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2019 Southwest Nova Scotia/Bay of Fundy Atlantic Herring Framework: Data Inputs

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

In 2019/2020, the Maritimes Region of Fisheries and Oceans Canada will be undertaking a framework assessment of the Southwest Nova Scotia/ Bay of Fundy (SWNS/BoF) spawning component of 4VWX Atlantic Herring (*Clupea harengus*). Such assessments are intended to be a comprehensive review of the biology, stock structure, the fishery, abundance indices, current assessment methodology and approaches for determining acceptable harvest limits. The framework assessment, Part 1, Data and Inputs, was held February 5–6, 2019. This document explores a variety of data sources available for SWNS/BoF Herring, including tagging projects, commercial fishery information, acoustic surveys, and groundfish research vessel surveys. The current understanding of stock structure, spatial and temporal patterns in fishery distribution, bycatch, biological attributes (length and weight at age, condition factor, growth, and maturity), and updates to data inputs for stock assessment (fishery catch-at-age, acoustic survey index of abundance, and total mortality estimated from acoustic data) are also described here. Any persistent data gaps are identified. Finally, a preliminary review of ecosystem indicators and accompanying data considered relevant to the SWNS/BoF spawning component are summarized.

INTRODUCTION

Atlantic Herring (*Clupea harengus*) is a pelagic species found on both sides of the North Atlantic. Herring spawn in discrete locations to which they have a strong affinity. The majority of Herring in the 4VWX area are fall spawners. These Herring mature in 4VWX and first spawn at three or four years of age, then begin an annual pattern of spawning, over-wintering, and summer feeding. This often involves considerable migration and mixing with members of other spawning components and stocks. Fishing takes place on dense summer feeding, over-wintering, and spawning aggregations; however, since 2002, there have been no directed winter fishery.

The 4VWX management unit contains a number of spawning areas, separated to various degrees in space and time. Spawning areas in close proximity with similar spawning times, and which share a larval distribution area, are considered part of the same component. These undoubtedly have much closer affinity than spawning areas that are widely separated in space or time and do not share a common larval distribution. Some spawning areas are large and offshore, whereas others are small and more localized, sometimes very near shore or in small embayments. The stock structure is complicated further as Herring migrate long distances and mix outside of the spawning period, both with members considered part of the same component and with members of other components. For the purposes of evaluation and management, the 4VWX Herring fisheries are divided into four components (Figure 1, Figure 2):

1. Southwest Nova Scotia/Bay of Fundy (SWNS/BoF) spawning component
2. Offshore Scotian Shelf banks spawning component
3. Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component
4. Southwest New Brunswick (SWNB) migrant juveniles

Each component except SWNB migrant juveniles has several spawning areas, and there is mixing of fish among spawning components outside of the spawning period.

The last major review of the assessment framework was conducted in 2006/07 (DFO 2007a), followed by a framework meeting in 2011. No model was chosen but recommendations for the assessment were provided in the report (DFO 2011). In 2012, a limit reference point (LRP) was set for spawning biomass in Scots Bay and German Bank to be evaluated based on the three-year moving average (Clark et al. 2012). The last full assessment for 4VWX Herring was conducted in 2018, which concluded that this stock was at the LRP (DFO 2018a). This research document is intended to provide descriptions of the several biological and fishery survey data sets, and constitutes the first part of the SWNS/BoF component of 4VWX Herring Framework Review.

Figure 3–5 show the place names and fishing locations for SWNB, Coastal Nova Scotia and Scotian Shelf/Bay of Fundy, the North Atlantic Fisheries Organization divisions, subareas, and unit areas used for sample and landings data aggregation, and herring fishing grounds.

FRAMEWORK REVIEW AND OBJECTIVES

The objectives for the Framework Review meeting are to review the data inputs for 4VWX Herring, especially the main SWNS/BoF stock component, as well as the proposed model(s) to determine stock status, reference points, risk analysis, management strategy evaluations and the inter-framework assessment strategy. There will be two parts to this process:

Part 1 - Review of all Data Inputs and Indices of Abundance (February 2019):

The objective of this first meeting is to review the data inputs and indices of abundance relevant for SWNS/BoF Herring:

- Summarize the definition of the SWNS/BoF Herring management unit (growth, morphometrics, movement) provided at the 2006 Framework meetings. Present any relevant new information that might change the definition of the management unit.
- Review SWNS/BoF Herring fishery distribution, landings, age composition, condition, weight/length at age, maturity, timing and bycatch.
- Review data that account for all fishing mortality and reporting separately, including bait fisheries (since 2016), silver hake fishery, NS weirs, gillnets, adult herring in NB weirs and purse seine fisheries.
- Review the acoustics data series (1999 to present), including the methods, coverage and turnover biomass estimates (as discussed at the 2018 stock assessment).
- Review the groundfish research vessel survey age-specific indices of abundance and acoustic data.
- Examine sources of ecosystem information (environmental factors, diet information, unaccounted for sources of mortality, etc.) and identify how this information might be incorporated into the assessment framework.
- Review EBFM (Ecosystem Based Fisheries Management) framework and identify how it could be incorporated into the assessment framework.
- Provide information on ongoing research related to Herring in academia or other regions of DFO.

Part 2 - Assessment of Model(s) to determine stock status, reference points, risk analysis, management strategy evaluations and the inter-framework assessment strategy (Financial Year 2019/2020).

BACKGROUND

STOCK STRUCTURE OF HERRING IN NAFO AREAS 4VWX

The biological basis for the management unit is based on a number of observations/hypotheses or assumptions related to population structure. These include that Herring spawn in discrete locations, that these locations are predictable (in both space and time), and that there may be multiple spawning locations and/or times within an area (DFO 2007a). Herring is believed to spawn completely, in schools, in events that have been described as waves, and most spawning grounds have multiple waves of Herring during a spawning season (Lambert 1987). Once eggs are hatched, the larvae remain aggregated and there are predictable patterns of distribution of larvae (‘larval retention’ areas - Iles and Sinclair 1982).

There are general patterns of distribution of juveniles and adults, and movement among spawning, overwintering, and summer feeding areas (Hay et al. 2001). Herring migrate widely and return (annually) to spawning grounds they have used previously (presumed to 'home') (Stephenson 1991). Herring mix (with those from other spawning areas) at juvenile and non-spawning adult stages, and mixing is not uniform – they remain aggregated or clumped in schools. Herring exhibit a high degree of population 'complexity' or 'richness' (Stephenson et al. 2009).

The fishery in the Southwest Nova Scotia/Bay of Fundy has documented discrete locations (for example, German Bank, and Scots Bay) at which there are tightly aggregated schools of herring spawning every year. Figure 6 shows locations of catches of spawning herring on the German Bank and Scots Bay spawning grounds from 2008 to present. The Trinity Ledge spawning ground was a major spawning ground until about 2003, after which it collapsed. Each spawning ground has a predictable spawning time, but the time differs among areas. The fishery in Scots Bay (Figure 7) and on German Bank (Figure 8) usually occurs when herring in ripe and running reproductive conditions are present.

It is a general characteristic of Herring that they spawn only once a year, and that all of the eggs are released within a single spawning event (Hay et al. 2001). Spawning events involve whole schools. There are typically several events or waves of spawning on a spawning ground in a season (Lambert 1987).

Seven to ten days after spawning, the eggs begin to hatch into larvae with yolk sac. The yolk sac diminishes in size until they are about 10 mm in length (Bigelow and Schroeder 1953). The distribution and abundance of Herring larvae originating from spawning grounds off SW Nova Scotia and in the Bay of Fundy were determined from larval surveys conducted between 1975 and 1999.

Within the Bay of Fundy, another spawning population that has been documented and is the spring spawning population in the Minas Basin (Bradford 1987, Bradford and Iles 1992). This population was the target of a fishery between 1974 and 1985 with landings of <50 t per year (Bradford and Iles 1992). Spawning occurs in May–June, and the population is considered to be much smaller than the population that spawns from June–August in Scots Bay.

The Offshore Scotian Shelf Banks spawning component has not been well documented (Harris and Stephenson 1999), but spawning occurs during the fall. The Coastal (South Shore, Eastern Shore and Cape Breton) NS spawning component consist of separate spawning areas along coastal NS with spawning occurring during the fall (Clark et al. 1999).

HISTORY OF THE FISHERY FOR THE SWNS/BOF STOCK COMPONENT

Fisheries in the 4VWX area in recent years have been dominated by purse seine, weir, and gillnet, with relatively minor landings by shutoff and trap. A variety of Herring fishing locations, NAFO areas and fishing ground areas are used to describe fishing activities and group the data for analysis of catch and sampling (Figure 3–Figure 5). The main spawning and fishing areas for the SWNS/BoF component are German Bank and Scots Bay. While historically the Trinity Ledge area was a major fishing and spawning area, it collapsed and is no longer considered important to the fishery. Trinity Ledge has been closed to all fishing since 2015; however, there were some indications in 2017 of improvements to spawning biomass in the area.

Additional fishing has occurred in the past by the NS weirs in St. Mary's Bay and along the Long Island shore; however, no landings have been reported recently (since 2012). Since only weirs with catches are reported, it is not possible to say if any weirs were set and had no catches since 2012. There is also an occasional small gillnet fishery in the spring on spawning Herring near Spectacle Buoy, which is just southeast of Yarmouth, but there has been no reported landings since 2011.

Based on tagging studies conducted in the 1980s (Stobo and Fowler 2009), it was determined that overwintering Herring aggregations in Chedabucto Bay were part of the SWNS/BoF spawning component; however, it is possible also that Herring from the 4T area were also overwintering in the Chedabucto Bay (Sinclair 1997). These aggregations were the target of the winter fishery (Iles 1993); however, there was a significant reduction in landings from Chedabucto Bay in 1993 and, since 2002, there have been no landings or surveys. Before the Chedabucto Bay winter fishery ceased operation, later arrival, earlier departure, and reduced aggregation size were documented. Chedabucto Bay was abandoned as a fishing area when fishing vessels started being unable to find fishable aggregations. As a result, the overwintering locations of SWNS/BoF spawning component Herring are presently unknown.

Landings for the SWNS/BoF stock component have recently tracked the total allowable catch (TAC) with most of the quota being taken each year since 2002 (Table 1, Figure 9). As a result of the reduced quota since 2005, total landings from this component remain near the lowest on record since 1963. Most of the catch over the history of this fishery has been caught by purse seine gear, with the 4X summer purse seine fishery being the most important (Figure 10). While in the past the fishery was pursued throughout the year, since around 2011, there have been very minimal landings reported during the winter months. Most of the landings occur during the months of May to September (Table 2).

HISTORY OF THE ASSESSMENT APPROACH FOR THE SWNS/BOF STOCK COMPONENT

Assessment approaches have varied since quotas were first established for this stock component in 1976 (Table 3). A variety of survey indices have been evaluated, used, and then rejected and sometimes reintroduced often as inputs into Virtual Population Analysis (VPA) models. The larval survey series was an important index for many years but was eventually replaced by acoustic surveys as the basis for stock evaluation.

Presently, an analytical model is not used for the SWNS/BoF Herring spawning component, but the 2011 Framework review recommended the following indicators for signs of change (DFO 2011a):

- Acoustic survey biomass trends,
- Fishermen input,
- Numbers or proportion at age in catch,
- Trends in exploitation rates from survey, and
- Mortality rate trends based on age composition, F=Z-M.

The status of this spawning component has been of concern for more than a decade, and stock status reports have indicated the need for rebuilding since 2001 (DFO 2001, 2002, 2003a, 2004, 2005, 2006a, 2007b, 2008, 2009, 2010, 2011b, 2013, 2014, 2015, 2016, 2017a, 2018).

The 2003–2010 Scotia-Fundy Herring Integrated Fisheries Management Plan (IFMP) set out principles, conditions, and management measures for the 4VWX Herring fisheries (DFO 2003b). The main principle stated in the plan is, “the conservation of the herring resource and the preservation of all of its spawning components”. Three conservation objectives that were developed at a Herring Workshop in 1997 (Sinclair 1997) appear in the plan:

1. To maintain the reproductive capacity of herring in each management unit through:
   - persistence of all spawning components in the management unit;
   - maintenance of biomass of each spawning component above a minimum threshold;
   - maintenance of a broad age composition for each spawning component; and
   - maintenance of a long spawning period for each spawning component.
2. To prevent growth overfishing:
   - continue to strive for fishing mortality at or below $F_{0.1}$.
3. To maintain ecosystem integrity/ ecological relationships ("ecosystem balance"):
   - maintain spatial and temporal diversity of spawning; and
   - maintain herring biomass at moderate to high levels.

An "in-season" management process, first implemented in the southwest Nova Scotia fishery during 1995, was used within the 4VWX management area (DFO 1997, Stephenson et al. 1996, 1999a). The approach used acoustic surveying using the commercial fleet under scientific direction prior to fishing ("survey, assess, then fish" protocol) to ensure that effort is distributed appropriately among various components of the stock (particularly among spawning components) according to the relative size and current state of each component. This meant that decisions regarding the spatial and temporal distribution of quota within the season and, hence, the timing and distribution of fishing within the overall plan, were delegated to an industry-government team.

Over the years, this approach has evolved, and although the survey results are monitored throughout the year, generally management decisions for harvest levels are based on the previous years' surveys and indicators. Additionally, industry has implemented voluntary management measures to distribute fishing effort on the different spawning grounds. Observations on changes in the numbers at age in the catch and trends in exploitation and mortality rates are also used in determining the management advice provided.

TAGGING STUDIES

Tagging studies have been conducted intermittently on this stock since the 1930s (Stobo and Fowler 2009, Mouland et al. 2003, Power et al. 2009). A large-scale tagging study was conducted from 1998–2002 with 92,647 tags released on major overwintering and spawning grounds (Paul 1999, Waters et al. 2000, Mouland et al., 2003). In 2005, a tagging project was conducted on Herring caught in weirs (Waters and Clark 2005). Another tagging study was conducted on spawning grounds to study turnover (Clark 2006), with 13,627 tags released. This was followed by a three-year tagging program conducted to continue to investigate turnover time on the German Bank spawning grounds, with 22,992 tags being deployed (Maxner et al. 2010, Melvin et al. 2014). Tagging information on studies between 1998 and 2011 are summarized in Table 3.

Martin (2013) analysed the data collected from the tagging from 1998 to 2011 and concluded that herring tagged on German Bank were more broadly distributed when feeding and were recaptured near the approaches of the Bay of Fundy, throughout the Gulf of Maine, and on the offshore banks of the Scotian Shelf. More than 99% of Herring tagged on the Scots Bay spawning ground were recaptured within the Bay of Fundy. During feeding, herring from Scots Bay were distributed primarily off SWNB, Grand Manan Island and Long Island Shore, Nova Scotia. There was no significant difference in the distances moved between German Bank and Scots Bay Herring (Martin 2013). Outside of the spawning season, both populations tended to occur in the approaches of the Bay of Fundy where they mixed during feeding. There was no mixing of the two populations during the spawning season.

The movement of Herring tagged in Scots Bay, German Bank, the NB Weirs and Chebucto Head in the 1980s, 1990, and 2000s are best summarized in Figure 11. In all cases, the majority of tag returns came from the site of application; however, returns also indicate that there is movement between locations. Herring tagged in Canadian waters were also recovered in the United States (US) waters.

Additional tagging studies were conducted in US waters between 2003 and 2006, with 85,561 tags released in the Gulf of Maine during the summer feeding/spawning period, and in the Southern New England during the winter feeding period (Kanwit and Libby 2009). The results indicated that herring migrated seasonally from Southern New England in the winter to Nova Scotia in the summer. Herring migrate to the SWNS/BoF area after spending the January to April period in Southern New England. Tag returns from fish tagged on spawning grounds in the SWNS/BoF area were also recovered in the Southern New England during the January to April period (Clark 2006), confirming the seasonal migration.

A new industry-led tagging program to determine Herring pre-spawn migration patterns was started in 2016 and 26,335 tags (as of end of 2017) have been applied on herring pre-spawn aggregations on Gannet Dry Ledge, Grand Manan Banks, and German Bank. Preliminary analyses of 2016 data showed recaptures in those same areas as well as Scots Bay and the Long Island Shore. Temporal trends are apparent that coincide with where the fleet fishes as the season progresses. Tagged fish from Gannet and German Bank in the pre-spawning season resulted in returns on both spawning grounds, Scots Bay and German Bank indicating pre-spawners in this area may be of mixed spawning origin; however, further study is required (J. Munden, per. comm.).

COMMERCIAL FISHERY

In the Maritimes Region, the fishery for Atlantic Herring has been recorded within the 4VWX and Canadian portion of 5Yb. Fisheries in 4VWX in recent years have been dominated by purse seine, weir, and gillnet, with relatively minor landings by shutoff and trap.

DATA QUALITY FROM FISHERY

In 1984, it was noted that there were errors in the recorded landings from 1973 to 1991. There was agreement that the nominal catch statistics for the 4WX purse seine fisheries were low compared to actual removals (Iles et al. 1984), and, in 1985, the catch matrix for this period was revised (Mace 1985, Stephenson et al. 1985). The TAC was increased to reduce the need or incentive to misreport and this, along with increased monitoring and a fragmented (weekly) license scheme, resulted in some improvements in the quality of landings data in 1985 (Stephenson et al. 1986, 1987). The situation worsened in later years and there were increasing reports of misreporting, but these were not verified or quantified until 1991, when roe production figures demonstrated that substantially more must have been landed in the 1990 summer fishery than was reported (Stephenson et al. 1991). The same calculation indicated a variable degree of misreporting in some of the previous years. The result was an inability to undertake an analytical assessment in 1991 and a large impact on the quality of advice (CAFSAC 1991). As a result of these problems, increased fishery observer monitoring and 100% dockside monitoring were implemented. Since the implementation of these measures, there have been no evidence of large-scale misreporting of landings.

FISHERY SAMPLES

Biological characteristics of Herring from the commercial fishery and research surveys in the Atlantic region have been collected since 1932. All the biological data are on an Oracle database (Pelagic Samples Database); however, some data from prior to 1982 were lost during migration from tape to digital format. An ongoing audit of the database continues to address lost data along with data never entered into the database. As a result, the data input prior to 1982 must be considered a work in progress, as they are intermittent and in some years incomplete.

Comprehensive biological sampling for this fishery includes substantial involvement of the fishing industry, which supplies data in the form of length frequencies and maturity reports, and saves frozen fish samples for analysis by DFO personnel. Sampling from the commercial fishery is well matched to the spatial and temporal distribution of the fishery, and additional sampling from research vessel surveys during the spring and summer results in widespread geographic coverage for the stock area.

Length-frequency sampling typically involves the random selection and measurement to the nearest half cm of approximately 150–200 fish from a landing. When a detailed biological sample is collected, two fish per half cm interval are retained for sizes greater than 24.5 cm and one fish per half cm less than 24.5 cm, labeled and frozen for future analysis from selected length frequency samples. The number of fish retained is, thus, dependent upon the number of length intervals in the length frequency sample.

All detailed samples of herring are frozen and processed in the lab at St. Andrews. In the lab, DFO personnel perform measurements on length, weight, sex, gonad weight, gonad maturity stage, stomach fullness, and stomach content identification to taxonomic group level. The otoliths of at least two fish from each half centimetre length grouping are extracted and used for subsequent age determination.

FISHERY LANDINGS AND CATCH DISTRIBUTION

Historically, Herring have been caught in the 4VWX area using several gear types. In recent years, the fishery has been dominated by purse seine, weir, and gillnet, with relatively minor landings by shutoff and trap.

As seen in Figure 12, catches of herring during the period 1995–2001 occurred mainly in the SWNS/BoF area. This pattern of catches is mostly maintained during the period 2002–2017, with one notable exception of no landings from the Chedabucto Bay since 2001 (Figure 13). Based on results of tagging studies, the winter fishery in Chedabucto Bay, and in the Chebucto Head area near Halifax, were considered to be targeting fish from the SWNS/BoF stock. Most of the landings from these areas were from the purse seine fleet on over-wintering Herring. The Chedabucto Bay winter fishery occurred during the 1970s to the 1990s, with the last recorded fishing in the area being 2001. The Chebucto Head winter fishery occurred during the period 1996–2002.

The purse seine fleet was made up of as many as 42 vessels in 1990; however, that number has gradually decrease to 9 vessels in 2018. Fishing by the fleet occurs in the Bay of Fundy, the approaches to the Bay of Fundy, and on German Bank. Since the 1980s, landings from German Bank (spawning area, see Figure 6) have increased as a percentage of the TAC, with fishing occurring both before spawning and during the spawning season (Table 5). As a result, this area contributes the largest percentage of landings to the TAC. The other important fishing area for the purse seine fleet is the Scots Bay spawning area (see Figure 6) (Table 6).

Gillnetters from the Yarmouth area have fished in the SWNS/BoF stock quota area and hence landings are part of the quota. Gillnetting has taken place on Trinity Ledge and in the Spectacle

Buoy area in the past. As shown in Table 7, there has been no reported landings from the Spectacle Buoy area since 2012, while no landings have been reported from Trinity Ledge since 2015. More recently, gillnet fishing has also occurred on German Bank (since 2005) and in Scots Bay (since 2009) (Table 8).

Herring caught in the Nova Scotia weirs are considered to be part of the SWNS/BoF stock component. Weirs were located along the Long Island Shore, within St. Marys Bay and in the Minas Basin area. Landings from these weirs usually occur between the months of May and September, and highest recorded landing was in 1978 with 7,858 t reported. There were 31 NS weirs reporting landings in 1978, and this number has decreased over time, with no landings reported in two of the last three years (Table 9). The only NS weir reporting a landing in 2016 was in the Minas Basin area.

Additional small bycatch of Herring are taken by groundfish directed fisheries (mostly Silver Hake) using bottom trawl gear. Figure 14 and Figure 15 show the distribution of Herring catches <0.15 mt; most of the offshore catches are bycatches from bottom trawl gear with most of the inshore catches being from gillnets. There were not as many small catches in the MARFIS database prior to 2001 with more appearing during the period 2002–2017 (Figure 15).

NB weirs

For over a century, the SWNB weir and shutoff fisheries have relied on the aggregation of large numbers of juvenile Herring (ages 1–3) near shore at the mouth of the Bay of Fundy. These fish have been considered to be a mixture of juveniles, dominated by those originating from NAFO Subarea 5 spawning components and have, therefore, been excluded from the 4WX (SWNS/BoF) quota. The 2006 Framework meeting reviewed tagging of fish caught in the NB weirs (DFO 2007a). The data review concluded that weirs capture a mixture of Herring from different spawning areas.

NB weir catches are taken into consideration in the Atlantic Herring assessments done by the US National Oceanographic and Atmospheric Administration (NOAA). Catches in the NB weirs are mostly juveniles (2 year olds); however, there are occasional catches of mature adult Herring. The success of this passive fishery is historically unpredictable, and the landings time series for this fishery may not be indicative of abundance because catches are extremely susceptible to many factors in addition to abundance, including effort. The number and distribution of active weirs have decreased over the past decade, due in part to the conversion of sites to aquaculture, as well as reduced landings in the past 30 years in the Passamaquoddy Bay area (Table 10), Most of the landings from the NB weirs occur between May and October (Table 11).

In SWNB (Fundy Isles and Grand Manan areas), spawning is thought to occur in areas near weirs. This is based on various circumstantial evidence, but there is little information on these possible spawning groups. These groups are considered to be small in comparison to the well documented spawning areas in other parts of the SWNS/BoF area such as Scots Bay and German Bank. In 2008, a study was conducted to document these spawning locations (Figure 16). Using modified lobster traps as collectors, no spawning events were recorded. Acoustic recording in the area indicated that Herring were present in all the areas where the study was conducted, but no abundance estimates were available.

BAIT LANDINGS

Since 2015, bait licence landings have been coded in the MARFIS database to allow for easy reporting. Most of the bait licence landings come from the non-quota (outside the SWNS/BoF) area. In 2015 and 2016, only 1% and 0.05% of the bait licence landings were from the quota area, with no bait licence landings reported in 2017 and 2018 (Table 12).

Herring caught and sold as bait are reported as commercial bait for the period 2015 to 2018 are shown in Table 13. Herring caught in the purse seine fishery make up the largest amount sold as bait, with smaller amounts recorded from the fixed and drift gillnet fishery. Taking into consideration all the gear types, the commercial bait landings from the quota area was highest in 2016 (2,120 t) and lowest in 2015 (139 t). During the reporting period (2015–2018), 76–99% of the commercial Herring bait landings came from the SWNS/BoF quota area. Herring caught in the quota area and sold as commercial bait during the period 2015–2018, ranged from 0.2% to 4.0% of the overall quota (Table 13).

CATCH-AT-AGE DETERMINATION

For all Herring assessments, the catch-at-age is constructed using the 'Catch-at-Age' application (version 10.4), a DFO windows based program for computing catch-at-age statistics as part of the stock assessment process. The collecting of otoliths and the development of age-length keys are critical steps in developing the catch-at-age. Typically, the number of otoliths per gear type per month per year equals the number of fish collected in the detailed samples.

Data files used by the 'Catch-at-Age' application are selected from the data in the Pelagic Samples Database. These data included a 2% adjustment for the shrinkage due to freezing on the length measurements for frozen samples (Hunt et al. 1986). The length-weight relationships are also required as input to the 'Catch-at-Age' application and calculated using an Oracle SQL*Plus script. The length-weight relationship is calculated every year by month using all Herring in the database. The catch-at-age statistics are then calculated from length-frequency and age-length key samples expanded to total catch using appropriate monthly length-weight relationships. The data are grouped or combined and then age-length keys applied to length frequencies to produce catch-at-age statistics by unit area, gear-type, and month.

Inconsistencies in the ageing of Herring were first noted in 2003 (DFO 2006b, Melvin et al. 2010). Following a number of regional and international exchanges, the implication of under-ageing error on the evaluation of the Gulf of Maine stock complex and the 4WX Herring stock was considered severe enough to require re-aging for the period 1999 to 2005 (Melvin and Power 2007). This resulted in re-ageing of only 20% of the ages in the database and the removal of the remaining 80%. Using the re-aged 20% revisions were made to the catch-at-age from 1999 to 2005. Since 2005, ageing has been done by one primary ager. A new and enlarged otolith reference collection has been established to provide a standard for intra-reader comparisons and to train new readers following the methodology agreed to at the 2006 framework meeting. Primary ager bias testing is done using the otolith reference collection as well as the ager against self on a random selection of all otoliths collected each year.

A couple of issues with the historical catch-at-age has been identified. One was that during the time that there was a purse seine fishery in Chedabucto Bay (prior to 2001), the data from this area was included in the catch-at-age for the SWNS/BoF stock. Tagging studies showed that SWNS/BoF fish over-wintered in the Chedabucto Bay. This area is also believed to be an overwintering area for fish from the 4T stocks (Chadwick et al. 1993) and the relative proportions would need to be explored and taken into consideration. The second issue was the inclusion of purse seine catches from the Little Hope area for one or two years before the implementation of a 25-mile purse seine exclusion line (see Figure 5) along the Atlantic coast of Nova Scotia (M. Power per. comm.).

CATCH-AT-AGE

The historical time series of catch-at-age data indicates there have been few fish older than age 8 since 1995, and this time series continues to be dominated by ages 2–5 (Table 14 and Table 15, Figure 17). Older ages, which had been a feature when strong year-classes (i.e., 1976 and 1983) were progressing through the fishery, are no longer prominent. These stronger year-classes had persisted in the catch to older ages in the 1970s through to the early 1990s. In recent years, the rapid decline of year-classes in the landings and the continued lack of older fish imply a high total mortality (Power et al. 2006a). There appears to be some improvement in around 2014, with more age 8 fish in the catch; however, the fishery still depends on younger fish, with ages 2, 3, and 4 dominating in the catch.

NB weirs catch-at-age

The SWNB weir and shutoff fisheries have relied on the aggregation of large numbers of juvenile Herring (ages 1–3) near shore at the mouth of the Bay of Fundy. While mature fish are also landed from the weirs, the percentage shows a great deal of inter-annual variability ranging from a low of 4% (1995) to a high of 40% (1989 and 2000) (Figure 18, Table 16). In 2017, 24% were age 3 and older (Figure 19). An examination of the mature fish caught in the weirs showed that the reproductive condition were either stages 3, 4, 5 (maturing/hard), or 7 (spent); however, in some years with mature fish, ripe and running stages were observed.

At the first Framework review meeting in 2006, it was agreed that the biological definition of the SWNS/BoF Herring spawning component was appropriate and there was no need to change it. However, it was suggested that a sensitivity analysis be undertaken to evaluate the impact of different assumed proportions of US origin Herring in the NB weir catch on the assessment.

In 2011, the catch-at-age data for the NB weir catch was compiled for use in such an analysis using data to 2010 (Table 16) and was added to the existing catch-at-age for use in exploratory VPA analysis. The NB weir catch-at-age is dominated by juvenile (pre-spawning) herring at ages 2 and 3, with occasional catches at age 1 as ‘brit’. Except for the 1983 year-class, there is poor year-class tracking and a lack of older fish except during a period from 1985 to 1994. The model resulted in low fishing mortality (F) on ages 2–4 and high F on ages 5–8 and was not explored further at the time (Power and Melvin 2011).

WEIGHT AT AGE

The fishery weighted average weight at age for the SWNS/BoF spawning component continues to be below the long-term 1965–2017 average years, possibly reflecting changes in fishing patterns and timing (Figure 20, Table 17). Consistent with the data in the last two assessments (Singh et al. 2016, 2019 (unpublished)), the weights at age are slightly lower than the most recent five-year average and consistently less than the overall time-series average (Figure 20).

This decrease in the weights at age (WAA) for commercial landings in the SWNS/BoF spawning component is seen more clearly in Figure 21. Around 1987, there was a general decline in the WAA for all ages. A further decline is evident for older ages (6 to 10) after 1997, with ages 8+ fish now consistently below 300 g. There appears to be some increases in the weights for the ages 1 and 2 over recent averages; however, samples of age 1 fish in the catch are usually small and may not be reflective of the actual weights of age 1 fish in the fishing area.

LENGTH AT AGE AND CONDITION

Consistent with the decrease in the weights at age, there has been a similar decrease in the lengths at age (Figure 22). As in the WAA, the decrease is evident in fish older than age 2.

There appears to be a general increase in the length of age 2 fish with all other ages showing a decrease in lengths. The decrease in the length of age 3 fish is not as large as seen in ages 4-10.

Fulton's K is a measure of fish condition calculated as weight over length cubed. Using this relationship, the condition factor was calculated for Herring caught in the SWNS/BoF area by the purse seine fishery from 1970 to 2017. The mean condition factor was calculated for each year using data for the entire year. Data from the early years in the time series may contain errors; however, the general trends are not expected to be change much with correction. This process to correct such data in the database is ongoing, with corrected data from the early 1980s onwards. As seen in Figure 23, the condition factor for ages 2, 3, and 4 seemed to have improved over the 1970s and 1980s. Age 2 herring had lower condition factor than age 3, which were lower than age 4. The condition factor for ages 5–10 are similar and seems to have fluctuated without trend over the time series ending with similar values in the final year as in the early years in the time series (Figure 23).

LENGTH AND AGE AT MATURITY AND FECUNDITY

The data collected from the sampling program were analyzed to determine the size and age at various maturity proportions and to calculate the median length (L_{50}) and median age (A_{50}) at maturity. These parameters are defined as the length and age at which 50% of individuals are mature and are generally used to describe the sexual maturity of fish stocks. The size at 50% maturity has shown a steady decline since the 1970s, with a gradual decline occurring in each decade. In the 1970s, the L_{50} was 246 mm, while in the 2010s this value has decreased to 224 mm (Figure 24). This gradual decease in the L_{50} is seen more clearly in Figure 25, which shows strong decreasing relationship over time. This decrease in the length at maturity may be influenced by exploitation or environmental factors.

There appears to be a decrease in the median age at maturity (A_{50}). The age at maturity during the 1970s was 3.1 years, deceased to 3.0 during the 1980s, increased to 3.1 again during the 1990s, and finally decreased to 2.9 years in the 2000s and 2010s (Figure 26). Overall, there appears to be a 0.2 years decrease in the median age at maturity. It is important to note that, generally, there are fewer age 1 fish caught in the fishery, and this may influence the curve fit for the youngest ages.

Óskarsson et al. (2016) studied the reproductive potential of Herring in the 4WX area and concluded that potential fecundity (F_P; number of vitellogenic oocytes in mature ovaries) was a linear function of total length (r^2=0.89). Length-specific F_P was weakly (r^2=0.10) and positively related to Fulton's body condition index (K), and relative fecundity (eggs per unit somatic weight) was a positive linear function of total length (r^2=0.61). The length-specific fecundity estimates in 2001 were higher than estimates recorded during the late 1960s and mid 1970s. Decreases in length-at-age, age-at-maturity, and length-at-maturity, and total egg production, particularly contributions from the larger (older) spawners, were observed over the period 1970–2001. The relationship between annual estimates of E (total egg production) and SSB for the stock over the same period approached proportionality, with both recruit and repeat spawners indicating that reproductive potential may be adequately estimated from SSB. When determining the recruitment potential of the stock, it may be essential to be able to partition the reproductive potential between recruit and repeat spawners or among different age or length classes.

OBSERVER DATA AND BY-CATCH

The nature of the Herring fishery, which targets a schooling fish found in dense single species aggregations is such that most catches are entirely Herring. The main gear types take advantage of this behaviour and target these dense schools, resulting in very little by-catch of incidental non-target species.

Although protocols require observations of by-catch, observer estimates of by-catch may be underestimated since large quantities of Herring and the speed of pumping could obscure other species of similar size. It can also be difficult to quantify this incidental catch if fishing operations do not permit visual inspection of the entire catch and because it is not always possible to weigh components of the catch.

Stephenson et al. (1999b) reported the incidental catch in the 4WX Herring purse seine fishery for 1991 to 1998, while Gavaris et al. (2010) evaluated the by-catch in the observer data from 2002 to 2006. In both studies, the incidence and magnitude of by-catch in the purse seine fleet was generally low, although the estimates in both cases were influenced by the low observer coverage. Dogfish were the major by-catch species in both studies. The discard amounts and incidence by sets were found to be low with Silver Hake, Mackerel and Spiny Dogfish, the most common species caught along with Herring.

Incidence and magnitude of by-catch in the 4VWX purse fleet varied over time but was generally low. Data quality in records from Herring and the Silver Hake fisheries in the IOP (International Observer Program) database should be comparable since they are both collected by observers from the IOP. The overall recorded by-catch from the Herring fishery from 1990 to 1998 is 0.4%, while it was 12.4% in the Silver Hake fishery for a similar time period.

The most prevalent by-catch in the 4WX Herring fishery was dogfish, Mackerel, squid, Haddock, and Cod. The maximum observed occurrence was 27% of sets (dogfish and squid) when specifically watching for incidental catch. Prevalence in this case was very low, with an average of only 10 individual dogfish and 15 squid per 50-ton set of Herring. In the Observer Program database, dogfish and Mackerel were the most prevalent, but these catches represented less than a percent of total catches. The over-the-side-sales (OSS) data had similarly low by-catch.

Large animals (whales, sharks, etc.) can be, and usually are, released from the set unharmed. Early indication of a significant by-catch often leads to release of the set (dogfish, for example, interfere with pumping and so are avoided).

Herring as a by-catch from other fisheries

Herring is also caught as a by-catch in other directed fisheries using bottom trawl gear. This includes the Silver Hake fisheries on the Scotian Shelf, which is believed to make up the largest amount of Herring caught by bottom trawl. Table 18 shows the recorded Herring by-catch since 1991, with the highest amounts being landed in the early years (1991–1998). The average landings between 1991–1998 was 109 t, between 1999–2008 was 86t and between 2009–2018 was 32 t. There has been a general trend of decreasing amounts of Herring caught as by-catch in the bottom trawl fisheries (Figure 27).

SURVEYS

RESEARCH VESSEL SURVEY: JULY BOTTOM TRAWL SURVEY

The annual bottom trawl Research Vessel (RV) survey has been conducted since 1970. Three vessels have been used to conduct the surveys: *AT Cameron* 1970–81, *Lady Hammond* 1982, and *Alfred Needler* 1983–2017, with a gap in 2004 that was filled by the *Teleost.* Survey coverage is restricted to depths of >15 fathoms in Bay of Fundy and >50 fathoms off southern Nova Scotia, except for an area north of Browns Bank, which is not surveyed due to un-trawlable bottom. The survey is based on a stratified random sampling design, with 244 stations allocated to 57 strata (Figure 28). The survey uses a bottom trawl with a 19 mm Cod end liner and samples both fish and invertebrates. Sampling is generally conducted during the summer season (June–August). Additional detail on survey coverage and sampling is available in DFO (2016).

Herring caught are sampled for numbers and weight with length measured as fork length by cm. Since 1995, detail samples are retained for maturity and age determination. The summer research bottom trawl surveys have indicated relatively widespread Herring distribution on the Scotian Shelf (Power et al. 2013; Singh et al. 2014, 2016).

At the previous framework meeting, several shortcomings to using bottom trawl data as an overall abundance for a schooling pelagic species, like Herring, were identified. There are catchability issues related to the changes in vertical distribution of Herring, which would influence the catch. As a result, the bottom trawl data, while useful for documenting size, maturity, and distribution, are not considered indicative of overall Herring abundance (Power et al. 2005b). All subsequent assessments have identified these shortcomings as reasons why the bottom trawl data are not used as an abundance index for Herring.

Abundance and Distribution of Survey Catches

Table 19 presents Herring abundances from 1970–2017 summer bottom trawl surveys. There appeared to be increased catch rates by bottom trawl over the series, with some years (such as 1987, 1994, 1999) more than others (Power et al. 2006a). While the trawl survey abundance was relatively constant between 2011 and 2014, there has been an increase in 2015 and again in 2017. The mean number per tow for the 4WX and Offshore Banks was 91 in 2014, 167 in 2015, 119 in 2016, and 233 in 2017. Herring abundance (number per tow) increased in the Bay of Fundy (4X) from 96 (2014), to 105 (2015), to 111 (2016) and to 189 (2017). The overall 4VWX area showed an increase in abundance by number in the last three years from 67 in 2014 up to 158 in 2017 (Table 19).

These increases in abundance of Herring caught in the summer bottom trawl surveys may be due to changes in behaviour, with schools being closer to the bottom, and, as a result, there is a change in catchability. While this is a possibility, there is no other supporting data other then occasional anecdotal information from the fishery of times when Herring may be close to the bottom and, hence, cannot be caught using purse seines. Many of these anecdotal reports have come during spawning events when Herring tend to be close to the bottom.

Figure 29 and Figure 30 show the distribution of Herring catches from the 1998–2017 DFO summer bottom trawl surveys. Locations of catches in the trawl surveys do not appear to change over time, with Herring showing a widespread distribution in the Bay of Fundy and on the Scotian Shelf. As seen in Figure 29 and Figure 30, there is little or no survey coverage on the main spawning areas, which are also major fishing areas.

Survey Length Frequencies and Maturity

Figure 31 and Figure 32 present the 1998–2017 Herring size distribution from the summer bottom trawl research survey for the entire 4VWX area. In 2004 and 2011, there appears to be larger numbers of small Herring caught in the trawl. A wide distribution of sizes of Herring were caught in the trawl in 2008 and 2009; however, for most years, the size distributions tended to be for larger Herring with mean lengths >23 cm. The overall distribution for catches from all strata in 4WX shows that the bottom trawl is capable of catching a wide range of sizes of Herring from 5 cm up to 40 cm.

The maturity data from the summer bottom trawl research survey for the entire 4VWX area are presented in Figure 33 and Figure 34. While there appears to be an increase in the number of Stage 8 Herring in the samples from the surveys starting in 2008, it is not clear whether this is a result of changes in the maturity of the fish caught or the result of changes in the determination of the maturity condition by the person performing the staging, since Stage 8 fish are not easily distinguished from Stage 3.

Survey Catch-at-Age

At the previous framework meeting, the catch-at-age generated from the bottom trawl survey was presented and reviewed. The survey data for areas 4WX combined were analysed by age to produce stratified mean numbers per tow over the series (Figure 35). There was a lack of consistency with the large year-classes observed in the fishery and a lack of tracking of these year-classes from year to year. The plot by age and year showed a lack of older ages in the catch over the decade (1995–2005) but does not appear to track strong year-classes consistently (Figure 36).

It was suggested that the age composition for strata 484 to 495 in the bottom trawl survey be re-examined once the aging problem has been solved to see if year classes can be tracked. This does not appeared to have been done (Mike Power, per. comm.) and was not identified as a priority because of the shortcomings associated with the surveys. This is identified as something that perhaps should be completed to see if there still is a lack of year-class tracking.

The number of Herring of different ages from the bottom trawl surveys increased since 2008 compared to prior years (Table 20, Figure 37). No ages were reported in 2005 and 2007, while only 3 age one fish were reported in 2006. This was the result of re-aging for the years between 1999 and 2005. All the original ages were deleted from the database, and only 20% was attempted to be re-aged. As seen in Table 21, it is clear that, for the bottom trawl survey Herring, the re-aging process was incomplete and, in 2007, no fish was aged even though otoliths were collected. Again, this is identified as requiring completion.

The percentages of Herring of the different ages (including re-aged ones) presently in the database are shown in Figure 38. The number of fish aged is related to the number of sets with Herring and, as in the case of the fishery samples, when a detailed biological sample is collected, two fish per half cm interval are retained for sizes greater than 24.5 cm and one fish per half cm less than 24.5 cm. The number of fish retained is, thus, dependent upon the number of length intervals in the length-frequency sample.

ACOUSTIC SURVEYS

During the early years, commercial fishing vessels were responsible for undertaking acoustic surveys to document the distribution of mature fish during the spawning season and to obtain a rough estimate of harvestable biomass prior to commencement of the roe fishery (Melvin et al. 2002). In essence, the fleet was allowed to remove a portion (up to 20%) of the observed biomass. If only small quantities of Herring were reported on the spawning grounds during a given survey, the area remained closed to fishing until sufficient quantities of fish were documented (i.e., another survey was undertaken). The primary objective of the approach was to provide a second level of protection for individual spawning components within a global TAC. The surveys, while adhering to the standard acoustic practice of employing randomly spaced transects to sample an aggregation of fish, did not prescribe to any predefined area or strata for regular coverage. However, it was recognised that, given an appropriate and standardised survey design, the data/biomass estimates obtained by the commercial fishing vessels could be used in a relative sense to evaluate stock status and over time as an index of abundance for the stock.

Based on an examination of the catch distribution, the survey coverage on each of the three spawning grounds (Scots Bay, German Bank, and Trinity Ledge) was restricted to the area that comprised the largest portion of reported catches (Melvin and Power 1999). Each spawning area was subsequently partitioned into a Survey Box, a geographical sub-section within the spawning area that on average accounted for 90% or more of the reported catch. It was assumed that surveying 90% or more of the annual spawning distribution within each component was sufficient to monitor trends in the biomass. Survey box boundaries represent the minimum area that must be covered by the commercial fleet during a spawning ground survey. The differences between catch area, spawning area, and survey box areas are shown in Figure 39.

Automated acoustic recording systems deployed on commercial fishing vessels have been used since 1999, along with the survey design, and form the basis for multiple surveys on the major spawning grounds within the SWNS/BoF area. Structured scheduled surveys are now conducted each year, with surveys every two weeks or at a minimum of 10 days intervals on each of the main spawning grounds. When the individual acoustic surveys are processed, details about the size and maturity are always incorporated into the results so that any small immature Herring are excluded from the calculation of spawning biomass.

Biomass is estimated from the acoustic data by using the total amount of energy backscattered, in one of several forms such as nautical area scattering coefficient (NASC) or area backscatter coefficient (Sa), and the energy associated with the contributing backscatters or the target strength (TS) (Melvin 2007). Target strength of a target or fish is normally expressed in decibel units to reflect the broad range of potential values. Target strength equations are normally developed for a specific species and transducer frequency and in fisheries acoustics, TS has traditionally been found to be strongly correlated with, and expressed as a function of fish length. The following equation estimates the TS of an individual Herring based on length.

TSLen = 20 Log (length in cm) – 71.9 (Foote, 1987)

To convert the backscatter to weight, an additional coefficient, based on weight/length relationship of Herring, is incorporated into the equation.

TSWeight = 20 Log (length in cm) – 71.9 – 10 Log (wt in kg)

This allows the direct conversion of acoustic energy into tonnes/unit area.

The length parameter of the TS equation utilizes the mean length determined from commercial purse seine collected length-frequency samples during the night of the survey, or fishing activity within 1–2 days before or after the survey. Only samples collected from commercial sets within the defined spawning box of each spawning ground were included in the estimation of TS. All length-frequency samples from the survey period are pooled but not weighted by catch, to estimate a mean length for inclusion in the TS equation. The weight function was estimated from a length/weight relationship determined from detailed biological samples collected within a 9-day window (4 days prior to or after) around each survey (Power and Melvin 2010).

In the early years of the time series, all data were collected and processed using the Hydroacoustics Data Processing System from Femto Electronics. There has been a gradual migration to using Echoview (Echoview Software Pty Ltd) to process the data collected from the surveys. Automated logging systems deployed on commercial vessels consist of Femto Model DE9320, Simrad Model ES60, or Simrad Model ES70.

In 2003, a calibration integration factor (CIF) was introduced during the calibration of the echo sounder (Power et al. 2006a). The inclusion of the CIF is deemed to provide a more accurate estimate of biomass. This lead to a recalculation of all the biomass estimates from the previous years (Melvin et al. 2014b).

Sources of Uncertainty

When using acoustic survey results as a measure of absolute abundance, there are numerous variables for which information is lacking (e.g., residence time on the spawning grounds and estimation of biomass in the acoustic dead/blind zones at the surface and close to bottom). Between 1999 and 2003, acoustic survey results were used as minimum estimates of absolute SSB abundance, and the population was considered to be approximately 500,000 t. An SSB of that size would have been expected to result in substantial growth of the population, improved age composition, and low fishing mortality, given reasonable recruitment and the landings over that period. This has not occurred.

Collected backscatter data has always been visually edited to remove non-Herring targets. In addition, targets that are more spread out in the water column (and not considered parts of Herring schools) have been left in the backscatter data. There is some uncertainty on whether these are Herring targets should have been removed. At certain times of the survey season, backscatter in the water column that may not be Herring (such as plankton including salps) have been included, and this may have resulted in over-estimates of Herring biomass. While attempts are made to reduce vessel noise in the backscatter, this can still occasionally occur.

The assumption that surveys are additive continues to be a source of uncertainty (DFO 2007a)[1]. Other significant issues relate to inter-annual turn-over processes on each area, and factors that influence the target strength and acoustic backscatter (DFO 2007a). Additionally, the mechanisms causing changes in fish condition is not understood. The acoustic survey index provides fisheries-independent information on the SSB but does not provide data on younger age classes. The size of recruiting Herring year-classes is highly variable and, with no index of recruitment, a large fraction of the catch is dependent on recruiting year-classes of uncertain abundances.

Acoustic Index

The trend in the three-year moving average acoustic biomass for the combined, German Bank and Scots Bay, is the main index used in guiding the setting the TAC for the SWNS/BoF Herring spawning component. In 2012, a conservation LRP for the component was identified as the 2005–2010 average acoustic survey biomass for the two major spawning grounds of German Bank and Scots Bay, below which the risk of serious harm is unacceptable (Clark et al. 2012). The assessment meeting in March 2018 (after this Data and Inputs meeting) accepted a method to adjust the biomass estimates for turnover rates on the two major spawning grounds (Melvin et al. 2018). All the biomass estimate data in this document, however, are the unadjusted numbers.

Table 22 provides data on the acoustic survey biomass index (prior to adjustment for turnover) for SWNS/BoF spawning component for the entire time series from 1999 to 2017. Figure 40 presents the relative acoustic spawning biomass index for the period 1999 to 2017, along with

[1] At the 2018 assessment subsequent to this Data Inputs meeting, a method to estimate acoustic biomass turnover on the Scots Bay and German Bank spawning grounds was presented by Melvin et al. (2018) and accepted.

the three-year moving average, the long-term average, and the LRP. Biomass estimates have fluctuated about this LRP since 2010. Since 2010, the confidence intervals have included the LRP. The three-years moving average has been relatively flat between 2011 and 2016; however, in 2017 the average decreased to 6% above the LRP. A similar trend is seen when the overall SWNS/BoF spawning biomass is examined over time (Figure 41).

In addition to German Bank, Scots Bay, and Trinity Ledge, the other areas that have been surveyed in the SWNS/BoF stock area are Spectacle Buoy (Table 7), Seal Island and Browns Bank (Table 22). Seal island historically made a large contribution to the biomass of the stock area but surveys have been intermittent (Melvin et al. 2004).

Acoustic Catch-at-Age

Age specific indices of abundance were also constructed from the acoustic survey data using samples appropriate for each survey by area and year since 1999 and applying the biomass estimates that were determined for the overall combined survey areas within the SWNS/BoF component (Table 23, Figure 42). Indices were also constructed for the German Bank (Table 24, Figure 43) and Scots Bay survey areas (Table 25, Figure 44). These acoustic surveys, which document primarily spawning fish, have an age composition differing from the overall fishery, with few fish younger than age 3 (age of first spawning), and higher numbers in proportion, up to age 11, than is seen in the catch.

Total Mortality Estimates from Acoustic Data

The 2011 Framework recommended that mortality rate based on age composition (F=Z-M) be used to determine trends. Estimates of Total mortality (Z) = Fishing mortality (F) + Natural mortality (M) were calculated using the acoustic catch-at-age data. When completed in this manner, Z calculations are typically quite variable but can often be used to detect broad patterns. Total mortality was calculated using ages 4 to 8 combined compared with ages 5 to 9 in the following year (overall SWNS/BoF component: Table 23, Figure 42, German Bank: Table 24, Figure 43 and Scots Bay: Table 25, Figure 44). The results for 1999 to 2017 have highly variable Z values, ranging from -0.3 to 1.3 for the overall SWNS/BoF component (Figure 45) and German Bank spawning area (Figure 46), and from -1.3 to 2.2 for the Scots Bay spawning area (Figure 47). There is no strong trend, for the most part; however, there appears to be a slightly decreasing trend in both Scots Bay and German Bank. The overall SWNS/BoF component trend also appears to show decreasing estimates of Z.

LARVAL SURVEYS

From 1972 to 1998, annual plankton research surveys were conducted in late October / early November in the SWNS/BoF area to determine larval Herring distribution and abundance (Stephenson et al. 1999b). Sampling stations were spaced 10 nautical miles apart, and sampling was consistent with standard international sampling protocols at the time (Anon 1972). These autumn surveys used a set of 79 sampling stations along a series of transects normal to the axis of the Bay of Fundy (Figure 48). This series concluded in 1998 for fiscal reasons and because the survey had limited use in the stock assessment (Stephenson et al. 1998). This survey was reinstituted in 2009 for a single year in order to provide a ‘snapshot’ of the marine plankton environment for comparison with the earlier data series and as a measure of the biodiversity of the ecosystem. Of particular interest is the spatial distribution and abundance of Herring larvae in 2009 in relation to the historical distribution and in comparison to known spawning grounds. The larval abundance index of 19.9 larvae/m^2 was lower than the previous value of 33.6 larvae/m^2 recorded in 1998 (Table 26, Figure 49) and lower than the average of the 27 year time series (25.6), with similar distribution patterns as seen by the earlier surveys.

Additional larval surveys were also conducted in the spring. These surveys were conducted for 9 years (1975–1984) either in the last week of March and first week of April (1975–1979), or 1 week earlier in the second and third weeks of March (1980–1984) using the same bongo net (Figure 48).

Based on the data obtained in the fall and spring larval surveys, Stephenson et al. (2015) concluded that larvae of all sizes, from hatch to nearly 4 months post-hatch, were located in two major aggregations: one off southwestern Nova Scotia, and the other in the mid-inner Bay of Fundy off the northwestern shore of Nova Scotia (Figure 50).

From these surveys it was concluded that:

1. There are dense aggregations of larvae in the proximity of known spawning grounds (Figure 50);
2. The distributions of different ages of larvae overlap and the centre of mass are relatively stable over time (i.e., there is 'retention');
3. The pattern is similar each year (over the 20+ year time period).

'Retention' of larvae in the Bay of Fundy has an active behavioural component (Stephenson and Power 1988, 1989). It has been proposed that larval retention is important to population structure (Iles and Sinclair 1982, Sinclair 1988). At the length of about 40 mm, Herring larvae begin to take on a more adult Herring shape and appearance and become a juvenile Herring.

The last time the larval survey data was used in a VPA formulation was in the 1998 assessment (Stephenson et al. 1998). The sudden, large drop in larval abundance index in 1994 was difficult to explain. The analytical assessment (Sequential Population Analysis (SPA)) model used larval abundance as an index of spawning stock abundance (SSA). Larval abundance, which is considered to represent spawning stock biomass (SSB) near the end of the fishery was related to SSB (population x weight at age x maturity at age) at the beginning of the year following the November larval survey. The analysis showed a weak relationship between the larval abundance index and SSB, poor model resolution, and a strong retrospective pattern, and was not considered to give valid estimates of stock size (Power 2007).

ECOSYSTEM CONSIDERATIONS

Herring is a prominent species in the diets of many other fish, birds, and marine mammals, and should be managed with these interactions in mind. At present, a natural mortality rate of 0.2 is assumed to account for these interactions. As part of a complex ecosystem, changes to Herring population are also linked to bottom-up or top-down ecosystem processes (e.g., predator abundance, food availability, temperature). An important step towards implementing an Ecosystem Approach (EA) to fisheries management is the ability to identify which of these processes, and their associated indicators, are directly and indirectly linked to Herring population dynamics (Bundy et al. 2017).

The suite of indicators that are important would include Herring prey, Herring predators, and environmental factors. The relevant ecosystem factors and availability of their respective indices are summarized below.

HERRING PREY

Herring is a plankton feeder and, when first hatched, the larvae start feeding before the yolk sac is completely absorbed (Bigelow and Schroeder 1953). Larval Herring feed opportunistically on up to 15 different groups of zooplankton, including larval snails and crustaceans, on diatoms, and on peridinians, but they soon begin taking copepods, and depend exclusively on these for a time after they get to be 12 mm long, especially on *Pseudocalanus* sp. (Hardy 1924, Jespersen 1928). As they grow older, they feed more and more on the larger copepods, amphipods, pelagic shrimps, and decapod crustacean larvae. Euphausiids, chaetognaths, and copepods make up the bulk of the diet of adult Herring (Bigelow and Schroeder 1953).

Copepods *Calanus finmarchicus* predominates in the diet of Herring while other copepods such as *Pseudocalanus, Acartia*, *Centropages*, and *Temora* may also at times of abundance be consumed. Sometimes, Herring feed on whatever is plentiful such as molluscan larvae, fish eggs, Sagittae, pteropods, annelids, and even on microscopic organisms as small as tintinnids and Halosphaera. The most important prey items of adult Herring collected on Georges Bank were chaetognaths, euphausiids, pteropods, and copepods (Maurer 1976). Although Herring normally are not fish predators, sand lance, silversides, and the young of their own species have been found in their stomachs.

Stomach content data of Herring have been recorded down to the group level from samples collected in 4VWX by the commercial fishery and from DFO ecosystem surveys. The collected data were stored in the Pelagic Samples Database, and data from 2006 to 2015 were complied and analysed (DFO, unpublished data). The data indicate that copepods were usually the most dominant group by number in Herring diet, along with krill and amphipods and, over the time series (2006–2015), they generally comprised over 90% of the diet (DFO, unpublished data) (Figure 51). The stomach content data also show that adults eat more amphipods and krill than juveniles, and juveniles eat more copepods than adults. The other food items appear to occur in similar percentages in the diets of both adults and juveniles (Figure 52).

HERRING PREDATORS

Herring is a source of food for many species of fish, bird, and marine mammals. As a plankton feeder, Herring is a critical link between the plankton at the base of the food web and other marine organisms. Both juvenile and adult Herring are preyed on by many marine species, including Sand Lance (*Ammodytes hexapterus*), Cod (*Gadus morhua*), Pollock (*Pollachius virens*), Haddock (*Melanogrammus aeglefinus*), Silver Hake (*Merluccius bilinearis*), White Hake (*Urophycis tenuis*), Striped Bass (*Morone saxatilis*), Mackerel (*Scomber scombrus)*, Billfish, tuna, Salmon, sculpins, Winter Flounder (*Pseudopleuronectes americanus*), dogfish, porbeagle shark, and skates (*Raja* spp.) (Stevenson and Scott, 2005). Fish predation can be a significant source of mortality, especially at spawning time. Several fish species, as well as American lobster (*Homarus americanus*) and starfish, eat Herring eggs. Sand lance may consume large quantities of eggs and larvae, which are sometimes cannibalized by adult Herring as well. Jellyfish may also be an important predator on the early life stages. Large numbers of Herring are also eaten by marine birds, northern shortfin squid (*Illex illecebrosus*), seals, porpoises, and whales (Stevenson and Scott, 2005).

Guenette and Stephenson (2012) quantified the level of predation compared to fishing and estimated natural mortality at age using a simple multi-species virtual population analysis (MSVPA) centered on Herring for the period 1970–2008 that included all predators known to commonly consume Herring. Herring predators were structured in 16 groups among which 12 were fish (Table 27). Diet and ration for demersal fish were obtained from the DFO stomach content database (Laurinolli et al. 2004, Carruthers et al. 2005) and from the literature for sharks and tuna. Abundance estimates of the 10 most important pelagic birds were obtained from the PIROP (Programme intégré de recherches sur les oiseaux pélagiques) survey (Huettmann 2000), while data on nesting birds (Atlantic Puffin, Arctic Tern, Common Tern, Razorbill) were obtained from A.W. Diamond in 2010. Food consumption was obtained from activity budgets, general diet types, and prey caloric content. Diet compositions were assembled from various studies on the Canadian Atlantic coast (Guenette and Stephenson 2012).

Marine mammals were organized in three groups, Humpback whale, Grey Seal, and “other mammals”. Abundance estimates for marine mammals were obtained from the annual summer survey carried out by NOAA for the Northeastern coast, which includes the lower Bay of Fundy and southern tip of the Scotian Shelf in Canadian waters. Residence time was either obtained by averaging the proportion of the population abundance per season compared with the peak season, or derived from the literature (Guenette and Stephenson 2012).

Guenette and Stephenson (2012) concluded that the most important predators of Herring were Cod, Pollock, White Hake, dogfish, birds, Grey Seal, and other mammals (Figure 53) which are responsible for 95% of the Herring consumed. On average, birds accounted for 8.5% of Herring predation, Cod and the marine mammals (all groups) for 25% each, White Hake and Pollock 15%. Herring consumption by Grey Seal and dogfish augmented as their populations increased in the area. Predation was taking a similar amount of Herring biomass as the fishery and even more in the 1980s, and consequently the average mortality rates for predation and fishing were estimated at 0.44 and 0.43 respectively.

Different predators consume different sizes (and therefore age classes) of the Herring. Juvenile Herring hatched in fall are referred to as “0-group” until 1 January when they become 1-group (or 1-year-olds). Herring reach sexual maturity at 3 to 4 years but can enter the fishery at age 2 (Figure 54). Scopel et al. (2017) assessed the possible relationships between the Herring content in the diet of seabird chicks and various measures of Herring abundance, with a view to identifying possible predictors of future Herring stock size. They used regression analyses to model relationships between Herring in the diet of seabird chicks at nine nesting colonies in the Gulf of Maine and four types of fishery- and survey-derived Herring data.

Several strong relationships were found, which suggested spatial structuring in Herring stocks and likely patterns of Herring movements before they recruit into the fishery. Herring data from acoustic surveys, fixed-gear landings, and WAA correlated as strongly with seabird data as more commonly used series, such as mobile-gear landings and modeled SSB. Scopel et al. (2017) concluded that seabird chick diets collected at specific locations offer a promising means to assess the size, distribution, and abundance of juvenile Herring across a broad area prior to recruitment (Figure 55). Common Terns (*Sterna hirundo*) showed the most potential as a bioindicator, correlating well and showing consistent spatial patterns with 11 of 13 fishery data series.

Deroba (2018) modeled the amount of Herring identified in predator stomachs from bottom trawl surveys since 1973. Prey items were identified to the lowest possible taxonomic group and only 15 predators with at least 10 stomach observations that contained Herring and at least 0.1% of all stomachs sampled among all years containing Herring were included. Both the amount of Herring in stomachs and the probability of a stomach containing Herring varied seasonally, spatially, and among years. The index of Herring abundance derived from the stomach-contents data was generally consistent with recent NOAA Atlantic Herring stock assessments (Deroba 2018).

ENVIRONMENTAL INDICATORS

The Atlantic Zone Monitoring Program (AZMP) measures a suite of environmental variables across the Scotian Shelf and Gulf of Maine (Figure 56) (Johnson et al. 2017, DFO 2017).

These are a few of the variables that may be relevant to the biology and ecology of Herring. This list is not intended to be comprehensive but gives the reader some idea of the types of environmental variables that are available:

- Mixing properties (Mixed Layer Depth [MLD], stratification index) at the Halifax-2 and Prince-5 fixed stations comparing 2015 data with mean conditions from 1999–2010 (Figure 57, Johnson et al. 2017).
- Annual anomaly scorecard for phytoplankton (chlorophyll) and zooplankton abundance or biomass (1999–2010) (Figure 58, Johnson et al. 2017).
- Annual anomaly scorecard for microplankton abundance for the Halifax 2 and Prince 5 Stations (1999–2010) (Figure 59, Johnson et al. 2017).
- Annual anomaly scorecard for copepod indicator species group abundances (1999–2010) (Figure 60, Johnson et al. 2017).
- Zooplankton biomass (integrated surface to bottom) in 2015 and mean conditions 1999–2010 at Prince-5 (Figure 61, from Johnson et al. 2017).

Prince 5 Data

Prince-5 is the only station located within the Bay of Fundy (Figure 56), and the data collected would be of most relevance to the SWNS/BoF Herring spawning component.

At Prince-5, the MLD is deeper and more variable and stratification is weaker than at the Halifax-2 station due to strong tidal mixing. The stratification index normally remains low (below 0.01 kg m^{-4}) for most of the year, and the MLD varies from nearly full depth (90 m) in winter to approximately 40 m in summer (Figure 57). The stratification index at Prince-5 exhibited typical low values in 2015, with lower than normal stratification in April when the index would typically rise, suggesting delayed onset of stratification in 2015.

Phytoplankton abundances at Prince-5 in 2015 are summarized in Johnson et al. (2017). Abundances were above normal during the spring bloom and were dominated by diatoms, and the summer phytoplankton bloom was about a month earlier than normal but of normal duration. The phytoplankton community at Prince-5 is normally dominated year-round by diatoms, but their relative abundance was lower than normal at times of low phytoplankton abundance, when the relative abundance of dinoflagellates (winter and early fall) or ciliates (microzooplankton, late spring) was higher than normal. Overall, the annual integrated chlorophyll anomaly at Prince-5 was positive in 2015 (Figure 58).

Overall at Prince-5 in 2015, annual abundance anomalies for *C. finmarchicus* and *Pseudocalanus* spp. were weakly negative, and anomalies of total copepod and non-copepod abundance and zooplankton biomass were positive (Figure 58, from Johnson et al. 2017). Figure 60 shows the annual anomaly scorecard for phytoplankton (chlorophyll) and zooplankton abundance or biomass. According to Johnson et al. (2017), zooplankton biomass and total abundance at Prince-5 are typically lowest in January to May and increase to maximum values in July to September, lagging increases in phytoplankton by about a month, before declining to low levels again in the late fall (Figure 61). In 2015, zooplankton biomass was lower than normal in winter and late fall, and higher than normal in spring and early fall. Total zooplankton abundance at Prince-5 in 2015 was close to normal during much of the year, but it was higher than normal in April and May and lower than normal in October. The zooplankton community was mostly dominated by copepods throughout the year, except for larger than normal relative abundance of barnacles (“Others”) during spring and of Cladocera and Bivalvia in August (Johnson et al. 2017).

- Sea surface temperature 1985–2016 anomaly (Figure 62, DFO 2017b).
- Time series of oceanographic variables (temperature 0–50 m, bottom temperature, salinity, stratification) at AZMP high-frequency sampling stations, 1980–2016 (Figure 63, from DFO 2017b).

CONCLUSIONS

The stock structure of Herring in 4VWX is complicated due to the presence of a number of spawning areas, separated to various degrees in space and time. Some spawning areas are large and offshore, whereas others are small and more localized, sometimes very near shore or in small embayments. Herring migrate long distances and mix outside of the spawning period, both with members considered part of the same component and with members of other components. There is mixing of fish among spawning components outside of the spawning period. The four components presently identified are the SWNS/BoF spawning component, the Offshore Scotian Shelf banks spawning component, the coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component, and the SWNB migrant juveniles

Assessment approaches have varied since quotas were first established for SWNS/BoF stock component in 1976. A variety of survey indices have been evaluated, used and then rejected and sometimes reintroduced, often as inputs into VPA models. Presently, an analytical model is not used for the SWNS/BoF Herring spawning component, but the following indicators are used for signs of change: acoustic survey biomass trends, fishermen input, numbers or proportion at age in catch, trends in exploitation rates from survey, and mortality rate trends based on age composition.

In the Maritimes Region, the fishery for Atlantic Herring has been recorded within 4VWX and the Canadian portion of 5Yb. Fisheries in the 4VWX area in recent years have been dominated by purse seine, weir and gillnet, with relatively minor landings by shutoff and trap.

The annual bottom trawl RV survey has been conducted since 1970. Survey coverage is restricted to depths of >15 fathoms in Bay of Fundy and >50 fathoms off southern NS, except for an area north of Browns Bank, which is not surveyed due to un-trawlable bottom. The survey uses a bottom trawl with a 19 mm Cod end liner and samples both fish and invertebrates. Sampling is generally conducted during the summer season (June–August).

Herring is a prominent species in the diets of many other fish, birds, and marine mammals, and should be managed with these interactions. As part of a complex ecosystem, changes to Herring population are also linked to bottom-up or top-down ecosystem processes (e.g. predator abundance, food availability and temperature). The suite of indicators that are important would include Herring prey, Herring predators, and environmental factors.

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TABLES

Table 1. Historical series of nominal and adjusted annual landings (t) by major gear components and seasons of the 4WX Herring fishery from 1963–2017. The 1963–1973 offshore Scotian Shelf landings are from Stephenson et al. (1987). A dash (-) indicates no data.

Year^	4W Winter Purse Seine	4Xs Fall & Winter Purse Seine	4Xqr Summer Purse Seine	4X Summer Gillnet	4Xr Nova Scotia Weir	4WX Stock Nominal Landings	4WX Stock Adjusted Landings*	4WX Stock TAC	Non-Stock 4Xs N.B. Weir & Shutoff	4VWX Coastal Nova Scotia	Offshore Scotian Shelf Banks	Total 4VWX Adjusted Landings
1963	-	6,871	15,093	2,955	5,345	30,264	30,264	-	29,366	-	3,000	62,630
1964	-	15991	24,894	4,053	12,458	57,396	57,396	-	29,432	-	2,000	88,828
1965	-	15,755	54,527	4,091	12,021	86,394	86,394	-	33,346	-	6,000	125,740
1966	-	25,645	112,457	4,413	7,711	150,226	150,226	-	35,805	-	2,000	188,031
1967	-	20,888	117,382	5,398	12,475	156,143	156,741	-	30,032	-	1,000	187,773
1968	-	42,223	133,267	5,884	12,571	193,945	196,362	-	33,145	-	18,000	247,507
1969	25,112	13,202	84,525	3,474	10,744	137,057	150,462	-	26,539	-	121,000	298,001
1970	27,107	14,749	74,849	5,019	11,706	133,430	190,382	-	15,840	-	87,000	293,222
1971	52,535	4,868	35,071	4,607	8,081	105,162	129,101	-	12,660	-	28,000	169,761
1972	25,656	32,174	61,158	3,789	6,766	129,543	153,449	-	32,699	-	21,000	207,148
1973	8,348	27,322	36,618	5,205	12,492	89,985	122,687	-	19,935	-	14,000	156,622
1974	27,044	10,563	76,859	4,285	6,436	125,187	149,670	-	20,602	-	-	170,272
1975	27,030	1,152	79,605	4,995	7,404	120,186	143,897	-	30,819	-	-	174,716
1976	37,196	746	58,395	8,322	5,959	110,618	115,178	-	29,206	-	-	144,384
1977	23,251	1,236	68,538	18,523	5,213	116,761	117,171	109,000	23,487	-	-	140,658
1978	17,274	6,519	57,973	6,059	8,057	95,882	114,000	110,000	38,842	-	-	152,842
1979	14,073	3,839	25,265	4,363	9,307	56,847	77,500	99,000	37,828	-	-	115,328
1980	8,958	1,443	44,986	19,804	2,383	77,574	107,000	65,000	13,525	-	-	120,525
1981	18,588	1,368	53,799	11,985	1,966	87,706	137,000	100,000	19,080	-	-	156,080
1982	12,275	103	64,344	6,799	1,212	84,733	105,800	80,200	25,963	-	-	131,763
1983	8,226	2,157	63,379	8,762	918	83,442	117,400	82,000	11,383	-	-	128,783
1984	6,336	5,683	58,354	4,490	2,684	77,547	135,900	80,000	8,698	-	-	144,598
1985	8,751	5,419	87,167	5,584	4,062	110,983	165,000	125,000	27,863	-	-	192,863
1986	8,414	3,365	56,139	3,533	1,958	73,409	100,000	97,600	27,883	-	-	127,883
1987	8,780	5,139	77,706	2,289	6,786	100,700	147,100	126,500	27,320	-	-	174,420
1988	8,503	7,876	98,371	695	7,518	124,653	199,600	151,200	33,421	-	-	233,021
1989	6,169	5,896	68,089	95	3,308	83,557	97,500	151,200	44,112	-	-	141,612
1990	8,316	10,705	77,545	243	4,049	102,627	172,900	151,200	38,778	-	-	211,678
1991	17,878	2,024	73,619	538	1,498	97,010	130,800	151,200	24,576	-	-	155,376
1992	14,310	1,298	80,807	395	2,227	100,227	136,000	125,000	31,967	-	-	167,967
1993	10,731	2,376	81,478	556	2,662	98,464	105,089	151,200	31,573	-	-	136,662
1994	9,872	3,174	64,509	339	2,045	80,099	80,099	151,200	22,241	-	-	102,340
1995	3,191	7,235	48,481	302	3,049	62,499	62,499	80,000	18,248	-	-	80,747
1996	2,049	3,305	42,708	6,340	3,476	58,068	58,068	57,000	15,913	1,450	11,745	87,176
1997	1,759	2,926	40,357	6,816	4,019	56,117	56,117	57,000	20,552	2,340	20,261	99,270
1998	1,405	1,494	67,433	2,231	4,464	77,027	77,027	90,000	20,091	4,120	5,591	106,829
1999	1,235	4,764	64,432	1,660	5,461	77,552	77,552	105,000	18,644	5,618	12,646	114,460

Year^	4W Winter Purse Seine	4Xs Fall & Winter Purse Seine	4Xqr Summer Purse Seine	4X Summer Gillnet	4Xr Nova Scotia Weir	4WX Stock Nominal Landings	4WX Stock Adjusted Landings*	4WX Stock TAC	Non-Stock 4Xs N.B. Weir & Shutoff	4VWX Coastal Nova Scotia	Offshore Scotian Shelf Banks	Total 4VWX Adjusted Landings
2000	1,012	4,738	78,010	823	701	85,284	85,284	100,000	16,829	4,283	2,182	108,578
2001	0	4,001	62,004	1,857	3,708	71,570	71,570	78,000	20,209	6,006	12,503	110,288
2002	367	5,257	69,894	393	1,143	77,054	77,054	78,000	11,874	10,375	7,039	106,342
2003	0	8,860	79,140	439	921	89,360	89,360	93,000	9,003	9,162	998	108,523
2004	0	5,659	69,015	225	3,130	78,029	78,029	83,000	20,686	6,924	4,165	109,804
2005	0	2,601	43,487	566	2,245	48,899	48,899	50,000	13,055	6,311	5,263	73,528
2006	0	930	45,002	719	2,508	49,159	49,159	50,000	12,863	6,566	9,809	78,397
2007	0	1,847	46,045	1,334	1,130	50,356	50,356	50,000	30,944	5,240	5,385	91,925
2008	0	2,000	50,022	15	2,524	54,561	54,561	55,000	6,447	3,704	918	65,631
2009	0	2,807	50,802	117	387	54,113	54,113	55,000	4,031	9,783	9,088	77,015
2010	0	2,787	41,345	204	1,198	45,534	45,534	55,000	10,958	5,575	11,862	73,929
2011	0	1,584	46,784	638	1,004	50,010	50,010	50,000	3,711	3,606	10,482	67,809
2012	0	1,077	45,918	471	149	47,614	47,614	50,000	504	3,007	1,255	52,381
2013	0	358	44,884	1,270	43	46,554	46,554	50,000	6,431	3,937	1,515	58,437
2014	0	1,460	46,522	2,102	166	50,250	50,250	50,000	2,149	4,760	58	57,216
2015	0	[redacted]	45,927	1,806	0	49,024	49,024	50,000	146	5,166	1,803	56,139
2016	0	[redacted]	46,983	1,477	[redacted]	50,012	50,012	50,000	4,060	7,805	1,035	62,912
2017	0	[redacted]	37,590	655	0	39,430	39,430	42,500	2,102	7,828	3,955	53,315

^Annual landings by purse seiners are defined for the period from October 15 of the preceding year to October 14 of the current year.
*Adjusted totals include misreporting adjustments for 1978–84 (Mace 1985) and for 1985–93 (Stephenson 1993; Stephenson et al. 1994).

All landings by other gear types are for the calendar year.

Note: Redacted data for 2015–2017 does not meet DFO's policies for releasing commercial fishing information.

Table 2. Monthly landings (t) for 4VWX Herring from all gear types for calendar year.

Year	Jan.	Feb.	Marc	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1967	6,196	3,274	906	493	1,79	36,17	62,60	71,72	44,33	14,28	7,349	5,598	254,73
1968	4,017	7,144	10,29	2,01	5,18	22,53	61,00	72,01	41,49	22,28	7,377	7,631	262,98
1969	9,645	12,86	10,09	3,24	7,80	23,24	31,52	38,66	25,82	10,44	3,107	2,744	179,21
1970	8,603	8,565	7,811	8,45	3,22	15,27	26,99	33,27	21,70	11,30	8,691	7,749	161,64
1971	18,87	15,38	13,53	7,01	3,21	12,10	18,68	24,89	19,82	5,840	2,227	11,42	153,02
1972	11,89	3,140	3,618	1,81	2,98	9,209	26,54	42,27	32,52	20,24	16,17	6,999	177,41
1973	9,687	424	2,278	2,00	4,10	15,85	36,28	37,35	9,022	3,519	5,340	8,852	134,71
1974	17,43	9,206	385	2,23	3,47	19,69	44,25	33,55	11,00	4,194	8,509	9,365	163,31
1975	1,127	131	91	834	2,81	23,95	38,41	41,65	16,63	5,821	3,489	3,166	138,14
1976	17,98	7,170	76	161	1,52	12,42	25,37	31,93	28,49	4,500	4,803	11,92	146,36
1977	14,02	872	30	881	4,41	24,24	29,32	32,17	19,52	4,421	7,202	4,239	141,35
1978	19,02	1,286	282	261	3,11	22,50	30,51	26,44	20,49	12,87	4,071	8,235	149,11
1979	7,378	754	1,405	876	2,17	8,505	18,63	20,60	14,84	9,092	3,262	1,458	88,994
1980	8,970	1,987	1,990	424	867	11,01	24,40	30,54	10,91	2,724	2,190	4,886	100,92
1981	11,05	2,659	309	2,26	1,10	9,755	26,86	28,87	15,63	5,059	6,649	4,601	114,83
1982	2,627	438	55	3,13	427	2,480	19,74	33,42	31,91	8,450	1,191	5,353	109,24
1983	3,486	3,224	1,576	284	740	5,035	16,67	28,10	29,19	8,890	5,768	3,133	106,10
1984	3,256	1,075	217	202	496	2,453	12,76	26,82	28,63	7,841	7,889	3,070	94,722
1985	4,548	468	6	118	1,25	2,959	19,40	42,10	47,72	13,83	7,296	3,653	143,36
1986	4,944	3	10	92	624	755	9,624	31,25	35,64	13,14	8,598	3,469	108,16
1987	5,247	21	6	369	1,92	6,836	19,01	33,71	34,13	12,66	6,664	1,883	122,48
1988	6,148	2,333	1,288	362	3,04	15,50	32,38	36,11	47,94	11,49	6,652	3,544	166,82
1989	5,701	2,363	1,388	248	541	10,74	27,75	29,12	29,72	18,57	7,537	5,207	138,90
1990	5,362	4,569	361	135	733	11,56	30,29	23,80	41,51	16,09	15,87	5,034	155,34
1991	3,095	310	0	93	517	10,49	25,22	26,86	29,74	9,037	14,55	1,790	121,72
1992	4,176	268	184	223	1,09	13,93	26,88	24,16	40,58	10,35	13,21	521	135,60
1993	2,057	88	75	85	1,65	17,85	32,13	27,43	20,99	18,56	11,42	122	132,48
1994	4,171	0	0	201	2,43	9,299	19,80	24,53	23,70	13,87	5,530	541	104,08
1995	3,535	127	8	151	1,00	5,442	15,70	16,72	25,15	8,194	6,901	37	82,986
1996	1,068	23	0	178	3,10	13,11	18,88	23,21	16,39	12,94	5,643	623	95,200
1997	648	100	9	97	3,13	19,27	21,42	20,19	20,32	11,91	5,769	0	102,88
1998	343	1	0	142	3,80	11,41	19,30	25,13	31,39	15,10	1,963	0	108,60
1999	0	1	2	520	7,67	22,38	26,22	19,80	23,78	13,63	1,730	1	115,76
2000	1,262	3	7	132	2,40	8,817	20,68	29,91	26,14	18,02	1,996	15	109,41
2001	478	5	16	305	4,63	17,14	21,48	27,59	26,39	16,08	430	1	114,58
2002	1,627	3	5	1,03	5,03	8,453	23,50	24,71	23,55	20,67	2,708	145	111,44
2003	1,894	494	3	5	4,69	5,089	21,21	24,46	30,17	19,69	4,913	85	112,71
2004	1,313	184	0	3	4,79	12,08	16,76	31,71	25,96	15,93	632	15	109,40
2005	571	1	1	14	2,07	7,537	14,89	17,12	16,17	12,15	1,056	231	71,827
2006	1,192	1	4	420	1,78	7,773	17,44	16,82	16,56	14,63	804	1,777	79,218
2007	1,184	0	20	33	1,84	9,643	19,89	22,03	21,06	15,96	918	101	92,706
2008	458	1	3	4	1,16	10,61	14,75	12,46	14,62	12,09	747	32	66,951
2009	932	1	0	3	3,97	13,25	12,89	14,89	18,11	12,40	591	14	77,076
2010	1,123	0	0	98	9,68	8,652	10,34	16,44	21,49	6,312	752	0	74,910
2011	0	0	0	1	9,55	8,637	11,32	7,277	21,61	8,573	336	0	67,317
2012	0	1	2	77	2,34	4,326	5,352	15,38	17,16	6,888	114	1	51,664
2013	7	6	5	20	2,59	9,574	13,57	13,48	11,67	8,504	141	2	59,592
2014	1	4	5	2	1,51	9,139	11,05	19,44	10,34	5,234	364	10	57,117
2015	1	1	5	3	1,08	11,04	6,937	12,27	17,00	7,036	933	74	56,406
2016	1	4	7	28	988	10,14	11,77	16,75	14,72	6,924	1,239	1	62,595
2017	0	1	2	2	607	5,812	10,84	11,66	11,88	10,67	2,293	1	53,777

Table 3. History of southwest Nova Scotia/Bay of Fundy (4WX) Herring stock assessment evaluation by fishery year with authors, indices and models evaluated, and the research document reference.

Fishery Year	Res Doc Authors	Indices and models used to evaluate stock status	Research Document
1976	Miller & Stobo	Logbook catch effort considered unreliable. VPA with assumed fully recruited F=0.35.	1977/011
1977	Stobo et al.	Purse seine and weir cpue. VPA with projection.	1978/025
1978	Sinclair et al.	Purse seine, NS gillnet, NB & NS weir CPUE, larval considered. VPA with projection.	1979/019
1979	Sinclair & Iles	Purse seine CPUE learn and non-learn. VPA with projection.	1980/047
1980	Sinclair & Iles	Larval survey (LAI), juvenile catch-at-age for NB weirs. VPA with projection.	1981/010
1981	Sinclair et al.	Larval index declined sharply & not used; gillnet & NB weir catch rates for ages 1-3. VPA with projection.	1982/036
1982	Iles & Simon	Larval index used for tuning. Purse seine, gillnet, NB weir catch rates rejected as indices. VPA with projection.	1983/089
1983	Iles et al.	Larval index used; fishery indices considered but not used. VPA with projection.	1984/072
1984	Stephenson et al.	Larval index used. VPA with projection.	1985/078
1985	Stephenson et al.	Larval index used; reviewed other indices and rejected their use. VPA with projection.	1986/043
1986	Stephenson et al.	Larval index used. VPA with projection.	1987/075
1987	Stephenson et al.	Revised LAI (115 to 79 standard stations). Chedabucto acoustic survey considered but not used. ADAPT VPA but no projection.	1988/069
1988	Stephenson & Power	LAI highest in series. VPA rejected. Ched. Bay acoustics used as indication of stock size. Projection based on acoustic SSB.	1989/059
1989	Stephenson et al.	LAI and Ched. Bay reduced; bottom trawl survey; ADAPT VPA with various formulations but was rejected.	1990/050
1990	Stephenson et al.	LAI reduced. Ched. Bay acoustics rejected. Bottom trawl survey considered. Catch misreporting high. No VPA due to catch problems.	1991/058
1991	Stephenson et al.	LAI, bottom trawl, Ched Bay low, experimental BOF acoustic surveys. VPA not possible due to catch data problems.	1992/069
1992	Stephenson et al.	LAI adjust for growth & mort; bottom trawl by age; Ched Bay not valid. Further work on catch and indices needed before VPA can be done.	1993/076
1993	Stephenson et al.	Dockside monitoring implemented. LAI, bottom trawl by age and acoustic surveys considered but no VPA.	1994/088
1994	Stephenson et al.	LAI large decline (new vessel). Bottom trawl does not track year-classes. Spring 4VW & US trawl survey in 4X. VPA with larval index.	1995/083
1995	Stephenson et al.	Larval index, bottom trawl for info, Scots Bay acoustic trials. Illustrative VPA used to bracket possible stock size assumed at 100-200kt.	1996/028
1996	Stephenson et al.	Larval index lowest since 81. Acoustic surveys of 195kt and VPA with LAI at 300kt used to bracket stock size.	1997/061
1997	Stephenson et al.	Larval with VPA rejected. Acoustic estimate of 568kt used as basis for stock status.	1998/072
1998	Stephenson et al.	LAI considered but end of series (94 drop 'still unexplained'). Acoustics surveys. No VPA. Acoustic surveys used as basis for stock status.	1999/064
1999	Stephenson et al.	No larval survey. Acoustics surveys similar. VPA illustrative using acoustics is inconsistent with large increase in SSB.	2000/065
2000	Power et al.	Acoustics surveys. Need to follow survey design for consistent series for future index. No VPA.	2001/057
2001	Stephenson et al.	Acoustics surveys. Lack of rebuilding in stock objectives evaluation noted. No VPA.	2002/045
2002	Power et al.	Acoustics surveys. Concerns about lack of older fish in catch. No VPA.	2003/035

Fishery Year	Res Doc Authors	Indices and models used to evaluate stock status	Research Document
2003	Power et al.	Acoustics indicated stock deteriorating. Gillnet and purse seine total catch and effort only. No VPA.	2004/030
2004	Power et al.	Acoustics surveys. VPA with surveys as either absolute or as an index. Projection and risk analysis.	2005/023
2005	Power et al.	Acoustics surveys. VPA using German Bank area. Projection and risk analysis. Assessment put on hold due to questions with ageing.	2006/049
2006	Power et al.	Acoustics biomass slight increase. Concern for stock status from checklist of objectives. No VPA due to ageing problem identified.	2007/040
2007	Power et al.	Acoustics biomass increase. Improvements in evaluation of objectives. No VPA due to reageing in progress.	2008/023
2008	Power et al.	Acoustics biomass decreased and near lowest for each area. Mixed signals from checklist evaluation. No VPA due to reageing in progress.	2010/111
2009	Power et al.	Acoustics increased. Larval survey done. Some objectives improved. Catch-at-age revised 1999-2009. VPA rejected as 'not fully explored'.	2010/112
2010	Power et al.	Framework recommendations: acoustic biomass, catch-at-age, trends in exploitation rates, age based mortality trends.	2011/031
2011	Power et al.	Acoustic biomass decreased. Reduction in fish condition and weights. Lack of older fish.	2012/085
2012	Clark et al.	No assessment. Limit reference point identified using acoustic survey biomass.	2012/025
2013	Singh et al.	Covered data from 2012 and 2013. Acoustics biomass decreased. Lack of 2 year olds and absence from weirs.	2014/056
2014	Update only - SR	Acoustic biomass decreased. No change on German Bank. Improvement in age ranges in the fishery.	2014.029
2015	Singh et al.	Acoustic biomass increased. Fluctuations occurred in Scots Bay. Decreasing trend on German Bank. Broad age ranges in catch.	2016/073
2016	Update only - SR	Slight decrease in acoustics biomass. Historical low biomass on German Bank. Broad age ranges in catch.	2016/036
2017	Update only - SR	Large decrease in acoustic biomass in Scots Bay. November-December 2016, mortality event in St. Marys Bay.	2017/037
2018	Singh et al.	Decrease in acoustic biomass to LRP.	(in press)

Table 4. Summary of tagging events, application dates, number of Herring tagged and recaptured for German Bank and Scots Bay (from Mouland et al. 2003). A dash (-) indicates no data.

Spawning ground tagging location	Year	Tagging dates	Number of tagging days	Number of fish tagged on spawning ground	Number of tags returned	Percent recaptured
German Bank	1998	Aug 20–Sep 22	14	9730	34	0.3
	1999	Sep 21–Sep 22	2	821	2	0.2
	2001	Sep 17–Sep 19	3	9402	56	0.6
	2005	Aug 30–Oct 5	5	8487	58	0.7
	2009	Aug 19–Sep 30	15	10333	104	1.0
	2010	Aug 19–Oct 12	10	6036	41	0.7
	2011	Aug 24–Sep 29	12	6623	54	0.8
Scots Bay	1998	Aug 23–Aug 25	2	2367	24	1.0
	1999	Aug 11–Aug 21	2	2832	6	0.2
	2005	Jul 28–Aug 24	4	5047	204	4.0
	2006	Jul 28–Aug 20	3	3800	30	0.8
Trinity	1998	-	-	4510	7	0.1
Chedabucto Bay	1999	Nov 29	-	3505	16	0.5
Chebucto Head	1999	Jan 21–Jan 26	-	11104	105	1.0
	2000	Jan 8–Jan 9	-	10306	61	0.6
NB Weirs	1999	-	-	9700	280	1.92
	2002	Aug– Nov	-	13760	-	-
	2003	Jun 16–Oct 9	-	32570	-	-
	2004	-	-	31627	-	-
USA	1999	-	-	1389	6	-

Table 5. German Bank (spawning box as shown in Figure 6) Herring landings (t) (includes purse seines and gillnets) for 1985–2017 with start date, end date, landings (t) before August 15 (pre-spawning period), landings (t) after August 14 (spawning period), and proportion of Total Allowable Catch (TAC).

Year	Start Date	End Date	Duration No. Days	Total No. Slips	Landings before Aug. 15 (pre-spawn)	Landings on/ after Aug. 15 (spawning)	Total Landing t	% Landings on/after Aug-14	TAC	German as % TAC
1985	22-Jun-85	08-Oct-85	109	428	8,856	14,228	23,084	62%	125,000	18%
1986	18-Jun-86	01-Oct-86	106	349	2,349	13,542	15,892	85%	97,600	16%
1987	26-May-87	14-Oct-87	142	403	5,138	13,218	18,357	72%	126,500	15%
1988	29-May-88	06-Oct-88	131	610	14,776	18,348	33,125	55%	151,200	22%
1989	28-May-89	15-Oct-89	141	313	2,061	12,087	14,148	85%	151,200	9%
1990	23-May-90	23-Oct-90	154	428	1,220	23,647	24,867	95%	151,200	16%
1991	02-Jun-91	15-Oct-91	136	621	11,800	18,328	30,127	61%	151,200	20%
1992	31-May-92	04-Oct-92	127	556	13,175	10,985	24,160	45%	125,000	19%
1993	24-May-93	29-Sep-93	129	192	7,912	1,092	9,003	12%	151,200	6%
1994	05-May-94	28-Sep-94	147	252	1,186	11,454	12,641	91%	151,200	8%
1995	05-Jun-95	06-Oct-95	124	301	434	21,339	21,773	98%	80,000	27%
1996	20-Jun-96	27-Oct-96	130	260	2,229	16,091	18,320	88%	57,000	32%
1997	11-Jul-97	14-Oct-97	96	327	2,009	17,110	19,119	89%	57,000	34%
1998	10-Jun-98	14-Oct-98	127	516	3,231	21,489	24,720	87%	90,000	27%
1999	20-Apr-99	20-Oct-99	184	666	18,508	16,401	34,909	47%	105,000	33%
2000	18-Apr-00	26-Oct-00	192	598	9,806	26,171	35,977	73%	100,000	36%
2001	22-May-01	20-Oct-01	152	521	5,312	22,156	27,468	81%	78,000	35%
2002	18-Apr-02	12-Oct-02	178	643	10,871	19,935	30,806	65%	78,000	39%
2003	05-May-03	15-Oct-03	164	392	8,900	20,070	28,970	69%	93,000	31%
2004	10-May-04	15-Oct-04	159	238	5,680	12,345	18,025	68%	83,000	22%
2005	16-May-05	13-Oct-05	151	364	8,069	12,039	20,107	60%	50,000	40%
2006	27-Jun-06	16-Oct-06	112	475	12,227	12,504	24,731	51%	50,000	49%
2007	15-May-07	05-Oct-07	144	540	13,948	13,307	27,255	49%	50,000	55%
2008	03-May-08	16-Oct-08	167	590	16,845	14,447	31,291	46%	55,000	57%
2009	05-May-09	13-Oct-09	162	502	12,092	16,454	28,546	58%	55,000	52%
2010	03-May-10	14-Oct-10	165	382	1,804	17,158	18,961	90%	55,000	34%
2011	03-May-11	13-Oct-11	164	421	5,512	19,175	24,687	78%	50,000	49%
2012	02-May-12	27-Oct-12	179	780	5,369	29,582	34,951	85%	50,000	70%
2013	06-May-13	11-Oct-13	159	686	6,324	12,700	19,025	67%	50,000	38%
2014	14-May-14	29-Sep-14	139	922	15,077	10,080	25,157	40%	50,000	50%
2015	04-Jun-15	06-Oct-15	125	873	6,197	14,789	20,986	70%	50,000	42%
2016	02-Jun-16	27-Sep-16	118	830	10,522	9,633	20,154	48%	50,000	40%
2017	01-Jun-17	07-Oct-17	129	386	3,007	11,515	14,523	79%	42,500	34%

Table 6. Scots Bay Herring purse seine landings (t) for 1987–2017.

Year	Min. Date	Max. Date	Duration in Days	Days with Landings	Landings t	No. Slips	Catch/Day with Catch	Catch/Slip
1987	08-Jul-87	06-Aug-87	30	20	3,398	91	169.88	37.34
1988	20-Jul-88	29-Jul-88	10	9	3,780	65	419.99	58.15
1989	19-Jul-89	13-Sep-89	57	35	6,021	164	172.04	36.72
1990	22-Jul-90	14-Aug-90	24	11	8,088	108	735.24	74.89
1991	05-Jul-91	14-Aug-91	41	16	7,365	163	460.30	45.18
1992	25-Jul-92	11-Aug-92	18	18	7,960	189	442.22	42.12
1993	25-Jul-93	01-Sep-93	39	32	5,228	100	163.36	52.28
1994	10-Jul-94	25-Aug-94	47	36	10,610	286	294.72	37.10
1995	24-Jul-95	26-Jul-95	3	3	907	33	302.33	27.48
1996	25-Jul-96	20-Aug-96	27	13	8,939	151	687.58	59.20
1997	30-Jul-97	27-Aug-97	29	19	4,847	91	255.11	53.26
1998	20-Jul-98	10-Sep-98	53	29	7,880	163	271.72	48.34
1999	19-Jul-99	17-Aug-99	30	16	1,789	40	111.81	44.73
2000	25-Jul-00	30-Aug-00	37	26	10,853	171	417.44	63.47
2001	10-Jul-01	21-Aug-01	43	30	10,739	176	357.97	61.02
2002	22-Jul-02	09-Sep-02	50	36	7,994	160	222.06	49.96
2003	21-Jul-03	05-Sep-03	47	34	19,196	237	564.59	81.00
2004	19-Jul-04	16-Sep-04	60	42	24,388	330	580.67	73.90
2005	26-Jul-05	09-Sep-05	46	27	5,872	96	217.48	61.17
2006	24-Jul-06	04-Sep-06	43	16	3,352	43	209.50	77.95
2007	16-Jul-07	31-Aug-07	47	21	4,116	79	196.00	52.10
2008	14-Jul-08	27-Aug-08	45	14	2,373	43	169.50	55.19
2009	12-Jul-09	11-Aug-09	31	8	902	18	112.75	50.11
2010	09-Jul-10	07-Sep-10	61	17	4,086	70	240.35	58.37
2011	04-Jul-11	01-Sep-11	60	16	5,093	72	318.31	70.74
2012	02-Jul-12	28-Aug-12	58	10	4,940	78	494.00	63.33
2013	24-Jun-13	02-Sep-13	71	9	4,702	58	522.44	81.07
2014	23-Jun-14	01-Sep-14	71	17	4,498	68	264.60	66.15
2015	28-Jun-15	13-Sep-15	78	19	6,951	85	365.84	81.78
2016	20-Jun-16	17-Aug-16	59	17	6,010	88	353.51	68.29
2017	22-Jun-17	27-Sep-17	98	21	8,652	86	412.01	100.61

Table 7. Summary of 1998–2017 Spectacle Buoy and Trinity Ledge Herring gillnet landings (t) with start and end dates, acoustic survey biomass estimates (t), and overall gillnet landings (t) reported from the area. Shaded cells refer to spring Spring Stock Biomass (SSB) estimates calculated without the Calibration Integration Factor. In 2000, the exploitation rate exceeded 100%. A dash (-) indicates no data.

Year	Spec. Buoy landings and surveys				Trinity Ledge Strata Box landings and surveys					Overall Stock Gillnet Landings (t)
	Start Day	End Day	Landings t	Survey SSB t*	Start Day	End Day	Landings t	Survey SSB t*	Exploitation Landings/ SSB	
1998	10-May-98	30-Jun-98	484	n/s	24-Aug-98	21-Sep-98	1,668	n/s	n/s	2,153
1999	10-May-99	16-Jul-99	355	n/s	12-Aug-99	15-Sep-99	1,257	3,885	32%	1,612
2000	11-Jun-00	14-Jun-00	80	n/s	30-Aug-00	12-Sep-00	682	621	110%	814
2001	11-Jun-01	10-Jul-01	699	1,110	21-Aug-01	26-Sep-01	781	14,797	5%	1,576
2002	15-May-02	01-Jul-02	137	n/s	02-Sep-02	30-Sep-02	204	8,096	3%	378
2003	04-Jun-03	06-Jun-03	69	1,420	21-Aug-03	18-Sep-03	361	12,117	3%	439
2004	17-Jun-04	15-Jul-04	5	n/s	02-Sep-04	15-Sep-04	229	12,022	2%	229
2005	09-Jun-05	11-Jul-05	124	290	05-Sep-05	20-Sep-05	427	10,701	4%	570
2006	03-Jun-06	22-Jun-06	2	n/s	23-Aug-06	21-Sep-06	647	16,076	4%	719
2007	07-May-07	22-Jun-07	243	310	27-Aug-07	20-Sep-07	1,042	3,113	33%	1,334
2008	29-May-08	19-Jun-08	6	0	21-Aug-08	25-Sep-08	7	516	1%	15
2009	11-Jun-09	25-Jun-09	0.2	n/s	01-Sep-09	11-Sep-09	102	1,575	6%	117
2010	02-Jun-10	19-Jun-10	-	1,859	09-Aug-11	24-Sep-10	145	2,405	6%	204
2011	22-Jun-11	29-Jun-11	1	282	09-Aug-11	20-Sep-11	598	7,316	8%	638
2012	31-May-12	31-May-12	-	n/s	31-May-12	18-Sep-12	177	2,754	6%	471
2013	31-May-13	31-May-13	-	n/s	13-Aug-13	18-Sep-13	99	950	10%	1270
2014	31-May-14	31-May-14	-	n/s	12-Aug-14	30-Sep-14	123	4,772	3%	2,102
2015	31-May-15	31-May-15	-	n/s	17-Aug-15	18-Sep-15	-	657	0%	1,806
2016	31-May-16	31-May-16	-	n/s	31-Jul-16	03-Oct-16	-	506	0%	1,477
2017	31-May-16	31-May-16	-	8,726	04-Jun-17	16-Sep-17	-	13,866	0%	655
Spec. Buoy Average			110	1,750	Gillnet Average		427	6,144	-	929

*SSB estimates calculated with Calibration Integration Factor after 2003 inclusive. No survey in 1998.

Table 8. Gillnet landings (t) for Scots Bay and German Bank Herring from 2004–2017. A dash (-) indicates no data.

Year	Scots Bay Gillnet			German Bank Gillnet		
	Start Day	End Day	Landings (t)	Start Day	End Day	Landings (t)
2004	-	-	-	-	-	-
2005	-	-	-	09-Jun-05	11-Jul-05	80
2006	-	-	-	-	-	-
2007	-	-	-	11-Jun-07	20-Sep-07	22
2008	-	-	-	25-Sep-08	25-Sep-08	6
2009	15-Apr-09	11-May-09	1	10-Sep-09	11-Sep-09	1
2010	16-Apr-10	14-Jun-10	1	19-Aug-10	24-Sep-10	33
2011	-	-	-	20-Sep-11	20-Sep-11	1
2012	14-Apr-12	09-May-12	1	15-Aug-12	03-Oct-12	296
2013	23-Jul-13	21-Aug-13	305	19-Aug-13	09-Sep-13	854
2014	30-Apr-14	13-Aug-14	418	12-Aug-14	09-Sep-14	1523
2015	14-Jul-15	26-Jul-15	172	17-Aug-15	18-Sep-15	1538
2016	27-Jun-16	18-Jul-16	133	22-Aug-16	13-Sep-16	1290
2017	25-Jun-17	28-Jun-17	6	28-Aug-17	16-Sep-17	648
Scots Bay Landings Average			145	German Bank Landings Average		313

Table 9. Monthly Nova Scotia weir landings of Herring (t) for 1978–2017.

YEAR	MONTH												Year Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1978	0	0	0	1	490	3,704	2,990	239	46	111	198	79	7,858
1979	0	0	0	0	811	3,458	1,418	420	39	136	57	0	6,339
1980	0	0	0	0	69	647	1,271	395	0	0	0	0	2,383
1981	0	0	0	0	50	437	983	276	37	0	41	0	1,824
1982	0	0	0	0	16	267	468	195	172	12	0	0	1,130
1983	0	0	0	2	286	141	188	208	53	0	18	0	896
1984	0	0	0	0	113	1,032	736	602	220	0	0	0	2,702
1985	0	0	0	0	378	1,799	1,378	489	0	0	11	0	4,055
1986	0	0	0	0	385	403	71	704	390	5	0	0	1,957
1987	0	0	0	0	1,503	2,526	1,215	1,166	367	0	0	0	6,776
1988	0	0	0	0	1,217	2,976	1,696	1,204	386	0	0	0	7,480
1989	0	0	0	0	340	1,018	870	843	226	0	0	0	3,296
1990	0	0	0	0	208	973	1,482	879	538	52	0	0	4,132
1991	0	0	0	3	23	149	719	342	262	0	0	0	1,498
1992	0	0	0	0	35	659	405	754	371	0	0	0	2,224
1993	0	0	0	0	226	908	608	867	53	0	0	0	2,662
1994	0	0	0	0	111	736	499	519	180	0	0	0	2,045
1995	0	0	0	0	236	1,255	1,059	470	29	0	0	0	3,049
1996	0	0	0	0	430	1,267	1,232	358	188	0	0	0	3,476
1997	0	0	0	0	70	1,874	1,739	271	65	0	0	0	4,019
1998	0	0	0	0	1,304	1,677	390	359	317	0	0	0	4,048
1999	0	0	0	0	1,958	1,513	547	488	31	0	0	0	4,537
2000	0	0	0	0	0	16	151	326	191	0	0	0	683
2001	0	0	0	0	105	1,439	1,565	391	207	0	0	0	3,708
2002	0	0	0	0	23	95	240	558	228	0	0	0	1,143
2003	0	0	0	0	98	126	68	344	284	0	0	0	921
2004	0	0	0	0	0	667	873	1,370	219	0	0	0	3,130
2005	0	0	0	11	84	731	472	828	118	0	0	0	2,245
2006	0	0	0	0	195	138	414	1,447	182	115	0	0	2,491
2007	0	0	0	0	26	11	290	579	224	0	0	0	1,130
2008	0	0	0	0	0	1,136	381	836	171	0	0	0	2,524
2009	0	0	0	0	0	110	233	44	0	0	0	0	387
2010	0	0	0	0	89	391	320	398	0	0	0	0	1,198
2011	0	0	0	0	0	[redacted]	[redacted]	[redacted]	[redacted]	0	0	0	[redacted]
2012	0	0	0	0	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	0	0	[redacted]
2013	0	0	0	[redacted]	[redacted]	[redacted]	[redacted]	0	0	0	0	0	[redacted]
2014	0	0	0	[redacted]	[redacted]	[redacted]	0	0	0	0	0	0	[redacted]
2015	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	[redacted]	[redacted]	[redacted]	0	0	0	0	0	0	[redacted]
2017	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0

YEAR	MONTH												Year Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
NS Average Landings (t)	0	0	0	1	269	837	673	477	145	10	8	2	2,423
NS Minimum Landings (t)	0	0	0	0	0	0	0	0	0	0	0	0	0
NS Maximum Landings (t)	0	0	0	18	1,958	3,704	2,990	1,447	538	136	198	79	7,858

Note: Redacted data do not meet DFO's policies for releasing commercial fishing information.

Table 10. Annual landings (t), number of active weirs (defined here as weirs with catch), and the catch per weir (t) of herring for New Brunswick and Nova Scotia weirs from 1978 to 2017.

	Annual Landings (t)			No. Active Weirs			Catch per weir (t)		
Year	NB	NS	Total Landings	NB	NS	Total No.	NB	NS	Average
1978	33,599	7,858	41,458	208	31	239	162	253	173
1979	32,579	6,339	38,918	210	27	237	155	235	164
1980	11,066	2,383	13,449	120	29	149	92	82	90
1981	14,968	1,824	16,793	147	28	175	102	65	96
1982	22,181	1,130	23,311	159	19	178	140	59	131
1983	12,568	896	13,464	143	23	166	88	39	81
1984	8,353	2,702	11,056	116	13	129	72	208	86
1985	26,718	4,055	30,774	156	14	170	171	290	181
1986	27,516	1,957	29,473	105	18	123	262	109	240
1987	26,621	6,776	33,397	123	21	144	216	323	232
1988	38,235	7,480	45,715	191	21	212	200	356	216
1989	43,520	3,296	46,817	171	20	191	255	165	245
1990	39,808	4,132	43,940	154	22	176	258	188	250
1991	23,717	1,498	25,216	143	20	163	166	75	155
1992	31,981	2,224	34,206	151	12	163	212	185	210
1993	31,328	2,662	33,990	145	10	155	216	266	219
1994	20,618	2,045	22,662	129	11	140	160	186	162
1995	18,228	3,049	21,277	106	10	116	172	305	183
1996	15,781	3,476	19,257	101	12	113	156	290	170
1997	20,396	4,019	24,415	102	15	117	200	268	209
1998	19,529	4,048	23,577	108	15	123	181	270	192
1999	19,063	4,537	23,600	100	14	114	191	324	207
2000	16,376	683	17,058	77	3	80	213	228	213
2001	20,064	3,708	23,772	101	14	115	199	265	207
2002	11,807	1,143	12,950	83	9	92	142	127	141
2003	9,003	921	9,924	78	8	86	115	115	115
2004	20,620	3,130	23,750	84	8	92	245	391	258
2005	12,639	2,245	14,884	76	10	86	166	225	173
2006	11,641	2,491	14,132	89	6	95	131	415	149
2007	30,145	1,130	31,275	97	8	105	311	141	298
2008	6,041	2,524	8,565	76	8	84	79	315	102
2009	3,603	387	3,990	38	7	45	95	55	89
2010	10,671	1,198	11,868	77	8	85	139	150	140
2011	2,643	[redacted]	[redacted]	37	2	39	71	[redacted]	[redacted]
2012	494	[redacted]	[redacted]	4	2	6	124	[redacted]	[redacted]
2013	5,902	[redacted]	[redacted]	49	3	52	120	[redacted]	[redacted]
2014	1,571	[redacted]	[redacted]	26	3	29	60	[redacted]	[redacted]
2015	146	0	146	11	0	11	13	0	13
2016	2,777	[redacted]	[redacted]	26	1	27	107	[redacted]	[redacted]
2017	1,732	0	1,732	11	0	11	157	0	157
Average	17,656	2,483	20,139	103	13	116	158	191	161

Note: Redacted data do not meet DFO's policies for releasing commercial fishing information.

Table 11. Monthly landings (t) of Herring from weirs located in New Brunswick from 1978 to 2018.

YEAR	MONTH												Year Total
	Jan	Feb	Mar	Apr	May	June	July	Aug.	Sept	Oct	Nov	Dec	
1978	3	0	0	0	512	802	5,499	10,275	10,877	4,972	528	132	33,599
1979	535	96	0	0	25	1,120	7,321	9,846	4,939	5,985	2,638	74	32,579
1980	0	0	0	0	36	119	1,755	5,572	2,352	1,016	216	0	11,066
1981	0	0	0	0	70	199	4,431	3,911	2,044	2,435	1,686	192	14,968
1982	0	17	0	0	132	30	2,871	7,311	7,681	3,204	849	87	22,181
1983	0	0	0	0	65	29	299	2,474	5,382	3,945	375	0	12,568
1984	0	0	0	0	6	3	230	2,344	2,581	3,045	145	0	8,353
1985	0	0	0	0	22	89	4,217	8,450	6,910	4,814	2,078	138	26,718
1986	43	0	0	0	17	0	2,480	10,114	5,997	6,233	2,564	67	27,516
1987	39	21	6	12	10	168	2,575	10,893	6,711	5,362	703	122	26,621
1988	0	12	1	90	657	287	5,993	11,975	8,375	8,457	2,343	43	38,235
1989	0	24	0	95	37	385	8,315	15,093	10,156	7,258	2,158	0	43,520
1990	0	0	0	0	93	20	4,915	14,664	12,207	7,741	168	0	39,808
1991	0	0	0	0	57	180	4,649	10,319	6,392	2,028	93	0	23,717
1992	0	0	0	15	50	774	5,477	10,989	9,597	4,395	684	0	31,981
1993	0	0	0	0	14	168	5,561	14,085	8,614	2,406	470	10	31,328
1994	0	0	0	18	0	55	4,529	10,592	3,805	1,589	30	0	20,618
1995	0	0	0	0	15	244	4,517	8,590	3,956	896	10	0	18,228
1996	0	0	0	0	19	676	4,819	7,767	1,917	518	65	0	15,781
1997	0	0	0	8	153	1,017	6,506	7,396	5,316	0	0	0	20,396
1998	0	0	0	0	560	713	3,832	8,295	5,604	525	0	0	19,529
1999	0	0	0	0	690	805	5,155	9,895	2,469	48	0	0	19,063
2000	0	0	0	0	10	7	2,105	7,533	4,940	1,713	69	0	16,376
2001	0	0	0	0	35	478	3,931	8,627	5,514	1,479	0	0	20,064
2002	0	0	0	0	84	20	1,099	6,446	2,878	1,260	20	0	11,807
2003	0	0	0	0	257	250	1,423	3,554	3,166	344	10	0	9,003
2004	0	0	0	0	21	336	2,694	8,354	8,298	913	3	0	20,620
2005	0	0	0	0	0	213	802	7,145	3,729	740	11	0	12,639
2006	0	0	0	0	8	43	1,112	3,731	3,832	2,328	125	462	11,641
2007	182	0	20	30	84	633	3,241	11,363	7,637	6,567	314	73	30,145
2008	0	0	0	0	0	81	1,502	2,479	1,507	389	49	32	6,041
2009	0	0	0	0	5	239	699	1,111	1,219	330	0	0	3,603
2010	0	0	0	6	64	1,912	2,560	3,903	1,933	247	46	0	10,671
2011	0	0	0	0	0	250	656	1,097	500	140	0	0	2,643
2012	0	0	0	0	29	140	5	5	98	217	0	0	494
2013	0	0	0	0	7	612	1,517	1,797	1,051	919	0	0	5,902
2014	0	0	0	0	0	70	130	147	449	774	0	0	1,571
2015	0	0	0	0	12	32	28	36	5	33	0	0	146
2016	0	0	0	0	3	0	102	1,034	1,153	485	0	0	2,777
2017	0	0	0	0	0	0	35	220	1,478	0	0	0	1,732
2018	0	0	0	0	0	166	2,129	1,798	767	506	15	0	5,382
Average (t)	20	4	1	7	94	326	2,969	6,615	4,489	2,348	450	35	17,357
NB Minimum Landings (t)	0	0	0	0	0	0	5	5	5	0	0	0	146
NB Maximum Landings (t)	535	96	20	95	690	1,912	8,315	15,093	12,207	8,457	2,638	462	43,520

Table 12. Reported Herring bait licence landings for the calendar year in tonnes for 2015–2018.

NAFO Area	2015	2016	2017	2018
4VN	2.27	2.83	0.60	8.73
4WD	0	0.28	1.41	0
4WK	1.81	2.50	0	0
4XM	2.27	2.84	3.14	10.56
4XO	2.81	13.62	0	6.46
4XU	5.44	0	0	0
Total non-quota	14.61	22.07	5.15	25.74
4XQ	0	0	0	0
4XR	0.18	0.01	0	0
Total quota area	0.18	0.01	0	0
Overall total	14.79	22.08	5.15	25.74

Table 13. Reported Commercial Herring landings sold as Herring bait by gear type for calendar year in tonnes for 2015–2018.

Gear Type	2015	2016	2017	2018
Purse seine	121.0	2089.0	1323.0	1448.0
Gillnet fixed	4.3	31.1	12.0	12.2
Gillnet drift	14.0	0.5	30.1	0.0
Handline	0	0.2	0	0
Trapnet	0	0	0.7	0.0
Total	**139.4**	**2120.8**	**1365.7**	**1460.2**
Quota area	121.0	2024.2	1038.4	1450.2
Non-quota area	18.4	96.6	327.4	10.0
Overall area	**139.4**	**2120.8**	**1365.7**	**1460.2**
% Quota as bait	0.2	4.0	2.5	3.4

Table 14. Catch-at-age (millions) for the SWNS/BoF Herring spawning component from 1965–2017. Some relatively strong year-classes that persisted in the fishery catch have been highlighted.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11+	Total
1965		1,085	35	234	50	11	2	1	0	0	0	1,417
1966	154	914	449	73	322	46	14	8	2	0	0	1,982
1967	722	614	154	266	110	159	58	4	0	0	0	2,089
1968	165	2,389	225	83	290	73	91	32	15	6	1	3,370
1969	109	290	532	132	162	113	63	23	6	3	1	1,433
1970	700	577	77	286	201	120	112	41	21	7	3	2,145
1971	88	404	184	107	114	76	94	50	37	8	6	1,165
1972	-	649	72	149	77	75	49	49	26	14	12	1,172
1973	1	167	781	131	40	30	22	20	24	12	13	1,242
1974	18	766	94	804	68	19	10	7	13	7	9	1,815
1975	3	318	240	125	515	66	12	4	5	4	6	1,298
1976	0	56	207	154	69	269	21	6	4	2	3	790
1977	1	154	32	218	119	51	177	14	3	1	4	775
1978	35	384	41	13	122	68	31	109	11	2	2	819
1979	0	184	250	55	5	23	18	12	41	5	2	596
1980	2	13	81	474	28	4	5	7	3	11	3	629
1981	-	103	51	103	451	33	2	3	2	1	2	751
1982	4	102	151	23	98	211	15	2	1	1	1	609
1983	5	192	150	244	24	61	90	10	2	1	1	781
1984	-	88	244	224	146	23	22	28	10	2	9	796
1985	9	217	338	303	148	42	14	18	8	1	0	1,098
1986	0	125	276	293	57	32	11	4	3	1	0	802
1987	2	83	126	527	243	46	19	7	3	3	1	1,062
1988	0	148	113	195	434	236	43	21	4	4	3	1,202
1989	0	102	114	62	79	169	77	18	8	4	3	636
1990	-	179	130	172	90	101	202	117	31	11	7	1,039
1991	-	97	179	184	88	41	50	81	46	18	14	798
1992	0	169	133	287	127	75	34	35	59	35	21	974
1993	0	76	44	194	131	68	34	21	22	21	11	622
1994	0	104	142	54	118	73	36	15	9	10	16	576
1995	2	113	220	112	37	36	22	6	4	3	4	560
1996	-	37	38	256	55	17	9	3	2	1	2	420
1997	0	57	87	78	131	19	5	4	1	1	1	384
1998	0	265	62	139	97	97	21	4	2	1	0	689
1999	9	151	253	72	104	63	26	6	2	0	1	686

Year	Age											Total
	1	2	3	4	5	6	7	8	9	10	11+	
2000	0	378	53	123	109	56	30	12	1	1	0	764
2001	0	81	311	54	64	31	17	5	3	0	0	566
2002	16	310	107	189	84	25	9	6	3	2	2	753
2003	0	479	255	81	109	19	10	3	3	2	1	961
2004	4	322	315	161	40	37	11	2	3	1	2	897
2005	1	66	131	174	59	12	9	4	1	0	1	457
2006	3	112	102	68	82	34	16	4	0	0	0	422
2007	0	186	56	34	39	71	25	7	1	0	0	419
2008	1	78	220	53	25	32	31	11	4	0	0	457
2009	1	263	118	139	22	12	11	13	6	1	0	587
2010	-	482	177	53	63	7	4	4	4	2	1	796
2011	0	60	227	112	50	38	5	2	2	2	1	498
2012	0	108	58	118	84	39	19	3	2	1	1	432
2013	0	148	92	39	57	55	25	10	2	0	0	429
2014	0	136	131	52	29	53	33	11	3	0	0	448
2015	0	175	8	61	38	33	38	22	5	1	0	443
2016	0	127	183	49	48	21	21	20	5	1	0	476
2017	0	56	126	114	31	24	13	8	3	1	0	376

Table 15. Catch-at-age (percent by numbers) for the SWNS/BoF Herring spawning component, 1965–2017. Proportions for some relatively strong year-classes that persisted in the fishery catch have been highlighted. Note: green bolded highlight is greater or equal to 50% by number for age group.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11+	Total
1965	-	**77**	2	17	4	1	0	0	0	0	0	100
1966	8	46	23	4	16	2	1	0	0	0	0	100
1967	35	29	7	13	5	8	3	0	0	0	0	100
1968	5	**71**	7	2	9	2	3	1	0	0	0	100
1969	8	20	37	9	11	8	4	2	0	0	0	100
1970	33	27	4	13	9	6	5	2	1	0	0	100
1971	8	35	16	9	10	6	8	4	3	1	0	100
1972	-	**55**	6	13	7	6	4	4	2	1	1	100
1973	0	13	**63**	11	3	2	2	2	2	1	1	100
1974	1	42	5	44	4	1	1	0	1	0	0	100
1975	0	24	18	10	40	5	1	0	0	0	0	100
1976	0	7	26	19	9	34	3	1	0	0	0	100
1977	0	20	4	28	15	7	23	2	0	0	1	100
1978	4	47	5	2	15	8	4	13	1	0	0	100
1979	0	31	42	9	1	4	3	2	7	1	0	100
1980	0	2	13	75	4	1	1	1	0	2	0	100
1981	-	14	7	14	60	4	0	0	0	0	0	100
1982	1	17	25	4	16	35	2	0	0	0	0	100
1983	1	25	19	31	3	8	12	1	0	0	0	100
1984	-	11	31	28	18	3	3	4	1	0	1	100
1985	1	20	31	28	13	4	1	2	1	0	0	100
1986	0	16	34	36	7	4	1	1	0	0	0	100
1987	0	8	12	**50**	23	4	2	1	0	0	0	100
1988	0	12	9	16	36	20	4	2	0	0	0	100
1989	0	16	18	10	12	27	12	3	1	1	0	100
1990	-	17	13	17	9	10	19	11	3	1	1	100
1991	-	12	22	23	11	5	6	10	6	2	2	100
1992	0	17	14	29	13	8	4	4	6	4	2	100
1993	0	12	7	31	21	11	5	3	4	3	2	100
1994	0	18	25	9	20	13	6	3	2	2	3	100
1995	0	20	39	20	7	7	4	1	1	1	1	100
1996	-	9	9	**61**	13	4	2	1	0	0	0	100
1997	0	15	23	20	34	5	1	1	0	0	0	100
1998	0	38	9	20	14	14	3	1	0	0	0	100
1999	1	22	37	10	15	9	4	1	0	0	0	100

Year	Age 1	2	3	4	5	6	7	8	9	10	11+	Total
2000	0	49	7	16	14	7	4	2	0	0	0	100
2001	0	14	55	10	11	5	3	1	1	0	0	100
2002	2	41	14	25	11	3	1	1	0	0	0	100
2003	0	**50**	27	8	11	2	1	0	0	0	0	100
2004	0	36	35	18	4	4	1	0	0	0	0	100
2005	0	15	29	38	13	3	2	1	0	0	0	100
2006	1	26	24	16	19	8	4	1	0	0	0	100
2007	0	44	13	8	9	17	6	2	0	0	0	100
2008	0	17	48	12	5	7	7	2	1	0	0	100
2009	0	45	20	24	4	2	2	2	1	0	0	100
2010	-	**60**	22	7	8	1	0	1	0	0	0	100
2011	0	12	46	22	10	8	1	0	0	0	0	100
2012	0	25	13	27	19	9	4	1	0	0	0	100
2013	0	34	21	9	13	13	6	2	0	0	0	100
2014	0	30	29	12	7	12	7	2	1	0	0	100
2015	0	40	15	14	9	8	9	5	1	0	0	100
2016	0	27	38	10	10	5	4	4	1	0	0	100
2017	0	15	33	30	8	6	3	2	1	0	0	100

Table 16. Catch-at-age (thousands) for the New Brunswick weir and shutoff juvenile Herring component, updated from 1978–2017. Data prior to 1978 was not available from previous analyses. A dash (-) indicates no data.

Year	Age 1	2	3	4	5	6	7	8	9	10	11+	Total
1978	213,778	894,372	52,125	3,665	810	1,064	280	132	-	-	-	1,166,226
1979	2,396	423,731	247,356	12,236	822	841	479	1,005	190	-	-	689,056
1980	257,995	5,325	62,087	21,615	924	125	124	67	57	63	-	348,382
1981	53,336	294,720	18,781	10,199	5,368	306	46	34	27	-	-	382,817
1982	30,210	395,416	73,197	3,199	1,795	1,596	196	42	68	-	-	505,719
1983	2,532	135,283	21,684	7,526	444	398	189	-	-	-	-	168,056
1984	14,353	82,920	17,292	5,658	4,332	611	251	15	85	-	-	125,517
1985	20,295	385,381	45,879	17,936	7,411	3,507	304	71	73	-	-	480,857
1986	3,210	136,292	119,736	24,061	10,636	4,644	2,272	335	94	66	9	301,355
1987	35,677	129,348	47,981	53,150	22,941	7,097	2,472	606	173	96	-	299,541
1988	76,053	347,765	45,078	22,366	38,843	14,212	1,680	101	247	1	9	546,355
1989	26,855	331,014	81,410	21,442	22,723	43,020	11,532	3,095	810	121	249	542,271
1990	12,576	454,802	69,004	30,689	6,358	7,230	15,031	3,420	2,520	620	310	602,560
1991	5,530	338,263	44,450	23,618	9,532	3,154	2,620	3,436	1,461	267	150	432,481
1992	799	375,772	97,678	36,438	10,378	3,992	1,613	1,360	558	245	44	528,877

Year	Age											Total
	1	2	3	4	5	6	7	8	9	10	11+	
1993	1,718	244,079	106,099	37,186	23,218	12,260	4,915	1,120	1,101	864	175	432,735
1994	1,986	291,956	63,902	9,972	16,258	9,332	3,893	1,479	1,080	544	334	400,736
1995	57,844	259,741	40,122	14,803	1,822	1,567	1,549	30	-	-	-	377,478
1996	5,351	269,431	22,390	9,342	4,302	1,147	1,273	426	38	9	2	313,711
1997	9,309	216,159	113,197	11,333	3,597	523	206	95	11	-	-	354,430
1998	440	387,723	36,062	9,595	3,404	1,842	297	69	25	1	-	439,458
1999	168	106,128	100,722	11,903	9,057	3,969	1,366	155	4	4	8	233,484
2000	1,665	256,785	8,082	7,872	5,377	1,417	521	101	-	-	-	281,821
2001	1,321	113,200	119,194	8,019	5,713	1,824	588	95	102	2	-	250,058
2002	31,859	180,051	16,260	11,529	3,020	432	102	49	19	20	12	243,352
2003	11,471	162,211	15,488	2,913	1,987	457	128	28	28	14	12	194,737
2004	6,711	184,123	103,911	18,753	2,537	1,751	306	358	93	31	45	318,619
2005	1,152	102,401	73,913	19,379	4,269	534	269	109	14	0	2	202,044
2006	201,207	139,578	25,001	3,786	3,706	1,276	684	139	7	1	2	375,386
2007	6,323	571,186	31,093	2,645	812	1,275	420	63	14	2	0	613,832
2008	27,894	122,185	19,783	203	82	105	120	46	17	1	0	170,438
2009	12,987	99,615	3,303	141	4	1	1	0	0	-	-	116,053
2010	7	371,401	16,968	523	463	29	22	29	16	6	1	389,464
2011	14,254	44,743	21,030	2,153	263	61	4	-	-	-	-	82,509
2012	23,399	4,309	468	611	232	62	17	3	1	1	0	29,104
2013	35,483	126,917	10,475	643	436	216	52	14	1	-	0	174,236
2014	21,037	38,785	1,422	712	288	219	76	31	9	0	2	62,581
2015	429	5,945	50	7	4	2	1	-	1	-	-	6,438
2016	832	61,494	9,109	1,707	657	253	145	181	15	5	-	74,399
2017	2,428	13,588	2,361	5,096	1,861	1,234	584	285	82	22	-	27,540

Table 17. Average (fishery weighted) weights at age (g) for the SWNS/BoF component of the 4WX Herring fishery for 1965–2017. Data for 1965–1967 and 1979–1983 are averages for the period 1968–1978. Note: years 1965–1967 (except age 11 for 1967) and 1979–1983 have average weights for 1967–2000 applied.

Year	Average weight (kg)										
	1	2	3	4	5	6	7	8	9	10	11
1965	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1966	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1967	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.392
1968	0.010	0.033	0.112	0.148	0.185	0.244	0.276	0.399	0.338	0.410	0.409
1969	0.010	0.037	0.105	0.162	0.207	0.242	0.282	0.306	0.334	0.390	0.391
1970	0.010	0.032	0.119	0.169	0.211	0.257	0.292	0.332	0.369	0.389	0.389
1971	0.010	0.066	0.143	0.199	0.230	0.254	0.293	0.329	0.362	0.388	0.388
1972	0.010	0.044	0.138	0.192	0.223	0.262	0.292	0.322	0.345	0.380	0.380
1973	0.010	0.029	0.106	0.143	0.225	0.252	0.279	0.331	0.360	0.389	0.389
1974	0.010	0.048	0.110	0.175	0.206	0.240	0.277	0.322	0.342	0.352	0.344
1975	0.010	0.021	0.094	0.179	0.216	0.240	0.268	0.333	0.358	0.379	0.379
1976	0.010	0.033	0.114	0.159	0.233	0.249	0.277	0.317	0.382	0.404	0.404
1977	0.010	0.065	0.113	0.174	0.214	0.274	0.293	0.325	0.328	0.416	0.416
1978	0.010	0.028	0.112	0.181	0.229	0.259	0.302	0.330	0.351	0.397	0.397
1979	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1980	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1981	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1982	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1983	0.010	0.041	0.112	0.172	0.218	0.254	0.286	0.323	0.354	0.389	0.389
1984	0.010	0.038	0.132	0.191	0.229	0.259	0.280	0.296	0.309	0.364	0.364
1985	0.010	0.053	0.118	0.204	0.249	0.278	0.315	0.334	0.344	0.440	0.440
1986	0.010	0.055	0.124	0.182	0.239	0.271	0.306	0.329	0.360	0.400	0.399
1987	0.012	0.050	0.098	0.153	0.199	0.245	0.274	0.290	0.318	0.350	0.349
1988	0.013	0.021	0.088	0.154	0.196	0.242	0.281	0.304	0.327	0.341	0.371
1989	0.007	0.033	0.079	0.162	0.207	0.238	0.274	0.303	0.324	0.353	0.365
1990	0.010	0.031	0.092	0.161	0.200	0.234	0.255	0.287	0.319	0.336	0.364
1991	0.010	0.048	0.100	0.147	0.186	0.217	0.251	0.270	0.303	0.322	0.332
1992	0.009	0.025	0.100	0.148	0.181	0.216	0.252	0.275	0.295	0.313	0.333
1993	0.018	0.029	0.108	0.153	0.188	0.215	0.251	0.279	0.302	0.324	0.357
1994	0.012	0.037	0.079	0.131	0.175	0.203	0.223	0.253	0.289	0.304	0.326
1995	0.015	0.042	0.076	0.136	0.187	0.223	0.247	0.293	0.300	0.326	0.363
1996	0.010	0.033	0.098	0.137	0.168	0.228	0.266	0.308	0.332	0.355	0.384
1997	0.019	0.034	0.080	0.161	0.190	0.238	0.284	0.314	0.358	0.376	0.397
1998	0.010	0.038	0.076	0.131	0.177	0.210	0.251	0.296	0.308	0.337	0.376
1999	0.024	0.052	0.087	0.137	0.166	0.199	0.213	0.243	0.259	0.311	0.274
2000	0.023	0.062	0.095	0.139	0.173	0.198	0.214	0.232	0.270	0.295	0.311
2001	0.023	0.058	0.109	0.147	0.185	0.221	0.249	0.269	0.263	0.317	0.312

Year	Average weight (kg)										
	1	2	3	4	5	6	7	8	9	10	11
2002	0.019	0.045	0.107	0.149	0.176	0.215	0.243	0.251	0.238	0.252	0.274
2003	0.013	0.044	0.090	0.146	0.176	0.196	0.225	0.253	0.250	0.257	0.260
2004	0.011	0.035	0.084	0.136	0.178	0.195	0.204	0.242	0.228	0.249	0.253
2005	0.022	0.035	0.074	0.130	0.153	0.184	0.207	0.214	0.246	0.273	0.254
2006	0.023	0.056	0.091	0.141	0.164	0.181	0.204	0.222	0.252	0.267	0.307
2007	0.027	0.055	0.104	0.148	0.184	0.204	0.215	0.242	0.270	0.269	0.287
2008	0.025	0.050	0.095	0.146	0.175	0.207	0.228	0.240	0.254	0.293	0.325
2009	0.011	0.041	0.085	0.138	0.172	0.203	0.232	0.246	0.257	0.281	0.297
2010	0.010	0.030	0.060	0.119	0.149	0.181	0.209	0.234	0.245	0.253	0.260
2011	0.029	0.054	0.077	0.116	0.145	0.170	0.196	0.231	0.252	0.255	0.274
2012	0.023	0.051	0.084	0.117	0.143	0.165	0.186	0.221	0.246	0.258	0.266
2013	0.021	0.065	0.087	0.122	0.143	0.162	0.182	0.197	0.216	0.290	0.277
2014	0.023	0.056	0.095	0.136	0.160	0.174	0.189	0.209	0.221	0.249	0.292
2015	0.023	0.048	0.080	0.145	0.169	0.188	0.198	0.205	0.215	0.257	0.295
2016	0.029	0.057	0.085	0.125	0.160	0.182	0.194	0.201	0.213	0.215	0.228
2017	0.031	0.052	0.081	0.115	0.143	0.167	0.187	0.192	0.194	0.214	0.233
Average 1965–2017	0.015	0.043	0.100	0.154	0.193	0.225	0.253	0.283	0.303	0.334	0.343
Minimum	0.007	0.021	0.060	0.115	0.143	0.162	0.182	0.192	0.194	0.214	0.210
Maximum	0.031	0.066	0.143	0.204	0.249	0.278	0.315	0.399	0.382	0.440	0.440
Avg 1970–79	0.010	0.041	0.116	0.174	0.221	0.254	0.286	0.326	0.355	0.388	0.387
Avg 1980–89	0.010	0.041	0.109	0.173	0.219	0.255	0.287	0.315	0.340	0.380	0.384
Avg 1990–99	0.014	0.037	0.090	0.144	0.182	0.218	0.249	0.282	0.307	0.330	0.351
Avg 2000–09	0.020	0.048	0.093	0.142	0.174	0.200	0.222	0.241	0.253	0.275	0.288
Prev 10yr: 2008–2017	0.022	0.050	0.083	0.128	0.156	0.180	0.200	0.218	0.231	0.257	0.273
Prev 5yr: 2012–2016	0.024	0.056	0.086	0.129	0.155	0.174	0.190	0.207	0.221	0.255	0.268

Table 18. Herring caught as bycatch in all bottom trawl fisheries on the Scotian Shelf from 1991–2018 and Herring caught in the Silver Hake fishery from 2002–2018. Data from prior to 2002 are from COMLAND, others are from MARFIS. (n.a. = not available).

Year	All bottom trawls (t)	Silver Hake trawls only (t)
1991	1.3680	n.a.
1992	244.3240	n.a.
1993	55.0080	n.a.
1994	0.9010	n.a.
1995	3.4000	n.a.
1996	208.2610	n.a.
1997	210.5480	n.a.
1998	152.4360	n.a.
1999	190.3840	n.a.
2000	91.0520	n.a.
2001	44.0650	n.a.
2002	89.2515	75.4092
2003	90.9486	66.7021
2004	69.8671	69.8396
2005	74.5883	74.2448
2006	41.6206	41.6434
2007	80.6645	79.1023
2008	37.0625	36.4256
2009	42.7151	42.6670
2010	24.7048	24.0970
2011	26.7658	26.1766
2012	44.8135	43.5053
2013	46.8459	46.5958
2014	35.4224	34.0171
2015	39.9217	39.8304
2016	35.9922	34.6237
2017	10.0861	9.6288
2018	17.2707	14.6563

Table 19. Herring abundance indices from the July bottom trawl survey (stratified numbers per tow): 1970–2017. Note: 2005 had duplicate coverage of the entire area with comparative surveys by the CCGS Alfred Needler *and CCGS* Templeman *research vessels (shaded rows).*

		4V only strata 440/452		4W Only strata 453/466		4X Only strata 470/495		4WX combined strata 453/495		4X BOF strata 480/495		4WX Offshore Banks strata 455/478		4VWX All Strata strata 440/498	
Year	Cruise	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1970	A175/176	12.8	9.8	4.9	2.4	1.6	0.6	4.1	1.5	1.0	0.6	5.7	2.4	6.5	3.1
1971	A188/189	4.4	4.4	2.6	1.2	3.6	2.6	4.0	1.9	1.4	1.0	5.3	2.8	4.0	1.9
1972	A200/201	4.5	3.7	1.7	1.0	0.5	0.1	1.4	0.6	0.3	0.1	2.0	1.0	2.3	1.1
1973	A212/213	19.2	19.2	0.4	0.3	1.0	0.4	0.9	0.3	1.0	0.4	0.9	0.4	6.1	5.4
1974	A225/226	0.0	0.0	0.2	0.0	1.0	0.4	0.7	0.3	1.4	0.6	0.5	0.2	0.6	0.2
1975	A236/237	2.2	2.2	0.8	0.4	0.7	0.4	0.9	0.4	1.3	0.7	0.7	0.4	1.3	0.7
1976	A250/251	0.0	0.0	0.1	0.1	0.5	0.3	0.4	0.2	0.9	0.6	0.1	0.1	0.3	0.2
1977	A265/266	1.6	1.4	0.0	0.0	0.8	0.5	0.5	0.3	1.5	0.9	0.1	0.1	0.9	0.5
1978	A279/280	0.0	0.0	0.5	0.5	0.1	0.0	0.4	0.3	0.1	0.0	0.5	0.5	0.3	0.2
1979	A292/293	0.0	0.0	0.0	0.0	1.0	0.7	0.6	0.5	1.5	1.3	0.2	0.2	0.4	0.3
1980	A306/307	0.0	0.0	0.0	0.0	0.8	0.8	0.5	0.5	1.6	1.6	0.0	0.0	0.4	0.4
1981	A321/322	0.0	0.0	0.0	0.0	2.3	2.1	1.5	1.4	4.6	4.1	0.0	0.0	1.1	1.0
1982	H080/081	0.0	0.0	0.5	0.3	1.9	1.4	1.9	1.1	0.8	0.3	2.5	1.7	1.3	0.8
1983	N012/013	0.1	0.0	2.6	1.2	2.2	1.0	2.4	0.8	3.1	1.6	2.1	1.0	1.7	0.6
1984	N031/032	4.0	2.9	3.3	1.2	10.5	6.8	7.0	3.6	4.6	2.5	8.5	5.4	6.2	2.7
1985	N048/049	0.0	0.0	6.6	3.8	0.3	0.1	3.4	1.8	0.4	0.2	5.0	2.9	2.4	1.3
1986	N065/066	0.5	0.4	30.8	26.7	16.0	14.3	23.4	15.0	24.9	22.3	23.4	20.3	16.9	10.8
1987	N85/86/87	117.4	90.5	17.0	11.3	4.0	1.8	10.4	5.6	6.3	2.8	12.9	8.6	40.8	26.0
1988	N105/106	0.3	0.2	2.7	1.2	1.5	0.5	2.1	0.6	2.3	0.8	2.0	0.9	1.6	0.5
1989	N123/124	3.6	3.1	11.8	3.4	4.5	1.2	8.0	1.8	4.9	1.4	9.8	2.7	6.7	1.5
1990	N139/140	0.3	0.2	7.4	3.6	3.4	1.0	5.3	1.9	3.4	0.8	6.5	2.9	3.9	1.4
1991	N154/H231	10.2	9.9	13.0	8.8	5.0	1.8	10.9	5.9	4.9	2.3	14.3	9.0	10.7	5.1
1992	N173/174	0.2	0.1	16.2	6.6	40.8	15.7	29.1	8.7	41.8	22.2	23.6	7.4	20.9	6.3
1993	N189/190	1.0	0.6	6.3	2.5	30.4	8.5	18.8	4.6	27.6	10.3	15.0	4.7	13.8	3.3
1994	N221/222	25.7	22.0	108.4	58.9	45.9	18.4	75.9	30.4	51.1	26.0	91.1	45.1	61.6	22.7

Year	Cruise	4V only strata 440/452		4W Only strata 453/466		4X Only strata 470/495		4WX combined strata 453/495		4X BOF strata 480/495		4WX Offshore Banks strata 455/478		4VWX All Strata strata 440/498	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1995	N226/227	7.9	6.1	100.5	47.9	28.4	12.8	63.9	24.5	11.4	5.4	92.7	37.6	46.8	17.2
1996	N246/247	0.2	0.1	53.2	24.5	27.1	14.1	39.4	14.3	32.1	20.8	46.5	19.5	27.5	9.9
1997	N726/734	0.2	0.1	34.6	10.1	51.3	39.3	43.2	20.8	72.8	60.9	29.3	7.7	30.2	14.5
1998	N827/832	0.8	0.3	147.6	39.9	54.8	14.5	99.5	20.7	45.6	19.4	130.3	30.3	69.7	14.6
1999	N925/929	24.9	15.2	264.2	101.0	199.4	130.2	229.8	83.8	251.4	203.6	226.2	74.4	163.7	58.6
2000	NED2000-426/431	2.0	0.6	146.3	40.6	38.7	7.4	90.6	20.0	29.5	9.1	124.7	30.5	63.8	13.9
2001	NED2001-032/037	53.9	49.2	152.7	81.3	139.5	52.5	145.9	47.7	181.3	80.9	132.4	60.9	116.7	36.0
2002	NED2002-037/040	4.9	2.6	172.7	81.3	151.9	55.6	161.9	48.6	170.9	85.3	162.6	61.1	114.4	34.0
2003	NED2003-036/042	4.9	2.0	207.8	145.4	58.7	14.5	130.6	70.5	50.3	14.0	175.8	108.6	92.5	49.2
2004t	TEL2004-529/530	1.4	0.4	307.6	134.5	285.0	147.4	295.9	100.2	198.0	170.9	355.6	127.6	209.2	70.7
2005t	TEL2005-605/633	7.4	2.2	13.7	8.7	130.5	23.1	74.1	13.7	51.8	34.4	88.0	6.6	53.9	9.1
2005n	NED2005-027/034	13.6	5.4	36.0	13.1	88.2	38.5	63.1	20.9	61.0	30.2	66.2	28.4	47.7	14.7
2006	NED2006-030/036	15.2	11.0	133.3	59.2	40.7	15.5	85.7	29.7	26.7	9.8	118.6	45.6	66.4	21.0
2007	TEL2007-745	0.9	0.5	20.0	8.0	59.9	17.3	40.7	9.8	85.8	26.9	19.0	6.2	29.1	6.9
2008	TEM2008-830	2.0	0.8	46.8	24.7	40.9	10.1	43.7	12.9	50.8	14.3	40.2	18.1	31.1	9.1
2009	NED2009-027	6.1	4.8	44.6	21.0	61.4	12.1	53.3	11.9	85.4	18.1	38.6	15.9	40.7	8.4
2010	NED2010-027	38.4	31.2	163.4	60.8	256.4	215.5	211.5	115.4	50.8	10.2	300.5	178.0	158.3	81.0
2011	NED2011-025	15.4	10.6	83.8	21.5	151.3	83.9	118.7	44.9	219.0	131.1	71.3	16.2	87.1	31.4
2012	NED2012-022	8.7	3.5	108.3	40.0	122.8	31.6	115.8	25.3	139.2	40.3	107.7	33.1	83.3	17.7
2013	NED2013-022	91.8	54.9	91.2	19.9	115.6	30.4	103.8	18.5	121.6	41.7	98.1	18.9	97.9	19.9
2014	NED2014-018	11.4	4.9	101.1	54.2	81.7	27.7	91.1	29.8	96.1	39.7	90.9	41.3	66.7	21.0
2015	NED2015-017	37.2	16.2	205.2	80.2	85.2	37.4	143.1	43.2	104.5	57.9	167.4	59.8	110.8	30.7
2016	NED2016-016	121.9	57.8	139.2	40.2	92.3	47.2	114.0	31.0	111.4	73.4	119.1	29.9	113.3	26.9
2017	NED2017-020	26.2	14.7	253.2	124.9	177.2	59.0	213.8	67.2	189.4	80.2	233.3	94.5	157.5	47.3
Overall Mean		14.4	9.5	66.6	28.9	55.5	24.9	61.0	20.7	53.7	28.2	66.7	25.9	46.8	15.5
Minimum		0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.2	0.1	0.0	0.0	0.0	0.3	0.2
Maximum		121.9	90.5	307.6	145.4	285.0	215.5	295.9	115.4	251.4	203.6	355.6	178.0	209.2	81.0

Table 20. Number of Herring aged in bottom travel surveys from 1999–2018.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10+	Total
1999	0	0	1	5	6	6	9	0	1	1	30
2000	0	17	28	77	41	29	25	7	3	0	227
2001	0	11	149	45	104	55	53	7	1	6	437
2002	5	34	18	32	10	8	4	2	0	0	113
2003	2	70	49	14	15	7	4	7	1	0	169
2004	1	11	31	6	3	6	4	1	1	0	64
2005	0	0	0	0	0	0	0	0	0	0	0
2006	3	0	0	0	0	0	0	0	0	0	3
2007	0	0	0	0	0	0	0	0	0	0	0
2008	0	58	193	63	39	57	67	46	20	5	548
2009	3	91	140	307	78	65	77	73	48	22	905
2010	2	102	186	220	323	89	53	77	71	54	1177
2011	6	58	170	199	246	348	105	73	61	106	1372
2012	27	66	172	228	270	240	191	68	49	69	1380
2013	0	73	197	99	136	153	119	49	19	27	872
2014	4	40	176	122	95	187	163	76	33	8	904
2015	1	72	182	175	99	97	100	64	29	9	828
2016	0	14	74	72	52	38	42	61	24	18	395
2017	0	31	92	157	117	110	85	63	26	16	697
2018	0	29	34	52	58	40	71	26	28	17	355
Total	54	777	1892	1873	1692	1535	1172	700	415	358	10476

Table 21. Number of Herring otoliths collected from bottom travel surveys from 1999–2007, number re-aged, percentage re-aged, and number read by Ager 1 and Ager 2.

Year	Otoliths	Re-aged	% Re-aged	Ager1	Ager2
1999	2750	184	7	2718	22
2000	2383	246	10	2246	3
2001	2404	1235	51	2354	4
2002	1921	114	6	1907	7
2003	2229	170	8	2210	30
2004	997	65	7	987	4
2005	1323	0	0	1276	15
2006	921	12	1	12	1
2007	1081	0	0	0	0
Total	16009	2026	13	13710	86

Table 22. Summary of the minimum observed Spring Stock Biomass (SSB) for each of the surveyed spawning grounds in the SWNS/BoF component of the 4WX Herring stock complex. Total SSB is rounded to nearest 100 t (except 2015_2017) (n/d = no data). A dash (-) indicates no data. Note: Scots Bay 2014 data updated; overall standard error (SE) (t and %) recalculated and updated for all years. Does not reflect biomass turnover estimates (see Melvin et al. 2018).

Location/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average 2005–2010	Average 1999 – 2017
Scots Bay (inbox)	45,909	185,498	216,000	129,300	123,000	115,000	21,200	31,600	50,500	23,300	81,600	42,300	105,600	143,500	66,900	221,300	260,215	110,002	160,330	41,750	112,267
Scots Bay (outbox)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	2,200	100	6,100	11,700	35,100	41,300	9,300	4,800	24,979	5,667	12,525	5,025	13,981
Scots Bay total	45,909	185,498	216,000	129,300	123,000	115,000	21,200	31,600	52,700	23,400	87,700	54,000	140,700	184,800	76,200	226,100	285,194	115,669	172,855	45,100	120,361
German Bank (inbox)	495,360	333,940	257,300	416,200	348,800	392,000	268,600	290,500	495,400	238,600	395,900	234,700	289,000	278,300	253,900	230,300	176,389	212,078	197,949	320,617	305,802
German Bank (outbox)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	4,900	4,000	2,400	1,700	19,100	11,500	10,100	10,600	2,800	0	0	0	6,420	5,591
German Bank total	495,360	333,940	257,300	416,200	348,800	392,000	268,600	295,400	499,400	241,000	397,600	253,800	300,500	288,400	264,500	233,000	176,389	212,078	197,949	325,967	309,332
Trinity Ledge	4,061	1,336	14,800	8,900	12,100	12,000	10,700	16,100	3,100	500	1,600	2,400	7,300	2,800	900	4,800	657	506	13,866	5,733	6,234
Spec Buoy (spring)	n/d	n/d	1,100	n/d	1,200	n/d	600	n/d	300	0	n/d	1,900	300	n/d	0	n/d	n/d	n/d	n/s	700	771
Spec Buoy (fall)	n/d	n/d	87,500	n/d	n/d	n/d	n/d	30	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0	0	n/d	8,726	-	32,085
Overall Stock Area	545,330	520,774	576,700	554,400	485,100	519,000	301,100	343,130	555,500	264,900	486,900	312,100	448,800	476,000	341,700	464,000	462,241	328,253	393,396	377,272	441,289
Seal Island	n/d	n/d	3,900	1,200	11,900	n/d	n/d	10,000	n/d	n/d	n/d	n/d	1,500	n/d	n/d	n/d	n/d	n/d	n/d	-	-
Browns Bank	n/d	n/d	45,100	n/d	n/d	n/d	n/d	7,700	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	-	-
Total All Areas	545,330	520,774	625,700	555,600	497,000	519,000	301,100	360,830	555,500	264,900	486,900	312,100	450,300	476,000	341,700	464,000	462,241	328,253	393,396	380,214	445,564
Overall SE (t)	24,488	22,715	5,961	25,406	24,646	25,199	35,843	16,876	38,290	24,758	29,039	11,609	25,339	11,664	17,214	22,640	17,044	13,075	14,352	-	-
Overall SE (%)	5%	4%	1%	5%	5%	5%	12%	5%	7%	9%	6%	4%	6%	2%	5%	5%	4%	4%	4%	-	-

Location/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Long term Average since 1999	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289	441,289
Difference from Long Term	104,011	79,484	135,445	112,993	43,789	77,730	-140,134	-98,177	114,190	-176,382	45,633	-129,234	12,849	34,737	-99,595	22,639	20,951	-113,036	-47,894
% difference from Long Term	24%	18%	31%	26%	10%	18%	-32%	-22%	26%	-40%	10%	-29%	3%	8%	-23%	5%	5%	-26%	-11%

Table 23. Acoustic age composition of Herring for the overall SWNS/BoF component from 1999 to 2017. A dash (-) indicates no data.

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total SSB
1999 Acoustics Overall (with CIF)	% catch wt.	0%	0%	4%	14%	35%	30%	11%	3%	1%	0%	0%	100%
2000 Acoustics Overall (with CIF)	% catch wt.	0%	0%	3%	25%	31%	19%	13%	7%	1%	1%	0%	100%
2001 Sub-total Stock Acoustic (with CIF)	% catch wt.	0%	2%	39%	14%	20%	13%	8%	2%	2%	0%	0%	100%
2002 Acoustics Stock Overall (with CIF)	% catch wt.	0%	1%	15%	44%	21%	7%	4%	3%	2%	1%	1%	99%
2003 Overall Acoustics (with CIF)	% catch wt.	0%	1%	28%	21%	34%	7%	4%	1%	1%	1%	1%	99%
2004 Acoustics Overall (with CIF)	% catch wt.	0%	0%	21%	43%	16%	11%	3%	1%	2%	0%	1%	99%
2005 Acoustics Overall (with CIF)	% catch wt.	0%	0%	10%	47%	20%	8%	8%	4%	1%	0%	1%	99%
2006 Acoustics Overall (with CIF)	% catch wt.	0%	0%	8%	21%	37%	19%	11%	3%	0%	0%	0%	100%
2007 Overall Acoustics (with CIF)	% catch wt.	0%	1%	8%	13%	17%	37%	19%	3%	1%	0%	0%	100%
2008 Overall Acoustics (with CIF)	% catch wt.	0%	0%	24%	12%	9%	14%	24%	12%	5%	1%	0%	100%
2009 Acoustics Overall (with CIF)	% catch wt.	0%	1%	17%	49%	8%	5%	7%	8%	4%	1%	0%	100%
2010 All Acoustics (with CIF)	% catch wt.	0%	0%	11%	21%	44%	6%	3%	6%	5%	2%	1%	99%
2011 Acoustics Overall (with CIF)	% catch wt.	0%	2%	18%	30%	23%	21%	2%	1%	1%	1%	0%	100%
2012 Acoustics Overall (with CIF)	% catch wt.	0%	0%	5%	25%	33%	19%	12%	2%	1%	1%	1%	99%
2013 Acoustics Overall (with CIF)	% catch wt.	0%	3%	15%	14%	23%	24%	12%	6%	1%	0%	0%	100%
2014 Acoustics Overall (with CIF)	% catch wt.	0%	0%	20%	18%	11%	21%	18%	8%	3%	1%	0%	100%
2015 Acoustics Overall (with CIF)	% catch wt.	0%	0%	6%	28%	19%	15%	18%	10%	3%	1%	0%	100%
2016 Acoustics Overall (with CIF)	% catch wt.	0%	0%	15%	15%	19%	14%	15%	15%	4%	1%	0%	100%
2017 Acoustics Overall (with CIF)	% catch wt.	0%	0%	10%	30%	15%	22%	13%	7%	2%	1%	0%	100%
1999 Acoustics Overall (with CIF)	% numbers	0%	0%	6%	17%	37%	27%	9%	2%	1%	0%	0%	100%
2000 Acoustics Overall (with CIF)	% numbers	0%	1%	5%	31%	30%	16%	11%	5%	1%	0%	0%	100%
2001 Sub-total Stock Acoustic (with CIF)	% numbers	0%	4%	50%	14%	17%	9%	5%	1%	1%	0%	0%	100%
2002 Acoustics Stock Overall (with CIF)	% numbers	0%	4%	19%	46%	19%	5%	3%	2%	1%	0%	0%	100%
2003 Overall Acoustics (with CIF)	% numbers	0%	2%	37%	21%	28%	6%	3%	1%	1%	0%	0%	100%
2004 Acoustics Overall (with CIF)	% numbers	0%	1%	28%	44%	12%	9%	2%	1%	2%	0%	1%	99%
2005 Acoustics Overall (with CIF)	% numbers	0%	0%	14%	50%	19%	7%	6%	3%	1%	0%	0%	100%
2006 Acoustics Overall (with CIF)	% numbers	0%	0%	12%	23%	37%	17%	9%	2%	0%	0%	0%	100%
2007 Overall Acoustics (with CIF)	% numbers	0%	1%	13%	16%	17%	33%	17%	2%	1%	0%	0%	100%
2008 Overall Acoustics (with CIF)	% numbers	0%	0%	35%	14%	8%	12%	18%	9%	3%	0%	0%	100%

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total SSB
2009 Acoustics Overall (with CIF)	% numbers	0%	2%	23%	52%	7%	4%	4%	5%	2%	1%	0%	100%
2010 All Acoustics (with CIF)	% numbers	0%	0%	17%	24%	43%	5%	2%	3%	3%	1%	0%	100%
2011 Acoustics Overall (with CIF)	% numbers	0%	4%	26%	31%	20%	16%	2%	1%	0%	1%	0%	100%
2012 Acoustics Overall (with CIF)	% numbers	0%	0%	7%	29%	33%	17%	10%	1%	1%	1%	0%	100%
2013 Acoustics Overall (with CIF)	% numbers	0%	6%	20%	15%	23%	20%	9%	4%	1%	0%	0%	100%
2014 Acoustics Overall (with CIF)	% numbers	0%	0%	28%	20%	11%	18%	14%	6%	2%	0%	0%	100%
2015 Acoustics Overall (with CIF)	% numbers	0%	0%	8%	32%	19%	14%	16%	8%	2%	0%	0%	100%
2016 Acoustics Overall (with CIF)	% numbers	0%	1%	23%	18%	19%	12%	12%	12%	3%	1%	0%	100%
2017 Acoustics Overall (with CIF)	% numbers	0%	0%	15%	35%	14%	18%	10%	5%	2%	0%	0%	100%
1999 Acoustics Overall (with CIF)	Catch wt. (t)	-	96	24,192	77,967	189,673	166,157	62,435	17,088	4,610	1,697	1,414	545,330
2000 Acoustics Overall (with CIF)	Catch wt. (t)	-	1,967	15,228	130,629	159,199	99,112	69,368	36,577	5,245	2,903	546	520,774
2001 Sub-total Stock Acoustic (with CIF)	Catch wt. (t)	-	8,962	226,129	78,412	117,923	77,160	47,004	11,357	8,874	925	8	576,753
2002 Acoustics Stock Overall (with CIF)	Catch wt. (t)	74	7,519	83,622	246,962	118,066	41,279	23,066	15,020	10,427	4,707	4,840	555,582
2003 Overall Acoustics (with CIF)	Catch wt. (t)	-	6,356	141,540	104,192	167,881	36,889	20,239	6,916	5,823	3,767	3,323	496,924
2004 Acoustics Overall (with CIF)	Catch wt. (t)	-	1,841	108,188	222,883	81,843	60,077	18,071	6,627	12,335	2,117	5,038	519,019
2005 Acoustics Overall (with CIF)	Catch wt. (t)	-	280	30,686	143,951	60,907	24,217	24,136	11,077	3,128	590	2,152	301,125
2006 Acoustics Overall (with CIF)	Catch wt. (t)	-	416	27,544	71,463	127,551	64,562	39,216	10,082	1,145	772	340	343,092
2007 Overall Acoustics (with CIF)	Catch wt. (t)	-	3,040	46,123	72,547	97,393	206,507	106,409	14,277	6,624	1,471	1,090	555,480
2008 Overall Acoustics (with CIF)	Catch wt. (t)	-	16	63,007	31,776	23,445	36,090	64,098	31,902	12,279	2,034	261	264,908
2009 Acoustics Overall (with CIF)	Catch wt. (t)	-	5,283	81,430	240,978	39,943	26,608	31,759	36,917	18,285	4,791	998	486,992
2010 All Acoustics (with CIF)	Catch wt. (t)	-	349	35,859	65,554	138,675	20,324	10,438	17,461	14,494	6,258	2,646	312,057
2011 Acoustics Overall (with CIF)	Catch wt. (t)	0	8,260	82,324	136,092	101,658	93,000	10,640	5,602	4,421	5,103	1,670	448,770
2012 Acoustics Overall (with CIF)	Catch wt. (t)	2	203	23,020	120,016	158,702	93,348	56,656	10,103	6,070	4,526	3,379	476,026
2013 Acoustics Overall (with CIF)	Catch wt. (t)	0	12,011	49,864	47,325	80,586	82,660	42,377	20,896	3,460	991	1,525	341,695
2014 Acoustics Overall (with CIF)	Catch wt. (t)	-	705	93,800	81,948	51,581	97,380	83,326	36,375	13,617	3,206	510	462,447
2015 Acoustics Overall (with CIF)	Catch wt. (t)	-	257	25,989	127,874	87,111	69,615	85,304	48,134	14,438	2,683	836	462,241
2016 Acoustics Overall (with CIF)	Catch wt. (t)	-	1,224	48,820	50,631	63,811	46,827	49,727	48,665	14,078	3,728	741	328,252
2017 Acoustics Overall (with CIF)	Catch wt. (t)	-	245	33,512	98,026	48,062	71,782	43,707	23,905	7,625	2,573	1,027	330,462
1999 Acoustics Overall (with CIF)	Numbers (x1,000)	-	972	183,418	489,829	1,062,907	786,929	263,817	62,824	15,293	5,294	3,652	2,874,933
2000 Acoustics Overall (with CIF)	Numbers (x1,000)	-	20,042	134,995	899,046	883,867	480,402	316,374	153,234	18,167	9,466	1,370	2,916,964

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total SSB
2001 Acoustic Overall (with CIF)	Numbers (x1,000)	-	138,378	1,863,364	520,051	629,493	344,389	185,290	40,507	33,537	2,907	25	3,757,943
2002 Acoustics Overall (with CIF)	Numbers (x1,000)	2,847	132,918	666,501	1,632,217	675,677	191,965	93,831	58,234	43,805	17,392	17,274	3,532,661
2003 Acoustics Overall (with CIF)	Numbers (x1,000)	-	75,899	1,280,141	716,456	968,658	192,680	91,717	27,831	23,605	14,876	13,196	3,405,060
2004 Acoustics Overall (with CIF)	Numbers (x1,000)	-	29,138	977,495	1,564,177	429,090	301,861	86,440	27,005	54,019	7,473	19,841	3,496,538
2005 Acoustics Overall (with CIF)	Numbers (x1,000)	-	5,743	270,611	989,364	375,723	128,849	112,316	50,960	12,657	2,161	8,707	1,957,092
2006 Acoustics Overall (with CIF)	Numbers (x1,000)	-	5,925	237,497	459,245	738,445	339,588	186,063	44,547	4,543	2,894	1,191	2,019,938
2007 Acoustics Overall (with CIF)	Numbers (x1,000)	-	30,745	378,840	471,617	523,359	1,008,862	506,663	54,973	25,067	5,177	3,699	3,009,003
2008 Acoustics Overall (with CIF)	Numbers (x1,000)	-	200	530,159	208,001	124,260	172,143	273,854	130,451	47,003	7,018	862	1,493,951
2009 Acoustics Overall (with CIF)	Numbers (x1,000)	-	80,153	748,194	1,675,788	228,794	128,524	135,293	147,571	69,756	17,166	3,339	3,234,577
2010 Acoustics Overall (with CIF)	Numbers (x1,000)	-	5,321	364,994	521,396	911,479	112,611	48,457	73,892	59,104	24,968	10,290	2,132,512
2011 Acoustics Overall (with CIF)	Numbers (x1,000)	0	144,094	886,891	1,083,801	675,731	543,019	54,854	24,559	17,249	19,710	6,191	3,456,098
2012 Acoustics Overall (with CIF)	Numbers (x1,000)	130	3,028	227,273	961,371	1,088,022	565,948	311,235	47,020	24,713	17,761	12,766	3,259,266
2013 Acoustics Overall (with CIF)	Numbers (x1,000)	18	154,304	514,279	382,897	577,748	513,497	235,337	107,002	15,930	3,557	5,426	2,509,994
2014 Acoustics Overall (with CIF)	Numbers (x1,000)	-	8,860	797,713	570,309	315,593	524,273	413,167	162,800	58,365	12,134	1,790	2,865,003
2015 Acoustics Overall (with CIF)	Numbers (x1,000)	-	3,531	231,550	875,133	522,490	372,454	430,084	230,537	65,519	10,264	2,722	2,744,285
2016 Acoustics Overall (with CIF)	Numbers (x1,000)	-	13,651	457,259	365,916	376,658	245,318	242,616	234,091	64,209	16,423	3,185	2,019,326
2017 Acoustics Overall (with CIF)	Numbers (x1,000)	-	4,345	344,202	803,832	322,740	423,675	227,826	117,497	37,041	11,143	4,469	2,296,772

Table 24. Acoustic age composition of Herring for the German Bank component from 1999 to 2017 (with % by weight, % by number, catch/survey biomass (t) and numbers (thousands) by age). A dash (-) indicates no data.

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
1999 German Bank Acoustics (with CIF)	% catch wt.	0%	0%	4%	14%	34%	30%	11%	3%	1%	0%	0%	100%
2000 German Bank Acoustics (with CIF)	% catch wt.	0%	1%	3%	26%	30%	17%	15%	7%	1%	1%	0%	100%
2001 German Bank Acoustic (with CIF)	% catch wt.	0%	3%	41%	12%	19%	13%	8%	2%	2%	0%	0%	100%
2002 German Bank Acoustics (with CIF)	% catch wt.	0%	1%	16%	42%	21%	7%	4%	3%	2%	1%	1%	99%
2003 German Bank Acoustics (with CIF)	% catch wt.	0%	1%	32%	20%	30%	8%	4%	1%	1%	1%	1%	99%
2004 Acoustics German Bank (with CIF)	% catch wt.	0%	0%	19%	46%	16%	10%	3%	1%	3%	0%	1%	99%
2005 German Bank Acoustics (with CIF)	% catch wt.	0%	0%	10%	47%	20%	8%	8%	4%	1%	0%	1%	99%
2006 German Bank Acoustics (with CIF)	% catch wt.	0%	0%	8%	20%	37%	19%	12%	3%	0%	0%	0%	100%
2007 German Bank Acoustics (with CIF)	% catch wt.	0%	1%	8%	12%	17%	38%	20%	2%	1%	0%	0%	100%
2008 German Bank Acoustics (with CIF)	% catch wt.	0%	0%	24%	12%	9%	13%	24%	12%	5%	1%	0%	100%
2009 German Bank Acoustics (with CIF)	% catch wt.	0%	1%	16%	49%	8%	5%	7%	8%	4%	1%	0%	100%
2010 German Bank Acoustics (with CIF)	% catch wt.	0%	0%	10%	20%	44%	6%	3%	6%	5%	2%	1%	99%
2011 German Bank Acoustics (with CIF)	% catch wt.	0%	3%	19%	29%	22%	21%	2%	1%	1%	1%	0%	100%
2012 Acoustics German Bank (with CIF)	% catch wt.	0%	0%	6%	31%	32%	16%	9%	2%	2%	1%	1%	99%
2013 Acoustics German Bank (with CIF)	% catch wt.	0%	4%	17%	14%	24%	22%	11%	6%	1%	0%	0%	100%
2014 Acoustics German Bank (with CIF)	% catch wt.	0%	0%	16%	22%	14%	21%	16%	7%	3%	0%	0%	100%
2015 Acoustics German Bank (with CIF)	% catch wt.	0%	0%	9%	24%	26%	16%	15%	7%	3%	0%	0%	100%
2016 Acoustics German Bank (with CIF)	% catch wt.	0%	1%	14%	17%	17%	15%	15%	16%	4%	1%	0%	100%
2017 Acoustics German Bank (with CIF)	% catch wt.	0%	0%	9%	33%	20%	14%	16%	7%	1%	0%	0%	100%
1999 German Bank Acoustics (with CIF)	% numbers	0%	0%	6%	17%	37%	27%	9%	2%	1%	0%	0%	100%
2000 German Bank Acoustics (with CIF)	% numbers	0%	1%	5%	31%	29%	15%	12%	5%	1%	0%	0%	100%
2001 German Bank Acoustic (with CIF)	% numbers	0%	8%	50%	12%	15%	9%	5%	1%	1%	0%	0%	100%
2002 German Bank Acoustics (with CIF)	% numbers	0%	4%	20%	44%	19%	5%	3%	2%	1%	0%	0%	100%
2003 German Bank Acoustics (with CIF)	% numbers	0%	2%	41%	20%	25%	6%	3%	1%	1%	0%	0%	100%
2004 Acoustics German Bank (with CIF)	% numbers	0%	1%	25%	48%	12%	7%	2%	1%	2%	0%	1%	99%
2005 German Bank Acoustics (with CIF)	% numbers	0%	0%	14%	50%	19%	7%	6%	3%	1%	0%	0%	100%
2006 German Bank Acoustics (with CIF)	% numbers	0%	0%	12%	22%	36%	17%	9%	2%	0%	0%	0%	100%
2007 German Bank Acoustics (with CIF)	% numbers	0%	1%	12%	15%	17%	34%	18%	2%	1%	0%	0%	100%
2008 German Bank Acoustics (with CIF)	% numbers	0%	0%	36%	14%	8%	11%	18%	9%	3%	0%	0%	100%
2009 German Bank Acoustics (with CIF)	% numbers	0%	2%	22%	52%	7%	4%	4%	5%	2%	1%	0%	100%

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
2010 German Bank Acoustics (with CIF)	% numbers	0%	0%	16%	24%	43%	5%	2%	4%	3%	1%	1%	99%
2011 German Bank Acoustics (with CIF)	% numbers	0%	6%	27%	29%	19%	15%	1%	1%	1%	1%	0%	100%
2012 Acoustics German Bank (with CIF)	% numbers	0%	0%	9%	36%	31%	14%	7%	1%	1%	1%	1%	99%
2013 Acoustics German Bank (with CIF)	% numbers	0%	8%	23%	15%	23%	18%	8%	4%	1%	0%	0%	100%
2014 Acoustics German Bank (with CIF)	% numbers	0%	0%	22%	25%	14%	18%	13%	5%	2%	0%	0%	100%
2015 Acoustics German Bank (with CIF)	% numbers	0%	0%	13%	28%	25%	14%	12%	5%	2%	0%	0%	100%
2016 Acoustics German Bank (with CIF)	% numbers	0%	1%	21%	20%	16%	13%	12%	13%	3%	1%	0%	100%
2017 Acoustics German Bank (with CIF)	% numbers	0%	0%	14%	38%	18%	12%	12%	4%	1%	0%	0%	100%
1999 German Bank Acoustics (with CIF)	Catch wt. (t)	-	94	22,020	71,969	170,866	150,058	56,609	16,095	4,580	1,666	1,403	495,360
2000 German Bank Acoustics (with CIF)	Catch wt. (t)	-	1,714	11,428	85,499	99,807	57,948	48,812	22,450	3,959	1,781	542	333,940
2001 German Bank Acoustic (with CIF)	Catch wt. (t)	-	8,709	105,329	31,035	47,725	33,793	21,101	4,622	4,485	512	-	257,310
2002 German Bank Acoustics (with CIF)	Catch wt. (t)	65	6,286	67,234	176,687	90,152	30,366	17,751	11,648	9,474	3,049	3,468	416,181
2003 German Bank Acoustics (with CIF)	Catch wt. (t)	-	4,120	111,880	70,453	105,752	28,232	14,854	4,812	3,817	2,258	2,597	348,776
2004 Acoustics German Bank (with CIF)	Catch wt. (t)	-	1,543	74,501	181,390	64,019	38,787	11,728	5,034	10,206	1,124	3,625	391,955
2005 German Bank Acoustics (with CIF)	Catch wt. (t)	-	253	28,259	127,632	53,781	22,164	21,719	9,605	2,690	537	1,939	268,580
2006 German Bank Acoustics (with CIF)	Catch wt. (t)	-	385	24,848	60,454	109,208	55,536	34,201	8,844	973	649	293	295,390
2007 German Bank Acoustics (with CIF)	Catch wt. (t)	-	2,626	38,067	61,417	85,462	188,827	102,160	12,151	6,359	1,334	957	499,361
2008 German Bank Acoustics (with CIF)	Catch wt. (t)	-	-	58,937	28,340	21,000	30,528	58,958	29,408	11,722	1,797	261	240,950
2009 German Bank Acoustics (with CIF)	Catch wt. (t)	-	3,753	64,068	196,736	32,188	21,514	26,020	31,485	16,399	4,519	978	397,660
2010 German Bank Acoustics (with CIF)	Catch wt. (t)	-	224	26,819	52,092	113,756	15,750	8,461	15,402	13,099	5,679	2,487	253,769
2011 German Bank Acoustics (with CIF)	Catch wt. (t)	-	7,846	56,905	87,082	67,336	62,429	5,092	4,232	3,545	4,494	1,499	300,460
2012 Acoustics German Bank (with CIF)	Catch wt. (t)	-	134	17,915	88,968	92,271	45,791	27,105	5,077	4,732	3,500	2,951	288,443
2013 Acoustics German Bank (with CIF)	Catch wt. (t)	-	11,688	45,041	37,523	63,130	57,987	28,921	15,801	2,379	855	1,204	264,528
2014 Acoustics German Bank (with CIF)	Catch wt. (t)	-	489	36,873	52,144	31,877	47,689	37,741	17,089	6,181	1,095	373	231,552
2015 Acoustics German Bank (with CIF)	Catch wt. (t)	-	103	15,412	42,893	45,756	27,909	26,455	11,815	5,369	202	476	176,389
2016 Acoustics German Bank (with CIF)	Catch wt. (t)	-	1,099	29,194	36,317	36,260	32,754	32,429	33,696	7,514	2,632	184	212,078
2017 Acoustics German Bank (with CIF)	Catch wt. (t)	-	223	12,592	44,461	26,470	18,894	22,053	8,790	992	539	-	135,014
1999 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	948	166,864	451,905	959,130	709,941	237,407	58,820	15,194	5,192	3,624	2,609,024
2000 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	17,625	102,000	589,063	553,882	289,467	226,575	96,514	13,709	5,760	1,361	1,895,957
2001 German Bank Acoustic (with CIF)	Numbers (x1,000)	-	135,703	894,080	210,906	258,067	152,649	84,043	16,527	17,480	1,604	-	1,771,058
2002 German Bank Acoustics (with CIF)	Numbers (x1,000)	2,537	111,379	539,725	1,166,924	519,058	142,215	72,525	45,273	39,941	11,155	12,261	2,662,994
2003 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	46,007	1,004,407	494,420	612,116	148,687	67,475	19,473	15,492	8,908	10,457	2,427,440

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
2004 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	24,531	677,770	1,277,135	332,022	196,099	56,805	20,672	45,133	3,596	14,378	2,648,140
2005 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	5,182	248,168	870,294	330,085	118,133	100,841	44,127	10,910	1,977	7,905	1,737,625
2006 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	5,494	214,151	386,345	629,197	290,199	161,640	39,049	3,876	2,456	1,029	1,733,437
2007 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	26,261	310,742	397,519	458,661	920,624	486,502	46,109	24,135	4,666	3,250	2,678,468
2008 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	-	496,210	185,856	110,437	146,499	252,158	120,986	44,750	6,190	862	1,363,949
2009 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	54,955	583,192	1,360,737	182,941	103,267	109,573	124,811	62,074	16,154	3,273	2,600,976
2010 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	3,316	272,314	414,147	744,621	86,016	39,053	64,928	53,120	22,533	9,635	1,709,683
2011 German Bank Acoustics (with CIF)	Numbers (x1,000)	-	136,458	624,134	684,168	434,182	360,193	24,543	18,531	13,595	17,288	5,549	2,318,639
2012 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	1,946	174,959	711,646	623,273	271,374	142,452	22,099	18,998	13,364	11,056	1,991,166
2013 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	150,296	466,144	302,837	455,609	358,555	161,390	81,112	10,799	3,040	4,257	1,994,037
2014 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	5,678	305,885	350,889	189,632	247,476	183,560	73,417	25,776	4,374	1,334	1,388,020
2015 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	1,334	135,807	290,328	266,660	144,320	128,599	51,818	25,213	779	1,477	1,046,334
2016 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	12,087	269,929	260,999	212,780	172,504	158,931	163,684	34,794	11,753	753	1,298,213
2017 Acoustics German Bank (with CIF)	Numbers (x1,000)	-	4,007	133,178	366,157	177,047	114,131	115,785	42,065	4,834	2,127	-	959,332

Table 25. Acoustic age composition of Herring for the Scots Bay component from 1999 to 2017 (with % by weight, % by number, catch/survey biomass (t) and numbers (thousands) by age). A dash (-) indicates no data.

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
1999 Scots Bay Acoustics (with CIF)	% catch wt.	0%	0%	4%	14%	34%	30%	11%	3%	1%	0%	0%	100%
2000 Scots Bay Acoustics (with CIF)	% catch wt.	0%	1%	3%	26%	30%	17%	15%	7%	1%	1%	0%	100%
2001 Scots Bay Acoustic (with CIF)	% catch wt.	0%	3%	41%	12%	19%	13%	8%	2%	2%	0%	0%	100%
2002 Scots Bay Acoustics (with CIF)	% catch wt.	0%	1%	16%	42%	21%	7%	4%	3%	2%	1%	1%	99%
2003 Scots Bay Acoustics (with CIF)	% catch wt.	0%	1%	32%	20%	30%	8%	4%	1%	1%	1%	1%	99%
2004 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	19%	46%	16%	10%	3%	1%	3%	0%	1%	99%
2005 Scots Bay Acoustics (with CIF)	% catch wt.	0%	0%	10%	47%	20%	8%	8%	4%	1%	0%	1%	99%
2006 Scots Bay Acoustics (with CIF)	% catch wt.	0%	0%	8%	20%	37%	19%	12%	3%	0%	0%	0%	100%
2007 Scots Bay Acoustics (with CIF)	% catch wt.	0%	1%	8%	12%	17%	38%	20%	2%	1%	0%	0%	100%
2008 Scots Bay Acoustics (with CIF)	% catch wt.	0%	0%	24%	12%	9%	13%	24%	12%	5%	1%	0%	100%
2009 Scots Bay Acoustics (with CIF)	% catch wt.	0%	1%	16%	49%	8%	5%	7%	8%	4%	1%	0%	100%
2010 Scots Bay Acoustics (with CIF)	% catch wt.	0%	0%	10%	20%	44%	6%	3%	6%	5%	2%	1%	99%
2011 Scots Bay Acoustics (with CIF)	% catch wt.	0%	3%	19%	29%	22%	21%	2%	1%	1%	1%	0%	100%
2012 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	6%	31%	32%	16%	9%	2%	2%	1%	1%	99%
2013 Acoustics Scots Bay (with CIF)	% catch wt.	0%	4%	17%	14%	24%	22%	11%	6%	1%	0%	0%	100%
2014 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	16%	22%	14%	21%	16%	7%	3%	0%	0%	100%
2015 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	4%	30%	14%	15%	21%	13%	3%	1%	0%	100%
2016 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	17%	12%	24%	12%	15%	13%	6%	1%	0%	100%
2017 Acoustics Scots Bay (with CIF)	% catch wt.	0%	0%	10%	25%	10%	29%	11%	8%	4%	1%	1%	100%
1999 Scots Bay Acoustics (with CIF)	% numbers	0%	0%	6%	17%	37%	27%	9%	2%	1%	0%	0%	100%
2000 Scots Bay Acoustics (with CIF)	% numbers	0%	1%	5%	31%	29%	15%	12%	5%	1%	0%	0%	100%
2001 Scots Bay Acoustics (with CIF)	% numbers	0%	8%	50%	12%	15%	9%	5%	1%	1%	0%	0%	100%
2002 Scots Bay Acoustics (with CIF)	% numbers	0%	4%	20%	44%	19%	5%	3%	2%	1%	0%	0%	100%
2003 Scots Bay Acoustics (with CIF)	% numbers	0%	2%	41%	20%	25%	6%	3%	1%	1%	0%	0%	100%
2004 Acoustics Scots Bay (with CIF)	% numbers	0%	1%	25%	48%	12%	7%	2%	1%	2%	0%	1%	99%
2005 Scots Bay Acoustics (with CIF)	% numbers	0%	0%	14%	50%	19%	7%	6%	3%	1%	0%	0%	100%
2006 Scots Bay Acoustics (with CIF)	% numbers	0%	0%	12%	22%	36%	17%	9%	2%	0%	0%	0%	100%
2007 Scots Bay Acoustics (with CIF)	% numbers	0%	1%	12%	15%	17%	34%	18%	2%	1%	0%	0%	100%
2008 Scots Bay Acoustics (with CIF)	% numbers	0%	0%	36%	14%	8%	11%	18%	9%	3%	0%	0%	100%
2009 Scots Bay Acoustics (with CIF)	% numbers	0%	2%	22%	52%	7%	4%	4%	5%	2%	1%	0%	100%

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
2010 Scots Bay Acoustics (with CIF)	% numbers	0%	0%	16%	24%	43%	5%	2%	4%	3%	1%	1%	99%
2011 Scots Bay Acoustics (with CIF)	% numbers	0%	6%	27%	29%	19%	15%	1%	1%	1%	1%	0%	100%
2012 Acoustics Scots Bay (with CIF)	% numbers	0%	0%	9%	36%	31%	14%	7%	1%	1%	1%	1%	99%
2013 Acoustics Scots Bay (with CIF)	% numbers	0%	8%	23%	15%	23%	18%	8%	4%	1%	0%	0%	100%
2014 Acoustics Scots Bay (with CIF)	% numbers	0%	0%	22%	25%	14%	18%	13%	5%	2%	0%	0%	100%
2015 Acoustics Scots Bay (with CIF)	% numbers	0%	0%	6%	34%	15%	13%	18%	11%	2%	1%	0%	100%
2016 Acoustics Scots Bay (with CIF)	% numbers	0%	0%	26%	15%	23%	10%	12%	10%	4%	1%	0%	100%
2017 Acoustics Scots Bay (with CIF)	% numbers	0%	0%	15%	31%	10%	26%	9%	6%	3%	1%	0%	100%
1999 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	94	22,020	71,969	170,866	150,058	56,609	16,095	4,580	1,666	1,403	495,360
2000 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	1,714	11,428	85,499	99,807	57,948	48,812	22,450	3,959	1,781	542	333,940
2001 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	8,709	105,329	31,035	47,725	33,793	21,101	4,622	4,485	512	-	257,310
2002 Scots Bay Acoustics (with CIF)	Catch wt. (t)	65	6,286	67,234	176,687	90,152	30,366	17,751	11,648	9,474	3,049	3,468	416,181
2003 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	4,120	111,880	70,453	105,752	28,232	14,854	4,812	3,817	2,258	2,597	348,776
2004 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	1,543	74,501	181,390	64,019	38,787	11,728	5,034	10,206	1,124	3,625	391,955
2005 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	253	28,259	127,632	53,781	22,164	21,719	9,605	2,690	537	1,939	268,580
2006 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	385	24,848	60,454	109,208	55,536	34,201	8,844	973	649	293	295,390
2007 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	2,626	38,067	61,417	85,462	188,827	102,160	12,151	6,359	1,334	957	499,361
2008 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	-	58,937	28,340	21,000	30,528	58,958	29,408	11,722	1,797	261	240,950
2009 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	3,753	64,068	196,736	32,188	21,514	26,020	31,485	16,399	4,519	978	397,660
2010 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	224	26,819	52,092	113,756	15,750	8,461	15,402	13,099	5,679	2,487	253,769
2011 Scots Bay Acoustics (with CIF)	Catch wt. (t)	-	7,846	56,905	87,082	67,336	62,429	5,092	4,232	3,545	4,494	1,499	300,460
2012 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	134	17,915	88,968	92,271	45,791	27,105	5,077	4,732	3,500	2,951	288,443
2013 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	11,688	45,041	37,523	63,130	57,987	28,921	15,801	2,379	855	1,204	264,528
2014 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	489	36,873	52,144	31,877	47,689	37,741	17,089	6,181	1,095	373	231,552
2015 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	154	10,537	84,846	41,185	41,591	58,733	36,268	9,039	2,481	360	285,195
2016 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	124	19,509	14,203	27,471	14,009	17,236	14,915	6,550	1,094	556	115,668
2017 Acoustics Scots Bay (with CIF)	Catch wt. (t)	-	17	17,284	43,642	17,140	50,911	19,654	14,646	6,501	2,033	1,027	172,855
1999 Scots Bay Acoustic (with CIF)	Numbers (x1,000)	-	948	166,864	451,905	959,130	709,941	237,407	58,820	15,194	5,192	3,624	2,609,024
2000 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	17,625	102,000	589,063	553,882	289,467	226,575	96,514	13,709	5,760	1,361	1,895,957
2001 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	135,703	894,080	210,906	258,067	152,649	84,043	16,527	17,480	1,604	-	1,771,058
2002 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	2,537	111,379	539,725	1,166,924	519,058	142,215	72,525	45,273	39,941	11,155	12,261	2,662,994
2003 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	46,007	1,004,407	494,420	612,116	148,687	67,475	19,473	15,492	8,908	10,457	2,427,440

Year and Area	Type Data	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Total
2004 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	24,531	677,770	1,277,135	332,022	196,099	56,805	20,672	45,133	3,596	14,378	2,648,140
2005 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	5,182	248,168	870,294	330,085	118,133	100,841	44,127	10,910	1,977	7,905	1,737,625
2006 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	5,494	214,151	386,345	629,197	290,199	161,640	39,049	3,876	2,456	1,029	1,733,437
2007 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	26,261	310,742	397,519	458,661	920,624	486,502	46,109	24,135	4,666	3,250	2,678,468
2008 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	-	496,210	185,856	110,437	146,499	252,158	120,986	44,750	6,190	862	1,363,949
2009 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	54,955	583,192	1,360,737	182,941	103,267	109,573	124,811	62,074	16,154	3,273	2,600,976
2010 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	3,316	272,314	414,147	744,621	86,016	39,053	64,928	53,120	22,533	9,635	1,709,683
2011 Scots Bay Acoustics (with CIF)	Numbers (x1,000)	-	136,458	624,134	684,168	434,182	360,193	24,543	18,531	13,595	17,288	5,549	2,318,639
2012 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	1,946	174,959	711,646	623,273	271,374	142,452	22,099	18,998	13,364	11,056	1,991,166
2013 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	150,296	466,144	302,837	455,609	358,555	161,390	81,112	10,799	3,040	4,257	1,994,037
2014 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	5,678	305,885	350,889	189,632	247,476	183,560	73,417	25,776	4,374	1,334	1,388,020
2015 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	2,192	95,390	583,918	254,862	227,555	300,934	178,503	40,169	9,485	1,245	1,694,254
2016 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	1,554	186,244	104,106	163,402	72,468	83,359	70,140	29,347	4,662	2,429	717,711
2017 Acoustics Scots Bay (with CIF)	Numbers (x1,000)	-	256	172,318	356,254	115,767	298,603	101,411	72,992	31,619	9,016	4,469	1,162,704

Table 26. Herring larval abundance index from autumn Bay of Fundy bongo survey (average number of larvae per m² from 79 index stations). (SE = standard error).

Year	Cruise	Mean	SE	N
1972	P109	9.4	1.8	79
1973	P127	6.6	1.3	79
1974	P147	49.5	10.9	79
1975	P160	11.7	1.5	58
1976	P175	13.5	2.9	79
1977	P190	6.3	1.0	79
1978	P207	4.5	0.5	77
1979	P232	7.1	2.1	79
1980	P246	26.2	6.7	79
1981	P263	2.7	0.3	78
1982	P280	10.6	1.2	77
1983	P298	13.9	1.6	74
1984	P315	12.7	1.4	78
1985	P329	40.8	4.6	79
1986	P344	18.9	2.1	78
1987	P361	27.9	3.2	78
1988	P377	100.7	11.5	76
1989	P391	54.5	6.1	79
1990	P408	27.2	3.1	79
1991	P422	48.2	5.5	78
1992	P437	57.0	6.4	79
1993	P451	55.0	6.2	78
1994	N211	5.4	0.7	77
1995	N232	20.3	4.6	78
1996	N252	9.5	1.6	77
1997	N765	23.3	2.7	77
1998	N865	33.6	3.8	77
2009	DV–57	19.9	4.2	79

Table 27. Ration, consumption per unit biomass (Q/B), percent Herring in diet, reference years, residency, and sources for diet and abundance time series for fish species. Fish lengths are in fork length (FL) (from Guenette and Stephenson 2012). A dash (-) indicates no data.

Species	Age/size group	Q/B (per yr)	Ration (kg/yr)	% Herring		Diet reference years	Residency	Sources	
				Juvenile	Adult			Diet	Abundance
Cod, *Gadus morhua*	Age 1–6	3.39	2.83	10.99	10.08	2000–2008	1	a	c
Pollock, *Pollachius virens*	Age 1–6	9.42	4.10	5.36	8.14	2000–2008	1	a	c
Silver hake, *Merluccius bilinearis*	<25 cm	4.86	0.59	0	0	2000–2008	1	a	d
	25-31 cm	3.16	1.11	0	0	2000–2008	1	a	d
	>31 cm	2.47	2.12	23.48	4.98	2000–2008	1	a	d
White hake, *Urophycis tenuis*	<41 cm	7.81	1.91	0.008	0	2000–2008	1	a	d
	>41 cm	4.57	6.99	16.76	3.33	2000–2008	1	a	d
Halibut, *Hippoglossus hippoglossus*	<46 cm	7.15	3.59	3.48	0	2000–2008	1	a	e
	46-81 cm	4.15	11.01	10.92	0	2000–2008	1	a	e
	>81 cm	2.27	39.34	1.87	0	2000–2008	0.5	a	e
Bluefin tuna, *Thunnus thynnus*	-	7.3	-	0	52.80	1988–1992	0.33	f	g
Dogfish, *Squalus acanthias*	-	2.46	3.81	2.84	1.11	2000–2008	1	a	d
Mako, *Isurus oxyrhinchus*	-	6.94	56.65	0	2	1972–1978	0.33	h	i
Porbeagle, *Lamna nasus*	-	0.73	-	0	6.20	1999–2001	0.33	j	k
Blue shark, *Prionace glauca*	-	1.24	448.95	0	2.50	1972–1978	0.5	l	m
Monkfish, *Lophius americanus*	-	3.13	3.53	12.46	14.71	2000–2008	1	a	d
Sea raven, *Hemitripterus americanus*	-	3.82	2.66	14.01	0	2000-2008	1	a	d

a Ration, Q/B, and diet composition from the database (Laurinolli et al. 2004).

b VPA (Clark and Perley 2006).

c Combination of VPA and survey (H. Stone, DFO, St. Andrews, 2010, pers. comm.).

d Annual survey.

e Stock assessment (K. Trzcinski, DFO, Dartmouth, pers. comm.).

f Ration and Q/B (Butler et al. 2010); diet (Chase 2001); residency from tagging data (J. Neilson, DFO, St. Andrews, pers. comm.).

g ICCAT 2008a.

h (Stillwell and Kohler 1978, Kohler and Stillwell 1981); residency (Campana et al. 2007).

i (ICCAT 2008b, fig. 24).

j (Joyce et al. 2002); residency (Campana et al. 2009, ICCAT 2008a).

k (Campana et al. 2009, p. 13).

l (Kohler and Stillwell 1981); residency (Campana et al. 2004).

M (Campana et al. 2004).

FIGURES

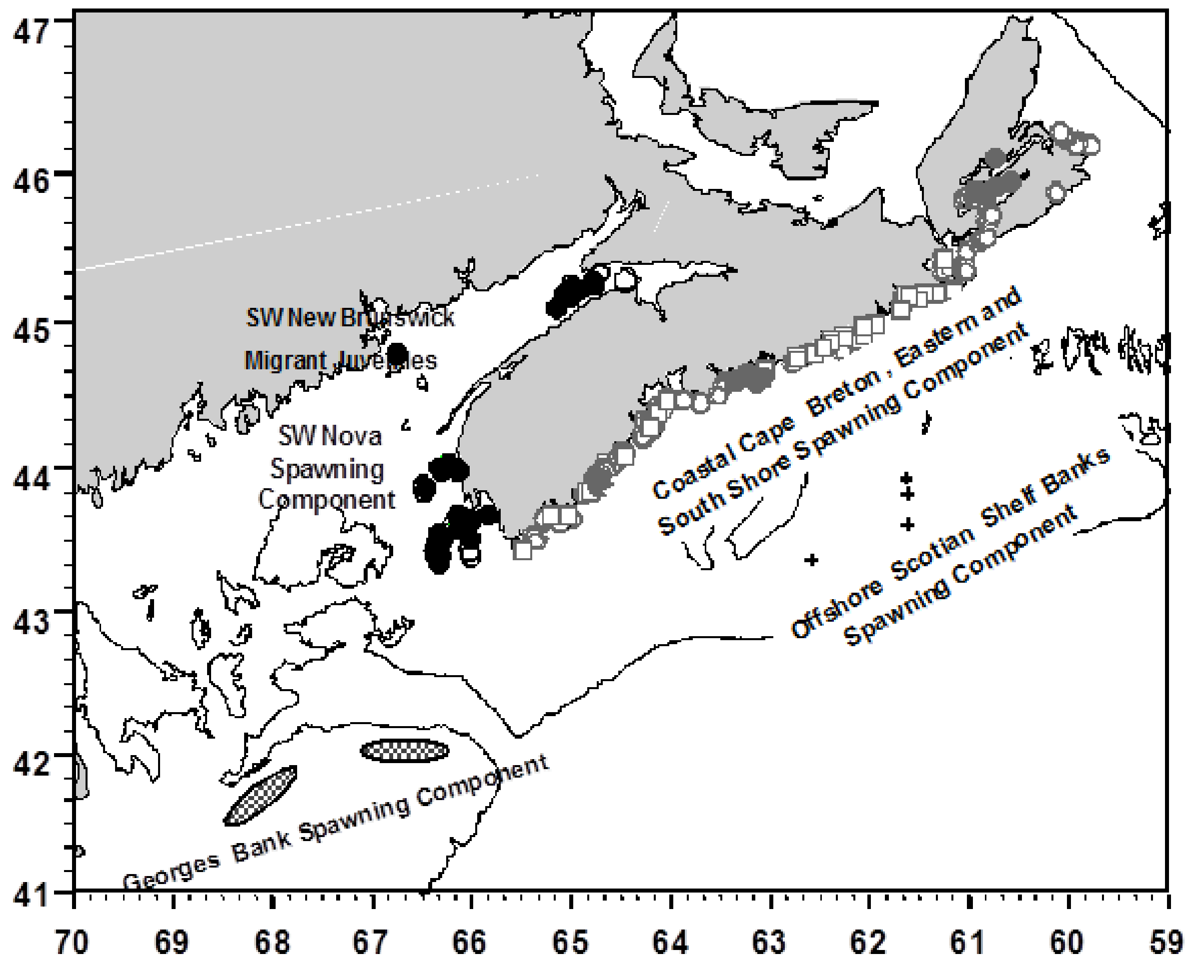

Figure 1. Management units for Herring in NAFO Divisions 4VWX and 5YZ showing locations of known current (solid) and historical (open) spawning locations.

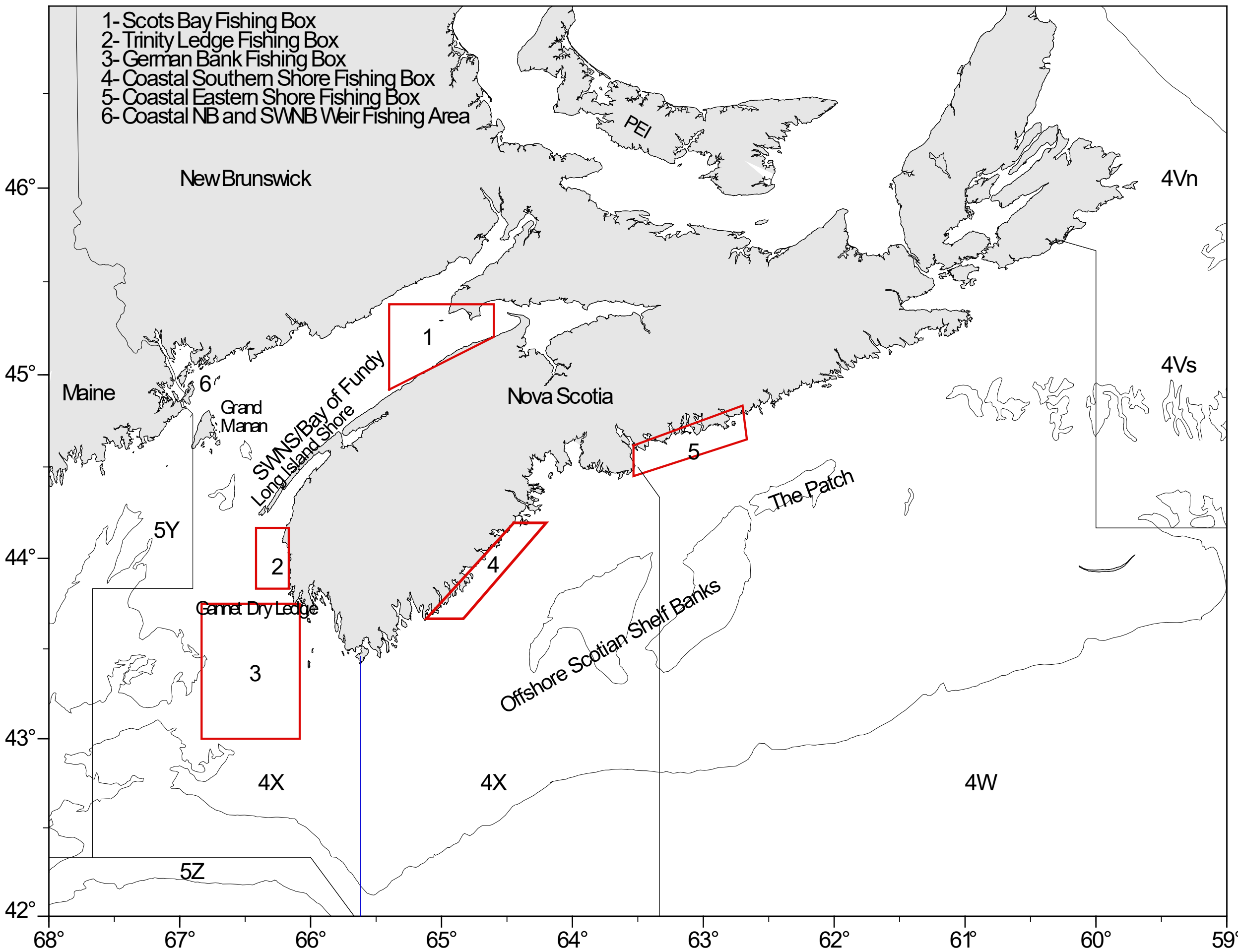

Figure 2. The main 4VWX Herring fisheries areas and the spawning grounds that make up the four spawning components.

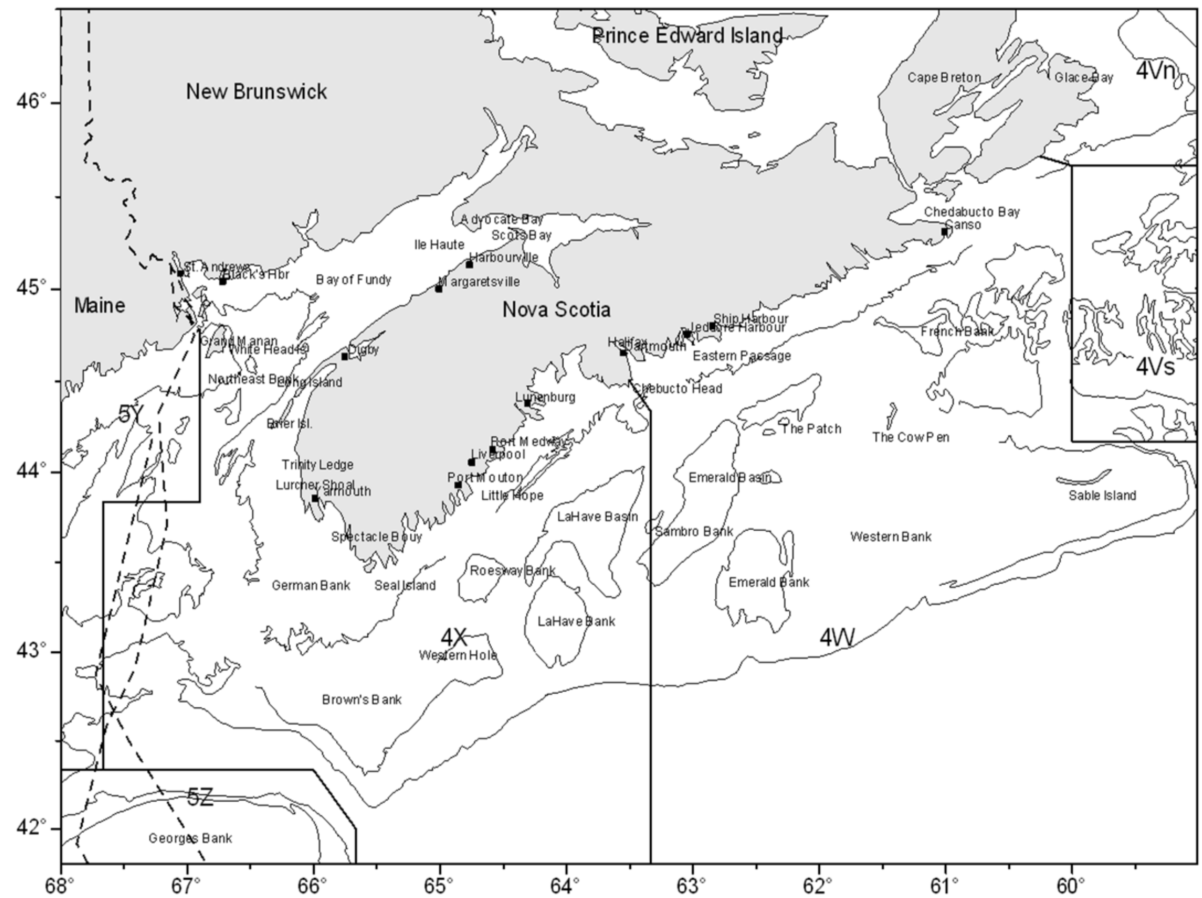

Figure 3. Place names and fishing locations for South West New Brunswick (SWNB), Coastal Nova Scotia and Scotian Shelf/Bay of Fundy.

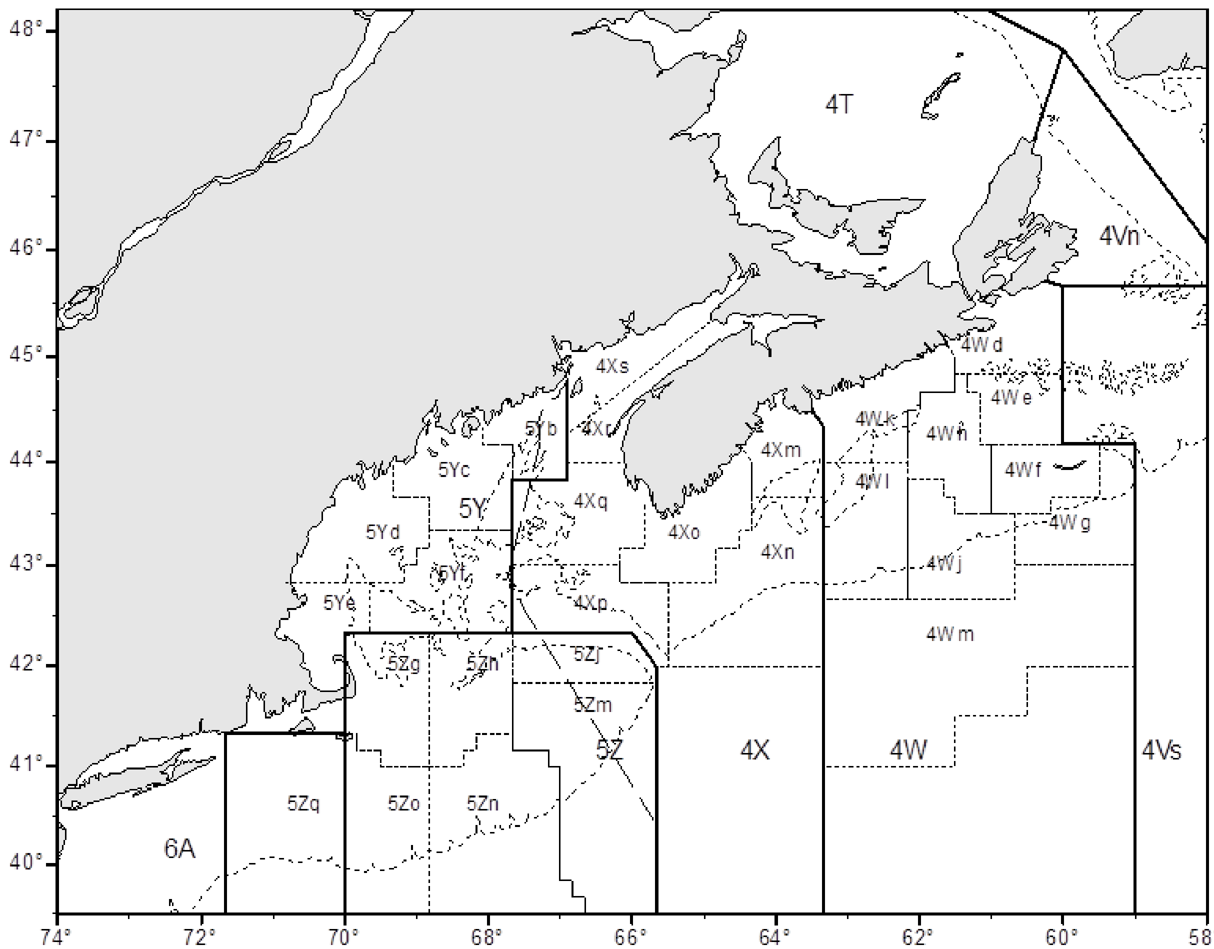

Figure 4. NAFO divisions, subareas, and unit areas used for sample and landings data aggregation.

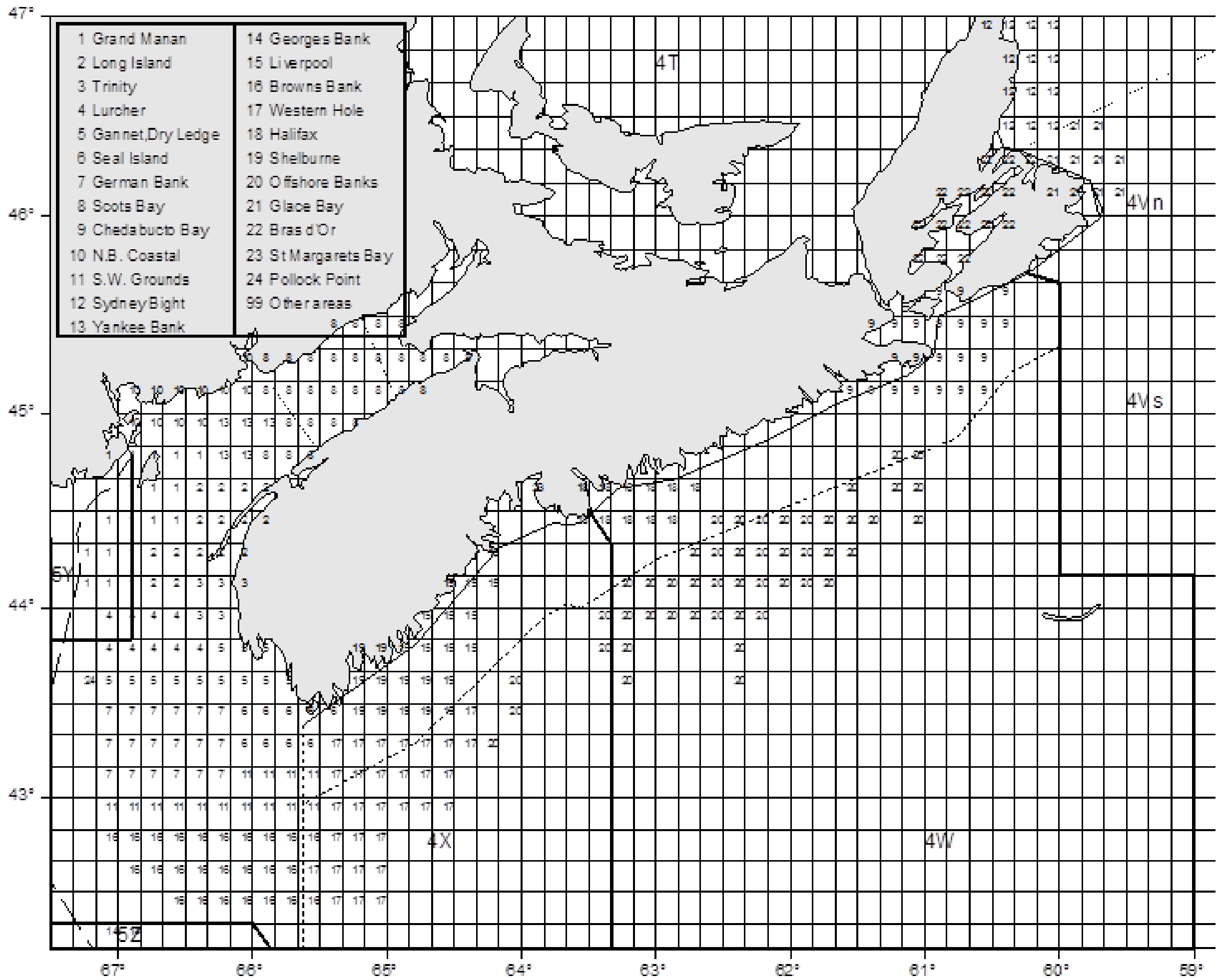

Figure 5. Herring fishing ground areas by 10-mile boxes and management lines for NAFO divisions, 25-mile offshore line, coastal embayment line, and Herring area lines.

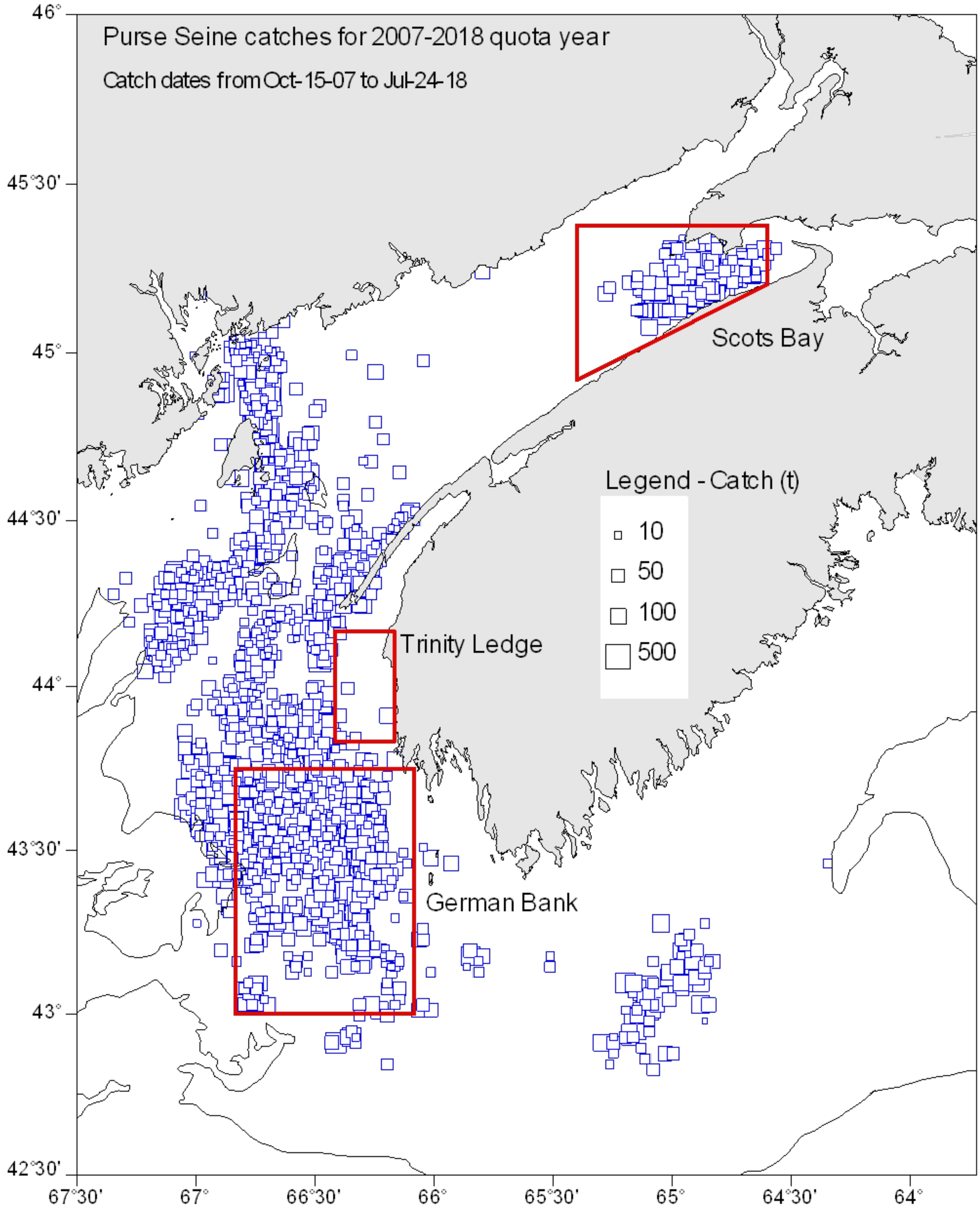

Figure 6. Herring catches on the three spawning grounds (Scots Bay, Trinity Ledge and German Bank) for the period 2007–2018.

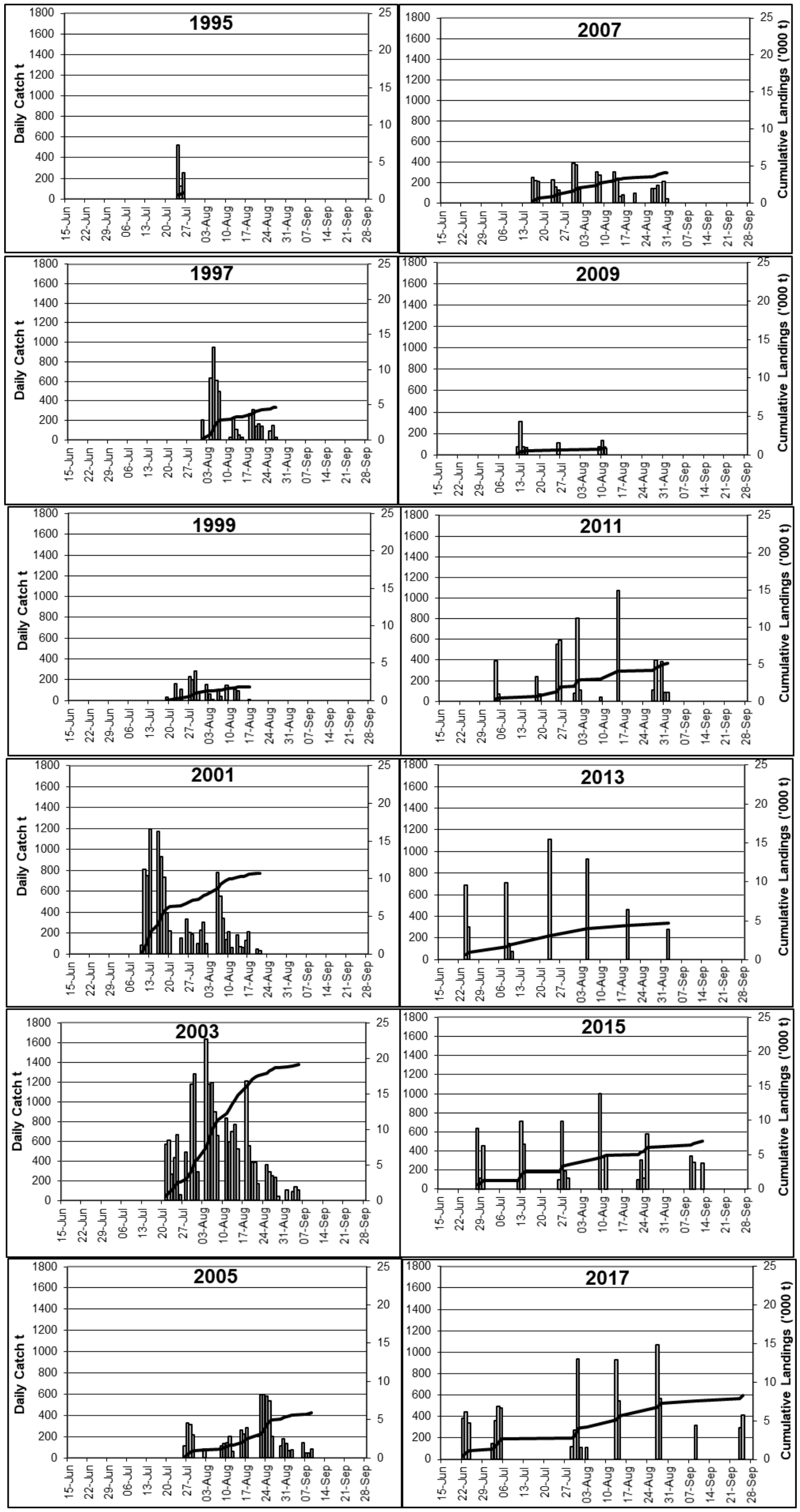

Figure 7. Timing of the 1995 to 2017 (on alternate years) Scots Bay fishery with daily catches in tonnes (bars) and the cumulative total catch (solid line) over the entire season.

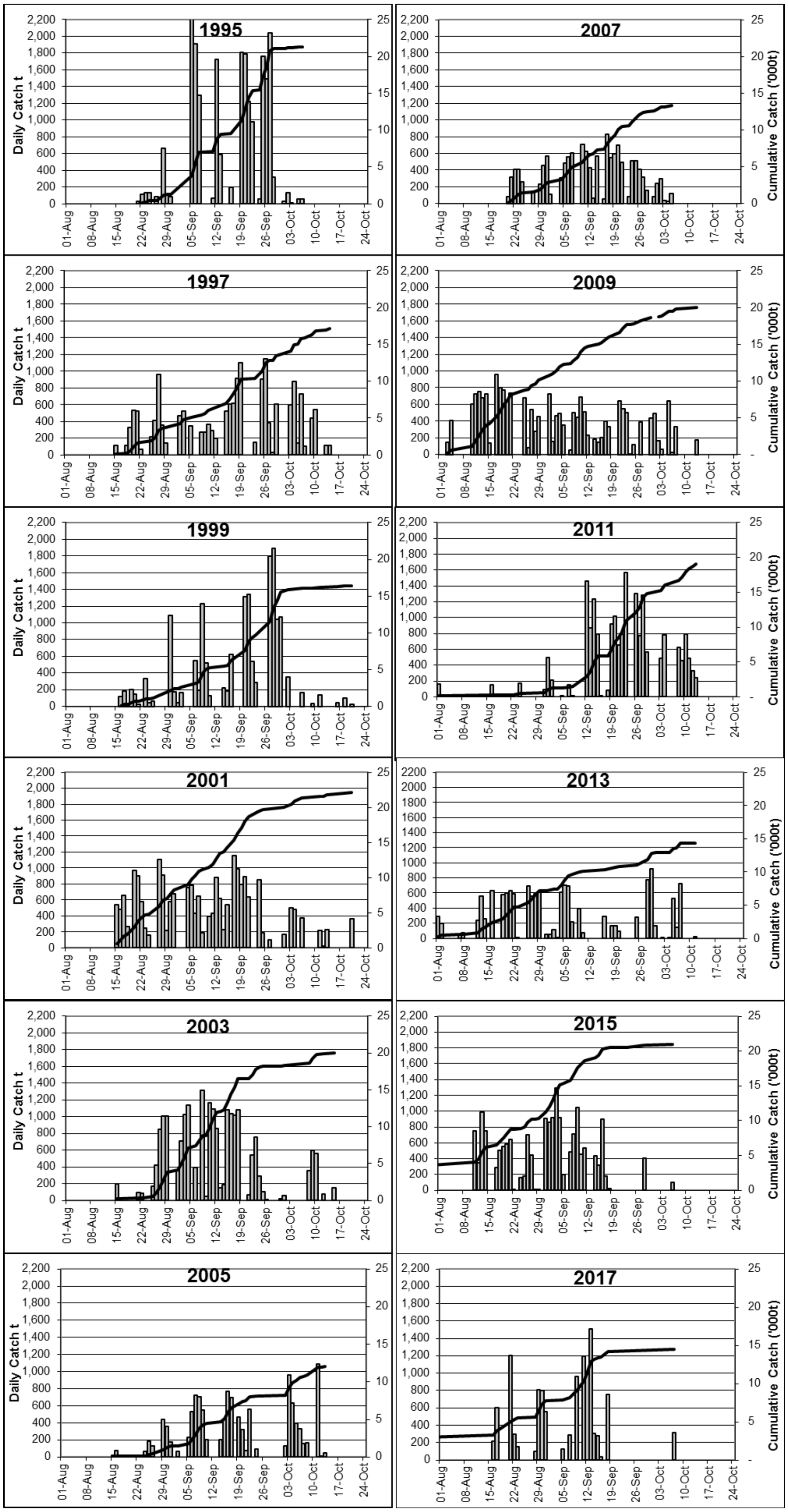

Figure 8. Timing of the 1995 to 2017 (on alternate years) German Bank fishery with daily catches in tonnes (bars) and the cumulative total catch (solid line) over the entire season.

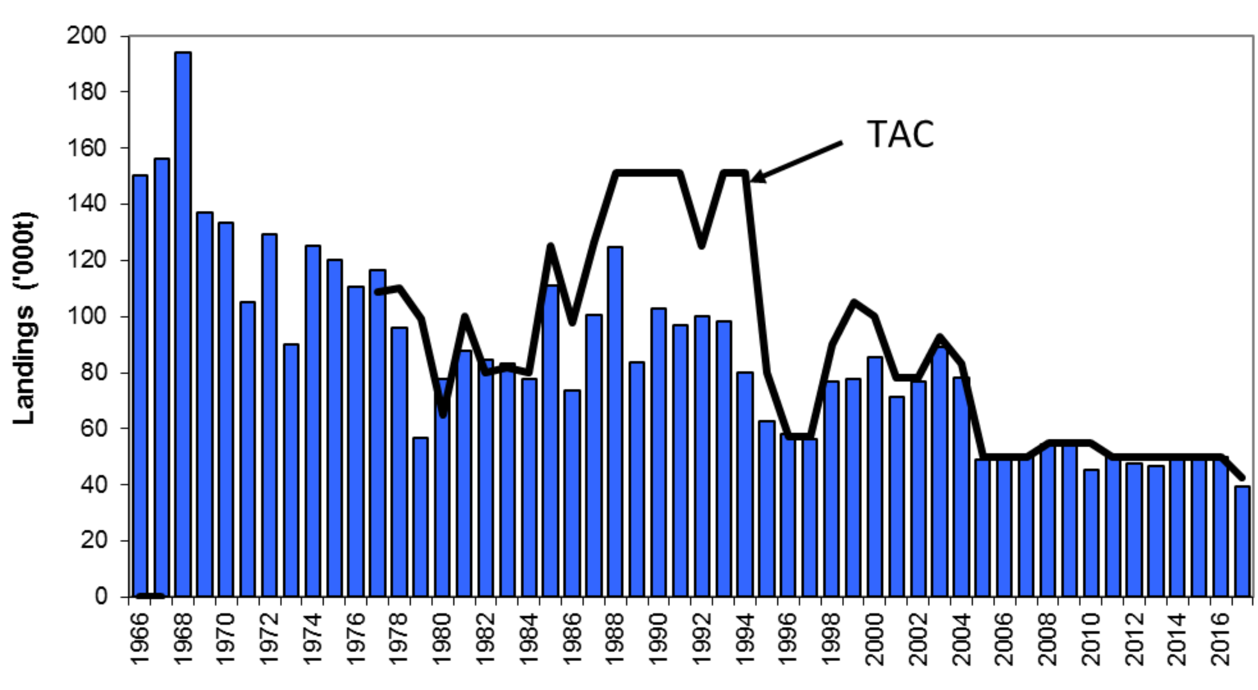

Figure 9. Annual adjusted Herring landings [bars] and TAC [solid line] for the SWNS/BoF spawning component (4WX stock).

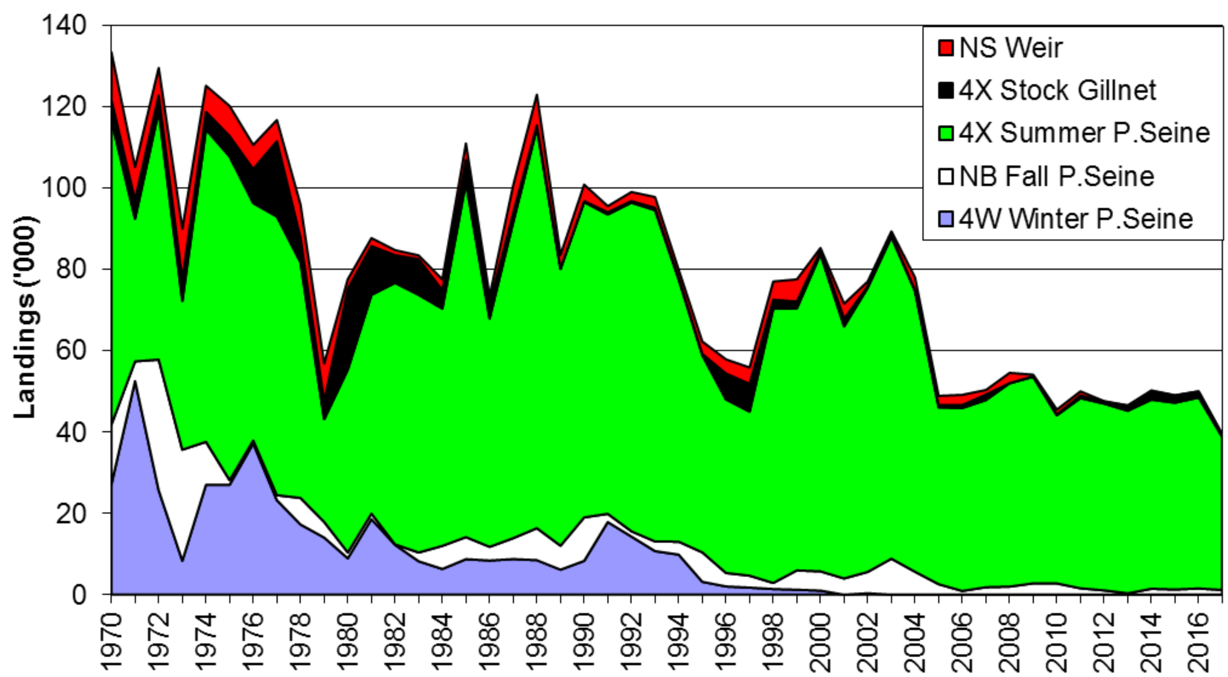

Figure 10. Annual Herring landings by gear component for the SWNS/BoF spawning component (4WX stock) from 1970–2017.

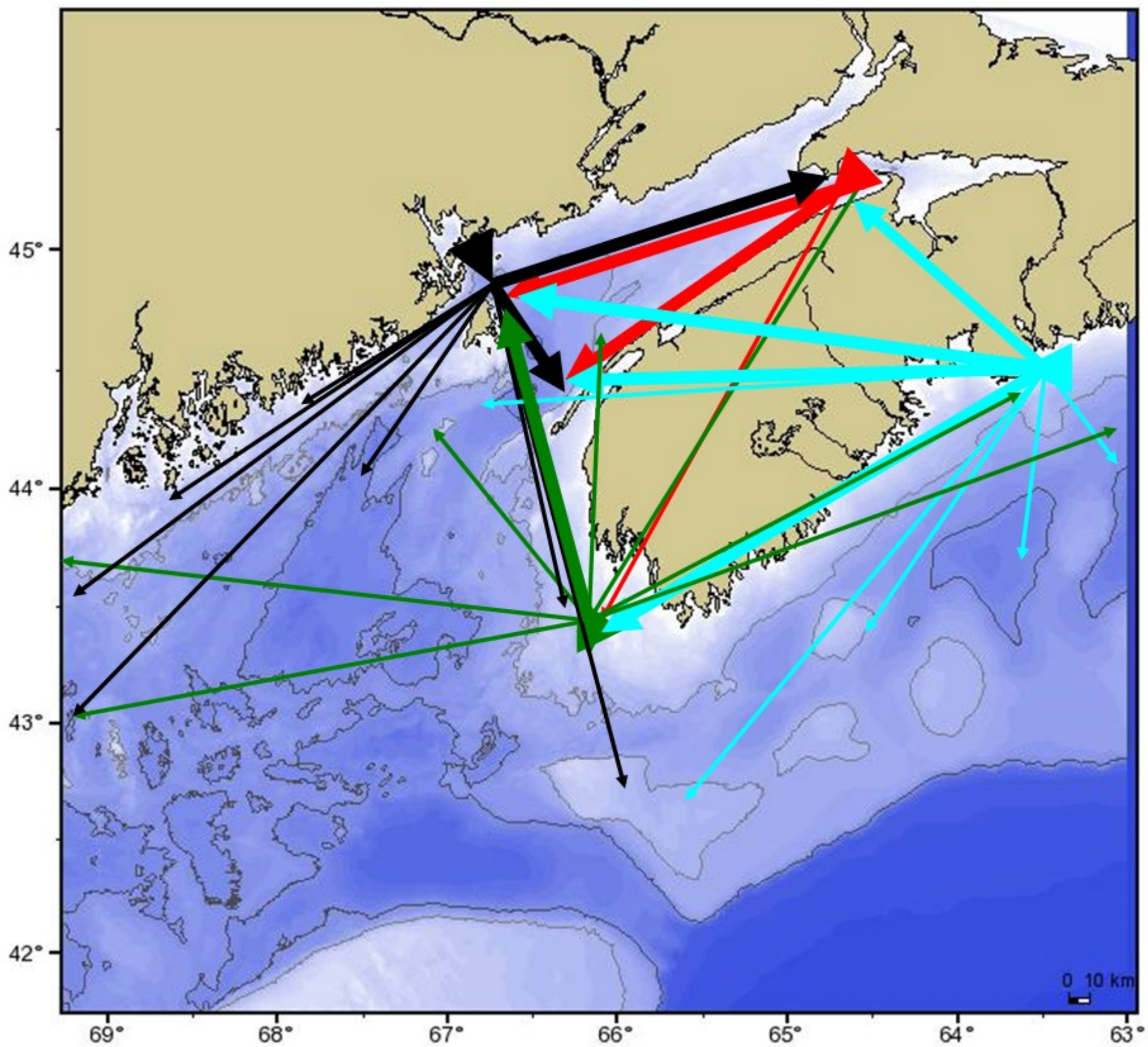

Figure 11. Movement of Herring tagged in Scots Bay (1998–2006), NB Weirs (1999–2004), German Bank (1998–2011) and off Chebucto Head (1999).

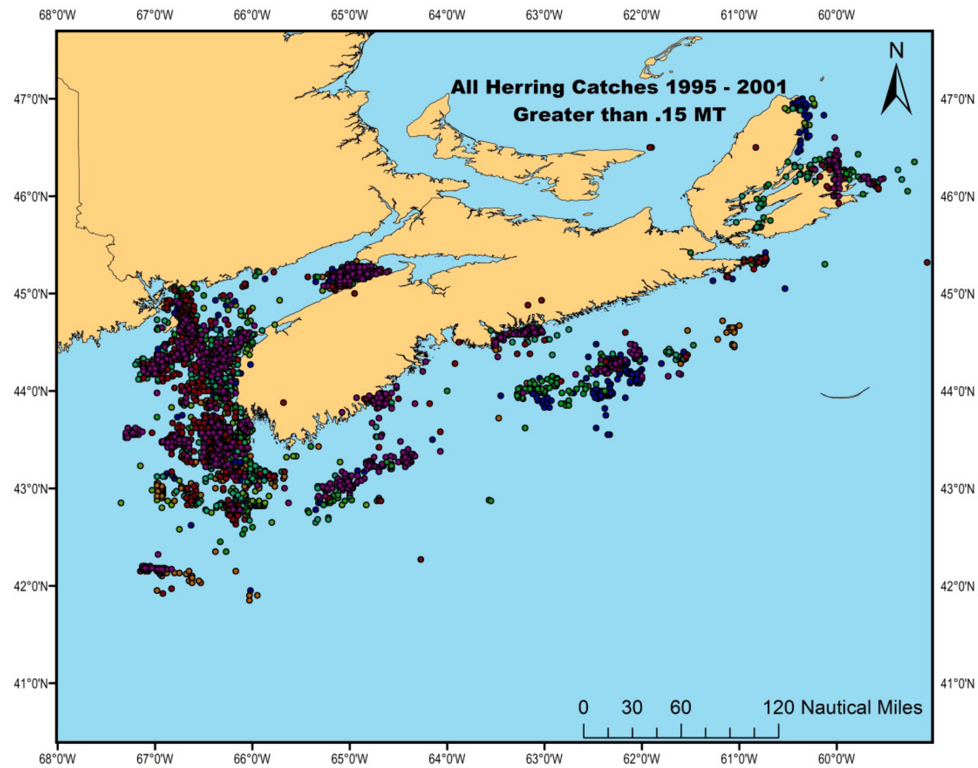

Figure 12. Herring landings greater than 0.15 mt from 1995–2001 for the entire 4VWX area.

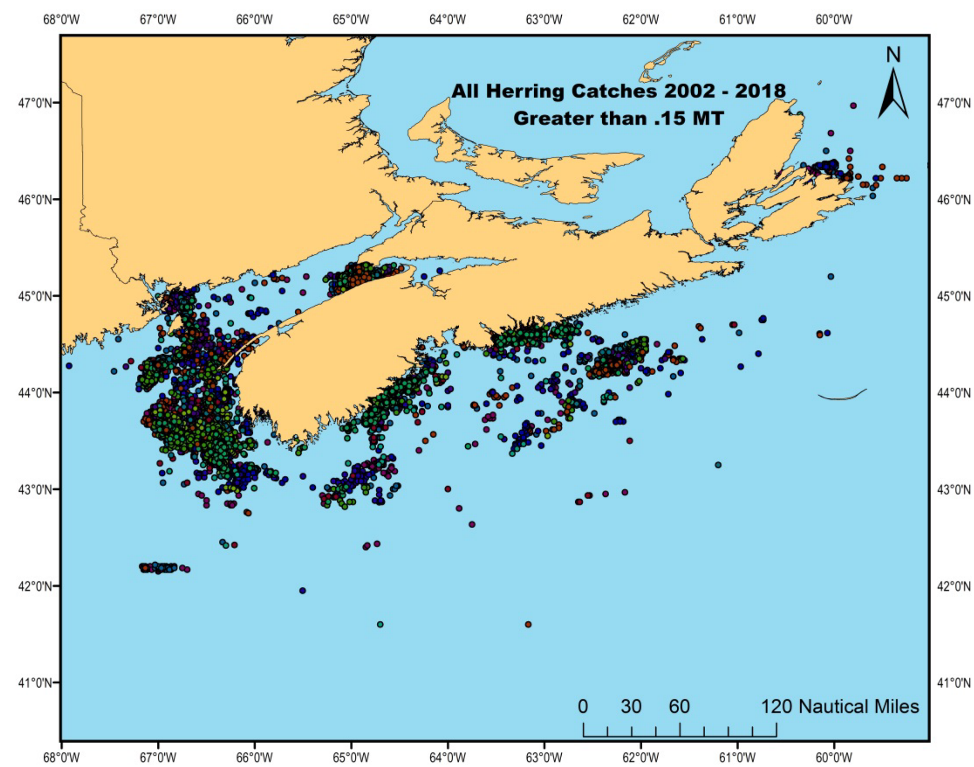

Figure 13. Herring landings greater than 0.15 mt from 2002–2018 for the entire 4VWX area.

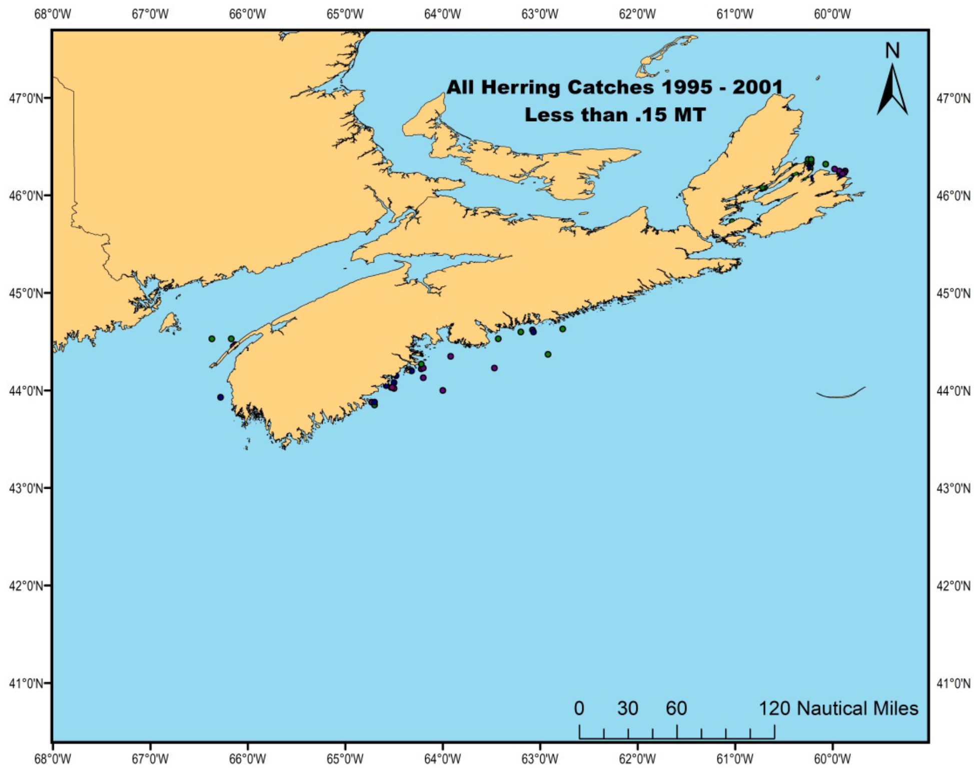

Figure 14. Herring landings less than 0.15 mt from 1995–2001 for the entire 4VWX area.

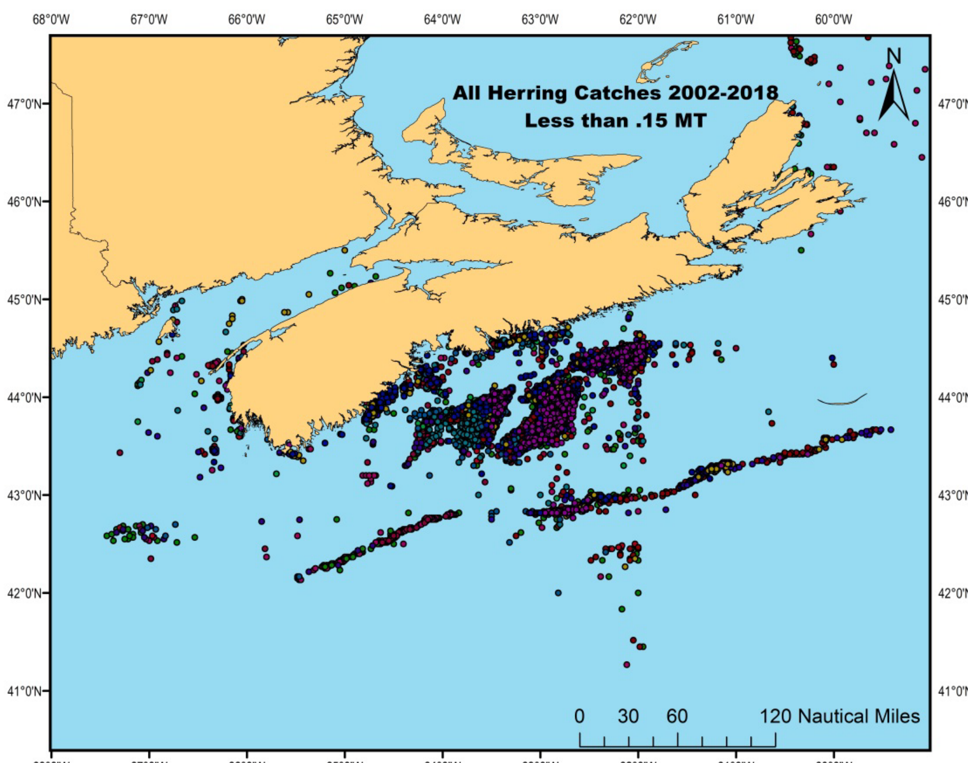

Figure 15. Herring landings less than 0.15 mt from 2002–2018 for the entire 4VWX area.

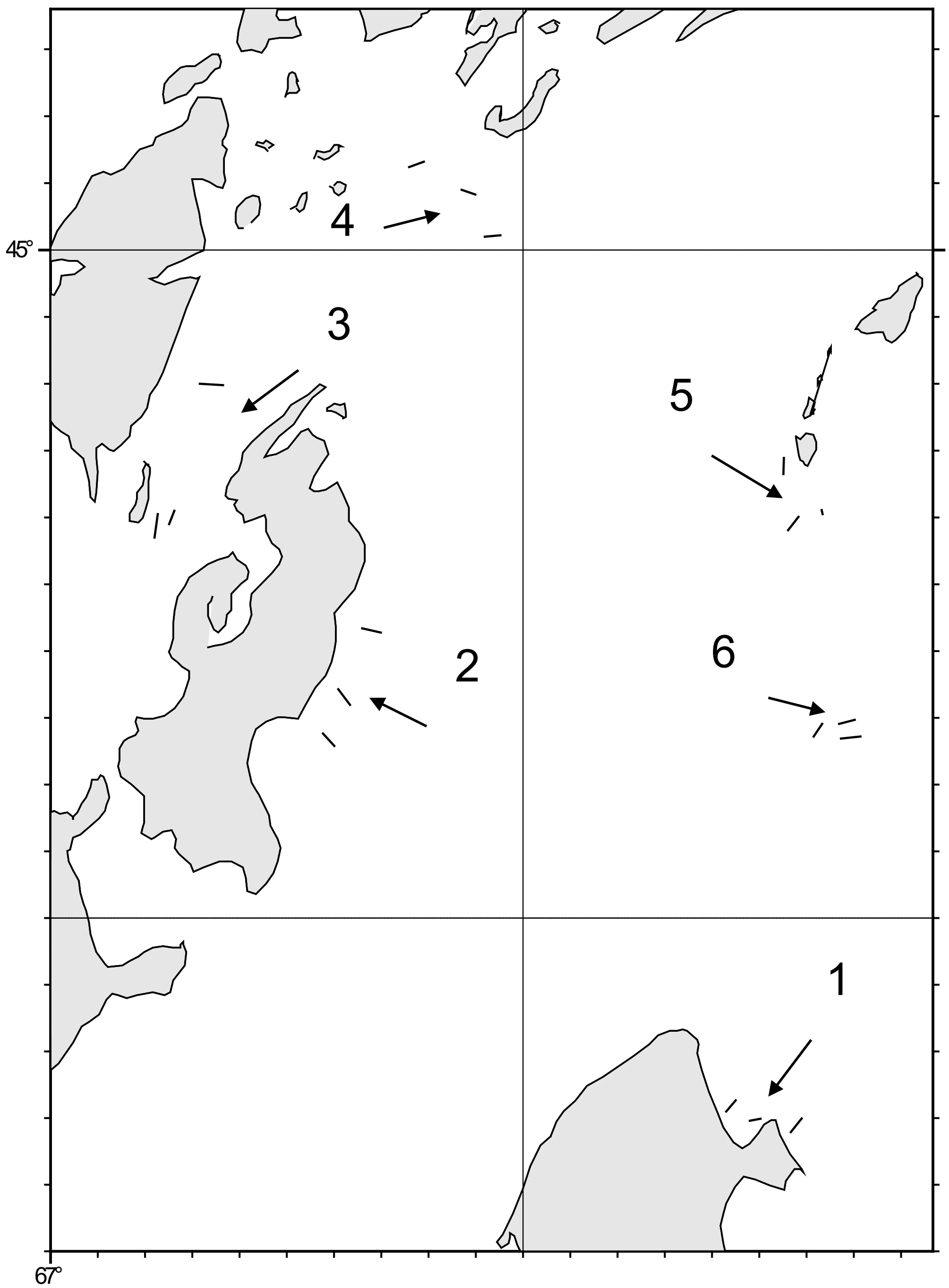

Figure 16. Chart showing 2008 spawning study areas: from northern Grand Manan Island clockwise to Campobello Island coast, Indian and Deer Islands, Bliss Island, the Wolves Islands and Wolves Bank.

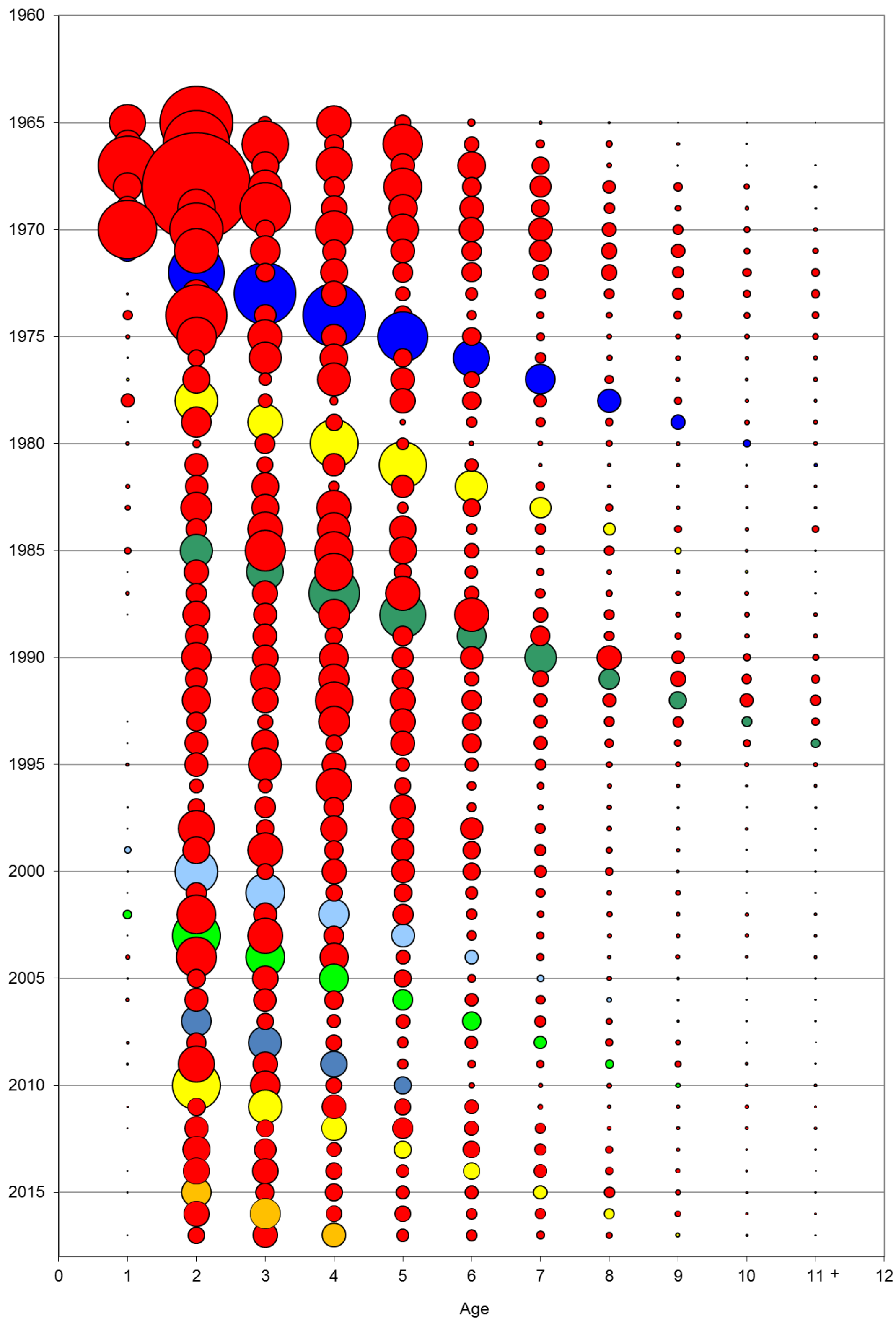

Figure 17. Historical relative numbers at age (denoted by circle size) for the SWNS/BoF Herring spawning component from 1965–2017. Several of the stronger year-classes are indicated by colours including the 1970, 1978, 1983, 1998, 2001, 2005, 2008 and 2013 year-classes.

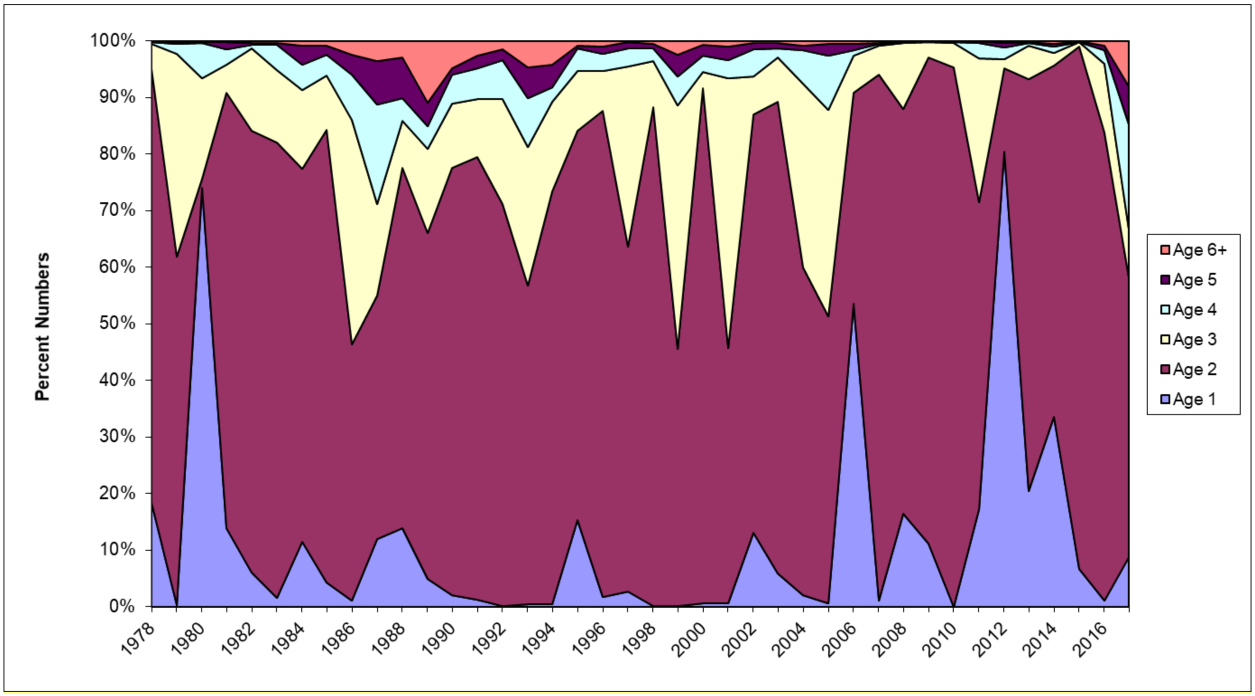

Figure 18. Historical New Brunswick (NB) weir catch-at-age for 1978 to 2017 for ages 1 to 6+.

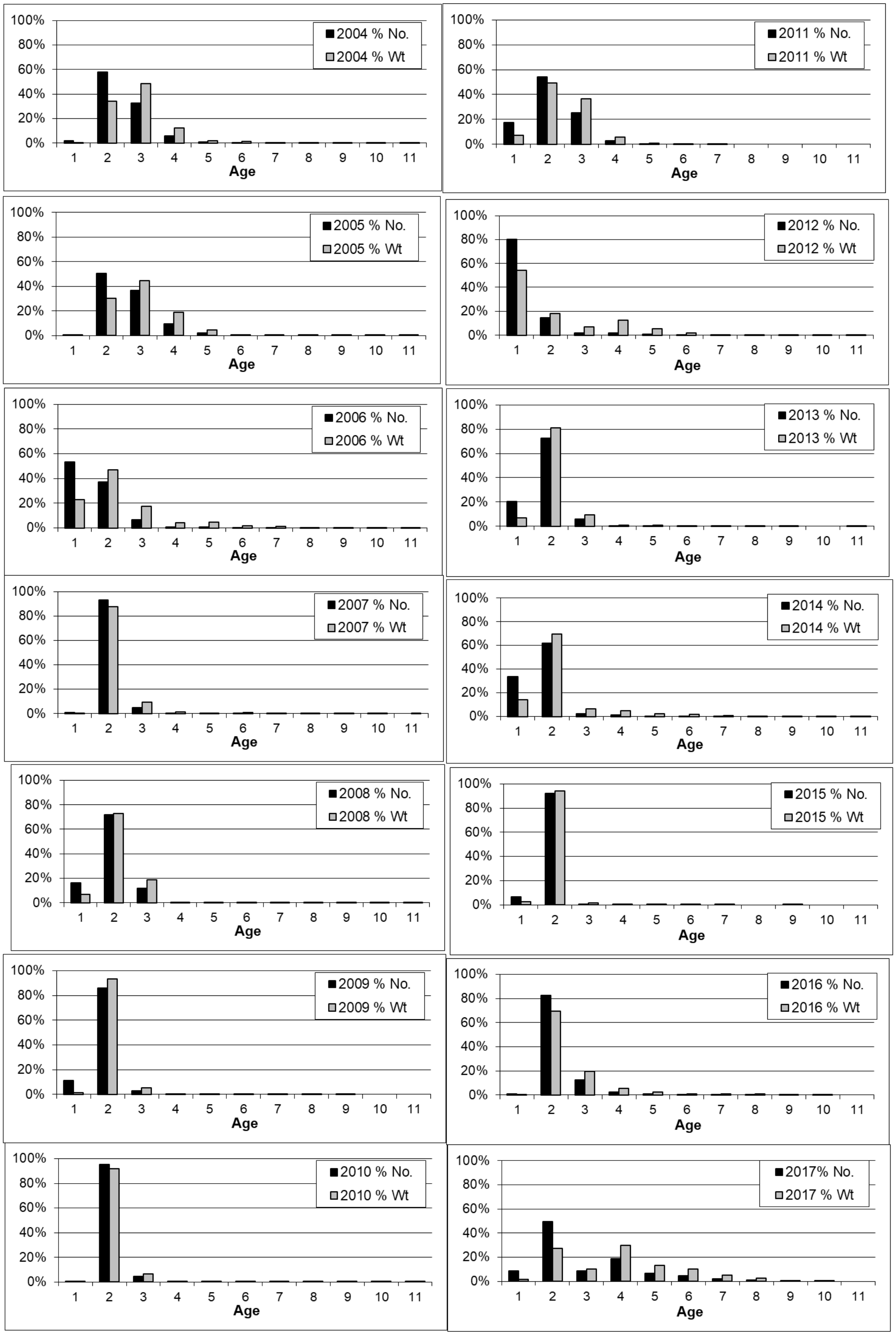

Figure 19. Catch-at-age for New Brunswick (NB) weir and shutoff (% numbers and % weight) from 2005 to 2017.

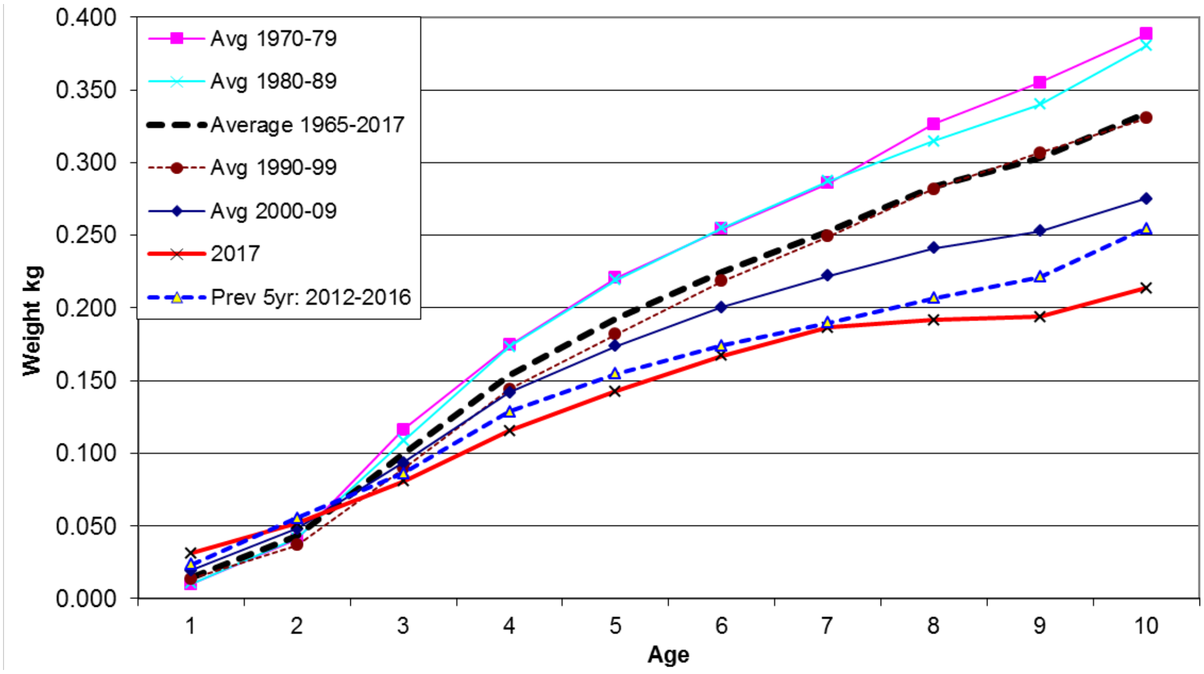

Figure 20. Average weights at age (kg) for the SWNS/BoF component of the 4WX Herring fishery (fishery weighted) for the most recent year, by decade and the long term for the historical series.

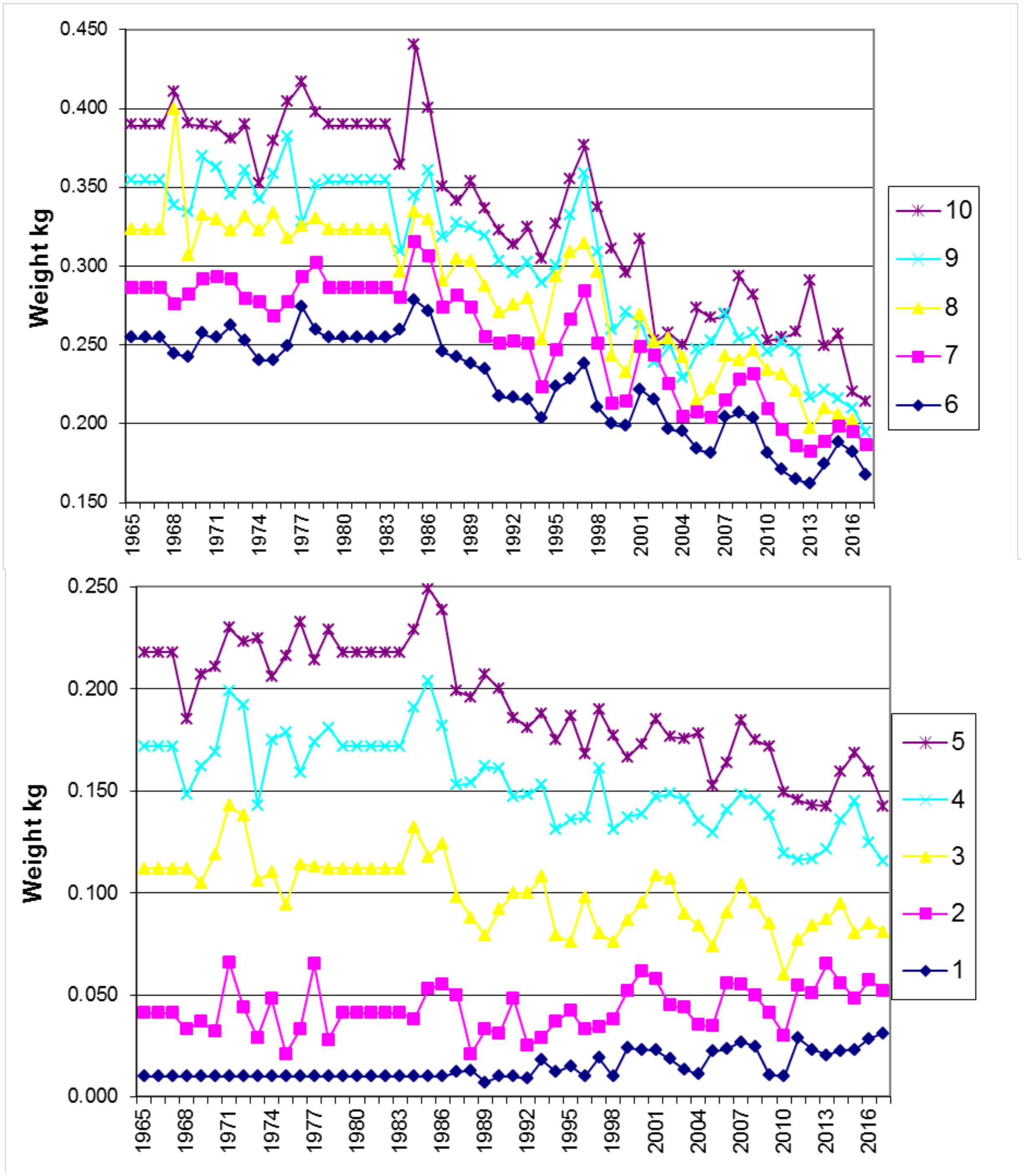

Figure 21. Average weights at age (kg) for the SWNS/BoF component of the 4WX Herring fishery (fishery weighted) for 1965–2017.

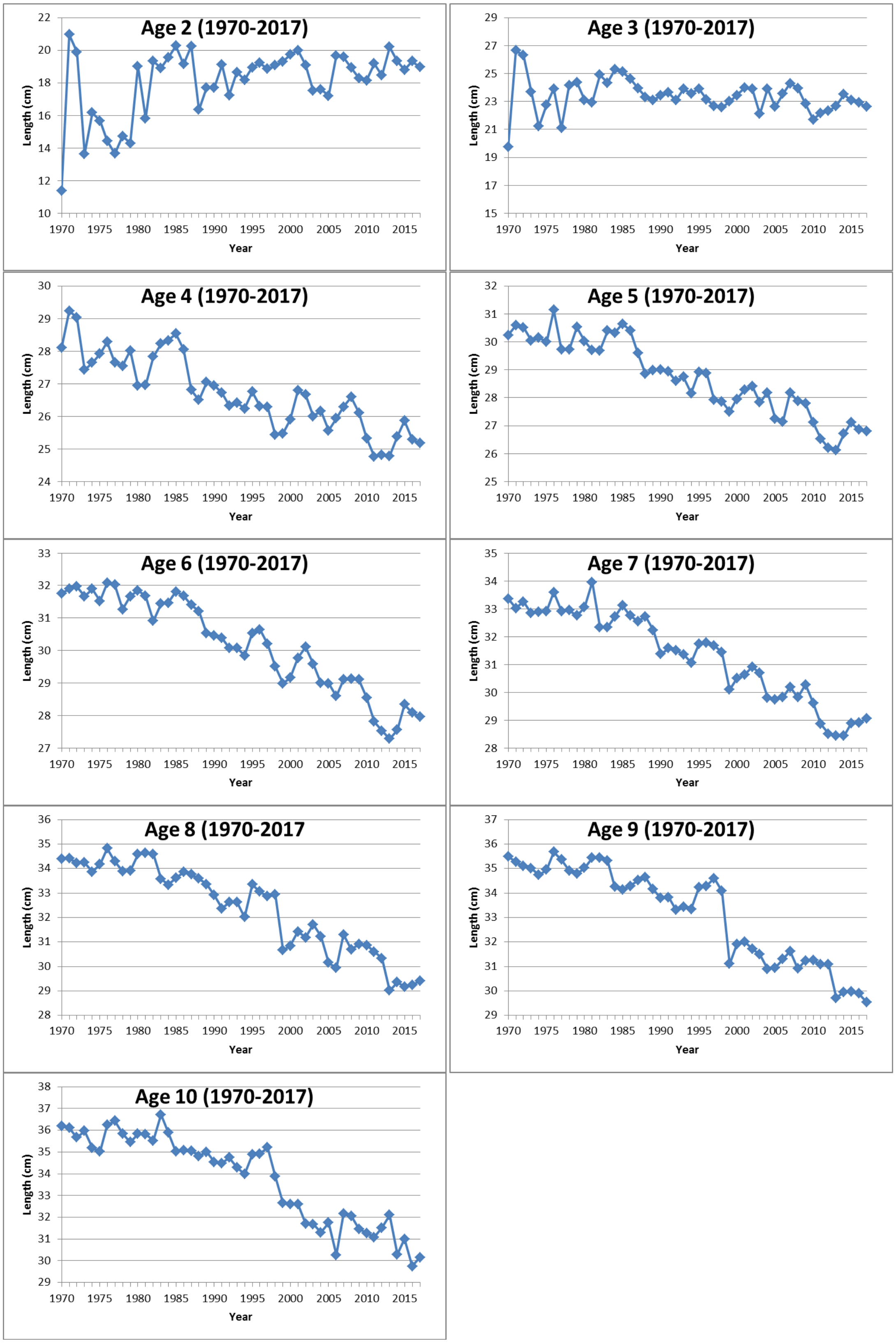

Figure 22. Average lengths (cm) at age for the SWNS/BoF component of the 4WX Herring fishery (fishery weighted) for 1970–2017.

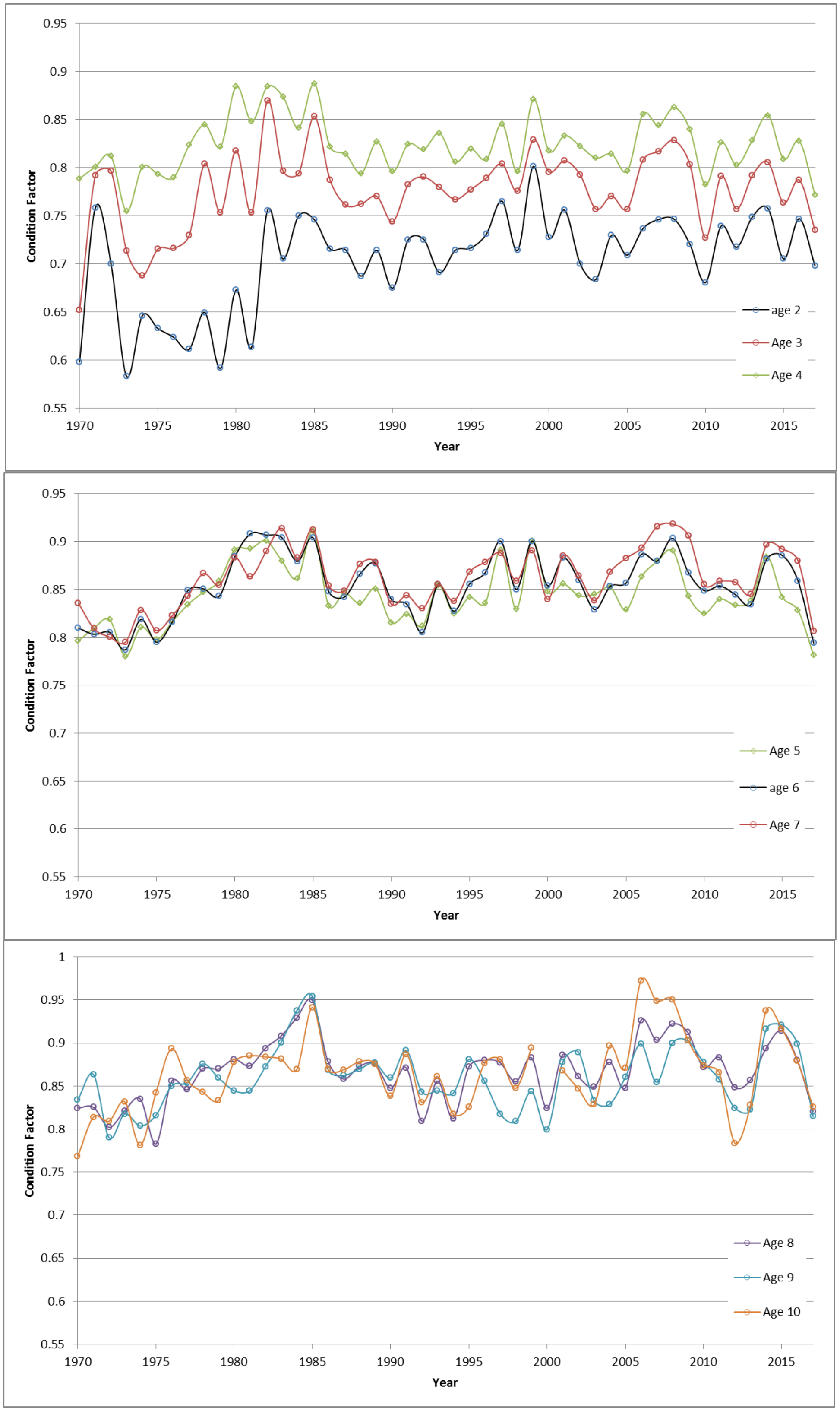

Figure 23. Condition factor for ages 2–10 Herring caught by the purse seine fishery in the SWNS/BoF area from 1970 to 2017.

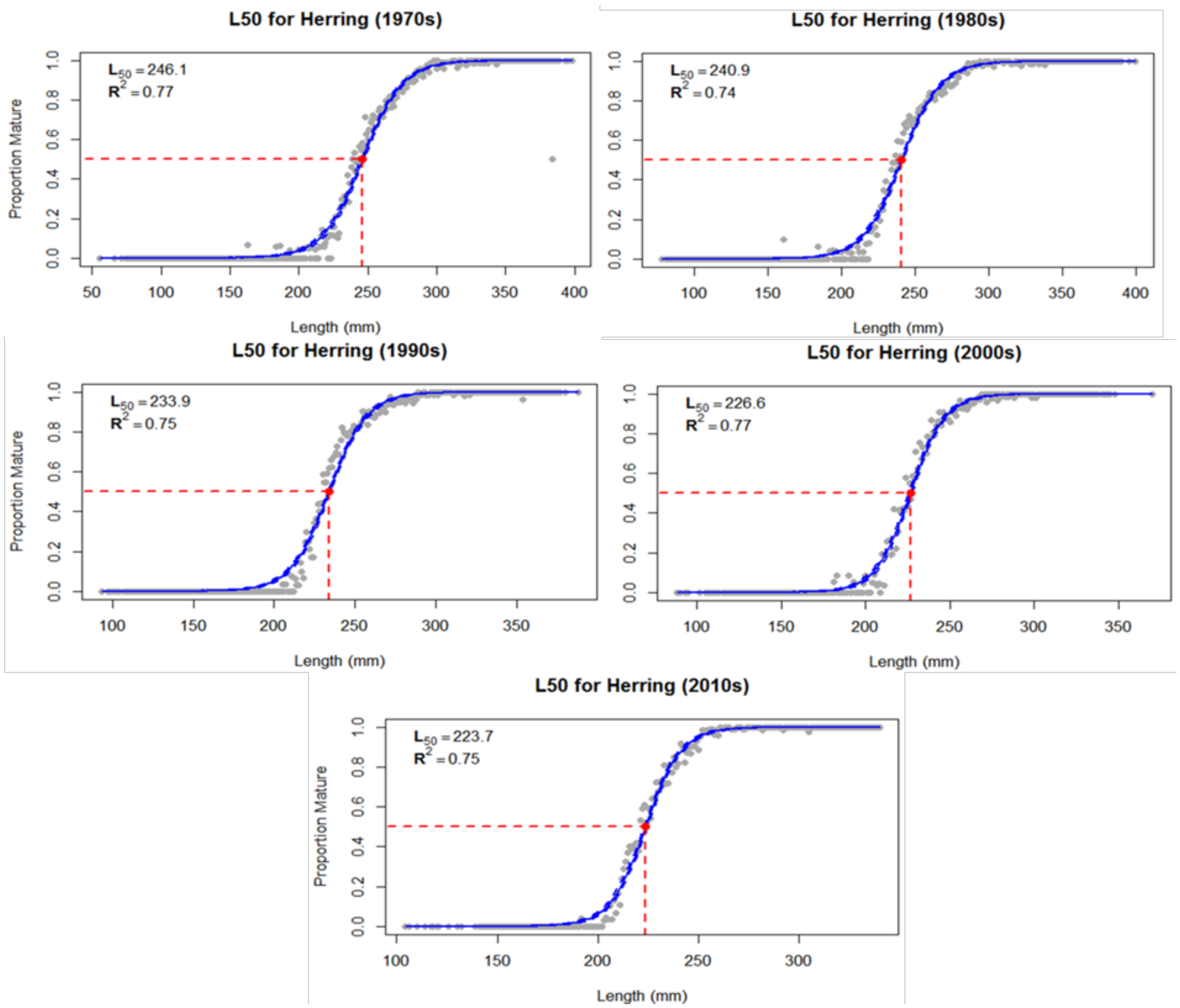

Figure 24. Average length (mm) at 50% maturity for the SWNS/BoF component of the 4WX Herring by decade with data range from 1970–2017.

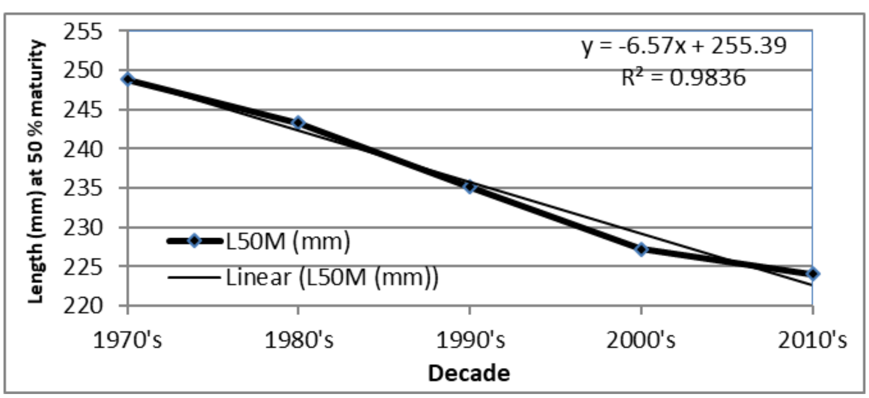

Figure 25. Regression of average length (mm) at 50% maturity by decade for the SWNS/BoF component of the 4WX Herring.

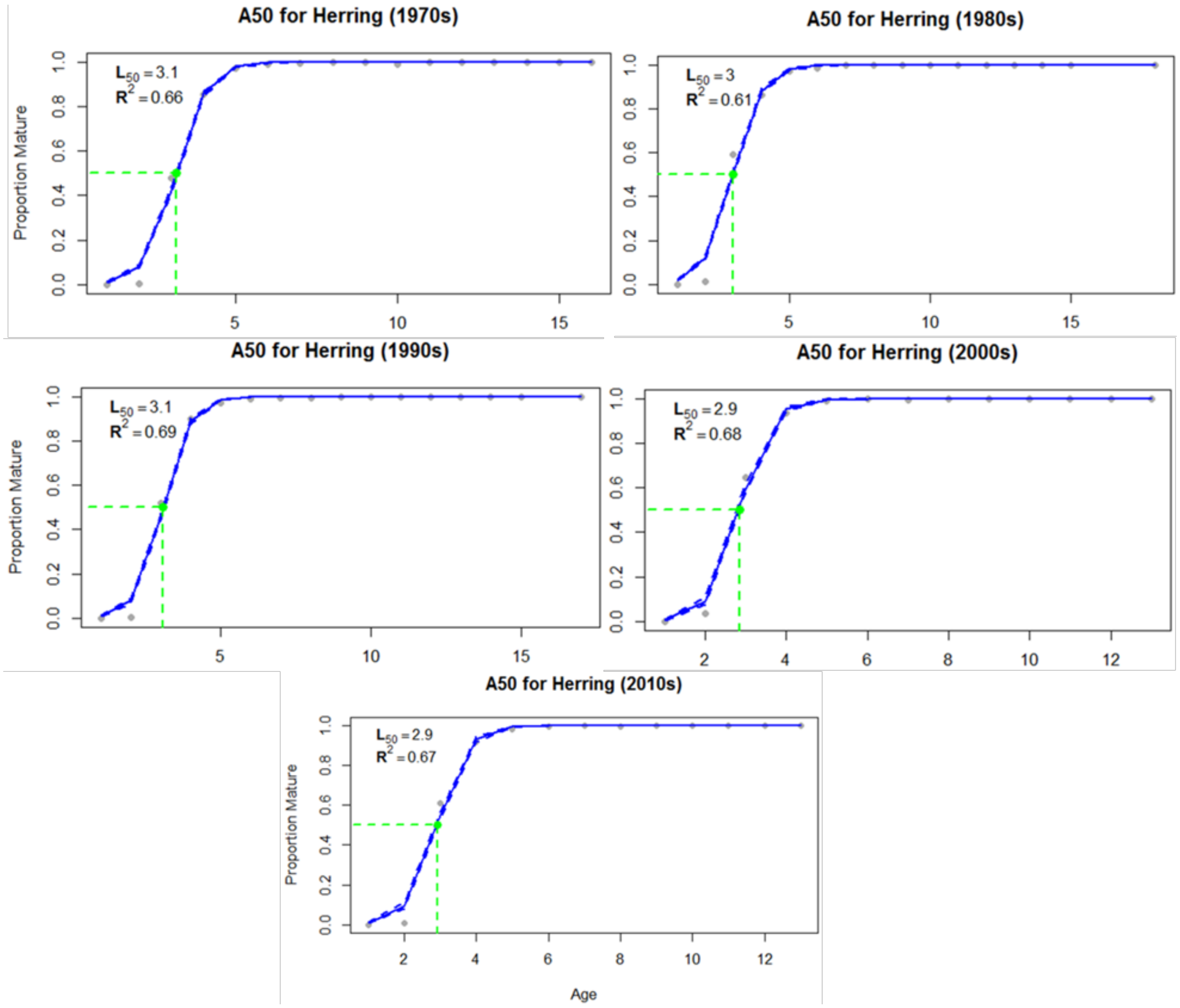

Figure 26. Age at 50% maturity for the SWNS/BoF component of the 4WX Herring by decade with data range from 1970–2017.

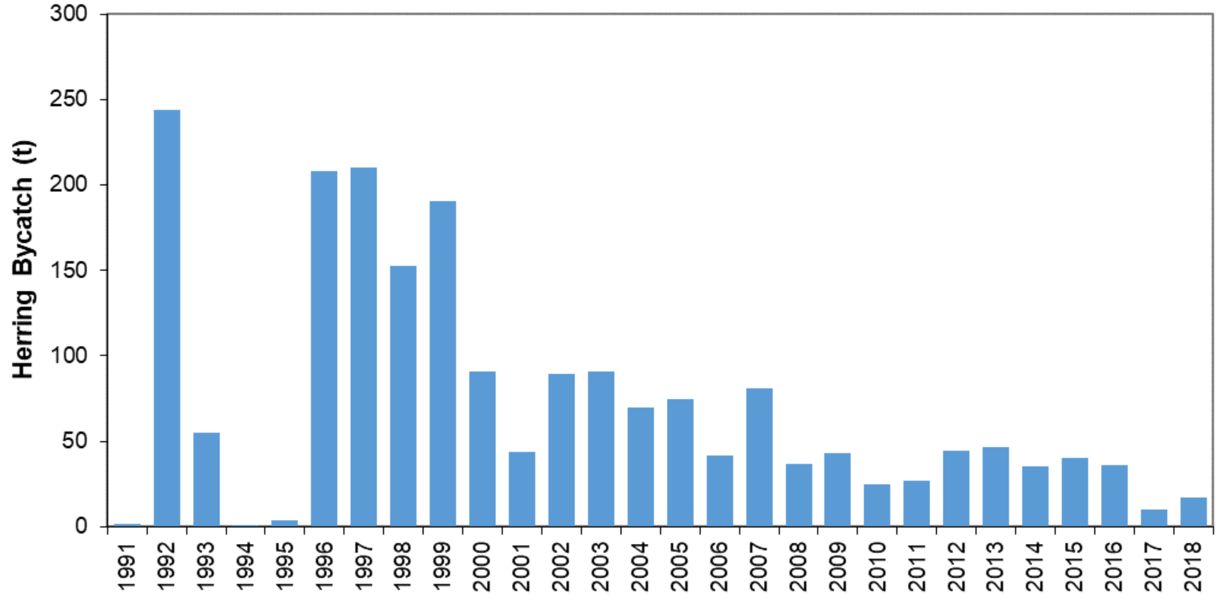

Figure 27. Herring bycatch from the all bottom trawl fisheries on the Scotian Shelf from 1991–2018.

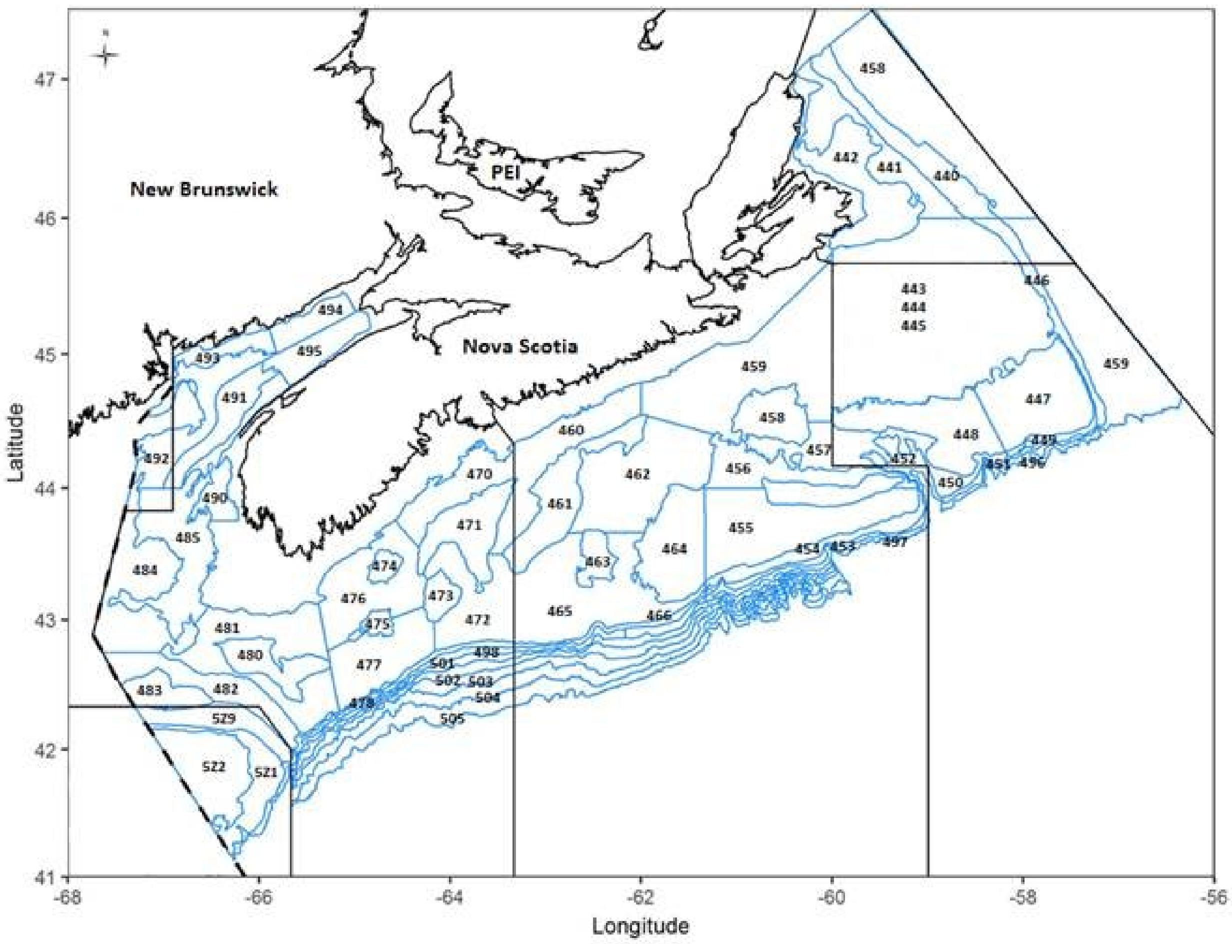

Figure 28. Groundfish survey strata in NAFO Divisions 4V, 4W, and 4X (from DFO 2018b).

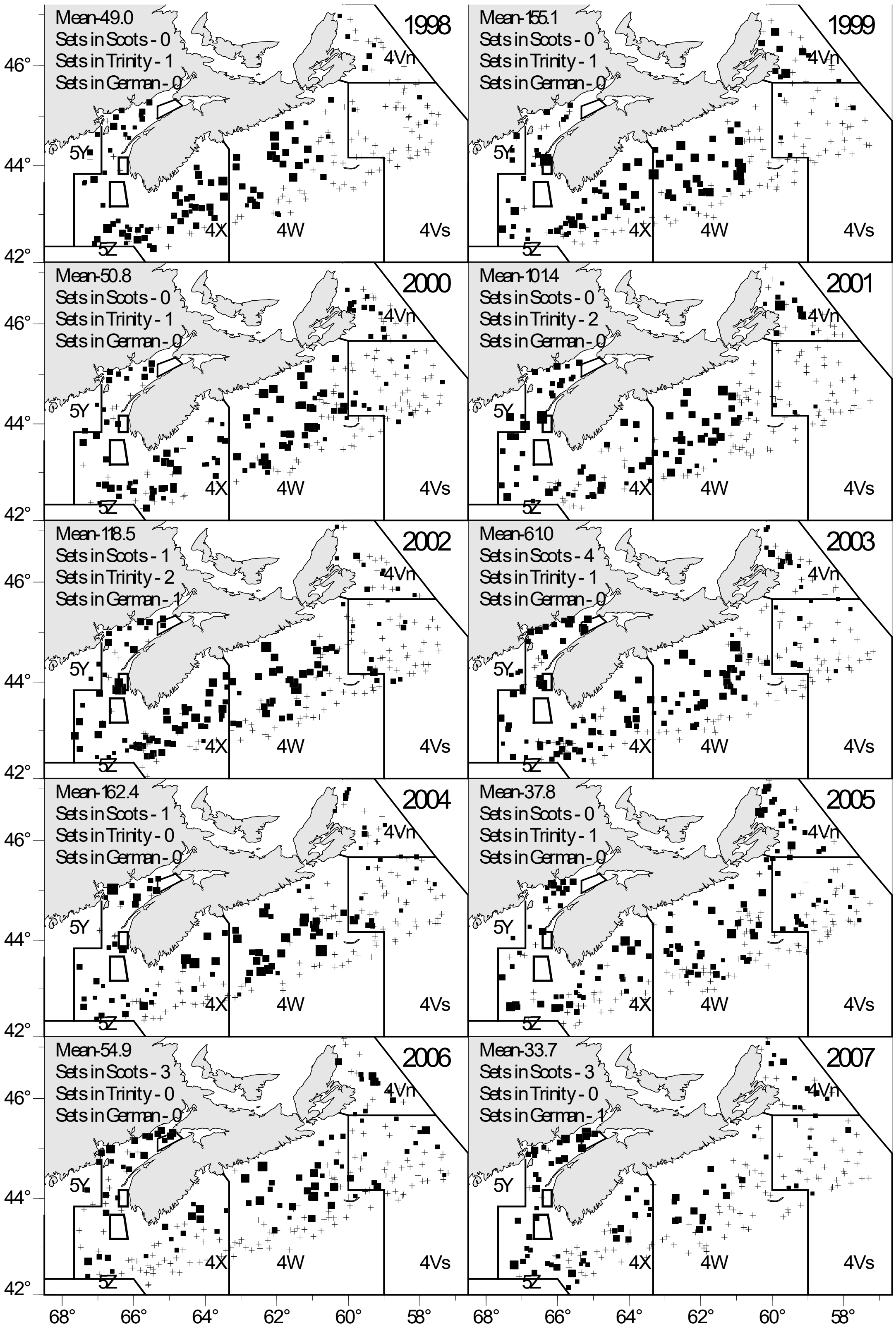

Figure 29. Herring catches (by number) from the DFO summer bottom trawl research survey for 1998–2007. Mean numbers per standard tow and count of sets in Scots, Trinity, and German spawning areas.

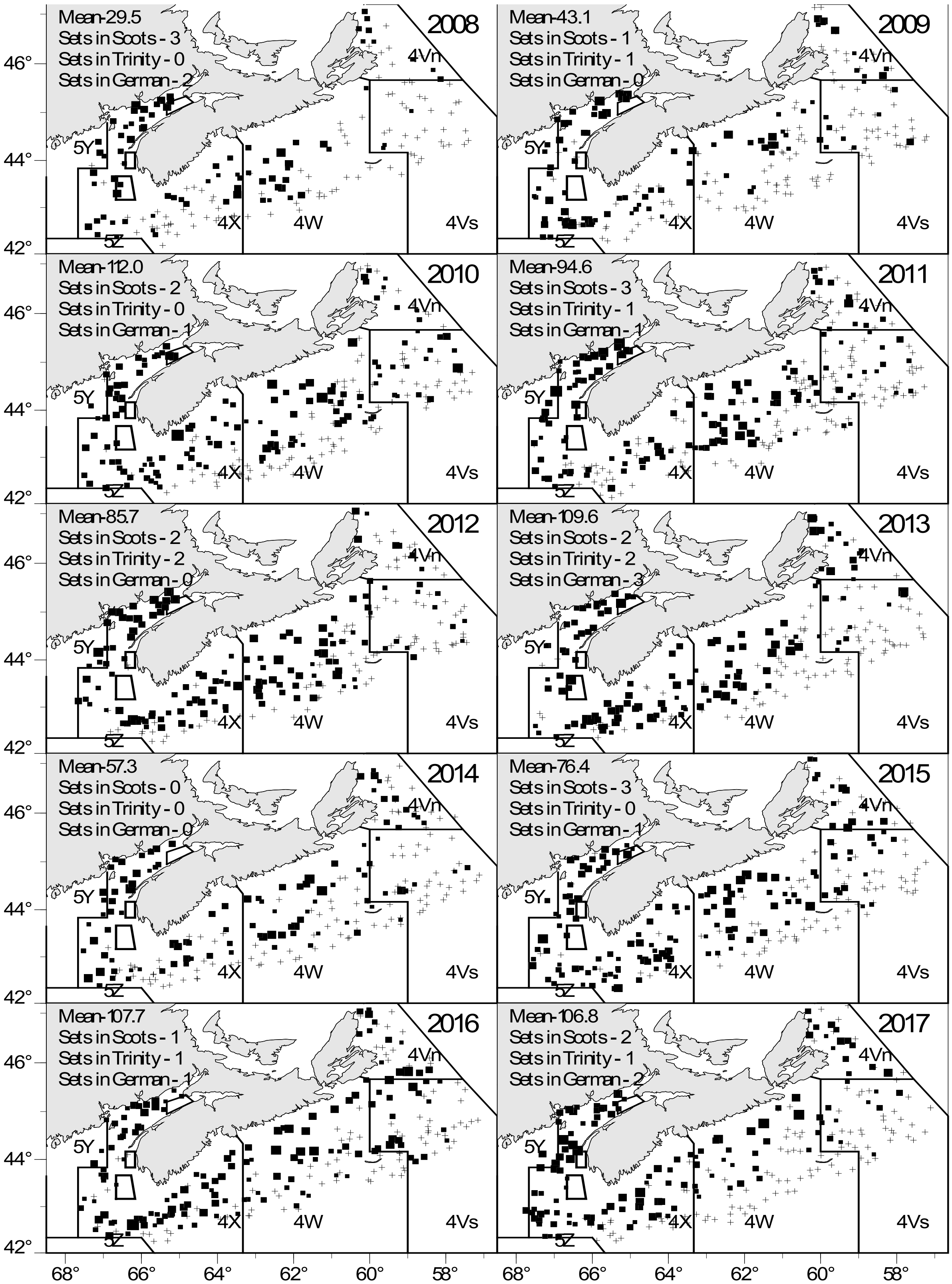

Figure 30. Herring catches (by number) from the DFO summer bottom trawl research survey for 2008–2017. Mean numbers per standard tow and count of sets in Scots, Trinity, and German spawning areas.

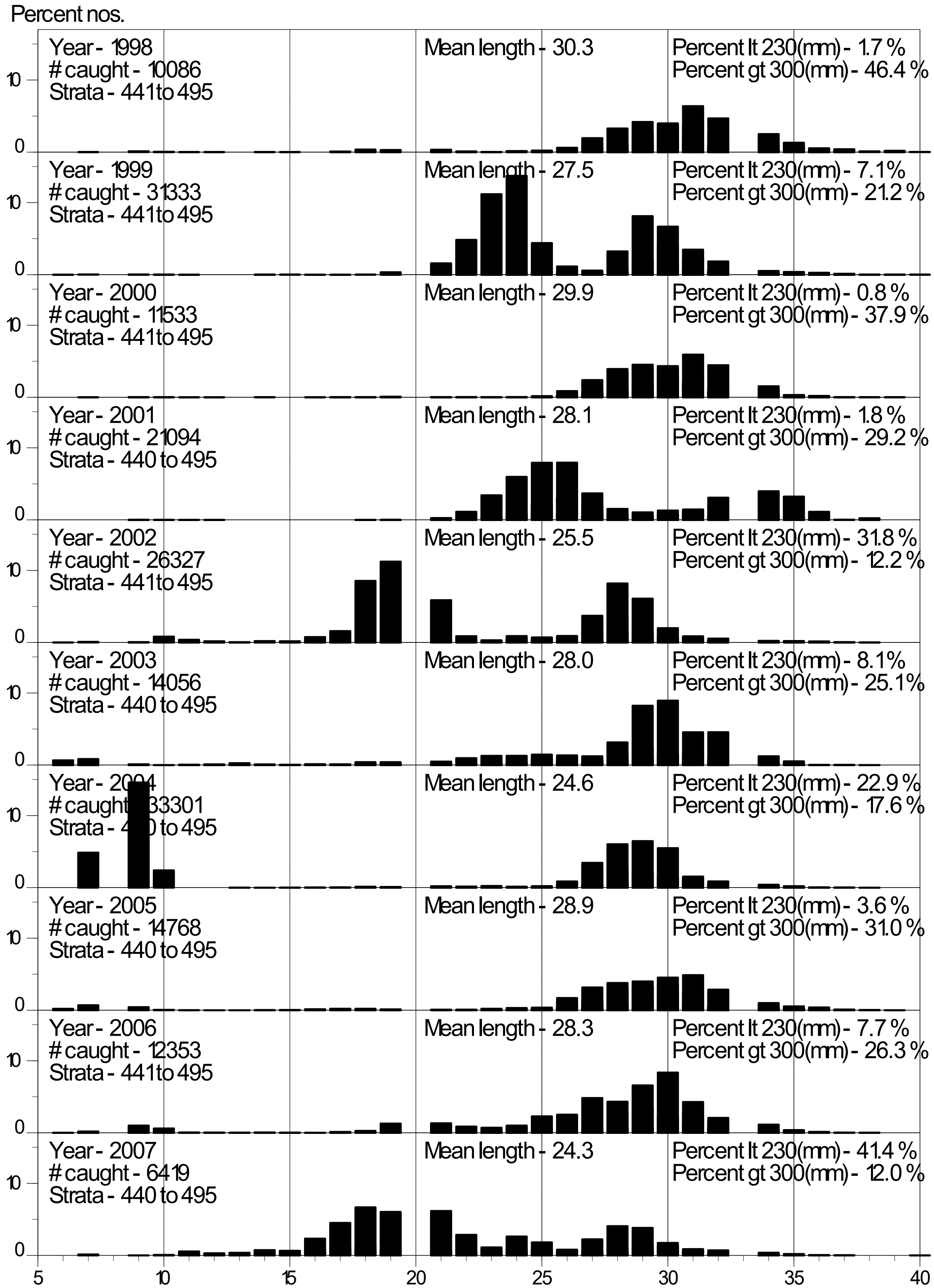

Figure 31. The 1998–2007 Herring size distribution (fork length converted to total length cm) from the July bottom trawl research survey for the entire 4VWX area of coverage.

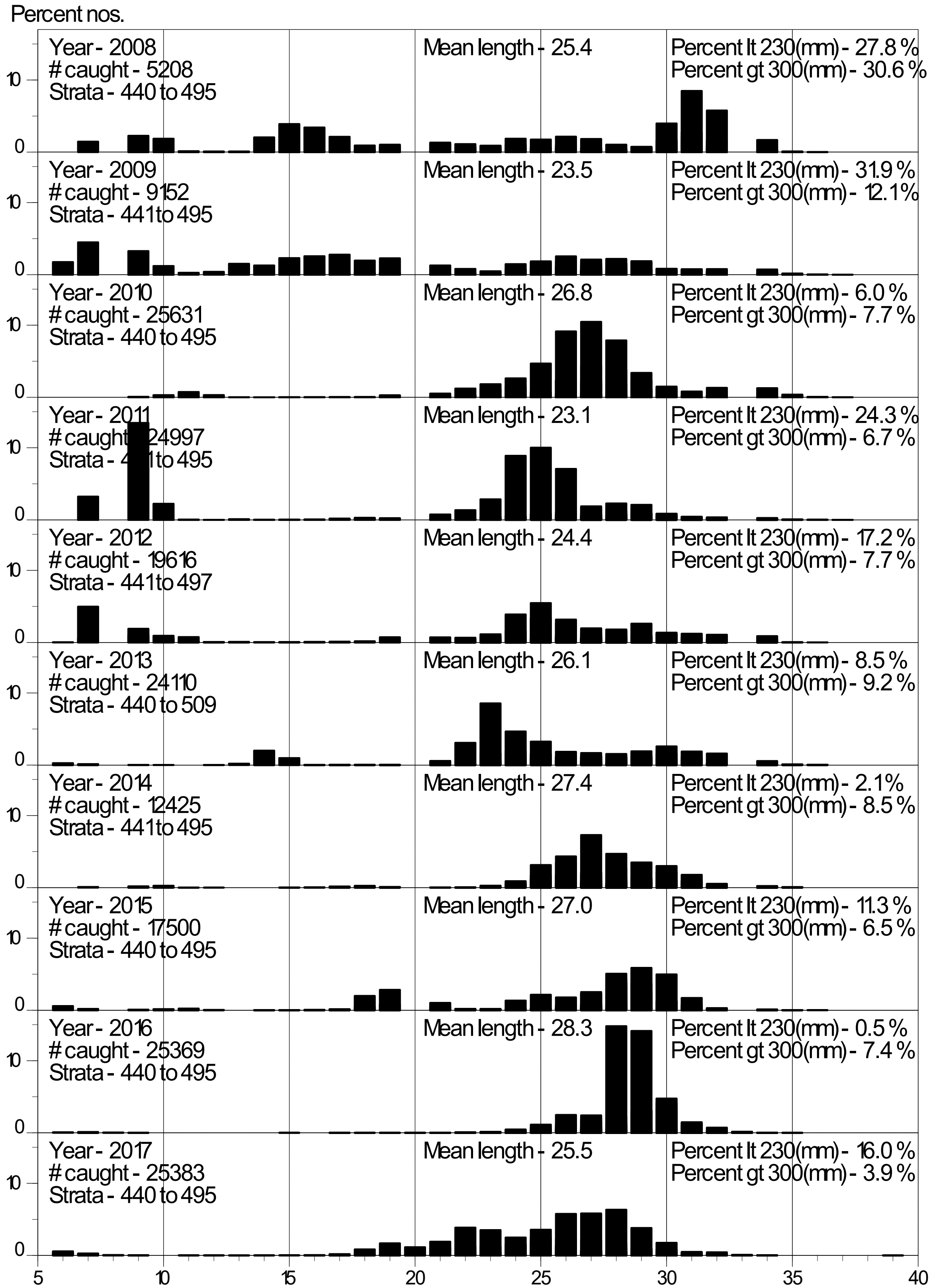

Figure 32. The 2008–2017 Herring size distribution (fork length converted to total length cm) from the July bottom trawl research survey for the entire 4VWX area of coverage.

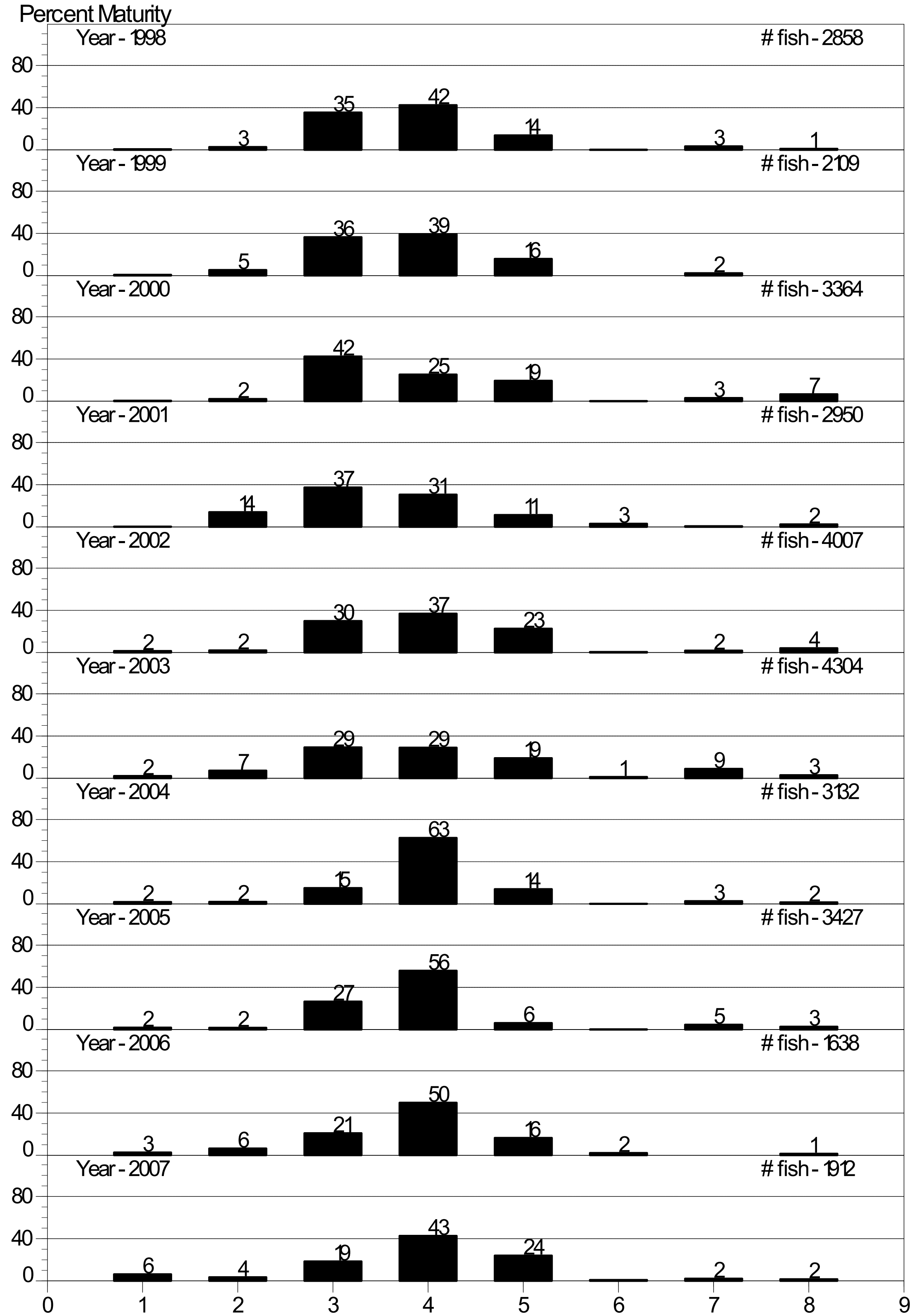

Figure 33. The 1998–2007 Herring maturity from the July bottom trawl research survey for the entire 4VWX area of coverage. Staging codes are: 1-2=immature; 3-4-5=maturing/hard; 6=ripe and running; 7=spent; and 8=recovering.

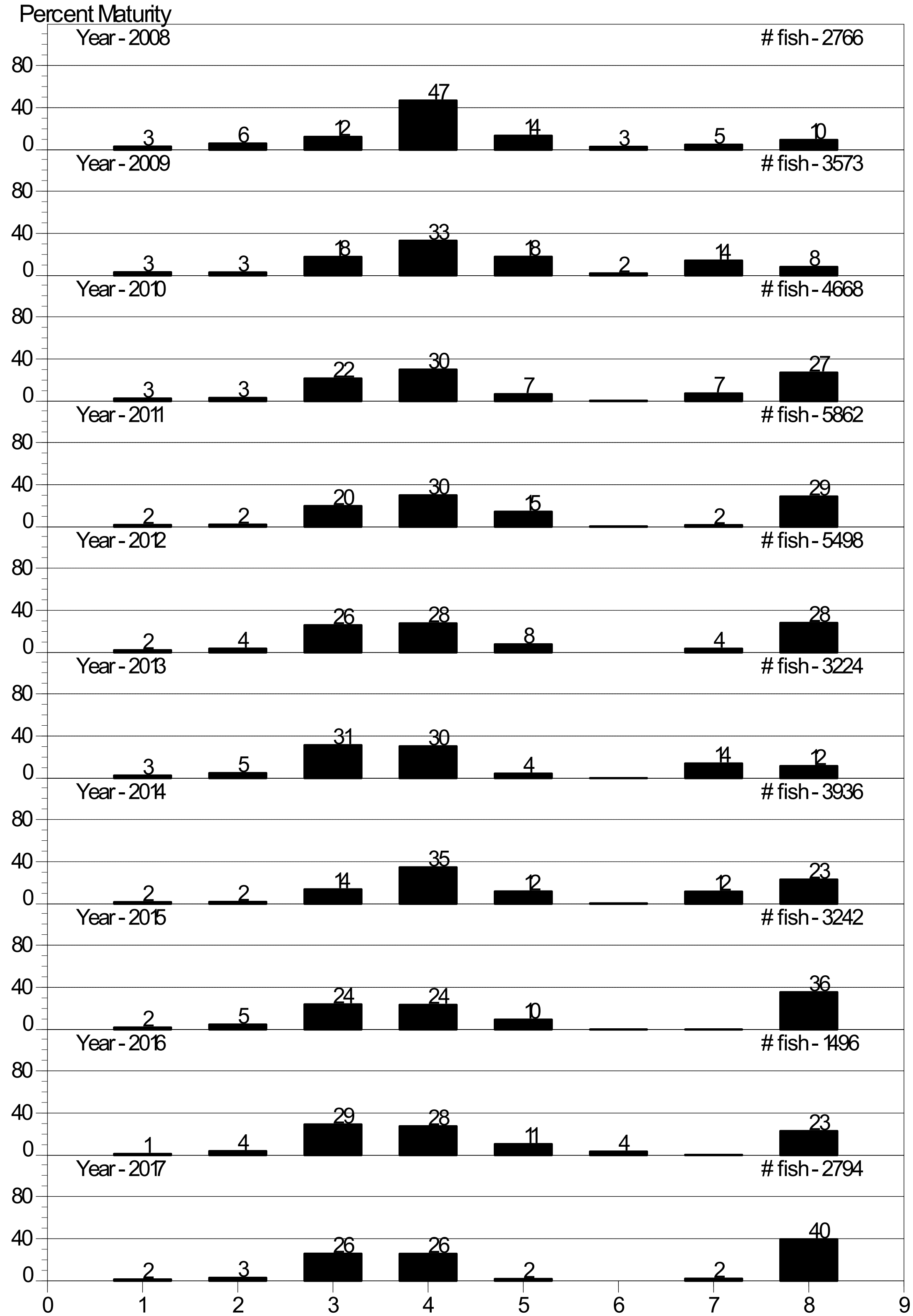

Figure 34. The 2008–2017 Herring maturity from the July bottom trawl research survey for the entire 4VWX area of coverage. Staging codes are: 1-2=immature; 3-4-5=maturing/hard; 6=ripe and running; 7=spent; and 8=recovering.

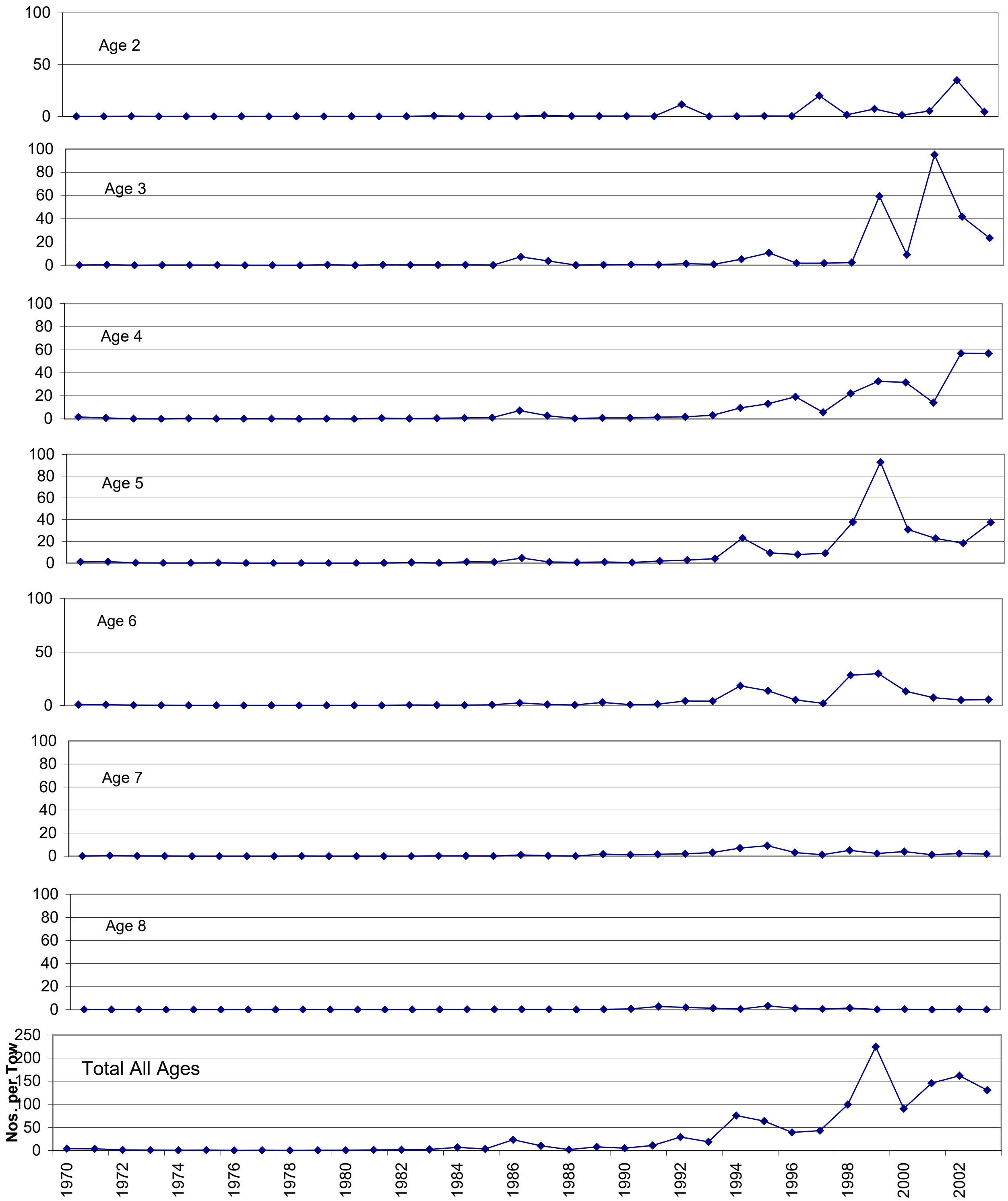

Figure 35. Stratified Herring abundance by age and overall for all ages combined (numbers per tow) from the July ground trawl survey for area 4WX (strata 53 to 95) from 1970 to 2004.

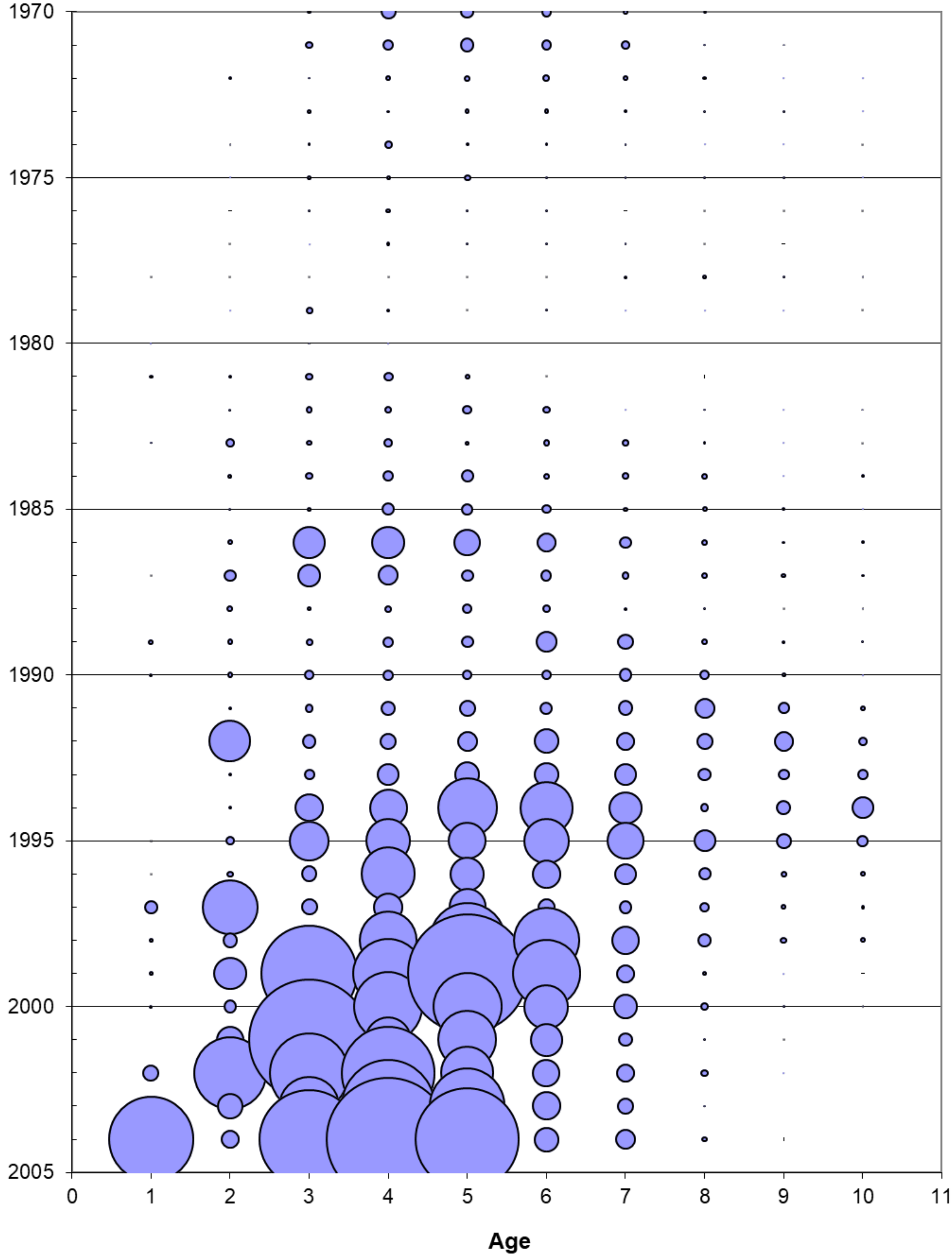

Figure 36. Stratified Herring abundance by age from 1970 to 2004 (stratified numbers per tow) from the July ground trawl survey for 4WX (strata 53 to 95).

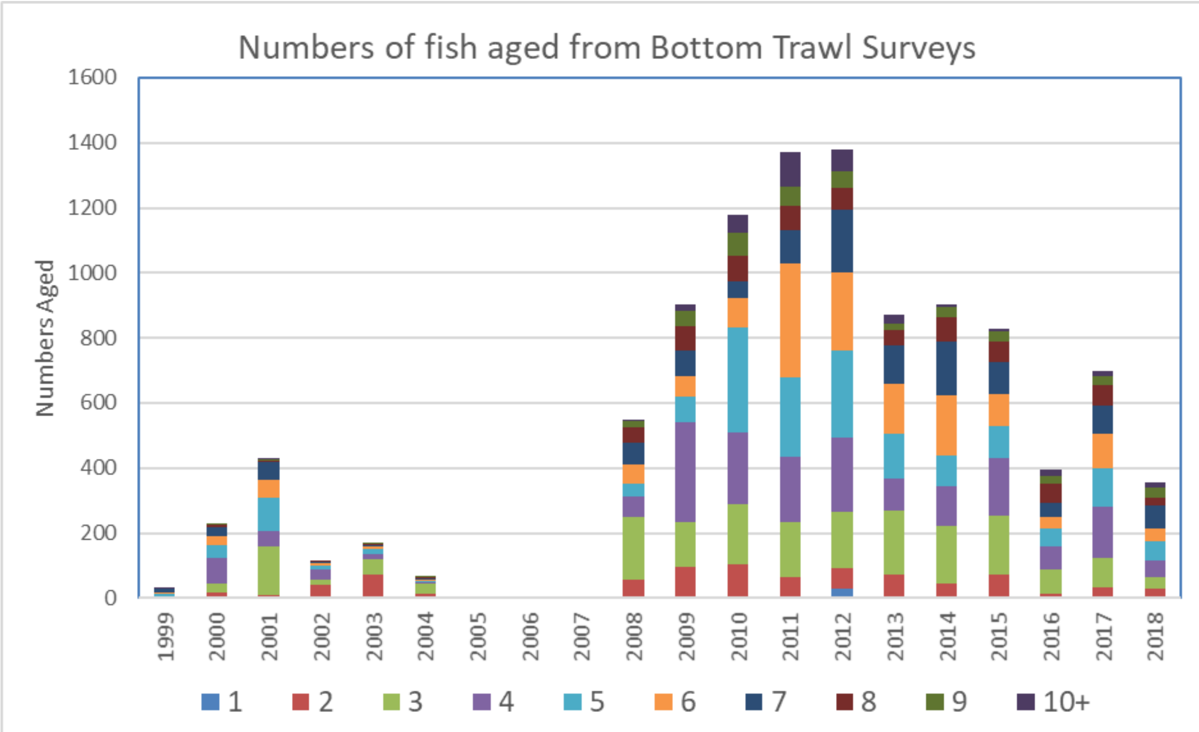

Figure 37. Number of Herring ages 1–10+ aged in bottom trawl survey from 1999–2018.

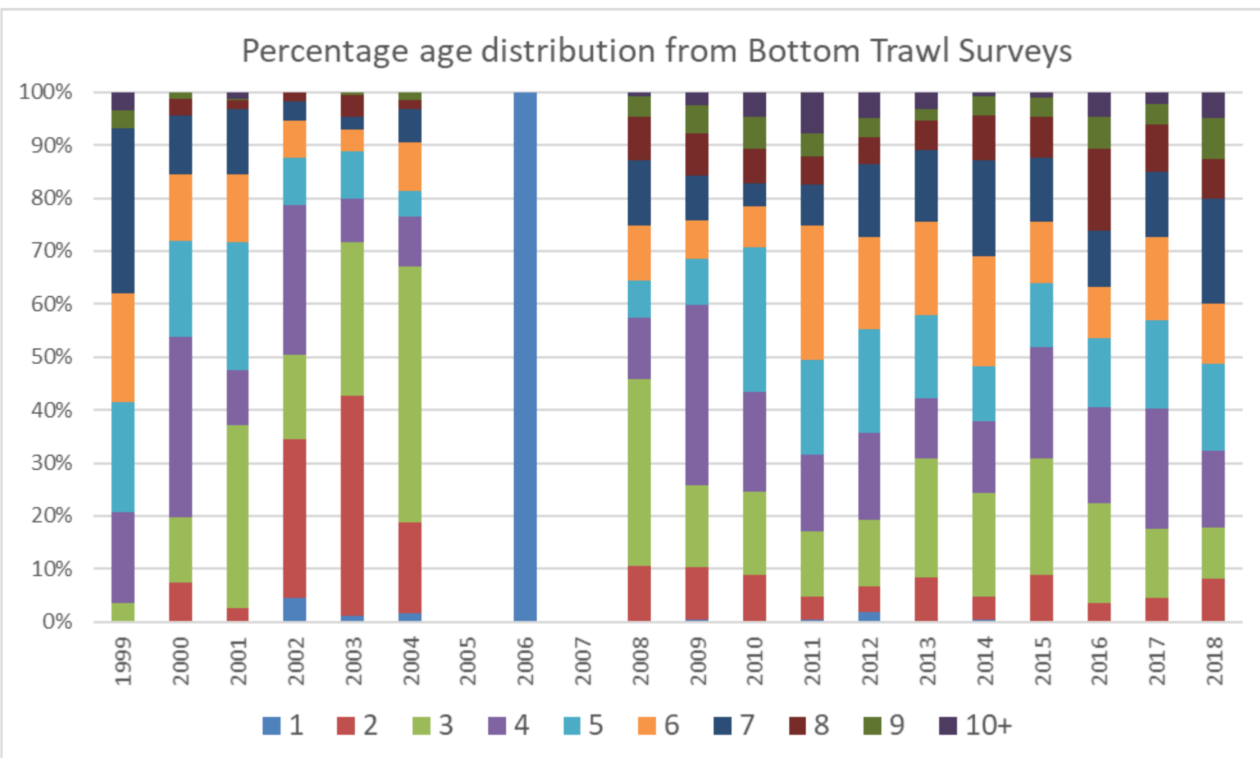

Figure 38. Percentages by year of Herring ages 1–10+ aged in bottom trawl surveys from 1999–2018.

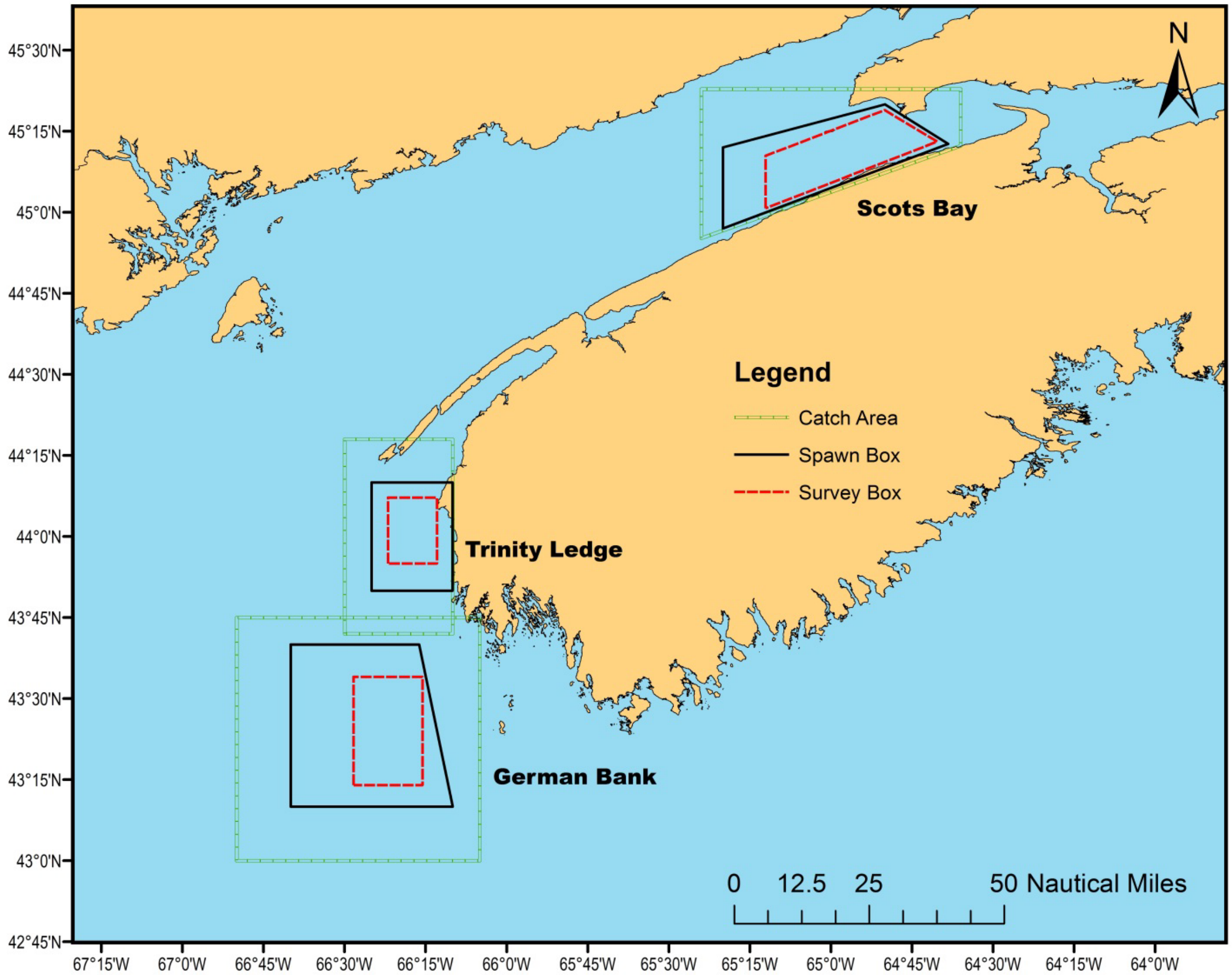

Figure 39. Locations of the three main spawning areas within the SWNS/BoF Herring spawning component along with the boxes representing the catch area, spawning area and survey areas.

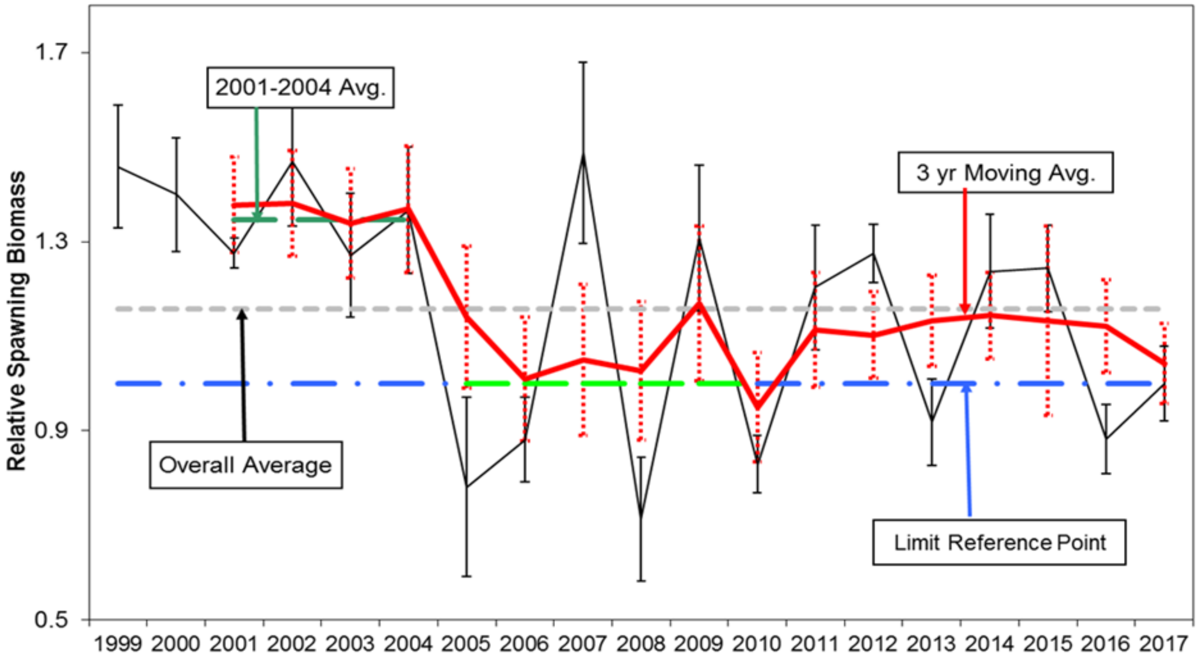

Figure 40. Relative spawning stock biomass index (with 95% C.I.), the calculated three-year moving average, the long-term average, and the Limit Reference Point for the SWNS/BoF spawning component of Herring (German Bank and Scots Bay). See Melvin et al. (2018) for updated figure.

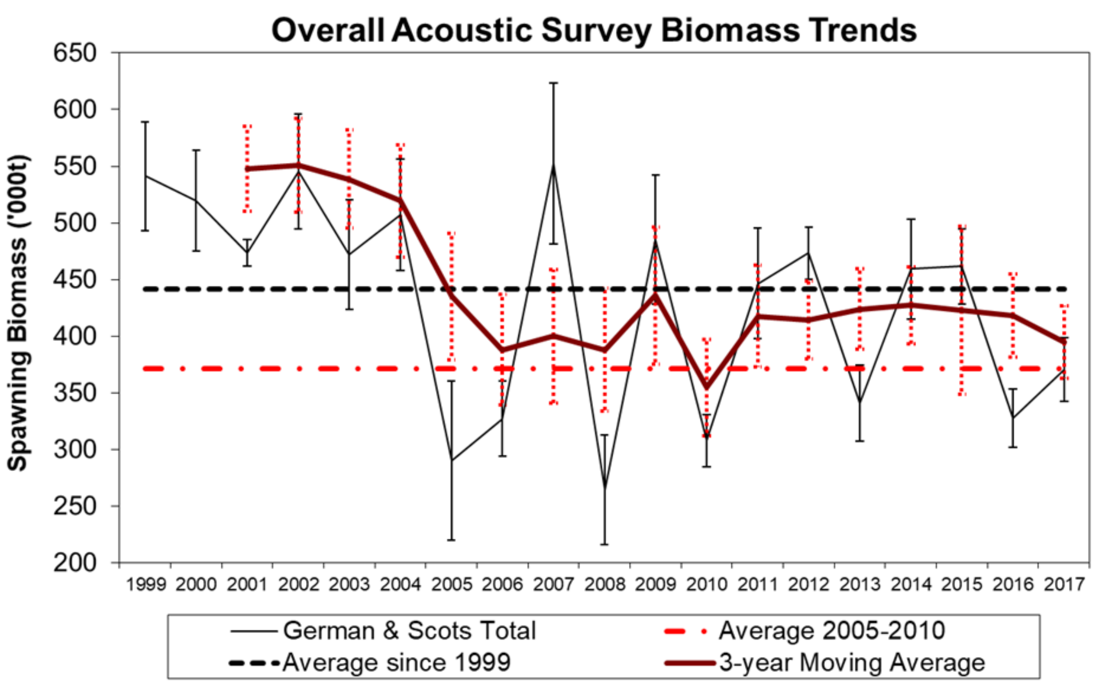

Figure 41. Spawning stock biomass for the overall stock area (with 95% C.I.), the calculated three-year moving average, the long-term average and the 2005–2010 average for the SWNS/BoF spawning component of Herring, (German Bank, Scots Bay and Trinity Ledge).

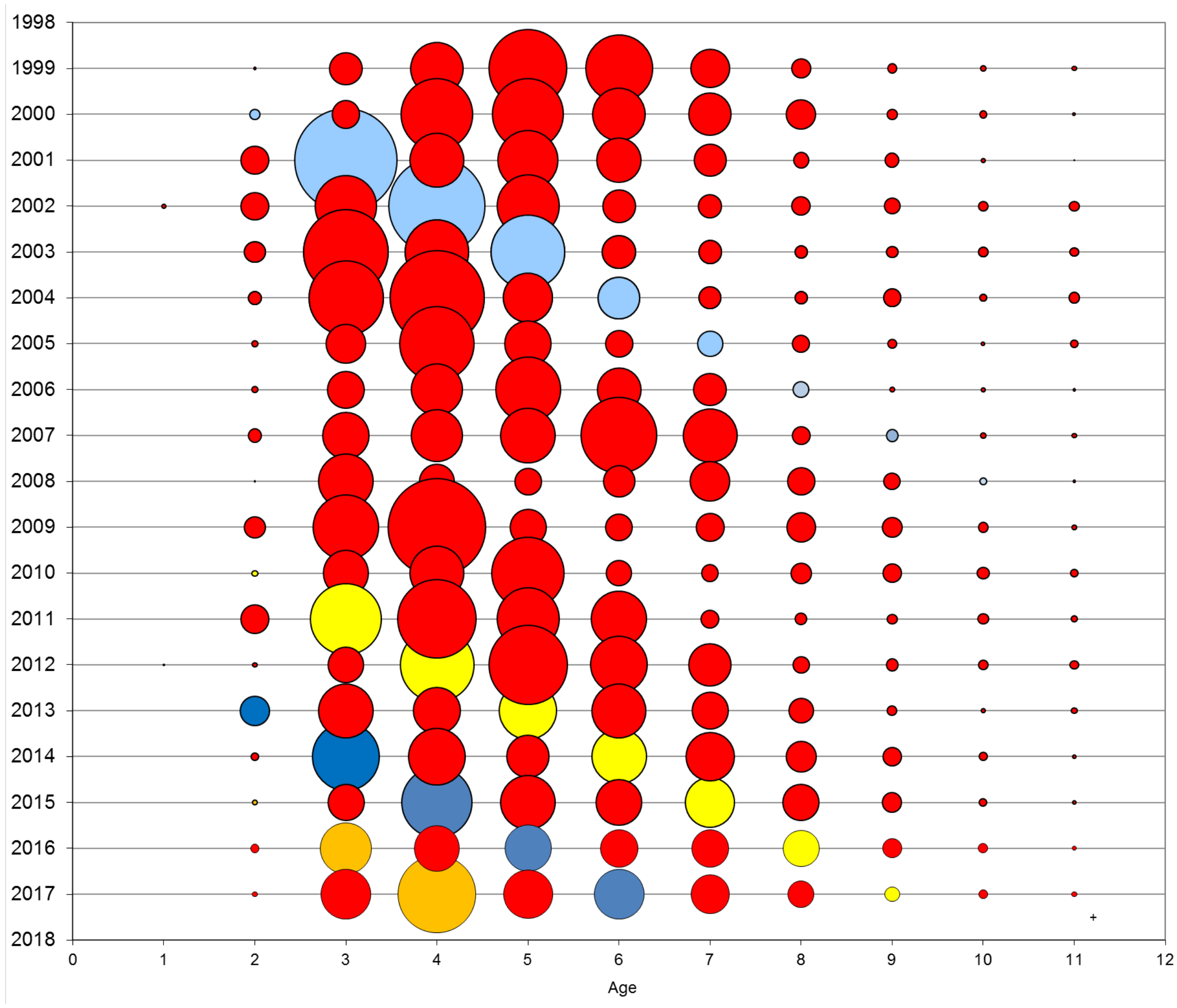

Figure 42. Acoustic survey relative numbers at age (denoted by circle size) of Herring for the overall SWNS/BoF component. Selected year-classes are indicated by colours.

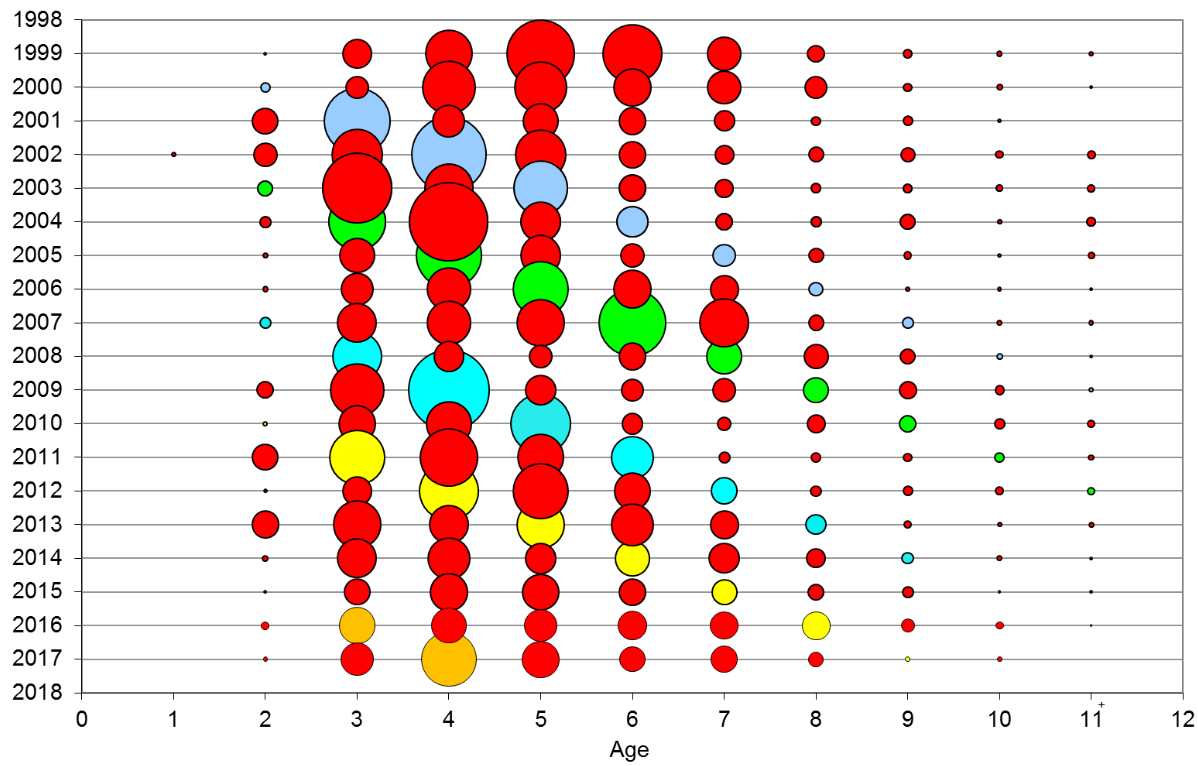

Figure 43. Acoustic survey relative numbers at age (denoted by circle size) of Herring for the German Bank spawning area in the SWNS/BoF component. Selected year-classes are indicated by colours.

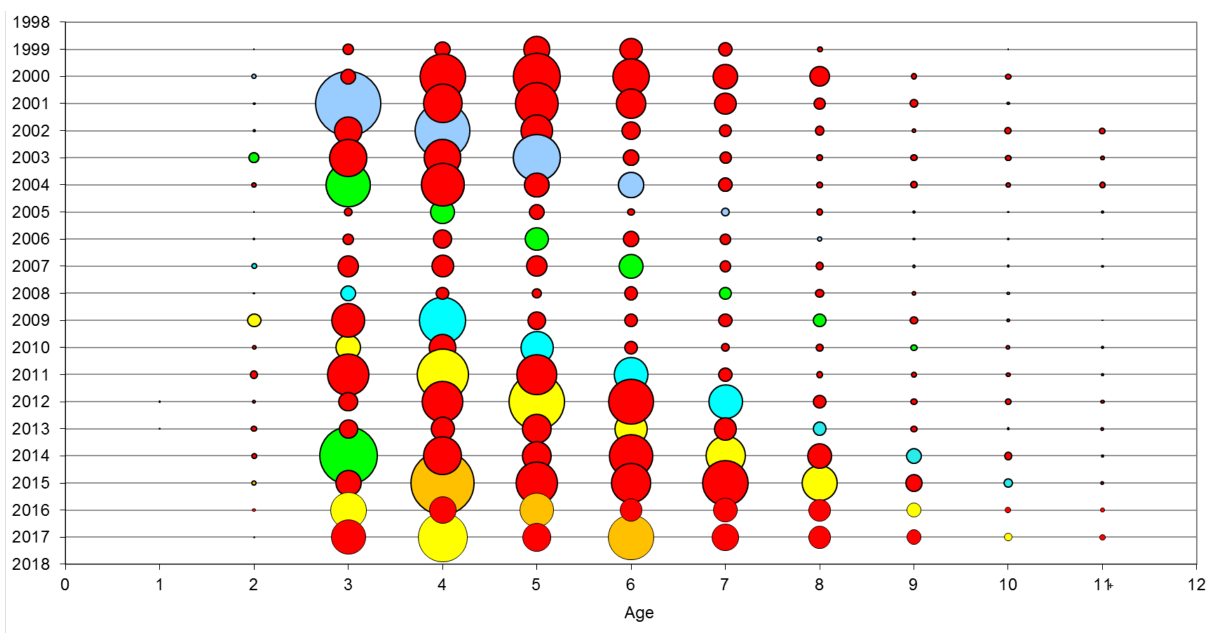

Figure 44. Acoustic survey relative numbers at age (denoted by circle size) of Herring for the Scots Bay spawning area in the SWNS/BoF component. Selected year-classes are indicated by colours.

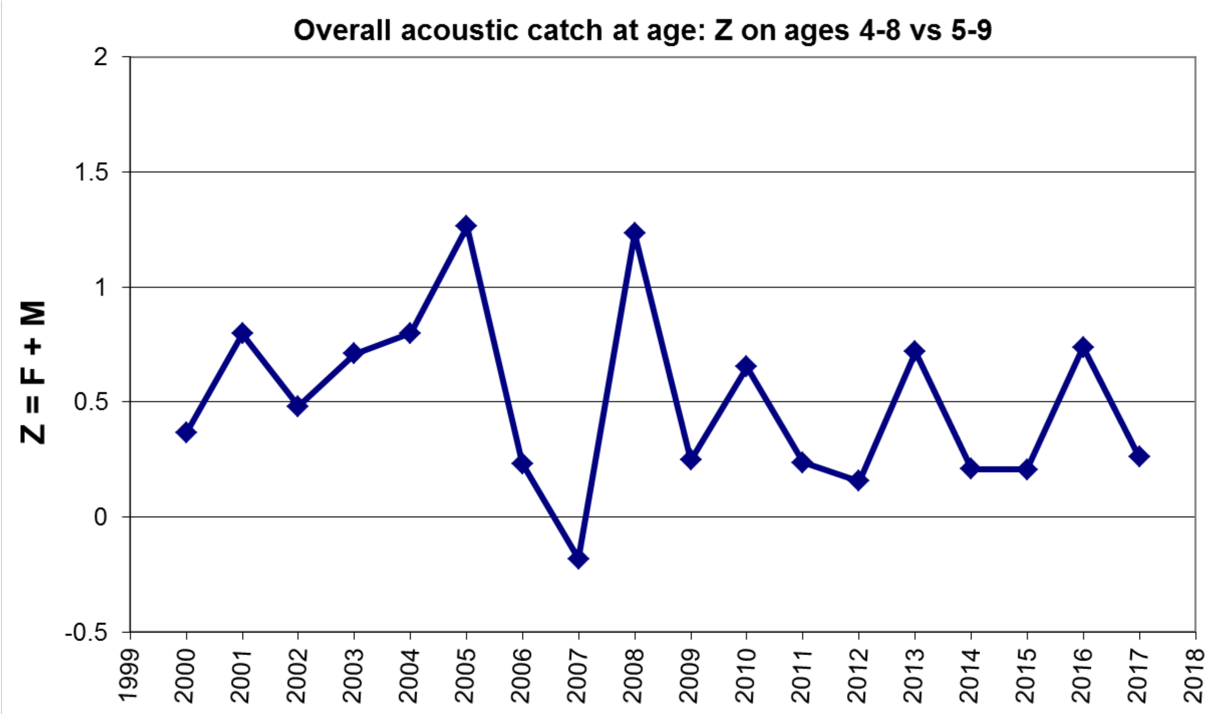

Figure 45. Total mortality estimates (Z=F+M) of Herring from the overall SWNS/BoF component acoustic catch-at-age data for ages 4 to 8 combined, compared with ages 5 to 9 in the following year.

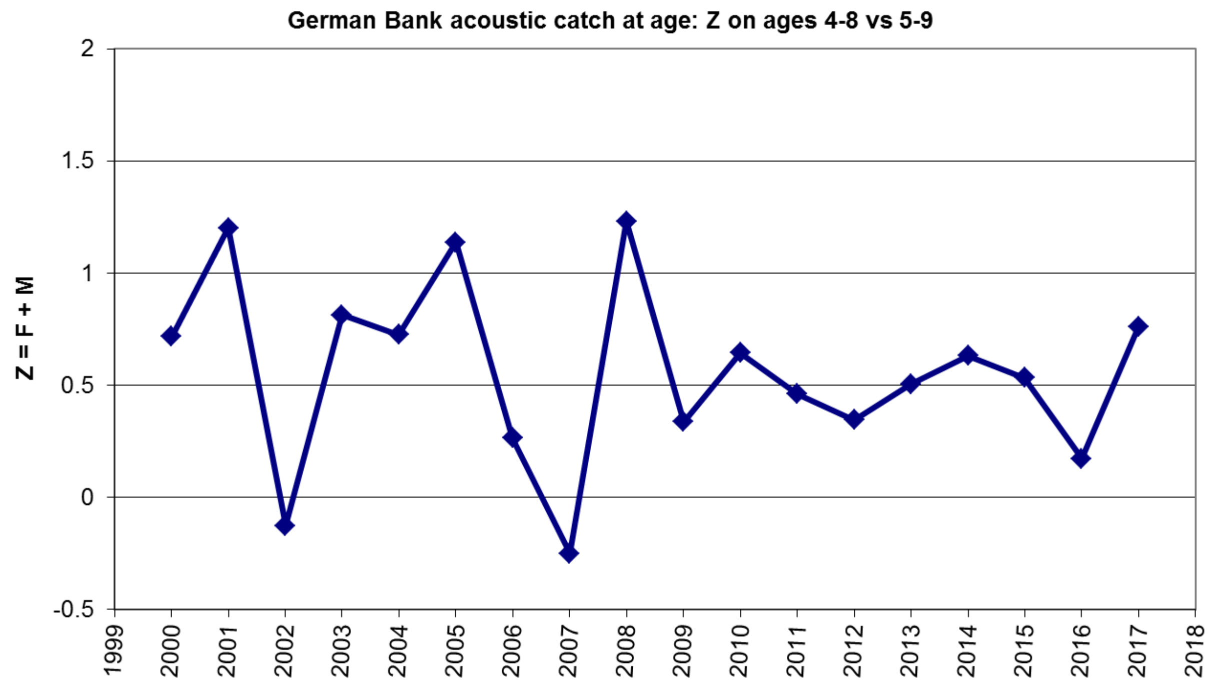

Figure 46. Total mortality estimates (Z=F+M) of Herring for the German Bank spawning area acoustic catch-at-age data for ages 4 to 8 combined, compared with ages 5 to 9 in the following year.

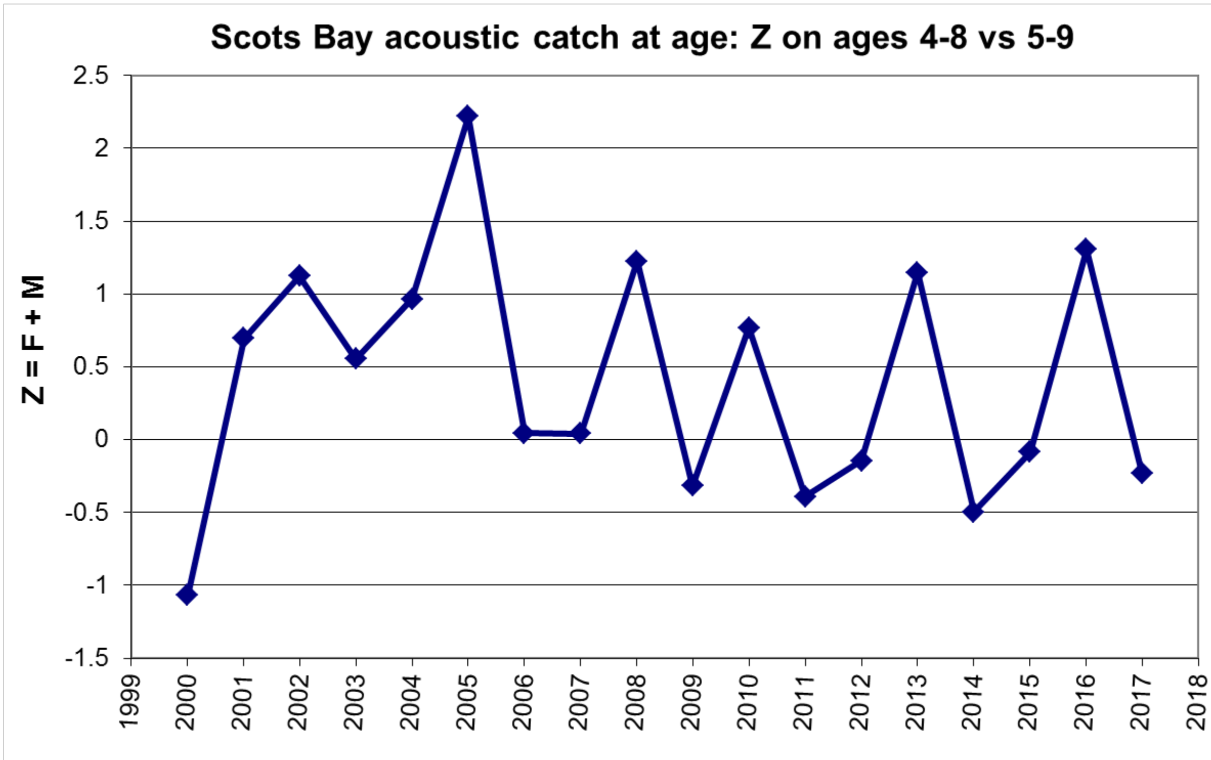

Figure 47. Total mortality estimates (Z=F+M) of Herring for the Scots Bay spawning area acoustic catch-at-age data for ages 4 to 8 combined, compared with ages 5 to 9 in the following year.

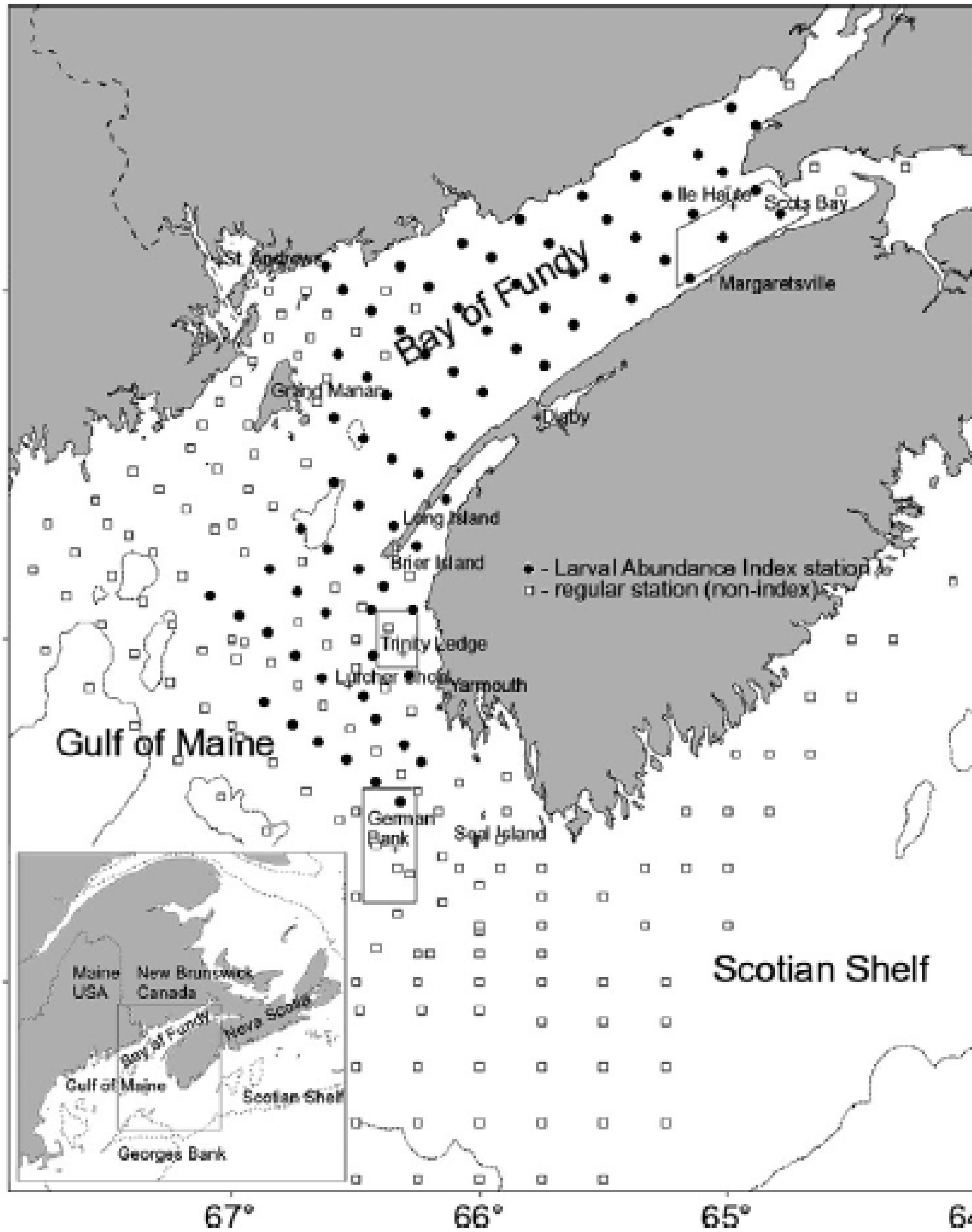

Figure 48. Bay of Fundy larval Herring survey stations (●, 79 standard larval abundance stations; □, other stations occupied from 1972 to 1998). The boxed regions indicate locations of major Herring spawning grounds: Scots Bay (mid-summer), Trinity Ledge (autumn), and German Bank (autumn) (from Stephenson et al. 2015).

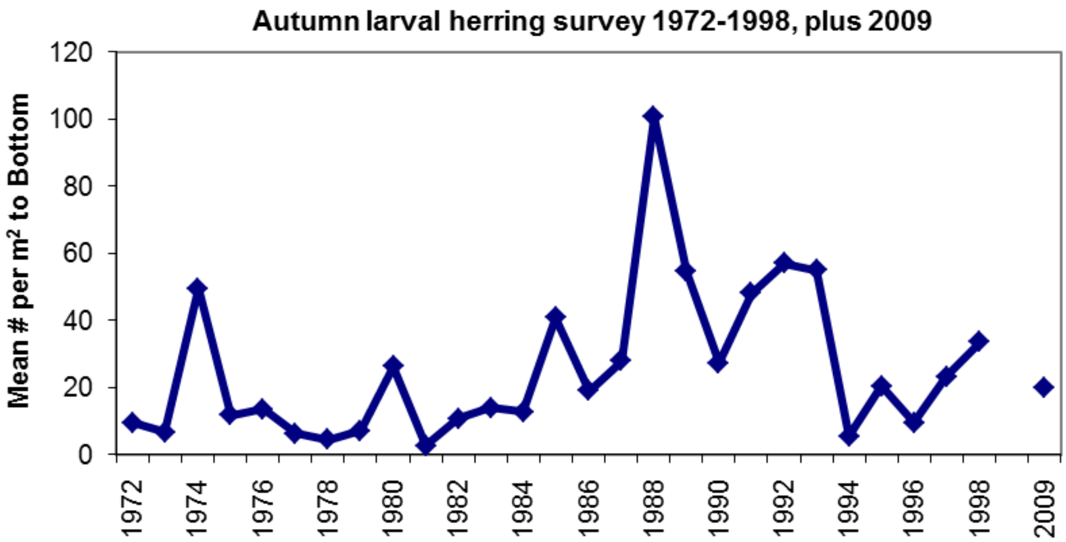

Figure 49. Annual larval Herring mean number per m² from 1972 to 1998 and 2009 collected from bongo tows at 79 stations in the Bay of Fundy.

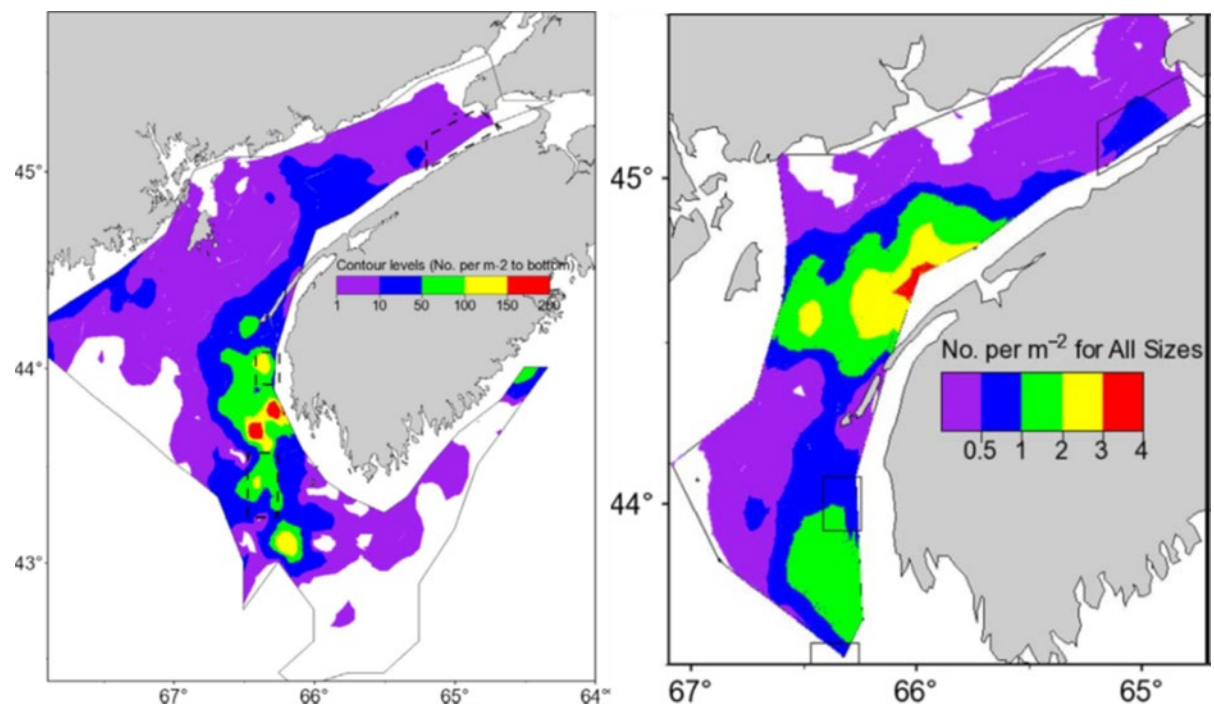

Figure 50. Contours (number m²) to the bottom of the average Bay of Fundy autumn larval Herring abundance for all stations (standard and others) for the period 1975–1998 (left) and for the average spring (March) surveys for all larval and pelagic juvenile Herring,1975–1984 (except 1980) (right) (from Stephenson et al. 2015).

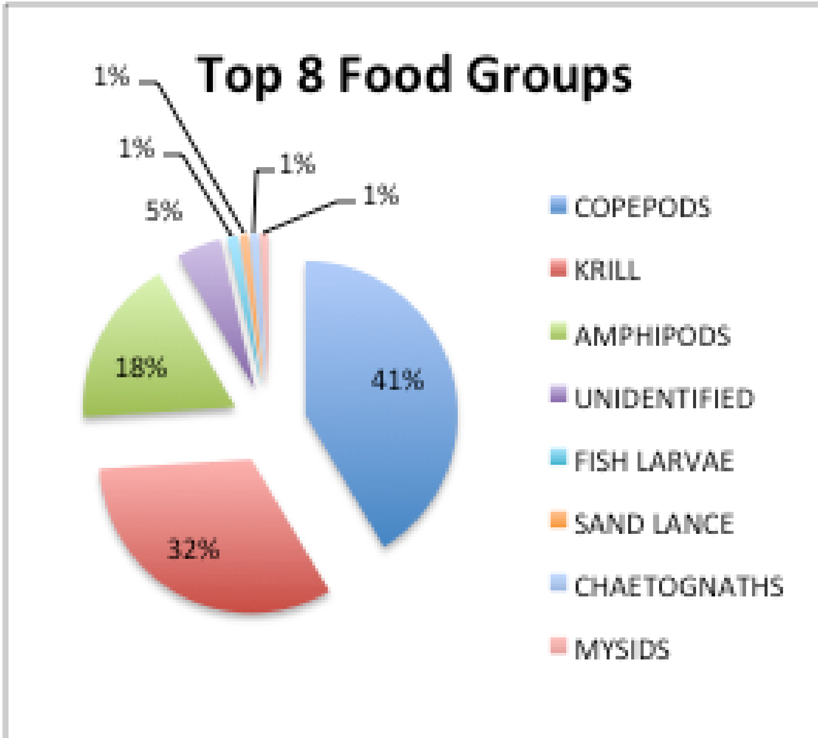

Figure 51. Percentage of Herring stomachs containing the top eight food items plotted by frequency.

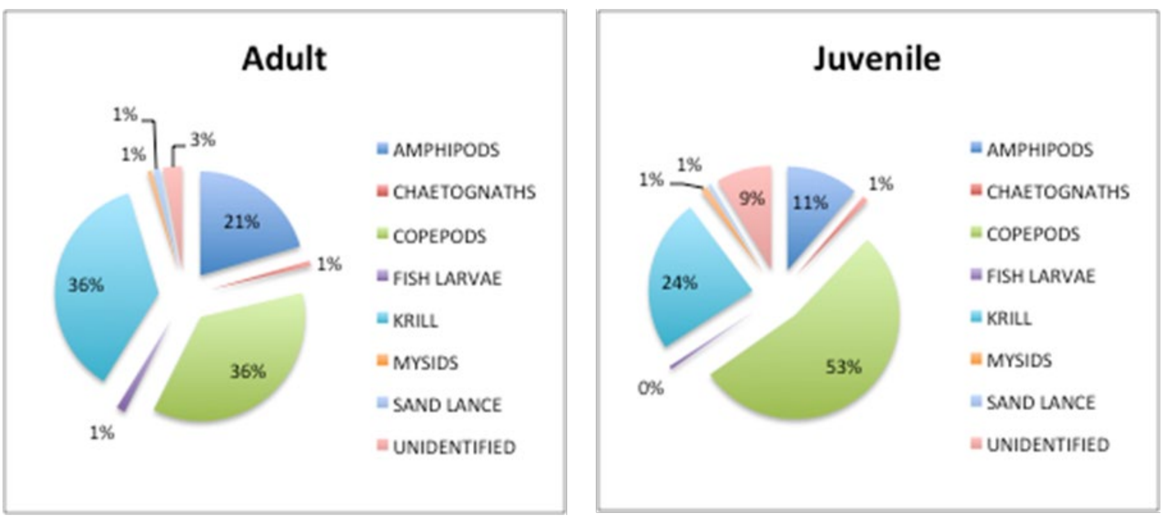

Figure 52. Percentage of adult and juvenile Herring stomachs containing the top seven food items plotted by frequency.

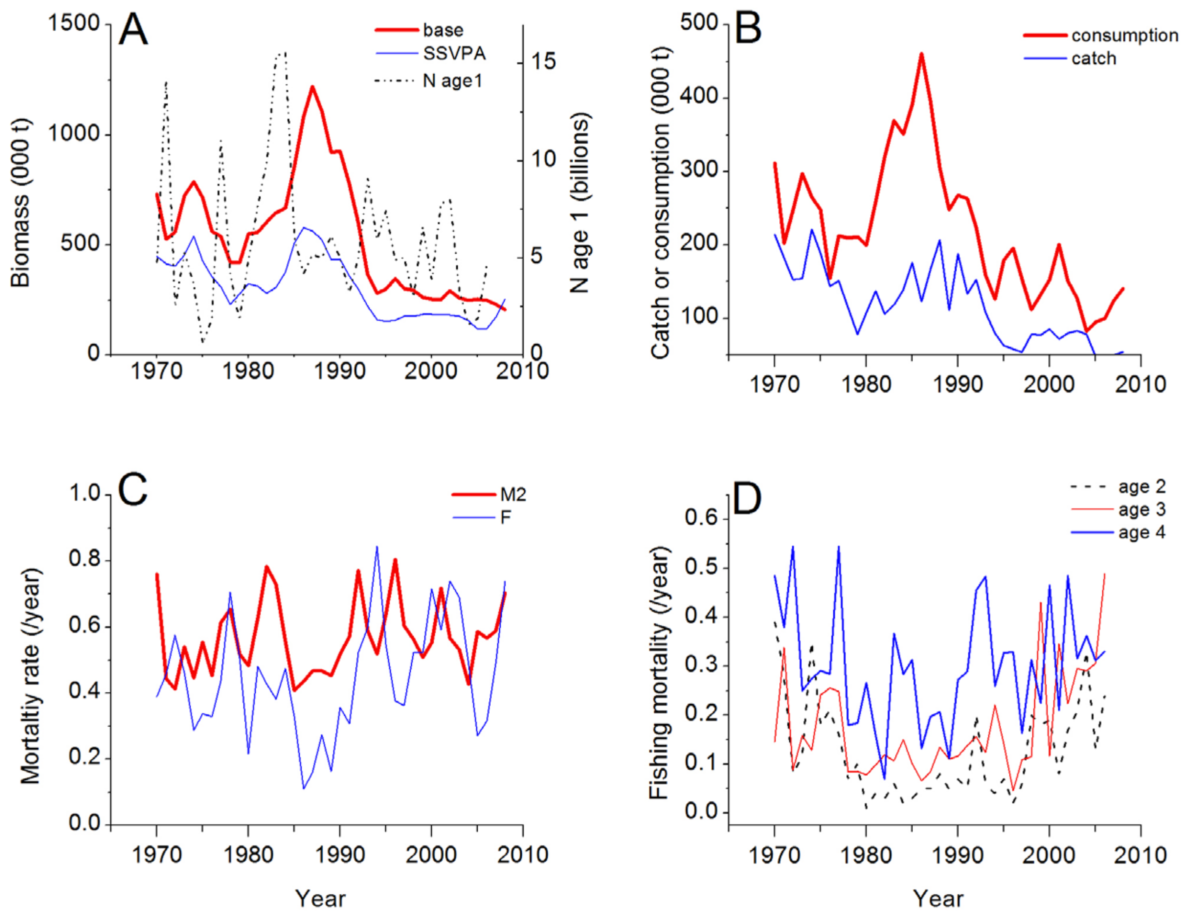

Figure 53. Results from the MSVPA base scenario. (A) Herring biomass estimates from the SSVPA and the MSVPA base, and the number of Herring at age 1 estimated by the MSVPA. (B) Herring deaths by fishing and predation. (C) Herring fishing (for ages 5+) and natural mortality rates. (D) Herring fishing mortality by age group under the base scenario (from Guenette and Stephenson 2012).

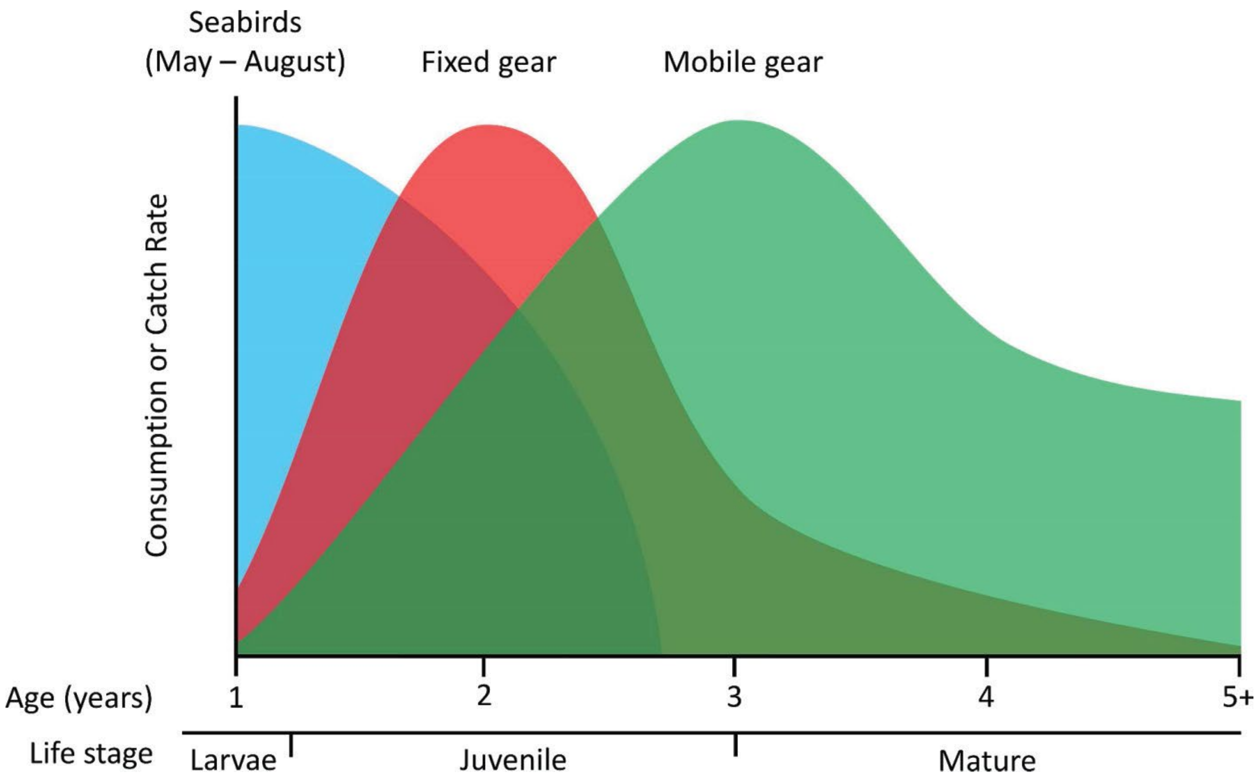

Figure 54. Stages of Atlantic Herring life cycle and timing of peak mortality from seabirds and fisheries. Herring hatch in the fall (age-0, not shown) and become age-1 on 1 January; fall-spawned Herring do not overlap with the seabird breeding season at age-0. Seabirds target age-1 Herring in summer, and, to a lesser extent, age-2 Herring the following summer. The fixed-gear fishery primarily catches age-2 Herring, and the mobile-gear fishery catches a range of fish cohorts, especially ages 3 to 5 (from Scopel et al. 2017).

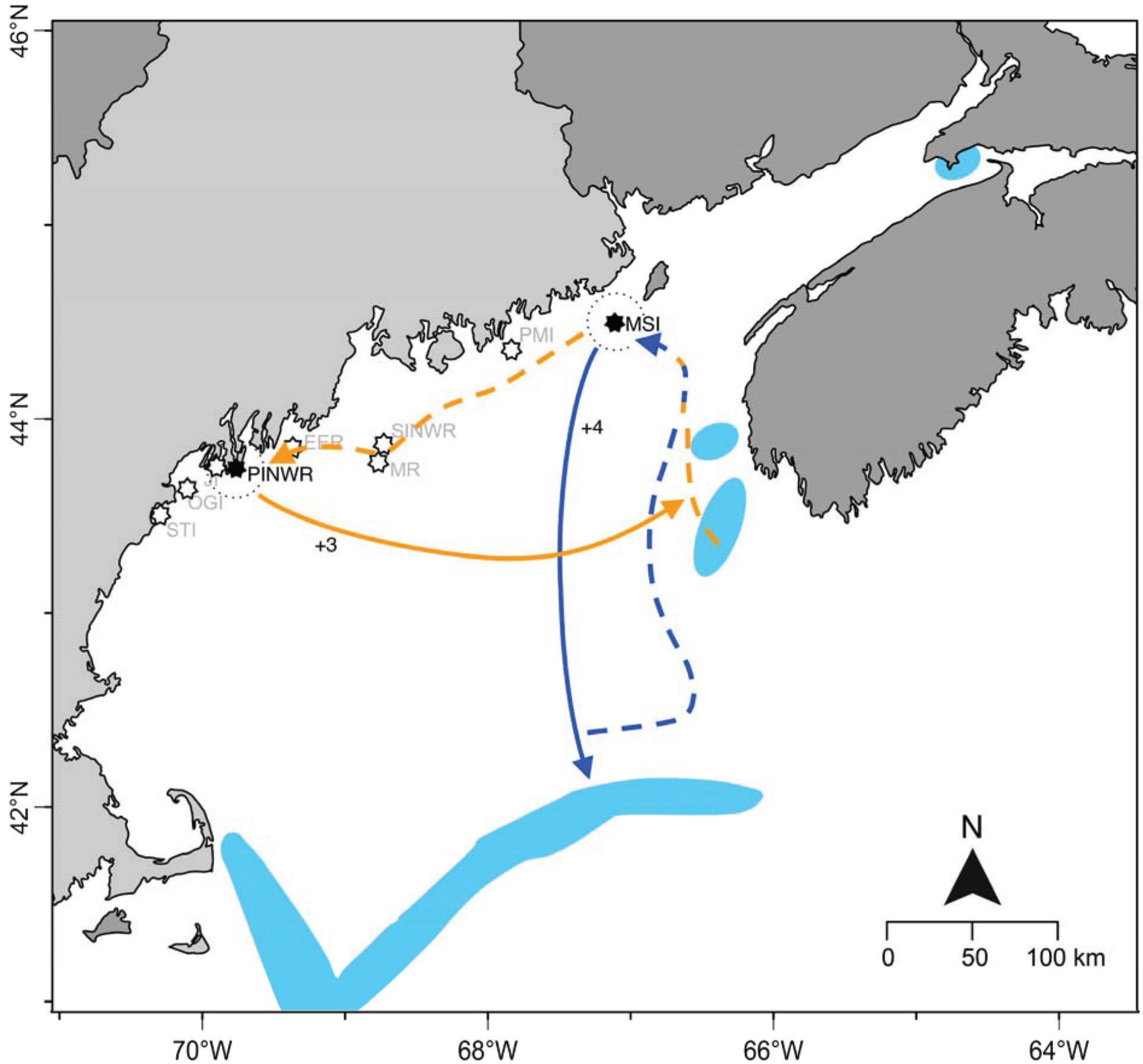

Figure 55. Top-ranked models showing relationships between seabird diet data and American (blue) and Canadian (orange) acoustic surveys in the Gulf of Maine and Bay of Fundy region. Common and Arctic tern diet data at Machias Seal Island (MSI) predicted acoustic surveys at Georges Bank 4 years later, while Common Terns at Pond Island (PINWR) predicted acoustic surveys from the Bay of Fundy 3 years later. Dashed lines suggest proposed larval movements from spawning areas toward seabird colonies, where seabirds consume juvenile Herring. Solid lines indicate connectivity back to natal grounds (from Scopel et al. 2017).

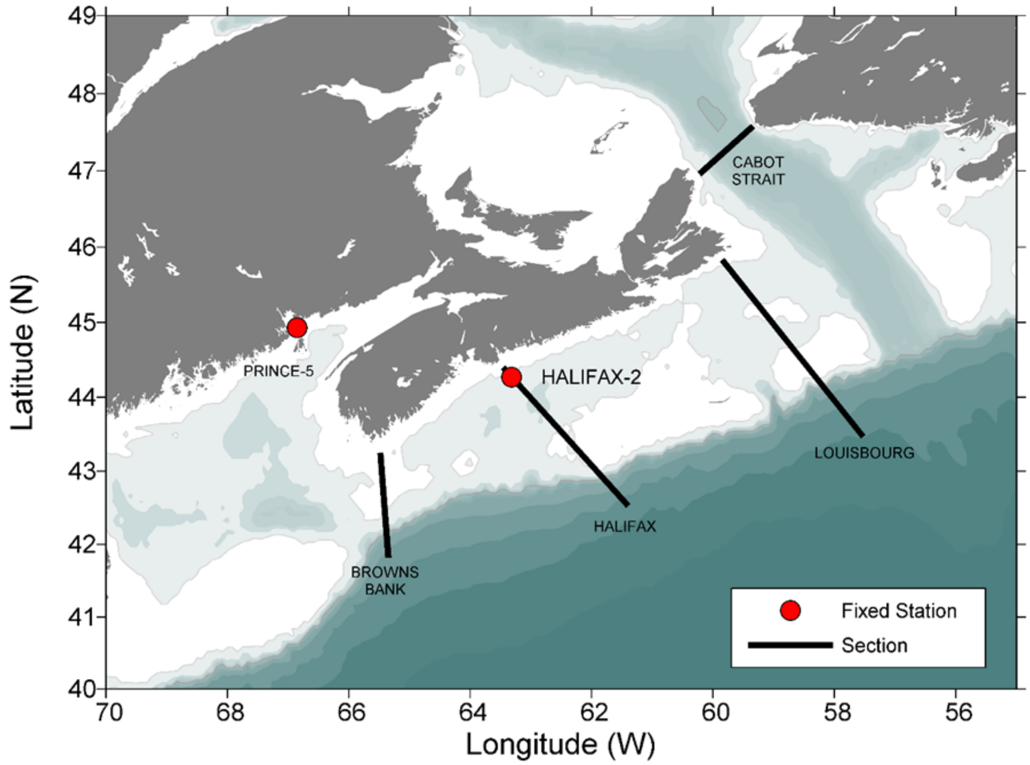

Figure 56. Map of primary sections (Cabot Strait, Louisbourg, Halifax, and Browns Bank) and fixed stations (Halifax-2, and Prince-5) sampled in the DFO Maritimes Region (from Johnson et al. 2017).

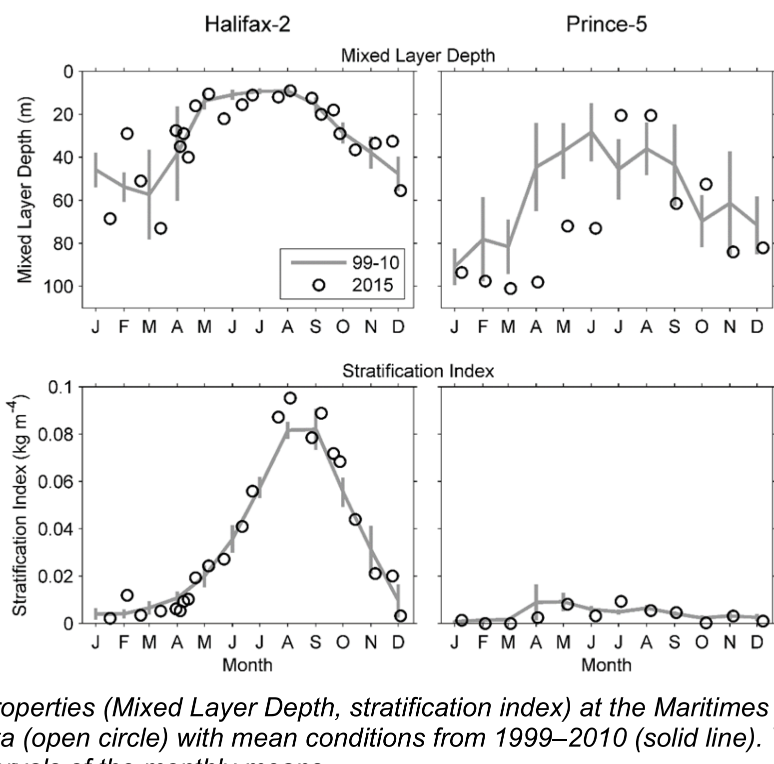

Figure 57. Mixing properties (Mixed Layer Depth, stratification index) at the Maritimes fixed stations comparing 2015 data (open circle) with mean conditions from 1999–2010 (solid line). Vertical lines are 95% confidence intervals of the monthly means.

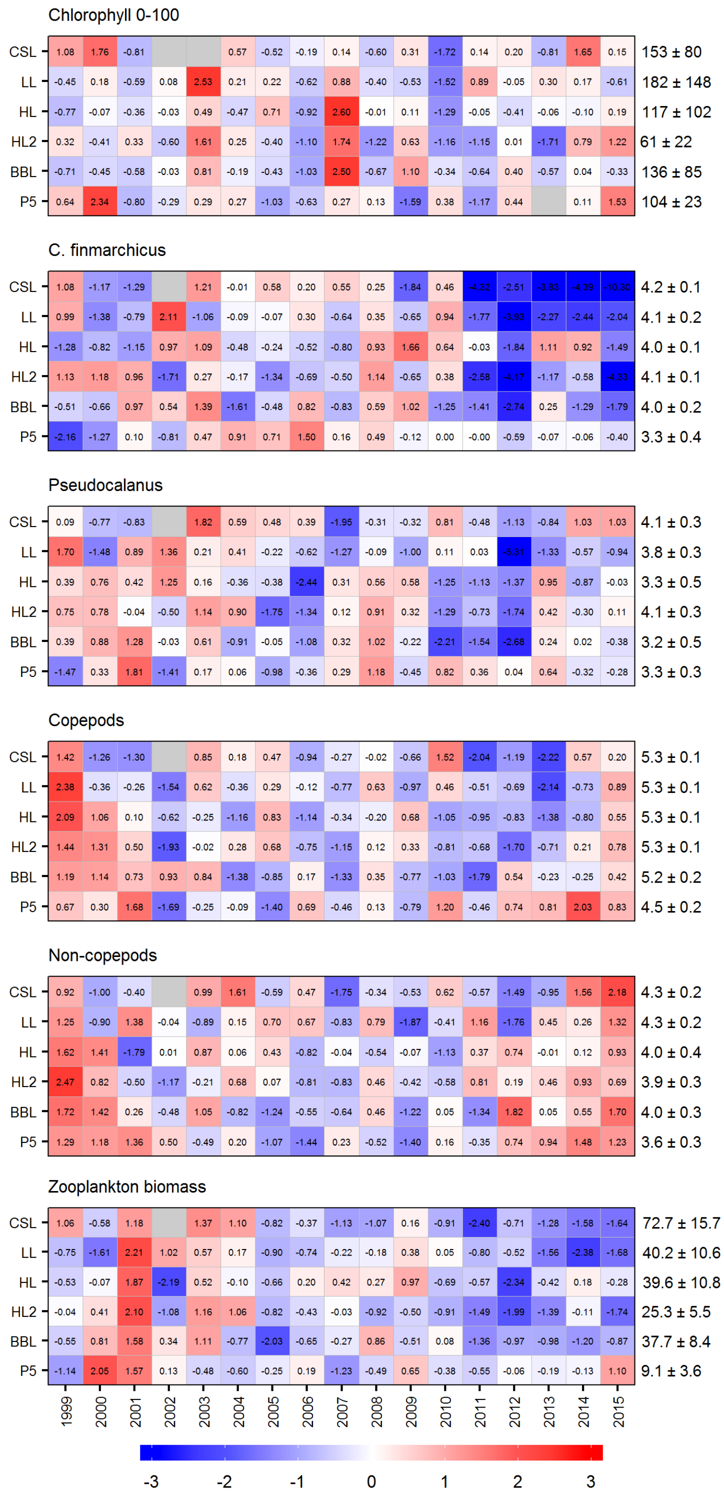

Figure 58. Annual anomaly scorecard for phytoplankton (chlorophyll) and zooplankton abundance or biomass. Values in each cell are anomalies from the mean for the reference period, 1999–2010, in standard deviation (sd) units (mean and sd listed at right). A blank cell indicates missing data. Red (blue) cells indicate higher (lower) than normal nutrient levels. CSL: Cabot Strait section; LL: Louisbourg section; HL: Halifax section; HL2: Halifax-2; BBL: Browns Bank section; P5: Prince-5 (from Johnson et al. 2017).

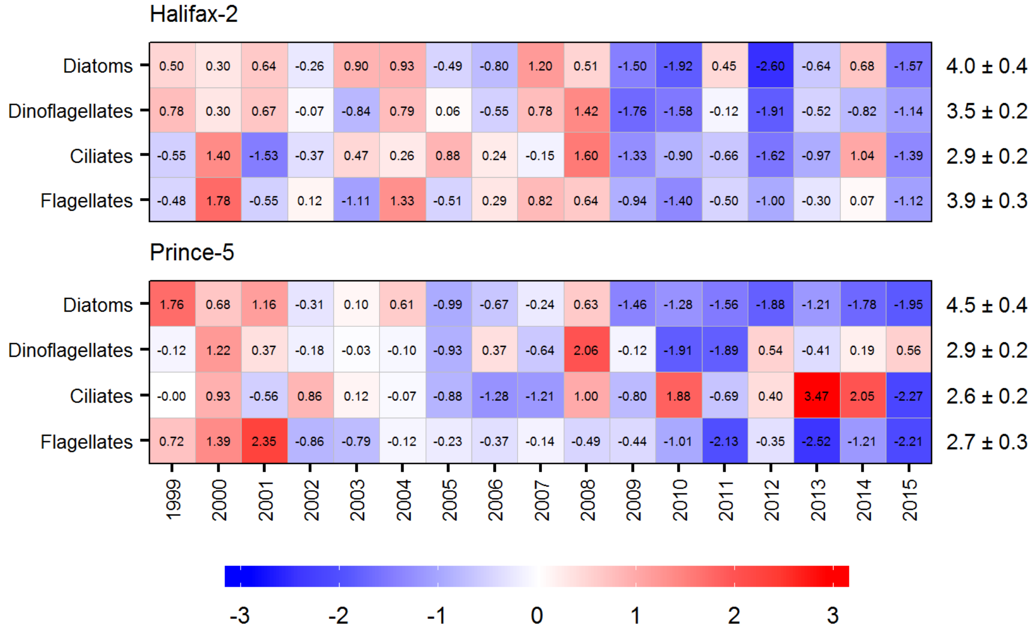

Figure 59. Annual anomaly scorecard for microplankton abundance. Values in each cell are anomalies from the mean for the reference period, 1999–2010, in standard deviation (sd) units (mean and sd listed at right). A blank cell indicates missing data. Red (blue) cells indicate higher (lower) than normal nutrient levels (from Johnson et al. 2017).

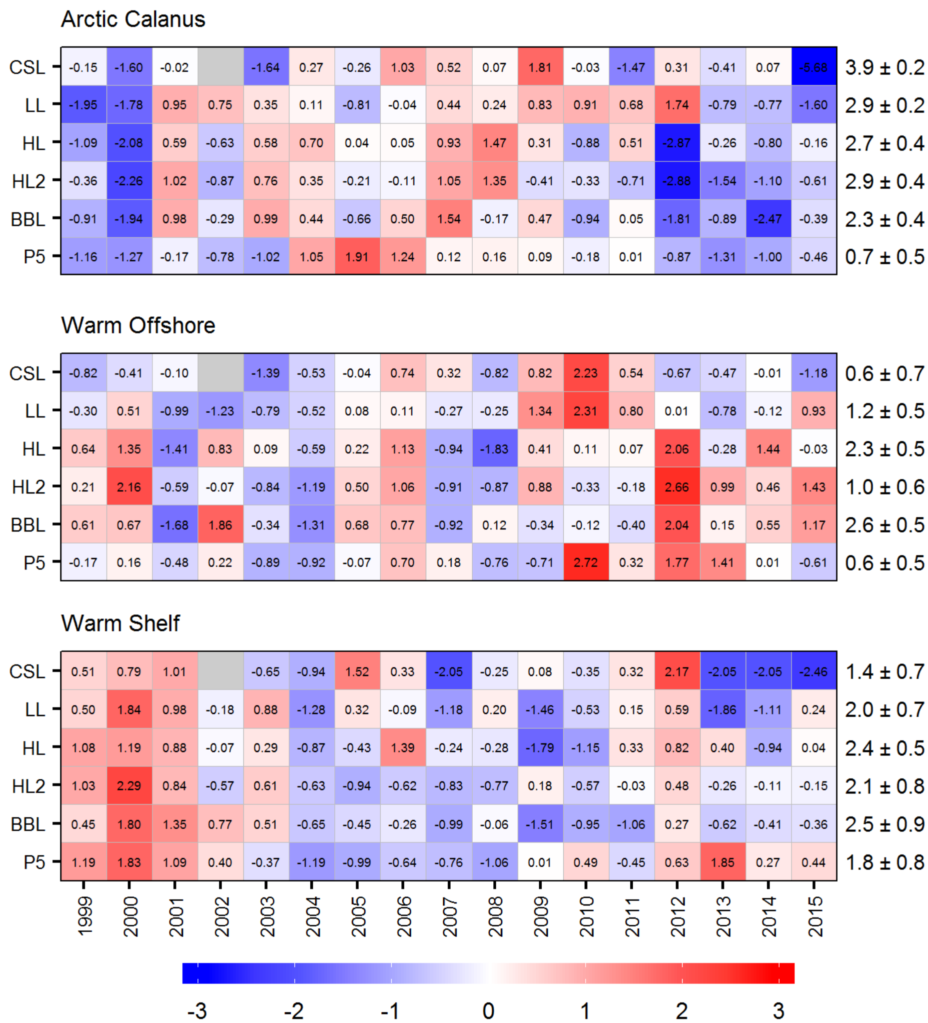

Figure 60. Annual anomaly scorecard for copepod indicator species group abundances. Values in each cell are anomalies from the mean for the reference period, 1999–2010, in standard deviation (sd) units (mean and sd listed at right). A blank cell indicates missing data. Red (blue) cells indicate higher (lower) than normal nutrient levels. CSL: Cabot Strait section; LL: Louisbourg section; HL: Halifax section; HL2: Halifax-2; BBL: Browns Bank section; P5: Prince-5 (from Johnson et al. 2017).

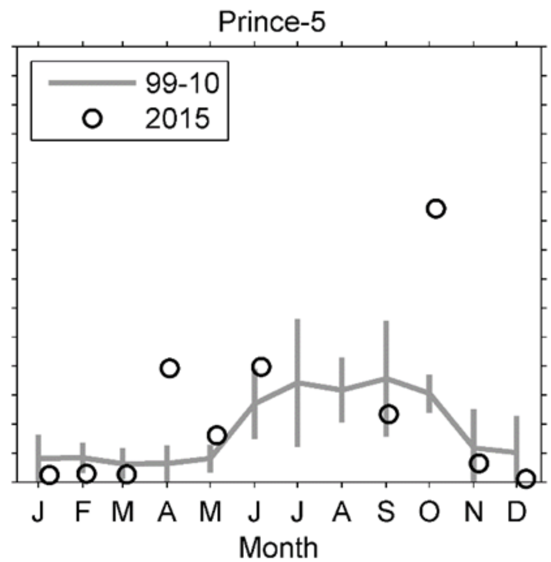

Figure 61. Zooplankton biomass (integrated surface to bottom) in 2015 (open circle) and mean conditions 1999–2010 (solid line) at Prince-5. Vertical lines are 95% confidence intervals of the monthly means. (from Johnson et al. 2017).

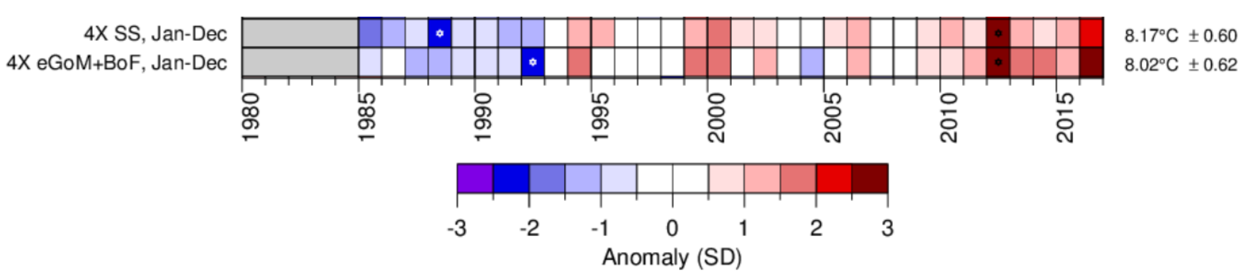

Figure 62. Time series of Sea Surface Temperature (1985–2016). A white cell is within 0.5 SD of the long-term mean; red cell is above normal, blue cell is below normal. Minimums and maximums are indicated by a star. Long-term means are displayed on the far right hand side (from DFO 2017).

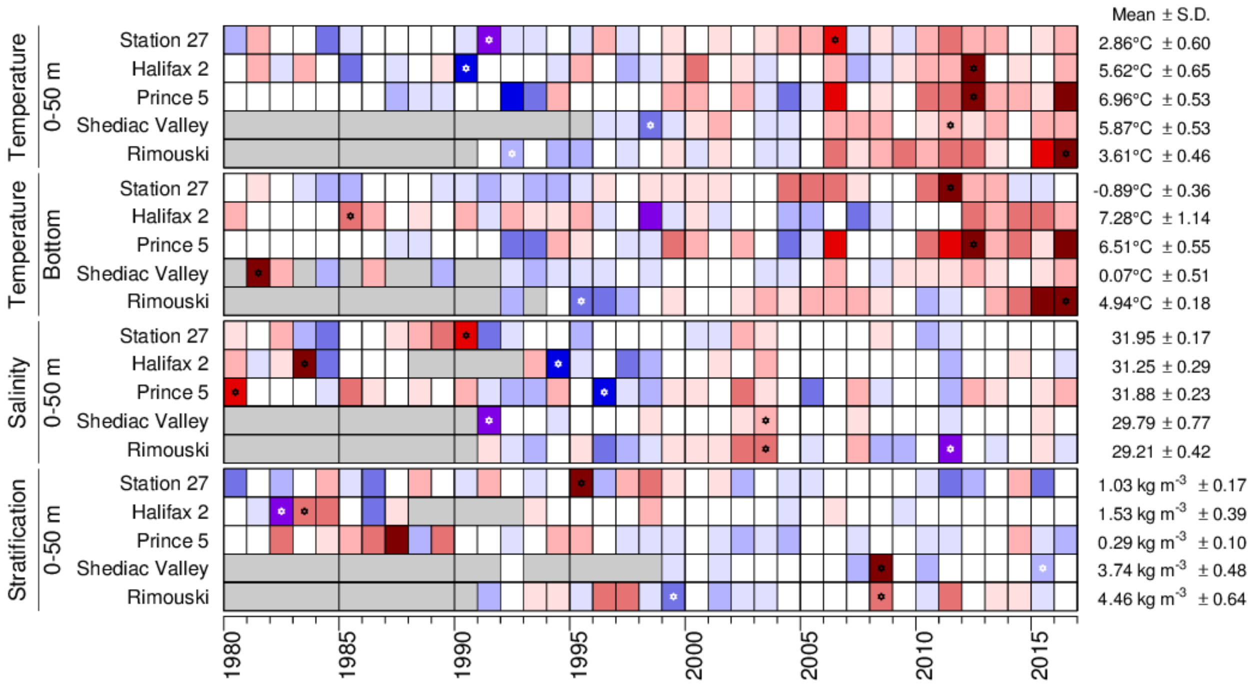

Figure 63. Time series of oceanographic variables at AZMP high-frequency sampling stations, 1980–2016. A grey cell indicates missing data, a white cell is a value within 0.5 SD of the long-term mean based on data from 1981–2010 when possible; for high-frequency station depth-averaged temperature, a red cell indicates warmer-than-normal conditions, a blue cell colder than normal. More intense colours indicate larger anomalies. For salinity and stratification, red corresponds to above-normal conditions. Series minimums and maximums are indicated by a star when they occur in the displayed time span. Climatological means and standard deviations are shown on the right-hand side of the figure (from DFO 2017).