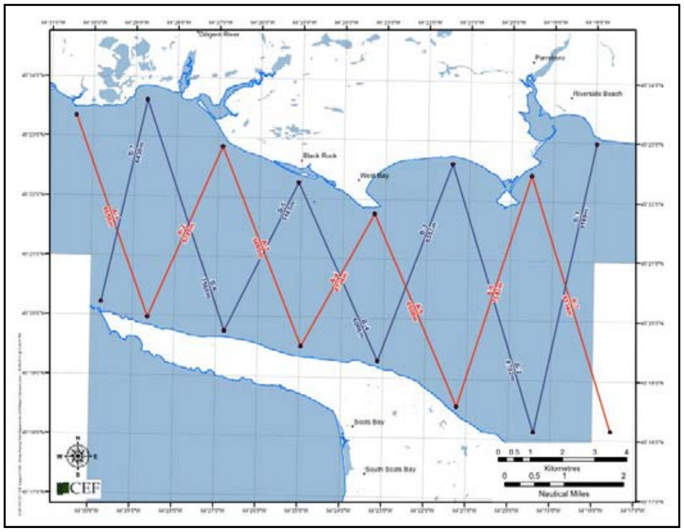


# Fish Surveys in Minas Channel

## Final Report on 2010 Surveys


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FORCE and NSPI

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## EXECUTIVE SUMMARY

Fish surveys were conducted from June to October of 2010 in Minas Channel using an 18.6 m stern trawler outfitted with a mid-water trawl and a hydroacoustic fish monitoring system. Surveys sampled acoustic backscatter from throughout the water column, which after editing was converted to fish density, and collected species and fish size from discrete depth intervals. The collection of fish and acoustics is common practice in the herring seining industry within the Bay of Fundy, but previous hydroacoustic surveys associated with assessment of tidal power generation had not caught fish within Minas Channel.

Fishing in the high tidal currents of Minas Channel is challenging, requiring appropriate gear and sufficient vessel horsepower. Apart from one or two small shore-based weirs, commercial fishing for finfish in Minas Channel is almost entirely restricted to herring seining when currents permit. Most herring seining occurs in and around Scotts Bay with a few excursions by seiners following schools into the channel. Commercial fishing for any species other than lobster is infrequent within the tidal power lease area.

The fish survey was intended to identify seasonal changes in fish distribution both spatially and vertically in the water column. The primary data collection method was hydroacoustics, which provided information on fish biomass seasonally and spatially, coupled with fishing to identify specific species and sizes of fish likely forming the acoustic targets. Initial survey trials to develop protocols were carried out in June with approximately bi-weekly surveys conforming to a consistent methodology conducted from July to October. The NSPI/OH turbine was in place within the tidal power lease area during these surveys. This report focuses on the joint interpretation of July to October acoustic and tow results, but also incorporates information from earlier 2010 surveys.

Permits were required to carry out net sampling with a midwater trawl in Minas Channel. Two permits were obtained from Fisheries & Oceans Canada for these studies: Permit #326039 was a Scientific Licence; and, Permit #326040 was a Species at Risk Act (SARA) Licence. No species listed under SARA were caught during any survey work in 2010.

Herring dominated the catch, especially in June and early July. The patchiness and dominance of herring in the data reduced the correlation between hydroacoustic data and biomass of non-herring species because they increased the probability that the beam of the sonar and the net sampled different densities of fish. Nonetheless, the quality of the data was considered good and there was reasonable consistency between catch data and the acoustic record for the water interval sampled by the net.

Herring, dollar fish, mackerel, gaspereau, smelt, and lump fish were the most consistent species caught. At times predominately bottom species, such as sea raven, summer flounder,

and winter skate were caught well above the bottom[1]. Gadoid (cod-like) fishes, including tom cod, silver hake, red hake, and pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm FL). Around 10 krill were also caught frequently in tows. The main seasonal change noted in catch was the decline in numbers of herring in July[2] and the catch of large striped bass and dogfish in September and October.

The midwater trawl and survey vessel worked well under difficult fishing conditions. The net was able to catch what appears to be a representative sample of species and size ranges regardless of tidal stage and current speed. The low number of large fish caught may have been due in part to the short duration of the tow. The high currents largely controlled the direction of tow, sometimes in hard to predict ways.

Key findings:

- Surveys found that fish were relatively evenly distributed throughout Minas Channel between July and October.
- Spatial differences were noted in gaspereau and dollar fish distributions, whereas mackerel showed distinct differences between day and night concentrations.
- The tidal power lease area had biomass densities similar to other parts of Minas Channel and was not found to be a specific migration or passage route for any species.
- Correlation between estimated acoustic biomass and catch biomass by tow was significant ($p<0.05$), but was clearly reduced by a few exceptional values.
- Major differences between tow and acoustic estimates of biomass were most probably a result of differences in catch and acoustic detection of herring and the patchiness of schools.
- The major components of finfish biomass in Minas Channel appear to be adult herring moving into the channel in June, followed by young herring in later July and August, gaspereau in September, and a broader mix of species leaving the upper Bay of Fundy in October.
- Both acoustic and tow data indicated a relatively even distribution of biomass throughout Minas Channel, with little spatial differences or concentration by species.
- Depth preferences were observed for some species but trends were not statistically significant or were heavily weighted by results from a single tow.

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[1] Juveniles of many bottom-associated species may be found higher in the water column at early life stages, but many of the individuals caught were not juveniles. For example, 3 of 7 sea raven and 2 of 14 summer flounder were greater than 30 cm in length.

[2] The abundance of adult herring has been reported to reach a maximum in July and early August in the inner Bay of Fundy (Melvin, G. pers. comm.)

- Tidal conditions were not a significant predictor of biomass, but the strong tidally-induced currents may have increased the variation and range in spatial and vertical fish distributions.
- Fish were acoustically observed moving upwards in the water column at night, but catches were higher during the day, suggesting visual cues increased catch efficiency.
- Mackerel catch was significantly different between day and night, as was acoustic biomass in the near bottom layer.

Further analysis of acoustic data, especially the data collected concurrently with tows, could be examined to evaluate target strength estimates for key species. Individual acoustic targets could be isolated and examined in more detail in an effort to associate acoustic targets with specific components of the catch.

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# 1 BACKGROUND

## 1.1 Purpose

The Upper Bay of Fundy is an important rearing, feeding and reproduction area for many fish species. Commercial species of importance include herring, dogfish, and flounder. Recreational species include striped bass, shad and in very limited numbers salmon. Most of these fish move in and out of the bay seasonally and would potentially pass through the tidal power lease/demonstration area in Minas Channel. Fish passing through this lease area could possibly interact with the underwater turbine units, referred to as Tidal In-Stream Energy Conversion (TISEC) devices. Thus, it is important to understand the relative numbers of fish passing through different areas and their distribution within the water column.

Fishing in the high tidal currents of Minas Channel is challenging, requiring appropriate gear and sufficient vessel horsepower. Apart from one or two small shore-based weirs, commercial fishing for finfish in Minas Channel is almost entirely restricted to herring seining when currents permit. Most herring seining occurs in and around Scotts Bay with a few excursions by seiners following schools into the channel. Commercial fishing for any species other than lobster is infrequent within the tidal power lease area.

Fish distribution studies conducted in 2010 were carried out to provide information on the relative density of fish moving in the bay through Minas Channel seasonally. Relative biomass and target depth in the water column were determined by hydroacoustic survey methods, while species and size was determined by fishing using midwater trawl.

## 1.2 Objective

The fish surveys were carried out to identify seasonal changes in fish distribution in three dimensions, between areas and vertically in the water column. Information collected could also shed light on migration paths, including depth intervals, used by major species migrating in and out of the Bay of Fundy through Minas Channel. The study aimed to identify relative densities of fish within Minas Channel and changes in abundance with respect to tides and season. The primary data collection method was hydroacoustics, but correlation with acoustic signals of fish species through sampling of fish was also an important part of this study.

These surveys are part of the Fundy Ocean Research Center for Energy's (FORCE) ongoing environmental effects monitoring program as part of the Environmental Assessment approval for the Fundy Tidal Energy Demonstration Project. It is part of longer term fish studies related to tidal power research to collect acoustic data, to test fish capture gear in strong current areas, and to monitor the environmental effects of tidal power generation within the Minas Basin. The high currents and tides present unique challenges and in many ways this work incorporates scientific research that will inform future EEM work.

## 1.3 This Report

This report includes detailed analysis of acoustic transect data and catch data from all 2010 fish surveys funded by the Fundy Ocean Research Centre for Energy (FORCE). Acoustic data collected along transects across Minas Channel are compared to catch from midwater tows and additional acoustic data collected over sections of the water column corresponding to that strained by the net. The NSPI/OH turbine was in place within the tidal power lease area during these surveys.

This report follows a preliminary report of findings based primarily on catch data. It briefly summarizes previous studies conducted in relation to tidal power in Minas Channel, but focuses on the 11 surveys completed between July and October, 2010. A database of all survey data, including survey logs, fish catch records, and trawl operating parameters for 92 separate tows has been assembled and will be made available through FORCE.

Generally speaking the midwater trawl used performed very well and caught a wide range of specimens, including very small (3 cm) to relatively large (70 cm) fish. Information presented focuses on the five species caught most consistently, but all species caught are described. Acoustic data from the eleven 14-transect surveys, as well as acoustic data collected concurrent with fishing, are also presented and analyzed.

## 1.4 Previous Surveys

Previous acoustic surveys of Minas Channel were conducted in August 2009 by the *MV Secord #1* and in April and May of 2010 by the herring seiner *Canada 100*. The zigzag transects were similar to those used in the current trial series but did not extend as close into shore.

The two acoustic surveys completed in April and May of 2010 along similar transects found lower biomass densities than trial surveys in June. All survey work in April and May was carried out during falling tide. Both surveys began in the dark and continued into daylight. In April, 3 of 10 surveys were run at night and in May, 5 of 10. April densities along transects ranged from 0.021 to 0.125 g/m$^2$ and in May they ranged from 0.003 to 0.473 g/m$^2$. Differences in the vertical distribution of biomass were noted, but no consistent difference was observed between night and daytime fish densities.

# 2 METHODS

## 2.1 Survey Components

### 2.1.1 Survey Design

Transects used in the surveys from June 2010 onward were closer spaced than earlier surveys and extended as close to shore as possible to detect nearshore migration of fish (Figure 2-1).

Earlier studies reported in Section 1.4 had a total of 10 transect lines and the trial survey had 14 over a similar area.

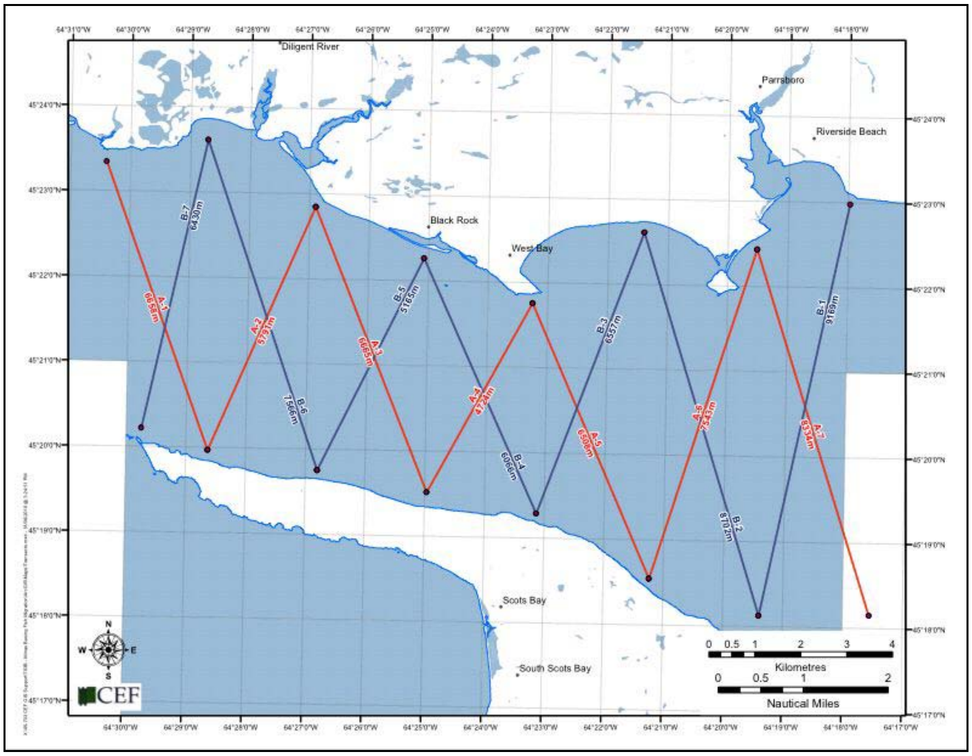



**Figure 2-1: Transect Layout for 2010 Surveys**

In relation to fish migration, many species are known to favour near shoreline areas for major migration paths (Jacques Whitford 2008; Parker et al. 2007; Jacobson et al. 2004). In early surveys more fish (in numbers caught) appeared to be found in the central deep water portion of Minas Channel (Figure 2-2). To determine if shoreline or central deep water channels were preferred by some species and not others, tows were generally made either near shore or in central deep water areas. However, the strong currents of the area tended to dictate the track of the tow regardless of its start location, thus positioning of the tow was only possible to a limited degree.

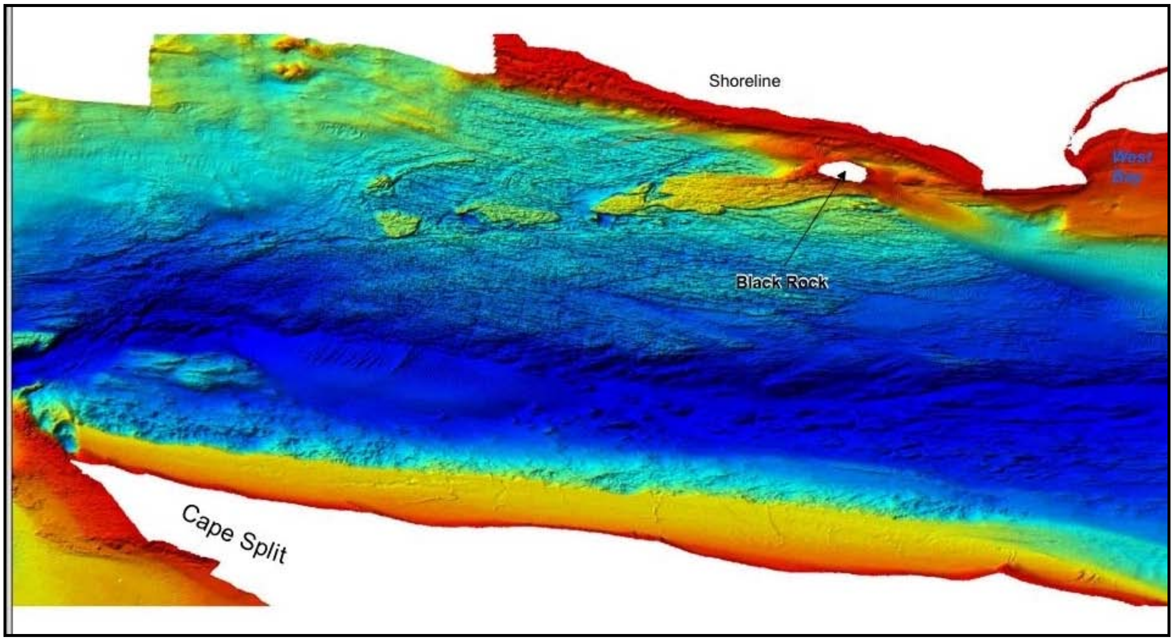



**Figure 2-2: Bathymetry of Minas Channel**

### 2.1.2 Analytical Methods

Guillard and Verges (2007) compared differences in biomass estimates in a small lake using different survey designs and statistical analyses. Sampling protocols, including zigzag, parallel and longitudinal transects, all produced comparable results; but autocorrelation between the data collected at the extremities of the zigzag transects could lead to difficulties in statistical analysis. Differences in acoustic biomass between day and night and in vertical distribution in the water column were statistically significant in the small lake studied. Similar comparisons seemed appropriate to the study in Minas Basin, with the addition of examining the potential effect of tidal conditions.

To reduce autocorrelation concerns and to reduce the volume of data analyzed, most statistical analyses of transect data were carried out on a randomly drawn 10% sample (by distance along a transect) of biomass from each of eleven surveys carried out from July to October.

### 2.1.3 Survey Equipment

The Carmelle #2 (Photo 2-1) was the survey vessel carrying out both the acoustics surveys and the midwater trawling. The Carmelle #2 is a 18.6 m LOA stern trawler of 63.8 tons and 442 HP with a 3.3 m draft. The vessel can sleep 5, has a hull speed of 10 knots, and is equipped with 2 hydraulic winches with a capacity of 500 fathoms (~ 915 m) of 1.4 cm wire rope on each drum. The vessel owner, Scotia Harvest Seafoods, owns the midwater trawl and has trawl monitoring equipment from CMC Electronics.

**Photo 2-1: The MV Carmelle #2**

The acoustic equipment used for these surveys was a Femto DE9320 Digital Echosounder. The data was logged to the computer hard-drive for post processing using the Femto Hydroacoustic Data Processing System (HDPS). The sounder was combined with a Furuno CA50B12, 50 kHz 12-degree transducer. The system output a 1.0mSec constant wave pulse at 60 ppm with a nominal output power of 1Kw. An acoustic ball calibration using a standard 38.1mm TG calibration sphere was performed by Femto Electronics on 17 June 2010 in Metaghan, Nova Scotia. Because profiling equipment was not available for sampling during surveys, estimated water column values for water temperature, mean depth, salinity and PH were fixed at 5 degrees, 40 meters, 32 ppt, and 8 respectively. Placement on the hull of the Carmelle 2 resulted in a 1.9 m offset plus an additional 3 m for 'ringdown' – thus data collection began approximately 5 m below the water surface. Similar equipment was used in the previous surveys aboard the fishing vessels *Secord* and *Canada 100*.

A midwater trawl equipped with gear monitoring sensors was used to sample fish identified by acoustic sampling. The midwater trawl had large mesh in the front of the trawl reducing progressively to 4 cm mesh, with 1.4 cm mesh in the codend. The net appeared to effectively catch fish in the 5 to 8 cm range and caught fish as small as 3 cm. All fish caught were identified to species, counted and fork length (FL) measured. In initial trial surveys large numbers of herring were enumerated by estimating total weight.

In June and July, most tows were conducted by interrupting an acoustic transect when a large group of targets was identified – a trawl was conducted at the appropriate depth interval to catch the fish associated with the acoustic targets. As the surveys progressed, fishing began to be carried out separately from the acoustic transects, with fishing carried out most often after one complete set of acoustic transects had been run (seven transects cover the channel and are considered a set, see Figure 2-1). In these latter cases a search was made for acoustic targets in areas near shore and in the deep central trough to identify appropriate tow locations.

The trawl used had a 15 m x 15 m mouth opening, which appeared appropriate for this work. When 45.7 m of warp were used, door spread indicated by the monitoring sensors was 30 to 35 m; fishing area is generally considered to extend from door to door. The doors for the midwater trawl are shown in Photo 2-2 and the net monitoring system display in Photo 2-3.

Logs were completed for both tows and acoustic transect surveys. All times were recorded in Atlantic Daylight Time. Transect logs recorded date, transect number, time every ten minutes, tide stage, ground speed, RPM and comments on relevant conditions such as weather or turbulence. Tow logs recorded date, time every 5 minutes, door spread, headline depth, warp out, ground speed, RPM, water depth, and comments.

**Photo 2-2: Trawl Door for the Midwater Trawl used on the Carmelle #2**


**Photo 2-3: Marport Trawl Sensor Monitoring Display**

### 2.1.4 Permitting

Permits were required to carry out net sampling with a midwater trawl in Minas Channel. Two permits were obtained from Fisheries & Oceans Canada for these studies: Permit #326039 was a Scientific Licence; and, Permit #326040 was a Species at Risk Act (SARA) Licence.

The Scientific Licence was issued pursuant to Section 52 of the Fishery General Regulations. It allowed CEF Consultants to determine the species and size of fish migrating in and out of the Minas Basin. The licence set out the vessel and type of gear, mesh size and established a maximum tow duration of 20 minutes. A report of species, number caught and size was required to be submitted immediately following each weekly survey.

The SARA licence considered the potential catch of at risk Inner Bay of Fundy Atlantic Salmon and set out provisions to minimize this risk. Requirements to minimize the potential capture of salmon included fishing at depths below 15 m and towing for no more than 20 minutes. Any mortality of an Atlantic salmon was required to be reported immediately – fortunately no salmon were captured. A comprehensive report was to be filed within 30 days of completion of the surveys.

## 2.2 Species Catchability

Since it is known that some species of fish are more easily caught by some fishing gear than others, the scientific literature on catchability of different species was reviewed. The primary reason for adjusting catch in most cases is to obtain more reliable population estimates by accounting for the differences in fishing efficiency for various species. The Minas Basin surveys are not intended to estimate populations but rather to identify relative seasonal movements of different species through the channel and differences in their vertical migrations. Nonetheless, catch and acoustic data were all converted to biomass for comparison. Thus, it is important to understand the magnitude of differences in catchability that might exist between different species, especially when comparing catch to acoustic data.

Table 2-1 provides coefficients from a review by Harley et al. (2001) to adjust catch for differences in relative catch success between trawls conducted in daylight and at night, and for differences in the relative catchability between species. These adjustments reflect differences between the biomass of the catch and the biomass of fish present in the area, and are based on vulnerability to the gear. Therefore, IYFS catchabilities combine the effect of probability of capture of fish in the path of the trawl with their vulnerability.

For example, the coefficient from the International Young Fish Survey (IYFS) is based on the use of midwater trawls and most bottom dwelling species like flounder are rarely present in the water fished by the trawl. Thus, the coefficient for this gear is extremely low because it largely reflects the small proportion of flounder that are in the trawl path. In the case of the Minas Channel surveys, however, we are not trying to estimate the population of fish over an extended area, but rather the biomass (or local abundance) within a column of water based on samples at a particular depth interval. Factors affecting the local probability of capture are different than those affecting the vulnerability to the gear, and include things like swimming speed and reaction to visual cues and/or noise.

**Table 2-1: Coefficients to Adjust Catch Between Night and Day and Between Species**

| Species | Diel $c_n$ | IYFS Catchability | Relative Catchability to Herring |
|---|---|---|---|
| Alewife | 1.00 | 0.257 | 1.00 |
| American plaice | 1.22 | 0.0438 | 0.171 |
| Atlantic cod | 1.00 | 0.561 | 2.183 |
| Atlantic herring | 1.00 | 0.257 | 1.00 |
| Sea raven | 0.57 | 0.561 | 2.183 |
| Silver hake | 1.00 | 0.13 | 0.506 |
| Spiny dogfish | 1.00 | 0.561 | 2.183 |
| Thorny skate | 0.38 | 0.0438 | 0.171 |
| Witch flounder | .90 | 0.0438 | 0.171 |

Source: Adapted from Harley et al. (2001)

The catchability coefficients indexed to herring are included in Table 2-1 because herring are the dominant species in overall catch in the Minas Channel surveys. As indicated, the adjustments for the various species of concern range from 0.171 to 2.183. The magnitude of the smaller coefficients almost certainly more influenced by the relative location of the fish and the gear (vulnerability) than the probability of capture for fish in the trawl path.

The diel coefficients in Table 2-1 come from Edwards (1968) and are proposed to convert biomass from trawls conducted at night to the equivalence of those carried out in daylight. The adjustments for day and night for the most abundant of our species are negligible. To obtain least-biased estimates of absolute (real) biomass, the caught biomass is divided by the IYFS catchability coefficient, and for night catches is further multiplied by the Diel ($C_n$) coefficient.

Mackerel are a potentially important species in Minas Channel but were not included in coefficients provided by Harvey et al. (2001). However, Deroba (2009) reviewed the catchability of mackerel in relation to US data from National Marine Fisheries bottom trawl surveys. Mackerel were assumed to have behaviour similar to herring in relation to door and net configurations. The behaviour of mackerel was also suggested to be similar to that of walleye pollock where catchability was greater during daylight when the fish were schooling, than during nighttime when the fish spread out to forage.

The coefficients for catchability reviewed here do not apply directly to the gear used in these surveys, but provide an indication of the likely magnitude of potential adjustments. As Benoit and Swain (2003) reported, small pelagic fishes, namely herring, alewife (gaspeareau), rainbow smelt, and mackerel, were all much more catchable during the day. The majority of flatfishes, all of the skates, and most of the sculpins had higher relative catchability during the night. Benoit and Swain (2003) also report length dependency in relative diel catchability in about half the species considered. Catchability for most species declines as fish length increases.

Overall, review of the literature did not identify variations in catchability for the various species caught in Minas Channel large enough to warrant adjustment in the catch, nor was it felt that the coefficients available were appropriate. For example, the low coefficient for flounder in Table 2-1 would not fully reflect the larger observed proportion of fish up in the water column due to high currents and upwelling found in Minas Channel. The available estimates, however, provide guidance in comparison of the results for the various species involved.

## 2.3 Comparing Acoustic and Catch Data

### 2.3.1 Net Monitoring Equipment

Many variables associated with fishing gear and vessel, including gear type, net opening, door spread, vessel, tow depth, and duration of tow, affect the quantity and quality of the catch. Some factors, such as gear, vessel and tow length, are key factors used to standardize effort between tows. Other variables may change between tows, such as effective fishing area of the net and the volume of water strained by the net, which can vary based on speed, warp length and currents. Of these, the effective net area likely has the largest effect, followed by the flow rate through the net, which determines the total volume strained.

The midwater trawl was equipped with a Marport system that reported trawl door, headline and bottomline performance. At times turbulence interfered with reception from the headline transmitter; in those cases the Vemco depth sensor provided headline depth data. The biggest advantage of the Marpot system when it operates well is that it allows the headline to be positioned at a particular depth layer to better sample targets being displayed on the hydroacoustic system.

The headline transducer did not provide reliable information on headline depth or net opening and a bottomline unit was not available during initial cruises. In July only trawl door operating parameters – depth, pitch and roll – were available. In early August two Vemco depth recorders were borrowed from DFO at Bedford Institute of Oceanography to record headline and bottomline performance for comparison with the door data. This comparison indicated the net opening remained generally consistent between 9 and 12 m, indicating good trawl performance, under all tow conditions.

The comparison of headline and bottomline depths helped establish the relationship between warp length and headline depth. In almost all tows a choice was made between three lengths of warp: 18.3, 45.7 or 91.5 m. While the door depth could be controlled by vessel speed, this comparison indicated that the headline of the net was only loosely correlated with door depth (Table 2-2). The primary factor affecting headline depth appeared to be warp length, with door depth only somewhat modifying the depth of the headline. In surveys following this comparison, warp length was used as the primary parameter determining desired fishing depth. While engine horsepower affected the depth of the doors to some degree, horsepower and rudder were primarily used to maintain a proper fishing configuration of the net.

**Table 2-2: Range of Headline Depths at Different Warp Lengths, August 10 and 11**

| Warp Length (m) | Range of Door Depth (m) | Range of Headline Depth (m) |
|---|---|---|
| 18.3 | 0.9 – 2.7 | 0.9 – 7.0 (average) |
| 45.7 | 5.1 – 17.4 | 10 .1 – 13.3 (average) |
| 91.5 | 23.8 – 31.0 | 20 – 31 (range) |

Note: Range of headline depth was based on averages within a tow, except for deeper tows where average values were not available.

Since the Vemco depth sensor had proven useful, the same type of sensor was purchased for use in the survey and used on most subsequent surveys. The disadvantage of this sensor is that it does not provide real time information; information can only be downloaded after the survey and analyzed. As a result, attempts continued to get the Marpot system to provide reliable information on headline and bottomline depth.

On September 1, a new Marport headline sensor provided a more consistent and reliable reading for the headline depth but did not appear to provide a reasonable figure for net opening based on the bottomline sensor. Comparison with the Vemco sensor on the bottomline again indicated that the net opening (in this case, the distance between the headline and bottomline) remained relatively consistent with door spread relative to the length of warp out. On September 16, further improvements were made to the Marport system and the system provided generally consistent and reliable readings for the headline depth and net opening for subsequent surveys.

The relative similarity of the catch between tows supports that fishing effort was quite consistent – duration of tow usually has the most influence on effort providing the net is in a proper fishing configuration. A flow meter was installed during the last survey to measure flow through the net to provide additional information on volume strained, but results were unreliable because the propeller did not appear always free to rotate. Further research to determine better installation methods for a flow meter should be undertaken in future surveys.

### 2.3.2 Determining Water Depth Fished

Determining the depth distribution of different fish species was an important aim of the study. Thus, an estimate of the depth interval sampled by the net was needed for all tows, particularly for comparison to the acoustic targets observed over the time of the tow by the sonar system. Warp length and door depth were the two parameters most often available for all tows, while headline depth was the next most frequently available and bottomline depth the next. Surveys conducted earlier in 2010 tended to have only warp length and door depth operating parameters available, while later surveys tended to have direct measurement of headline and bottomline depths in addition to other parameters. Linear regression was used to determine how well door depth and warp length could predict headline and bottomline depth.

Including tows carried out during trial surveys in June, 2010, a total of 96 tows had both door depth and headline depth while 116 tows had headline depth and warp length. Since the headline and door depths varied throughout a tow, the most consistent values over the two parts of the tow of longest duration were usually used for analysis. Warp length was fixed over a tow and known for all tows. Both door depth and warp length were statistically significant ($p<0.0001$) predictors of headline depth, but door depth explained 78.7% ($R^2$) of the variation in the data whereas warp length explained 65.7%. The relationship between door depth (m) and headline depth (m) is shown in Figure 2-3.

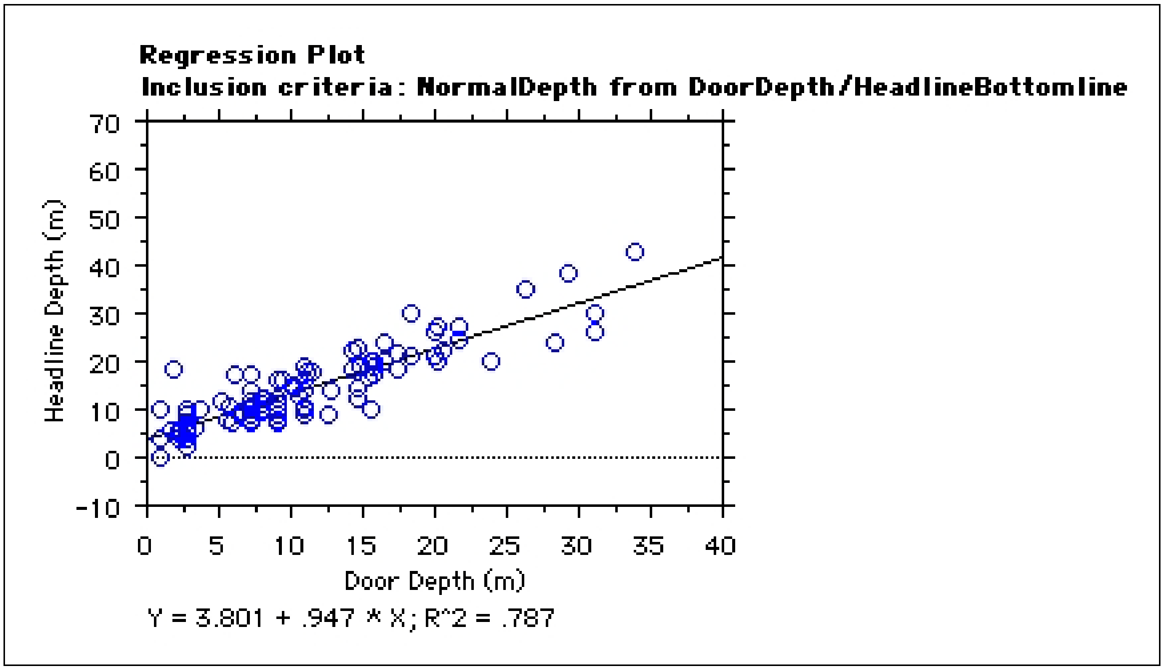



**Figure 2-3: Linear Relationship Between Headline Depth and Door Depth**

As Figure 2-3 illustrates, the fit of the data to the line was consistent over the range of depths. When both door depth and warp length were used to predict headline depth, $R^2$ increased to 0.892 and both variables were significant ($p<0.05$).

Headline and bottomline depth, or net opening, were directly related to warp length. As warp length increased, door spread increased resulting in a decrease in net opening (Figure 2-4). The linear equation predicting bottomline depth using both headline depth and warp length was significant (<0.05) and explained 89.2% ($R^2$) of the variation in the data. Note Figure 2-4 is shown to illustrate the effect of warp length on net opening, but the relationship by itself is not significant unless combined with door depth.

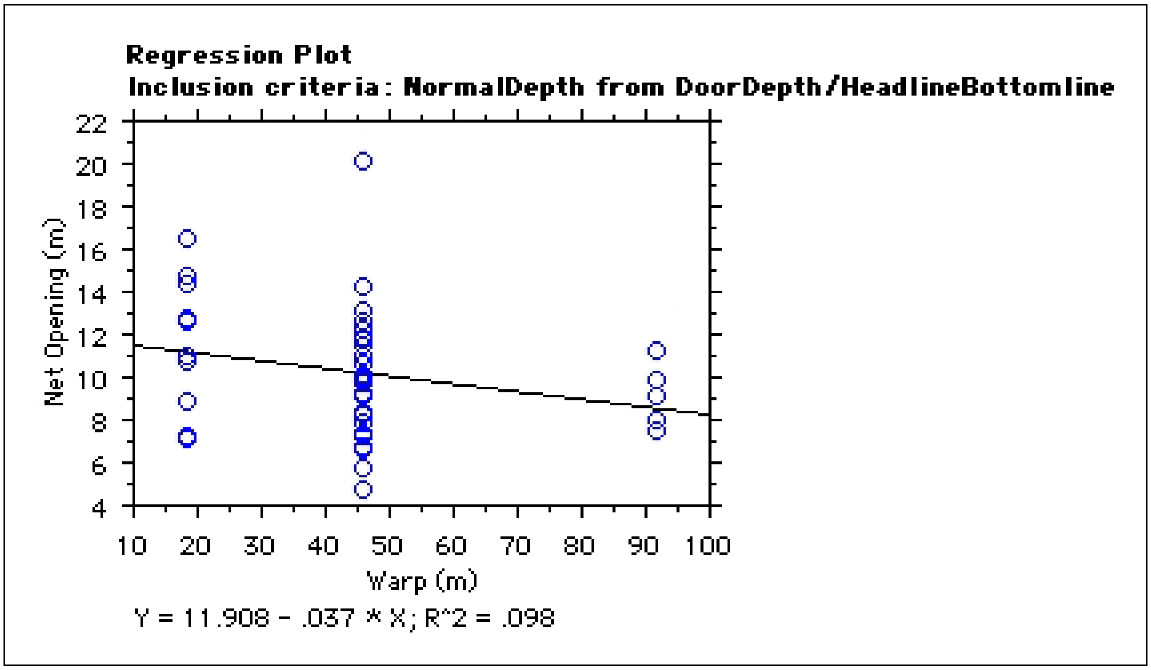



**Figure 2-4: Relationship Between Warp Length and Net Opening**

As indicated in Figure 2-4, net opening was more predictable when warp length was long; a short warp length was necessary to raise the net in the water and fish close to the surface but a short warp length also made the doors and net less stable.

Door depth and warp length were used to predict headline and bottomline depths where necessary to determine the appropriate depth interval for extraction of acoustic data collected during tows. Additional tow parameters that were used to determine the time interval between when a target appearing on the sonar record would be expected to enter the net were:

- vessel speed (6480 m/hr)
- length of warp (18 - 90 m)
- length of bridles (73 m)
- door spread (20 - 60 m)

The start of tow was considered to be the closest minute to when the desired length of warp had been released and the warp drums were locked in position. Considering these factors, a time delay of two minutes was used to match datasets between the noted start of the tow and the start of the acoustic data record.

### 2.3.3 Estimating Target Strength

The swim bladder is responsible for approximately 90-97% of acoustic energy reflected from a typical fish (Foote, 1980). The orientation of the fish within the sonar beam and changes in swim bladder volume with depth cause variations in target strength (TS). Thus target strengths of fish vary somewhat from study environment to study environment. In addition, the echo amplitude arising from a target of a given acoustic target strength will depend on the target's position with respect to the center of the acoustic beam, which in this case is 12 degrees.

Boswell et al. (2009) simulated the effects of fish orientation and length on acoustic biomass estimates based on data for Gulf menhaden. Target strength was based on:

$$TS = a \log_{10}(L) + b, \text{ where } a = 26.1,\ b = -65.6, \text{ and } L = \text{length in cm}$$

Other values for *b* in the above formula include -71.9 for herring and -84.9 for mackerel with the value of *a* remaining the same. The lack of a swim bladder in mackerel results in a lower target strength than for gadoids or herring.

Combined acoustic and trawl surveys have been conducted in the Barents Sea by Russia since 1982 (Shevelev et al. 1998). In 1995, echo intensities of cod, haddock and redfish were isolated into three length groups and relationships between length-weight and target strength developed. Mean echosounder target strength values *in situ* for cod and haddock of 16 and 40 cm length were determined to be about -46 and -38 dB, respectively.

Surveys found that the vertical distribution of fish by size class between the bottom and pelagic layers was due primarily to behaviour of fish at different sizes. Determining these types of vertical segregation of species or size classes of fish is important to allow interpretation of acoustic information.

To arrive at a calculated biomass for catch for comparison to the acoustic biomass measured during tows, the target strength for most species of fish was estimated using a value of 16.5 for *a*, and -65.6 for *b* to match the TS of -46 and -38 dB from Shevelev for cod and haddock. A value of 26.1 for *a* was used for herring and a value of -84.9 for *b* for mackerel.

In the Boswell et al. (2010) study, target strengths in dB were converted to equivalent backscattering cross section by:

$$\text{Sigma} = 10^{TS/10}$$

The backscattering cross section is a linear function and can be summed to provide a total number for a tow that should be proportion to the acoustic biomass, assuming the mix of fish is consistent. This formula was used to calculate what is referred to in this report as the calculated (from catch) and/or acoustic biomass expressed in $g/m^2$.

### 2.3.4 Processing Sonar Data

Echo targets recorded by the acoustic system were reported as Sa in dB. Sa was determined by summing the (linear) Volume Scattering Coefficients (Sv) and converting them to Sa for each ping by multiplying by the sample interval in meters and then converting to dB. Following this calculation for each ping, the (linear) average was calculated over a number of pings based on "good" navigation fixes, with generally 10 fixes per interval. This averaging was done to remove navigation jitter due to GPS resolution and precision.

A distance weighted mean of all (linear) interval Sas was calculated to get a single distance weighted Sa in dB for a particular transect, tow, etc., depending on the particular analyses to be conducted. This algorithm was selected because it was the most efficient and least affected by navigation inaccuracies.

A value of -199.9 was selected to represent the equivalent of zero targets as a minimum Sv level. If an interval has a value -90 dB and all the remaining have no targets and are thus represented by -199.9, the linear mean distance weighted Sa converted to dB will be between -90 and -199.9 depending on how many intervals are in the transect.

Volume backscattering strength in decibels was converted to volume backscattering cross section, which is a linear measure. Once the backscatter is in a linear form it should be proportional to biomass provided the fish mixture remains the same. A proportionality factor, i.e., so many g of biomass per unit backscattering cross section, can be used to adjust backscatter based on a mix of fish consistent in species and size over transect lines. No proportionality factor was used because an appropriate methodology has not yet been developed. Part of the study was intended to examine whether adjustments for species mix would significantly affect interpretation of results.

### 2.3.5 Estimating Biomass

Obtaining biomass estimates from the acoustic data over the duration of the tow was straightforward. The start and end time of the acoustic data section comparable to the section of water actively fished by the net was determined from the tow log. A lag time of two minutes was used to account for the distance between the acoustic beam and the front of the net (headline). The depth interval from which targets were extracted was determined from the best estimate of headline and bottomline depth. The resulting vertically integrated backscatter was determined over the net sampling depth, then averaged over the length of the tow and subsequently converted to decibel form by Femto. This backscatter value was converted to biomass using the Sigma equation in the previous section.

Converting trawl catch to a biomass estimate equivalent to the acoustic estimate required consideration of different target strengths between species and size of the fish (length). Appropriate target strength (TS) versus length relations for each biological component were needed to compute an overall estimate of acoustic backscattering cross section per unit of biomass. Major differences in target strength between some species are known, for example, mackerel and dogfish are known to have lower target strengths than other species that possess a swim bladder. For this study, target strengths were estimated by the TS equation in the previous section for three major groups of fish caught, namely:

- herring (using a = 26.1 and b = -65.6)
- cod, haddock and most other species (using a = 16.5 and b = -65.6)
- mackerel (using a = 26.1 and b = -84.9)

Using the above formula, estimates of target strength were calculated for each size class of fish at 2 to 4 cm length intervals. Once a target strength was obtained, it was converted to a biomass estimate using the Sigma formula in the previous section and multiplied by the number of fish in that size class. All biomass numbers for all species and size classes were summed to provide an estimated total biomass for the tow.

These TS estimates were general approximations based on literature values. Special consideration was made for dogfish based on review of the literature. Using the mackerel equation for TS for dogfish would have produced a value of -37 dB, but a TS value of -30 dB was used based on a report by O'Driscoll (2004). Cochrane (pers. comm.) suggested a value of -49 dB would be more appropriate for the size of the fish (66-69 cm) based on other literature. Consideration of how these different values of TS for dogfish effect estimates of overall biomass helps clarify the influence of individual fish on summed tow biomass. Only three dogfish were caught during the survey program and all three were caught in a single tow on October 25. Reduction in the target strength for dogfish would have reduced the biomass estimate for that tow from 0.00419 to 0.00123 g/m$^2$. Overall, total biomass values in any one tow ranged from 1.65 to 0.000005 g/m$^2$ and the effect of the different target strength values was relatively small in comparison to this range.

More analyses of acoustic targets collected concurrent to trawling could be used to investigate the suitability of these target strength estimates and possible variation between species, but this work was not carried out. The emphasis was to develop estimates of biomass that were comparable in magnitude to that collected during acoustic transects, but were not intended to estimate population biomass.

Biomass estimates were reported in square metres rather than adjusting them to reflect a specific volume of water. This suggests that the biomass is evenly distributed over a column of water from the surface to the bottom regardless of the particular depth interval selected. Corrections for volume would be required if estimates of population biomass were desired.

Additional adjustments to biomass numbers were not made for species catchability, trawl parameters or species mix. Adjustments for net performance were not made because monitoring equipment had indicated that net opening was relatively consistent and no clear relationship could be determined between trawl parameters and size of catch or size of fish caught. Adjustments for catchability were not made because coefficients for catchability by species and size were not appropriate for the conditions encountered in Minas Channel. Adjustments to acoustic backscatter estimates based on species mix were not made because consistent relationships between survey factors, such as light, water depth or tide, and species mix were not established in the analyses conducted. Adjustment for either catchability or trawl parameters was considered unlikely to result in changes to magnitude of biomass estimates sufficiently large to affect the results from analyses conducted.

# 3 INITIAL TRIAL SURVEYS

Two trial surveys were conducted in June of 2010 to determine parameters for a longer-term survey. An initial requirement was to determine if the midwater trawl available to the Carmelle #2 could adequately catch fish in the strong and variable currents of Minas Channel.

## 3.1 First Survey

The first trial survey took place on June 19. The emphasis in this first survey was to determine if the midwater trawl could be fished effectively and if the hydroacoustic system would provide data relatively free of turbulence. At Parrsboro, high tide was at 06:46 (all times are in ADT) and low tide at 12:59. An initial tow was carried out at 08:30 during a strong ebb tide to test the net and net monitoring equipment. The tow was conducted on the eastern side of the survey area in 90 m of water with the headline at depths of 30 to 50 m and door spread of 30 to 55 m.

The tow was conducted into the tidal current and the vessel had a negative ground speed during the tow. The tow was continued for about 35 minutes as the effects of changes in warp length and ship speed on the net were evaluated. Catch in the initial tow is provided in Table 3-1.

**Table 3-1: Catch in Initial Tow of First Survey, June 19**

| Quantity | Species | Length (cm) |
|---|---|---|
| 1 | Dollar fish | 10 |
| 2 | Silver hake | 18 |
| 1 | Sea raven | 30 |
| 1 | Herring | 22 |
| 1 | Mackerel | 20 |
| 3 | Tomcod | 8, 10, 25 |
| 1 | Gaspereau | 30 |
| 3 | Summer flounder | 25 |
| 2 | Winter skate | 35 |

Note: A single length indicates all fish were the same size.

After the initial tow, acoustic transects were run between 09:50 and 16:15. A second tow was carried out at 10:50 as the vessel was part way along Transect A3 to investigate surface to bottom blue 'haze' on the echo sounder similar to that shown in Figure 3-1. The source of the haze was not determined but it did not recur often and did not appear to have an important effect on data analysis. System gain was not changed nor was a signal threshold increased to remove the "haze". For reference, water depth in Figure 3-1 ranged from about 10 m to 120 m. The blank data space at the top of the record represents the transducer offset of 1.9 m below the water surface plus approximately 3 m for 'ringdown' where reliable data cannot be obtained..

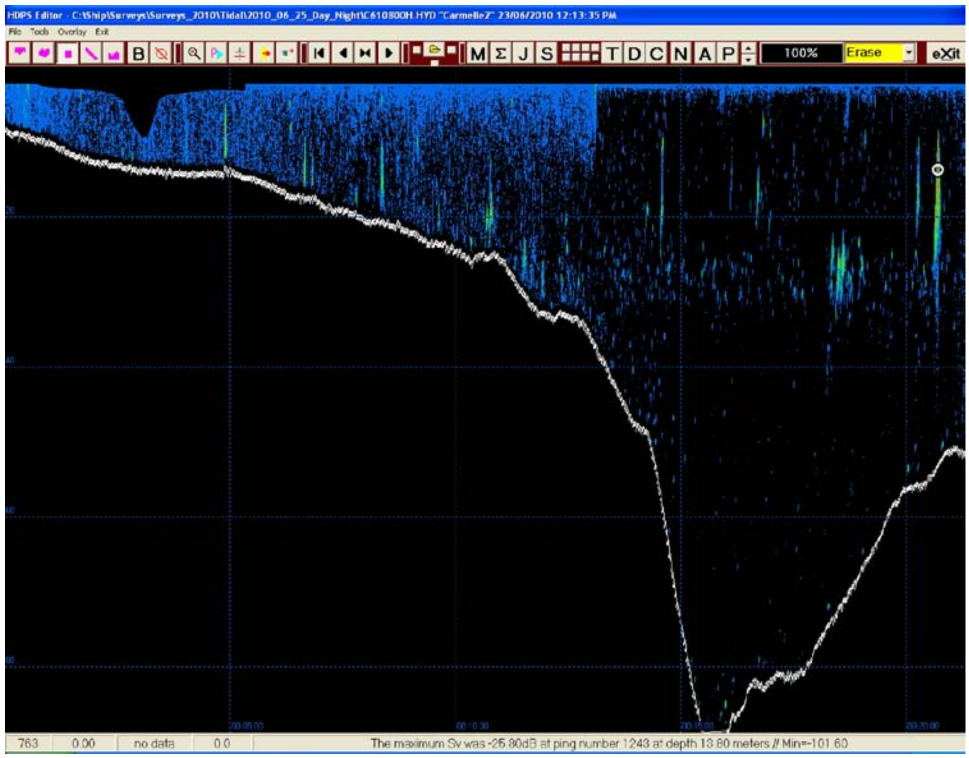



**Figure 3-1: An Echogram Showing Blue Haze (left) and Typical Targets (right)**

The second tow was carried out in 85 m of water with an initial depth of doors at 35 m. Approximately 10 minutes into the tow the doors dropped to 50 m in 65 m of water and the net touched bottom, indicated by a small tug on the vessel. The net was immediately retrieved but it had a large rip in the bottom. Catch consisted of one small sea raven and one dogfish. Further fishing was not possible but acoustic transects were continued beginning near Cape Split (B7) until tide was high enough to allow docking at the wharf at the end of the next rising tide. The net was taken to Dartmouth for repair.

Even though the net was damaged, the first survey had met the survey objective – it was demonstrated that the midwater trawl could effectively catch a wide range of species under the difficult conditions found in Minas Channel. In addition, fishing techniques were identified that would avoid future net damage. The hydroacoustic system was also shown to provide relatively clean imaging, free from interference of turbulence.

## 3.2 Second Survey

The second survey took place between 12:00 June 24 and 21:00 June 25, 2010. The net was repaired and in good working order for these trials. However, tides were high and the weather was poor with winds from the southwest resulting in heavy turbulence for much of the survey. The turbulence made conditions poor for collection of acoustic data. Turbulence[3] was visible on the echo sounder extending 5 to 15 m below the transducer over a large proportion of the transect lines run in the outer portion of the survey area (near Cape Split). For this reason, most analysis was focused on the inner portion of the survey area (between Parrsboro and Cape Blomidon) where turbulence was generally less.

It should be noted that the vessel was not a major source of turbulence. Observation suggested that waves would entrain air bubbles and the strong current eddies would carry these air bubbles downward throughout the surface layer of water. Vessel speed or direction had little, if any, influence on the appearance of the turbulence on the echo sounder.

A total of 32 transect lines were run and 9 tows conducted. The midwater trawl was fished with variations in net floatation, weight and warp length. Typically three spherical floats were attached to each edge of the headline and heavy steel weights to the edge of the bottom line. Initially the headline transducer indicated the net was deeper than the doors. The additional floats were removed and bottomline weight reduced to allow the net to fish more in line with the depth of the doors for the third tow. Combinations of floatation and weights were tested but the headline transducer did not provide consistently useful information concerning the configuration of the net. Door sensors reliably transmitted depth, spread and orientation.

## 3.3 Differences in Acoustic Backscatter Between Night and Day

During the second survey, transects were run during different tides and during day and night. Unfortunately the wind came up the evening of June 24 and considerable turbulence impaired data quality between 20:00 June 24 and 11:00 June 25. Acoustic biomass along transects surveyed in the day and in the night were compared in the eastern portion of the survey area (Figure 3-2) to minimize the impact of the turbulence. Data from eight transects run in the daytime and three night transects were available for comparison. Acoustic biomass density was 0.016 kg/m$^2$ in day transects and 0.012 kg/m$^2$ in night transects (Clay 2010e).

[3] Turbulence, as used in this report, is a distinctly different phenomenon from the "blue haze" illustrated in Figure 3-1. Turbulence is characterized by higher signal strengths resulting in display colours ranging from primarily yellow (moderate strength) to spots of red (high strength) and it emanates from the surface in a series of coherent downward spikes. It is likely generated by small air bubbles entrained in the water by wave and current action.

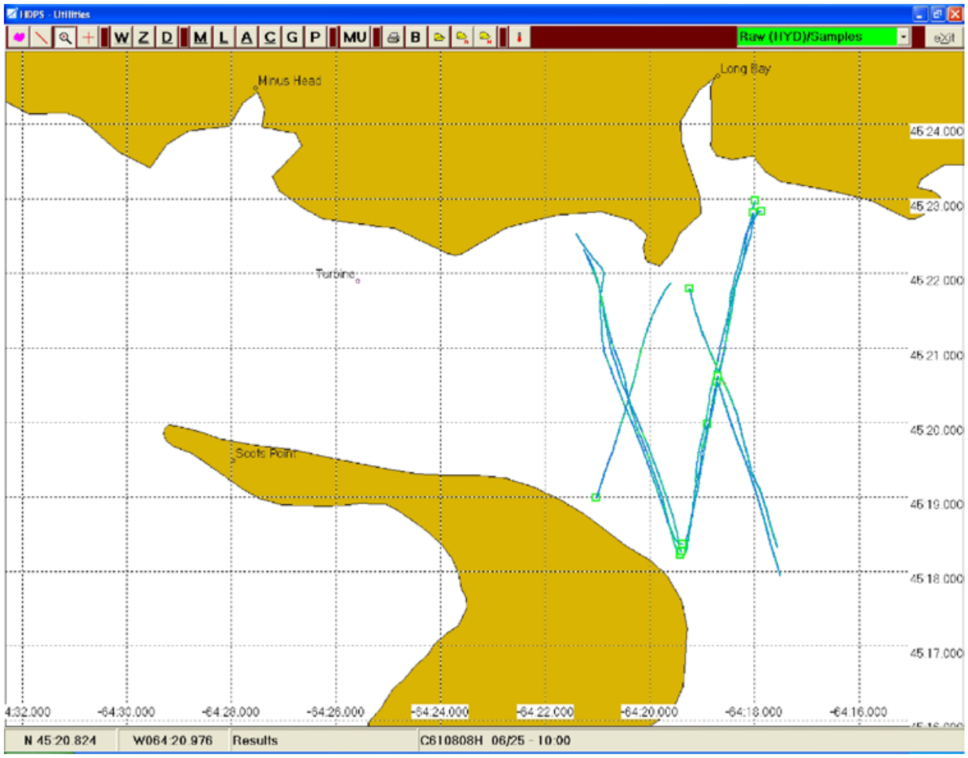
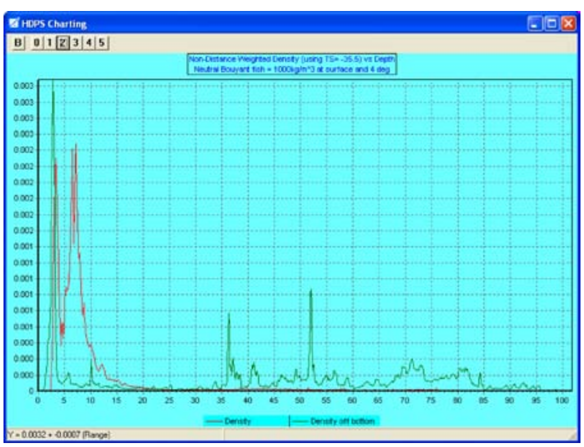



**Figure 3-2: Day and Night Transects in the Eastern Survey Area**

While the density of acoustic targets was not significantly different (ANOVA, p=0.34), there was more difference due to location of targets in the water column. Figures 3-3 and 3-4 illustrate the overall depth of targets from the transducer in night and day transects, respectively. Note the red line indicates the change in target density (kg/m$^3$) from the surface down while the green line indicates target density from the bottom up.



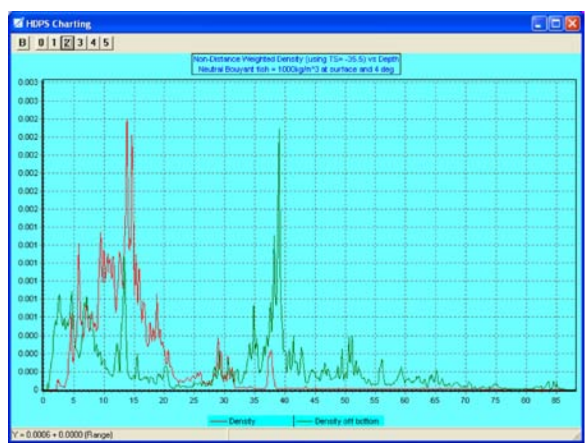




**Figure 3-3: Night Time Depth of Targets** **Figure 3-4: Day Time Depth of Targets**

Figures 3-3 and 3-4 illustrate the general upward shift in acoustic target density at night (vertical scale), especially near the surface in the upper 20 m of the water column (horizontal scale). Depth to the center of mass[4] of daytime transects was 14.8 meters and for nighttime 10.1 meters. In the daytime, targets were more widely dispersed in the water column and there were more targets observed near bottom. This observation would be consistent with a general trend in fish behaviour of fish moving up off the bottom at night.

## 3.4 Comparison of Catch and Acoustics Data

Midwater trawls were carried out throughout the survey area (Figure 3-5). Generally a tow was made when a group of targets considered to represent fish were observed during a transect. The final tow, Tow #9, was carried out in an area where few but distinct low amplitude targets were observed, which were presumed not to be fish, for comparison to other tow results. Efforts were also made to carry out tows in different parts of the survey area under different tide and wind conditions.

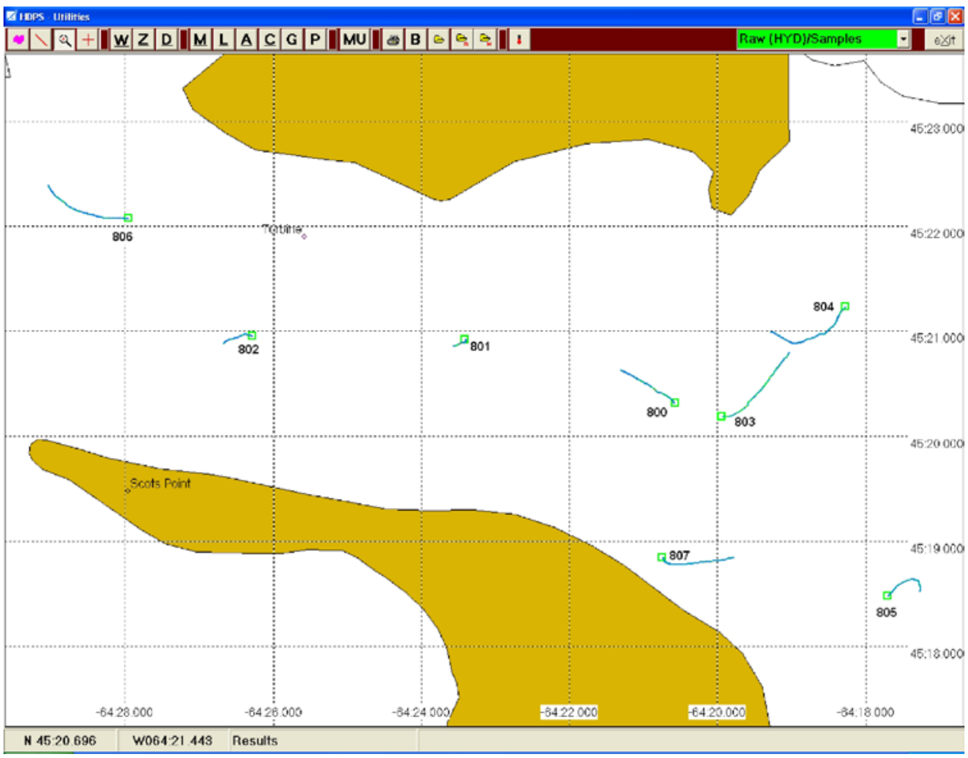



**Figure 3-5: Location of Tows, June 24 and 25**

Generally the acoustic biomass density during tows was higher than that found on a typical transect (Table 3-2), indicating that the vessel was successful at carrying out tows in locations of higher acoustic biomass density. The acoustic biomass in Table 3-2 was determined for the entire water column because in these early surveys a reliable estimate of

[4] Depth to the centre of mass is calculated by multiplying the linear volume scattering coefficient at each sample by the depth of that sample; then dividing the result by the sum of all the linear volume scattering coefficients.

the depth interval sampled by the net was not yet available. However, the tow was made at the depth interval where most targets were observed. . It should be noted that the low biomass density of Tow 9 was intentional for comparison to other tow results.

**Table 3-2: Catch and Acoustic Biomass by Tow, June 24 and 25**

| Date | Tow # | Transect # | Acoustic Biomass (kg/m$^2$) | Total Catch (kg) |
|---|---|---|---|---|
| June 24 | Tow 1 | 800 | 0.127351 | .2 |
| | Tow 2 | 801 | 0.572319 | 100 |
| | Tow 3 | 802 | 0.114551 | 50 |
| | Tow 4 - bad deployment | | | |
| June 25 | Tow 5 | 803 | 0.124851 | 15 |
| | Tow 6 | 804 | 0.003507 | 15 |
| | Tow 7 | 805 | 0.065824 | 12 |
| | Tow 8 | 806 | 0.138374 | 75 |
| | Tow 9 | 807 | 0.000741 | .05 |

The catch was significantly correlated with the acoustic biomass density ($p=0.02$, $r^2=0.63$). The catch in Tow 1 may have been low due to net malfuction; if data from Tow 1 is excluded from the analysis, $r^2$ increases to 0.70.

Variations in net flotation, weight and warp length and poor reception of headline information likely reduced the correlation between acoustic biomass and catch, as well as reduced the ability to target a specific portion of the water column. Nonetheless, data quality was adequate and can be improved upon in future surveys.

The catch was almost exclusively herring in weight and numbers, but a number of other species were also caught (Table 3-3).

**Table 3-3: Catch in Tows During Survey 2, June 24 and 25**

| Date | Tow No. | Time | Catch |
|---|---|---|---|
| June 24 | 1 | 1355 to 1415 | 22 herring |
| | 2 | 1710 to 1732 | 90 kg of herring, 5 mackerel |
| | 3 | 1900 to 1920 | 45 kg of herring |
| | 4 | | No catch, bad deployment |
| June 25 | 5 | 1104 to 1125 | 15 kg of herring, 1 mackerel, 1 smelt |
| | 6 | 1245 to 1306 | 15 kg of herring, 2 mackerel |
| | 7 | 1402 to 1425 | 10 kg of herring, 1 mackerel, 1 lump fish, 1 dollar fish |
| | 8 | 1902 to 1923 | 70 kg of herring, 2 smelt |
| | 9 | 2028 to 2050 | 2 silver hake, 1 smelt |

The small catch in the first tow likely resulted from a tangle in the bottom line as the net was being deployed. Sensors indicated the net was not fishing properly and when the net was retrieved a small hole in the second belly was found and repaired. No further net damage was experienced but the doors would not assume an appropriate position during Tow #4 and no catch was obtained.

Herring were consistently caught regardless of the variations in net configuration or locations and timing of tows. Other species, such as mackerel, are likely more difficult to catch so the proportion of species in the catch is not likely a direct ratio of what is in the water column[5]. Duration of tow also affects the selectivity of the gear with shorter tows lessening the catch of faster and larger fish. The trawl doors act as initial herding cues and thus the alignment of the net behind the doors can also affect the selectivity of the gear.

## 3.5 Components of a Typical Survey

Based on results from the trial surveys conducted in June, a series of surveys were planned and conducted at regular intervals from July to October. Surveys were generally spaced by between 6 and 14 days. All surveys, except one that was carried out from Halls Harbour, were conducted from the Minas Basin Pulp & Power wharf in Hantsport. As in the trial surveys, all routine surveys were performed by the trawler Carmelle #2 using a midwater trawl, with acoustic data collected by the Femto DE9320 echosounder system. Based on the results of trial surveys conducted in June of 2010 and earlier acoustic surveys, combined trawling and acoustic transect surveys incorporated:

- both day and night transects; and,

[5] Catchability coefficients are commonly used to adjust catch in trawls by species, but appropriate coefficients for the mid-water trawl used in this survey are unknown. No adjustment for catchability differences among species was done in this report.

- day and night fishing of selected target groups.

Available information suggested that efforts should be made to survey the outer portion of the survey area near Cape Split at slack tide to minimize the potential problems of turbulence in this area. This was facilitated by running transect lines from east to west on the falling tide and from west to east on the rising tide.

A typical survey required 21 hours from wharf to wharf to allow sufficient time to travel between Hantsport and the survey area and to complete a full survey under different tides as well as fishing within day and night periods. The balance of effort between night and day work was influenced by the timing of high tides for departure and arrival at the wharf. The trip from Hantsport to and from the survey area required about 1.5 hours with the appropriate tide.

# 4 SURVEY RESULTS

Following the trial surveys, hydroacoustic data were collected and uploaded to the Femto ftp site but not processed until late in 2010. Thus preliminary reports on the routine surveys conducted between July and October were focused almost entirely on fish catch and trawl performance. Table 4-1 outlines the number of surveys and tows carried out from July to October.

**Table 4-1: Numbers and Surveys and Tows by Month in 2010**

| Month | Survey Dates | Number of Surveys | Number of Tows |
|---|---|---|---|
| July | July 12 | 1 | 5 |
| | July 21-22 | 1 | 9 |
| | July 26-27 | 1 | 8 |
| August | August 10-11 | 1 | 7 |
| | August 19-20 | 1 | 10 |
| | August 24-25 | 1 | 9 |
| September | September 1-2 | 1 | 10 |
| | September 16-17 | 1 | 9 |
| | September 30- | 1 | 2 |
| October | October 1 | | 8 |
| | October 5-6 | 1 | 8 |
| | October 25-26 | 1 | 7 |
| Totals | | 11 | 92 |

The trial surveys carried out in June were undertaken at a time when herring were abundant in the Minas Channel and were discussed fully in Section 3. Estimates of acoustic biomass indicate that herring biomass was substantially higher in June than earlier or later in the season. Emphasis in this section is on the main surveys carried out July to October, 2010 and focuses on a wider range of species.

The acoustic data quality is affected by turbulence, which at times obscured the acoustic record from surface to bottom. Heavy turbulence was associated with either wind and waves or high tidal currents. It appeared that deep eddies, when tidal currents were particularly strong, could induce heavy turbulence similar to that produced by wind and waves. As a result, turbulence was hard to predict and did not always occur in similar areas. Turbulence has been removed from the acoustic data by visual inspection of the echogram. The resulting information is considered to be relatively free of the effects of turbulence.

## 4.1 Seasonal Trends in Acoustic Transects

All acoustic transect data was divided into three depth intervals: 1-14.9 m; 15- 29.9 m and 30-44.9 m, as well as a layer 15 m off bottom and an integrated total depth interval. Table 4-2 provides the mean backscatter (Sa in dB) averaged from each survey transect for the three upper depth intervals.

**Table 4-2: Relative Backscatter (Sa) at Depth Intervals by Survey**

| | Backscatter (Sa in dB) | | |
|---|---|---|---|
| **Survey** | **Depth 1-14.9 m** | **Depth 15-29.9 m** | **Depth 30-44.9 m** |
| July 12 | -98.037 | -109.177 | -147.269 |
| July 21 | -76.328 | -80.870 | -80.266 |
| July 26 | -79.434 | -77.826 | -91.326 |
| August 10 | -71.705 | -78.227 | -92.190 |
| August 19 | -68.831 | -75.7999 | -91.359 |
| August 24 | -81.611 | -81.098 | -95.510 |
| September 1 | -80.897 | -75.195 | -92.186 |
| September 16 | -72.550 | -73.236 | -86.825 |
| September 30 | -83.364 | -74.792 | -88.811 |
| October 5 | -70.509 | -69.834 | -98.103 |
| October 25 | -83.380 | -79.036 | -96.333 |

In Table 4-2 the higher backscatter levels are indicated in red and yellow, with red the highest. The higher backscatter levels shift from the surface 15 m to the intermediate 15 to 30 m depths as the season progresses, moving deeper after the end of August. The potential affect of tide and light conditions are described later in this section. Backscatter levels during the August 24 survey were lower than surveys earlier or later in the summer, indicating a mid-summer trough in fish biomass.

Figure 4-1 illustrates the seasonal change in surveys by depth interval when backscatter is converted to an equivalent acoustic biomass ($g/m^2$). The term equivalent biomass is used to indicate that the conversions used attempt to make acoustic and catch numbers equivalent and comparable to each other but may not reflect true biomass because of the mix of species observed and limited background information on target strength. A seasonal shift in biomass is observed from the surface layer (0-14.9 m) to the intermediate layer (15-29.9 m) and possibly deeper as well.

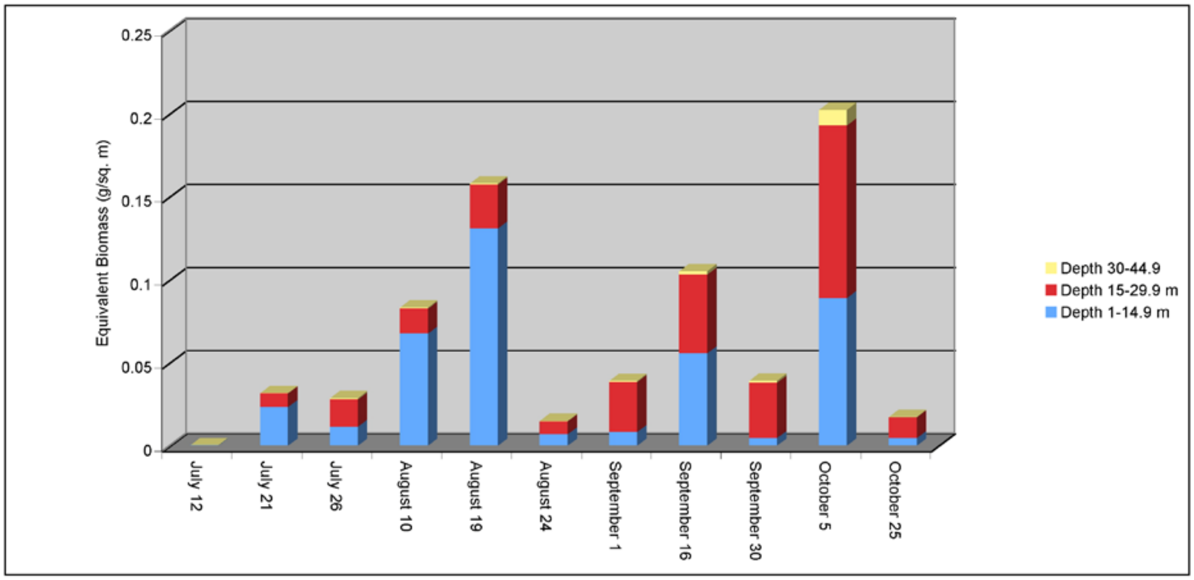



**Figure 4-1: Comparison of Acoustic Biomass by Depth Interval Between Surveys**

## 4.2 Species Composition

Herring, dollar fish, mackerel, gaspereau, smelt and lump fish were the most consistent species caught. At times predominately bottom species, such as sea raven, summer flounder, and winter skate were caught well above the bottom. Gadoid (cod-like) fishes, including tom cod, silver hake, red hake, and pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm FL). Around 10 krill[6] were also caught frequently in tows.

The relative abundance of different species of fish changed seasonally. Total catch in all tows by month is provided in Table 4-3 for the most common species caught. Herring, by far, outnumbers all other species caught in the spring, with herring catch beginning to drop in July. In October, when most herring are thought to leave Minas Basin, herring still make up the largest single component in most tows, but have dropped to about 7% of their June average.

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[6] Krill were not likely identified as targets by the 38 kHz echosounder unless tightly aggregated.

**Table 4-3: Monthly Total Catch in Tows by Selected Species**

| | Species (number of fish) | | | | | |
|---|---|---|---|---|---|---|
| **Month** | **Herring** | **Dollar fish** | **Mackerel** | **Gaspereau** | **Smelt** | **Lump fish** |
| June | 8096 | 1 | 9 | 0 | 4 | 1 |
| July | 5749 | 151 | 20 | 17 | 31 | 0 |
| August | 1047 | 431 | 167 | 100 | 173 | 5 |
| September | 1335 | 36 | 55 | 24 | 12 | 6 |
| October | 582 | 13 | 42 | 8 | 3 | 7 |

The average catch per tow shows a greater dominance of herring in June than in other months (Figure 4-2).

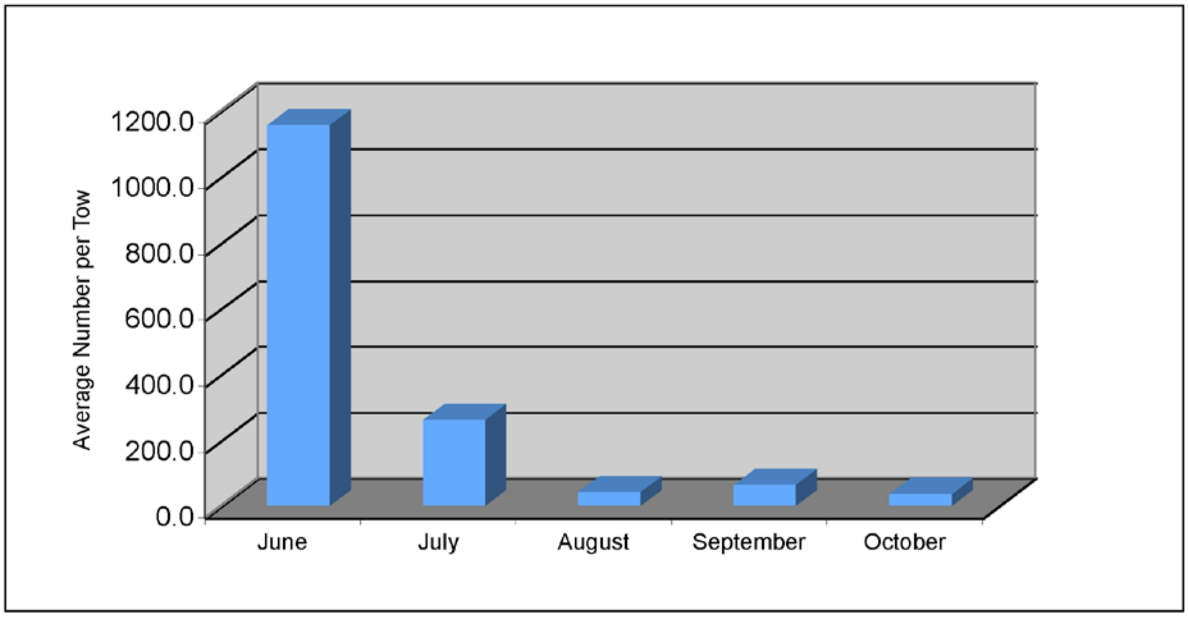


**Figure 4-2: Average Number of Herring Caught per Tow by Month**

The seasonal distribution for other species is generally different than that of herring – other species tend to be most abundant in August (Figure 4-3). Dollar fish tended to dominate the catch in July and August. No gaspereau were caught in June and no lump fish were caught in July, but other species listed in Figure 4-3 were caught in some numbers throughout the season.

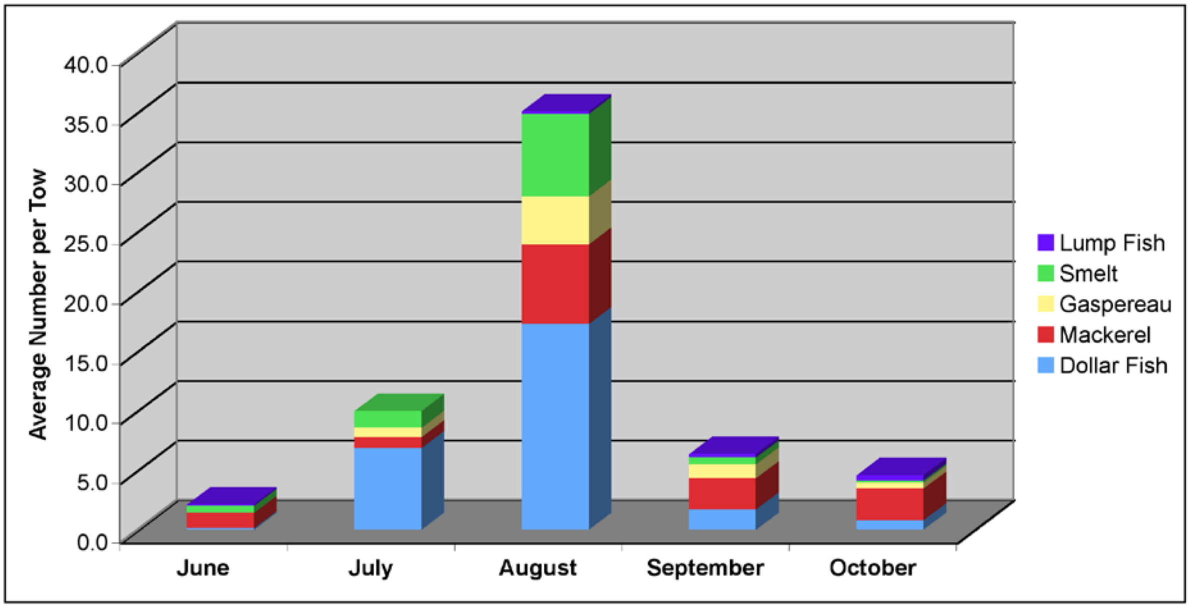


**Figure 4-3: Average Number Caught by Species (except herring) per Tow by Month**

Figure 4-4 illustrates the same catch data converted to equivalent biomass[7] by survey without correcting for catchability. Note that the large herring catch on July 12 is shown truncated to improve clarity in the relative catch in other surveys and of other species. Mackerel abundance showed the largest difference in the catch composition, largely because of the low target strength of mackerel. Dollar fish form a high proportion of the biomass in August, with a gradual shift to gaspereau in late August and September.

[7] The biomass units are reported in $g/m^2$ because corrections were not made for sampling volume, however, sampling volume of the net appeared sufficiently consistent that comparison of catch between tows was realistic.

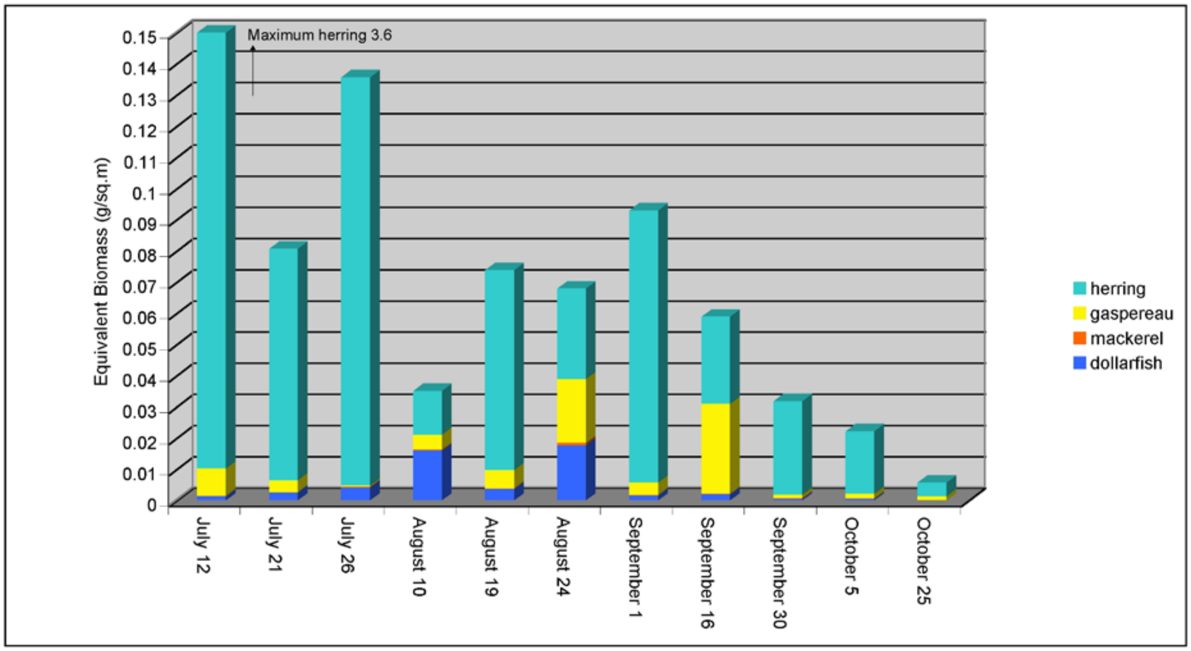


**Figure 4-4: Calculated Biomass of Catch by Major Species and Survey**

Surveys likely missed spring migrations into Minas Basin. Shad, striped bass and larger gaspereau known to move through Minas Channel early in the season were not sampled.

## 4.2.1 Length Frequency

Some of the species passing through the Minas Channel spawn in the area and length frequencies in the catch tend to be bimodal, representing older spawning fish and younger juveniles or young-of-the-year. Herring and gaspereau are examples of small pelagic species that spawn in the area and showed bimodal length frequencies. Almost all the large herring greater than 17 cm in length (Figure 4-5) were caught in the July 12 survey; herring in the catch from July 21 onwards were primarily in the 8-15 cm length.

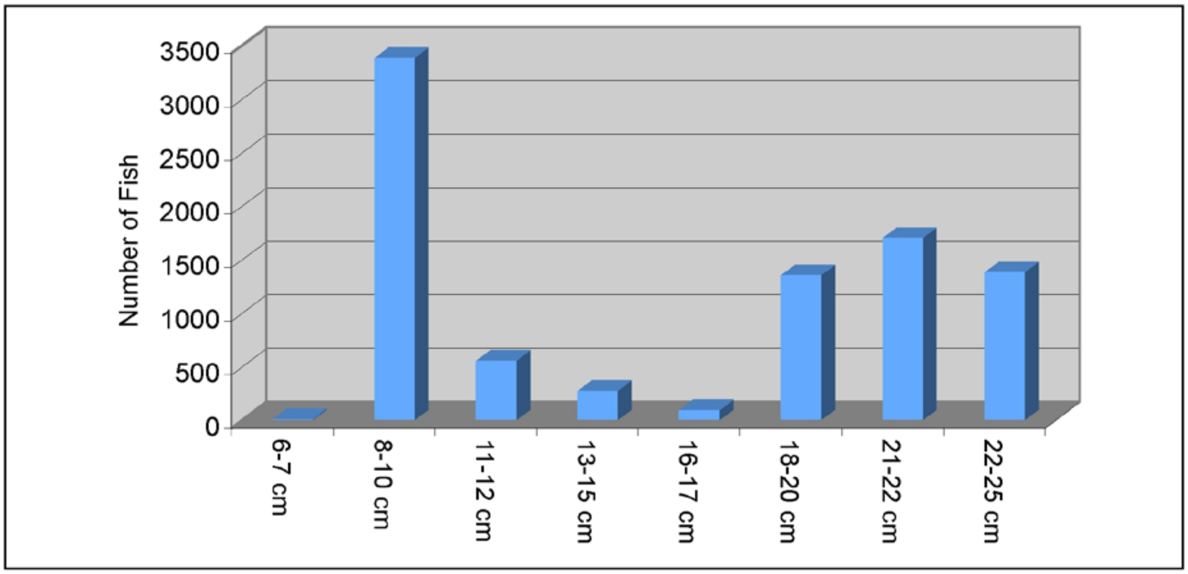


**Figure 4-5: Length Frequency of Herring in Survey Tows**

Most of the large gaspereau (23-25 cm) were caught in the September 16 survey, with 3 caught during the Jul 12 survey. The few gaspereau larger than 25 cm (Figure 4-6) occurred sporadically through the survey period. The largest number of mid-sized gaspereau (13-17 cm) was caught during the August 24 survey. The smaller size class (8-10 cm) of fish was caught primarily on October 25 and may represent young-of-the-year fish beginning to leave the upper Bay of Fundy.

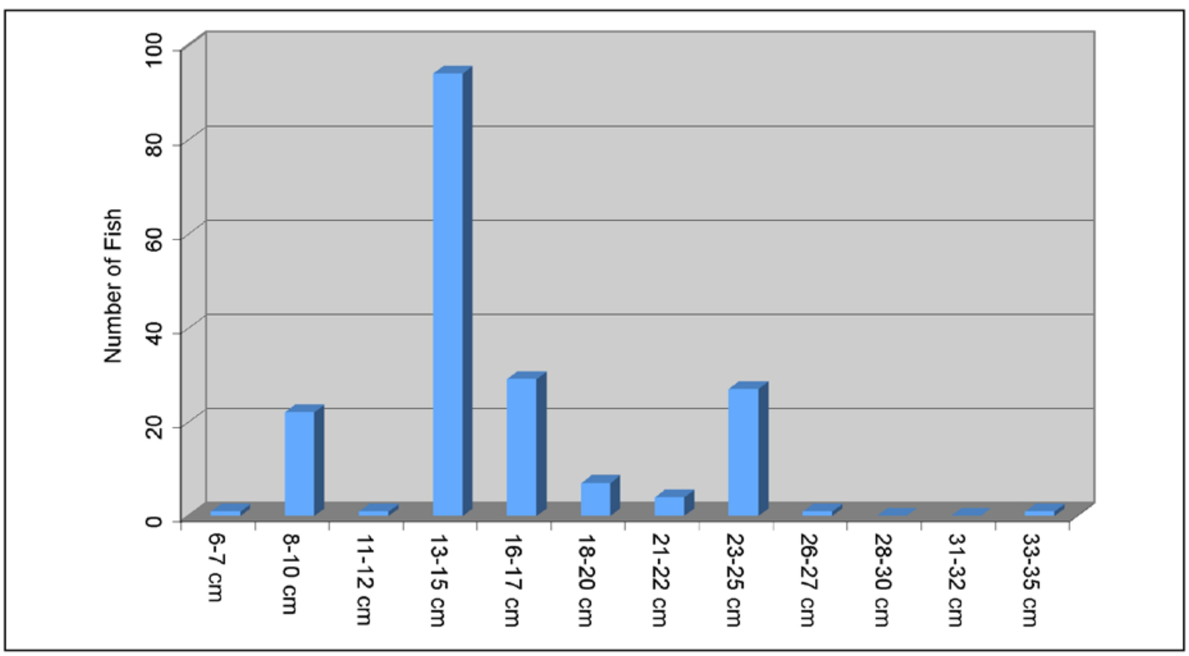


**Figure 4-6: Length Frequency of Gaspereau in Survey Tows**

Most gadoids caught were small (<16 cm in length) juvenile fish, but 1 pollock and 2 silver hake between 26-30 cm were caught.

Small (2-4 cm FL) 3-spine stickleback were the smallest fish caught. The largest fish caught were striped bass (67-77 cm FL) and dogfish (69 cm FL). The striped bass and dogfish were caught in later surveys on September 17 and October 26, although a dogfish was also caught in the initial June survey when the net was damaged fishing too close to bottom.

## 4.3 Location Preference

Figure 4-7 illustrates the distribution of acoustic backscatter (Sa in dB) over all transects carried out on July 12. Maps of acoustic backscatter for all transects are provided in Appendix A. Review of these maps shows a relatively even, broad distribution of acoustic backscatter, but as noted previously, a gradual shift in maximum biomass from the surface depth layer to the intermediate layer is observed most clearly in late in August. At the same time, spatially, fish appear evenly distributed throughout the channel with no apparent concentrations in specific areas.

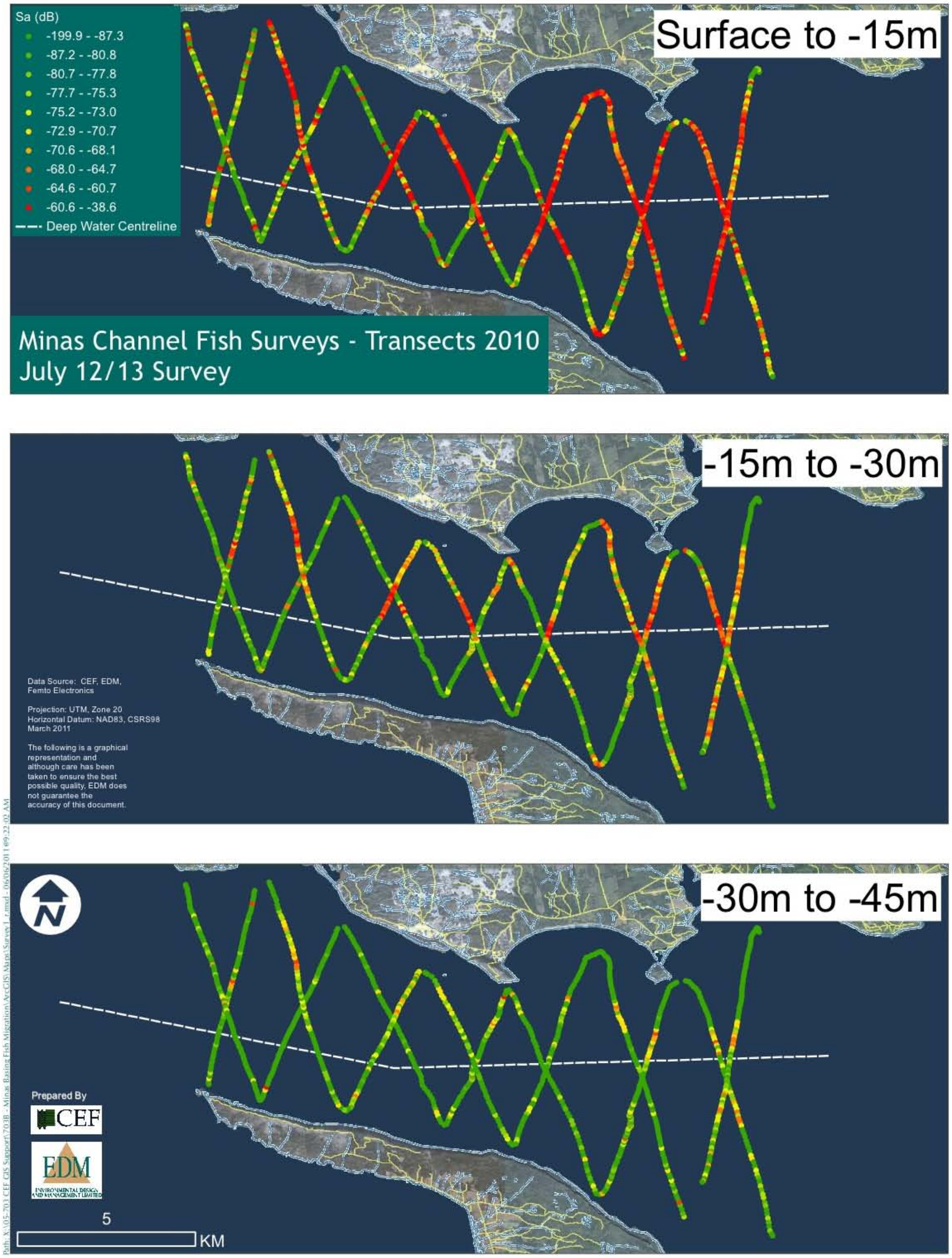


**Figure 4-7: Distribution of Backscatter (Sa in dB) in July 12-13 Transects at Three Depth Intervals**

Behaviour of some fishes, such as salmon, would suggest that migrating fish would have a preference to move near shore. Fish are caught commercially in a few shore-based weirs along the north shore of Minas Channel supporting that some fish move near shore[8]. However, prior to these surveys in Minas Channel no information was available to indicate the relative proportion of most fish moving through different parts of the Channel. When selecting locations to tow based on visual interpretation of the sounder record, locations tended to divide into central deep-water channel areas and shallower areas closer to shore.

An equal distribution of tows to the north and south were desired, but the commercial lobster fishery complicated selection of tow sites because it was important to avoid tangling the net and lines with buoy ropes from lobster traps. Many areas near shore, particularly on the north side of the channel, could not be fished because lobster traps were located in the area. The commercial lobster season normally extends from March 1 to July 31 and October 15 to December 31.

Table 4-4 indicates the number of tows carried out in the north, central and southern portions of Minas Channel. These areas were demarked generally by the start position of the tow. A large proportion of tows (68.1%) were initiated in the central, deep-water trough of the channel, but strong tidal currents caused tows to proceed in various directions.

**Table 4-4: Number of Tows Across the Minas Channel**

| Location | Number of Tows |
|---|---|
| North | 10 |
| Central - Deep | 62 |
| South | 19 |

When GPS positions for tow tracks became available, it was possible to define tow tracks in proximity to the central, deep-water trough. Table 4-5 compares the catch from tows where the track was within 750 m of the mid-line (see Figure 4-10) to tows from other areas. Similar numbers of most species were caught in the deep, central trough area, with percentages ranging between 45 and 55%. Exceptions were dollar fish, which were more concentrated (61.3%) outside the deep, central area, and gaspereau, which were more concentrated (69.5%) within the deep, central area.

[8] A shore-based weir is located near the tidal power lease area but catches from this weir have not been monitored. Catch of SARA species, such as Atlantic salmon, are not reported to be a concern at this weir.

**Table 4-5: Number of Fish Caught by Location**

| Species/Size | Central Deep Area | Other Areas | Percent Deep |
|---|---|---|---|
| Herring, young[9] | 2153 | 2161 | 49.91% |
| Herring, adult | 2511 | 2019 | 55.43% |
| All Herring | 4664 | 4180 | 52.74% |
| Dollar fish | 244 | 387 | 38.67% |
| Mackerel | 133 | 145 | 47.84% |
| Gaspereau | 130 | 57 | 69.52% |
| Lump fish | 10 | 8 | 55.56% |

When the mean calculated biomass from tows was compared between tows within 750 m of the centerline and others, none of the means were statistically significant. Even though only one of 28 gaspereau larger than 23 cm in length was captured outside the central, deep area, the mean difference in biomass was not significant (p=0.143, n=47, 45). Similarly, the mean difference in calculated biomass for dollarfish was not significantly different (p=0.591, n=47, 45) between areas.

## 4.4 Comparison of Acoustic and Tow Biomass

Figure 4-8 illustrates the overall distribution of acoustic backscatter (Sa expressed in dB) recorded during tows carried out during the eleven surveys between July and October. The tows are relatively evenly spread through Minas Channel and no apparent pattern in fish density is obvious. Maps of fish catch by species are provided in Appendix B.

[9] Herring were divided into young and adult based on the length frequency shown in Figure 4-5, with fish less than 18 cm in length referred to as young, and larger fish as adults.

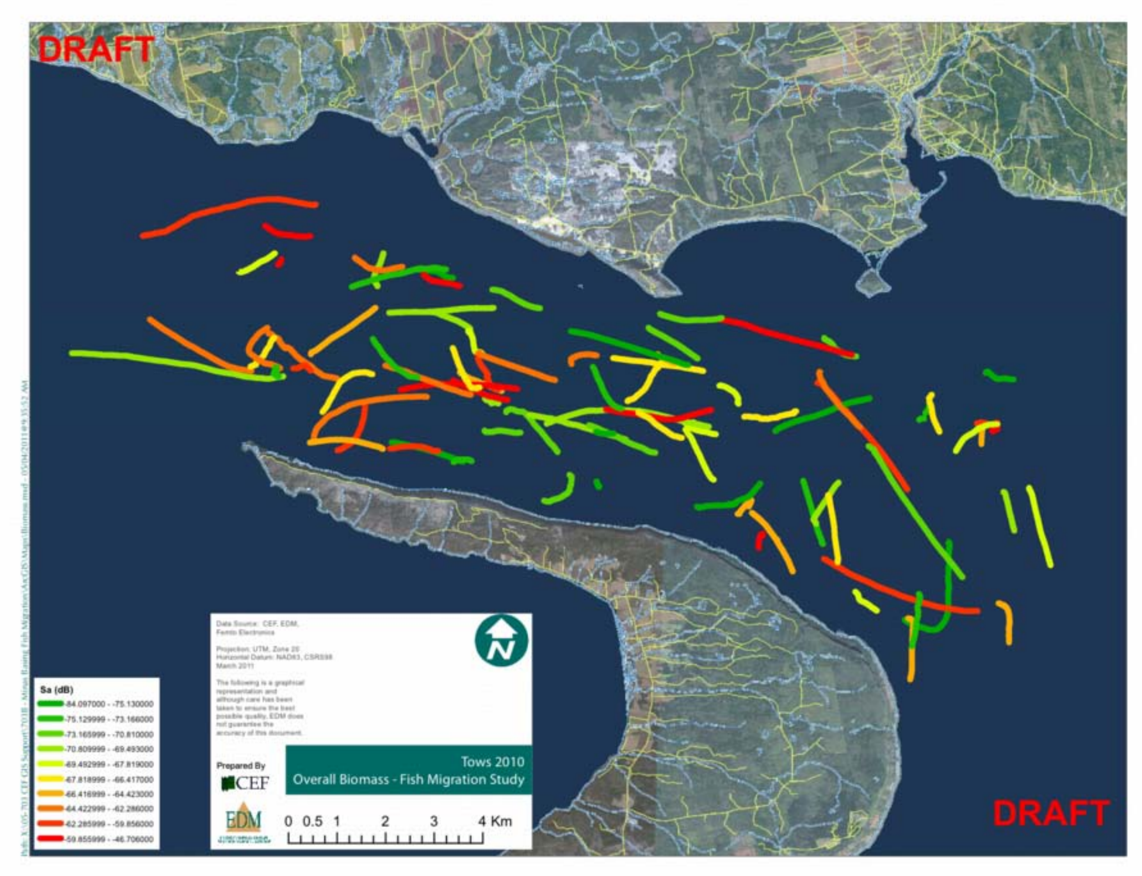


**Figure 4-8: Composite Backscatter (Sa in dB) Collected During All Tows**

The correlation between catch-based and acoustic backscatter converted to biomass was determined by simple linear regression. One tow did not have an acoustic biomass because of equipment failure and three tows did not obtain a catch. These points were dropped from the analysis leaving a total of 87 data points for comparison.

An initial linear regression did not indicate a significant ($p=0.97$, $n=87$) correlation between the catch and acoustic estimates of biomass. Figure 4-9 illustrates that eight data points substantially diverge from the general cluster of data points.

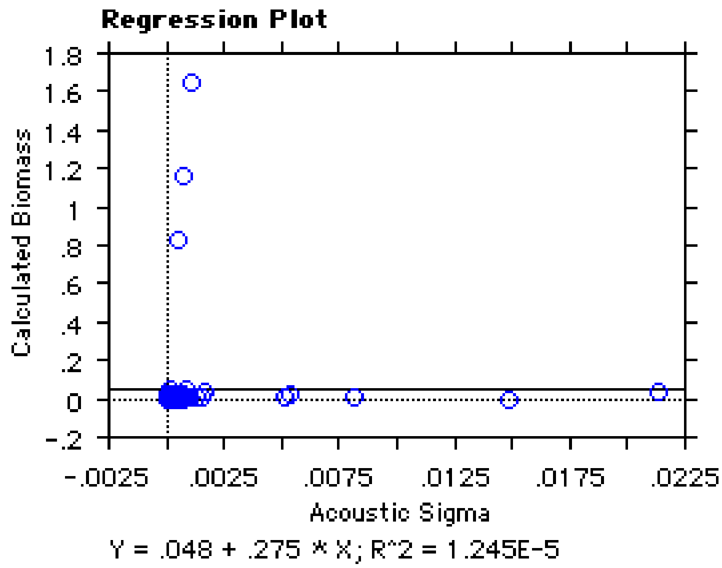


**Figure 4-9: Regression Plot of Catch Biomass to Acoustic Biomass**

The three high values in calculated biomass represent large catches of herring, which may be related to the schooling nature of the fish and the random chance of the net passing through a small school. The high values of acoustic sigma (backscatter converted to equivalent biomass) could similarly be a result of the net not following directly in the path of the sonar beam or insufficient time for the net to herd the fish observed on the sonar into the net. The regression was calculated a second time with these eight outliers removed (Figure 4-10), and a significant correlation ($p=0.0002$, $n=79$) was obtained. $R^2$ was 0.159, indicating that the correlation explained almost 16% of the variation in the data.

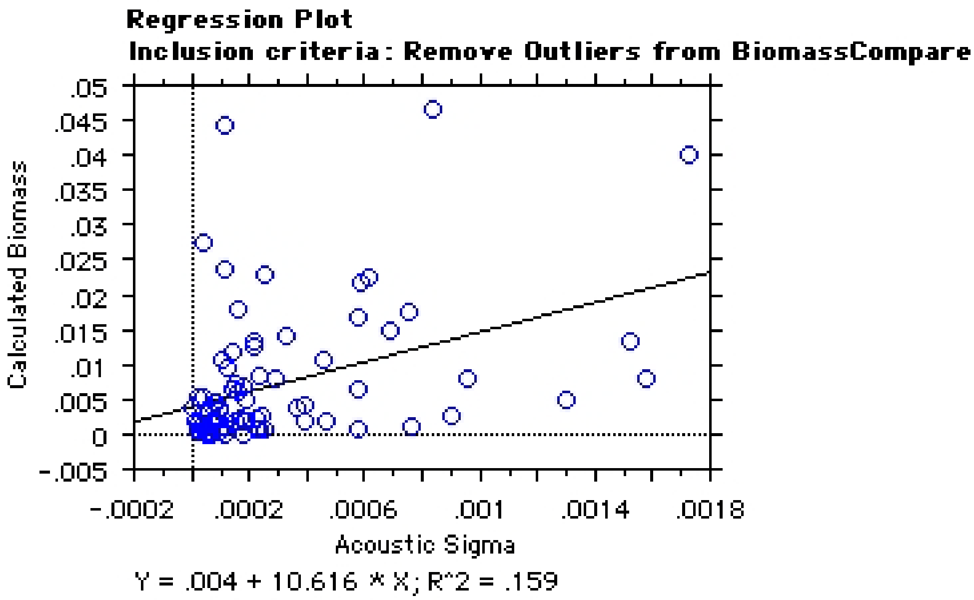


**Figure 4-10: Regression Plot of Catch Biomass to Acoustic Biomass with Outliers Removed**

Correlation of calculated and acoustic biomass for herring alone was investigated to see if a better fit was obtained. The correlation of herring only catch and acoustic biomass was higher than for catch of all species combined. A regression of herring catch and acoustic biomass with the eight outliers removed was significant ($p<0.0001$, $n=90$) and $R^2$ increased to 0.222. Correlations with catch of other species caught frequently were poor, supporting that herring have a dominant influence on the acoustic biomass overall.

The strong influence of herring on the correlation between catch and acoustic biomass and the low correlation for other species suggests that adjusting the biomass catch calculations by estimates of catchability for other species would not likely increase the significance of the correlation.

## 4.5 Depth Preference

An initial review of the depth distribution of fish in the catch divided tows into near surface, intermediate, and deep categories. These initial categories were defined based on door depth (Table 4-6). As more data from the trawl monitoring equipment was collected and analyzed, the relationship between door depth, warp length, and headline depth became clearer. Once headline and bottomline depth estimates were available for all tows, a mid-tow depth was calculated based on the average of headline and bottomline depths over the tow. This more accurate depth estimate was then used to define depth intervals that better reflected the depth interval fished. In some tows the headline depth was considerably deeper than the door depth, and as a result some tows changed depth category. Overall, net opening generally ranged between 8 and 12 m, and a single deep tow was made at a maximum headline depth of 65.9 m.

**Table 4-6: Number of Tows by Depth Interval Based on Door Depth or Mid-Tow Depth**

| | Based on Door Depth | | Based on Mid-Tow Depth[1] | |
|---|---|---|---|---|
| **Depth Interval** | **Range (m)** | **Number of Tows** | **Range (m)** | **Number of Tows** |
| Surface | 0-2.9 | 18 | 0-13.9 | 19 |
| Intermediate | 3-17.9 | 59 | 14-19.9 | 42 |
| Deep | 18-33.8 | 14 | 20-56.3 | 26 |

[1]Mid-Depth refers to the average of headline and bottomline depths over the tow. Tows without catch were removed from the mid-tow depth calculations.

Initial review of the catch by depth interval suggested that most fish were caught at intermediate depths, with an average of 219.8 herring/tow caught compared to 81.6 herring/tow at the surface or 137.8 herring/tow in deep water. Catch was converted to biomass based on length and the depth distribution re-examined using intervals based on Mid-Tow depths. Tows prior to July 21 were excluded from the analysis because high catches of herring on July 12, when only intermediate depths were fished, weighted the comparison heavily in favour of high catches at intermediate depths.

Figure 4-11 illustrates the average catch per tow expressed as biomass for herring and all species combined for all tows after July 12. This comparison indicates that average catch of herring and all species combined was highest in the near surface interval. The catch of herring versus all species was most different at the deep interval, indicating depth preferences likely varied by species.

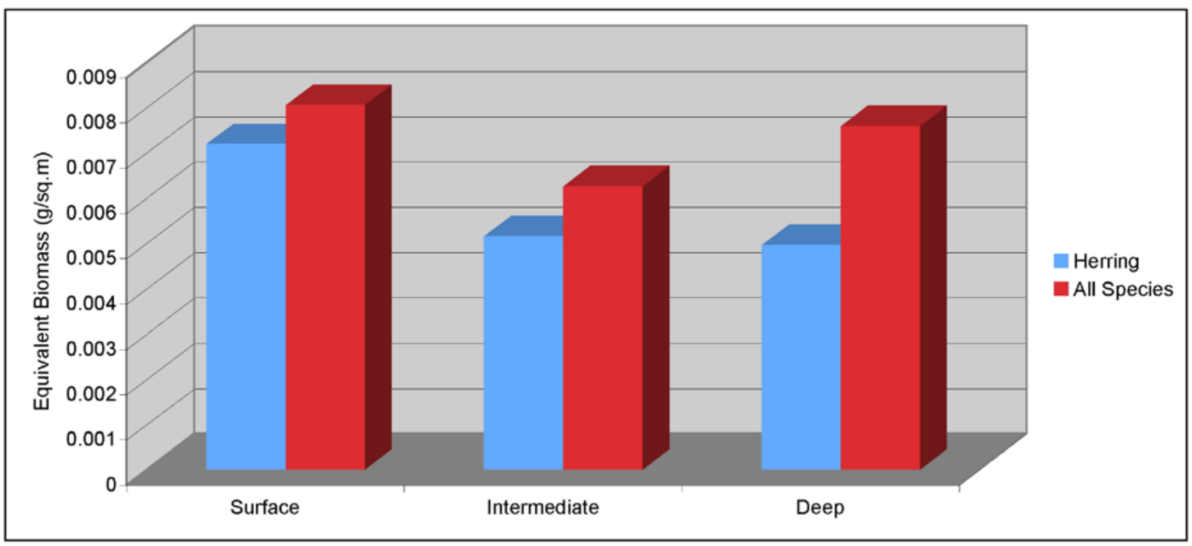


**Figure 4-11: Average Biomass per Tow by Depth Category for Herring and All Species**

Note that tows prior to July 21 with high numbers of herring were excluded from this analysis to avoid a heavy bias to herring at intermediate depths.

Figure 4-12 illustrates the average relative catch per tow in terms of biomass for each of the three depth intervals. Herring and mackerel had the most similar profile by depth interval, with relatively even catch by biomass at all depths fished. Dollar fish, smelt and lumpfish were caught more at intermediate depths than near surface or deep, but gaspereau showed a definite preference for deeper water (Figure 4-12).

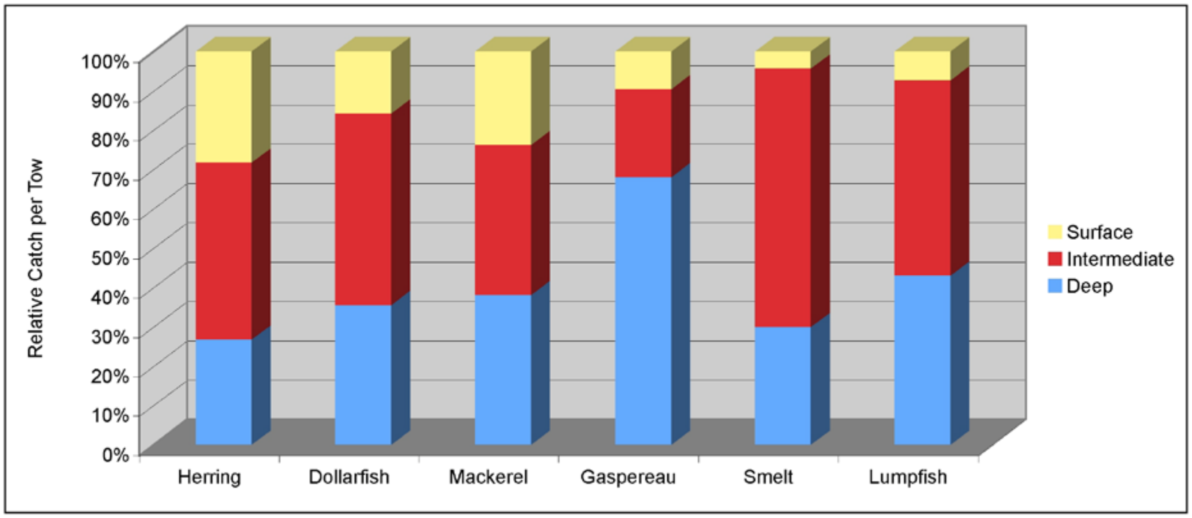


**Figure 4-12: Relative Catch per Tow by Depth Interval for Selected Species**

Once headline and bottomline depths were estimated for all tows to extract comparable acoustic data, individual correlations between catch of different species and mid-tow[10] depth could be tested statistically. In addition, the distribution of tows across water depths could be compared spatially (Figure 4-13). The data used to construct Figure 4-13 comes from the acoustic system and reflects the changing depths along each tow. The deep-water mid-line was used to delineate the deep-water, central trough and to divide the Minas Channel into deep central, northern and southern sections.

[10] Mid-tow depth refers to the mean depth below the water's surface when all positions for the headline and bottomline are averaged to determine a single mean depth for the tow – usually two depths for the headline and bottomline were used.

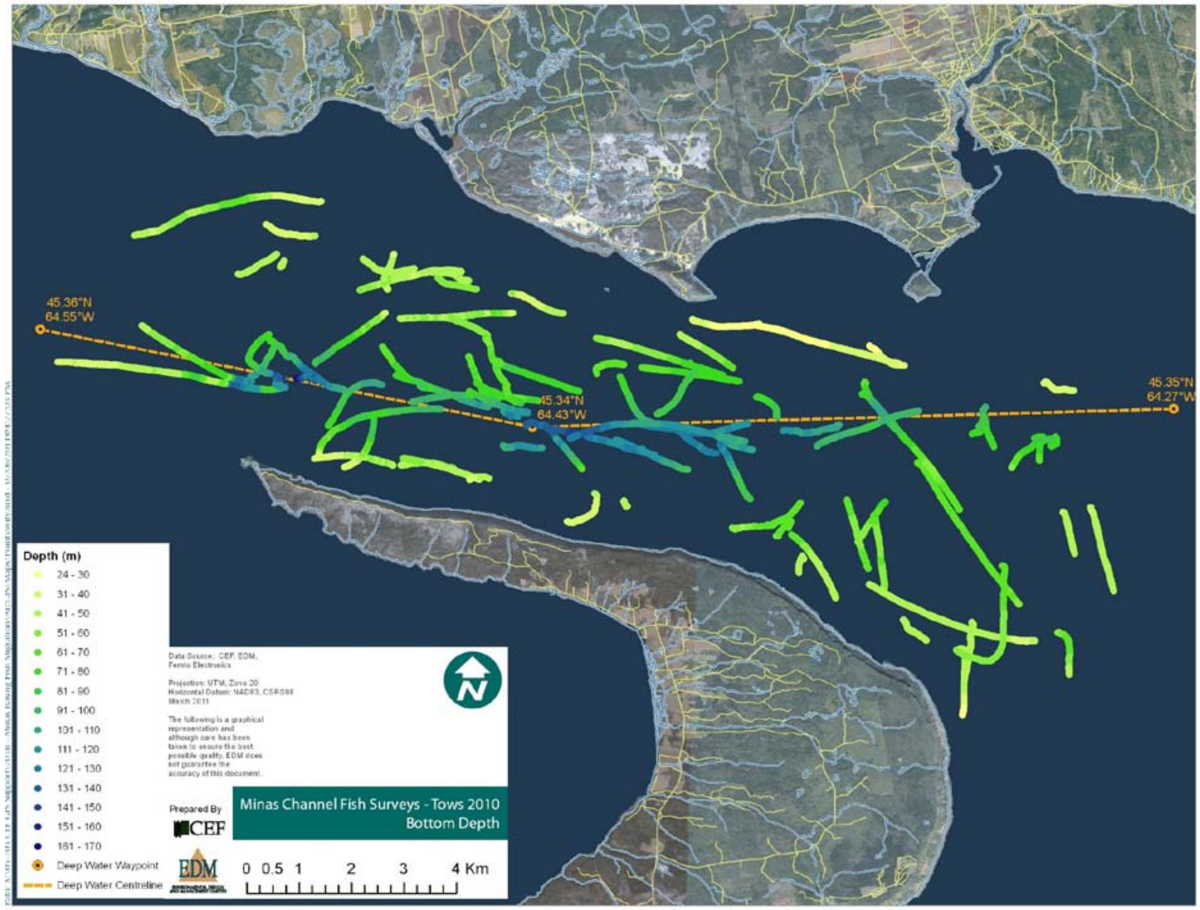


**Figure 4-13: Water Depths Along Tows Conducted from July to October, 2010**

Using the calculated biomass derived from target strength calculations, no correlation was found between mid-tow depth and catch of herring, dollarfish, mackerel, and smelt, but a significant ($p<0.0001$, $n=42$) correlation was found between gaspereau catch and mid-tow depth (Figure 4-14), supporting that gaspereau had the greatest tendency to be caught in deeper water than other commonly caught species.

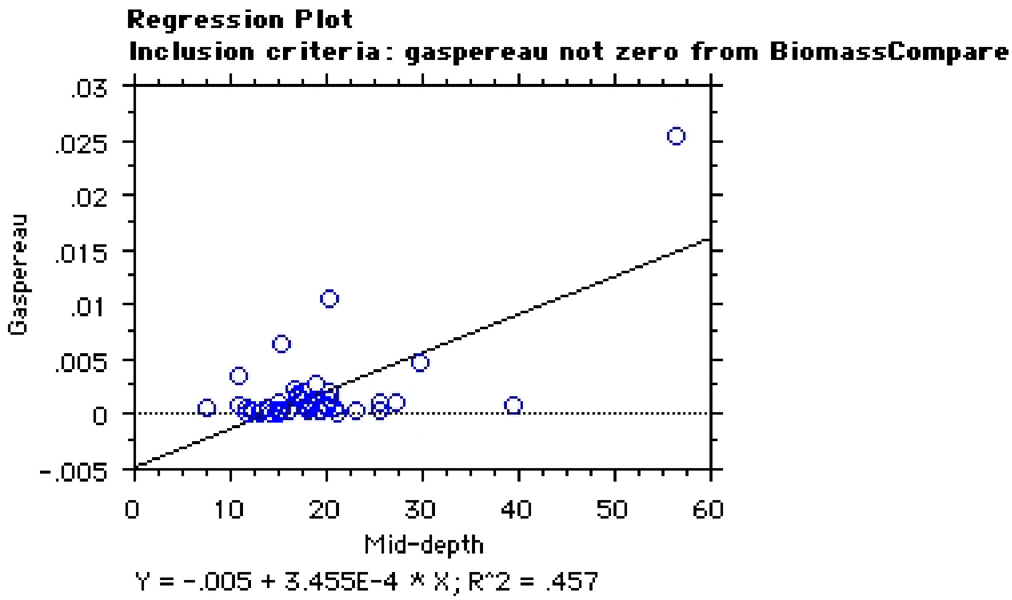


**Figure 4-14: Correlation Between Mid-tow Depth and Gaspereau Calculated Biomass**

As Figure 4-14 indicates, the positive correlation between gaspereau biomass and depth from the surface is largely attributable to a single data point, which corresponds to Tow 2 on September 16 at a mid-depth of 56.3 m and a calculated biomass of 0.025 g/m$^2$. This tow represents the biggest proportion of larger gaspereau caught during all surveys (23 of 33 fish larger than 21 cm in length). If this one tow is removed from the analysis, no significant ($p$=0.489) correlation with depth remains. It is possible that adult gaspereau prefer deeper water to juvenile gaspereau but insufficient information is available to draw statistically valid conclusions.

## 4.6 Influence of Light Conditions

The survey vessel was equipped with lights for working at night, but the majority of tows were made during daylight (Table 4-7). There was a tendency to run acoustic transects at night and trawl during daylight for two reasons: deck work in daylight was easier and safer; and, some species of fish move up off bottom at night making them more detectable by hydroacoustics. An effort was made to also collect tow data at night to detect species differences in catch in response to light conditions. As Table 4-7 indicates, a higher proportion of acoustic transect data was collected at night and a great proportion of trawls were conducted during the day.

**Table 4-7: Light Condition During Tows and Transect Surveys**

| Time of Day | Number of Tows | Transect Observations* |
|---|---|---|
| Day | 61 | 162 |
| Morning Twilight | 4 | 82 |
| Evening Twilight | 6 | 40 |
| Night | 20 | 847 |

*Observations are the number of samples in a 10% random sample of transect points, but reflect the general distribution of sampling effort

Catch of all species caught on a consistent basis in the midwater trawl were higher during daylight than at night. Visual cues from the doors and bridles help herd the fish into the net, and these cues are more effective in daylight.

Analysis of variance was conducted to examine whether significant (p=0.05) interactions occurred between trawl catch and light conditions for the commonly caught species. The light conditions evaluated were represented by three conditions: nautical twilight, day, and night. Only the catch of mackerel was found to be significantly related to light conditions (p=0.021) when twilights were combined to a single light category (Figure 4-15). The catch of mackerel is known to be influenced by light, with catch reduced at night when mackerel are more dispersed (Deroba 2009).

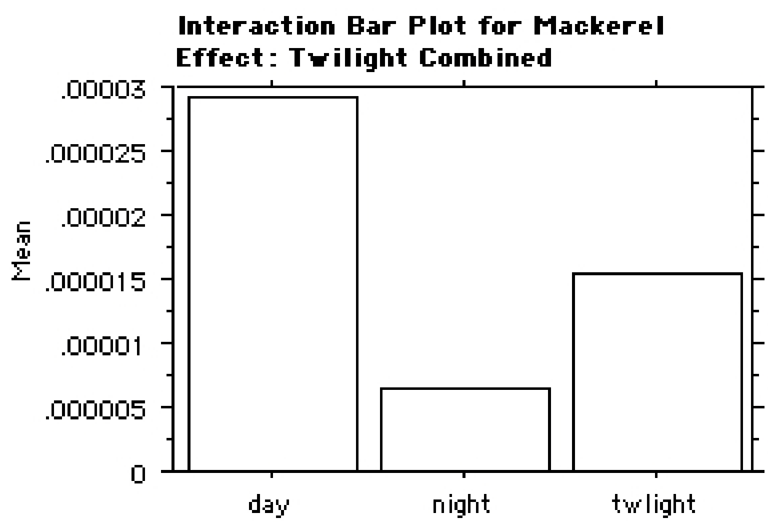


**Figure 4-15: Average Catch (Equivalent Biomass) of Mackerel by Time of Day**

Potential differences in depth distribution of dollar fish were examined with respect to time of day because the numbers were higher in both day and night than other commonly-caught species. The larger proportion of the catch at the surface at night suggests dollar fish move up in the water column at night (Figure 4-16). Only one deep tow was conducted at night and no dollar fish were caught.

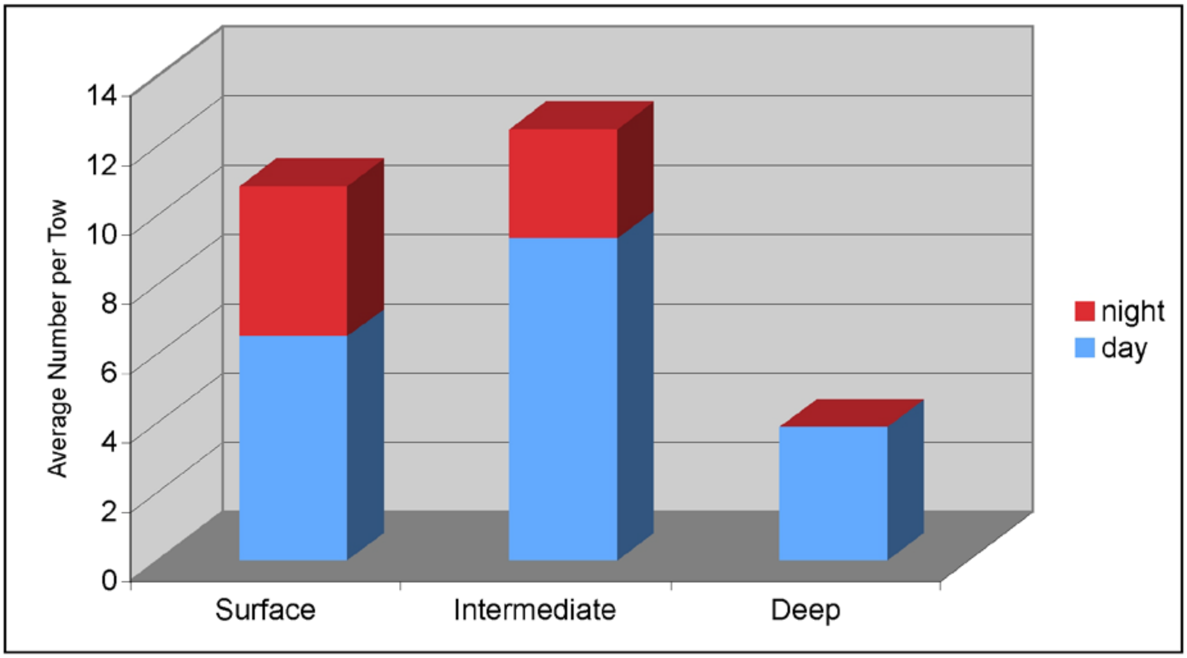


**Figure 4-16: Average Catch per Tow of Dollar Fish by Depth and Time of Day**

The catch of dollarfish was examined using analysis of variance with light and depth interval as factors (Table 4-8). No effect of light, depth interval or covariance of light and depth was found to be significant.

**Table 4-8: Analysis of Variance for Dollarfish Biomass by Light and Depth**

| Factor | df | Sum of Squares | Mean Square | F-Value | P-Value |
|---|---|---|---|---|---|
| Light | 2 | $1.620 \times 10^{-6}$ | $8.102 \times 10^{-7}$ | 0.424 | 0.6557 |
| Depth | 2 | $7.313 \times 10^{-7}$ | $3.657 \times 10^{-7}$ | 0.191 | 0.8261 |
| Covariance | 4 | $1.444 \times 10^{-6}$ | $3.609 \times 10^{-7}$ | 0.189 | 0.9435 |
| | 83 | $1.585 \times 10^{-4}$ | $1.910 \times 10^{-6}$ | | |

## 4.7 Influence of Tidal Conditions

Tidal conditions were defined as categories of falling, rising or slack according to tide predictions for Hantsport, Nova Scotia. Slack conditions were considered to occur an hour before or after low or high tide. Falling or rising tides were considered to be extreme when high tides were 14 m or greater or low tides were less than 1 m. The number of observations by tidal condition for acoustic transects and tows are indicated in Table 4-9.

**Table 4-9: Tidal Condition During Tows and Transect Surveys**

| Tidal Conditions | Number of Tows | Transect Observations* |
|---|---|---|
| Falling | 23 | 264 |
| Rising | 31 | 270 |
| Falling - extreme | 6 | 38 |
| Rising - extreme | 2 | 97 |
| Slack high | 5 | 286 |
| Slack low | 22 | 176 |

*Observations are the number of samples in a 10% random sample of transect points

Effect of tidal conditions on acoustic transect biomass densities is small – not significant within the 1-14.9 m interval ($p=0.186$), but significant within the 15-29.9 m ($p<0.0001$) and 30-44.9 m intervals ($p<0.0001$). Examination of the relationship between tide and biomass indicated a reduced biomass at extreme tides was primarily responsible for the significance of the relationship. Overall, the small effect of tide on estimates of biomass supports that the acoustic data is of good quality, since turbulence would be expected to be greater during periods of flood or ebb tide, or especially extreme tides.

The effect of tides on transect data was also carried out by examining the biomass estimates within the 15 m closest to the bottom. Since many species of fish are known to exhibit diel behaviour and rise up off the bottom at night, a strong relationship would be expected between light conditions and near bottom biomass. The potential impact of turbulence would also be expected to be the least within the near bottom environment. Previous analysis had shown that separate consideration of nautical twilight from day and night did not identify useful patterns in the data, thus the simpler separation of light conditions into day and night was used for subsequent analyses. As anticipated, the strongest relationship was between near bottom biomass and light conditions when twilight and daylight conditions were merged ($p=0.0001$). Addition of tide to an ANOVA of near bottom biomass and light conditions did not result in increased explanation of variation.

The relationship between tidal conditions and catch was also examined. Using ANOVA, a significant relationship was found between tidal condition and biomass of overall catch ($p=.0093$), and catch of herring ($p=0.0086$), dollarfish ($p=0.001$) and smelt ($p<0.0001$). When this relationship was examined, it was found that two tows conducted during extreme rising tides were entirely responsible for the perceived relationship. Since no other similar trends were observed in the data, these two points were considered likely outliers.

# 5 CONCLUSIONS

Fish surveys conducted in Minas Channel in 2010 by the Carmelle #2 involved the application of standard technology (i.e., a midwater trawl and hydroacoustic data acquisition system) in an unusual setting. Commercial fishing is uncommon in the Channel because of the extreme tidal currents. Herring seiners fish primarily in Scott’s Bay, west of the Channel, but do follow schools of herring into the Channel and fish when currents allow. To sample fish distributions that might interact with TISEC devices within the demonstration area, it was important to be able to sample under all tide conditions and water depths. The midwater trawl gear used proved able to fish under the range of extreme currents and eddies present and catch a representative sample of most fish species present at various depths. However, shad, a common surface water species in the area, was distinctly under represented in the samples.

The Marport trawl monitoring equipment showed that the net was maintained in appropriate fishing configuration under a wide range of currents. At the same time, it is important to understand that the net cannot be maintained in a specific position or along a specific course. Two tows carried out in succession will likely follow different paths because of the constant variation in currents. Although it took time to get all components of the Marport system working, no serious data deficiencies resulted from early problems primarily with the headline transponder.

Potential catch of Atlantic salmon was a special concern associated with sampling fish in the Channel. The Inner Bay of Fundy stock of Atlantic salmon is listed as *Endangered* and protected under the Canadian Species At Risk Act (SARA). Measures were taken to avoid capture of Atlantic salmon, such as adopting a 20-minute tow duration, and none were caught in any of the 2010 surveys.

## 5.1 Agreement Between Acoustic and Catch Data

Acoustic surveys were successful in that they documented seasonal changes in temporal and spatial distributions of fish density throughout the water column. Correlation between estimated acoustic biomass and catch biomass by tow was significant ($p<0.05$), but was clearly reduced by a few exceptional values. Differences between tow and acoustic biomass (Figure 5-1) could be due to difficulty of targeting by the trawl where herring are most concentrated, differences in sampling volume, or possibly variation in the ability of the acoustic biomass estimator to reflect the true densities of herring.

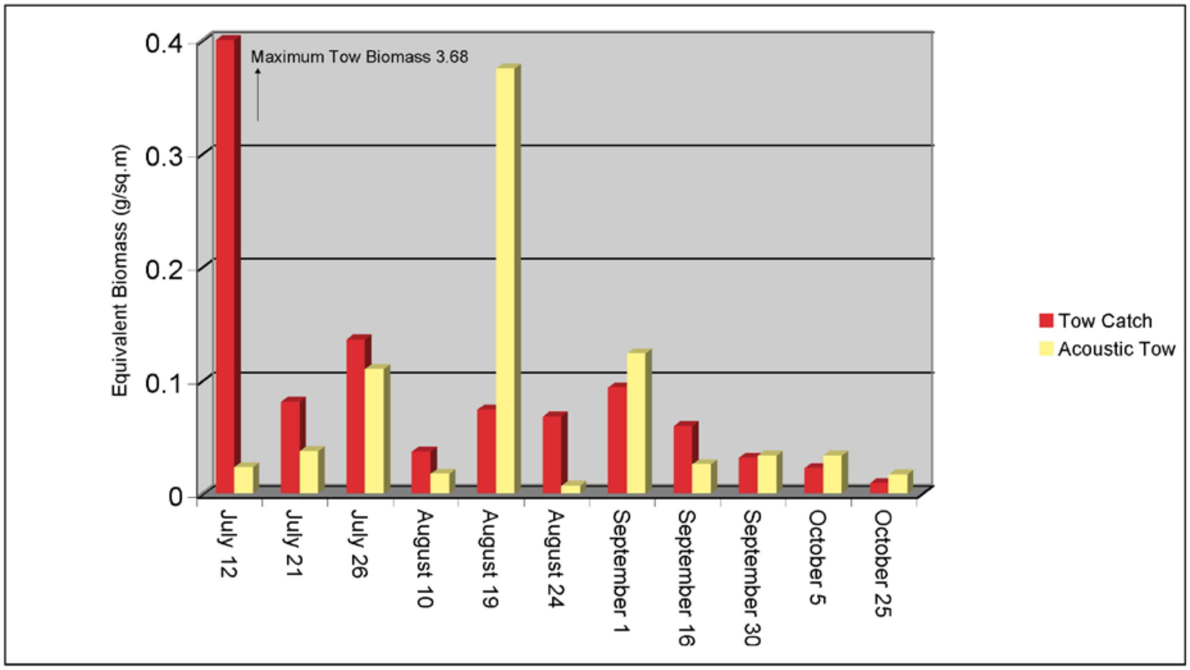


**Figure 5-1: Comparison of Biomass Estimates from Catch and Acoustic Observations Along Tow Path**

A large catch of herring on July 12 coincided with a relatively low biomass estimate from the concurrent acoustic backscatter. The difference in biomass estimates can be explained by the schooling nature of the species and the difference in sampling volumes between the net and the sonar – the net has a much larger sampling volume.

On the other hand, the concurrent acoustic estimate of biomass was unusually high on August 19. Two of the ten tows conducted during the August 19 survey had high concurrent estimates of acoustic biomass, which did not translate into similarly high catch. Examination of the acoustic record for these tows showed what appeared to be a number of small compact schools and no influence of turbulence. The discrepancy between the estimates of biomass from the concurrent acoustic sampling and the net catch may well be due to the fluctuations in the path of the net caused by strong shifting currents – the net does not stay in consistent position behind the vessel.

Further analysis of acoustic data, especially the data collected concurrently with tows, could be examined to evaluate target strength estimates for key species. Individual acoustic targets could be isolated and examined in more detail in an effort to associate acoustic targets with specific components of the catch.

Figure 5-2 illustrates a similar comparison of biomass between the overall acoustic transects and the tow catch of all species. The relationship illustrated supports a general correlation between acoustic and catch data and the conversions used to estimate equivalent biomass ($g/m^2$).

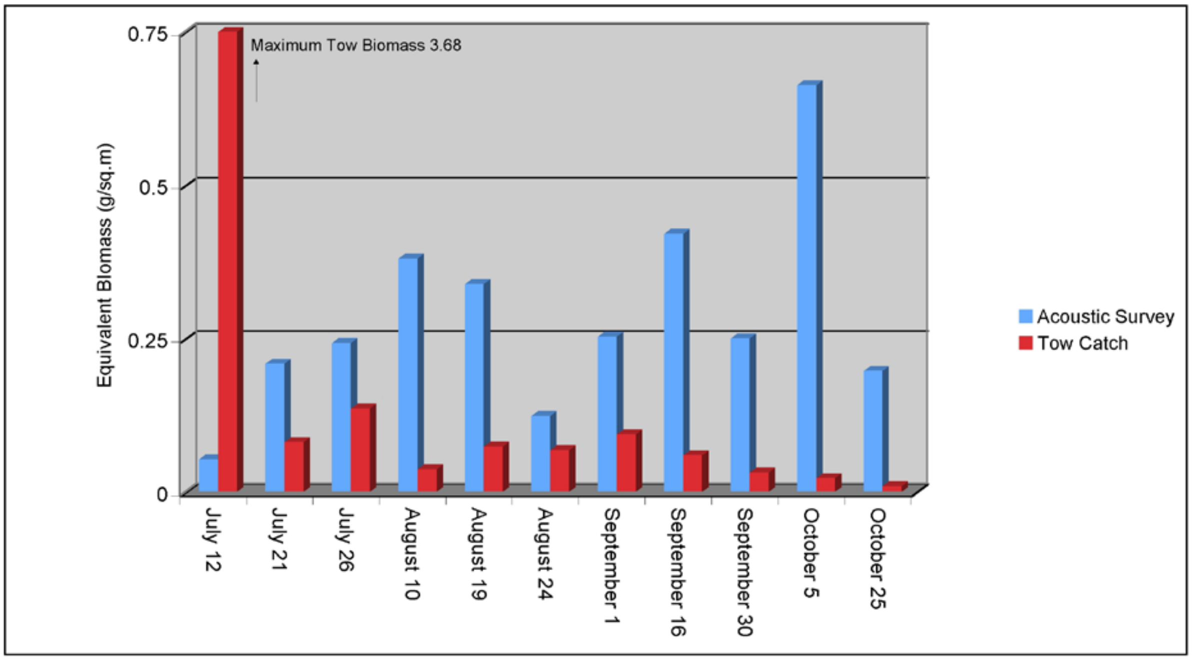


**Figure 5-2: Comparison of Biomass Estimates from Catch of All Species and Acoustic Transect Surveys**

## 5.2 Overall Trends in Abundance

Figure 5-3 illustrates the overall trend in estimates of biomass over the year in Minas Channel from all 2010 survey data. In Figure 5-3, the larger transect biomass numbers from the April and May 2010 surveys as described in Section 1.4 were used. For June, the average biomass between day and night transects as described in Section 3.3 was used. The remaining biomass numbers are based on the average survey biomass from on a 10% sample of the area surveyed, the same dataset used in most analyses conducted.

The major components of the biomass appear to be adult herring moving into the channel in June, followed by young herring in later July and August, gaspereau in September and a broader mix of species leaving the upper Bay of Fundy in October.

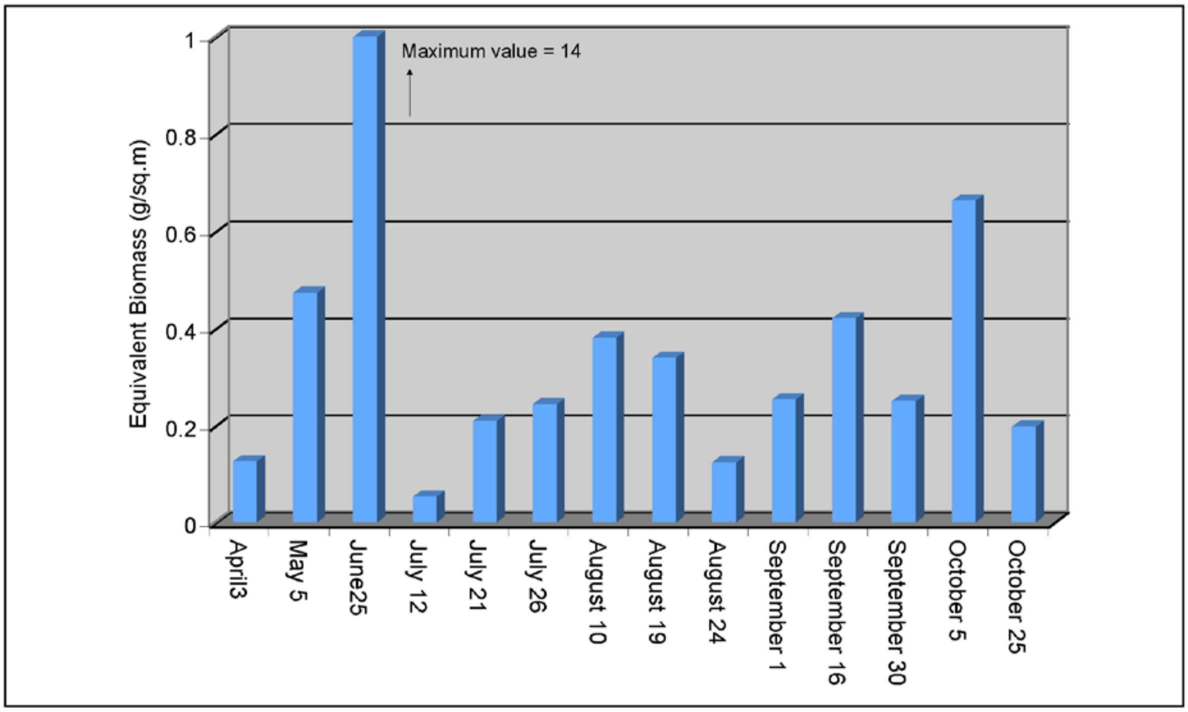


**Figure 5-3: Estimation of Acoustic Biomass in Minas Basin from All 2010 Surveys**

## 5.3 Spatial Distributions

Overall, the combined tow and acoustic transect data support some key findings with regard to spatial distributions. Overall biomass is distributed relatively evenly across Minas Channel, but specific species preferences exist. Depth preferences for some species, particularly gaspereau, affect where they are most common. Gaspereau showed a preference for deeper water and were located in the central, deep-water trough more often than other species. Dollarfish were found least often in the same area. The differences in variation of biomass for these two species, however, were not statistically significant ($p=0.311$).

Observations during the surveys left the impression that more fish (i.e., acoustic targets) tended to be observed in the central, deep trough running through Minas Basin. However, analysis indicated that spatial, seasonal or species differences were relatively small and did not support significant differences between the central trough and other areas in the statistical tests conducted.

The tidal power lease area had biomass densities similar to other parts of Minas Channel and was not found to be a migration route for any specific species. A clear increase in biomass with depth from the surface was not statistically significant ($p>0.05$) for any species, but some trends were observed with dollar fish and smelt caught more frequently at intermediate depths from the surface and adult gaspereau at deeper depths. Bathymetry no doubt has some effect on vertical distributions of fish as well, but water depth also restricted the maximum depth of fishing and thus limited our ability to detect deeper depth/biomass relationships.

As noted, sampling in nearshore areas was complicated by the presence of lobster buoys that could tangle with towed fishing gear. A higher perceived density of fish in and near the central deep water trough frequently triggered the start of a tow to sample species, however, the tow did not necessarily remain within 750 m of this deep-water feature. When the tow tracks and associated catch was examined spatially, a higher density in this deep-water area could not be confirmed. In addition, no indication of a near shoreline preference for movements in or out of the Minas Channel was detected in the surveys. The overall impression from variations in catch is that most fish distributions are randomized to some degree by the strong currents and eddies within Minas Channel.

It would be helpful to work with lobster fishermen to outline areas where midwater trawling could occur near shore without potential interaction with lobster gear. Potential fishing areas would need to be relatively large (e.g., one km square) because the path of the trawl can only be controlled within broad parameters.

## 5.4 Tides, Currents and Wind

Wind and currents can produce turbulence that reduces the quality of the acoustic data collected. Experience with weather in Minas Channel and the factors causing turbulence suggests that weather forecasts are not good predictors of turbulence and thus not reliable to adjust the work schedule. This is further complicated by the requirement to leave the wharf at high tide relatively far from the work area. Working in the Cape Split area during slack tide appeared to be the most predicable way to minimize the effect of turbulence on this type of acoustic data collection.

Fish normally associated with the ocean bottom habitat, for example summer flounder, were sometimes caught well off bottom. The high currents in the Channel may mix fish in ways not typical of other ocean areas.

Because of the travel time required to reach the survey area and the requirement to leave port over a relatively narrow window of high tide, it is difficult to schedule surveys with regard to weather. Review of the acoustic data did not identify concerns associated with turbulence. Perhaps the most promising support that the acoustic data are relatively free from effects of turbulence is the clear differences between day and night and the much stronger statistical correlations of acoustic biomass with light conditions than with tide. However, considerable turbulence was frequently encountered near Cape Split and sometimes throughout much of the channel.

## 5.5 Day and Night Comparisons

Overall, light conditions had substantially more influence on catch size and composition than did tidal conditions. The catch of mackerel was significantly correlated with light, as anticipated from the literature. Including twilight conditions with day generally improved the correlation between light conditions and catch. Even then, however, overall biomass estimates were not significantly different between day and night transects.

Consistent differences in vertical distribution between day and night were observed in the acoustic system with some fish moving up in the water column at night. This would suggest fish would be more concentrated and result in larger catch rates at night. However, higher catches per tow were noted on average during the daytime. Higher catch rates in daylight could indicate the net operates more efficiently when fish can respond to visual cues. For some species, fish may rise higher in the water column at night than the midwater gear was able to fish.

In a few instances a large number of targets were observed near bottom at night, but these could not be sampled with the midwater gear available. Acoustic biomass in the near bottom layer (to 15 m from the seabed) was significantly different between day and night ($p=0.0001$).

## 5.6 Trawl Performance

The midwater trawl and survey vessel worked well under difficult fishing conditions. The net was able to catch what appears to be a representative sample of species and size ranges regardless of tide stage and current speed. The high currents largely controlled the direction of tow, sometimes in hard to predict ways. For example, in more than one instance currents near the Blomidon shore pushed the vessel directly towards shore even though the tow was being made parallel to shore and in the opposite direction to the main tidal flow.

The Marport system operation was gradually improved throughout the surveys. By mid-September generally complete information on headline depth and net opening was being received reliably. The Vemco depth recorder provided good post survey comparison information.

A flow meter was installed for the last survey but consistent information was not obtained. Further experimentation with a housing for the flow meter and attachment to the net will be required. RPM, reflective of engine horsepower, currently provides the most useful indicator of flow through the net.

Trawl speed and duration has an influence on how effective a trawl is in relation to specific species and fish size – generally larger fish can swim faster and a longer duration of tow will catch more, larger fish. Trawl duration was varied during one early survey and not found to result in much change in species composition. In addition, in October large striped bass and dogfish were caught, suggesting that tow duration of 20 minutes is adequate for sampling.

Coefficients to adjust catch based on length and species were examined but were considered not well-suited to the purpose of these studies. In most cases correlation between biomass and environmental variables such as tide were sufficiently low that adjustments for catchability were unlikely to result in relationships becoming significant. In cases where a significant relationship was initially found, it was most often associated with two or three data points in a particular survey, which would not be altered noticeably by adjusting for catchability.

On the other hand, comparative fishing trials between different fishing gears would be useful to better understand variations in catchability and their effect on these analyses. For example, comparative fishing between the midwater gear used in this study and drift near-surface gillnets could be helpful.

## 5.7 Seasonal Differences

The main seasonal change noted in catch was the decline in numbers of herring in July and the catch of large striped bass and dogfish in September and October. Surveys should start earlier in the year, at least May, to include sampling of fish migrating up the Bay of Fundy into Minas Basin.

Herring overwhelm the fish biomass in June and July and remain the dominant component of the catch throughout most of the season. The dominance of herring and the similarity of depth distributions for most species may mask differences in biomass or depth distributions of other species in acoustic backscattering summaries. For this reason, fishing may remain a primary method of obtaining information on distributions of species other than herring within Minas Channel.

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