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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) 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 2-3 molts and notched females cannot be retained in the fishery. The practice thus serves to protect proven spawners even when they are not brooding eggs externally. The number of licenses is currently around 2,450 and trap limits range from 100 to 300 depending on the Lobster Fishing Area (LFA).

This stock was last assessed in 2013 and is currently assessed every three years. The present assessment of this stock is requested by Fisheries Management, Fisheries and Oceans Canada (DFO) to provide current information on the status of the resource and provide the data that will be used in the updated Integrated Fisheries Management Plan. The LFAs were assessed based on four regions: Northeast (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, nominal effort, mean catch per unit effort (CPUE), and relative survival fraction.

Total reported landings for Newfoundland have remained relatively stable since the 1960s, and were 2,750 t in 2015. Since 2010, landings have decreased in the Avalon, increased in the South and West Coast regions and have not changed in the Northeast. Nominal effort (based on active fishers, trap limits and fishing days) decreased by 45% since 2006 due to license retirements, fewer active fishers, shorter seasons, and trap limit reductions. Catch per unit effort has increased gradually over the past decade (2005-15). Most size frequency plots clearly show a sharp drop at legal size and few lobsters achieving the second molt class, indicating that most of the exploitable biomass is caught in the year of recruitment to the fishery. Survival of unprotected lobsters (males, non-ovigerous non-v-notched females), relative to protected lobsters (ovigerous females) is low. In addition, for lobsters within the legal size, large lobsters survive longer than small lobsters.

INTRODUCTION

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. 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) (Collins et al. 2009). They 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 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 (egg-bearing) female lobsters carry the eggs in clutches on the underside of their tail, protecting and maintaining them for 9-12 months. Thus, female lobsters are characterized by a biennial molt-reproductive cycle, though smaller mature females sometimes molt and spawn within the same year. Fecundity of females increases on a logarithmic scale. 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 release 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. This is when most mortality is thought to occur. 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, molluscs, echinoderms, and various finfish.

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 (Fig. 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, from 1925 to 1927. 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.

Following a 17-year period of general decline reaching 1,200 t in 1972, landings increased to about 2,600 t in 1979 (Fig. 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 (i.e., temperature and salinity) and 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 had been implemented in 1910, were replaced by Lobster Fishing Areas, or LFAs (Fig. 2). A conversion to uniform trap limits, which differ by LFA, 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 included recommendations of several conservation measures for increasing egg production and reducing exploitation rates some of which were implemented in the 1998-2002 management plan for the lobster fishery in Newfoundland. These measures included an increase in minimum legal size (MLS) from 81 mm CL to 82.5 mm CL in the lobster fishery along with a maximum legal size restriction of 127 mm CL for the west coast LFAs. In addition, there was a 25% reduction in lobster licenses in Newfoundland. Reductions in trap limits, season lengths, and licenses issued were put in place and deemed necessary by fishery managers. In recent years, a Lobster Enterprise Retirement Program (LERP) and the Atlantic Lobster Sustainability Measures Program (ALSM) were implemented. 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 2,450 licenses, with trap limits varying from 100 to 300 per licensed fisher (Table 1) depending on LFA. 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, 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 2-3 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 assessment regions which are a geographical grouping of LFAs and are based on trends in landings: (1) the Northeast 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) (Fig. 2). The data available for assessing lobsters in Newfoundland are all fishery-dependent and each LFA/region has varying data sources and availability for each year.

LANDINGS AND NOMINAL FISHING EFFORT

Data sources include reported landings (provided by the Statistics Division, Policy and Economics Branch, DFO) which are available for each LFA and hence each region. However, due to the Government of Canada’s ‘Rule of 5’ policy the landings and CPUE for each LFA are not presented because 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.

In addition, information provided by Fisheries Management, DFO on the number of active licenses, season length, and daily trap limits were used to calculate the nominal effort. It is considered the maximum potential number of trap hauls within each region during the fishing season and is the product of the number of active fishers, the daily trap limit, and the length of the fishing season in days.

LOBSTER FISHERY MONITORING

The lobster fishery monitoring program provides key data sources including logbook data from Fish, Food and Allied Workers Union (FFAW) index fishers and at-sea sampling data collected by observers during the lobster fishing season. These data have been collected from 2004 to 2015 with representation from each LFA in most regions except for LFA 5, where the Eastport Marine Protected Area is located and 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. At-sea sampling data are collected by observers on all lobsters caught from commercial and modified (closed escapement targeting smaller size lobster) traps and available for various LFAs from 2004 to 2015. DFO logbooks were implemented in 2010 in all LFAs; however the return rate of logbooks has been low in the last few years.

AT-SEA SAMPLING DATA

At-sea sampling data from 2004 to 2015 were utilized in the 2016 assessment. At-sea sampling data have consistently been collected in the Northeast region (LFA 5 since 1998 and LFA 4B since 2004) and in the South Coast (LFA 11) and West Coast regions (LFAs 14A and 14B) since 2004 and Avalon region (LFA 10) since 2005 with data from additional LFAs available in 2004-05 and since 2009.

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 carapace lengths 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. Animals 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:

- male
- female, non-ovigerous, no v-notch
- female, non-ovigerous, new v-notch
- female, non-ovigerous, old v-notch
- female, ovigerous, no v-notch
- female, ovigerous, new v-notch
- female, ovigerous, old v-notch

POPULATION STRUCTURE

The at-sea sampling data were used to generate information on the population structure, including percentages of males, ovigerous females, old v-notched ovigerous females, non-ovigerous females, and old v-notched non-ovigerous females as size frequency distributions by carapace length for each region.

The size ranges for the two molt classes, N1 (number of animals in first molt class after reaching MLS) and N2 (number of animals in second molt class), which are dependent on sex and location, were based on growth information provided in Ennis et al. (1989) for the Northeast region, Ennis et al. (1986) for the Avalon region and South Coast region, and Ennis et al. (1994) for the West Coast region (Table 3). These molt classes/size ranges were outlined on the size frequency distributions. The average size of ovigerous females and of all lobsters caught in the fishery within each region was also calculated for each year between 2004 and 2015.

In addition, Catch per Unit Effort (CPUE) of pre-recruit (<83 mm CL), recruit (83-93 mm CL), and jumbo (>120 mm CL) lobsters were examined using at-sea sampling data. 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.

RELATIVE SURVIVAL FRACTION

At-sea sampling data were used to calculate relative survival fractions within each region annually from 2004 to 2015. This fraction was calculated using the molt classes (N1 and N2, defined in Table 3) along with respective categories (ovigerous and non-ovigerous). A logarithm of the ratio was calculated for N1 males, N2 males, N1 non-ovigerous, N2 non-ovigerous, and N2 ovigerous, as a fraction of N1 ovigerous over the course of the fishing season (example of methodology, Fig. 3). The fractional difference in predicted ratio at the beginning and end of the fishing season is interpreted as the relative survival fraction of the numerator category (relative to the denominator category). The actual survival fraction will be less than this, because the denominator category itself will suffer some mortality.

At-sea sampling data were used to determine the number of lobster in each molt class/size range, N1 (number of animals in first molt class after reaching MLS), and N2 (number of animals in second molt class) for both males and females within each region.

FISHERY LOGBOOK DATA

Logbook data from index fishers were available from 2004 to 2015 for each region, with representation from most LFAs for most years (Table 4). Throughout the commercial lobster fishing season, these fishers collect information on the catch from commercial and modified traps (modified to prevent escapement of pre-recruit lobsters), including number of legal sized lobsters, traps hauled, ovigerous females caught, and undersized males and females caught. Fishers are also required to complete a DFO lobster logbook. These logbooks were implemented in the Newfoundland lobster fishery in 2010.

CPUE

Using both the index fisher (2004-15) and DFO logbook (2010-15) data within each region, CPUE (number of lobsters caught/number of traps hauled) was calculated by day, month, and year, for individual harvesters for each region. Mean CPUEs were calculated by year and CPUE plots were generated. CPUE was also calculated on a weekly basis to assess fishery performance throughout the season in each region for each year (2004-15). In addition, weekly

CPUEs were compared against the weekly cumulative catch, as reported in logbooks, to assess the performance of the fishery against the level of removals for each year. Mean CPUEs from index fisher logbooks and DFO logbooks were compared.

Modified traps were distributed to index fishers and deployed throughout various LFAs. Logbook data and at-sea data were collected and reported on all lobsters caught from these traps. The modified trap data were used to depict the trends of the three size groups of pre-recruit lobsters within each region.

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 AND NOMINAL FISHING EFFORT

Total reported landings for Newfoundland have remained relatively stable since the 1960s and were 2,750 t in 2015, Table 2). Since 2010, landings have decreased in the Avalon region, have increased in the West Coast region, and have remained stable in the Northeast and South Coast regions (Fig. 4). The reported landings have become spatially concentrated. The percent of total landings from the South Coast region has increased from less than 15% in the early 1990s to approximately 45% in the last five years. However, reported landings 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.

Nominal effort is the maximum potential number of trap hauls within a region during a fishing season (Table 5). Nominal effort has decreased by 45% since 2006, because of license retirements, fewer active fishers, shorter seasons, and trap limit reductions (Fig. 1).

POPULATION STRUCTURE

Size Frequency Distributions

Most size frequency distributions from at-sea data clearly illustrate a sharp drop at legal size and few lobsters achieving the second molt class. This indicates that most of the exploitable biomass is caught in the year of recruitment to the fishery.

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.

Average Carapace Length

The at-sea sampling data were also used to calculate the average carapace length of lobster within each region. Average size is larger (above MLS) within the Northeast 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 high (Fig. 4). This suggests a more truncated size structure and stronger fishing pressure in the South and West Coast regions compared to the Northeast and Avalon regions. In recent years there has been a slight increase

in the average size of lobsters caught within the Northeast and Avalon regions, while in the West Coast region the average size slightly decreased and in the South Coast region the average size has remained below MLS (Fig. 5).

Ovigerous females within the South and West Coast regions are smaller than those from the Northeast and Avalon regions (Fig. 6). 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 regions are consistently above MLS with an average size ranging between 83 mm and 91 mm CL. This could suggest a high fishing pressure in the South and West Coast regions once females recruit to the fishery compared to the Northeast and Avalon regions.

On a regional scale the trends in CPUE are similar between the pre-recruits and recruits (Figs. 7 and 8). CPUE of pre-recruit and recruit sized lobsters was highest in the South Coast region. The CPUE of jumbo lobsters was consistently low in all regions (Fig. 9), with the lowest CPUE in the South and West Coast regions. This further illustrates the truncated size structure in the Newfoundland lobsters, as was also observed in the size frequency distributions, possibly suggesting high fishing pressure.

Relative Survival Fraction

At-sea sampling data typically show a marked decrease over the fishing season in the ratio of unprotected lobsters (males, non-ovigerous females) to protected lobsters (ovigerous females). The trend can be well represented by a linear decrease in the logarithm of the ratio, fitted by weighted (by the sample size of the denominator) least squares (Fig. 3). Survival of unprotected lobsters relative to protected lobster is low. Males and females differ in growth rates (Wilder 1953; Campbell 1983; Comeau and Savoie 2001) and there is a greater rate of catchability of males during the commercial season (Miller 1990; Tremblay and Smith 2001). 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 (Figs. 16, 25, 34, and 43).

Among legal sized lobsters, N1 is the first molt class and N2 is the second. Of these two groups, large lobsters (N2) have higher survival than small lobsters (N1) of the same category (e.g. males, and non- ovigerous females).

This index does not account for impacts of natural mortality, potential differences in intermolt periods between the recruit size group and larger sizes, and annual variations in recruitment. Natural mortality of adult lobsters is not precisely known, but is generally assumed to be low (between 10-15%) and relatively constant over time (Gendron and Gagnon 2001). Natural mortality can vary and is dependent upon habitat, predator abundance, and lobster size (Tremblay et al. 2013).

FISHERY LOGBOOK DATA

CPUE trends

The mean CPUE (number of lobsters caught/number of commercial traps hauled) was calculated based on index fisher and DFO logbook data. CPUE has changed little over the time period for which data are available (2004-15) for the Northeast, Avalon and West Coast regions, and has increased in the South Coast region since 2011 (Fig. 10). The highest CPUE of legal lobsters was in the South Coast region in all years. This is consistent with high landings concentrated from a smaller area. CPUE in both Northeast and Avalon regions was low, consistent with the low landings (Fig. 4). The CPUE for the West Coast region was lower than

the South Coast region, consistent with high landings accumulated from a larger area. Landings and CPUE data suggest higher density of lobsters along the South Coast, compared to the other regions.

There are uncertainties around using CPUE as an index of abundance. There are problems of estimating local density and it is unclear how to integrate local concentrations over space and time. Trap density and competition can affect how well catch rates measure local densities. A decrease in the number of active fishers, which have been seen in some regions through the Lobster Enterprise Retirement Program (LERP), will reduce gear competition and result in an increase in CPUE. In addition, CPUE is not standardized in that it does not account for variation in water temperatures which can affect catchability (McLeese and Wilder 1958; Miller 1990). Fishing practices may also vary between fishers where soak times and redistribution of traps can vary greatly, and it is not uncommon for many 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 was used to depict the CPUE trends of the three size classes (<72 mm, 72-74 mm, 74-82.5 mm CL) of pre-recruit lobsters within each region from 2006 to 2015 (Fig. 11). Overall the CPUE for the three pre-recruit size classes was higher in the South and West Coast regions (0.25-1.0 lobsters/traps hauled) and lower in the Northeast and Avalon regions (0.05-0.35 lobsters/traps hauled).

V-Notching

Overall, the percentage of v-notching in all LFAs/regions ranged from 4-35% (Fig. 12, Table 6) with the lowest rate of v-notching in the South Coast and the highest rates in the Avalon region since 2006.

V-notching of ovigerous female lobsters has been taking place annually since its initiation in the mid-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.

There are studies demonstrating that large female lobsters produce larger 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.

REGIONS

The indices described above are discussed in more detail below for each region.

Northeast Region (LFAs 3-6)

Reported landings have declined from approximately 750 t in the early 1990s to 225 t in 2015 (Fig. 13). Nominal effort has decreased by 16% since 2012 due to fewer active fishers (Fig. 13).

The size frequency distributions for both males and females within this region show a decline at MLS (Figs. 14 and 15). This suggests that although the landings are relatively low, there is still high fishing pressure in this region and very few large lobsters are surviving beyond the MLS. Being a recruitment based fishery, this is to be expected. The size frequencies of females (Fig. 15) illustrate that the conservation measures (i.e., protection of ovigerous and v-notching) are effective as the small number of lobster that are surviving beyond MLS and the second molt class, in some cases, represent the old v-notched (i.e., notched in previous years) and ovigerous females.

Relative to protected females (ovigerous), survival over the fishing season for unprotected female lobsters (N1 and N2 non- ovigerous) has increased slightly in recent years (Fig. 16). Within the legal size classes, large lobsters (N2) have higher survival than small lobsters of the same category (e.g., males and non-ovigerous females). Since 2004, survival for N1 male lobsters has remained unchanged, at approximately 20% (Fig. 16).

Mean CPUE based on logbook data increased gradually from 2004-15 (Fig. 17). The CPUE that was calculated based on the DFO logbooks was slightly higher from 2013-15 (Fig. 17). When observing the change in CPUE (based on DFO logbooks and index fisher logbooks) on a weekly basis, the general trend is similar; CPUE begins high early in the season and levels off at the end of the season (Fig. 18 and 19). The CPUE based on both logbooks over the last three years was similar except for a stronger increase in CPUE in 2014 based on the index fisher logbooks towards the end of the season (Fig. 18).

In relation to cumulative removals, in recent years (2014-15) the fishery performed well while maintaining the same CPUE with cumulative catch of up to 200,000 lobsters based on the DFO logbooks (Fig. 20), and 35,000 lobsters based on the FFAW index fisher logbooks (Fig. 21). The highest cumulative catch was in 2010 at 400,000 lobsters (DFO logbooks) (Fig 20).

Avalon Region (LFAs 7-10)

Reported landings have declined from approximately 460 t in the early 1990s to approximately 30 t in 2015 (Fig. 22). Nominal effort increased between 2007 and 2008 likely due to the trap limit increase from 100 to 200 traps in 2007 in LFA 10 and the increase from 100 to 150 traps in LFA 7. However, nominal effort decreased by approximately 45% since 2009 due to fewer active fishers (Fig. 22).

Similar to the Northeast region, the size frequency distributions show a pattern of decline after MLS for both males and females within the Avalon region (Figs. 23 and 24). The majority of lobsters surviving beyond the second molt class are old v-notched and ovigerous females (Fig. 24). Based on observation of the sample sizes within each LFA in this region, LFA 10 has driven the size distribution patterns as the majority of the at-sea sampling data was collected in this area.

Relative to protected (ovigerous) females, survival over the fishing season for both male and non-protected female lobsters has increased from approximately 10% before 2012 to approximately 30% since 2012 (Fig. 25). The relative survival of larger (N2) ovigerous females was highest between 2008 and 2011 with a decline since 2012. This is also shown in the size frequency distributions where there is a larger spread in the size structure for both males (Fig. 25) and non-ovigerous females with more lobsters surviving to reach larger sizes (>120 mm). The average size of all lobsters caught from the commercial fishery since 2005 was largest in the Avalon region.

Mean CPUE based on logbook data (index fisher logbooks and DFO logbooks) increased gradually from 2005 to 2015 with a slightly higher CPUE in 2014 based on the DFO logbooks (Fig. 26). When observed throughout the season on a weekly basis, the mean CPUE follows a similar trend each year, showing little change throughout the season (Fig. 27 and 28) with comparable trends based on both logbook data sources (DFO and index fisher logbooks). In the last two years (2014-15) there was an increase in CPUE from earlier to later in the season (Fig. 28).

When comparing the CPUE to cumulative catch from both DFO and index fisher logbooks, the fishery performed at its best in 2010 when it maintained the same level of CPUE and had the highest landings, with more than 150,000 lobsters (DFO logbooks) (Fig. 29) and 40,000 lobsters

(index fisher logbooks) (Fig. 30). In 2014 and 2015, the CPUE was stable and sustained relatively high landings of more than 180,000 lobsters (DFO logbooks) (Fig. 29).

South Coast Region (LFAs 11-12)

Reported landings increased from approximately 400 t in the early 1990s to peak at approximately 1,300 t in 2010 with an average of 1,100 t from 2011 to 2015 (Fig. 31). Nominal effort has decreased by 15% since 2012 due to license retirements and fewer active fishers (Fig. 31).

Within this region the size frequency distributions show a sharp drop in both males and females at MLS and minimal, or no, survival of large lobsters including the ovigerous and/or v-notched females beyond the second molt class (Figs. 32 and 33). This region has the highest landings in Newfoundland and Labrador, and also the lowest percent v-notching (4-7% since 2006) (Fig. 12). Therefore, a low rate of survival beyond the second molt class is expected, as the number of ovigerous and v-notched animals were minimal and there seems to be a high rate of exploitation (Fig. 33). This region has a higher fishing pressure compared to the Northeast and Avalon regions.

Relative to protected (ovigerous) females, survival of the non-protected female lobsters has fluctuated over the fishing season with higher relative survival of the larger (N2) non-protected females (Fig. 34) when compared to the small legal sized lobsters (N1). For the males the survival again relative to protected (ovigerous) females was also higher for the large (N2) male lobsters with an increase in relative survival between 2004 and 2015 (Fig. 34).

Mean CPUE based on logbook data has increased gradually from 2005 to 2015. Mean CPUE for the DFO logbook data and index fisher logbook data depict similar trends over the last few years (Fig. 35). Observations of the weekly change in CPUE show a standard trend of starting high early in the season and gradually decreasing by the end of the season, with the highest CPUE shown throughout the fishing season in 2014 and 2015 (Figs. 36 and 37).

In relation to cumulative removals, the overall fishery in this region has performed well, showing signs of recruitment in each consecutive year especially in the last few years where the landings have sustained levels of up to 2.0 million lobsters (DFO logbooks) (Figs. 38 and 39).

West Coast Region (LFAs 13-14)

Reported landings have varied since the early 1990s and totaled 1,200 t in 2015 (Fig. 40). Since 2011, the landings have increased from 780 t to 1,200 t in 2015. Similar to the South Coast region, nominal effort has decreased by 15% since 2012 due to license retirements and fewer active fishers (Fig. 40).

As in other regions, the size frequency distributions show a sharp decline at MLS in the West Coast region (Figs. 41 and 42). This suggests minimal survival of the larger lobsters including ovigerous and/or v-notched females. Based on these observations this region also seems to have high fishing pressure with high landings and good recruitment.

Relative to protected females, survival over the fishing season for male and non-protected female lobsters has remained low since 2004. The relative survival of larger (N2) males was higher than the smaller (N1) males, and the larger (N2) protected ovigerous females was consistently higher than all categories with an increase in relative survival since 2012 (Fig. 43).

Mean CPUE based on logbook data has increased gradually from 2004 to 2015 (Fig. 44). Mean CPUE for the DFO logbook data and index fisher logbook data depict similar trends over the last few years (Fig. 44). Observations of the weekly change in CPUE (based on both DFO and index

fisher logbooks) show that it started high early in the season for most years and gradually declined by the end of the season (Figs. 45 and 46).

In relation to cumulative removals, the fishery in this region has performed well overall and similar to other regions one of the best years was 2010 (Figs 47 and 48). There are signs of recruitment in each consecutive year, especially in the last few years where the landings reached levels up to 1.2 million (DFO logbooks) (Fig. 47).

CONCLUSIONS

Each year the catch consists largely of new recruits. Preliminary analysis of mean catch rates of pre-recruit lobsters suggests little annual variation and there is no apparent relationship between these catch rates and future commercial reported landings or CPUE. The reported landings have become spatially concentrated. Nominal effort has decreased by 31% since 2008 and, due to data limitations, there is uncertainty in calculating nominal effort for earlier years. The population structure in each region showed a low number of larger animals which depicts a recruit-based fishery with high exploitation.

While long-term trends in landings are believed to reflect abundance, there is uncertainty in inferring year-to-year changes in abundance based on landings. Landings are affected by changes in fishing effort and survival. Furthermore, reported landings do not account for local sales, poaching, and handling mortalities. The extent of local sales, in particular, can be considerable and varies by location and year. The assessment is based solely on fishery-dependent data. Given the nearshore distribution of the Newfoundland lobster, it is difficult to assess all LFAs without a localized monitoring program in all areas where active lobster fishing occurs. In order to cover all areas, sampling would need to be expanded. At a minimum, sustaining at-sea sampling within each of the four regions is crucial for providing information on the population structure. In addition, considering the unattainable amount of local sales it is important that the logbook programs (DFO and index- fishers logbooks) are maintained to effectively assess the fishery performance and health of the lobster stock in all Newfoundland LFAs (LFAs 3-14).

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APPENDIX I- TABLES

Table 1: Daily trap limits per licensed fisher, by LFA in 2015.

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. Reported lobster landings (tonnes) by region and total NL landings from 1990 to 2015.

Year	Northeast	Avalon	South Coast	West Coast	Total
1990	733	360	368	1461	2921
1991	729	441	448	1461	3079
1992	720	464	544	1478	3206
1993	467	333	557	1266	2623
1994	544	321	541	1232	2639
1995	506	337	501	1204	2547
1996	489	249	492	1153	2382
1997	434	185	464	1096	2178
1998	428	177	542	887	2034
1999	400	151	496	767	1814
2000	348	115	547	746	1756
2001	385	128	620	985	2118
2002	321	125	662	951	2059
2003	313	97	722	1125	2257
2004	223	70	730	888	1911
2005	309	78	949	1276	2612
2006	254	82	1031	1275	2642
2007	197	44	1066	1260	2567
2008	236	51	1280	1404	2971
2009	197	61	1145	1096	2499
2010	197	70	1307	1022	2596
2011	126	45	994	769	1934
2012	137	48	1089	875	2149
2013	135	30	1164	873	2202
2014	126	23	1084	906	2139
2015	205	19	1219	1211	2654

Table 3. Growth information (N1 and N2 size ranges/molt classes) for males and females from representative LFAs within each respective region. (References: Ennis et al. 1989 for LFA 5; Ennis et al. 1986 for LFA 10; Ennis et al. 1994 for LFA 14B).

Growth information locations	Size Ranges	Males	Females
LFA 5	N1	83-95 mm	83-92 mm
LFA 5	N2	96-109 mm	93-102 mm
LFA 10	N1	83-95 mm	83-92 mm
LFA 10	N2	96-110 mm	93-101 mm
LFA 14 B	N1	83-94 mm	83-91 mm
LFA 14 B	N2	95-108 mm	92-101 mm

Table 4: The number of index fishers (commercial logbooks) and DFO logbook (mandatory logbooks) returns in the Newfoundland Lobster Fishery (LFAs 3-14ABC). (Entries were omitted in several locations due to a small fishery and/or small number of returns.

NORTHEAST REGION (LFAs 3, 4A, 4B, 5 & 6)

-	**LFA 3**	-	**LFA 4A**	-	**LFA 4B**	-	**LFA 5**	-	**LFA 6**	-
-	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks
2004	-	-	-	-	14	-	6	-	7	-
2005	-	-	8	-	16	-	-	-	-	-
2006	-	-	-	-	14	-	10	-	6	-
2007	-	-	-	-	15	-	9	-	7	-
2008	-	-	11	-	6	-	11	-	8	-
2009	-	-	12	-	-	-	8	-	9	-
2010	-	14	19	158	33	204	13	177	18	150
2011	-	14	11	98	35	149	12	103	15	102
2012	-	7	11	34	35	88	13	74	14	63
2013	-	-	-	-	29	-	9	7	13	-
2014	-	10	-	45	29	96	8	89	10	84
2015	-	12	-	46	27	85	7	74	7	62

AVALON REGION (LFAs 7, 8, 9 & 10)

-	**LFA 7**	-	**LFA 8**	-	**LFA 9**	-	**LFA 10**	-
-	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks
2004	-	-	-	-	-	-	-	-
2005	6	-	-	-	6	-	12	-
2006	6	-	-	-	7	-	24	-
2007	7	-	-	-	6	-	21	-
2008	7	-	-	-	6	-	21	-
2009	7		-	-	-	-	23	-
2010	13	70	-	29	-	16	32	164
2011	10	39	-	23	-	9	30	96
2012	12	26		15	-	9	27	55
2013	7	-	-	-	-	-	21	-
2014	6	38	-	11	-	9	19	48
2015	7	30	-	11	-	7	17	43

SOUTHCOAST REGION (LFAs 11 & 12)

-	**LFA 11**	-	**LFA 12**	-
-	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks
2004	-	-	-	
2005	13	-	-	-
2006	18	-	7	-
2007	15	-	7	-
2008	20	-	7	-
2009	22	-	8	-
2010	34	303	8	43
2011	33	165	8	35
2012	32	134	7	31
2013	33	13	8	
2014	31	141	7	27
2015	32	105	7	20

WEST COAST REGION (LFAs 13A, 13B, 14A, 14BC)

-	LFA 13A	-	LFA 13B	-	LFA 14A	-	LFA 14BC	-
-	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks	Index Fishers Logbooks	Mandatory Logbooks
2004	-	-	-	-	-	-	6	-
2005	-	-	-	-	-	-	6	-
2006	-	-	8	-	8	-	11	-
2007	-	-	8	-	6	-	11	-
2008	-	-	-	-	6	-	7	-
2009	-	-	-	-	8	-	12	-
2010	7	132	7	147	19	172	21	154
2011	6	77	6	88	17	108	19	106
2012	8	27		55	17	72	19	62
2013	-	-	6	6	19	10	19	-
2014	-	48	-	55	14	70	17	63
2015	-	36	-	50	13	56	17	51

Table 5: Effort (approximate trap hauls) in the Newfoundland Lobster Fishery from 2006-15. Nominal Effort (Active Fishers, Trap Limits, Fishing Days) x 1000.

Year	Northeast	Avalon	South Coast	West Coast
2006	920	146	394	1275
2007	826	110	390	1273
2008	654	186	396	1229
2009	603	187	386	1243
2010	586	177	393	1181
2011	478	146	386	940
2012	444	135	351	855
2013	388	102	305	778
2014	335	69	297	711
2015	371	92	297	725

Table 6: Percentage (%) of V-notched lobsters (based on the index fishers logbooks) within each region during the Newfoundland lobster fishery from 2004-15.

Year	Northeast	Avalon	South Coast	West Coast
2004	37.35	-	-	-
2005	30.49	-	-	-
2006	7.69	13.44	5.55	9.11
2007	13.08	16.70	7.11	7.79
2008	12.14	22.84	4.90	10.24
2009	12.28	13.86	4.68	10.67
2010	12.63	16.16	6.59	12.30
2011	8.57	18.33	3.87	10.78
2012	7.73	15.57	4.03	9.96
2013	6.32	17.01	5.50	8.10
2014	5.99	12.93	3.81	5.29
2015	4.88	14.84	4.72	7.93

APPENDIX II- FIGURES

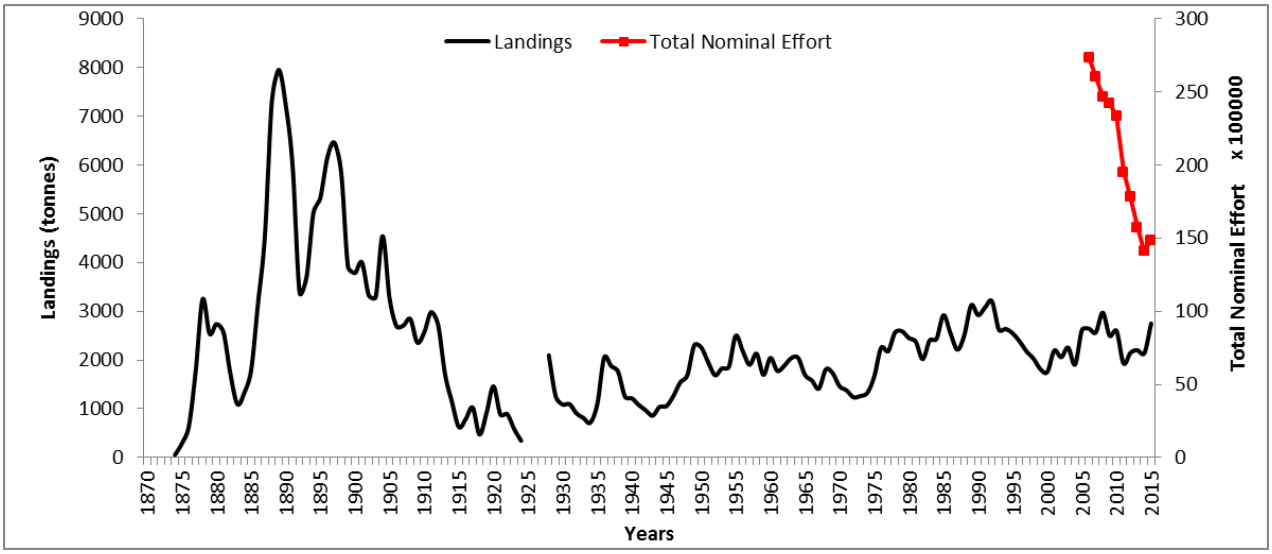

Figure 1.Trends in reported landings (tonnes) and nominal effort (active license x daily trap limit x fishing days) (2007-15) for the Newfoundland lobster fishery from the late 1870s to 2015.

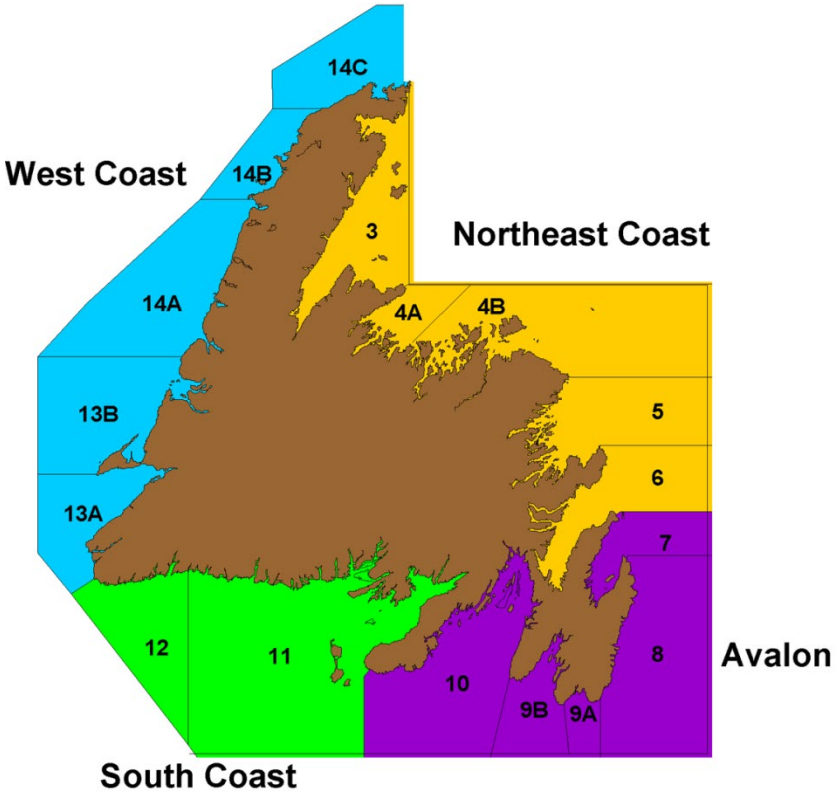

Figure 2. Newfoundland Lobster Fishing Areas (LFAs 3-14) combined into assessment regions.

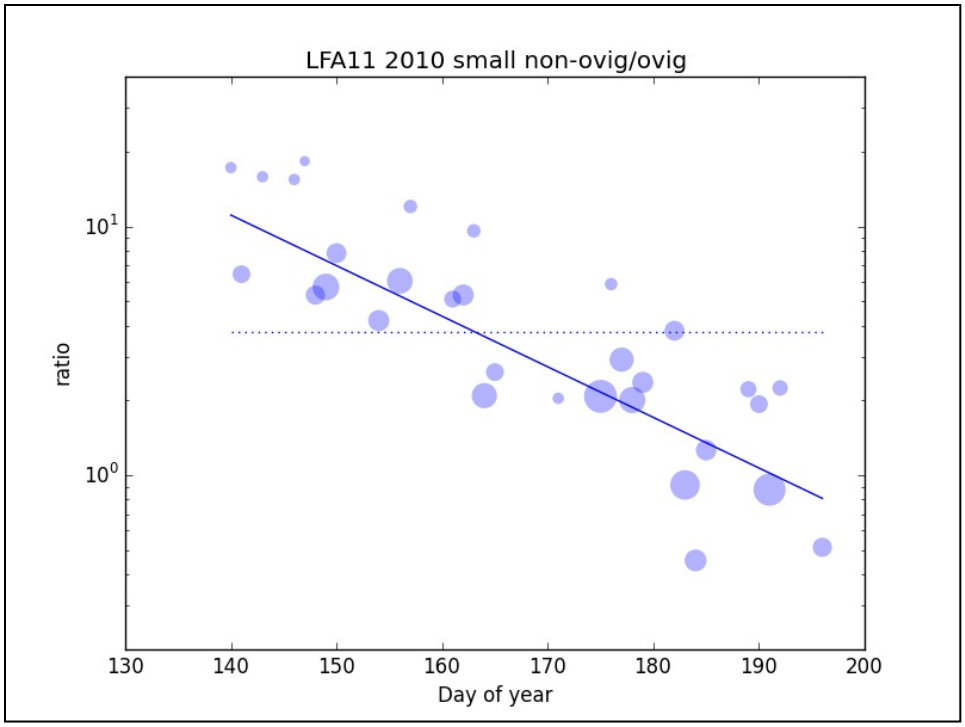

Figure 3. A graph outlining components of the relative survival fraction methodology. The expanding circles represent samples of non-ovigerous and ovigerous small (N_1) females over the course of a fishing season; the area of a symbol is proportional to the number of ovigerous females in the sample; the y-coordinate is the ratio of non-ovigerous to ovigerous. The solid line represents the weighted least-squares fit; and the dotted line indicates the ratio of the two numbers for all samples combined.

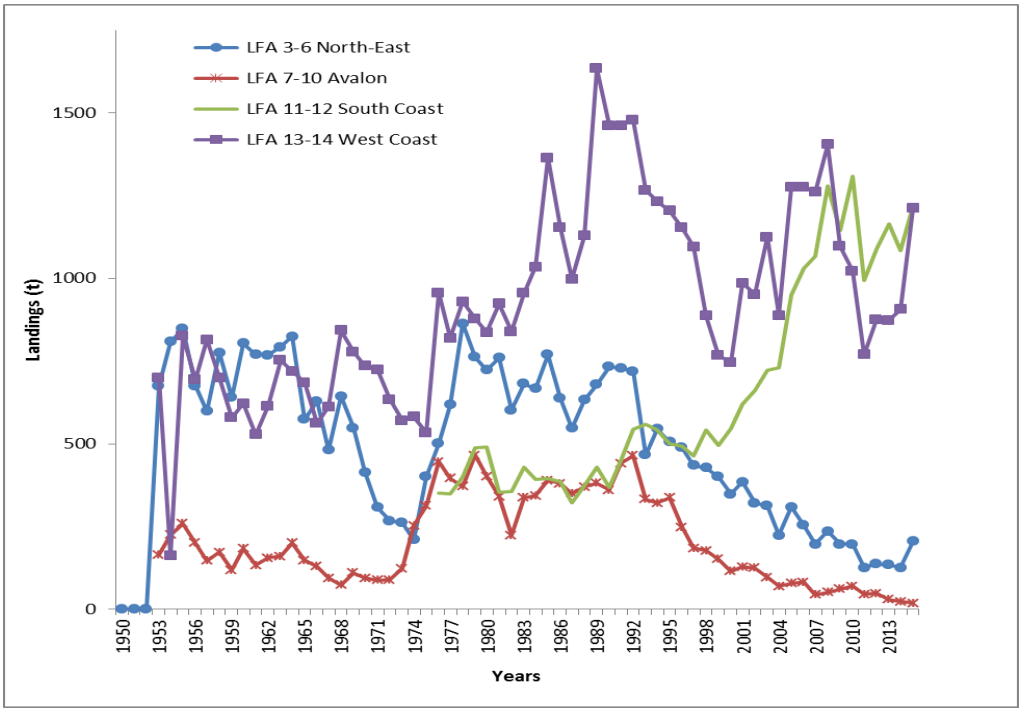

Figure 4. Trends in reported landings (t) for the lobster fishery in each region.

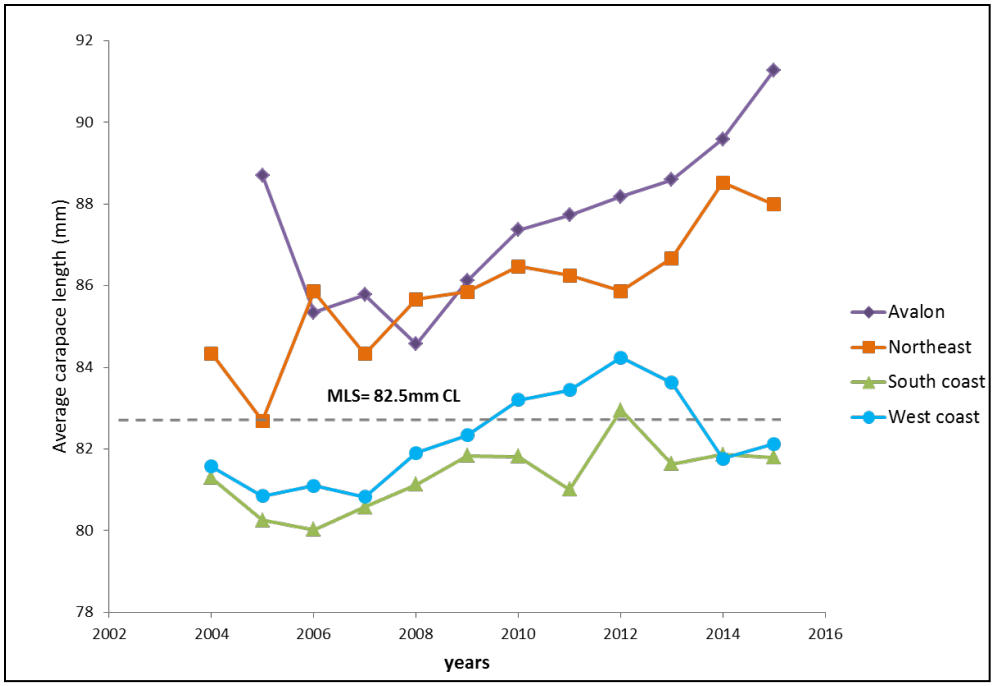

Figure 5. Average carapace length (mm) of total catch based on at-sea sampling data collected in each region.

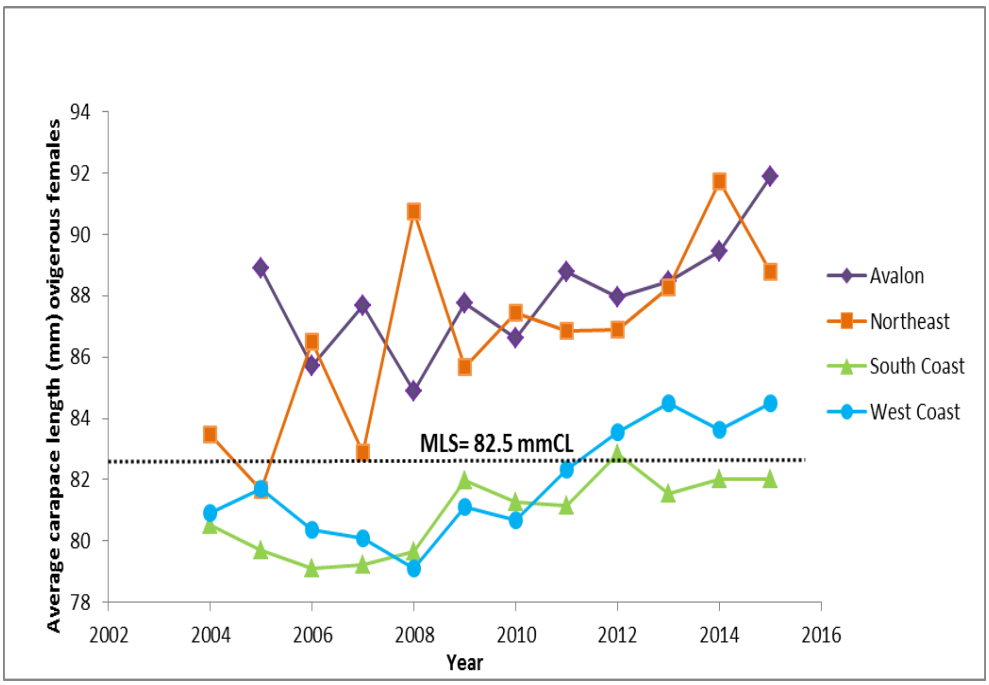

Figure 6. Average carapace length (mm) of ovigerous females based on at-sea sampling data collected in each region from 2004-15.

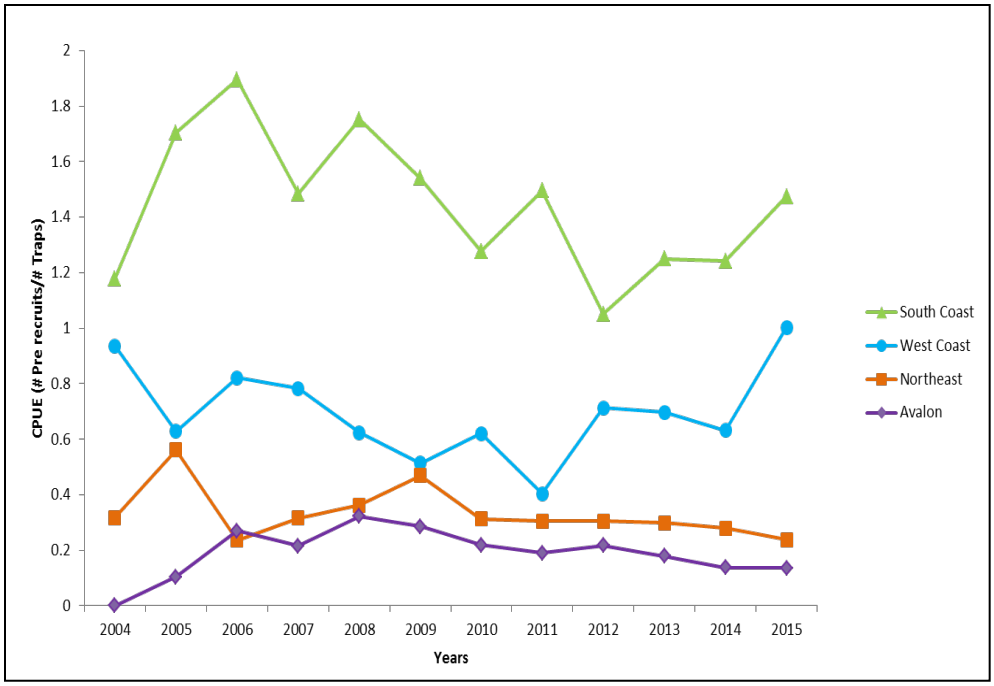

Figure 7. Catch per unit effort (CPUE) of pre-recruit (<83 mm CL) lobsters based on at-sea sampling data (commercial traps) collected in each region from 2004-15.

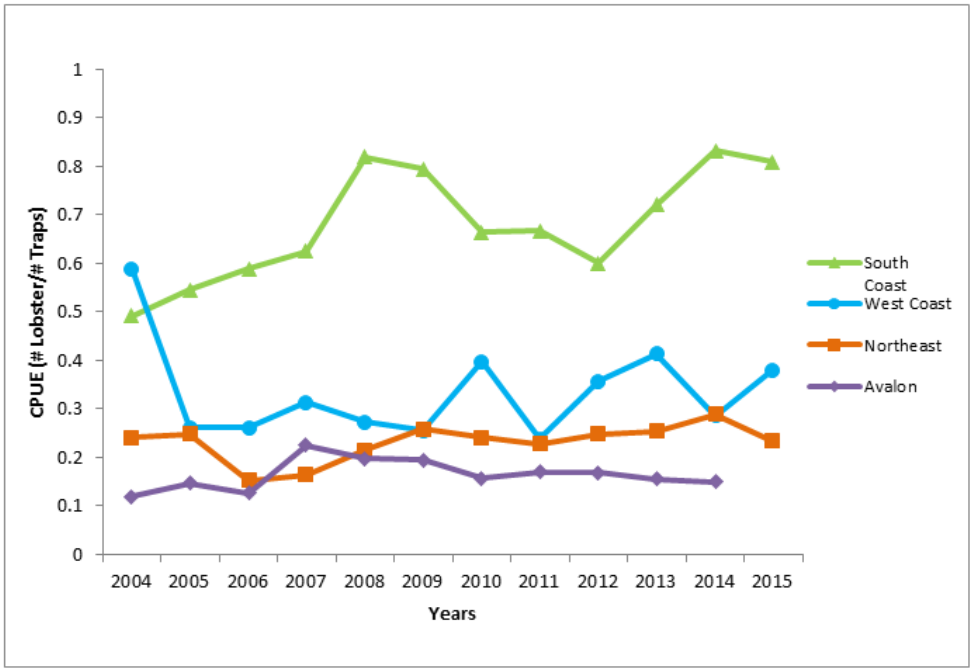

Figure 8. Catch per unit effort (CPUE) of recruit (83-93 mm CL) lobsters based on at-sea sampling data (commercial traps) collected in each region from 2004-15.

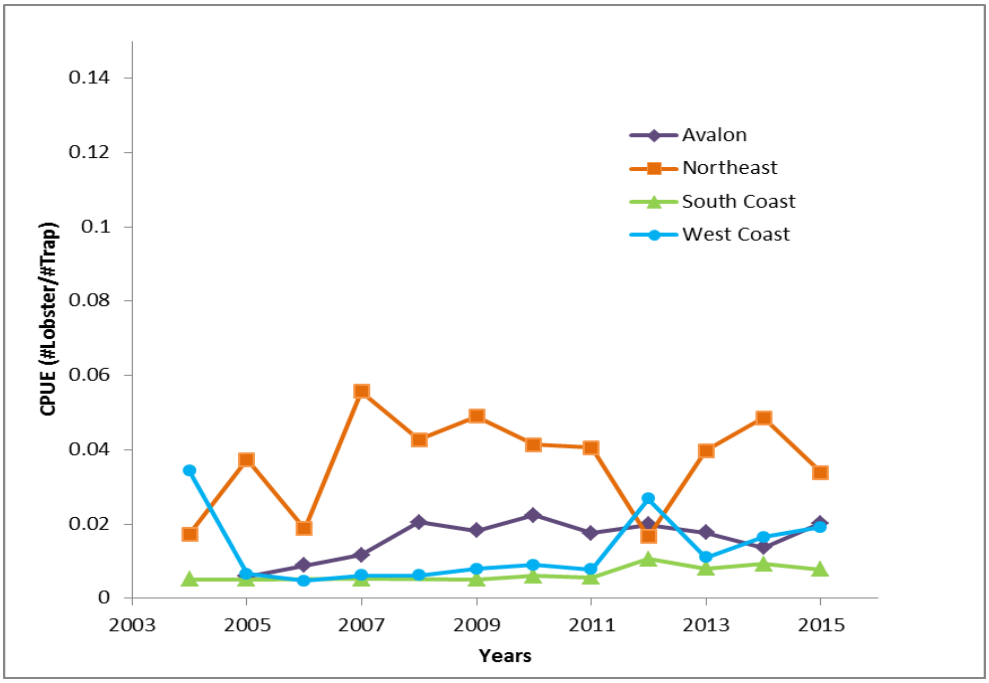

Figure 9.Catch per unit effort (CPUE) of jumbo (>120 mm CL) lobsters based on at-sea sampling data (commercial traps) collected in each region from 2004-15.

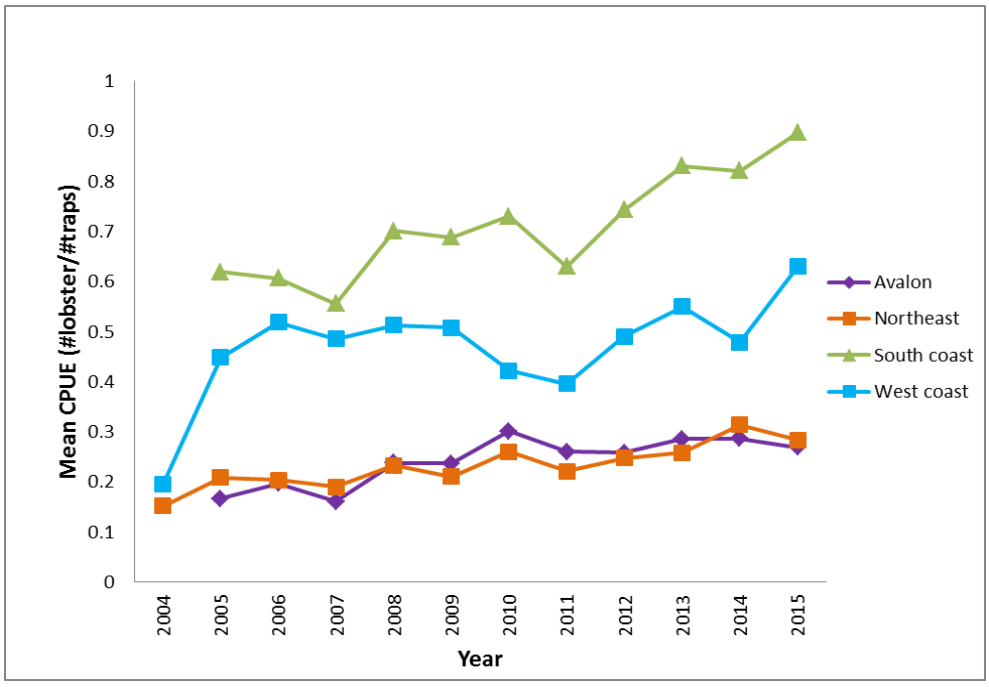

Figure 10. Mean catch per unit effort (CPUE) based on index fishers logbooks of recruit size lobster (>82.5 mm CL) for each region from 2004-15.

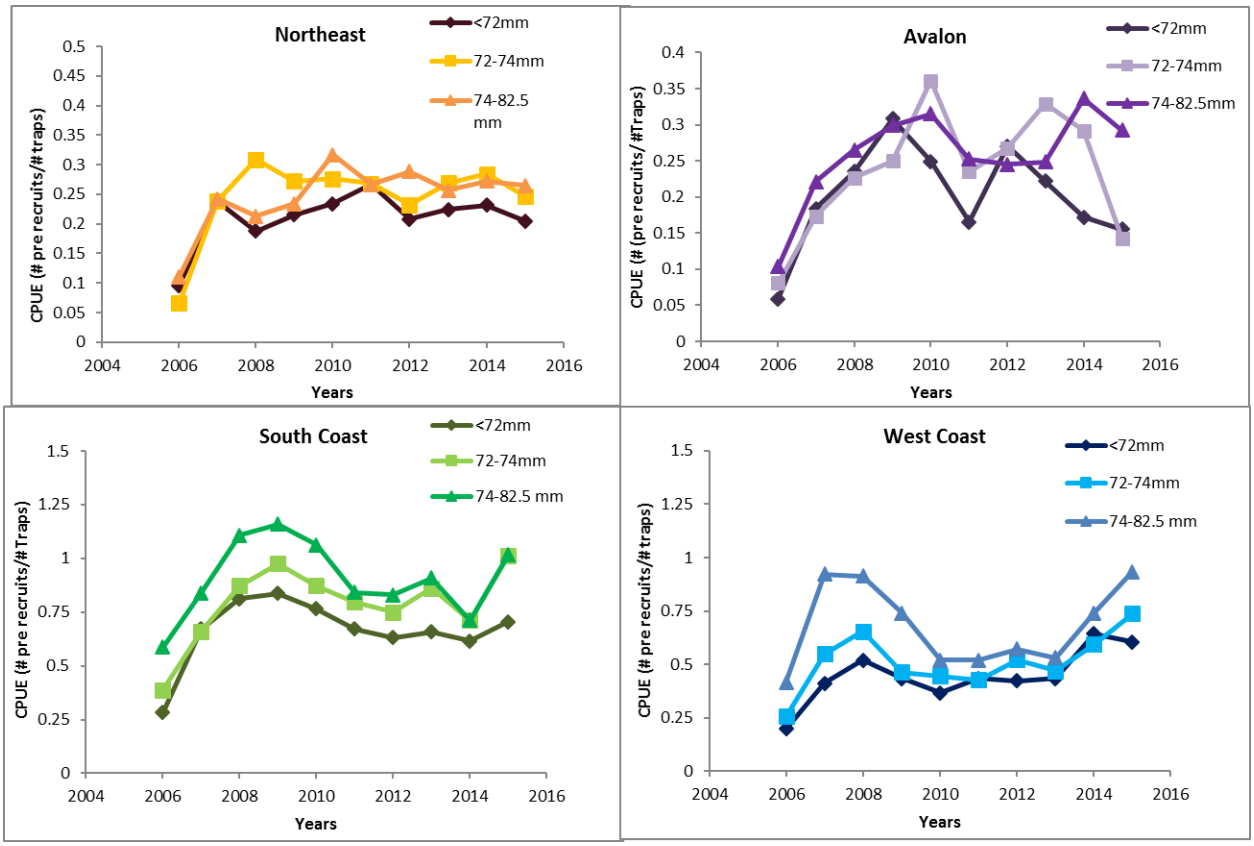

Figure 11. CPUE trends for each of the regions from 2006-15 based on the logbook data from the modified traps for pre-recruit lobster within 3 size classes (<72 mm, 72-74 mm, 74-82.5 mm CL).

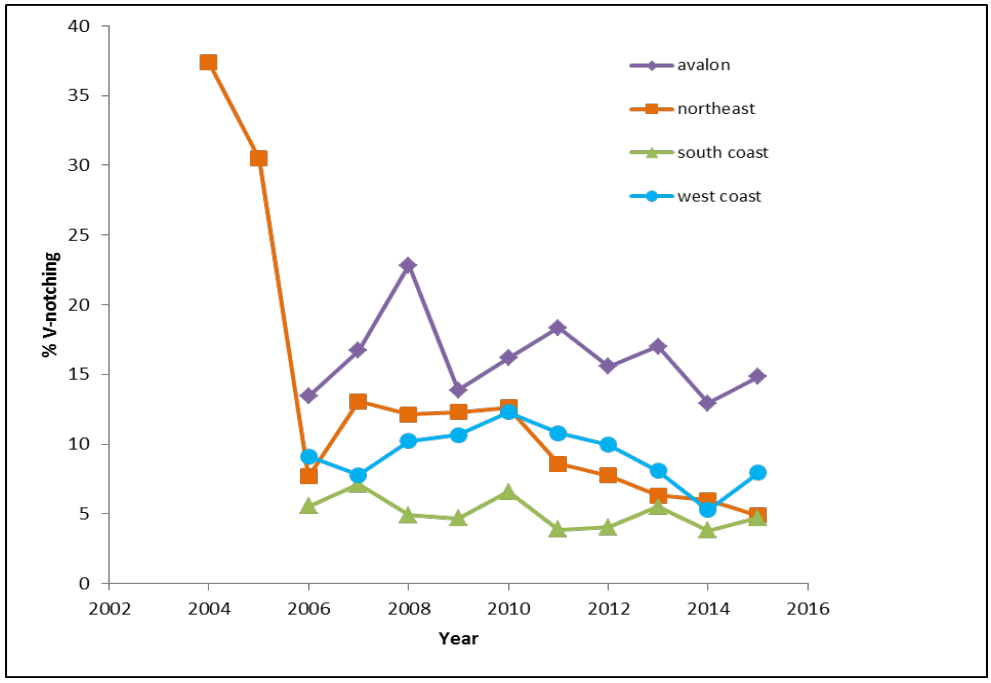

Figure 12. Percentage of v-notching (based on the index fishers logbook data) in each region from 2004-15.

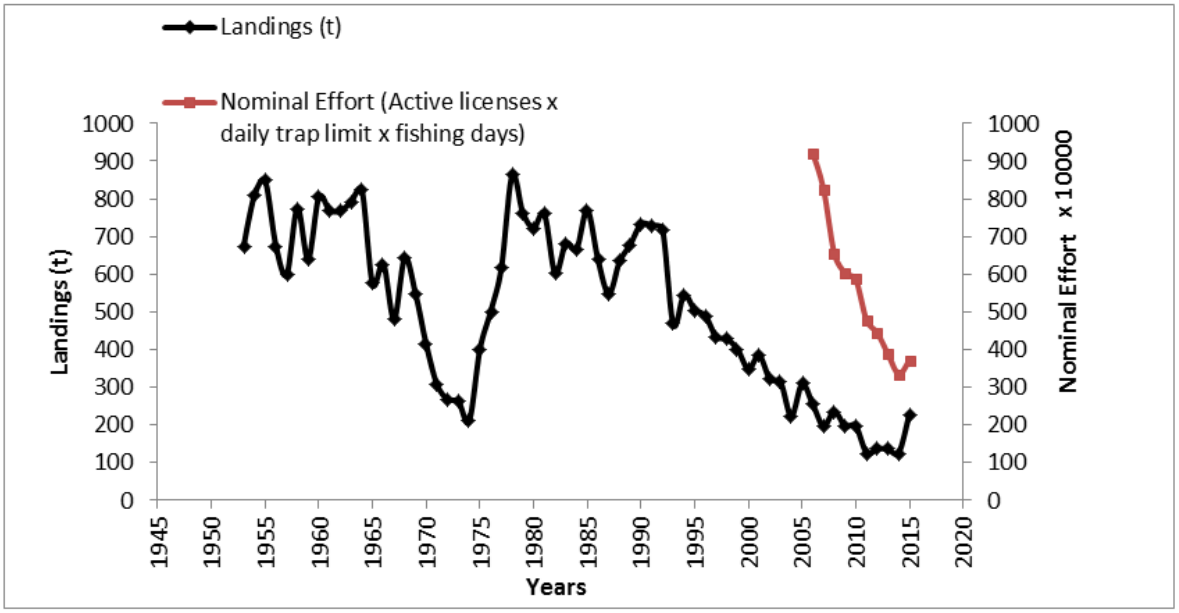

Figure 13. Trends in reported landings (t) and nominal effort (active license x daily trap limit x fishing days) (2007-15) in the Northeast region.

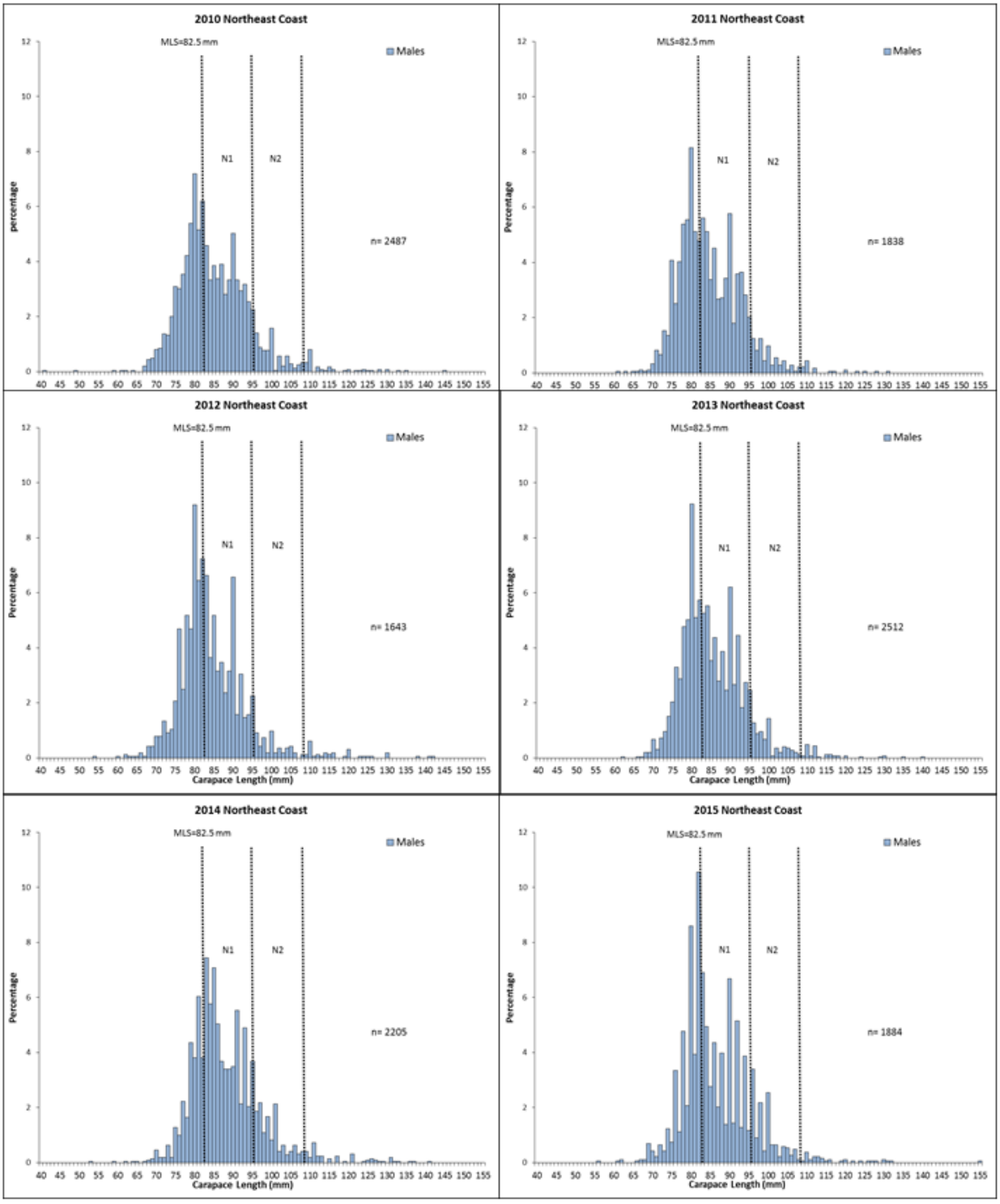

Figure 14. Size frequency distributions from 2010-15 for males in the Northeast region.

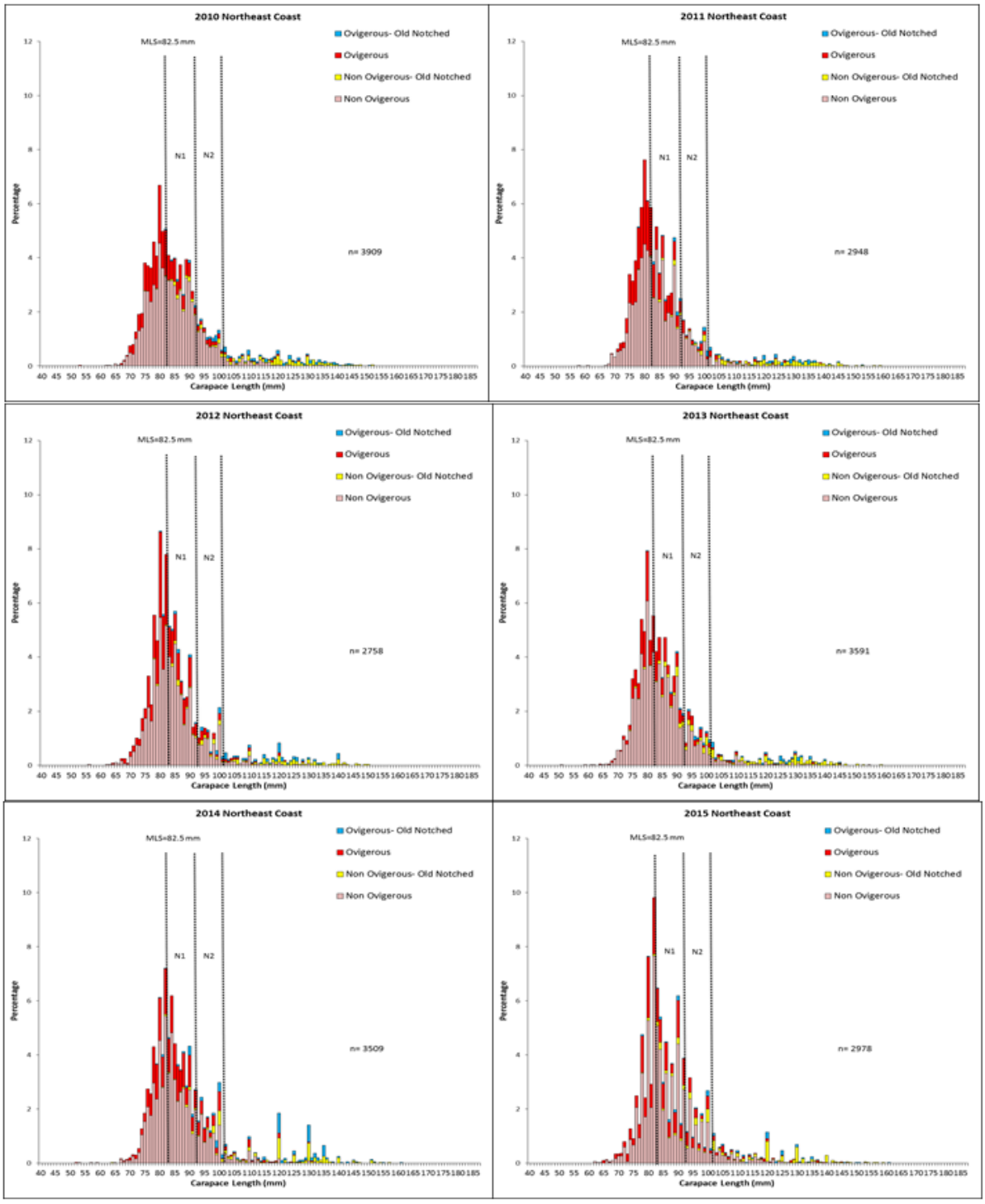

Figure 15. Size frequency distributions from 2010-15 for females in the Northeast region.

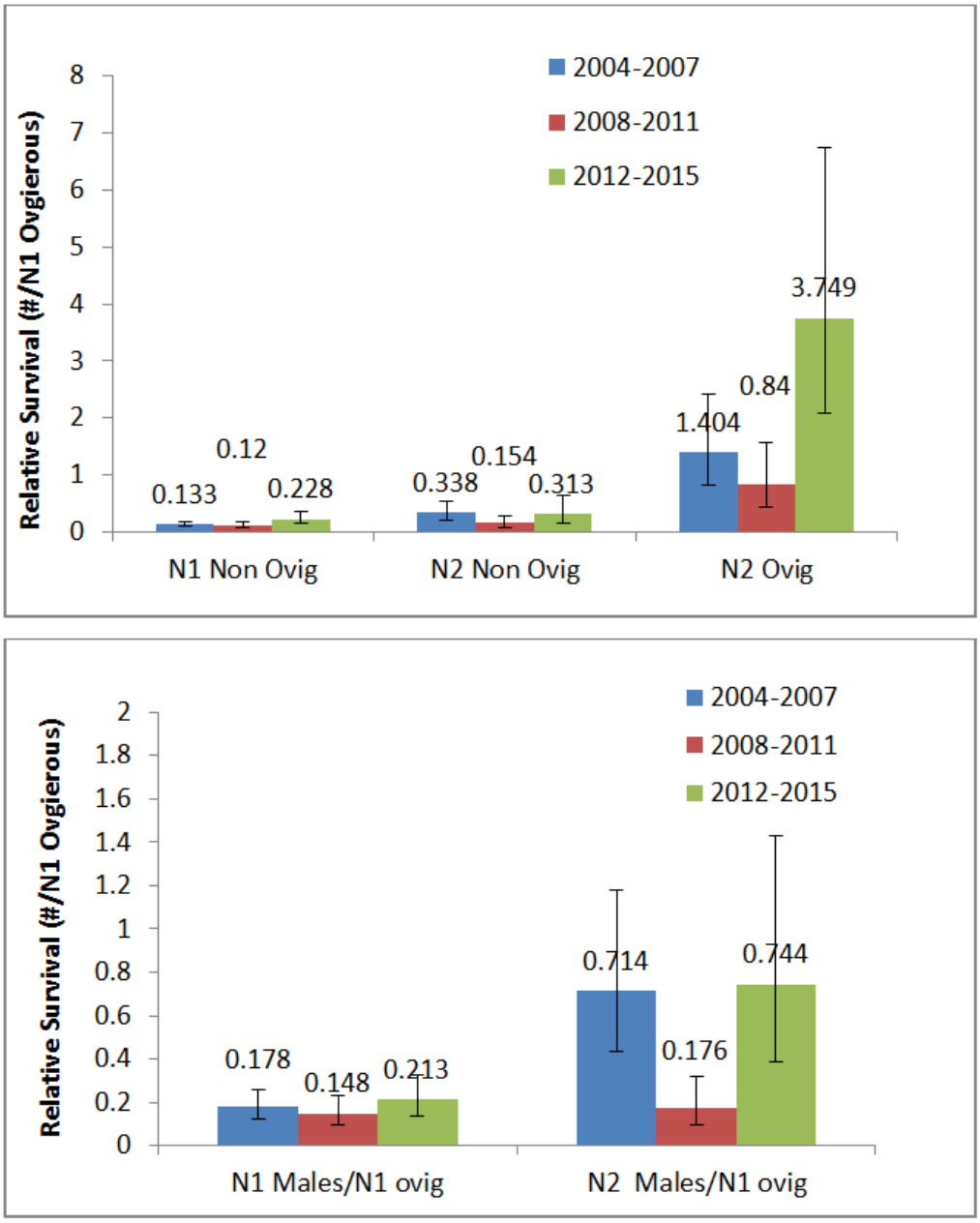

Figure 16. Relative survival fraction for female (top panel) and male (bottom panel) lobsters in the Northeast region. N1 are small legal sized lobsters (first molt class) and N2 are large lobsters (second molt class).

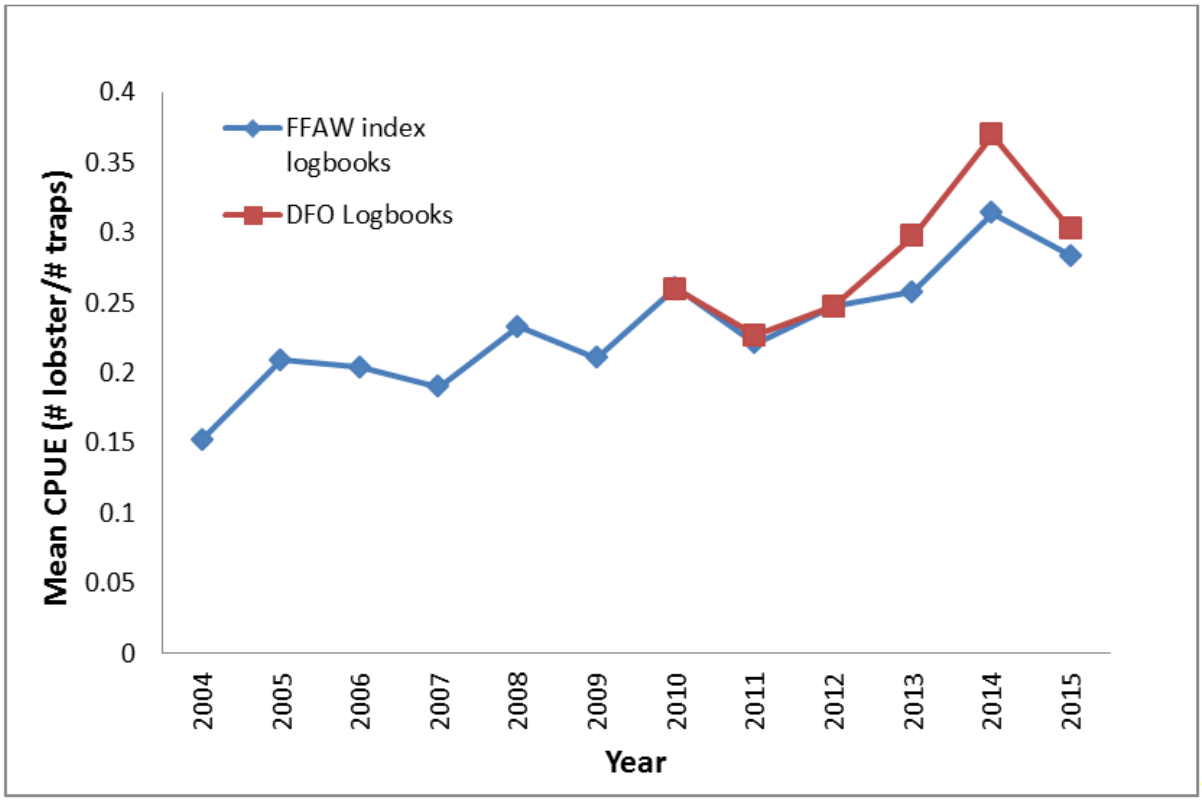

Figure 17. Mean CPUE from index fishers logbooks (2005-15) and DFO logbooks (2010-15) for the Northeast region.

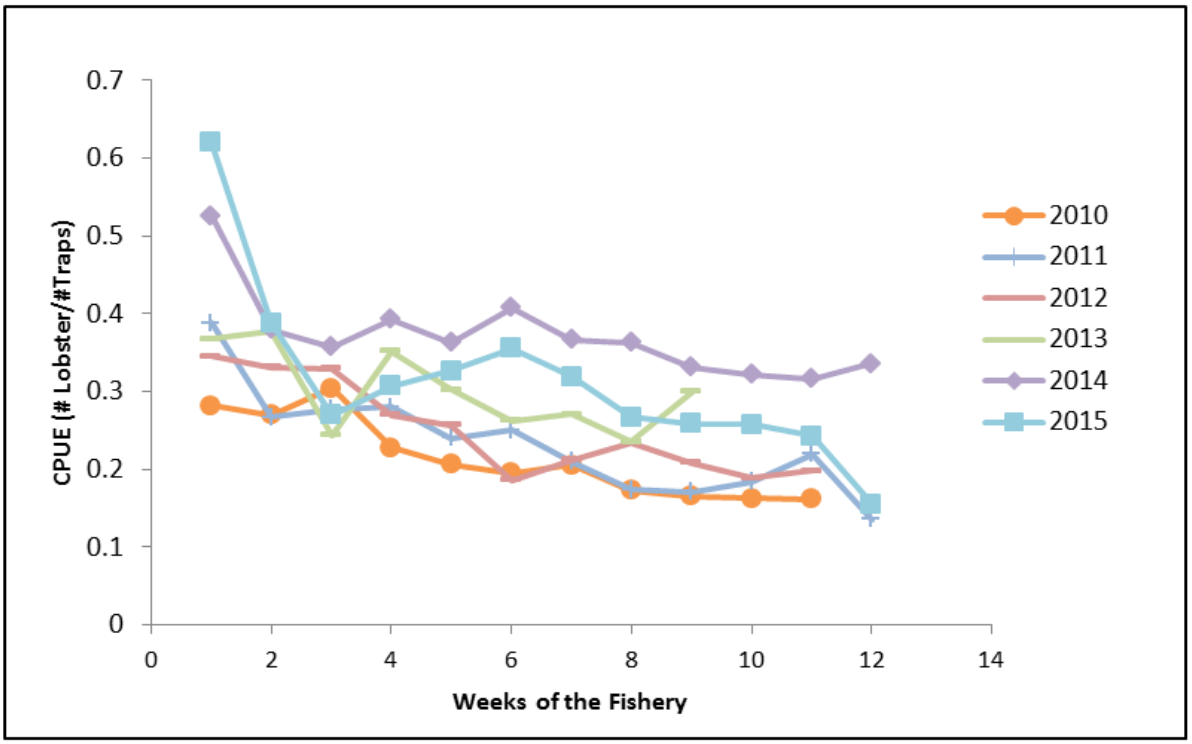

Figure 18. Weekly CPUE from DFO logbooks (2010-15) in the Northeast region.

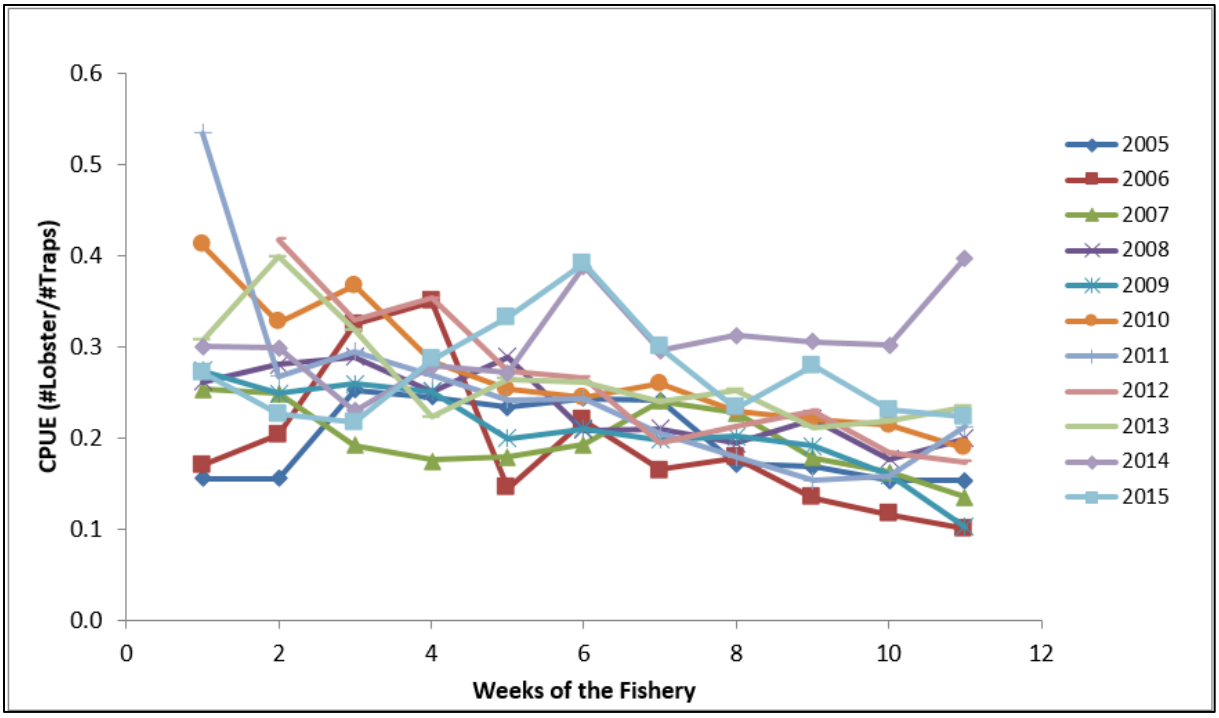

Figure 19. Weekly CPUE from index fisher logbooks (2005-15) in the Northeast region.

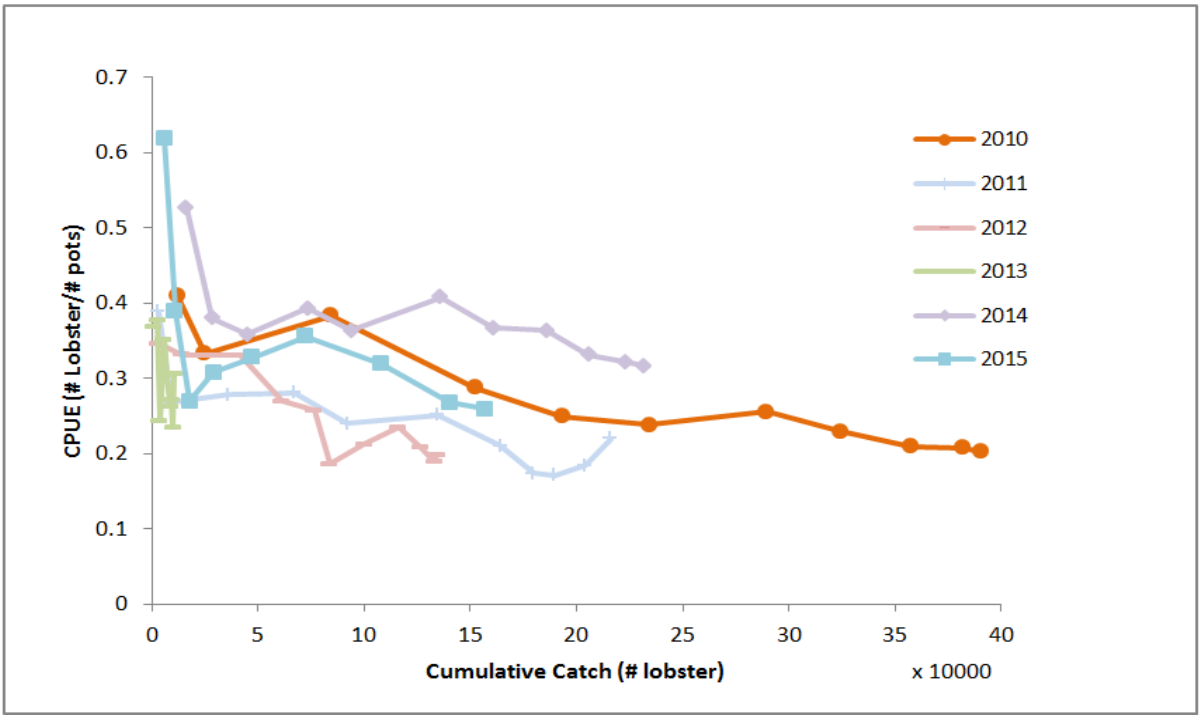

Figure 20. CPUE and cumulative catch from DFO logbooks (2010-15) in the Northeast region.

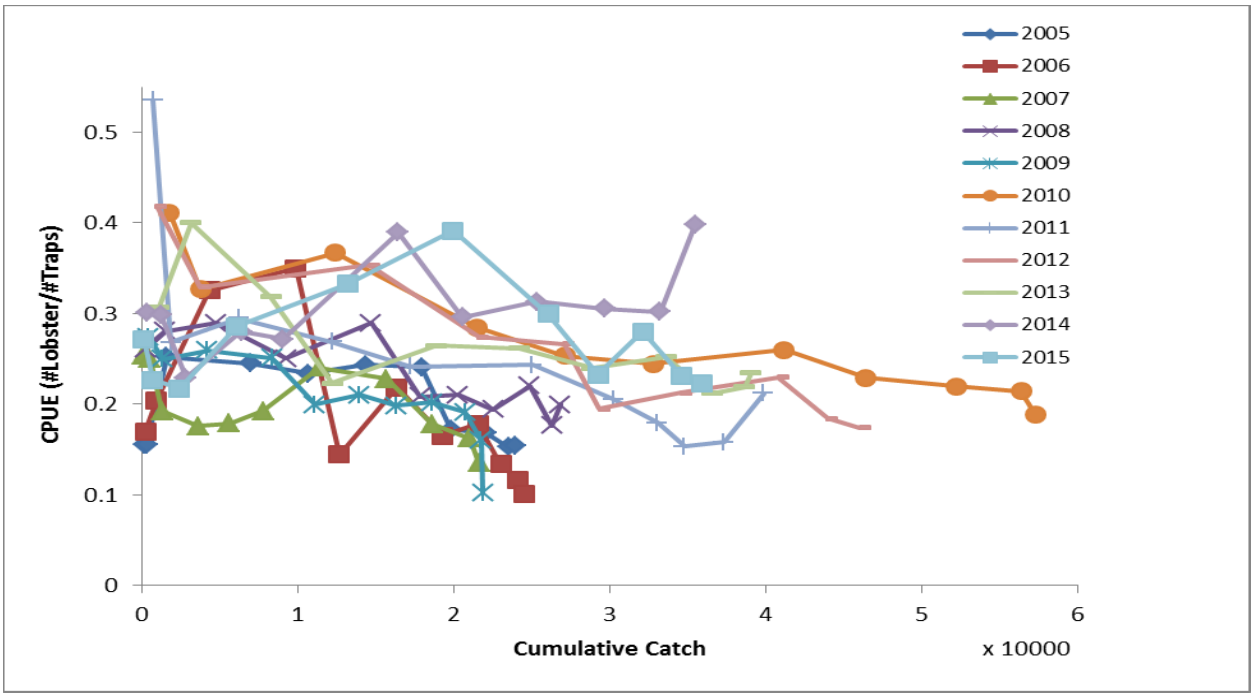

Figure 21. CPUE and cumulative catch from index fishers logbooks (2005-15) in the Northeast region.

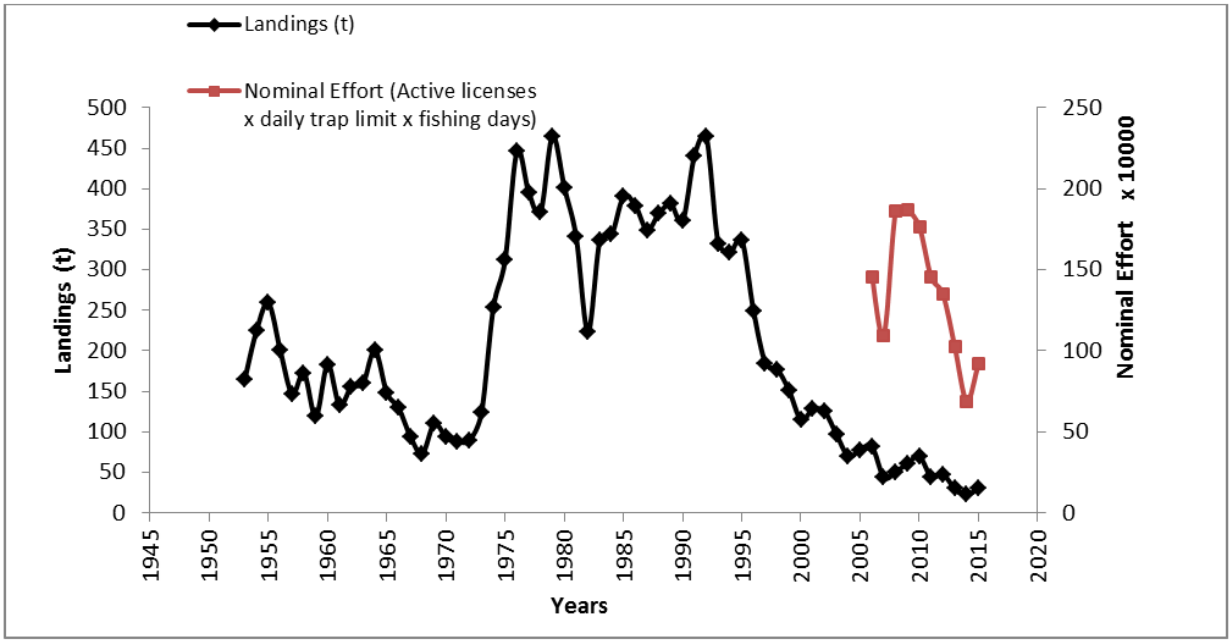

Figure 22. Trends in reported landings (t) and nominal effort (active license x daily trap limit x fishing days) (2005-15) in the Avalon region.

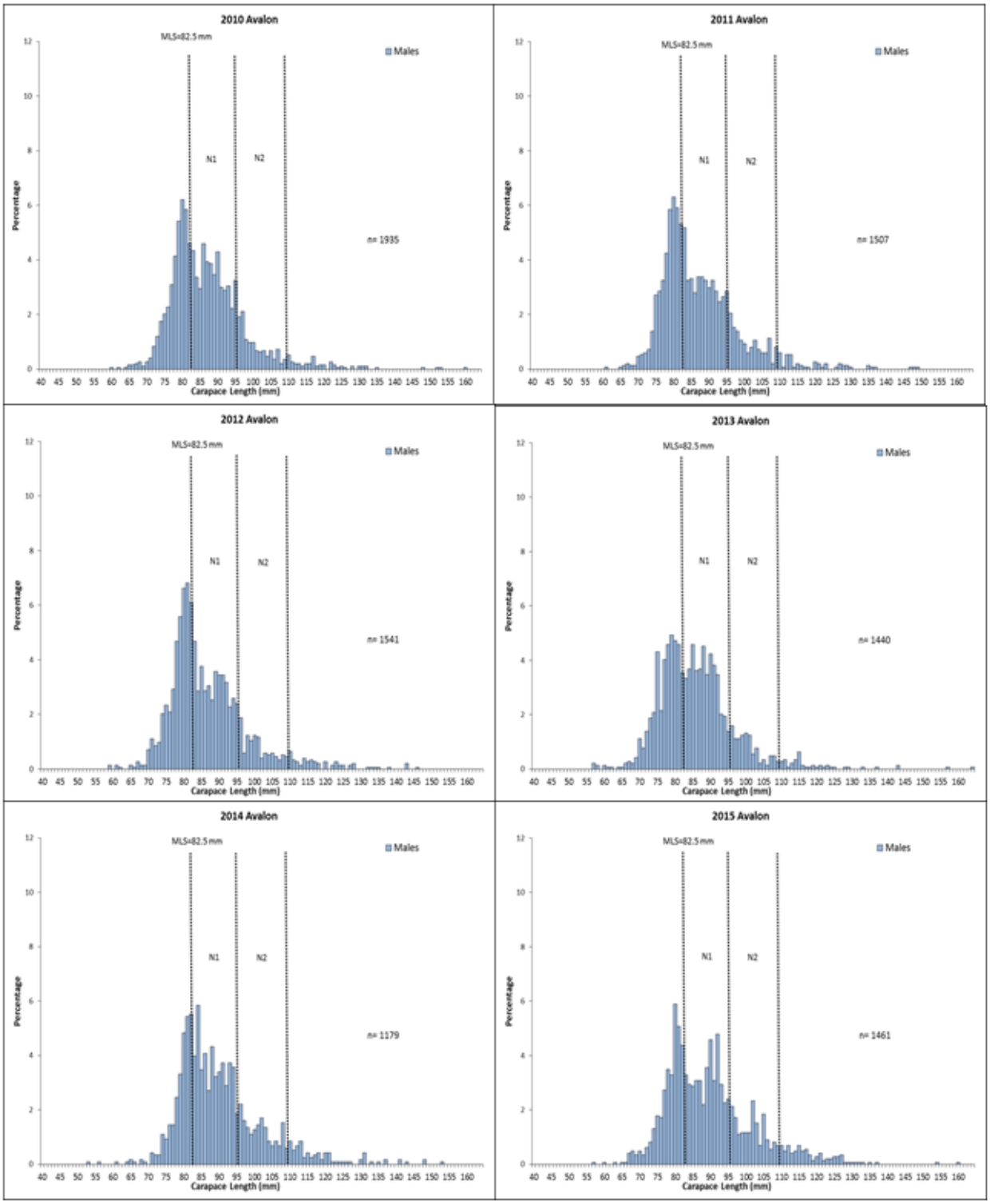

Figure 23. Size frequency distributions from 2010-15 for males in the Avalon region.

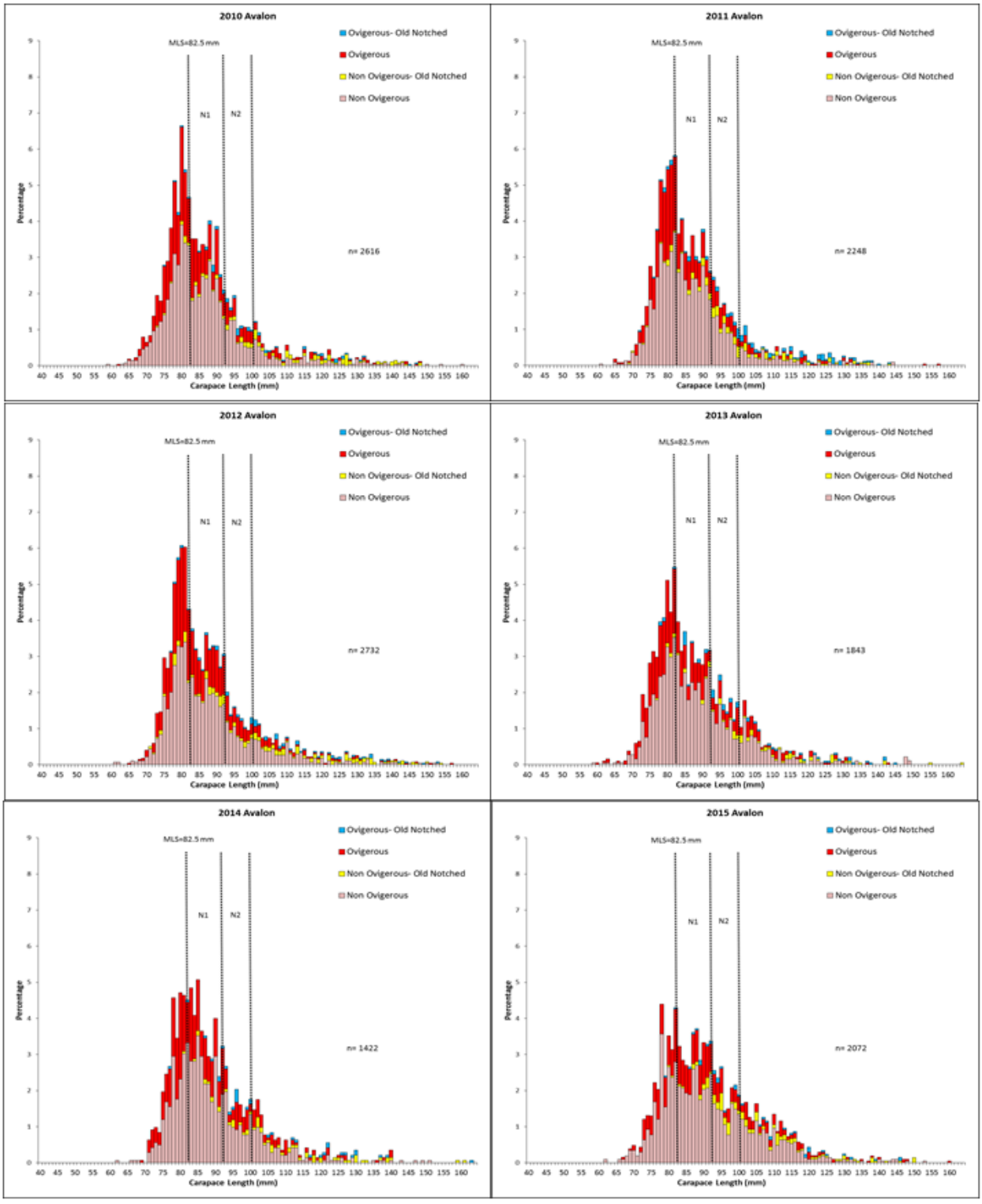

Figure 24. Size frequency distributions from 2010-15 for females in the Avalon region.

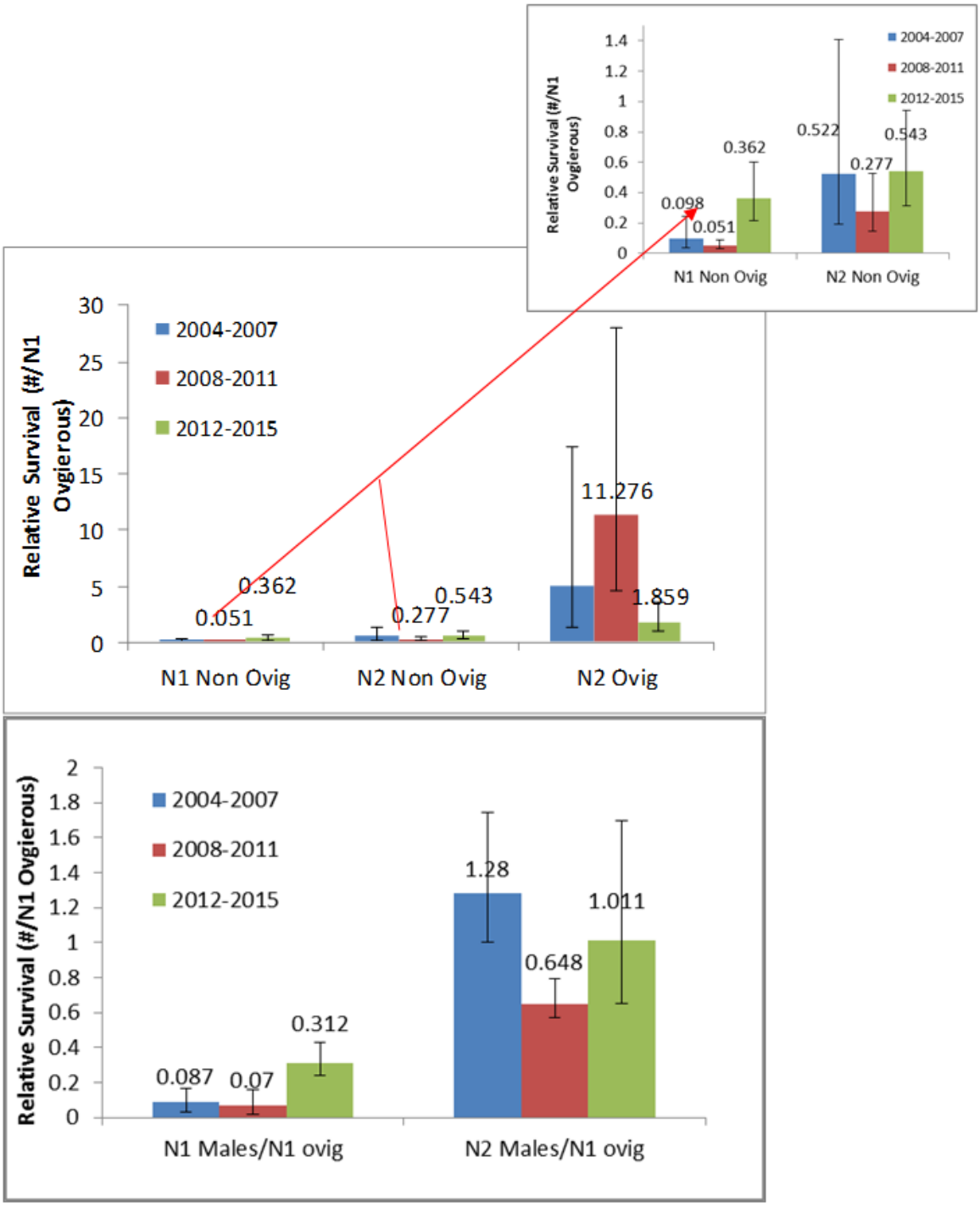

Figure 25. Relative survival fraction for female (top panel) and male (bottom panel) lobsters in the Avalon region. N1 are small legal sized lobsters (first molt class) and N2 are large lobsters (second molt class). Note the smaller graph for the non ovigerous females in the top right corner displays the trends at a smaller scale.

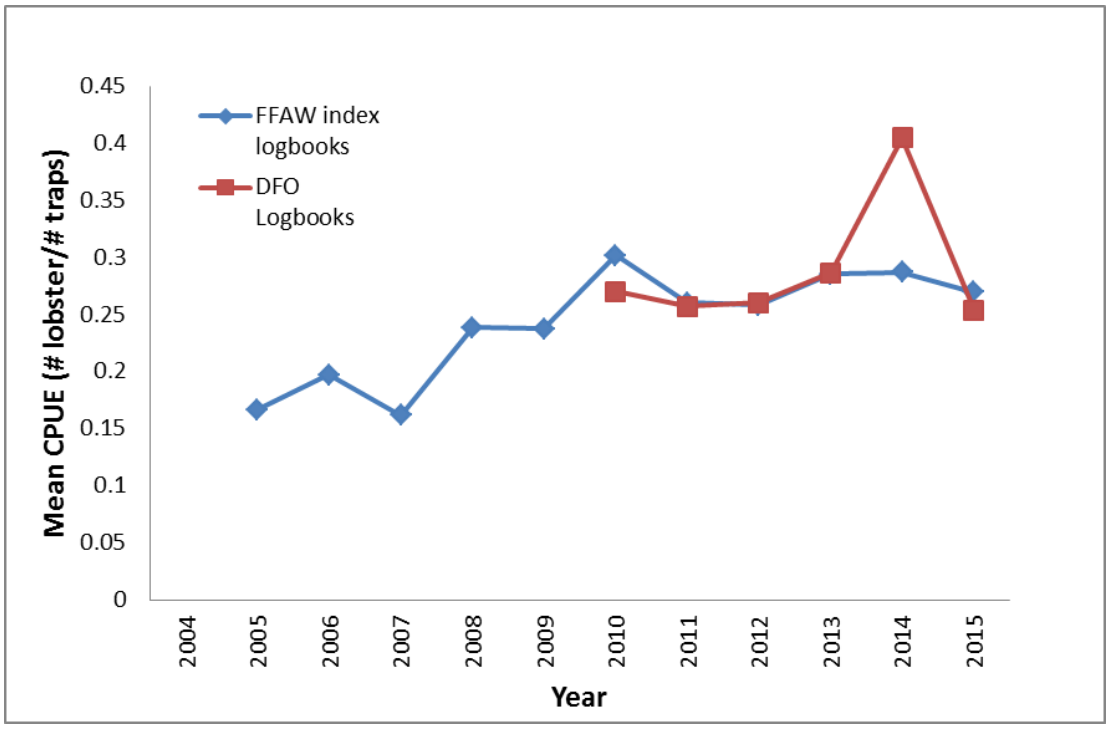

Figure 26. Mean CPUE from index fishers logbooks (2005-15) and DFO logbooks (2010-15) for the Avalon region.

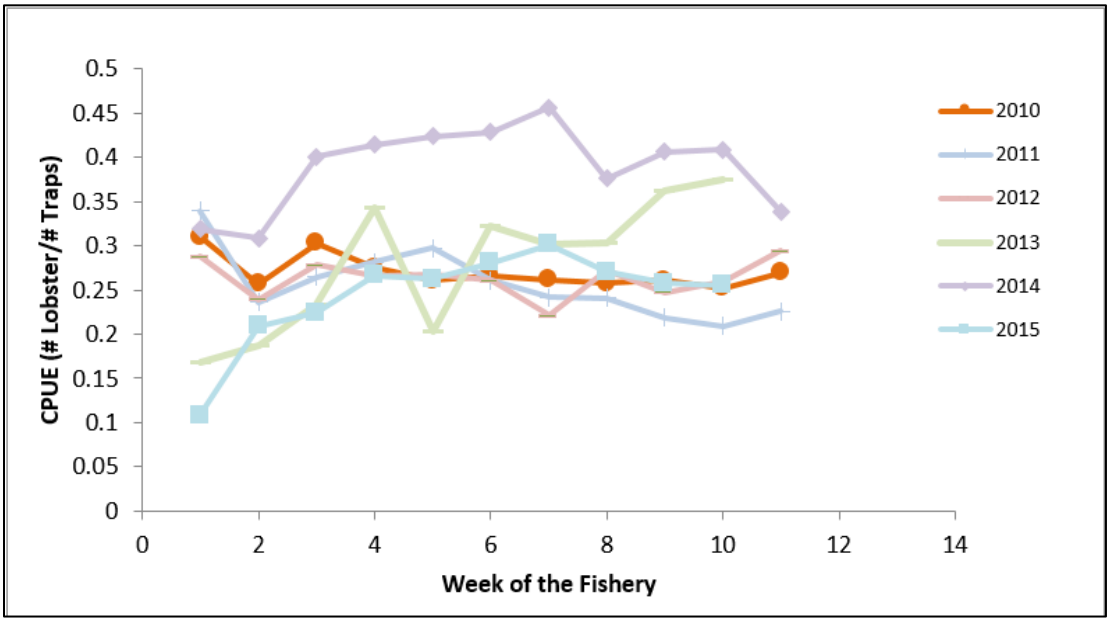

Figure 27. Weekly CPUE from DFO logbooks (2010-15) in the Avalon region.

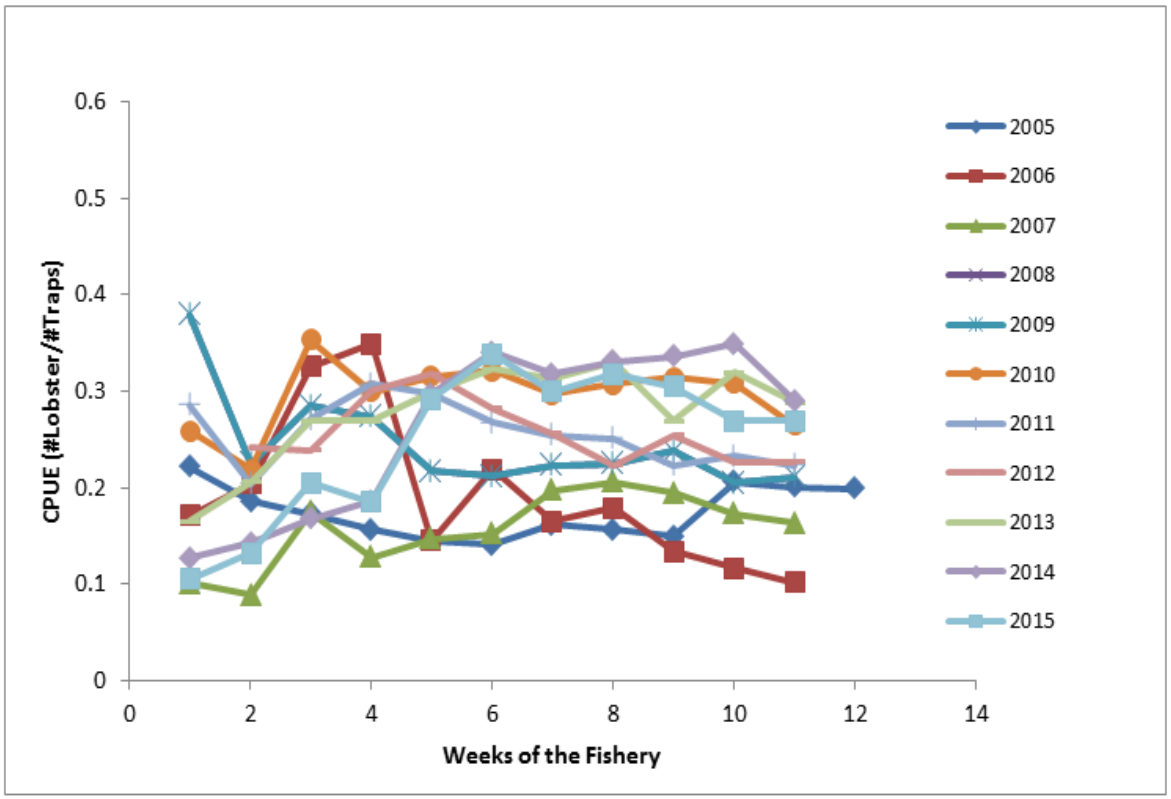

Figure 28. Weekly CPUE from index fishers logbooks (2005-15) in the Avalon region.

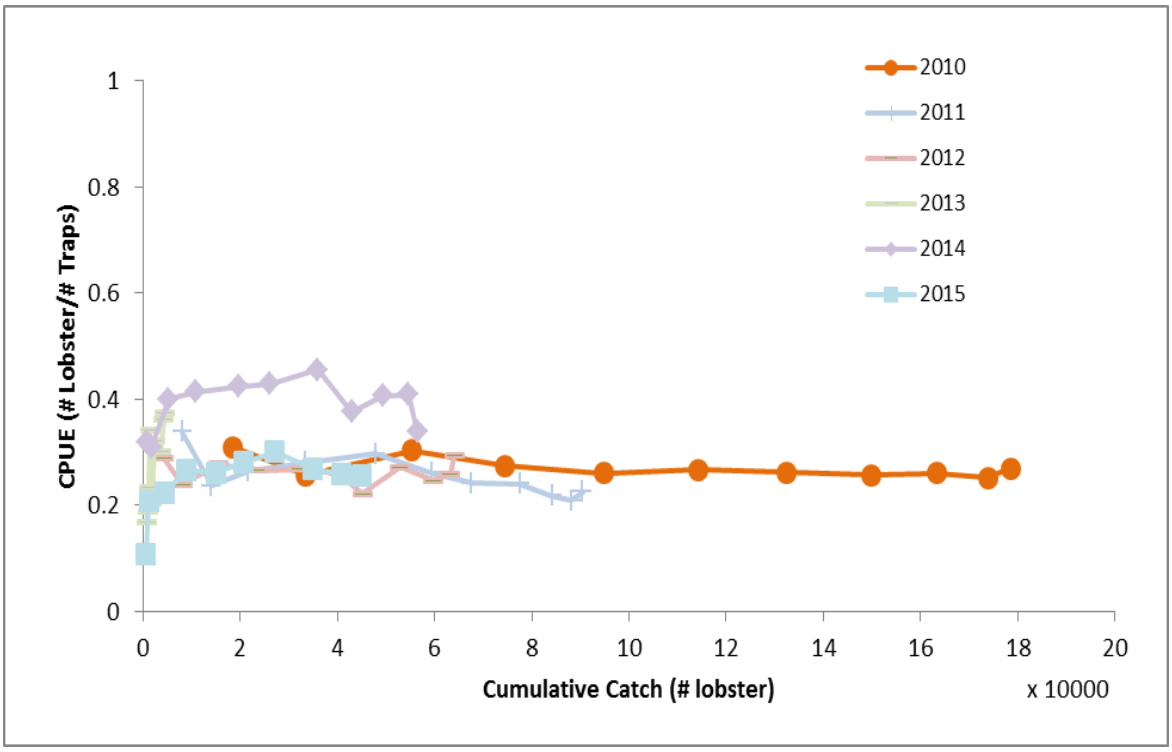

Figure 29. CPUE and cumulative catch from DFO logbooks (2010-15) in the Avalon region.

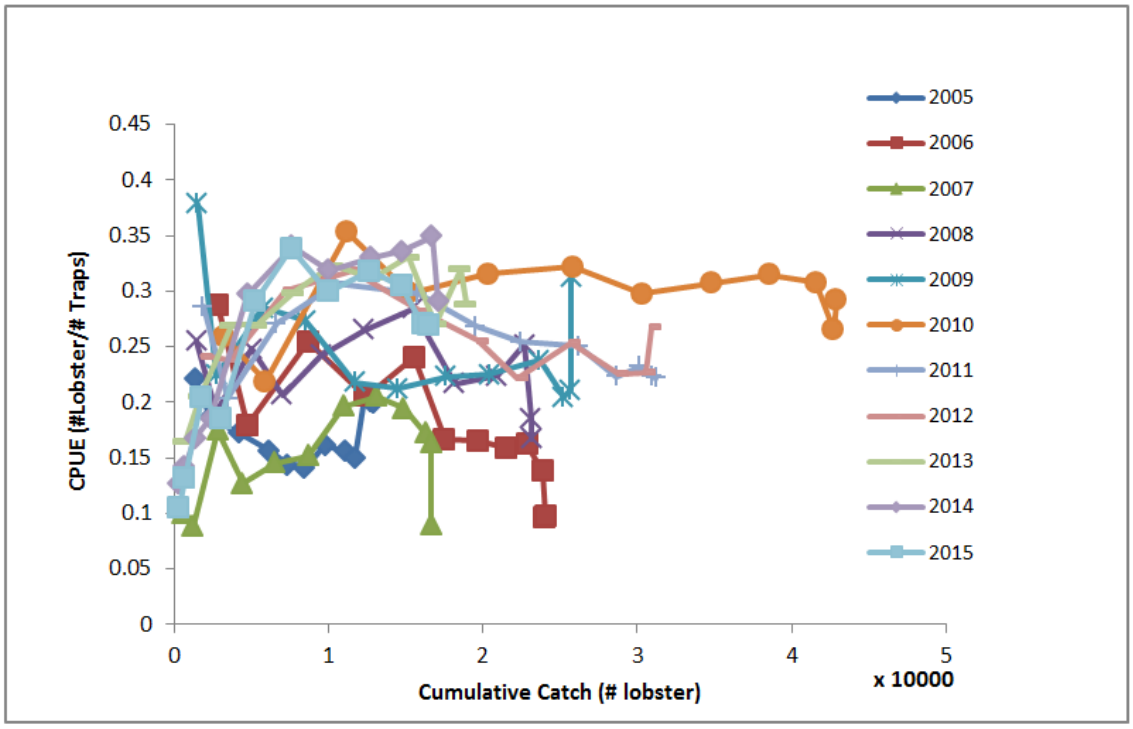

Figure 30. CPUE and cumulative catch from index fishers logbooks (2005-15) in the Avalon region.

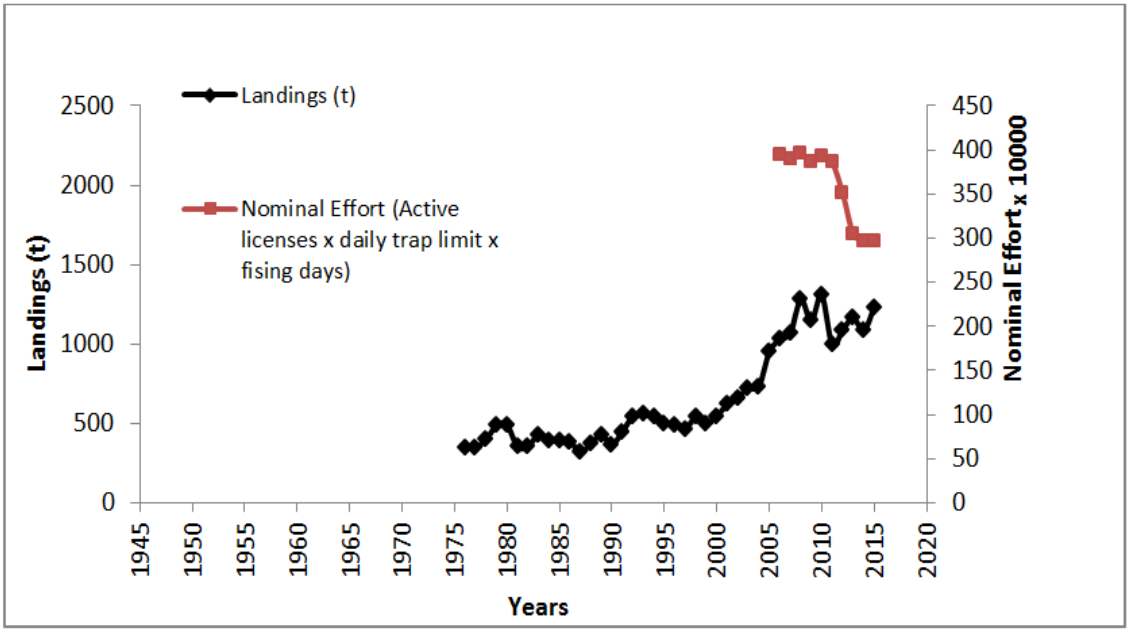

Figure 31. Trends in reported landings (t) and nominal effort (active licenses x traps x fishing days) (1976-2015) in the South Coast region.

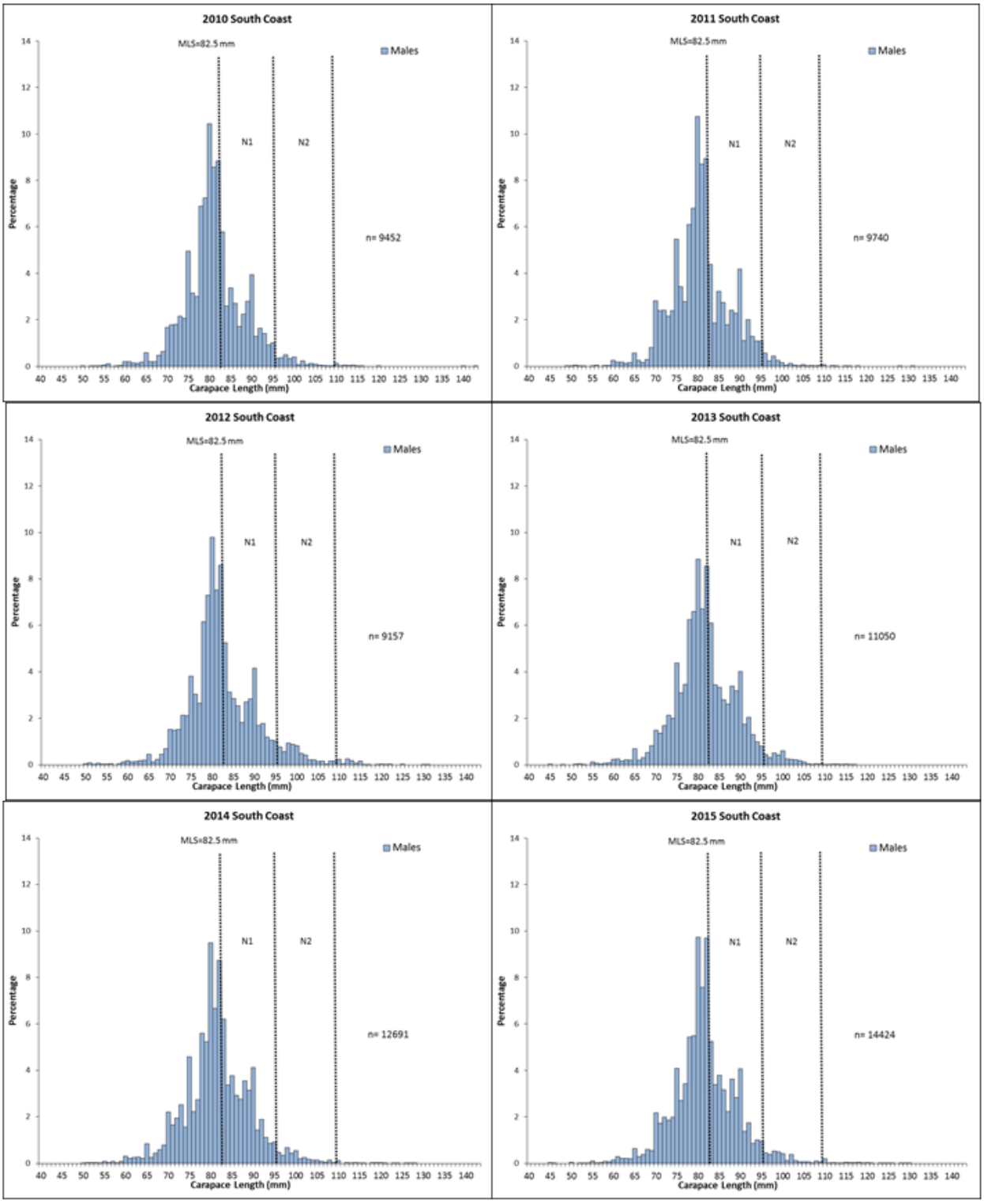

Figure 32. Size frequency distributions from 2010-15 for males in the South Coast region.

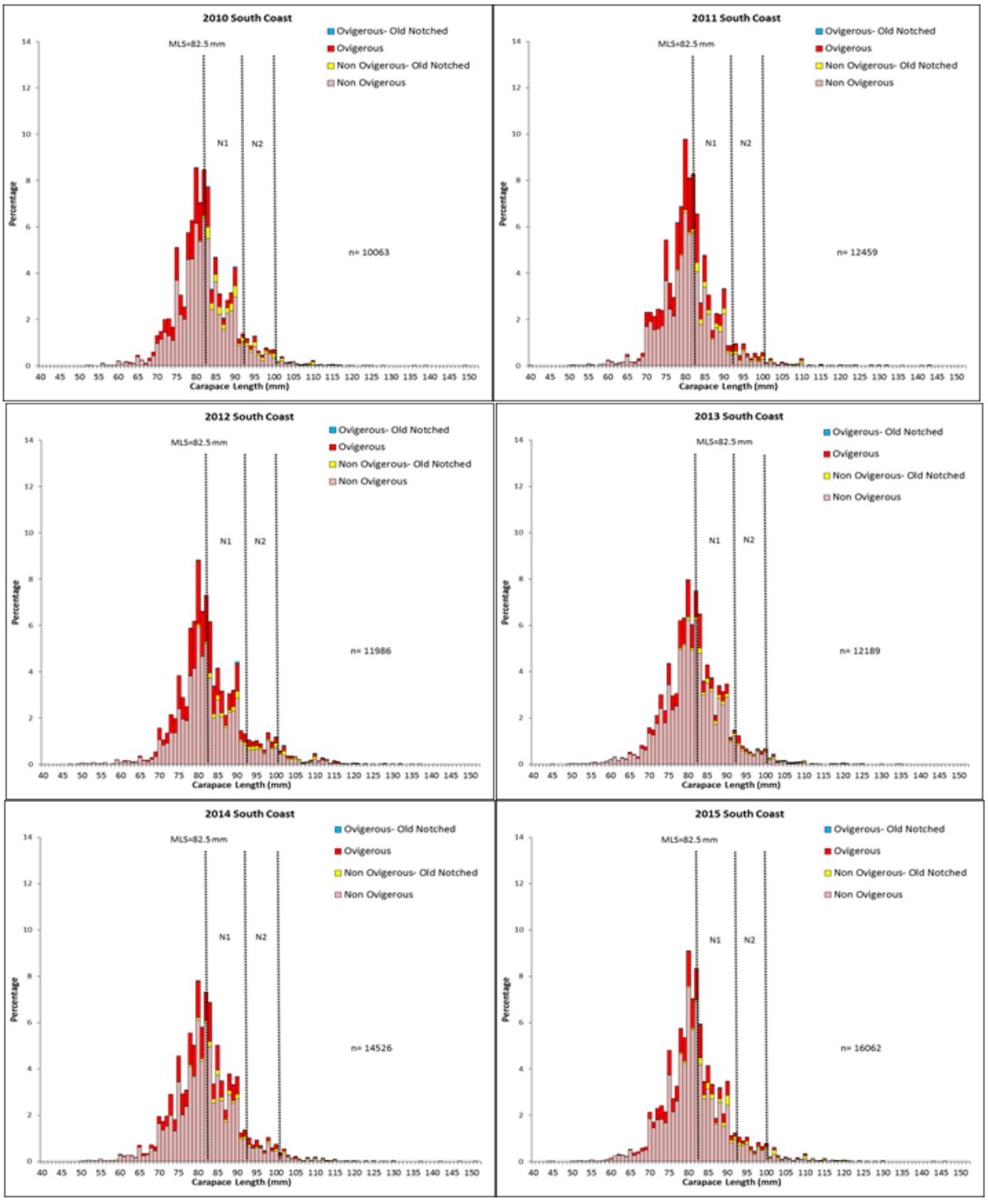

Figure 33. Size frequency distributions from 2010-15 for females in the South Coast region.

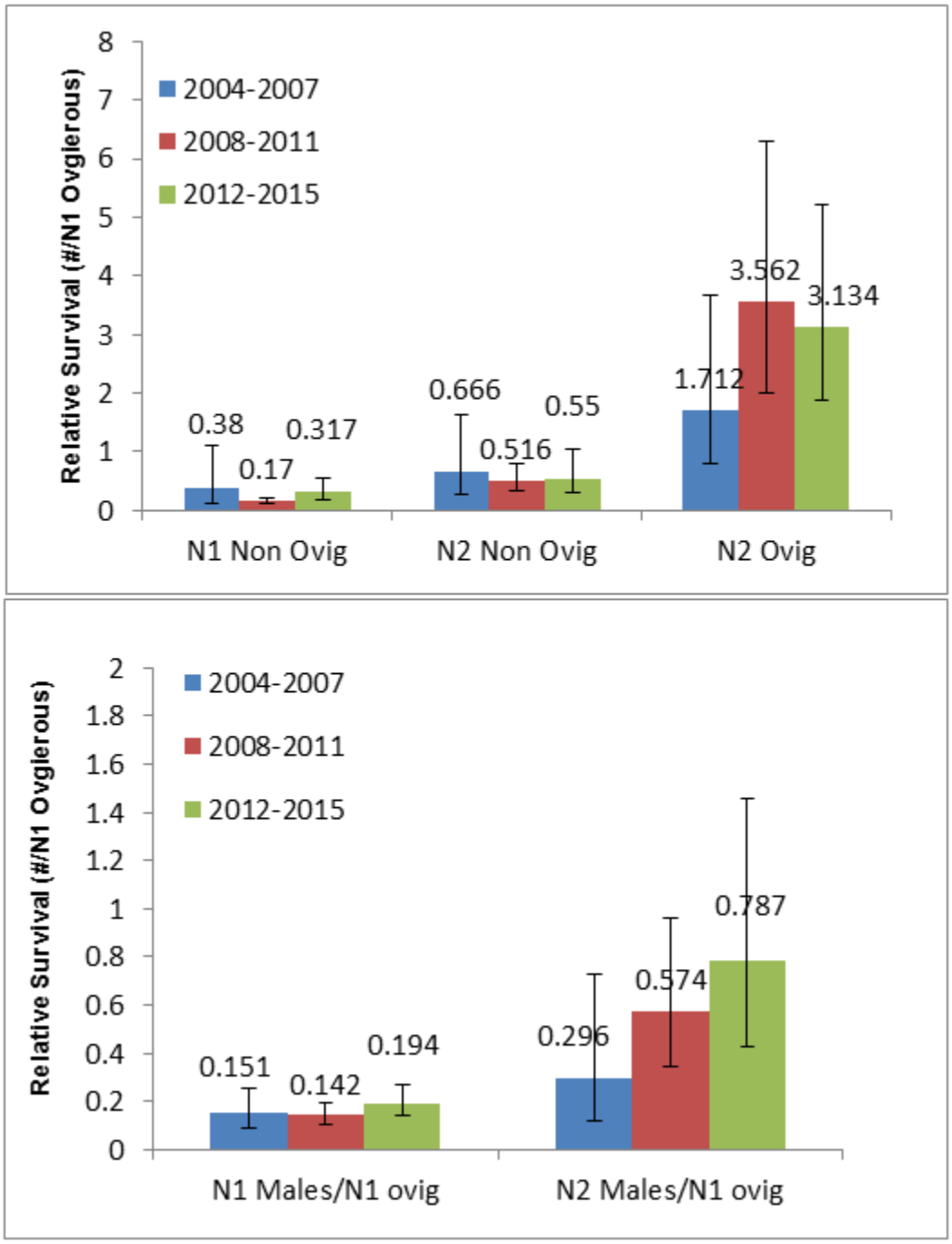

Figure 34. Relative survival fraction for female (top panel) and male (bottom panel) lobsters in the South Coast region. N1 are small legal sized lobsters (first molt class) and N2 are large lobsters (second molt class).

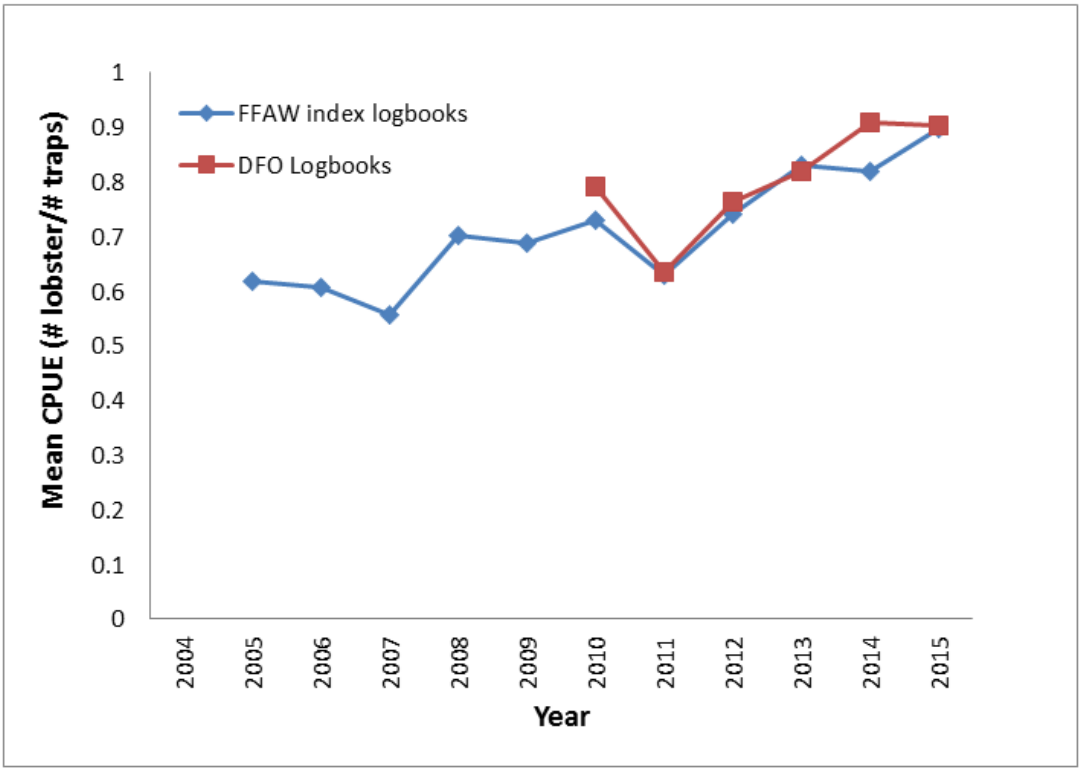

Figure 35. Mean CPUE from index fishers logbooks (2005-15) and DFO logbooks (2010-15) for the South Coast region.

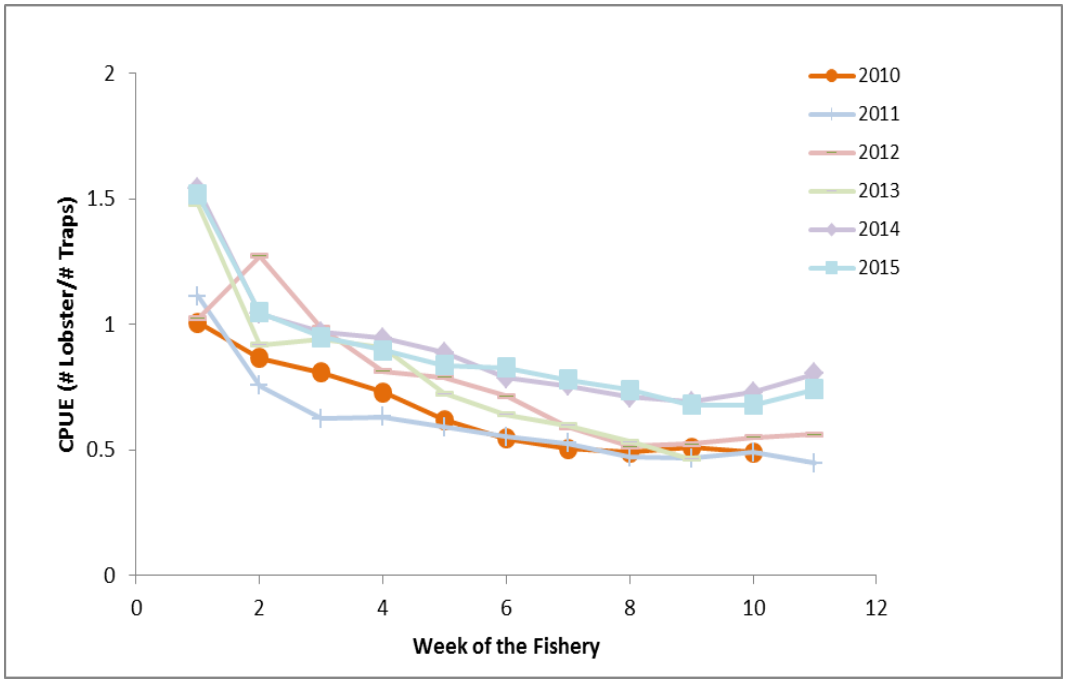

Figure 36. Weekly CPUE from DFO logbooks (2010-15) in the South Coast region.

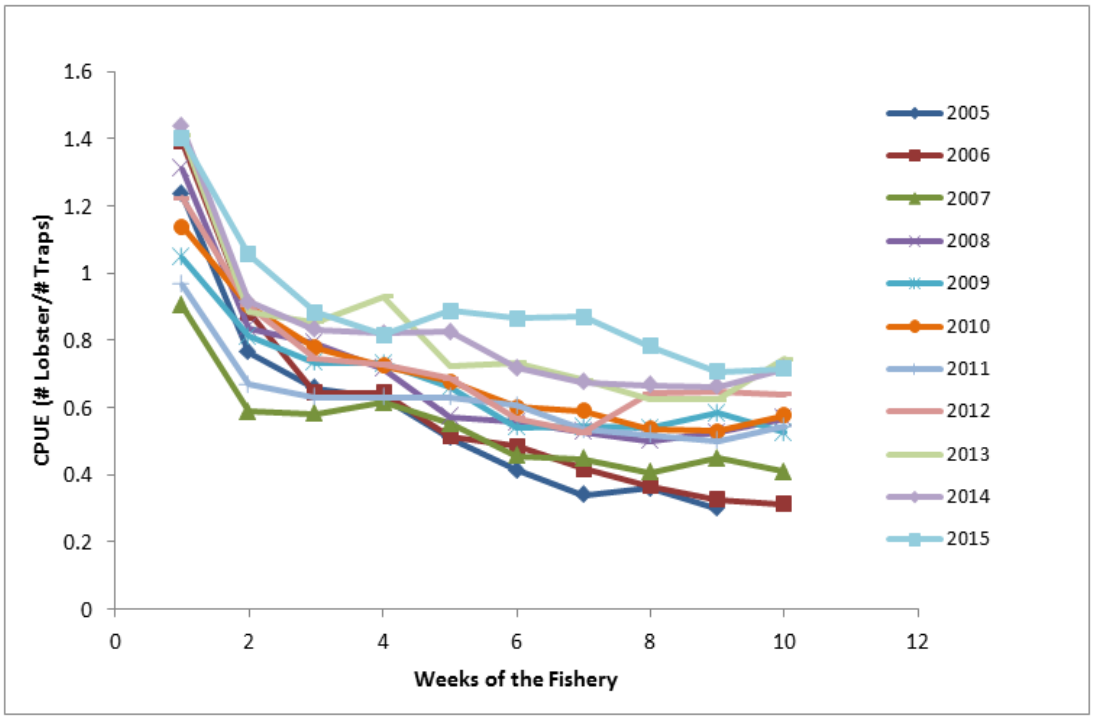

Figure 37. Weekly CPUE from index fishers logbooks (2005-2015) in the South Coast region.

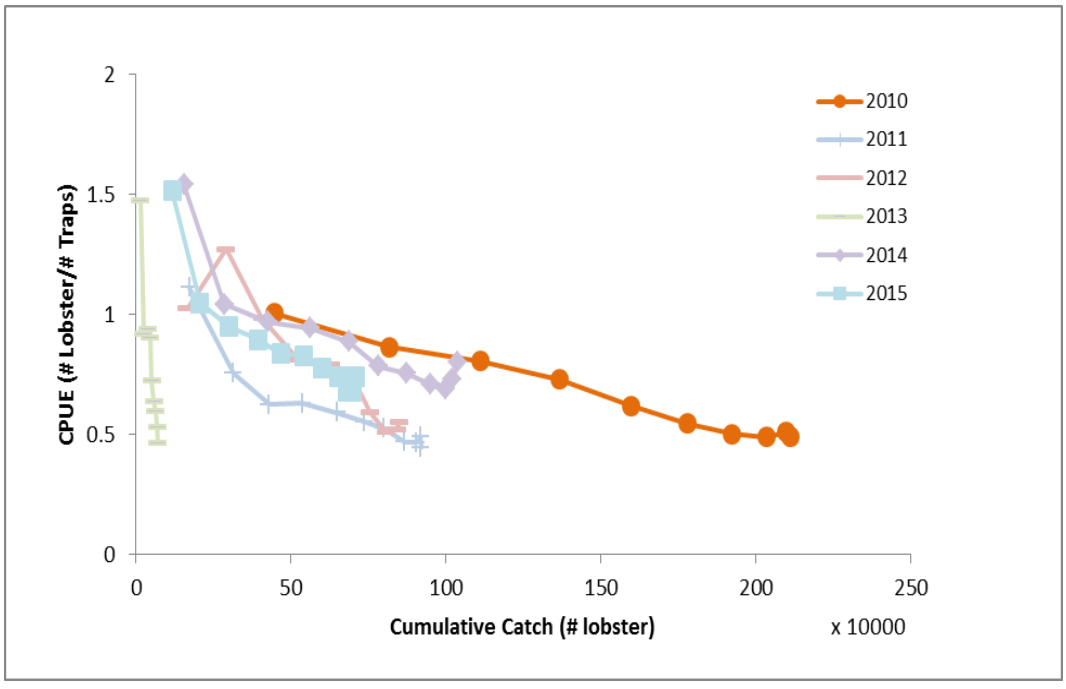

Figure 38. Weekly CPUE from DFO logbooks (2010-15) in the South Coast region.

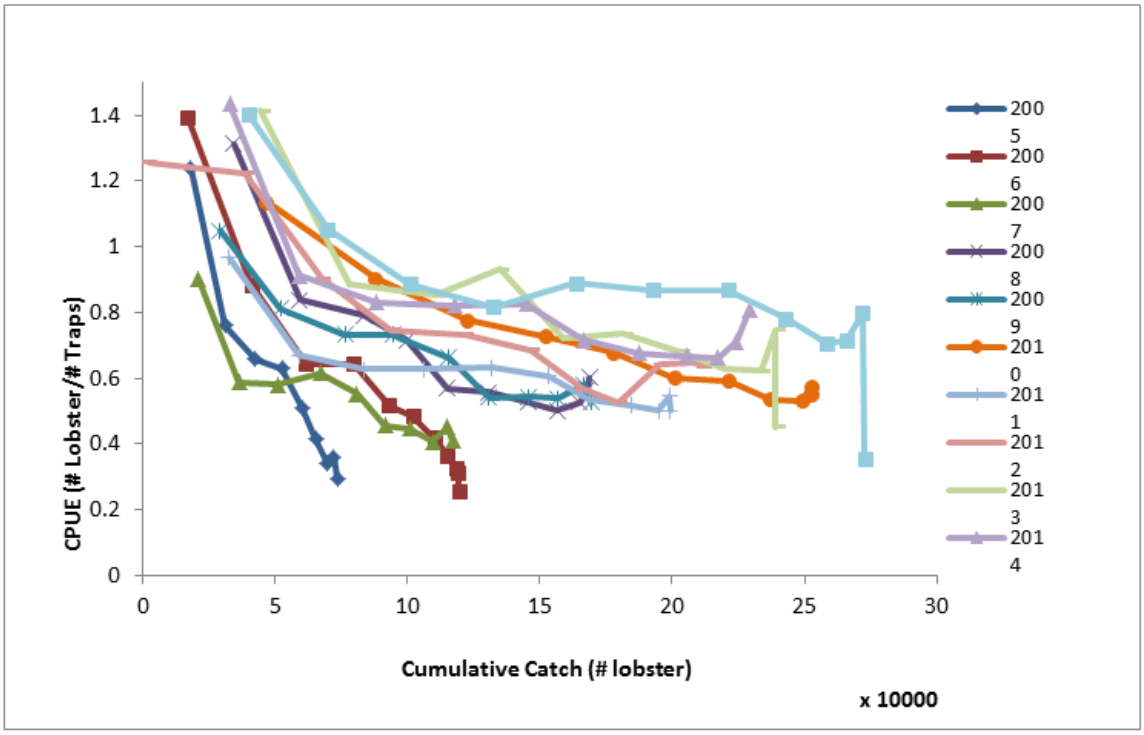

Figure 39. CPUE and cumulative catch from index fishers logbooks (2005-15) for the South Coast region.

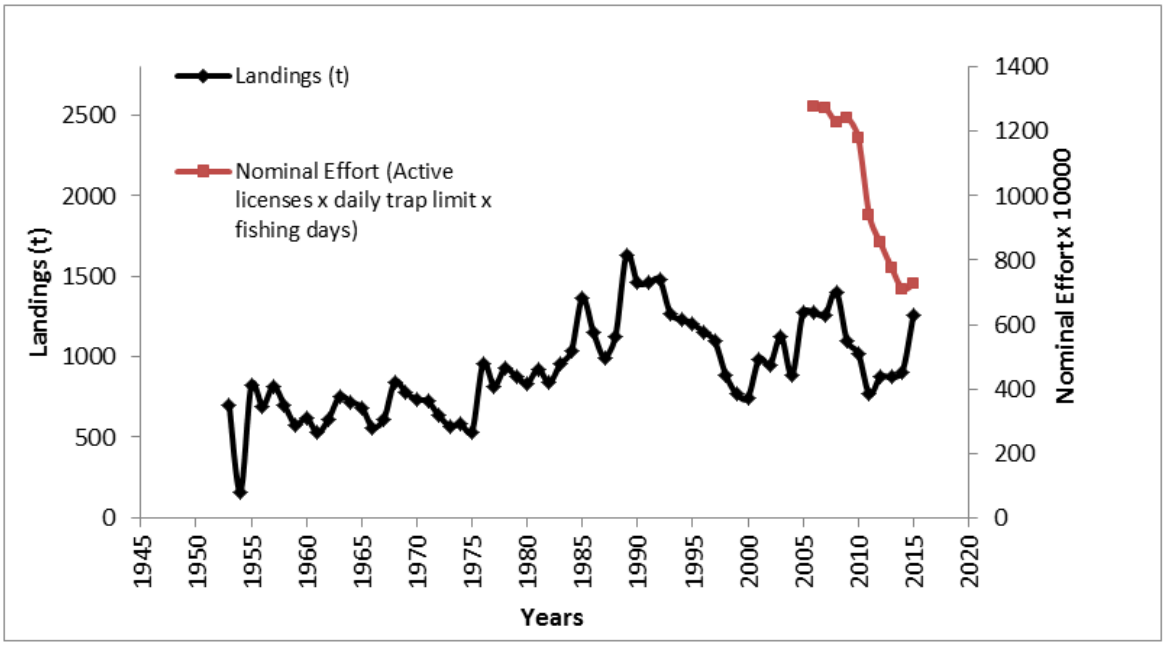

Figure 40. Trends in reported landings (t) and nominal effort (active license x daily trap limit x fishing days) in the West Coast region.

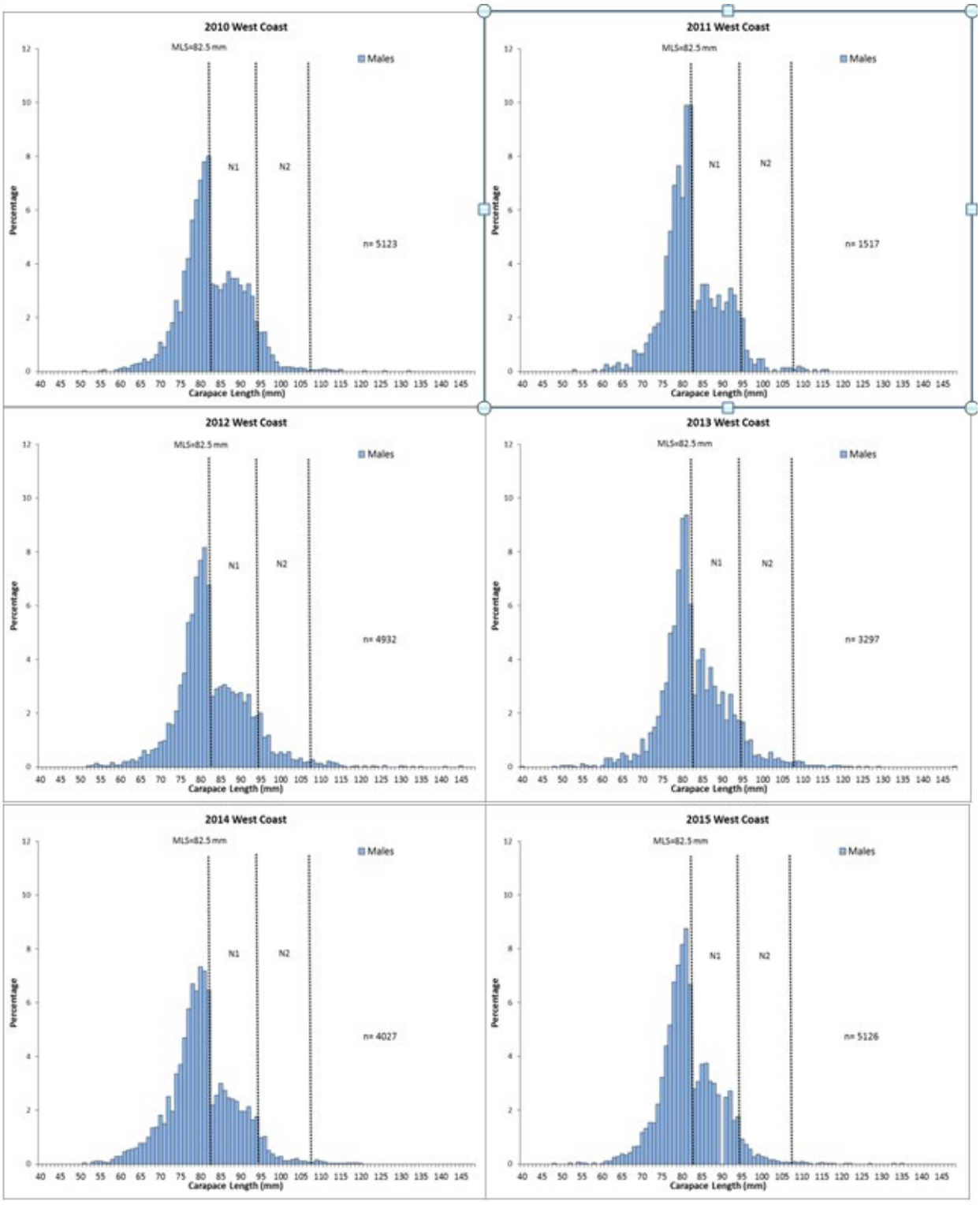

Figure 41. Size frequency distributions from 2010 to 2015 for males in the West Coast region.

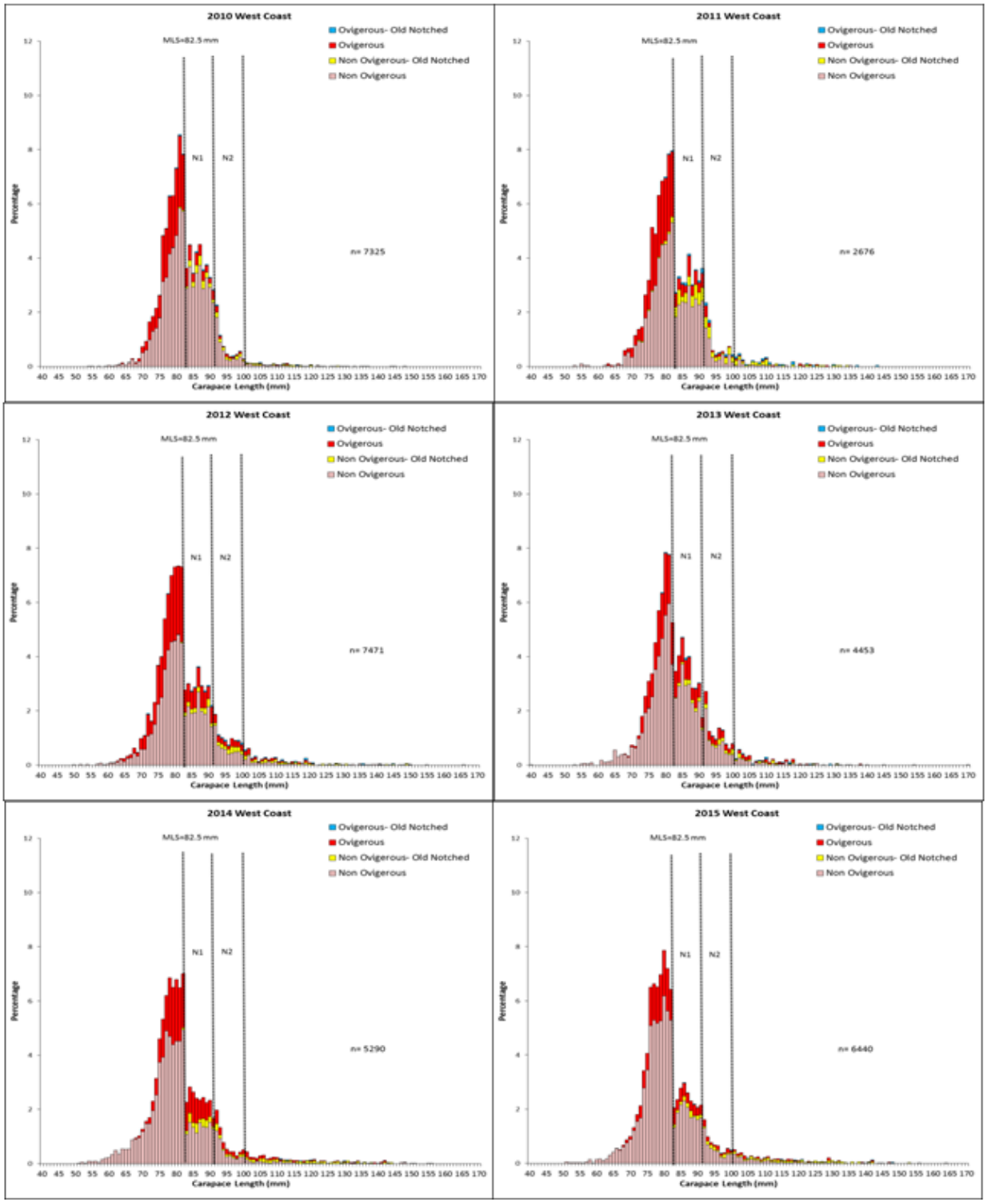

Figure 42. Size frequency distributions from 2010 to 2015 for females in the West Coast region.

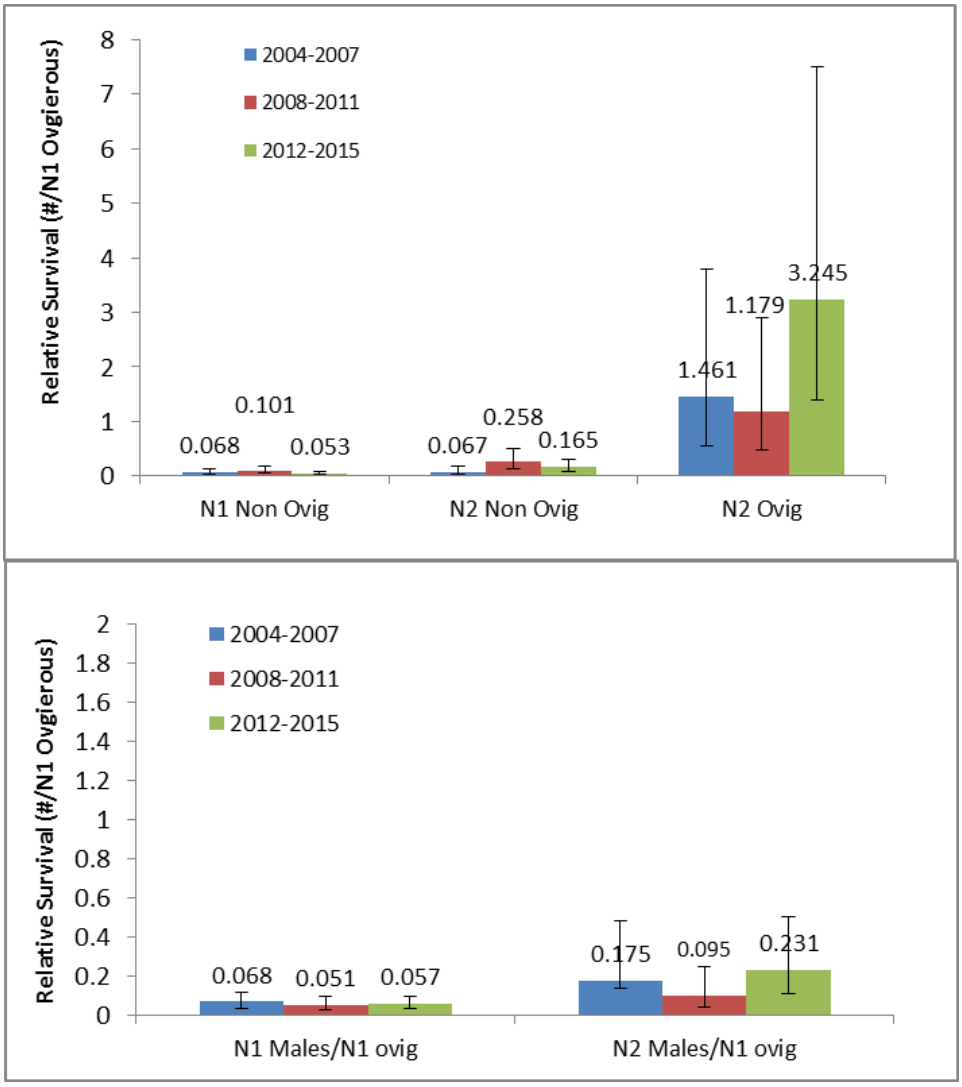

Figure 43. Relative survival fraction for female (top panel) and male (bottom panel) lobsters in the West Coast region. N1 are small legal sized lobsters (first molt class) and N2 are large lobsters (second molt class).

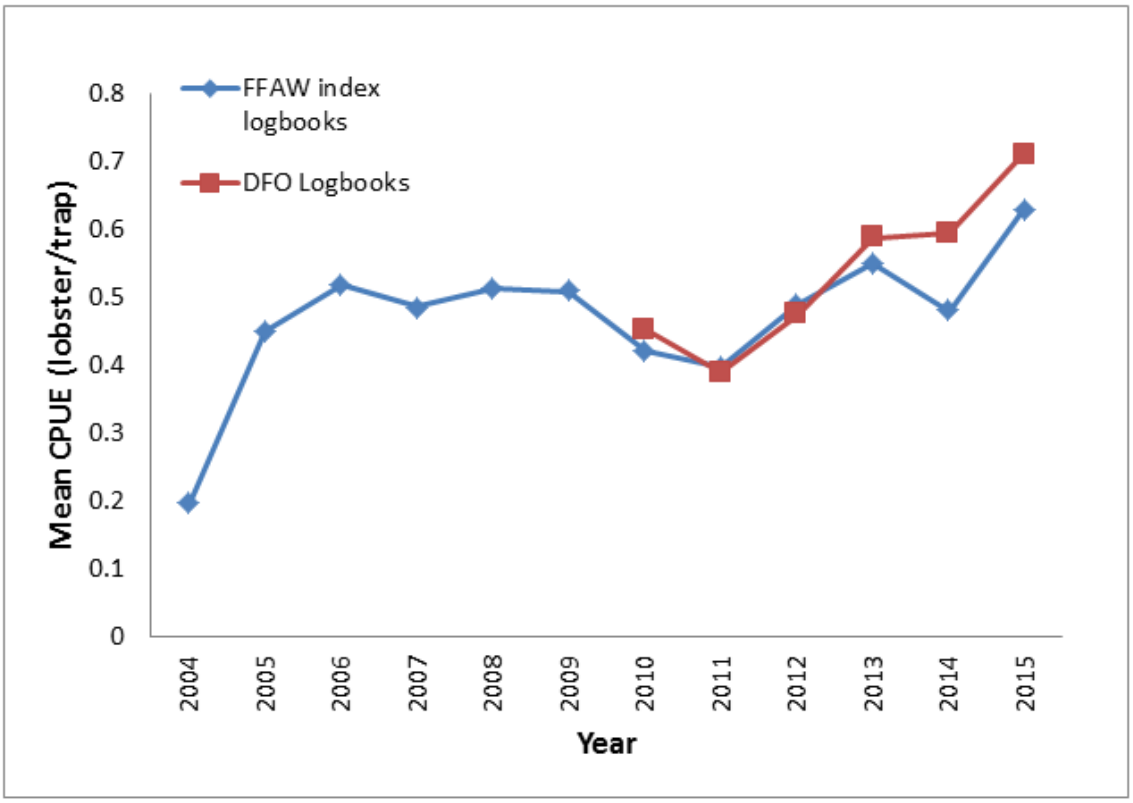

Figure 44. Mean CPUE from index fishers logbooks (2004-15) and DFO logbooks (2010-15) for the West Coast region.

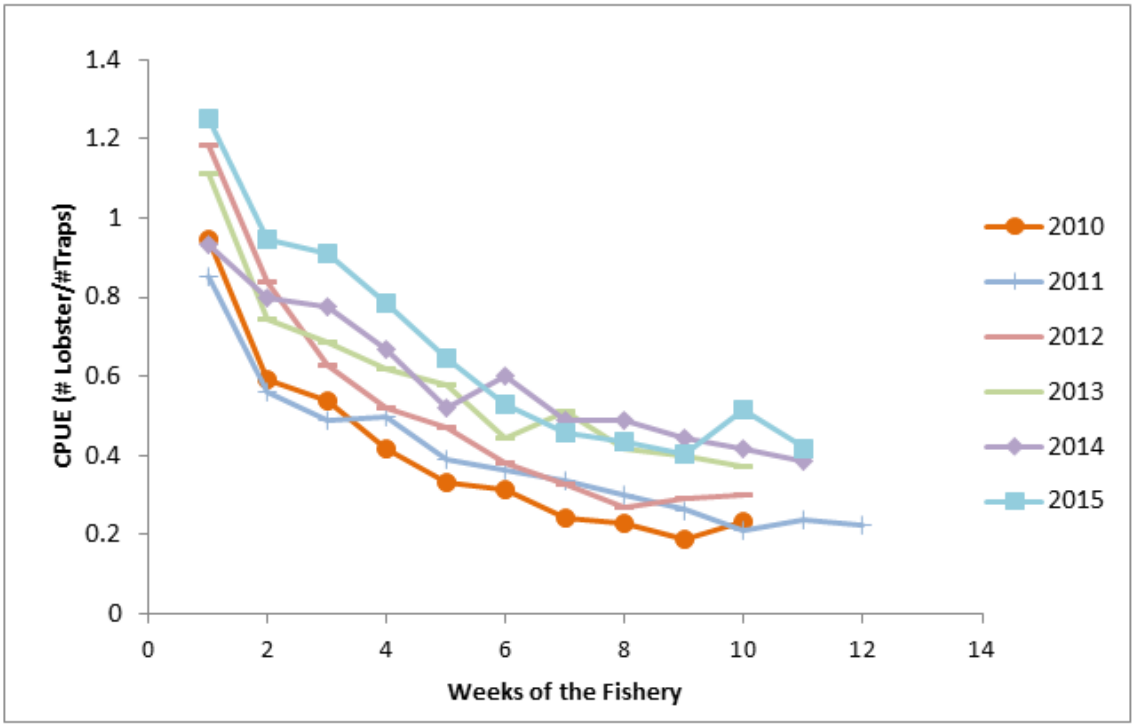

Figure 45. Weekly CPUE from DFO logbooks (2010-15) in the West Coast region.

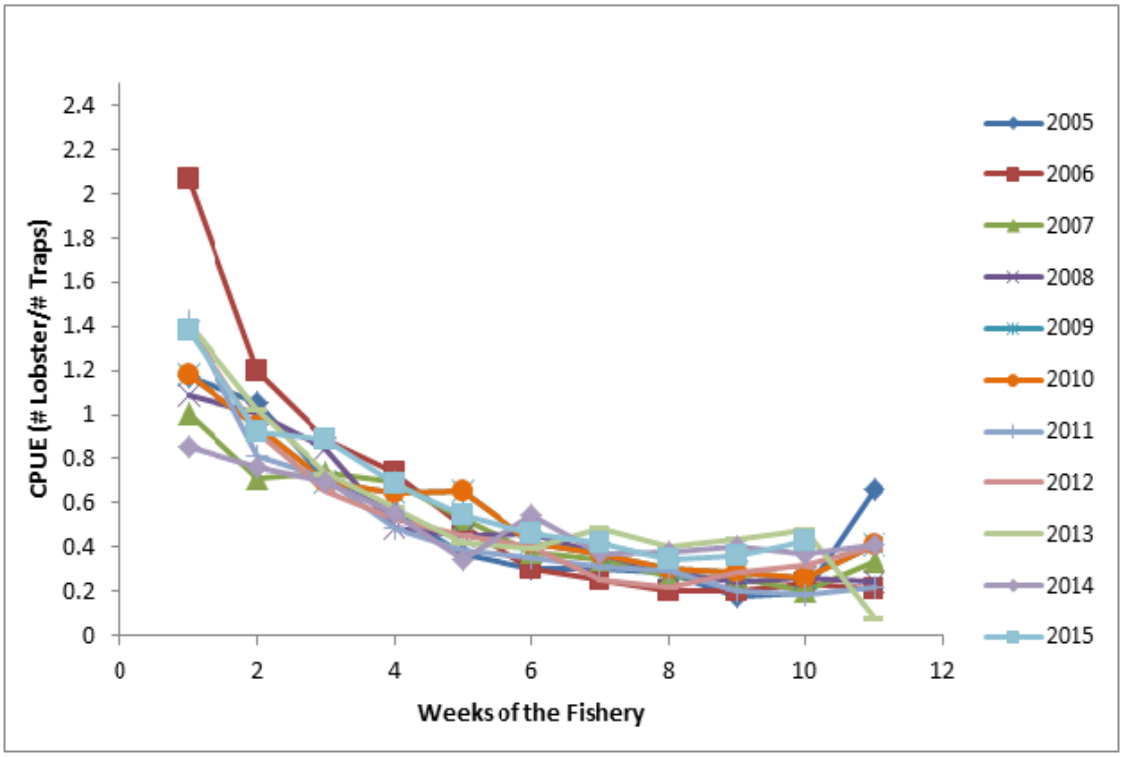

Figure 46. Wekly CPUE from index fishers logbooks (2005-15) in the West Coast region.

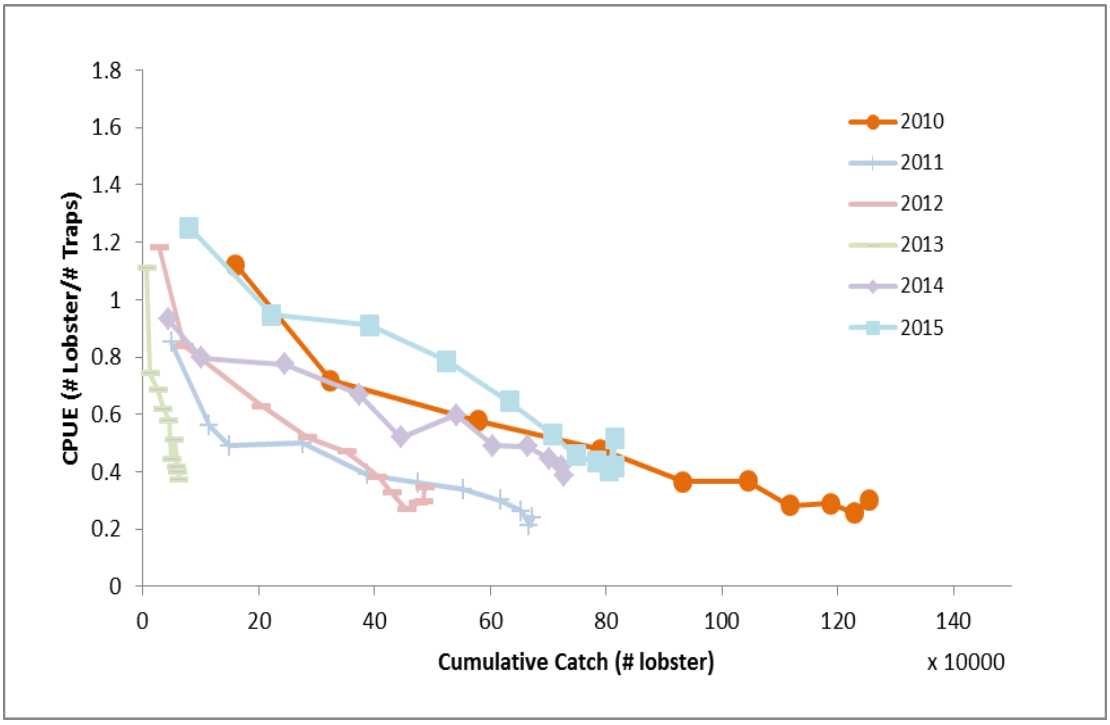

Figure 47. CPUE and cumulative catch from DFO logbooks (2010-2015) for the West Coast region.

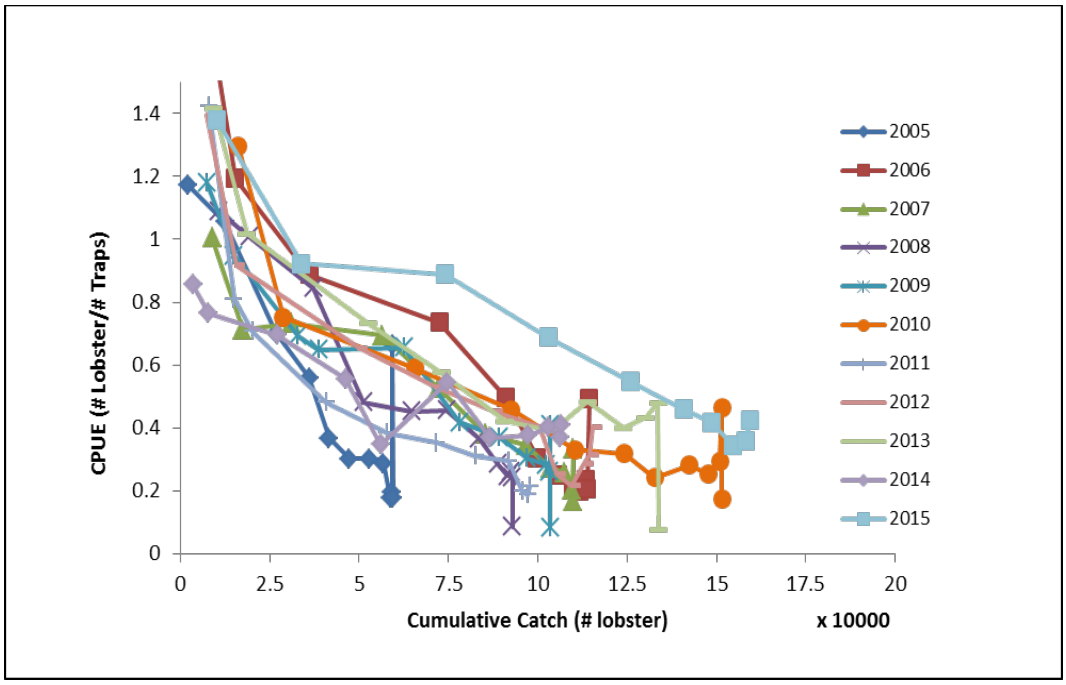

Figure 48. CPUE and cumulative catch from index fishers logbooks (2005-2015) for the West Coast region.