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An assessment of the American Lobster (*Homarus americanus*) stock status in Newfoundland (LFAs 3–14C)

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The American Lobster (*Homarus americanus*) is distributed near shore around the island of Newfoundland and along the Strait of Belle Isle portion of the Labrador coast. Major life-history events (i.e., molting, mating, egg extrusion, and hatching) generally take place during mid-July to mid-September, following the fishing season.

The fishery is localized and prosecuted from small open boats during an 8–10 week spring fishing season. Traps are set close to shore, at depths generally less than 20 m. Fishing effort is controlled through restrictive licensing and daily trap limits. Regulations prohibit the harvest of undersized (<82.5 mm carapace length [CL]) and ovigerous (egg-bearing) lobster. In addition, there is a voluntary practice called v-notching, which involves cutting a shallow mark in the tail fan of an ovigerous female. The mark is retained for multiple molts and notched females cannot be retained in the fishery. The practice serves to protect mature females from harvest even when they are not brooding eggs externally. The number of licenses is currently around 2,300 and trap limits range from 100 to 300 depending on the Lobster Fishing Area (LFA).

This stock was last assessed in 2016 and is currently assessed every three years. The present assessment of this stock was requested by Fisheries and Oceans Canada (DFO) Resource Management to provide current information on the status of the resource to be used in an updated Integrated Fisheries Management Plan. The LFAs were assessed based on four regions: Northeast Coast (LFAs 3–6), Avalon (LFAs 7–10), South Coast (LFAs 11–12), and West Coast (LFAs 13–14). The key indicators for the assessment are reported landings, fishery catch per unit effort (CPUE), and annual survival index. Total reported landings in 2019 were at their highest level in a century (4,400 t); this reflects increasing trends in the South and West regions, while reported landings in the Northeast and Avalon regions remained near historic lows.

Since 2004, the CPUE index (unstandardized) has steadily increased to recent highs in the South and West Coast regions, while it has remained unchanged and at low levels in the Northeast Coast and Avalon regions. Most size frequency distributions clearly show a sharp drop at legal size and few lobsters surviving to larger sizes, suggesting higher fishing pressure on the South and West Coast regions, relative to the Northeast Coast and Avalon regions. The annual survival index of females is higher in all regions except for the South Coast, where both females and males follow the same trend. In the South and West Coast regions, where fishing pressure is stronger, the survival of both sexes is lower overall. V-notching was shown to have a high level of efficacy in protecting egg-bearing females from fishing mortality. In all regions, the majority of large surviving lobster in the population were v-notched females.

BACKGROUND

SPECIES BIOLOGY

The American Lobster (*Homarus americanus*) is a decapod crustacean characterized by a life cycle which is predominately benthic. Adult lobsters prefer rocky substrates where they can find shelter, but also live on sand and even muddy bottoms (Jarvis 1989, Dinning and Rochette 2019). In Newfoundland waters, at the northern range of the species distribution, it takes approximately 8–10 years for a newly hatched lobster to reach the minimum legal size (MLS) of 82.5 mm in carapace length (CL) (Ennis 1978, 1980). Lobsters have a total lifespan of more than 30 years (Lawton and Lavalli 1995). Growth is achieved through molting. Frequency of molting decreases with increasing age, with large lobsters molting once every few years. Growth is also affected by temperature; molting frequency tends to increase with water temperature (Fogarty 1989).

Molting and mating occur from July to September and females typically extrude (spawn) eggs roughly one year subsequent to mating. Ovigerous (i.e., egg-bearing) female lobsters carry the eggs in clutches on the underside of their tail, protecting and maintaining the eggs for 9–12 months. Thus, female lobsters are typically characterized by a biennial molt-reproductive cycle (Aiken and Waddy 1982) although smaller mature females sometimes molt and spawn within the same year. Moreover, laboratory studies have shown that large female lobsters (>120 mm CL) can also deviate from the typical biennial molt-reproductive cycle (e.g., successive-year spawning without an intervening molt) (Waddy and Aiken 1986, Waddy and Aiken 1990); however, the size at which large female lobsters in nature can spawn in successive years without an intervening molt may vary from what is observed in laboratory studies (Comeau and Savoie 2002).

Fecundity and egg quality increase with size (Aiken and Waddy 1980). Eggs from larger lobsters tend to contain more energy per unit weight, and larger females tend to release larvae earlier in the season, potentially enhancing growth and survival (Attard and Hudon 1987).

Hatching occurs during a four-month period extending from late May through most of September, and newly hatched prelarvae undergo an initial molt to Stage 1 before being released by the ovigerous female (Ennis 1995). Once released, the larvae swim upward and undergo a series of three molts during a 4–6 week planktonic phase. During this time, mortality is thought to be greatest. With the third molt, a metamorphosis occurs and the newly developed postlarvae, which resemble miniature adults, are prepared to settle to the benthic environment. Newly-settled lobsters progress through several stages before reaching sexual maturity (Lawton and Lavalli 1995).

The adult lobster is thought to have few natural predators and commercial harvesting accounts for most adult mortality. Lobster diet typically consists of rock crab, polychaetes, gastropods, molluscs, echinoderms, and various finfish (Ennis 1973; Scarratt 1980).

THE FISHERY

The history of the American Lobster fishery in Newfoundland dates back to the early 1870s. The fishery is prosecuted from small open boats during an 8–10 week spring fishing season. Traps are set close to shore, at depths generally less than 20 m. Reported landings peaked at almost 8,000 t in 1889 (Figure 1). Early documentation indicates that all lobsters captured were landed and processed by small canning operations that existed around the coast. A stock collapse occurred in the mid-1920s, after which the fishery was closed for three years (1925–27). The fishery reopened in 1928, and reported landings reached over 2,000 t, but dropped sharply the following year. In the early 1930s, shipment of live animals to United States (US) markets commenced, and regulations protecting undersize and ovigerous animals were strictly enforced. By the early 1950s, essentially all landed lobsters were shipped to the US, and the fishery has remained a live-market industry since. Effort was largely uncontrolled up to 1976, at which point a limited entry licensing policy was implemented, and daily trap limits were regulated (Ennis et al. 1997).

Following a 17-year period of general decline reaching 1,200 t in 1972, reported landings increased to about 2,600 t in 1979 (Figure 1). This trend was consistent with those of other Atlantic regions and was attributed to a period of strong recruitment associated with persistent favorable environmental/ecological factors which are still not fully understood. This general increasing trend in Newfoundland landings continued through the 1980s. In January 1986, a new geographical management system was introduced. Lobster fishing districts, which were implemented in 1910, were replaced by Lobster Fishing Areas, or LFAs (Figure 2). A conversion to uniform trap limits, which differ between LFAs, was implemented for all LFAs between the late 1980s and early 1990s.

In 1995, the Fisheries Resource Conservation Council (FRCC) published “A conservation framework for Atlantic lobster”. In this report, the FRCC expressed concerns about the future viability of Atlantic Canada’s lobster stocks, suggesting that high exploitation rates, combined with the considerable harvesting of immature animals could result in decreased egg production and recruitment failure in periods characterized by adverse environmental conditions (FRCC 1995). The report suggested several methods for increasing egg production and reducing exploitation rates, some of which were incorporated into subsequent management plans for the lobster fishery in Newfoundland. Over the course of the 1998–2002 management plan, there was a 25% reduction in licenses in the Newfoundland lobster fishery, and the minimum legal size for retention was increased from 81 mm CL to 82.5 mm CL in May of 1998. Additionally, a maximum legal size restriction of 127 mm CL was implemented for west coast LFAs. Reductions in trap limits, season lengths, and licenses issued were put in place and deemed necessary by fishery managers. The Atlantic Lobster Sustainability Measures Program (ALSM) and a Lobster Enterprise Retirement Program (LERP) were implemented in 2010 and 2011, respectively. Together these programs have led to license and trap limit reductions in the Newfoundland lobster fishery, particularly in the South and West Coast regions.

There are currently about 2,300 licenses with trap limits varying from 100 to 300 per licensed fisher, depending on LFA (Table 1). Traps must possess vents which allow undersized lobsters to escape. The lobster fishery is managed by input controls including number of days fished (i.e., seasons), daily trap limits, minimum CL for retention, and prohibition on landing berried or v-notched female lobsters. V-notching is a voluntary practice which involves cutting a shallow v-notch in the tail fan of an ovigerous female. The v-notch is retained for multiple molts and v-notched females cannot be retained in the fishery. The practice serves to protect proven spawners even when they are not brooding eggs externally.

DATA SOURCES AND METHODOLOGY

This assessment was conducted on four regions (Figure 2) which are geographical groupings of LFAs and are based on trends in landings:

1. Northeast Coast region (LFAs 3–6),
2. Avalon region (LFAs 7–10),
3. South Coast region (LFAs 11–12), and
4. West Coast region (LFAs 13–14).

The available data were all fishery-dependent, and varied by year, and LFA/region.

LANDINGS

Data sources included reported landings (provided by the Statistics Division, Policy and Economics Branch, DFO) which were available for each LFA and hence each region. However, due to the Government of Canada's 'Rule of 5' policy, the landings (and catch per unit effort, CPUE, from fishery monitoring data described below) for each LFA were either not presented or were combined with adjacent LFAs, as several of the LFAs have less than five fishers, buyers, or vessels. Reported landings are based on purchase and sale slips and are underestimated by an unknown amount because they do not account for local sales, poaching, and handling mortalities that can occur prior to the sale of the catch. The extent of local sales, in particular, can be considerable and varies by location and year. Despite a level of underestimation, reported landings are thought to reflect abundance to some extent, since most of the exploitable biomass is caught in the year of recruitment to the fishery.

LOBSTER FISHERY MONITORING

The lobster fishery monitoring program provides key information sources including logbook data from Fish, Food & Allied Workers Union (FFAW) index fishers and at-sea sampling data collected by observers through the Fisheries Science Collaborative Program (FSCP) during the lobster fishing season. These data were collected from 2004 to 2018 in most LFAs except LFA 5, where the Eastport Marine Protected Area (Figure 3) is located and where logbook and at-sea data have been collected since 1997–98, and in LFAs 11 and 14B, where logbook data were collected from 1999 to 2001. Observers collect data for each lobster caught from commercial and modified (closed escapement targeting smaller size lobsters) traps. In addition, mandatory DFO logbooks were implemented in 2010 for all LFAs. The return rate of these logbooks has averaged approximately 50% since 2010, and was as low as 30% in 2014.

At-Sea Sampling Data

At-sea sampling data from 2004 to 2018 were utilized in the 2019 assessment. These data have consistently been collected in the Northeast Coast region (LFA 5 [since 1998] and LFA 4B) and in the South Coast (LFA 11) and West Coast regions (LFAs 14A and 14B) since at least 2004 and in the Avalon region (LFA 10) since 2005, with data from additional LFAs available in 2004–05 and since 2009 (Figure 4, Table 2).

At-sea sampling programs have employed observers who record daily catches onboard fishers' boats in specific locations around the province. Where possible, every trap is sampled and CLs of all lobsters, both commercial and non-commercial size, are recorded to the nearest mm. Lobsters which measure the MLS of 82.5 mm CL are recorded as 83 mm CL. Individuals are placed into one of seven categories to account for sex and, if female, reproductive status and presence or absence of a v-notch. These data are used to produce an index of population structure. The categories are as follows:

1. male,
2. female, non-ovigerous, no v-notch,
3. female, non-ovigerous, new v-notch,
4. female, non-ovigerous, old v-notch,
5. female, ovigerous, no v-notch,
6. female, ovigerous, new v-notch, and
7. female, ovigerous, old v-notch.

Population Dynamics

The at-sea sampling data were used to generate information on the population dynamics, including percentages of males, ovigerous females, old v-notched ovigerous females, non-ovigerous females, and old v-notched non-ovigerous females, presented as size frequency distributions for each of the four regions from 2010 to 2018. The average size of ovigerous females and of all lobsters caught in the fishery within each region was also calculated for each year, and displayed in a line plot to compare trends.

At-sea sampling data were also used to generate catch per unit effort (CPUE) values. CPUEs of pre-recruits (<83 mm CL), recruits (83–93 mm CL), larger lobster (>110 mm CL) and ovigerous female lobsters were examined. Mean CPUE was generated annually within respective size categories by calculating the sum of total catch from traps sampled divided by the average number of traps sampled for each fisher, day, month, and year.

The at-sea sampling data was used to estimate proportions of females for each maturity category over the size ranges, for all years combined (i.e., 2004–18) for each of the four regions. In addition, the sex ratio was estimated for each year as proportion of females over males for each of the four regions from 2004 to 2018.

Annual Survival Index

Based on the at-sea sampling data, a mean-length mortality equation (Beverton and Holt 1956) was used to determine relative levels of instantaneous mortality during the fishery annually from catch sampled throughout the season. Input parameters for the equation are length-at-first capture (*Lc*) and maximum size (*Linf*), with the mean length of legal-sized individuals in the catch constituting a continuous measured input variable that ultimately scales the magnitude of the index, with a low mean size suggesting high mortality in the population. The analysis is sensitive to the *Linf* parameter, which was based at 110 mm CL, as few lobsters larger than this size have been captured over the available time series. It is recognized that this parameter estimate is lower than the maximum size biologically possible for Newfoundland lobster, and the analysis outcome is only viewed as a relative index of mortality. The instantaneous mortality estimate was subsequently converted to an annual survival estimate (Equation 1).

Equation 1

$$Z/K = (Linf - Lbar) / (Lbar - Lc)$$

$$Z/K = Z \text{ (with implicit growth parameter K)}$$

$$Linf = 110 \text{ mm CL}$$

$$Lbar = \text{mean of all sizes between MLS and Linf (110 mm)}$$

$$Lc = MLS$$

$$S = \exp(-(Z/K))$$

The annual survival index was calculated as S = exp (-[Z/K]) from 2004 to 2018 within each of the four regions. This index was also calculated for each region from 2004 to 2018 for the end (weeks 9–13) of the fishing season and for the overall fishing season.

Fishery Logbook Data

Logbook data from FFAW index fishers were available from 2004 to 2018 for each region, with representation from most LFAs for most years (Tables 3a and 3b). Throughout the commercial lobster fishing season, these fishers collect information from commercial traps as well as from traps modified to prevent escapement of pre-recruit lobsters. Fishers record the catch, in numbers, of lobsters eligible for harvest, as well as ovigerous females, and undersized lobster of both sexes. Fishers are also required to complete a mandatory DFO lobster logbook, which was implemented in the Newfoundland lobster fishery in 2010.

CPUE

Using both the FFAW index fisher (2004–18) and DFO (2010–18) logbook data collected within each region, CPUE (number of lobsters caught/number of traps hauled) was calculated by day, month, and year, for individual harvesters for each of the four regions. Mean annual CPUEs were calculated within each region, and CPUE plots were generated to compare trends from both logbook data sources. Using the DFO logbook data, CPUE was also calculated on a weekly basis (5-day bins) to assess fishery performance throughout the season in each region for each year from 2004 to 2018.

Since 2007, modified traps have been distributed to index fishers and deployed throughout various LFAs (Figure 5). Logbook data and at-sea sampling data were collected and reported on all lobsters caught from these traps. The modified trap data were used to depict the trends of CPUE for three size groups (<72 mm, 72–74 mm, 74–82.5 mm CL) of pre-recruit lobsters within each region from 2007 to 2018 and to demonstrate the CPUE trends of pre-recruit lobster. Temperature probes were also attached to several of these modified traps during the fishing season (Figure 5).

V-notching

Index fisher logbook data were also used to generate plots displaying the percentage of v-notching of ovigerous females (number of ovigerous females v-notched that day/total commercial ovigerous females) annually within each region.

RESULTS AND DISCUSSION

LANDINGS

Total reported landings for Newfoundland increased from approximately 1,900 t in 2010 to the highest level in a century, with landings of 4,400 t in 2019 (Figure 1, Table 4). This reflects increasing trends in the South and West Coast regions, while the landings in the Northeast Coast and Avalon regions declined throughout the 1990s to mid-2000s and have remained near historic lows for more than a decade (Figure 6, Table 5). Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

Northeast Coast Region (LFAs 3–6)

From the early 1950s to the late 1960s, the reported landings in the Northeast Coast region averaged approximately 700 t then declined to around 300 t by the mid-1970s (Figure 6). The landings increased again to an average of 700 t in the 1980s then declined from 750 t in the early 1990s to an average of approximately 170 t in the last 10 years, with 200 t in 2019 (Table 6). Since 2009, the combined landings in LFA 3 (White Bay) and 4A (Notre Dame Bay) have averaged approximately 20 t, with 21 t in 2019. In each of LFAs 4B and 5 (Bonavista Bay), the landings have declined from approximately 100 t in 2015 to approximately 80 t in each respective LFA in 2019. The landings in LFA 6 increased by 54% from 10 t in 2015 to 22 t in 2019 (Figure 7).

Avalon Region (LFAs 7–10)

Reported landings in the Avalon region averaged 150 t from the early 1950s to the mid-1970s, then increased to an average of 460 t in the 1980s and up to the early 1990s (Figure 8). The landings have since declined from approximately 460 t in the early 1990s, averaging 40 t since 2009, with approximately 50 t in 2019 (Table 7). The 2019 value represents a 90% reduction in landings, which peaked at 460 t in 1992. In LFA 10 (Placentia Bay), the landings have declined from approximately 53 t in 2009 to 20 t in 2019. In LFA 7 (Conception Bay), the landings have averaged 10 t since 2009 and have increased to 27 t in 2019, which constitutes 50% of the landings for the Avalon region. The combined landings from LFA 8 and 9AB (St. Mary's Bay) have averaged 1 t since 2009, with 2 t in 2019.

South Coast Region (LFAs 11–12)

In the last decade, commercial lobster fishing in the South Coast region accounted for almost half of the reported landings for Newfoundland. From mid-1970s to early 1990s, reported landings averaged 400 t and increased by 70% to peak at approximately 1,300 t in 2010 (Figure 9); reported landings averaged 1,100 t from 2011 to 2015, and then increased to 1,700 t in 2019 (Table 8). LFA 11 (Fortune Bay) accounts for 75–85% of the landings in the South Coast region.

West Coast Region (LFAs 13A–14C)

Since the early 2000s, the reported landings in the West Coast region have accounted for approximately 50% of the total reported landings in Newfoundland. Reported landings in this area have varied since the early 1950s, and averaged 600 t up to early 1970s, then increased from 950 t in 1976 to 1,600 t in 1989. They continued to vary before decreasing to approximately 750 t in 2000; they have since increased up to 2,400 t in 2019 (Table 9). In LFAs 13A and 13B, the reported landings have increased by 50% since 2015, to 640 t and 840 t, respectively, in 2019. In LFA 14ABC, combined landings increased by 40%, from approximately 550 t in 2015 to 950 t in 2019 (Figure 10).

POPULATION DYNAMICS

Size Frequency Distributions

At-sea sampling data were used to generate size frequency distributions for males, ovigerous females, old v-notched/ovigerous females, non-ovigerous females, and old v-notched/non-ovigerous females for each region from 2010 to 2018 (Figure 11). Size compositions and catch rates are influenced by catchability. Environmental conditions, soak time, and changes in fishing gear can affect catchability (Miller 1990). Unlike the commercial component of the catch, which is removed after the first capture, sublegal lobsters could be captured multiple times during a fishing season, potentially biasing interpretation of size compositions.

In the Northeast Coast and Avalon regions, the size frequency distributions for both males and females show a sharp decline at MLS, consistent with knife-edge recruitment to the fishery, with few lobsters surviving past the first molt class (Figure 11). This suggests that, although the landings are relatively low, there is still high fishing pressure in these regions. The size frequency distributions illustrate that the conservation measures (i.e., protection of ovigerous and v-notched animals) are effective as the few lobster that are surviving beyond 92 mm CL are more likely to be ovigerous and/or v-notched females. It is important to note that most at-sea sampling data were collected from LFA 4B in the Northeast Coast region and LFA 10 in the Avalon region. Therefore, these LFAs have driven the interpretation of overall size distribution patterns in respective regions.

Within the South and West Coast regions, the size frequency distributions for both males and females show a sharp decline at MLS, consistent with knife-edge recruitment to the fishery, with few lobsters surviving past the first molt class (Figures 11, 12, 13). This suggests that fishing pressure is high in these regions.

With respect to the size structure, there was a larger range of sizes caught in the Northeast Coast and Avalon regions for both sexes, with more lobster surviving to attain larger sizes (i.e., larger than 92 mm CL) throughout the time series; in the South Coast and West Coast regions, there was little sign of lobster surviving to larger sizes (Figures 11, 12, 13). This, in combination with the knife-edge recruitment shown in the size frequency distributions, suggests higher fishing pressure on the South and West Coast regions, relative to the Northeast Coast and Avalon regions.

Average Carapace Length

The at-sea sampling data were also used to calculate the average CL of lobster within each region. Average size is larger (above MLS) within the Northeast Coast and Avalon regions (where landings are low), and smaller (generally below or very close to MLS) within the South and West Coast regions, where landings are considerably higher (Figure 14). From 2004 to 2016, the average size of lobster has increased in the Avalon region then decreased in recent years, from 91 mm CL in 2016 to 87 mm CL in 2018; average size increased in the Northeast Coast region between 2004 and 2014 to 89 mm CL then decreased to 86 mm CL in 2018. In the South and West Coast regions, the average size of lobster peaked in 2012 at close to MLS and has remained below MLS since 2014, at approximately 81 mm CL (Figure 14).

The average size of ovigerous females within the South and West Coast regions is smaller than that of the Northeast Coast and Avalon regions (Figure 15). For the South Coast region, in particular, the average size of ovigerous lobsters is consistently below MLS, while the average size of ovigerous lobster in the Avalon and Northeast Coast regions is consistently above MLS, averaging between 83 mm and 91 mm CL.

A reduction in larger size lobster and a truncation of the size distribution suggests higher exploitation and fishing pressure. In Pezzack et al. (2015), the abundance of larger female lobster was used as a proxy for exploitation rates and reproductive potential whereby the lower large female lobster abundance in the population indicates higher exploitation.

Overall, the results suggest a high fishing pressure in the South and West Coast regions compared to the Northeast Coast and Avalon regions.

CPUE Trends of Size Ranges

On a regional scale, the trends in CPUE are similar between the pre-recruit and recruit lobsters (Figures 16, 17). CPUEs of pre-recruit and recruit lobsters were highest in the South Coast region. For pre-recruit and recruit lobster, the CPUEs increased in the South and West Coast regions but remained low and variable in the Northeast Coast and Avalon.

The CPUE for the ovigerous females followed the same pattern as the pre-recruit and recruit lobster, with the highest CPUE in the South Coast region, and lower CPUEs in the Northeast Coast and Avalon regions from 2004–18 (Figure 18). In the Avalon region, the CPUE of ovigerous females has declined from 0.13 lobster/trap in 2009 to less than 0.1 lobster/trap over the last 10 years; in the Northeast Coast region, the CPUE of ovigerous females has remained close to 0.1 lobster/trap since 2010. (Figure 18). The CPUE of ovigerous females in the West Coast region varied between 0.15 and 0.25 lobster/trap throughout the time series. In the South Coast region, the CPUE of ovigerous females varied without trend, between 0.25 and 0.4 lobster/trap.

The CPUE of large lobster (>110 mm CL) was consistently low in all regions, with the lowest CPUE in the South and West Coast regions and highest CPUE in the Avalon and Northeast Coast regions (Figure 19). Since 2012/13, the CPUE of large lobster in the Avalon and

Northeast Coast regions has decreased, ranging between 0.025–0.075 lobster/trap; since 2013, the CPUE of large lobster in the South and West Coast ranged from 0.020–0.025 lobster/trap.

Proportions of Females

The at-sea sampling data were also used to examine the proportion of females in each maturity category for all years sampled (2004–18) over the size ranges within each region (Figure 20). The results showed that the highest proportion of larger females in each region were v-notched (including non-ovigerous/old v-notched or ovigerous/ old v-notched) or ovigerous (Figure 20).

Additionally, it was shown in most regions that the proportion of ovigerous females as compared to non-ovigerous females increased for larger size lobster (>110 mm CL). However, in the South Coast region the proportion of ovigerous female lobster was lower at 0.5 compared to the other three regions which are above 0.75 (Figure 21).

With the exception of the last few years in the Avalon region, more large lobster >110 mm CL are v-notched in the Avalon, Northeast Coast, and West Coast regions compared to the South Coast region, where the proportion of v-notched females is low in most years (Figure 22).

Figures 21 and 22 clearly show that the prohibition against landing ovigerous and/or v-notched lobster is effective in protecting larger female lobster in the population. According to Attard and Hudon (1987) and Koopman et al. (2015), as noted in Cook et al. (2017), the protection of larger females can help increase or maintain the level of productivity in the population whereby large females produce more eggs and are known to spawn more frequently (Aiken and Waddy 1980).

Sex Ratios

Overall, the sex ratios from at-sea sampling data demonstrated a higher proportion of females. This was particularly evident in the larger lobster throughout the population. This skew towards females could be largely driven by fishery regulations whereby female lobster are protected and cannot be retained when they are ovigerous and/or v-notched. Skewed ratios can be a result of differences in fishing mortality due to differences in catchability between the sexes. Differences in habitat structure, temperatures, and salinity preferences can affect the movement patterns of males and females, which could potentially lead to skewed sex ratios (Jury and Watson 2013, Boudreau et al. 2015).

The sex ratios in the Northeast Coast and the Avalon regions over the time series (2004–18) were between 0.5 and 0.6 for undersized lobster. Beyond the MLS (i.e., 82.5 mm CL), the proportion of females to males increased to 0.7, and then to approximately 0.8 in lobster larger than 110 mm CL (Figures 23, 24). In the South Coast region, females are generally smaller than 120 mm CL; however, since 2015, there have been larger lobster noted in the South Coast region and an increase (from below 0.75 to closer to 0.85) in the proportion of larger sized females (Figures 23, 24).

Annual Survival Index

The instantaneous mortality estimate determined for males and females in each region (Figure 25) was subsequently converted to an annual survival index. The annual survival index of females is higher than males in all regions except for the South Coast, where females and males have similar survival indices and follow similar trends through the time series. In the South and West Coast regions, where fishing pressure is stronger, the survival of both sexes is generally lower throughout the time series (Figure 26). In the Avalon region, the survival index increased from 0.1 and 0.2 for males and females, respectively, in 2008 to approximately 0.3 and 0.4, respectively, in 2016; the index decreased slightly in the most recent years for both sexes. In the Northeast Coast region, throughout the time series the males and females maintained a survival index of close to 0.1 and 0.2 for males and females, respectively (Figure 26).

The annual survival index was calculated for each region from 2004 to 2018 for the overall fishing season (Figure 26), and for the end of the fishing season (i.e., weeks 9–13; Figure 27). When comparing the trends of the survival index from the later weeks of the fishing season to all weeks of the season, the trends are similar, with low survival of males and females over the time series in the South and West Coast regions. In addition, the survival throughout the season and at the end of the season was higher in the Avalon and Northeast Coast regions, with the Avalon region having the highest survival overall.

Males and females differ in growth rates (Wilder 1953; Campbell 1983; Comeau and Savoie 2001) and survival likely due to the protection provided for ovigerous and v-notched females. Therefore, they are subject to different rates of survival which was evident in all four regions where the annual estimates of survival for males were consistently lower than those obtained for females (Figure 26).

FISHERY LOGBOOK DATA

CPUE Trends

FFAW index logbook data, available since 2004, were used to compute annual mean CPUE (i.e., number of lobster caught per trap haul) for each region. CPUE was also calculated from the DFO mandatory logbooks (2010–18), and comparisons with FFAW index logbook data showed similar trends within the four regions (Figure 28).

Throughout the time series, the highest mean unstandardized CPUE values were from the South Coast and West Coast regions. In the South Coast region, the CPUE increased from 0.75 in 2011 to approximately 1.25 in 2018; in the West Coast region CPUE increased from 0.45 in 2011 to 0.75 in 2018 (Tables 8, 9). In the South Coast region, the CPUE peaked in 2018. In both the Northeast Coast and Avalon regions, the CPUE remained low throughout the time series, and was approximately 0.25 in 2019 (Figure 28, Tables 6, 7).

The highest CPUE of legal lobsters was in the South Coast region in all years. Landings and CPUE data suggest higher density of lobsters along the South and West Coasts, compared to the other regions.

DFO logbook data were also used to calculate unstandardized CPUE through the fishing season within 5-day bins for each region from 2010 to 2018. The general trend is similar in the South and West Coast regions, where CPUE begins high early in the season and then declines and stabilizes at a relatively low level near the end of the season (Figure 29). However, for the Avalon and Northeast Coast regions, the CPUE values tended to remain at a low level throughout the season and were often consistently low over the entire time series.

There are issues associated with using CPUE as an index of abundance. Trap density and competition can affect how well catch rates measure local densities. In addition, CPUE is not standardized, so it does not account for variation in water temperatures and fishing practices that can affect catchability (McLeese and Wilder 1958; Miller 1990). Fishing practices may vary between fishers where soak times and redistribution of traps can vary greatly, and it is common for fishers to reduce effort substantially in the final weeks of the lobster season. Also, many lobster fishers hold licenses for other species (e.g., Snow Crab) and will adjust effort to permit harvest of these other species (Collins et al. 2009).

The modified-trap logbook data were used to explore CPUE trends of three size classes (<72 mm, 72–74 mm, 74–82.5 mm CL) and sex/maturity status of pre-recruit lobster within each region, from 2007 to 2018 (Figure 30). In the South and West Coast regions, the CPUE of the size classes (>72 mm) increased from approximately 0.5 to 0.8–1.0 lobster/traps hauled respectively. The CPUE of the three pre-recruit sizes remained close to 0.25–0.4 lobster/traps hauled throughout the times series in the Avalon and Northeast Coast regions. Overall, the CPUE for the three pre-recruit size classes was higher in the South and West Coast regions (0.25–1.0 lobster/traps hauled) and lower in the Northeast Coast and Avalon regions (0.05–0.35 lobster/traps hauled). The CPUE for the males and females was higher in the South and West Coast regions which gradually increased between 2013 and 2018 compared to the Avalon and Northeast Coast regions, where the CPUE remained low throughout the time series. Overall, when comparing the CPUE of the males and females (undersized ovigerous/non-ovigerous) within the four regions, the CPUE for males was higher and the undersized ovigerous female lobster had the lowest CPUE (Figure 31).

The trends in the average temperature from 2007 to 2018, based on the temperature probes attached to the modified traps, were variable (Figure 32), as these probes were not always consistently placed in the same locations annually. In the Northeast Coast, the average temperature increased until it peaked in 2017 at approximately 7°C. In other regions, the average temperatures were variable, but followed similar trends through the time series, with average temperatures usually below 5°C.

V-notching

V-notching of ovigerous female lobsters has been taking place annually since its introduction in the Newfoundland in the 1990s. There are no reliable accounts of the amount of v-notching taking place, but it is believed to be less than 15%, and variable among areas.

FFAW index logbooks were used to estimate the percentage of v-notching (number of ovigerous females v-notched/total ovigerous females) annually for all regions. On average, the extent of v-notching ranged from 4% to 20%, with the lowest rate of v-notching in the South Coast region and the highest in the Avalon region (Figure 33). In general, there has been an overall decline in the percent of ovigerous females v-notched since the late 2000s.

Large female lobster are thought to produce more viable eggs than smaller females (Attard and Hudon 1987). Protecting these large females in the population is a reasonable step towards increasing egg production and the practice should be encouraged among harvesters.

Based on the proportions of v-notched lobster over the size range, it was evident in all regions, that majority of large surviving lobster in the population were v-notched females (Figure 20). This indicates that v-notching has a high level of efficacy at protecting egg-bearing females from fishing mortality.

ECOSYSTEM CONSIDERATIONS

A diver survey of 18 sites in Placentia Bay, Fortune Bay, and Port Saunders during September/October in 2017–18 found that juvenile lobster densities over various substrates were low in Placentia Bay sites, compared to those in Port Saunders and Fortune Bay. Juvenile distributions indicated a selection for shallow depths compared to adult lobsters, but little evidence of selection for specific substrate and vegetation types (Lancaster et al. in prep[1]).

Summer sea surface temperature has increased since 1981 over the four geographical regions, characterized by a low in the early-1990s and a high in the early-2010s. This has led to more favorable oceanographic habitat conditions for lobster (Figure 34).

CONCLUSIONS

Some of the key indices used to assess the status of the population of the lobster stock in LFAs 3–14C, including the size frequency distributions, average size, CPUE, and annual survival index, clearly suggest signs of higher fishing pressure on the South and West Coast regions, relative to the Northeast Coast and Avalon regions. The population structure in each region showed a low number of larger individuals (>110 mm CL) which depicts a recruit-based fishery with high exploitation.

Most size frequency distributions clearly show a sharp drop at MLS and few lobsters surviving to larger sizes (i.e., past the first molt into fishery eligibility). From 2004 to 2018, the average size of lobster was larger in the Northeast Coast and Avalon Regions, and smaller (below MLS) in the South and West Coast regions. When comparing the CPUE at different size ranges, the CPUE of smaller lobster (pre-recruits) was highest in the South and West Coast regions, and CPUE for the larger lobster (>110 mm CL) was highest in the Northeast Coast region. The annual survival index of females is higher relative to males in most regions, except in the South Coast where females and males follow the same trend and have a lower survival index. In the South and West Coast regions, where fishing pressure is stronger, the survival of both sexes is lower overall.

Total reported landings in 2019 were at their highest level in a century (4,400 t); this reflects increasing trends in the South and West Coast regions, while reported landings in the Northeast Coast and Avalon regions remain near historic lows. Summer sea surface temperature has increased since 1981 over the four geographical regions, characterized by a low in the early-1990s and a high in the early-2010s. This has led to more favourable oceanographic habitat conditions for lobster.

Over the time series, CPUEs have increased in the South and West Coast regions, and have remained low in the Northeast Coast and Avalon regions.

V-notching was shown to be effective at protecting egg-bearing females from fishing mortality. In all four regions, the majority of large surviving lobster in the population were v-notched females.

REFERENCES CITED

Aiken, D.E., and Waddy, S.L. 1980. Reproductive Biology. In: The Biology and Management of Lobsters Vol. I: Physiology and Behavior. Edited by J.S. Cobb and B.F. Philips. Academic Press. New York. Pp. 215–276.

Aiken, D.E., and Waddy, S.L. 1982. Cement Gland Development, Ovary Maturation, and Reproductive Cycles in the American Lobster *Homarus Americanus*. J. Crustac. Biol. 2(3): 315–327.

[1] Lancaster, D., Gregory, R.S., Sargent, P.S., and Matheson, K. In prep. Habitat associations of juvenile American lobster in three nearshore areas of Newfoundland. DFO Can. Sci. Advis. Sec. Res. Doc.

Attard, J., and Hudon C. 1987. Embryonic Development and Energetic Investment in Egg Production in Relation to Size of Female Lobster (*Homarus americanus*). Can. J. Fish. Aquat. Sci. 44(6): 1157–1164.

Beverton, R.J.H. and Holt, S.J. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration Scientifique de la Mer Méditerranée. 140: 67–83.

Boudreau, S.A., Anderson, S.C., and Worm, B. 2015. Top-down and bottom-up forces interact at thermal range extremes on American lobster. J. Anim. Ecol. 84(3): 840–850.

Campbell, A. 1983. Growth of tagged lobsters (*Homarus americanus*) off Port Maitland, Nova Scotia, 1948–80. Can. Tech. Rep. Fish. Aquat. Sci. 1232: iii + 10 p.

Collins, R., Stansbury, D., Veitch, P., and Janes, J. 2009. Recent trends and management changes in the American lobster (*Homarus americanus*) fishery in Newfoundland. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/096. iv + 29 p.

Comeau, M., and Savoie, F. 2001. Growth Increment and Molt Frequency of the American Lobster (*Homarus Americanus*) in the Southwestern Gulf of St. Lawrence. J. Crustac. Biol. 21(4): 923–936.

Comeau, M., and Savoie, F. 2002. Maturity and Reproductive Cycle of the Female American Lobster, *Homarus americanus*, in the Southern Gulf of St. Lawrence, Canada. J. Crustac. Biol. 22(4): 762–774.

Cook, A.M., Cassista Da-Ros, M., and Denton, C. 2017. Framework Assessment of the Offshore American Lobster (*Homarus americanus*) in Lobster Fishing Area (LFA) 41. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/065. viii + 186 p.

Dinning K.M., and Rochette, R. 2019. Evidence that mud seafloor serves as recruitment habitat for settling and early benthic phase of the American lobster *Homarus americanus* H. (Decapoda: Astacidea: Nephropidae). J. Crustac. Biol. 39(5): 594–601.

Ennis, G.P. 1973. Food, Feeding, and Condition of Lobsters, *Homarus americanus*, Throughout the Seasonal Cycle in Bonavista Bay, Newfoundland. J. Fish Res. Board. Can. 30(12): 1905–1909.

Ennis, G.P. 1978. Growth curves for Newfoundland lobsters from data on molt increment and proportion molting. DFO. CAFSAC Res. Doc. 1978/29. 11 p.

Ennis, G.P. 1980. Recent and Current Canadian Research on Growth of Lobsters in the Wild. In: Proceedings of the Canada-U S. Workshop on Status of Assessment for N.W. Atlantic Lobster (*Homarus americanus*) Stocks. Edited by V.C. Anthony, and J.F. Caddy. Can. Tech. Rep. Fish. Aquat. Sci. No. 932: 9–15.

Ennis, G.P. 1995. Larval and Postlarval Ecology. In: Biology of the Lobster *Homarus americanus*. Edited by J.R. Factor. Academic Press. San Diego, California. Pp. 23–46.

Ennis, G.P., Collins, P.W., Badcock, G.D., and Dawe, G. 1997. Review of the Newfoundland Lobster Fishery. DFO. Can. Stock Asses. Sec. Res. Doc. 1997/126. 55 p.

Fogarty, M.J. 1989. Forecasting Yield and Abundance of Exploited Invertebrates. In: Marine Invertebrate Fisheries: Their Assessment and Management. Edited by J.F. Caddy. Wiley-Interscience. New York. Pp. 701–724.

FRCC. 1995. A conservation framework for Atlantic lobster : report to the Minister of Fisheries and Oceans. Dept. Cat. No. FRCC95.R.1. Cat No. Fs23-278/1995E. 96 p.

Jarvis, C. 1989. Movement Patterns of Late-Stage Ovigerous Female Lobsters (*Homarus americanus* Milne-Edwards) at Jeddore, Nova Scotia. M.S. thesis. Dalhousie University, Halifax, Nova Scotia, Canada.

Jury, S.H., and Watson, W.H. 2013. Seasonal and sexual differences in the thermal preferences and movements of American lobsters. Can. J. Fish. Aquat. Sci. 70(11): 1650–1657.

Koopman, H.N., Westgate, A.J., and Siders, Z.A. 2015. Declining Fecundity and Factors Affecting Embryo Quality in the American Lobster (*Homarus americanus*) from the Bay of Fundy. Can. J. Fish. Aquat. Sci. 72: 352–363.

Lawton, P., and Lavalli, K.L. 1995. Postlarval, Juvenile, Adolescent, and Adult Ecology. In: Biology of the Lobster *Homarus americanus*. Edited by J.R. Factor. Academic Press. San Diego, California. Pp. 47–88.

McLeese, D.W., and Wilder, D.G. 1958. The Activity and Catchability of the Lobster (*Homarus americanus*) in Relation to Temperature. J. Fish. Res. Board Can. 15(6): 1345–1354.

Miller, R.J. 1990. Effectiveness of Crab and Lobster Traps. Can. J. Fish. Aquat. Sci. 47(6): 1228–1251.

Pezzack, D.S., Denton, C., Cassista-Da Ros, M., and Tremblay, M.J. 2015. Assessment of the Canadian LFA 41 Offshore Lobster (*Homarus americanus*) Fishery (NAFO Divisions 4X 5Zc). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/066. v + 79 p.

Reynolds, R.W., Smith, T.M., Liu, C., Chelton, D.B., Casey, K.S., and Schlax, M.G. 2007: Daily High-Resolution-Blended Analyses for Sea Surface Temperature. J. Climate. 20(22): 5473–5496.

Scarratt, D.J. 1980. The food of lobsters. Can. Tech. Rep. Fish. Aquat. Sci. 954: 66–91.

Waddy, S.L., and Aiken, D.E. 1986. Multiple Fertilization and Consecutive Spawning in Large American Lobsters, *Homarus americanus*. Can. J. Fish. Aquat. Sci. 43(11): 2291–2294.

Waddy, S.L., and Aiken, D.E. 1990. Intermolt Insemination, an Alternative Mating Strategy for the American Lobster (*Homarus americanus*). Can. J. Fish. Aquat. Sci. 47(12): 2402–2406.

Wilder, D.G. 1953. The Growth Rate of the American Lobster (*Homarus americanus*). J. Fish. Res. Board Can. 10(7): 371–412.

APPENDIX I - TABLES

Table 1. Daily trap limits per licensed fisher, by LFA in 2019.

LFA	Number of Traps
3	200
4A	200
4B	200
5	150
6	100
7	150
8	100
9A	200
9B	100
10	200
11	185
12	135
13A	180
13B	220
14A	250
14B	250
14C	300

Table 2. LFAs where at-sea sampling took place for each of the four regions, from 2004–18.

Year	Northeast	Avalon	South Coast	West Coast
2004	4A, 4B, 5, 6	-	11	13B, 14A, 14B
2005	4A, 5	10	11	14A, 14B
2006	5	10	11	14A, 14B
2007	4B, 5	10	11	14A, 14B
2008	4B, 5	10	11	14A, 14B
2009	4A, 4B, 5	10	11	14A, 14B
2010	3, 4A, 4B, 5, 6	7, 8, 9A, 10	11, 12	13A, 13B, 14A, 14B
2011	4B, 5	8, 9A, 10	11	14A, 14B
2012	3, 4A, 4B, 5, 6	7, 8, 9A, 10	11, 12	13A, 13B, 14A, 14B
2013	4B, 5, 6	7, 8, 9A, 9B, 10	11, 12	13A, 13B, 14A, 14B
2014	4B, 5	8, 9A, 9B, 10	11, 12	14A, 14B
2015	4B, 5	8, 9A, 9B, 10	11, 12	14A, 14B
2016	4B, 5, 10,11,12	7,8, 9A, 9B	11, 12	-
2017	4B, 5, 6	7, 10	11, 12	14A, 14B
2018	4B 5, 6	7, 10	11, 12	14A, 14B

Table 3a. The number of index fisher logbook and mandatory DFO logbook returns in the Northeast Coast and Avalon regions (LFAs 3–10) Entries were omitted in several locations due to a small fishery and/or small number of returns.

Northeast Coast Region (LFAs 3, 4A, 4B, 5, 6)										
	LFA 3		LFA 4A		LFA 4B		LFA 5		LFA 6	
	Logbooks									
Year	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO
2004	1	-	-	-	7	-	3	-	2	-
2005	2	-	2	-	6	-	3	-	2	-
2006	1	-	2	-	14	-	7	-	6	-
2007	2	-	2	-	15	-	6	-	7	-
2008	2	-	9	-	5	-	6	-	7	-
2009	1	-	12	-	5	-	6	-	9	-
2010	1	14	19	158	33	204	13	177	18	151
2011	2	16	11	114	35	167	12	125	15	114
2012	1	7	11	34	35	88	13	74	14	63
2013	1	2	5	2	29	5	8	7	13	2
2014	-	10	3	47	29	100	7	95	9	86
2015	-	13	4	50	26	86	7	80	7	66
2016	-	10	7	48	22	123	9	86	10	69
2017	-	11	5	72	21	123	10	87	7	92
2018	-	10	4	74	17	116	7	103	8	93
Avalon Region (LFAs 7, 8, 9A, 9B, 10)										
	LFA 7		LFA 8		LFA 9A		LFA 9B		LFA 10	
	Logbooks									
Year	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO
2004	-	-	-	-	-	-	-	-	-	-
2005	3	-	1	-	-	-	2	-	7	-
2006	6	-	3	-	1	-	4	-	22	-
2007	7	-	3	-	1	-	5	-	21	-
2008	5	-	3	-	1	-	4	-	19	-
2009	7	-	2	-	1	-	4	-	23	-
2010	13	70	5	29	1	2	4	14	32	164
2011	10	48	5	21	2	2	1	7	30	108
2012	12	26	5	15	2	2	2	7	27	55
2013	7	1	3	2	1	-	-	-	21	6
2014	7	39	3	13	1	4	1	5	19	54
2015	7	33	4	10	1	3	-	4	17	47
2016	6	40	4	18	2	4	-	4	21	49
2017	7	50	4	25	1	3	-	3	17	59
2018	5	43	3	30	1	2	-	5	15	56

Table 3b. The number of index fisher logbook and mandatory DFO logbook returns in the South Coast and West Coast regions (LFAs 11–14C) Entries were omitted in several locations due to a small fishery and/or small number of returns.

South Coast Region (LFAs 11,12)					West Coast Region (LFAs 13A, 13B, 14A,14B, 14C)									
	LFA 11		LFA 12		LFA 13A		LFA 13B		LFA 14A		LFA 14B		LFA 14C	
Logbooks														
Year	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO	Index Fisher	DFO
2004	-	-	-	-	-	-	-	-	-	-	6	-	-	-
2005	5	-	-	-	1	-	2	-	1	-	4	-	1	-
2006	13	-	7	-	3	-	8	-	8	-	11	-	-	-
2007	15	-	7	-	3	-	8	-	6	-	11	-	1	-
2008	17	-	5	-	3	-	5	-	4	-	5	-	3	-
2009	22	-	8	-	5	-	5	-	8	-	12	-	3	-
2010	34	303	8	43	7	132	7	147	19	172	21	154	2	4
2011	33	210	8	38	6	92	6	103	17	129	19	124	-	3
2012	32	135	7	31	8	27	5	56	17	71	19	62	1	2
2013	33	14	8	-	5	3	6	7	19	9	19	5	1	-
2014	31	152	7	26	4	49	5	57	14	77	17	62	1	15
2015	32	133	7	23	4	42	4	52	12	62	17	58	1	4
2016	30	143	7	35	3	53	5	58	12	85	16	76	1	6
2017	29	172	7	35	3	49	5	62	13	106	15	90	1	8
2018	28	149	7	23	2	44	3	61	11	90	14	72	1	11

Table 4. Annual licenses issued, trap limits, and reported landings for Newfoundland, 2004–2019. Note: Reported landings for 2019 are preliminary (up to October 2019).

Year	Licenses Issued	Trap Limits	Landings (t)
2004	-	-	1,911
2005	-	-	2,612
2006	2,908	3,400	2,642
2007	2,888	3,400	2,567
2008	2,887	3,350	2,971
2009	2,841	3,350	2,499
2010	2,835	3,350	2,596
2011	2,793	3,150	1,934
2012	2,690	3,120	2,149
2013	2,563	3,120	2,202
2014	2,491	3,120	2,139
2015	2,450	3,120	2,654
2016	2,353	3,120	2,852
2017	2,322	3,120	2,911
2018	2,280	3,120	3,395
2019	-	3,120	4,433

Table 5. Reported lobster landings (tonnes) by region and total Newfoundland landings, 1990 to 2019.

Year	Northeast Coast	Avalon	South Coast	West Coast	Total Landings
1990	733	360	368	1,461	2,922
1991	729	441	448	1,461	3,079
1992	720	464	544	1,478	3,206
1993	467	333	557	1,266	2,623
1994	544	321	541	1,232	2,638
1995	506	337	501	1,204	2,548
1996	488	248	490	1,152	2,378
1997	435	185	463	1,096	2,179
1998	428	181	543	895	2,047
1999	398	151	496	773	1,818
2000	348	114	547	753	1,762
2001	386	127	619	1,032	2,164
2002	321	125	662	948	2,056
2003	313	97	722	1,122	2,254
2004	223	70	730	887	1,910
2005	309	78	949	1,274	2,610
2006	254	82	1,031	1,273	2,640
2007	197	44	1,066	1,258	2,565
2008	236	51	1,280	1,403	2,970
2009	197	61	1,145	1,094	2,497

Year	Northeast Coast	Avalon	South Coast	West Coast	Total Landings
2010	197	70	1,307	1,020	2,594
2011	126	45	994	769	1,934
2012	137	48	1,089	875	2,149
2013	135	30	1,164	873	2,202
2014	126	23	1,084	906	2,139
2015	229	30	1,232	1,261	2,752
2016	157	37	1,329	1,329	2,852
2017	154	37	1,230	1,490	2,911
2018	161	28	1,450	1,756	3,395
2019	208	48	1,738	2,439	4,433

Table 6. Annual licenses issued, trap limits per license, reported landings, and mean CPUE for Northeast Coast region (LFAs 3, 4A, 4B, 5 & 6).

Year	Licenses Issued	Trap Limits	Landings (t)	Index Fishers logbooks Mean CPUE (#/Trap)	DFO logbooks Mean CPUE (#/Trap)
2004	-	-	223	0.15	-
2005	-	900	309	0.20	-
2006	1,167	1,000	254	0.20	-
2007	1,157	1,000	197	0.19	-
2008	1,155	850	236	0.24	-
2009	1,130	850	197	0.21	-
2010	1,126	850	197	0.26	0.27
2011	1,095	850	126	0.22	0.24
2012	1,117	850	137	0.25	0.26
2013	1,091	850	135	0.26	0.32
2014	1,070	850	126	0.31	0.35
2015	1,036	850	205	0.28	0.32
2016	957	850	157	0.26	0.26
2017	941	850	154	0.37	0.36
2018	913	850	161	0.28	0.30
2019	-	850	208	-	-

Table 7. Annual licenses issued, trap limits per license, reported landings and mean CPUE for Avalon region (LFAs 7, 8, 9A, 9B & 10).

Year	Licenses Issued	Trap Limits	Landings (t)	Index Fishers- Mean CPUE (#/Trap)	DFO logbooks Mean CPUE (#/Trap)
2004	-	-	70	-	-
2005	-	750	78	0.17	-
2006	612	650	82	0.20	-

Year	Licenses Issued	Trap Limits	Landings (t)	Index Fishers- Mean CPUE (#/Trap)	DFO logbooks Mean CPUE (#/Trap)
2007	605	650	44	0.16	-
2008	605	750	51	0.24	-
2009	584	750	61	0.24	-
2010	585	750	70	0.30	0.28
2011	574	750	45	0.26	0.27
2012	589	750	48	0.26	0.28
2013	570	750	30	0.29	0.37
2014	560	750	23	0.29	0.34
2015	553	750	30	0.27	0.28
2016	537	750	37	0.28	0.30
2017	522	750	37	0.29	0.30
2018	508	750	28	0.26	0.29
2019	-	750	48	-	-

Table 8. Annual licenses issued, trap limits per license, reported landings and mean CPUE for South Coast region (LFAs 11 & 12).

Year	Licenses Issued	Trap Limits	Landings (t)	Index Fishers- Mean CPUE (#/Trap)	DFO logbooks Mean CPUE (#/Trap)
2004	-	-	730	-	-
2005	-	350	949	0.62	-
2006	367	350	1,031	0.61	-
2007	364	350	1,066	0.56	-
2008	364	350	1,280	0.70	-
2009	364	350	1,145	0.69	-
2010	364	350	1,307	0.72	0.80
2011	364	350	994	0.63	0.66
2012	329	320	1,089	0.74	0.78
2013	306	320	1,164	0.83	0.89
2014	300	320	1,084	0.82	0.92
2015	300	320	1,232	0.90	0.96
2016	300	320	1,329	0.95	0.94
2017	300	320	1,230	0.98	0.97
2018	300	320	1,450	1.20	1.16
2019	-	320	1,738	-	-

Table 9. Annual licenses issued, trap limits per license, reported landings and mean CPUE for West Coast region (LFAs 13A, 13B, 14A, 14B & 14C).

Year	Licenses Issued	Trap Limits	Landings (t)	Index Fishers-Mean CPUE (#/Trap)	DFO logbooks Mean CPUE (#/Trap)
2004	-	-	888	0.20	-
2005	-	1,400	1,276	0.44	-
2006	762	1,400	1,275	0.52	-
2007	762	1,400	1,260	0.49	-
2008	763	1,400	1,404	0.51	-
2009	763	1,400	1,096	0.51	-
2010	760	1,400	1,022	0.42	0.47
2011	760	1,200	769	0.40	0.45
2012	655	1,200	875	0.49	0.50
2013	596	1,200	873	0.55	0.63
2014	561	1,200	906	0.48	0.59
2015	561	1,200	1,211	0.63	0.73
2016	559	1,200	1,329	0.63	0.68
2017	559	1,200	1,490	0.70	0.72
2018	559	1,200	1,756	0.71	0.82
2019	-	1,200	2,439	-	-

APPENDIX II - FIGURES

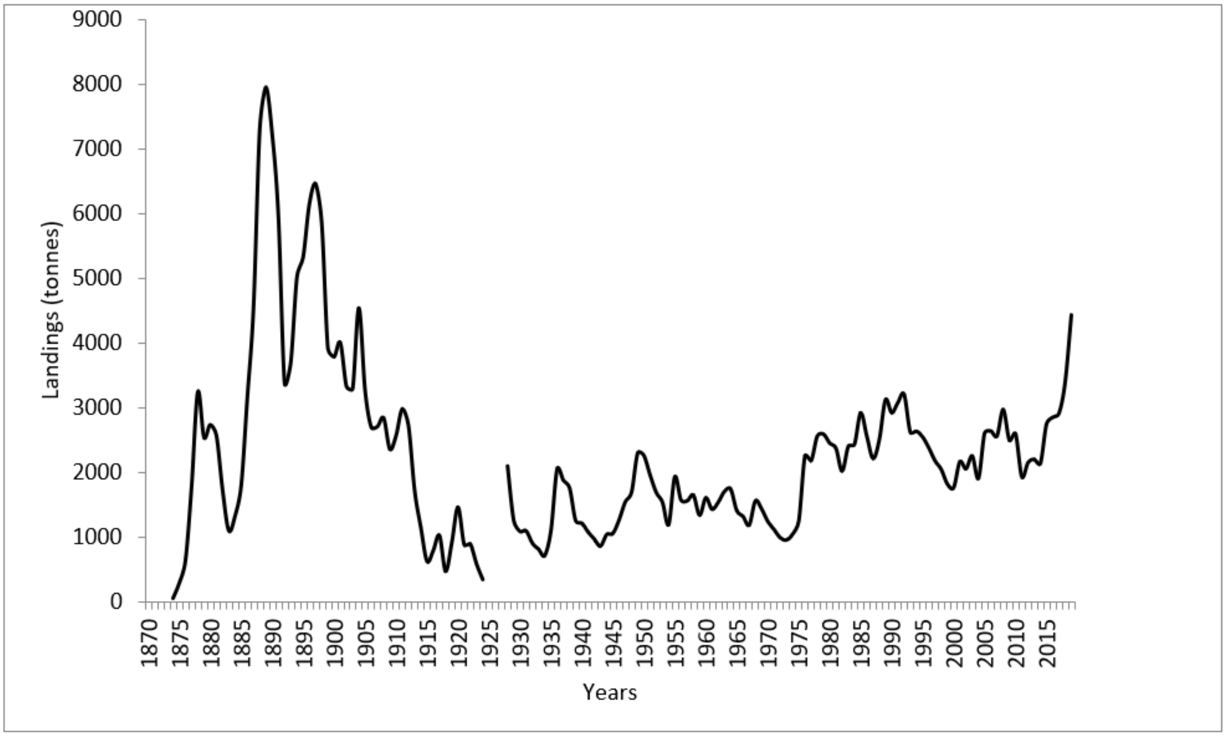

Figure 1. Reported landings (tonnes) for the Newfoundland lobster fishery from the mid-1870s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

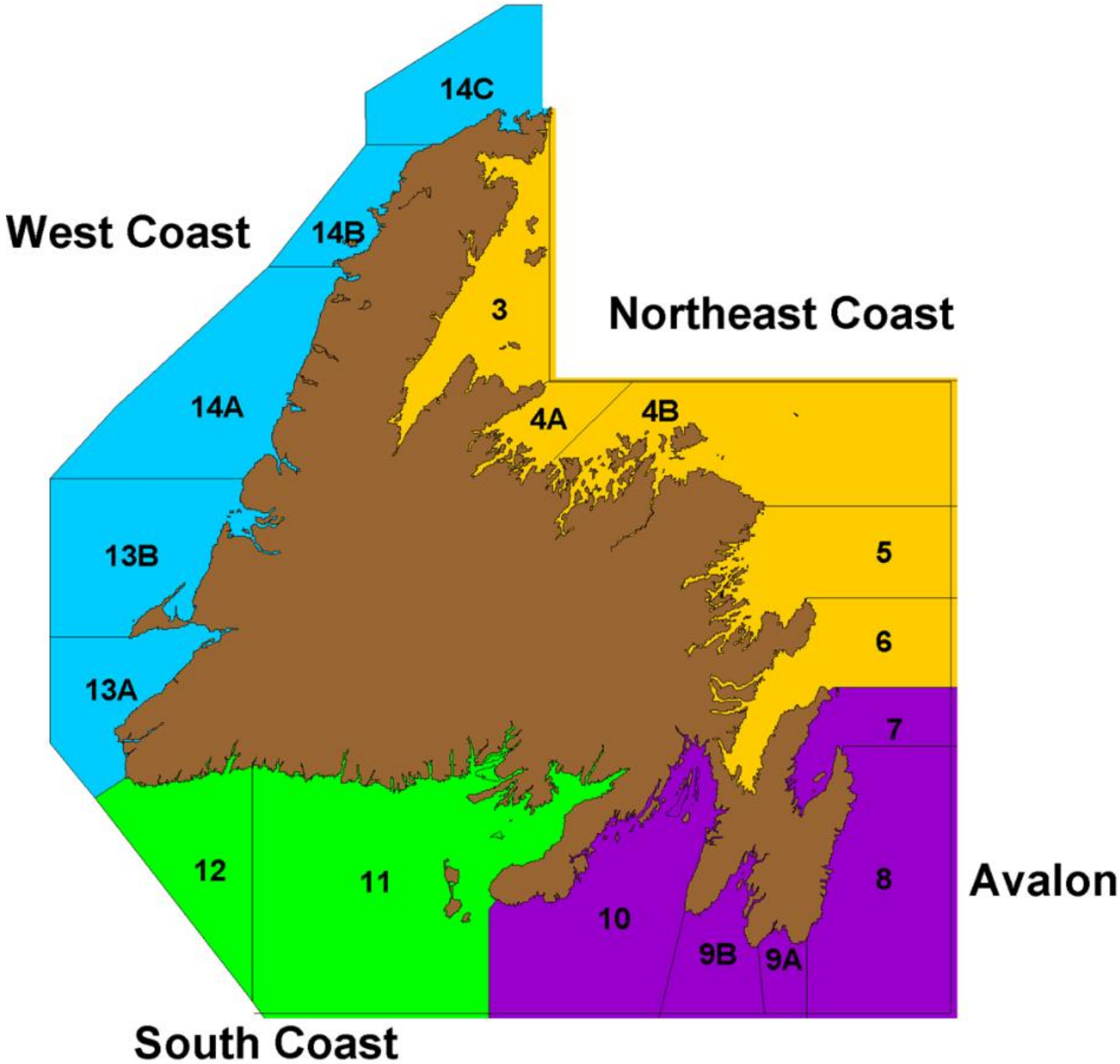

Figure 2. Newfoundland Lobster Fishing Areas (LFAs 3–14) combined into assessment regions (Northeast Coast, Avalon, South Coast, and West Coast).

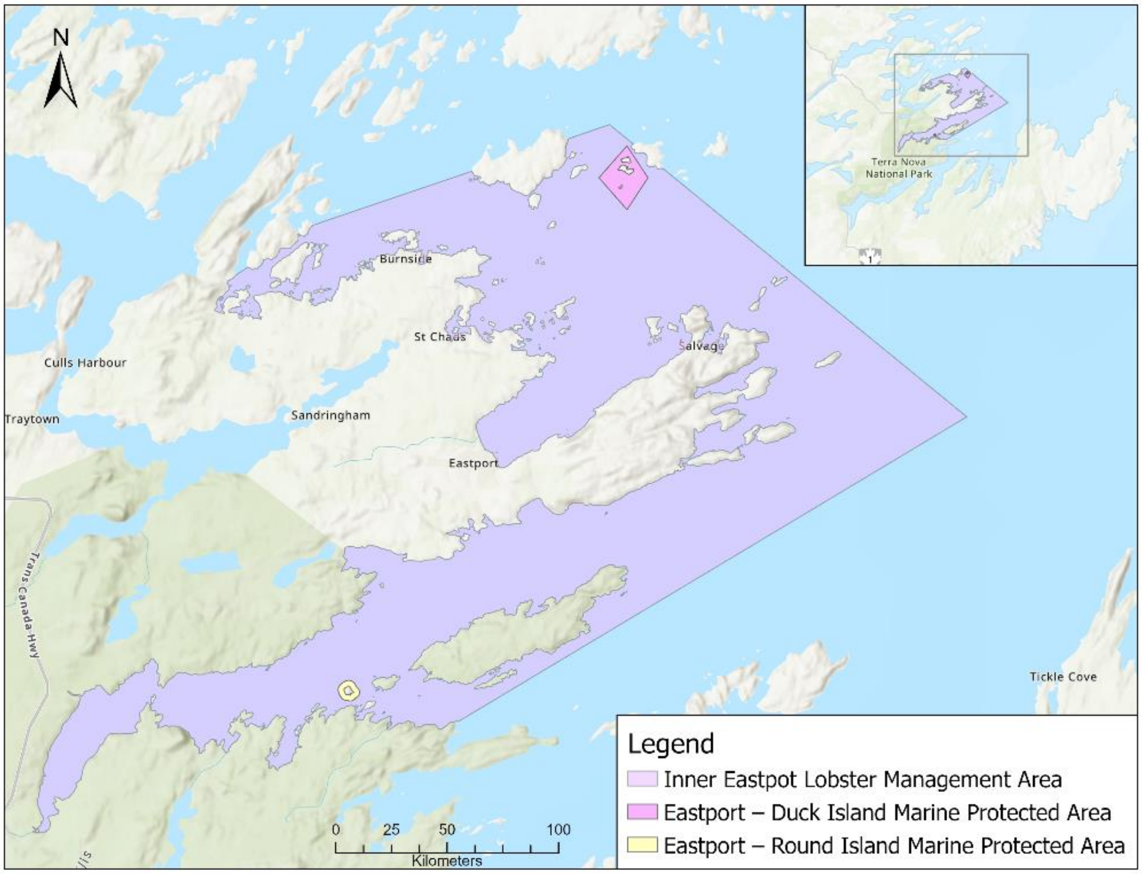

Figure 3. Map showing the Eastport Marine Protected Area within LFA 5 in Bonavista Bay, NL.

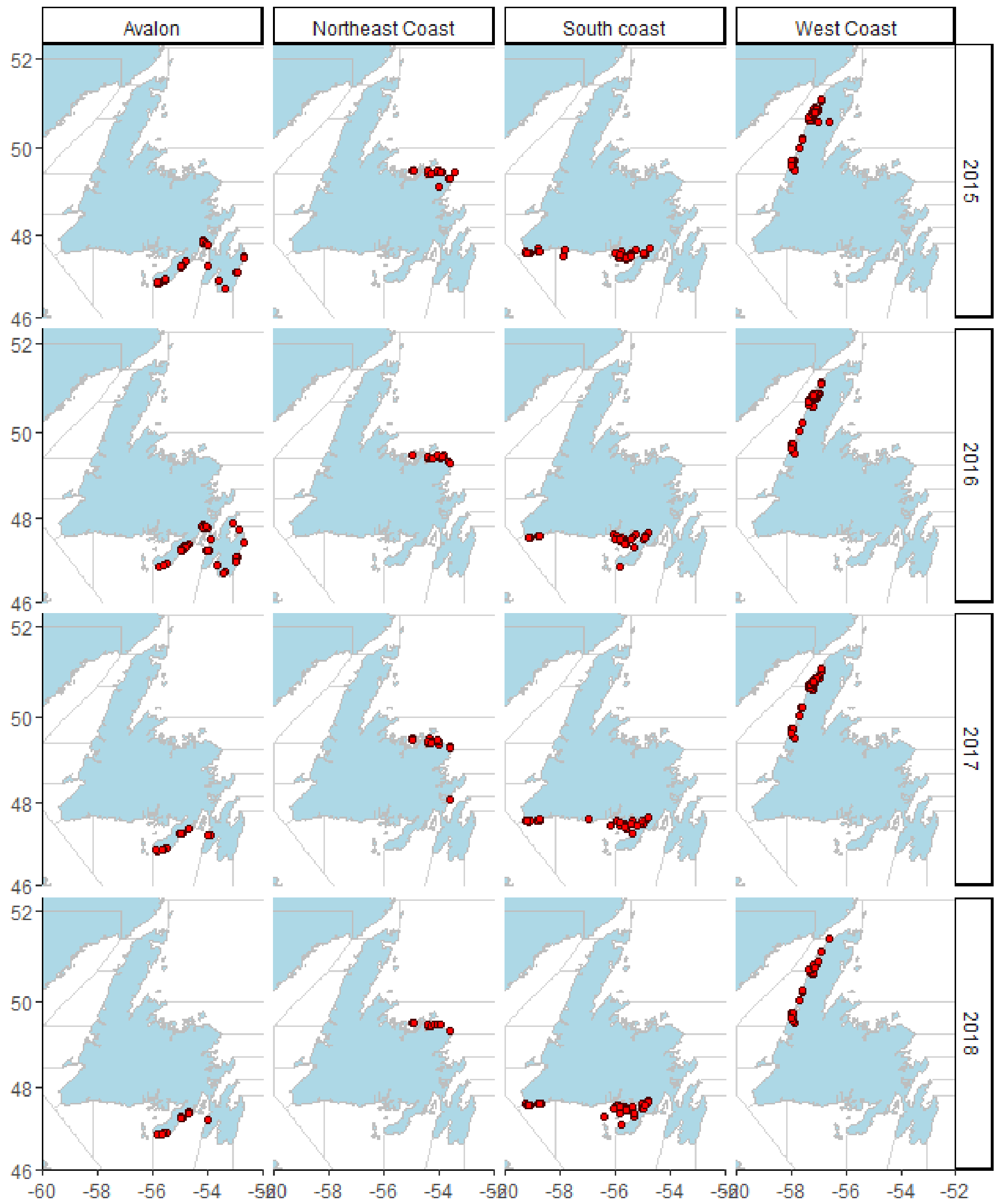

Figure 4. At-sea sampling locations within each region from 2015–18.

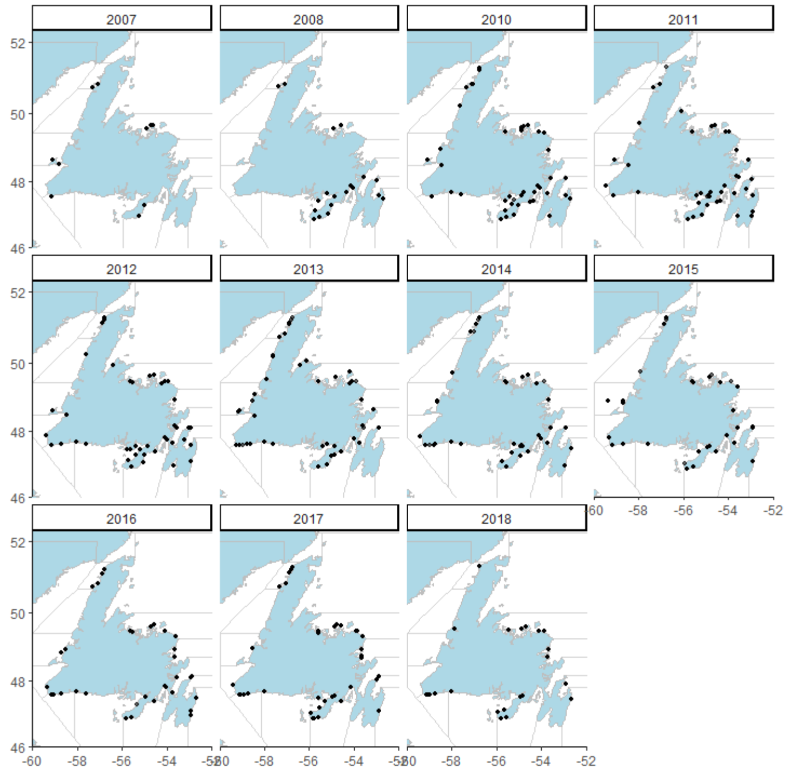

Figure 5. Map of modified trap and temperature probe locations for each year (2007–18).

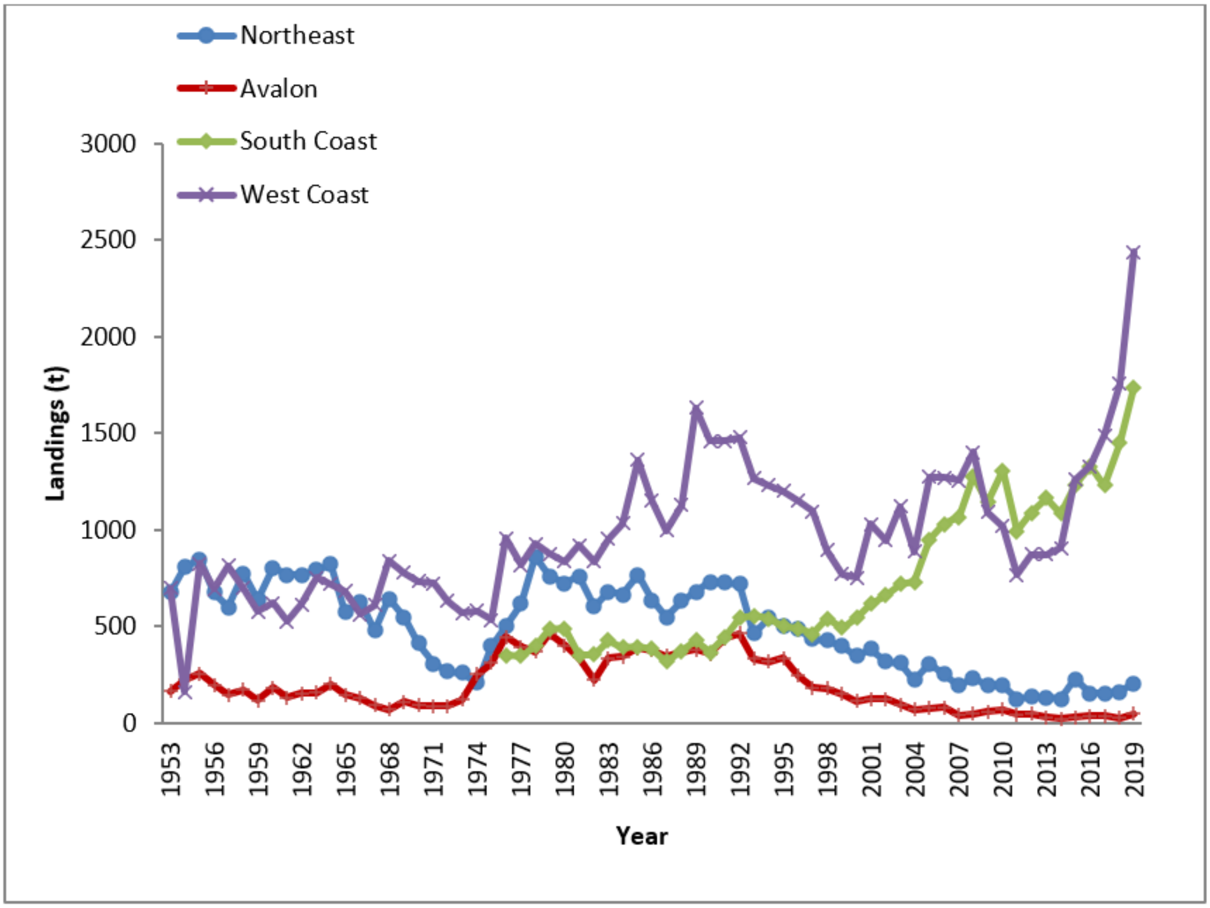

Figure 6. Reported landings (t) for the lobster fishery in each assessment region from the early 1950s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

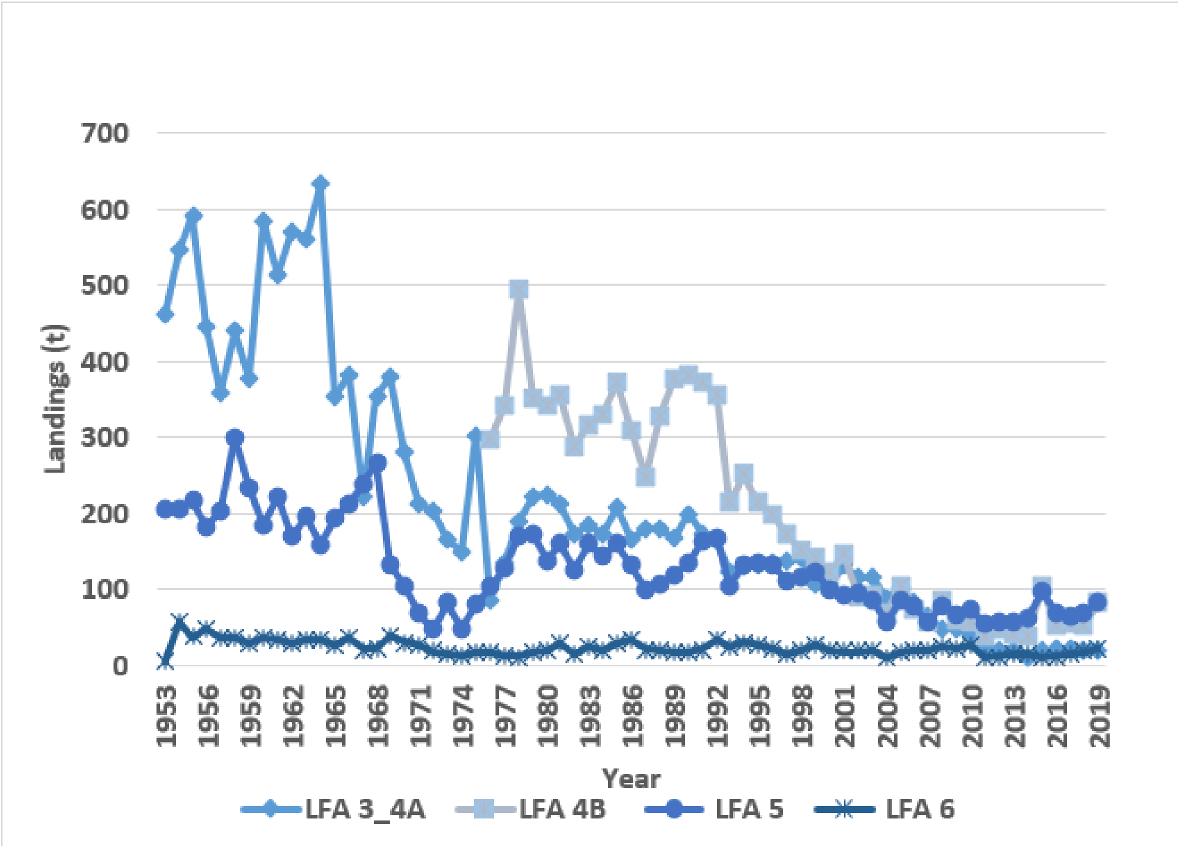

Figure 7. Reported landings (t) for the lobster fishery in LFAs within the Northeast Coast region from the early 1950s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

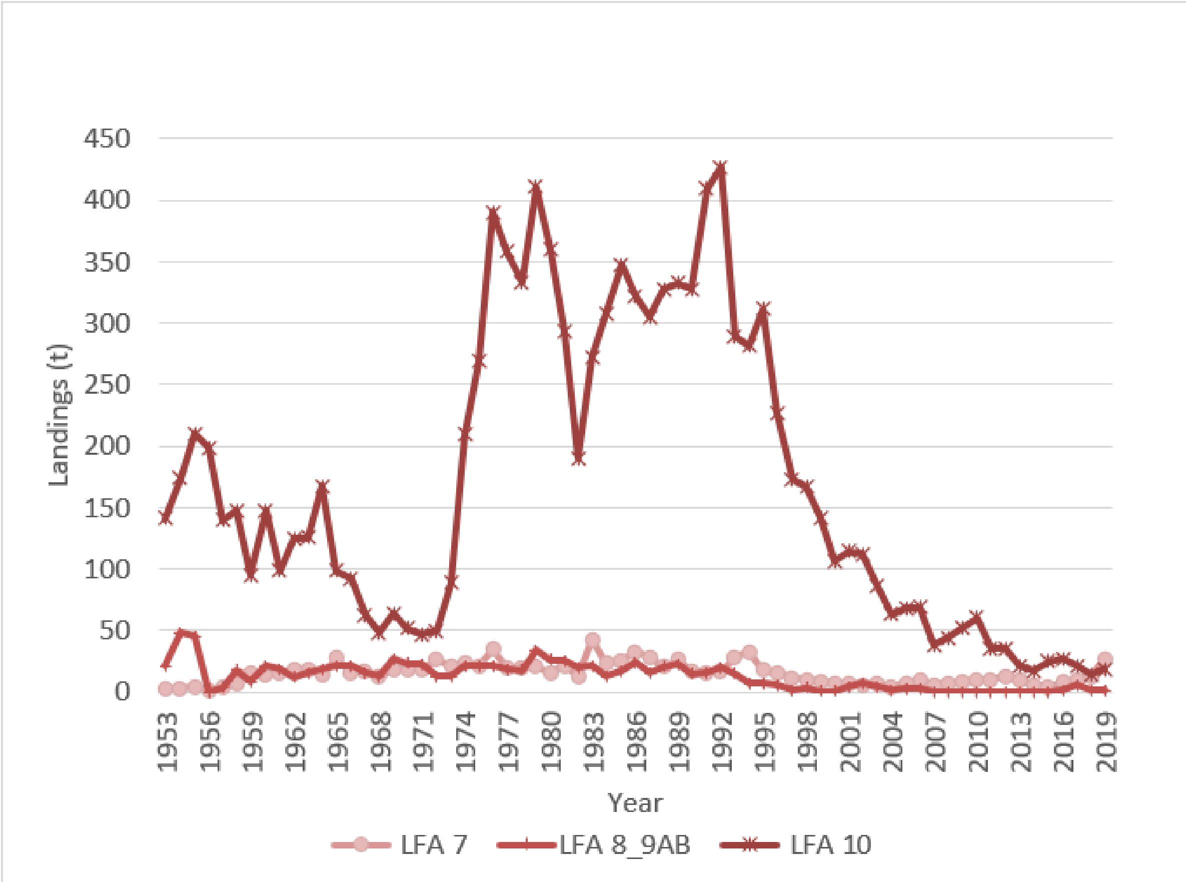

Figure 8. Reported landings (t) for the lobster fishery in LFAs within the Avalon region from the early 1950s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

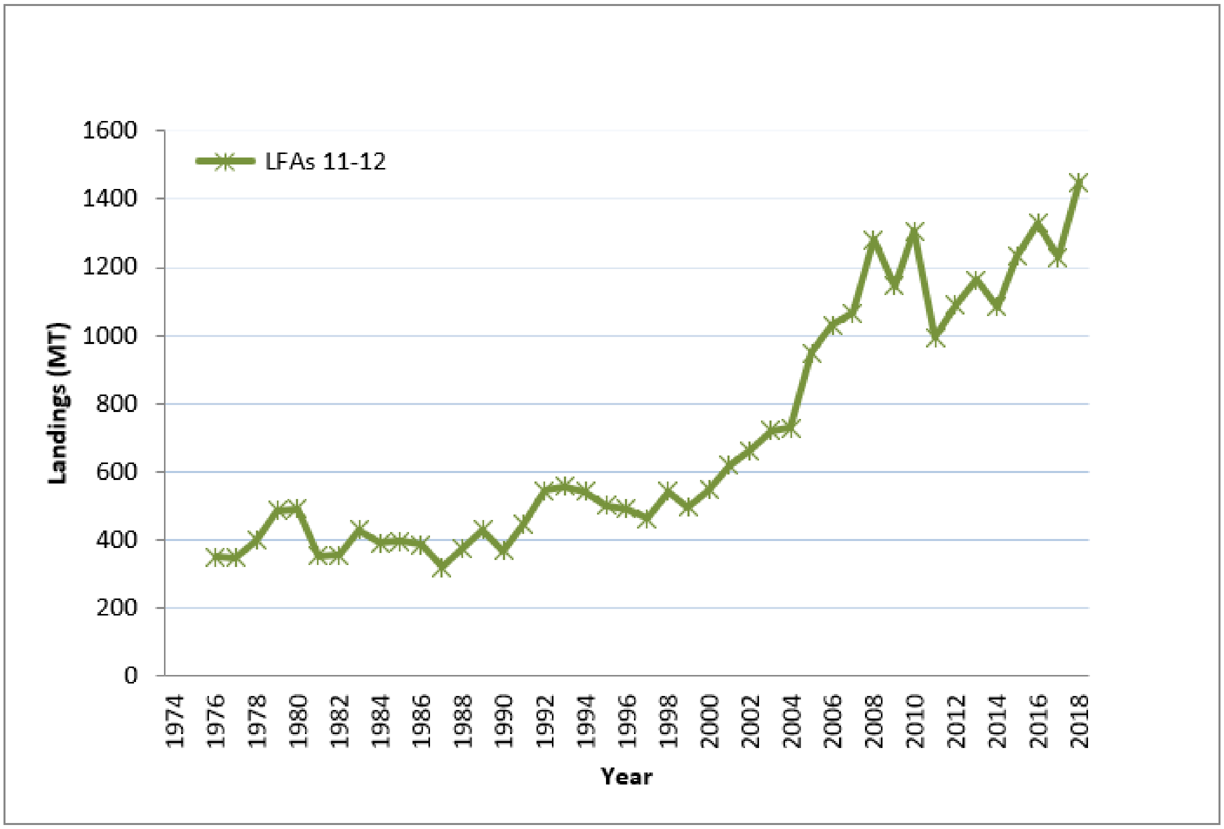

Figure 9. Reported landings (t) for the lobster fishery within the South Coast region from the mid-1970s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

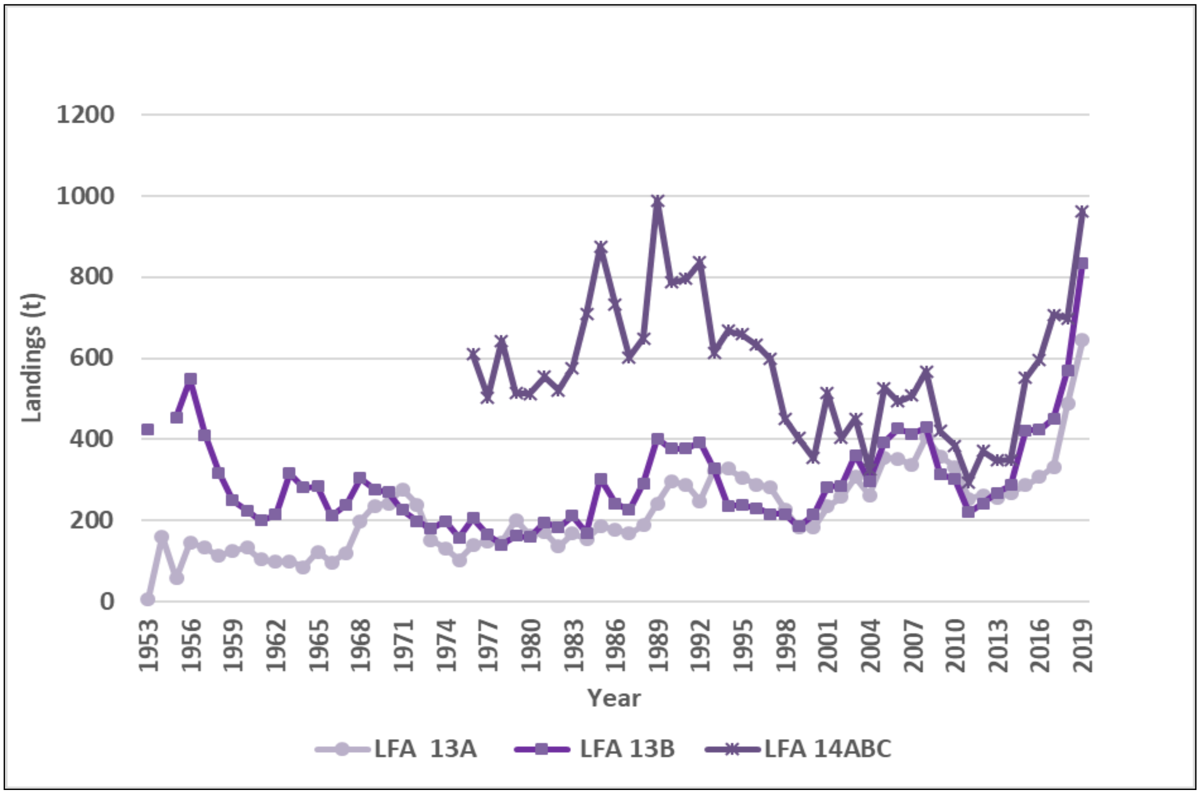

Figure 10. Reported landings (t) for the lobster fishery in LFAs within the West Coast region from the early 1950s to 2019. Reported landings for 2019 are preliminary and are based on catch and effort reports up to October 2019.

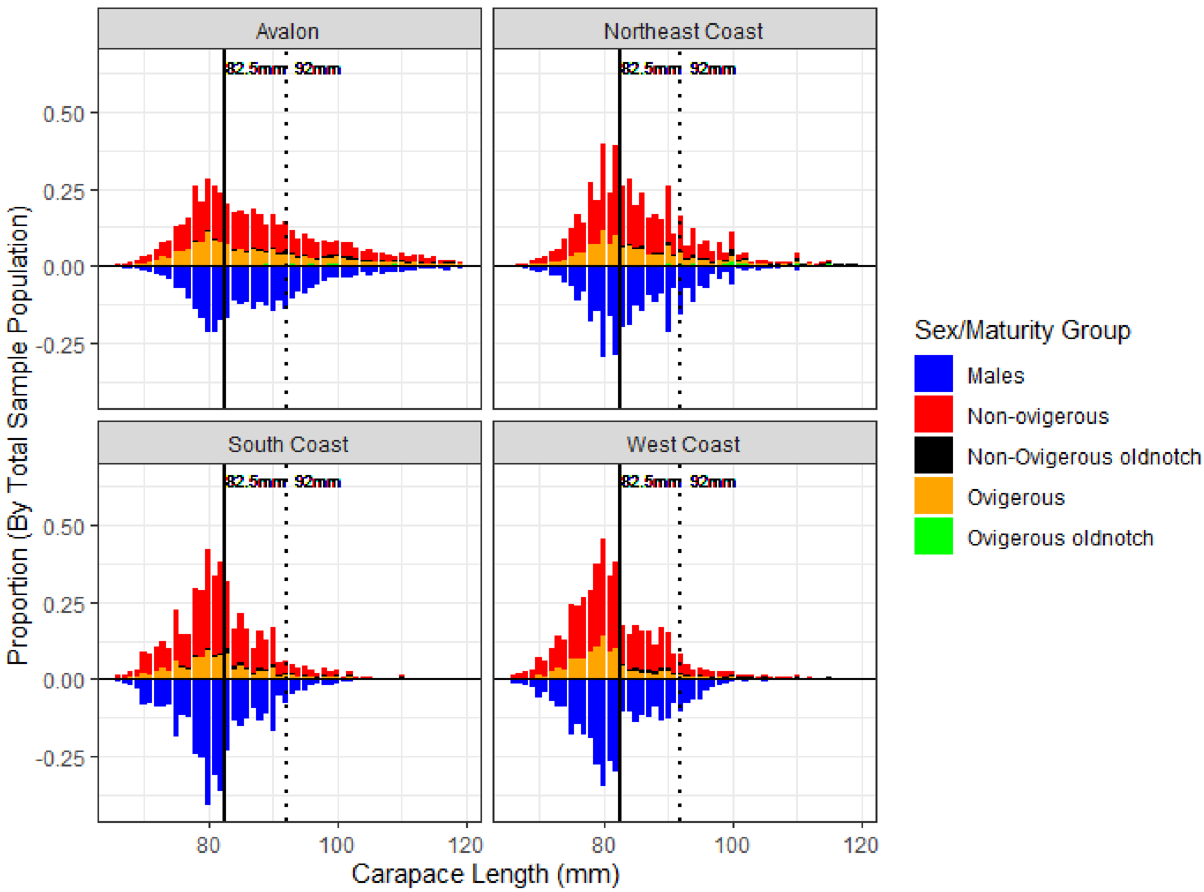

Figure 11. Size-frequency distributions for males (bottom half of each panel) and females (top half of each panel) from at-sea sampling data in each of the four regions, 2010–18. The black vertical line represents the minimum legal size, and the black dotted line represents 92 mm carapace length.

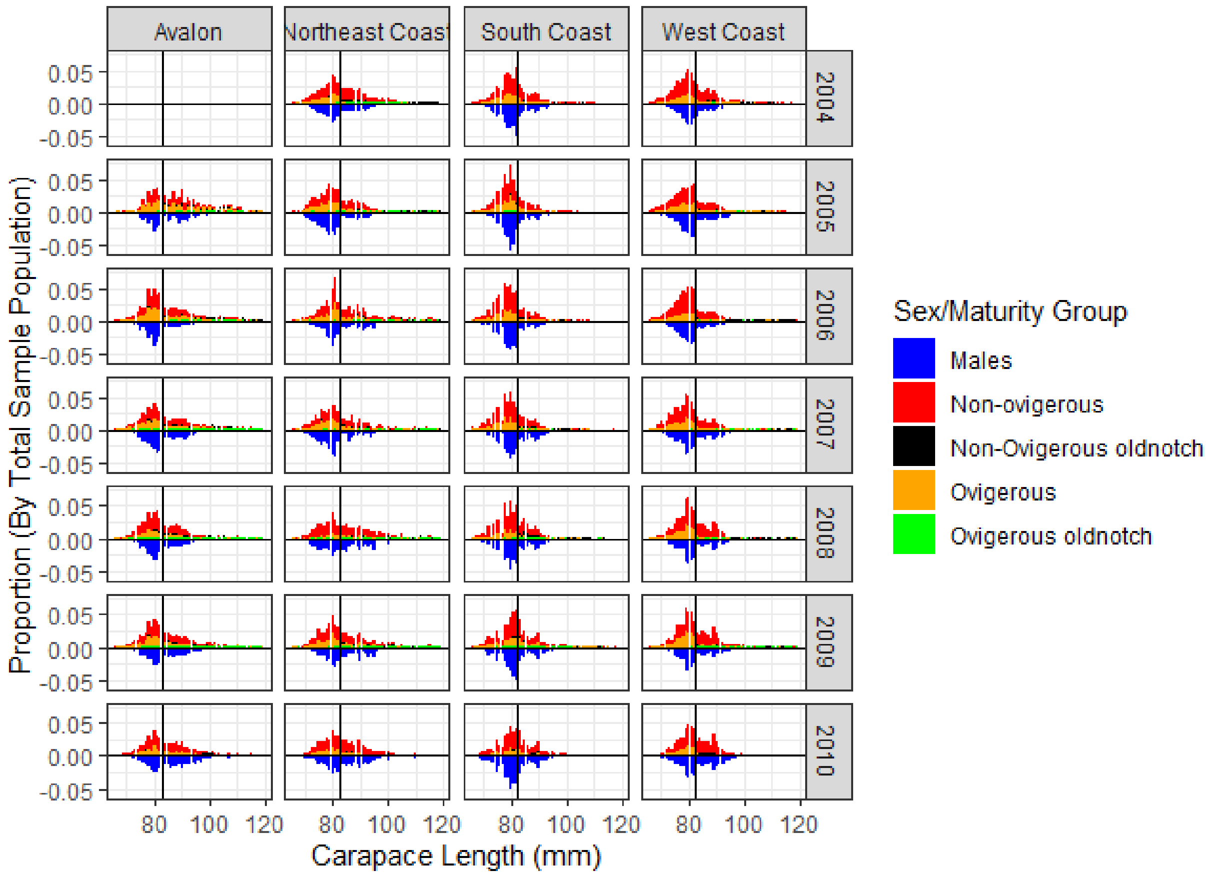

Figure 12. Size-frequency distributions for males (bottom half of each panel) and females (top half of each panel) from at-sea sampling data in each of the four regions, 2004–10. The black vertical line represents the minimum legal size.

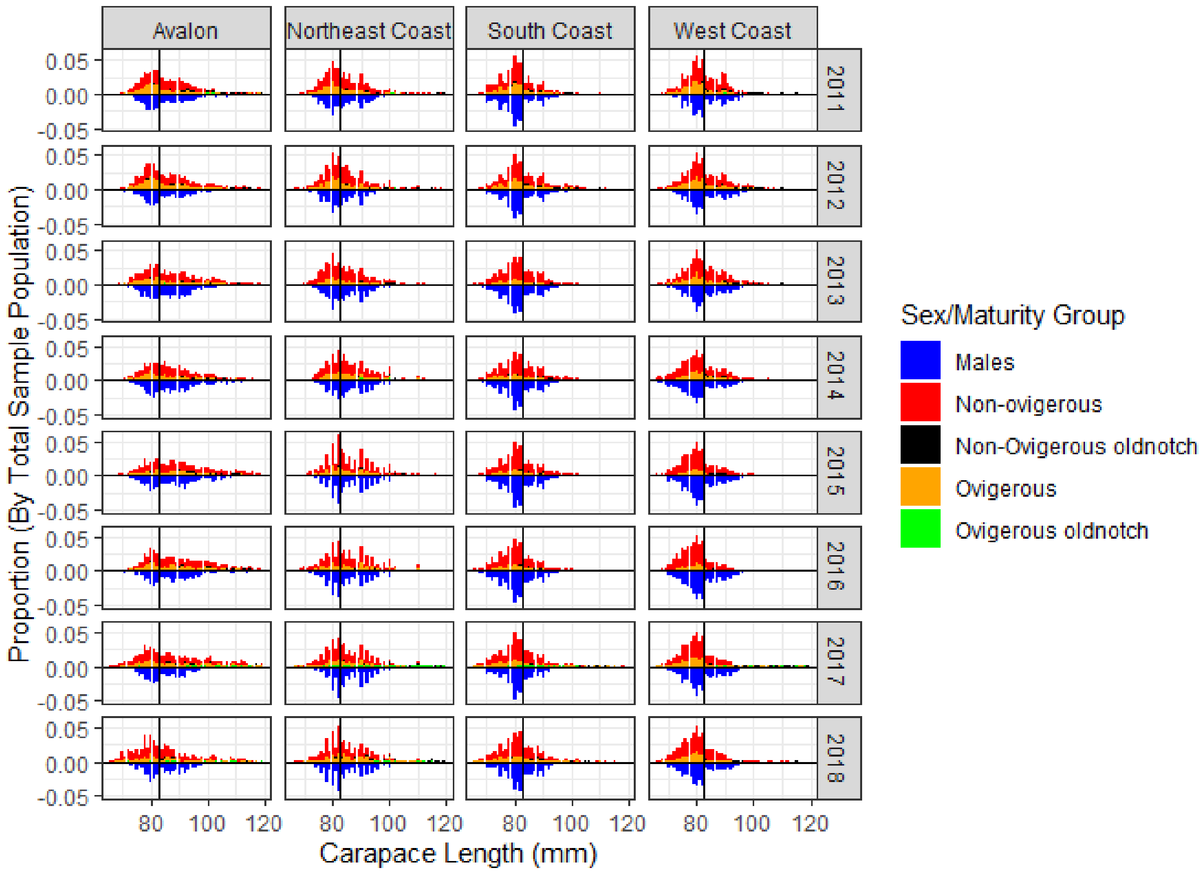

Figure 13. Size-frequency distributions for males (bottom half of each panel) and females (top half of each panel) from at-sea sampling data in each of the four regions, 2011–18. The black vertical line represents the minimum legal size.

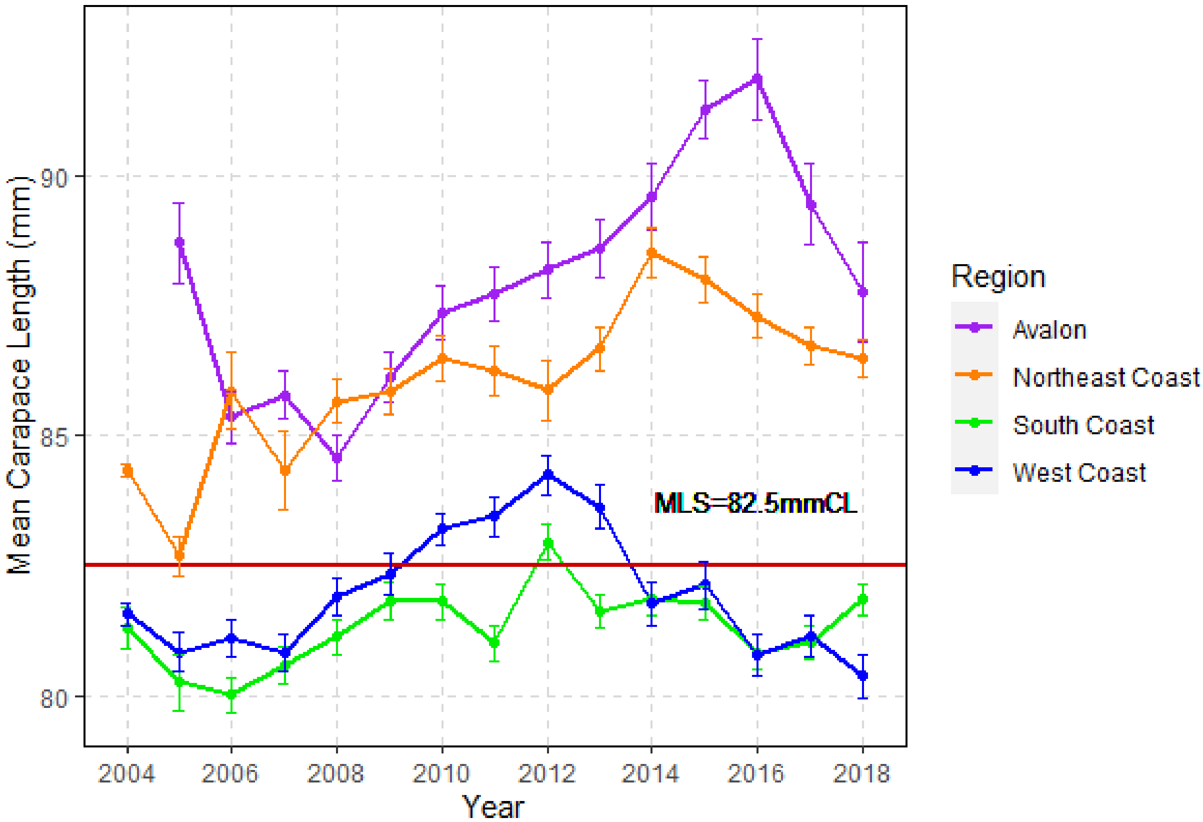

Figure 14. Mean carapace length (CL; in mm) of total catch from at-sea sampling data for each region, 2004–18. The red horizontal line represents the minimum legal size and error bars represent 95% confidence intervals.

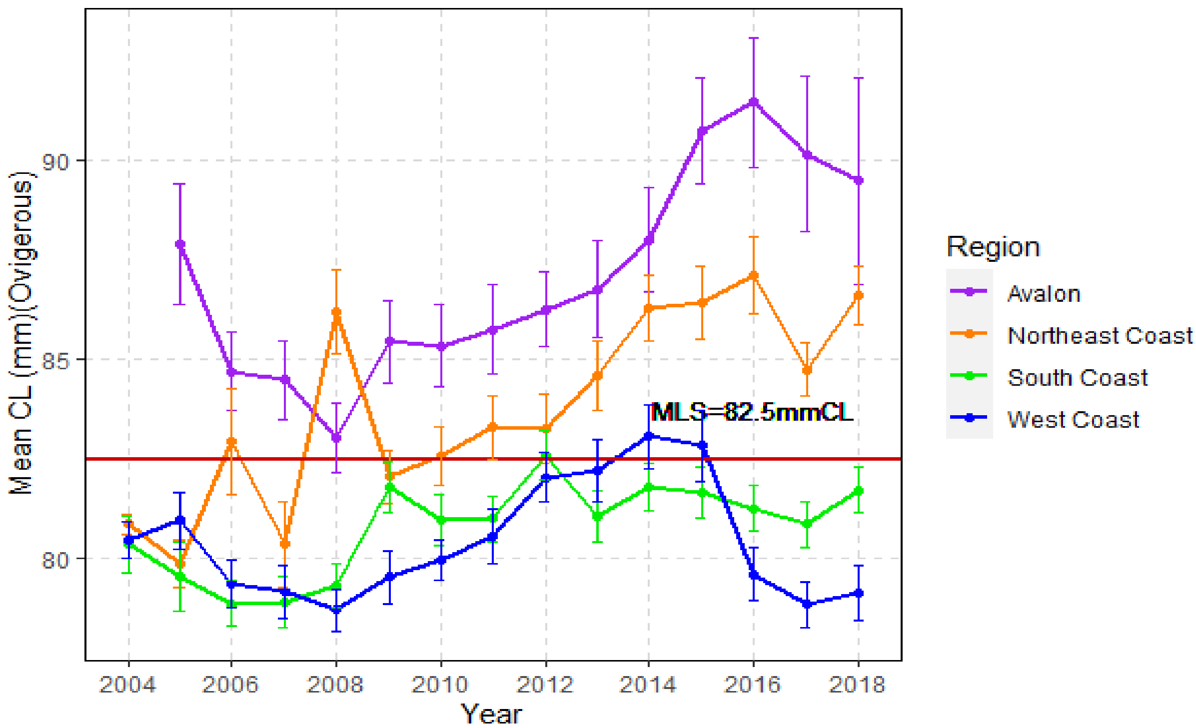

Figure 15. Mean carapace length (CL; in mm) of ovigerous female lobster from at-sea sampling for each region, 2004–18. The red horizontal line represents the minimum legal size and error bars represent 95% confidence intervals.

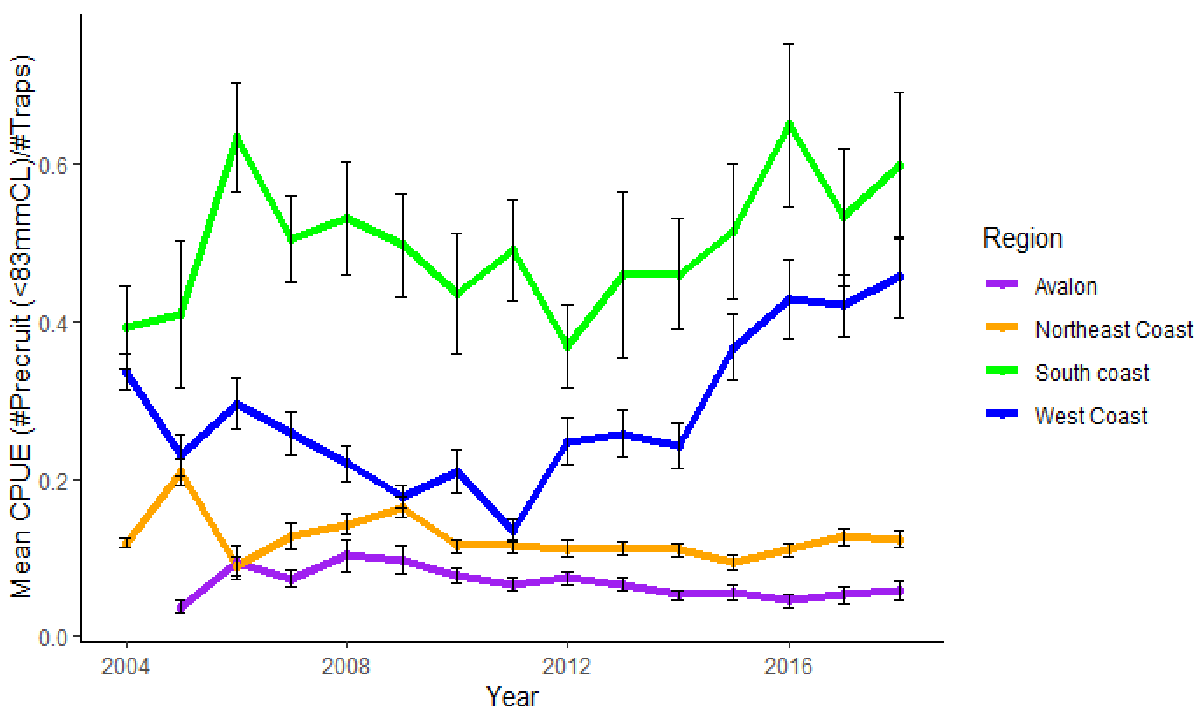

Figure 16. Catch per unit effort (CPUE) of pre-recruit (<83 mm CL) lobster from at-sea sampling data (commercial traps) collected in each region, 2004–18. Error bars represent 95% confidence intervals.

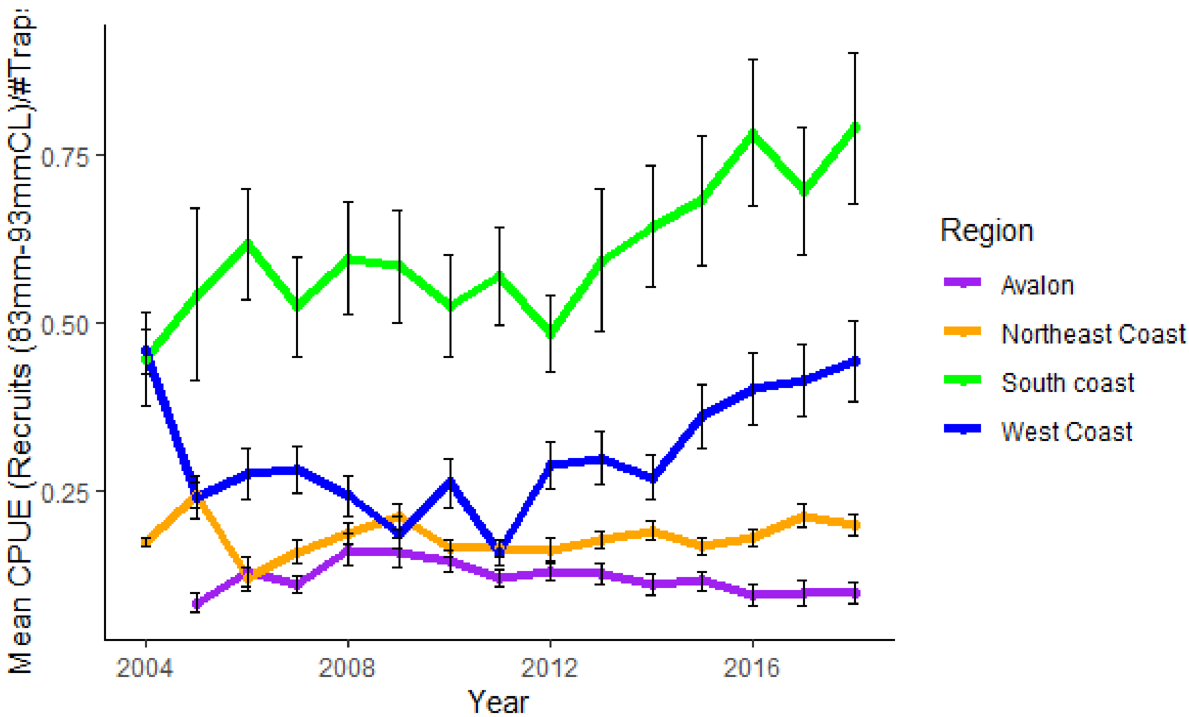

Figure 17. Catch per unit effort (CPUE) of recruit size (83–93 mm) lobster from at-sea sampling data (commercial traps) collected in each region, 2004–18. Error bars represent 95% confidence intervals.

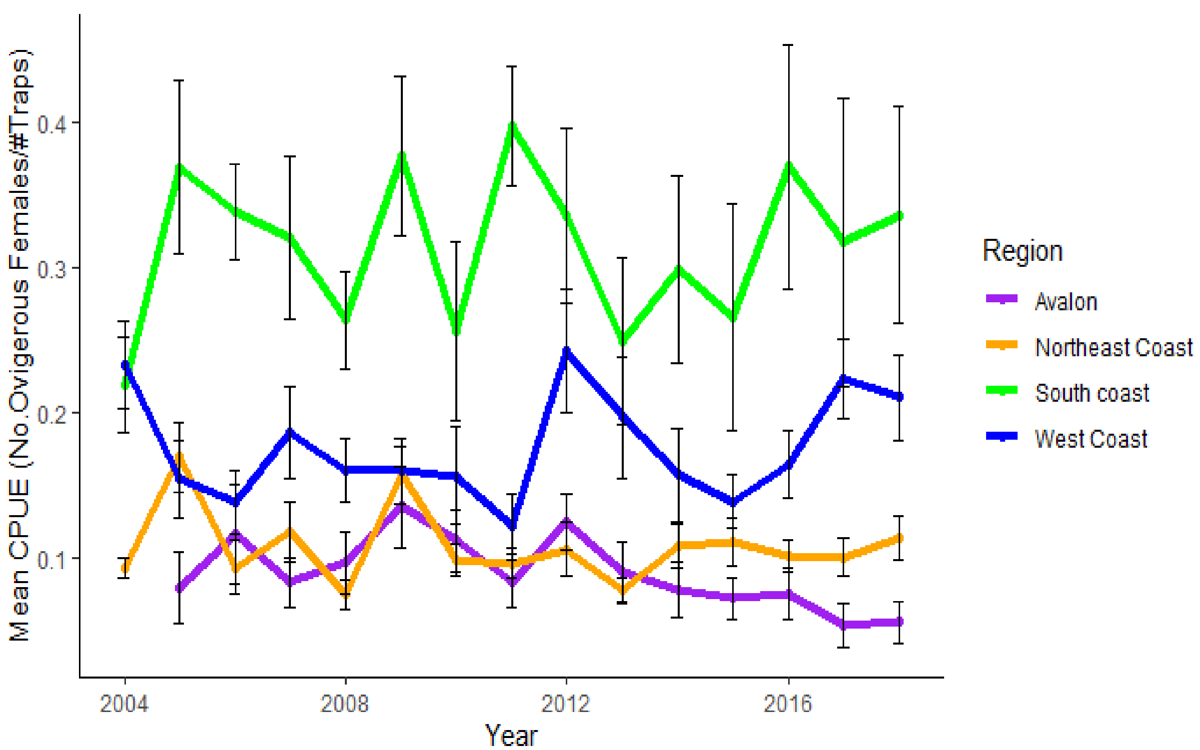

Figure 18. Catch per unit effort (CPUE) of ovigerous female lobster in each of the four regions from at-sea sampling data, 2004–18. Error bars represent 95% confidence intervals.

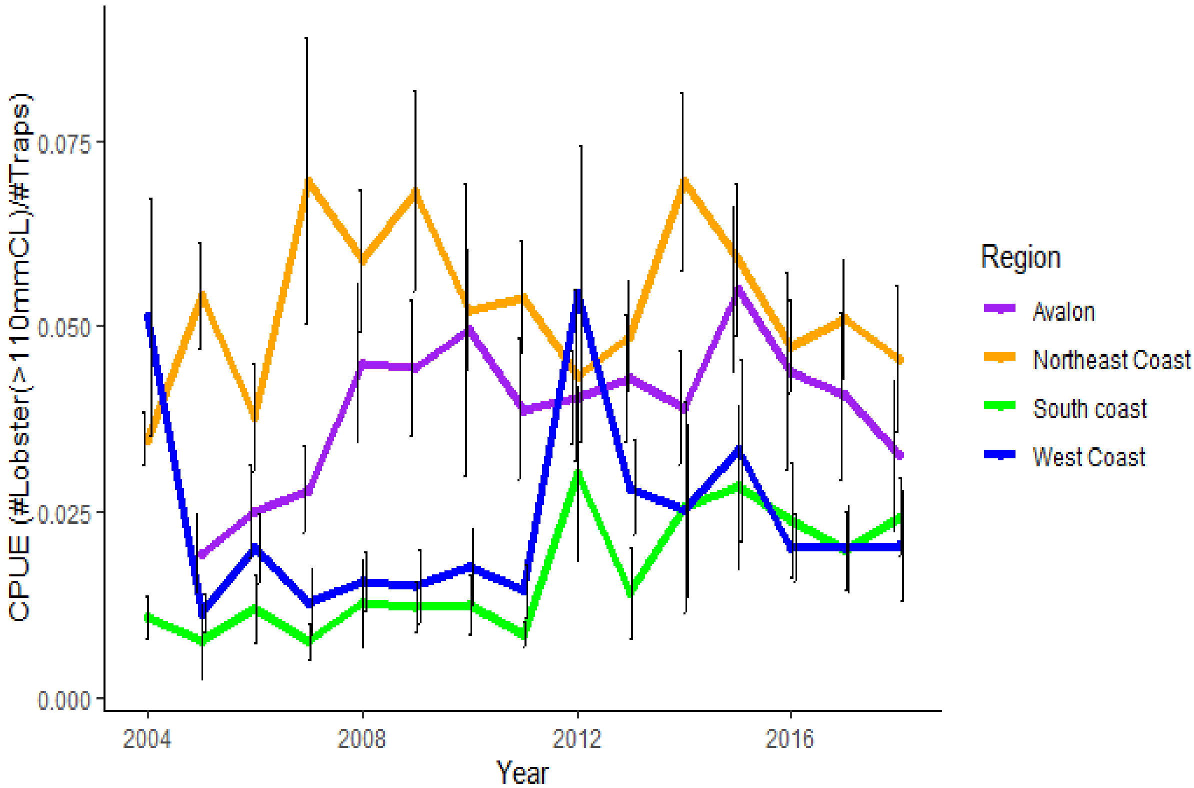

Figure 19. Catch per unit effort (CPUE) of large lobster (>110 mm CL) in each of the four regions from at-sea sampling data, 2004–18. Error bars represent 95% confidence intervals.

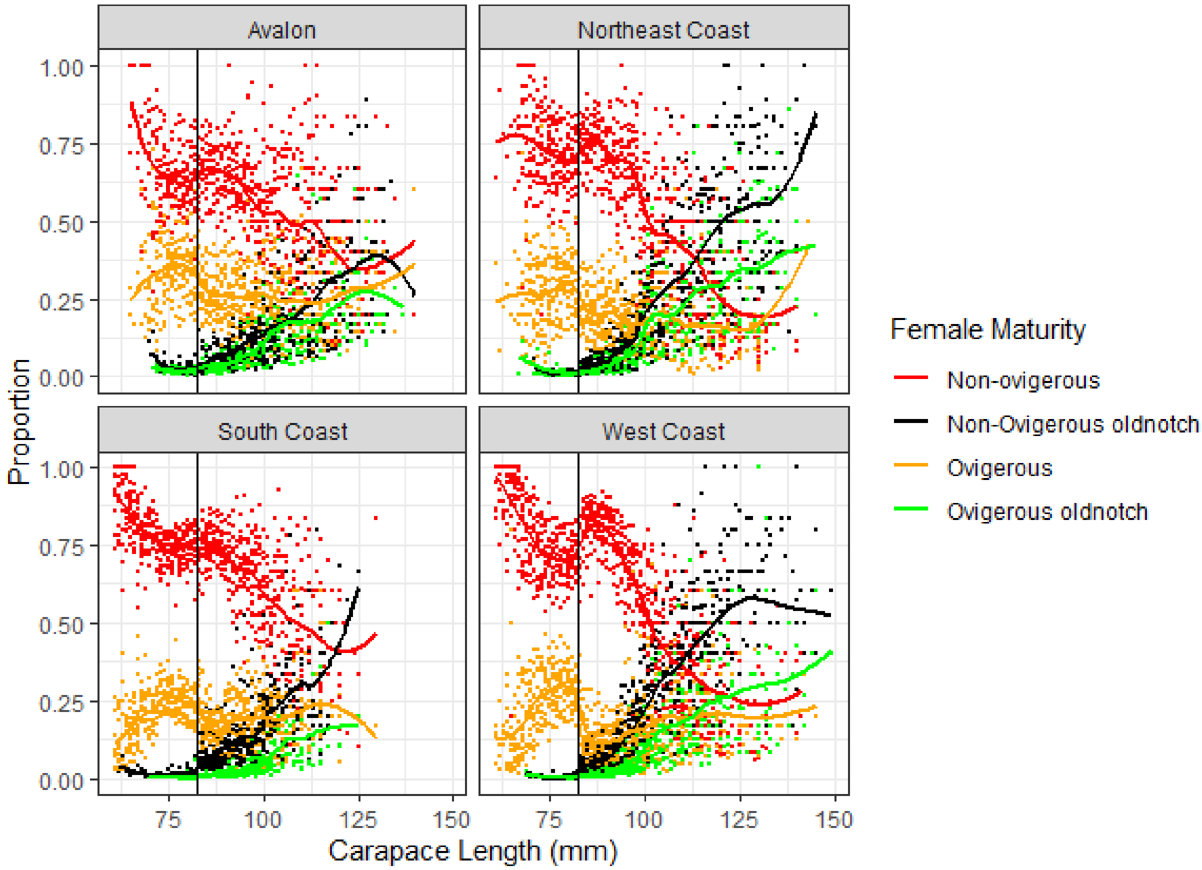

Figure 20. Proportion of females within each maturity category from all at-sea sampling data collected over 2004–18, for each of the four regions. The black vertical line represents the minimum legal size.

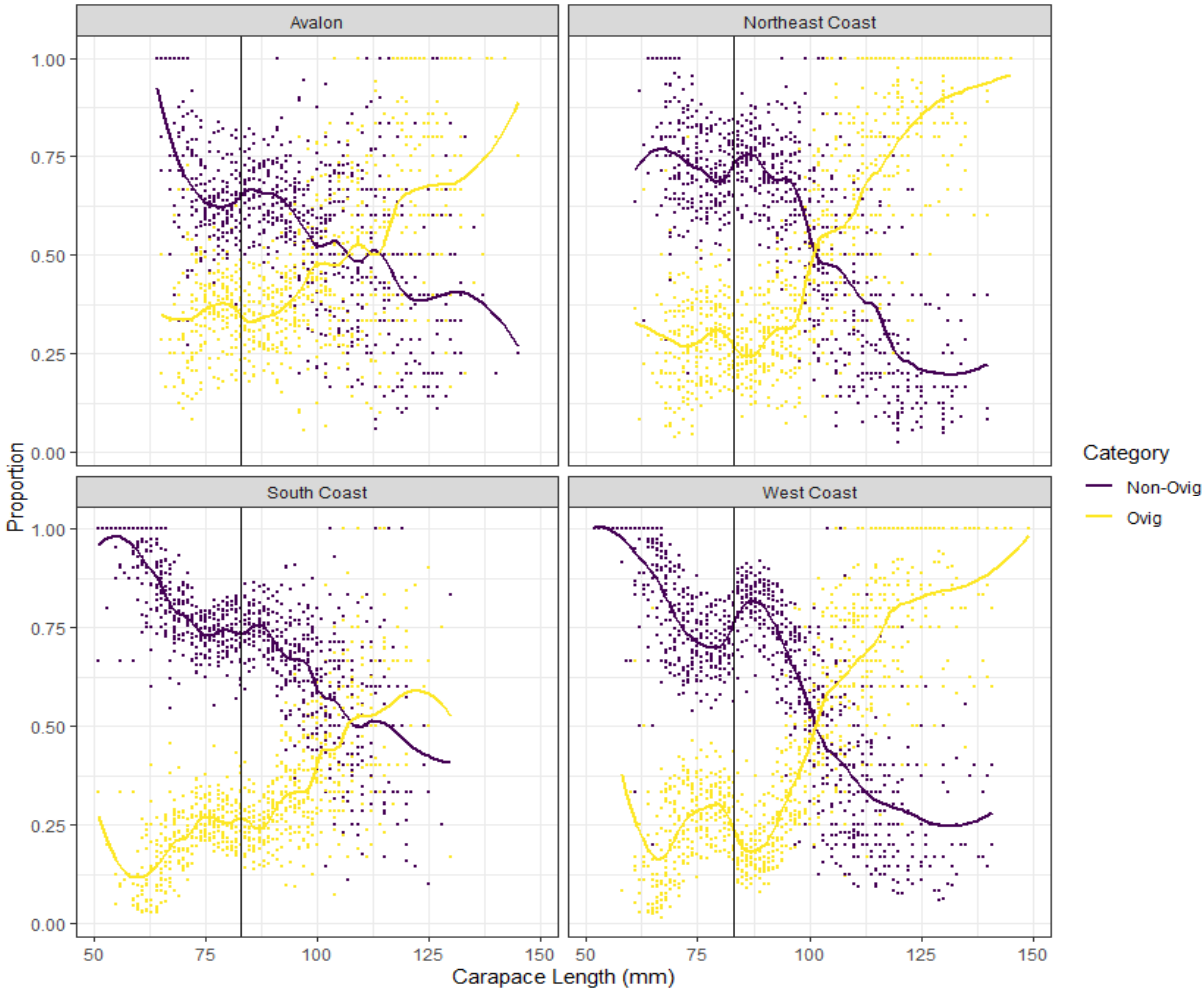

Figure 21. Proportion of ovigerous (yellow) and non-ovigerous (black) females from all at-sea sampling data collected over 2004–18, for each of the four regions. The black vertical line represents the minimum legal size.

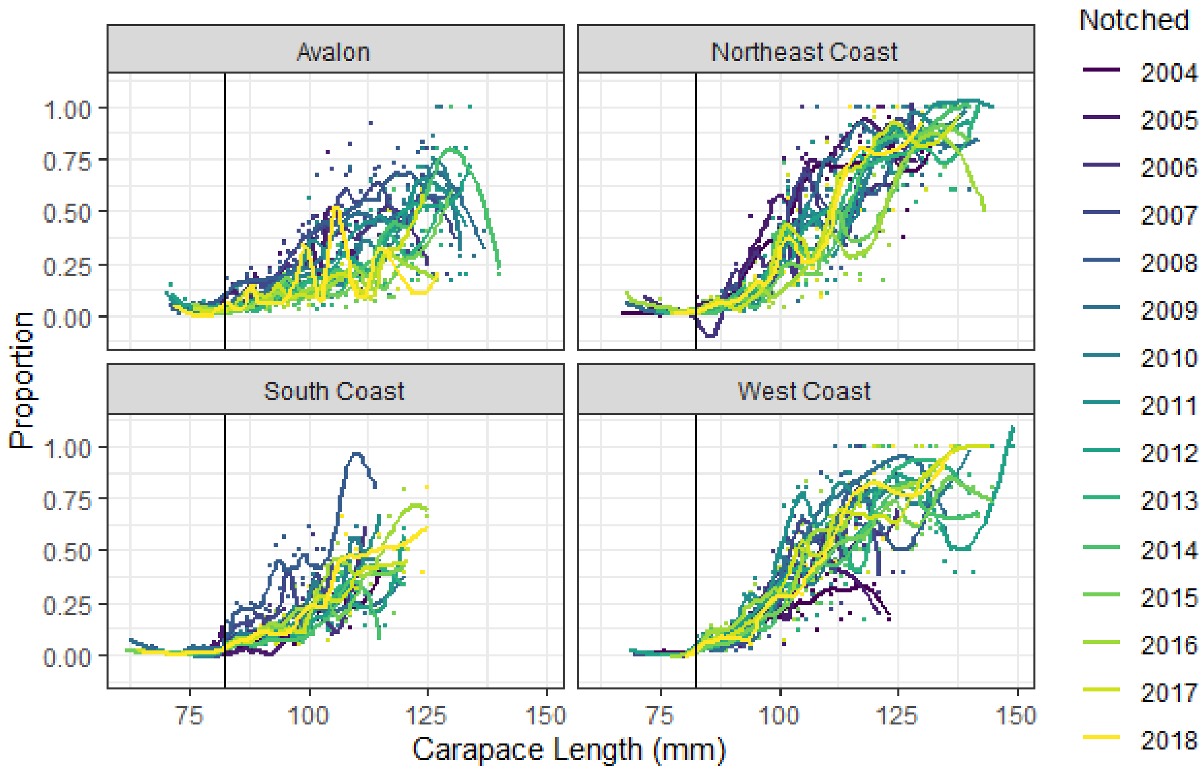

Figure 22. Annual proportions of v-notched females in each region from at-sea sampling data, 2004–18. The black vertical line represents the minimum legal size.

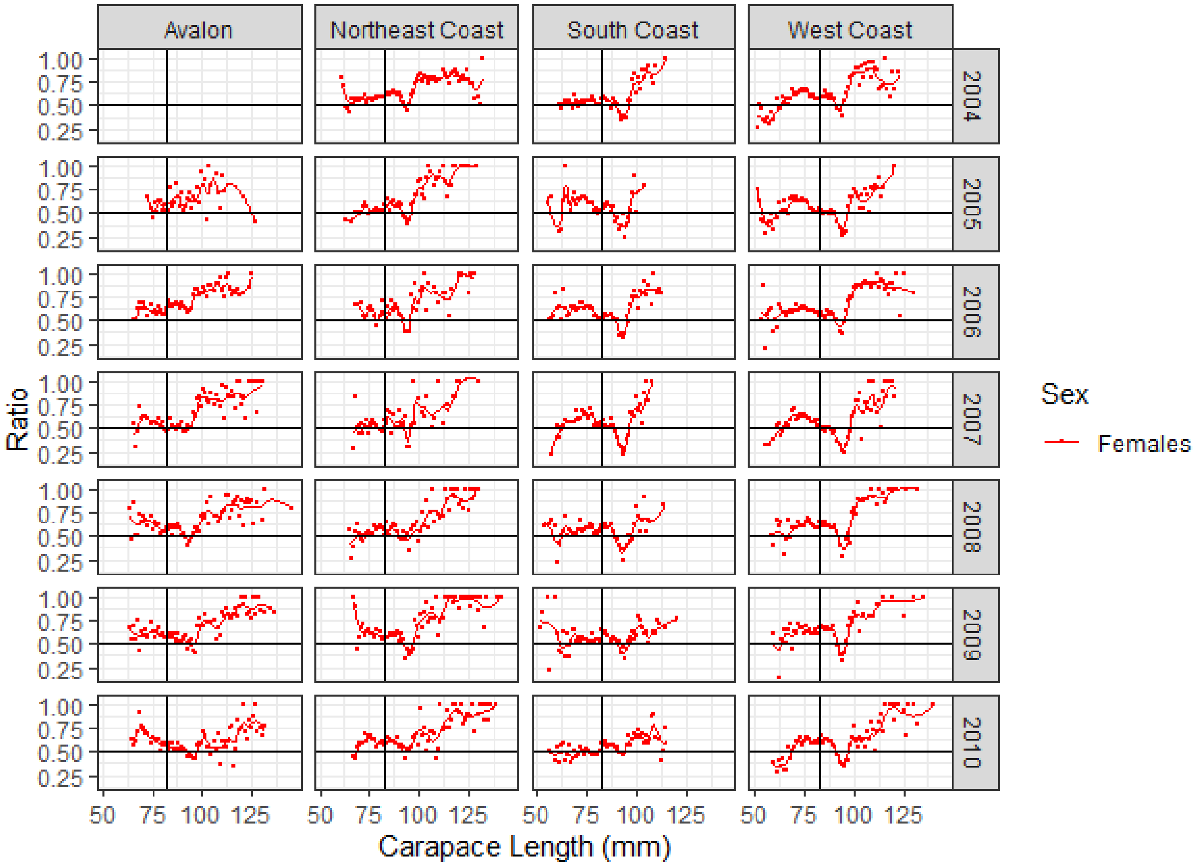

Figure 23. Annual sex ratios (proportion of females from at-sea sampling data) within each of the four regions, 2004–10. The black vertical line represents the minimum legal size.

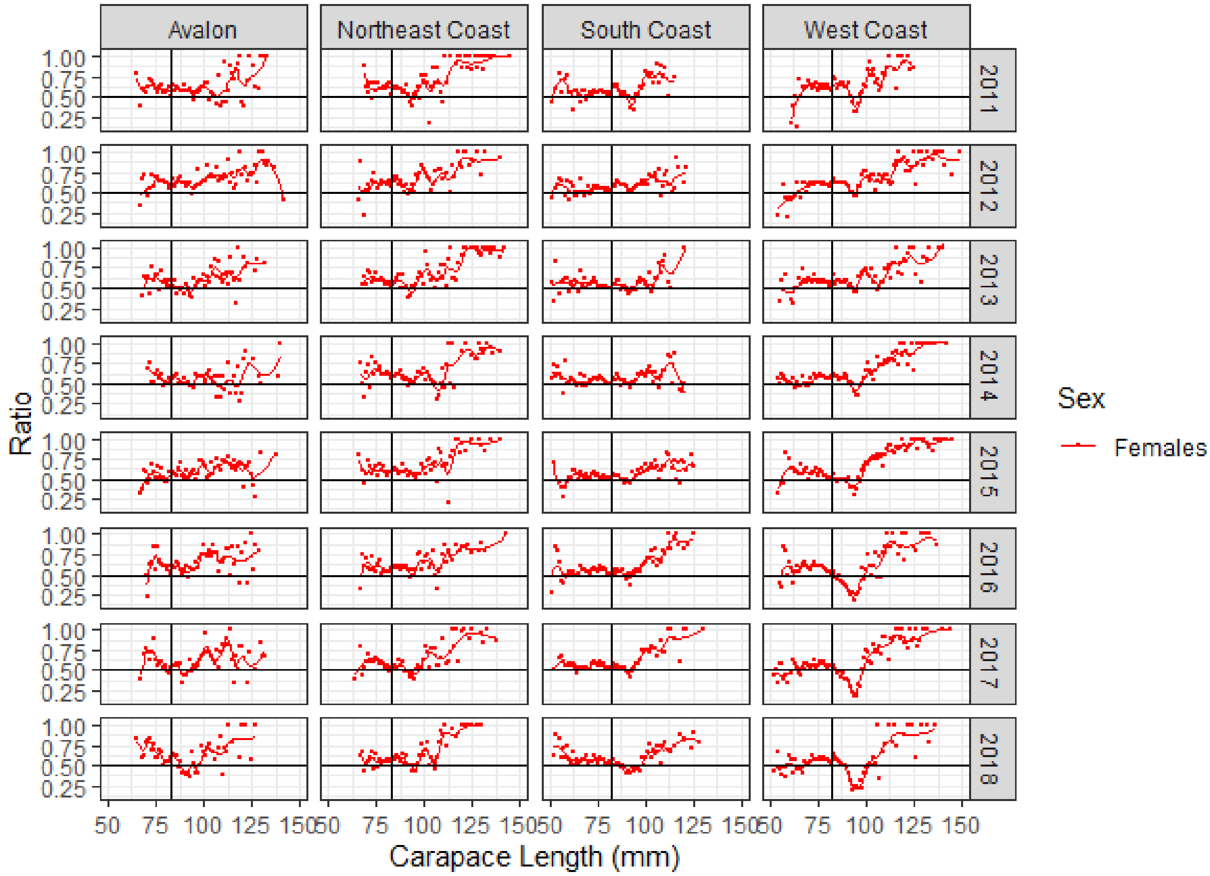

Figure 24. Annual sex ratios (proportion of females from at-sea sampling) within each of the four regions, 2011–18. The black vertical line represents the minimum legal size.

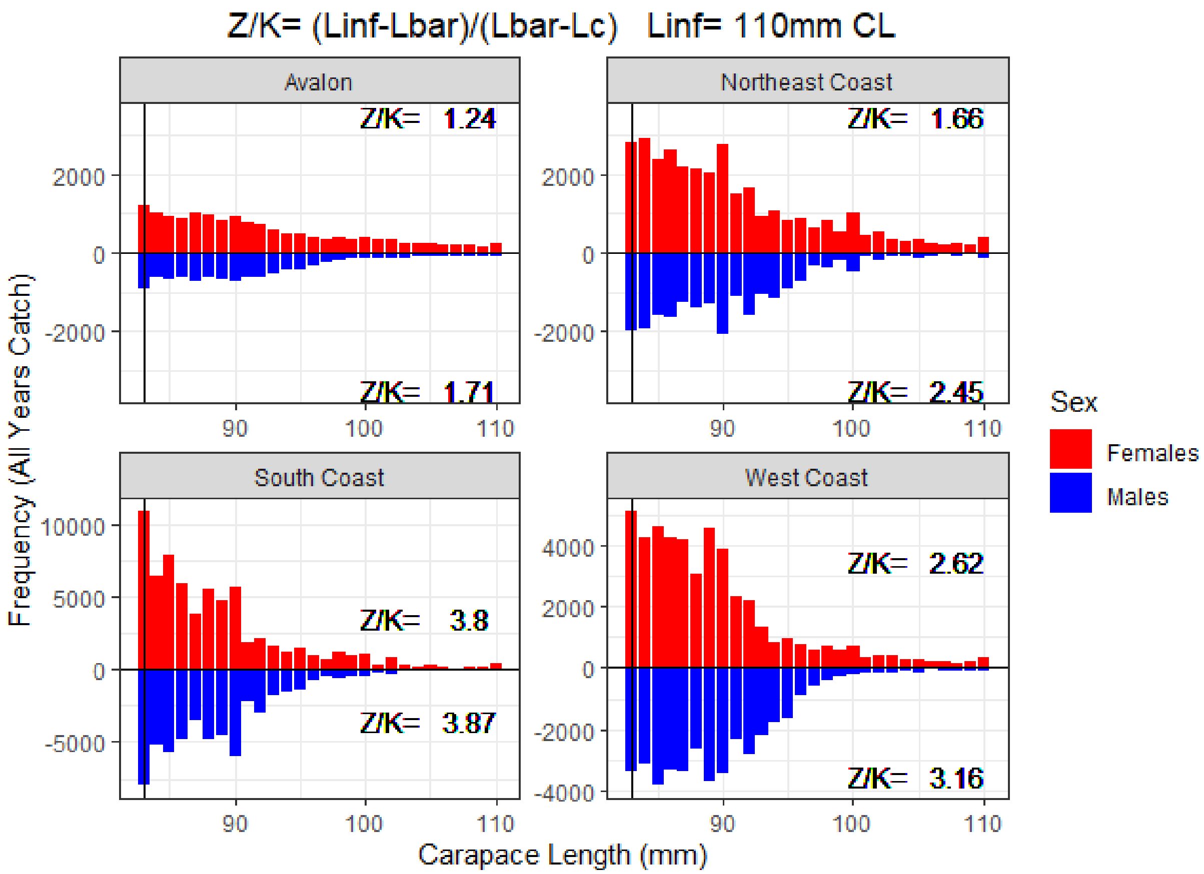

Figure 25. Size frequencies of both sexes for each region describing the Beverton and Holt (1956) Mean Length Mortality Equation, with Z/K defined and identified for each sex within each regional plot. The black vertical line represents the minimum legal size. Data source: at-sea sampling, 2004–18.

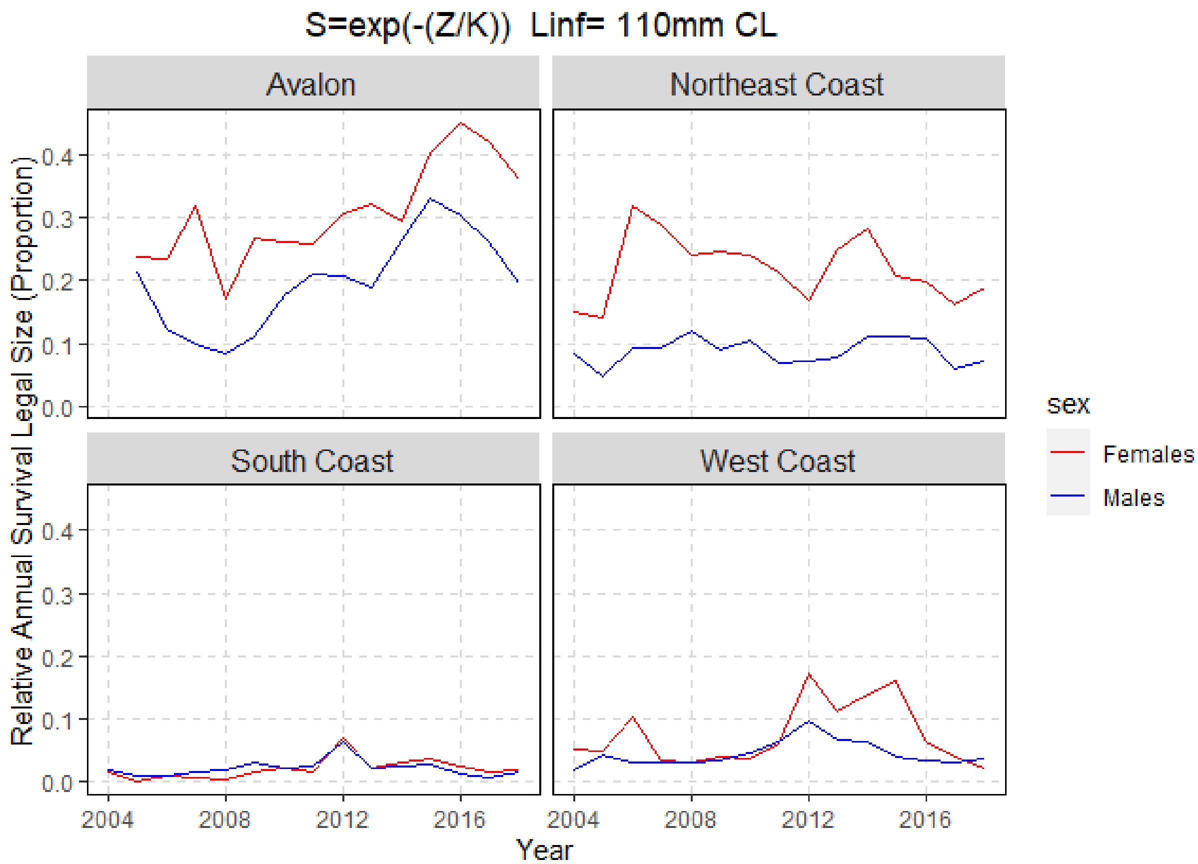

Figure 26. Annual survival index of male (blue) and female (red) lobster from at-sea sampling data within each region, 2004–18.

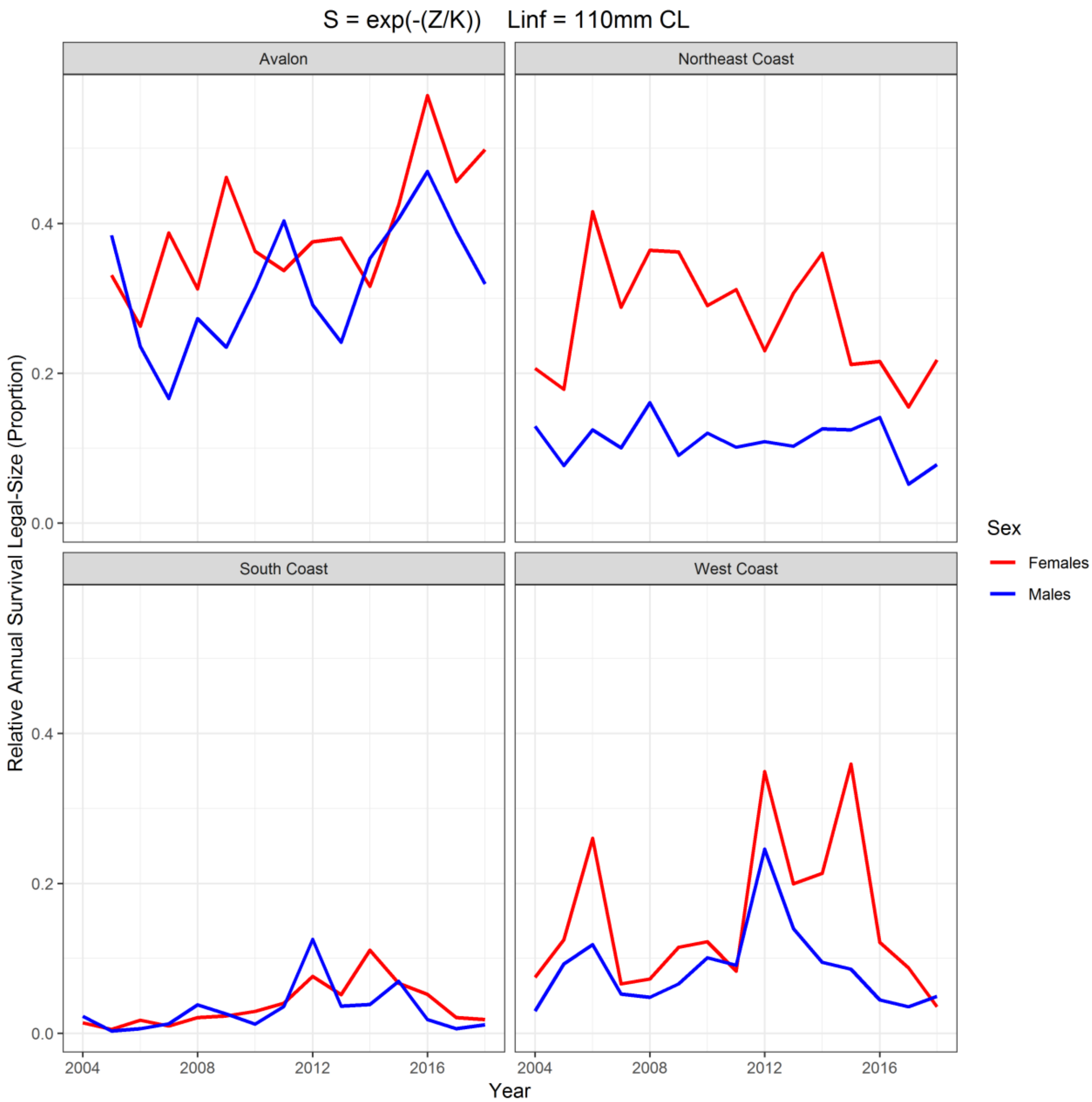

Figure 27. Annual survival index of male (blue) and female (red) lobster from at-sea sampling data within each region at the end of the fishing season (weeks 9–13), 2004–18.

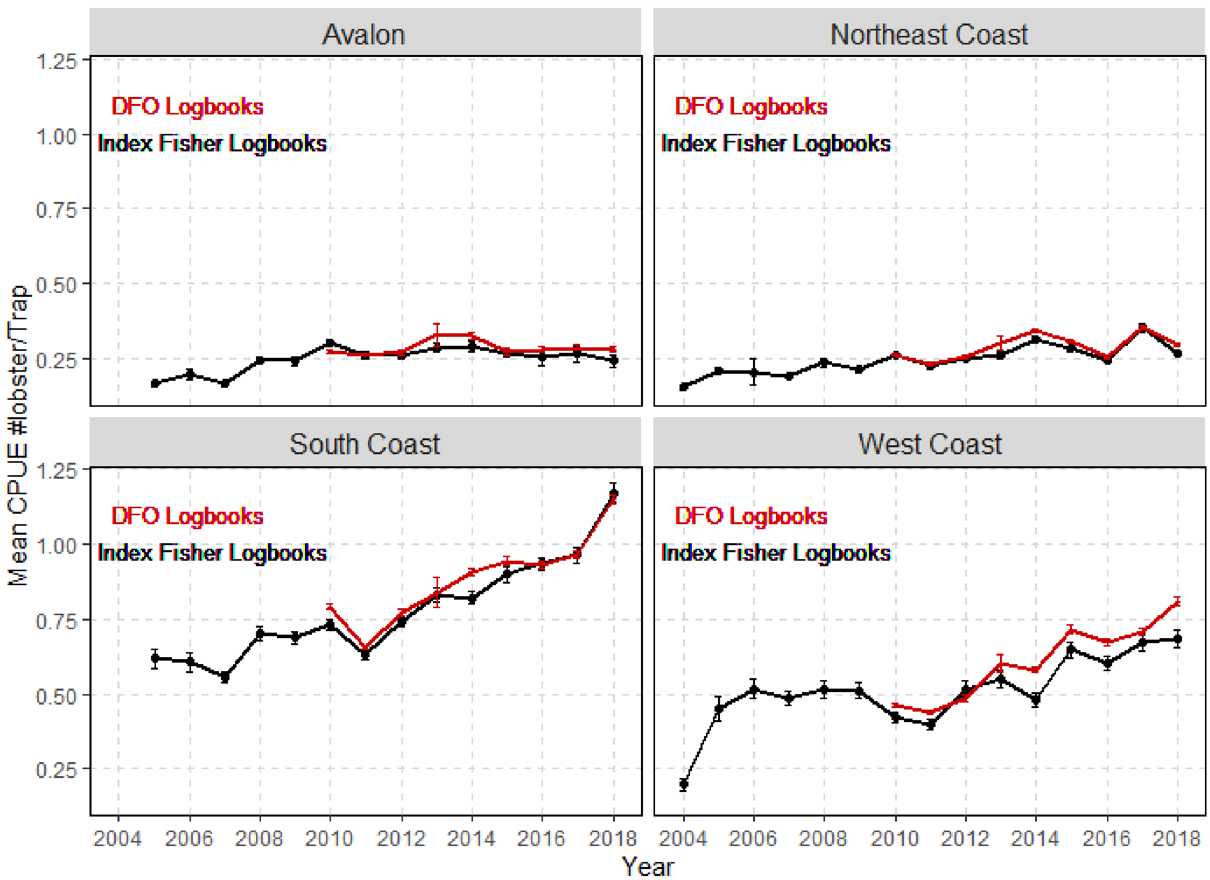

Figure 28. Annual mean catch per unit effort (CPUE) for each of the four regions from FFAW logbooks (2004–18) and from DFO logbooks (2010–18). Error bars represent 95% confidence intervals.

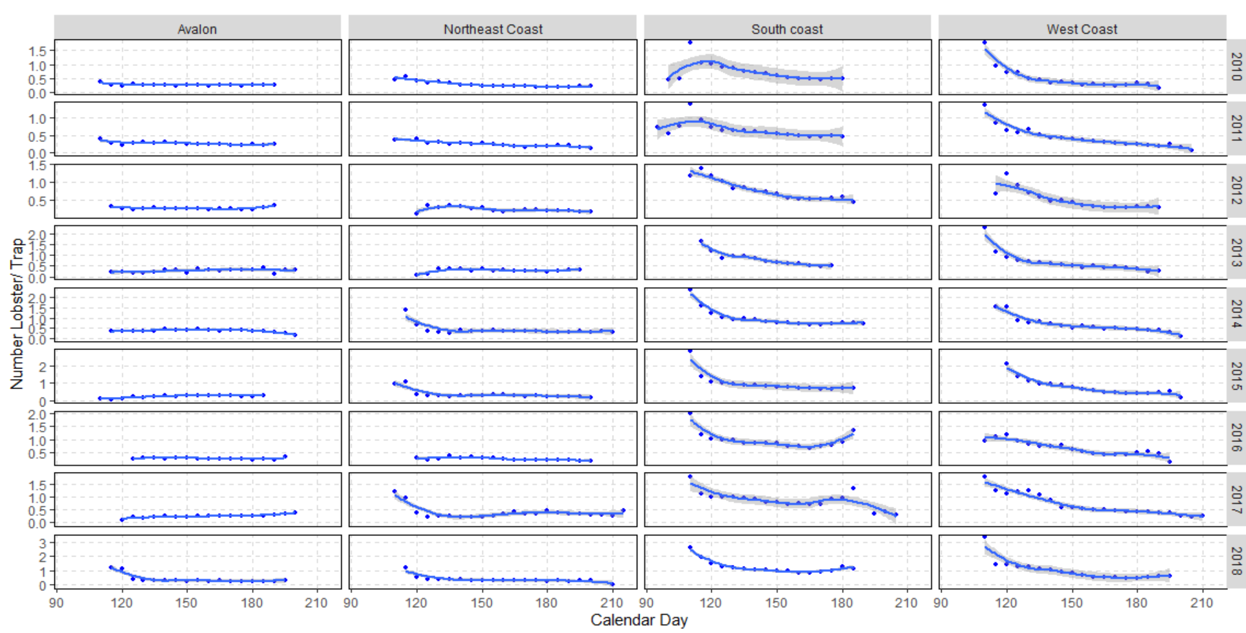

Figure 29. DFO logbook catch per unit effort (number of lobster/trap) for each of the four regions over the entire fishing season (5-day bins), 2010–18.

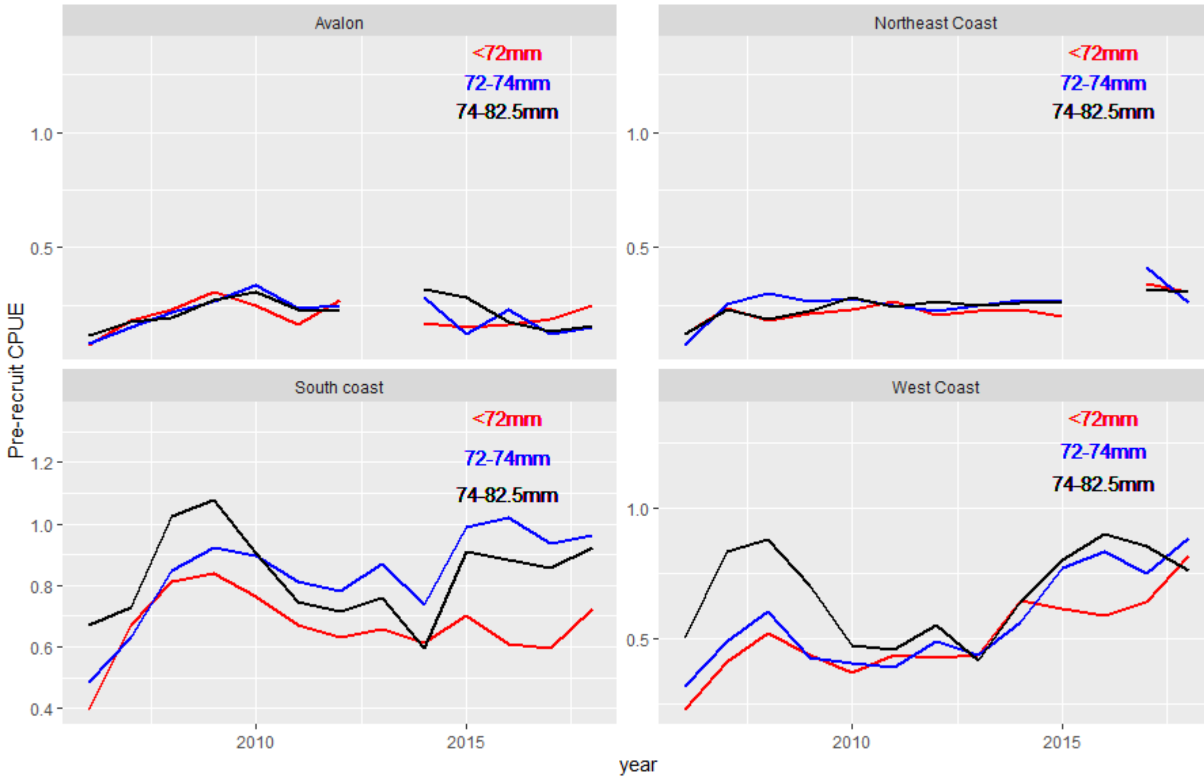

Figure 30. Catch per unit effort (CPUE) of pre-recruit size lobster (<72 mm, 72–74 mm, 74–82.5 mm) in modified traps for each region from FFAW index fisher logbooks, 2007–18.

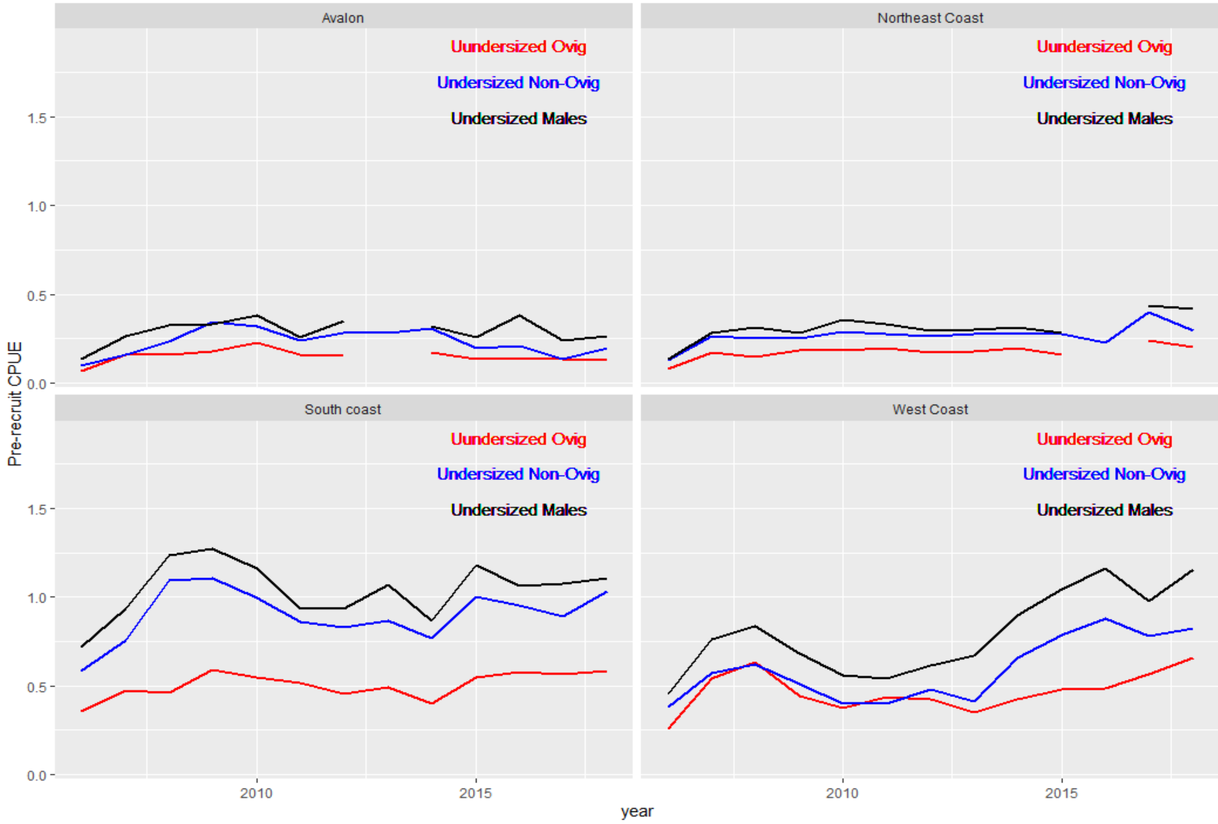

Figure 31. Catch per unit effort (CPUE) of pre-recruit (<83 mm CL) males and females (both ovigerous and non-ovigerous) in modified traps for each region from FFAW index fisher logbooks, 2007–18.

Figure 32. Annual mean temperature based on temperature probe data for each of the four regions, 2007–18.

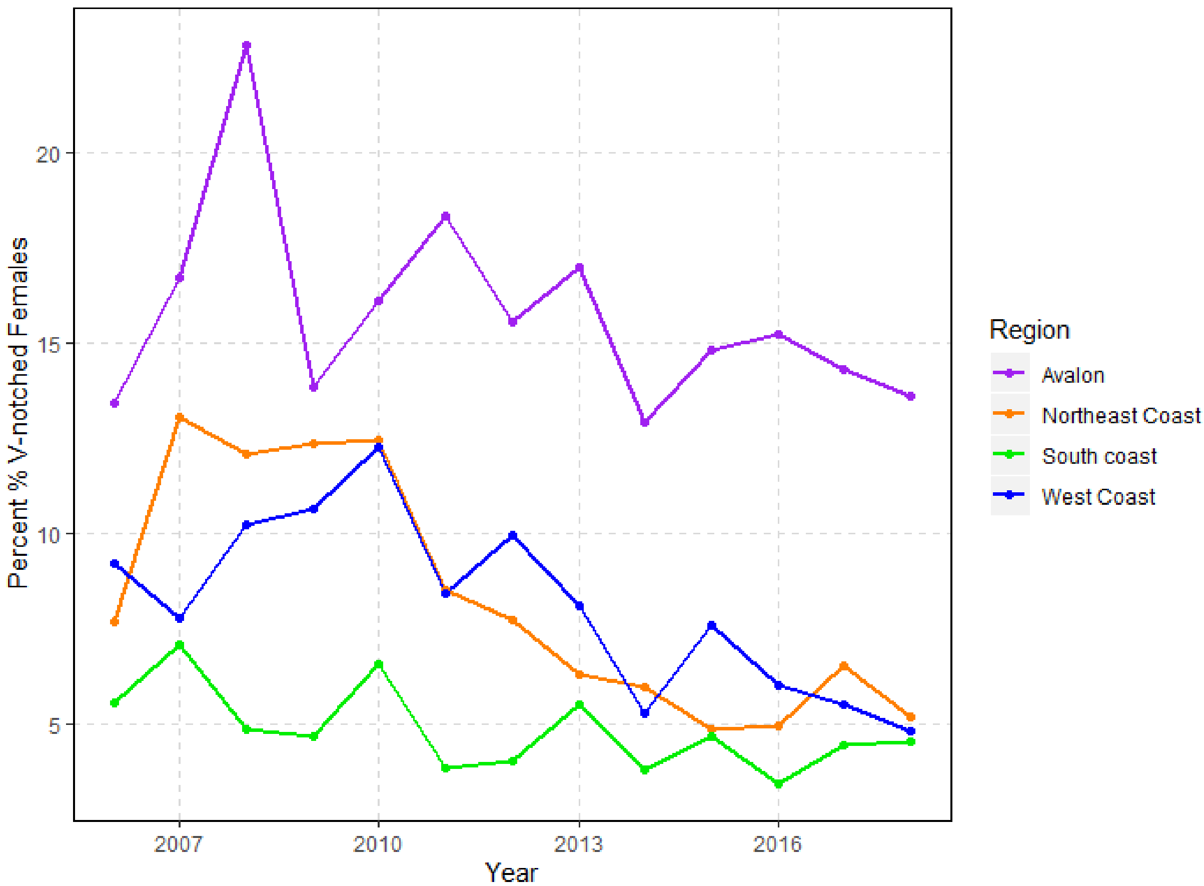

Figure 33. Percentage of ovigerous females v-notched in each region, from FFAW index fisher logbooks, 2004–18.

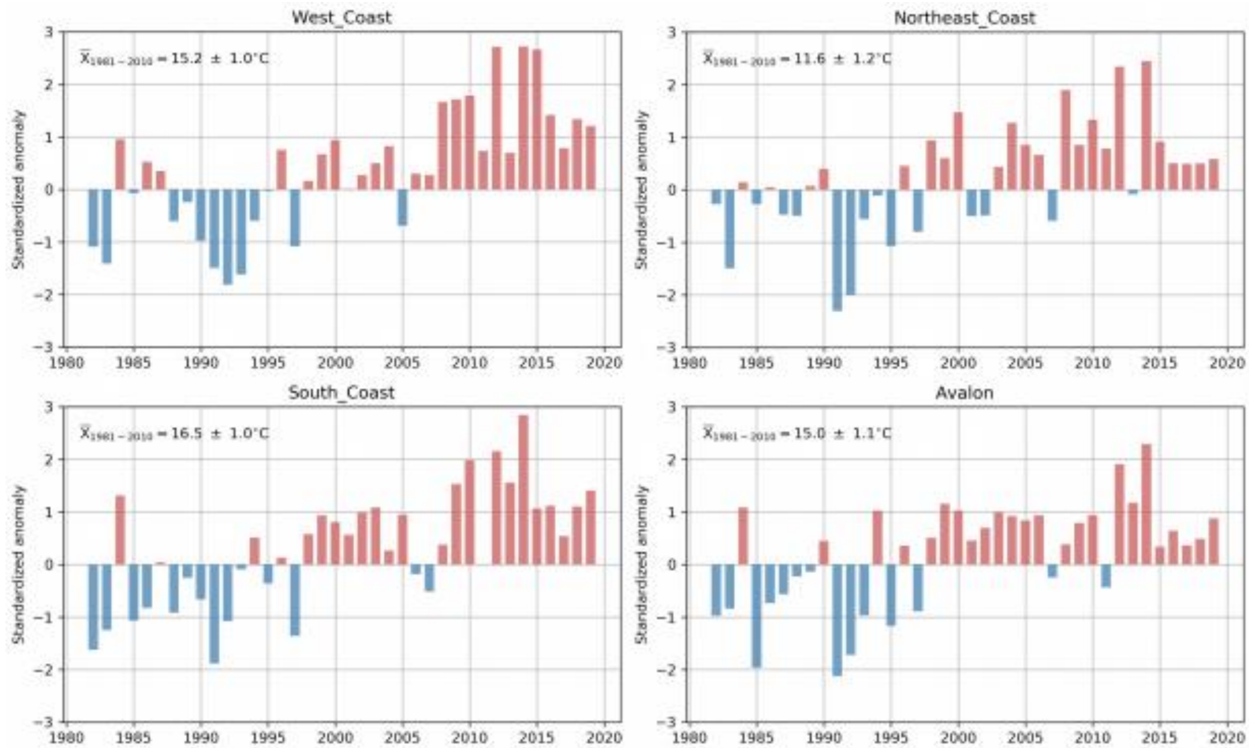

Figure 34. Standardized anomalies of the mean sea surface temperature (SST) for the warmest week of the year in the four lobster assessment regions, 1981–2019. The standardized anomalies are expressed as the departure (by standard deviation increment) from the 1981–2010 climatological average. The climatological average and standard deviation for each region is shown in the upper left of each panel. Data are from the NOAA High-resolution Blended Analysis of Daily SST on 1/4 deg. global grid (Reynolds et al. 2007). Only grid points in the regions truncated at 46°N and 51°W are considered.