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Newfoundland East and Southeast Coast Herring - An Assessment of Stocks to the Spring of 1998

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Abstract

Results of analysis of data from 1996 to the spring of 1998 are presented for herring stocks along the east and southeast coasts of Newfoundland. Commercial landings in 1996 (2500 t) were lower than in 1995 (4600 t) due to reduced quotas and poor market conditions. Landings in 1997 increased to 7900 t, due to increased quotas, which were the result of more optimistic projections in the 1996 stock assessment. Spring spawners of the 1990 and 1991 year classes continued to dominate in the 1996 and 1997 fisheries, in most areas. There was little or no evidence of recruitment of younger year classes. Five series of abundance indices were available for the assessment, research gill net catch rates and acoustic survey biomass estimates extending back to the early 1980's, and commercial gill net catch rates, gill net fisher observations, and purse seine fisher observations commencing in 1996. Stock abundances were estimated from integrated catch at age analysis for three of four stock areas and from a research gill net catchability analysis for the remaining area. A retrospective analysis and a risk analysis was calculated for each of the stocks. The status of each stock was defined by a stock status classification system based upon environmentally dependent stock-recruit relationships. The status of the White Bay - Notre Dame Bay stock was classified as poor to moderate. The Bonavista Bay - Trinity Bay and St. Mary's Bay - Placentia Bay stocks were classified as moderate to good, and the Fortune Bay stock was classified as good to very good.

Résumé

Les résultats de l'analyse des données obtenues de 1996 au printemps de 1998 sont présentés pour les stocks de hareng des côtes est et sud-est de Terre-Neuve. Les débarquements commerciaux de 1996 (2 500 t) ont été inférieurs à ceux de 1995 (4 600 t) suite à la réduction des quotas et à la baisse des marchés. Les débarquements de 1997 ont atteint 7 900 t à cause d'un accroissement des quotas s'expliquant par les prévisions à la hausse de l'évaluation des stocks de 1996. Les géniteurs de printemps des classes d'âge de 1990 et 1991 ont continué de dominer les pêches de 1996 et 1997 dans la plupart des zones. Il y avait peu ou pas d'indices de recrutement de classes plus jeunes. Cinq séries d'indices d'abondance ont été obtenues pour l'évaluation : des taux de capture de la pêche de recherche au filet maillant, des estimations de biomasse par relevés acoustiques remontant au début des années 1980, des taux de capture de la pêche commerciale au filet maillant, des observations de pêcheurs au filet maillant et des observations de pêcheurs à la senne coulissante débutant en 1996. L'abondance des stocks a été estimée à partir de l'analyse des captures intégrées selon l'âge, pour trois des quatre zones de stock, et à partir d'une analyse de la vulnérabilité au filet maillant de la pêche de recherche, pour l'autre zone. Une analyse rétrospective et une analyse des risques ont été faites pour chacun des stocks. L'état de chaque stock a été défini à l'aide d'un système de classement fondé sur des relations stock-recrutement fonction des conditions environnementales. L'état du stock des baies White-Trinity et des baies St. Mary's-Placentia a été qualifié de faible à moyen. Celui des stocks des baies Bonavista-Trinity et des baies St. Mary's-Placentia l'a été de moyen à bon et celui du stock de la baie Fortune de bon à très bon.

Introduction

There are five herring stocks distributed along the east and southeast coasts of Newfoundland (Figure 1): White Bay - Notre Dame Bay (WB-NDB), Bonavista Bay - Trinity Bay (BB-TB), Conception Bay - Southern Shore (CB-SS), St. Mary's Bay - Placentia Bay (SMB-PB), and Fortune Bay (FB). This document provides an assessment of four of these stocks to the spring of 1998; CB-SS was excluded from the analysis as there were insufficient data to calculate stock biomass.

In recent years, east and southeast Newfoundland herring stocks have been assessed bi-annually, most recently in the fall of 1996 (Wheeler et al. 1997). The major changes since the last assessment include: the use of three additional abundance indices, the use of integrated catch at age (ICA) analysis (Patterson 1998) to estimate stock sizes for three of the stocks, the revision of environmentally dependant stock - recruit relationships, and changes in the method of risk analysis.

This document is divided into several sections, outlining the steps taken to assess these herring stocks in 1998. The first section examines the commercial fishery data and the associated biological sampling used to calculate the 1996 and 1997 commercial catches at age. The next section examines the abundance indices for each of the stocks. This section is sub-divided as five series of abundance indices were available, research gill net catch rates and acoustic survey biomass estimates extending back to the early 1980's, and commercial gill net catch rates, gill net fisher observations and purse seine fisher observations commencing in 1996. The third section describes the estimation of stock sizes using the ICA for three of the four stock areas, and using the research gill net catchability analysis for the fourth (FB). Risk analysis methodology is also included in this section. The fourth section provides information on the current status of each stock and the associated risk analysis. The document concludes with a summary of each of the above sections. Assessment proceedings and management deliberations are provided in Appendix 5.

Section 1.0 - Description of the 1996 and 1997 Commercial Fisheries and Catches at Age

1.1 Biological Sampling

Biological samples are collected each year from the east and southeast Newfoundland commercial herring fisheries. As well as providing information on the age distribution of commercial landings, commercial catch at age data are used in sequential population models (eg: ICA) to estimate stock sizes.

Samples are collected from individual fishers and from processing plants within each stock area. A sample consists of 50 fish, randomly selected from the catch. A sampling protocol of at least one sample per 500 t of landings, by bay, month and gear type, is employed. Samples are frozen and subsequently collected by Pelagic Section personnel for processing at the Northwest Atlantic Fisheries Centre (NAFC).

Biological measurements include: total length (mm), whole weight (g), gutted weight (g), gonad weight (g), sex, maturity stage, spawning type, age and degree of stomach fullness. All sampled fish are measured and aged.

Commercial catch data (t), by bay, month and gear type, are provided by the Policy and Economics Branch. Catch data for recent years are considered preliminary as the Policy and Economics Branch has not finalized catch statistics for these years.

1.2 The 1996 Fishery

Subsequent to the 1995 herring stock assessment meetings, Science Branch did not release a Stock Status Report (SSR) (Wheeler and Winters 1996). Therefore, in formulating a management plan for 1996, Fisheries Management Branch utilized a stock status classification system developed by the Herring Working Group of the Small Pelagics Advisory Committee which recommended a limited bait / science index fishery with projected fishing mortalities of 0% to 5%. Spring fixed gear quotas and fall purse seine quotas were established for each stock area. The spring gill net fisheries were open to all fixed gear fishers; however, given the small purse seine quotas, access to the fall purse seine fisheries was restricted and fishers were allocated individual quotas within their home bays, only to be fished during certain months. The limited fisheries were designed to address conservation concerns by minimizing fishing mortalities while allowing for the collection of scientific data.

To quantify the scientific information derived from the commercial fishery and to provide input from commercial fishers in the assessment process, a commercial purse seine questionnaire and a fixed gear logbook program were established prior to the 1996 commercial fishery. Results of these initiatives are provided later in this document and are used in the current assessment of these stocks.

The TAC's for the 1996 fisheries were low and similar in magnitude to those in 1995 (Table 1). Quotas were not taken in any of the stock areas and 1996 landings (2500 t) were lower than in 1995 (4600 t) (Tables 2 - 6 and Figure 2).

The level of biological sampling was more than adequate as 1212 herring were sampled from the 1996 fisheries (Table 7). When apportioned by stock area, month and gear type, samples were available from 96% of the catch. This was partly attributable to the cooperation of fishers as purse seine fishers provided samples of all of their catches as part of the science fishery concept.

As in 1995 (Wheeler et al. 1997), spring spawners of the 1990, 1991 and 1992 year classes dominated in the commercial catches (Tables 9 - 13 and Figure 3). The 1990 year class was dominant in WB-NDB, the 1991 year class in BB-TB, CB-SS, and SMB-PB, and the 1992 year class in FB. In all areas, a single year class accounted for at least 50% of the catch. Spring spawners accounted for greater than 84% of the catch in all areas.

Mean weights at age (Table 14), which had decreased during the early 1990's, exhibited an increasing trend for most ages and areas in 1996.

1.3 The 1997 Fishery

Fisheries Management Branch formulated a multi-year (1997 and 1998) management plan for east and southeast Newfoundland herring based upon the 1996 Draft SSR released by Science Branch after the 1996 herring stock assessment meetings (Wheeler et al. 1997). As defined by the stock status classification system, the plan allowed for a restricted fishery in WB-NDB and BB-TB and a commercial fishery in SMB-PB and FB. Restricted fisheries were established for the two northern areas as the status of these stocks was considered *poor to moderate* and fishing mortalities of 5% to 10% were recommended. The status of the two southern stocks was considered to be *good to very good* with recommended fishing mortalities of at least 20%.

Consequently, TAC's were increased substantially from levels in the 1996 bait / science index fishery (Table 1). Quotas were not taken in any of the stock areas; this was partly attributable to a 'reserve' system built into the management plan. Landings increased from 2500 t in 1996 to 7900 t in 1997 (Tables 2 - 6 and Figure 2)..

The management plan allowed for competitive spring and fall fixed gear fisheries in all stock areas, and competitive spring and fall purse seine fisheries in SMB-PB and CB-SS and fall only purse seine fisheries in WB-NDB and BB-TB.

The level of biological sampling was again more than adequate in 1997 as 1685 herring were sampled from the fisheries (Table 8). When apportioned by stock area, month, and gear type, samples were available for 92% of the catch.

Spring spawners of the 1990 and 1991 year classes dominated in the commercial catch in four of the five stock areas (Tables 9 - 13 and Figure 3); this was similar to 1996. However, in FB fish aged 11+ years dominated the 1997 catch. This may be a consequence of the sampling protocol, as only one sample was used to calculate the catch at age in FB (Table 8). There was only limited evidence of the recruitment of year classes subsequent to the 1992 year class, that being in WB-NDB and BB-TB, where the 1994 year class accounted for approximately 10% of the catch. Spring spawners accounted for greater than 93% of the catch in all areas except SMB-PB where they represented 71% of the catch.

Mean weights at age, on average, were smaller than in 1996 (Table 14).

Section 2.0 - Abundance Indices

2.1 Research Gill Net Program

The research gill net program was initiated in 1982 to derive abundance indices independent of the commercial fishery. Each year, commercial fishers are contracted to provide catch rate data and biological samples of their catch. As the time series has developed, catch rates at age from the program have become a vital component of annual stock assessments and are used to estimate year class sizes. Biological samples from the program also give an early indication of recruitment as herring are recruited to the research gill nets prior to maturity and normally earlier than to the commercial purse seine fishery.

Dependent upon the size of the stock area, three to seven research gill net sites are fished annually in each stock area (Figure 4). Over time, some of these locations have changed to meet the requirements of the contracted fisher; however, spatial coverage has been maintained through the years to ensure an adequate distribution of effort throughout each stock area.

Each year, commercial fishers are provided with a standardized fleet of five herring gill nets; the stretched mesh size of these nets measure 50.8 mm, 57.2 mm, 63.5 mm, 69.9 mm, and 76.2 mm respectively. Each net is 32 m long and 9 m deep, with the exception of the 50.8 mm mesh net which is 5 m deep. These nets are fished from a fixed location, for a period of one month each spring. Fishers are required to haul the nets once a day (weather permitting) for the duration of the contract, to maintain an accurate daily log record of their catch, and to collect and freeze specified samples of their catch at eight regular intervals during the month.

Biological samples and logbooks are collected at the end of the program each year and are subsequently processed and analyzed by Pelagic Section personnel. Each fisher is then provided with an annual summary sheet (Appendix 1) providing detailed information regarding age distribution and catch rates for the year.

Prior to 1997, fishers were contracted under the research gill net program in each of the five herring stock areas for east and southeast Newfoundland. However, in 1997 and 1998, the program was terminated in CB-SS due to budget cuts within the Department. In 1998, twenty-three fishers participated in the program (Figure 4), seven in WB-NDB, eight in BB-TB, five in SMB-PB and three in FB.

Age distributions of herring (by number) from the research gill net program were available up to and including 1997; biological samples from the 1998 program have not yet been processed. The age distributions up to and including 1997 were similar between areas and years (Figure 5). The 1990 and 1991 year classes continued to dominate the catches in WB-NDB and BB-TB. These two year classes were also important in the two southern areas, SMB-PB and FB, and were also supplemented by the 1992 year class and by fish aged 11+ years.

Spring spawning herring continued to dominate the catches in all areas (Figure 5) and represented approximately 90% of the catch in WB-NDB, BB-TB, and FB. In SMB-PB, the percentage of autumn spawning herring increased approximately 10% from 1996 to 1997, representing approximately 30% of the catch in 1997.

Year classes are normally recruited to the research gill nets by age three or four years (Wheeler et al. 1997). With the exception of SMB-PB, there was little or no evidence of the 1993 and 1994 year classes in the 1997 catches (Figure 5) and these year classes accounted for less than 7 % of the catch (by number) in SMB-PB.

Catch rates at age for spring spawning herring only from the research gill net program are presented by stock area in Table 15 and Figure 6. Catch rates only are available for 1998 as these biological samples have not yet been processed. Catch rates and age distributions by bay are presented in Figures 7 - 9.

Catch rates for WB-NDB have continued to decline since last examined in 1996 (Figure 6). This decline has been continuous since 1992; catch rates in 1998 were 29% of the peak catch rates in 1992 and were the second lowest in the time series. When examined by bay (Figure 7), catch rates have declined in both WB and NDB, but far more precipitously in NDB where 1998 catch rates were the lowest during the time series and were less than 10% of the peak catch rates.

Catch rates for BB-TB increased from 1996 to a peak in 1997 but decreased by a factor of 3.1 from 1997 to 1998 (Figure 6). Similar to WB-NDB, 1998 catch rates were the second lowest in the time series. The decline from 1997 to 1998 occurred in both bays (Figure 8) but was more pronounced in BB where 1998 catch rates were the lowest during the time series and were approximately 15% of the peak catch rates in the previous year.

Catch rates for SMB-PB have also declined from 1996 to 1998 and are currently approximately 30% of their peak in 1996 (Figure 6). The decline has been equally large in both bays (Figure 9); however, 1998 catch rates in PB were the second lowest during the time series.

FB is the only stock area to exhibit an increase in catch rates (Figure 6). This trend has been continuous since 1992 and 1998 catch rates were the highest in the time series. These catch rates were also the highest for any of the four stock area time series. Unlike the other stock areas where catch rates have been dependent on the 1990 - 1992 year classes (Figure 5), catch rates in Fortune Bay have also been sustained by fish aged 11+ years.

For the first time in the assessment of these stocks, temporal catch rate trends have been examined by comparing cumulative catch per day (numbers) for all fishers within a stock area for the period from 1996 to 1998 (Figure 10). Although the dates fished vary between stock areas, they have remained relatively constant within areas from 1996 to 1998. Fishing dates tended to be later in the two northern areas (WB-NDB and BB-TB) due to ice cover during the spring along the northeast coast.

With the exception of WB-NDB in 1997 and possibly in 1998, the annual fishing period in each of the stock areas appeared to cover the seasonal 'run' of herring in the area. This seasonal 'run' generally reflects the spawning period for the spring spawning herring. In all areas except WB-NDB, the peak catches were fairly consistent in each of the three years and normally occurred within a two to three week period.

The temporal trends in FB, although similar between years, differed from the other stock areas. Catches fluctuated more widely over the time period each year and did not exhibit a single peak; however, after spawning was completed in early May, catch rates declined significantly.

2.2 Acoustic Survey Biomass Estimates

Acoustic surveys have been conducted on an annual basis since the early 1980's as part of the research program to assess Atlantic herring stocks within the Newfoundland Region. Four of the coastal stocks are surveyed acoustically on an alternate year basis to

estimate stock biomass. Acoustic biomass estimates, and distributional and behavioral information are available from three surveys since the last assessment, one conducted in BB-TB in the fall of 1996, one conducted in FB during the winter of 1997, and one conducted in SMB-PB in late winter 1998. Distributional information only is available from a survey of WB-NDB conducted in November - December 1997.

In all surveys, the survey area was defined as the area from the coastline to the 120 m depth contour. The 120 m depth contour was selected as the outer boundary as it has been shown that most herring are distributed within this depth range during the survey period (Wheeler et al. 1989). The survey areas were divided into strata based upon geographical features and herring distribution patterns, 21 strata in BB-TB (Figures 11 and 12), 14 strata in FB (Figure 20), 22 strata in WB-NDB (Figures 28 and 29), and 26 strata in SMB-PB (Figure 35).

The design for the BB-TB and FB acoustic surveys remained unchanged from previously described herring acoustic surveys (Wheeler et al. 1997). It consisted of a series of equidistant parallel transects, within each stratum, from the coastline to the outer boundary. Acoustic sampling intensity (total transect length) was allocated to these strata on a 2:6:11 ratio (for low, medium, and high density strata) based upon herring distribution patterns observed in the commercial fishery and previous acoustic surveys. To maintain a random design, the placement of the first transect within each stratum was chosen randomly along a reference line drawn parallel to the coastline. Due to the irregular nature of the coastline, transects within strata were of unequal length. Herring densities, integrated on the transects, were weighted to adjust for transect length. A mean weighted density for the stratum was then calculated and extrapolated to the stratum area to estimate fish biomass. Strata estimates were summed to calculate a total biomass estimate for the survey area.

The design of the WB-NDB and SMB-PB acoustic surveys followed that described by Anderson et al. (1998). A multi-start systematic design was used which allowed for the calculation of a survey-based variance estimate. Each stratum was sub-divided into blocks with equal number of parallel transects per block. Placement of transects were randomly selected in the first block of a stratum but were defined by this placement in the remaining blocks. Acoustic sampling intensity (total transect length) was allocated to the strata and to subsequent blocks on a 0.5:2.0:6.0:11.0 ratio for very low, low, medium, and high density strata. Weighted herring densities were calculated for each block; a weighted mean density for the stratum was then calculated and extrapolated to the stratum area to estimate fish biomass as in previous surveys.

Age distributions were calculated from biological samples collected during the surveys.

The BB-TB and FB surveys were conducted from the *R. V. Shamook*, a 24 m Departmental research vessel. The first commenced in Hearts Content, Trinity Bay on November 10, 1996 and terminated in Valleyfield, Bonavista Bay on December 1, 1996. The second commenced in Fortune, Fortune Bay on January 10, 1997 and terminated in Bay L'Argent, Fortune Bay on February 5, 1997. Both surveys were disrupted due to vessel operational delays and bad weather conditions. Acoustic sampling of five strata in the Bonavista Bay - Trinity Bay survey had to be eliminated due to the delays. All of the eliminated strata were considered to be very low probability areas for herring. The Fortune

Bay survey was extended by eight days; however, three very low density strata were still not surveyed.

The WB-NDB survey was conducted as part of a larger scaled inshore acoustic survey of NAFO Div. 3KL (Anderson et al. 1998). Acoustic systems were deployed from the Departmental vessels *R. V. Shamook* and *R. V. Louis M. Lauzier*. Two commercial vessels were chartered to conduct biological sampling, the *Sea Gem*, a 19.8 m otter trawler, and the *Andrew and Nicholas*, a 16.8 m purse seiner. The survey commenced at Cape Freels in Notre Dame Bay on November 22, 1997 and terminated at Harbour Deep in White Bay on December 13, 1997. All strata were surveyed with the exception of some parts of strata in eastern Notre Dame Bay.

The SMB-PB survey was also conducted from the *Andrew and Nicholas*, a chartered commercial purse seine vessel. The survey commenced in Marystown, Placentia Bay on March 16, 1998 and terminated in Trepassey, St. Mary's Bay on April 6, 1998. All of the intended strata were surveyed and additional acoustic sampling was possible as the vessel was capable of surveying at a vessel speed of approximately 8 knots (compared to a speed of 5.5 knots for the *Shamook*).

A *Femto* Model 9001 acoustic data acquisition system was used in all of the surveys in conjunction with a *BioSonics* Model 105 echo sounder and 120 kHz transducer (operating in single beam mode). The transducer, mounted in a v-fin, was deployed at a depth of approximately 3 m astern and abeam of the vessel(s).

The acoustic system was calibrated in October 1996 and again in April, 1998 . The calibration parameters were as follows:

Parameters	October 1996	April 1998
Source Level / Receive Sensitivity:	42.26 dB	43.64 dB
Fixed Receiver Gain:	9.57 dB	11.16 dB
TVG Gain:	20 log R	20 log R
Attenuation Coefficient:	0.0347 dB/m	0.0347 dB/m
Pulse Length:	0.4 ms	0.4 ms
Average Beam Factor:	-29.4 dB	-29.4 dB

During the April 1998 calibration, it was determined that the *Femto* data acquisition system, used during the 1997 WB-NDB survey, was faulty and could not be calibrated; therefore, density and biomass estimates could not be calculated from this survey. Similar problems did not exist for the remaining surveys; the October 1996 calibration parameters were used for the BB-TB and FB surveys and the April 1998 parameters were used for the SMB-PB survey.

Where concentrations warranted, and depth and weather conditions permitted, biological samples of herring were collected during the surveys using a herring purse seine. Sampling was supplemented during the BB-TB and FB surveys from overnight sets of a five panel fleet of research gill nets, set in selected locations throughout the survey areas.

During the surveys, a detailed log record was maintained for each transect and also while steaming between transects. Observations were recorded of all fish concentrations (pelagic and groundfish) detected on both the echogram and oscilloscope.

The acoustic data, as recorded in the detailed log, were edited, subsequent to the surveys, using a *Femto* acoustic data editing system. All bottom signals were removed and only those fish concentrations considered to be herring (from visual inspection of oscilloscope and echogram images) were included in the analyses.

Acoustic back-scatter was converted to herring density using the following target strength - fish length relationship calculated for herring by Wheeler et al. (1994):

$$T.S. = 20 \log L - 65.5$$

Mean fish lengths were derived from biological samples collected during the survey. Target strength per fish was converted to target strength per unit fish weight using mean fish weights from the biological samples.

Formulas used to calculate mean densities, variances, and biomass estimates remained unchanged from previous surveys and are described in Wheeler (1991).

For the purpose of plotting herring distributions, mean densities (g/m^2) were calculated per 10 sec. (~30 m) intervals along each transect for the BB-TB and FB surveys and per 60 sec. intervals for the SMB-PB survey.

2.2.1 Bonavista Bay - Trinity Bay

During this survey, 163 transects were surveyed from Green's Harbour, Trinity Bay to Shoe Cove Point, Bonavista Bay (Figures 11 and 12). The total length of transects was 206 n.mi. Herring were acoustically detected in 6 of the 16 strata surveyed and were integrated on 17 (10.4%) transects (Figures 13 and 14). Herring were most prevalent in the northern portion of Bonavista Bay, in Indian Bay, near Dover, and near Hail Island and Bessys Island.

Herring were sampled by purse seine in one location only during the survey; in addition, purse seine samples from the commercial fishery were available from three other locations (Table 16). Samples of herring from research gill nets were available from 14 locations throughout the survey area. Mean lengths from the survey purse seine sample and a commercial purse seine sample from an adjacent stratum were not significantly different (Figure 15). Similarly, mean lengths from purse seine samples and research gill net samples were very similar in the four strata from which such comparisons could be made. Therefore, it was decided to combine purse seine and research gill net samples, on a stratum basis, to calculate mean fish lengths and weights required for target strength calculations (Table 17). Length distributions of combined samples for those strata in which herring were acoustically detected are presented in Figure 16.

A biomass estimate of 36849 t was derived from the survey area (Table 18), 99.9% of which was in Bonavista Bay. Approximately 78% of the estimated biomass was detected in one stratum, and on only 5 of 15 transects within that stratum.

Spring spawners accounted for 89.5% of the population estimate (Figure 17). The estimate of spring spawners (33000 t) represented a 268% increase from the last acoustic survey of the area (Table 19). As in the last survey, the 1991 year class dominated, accounting for 66% of the population estimate (Figure 17).

Herring were distributed in water depths as shallow as 17 m in the survey area (Figure 18). Most occurred in water depths of 20 - 40 m, with peak densities in depths of approximately 26 m. Due to rapid changes in water depth within strata and near stratum boundaries, approximately 2.3% of the transects occurred in water depths greater than 120 m. However, all detected herring densities were within the defined survey area, with the maximum depth of occurrence being 85 m.

As in previous years, the survey was conducted primarily during daylight hours (Figure 19). This was for safety reasons as in surveying the transects, the vessel must navigate very close to shore in restricted areas and depths. During the survey, there was a trend in the time of day when herring were acoustically detected. Approximately 95% of the herring were detected after 1200 h with peak densities between 1645 h and 1745 h, ie. at the end of the daily survey period.

2.2.2 Fortune Bay

During this survey, 148 transects were surveyed from Pass Islands in the west to Grand Jerseyman Head in eastern Fortune Bay. (Figure 20). The total length of transects was 120 n.mi. Herring were acoustically detected in 3 of the 11 strata surveyed and were integrated on 14 (9.5%) transects (Figures 21 and 22). Herring were most prevalent in the Long Harbour and Harbour Breton areas.

Herring were sampled by purse seine in one location only during the survey (Table 20). Samples of herring from research gill nets were available from 7 locations throughout the survey area. Mean lengths from all samples (purse seine and gill net) collected during the survey were similar and within 3.0 cm, and in some cases, sample sizes were very small (Figure 23). Therefore, it was decided to combine all samples, across strata, to calculate a mean fish length (29.9 cm) and weight (213 g) required for a target strength calculation (-59.27 dB/g). Length distributions of combined samples by stratum are presented in Figure 24.

A biomass estimate of 16885 t was derived from the survey area (Table 21). Approximately 89% of the estimated biomass was detected in one stratum (Long Harbour) where herring were detected on 10 of 17 transects within the stratum.

Spring spawners accounted for 92% of the population estimate (Figure 25). The estimate of spring spawners (15500 t) represented a 620% increase from the last acoustic survey of the area (Table 22). As in the last survey, the 1992 year class dominated, accounting for 60% of the population estimate (Figure 25).

Due to rapid changes in water depth within strata and near stratum boundaries, not all of the transect coverage was within the defined survey area; 5.0% of the transects occurred in water depths greater than 120 m (Figure 26). Herring were distributed over a broad range in water depths (14 -190 m), with peak densities in depths of approximately 33 m. Approximately 94% of detected herring densities were within the defined survey area (<= 120 m water depth).

As in BB-TB, the survey was conducted primarily during daylight hours (Figure 27). However, unlike the BB-TB, there was no trend in the time of day when herring were acoustically detected. Peak densities were detected between 1215 h and 1400 h.

2.2.3 White Bay - Notre Dame Bay

During this survey, 292 transects were surveyed from Cape Freels to Harbour Deep (Figures 28 and 29). The total length of transects was 292 n.mi. Herring were acoustically detected in 12 of the 22 strata surveyed and were integrated on 22 (8%) transects.

Herring were sampled from six locations during the survey (Table 23 and Figures 30 and 31). Five of the six samples were obtained by purse seine; one was obtained by otter trawl. The length distribution of samples tended to differ by strata (Figures 32 and 33) with smaller fish being distributed in the western portion of the stock area.

Spring spawners accounted for 97.8% of the sample numbers (Figure 34). Most (84%) of the fish sampled were immature (<= age 3); a sample consisting entirely of 1997 year class was caught near Hampden in White Bay.

2.2.4 St. Mary's Bay - Placentia Bay

During this survey, 213 transects were surveyed from Jude Island, Placentia Bay to Holyrood Pond, St. Mary's Bay (Figure 35). The total length of transects was 460 n.mi. Herring were acoustically detected in 3 of the 19 strata surveyed and were integrated on 5 (2.3%) transects only (Figure 36). Herring were detected in the Fair Haven and Placentia Sound areas of Placentia Bay and near St. Mary's in St. Mary's Bay.

Herring were sampled by purse seine in two locations during the survey (Table 24). Purse seine samples from the commercial fishery were also available from another location. Mean lengths from the survey purse seine sample and from the commercial samples in stratum 60 were not significantly different (Figure 37). These samples were therefore combined to calculate mean lengths and weights for the stratum. The mean length from the survey sample in stratum 67 was significantly different from the samples in stratum 60. Therefore, it was decided to use separate mean lengths and weights, by stratum, for target strength calculations (stratum 67: -59.78 dB; stratum 60: -59.59 dB). Length distributions of combined samples, by stratum, are presented in Figure 38.

A biomass estimate of 11572 t was derived from the survey area, 95.9% of which was detected in Placentia Bay (Table 25). Approximately 67% of the biomass estimate was detected in stratum 60; another 29% in stratum 60.

Spring spawners accounted for only 55.5% of the population estimate (Figure 39). The estimate of spring spawners (6600 t) represented a 66% decrease from the last survey of the area (Table 26). As in the last two acoustic surveys of the area, the 1991 year class dominated, accounting for 38% of the population estimate (Figure 39).

Herring were distributed in water depths from 19 to 34 m with peak densities in depths of 31 m (Figure 40). Less than 2% of the transects occurred in depths greater than 120 m and all detected herring densities were within the defined survey area.

As in the previous surveys, this one was also conducted during daylight hours (Figure 41). There was a trend in the time of day when herring were detected; approximately 99% of the herring were detected after 1400 h with peak densities at the end of the survey period (Figure 41).

2.2.5 Discussion

The success of estimating herring abundance from acoustic surveys in coastal Newfoundland waters is highly dependent upon knowing and accounting for the temporal pattern in herring migrations. Traditionally, the fall herring purse seine fishery in Bonavista Bay has occurred from mid October to late November. During this time, aggregations of herring migrate into the northern part of Bonavista Bay and move southward to overwintering areas in the deep water of Chandlers Reach (Wheeler and Winters 1984). However, during the early 1990's, when ocean temperatures were colder than normal, the fall migration of herring into the bays along the northeast coast of Newfoundland was delayed. In planning the 1996 BB-TB acoustic survey, it was attempted to account for this delay by scheduling the survey in November and surveying from south to north through the two bays. However, the herring distribution patterns observed during the survey (Figures 13 and 44) suggest that the migration of herring into the bays was in the early stages as most herring were detected in the latter part of the survey and in the northern part of Bonavista Bay.

The FB acoustic survey has always been conducted in January at a time when herring are considered to be in a relatively sedentary overwintering state. This was the case in both the 1990 and 1992 surveys (Wheeler 1990, 1992) when herring were detected in the same locations in both surveys and remained in those locations during the period of the surveys. However, this trend was not as evident in the 1995 survey (Wheeler and Winters 1996) when the estimated biomass decreased to 14% of the previous estimate (Table 22). During the 1997 FB survey, most of the estimated herring biomass was detected in the Long Harbour stratum. Herring were detected on 60% of the transects in the stratum, compared with <10% of transects for the total survey, and were much more abundant there than in any of the previous surveys. They were also detected on the outer transects in the stratum and, based upon echogram observations, may have been moving into Long Harbour at the time. Due to vessel and weather delays in 1997, the Long Harbour stratum was surveyed two weeks later than in 1995. This suggests that the seasonal timing of this survey is also very important; it

also further supports the conclusion of Wheeler et al. (1997) that the extremely low estimate from the 1995 survey estimate did not reflect stock abundance.

Although density and biomass estimates are not available from the 1997 WB-NDB survey, the distributional patterns of the fish and the age distribution of biological samples provide insights to the status of the stock. Herring were distributed through the stock area but were detected on relatively few transects. Most of the herring were also immature with smaller fish tending to be distributed to the westward. There was also no evidence that the timing of the survey was a problem as there was no greater occurrence of herring later in the survey and to the north as had occurred in BB-TB in 1996. Observations from the acoustic survey are confirmed from the 1997 commercial fishery data. Successful sets from the 1997 fall purse seine fishery were restricted to five strata with the majority of sets in one stratum near Fogo Island (Figure 57). Fishers also indicated that small fish was the primary reason for discards in 1997 (Figure 58).

The results of the 1998 SMB-PB survey are troublesome. Historically, this survey has been conducted in January - February for the same reasons as in FB. In 1998, the survey timing was shifted to March - April, still prior to spring spawning, but at the same time as the commercial purse seine fishery in the area. This was partly in response to commercial fishers who suggested that the distribution of herring at that time would be more amenable to the acoustic technology. The survey was conducted from a commercial purse seine vessel which had increased survey capabilities compared to the departmental research vessel which was used in the past. Acoustic sampling intensity (n. mi. surveyed) was increased by approximately 30% due to the increased speed at which the vessel could survey. The vessel was also more maneuverable and capable of surveying closer to shore. Due to their extensive commercial fishing experience, the crew was also more proficient in fishing the purse seine and consequently in collecting biological samples. However, given all of these advantages, herring were only detected in three areas during the survey and the biomass estimate was substantially lower than the last survey in 1996. This result is consistent with the observations of commercial purse seine and fixed gear fishers who indicated that abundance in 1998 was well below average and had decreased substantially from 1997 (Figures 46 and 48).

In both the BB-TB and the FB surveys, biological samples collected by purse seine during the survey were supplemented from other sources. The single purse seine sample caught during the BB-TB survey was supplemented by samples provided through a cooperative arrangement with commercial purse seine fishers. In both surveys, samples were also caught throughout the stock areas by research gill nets. Length distributions of purse seine and research gill net samples were very similar in each of the surveys. This may have been due largely to the presence of very dominant year classes in each of the stock areas; the same year classes were also important in the commercial fisheries in these areas (Figure 3). Nevertheless, it is important to note that the research gill nets do not sample juvenile herring (<= age 2) and that commercial purse seiner vessels often target mature fish, avoiding concentrations of juvenile herring.

The selection of the 120 m depth contour as the outer stock boundary in BB-TB and SMB-PB was again confirmed from the most recent survey data. Although depths to 140 m were surveyed, the maximum depth at which herring were detected was 85 m. However, in FB, approximately 6% of detected densities were from waters greater than 120 m deep.

In BB-TB and SMB-PB, there was a trend in the time of day when herring were acoustically detected. In FB, no similar trend existed. Caution should be exercised before drawing any conclusions from these results. In all surveys, most of the estimated biomass was detected in one or two strata. The temporal results may simply be an indication of the time of day that these strata were surveyed. There was also evidence from the 1996 - 1998 commercial purse seine fisheries that herring were readily detectable during daylight hours as the vast majority of successful purse seine sets were taken during daylight hours (Figure 57).

Unlike the 1995 surveys of BB-TB and FB which both may have underestimated stock sizes, the 1996 and 1997 surveys of these areas should more accurately reflect stock sizes, although both may still be conservative estimates. Herring were concentrated in the northern portion of Bonavista Bay and may not have fully migrated into the survey area. Similarly, herring may have been migrating into Long Harbour during the Fortune Bay survey. There is also no reason to discount the 1998 survey estimate of SMB-PB. In all of the most recent surveys, biological sampling was adequate and the intensity of survey coverage was good.

2.3 Commercial Gill Net Logbook Program

In 1996, a new initiative was undertaken by Science Branch within the Newfoundland region to increase the scientific information derived from the fixed gear herring fishery and to allow for the quantitative input of commercial fishers in the assessment process. Prior to the spring fishery, each herring gill net fisher along the east and southeast coast of Newfoundland was provided with a logbook in which to record daily catch rate information. The compilation of information and submission of logbooks was strictly on a voluntary basis. The format of the logbook was changed slightly in 1997 to include a series of questions asking fishers to quantify their observations regarding herring abundance and incidence of spawning in their area.

The long-term goal of this program is to develop a time series of catch per unit effort (CPUE) data from the commercial fixed gear fishery. These data will complement information derived from the research gill net program which has been used to track herring year class abundance since the early 1980's.

In 1996, 1997 and 1998, logbooks, prepared by Science Branch, were distributed by Fisheries Management Branch to greater than 2000 fishers along the east and southeast coasts of Newfoundland as part of the fisher's fixed gear herring licence package. In a covering letter, fishers were asked to participate on a voluntary basis in providing quantitative information on the herring resource in their area. It was stressed that this was a cooperative effort between fishers and Science to improve the knowledge of the herring resource.

The logbook (Appendix 2) was designed to be completed by gill net fishers involved in the spring commercial (food fish) fishery, spring bait (lobster) fishery, and/or fall commercial fishery . Fishers were asked to complete header information, including their name, mailing address, community, postal code, phone number, fisher identification number (F.I.N.), and the geographical location that they fished. They were also asked to provide information regarding their gill nets, including the number and dimensions (length and depth) by mesh size. A section was also provided for comments. In 1997 and 1998, fishers were also asked the following four questions: 1) using a scale of 1 to 10, with 1 being the lowest and 10 being the

highest, how abundant (fish numbers) were herring in your fishing area in the current year, 2) using a scale of 1 to 10, with 1 being the lowest and 10 being the highest, how abundant (fish numbers) were herring in your fishing area in the previous year, 3) do herring spawn each year in your area - if so, in what geographical location(s), and 4) using a scale of 1 to 10, with 1 being the lowest and 10 being the highest, how intense was herring spawning in your fishing area in the current year. They were then asked to complete a logbook entry for each day that a net or nets were hauled. This entry included the month, day, number of nets hauled by mesh size, number of nights that the nets had fished, the approximate catch weight (lbs.), and the wind direction and speed at the time the nets were hauled. A return address was provided to which the logbook was to be sent at the end of the fishery. In 1998, a postage paid return envelope was provided to fishers who had returned logbooks in either 1996 or 1997.

Each year, fishers who participated in the program and returned logbooks, were sent feedback information in the form of a summary graph of their individual catch per net per days fished (Appendix 3).

All logbooks received to September 15, 1998 have been included in the analysis.

2.3.1 White Bay - Notre Dame Bay

The number of logbook returns decreased from 16 in 1996 to 9 in 1997 and remained stable at 9 in 1998 (Table 27). The total number of nets fished decreased substantially from 106 in 1996 to 34 in 1997 and increased to 41 in 1998. The mean mesh size of nets fished decreased by 4% from 1996 to 1998. Mean panel area decreased each year over the three year period and was 19% less in 1998 than in 1996. The spatial distribution of fishing effort represented by the logbooks was similar in all years and was restricted primarily to the eastern portion of Notre Dame Bay (Figure 42). The temporal distribution of fishing effort was markedly different over the time period (Figure 45). Severe ice conditions in 1997 delayed the spring fixed gear fishery by approximately five weeks compared to 1996. The 1998 fishery commenced approximately two weeks later than in 1996. Peak catch rates in 1996 occurred in late April; in 1997, the fishery didn't commence until mid May and catch rates exhibited two peaks, in late May and in mid June. In 1998, catch rates again peaked twice, in late April (similar to 1996) and in late May (similar to 1997). Measures of effort, ie. total nights fished and total number of hauls, decreased substantially from 1996 to 1998 (Table 27). Catch rates decreased from 1996 to 1997 and again from 1997 to 1998; catch per net per night fished decreased from 35.9 kg in 1996 to 25.1 kg in 1997 and to 12.2 kg in 1998, a decrease of 66% over the period. Similarly, catch per net per haul decreased from 46.2 kg in 1996 to 39.3 kg in 1997 and to 16.7 kg in 1998, a decrease of 64% over the period. The decline in catch rates was consistent and comparable in magnitude with the observations of fishers who indicated a mean herring abundance of 6.0 in 1996, 5.4 in 1997, and 2.1 in 1998 (Figure 46). There was only one observation regarding spawning intensity in 1997, which suggested better than average spawning; in 1998, there were eight observations, seven of which suggested that spawning was well below average (Figure 47). Additional comments from fishers in 1998 (Table 29), echoed their observations regarding the lack of herring in 1998 and suggested the 1997 fall purse seine fishery in the eastern half of Notre Dame Bay may have been the cause.

2.3.2 Bonavista Bay - Trinity Bay (BB-TB)

The number of logbook returns decreased from 11 in 1996, to 6 in 1997, and to 3 in 1998 (Table 27). The number of nets fished decreased substantially, from 100 in 1996 to 38 in 1997 but remained stable at 34 in 1998. The mean mesh size of nets fished increased marginally (2%) from 1996 to 1998 while mean panel area fluctuated, increasing by 18% from 1996 to 1997 and then decreasing by 8% in 1998. The spatial distribution of fishing effort represented by the logbooks was similar in 1996 and 1997; however, in 1998 it was restricted to Trinity Bay only (Figure 43). The temporal distribution of fishing effort was comparable in the three years; however, nets were fished for an additional two to three weeks in 1997 and 1998 (Figure 45). Peak catch rates in 1996 occurred in late April; in 1997, there was a peak in late April and again in late May; in 1998, catch rates peaked in late April, similar to 1996 and 1997. Measures of effort, ie. total nights fished and total number of hauls, increased marginally from 1996 to 1997, but decreased substantially in 1998 (Table 27). Catch rates decreased marginally from 1996 to 1997, and then more substantially from 1997 to 1998; catch per net per night fished was 31.1 kg in 1996, 28.8 kg in 1997 and 10.4 kg in 1998, a decrease of 67% over the period, while catch per net per haul was 46.7 kg in 1996, 43.7 kg in 1997 and 18.9 kg in 1998, a decrease of 59% over the period. This did not coincide with the observations of fishers who indicated a mean herring abundance of 6.1 in 1996, increasing to 6.7 in 1997 and decreasing to 5.7 in 1998. There were three observations from fishers regarding spawning intensity in 1997 (Figure 47), all of which indicated that spawning was relatively high. Two observations in 1998 indicated that spawning was still above average, but less than in 1997. There were also three comments from fishers (Table 28) indicating that herring were abundant in 1997 and one to suggest fair abundance in 1998 (Table 29).

2.3.3 Conception Bay - Southern Shore (CB-SS)

There was only one logbook returned from this area in 1996 and none at all in 1997 or 1998.

2.3.4 St. Mary's Bay - Placentia Bay (SMB-PB)

The number of logbook returns decreased from 13 in 1996 to 6 in 1997 and increased slightly to 8 in 1998 (Table 27). Similarly, the total number of nets fished decreased from 56 in 1996 to 43 in 1997 but remained relatively stable at 41 in 1998. The mean mesh size of nets fished did not change significantly over the three years while mean panel area fluctuated, increasing by 5% from 1996 to 1997 and then decreasing 6% from 1997 to 1998. Even though there was a substantial decrease in the number of returned logbooks, the spatial distribution of fishing represented by the logbooks remained similar in all years (Figure 44). The temporal distribution of fishing effort was different in 1996 and 1997 as the fishery commenced approximately five weeks earlier in 1997. The temporal distribution of fishing effort in 1998 was similar to that in 1996 (Figure 45). Peak catch rates occurred in early April in 1996 but not until early June in 1997. Similarly, catch rates peaked in early June in 1998. Measures of effort, ie. total nights fished and total number of hauls, decreased by approximately 30% from 1996 to 1997 but increased to 1996 levels in 1998 (Table 27). Catch rates decreased substantially from 1996 to 1997 but stabilized in 1998. Catch per net per

nights fished decreased from 28.2 kg in 1996 to 18.5 kg in 1997 and then to 18.4 kg in 1998, a decrease of 35% over the period. Catch per net per haul decreased from 46.3 kg in 1996 to 34.8 kg in 1997 and then to 32.8 kg in 1998, for a decrease of 29% over the period. The decline in catch rates was consistent but not of the same magnitude with the observations of fishers who indicated a mean herring abundance of 5.5 in 1996, 3.4 in 1997, and 2.6 in 1998 (Figure 46). Observations by fishers on spawning intensity in 1997 and 1998 were quite divergent (Figure 47). Additional comments by fishers (Tables 27 and 28) echoed their observations regarding the decline in abundance in 1997 and 1998 and attributed the decline to the winter-spring purse seine fishery in Placentia Bay.

2.3.5 Fortune Bay (FB)

The number of logbook returns increased from 11 in 1996 to 13 in 1997 but decreased to 6 in 1998 (Table 27). The number of nets fished exhibited a similar pattern, increasing from 41 in 1996 to 50 in 1997 and decreasing to 17 in 1998. The mean mesh size of nets fished decreased by (2%) from 1996 to 1997 and by a further 4% from 1997 to 1998. Mean panel area decreased by 12% from 1996 to 1997 and by a further 3% from 1997 to 1998. The spatial distribution of fishing effort represented by the logbooks (Figure 44) increased slightly from 1996 to 1997 and remained stable in 1998 but still did not include the western most part of the stock area. The temporal distribution of fishing effort was very similar in the three years (Figure 45); peak catch rates in 1997 and 1998 occurred in early May, approximately one week later than in 1996. Measures of effort, ie. total nights fished and total number of hauls increased substantially from 1996 to 1997, relative to the increase in the number of fishers (Table 27); effort measures decreased substantially in 1998. Catch rates exhibited a declining trend from 1996 to 1998. Catch per net per nights fished was 39.2 kg in 1996, 37.7 kg in 1997, and 30.1 kg in 1998, a decrease of 23% over the period. Similarly, catch per net per haul was 63.1 kg in 1996, 60.9 kg in 1997, and 48.3 kg in 1998, a decrease of 23% over the period. This was opposite to the observations of fishers who indicated a mean herring abundance of 7.2 in 1996, 7.5 in 1997, and 7.8 in 1998 (Figure 46). Observations by fishers on spawning intensity in 1997 and 1998 also indicated that spawning was relatively high in both years (Figure 47). Additional comments by fishers were variable (Tables 28 and 29); one suggested that the stock was healthy and one did not catch sufficient herring for lobster bait purposes.

2.3.6 Discussion

Given that only three years of commercial gill net logbook data exist, it is difficult to examine trends in abundance. However, it is interesting to examine fishers' observations of abundance in previous years, as estimated retrospectively, with actual catch rates in those years. For the two stock areas where fishers perceived abundance to be relatively lower, ie. WB-NDB: 1996 = 6.0 1997 = 5.4 1998 = 2.1, and SMB-PB: 1996 = 5.5 1997 = 3.4 1998 = 2.6, their perception was consistent with their decline in catch rates. However, in BB-TB and FB, where they perceived that the stocks were relatively more abundant, their observations were not consistent with their catch rates. In FB, their perception of an abundant stock (1996 = 7.2, 1997 = 7.5, 1998 = 7.8) is consistent as the stock has been only lightly exploited for the past twenty-five years.

The logbook was designed to be relatively easy to complete in order to encourage as many fishers as possible to participate. To date, the participation rate as measured by the number of fishers has been low. Efforts have been made to encourage fishers to participate; the importance of the program has been emphasized at Herring Working Group meetings and at meetings of the Small Pelagics Advisory Committee, letters have been sent in 1998 to fishers who participated in 1996 and 1997 reminding them to return their logbooks and to encourage others to do so, and an announcement was made on the C.B.C Fisheries Broadcast immediately after the 1997 spring fishery encouraging fishers to return their logbooks.

Although participation numbers have been low, the 1996 total catch from the logbooks, relative to the 1996 provisionally reported total gill net landings from the fishery, show interesting results (Table 27). For WB-NDB and BB-TB, the total catch from the logbooks represented 30% and 15% of the commercial gill net landings respectively. However, for SMB-PB and FB, the catch from logbooks represented 122% and 194% of the respective total reported gill net landings. Similarly in 1997, the total catch from the logbooks represented 44% of the provisionally reported gill net landings for WB-NDB, 20% for BB-TB, 73% for SMB-PB and 246% for FB. There is no reason to suspect the catches as reported in the logbooks. Therefore, it must be assumed that the provisional landings from the fishery, as provided by Policy and Economics Branch, are incomplete for some areas. Consequently, it isn't possible to quantify the percentage of total commercial landings represented by the logbooks. It can be said for WB-NDB and BB-TB that the 1996 logbooks account for a maximum of 30% and 15% of the respective commercial landings. Similarly, in 1997, the logbooks account for a maximum of 44%, 20% and 73% of the commercial landings in WB-NDB, BB-TB and SMB-PB respectively.

The level of effort from the logbooks, as measured by total nights fished, is quite variable but favourable in relation to the research gill net program. In 1996, logbook effort ranged from 85% of research gill net effort in BB-TB to 509% in FB. In 1997, it similarly ranged from 86% in BB-TB to 844% in FB and again in 1998 from 40% in BB-TB to 415% in FB. Given the detailed mesh size and panel area information and the temporal and spatial coverage of the logbook data, this suggests that annual catch rates calculated from the same should be as reliable and comparable to those calculated from the same mesh size nets in the research gill net program.

2.4 Commercial Purse Seine Questionnaire

In 1996, a questionnaire was designed to quantitatively evaluate biological and fishery related information obtained from east and southeast Newfoundland herring purse seine fishers. The survey was undertaken to enhance the collection of scientific information on these herring stocks and to provide fishers from this fleet sector with an opportunity for direct input in the assessment process. The questionnaire was developed to supplement existing databases from the research gill net program, acoustic surveys, commercial gill net logbooks, and commercial sampling. This initiative was continued in 1997 and again in 1998.

The questionnaire (Appendix 4) was designed after that of Nakashima (1995) who used a similar approach to quantify the observations of fixed gear capelin fishers. Questions were designed to quantify observations on herring abundance, fleet characteristics, the fishery, and biological events (migration and spawning). In 1998, questions related to spawning (#'s 4 - 7) were deleted from the questionnaire; it was found that fishers did not have detailed observations of the spring spawning patterns of herring as most purse seine fisheries occurred in the fall.

Each year (1996, 1997, and 1998), a list of names and telephone numbers was provided by Fisheries Management Branch, DFO, of all east and southeast Newfoundland herring purse seine fishers who participated in the fishery. As the number of fishers was relatively small (Table 30), it was decided to contact all fishers rather than sub-sample the population. To minimize time and costs, the surveys were conducted by telephone.

For the 1996 survey, telephone interviews commenced on December 5, 1996 and were completed by January 8, 1997. The interviews were conducted immediately after the fall fishery in all stock areas but were nine to ten months after the spring fishery in Placentia Bay. Interviewers were able to contact 52 of 55 fishers (95%) who participated in the 1996 fishery.

For the 1997 survey, interviews were conducted from June 8, 1997 to August 12, 1997, ie. within three months of the completion of the spring purse seine fishery in St. Mary's Bay and Placentia Bay. Further interviews were conducted from December 15, 1997 to February 17, 1998, immediately subsequent to the fall fishery. In 1997, 48 of 51 fishers (94%) who participated in the fishery, were surveyed.

To date in 1998, interviews were conducted from May 18, 1998 to July 20, 1998 and 11 of 16 fishers (69%) who participated in the spring purse seine fishery in St. Mary's Bay - Placentia Bay have been contacted. In all years, a minimum of three attempts were made to contact the remaining fishers.

For the three northern areas, the purse seine fishery occurs in the fall only and survey results are available from 1996 and 1997. For St. Mary's Bay - Placentia Bay, there is a late winter / early spring fishery and a fall fishery. Survey results are available from 1996 to 1998 for the winter / spring fishery and from 1996 and 1997 only for the fall fishery.

2.4.1 Questions Regarding Herring Abundance

Three questions were asked to compare herring abundance in one's home bay in current and previous years (Figures 48 and 49). On a scale of one to ten (with one being the lowest and ten being the highest), respondents indicated that herring abundance in their home bay was well above average in all stock areas in 1996 and 1997. Although still high, abundance in all areas was observed to have decreased from 1996 to 1997. Abundance in SMB-PB was estimated to be well below average in 1998. For WB-NDB, average abundance decreased from 7.88 in 1996 to 6.92 in 1997. For BB-TB, average abundance decreased from 8.62 in 1996 to 6.93 in 1997. For CB-SS, average abundance decreased from 7.20 in 1996 to 6.00 in 1997. For SMB-PB, average abundance decreased from 8.67 in 1996 to 8.19 in 1997, and then decreased to 2.33 in 1998.

Fishers were also asked to retrospectively estimate abundance in their home bay in the previous year. Interestingly, for all stock areas, the retrospective estimate for 1996 from the 1997 survey and for 1997 from the 1998 survey, was lower than the current year estimate for the survey. For WB-NDB, the retrospective estimate for 1996 was 7.83 compared with the current year estimate of 7.88, a difference of 1%. For BB-TB, the retrospective estimate for 1996 was 7.38 compared with the current year estimate of 8.62, a difference of 14%. For CB-SS, the retrospective estimate for 1996 was 6.50 compared with the current year estimate of 7.20, a difference of 10%. For SMB-PB, the retrospective estimate for 1996 was 7.92 compared with the current year estimate of 8.67, a difference of 9%; similarly the retrospective estimate for 1997 was 7.78 compared with the current year estimate of 8.19, a difference of 5%.

In 1996, when asked to compare abundance in the current year to when they started fishing herring by purse seine (Figure 49), the majority of fishers in all stock areas indicated that current abundance was the same or higher than when they first started fishing. In 1997, there was a downward trend in the estimate of current abundance relative to the past in three of the four stock areas (the exception being SMB-PB). In 1998, SMB-PB also showed a substantial downward trend in current abundance. This agreed with the observations for 1997 and 1998 in Figure 48.

2.4.2 Fleet Characteristics

All respondents were asked a series of questions to characterize the demographics of the population of purse seine fishers; these were designed to monitor changes in fishing experience and fleet capacity.

Responses indicated a slight shift towards a younger mean age of fishers in 1997 in all areas, with more in the age 35 - 44 range compared to the age 45 - 55 range in 1996. This did not change in SMB-PB in 1998 (Figure 50).

Responses also indicated that participants in the 1997 fishery had less experience, on average, than those in the 1996 fishery (Figure 51). This is consistent with the shift in the age distribution of fishers, as indicated above.

The average fishing vessel length and capacity was smallest in BB-TB and greatest in WB-NDB (Table 31). Average vessel lengths and capacities decreased slightly from 1996 to 1997 in all areas. Similarly, the average seine size (length and depth) was marginally smaller in 1997 although these differences were very small. There was very little change in SMB-PB in 1998.

2.4.3 Questions on the Fishery

Fishers were asked questions regarding the bays in which they fished and the months in which they fished. In the three east coast areas (WB-NDB, BB-TB, and CB-SS), there was a fall purse seine fishery only in 1996 and 1997. In 1996, fishers in these areas were assigned boat quotas and were restricted to their home bays. These restrictions were lifted in

1997. The number of fishers participating in the fishery decreased from 1996 to 1997 in all areas except SMB-PB (Figure 52). This led to a change in the distribution of areas fished, as there was a substantial reduction in the number of fishers in White Bay and Bonavista Bay in 1997. The number of fishers doubled in SMB-PB from 1996 to 1997. The fall fishery in all areas occurred from October to December (Figure 53). The timing of this fishery was marginally earlier in 1997 than in 1996. The winter - spring fishery in SMB-PB occurred in March and April in 1996, was extended from March to May in 1997, and was further extended from January to May in 1998.

Three questions were asked regarding abundance of herring during the current fishery compared to previous years (Figures 54 - 56). The sample size of responses to these questions was reduced, as in some cases respondents did not fish in the previous year, or did not answer the question. In almost all cases, when asked to compare the number and size of herring schools detected in the current year fishery with the previous year (Figures 54 and 55), responses in 1997 indicated a slight decrease compared to responses in 1996. Responses from SMB-PB fishers in 1998 indicated a substantial decrease compared to the previous two years. When asked to compare abundance of herring detected in the fishery compared to when they first started fishing herring, responses differed by stock area (Figure 56). For the two northern most areas (WB-NDB and BB-TB), responses in 1997 indicated that current abundance relative to past abundance was lower compared to responses in 1996. For CB-SS and SMB-PB, responses in 1997 indicated that current abundance relative to past abundance was higher compared to responses in 1996. With the exception of CB-SS, these observations were consistent with the results in Figure 49. However, in 1998, fishers from SMB-PB indicated that current abundance was substantially lower than past abundance; this was very consistent with their observations in Figure 49.

A series of questions were asked to determine the distribution of fishing effort. To facilitate analysis, each stock area was divided into geographical sub-areas or strata (Figure 57). In all areas and years, successful sets were restricted to a few strata within each stock area; successful fishing sets were not widely distributed throughout the stock areas. The percentage of successful sets was relatively consistent from year to year in all areas except SMB-PB where there a substantial decline from 1996 to 1997 and again from 1997 to 1998. In all areas and years, the majority of successful sets occurred during daylight hours.

The total landings of the purse seine fleet (Table 32) increased in three of four stock areas from 1996 to 1997 due to an increased quota allocation. The discard rate at sea (total landings divided by amount discarded) decreased substantially; this, coupled with an increased estimate of the survival rate of discards, reduced the ratio of removals to landings. The reduction in the discard rate was probably attributed to the increased quota in 1997 (Figure 58). Whereas the principal reason for discarding in 1996 was quota restrictions, in 1997 and 1998, small fish or a mixture of fish sizes was given as the principle reason for discarding. There were mixed responses regarding the amount of herring discarded in the current fishery compared with the previous year (Figure 59). Respondents in WB-NDB indicated no overall change from 1995-96 to 1996-97. In BB-TB, respondents indicated an increase in the amount of herring discarded in 1996-97 compared to 1995-96. In CB-SS and SMB-PB, respondents indicated a decrease in discards in 1996-97 compared to 1995-96. Discard rates in SMB-PB increased in 1998.

2.4.4 Biological Events

A series of questions were asked in 1996 and 1997 regarding herring spawning. However, the sample size of responses to these questions was very small as most respondents had no reason to observe herring spawning activities. The responses have not been included in this report and the questions were dropped from the 1998 survey.

A question was asked to quantify observations regarding the seasonal timing of herring migration in the current year compared to the previous year (Figure 60). In all areas, the seasonal timing of herring migration was perceived to be earlier in 1996-97 compared with 1995-96. This trend continued in SMB-PB in 1998.

2.4.5 Comments

Respondents were provided any opportunity to provide unsolicited comments at the end of the interview (Tables 33 - 35). These cannot be quantified as they represent comments and not questions directed to all fishers. The most frequent comments in 1996 and 1997 concerned increased quotas, boat quotas, and the opening dates for the fishery. In 1998, concerns were expressed that some larger vessels were destroying a lot of herring.

Section 3.0 - Estimation of Stock Sizes

3.1 Integrated Catch at Age Analysis

In the most recent assessment of these stocks (Wheeler et al. 1997), an unsuccessful attempt was made to use integrated catch at age analysis (ICA) to estimate population sizes. However, subsequent changes to this software (Patterson 1998) eliminated restrictions on the length of time series of abundance estimates and on the estimate of minimum fishing mortality thereby making the software more robust.

In this assessment, numerous ICA runs were calculated for each stock area using different input data and input parameters. It became immediately apparent that the ICA model could not be fitted for the FB stock as catches and fishing mortalities were extremely low in some years, resulting in spurious results. An alternate approach had to be developed to estimate the FB biomass. For the remaining three stock areas (WB-NDB, BB-TB, and SMB-PB), the effects on long-term trends in biomass were examined by changing input data and ICA parameters. With respect to input data, results from the ICA model were not sensitive to the inclusion or exclusion of research gill net catch rates from the early 1970's. They were also not sensitive to the use of only the research gill net catch rates or a combination of research gill net catch rates and acoustic biomass estimates as abundance indices. With respect to the model parameters, results were somewhat sensitive to the choice for the number of years for separable constraint; choices of six years of less yielded less consistent results. Results were very sensitive to the choice of a catchability relationship for each of the abundance indices; ie. a direct identity relationship, a power relationship, or a linear proportionate relationship. Similarly, results were also very sensitive to the choice of estimates of the extent to which errors in each age of the age structured indices are

correlated, where 0 indicates independence and 1 indicated correlated errors. In the final analysis, the following input data and parameters were selected:

Input Data

- Catch numbers and weights at ages 2 to 11+ from 1970 (or 1971) to 1997 (dependent upon stock area) (Tables 36 - 38)
- Age-disaggregated research gill net catch rates (Tables 39 - 41)
  - WB-NDB: spring (1988-97) and fall (1981-91)
  - BB-TB: spring (1988-97) and fall (1980-91)
  - SMB-PB: spring (1982-97)
  - FB: spring (1982-97)
- Age-aggregated acoustic biomass estimates (Tables 39 - 41)
  - WB-NDB: 1983-94
  - BB-TB: 1984-96
  - SMB-PB: 1986-98
  - FB: 1986-97
- Natural mortality = 0.20 for all ages and years
- Maturity ogive (Wheeler et al. 1989)
  - Age 2 = 0.01
  - Age 3 = 0.35
  - Age 4 = 0.60
  - Age 5+ = 1.00
- Proportion of fishing mortality (F) and natural mortality (M) before spawning = 0.00

Input Parameters

- Number of years for separable constraint = 10
- Reference age for separable constraint = 5
- Constant selection pattern assumed
- Selection on last age = 1.00
- First age for calculation of reference F = 5
- Last age for calculation of reference F = 9
- All ages in catches at age weighted equally
- Acoustic biomass estimates treated as estimates of absolute stock size
- Research gill net catch rates treated as proportionate indices of abundance
- Range of feasible fishing mortalities = 0.02 to 3.00
- Equal weights assigned to the abundance indices relative to the catch at age
- Estimate of the extent to which errors in each age of the age structured indices are correlated = 0.50 for WB-NDB and BB-TB, 1.00 for SMB-PB

ICA population numbers at age, by year and by stock area are given in Tables 42 - 44. Biomass estimates, by year and stock area, are given in Figure 61; results from the last assessment (Wheeler et al. 1997) are provided for comparison.

A three year retrospective analysis was also conducted for each of the three stock areas (Figure 62) which provided consistent results over that time period.

3.2 Research Gill Net Catchability Analysis

As in the last assessment, the current stock size for the FB stock was estimated using a research gill net catchability analysis.

Population numbers at age were calculated from ICA for 1970 and 1971 (Table 45); these estimates were insensitive to the input parameters of the ICA model. The population numbers at age were then adjusted to account for catch. A research gill net catchability coefficient (q), defined as the probability of capture by a single unit of effort, was calculated by regressing the calculated population numbers at age of mature fish for 1970 and 1971 against research gill net catch rates at age for the same time period. As the research gill nets and their method of deployment have not changed from 1970 to the present, constant catchability over time was assumed and the calculated catchability coefficient was then applied to current and historical research gill net catch rates to estimate population sizes. Population numbers were converted to biomass using mean weights from the research gill net data.

Population estimates derived from the catchability coefficient were compared to acoustic biomass estimates (Table 45); three of four such estimates were within +/- 35%.

3.3 Stock-recruit Relationships and Stock Status Classification System

As in the last two assessments of these stocks (Wheeler and Winters 1996, Wheeler et al. 1997), stock status is described in relation to a stock status classification system. This system links exploitation rates to recruitment estimates at given spawning stock levels based upon stock specific environmentally dependent stock-recruit relationships. Stock status zones are then defined along these stock-recruit curves with appropriate exploitation levels (Figure 63).

The environmentally dependent stock-recruit relationships for WB-NDB, BB-TB, and SMB-PB were revised for this assessment to include recruitment, temperature and salinity data up to and including 1996 (Table 46). Changes to these relationships resulted in changes to the biomass reference levels between zones in the stock status classification system (Figure 64). For WB-NDB and SMB-PB, the revised biomass reference levels were within +/- 30% of those used in the last assessment. However, for BB-TB, the revised levels were 65% lower than those in the last assessment.

3.4 Projections and Risk Analysis

For the three stocks assessed by ICA (WB-NDB, BB-TB, and SMB-PB), two year projections (1999 and 2000) were run using the integrated catch projection (ICP) software of Patterson (1998).

For these projections, catches in 1998 were assumed to approximate 1997 catches; ie. WB-NDB = 3000 t, BB-TB = 1500 t, and SMB-PB = 4000 t. For WB-NDB, projections were run at fishing mortalities of F = 0.05 and F = 0.10, the lower and upper recommended fishing mortalities for the zone (zone 2) in which the current mature biomass was estimated to be

(Figure 64). Similarly, for BB-TB and SMB-PB, projections were run at fishing mortalities of F = 0.10 and F = 0.20, the lower and upper mortalities for zone 3, in which the current mature biomass was estimated to be (Figure 64).

The following parameters were used in the projections:

Projection Parameters

- Random number seed = 120
- Lag in years between spawning and recruitment at age = 2
- Single fleet per stock area with 100% retention at all ages
- Mean weights at age in the catch and discards equal to 1997 weights at age
- Mean natural mortality from 1994 to 1997 = 0.20
- Mean maturity ogive from 1994 to 1997
- Mean weights at age from 1994 to 1997
- Geometric mean recruitment
- Range of years for estimating recruitment = 1970 (or 1971) to 1997
- Stock-recruit residuals assumed to be auto-correlated
- Recruitment estimates for the last year of the catch at age data and for the subsequent year were taken from the ICA model fit
- 5%, 25%, 50%, 75% and 95% percentile points were used to calculate the distribution of fishing mortality, yield, stock size, and recruitment
- 200 simulations were run for making estimates of uncertainty, using random draws of population parameters as estimated from the ICA maximum likelihood fit

Results of the projections are provided in Table 47. A risk analysis of the probability that spawning stock biomass would be less than the reference biomass levels of the stock status classification system was also calculated. For WB-NDB, the risk was calculated that spawning biomass would be less than the reference level between zones 1 and 2. For BB-TB and SMB-PB, the risk was calculated that spawning biomass would be less than the reference level between zone 2 and 3 and also between zone 1 and 2.

Section 4 - Stock Status

4.1 White Bay - Notre Dame Bay

4.1.1 The Fishery

Landings in 1997 were 2500 t, 97% of which were taken by purse seines during the fall (Table 2) in the eastern portion of the stock area (Figure 57).

The commercial fishery was dominated by age 6 and 7 herring (1991 and 1990 year classes) which accounted for 80% of the landings (Figure 3).

4.1.2 Resource Status

Research gill net catch rates have exhibited a declining trend since 1991 and have decreased by 47% from 1996 to 1998 (Figure 6). Similar to the commercial fishery, the 1990 and 1991 year classes dominated in the research gill nets, accounting for 70% of the catch in 1997 (Figure 5). There was no evidence of recruitment of year classes subsequent to the 1991 year class.

Commercial gill net catch rates decreased by 65% from 1996 to 1998 (Table 27). The perception of abundance by gill net fishers decreased from a value of 6.0 to 2.1 (on a 10 point scale) over the same period (Figure 46). Purse seine fishers indicated that herring abundance decreased from 7.9 to 6.9 (on a 10 point scale) from 1996 to 1997 (Figure 48).

There were no acoustic biomass estimates available since the last assessment.

The 1998 mature biomass estimate from the integrated catch at age analysis is 30800 t (Figure 61).

4.1.3 Summary

The analyses indicate that this stock is at a low level relative to peak levels in the mid 1970's (Figure 61). This is due to continued poor recruitment through the 1980's and 1990's; there is no evidence of strong recruitment of recent year classes. Based upon the stock classification system, previously described, the status of this stock would be classified in zone 2, ***poor to moderate*** (Figure 64).

Risk analysis indicates that with 1999 and 2000 catches in the order of 1800 - 3500 t, there is less than 31% probability that the mature stock biomass would decrease to zone 1 within the stock status classification system (Table 47).

4.2 Bonavista Bay - Trinity Bay

4.2.1 The Fishery

Landings in 1997 were 1100 t (Table 3), approximately 60% of which were taken by purse seines in a fall fishery in both bays (Figure 57).

The commercial fishery was dominated by age 6 herring (1991 year class) which accounted for 75% of the landings (Figure 3).

4.2.1 Resource Status

Research gill net catch rates increased from 1996 to 1997 but decreased substantially in 1998 and are currently 60% lower than in 1996 (Figure 6). Similar to the commercial fishery, the 1991 year class dominated in the research gill nets in 1997, accounting for 60% of

the catch (Figure 5). There was no evidence of recruitment of year classes subsequent to the 1991 year class.

Commercial gill net catch rates decreased by 63% from 1996 to 1998 (based upon a small sample in 1998) (Table 27). The perception of abundance by gill net fishers decreased slightly from a value of 6.1 to 5.7 (on a 10 point scale) over the same period (Figure 46). Purse seine fishers indicated that herring abundance decreased from 8.6 to 6.9 (on a 10 point scale) from 1996 to 1997 (Figure 48).

The age 5+ biomass estimated from an acoustic survey in the fall of 1996 was 31200 t (Table 18).

The 1998 mature biomass estimate from the integrated catch at age analysis is 16800 t (Figure 61).

4.2.3 Summary

These analyses indicate that this stock is at a low level relative to peak levels in the mid 1970's (Figure 61). There is no evidence of strong recruitment of recent year classes. Based upon the stock classification system, previously described, the status of this stock would be classified in zone 3, ***moderate to good*** (Figure 64).

Risk analysis indicates that with 1999 and 2000 catches in the order of 1100 - 3200 t, there is less than 1.5% probability that the mature stock biomass would decrease to zone 1 within the stock status classification system and less than 22.5% probability that it would decrease to zone 2 (Table 47).

4.3 St. Mary's Bay - Placentia Bay

4.3.1 The Fishery

Landings in 1997 were 4000 t (Table 5), 96% of which were taken by purse seines during the late winter and spring in Placentia Bay and during the fall in St. Mary's Bay (Figure 57).

The commercial fishery was dominated by the 1991 year class, which accounted for 60% of the landings (Figure 3).

4.3.2 Resource Status

Research gill net catch rates decreased from 1996 to 1998 and are currently 30% of peak values in 1996 (Figure 6). Similar to the commercial fishery, the 1991 year class dominated in the research gill nets, accounting for 40% of the catch in 1997. There was limited evidence of recruitment as the 1994 year class accounted for 4% of the 1997 catch (Figure 5).

Commercial gill net catch rates decreased by 32% from 1996 to 1998 (Table 27). The perception of abundance by gill net fishers decreased from a value of 5.5 to 2.6 (on a 10 point scale) over the same period (Figure 46). Purse seine fishers indicated that herring abundance decreased from 8.7 to 2.3 (on a 10 point scale) from 1996 to 1998 (Figure 48).

The age 5+ biomass estimated from an acoustic survey in the early spring of 1998 was 10700 t (Table 25).

The 1998 mature biomass estimate from the integrated catch at age analysis is 14800 t (Figure 61).

4.3.3 Summary

These analyses indicate that this stock is at a moderate level relative to peak levels in the early 1970's (Figure 61). There is no evidence of strong recruitment of recent year classes. Based upon the stock classification system, previously described, the status of this stock would be classified in zone 3, ***moderate to good*** (Figure 64).

Risk analysis indicates that with 1999 and 2000 catches in the order of 1100 - 2500 t, there is less than 1.5% probability that the mature stock biomass would decrease to zone 1 within the stock status classification system and less than 41% probability that it would decrease to zone 2 (Table 47).

4.4 Fortune Bay

4.4.1 The Fishery

Landings in 1997 were 150 t, all of which were taken during the spring gill net fishery. There has been a very limited fishery on this stock since the early 1970's (Table 6).

The commercial fishery was dominated by age 11+ herring, which accounted for 95% of the landings (Figure 3).

4.4.2 Resource Status

Research gill net catch rates have exhibited an increasing trend since 1992 and are currently the highest in the time series (Figure 6). Similar to the commercial fishery, fish age 11+ dominated in the research gill net catches (40%); however, the 1990 - 1992 year classes also accounted for 45% of the catch (Figure 5). There was no evidence of recruitment of year classes subsequent to the 1992 year class.

Commercial gill net catch rates decreased by 23% from 1996 to 1998 (Table 27). However, gill net fishers indicated that herring abundance increased slightly from 7.2 to 7.8 (on a 10 point scale) over the same time period (Figure 46).

The age 5+ biomass estimated from an acoustic survey in the winter of 1997 was 15100 t (Table 21).

The 1998 age 5+ biomass estimate from the research gill net catchability analysis is 27300 t (Table 45).

4.4.3 Summary

These analyses indicate that this stock is at a good level. Fish aged 11+ continue to contribute significantly to the spawning biomass and there has been very limited fishing mortality. Based upon the stock classification system, previously described, the status of this stock would be classified in zone 4, ***good to very good*** (Figure 64).

The status of this stock has not changed significantly since the last assessment which projected a 1997 mature biomass estimate of 29700 t. A risk analysis at that time indicated that a catch of 5400 t in 1997 would not adversely affect recruitment to the stock. Combined landings for 1997 and 1998 are not expected to exceed 500 t. Consequently, annual catches of 5400 t (F =~0.20) in 1999 and 2000 would have minimal risk to this stock.

Section 5.0 - Summary

5.1 Description of the 1996 and 1997 Commercial Fisheries and Catches at Age

- The 1996 fishery in all stock areas was a bait / science index fishery, and was designed to address conservation concerns by minimizing fishing mortalities.
- Landings in 1996 (2500 t) were lower than in 1995 (4600 t).
- Spring spawners of the 1990, 1991 and 1992 year classes dominated the 1996 commercial catches in all areas; a single year class accounted for at least 50% of the catch in each area.
- In 1997, there was a restricted fishery in WB-NDB and BB-TB and a commercial fishery in SMB-PB and FB. A restricted fishery attempts to maintain fishing mortalities between 5 and 10%; a commercial fishery, between 10 and 20%.
- Landings increased from 2500 t in 1996 to 7900 t in 1997.
- Spring spawners of the 1990 and 1991 year classes dominated the 1997 commercial catches in all areas except FB where fish aged 11+ years were dominant.
- There was only limited evidence of the recruitment of year classes subsequent to the 1992 year class, that being in WB-NDB and BB-TB, where the 1994 year class accounted for approximately 10% of the catch.

- Biological sampling was good in 1996 and 1997; when apportioned by stock area, month, and gear type, samples were available for at least 92% of the catch.

- Mean weights at age increased from 1995 to 1996 but decreased from 1996 to 1997.

5.2 - Abundance Indices

5.2.1 Research Gill Net Program

- This age disaggregated index has an 11 year time series for WB-NDB and BB-TB, and a 17 year time series for SMB-PB and FB.

- In 1998, 23 commercial fishers provided catch rate data and biological samples under the program.

- In 1997, the last year for which age distributions were available, the 1990 - 1992 year classes dominated the catches in all areas except FB where fish age 11+ years were dominant.

- Spring spawning herring accounted for approximately 90% of the 1997 research gill net catch in three of the four stock areas; in SMB-PB spring spawners accounted for approximately 70% of the catch.

- There was little or no evidence of recruitment of year classes subsequent to the 1992 year class in 1997 catches in any of the stock areas.

- Catch rates of spring spawning herring have declined in WB-NDB, BB-TB, and SMB-PB from 1996 to 1998 and are currently approximately 30% of peak catch rates. However, in FB, catch rates during this period continued to increase and are currently the highest in the time series.

- Fishing dates for the research gill net program have remained relatively constant within stock areas from 1996 to 1998. Peak catches in most areas were consistent in each of the three years and occurred within the two to three week spring spawning period.

5.2.2 Acoustic Survey Biomass Estimates

- Acoustic biomass estimates, and distributional and behavioral information are available from the following surveys: 1996 BB-TB, 1997 FB, and 1998 SMB-PB. Distributional information only is provided from the 1997 WB-NDB survey.

- The 1996 BB-TB acoustic biomass estimate was 36800 t and consisted of 90% spring spawners; the 1994 estimate was 13000 t. The 1991 year class accounted for 66% of the population estimate.

- The 1997 FB acoustic biomass estimate was 16900 t and consisted of 92% spring spawners; the 1995 estimate was 2800 t. The 1992 year class accounted for 60% of the population estimate.

- Herring were not widely distributed during the 1997 WB-NDB survey and mature herring were very scarce; this is consistent with observations from the 1997 commercial fishery.

- The 1998 SMB-PB acoustic biomass estimate was 11600 t and consisted of 56% spring spawners; the 1996 estimate was 29400 t.

- The SMB-PB estimate is consistent with the observations of fishers who indicated that abundance in 1998 was well below average and had decreased substantially from 1997.

5.2.3 Commercial Gill Net Logbook Program

- The commercial gill net program is a new initiative and provides catch rates and detailed information on the number of fishers, total nets fished, mean mesh size and panel areas of nets fished, by stock area, for 1996, 1997 and 1998. It also quantifies the observations of fishers on herring abundance and the incidence of herring spawning.

- The level of effort, as measured by the number of nights fished, decreased from 1996 to 1998 in all stock areas, but still exceeded the level of effort derived from the research gill net program in three of four stock areas.

- Catch rates declined continuously from 1996 to 1998 in all stock areas. In WB-NDB, 1998 catch rates were approximately 65% lower than in 1996; in BB-TB, they were 64% lower; in SMB-PB, they were 32% lower and in FB, they were 23% lower.

- For the two stock areas where fishers perceived abundance to be lower (WB-NDB and SMB-PB), their observations were consistent with their decline in catch rates from 1996 to 1998. However, for the two stock areas where they perceived abundance to be higher (BB-TB and FB), their observations were not consistent with their catch rates.

- A longer time series is required to better evaluate trends in herring abundance from commercial gill nets and from fisher's observations.

5.2.4 Commercial Purse Seine Questionnaire

- Results from the telephone surveys quantified observations of herring purse seine fishers regarding herring abundance, the fishery and biological events since 1996.

- In all areas, fishers indicated that abundance was well above average in 1996 and 1997 but decreased (from 6 - 20%) from 1996 to 1997. Fishers from SMB-PB indicated that abundance was well below average in 1998 and had decreased by 72% from 1997.

- For all stock areas, the retrospective abundance estimate for 1996 from the 1997 survey and for 1997 from the 1998 survey was lower (by up to 15%) than the current year estimate for 1996 from the 1996 survey and for 1997 from the 1997 survey.

- In all stock areas, a large majority of fishers indicated that herring abundance was the same or greater in 1996 and 1997 than when they first started fishing herring; however, there was a downward trend in results from 1997 compared to 1996. There was a further shift in 1998 as SMB-PB fishers indicated that current abundance was substantially lower than when they first started fishing herring.

- The number of fishers participating in the purse seine fishery decreased from 1996 to 1997 in all areas except SMB-PB.

- In all areas and years, successful sets were restricted to a few geographical sub-areas within each stock area; successful sets were not widely distributed.

- Total landings of the purse seine fleet increased in three of four stock areas from 1996 to 1997 due to increased quota allocation.

- Discard rates at sea decreased substantially from 1996 to 1997.

- The seasonal timing of herring migration was perceived to be earlier in 1996-97 compared with 1995-96 and again earlier in 1997-98 compared with 1996-97.

5.3 - Estimation of Stock Sizes

5.3.1 Integrated Catch at Age Analysis (ICA)

- ICA was used to estimate stock sizes for WB-NDB, BB-TB, and SMB-PB.

- The 1998 mature biomass estimates for these areas were: WB-NDB = 30800 t, BB-TB = 16800 t, and SMB-PB = 14800 t.

- A three year retrospective analysis provided consistent results

5.3.2 Research Gill Net Catchability Analysis

- A research gill net catchability analysis was used to estimate the stock size for FB because the ICA model could not be fitted due to extremely low catches and fishing mortalities.

- The 1998 mature biomass estimate for FB = 27300 t.

5.3.3 Stock-recruit Relationships and Stock Status Classification System

- Stock-recruit relationships were revised to include recruitment, temperature and salinity data to 1996.

- Reference levels between zones of the stock status classification system were changed due to changes in stock-recruit relationships.

5.4 Stock Status

- For WB-NDB, the analyses indicated that this stock would be classified in zone 2, *poor to moderate*. With 1999 and 2000 catches in the order of 1800 - 3500 t, there is less than a 31% probability that the mature biomass would decrease to zone 1.

- For BB-TB, the analyses indicated that this stock would be classified in zone 3, *moderate to good*. With 1999 and 2000 catches in the order of 1100 - 3200 t, there is less than a 1.5% probability that the mature biomass would decrease to zone 1 and less than 22.5% probability that it would decrease to zone 2.

- For SMB-PB, the analyses indicated that this stock would be classified in zone 3, *moderate to good*. With 1999 and 2000 catches in the order of 1100 - 2500 t, there is less than a 1.5% probability that the mature biomass would decrease to zone 1 and less than 41% probability that it would decrease to zone 2.

- For FB, the analyses indicated that this stock would be classified in zone 4, *good to very good*. Annual catches of 5400 t in 1999 and 2000 would have minimal risk to this stock.

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