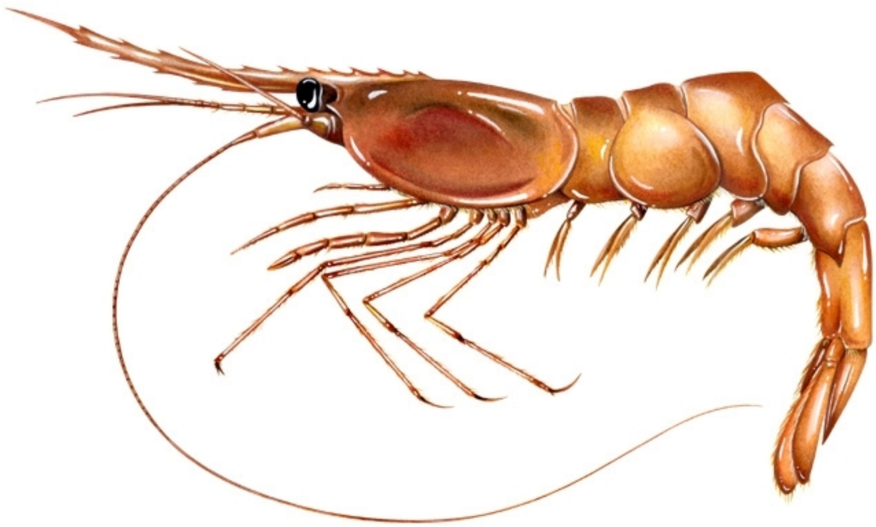
STOCK STATUS REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP — 2015



Prepared
November 23, 2015
by the
Atlantic States Marine Fisheries Commission's
Northern Shrimp Technical Committee

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SUMMARY

Landings in the Gulf of Maine Northern Shrimp fishery since the mid-1980s have fluctuated between 335–9,500 mt, reflecting variations in year class strength as well as regulatory measures, participation, and market conditions in the fishery. Landings in 2013 declined to 346 mt, which was 55% of the TAC set by ASMFC for 2013 (625 mt). Due to implementation of a fishery moratorium in 2014 and 2015, removals were 0.3 mt and 6.7 mt, respectively, as part of a cooperative winter sampling program and a research set aside program.

A benchmark assessment review in 2014 revealed problems with model performance in recent years for Gulf of Maine Northern Shrimp. The problems were thought to be due primarily to recent extreme fluctuations in abundance. No models were accepted for use in shrimp management. The current assessment therefore uses an index-based approach to evaluate the condition of the stock.

The Northern Shrimp Technical Committee (NSTC) evaluated a suite of indicators including fishery performance, survey indices of abundance and biomass, and environmental conditions. Abundance and biomass indices for 2012–2015 were the lowest on record of the thirty-two year time series. Recruitment indices for the 2010–2014 year classes were also well below average, and included the three smallest year classes on record. As a result, the indices of fishable biomass from 2013–2015 are the lowest on record. The recruitment index increased slightly in the 2014 survey (2013 year class), however, in 2015 the index dropped to the lowest in the time series. Recruits of the 2013 and 2014 year classes are not expected to reach exploitable size until 2017 and 2018, respectively. Despite the marginal increase in the recruitment index in 2014, the population continues to meet the criteria defining a collapsed stock.

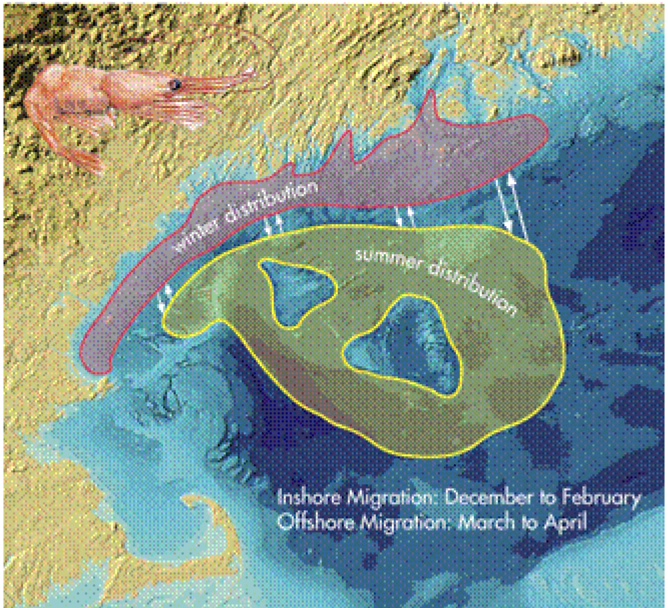
Recruitment of Northern Shrimp is related to both spawning biomass and ocean temperatures, with higher spawning biomass and colder temperatures producing stronger recruitment. Ocean temperatures in western Gulf of Maine shrimp habitat have increased over the past decade and reached unprecedented highs in the past several years. While 2014 and 2015 temperatures were cooler, temperatures are predicted to continue rising as a result of climate change. This suggests an increasingly inhospitable environment for Northern Shrimp and the need for strong conservation efforts to help restore the stock.

Given the depleted condition of the resource and poor prospects for the near future, the NSTC recommends that the Northern Shrimp Section extend the moratorium on fishing through 2016.

INTRODUCTION

Biological Characteristics

Northern Shrimp (*Pandalus borealis* Krøyer) are hermaphroditic, maturing first as males at about 2½ years of age and then transforming to females at about 3½ years of age in the Gulf of Maine. Spawning takes place in offshore waters beginning in late July. By early fall, most adult females extrude their eggs onto the abdomen. Egg-bearing females move inshore in late autumn and winter, where the eggs hatch. Juveniles remain in coastal waters for a year or more before migrating to deeper offshore waters, where they mature as males. The exact extent and location of these migrations is variable and somewhat unpredictable. The males pass through a series of transitional stages before maturing as females. Some females may survive to repeat the spawning process in succeeding years. The females are the individuals targeted in the Gulf of Maine fishery.



Distribution of adult female northern shrimp (NAMA, 2006)

Fishery Management

The Gulf of Maine fishery for Northern Shrimp is managed through an interstate agreement between the states of Maine, New Hampshire and Massachusetts (the Northern Shrimp Section). The management framework evolved during 1972–1979 under the auspices of the State/Federal Fisheries Management Program. In 1980, this program was restructured as the Interstate Fisheries Management Program (ISFMP) of the Atlantic States Marine Fisheries Commission (ASMFC). The Fishery Management Plan (FMP) for Northern Shrimp was first approved under the ISFMP in October 1986 (McInnes, 1986, FMR No. 9).

Amendment 1, which was implemented in 2004, established biological reference points for the first time in the Northern Shrimp fishery and expanded the tools available to manage the fishery. Management of Northern Shrimp under Amendment 1 resulted in a rebuilt stock and increased fishing opportunities. However, early season closures occurred in the 2010 and 2011 fishing seasons because landing rates were far greater than anticipated. Furthermore, untimely reporting resulted in short notice of the season closures and an overharvest of the recommended total allowable catch (TAC).

In response to these issues, Amendment 2, approved in October 2011, provides management options to slow catch rates throughout the season, including trip limits, trap limits, and days out of the fishery. Amendment 2 completely replaces the FMP. It modifies the fishing mortality reference points to include a threshold level, includes a more timely and comprehensive reporting system, and allows for the initiation of a limited entry program to be pursued through the adaptive management process.

Under Amendment 2, the fishing mortality target is $F_{1985–94}$ = 0.29, and is defined as the average fishing mortality rate during 1985 to 1994 when biomass and landings were "stable". The fishing mortality threshold is the maximum annual F during the same stable period (1985–94), which is F_{1987} = 0.37, as estimated by the NSTC in 2010. The fishing mortality limit is F = 0.6, and is based on the value that was exceeded in the early to mid-1970s and in the mid-1990s when the stock collapsed. The fishing mortality target, threshold and limit may be updated as the best scientific information becomes available through updated stock assessments. Overfishing is occurring if the threshold is exceeded.

Fishing mortality reference points were re-estimated by the NSTC in 2013 as F_{target} =0.38 and $F_{threshold}$= 0.48. F_{limit} is taken to be = 0.60, and is not re-estimated within the assessment framework. The F reference points were estimated under the assumption of natural mortality (M) = 0.25, as specified in Amendment 2. Higher values of M are considered more realistic (e.g. M=0.5); however using a higher constant value for M does not generally alter conclusions about stock status because the increased M scales the entire assessment.

Amendment 2 does not employ a biomass target because the Section did not want to set unlikely goals for a species whose productivity is sensitive to environmental conditions. The stock biomass threshold of $B_{Threshold}$ = 9,000 metric tons (mt) and limit of B_{Limit} = 6,000 mt are based on historical abundance estimates and response to fishing pressure, and remain unchanged from Amendment 1. The limit was set at 2,000 mt higher than the lowest observed biomass at that time. The Section stresses that the threshold is not a substitute for a target. It will manage the fishery to maintain stock biomass above the threshold. Furthermore, the Section's management decisions will be affected by the year class composition of the stock.

The process for setting fishery specifications under Amendment 2 is as follows. The NSTC annually reviews the best available data including commercial landings, stock status and survey indices, assessment modeling, etc., and recommends a target total allowable catch (TAC) to maintain healthy stock status relative to peer reviewed biological reference points. The Section meets annually during a public meeting in the fall to review the Advisory Panel and NSTC's recommendations, set a target TAC, and specify any combination of management measures outlined in Section 4.1 of Amendment 2 through a majority vote. Refer to Appendix 1 for NSTC recommendations and subsequent management action by year from 1986–2015.

Addendum I to Amendment 2, approved in November 2012, clarifies the annual specification process, and allocates the TAC with 87% for the trawl fishery and 13% for the trap fishery based on historical landings by each gear type. Additionally, Addendum II implemented a season closure provision designed to close down the Northern Shrimp fishery when a pre-determined percentage (between 80–95%) of the annual TAC has been projected to be caught. Lastly, the addendum instituted a Research Set Aside (RSA) program which allows the Section to "set aside" a percentage of the TAC to help support research on the Northern Shrimp stock and fishery. The Section may still set a RSA during years of a moratorium. The RSA was utilized in 2015 to continue the Technical Committee's (TC) time series of winter sampling of the exploitable stock during the fishery moratorium.

Since the implementation of Amendment 2, the Gulf of Maine Northern Shrimp fishery and population has experienced significant changes. Also, there have been substantial changes in other Northeast fisheries resulting in increased effort in the Northern Shrimp fishery. This increased fishing pressure, paired with failed recruitment, the lowest abundance indices on record, and unfavorable environmental conditions, has resulted in uncertainties in the future of the resource. To address these uncertainties, the Section initiated development of Amendment 3 which considers management measures to control effort and stabilize the fishery. The Public Information Document (PID) for Draft Amendment 3 sought public comment throughout the winter and early spring of 2015. The Section reviewed public comment on the PID and Advisory Panel (AP) recommendations in June 2015 and directed the Plan Development Team (PDT) to develop limited entry and state-by-state allocation programs for Draft Amendment 3. However, given the collapsed status of the stock and the fact that the fishery is currently under a moratorium, the Section decided to postpone further action on Amendment 3 until Maine can adequately address over-capacity in its fishery.

2014 Benchmark Assessment Review

A set of three stock assessment models for Northern Shrimp were presented to the Northeast Fisheries Science Center's Stock Assessment Workshop (SAW) for review as part of a benchmark assessment (NEFSC 2014). Several important conclusions came from the peer review panel. These are summarized below (the reviewers' reports can be accessed at http://www.nefsc.noaa.gov/saw/saw58/index.html.):

- Despite the high quality data available for Northern Shrimp, the models have difficulty fitting the data because of extreme fluctuations in recent years, including the exceptionally high 2006 shrimp survey index, and the sudden decline of all indices in 2012 followed by sustained extreme lows.
- A new statistical framework was developed for the catch-survey analysis (CSA, Collie and Sissenwine 1983; Cadrin et al. 1999). CSA has been used to guide management decisions in the shrimp fishery since 1997. The review panel considered the new statistical framework an important advance, but felt the results were overly sensitive to weightings chosen for different components of the model (e.g. catch data, survey data), and on this basis rejected the new CSA for management use. They were not able to comment on the applicability of the previously-accepted version of CSA because there was insufficient time to review the previous version (and this was not their remit).
- The review panel concluded that a new length-based model developed for Northern Shrimp has promise but needs further development and testing before application to management.
- The review panel agreed that the use of a surplus production model (ASPIC) as a confirmatory analysis should be discontinued. ASPIC is unable to adequately handle the large fluctuations in recruitment which are typical of Northern Shrimp population dynamics.

In light of the review panel's comments on the new version of CSA, the NSTC conducted exploratory work to evaluate whether the previous CSA version had similar issues (these issues could not have been detected under the previous statistical framework). The results of the exploratory analysis suggest that the previous CSA also had difficulty with the major swings in data in recent years, although the conclusions with respect to overfishing status were robust and did not differ with different weighting scenarios.

Given the results of the benchmark assessment review and exploratory CSA analysis, the NSTC is not presenting modeling results in this stock assessment. Instead, the assessment uses an index-based approach to evaluate stock status.

Management in the 2014 and 2015 Fishing Seasons
Following the 2013 stock status report, the Northern Shrimp Section imposed a moratorium on the fishery for the 2014 season. The Section considered several factors prior to closing the fishery in 2014. Northern Shrimp abundance in the western Gulf of Maine had declined steadily since 2006. The 2012 and 2013 survey indices of total biomass and spawning stock biomass were the lowest on record. Additionally, the stock experienced failed recruitment for three consecutive years prior to 2014 (2010–2012 year classes). The 2014 stock status report indicated continued poor conditions which prompted the Section to extend the moratorium through 2015.

Commercial Fishery Trends

The NSTC reviewed state and federal harvester reports (vessel trip reports (VTRs)) for the 2013 fishing season and updated landings and effort data in Tables 1–8 and associated figures. Cooperative winter sampling occurred in 2014 and 2015 to continue the time series of biological samples from the Gulf of Maine Northern Shrimp fishery during the fishery moratorium.

Cooperative Winter Sampling/Research Set Aside Program, 2014–2015
In the absence of a commercial fishery in 2014, the State of Maine contracted with a commercial shrimp trawler to collect northern shrimp samples during January – March near Pemaquid Point, in midcoast Maine, chosen as best representing the spatial "center" of a typical winter Maine shrimp fishery (Hunter, 2014). In 2015, four trawlers and five trappers collected northern shrimp samples in the Gulf of Maine during January – March under the research set aside (RSA) program implemented through Addendum II to Amendment 2 (Whitmore *et al.*, 2015). The traditional spatial range of the trawl fishery was divided into four regions: Massachusetts-New Hampshire, Western Maine (Kittery to Phippsburg), Midcoast Maine (Phippsburg to Rockland), and Eastern Maine (Vinalhaven to Lubec). One trawl captain for each of the four sampling regions was picked at random from among the qualified applicants from that region. Each trawler fished about once every two weeks, conducting at least three tows per trip, and made no more than five trips. Five trappers were selected from Midcoast and Eastern Maine and each fished ten traps, tended as often as needed.

Landings, 1969–2013
Annual landings of Gulf of Maine northern shrimp declined from an average of 11,400 metric tons (mt) during 1969–1972 to about 400 mt in 1977, culminating in a closure of the fishery in 1978 (Table 1, Table 2, Table 3 and Figure 1). The fishery reopened in 1979 and landings increased steadily to over 5,000 mt by 1987. Landings ranged from 2,100 to 6,500 mt during 1988–1995, and then rose dramatically to 9,500 mt in 1996, the highest since 1973. Landings declined to an average of 2,000 mt for 1999–2001, and dropped further in the 25-day 2002

season to 450 mt, the lowest northern shrimp landings since the fishery was closed in 1978. Landings then increased steadily, averaging 2,100 mt during the 2003 to 2006 seasons, then jumping to 4,900 mt in 2007 and 5,000 mt in 2008. In 2009, 2,500 mt were landed during a season that was thought to be market-limited. The proposed 180-day season for 2010 was cut short to 156 days with 6,140 mt landed, due to the industry exceeding the total allowable catch (TAC) for that year, and concerns about small shrimp.

As in 2010, the 2011 season was closed early due to landings in excess of the TAC. A total of 6,397 mt of shrimp were landed, exceeding the recommended TAC of 4,000 mt by approximately 2,400 mt (Table 1 and Figure 1). The average price per pound was $0.75 and the estimated landed value of the catch was $10.6 million (Table 2). In 2012, the season was further restricted by having trawlers begin on January 2 with 3 landings days per week and trappers begin on February 1 with a 1,000 pound limit per vessel per day. The TAC was set at 2,000 mt (later increased to 2,211 mt on January 20th) and would close when the projected landings reached 95%. The season was closed on February 17 and trawlers had a 21-day season and trappers had a 17-day season. Landings for 2012 were 2,485 mt and the average price per pound was $0.95 with an estimated landing value of $5.2 million. In 2013, the TAC was set at 625 mt with 5.44 mt set aside for research tows and closure when 85% of the TAC was reached in each fishery (trap and trawl). The trawl fishery was allocated a 539.02 mt TAC and the trap fishery was allocated an 80.54 mt TAC. Trawlers fished for 54 days and trappers fished 62 days culminating in 345.5 mt landed, which is 280 mt under the TAC. The average price per pound was $1.81 and is the highest observed since 1989 (inflation-adjusted values, Table 2) with an estimated value of $1,375,788. No shrimp were landed during the 2014 cooperative winter sampling program, except the collected samples. In the 2015 RSA fishery, about 6.7 mt were landed.

Most northern shrimp fishing in the Gulf of Maine is conducted by otter trawls, although traps are also employed off the central Maine coast. According to federal and state of Maine VTRs, trappers averaged 12% of Maine's landings during 2001 to 2007, 18% during 2008 to 2011, and 9% in 2012 (Table 4). Otter trawling effort has accounted for between 78% and 96% of Maine's landings during 2000 to 2013. Harvester reports indicate that trappers accounted for about 7% of Maine's landings in 2013, the lowest since 2004 (4%).

Size, Sex, and Maturity Stage Composition of Landings

Size and sex-stage composition data have been collected from port samples of fishery landings from each of the three states. One kilogram samples were collected from randomly selected landings. Data were expanded from the sample to the vessel's landings, and then from all sampled landings to total landings for each gear type, state, and month. Size composition data (Figure 2 and 3) indicate that trends in landings have been determined primarily by recruitment of strong (dominant) year classes.

Landings more than tripled with recruitment to the fishery of a strong assumed 1982 year class in 1985–1987 and then declined sharply in 1988. A strong 1987 year class was a major contributor to the 1990–1992 fisheries. A strong 1992 year class, supplemented by a moderate 1993 year class, partially supported large annual landings in 1995–1998. Low landings in 1999–2003 were due in part to poor 1994, 1995, 1997, 1998, and 2000 year classes with only moderate 1996 and

1999 year classes. A very strong 2001 year class supported higher landings in 2004–2006. In the 2007 fishery, landings mostly comprised assumed 4-year-old females from the moderate to strong 2003 year class, and possibly 6-year olds from the 2001 year class. Landings in 2008 were mostly composed of the assumed 4-year-old females from the strong 2004 year class, and the 2003 year class (assumed 5-year-old females, which first appeared as a moderate year class in the 2004 survey).

In the 2009 fishery, landings were comprised mainly of assumed 5-year-old females from the strong 2004 year class. Catches in the 2010 fishery consisted of assumed 5-year-old females from the 2005 year class and possibly some 4-year-old females from the weak 2006 year class. The 2011 fishery consisted mainly of 4-year-old females from the assumed 2007 year class. Numbers of 5-year-old shrimp were limited likely due to the weak 2006 year class. Transitionals and female stage Is from the 2008 year class, and some males and juveniles from the assumed 2009 year class were observed, especially in the Massachusetts and New Hampshire landings and Maine's December and January trawl landings. Trawl landings in the 2012 fishery were likely 4-year olds from the moderate 2008 year class, but they were small for their age. Low percentages of males and juveniles were caught in 2012 likely due to the later start date of January 2. In the 2013 fishery, landings were limited but likely comprised 4- and 5-year olds from the moderate 2009 and 2008 year classes that were small for their assumed age. Limited numbers of males and transitionals were observed in landings.

Samples from the cooperative winter sampling program in 2014 likely comprised 5-year-old shrimp from the 2009 year class and some small males from the fast-growing assumed 2013 year class. Samples from the 2015 RSA program (Figure 2) exhibited an unusually high percentage of small ovigerous females, possibly early-maturing, fast-growing primary females from the 2013 year class. The small females were more prevalent in the Maine trawl samples than in the trap samples or the Massachusetts trawl samples. Some larger females from the assumed 2010 year class were also evident in all samples.

Spatial and temporal differences in the timing of the egg-hatch can be estimated by noting the proportion of mature females (Female II) that have hatched their brood during the season and across geographic locations. In 2015, most of the female shrimp were still carrying eggs in late January and early February, and most had hatched off their eggs by the middle of March (Figure 2). The mid-point of the hatch period was estimated to have been February 16 in Massachusetts, March 12 in western Maine, and March 13 in midcoast Maine. Compared to the longer time series of hatch timing estimates (Figure 3), it appears that hatch metrics in 2014 and 2015 were similar to pre-2000 fisheries, when the hatch started later and the duration of the hatch period was shorter. Egg hatch trends observed in the 2015 winter sampling were consistent with historical regional trends of hatch beginning and ending earlier in the western Gulf of Maine and later in the eastern Gulf of Maine.

For more information about the 2014 cooperative sampling and 2015 RSA programs, see Hunter (2014) and Whitmore *et al*. (2015), or visit http://www.maine.gov/dmr/rm/shrimp/.

Discards

Discard rates of Northern Shrimp in the Northern Shrimp fishery are thought to be near zero because no size limits are in effect and most fishing effort occurs in areas where only the larger females are present. Data from a study which sampled the Northern Shrimp trap fishery indicated overall discard/kept ratios (kg) for Northern Shrimp of 0.2% in 2010 and 0.1% in 2011 (Moffett et al. 2012). Sea sampling data from Gulf of Maine shrimp trawlers in the 1990s indicated no discarding of Northern Shrimp (Richards and Hendrickson 2006). On an anecdotal level, port samplers in Maine reported seeing manual shakers (used to separate the small shrimp) on a few trawl vessels during April 2010, but made no similar observations in 2011 through 2013. Discarding of Northern Shrimp in other Gulf of Maine fisheries is rare (on average less than 0.001% during 2000–2013; Northeast Fishery Observer Program data, NMFS). For these reasons and because detailed data for estimating potential discards are lacking, shrimp discards from the shrimp and other fisheries are assumed zero in this assessment. However, it is important to note that in 2014, aside from the 2-kg samples that were provided to Maine DMR for analysis, all catches from the cooperative winter sampling program were discarded at sea.

Black Gill Syndrome

Shrimp collected during routine port-sampling in Maine in 2003 exhibited a high incidence (greater than 70%) of Black Gill Syndrome, also called Black Gill Disease or Black Spot Syndrome. Affected shrimp displayed melanized, or blackened gills, with inflammation, necrosis, and significant loss of gill filaments. Black Gill Syndrome was also documented in the Gulf of Maine in 1966 (Apollonio and Dunton, 1969; Rinaldo and Yevich, 1974). Its etiology is unknown, although fungal and ciliated protist parasites have been implicated. In samples collected in Maine during the 2004-2013 fisheries, the incidence of Black Gill Syndrome was much lower, and detected cases were much less severe, than in 2003.

Effort and Distribution of Effort

Since the 1970s, effort in the fishery (measured by numbers of trips in which shrimp gear is used) has increased and then decreased on several occasions. In the 1980s there was a gradual increase in the total number of trips (Table 5; refer to Table 6 for trips in the state of Maine only) to a peak of 12,497 during the 1987 season. Increases in season length, shrimp abundance, and record ex-vessel prices, coupled with reduced abundance of groundfish, all contributed to this increase. Effort subsequently fell to 5,990 trips in the 1994 season. Effort nearly doubled between 1994 and 1996 and then declined again from the 1996 level of 11,791 to 1,304 trips in 2002, a year with only a 25-day open season. The number of trips increased during 2003–2005 as the seasons were lengthened, to 3,866 trips in 2005. Trips in 2006 dropped to 2,478, likely due to poor market conditions, increased in 2007 to 4,163, and increased in 2008 to 5,587, the most trips since 1999.

In 2009, the length of the season was increased to 180 days while the effort decreased to 3,002 trips, likely caused by limited demand from the processors and poor market conditions. In what turned out to be a 156-day season in 2010, effort increased dramatically to 5,979 trips. The market conditions were improved from prior years due to Canada’s limited supply and an increase in local markets. In 2011, the truncated 90-day season yielded a higher effort than 2010 with 7,095 trips. The high level of effort was again due in part to a limited supply in Canada and demand from local markets. In 2012, the number of trips decreased to 3,666 due to the shortened season. The effort further decreased in 2013 to 1,549 trips, likely due to a low quota and poor fishing conditions (Table 5).

The number of vessels participating in the fishery in recent years (prior to the 2014 moratorium) has varied from a high of 347 in 1996 to a low of 144 in 2006. In 2013, there were 208 vessels; 182 from Maine, 13 from Massachusetts, and 14 from New Hampshire, including one that landed in both Maine and New Hampshire, according to harvester logbook data. Of the 182 vessels from Maine, 72 were trapping (Table 7).

Prior to 1994, effort (numbers of trips by state and month) was estimated from landings data collected from dealers, and landings per trip information (LPUE) from dockside interviews of vessel captains: $Effort = \frac{Landings}{LPUE}$

Beginning in the spring of 1994, a vessel trip reporting system (VTR) supplemented the collection of effort information from interviews. From 1995 to 2000, landings per trip (LPUE) from these logbooks were expanded to total landings from the dealer weigh-outs to estimate the total trips: $Total.Trips = VTR.Trips \frac{Total.Landings}{VTR.Landings}$

Since 2000, VTR landings have exceeded dealer weigh-out landings, and the above expansion is not necessary. The 1996 assessment report (Schick et al. 1996) provides a comparison of 1995 shrimp catch and effort data from both the NEFSC interview and logbook systems and addresses the differences between the systems at that time. It showed a slightly larger estimate from the logbook system than from the interview system. Thus effort statistics reported through 1994 are not directly comparable to those collected after 1994. However, patterns in effort can be examined if the difference between the systems is taken into account. An additional complication of the logbook system is that one portion of the shrimp fishery may not be adequately represented by the logbook system during 1994–1999. Smaller vessels fishing exclusively in Maine coastal waters are not required to have federal groundfish permits and were not required to submit shrimp vessel trip reports until 2000. In the 1994–2000 assessments, effort from unpermitted vessels was characterized by catch per unit effort of permitted vessels.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983–1994), logbook data (1995–2012), and Maine port interview data (1991–2013) and are measures of resource abundance and availability (Table 8 and Figure 4). They are typically measured in catch per hour (from Maine interview data) or catch per trip. A trip is a less precise measure of effort, because trips from interviews and logbooks include both trawl and trap trips, and single day trips and multiple day trips (in the spring), and the proportion of such trips can vary from season to season. Also, in some years, buyers imposed trip limits on their boats, and in 2012 and 2013, Maine DMR imposed day-length limits.

Pounds landed per trip (pounds/trip), from VTRs, averaged 1,410 pounds during 1995–2000. In 2001, the catch per trip dropped to 710 pounds, the lowest since 1994, and remained low, at 765 pounds, in 2002. During 2003–2005 it averaged 1,407 pounds/trip. The increasing trend continued in 2006 with 2,066 pounds per trip. In 2007, the highest pounds per trip of the time series was observed with 2,584 pounds. During 2008–2011, pounds per trip averaged 2,012, with a value of 2,264 in 2010, which is the second highest in the time series. There was a large decrease in 2012 to 1,497 pounds/trip. In 2013, the average pounds landed per trip was 492, with 619 pounds per trawl trip, both the lowest of their time series (Table 8 and Figure 4).

CPUE indices (pounds landed per hour trawling) have also been developed for both inshore (depth less than 55 fathoms) and offshore (depth more than 55 fathoms) areas using information collected by Maine's port sampling program, and agree well with the catch per trip data from logbooks (Table 8 and Figure 4). Maine’s inshore trawl CPUE for 2013 was 118 pounds/hour, offshore was 78 pounds/hour, and the season average was 110 pounds/hour, less than half the time series average of 250 pounds/hour (Table 8).

Refer to Figure 5 for comparison of 2015 RSA program trawl and trap locations relative to 2013 fishing effort from VTR data.

RESOURCE CONDITIONS

Trends in abundance of Gulf of Maine Northern Shrimp were monitored during 1963–1983 from data collected in Northeast Fisheries Science Center (NEFSC) autumn bottom trawl surveys and in summer surveys by the State of Maine (discontinued in 1983). The NEFSC fall survey has continued, however the survey vessel and gear were modernized in 2009, and this is considered the beginning of a new time series for shrimp. A state-federal (ASMFC) survey was initiated by the NSTC in 1984 to specifically assess the shrimp resource in the western Gulf of Maine. This survey is conducted each summer aboard the *R/V Gloria Michelle* employing a stratified random sampling design and shrimp trawl gear designed for Gulf of Maine conditions. An inshore trawl survey has been conducted by Maine and New Hampshire each spring and fall, beginning in the fall of 2000 (Sherman et al. 2005). The NSTC has placed primary dependence on the ASMFC summer shrimp survey for fishery-independent data used in stock assessments, although the other survey data are also considered (see survey areas in Figure 6).

Abundance and biomass indices (stratified geometric mean catch per tow in numbers and weight) for Northern Shrimp from the ASMFC summer survey from 1984–2015 are given in Table 9, Figures 7–10, and length-frequencies by year are provided in Figure 11 and 12. Indices were calculated using data from all random tows in strata (areas) 1, 3, 5, 6, 7, and 8 only (Figure 9). The series averaged 15.8 kg/tow from 1984 through 1990, then gradually declined to 4.3 kg/tow in 2001. Between 2003 and 2006 the index increased markedly, reaching a new time series high in 2006 (66.0 kg/tow). Although 2006 was a high abundance year, as corroborated by the fall survey index, the 2006 summer survey index should be viewed with caution because it was based on 29 survey tows compared with about 40 tows in most years (Table 9). The summer survey index was 16.8 kg/tow in 2008, and has dropped steadily since then. The most recent values are well below the time series average of 12.2 kg/tow (Table 9). The 2013, 2014, and 2015 biomass indices were the lowest in the series, with a mean weight per tow of 1.0, 1.7, and 1.3 kg/tow respectively. The total mean number of shrimp per tow demonstrated the same general trend as biomass over the time series (Table 9 and Figure 9).

The stratified mean catch per tow in numbers of assumed 1.5-year-old shrimp (Table 9 and graphically represented as the first (left-most) size mode in Figure 11 and 12) represents a recruitment index. Although these shrimp are not fully recruited to the survey gear, this index appears sufficient as a preliminary estimate of year class strength. This survey index indicated strong (more than 700 per tow) assumed 1987, 1992, 2001, and 2004 year classes. The assumed 1983, 2000, 2002, and 2006 age classes were weak (fewer than 100 per tow), well below the time series mean of 347 individuals per tow. From 2008 to 2010, the age 1.5 index varied around 500 individuals per tow, indicating moderate but above average assumed 2007, 2008, and 2009 year classes. The index dropped markedly to 44 individuals per tow in 2011 and has only exceeded 100 per tow in one year (2014) since then. Time series lows (fewer than 10 per tow) were observed in 2012, 2013, and 2015, indicating recruitment failure of the assumed 2011, 2012, and 2014 year classes. Surveys in 2011 and 2014 exhibited the eighth and tenth lowest recruitment indices in the time series (assumed 2010 and 2013 year classes), completing an unprecedented five consecutive years (2010–2014 year classes) of poor recruitment. The 1.5-year index for the 2015 survey (the assumed 2014 year class) was 0.8 individuals per tow, the lowest recruitment index in the 32-year time series.

Although the 2014 mean numbers per tow at size displayed in Figure 11 are too low to be clearly visible in the figure, further analyses of the distribution plotted with an expanded vertical axis in Figure 12 shows that the mean carapace lengths of the assumed age 1.5 shrimp were unusually large, suggesting a high growth rate for the 2013 year class. There was also a high proportion of small (<22 mm carapace length (CL)) female I shrimp, possibly early-maturing primary females from the 2013 year class. In 2015, the overall mean size of females was relatively small at 24.7 mm CL. This is the seventh smallest value in the time series, which suggests that female shrimp caught in a 2016 fishery would be relatively small, possibly due to continued fast growing and early maturing females in the assumed 2013 year class, and the paucity of larger shrimp from the 2012 and 2011 year classes.

Individuals >22 mm CL in the summer would be fully recruited to a fishery the following winter (primarily age 3 and older) and thus survey catches of shrimp in this size category provide indices of harvestable numbers and biomass for the coming season (Table 9 and Figure 10). The harvestable biomass index exhibited peaks in 1985, 1990, and 1995, reflecting the strong assumed 1982, 1987, and 1992 year classes respectively. The index then trended down through 2001. The 2001 index of 1.5 kg/tow represented a time series low, and is indicative of small assumed 1997 and 1998 year classes. From 2003 to 2006, the fully recruited index increased dramatically, reaching a time series high in 2006 (29.9). The index has declined steadily since 2006 despite above average recruitment of the 2007, 2008, and 2009 year classes discussed above, and reached a new times series low in 2014 (0.2 kg/tow), consistent with the low recruitment of the 2010, 2011 and 2012 year classes described above. The 2015 value of 0.4 kg/tow, the third lowest in the time series, reflects the failed recruitment of the 2011 and 2012 year classes, and the low recruitment of the 2013 year class.

An index of spawning stock biomass was estimated by applying a length-weight relationship for males and non-ovigerous females (Haynes and Wigley 1969) to the abundance of females at each length, and summing over lengths. The spawning biomass index averaged about 4.9 kg/tow during 1984–1993, then declined to an average of 2.7 during 1994–2003, then rose to a time series high of 28.4 in 2006, and has since declined to time-series lows (less than 1.0 kg/tow) in 2012–2015 (Table 9 and Figure 21).

A population egg production index (EPI) was estimated from summer shrimp survey data as the sum of the number of females at length times their fecundity at length:

$$EPI_t = \sum^{L} N_{tL} Fec_L$$

where t = year, L = carapace length (mm), N = abundance of females, Fec_L = fecundity at length. The length-fecundity relationship was derived from data in Haynes and Wigley (1969) (Richards et al. 2012):

$$Fec_L = -0.198L^2 + 128.81L - 17821 \qquad (r^2 = 0.76)$$

EPI for Gulf of Maine Northern Shrimp is presented in Table 9 and Figure 16. The index varied from about 0.3 million to 1.5 million until 2006 when it rose to a high of 5.6 million followed by a steep decline to time series lows in 2012–2015.

An index of survival to age 1.5 was estimated for each year class as the number of recruits resulting from the eggs that were produced for each year class, using summer shrimp survey data:

$$S_t = \exp(\ln(R_t) - \ln(EPI_{t-2}))$$

where S = survival index, R = abundance index of recruits (age 1.5), t = year, and EPI is expressed in millions. The survival index was highest (greater than 1,000) for the 1999, 2001, and 2004 year classes, and lowest (less than 20) for the 2006, 2011, 2012, and 2014 year classes (Table 9 and Figure 23).

The NEFSC fall survey, conducted by the NOAA Ship *Albatross IV*, provided an index of Northern Shrimp abundance from 1968 to 2008 (Table 10 and Figure 8). The index was near time series highs (above 3.0 kg/tow) at the beginning of the time series in the late 1960's and early 1970s. In the late 1970s the index declined precipitously to a time-series low (0.2 kg/tow) as the stock collapsed; this was followed by a substantial increase in the mid to late 1980's, reflecting recruitment and growth of the strong presumed 1982 and 1987 year classes. The index continued to vary with the influences of strong and weak year classes through the 1990s and 2000s, and the survey ended in 2008 with values well above the time series mean (>1.8 kg/tow) during its last four years, including the time series high of 6.6 kg/tow in 2006. This high value corresponded with the time series high seen in the ASMFC summer survey the same year (Table 9). In 2009, the NEFSC fall survey changed vessels and protocols, thus indices since 2009 are not directly comparable to earlier years. The biomass index from the new NEFSC fall survey declined rapidly, from 7.8 kg/tow in 2009 to 1.2 kg/tow in 2013 and 1.9 kg/tow in 2014, parallel to trends in the summer shrimp survey and the ME-NH survey (Figure 14). NEFSC fall survey values for 2015 are not yet available.

The Maine-New Hampshire inshore trawl survey takes place biannually, during spring and fall, in five regions and three depth strata (1 = 5–20 fa (9–37 m), 2 = 21–35 fa (38–64 m), 3 = 36–55 fa (65–101 m)). A deeper stratum (4 = > 55 fa (> 101 m) out to about 12 miles) was added in

2003 (Figure 6 and Figure 7). The survey consistently catches shrimp in regions 1–4 (NH to Mt. Desert Is.) and depths 3–4 (> 35 fa (>38 m)), and more are caught in the spring than the fall (Table 10). The stratified geometric mean weights per tow for *P. borealis* for the spring and fall surveys using regions 1–4 and depths 3–4 only are presented in Table 11 and Figure 14 and 15. The Maine-New Hampshire index rose steadily from 4.2 kg/tow during spring 2003 to a time series high of 17.9 kg/tow in spring 2011. The index then dropped abruptly, to a time series low of 1.7 kg/tow in 2013 and again in 2015 (preliminary). From 2007–2011, the ME-NH inshore trawl survey data did not match the declining trend in the summer survey data. Trends in the spring ME/NH survey may be affected by inter-annual variation in the timing of the offshore migration of post-hatch females. However, the low 2013–2015 biomass indices in the ME-NH survey are consistent with the 2013–2015 ASMFC summer survey results.

ENVIRONMENTAL CONDITIONS

Ocean temperature has an important influence on Northern Shrimp in the Gulf of Maine (Dow 1964; Apollonio et al. 1986; Richards et al. 2012) and is correlated with survival during the first year of life. Relatively cool temperatures during the larval period (winter–early spring) and early benthic juvenile stage (late summer) are beneficial to survival and thus recruitment (Richards et al. 2012; Richards et al., unpublished). Spawning stock abundance also influences recruitment, with more recruits resulting from higher spawning stock abundance (Richards et al. 2012).

Spring temperature anomalies (temperature changes measured relative to a standard time period) in offshore shrimp habitat areas were the highest on record during 2012 (surface temperature) and 2011–2012 (bottom temperature) (NEFSC trawl survey data, 1968–2015; Figure 17A–D). Spring temperature anomalies remained high in 2013, but were cooler in 2014 and 2015 (Figure 17A and 17C). Fall temperature anomalies were at record highs in 2012, and remained high during 2013–2014 (Figure 17B and 17D).

Sea surface temperature (SST) has been measured daily since 1906 at Boothbay Harbor, Maine, near the center of the inshore nursery areas for Northern Shrimp. Average winter SST (Feb–Mar) at Boothbay increased from an average of 0.8^{o} C during 1906–1948 to 3.2^{o} C during 2006–2015 (Figure 17E). Late summer SST (July 15–Sept. 1) did not increase as much relative to the early 20th century, but has increased steeply since the early 1990s, reaching a record high in 2000 (17.8 ^{o} C). Late summer SST remained high through 2012, but was lower during 2013–2015 (average=16.5^{o} C; Figure 17F).

Overall, temperature conditions for Northern Shrimp have been poor since around 2000. However, temperatures during periods thought to be critical for early life survival were cooler during 2014 and 2015. This should have been favorable but the survival index for the 2014 year class was low (Figure 23). Survival estimates for the 2015 year class are not yet available.

Ocean temperatures also affect timing of the shrimp larval hatch (Richards 2012). The start of the hatch period has become earlier as temperatures have increased, with the hatch in recent years beginning more than a month earlier than it did before 2000 (10% line in Figure 18). Since the mid-2000’s, the midpoint of the hatch period has been relatively stable compared to the start of the hatch (50% line in Figure 18). With cooler temperatures in 2014 and 2015, the trend in earlier hatch timing was reversed, and the hatch began later and reached its midpoint later than in other recent years (Figure 18).

STOCK STATUS

An index-based approach was used to assess stock status of Gulf of Maine Northern shrimp. The Traffic Light Approach, developed by Caddy (1999*a*, 1999*b*, 2004) and extended by McDonough and Rickabaugh (Appendix 2) was applied to the northern shrimp stock to characterize indices of abundance, fishery performance, and environmental trends from 1984 to present. The Strict Traffic Light and Fuzzy Traffic Light approaches categorize annual values of each index as one of three colors (red, yellow, or green) to illustrate the state of the population and fishery. Red designates unfavorable conditions or status, yellow designates intermediate values, and green designates favorable conditions or status.

The NSTC applied the Strict Traffic Light Approach (STLA) to a suite of indices (Figure 19). Fishery independent indices included survey total abundance and biomass estimated from the ASMFC summer shrimp and NEFSC fall surveys, and spawning stock biomass, recruitment, and early life survival estimated from the ASMFC summer shrimp survey. The survival index represents the number of eggs that survived to become recruits at age 1.5 ($\log_e$ ratio $R/E_{lag\ 2}$, scaled by 1,000,000). Environmental indices included an index of predation pressure on Gulf of Maine northern shrimp that was developed for the benchmark assessment (NEFSC 2014), and several sources of temperature data for the northern shrimp resource area. Fishery performance indices included commercial CPUE, price per pound, and annual landings value. Price per pound and annual landings values were standardized to 2015 US dollars (www.bls.gov).

Qualitative stock status reference levels were developed for the STLA based on the time series of observations, where annual values were defined relative to the 'stable period' (1985–1994) mean (SPM), which was the time period used to define previous reference points (Amendment 2 to the FMP). A 'limit' was considered to delineate an extremely adverse state and was based on the 20th percentile of the time series (1984–2015). For fishery dependent and fishery independent indices, red denotes values at or below the 20th percentile, while green denotes values at or above the SPM. For environmental indices, red denotes values at or above the 80th percentile and green denotes values at or below the SPM.

Fishery independent indices of total biomass (Figure 20) and spawning biomass (Figure 21) have remained at exceptionally low levels for the past four years (2012–2015). Recruitment has also been poor in recent years, and reached a time series low in 2015 (Figure 22). The early life survival index for the 2014 year class (observed in the 2015 survey) was poor (Figure 23) despite cooler spring temperatures observed in inshore nursery areas in 2013 and 2014. Environmental conditions show that predation pressure has lessened in the three most recent years (2012–2014), but has generally been high since the late 1990s (Figure 25). Temperatures were exceedingly warm from 2010 to 2013 but cooler in the springs of 2014 and 2015. In terms of fishery performance, CPUE was very low in 2013, however, price was the highest since 1989 (inflation-adjusted dollars) (Table 2). There were no fishery dependent indices for 2014 and 2015 due to a fishery moratorium.

The NSTC further examined a subset of key indicators using the Fuzzy Traffic Light Approach (FTLA). The FTLA gives a finer view of the classification of each indicator in each year. For each indicator, a line graph shows trends in the time series and the relation to the 'target' (stable period mean; SPM, 'limit' (20th percentile) and 10th percentile levels. A stacked bar graph reflects the proximity of each annual value to the SPM. The greater the proportion of green or red in each stacked bar, the further that year's index is in a favorable or unfavorable direction, respectively, relative to the SPM. A bar that is 100% yellow indicates a value close to the SPM. These reference levels are not management triggers, as they are not defined in the ASMFC Northern Shrimp FMP or its Amendments. The levels are used to illustrate the current condition of the stock relative to earlier time periods.

We evaluated nine indicators using the FTLA, including: 1) total biomass from the ASMFC Summer Shrimp survey, 2) recruit abundance from the ASMFC Summer Shrimp survey, 3) spawning biomass from the ASMFC Summer Shrimp survey, 4) commercial fishery CPUE (metric tons landed per trip), 5) early life survival, 6) predation pressure index (PPI), 7) spring sea surface temperature at Boothbay Harbor, ME, 8) spring bottom temperature anomaly from NEFSC shrimp habitat survey stations, and 9) summer bottom temperature from the ASMFC Summer Shrimp survey.

Of the three biomass/abundance indicators examined, all were below the 10th percentile of the time series for at least three of the last four years. Total biomass was below the 10th percentile from 2012–2015, with the lowest biomass on record in 2013 and second lowest in 2015 (Table 9, Table 12, and Figure 21). Spawning biomass was below the 10th percentile from 2012–2015, with the lowest spawning biomass on record in 2013 and second lowest in 2014 (Table 9, Table 12, and Figure 22). Total biomass and spawning biomass are currently at less than one tenth of what was observed during the stable period.

Recruitment was below the 10th percentile in 2012, 2013, and 2015, with the lowest recruitment on record observed in 2015 and second lowest in 2013 (Table 9, Table 12, and Figure 22). In 2013 and 2015, abundance of recruits was less than one shrimp per tow, as compared to a SPM of 382 shrimp per tow. Early life survival (to age 1.5) was at or below the 10th percentile for the 2012 and 2014 year classes, with the 2012 year class the lowest on record and 2011 the second lowest (Table 9, Table 12, and Figure 23). Early life survival of the 2013 year class was above the stable period mean, however recruitment of that year class was weak. The 2011–2013 year classes would be the target of a 2016 fishery.

Fishery performance, as characterized by catch rate (mt per trip) declined from 2007 to 2013 (Figure 24). No commercial catch occurred in 2014 or 2015 due to a harvest moratorium. In 2013, the catch rate was below the 10th percentile and a record low for the time series.

Trends in the four environmental indicators suggest that conditions have not been favorable for northern shrimp in recent years (Table 13). Predation pressure has generally increased since the late 1990s, with two values above the 90th percentile since 2010 (Figure 25)). Sea surface and bottom temperatures were colder in 2015 than in recent years, however an overall rise in temperature since the stable period is evident (Figure 26, Figure 27, and Figure 28), with spring and summer bottom temperatures in offshore shrimp habitat at or exceeding the 90th percentile from 2011–2013 (Table 13, Figure 27, and Figure 28).

Taken together, the FTLA indicators demonstrate that the Gulf of Maine Northern shrimp stock status continues to be critically poor. Indicators in recent years have been particularly unfavorable when compared to those of the stable period. Total biomass and spawning biomass have remained at unprecedented lows for four consecutive years. Recruitment of the 2014 year class was the weakest observed in the 32-year ASMFC summer shrimp survey index. The higher survival of the 2013 year class may have reflected reduced fishing effort on the spawning stock and cooler spring temperatures in 2013; however, similar conditions in 2014 did not produce the same trend for the 2014 year class. Despite the harvest moratorium and a slight improvement in environmental conditions, this stock has yet to show signs of improvement.

By accepted definitions of stock collapse (10% of unfished biomass, Worm et al. 2009; 20% of BMSY, Pinsky et al., 2011), using the summer survey biomass index as a proxy for biomass, and the 1984–1993 "stable period" survey mean as a highly conservative proxy for unfished biomass, the Gulf of Maine Northern Shrimp stock has collapsed (2015 survey index less than 10% of stable period mean).

RECOMMENDATIONS

The NSTC bases its recommendations to the Section on its assessment of current stock status, the biology of the species, and the stated management goal of protecting and maintaining the stock at levels that will support a viable fishery on a sustainable resource (Amendment 2 to the FMP, ASMFC 2011).

Short-term commercial prospects for the 2016 fishing season are very poor given the low index of exploitable biomass in 2015 and the relatively small size of females. Longer-term prospects are also poor due to the unprecedented low abundance of age 1.5 shrimp seen in the 2013–2015 summer surveys, which would be the main contributors to 2017–2019 fisheries. The recruitment index increased marginally in 2014, however the 2015 index dropped to a record low for the time series.

Low or failed recruitment of the five most recent year classes is unprecedented. Given the severe declines in abundance across survey indices, as well as other indicators, the NSTC considers the Gulf of Maine northern shrimp stock to have collapsed with little prospect of recovery in the near future.

Long term trends in environmental conditions are not favorable for Northern Shrimp. This suggests a need to conserve spawning stock biomass to help compensate for what may continue to be an unfavorable environment.

Given the depleted condition of the resource and poor prospects for the near future, the NSTC recommends that the Section extend the moratorium on fishing through 2016.

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Table 1: U.S. commercial landings (mt) of Northern Shrimp in the Gulf of Maine, by year (1958–1984, left) or by season (1985–2015, right). Landings by season include the previous December.

Year	Maine	Mass.	New Hamp.	Total
1958	2.2	0.0	0.0	2.2
1959	5.5	2.3	0.0	7.8
1960	40.4	0.5	0.0	40.9
1961	30.5	0.3	0.0	30.8
1962	159.5	16.2	0.0	175.7
1963	244.3	10.4	0.0	254.7
1964	419.4	3.1	0.0	422.5
1965	941.3	8.0	0.0	949.3
1966	1,737.8	10.5	18.1	1,766.4
1967	3,141.2	10.0	20.0	3,171.2
1968	6,515.2	51.9	43.1	6,610.2
1969	10,993.1	1,773.1	58.1	12,824.3
1970	7,712.8	2,902.3	54.4	10,669.5
1971	8,354.8	2,724.0	50.8	11,129.6
1972	7,515.6	3,504.6	74.8	11,095.0
1973	5,476.6	3,868.2	59.9	9,404.7
1974	4,430.7	3,477.3	36.7	7,944.7
1975	3,177.2	2,080.0	29.4	5,286.6
1976	617.3	397.8	7.3	1,022.4
1977	142.1	236.9	2.2	381.2
1978	0.0	3.3	0.0	3.3
1979	32.8	405.9	0.0	438.7
1980	69.6	256.9	6.3	332.8
1981	530.0	539.4	4.5	1,073.9
1982	883.0	658.5	32.8	1,574.3
1983	1,029.2	508.2	36.5	1,573.9
1984	2,564.7	565.4	96.8	3,226.9

Season	Maine	Mass.	New Hamp.	Total
1985	2,946.4	968.8	216.7	4,131.9
1986	3,268.2	1,136.3	230.5	4,635.0
1987	3,680.2	1,427.9	157.9	5,266.0
1988	2,258.4	619.6	157.6	3,035.6
1989	2,384.0	699.9	231.5	3,315.4
1990	3,236.3	974.9	451.3	4,662.5
1991	2,488.6	814.6	282.1	3,585.3
1992	3,070.6	289.3	100.1	3,460.0
1993	1,492.5	292.8	357.6	2,142.9
1994	2,239.7	247.5	428.0	2,915.2
1995	5,013.7	670.1	772.8	6,456.6
1996	8,107.1	660.6	771.7	9,539.4
1997	6,086.9	366.4	666.2	7,119.5
1998	3,481.3	240.3	445.2	4,166.8
1999	1,573.2	75.7	217.0	1,865.9
2000	2,516.2	124.1	214.7	2,855.0
2001	1,075.2	49.4	206.4	1,331.0
2002	391.6	8.1	53.0	452.7
2003	1,203.7	27.7	113.0	1,344.4
2004	1,926.9	21.3	183.2	2,131.4
2005	2,270.2	49.6	290.3	2,610.1
2006	2,201.6	30.0	91.1	2,322.7
2007	4,469.3	27.5	382.9	4,879.7
2008	4,515.8	29.9	416.8	4,962.4
2009	2,315.7	MA & NH	185.6	2,501.3
2010	5,604.3	35.1	501.4	6,140.8
2011	5,569.7	196.4	631.5	6,397.5
2012	2,219.9	77.8	187.8	2,485.4
2013	289.7	18.9	36.9	345.5
2014	0.0	0.0	0.0	0.0
*2015	6.1	0.6	0.0	6.7

*Landings in 2015 from the RSA Program

Table 2: Price per pound and value of U.S. commercial landings of Northern Shrimp in the Gulf of Maine, with inflation adjusted* prices and value for 1985–2015. No shrimp were sold or purchased from cooperative winter sampling in 2014. Price/value in 2015 are from the RSA program and are preliminary.

Year	Price $/Lb	Value $
1958	0.32	1,532
1959	0.29	5,002
1960	0.23	20,714
1961	0.20	13,754
1962	0.15	57,382
1963	0.12	66,840
1964	0.12	112,528
1965	0.12	245,469
1966	0.14	549,466
1967	0.12	871,924
1968	0.11	1,611,425
1969	0.12	3,478,910
1970	0.20	4,697,418
1971	0.19	4,653,202
1972	0.19	4,586,484
1973	0.27	5,657,347
1974	0.32	5,577,465
1975	0.26	3,062,721
1976	0.34	764,094
1977	0.55	458,198
1978	0.24	1,758
1979	0.33	320,361
1980	0.65	478,883
1981	0.64	1,516,521
1982	0.60	2,079,109
1983	0.67	2,312,073
1984	0.49	3,474,351

Season	Price $/Lb	Value $	Price ($/Lb) 2015 dollars	Value ($) 2015 dollars
1985	0.44	3,984,562	0.97	8,836,002
1986	0.63	6,451,206	1.37	13,999,243
1987	1.10	12,740,581	2.30	26,701,948
1988	1.10	7,391,777	2.22	14,857,022
1989	0.98	7,177,659	1.88	13,741,307
1990	0.72	7,351,420	1.30	13,362,769
1991	0.91	7,208,838	1.59	12,567,731
1992	0.99	7,547,941	1.68	12,815,030
1993	1.07	5,038,053	1.76	8,314,743
1994	0.75	4,829,106	1.21	7,776,568
1995	0.90	12,828,030	1.41	20,070,457
1996	0.73	15,341,504	1.11	23,344,163
1997	0.79	12,355,871	1.17	18,364,099
1998	0.96	8,811,938	1.40	12,860,710
1999	0.91	3,762,043	1.31	5,388,823
2000	0.79	4,968,655	1.09	6,860,685
2001	0.86	2,534,095	1.16	3,403,848
2002	1.08	1,077,534	1.43	1,427,077
2003	0.87	2,590,916	1.13	3,349,216
2004	0.44	2,089,636	0.56	2,631,381
2005	0.57	3,261,648	0.69	3,970,504
2006	0.37	1,885,978	0.43	2,201,863
2007	0.38	4,087,120	0.44	4,733,474
2008	0.49	5,407,373	0.55	6,017,089
2009	0.40	2,216,411	0.45	2,481,435
2010	0.52	6,994,106	0.56	7,581,322
2011	0.75	10,625,533	0.80	11,283,318
2012	0.95	5,230,481	0.99	5,424,640
2013	1.81	1,375,788	1.84	1,401,543
2014		0		0
2015	3.49	39,409	3.49	39,409

* Inflation adjustment from US Dept. of Labor, Bureau of Labor Statistics, at http://www.bls.gov/data/inflation_calculator.htm accessed Oct. 19, 2015.

Table 3: Distribution of landings (metric tons) in the Gulf of Maine Northern Shrimp fishery by season, state and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1985 Season, 166 days, Dec 1 - May 15								
Maine	335.7	851.8	1,095.5	525.1	116.8	21.5	0.0	2,946.4
Mass.	91.7	283.9	238.3	239.3	57.8	57.0	0.8	968.8
N.H.	67.0	86.2	50.4	11.6	1.3		0.2	216.7
Total	494.4	1,221.9	1,384.2	776.0	175.9	78.5	1.0	4,131.9
1986 Season, 196 days, Dec 1 - May 31, June 8-21								
Maine	346.9	747.8	1,405.3	415.4	104.2	149.2	99.4	3,268.2
Mass.	154.3	213.4	221.2	200.7	111.2	84.8	150.7	1,136.3
N.H.	57.7	75.9	70.8	14.2	1.3	0.0	10.6	230.5
Total	558.9	1,037.1	1,697.3	630.3	216.7	234.0	260.7	4,635.0
1987 Season, 182 days, Dec 1 - May 31								
Maine	485.9	906.2	1,192.7	672.9	287.6	127.9	7.0	3,680.2
Mass.	103.5	260.0	384.9	310.2	180.8	182.8	5.7	1,427.9
N.H.	18.4	53.6	62.8	15.7	7.3	0.0	0.1	157.9
Total	607.8	1,219.8	1,640.4	998.8	475.7	310.7	12.8	5,266.0
1988 Season, 183 days, Dec 1 - May 31								
Maine	339.7	793.9	788.1	243.6	24.6	67.3	1.2	2,258.4
Mass.	14.4	225.8	255.0	104.9	8.6	10.9	0.0	619.6
N.H.	13.0	72.6	53.7	14.9	0.3	0.0	3.1	157.6
Total	367.1	1,092.3	1,096.8	363.4	33.5	78.2	4.3	3,035.6
1989 Season, 182 days, Dec 1 - May 31								
Maine	353.6	770.5	700.6	246.4	218.7	94.2		2,384.0
Mass.	26.2	197.5	154.9	104.8	160.9	55.6		699.9
N.H.	28.5	106.9	77.0	15.4	3.7	0.0		231.5
Total	408.3	1,074.9	932.5	366.6	383.3	149.8	0.0	3,315.4
1990 Season, 182 days, Dec 1 - May 31								
Maine	512.4	778.4	509.8	638.7	514.1	282.8	0.1	3,236.3
Mass.	75.6	344.5	184.8	100.2	159.0	110.0	0.8	974.9
N.H.	111.3	191.7	116.2	30.7	1.4			451.3
Total	699.3	1,314.6	810.8	769.6	674.5	392.8	0.9	4,662.5
1991 Season, 182 days, Dec 1 - May 31								
Maine	238.3	509.2	884.1	455.0	251.8	148.2	2.0	2,488.6
Mass.	90.6	174.7	176.0	131.2	93.3	133.8	15.0	814.6
N.H.	107.3	104.4	33.8	27.8	7.8	1.0		282.1
Total	436.2	788.3	1,093.9	614.0	352.9	283.0	17.0	3,585.3
1992 Season, 153 days, Dec 15 - May 15								
Maine	181.2	881.0	1,295.0	462.6	163.6	87.2		3,070.6
Mass.	17.1	148.3	73.3	47.6	2.9		0.1	289.3
N.H.	33.4	47.0	11.9	6.8	1.0			100.1
Total	231.7	1,076.3	1,380.2	517.0	167.5	87.2	0.1	3,460.0

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1993 Season, 138 days, Dec 14 - April 30								
Maine	101.0	369.1	597.1	297.5	127.8			1,492.5
Mass.	19.6	82.0	81.9	62.3	42.0	5.0		292.8
N.H.	33.5	85.4	101.8	77.0	59.9			357.6
Total	154.1	536.5	780.8	436.8	229.7	5.0	0.0	2,142.9
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	171.5	647.8	972.1	399.6	48.7			2,239.7
Mass.	27.1	68.0	100.8	38.8	12.8			247.5
N.H.	117.2	124.3	128.7	49.6	8.2			428.0
Total	315.8	840.1	1,201.6	488.0	69.7	0.0	0.0	2,915.2
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	747.3	1,392.9	1,336.0	912.1	625.4			5,013.7
Mass.	160.6	154.0	104.1	111.0	139.5		0.9	670.1
N.H.	210.2	186.8	118.3	158.5	99.0			772.8
Total	1,118.1	1,733.7	1,558.4	1,181.6	863.9	0.0	0.9	6,456.6
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,122.0	1,693.1	3,236.9	795.6	361.5	897.6	0.4	8,107.1
Mass.	167.9	106.7	190.7	67.2	66.5	60.3	1.3	660.6
N.H.	189.8	169.5	234.0	81.9	78.8	17.1	0.6	771.7
Total	1,479.7	1,969.3	3,661.6	944.7	506.8	975.0	2.3	9,539.4
1997 Season, 156 days, Dec 1- May 27, two 5-day and four 4-day blocks off								
Maine	1,178.0	1,095.8	1,749.3	758.4	766.8	538.2	0.4	6,086.9
Mass.	90.2	110.4	111.4	49.0	1.2	0.5	3.7	366.4
N.H.	185.6	104.1	140.1	108.4	85.8	42.2	0.0	666.2
Total	1,453.8	1,310.3	2,000.8	915.8	853.8	580.9	4.1	7,119.5
1998 Season, 105 days, Dec 8-May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 c								
Maine	511.1	926.8	1,211.1	401.0	228.7	202.6		3,481.3
Mass.	49.1	73.3	88.6	14.0	15.3			240.3
N.H.	89.4	106.9	143.5	54.3	49.0	2.1		445.2
Total	649.6	1,107.0	1,443.2	469.3	293.0	204.7	0.0	4,166.8
1999 Season, 90 days, Dec 15 - May 25, weekends, Dec 24 - Jan 3, Jan 27-31, Feb 24-28, Mar 16-31, and Apr 29 - May 2								
Maine	79.9	192.7	599.3	247.9	205.3	248.1		1,573.2
Mass.	25.0	23.8	16.0	2.5	8.4			75.7
N.H.	46.5	63.2	52.2	10.0	36.5	8.6		217.0
Total	151.4	279.7	667.5	260.4	250.2	256.7	0.0	1,865.9
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		759.9	1,534.4	221.9				2,516.2
Mass.		25.9	86.0	12.2				124.1
N.H.		40.6	133.7	40.4				214.7
Total	0.0	826.4	1,754.0	274.6	0.0	0.0	0.0	2,855.0

Table 3 continued – Landings by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May								
Maine		575.8	432.8	36.6	29.8	0.3		1,075.2
Mass.		38.5	9.0	1.9		0.002		49.4
N.H.		127.9	78.6	conf	conf			206.4
Total	0.0	742.2	520.3	38.4	29.8	0.3	0.0	1,331.0
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			306.8	84.8				391.6
Mass.			8.1	conf				8.1
N.H.			38.6	14.4				53.0
Total	0.0	0.0	353.5	99.1	0.0	0.0	0.0	452.7
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		534.7	668.0	0.4			0.6	1,203.7
Mass.		12.0	15.7					27.7
N.H.		30.9	82.1					113.0
Total	0.0	577.6	765.8	0.4	0.0	0.0	0.6	1,344.4
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	1.8	526.2	945.1	446.4	4.7	2.7	0.04	1,926.9
Mass.		conf	21.3	conf				21.3
N.H.		27.3	94.8	61.1				183.2
Total	1.8	553.5	1,061.1	507.5	4.7	2.7	0.04	2,131.4
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	75.0	369.4	903.2	922.6			0.01	2,270.2
Mass.	7.2	8.1	24.9	9.4				49.6
N.H.	17.3	53.5	175.4	44.1				290.3
Total	99.5	431.0	1,103.6	976.0	0.0	0.0	0.01	2,610.1
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	144.1	691.7	896.9	350.8	118.0			2,201.6
Mass.	conf	conf	30.0	conf	conf			30.0
N.H.	3.4	27.9	9.6	50.3	conf			91.1
Total	147.5	719.6	936.5	401.1	118.0	0.0	0.0	2,322.7
2007 Season, 151 days, Dec 1 - Apr 30								
Maine	761.9	1,480.5	1,590.4	481.9	154.2	0.4	0.03	4,469.3
Mass.	conf	27.5	conf	conf				27.5
N.H.	52.5	222.6	81.6	26.1	conf			382.9
Total	814.4	1,730.6	1,672.0	508.1	154.2	0.4	0.0	4,879.7
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	408.5	1,053.7	2,020.4	983.8	49.3		0.1	4,515.8
Mass.	conf	conf	15.4	14.5				29.9
N.H.	94.2	123.7	161.6	37.4	conf			416.8
Total	502.6	1,177.4	2,197.3	1,035.7	49.3	0.0	0.1	4,962.4

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2009 Season, 180 days, Dec 1 - May 29								
Maine	134.6	595.9	988.2	560.1	34.9	1.8	0.2	2,315.7
Mass.& NH	conf	112.9	72.6	conf	conf			185.6
Total	134.6	708.8	1,060.8	560.1	34.9	1.8	0.2	2,501.2
2010 Season, 156 days, Dec 1 - May 5								
Maine	263.4	1,683.1	2,914.5	515.6	194.3	33.0	0.4	5,604.3
Mass.	conf	16.9	18.2	conf	conf			35.1
N.H.	107.3	152.4	200.0	14.2	27.4	conf		501.4
Total	370.7	1,852.5	3,132.7	529.8	221.7	33.0	0.4	6,140.8
2011 Season, 90 days, Dec 1 - Feb 28								
Maine	722.7	2,572.2	2,274.3	0.5				5,569.7
Mass.	20.8	100.9	74.7					196.4
N.H.	93.1	304.0	234.4					631.46
Total	836.6	2,977.0	2,583.4	0.5	0.0	0.0	0.0	6,397.5
2012 Season, Trawling Mon,Wed,Fri, Jan 2- Feb 17 (21 days); Trapping Feb 1-17 (17 days)								
Maine	0.5	1,130.6	1,088.2	0.5				2,219.9
Mass.		58.4	19.4					77.8
N.H.		119.2	68.6					187.8
Total	0.5	1,308.2	1,176.2	0.5	0.0	0.0	0.0	2,485.4
2013 Season, Trawling 3 to 7 days/wk, Jan 23 - Apr 12 (54 days); Trapping 6 or 7 days/wk, Feb 5 - Apr 12 (62 days								
Maine		64.9	179.7	42.5	2.6			289.7
Mass.		5.3	8.9	4.7				18.9
N.H.		13.8	16.3	6.9	conf			36.9
Total	0.0	84.0	204.9	54.1	2.6	0.0	0.0	345.5
2014 Season, Closed								
2015 Season, Limited research fishery for data collection only								
Maine		0.2	3.7	2.3				6.1
Mass.		0.1	0.1	0.3				0.6
N.H.		0.0	0.0	0.0				0.0
Total	0.0	0.3	3.8	2.6	0.0	0.0	0.0	6.7

conf = Confidential data were combined with an adjacent month.

Table 4: Distribution of landings (metric tons) in the Maine Northern Shrimp fishery by season, gear type, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off									
Trawl		731.1	1,354.8	163.6				2,249.47	89%
Trap		28.9	179.6	58.3				266.7	11%
Total	0.0	759.9	1,534.4	221.9	0.0	0.0	0.0	2,516.2	
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May									
Trawl		533.0	360.1	30.9	29.8	0.3		954.0	89%
Trap		42.9	72.6	5.7				121.2	11%
Total	0.0	575.8	432.8	36.6	29.8	0.3	0.0	1,075.2	
2002 Season, 25 days, Feb 15 - Mar 1									
Trawl			263.6	77.2				340.8	87%
Trap			43.2	7.6				50.8	13%
Total	0.0	0.0	306.8	84.8	0.0	0.0	0.0	391.6	
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off									
Trawl		467.2	518.8	0.4			0.6	987.0	82%
Trap		67.5	149.2					216.7	18%
Total	0.0	534.7	668.0	0.4	0.0	0.0	0.6	1,203.7	
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off									
Trawl	1.8	514.0	905.5	430.0	4.7	2.7	0.04	1858.7	96%
Trap		12.2	39.5	16.5				68.1	4%
Total	1.8	526.2	945.1	446.4	4.7	2.7	0.04	1926.9	
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off									
Trawl	75.0	369.4	770.6	663.6			0.01	1878.5	83%
Trap		conf	132.6	259.0				391.6	17%
Total	75.0	369.4	903.2	922.6	0.0	0.0	0.01	2270.2	
2006 Season, 140 days, Dec 12 - Apr 30									
Trawl	144.1	675.0	733.8	256.9	117.1			1927.0	88%
Trap	conf	16.7	163.1	93.9	0.9			274.6	12%
Total	144.1	691.7	896.9	350.8	118.0	0.0	0.0	2201.6	
2007 Season, 151 days, Dec 1 - Apr 30									
Trawl	758.2	1,443.3	1,275.6	362.1	143.6	0.4	0.0	3,983.2	89%
Trap	3.7	37.2	314.7	119.8	10.6			486.1	11%
Total	761.9	1,480.5	1,590.4	481.9	154.2	0.4	0.0	4,469.3	
2008 Season, 152 days, Dec 1 - Apr 3									
Trawl	408.5	989.6	1,680.8	603.4	42.6		0.1	3,724.9	82%
Trap	conf	64.1	339.6	380.4	6.7			790.8	18%
Total	408.5	1,053.7	2,020.4	983.8	49.3	0.0	0.1	4,515.8	
2009 Season, 180 days, Dec 1 - May 29									
Trawl	134.3	579.7	780.9	405.4	33.6	1.8	0.2	1,935.9	84%
Trap	0.4	16.2	207.3	154.7	1.3			379.8	16%
Total	134.6	595.9	988.2	560.1	34.9	1.8	0.2	2,315.7	
2010 Season, 156 days, Dec 1 - May 5									
Trawl	263.4	1,488.3	2,091.1	326.3	194.3	33.0	0.4	4,396.7	78%
Trap	conf	194.8	823.4	189.3	conf			1,207.6	22%
Total	263.4	1,683.1	2,914.5	515.6	194.3	33.0	0.4	5,604.3	
2011 Season, 90 days, Dec 1 - Feb 28									
Trawl	720.8	2,194.5	1,728.5	0.5				4,644.4	83%
Trap	1.9	377.7	545.8					925.3	17%
Total	722.7	2,572.2	2,274.3	0.5	0.0	0.0	0.0	5,569.7	
2012 Season, Trawling Mon,Wed,Fri, Jan 2- Feb 17 (21 days); Trapping Feb 1-17 (17 days)									
Trawl	0.5	1,130.6	895.2	0.5				2,026.8	91%
Trap			193.1					193.1	9%
Total	0.5	1,130.6	1,088.2	0.5	0.0	0.0	0.0	2,219.9	
2013 Season, Trawl 2-7 days/wk, Jan 23-Apr 12 (54 days); Trap 6-7 days/wk, Feb 5-Apr 12 (62 days									
Trawl		64.9	164.5	37.5	2.4			269.3	93%
Trap			15.2	4.9	0.2			20.4	7%
Total	0.0	64.9	179.7	42.5	2.6	0.0	0.0	289.7	
2014 Season, Closed									
2015 Season, Limited research fishery for data collection only									
Trawl		0.2	3.4	2.0				5.6	92%
Trap		0.0	0.3	0.2				0.5	8%
Total	0.0	0.2	3.7	2.3	0.0	0.0	0.0	6.1	

conf = Confidential data were combined with an adjacent month.

Table 5: Distribution of fishing effort (number of trips) in the Gulf of Maine Northern Shrimp fishery by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1985 Season, 166 days, Dec 1 - May 15								
Maine	552	1,438	1,979	1,198	260	35		5,462
Mass.	127	269	224	231	92	73		1,016
N.H.	118	135	78	26	22			379
Total	797	1,842	2,281	1,455	374	108	0	6,857
1986 Season, 183 days, Dec 1 - May 31								
Maine	590	1,309	2,798	831	224	133	68	5,953
Mass.	128	235	225	320	194	133	159	1,394
N.H.	156	163	165	51	3		17	555
Total	874	1,707	3,188	1,202	421	266	244	7,902
1987 Season, 182 days, Dec 1 - May 31								
Maine	993	2,373	3,073	2,241	617	340	16	9,653
Mass.	325	354	414	426	283	317	164	2,283
N.H.	67	164	175	95	28		32	561
Total	1,385	2,891	3,662	2,762	928	657	212	12,497
1988 Season, 183 days, Dec 1 - May 31								
Maine	972	2,183	2,720	1,231	193	122		7,421
Mass.	28	326	426	315	26	57		1,178
N.H.	72	231	236	99	3			641
Total	1,072	2,740	3,382	1,645	222	179	0	9,240
1989 Season, 182 days, Dec 1 - May 31								
Maine	958	2,479	2,332	936	249	84		7,038
Mass.	103	479	402	254	297	102		1,637
N.H.	120	369	312	69	16			886
Total	1,181	3,327	3,046	1,259	562	186	0	9,561
1990 Season, 182 days, Dec 1 - May 31								
Maine	1,036	1,710	1,529	1,986	897	238		7,396
Mass.	147	459	273	202	175	118		1,374
N.H.	178	363	284	157	6			988
Total	1,361	2,532	2,086	2,345	1,078	356	0	9,758
1991 Season, 182 days, Dec 1 - May 31								
Maine	568	1,286	2,070	1,050	438	139		5,551
Mass.	264	416	401	231	154	147		1,613
N.H.	279	285	135	82	22	1		804
Total	1,111	1,987	2,606	1,363	614	287	0	7,968
1992 Season, 153 days, Dec 15 - May 15								
Maine	411	1,966	2,700	1,222	318	141		6,758
Mass.	59	337	145	101	41			683
N.H.	96	153	76	29	3			357
Total	566	2,456	2,921	1,352	362	141	0	7,798

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1993 Season, 138 days, Dec 14 - April 30								
Maine	249	1,102	1,777	1,032	227			4,387
Mass.	60	200	250	185	72			767
N.H.	76	246	275	256	151			1,004
Total	385	1,548	2,302	1,473	450	0	0	6,158
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	265	1,340	1,889	1,065	122			4,681
Mass.	58	152	147	83	15			455
N.H.	169	228	266	173	18			854
Total	492	1,720	2,302	1,321	155	0	0	5,990
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	879	2,341	2,641	1,337	694			7,892
Mass.	145	385	275	157	109			1,071
N.H.	189	331	279	359	344			1,502
Total	1,213	3,057	3,195	1,853	1,147	0	0	10,465
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,341	2,030	3,190	1,461	444	457		8,923
Mass.	299	248	325	269	106	126		1,373
N.H.	331	311	389	248	155	61		1,495
Total	1,971	2,589	3,904	1,978	705	644	0	11,79[illegible]
1997 Season, 156 days, Dec 1- May 31, two 5-day and four 4-day blocks off								
Maine	1,674	1,753	2,737	1,178	793	530		8,665
Mass.	184	226	245	114	7	1		777
N.H.	277	245	301	218	189	62		1,292
Total	2,135	2,224	3,283	1,510	989	593	0	10,734
1998 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	852	1,548	1,653	725	346	189		5,313
Mass.	94	200	148	70	3	1		515
N.H.	141	216	182	134	83	22		778
Total	1,087	1,964	1,983	929	432	212	0	6,606
1999 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	190	556	1,125	553	324	172		2,920
Mass.	39	57	71	9	40			216
N.H.	82	192	213	44	123	21		675
Total	311	805	1,409	606	487	193	0	3,811
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		897	2,494	647				4,038
Mass.		33	117	32	1			183
N.H.		45	201	87				333
Total	0	975	2,812	766	1	0	0	4,554

Table 5 continued – Trips by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 15 off, experimental offshore fishery in May								
Maine		1,683	1,551	177	43	6		3,460
Mass.		111	48	10		1		170
N.H.		303	200	conf	conf			503
Total	0	2,097	1,799	187	43	7	0	4,133
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			799	299				1,098
Mass.			31	conf				31
N.H.			119	56				175
Total	0	0	949	355	0	0	0	1,304
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		1114	1,582	1			2	2,699
Mass.		41	50					91
N.H.		81	151					232
Total	0	1,236	1,783	1	0	0	2	3,022
2004 Season, 40days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	7	647	1,197	482	13	14	6	2,366
Mass.		conf	56	conf				56
N.H.		46	147	66				259
Total	7	693	1,400	548	13	14	6	2,681
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun of								
Maine	140	667	1,305	1,255	0	0	1	3,368
Mass.	15	18	49	23				105
N.H.	24	76	216	77				393
Total	179	761	1,570	1,355	0	0	1	3,866
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	148	585	947	530	101			2,311
Mass.	conf	conf	58	conf	conf			58
N.H.	5	23	19	62	conf			109
Total	153	608	1,024	592	101	0	0	2,478
2007 Season, 151 days, Dec 1 - Apr 30								
Maine	437	1,102	1,514	669	136	1	3	3,862
Mass.	conf	45	conf	conf				45
N.H.	26	115	71	44	conf			256
Total	463	1,262	1,585	713	136	1	3	4,163
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	418	1,291	2,076	1,286	102	0	9	5,182
Mass.	conf	conf	25	13				38
N.H.	63	141	125	38	conf			367
Total	481	1,432	2,226	1,337	102	0	9	5,587

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2009 Season, 180 days, Dec 1 - May 29								
Maine	134	785	1,122	739	47	5	1	2,833
Mass.& NH	conf	107	62	conf	conf			169
Total	134	892	1,184	739	47	5	1	3,002
2010 Season, 156 days, Dec 1 - May 5								
Maine	241	1,561	2,593	911	185	29	1	5,521
Mass.	conf	26	23	conf	conf			49
N.H.	54	127	151	21	56	conf		409
Total	295	1,714	2,767	932	241	29	1	5,979
2011 Season, 90 days, Dec 1 - Feb 28								
Maine	599	2,880	2,875	1				6,355
Mass.	28	92	73	0	0			193
N.H.	108	241	198					547
Total	735	3,213	3,146	1	0	0	0	7,095
2012 Season, Trawling Mon,Wed,Fri, Jan 2- Feb 17 (21 days); Trapping Feb 1-17 (17 days)								
Maine	1	1,305	2,014	1				3,321
Mass.		74	43					117
N.H.		129	99					228
Total	1	1,508	2,156	1	0	0	0	3,666
2013 Season, Trawl 2-7 days/wk, Jan 23-Apr 12 (54 days); Trap 6-7 days/wk, Feb 5-Apr 12 (62 days)								
Maine		202	889	260	22			1,373
Mass.		9	28	19	0			56
N.H.		20	73	27	conf			120
Total	0	231	990	306	22	0	0	1,549
2014 Season, Closed								
2015 Season, Limited research fishery for data collection only								
Maine		1	24	20				45
Mass.		1	2	2				5
N.H.								0
Total	0	2	26	22	0	0	0	50

conf = Confidential data were combined with an adjacent month.

Table 6: Distribution of fishing trips in the Maine Northern Shrimp fishery by season, gear type, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	%
2000									
Trawl		818	2,073	462				3,353	97%
Trap		79	421	185				685	20%
Total	0	897	2,494	647	0	0	0	4,038	
2001									
Trawl		1,500	1,214	112	43	6		2,875	83%
Trap		183	337	65				585	17%
Total	0	1,683	1,551	177	43	6	0	3,460	
2002									
Trawl			595	236				831	76%
Trap			204	63				267	24%
Total	0	0	799	299	0	0	0	1,098	
2003									
Trawl		850	1,081	1			2	1,934	72%
Trap		264	501					765	28%
Total	0	1,114	1,582	1	0	0	2	2,699	
2004									
Trawl	7	566	965	382	13	14	6	1,953	83%
Trap		81	232	100				413	17%
Total	7	647	1,197	482	13	14	6	2,366	
2005									
Trawl	140	647	953	778			1	2,519	75%
Trap		conf	372	477				849	25%
Total	140	647	1,325	1,255	0	0	1	3,368	
2006									
Trawl	145	490	563	273	88			1,559	67%
Trap	conf	98	384	257	13			752	33%
Total	145	588	947	530	101	0	0	2,311	
2007									
Trawl	425	977	921	349	119	1	3	2,795	72%
Trap	12	125	593	320	17			1,067	28%
Total	437	1,102	1,514	669	136	1	3	3,862	
2008									
Trawl	414	1,062	1,393	661	51	0	9	3,590	69%
Trap	conf	233	683	625	51			1,592	31%
Total	414	1,295	2,076	1,286	102	0	9	5,182	
2009									
Trawl	130	705	673	381	32	5	1	1,927	68%
Trap	4	80	449	358	15			906	32%
Total	134	785	1,122	739	47	5	1	2,833	
2010									
Trawl	238	1,230	1,512	447	157	29	1	3,614	65%
Trap	conf	334	1,081	492	conf			1,907	35%
Total	238	1,564	2,593	939	157	29	1	5,521	
2011									
Trawl	577	2,068	1,692	1				4,338	68%
Trap	22	812	1,183					2,017	32%
Total	599	2,880	2,875	1	0	0	0	6,355	
2012									
Trawl	1	1,305	1,046	1				2,353	71%
Trap			968					968	29%
Total	1	1,305	2,014	1	0	0	0	3,321	
2013									
Trawl		202	607	158	14			981	71%
Trap		0	282	102	8			392	29%
Total	0	202	889	260	22	0	0	1,373	
2014									
2015									
Trawl		1	8	5				14	31%
Trap		0	16	15				31	69%
Total	0	1	24	20	0	0	0	45	

conf = Confidential data were included in an adjacent month.

Table 7: Estimated numbers of vessels in the Gulf of Maine Northern Shrimp fishery by fishing season and state. 2015 data are for the RSA.

Season	Maine			Massachusetts	New Hampshire	Total
	Trawl	Trap	Total			
1980			15-20	15-20		30-40
1981			~75	~20-25		~100
1982			>75	~20-25		>100
1983			~164	~25	~5-8	~197
1984			239	43	6	288
1985			~231	~40	~17	~300
1986						~300
1987			289	39	17	345
1988			~290	~70	~30	~390
1989			~230	~50	~30	~310
1990			~220			~250
1991			~200	~30	~20	~250
1992			~259	~50	16	~325
1993			192	52	29	273
1994			178	40	29	247
1995						
1996			275	43	29	347
1997			238	32	41	311
1998			195	33	32	260
1999			181	27	30	238
2000	207	68	265	17	27	304
2001	174	60	234	19	27	275
2002	117	52	168	7	23	198
2003	142	49	191	12	22	222
2004	114	56	170	7	15	192
2005	102	64	166	9	22	197
2006	68	62	129	4	11	144
2007	97	84	179	3	15	196
2008	121	94	215	4	15	234
2009	80	78	158	12 (MA and NH combined)		170
2010	124	112	236	6	14	256
2011	172	143	311	12	19	342
2012	164	132	295	15	17	327
2013	110	72	182	13	14	208
2014	0	0	0	0	0	0
2015	3	5	8	1	0	9

Note that some boats reported both trapping and trawling, and some landed in more than one state.

Table 8: Gulf of Maine Northern Shrimp trawl catch rates by season. Mean CPUE in pounds/hour towed is from Maine trawler port sampling. Mean catch in pounds/trip is from NMFS weigh-out and logbook data for all catches for all states. Trawl pounds/trip is trawler only catch. Moratorium implemented for 2014 and 2015 seasons.

Season	Maine pounds per hour towing			Pounds/trip	Trawl lbs/trip
	Inshore (<55F)	Offshore (>55F)	Combined		
1991	94	152	140	992	
1992	132	93	117	978	
1993	82	129	92	767	
1994	139	149	141	1,073	
1995	172	205	193	1,360	
1996	340	203	251	1,784	
1997	206	192	194	1,462	
1998	158	151	154	1,391	
1999	148	147	147	1,079	
2000	279	224	272	1,382	1,475
2001	100	135	109	710	752
2002	223	91	194	765	854
2003	174	215	182	981	1,102
2004	361	310	351	1,753	2,006
2005	235	212	228	1,488	1,621
2006	572	345	499	2,066	2,616
2007	531	477	507	2,584	3,129
2008	350	327	343	1,958	2,302
2009	400	315	370	1,837	2,231
2010	424	354	401	2,264	2,671
2011	334	435	347	1,988	2,376
2012	407	313	399	1,497	1,873
2013	118	78	110	492	619
2014	---	---	---	---	---
2015	---	---	---	---	---

Table 9: Stratified geometric mean number (abundance) and weight (biomass, kg) per tow and derived indices of northern shrimp from summer shrimp surveys (strata 1, 3, 5, 6, 7 and 8). Recruit index is abundance of presumed age 1.5 shrimp. Other derived indices are described in text. YC=year class, EPI=egg production index.

Year	N Tows	Total Abundance	Total Biomass	Recruit Index	Spawner Biomass	EPI millions	YC Survival index	>22 mm* Number	>22 mm Weight (kg)
1984	37	1,152	10.5	18	3.6	0.72		316	3.4
1985	44	1,825	17.7	332	5.7	1.19	496	1,169	11.5
1986	40	1,695	19.6	358	7.2	1.48	287	860	10.0
1987	41	1,533	15.4	342	6.2	1.25	559	854	9.5
1988	41	1,269	12.8	828	2.5	0.52	222	298	3.4
1989	43	1,884	17.0	276	5.0	1.01	274	564	6.1
1990	43	1,623	18.1	142	6.0	1.25	476	1,127	12.0
1991	43	1,256	11.7	482	6.5	1.34	226	657	8.0
1992	45	955	9.4	282	4.3	0.85	565	397	4.8
1993	46	1,157	9.1	757	2.2	0.44	431	250	2.8
1994	43	984	8.7	368	2.3	0.46	664	243	2.7
1995	35	1,449	13.3	292	6.2	1.27	506	628	7.0
1996	32	776	8.8	232	3.1	0.63	294	358	4.0
1997	40	762	7.7	374	2.3	0.48	212	245	2.8
1998	35	583	6.3	134	1.8	0.35	239	170	1.9
1999	42	398	5.8	114	1.5	0.31	1,294	174	1.9
2000	35	808	6.4	450	2.9	0.58	57	283	3.2
2001	36	451	4.3	18	1.7	0.31	1,992	146	1.5
2002	38	1,445	9.2	1,164	2.8	0.54	35	261	2.9
2003	37	564	5.5	11	2.0	0.34	527	173	1.7
2004	35	887	10.3	286	3.1	0.63	5,155	519	5.3
2005	46	3,661	23.4	1,752	9.2	1.89	589	871	10.3
2006	29	9,998	66.0	374	28.4	5.58	15	2,773	29.9
2007	43	887	11.5	28	3.4	0.67	91	412	4.1
2008	38	1,737	16.8	506	5.9	1.22	828	995	10.8
2009	49	1,627	15.4	555	6.4	1.29	391	702	8.5
2010	49	1,373	13.9	475	3.9	0.79	34	413	4.8
2011	47	830	8.6	44	3.0	0.57	8	316	3.2
2012	49	138	2.5	7	0.7	0.15	2	81	0.9
2013	40	27	1.0	1	0.2	0.05	773	24	0.3
2014	46	139	1.7	116	0.3	0.04	17	16	0.2
2015	32	55	1.3	1	0.4	0.08		41	0.4
Mean	41	1373	12.2	347	4.4	0.88	575	511	5.6
Median	41	1068	9.9	289	3.1	0.63	343	337	3.7
1984-93	42	1,435	14.1	382	4.9	1.01	393	649	7.1
Median	43	1,401	14.1	337	5.4	1.10	431	611	7.0

*Will be fully recruited to the winter fishery.

Table 10: Biomass indices (stratified mean kg per tow) from NEFSC fall surveys by vessel. The survey vessel and gear changed in 2009. No conversion factors are available for Northern Shrimp.

	kg/tow		kg/tow	
Year	***Albatross***	**Year**	***Albatross***	***Bigelow***
1968	3.2	**1992**	0.4	
1969	2.7	**1993**	1.9	
1970	3.7	**1994**	2.2	
1971	3	**1995**	1.2	
1972	3.3	**1996**	0.9	
1973	1.9	**1997**	1.1	
1974	0.8	**1998**	2.0	
1975	0.9	**1999**	2.3	
1976	0.6	**2000**	1.3	
1977	0.2	**2001**	0.6	
1978	0.4	**2002**	1.7	
1979	0.5	**2003**	1.1	
1980	0.5	**2004**	1.6	
1981	1.5	**2005**	2.8	
1982	0.3	**2006**	6.6	
1983	1.0	**2007**	4.1	
1984	1.9	**2008**	3.1	
1985	1.6	**2009**		7.8
1986	2.5	**2010**		5.0
1987	1.7	**2011**		5.6
1988	1.2	**2012**		2.8
1989	1.8	**2013**		1.2
1990	2.0	**2014**		1.9
1991	0.4			

Table 11: Stratified geometric mean weights (kg) per tow of Northern Shrimp collected during the Maine - New Hampshire inshore trawl surveys by year, regions 1–4 (NH to Mt. Desert) and depths 3–4 (> 35 fa.) only, with number of tows (n) and 80% confidence intervals.

	Spring				Fall			
	kg/tow	n	80% CI		kg/tow	n	80% CI	
2003	**4.2**	40	3.4	5.1	**1.9**	33	1.4	2.6
2004	**3.9**	42	3.3	4.5	**1.5**	38	1.0	2.1
2005	**7.8**	40	6.6	9.2	**3.6**	25	2.5	5.1
2006	**11.0**	46	8.5	14.1	**2.1**	38	1.4	2.8
2007	**10.7**	43	7.9	14.3	**4.0**	45	3.1	5.1
2008	**15.4**	45	12.7	18.6	**3.6**	37	2.3	5.4
2009	**9.7**	45	7.7	12.1	**2.7**	41	2.3	3.3
2010	**16.0**	48	12.6	20.1	(samples lost)			
2011	**17.9**	51	14.9	21.4	**4.2**	32	3.2	5.4
2012	**7.5**	50	6.1	9.2	**1.9**	42	1.5	2.3
2013	**1.7**	46	1.1	2.5	**0.6**	45	0.4	0.8
2014	**2.1**	47	1.7	2.5	**0.2**	43	0.2	0.3
***2015**	**1.7**	52	1.4	2.1				

* 2015 data are preliminary.

Table 12: Recent (2012–2015) Gulf of Maine Northern Shrimp FTLA indicator values relative to reference levels. RED = at or below 10th percentile of time series; BLACK = at or below 20th percentile of time series; YELLOW = between 20th percentile and stable period (1985–1994) mean (SPM); GREEN = at or above SPM.

	Indicator values				Reference levels		
						percentile	
	2012	2013	2014	2015	SPM	20th	10th
Total Biomass	2.5	1.0	1.7	1.3	14.1	5.9	2.6
Spawner Biomass	0.7	0.2	0.3	0.4	4.9	1.8	0.8
Recruit Abundance	6.7	0.9	116.2	0.8	381.7	31.4	11.4
Early Life (YC) Survival	2	773	17		393	52	17
CPUE (mt/trip)	0.68	0.23			0.45	0.4	0.35

KEY

- ≥ SPM
- > 20th percentile but < SPM
- ≤ 20th percentile
- ≤ 10th percentile

Table 13: Recent (2012–2015) Gulf of Maine Northern Shrimp FTLA environmental indicator values relative to reference levels. RED = at or above 90th percentile of time series; BLACK = at or above 80th percentile of time series; YELLOW = between 80th percentile and stable period (1985–1994) mean (SPM); GREEN = at or below SPM.

	Indicator values				Reference levels		
						percentile	
	2012	2013	2014	2015	SPM	80th	90th
Predator Predation Index	1118	888	1005		546	1136	1185
Boothbay Feb-Mar SST	5.5	3.9	2.3	1.4	2.4	3.4	4.0
Spring Bottom Temp NEFSC	2.0	1.3	0.5	0.1	0.4	1.3	1.3
Summer Survey Bottom Temp	7.9	7.1	6.2	5.8	5.4	7.0	7.1

KEY

- ≤ SPM
- < 80th percentile but > SPM
- ≥ 80th percentile
- ≥ 90th percentile

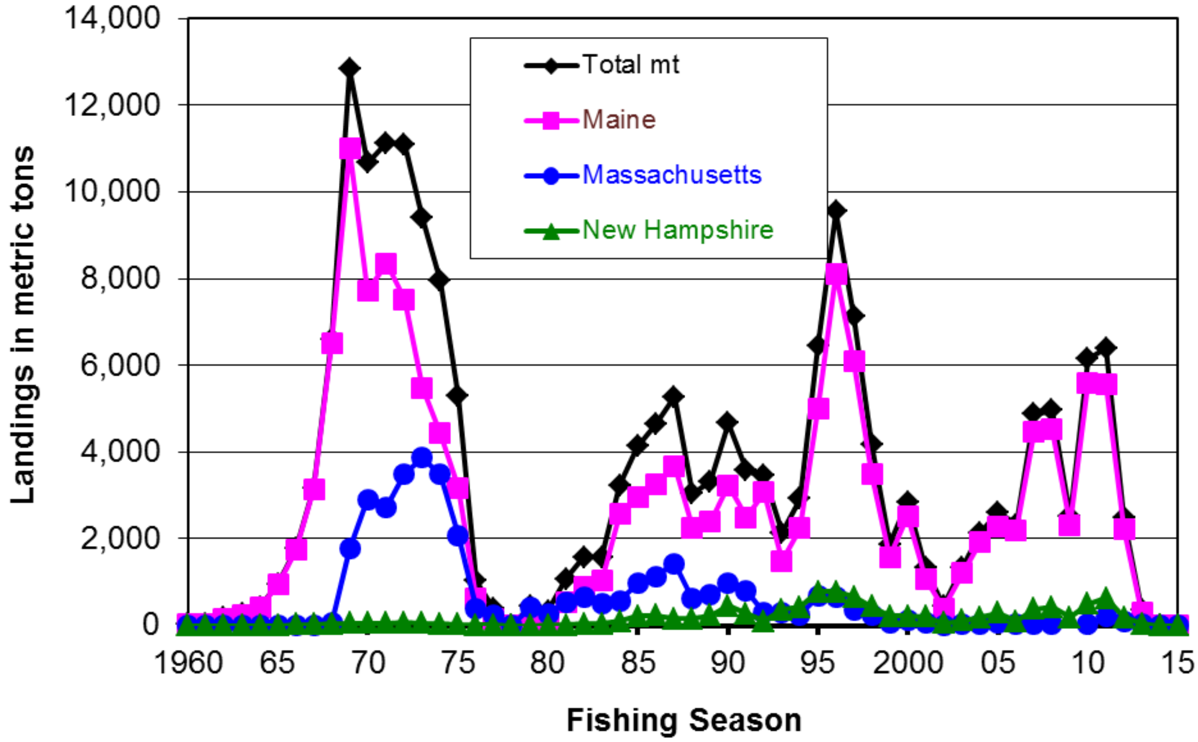


Figure 1: Gulf of Maine Northern Shrimp landings by season and state. Massachusetts landings are combined with New Hampshire landings in 2009 to preserve confidentiality.

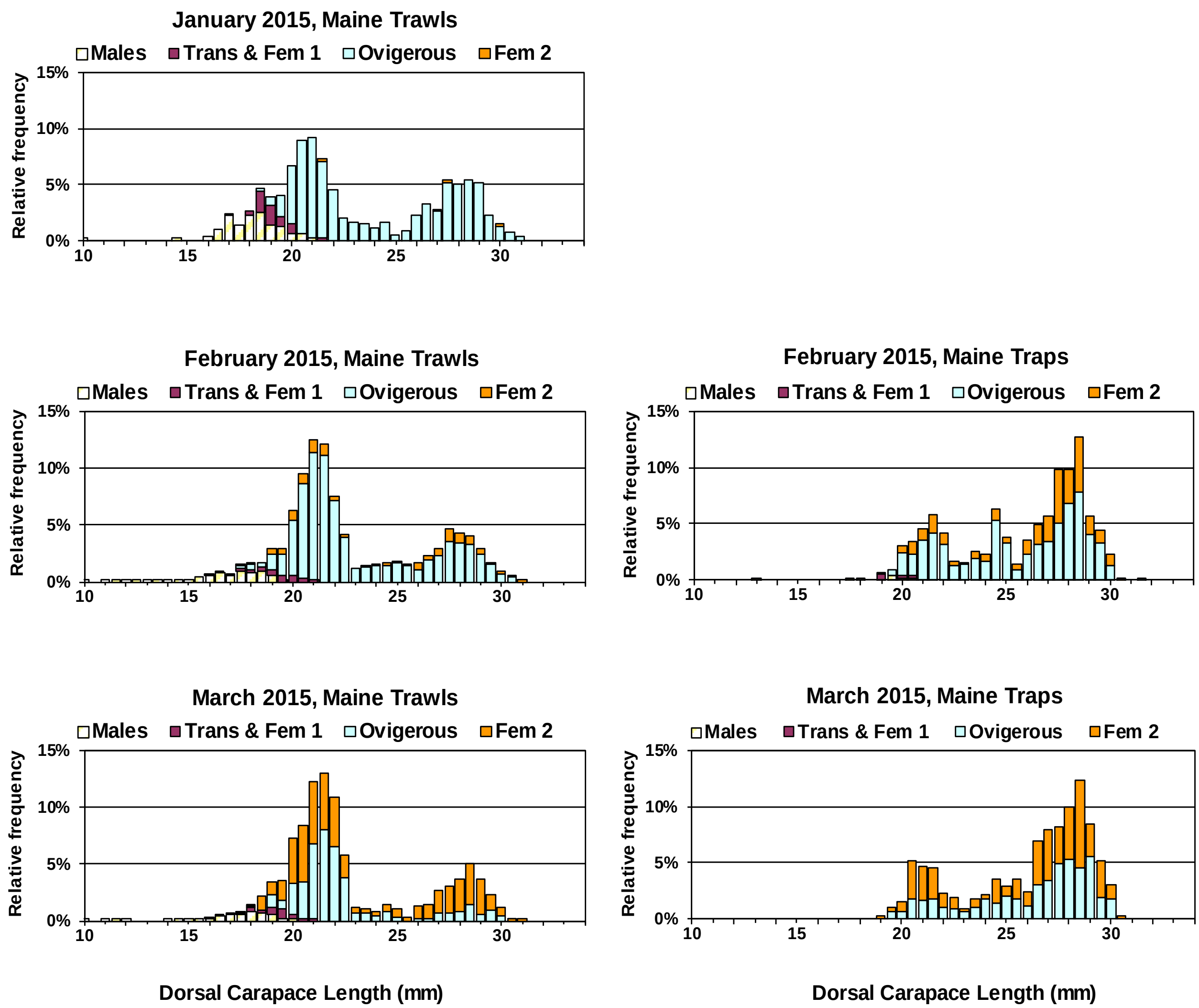


Figure 2: Gulf of Maine Northern Shrimp size-sex-stage frequency distributions from 2015 winter samples by month — Maine trawls (left) and traps (right). See Whitmore *et al.* (2015) for details.

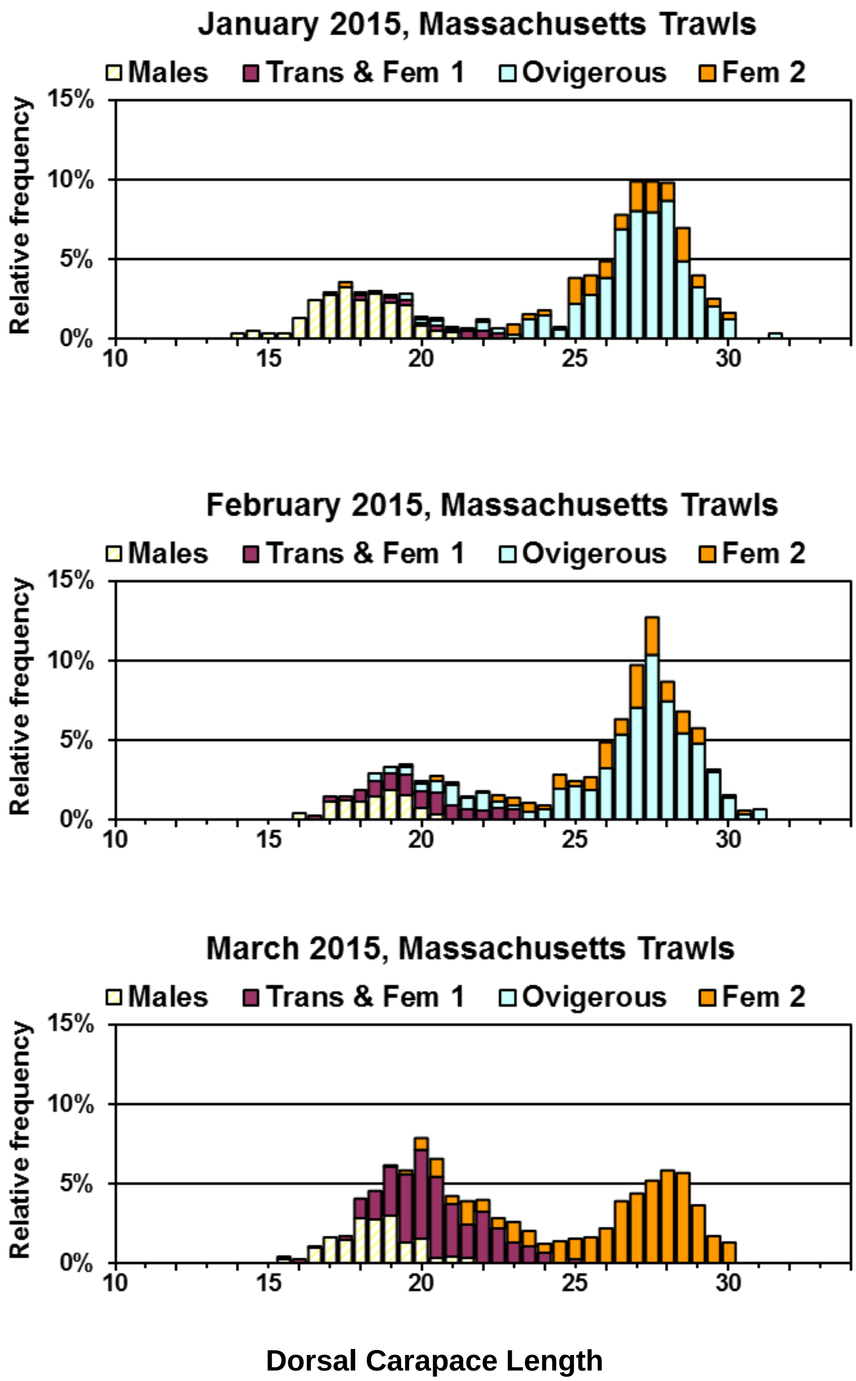


Figure 2 continued. Gulf of Maine Northern Shrimp size-sex-stage frequency distributions from 2015 winter samples by month — Massachusetts trawls. See Whitmore *et al.* (2015) for details.

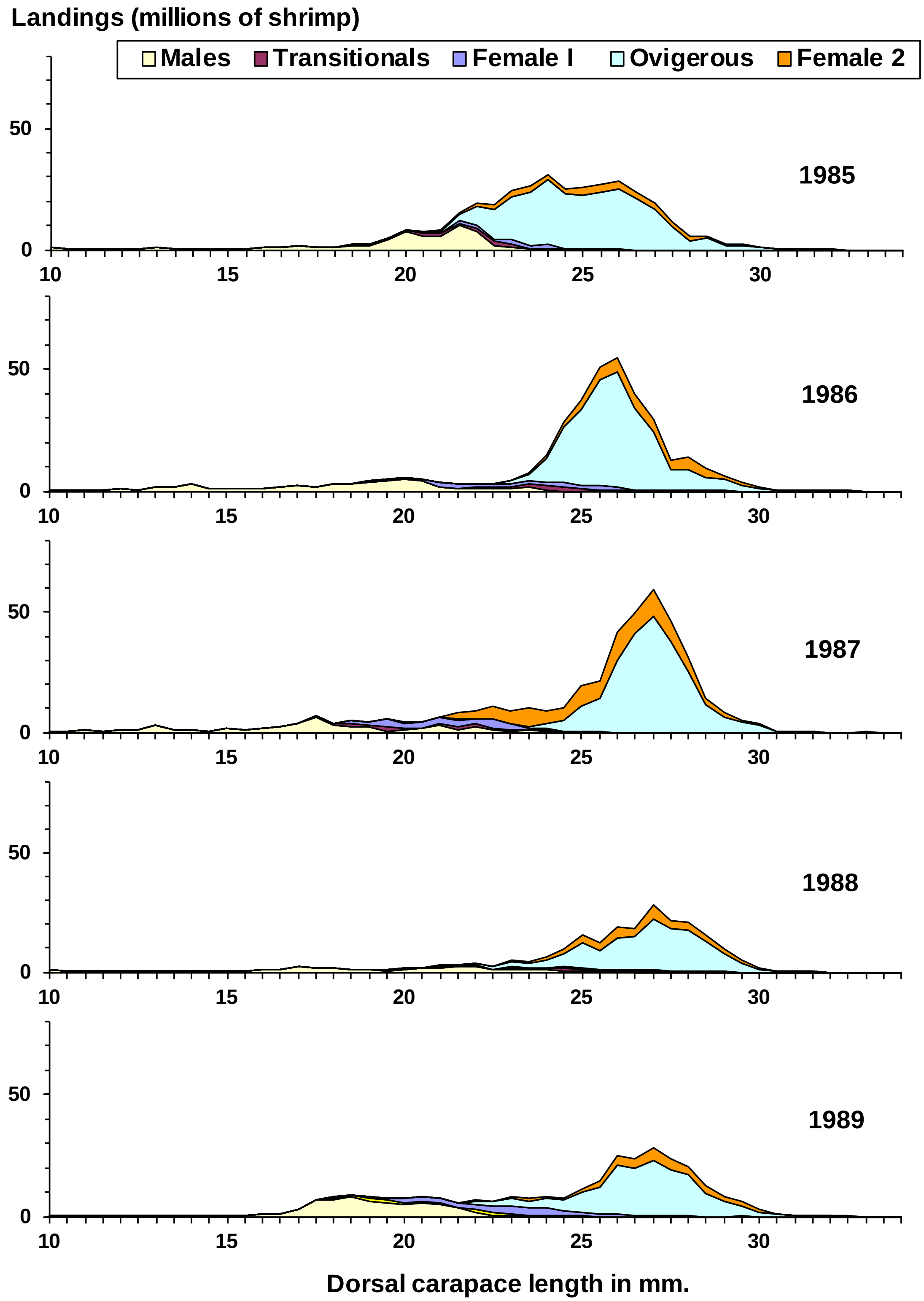


Figure 3: Gulf of Maine Northern Shrimp landings in estimated numbers of shrimp, by length, development stage, and fishing season.

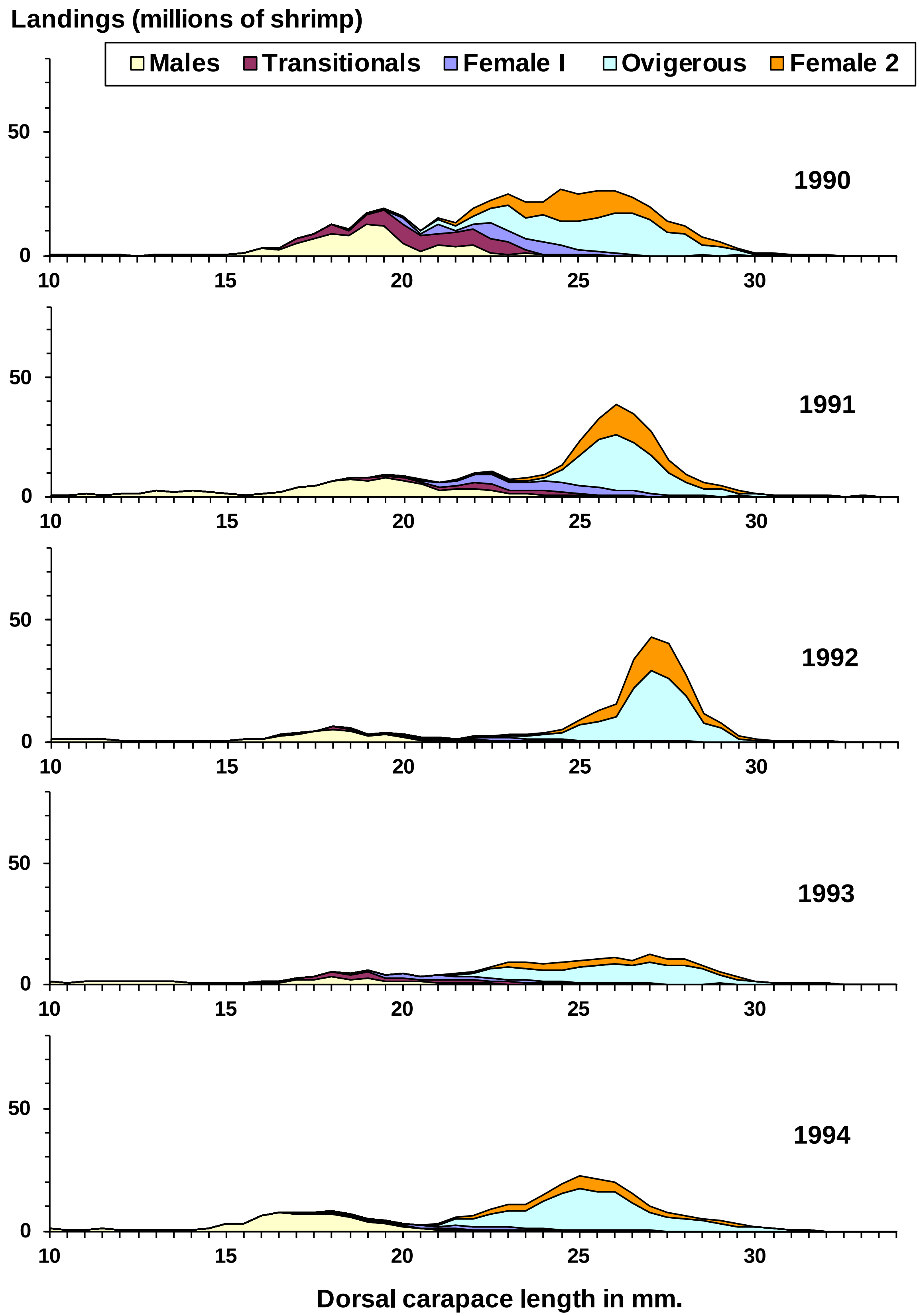


Figure 3 continued – Landings in estimated numbers of shrimp.

Landings (millions of shrimp)

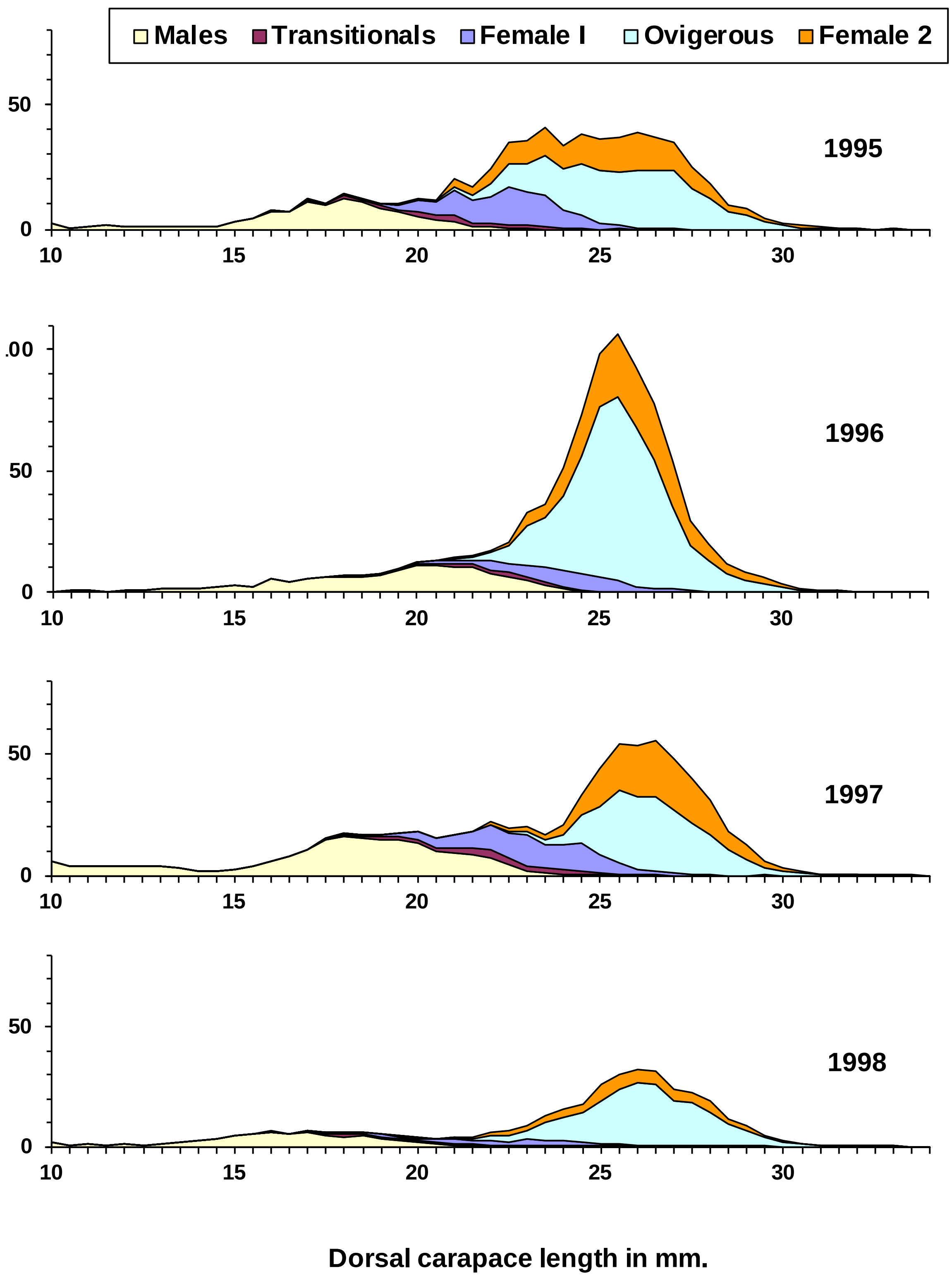


Figure 3 continued –Landings in estimated numbers of shrimp.

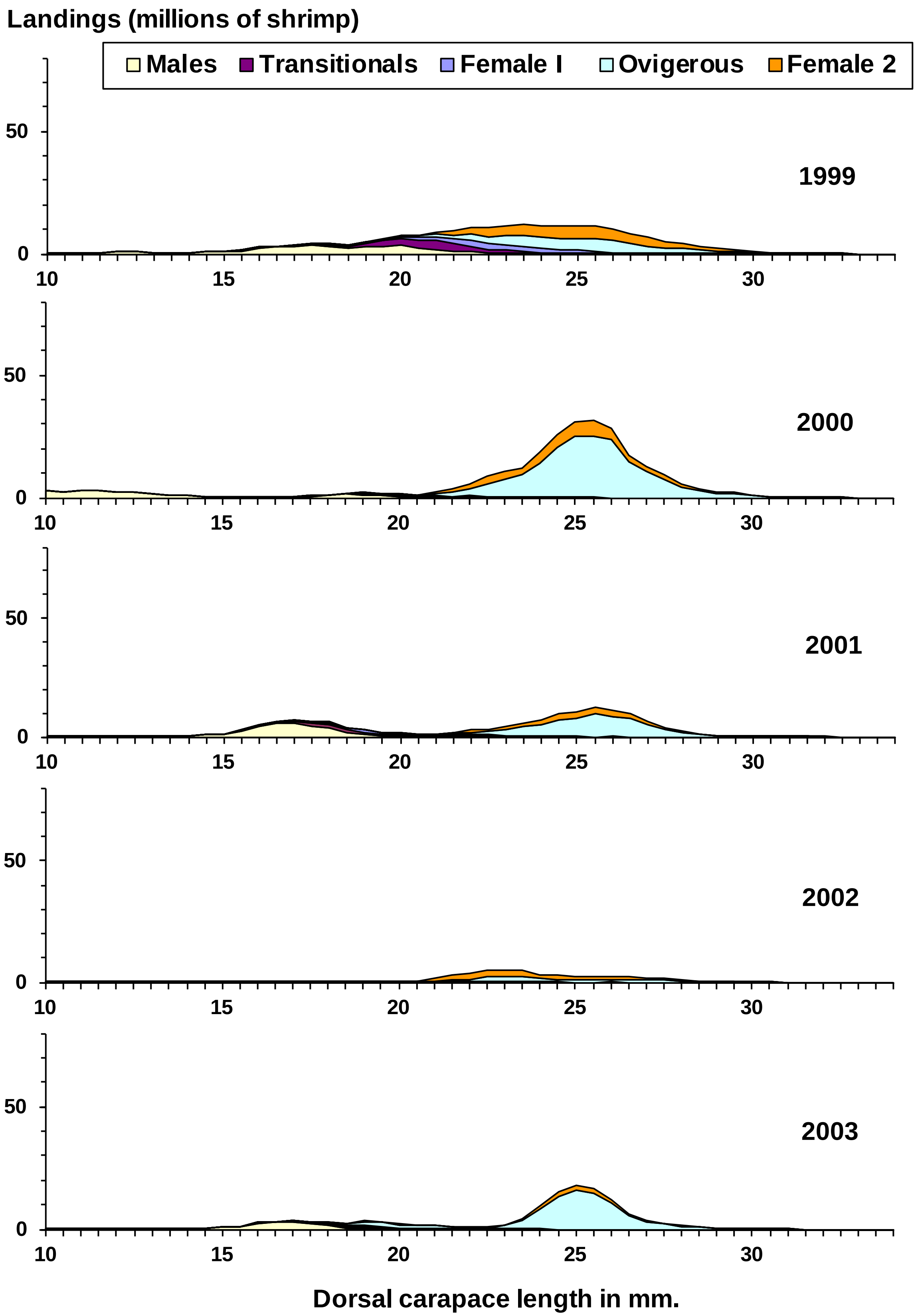


Figure 3 continued – Landings in estimated numbers of shrimp.

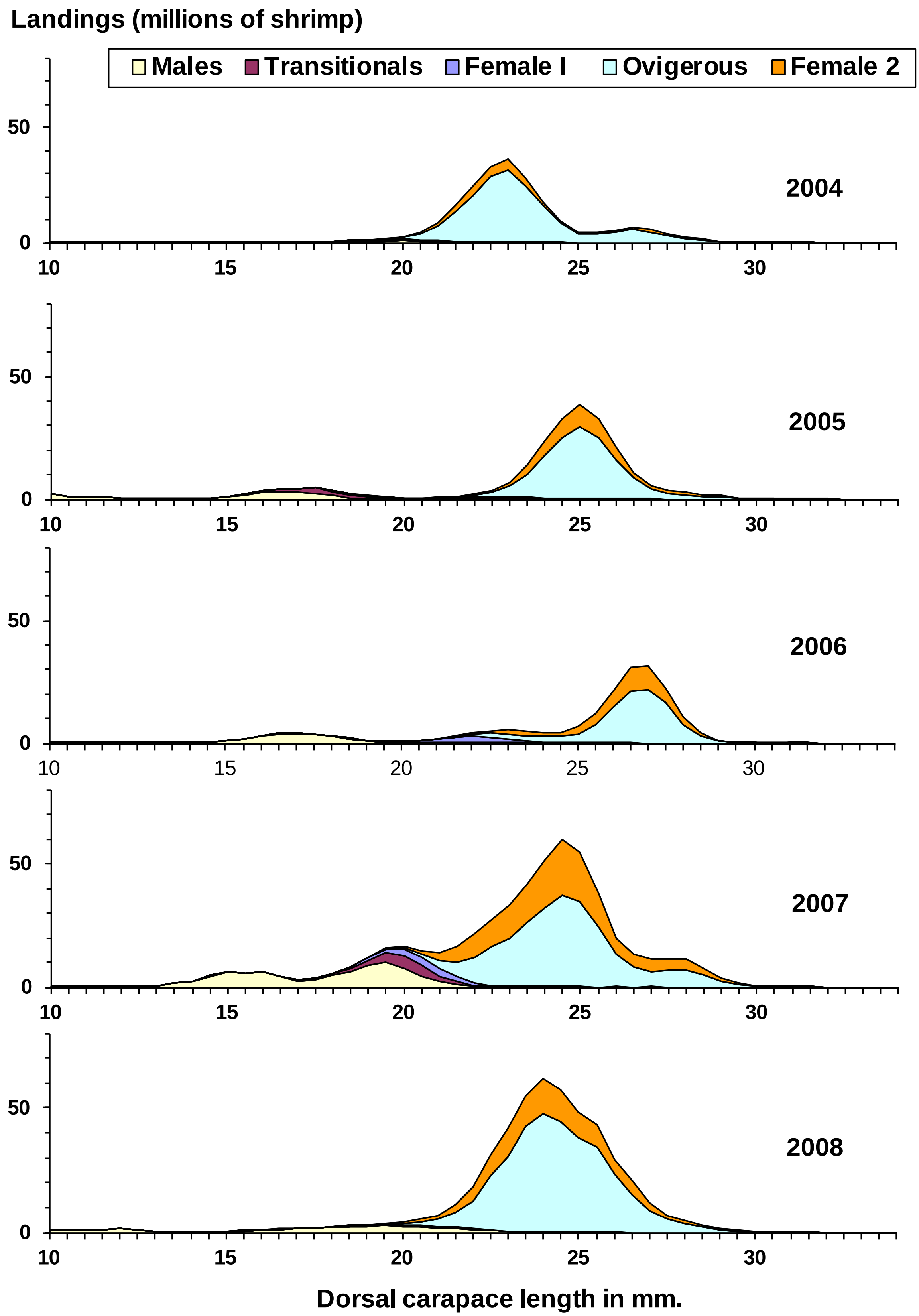


Figure 3 continued – Landings in estimated numbers of shrimp.

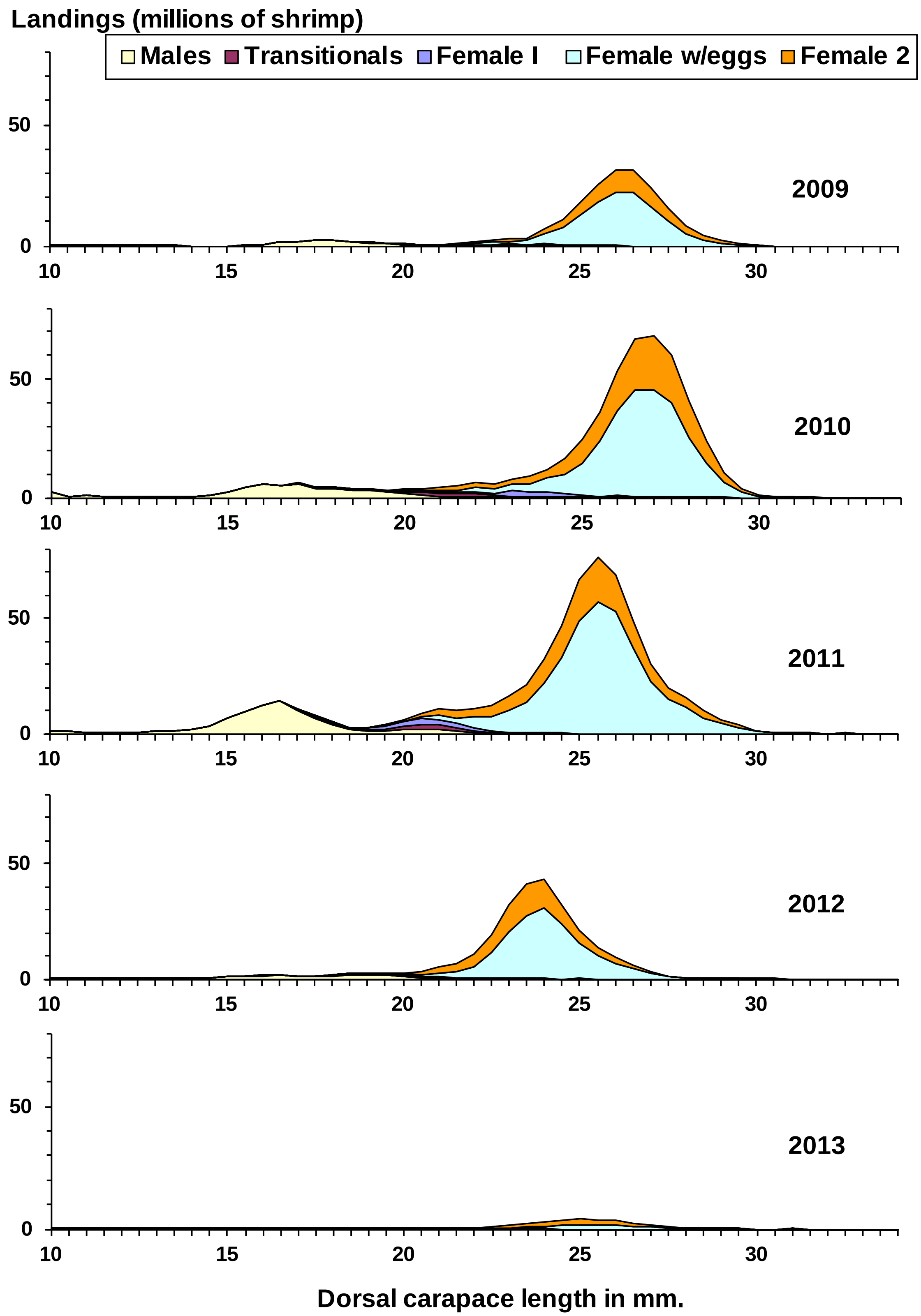


Figure 3 continued – Landings in estimated numbers of shrimp. Data for 2013 are preliminary.

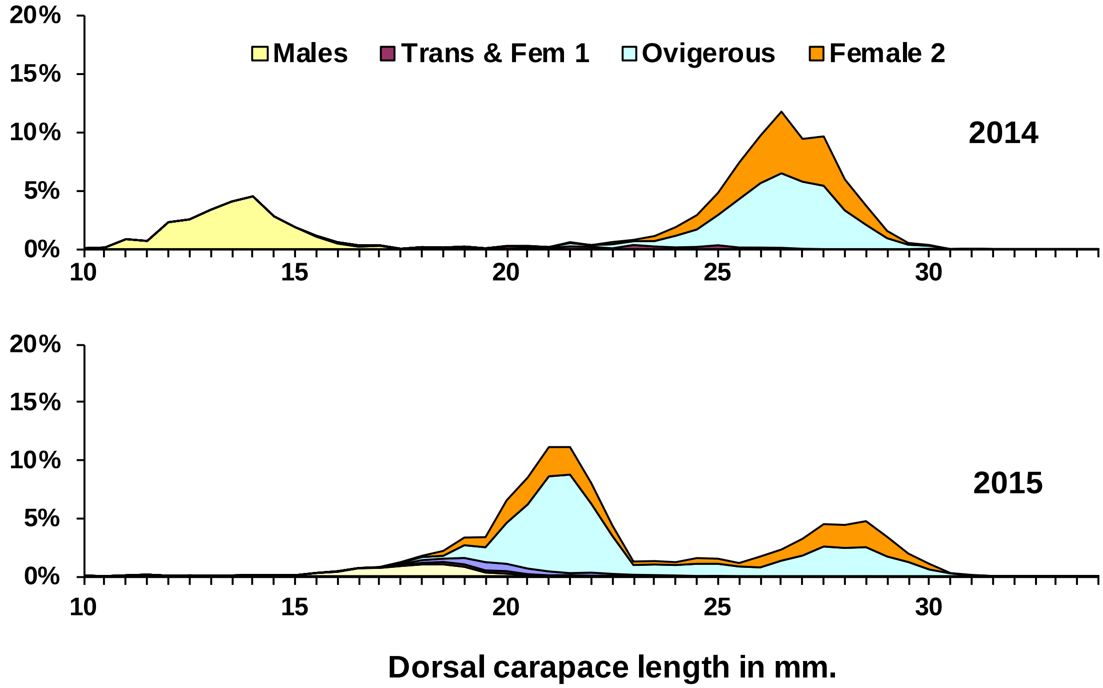
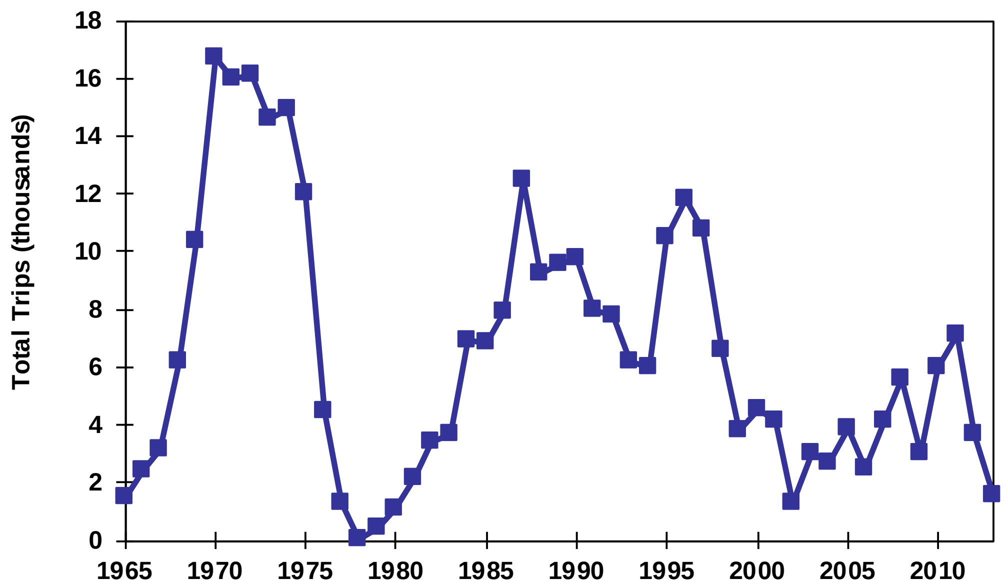


Figure 3 continued – Landings in estimated numbers of shrimp, expressed as percentages. 2014 data are from cooperative winter sampling with no landings. 2015 data are from the Gulf of Maine RSA program. See Hunter (2014) and Whitmore *et al.* (2015) for details.



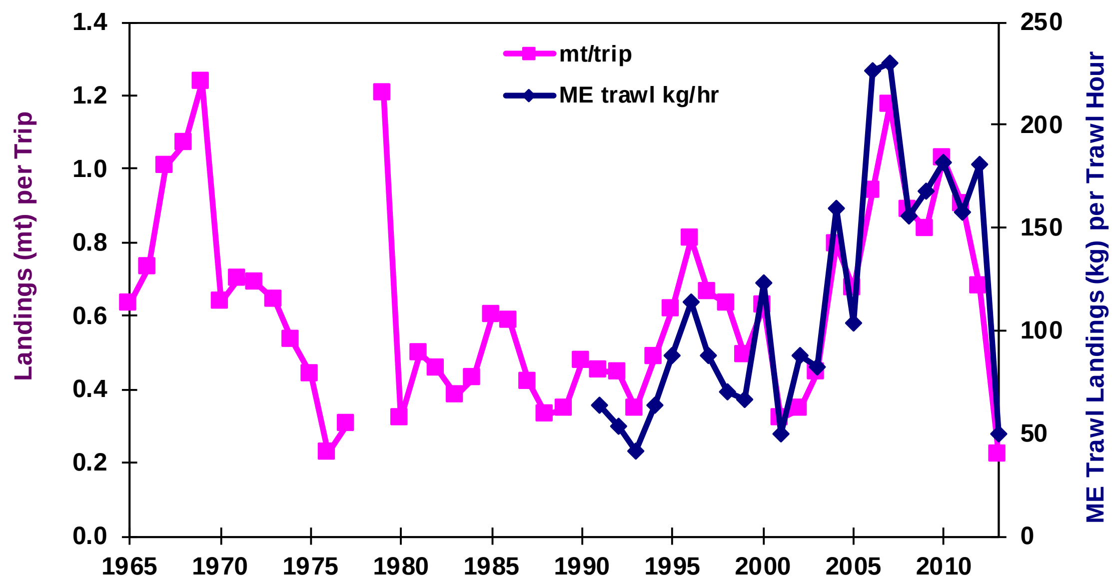


Figure 4: Nominal fishing effort (trips) (above) and catch per unit effort (below), in the Gulf of Maine Northern Shrimp fishery by season, 1965–2013. There was no fishery in 2014 or 2015.

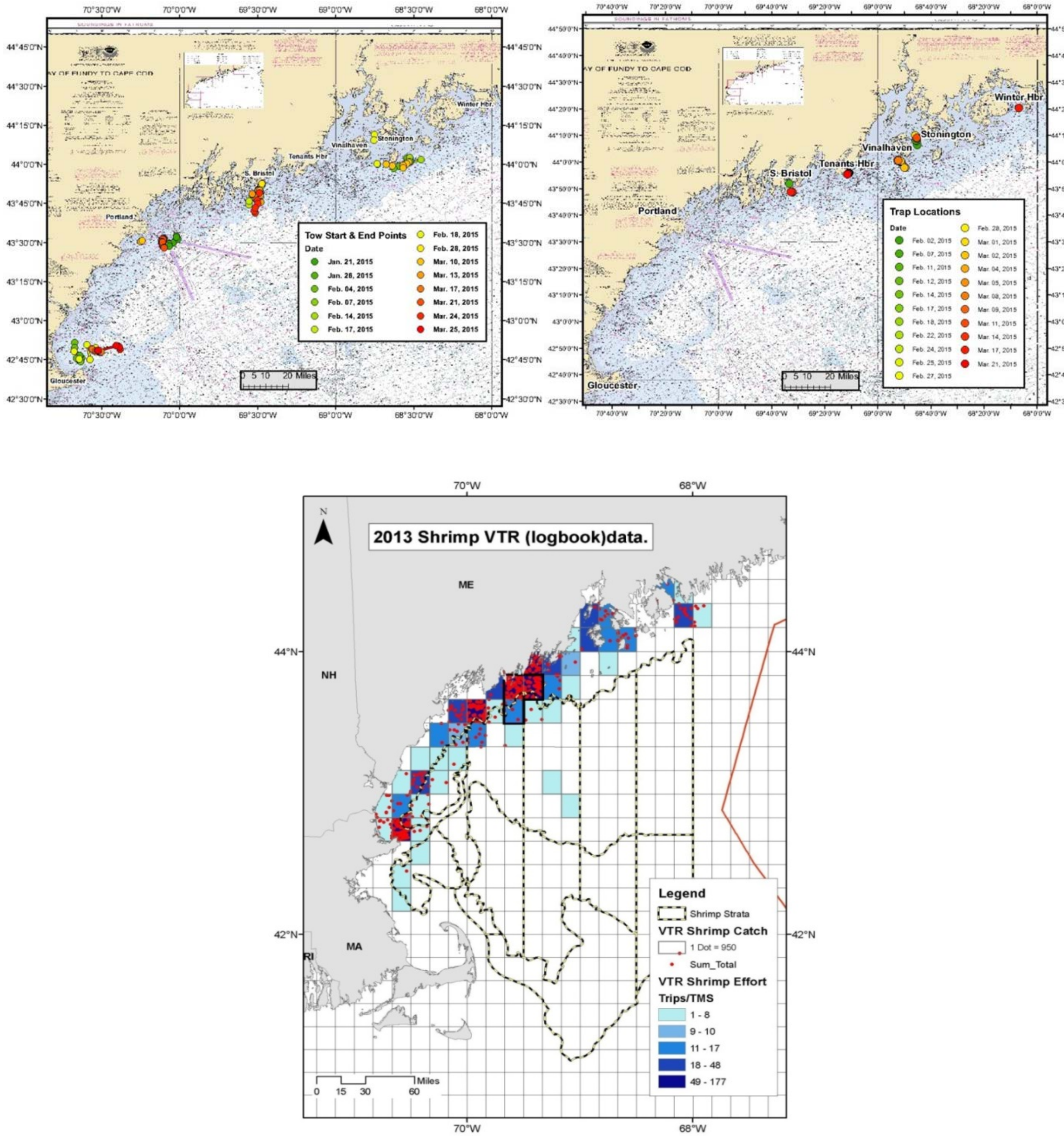


Figure 5: Locations of tows (top left) and traps (top right) for the 2015 Gulf of Maine Northern Shrimp RSA program relative to 2013 fishing effort from preliminary VTR data (bottom).

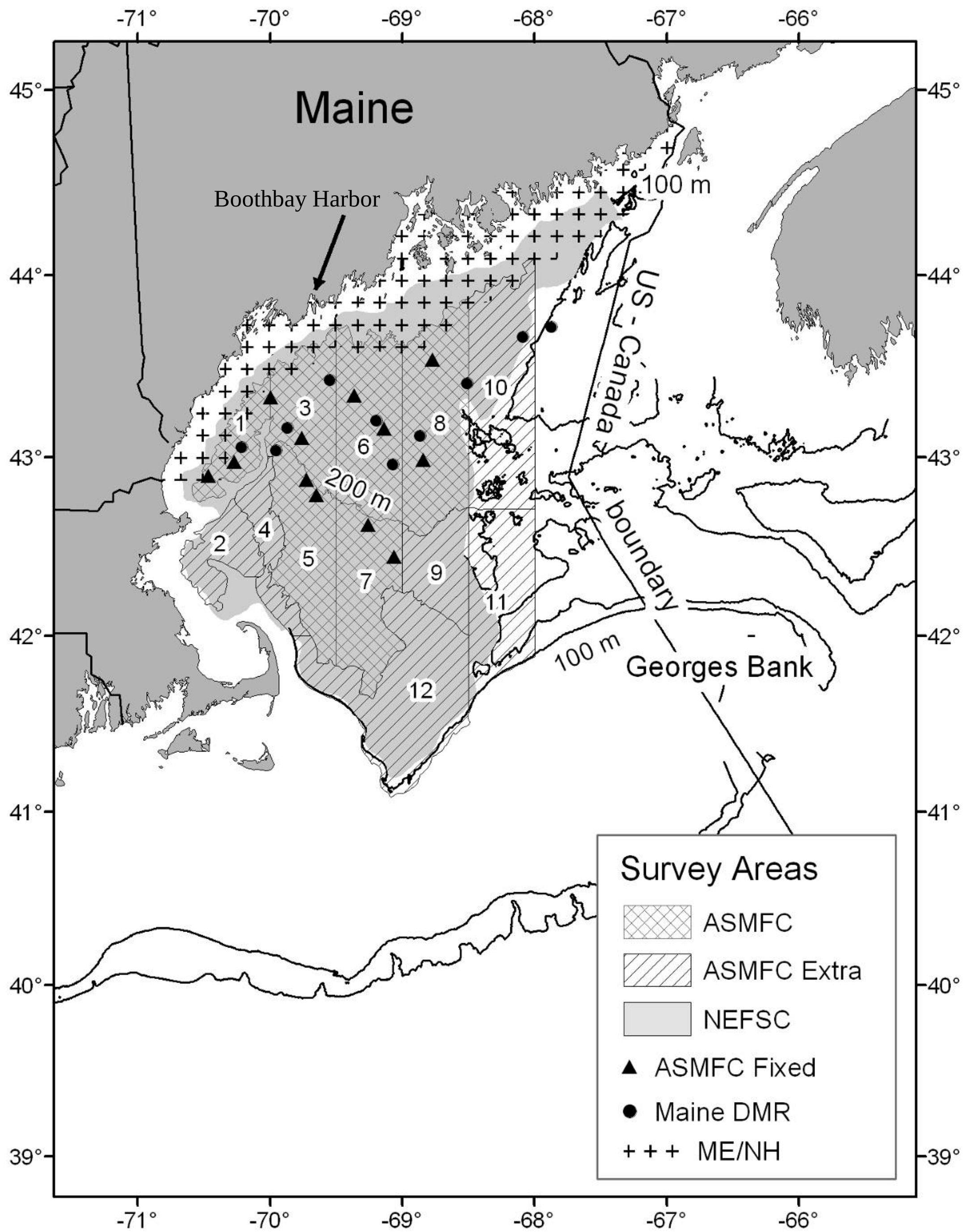


Figure 6. Gulf of Maine survey areas and station locations.

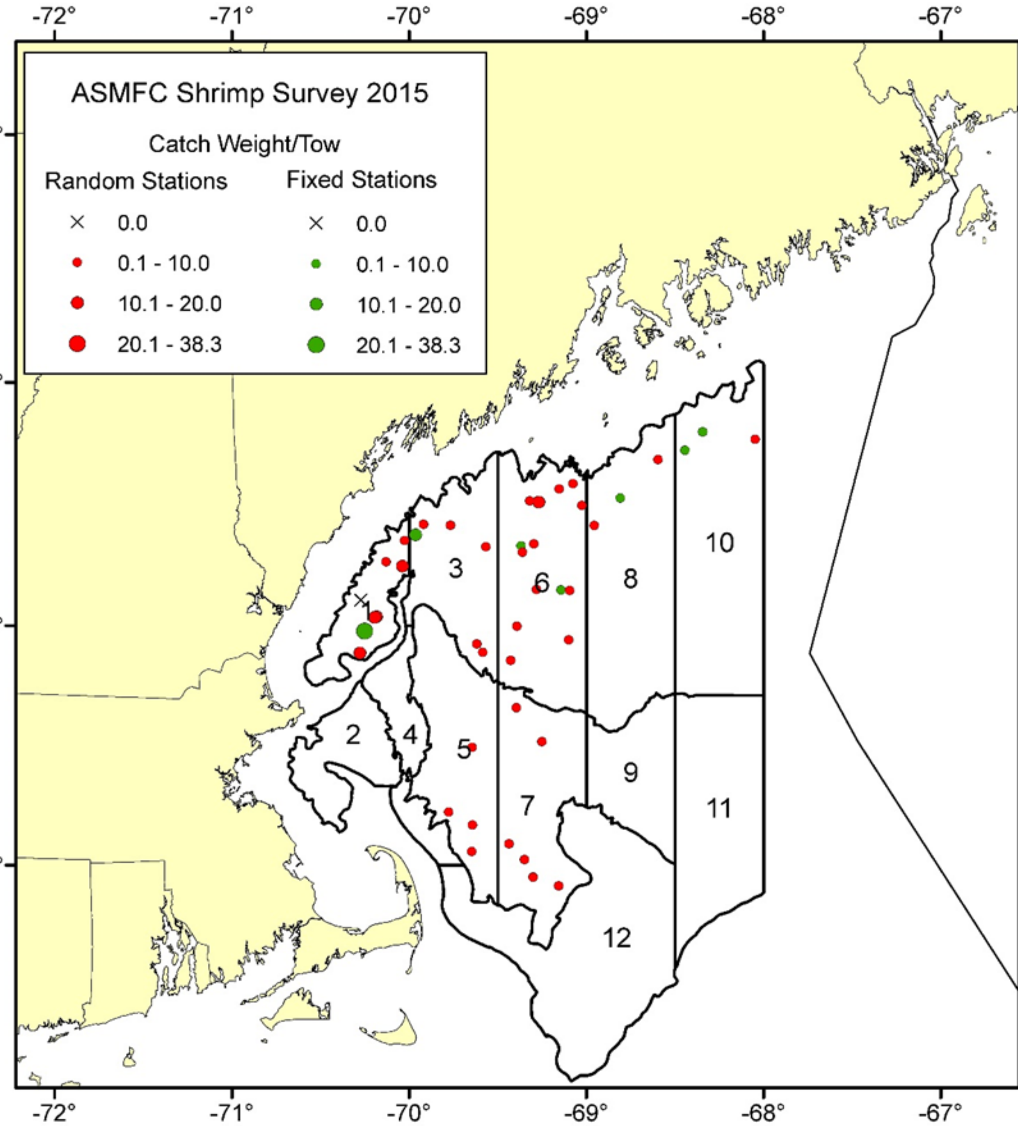


Figure 7: 2015 ASMFC Northern Shrimp summer survey aboard the R/V *Gloria Michelle*, fixed and random survey sites and shrimp catches in kg/tow.

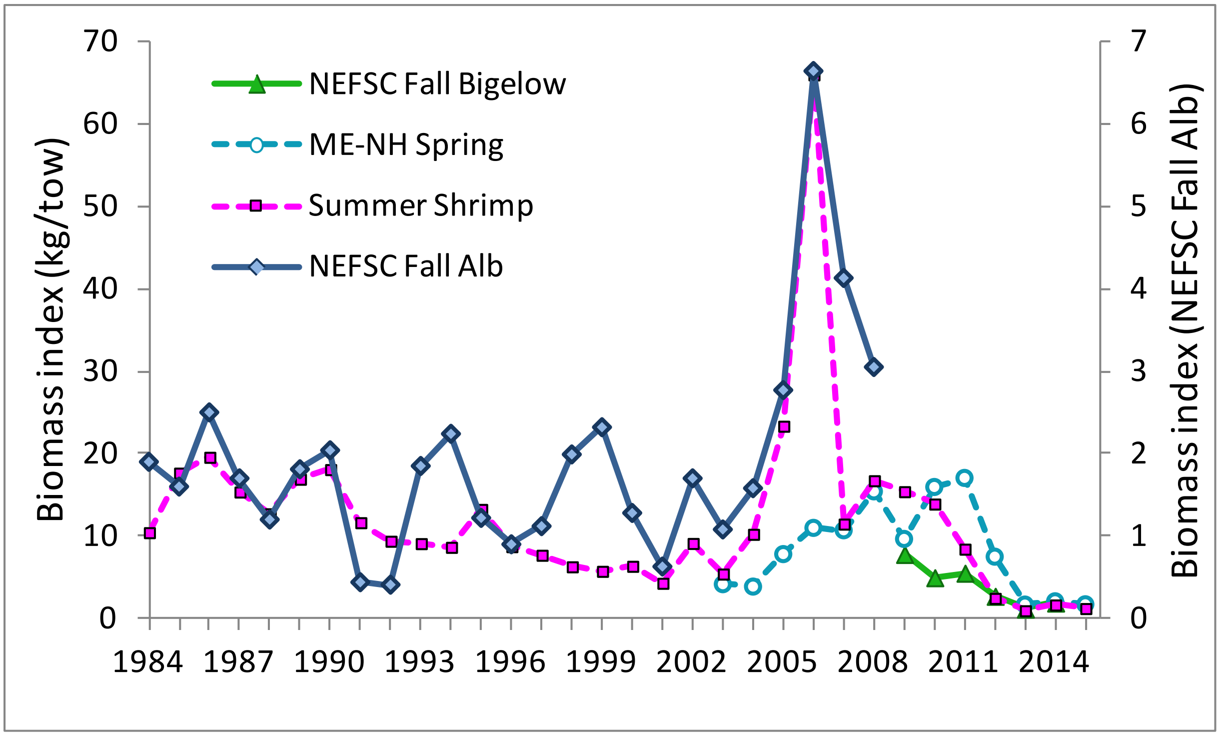


Figure 8: Biomass indices (kg/tow) from various Northern Shrimp surveys in the Gulf of Maine.

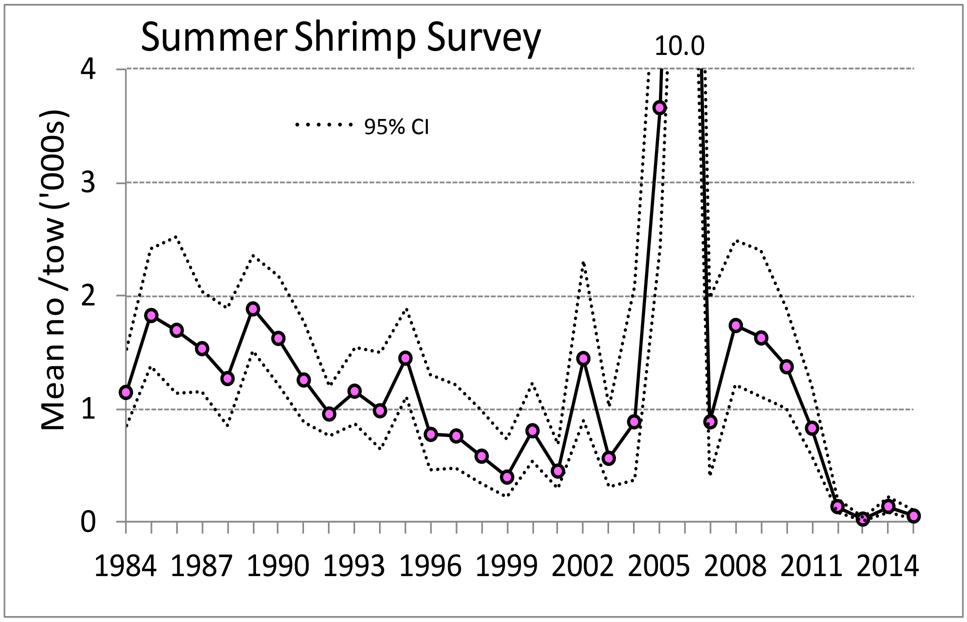


Figure 9: Gulf of Maine Northern Shrimp ASMFC summer survey indices of abundance by year.

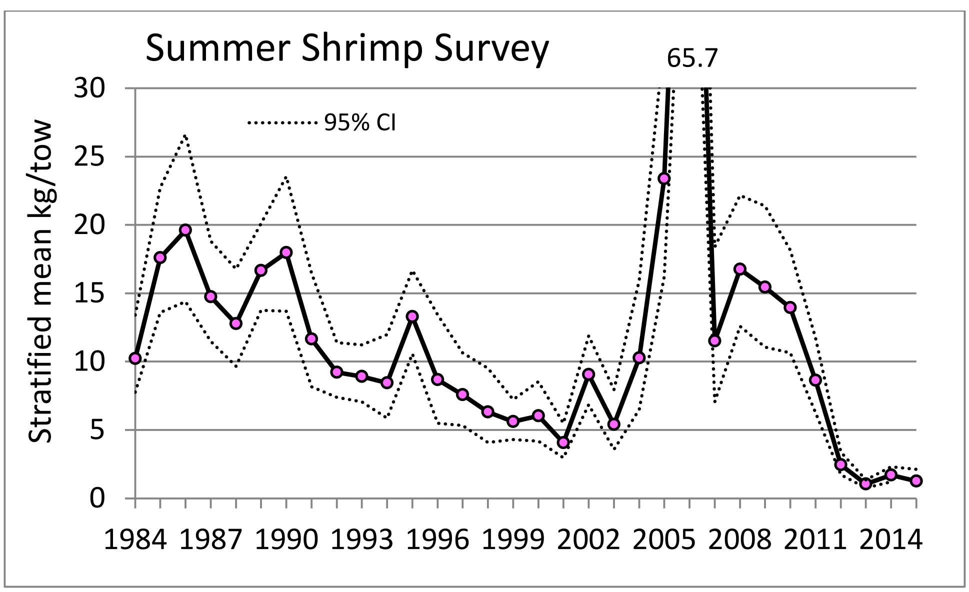


Figure 10: Gulf of Maine Northern Shrimp ASMFC summer survey indices of biomass by survey year.

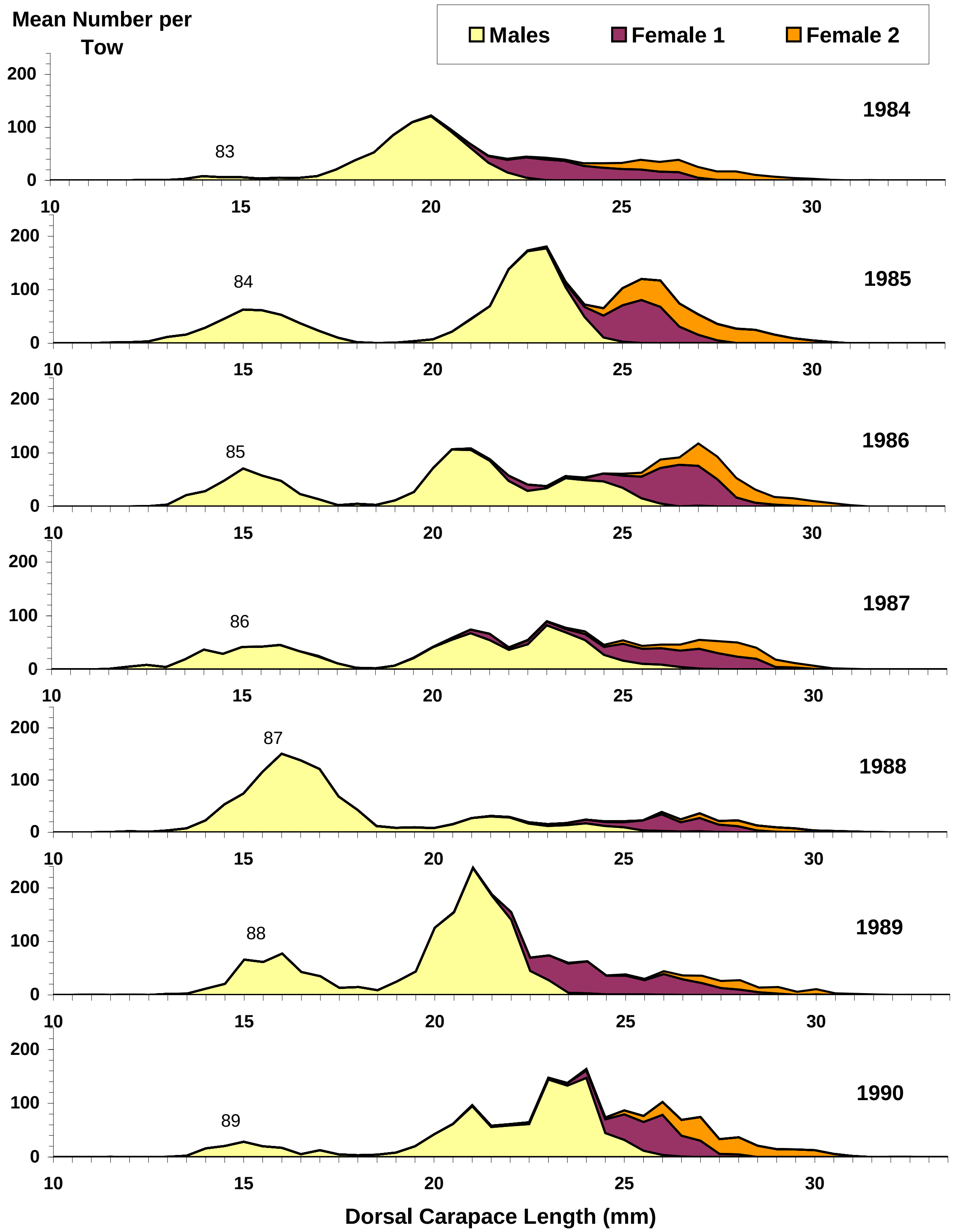


Figure 11: Gulf of Maine Northern Shrimp summer survey mean catch per tow by year, length, and development stage. Two-digit years are year class at assumed age 1.5.

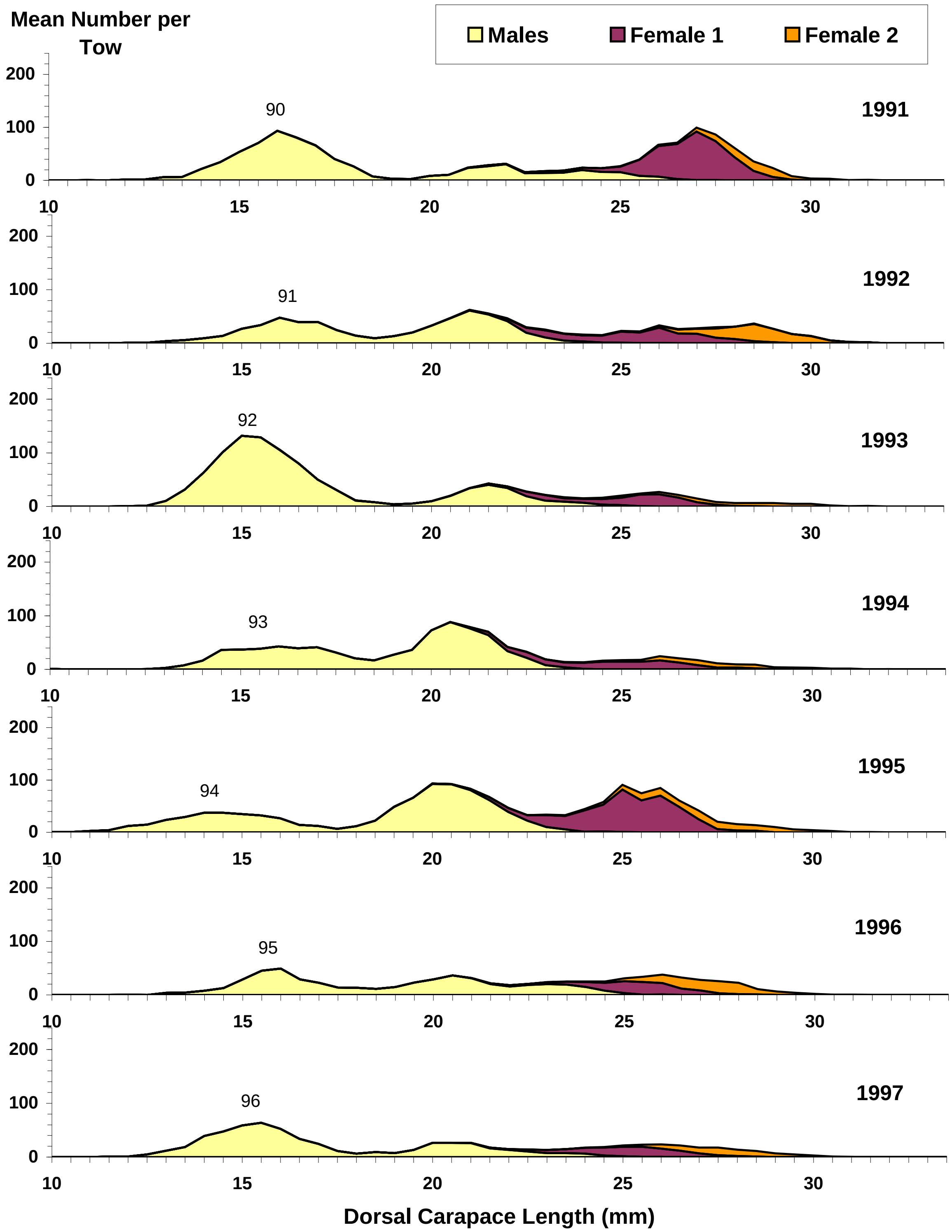


Figure 11 continued – summer survey.

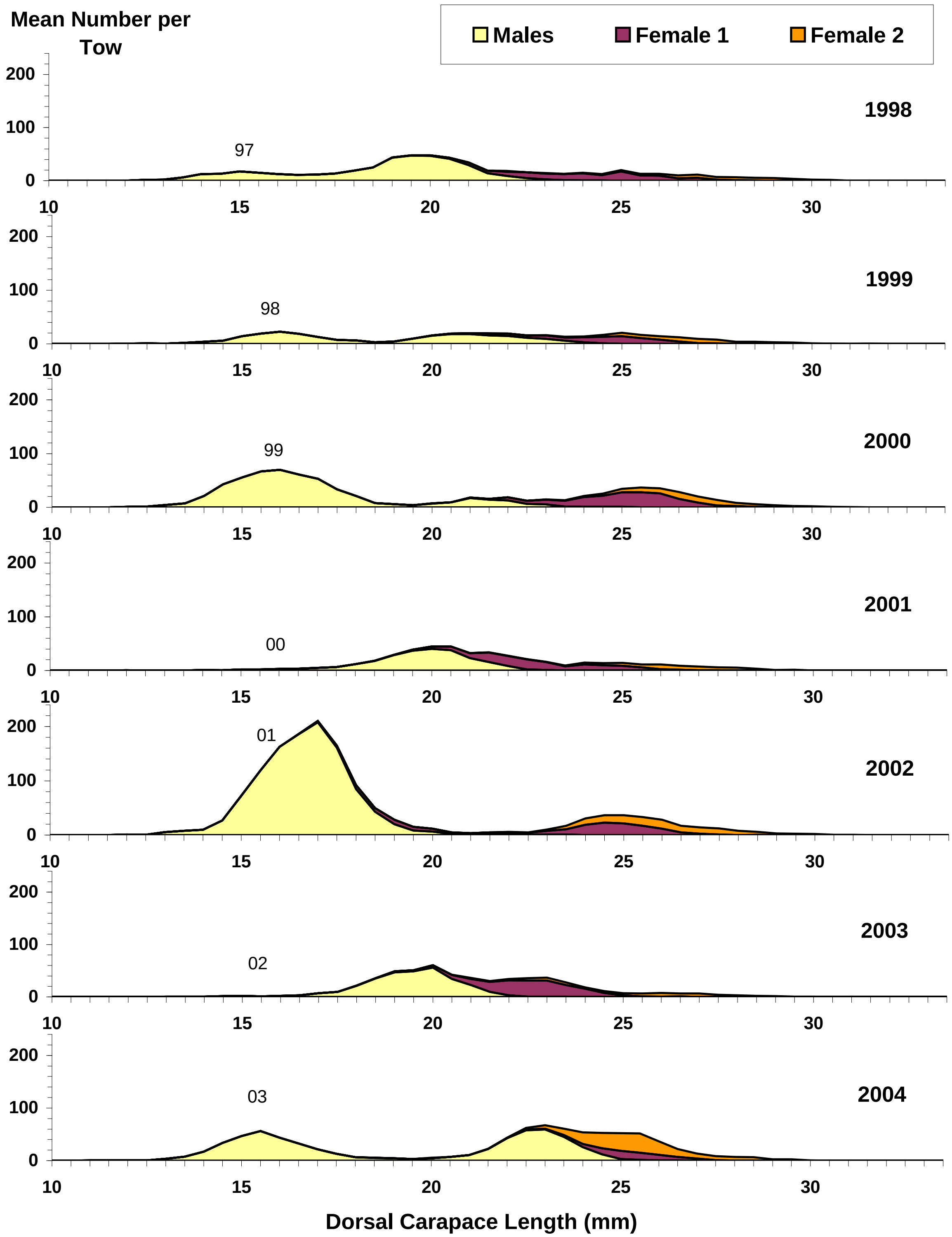


Figure 11 continued – summer survey.

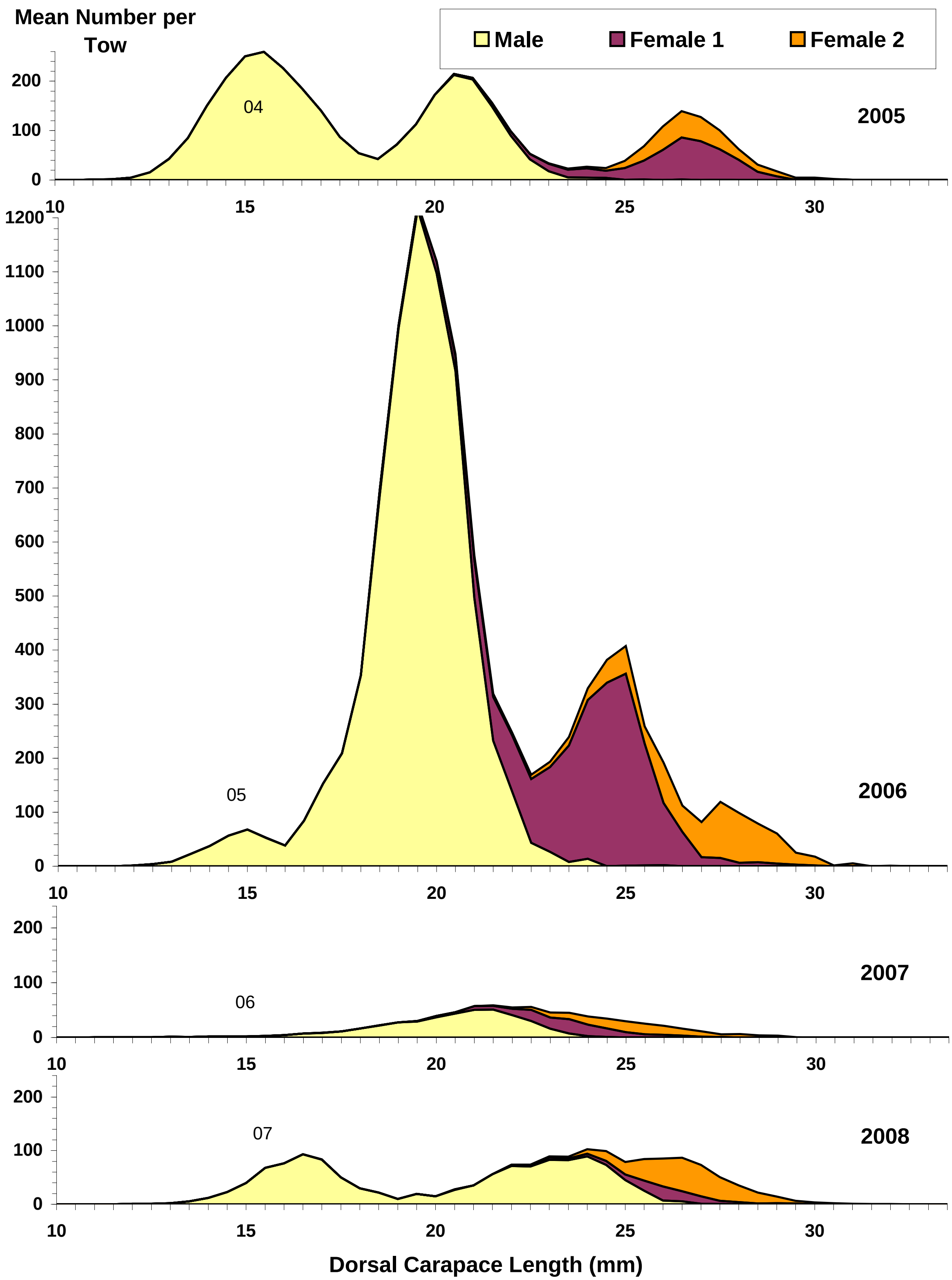


Figure 11 continued – summer survey.

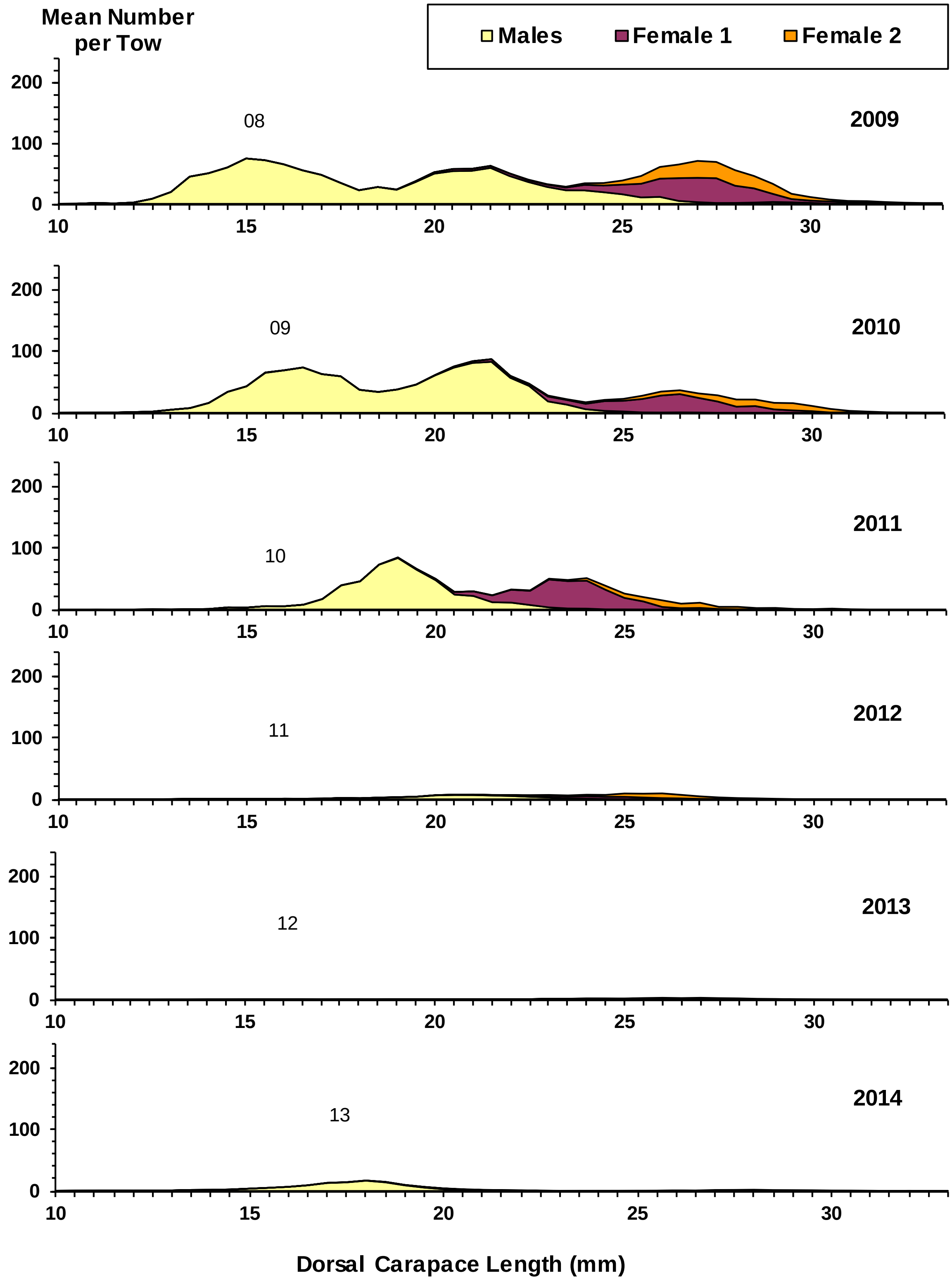


Figure 11 continued – summer survey.

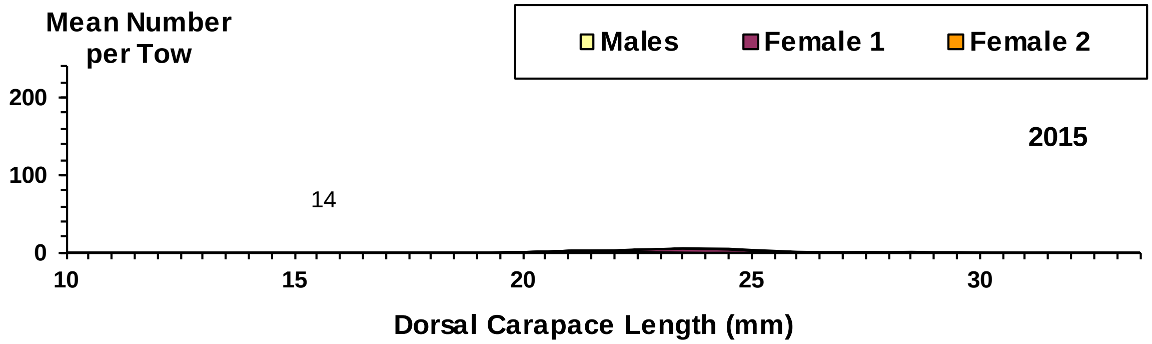


Figure 11 continued – summer survey.

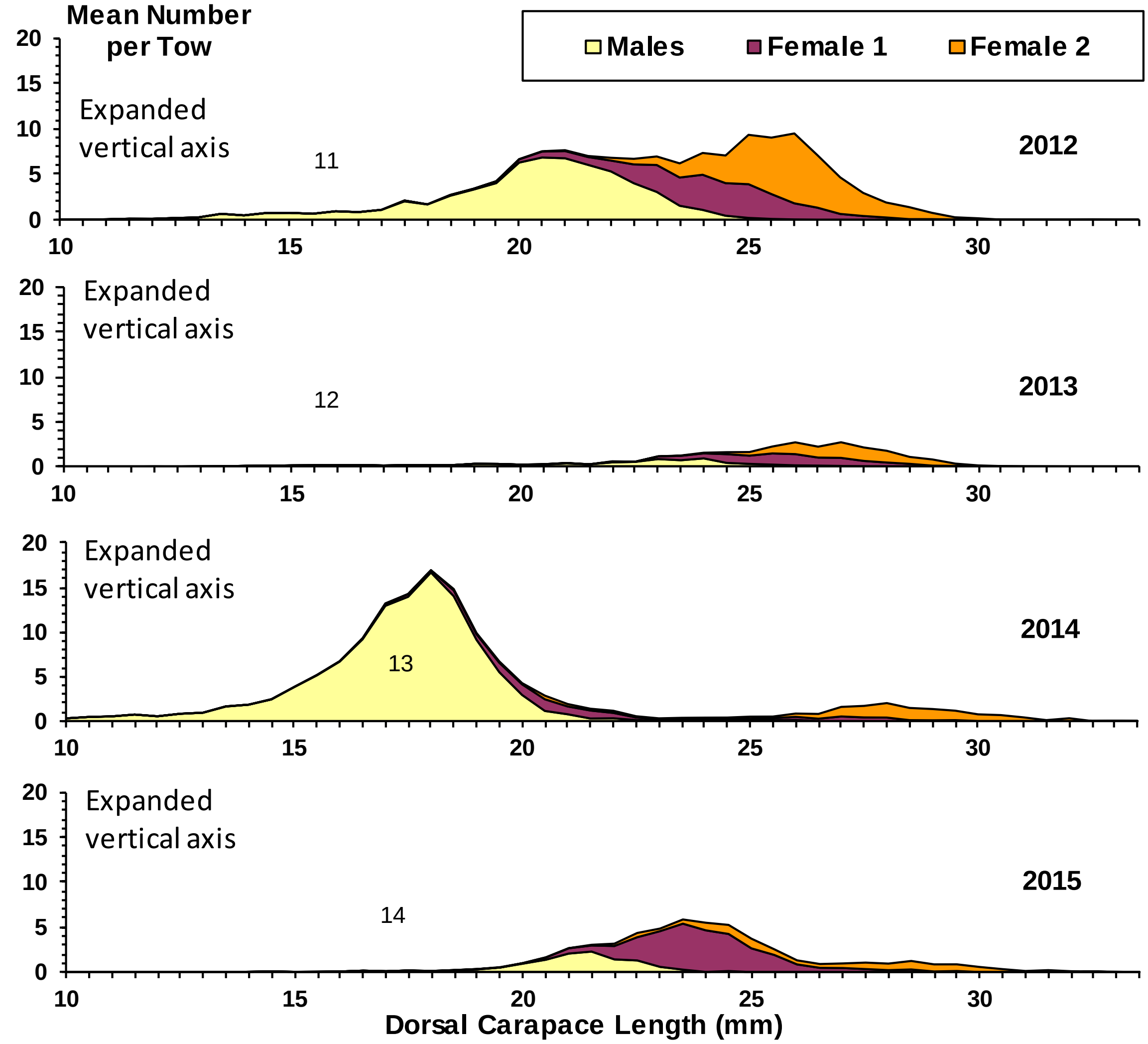


Figure 12: Gulf of Maine Northern Shrimp summer survey mean catch per tow by year (2012–2015 only), length, and developmental stage, with expanded vertical axes. Two-digit years indicate the year class mode at assumed age 1.5.

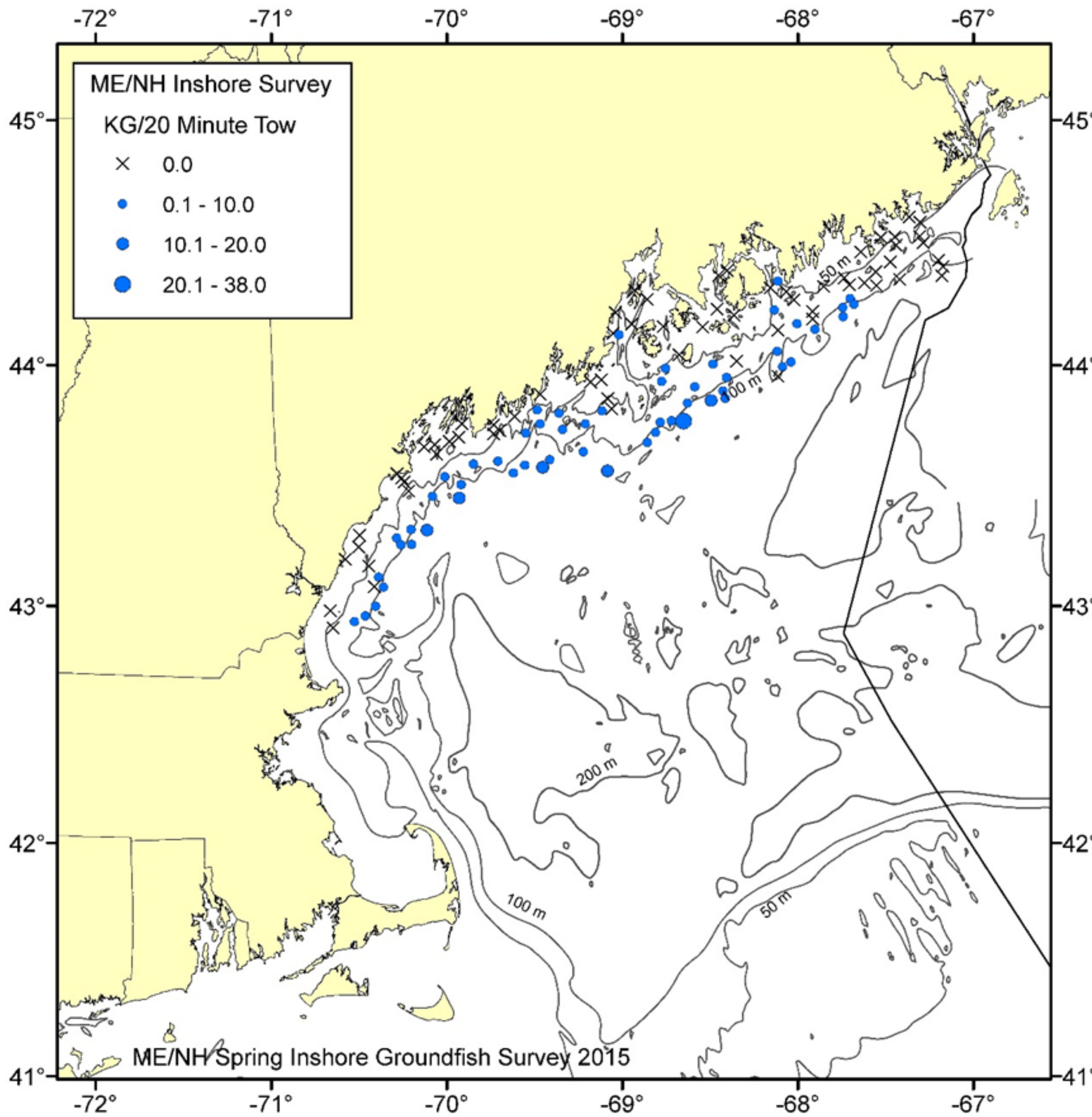
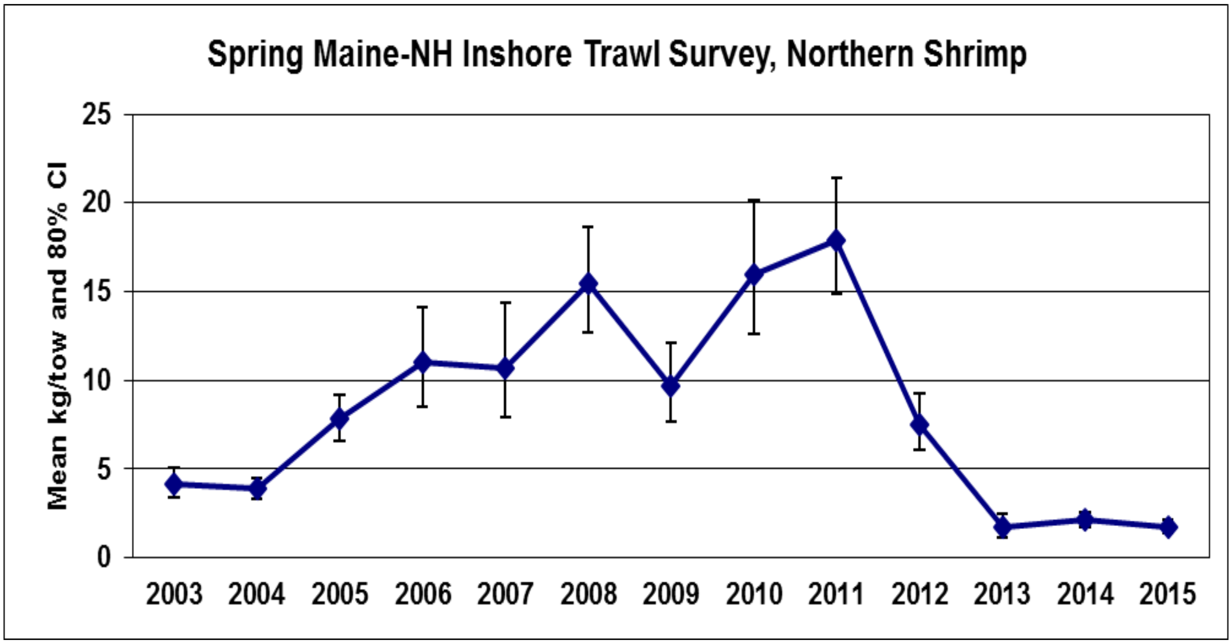


Figure 13: Distribution of Northern Shrimp catches (kg/tow) in the spring 2015 Maine-New Hampshire inshore trawl survey. Sites with "x" had less than 0.1 kg/tow.



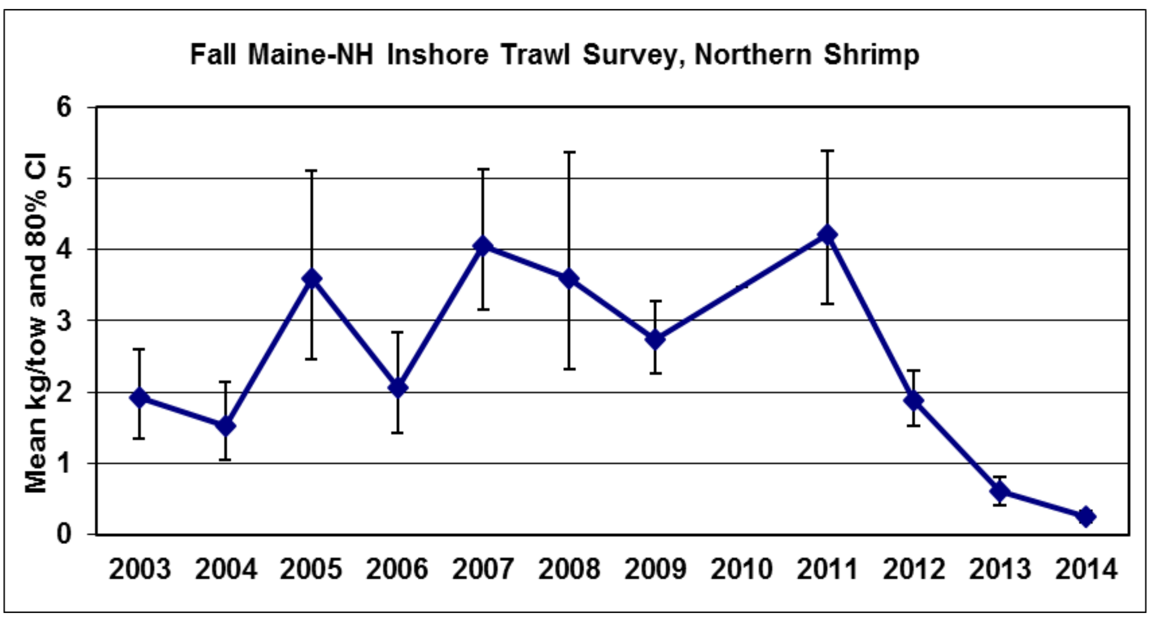


Figure 14: Maine-New Hampshire Spring (top) and Fall (bottom) inshore trawl survey biomass indices for Northern Shrimp with 80% confidence intervals. 2015 spring survey data are preliminary.

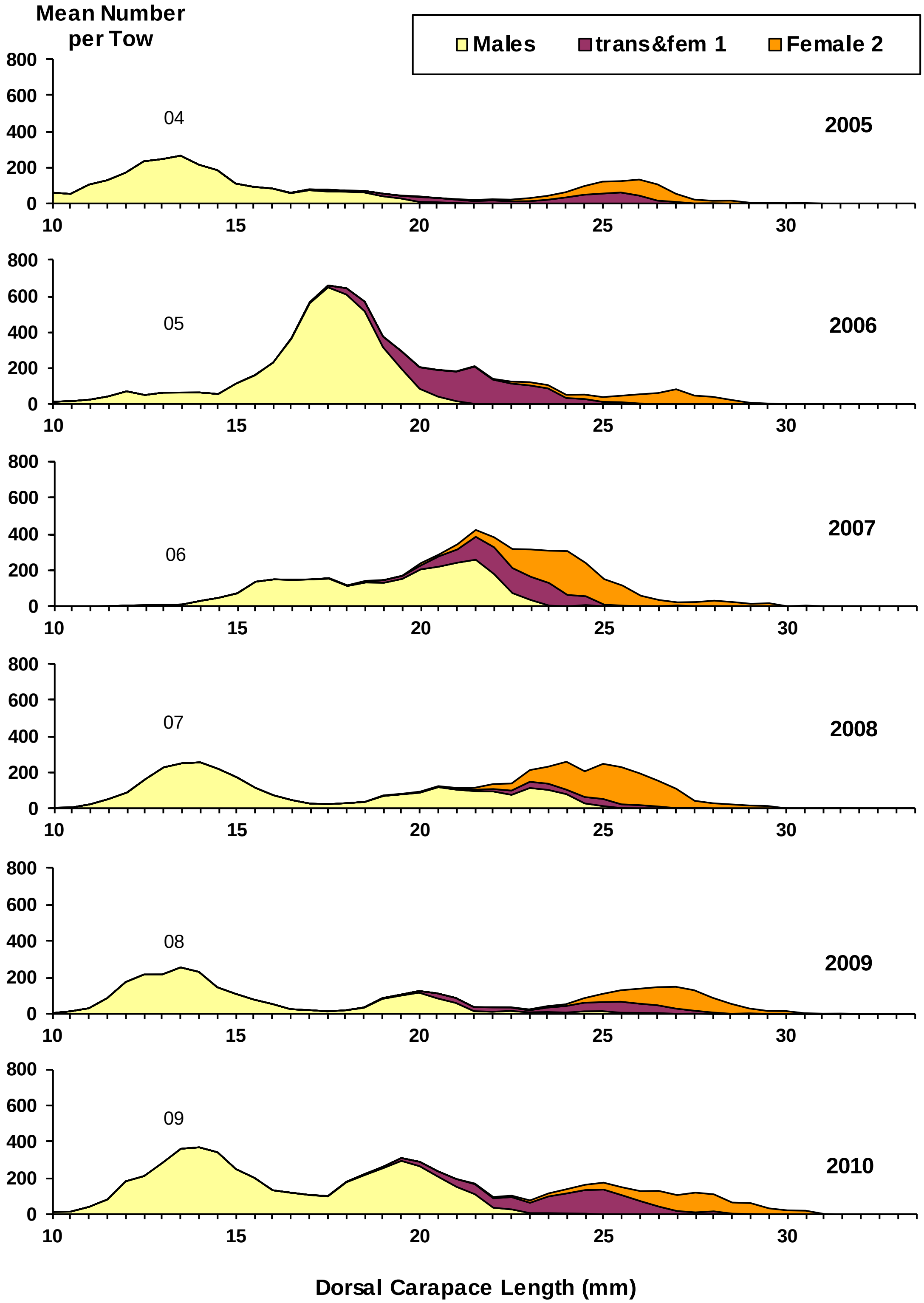


Figure 15: Maine-New Hampshire spring inshore survey mean catch per tow by year, length, and development stage. Two-digit years are the year class at assumed age 1.

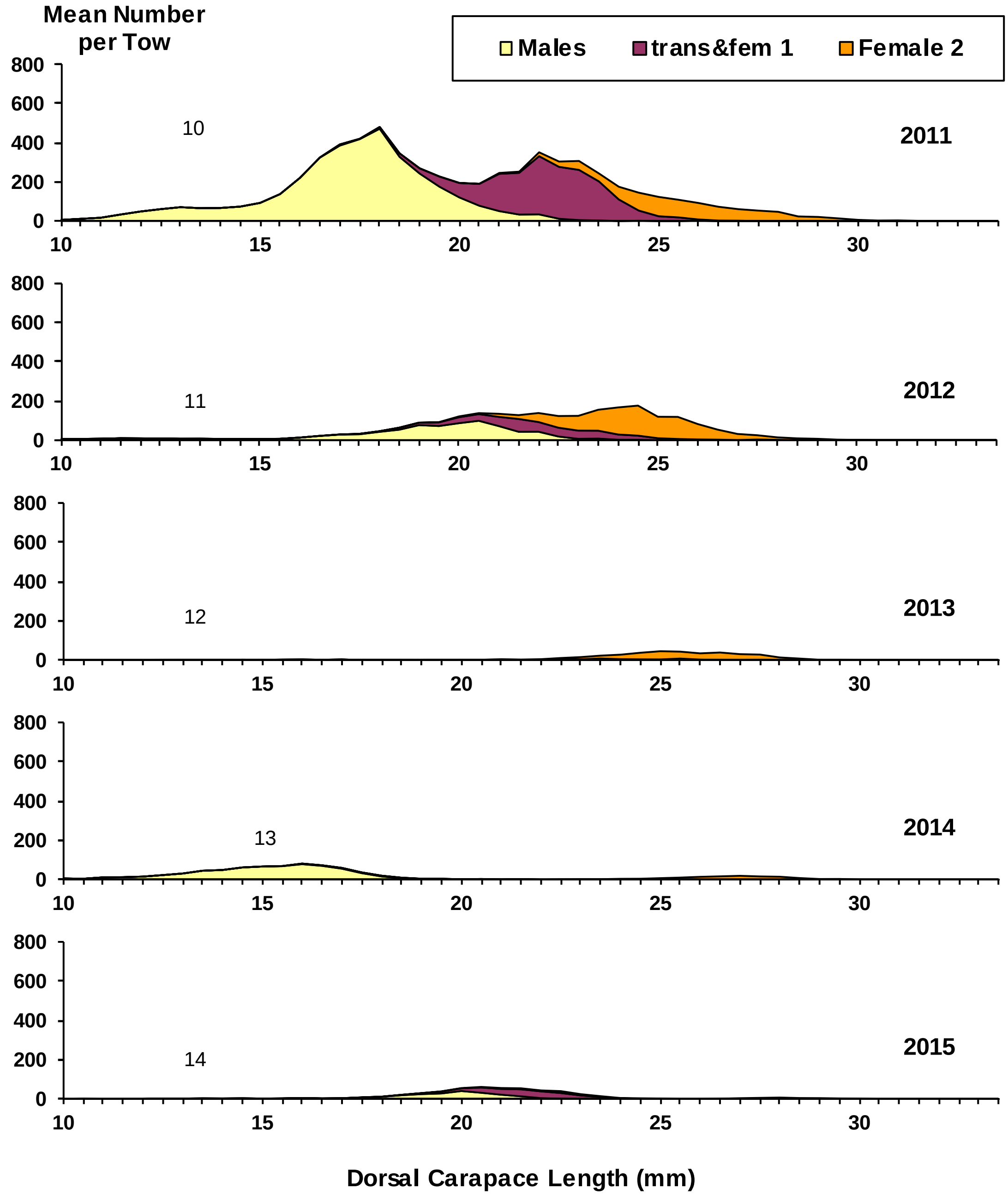


Figure 15 continued — ME/NH spring inshore survey. 2015 data are preliminary.

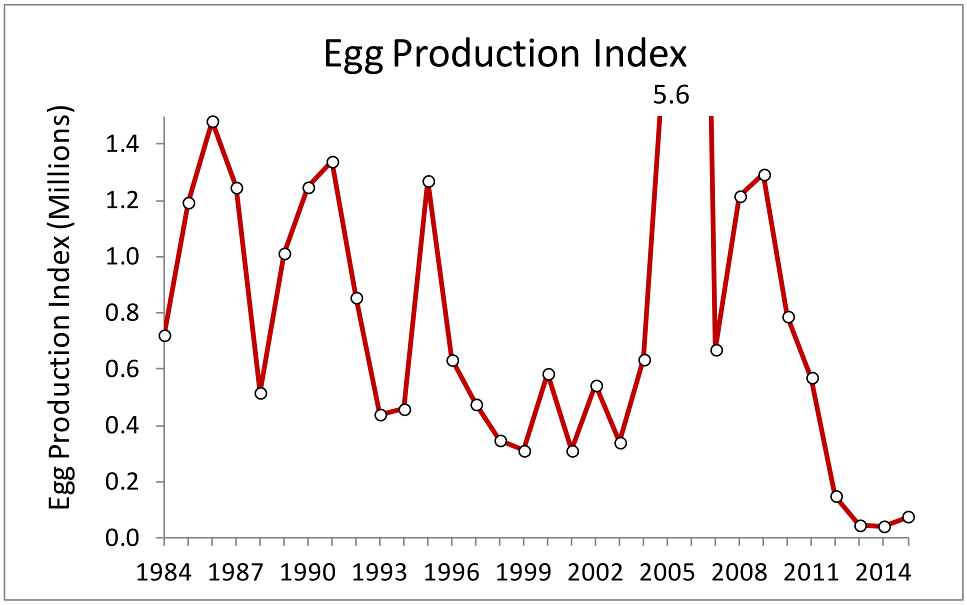


Figure 16: Egg production index for Gulf of Maine Northern Shrimp based on stratified mean number of females at length from the summer shrimp survey and estimated fecundity at length (Haynes and Wigley 1969). Index for 2006 (off scale) was 5.6 million.

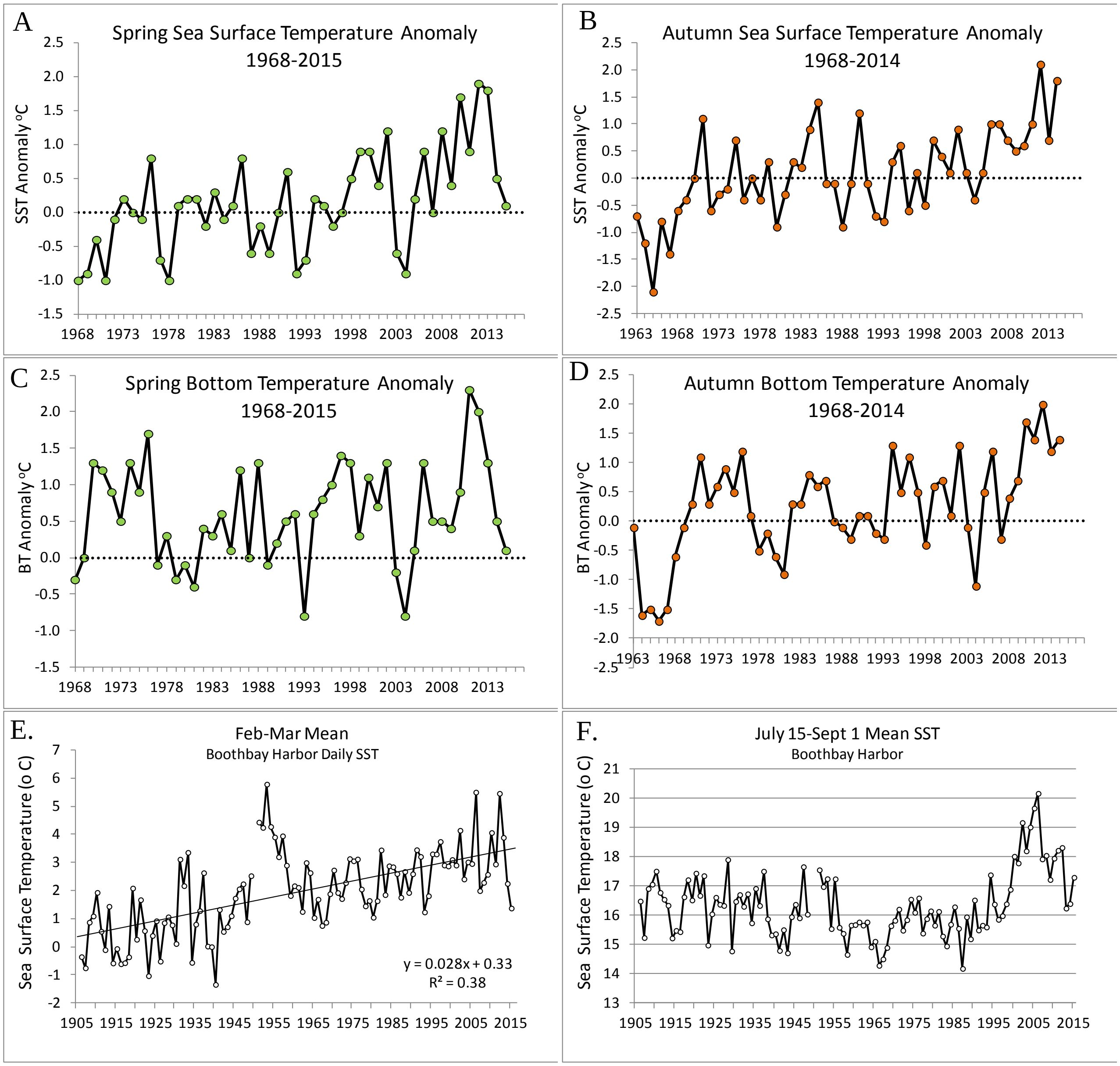
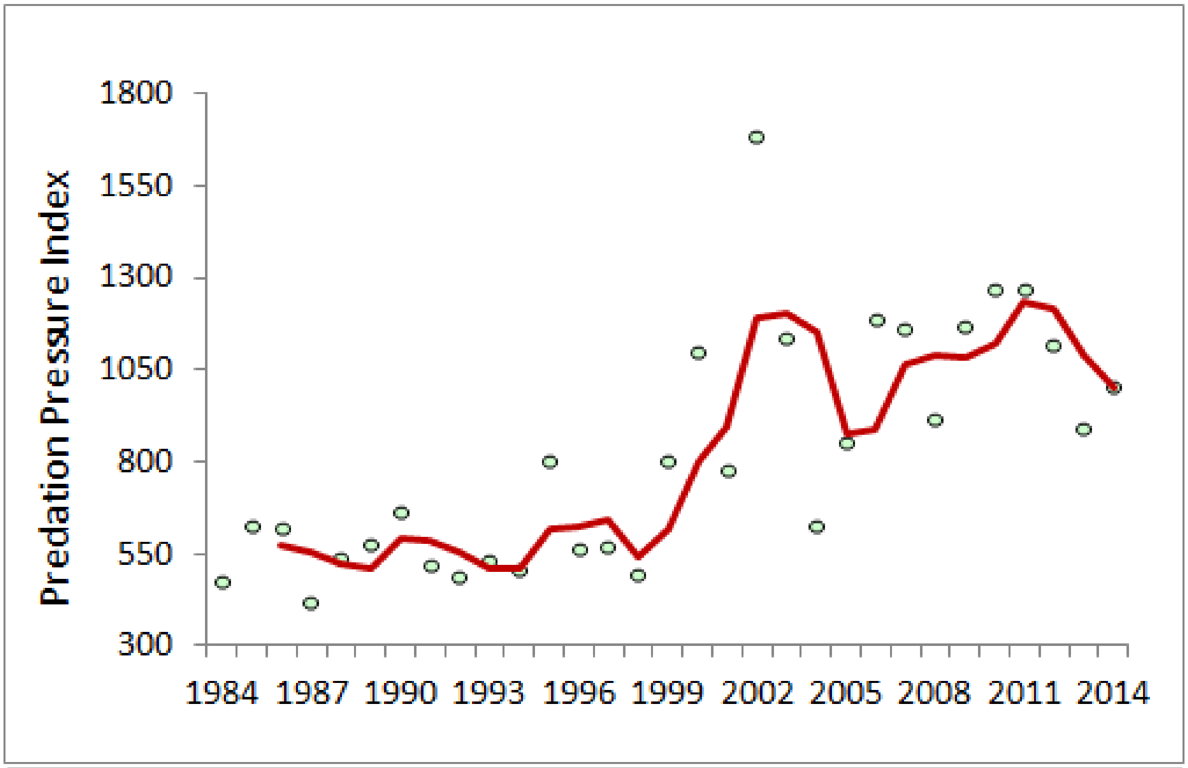


Figure 17: Temperature anomalies in the Gulf of Maine. (A) and (B) — spring and autumn sea surface temperature and anomaly in shrimp offshore habitat areas from NEFSC trawl surveys, 1968–2015 (through 2014 for autumn temperatures). (C) and (D) — spring and autumn bottom temperature anomaly in shrimp offshore habitat areas from NEFSC trawl survey, 1968–2015 (through 2014 for autumn temperature). (E) and (F) — average sea surface temperature during February–March and July 15–September 1 at Boothbay Harbor, Maine, 1906–2015.



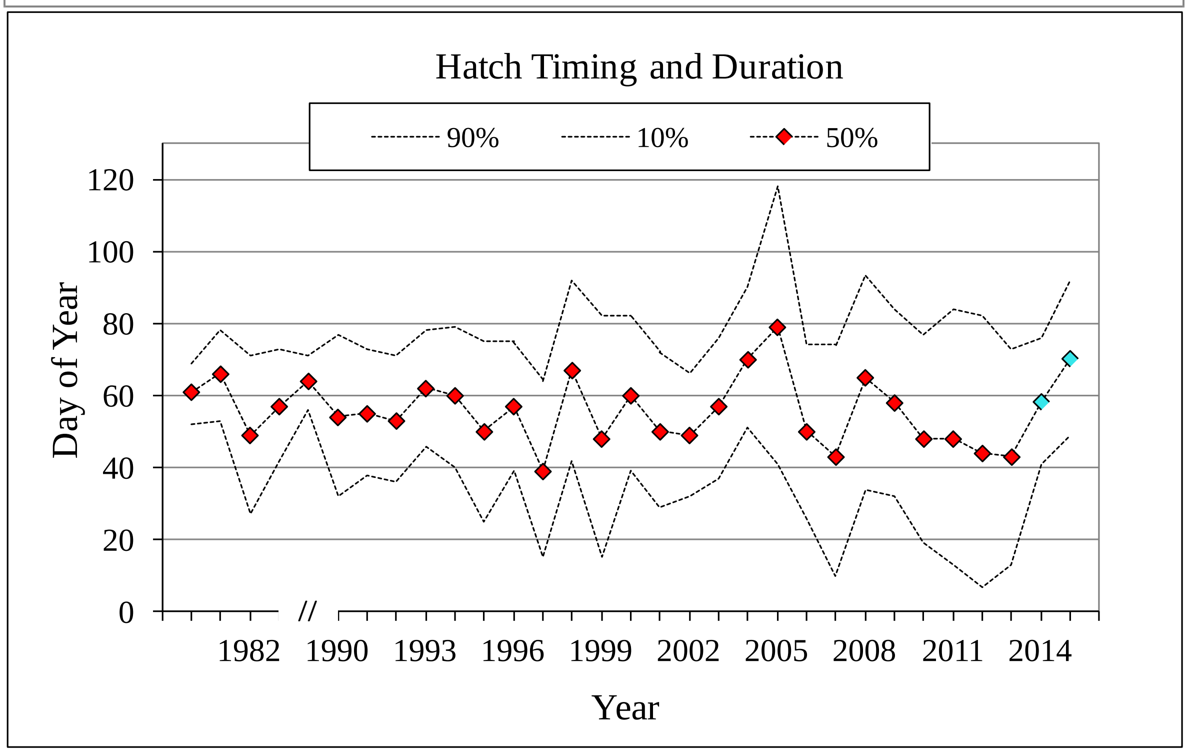


Figure 18: Predation pressure index (top) and hatch timing and duration (bottom) for Northern Shrimp in the Gulf of Maine.

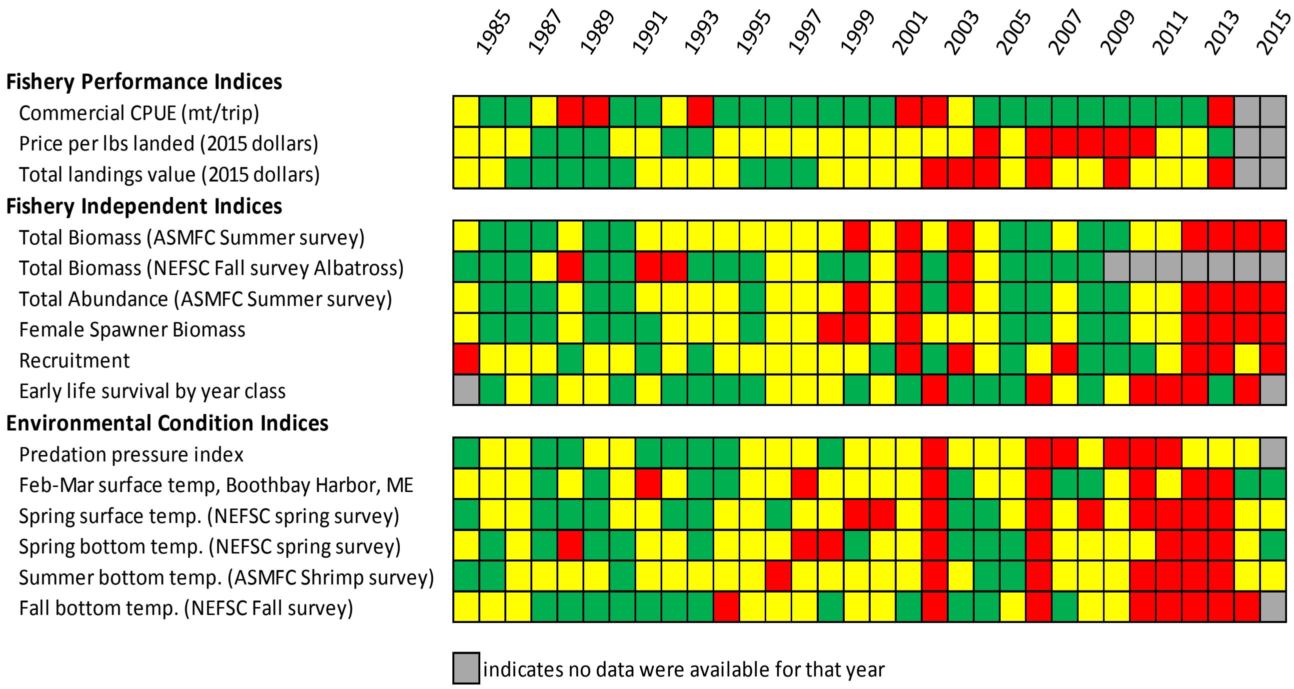


Figure 19: Strict Traffic Light Approach (STLA) results. Red indicates unfavorable conditions or status, yellow indicates intermediate values, and green indicates favorable conditions or status.

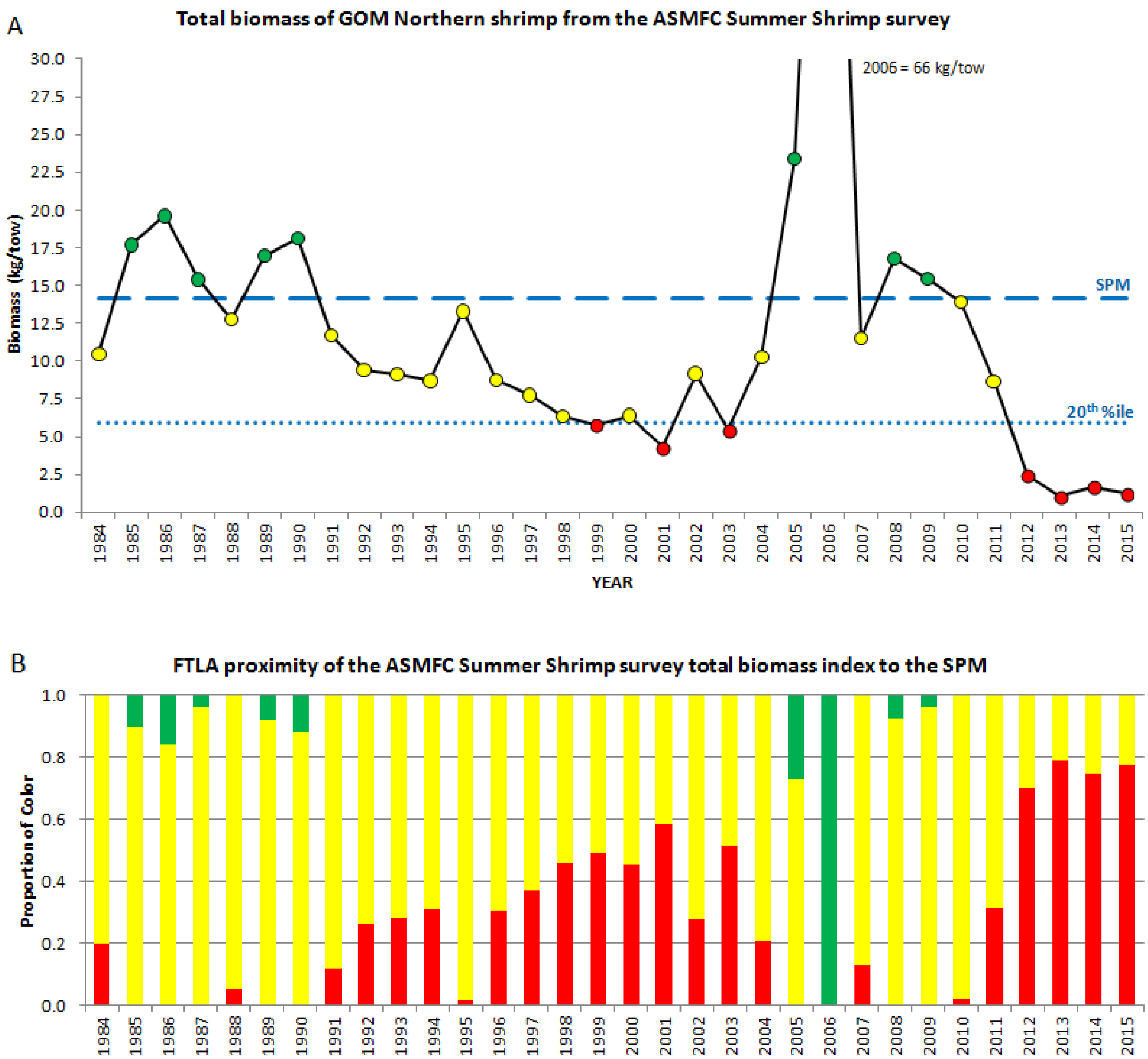


Figure 20: (A) Total biomass of Gulf of Maine Northern Shrimp from the ASMFC Summer Shrimp survey 1984–2015, with the 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≥ SPM; red values ≤ 20th percentile; yellow values > 20th percentile and < SPM. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

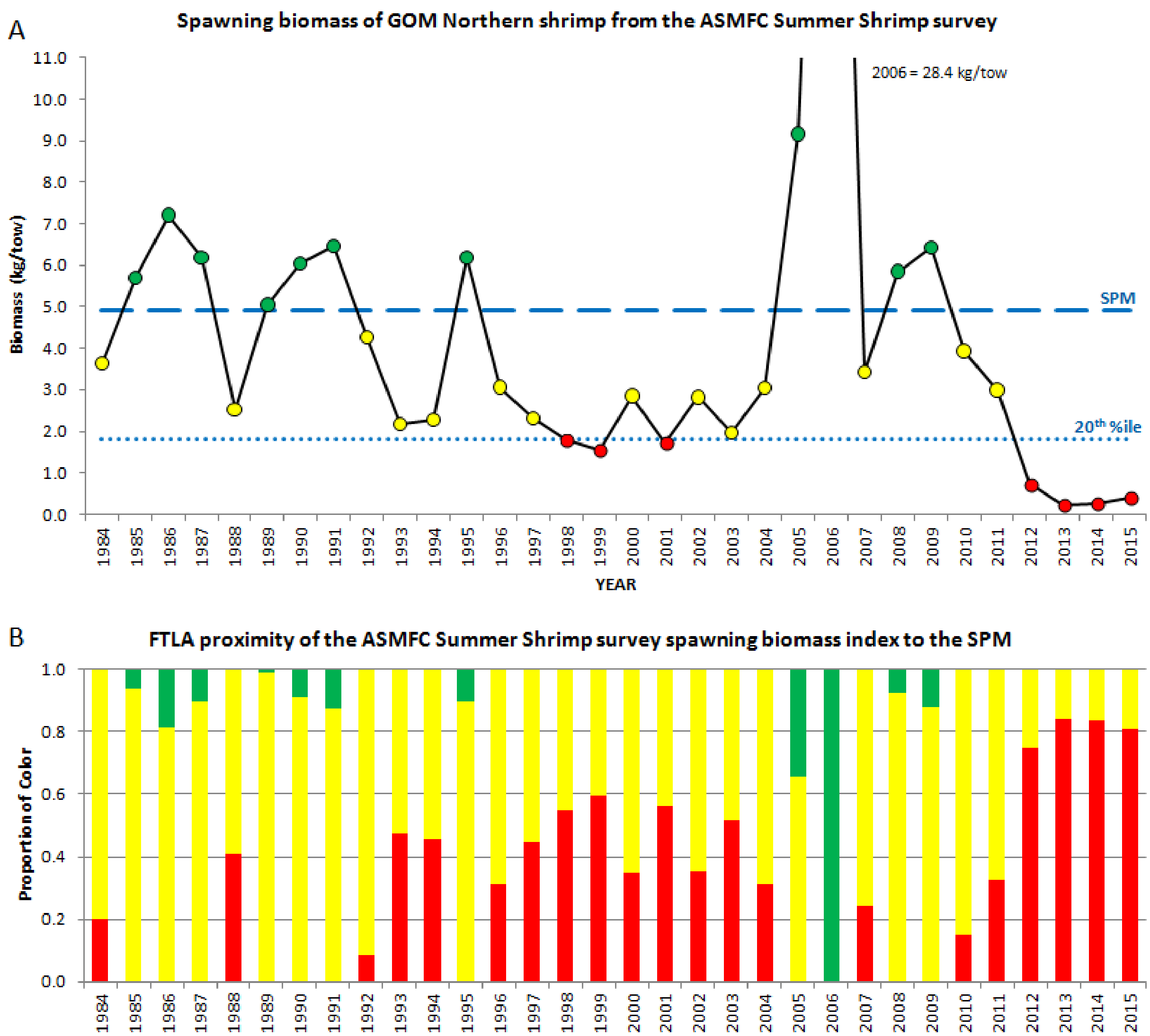


Figure 21: (A) Spawning biomass of Gulf of Maine Northern Shrimp from the ASMFC Summer Shrimp survey 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≥ SPM; red values ≤ 20th percentile; yellow values > 20th percentile and < SPM. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

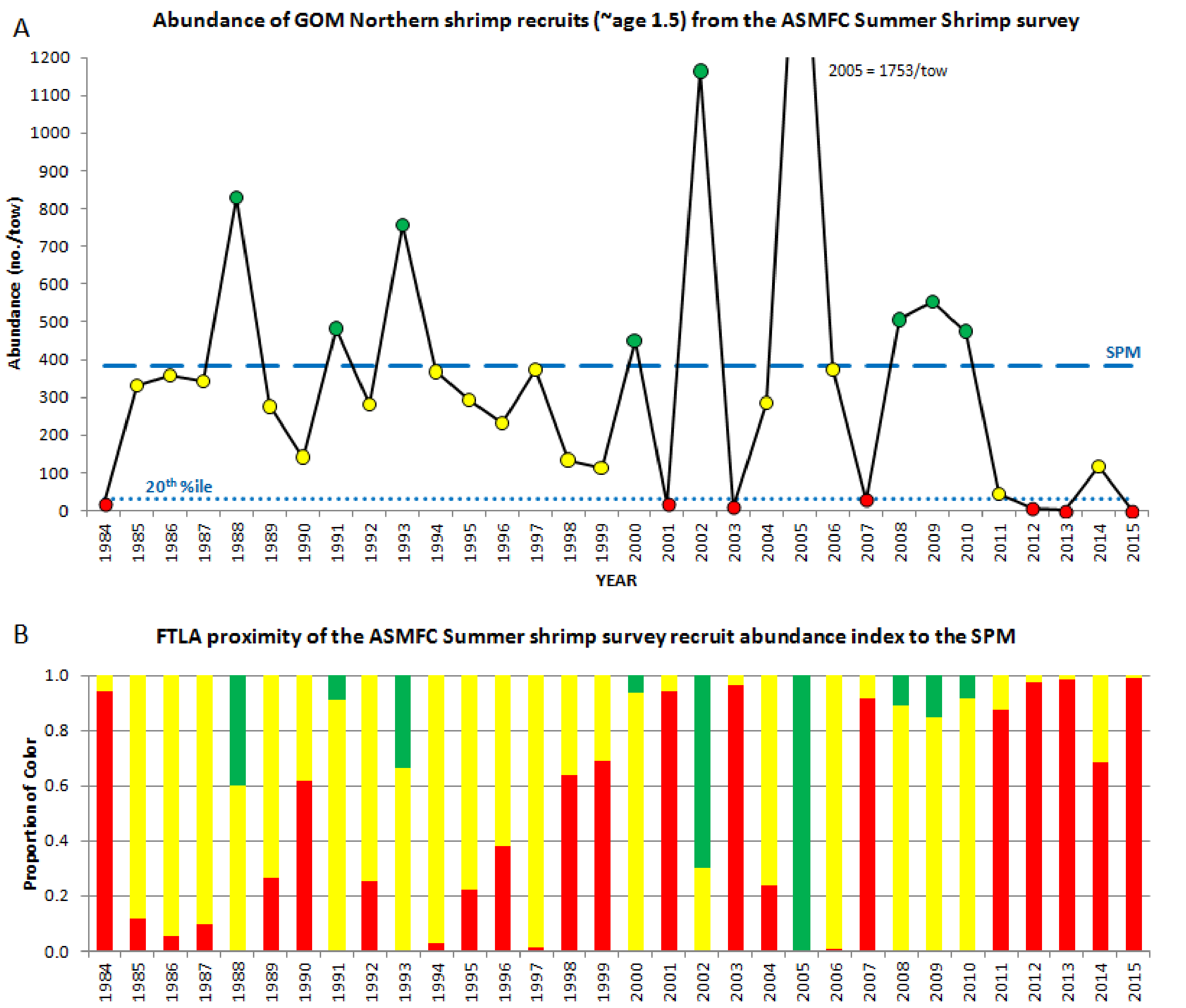


Figure 22: (A) Recruit abundance of Gulf of Maine Northern Shrimp from the ASMFC Summer shrimp survey 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≥ SPM; red values ≤ 20th percentile; yellow values > 20th percentile and < SPM. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

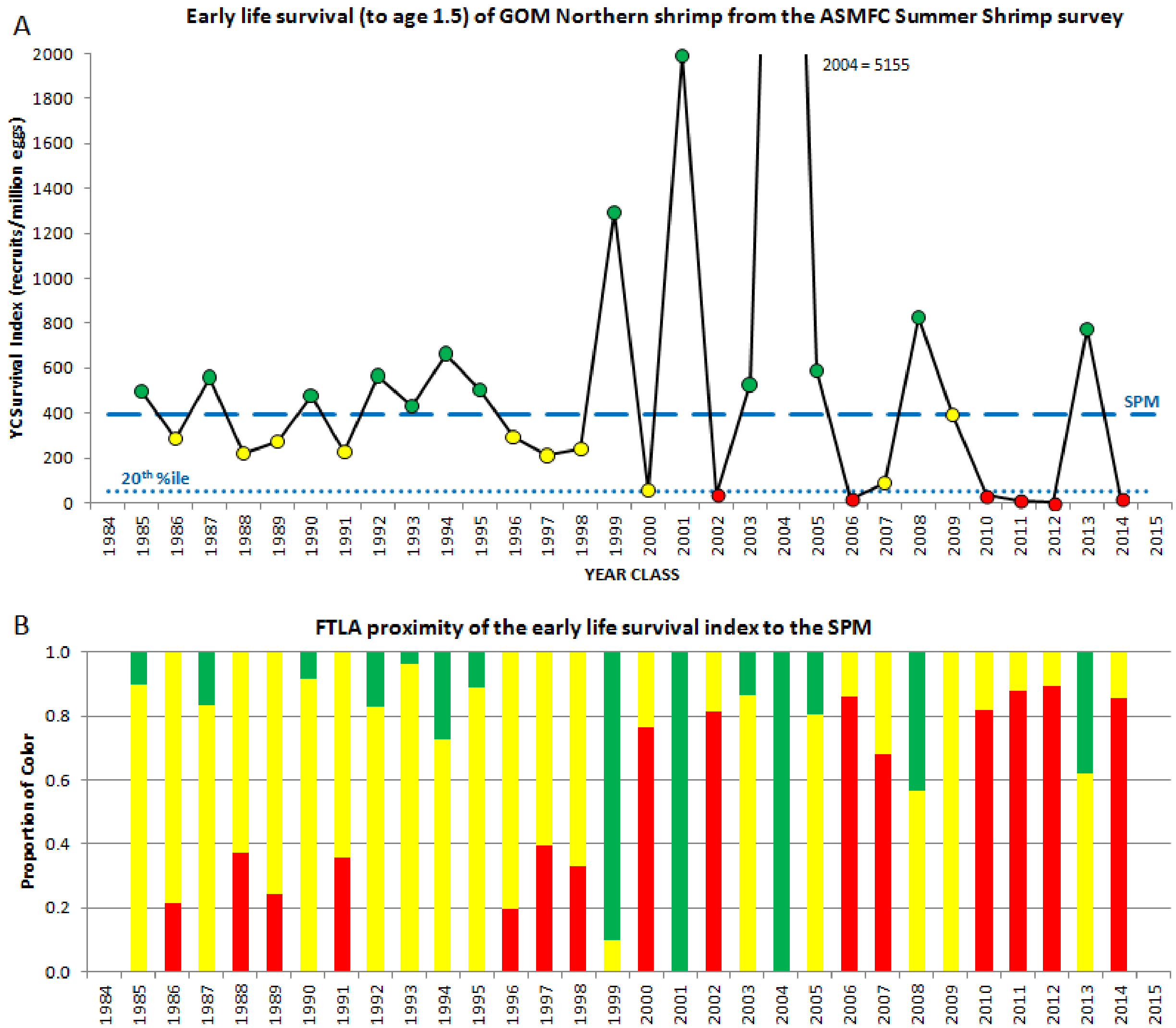


Figure 23: (A) Early life survival (to age 1.5) by year class of Gulf of Maine Northern Shrimp from the ASMFC Summer Shrimp survey 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series by year class 1985–2014 (dotted) indicated. Green values ≥ SPM; red values ≤ 20th percentile; yellow values > 20th percentile and < SPM. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

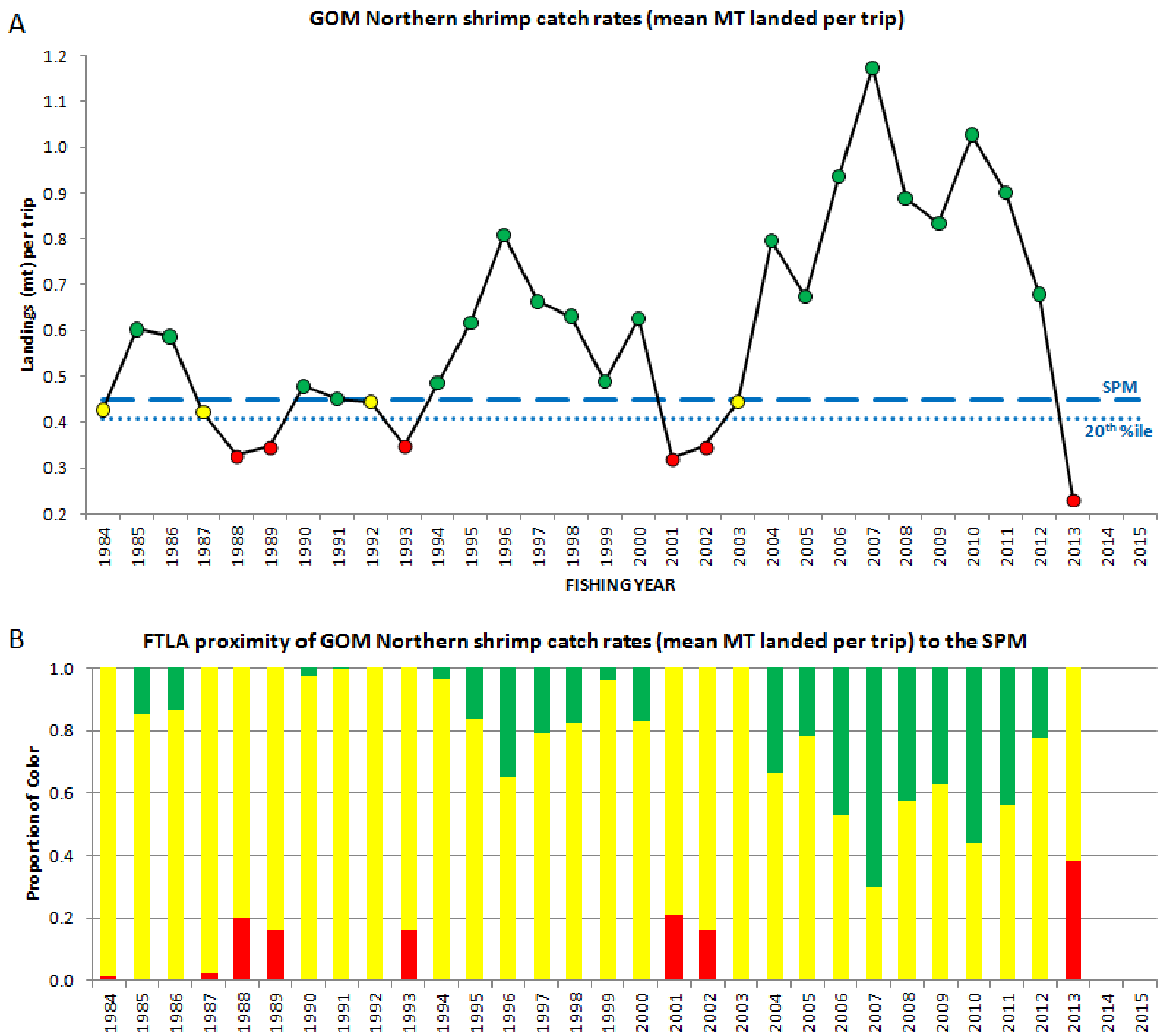


Figure 24: (A) Gulf of Maine Northern Shrimp fishery catch rates (mt of landings per trip) by fishing year from 1984–2013 (fishery closed 2014–2015), with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2013 (dotted) indicated. Green values ≥ SPM; red values ≤ 20th percentile; yellow values > 20th percentile and < SPM. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

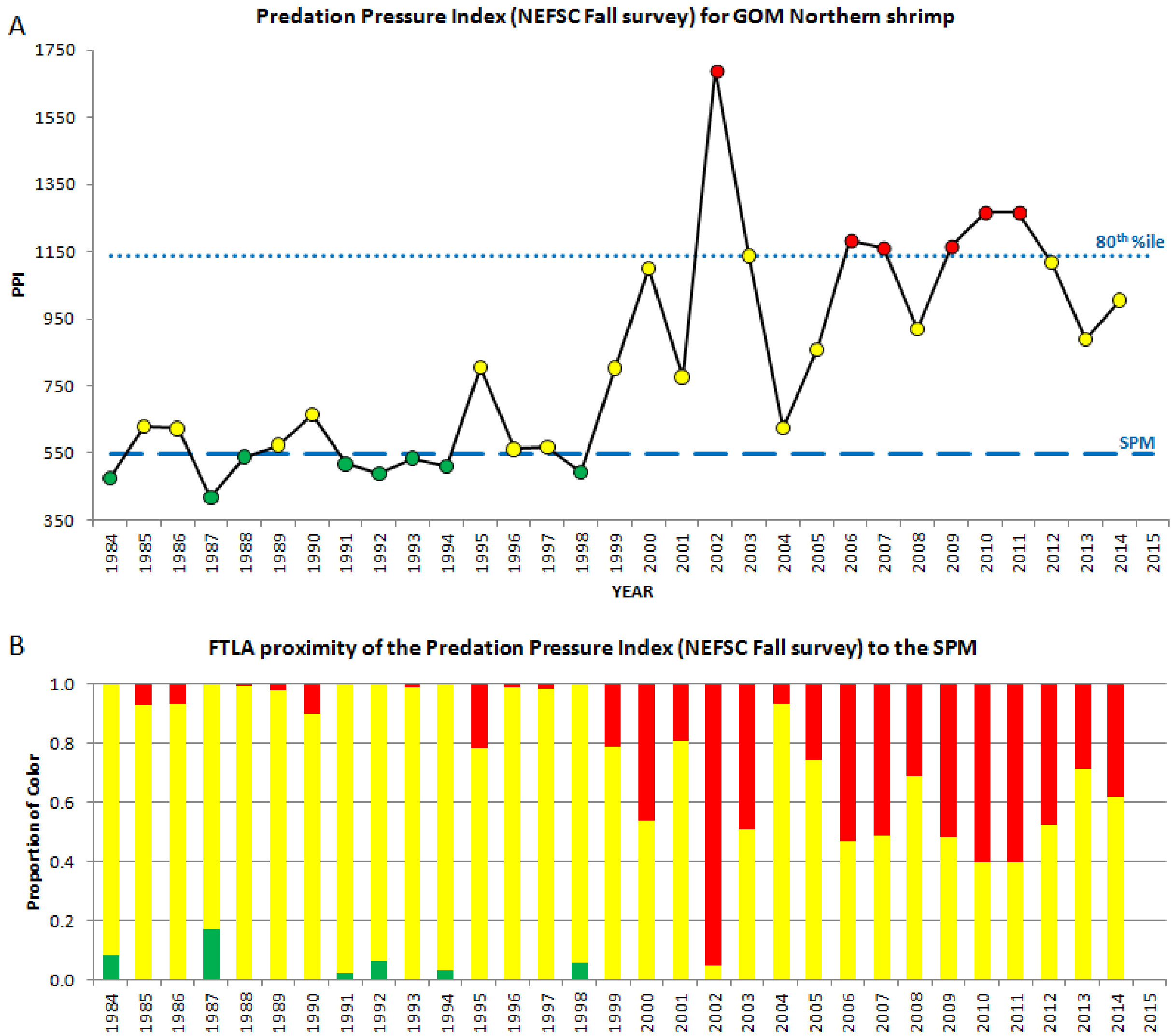
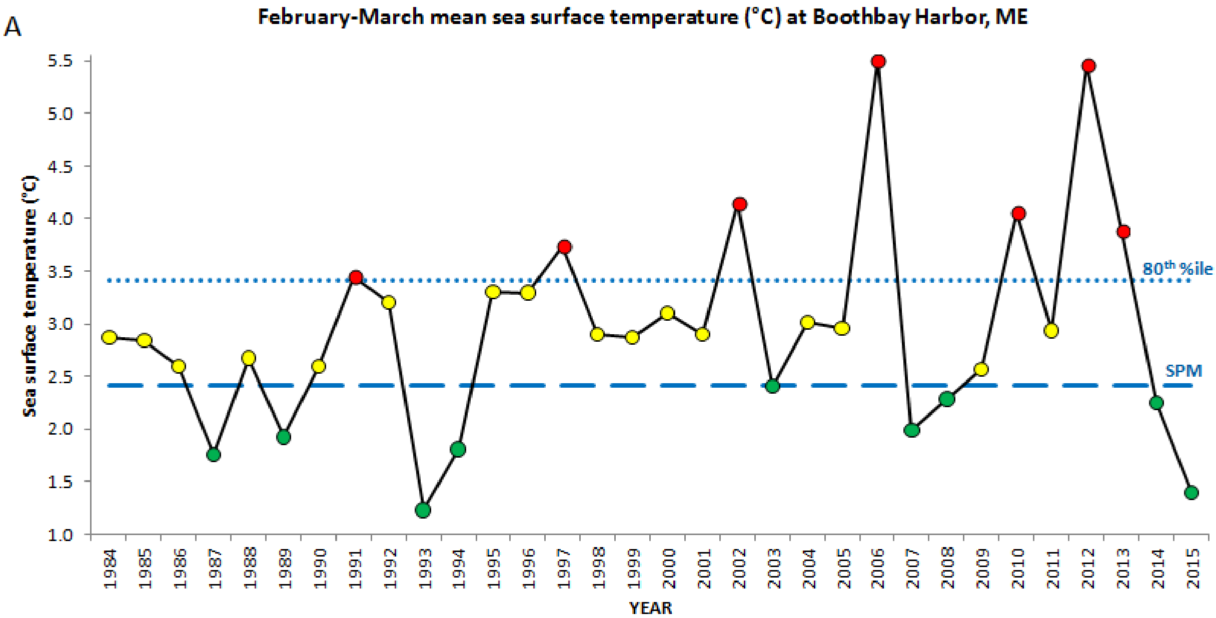


Figure 25: (A) Predation Pressure Index (PPI) for Gulf of Maine Northern Shrimp from 1984–2014, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2014 (dotted) indicated. Green values ≤ SPM; red values ≥ 80th percentile; yellow values > SPM and < 80th percentile. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

A



B

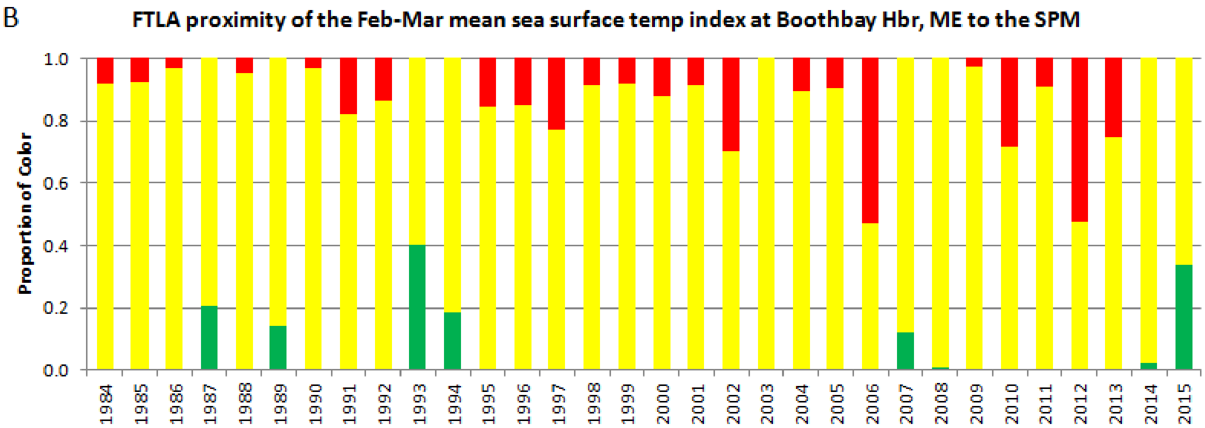


Figure 26: (A) February to March mean sea surface temperature (°C) at Boothbay Harbor, ME from 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≤ SPM; red values ≥ 80th percentile; yellow values > SPM and < 80th percentile. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

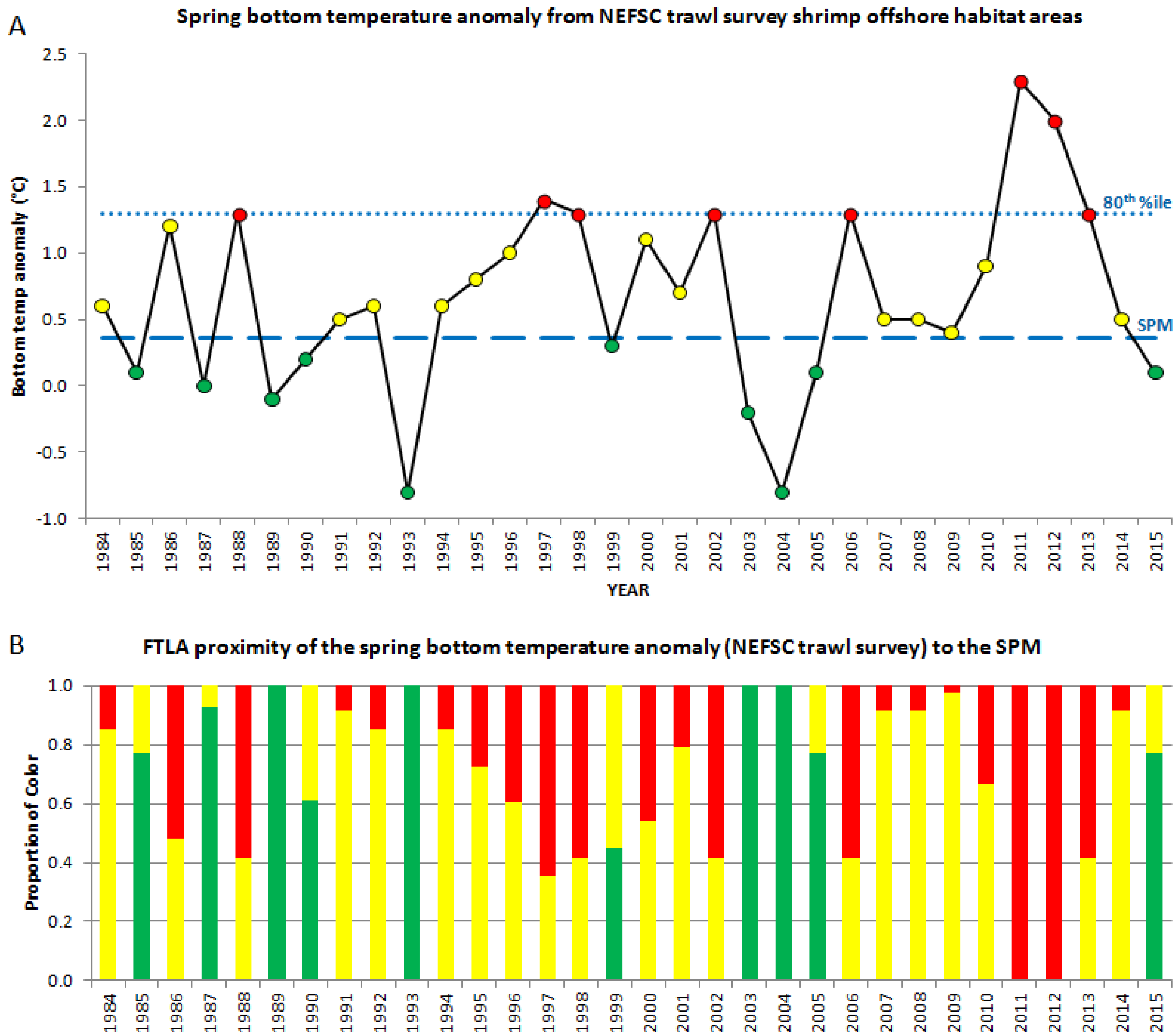


Figure 27: (A) Spring bottom temperature anomaly (°C) from the NEFSC trawl survey in shrimp offshore habitat areas from 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≤ SPM; red values ≥ 80th percentile; yellow values > SPM and < 80th percentile. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

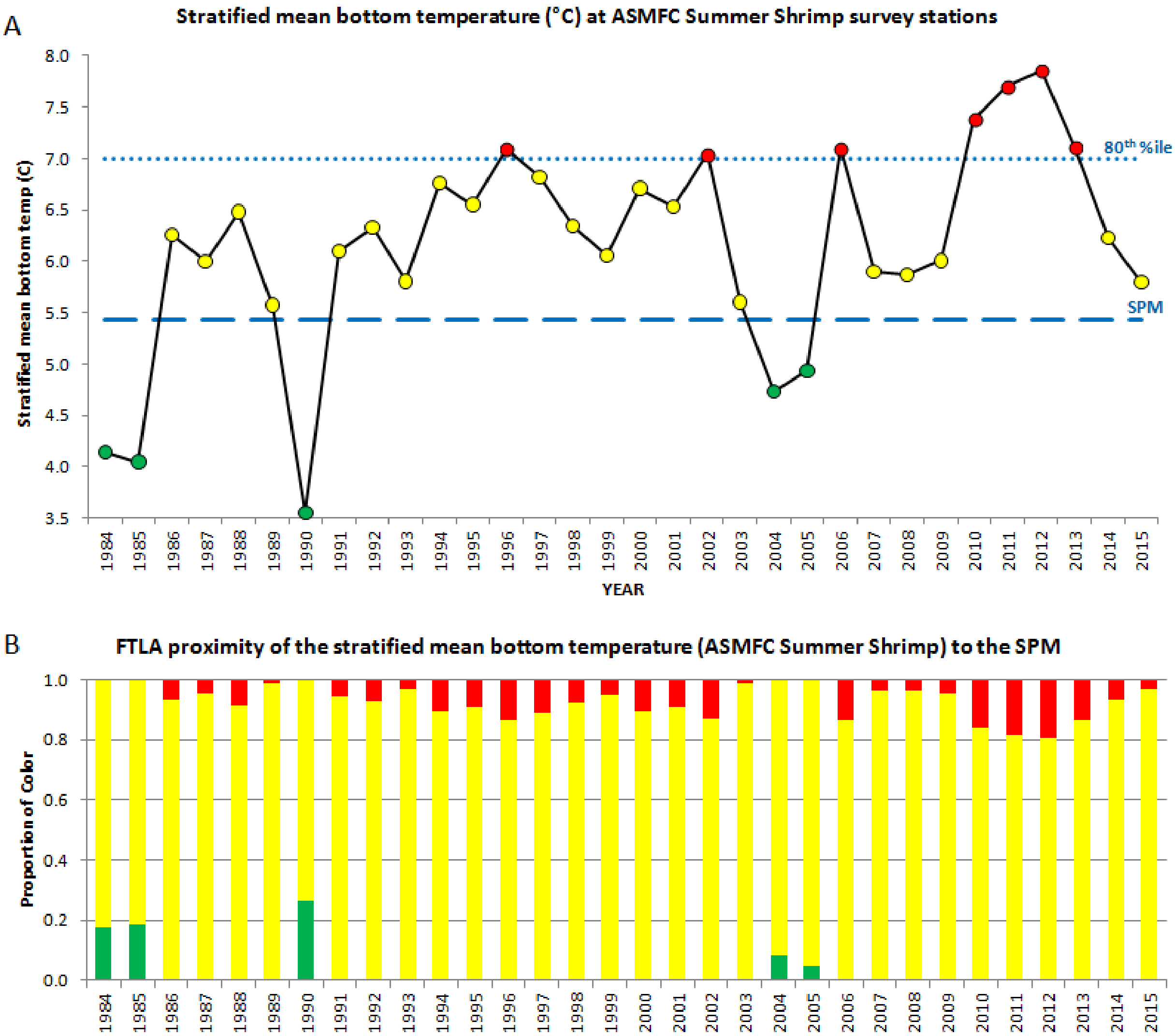


Figure 28: (A) Summer stratified mean bottom temperature (°C) at ASMFC Summer Shrimp survey stations from 1984–2015, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2015 (dotted) indicated. Green values ≤ SPM; red values ≥ 80th percentile; yellow values > SPM and < 80th percentile. (B) Fuzzy Traffic Light Analysis (FTLA) color proportions indicate proximity of annual indices to the SPM (red = unfavorable; green = favorable).

Appendix 1. NSTC recommendations made and actions taken by the ASMFC Northern Shrimp Section for management of the Gulf of Maine northern shrimp fishery, 1987– 2015 (adapted from 58th SAW Report, NEFSC 2014).

Fishing Season	Recommendations	Actions Taken
1987	• Extension of season to maximum allowed • Continuation of mesh regulations	• Open season (182 days) • Continuation of mesh regulations
1988	• Restriction of season to winter and spring • Continuation of mesh regulations	• Open season (183 days) • Continuation of mesh regulations, except 0.25 inch tolerance in codend eliminated
1989	• Extension of season to maximum allowed • Continuation of mesh regulations	• Open season (182 days) • Continuation of mesh regulations • Shrimp separator trawls required in April and May
1990	• Extension of season to maximum allowed • Continuation of mesh regulations	• Open season (182 days) • Continuation of mesh regulations • Shrimp separator trawls required in December, April, and May
1991	• Extension of season to maximum allowed • Continuation of mesh regulations	• Open season (182 days) • Continuation of mesh regulations • Shrimp separator trawls required throughout season
1992	• Restriction of season from January – March • Continuation of mesh regulations	• Open season (153 days). December 16, 1991 – May 15, 1992. • No fishing on Sundays • Continuation of mesh regulations • Shrimp separator trawls required throughout season • Finfish excluder devices required April 1 – May 15
1993	• Restriction of season from January – March • Continuation of mesh regulations	• Open season (138 days). December 14, 1992 – April 30, 1993 • No fishing on Sundays • Continuation of mesh regulations • Finfish excluder devices and separator panels required
1994	• Restriction of season from January – March • Continuation of mesh regulations	• Open season (122 days) December 15, 1993 – April 15, 1994. • Continuation of mesh regulations • Finfish excluder devices
1995	• Restriction of season from January – March • Continuation of mesh regulations	• Open season (128 days). December 1, 1994 – April 30, 1995. • No fishing Fridays or Sundays (state choice) • Continuation of mesh regulations • Finfish excluder devices required
1996	• Extension of season to maximum allowed • Continuation of mesh regulations	• Open season (152 days). December 1, 1995 – May 31, 1996 for mobile gear; no fishing one day per week. • Open season (121 days). January 1 – May 31, 1996 for fixed gear (traps) • Continuation of mesh regulations • Finfish excluder devices required
1997	• Restriction of effort in December, April, and May • Continuation of mesh regulations	• Open season (156 days). December 1, 1996 – May 31. Two 5-day and four 4-day blocks of no fishing. Trap gear may be left untended. • Finfish excluder devices required • Continuation of mesh regulations

1998	• Restriction of effort in February – March • Continuation of mesh regulations	• Open season (105 days). December 1, 1997 – May 22, 1998 for mobile gear; no fishing weekends except March 14 – 15 and December 25–31 and March 16 – 31. • Open season (65 days). January 1 – March 15 for trap
1999	• Restriction of season to 40 days during February – March • Continuation of mesh regulations	• Open season (90 days). December 15, 1998 – May 25, 1999 for mobile gear. No fishing on weekends plus December 24–25, December 28 – January 1, January 27–29, February 24–26, March 17–31, and April 29–30. • Open season (61 days). January 10 – March 10 for trap
2000	• No fishing; closed season	• Open season (51 days). January 15 – March 15. No fishing on Sundays. • Continuation of mesh regulations • Finfish excluder devices required
2001	• Restriction of season to 61 days • Continuation of mesh regulations	• Open season (83 days). January 9 – April 30. March 18–April 15 no fishing. Experimental offshore fishery in May. • Continuation of mesh regulations
2002	• No fishing; closed season	• Open season (25 days). February 15 – March 11. • Continuation of mesh regulations • Finfish excluder devices required
2003	• No fishing; closed season	• Open season (38 days). January 15 – February 27. No fishing on Fridays. • Continuation of mesh regulations • Finfish excluder devices required
2004	• No fishing; closed season	• Open season (40 days). January 19 – March 12. No fishing on weekends. • Continuation of mesh regulations • Finfish excluder devices required
2005	• Landings should not exceed 2,500 metric tons • Continuation of mesh regulations	• Open season (70 days). December 19 – 30, no fishing on Friday and Saturday; January 3 – March 25, no fishing on weekends. • Continuation of mesh regulations
2006	• Landings should not exceed 5,200 metric tons • Continuation of mesh regulations	• Open season (140 days). December 12 – April 30. • 2007 fishing season tentatively set at 140 days. • Continuation of mesh regulations • No mechanical shakers allowed on vessel
2007	• No recommendation against 140-day season • Continuation of mesh regulations	• Open season (151 days). December 1 – April 30. • 2008 fishing season tentatively set at 151 days. • Continuation of mesh regulations • No mechanical shakers allowed on vessel
2008	• No recommendation against 152-day season • Maintain fishing mortality at or below the target/threshold	• Open season (152 days). December 1 – April 30. • 2009 fishing season tentatively set from December to April • Continuation of mesh regulations
2009	• Landings should not exceed 5,103 metric tons • Maintain fishing mortality at or below the target/threshold	• Open season (180 days). December 1 – May 29. • Continuation of mesh regulations • No mechanical shakers allowed on vessel
2010	• Landings should not exceed 4,400 to 4,900 metric tons • Maintain fishing mortality at or below the target/threshold	• Open season (180 days). December 1 – May 29. Closed early on May 5, 2010. • Continuation of mesh regulations • No mechanical shakers allowed on vessel

2011	• Based on favored fishing mortality rate, landings should not exceed 3,200 metrics tons (F = 0.22) or 4,000 metric tons (F = 0.29)	• Open season (136 days). December 1 – April 15. Closed early on February 28, 2011. • Continuation of mesh regulations • No mechanical shakers allowed on vessel
2012	• Maintain fishing mortality at or below the target value (F = 0.32) • Landings should not exceed 1,834 metric tons	• Total allowable catch (TAC) of 2,000 metric tons; increased to 2,211 metric tons on January 20, 2012 • Trap season start on February 1 with a 1,000 pound landing limit per vessel per day
2013	• Moratorium on fishing • If fishing is allowed, start season after 50% of shrimp have hatched their brood	• TAC of 625 metric tons; divided 17% to trap fishery and 83% to trawl fishery • Trawl fishery start on January 22, 2013with two landings days
2014	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing
2015	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing

Appendix 2: Application of the Traffic Light Analysis Model for Developing Management Framework for Atlantic Croaker and Spot for the Atlantic States Marine Fisheries Commission.

Chris McDonough: South Carolina Dept. of Natural Resources
(Atlantic Croaker Technical Committee Chair)
Harry Rickabaugh: Maryland Dept. of Natural Resources

THIS DRAFT DOCUMENT WAS DEVELOPED FOR MANAGEMENT BOARD REVIEW AND DISCUSSION. THIS DOCUMENT IS NOT INTENDED TO SOLICIT PUBLIC COMMENT AS PART OF THE COMMISSION/STATE FORMAL PUBLIC INPUT PROCESS. COMMENTS ON THIS DRAFT DOCUMENT MAY BE GIVEN AT THE APPROPRIATE TIME ON THE AGENDA DURING THE SCHEDULED MEETING. IF APPROVED, A PUBLIC COMMENT PERIOD WILL BE ESTABLISHED TO SOLICIT INPUT ON THE ISSUES CONTAINED IN THE DOCUMENT.

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015.

The current management scheme for Atlantic croaker compares annual changes in various trigger indices with the previous two year's average index value. If the index value drops below 70% of the previous two year average, at a minimum examination of the data is required by the ASMC technical committee. For spot index values are compared to the 10^{th} percentile of the indices time series. If two of these indices (one of which must be an independent index) is below the 10^{th} percentile the plan review team is to recommend the Board consider management action.

This type of management trigger scheme does not illustrate long term declines or increases in stock since they don't make comparisons over longer time periods. Under the current trigger schemes, the high degree of variability in year to year index values results in rapid changes that make it difficult to respond to rapid decreases in the trigger indices beyond a general review by the TC or PRT because of the effort involved. In relatively short lived species like Atlantic croaker and spot it is not always necessary to respond to rapid annual changes in management index triggers but rather to persistent periodic declines that occur over several years. Declines that might occur over several years require close monitoring in order to anticipate when management action may be required. With this in mind, a management response scheme which uses techniques that illustrate multi-year changes and trends would be more useful than simply examining year to year changes against the previous year or 2 years or sharp declines in a single year compared to the time series. Knowing the level at which to respond or initiate some type of management action should be based on long term knowledge of general stock levels as well as how that stock has changed over time. The traffic light model offers the ability to illustrate changing trends based on relevant stock parameters based on historical abundance, life history parameters, and response to fishing pressure by using assessment based reference points.

The Traffic Light method was originally developed (Caddy and Mahon, 1995; Caddy, 1998, 1999) as a precautionary management framework for data poor fisheries whereby reference points could be developed that would allow for a reasonable level of resource management. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of different indicators of the state of either a fish population or a fishery. These indicators can be combined to form composite characteristics within similar categories and can include biological indicators such as growth and reproduction, population level indicators such as abundance and stock biomass estimates, or fishery indicators such as harvest/landings and fishing mortality.
However, each indicator must be evaluated separately in order to determine its appropriateness for use in a management scheme. The indicators we are interested in for this exercise are primarily abundance and harvest or landings indices as they are the primary trigger mechanisms used for evaluation of whether to implement management actions.

There are several different approaches that can be used for the traffic light method, but we are concerned with two:

1. ***Strict (regular) Traffic Light Method (STLA)***: This method uses defined reference points to designate the boundaries between green/yellow and yellow/red

and annual indicator values can only be assigned one color depending on where they fall relative to the boundary values.

2. ***Fuzzy Traffic Light Method (FTLA)***: This method uses a fuzzy logic model instead of a binary logic model such that the transitional color (yellow) can be expressed as the proportion of the neighboring color it is trending towards (yellow/red or yellow/green).

The tricky part is determining the reference points in relation to where the boundaries are placed between the color indicators (red, yellow, green). There are two types of reference points used in the system (Caddy & Mahon, 1995; Halliday et al., 2001):

1. ***Limit Reference Point*** (LRP): Typically, a LRP is associated with an unacceptable outcome as when an indicator value may pass or cross from a yellow to red using the traffic light indicators.
2. ***Target Reference Point*** (TRP): This defines a desirable condition or status of a stock. However, this is not the yellow/green boundary, but rather a point where some indicator demonstrates stock status has reached a desired objective (such as $F_{0.1}$ or a target SPR or SSB). Generally a TRP is acknowledged as the optimal balance point between conservation and economic benefit.

In order to tie these reference points together using the traffic light method, the LRP would be defined as the yellow/red boundary and the yellow/green boundary would be a predetermined value based on an acceptable or desired stock condition such as long term mean abundance values for a given indicator index. The yellow/green boundary should also be used to define a buffer zone between fully acceptable conditions and those that give warning of proximity to unacceptable conditions (yellow).

Establishing Reference Boundary Points

Strict Traffic Light Model (STLA)

The most commonly used method uses the data series long term mean to establish the yellow/green boundary. Any indicator value above this boundary would be considered green. The yellow/red boundary (LRP) would be based on a percentage of the average value (ex: 60%, which would represent a 40% decrease in CPUE from the index mean). This is most appropriate for data sets with a long time series (≥ 1 generation time period for a given species) which would more accurately illustrate population trends over multiple generations or year classes.

Figure 1 shows and example of the STLA strict model using catch effort data from the Southeast Atlantic Monitoring Area Program using Spot. Each year was given a color code based on the long term stratified catch mean of the series (green/yellow boundary) and 60% of the long term mean (yellow/red boundary). While the strict model clearly demonstrates periods of decline (yellow/red) and periods of higher abundance (green), it doesn't illustrate relative catch levels, annual changes or what is happening during the transitional years (yellow).

Figure 1. Strict Traffic Light Analysis Model for Spot from SEAMAP trawl survey

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
STLA																								

Another way to illustrate changing trends while incorporating the TLA designations can be seen in figure 2.

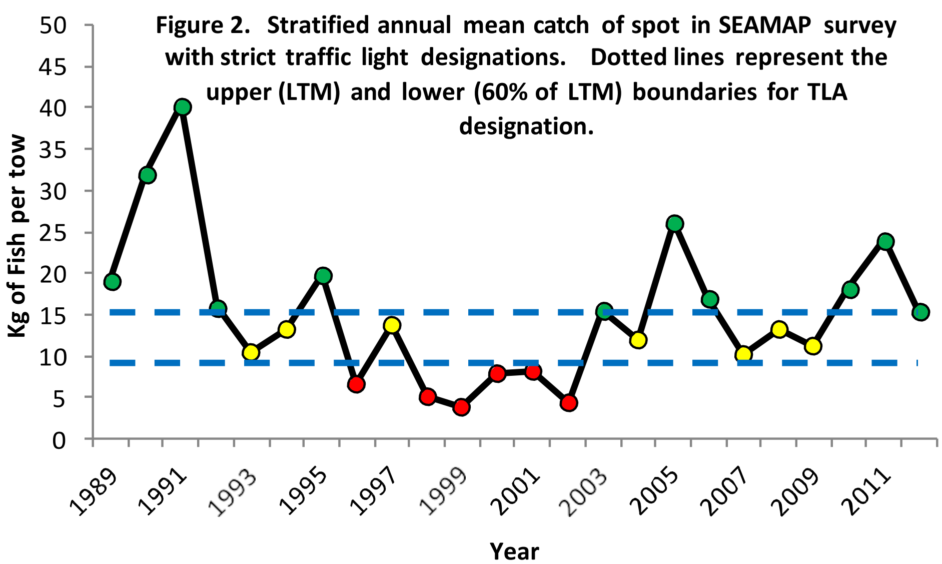


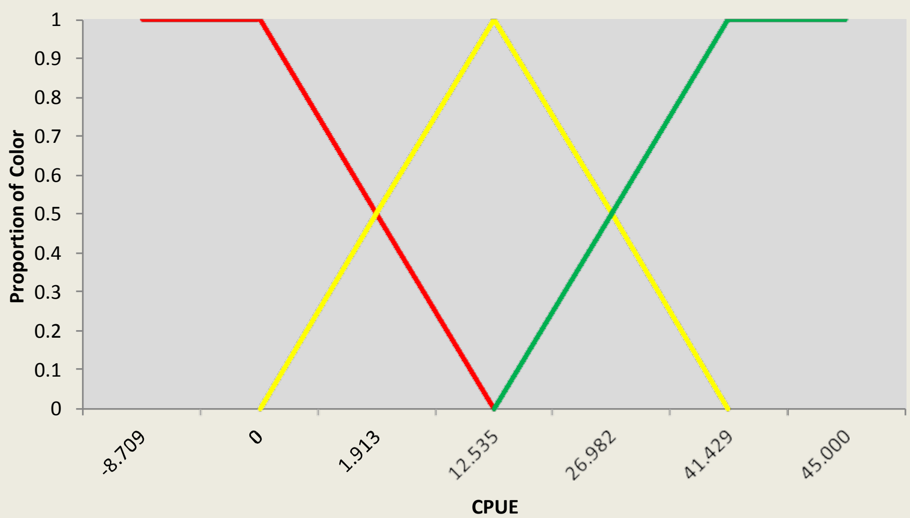
Figure 2. Stratified annual mean catch of spot in SEAMAP survey with strict traffic light designations. Dotted lines represent the upper (LTM) and lower (60% of LTM) boundaries for TLA designation.

This figure shows the annual STLA designations relative to where the actual boundaries are for a given level of catch effort while at the same time showing long term trends of relative declines (1991–2002) or increases (2002–2011). However, because of scalar differences, we aren't necessarily able to take this index and compare it directly with another index side by side. The primary limitation of the strict STLA model is that while it clearly shows changes in abundance relative to the reference boundaries (in this example), it doesn't illustrate the relative level of change within a given color outside of the reference boundaries.

Fuzzy Traffic Light Model (FTLA)

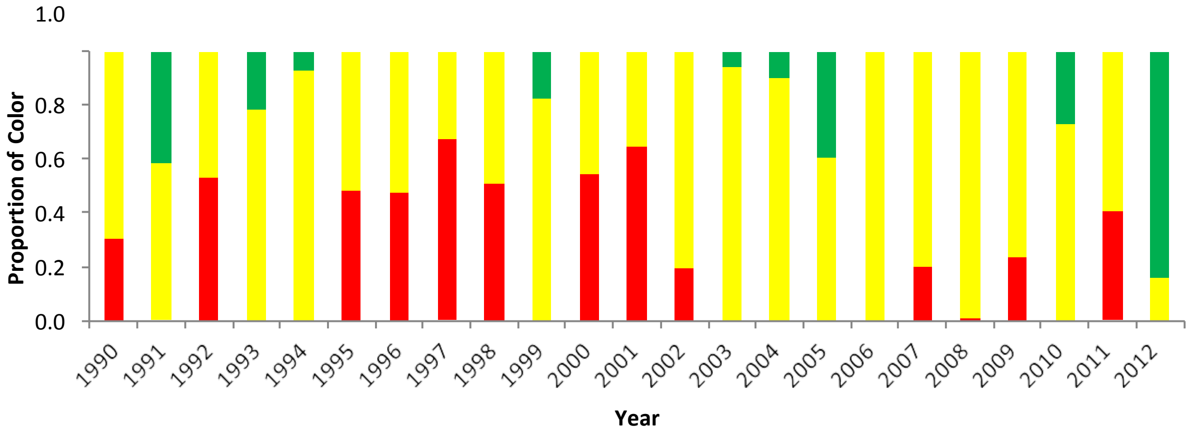
In the fuzzy traffic light model, we use the boundary reference points to determine the relative proportion of each color that includes the buffer (yellow) zone based on the upper and lower 95% confidence intervals from the index values for either the entire data series or a predetermined reference period (Halliday et al., 2001). This is done by setting the mean index value at 1.0 for yellow and 0.0 for both red and green as this is the exact center of the buffer zone. The 1.5 proportion value for all three colors is set at the mean index value minus the lower 95% confidence interval (CI) (red and left yellow leg) and the mean index value plus the upper CI (green and the right yellow leg). Finally, the value of 1.0 is set for red at the mean index value minus 2X the lower CI or zero, if the index mean minus 2X the lower CI is a negative number. For green the 1.0 value is set at 2X the upper 95% confidence limit. Once the known index values at the proportion values for each color are determined, the relative color proportions for each year can be estimated via linear regression using the annual values of the index. Any negative values are reset to zero and the proportion of yellow are set at 1 minus the color proportion for either red or green in that year. This allows a better illustration of the annual trends within a given color and whether or not values are approaching levels of concern about the reference boundaries. Figure 3 shows a schematic representation of the color proportions using catch per unit effort (CPUE) for Atlantic croaker from the SEAMAP survey.

Figure 3. Fuzzy Traffic Light Model Schematic for color proportions in annual CPUE for Atlantic Croaker from the SEAMAP survey.



Composite figures of combined indices can then be created using the color proportion tables from each individual index (Fig. 4). These indexes are additive and the total index is re-scaled to 0-1. It is possible to add weighting factors to each index via the color proportion tables if necessary. This type of composite index is what Halliday et al. (2001) referred to as a Characteristic, while the individual indices that make it up are the Indicators.

Figure 4. FTLA model for Atlantic croaker from SEAMAP survey using 1996-2008 reference period.



Atlantic Croaker: Comparing 70% Management Scheme with FTLA

For Atlantic croaker the current trigger indices from Amendment 1 section 3.2 are the coastwide commercial and recreational harvest (hard triggers) as well as four fishery independent indices using a 70% threshold of the previous 2-year index average and a Fuzzy Traffic Light Analysis (FTLA) of these same indices.

The fishery independent indexes used for Atlantic croaker were the following:

1. NEFSC Fall Groundfish trawl survey (NMFS)
2. VIMS Juvenile fish and blue crab survey
3. NCDMF Program 195 Survey
4. SEAMAP trawl survey of the south Atlantic coast

All years that triggered for Atlantic croaker using the 70% threshold of the previous 2-year index average for the hard triggers and the fishery independent surveys are highlighted in Table 1. The 1996-2008 time period was used to set reference boundaries for color transition zones for the FTLA. This time period was chosen because it encompassed known population changes that were documented in the 2010 stock assessment (ASMFC, 2010) where reference estimates of population characteristics (SSB, F_{msy}, M) were available. Additionally, setting population mean over a longer time period allows inclusion of documented increases and declines in the population.

Table 1. Percent change from previous 2-year average for current trigger indices for Atlantic Croaker: Pink highlighted cells indicate years where trigger was tripped for that particular index.

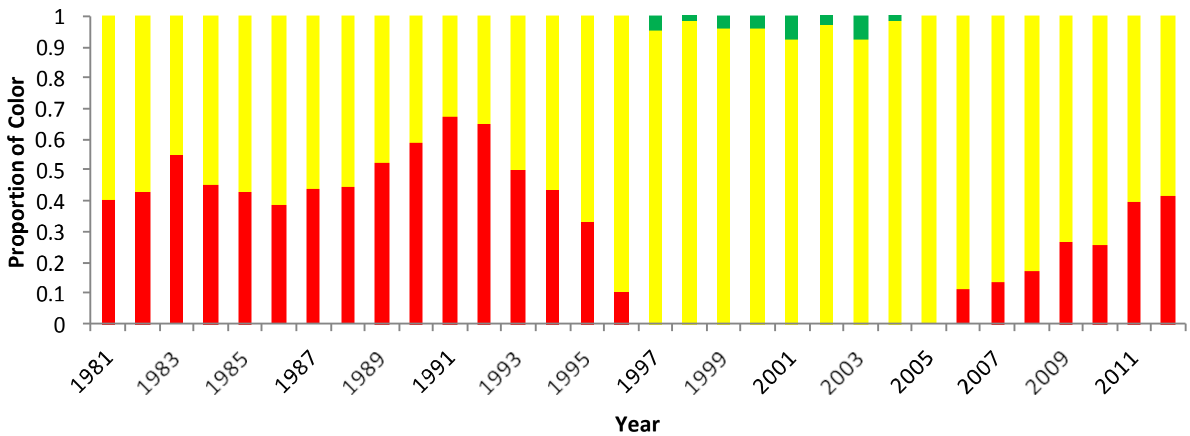
	Commercial	Recreational	VIMS	NCDMF(P195)	NMFS	SEAMAP
	Harvest	Harvest	Survey	Survey	Fall-Survey	Fall-Survey
Year	LBS	Number	Num/Set	Num/Set	Num/Tow	Num/Tow
1981	-	-	-	-	-	-
1982	94.1	96.6	-	-	27.3	-
1983	65.7	163.0	-	-	85.4	-
1984	110.2	224.6	-	-	790.0	-
1985	124.8	74.6	-	-	82.6	-
1986	114.9	201.9	-	-	69.6	-
1987	92.1	82.3	-	-	128.4	-
1988	91.2	75.4	-	71.7	9.1	-
1989	76.5	57.1	1496.0	138.5	226.9	-
1990	65.5	70.1	84.9	352.6	104.2	-
1991	52.2	152.4	276.5	110.5	2.5	317.8
1992	87.4	130.2	16.1	21.2	58.5	26.8
1993	224.1	104.6	46.3	263.7	34.3	129.5
1994	164.0	150.4	10.5	65.4	5458.0	127.3
1995	141.1	85.6	53.3	52.3	30.7	30.5
1996	168.5	74.2	2.1	40.6	52.8	52.2
1997	155.2	159.4	6272.0	347.3	49.7	45.0
1998	105.8	106.3	38.7	309.6	120.0	125.1
1999	102.2	89.8	12.7	137.0	580.2	502.8
2000	102.6	114.7	13.3	23.5	97.6	37.8
2001	107.1	134.7	50.3	24.6	9.6	24.6
2002	94.1	98.4	562.8	54.9	75.0	269.9
2003	104.4	85.0	19.7	180.4	302.2	237.3
2004	93.3	106.6	101.9	358.9	220.2	131.7
2005	90.7	103.6	103.4	73.1	84.1	161.5
2006	82.7	88.2	267.5	38.5	102.7	61.6
2007	87.9	88.3	104.4	63.0	356.6	51.2
2008	92.8	111.2	354.7	249.2	16.0	112.9
2009	82.3	83.2	59.3	38.6	143.6	81.9
2010	93.4	69.6	151.9	624.4	61.7	196.9
2011	74.1	67.5	22.5	14.2	110.6	42.6
2012	81.6	97.0	317.1	180.3	106.1	276.3

Commercial Harvest

The commercial harvest index was examined beginning in 1981 since the recreational index only went back to 1981 and the first year where a comparison could be made to the previous 2-year average would have been 1984. However, commercial landings were available back to 1951.

The 70% trigger was tripped in 1990-1991 (Table 1). The FTLA model showed steady decline with the increasing proportion of red from 1982-1992 matching the decline seen in total harvest. The years where the index shows some improvement (1997-2003), there was still a relatively high proportion of yellow. The increasing proportion of green in 1997-2003 supports the positive trend in commercial harvest. However, the FTLA does show the beginning of the recent decline beginning in 2004 where the proportion of green decreases until getting back into the

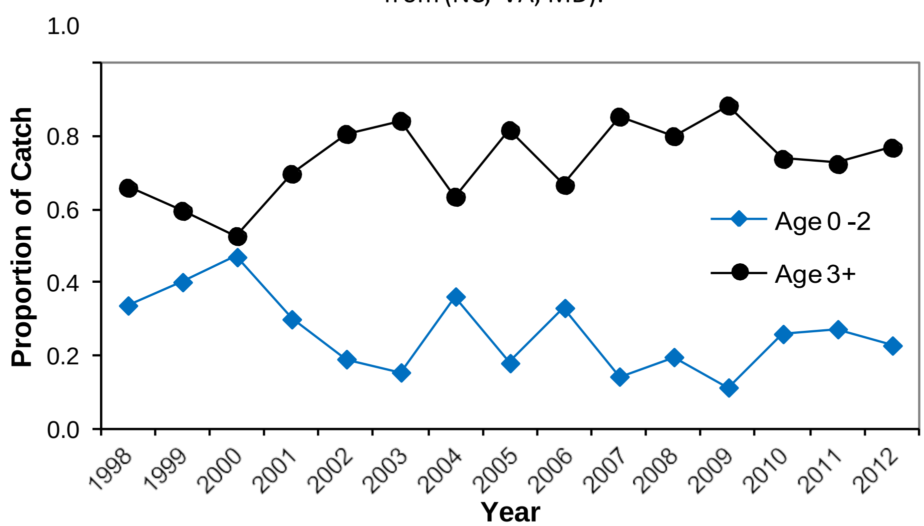
Figure 5. Annual FTLA color proportions for Atlantic croaker from Atlantic coast commercial landings of the United States based on a 1996-2008 reference period.



yellow/red zone in 2006. All of the trends shown in stock changes appear more detailed and better reflected in the FTLA. It should be noted that the harvest levels during the reference time period (1996-2008) were among the highest in the time series and resulted in higher values for the boundary reference points. The reason this reference time period was chosen was because it incorporated data used during the most recent benchmark assessment for Atlantic croaker (ASMFC, 2010). Had a broader time range been used, the overall trends would have remained the same with proportions shifting slightly up with the green and down in the red. However, the FTLA still was more sensitive to changes than the 70% trigger because it takes the longer reference time frame into consideration showing declining trends in the last decade that did not appear with the 70% trigger. It must also be noted that the commercial landings were primarily driven by harvest in only a few states (MD, VA, NC) compared to the recreational harvest.

An additional factor that influencing harvest levels, and the resulting FTLA ,was the age distribution from the commercial harvest. There was no size distribution data available on the commercial harvest but there was age data from MD, VA, and NC for 1998-2012. The annual proportion at age of the harvest during this time period was estimated using a weighted catch at age model of the combined states age data sets. The age range of Atlantic croaker from this data ranged from 0-13 years. The ages were divided into a 0-2 age group and a 3+ group as most croaker had recruited to the fishery by age 3. The resulting annual proportions of the two age groups indicated that the 3+ age group accounted for higher proportions of the sampled harvest than the younger age group (Fig. 6). As this proportion of ages may not be indicative of the age distribution in the population, it could account for discrepancies between the FTLA for the commercial harvest and the fishery independent indices.

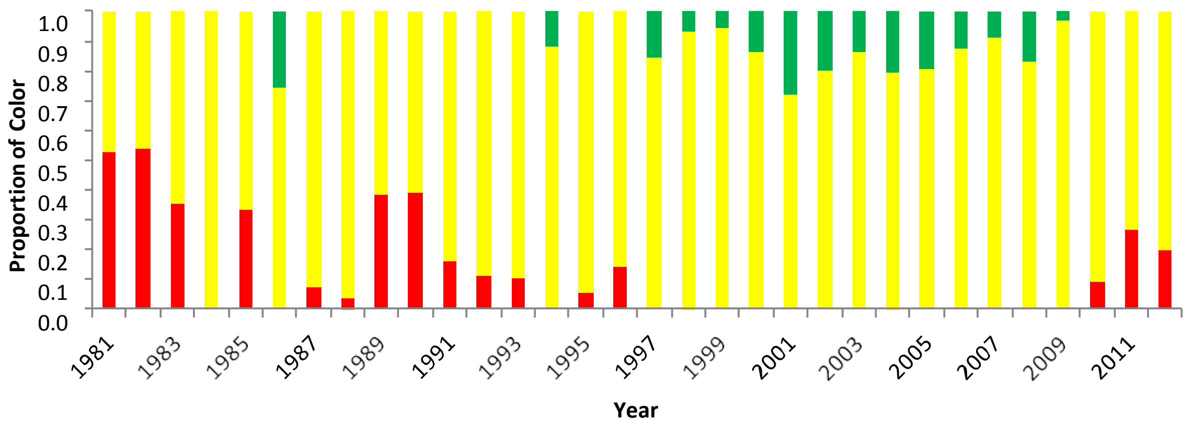
Figure 6. Annual proportion of catch by age groups for commercially harvested Atlantic croaker on the Atlantic coast of the U.S. Age data from (NC, VA, MD).



Recreational Harvest

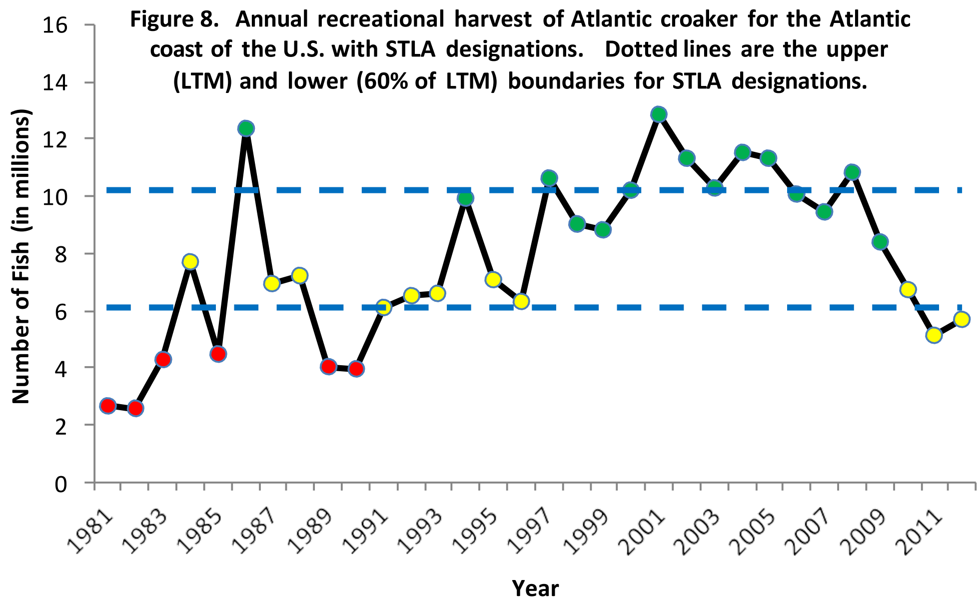
For the recreational harvest, the 70% trigger was tripped in 1989-1990 and 2011 (Table 1). In comparison, the FTLA model showed declining red with single peak (green) year in 1986.
Declining proportions of red began in 1989, indicating increasing harvest, the first indication of green proportions showing up in 1997 (Fig. 7). The FTLA model has red showing up 3 years earlier than the STLA model indicating the beginning of the recent declining trend. The boundaries and trends in the FTLA model held with both the entire time series mean as well as the 1996-2008 mean and boundary values.

Figure 7. Annual FTLA color proportions for Atlantic croaker from Atlantic coast recreational harvest of the United States based on a 1996-2008.

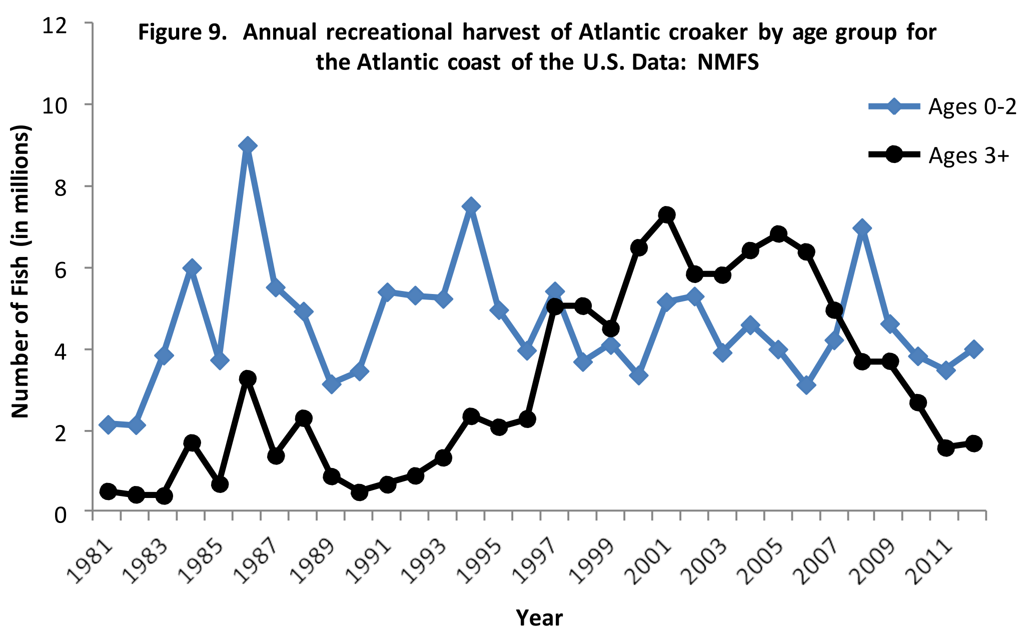


One important point to mention using the harvest data, particularly at the coast wide level, is that trends in annual harvest can be subject to different state management structures, angler effort and preferences in addition to variation in overall abundance and distribution of the population. Fish harvested as part of the fishery may not be representative of the overall population in terms of the general size or age distribution and thus use of harvest landings as a trigger (either recreationally or commercially) should be approached with caution. These types of differences can (and often do) result in disparate results between fishery dependent indices and fishery independent survey indices. Typically, if fishery dependent indices match trends with fishery independent indices they are considered as supporting the general trends found in both and greater weight may be given to the results as a proxy for population trends. However, when the trends between different indices are variable, less weight is usually given to the fishery dependent surveys because fewer control factors are known compared to the fishery independent surveys. The differences between the two index types can sometimes be reconciled by taking into consideration the size and age structure of the data set to make sure the comparisons are being made between similar data structures.

A good example of this can be made with the recreational harvest data for Atlantic croaker. The incorporation of the annual harvest and STLA designations for the Atlantic coast harvest can be seen in figure 8. There is a wide range of sizes (10-54 cm fork length) represented in this data set. Since age data is not taken from recreational surveys an age length key (ALK) must be applied to the length distribution data from the MRIP survey to estimate an age distribution. For this data set, an ALK from the last benchmark assessment (ASMFC, 2010) was used to estimate annual age frequency distribution. The length distribution has a typical unimodal distribution with the mid-range sizes being the most abundant while age frequencies are dominated by



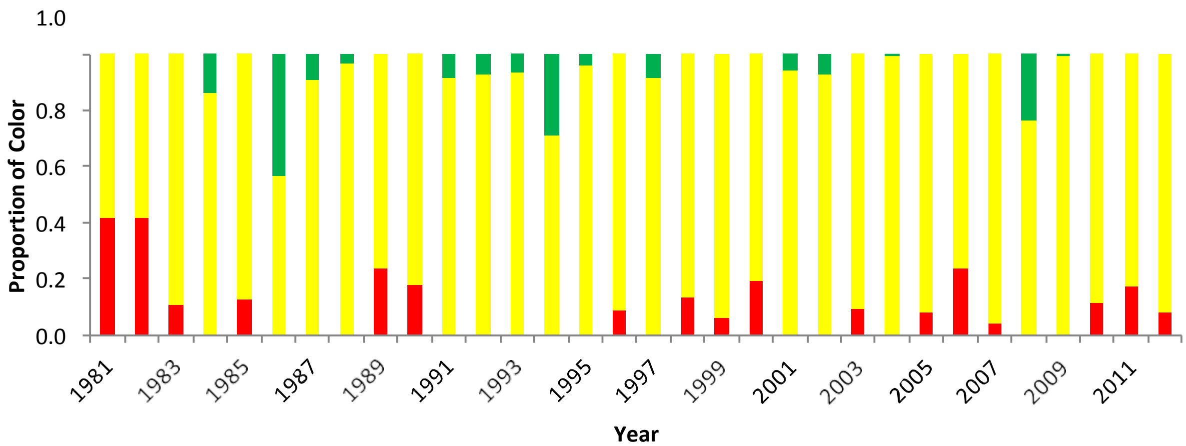
younger age classes (0-2) and account for approximately 66% of the harvest over the entire data set. Since the majority of croaker from the ALK estimates were ages 0-2, the data was divided between two sets of age groups, ages 0-2 and ages 3+. The annual recreational harvest for each of the two age groups can be seen in figure 9.



The changes in total annual recreational harvest appears to be driven more by the 3+ age group than the by the younger age groups. This can affect how the FTLA is interpreted depending on which group is exerting the greater influence on harvest trends. If the FTLA is run on just age 0-

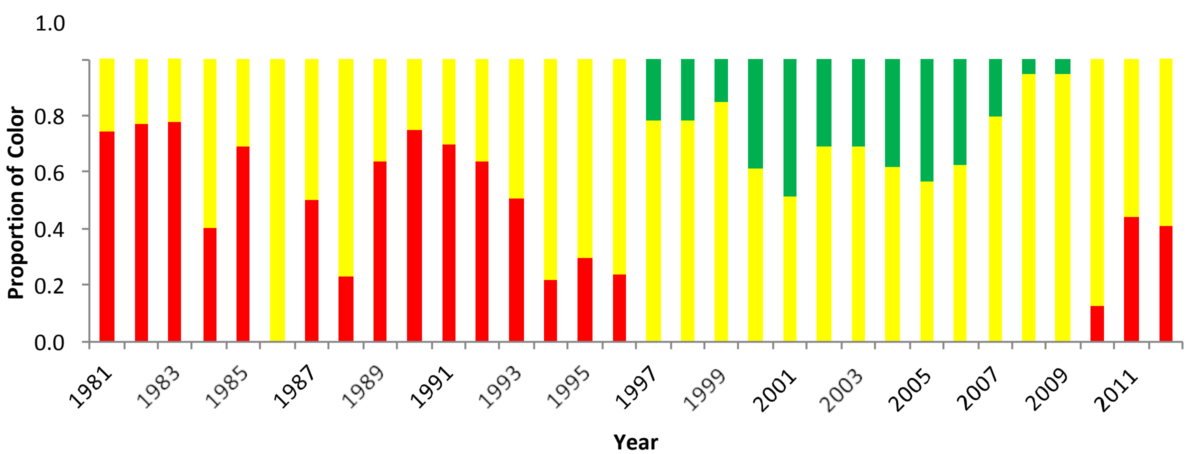
2 (Fig. 10), the pattern is quite different than the total harvest data set with green occurring in more years than with the total data set.

Figure 10. Annual FTLA color proportions for Atlantic croaker recreational harvest for ages 0-2 for the Atlantic coast of the U.S. based on 1996-2008 reference period.



If the FTLA is run using the older (3+) age groups (Fig. 11) the resulting pattern more closely resembles the results from the overall data set and in fact accentuates the shifts in harvest with greater proportions of red and green. Overall this is an indication that the fishery impacts the older age groups more heavily than younger age classes.

Figure 11. Annual FTLA color proportions for Atlantic croaker recreational harvest for ages 3+ for the U.S. Atlantic coast based on a 1996-2008 reference period.

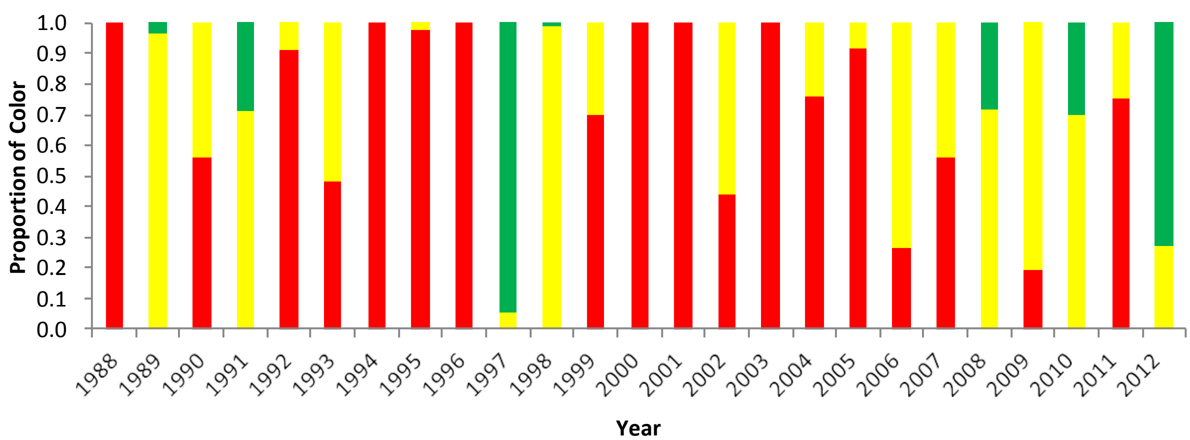


Knowing, in general, what size and/or age classes make up the fishery can allow a more equitable comparison of index changes between both fishery dependent and fishery independent data sources, which in part could account for discrepancies between index trends.

VIMS Spring Surveys

The VIMS survey was conducted in Chesapeake Bay and the rivers in Virginia. This was a juvenile survey and shows a high degree of year to year variability which likely reflects variable recruitment and year-class strength. The FTLA model reflects extended periods of low abundance (1988, 1994-1996, 1999-2005, and 2011) and some periods of highly elevated catches (1997, 2008, 2010, and 2012) (Fig. 12). The FTLA showed high proportions of red the same years that the 70% threshold index triggered, except in 2010 where only the 70% threshold triggered (Table 1). The FTLA model showed the changes in index values earlier as well as covering the overlapping time periods of the 70% threshold scheme. The FTLA model generally showed greater sensitivity to changes than the 70% threshold model or an STLA. There was a greater degree of transition between red and green in the STLA compared to the FTLA which likely reflects that these indexes were being influenced by changes in annual recruitment and year-class strength increasing year to year variability compared to some of the other trigger indexes that sampled adult Atlantic croaker.

Figure 12. FTLA for VIMS Chesapeake survey of Atlantic croaker

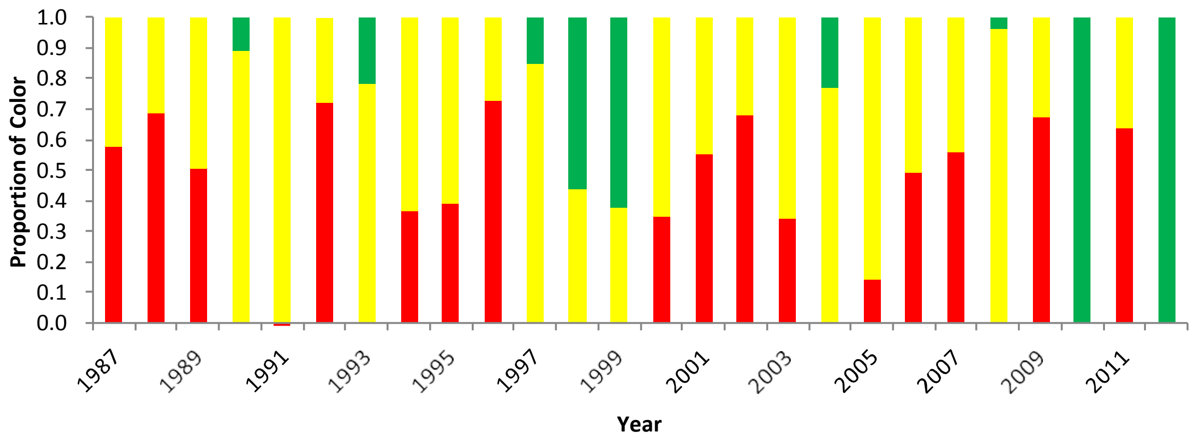


NCDMF- Program 195

The 70% threshold scheme was tripped in 11 out of 26 years (Table 1) indicating a high degree of variability in catch effort. The STLA model showed red for 14 of the 26 years with the red years in the STLA model and the 70% threshold scheme overlapping in all but 3 years (1987- 1989). The STLA model showed greater sensitivity with critical levels generally reached earlier than with the 70% threshold scheme.

The FTLA model was, again, more sensitive with the degree of change from year to year being reflected in the changing proportions of colors. This was particularly true in years where the STLA model showed green and the FTLA model would have some proportion of green but a much greater proportion of yellow. There were only a few years where the proportion on green was greater than that of yellow (1998-1999, 2010, 2012) (Fig. 13).

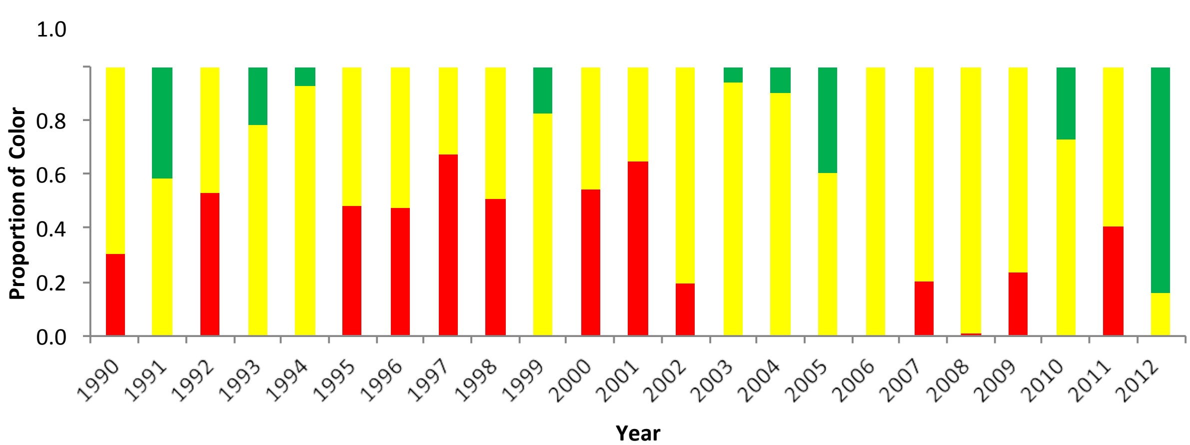
Figure 13. NCDMF Program 195 FTLA color proportions for Atlantic croaker



SEAMAP Fall Trawl Survey

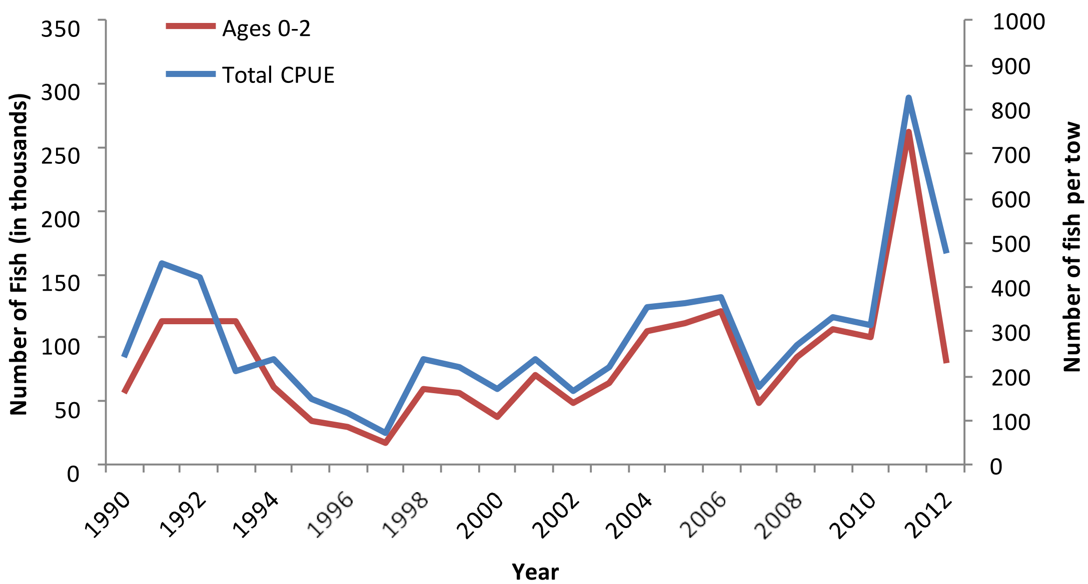
For the SEAMAP survey, the 70% threshold was tripped in 9 out of 20 years: 1992, 1995-1997, 2000-2001, 2006-2007, and 2011 (Table 1). The FTLA model agreed with 7 of the 9 years where the 70% threshold had tripped with high proportions of red (1992, 1995-1997, 2000-2001, 2011) (Fig. 14). The FTLA model generally showed the general decline beginning from 1994- 2001, with the exception of one year (1999) in that time period. The FTLA model showed higher proportions of yellow indicating the early declining trends, except in 2005 which was the second highest CPUE in the index. The most recent year (2012) was the highest year in the entire index for CPUE.

Figure 14. FTLA model for Atlantic croaker from SEAMAP survey using 1996-2008 reference period.



The SEAMAP data set did have age and length data corresponding to the catch data. The annual proportionate age at length distributions were applied to the annual length frequency distributions to estimate the annual catch at age for ages 0-7. Ages 0-2 accounted for the majority of samples (95.9%) and so ages were divided into two groups of age 0-2 and age 3+ (similar to the recreational and commercial age comparisons). As would be expected, given that most of the fish were ages 0-2, the annual stratified mean CPUE is driven almost entirely by the 0-2 age classes (Fig. 15).

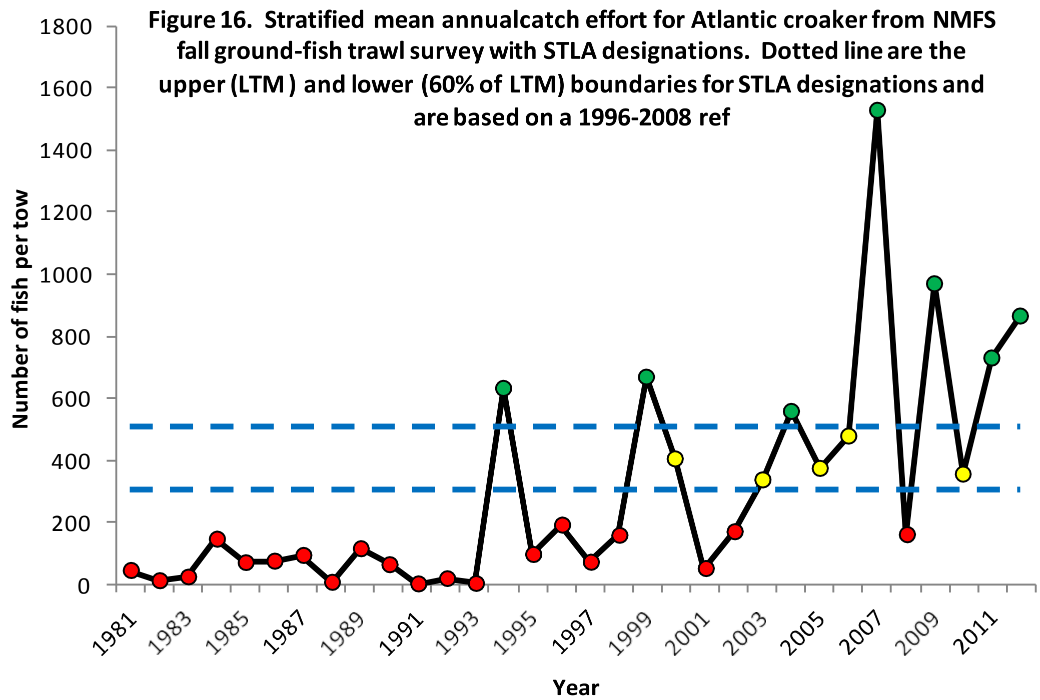
FIGURE 15. TOTAL ANNUAL NUMBER OF ATLANTIC CROAKER FOR AGES 0-2 AND MEAN ANNUAL CPUE FROM SEAMAP SURVEY ON THE SOUTH ATLANTIC COAST OF THE U.S.



This result would indicate that the FTLA from the SEAMAP survey was indicative of changes in the younger (and dominant) age classes.

NMFS Fall Ground-Fish Survey

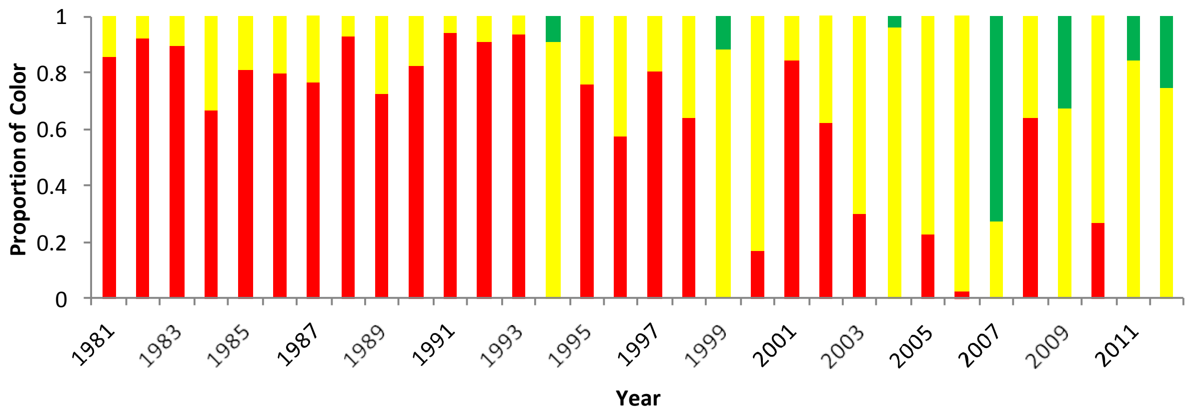
The NMFS fall ground-fish survey was the longest time series (1972-2012) and had two different trends in the overall abundance index. From 1972 to 1993 the range of annual CPUE values was relatively narrow, while the most recent years (1994-2012) have shown an approximate 80% increase in mean annual CPUE and a much higher degree of year to year variability (Fig. 16). During the early time period (1972-1993) the CPUE was well below the lower threshold for both the long term mean for the data series as well as the 1996-2008 time period, which represented the yellow/red boundary. During the second time period (1994-2012) the mean CPUE increased approximately 80% with 7 years above the series long-term mean and 7 years below.



Under the 70% threshold scheme, the entire index has tripped 15 out of 41 years, with 9 of those events occurring in the 1972-1993 time period. In recent years, the threshold was tripped 6 times from 1994-2012 and 4 times in the 1996-2008 reference time period (Table 1). The overall increase in the index in the last 20 years has resulted in fewer instances where the 70% threshold could be tripped unless there was a single year where a drastic reduction in CPUE occurred.

The FTLA was run using the same time frame as the commercial and recreational harvest data sets (1981-2012), with the 1996-2008 reference period for setting the color proportion boundaries. The FTLA model (Fig. 17) had highest proportions of red (> 50%) prior to 1998 (with the exception of 1994 and 1996). This was due to the increase in the long term mean from the increased catch levels which occurred in the reference time period, although, this same pattern occurs using the entire time series as the reference time period as well. The FTLA model was more sensitive to changes with downward or upward shifts occurring earlier than would have occurred in the STLA model.

Figure 17. Annual FTLA color proportions for Atlantic croaker from NMFS ground-fish trawl survey based on a 1996-2008 reference time period.

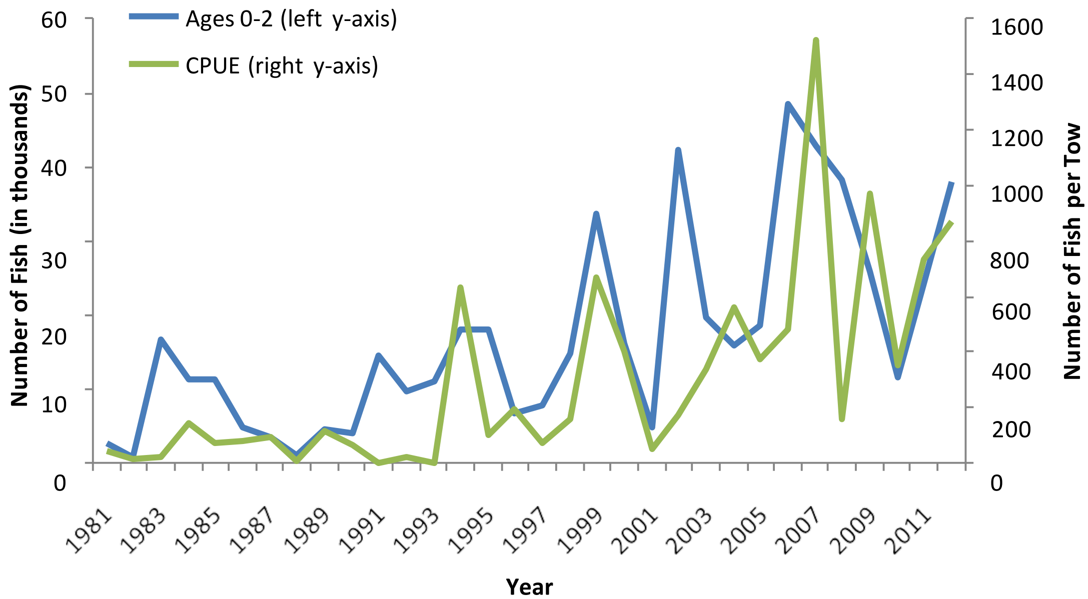


Given the changes in catch levels that occurred after 1994, the use of the entire time series means to set boundary reference points would not be prudent because of the level of low catches which occurred in the first 20 years of the data series, relative to catch levels in the second 20 years of the time series. Additionally, increased year to year variability in catch levels since 1994 makes the use of the 70% threshold problematic since catch levels can shift by this amount annually and could be the result of stochastic and system perturbations as opposed to fishing pressure. The NMFS survey data set is a good example of why it is important to pick representative time periods for setting reference points and color boundaries for the traffic light method that relate to the current time period, as well as, documented population trends from the most recent stock assessment.

There was age data available from the NMFS survey from 1997-2012 which ranged from ages 0-

13. As with the SEAMAP data set, the majority of specimens fell in the 0-2 age range (65.7%) and the comparison of annual numbers of this age grouping versus the mean annual CPUE revealed that the catch trend was driven primarily by this age group as well (Fig. 18).

FIGURE 18. ANNUAL TOTAL CATCH FOR 0-2 AGE GROUPS AND STRATIFIED ANNUAL MEAN CPUE FOR ATLANTIC CROAKER FROM NMFS FALL GROUND-FISH SURVEY.



FTLA Composite Models Summary:

One important thing to note on the composite models is that since each indicator is additive within a given characteristic (abundance, harvest, etc) all three colors can occur within a given year for any particular composite characteristic. The abundance characteristic was separated into adult and juvenile models because of the differences in distribution and life history stage as well as year to year variability. All of the composite FTLA models were run using the 1990-2012 time period which was when all of the indicator component indices were available.

The composite FTLA model for harvest (commercial and recreational harvest combined) showed peak harvests occurring from 1997-2005 with only yellow and green lights present (Fig. 19).
The 1990-1996 time period, while having red lights present, did show the increase in general harvest levels via the decreasing proportion of red during this time period. While the decrease in red was a positive sign, the presence of the red light was indicative that relative harvest levels were still low. The increase in harvest that occurred from 1997-2005 still had relatively high proportions of yellow compared to green which indicated that while harvest was up, it was still

largely in the transition (yellow) zone. In the most recent years (2006-2012), harvest has declined, indicated by the increasing proportion of red in the FTLA harvest index. The years with highest proportions of green in the harvest composite FTLA (2001-2004) coincided with decreasing abundance in the FTLA fishery independent composite model during those years, which suggests that there is either a lag between peak abundance years and general harvest levels or that the two are not directly comparable. The harvest FTLA levels might be affected by additional fishery related factors that would not influence the fishery independent FTLA composite model. It must also be noted that while recreational harvest occurred all along the Atlantic coast, the majority of the commercial harvest occurred in only two states (VA, NC), which may also be a contributing factor. Additionally, the estimated age distribution of the recreational harvest indicated harvest patterns were influenced more by age 3+ fish versus younger age groups.

The juvenile FTLA showed much greater variability with rapid shifts between red and green and not as high a proportion of yellow (indicating rapid transition) in most years (Fig. 20). This should be somewhat expected given the high degree of variability in juvenile recruitment indices in most fishery independent surveys. The green years would be those years with strong recruitment and (likely) subsequent strong year classes. Strong recruitment years included 1991, 1997, 1998, 2008, 2010, and 2012. Two of the most recent years (2010, 2012) appear to be a particularly strong year-classes. The FTLA juvenile index's higher proportion of red during the 1993-1996 and 1999-2005 time periods would indicate periods of poor recruitment but should not be used to draw conclusions on trends in the adult population.

The adult FTLA composite model had higher proportions of green occurring at approximately 5- 6 year intervals (1994, 1999, 2004) through the mid 2000's (Fig. 21). After 2005, the years with higher proportions of green occurred in shorter intervals of approximately every 2 years (2005, 2007, 2010, 2012). Declining trends (higher proportions of red) showed this cyclical pattern for similar time periods (1990-1992, 1994-1998, 2000-2003) but after 2006 the relative proportion of red remains at a similar level, except in 2012 where there is no red due to the high proportion of green in the index that year. The long term trend in the FTLA beginning in 2003 is an overall increasing trend in the all of the threshold indices.

Figure 19. Annual FTLA composite index for commercial and recreational (all ages) Atlantic croaker harvest on the Atlantic coast of the United States, 1990-2012.

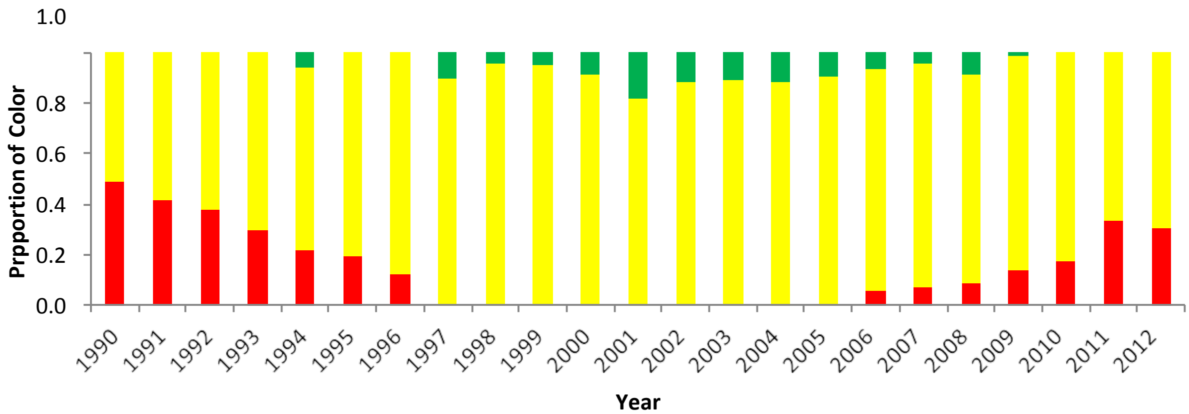


Figure 20. Fuzzy Traffic Light Composite index for juvenile fishery independent surveys (VIMS, NCDMF) of Atlantic croaker used as trigger indices by ASMFC, 1990-2012

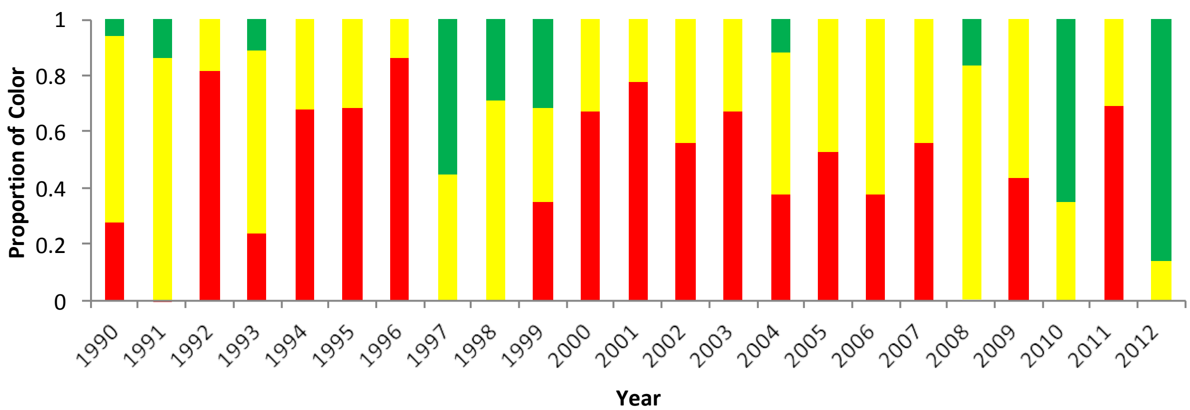
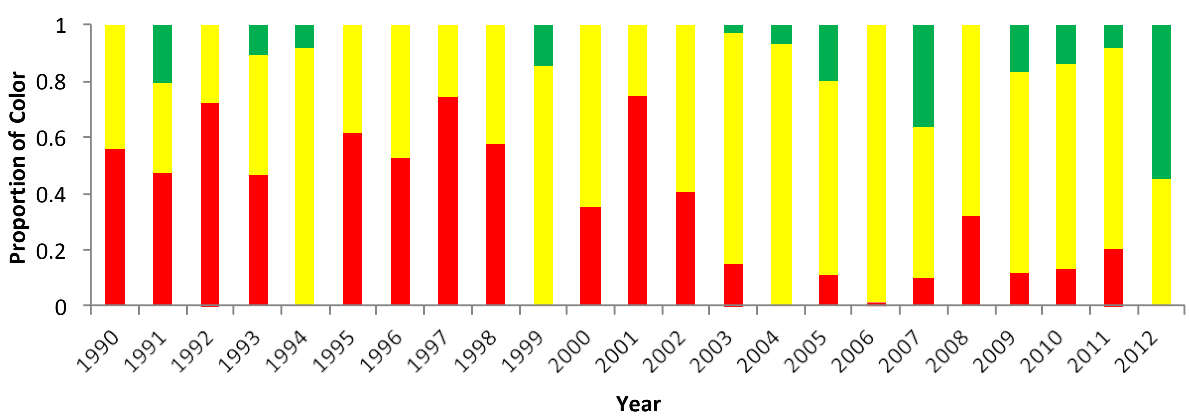


Figure 21. Fuzzy Traffic Light Composite index for adult fishery independent surveys (NMFS, SEAMAP) of Atlantic croaker used as trigger indices by ASMFC, 1990-2012.



SPOT: COMPARING 10TH PERCENTILE MANAGEMENT SCHEME WITH FTLA

For spot, the current trigger indices used are also the coastwide commercial and recreational harvest as well as three different fishery independent surveys. For spot, all changes using the 10th percentile threshold of the time series average for the fishery dependant data and fishery independent surveys are highlighted in Table 2.

The fishery independent indexes used for spot were the following:

1. NMFS Fall Ground-fish trawl survey (NEFSC, Woodshole, MA)
2. Maryland Chesapeake Bay Seine Survey
3. SEAMAP trawl survey of the south Atlantic coast

Commercial Harvest

The period examined for spot landings was 1981-2012. This was done because it matched the same time period as the recreational harvest index , although commercial landings were available back to 1950. Overall, spot landings have been on a declining trend since the 1980's, however this trend has become more pronounced since 1999 (Fig. 22). Recent years (2005-2012) have seen a high degree of annual variability in landings remaining below the long term mean harvest and the green/yellow boundary from the FTLA. The FTLA mirrored this trend (Fig. 23) with increasing proportions of red beginning in 1999. The 10th percentile trigger would have been set off in 2006, 2008, 2010, and 2012 (Table 2), while the FTLA began showing signs of decline with increasing proportions of red and declining proportions of green beginning in 1999.

Figure 22. Annual commercial landings of Spot on the Atlantic coast of the United States with STLA designations. Dotted lines are the upper (LTM) and the lower (60% of the LTM) boundaries of the FTLA. The red dotted line is the current 10th percentile trigger level.

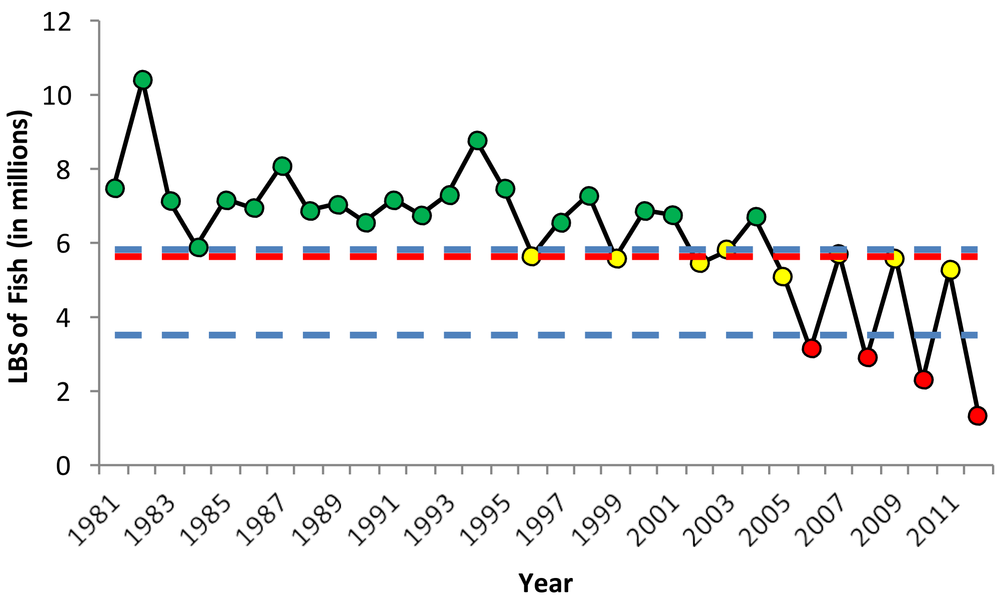


Figure 23. Annual FTLA color proportions using 1989-2012 reference time period for Spot from NMFS commercial landings for the Atlantic coast of the U.S.

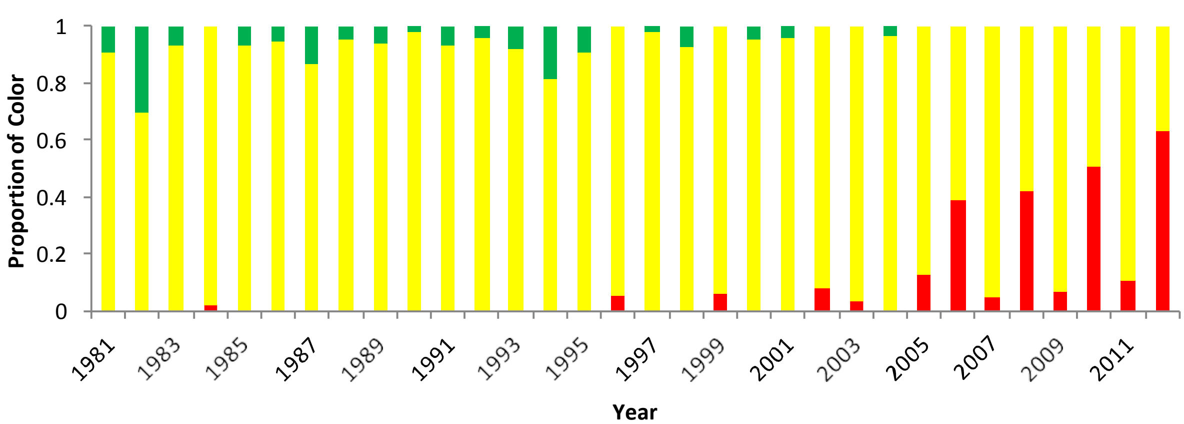
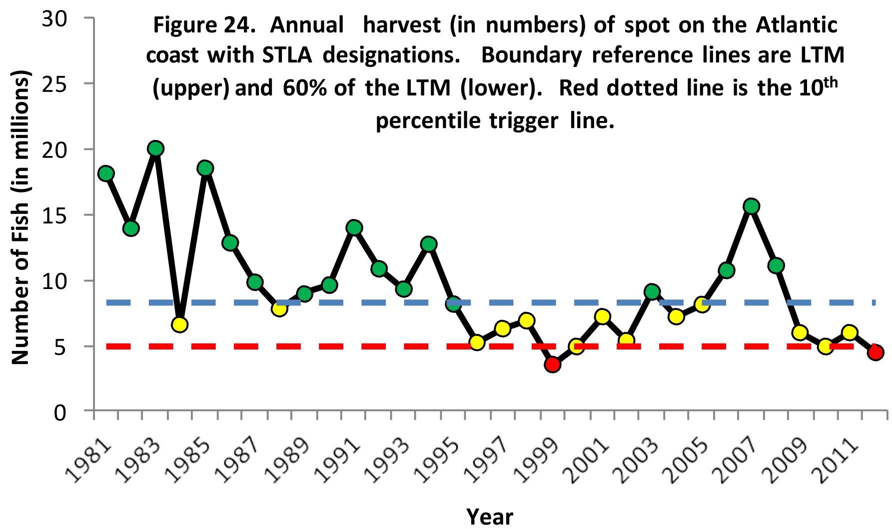


Table 2. The current fishery dependent (commercial and recreational harvest) and fishery independent (NMFS, SEAMAP, and MD Chesapeake seine survey) management trigger indices used for spot on the Atlantic coast of the United States. Pink highlighted cells are years where the index value fell below the 10th percentile for the entire data set and would have triggered a management response.

	Commercial	**Recreational**	**NMFS**	**SEAMAP**	**MD(Juv)**
	Harvest	**Harvest**	**CPUE**	**CPUE**	**CPUE**
Year	**LBS**	**Number**	**Num/tow**	**Kg/tow**	**Num/tow**
1981	7502660	18211373	233.3	-	1.647
1982	10440456	14035394	45.6	-	2.254
1983	7156787	20125239	246.8	-	1.074
1984	5899237	6662176	322.9	-	3.428
1985	7175456	18616969	51.7	-	1.498
1986	6965468	12932596	256.4	-	1.766
1987	8100735	9927128	180.2	-	1.174
1988	6885465	7888631	180.2	-	4.495
1989	7053374	9022104	453.8	19.2	0.697
1990	6563745	9699092	102.4	32.1	1.046
1991	7176632	14083432	47.6	40.3	0.809
1992	6765078	10945571	10.1	15.9	0.441
1993	7315577	9399408	7.9	10.5	1.425
1994	8795939	12819339	411.7	13.3	1.486
1995	7489478	8258786	65.1	19.9	0.096
1996	5647298	5234337	77.4	6.6	0.283
1997	6570132	6346999	29.7	13.7	1.343
1998	7293919	6928839	17.4	5.0	0.437
1999	5589288	3624213	67.8	3.7	0.607
2000	6884989	4976923	59.0	8.0	0.828
2001	6770093	7239378	0.2	8.1	0.367
2002	5449507	5327170	60.4	4.3	0.357
2003	5808929	9189041	31.0	15.6	0.306
2004	6730217	7166471	85.0	12.0	0.805
2005	5120448	8166637	187.8	26.2	3.485
2006	3137120	10818374	144.9	17.1	0.342
2007	5684401	15717617	166.2	10.2	0.609
2008	2883286	11200109	225.2	13.2	0.867
2009	5578379	6035163	136.9	11.2	0.443
2010	2275959	4951340	635.3	18.2	2.889
2011	5267410	5989196	436.1	24.0	0.065
2012	1328774	4448237	825.4	15.5	0.827
10th Percentile	3335453	5002664	18.628	5.511	0.310

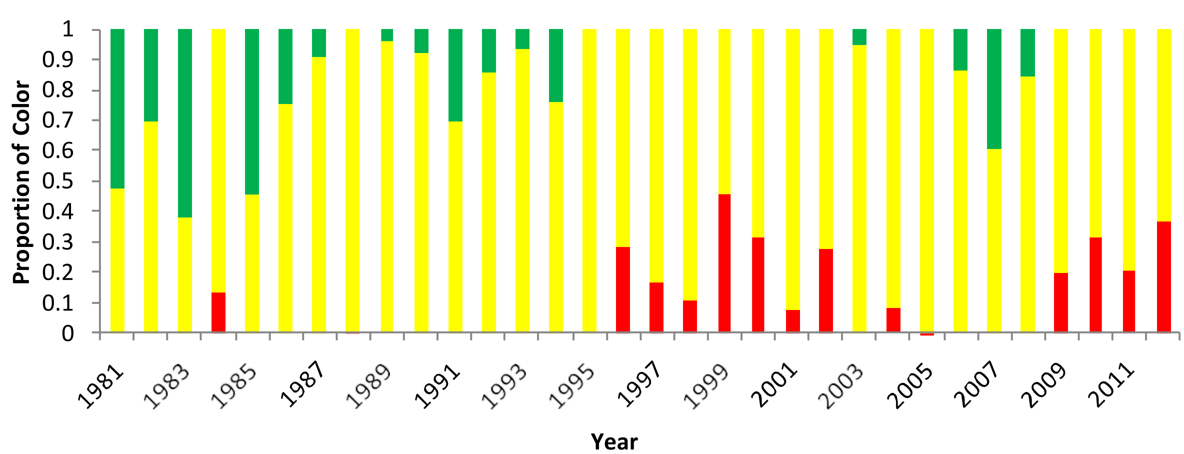
Recreational Harvest

The recreational harvest of spot (in numbers) has been generally declining along the Atlantic coast since the mid-1980's, with the exception of 2006-2008 (Fig. 24). The lowest index values occurred in 1996-2002 and 2009-2012.



The 10th percentile trigger was tripped in 1999-2000, 2010, and 2012, while the FTLA began to show increasing proportions of red 1-2 years before the 10th percentile trigger was tripped (Fig. 25).

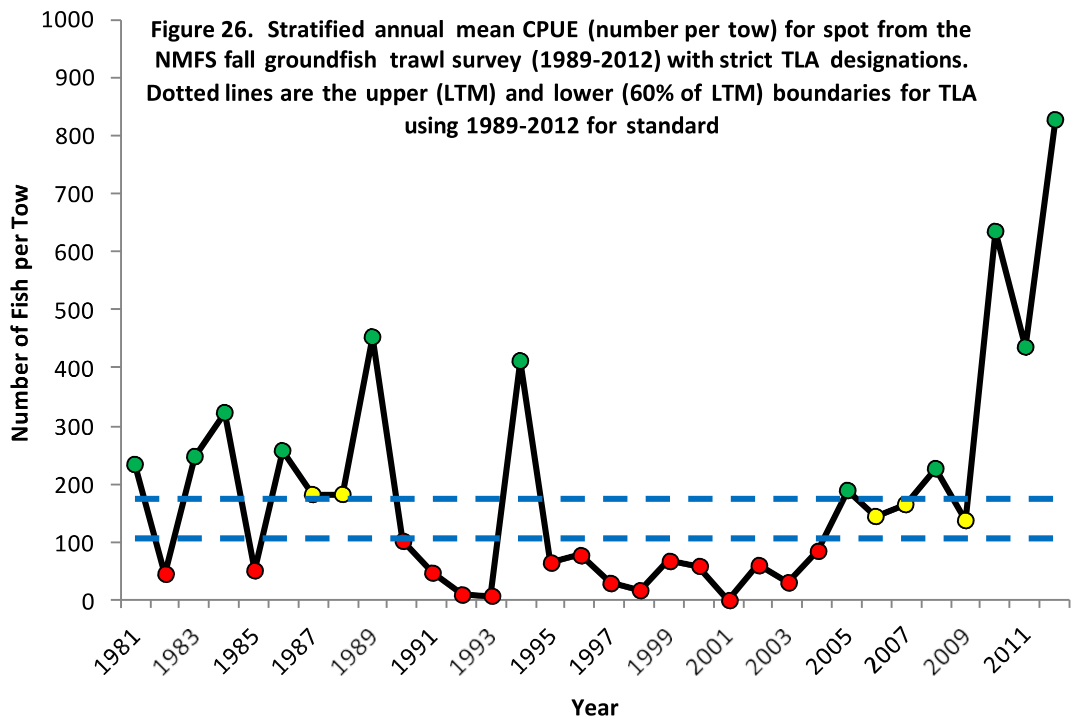
Figure 25. Annual FTLA color proportions using 1989-2012 reference time period for Spot from recreational harvest on the Atlantic coast of the U.S.



The level of the 10th percentile trigger was very close in value to the red/yellow boundary of the FTLA (5,002,664 vs. 4,939,694 respectively) and would indicate that the 10th percentile trigger is a poor indicator, relative to the FTLA, because it did not trip until reaching some of the lowest index values. The FTLA provided better reference points for relative harvest levels with a higher and more conservative limit reference point (green/yellow boundary) that would trigger (at a minimum) a management review by the ASMFC.

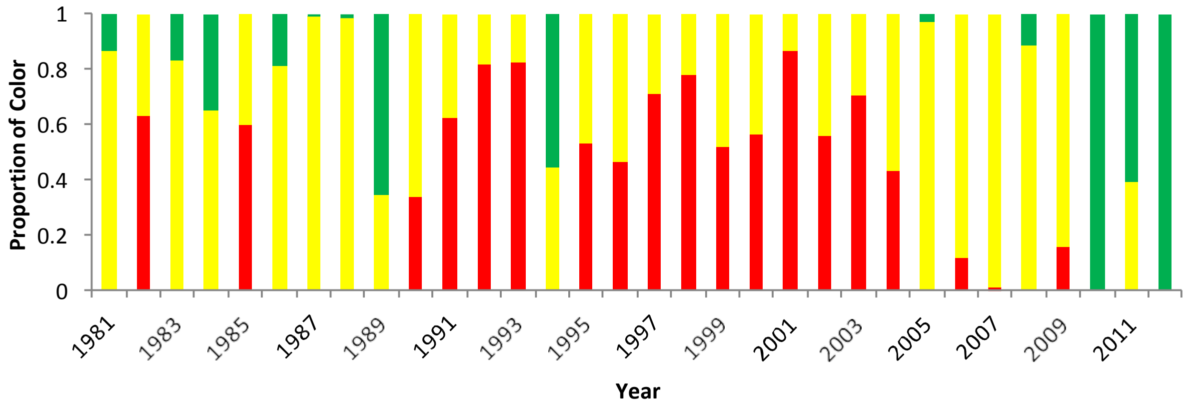
<u>NMFS Fall Ground-Fish Trawl Survey</u>

The NMFS index went through a period of decline from the 1980's through 2004, with the exception of two peak years (1989 and 1994) (Fig. 26). Index values began increasing in 2005 and reached the highest values for the entire survey time period (1972-2012) in the last three years.



The 10th percentile trigger was only tripped in four years (1992-1993, 1998, 2001) (Table 2). The index value for the 10th percentile trigger (18.6 fish/tow) was essentially an order of magnitude less than the long term mean for the 1989-2012 reference period (177.7 fish/tow). The FTLA was a much better indicator of trends in catch with more realistic reference boundaries based on the catch effort. In order for the 10th percentile trigger to be tripped, index values had to drop significantly, making possible management responses more drastic or reactionary. The 10th percentile trigger vastly underestimates when a problem may be occurring. The FTLA (Fig. 27), while also showing green peak years during the declining period (1989 and 1994), better demonstrated the drop in index values through the increasing proportions of red, accentuating the two major periods of decline in the index (1990-1993 and 1995-2004). With exception of the two peak years in the midst of the declines, the FTLA essentially demonstrated a steady decline in the index for almost a 20 year period, until recent years where the index has reached catch levels over four times the series average.

Figure 27. Annual FTLA color proportions for spot from NMFS fall groundfish survey using 1989-2012 reference time period.

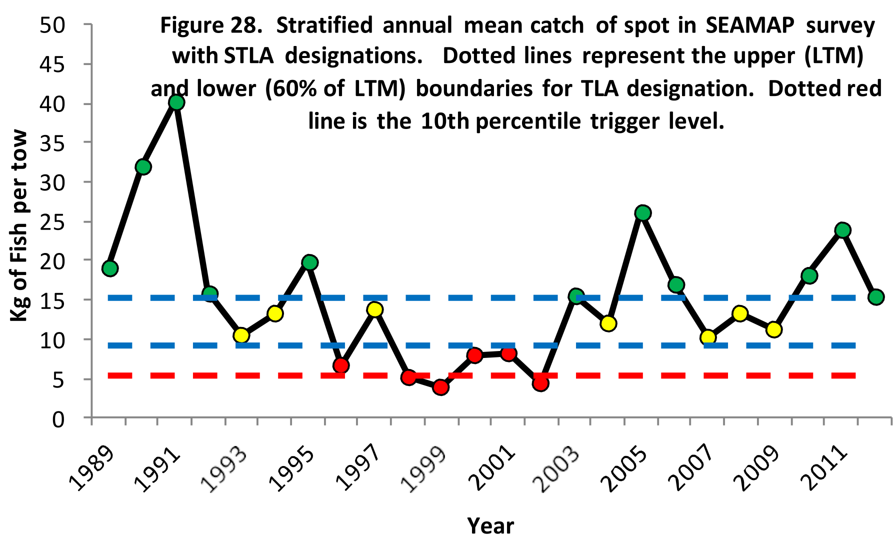


For this data set, the FTLA is a much better indicator of changes in catch effort compared to the 10th percentile trigger. By setting a limit reference point at the series mean over an extended reference period, the FTLA would give an earlier indicator of changes in the index which would allow more timely management responses if warranted.

SEAMAP Trawl Survey

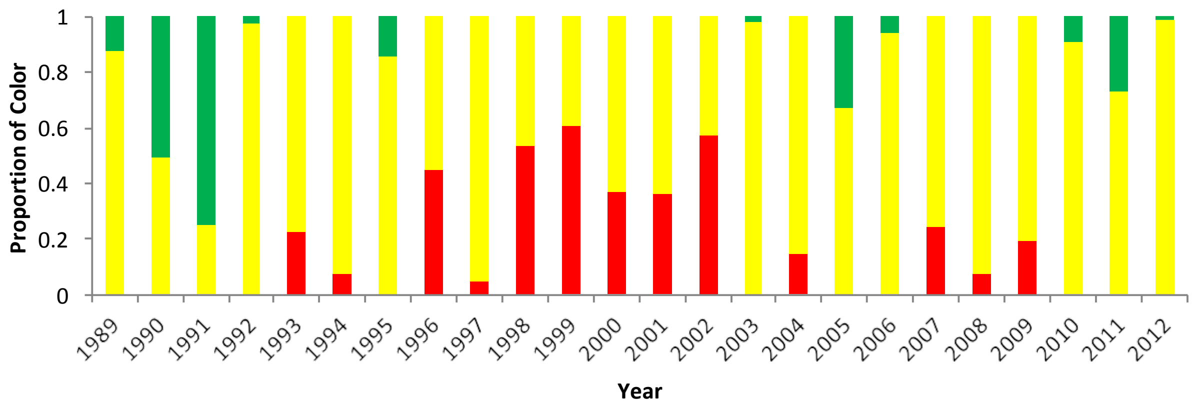
The overall index trend from the SEAMAP survey showed a decline from 1991-2002 and an increasing trend from 2003-1012, although index values have not reached the levels seen in the early 1990's (Fig. 28).

Figure 28. Stratified annual mean catch of spot in SEAMAP survey with STLA designations. Dotted lines represent the upper (LTM) and lower (60% of LTM) boundaries for TLA designation. Dotted red line is the 10th percentile trigger level.



The 10th percentile trigger for SEAMAP tripped in 1999, 2002, and 2007, which was far below the lower yellow/red reference boundary. The FTLA showed steady index level decline (through increasing proportions of red) from 1993-2002 (except one year, 1995) (Fig. 29).

Figure 29. Annual FTLA color proportions for spot from SEAMAP survey using 1989-2012 reference time period.



The FTLA indicated a drop below the limit reference boundary (LTM) in 1996, three years before the 10th percentile was tripped for the first time. While index values had been increasing from 2003 to the present, the high proportion of yellow indicated index values were still close to the limit reference (green/yellow) boundary. The 10th percentile trigger was too low to allow a timely response to decreasing index values, only tripping after index values reached a level well below even the red/yellow boundary from the FTLA. The FTLA, as with the other indices, provided earlier warning to decreasing values which would allow a more timely management response if warrented.

<u>Maryland Chesapeake Bay Seine Survey</u>

The MD JI survey was conducted in Chesapeake Bay tributaries in Maryland's portion of the bay. The index indicated a high degree of year to year variability which likely reflects variable recruitment and year-class strength (Fig. 30). Peak recruitment years occurred in 1988, 2005, and 2010, however the long term linear trend was a general decline.

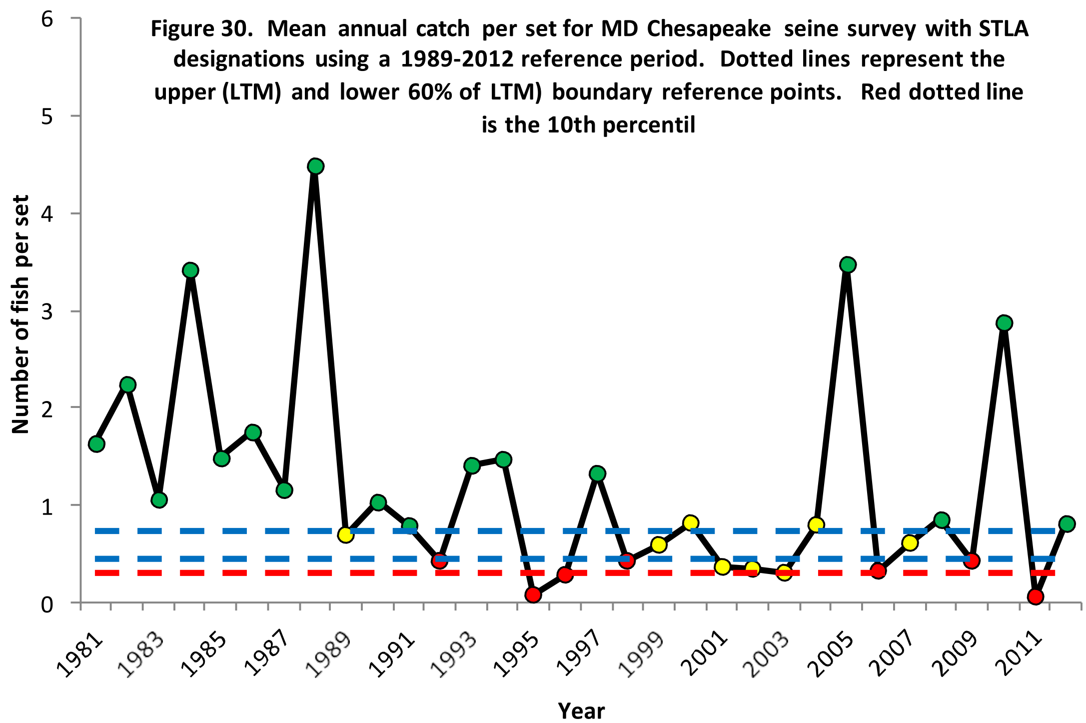
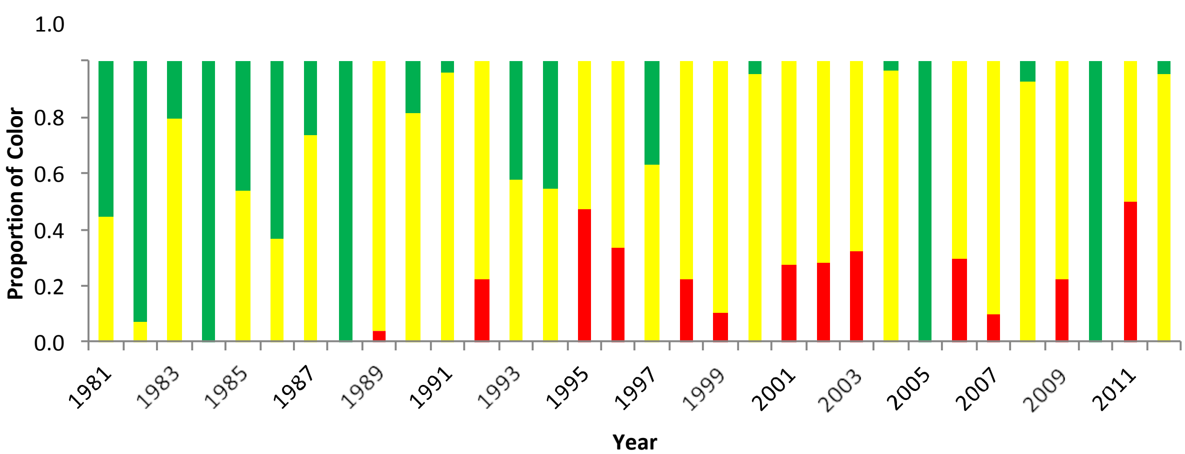


Figure 30. Mean annual catch per set for MD Chesapeake seine survey with STLA designations using a 1989-2012 reference period. Dotted lines represent the upper (LTM) and lower 60% of LTM) boundary reference points. Red dotted line is the 10th percentil

The FTLA model reflects an extended period of high abundance in the mid 1980s and some periods of low catches in 1995 – 1996, 2001 – 2003 and in 2011. The FTLA showed high proportions of red the same years that the 10th percentile threshold index triggered, except during the 2001-2003 period when the 10th percentile threshold did not trigger (Table 2). The FTLA model indicates a more prolonged period of generally poor year classes from 1995-2003, a trend that has generally continued with the exception of two very strong index values in 2005 and 2010.

Figure 31. Annual FTLA color proportions for spot from Maryland Chesapeake Bay seine survey using 1989-2012 reference time period.



FTLA Composite Models Summary:

One important thing to note on the composite models is that since each indicator is additive within a given characteristic (abundance, harvest, etc) all three colors can occur within a given year for any particular composite characteristic. The abundance characteristic was separated into adult and juvenile models because of the differences in distribution and life history stage as well as year to year variability. All of the composite FTLA models were run using the 1989-2012 time period which was when all of the indicator component indices were available.

The FTLA composite for the harvest data (commercial and recreational) showed that peak harvests occurred in the early 1990's and then small peak in 2007 (Fig. 32). The increase in the proportion of red indicated a steady decrease in spot harvest beginning in 1996 continuing through 2012. The lowest harvest levels, and consequently the highest proportion of red, occurred in two of the last three years in the index.

In comparison, the FTLA composite for the adult spot catch effort (NMFS and SEAMAP indices) showed a steady decline in abundance throughout the 1990's and early 2000's (Fig. 33). The increased proportion of green in the last three years were largely driven by the four-fold increase in CPUE in the NMFS survey index, although the SEAMAP index also has increased during this time period. There is a disparity in the FTLA's between the harvest and catch effort composite indexes that, like Atlantic croaker, is likely due to differences in the age distribution of the harvest composite. Both the NMFS and SEAMAP survey catch primarily smaller, and presumably younger, spot than the recreational harvest index.

The Maryland Chesapeake seine survey is the only juvenile index currently used as a trigger index for spot and it generally reflects the typical variable annual recruitment levels seen in most estuarine fishes (Fig. 34). However, taking into consideration a 1-2 year lag in the juvenile composite index, the evident strong year-classes of juveniles in 1993-1994, 2005, and 2010 match up with several of the higher proportion green years (1994-1995, 2005, and 2010-2011). However, disparities between the two composite indexes could also be attributed to differences in geographic range as the MD survey only covers a potion of the Chesapeake Bay and both the NMFS and SEAMAP survey cover much larger geographical areas of the Atlantic coast. Adding additional juvenile indices from other estuaries within the south and mid-Atlantic to this composite index in the future may provide a better fit with the adult composite index.

In all of the current trigger indices, the FTLA offers a better tool for examining year to year changes in index values with more sensitive reference points that can be set using historic and know levels of abundance or harvest compared to the 10^{th} percentile method currently used. The current 10^{th} percentile trigger was rarely tripped in most of the indexes and when it was it occurred at some of the lowest values for each index. While this does provide a conservative measure for management responses or action, the triggers should be more responsive at higher levels because this would allow a management response before stock levels got to such low values.

Figure 32. Annual FTLA composite of color proportions for commercial and recreational harvest of spot on the Atlantic coast of the U.S. Data source: NMFS

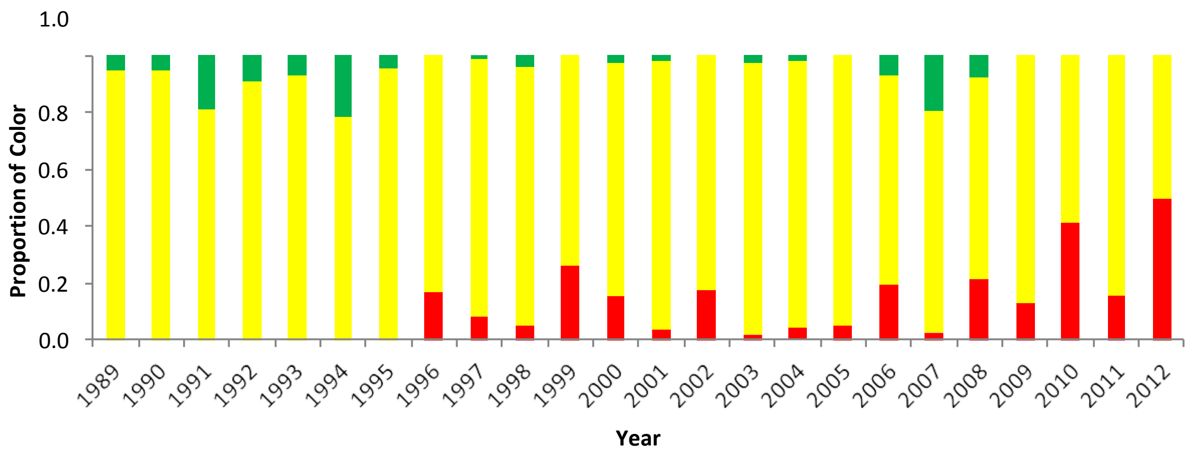


Figure 33. Annual FTLA composite of color proportions for adult spot from NMFS and SEAMAP index surveys on the Atlantic coast of the U.S. based on CPUE.

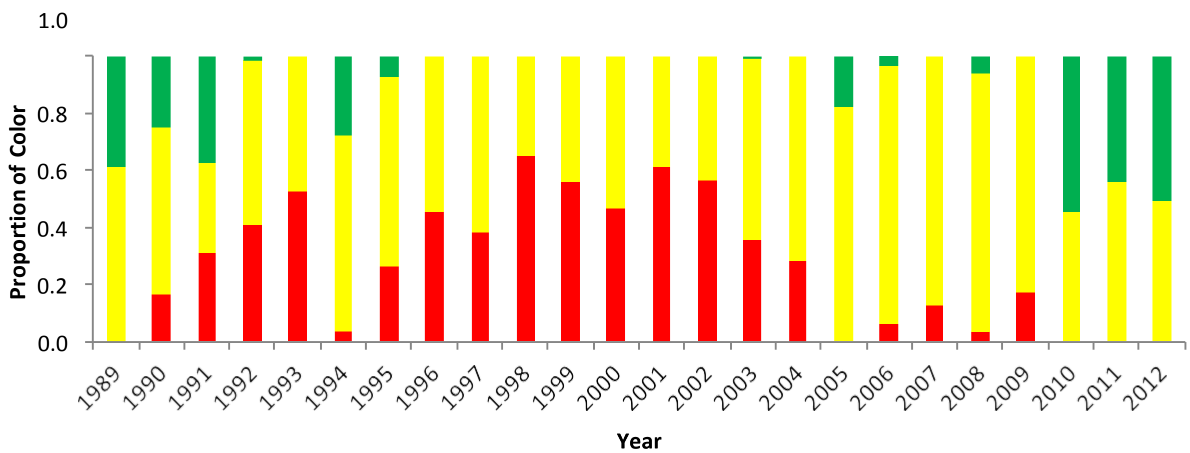
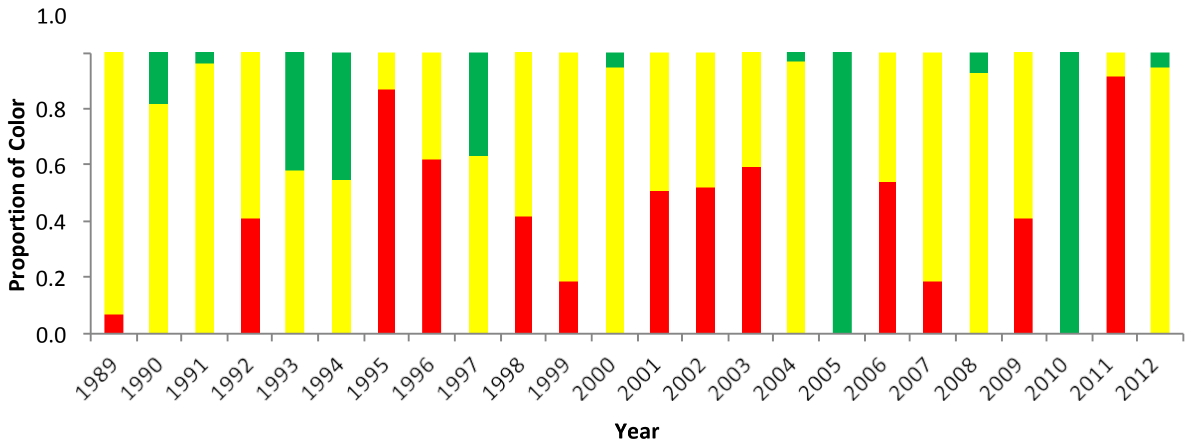


Figure 34. Annual FTLA for juvenile spot from the Maryland Chesapeake Bay seine survey using a 1989-2012 reference period.



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