Atlantic States Marine Fisheries Commission

Jonah Crab Pre-Assessment Data Workshop Report

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Cooperative interstate management of Jonah crab (*Cancer borealis*) in U.S. waters was first implemented in 2015 with the adoption of the Atlantic States Marine Fisheries Commission's (ASMFC) Interstate Fishery Management Plan (FMP; ASMFC 2015). However, there has been no stock assessment of U.S. Jonah crab to date, stock status is unknown, and there has been limited science-based advice available to support management of Jonah crab fisheries. The Jonah Crab Technical Committee (TC) met in August 2017 to review research projects and discuss data limitations. This review identified limitations on understanding of basic life history processes, but also identified several projects in progress that could help fill some information gaps in coming years. The TC met again in April 2020 and reviewed ongoing research as well as regular agency monitoring efforts. During this meeting, the TC recommended a more in-depth review of available data to better understand limitations and identify stock assessment approaches that could be supported with available data. Subsequently, the ASMFC American Lobster Management Board (Board) tasked the TC in August 2020 with conducting a pre-assessment workshop for Jonah crab and providing a report on available data and recommended assessment approaches. A series of webinars was held November 16-18, 2020, February 11, 2021, June 3, 2021, and June 29, 2021 to review and discuss available Jonah crab data sets, potential assessment approaches, and remaining data limitations. This report provides the TC's evaluation of the data sets, findings on potential approaches for a near-term stock assessment to provide management advice, and research recommendations to advance future stock assessments.

1.1 Brief Overview and History of the Fisheries

Until recently, Jonah crab were predominantly a bycatch species in the American lobster fishery—annual commercial Jonah crab landings were generally lower than 6 million pounds through 2000 (Figure 1). Since then, as the lobster fishery has declined in southern New England (SNE) and the market for crab has expanded, harvesters have pivoted to target Jonah crab in addition to (or instead of) lobster. A mixed crustacean fishery now exists in which fishers seasonally adjust their fishing strategies to target Jonah crab or lobster. Harvest pressure on Jonah crab has increased substantially over the past two decades, with landings increasing steadily since around 2000 (Figure 1). Total Jonah crab commercial catch in 2019 was 17.7 million pounds, with a total ex-vessel value exceeding $13 million.

The Jonah crab commercial fishery occurs predominantly in SNE. Most of the U.S. Jonah crab commercial catch is landed in Massachusetts (57.4%, 2017-2019 average) and Rhode Island (21.4%), and most harvest occurs offshore in NOAA Fisheries statistical areas (hereafter, statistical area) 537 (71.5%), 526 (10.5%), and 525 (9.9%) - hereafter, the core statistical areas. Most Jonah crab commercial landings are reported as having been caught in traps and pots (92.7%, 2012-2019), and most harvest that is not reported as trap-caught does not have a gear type reported (6.1% of total harvest). Less than 1% of the commercial harvest is reported as coming from trawls (0.2%) or dredges (0.1%).

Coastwide, commercial landings of Jonah crab are highest in the late autumn and winter months (October to February). In an interview study, fishermen indicated that this seasonal shift was driven by the lobster fishery—lobster are less abundant in winter, so harvesters transition to target Jonah crab during these months. Based on interviews with fifteen Jonah crab fishermen from Rhode Island and Massachusetts (Truesdale et al. 2019a), the number of traps set to target Jonah crab over lobster increased by 73% in the winter compared with the summer months. Fishing strategy adjustments made to transition between Jonah crab and lobster include escape vent modifications, bait type, and fishing location changes.

A small Jonah crab claw fishery operates in Delaware, Maryland, and Virginia, wherein the claws of large Jonah crabs are removed and the animal is returned to the ocean alive. Claw harvest comes mostly from lobster vessels fishing in Lobster Conservation Management Area (LCMA) 5 and accounts for less than 1% of the coastwide commercial landings.

There is no regulatory distinction between a lobster trap and a Jonah crab trap, and a vessel's target species can often not be determined from trip reports and dealer data. Because of the issue of identifying target species and because the Jonah crab fishery is recently developed and still evolving, Jonah crab fishing effort is not yet well characterized and there is little literature describing the seasonal dynamics, fishing strategies, and socioeconomic aspects of the fishery. Some anecdotal information has been summarized and may provide a starting point for analyzing and characterizing the fishery (Truesdale et al. 2019a), but quantifying fishing effort for Jonah crab versus lobster remains a data need for future assessments.

1.2 Management Unit Definition

The management unit for Jonah crab includes the U.S. Atlantic states from Maine through Virginia, though the biological range of the species extends from Newfoundland, Canada to Florida.

1.3 Regulatory History

The ASMFC coordinates the interstate management of Jonah crab in state waters (from 0-3 miles offshore). The ASMFC manages Jonah crab through the FMP, which was approved by the Board in August 2015 under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (1993). Management authority in the exclusive economic zone (EEZ), which extends from 3-200 miles offshore, lies with NOAA Fisheries. The FMP was initiated in response to concern about increasing targeted fishing pressure for Jonah crab, which has long been considered a bycatch species in the lobster fishery. The mixed nature of the fishery created a challenge for managing a Jonah crab fishery completely separate from the lobster fishery without impacting the number of vertical lines and traps in state and federal waters. Furthermore, a lack of universal permitting and reporting requirements made it difficult to characterize catch and effort to the full extent in order to manage the fishery.

The goal of the FMP is to promote conservation, reduce the possibility of recruitment failure, and allow for the full utilization of the resource by the industry. The FMP lays out specific management measures in the commercial fishery to limit effort and protect spawning stock biomass in the absence of a range-wide stock assessment. These include a 4.75" minimum size carapace width (CW) and a prohibition on the retention of egg-bearing females. To prevent the fishery from being open access, the FMP states that participation in the directed trap fishery is limited to lobster permit holders or those who can prove a history of crab-only pot fishing. All others must obtain an incidental permit. In the recreational fishery, the FMP sets a possession limit of 50 whole crabs per person per day and prohibits the retention of egg-bearing females. Due to the lack of data on the Jonah crab fishery, the FMP implements a fishery-dependent data collection program. The FMP also requires harvester and dealer reporting along with port and sea sampling.

Addendum I was approved by the Board in May 2016, and states were required to implement the management measures in Addendum I by January 1, 2017. Addendum I establishes a bycatch limit of 1,000 pounds of crab/trip for non-trap gear (e.g., otter trawls, gillnets) and non-lobster trap gear (e.g., fish, crab, and whelk pots). In doing so, the Addendum caps incidental landings of Jonah crab across all non-directed gear types with a uniform bycatch allowance. While the gear types in Addendum I make minimal contributions to total landings in the fishery, the 1,000 pound limit provides a cap to potential increases in effort and trap proliferation.

Addendum II was approved in January 2017, with associated measures required by January 1, 2018. Addendum II establishes a coastwide standard for claw harvest. Specifically, it permits Jonah crab fishermen to detach and harvest claws at sea, with a required minimum claw length (measured along the bottom of the claw, from the joint to the lower tip of the claw) of 2.75” if the volume of claws landed is greater than five gallons. Claw landings less than five gallons do not have to meet the minimum claw length standard. The Addendum also establishes a definition of bycatch in the Jonah crab fishery, whereby the total pounds of Jonah crab caught as bycatch must weigh less than the total amount of the targeted species at all times during a fishing trip. The intent of this definition is to address concerns regarding the expansion of a small-scale fishery under the bycatch limit.

In response to concerns regarding deficits in existing reporting requirements, the Board approved Addendum III in February 2018, which improves the collection of harvester and biological data in the Jonah crab fishery. Specifically, the Addendum improves the spatial resolution of harvester data collection by requiring fishermen to report via 10 minute squares. It also expands the required harvester reporting data elements to collect greater information on gear configurations and effort. In addition, the Addendum established a deadline that within five years, states are required to implement 100% harvester reporting, with the prioritization of electronic harvester reporting development during that time. Finally, the Addendum improves the biological sampling requirements by establishing a baseline of ten sampling trips/year, and encourages states with more than 10% of coastwide landings to conduct additional sampling trips. The provisions of Addendum III went into effect January 1, 2019, however, implementation of the requirement for commercial harvesters to report their fishing location by 10 minute longitudinal/latitudinal square was delayed until January 1, 2021.

Federal regulations complementing the majority of measures included in the FMP and Addenda I and II became effective on December 12, 2019. Commercial measures included requiring a federal lobster permit, a minimum CW, a prohibition on retaining egg-bearing females, incidental catch limits, and federal dealer permitting and reporting requirements. Recreational measures included a daily catch limit and a prohibition on retaining egg-bearing females. The Jonah crab claw-only fishery is not directly regulated in federal waters; harvesters must abide by state requirements.

1.4 Assessment History

The only stock assessments conducted for Jonah crab to date have been in Canadian Lobster Fishing Area (LFA) 41 where Jonah crab have been caught as directed catch starting in 1995. In response to the developing fishery, a total allowable catch (TAC) of 720 metric tons that was not based on scientific advice was implemented for the fishery. This TAC was fully or nearly caught in all seasons from the 1996-1997 fishing season through the 2000-2001 fishing season and was followed by a continuous decline in catch through the 2008 fishing season. Assessments were conducted in 2000 and, most recently, in 2009 (Fisheries and Oceans Canada 2009). These assessments provided empirical-based stock indicators developed from existing monitoring programs. Indicators included abundance indicators (fishery-independent indices of abundance, fishery CPUE, and total landings) and fishing pressure indicators (number of traps hauled and median size). Indicators were categorized as positive, neutral, or negative and used to provide qualitative characterizations of stock status. In the most recent assessment, all indicators were negative relative to the previous assessment time period (1995-1999), with the exception of median size. Abundance indicators from surrounding LFAs where directed Jonah crab fisheries had not developed indicated no clear abundance declines over the same time period. Although the assessment notes some uncertainty in the cause(s) of negative stock conditions, the results suggest the TAC was not sustainable and declines are due to fishing down the biomass from the start of the fishery.

2 LIFE HISTORY

2.1 Summary

Jonah crab range from Newfoundland to Florida (see Section 3 for more detail on habitat). Movements of mature Jonah crabs are generally limited (<5 km), particularly compared to the similar species Atlantic rock crab (*Cancer irroratus*; Stehlik et al. 1991), but some may travel over 100 km (Perry et al. 2019).

Maximum reported size is 222 mm CW for males (Pezzack et al. 2011) and 152 mm CW for females (Haefner 1977). Recent work using the gastric mill to age Jonah crab has shown promise, but the gastric mill is shed during ecdysis so it is unknown how an annulus could be formed. Using the gastric mill method, male Jonah crabs are estimated to reach minimum legal size (120.65 mm CW) at 4 to 7 years of age (Huntsberger 2019). Male crabs below 120 mm molted in June in southern New England (Truesdale et al. 2019b). Molt probability of male crabs decreases with increasing CW (Truesdale et al. 2019b). In a tagging study, some crabs had not molted when recaptured nearly three years after their initial capture (MA DMF unpublished data).

Male crabs have been estimated to reach morphometric maturity at 128 mm CW in Canada (Moriyasu et al. 2002), but all studies in U.S. waters (Carpenter 1978, Ordzie and Satchwill 1983, Perry et al. 2017, Lawrence 2020, Olsen and Stevens 2020) have shown that male and female crabs reach maturity below the current minimum legal size. Estimated size-at-maturity in U.S. waters ranges from 90 to 117 mm CW for male crabs (Table 1) and 40 to 94 mm CW for female crabs (Table 2).

In nearshore waters, Jonah crab prey upon polychaetes, mussels, snails, and other shellfish (Stehlik 1993 Donahue et al. 2009). Jonah crab are consumed by tautog, smooth dogfish, lobsters, cunner, cod, and gulls (Richards 1992, Donahue et al. 2009). Food habits data collected from the NOAA Fisheries Northeast Fisheries Science Center (NEFSC) trawl survey showed cod, longhorn sculpin, smooth dogfish, little skate and barndoor skate had the highest number of sampled stomachs containing Jonah crab (NEFSC unpublished data).

2.2 Recent Jonah Crab Life History Studies

2.2.1 Massachusetts Division of Marine Fisheries Tagging Study

The Massachusetts Division of Marine Fisheries (MA DMF), in collaboration with the Atlantic Offshore Lobstermen's Association (AOLA), New Hampshire Fish and Game (NH F&G), and Maine Department of Marine Resources (ME DMR), completed a Jonah crab tagging study in 2018 in which over 32,000 Jonah crabs were tagged across 12 different statistical areas. Two types of tags were used; a t-bar tag designed to stay with the crab through a molt, and a cinch tag that would be lost after a molt. Other data collected at the time of release included CW, sex, egg status, and cull status. Preliminary data suggests that most Jonah crab do not migrate far. Most of the recaptures (over 900 crabs) occurred within 5 km of where they were released, though six crabs traveled more than 100 km. None of the 25 crabs recaptured after more than 600 days had molted.

2.2.2 University of Maine Growth Study

A growth study including techniques for age determination was completed by Huntsberger (2019) for Jonah crabs from the Gulf of Maine (GOM). Three independent methods of age determination were compared: (1) length frequency analysis of crabs sampled periodically in wild nursery populations including young-of-year (YOY) crabs, (2) building a probabilistic growth model informed with data from a laboratory growth study, and (3) applying the method of direct gastric mill band counts from crabs collected in two contrasting temperature regimes along Maine's coast.

In summary, the length frequency analysis was conducted at a weekly scale with passive collectors in the water column during the late summer, a monthly scale collecting size frequency on 358 crabs with benthic suction sampling at four sites near the mouth of the Damariscotta River estuary, and a yearly scale using existing survey data from the American Lobster Settlement Index (ALSI) and Maine-New Hampshire trawl survey. These three methods provided size-at-age estimates for the first three year classes, clear size ranges for YOY (3.8-6.6 mm CW), and showed correlation between YOY and legal size crabs 4 to 6 years later (Figure 2).

For the laboratory growth study, 464 Jonah crabs from mid-coast between 3.1-143mm CW were monitored in captivity for up to two years. Overall, 172 individuals (40%) molted while in captivity. The data fields recorded were date and size at capture, weekly size, date of molt and new size, and date of mortality. No molts were observed in the winter and molting peaked in the late spring and early summer. Molt increment decreased with larger crabs, averaging between 12 and 40% of the pre-molt size. The data collected were used to build a probabilistic molt model estimating the growth of an individual male crab until it reached legal size. Modeled growth of 1,000 crabs highlighted variability in growth, as males reached minimum legal size at an estimated four to nine years of age. No growth data for mature females or males over 100 mm were collected.

2.2.3 Rhode Island Growth Study

From 2016 to 2017, a growth study was conducted by a University of Rhode Island (URI) graduate student in collaboration with the Rhode Island Department of Environmental Management Division of Marine Fisheries (RIDEM DMF). Molt increment data were collected from Jonah crabs observed in the laboratory, as well as from Jonah crabs that molted in commercial traps. These crabs were caught in statistical areas 539 and inshore 537. Regression analysis of growth-per-molt was conducted on 119 growth increments from females ranging in post-molt CW from 73 to 113 mm and 91 increments collected from males ranging between 97 and 149 mm (Truesdale et al. 2019b). Molting seasonality was also observed, and molt probabilities were estimated for male crabs via repeated sampling and laboratory observation. These observations indicated a discrete molting period in the summer for male Jonah crabs at the observed sizes, with decreasing molting probabilities as crabs increased in size. Female Jonah crabs were not consistently sampled because they were caught in commercial traps sporadically, so molting seasonality and molt probabilities could not be estimated for females.

2.2.4 Jonah Crab Maturity Studies

There have been three recent Jonah crab size-at-maturity studies conducted since the Jonah crab FMP was approved in 2015. These studies cover a wide area, from the mid-Atlantic to the GOM and expand upon previous research in the mid-Atlantic (Carpenter 1978), SNE (Ordzie and Satchwill 1983) and Nova Scotia (Moriyasu et al. 2002).

From 2015 to 2017, MA DMF, AOLA and the Commercial Fisheries Research Foundation (CFRF) partnered on a Jonah crab maturity study. Over 2,400 male and female crabs from five geographic areas (inshore SNE, offshore SNE, inshore GOM, offshore GOM, and Georges Bank (GB)) were analyzed for morphometric and gonadal maturity. Morphometric data collected included sex, CW, body depth, and chelae dimensions (height, length, and depth). Additionally, width of abdominal (“apron”) segments, egg clutch presence/absence, and presence/absence of a sperm plug in female vulva were recorded for female crabs.

Crabs were collected opportunistically throughout the year. For gonadal analysis, seasons were defined as: January-March (winter), April-June (spring), July-September (summer), and October-December (fall). Male (testes and vas deferens combined) and female (ovaries) gonads were classified based on relative gonad size and color, similar to Haefner (1977) but instead of comparing the size of the gonad to the size of the hepatopancreas, the area of the gonad was compared to the area within the perimeter of the carapace. Male gonad color was classified as white (indicative of the presence of sperm) or clear/undetectable gonads. Female ovaries were classified as orange, peach, tan, or clear/undetectable gonads.

Male crabs reached morphometric maturity between 103 to 117 mm CW depending on region. The size at 50% morphometric maturity could not be detected in inshore SNE. The size at 50% gonadal maturity also could not be estimated due to the paucity of physiologically immature male crabs in all regions. SNE and GB female crabs reached 50% morphometric maturity at 88 and 94 mm CW, respectively. Morphometric maturity could not be estimated in other regions. The size at which 50% of female crabs reached gonadal maturity varied by region from as little as 86 mm CW (inshore SNE), to as much as 98 mm CW (offshore GOM).

Olsen and Stevens (2020) conducted a maturity study in the Middle Atlantic Bight, collecting samples from 2015 to 2017. Morphometric data was collected on carapace length, CW, spine width, abdomen width, chela length, chela height, and chelae weight. Morphometric size-at-maturity for male crabs (n=562) was determined to be 98.3 mm CW, and 88.2 mm CW for females (n=798). Crabs with claws at the minimum legal size for the claw-only fishery (69.85 mm in claw length) were predicted to be 126 mm CW and 150 mm CW for males and females, respectively.

Lawrence (2020) studied physiological and morphometric maturity in male Jonah crab from SNE. The estimated size at morphometric maturity was 106 mm CW.

3 HABITAT DESCRIPTION

Jonah crabs can be found from Newfoundland to Florida at depths ranging from the intertidal to 800m but are most abundant in the northern latitudes (Pezzack et al. 2011, Haefner 1977, Stehlik et al. 1991). Limited specific information is available for the distribution as depth, season, habitat, and temperature affect the abundance of Jonah crabs (Stehlik et al. 1991, Carpenter 1978, Haefner 1977, Krouse 1980). The highest abundance of Jonah crabs are found in water temperatures of 6-14^{o}C (Stehlik et al. 1991, Haefner 1977, Krouse 1980, Pezzack et al. 2011). Krouse (1980) suggests Jonah crabs have a narrower temperature range tolerance than *Cancer irroratus* and may stay further offshore to attain more stable bottom temperatures. At the southern end of their range, Jonah crab prefer greater depths (Jeffries 1966). In the Mid Atlantic Bight, Haefner (1977) provides evidence for an increase in size as depth increases while Carpenter (1978) suggests relative abundances of distinct size groups can be found at different depths depending on the time of year. Carpenter (1978) found female Jonah crabs are more abundant at depths less than 150m while the males are in deeper water.

Historic offshore trawl surveys and recent interviews with SNE fishermen found the highest abundance of Jonah crabs in silty sand and flat muddy habitats (Haefner 1977, Stehlik et al. 1991, Truesdale et al. 2019a), but studies, mostly in the GOM based on inshore SCUBA work, trapping, and video survey, found Jonah crabs associated with more complex cobble, boulder, and sand substrate (Jeffries 1966, Krouse 1980, Richards 1992, Palma et al. 1999, Reardon 2006). YOY and juvenile Jonah crabs are found in relatively high numbers during the settlement surveys (Section 5.2) in the surveyed cobble habitat. Whether offshore areas provide important settlement or nursery habitat is poorly understood. The discrepancy of observed crab habitat could be due to lower catchability of crabs by trawl surveys and commercial pot gear in complex habitat, difference of primary substrate type by life stage, or correlation of substrate with depth.

4 FISHERY DEPENDENT DATA SOURCES

4.1 Commercial

4.1.1 Landings Data Collection and Treatment

4.1.1.1 Maine

A Lobster and Crab Fishing License is required to commercially harvest Jonah crab in Maine, and it has historically been a bycatch species of the lobster fishery. A permit endorsement is also available for the drag fishery, which allows a limit of 200 pounds per day and 500 pounds of Jonah crab per trip. Traps are subject to the lobster rules including maximum size, escape vents, and trap tags. There is a recent prohibition of claw harvest, except for a personal use exemption of a 5-gallon bucket maximum. While the market has always dictated a male-only fishery, the recent FMP provided the guidelines for regulations on size of greater than 4.75 inches.

Misidentification of Jonah crab creates challenges in the landings data because both *Cancer irroratus* (Atlantic rock crab) and *Cancer borealis* (Jonah crab) are harvested as bycatch and have an identical common name of "rock crab". Historically, crab landings were reported on a monthly basis, but were not mandatory until 2004 and were not linked to state harvester identification numbers in the CFDERS database. In 2006, Maine shifted to using the Atlantic Coastal Cooperative Statistics Program's (ACCSP) Standard Atlantic Fisheries Information System (SAFIS) and Maine's MARVIN database for monthly mandatory reporting of landings with associated harvester identification numbers that add accountability. In 2008, the mandatory reporting was required on a trip and species level, yet there are still "Crab unclassified" landings in 2020, albeit much reduced as compared to prior to 2008.

Both *Cancer* crab species were considered lower value species compared to lobster and were commonly sold for cash prior to reporting requirements; as such, landings prior to (and potentially after) 2008 should be considered an underestimate. Of the reported landings, ME DMR expects most reported volume and market demand has been for Jonah crab as opposed to Atlantic rock crab, so it is expected that historical and recent landings trends for Jonah crab should include most of the "crab unclassified" and "rock crab" landings. It may be possible to use a price threshold of $0.35 to identify the likely Jonah crab landings, but there is uncertainty on this threshold, especially earlier in the time series.

4.1.1.2 New Hampshire

New Hampshire lobster and crab harvesters have been reporting annual landings from state waters since 1969 to the NH F&G, but only reporting of lobster landings was mandatory prior to 2016. While Jonah crab catch and effort was not mandatory during this period, harvesters were provided the opportunity to report crab bycatch at the monthly level. In 2016, with the adoption of the Jonah crab FMP, New Hampshire implemented mandatory Jonah crab harvest reporting on both monthly-summary and trip-level reports. Only commercial harvest by state lobster and crab license holders is included.

Historically, the quantity of lobsters and crabs landed in New Hampshire harvested from federal waters was derived from a combination of the NOAA Fisheries weighout and canvas database and federal vessel trip reports (VTRs). Currently, NOAA Fisheries has mandatory reporting of harvest data for the majority of federally permitted vessels that land in New Hampshire through VTRs.

In cooperation with NOAA Fisheries, New Hampshire instituted mandatory lobster dealer reporting in 2005 and began collecting all data required under ACCSP standardized data submission standards. New Hampshire lobster dealers report transaction-level data on a monthly basis through use of paper logbooks or directly through electronic dealer reports (EDR). Dealers report all species harvested and both state and federal dealers have been able to report Jonah crab since implementation. Jonah crab landings in New Hampshire have been reported by dealers since 1994.

Total monthly landings from dealer reports, catch data from federal VTRs, and catch data from state logbooks are available for use for stock assessment purposes. In order to assign areas to the dealer report records and calculate effort estimates, VTRs and state logbooks may be used to identify statistical areas and effort values as dealer reports do not contain area and effort data.

4.1.1.3 Massachusetts

Participation in the Massachusetts Jonah crab fishery has been limited to those that hold a commercial lobster/edible crab permit since 1948. Reporting of landings through Massachusetts trip level reports (MATLR) or NOAA Fisheries VTRs has been mandatory since 2010. On MATLR, fishermen are asked to report location of catch, gear type, amount of gear, soak time, number of trawls, and quantity landed.

Most Jonah crab landed in Massachusetts are caught in federal waters and reported on NOAA Fisheries VTRs. A small number of boats targeting Jonah crab are usually responsible for a large portion of the state Jonah crab landings, but there are numerous fishery participants targeting lobster that land smaller amounts of Jonah crab. Landings are generally in pounds, but occasionally bushels of crabs are reported. In these cases, the number of bushels is multiplied by 65. The landing of anything other than whole crabs is prohibited. There is speculation that landings may have been under-reported prior to 2010, as Jonah crab was considered a low value species and some catch may have been sold for cash at the dock.

4.1.1.4 Rhode Island

Before 2003, commercial landings in Rhode Island are derived using NOAA Fisheries' data collection methods. Beginning in 2003, 100% electronic dealer reporting was implemented in Rhode Island through the Rhode Island Fisheries Information System, the predecessor of the SAFIS. It took a period of about three years to develop consistency in reporting among all dealers with the new trip-level system but from 2006 on, electronic dealer reports are believed to be a fully reliable source of information on Jonah crab landings. It is unknown to what degree

Jonah crab and Atlantic rock crab have been confused in commercial landings for Rhode Island. However, based on discussions with fishers who have landed Jonah crab for a period of decades, this is not expected to be a significant issue for the Rhode Island fishery.

4.1.1.5 Connecticut

Landings are recorded in the NOAA Fisheries weighout and general canvas database as landings at state ports. Connecticut also records landings by licensed commercial fishermen in any port (inside or outside Connecticut) by means of a mandatory logbook system that provides catch and effort information from 1979 to the present. This mandatory monthly logbook system provides detailed daily catch data by species, area, and gear as well as port landed, traps hauled, set over days, and hours trawled (for draggers). The logbook provides a means to look at fundamental changes in the operating characteristics of the lobster fishery within Long Island Sound. Since 1995, the program has required fishermen to report information on the sale and disposition of the catch, including the state or federal permit number of the dealer to whom they sold their catch. Seafood dealers are also required to report all of their individual purchases from commercial fishermen using either the NOAA form Purchases from Fishing Vessels, a Connecticut Seafood Dealer Report, Abbreviated Form for Lobster Transactions Only, or through the ACCSP's SAFIS. A quality assurance program has been established to verify the accuracy of reported statistics through law enforcement coverage and electronic crosschecking of harvester catch reports and seafood dealer reports.

4.1.1.6 New York

The commercial harvesting of Jonah crab requires a New York commercial crab permit. The crab permit has been limited entry since 6/29/1999. The limited entry stipulates that no new permits are issued, but a certain percentage of forfeited permits from the previous year are made available the following year. The limited entry permit resulted in an overall decrease in permits over time. Permit holders have until December 30th and may renew anytime during the calendar year.

New York's commercial fishery harvest data has been collected through state and federal VTRs since 2012 for food fish, lobster, and crab commercial permits. State VTR data is entered by staff into the New York Fishery Information on Sales and Harvest (NYFISH) database or entered directly by fishermen into the ACCSP's eTrips online database. New York landings reported through federal VTRs are entered by federal staff and shared with New York on a weekly basis in order to provide timely and accurate landings estimates. Landings data are reported by statistical area.

4.1.1.7 New Jersey

The commercial harvest of Jonah Crab within state waters of New Jersey does not occur, therefore is not collected. New Jersey reported landings are obtained from NOAA Fisheries.

4.1.1.8 Delaware

The commercial harvest of Jonah Crab requires either a Directed Jonah Crab Landing Permit issued to those who hold a valid Delaware Commercial Lobster Pot License or federal lobster permit, or an Incidental Jonah Crab Landing Permit issued by the Delaware Department of Natural Resources and Environmental Control. Delaware's commercial landings are collected through state logbooks. State logbook data is entered into a state-owned database and uploaded annually to the ACCSP data warehouse. Logbooks report daily catch and are required to be submitted on a monthly basis.

4.1.1.9 Maryland

Maryland is a *de minimis* state and all Jonah crab landings are caught in federal waters and reported on NOAA Fisheries VTRs and through SAFIS. There is no directed fishery toward Jonah crab and landings are predominately claws. A small fleet of commercial fishing vessels targeting lobster harvest Jonah crab, predominately in LCMA 5, statistical area 626. In addition to the required federal lobster permit, the Maryland Jonah crab permit is required. The Maryland limited entry Jonah crab claw permit was eliminated by Addendum II (2017).

4.1.1.10 Virginia

Virginia data are collected via required monthly reporting by harvesters. The majority of landings are from a single harvester and all landings are confidential.

4.1.2 Biological Sampling Methods

4.1.2.1 NOAA Fisheries

Sea Sampling

The Northeast Fisheries Observer Program (NEFOP) has collected data from vessels engaged in the lobster fishery, including the associated Jonah crab fishery, as funding allows since 1991. Because there is no mandate under the Standardized Bycatch Reporting Methodology (SBRM) to monitor the federal lobster and Jonah crab fishery to support the management of these fisheries, the number of NEFOP sea days are allocated based on the needs to monitor bycatch of species included in SBRM, including groundfish. Thus, sampling intensity is inconsistent and varies across years. In recent years, NEFOP observer coverage peaked at 60 sea days in 2015 but coverage has since dropped to about 4 sea days per year. Data collected by NEFOP observers include CW (mm), sex, presence of eggs, kept and discarded catch weights, bycatch data (including finfish lengths and weights), gear and bait characteristics, haul locations, water depth, trip costs, and incidental takes.

Port Sampling

The NOAA Fisheries Greater Atlantic Regional Fisheries Office initiated a port sampling program for the targeted Jonah crab fishery in 2021. Annual sample requests are stratified by region, stock area, gear type, and calendar quarter and are allocated to focus on the regions where most of the Jonah crab fishery occurs and be complementary to spatial coverage of port and sea sampling by state agencies. Port samplers select vessels for sampling based on current and historical landings data, real-time vessel tracking, and local knowledge of the fisheries. NOAA Fisheries anticipates collecting 74 port samples per year with a standard sample consisting of 40 CW measurements with gender.

4.1.2.2 Commercial Fisheries Research Foundation

Sea Sampling

CFRF has conducted a fishery-dependent Jonah crab data collection project since 2014, and provided 2014-2019 data for the data workshop. As of November 2020, the Research Fleet has sampled over 92,900 Jonah crabs. The CFRF project has involved 25 vessels over the time series and offered coverage of inshore and offshore SNE, GB, and offshore GOM. Typically, three sampling sessions are conducted per month from fishermen's regular commercial catch. A sampling session consists of sampling catch from a trawl starting with the first trap hauled until 20 traps have been sampled or 50 crabs have been sampled, whichever comes first. For sampling the regular catch, fishermen decide which day(s) sampling sessions are conducted, but the trawl(s) sampled on those days is selected at random. Data collected include vessel ID, date, time, location, depth (feet), sex, CW (mm), egg-bearing status, shell hardness, and disposition (kept or discarded). Data are collected on Samsung tablets using CFRF's On Deck Data application and periodically uploaded to a database at CFRF where they are QA/QC'd and provided to ACCSP.

In addition to regular commercial trap (i.e., vented) sampling, each vessel is given three ventless traps to use during the course of this project. To maintain general consistency with most configuration specifications of other ventless trap sampling programs in Rhode Island, Massachusetts, New Hampshire, and Maine, the Lobster and Jonah Crab Research Fleet deploys ventless traps with the following configurations: 40" length x 21" width x 14" height, single parlor, 1" square rubber-coated 12-guage wire, standard mesh netting, cement runners, and a 4" x 6" disabling door. One ventless trap is deployed at a fixed temperature monitoring station, and the others are deployed as the lobstermen see fit. Ventless trap sampling is not associated with commercial trap sampling, and thus is recorded in a different sampling session. CFRF encourages fishing vessels to record at least one ventless Jonah crab sampling session per month at the bottom temperature monitoring site. Only data from the regular catch samples should be used to characterize the commercial catch size and sex composition since ventless trap catch is not representative of the regular commercial catch.

4.1.2.3 Maine

Sea Sampling

ME DMR does not have a formal Jonah crab sea sampling program as it has been considered a low value species as compared to lobster and is not a target species for the Maine fishery. Some research trips were completed in 2003 and 2004 when the ME DMR was exploring experimental Jonah crab traps that would exclude lobsters yet catch Jonah crab. Those trips included subsampled biological data from both the experimental traps and standard commercial lobster traps. Since 2017, the Lobster Sea Sampling program includes an opportunistic protocol to collect Jonah crab data if they are harvested for commercial sale and the sampler has the capacity to do so. If crabs are sampled, the protocol includes collecting biological data including CW, sex, reproductive status, cull status, and shell hardness. In the future, a standardized subsampling protocol will be developed. ME DMR proposes only using data from trips with more than 20 crabs measured.

4.1.2.4 New Hampshire

Sea Sampling

Jonah crabs have been sampled by NH F&G as bycatch on lobster sea sampling trips since 2015. Samples are collected monthly from May through November at two different locations: the Isles of Shoals, and the coast (Portsmouth harbor to Massachusetts Border). Bycatch is sampled on all observed hauls (50% or more of the total hauls for the day). Data collected on Jonah crabs include sex, CW, shell condition, and cull status. Bycatch data are entered into an Access Database along with the coordinates of the trawl, number of set days, bait type, and water depth. Between 2015 and 2019 a total of 529 Jonah crabs have been sampled on 47 sea sampling trips (Table 3). The overall average CW was 97.2 mm.

Port Sampling

NH F&G has conducted Jonah crab port sampling at local dealers on the New Hampshire coast since 2016. Initially, samples were collected from commercial lobster boats harvesting from several different statistical areas throughout the GOM and GB. More recently, due to a lack of fishing effort in some of the statistical areas farther offshore, samples have been obtained from dealers who purchase crabs from vessels fishing in statistical area 513, which includes both state and federal waters. Biological data (CW, sex, molt stage, shell disease, and cull status) are collected on the landed catch, and information is obtained from the dealer to determine total catch and effort where available. Table 4 provides a summary of number of samples collected per year and quarter.

4.1.2.5 Massachusetts

Sea Sampling

MA DMF does not have a formal Jonah crab sea sampling program because roughly 99% of Massachusetts landings come from federal waters, though some samples have been collected opportunistically. Jonah crab sea sampling data were collected during directed lobster trips in Cape Cod Bay (southern statistical area 514) from 2016 to 2018, and during a Jonah crab tagging project in statistical areas 537, 526, 525 from 2016 to 2017. Target species (lobster or Jonah crab) varied during the Jonah crab tagging project trips. Samplers recorded CW (nearest mm), sex, cull status, mortalities, and presence of extruded eggs. Catch was separated by trap. The start of each trawl was recorded using a handheld GPS. The percent cover of shell disease (black spotting) was characterized in 2017 and 2018.

Port Sampling

MA DMF began a Jonah crab port sampling program in the fall of 2013. Sampling intensity was low during 2013 (2 trips) and 2014 (4 trips). A minimum of 10 trips have been conducted annually since 2015. Vessels sampled in 2013 and 2014 were vessels which had previously participated with MA DMF on cooperative research projects. Starting in 2015, vessels and dealers with the most state landings were targeted for sampling. The vast majority of the sampled catch is from statistical areas 537 and 526. Statistical areas 525, 562, and 514 have been sampled with less regularity. A minimum of five crates or the entire catch, whichever is less, is sampled per trip. Data collected include: CW (mm), sex, and cull status. Shell disease and mortalities have been recorded since 2017.

4.1.2.6 Rhode Island

Sea Sampling

Rhode Island does not currently have a sea sampling program for Jonah crab as funds are not available for this purpose. In 2016 and 2017, 12 sea sampling trips did occur which were part of a URI research project. These trips occurred in inshore statistical areas 539 and 537 (Table 5). Data collected include number of traps per trawl, soak time, bait, bottom type, depth, trap location (latitude/longitude), and trap configuration. From each sampled trawl, effort was made to sample all captured Jonah crabs—whenever this was not feasible, a systematic random sampling frame was used to census every second or third trap in a trawl. The following data were recorded for each sampled crab: CW, sex, ovigerous condition, shell disease level, molt condition, and number of claws missing.

Port Sampling

The RIDEM DMF initiated Jonah crab port sampling efforts in 2015; four trips were sampled during the initial year, before staffing and funding limitations placed this program on hold until 2019 (Table 6). Since the resumption of the program in late 2019, RIDEM DMF has strived to conduct ten port sampling trips for Jonah crabs per year. Most port samples have come from fishing trips taking place in offshore statistical areas 525 and 526. Port samplers reach out to captains and owners of offshore fishing vessels and coordinate with these parties to intercept a portion of their catch before it is offloaded to seafood transporters and dealers. At the trip level, samplers collect information from vessel captains on fishing area, bait, soak type, bottom type in fishing area, number of traps set, and average depth. Biological data are collected from a minimum of two totes of Jonah crab per port sample (about 200 crabs). Collected biological variables include CW, sex, shell disease level, molt condition, and cull status (number of claws missing).

4.1.2.7 New York

Sea Sampling

New York State Department of Environmental Conservation (NYDEC) sea sampling data are collected on cooperating commercial vessels in Long Island Sound (statistical area 611) and the Atlantic Ocean side of Long Island (statistical areas 612 and 613). However, Jonah crab were not included in the program until 2017, after the ASMFC Jonah crab FMP was adopted, and no Jonah crab have been sampled during the program. Much of the sea sample effort has been in statistical area 611, where few Jonah crab reside.

Port Sampling

A port sampling program began in 2005. The main objective of the program is to enhance the collection of biological data from lobsters harvested from LCMAs 3, 4 and 5. A communication network was developed with cooperating dealers and fishermen who fish these areas. This network is contacted to identify days and times of vessel landings to provide sampling opportunities. Utilizing this network of contacts allows for the sampling of lobster fishing trips landed in New York from the appropriate LCMAs. Sampling protocol adheres to the standards and procedures established in NOAA Fisheries Fishery Statistics Office Biological Sampling Manual. This program was expanded to collect data from LCMA 6 starting in 2013. Limited

Jonah crab sampling was conducted in 2014 and directed sampling was initiated in 2017. Jonah crab have only been sampled during market sampling.

4.1.2.8 Maryland

Sea Sampling

Maryland is a *de minimis* state and does not currently have a sea sampling program for Jonah crab, as funds are not available and there is no requirement to do so. However, state biologists have conducted sea sampling in previous years aboard federally permitted lobster fishing vessels in Ocean City, Maryland. Sampling occurred during calendar years 2015, 2016, 2018 and 2019 with 315 randomly selected Jonah crab caught in lobster pots from LCMA 5 (statistical area 626) sampled for CW and sex. Biologists will attempt to randomly measure Jonah crab during lobster sea sampling with the goal of 100 crabs per multiday trip.

4.1.3 Trends

4.1.3.1 Commercial Landings

Coastwide Jonah crab landings were queried from the ACCSP Data Warehouse and validated for accuracy with state partners. Landings were low in the early 1980s, increased in the mid-1980s, and became relatively stable through the mid-1990s, averaging 4.5 million pounds per year from 1984-1995 (Table 7, Figure 3). Landings have increased steadily since the mid-1990s, with a maximum of 22.6 million pounds landed in 2018. Massachusetts, Rhode Island, and Maine were the top contributors to landings during this increasing trend, averaging 5.4, 2.3, and 3.6 million pounds per year from 1996-2019, respectively. However, these states have had different trends in landings over this period. Massachusetts and Rhode Island landings have followed an increasing trend similar to the total coastwide landings, while Maine landings increased sharply in the early 2000s and then declined through the early 2010s before increasing in the most recent years. Since 2006, Massachusetts, Rhode Island, and Maine annual landings have averaged 8.0, 3.6, and 2.9 million pounds, respectively. Pots and traps have accounted for the vast majority (>90%) of Jonah crab landings.

In addition to total annual landings, seasonality (quarter) and spatial (statistical area) data were also queried. These data have yet to be validated by state partners and may require the development of a process to gap-fill data by pairing seasonality and spatial data from harvester reports to total landings from dealer reports. These data are important for understanding the temporal and spatial dynamics of the fishery and for improving resolution of characterizing biological attributes (size, sex, egg-bearing status) of the landings with paired biosampling data. Seasonality data are widely available for the bulk of landings since 1990 (Figure 4). Spatial data are well represented for Jonah crab harvest since 2004 (Figure 5).

4.1.3.2 Commercial Biosampling

Commercial biosample data were submitted to the ACCSP Data Warehouse and a coastwide data set was queried. Sea sampling is useful to characterize the biological attributes of the total Jonah crab catch including discarded Jonah crabs. Port or market sampling is useful to characterize the biological attributes of the landed Jonah crab catch. The coastwide data set included all biosamples except NOAA Fisheries port sampling and NH F&G sea sampling which were not available for upload to the ACCSP Data Warehouse.

Biosampling trips are treated as sampling replicates. Only NOAA Fisheries sea sampling data had unique trip identifiers, so all other biosampling data were assigned a trip identifier based on a unique combination of agency, type (sea vs. port sample), date, port landed, and statistical area.

The number of sampling trips conducted by year and statistical area are in Table 8. The core statistical areas reflect the greatest sampling intensity, in addition to the inshore statistical area 539. Table 9 shows a finer breakdown of sampling in the core statistical areas including the number of trips by type. Sampling intensity, particularly sea sampling, tends to improve through time and shows a gradient in intensity with the highest intensity inshore (statistical area 537) and the lowest intensity offshore (statistical area 525). This gradient of sampling intensity matches the gradient in landings by statistical area.

Sea sampling data indicate larger average sizes of males encountered by the fishery (Figure 6 and Figure 7) and a smaller average size of both sexes caught in the inshore statistical area 539 (Figure 6). There do not appear to be any discernible trends in mean size of the catch in the core statistical areas during the short time series (Figure 7). Port sampling data show larger average sizes of Jonah crabs retained for sale in most cases (Figure 8), indicating selectivity of the fishery even prior to the implementation of a minimum size in the FMP (June 1, 2016).

Available Jonah crab maturity data are in Table 10. There has not been an effort to standardize Jonah crab maturity codes across agencies for use in stock assessment and this is recommended at the beginning of the stock assessment when it occurs.

4.1.4 Commercial Discards/Bycatch

4.1.4.1 NOAA Fisheries

Discard information from 2005-2019 is available from data collected during the NEFOP. Due to confidentiality issues, data were grouped in 5 year increments and by statistical area. Gears were grouped into the following categories:

- TRAPS:
    - POTS + TRAPS,OTHER/NK SPECIES
    - POTS + TRAPS,FISH
    - POTS + TRAPS,CONCH
    - POTS + TRAPS, HAGFISH
    - POTS + TRAPS,SHRIMP
    - POT/TRAP, LOBSTER OFFSH NK
    - POT/TRAP, LOBSTER OFFSH WD/WR
    - POT/TRAP, LOBSTER OFFSH PLASTIC

- POT/TRAP, LOBSTER INSH NK
  - POTS + TRAPS,CRAB OTHER
- BOTTOM TRAWL:
  - TRAWL,OTTER,BOTTOM,FISH
  - TRAWL,OTTER,BOTTOM,CRAB
  - TRAWL,OTTER,BOTTOM,SCALLOP
  - TRAWL,OTTER,BOTTOM,TWIN
  - TRAWL,OTTER,BOTTOM,RUHLE
  - TRAWL,OTTER,BOTTOM PAIRED
  - TRAWL,OTTER,BOTTOM,HADDOCK SEPARATOR
  - TRAWL,OTTER,BOTTOM,SHRIMP
- OTHER: all other gears

Figure 9 - Figure 11 summarize the amount of discards (pounds) and the discard rate (discard/$kept_{all}$ for those combined observed trips) by gear category. In general, discards of Jonah crabs have increased over the time series, with clearer trends in trawl and other gear. This is expected, as trap fisheries have not received substantial observer coverage until more recent years.

No overall discard rate could be estimated due to the lack of VTR data in the lobster/crab trap fishery.

4.1.4.2 New Hampshire

Commercial discards of Jonah crab have not been required on New Hampshire state lobster and crab reports, but have been reported as required by harvesters landing catch in NH with a Federal VTR reporting requirement. Discarded pounds of Jonah crab by gear type are included for 2004 to the present from Federal VTRs (Table 11). The overwhelming majority of discards occur in the pot and trap fisheries. Other fisheries represent infrequent and minimal discards.

4.1.4.3 Rhode Island

The RIDEM DMF does not have consistent records of Jonah crab discards in its commercial fisheries. Catch rates of sublegal and culled Jonah crabs may be estimated using the limited sea sampling data available from 2016 and 2017 by isolating measured crabs that fall below the minimum size and crabs missing both claws.

4.2 Recreational

4.2.1 Catch Data Collection and Treatment

4.2.1.1 New Hampshire

Recreational lobster and crab fishing in New Hampshire represents those harvesters that fish with five or fewer traps with no sale of harvested lobsters allowed. Recreational catch and effort data have been collected in the same manner as the commercial harvest for state landings.

Any recreational harvester may elect to use the ACCSP's eTrips electronic reporting program to report trip-level data on a monthly basis. In 2016 with the adoption of a Jonah crab FMP, New Hampshire implemented mandatory Jonah crab harvest reporting on both monthly-summary and trip-level reports. Recreational Jonah crab harvest is included in Table 12.

4.2.1.2 Massachusetts

Massachusetts issues a recreational lobster/edible crab license that allows the permit holder to harvest lobster and edible crabs using 10 traps, SCUBA gear, or a combination of both. There are daily limits of 15 lobsters, 50 *Cancer* crabs (Jonah and Atlantic rock crabs combined count), and 25 blue crabs. While recreational lobster data has been collected during the permit renewal process since 1971, MA DMF has only begun to collect recreational harvest data for Jonah crab in 2018. Harvesters renewing a recreational lobster/edible crab permit are now asked how many Jonah crabs they harvested in the previous year and how many traps they used. Respondents are also asked where most of their harvest effort was located.

The only year for which data is currently available is 2018 when recreational harvesters reported retaining 10,001 Jonah crab.

4.2.1.3 Rhode Island

The recreational Jonah crab fishery in Rhode Island is open year-round with a possession limit of fifty (50) whole Jonah crabs per person per day. While recreational harvest of Jonah crab is not reported in Rhode Island, this is believed to be minimal in comparison with the magnitude of commercial harvest.

5 FISHERY INDEPENDENT DATA SOURCES

Details are provided in this section for surveys that were identified as having potential utility for providing indices of abundance for a near-term stock assessment. Additional surveys considered that were identified as having limited utility are included in Table 13 and Table 14.

5.1 Post-Settlement Surveys

5.1.1 NEFSC Trawl Survey

The NEFSC bottom trawl survey began collecting Jonah crab data in 1979. The spring survey is generally conducted from March to May and the fall survey is generally conducted in September and October.

The NEFSC bottom trawl survey utilizes a stratified random sampling design that provides estimates of sampling error or variance. The study area, which now extends from the Scotian Shelf to Cape Hatteras including the GOM and GB, is stratified by depth. The stratum depth limits are < 9 m, 9-18 m, >18-27 m, >27-55 m, >55-110 m, >110-185 m, and >185-365 m. Stations are randomly selected within strata with the number of stations in the stratum being proportional to stratum area. The total survey area is 2,232,392 km^2. Approximately 320 hauls are made per survey, equivalent to one station roughly every 885 km^2.

Most survey cruises prior to 2008 were conducted using the NOAA ship R/V Albatross IV, a 57 m long stern trawler. However, some cruises were made on the 47 m stern trawler NOAA ship R/V Delaware II. On most spring and fall survey cruises, a standard, roller rigged #36 Yankee otter trawl was used. The standardized #36 Yankee trawls are rigged for hard-bottom with wire foot rope and 0.5 m roller gear. All trawls were lined with a 1.25 cm stretched mesh liner. BMV oval doors were used on all surveys until 1985 when a change to polyvalent doors was made (catch rates are adjusted for this change). Trawl hauls are made for 30 minutes at a vessel speed of 3.5 knots measured relative to the bottom (as opposed to measured through the water).

Beginning in 2009, the spring and fall trawl surveys were conducted from the NOAA ship R/V Henry B. Bigelow; a new, 63 m long research vessel. The standard Bigelow survey bottom trawl is a 3-bridle, 4-seam trawl rigged with a rockhopper sweep. This trawl utilizes 37 m long bridles and 2.2 m^2, 550 kg Poly-Ice Oval trawl doors. The cod-end is lined with a 2.54 cm stretched mesh liner. The rockhopper discs are 40.64 cm diameter in the center section and 35.56 cm in each wing section. Standard trawl hauls are made for 20 minutes on-bottom duration at a vessel speed over ground of 3.0 kts. Paired tow calibration studies were carried out during 2008 to allow for calibration between the R/V Bigelow and R/V Albatross IV and their net types. However, calibrations have not been estimated for Jonah crab. Thus, it is appropriate to treat this survey as separate time series since 2009 until a calibration can be produced.

Regional indices (Figure 12 and Figure 13) were calculated from strata in SNE, GB, GOM, and a region identified as covering the core statistical areas of Jonah crab landings which includes both SNE and GB strata (Core). Spring indices for the SNE and Core regions tend to vary without trend, while GOM and GB indices increase after ≈2000. There is a more consistent increase among regions after ≈2000 in the fall indices.

5.1.2 Maine/New Hampshire Trawl Survey

The ME/NH Inshore Trawl Survey began in 2000 to fill a significant information gap in resource assessment surveys on approximately two-thirds of the inshore portion of the GOM. The survey is conducted in collaboration with NH F&G and its industry partner, Robert Michael, Inc. Conducted biannually, spring and fall, the survey operates on a random stratified sampling design. A goal of 120 survey stations are sampled in 20 strata that are distributed over four depths: 5-20 fathoms, 21-35 fathoms, 36-55 fathoms, and >56 fathoms roughly bounded by the 12-mile limit in five longitudinal regions (Figure 14). The survey samples a portion of 3 statistical areas, 513, 512, and 511. Jonah crab biological data were not fully collected until 2004.

Seasonal indices of abundance both show declines starting in the late 2000s followed by increases to time series highs around 2015 (Table 15; Figure 15 and Figure 16). These increases were short lived, declining to lower levels in the last few years of the time series. Mean CVs for seasonal indices are 0.41 and 0.33 for the spring and fall, respectively (Table 15).

5.1.3 MA DMF Resource Assessment Program Trawl Survey

Since 1978, the MA DMF Resource Assessment Program has conducted an annual spring (May) and fall (September) bottom trawl survey within state territorial waters. The survey obtains fishery-independent data on the distribution, relative abundance and size composition of finfish and select invertebrates, including Jonah crab. A random stratified sampling design is used to select stations from five bio-geographic regions and six depth zones (Figure 17). Stations are selected before each survey and drawn proportional to the area each stratum occupies within the survey area. A minimum of two stations are drawn per stratum. Stations chosen in un-towable locations are redrawn.

The F/V Frances Elizabeth conducted all surveys through fall 1981. All subsequent surveys have been conducted onboard the NOAA ship R/V Gloria Michelle. A 3/4 size North Atlantic type two seam otter trawl (11.9 m headrope/15.5 m footrope) with a 7.6 cm rubber disc sweep; 19.2 m, 9.5 mm chain bottom legs; 18.3 m, 9.5 mm wire top legs; and 1.8 x 1.0 m, and 147 kg wooden trawl doors have been used for the duration of the survey. A 6.4 mm knotless liner is used in the codend to retain small organisms. Standard tows are 20 minutes but tows of at least 13 minutes are accepted as valid and expanded to the 20 minute standard. Tows are conducted during daylight hours at a tow speed of 2.5 kts. More information on the MA DMF trawl survey can be found by visiting https://www.mass.gov/files/documents/2016/08/tm/tr-38.pdf.

Jonah crabs have been weighed collectively for each tow to the nearest 0.1 kg since 1978, and by sex since 1981. From 1978 through 2009, Jonah crab CW measurements were taken on a wooden measuring board and recorded to the nearest cm on paper logs. Starting during the 2010 spring survey, crabs were measured on electronic length boards and recorded directly in to Fisheries Scientific Computer System (FSCS) data tables. Since the fall 2014 survey, Jonah crab measurements have been recorded with digital calipers to the nearest cm and recorded directly into FSCS. The change to digital calipers was made to improve measurement accuracy, as crab legs sometimes made it difficult to measure crabs on a length board. Female crabs have been inspected for extruded eggs since the fall 2014 survey, but observations of egg bearing crabs are very rare.

Jonah crab are infrequently encountered in SNE strata (Figure 17, regions 1-3), so indices of abundance are only calculated for GOM strata (regions 4-5). Seasonal indices generally show higher relative abundance at the beginning of the time series, lower abundance through the 1990s, and higher abundance since (Table 16-Table 17 and Figure 18-Figure 19). The fall index shows a more consistent increasing trend since the early 2000s, while the spring index is more variable during these years.

5.1.4 NJ DFW Ocean Trawl Survey

The NJ DFW has conducted a groundfish survey along the New Jersey coast since August 1988. The survey area is about 1,800 square miles of coastal waters between Sandy Hook, NJ and Cape Henlopen, DE and from a depth of 18 to 90 ft (5 – 27 m). The area is divided into 15 strata that are bounded by the 30, 60, and 90 ft (9, 18, and 27 m) isobaths (Figure 20). The survey design is stratified random. Since 1990, cruises have been conducted five times a year; in January, April, June, August, and October. Two 20-minute tows are made in each stratum, plus one more in each of the nine larger strata, for a total of 39 tows per cruise in all months except January, when the additional tows are omitted. The trawl gear is a two seam three-in-one trawl (so named because all the tapers are three to one) with 12 cm mesh in the wings and belly and 7.6 cm in the codend with a 6.4 mm liner. The headrope measures 25 m and the footrope 30.5 m. Rubber cookies measuring 2 3/8 inch (60.3 mm) in diameter are used on the trawl bridles, ground wires, and footrope. Five different vessels have been used to conduct the surveys to date.

Jonah crab have been caught in 7% of tows on average while the index of abundance generally increased through the 2000s and varied highly since (Figure 21). The index of biomass (Figure 22) shows three periods of catch rates without trend, with a period of what appears to be heavier crabs caught in the mid to late 1990s, given the average or relatively low catch rates in numbers during the same period (Figure 21), straddled by an earlier and later period with lower biomass catch rates.

5.2 Settlement/YOY Surveys

5.2.1 ME DMR Settlement Surveys

The ME DMR settlement survey primarily was designed to quantify lobster YOY but has also collected Jonah crab data from the sites throughout the time series. The survey was started in 1989 in a smaller regional area close to Boothbay Harbor within statistical area 513 but was expanded to statistical areas 512 and 511 in 2000. The Maine survey currently monitors 40 sites coastwide within 1-10m in depth. The timing of this survey has shifted over time due to dive staff availability to complete the work, but it has generally occurred between September and December annually. Jonah crab information collected includes CW and location. Notations are made if small crabs carry eggs.

Indices for all statistical area have generally increased through time (Table 18; Figure 23). There were consistent decreases in the indices in 2019.

5.2.2 NH F&G Settlement Survey

NH F&G has participated in the ALSI since 2008, and biological information has been collected on Jonah crabs since 2009. New Hampshire follows the standardized coastwide procedures and monitors three sites along the NH Coast. The index of abundance generally increased through the duration of the time series (Figure 24).

5.2.3 MA DMF Settlement Survey

Massachusetts has conducted a juvenile lobster settlement survey since 1995. The survey begins in mid to early August, and generally runs through late September. The survey started with nine fixed stations in three regions and by 2018, had grown to include 23 fixed stations in seven different regions. The survey extent contracted in 2019 to 14 sites in five regions. The Vineyard Sound region and two of the Buzzards Bay sites were discontinued because juvenile lobsters are rarely encountered in these areas. The Cape Cod region and some South Shore stations were discontinued due to the increasing presence of white sharks at survey sites during the survey time period.

The survey is conducted at fixed stations by a team of divers. Divers selectively place 0.5 m^2 quadrats over areas of cobble. Twelve quadrats are sampled per station, which are then immediately sorted on the boat.

Jonah crabs have been consistently identified to species in the survey since 2011. Though the survey has not always identified crabs to species, it has consistently identified *Cancer* crabs to genus over the entire time series. Jonah crabs are counted, measured (CW in mm) and sexed when possible. Crabs less than 5 mm are generally too small to sex or identify to species.

Indices of Jonah crab settlement generally varied with no discernible trend until increasing to the highest values of the time series in 2018 or 2019, depending on sampling area (Figure 25).

5.2.4 RIDEM DMF Settlement Survey

The RIDEM DMF conducts a yearly lobster settlement survey at six fixed stations (Figure 26) along Rhode Island's south coast—outside of Narragansett Bay—in late August to early September. At each site, SCUBA divers randomly place twelve quadrats to sample. Once these quadrats are placed, an air lift suction device is used to collect each sample. The survey is intended to measure the abundance of juvenile lobsters, but all other crustaceans, including Jonah crabs, are counted and measured.

The index of Jonah crab settlement shows a period of higher average settlement from the late 1990s through the mid-2000s followed by lower settlement for the remainder of the time series (Figure 27).

6 RECOMMENDATIONS FOR A COASTWIDE STOCK ASSESSMENT

6.1 Need for Coastwide Stock Assessment

Landings of Jonah crab from U.S. waters have increased significantly over the last 20 years, quadrupling from an average of 4.8 million pounds per year during 1997-1999 to an average of 20.1 million pounds per year during 2017-2019. This increase has been driven by several factors including decreased abundance of the SNE lobster stock and increasing prices for Jonah crab landings. There have been no formal analyses to determine if increasing Jonah crab abundance is an additional factor driving the increase in landings. Further, the current minimum legal size established in the FMP (4.75 inch CW) was largely based on market preference for Jonah crabs at the time. The Canada DFO stock assessment (Fisheries and Oceans Canada 2009) provides a precedent for management of Jonah crab without science-based guidance. This stock experienced rapid increases in landings similar to increases seen in the U.S. fishery, before declining to low abundance levels.

From a socioeconomics standpoint, further market development has likely been hindered by the hesitancy of NGO seafood sustainability organizations to fully recognize the sustainability of the U.S. Jonah crab fishery without more rigorous science-based management advice. In 2013, the Delhaize grocery store chain determined that Jonah crab did not meet its standards of sustainably caught seafood. Rather than remove Jonah crab from their shelves, Delhaize started a Fisheries Improvement Project, which requested that ASMFC develop a Jonah crab FMP and identified a stock assessment as a critical need to inform the FMP (Swenton et al. 2014). In 2015, the Monterey Bay Aquarium Seafood Watch "red-listed" Jonah crab, advising consumers to avoid eating it due to the lack of abundance and life history information (Bradt 2015). The Monterey Bay Aquarium later revised this information and reclassified U.S. Northwest Atlantic Jonah crabs as a "good alternative" in 2016, though this classification is still lower than the most favorable classification of "best choice". The Seafood Watch report cites the lack of a formal stock assessment and reference points (Bradt et al. 2016).

6.2 Evaluation of Available Data Sources

The TC evaluated three data types that serve as the pillars to stock assessment: life history, indices of abundance, and fishery removals.

6.2.1 Life History Data

There is limited life history information available for Jonah crab. The best understood life history parameters are size-at-maturity and growth of immature crabs. Growth data are far more limited for legal-sized crabs and do not support robust growth estimates for the full size range of Jonah crab. This data limitation and unknown longevity of the species also contributes to uncertainty in natural mortality, another crucial, but poorly understood life history parameter. Uncertainty of natural mortality is not unique in stock assessment, but, without additional information for Jonah crab, a broad range of potential natural mortality levels would need to be considered in a stock assessment.

6.2.2 Indices of Abundance

A total of thirty one surveys that encounter Jonah crab were reviewed for their utility to provide indices of abundance that could support assessment approaches (Table 13 and Table 14). There are currently no surveys designed specifically to track Jonah crab abundance. Therefore, surveys designed to track abundance of other species were reviewed. Several issues that could potentially limit the utility of using these surveys to generate reliable indices of Jonah crab abundance are discussed below.

- Spatial coverage: Several surveys reviewed occur in areas that are not primary habitat for the exploitable Jonah crab population (i.e., shallow, inshore). Further, some surveys were designed to address objectives other than tracking population abundance (i.e., wind farm impacts) and have spatial footprints that are too small to capture population-wide trends.
- Time series: Given the low priority of Jonah crab prior to the increase in landings in recent years, several survey sampling protocols limited or completely excluded Jonah crab data collection. This has changed, particularly since about the mid-2010s, and should support an increase in useful abundance trend information in the next five to ten years.

- Catchability: For the surveys identified as likely candidates to provide reliable indices of post-settlement Jonah crab abundance (i.e., trawl surveys), catchability remains the primary issue that needs additional research. Behavioral aspects such as burrowing likely make Jonah crabs even less vulnerable to trawl gears than lobsters. These catchability issues result in relatively low catch rates. Preliminary analyses of length composition data show limited exploitation signals (i.e., changes in mean size) and tracking of cohorts even during periods of higher abundance and fishery landings.

Given the issues identified for interpreting indices from surveys encountering Jonah crab and uncertainty about stock structure, several trawl survey indices were compared to provide information on the utility of these data as abundance indices for stock assessment and to explore for potential spatial heterogeneity that might indicate discrete structuring of the population. Seasonal indices were compared with a Spearman's rank-order correlation analysis. Length compositions were also compared to determine if selectivity varied among the indices. Seasonal length compositions were aggregated across years due to low encounter rates and noisy annual composition data within periods defined by the vessel change in the NEFSC trawl survey ("early" period from 1980-2008 and "late" period from 2009-2019). Proportional stratified length compositions were expanded to length samples by the number of Jonah crab measured. A Kolmogorov-Smirnov test was applied to length data to test for differences in shape and mean of the length distributions.

Regional indices calculated from the NEFSC trawl survey (Figure 12 and Figure 13) were compared to examine degree of spatial corroboration within this survey domain. Despite the vessel change in 2009 and lack of data to calibrate catch rates between vessels, the full time series of indices were analyzed assuming vessel effects impacted indices (and annual index rank values) across regions similarly. There were some years when multiple vessels conducted seasonal surveys and these occurrences were dropped from the data set. Correlation coefficients indicate corroboration among the Core, GB, and SNE indices, slightly less corroboration between GB and GOM indices, and the least corroboration between the Core/SNE and GOM indices (Figure 28 and Figure 29). The Core index was generally more highly correlated with the other regional indices during the fall survey when Jonah crab appear to be more available to the survey (Figure 12). Not surprisingly due to the spatial overlap between SNE and Core indices, length compositions between these regions were similar in all periods (Figure 30 and Figure 31). However, there was limited support for similar selectivity between other regions for most periods including between the overlapping GB and Core indices (Table 19). Similar to the correlation analysis, the fall survey during the later period was most similar among regions with no significant difference detected among SNE, Core, and GOM length compositions.

To examine corroboration of indices among various trawl surveys operating in a similar region, indices calculated from GOM strata covered by the NEFSC, MA DMF, and ME/NH trawl surveys (Figure 32 and Figure 33) were compared. Indices were split into early and late time periods based on the NEFSC vessel change in 2009. Length composition data prior to the ME/NH trawl survey were excluded from the data set. Correlation coefficients indicate relatively weak to no correlation among indices (Figure 34 - Figure 37). Although selectivity between the state trawl surveys appear similar in most periods (Figure 38 and Figure 39), only the early spring MA DMF and NEFSC and late fall MA DMF and ME/NH surveys were found to have had a shared selectivity pattern (Table 20).

These results highlight the issues identified for potential Jonah crab indices of abundance, though do not isolate any particular factor in interpretation of the signals. The higher correlation of the NEFSC regional indices suggests factors like catchability might be more similar due to the shared vessel characteristics and habitats sampled (deeper, offshore habitat). The weaker correlation between SNE/Core and GOM indices along with similar selectivity patterns indicate some spatial differences that could be driven by stock structure or other spatial processes. The weaker correlation among GOM indices might be driven more by differences in catchability among vessels and spatial differences with state surveys sampling less preferable habitat (shallower, inshore habitat) than the federal survey. Selectivity is likely another factor that explains some lack of correlation, though there is no clear pattern with some comparisons suggesting similar selectivity while others suggest differences in selectivity. Multiple indices with low correlation can be misleading and difficult to objectively choose among for use in stock assessment, and can result in poor stability of population dynamics models when used together (Conn 2010). If differences in trends among indices are reflective of stock structure and not accounted for when being fit in stock assessment models, resultant population and stock status estimates can be biased (Guan et al. 2013). The results of these trawl survey comparisons support the need for additional research on Jonah crab index selection, index treatment in assessment approaches, and stock structure within a stock assessment.

Of the thirty one surveys reviewed, six and five were identify as likely candidates to provide reliable indices of Jonah crab settlement and post-settlement abundance, respectively (Table 13 and Table 14). Details for these surveys are in Section 5.

6.2.3 Fishery Removals

Three primary issues were identified and discussed with regard to total Jonah crab landings: species misidentification, underreporting, and landings units.

As described in Section 4.1.1.1 Jonah crabs and the similar species, Atlantic rock crab, have likely been misidentified as each other, landed using the same common name of "rock crab", and landed individually or mixed as "crab unclassified". This was noted as a prevalent issue in Maine, but is believed to be more limited in other states. To evaluate this issue, Atlantic rock crab landings in the ACCSP Data Warehouse were also queried and validated with state partners. Atlantic rock crab landings have been minimal compared to the validated Jonah crab landings (Figure 40), particularly in more recent years as Jonah crab landings have increased. Although species misidentification is an issue that should be further explored in a benchmark stock assessment, the TC anticipates this to be a minor issue given the comparison of landings magnitude of the *Cancer* crab species.

Due to the historical status of Jonah crab as relatively low value bycatch and the lack of/limited reporting requirements in earlier years (≈mid-2000s), there is speculation that some Jonah crab harvest may have been sold off the docks for cash and, therefore, unreported in dealer reports. The TC believes this underreporting may be a minor limitation as it occurred during the period of lower Jonah crab harvest due to lack of incentive for harvesting Jonah crab (i.e., low market demand, robust lobster fishery with higher prices per pound).

There were some occurrences of erroneous landings units encountered during landings validation. In some cases, landings were in pounds and reported in bushels or vice versa. However, these discrepancies were resolved during the validation process and should not be a limitation of landings data in a stock assessment.

After discussing these issues, particularly in the states that are primary contributors to Jonah crab harvest, the TC believes 2006 is likely a reliable start year for total coastwide landings data. Both seasonal and spatial data are widely available during this period and should allow partitioning of annual coastwide landings if necessary.

Preliminary investigation of biosampling intensity suggests reasonable coverage of core statistical areas starting in 2014. The developing time series and plans to continue biosampling is promising, though the time series is too short for use in population dynamics modeling approaches in a near-term stock assessment. Dedicated funding for Jonah crab biosampling programs would also help shift current sampling by some agencies from an opportunistic effort to more systematic sampling designed to characterize biological attributes of the Jonah crab catch.

6.3 Potential Stock Assessment Approaches

Based on the available Jonah crab data, some potential assessment approaches are outlined below to provide information on the products that could result from a near-term stock assessment to be used for management guidance. The approaches are generally listed in order of data requirements, with the first being the least data-intensive and the last being the most data-intensive.

Stock Indicators
Stock indicators are simple, empirical time series analyses that do not require assumptions typical of population dynamics models. These indicators can be used in a framework to provide a categorical characterization of stock conditions to complement stock status estimates from other assessment approaches and/or pre-defined triggers for management responses.

Data requirements: Variable, but would likely include indices of abundance/biomass, fishery removals, changes in size structure (e.g., median size), and/or relative exploitation

Outputs: Annual indicator values relative to time period-based reference values

Examples of other ASMFC-managed species assessed with these approaches: American lobster (categorical characterization of stock conditions to complement stock status estimates from other assessment approaches), spot and Atlantic croaker (pre-defined triggers for management responses)

Index-Based Methods
These assessment approaches include a number of methods that utilize indices of abundance to provide stock status based on an ad hoc, historical time period (e.g., ARIMA) or catch-based management advice (e.g., PlanB). Performance of several of these methods when natural

mortality is misspecified or annual catch data is incomplete, two areas of uncertainty facing Jonah crab assessment, was recently evaluated through a research track assessment conducted by the NEFSC (Legault et al. 2020). The assessment found two groups of methods tend to perform best dependent on the condition of the stock (i.e., favorable or unfavorable) for groundfish species and could be useful for short-term management advice while working towards advice from models that account for size/age structure of the stock.

Data requirements: Index of abundance, but some methods also require fishery removals and a natural mortality estimate

Outputs: Stock status based on an ad hoc, historical time period or sustainable catch levels

Examples of other ASMFC-managed species assessed with these approaches: Horseshoe crab (stock status based on an ad hoc, historical time period)

Biomass Dynamics-Based Data Poor Models (e.g., Depletion-Based Stock Reduction Analysis, Depletion-Corrected Average Catch)

These assessment approaches apply surplus production theory to observed fishery removal time series to estimate exploitation, total stock biomass, and MSY-based reference points for exploitation, total stock biomass, and catch. These methods were developed to provide catch advice in the interim while necessary data are collected to support more data-rich assessment methods. However, there are concerns changing environmental conditions may violate steady-state assumptions required by these methods that may preclude reliable estimation of catch advice. Some of these methods also require complete time series of fishery removals which may preclude their use for Jonah crab assessment.

Data requirements: Total fishery removals in weight, assumptions about stock depletion levels, and a natural mortality estimate

Outputs: Exploitation and biomass estimates and MSY-based reference points

Examples of other ASMFC-managed species assessed with these approaches: Black drum

Biomass Dynamics Model (e.g., surplus production model)

These assessment approaches are more comprehensive methods than the similar biomass dynamics-based data poor models that can be used if a reliable index of exploitable biomass is available to estimate exploitation, total stock biomass, and MSY-based reference points for exploitation, total stock biomass, and catch. These methods also allow for relaxing some of the assumptions of their data poor counterparts such as depletion levels or early catch histories. However, the same concerns about changing environmental conditions violating steady-state assumptions apply to these models.

Data requirements: Index of exploitable biomass and total fishery removals in weight

Outputs: Exploitation and biomass estimates and MSY-based reference points

Examples of other ASMFC-managed species assessed with these approaches: None

Collie-Sissenwine Analysis

This assessment approach tracks abundance of two stages, recruits entering the fishery in a given year and fully-recruited individuals, through time. This assessment approach has frequently been applied to crustacean species that lack age composition data. Estimates of fishing mortality and abundance could be compared to complementary per-recruit analyses or, if changing environmental conditions invalidate steady-state assumptions of per-recruit analyses, an ad hoc, historical time period-based reference point to estimate stock status. A limitation that may preclude the use of this approach for Jonah crab assessment is limited data available for converting fishery removals in weight to number of individuals, particularly for earlier years.

Data requirements: Index of recruit and post-recruit abundance, total fishery removals in numbers, and a natural mortality estimate

Outputs: Fishing mortality, abundance, and stock status using complementary per-recruit analyses or an ad hoc time period-based reference point

Examples of other ASMFC-managed species assessed with these approaches: American lobster (historically)

Statistical Catch-at-Length Model (e.g., University of Maine Lobster Model)
These models track stock abundance-at-length through time by explicitly accounting for important processes such as individual growth. As with the Collie-Sissenwine analysis, estimates of fishing mortality and abundance could be compared to complementary per-recruit analyses or, if changing environmental conditions invalidate steady-state assumptions of per-recruit analyses, an ad hoc, historical time period-based reference point to estimate stock status. However, available data likely do not support the use of this assessment method to estimate Jonah crab stock status in the near-term. Future research needs to be done to determine if both fishery-independent and fishery-dependent size composition data sets contain measurable exploitation signals.

Data requirements: Index of abundance and size composition, total fishery removals and size composition, a natural mortality estimate, and growth transition matrices

Outputs: Fishing mortality, abundance, and stock status using complementary per-recruit analyses or an ad hoc time period-based reference point

Examples of other ASMFC-managed species assessed with these approaches: American lobster

6.4 Recommendation on Jonah Crab Stock Assessment Schedule

The TC believes it would be worthwhile to conduct a near-term stock assessment and recommends moving forward with a stock assessment to be completed in 2023, consistent with current Northeast Region Coordinating Council and ASMFC assessment schedules. The Jonah crab FMP is the result of industry concern over a lack of management, and questions regarding the status and sustainability of the Jonah crab resource. Management is now in place, but an assessment could help answer questions about the status and sustainability of the resource, provide more information with which to manage the fishery, as well as identify data needs, in addition to those identified during the pre-assessment data workshop (below), which if addressed, could help strengthen future assessments.

7 RESEARCH RECOMMENDATIONS

High Priority

- Information should be collected to help delineate stock boundaries (e.g. genetics). Identification of stock boundaries is an essential step in stock assessment that will inform many subsequent steps including development of input data and identification of methods applicable to the stock(s). Note: Some genetic research is currently being conducted by the Gloucester Marine Genomics Institute that may address this recommendation.
- Female migration pathways/seasonality and larval duration and dispersal need to be researched. Anecdotal information suggests seasonal aggregations in inshore areas, but research would help to understand these mechanisms and inform stock boundaries.
- Inter-molt duration of adult crabs is currently unknown and growth increment data for mature crabs is limited. These data will be necessary to transition to size- or age-based assessment methods.
- Develop fisheries-independent surveys (e.g. trap survey) to index post-settlement Jonah crab abundance from offshore areas where most of the fishery is executed.
- Increase fisheries-dependent monitoring of the offshore fleet. Sampling intensity by statistical area should be based on landings.
- Reproductive studies pertaining to male-female spawning size ratios, the possibility of successful spawning by physiologically mature but morphometrically immature male crabs, and potential for sperm limitations should be conducted.
- The amount of directed commercial effort on Jonah crabs vs. lobster should be quantified on a per trip basis.

Moderate Priority

- Cohort tracking analyses with existing data should be conducted across and within surveys to better understand if surveys are tracking true abundance signals and provide information on growth, mortality, and other demographic factors.
- Investigate the efficacy of existing lobster ventless trap surveys, including interaction between lobster and Jonah crab, to determine utility for indexing Jonah crab abundance. Research has shown that as lobster trap catch increases; crab catch within the same trap decreases (Miller and Addison 1995, Richards et al. 1983). This suggests abundance trends for Jonah crab will be heavily influenced by lobster density.

Low Priority

- Additional sampling to expand upon the University of Maine Settlement Collector Sampling should be conducted to provide a more comprehensive understanding and tracking of temporal and spatial settlement dynamics.
- The development of aging methods or determination of the mechanism responsible for the suspected annuli formation found in the gastric mill should be explored.

- Food habits data should be analyzed from offshore areas to better understand predation of Jonah crab.

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9 TABLES

Table 1. Morphometric and Gonadal size-at-maturity of male crabs.

Study	Year	Region	Morphometric	Gonadal
Moriyasu et al.	2002	Nova Scotia	128	69
Perry et al.	2017	GOM inshore	103	
Perry et al.	2017	GOM offshore	115	
Perry et al.	2017	Georges Bank	109	
Perry et al.	2017	SNE inshore		
Perry et al.	2017	SNE offshore	117	
Ordzie and Satchwill	1983	SNE inshore		50-60
Lawrence	2020	SNE	106	
Carpenter	1978	Mid Atlantic	90-100	
Olsen and Stevens	2020	Mid Atlantic	98	

Table 2. Morphometric and Gonadal size-at-maturity of female crabs.

Study	Year	Region	Morphometric	Gonadal
Perry et al.	2017	GOM offshore		98
Perry et al.	2017	Georges Bank	94	93
Perry et al.	2017	SNE inshore		86
Perry et al.	2017	SNE offshore	88	89
Ordzie and Satchwill	1983	SNE inshore	40-50	40-50
Carpenter	1978	Mid Atlantic	85	
Olsen and Stevens	2020	Mid Atlantic	88	

Table 3. Summary of Jonah crab sea sampling trips conducted by NH F&G.

Year	Total Number of Sampled Jonah Crabs	Number of Trips with Jonah crab Bycatch	Number of Trips without Jonah crab Bycatch*
2015	198	18	0
2016	192	7	7
2017	50	7	7
2018	22	7	7
2019	67	8	6

*River samples excluded from total number of trips without bycatch since no Jonah crab sampling occurs on these trips.

Table 4. Summary of Jonah crab port sampling trips conducted by NH F&G.

Year	Sample Number	Quarter	Number Sampled	Yearly totals
2016	201601	4	172	172
2017	201701	1	185	642
	201702	2	178	
	201703	3	154	
	201704	4	125	
2018	201801	1	19	675
	201802	2	5	
	201803	2	89	
	201804	3	238	
	201805	3	241	
	201806	4	83	
2019	201901	1	64	222
	201902	2	25	
	201903	3	33	
	201904	4	100	
2020	202001	1	100	400
	202002	2	100	
	202003	3	100	
	202004	4	100	
Total Jonah Crabs Sampled				2,111

Table 5. Summary of Jonah crab sea sampling trips conducted by RIDEM DMF.

Year	Quarter	Statistical Area(s)	Crabs Sampled
2016	2	537	329
2016	1	537	321
2016	3	539	869
2016	3	537	919
2016	3	539	616
2016	4	537	679
2016	4	539	838
2016	4	539	1219
2017	1	539	870
2017	2	539	1204
2017	2	539	467
2017	3	539	322

Table 6. Summary of port sampling trips for Jonah crab conducted by RIDEM DMF.

Year	Quarter	Statistical Area(s)	Crabs Sampled
2015	4	537	514
2016	1	526	228
2016	1	525	82
2016	2	526	142
2019	4	537	208
2019	4	526	137
2020	1	525	194
2020	1	526	229
2020	2	526	253
2020	2	616	155
2020	3	526	212

Table 7. Validated Jonah crab landings by state from the ACCSP Data Warehouse. Asterisks indicate confidential landings data that have been redacted.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1981			99,300	356,900		1,400		15,000	41,300			513,900
1982						7,300	14,200		52,200			73,700
1983			15,600	15,700		400	1,800		15,600	1,900		51,000
1984	2,330,960		3,120,498	114,900		5,800	12,000		35,800	12,400		5,632,358
1985	2,321,353		28	424,000		741	23,400	14,000	15,400	14,900		2,813,822
1986	1,862,525		43	580,900		400	9,500		18,200	38,100		2,509,668
1987	3,303,457		621,200	856,400		3,400	7,300		23,800	47,900		4,863,457
1988	3,120,498		1,065,000	1,192,900		100	5,500		10,000	34,000		5,427,998
1989	3,433,600		1,222,400	1,165,300			3,100		8,400	21,500		5,854,300
1990	3,596,796		1,264,321	882,843		480	18,845		6,573	13,044		5,782,902
1991	2,968,451		979,250	976,744			38,040		7,209	2,046		4,971,740
1992	1,930,396		1,487,991	1,067,826		1,040	37,833		5,448	28		4,530,562
1993	2,124,193		1,312,751	1,028,322		10,459	18,548	2,000	5,725	64		4,502,062
1994	2,012,073	**	1,294,893	1,059,321		249,150	22,431	400	**			4,638,268
1995	**		1,048,824	731,518	10	39,074	22,101		**	25		1,841,552
1996	1,800,214		1,202,790	958,031	9	331,467	26,253		1,028			4,319,792
1997	2,820,385	**	2,693,851	534,319	267	120,069	20,700		**	**		6,189,591
1998	**	**	1,118,194	843,575	535	115,261	76,792		490	**		2,154,847
1999	2,752,114	**	1,739,112	1,396,757	1,022	757	14,037		2,925	**		5,906,724
2000	**	**	1,358,571	225,435	16,806	54,919	16,446		**	**	**	1,672,177
2001	**	**	1,507,268	5,535	6,244	111,845	18,668		33,210		**	1,682,770
2002	9,535,874	**	1,667,683	127,992	688	34,763	18,308		**			11,385,308
2003	6,554,939	**	1,530,595	308,681		62,426	22,698	**	**			8,479,339
2004	6,065,510	**	933,869	906,661	570	35,444	7,209		93			7,949,356
2005	6,005,511		3,663,582	754,594	328	12,641	29,254		**	**		10,465,910
2006	4,489,135		3,614,261	1,096,857	2,460	26,387	**		3,416	**		9,232,516
2007	4,767,353		4,118,472	2,573,573	295	202,898	80,092		8,720	**		11,751,402
2008	3,588,218	**	4,478,547	3,265,159	287	561,386	115,995		12,188	**		12,021,779
2009	3,289,394	**	4,869,605	2,552,779	3,196	509,874	38,482		11,657	**		11,274,987
2010	3,231,202	**	5,689,431	3,720,443	955	968,122	28,400		18,045		**	13,656,598
2011	2,477,058	**	5,379,792	3,213,119	340	172,311	26,286		92,401	**	**	11,361,306
2012	1,725,695	**	7,540,819	3,774,300	2,349	411,657	68,252		**	**		13,523,072
2013	1,383,877	340,751	10,117,542	4,642,196	51,462	375,101	7,803		**	**		16,918,733
2014	1,793,245	404,703	11,904,611	4,435,038	50,070	78,115	33,104		153,714	**	**	18,852,600
2015	1,799,799	**	9,128,900	3,850,894	5,930	208,607	59,156	**	39,750	**		15,093,036
2016	2,085,038	150,341	10,660,653	4,224,092	145	166,197	241,528	**	14,656	3,088		17,545,739
2017	3,369,809	113,354	11,698,342	4,106,481	796	158,089	432,754	**	18,745	**		19,898,370
2018	3,608,046	22,118	13,227,083	4,627,043	320	195,143	868,211	**	14,922	**		22,562,885
2019	2,713,228	70,704	9,697,607	4,078,772	482	106,244	1,046,466	**	14,314		40	17,727,857

Table 8. Number of commercial biosampling trips by year and statistical area. The core statistical areas are bolded and underlined. Colors are scaled to the minimum and maximum number of trips, with green indicating the greatest sampling intensity and red indicating the lowest sampling intensity.

Year	626	627	622	623	616	612	613	611	**537**	**526**	**525**	539	522	562	561	514	515	464	513	465	512	511
2003	0	0	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	0	0	0	9	1
2004	0	0	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	0	1	0	2	0
2005	0	0	0	0	0	0	0	0	**0**	**1**	**0**	0	0	0	0	1	0	0	0	0	0	0
......																						
2013	0	0	0	0	0	0	0	0	**2**	**0**	**0**	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	3	0	1	0	**26**	**2**	**18**	44	0	9	0	0	0	0	0	0	0	0
2015	1	0	0	0	1	0	3	0	**44**	**24**	**20**	77	0	9	4	3	0	1	0	2	2	0
2016	1	0	0	0	0	1	1	0	**41**	**13**	**23**	91	0	8	13	4	3	9	0	2	4	0
2017	0	0	5	0	0	0	26	0	**19**	**7**	**17**	92	0	4	17	6	2	1	5	1	6	1
2018	2	0	4	0	13	0	0	0	**32**	**25**	**9**	71	0	9	8	13	1	10	12	5	8	6
2019	3	1	3	1	11	0	0	1	**49**	**26**	**4**	72	0	3	23	0	10	6	12	12	13	1

Table 9. Number of commercial biosampling trips and individual Jonah crabs sampled by year, quarter, and trip type in the core statistical areas. Colors are scaled to the minimum and maximum number of trips within each trip type, with green indicating the greatest sampling intensity and red indicating the lowest sampling intensity.

Year	Quarter	537						526						525					
		SEA		PORT		TOTAL		SEA		PORT		TOTAL		SEA		PORT		TOTAL	
		Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples	Trips	Samples
2013	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	4	0	0	2	714	2	714	0	0	0	0	0	0	0	0	0	0	0	0
2014	1	3	459	2	2,600	5	3,059	1	3	0	0	1	3	0	0	0	0	0	0
2014	2	3	273	0	0	3	273	0	0	0	0	0	0	0	0	0	0	0	0
2014	3	13	959	0	0	13	959	0	0	0	0	0	0	7	694	0	0	7	694
2014	4	5	211	0	0	5	211	1	632	0	0	1	632	11	966	0	0	11	966
2015	1	2	543	0	0	2	543	7	4,727	1	754	8	5,481	3	310	0	0	3	310
2015	2	9	842	2	2,561	11	3,403	6	836	2	1,268	8	2,104	9	854	0	0	9	854
2015	3	12	8,085	0	0	12	8,085	3	531	0	0	3	531	4	1,357	0	0	4	1,357
2015	4	14	12,497	5	3,322	19	15,819	4	3,206	1	455	5	3,661	4	1,258	0	0	4	1,258
2016	1	7	1,280	3	2,227	10	3,507	0	0	3	1,608	3	1,608	4	383	1	82	5	465
2016	2	7	2,353	3	1,710	10	4,063	3	3,601	4	2,290	7	5,891	11	1,172	0	0	11	1,172
2016	3	11	1,612	1	760	12	2,372	2	130	1	640	3	770	6	263	0	0	6	263
2016	4	8	792	1	584	9	1,376	0	0	0	0	0	0	1	50	0	0	1	50
2017	1	3	182	0	0	3	182	1	101	0	0	1	101	1	67	0	0	1	67
2017	2	1	52	0	0	1	52	2	69	0	0	2	69	2	368	0	0	2	368
2017	3	9	2,285	0	0	9	2,285	4	306	0	0	4	306	9	388	0	0	9	388
2017	4	6	212	0	0	6	212	0	0	0	0	0	0	5	244	0	0	5	244
2018	1	5	463	0	0	5	463	0	0	0	0	0	0	2	86	0	0	2	86
2018	2	3	280	0	0	3	280	8	550	1	1,608	9	2,158	3	134	0	0	3	134
2018	3	11	563	0	0	11	563	7	449	0	0	7	449	2	101	0	0	2	101
2018	4	12	687	1	641	13	1,328	9	594	0	0	9	594	2	87	0	0	2	87
2019	1	4	545	0	0	4	545	2	337	1	711	3	1,048	2	159	1	626	3	785
2019	2	11	787	1	714	12	1,501	4	296	0	0	4	296	0	0	0	0	0	0
2019	3	13	600	1	14	14	614	10	870	1	570	11	1,440	1	52	0	0	1	52
2019	4	16	861	3	1,034	19	1,895	6	554	2	718	8	1,272	0	0	0	0	0	0

Table 10. ACCSP codes and descriptions for crab maturity data and number of Jonah crab assigned each code by agency.

ACCSP Codes	Description	Maine	Massachusetts	CFRF	NOAA Fisheries
C1	Immature	0	0	0	0
C2	Maturing	0	0	0	0
C3	Yellow-orange	11	0	0	0
C4	Brown	4	0	0	0
C5	Black	0	0	0	0
C6	Spent	0	0	0	0
C7	Inactive	769	0	7371	0
CX	Eggs present	0	0	72064	25
NA	orange	0	3	0	0

Table 11. Commercial discards of Jonah crab reported on Federal VTRs by harvesters with VTR reporting requirements landing in New Hampshire.

Year	Gill Net	Otter Trawl	Lobster or Crab Pot/Trap	Total
2004			118,090	118,090
2005			107,420	107,420
2006	XX		64,107	64,117
2007			54,280	54,280
2008			59,180	59,180
2009			49,440	49,440
2010	XX		80,537	80,538
2011			37,644	37,644
2012			18,512	18,512
2013			39,097	39,097
2014			88,543	88,543
2015			102,165	102,165
2016			97,745	97,745
2017			69,940	69,940
2018			84,151	84,151
2019			108,851	108,851
2020		XX	76,247	76,297

*Confidential values are indicated in red

Table 12. Recreational Jonah crab harvest from New Hampshire.

Year	Recreational Harvest (lbs)
2016	69
2017	70
2018	15
2019	11

Table 13. Summary of surveys encountering settling Jonah crabs and their likely utility for providing an index of abundance for a near-term stock assessment. Reasons identified for surveys unlikely to provide an index of abundance for a near-term assessment were lack of *Cancer* crab species identification (SID) and short and/or discontinuous time series (TS).

Survey	*Time Series*	*Carapace Widths*	*Unlikely to Provide an Index of Abundance for Assessment*	*Reason*
ME DMR Settlement Survey - Statistical Area 511	2001-present	Y		
ME DMR Settlement Survey - Statistical Area 512	2000-present	Y		
ME DMR Settlement Survey - Statistical Area 513	1989-present	Y		
NH F&G Settlement Survey	2009-present	Y		
Normandeau Plankton Survey	1982-present	N	Y	SID
MA DMF Settlement Survey	2011-present	Y		
RIDEM DMF Settlement Survey	1990-present	Y		
UMaine Deepwater Collectors	2007-present	Y	Y	TS

Table 14. Summary of surveys encountering post-settlement Jonah crabs and their likely utility for providing an index of abundance for a near-term stock assessment. Data fields collected after the start year when Jonah crab counts were added to survey protocols are included in parentheses. Reasons identified for surveys unlikely to provide an index of abundance for a near-term assessment were lack of spatial overlap between the survey domain and Jonah crab population and/or small spatial domain (SS), short and/or discontinuous time series (TS), and inadequate catch rates (CR).

Survey	*Time Series*	*Carapace Widths*	*Sex*	*Unlikely to Provide an Index of Abundance for Assessment*	*Reason*
ME Urchin Survey	2004-present	Y	Y	Y	SS
ME VTS	2011-present	Y (2016)	Y (2016)	Y	SS
NH VTS	2009-present	Y (2015)	Y (2015)	Y	SS
Normandeau VTS	1982-present	Y	Y	Y	SS
MA VTS	2007-present	Y	Y (2015)	Y	SS
SMAST VTS	2019	Y	Y	Y	SS, TS
CFRF VTS	2014-present	Y	Y		
CFRF SNE Cooperative VTS	2014-2018	Y	Y	Y	SS, TS
RI VTS	2006-present	Y	Y	Y	SS
NY VTS	2006-2010	N	N	Y	TS
NJ Fixed Gear Survey	2016-present	Y	Y	Y	TS
DE Structure Oriented Survey	2018-present	Y	Y (2020)	Y	TS
CFRF-South Fork Wind Farm Cox's Ledge/RI Sound Trawl	2020-present	Y	Y	Y	SS, TS
Coonamessett Farm Foundation Scallop Dredge	2010-present	N	N	Y	TS
ME/NH Trawl Survey	2001-present	Y	Y (2004)		
MA DMF Trawl Survey	1978-present	Y	Y (1981)		
RI Trawl Survey	2015-present	Y	Y	Y	TS
URI GSO Trawl Survey	2016-present	Y	Y	Y	TS
CT Trawl Survey	1979-present	Y	Y	Y	SS, CR
NY Trawl Survey	2017-present	Y	Y	Y	TS
NJ DFW Ocean Trawl Survey	1989-present	Y	Y (2021)		
NEAMAP Trawl Survey	2007-present	Y	Y	Y	CR
NEFSC Trawl Survey	1969-present	Y	Y		

Table 15. ME/NH seasonal indices of abundance (mean numbers per tow) and coefficients of variation.

Year	Spring		Fall	
	Index	CV	Index	CV
2000			1.83	0.49
2001	4.63	0.87	13.13	0.24
2002	4.41	0.71	6.91	0.68
2003	4.85	0.32	3.80	0.20
2004	6.71	0.51	7.26	0.32
2005	9.51	0.32	4.40	0.33
2006	7.87	0.51	4.03	0.40
2007	5.06	0.31	5.37	0.26
2008	3.93	0.21	6.37	0.20
2009	3.67	0.21	1.86	0.31
2010	2.20	0.39	2.09	0.34
2011	2.21	0.35	1.92	0.30
2012	1.87	0.23	1.68	0.26
2013	1.47	0.40	2.54	0.33
2014	4.98	0.50	1.30	0.33
2015	4.18	0.38	16.73	0.52
2016	12.06	0.44	11.83	0.25
2017	2.95	0.30	5.93	0.23
2018	2.09	0.31	3.93	0.35
2019	1.63	0.51	3.69	0.20

Table 16. MA DMF Spring Trawl Survey index of abundance, coefficients of variation, and percent of catch that is males from Gulf of Maine strata.

Year	Index (N)	CV	% male	Year	Index (N)	CV	% male
1978	2.95	0.63		1999	0.19	0.58	24%
1979	0.11	0.46		2000	0.75	0.31	53%
1980	0.13	0.90		2001	1.63	0.30	47%
1981	1.00	0.64		2002	0.45	0.31	63%
1982	2.25	0.67	40%	2003	0.29	0.32	55%
1983	0.03	1.00	100%	2004	0.43	0.50	29%
1984	0.21	0.45	18%	2005	0.63	0.65	50%
1985	0.31	0.56	82%	2006	0.93	0.30	37%
1986	0.25	0.52	42%	2007	0.35	0.35	62%
1987	0.63	0.65	51%	2008	0.84	0.33	64%
1988	0.03	1.00	100%	2009	0.52	0.26	71%
1989	0.23	0.63	77%	2010	0.12	0.61	41%
1990	0.16	0.61	24%	2011	1.12	0.39	41%
1991	0.05	0.71	96%	2012	0.09	0.50	100%
1992	0.18	0.53	87%	2013	0.31	0.62	56%
1993	0.50	0.60	60%	2014	0.04	0.72	100%
1994	0.39	0.50	48%	2015	2.56	0.31	97%
1995	0.19	0.41	84%	2016	7.75	0.18	71%
1996	0.33	0.39	48%	2017	1.99	0.22	81%
1997	0.18	0.40	60%	2018	1.27	0.32	41%
1998	0.44	0.52	38%	2019	1.15	0.24	56%

Table 17. MA DMF Fall Trawl Survey index of abundance, coefficients of variation, and percent of catch that is males from Gulf of Maine strata.

Year	Index (N)	CV	% male	Year	Index (N)	CV	% male
1978	5.07	0.29		1999	1.75	0.33	65%
1979	2.01	0.37		2000	3.47	0.24	63%
1980	0.98	0.45		2001	0.96	0.31	79%
1981	0.46	0.69		2002	5.13	0.48	45%
1982	1.12	0.39	26%	2003	5.75	0.14	47%
1983	5.4	0.32	28%	2004	2.54	0.27	46%
1984	4.15	0.61	10%	2005	1.31	0.43	45%
1985	3.66	0.32	41%	2006	4.01	0.26	36%
1986	1.98	0.19	25%	2007	3.47	0.17	38%
1987	3.03	0.43	36%	2008	8.77	0.23	30%
1988	1.07	0.18	46%	2009	0.87	0.26	41%
1989	0.32	0.59	80%	2010	3.86	0.21	39%
1990	0.25	0.27	56%	2011	8.09	0.24	30%
1991	1.09	0.38	47%	2012	6.08	0.23	34%
1992	1.36	0.38	35%	2013	1.46	0.19	49%
1993	0.4	0.41	38%	2014	1.58	0.34	55%
1994	0.13	0.69	18%	2015	18.75	0.22	83%
1995	3.81	0.28	42%	2016	8.38	0.21	64%
1996	0.53	0.40	10%	2017	13.61	0.31	13%
1997	0.25	0.47	33%	2018	9.52	0.21	22%
1998	0.74	0.49	33%	2019	1.3	0.39	21%

Table 18. ME DMR Settlement Survey indices of abundance (mean number per square meter) by NOAA statistical area for all sizes encountered and crabs less than 13 mm carapace width with coefficients of variation.

Year	513				512				511			
	All Sizes		<13 mm CW		All Sizes		<13 mm CW		All Sizes		<13 mm CW	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1989	0.02	1.00	0.00									
1990	0.14	0.50	0.00									
1991	0.09	0.78	0.00									
1992	0.11	0.45	0.00									
1993	0.00		0.00									
1994	0.39	0.46	0.09	0.56								
1995	0.20	0.35	0.00									
1996	0.84	0.45	0.11	1.00								
1997	0.43	0.47	0.00									
1998	0.55	0.35	0.11	0.45								
1999	3.09	0.31	1.54	0.38								
2000	6.75	0.09	1.83	0.24	1.17	0.13	0.04	1.34				
2001	2.87	0.10	0.36	0.53	1.13	0.15	0.22	0.56	0.16	0.44	0.04	1.00
2002	4.73	0.05	0.71	0.23	0.55	0.19	0.00		0.04	1.00	0.00	
2003	2.58	0.10	0.48	0.40	0.76	0.19	0.00		0.03	1.00	0.00	
2004	1.95	0.13	0.37	0.48	0.63	0.22	0.06	1.28	0.00		0.00	
2005	0.98	0.24	0.17	1.27	0.55	0.21	0.00		0.04	1.00	0.00	
2006	2.63	0.11	0.77	0.24	1.42	0.13	0.00		0.16	0.63	0.00	
2007	2.55	0.08	0.82	0.23	0.57	0.25	0.03	2.09	0.16	0.56	0.00	
2008	2.09	0.15	0.40	0.85	0.51	0.31	0.02	2.88	0.16	0.63	0.03	1.00
2009	3.01	0.14	1.23	0.24	0.49	0.21	0.02	1.93	0.06	1.00	0.00	
2010	2.52	0.11	0.83	0.32	0.36	0.40	0.01	2.82	0.07	0.57	0.03	1.00
2011	2.91	0.10	1.22	0.21	0.77	0.18	0.13	0.66	0.00		0.00	
2012	5.60	0.07	3.19	0.14	2.42	0.09	1.57	0.12	2.22	0.21	1.50	0.20
2013	3.64	0.06	0.71	0.25	2.50	0.05	0.18	0.47	1.88	0.17	0.35	0.37
2014	3.75	0.05	0.85	0.16	2.25	0.07	0.30	0.52	1.85	0.25	0.35	0.74
2015	3.34	0.10	1.72	0.16	1.42	0.14	0.33	0.53	0.57	0.39	0.04	1.00
2016	4.20	0.06	2.64	0.09	3.35	0.05	1.53	0.14	1.26	0.34	0.60	0.45
2017	5.49	0.13	2.30	0.18	2.56	0.18	0.45	0.22	1.85	0.09	0.47	0.28
2018	4.98	0.15	3.10	0.21	2.95	0.14	1.15	0.22	2.27	0.44	1.14	0.49
2019	2.27	0.15	0.68	0.20	2.18	0.13	0.37	0.16	0.85	0.18	0.38	0.50

Table 19. Results of Kolmogorov-Smirnov tests comparing shape and location of length compositions between regional NEFSC trawl survey indices by period and season. Significant p-values (<0.05) are bolded and italicized.

Survey X	Survey Y	Period	Season	p-value
GB	SNE	Early	Spring	***0.013***
GB	SNE	Early	Fall	***0.001***
GB	SNE	Late	Spring	***0***
GB	SNE	Late	Fall	***0***
GOM	GB	Early	Spring	***0***
GOM	GB	Early	Fall	***0***
GOM	GB	Late	Spring	***0***
GOM	GB	Late	Fall	***0***
GOM	SNE	Early	Spring	***0***
GOM	SNE	Early	Fall	***0***
GOM	SNE	Late	Spring	***0***
GOM	SNE	Late	Fall	0.196
Core	GOM	Early	Spring	***0***
Core	GOM	Early	Fall	***0***
Core	GOM	Late	Spring	***0***
Core	GOM	Late	Fall	0.149
Core	GB	Early	Spring	***0***
Core	GB	Early	Fall	***0.023***
Core	GB	Late	Spring	***0***
Core	GB	Late	Fall	***0***
Core	SNE	Early	Spring	0.138
Core	SNE	Early	Fall	0.255
Core	SNE	Late	Spring	0.22
Core	SNE	Late	Fall	0.76

Table 20. Results of Kolmogorov-Smirnov tests comparing shape and location of length compositions between Gulf of Maine trawl survey indices by period and season. Significant p-values (<0.05) are bolded and italicized.

Survey X	Survey Y	Period	Season	p-value
MA DMF	NEFSC	Early	Spring	0.148
MA DMF	NEFSC	Early	Fall	***0***
MA DMF	NEFSC	Late	Spring	***0***
MA DMF	NEFSC	Late	Fall	***0***
MA DMF	ME/NH	Early	Spring	***0.001***
MA DMF	ME/NH	Early	Fall	***0***
MA DMF	ME/NH	Late	Spring	***0.025***
MA DMF	ME/NH	Late	Fall	0.054
NEFSC	ME/NH	Early	Spring	***0***
NEFSC	ME/NH	Early	Fall	***0***
NEFSC	ME/NH	Late	Spring	***0***
NEFSC	ME/NH	Late	Fall	***0***

10 FIGURES

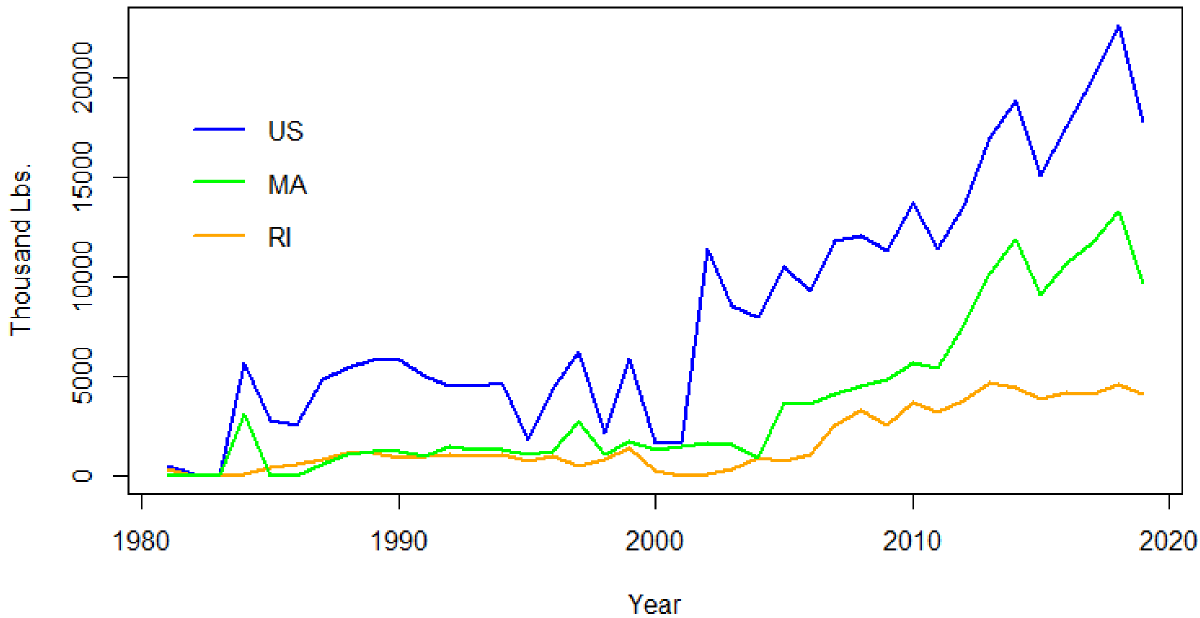


Figure 1. Total Jonah crab landings from U.S. waters and from states that are primary contributors to total landings.

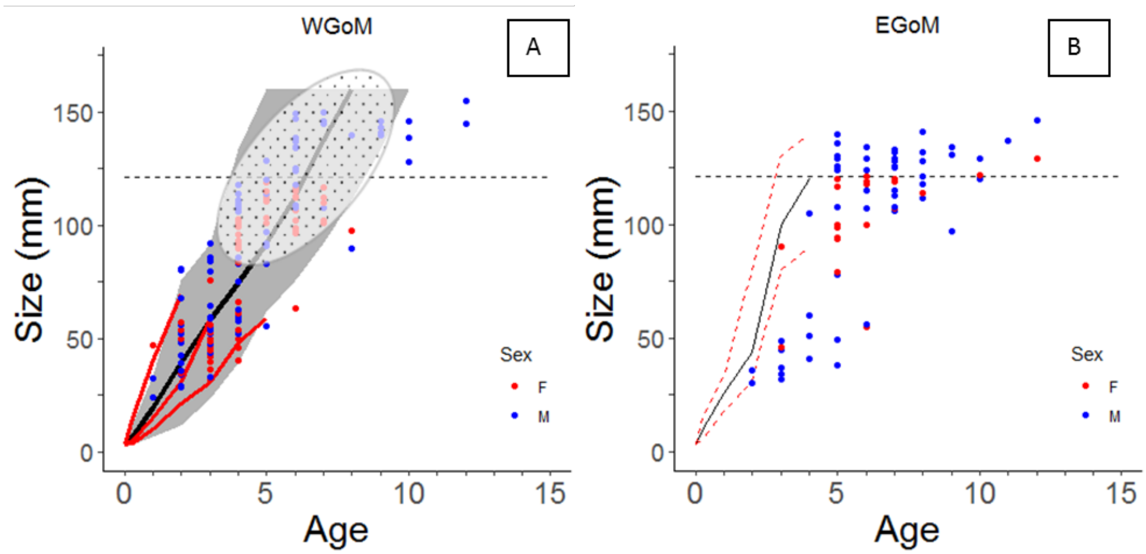


Figure 2. Size at age estimated for all methods for each contrasting thermal regime. A) WGOM, where direct band counts are shown as points, solid black line denotes growth model average with the gray area representing the 95% confidence interval; solid red lines represent the estimated range of age at size from length-frequency analysis. The dotted area represents the areas of increased correlation between settlement and time lagged survey catch at sizes. B) EGOM with the black line representing average size at age for the 2012 cohort in EGOM following the peak of settlement from ALSI through to the ME-NH trawl survey, with the dashed curves representing the range of sizes. The horizontal line denotes legal harvestable size.

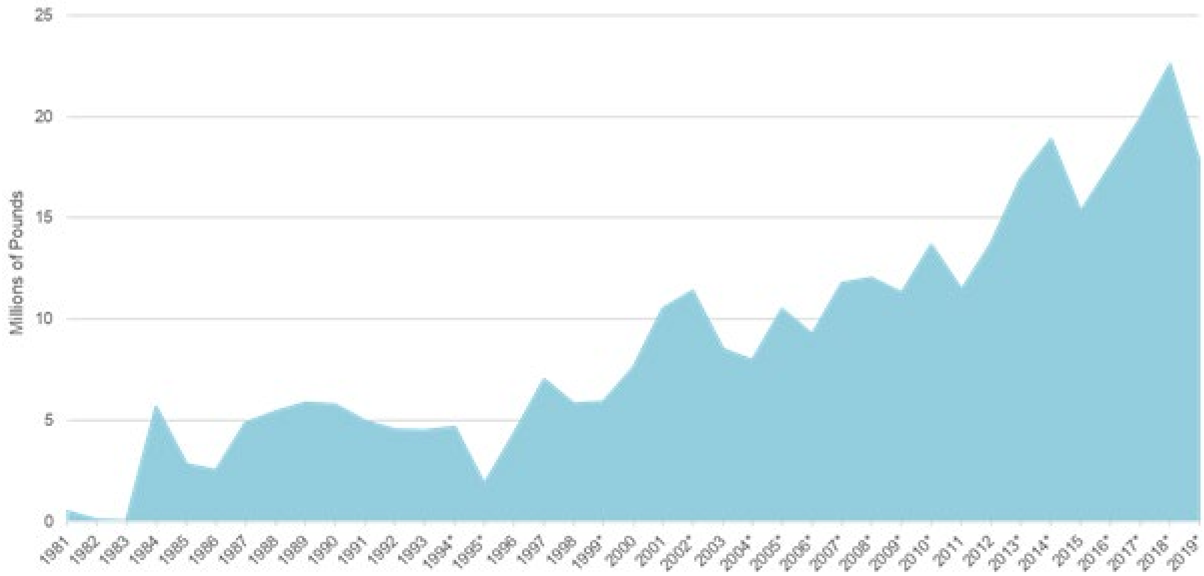


Figure 3. Validated coastwide Jonah crab landings from the ACCSP Data Warehouse. Asterisks indicate confidential landings data have been redacted from the total.

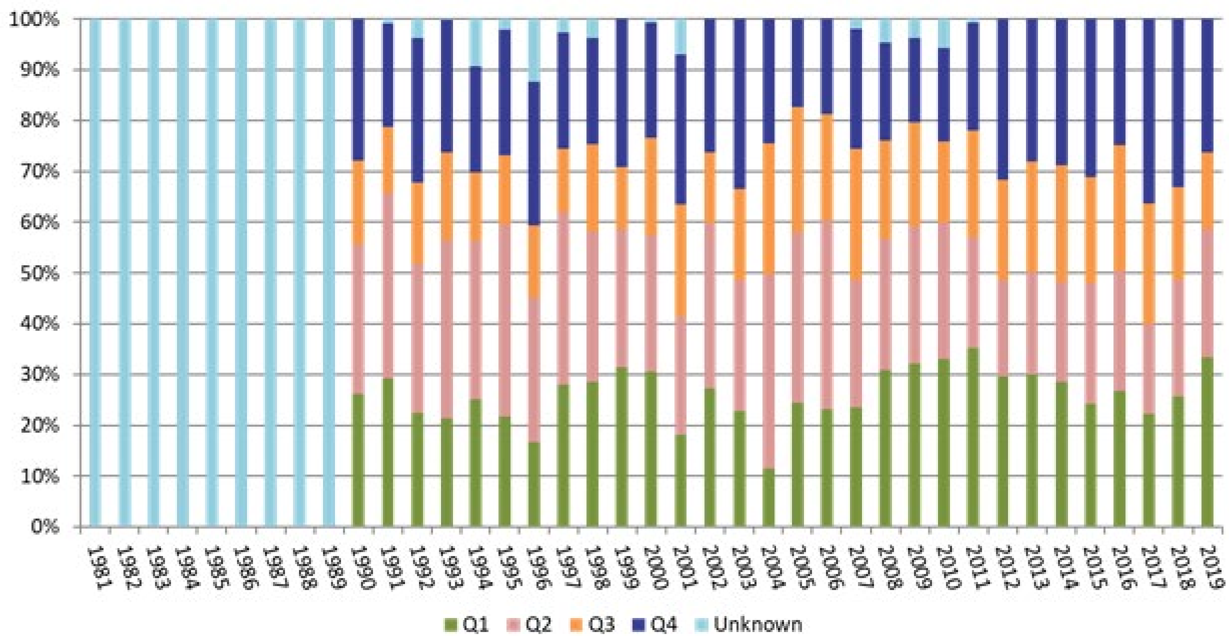


Figure 4. Proportion of coastwide Jonah crab landings by quarter and with unknown quarter. Quarters are three month time periods starting with January-March in quarter one. These seasonality data still need to be validated with state partners.

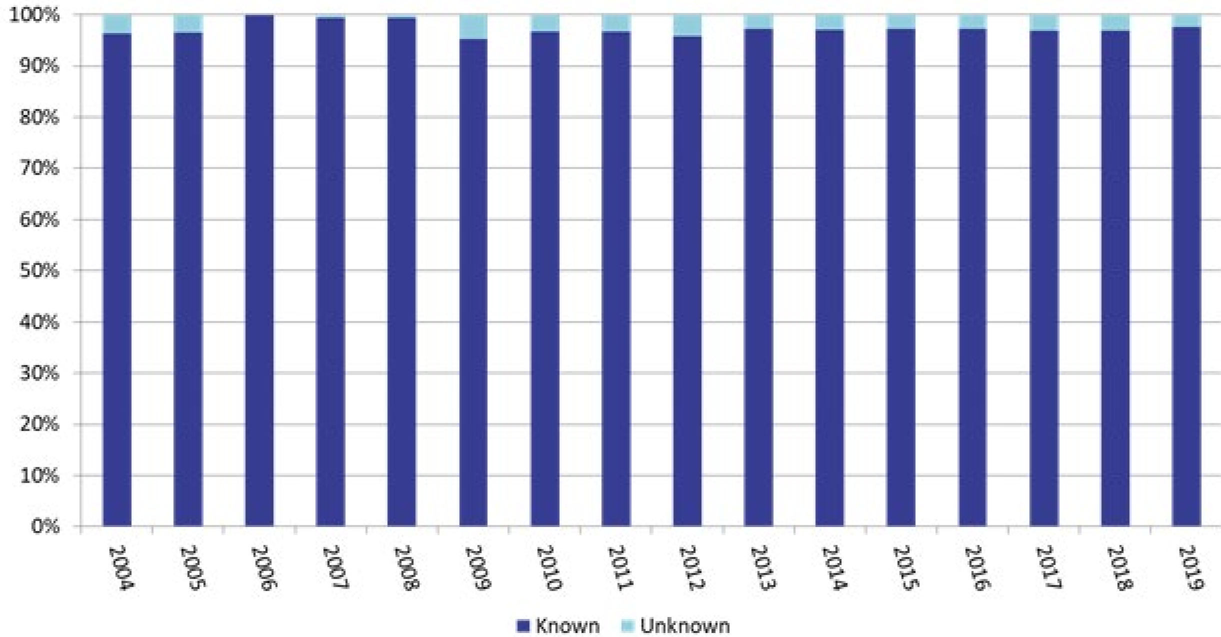


Figure 5. Proportion of Jonah crab landings with known and unknown statistical area from VTRs.

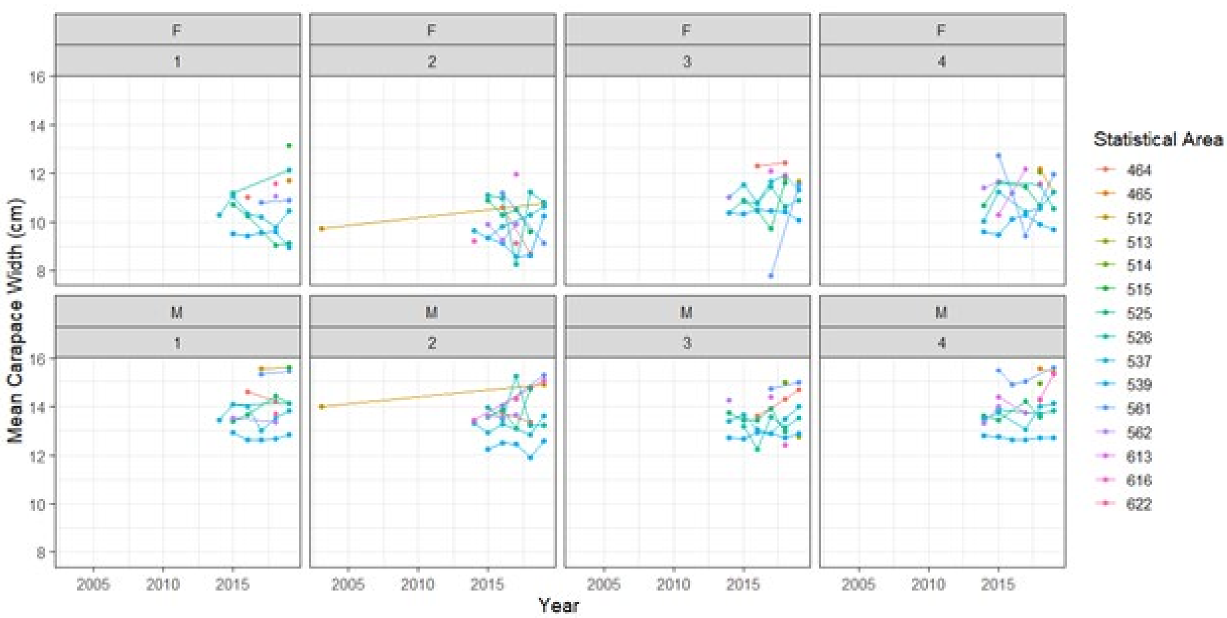


Figure 6. Mean size of Jonah crab sampled during sea sampling trips by sex, (top figure label), quarter (bottom figure label), and statistical area.

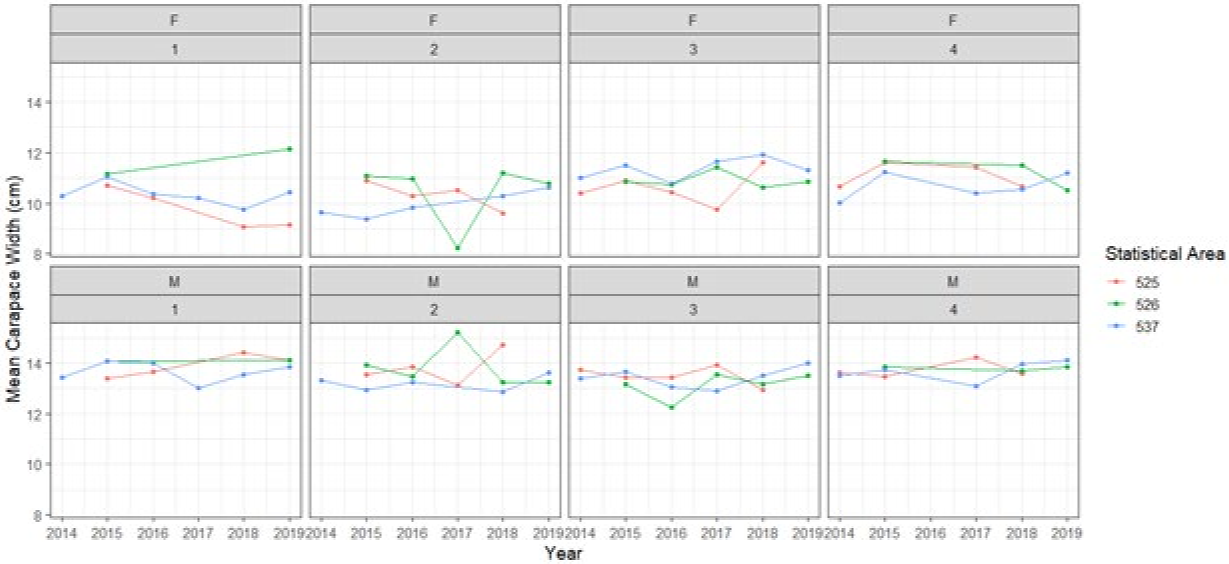


Figure 7. Mean size of Jonah crab sampled during sea sampling trips by sex, (top figure label) and quarter (bottom figure label) in core statistical areas.

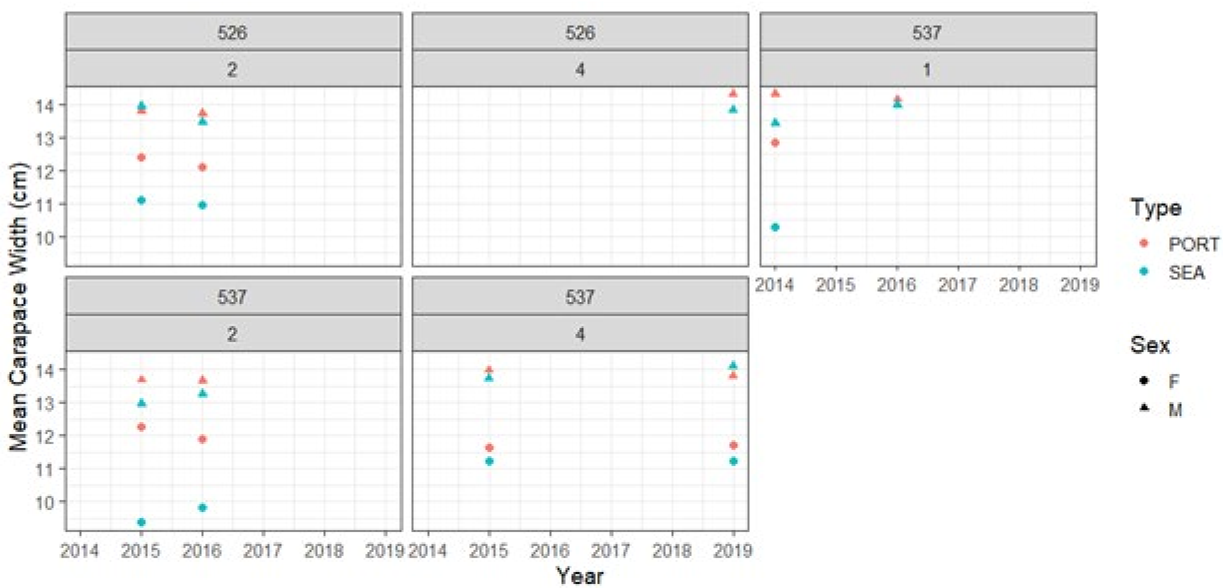


Figure 8. Mean size of Jonah crab sampled during biosampling trips by trip type, sex, statistical area (top figure label), and quarter (bottom figure label) in core statistical areas.

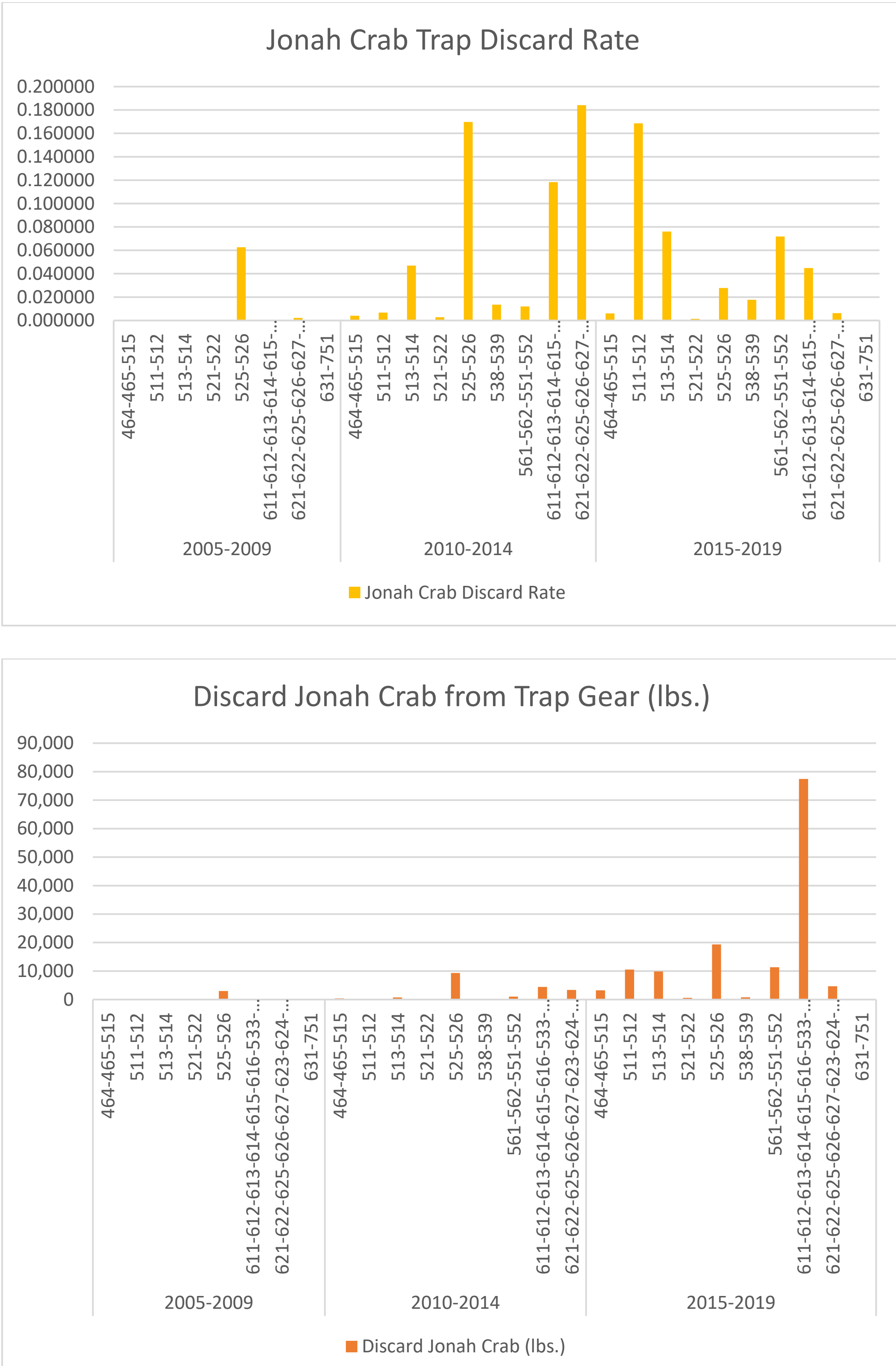
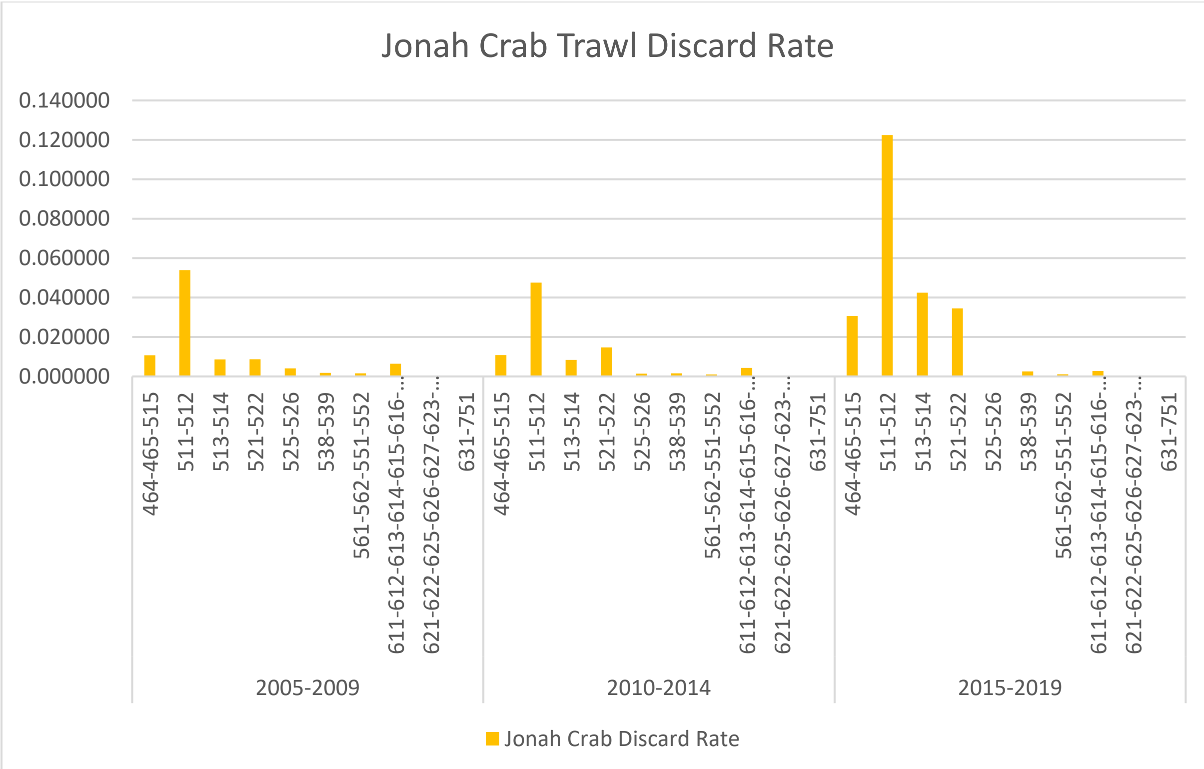


Figure 9. Trap gear discard estimates from data collected during the Northeast Fisheries Science Center's Northeast Fisheries Observer and At-Sea Monitoring programs.



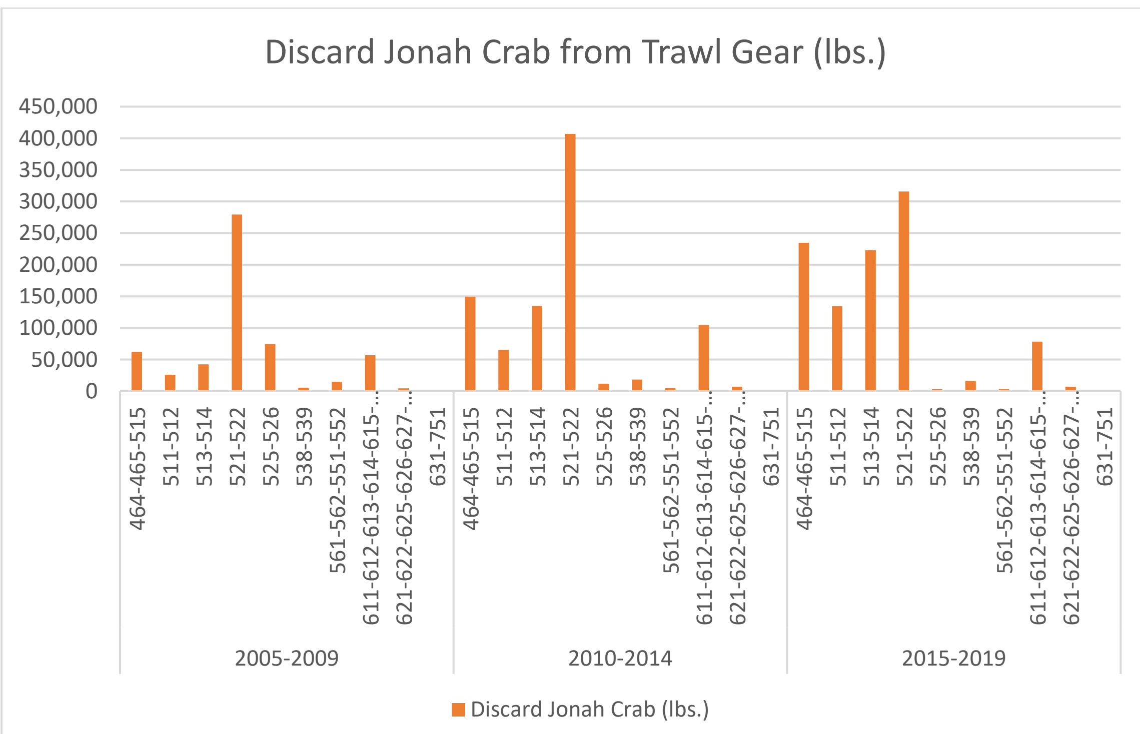
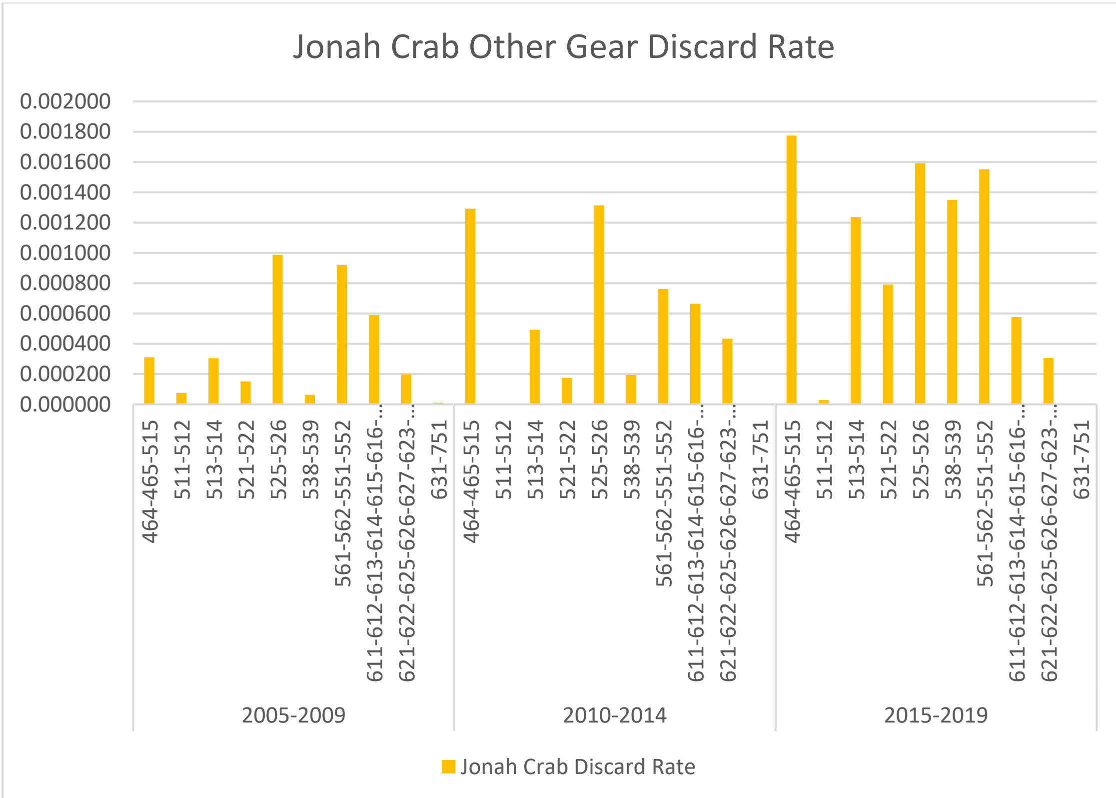


Figure 10. Trawl gear discard estimates from data collected during the Northeast Fisheries Science Center's Northeast Fisheries Observer and At-Sea Monitoring programs.



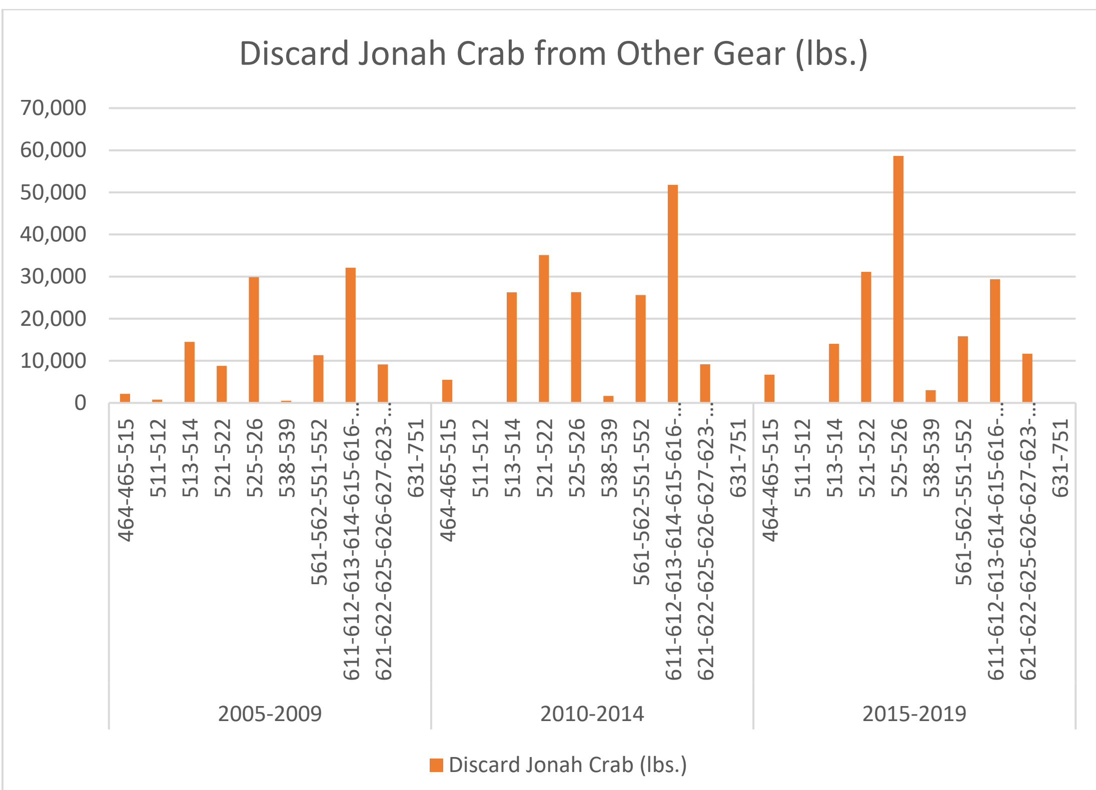


Figure 11. Other gear discard estimates from data collected during the Northeast Fisheries Science Center's Northeast Fisheries Observer and At-Sea Monitoring programs.

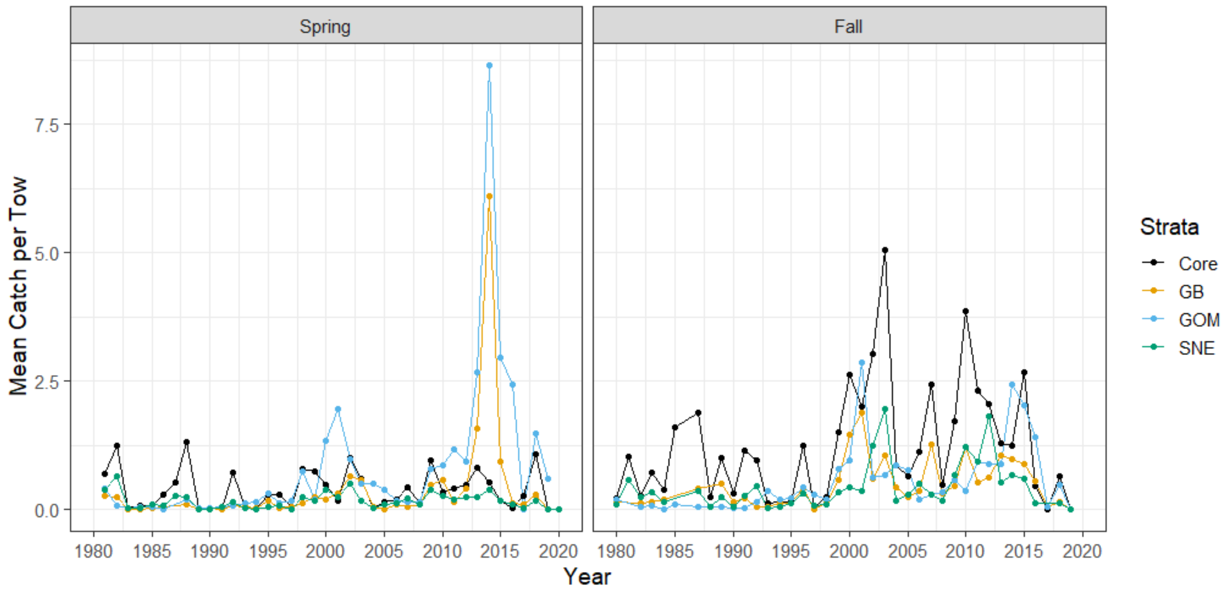


Figure 12. NEFSC trawl survey indices from regions sampled.

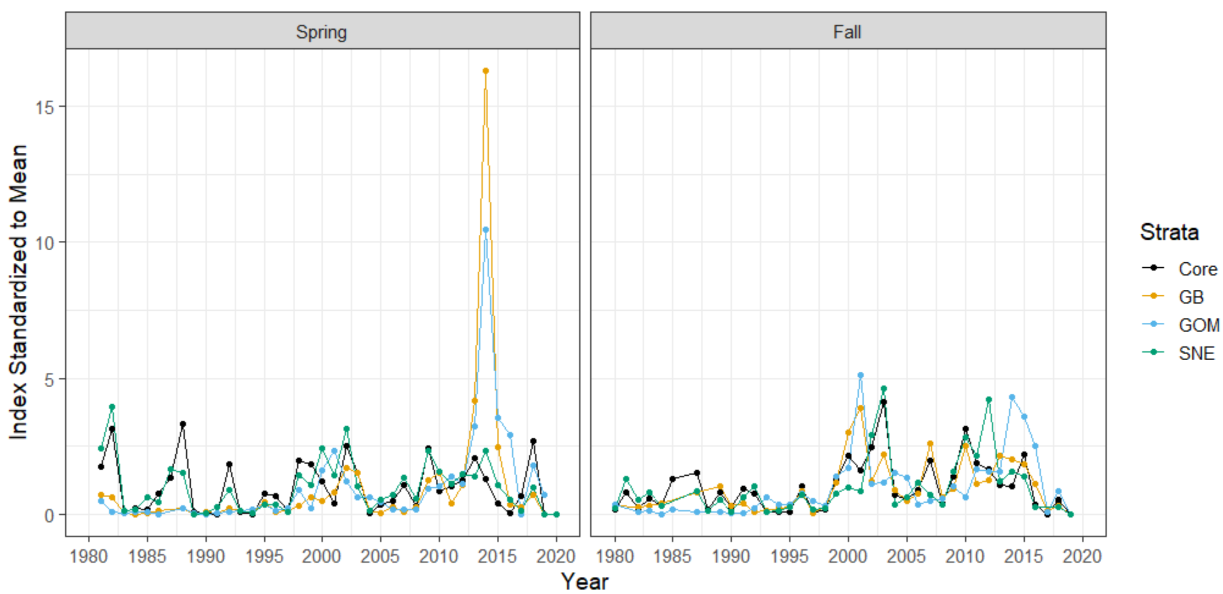


Figure 13. NEFSC trawl survey indices from regions sampled scaled to time series means.

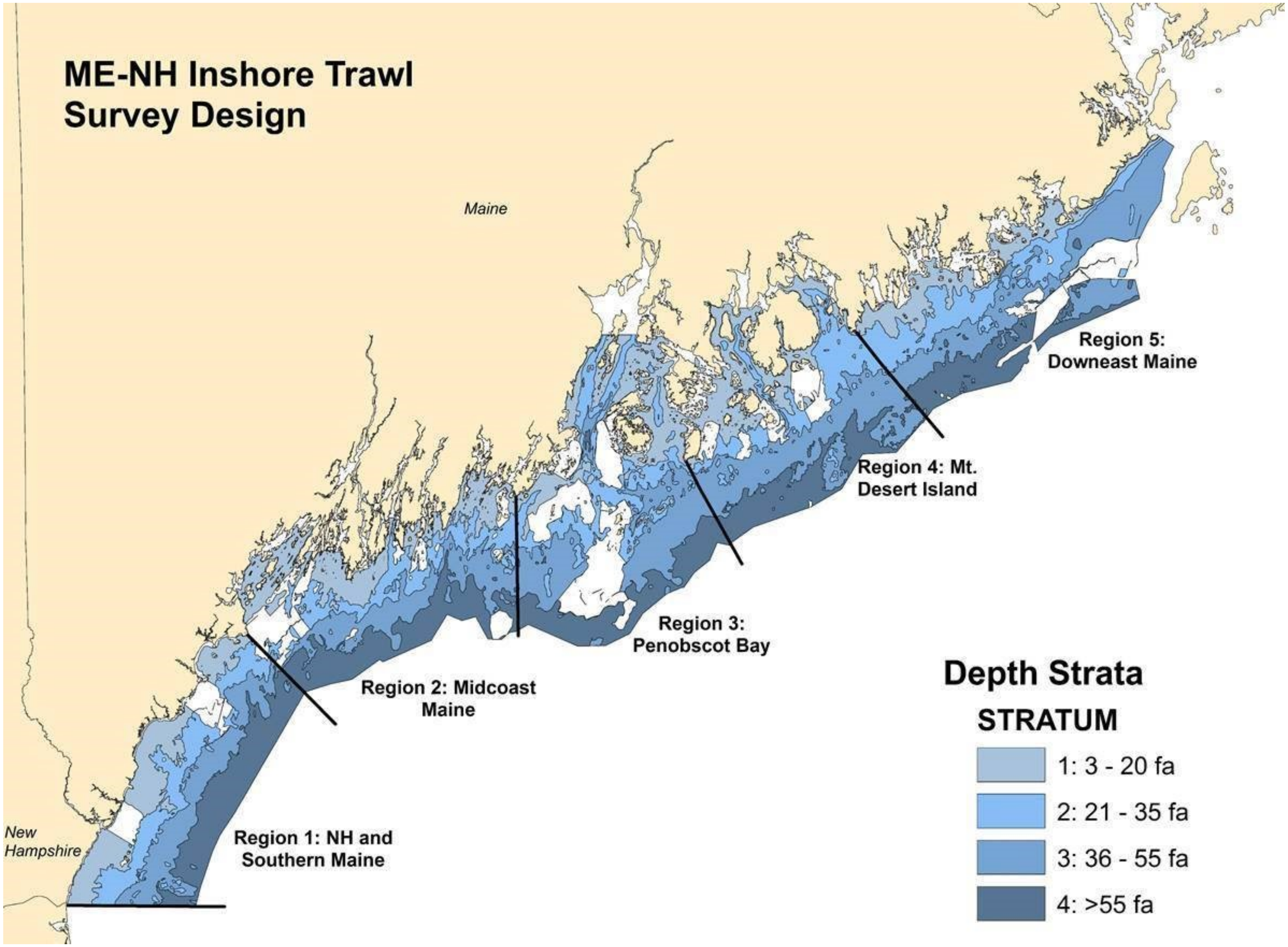


Figure 14. Sampling regions and depth strata for the Maine/New Hampshire trawl survey.

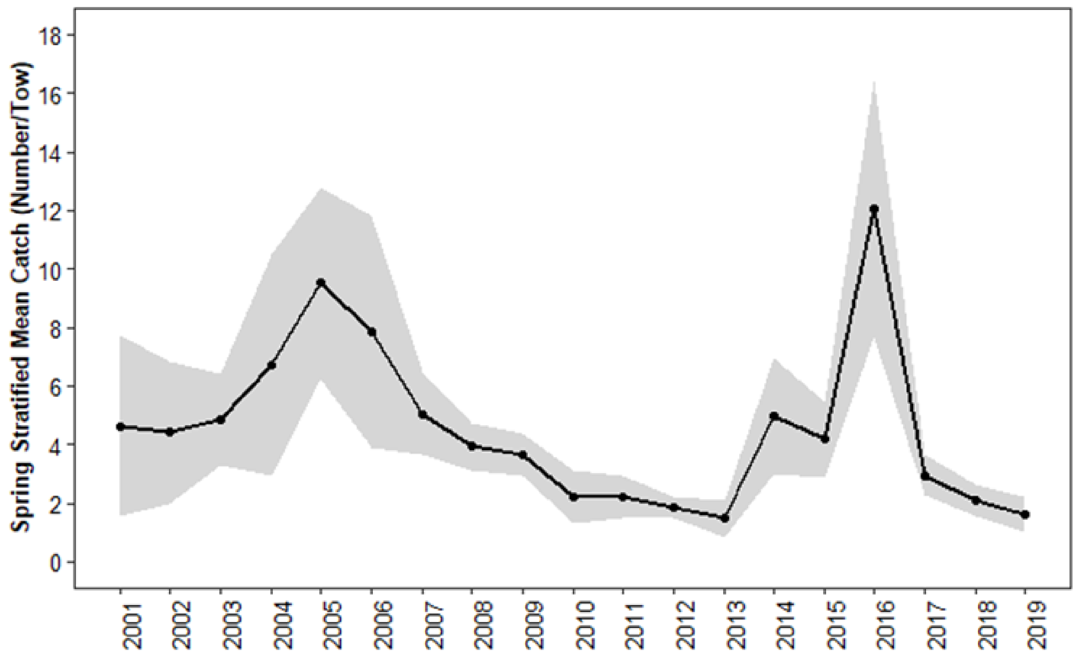


Figure 15. ME/NH spring trawl survey index of abundance (solid line with circles) with 95% confidence interval (shaded region).

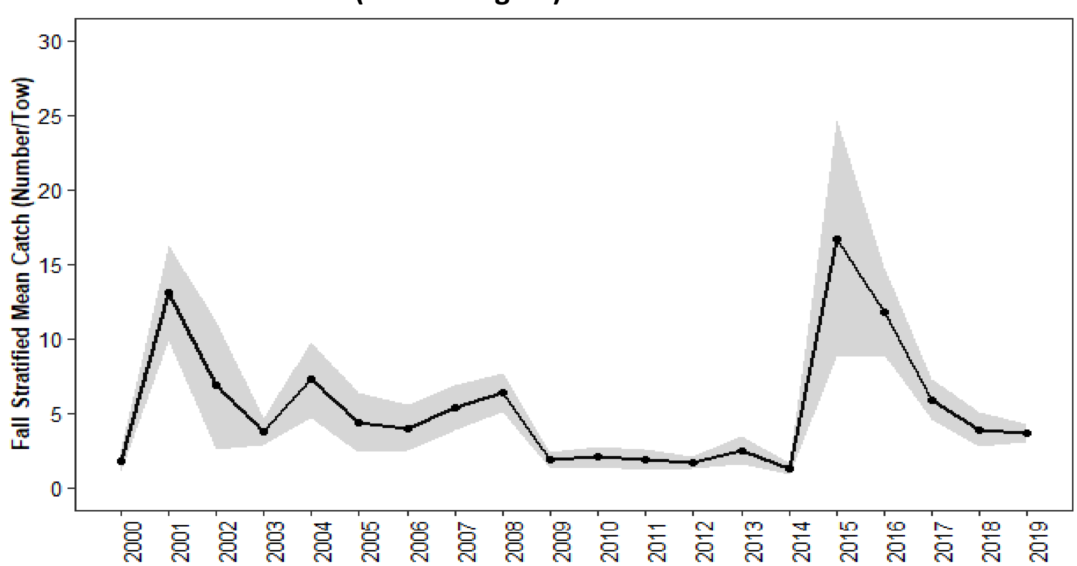


Figure 16. ME/NH fall trawl survey index of abundance (solid line with circles) with 95% confidence interval (shaded region).

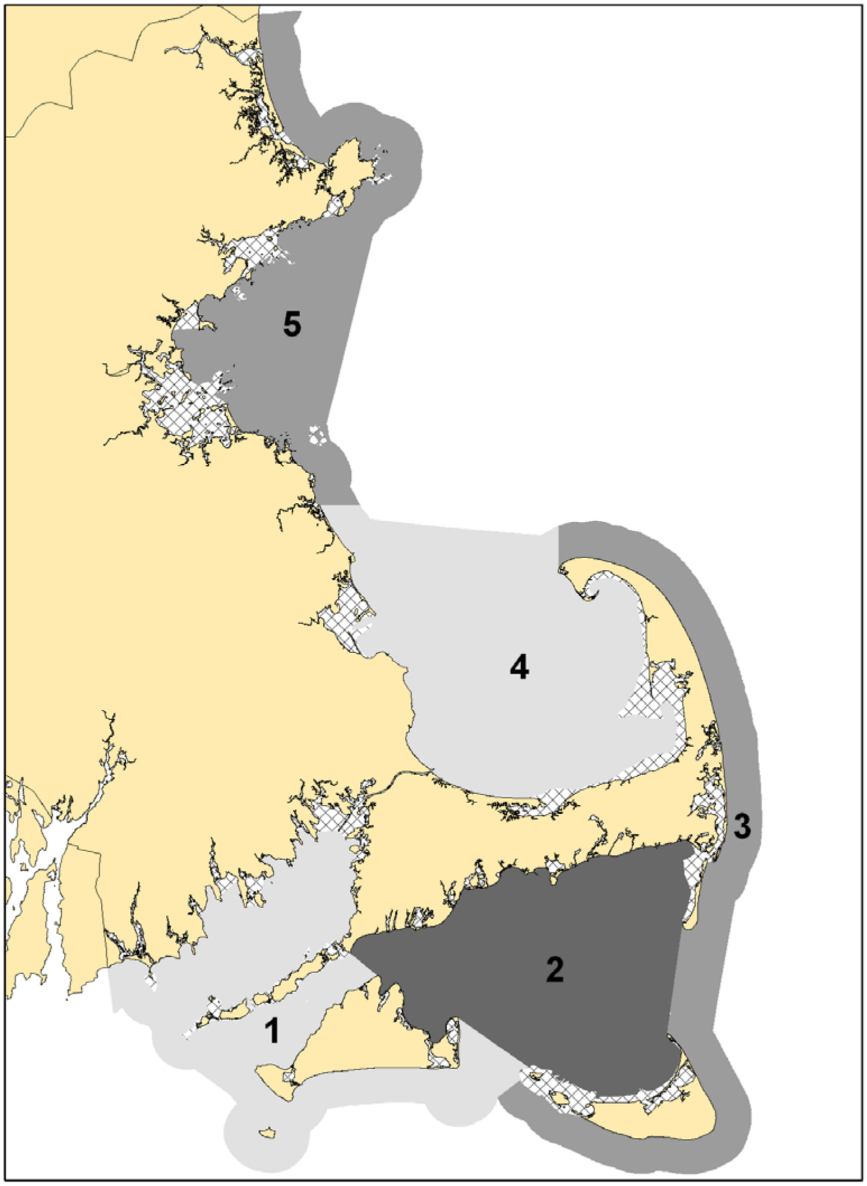


Figure 17. Sampling regions for the MA DMF trawl survey.

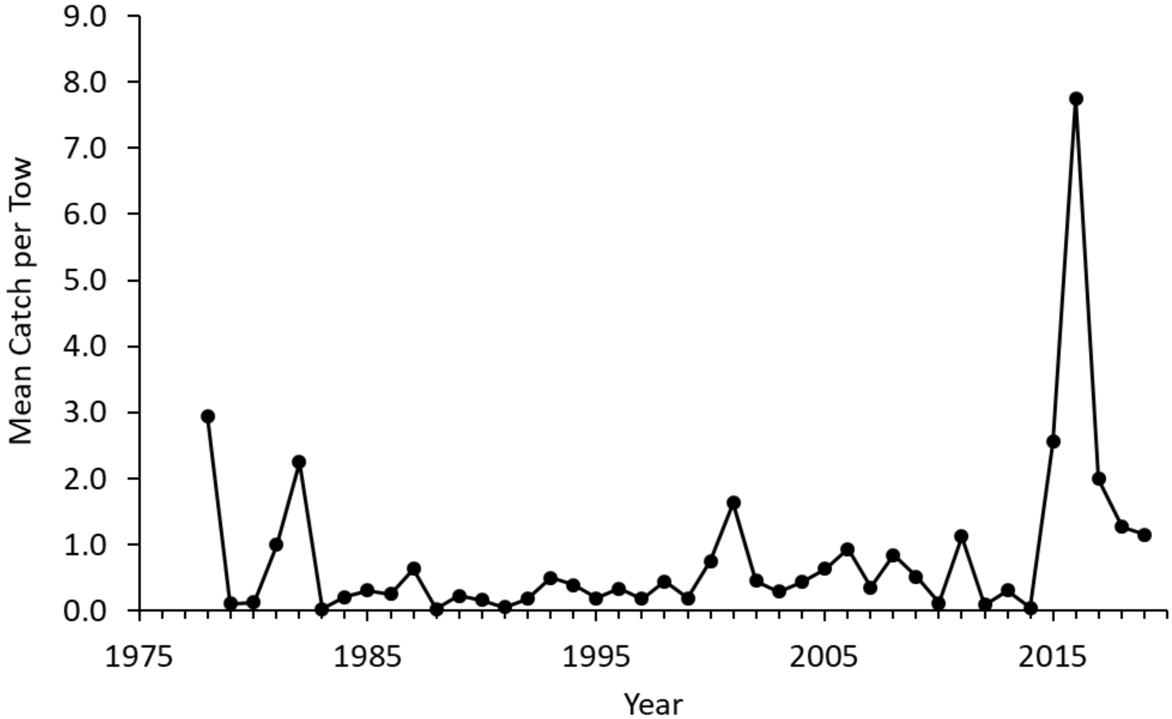


Figure 18. MA DMF Spring Trawl Survey index of abundance for Gulf of Maine strata.

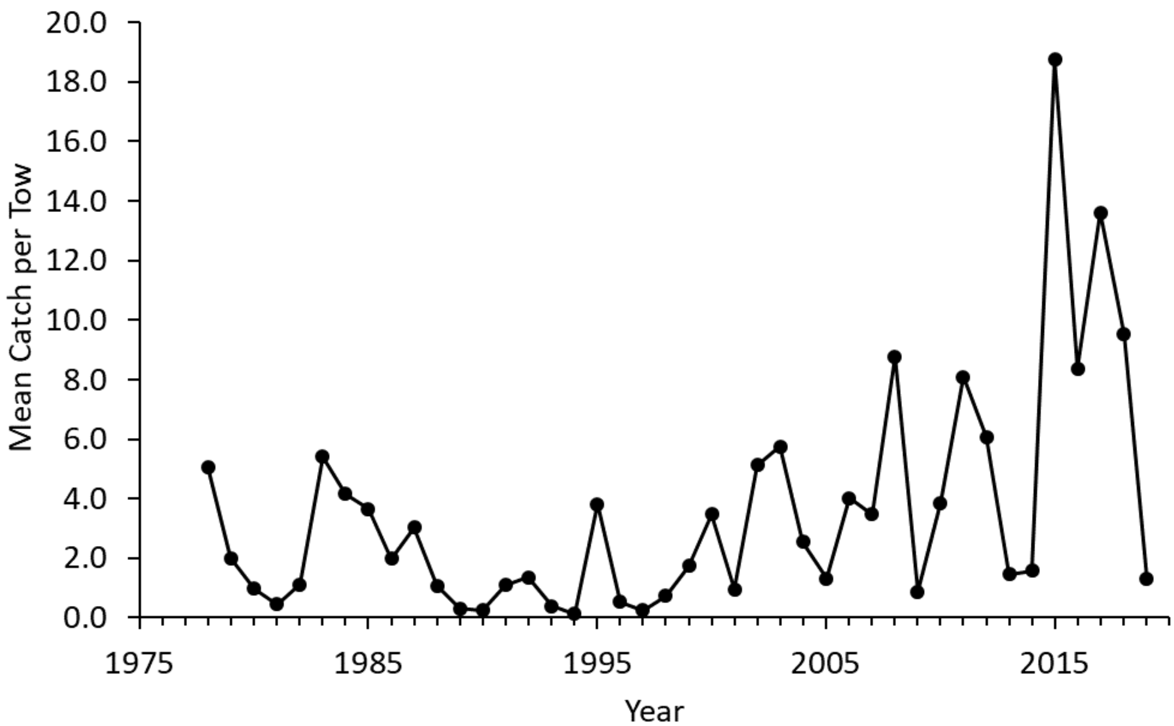


Figure 19. MA DMF Fall Trawl Survey index of abundance for Gulf of Maine strata.

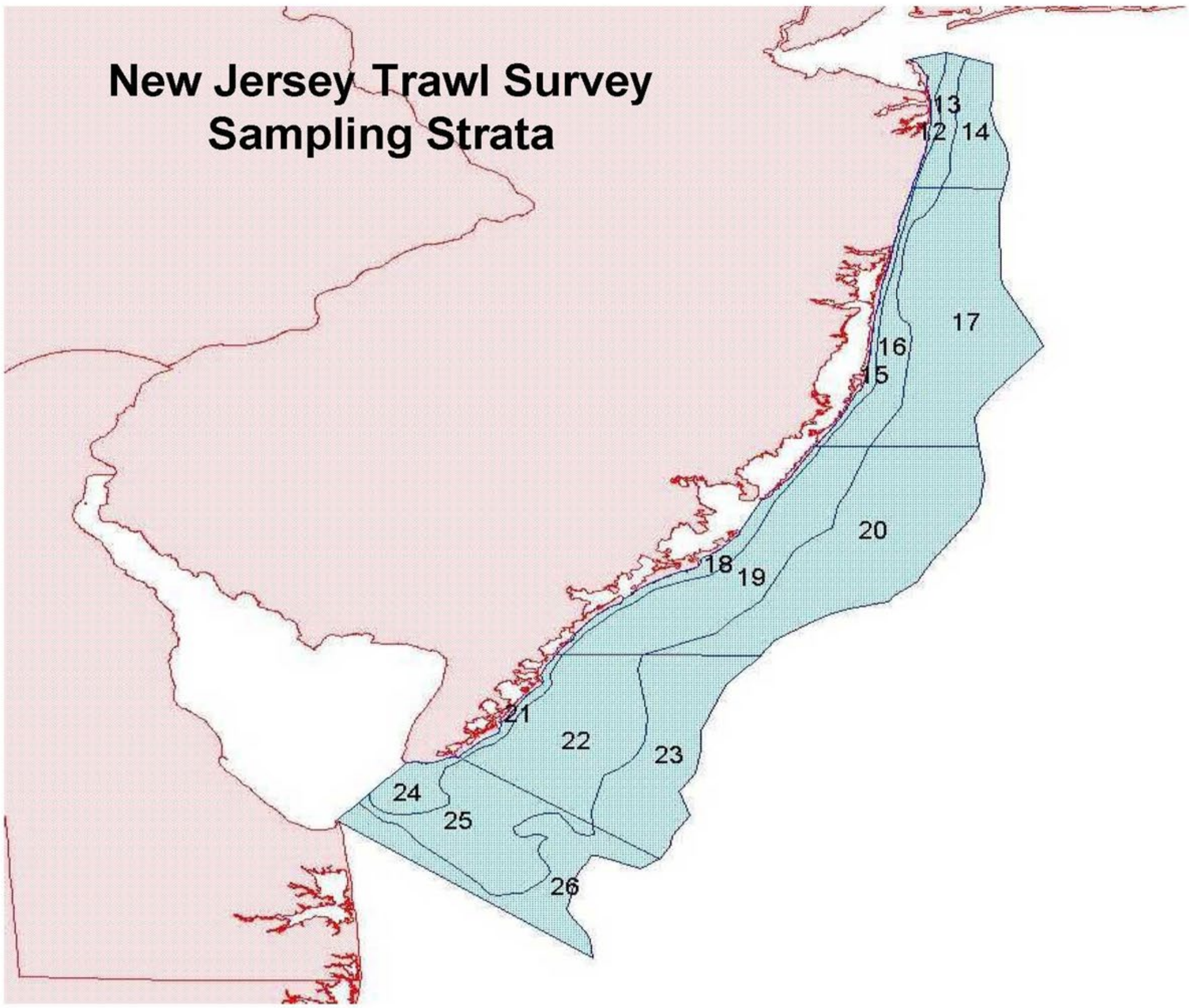


Figure 20. Sampling strata for the New Jersey Ocean Trawl Survey.

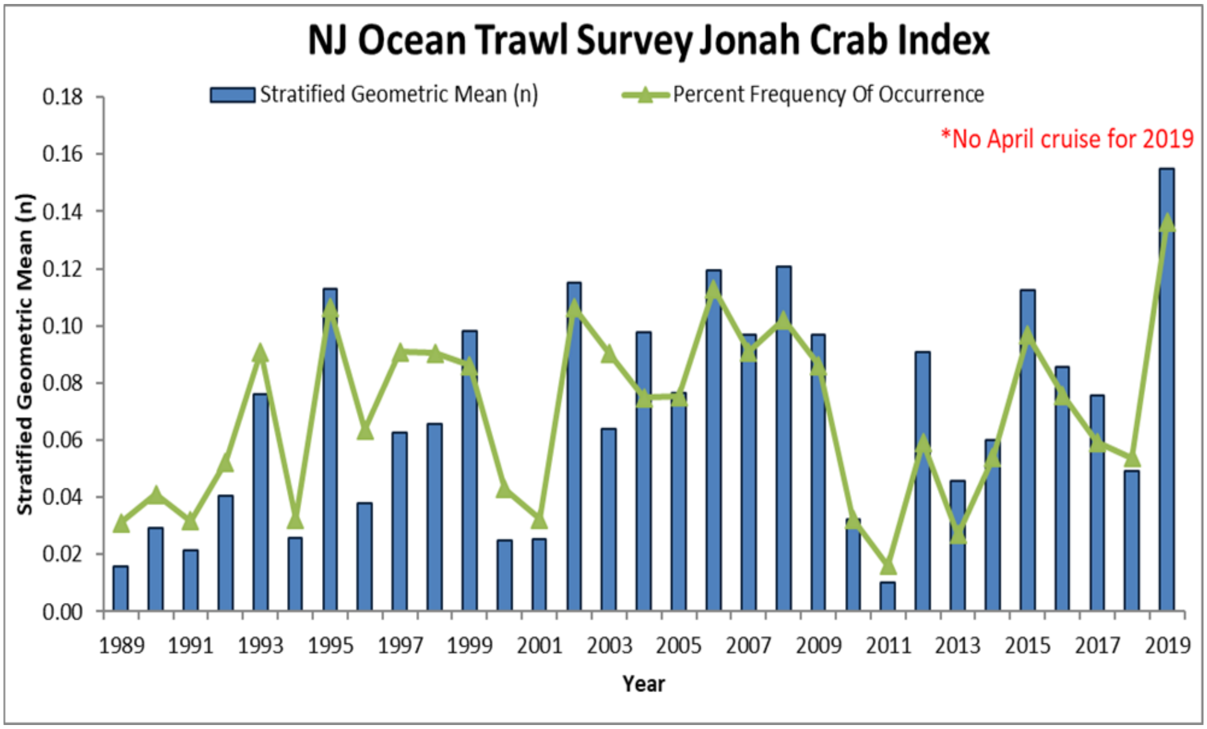


Figure 21. Jonah crab index of abundance and percent frequency occurrence on tows conducted by the New Jersey Ocean Trawl Survey.

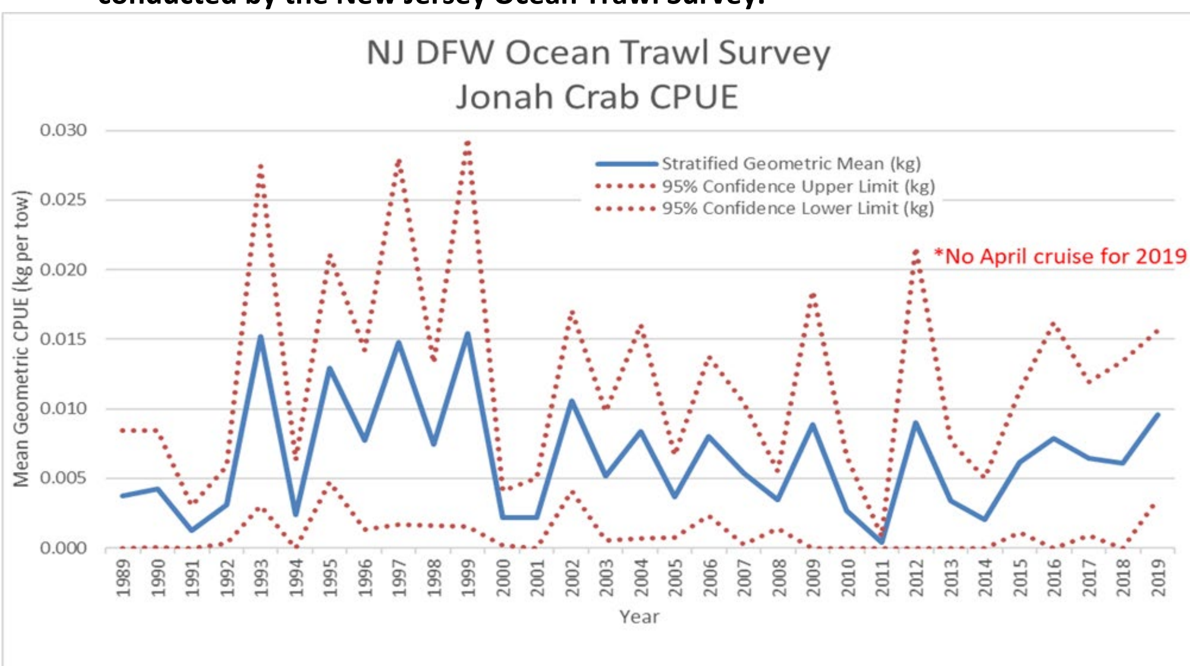


Figure 22. Jonah crab index of biomass for the New Jersey Ocean Trawl Survey.

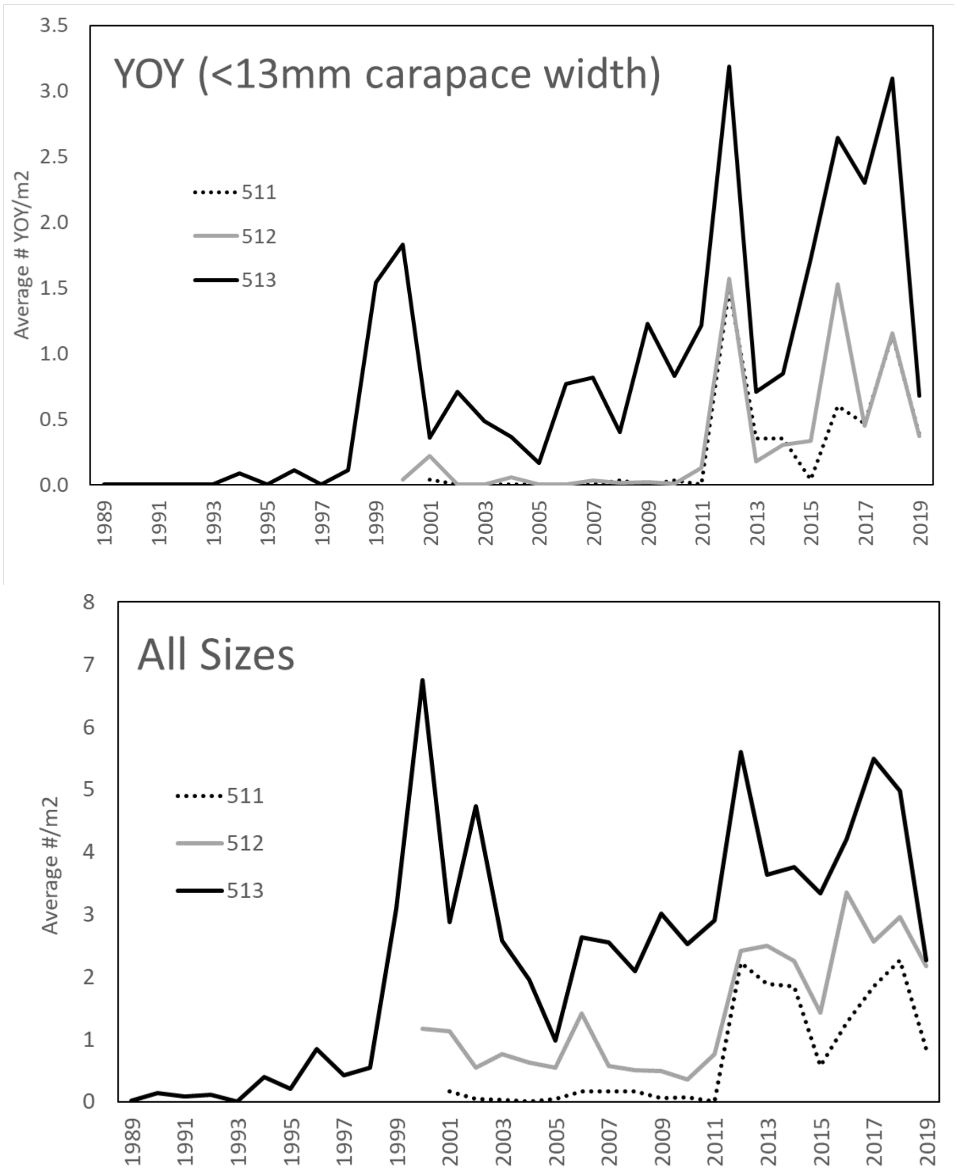


Figure 23. Indices of abundance by NOAA statistical area from the Maine DMR Settlement Survey.

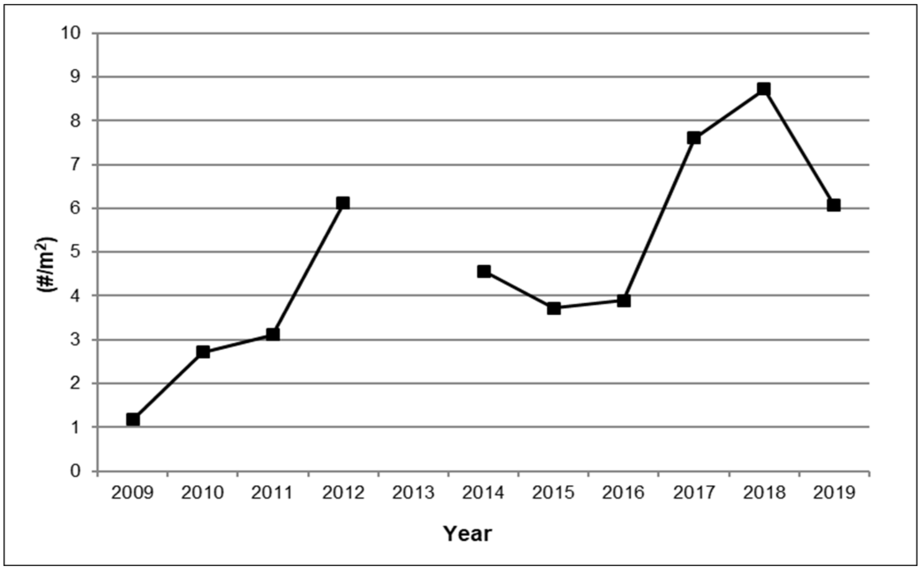


Figure 24. Index of abundance from the NHF&G American Lobster Settlement Survey.

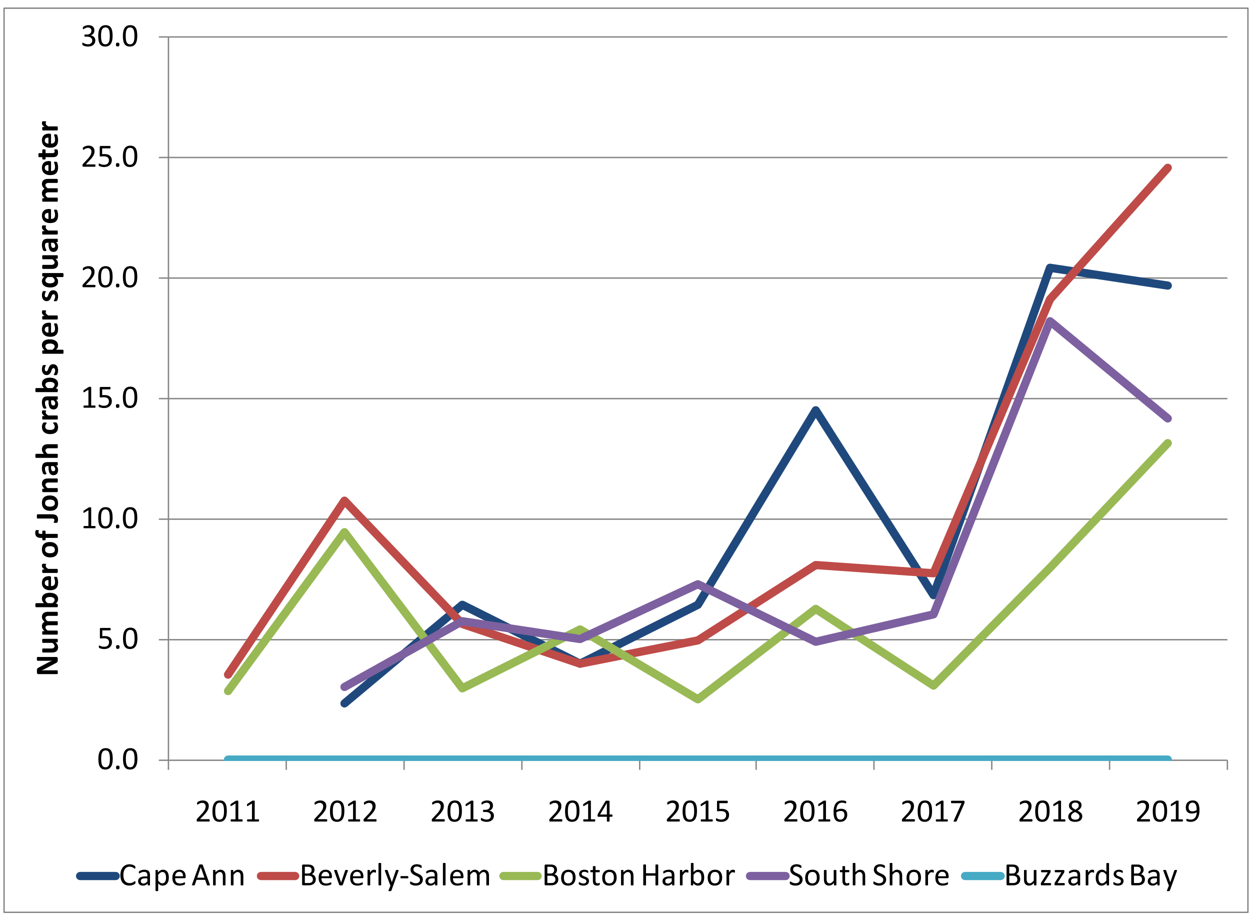


Figure 25. Indices of Jonah crab settlement by sampling area from the MA DMF Settlement Survey.

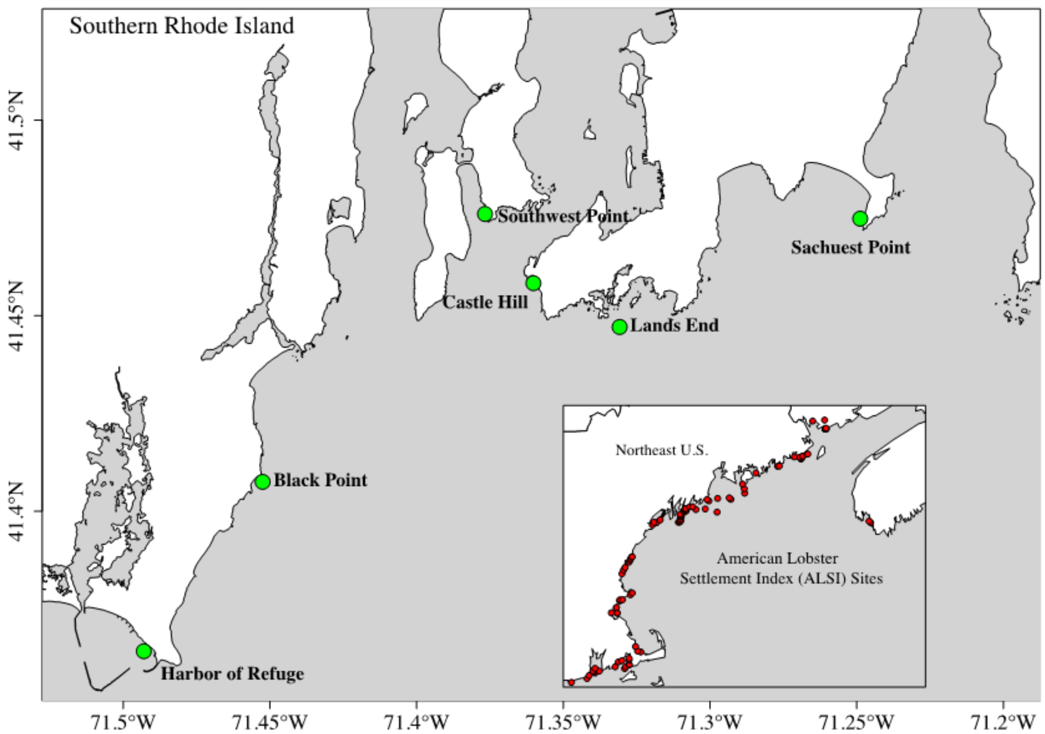


Figure 26. Map of six sites sampled by RIDEM DMF in yearly settlement survey.

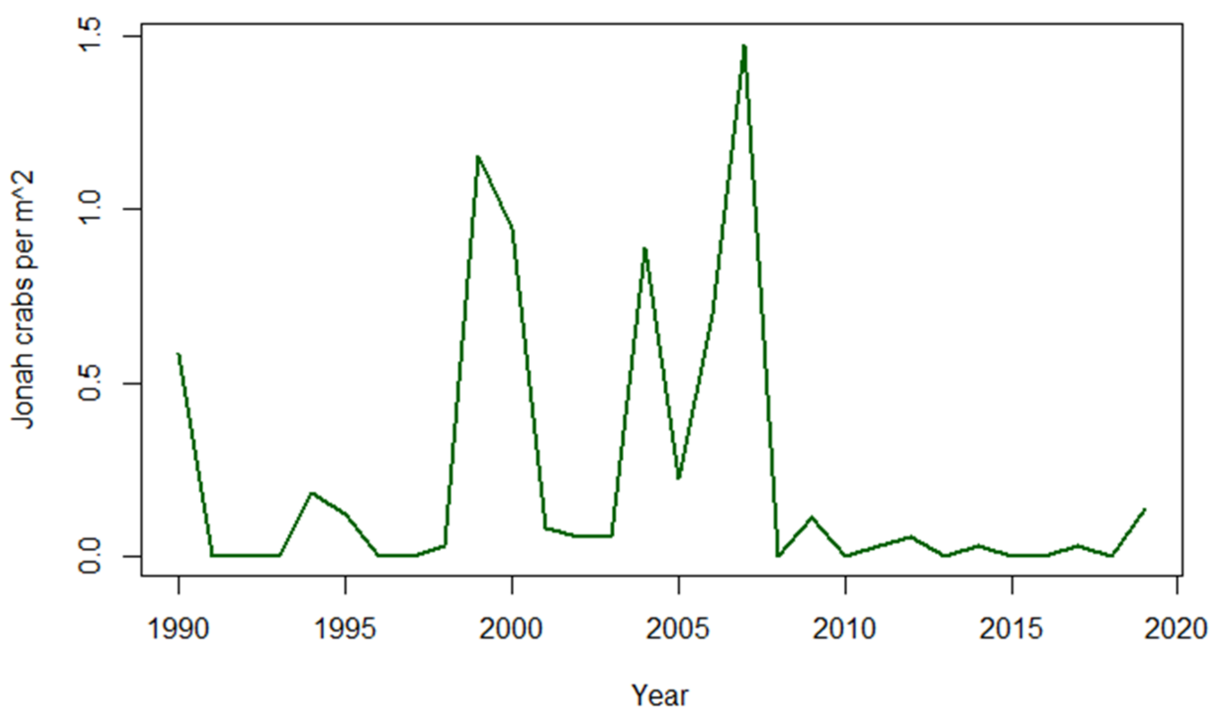


Figure 27. RIDEM DMF settlement survey index of abundance.

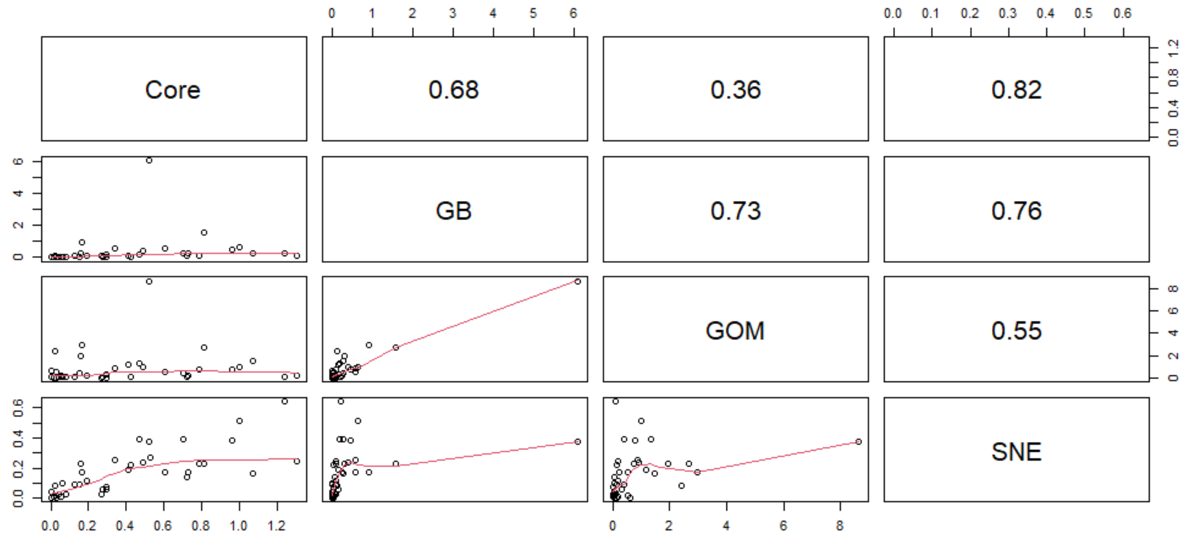


Figure 28. Spearman's rank-order correlation of NEFSC spring trawl survey indices from regions sampled. Plots in the lower panels are pairwise indices (black circles) from regions on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from regions on the corresponding column and row of the diagonal.

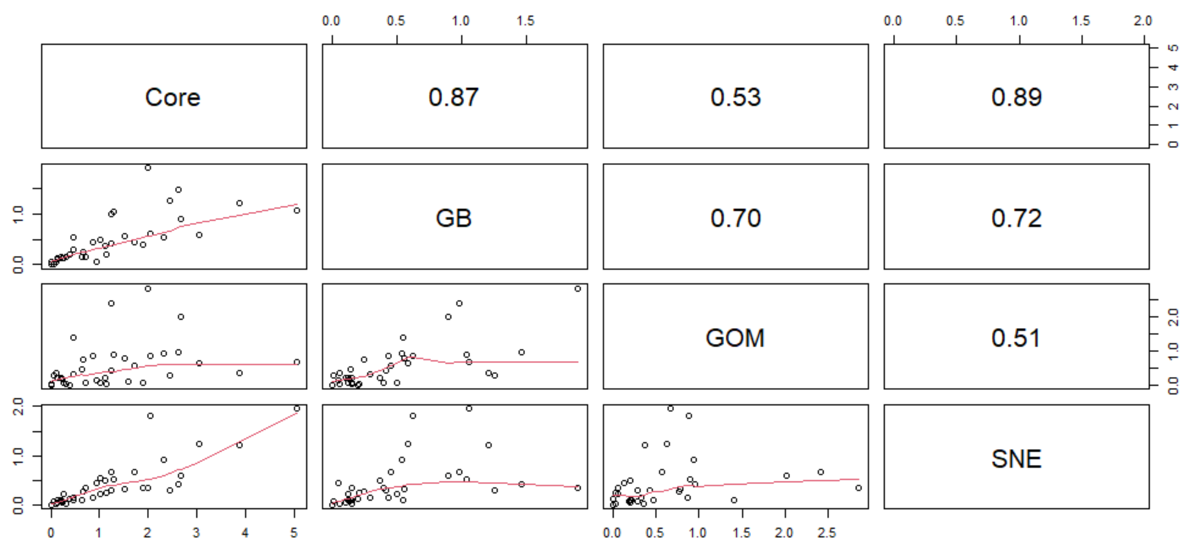


Figure 29. Spearman's rank-order correlation of NEFSC fall trawl survey indices from regions sampled. Plots in the lower panels are pairwise indices (black circles) from regions on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from regions on the corresponding column and row of the diagonal.

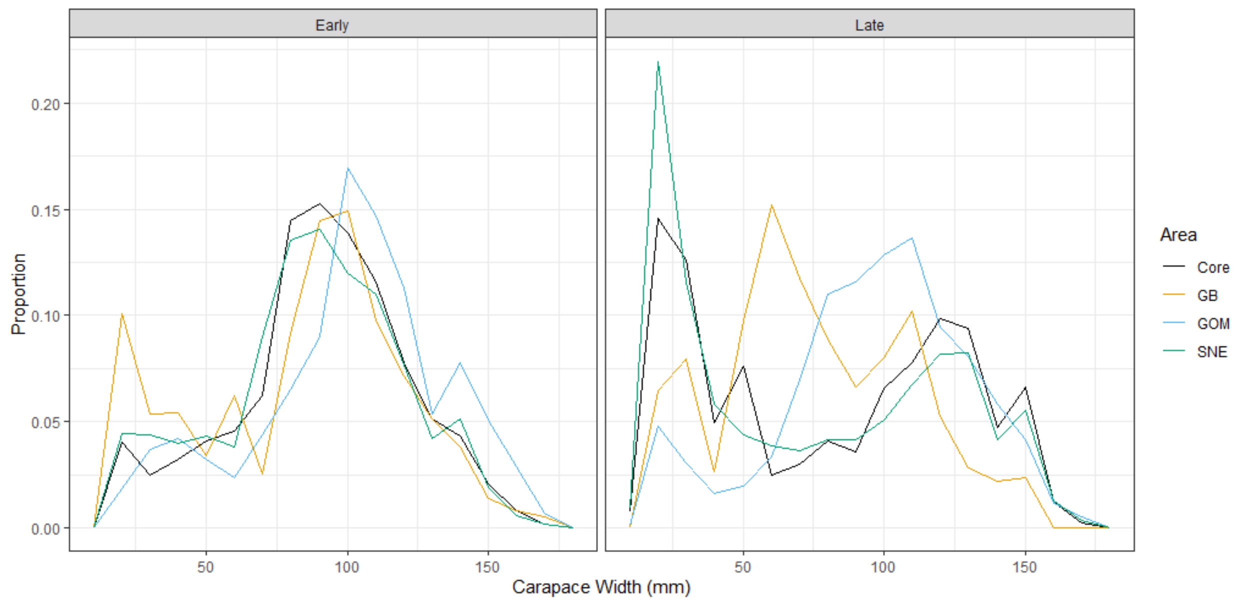


Figure 30. Length compositions of Jonah crab caught by period during the NEFSC spring trawl survey from regions sampled.

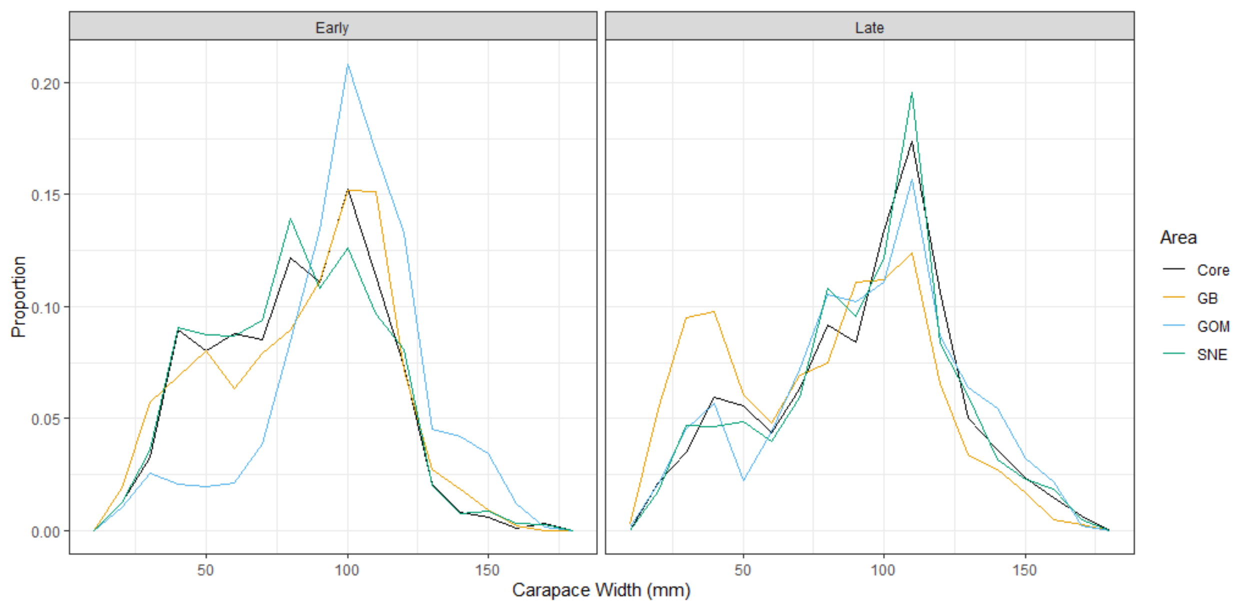


Figure 31. Length compositions of Jonah crab caught by period during the NEFSC fall trawl survey from regions sampled.

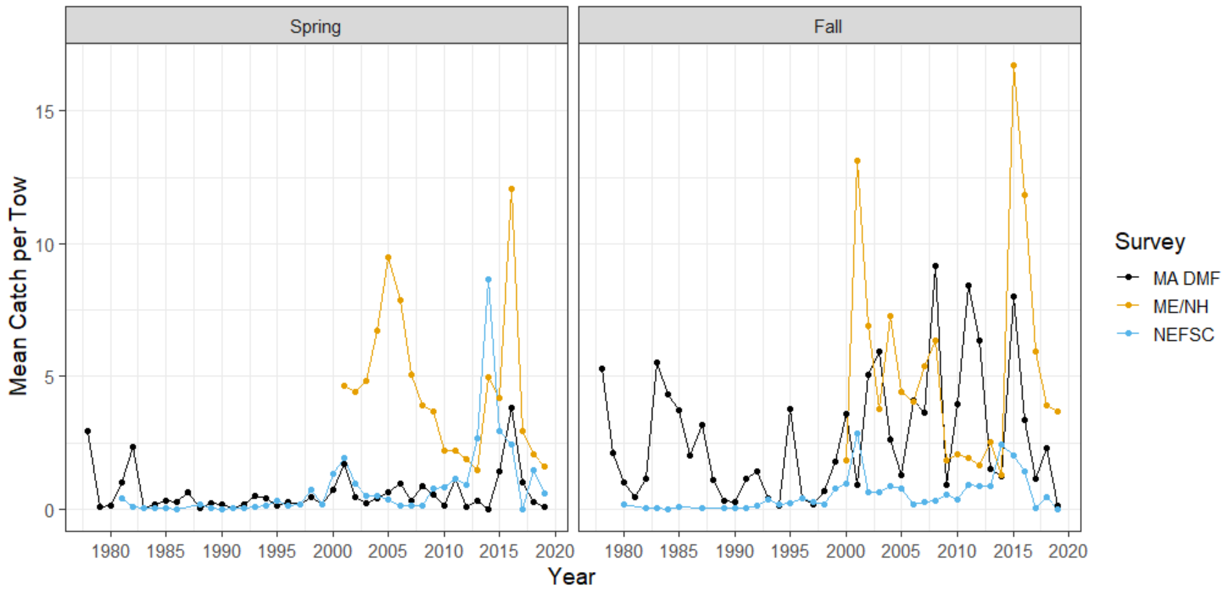


Figure 32. Indices from trawl surveys sampling the Gulf of Maine.

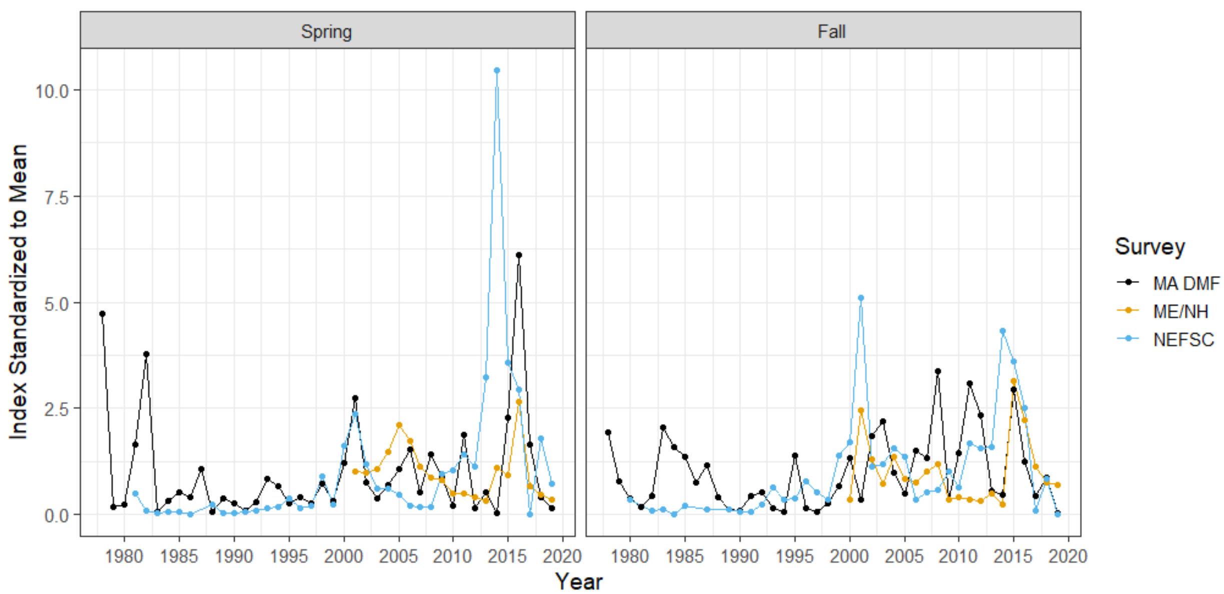


Figure 33. Indices from trawl surveys sampling the Gulf of Maine scaled to time series means.

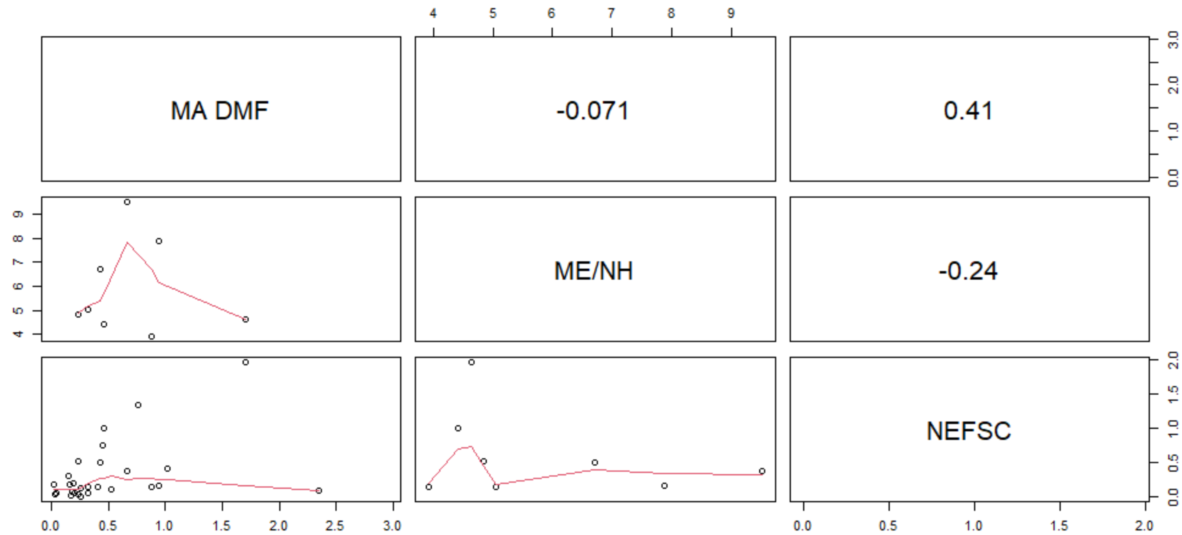


Figure 34. Spearman's rank-order correlation of spring indices from trawl surveys sampling the Gulf of Maine prior to the NEFSC Trawl Survey vessel change in 2009. Plots in the lower panels are pairwise indices (black circles) from surveys on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from surveys on the corresponding column and row of the diagonal.

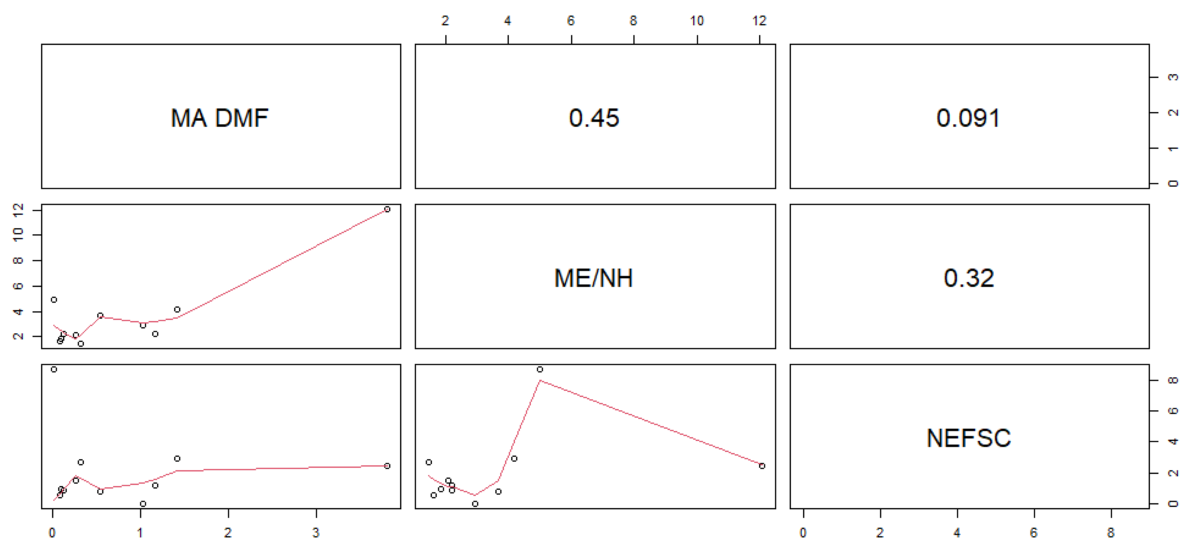


Figure 35. Spearman's rank-order correlation of spring indices from trawl surveys sampling the Gulf of Maine following the NEFSC Trawl Survey vessel change in 2009. Plots in the lower panels are pairwise indices (black circles) from surveys on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from surveys on the corresponding column and row of the diagonal.

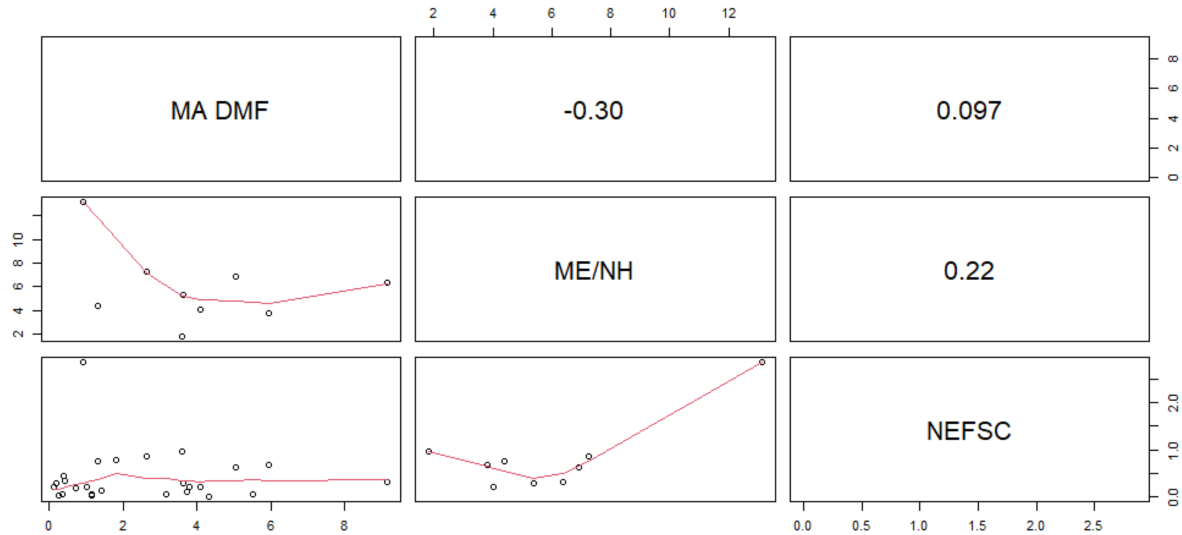


Figure 36. Spearman's rank-order correlation of fall indices from trawl surveys sampling the Gulf of Maine prior to the NEFSC Trawl Survey vessel change in 2009. Plots in the lower panels are pairwise indices (black circles) from surveys on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from surveys on the corresponding column and row of the diagonal.

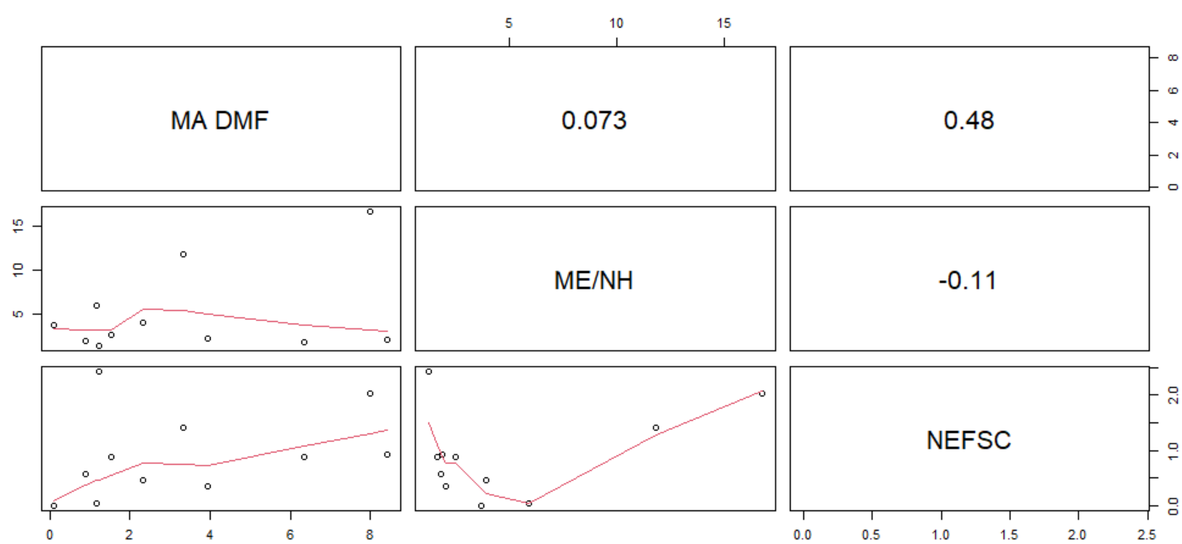


Figure 37. Spearman's rank-order correlation of fall indices from trawl surveys sampling the Gulf of Maine following the NEFSC Trawl Survey vessel change in 2009. Plots in the lower panels are pairwise indices (black circles) from surveys on the corresponding column and row of the diagonal fit with a LOWESS smoother (red line). Numbers in the upper panel plots are correlation coefficients between indices from surveys on the corresponding column and row of the diagonal.

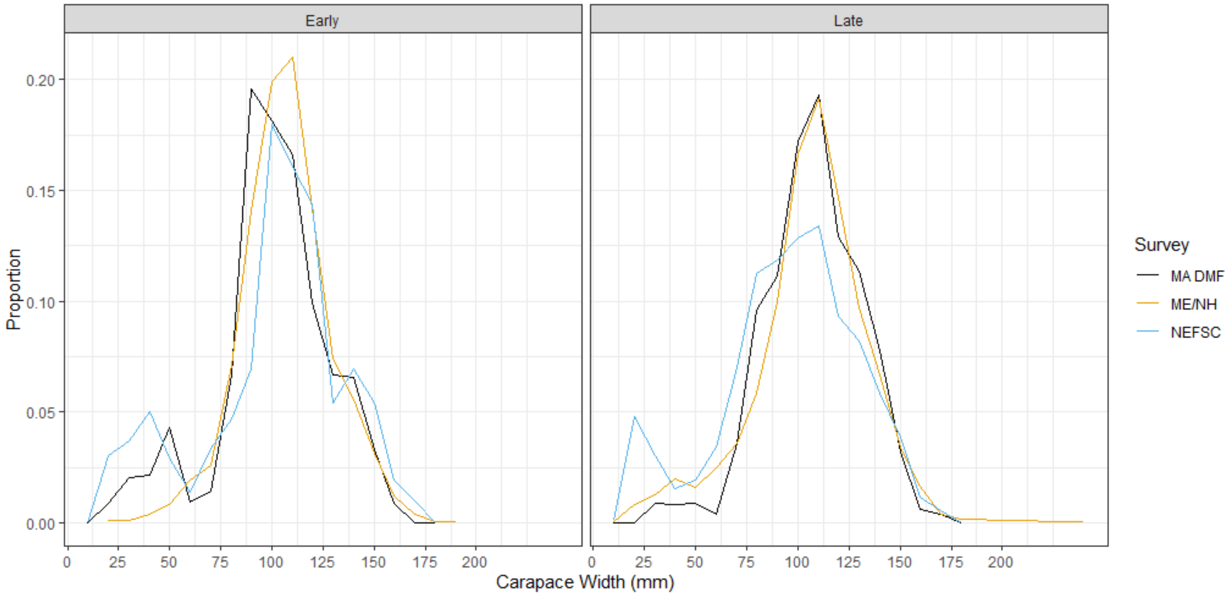


Figure 38. Length compositions of Jonah crab caught by period during spring trawl surveys sampling the Gulf of Maine.

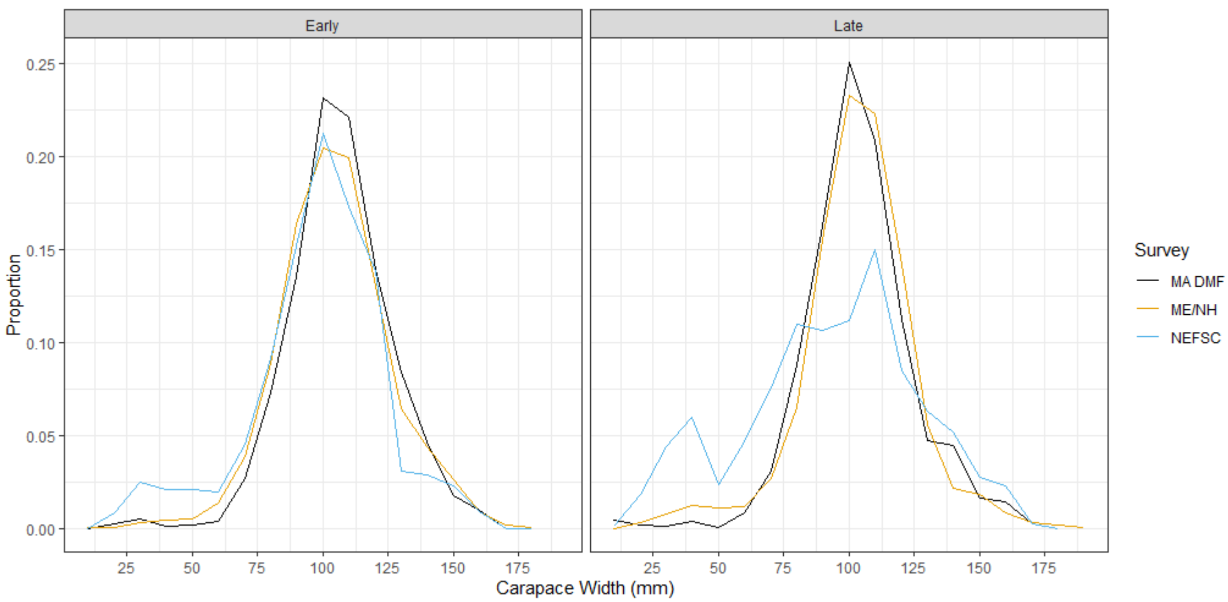


Figure 39. Length compositions of Jonah crab caught by period during fall trawl surveys sampling the Gulf of Maine.

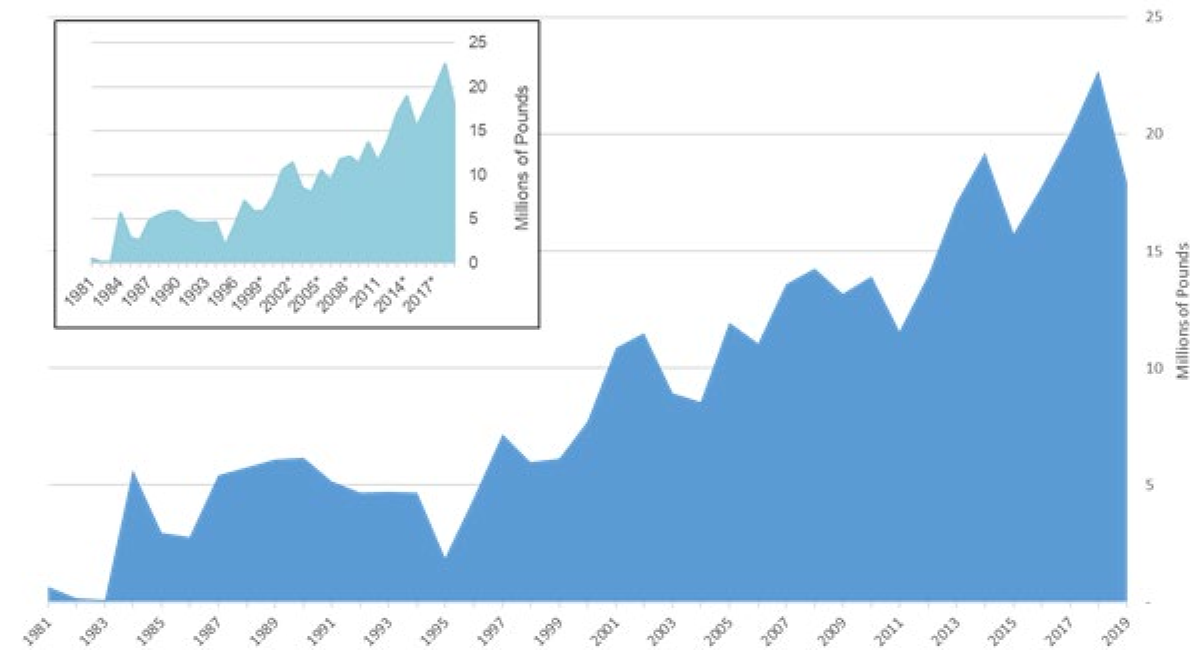


Figure 40. Coastwide Jonah crab landings (small, inset plot) and combined coastwide Jonah crab and Atlantic rock crab landings (large, main plot) from the ACCSP Data Warehouse. Asterisks indicate confidential landings data have been redacted from the total.