Atlantic States Marine Fisheries Commission

2017 Stock Status Report
for
Gulf of Maine Northern Shrimp (*Pandalus borealis*)

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November 2017

ACKNOWLEDGMENTS

The Northern Shrimp Technical Committee sincerely thanks all those people who have contributed to this report through their time and efforts as part of the crew on the *R/V Gloria Michelle* shrimp survey, as selected vessels in the cooperative winter sampling program, and as port samplers, sample processors, and data entry personnel. Their hard work has made this effort possible.

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery since the mid-1980s have fluctuated between 346–9,500 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). The fishery was closed during 2014-2017 due to poor resource conditions. Removals in 2014, 2015, 2016 and 2017 were 0.3 mt, 6.7 mt, 13.3 mt, and 32.6 mt, respectively, as part of a cooperative winter sampling program during the moratorium. Samples from the 2017 winter sampling program were composed mostly of ovigerous females from the 2013 year class and males probably from the 2015 year class.

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 assessment and management. The current assessment therefore uses an index-based approach to evaluate the condition of the stock. A benchmark assessment which will explore alternative modeling approaches is scheduled for peer-review in 2018.

The index-based assessment approach evaluates a suite of indicators including fishery performance, survey indices of abundance and biomass, and environmental conditions. Abundance and biomass indices for 2012–2017 are the lowest on record of the thirty-four year time series, with 2017 being the lowest observed. Recruitment indices for the 2010–2016 year classes are also generally poor and include the four smallest year classes on record. The recruitment index in 2017 (2016 year class) was the second lowest observed. As a result, the 2012–2017 indices of harvestable biomass are the lowest on record. Current harvestable biomass is mainly comprised of females from the weak 2013 year class and some small, early-maturing females from the below-average 2015 year class.

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 within the past several years. While 2014 and 2015 temperatures were cooler, 2016 and 2017 temperatures were again high, and temperature is 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 and maintain a fishable stock. Given the continued poor condition of the resource and poor prospects for the near future, the Northern Shrimp Technical Committee recommends that the Northern Shrimp Section extend the moratorium on fishing through 2018.

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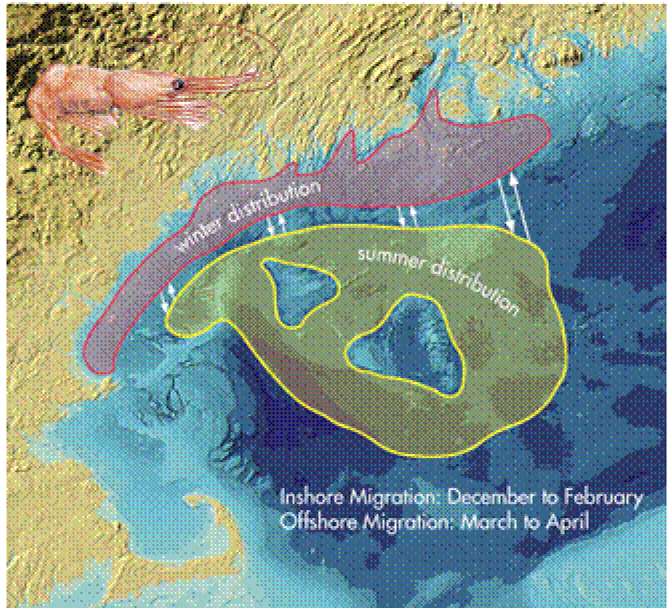
1.0 INTRODUCTION

1.1 Biological Characteristics



Distribution of adult female northern shrimp (NAMA, 2006)

Northern shrimp (*Pandalus borealis* Krøyer) are hermaphroditic, maturing first as males at about 1½ years of age and then transitioning to females at about age 3 in the Gulf of Maine (Haynes and Wigley 1969). Spawning takes place in offshore waters beginning in late July. By early fall, most adult females have extruded 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. Northern shrimp are also an important food source for marine fish, mammals and invertebrates (Parsons 2005).

1.2 Fishery Management

The Gulf of Maine Northern Shrimp fishery is managed by the ASMFC Northern Shrimp Section (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, ASMFC 1986).

In 2004, the Section implemented Amendment 1 which 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 due to untimely reporting and landing rates being greater than anticipated, resulting in short notice of the season closure and an overharvest of the recommended total allowable catch (TAC).

In 2011, the Section implemented Amendment 2. The amendment provided management options to slow catch rates throughout the season, including trip limits, trap limits, and days out of the fishery. The amendment also modified the fishing mortality reference points to include a threshold level, a more timely and comprehensive reporting system, and allowed for the initiation of a limited entry program to be pursued through the adaptive management process.

In November 2012, the Section implemented Addendum I to Amendment 2. The addendum, clarified the annual specification process, and allocated the annual hard TAC with 87% for the trawl fishery and 13% for the trap fishery based on historical landings by each gear type. Addendum I also implemented a season closure provision designed to close the northern shrimp fishery when a pre-determined percentage (between 80–95%) of the annual TAC had 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 annual TAC to help support research on the Northern Shrimp stock and fishery. The Section may set a RSA during years of a moratorium.

In 2013, the Northern Shrimp Section imposed a moratorium on the fishery for the 2014 season. The Section considered several factors prior to closing the fishery: (1) Northern shrimp abundance in the western Gulf of Maine had declined steadily since 2006, (2) the 2012 and 2013 survey indices of total biomass and spawning stock biomass were the lowest on record, (3) the stock experienced failed recruitment for three consecutive years prior to 2014 (2010–2012 year classes), and (4) long term trends in environmental indices were not favorable for northern shrimp in the Gulf of Maine. The 2014, 2015, and 2016 stock status reports indicated continued poor trends in biomass, recruitment, and environmental indices which prompted the Section to extend the moratorium each year through 2017. Winter sampling via selected commercial shrimp vessels occurred in each year of the moratorium (2014, 2015, 2016, and 2017) to continue the time series of biological samples that had been obtained from the Gulf of Maine commercial northern shrimp fishery.

Since the implementation of Amendment 2 the Gulf of Maine northern shrimp fishery and population has experienced significant changes. Also, substantial changes in other Northeast fisheries resulted in increased effort in the northern shrimp fishery in 2010 – 2012. This increased fishing pressure, coupled with failed recruitment, the lowest abundance indices on record, and unfavorable environmental conditions have resulted in a highly uncertain future for the resource. To address these uncertainties, the Section implemented Amendment 3 in August 2017 which is designed to improve management of the northern shrimp resource in the event the fishery reopens. Specifically, the Amendment refines the FMP objectives and provides the flexibility to use the best available information to define the status of the stock (i.e., definition of overfished/overfishing) and set the total allowable catch (TAC). Furthermore, Amendment 3 implements a state-specific allocation program to better manage effort in the fishery; 80% of the annual TAC will be allocated to Maine, 10% to New Hampshire, and 10% to Massachusetts. The Section also has the discretion to roll over unused quota from the states of New Hampshire and Massachusetts to Maine by a date determined during annual specifications.

1.3 Benchmark Stock Assessment Peer-Review, 2014

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 the most recent 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.
- 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 Northern Shrimp Technical Committee (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, stock status is evaluated using an index-based approach, which the NSTC deems the best available science to support management as outlined in Amendment 3.

1.4 Annual Fishery Specifications Process

The process for setting fishery specifications under Amendment 3 is as follows: the NSTC will annually review the best available data which may include, but are not limited to, catch and landing statistics, current estimates of fishing mortality, stock status, shrimp survey indices, assessment modeling results, and target and threshold mortality levels; and recommend a hard TAC to maintain or reach healthy stock status relative to peer reviewed biological reference points, if available.

The Section meets annually during a public meeting in the fall or early winter to review the Advisory Panel and NSTC recommendations, sets a hard TAC that is associated with managing the northern shrimp fishery at the F_{target}, at the $F_{threshold}$, or between the F_{target} and $F_{threshold}$, when possible, and specify any combination of management measures outlined in *Section 4.1.1* of Amendment 3 through a majority vote. Refer to Appendix 1 for NSTC recommendations and subsequent management action by year from 1986-2017.

2.0 COMMERCIAL FISHERY TRENDS

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 vessel trip reports (VTRs), trappers averaged 12% of Maine's landings during 2001 to 2007, 18% during 2008 to 2011, and 8% in 2012 to 2013 (Table 4). Otter trawling effort has accounted for between 78% and 96% of Maine's landings during 2000 to 2013.

2.1 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 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 second lowest landings estimate in time series at that time. 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.

In 2010, the proposed 180-day season was cut short to 156 days due to landing rates being higher than expected, and concerns about catching small shrimp. Landings were estimated at 6,263 mt, while the TAC was set at 4,900 mt. In 2011, the season was similarly closed early due to landings in excess of the TAC. A total of 6,398 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 three 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% of the TAC. The season was closed on February 17; 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 would close when the projected landings reached 85% of the TAC 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.

2.2 Cooperative Winter Sampling/Research Set Aside Program, 2014–2017

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). No shrimp were landed during the 2014 cooperative winter sampling program, except the collected samples.

In 2015, the sampling program was expanded; four trawlers and five trappers collected northern shrimp during January-March under the 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 from the qualified applicants was picked at random for each of the four sampling regions. 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 also selected from Midcoast and Eastern Maine and each fished ten traps, tended as often as needed. 2015 RSA catches were estimated at 6.7 mt.

In 2016, four trawlers and two trappers collected northern shrimp during January-April under the RSA program (Hunter 2016). All fishing regions were defined the same as in 2016, except for eastern Maine which consisted of anything east of Monhegan Island. Similiarly, one trawl captain from the qualified applicants was picked at random for each of the four sampling regions. Each trawler fished about once every two weeks, conducting at least three tows per trip, and made no more than five trips. Two trappers were also selected from midcoast Maine and each fished forty traps, tended as often as needed. 2016 RSA catches were estimated at 13.3 mt.

In 2017, the RSA program continued and was expanded to ten trawlers and five trappers collecting northern shrimp during January-March (Hunter 2017): one vessel from Massachusetts, one from New Hampshire, three from western Maine, three from midcoast Maine, and two from eastern Maine were picked at random from among qualified applicants from that state and region. Four trappers were also selected from midcoast Maine and one from eastern Maine and each fished up to forty traps, tended as often as needed. 2017 RSA catches were estimated at 32.6 mt. All 2014-2017 RSA catches, including discards, are included in Tables 1, 3 and 4 and relevant figures.

2.3 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 Figure 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 mostly comprised 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 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. Transitional stage shrimp and female stage Is (ones) from the 2008 year class, and some males and juveniles from the assumed 2009 year class were observed in 2011, 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 comprised of assumed 5-year-old shrimp from the 2009 year class and some small males assumed to be from the fast-growing 2013 year class. Samples from the 2015 RSA program exhibited an unusually high percentage of small ovigerous females, likely early-maturing and fast-growing 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. Samples from the 2016 RSA program confirmed that members of the 2013 year class were ovigerous (at only three years old) and available inshore, and represented a greater proportion of the catch than older year classes (2010-2012). Some 2016 samples, particularly those from the New Hampshire boat, contained a portion of very large females, possibly from the assumed 2010 year class. Samples from the 2017 RSA program were composed mostly of ovigerous females from the 2013 year class and males probably from the 2015 year class (Figure 2 and Figure 3).

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 2016, similar to 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. The 2017 hatch midpoint was February 21, earlier than in 2014-2016, but within the historical time series range (Figure 19). Egg hatch trends observed in the 2017 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.

2.4 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 northern shrimp stock status report. However in 2014, aside from the 2-kg samples that were provided to Maine DMR for analysis, all catches (0.3 mt) from the cooperative winter sampling program were discarded at sea. In 2017, all six trawl vessels in western Maine and midcoast Maine exceeded the 1,200 pound trip limit at least once and had to discard excess northern shrimp. An estimated 2,335 pounds of northern shrimp were discarded in 2017 (ASMFC 2017). All 2014-2017 RSA catches, including discards, are included in Tables 1, 3, and 4 and relevant figures.

2.5 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 uncertain, although 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.

2.6 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. Effort increased again during 2003–2005 as the seasons were lengthened, to 3,866 trips in 2005. Effort in 2006 dropped to 2,478, likely due to poor market conditions, increased in 2007 to 4,163, and further increased in 2008 to 5,587, the most trips since 1999.

In 2009, the length of the season was increased to 180 days while 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 in part 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 due 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).

Refer to Figure 5 for comparison of 2017 RSA program trawl and trap locations relative to 2013 fishing effort from VTR data.

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 trappers (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.

2.7 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 utilized as measures of resource 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 pounds per trip averaged 1,407. 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).

3.0 RESOURCE CONDITIONS

Trends in abundance of Gulf of Maine northern shrimp were monitored during 1963–1983 from data collected in the Northeast Fisheries Science Center’s (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 survey 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 assessment, although the other survey data are also considered. See Figure 6 for a map of the areas covered by the different surveys.

For the 2017 ASMFC summer survey aboard the R/V *Gloria Michelle*, the vessel's winches were replaced and new Bison trawl doors replaced the old Portuguese trawl doors, which had been in use since the first year of the survey in 1984. Before the 2017 survey, eight pairs of calibration tows were made to compare the performance of the gear with the old and new doors and winches. Results for these tows are shown in Appendix 2. More calibration tows are planned for 2018. Averaged over the eight pairs of tows, the new gear caught 98% of what the old gear caught, in northern shrimp weight, and 1.05% of the old gear, in numbers. The differences were not statistically significant (Wilcoxon paired-sample test, p=0.46 for shrimp weight, p=0.95 for shrimp numbers). The data and discussion below assume that there was no significant difference in the performance of the 2017 survey gear, compared with prior years.

Abundance and biomass indices (stratified geometric mean catch per tow in numbers and weight) for northern shrimp from the ASMFC summer survey from 1984–2017 are given in Table 9 and Figures 7–10 and 21-24, and length-frequencies by year are provided in Figures 11 and 12. Indices were calculated using data from successful random tows in strata (areas) 1, 3, 5, 6, 7, and 8 only (Figure 7). Total biomass averaged 15.9 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 (see below), 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 dropped steadily to a time series low of 0.9 kg/tow in 2017. The 2016 value of 3.8 kg/tow was higher than each of the previous four years but is the sixth lowest in the time series, well below the time series average of 11.6 kg/tow (Table 9). The six values for 2012-2017 (2.5, 1.0, 1.7, 3.8, and 0.9 respectively) are the six lowest values in the time series. 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, Figure 24, and graphically represented as the first (left-most) size mode in Figures 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. The recruitment 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 334 individuals per tow. From 2008 to 2010, the recruitment 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. Time series lows (fewer than 10 per tow) were observed in 2012, 2013, 2015, and 2017, indicating recruitment failure of the assumed 2011, 2012, 2014, and 2016 year classes. In 2014, the index was 116 per tow, reflecting below-average recruitment of the 2013 year class. The recruitment index for the 2016 survey (the assumed 2015 year class) was 226 individuals per tow, the highest since 2010, but still below the time series average of 334 per tow. Surveys since 2011 have shown an unprecedented seven consecutive years (2010–2016 year classes) of below-average recruitment.

Mean numbers per tow at size for 2012-2017 are too low to be clearly visible in Figure 11, which uses a constant y-axis scale for the time series. Expanded vertical axes for the 2012-2017 data show that the mean carapace lengths of the assumed age-1.5 shrimp in the 2014 and 2016 surveys were unusually large, suggesting a high growth rate for the 2013 and 2015 year classes (Figure 12).

Individuals larger than 22 mm carapace length (CL) in the summer are expected to be fully recruited to a fishery the following winter (as primarily age 3 and older). Thus, survey catches of shrimp in this size category provide indices of harvestable numbers and biomass for the coming winter (Table 9 and Figure 23). 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 to a time series low of 1.5 kg/tow, and is indicative of small assumed 1997 and 1998 year classes. From 2003 to 2006, the index increased dramatically, reaching a time series high in 2006 (29.9 kg/tow). 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 time series low in both 2014 and 2017 (both 0.2 kg/tow), consistent with the low recruitment of the 2010, 2011, and 2013 and 2014 year classes.

An index of spawning stock biomass was estimated by applying a length-weight relationship for non-ovigerous shrimp (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. Since 2006, the index declined to less than 1.0 kg/tow in 2012–2015, and reached a new time series low (0.1) in 2017 (Table 9 and Figure 22).

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):

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

The EPI index for Gulf of Maine northern shrimp 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 (<0.2 million; Table 9 and Figure 16). The value was 0.03 million in 2017, the lowest value in the time series.

An index of survival to age 1.5 was estimated for each year class as the log ratio of the number of age 1.5 recruits to the number of eggs that produced 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 high (greater than 1,000) for the assumed 1999, 2001, and 2004 year classes, and low (less than 20) for the 2006, 2011, 2012, and 2016 year classes (Table 9 and Figure 25). The index for the 2013 year class was slightly above the average, and the 2015 year class index was 5,291, the highest in the time series. This is encouraging, but it should be noted that estimating the survival index (a ratio) is difficult when abundance is at extreme lows, as is currently the case.

The NEFSC fall survey conducted by the NOAA Ship *Albatross IV* provided an index of northern shrimp biomass 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) in 1977 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 and Figure 8). In 2009, the NEFSC fall survey changed vessels, gear 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 0.5 kg/tow in 2016, parallel to trends in the summer shrimp survey and the ME-NH survey (Figure 8, Figure 10, and Figure 14). NEFSC fall survey values for 2017 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). The survey consistently catches shrimp in regions 1–4 (NH to Mt. Desert Is.)

and depths 3–4 (> 35 fa (>64 m)), and more are caught, with less variability, in the spring than the fall. The stratified geometric mean weights per tow for northern shrimp for the spring and fall surveys using regions 1–4 and depths 3–4 only are presented in Table 11 and Figures 13–14. The Maine-New Hampshire spring index rose steadily from 4.2 kg/tow in 2003 to a time series high of 17.9 kg/tow in spring 2011. The index then dropped abruptly and reached a time series low of 1.7 kg/tow in 2013 and 2015. The preliminary 2017 value was 2.0 kg/tow. 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 2013–2017 biomass indices and size and sex-stage structure in the ME-NH survey (Figure 15, unstratified untransformed mean numbers by size and sex-stage) are consistent with the 2013–2017 ASMFC summer survey results.

4.0 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; Richards et al. 2016). Survival during the first year of life has been negatively correlated with ocean temperature during two periods: (1) during the time of the hatch and early larval period, and (2) during the late summer when ocean temperatures and water column stratification are reaching their maximum (Richards et al. 2016). Relatively cool temperatures during these sensitive periods are associated with higher recruitment indices in the summer shrimp survey. Spawner abundance also influences recruitment, with more recruits produced with higher spawner abundance, but environmental influences have increased in importance since around 1999 (Richards et al. 2012).

Spring surface and bottom temperature anomalies (temperature changes measured relative to a standard time period) in offshore shrimp habitat areas in 2017 were cooler than in 2016, but remained high relative to the baseline period (1978-1987) (Figures 17A and 17C). Fall temperature anomalies have consistently been above the baseline average (anomaly=0) for about a decade, although the fall bottom temperature was cooler in 2015 than in most recent years (Figures 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 has increased fairly steadily from an average of 0.8^{o} C during 1906-1948 to 3.3^{o} C during 2008-2017 (Figure 17E). Average winter SST during 2017 was 3.8^{o} C. Late summer SST (July 15-Sept. 1) did not show a similar long term increasing trend during the 20th century, but increased sharply during the mid-1990s, reaching a record high in 2006 (20.2^{o} C) (Figure 17F). Late summer SST in 2017 was equal to the long term mean of 16.3^{o} C.

Ocean temperatures also affect timing of the shrimp larval hatch (Richards 2012). The start of the hatch period became earlier in the 1990s as temperatures increased, and by the mid-2000s was beginning about a month earlier than it did before 2000 (10% line in Figure 18). The midpoint of the hatch period has changed less than the start of the hatch (50% line in Figure 18). During the past four years (2014-2017), hatch timing has been similar to hatch periods observed before 2000 (Figure 18).

To evaluate whether there may have been a recent 'regime shift' in temperatures affecting shrimp or in shrimp population dynamics, a regime shift detection algorithm (STARS, Rodionov 2004; Rodionov and Overland 2005) was applied to the temperature times series discussed above, and to biological data relevant to shrimp. The biological data included time series of shrimp recruitment indices, mean size of recruits (presumed age 1.5), size at sex transition, early life survival indices, and predation pressure indices (NEFSC 2014; Richards and Jacobson 2016) based on fall and spring NEFSC surveys (see Appendix 3 for details).

Overall, the results of the regime shift detection algorithm suggested a shift in temperature regime occurred around 2010, but with no clear effect on shrimp. Individual temperature time series that suggested a potential shift included the spring sea surface temperature anomaly, fall bottom temperature anomaly, summer shrimp survey bottom temperature, a composite temperature index, timing of the spring thermal transition, and length of summer. The temperature time series that did not show a change point near 2010 were winter surface temperature at Boothbay Harbor and spring bottom temperature anomaly.

For the biological variables, potential change points were identified for mean size at age 1.5 (in 2014) and possibly for early life survival (in 2015). Both of these change points were very recent and thus bear watching to determine whether a regime shift has occurred. It should be noted that the survival indices may not be very meaningful at the current low abundance. A possible regime shift was detected in the time series of recruitment indices based on a geostatistical method of estimating shrimp abundance (Cao et al. 2017), but not in the standard recruitment indices used in past northern shrimp assessments. The regime shift was only detected in one of the three statistical configurations tested. The results for the spring and fall predation pressure indices suggested change points near the end of the time series (2015, 2016), which will need to be evaluated as more years of data are added.

5.0 STOCK STATUS

The NSTC utilized an index-based approach 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 (2014) was applied to the northern shrimp stock to characterize indices of abundance, fishery performance, and environmental trends from 1984 to present. The approach categorizes annual values of each index as one of three colors (red, yellow, or green) to illustrate the state of the population, environmental conditions, 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, Caddy 1999*a*, 1999*b* and 2004) to a suite of indices (Figure 20). Fishery independent indices included survey total abundance and biomass estimated from the ASMFC summer shrimp and NEFSC fall surveys, and harvestable biomass, 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; Richards and Jacobson 2016), 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 2017 US dollars (www.bls.gov).

Two qualitative stock status reference levels were developed for the traffic light approach, one based on the 'stable period' mean (SPM, 1985–1994), which was the time period used to define the reference points in Amendment 2. The second qualitative status indicator was based on the entire time series of observations. The 20th percentile of the time series (1984-2017) was considered to delineate an extremely adverse state. 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 and spawning biomass have remained at historic lows for the past six years (2012–2017). Recruitment has been low to extremely poor for seven consecutive years and reached time series lows in 2013 and 2017. The index of early life survival has been variable in recent years. Despite a very high survival index for the 2015 year class, suggesting that an unusually high proportion of the eggs produced in 2015 persisted to age 1.5 shrimp, recruitment of that year class was weak. The survival index of the 2016 year class was very low, as was its recruitment. The predation pressure index had decreased in recent years (2013–2015) however, increased to a time series high in 2017. In general, the predation pressure index has been high since the late 1990s. Water temperatures were at or near record highs in 2012, cooler in 2014 and 2015, and high again in 2016 and 2017. There were no fishery dependent indices for 2014-2017 due to a fishery moratorium.

The NSTC also examined a subset of key indicators using the Fuzzy Traffic Light Approach (FTLA; McDonough and Rickabaugh 2014). 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 stable period mean (SPM) and the 20th 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.

The NSTC evaluated 10 indicators using the FTLA, including: 1) total biomass, 2) recruit abundance, 3) spawning biomass, 4) harvestable biomass, 5) commercial fishery CPUE (metric tons landed per trip; fishery closed 2014 – 2017), 6) early life survival, 7) predation pressure index (PPI), 8) spring sea surface temperature at Boothbay Harbor, ME, 9) spring bottom temperature anomaly from NEFSC surveys in shrimp resource areas, and 10) summer bottom temperature from the ASMFC summer shrimp survey (1 – 4 and 6 are also from the ASMFC summer shrimp survey).

Total biomass indices have remained below the 20th percentile during 2012–2017, with those six values being the lowest biomass estimates on record (Table 9, Table 12, and Figure 21). Similarly, spawning biomass and harvestable biomass indices have remained below the 20th percentile during 2012–2017, and are also the lowest estimates on record (Table 9, Table 12, and Figure 22 and Figure 23). Total, spawning, and harvestable biomass indices in 2017 were the lowest observed in the 34 years of survey.

Recruitment was below the 20th percentile in 2012, 2013, 2015, and 2017, with the lowest recruitment on record observed in 2013 and second lowest in 2017 (Table 9, Table 12, and Figure 24). In 2013, 2015, and 2017, the abundance of recruits was less than three shrimp per tow, as compared to the SPM of 382 shrimp per tow. Early life survival (to age 1.5) was at or below the 20th percentile for the 2012 and 2016 year classes, with survival of the 2012 year class the lowest on record and 2011 the second lowest (Table 9, Table 12, and Figure 25). Early life survival of the 2013 and 2015 year classes was above the SPM but recruitment of those year classes was weak. The survival index for the 2015 year class was the highest on record, possibly reflecting favorable temperatures during the larval period; however the reliability of survival estimations may be compromised at such low population levels. The 2013–2014 year classes would be the target of a 2018 fishery.

No commercial catch occurred in 2014, 2015, 2016, or 2017 due to a harvest moratorium. In 2013, the last year prior to the moratorium, the catch rate was below the 20th percentile and a record low for the time series (Table 12 and Figure 26).

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. During 2009-2011, the PPI was above the 80th percentile; however during 2013-2015 it fluctuated around a lower level (Figure 27). In 2016, predation pressure jumped to a time series high, attributable to an increased biomass index of spiny dogfish (*Squalus acanthias*) (unpub. data, NEFSC 2017). Sea surface and bottom temperatures were colder in 2015 than in prior years, however temperatures in 2016 and 2017 warmed to around the 80th percentile of the time series. An overall rise in water temperature since the stable period is evident (Figure 28, Figure 29, and Figure 30), with spring anomalies and summer bottom temperatures in offshore shrimp habitat at or exceeding the 80th percentile from 2011 to 2013 and again in 2016 (Table 13, Figure 29, and Figure 30).

Taken together, the FTLA indicators demonstrate that the Gulf of Maine northern shrimp stock status continues to be very poor. Total biomass, spawning biomass and harvestable biomass have remained at unprecedented lows for six consecutive years. Recruitment of the 2011, 2012, 2014, and 2016 year classes were the weakest observed in the 34-year time series, although recruitment of the 2015 year class was marginally higher. The stock remains in a depleted condition. Protection of the 2013 and 2015 year classes may provide a foundation for stock recovery if these year classes survive to spawn successfully.

Accepted definitions of stock collapse include a population at 10% of un-fished biomass (Worm et al. 2009) or at 20% of B_{MSY} (Pinsky et al. 2011). Using summer survey biomass indices and the 1984–1993 "stable period" survey mean as a highly conservative proxy for un-fished biomass, the Gulf of Maine northern shrimp stock was considered collapsed during 2012 – 2015, slightly above this threshold in 2016, and collapsed in 2017. Using the stable period mean as a proxy for B_{MSY} instead (likely a more reasonable assumption), the stock has remained in a collapsed state since 2012.

6.0 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 objective to protect and maintain the northern shrimp stock at sustainable levels that will support a viable fishery (Amendment 3 to the FMP, ASMFC 2017).

Short-term commercial prospects for the 2018 fishing season are very poor given the low index of harvestable biomass in 2017. Longer-term prospects remain poor with moderate but below-average recruitment observed in 2016 and very low recruitment observed in 2017.

Indices of total biomass and spawning biomass have remained at unprecedented lows for six consecutive years, including 2017. The 2017 biomass indices were the lowest values on record.

Recruitment failure has been observed in four of the past six years (the 2011, 2012, 2014, and 2016 year classes). The 2013 year class, which was well below the long-term average recruit abundance, was responsible for the increase in spawning biomass observed in 2016. The 2013 year class would have spawned as four-year-old shrimp in 2017, and are expected to spawn again in 2018. The 2016 recruitment index (the 2015 year class) was also below the long-term average, but was the highest value observed in the past six years; this year class is expected to enter the spawning stock in 2019. The 2017 recruitment index (the 2016 year class) was the second lowest on record.

Long term trends in environmental conditions have not been favorable for northern shrimp in the Gulf of Maine. This suggests a need to conserve spawning stock biomass to help compensate for what may continue to be an unfavorable environment.

Given the continued poor condition of the resource, the poor prospects for a 2018 commercial season, and the value of maximizing spawning potential to rebuild the stock, the NSTC recommends that the Section extend the moratorium on fishing through 2018.

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8.0 TABLES

Table 1: U.S. commercial landings (mt) of northern shrimp in the Gulf of Maine, by year (1958–1984, left) or by season (1985–2017, right). Landings by season include the previous December. No shrimp were sold or purchased from cooperative winter sampling in 2014. Landings in 2015 - 2017 are from the RSA Program.

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	2,501.2
2010	5,721.4	35.1	506.8	6,263.3
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	0.3	0.0	0.0	0.3
2015	6.1	0.6	0.0	6.7
2016	11.5	0.0	1.8	13.3
2017	31.2	0.9	0.5	32.6

* Landings by Season include the previous December.

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 1985–2017. No shrimp were sold or purchased from cooperative winter sampling in 2014. 2015 – 2017 prices and value are from the RSA program.

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 ($/Lb) 2017 dollars	Value ($) 2017 dollars
1985	0.44	3,984,562	1.01	9,200,373
1986	0.63	6,451,206	1.40	14,305,796
1987	1.10	12,740,581	2.40	27,862,903
1988	1.10	7,391,777	2.31	15,459,334
1989	0.98	7,177,659	1.96	14,326,043
1990	0.72	7,351,420	1.37	14,082,303
1991	0.91	7,208,838	1.64	12,962,943
1992	0.99	7,547,941	1.74	13,272,710
1993	1.07	5,038,053	1.82	8,598,200
1994	0.75	4,829,106	1.25	8,033,645
1995	0.90	12,828,030	1.45	20,639,831
1996	0.73	15,341,504	1.15	24,185,394
1997	0.79	12,355,871	1.21	18,991,931
1998	0.96	8,811,938	1.44	13,228,159
1999	0.91	3,762,043	1.35	5,553,367
2000	0.79	4,968,655	1.13	7,112,453
2001	0.86	2,534,095	1.19	3,491,878
2002	1.08	1,077,534	1.48	1,476,975
2003	0.87	2,590,916	1.16	3,438,133
2004	0.44	2,089,636	0.58	2,725,359
2005	0.57	3,261,648	0.72	4,143,134
2006	0.37	1,885,978	0.45	2,304,275
2007	0.38	4,087,120	0.45	4,841,053
2008	0.49	5,407,373	0.56	6,126,491
2009	0.40	2,216,411	0.46	2,536,578
2010	0.52	7,133,718	0.58	8,008,822
2011	0.75	10,625,533	0.83	11,706,442
2012	0.95	5,230,481	1.02	5,589,023
2013	1.81	1,375,788	1.90	1,447,246
2014		0		0
2015	3.49	51,282	3.62	53,240
2016	6.67	195,925	6.85	201,133
2017	6.30	452,379	6.30	452,379

* Inflation adjustment from US Dept. of Labor, Bureau of Labor Statistics, at http://www.bls.gov/data/inflation_calculator.htm accessed Oct. 20, 2017.

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. 2015 - 2017 data are for the RSA.

	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	377.9	894.7	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	439.5	1,095.0	976.0	0.0	0.0	0.01	2,610.1
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	144.2	691.6	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	147.6	719.5	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	408.6	1,053.6	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	502.7	1,177.3	2,197.3	1,035.7	49.3	0.0	0.1	4,962.4

conf = Confidential data were combined with an adjacent month.

	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	264.1	1,689.2	2,956.0	524.3	254.4	33.0	0.4	5,721.44
Mass.	conf	16.9	18.2	conf	conf			35.1
N.H.	112.8	152.4	200.0	14.2	27.4	conf		506.8
Total	376.9	1,858.6	3,174.2	538.5	281.8	33.0	0.4	6,263.3
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, 5 Maine trawl trips made to collect samples								
Maine		0.05	0.13	0.08				0.3
Mass.								0.0
N.H.								0.0
Total	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.3
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
2016 Season, Limited research fishery for data collection only								
Maine		1.5	3.7	6.3	0.01			11.5
Mass.								0.0
N.H.		0.4	1.2	0.3				1.8
Total	0.0	1.9	4.9	6.5	0.01	0.0	0.0	13.3

2014-2017 research fishery data include some discards.

Table 3 continued – Landings by season, state, and month. 2015 - 2017 data are for the RSA.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2017 Season, Limited research fishery for data collection only								
Maine		4.8	19.2	7.2				31.2
Mass.		0.4	0.4	0.0				0.9
N.H.		0.2	0.3	0.0				0.5
Total	0.0	5.4	19.9	7.2	0.0	0.0	0.0	32.6

2014-2017 research fishery data include some discards.

Table 4: Distribution of landings (metric tons) in the Maine northern shrimp fishery by season, gear type, and month. 2015 – 2017 data are for the RSA.

	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	377.9	770.6	663.6			0.01	1887.1	83%
Trap		conf	124.0	259.0				383.1	17%
Total	75.0	377.9	894.7	922.6	0.0	0.0	0.01	2270.2	
2006 Season, 140 days, Dec 12 - Apr 30									
Trawl	144.2	675.0	733.8	256.9	118.0			1928.0	88%
Trap	conf	16.6	163.1	93.9	conf			273.6	12%
Total	144.2	691.6	896.9	350.8	118.0	0.0	0.0	2201.6	
2007 Season, 151 days, Dec 1 - Apr 30									
Trawl	761.9	1,443.3	1,275.6	362.1	143.6	0.4	0.0	3,986.9	89%
Trap	conf	37.2	314.7	119.8	10.6			482.4	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	408.6	989.6	1,680.8	603.4	42.6		0.1	3,725.0	82%
Trap	conf	64.0	339.6	380.4	6.7			790.7	18%
Total	408.6	1,053.6	2,020.4	983.8	49.3	0.0	0.1	4,515.8	

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
2009 Season, 180 days, Dec 1 - May 29									
Trawl	134.6	579.7	780.9	405.4	33.6	1.8	0.2	1,936.3	84%
Trap	conf	16.2	207.3	154.7	1.3			379.4	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	264.1	1,495.2	2,132.6	338.3	254.4	33.0	0.4	4,517.9	79%
Trap	conf	194.1	823.4	186.0	conf			1,203.5	21%
Total	264.1	1,689.2	2,956.0	524.3	254.4	33.0	0.4	5,721.4	
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	2.6			269.5	93%
Trap			15.2	4.9	conf			20.2	7%
Total	0.0	64.9	179.7	42.5	2.6	0.0	0.0	289.7	
2014 Season Closed, 5 Maine trawl trips to collect samples									
Trawl		0.0	0.1	0.1				0.3	100%
Trap								0.0	
Total	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.3	
2015 Season, Limited research fishery for data collection									
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	
2016 Season, Limited research fishery for data collection									
Trawl		1.4	1.9	4.1				7.4	64%
Trap		0.1	1.8	2.2	0.01			4.1	36%
Total	0.0	1.5	3.7	6.3	0.01	0.0	0.0	11.5	
2017 Season, Limited research fishery for data collection									
Trawl		4.7	14.0	5.4				24.1	77%
Trap		0.1	5.2	1.8				7.1	23%
Total	0.0	4.8	19.2	7.2	0.00	0.0	0.0	31.2	

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. 2015 – 2017 data are for the RSA.

	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
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. 2015 – 2017 data are for the RSA.

	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 ofl								
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	1,562	2,602	914	194	29	1	5,543
Mass.	conf	26	23	conf	conf			49
N.H.	55	127	151	21	56	conf		410
Total	296	1,715	2,776	935	250	29	1	6,002
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, 5 Maine trawl trips made to collect samples								
Maine		1	2	2				5
Mass.								0
N.H.								0
Total	0	1	2	2	0	0	0	5
2015 Season Closed, 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
2016 Season Closed, Limited research fishery for data collection only								
Maine		8	21	31	3			63
Mass.								0
N.H.		1	2	2				5
Total	0	9	23	33	3	0	0	68

conf = Confidential data were combined with an adjacent month.

Table 5 continued – Trips by season, state, and month. 2015 – 2017 data are for the RSA.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2017 Season, Limited research fishery for data collection only								
Maine		15	73	51				139
Mass.		3	3	1				7
N.H.		3	4	0				7
Total	0	21	80	52	0	0	0	153

Table 6: Distribution of fishing trips in the Maine northern shrimp fishery by season, gear type, and month. 2015 – 2017 data are for the RSA.

	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	667	953	778			1	2,539	75%
Trap		conf	352	477				829	25%
Total	140	667	1,305	1,255	0	0	1	3,368	
2006									
Trawl	148	490	563	273	101			1,575	68%
Trap	conf	95	384	257	conf			736	32%
Total	148	585	947	530	101	0	0	2,311	
2007									
Trawl	437	977	921	349	119	1	3	2,807	73%
Trap	conf	125	593	320	17			1,055	27%
Total	437	1,102	1,514	669	136	1	3	3,862	
2008									
Trawl	418	1,062	1,393	661	51	0	9	3,594	69%
Trap	conf	229	683	625	51			1,588	31%
Total	418	1,291	2,076	1,286	102	0	9	5,182	

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	%
2009									
Trawl	134	705	673	381	32	5	1	1,931	68%
Trap	conf	80	449	358	15			902	32%
Total	134	785	1,122	739	47	5	1	2,833	
2010									
Trawl	241	1,231	1,520	450	194	29	1	3,666	66%
Trap	conf	331	1,082	464	conf			1,877	34%
Total	241	1,562	2,602	914	194	29	1	5,543	
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	22			989	72%
Trap		0	282	102	conf			384	28%
Total	0	202	889	260	22	0	0	1,373	
2014									
Trawl		1	2	2				5	100%
Trap								0	0%
Total	0	1	2	2	0	0	0	5	
2015									
Trawl		1	8	5				14	31%
Trap		0	16	15				31	69%
Total	0	1	24	20	0	0	0	45	
2016									
Trawl		3	3	9				15	24%
Trap		5	18	22	3			48	76%
Total	0	8	21	31	3	0	0	63	
2017									
Trawl		12	29	22				63	45%
Trap		3	44	29				76	55%
Total	0	15	73	51	0	0	0	139	

conf = Small amounts of confidential trap data were combined with trawl data for that month.

Table 7: Estimated numbers of vessels in the Gulf of Maine northern shrimp fishery by fishing season and state. 2015 – 2017 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	235	6	15	256
2011	172	143	311	12	19	342
2012	164	132	295	15	17	327
2013	110	72	182	13	14	208
2014	1	0	1	0	0	1
2015	3	5	8	1	0	9
2016	3	2	5	0	1	6
2017	8	5	13	1	1	15

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 – 2017 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	1,617
2006	572	345	499	2,066	2,613
2007	531	477	507	2,584	3,119
2008	350	327	343	1,958	2,300
2009	400	315	370	1,837	2,228
2010	424	354	401	2,301	2,704
2011	334	435	347	1,988	2,376
2012	407	313	399	1,495	1,873
2013	118	78	110	492	616

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	779	24	0.3
2014	46	139	1.7	116	0.3	0.04	58	16	0.2
2015	32	58	1.3	3	0.4	0.08	5,291	38	0.4
2016	41	332	3.8	226	1.1	0.23	16	103	1.2
2017	45	26	0.9	1	0.1	0.03		13	0.2
Mean	41	1303	11.6	334	4.2	0.84	707	484	5.3
Median	41	970	9	284	3	1	343	316	3
1984-93 Mean	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

*Would be fully recruited to a 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.

Year	RV *Albatross* Biomass index	Year	RV *Albatross* Biomass index	RV *Bigelow* Biomass index
1968	3.2	2003	1.08	
1969	2.7	2004	1.58	
1970	3.7	2005	2.77	
1971	3.0	2006	6.64	
1972	3.3	2007	4.13	
1973	1.9	2008	3.05	
1974	0.8	2009		7.8
1975	0.9	2010		5.0
1976	0.6	2011		5.6
1977	0.2	2012		2.8
1978	0.4	2013		1.2
1979	0.5	2014		1.9
1980	0.5	2015		0.7
1981	1.5	2016		0.5
1982	0.3			
1983	1.0			
1984	1.90			
1985	1.60			
1986	2.50			
1987	1.70			
1988	1.20			
1989	1.81			
1990	2.04			
1991	0.44			
1992	0.41			
1993	1.85			
1994	2.24			
1995	1.22			
1996	0.90			
1997	1.12			
1998	1.99			
1999	2.32			
2000	1.28			
2001	0.63			
2002	1.70			

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	80% CI	n	kg/tow	80% CI	n
2003	**4.2**	3.4 - 5.1	40	**1.9**	1.4 - 2.6	33
2004	**3.9**	3.3 - 4.5	42	**1.5**	1.0 - 2.1	38
2005	**7.8**	6.6 - 9.2	40	**3.6**	2.5 - 5.1	25
2006	**11.0**	8.5 - 14.1	46	**2.1**	1.4 - 2.8	38
2007	**10.2**	7.6 - 13.7	43	**4.0**	3.1 - 5.1	45
2008	**15.4**	12.7 - 18.6	45	**3.6**	2.3 - 5.4	37
2009	**9.7**	7.7 - 12.1	45	**2.8**	2.3 - 3.4	41
2010	**15.0**	12.1 - 18.5	48		(samples lost)	
2011	**17.9**	14.9 - 21.4	50	**4.2**	3.2 - 5.4	32
2012	**7.5**	6.1 - 9.2	50	**1.9**	1.5 - 2.3	42
2013	**1.7**	1.1 - 2.5	46	**0.6**	0.4 - 0.8	45
2014	**2.1**	1.7 - 2.5	47	**0.3**	0.2 - 0.3	43
2015	**1.7**	1.3 - 2.0	52	**0.3**	0.2 - 0.4	37
2016	**2.2**	1.8 - 2.5	48	**0.4**	0.3 - 0.5	39
***2017**	**2.0**	1.6 - 2.5	52			

* 2017 data are preliminary.

Table 12: Recent (2013–2017) Gulf of Maine northern shrimp FTLA indicator values relative to reference levels. RED = 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	
	2013	2014	2015	2016	2017	SPM	20th percentile
Total Biomass	1.0	1.7	1.3	3.8	0.9	14.1	5.0
Spawner Biomass	0.2	0.3	0.4	1.2	0.1	4.9	1.6
Harvestable Biomass	0.3	0.2	0.4	1.2	0.2	7.1	1.6
Recruit Abundance	1	116	3	226	1	382	24
Early Life (YC) Survival	779	58	5291	16		393	57
CPUE (mt/trip)	0.23					0.45	0.40

KEY

- ≥ SPM
- >20th percentile but <SPM
- ≤ 20th percentile
- data not available

Table 13: Recent (2013–2017) Gulf of Maine northern shrimp FTLA environmental indicator values relative to reference levels. RED = 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	
	2013	2014	2015	2016	2017	SPM	80th percentile
Predator Predation Index	888	1005	890	1913		546	1151
Boothbay Feb-Mar SST	3.9	2.3	1.4	4.1	3.8	2.4	3.8
Spring Bottom Temp NEFSC	1.3	0.5	0.1	1.4	1.0	0.4	1.3
Summer Survey Bottom Temp	7.1	6.2	5.8	7.2	6.9	5.4	7.1

KEY

- ≤ SPM
- < 80th percentile but >SPM
- ≥ 80th percentile
- data not available

9.0 FIGURES

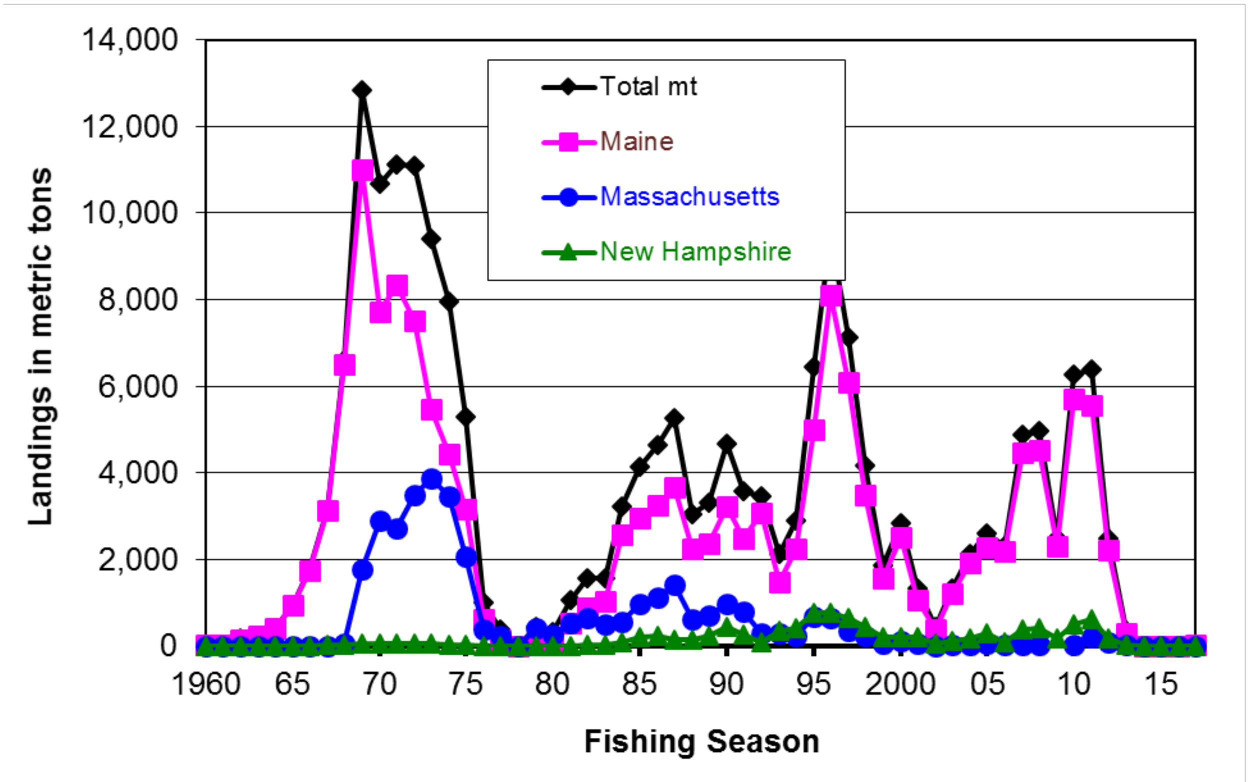


Figure 2: Gulf of Maine northern shrimp landings by season and state. Massachusetts landings are combined with New Hampshire landings in 2009 to preserve confidentiality.

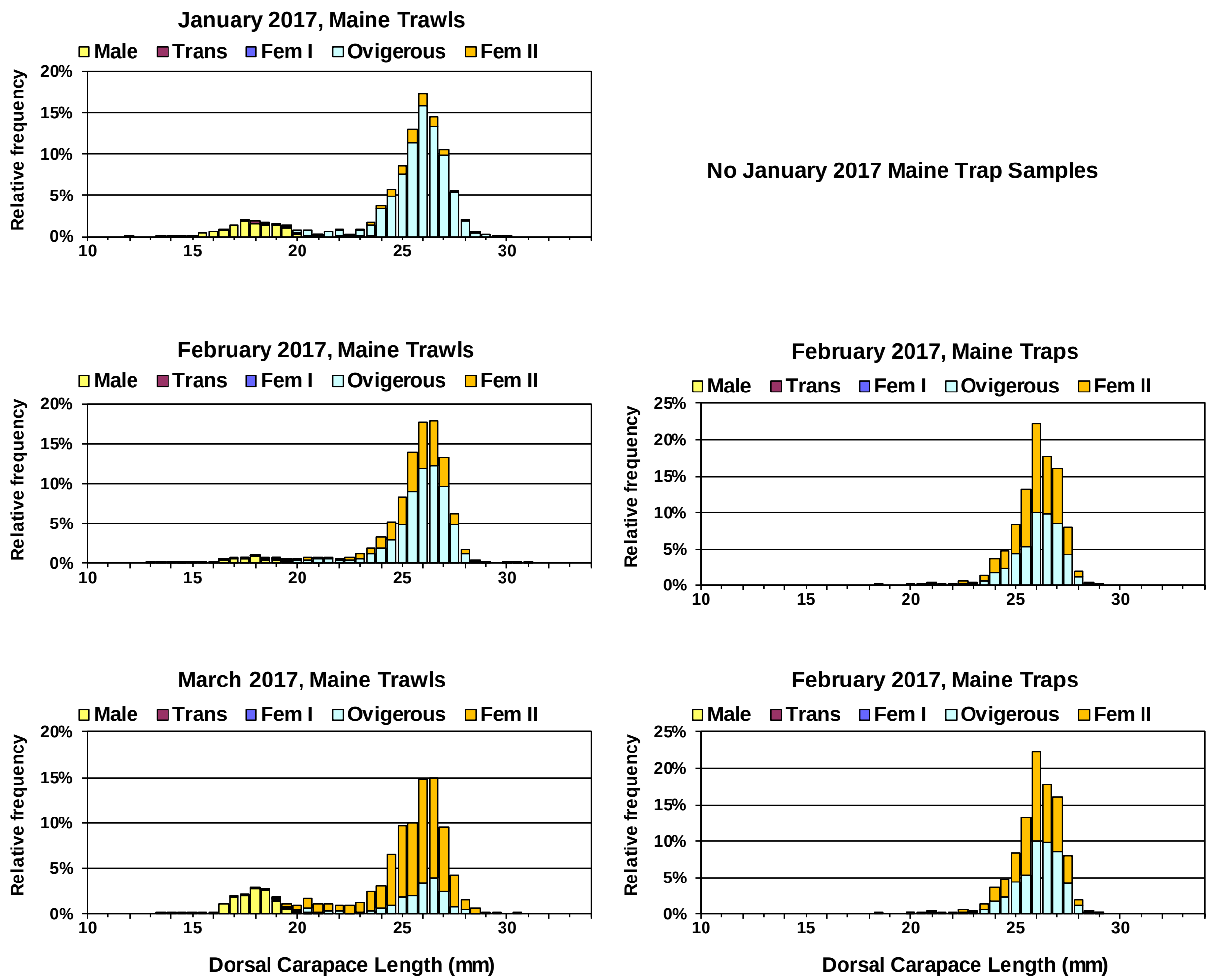


Figure 3: Gulf of Maine northern shrimp size-sex-stage frequency distributions from 2017 winter samples by month for Maine trawls (left) and traps (right). See ASMFC 2017 for details.

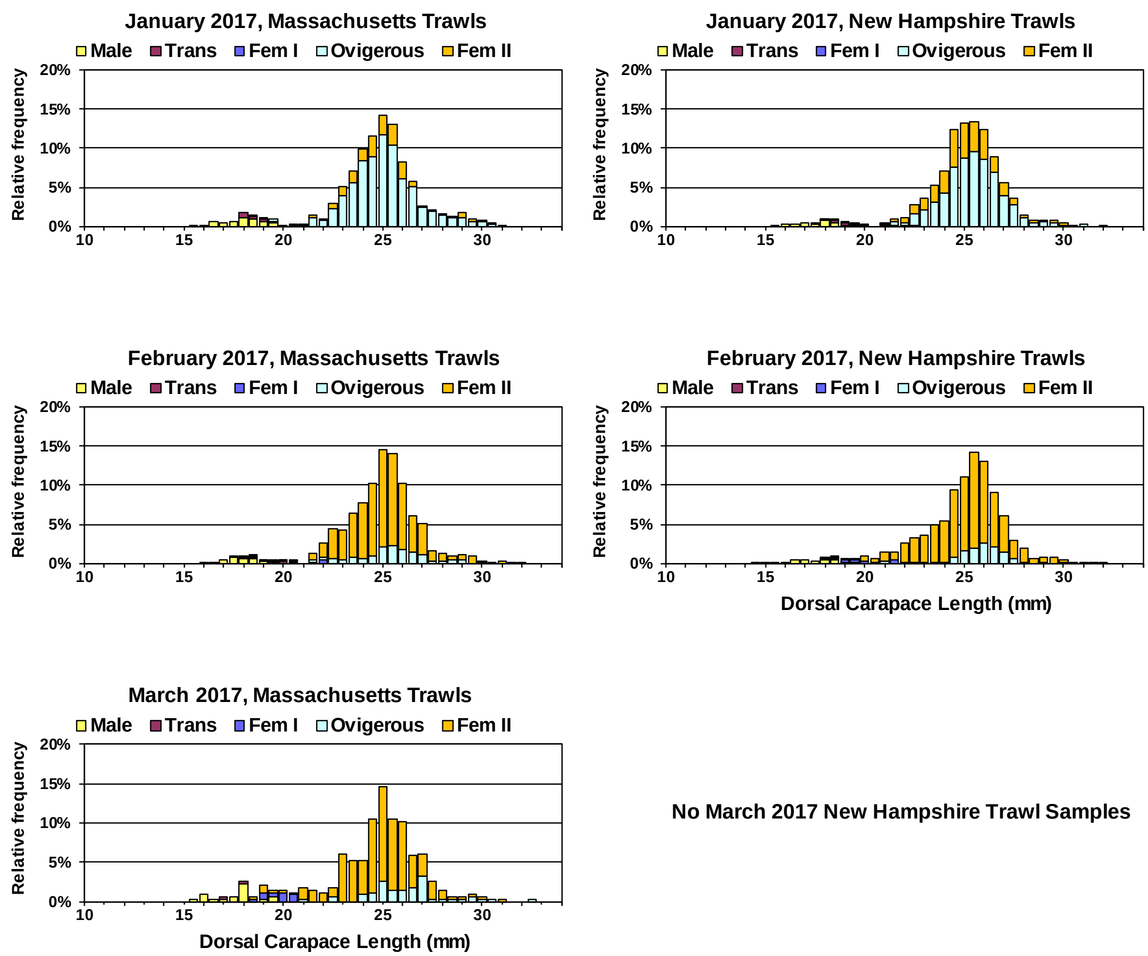


Figure 2 continued. Gulf of Maine northern shrimp size-sex-stage frequency distributions from 2017 winter samples by month for Massachusetts (left) and New Hampshire (right) trawls.

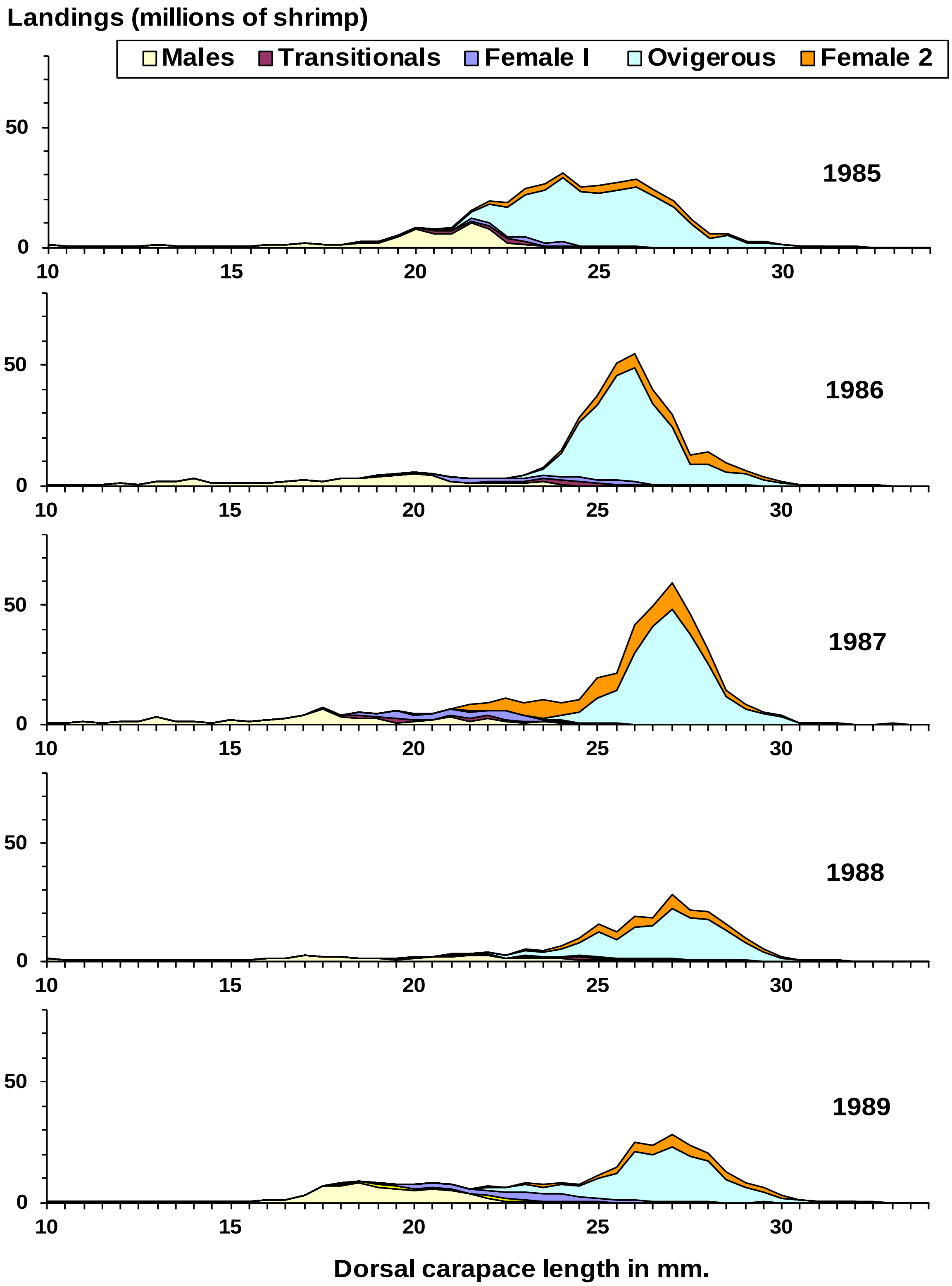


Figure 4: Gulf of Maine northern shrimp landings in estimated numbers of shrimp, by length, development stage, and fishing season.

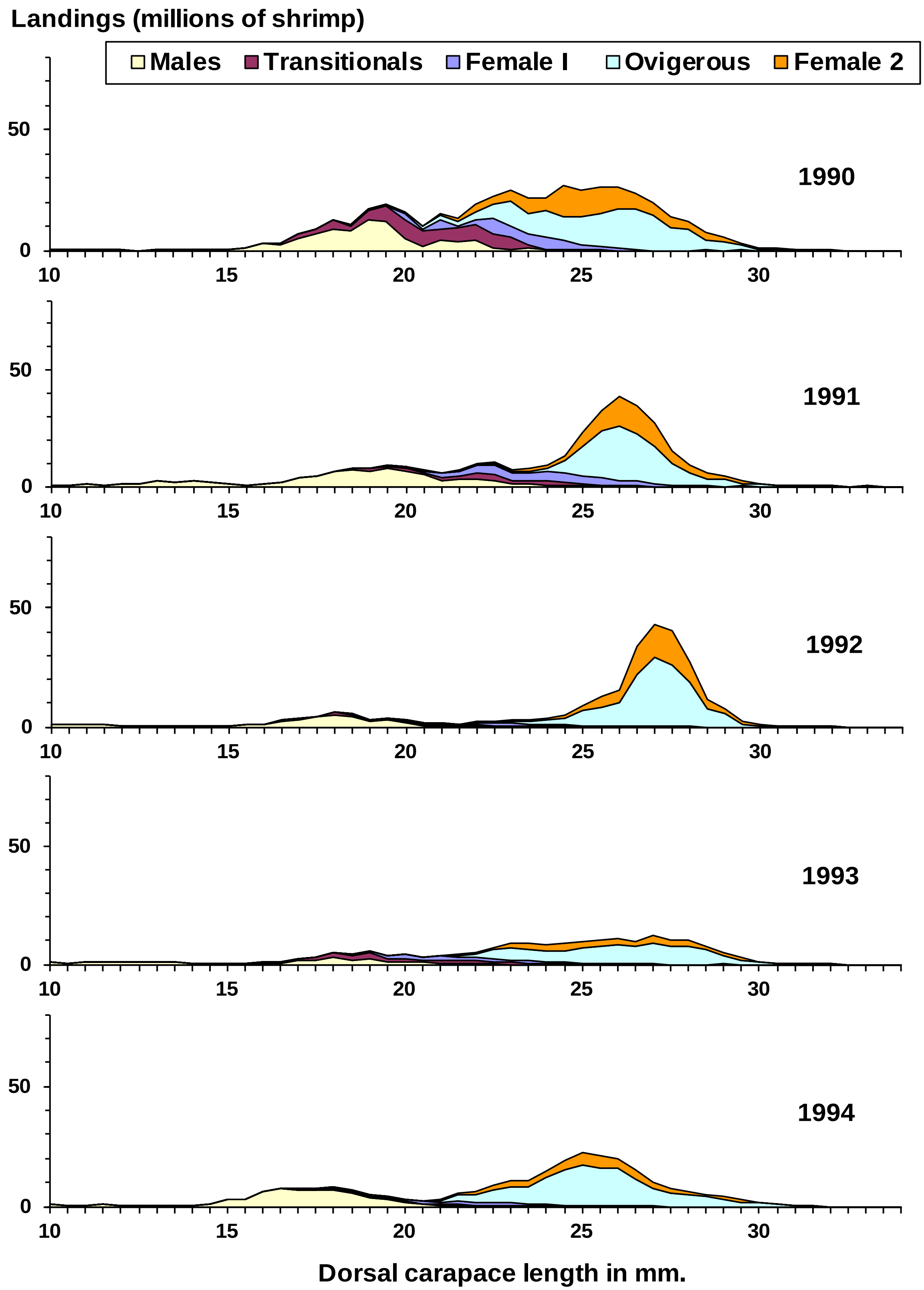
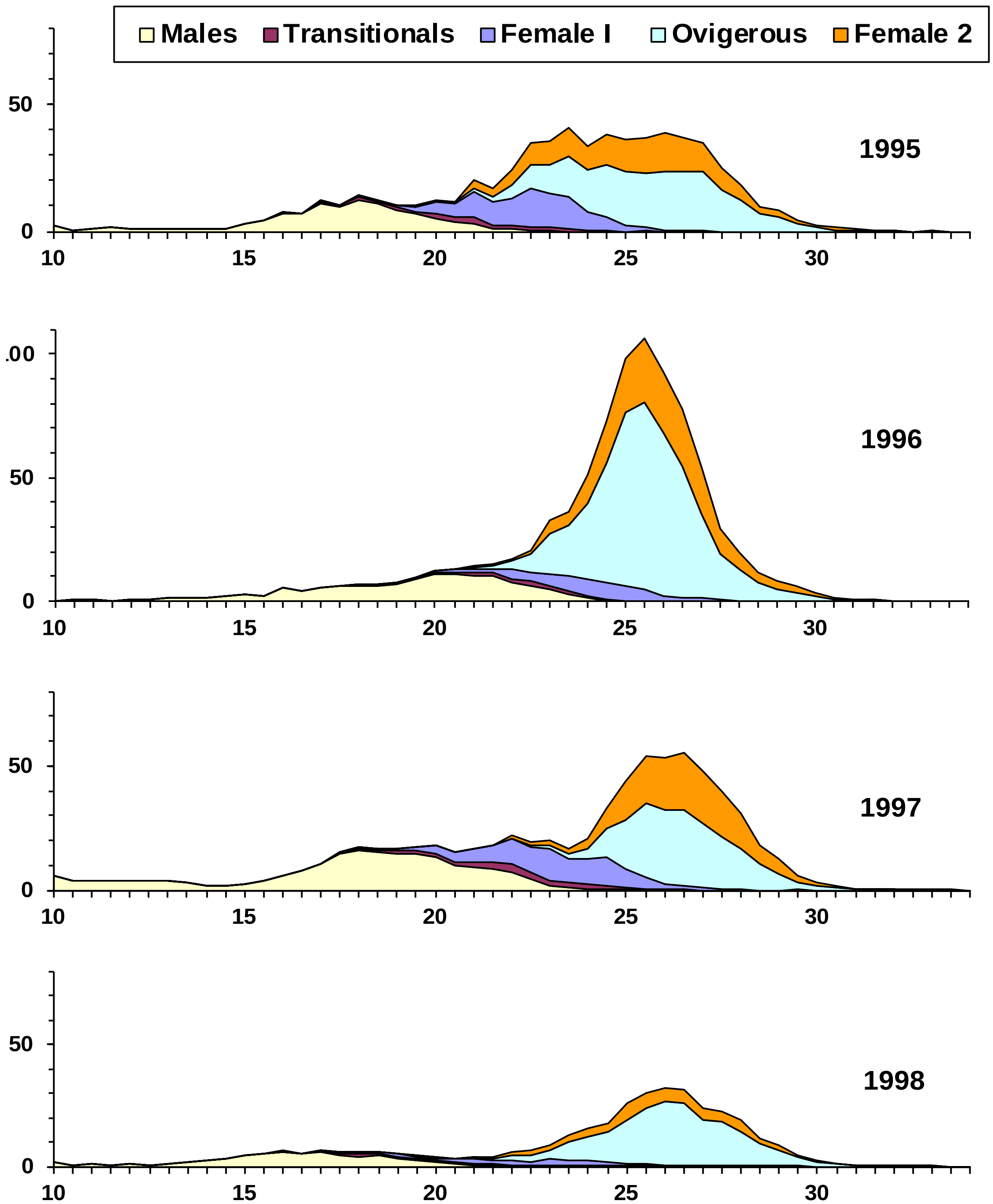


Figure 3 continued – Landings in estimated numbers of shrimp.

Landings (millions of shrimp)



Dorsal carapace length in mm.

Figure 3 continued –Landings in estimated numbers of shrimp.

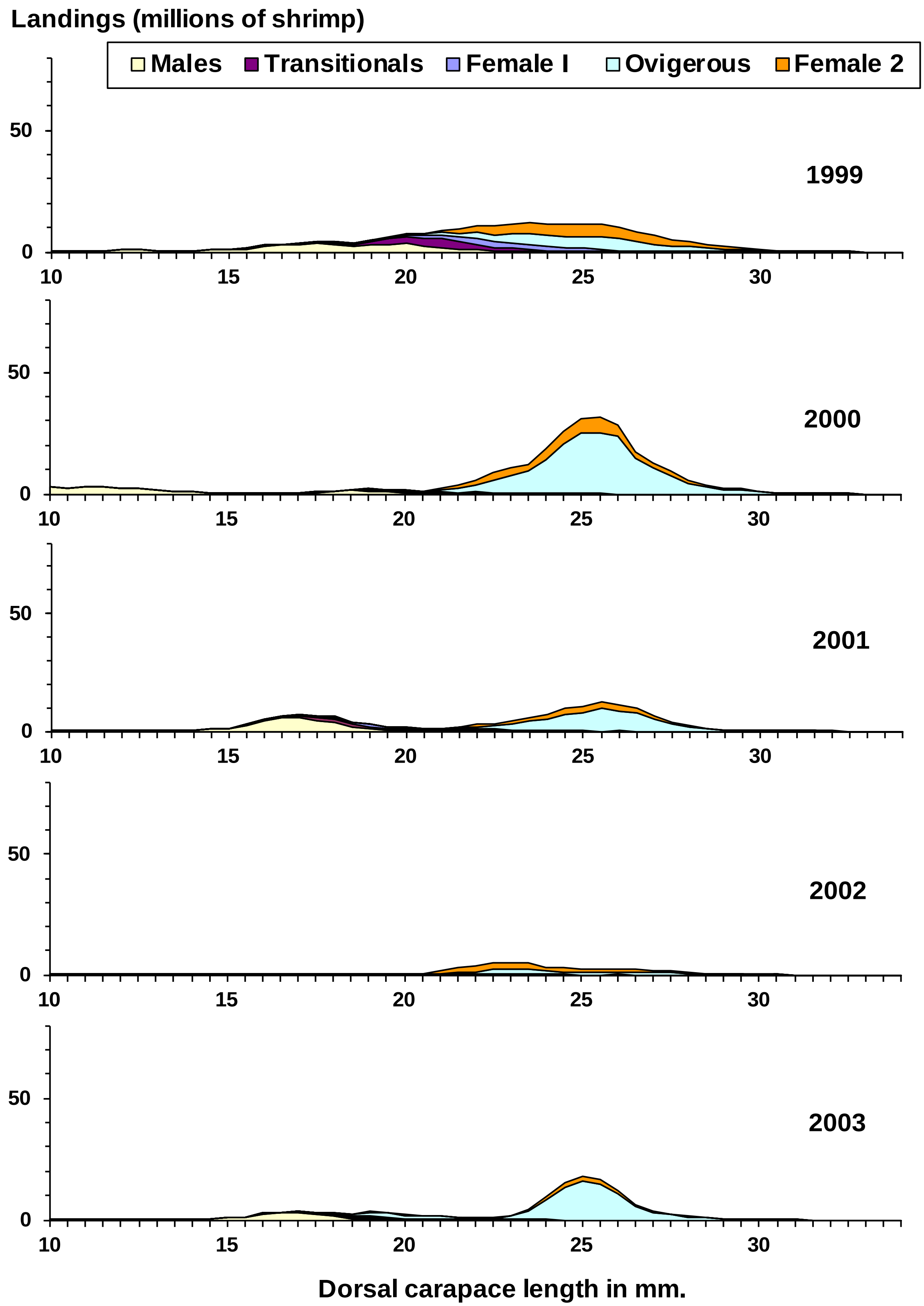


Figure 3 continued – Landings in estimated numbers of shrimp.

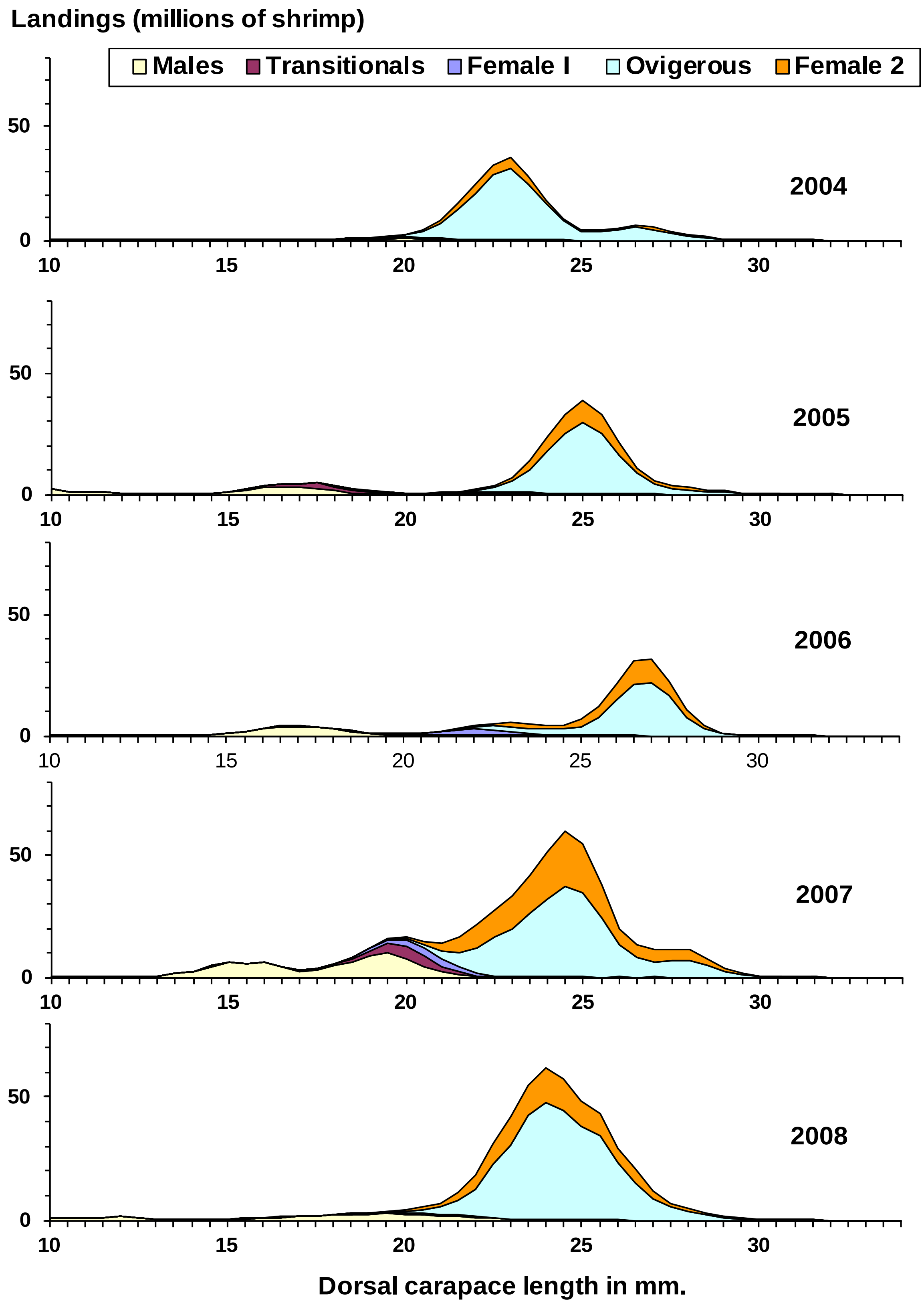


Figure 3 continued – Landings in estimated numbers of shrimp.

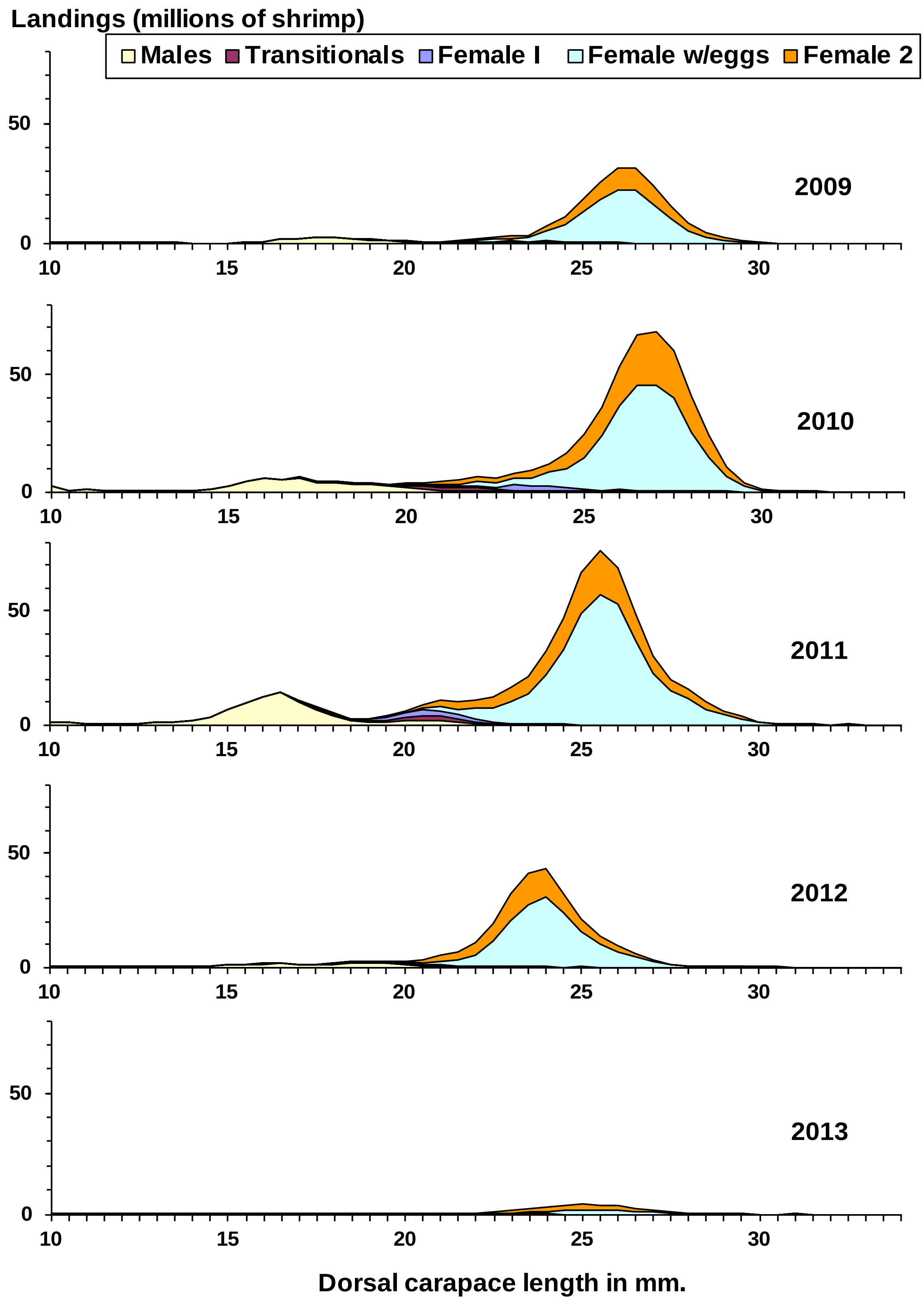


Figure 3 continued – Landings in estimated numbers of shrimp.

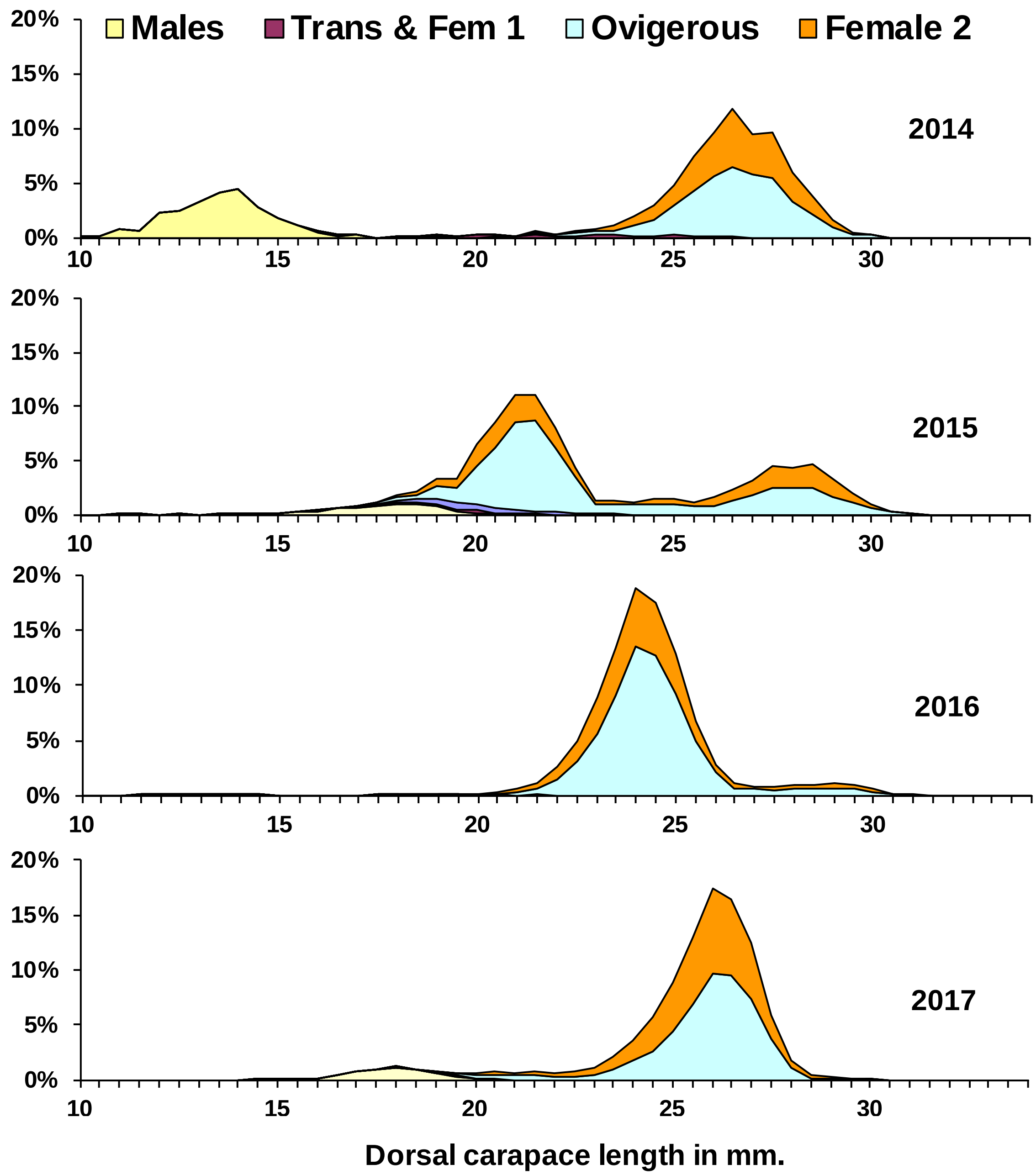


Figure 3 continued – Landings in estimated numbers of shrimp, expressed as percentages. 2014 data are from cooperative winter sampling with no landings. 2015 – 2017 data are from the Gulf of Maine RSA program. See Hunter (2014, 2016), Whitmore et al. (2015), and ASMFC (2017) for details.

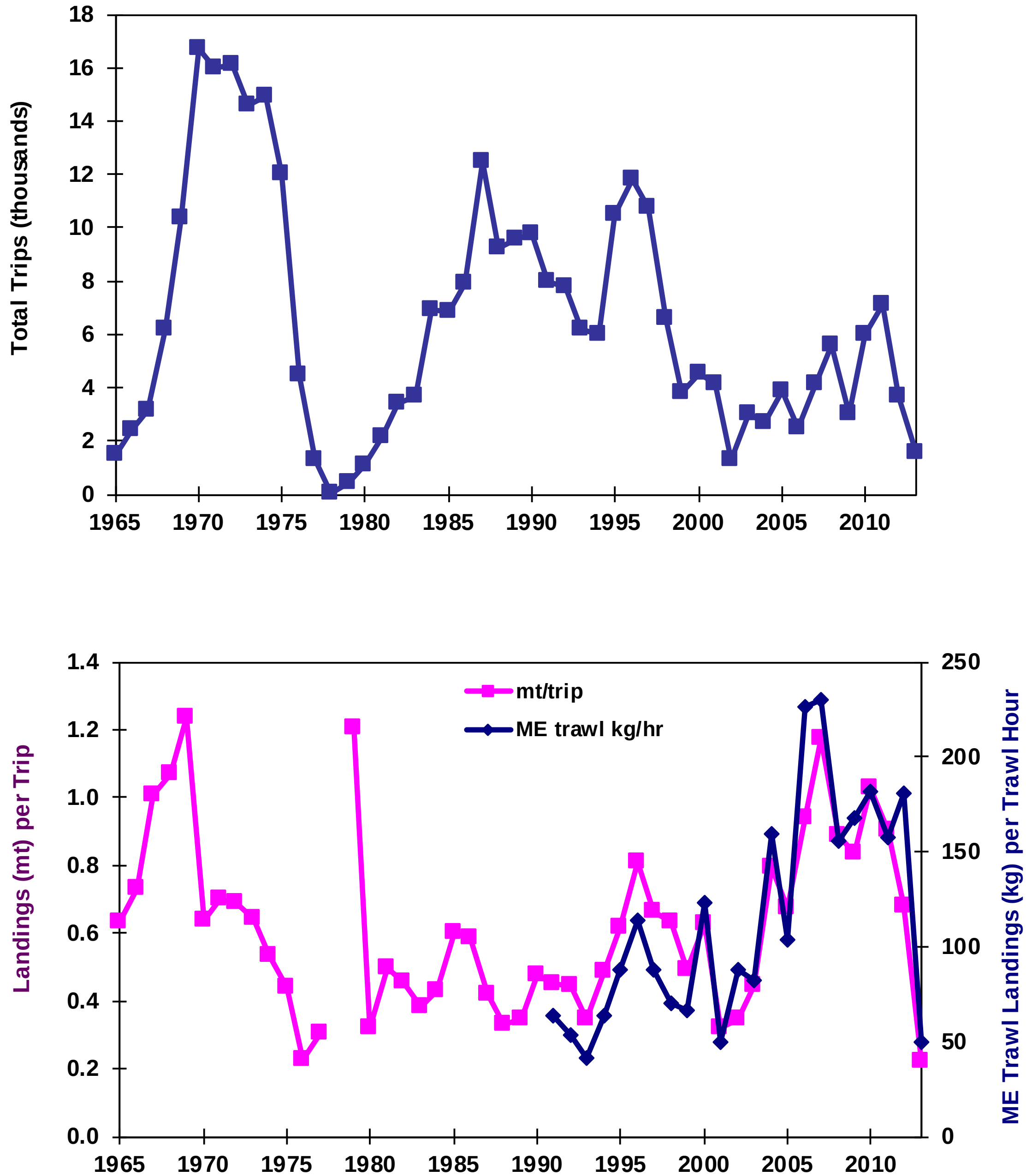


Figure 5: Nominal fishing effort (trips) (above) and catch per unit effort (below), in the Gulf of Maine northern shrimp fishery by season, 1965–2013. There was no commercial fishery in 2014 – 2017.

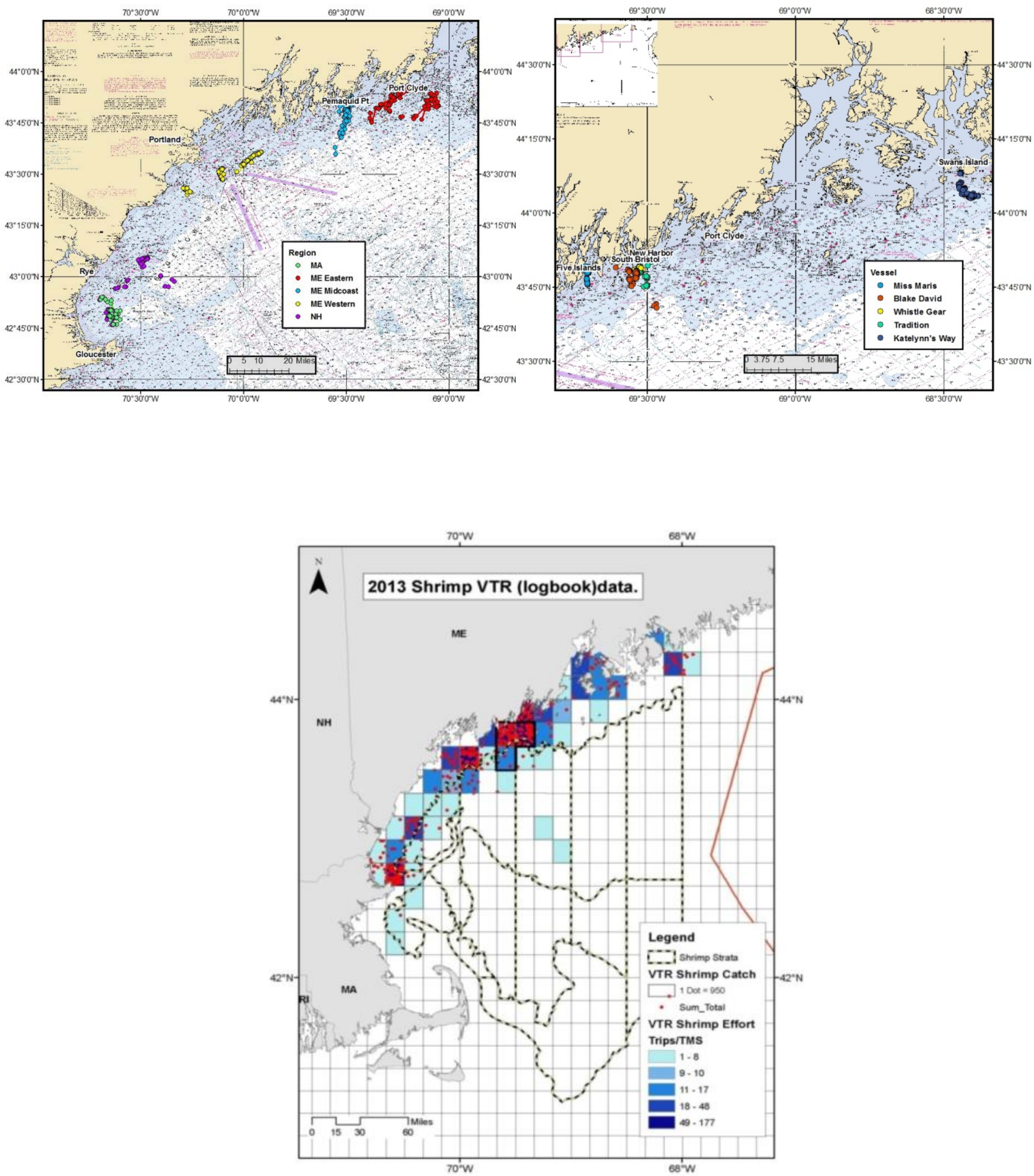


Figure 6. Locations of tows (top left) and traps (top right) for the 2017 Gulf of Maine northern shrimp RSA program relative to 2013 fishing effort from preliminary VTR data (bottom).

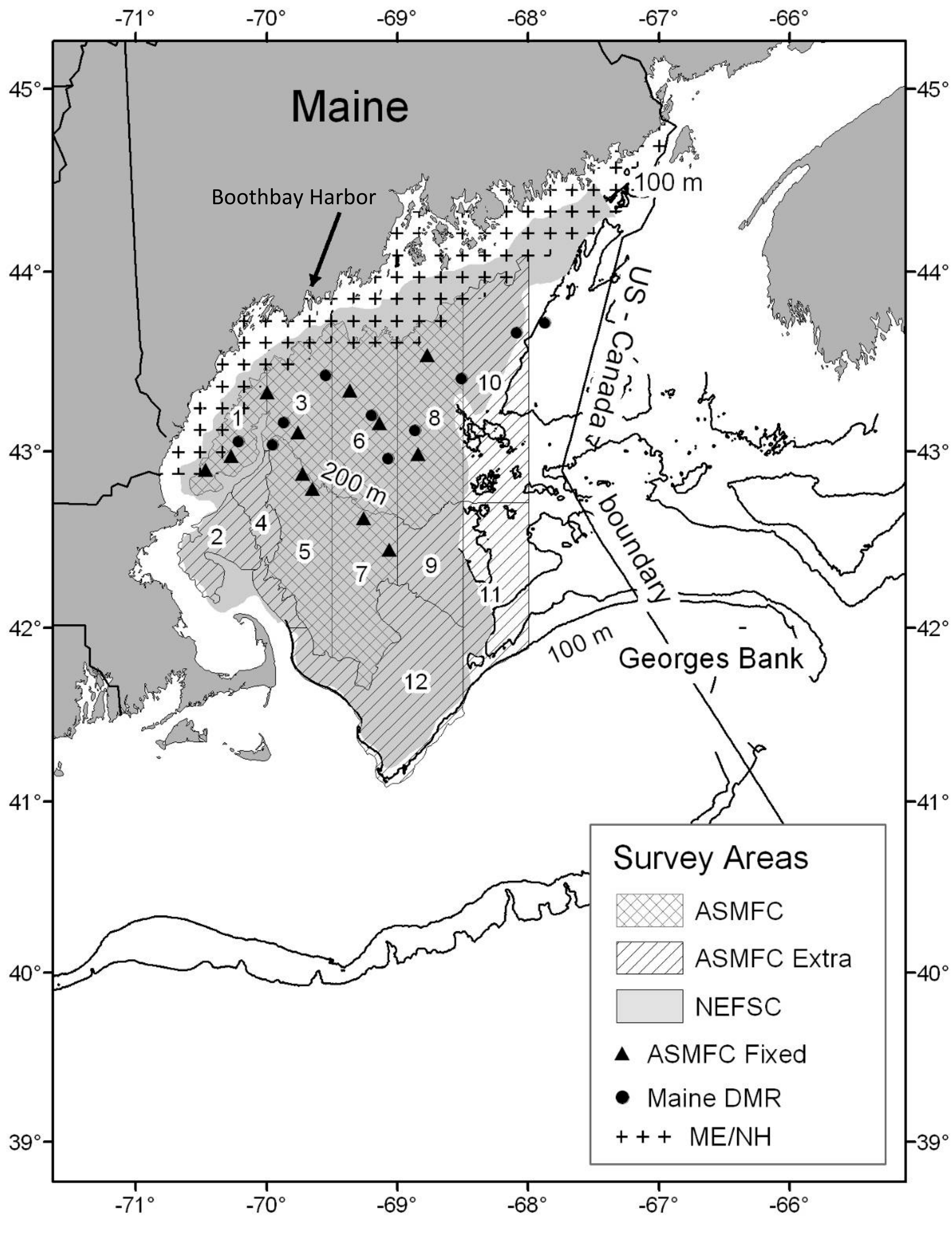


Figure 7: Gulf of Maine survey areas and station locations.

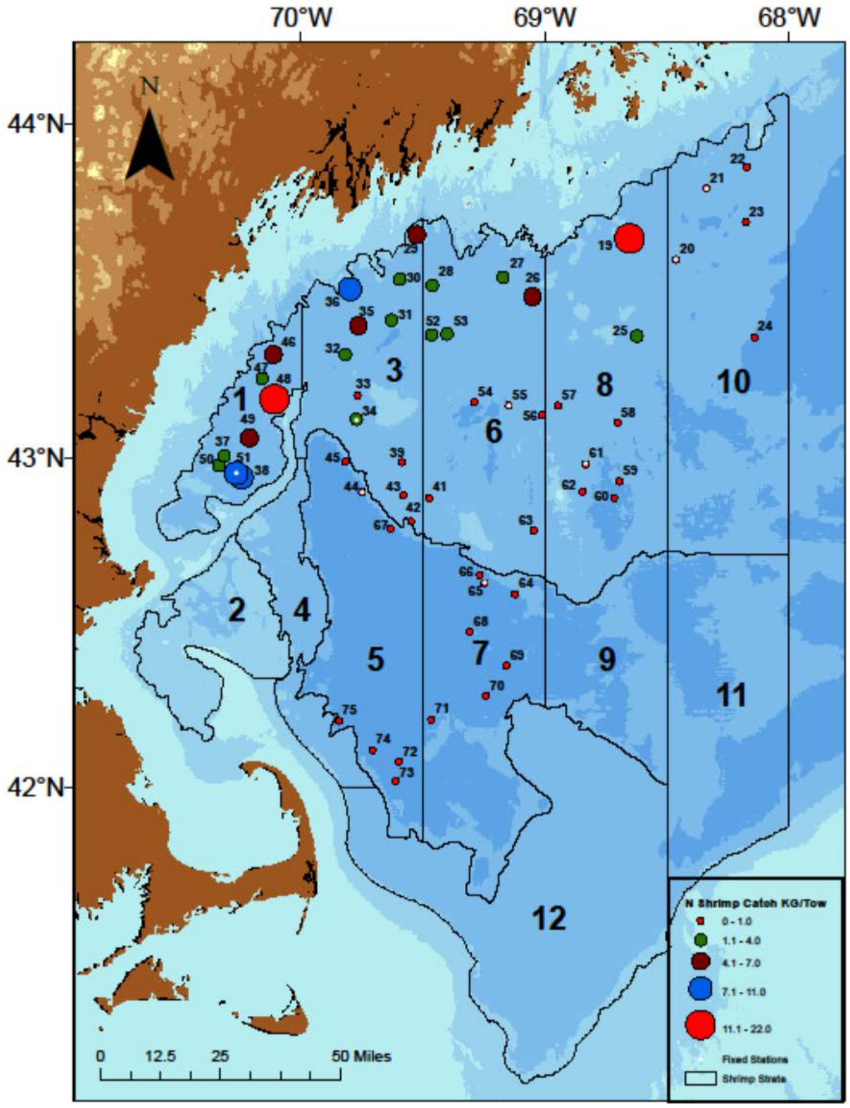


Figure 8: Shrimp catches (kg/tow) at stations surveyed during the 2017 ASMFC northern shrimp summer survey aboard the R/V Gloria Michelle, fixed and random survey sites.

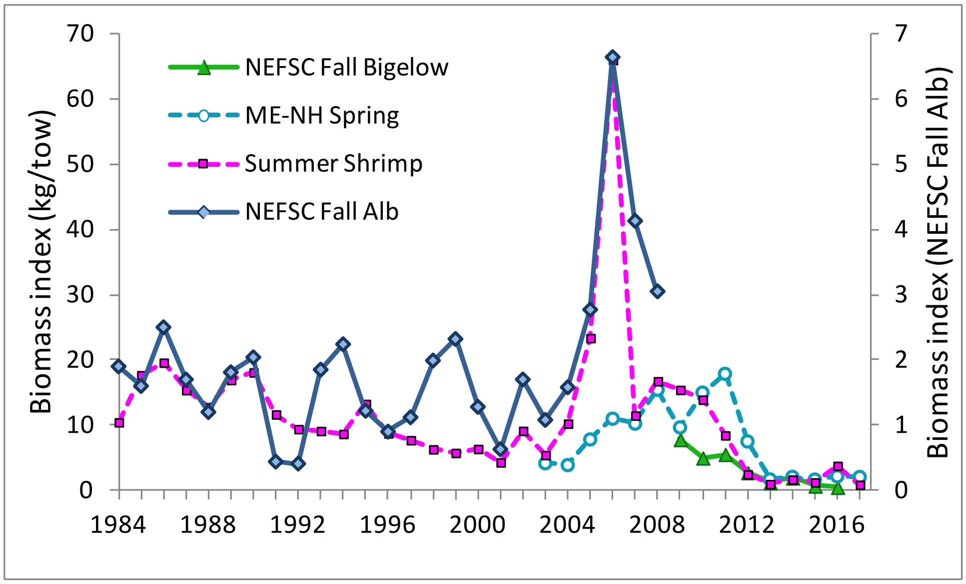


Figure 9: Biomass indices (kg/tow) from fishery-independent surveys in the Gulf of Maine.

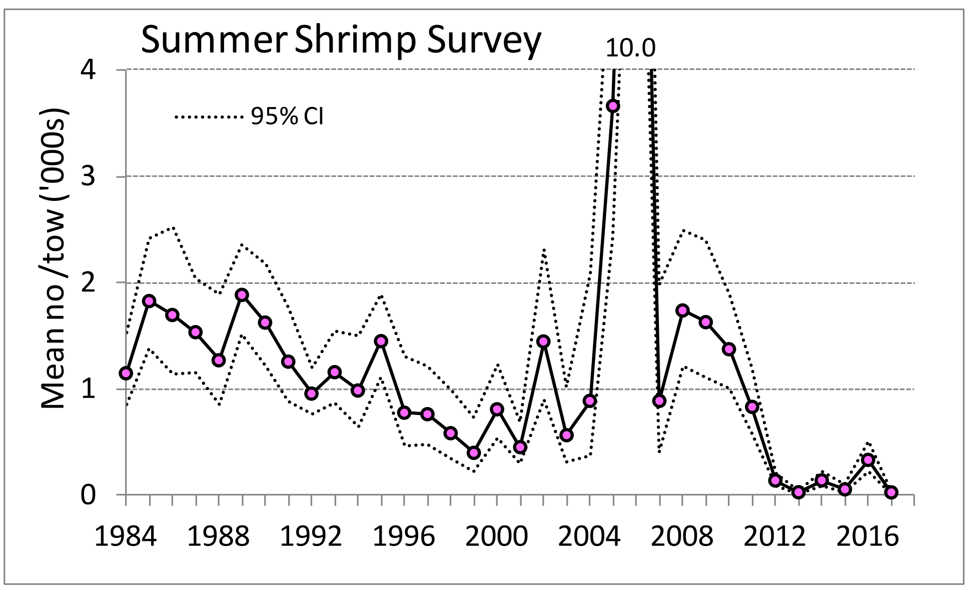


Figure 9. Abundance indices (stratified geometric mean number per tow) of northern shrimp from ASMFC summer surveys in the Gulf of Maine.

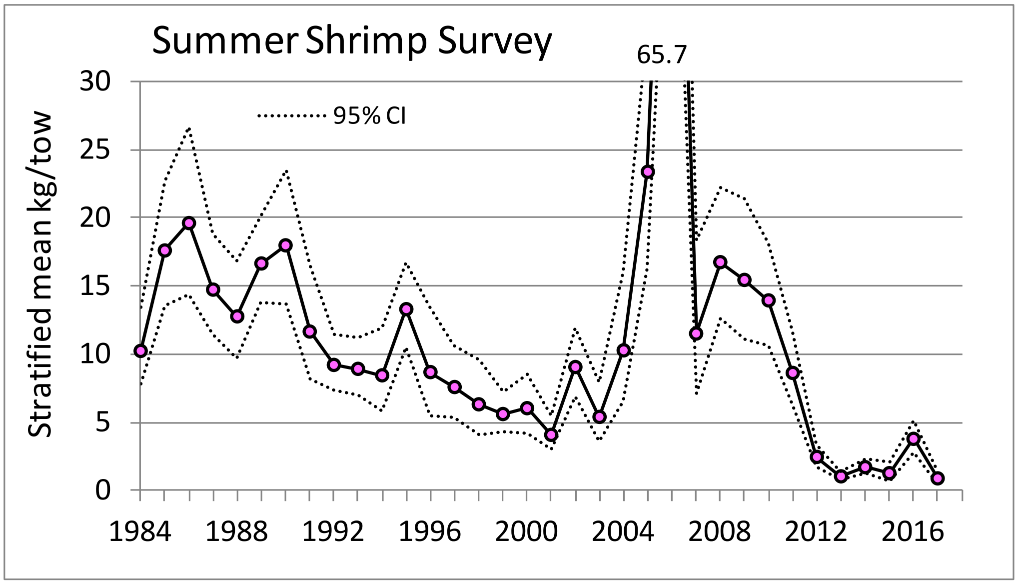


Figure 10. **Biomass indices (stratified geometric mean kg per tow) of northern shrimp from ASMFC summer surveys in the Gulf of Maine.**

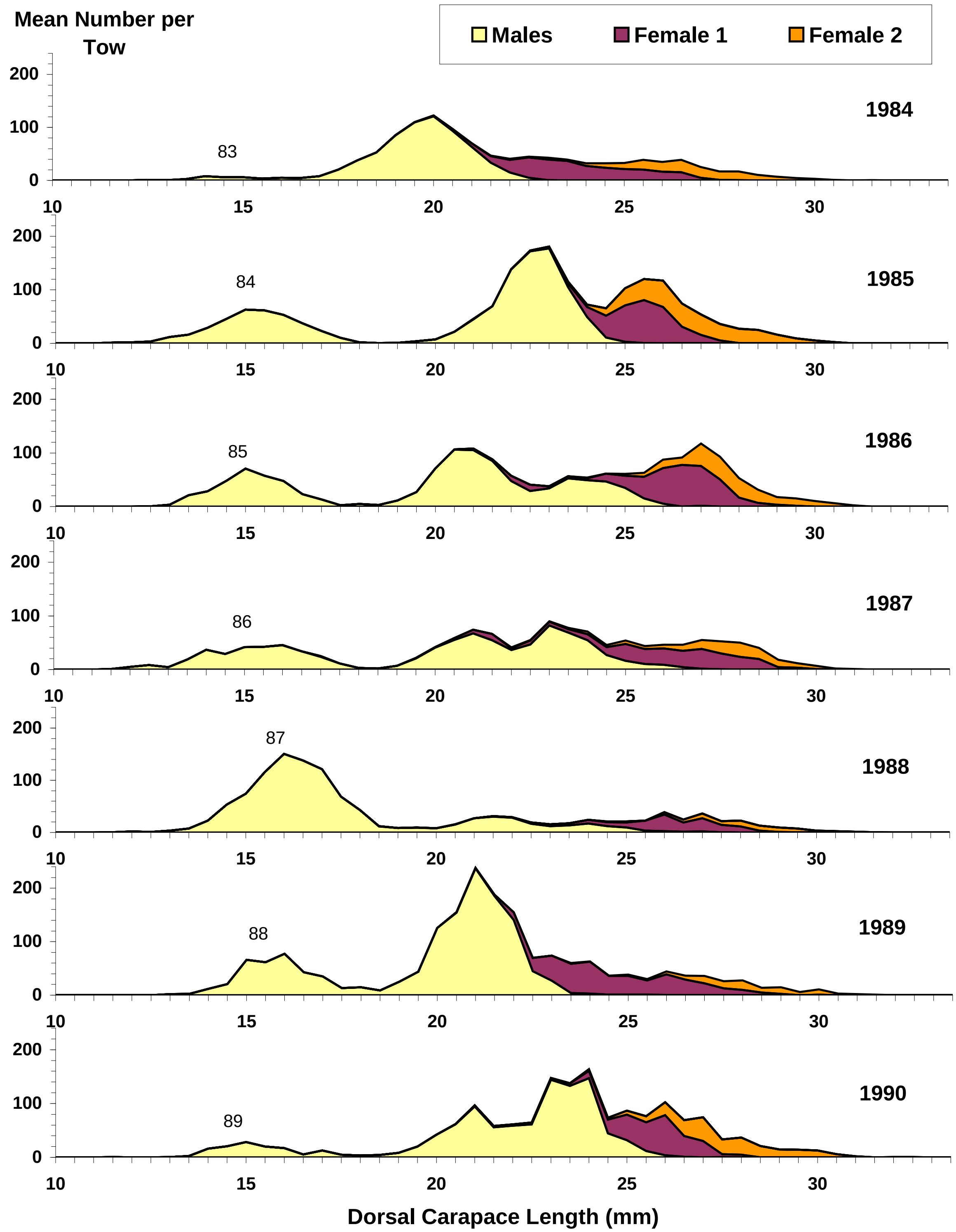


Figure 11: Gulf of Maine northern shrimp summer survey mean catch per tow by year, length, and life history stage. Two-digit years are year class at assumed age 1.5.

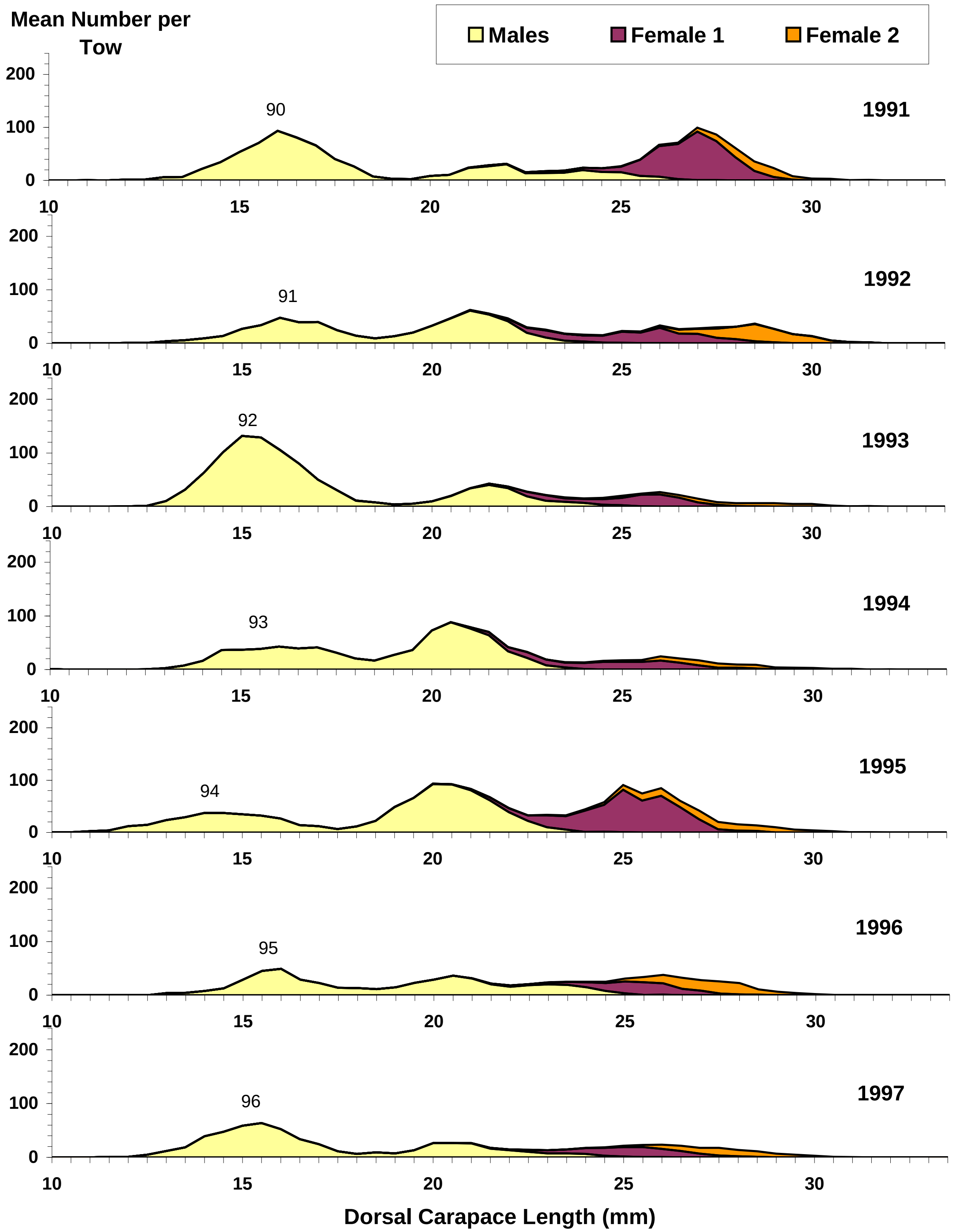


Figure 11 continued – summer survey.

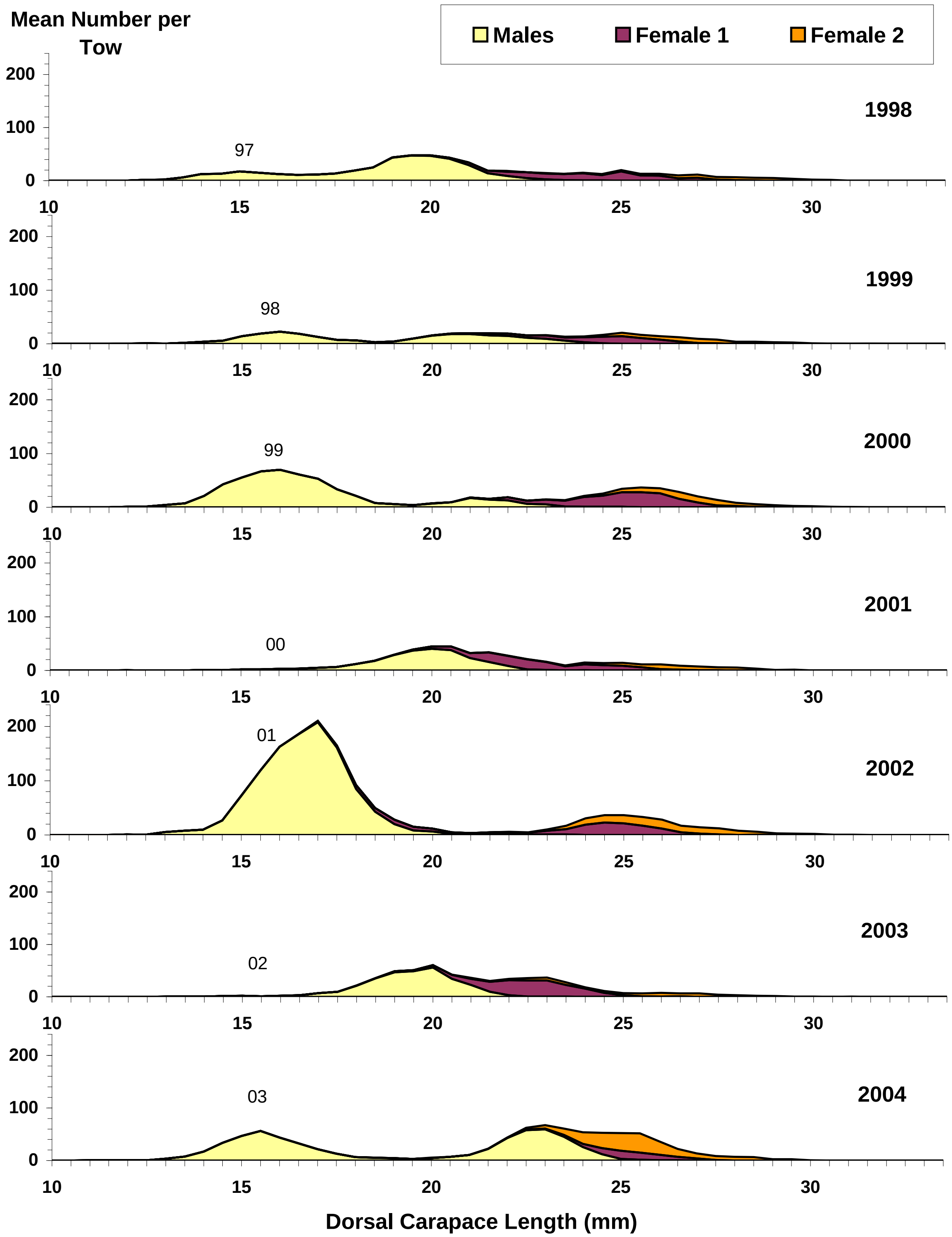


Figure 11 continued – summer survey.

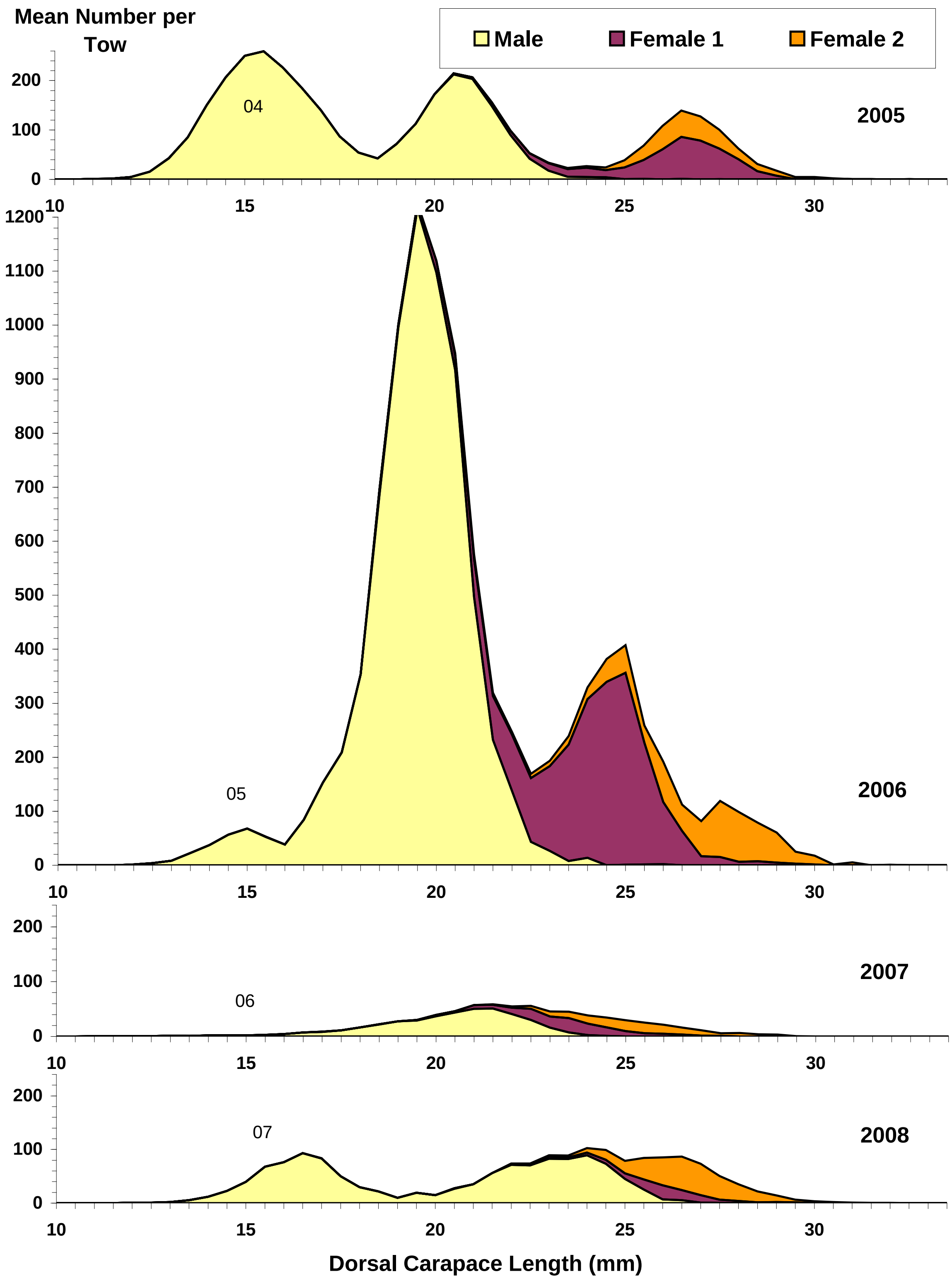


Figure 11 continued – summer survey.

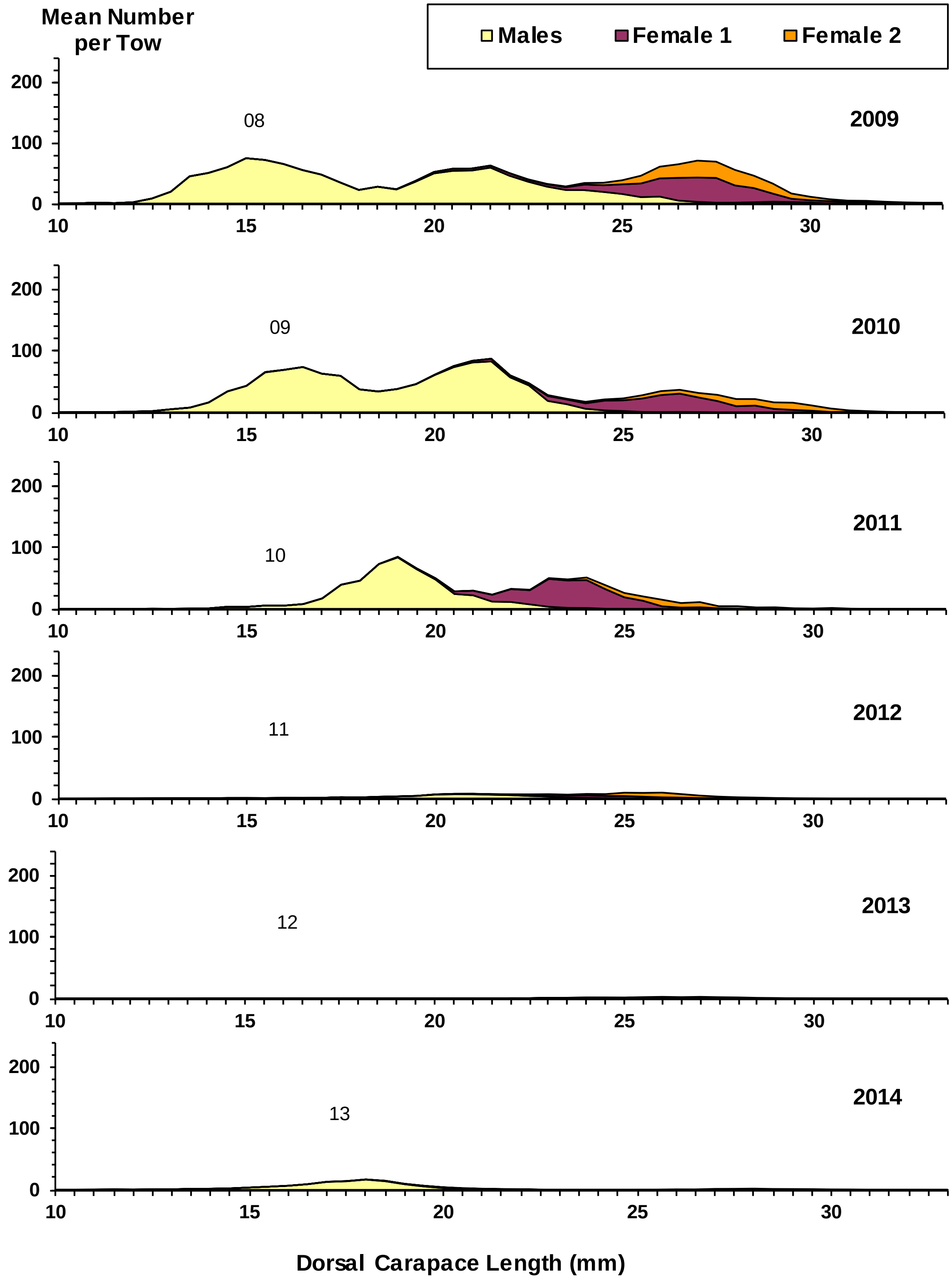


Figure 11 continued – summer survey.

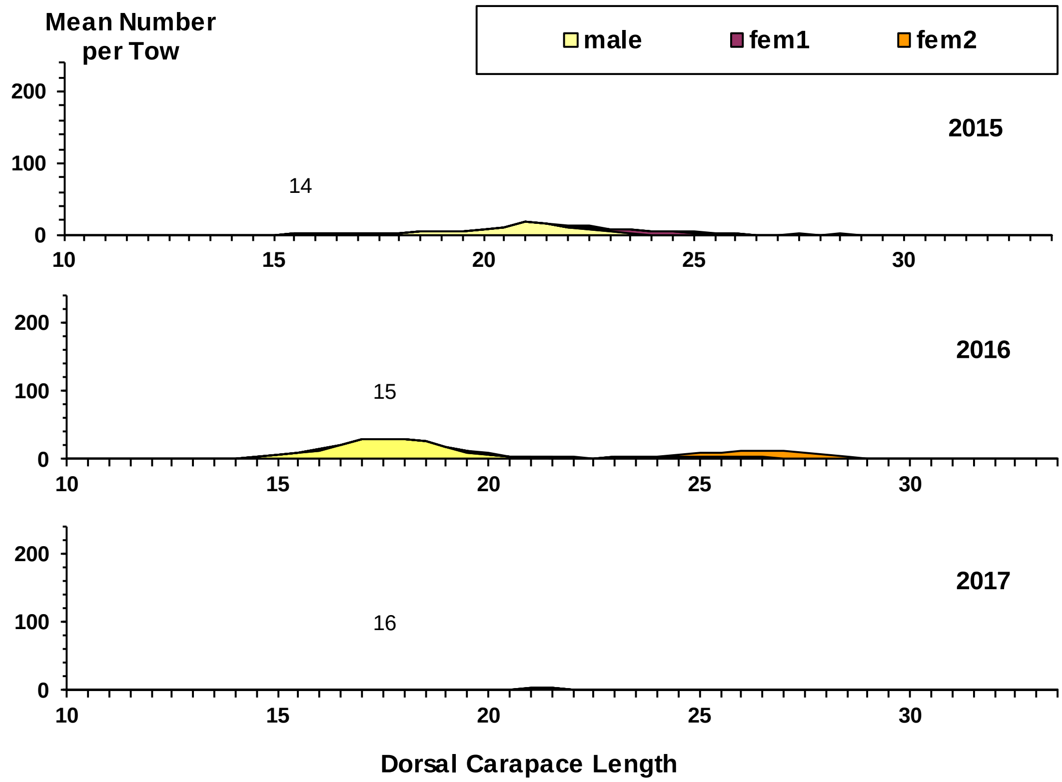


Figure 11 continued – summer survey.

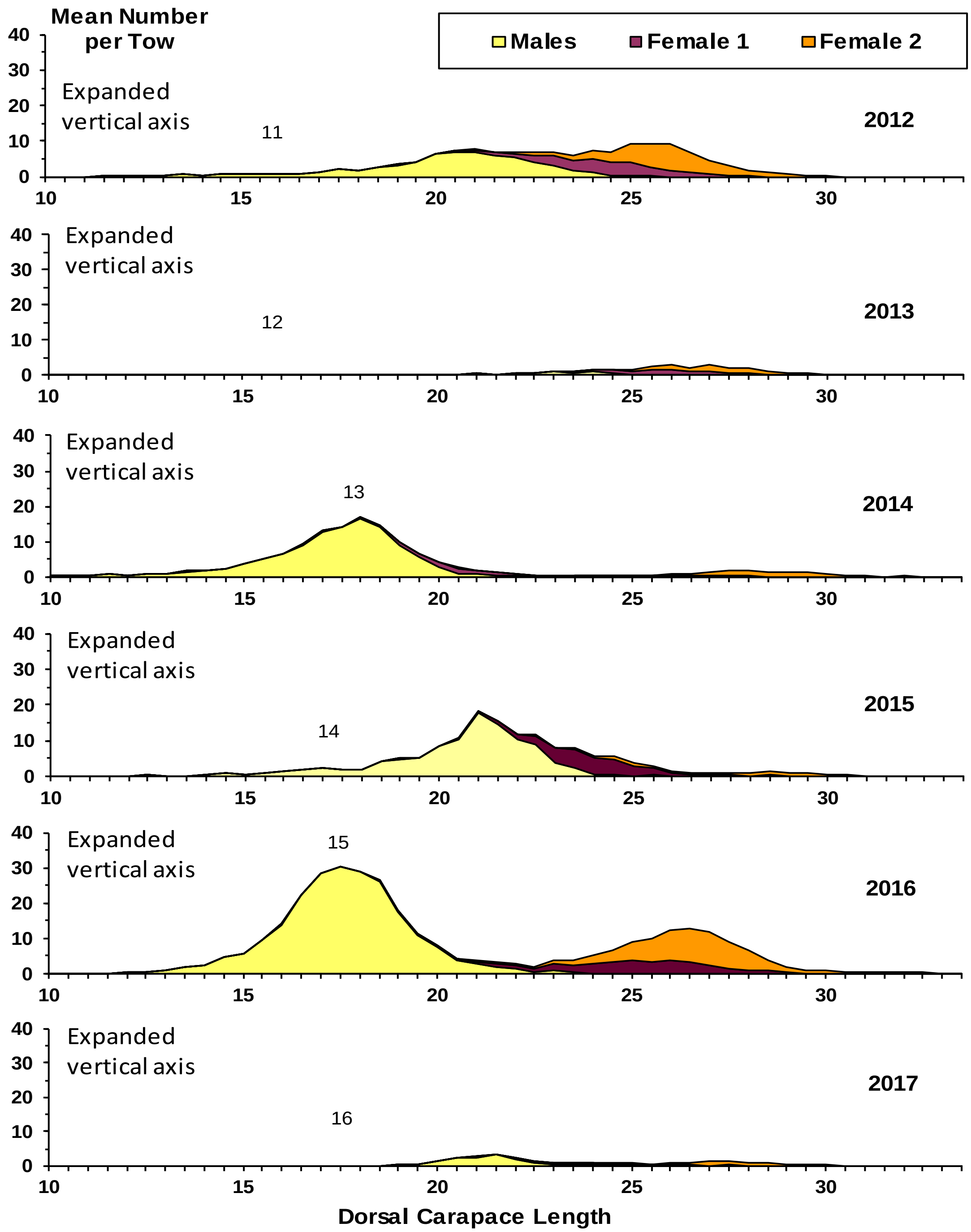


Figure 12: Gulf of Maine northern shrimp summer survey mean catch per tow by year (2012–2017 only), length, and life history stage, with expanded vertical axes. Two-digit years indicate the year class mode at assumed age 1.5.

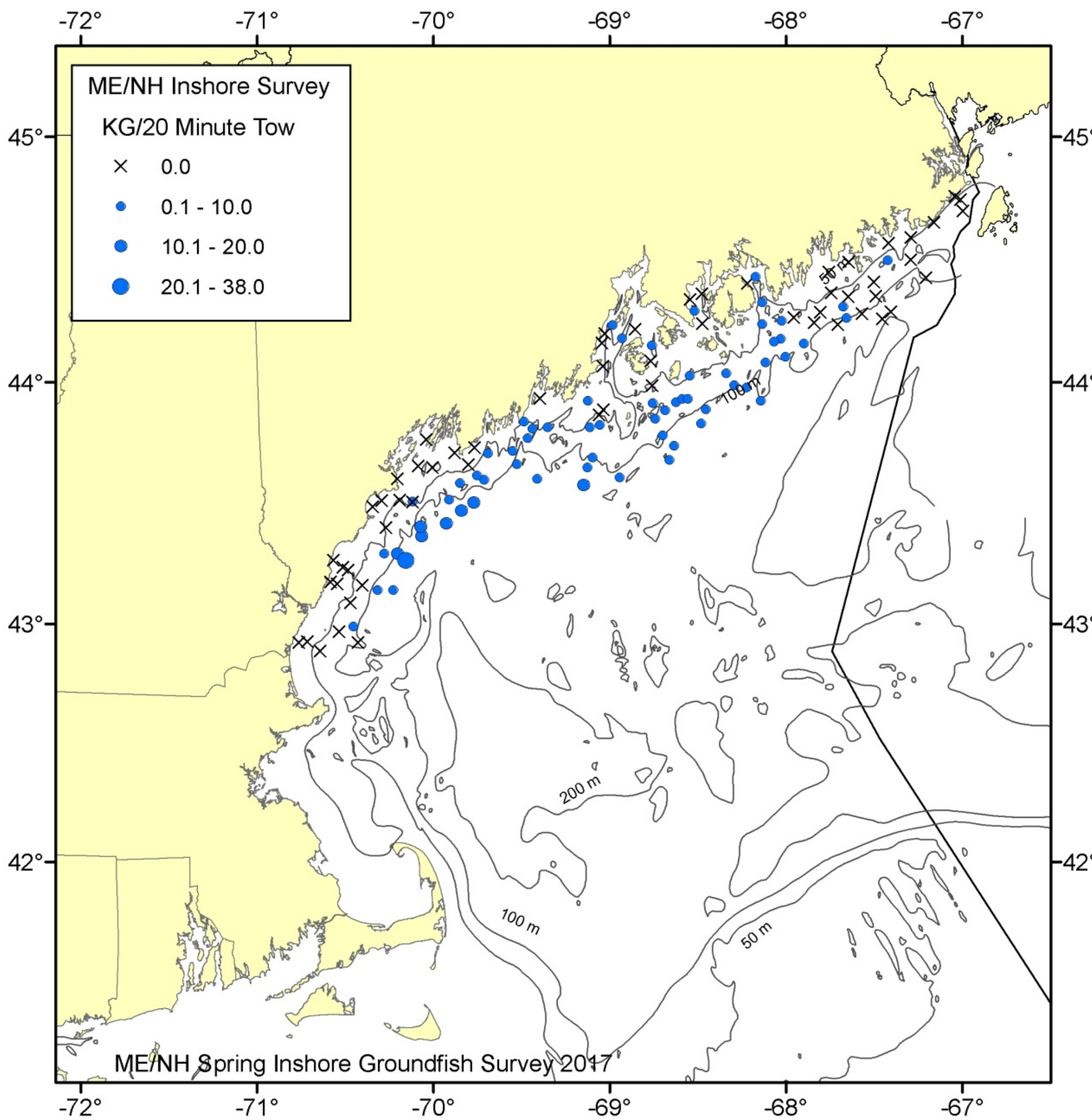
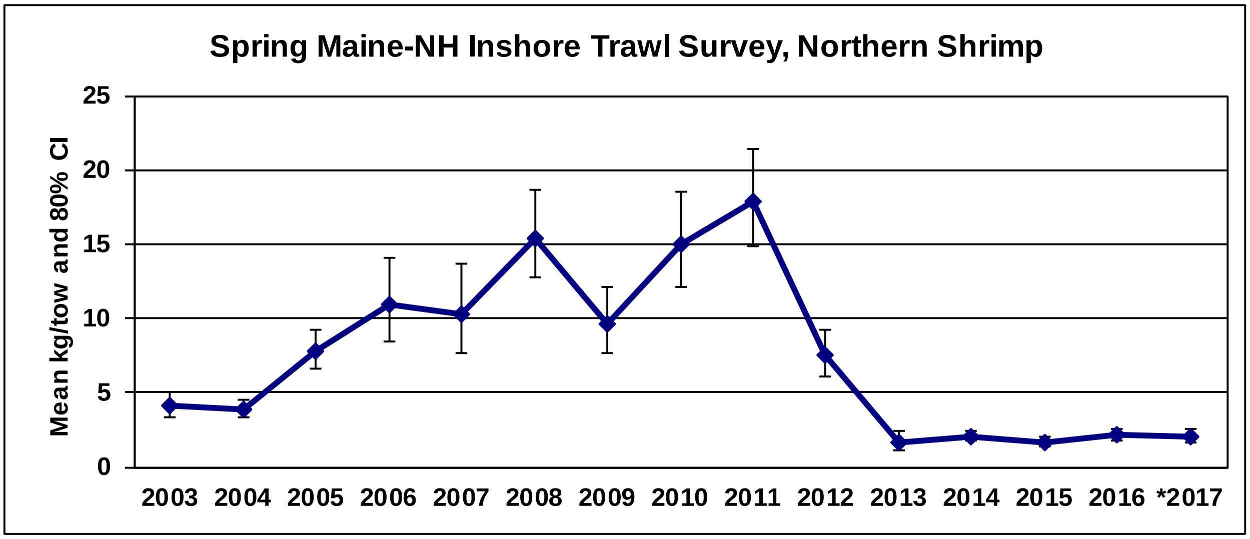


Figure 13: Distribution of northern shrimp catches (kg/tow) in the spring 2017 Maine-New Hampshire inshore trawl survey.



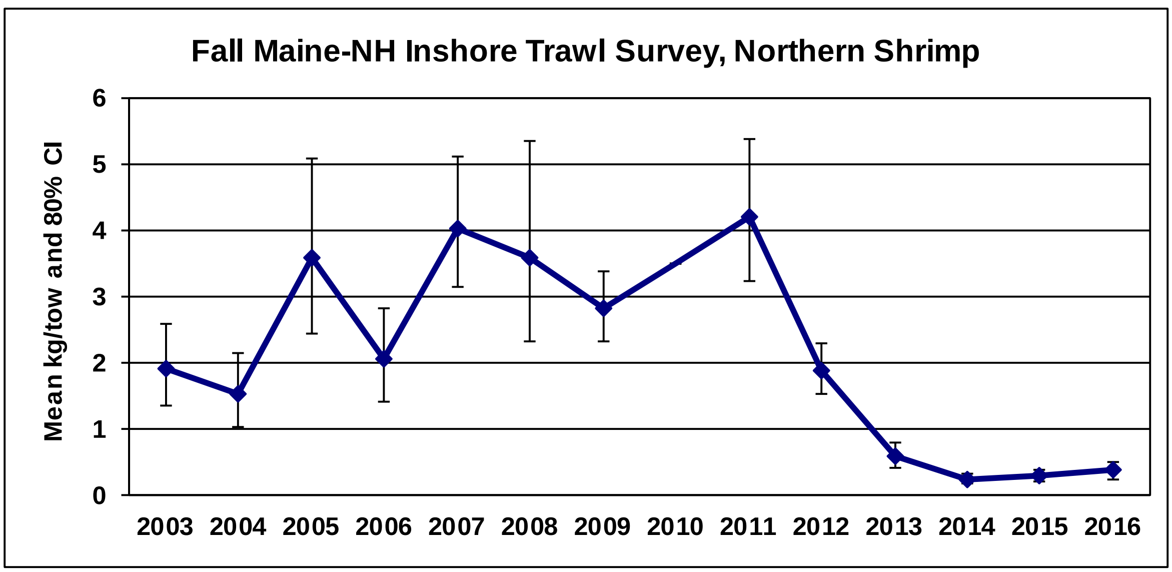


Figure 14: **Maine-New Hampshire Spring (top) and Fall (bottom) inshore trawl survey biomass indices for northern shrimp with 80% confidence intervals. *2017 spring survey data are preliminary.**

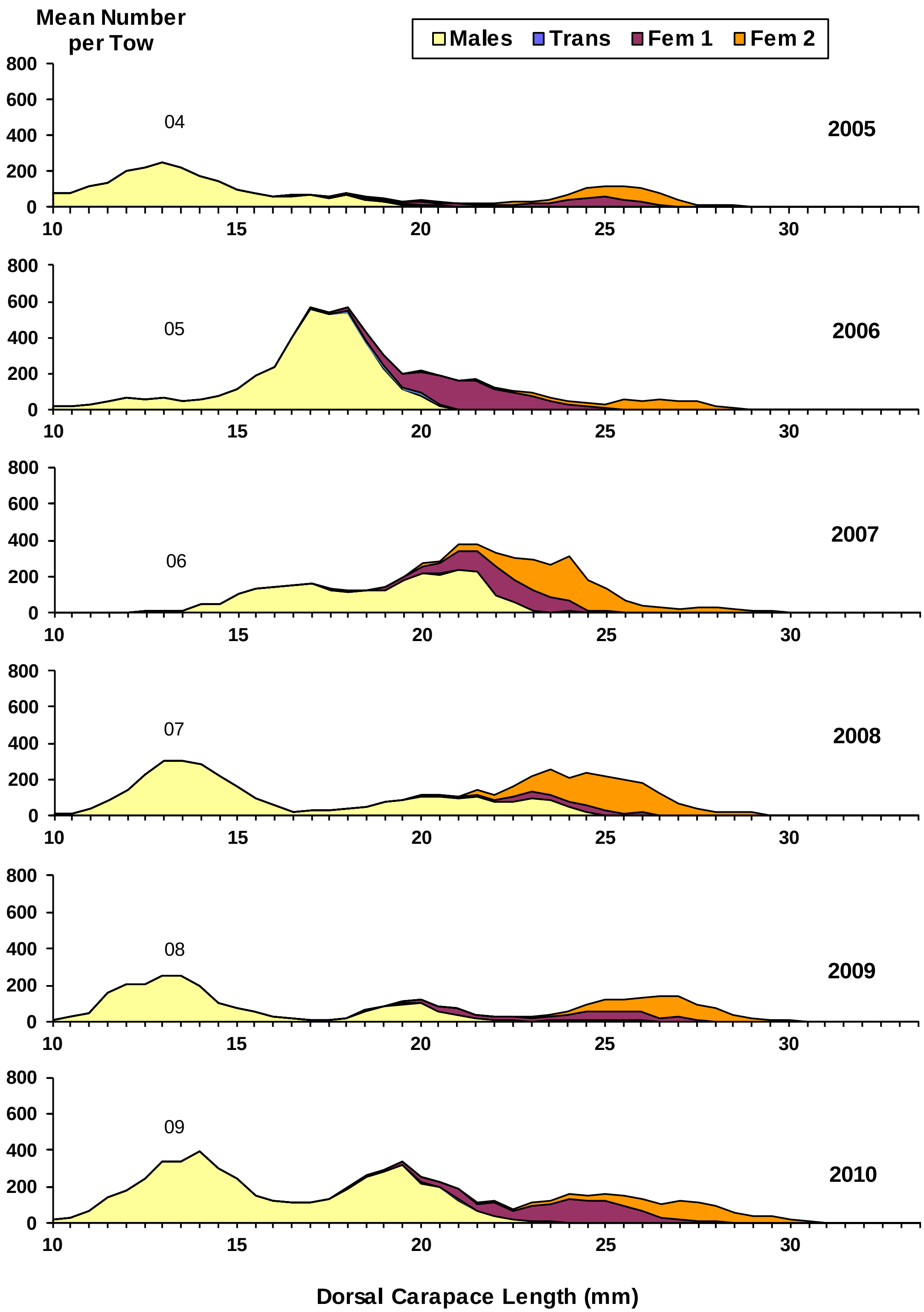


Figure 15: Maine-New Hampshire spring inshore survey mean catch per tow by year, length, and life history stage. Two-digit years are the year class at assumed age 1.

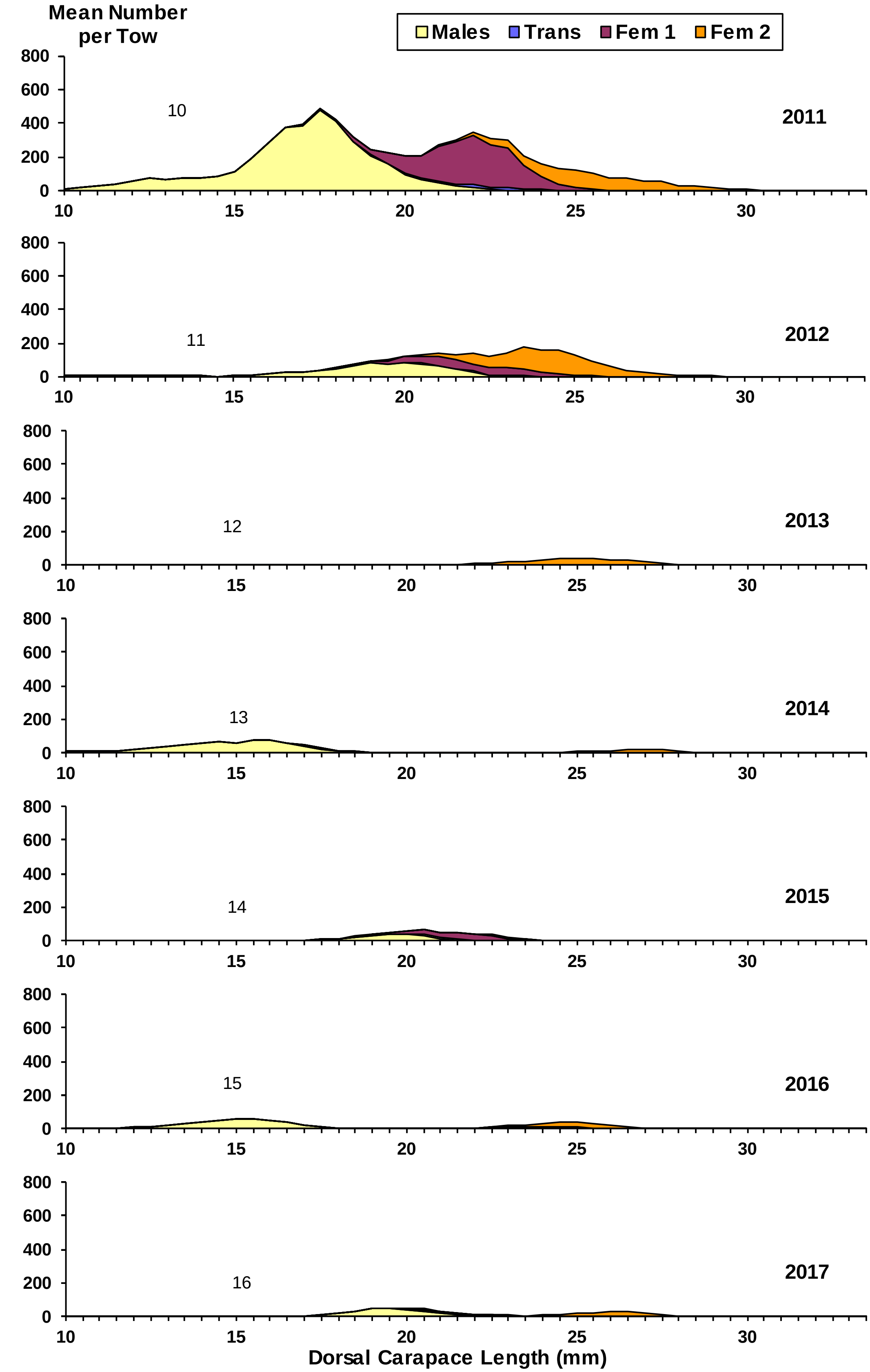


Figure 15 continued — ME/NH spring inshore survey. 2017 data are preliminary.

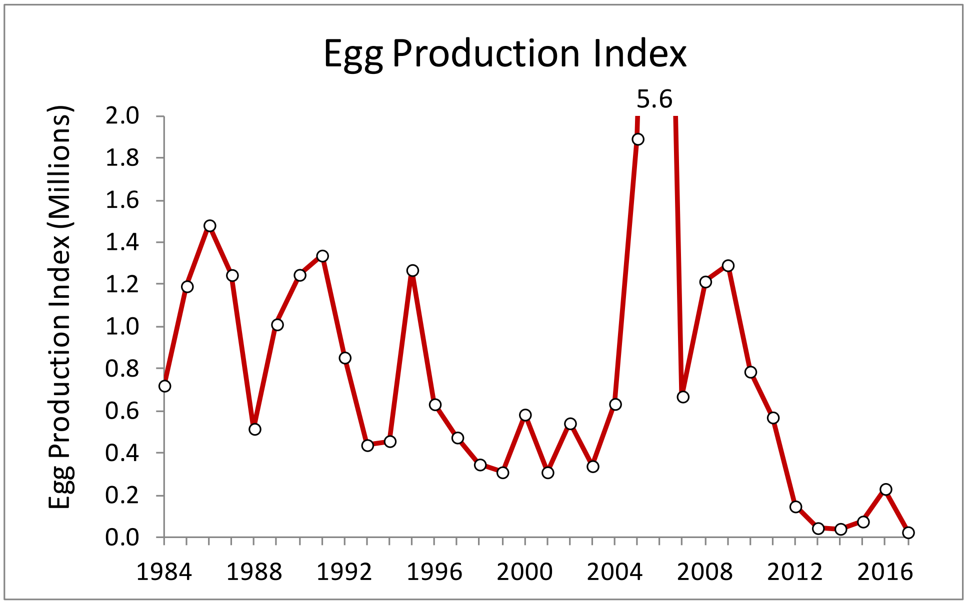


Figure 16: Egg production index for Gulf of Maine northern shrimp based on stratified mean number of females at length from the summer shrimp survey and estimated fecundity at length (Haynes and Wigley 1969). Index for 2006 (off scale) was 5.6 million.

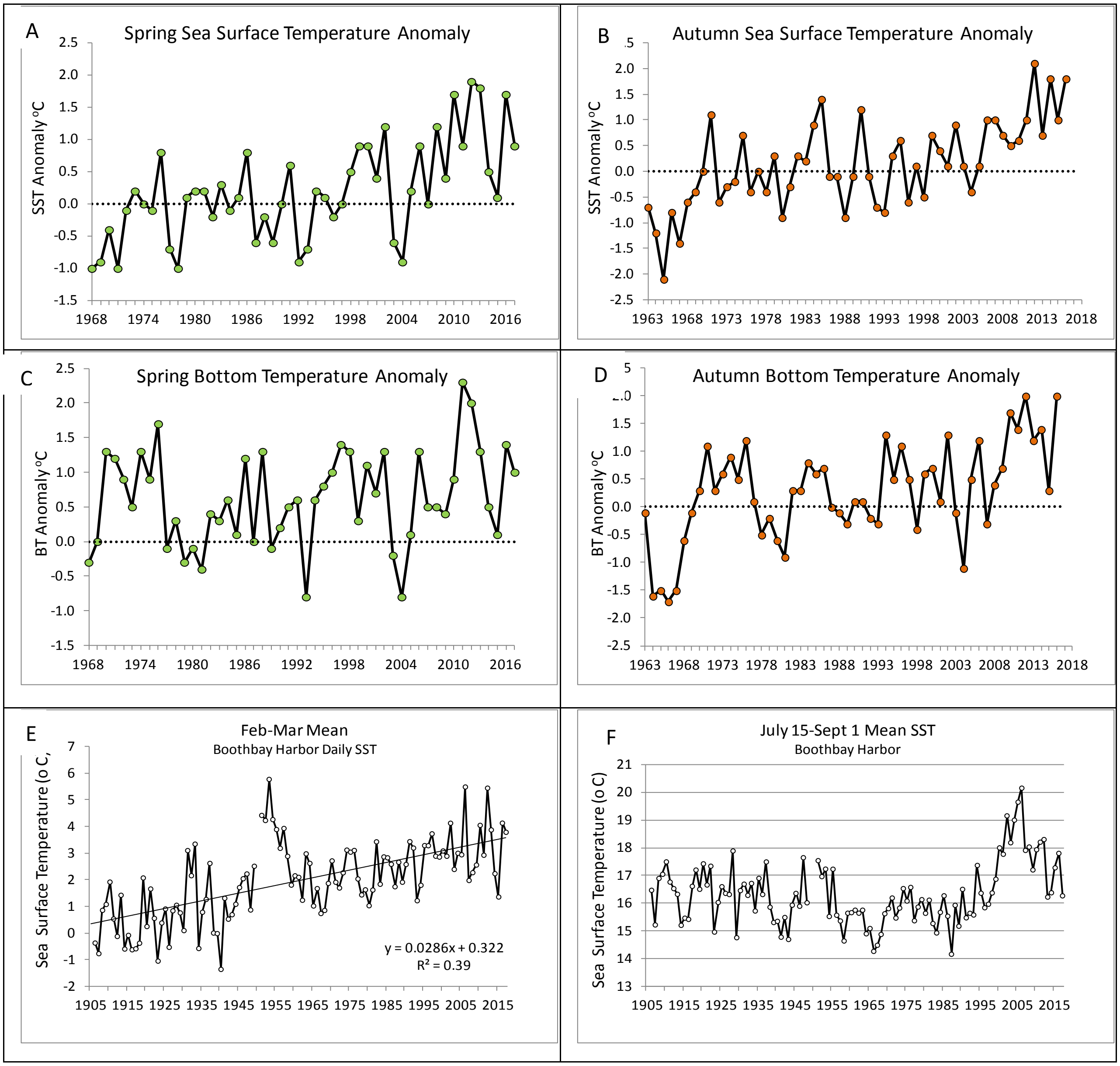


Figure 17: Ocean temperature anomalies in the Gulf of Maine. (A) spring and (B) autumn sea surface temperature anomalies in shrimp offshore habitat areas from NEFSC trawl surveys, 1968–2017 (through 2016 for autumn temperatures). (C) spring and (D) autumn bottom temperature anomalies in shrimp offshore habitat areas from NEFSC trawl survey, 1968–2017 (through 2016 for autumn temperature). (E – F) average sea surface temperature during (E) February–March and (F) July 15–September 1 at Boothbay Harbor, Maine, 1906–2017.

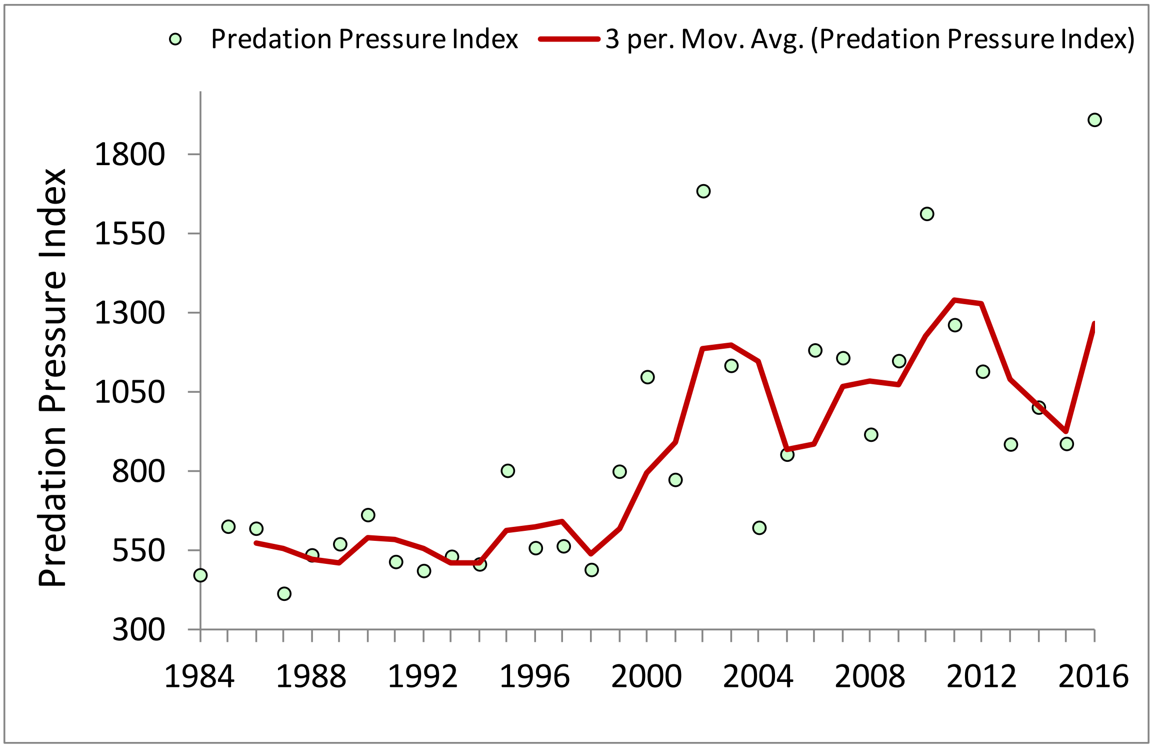


Figure 18: Predation pressure index for northern shrimp in the Gulf of Maine.

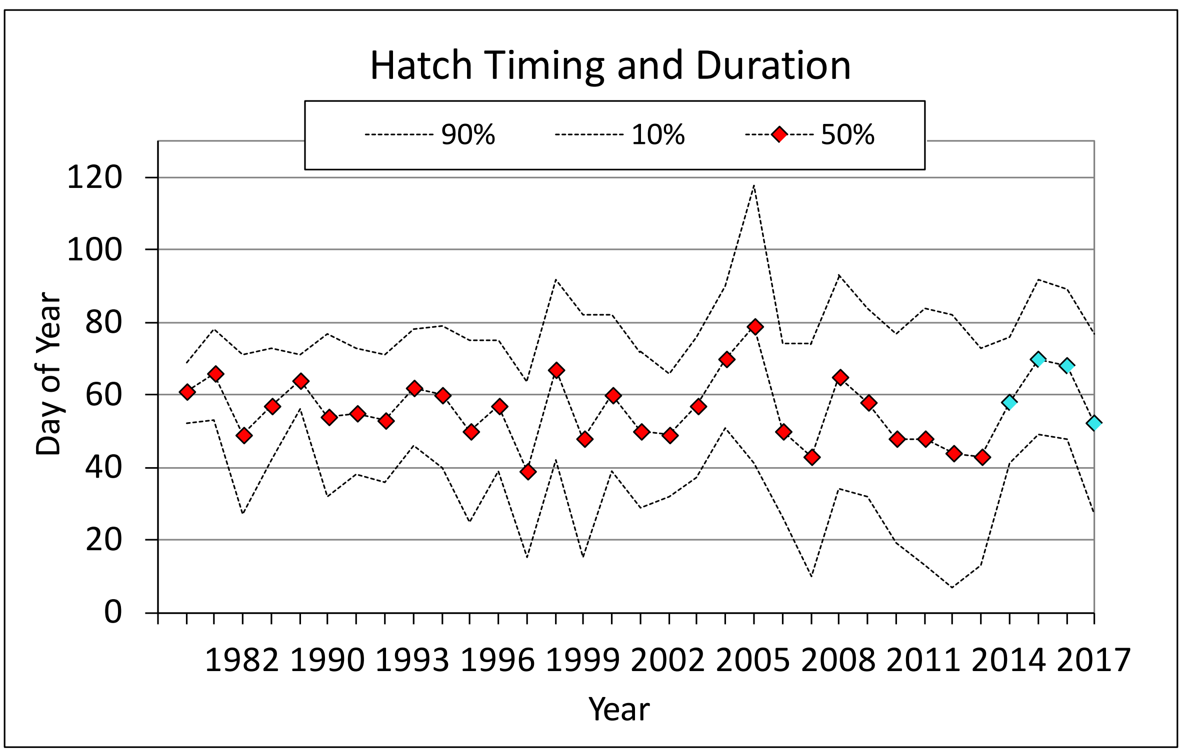


Figure 19: Timing and duration of the hatch period for northern shrimp in the Gulf of Maine. Turquoise points indicate winter sampling done by the states while the fishery was closed.

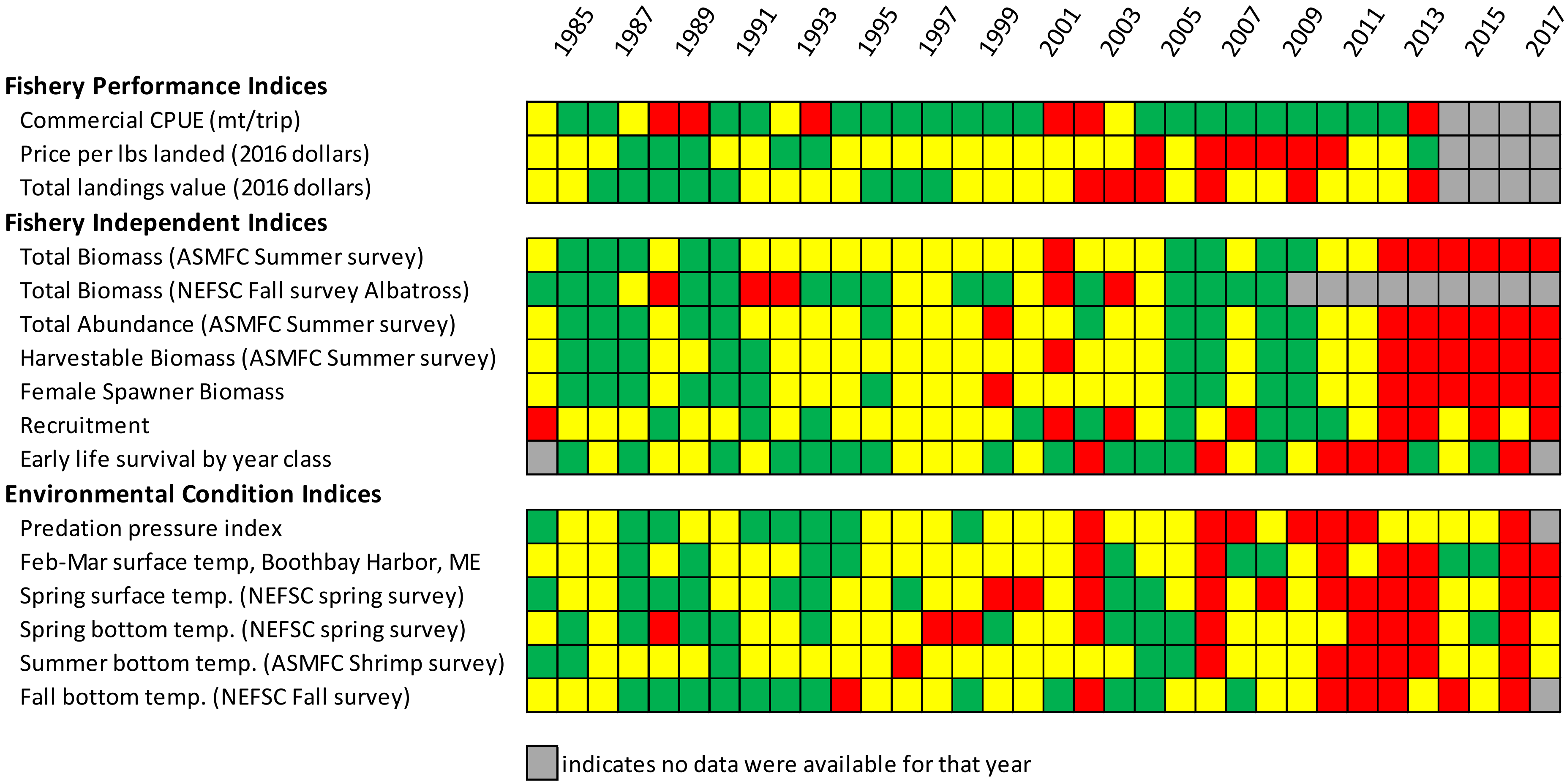


Figure 20: Strict Traffic Light Approach (STLA) results. Red indicates unfavorable conditions or status, yellow indicates intermediate values, and green indicates favorable conditions or status.

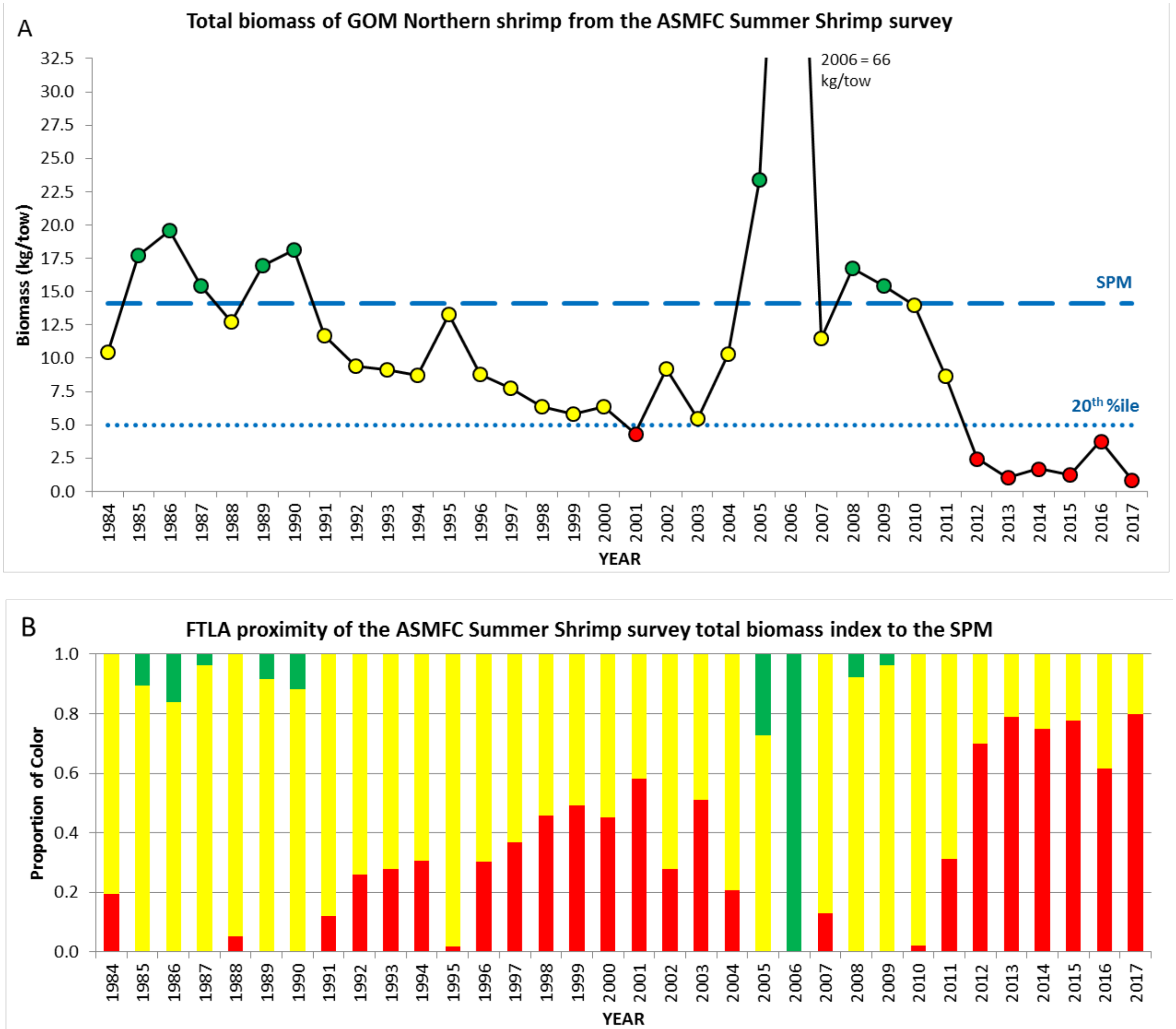
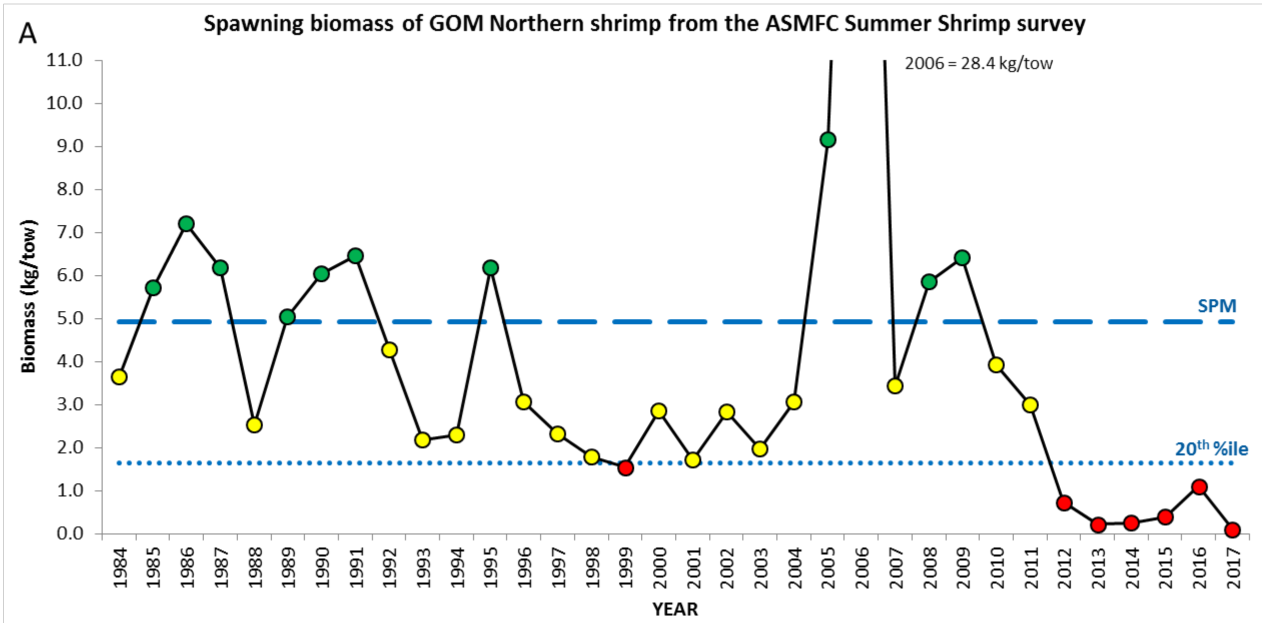


Figure 21: Traffic light analysis for total biomass. (A) Total biomass of Gulf of Maine northern shrimp from the ASMFC Summer Shrimp survey 1984–2017, with the 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2017 (dotted) indicated. Green values ≥ SPM; 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).



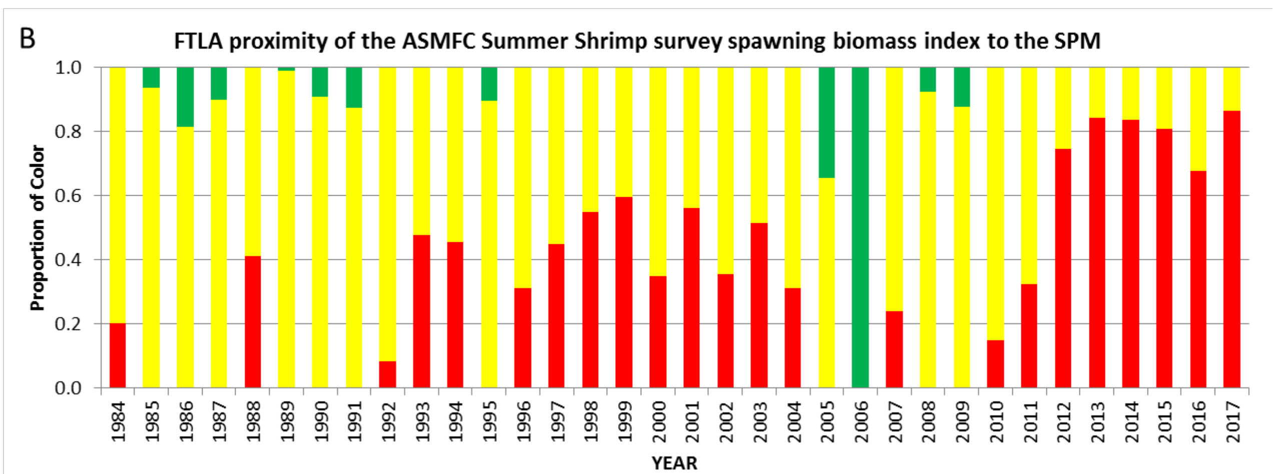


Figure 22: Traffic light analysis of spawning stock biomass. (A) Spawning biomass of Gulf of Maine northern shrimp from the ASMFC Summer Shrimp survey 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2017 (dotted) indicated. Green values ≥ 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).

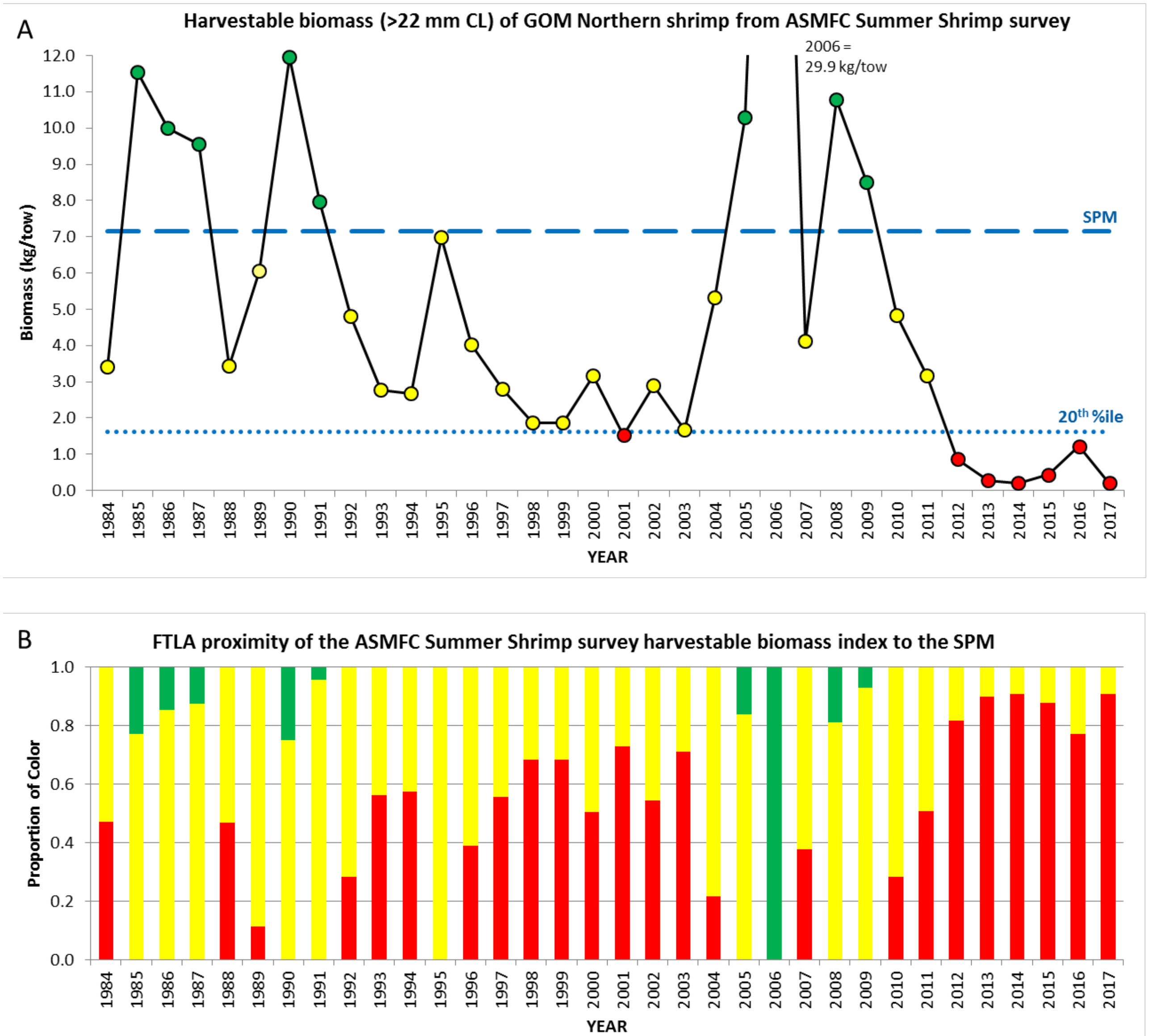


Figure 23: Traffic light analysis for harvestable biomass. (A) Harvestable biomass of Gulf of Maine northern shrimp from the ASMFC Summer Shrimp survey 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2017 (dotted) indicated. Green values ≥ 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).

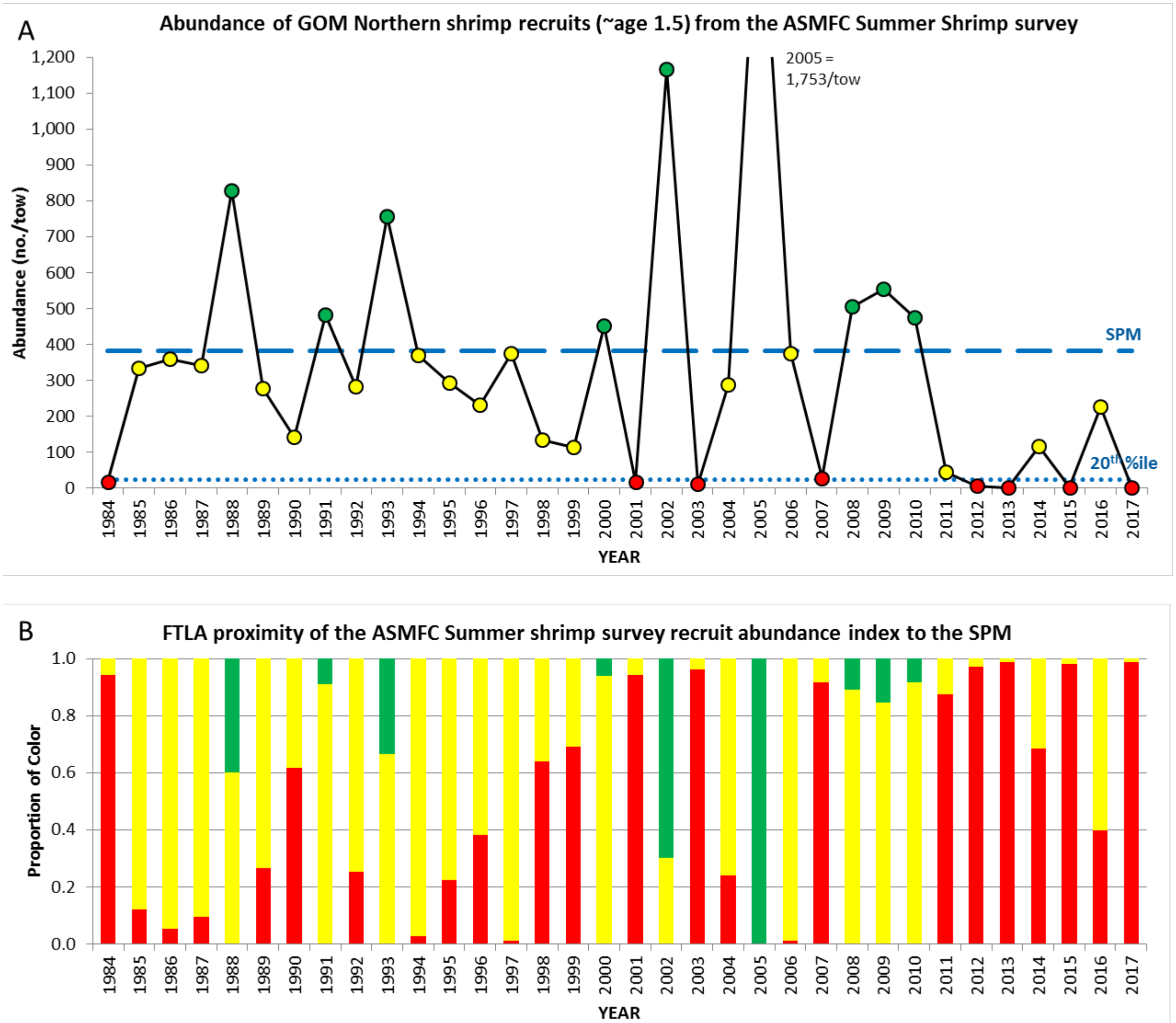


Figure 24: Traffic light analysis of northern shrimp recruitment. (A) Recruit abundance of Gulf of Maine northern shrimp from the ASMFC Summer shrimp survey 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series from 1984–2017 (dotted) indicated. Green 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).

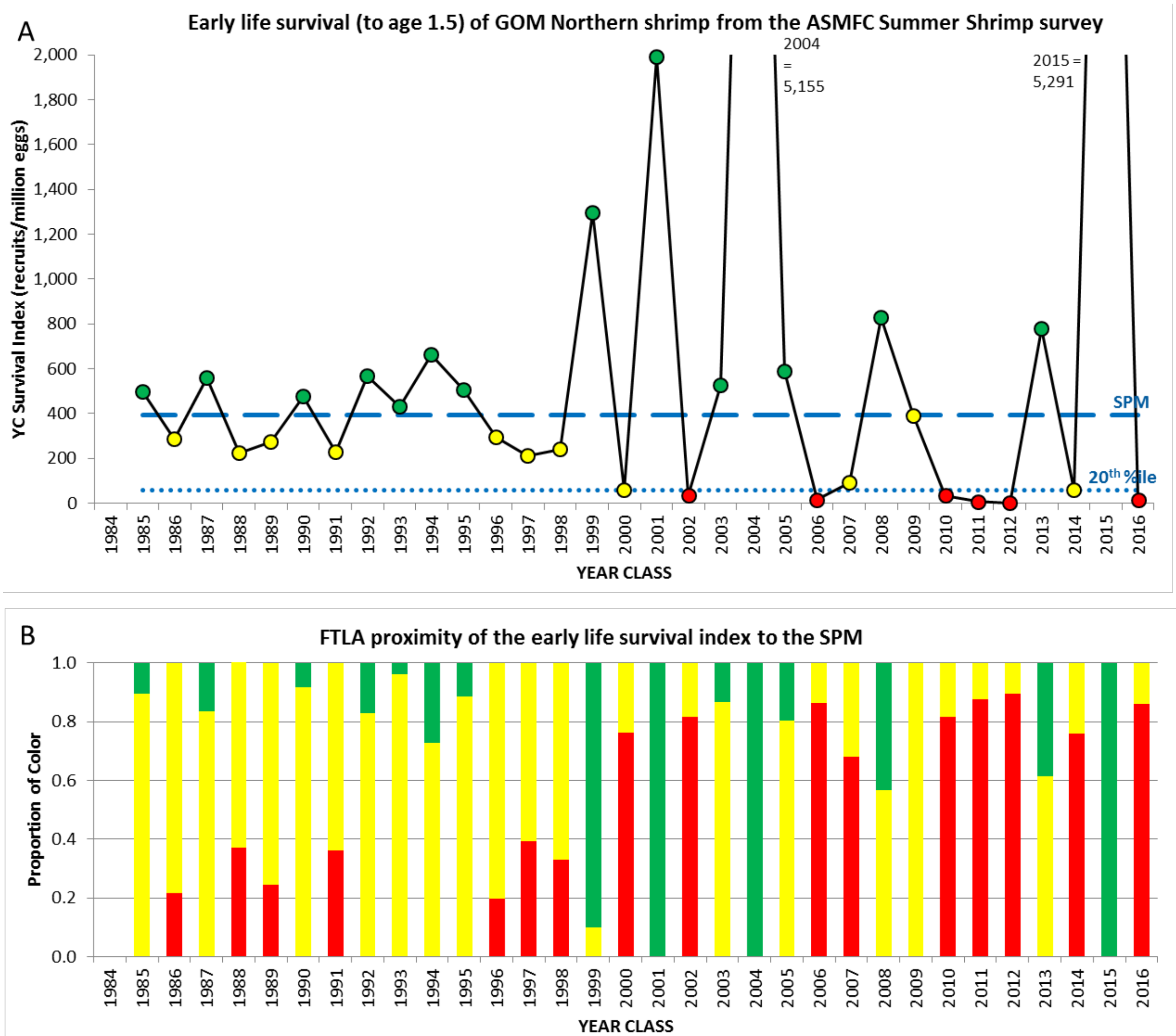


Figure 25: **Traffic light analysis of northern shrimp early life survival. (A) Early life survival (to age 1.5) by year class of Gulf of Maine northern shrimp from the ASMFC Summer Shrimp survey 1984–2016, with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series by year class 1985–2016 (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).**

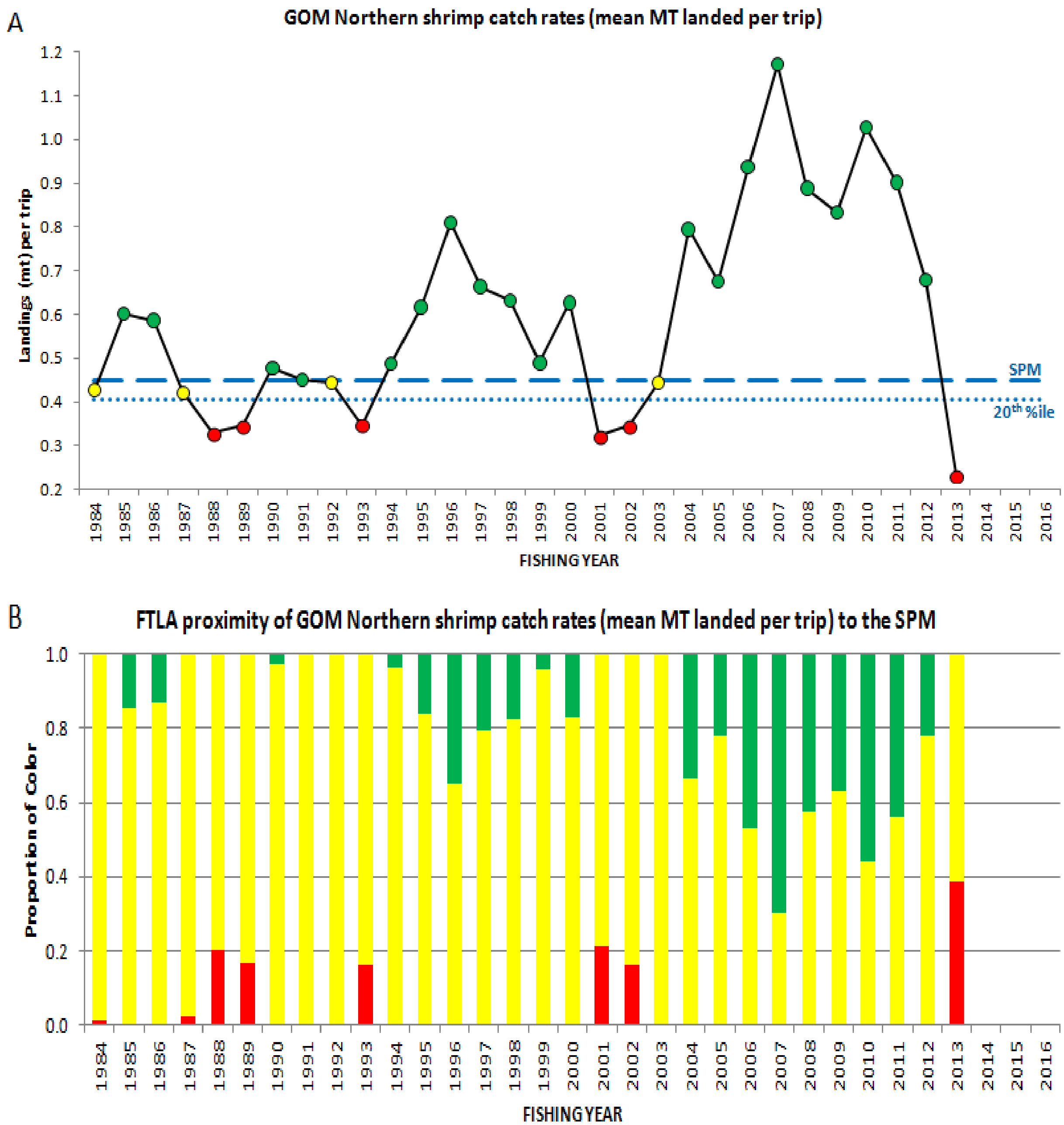


Figure 26: Traffic light analysis of northern shrimp commercial CPUE. (A) Gulf of Maine northern shrimp fishery catch rates (mt of landings per trip) by fishing year from 1984–2013 (fishery closed 2014–2017), with 'stable period' (1985–1994) mean (SPM) (dashed) and 20th percentile of the time series 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).

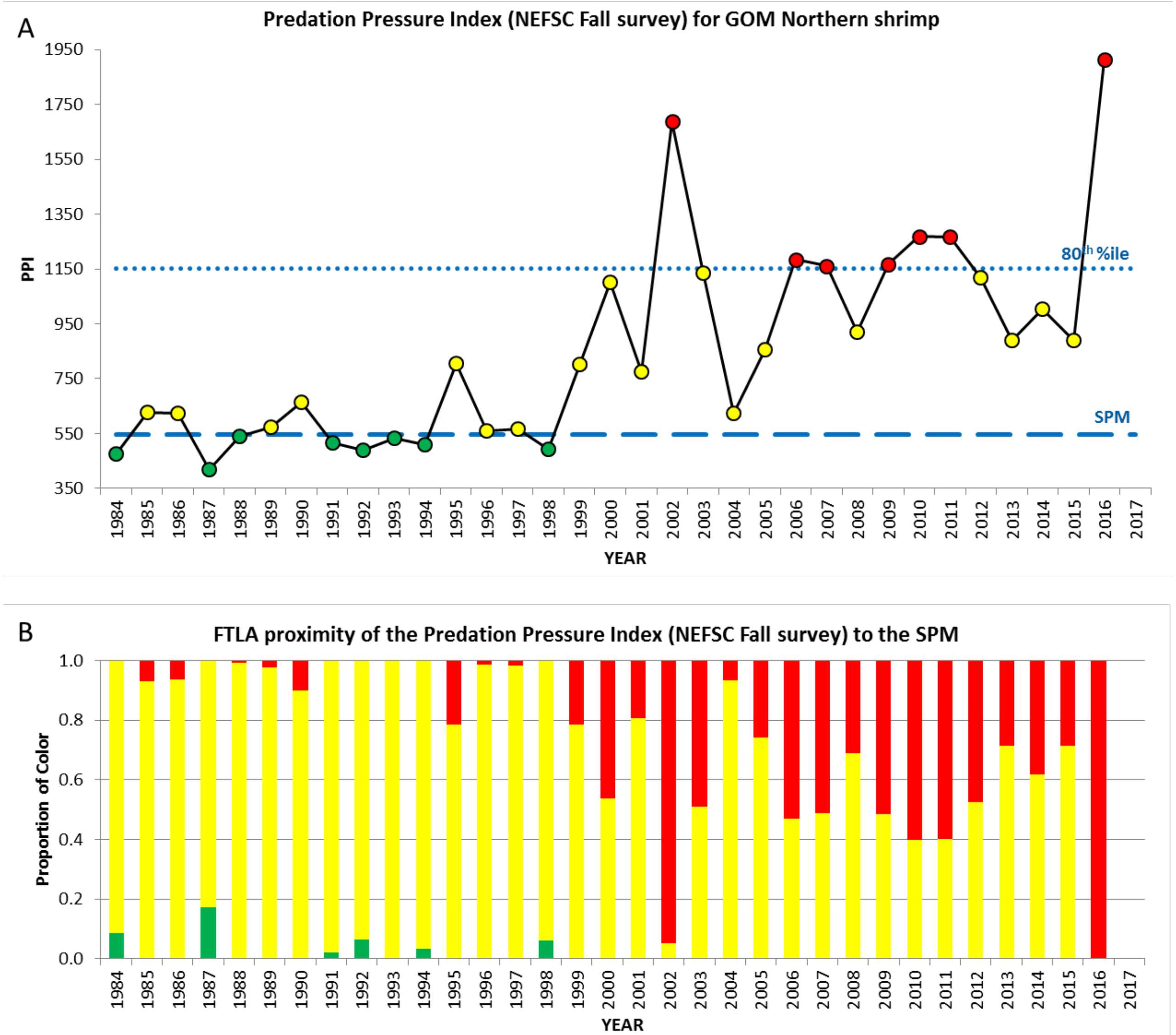


Figure 27: **Traffic light analysis of northern shrimp predation pressure index. (A) Predation Pressure Index (PPI) for Gulf of Maine northern shrimp from 1984–2016, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2016 (dotted) indicated. Green values ≤ 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).**

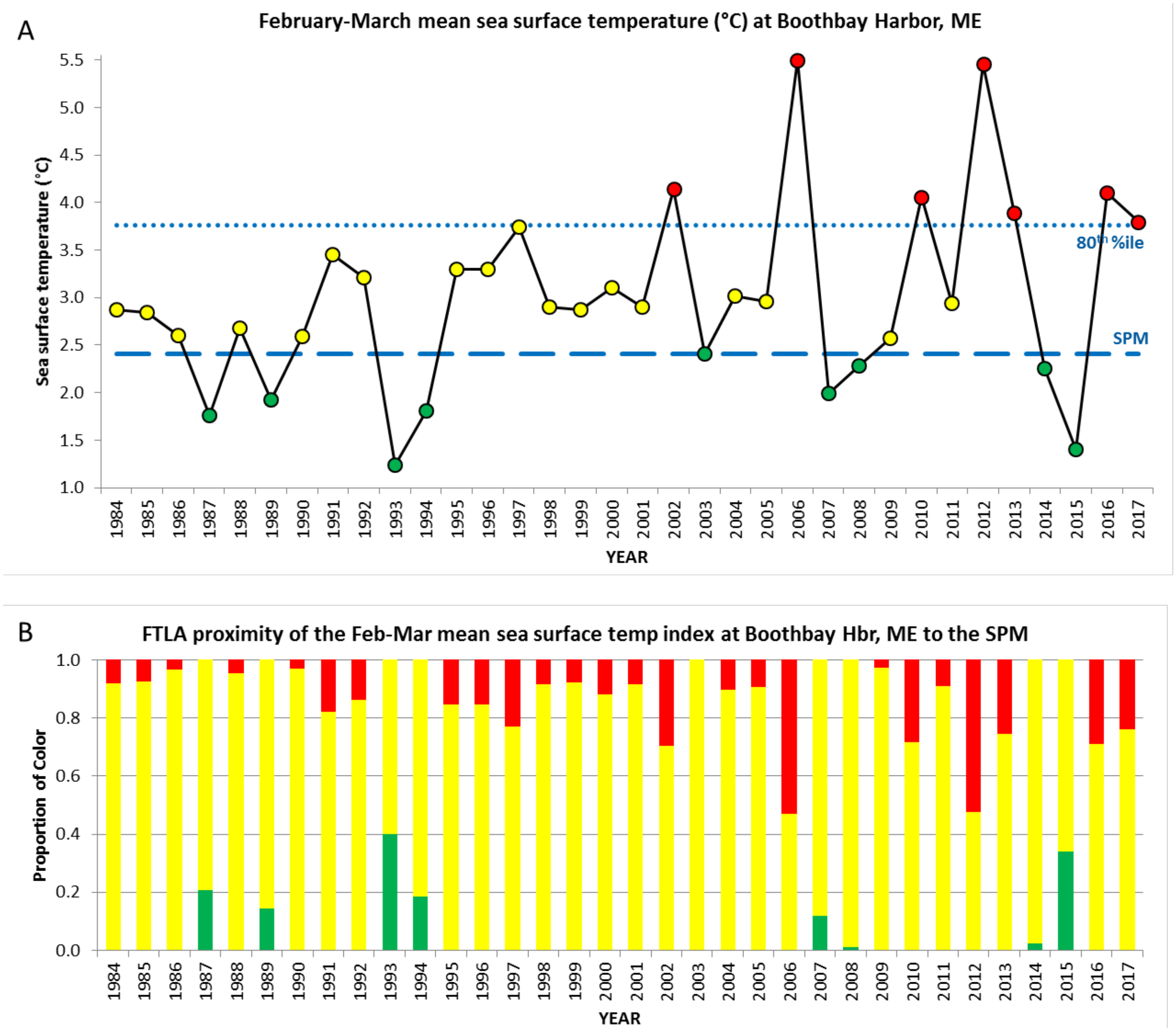


Figure 28: Traffic light analysis of Feb-Mar sea surface temperature at Boothbay Harbor, ME. (A) February to March mean sea surface temperature (°C) at Boothbay Harbor, ME from 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2017 (dotted) 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).

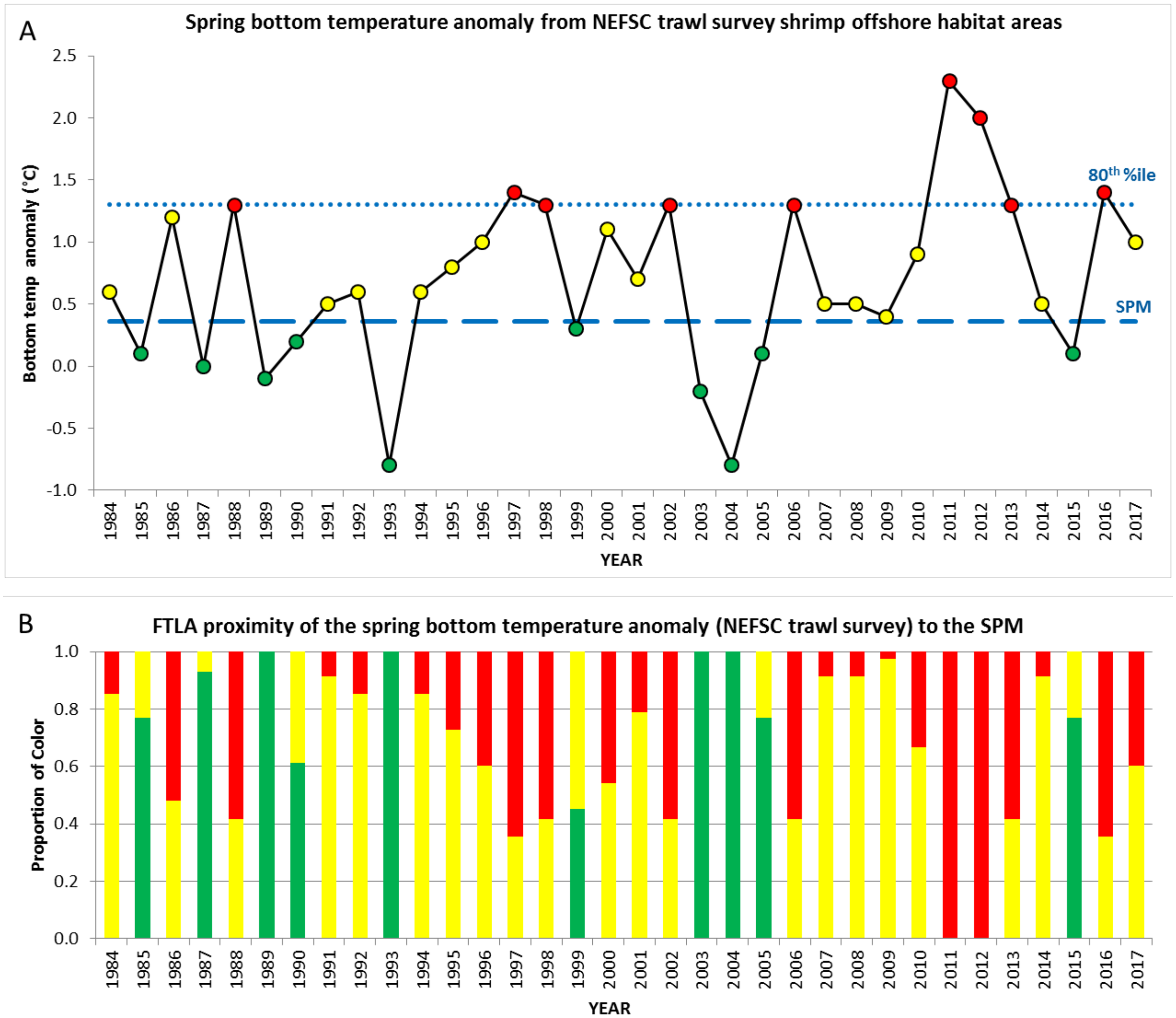


Figure 29: Traffic light analysis of spring bottom temperature anomalies from the NEFSC trawl survey. (A) Spring bottom temperature anomaly (°C) from the NEFSC trawl survey in shrimp offshore habitat areas from 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2017 (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).

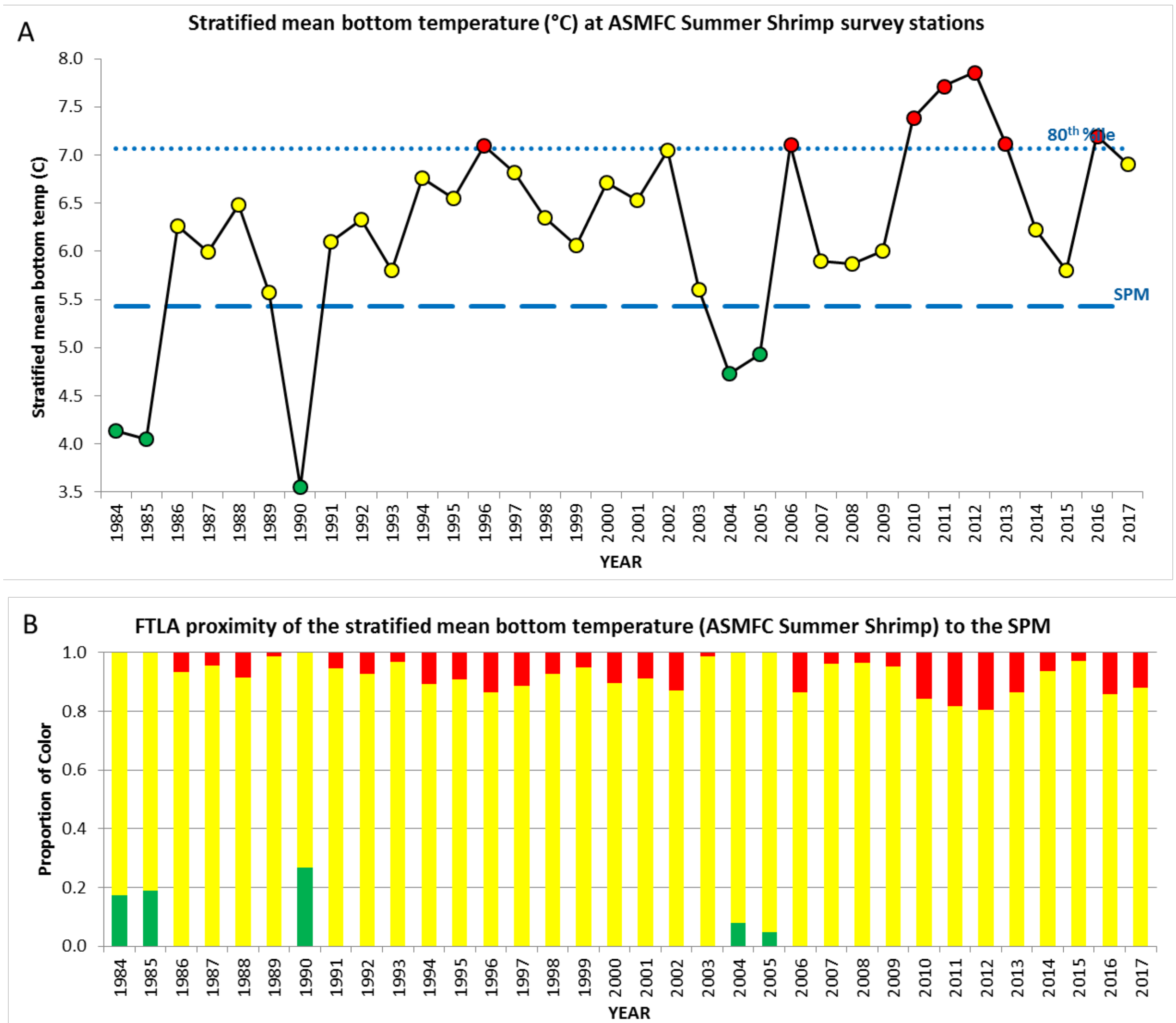


Figure 30: Traffic light analysis of summer bottom temperature from the ASMFC summer survey. (A) summer stratified mean bottom temperature (°C) at ASMFC Summer Shrimp survey stations from 1984–2017, with 'stable period' (1985–1994) mean (SPM) (dashed) and 80th percentile of the time series from 1984–2017 (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).

10.0 APPENDIX

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– 2017 (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

Fishing Season	Recommendations	Actions Taken
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
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 gear. No fishing on Sundays except March 15. • Continuation of mesh regulations • Finfish excluder devices required
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 gear. • Continuation of mesh regulations • Finfish excluder devices required
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 • Finfish excluder devices required
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

Fishing Season	Recommendations	Actions Taken
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 • No mechanical shaking of net on vessel
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 • Finfish excluder devices required • No mechanical shaking of net on vessel
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 • No mechanical shakers allowed on vessel
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 • Trawl season start on January 2, 2012 with three landing days a week

Fishing Season	Recommendations	Actions Taken
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, 2013 with two landings days per week • Trap fishery start on February 5, 2013 with 6 landings days and an 800 lb limit • Landings days modified throughout season
2014	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing • Maine DMR contracted one shrimp trawler to collect samples during the winter
2015	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing • 25 metric ton RSA for cooperative winter sampling program; 4 trawlers with an 1,800 pounds per trip limit were allowed to sell their landings; 5 trappers had 10 trap and 100 lbs/week limits, no sale.
2016	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing • 22 metric ton RSA for cooperative winter sampling program; 4 trawlers with an 1,800 pounds per trip limit and 2 trappers with a 40 traps and 600 pounds per week limit. • Selected vessels were permitted to sell their landings
2017	• Moratorium on fishing; the stock has collapsed	• Moratorium on fishing • 53 metric ton RSA for cooperative winter sampling program; 10 trawlers with a 1,200 pounds per trip limit and 5 trappers with a 40 traps and 500 pounds per week limit. Preference was given to individuals using size sorting grates and having a history in the fishery prior to the June 7, 2011 control date • Selected vessels were permitted to sell their landings

Appendix 2. Preliminary Results from NEFSC/ASMFC Summer Shrimp Survey Door Calibration aboard the RV Gloria Michelle, July 2017

The first week of the 2017 NEFSC/ASMFC summer shrimp survey (July 9-13) aboard the *RV Gloria Michelle* was dedicated to performing comparison tows between the standard ("old") 350KG Portuguese doors and new Bison size 7+ doors. Non-random station locations were selected based on historical survey tows (Figure 3). Each plotted station was sampled once with each door type to obtain catch comparison data. All operational protocols were the same as for the regular survey. Results are plotted below (Figures 1-2). The new Bison doors were used for the rest of the 2017 survey. More calibrations tows are planned for 2018.

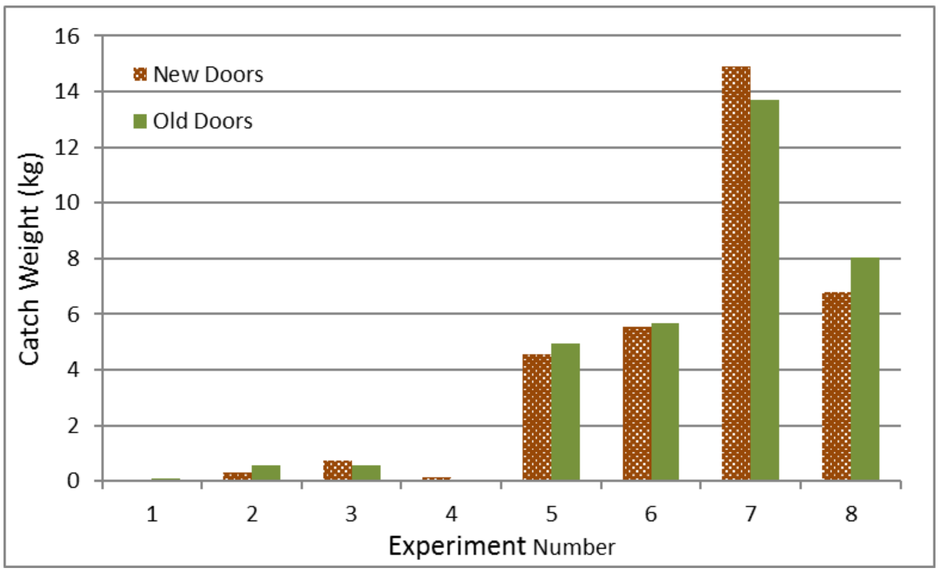


Figure 1. Northern shrimp catch (kg/tow) for the eight paired calibration tows.

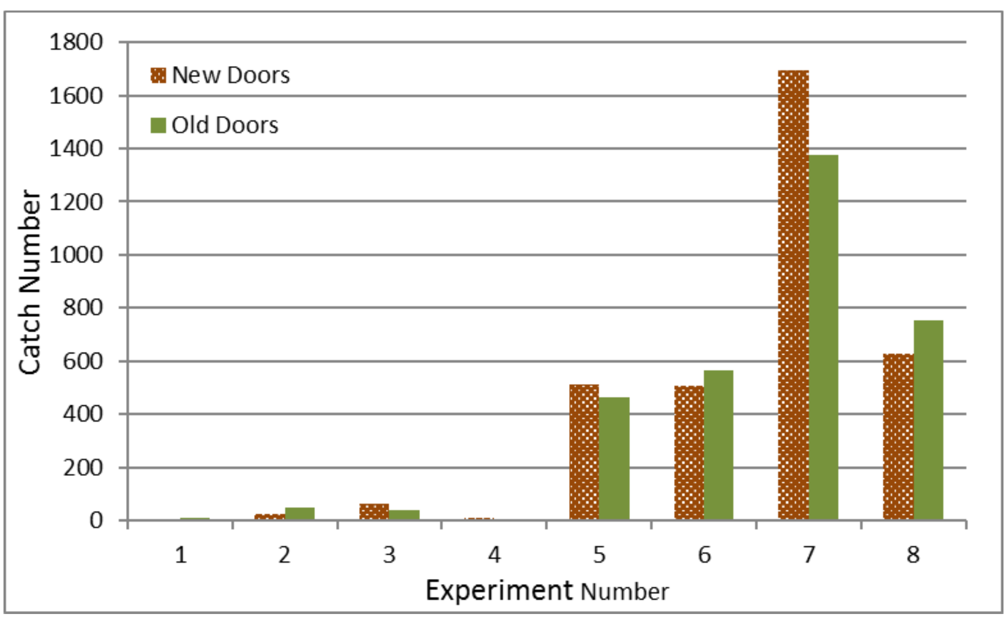


Figure 2. Northern shrimp catch (numbers/tow) for the eight paired calibration tows.

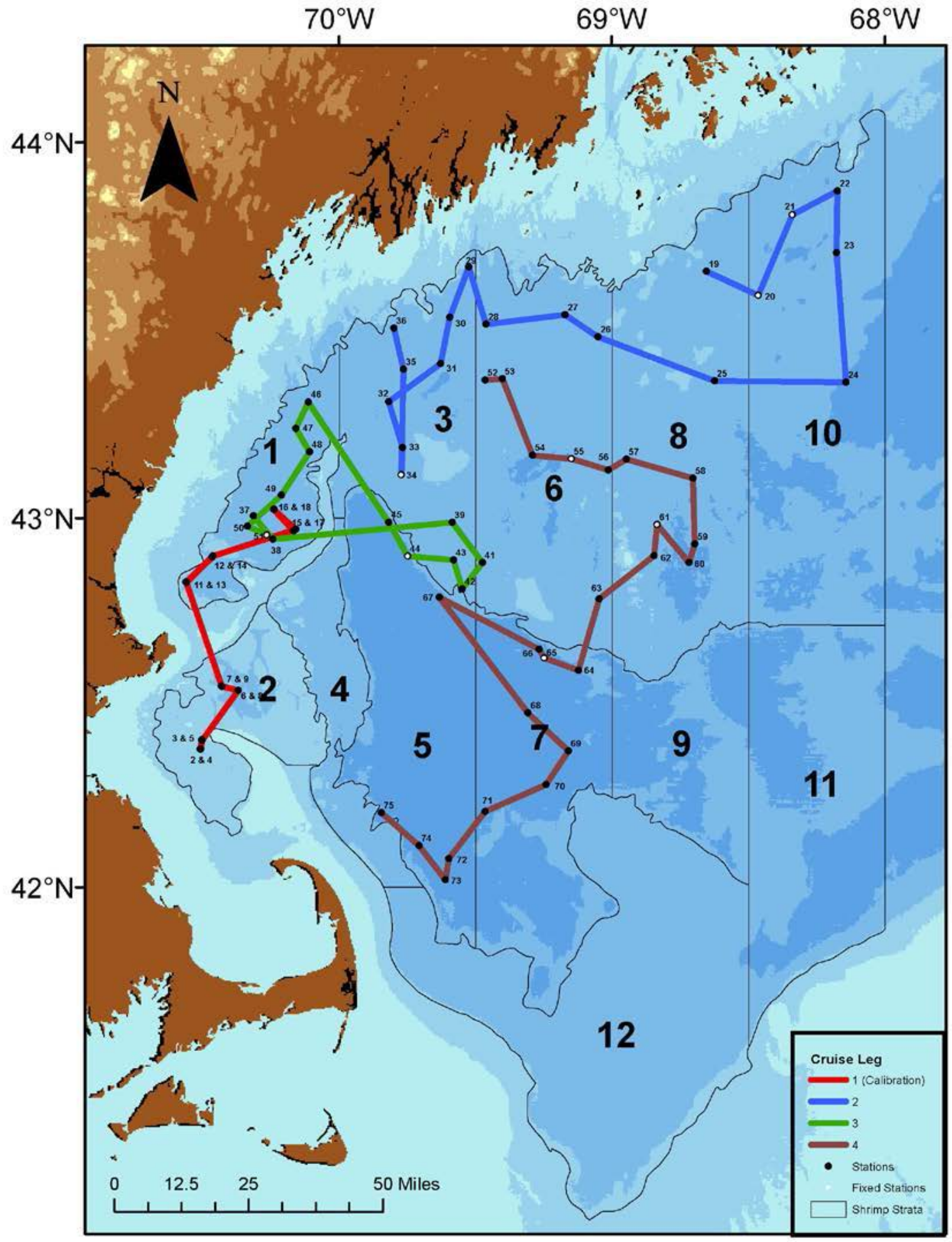


Figure 3. Trawl hauls made during the 2017 NEFSC/ASMFC northern shrimp survey and trawl door calibration (red track in regions 1 and 2) in the Gulf of Maine aboard FRV *Gloria Michelle*, 9 July – 4 August 2017.

Appendix 3: Identification of Potential Regime Shifts Relevant to Northern Shrimp

To address the question of whether we may be in a new 'productivity regime' for northern shrimp in the Gulf of Maine, a statistical method for regime shift detection was applied to time series of environmental (temperature) and biological data relevant to northern shrimp.

Methods

The STARS (Sequential t-test Analysis of Regime Shifts) method for regime shift detection was used to evaluate possible regime shifts (Rodionov 2004; Rodionov and Overland 2005). The method is based on a series of sequential t-tests comparing the current (most recent) value to the mean of the time series for the current regime to identify potential change points. A significantly different value indicates a potential regime shift, and subsequent observations are used to confirm this. Many methods for regime shift detection have difficulty detecting shifts near the end of the time series, thus shifts cannot be detected in a timely fashion. The STARS method was developed the address this problem.

The time series examined are shown in Tables 1 (temperature data) and 2 (biological data). The data were prewhitened to correct for auto-regression in the time series so that the correlation between successive years did not influence the results. Autocorrelation can lead to spurious detection of regime shifts (Rodionov 2006). Huber's h=1.345 (Huber 1964) was used for down-weighting outliers.

Two parameters determine the sensitivity of regime detection by STARS – (1) the significance level used for the t-tests (the lower the P level, the larger the magnitude of the shift must be in order to be detected), and (2) the cut-off length. The implications of cut-off length are described by Rodionov (http://www.beringclimate.noaa.gov/regimes/help.html): "The regimes that are longer than the cut-off length will all be detected. If the regimes are shorter than the cut-off length, the probability for them to be detected reduces proportionally to their length. Some of them, however, may still be selected if the magnitude of the shift is significant enough. Generally speaking, the shorter the cut-off length, the shorter the regimes that will be selected (and vice versa), but it's not always true."

As a base case, a cut-off length of 5 years and a P value of 0.10 for significance of the t-tests were used. To test the sensitivity to these parameters, the analysis was repeated using a 10-year cut-off, and P=0.05 or P=0.10.

Results

Temperature Data

Using the base case parameters, regime shifts were detected for all temperature variables except spring bottom temperature anomaly (BTA) and Feb-Mar average sea surface temperature (SST) at Boothbay Harbor (Figure 1). A regime change point was detected in 2010 for spring sea surface temperature anomaly (SSTA), summer shrimp survey bottom temperature (BT), fall BTA, PC1 (composite temperature index), and day of year (DOY) of spring thermal transition. A change point was detected in 2009 for the length of summer. Earlier change points were identified in some series, but did not occur at the same time in different time series.

When the cut-off length was increased to 10 years (with P=0.10), several changes in timing of change points were seen (shaded plots in Figure 2), but change points were still identified in 2010 for summer BT, fall BTA and PC1. The change point for spring SSTA changed from 2010 to 2008, for spring transition from 2010 to 2009, and for summer length from 2009 to 2008. An additional regime shift was detected in 2011 for spring BTA.

When the P value for significance was reduced to P=0.05 (cut-off length held at 10 yr), the change point identified at 2010 for summer BT was no longer significant (Figure 3). No other changes were seen.

Biological Data
Under the base case scenario, no regime shifts were detected for shrimp recruitment or survival indices (Figure 4). The mean size of presumed age 1.5 shrimp (recruits) showed a possible change point in 2014. The spring and fall PPI indices showed change points in 2000 and 1999, respectively, and potential change points near the end of the time series as well (2015, 2016).

With a cut-off length of 10 years and P=0.10, the only changes from the base case results were a possible regime shift to lower recruitment starting in 2011 (recruitment index estimated using the geostatistical method), and a possible change point in survival (higher) identified in 2015 (Figure 5).

With a cut-off length of 10 years and P=0.05, the possible regime shift in 2011 to lower recruitment was no longer identified (Figure 6). No other changes were seen.

Discussion
Identifying possible regimes is not an exact science. Choice of methods and parameters can affect whether a time period is identified as a regime. In addition, though the STARS method can identify potential change points near the ends of time series, these change points should be viewed as provisional until more years are added.

A regime shift was detected at or near 2010 in several of the temperature time series (spring SSTA, fall BTA, summer shrimp survey BT, PC1, DOY of spring thermal transition, length of summer). It should be noted that PC1 is somewhat redundant with several individual time series, since it is a composite of spring SSTA, spring BTA and fall BTA. The temperature series that did not show a change point near 2010 were winter SST at Boothbay Harbor and spring BTA, which is consistent with other studies showing that the recent warming in the Gulf of Maine has been stronger during summer and fall than winter and spring (Friedland and Hare 2007; Thomas et al. 2017).

For the five shrimp variables, two of the identified change points (in mean size at age 1.5 and early life survival) are very recent and thus bear watching to determine whether a regime shift has occurred. It should be noted that the survival indices (which are ratios of recruitment indices to indices of population fecundity) may not be very meaningful at the low current abundance. The possible regime shift to lower recruitment indices in 2011 was seen under only one set of parameters, so also bears watching.

The results for the spring and fall predation pressure indices suggest a change point near the ends of the time series, which will need to be evaluated as more years of data are added. Overall, the results suggest a shift in temperature regime occurring around 2010, but no clear effect on shrimp as yet.

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Table 1. Temperature-related time series tested for regime shifts. SST=surface temperature, BT=bottom temperature, SSTA=surface temperature anomaly, BTA=bottom temperature anomaly, DOY=day of year. PC1 is composite temperature index from principal components analysis of NEFSC spring SSTA, spring BTA and fall BTA. BBY is Boothbay Harbor daily SST. Spring thermal transition and summer length is for western Gulf of Maine, provided by Kevin Friedland (personal communication).

Year	Temperature PC1	BBY Feb-Mar avg SST	BBY-Jul 15-Sep 1 avg SST	NEFSC Spring SSTA	NEFSC Spring BTA	NEFSC Fall BTA	Shrimp Survey BT	DOY spring thermal transition	Summer length (days)
1984	-0.226	2.9	15.7	-0.1	0.6	0.8	4.1	155	180
1985	-0.628	2.8	16.3	0.1	0.1	0.6	4.0	154	173
1986	0.851	2.6	15.5	0.8	1.2	0.7	6.3	153	161
1987	-1.712	1.8	14.2	-0.6	0.0	0.0	6.0	150	161
1988	-0.460	2.7	15.9	-0.2	1.3	-0.1	6.5	151	159
1989	-2.028	1.9	15.2	-0.6	-0.1	-0.3	5.6	144	176
1990	-1.020	2.6	16.5	0.0	0.2	0.1	3.6	158	156
1991	-0.329	3.4	15.5	0.6	0.5	0.1	6.1	142	169
1992	-1.622	3.2	15.7	-0.9	0.6	-0.2	6.3	158	144
1993	-2.657	1.2	15.6	-0.7	-0.8	-0.3	5.8	158	149
1994	0.396	1.8	17.4	0.2	0.6	1.3	6.8	157	166
1995	-0.154	3.3	16.4	0.1	0.8	0.5	6.6	156	166
1996	0.252	3.3	15.9	-0.2	1.0	1.1	7.1	151	162
1997	0.245	3.7	16.0	0.0	1.4	0.5	6.8	157	159
1998	-0.167	2.9	16.4	0.5	1.3	-0.4	6.3	146	160
1999	0.135	2.9	16.9	0.9	0.3	0.6	6.1	144	177
2000	0.847	3.1	18.0	0.9	1.1	0.7	6.7	150	175
2001	-0.322	2.9	17.8	0.4	0.7	0.1	6.5	153	167
2002	1.707	4.1	19.2	1.2	1.3	1.3	7.1	154	170
2003	-1.949	2.4	18.2	-0.6	-0.2	-0.1	5.6	160	159
2004	-3.441	3.0	19.0	-0.9	-0.8	-1.1	4.7	160	151
2005	-0.632	3.0	19.7	0.2	0.1	0.5	4.9	157	163
2006	1.401	5.5	20.2	0.9	1.3	1.2	7.1	147	170
2007	-1.099	2.0	17.9	0.0	0.5	-0.3	5.9	149	164
2008	0.362	2.3	18.0	1.2	0.5	0.4	5.9	150	174
2009	-0.085	2.6	17.2	0.4	0.4	0.7	6.0	147	182
2010	2.085	4.1	17.9	1.7	0.9	1.7	7.4	140	186
2011	2.350	2.9	18.2	0.9	2.3	1.4	7.7	147	189
2012	3.344	5.5	18.3	1.9	2.0	2.0	7.9	136	207
2013	2.082	3.9	16.2	1.8	1.3	1.2	7.1	133	192
2014	0.623	2.2	16.4	0.5	0.5	1.4	6.2	141	193
2015	-0.866	1.4	17.3	0.1	0.1	0.3	5.8	145	194
2016	2.718	4.1	17.8	1.7	1.4		7.2	143	199
2017		3.8	16.3						

Table 2. Time series of biological data tested for regime shifts.

Year	Recruitment index	Geostatistical recruit index ('000)	Recruit average size (mm CL)	Transitional mean size (mm CL)	Survival-Recruits per million eggs (YC)	Fall Predation Pressure Index	Spring Predation Pressure Index
1984	18.4	0.016	15.1			475	286
1985	332.2	0.246	15.8	21.61	496	629	810
1986	358.1	0.243	15.3	23.36	287	622	420
1987	342.0	0.189	15.4	20.62	559	417	338
1988	827.9	0.826	16.3	24.27	222	538	269
1989	276.3	0.175	15.9	20.48	274	573	292
1990	141.7	0.090	15.6	20.63	476	665	231
1991	482.1	0.288	16.1	22.02	226	517	253
1992	281.6	0.143	16.2	20.20	565	489	413
1993	756.6	0.733	15.5	19.89	431	534	267
1994	368.1	0.397	16.4	20.13	664	510	227
1995	292.1	0.186	14.7	20.65	506	805	223
1996	231.9	0.257	15.9	21.66	294	561	243
1997	373.8	0.438	15.3	21.64	212	567	533
1998	134.0	0.153	15.9	19.51	239	492	303
1999	113.7	0.174	16.0	20.64	1294	802	437
2000	450.3	0.460	16.0	19.63	57	1101	904
2001	17.6	0.010	15.1	18.55	1992	776	559
2002	1164.5	0.808	16.7	17.99	35	1688	576
2003	10.7	0.014	15.3	17.90	527	1136	706
2004	286.4	0.354	15.8	19.87	5155	625	504
2005	1752.5	1.134	15.5	18.71	589	856	529
2006	374.3	0.146	15.2	18.78	15	1185	209
2007	28.3	0.049	15.3	19.87	91	1161	691
2008	505.7	0.444	16.3	21.38	828	919	731
2009	554.5	0.580	15.5	21.57	391	1167	275
2010	474.7	0.522	16.3	20.88	34	1268	632
2011	43.7	0.047	15.2	20.11	8	1267	782
2012	6.7	0.014	14.6	19.59	2	1118	804
2013	0.9	0.002	15.0	19.44	779	888	406
2014	116.2	0.201	17.4	20.92	17	1005	613
2015	2.7	0.003	16.4	19.25	5291	890	960
2016	225.8	0.190	16.7	18.78	16	1913	1207
2017	1.2		17.2	19.15			932

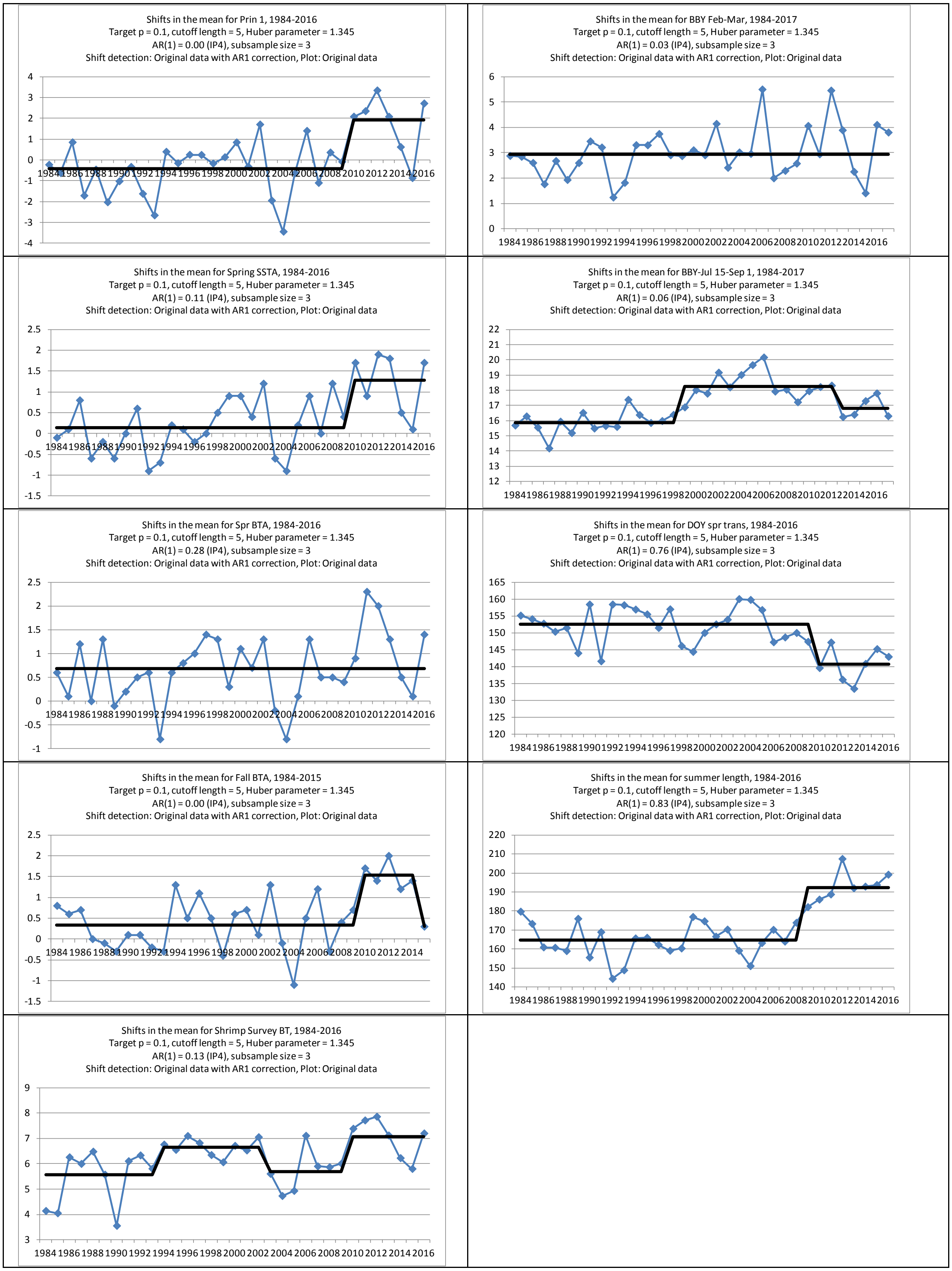

Figure 1. Shift detection results for temperature data. Blue lines represent original data, black line indicates mean for 'regimes' detected using 5-year windows, Huber's weight=1.345 and P=0.10 for detecting significance.

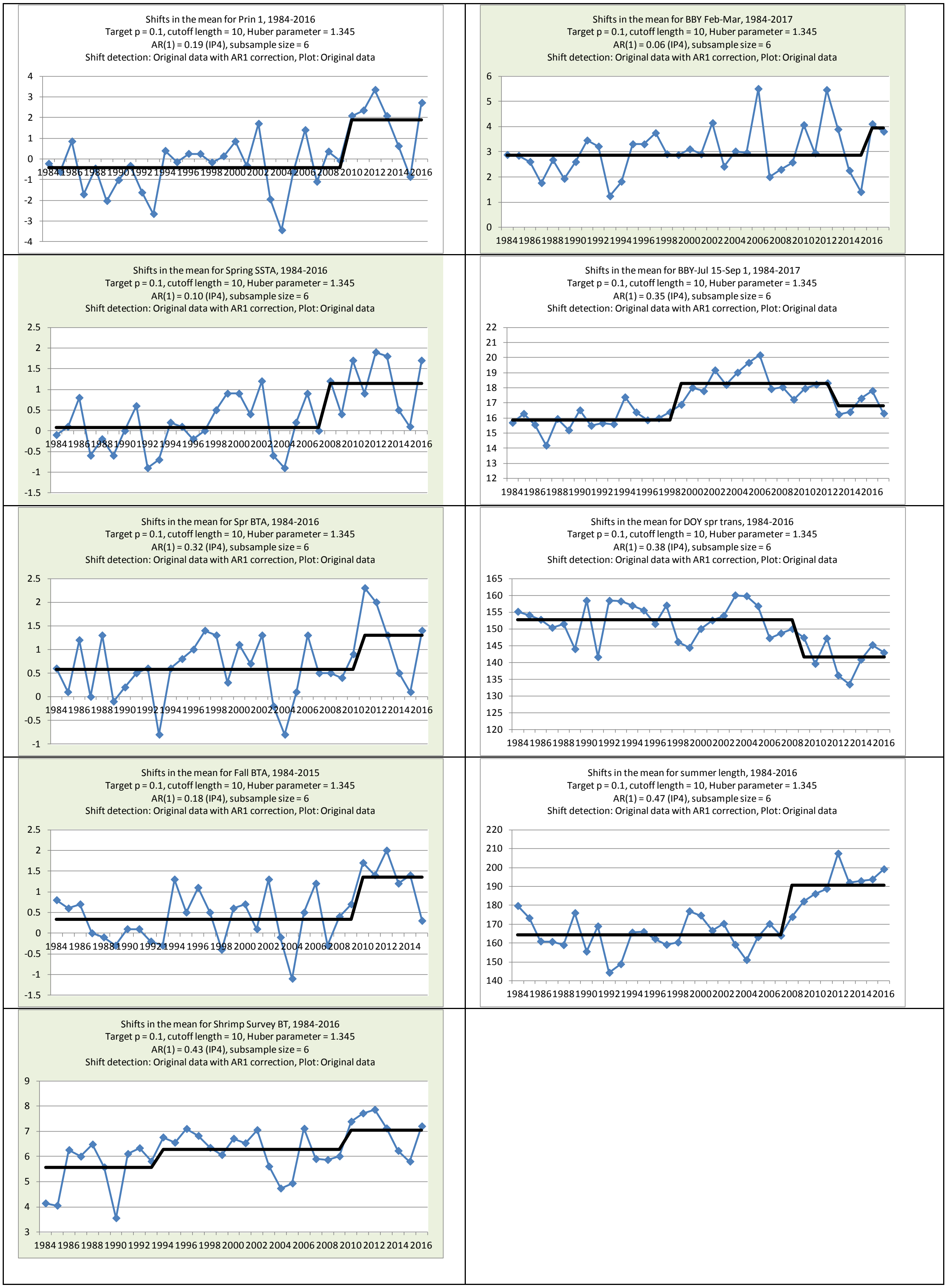

Figure 2. Shift detection results for temperature data. Blue lines represent original data, black line indicates mean for ‘regimes’ detected using 10-year windows, Huber’s weight=1.345 and P=0.10 for detecting significance. Green shaded charts are series that have different regimes identified than the runs in Figure 1 (due to changing from 5-year to 10-year windows).

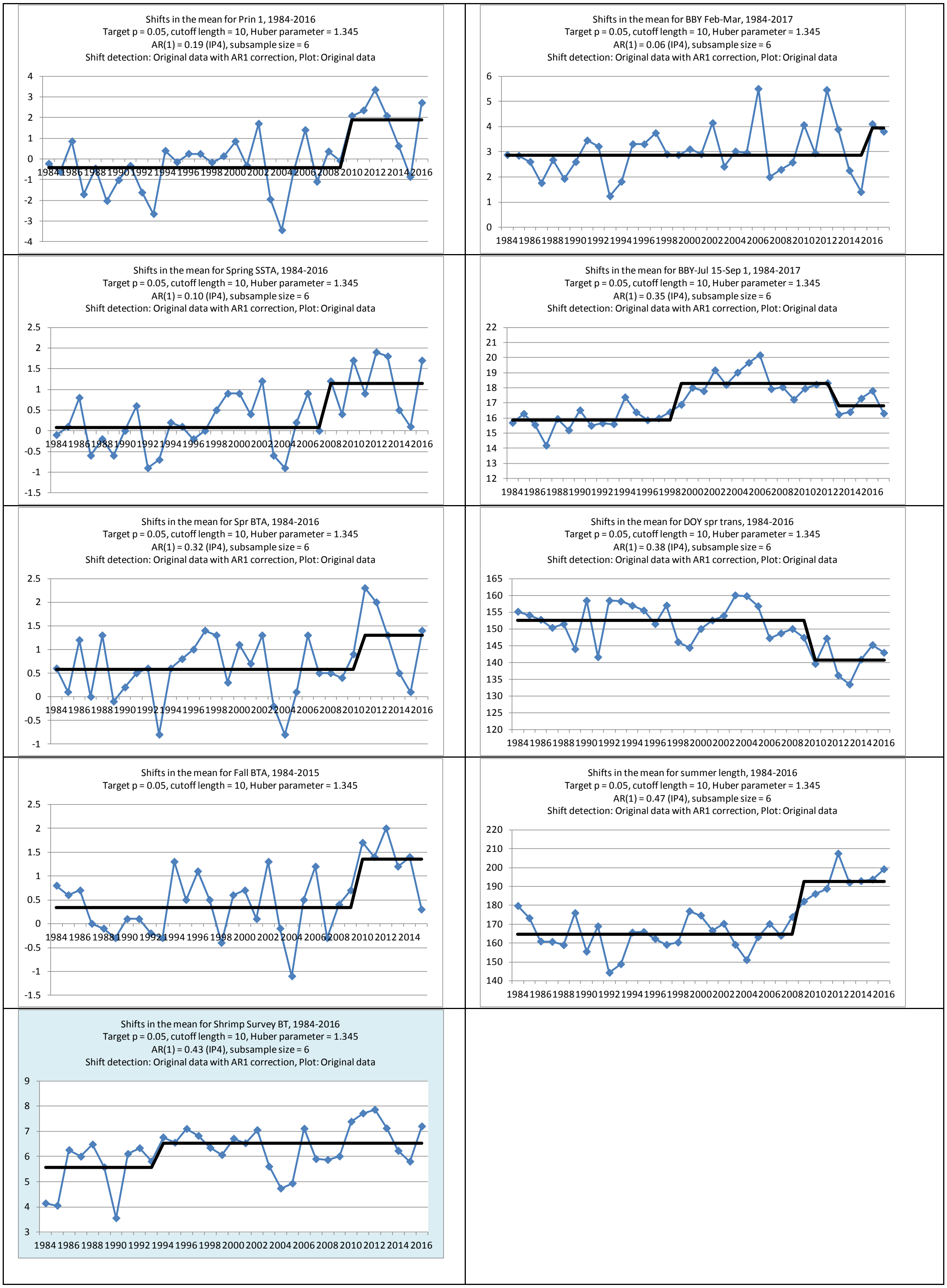

Figure 3. Shift detection results for temperature data. Blue lines represent original data, black line indicates mean for 'regimes' detected using 10-year windows, Huber's weight=1.345 and P=0.05 for detecting significance. Blue shaded chart is series that has different regimes identified than the runs in Figure 2 (due to changing P value from 0.10 to 0.05).

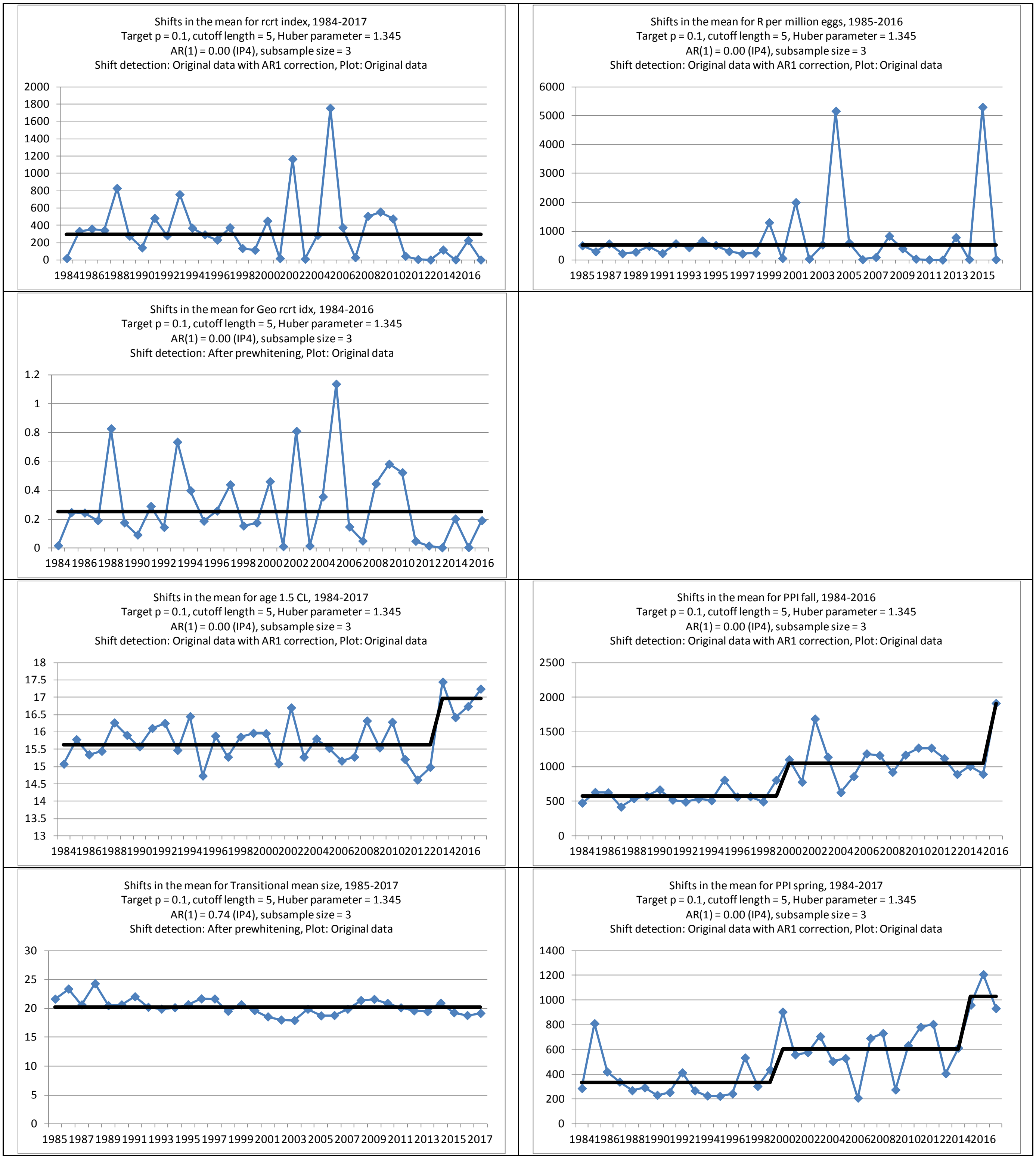

Figure 4. Shift detection results for biological data. Blue lines represent original data, black line indicates mean for 'regimes' detected using 5-year windows, Huber's weight=1.345 and P=0.10 for detecting significance.

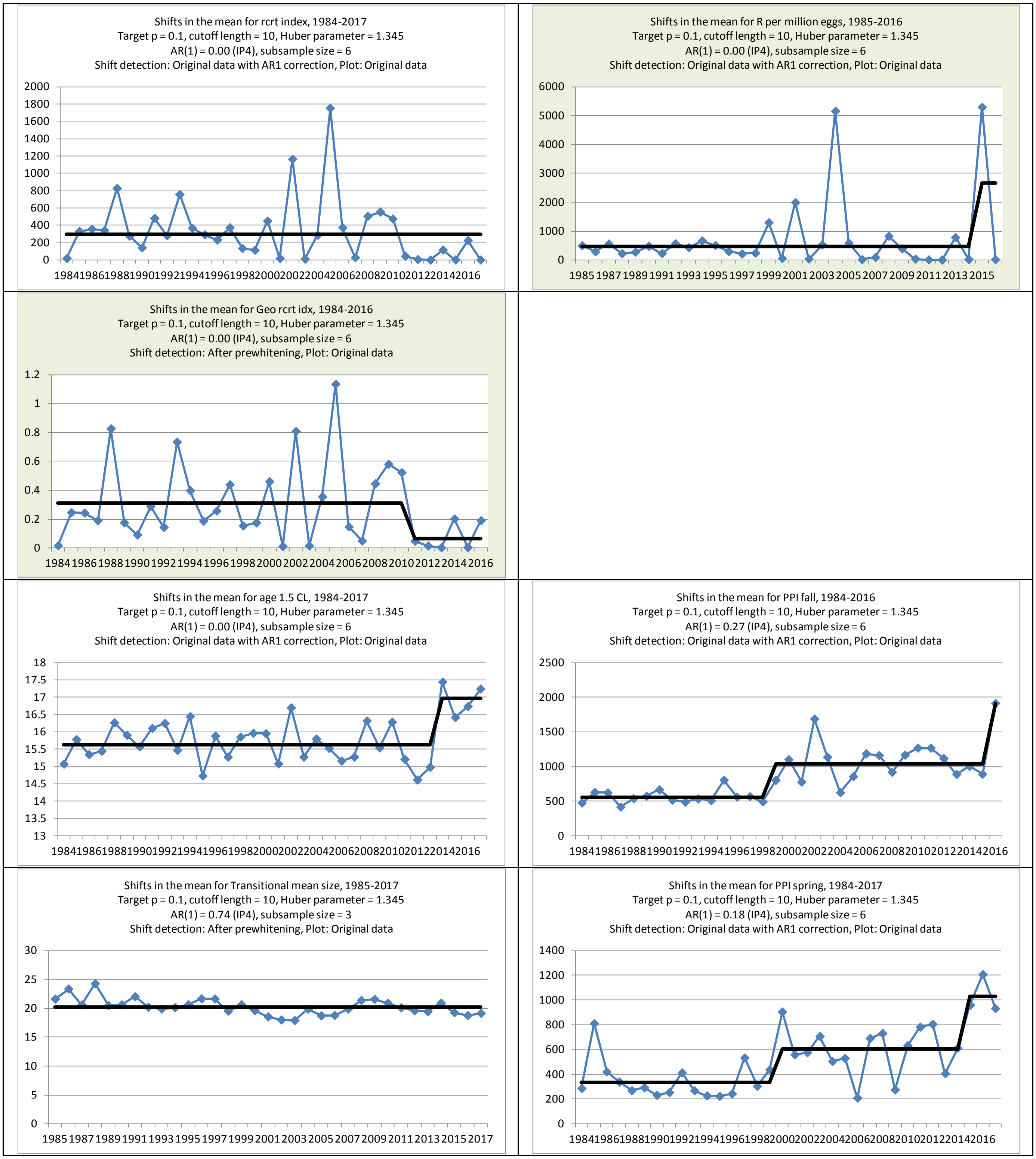

Figure 5. Shift detection results for biological data. Blue lines represent original data, black line indicates mean for ‘regimes’ detected using 10-year windows, Huber’s weight=1.345 and P=0.10 for detecting significance. Green shaded charts are series that have different regimes identified than the runs in Figure 4 (due to changing from 5-year to 10-year windows).

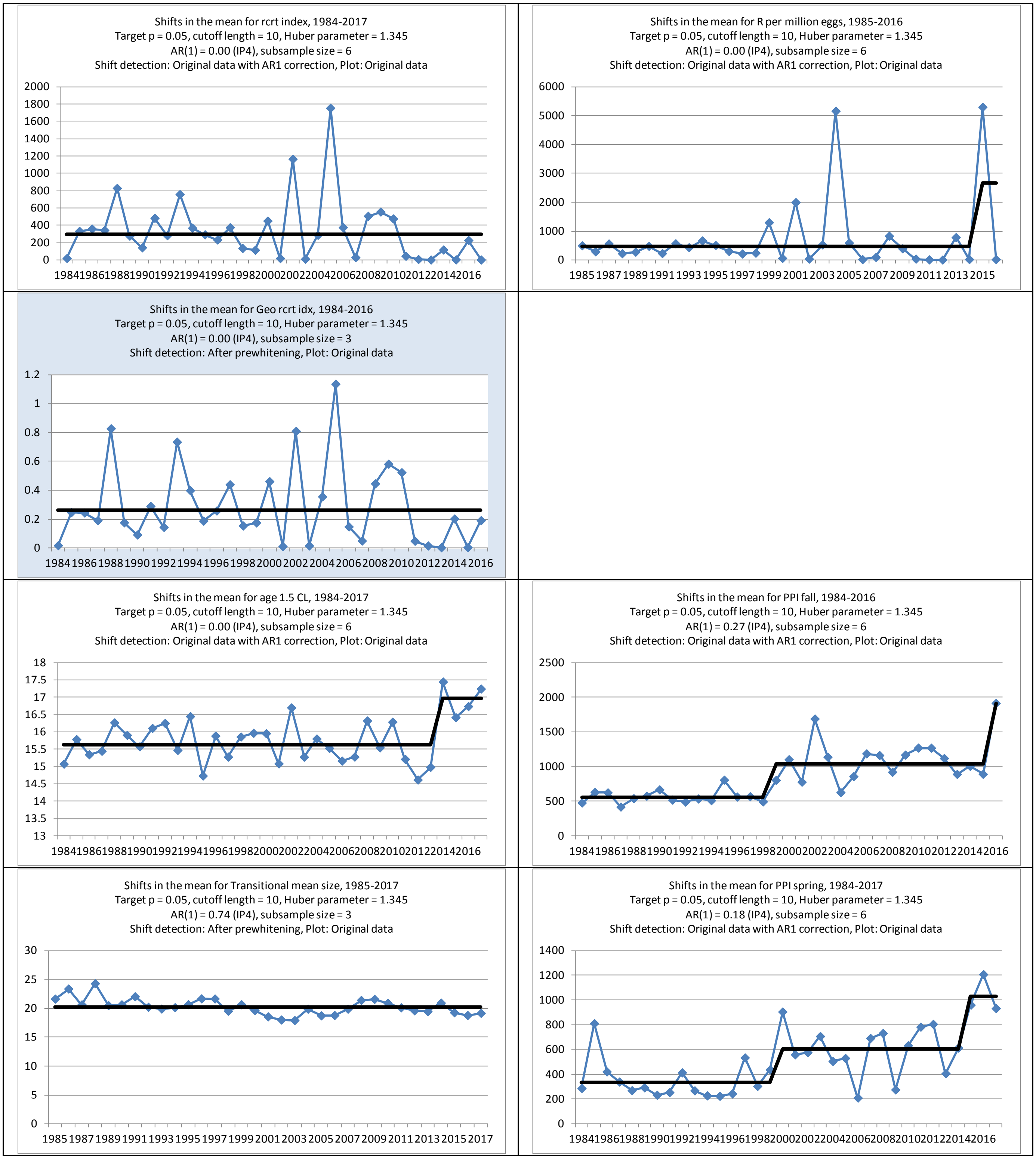

Figure 6. Shift detection results for biological data. Blue lines represent original data, black line indicates mean for ‘regimes’ detected using 10-year windows, Huber’s weight=1.345 and P=0.05 for detecting significance.