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History of the assessment of southern Gulf of St. Lawrence Atlantic herring (*Clupea harengus*) stocks to 2013

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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

This document was part of the information presented at a regional peer review of the assessment framework for the fall spawning component of Atlantic herring in the southern Gulf of St. Lawrence (sGSL) (NAFO Div. 4T). The stock area for the sGSL Atlantic herring extends from the north shore of the Gaspe Peninsula (Quebec) to the northern tip of Cape Breton Island (Nova Scotia) and includes the Magdalen Islands. The two seasonal herring spawning components that are assessed for the sGSL are spring spawners and fall spawners. SGSL herring are harvested by an inshore gillnet fleet fishing in coastal waters and a purse seine fleet of a maximum of 12 seiners (>65') fishing in deeper water. Since 1999, fall spawners have comprised 70% or more of the total catch in the sGSL. Market conditions have played a large role in determining catch levels in this fishery. There are approximately 3,000 herring bait licenses for personal use in the sGSL. In 2012 and 2013, there was an average of 712 actively fishing gillnet commercial licenses out of a possible total of 2,590 license holders. The assessment for each herring component currently provides a $F_{0.1}$ fishing level calculation. Gillnet catch-per-unit-effort (CPUE) and acoustic survey indices were used to calibrate the population models. Spawning stock biomass reference points consistent with the Precautionary Approach were derived for both spawning components in 2005. The latest assessment of the sGSL herring stocks in 2013 showed pathological problems including blocks of residuals and large retrospective patterns when fitting the current population model. Similar problems were encountered in past assessments of the sGSL herring stocks.

Historique des évaluations des stocks de hareng de l'atlantique (*Clupea harengus*) du sud du golfe du Saint-Laurent jusqu'en 2013

RÉSUMÉ

Ce document faisait partie de la documentation présentée lors d'une revue régionale par les pairs sur le cadre de l'évaluation de la composante des géniteurs d'automne de hareng du sud du golfe Saint-Laurent (sGSL) (région 4T de l'OPANO). L'aire géographique du stock du hareng de l'Atlantique du sGSL est située dans la zone comprise entre la côte nord de la péninsule de Gaspé (Québec) et l'extrémité nord de l'île du Cap-Breton (Nouvelle-Écosse), incluant les Îles-de-la-Madeleine. La population de hareng du sGSL est constituée de deux composantes qui sont évaluées séparément : les géniteurs de printemps et les géniteurs d'automne. Le hareng du sGSL est exploité par une flottille qui pêche aux filets maillants dans les eaux côtières et une flottille de 12 senneurs (maximum) qui pêchent en eau plus profonde. Depuis 1999, les captures de géniteurs d'automne comptent pour 70% et plus des prises totales. Les conditions du marché ont joué un rôle important dans la détermination des niveaux de captures dans cette pêcherie. Il y a approximativement 3 000 détenteurs de permis d'appât pour utilisation personnelle dans le sGSL. En 2012 et 2013, il y avait en moyenne 712 permis commerciaux actifs aux filets maillants sur un total de 2 590 détenteurs de permis. L'évaluation de chaque composante de géniteurs est basée sur un taux d'exploitation de référence à $F_{0,1}$. Les prises par unité d'effort (PUE) des filets maillants et les nombres évalués dans le relevé acoustique sont les indices utilisés pour étalonner les modèles de population. Les limites inférieure et supérieure de référence en tenant compte de l'approche de précaution pour les deux groupes de géniteurs ont été établit en 2005. Lors de la plus récente évaluation des stocks de hareng 4T en 2013, des problèmes d'ajustements de modèles ont été soulignés, y compris des blocs de résiduels et des patrons de tendances rétrospectives. Des problèmes similaires ont existé dans le passé.

INTRODUCTION

This research document was presented at a regional science peer review meeting held from April 13 to 15, 2015 on a framework assessment for the fall spawning component of Atlantic herring in the southern Gulf of St. Lawrence (NAFO Div. 4T). This paper cites large portions of Chapter 3 called “Assessment background for southern Gulf of St. Lawrence herring” (Claytor 2001) who provided an extensive description of the historical southern Gulf of St. Lawrence (sGSL) herring stocks. The information was updated to include the most recent history up to 2013.

Assessment of the sGSL herring stocks has long depended on fishery catch rates as the principal abundance index. The first assessments relied on purse seine catch rates (Winters et al. 1977; Winters 1978; Winters and Moores 1979, 1980; Lett et al. 1978). However, as the gillnet fishery became more important, subsequent assessments relied increasingly on gillnet catch rates (see Cleary 1981; Ahrens 1985; Clay and Chouinard 1986; Chadwick et al. 1989; Claytor and LeBlanc 1999; Poirier 2002; LeBlanc et al. 2012).

ASSESSMENT BACKGROUND FOR SOUTHERN GULF OF ST. LAWRENCE HERRING

STOCK AREA AND STRUCTURE

The stock area for the sGSL herring extends from the north shore of the Gaspe Peninsula (Quebec), to the northern tip of Cape Breton Island (Nova Scotia) and includes the Magdalen Islands (Fig. 1). This area is consistent with the Northwest Atlantic Fisheries Organization (NAFO) Division 4T. For quota allocation and management purposes the area is divided into herring fishing areas that correspond to spawning aggregations and local fishing fleet areas (Fig. 1). Adult herring overwinter in deeper waters off the Laurentian Channel in Div. 4T as well as the east coast of Cape Breton in NAFO Div. 4Vn which is included in the stock area and the assessment of sGSL herring.

Two seasonal herring spawning components are assessed for the sGSL: spring spawners and fall spawners. At present, Gulf Region Science uses three techniques to assign herring samples to either spring (P) or autumn (A) spawning components based on gonad maturity stages (Cleary et al. 1982).

- For immature herring of maturity stages 1 and 2 (juveniles), the season of hatching is based on the size at capture and visual examination of otolith characteristics. The spawning component assignment for juvenile herring is its hatching season. Juveniles represent a small percentage of commercial catch, but are a higher proportion in the research survey samples.
- Adult herring with ripe or spent gonads (maturity stages 6 and 7) are assigned their maturity stage by macroscopic laboratory examination of the gonads. The fish are assumed to belong to the spawning component of the season in which they were caught. These currently represent over 90% of the gillnet catches and 75% of the total yearly landings.
- Adult herring with non-ripe gonads (maturity stages 3, 4, 5 and 8) are assigned their maturity stage by using a gonadosomatic index (GSI) based on a discriminant function model. The GSI is based on the length of the fish and its gonad weight (McQuinn 1989). Once the maturity stage is determined by GSI, the spawning component is assigned by

using a maturity schedule decision rule (a table cross-referencing maturity stage assigned by GSI and the date of capture).

Stock identification research

Stock identification research on 4T herring from different local spawning areas and/or season has been conducted by DFO Science, some in collaborative projects with fish harvester associations.

An analysis of trace elements from 1,017 4T herring otoliths (2003 to 2006) from both spawning seasons and within areas in a season indicated that some trace elements could potentially distinguish herring between seasons, but not within areas of the same season.

An otolith shape analysis pilot study also suggested that shape analysis could be used to distinguish spring and fall hatched 4T herring, but spawners among areas of the same season overlapped.

Yearly 4T herring tissue samples have been collected from 2005 to 2007 and again from 2012 to 2014, in order to have temporal replicates, for analysis of genetic differentiation among herring spawning areas and season as part of a collaborative project with Dr. Ruzzante of Dalhousie University. Results are pending.

MIGRATION AND SPAWNING

SGSL spring and fall spawning herring both over-winter in NAFO Div. 4Vn (Fig. 1). When the ice breaks up in the spring both spawning groups begin to return to the sGSL. Spring spawners migrate first to spawning areas and peak spawning occurs during April and May in various areas of the sGSL at depths of < 10m.

Fall spawners remain widely distributed throughout the Gulf from late May to July. In mid-August, they migrate to spawning areas at depths from 5 to 20 m with peak spawning occurring during late August to the end of September (Fig. 2). Large concentrations of post-spawning spawners are observed in Chaleur Bay and north of Prince Edward Island in late September and October research surveys. During the fall, mixtures of spring and fall spawners occur in these areas. By November, migration to the over-wintering area has begun and is generally well underway by December 1st. During January, herring are found at depths greater than 80 m in waters off the Laurentian Channel in 4T as well as the 4Vn area (Claytor 2000).

Juvenile herring (age 2 and less) possess anti-freeze proteins and remain in the southern Gulf for the winter (Chadwick et al. 1990). From 1991 to 1995, a December stratified random bottom trawl survey was conducted in the sGSL, covering selected areas which were known or thought to harbour juvenile Atlantic herring. There was evidence of both geographical and depth-related distribution preferences. Three main geographical areas had larger numbers of juvenile herring, with greater abundance only in specific strata with depths less than 73 m (LeBlanc et al. 1998).

Tagging studies conducted in 1970 to 1971 indicated that southern Newfoundland was also an over-wintering area for this stock during that period (Winters 1977; Winters and Beckett 1978). The tagging returns indicated that beginning in April there was a westward movement of herring into the sGSL and towards the Magdalen Islands. In October and November they migrated back to southern Newfoundland (Winters and Beckett 1978). Few herring have been observed in this area since the early 1980s and an exploratory fishery survey in 2006 did not find any concentrations in this area (Wheeler et al. 2006).

In recent years, the largest spring spawning areas are in the coastal waters of Northumberland Strait and the inner Chaleur Bay, while the largest fall spawning areas are in coastal waters off

Miscou Island and Escuminac (NB), North Cape and Cape Bear (PEI), and Pictou (NS) (Fig. 2) (LeBlanc et al. 2012).

COMMERCIAL FISHERY

TAC and quota allocations

SGSL herring are harvested by an inshore gillnet fleet, fishing in 4T coastal waters, and a purse seine fleet (>65'), of a current maximum of 12 seiners licenses, fishing in deeper water. Some small seiners (<65') also participate in the inshore fishery. Unless specifically stated as small seiners, the terms purse seiners or seiners refer to the purse seine fleet with vessels > 65'. During the spring and fall fishing seasons, seiners are prohibited from fishing in several areas set aside exclusively for the inshore fleet (Claytor et al 1997).

Prior to 1967, sGSL herring were exploited mainly by gillnets, and average landings from 1935 to 1966 were 34,000 tonnes. In the mid-1960s, a purse seine fishery was introduced and average landings were 166,000 tonnes during 1967 to 1972. A quota of 166,000 tonnes was introduced in 1972 and reduced to 40,000 tonnes in 1973 (Fig. 3). The purse seine fleet accounted for most of the catch from the time of its introduction until 1981.

Beginning in 1981, a change in the management plan altered the relative allocation of the TAC between the inshore and purse seine fleets. The purse seine fleet was allocated 20% of the TAC within the sGSL plus approximately 4,000 tonnes from the over-wintering area off Cape Breton. In 1992, the Cape Breton portion of the allocation was formally recognized as part of the southern Gulf TAC. The allocation split since 1992 has been 23% to the purse seine fleet and 77% to the inshore fleet (Claytor 2000).

Separate quotas for spring and fall spawners began in 1985. Separate quotas by management zone (Fig. 1) for the fall inshore fleet began in 1987 and for the spring inshore fleet in 1998. Catches of spring and fall spawners combined have been below the TAC since 2003 (Fig. 3).

To simplify fishery management, quota allocations are made on a seasonal, rather than spawning group basis. The spring season extends from January 1 to June 30 and the fall season from July 1 to December 31.The seasonal allocation is a practical consideration because purse seiners harvest both spawning groups throughout the year, while the inshore fleet harvests primarily spring spawners in the spring, and fall spawners in the fall.

Since 2005, a gear conflict Ministerial decision has restricted access of the purse seine fleet from fishing in north-eastern PEI inshore waters at depths less than 25 fathoms. Furthermore, during the fall fishery, the purse seine fleet is not allowed to fish west of a line between Grande-Anse (NB) and Paspébiac (QC) in Chaleur Bay, in order to limit catches of spring spawners. They are also not allowed to catch more than half of their fall allocation in the remaining portion of Chaleur Bay.

The assessment of the fishery and management is based on spawning group.

Spring and fall spawner composition

Since 1999, fall spawners have comprised 70% or more of the total catch in the sGSL (Table 1). Since 2010, mostly fall spawners are harvested by purse seiners during their late May and June spring fishery which occurs northeast of the Magdalen Islands on the edge of the Laurentian Channel. From 1991 to 2004, a spring seiner fishery took place along the Gulf of St. Lawrence coast of northern Cape Breton, where a mixture of spring and fall spawners was caught. Spring spawners are also harvested by purse seiners during their fall fishery in 4T and used to be caught in the over-wintering 4Vn area off the east coast of Cape Breton. No fall purse seiner fishery has occurred in the 4Vn area since 1999.

The inshore gillnet fleet harvests >97% spring spawners during their April and May spring fishery which occurs on or near spawning grounds. However, a small gillnet fishery in June captures mostly fall spawners. Less than 1% of spring spawners are caught during the inshore fall fishery, which occurs almost exclusively on spawning aggregations. Inshore fleets are based in their local areas and the number of boats in each fleet is more a function of the fishing community population size than of available biomass.

The dominance of fall spawners in the present day is a considerable change from the 1940s, when 90% of the catch was made up of mature spring herring from spawning concentrations in April and May. Most of these catches came from the Magdalen Islands and the New Brunswick portion of the Northumberland Strait. The fall inshore fishery was very small and only occurred around Cape Breton and there was no fall fishery in New Brunswick, Northumberland Strait because it would have been coincident with an established lobster season (Day 1957b).

At the present time there is no fall fishery along the Gulf shore of Cape Breton.

In the Chaleur and Gaspe areas of the southern Gulf, spring spawners also dominated the fishery of the 1940s. In Chaleur Bay, herring was the most economically important species after lobster and cod. A large percentage of older herring made up the catches in these areas and Day (1957a) and Tibbo (1957) suggested that fishing pressure could be increased.

The spring spawner TAC has not been exceeded since 2003 (Table 1). Most of the spring spawner inshore catches occur during the spring season in areas 16B and 16E (Table 2; Fig. 1).

The fall spawner TAC has not been exceeded since 1986. By agreement, within industry and not by regulation, fall inshore catches are for a roe market, and fall purse seine catches are for a filet market. About 50% of the fall spawner inshore catches come from 16B during the fall fishing season (Table 2; Fig. 1).

Influence of market on commercial fishery catches

Market conditions have played a large role in determining catch levels in this fishery. Prior to 1965, landings were primarily by fixed gear (Winters and Hodder 1975) and markets varied by area. Catches went to canned round, kipper snacks, and smoked bloaters in the Northumberland Strait, to smoked bloaters in the Magdalen Islands, and for bait in Prince Edward Island and Nova Scotia (Day 1957b). With the discovery in 1965 of herring over-wintering areas in southern Newfoundland, catches increased considerably as a purse seine fleet expanded from 1 to 50 vessels by 1968. The increase in purse seiners and catches was followed by an increase in reduction plants for the production of herring meal and oil (Winters and Hodder 1975).

Food markets opened in Europe as a result of the declines in Northeast Atlantic stocks and by 1972, 40% of total landings were sent to European markets (Winters and Hodder 1975). In the early 1980s a Japanese roe market for fall spawners was developed and most of the fall inshore catch goes for this market at the present time. The price for roe has a considerable effect on fall inshore catch and effort.

Currently, the spring catches by both fleets remain primarily for smoked or bait markets.

Reported bait for personal use catches

There are approximately 3,000 herring bait licenses for personal use in the southern Gulf. Each license allows catches of bait for personal use by fishing a maximum of three gillnets per day.

These herring bait catches are not fully accounted for in the landings statistics. Herring bait is in high demand, especially in the spring, for use in the snow crab and lobster fisheries. Herring bait is also used in the fall Northumberland Strait lobster fishery and the Gulf tuna fishery, which uses some herring and mackerel as bait to lure the tuna (chumming).

Until the mid 2000's, bait catches were partially recorded in the landings statistics with reporting slips called supplementary B's(Table 3). Efforts since the mid 2000's to use personal logbooks and dockside monitoring companies (DMC) to record bait licence catches have not improved the reporting which remains sporadic and limited to a few areas (Table 3). Although a logbook return is a condition of bait license renewal, it remains unclear whether reporting is poor due to low personal logbook returns or because this data is only partially recorded by DMC.

FISHING METHODS

The spring and fall commercial gillnet fisheries differ in the type of fishing and the mesh size of nets used. For example, most spring gillnet mesh sizes are $2^1/_4$", with some up to $2^1/_2$", and nets have a length of about 15 fathoms. In the southern Gulf fall inshore fishery, $2^5/_8$" is the most commonly used mesh size throughout, with a small percentage using $2^3/_4$" or $2^7/_8$" mesh (Table 4). Nets used in the fall are similar in length to the spring, about 15 fathoms (LeBlanc et al. 2012).

Fishing methods differ between the two seasons. In the spring almost all nets are anchored overnight and hauled the next morning. In the fall, spawning schools are searched for, and nets are set when a school of sufficient size is found. In the fall Chaleur Bay gillnet fishery, nets are fished with one end tied to the boat and the other end anchored. In other areas, nets are anchored at both ends and two or more strings may be set (LeBlanc et al. 2012).

Purse seiners generally fish in depths of 30 to 60 meters during the fall fishery and alongside the Laurentian Channel edge in deeper water during the late spring fishery. Seines are about 800 m long. There is currently a maximum of 12 seiner license holders in 4T, although less are actively fishing per year depending on quota allocations, area closures, and market conditions.

Fishing effort – Inshore commercial fishery

In 2012 and 2013, there was an average of 712 actively fishing gillnet commercial licenses out of a possible total of 2,590 license holders. From 1978 to 1985, the number of gillnets used was estimated for the entire sGSL, without distinction for area. Since 1986, the inshore fishing effort was calculated using the average number of nets used in each area, obtained either from the telephone survey or dockside monitoring data. Industry input for the assessment is acquired primarily from an annual phone survey conducted from December to January since 1986, and from the small pelagics advisory committee meetings and other workshops.

The annual phone survey collects information on the fishery and opinions on abundance trends (LeBlanc and LeBlanc 1996). A subset of about 30% of actively fishing gillnet commercial license holders, stratified by area, are phoned and asked a series of questions concerning number and size of nets used, frequency of fishing, and how the abundance in the current year compares to the previous year and their views on long-term trends.

The number of nets used in the spring is higher than the fall but has decreased in recent years, mostly due to a substantial decrease in abundance and measures put in place to reduce effort (Table 5). The number of hauls per day remains at one in the spring.

In the late 1970s and early 1980s, about twice as many nets were used in the fall fishery as in recent years, where the number of nets has been fairly constant but the number of hauls per night has increased (Table 6).

The fall gillnet fishery effort trends have changed over the years. Gillnets used to be deployed at neap or slack tide on the spawning aggregations. In recent years, net deployment is throughout the night and nets are also deployed in deeper water to intercept incoming spawners. These changes could affect the catch per net haul used as an abundance index for the population model.

ASSESSMENT MODELS

Formal assessments began with the International Commission for Northwest Atlantic Fisheries (ICNAF) in 1975 (Winters and Hodder 1975). These first assessments, including initial assessments conducted under the auspices of the Department of Fisheries and Oceans (DFO) (Winters et al. 1977; Winters and Moores 1979, 1980; Lett et al. 1978), used purse seine catch rates as the principal abundance index. Estimates of combined spring and fall spawner biomass were made using sequential population analysis models, as well as separate spring and fall estimates.

In the early 1980s, gillnet catch rates began to be used as the principal abundance index. Interviews and aerial surveys (Cleary 1981, 1982, 1983; Messieh 1984) gathered effort data. Trends in trap catches on the Magdalen Islands were investigated as an index for that area but no formal assessment models were examined (Powles et al. 1979). Data inconsistencies and analytical problems plagued these assessments. Results often differed considerably between assessments depending on method and data treatments. The situation in 1983 was summed up by one author of the assessments: “4T herring stock assessment is based on much imprecise data: real total catch is not known, various catch rate indices are biased, the spawning type and age assignment of fish is still often subjective, and recruitment is almost impossible to predict” (Cleary 1982).

Subsequent assessments improved on the estimates of effort using the phone survey and index gillnetters (for examples see Ahrens 1985; Clay and Chouinard 1986; Chadwick et al. 1989; Claytor and LeBlanc 1999). Poor spring inshore catch statistics precluded assessments of the spring stock using sequential population analysis until an improved dockside system came into effect in 1990.

The assessment for each herring component currently provides an $F_{0.1}$ fishing level calculation. In general, this level has been used to set the TAC when the stock is in the healthy zone. An ADAPT-VPA is currently the main assessment method. Fishery catch-at-age and weight-at-age matrices from 1978 to the present are estimated for each spawning group by fishing area. Gillnet fishery catch-per-unit-effort (CPUE) and acoustic survey abundance estimates have been used to calibrate the VPA (LeBlanc et al. 2012).

Gillnet CPUE (ages 4 to 10) and juvenile herring (ages 2 and 3) acoustic survey indices are used to calibrate the fall spawner population model, while gillnet CPUE (ages 4 to 10) and adult (ages 4 to 8) acoustic survey indices are used to calibrate the spring spawner population model.

GILLNET CPUE INDICES

Gillnet fishery catch–per-unit-effort (CPUE) from 1978 to the present was the main abundance index used to calibrate the VPA. Poirier (2002) reviewed the catch and effort data used in the assessment of herring populations in the sGSL.

Fishing effort was calculated as the average number of gillnets deployed by season and area for the entire sGSL since 1978. From 1978 to 1985, the average number of nets used was collected by questionnaires done on wharves and by mail (Clay and Chouinard 1986). Since 1986, the effort measurement used to calculate the abundance indices based on gillnet fishery catch rates is the number of standard gillnets used in the spring and fall fisheries as estimated from the telephone survey (LeBlanc and LeBlanc 1996) and, since 2005, from dockside observer data, where available. A standard net is 15 fathoms (27.4 m) in length.

For the spring spawner assessment, since 2003, the catch-weighted gillnet CPUE index was deemed more consistent with the spring stock trends (Poirier 2002). Therefore, the gillnet CPUE series chosen to calibrate the spring VPA model included the April and May dockside monitoring data from all areas, aggregated by day and area and weighted by the catch for that area. Daily effort was estimated by multiplying the number of trips by the average number of standard nets per fisher for each area. The fishing effort for the season was obtained by adding the fishing effort for all days. Thus, the units of measurement for effort were net-days.

Since the 2002 assessment, the fall spawner gillnet CPUE index, not weighted by the catch, was deemed more consistent with the fall stock trends thus used to calibrate the fall VPA models (Poirier 2002). The current fall gillnet CPUE index, which was accepted in the 2008 assessment, is defined as catches in kg/net*hauls/day (or kg/net*hauls/trip). The daily fishing effort was calculated by multiplying the number of standard nets by the number of hauls (Table 7), and the number of trips taken that day. Thus, the units of measurement for effort are net*hauls-days or net*hauls-trips.

To estimate annual gillnet CPUE abundance indices for both the spring and fall spawner components, a multiplicative model (GLM) was used with week, area, and year effects (LeBlanc et al. 2012).

ACOUSTIC SURVEY INDICES

The first extensive acoustic surveys used small boats (< 50 feet) and were done from 1946 to 1949. No biomass estimates were made but herring were found during spring and fall surveys along the Gaspe coast and in Chaleur Bay. In addition, extensive schools of fish were found in the Northumberland Strait areas of New Brunswick, Nova Scotia, and Prince Edward Island and around the Magdalen Islands. Maps of these distributions look similar to those of today. The conclusion from these surveys was that large spring spawning concentrations in the sGSL might be purse seined successfully (Leim et al. 1957).

Beginning in the mid 1980s, an acoustic survey was designed to estimate biomass in order to develop an abundance index for spring and fall spawners in the sGSL (Cairns et al. 1989). Inconsistencies in survey techniques and high variance prohibited its use in assessments until 1999, when a consistent data series from 1994 to 1998 was developed and utilized in the assessment model (Claytor and LeBlanc 1999).

These annual fishery-independent acoustic surveys of early fall (September-October) concentrations of herring in the sGSL have been concentrated in the Chaleur Bay-Miscou Bank area, but additional areas north of Prince Edward Island and Cape Breton were scheduled sporadically time permitting. The 2012 area surveyed is shown as an example (Fig. 4). These areas are where NAFO Div. 4T herring aggregate in the fall. The survey design uses random parallel transects within strata.

Data for the acoustic survey abundance indices for both spring and fall spawners were derived from the Chaleur-Miscou strata surveyed consistently from 1994 to present. This includes acoustic data collected when all transects were done at night and the same vessel, transducer, and sounder were used (Fig. 5). Sampling to determine biological characteristics, spawning group, and target strength determination was carried out wherever major concentrations were observed. The acoustic survey catch-at-age was estimated using samples collected from most strata and weighted by the acoustic estimated biomass of the most proximate strata. The numbers-at-age, scaled to the catch rate index formed the age-disaggregated abundance indices for spring and fall spawners (LeBlanc et al. 2012).

For the spring spawners, the current VPA used the age-disaggregated acoustic survey abundance index for ages 4 to 8 and years 1994 to 2013. For the fall spawners, catch-at-age from the acoustic survey still shows little correlation with cohorts from one year to the next, except for ages 2 to 3 and ages 9 to 10. The current fall spawner VPA used the juvenile ages 2 and 3 as an age-disaggregated juvenile abundance index (LeBlanc et al. 2012).

TRAWL SURVEY INDICES

Surveys with mid-water and bottom trawls were also completed between 1946 and 1949. While these surveys caught herring, they were not very useful in providing information on stock status or distribution (Leim et al. 1957). An annual multispecies bottom trawl survey throughout the sGSL has been conducted consistently during the month of September since 1971. While this survey has not been used as an abundance index it does seem to track contraction of the stock range during the years of depletion and the recovery in the mid-1980s (Claytor and LeBlanc 1999).

The herring catch-at-age from the September multispecies bottom trawl survey was last examined in 2008 to determine the feasibility of using it an index of 4T herring abundance (LeBlanc et al. 2009). A SAS procedure (proc corr) was performed to determine any correlation of age-class abundance from one year to the next, as well as with a 2 and 3 year lag. No correlation was found for the spring spawning component, while the fall spawning component showed poor correlation, with the best fit being on a two year lag. Both the spring and fall spawner catch-at-age numbers from the bottom trawl survey showed little correlation with cohorts from one year to the next.

REFERENCE POINTS

Since the first assessments the management goal for this stock has been to restrict fishing mortalities to below $F_{0.1}$ levels. Reference points have been calculated from yield per recruit models with $F_{0.1}$ varying from 0.30 to 0.44 per year whenever it has been calculated (Winters et al. 1977; Cleary 1981; Claytor et al. 1995). Doubleday (1985) investigated the effects of fishing level on herring stock stability by modelling recruitment trends and errors in biomass estimates. He concluded that an average fishing mortality of 0.2 would allow about 75% of the theoretical maximum yield to be taken and would not dramatically reduce or destabilize stocks. Exploitation rates exceeding 0.3 resulted in reduction of spawning stock size to a value equivalent to one successful year-class failure every 10 years. In 1997, a workshop was held that identified a number of ecological and life history target or reference points for herring in the sGSL, Bay of Fundy, Scotian Shelf, and Cape Breton. These included maintenance of all spawning components in time and space and healthy age structure (Anon 1997).

Spawning stock biomass reference points consistent with the Precautionary Approach were derived for the spring and fall spawning components of sGSL herring in 2005 (Chouinard et al. 2005; DFO 2005). The two reference points were the Limit Reference Point (LRP) and the Upper Stock Reference (USR). Stock and recruitment data for the two components were fitted to Beverton-Holt and Ricker stock-recruit models to determine if the two models can be used to identify the LRP. However, the model fits were poor. Given high recruit per spawning biomass ratios when the two components recovered, appropriate LRPs were calculated as the average of the four lowest biomass estimates, which occurred about the late 1970’s and early 1980’s. LRPs for the spring and fall components were 22,000 t and 51,000 t, respectively. To determine the USR, expected spawning stock biomass assuming average recruitment (age 2) and the removal rate reference ($F_{0.1}$; 0.35 for the spring component and 0.32 for the fall component) were calculated using spawner per recruit analyses. Interim values for the USR for the spring and fall components were 54,000 t and 172,000 t, respectively.

POPULATION TRENDS

The overwhelming feature of population trends in many herring stocks, including the sGSL, is one of large year-class fluctuations. These fluctuations were observed as early as the 1940s when Day (1957a,b) noted that the 1939, 1941, and 1943 year-classes were strong, but that the 1940 and 1942 year-classes were weak. Similarly, after the decline in population resulting from an epizootic in the mid-1950s, the very large 1958 fall and 1959 spring year-classes supported the fishery for 10 years. Poor year-classes combined with high fishing levels led to the decline during the late 1960s and 1970s (Winters and Hodder 1975). Since 1978, above average year-classes in the fall continued to drive the fishery for periods of 3 to 4 years, while the abundance of the recruiting spring spawner year-classes (at age 4) were below average after 1995.

Advice on fishing levels, with respect to estimated or inferred trends in biomass began in 1957. At that time, the lack of appreciable change in size and age composition of the stocks of herring since 1914 led to the conclusion that the commercial fishery had not reduced the level of abundance. In addition, accumulations of large, old fish in the spring and fall suggested that sGSL herring populations were under fished (Day 1957a, b). A great deal of effort was spent looking for ways to increase the yield from these stocks.

Efforts to increase yield were largely successful. The 1975 assessment estimated a decline in combined spring and fall spawners total biomass from 1,840,000 tonnes in 1965 to 506,000 tonnes in 1971. Adult biomass in 1971 was 12% of the 1965 value. The very large 1958 fall and 1959 spring year-classes, which appeared after the devastating epizootic of the mid-1950s were the principal reason for the high biomass in the mid-1960s. These assessments concluded that excessive fishing mortalities accelerated a decline which would have occurred anyway because the strength of the 1958 and 1959 year-classes was so atypical. Fishing mortalities were estimated to be below 0.4 for these years.

Subsequent estimates of biomass changed appreciably as stock assessment methods and data were updated. In general the trend was that successive assessments estimated higher fishing mortalities and lower population sizes than previous assessments. Current assessment advice is provided separately for each seasonal spawning stock. The division of the total TAC amongst the components may be a way of reducing the chance for the kind of overall stock collapse that has been seen in the past. It does not, however, guarantee that individual components will not be lost, as emphasized by the dramatic decline in spring catches in Escuminac since the late 1990s.

The latest assessment of the sGSL herring stocks in 2013 (DFO 2014) showed pathological problems when fitting the current population model. For the spring spawner component, overall fit of the population model was poor and there were residual patterns for the commercial CPUE index. There was a retrospective pattern in the estimate of SSB. The two indices used to tune the population model had dissimilar rates of change. This results in greater uncertainty in the estimates of abundance.

For the fall spawner component, two models were presented because the diagnostics of the model fits did not allow a clear choice between models. Both models showed retrospective patterns. There were also strong residual patterns in both models, with blocks of residuals suggesting the models do not capture important population or fishery dynamics. Possible causes for these patterns are hyperstability in the CPUE index, changes in natural mortality, and changes in catchability associated with variations in size at age or fishing practices. The estimated absolute biomass values differed substantially between models, however the trend in abundance from both were the same.

PAST FRAMEWORK MEETINGS

Similar analytical problems were encountered in past assessments of the sGSL herring stocks. In the recent past, two framework meetings were held for 4T herring, one in March 2003 and a second one in December 2005.

The March 2003 review examined problems encountered in both the spring and fall spawner assessment of 2002 (O'Boyle 2003). The review included potential causes of retrospective patterns and abundance indices used. An analysis of the retrospective problem was presented and diagnostics were examined to determine the more likely causes (Cadigan and Farrell 2003, 2005). Local influence diagnostics were used to investigate whether small changes or perturbations to sequential population analysis (SPA) input components such as catch or natural mortalities could remove or reduce retrospective patterns. For the fall spawner SPA, relatively small age- and year-specific changes to the SPA assumptions about the proportional relationship between an abundance index and stock size resulted in greatly reduced retrospective patterns and it was concluded that these assumptions were a plausible source of the retrospective pattern. Larger changes to catches, natural mortality assumptions, or estimation weights were required to reduce the retrospective pattern. These other factors seemed to be less plausible sources of the retrospective pattern. Some modifications for the VPA formulation were suggested that could lead to a significant reduction in the retrospective problem and suggestions were made to enhance the treatment of the VPA data inputs.

In December 2005, several issues related to the assessment of 4T herring stocks were discussed (DFO 2006). Limit reference and upper stock reference levels were defined for both the spring and fall spawning components (Chouinard et al. 2005; DFO 2005). Further analysis of causes and possible solutions to the retrospective patterns in the fall spawning component were reviewed, including (i) the relationship between CPUE and population, (ii) fishing mortality on oldest age, and (iii) natural mortality. Additionally, the input variables and the assumptions in the calculation of the fishing rate reference ($F_{0.1}$), such as yield per recruit, and the projection analysis were reviewed.

REFERENCES CITED

Ahrens, M. 1985. Annual assessment of herring in NAFO Division 4T. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 85/45.

Anon. 1997. Report of the Maritimes Region herring workshop, 18-19, February, 1997. Canadian Stock Assessment Proceedings Series 97/12.

Cadigan, N.G., and Farrell, P.J. 2003. Local influence diagnostics for the retrospective problem in sequential population analysis. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/057. 43 p.

Cadigan, N.G., and Farrell, P.J. 2005. Local influence diagnostics for the retrospective problem in sequential population analysis. ICES J. Mar. Sci. 62: 256-265.

Cairns, D.K., Wright, J.A., and Chadwick, E.M.P. 1989. Distribution and acoustic backscatter of herring in NAFO Divisions 4T and 4Vn, November - December 1988. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 89/42.

Chadwick, E.M.P., Cairns, D.K., and Dupuis, H.M. 1989. Assessment of Atlantic herring in NAFO Division 4T, 1988. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 89/63.

Chadwick, E.M.P., Cairns, D.K., Dupuis, H.M.C., Ewart, E.V., Kao, M.H., and Fletcher, G.L. 1990. Plasma antifreeze levels reflect the migratory behaviour of Atlantic herring (*Clupea harengus harengus*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 47: 1534-1536.

Chouinard, G.A., Poirier, G.A., and LeBlanc, C. 2005. Spawning Stock Biomass Reference Points for spring and fall spawning herring in the Southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/082. 14 p.

Clay, D., and Chouinard, G. 1986. Southern Gulf of St. Lawrence herring: Stock status report 1985. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 86/4.

Claytor, R.R. 2000. Conflict resolution in fisheries management using decision rules: an example using a mixed-stock Atlantic Canadian herring fishery. ICES J. Mar. Sci. 57: 1110-1127.

Claytor, R.R. 2001. Fishery acoustic indices for assessing Atlantic herring populations. Can. Tech. Rep. Fish. Aquat. Sci. No. 2359: 213 p.

Claytor, R., Dupuis, H., Mowbray, F., Neilsen, G., LeBlanc, C., Paulin, L., Bourque, C., and MacDougall, C. 1995. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring, 1994. DFO Atlantic Fisheries Research Document 95/69.

Claytor, R., LeBlanc, C., Sinclair, A., Poirier, G., and Paulin, L. 1997. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring stock, 1996. DFO Can. Stock Assess. Sec. Res. Doc. 97/30.

Claytor, R.R., and LeBlanc, C. 1999. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring stocks in 1998. DFO Can. Stock Assess. Sec. Res. Doc. 99/54.

Cleary, L. 1981. An assessment of the Gulf of St. Lawrence herring stock complex. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 81/23.

Cleary, L. 1982. Assessment of the 4T herring stock. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 82/47.

Cleary, L. 1983. An assessment of the southern Gulf of St. Lawrence herring stock complex. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 83/69.

Cleary, L., Hunt, J., Moores, J., and Tremblay, D. 1982. Herring aging workshop, St. John's, Newfoundland, March 1982. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 82/41.

Day, L.R. 1957a. Populations of herring in the northern Gulf of St. Lawrence. Bull. Fish. Res. Board Can. 111: 103-119.

Day, L.R. 1957b. Populations of herring in the southern Gulf of St. Lawrence. Bull. Fish. Res. Board Can. 111: 121-137.

DFO. 2005. Spawning Stock Biomass Reference Points for Southern Gulf of St. Lawrence Herring. DFO Can. Sci. Advis. Sec. Advis. Rep. 2005/070.

DFO. 2006. Proceedings of the Maritimes Provinces Regional Advisory Process Meeting on the assessment framework for 4T herring; 5 – 7 December 2005. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/008

DFO. 2014. Assessment of Atlantic herring in the southern Gulf of St. Lawrence (NAFO Div. 4T) to 2013. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/040.

Doubleday, W.G. 1985. Managing herring fisheries under uncertainty. Can. J. Fish. Aquat. Sci. 42: 245-257.

LeBlanc, C., and LeBlanc, L. 1996. The 1995 NAFO Division 4T herring gillnet telephone survey. DFO Atlantic Fisheries Res. Doc. 96/77.

LeBlanc, C.H., Mello, L., and Dupuis, H.M.C. 1998. Juvenile Atlantic herring 1991 to 1995 December bottom-trawl survey results in the southern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2244: 45 p.

LeBlanc, C.H., MacDougall, C., and Bourque, C. 2009. Assessment of the NAFO 4T southern Gulf of St. Lawrence herring stocks in 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/049.

LeBlanc, C.H., Mallet, A., MacDougall, C., Bourque C., and Swain, D. 2012. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring stocks in 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/111.

Leim, A.H., Tibbo, S.N., and Day, L.R. 1957. Explorations for herring in Canadian Atlantic waters, 1945-1950. Bull. Fish. Res. Board Can. 111: 35-83.

Lett, P.F., O'Boyle, R.N., and Messieh, S.N. 1978. Gulf of St. Lawrence herring stock complex - spring 1978 status report. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 78/4.

McQuinn, I.H. 1989. Identification of spring- and autumn spawning herring (Clupea harengus) using maturity stages assigned from a gonadosomatic index model. Can. J. Fish. Aquat. Sci. 46: 969-980.

Messieh, S.N. 1984. Recent changes in fishing effort and catch rates of inshore herring fisheries in the southern Gulf of St. Lawrence. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 84/59.

O'Boyle, R.N. 2003. Proceedings of the Maritimes Regional Advisory Process: Meeting on the assessment framework for 4T herring; 18 – 19 March 2003. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2003/009.

Poirier, G.A. 2002. Catch and effort data used in the assessment of herring populations in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/061.

Powles, H., Boulva, J., and Spenard, P. 1979. Herring catch per unit effort in the Magdalens traps fishery and implications for Gulf herring stock assessments. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 79/29.

Tibbo, S.N. 1957. Herring of the Chaleur Bay area. Bull. Fish. Res. Board Can. 111: 85-102.

Wheeler, J.P., Squires, B., and Williams, P. 2006. An assessment of Newfoundland east and south coast herring stocks to the spring of 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/101.

Winters, G.H. 1977. Migrations and activity levels of overwintering Atlantic herring (*Clupea harengus harengus*) along southwest Newfoundland. J. Fish. Res. Board Can. 34: 2396-2401.

Winters, G.H. 1978. Recent trends in stock size, recruitment and biological characteristics of southern Gulf herring. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 78/3.

Winters, G.H., and Hodder, M. 1975. Analysis of the southern Gulf of St. Lawrence herring stock and implications concerning its future management. ICNAF Res. Bull. 11: 43-59.

Winters, G.H., Miller, D.S., and Moores, J.A. 1977. Analysis of the stock size and yield of southern Gulf herring. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 77/2.

Winters, G.H., and Beckett, J.S. 1978. Migrations, biomass and stock interrelationships of southwest Newfoundland-southern Gulf herring from mark-recapture experiments. ICNAF Res. Bull. No. 13: 67-79.

Winters, G.H., and Moores, J.A. 1979. An evaluation of recent changes in the population dynamics of southern Gulf herring. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 79/28.

Winters, G.H., and Moores, J.A. 1980. An evaluation of the current status of southern Gulf herring. DFO Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 80/54.

TABLES

Table 1a. Annual landings (t) of 4T herring for the spring spawning group by fleet and the corresponding TACs (t), 1996 to 2013.

	Landings (t)				TAC (t)	
Year	Gillnet	Seiner	Total	% from gillnet	Gillnet	Seiner
1996	16,775	5,452	22,226	75	11,638	3,476
1997	12,943	4,473	17,416	74	12,705	3,795
1998	13,503	1,718	15,220	89	12,705	3,795
1999	10,432	4,457	14,889	70	14,245	4,255
2000	15,292	2,334	17,626	87	12,705	3,795
2001	10,674	3,446	14,120	76	9,625	2,875
2002	8,815	1,124	9,939	89	6,160	1,840
2003	8,496	490	8,986	95	8,470	2,530
2004	7,792	431	8,223	95	10,395	3,105
2005	3,585	1,084	4,669	77	8,470	2,530
2006	1,703	745	2,447	70	6,930	2,070
2007	1,744	2,414	4,158	42	3,851	1,149
2008	1,538	1,473	3,012	51	1,921	579
2009	1,326	519	1,844	72	1,921	579
2010	771	600	1,371	56	1,537	463
2011	854	664	1,518	56	1,537	463
2012	333	267	600	56	1,537	463
2013	875	829	1,704	51	1,537	463
Mean 2009 to 2013	832	576	1407	58	1,614	486

Table 1b. Annual landings (t) of 4T herring for the fall spawning group by fleet and the corresponding TACs (t), 1996 to 2013.

	Landings (t)				TAC (t)	
Year	Gillnet	Seiner	Total	% from gillnet	Gillnet	Seiner
1996	45,075	8,744	53,819	84	52,976	15,824
1997	35,354	6,363	41,717	85	45,237	13,512
1998	39,537	3,914	43,451	91	38,500	11,500
1999	46,240	9,464	55,704	83	44,327	13,241
2000	51,272	6,911	58,183	88	46,585	13,915
2001	45,445	7,923	53,368	85	54,670	16,330
2002	42,256	11,362	53,618	79	46,585	13,915
2003	48,374	12,839	61,213	79	39,655	11,845
2004	36,277	7,121	43,398	84	47,740	14,260
2005	52,640	7,756	60,396	87	56,210	16,790
2006	48,887	4,409	53,296	92	53,018	15,782
2007	43,657	4,426	48,084	91	53,018	15,782
2008	39,017	2,738	41,756	93	53,018	15,782
2009	44,874	1,939	46,812	96	50,090	14,910
2010	42,844	4,451	47,295	91	50,090	14,910
2011	37,092	1,372	38,464	96	50,090	14,910
2012	31,972	604	32,576	98	33,522	9,978
2013	29,935	4,434	34,369	87	33,522	9,978
Mean 2009 to 2013	37,343	2,560	39,903	94	43,463	12,937

Table 2a. Fixed gear Atlantic herring catches (t) during the spring fishery season by herring fishing area in NAFO Div. 4T, southern Gulf of St. Lawrence, 1993 to 2013. The data were obtained from ZIF raw data files, purchase slip files, dockside monitoring, or logbook reports. Data for 2012 and 2013 are preliminary.

Year	16A	16B	16C	16D	16E	16F	16G	Total
1993	106	2,397	4,543	885	6,829	200	126	15,086
1994	311	1,561	6,284	218	10,842	158	76	19,450
1995	66	1,844	4,909	1,043	7,988	96	27	15,973
1996	101	882	5,423	1,628	9,016	231	579	17,860
1997	91	622	3,085	1,552	9,921	49	499	15,819
1998	60	441	3,024	1,907	8,104	176	611	14,322
1999	62	277	2,343	2,699	5,534	162	628	11,704
2000	62	911	2,336	3,855	8,372	127	526	16,189
2001	34	582	1,287	2,624	5,242	270	556	10,595
2002	12	595	1,106	2,155	4,053	499	590	9,010
2003	11	511	374	2,806	4,426	410	524	9,062
2004	20	694	325	3,087	3,696	564	516	8,902
2005	1	815	109	1,095	2,009	546	374	4,949
2006	7	835	73	160	611	597	377	2,660
2007	6	615	159	21	888	146	377	2,212
2008	13	499	58	71	859	76	114	1,689
2009	9	286	12	47	949	25	23	1,351
2010	15	533	41	90	193	97	187	1,156
2011	7	424	59	10	379	76	89	1,044
2012	15	307	6	3	47	19	21	416
2013	6	377	19	3	450	20	23	899
2008 to 2012 Mean	12	410	35	44	485	58	87	1,131

Table 2b. Fixed gear Atlantic herring catches (t) during the fall fishery season by herring fishing area in NAFO Div. 4T, southern Gulf of St. Lawrence, 1993 to 2013. The data were obtained from ZIF raw data files, purchase slip files, dockside monitoring, or logbook reports. Data for 2012 and 2013 are preliminary.

Year	16A	16B	16C	16D	16E	16F	16G	Total
1993	103	14,504	3,060	618	2,137	935	1,776	23,133
1994	118	34,414	4,367	1,459	2,119	0	3,590	54,100
1995	60	29,992	4,921	1,901	5,006	10,141	4,244	56,265
1996	86	21,741	2,841	1,447	5,179	7,852	7,978	47,124
1997	106	18,460	2,013	407	4,447	6,278	7,331	39,041
1998	13	17,831	1,819	1,213	6,197	5,498	7,045	39,615
1999	6	21,627	3,897	389	4,531	5,957	8,909	45,316
2000	16	24,474	5,403	291	4,890	5,048	10,366	50,488
2001	3	21,750	4,750	0	3,232	6,749	9,022	45,506
2002	23	18,666	4,655	0	3,257	8,007	7,448	42,056
2003	3	21,387	5,756	0	2,423	9,116	9,025	47,710
2004	2	14,764	7,056	8	2,910	5,477	6,990	37,207
2005	2	24,116	5,052	0	4,479	8,916	9,251	51,816
2006	5	21,645	4,637	14	4,125	8,960	8,532	47,918
2007	15	19,560	3,099	34	4,283	8,684	7,493	43,168
2008	11	18,766	2,820	71	5,126	5,332	6,739	38,865
2009	14	19,407	4,197	117	4,333	8,317	8,467	44,852
2010	10	15,803	3,754	177	5,792	7,951	8,970	42,457
2011	57	15,159	2,866	38	5,857	8,675	4,247	36,899
2012	10	14,937	2,490	0	4,343	6,833	3,273	31,886
2013	20	15,440	1,905	36	4,030	5,577	2,922	29,929
2008 to 2012 Mean	20	16,814	3,225	81	5,090	7,422	6,339	38,992

Table 3a. Summary of reported personal use herring bait fishery catches (t), 1986 to 2001.

Year	Fall season	Spring season	Total
1986	518	2,333	2,851
1987	388	2,619	3,007
1988	559	2,063	2,622
1989	694	2,082	2,776
1990	936	2,041	2,977
1991	294	1,764	2,058
1992	226	1,299	1,525
1993	791	1,615	2,406
1994	517	2,448	2,965
1995	613	2,040	2,653
1996	1,844	1,924	3,768
1997	1,583	1,694	3,277
1998	1,182	557	1,739
1999	1,216	647	1,863
2000	1,818	1,361	3,179
2001	2,235	1,135	3,370
Average	963	1,726	2,690

Table 3b. Detailed estimates by fishing area of herring used as bait in the fisheries of the southern Gulf of St. Lawrence for 2002.

Fishing area	Active herring commercial fishers Spring season 2002	Active herring commercial fishers Fall season 2002	Number of herring bait licenses All seasons 2002	Herring bait fishery landings (t) 2002	Lobster licenses spring season [2]
16A	6	1	153	unk	na
16B	36	283	459	unk	na
16C	120	91	159	unk	722
16D [1]	126	0	410	505	324
16E	223	77	750	unk	793 (summer) [3]
16F	39	134	336	unk	749
16G	36	125	563	unk	614
All areas	586	711	2,830	unk	3,202

[1] 16D Iles-de-la-Madeleine: approximate bait needed for lobster traps = number of licences x 1 lb per trap x number of traps x number of fishing days = 324 licences x 300 traps per licence x 30 days / 2.2 lbs per kg = 1,325 t of bait

[2] Spring total: approximate bait needed for lobster traps = number of licences x 1lb per trap x number of traps x number of fishing days = 3,202 x 300 x 30 / 2.2 lbs per kg = 6,500 t plus of herring bait for spring fishery, even if use is 50% mackerel and 50% herring

[3] Fall: the fall tuna fishery uses herring as bait to lure tuna (chumming) as well as mackerel. Total estimated fall herring bait used in 2002 = 1,400 to 2,800 t.

Table 3c. Number of bait licences issued, number of logbooks returned and reported landings (t) of herring used for bait in 2006. Data are from DFO Fisheries and Aquaculture Management (unpublished).

Province	Number of bait licences	Number of logbooks returned	Reported bait landings (t) in logbooks
NB	690	4	10.6
NS	547	57	106.6
PEI	1,112	7	7.5
QC	1,037	na	15
Total	3,386	na	139.7

Table 3d. Herring bait catches (t) used for personal use in the spring lobster fishery by NAFO area as reported from dockside monitoring, 2009 to 2013. For NAFO areas 4Th and 4Tl, only half the area is open to lobster fishing in the spring season. The data exclude the Quebec portion of the fisheries.

		NAFO area						
Year	Data	4Tg	4Th	4Tj	4Tl	4Tm	4Tn	Total
2009	Tons	28.2	3.5	12.5	2.7	na	na	47
	Number of records	358	10	142	10	na	na	520
	Number of participants	32	2	22	3	na	na	59
2010	Tons	53.7	5.3	44.1	39.7	5.0	4.2	152
	Number of records	533	22	383	333	16	36	1323
	Number of participants	44	7	46	37	2	2	138
2011	Tons	68.5	3.4	20.5	25.0	14.9		132
	Number of records	571	18	276	172	97		1134
	Number of participants	78	5	54	41	13		191
2012	Tons	12.5	9.5	11.3	14.9	4.0	6.0	58.1
	Number of records	169	97	198	148	49	35	696
	Number of participants	19	10	28	19	9	6	91
2013	Tons	23.4	3.6	15.8	17.0	5.0	0.1	65
	Number of records	198	33	113	81	32	6	463
	Number of participants	14	7	18	15	7	1	62
Mean	Tons							90.8
	Number of records							827.2
	Number of participants							108.2
Approximate number of bait licences per year								2,600

Table 3e. Herring bait catches (t) used for personal use in the fall lobster fishery by NAFO area as reported from dockside monitoring, 2009 to 2013. For NAFO areas 4Th and 4Tl, only half the area is open to lobster fishing in the fall season. The data exclude the Quebec portion of the fisheries.

		NAFO area						
Year	Data	4Tg	4Th	4Tj	4Tl	4Tm	4Tn	Total
2009	Tons	13.5	3.0	0.3	0.1	na	na	17
	Number of records	10	16	8	1	na	na	35
	Number of participants	4	3	2	1	na	na	10
2010	Tons	67.6	3.6	1.2	41.6	na	na	114
	Number of records	43	9	12	151	na	na	215
	Number of participants	8	1	1	15	na	na	25
2011	Tons	53.9	27.0	1.0	146.9	2.1	na	231
	Number of records	130	23	55	118	10	na	336
	Number of participants	42	5	20	25	2	na	94
2012	Tons	3.7	4.3	1.9	1.4	0.1	0.1	12
	Number of records	26	30	31	27	1	1	116
	Number of participants	6	4	7	6	1	1	25
2013	Tons	2.9	0.0	0.4	2.9	na	na	6
	Number of records	18	2	6	15	na	na	41
	Number of participants	4	2	2	3	na	na	11
Mean	Tons							75.9
	Number of records							148.6
	Number of participants							33
Approximate number of bait licences per year								2,600

Table 4. Percentage of nets, weighted by landings per area, that are 2 ⅝" in the fall gillnet fishery for Atlantic herring from the southern Gulf of St. Lawrence, 1986 to 2013.

Year	% of nets 2⅝"	Year	% of nets 2⅝"
1986	75	2000	70
1987	92	2001	72
1988	91	2002	79
1989	89	2003	81
1990	81	2004	82
1991	79	2005	87
1992	68	2006	91
1993	63	2007	88
1994	61	2008	96
1995	54	2009	97
1996	56	2010	94
1997	58	2011	95
1998	60	2012	97
1999	64	2013	99

Table 5. Average number of standard gillnets used by fishers during the spring fishery (1 standard net = 15 fathoms) in the southern Gulf of St. Lawrence. Data are from responses during the telephone survey. Bold underlined values are taken from dockside monitoring data where number of records are higher than the number of records from the telephone survey. The values with an asterisk (Escuminac 2009 and 2010) are the previous year's value because of a lack of respondents.

Year	Gaspe	Acadian Peninsula	Escuminac	West P.E.I.	Southeast New Brunswick	Magdalen Islands
1986	9	-	25	34	26	-
1987	17	-	21	-	30	-
1988	13	-	21	27	29	-
1989	20	-	22	29	28	-
1990	25	-	23	20	28	-
1991	20	-	24	27	28	-
1992	19	-	23	23	23	-
1993	16	-	23	23	23	-
1994	16	-	21	21	24	-
1995	7	-	22	18	21	-
1996	5	-	20	17	27	12
1997	15	-	19	17	25	10
1998	14	-	25	18	24	15
1999	16	19	24	21	28	14
2000	21	11	29	25	28	18
2001	20	20	27	24	28	18
2002	22	21	29	22	29	16
2003	19	9	29	26	29	20
2004	20	17	29	28	31	23
2005	20	**<u>10</u>**	28	**<u>27</u>**	29	24
2006	27	**<u>14</u>**	**<u>27</u>**	**<u>23</u>**	28	21
2007	23	24	**<u>18</u>**	**<u>18</u>**	**<u>20</u>**	**<u>17</u>**
2008	19	**<u>9</u>**	**<u>23</u>**	**<u>19</u>**	**<u>23</u>**	**<u>12</u>**
2009	16	15	**<u>23 *</u>**	**<u>17</u>**	**<u>22</u>**	**<u>14</u>**
2010	20	**<u>18</u>**	**<u>23 *</u>**	**<u>17</u>**	**<u>22</u>**	**<u>14</u>**
2011	18	**<u>19</u>**	**<u>17</u>**	**<u>17</u>**	**<u>21</u>**	12
2012	14	**<u>15</u>**	**<u>16</u>**	**<u>18</u>**	**<u>18</u>**	**<u>12</u>**
2013	**<u>17</u>**	**<u>15</u>**	**<u>21</u>**	**<u>14</u>**	**<u>20</u>**	**<u>11</u>**

Table 6. Average number of standard nets used during the fall inshore fishery (1 standard net = 15 fathoms) in the southern Gulf of St. Lawrence. Data are from responses during the telephone survey and dockside monitoring program (DMP) data. Bold underlined values are taken from dockside monitoring data where number of records are higher than the number of records from the telephone survey.

Year	Acadian Peninsula	Escuminac	Nova Scotia	East P.E.I.	West P.E.I.
1986	5	9	7	9	8
1987	5	9	7	7	7
1988	5	6	6	7	7
1989	5	9	6	6	6
1990	5	11	6	7	7
1991	5	7	6	7	7
1992	5	9	5	5	11
1993	6	7	4	5	7
1994	5	8	5	7	10
1995	5	8	6	7	7
1996	5	8	6	6	6
1997	5	8	5	7	7
1998	5	7	6	8	7
1999	6	8	6	8	9
2000	5	9	6	8	8
2001	5	9	7	8	9
2002	6	9	7	8	9
2003	5	8	6	8	8
2004	6	8	7	10	10
2005	6	8	6	8	8
2006	6	8	5	8	**<u>12</u>**
2007	6	**<u>10</u>**	4	8	7
2008	6	**<u>10</u>**	**<u>6</u>**	**<u>8</u>**	**<u>7</u>**
2009	6	**<u>10</u>**	**<u>5</u>**	**<u>7</u>**	**<u>7</u>**
2010	6	**<u>10</u>**	6	**<u>9</u>**	**<u>9</u>**
2011	7	**<u>10</u>**	6	**<u>9</u>**	**<u>9</u>**
2012	7	**<u>8</u>**	**<u>7</u>**	**<u>8</u>**	**<u>8</u>**
2013	7	**<u>8</u>**	6	**<u>9</u>**	**<u>8</u>**

Table 7. Average number of standard gillnets (15 fathoms) and number of net-hauls (product of nets and number of hauls) used in the main fishing areas of the fall inshore Atlantic herring fishery in the southern Gulf of St. Lawrence, 1986 to 2013. Data are based on responses during the telephone survey.

Year	Gaspe	Acadian Peninsula	Escuminac	West P.E.I.	Southeast New Brunswick	Magdalen Islands
1986	9	na	25	34	26	na
1987	17	na	21	na	30	na
1988	13	na	21	27	29	na
1989	20	na	22	29	28	na
1990	25	na	23	20	28	na
1991	20	na	24	27	28	na
1992	19	na	23	23	23	na
1993	16	na	23	23	23	na
1994	16	na	21	21	24	na
1995	7	na	22	18	21	na
1996	5	na	20	17	27	12
1997	15	na	19	17	25	10
1998	14	na	25	18	24	15
1999	16	19	24	21	28	14
2000	21	11	29	25	28	18
2001	20	20	27	24	28	18
2002	22	21	29	22	29	16
2003	19	9	29	26	29	20
2004	20	17	29	28	31	23
2005	20	**10**	28	**27**	29	24
2006	27	**14**	**27**	**23**	28	21
2007	23	24	**18**	**18**	**20**	**17**
2008	19	**9**	**23**	**19**	**23**	**12**
2009	16	15	**23** [1]	**17**	**22**	**14**
2010	20	**18**	**23** [1]	**17**	**22**	**14**
2011	18	**19**	**17**	**17**	**21**	12
2012	14	**15**	**16**	**18**	**18**	**12**
2013	**17**	**15**	**21**	**14**	**20**	**11**

[1] previous year value used because of lack of respondents

FIGURES

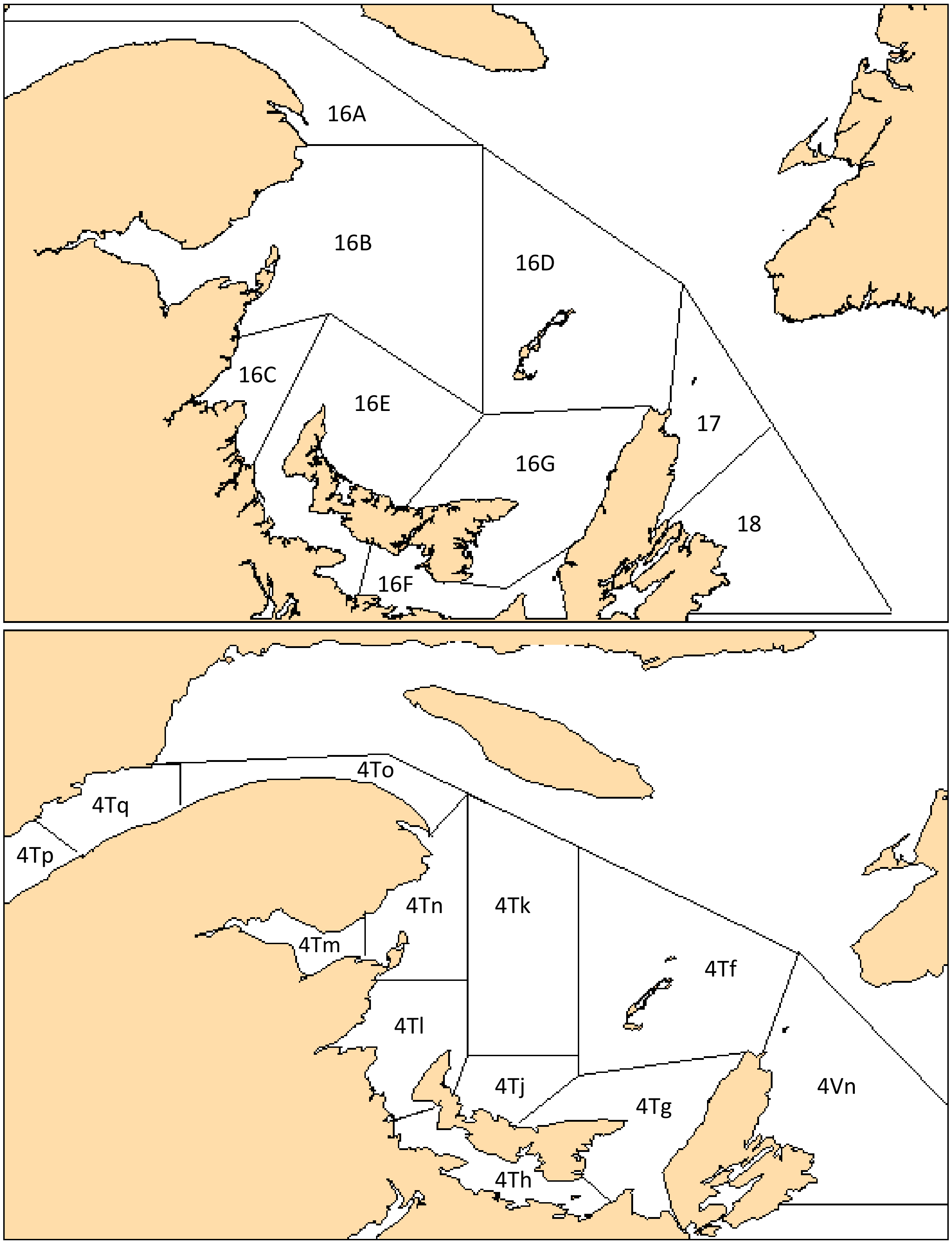

Figure 1. Southern Gulf of St. Lawrence herring fishing areas (upper panel) and Northwest Atlantic Fisheries Organization (NAFO) divisions 4T and 4Vn with 4T unit areas (lower panel).

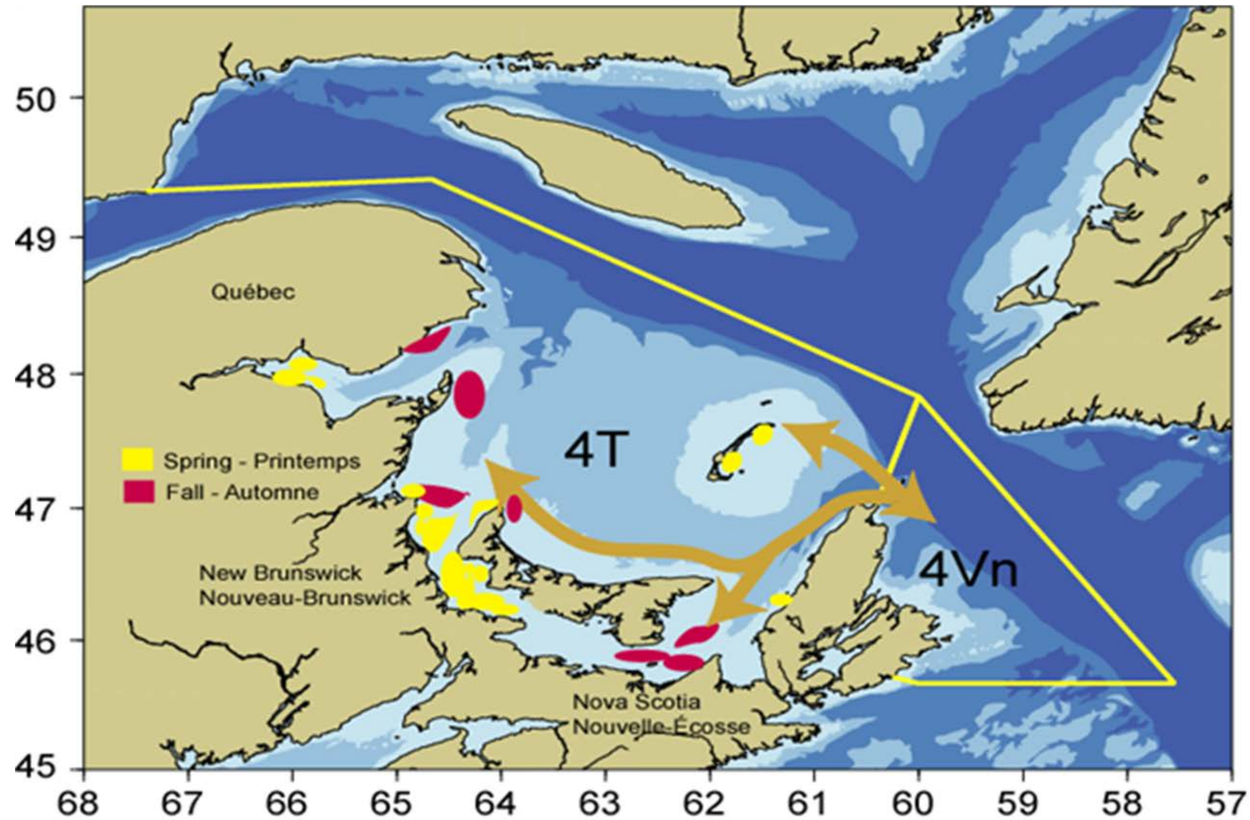

Figure 2. Spring and fall herring spawning areas and schematic of migration of Atlantic herring into the Gulf and out of the Gulf to overwintering areas in the southern Gulf of St. Lawrence.

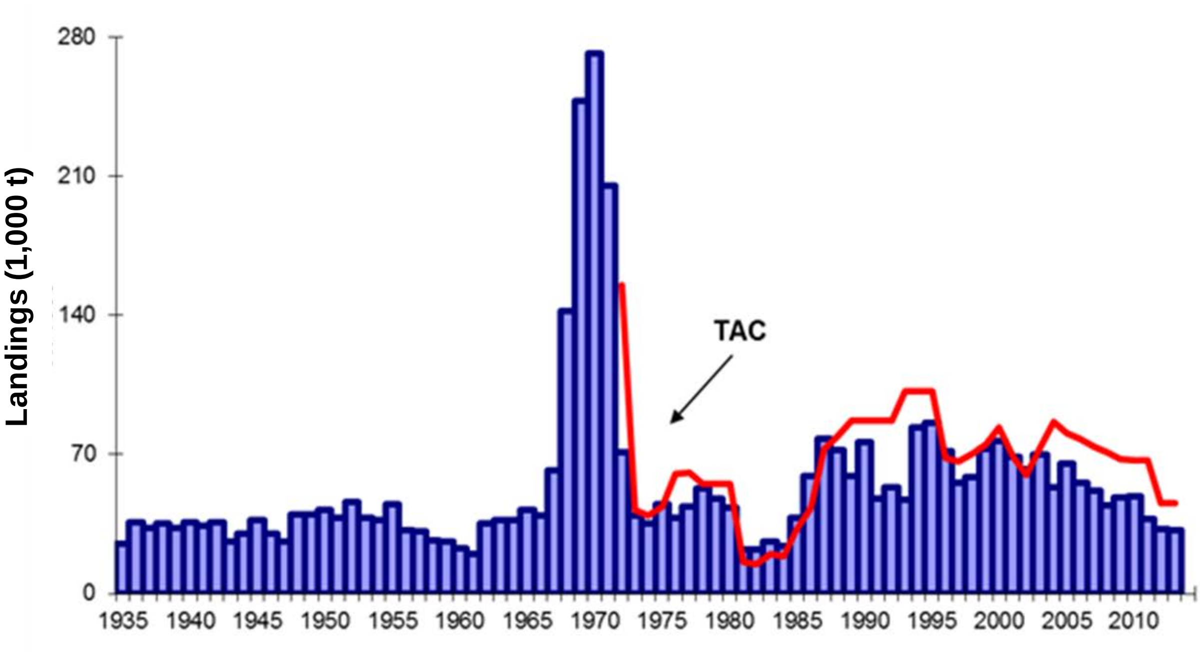

Figure 3. Combined spring and fall Atlantic herring landings from NAFO Div. 4T and the corresponding overall spring and fall spawning herring TAC, 1935 to 2013. The data from 2012 and 2013 are preliminary.

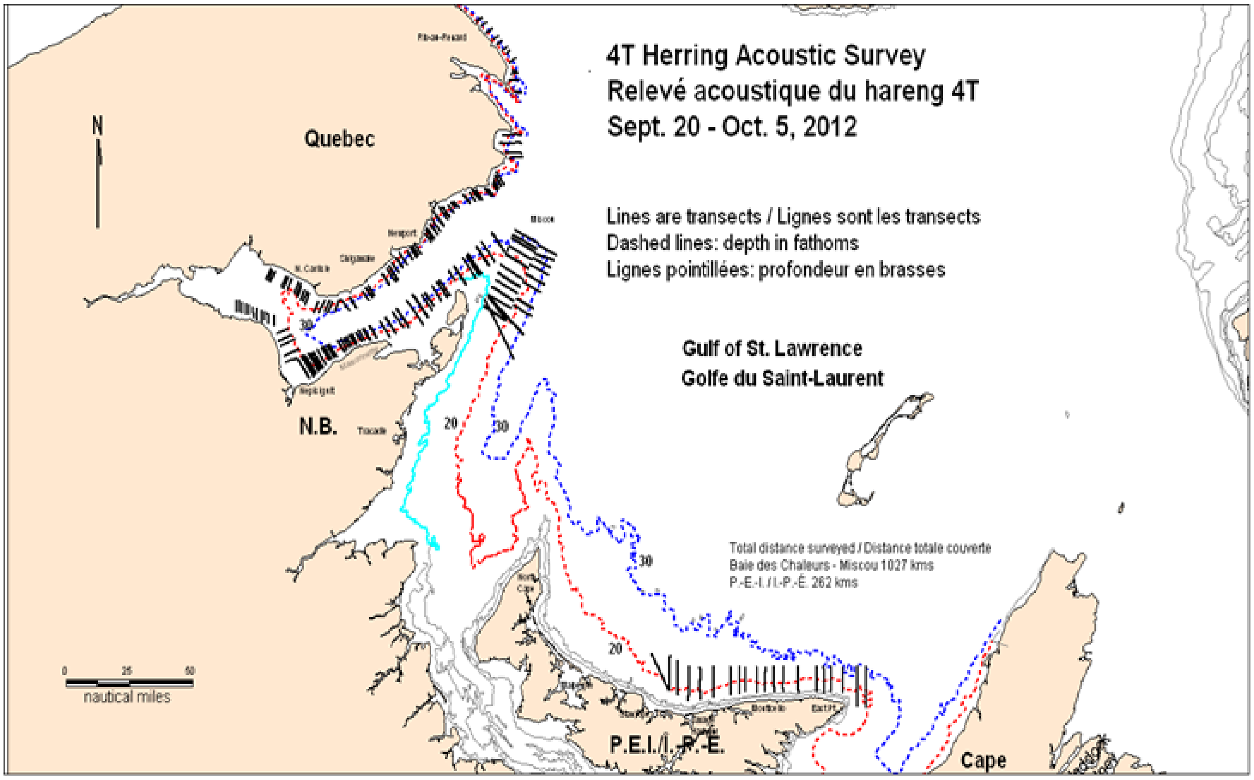

Figure 4. Surveyed transects (lines) covered during the 2012 acoustic survey of Atlantic herring from the southern Gulf of St. Lawrence.

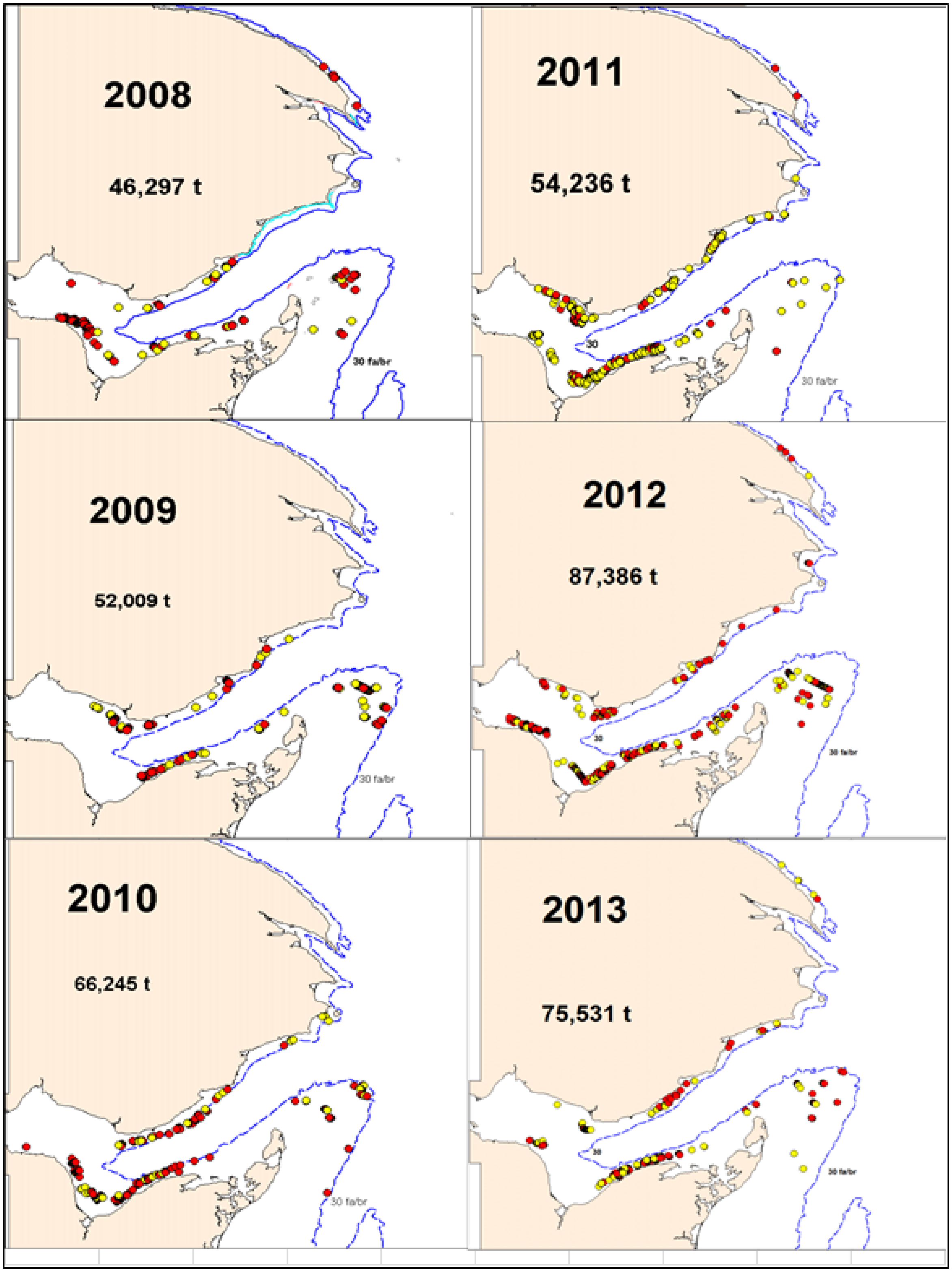

Figure 5. Estimated Atlantic herring distribution, density (coloured symbols) and biomass estimates for the Chaleur-Miscou area, based on the acoustic surveys of 2008 to 2013. Densities are defined as: yellow circles represent 0 to 0.15 kg per m^2 and red circles represent 0.15 to 10 kg per m^2.