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2017 Assessment of Newfoundland East and South Coast Atlantic Herring (*Clupea harengus*) Stock Complexes

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Foreword

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ABSTRACT

The assessment of Newfoundland east and south coast Atlantic herring (*Clupea harengus*) stock complexes considered data to the spring of 2016. Stock status index updates were provided for the Bonavista Bay-Trinity Bay (BBTB), St. Mary's Bay-Placentia Bay (SMBPB), and Fortune Bay (FB) stock complexes; biological updates only were provided for White Bay-Notre Dame Bay (WBNDB) and Conception Bay-Southern Shore (CBSS). All stock complexes with the exception of FB are currently dominated by fall spawning herring, following a shift in spawning stock composition which occurred during the early-2000s that was potentially correlated with environmental drivers. The age distribution of all stock complexes except FB was broad in 2015, with the strength of multiple year classes above the long term mean; the 2008 fall year class was particularly strong on the northeast coast (WBNDB, BBTB, CBSS).

With a general increasing trend in catch rates (with the exception of 2016), a broad age distribution, and good recruitment of age 4 herring in 2015 in the spring research gillnet program, the stock status index and short term prospects for BBTB were positive. An opportunistic acoustic survey conducted in February 2016 determined that relative abundance of herring in SMBPB was slightly below the mean of surveys conducted between 1986 and 2000, giving a positive stock status evaluation. In FB, catch rates in the spring research gillnet program have been well below average since 2011, the age distribution has been largely skewed toward older fish (age 11+), and recruitment was extremely poor from 2003-15; based on this information, the stock status index is negative and future prospects for the stock complex are poor. Without acoustic or gillnet surveys, stock status could not be updated for the WBNDB or CBSS stock complexes.

Évaluation de 2017 des complexes de stocks de hareng de l’Atlantique *(Clupea harengus)* des côtes est et sud de Terre-Neuve-et-Labrador

RÉSUMÉ

L’évaluation des complexes de stocks de hareng de l’Atlantique (Clupea harengus) des côtes est et sud de Terre-Neuve-et-Labrador a pris en compte les données jusqu’au printemps 2016. Des mises à jour de l’indice de l’état du stock ont été fournies pour les complexes de stocks de la baie de Bonavista et baie de la Trinité (BB-BT), de la baie St. Mary’s et baie Placentia (BSM-BP) et de la baie de Fortune (BF), mais des mises à jour biologiques n’étaient disponibles que pour la baie White et baie Notre Dame (BW-BND) et la baie de la Conception et côte sud (BC-CS). À l’exception de celui de la BF, tous les complexes de stocks sont dominés actuellement par le hareng reproducteur d’automne, après le changement intervenu dans la composition du stock reproducteur au début des années 2000 qui pourrait être corrélé à des facteurs environnementaux. La répartition selon l’âge de tous les complexes de stocks, sauf pour celui de la BF, était vaste en 2015, plusieurs classes d’âge se situant au-dessus de la moyenne à long terme; la classe d’âge de l’automne 2008 était particulièrement forte sur la côte nord-est (BW-BND, BB-BT, BC-CS).

Compte tenu de la tendance générale à la hausse dans les taux de prise (à l’exception de 2016), d’une large répartition selon l’âge et d’un bon recrutement du hareng de quatre ans en 2015 dans le programme printanier de recherche reposant sur l’utilisation de filets maillants, l’indice de l’état du stock et les perspectives à court terme pour la BB-BT étaient positifs. Un relevé acoustique opportuniste réalisé en février 2016 a permis de déterminer que l’abondance relative du hareng dans la BSM-BP se situait légèrement en dessous de la moyenne des relevés effectués entre 1986 et 2000, ce qui a donné une évaluation positive de l’état du stock. Dans la BF, les taux de prise dans le programme de recherche reposant sur l’utilisation de filets maillants ont été nettement inférieurs à la moyenne depuis 2011, la répartition selon l’âge est largement dominée par les poissons plus âgés (11 ans et plus) et le recrutement était extrêmement faible de 2003 à 2015; compte tenu de cette information, l’indice de l’état du stock est négatif et les perspectives pour le complexe du stock sont mauvaises. Sans relevé acoustique ou au filet maillant, il n’a pas été possible d’évaluer l’état du stock pour les complexes de stocks de la BW-BND ou de la BC-CS.

INTRODUCTION

Atlantic herring spawn and migrate largely in coastal waters around Newfoundland and southern Labrador. Being at the northern extent of their range in the northwest Atlantic, these stocks are subject to environmental extremes, which in turn lead to highly variable recruitment –strong year classes may be separated by as much as a decade. Shifts in herring stock composition and distribution occurred during the early-2000s, concurrent with changes in environmental conditions and the marine ecosystem. Most notable has been a shift in spawning stock composition from largely spring spawners to fall and possibly summer-spawning herring in all stock areas except Fortune Bay. Similar changes have taken place in other northwest Atlantic herring stocks since the 1990s and have been correlated with increasing water temperature, though it is suspected that other underlying environmental variables are likely driving these changes (Melvin et al. 2009). In addition there have been indications that the migration and distribution patters of NL herring have also shifted, with increasing occurrences offshore in NAFO Division 3Ps and delayed timing of spring spawning on the northeast coast during the 2000s.

STOCK COMPLEXES

STOCK STRUCTURE AND COMPOSITION

Herring on the south and northeast coasts of Newfoundland are divided into five stock complexes (Fig. 1): White Bay-Notre Dame Bay (WBNDB), Bonavista Bay-Trinity Bay (BBTB), Conception Bay-Southern Shore (CBSS), St. Mary's Bay-Placentia Bay (SMBPB), and Fortune Bay (FB). These complexes were delineated via tagging studies in the 1970s and 1980s, based on spring spawning locations (Winters and Wheeler 1984). Herring also occur along the south coast of Newfoundland in NAFO Division 3Pn and on the south coast of Labrador; it is not known which stock complexes they are affiliated with.

Over the past several decades there have been changes in both the NL marine ecosystem and local herring population dynamics. There was a decline in overall abundance of herring during the 1990s and early 2000s in most areas (Fig. 2). Prior to this, spring-spawning herring dominated all stock complexes. When abundance increased from lower levels on the northeast coast in the early-2000s, fall spawners accounted for as much as 80% of the catch. This shift was not as dramatic on the south coast, as fall spawners have always been more prevalent in SMBPB compared to other stock areas, and fall spawner recruitment did not increase in FB (Fig. 2 and 3).

In addition to changes in spawning stock composition, there have also been indications of shifts in distribution and spawning times during the 2000s. The relative amount of herring caught per fishing set in the annual spring multispecies bottom trawl surveys in NAFO Division 3Ps has increased through the 2000s, particularly after 2010 (Fig. 4 and 5). While bottom trawl surveys do not reliably capture Atlantic herring and therefore cannot be used to provide abundance estimates, this increased occurrence in the survey is a potential indicator of a distribution shift of south coast stock complexes. It is unknown whether herring distribution has shifted in northern areas as spring multispecies surveys do not cover NAFO Divisions 2H or 3K due to ice coverage. There have been no indications of increased offshore occurrence during fall multispecies surveys in any division. Both genetic and otolith-based studies are currently being conducted to examine the origin of herring collected offshore, and to explore other shifts which may have occurred since stock relationships were last studied in the 1980s.

LENGTH AT AGE AND MATURITY

Spring spawner lengths at age peaked in the late 1970s, declined through the 1990s and stabilized in the early-2000s (Wheeler et al. 2009). This has not changed significantly since, with lengths at age during the 2010s near those of the 1990s and still well below the 1980s (Fig. 6). There was no significant difference in length at age between spawning stock components or stock areas.

The length at 50% maturity (L50) was updated using a generalized linear model (GLM) with a logit-link function in R. Analysis was completed using data from samples collected in the research gillnet program, bait fishery, and commercial fishery. Fish were grouped by age, spawning type, and maturity (either immature or mature); if there were less than 30 individuals in a group, it was excluded from the analysis. Sample sizes were insufficient to estimate L50 for each stock area for most years, but comparisons between years when possible did not show a significant difference so all regions were combined. Similar trends were noted by Wheeler et al. (2009) when a previous L50 analysis was conducted.

After a relatively low L50 for the 2008 spring spawner year class at 251 mm (total length), the L50 of the 2009, 2010, and 2011 year classes increased, with a mean value of 273 mm. These values are over or near the current minimum size limit of 270 mm in the commercial fishery, which is intended to remain at or near the current L50 value (Fig. 7). During this assessment it was also possible to evaluate the L50 of recent fall spawner year classes, this had not been possible in the past due low numbers of fall spawners. As with spring spawners, the L50 of fall-spawning herring increased in 2009; the mean L50 of the 2009-11 year classes is 282 mm, above the commercial size limit (Fig. 7).

ECOSYSTEM CONSIDERATIONS

PHYSICAL AND BIOLOGICAL OCEANOGRAPHY

The Newfoundland marine ecosystem experienced a regime shift in the early to mid-1990s. A standardized physical environment composite index based on 28 time series of climate data (Colbourne et al. 2017) demonstrates a clear shift from colder conditions in the 1990s to warmer in the 2000s (Fig. 8); this coincides with the shift from spring to fall spawner dominance in most Newfoundland herring stocks (Fig. 9). While the composite index was below average for 2014 and 2015, it returned to above average in 2016 (Fig. 8). Biological oceanographic conditions also changed in the 2000s, with later onset in peak timing and reduced duration of the spring phytoplankton bloom since 2010 compared to normal conditions (Fig. 10). There have also been major shifts in zooplankton phenology, with overall declines in biomass from 2002 to 2015 and changes in the occurrence of adult stages of copepodites starting in the fall of 2006 (DFO 2017).

ECOSYSTEM AND PREDATION

Ecosystem data analysis shows that total finfish biomass in the NL shelves bioregion increased from the mid-2000s to early-2010s, then leveled off, and over the last couple of years has shown signals of decline (Fig. 11). These signals are not homogeneous across all ecosystem units; they appear stronger in the southern regions (3LNO and 3Ps). These signals could be associated with the joint reduced availability of key forage species like capelin and shrimp in the offshore since 2014, as well as other changes in ecosystem conditions (e.g. declines in zooplankton levels in recent years). Diet compositions of predators indicate that herring has been an important prey for harp seals in inshore areas in the past, and only occasionally appeared in the Atlantic Cod diet, most notably in southern Newfoundland (3Ps). This low importance in the diet of cod has been attributed in part to the more inshore distribution of herring in the NL bioregion, but also to timing of the surveys. Under current conditions of reduced availability of capelin and shrimp in the offshore, there is potential for an increase in predation pressure on herring if predators like cod increase their foraging/residence in inshore waters.

ENVIORNMENTAL CONDITIONS AND RECRUITMENT

Previous analyses found that the recruitment of spring spawners was largely influenced by January sea temperatures, with warmer temperatures triggering earlier maturation and spawning (Winters and Wheeler 1996). However, after environmental conditions changed in the 1990s and a general warming trend occurred, this relationship did not persist (Bourne et al. 2015). Winters and Wheeler (1996) also hypothesized that the timing and duration of the spring plankton bloom would also influence spring spawner recruitment, but lacked the biological data to explore this potential relationship. Using the Atlantic Zonal Monitoring Program (AZMP) spring bloom time series (1999-2015), a new regression analysis was performed for this assessment and a correlation (R^2=0.537, p=0004) between spring spawner recruitment in BBTB and the duration of the spring bloom on the Northeast Newfoundland Shelf was found (Fig. 12). This potential relationship supports the theory that the timing of the spring bloom causes a match-mismatch effect in spring spawner recruitment and that when spawning overlaps favorably with the bloom, larval survival and thus recruitment is high. No similar correlation was found for FB spring spawners; this reflects past studies which found that environmental influences on recruitment were apparently stronger on the northeast coast (Winters and Wheeler 1987).

Unlike spring spawning herring, mean January sea temperatures had the strongest correlation (R^2=0.484, p=0.0002) with fall spawner recruitment strength of all environmental variables examined (Fig. 13); temperature data was lagged 1 year as fall spawners are assigned to the year of hatching but January temperatures are encountered in the following calendar year (several months after hatch). Fall-spawned herring larvae overwinter and fall spawner recruitment tends to be stronger warmer areas (Melvin et al. 2009), so this potential relationship may demonstrate the influence of warming temperatures on larval/young fall spawner survival and thus recruitment strength. Again, no similar relationship was found for FB herring, which was expected given the low number of fall spawners in that area and the lack of internal consistency in the fall spawner recruitment index.

If these regression equations are used to predict recruitment for the 2012-15 spring and 2012-16 fall year classes, based on spring bloom and temperature data which was available at the time of this assessment, fall spawner recruitment declines to poor levels for the most recent year classes while spring spawner recruitment varies from low to average (Fig. 14). However these models are preliminary; they will be further investigated using more robust statistical analysis before any projections can be made with enough certainty to be included in the determination of stock status or future prospects.

THE FISHERY

FISHERY OVERVIEW

Atlantic herring are fished along the north and south coasts of Newfoundland and southern Labrador, both commercially and for bait. The commercial herring fishery peaked in the late-1970s at over 30,000 t total catch when the presence of several strong year classes and the introduction of purse seiners allowed intensive exploitation. All stocks were placed under quota regulation by the early 1980s as landings decreased sharply. Since then combined TAC's for all stock areas have not been met or exceeded (Fig. 15). The current combined TAC from Southern Labrador to Cinq Cerf Bay is 14,291 t. The commercial fishery is persecuted via both mobile and fixed gear, while the bait fishery uses gillnets only. Purse seines and tuck seines currently account for the largest proportion of total landings, though on the south coast the majority of landings are from the bar seine fishery in Fortune Bay (Fig. 16).

BAIT FISHERY

The herring bait fishery takes place largely in the spring, preceding the lobster fishery; however, bait landings have not been included in commercial landing statistics since 1996. Bait allocations are included in TAC's; voluntary logbooks and an annual telephone survey are used each year to estimate bait removals, which typically do not exceed those allocations (Fig. 17); see "Gillnet survey and logbooks" section below for further details.

COMMERCIAL LANDINGS

Total commercial landings were 6,475 t and 6,546 t in 2015 and 2016 respectively, representing approximately 50% of the overall TAC (Fig. 15); however, the landings for 2016 presented in this assessment were updated on January 17, 2017 at which time data were considered preliminary.

There has been a small fishery in Southern Labrador since 2013, with a 500 t exploratory fixed gear TAC. 111 t were landed in 2015 and 11 t in 2016 (Fig. 18). Most herring in this area are caught via traps and the fishery takes place in the summer (August-September). It is not currently known which stock complex these herring belong to.

In WBNDB, 616 t were landed in 2015, nearly double the amount of the previous year; landings in 2016 were the highest in nearly 20 years at 1,709 t, representing 65% of the TAC (Fig. 18) The majority of herring in this fishery were caught via purse seins and traps.

In BBTB, the TAC was increased in 2015 from 4,950 t to 6,110 t. Landings remained near the same levels as previous years, with 4,445 t in 2015 and 3,650 t in 2016, 73% and 60% of the increased TAC respectively (Fig. 18). The majority of landings are attributable to purse and tuck seines.

Commercial landings in CBSS have increased in recent years and the TAC was raised from 600 t to 700 t in 2015; 150 t were landed in 2015 and 480 t in 2016 (Fig. 18). Most landings in this area are attributable to purse and tuck seines, all occurring in Conception Bay.

In SMBPB landings continued to increase in 2015 and 2016, with 351 t and 539 t landed respectively, representing 16% and 24% of the TAC (Fig. 18). Landings are largely via purse seine, with a small percentage attributable to gillnets; all landings occurred in Placentia Bay.

Landings in FB have been declining since 2009; despite a reduction from 2,880 t to 2,260 t in 2013, and again to 1,200 t in 2015, the TAC has not been taken in recent years. Landings increased slightly in 2015 to 802 t and only 137 t were landed in 2016 (Fig. 18).

COMMERCIAL CATCH AT AGE

Commercial catch at age is calculated using samples collected from the fishery; an effort is made to collect a sample of 55 randomly selected fish per 500 t of landings by gear, month, and bay. An annual commercial catch numbers-at-age vector, by stock area and spawning type, is calculated by converting the catch (t) to fish numbers using the mean whole weight from the sample being applied to that portion of the catch. Those numbers are then apportioned by age using the sample numbers-at-age. At the time of this assessment, ages and spawning type designation were available for all samples up to and including 2015.

The age structure of commercial samples collected in the Labrador fishery in 2014 was similar to that seen on the north coast, with strong 2008 fall and 2009 spring year classes comprising a large proportion of the catch; however in 2015, no spring spawners were present– this may be attributable to the small sample size for this area (Fig. 19a).

In WBNDB in 2014, the strong 2008 year class (age 6) accounted for over 50% of the catch, with a mix of age 4, 5, and 11 + herring composing a further 35%. In 2015, there was a broader age distribution, with signs of a potentially strong 2013 spring year class that accounted for almost 20% of the catch; however it should be noted that sample sizes in this area are also small (Fig. 19a). Fall spawners continue to account for over 50% of the catch in this area: 58% in 2014 and 68% in 2015 (Fig. 2, Fig. 21).

As with WBNDB, the 2008 fall year class dominated the catch in 2014 in BBTB, accounting for over 50% of landings. In 2015, this year class remained strong while ages 3-6 also accounted for over 10% of the catch each. The 2013 spring year class also appears to be potentially strong in this stock area, though less so than in WBNDB, with age 2 fish accounting for about 3% of the catch (Fig. 19a). Fall spawners also continue to dominate the commercial catch in BBTB, comprising 80% of landings in 2014 and 2015 (Fig. 2, Fig. 21).

In the CBSS stock area, the catch at age in 2014 and 2015 was similar to that seen to the north, with a strong 2008 fall year class dominating the catch in both years and signs of a potentially strong 2013 year class (Fig. 19b). Fall spawners comprised 95% of the 2014 catch and 73% of the 2015.

There was a broad age distribution in the SMBPB commercial catch in 2014, with the 2008 year class comprising the largest proportion (25%), followed by age 11+ and age 5 fish. In 2015 the age distribution was truncated with all fish age 6+, and again the 2008 year class and age 11+ dominating the catch. These age distributions were based on only 2 samples obtained from the spring purse seine fishery in Placentia Bay (Fig. 19b). Fall spawners accounted for 49% of the commercial catch in 2015 and 95% in 2015 (Fig. 2, Fig. 21). In an effort to obtain more information from this area where sample size has been an issue in recent years, extra samples were collected from gillnet bait fishers in 2015. The age distribution from the 3 samples collected was somewhat less truncated than that of the purse seine samples, with 41% spring spawners (Fig. 20).

In FB the commercial catch at age continued to be extremely truncated, with age 11+ fish comprising over 90% of landings in both 2014 and 2015 (Fig. 19b); this is a cause for serious concern as declining catch numbers indicate that the remaining fish in this stock are now experiencing significant mortality. FB remains the only stock area where fall spawner recruitment did not increase during the 2000s and spring spawners still consistently comprise the majority of the catch: 99% in 2014 and 85% in 2015 (Fig. 2, Fig. 21).

INDUSTRY INPUT

SEINER SURVEY

The seiner telephone survey has been conducted twice a year since 1996, to collect information from purse seine fishers who were active in the spring and/or fall fisheries. During the survey, attempts are made to contact all fishers who reported purse seine landings each season; response rates are generally 90% or higher. The survey has included fishers in WBNDB, BBTB, and SMBPB since 1996, and CBSS since 2013 when purse seine landings began to increase in that area; there is no purse seine fishery in FB. Respondents are asked to provide estimates of their total landings, discards, percent survival, and number of sets for the season, as well as their observations of overall abundance, which are used to update the Cumulative Change index (see below). At the time of this assessment, the spring 2016 survey had been completed but the fall survey was still taking place.

Most estimated discards from this survey are typically attributed to undersized herring, as current management measures state that if more than 10% of herring sampled from a purse seine set are below the minimum size limit (currently 9 ¾ inches/248 mm fork length), then the set must be released. Due to the variable recruitment of Atlantic herring, strong cohorts tend to be separated by a number of years. This causes a ‘pulse’ of undersized fish to enter the fishery and often dominate the catch for a period of time. Until that cohort reaches the minimum size for the fishery there will likely be issues with high percentages small herring and thus discards.

In WBNDB, purse seine landings were down from previous years, with 127 t landed in 2014, largely caught in the fall. Fishers estimated that 92 t of herring were discarded, representing 42% of total removals (Fig. 22). Effort was high in 2014 with a total of 92 estimated sets, but the landings/set ratio was at the lowest in the series at 2 t/set. In 2015, 329 t were landed by purse seines, again largely in the fall. Fishers estimated that 200 t were discarded due to size, representing 38% of the total removals. The landings/set ratio was at its highest since 2006, at 29 t/set. There were no spring purse seine landings in this area in spring 2016.

In BBTB, purse seine landings remained high in 2014 and 2015, at 2,413 t and 3,074 t respectively. The fall fishery accounted for approximately 60% of landings in recent years. Fishers in 2014 indicated that approximately 115 t were discarded – just 5% of the total removals. Similarly, in 2015, 98 t discards were estimated, 3% of total removals (Fig. 22). Landings/set were high in both years at 33t/set in 2014 and 25 t/set in 2015. The spring survey for BBTB in 2016 indicated that in addition to the 677 t reported landings, 325 t had been discarded. This accounted for 32% of total removals (Fig. 22). This increase was likely due to the recruitment of a potentially strong cohort of young fish (age 2-3).

In CBSS, 313 t were landed in 2014 and an estimated 75 t discarded, representing 19% of total removals. Landings decreased to 83 t in 2015 and estimated discards were 50 t, increasing the percentage to 38% of total removals. Landings increased again in 2016 to 265 t, and there was 100 t estimated discards – 27% of total removals (Fig. 22).

In SMBPB the purse seine fishery was largely inactive from 2011 to 2013, but has since resumed at a reduced level. In 2014, 338 t were landed and an estimated 120 t discarded, representing 25% of total removals. Similarly, in 2015, 348 t were landed and 105 t estimated as discards (23% of total removals). The percentage of discards increased to 45% in 2016, when 244 t were landed and an estimated 200 t discarded (Fig. 22).

GILLNET SURVEY AND LOGBOOKS

The herring gillnet telephone survey was implemented in 2006 to obtain estimates of herring bait removals, which are not included in landings data. The survey is also used to get fishers’ perceptions of changes in abundance in their areas (see Cumulative Change Index below), and since 2013, collect information about bycatch in the herring bait fishery.

Each fall, a random subset of herring fixed gear licence and bait permit holders are selected for the survey within each stock area to provide a 10% margin of error, assuming an 80% response rate. The CBSS stock area was added to the survey in 2016. The total number of licence and permit holders has dropped during the time series from 2,465 in 2006 to 1,572 in 2016. Overall the percentage of fishers actively fishing bait gillnets has remained near 40% on average, but this varies by stock area; currently there are approximately 553 active bait gillnet fishers in total (Fig. 23).

In 2015 and 2016 the survey achieved an 82% response rate, with 306 fishers successfully contacted in 2015 and 293 in 2016 (Fig. 23). The majority of bait fishers were active in May, June, and July, and a small percentage in the fall on the north coast (September to December). Atlantic cod accounts for the majority of reported bycatch in the survey, along with other cod species (tomcod, Greenland cod); Atlantic salmon have been reported as bycatch primarily in WBNDB, and mackerel accounted for larger proportions of bycatch in WBNDB and BBTB in 2015 and 2016 (Fig. 24). In addition, bycatch of larger animals was noted by some fishers including: 4 northern gannets in WBNDB in 2016; 5 seals in BBTB in 2015; and 10 seals, 4 sharks, and 1 large turtle (released alive) in CBSS in 2016 (Fig. 24). There were fishers in all stock areas who commented that a new bait licence condition requiring gillnets nets to be set parallel to shore is having a negative impact on their catch rates.

In WBNDB the number of active bait fishers has declined throughout the survey, with 189 in 2015 and 166 in 2016 – about 25% of licence and permit holders (Fig. 23, 25). Estimated bait removals for this area declined concurrently, with 151 t in 2015 and a time series low of 121 in 2016. Bait removals in this area have been well below the bait allocation in recent years and in 2015/2016 accounted for a small proportion of total estimated landings (Fig. 17). Fishers in this area commented that (purse) seiners have been overfishing and depleting stocks; herring are scarce inshore and arriving later; and that fall now is the best season for fish for bait.

BBTB continues to have the highest estimated bait removals, with 283 t in 2015 and 272 t in 2016, near the bait allocation of 300 t (Fig. 17); there were an estimated 194 active fishers in 2015 and 182 in 2016, representing approximately 30-35% of bait permit holders (Fig. 23, 25). Fishers in this stock area also commented that seiners are depleting the stocks and that summer/fall is now the best time to catch herring.

Fishers in CBSS were surveyed for the first time in 2016. There are an estimated 60 active fishers in this area; approximately 13% of bait permit holders, and that 81 t of herring were removed as bait, exceeding the bait allocation of 50 t (Fig. 17, 23, 25).

The survey indicated a significant increase in bait fishing in SMBPB with 12% of bait and permit holders actively fishing in 2015 and 30% in 2016, with the estimated number of active bait fishers jumping from 26 to 115 (Fig. 23). Estimated landings increased from 18 t to 180 t, exceeding the bait allocation of 150 t (Fig. 17). In 2015 most fishers contacted in this area commented that herring were scarce and that they had to purchase their bait, many blamed seiners for depleting the stock. In 2016, while some fishers did still consider abundance to be low, most commented that numbers were up and there was a lot of small herring in the area.

In FB, there were an estimated 76 active bait fishers in 2015 and 87 in 2016, approximately 24% of bait permit holders (Fig. 23). Bait landings increased in this area from 64 t in 2015 to an estimated 128 t in 2016, still well below the bait allocation of 400 t (Fig. 17). As in past surveys, all fishers contacted in this area commented that seiners in Long Harbour are depleting this stock and that abundance is extremely low. In 2016 some fishers did note the presence of small fish in small mesh gillnets, but added that these fish would not get to spawn due to seiner activity.

In addition to the telephone survey, all herring bait permit holders have also been sent voluntary logbooks since 1996. Return rates of these logbooks have been poor throughout the time series (Fig. 26) and currently they are used only to collect data on the timing of the fishery (active months) and perceptions of abundance. Bait logbooks will be mandatory as of 2017 and it is hoped that return rates will increase.

CUMULATIVE CHANGE INDEX

All fishers who complete logbooks (both bait and research) and take part in telephone surveys are asked to provide their perception of changing herring abundance by answering the following question:

"Using a scale of 1 to 10 (1 being lowest, 10 highest), how abundant were herring in your fishing area in (current year) compared to (previous year)?"

The answers are used to calculate the Cumulative Change Index. The 1 to 10 scale of abundance is converted to a scale of -4.5 to 4.5, where 0 is average (no change). An average value is derived from all fishers' responses for each stock area; as of the 2014 assessment, these indices were further split into fixed and mobile gear, as perceptions of abundances at times differed significantly between the two. The index was expanded in 2015 to include bar seine fishers from FB, as there is no purse seine fishery in the area and the index had previously only included gillnet fishers, which did not provide a complete perspective from the industry in the area. In 2016 the index was further expanded to include gillnet and purse seine fishers in CBSS and results for that stock area will be presented in assessments going forward.

Trends in the index in WBNDB and BBTB have been similar in recent years. Mobile gear fishers in both areas indicated a general increase in abundance over the past 5 years, with just a slight change between 2014 and 2015, but a greater increase in 2016. Fixed gear fishers in both areas reported sharp declines in abundance in 2011, followed by a general increasing trend until 2014 in WBNDB and 2015 in BBTB, after which abundance decreased in both areas. In SMBPB, mobile gear fishers reported a general increasing trend since 1999, though there was no purse seine activity in 2011 or 2012 so there is a break in the series at this point; fishers indicated little change to 2014, but increasing abundance in 2015 and 2016. Fixed gear fishers in SMBPB indicated a general decrease in abundance since 2010, with the exception of 2012 when the trend increased slightly, and again in 2016. Bar seine fishers in FB indicated that abundance had increased in 2015 and slightly more in 2016. In contrast, gillnet fishers in FB have been indicating declining abundance in the area since 2000 (Fig. 27)

RESEARCH GILLNET PROGRAM

OVERVIEW

The herring research gillnet program is a long-running project which provides the only fishery-independent index of relative abundance. Each spring, 8 fishers in BBTB and 4 in FB are contracted to fish a standardized fleet of 5 gillnets of varying mesh size for a 45 day period between April 1 and July 31. The timing of the program is intended to intercept spring spawners during their annual inshore spawning migrations. In the past the program as also operated in other stock areas and in some cases during the fall, but the scope has since been reduced (see Bourne et al. 2015).

Fishers set their nets in the same location and, when possible, at the same time of year each spring. The same fishers are contracted each year; if a fisher can no longer take part in the program, efforts are made to replace he or she with another local fisher who is able to set the fleet of gillnets in the same general location to preserve the integrity of the historical time series (which runs from 1982 in FB and 1988 in BBTB). During the 45 day fishing period, fishers keep detailed logbooks and collect 2 samples of 55 fish per week. These samples are then used to calculate mesh-disaggregated catch rates at age by spawning type, and to derive a recruitment index based on catch rates of age 4 fish.

CATCH RATES AND AGE STRUCTURE

In BBTB the combined catch rate (both spring and fall spawners) in 2015 was the second highest in the time series, well above both the time-series and decadal means; however catch rates fell steeply in 2016 to the lowest point since the early-2000s (Fig. 28). Comments from fishers in this area indicate that herring were very late arriving to their usual spawning areas in 2016. The proportion of fall spawners in BBTB increased during the 2000s and has remained high, accounting for 76% of the catch in 2014 and 69% in 2015 (Fig. 2, 29) – biological data from samples collected in 2016 was not available at the time of this assessment. The catch at age in 2014 was dominated by age 6 fall spawners (2008 year class) which accounted for over 35% of the catch, followed by age 11+ fish at 30%, and age 5’s (largely spring spawners) at 15%. The strong 2008 fall year class continued to dominate in 2015, again accounting for about 35%, and the 2007 year class accounted for over 20% with a mix of spring and fall spawners (Fig. 30). Generally, since 2000 the catch in this area has been driven by the relatively strong 2002 spring and fall, 2008 fall, and 2009 spring year classes (Fig. 31a, 32a).

In FB the combined catch rates have been well below the time series mean since 2004 and have been at extremely low levels since 2011 (Fig. 28). Unlike the other stock areas, after spring spawners declined in the late 1990s, fall spawner recruitment did not increase in FB; spring spawner numbers remain low but they still dominate the catch, comprising 81% in 2016 (Fig. 2, 29). The catch at age in FB has been extremely skewed in this area for several years, with age 11+ spring spawners accounting for 80% or more of the catch. In 2015 this declined to about 60%, but the age distribution was still highly skewed. The age distribution in 2016 changed, with age 4 spring spawners accounting for nearly 40% of the catch, an equal proportion to the age 11+ group (Fig. 30). Though this recruitment of spring spawners does signal potential for this stock to recover, the current age distribution is still not considered to be indicative of a stable stock. Up to this recent recruitment, the fishery was carried entirely by the 2002 spring year class, which is now being depleted and catch rates remain low (Fig. 31b, 32b).

RECRUITMENT

The recruitment index of spring spawners (natural logarithm of age 4 catch numbers) in BBTB was well above average in 2009, below average in 2010 and average in 2011. The 2009 year class is currently the only mature spring spawner year class that is of above average relative strength. Recruitment of fall spawners was above average in 2008, average in 2009 and 2010, and above average in 2011. All mature fall spawner year classes are of above average relative strength. When spring and fall spawners are combined, only the 2008 and 2009 year classes are above average, and these are currently dominating the catch in this area (Fig. 32a).

There are indications that peak spring spawning times on the north coast, including BBTB, have shifted into July and August (Bourne et al. 2015). This was noted in particular in 2011 and again in 2016 when research gillnet catch rates were extremely low and comments from fishers indicated that this was due to the late or non-arrival of herring during the spring fishing period (April 1-July 31). However, the index provided by the program still appears to be reliable, as a test of internal consistency was conducted through regressions of age class catch rates with a one year lag and no significant issues were found; the program appears to give reliable estimates of both spring and fall spawner year class strength through the time series (Fig. 33a and 34b).

In FB spring spawner recruitment had been well below average since 2004, but rose to above average in 2012, indicating a potentially strong year class entering the fishery. Currently, all of the mature spring spawner year classes in this area are below average. Fall spawner recruitment has been very low since 2009 and only 2 mature year classes in the fishery are average or above average. When spring and fall spawners are combined, all mature year classes are below average (Fig. 32b). When internal consistency of the index was tested for FB, strong correlations with spring spawner year classes were observed but not for fall spawners (Fig. 33b, 34b). This is not surprising given the low abundance of fall spawners in this stock area. Based on this it was concluded that fall spawner recruitment strength cannot be evaluated in this stock area using the spring research gillnet program.

2016 ACOUSTIC SURVEY

The Laurentian Channel is currently an Area of Interest (AOI) to be developed as a Marine Protected Area (MPA) (Lewis et al. 2014). One aspect of designating an MPA is obtaining baseline ecosystem information. The recent increased occurrence of herring in offshore 3Ps and 3Pn waters (Fig. 5) indicated that they may be an important forage species in and around the Laurentian Channel. Based on this information, stock identification of offshore herring was prioritized. Further to an ongoing investigation of spring/fall spawner genetic analysis (Lamichhaney et al. 2017), a joint project with Dr. Daniel Ruzzante at Dalhousie University was expanded to add an additional component to investigate potential genetic differentiation of Newfoundland herring stocks. To facilitate this analysis, additional samples were required from stocks on the south coast of Newfoundland. To accomplish this, an acoustic survey was conducted in Placentia Bay in February 2016. This survey was also used to obtain an estimate of biomass which could be compared to past surveys and provide a stock status update for the area.

From the mid-1980s to 2000, acoustic surveys were conducted on a bi-annual basis for NL herring stock complexes; this included 7 surveys in SMBPB. All surveys took place in early winter (February-March) and because herring in these areas are distributed primarily in the shallow coastal waters (<100 m) surveys were conducted from a mid-size platform (15-25 m). Efforts were made to duplicate past methodology for the 2016 survey to enable direct comparison of the data obtained to the previous time series.

The 2016 survey was conducted from the Fortress Isle, a 12 m chartered purse seine vessel. The vessel was outfitted with a Simrad EK60 echosounder with a towed 120 kHz transducer; the acoustic system was calibrated prior to deployment. Sound speed was set to 1,452 m/s and the transducer was towed approximately 1.5 m below the surface at a speed of 3-5 kts, depending on the navigability of the area being surveyed. Bottom detection was carried out using the best bottom pick algorithm with a -40 peak threshold, -40 dB discrimination level and a 0.1 m backstep. Manual editing was conducted to remove slope effects in areas of rugged bottom topography. In areas where fish occurred in high densities adjacent to the seabed, the bottom line was re-drawn manually using a re-scaled color palette to aid the analyst. Herring, Atlantic cod, capelin and kelp were identified on echograms. Edited echograms were integrated at -70 dB Sv threshold using Echoview software version 7.1.

In previous surveys Placentia Bay had been divided into 21 strata (Fig. 35), however due to time limitations, only strata 60-71 in the inner portion of the bay were surveyed in 2016 with 130 transects completed (Fig. 36). During the course of the survey a logbook was maintained indicating the start and end of each transect, as well as any deviations and fishing activity or other events of interest. Feather hooks and lures were used to determine species composition of backscatter at 5 locations and purse seine sets were conducted on two aggregations. The purse seine could not be deployed in all areas where herring were detected due to poor weather conditions, fishing gear limitations, or inappropriate bottom topography. Note that although the analyst classified some marks as sandlance and capelin, neither of these species were caught during fishing efforts.

Samples of 50 fish each were collected from each of the two purse seine sets and frozen for later processing, during which detailed sampling was conducted, including otolith collection, gonad weight and maturity and muscle tissue preservation for DNA analysis. The mean length of herring sampled was 184 mm and the mean weight was 308 g. Samples were pooled to determine herring target strength, which was calculated using the equation derived from in-situ herring TS measurements on caged fish (Wheeler 1991):

TS = 20 log L – 65.5

Herring were present in 6 of 12 strata surveyed, although only one stratum had high densities (Fig. 36). Surveyed abundance was calculated using the methods as described in Wheeler 1991. The biomass of herring in the inner Placentia Bay was estimated at 19,834 t, below the time series mean and approximately half the series maximum (Fig. 37). It was noted during the meeting that TS values for Newfoundland herring differ from those used in most other herring stocks globally and may not give accurate estimates, therefore values presented are considered a relative index of abundance, not absolute biomass.

STOCK STATUS

Since regular acoustic surveys ceased in 2000, stock status for Newfoundland herring has been reported via performance reports, using a ‘traffic light’ approach of red (-), yellow (?) or green (+) ‘lights’ to categorize the stock status evaluation as cause for concern’, ‘uncertain’, or ‘positive.’ These outcomes were based on performance tables which incorporated a range of parameters, as well as a calculated stock status index value. The inputs to the calculation of the stock status and their relative weights were discussed at the previous assessment (Bourne et al. 2015); at that time it was decided that while performance table would still be provided for all stock areas to summarize available information, only three metrics would be used to update the stock status index and determine the ‘traffic light’ color for the stock area. These metrics, which are evenly weighted in the stock status index calculation, are: overall catch rates in the research gillnet program (scored as a percentage of the long-term mean), catch rates of mature year classes (ages 7-11, scored as a percentage of the long-term mean), and the number of mature year classes that are of above average strength. As the calculation of stock status is dependent on indices derived from the research gillnet program, WBNDB and CBSS could not be evaluated during this assessment. There is no longer a research gillnet program in SMBPB but for this assessment the results of the opportunistic 2016 acoustic survey were used to update stock status.

In BBTB commercial landings were at their highest since the 1990s in 2015 (Fig. 15). Both purse seine and gillnet fishers reported increasing abundance over the past several years, however gillnet fishers noted a sharp decrease in 2016, which corresponds to a drop in research gillnet catch rates (Fig. 27, 28). The strong 2008 fall cohort dominated both the commercial and research gillnets catch; the age distribution is stable and the relative strength of all mature fall year classes above average (Fig. 19a, 30). Fall spawners comprise up to 80% of the catch in this area (Fig. 2, 3). In the past stock status was calculated for spring spawners only, but for this assessment it was first calculated for both spawning components separate, and these values were then combined, weighting them by the percentage of the stock each component comprised to provide an overall stock status index value. This was done for all past years as well to provide an update index for the entire time series. The combined stock status index had an increasing trend over the past 5 years and the 2014 and 2015 values were among the highest in the time series (Fig. 38); this gave an overall positive stock status evaluation (Table 1a-d).

Though there is no longer a research gillnet program in SMBPB, the stock status for this stock area was evaluated based on the results of the 2016 acoustic survey and available biological data. Given that the age structure in this area is stable with potential signs of recruitment (19b) and the estimate of relative abundance derived from the survey was slightly below the mean of previous surveys (Fig. 37), the stock status was evaluated as positive.

In FB commercial landings have been declining steadily and only 11% of a reduced TAC was taken in 2016 (Fig. 15). Gillnet fishers have reported declining trends in abundance since 2000, while bar seine fishers indicated increasing abundance from 2014 to 2016 (Fig. 27). The age distribution of the commercial and research gillnet catch has been extremely skewed toward age 11+ spring spawners for several years, indicative of a highly unstable age structure (Fig. 19b, 30). Spring spawners continue to dominate the catch in this area but all mature year classes are below average strength (Fig. 29, 32b). Recruitment of age 4 spring spawners in 2016 was strong, however the age structure in this area is still not well distributed and it remains to be seen if strong recruitment will continue going forward to contribute to a healthier stock composition (Fig. 31b, 32b). The stock status index for FB was calculated based on spring spawners only, as fall spawners still comprise a very small proportion of this population and analysis demonstrated that the spring research gillnet program likely does not adequately track fall spawners in this stock (Fig. 34b). The stock status index has been declining since 2010 (Fig. 38), giving an overall negative stock status evaluation (Table 2a-d).

AREAS OF UNCERTAINTY

The inability to estimate spawning stock biomass and exploitation rates continues to be a major source of uncertainty for this stock assessment.

The lack of a fishery-independent abundance index in three of five stock areas makes it impossible to update the standardized stock status index unless an acoustic survey is completed, otherwise only biological updates could be provided, based on limited data from the commercial fishery.

There has been an apparent change in spring spawning time on the northeast coast, shifting toward mid/late-summer. This may have implications on the designation of spawning component and subsequently age structure calculated from biological samples.

Distribution of herring has likely changed since stock complexes were delineated in the 1980s; it is currently not known how migration patterns may have changed and what impact this could have on stock structure.

The inability to estimate population sizes has precluded (to date) the calculation of stock status zones and reference points. This severely limits the implementation of the precautionary approach in fisheries management decisions.

As of 2016 gillnet bait fishers were required to set their nets parallel to shore as a licence condition. This likely impacted their perceptions of abundance provided for the cumulative change index.

SUMMARY AND RESEARCH RECOMMENDATIONS

During the meeting, the following key issues for stock assessments of herring were recognized:

1. Reinstate regular acoustic surveys in all stock areas to get an estimation of biomass and reinstate the research gillnet program in WBNDB, CBSS, and SMBPB.
2. Reassess the target strength used to estimate biomass from acoustic survey data.

3. Continue to investigate stock complex migration; investigate most appropriate method to obtain information on migration patterns, including the use of telemetry.
4. Develop a gonadosomatic index (GSI) to identify spring and autumn stock spawning components.
5. Investigate the potential impact of the new licence condition requiring bait nets to be set parallel to shore on the bait survey.
6. Use a fixed reference period when calculating average catch rate numbers for each stock area.
7. Ask on commercial logbooks what the size frequency is of fish in sets which are released.
8. Continue to investigate relationships between recruitment and environmental drivers.
9. Investigate changes in the timing of spring spawning/availability to the spring research gillnet program.

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APPENDIX

Table 1a: Bonavista Bay-Trinity Bay performance table to the spring of 2016 – summary of fishery.

The Fishery	***Observation***
Reported Landings: 2015/2016	Landings in 2015 were the highest since the early 1990s, 73% of the TAC was taken. Initial data indicates landings were down in 2016 but still high relative to the time series.
Bait Removals: 2015/2016	Estimated bait removals in 283 t in 2015 and 272 t in 2016, near the bait allocation of 300 t.
Estimated Discards: 2015	Fishers estimated that 98 t were discarded in the purse seine fishery in 2015, representing 3% of total estimated removals.

Table 1b: Bonavista Bay-Trinity Bay performance table to the spring of 2016– indices and interpretations.

Cumulative Indices	***Observation***	***Interpretation***
Gillnet Fisher Observations 1996-2015 from telephone surveys and logbooks	Gillnet fishers reported increasing abundance from 2011 to 2015.	Increasing trend in abundance.
Purse Seine Fisher Observations 1996 - 2015	Purse seine fishers reported a general increasing trend in abundance since 2010.	Increasing trend in abundance.
Commercial catch at age 2015	The strong 2008 fall year class (age 7) continued to dominate the catch, accounting for over 35% of landings. Other younger year classes accounted for 10-15% each. Fall spawners compose approximately 80% of landings.	Age structure is stable. Fall spawners dominate the catch.
Length and weight at age	Lengths and weights at age have remained stable through the 2000s for both spawning components.	Size at age is stable.

Table 1c: Bonavista Bay-Trinity Bay performance table to the spring of 2016– research gillnet program.

Research Gillnet Program	***Observation***	***Interpretation***
Research gillnet catch rates	Catch rates increased in 2014 and again in 2015, reaching the second highest point in the time series. However, catch rates declined sharply in 2016, below the decadal and time series mean.	Increasing trend in abundance, but sharp decrease in 2016.
Research gillnet age composition and recruitment	The 2008 fall cohort dominates the catch but the age distribution is widespread. Recruitment of fall spawners remains high. Recruitment of spring spawners was average for the most recent year class assessed.	Population structure stable, good recruitment.

Table 1d: Bonavista Bay-Trinity Bay performance table to the spring of 2016– stock status.

Stock Status Index	***Evaluation***
The age distribution is stable with several strong year classes. Recruitment of fall spawners is above average and average for spring spawners. The stock status index has an increasing trend over the past 5 years. Current stock status is positive.	**+**

+ = positive evaluation

Table 2a: Fortune Bay performance table to the spring of 2016 – summary of fishery.

The Fishery	***Observation***
Reported Landings: 2015/2016	Landings increased slightly in 2015 but only 65% of a reduced TAC was taken. In 2016 there was a steep decline with only 11% of the reduced TAC landed.
Bait Removals: 2015/2016	Estimated bait removals were 64 t in 2015 and increased to 128 t in 2016, still well below the bait allocation of 400 t.

Table 2b: Fortune Bay performance table to the spring of 2016 – indices and interpretations.

Cumulative Index	***Observation***	***Interpretation***
Gillnet Fisher Observations 1996-2015 from telephone surveys and logbooks	Gillnet fishers have reported decreasing abundance since 2000.	Decreasing trend in abundance.
Bar Seine Fisher Observations 2014-2016	Bar seine fishers indicated increasing abundance from 2014 to 2015.	Increasing abundance.
Commercial catch at age	The age distribution is extremely skewed, with age 11+ herring comprising over 90% of the catch. Spring spawners comprise 85% of landings.	Age distribution is highly skewed toward older fish; not stable. Spring spawners dominate the catch.
Length and weight at age	Lengths and weights have remained stable through the 2000s.	Size at age is stable.

Table 2c: Fortune Bay performance table to the spring of 2016 – research gillnet program.

Research Gillnet Program	***Observation***	***Interpretation***
Research gillnet catch rates	Catch rates declined sharply between 2010 and 2012 and though there was a slight increase in 2016, still remain well below decadal and time series mean.	No change in abundance/abundance low.
Research gillnet age composition and recruitment	The age composition has been highly skewed toward age 11+ spring spawners. Recruitment of age 4 spring spawners was above average in 2016.	Age distribution is unstable. Recruitment increased in 2016 but year class strength is below average overall.

Table 2d: Fortune Bay performance table – stock status.

Stock Status Index	***Evaluation***
The age distribution is unstable, with predominant age 4 and 11+ year classes. Recruitment was above average in 2016. The stock status index has shown a decreasing trend since 2010. Current stock status is negative.	-

- = negative evaluation

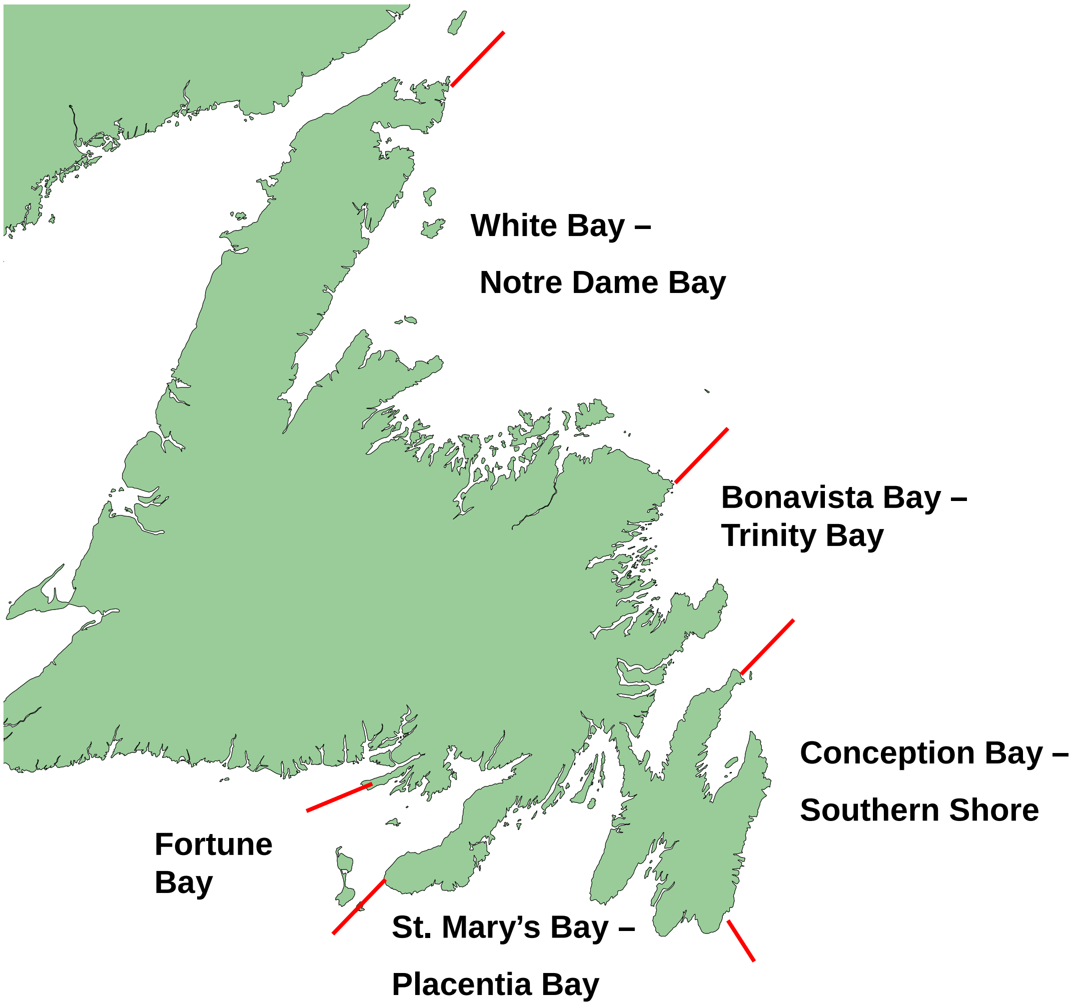


Figure 1: Map of Newfoundland east and south coast Atlantic Herring stock complexes.

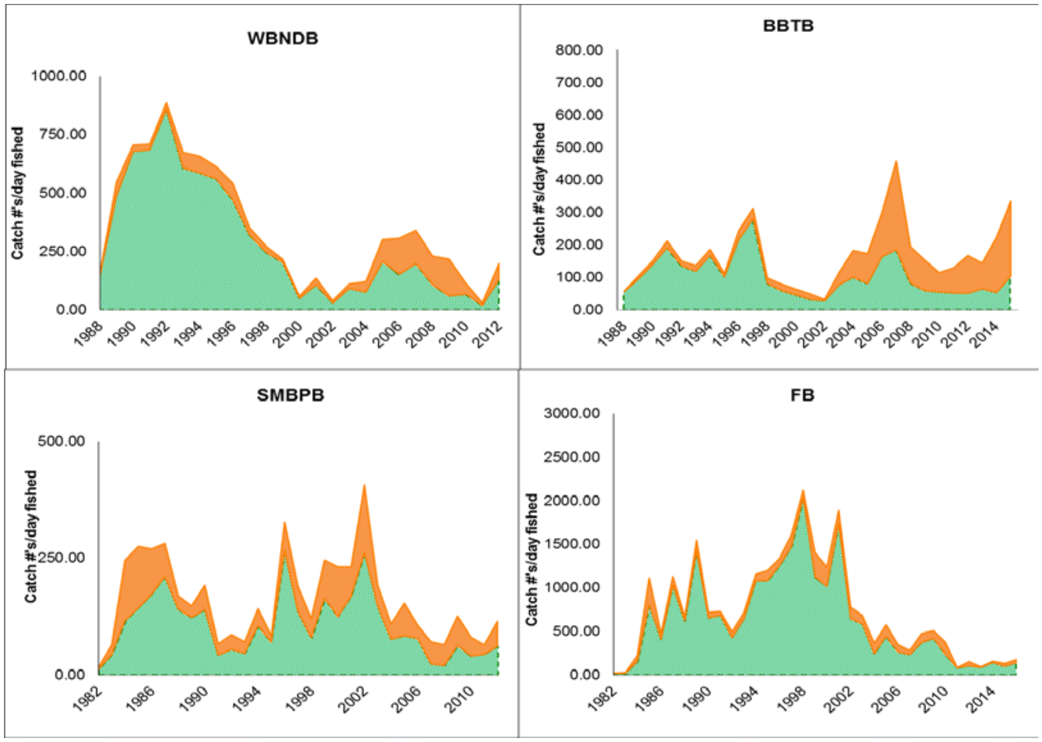


Figure 2: Research gillnet program catch rates by spawning type (upper/orange area = fall spawners; lower/green area = spring spawners) to 2012 in WBNDB/SMBPB and 2015 in BBTB/FB.

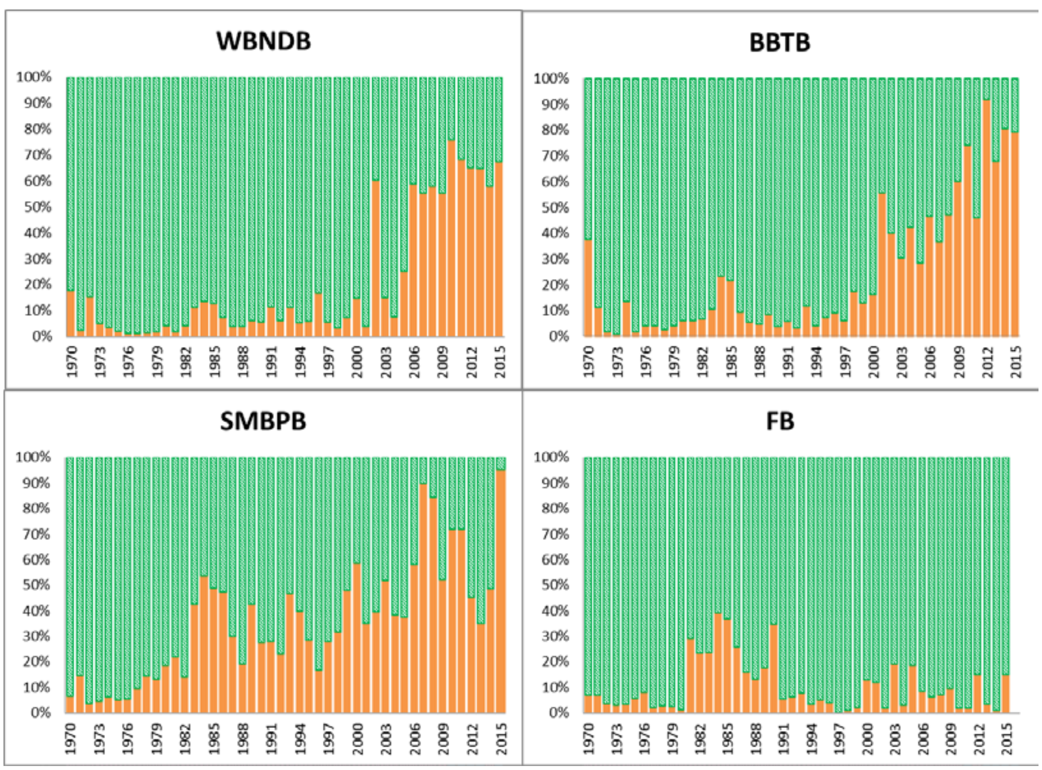


Figure 3: Percentage of commercial catch composed of spring (upper/green bars) and fall (lower/orange bars) spawners in four stock areas from 1970 to 2015.

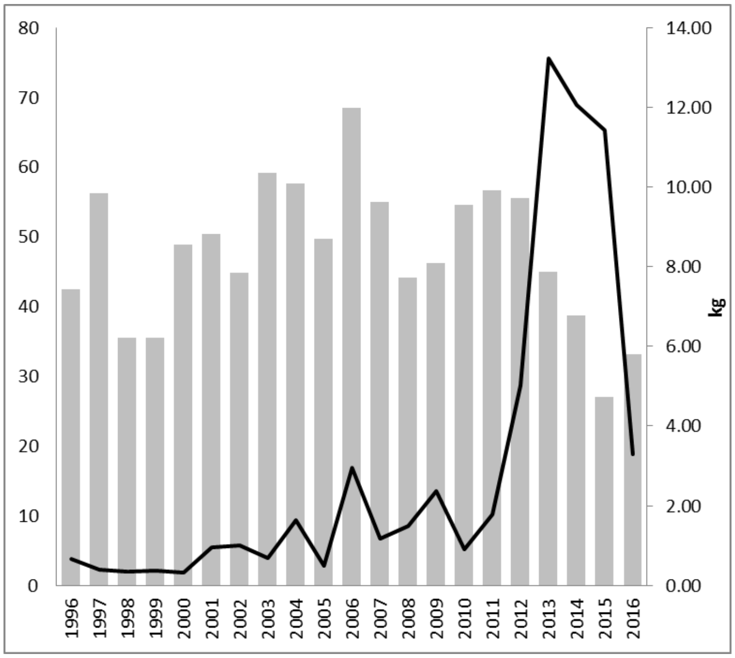


Figure 4: Percentage of spring multispeices survey bottom trawl fishing sets in NAFO Division 3Ps in which herring were caught (grey bars/left axis) and mean weight of herring caught per set (black line/right axis).

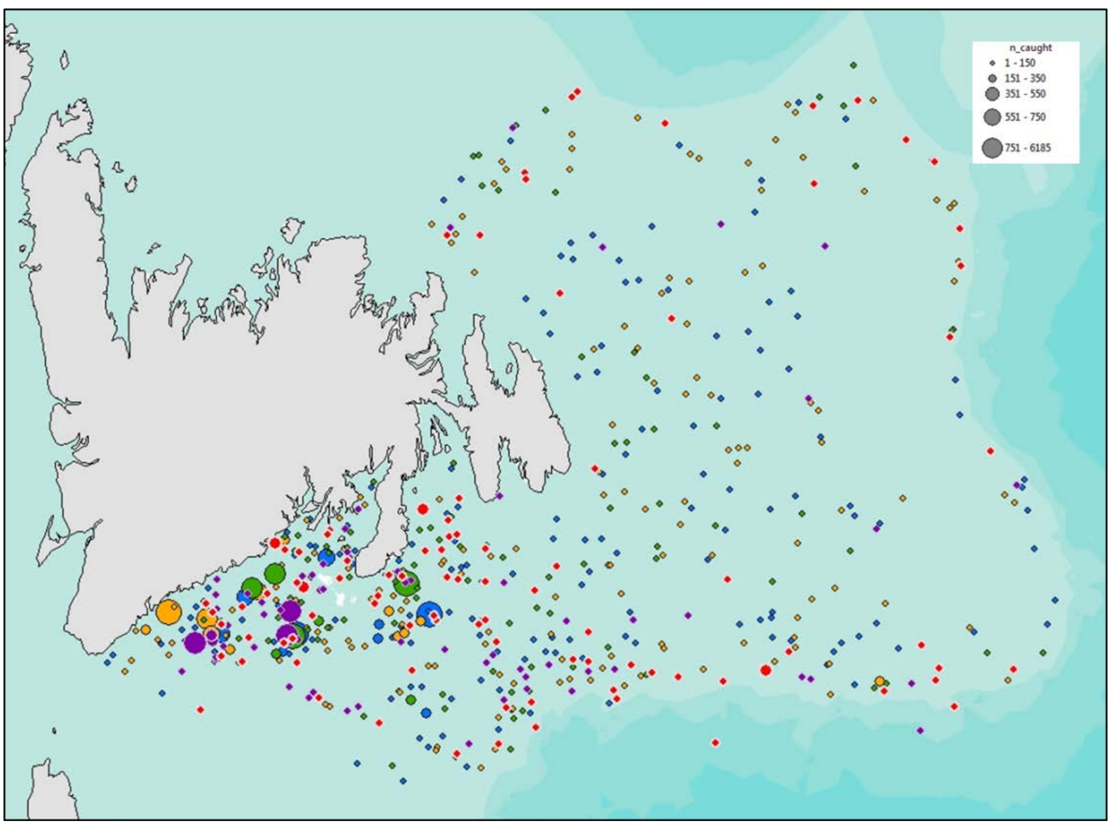


Figure 5: Location of fishing sets with herring and number of herring caught (point size) in spring multispecies bottom trawl surveys in 2012 (blue), 2013 (orange), 2014 (green), 2015 (purple) and 2016 (red).

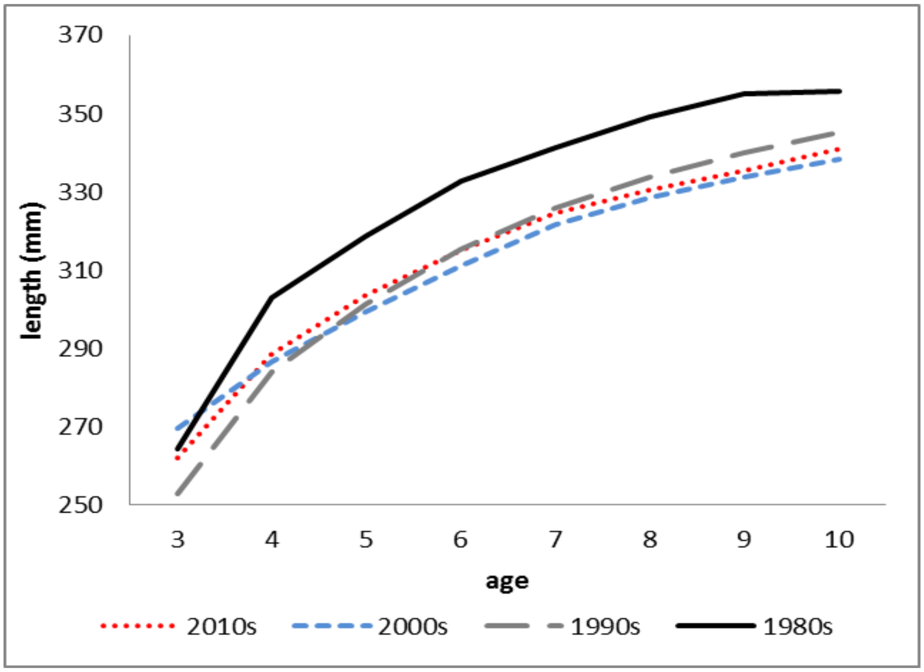


Figure 6: Mean length at age (total length) for spring and fall spawning herring stock components combined across stock areas by decade.

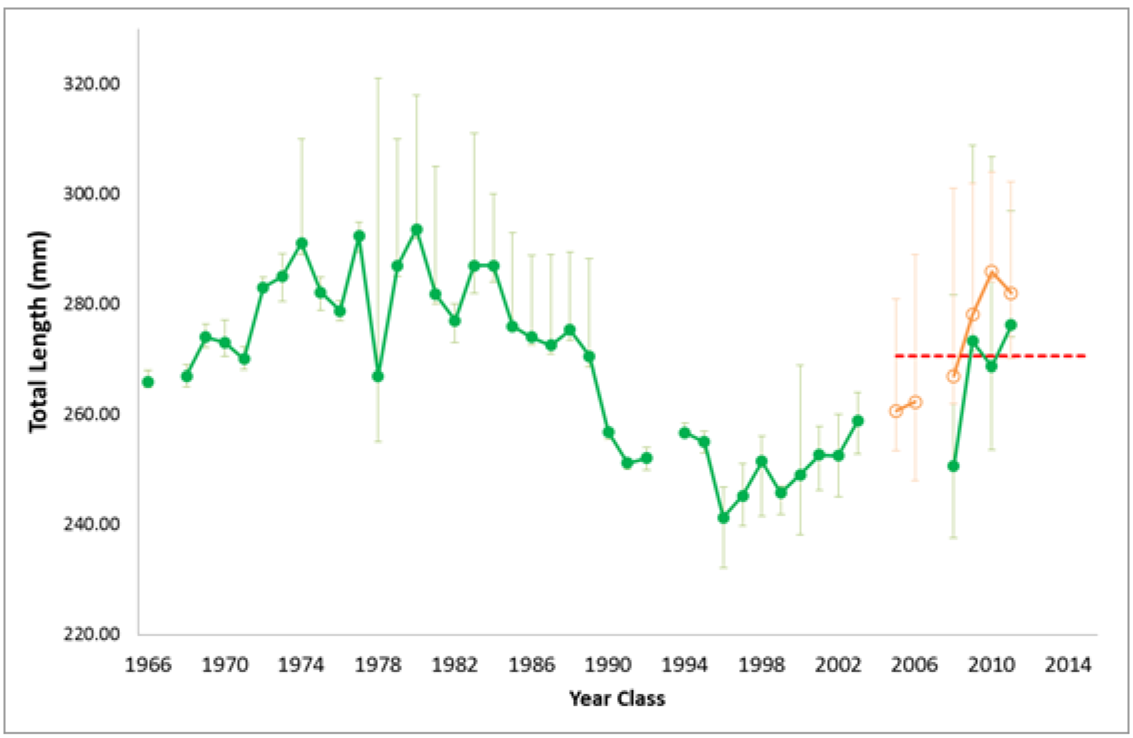


Figure 7: Length at 50% maturity (L50) of spring spawner (green line/solid markers) and fall spawner (orange line/open markers) year classes, and current minimum size limit in the commercial fishery (red/broken horizontal line).

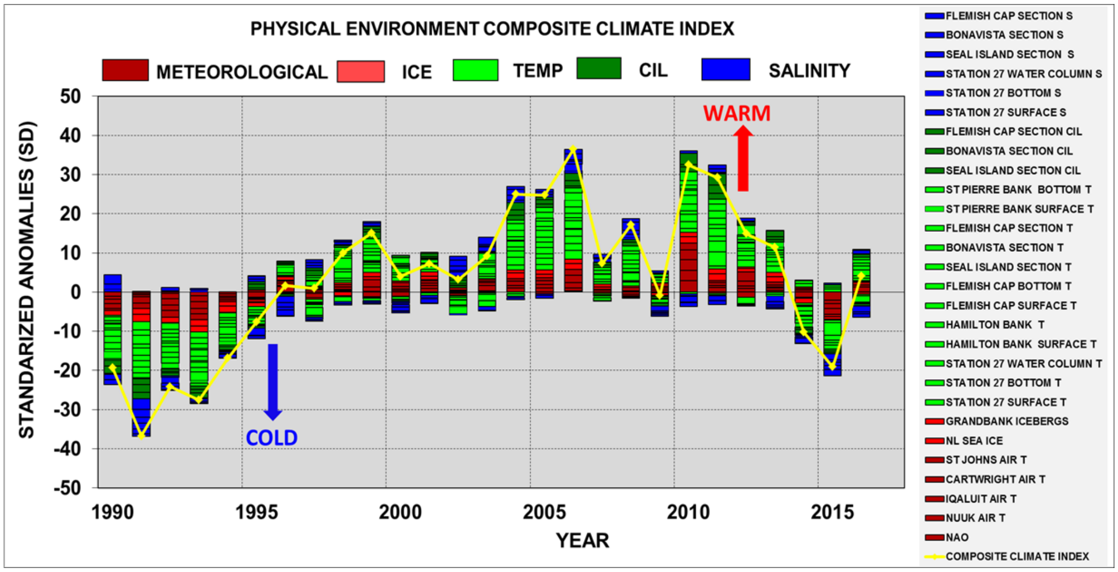


Figure 8: Standardized physical enviornemt composite index based on 28 time series of climate data, presented as normalized cumulaitve anomalies.

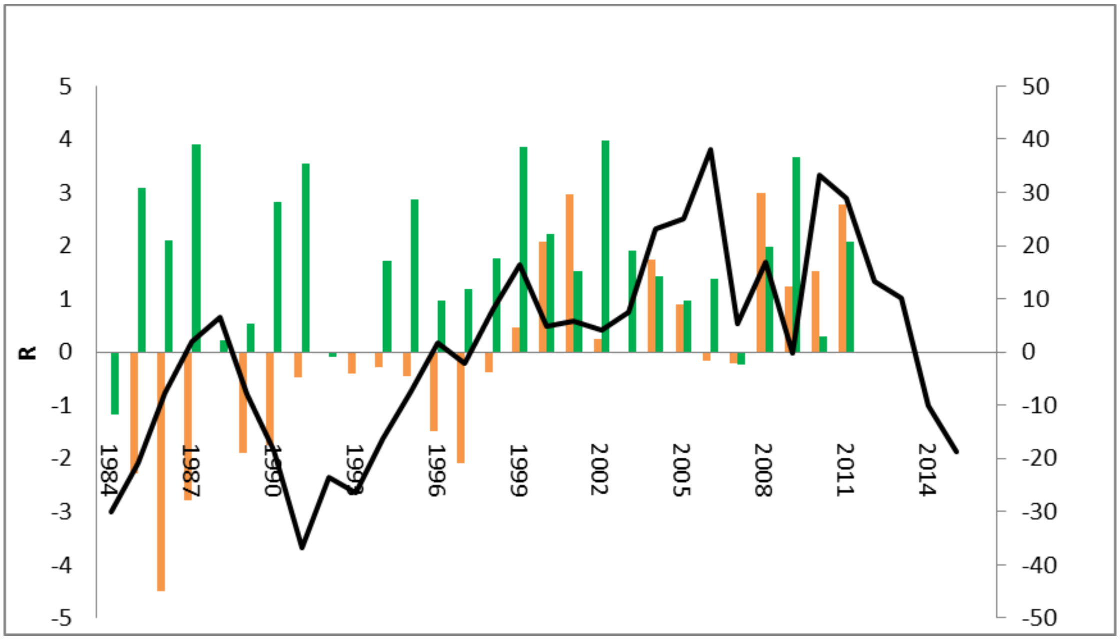


Figure 9: BBTB spring (green bars) and fall (orange bars) spawner recruitment index (left axis) and composite climate index (black line/right axis).

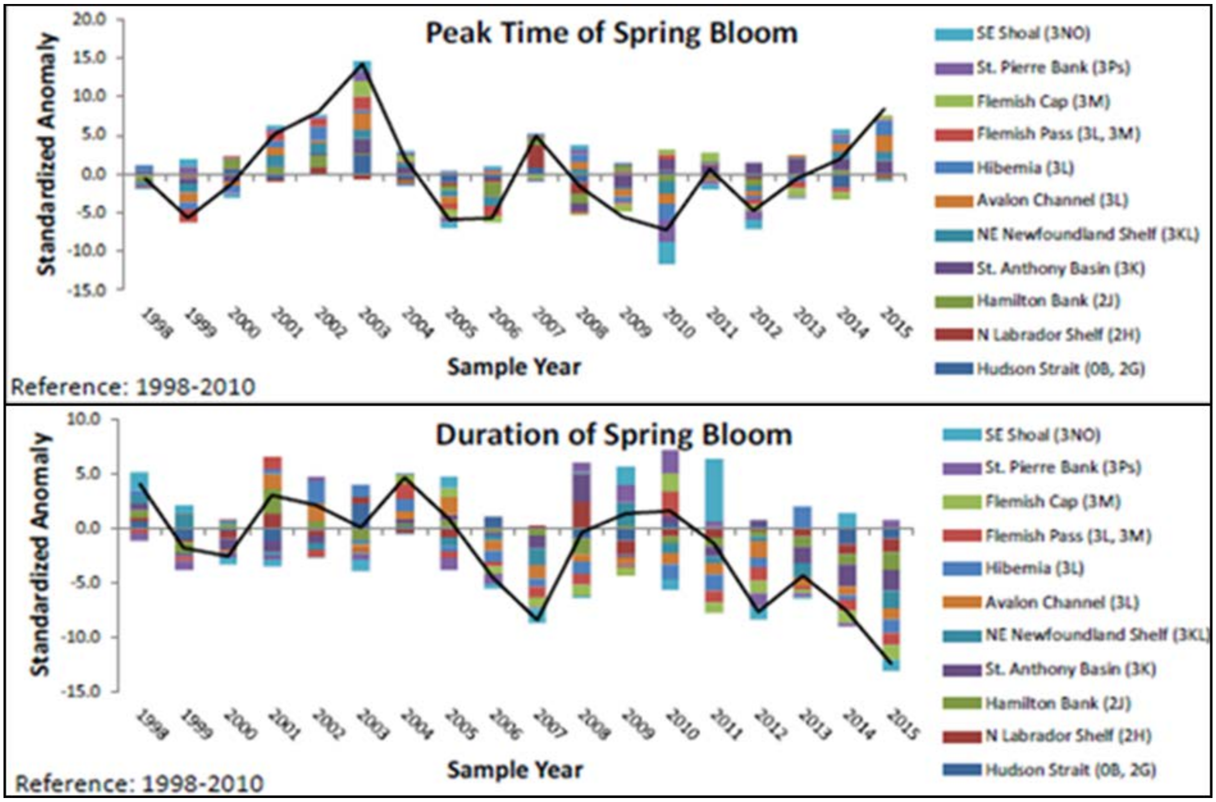


Figure 10: Standardized anomaly plots of peak timing (top) and duration (bottom) of spring bloom.

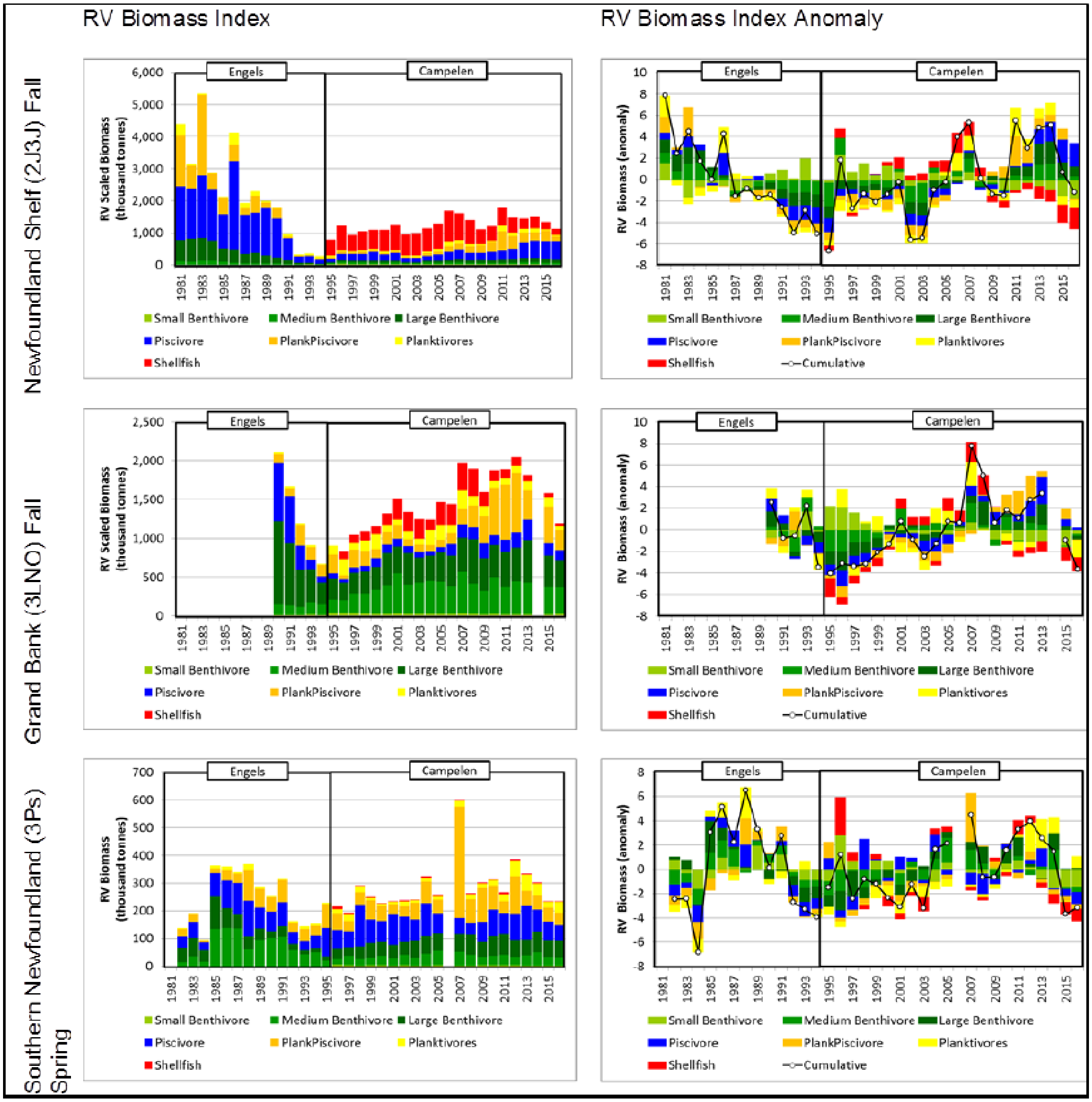


Figure 11: Trends in the Research Vessel (RV) Biomass Index by fish functional groups in core strata of the Newfoundland Shelf (2J3K), Grand Bank (3LNO) and Southern Newfoundland (3Ps) Ecosystem Production Units (EPUs). The black boxes indicates a change in survey gear from Engels to Campelen. The shellfish functional group includes Pandalus shrimp and Snow Crab, but its signal is heavily dominated by shrimp; reliable RV survey data for these species are only available since the introduction of the Campelen gear in the survey. Conversion factors between gears are only available for a handful of groundfish species; the scaling factors used here for 2J3K and 3LNO were applied at the fish functional group level and provide a general approximation for comparing across gears. Standardized anomalies were calculated within each gear-specific portion of the time series.

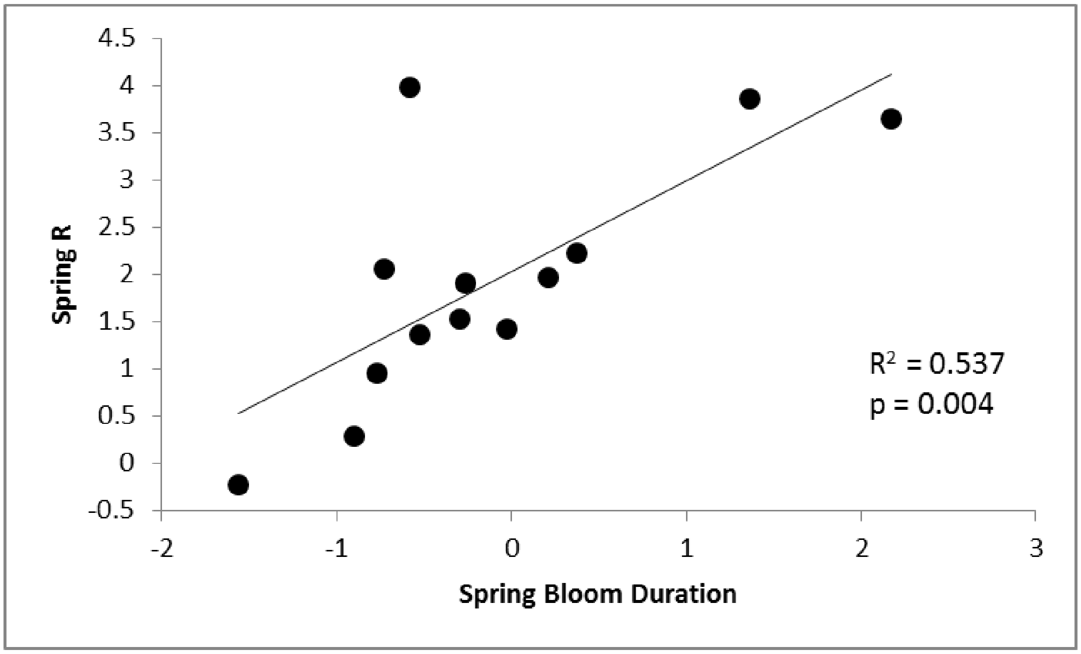


Figure 12: BBTB spring spawner recruitment index vs spring bloom duration index for the Northeast Newfoundland Shelf

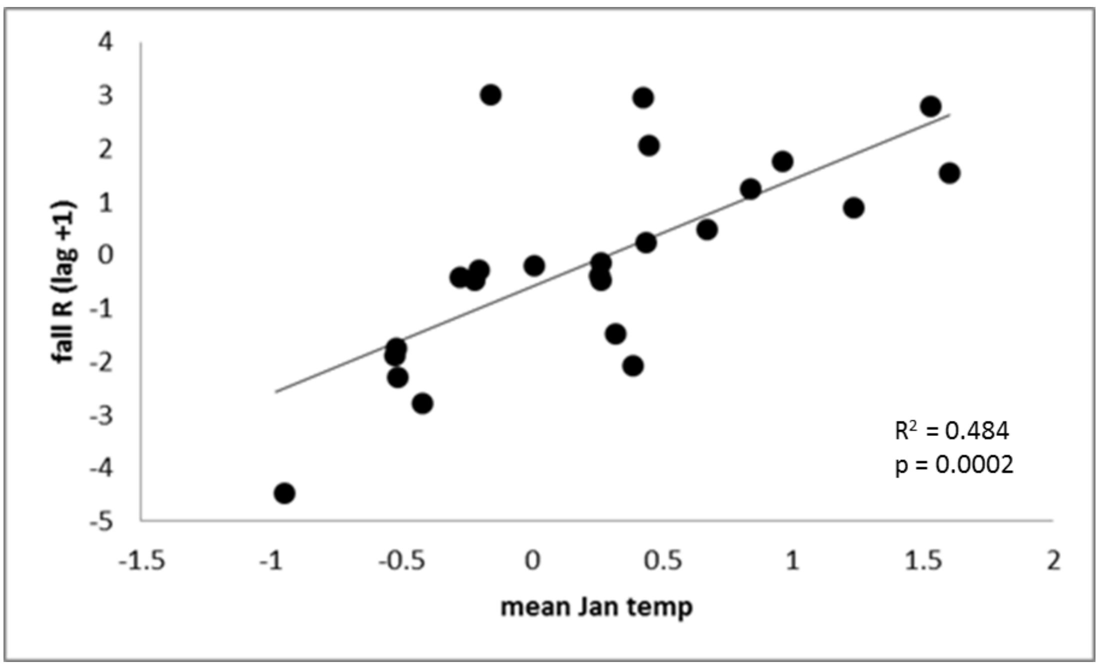


Figure 13: BBTB fall spawner recruitment index (lag +1) vs mean January temperature at Station 27.

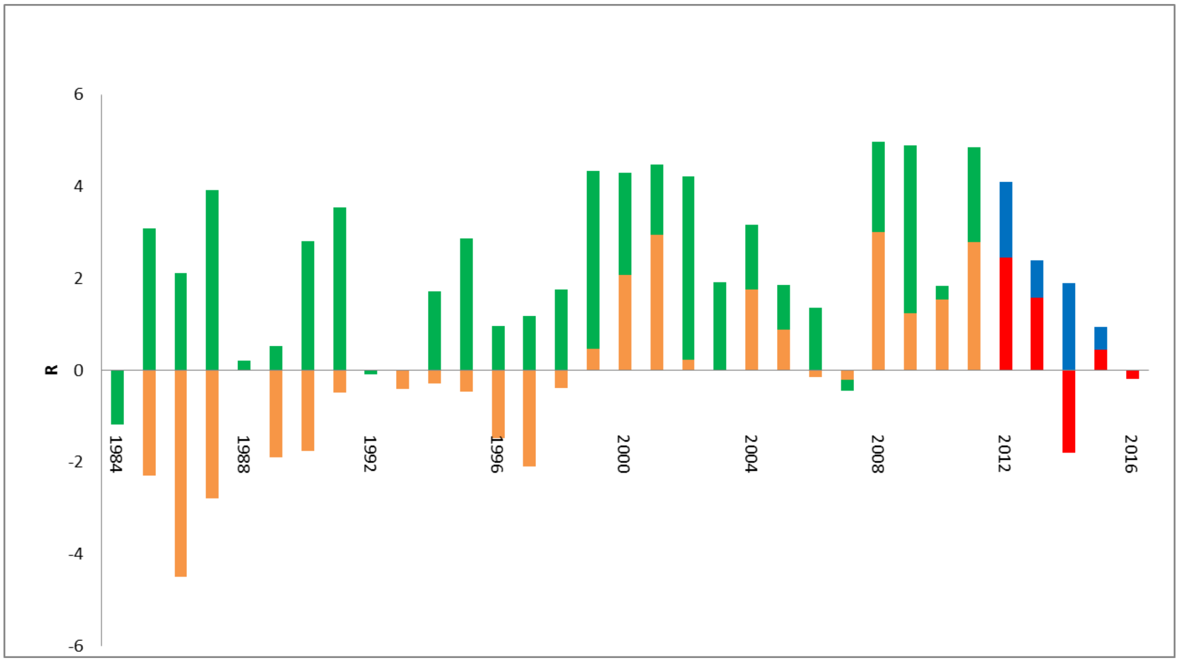


Figure 14: BBTB spring spawner (green bars) and fall spawner (orange bars) recruitment index and potential projections of spring spawner (blue bars) and fall sapwner (red bars) recruitment based on spring bloom and sea surface temperature data.

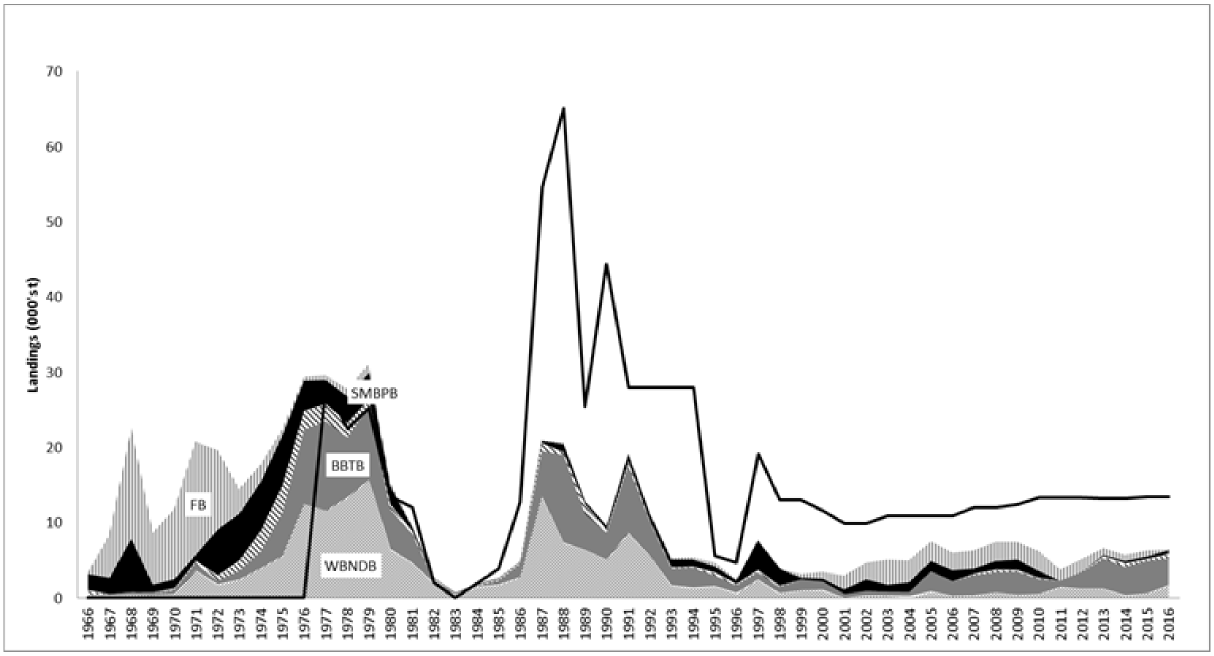


Figure 15: Commercial landings (000's t) and total TAC (dashed line) for all stock areas combined from 1966-2016 (*note 2016 landings based on preliminary data).*

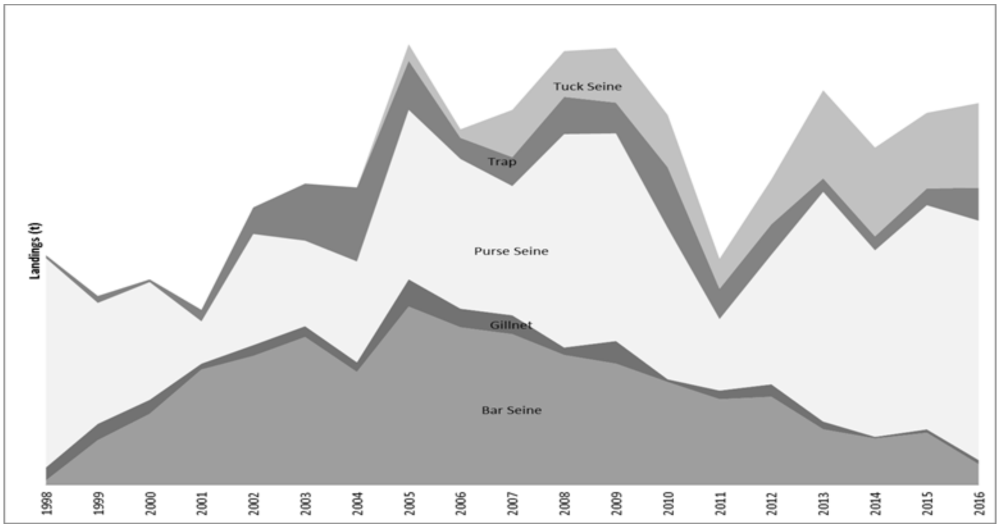


Figure 16: Proportion of total combined commercial landings by Newfoundland by fishing gear type, 1998-2016.

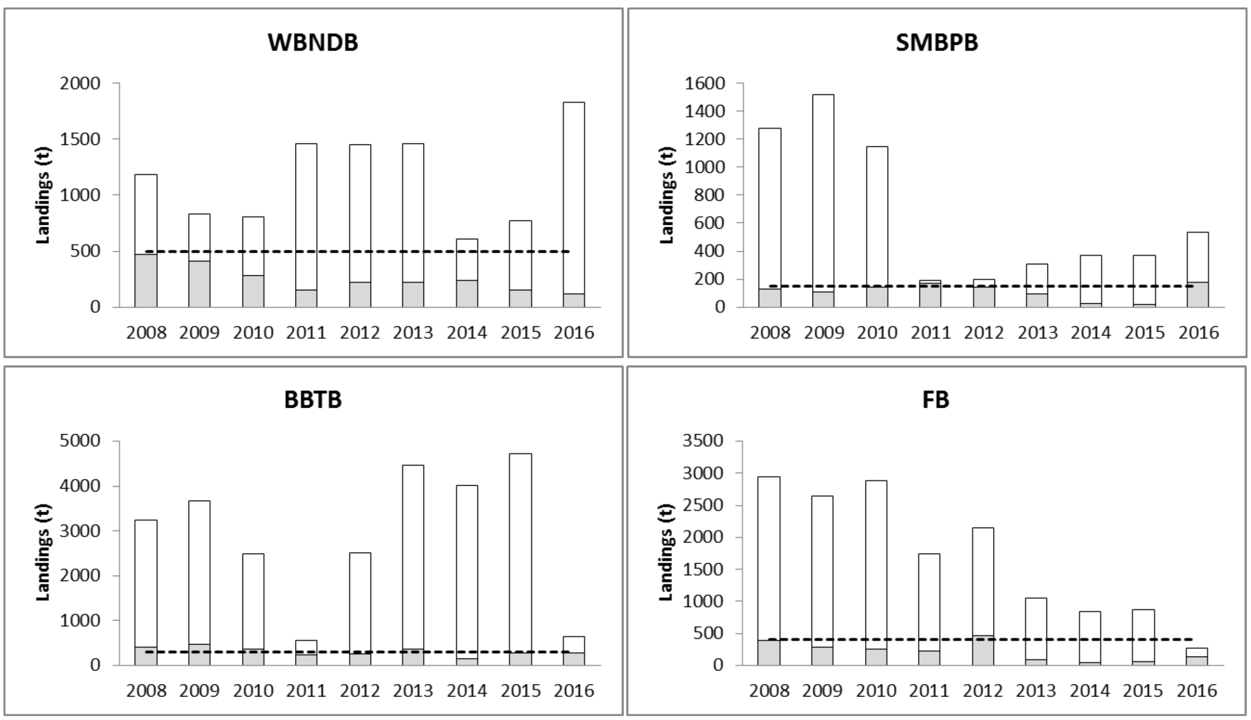


Figure 17: Commercial herring landings (white bars), estimated bait removals (grey bars),and bait allocation (dashed line)based on landings data and gillnet telephone survey.

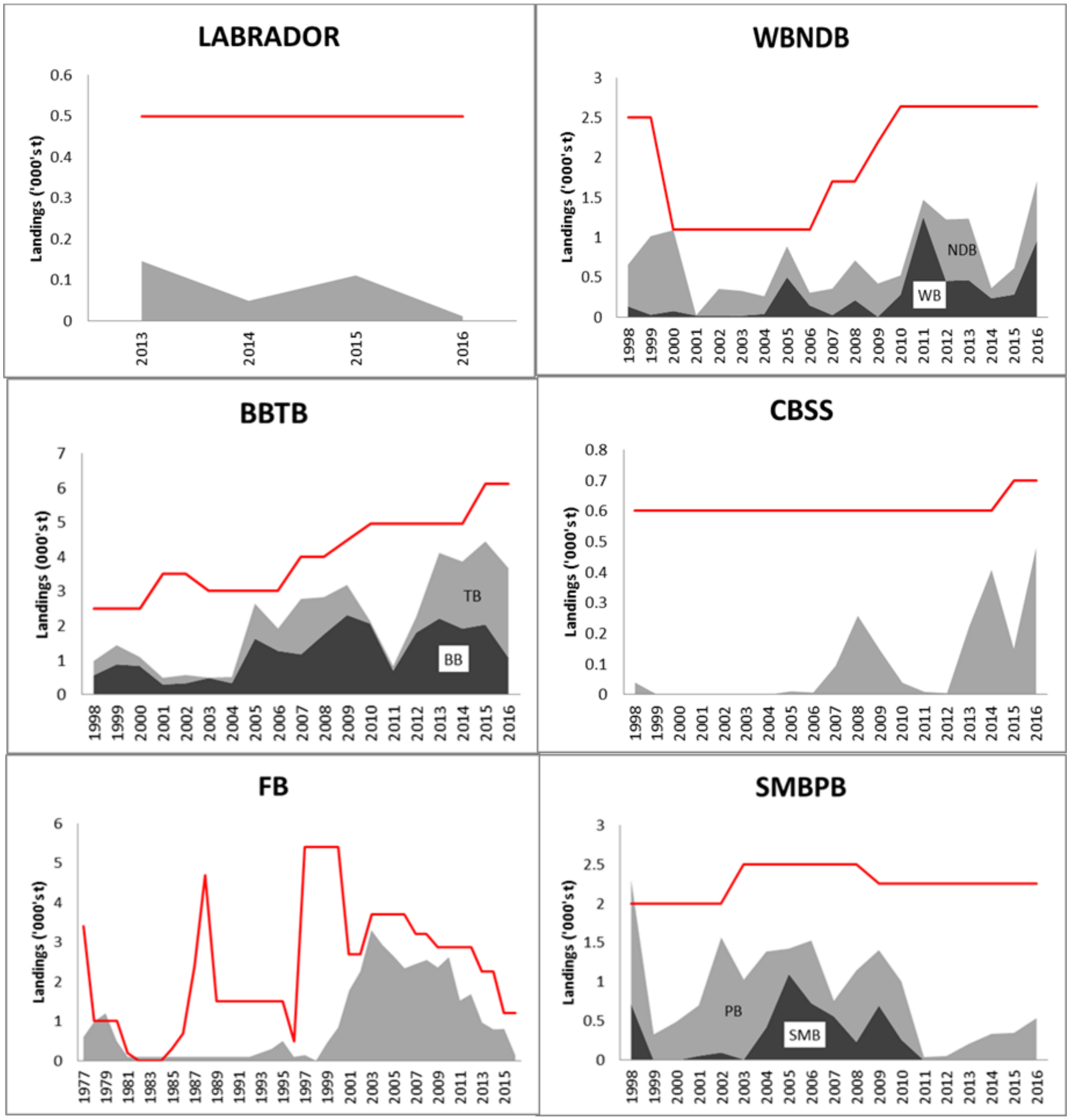


Figure 18: Commercial landings and TAC's 1998-2016 by stock area and bay.

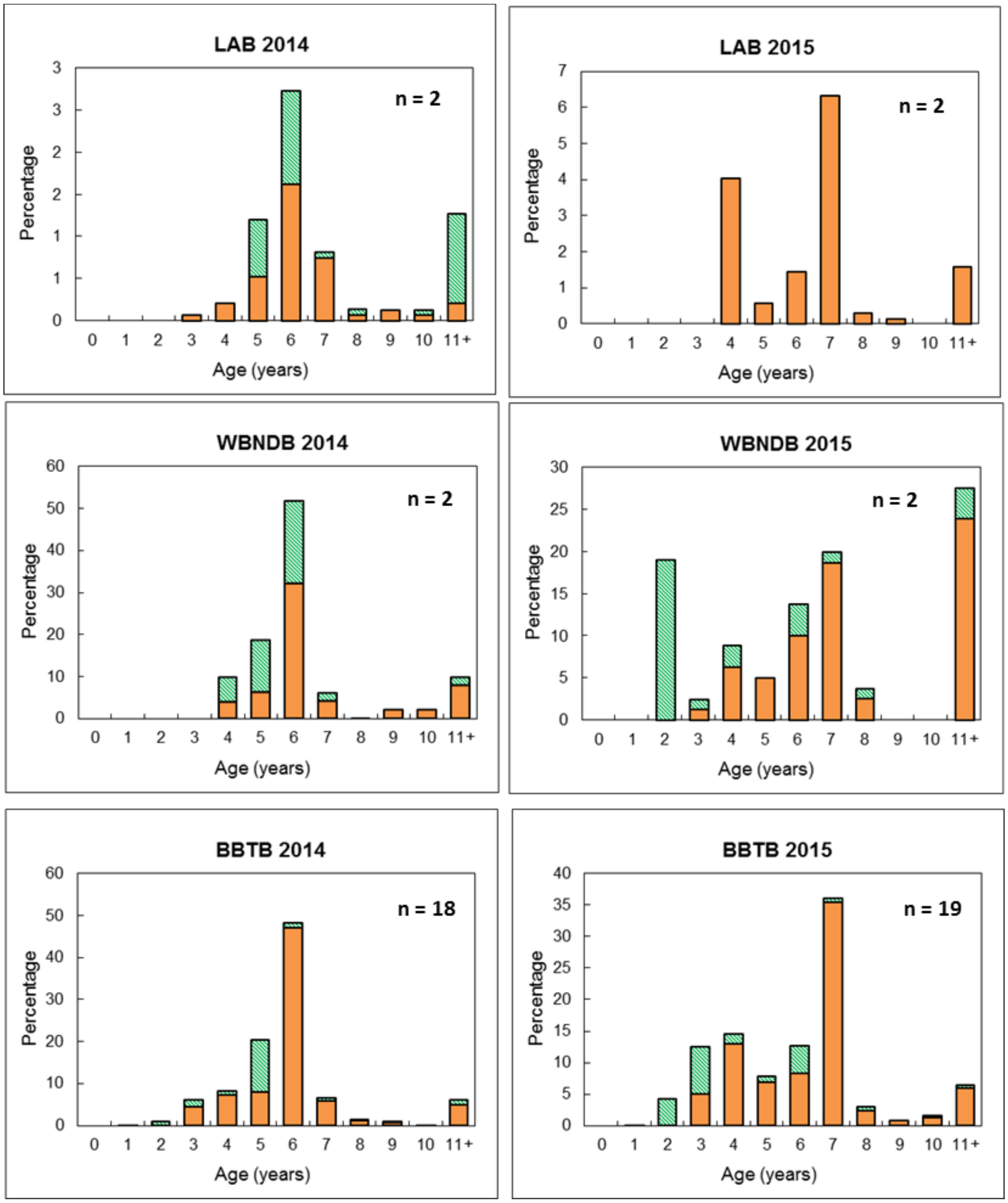


Figure 19a: Catch at age by stock area and spawning type (orange/lower bars = fall spawners; green/upper bars = spring spawners) of commercial landings in 2014 and 2015.

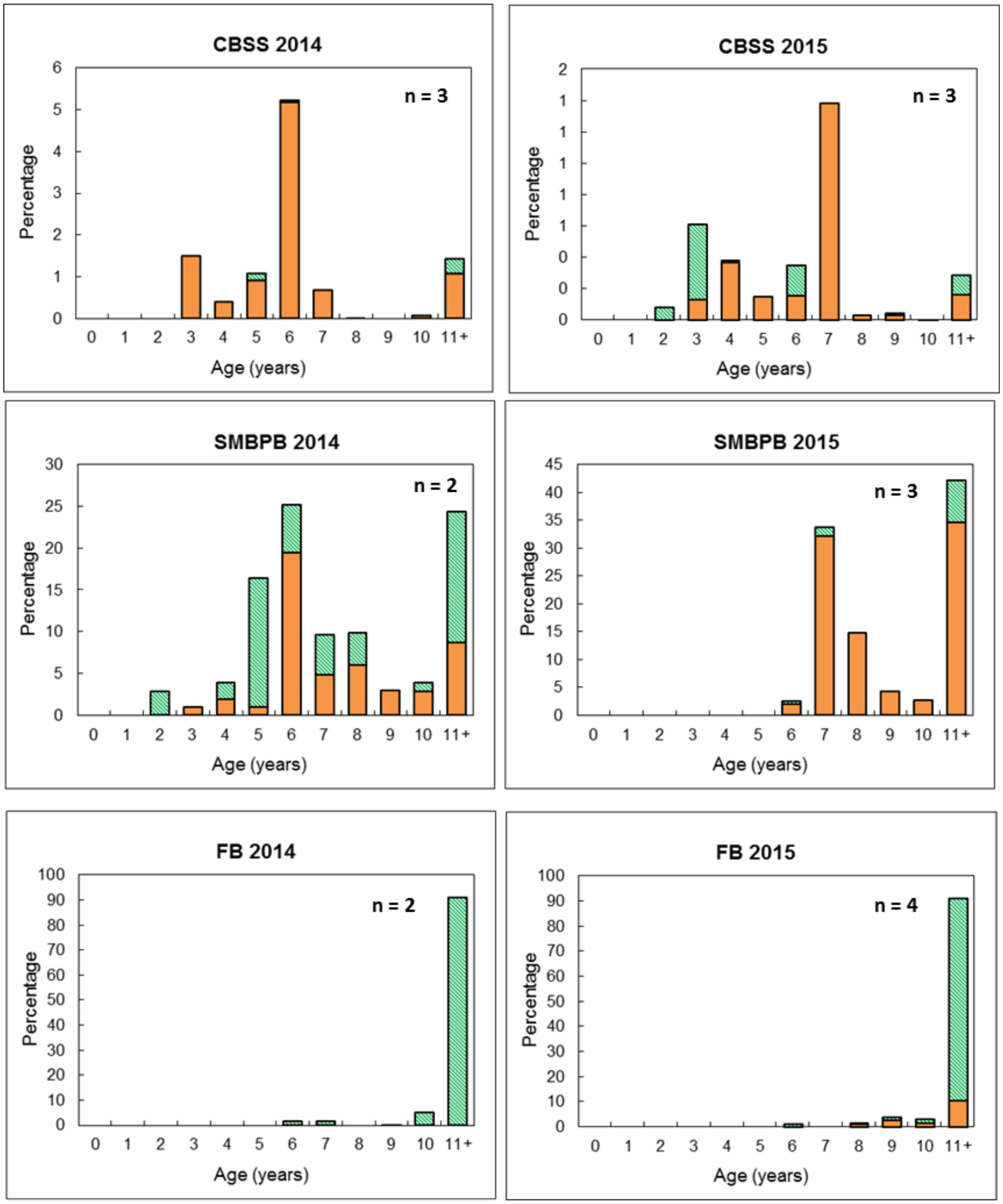


Figure 19b: Catch at age by stock complex and spawning type (orange/lower bars = fall spawners; green/upper bars = spring spawners) of commercial landings in 2014 and 2015.

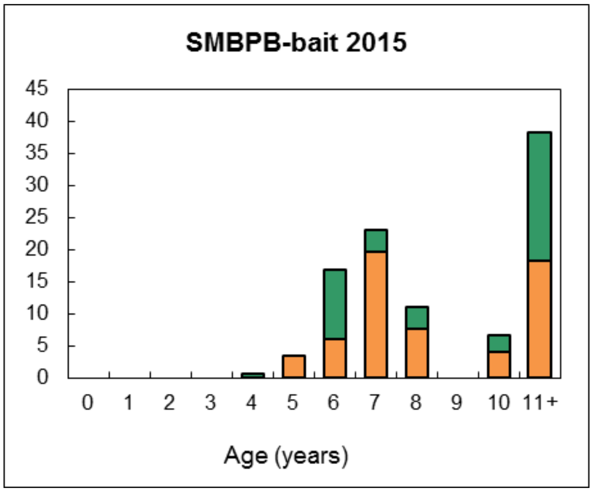


Figure 20: Catch at age from bait (gillnet) samples collected in SMBPB 2015 during commercial fishery.

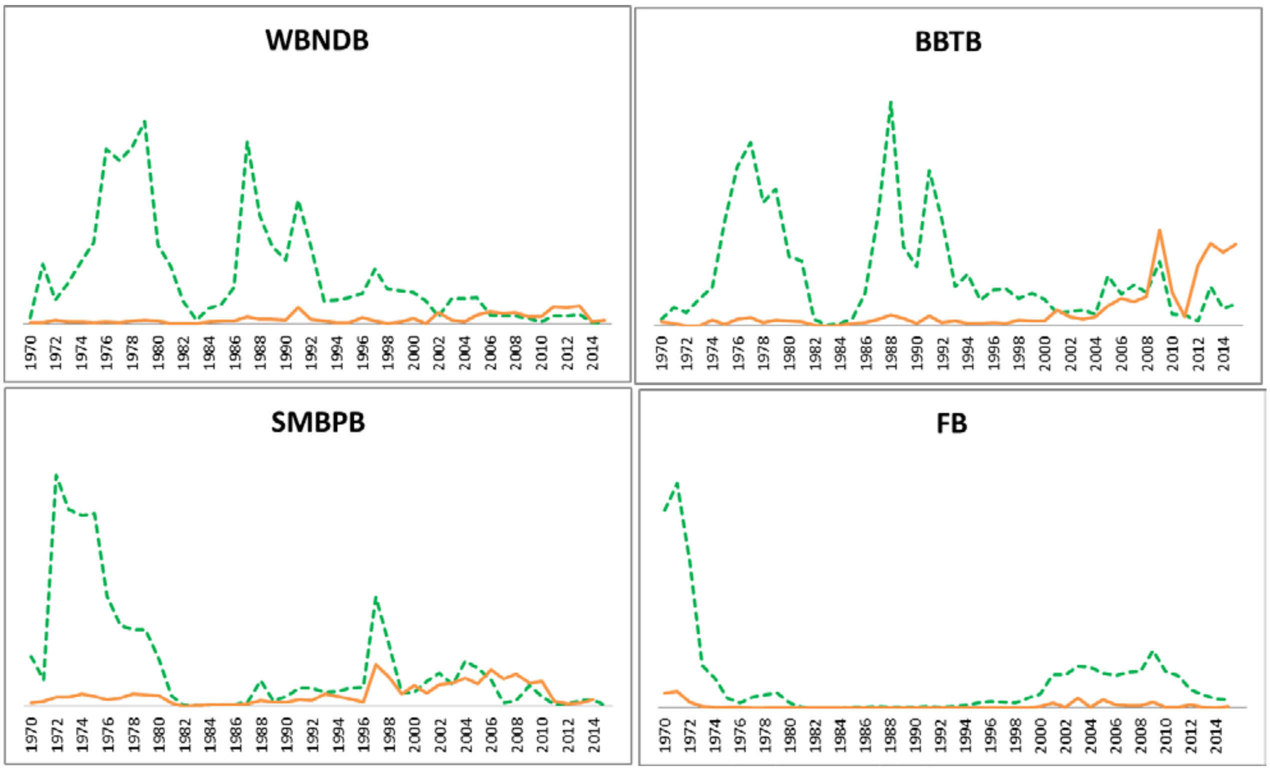


Figure 21: Spawning stock composition of commercial landings by stock area (green/broken line = spring spawners; orange/solid line = fall spawners).

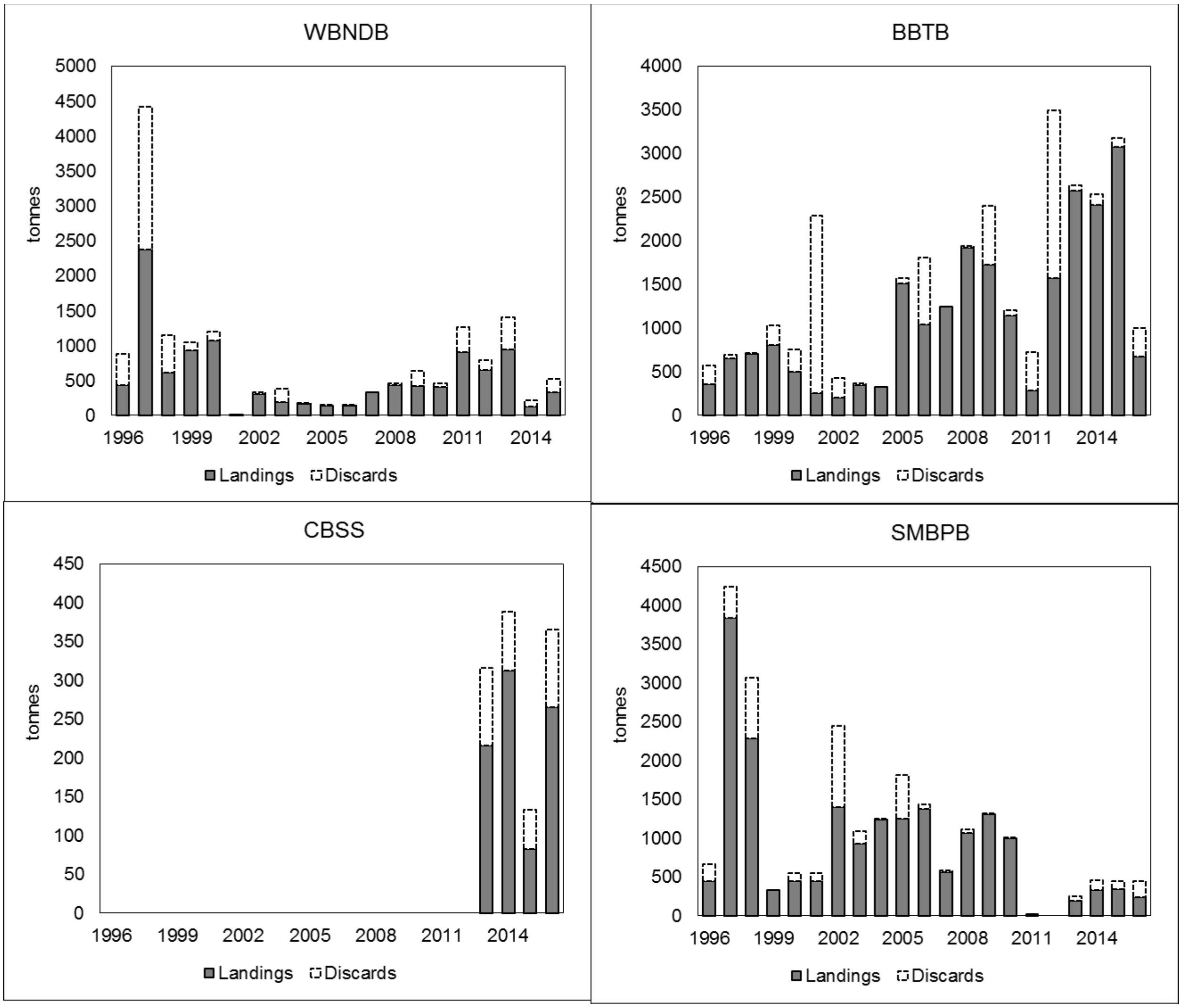


Figure 22: Purse seine landings (grey bars) and estimated discards (white bars) in the purse seine fishery by stock area, based on annual seiner telephone survey.

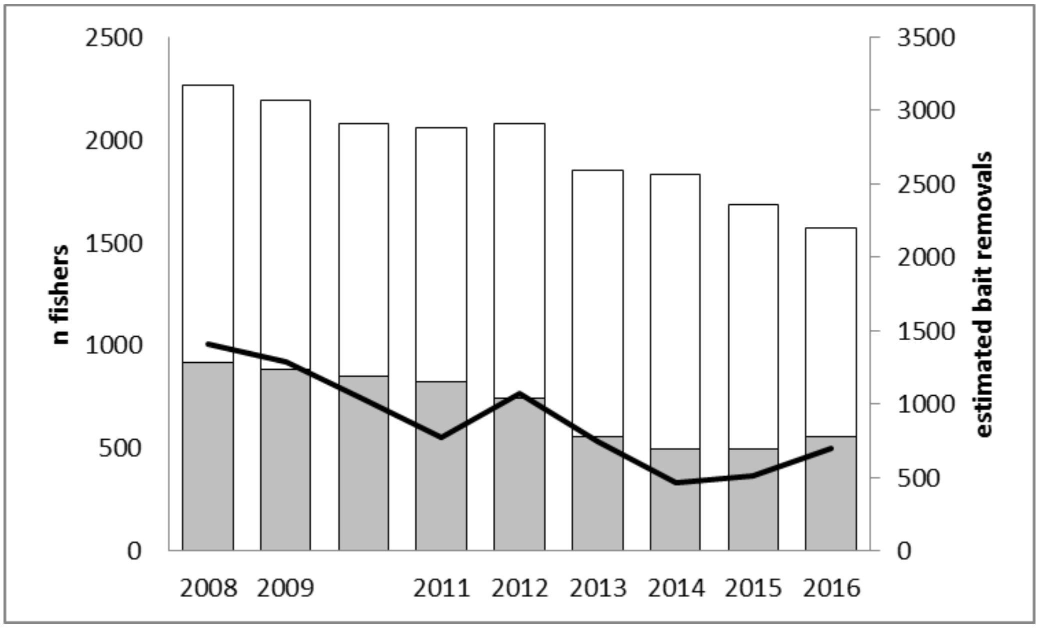


Figure 23: Number of herring fixed gear licence and bait holders (white bars), estimated number of active fishers (grey bars) and total bait removal estimate (black line) as determined by annual gillnet telephone survey.

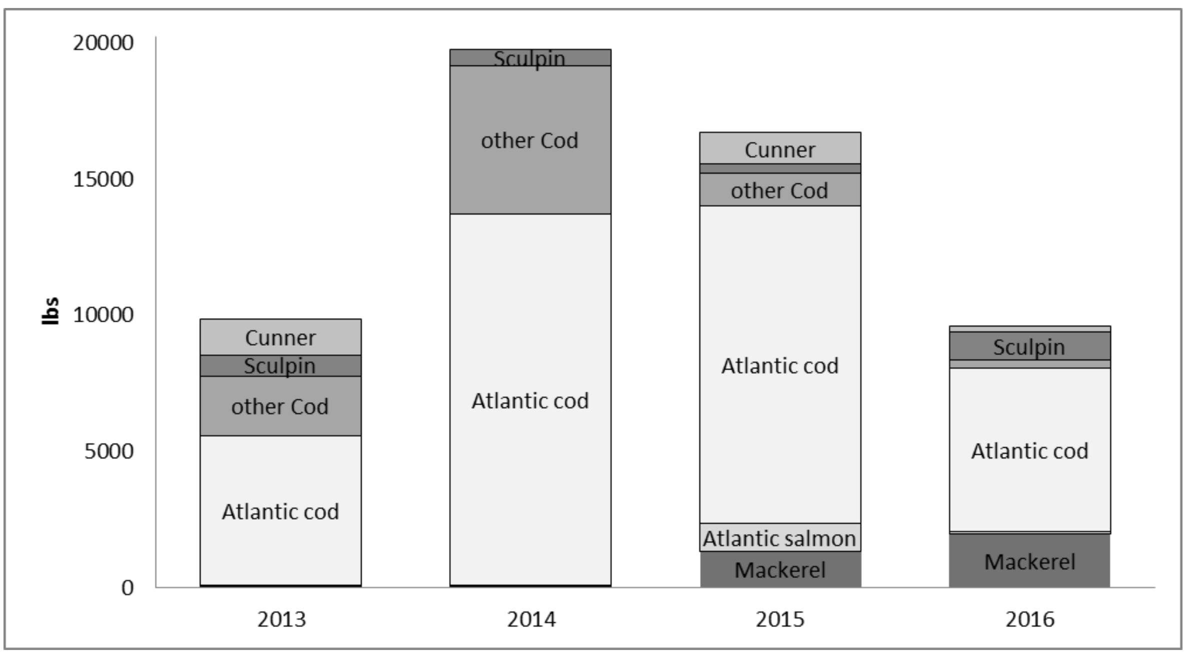


Figure 24: Estimated total bycatch in the herring gillnet bait fishery (all stock areas combined) from 2013-2016 based on annual telephone survey.

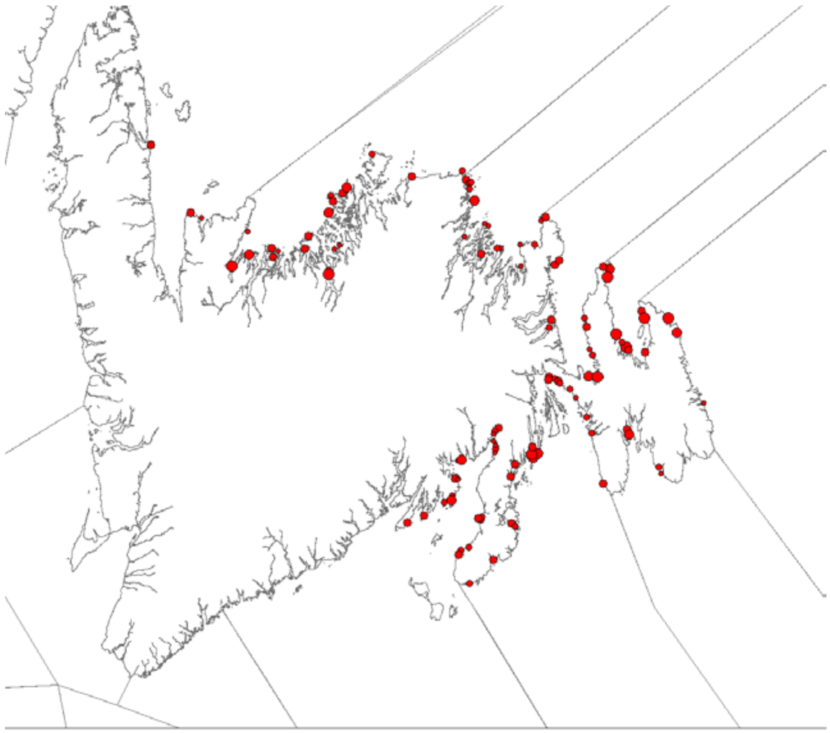


Figure 25: Locations of active bait fishers contacted during the 2016 herring gillnet survey.

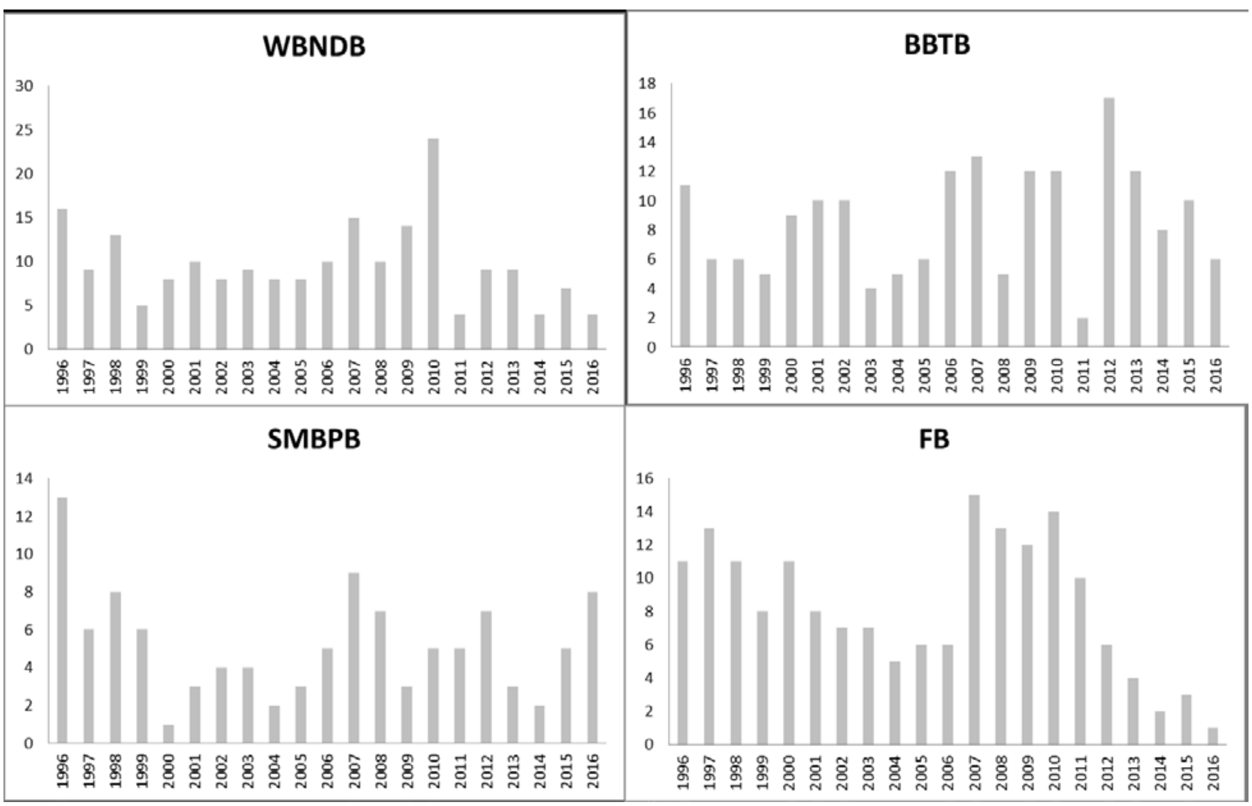


Figure 26: Number of herring bait logbooks returned from 1996-2016.

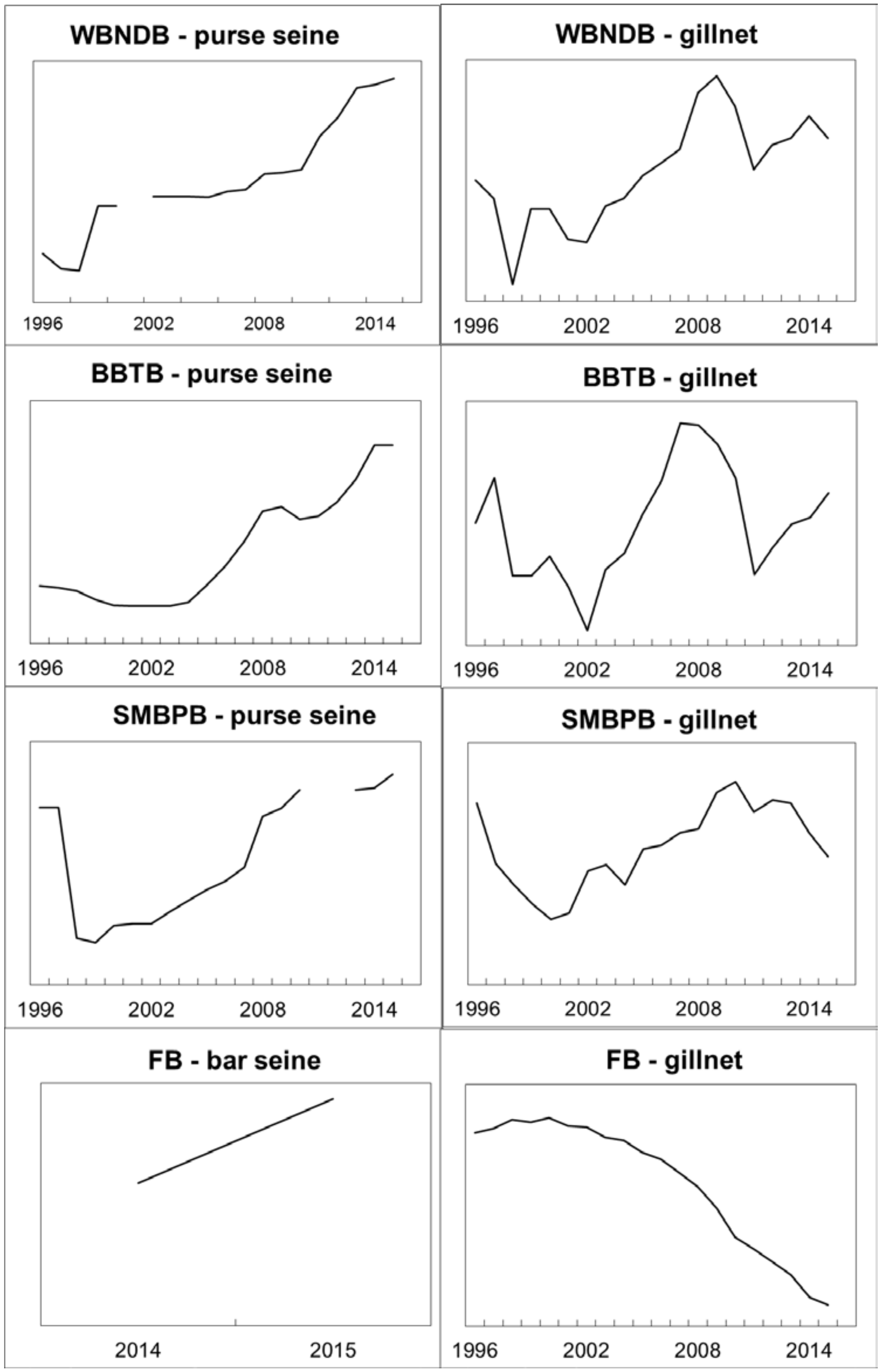


Figure 27: Cumulitve change index by gear type and stock area, based on fisher responses to the purse seine/bar seine and gillnet telphone sureys.

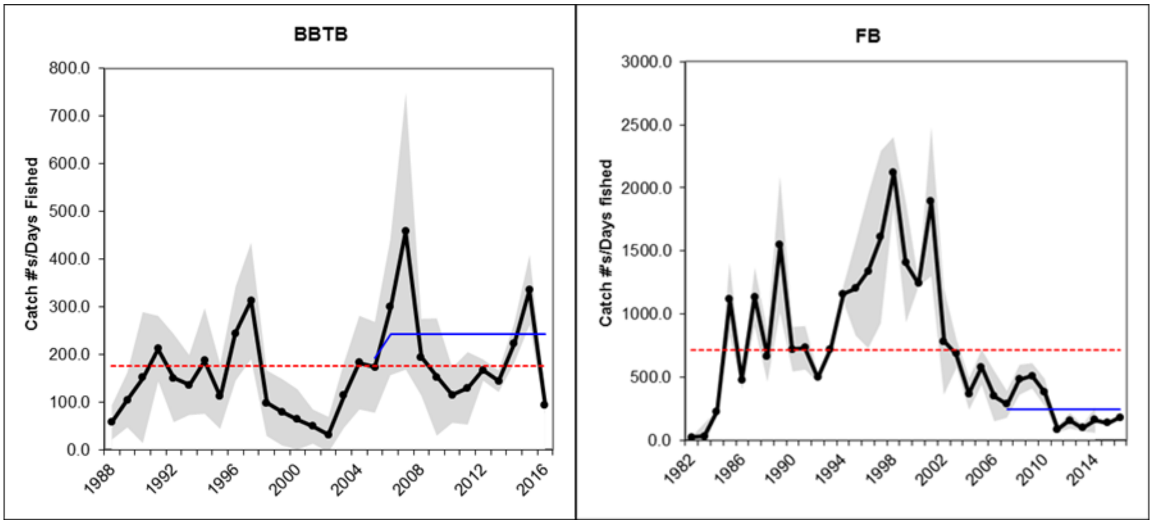


Figure 28: Combined catch rates (spring and fall spawners) in the spring research gillnet program in BBTB and FB (dashed/red line = timeseries mean; solid/blue line = decadal mean).

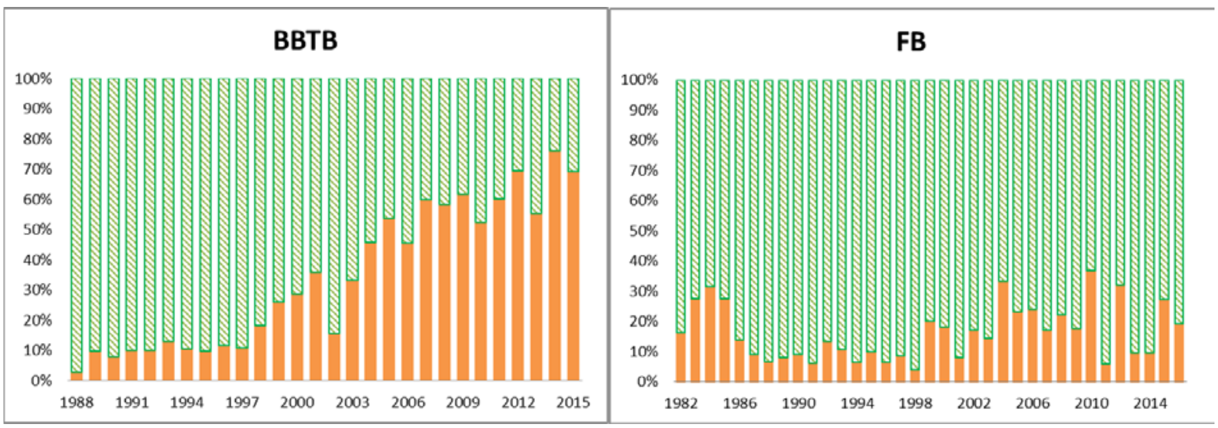


Figure 29: Proportion of spring and fall spawning herring in the spring research gillnet program in the BBTB and FB stock areas (green/patterned bars = spring spawners; orange/solid bars = fall spawners).

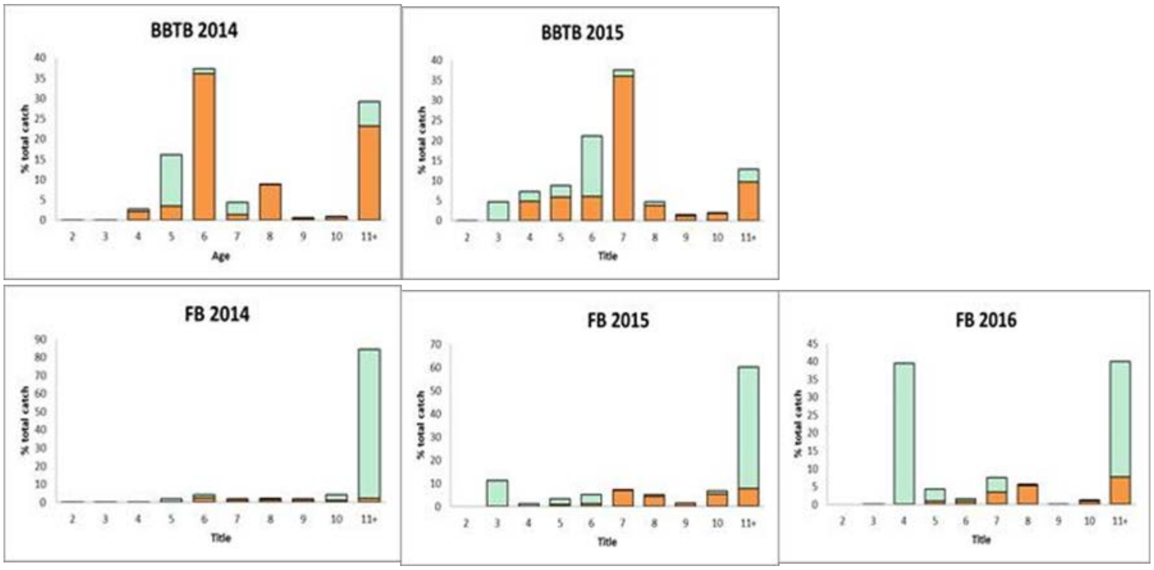


Figure 30: Age distribution by spawning type (fall spawners = orange/lower bars; spring spawners = upper/green bars) in the spring research gillnet program by year and stock area.

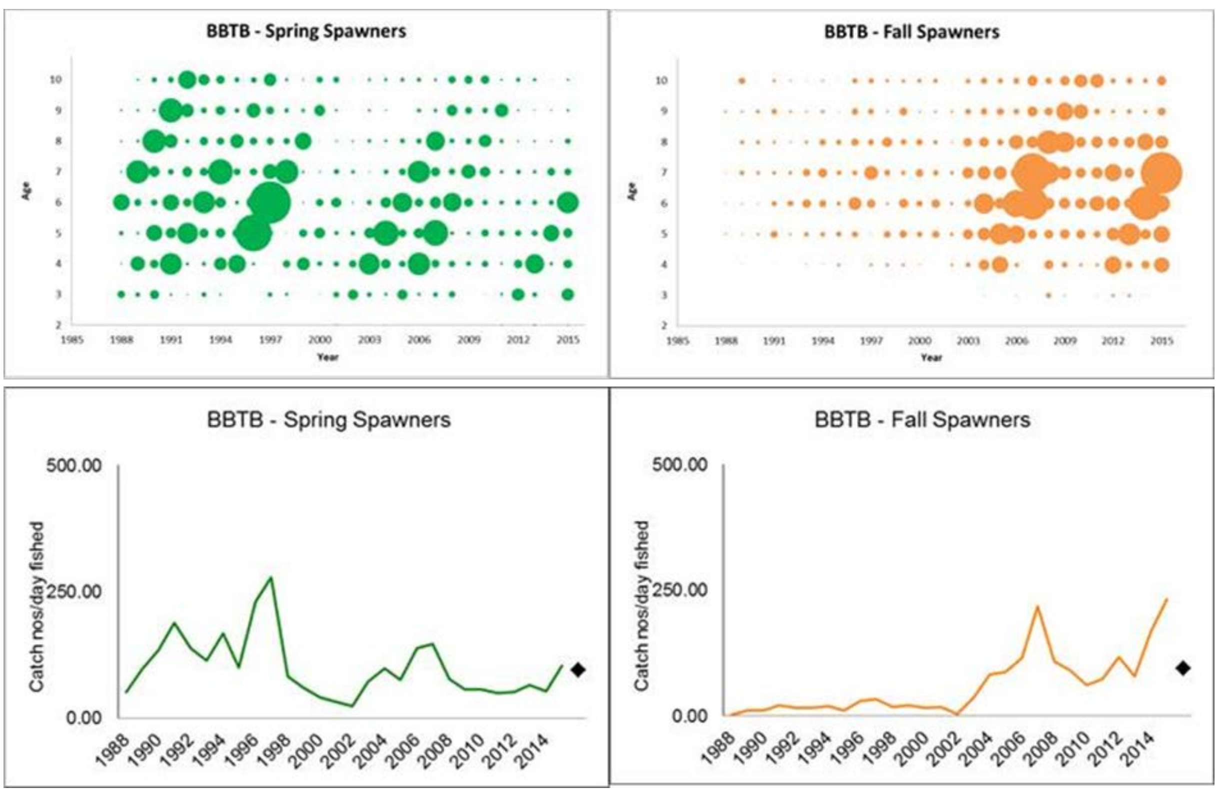


Figure 31a: Catch rates (numbers/nights fished) at age (upper panels) by spawning type (upper and lower panels) in the research gillnet program (point on lower panels represents 2016 catch rate which has not yet been seperated by spawning type).

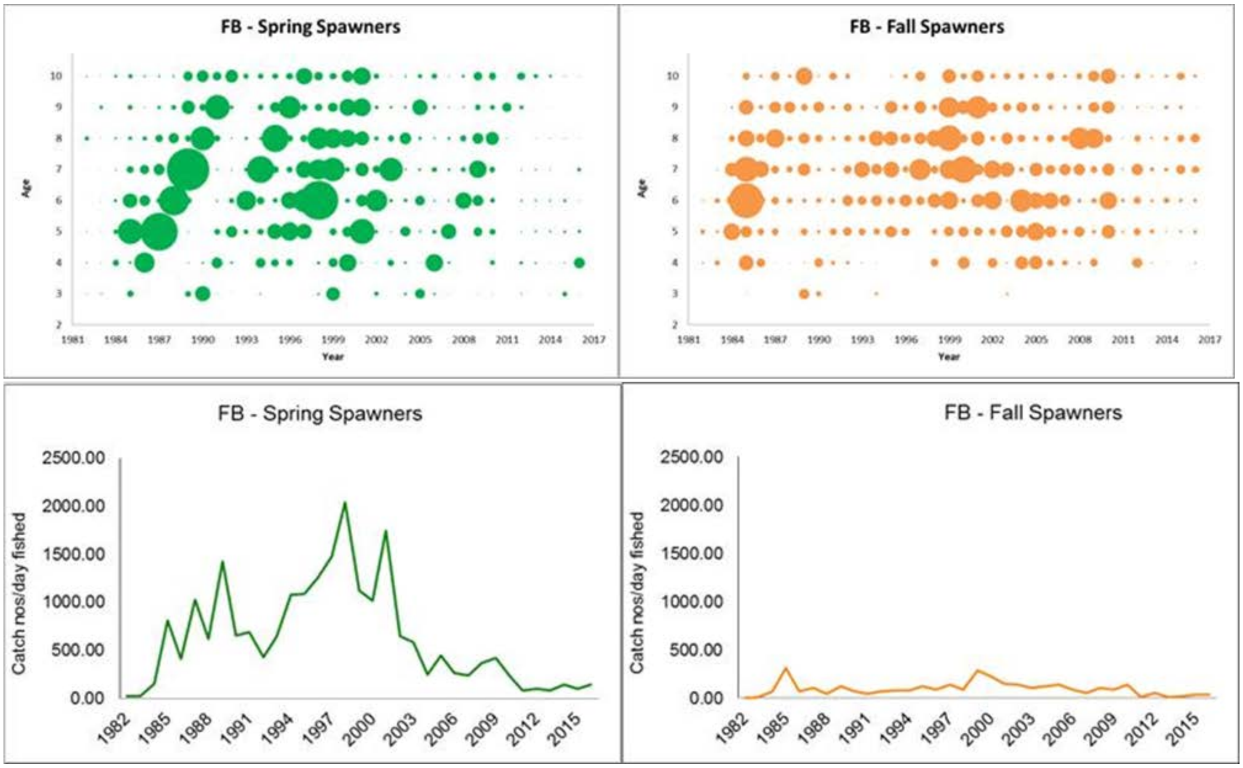
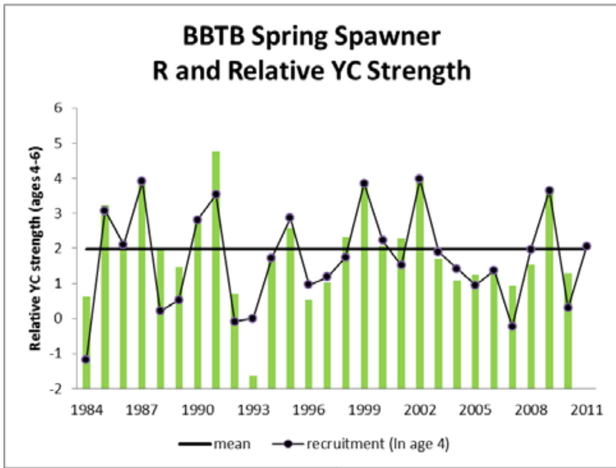
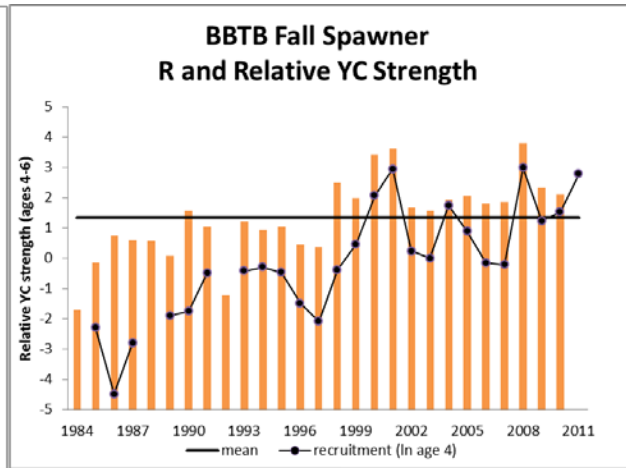


Figure 31b: Catch rates (numbers/nights fished) at age (upper panels) by spawning type (upper and lower panels) in the research gillnet program.





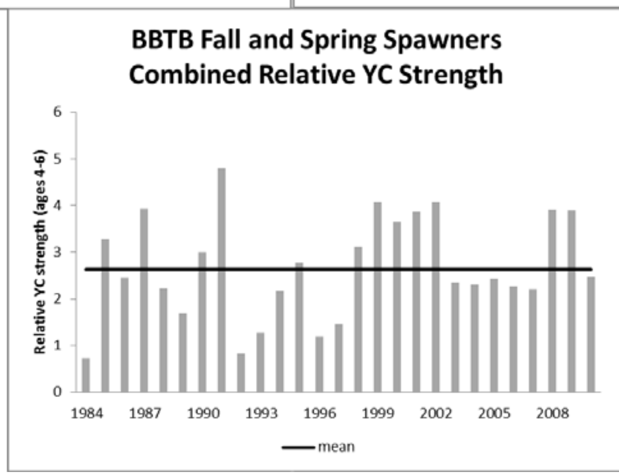


Figure 32a: Relative year class strength (bars), series mean (horizontal line), and recruitment (moving line) estimates by spawning type in BBTB.

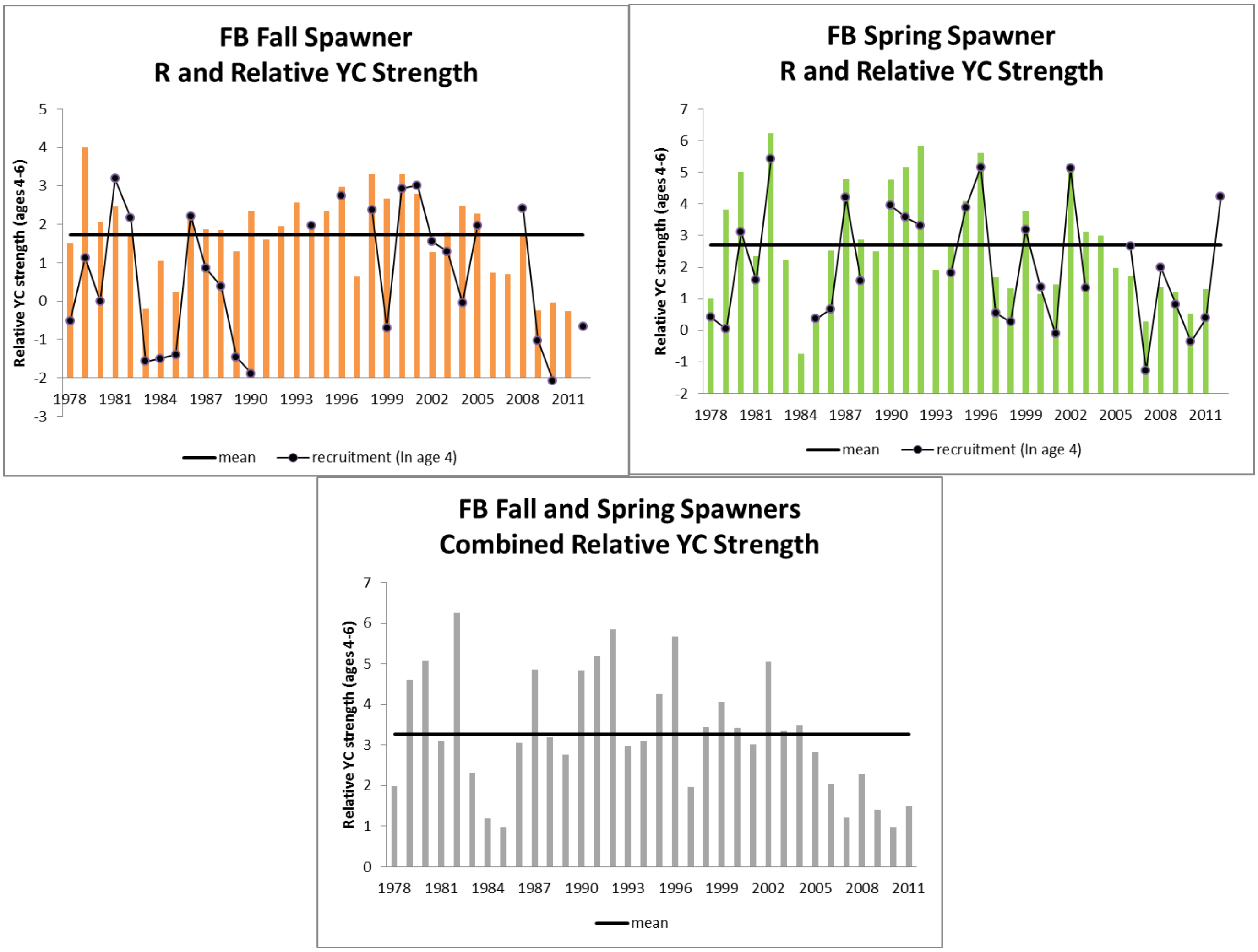


Figure 32b: Relative year class strength (bars), series mean (horizontal line), and recruitment (moving line) estimates by spawning type in FB.

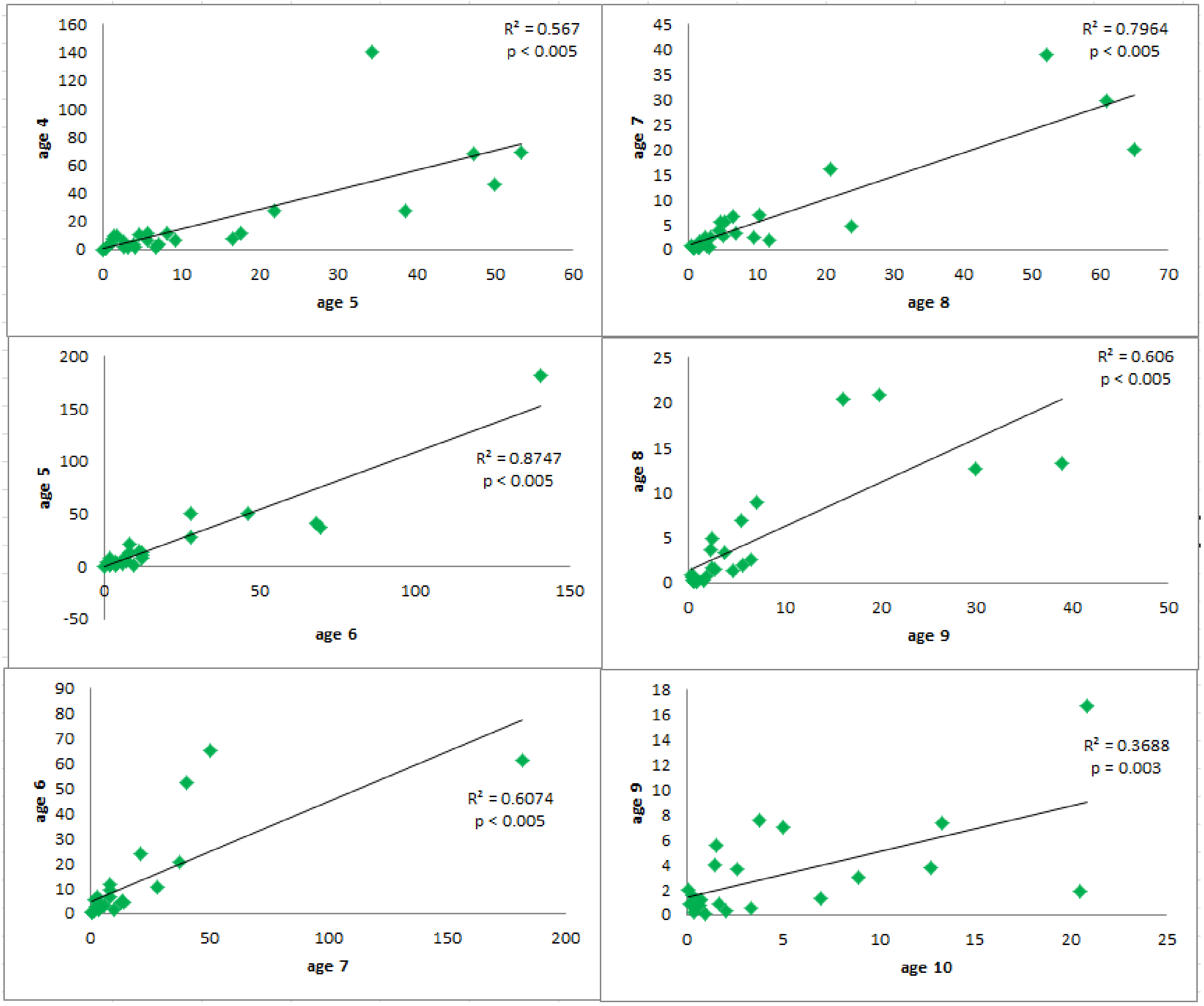


Figure 33a: Catch rates of age n vs age n+1 (lagged) spring spawning herring in the BBTB spring research gillnet program.

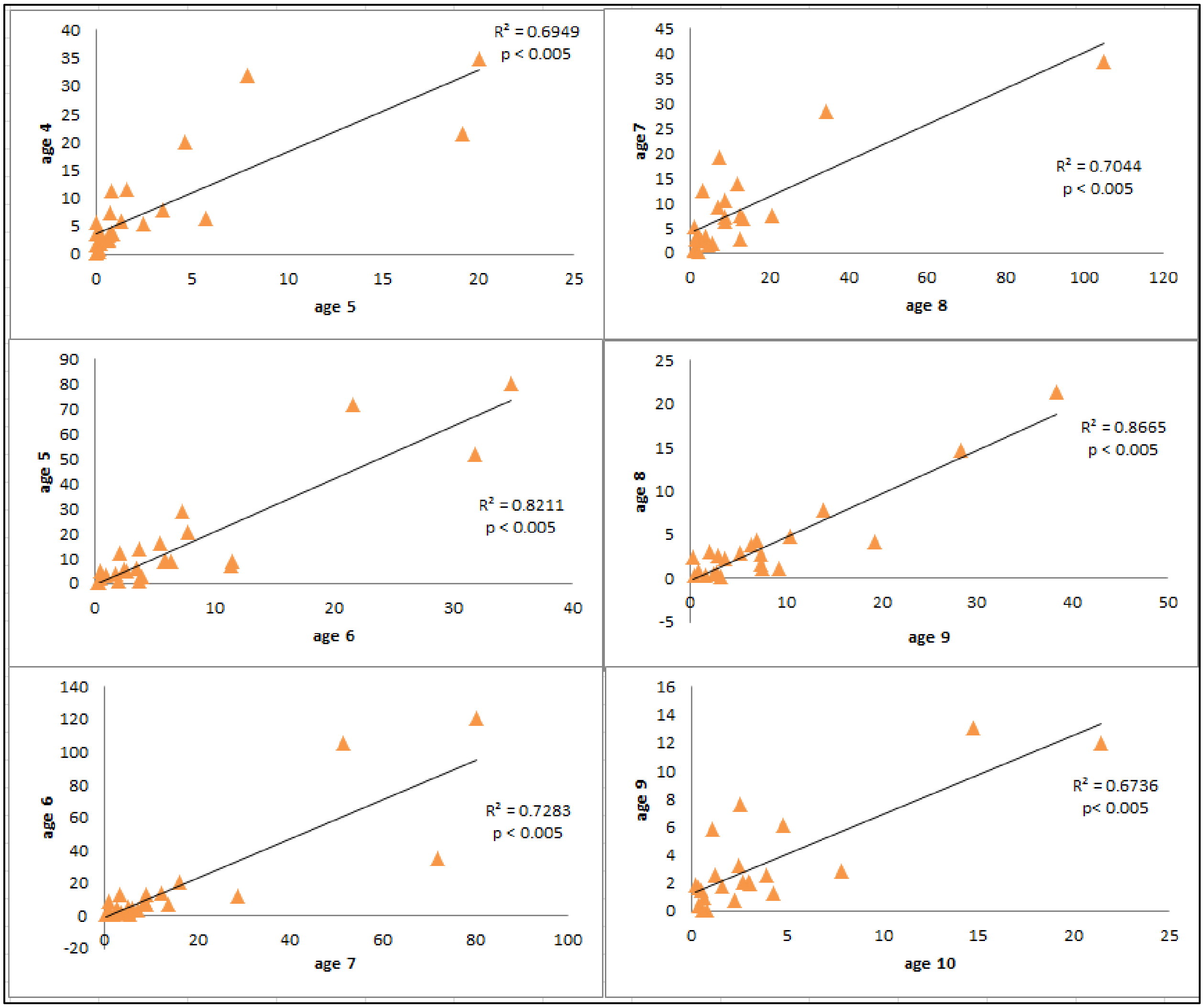


Figure 33b: Catch rates of age n vs age n+1 (lagged) fall spawning herring in the BBTB spring research gillnet program.

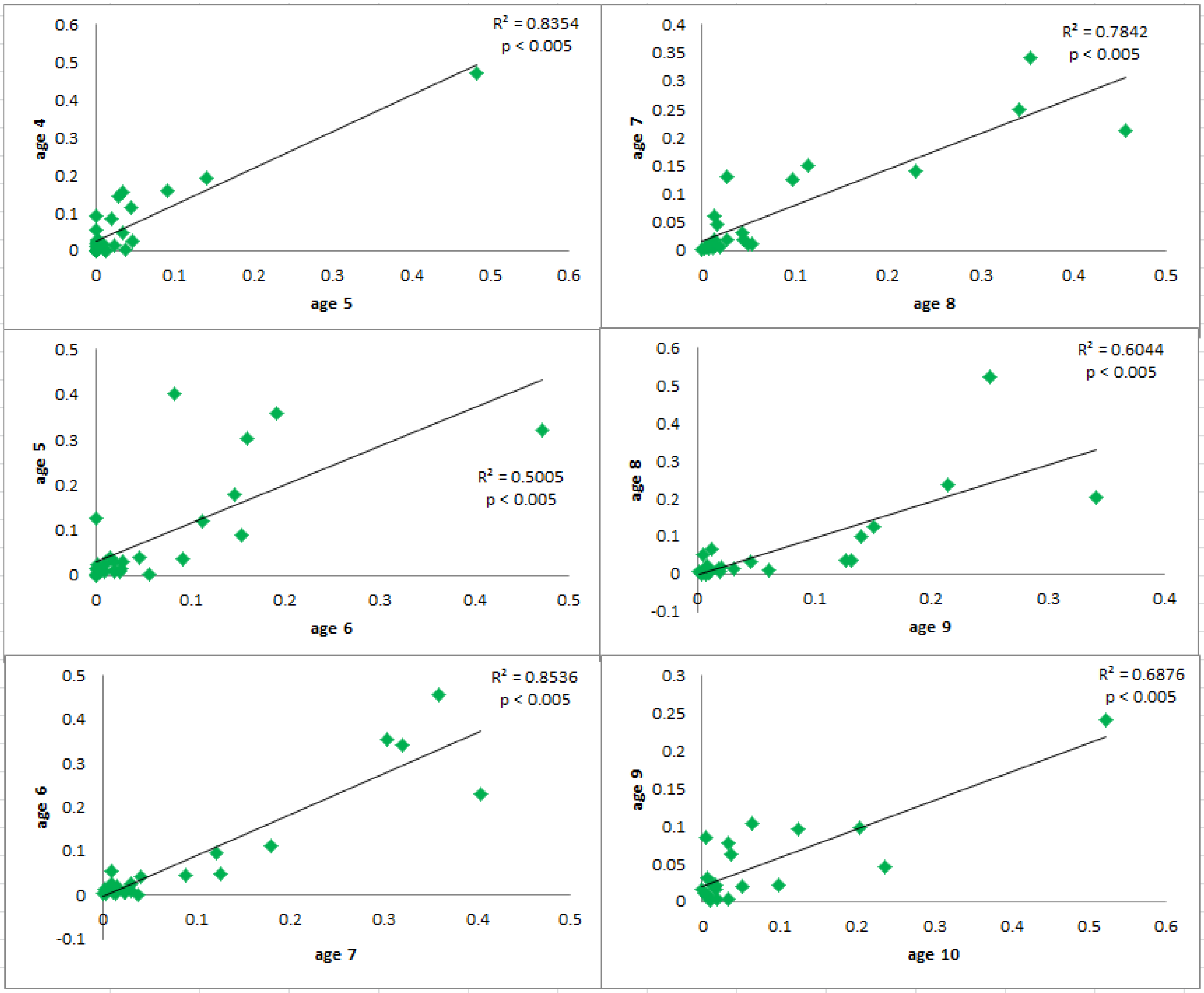


Figure 34a: Catch rates of age n vs age n+1 (lagged) spring spawning herring in the FB spring research gillnet program.

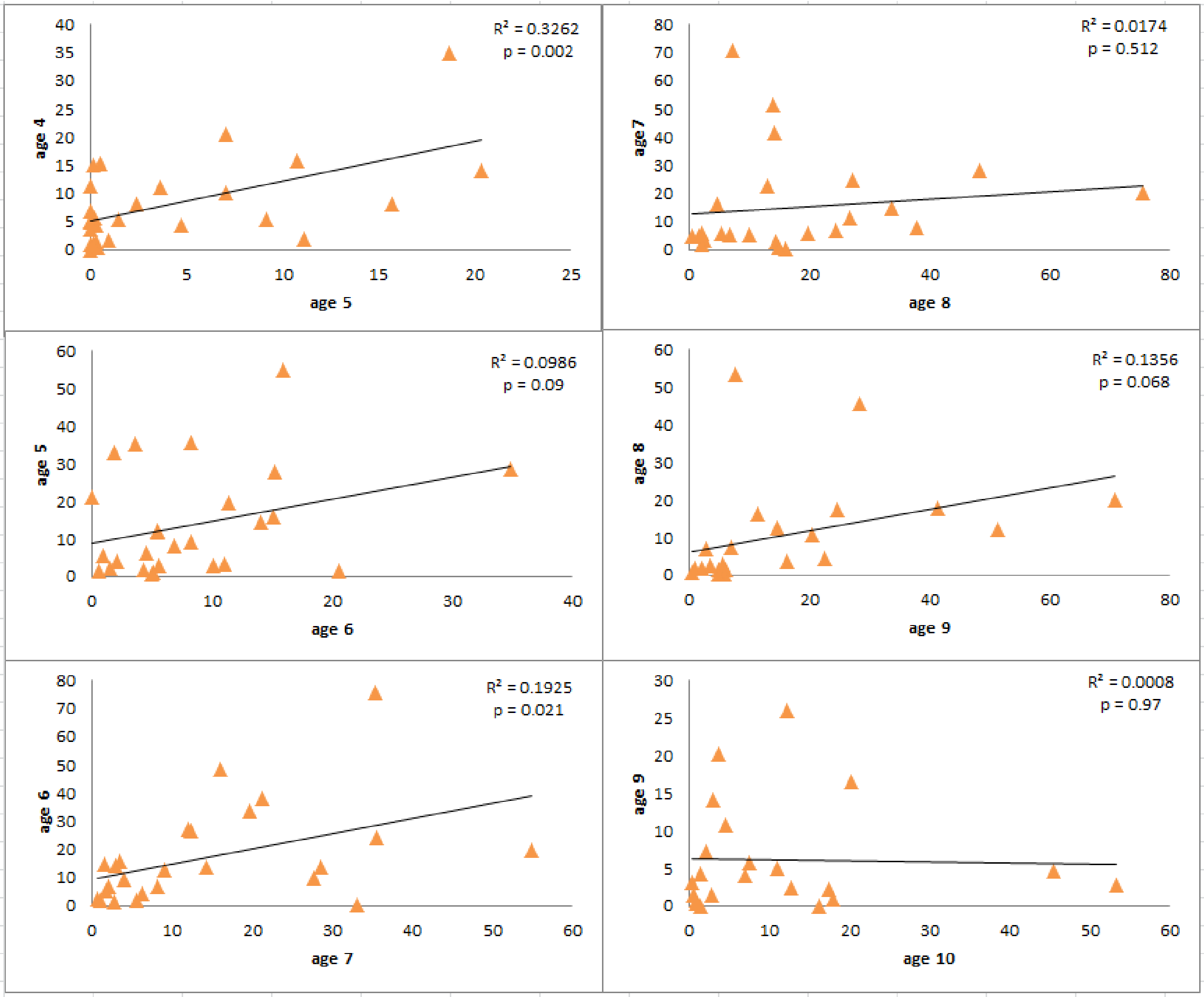


Figure 34b: Catch rates of age n vs age n+1 (lagged) fall spawning herring in the FB spring research gillnet program.

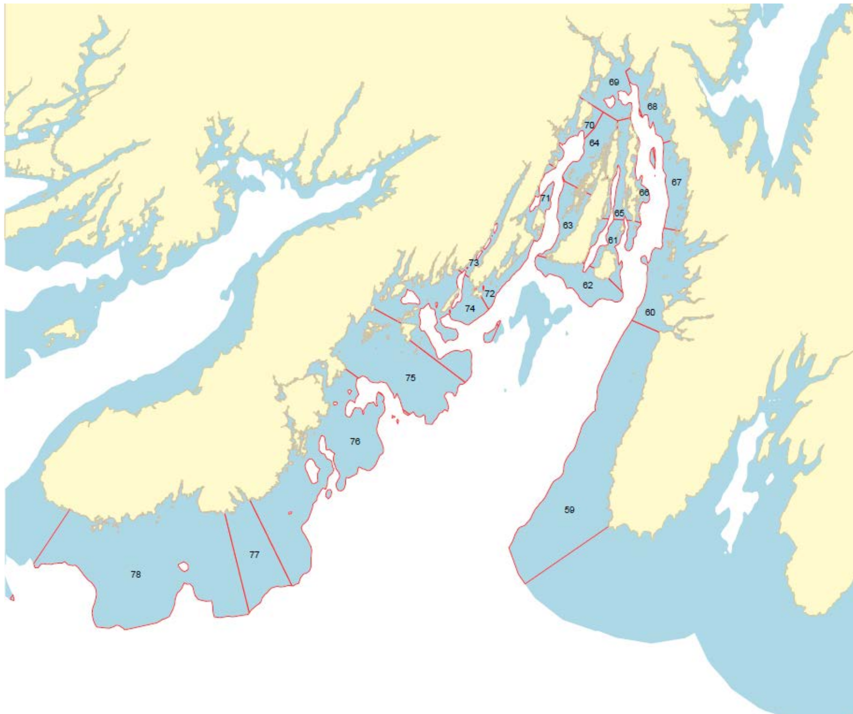


Figure 35: Historical strata used in Placentia Bay acoustic herring surveys.

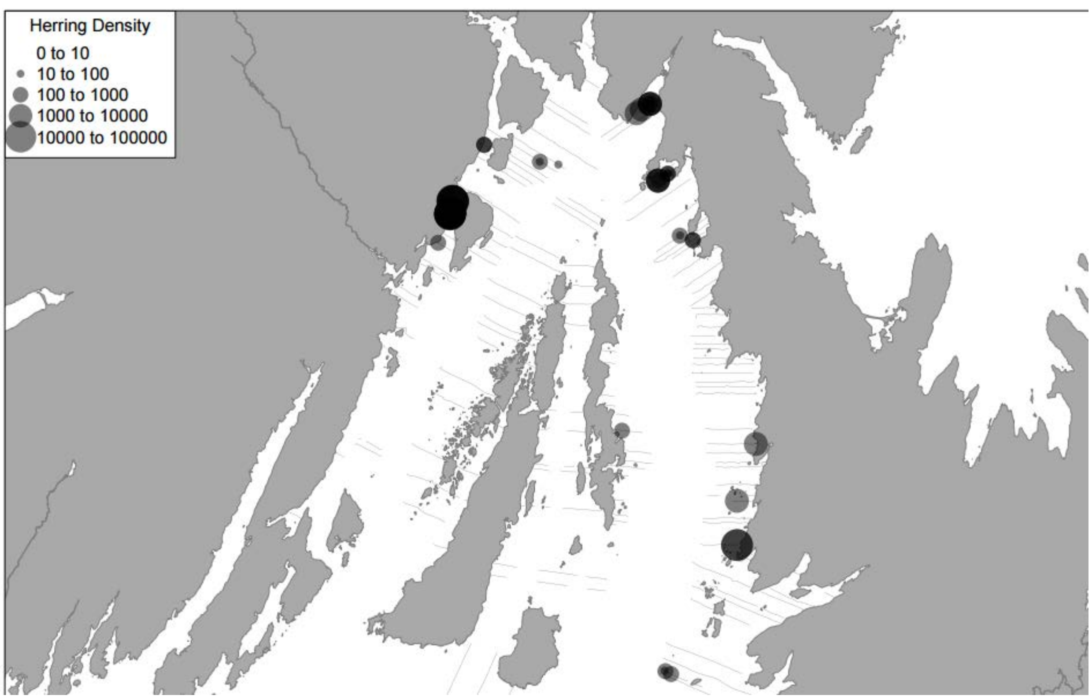


Figure 36: Completed transect lines and herringdensity in February 2016 Placentia Bay acoustic herring survey.

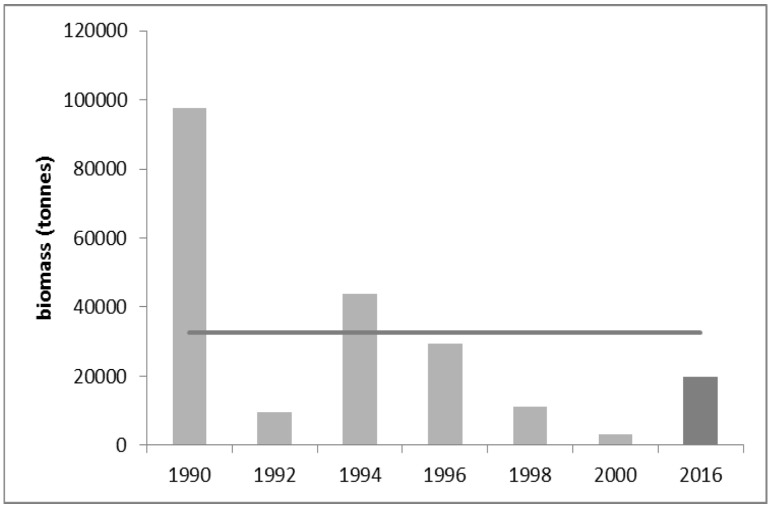


Figure 37: Herring biomass estimates from acoustic surveys (bars) and time series mean (solid line).

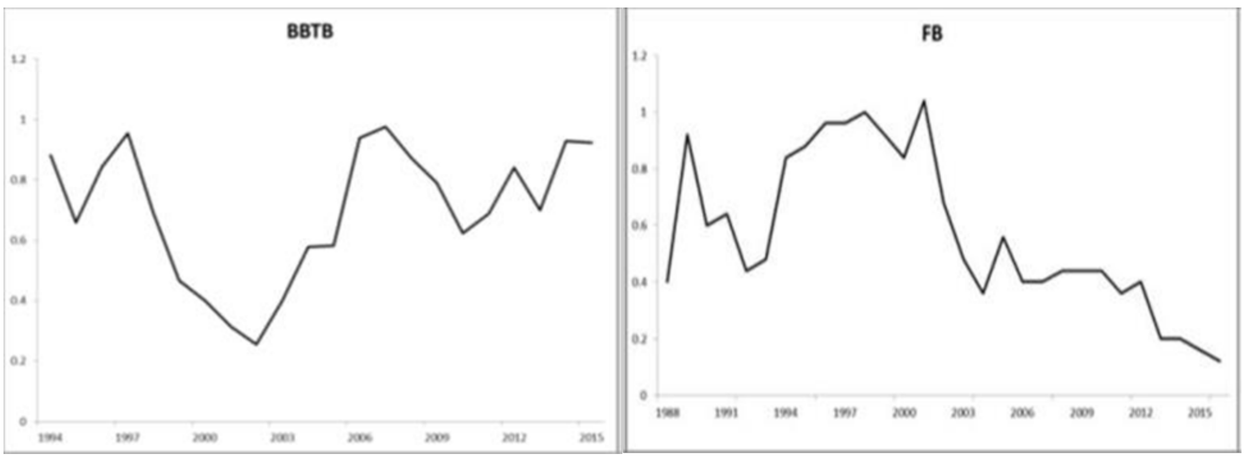


Figure 38: Stock status index for BBTB and FB to 2015.