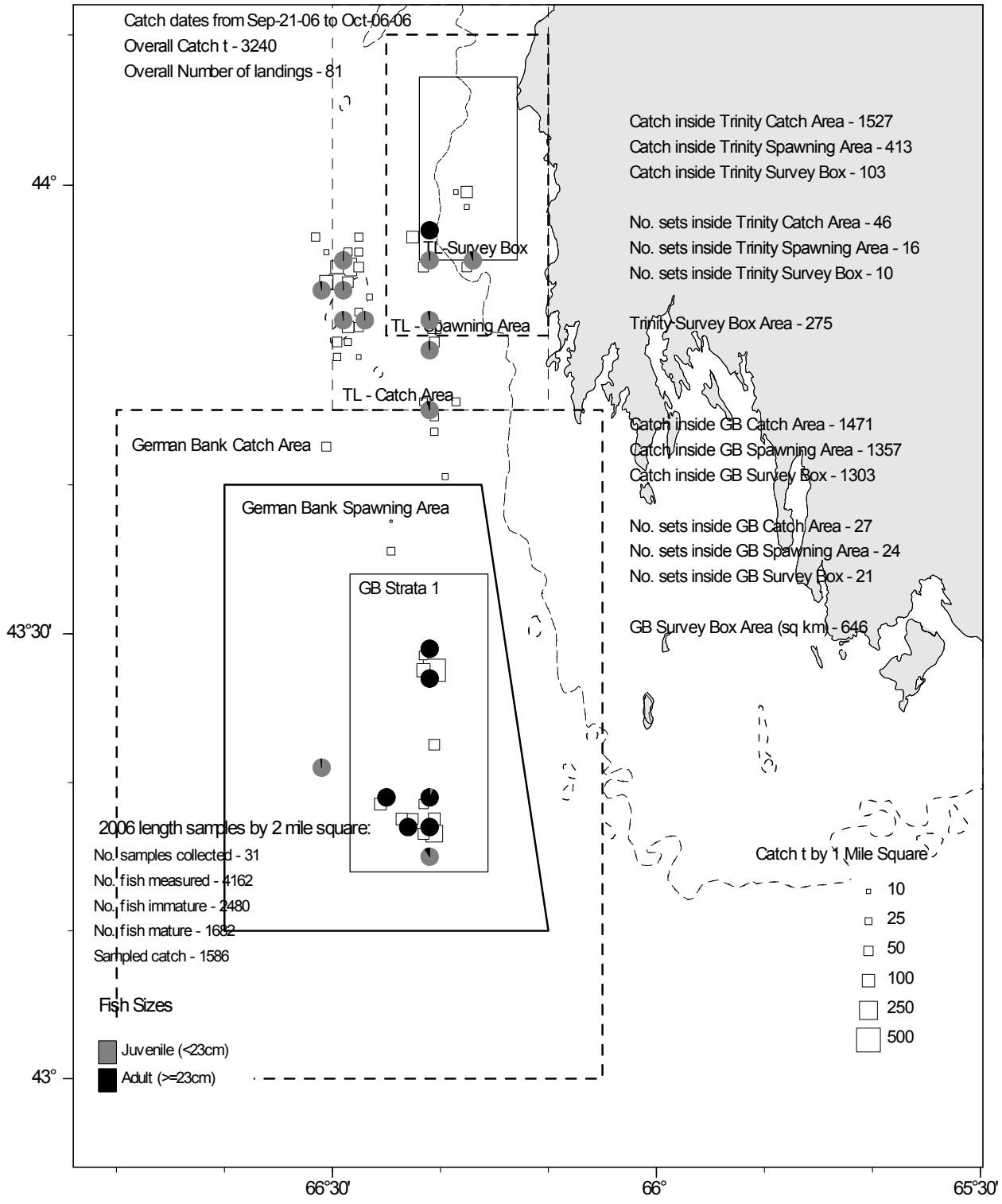

Figure 29. German Bank and Trinity Ledge area herring catches and length samples from all gear types for the period from Sept. 21 to Oct. 6. Open rectangles represent catches by 1 mile aggregation and colored circles show length sampling by size with pies showing the proportion of adult (>=23cm) in black and juvenile (<23cm) in grey.

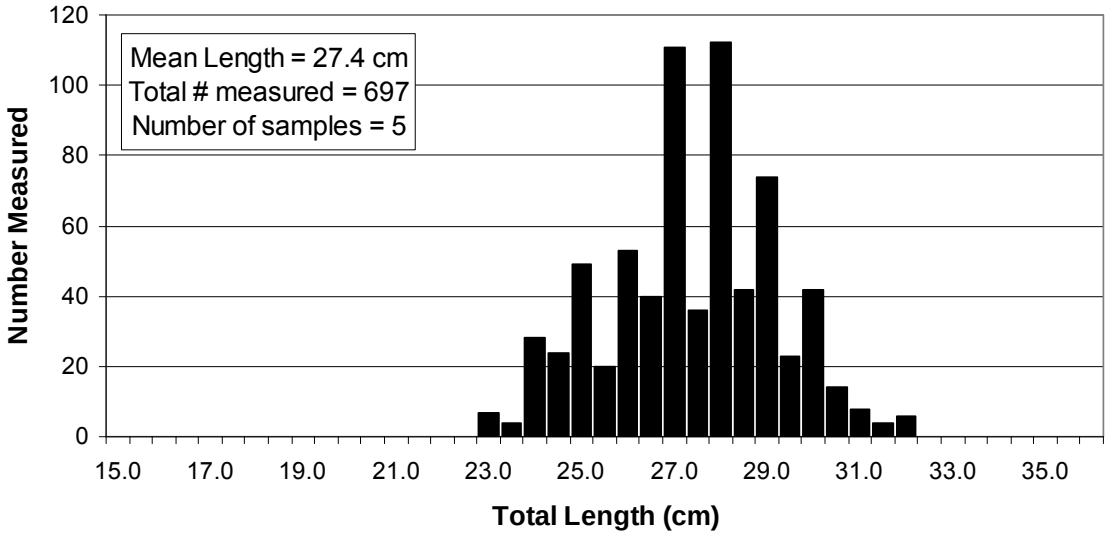

Figure 30. Length frequency distribution from samples within German Bank survey box collected on Oct. 4, 2006 and used in the calculation of target strength (TS).

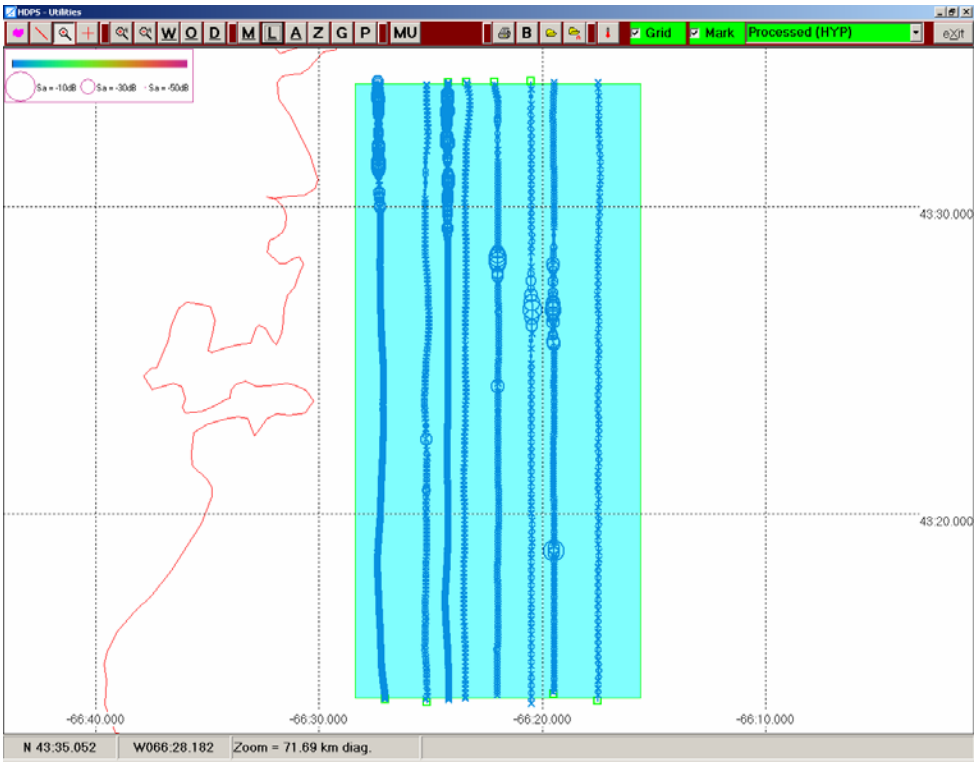

Figure 31. Acoustic transects showing total backscatter (Sa) and survey box area of 646 km^2 for German Bank survey on Oct. 1, 2006..

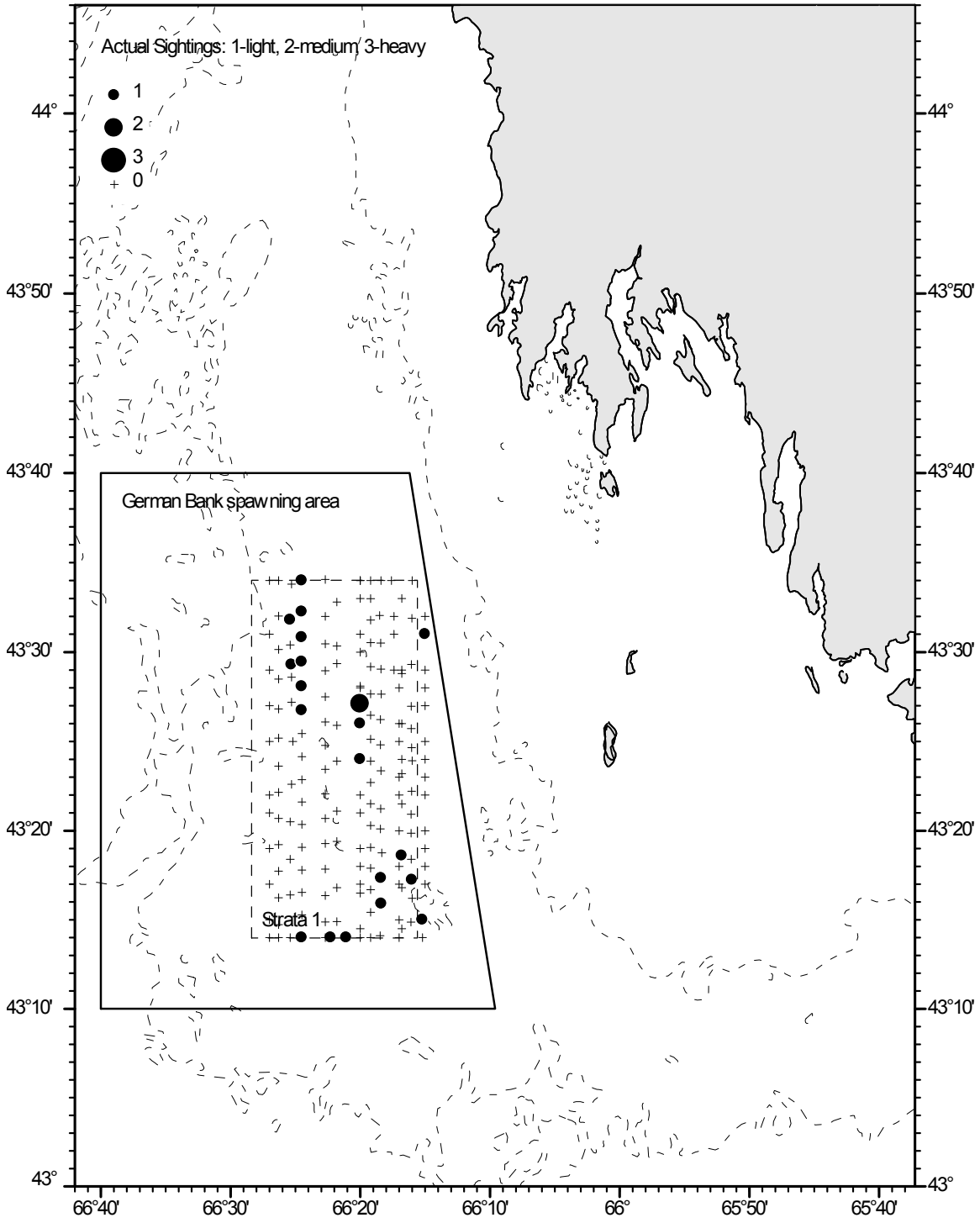

Figure 32. Herring survey deck sheet observations for Oct. 15, 2006 within the defined German Bank spawning area (solid line, outer box) and the standard survey area or Strata 1 (dashed line, inner box).

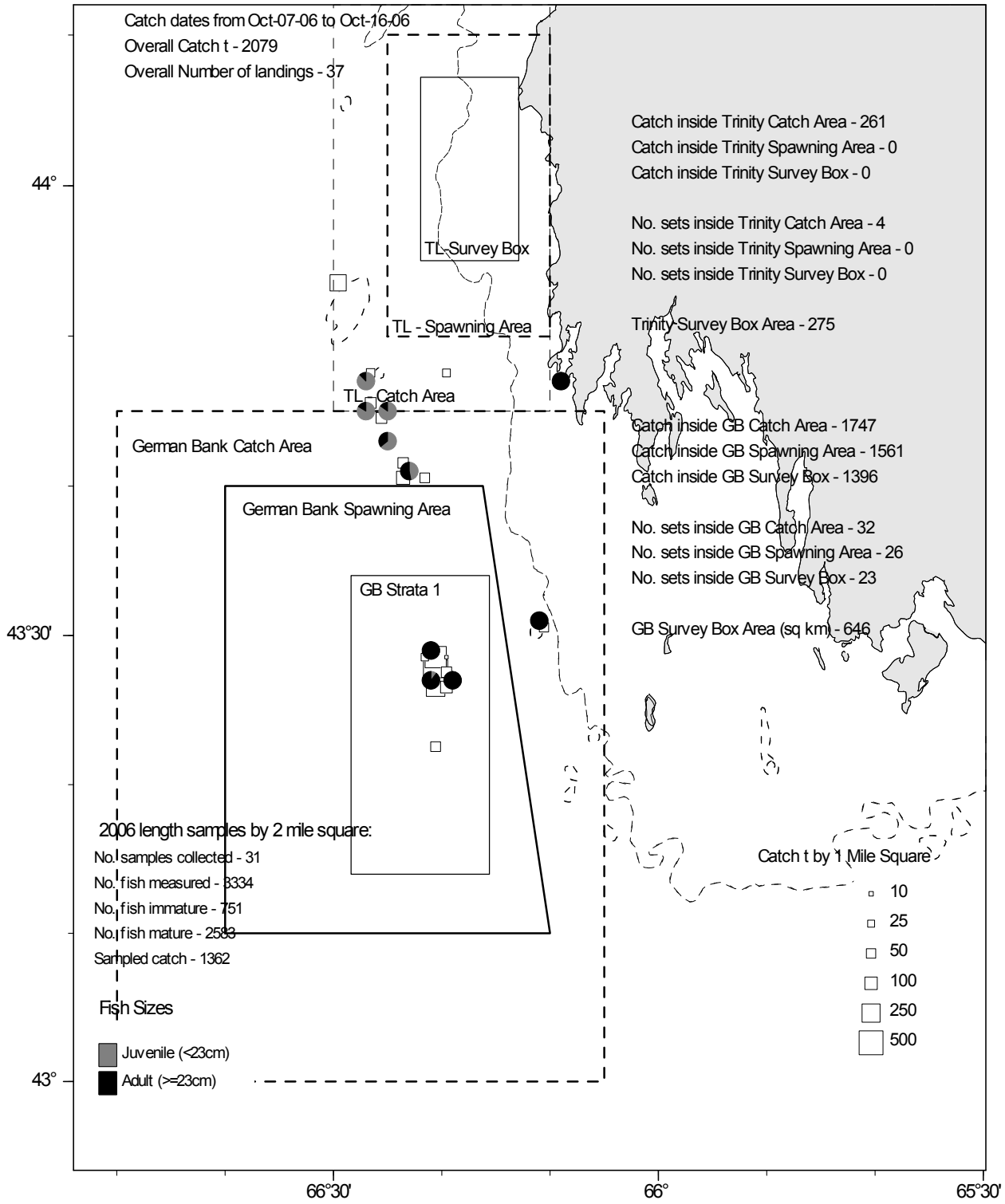

Figure 33. German Bank and Trinity Ledge area herring catches and length samples from all gear types for the period from Oct. 7-16. Open rectangles represent catches by 1 mile aggregation and colored circles show length sampling by size with pies showing the proportion of adult (>=23cm) in black and juvenile (<23cm) in grey.

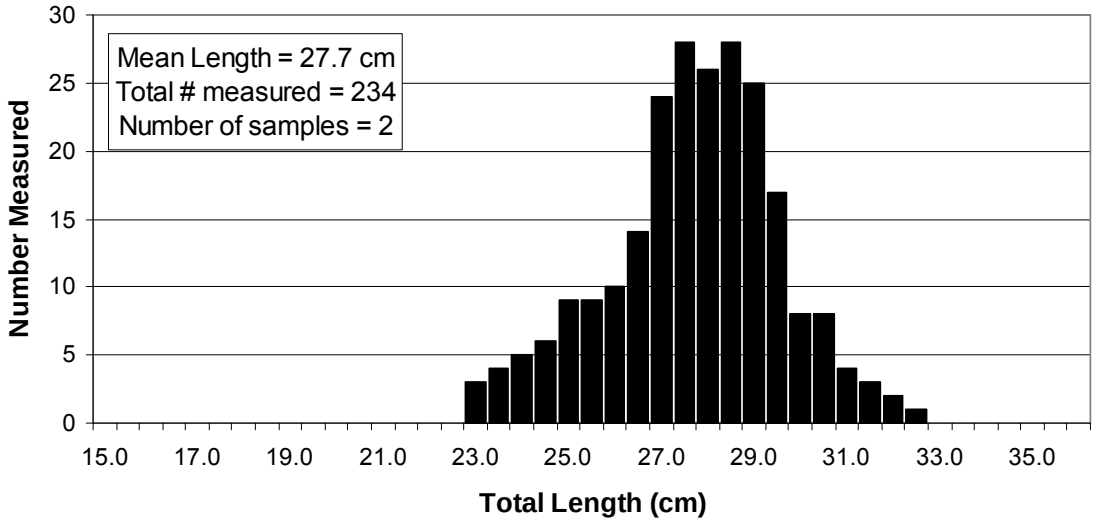

Figure 34. Length frequency distribution from samples within the German Bank survey box collected on Oct. 14, 2006 and used in the calculation of target strength (TS).

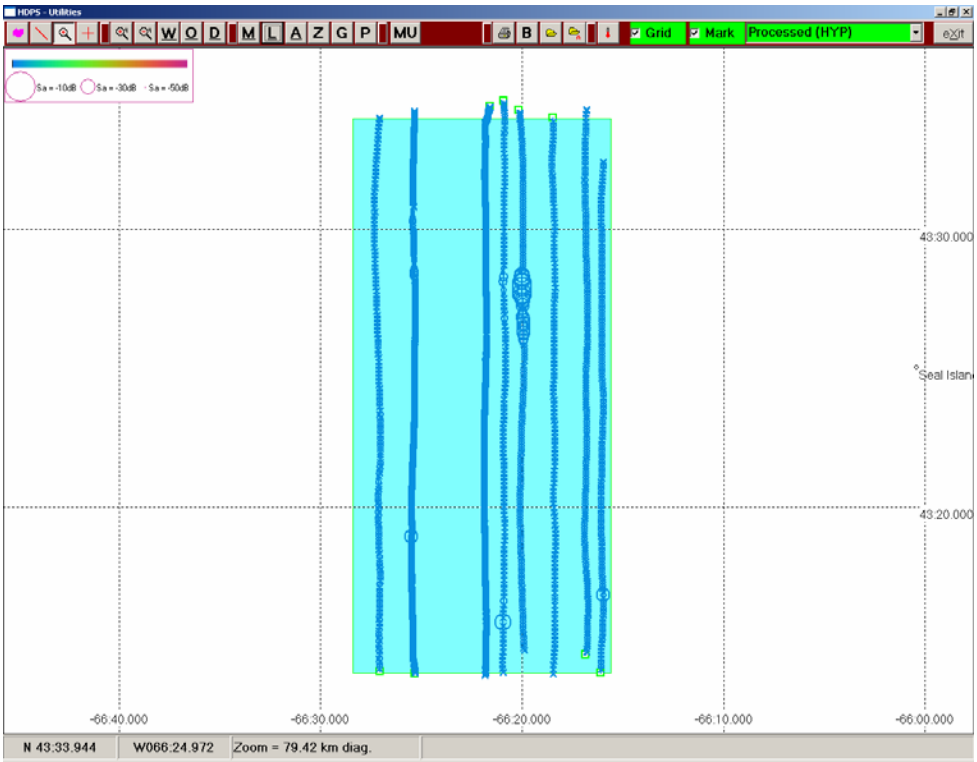

Figure 35. Acoustic transects showing total backscatter (Sa) and survey box area of 646 km^2 for German Bank survey on Oct. 15, 2006.

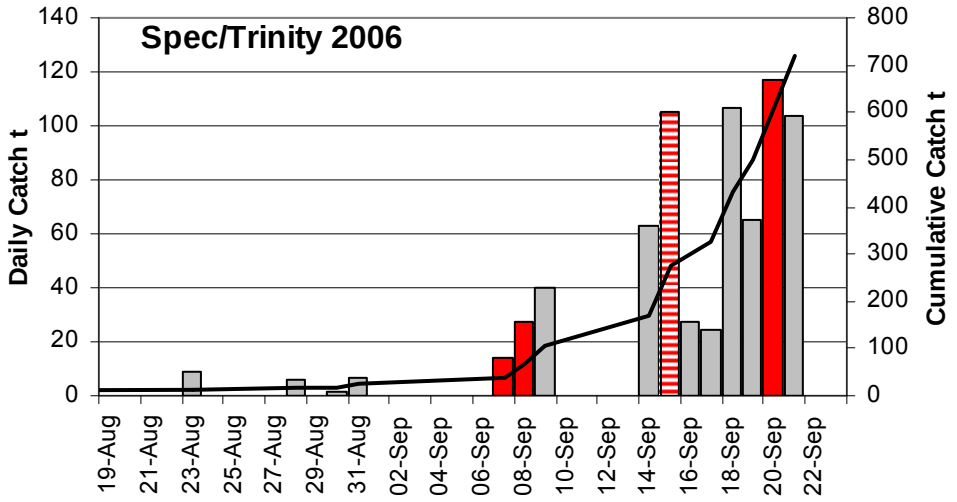

Figure 36. Daily herring landings for 2006 Trinity Ledge/Spectacle Buoy area with acoustic survey dates highlighted for nights of Sept. 7, 8, 15 (purse seiner) and 20th. Note that an additional survey on Sept. 3 where there were no landings is not shown.

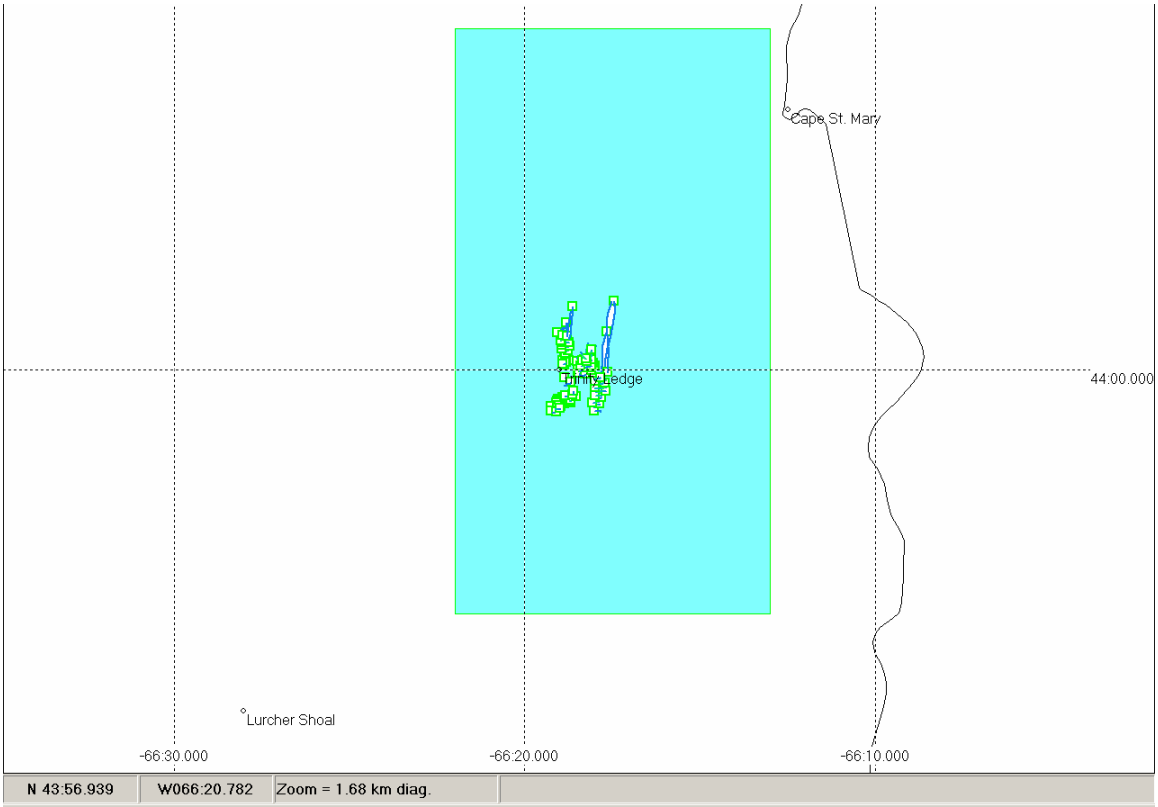

Figure 37. Acoustic survey lines for the Trinity Ledge area on Sept. 3, 7, 8 and Sept. 20 by the gillnet vessel *Sea Quiz* and by the purse seine vessels *Dual Venture* and *Secord* on Sept. 15, 2006.

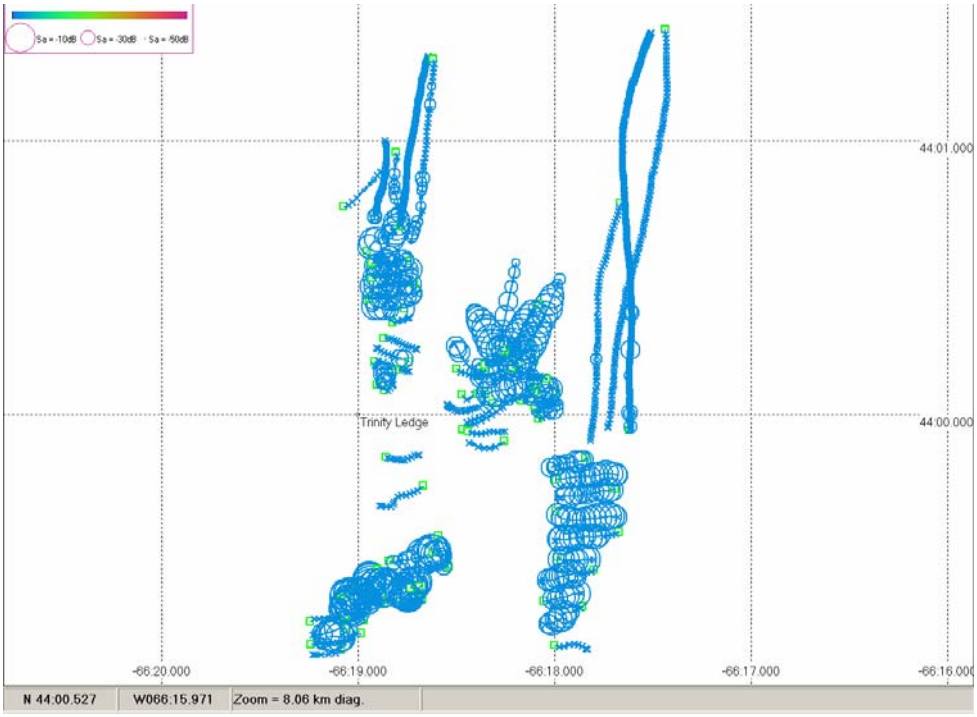

Figure 38. Trinity Ledge acoustic surveys showing average backscatter (Sa) for all 2006 surveys completed.

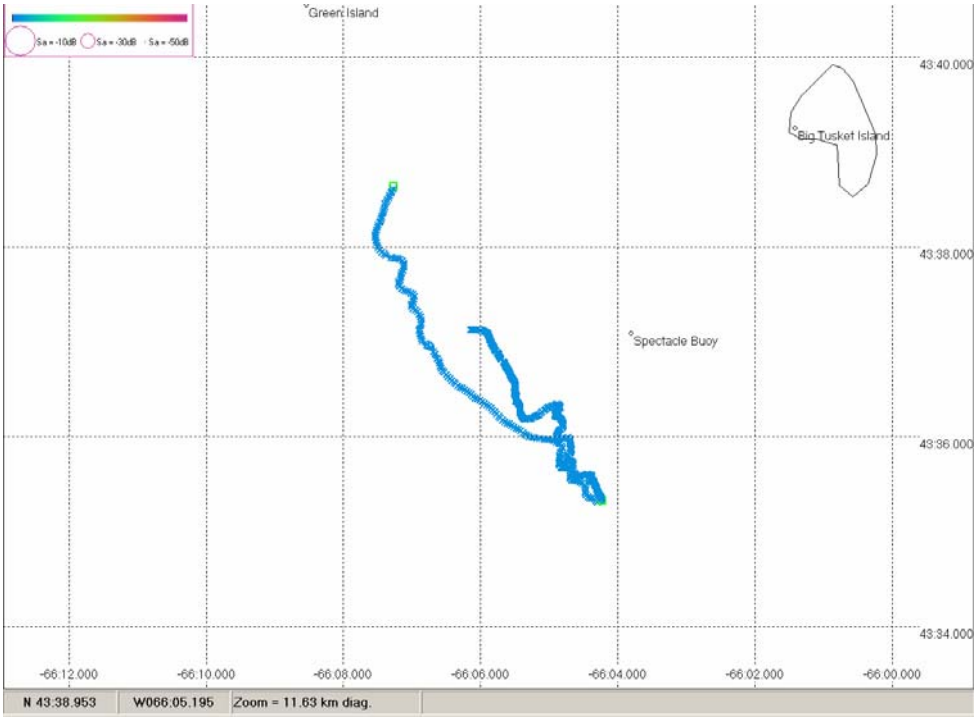

Figure 39. Spectacle Buoy area survey on Sept. 10, 2006 showing average backscatter (Sa) for lines completed.

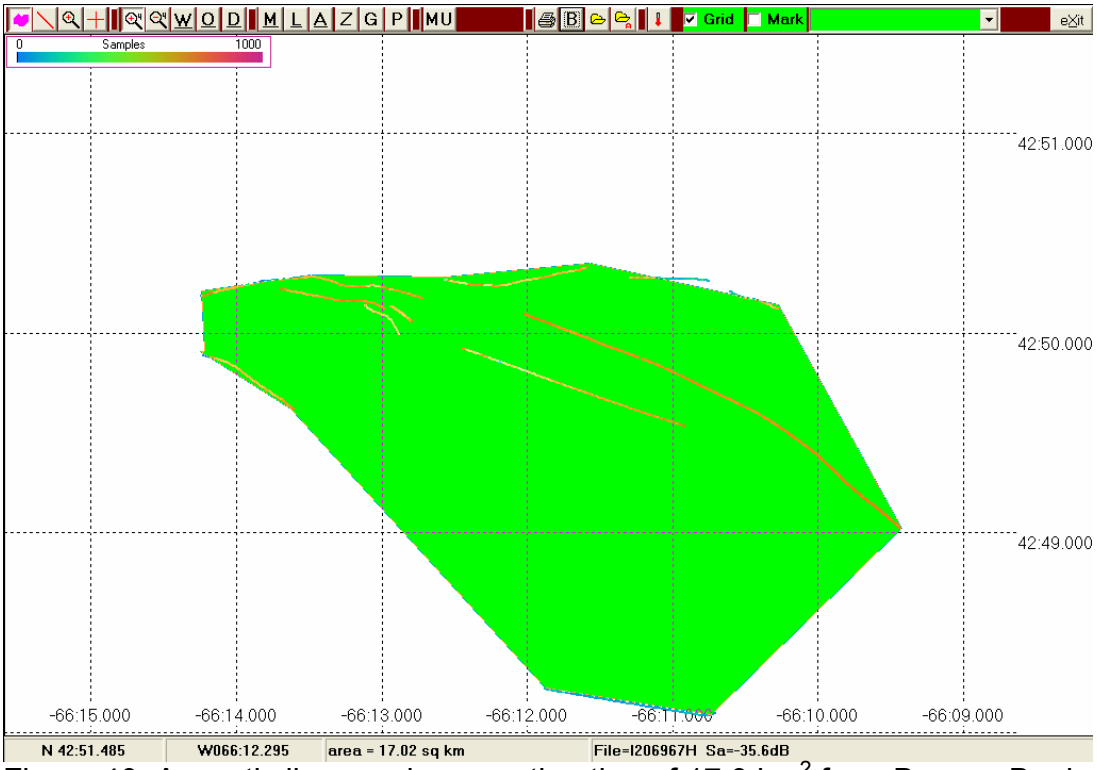

Figure 40. Acoustic lines and area estimation of 17.0 km^2 for a Browns Bank area survey on Sept. 5, 2006 by the purse seine vessel *Lady Melissa*.

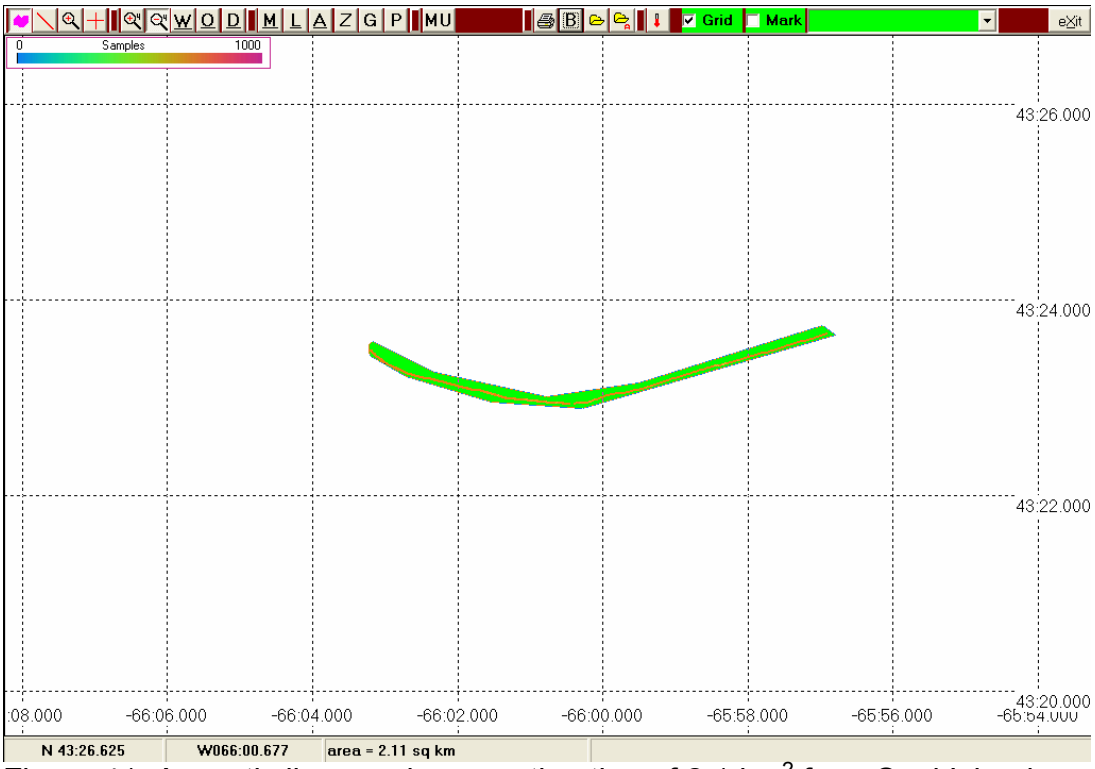

Figure 41. Acoustic lines and area estimation of 2.1 km^2 for a Seal Island area recording made on Sept. 15, 2006 by the purse seine vessel *Island Pride*.

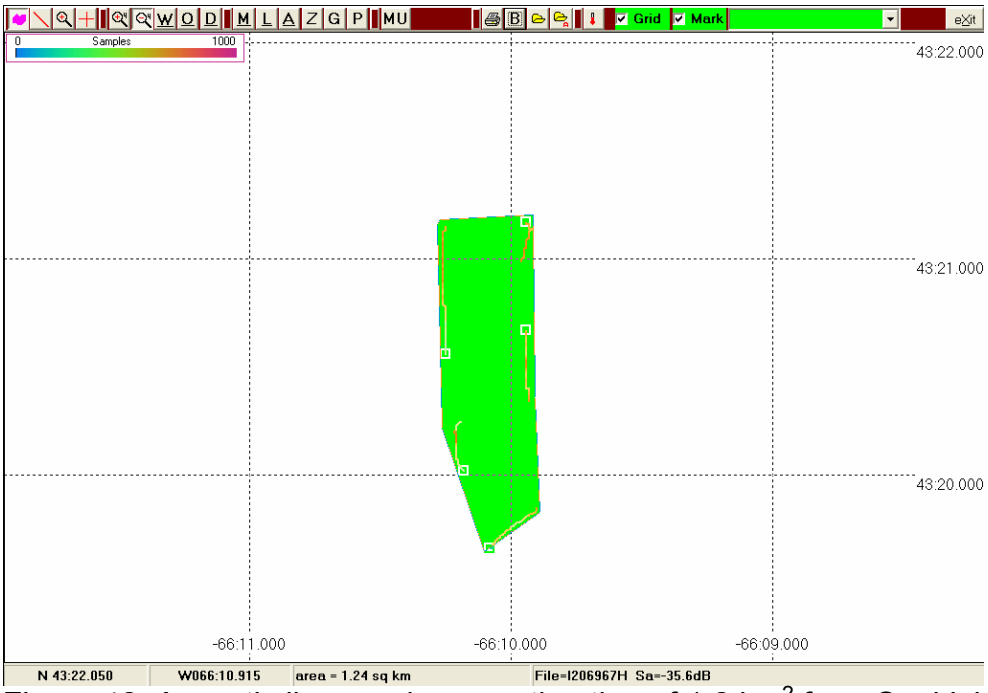

Figure 42. Acoustic lines and area estimation of 1.2 km^2 for a Seal Island area survey completed on Sept. 19, 2006 by the purse seine vessel *Island Pride*.

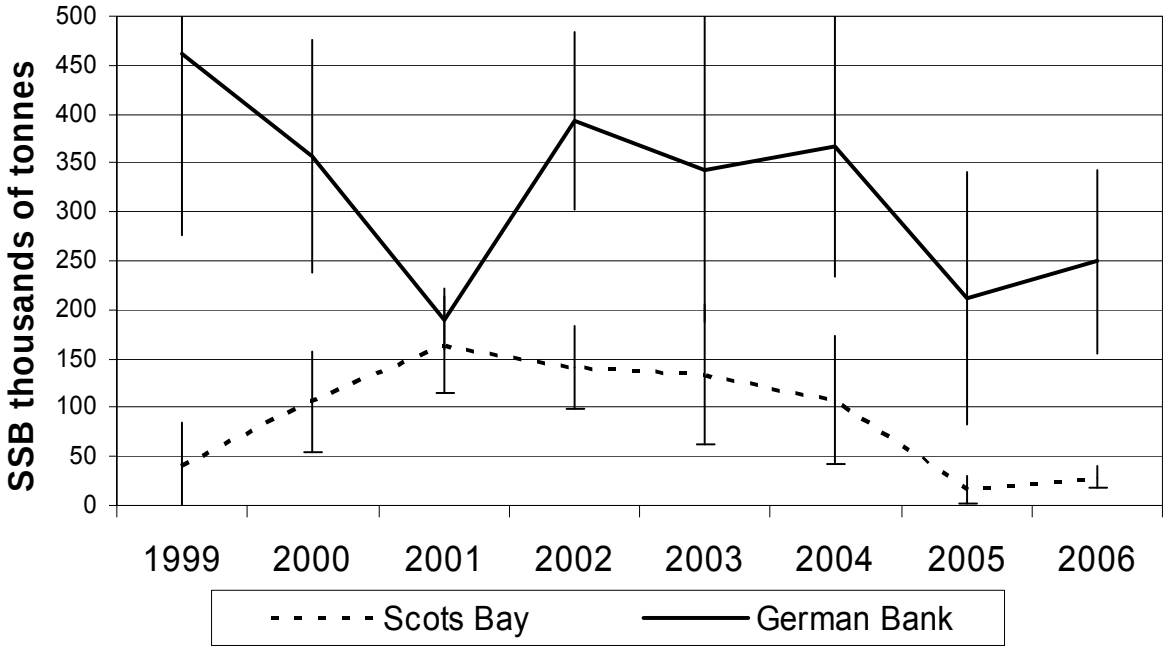

Figure 43. Trends in herring spawning stock biomass from acoustic surveys in Scots Bay and German Bank areas with 95% confidence intervals (equivalent to 2 times SE).

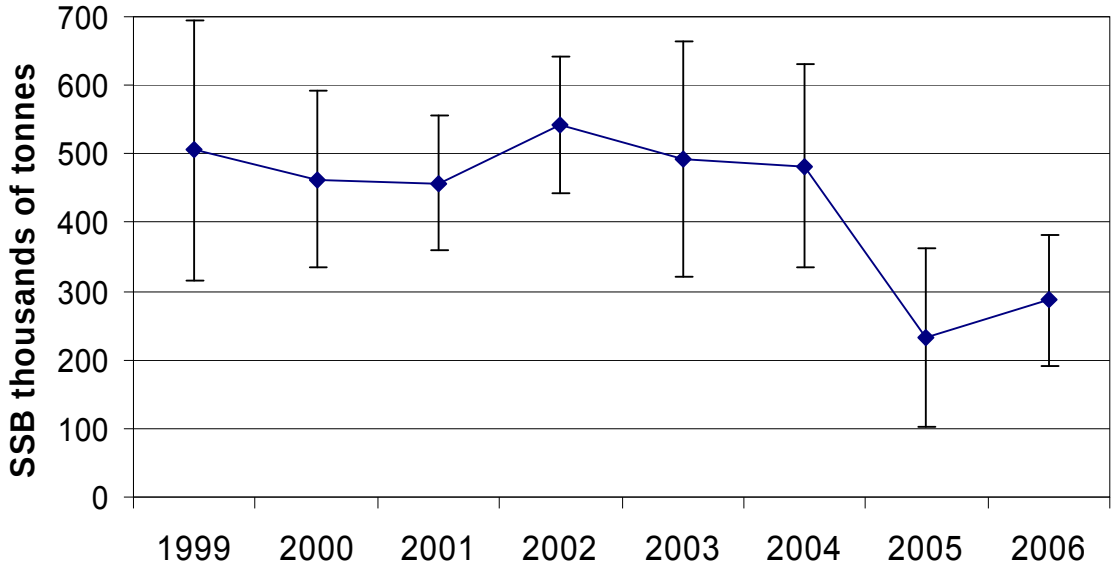

Figure 44. Trends in herring spawning stock biomass from acoustic surveys for the combined southwest Nova Scotia areas with 95% confidence intervals (equivalent to 2 times SE).

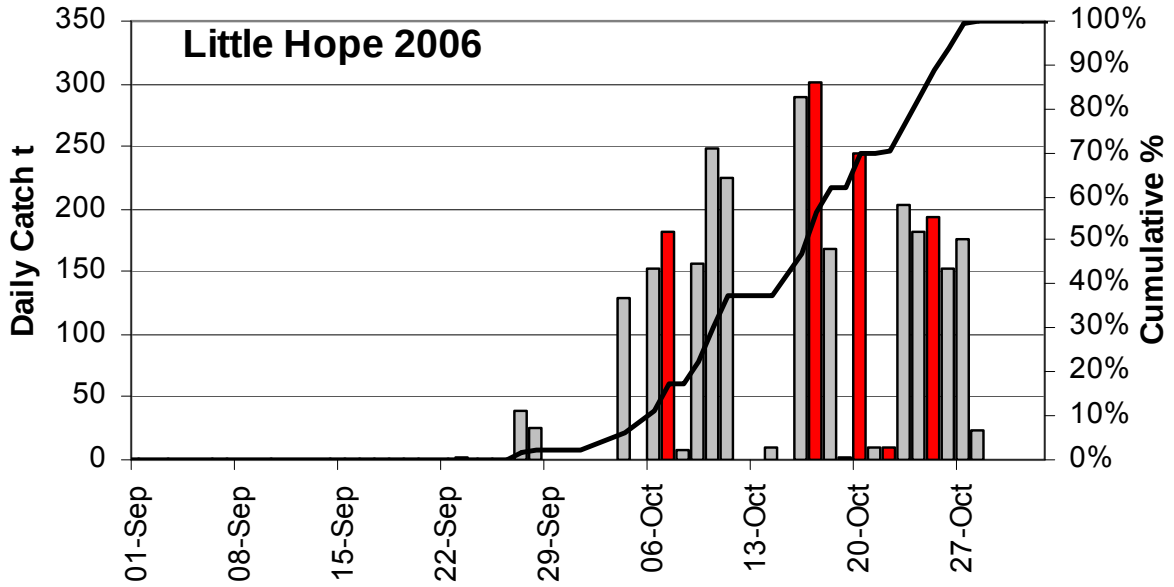

Figure 45. Daily herring landings for 2006 Little Hope/Port Mouton area with acoustic survey dates highlighted for nights of Oct. 7, 17, 19-20, 22 and Oct. 25.

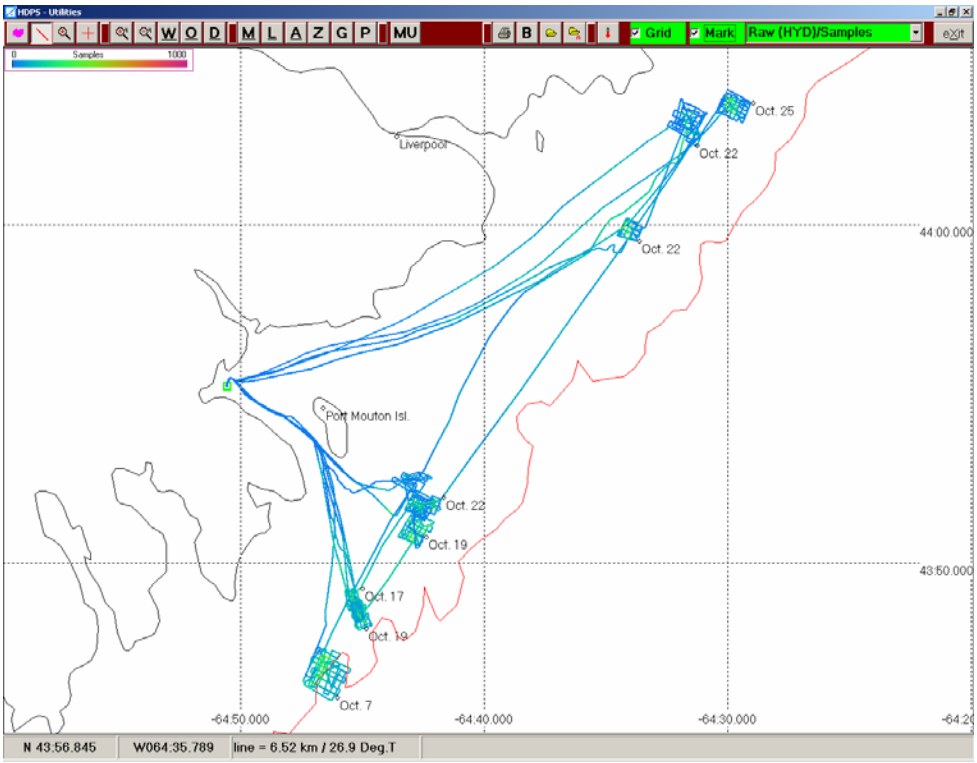

Figure 46. Acoustic survey lines in 2006 for surveys on Oct. 7, 17, 19, 22 and 25 along the Little Hope/Port Mouton fishing area by the gillnet vessel *Knot Paid For*.

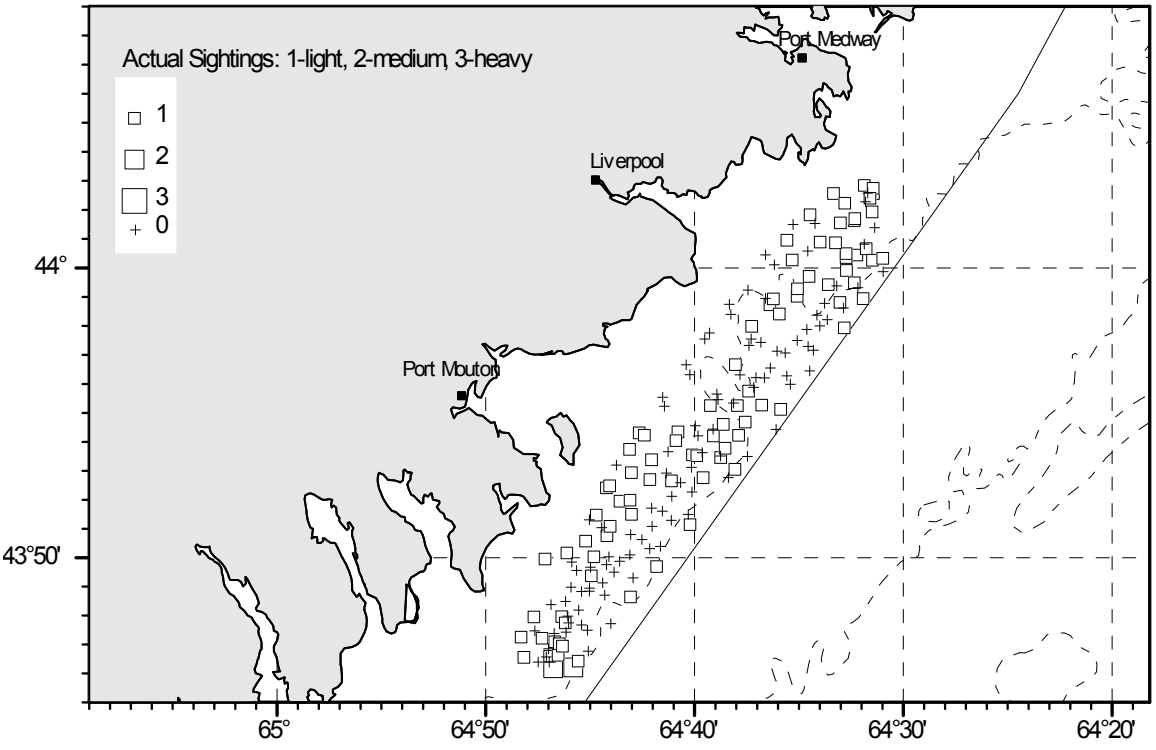

Figure 47. Herring deck sheet observations for Oct. 7, 2006 survey along the Little Hope/Port Mouton fishing area.

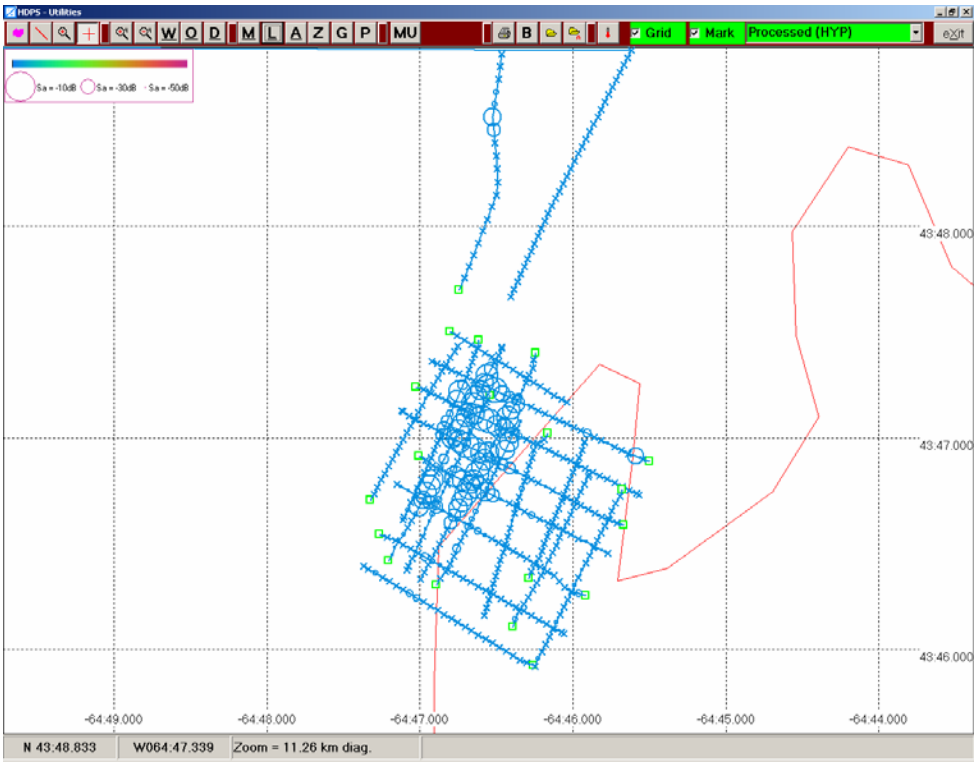

Figure 48. Survey lines showing backscatter distribution (Sa) on Oct. 7, 2006 with transects completed in two directions across the herring school encountered.

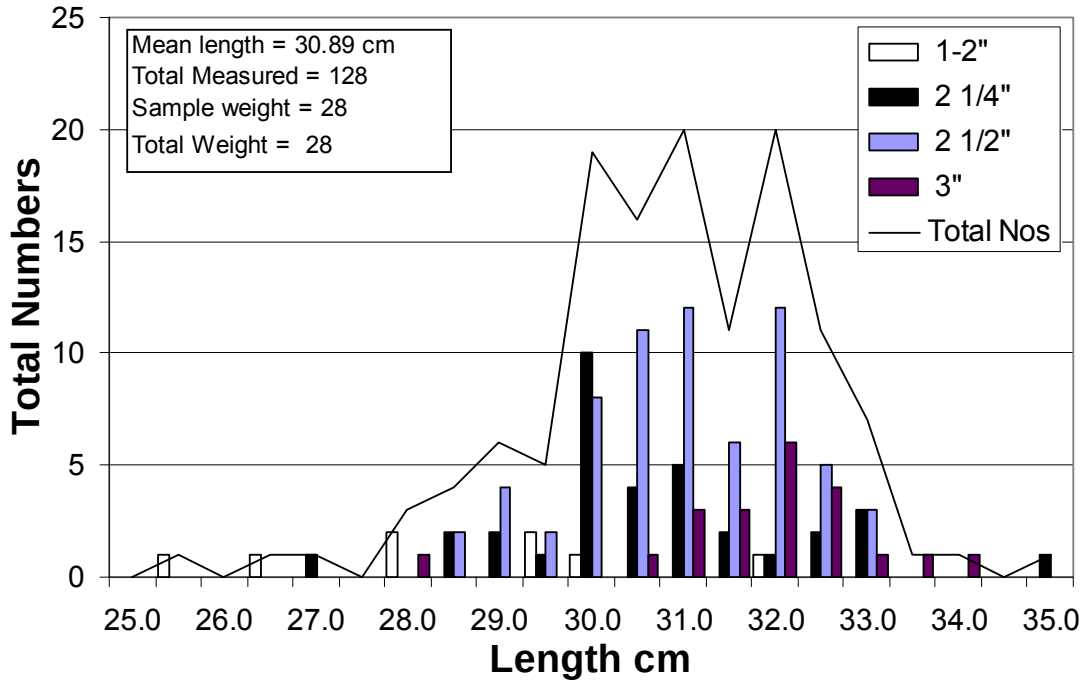

Figure 49. Multi-panel gillnet sample for the herring acoustic survey collected on Oct. 7, 2006 from the Little Hope/Port Mouton area. Separate panels were used with mesh size of 1”, 2”, 2 ¼”, 2 ½” (as used in fishery) and 3”.

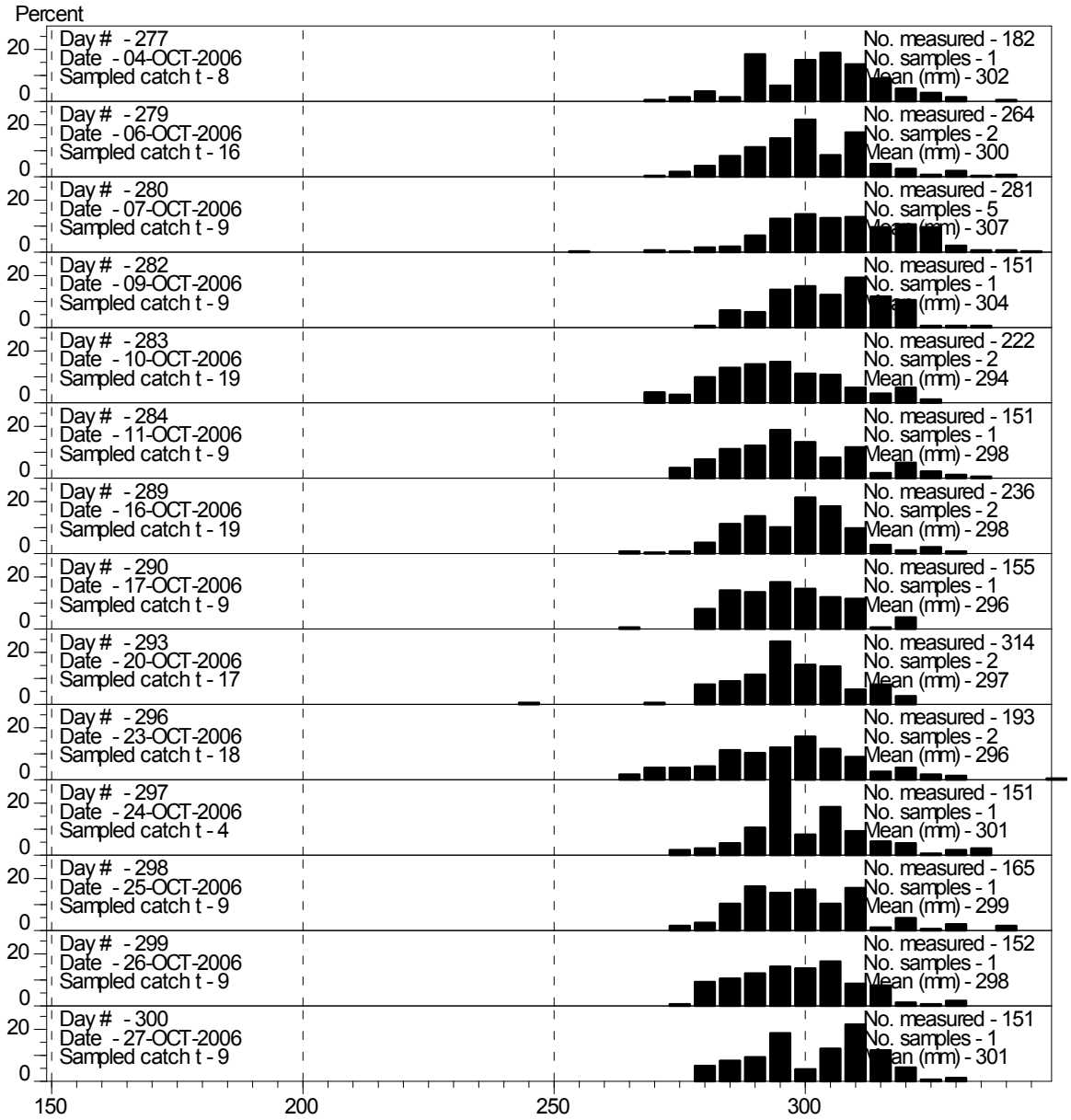

Figure 50. Daily length sampling for the 2006 Little Hope/Port Mouton area including a single multi-panel gillnet sample on Oct. 7. The standard fishery mesh size is 2 ½".

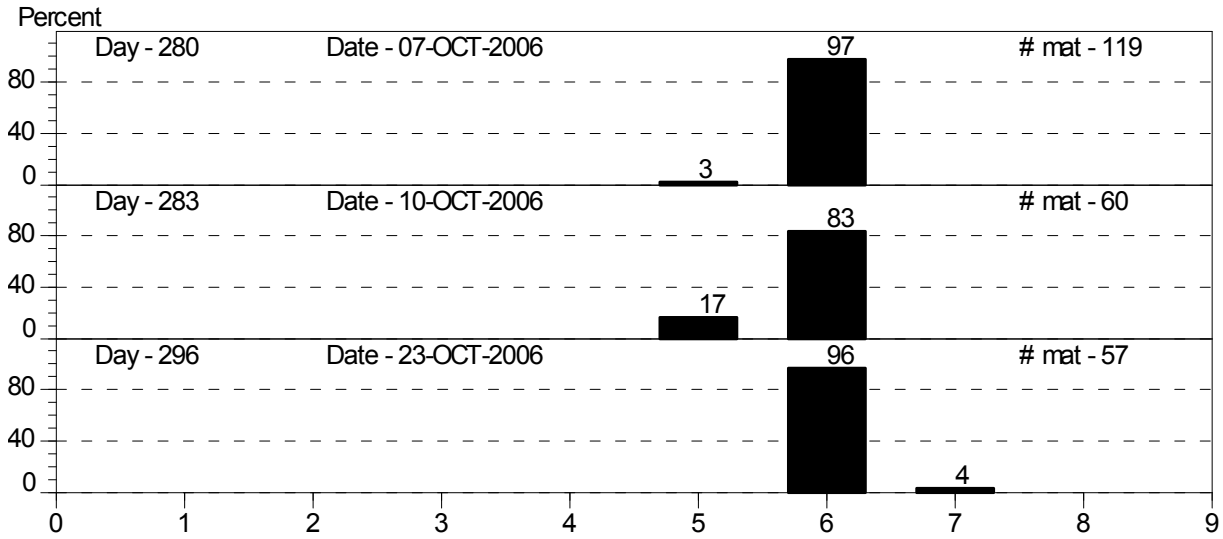

Figure 51. Herring maturities (% number by stage) for the 2006 Little Hope/Port Mouton area as processed at SABS (stage 5 is hard roe, stage 6 is ripe and running and stage 7 is spent).

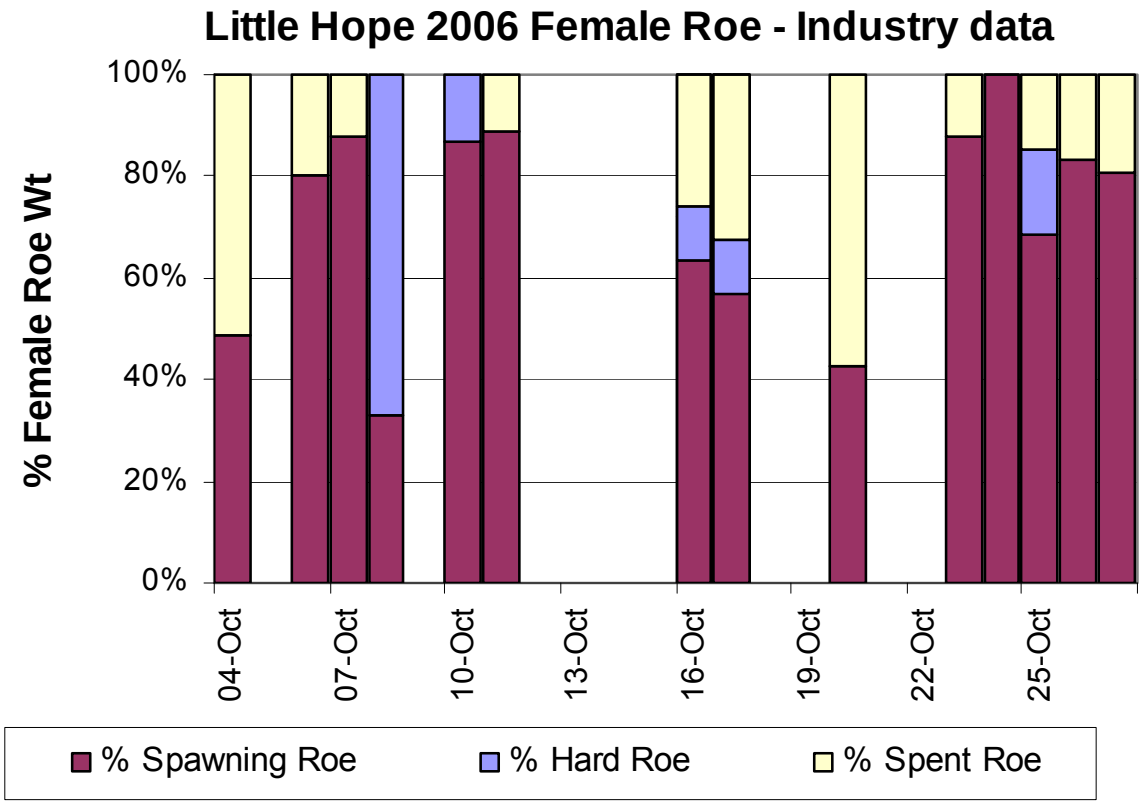

Figure 52. Daily herring female roe samples (% roe weight) from industry sources for the Little Hope/Port Mouton area in 2006.

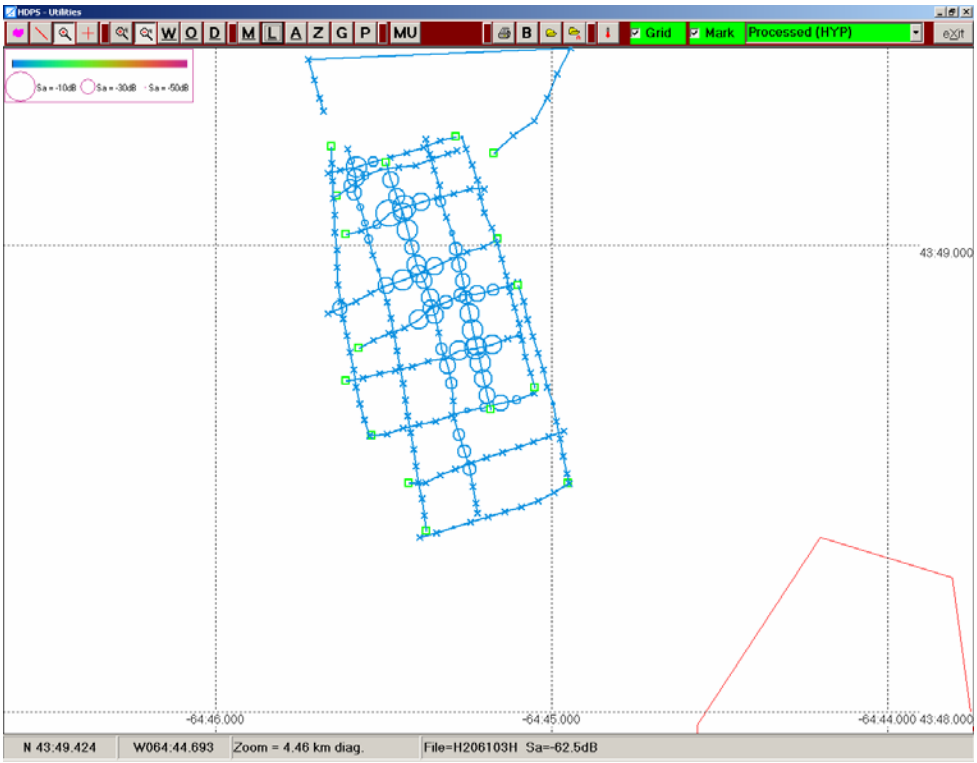

Figure 53. Survey lines on Oct. 17, 2006 for the southwestern school showing backscatter distribution (Sa) for transects completed in two different directions.

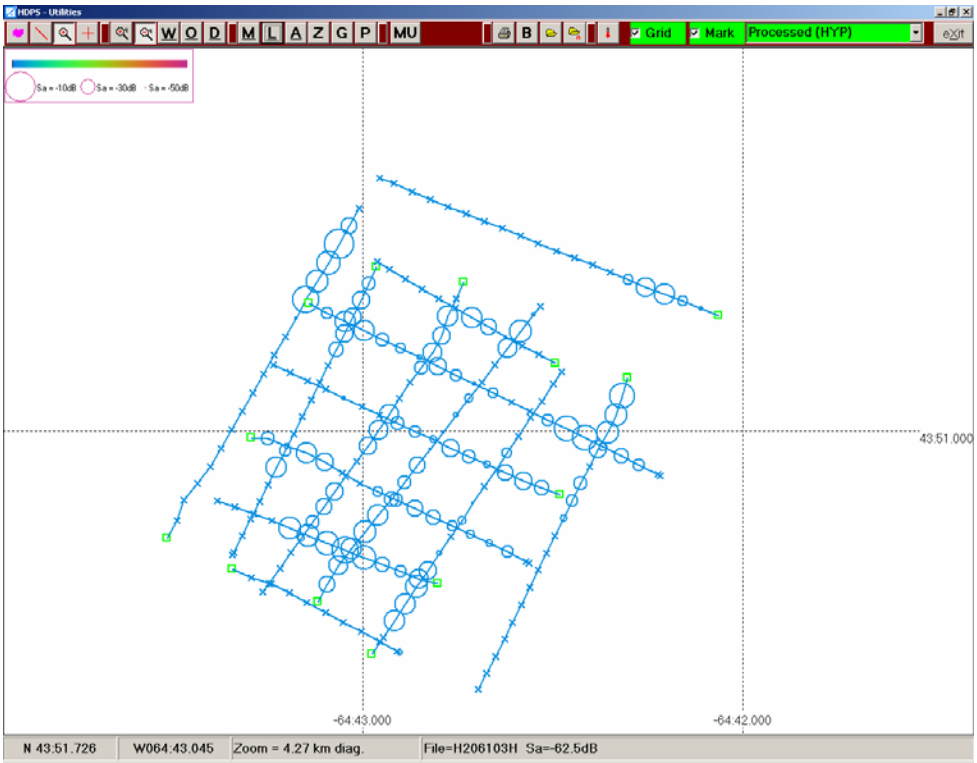

Figure 54. Survey lines on Oct. 19, 2006 for the north-eastern school showing backscatter distribution (Sa) for transects completed in two different directions.

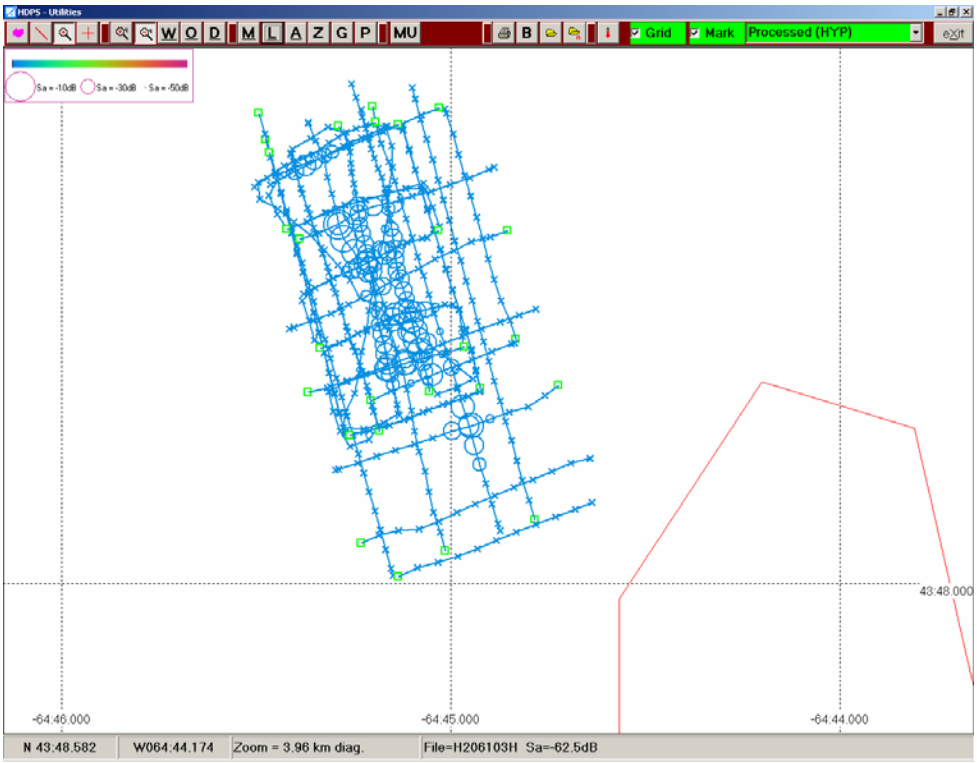

Figure 55. Survey lines on Oct. 19, 2006 for the south-western school showing backscatter distribution (Sa) for transects completed on the four separate passes on the school.

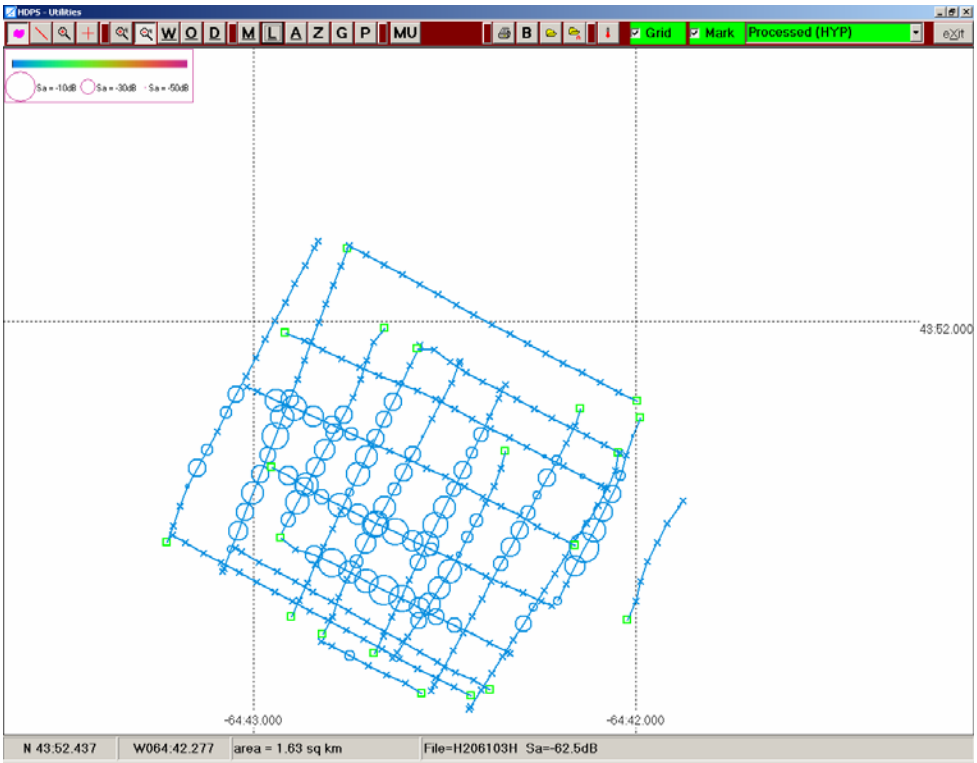

Figure 56. Survey lines on Oct. 22, 2006 for the south-western school showing backscatter distribution (Sa) for transects completed in two different directions.

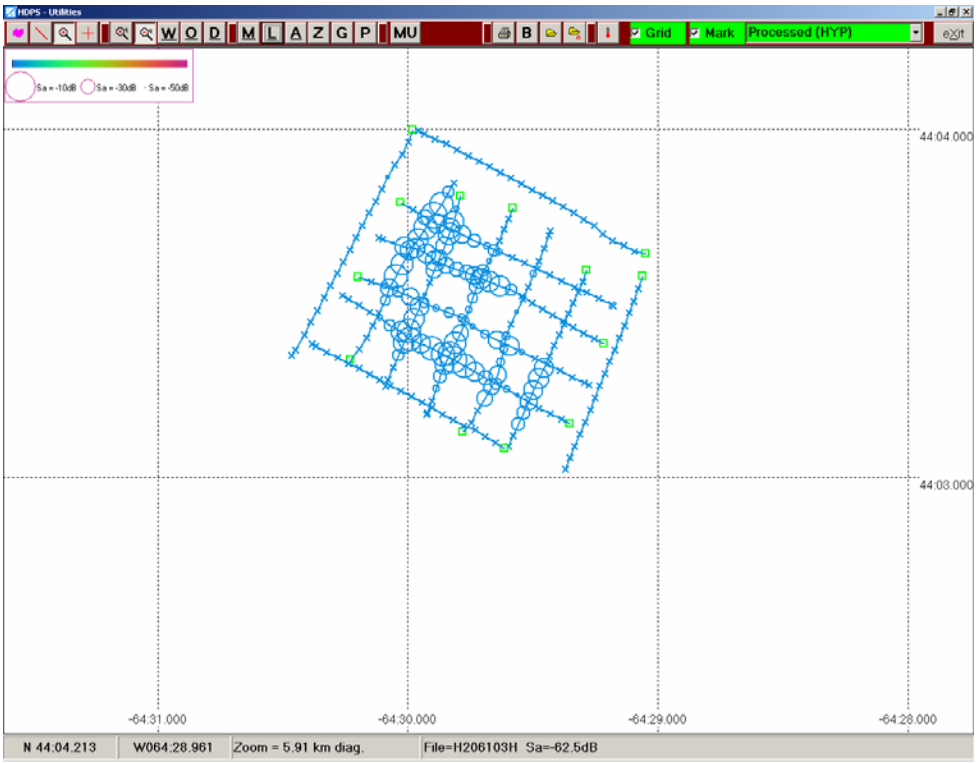

Figure 57. Survey lines on Oct. 25, 2006 for the north-eastern school showing backscatter distribution (Sa) for transects completed in two different directions.

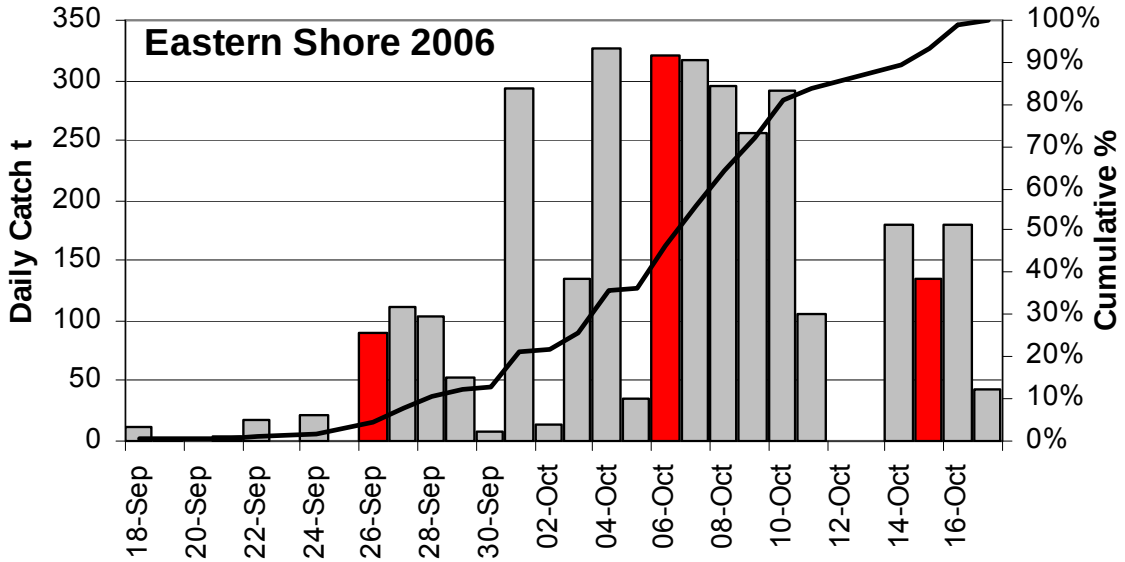

Figure 58. Daily herring landings for 2006 Eastern Shore area with acoustic survey dates highlighted for nights of Sept. 26, Oct. 6 and Oct. 15.

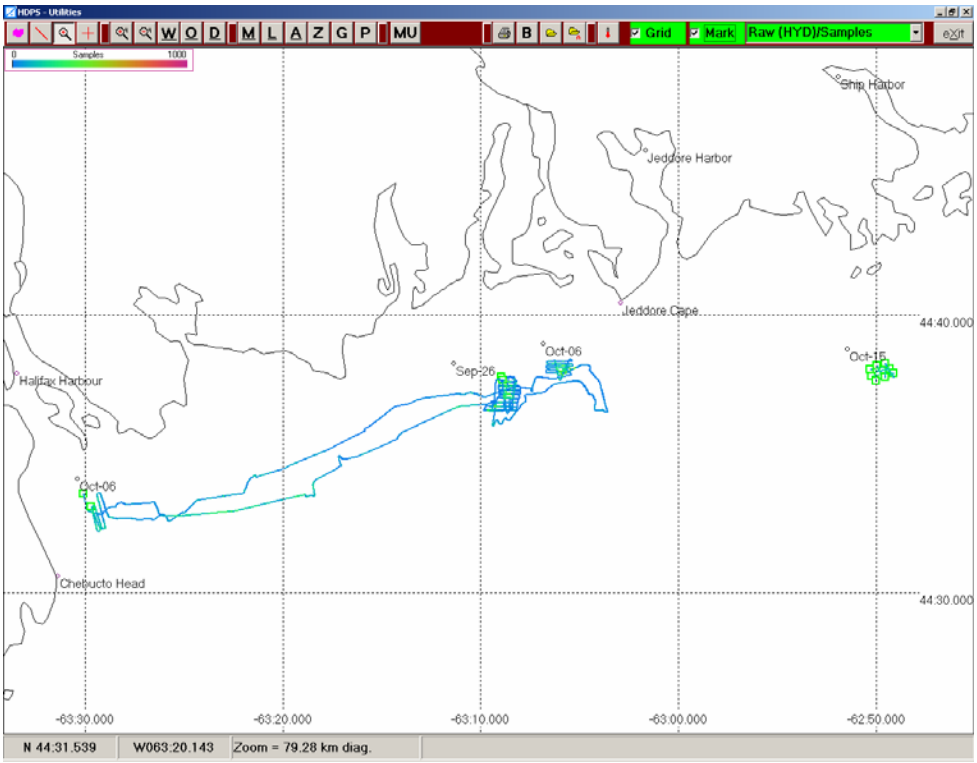

Figure 59. Acoustic survey lines for surveys on Sept. 26, Oct. 6 and Oct. 15 2006 along the Eastern Shore fishing area by the *Bradley K* and *Miss Owls Head*.

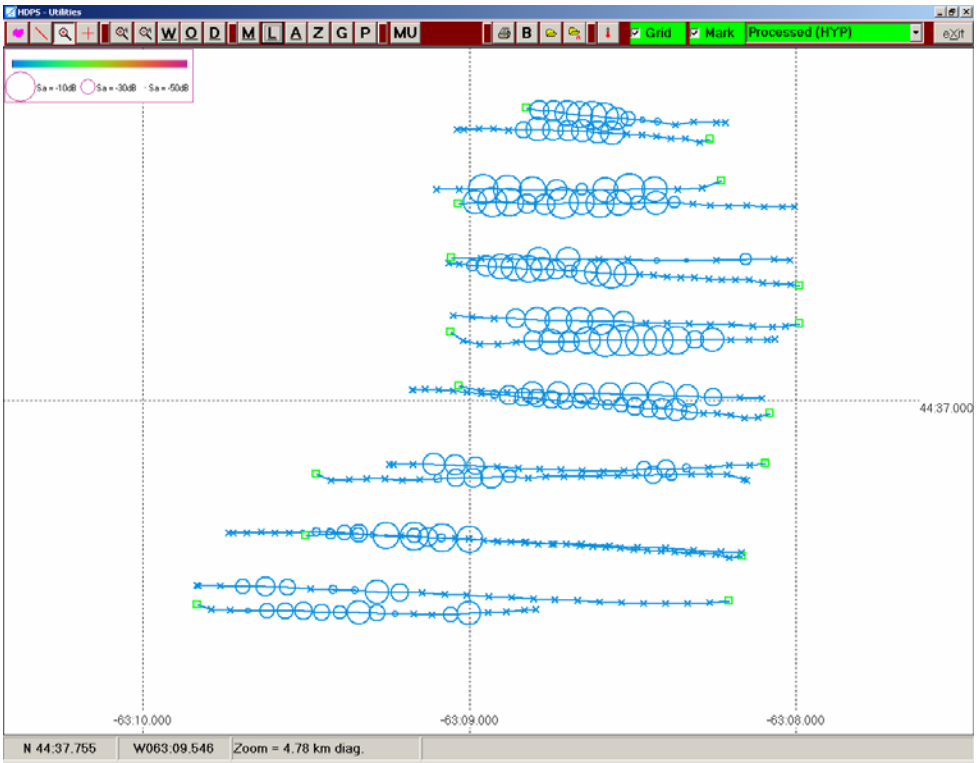

Figure 60. Survey transects showing total backscatter (Sa) as completed by *Bradley K* and *Miss Owls Head*, southwest of Jeddore Cape on Sept. 26, 2006.

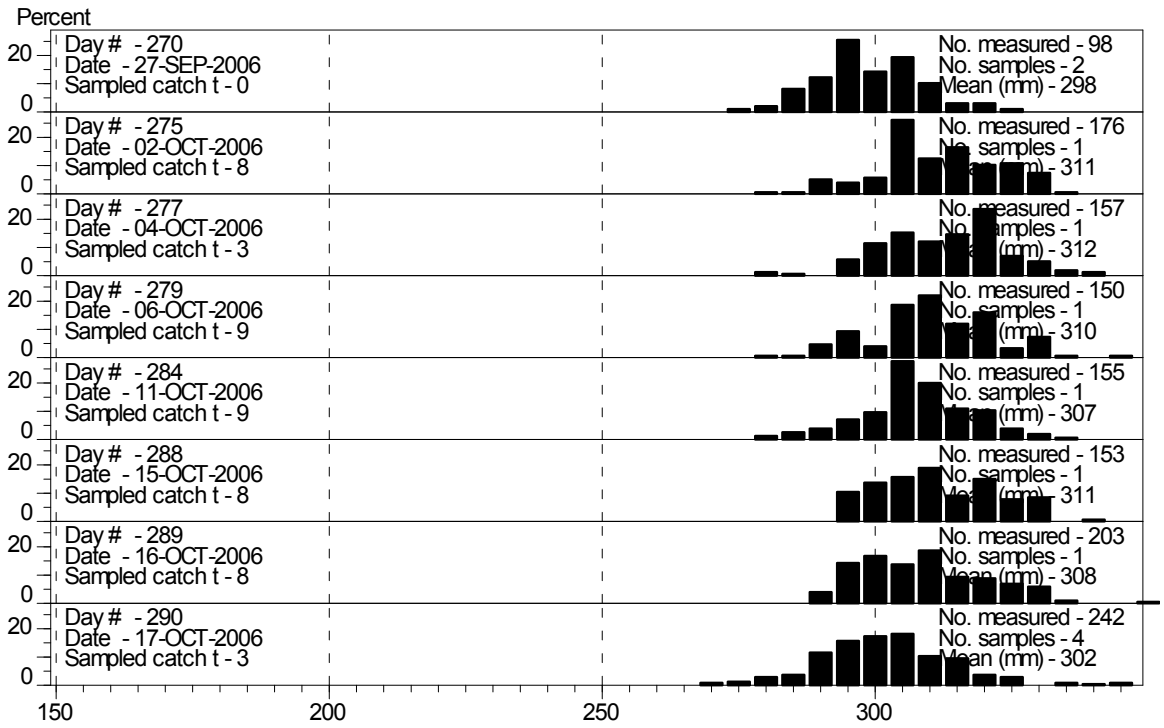

Figure 61. Daily length sampling for the 2006 Eastern Shore area including multi-panel gillnet samples on Sept. 27 and Oct. 17.

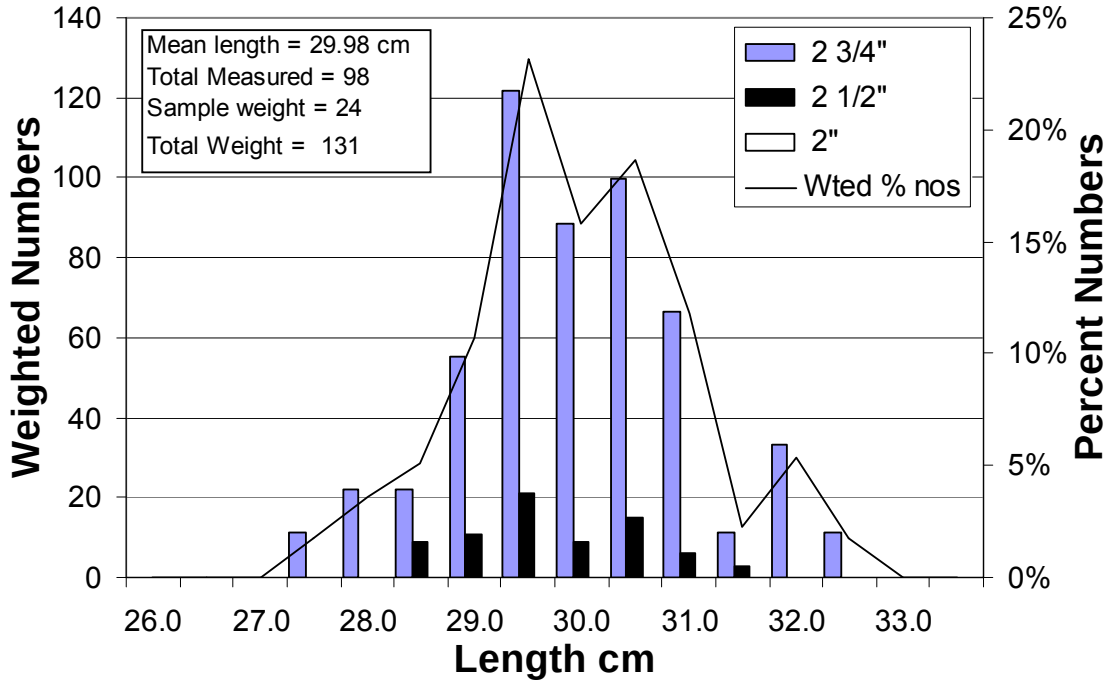

Figure 62. Multi-panel gillnet sample for the herring acoustic survey collected on Sept. 26, 2006 off Jeddore along the Eastern Shore fishing area.

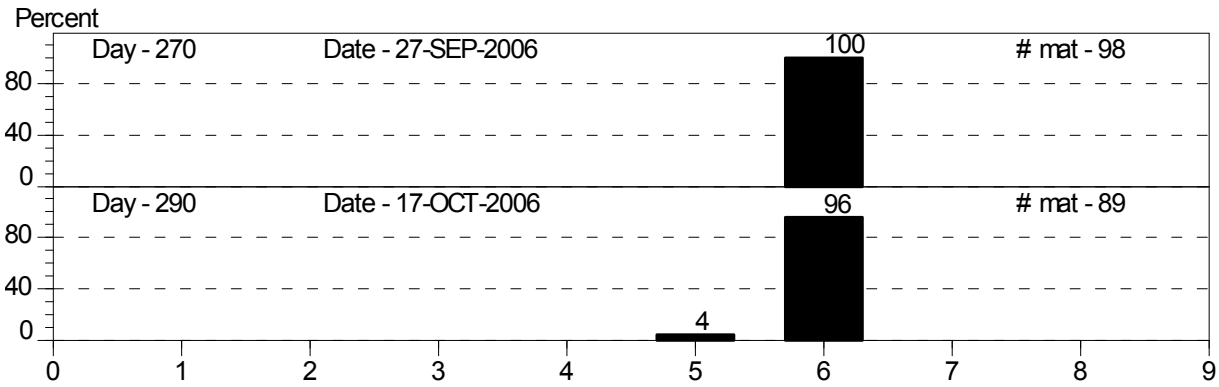

Figure 63. Herring maturity sampling (% number by stage) for the 2006 Eastern Shore area from multi-panel gillnet catches (stage 5 is hard roe, stage 6 is ripe and running).

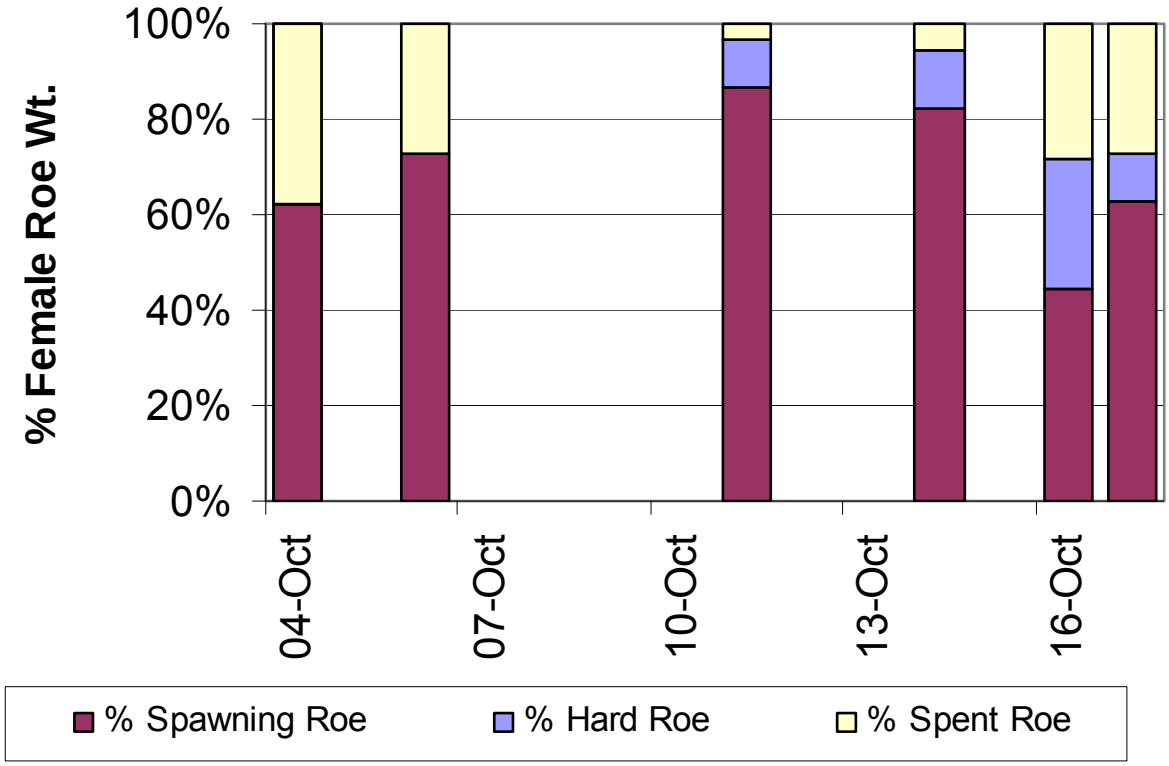

Figure 64. Daily herring female roe samples (% roe weight) from industry sources for the Eastern Shore area in 2006.

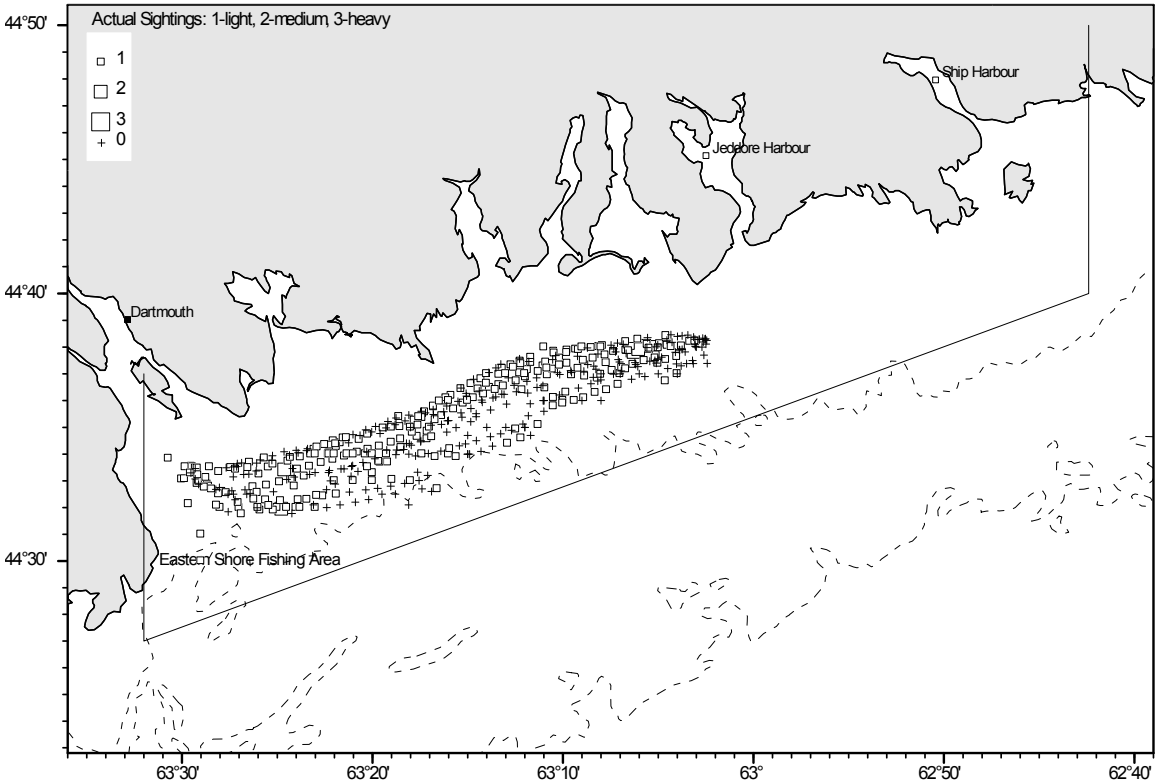

Figure 65. Herring deck sheet observations for Oct. 6, 2006 survey along the Eastern Shore fishing area.

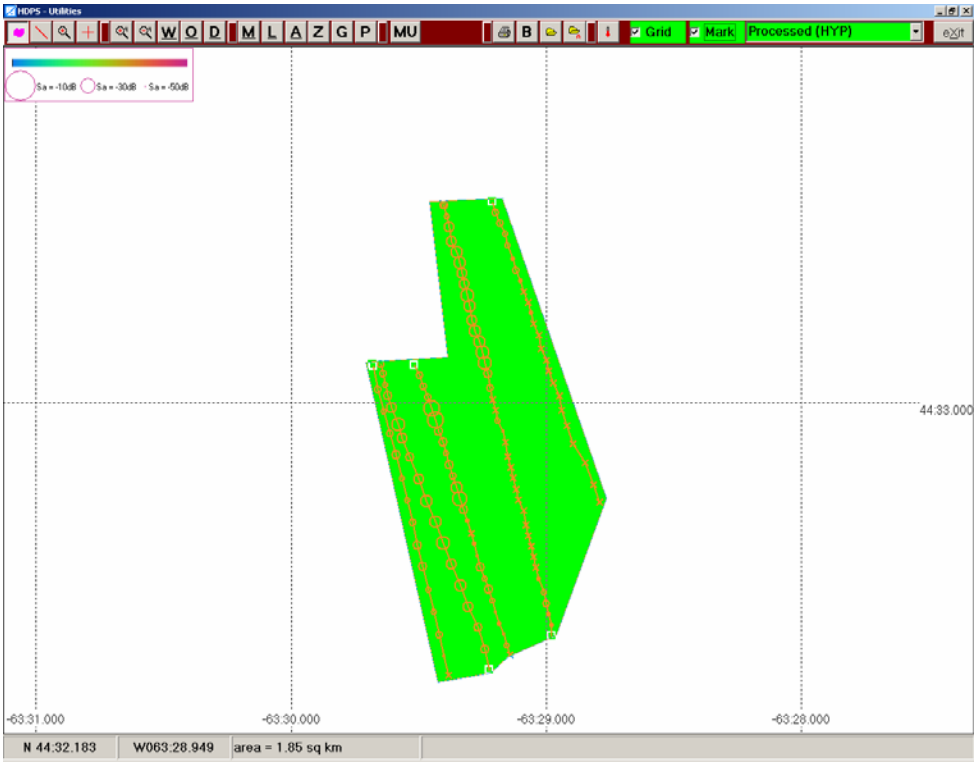

Figure 66. Acoustic transects showing total backscatter (Sa) for the Oct. 6 survey near Halifax Harbour by the *Miss Owls Head* with an estimated area of 1.85 km^2.

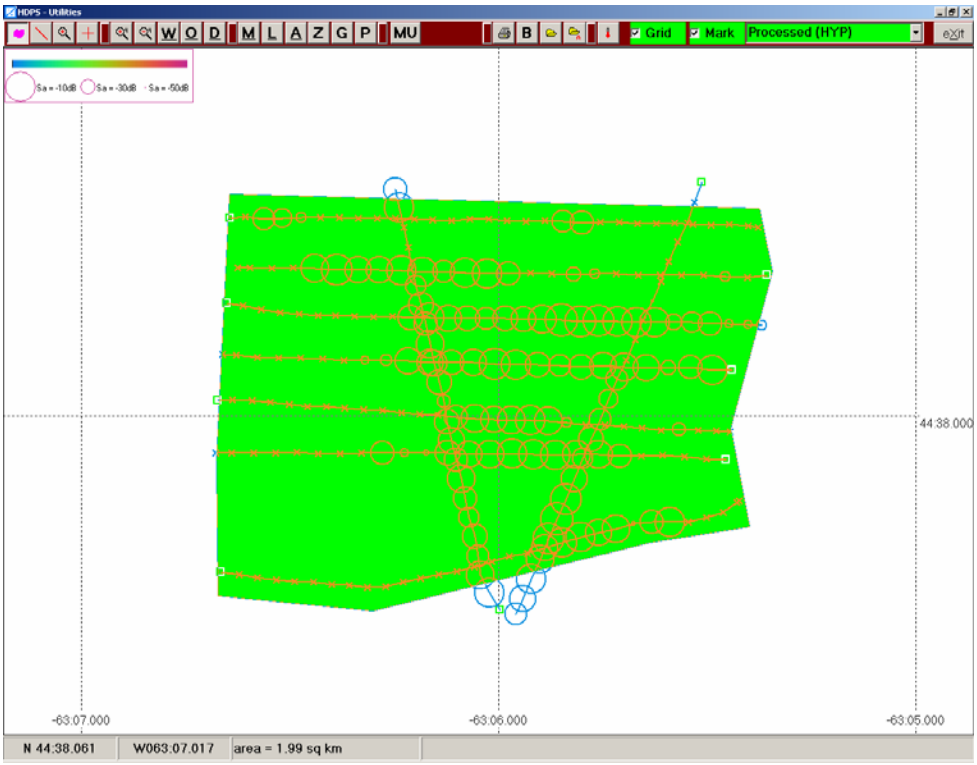

Figure 67. Acoustic transects showing total backscatter (Sa) for the Oct. 6 survey southwest of Jeddore Cape by the *Bradley K* with an estimated area of 2 km^2.

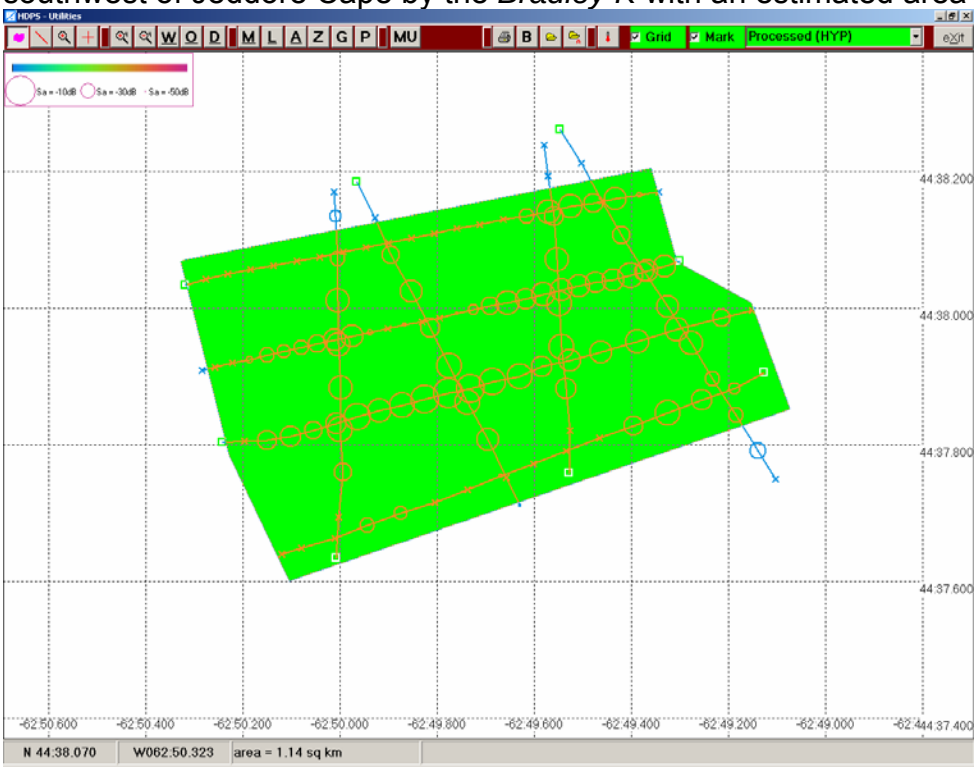

Figure 68. Acoustic transects showing total backscatter (Sa) for the Oct 15 survey off Ship Harbour, N.S. with estimated area of 1.14 km^2 along the east to west axis.

Figure 69. Acoustic transects showing total backscatter (Sa) along the north to south axis for the Oct 15 survey off Ship Harbour, N.S. with estimate area of 1.0 km^2.

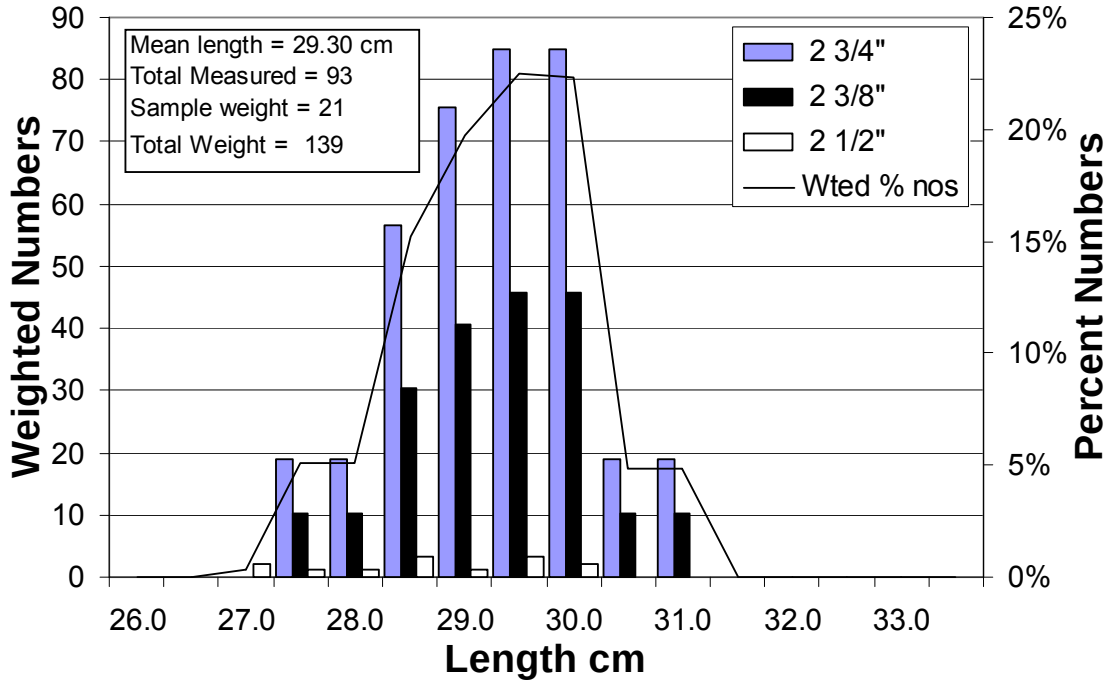

Figure 70. Multi-panel gillnet sample collected south of Ship Harbour, N.S. on Oct. 17, 2006 along the Eastern Shore fishing area.

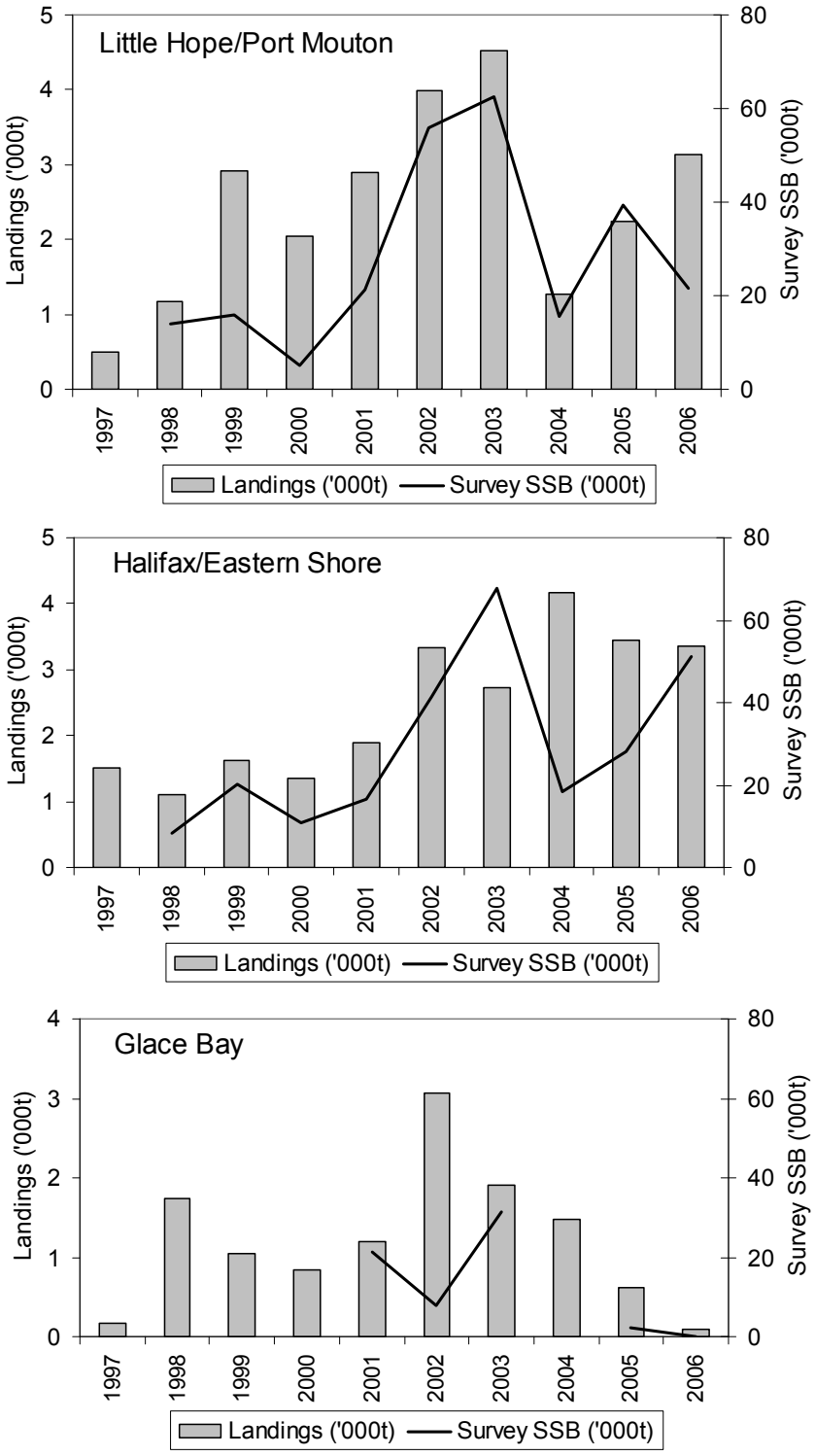

Figure 71. Summary of landings (bars) and surveyed biomass as calculated without the CIF (solid line) for the coastal Nova Scotia herring spawning areas near Little Hope/Port Mouton, Halifax/Eastern shore and Glace Bay.

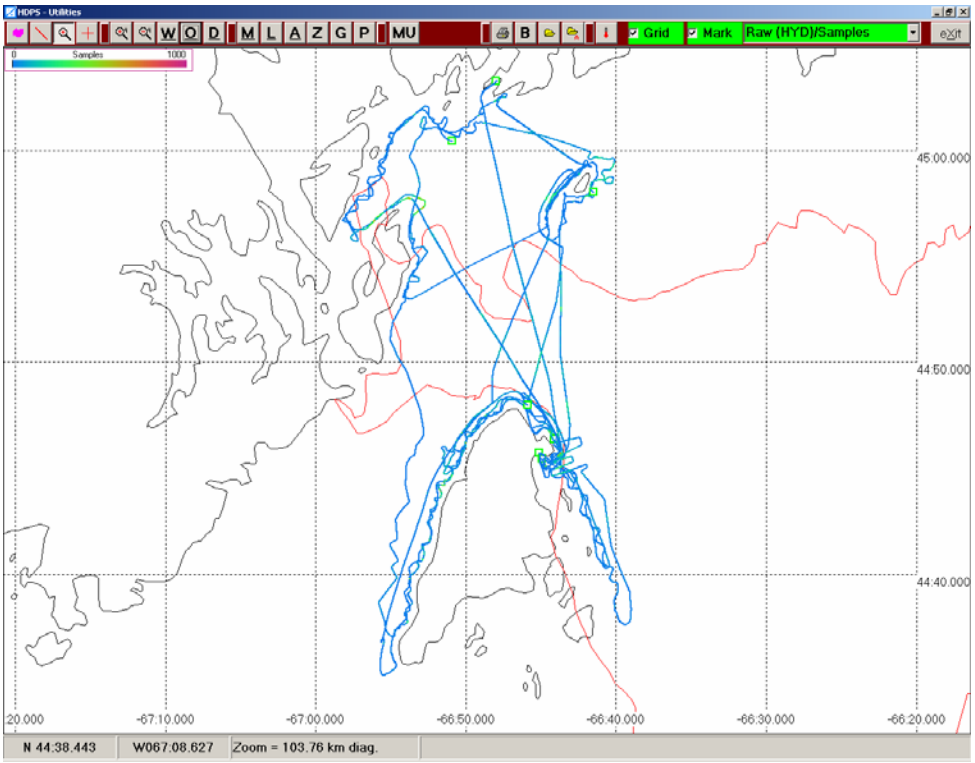

Figure 72. Acoustic recordings by the *Strathaven* with all survey lines from July 1 to Sept. 21, 2006.

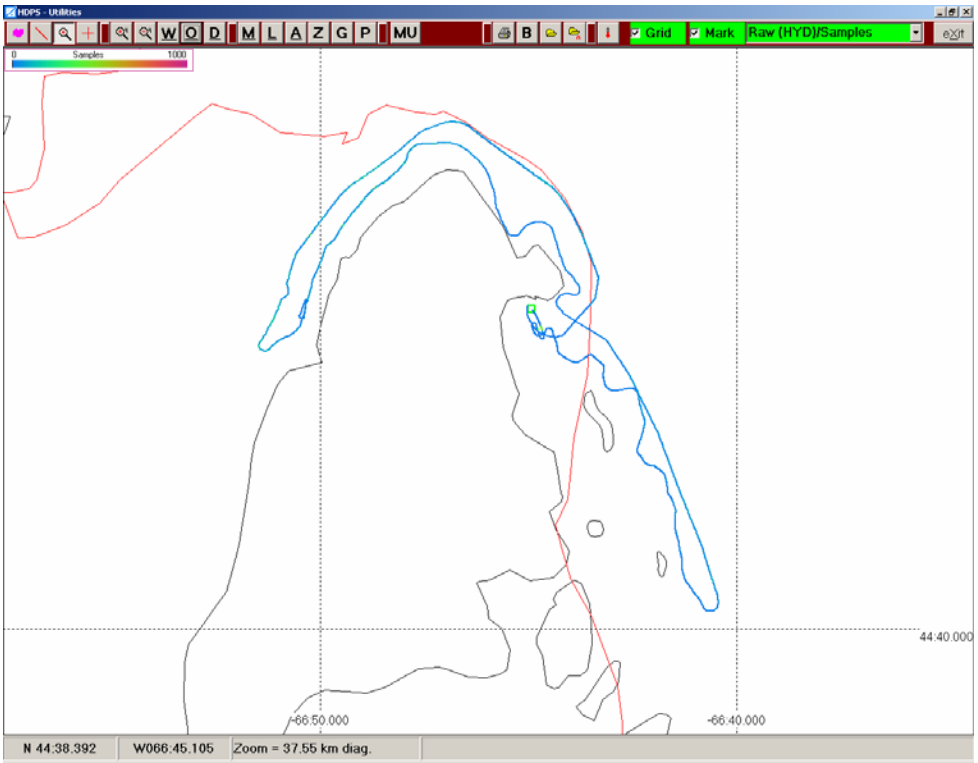

Figure 73. Acoustic recordings by the *Strathaven* near Grand Manan for September 13, 2006

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 A1) (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 (Foote, 1987)) 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 in 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:

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

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.

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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.

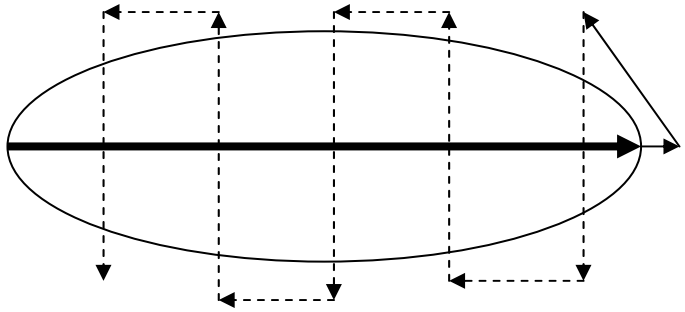
Category	Tonnes/Set	Tonnes/km^2	Acoustic (tonnes/km^2)
No Fish	0	0	0
Light	5	200	230 - 250
	10	400	
Moderate	25	1000	600 - 1300
	50	2,000	
Heavy	100	4,000	2,000 – 11,000
	200	8,000	
Very Heavy	250	10,000	20,000+
	500	21,000	

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.

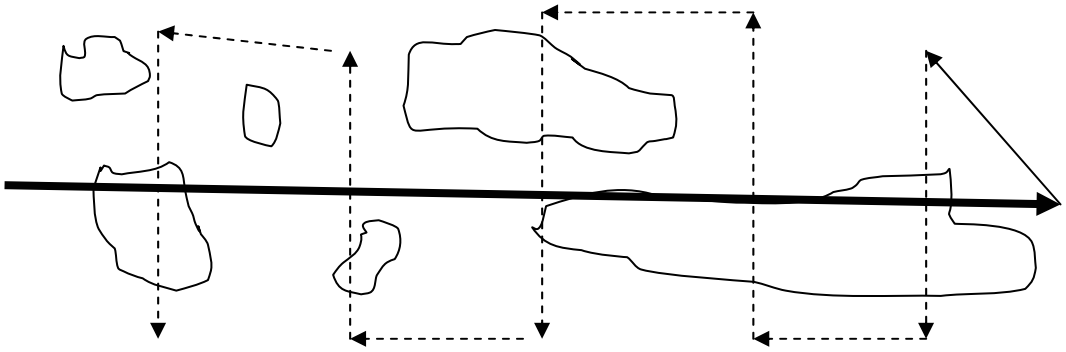


The first step to surveying the school of fish is to determine the long axis of the school as indicated above by the thick black solid line. Thereafter, a series of line transects should be run perpendicular to the long axis of the fish (dashed lines). The number of transects will be restricted to the 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								
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