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Assessment of the Canadian LFA 41 Offshore Lobster (*Homarus americanus*) Fishery (NAFO Divisions 4X 5Zc)

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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 offshore fishery for American Lobster (*Homarus americanus*) in Lobster Fishing Area (LFA) 41 was assessed based on indicators from the fishery and from fishery-independent trawl surveys. A series of primary indicators were chosen, and boundary levels proposed for each. Secondary indicators that aid in interpretation of trends were also evaluated. The primary indicator boundaries were not considered equivalent to limit reference points and uppers stock references in the sense of Fisheries and Oceans Canada's (DFO) Precautionary Approach since consideration of multiple indicators is important for this stock. Instead, it is proposed that a combination of abundance and size indicator values be used to define the cautious zone. The primary indicators for abundance are based on the mean number per tow in the DFO Maritimes Region Research Vessel trawl surveys (RV surveys). These indicators have been increasing since the mid-1990s, and are at an all-time high for the 30 year time series. The lowest values are considered to correspond with a healthy and productive state. As a result, there is no "low" point from which to judge potential for recovery. Size is regarded as indicative of the exploitation rate.

Throughout the history of the LFA 41 fishery, lobsters caught have been larger than those in inshore fisheries. A relative fishing mortality rate estimate based on landings and the biomass index from the RV surveys indicates fishing mortality is low and has been declining since the mid-1990s. Primary indicators for size were based on the size of lobsters in the RV surveys and in at-sea samples of the trap catch. The current values of all but one of the eight size-based indicators are above the proposed upper boundaries and, overall, the population size structure continues to be dominated by mature sizes. Based on the current indicators of abundance and fishing pressure, the LFA 41 lobster stock is in the healthy zone and the current total allowable catch (TAC) of 720 metric tonnes (mt), which has been in place since 1985, has had no detectable negative impacts on the lobsters in LFA 41 overall. As such the TAC is considered to represent an acceptable harvest strategy at this time. In the context of the ecosystem, the fishery footprint of the LFA 41 fishery is low compared to the inshore fisheries. This is due to the combination of low fishing effort and large fishing area. The incidental catch of species other than lobsters in traps consists primarily of Jonah Crab, Cusk, Cod, Red and White Hake, and Haddock. The overall incidental catch in 2006 of 154 mt declined to an estimated 46 mt in 2012. Jonah Crab have not been actively fished and retained by the LFA 41 fishery since 2008.

Évaluation de la pêche canadienne du homard (*Homarus americanus*) du large dans la ZPH 41 (divisions 4X et 5Zc de l'OPANO)

RÉSUMÉ

La pêche hauturière du homard (*Homarus americanus*) dans la zone de pêche du homard (ZPH) 41 a été évaluée en fonction des indicateurs de la pêche et de relevés au chalut indépendants de la pêche. Une série d'indicateurs primaires ont été choisis, et des limites ont été proposées pour chacun. Des indicateurs secondaires pour faciliter l'interprétation des tendances ont aussi été évalués. Les limites des indicateurs primaires n'ont pas été considérées comme équivalant aux points de référence limites et aux points de référence supérieurs au sens de l'approche de précaution de Pêches et Océans Canada (MPO) étant donné qu'il est important de prendre en compte de nombreux indicateurs pour ce stock. Il est plutôt proposé qu'une combinaison de valeurs pour les indicateurs d'abondance et de taille soit utilisée pour définir la zone de prudence. Les indicateurs primaires de l'abondance sont fondés sur le nombre moyen par trait dans les relevés au chalut par navire scientifique de la région des Maritimes du MPO (relevés par navire scientifique). Ces indicateurs sont en augmentation depuis le milieu des années 1990, et ils sont à un niveau record pour la série chronologique de 30 ans. On considère que les valeurs les plus basses correspondent à un état sain et productif. Par conséquent, il n'y a pas de point « faible » permettant de juger le potentiel de rétablissement. La taille est considérée comme une indication du taux d'exploitation.

Tout au long de l'histoire de la pêche dans la ZPH 41, les homards capturés ont été plus gros que ceux dans les pêches côtières. Une estimation du taux de mortalité par pêche relative en fonction des débarquements et de l'indice de la biomasse tiré des relevés par navire scientifique indique que la mortalité par pêche est faible et qu'elle est à la baisse depuis le milieu des années 1990. Les principaux indicateurs de taille étaient basés sur la taille des homards dans les relevés par navire scientifique et les échantillons en mer des prises par casier. Les valeurs actuelles des huit indicateurs de taille, à l'exception d'un, se trouvent toutes au-dessus des limites supérieures proposées et, dans l'ensemble, la structure de tailles de la population continue d'être dominée par des homards matures. D'après les indicateurs actuels d'abondance et de pression de la pêche, le stock de homard dans la ZPH 41 se situe dans la zone saine, et le total autorisé des captures (TAC) de 720 tonnes métriques (tm), qui est en place depuis 1985, n'a pas eu de répercussions négatives détectables sur les homards dans la ZPH 41 de façon générale. Par conséquent, on considère que le TAC représente une stratégie de pêche acceptable à l'heure actuelle. Dans le contexte de l'écosystème, l'empreinte de la pêche dans la ZPH 41 est faible comparativement aux pêches côtières. Cela est dû à l'effet combiné du faible effort de pêche et de la grande zone de pêche. Les prises accidentelles d'espèces autres que le homard dans les casiers se composent principalement de crabes nordiques, de brosmes, de morues, de merluches rouges, de merluches blanches et d'aiglefins. Le total des prises accessoires a diminué, passant de 154 tm en 2006 à 46 tm (estimation) en 2012. Dans la ZPH 41, le crabe nordique n'a pas fait l'objet d'une pêche active avec conservation depuis 2008.

INTRODUCTION

The offshore fishery for American Lobster (*Homarus americanus*) in Lobster Fishing Area 41 (LFA 41) occurs from the 50 nautical mile line (92 km) off Nova Scotia (Figure 1 and 2) to the upper continental slope (<450 m water depth), and was established in 1972. The status of lobsters in LFA 41 was last assessed in 2009 (DFO 2009a). The fishery operates under the Integrated Fisheries Management Plan (IFMP) for LFA 41 (DFO 2014). There are 8 licences and a total allowable catch (TAC) of 720 metric tonne (mt) lobsters and 540 mt of Jonah Crab (*Cancer borealis*). Jonah Crab was also assessed in 2009 (DFO 2009b); there has been no directed fishing for Jonah Crab in LFA 41 since 2008. While LFA 41 includes parts of the Northwest Atlantic Fisheries Organization (NAFO) divisions 4Vs, 4W, 4X and 5Z, lobster fishing is authorized only in 4X and 5Zc. LFA 41 is the only lobster fishery in Canada that is managed with a TAC.

The fishery is managed by input and output controls including an 82.5 mm minimum size carapace length (CL), prohibition on landing berried or v-notched female lobsters, limited entry, and a TAC. An area encompassing all parts of Browns Bank less than 50 fathoms (91.4 m) was closed to lobster fishing in 1979, though other fishing activity still occurs in this area. This area is referred to as the Browns Bank closed area or LFA 40 (Figure 2).

Current management measures applicable to LFA 41 are summarized below; a more detailed history is found in the IFMP:

Season: Year-round quota year (January 1 to December 31)
Minimum Legal Size: 82.5 mm CL
Landing of Berried and V-Notched Females: Prohibited
Trap Limit: None
Number of Licences: 8
Lobster TAC: 720 mt
Jonah Crab TAC: 540 mt

BACKGROUND INFORMATION ON BIOLOGY

DISTRIBUTION

The American Lobster (*Homarus americanus*) is widely distributed in coastal waters from southern Labrador to Maryland, with the major fisheries concentrated in the Gulf of St. Lawrence and the Gulf of Maine (Figure 3). Though lobsters are most common in coastal waters, they are also found in deep water areas of the Gulf of Maine and along the outer edge of the continental shelf from Sable Island to off North Carolina. Lobsters are found in the offshore areas of the western Scotian Shelf and Georges Bank due to the presence of the warm slope water that keeps the slope and deep basins in the Gulf of Maine warm year-round. This warm deep water is not found on the eastern Scotian Shelf, in the Gulf of St Lawrence or off Newfoundland.

Lobster Fishing Areas are not self-sustaining biological units, but have the potential for both adult and larval exchange. Lobster concentrations are highest in coastal regions with lower concentrations associated with the offshore banks of Browns and Georges (Figure 3). Mature lobsters undertake seasonal movements with their largest concentrations in deep water (200-400 m) during the winter and moving to Browns Bank and Georges Bank in summer (Cooper and Uzmann 1971, Uzmann et al. 1977, Pezzack and Duggan 1986). The International Court of Justice (ICJ) line on Georges Bank divides the Georges Bank stock between Canada and the U.S. The 50-mile Offshore Lobster Boundary line divides both shallow and deep water areas west of Browns Bank; an area fished by both the inshore and offshore fleets.

Lobster stock structure in the Gulf of Maine is not fully understood. Current thinking holds that the Gulf of Maine lobster population can be viewed as a stock complex, suggesting that there are a number of sub-populations linked in various ways by movements of larvae and adults.

Larval exchange is possible over most of the Gulf of Maine and Georges Bank area, but recent modeling studies indicate that although larvae can be transported over large distances self-recruitment was almost always important (Xue et al. 2008, Incze et al. 2010).

Circulation models (Drinkwater et al. 2001) indicate strong retention of larvae on Georges Bank due to the strong cyclonic gyre with a summer residence time to 50 days inside the 100 m isobath. Wind and eddy events may periodically transport larvae off the Bank, but they are unlikely to strongly impact the supply of larvae to coastal Nova Scotia and other northern areas of the Gulf of Maine (Harding et al. 2005). The American assessment process treats Georges Bank as a stock unit (ASMFC 2009).

Browns Bank shows weaker retention, with potential exchange of larvae from Browns Bank to German Bank or to the Bay of Fundy. Exchange has not been observed from Browns Bank to the nearshore areas of Southwestern Nova Scotia or the South shore inside the 50 m isobath (Drinkwater et al. 2001).

In the past, it was assumed that recruitment was restricted to shallow coastal regions, but the presence of late stage IV larvae over the offshore banks and basin areas (Harding et al. 2005), small juvenile lobsters in scientific trawl surveys (i.e. DFO Maritimes Research Vessel stratified random bottom trawl survey (RV survey) and National Marine Fisheries Service (NMFS) bottom trawl survey), and in at-sea samples from trap catches, indicate the presence of small juvenile lobsters in these areas. This suggests that successful larval settlement likely occurs in the deep water basins of the Gulf of Maine and on the shallow areas of Georges Banks. The scale and importance of larval settlement in these regions is not known at this time.

Genetic studies (Kenchington et al. 2009) looking at the entire species range showed a North/South separation with a relatively homogenous population to the north (centered in the Gulf of St. Lawrence) and a more heterogeneous populations in the south (centered in the Gulf of Maine and the Mid-Atlantic Bight region). At smaller geographical scales, the analyses identified areas of low gene flow between nearest neighbours, which are likely to be shaped by ocean currents and lobster migration patterns. Areas of restricted gene flow were particularly common in the Gulf of Maine, Georges Bank and areas south of it, but the number and distribution of the subpopulations remains uncertain.

REPRODUCTIVE POTENTIAL

Lobsters mature at varying sizes depending upon local water temperatures (Aiken and Waddy 1980, Campbell and Robinson 1983, Aiken and Waddy 1986, Waddy and Aiken 1991, Comeau and Savoie 2002, Comeau 2003, Waddy and Aiken 2005), maturing at smaller sizes in regions with warm summer temperatures (Gulf of St. Lawrence, Southern New England) and at larger sizes in regions with cooler summer temperatures (Bay of Fundy). The size at which 50% of females are mature (size at onset of maturity or SOM50) in offshore areas varies from 82 mm CL on the Slope off New England, 92 mm CL for Georges Bank and Gulf of Maine (Little and Watson 2005), and approximately 97 mm CL for Northeast Georges and Browns Bank (Pezzack and Duggan 1989).

The median size of lobsters in the Canadian offshore catch is greater than the SOM50, and thus a high proportion of the females caught have had the opportunity to breed. This is in contrast to the coastal inshore fisheries of LFA 33-34 where the median size in the catch is below SOM50 (95 mm unpublished data) and only a small percentage of females have had the opportunity to breed (Pezzack et al. 2006).

After maturity, female lobsters produce eggs every second year. Based on laboratory studies using ambient inshore Bay of Fundy water temperatures, female lobsters appear able to spawn twice without an intervening molt (consecutive spawning) at a size greater than 120 mm CL (Waddy and Aiken 1986, Waddy and Aiken 1990), though this size may vary in nature (Campbell 1983, Comeau and Savoie 2001, Comeau and Savoie 2002). Consecutive spawning occurs in two forms: successive-year (spawning in two successive summers, a molt in the first and fourth years) and alternate-year (spawning in alternate summers). In both types, females often are able to fertilize the two successive broods with the sperm from a single insemination. Intermolt mating has also been observed in laboratory conditions (Waddy and Aiken 1990). Consecutive spawning enables large lobsters to spawn more frequently over the long term than their smaller counterparts. This combined with the logarithmic relationship between body size and numbers of eggs produced (Campbell and Robinson 1983, Estrella and Cadrin 1995) means that very large lobsters have a much greater relative fecundity.

Due to the uncertainty of stock structure within the Gulf of Maine the management plan and past assessments have looked at maintaining the high reproductive potential in this area by preserving its size structure dominated by mature animals. This has been done through a limited number of licences, a TAC and the closed area of Browns Bank. Prior to this assessment, the key indicator of the health of the stock was the size composition of the catch (DFO 2009a, Pezzack and Duggan 1988, Pezzack and Duggan 1995).

NATURAL MORTALITY

Natural mortality (M) has been estimated for some nearshore populations and is generally assumed to be between 10-15% for fully recruited legal sized animals. In most models (Fogarty and Idoine 1988, Gendron and Gagnon 2001, Idoine et al. 2001, Gendron 2005) M is assumed to be the same over time and for all size groups. However, general principles indicate that M will vary according to habitat, predator abundance, and lobster size. Predation rates are highly size-specific and decline as lobsters get larger.

The uncertainty of M for American Lobsters is in part due to the lack of an accurate ageing method. A constant M is usually chosen using life history criteria such as longevity, growth rate, and age at maturity (Hoenig et al. 1983, Hewitt and Hoenig 2005, Hoenig and Hewitt 2005). American Lobsters have a long life span and slow reproduction and are thus classification as "k-selected" with low natural mortality after the larval stage.

FOOD AND PREDATORS

Benthic stage lobsters are omnivorous, being mostly predators and scavenging prey items when available. Examination of juvenile and adult lobster stomach contents has found a wide variety of benthic organisms, including gastropods, bivalves (scallops, clams, and mussels), chitons, crustaceans (e.g. Rock Crab (*Cancer irroratus*), starfish and brittle stars, sea urchins), various marine worms (polychaetes), fish and occasionally plant material (Carter and Steele 1982, Elner and Campbell 1987, Gendron et al. 2001, Jones and Shulman 2008). Lobsters are also opportunistic feeding on fish eggs, discarded lobster shells and dead animals including fish, marine mammals and bait in lobster traps.

Known and suspected predators of lobsters include Cunners (*Tautogolabrus adspersus*), Sculpins, Skates, Cod (*Gadus morhua*), Spiny Dogfish (*Squalus acanthias*), Sea Ravens, Wolfish (*Anarhichas lupus*), Haddock (*Melanogrammus aeglefinus*), Hake and Crabs (Barshaw et al. 1994, Lavalli and Lawton 1996, Palma et al. 1998, Hanson and Lanteigne 2000, Nelson et al. 2003, Nelson et al. 2006, Boudreau and Worm 2010, Steneck et al. 2011).

DATA DESCRIPTION

SOURCES OF INFORMATION

- LFA 41 lobster logbooks, electronically available via the Fisheries and Oceans Canada (DFO) Maritimes Region Maritimes Fishery Information System (MARFIS)
- Landings from adjacent fisheries (LFA 34 logbooks, U.S. landings – Atlantic States Marine Fisheries Council and National Marine Fisheries Service)
- At-sea samples of commercial catch
- DFO Maritimes Region RV trawl survey (NAFO division 4X: Summer RV survey; NAFO division 5Z- Winter RV survey)
- Northeast Fisheries Science Center (NEFSC) bottom trawl survey (Spring and Fall surveys)

Logbook Landings

Catch, effort and location information is available for the LFA 41 lobster fishery since 1972 and the Jonah Crab bycatch fishery since 1995. Both fisheries became fully dockside monitored in 1996. Fishing trips in the offshore fishery have typically been several days in duration.

Offshore logbooks have changed over the history of the fishery, but they have provided the same basic information including: date, location, depth fished, effort, soak days and estimated catch. This information was provided on a daily basis in the earlier years of the lobster fishery, but is now provided on a string-by-string basis. In 2001, the logbook was modified to capture both American Lobster and Jonah Crab fishing activity on the same document. Upon landing, the catch is weighed and verified by a dockside monitor and recorded in the weigh-out section of the logbook.

Lobster data from 1981 to 2001 were accessed from the Zonal Interchange File Format (ZIFF), Oracle tables as well as the Oracle data table OFFLOG, and these were maintained by the Lobster Science group. Data from 2002 to present were accessed from the current MARFIS Oracle database.

Log data-estimated catch was prorated with the following formula:

ADJUSTED DAILY CATCH = (landed catch / total estimated catch)*estimated catch

The LFA 41 fishing season was based on calendar year up to 1985. Between 1985 and 2005, the season was from October 16 to October 15 on a year-over-year basis. In 2006, the season returned to the calendar year for seven of the eight vessels fishing. The eighth vessel continued under the October 16 to October 15 season. The remaining vessel switched to an annual fishing season in 2007. During these transitions, there was a seven month season in 1985 (January to August) and in the 1985/86 and 2004/2005 period, a 14 month season. The TAC was prorated to account for these altered season lengths. For simplicity in this report, the landings and TAC are expressed on an annual basis for all vessels from 2006 onward to reflect the majority of the fishery.

Analyses of log data were traditionally conducted by assigning catches and effort to five areas: 1) Crowell Basin; 2) Southwest (SW) Browns; 3) Georges Basin; 4) Southeast (SE) Browns; and 5) Georges Bank (Figure 4). The five areas represent the traditional lobster grounds used in past assessments (Pezzack and Duggan 1985, Pezzack and Duggan 1987, Pezzack and Duggan 1988, Pezzack and Duggan 1995, Robichaud et al. 2000, Pezzack et al. 2009). While these areas still reflect the general pattern of the fishery, changes over time have resulted in the need for more detailed mapping of effort and landings. For this assessment the above areas were redefined by 10-minute grid square groupings (Figure 5) that are slightly different from the traditional offshore areas.

Logbook Data Editing

Locations

In some cases, latitude and longitude were compiled in the ZIFF database in an alternate format (decimal degrees vs. degrees, minutes, decimal minutes). Locations were adjusted in the extracted data file to contain consistent formatting. As well, the data were mapped and obvious location errors were identified and corrected by referring to log records or by reviewing previous or post fishing trips by the vessel in question. The average duration of a fishing trip from 2010 to 2013 was between 6 and 7 days.

Effort

For certain vessels, trap hauls were not recorded consistently. By reviewing the fishing history of these vessels, it was decided to infer trap haul number from available data. This generally indicated 100 trap hauls per string.

Prorating

If no estimated catches were recorded and there was a landed weight, adjusted catches were calculated by prorating the landed weight by trap hauls.

CPUE Calculation

For the calculation of unstandardized Catch per Unit Effort (CPUE), only records with both an estimated catch and effort were used.

Landings from Adjacent Fisheries

U.S. landings by Statistical Area (Figure 6) were obtained from the Atlantic States Marine Fisheries Commission. Lobster Fishing Area 34 landings were obtained from MARFIS based on logbook records (Figure 7).

At-Sea Sampling

At-sea samples collect information from fishermen's catch during normal commercial fishing operation. The data collected includes: carapace size measured to the nearest millimetre (from the back of eye socket to the end of the carapace); sex, egg presence and stage; shell hardness; occurrence of culls and v-notches; and the number of traps, location and depth. At-sea sampling provides detailed information on the size-structure of animals in the traps (including sublegal, berried, and soft-shelled lobsters and crab).

Frequency and distribution of sampling (Figure 8 and 9) has varied over the history of the fishery, with several trips within the first year of fishing (1972-1973), periodic sampling from 1977-1983 and reduced sampling in the late-1980s and early-1990s due to reduced resources and the lack of observed changes in the size frequencies over time. Since 1995, offshore license holders have funded sampling and, in 1997, a plan to obtain one sample per grid grouping per quarter was initiated. This often was not obtained due to vessels not fishing the areas during the specified time periods or other logistical problems. Changes in the plan and its implementation have been made over time to better reach these goals.

The sampling protocol was reviewed in 2010 and adjustments made to provide more consistent coverage of the fishing activity to allow for better comparisons of the results over time. Based on the recent fishing patterns, and the historical time series of samples taken since 1972, samples were scheduled for periods of peak catches in the widest number of fishing grounds. The following is the sample plan initiated in 2011:

January – No sample
February – No sample
March – Sample 1st trip of the month
April – No sample
May – Sample 1st trip of the month
June – Sample 1st trip of the month
July – Sample 1st trip of the month
August – No sample
September – No sample
October – No sample
November – Sample 1st trip of the month
December – Sample 1st trip of the month

Prior to 2000, sampling was done by DFO or Javitech (a company that provided at-sea observer coverage), and other private contractors. Since 2000, Javitech has conducted all of the at-sea sampling in LFA 41. Part of Javitech's protocol is to estimate weights and species composition of all bycatch. This bycatch data is stored in a DFO Oracle database called the Industry Surveys Data Base (ISDB) and has been available for this fishery since 1988. As well, all length frequency data collected during Javitech sampling has been stored in the ISDB since 2008. At-sea sampling data prior to 2008 was stored in the Crustacean Research Information System (CRIS), another DFO Oracle database.

In 2008, a species at risk management initiative began to collect bycatch data from lobster fishing activities. During these sampling trips, all bycatch was evaluated. In addition, all lobsters and crabs were measured and sampled. During the species at risk sampling period, nine samples where completed in LFA 41, some of which were the regularly planned samples.

The following indicates the number of samples completed in LFA 41 for lobsters and Jonah Crab and the database in which they are stored:

Species	Dates	Number of Samples	Data Source
Lobster	1979-2008	255 (+3 in NAFO division 4W)	CRIS
Lobster	2008-2012	17	ISDB
Jonah Crab	1999-2005	24 (+17 in NAFO division 4W)	CRIS

A sample is counted as one complete fishing trip. This may then be subdivided by area fished for analysis purposes.

DFO Maritimes Region research vessel (RV) Trawl survey

The DFO Maritimes Region RV trawl survey (RV survey) has been conducted annually by DFO since 1970. It follows a stratified random design with strata defined by depth and includes both hydrographic sampling and sampling of fish and invertebrates using a bottom otter trawl (Western IIA trawl towed for approximately 30 min at 3.5 knots and 1.75 nautical miles). The calculated number per tow and kilogram (kg) per tow are adjusted to correct for variations in tow length. The survey generally occurs in early July in the Scotian Shelf and Bay of Fundy area (Summer RV survey) (Figure 10) and in February and March in the Georges Bank area (Winter RV survey) (Figure 11).

The survey was designed to provide abundance trends for groundfish at depths from about 50 m to 400 m and the survey catch rates are expected to be proportional to abundance for most species.

The stratified random sampling design allows the station locations to be spread over the entire area, provides differential sampling intensity among strata and facilitates analyses over various geographic regions corresponding to different stock or management definitions.

Beginning in 1999 during the summer survey, all crabs and lobsters were measured to the nearest millimetre (carapace width/length) and sexed. Beginning in 2007, lobsters were also measured during the winter surveys of Georges Bank. The surveys from 1999 to present have provided very useful data on a number of important benthic invertebrates (Tremblay et al. 2007).

The resulting data is stored in Oracle tables and is also available on the Maritimes Science Virtual Data Centre (VDC). Data corresponding to LFA 41 and parts of LFA 34 were extracted and summarized.

The abundance indicator from the bottom trawl survey is the mean number per tow (all sizes combined).

There were changes to the net used and the vessel conducting the survey in 1982 and 1983, along with some changes in data collection protocols. These changes may affect the biomass trends for some species and, although some earlier data is presented, all indicators are based on the post-1983 data.

Years	Vessel	Design	Trawl
1970-81	RV AT Cameron	side-trawler	Yankee 36 trawl
1982	RV Lady Hammond	stern-trawler	Western IIA trawl
1983- present	CCGS Alfred Needler	stern-trawler	Western IIA trawl

During years when the Alfred Needler was unavailable (2008), the sister ship CCGS Wilfred Templeman, was used as a replacement. In 2004 and 2007, sampling was conducted using the CCGS Teleost. No conversion factors were developed to adjust species-specific catches.

The methods and design of the RV Surveys are described in greater detail in publications (Clark et al. 2010, DFO 2011, Emberly and Clark 2012, Stone and Gross, 2012).

USA Trawl Survey

The U.S. National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) bottom trawl survey began in 1967. The fall survey is generally conducted in September and October. Lobster data used in this assessment are from the autumn survey since 1982.

The bottom trawl survey utilizes a stratified random sampling design and the study area, which extends from the Scotian Shelf to Cape Hatteras including the Gulf of Maine and Georges Bank, is stratified by depth. The stratum depth limits are <9 m, 9-18 m, >18-27 m, >27-55 m, >55-110 m, >110-185 m, and >185-365 m (Figure 12). Most strata are further subdivided into sampling units to achieve a more even sampling distribution across the area covered by the survey.

Stations are randomly selected within strata, with the number of stations in the stratum being proportional to stratum area. The total survey area is 283,137 km^2. About 320 hauls are made per survey, equivalent to one station for about every 885 km^2.

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

In 2009, a new vessel, trawl and protocol were introduced. Below are some of the changes (from Commercial Fisheries News Volume 37 Number 10 June 2010):

- The Bigelow (63.6m) replaced the Albatross (57m).
- The Bigelow is equipped with an auto trawl system that balances warp tensions throughout the duration of survey tows.
- The Bigelow uses a 400x12 four-seam bottom trawl with 550 kg, 2.2 m Poly-Ice oval trawl doors (The Albatross used a Yankee #36 bottom trawl and 450 kg euronet polyvalent trawl doors).
- Survey towing speed decreased from 3.8 knots to 3 knots.
- Previous surveys ran 30-minute tows, timed from when the winches were locked until they were re-engaged. The Bigelow tows involve 20 minutes of actual bottom time as determined by net monitoring systems.
- Changes in towing speed and tow duration have resulted in a decrease in average tow distance from 1.9 nautical miles (nm) to 1 nm.
- The number of days for the survey increased from 48 to 60. Some old sampling stations reallocated and station density increased for offshore strata “that have historically demonstrated higher densities of fish, particularly in the Mid-Atlantic and Southern New England regions”.

The catch rate changed considerably with the new trawl and protocol, and conversion factors are under development for lobsters that will allow comparison of the old and new data.

UNCERTAINTY

There are strengths and weaknesses in all data sets and this must be considered when choosing stock health indicators and reference levels. Localized or larger scale changes in ocean conditions and the ecosystem can affect distribution and concentrations of animals and efficiency of sampling gear. A limited number of samples used to represent a large area introduce additional uncertainty, although aggregation of data and tracking of longer term trends can mitigate some of these issues.

Fishery dependent data used for size related indicators are affected by changes in gear design, fishing strategy and distribution. Adjustments can be made to accommodate or contextualize some of these changes, but undocumented changes in gear selectivity and details of gear locations and fishing strategy cannot be.

To address some of these issues the data is divided into spatial areas and seasons that reflect areas and time consistently fished over the history of the fishery. Trap design and size has not been accounted for, as it was not consistently recorded.

Fishery independent trawl data used for abundance and size indicators are snapshots from a single month. The surveys are not optimized for catching lobsters. Trawl surveys sample all areas, although the gear is not designed to catch or retain the smaller sizes. The selectivity of the gear for lobsters is not known but the trawl design and vessels have remained the same over the majority of the time period. A change in the U.S, survey vessel, gear and survey protocol in 2009 has created uncertainty as there is an apparent change in the catchability of lobsters in that survey. Correction factors have been developed and will be used to adjust the values in future assessments.

PRECAUTIONARY APPROACH: CANADIAN OFFSHORE LOBSTER (LFA 41)

PRECAUTIONARY APPROACH

In 2009 DFO adopted a Precautionary Approach Policy as a component of the Sustainable Fishery Framework. The Precautionary Approach (PA) in fisheries management is about being cautious when scientific knowledge is uncertain, unreliable or inadequate, and not using the absence of adequate scientific information as a reason to postpone or fail to take action to avoid serious harm to the resource. This approach is widely accepted as an essential part of sustainable fisheries management. The PA is a decision making process with rules that identify triggers and responses during periods of changing stock health. A PA framework to guide management decisions on harvest rates under various stock status conditions are in the process of being developed for fish stocks in Canada.

The management of the LFA 41 fishery has always been considered as precautionary, with the goal of protecting the reproductive potential by maintaining a size structure dominated by mature sizes.

In Canada, the Sustainable Fisheries Framework and its policies, including the PA policy, is being implemented progressively over time according to the priorities identified through fishery planning sessions held across DFO regions. The framework will also continue to evolve as new policies and tools are created. The implementation process will use adaptive management principles, whereby experience applying the policies to fisheries management, will guide future applications.

Typically, the PA identifies reference points to define healthy, cautious and critical stock status ranges. These reference points are normally based on the productivity objectives of the fishery and include biological factors, but can also include social and economic aspects. Development of quantitative reference points requires data on the stock status and is often expressed as biomass, spawning biomass or abundance. In the case of lobsters in the DFO Maritimes Region, there are no direct estimates of biomass, so proxies were developed that will allow for the tracking of changes in stock status even though the absolute biomass estimates remains unknown.

There is recognition that a single reference point for the LFA 41 lobster fishery is inappropriate because abundance represents only one aspect of stock health; consequently a consideration f a variety of stock health indicators is more appropriate. Abundance, reproductive potential and the related population size structure, recruitment levels and exploitation rates are all important components of stock health.

In the absence of direct estimates of population abundance, a number of indicators were developed that can provide knowledge on trends in the stock and assist in determining appropriate management and harvest strategies.

The proposed PA framework for LFA 41 consists of a number of stock health indicators including primary indicators with boundaries (defined below) that will be monitored and reported on annually. These primary indicators are supplemented with a series of secondary indicators that may provide context to any observed changes in the primary indicators over time.

Primary Indicator - measure of stock health such as abundance, size structure, reproductive condition etc.

Secondary Indicators - Aspects that aid in interpretation of trends or provide information about the fishery. These could be for example abundance trends in adjacent fisheries.

Boundary - Set for each primary indicator to identify when they are considered to be outside normal variability. Individual indicators and associated boundaries do not define the cautious zone for this fishery.

SPATIAL UNITS

Separate indicators are developed for NAFO division 4X (Browns Bank and adjacent slope and basins) and NAFO division 5Z (Georges Bank) (Figure 2) based on observations of limited exchange of tagged lobsters between them (Uzmann et al. 1977, Pezzack and Duggan 1986, Pezzack et al. 1992, Pezzack et al. 19922009, ASMFC 2009) and the strong retention of larvae on Georges Bank (Harding et al. 1997, Drinkwater et al. 2001, Xue et al. 2008, Incze 2010). Additionally, in the U.S. assessments Georges Bank (5Z) is considered a stock unit.

It is also important to recognize potential interactions between areas, as well as the potential for common responses to environmental conditions. As such, the reference levels in adjacent offshore areas, inshore LFAs (34-38) and the U.S. (Georges Bank and Gulf of Maine) would also be considered as secondary indicators.

FISHERY PERFORMANCE

Fisheries performance presents a summary of the available data to provide the trends in landings, effort, overall CPUE and the seasonal and spatial pattern of the fishery. The data are useful in interpreting changes in the fishery, but are not reliable indicators of abundance as landings are limited by a TAC and the fishing strategy aims at maximizing CPUE through the movement of effort between the various grounds and tracking lobster movements.

LANDINGS

Total landings (Table 1) are limited by the TAC and therefore provide limited insight into overall abundance. Year-to-year landings are affected by lobster catchability, economics and market forces; with the decision as to when and where to fish influenced in part by lobster sizes, quality, and demand. Landings would be informative only if the fleet was consistently unable to catch the TAC.

Over the history of the fishery the quota-year has varied; being annual up to 1984, then Oct. 15-Oct .14 from 1985-2004, and then switching back to an annual period (Table 2, Figure 13a and Figure 13b). Higher TAC in 1985-1986 and 2004-2005 were due to extended seasons during transition to new quota periods. The 2004-2005 change in quota year resulted in 7 of the 8 licences having an extended season during the transition and an annual TAC (January to December) during 2006 to 2007, while one licence continued under the Oct. 16-Oct. 15 TAC during those years. The remaining licence switched to an annual quota year in 2007. For simplicity in this report, the landings and TAC are expressed on an annual basis for 2006 and 2007 to reflect the majority of the licences in the fishery. In recent years, TAC has been adjusted to account for allowed carry-over and over runs in some years.

In 2013, a multi-year management system began with a 3 year quota, Jan. 1, 2013-Dec. 31, 2016 of 2,160 mt (3x720 mt) with no more than 828 mt (720 mt + 15%) fished in a given year. The provision is only available when the resource is healthy, ceasing should there be a decrease in the TAC. The provision is to be evaluated at the end of 2015.

DISTRIBUTION OF LANDINGS

The spatial distribution of landings has varied over time with expansion and contraction of areas fished around core areas that have not changed significantly over the history of the fishery. Historically landings have been reported by the 5 assessment areas (Figures 14a and b) and

NAFO divisions 4X and 5Z (Figures 13b). Due to the small size of the fishery, a change in fishing strategy can result in a large shift in landings from one area to another. Therefore, year-to-year changes in landings within an area do not necessarily reflect changes in lobster abundance.

SEASONAL TRENDS IN LANDINGS

Monthly landings vary with area and over time, but there are persistent annual trends in landings within an area. Fishermen state that they target the seasonal movements of lobsters on and off the banks, and the timing of such movements determines their locations and landings. These seasonal movements are documented in numerous tagging studies.

Crowell Basin and SW Browns Bank have peak landings in the fall during what is thought to be the movement of animals from the bank into the deeper basins. Georges Basin is a winter to early-spring fishery. SE Browns Bank and Georges Bank landings peak in late-spring, and are thought to target the springtime movements onto the banks. Very little fishing occurs from August-September due to low catch rates and soft-shell conditions during and immediately following the moult.

Number of vessels active in the fishery has varied over the history of the fishery, but originally a share of the quota was assigned to each of eight vessels. Following introduction of the Enterprise Allocation in the mid-1980s, the number of vessels was reduced as companies matched operating cost with the TAC. The number of vessels increased again in the late 1990s with the introduction of the Jonah Crab fishery in late-1995, and some vessels began to target that species. With a decline in Jonah Crab effort in recent years, and some industry consolidation, the number of vessels declined to four in 2007. Vessel number was further reduced to two in 2010 and one in 2012 (Table 1).

The recent decrease in total trap hauls (Table 3, Figures 15, 16a and 16b) is due to a combination of factors, including the decline in the directed Jonah Crab fishery from 2001 to 2007 (when it ended), higher catch rates due to an overall increase in lobster abundance, and a change in fishing strategy to further optimize catch rates.

Information on changes in trap efficiency, fishing strategy or increased knowledge by the captains is not captured in the log books. Fishermen continually experiment with trap designs and bait to optimize their catch; over time the effectiveness of traps has increased.

CATCH PER UNIT EFFORT (CPUE)

In the past, assessments attempts were made to use Catch per Unit Effort (CPUE) as an indicator of abundance (Claytor et al. 2001; Pezzack et al. 2009), although the complexity of the LFA 41 fishery and its dynamic response to change has made the relationship between abundance and CPUE unclear. In particular, this proxy of abundance may only be informative when CPUE trends are strongly influenced at extreme low and high levels of abundance. The fleet has always been capable of moving gear between areas to maximize their CPUE and in recent years this ability has increased greatly. In addition, much of the fishing effort is targeting migratory periods as lobsters move on and off the banks and changes in CPUE can reflect the timing, speed and intensity of the movement as well as overall numbers. For these reasons no attempt was made to model or standardize the CPUE, but rather to present them as a general indication of the overall trends in the fishery (Table 4, and Figure 17a and 17b).

LANDINGS IN ADJACENT FISHERIES

Trends in adjacent fisheries can serve as an indication of pressure on the stocks exploited by both fisheries. While LFA 41 has been capped by the TAC, adjacent fisheries in LFA 34 and the U.S. are not quota limited and have shown increases over this same time period. The deep water fishery in LFA 34 began in the early 1980s, and has expanded with vessels fishing adjacent to the 50 mile offshore lobster boundary. The landings of the LFA 34 offshore areas exceeded the total for LFA 41 and during the 2010-2012 period, averaging three times more than the adjacent Gulf of Maine portion of LFA 41 (i.e. SW Browns, Crowell Basin and Georges Basin). The LFA 34 offshore and midshore areas averaged landings fourteen times the Gulf of Maine portion of LFA 41 from 2010 to 2012.

In 1978, LFA 41 landed 684 mt of lobsters, representing 21% of the combined LFA 34 and LFA 41 total of 3,331 mt landings, but in 2012 LFA 41 landings of 654 mt represented only 2.7% of the combined landings of 24,138 mt (Table 5, Figures 18 and 19). U.S. landings in the adjacent Gulf of Maine statistical areas show a similar pattern to those in LFA 34, having increased from an average of 121 mt during the 1980s to 897 mt during 2010-2012.

U.S. landings from NE Georges Bank have increased in recent years, while Canadian landings have declined slightly. During the 1990s, Canadian and U.S. landings were similar, but the U.S. portion averaged over six times that of Canada during the 2000-2009 period, and five times during 2010-2012 period (Table 5, Figure 20). U.S. landings on the southern portion of Georges Bank have increased slightly over the last 10 years.

EXPLOITATION RATE

Due to the size structure in the catch and the TAC, traditional methods used in the lobster fishery for estimating exploitation rates are not applicable. Exploitation rate for lobsters in LFA 41 has not been directly estimated, but is inferred to have been low for many years and lower now than during the early years of the fishery as landings have remained constant during a period of increasing abundance.

Exploitation of a previously unfished or lightly fished population normally results in a reduction of larger sizes and a truncation of the size frequency. The LFA 41 size structure has remained relatively stable, being dominated by mature sizes, indicating a low exploitation level similar to that estimated in the U.S. 2009 lobster assessment of Georges Bank (Fishing Mortality, F= 0.26).

Where absolute estimates of exploitation rates are not available, a relative fishing mortality (Relative F) can be estimated from the trawl survey data. Relative F is calculated from landings and the biomass index from the Summer RV survey:

Relative F=Landings/Biomass Index.

The spatial overlap of the fishery and survey needs to be evaluated to further develop this index of fishing mortality as an indicator for LFA 41 Lobster. Since the mid-1990s, the biomass index has increased (Figure 21), while the TAC has held landings to less than 720 t resulting in a low and declining Relative F.

JONAH CRAB

The offshore Jonah Crab fishery began in 1995 when a 720 mt TAC was established in LFA 41 (NAFO divisions 4X and 5Zc). The stock was assessed in 2009 (DFO 2009b, Pezzack et al. 2010). The species had previously been fished as incidental catch in the lobster fishery but with the introduction of the TAC, a few vessels began targeting crab and resulted in more widespread fishing activity as vessels fished further east, where crab concentrations were present. An experimental Jonah Crab fishery took place in NAFO division 4W between 1999 and 2002.

The fishery is managed by input and output controls including a minimum carapace width (CW) size, prohibition on landing females, limited entry and a TAC (DFO 2009b).

Crab landings rose rapidly at the start of the fishery, and the 720 mt TAC was caught or nearly caught between the 1996-1997 and 2000-2001 seasons (Figure 22). Landings then declined sharply with only 14 mt landed in 2007. During the period when overall landings were high, landings from individual areas rose and fell at different times (Figure 23). Initial landings for Georges Bank dropped in 1997-1998, while landings from areas in the Gulf of Maine increased, especially Crowell Basin in which landings remained high until 2000-2001 and then declined (Table 6). Landings in SE Browns Bank increased in 1999-2000 and were maintained until 2001-2002, when they began to decline (Table 6). The directed offshore fishery ended in 2007 and no Jonah Crab has been landed in LFA 41 since then.

Since the Jonah Crab component of the fishery has not been pursued since 2008, a detailed assessment is not undertaken here. Trends in the catch rate of Jonah Crab in the trawl surveys are presented for the offshore and inshore regions and Georges Bank (Figures 24 to 28), including maps of the Summer RV survey catch from 2000 to 2013 (Figure 29).

The data shows variation without trends for the inshore LFA 32-33 area and the Bay of Fundy (Figure 27-28). The three offshore areas remain low with no sustained trends that would indicate a recent change in the population.

The catchability of Jonah Crab by the trawl gear is unknown, but is potentially low, so there is a high degree of uncertainty in any interpretation of these data.

INDICATORS AND BOUNDARIES

The proposed PA framework consists of a number of stock health indicators for LFA 41, including primary indicators with defined boundaries that will be monitored and reported on annually. These boundaries were not considered equivalent to Limit Reference Points (LRPs) and Upper Stock Reference (USRs) given the use of multiple indicators to define stock status and the precautionary zone, rather than a single biomass indicator as is typical of DFO’s PA Policy. These primary indicators are supplemented with a series of secondary indicators that aid in interpreting trends and can provide important information about the ecosystem or the fishery that will aid in determining the type of response if the stock entered the cautious zone.

In assessing the health of the fishery, generally three key attributes are looked at: Abundance; Reproductive Potential; and Fishing Pressure or Exploitation Rates.

Many of the indicators are based on data from trawl surveys. The DFO Maritimes Region RV surveys and the U.S. trawl surveys are fishery independent, use standardized gear and procedures, and have a long time series (NAFO division 4X 1983-2013; NAFO division 5Z 1987-2013). The LFA 41 area is largely trawlable bottom and the survey covers the entire fishery and the majority of the lobster habitat, including the Lobster Closed Area on Browns Bank and the shoal waters on Georges Bank where trap fishing does not occur. The Canadian RV surveys have a shorter time series with size data (NAFO division 4X 1999-2013; NAFO division 5Z 2006-2013) while the U.S. size data exist for 1982-2012.

The trawl and the survey design were not originally designed for sampling lobsters, so strata and allocation of sets are not optimized for providing precise indices for lobsters. The survey provides a snap shot of the population during one period of the year and the distribution of sets do not in all years match with known distribution of lobsters. The Georges Bank survey (Winter RV survey) only covered depths less than 100 fathoms prior to 2010, though lobsters are found in deeper waters. In addition, the catchability of lobsters in trawls on different bottom types is not known.

For most indicators, the boundaries are set using 80% and 40% of the levels during a period of high productivity shown to be sustainable. The 80% and 40% levels are the default levels suggested in the DFO’s PA Policy when there is limited information to base stock-specific reference points. These levels are considered to represent a conservative approach. Other potential boundaries were examined including the lowest level from which there was subsequent recovery. Trawl survey catch rates were lower when the fishery began in 1972, and the LFA 41 fishery has been sustainable since. As such, a less conservative value of 50% of the initial levels for the upper boundary could be considered. However, given the low numbers of animals in the survey catches during the initial periods of the fishery, and the uncertainty associated with difference in the trawl survey in the early 1970s, it was felt that the more conservative 80% and 40% levels were appropriate in most cases.

The default historic period used to set the boundaries is 1983-1994. This period was chosen as data prior to this was limited to fishery dependent data from landings and at-sea samples, and it represents an early period in the fishery. Recruitment during this period contributed to the increase in abundance seen in subsequent years. The current high lobster abundance levels suggest that there was no fishery-imposed restriction on reproductive potential during that period and it represents a level from which it is reasonable to assume the stock could recover from in the future.

Indicators on size data from the Canadian RV surveys have a limited time series: NAFO division 4X (1999-2013) and NAFO division 5Z (2006-2013), while the U.S. surveys have size data for 1982-2012. These will be discussed under the details of the indicators.

The boundary is considered reached when the 3-year moving average drops below the boundary level. The moving average is used to reduce the impact of year-to-year variability in the values due to normal sampling variability.

PRIMARY INDICATORS

Trait	Indicator	NAFO Division	Data Source
Abundance	Level and trends in the stratified mean number of lobsters per tow from RV surveys	4X	Maritimes Region Summer RV survey 1983-2013 (Strata 477, 478, 480-84)
		5Z	Maritimes Region Winter RV survey 1987-2013 on Georges Bank (Strata 5Z1-4)
Abundance of Large size females (indication of exploitation rate)	Level and trends in the mean number per tow of females > 140 mm CL	4X	Maritimes Region Summer RV survey 1999-2013 (Strata 480-81)
		5Z	U.S. Fall RV survey for 5Z 1983-2012 (Strata 16-18, 21)
Size Structure of Population (Reproductive Potential)	Changes in median size of females in trawl surveys	4X	Maritimes Region Summer RV survey 1999-2013 (Strata 480-81)
		5Z	U.S. Fall RV survey for 5Z 1983-2012 (Strata 16-18, 21)
Size Structure of Population (Reproductive Potential)	Changes in female median size in at-sea samples of commercial catch	4X	SW Browns spring, SW Browns fall, Georges Basin sinter, Georges Basin spring, SE Browns spring
		5Z	Georges spring

Abundance Indicator - Mean Number Per Tow

Stratified mean number of lobsters per tow from the Canadian Summer RV survey (NAFO division 4X) and Winter RV survey (NAFO division 5Z) are primary indicators of abundance. The stratified mean number per tow is widely used as an index of abundance for various species.

The availability of data from the longer running U.S. trawl surveys provides a check on the quality and consistency of the Canadian data. There are some inconsistencies in DFO data from

1983 to the mid-1990s, but both the Canadian and U.S. surveys show similar trends in lobster catch rates for this period, indicating that the DFO data quality did not cause a consistent bias.

At the lower abundance levels during the 1980s, the numbers per tow were extremely low. However, this was also a period which sustained a new fishery and provided recruitment that led to the high abundance levels observed today.

The proposed lower boundary is 40% of the median survey catch during the 1983-1994 for NAFO division 4X and 1987-1994 for NAFO division 5Z (Table 7, Figures 30 and 31). The proposed upper boundary is 50% of the median survey catch of the 1995-2009. The rational for this upper boundary is based on concern of the detectability of population abundance changes at lower lobster abundance levels by the surveys and a significant change in abundance levels from those currently observed.

The U.S. NMFS Northeast Fisheries Centre RV fall and spring surveys offer additional information for the NAFO division 5Z region (Figure 32) and are monitored as secondary indicators to serve as a check on the Canadian data.

The abundance indicator cannot be consider alone and must be considered along with changes in the size indicators.

Strengths of this abundance indicator are:

- Fishery independent (trawl).
- Long time series (NAFO division 4X: 1983-2013; NAFO division 5Z: 1987-2013).
- Standardized gear and procedures.
- Survey covers the entire habit including the Lobster Closed area on Browns Bank and the shoal waters on Georges Bank where trap fishing does not occur.

Weaknesses of this indicator are:

- The trawl and the survey design were not originally intended for sampling lobsters, so strata and allocation of sets may not be optimized for lobsters.
- The distribution of sets within the strata is random, but it is known that seasonal lobster movement results in concentrations related to moulting and mating activities and the distribution of the sets can in some years give greater or lesser coverage to these areas resulting in variations in the estimates not related to abundance. Within the Browns Bank strata (480-481) there are known to be areas of consistent high numbers and other areas where lobsters are rarely caught; thus, the distribution of the sets can have an impact on the mean number per tow. Modifications in the assignment of sets or increasing the number of sets in the key Browns Bank strata would help reduce this variability.
- Variation in catchability of lobsters on different bottom types is not known.
- Only provides a snapshot of the population during a one month time period.
- Catch rate in the trawls is relatively low especially during the pre-1995 period.

Abundance Indicator - Large Lobsters

The large lobster size indicator is a proxy for exploitation rate and changes in reproductive potential, and is based on the mean number per tow of females >140 mm CL in the Summer RV Survey (NAFO division 4X: 1999-2013). The U.S. NMFS Trawl Surveys for NAFO division 5Z (1982-2012) provides a longer time series for this division; however, recent changes to the survey reduce their use in the last four years until conversion values are applied.

Exploitation of a previously unfished or lightly fished population normally results in a reduction of larger sizes and a truncation of the size frequency. This has been observed in the southern Georges Bank offshore lobster fishery from 1956-1967 (Skud 1970, Skud and Perkins 1970) and in the early years of the coastal fisheries (Rathbun 1884, Rathbun 1887, Wakeham 1909, Herrick 1911). Without a direct estimate of exploitation rates, it is proposed that changes in the abundance of larger sizes could serve as an index of the exploitation rate and an early signal of changes in abundance.

The short time series of size data from the Canadian trawl surveys in NAFO divisions 4X and 5Z does not allow for comparison to periods prior to the recent increase in abundance and covers a shorter time period than the overall abundance indicator. Caution is needed in the interpretation of this indicator due to the small sample size in the trawl surveys.

The proposed upper boundary in NAFO division 4X is 80% of the minimum value of the time series. No lower boundary is proposed (Figure 33). Due to the short time series no boundaries are proposed at this time for NAFO division 5Z based on the Canadian Winter RV survey (Figure 34).

Proposed upper and lower boundaries for NAFO division 5Z based on U.S. surveys are 80% and 40% of median value 1983-1994 (Figure 35).

Strengths of this indicator are:

- See previous indicator – Total Abundance.
- Long time series for U.S. survey in NAFO division 5Z (1982-2012).
- Survey covers the entire habitat including the Lobster Closed area on Browns Bank and the shoal waters on Georges Bank where trap fishing does not occur.
- Large sizes are sensitive to increases in exploitation rates.
- Older animals less affected by short term recruitment changes.

Weaknesses of this indicator are:

- See previous indicator - Total Abundance.
- Short time series (NAFO division 4X: 1999-2013; NAFO division 5Z: 2006-2013).
- Due to changes in the U.S. survey a conversion factor or long period to establish new baseline will be needed.

Median Female Size indicators

Median Female Size indicators based on trawl surveys and at-sea samples are considered proxies for exploitation rate and changes in reproductive potential. The offshore stock is characterized by a large median size with most of the catch being mature sizes that have reproduced at least once and a high proportion more than three times. This high proportion of mature sizes contrasts with adjacent nearshore fisheries, which are predominantly recruitment fisheries with the majority of lobsters harvested before maturity (Figure 36). Maintaining a high reproductive potential has been a goal of the LFA 41 fishery since its inception because stock relationships and recruitment sources remain uncertain. A high reproductive potential also reduces the risk of becoming a recruitment based fishery and the vulnerability to recruitment overfishing.

Size structure represents one aspect of the overall reproductive potential with abundance being the second. For this reason, the median size and abundance indicators must be looked at together when interpreting stock status. It is not always possible to distinguish the cause of the changes in median size, as it is influenced by changes in large size and recruitment of smaller sizes. Other primary and secondary indicators need to be looked at along with it.

The proposed lower boundary is the size of 50% maturity (historical estimate is 95 mm CL). At sizes below this, the reproductive capacity would be reduced to a level not seen in this fishery, though common in inshore fisheries and it is thought to represent a zone of potential high uncertainty. The proposed upper level is the midpoint between the long term medians and the size of 50% maturity. Setting the upper boundary at the midpoint between the historic size and the size of 50% maturity still provides a buffer, as even at this size it would be larger than that in any other major lobster fisheries.

Median Size based on RV Survey Data

Changes in the median size of females can be tracked using the RV Survey for NAFO division 4X (1999-2013; Strata 480-481) and U.S. trawl survey for NAFO division 5Z (1983-2013). Due to changes in the U.S. trawl survey protocol and trawl design in 2009, the initial indicator tracks trends up to 2008 and recalibration will be required for data after 2009.

Unlike sea samples, the lobster sizes in the fishery independent survey are not restricted by the limitations of the traps (i.e. escape vent for small lobsters and entry restrictions for very large sizes) and the surveys cover a wider area of the shelf and banks giving a more complete picture of the sizes present. Sizes are known to vary over the strata surveyed and location of sets could influence the overall median size. The Canadian RV surveys have a short time series when size data is available.

The proposed lower boundary is the size of 50% maturity (historic estimate is 95 mm CL). The proposed upper boundary is the midpoint between the median size for the reference period (NAFO division 4X: 1999-2012; NAFO division 5Z: 1983-1994) and the lower boundary size (95 mm CL) (Figures 37 and 38).

Strengths of this indicator are:

- See previous indicator - Total Abundance.
- Long time series in the U.S. NMFS survey.
- Covers the entire habitat including the Lobster Closed area on Browns Bank and the shoal waters on Georges Bank where trap fishing does not occur.

Weaknesses of the indicator are:

- See previous indicator - Total Abundance.
- Short time series for the NAFO division 4X Summer RV survey.
- Sizes are known to vary over the strata surveyed and location of sets could influence the overall median size.
- Size structure represents one aspect of the overall reproductive potential with abundance being the second. For this reason the median size and abundance indicators must be looked at together when interpreting the results.
- It is not always possible to distinguish the cause of the changes in median size as it is influenced by changes in large size and recruitment of smaller sizes. Other primary and secondary indicators need to be looked at along with it.

Median Size Based on At-Sea Samples

Size differences on the different fishing grounds have been present since the start of the fishery, with large sizes on the outer shelf areas of the Scotian Shelf and Georges Bank and smaller sizes in the Crowell Basin and SW Browns Bank areas. The at-sea samples allow monitoring of these site specific differences. The time periods and locations were selected based on their importance to the fishery and availability of a time series of data.

Area	Season
SW Browns Bank	Spring (May-July) & Fall (Nov.-Jan.)
Georges Basin	Winter (Feb-April) & Spring (May-July)
SE Browns Bank	Spring (May-July)
Georges Bank	Spring (May-July)

The lower boundary is set at 95 mm CL, the estimate of SOM50. The upper boundary is the midpoint between the median size for the period of sampling (1977-2012) and the lower boundary size (95 mm CL) (Figure 39).

Unlike other indicators a 3-year moving average cannot be applied due to gaps in the data. For the future, changes to the sampling protocol will result in more consistent sampling that should allow for a moving average to be applied in the future.

Strengths of the size indicators based on at-sea samples are:

- Long time series in most areas.
- Large sample sizes.
- Site and season specific sizes.
- Reflect what the fishery is catching.

Weaknesses:

- See Median Size based on RV survey data.
- Multiple indicators required as the median size has historically varied between fishing grounds.
- Traps are size selective towards commercial sized lobsters.
- Sizes influenced by changes in gear and fishing strategies which for the most part are not documented.
- Historically inconsistent sampling levels and timing resulting in gaps in the years.
- Changing fishing strategy and emphasis on areas may result in years with either no samples or very small samples.

SECONDARY INDICATORS

It is recognized that secondary indicators can be helpful to interpret trends and change the perception of stock status, provide important information about the ecosystem or the fishery, and aid in determining the type of response if the stock is in the cautious zone. Secondary indicators also include potential primary indicators that are under development or require a longer time series before meaningful boundaries can be applied.

Trait	Indicator	NAFO Division	Data Source
Abundance	Proportion of trawl survey sets with lobsters	4X	Maritimes Region Summer RV Trawl Survey 1983-2013 (Strata 477, 478, 480-84)
		5Z	Maritimes Region Winter RV Survey 1987-2013 Georges Bank (Strata 5Z1-4)
Structure of Population (Reproductive Potential)	Sex Ratio	4X	Maritimes Region Summer RV Trawl Survey 1999-2013 (Strata 480-81), and at sea samples (1977-2012)
		5Z	USA Fall RV Trawl Survey for 5Z. 1983-2012 (Strata 16-18, 21),and at sea samples (1977-2012)
Recruitment	Recruitment	4X	Maritimes Region Summer RV Trawl Survey 1999-2013 (Strata 480-81)
		5Z	USA Fall RV Trawl Survey for 5Z 1983-2012 (Strata 16-18, 21)

Proportion of trawl survey sets with lobsters

Changes in the proportion of sets with lobsters (non-null sets) can be an indicator of changes in abundance and distribution.

The indicator is based on presence/absence of lobsters in RV survey data in core strata of NAFO division 4X (Strata 477, 478 and 480-483) and NAFO division 5Z (Strata 5Z 1-4). These data would be used to determine if the changes in abundance (primary indicator) are a result of change in distribution or a change in the abundance at a few locations (Figure 40).

At low abundance, fewer sets will contain lobsters. If increasing abundance is due to increases in a few sets or areas, the numbers will increase but the proportion of sets with lobster may not. However, if abundance increases over a wider areas or distribution changes due to expansion of habitat than a greater portion of sets will contain lobsters.

Sex Ratio

The significance of various levels of the sex ratio is not clear, in part because there is no information of what a natural sex ratio would be in an unfished population. Males are able to mate with a large number of females each year and approximately 50% of the mature females are available (33% at sizes greater than 130 mm CL) to mate each year. Thus, the present skewed distribution is expected to have little impact on breeding success as long as the wide range of sizes is maintained.

The sampling methods can also affect the sex ratios as observed lobsters are migratory and at times of the year sexes may occupy different areas and have different activity levels. Trawl surveys cover wider areas and are less influenced by activity levels and thus provide a better sample of the population but seasonal depth and bottom type differences could still introduce bias. Distributional and activity differences will affect ratios in the trap based at-sea samples and fishermen generally avoid areas with high numbers of egg bearing females which could further bias the results.

Both the trawl and at-sea data from Georges Bank show a trend towards higher proportion of the catch being female at sizes >95 mm CL.

The sex ratio of sublegal (<82.5 mm CL) and newly recruited lobsters (82.5-94 mm CL) are close to 1:1 (Female:Male) (Figure 41). At maturity, the fishery gives greater protection to females through berried female and v-notch protection (Saila and Flowers 1965).

The sex ratio as measured in the Canadian Summer RV survey show a moderate bias to females in the mature sizes (>95mm CL) and lobsters >140 mm CL but with a declining trend in recent years (Figure 41).

The sex ratio as measured in the U.S. trawl survey on Georges Bank show a trend towards higher proportion of the catch being female at sizes >95 mm CL.

Sex ratios in the at-sea samples (Figure 42) are more variable with much higher ratios in some years. The variability may be due to the passive nature of the sampling tool, the trap, and seasonal variations in lobster behaviour and distribution.

Recruitment

Recruitment is difficult to detect in the offshore areas as the sizes are dominated by large mature sizes.

The number per tow of sublegal (<82.5 mm CL) and newly recruited females (82.5-94 mm CL), as an indicator of recruitment, suggests increasing recruitment levels in NAFO division 4X (Figure 43), matching trends seen in the adjacent areas of LFA 33-38. In NAFO division 5Z there are no long-term trends noted in the longer time series of the U.S. NMFS trawl survey (Figure 44).

ECOSYSTEM CONSIDERATIONS

FISHERY FOOTPRINT

The percentage of the area of LFA 41 contacted by lobster traps was estimated from the effort (annual number of trap hauls) for the last five years (2008-2012), together with the area of an average lobster trap used in the LFA 41 fishery (4 fee-by-2 feet or an area = 0.76 m^2). These estimates do not account for: 1) any movement of the traps over the bottom either due to storms or while setting or hauling; 2) any bottom contact by trawl lines; and 3) repeat contact with the bottom. The analysis provides estimates for the average bottom contact over the main fished areas.

The estimates for LFA 41 (Table 8, Figure 45) indicate a very low percentage of the bottom is contacted by traps, with an overall estimate for LFA 41 in 2012 of 0.0005%, with estimates for individual subareas all less than 0.006%. The SW portion of Browns Bank (the smallest subarea) had the highest estimate. The overall values have declined in the last few years with the decline in number of trap hauls. The risk to bottom habitat from trap contact in the LFA 41 fishery is thought to be low.

The percentage of bottom contacted by lobster traps in LFA 41 as a whole is less than one-hundredth that of LFA 34. Although the area of LFA 41 is somewhat greater than LFA 34 (32,619 km^2 compared to 20,346 km^2), the large difference in the estimates for area contacted by lobster traps for LFAs 34 and LFA 41 is the result of the much lower number of trap hauls in LFA 41 (198,900 in 2012) compared to LFA 34 (approximately 21 million in 2011-12).

PREDATION

The increase in lobster abundance in the Gulf of Maine has been hypothesized to be a release from predation by groundfish (Boudreau and Worm 2010, Steneck et al. 2011). The release from predation explanation is plausible in the Gulf of Maine given the sharp decline in abundance of some key groundfish, but the data to support it are correlative in nature and changing environmental conditions may also have contributed to increased lobster abundance.

Quantitative data on the predation impact of fish on lobsters in LFA 41 are not available. The DFO Maritimes Region Science Branch has done stomach content analyses for a portion of the fish captured in the Canadian RV surveys. Bundy et al. (2011), describes food habit data collected during the spring and autumn surveys in the U.S., and in the Summer RV survey in Canada. Lobsters have only rarely been observed in the stomachs. The consumed lobsters are identifiable for up to several days post consumption, depending on predator species, water temperature, size and stage of molt. For the Canadian Summer RV surveys from 1999-2009, lobsters were found in low numbers in the stomachs of the following fish: Haddock, Longhorn Sculpin, Cod, White Hake (*Urophysis tenuis*), Dogfish, Red Hake (*Urophysis chuss)*, Atlantic Wolffish and Barndoor Skate (*Dipturus laevis*) (Table 9).

To examine trends in potential lobster predators, biomass trends of fish species from the summer trawl survey were examined. The fish species selected were a combination of those in Table 9 together with other potential predators (e.g. Sea Raven and Cusk). Data were obtained on the trends in these species in the Canadian Summer RV survey strata 477-484. These strata were selected because they correspond to where offshore lobsters are fished or where they migrate to. All data were obtained from DFO's Virtual Data Centre (VDC).

The biomass trends in the Summer RV surveys of these species are either trending downwards or slightly above long-term means (Table 10). Those at low levels are Atlantic Cod, Cusk (*Brosme brosme*) and Atlantic Wolffish. Those at or above long-term means are Haddock, Longhorn Sculpin, Sea Raven and Spiny Dogfish. The predatory impact of fish is size-related and this is presumably important in the offshore where the average size of lobsters is greater than in inshore areas. Most lobsters in the offshore are vulnerable only to the largest fish predators. As such, the average size of fish needs to be considered in evaluating predation impact. It would be expected that species such as sculpins and Sea Ravens could only consume smaller juvenile lobsters.

Given the current biomass levels of the selected potential lobster predators, there is no expectation of a near-term increase in the natural mortality of lobsters due to these species.

INCIDENTAL CATCH

Incidental catch in the traps are designated as "by-catch" while those not landed are designated as "discards" or "non-retained bycatch". Licence conditions require that all species other than lobster, male Jonah Crab and male Rock Crab must be returned to the water immediately.

Incidental species that occur most frequently in the LFA 41 lobster fishery include Jonah Crab, Cusk, Cod, Red and White Hake, and Haddock.

Licence conditions require that lobsters under the minimum legal size (82.5mm CL), berried females (egg bearing) and v-notched females must be returned to the water. These rules are in place to protect the reproductive potential of the stock. Lobsters greater than 6 lbs. can be retained, although an industry-adopted policy is in place to return them to the water. Returning these large individuals provides significant additional protection to the reproductive potential. In addition, culls (missing claw), soft shell lobsters (pre and post moult) or injured or deformed lobsters may also be returned to the water.

Licence conditions also require that all female and undersized Jonah Crabs be returned to the water as part of the conservation measures to protect the reproductive potential of this species.

Survival of the non-retained crustaceans has not been studied for lobster trap fisheries and is unknown, although return rates from lobster tagging studies and knowledge of species biology suggest that it is high for most invertebrates. Work in various crab fisheries (Grant 2003, Tallack 2007) indicate high survival if air exposure and handling is minimized. On the LFA 41 vessels, traps are processed immediately on recovery minimizing any air exposure. Higher mortality would be expected for soft-shell lobsters and the fishery actively avoids fishing times or areas when these are present. Fish species with a swim bladder likely have a lower survival rate.

In LFA 41, at-sea observers are deployed to monitor and record fishing activities and record the location of the fishing activity and all associated catch information, including both retained and discarded incidental catch. At-sea observers record estimates of all species caught during fishery operations. Length measurements are taken of selected species including lobsters. The length measurements are not used in the determination of weights of the incidental catch, but lobster length and sex are used in estimation of the various types of lobster discards.

At-sea monitoring information is recorded in ISDB, which is maintained by the DFO Maritimes Region. The weight of incidental catch and non-retained incidental catch can be estimated from information collected by at-sea observers and the fishery log book. A ratio estimator method (Gavaris et al. 2010) was used to estimate incidental catch and non-retained incidental catch. This method involves an estimate of the ratio of the weight of incidental catch to the estimated weight of retained lobsters from the at-sea observer. The ratio is applied to the lobster landings for the trip as recorded in the MARFIS database to give the estimated incidental catch for the areas fished during the trip. This estimate is then expanded by season and area and summed to give an estimate of the total incidental catch in NAFO divisions 4X and 5Z for the season.

> RETAINED INCIDENTAL CATCH = lobster landings * (observer estimated retained incidental catch/observer estimated kept lobster)

> NON-RETAINED INCIDENTAL CATCHS = lobster landings * (observer estimated non-retained incidental catch/observer estimated kept lobster)

During a trip, a vessel can cover a large area and several assessment areas, with variable depths and with location varying from trip-to-trip in response to lobster movements and catch rates. Due to sampling and fishing logistics the number, timing and location of samples within a quarter varied from year-to-year. In some years, areas were not fished or fished but not sampled.

The variability in sample timing and level, and the low and variable nature of the incidental catch, makes year-to-year comparisons impossible at this time. A more representative picture can be obtained by pooling data over several years, with the ratio applied to the landings to give an estimate of the incidental catch for each year. In this report, the most recent four years (2009-2012) of observer data were combined by area and quarter. Data for the 2006-2008 period is also presented based on a pooling of the data for those years.

The discard rate of non-legal lobsters (e.g. undersize and berried females) can be estimated using the same ratio method as applied for the incidental catch.

> NON-RETAINED LOBSTER CATCHS = lobster landings * (observer estimated non-retained lobster catch/observer estimated kept lobster)

Observers did not always divide the non-retained lobsters into sub categories, so the lobster size data is used to determine the ratio of shorts, berried and greater than 6 lbs. in size in the catch. The level of v-notch females is small and not consistently recorded so it is not included. Similarly, the levels of cull and soft shell are not recorded, although they are thought to be small.

The overall incidental catch is low, though periodically higher catch rates of some species do occur in individual trips. Estimates of 2012 non-lobster incidental catch were 46 t. The overall incidental catch has declined since 2006 when it was 154 mt (Figures 46 and 47). The total incidental catch in 2012 represented 7% of the total lobster landings and only 3% when the Jonah Crab is not included. Previous analysis for 2002-2006 (Gavaris et al. 2010) produced similar results. The ending of the directed Jonah Crab fishery and concentration on areas of highest lobster CPUE are thought to have contributed to the reduced incidental catch.

The incidental catch of all species declined with the exception of hake, Sea Ravens and Haddock (which showed no change). Jonah Crab represents the largest incidental catch in 2012 at 26 t. No Atlantic Wolffish or Monkfish were observed in the recent years.

Table 11 shows estimated incidental catch of the species or species groups observed in the LFA 41 lobster fishery 2006 and 2012. It also describes the retained and returned portion of the Jonah Crab catch.

With regard to non-retained lobster catch, approximately 14% of the lobsters caught are returned to the sea. By comparison the average in the inshore lobster fisheries (LFA 27-34) is 44% by weight (range by LFA 20-56%). Based on tagging programs, post-release survival is known to be high. In 2012, sublegal sizes account for 20% of the returns (NAFO division 4X: 24%; NAFO division 5Z: 11%), lobsters greater than 6 lbs. 20% (NAFO division 4X: 20%; NAFO division 5Z: 20%) and berried females 60% (NAFO division 4X: 56%; NAFO division 5Z: 69%. This is down from the estimates for the previous period (Figures 48 and 49).

The non-retained lobsters in LFA 41 are predominantly larger berried females or lobsters larger than 6 lbs. (Figures 50, 51 and 52), while the non-retained portion of the inshore fisheries are predominantly undersized lobsters (less than approximately 1 lb.) or smaller berried females. Shifts in the proportion of the sublegal, jumbo and berried females may also be related to changes in the areas and times fished.

All measures that return lobsters to the water contribute to maintaining the high reproductive potential in this stock. Given the high and multiple return rates observed during lobster tagging studies it can be assumed that the returned berried females will hatch their eggs and that the large and cull lobsters will continue to reproduce with the potential to produce numerous broods with large numbers of eggs.

TRAFFIC LIGHT DISPLAY

A traffic light approach (Caddy 1999, Caddy 2004) was adopted to summarize the primary indicators. This approach offers a way of presenting multiple indicators related to stock health (Figure 53). In this display, red is below the lower boundary level, yellow is between the upper and lower boundary and green is above the upper boundary. As of December 2013, each of the four abundance indicators has been above the upper boundary and all but one of the eight size indicators is above the boundary. As such LFA 41 is considered to be in the healthy zone.

CONCLUSIONS

The Canadian offshore lobster fishery in LFA 41 was assessed based on indicators from the fishery and from fishery-independent trawl surveys. A series of primary indicators (Tables 7 and 12) were chosen and boundary levels proposed for each. Secondary indicators that aid in interpretation of trends were also evaluated.

The primary indicator boundaries were not considered equivalent to Limit Reference Points (LRP) and Upper Stock References (USR) in the sense of DFO’s Precautionary Approach since consideration of multiple indicators is important for this stock. Instead, it is proposed that a combination of abundance and size indicator values be used to define the cautious zone.

The primary indicators for abundance are based on the mean number per tow from the DFO Maritimes Region RV trawl surveys. These indicators have been increasing since the mid-1990s, and are at an all-time high for the 30 year time series. The lowest values are considered to correspond with a healthy and productive state. As a result, there is no “low” point from which to judge potential for recovery.

Size is regarded as indicative of the exploitation rate. Throughout the history of the LFA 41 fishery lobsters caught have been larger than those in inshore fisheries. A relative fishing mortality rate estimate based on landings and the biomass index from the RV survey indicates fishing mortality is low and has been declining since the mid-1990s.

Primary indicators for size were based on the size of lobsters in the RV surveys and in at-sea samples of the trap catch. The current values of all but one of the eight size based indicators are above the proposed upper boundaries and overall the population size structure continues to be dominated by mature sizes.

The median size indicators have variations with some declines evident. Interpretation of this is not straightforward, as the trawl and trap sizes are influenced by increased recruitment, and the trap sizes are influenced by changes in gear and fishing strategy, both of which have occurred over the history of the fishery. Gear changed significantly with the introduction of new designs and wire traps from the early-1980s to the 1990s, and trap design changed further after 2000. Fishing strategy has also changed over time with more emphasis on smaller sizes, as seen in the industry-adopted restrictions on landing lobsters greater than 6 lbs. The cessation in targeting Jonah Crab since 2008, as well as the reduction to one fishing vessel, has also influenced fishing locations and timing which can influence at-sea sample sizes.

Based on the current indicators of abundance and fishing pressure, the LFA 41 lobster stock is in the healthy zone. The current TAC of 720 mt (in place since 1985) has had no detectable negative impacts on the lobster in LFA 41 overall. As such, the TAC is considered to represent an acceptable harvest strategy at this time.

Secondary indicators that aid in interpretation of trends were also evaluated. The proportion of trawl sets with lobsters indicated that the increased abundance is broad-based and not restricted to a few large tows each survey. This increase was also noted in the Bay of Fundy, and the overall increase in all DFO Maritimes Region LFAs (Tremblay et al. 2013).

The Jonah Crab fishery has not been pursued by the LFA 41 fishery since 2008, but catch data is being collected as part of the Summer RV Survey data for strata within NAFO divisions 4X and 5Z.

The increase in lobster abundance in the Gulf of Maine has been hypothesized to be a release from predation by groundfish. The biomass trends in the Summer RV surveys of potential predators are either trending downwards or slightly above long-term means. Given the current biomass levels of the selected potential lobster predators, there is no expectation of a near-term increase in the natural mortality of lobsters due to these species.

The footprint of the LFA fishery is low compared to inshore lobster fisheries, given the low fishing effort and large fishing area. The incidental catch of species other than lobsters in LFA 41 lobster traps consists primarily of Jonah Crab, Cusk, Cod, Red Hake, White Hake and Haddock. The overall incidental catch of 154 mt in 2006 declined to an estimated 46 mt in 2012. Jonah Crab have not been actively fished and retained by the LFA 41 fishery since 2008.

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TABLES

Table 1. LFA 41 lobster landings in metric tonnes (mt) from 1981 to 2008 by subarea and fishing season, including total allowable catch (TAC) and vessel number. The TAC from 1976-1985 of 408 mt is applied to NAFO division 4X only. The 1985-present TAC of 720 mt is applied to the entire fishery. Fishing season is defined as the period for catching the TAC, which has varied over time (Jan. 1-Dec. 31 for 1981-1985; Aug. 1, 1985 to Oct. 15, 1986; Oct. 16-Oct. 15 for 1986-87-2003-04; Oct. 16-Oct. 15 for 1986-87-2003-04; Oct. 16, 2004 to Dec. 31, 2005 [7 of 8 licences with 1 licence retaining Oct. 16-Oct. 15]; and Jan. 1-Dec 31 for 2006-2008 [7 of 8 licences with 1 licence retaining Oct. 16-Oct. 15 year until 2007]). A dash (-) indicates 'no data'.

Season	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W	Missing or Incorrect Location	Total	TAC	Adjusted TAC	Vessel
1981	-	122	14	245	191	-	-	572	408 (4X)	408 (4X)	8
1982	31	112	8	152	166	-	-	469	408 (4X)	408 (4X)	8
1983	65	140	4	114	154	-	-	477	408 (4X)	408 (4X)	8
1984	50	94	28	127	140	-	-	439	408 (4X)	408 (4X)	7
1985/86	91	181	245	198	136	-	-	851	720	888	8
1986/87	85	132	176	145	179	-	-	717	720	720	8
1987/88	93	143	133	99	110	-	-	578	720	720	7
1988/89	81	120	32	57	114	-	-	404	720	720	6
1989/90	94	188	55	100	94	-	-	531	720	720	6
1990/91	92	242	164	101	115	-	-	714	720	720	5
1991/92	82	209	128	72	118	-	-	609	720	720	5
1992/93	102	157	88	68	129	-	-	544	720	720	5
1993/94	115	180	94	163	150	-	-	702	720	720	7
1994/95	143	209	83	169	113	-	-	717	720	720	6
1995-96	61	96	114	133	60	0.1	-	464	720	720	7
1996-97	89	150	104	196	134	-	-	673	720	720	7
1997-98	82	167	87	147	137	-	-	620	720	720	8
1998-99	80	135	92	130	152	-	-	589	720	720	8
1999-00	119	211	104	141	145	9.4	-	730	720	720	9
2000-01	139	252	163	84	79	-	-	717	720	720	8
2001-02	125	291	140	86	83	0.5	-	726	720	720	9
2002-03	166	286	95	103	67	-	-	718	720	720	8
2003-04	101	284	122	133	76	-	-	717	720	720	8
2004-05	72	390	177	224	150	-	-	1013	720	1008	7
2006	21	294	170	190	106	-	-	780	720	720	6
2007	12	224	149	175	132	-	-	691	720	720	4
2008	11	218	115	223	123	-	2	692	720	756	4
2009	29	198	83	102	125	-	4	541	720	784	4
2010	36	315	199	152	162	-	7	869	720	828	2
2011	28	217	241	95	166	-	6	752	720	679	2
2012	7	160	234	95	153	-	5	654	720	646	1

Table 2. LFA 41 lobster landings from 1971 to 2008 in metric tonnes (mt) by NAFO division and fishing season, including total allowable catch (TAC). The fishing season is defined as the period for catching the TAC, which has varied over time. NA indicates 'not applicable'.

Season	4X	5Z	Total	TAC	4X TAC
1971	8	92	100	NA	NA
1972	180	154	334	NA	NA
1973	317	176	493	NA	NA
1974	281	135	416	NA	NA
1975	372	173	545	NA	NA
1976	496	182	678	NA	NA
1977	358	277	635	NA	408
1978	381	303	684	NA	408
1979	373	236	609	NA	408
1980	357	192	549	NA	408
1981	382	190	572	NA	408
1982	303	166	469	NA	408
1983	323	154	477	NA	408
1984	299	140	439	NA	408
1985/86	715	136	851	888	NA
1986/87	538	179	717	720	NA
1987/88	468	110	578	720	NA
1988/89	290	114	404	720	NA
1989/90	437	94	531	720	NA
1990/91	599	115	714	720	NA
1991/92	491	118	609	720	NA
1992/93	415	129	544	720	NA
1993/94	552	150	702	720	NA
1994/95	604	113	717	720	NA
1995/96	404	60	464	720	NA
1996/97	539	134	673	720	NA
1997/98	483	137	620	720	NA
1998/99	437	152	589	720	NA
1999/00	575	145	720	720	NA
2000/01	638	79	717	720	NA
2001/02	642	83	725	720	NA
2002/03	650	67	717	720	NA
2003/04	640	76	716	720	NA
2004/05	863	150	1013	1008	NA
2006	675	106	780	720	NA
2007	560	132	691	720	NA
2008	568	123	692	756	NA
2009	414	125	541	784	NA
2010	706	162	869	828	NA
2011	584	166	752	679	NA
2012	501	153	654	646	NA

Table 3. LFA 41 lobster trap hauls 1995/1996-2012 by assessment area and fishing season.

Season	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	Total
1995/96	30950	75250	46100	106342	54050	312692
1996/97	54650	81470	52225	134150	101445	423940
1997/98	88787	81472	64063	119623	62200	416145
1998/99	143965	115939	92415	162858	80665	595842
1999/00	158945	84484	54787	195916	95640	589772
2000/01	121828	89777	54846	79544	55228	401223
2001/02	73258	99170	54820	125582	54912	407742
2002/03	74097	81773	38394	78850	35810	308924
2003/04	48730	89605	36450	80650	26300	281735
2004/05	43845	173022	69615	102120	55900	444502
2006	8070	95334	76092	79210	37180	295886
2007	5930	103500	58792	76370	43370	287962
2008	4657	93071	50380	106285	46650	301043
2009	11400	81470	44000	67950	57110	261930
2010	11510	101218	87620	73230	66444	340022
2011	5819	66402	82525	36629	53189	244564
2012	1834	57883	67767	30179	41237	198900

Table 4. Overall uncorrected Catch per Unit Effort (kg/Trap Haul) 1995/1996-2012 by assessment area and fishing season.

Season	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank
1995/96	3.6	2.6	3.0	1.6	2.0
1996/97	1.6	1.8	2.0	1.5	1.3
1997/98	0.9	2.1	1.4	1.2	2.2
1998/99	0.6	1.2	1.0	0.8	1.9
1999/00	0.8	2.5	1.9	0.7	1.5
2000/01	1.1	2.8	3.0	1.1	1.4
2001/02	1.7	2.9	2.6	0.7	1.5
2002/03	2.2	3.5	2.5	1.3	1.9
2003/04	2.1	3.2	3.3	1.7	2.9
2004/05	1.7	2.3	2.5	2.2	2.7
2006	2.6	3.1	2.2	2.4	2.9
2007	2.0	2.2	2.5	2.3	3.0
2008	2.3	2.4	2.3	2.1	2.6
2009	2.5	2.4	1.9	1.5	2.2
2010	3.1	3.1	2.3	2.1	2.4
2011	4.8	3.3	2.9	2.6	3.1
2012	3.9	2.8	3.4	3.1	3.7

Table 5. Annual lobster landings (metric tonnes) from Northeast Georges Bank (NAFO division 5Zc) and the Gulf of Maine (SW Browns, Georges Basin, and Crowell Basin) portions of LFA 41 and in adjacent inshore lobster fisheries: LFA 34 offshore (Grid Groups 5-6); and Midshore (Grid Group 4) and USA offshore fisheries on NE Georges Bank (Stat area 561-562); Central Gulf of Maine (Stat area 464-465, 515); and Southern Georges Bank (Stat area 522, 525). Maps of LFA 41 assessment areas, LFA 34 Grid groups, and USA Stat Areas are presented in Figures 5, 6, and 7. A dash (-) indicates 'no data'.

Season	NE Georges Bank LFA 41	GOM LFA 41 SW Browns, Georges/ Crowell Basin	LFA 34 Grid Group 5-6	LFA 34 Grid Group 4	NE Georges Stat Area 561-562 (USA)	Central GOM Stat Area 464-465, 515 (USA)	South Georges Stat Area 522, 525 (USA)
1981	190	136	-	-	220	95	517
1982	166	150	-	-	111	98	693
1983	154	210	-	-	161	179	983
1984	140	173	-	-	142	252	663
1985	114	456	-	-	292	228	504
1986	161	477	-	-	222	172	334
1987	145	351	-	-	298	35	274
1988	140	289	-	-	275	16	352
1989	84	307	-	-	318	15	212
1990	85	373	-	-	31	321	424
1991	129	435	-	-	66	416	486
1992	130	382	-	-	177	23	463
1993	164	393	-	-	120	222	506
1994	171	433	-	-	242	250	368
1995	121	387	-	-	163	386	324
1996	66	423	-	-	202	353	337
1997	168	326	-	-	197	308	397
1998	128	282	-	-	242	282	399
1999	168	412	243	1250	251	251	537
2000	111	532	372	1784	152	379	499
2001	79	573	574	2759	483	401	399
2002	78	569	745	2846	425	412	458
2003	68	477	1109	3144	573	550	552
2004	75	410	879	2692	720	530	502
2005	143	489	930	2794	1062	476	627
2006	106	484	958	3648	949	625	595
2007	132	384	634	2909	642	402	322
2008	123	344	823	3335	638	451	509
2009	125	311	860	3899	665	661	550
2010	162	549	1220	4978	767	814	818
2011	166	486	1311	5449	879	882	684
2012	153	401	1651	5280	836	996	713
Mean (81-89)	144	283	-	-	277	121	503
Mean (90-99)	133	385	-	-	169	281	424
Mean (00-09)	104	457	788	2981	626	476	521
Mean (10-12)	160	479	1394	5236	827	897	738

Table 6. LFA 41 Jonah Crab landings in metric tonnes (mt) from 1995/1996 to 2012 by assessment area and fishing season.

Season	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W	Total
1995-96	8	18	0	74	196	5	300
1996-97	165	128	46	125	224	0	688
1997-98	301	67	101	148	81	0	697
1998-99	315	158	80	104	49	0	705
1999-00	241	88	19	233	114	69	765
2000-01	300	78	13	223	116	19	750
2001-02	157	90	8	233	107	19	614
2002-03	80	43	23	95	71	0	312
2003-04	56	15	5	74	21	0	171
2004-05*	37	33	6	29	14	0	119
2006	0	2	1	21	0	0	25
2007	0	5	1	9	0	0	14
2008	0	0.1	0.2	3	0	0	3
2009	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0

Table 7. Summary of the primary indicators with data source, reference period and proposed Upper and Lower Boundaries. NA indicates 'not applicable'.

Trait	Indicator	NAFO Area	Data Source	Reference Period	Boundary Level	Upper Boundary	Lower Boundary
Abundance (all size and sex)	Level and trends in the stratified mean # of lobsters per tow from RV trawl surveys	4X	Maritime Region Summer RV survey 1983-2013 (Strata 477, 478, 480-84)	Upper Boundary 1995-2009	**Upper Boundary** # of lobsters / tow is 50% of the median value of the reference period.	1.48	NA
				Lower Boundary 1983-1994	**Lower Boundary** # of lobsters / tow is 40% of the median value of the reference period.	NA	0.16
		5Z	Maritime Region Winter RV survey 1987-2013 Georges Bank (Strata 5Z1-4)	Upper Boundary 1995-2009	**Upper Boundary** # of lobsters / tow is 50% of the median value of the reference period.	0.35	NA
				Lower Boundary 1987-1994	**Lower Boundary** # of lobsters / tow is 40% of the median value of the reference period.	NA	0.07
Abundance of large size females (indication of exploitation rate)	Level and trends in the mean # / tow of females > 140 mm CL	4X	Maritime Region Summer RV survey 1999-2013 (Strata 480-81).	1999-2009 (no data prior to 1999)	**Upper Boundary** # of lobsters / tow is 80% of the minimum value of the reference period.	0.27/tow	NA
					Lower Boundary No level is set.	NA	NA
		5Z	NMFS Northeast Fisheries Center Fall RV Trawl survey for 5Z. 1983-2012 (Strata 16-18, 21)	1983-1994	**Upper Boundary** # of lobsters / tow is 80% of the median value of the reference period.	0.12/tow	NA
					Lower Boundary # of lobsters / tow is 40% of the median value of the reference period.	NA	0.06/tow
Size Structure of Population (Reproductive Potential)	Changes in the median size of females in trawl surveys	4X	Maritime Region Summer RV survey 1999-2013 (Strata 480-81).	1999-2012 (no data prior to 1999)	**Upper Boundary** is when the median size reaches the halfway point between the median size between the historic reference period and the size of 50% maturity (present estimate is 95mmCL).	106 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm
		5Z	NMFS Northeast Fisheries Center Fall RV Trawl Survey for 5Z. 1983-2012 (Strata 16-18, 21)	1983-1994	**Upper Boundary** is when the median size reaches the halfway point between the median size between the historic reference period and the size of 50% maturity (present estimate is 95mmCL).	97 mm	NA
					Lower Boundary is when the	NA	95 mm

Trait	Indicator	NAFO Area	Data Source	Reference Period	Boundary Level	Upper Boundary	Lower Boundary
					median size reaches the size of 50% maturity (present estimate is 95mmCL).		
Size Structure of Population (Reproductive Potential)	Changes in the median size in at-sea samples of commercial catch	4X	At-Sea Samples SW Browns Spring	1977-2012	**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	101 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm
			At-Sea Samples SW Browns Fall		**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	99.3 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm
			At-Sea Samples Georges Basin Winter		**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	102.3 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm
			At-Sea Samples Georges Basin Spring		**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	102 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is	NA	95 mm

Trait	Indicator	NAFO Area	Data Source	Reference Period	Boundary Level	Upper Boundary	Lower Boundary
					95mmCL).		
			At-Sea Samples SE Browns Spring		**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	106.5 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm
		5Z	At-Sea Samples Georges Spring		**Upper Boundary** is when the median size reaches the halfway point between the average long term median the size of 50% maturity (present estimate is 95mmCL).	108 mm	NA
					Lower Boundary is when the median size reaches the size of 50% maturity (present estimate is 95mmCL).	NA	95 mm

Table 8. Estimates of area contacted by lobster traps in subareas of LFA 41 and in all of LFA 41. The area of each subarea and for all subareas is in brackets.

Season	Crowell ($5368\ km^2$)	SW Browns ($1343\ km^2$)	Georges Basin ($5831\ km^2$)	SE Browns ($11280\ km^2$)	Georges Bank ($8797\ km^2$)	All ($32619\ km^2$)
2008	0.00007%	0.00525%	0.00065%	0.00071%	0.00040%	0.00070%
2009	0.00016%	0.00459%	0.00057%	0.00046%	0.00049%	0.00061%
2010	0.00016%	0.00571%	0.00114%	0.00049%	0.00057%	0.00079%
2011	0.00008%	0.00374%	0.00107%	0.00025%	0.00046%	0.00057%
2012	0.00003%	0.00326%	0.00088%	0.00020%	0.00036%	0.00046%

Table 9. Potential lobster predators for NAFO division 4X as observed by stomach content analysis during the Canadian Summer RV survey 1999-2009. Table exhibits the number of stomachs examined, number of stomachs with identified lobster parts, and percentage of stomachs containing lobster parts (A. Cook, unpublished data). The mean carapace length (CL) for the consumed lobsters was 44 mm with a range of 1-84 mm.

Predators	No. of stomachs examined	No. of stomachs with Lobster	Percentage
Haddock	16553	8	0.05%
Longhorn Sculpin	576	3	0.52%
Cod	6760	2	0.03%
White Hake	1913	2	0.10%
Dogfish	1198	2	0.17%
Red Hake	718	1	0.14%
Atlantic Wolffish	162	1	0.62%
Barndoor Skate	117	1	0.85%

Table 10. Biomass in metric tonnes (mt) of potential predators of lobsters, showing the means for stratified annual totals (1970-2009) and the estimates for recent years (2010-2013). Data are from the Canadian Summer RV survey (strata 477-484). Values for 2004 and 2007 (Teleost) are included.

Predators	Long-term mean 1970-2009	Recent mean 2010-2013	Recent mean as % of long-term mean
Atlantic (Striped) Wolffish	842	170	20%
Cod	6054	1348	22%
Cusk	2200	154	7%
Haddock	23084	21449	93%
Longhorn Sculpin	369	458	124%
Sea Raven	209	317	151%
Spiny Dogfish	40477	63218	156%
White Hake	11312	4425	39%

Table 11. Estimated incidental catch in metric tonnes (mt) of the species or species groups observed in the LFA 41 lobster fishery in 2006 and 2012. Table also shows the returned and retained portion of the Jonah Crab catch.

Species or Species Groups	2006	2012
Jonah Crab Returned	88	26
Retained	30	0
Rock Crab	5.3	0.05
Cusk	26.6	8.6
Atlantic Cod	7.9	4.6
Hake species	4.1	4.8
Haddock	1.1	1.2
Pollock	0.07	0.02
Redfish species	0.40	0.17
Rosefish (black belly)	0.26	0.11
Sea Raven	0.09	0.31
Sea Robin	0.03	0.003
Sculpin species	0.05	0.05
Atlantic Wolffish	0.07	0.04
Total	164	46
Total (without Jonah Crab)	46	20

FIGURES

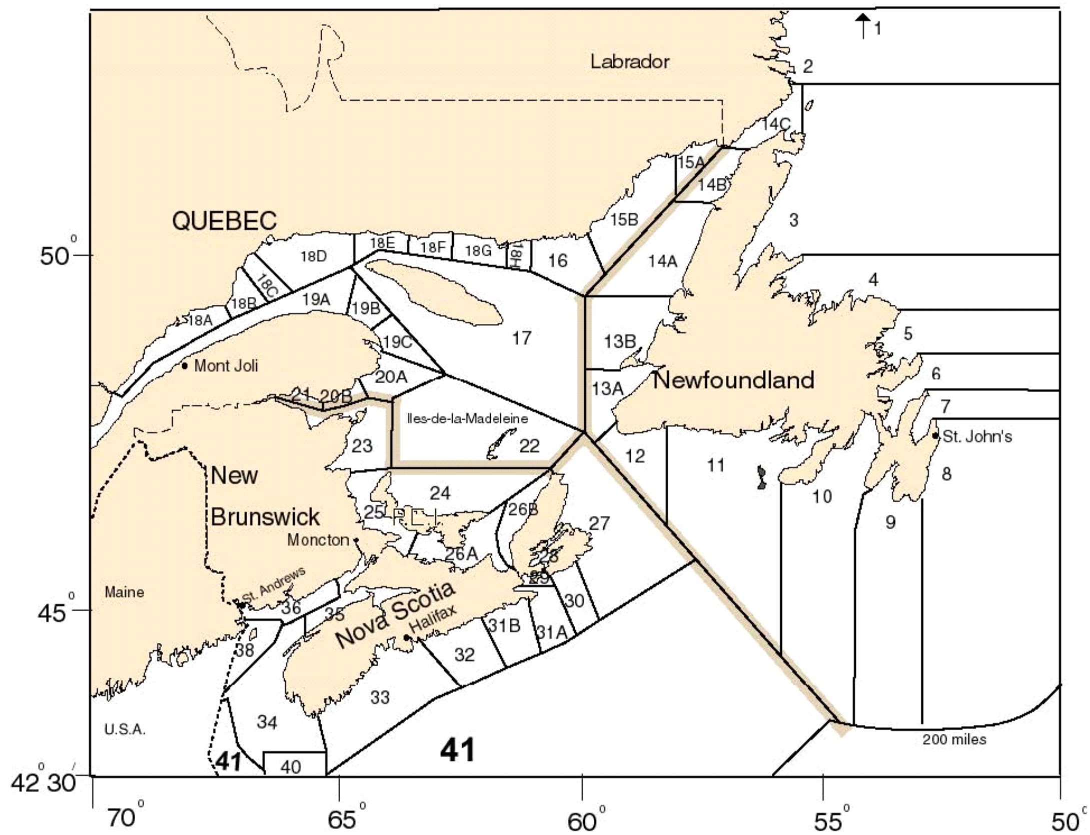

Figure 1. Map showing Canadian Lobster Fishing Areas (LFAs).

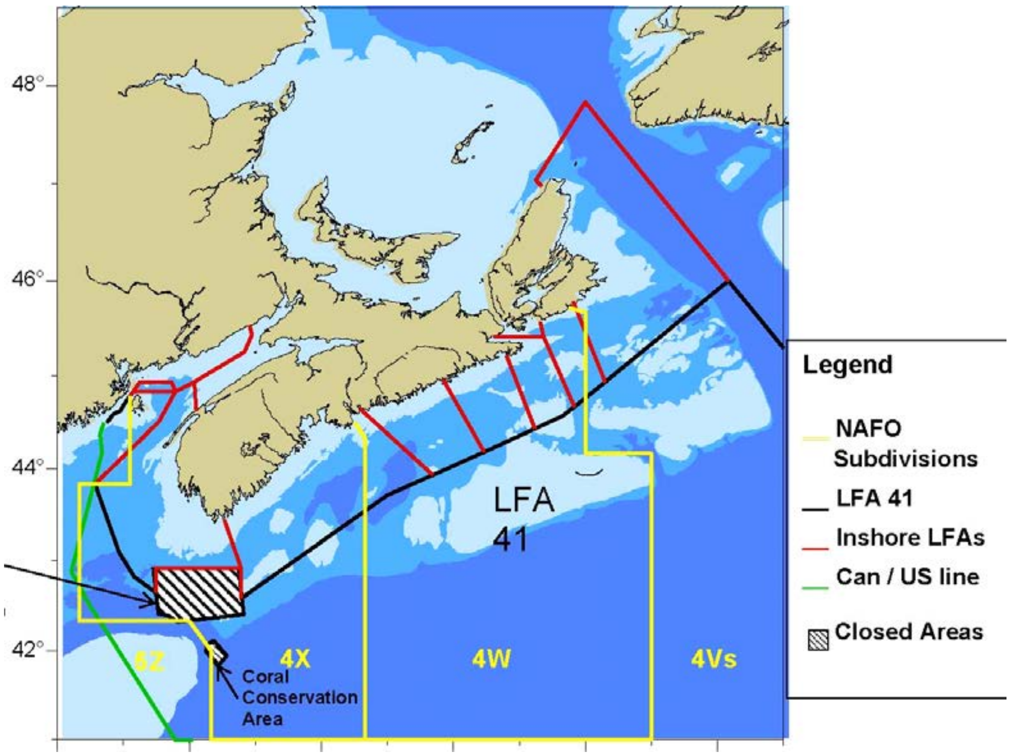

Figure 2. Map showing North Atlantic Fisheries Organization (NAFO) divisions 4Vs, 4W, 4X and 5Zc; LFA 41 and LFA 40 (Browns Bank closed area); and the Northeast Channel Coral Conservation Area.

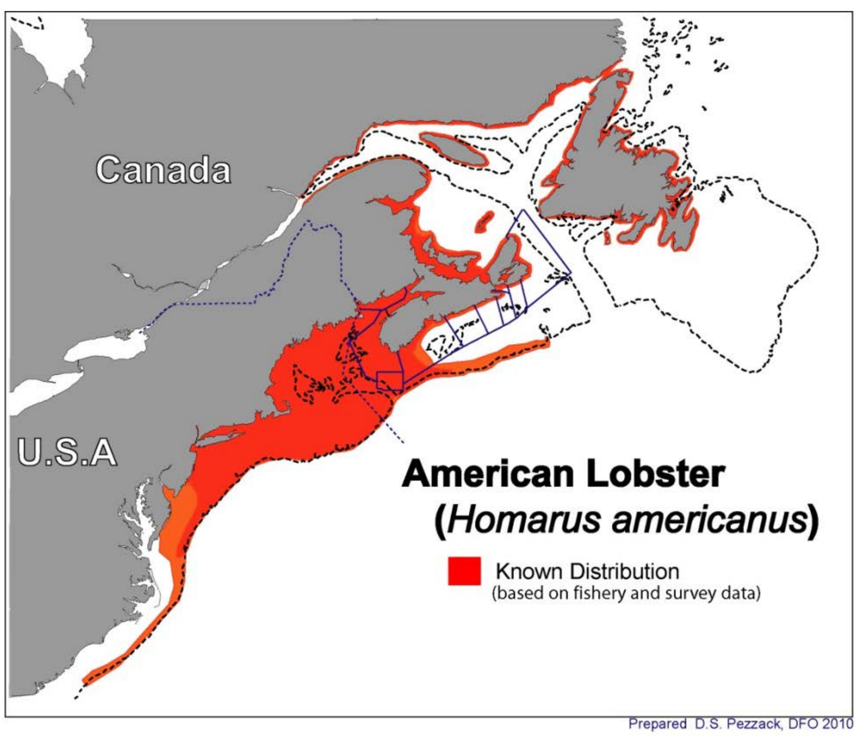

Figure 3. Map showing the range of the American Lobster (Homarus americanus) based on Canadian and U.S. fishery data and DFO and NMFS Northeast Fisheries Center bottom trawl survey data.

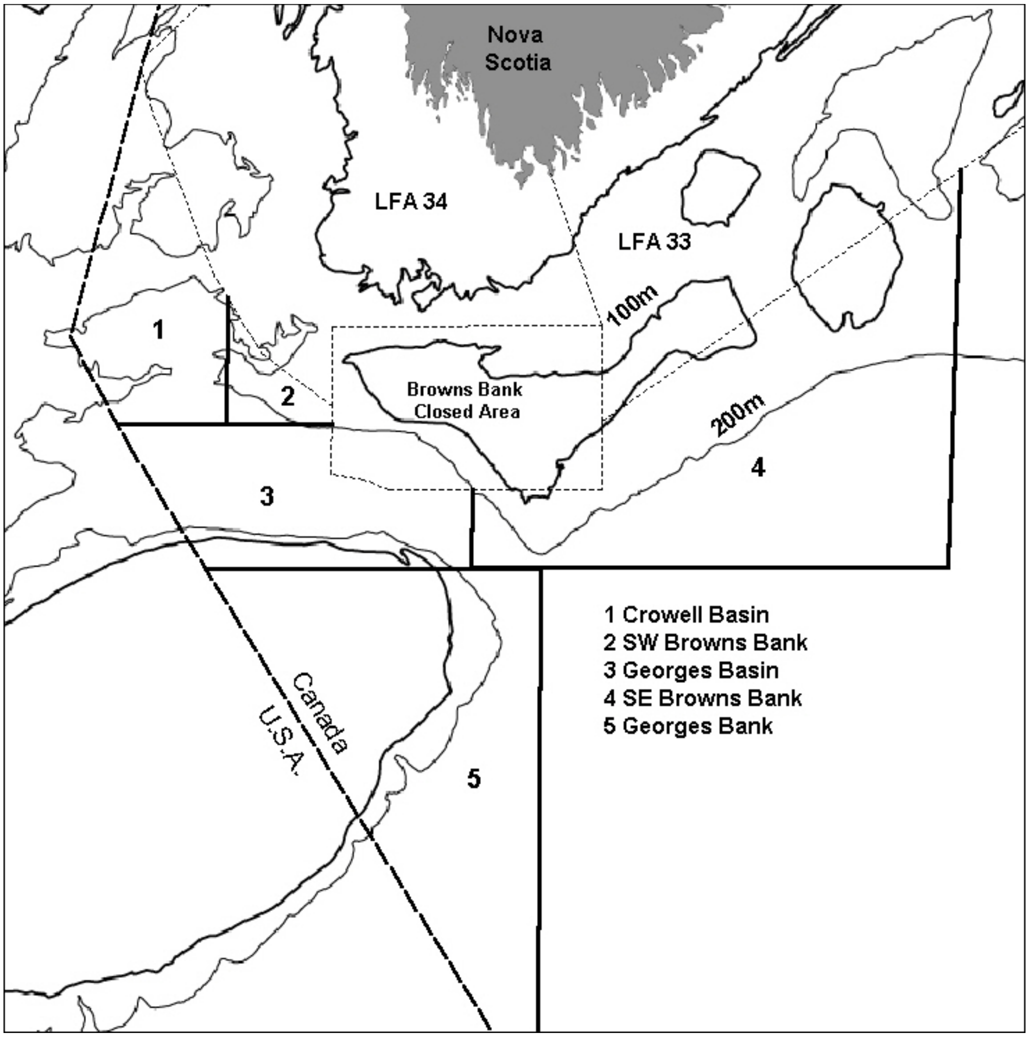

Figure 4. Map showing the traditional offshore subareas used in pre-2009 assessments for Crowell Basin, SW Browns, Georges Basin, SE Browns and Georges Bank.

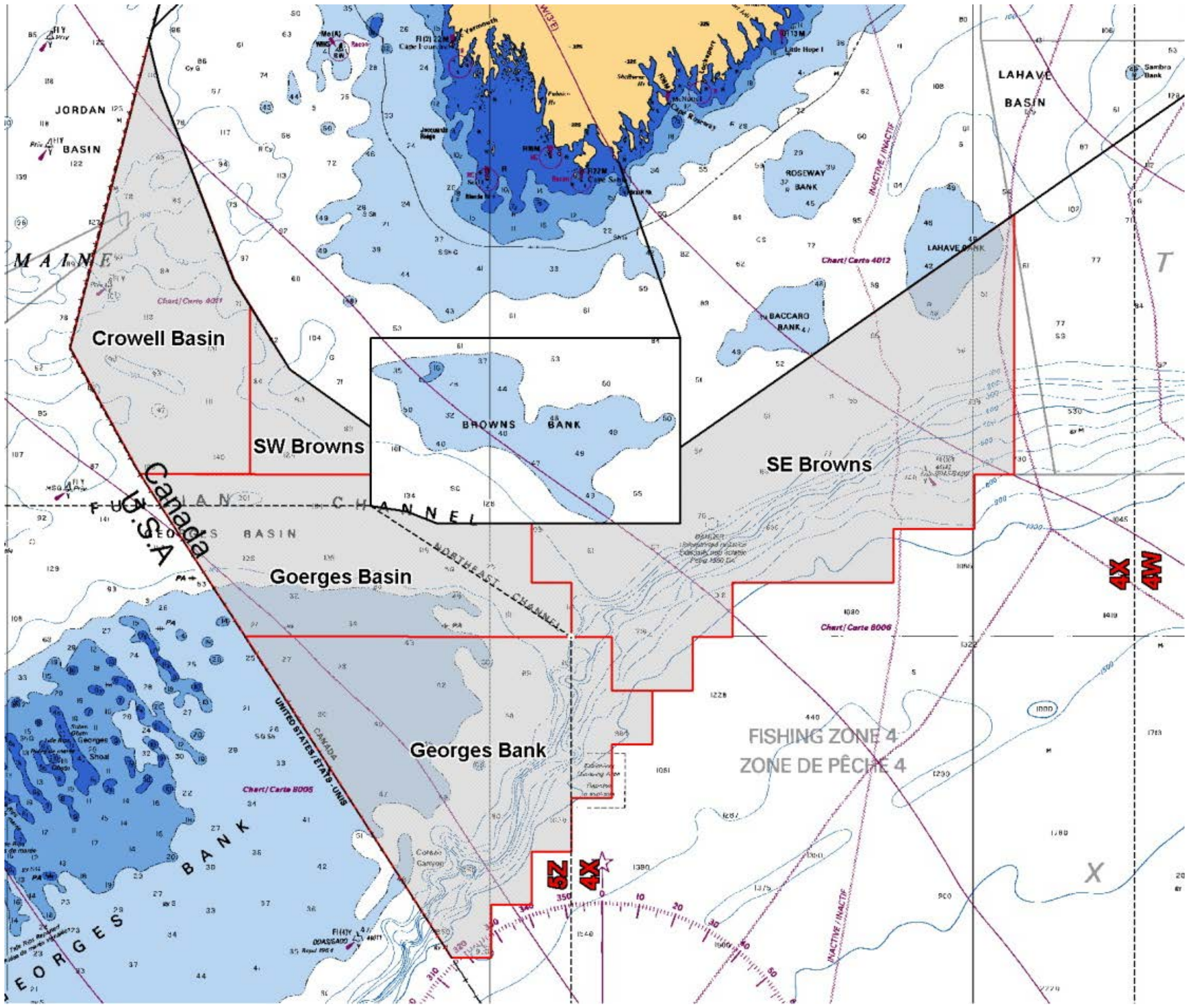

Figure 5. Map showing offshore subareas based on Grid Groupings of a 10-minute latitude and longitude grid (i.e. Crowell Basin, SW Browns, Georges Basin, SE Browns and Georges Bank).

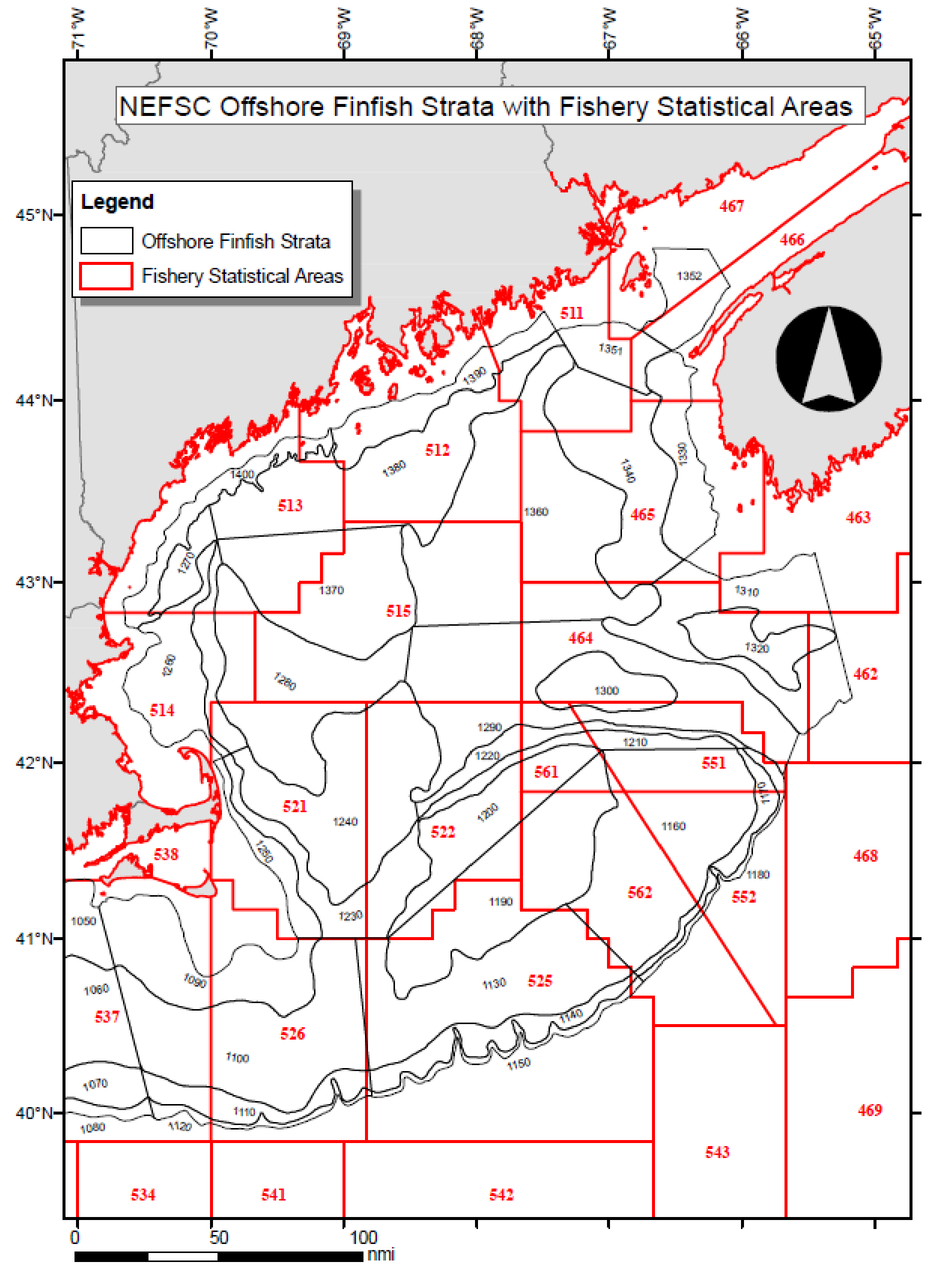

Figure 6. Map showing U.S. Fishery Statistical Area and offshore survey strata for Georges Bank and the Gulf of Maine.

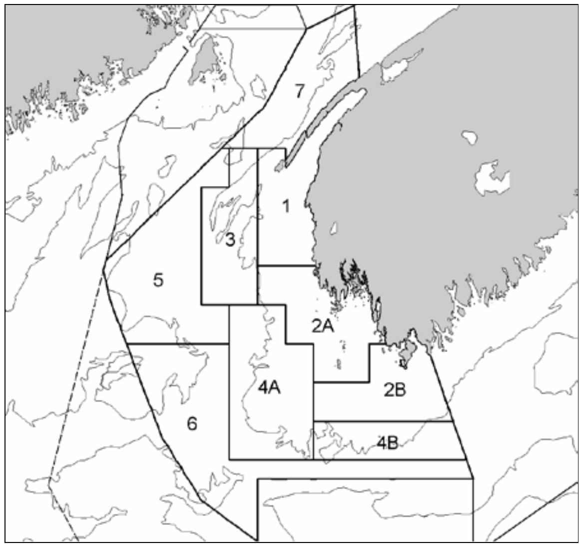

Figure 7. Map showing Grid Groupings used in LFA 34 assessments.

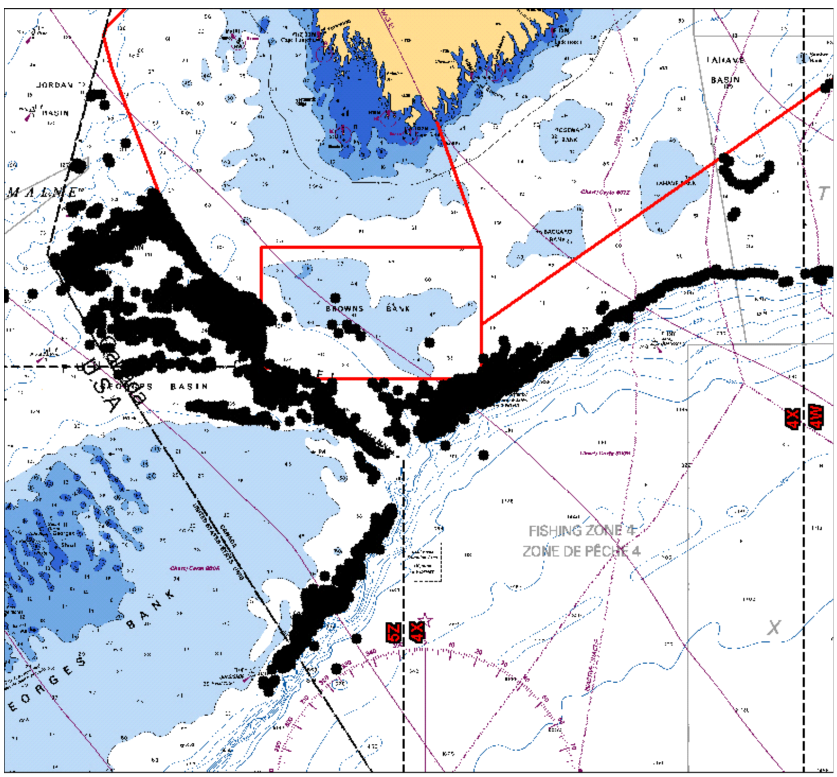

Figure 8. Map showing LFA 41 at-sea sampling locations from 1977 to 2007 (note: locations in the Browns Bank closed area were part of a DFO trapping survey).

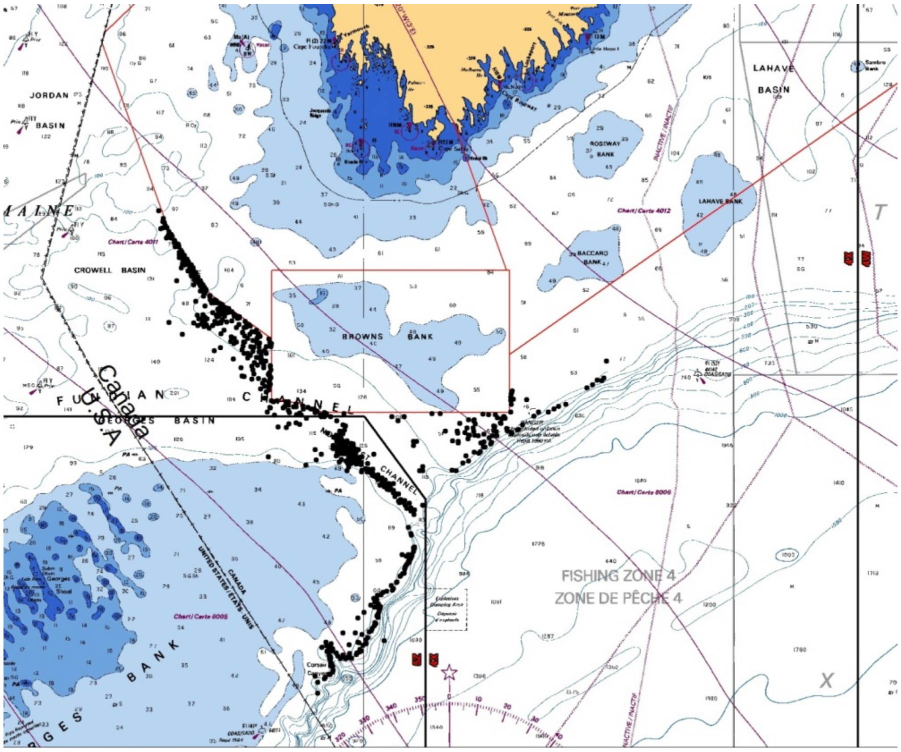

Figure 9. Map showing LFA 41 at-sea sampling locations from 2008 to 2012.

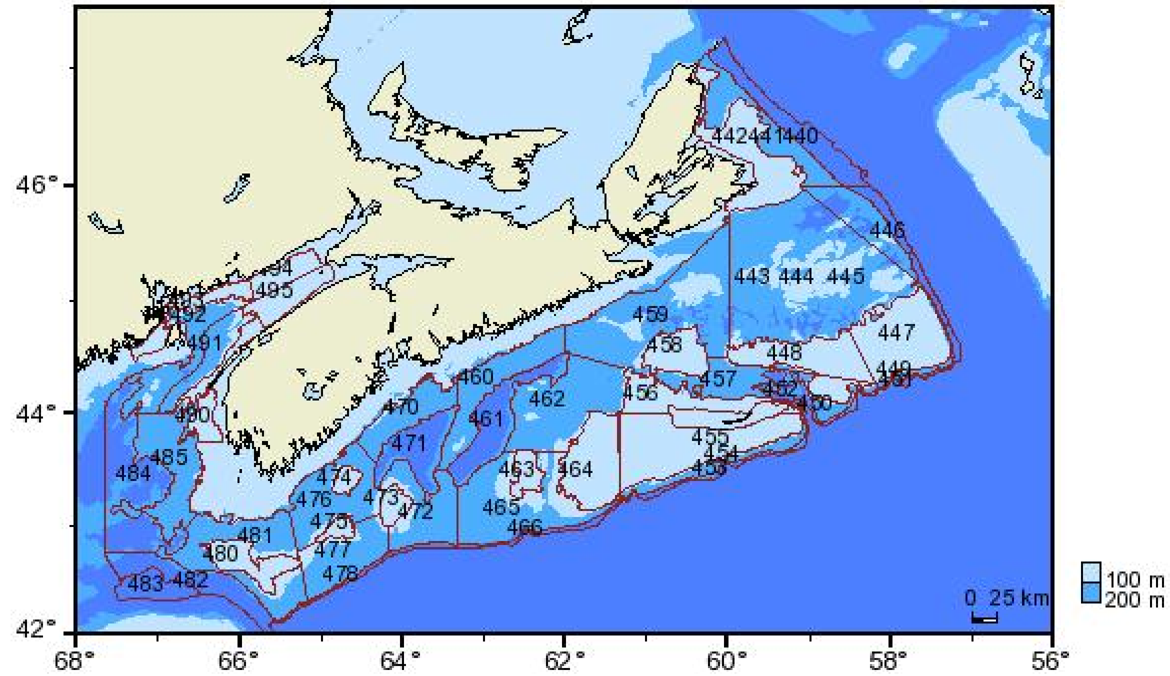

Figure 10. Map showing the sampling strata used in the DFO Maritimes Region Summer RV stratified-random trawl survey on the Scotian Shelf and Bay of Fundy. Numbers indicate survey strata.

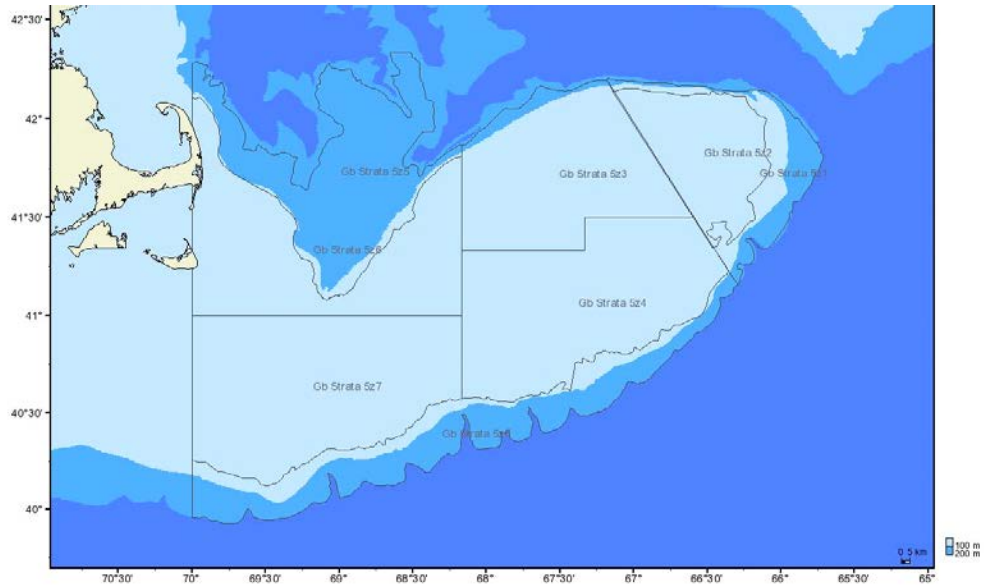

Figure 11. Map showing the sampling strata used in the DFO Maritimes Region Winter RV stratified-random trawl survey on Georges Bank. Numbers indicate survey strata.

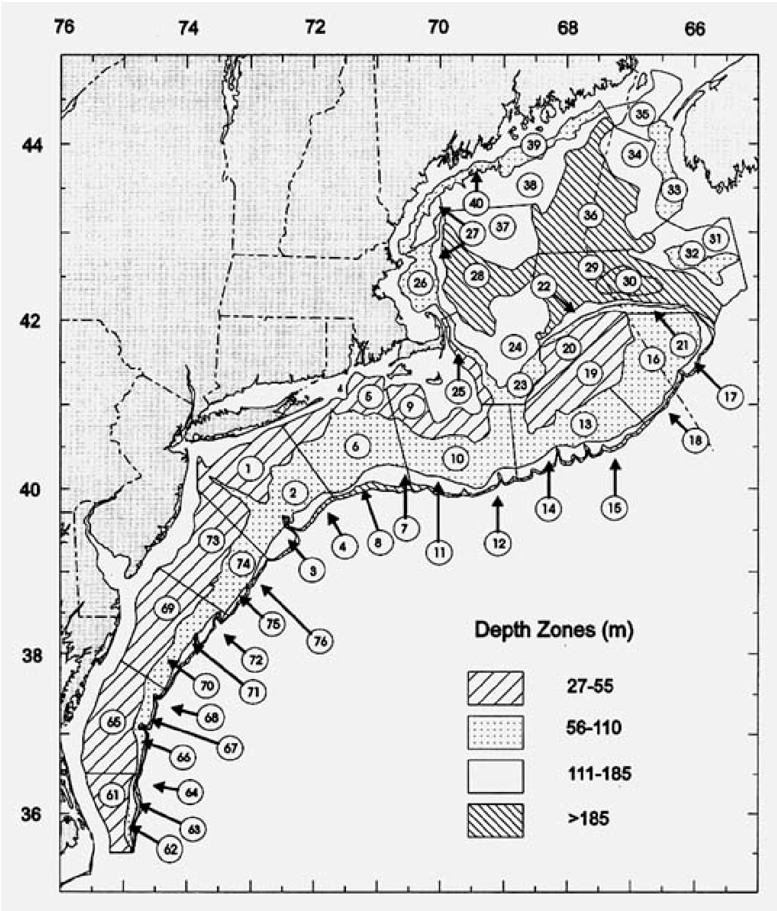

Figure 12. Map showing the sampling strata used in the U.S. NMFS Northeast Fisheries Center bottom trawl survey.

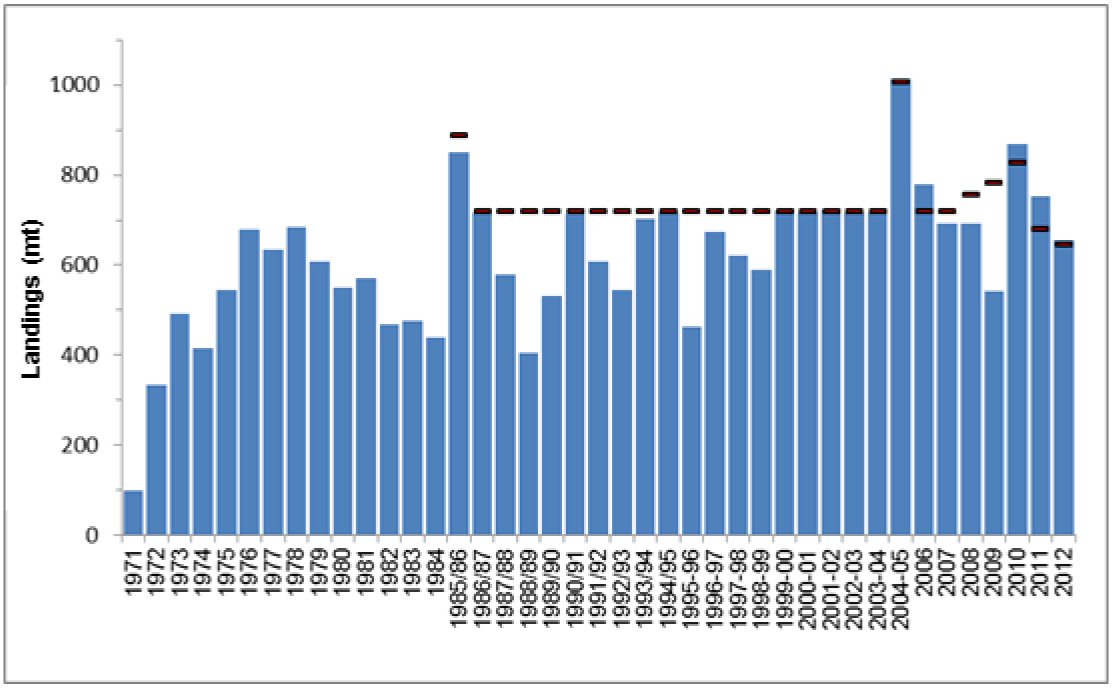

Figure 13a. LFA 41 quota season landings (bars) in metric tonnes (mt) from 1971 to 2012 showing adjusted total allowable catch (TAC) (dashed line) for the quota period. The change in the quota year in 1985-1986 resulted in a 14 month season and the TAC was adjusted to accommodate it. The change in the quota year in 2004 resulted in 7 of the 8 licences having an extended season during the transition in 2004-2005, and an annual TAC (Jan.-Dec.) during 2006 to 2007, while one licence continued under the Oct.16-Oct. 15 TAC during those years. The remaining licence switched to an annual quota year in 2007. For simplicity in this report, the landings and TAC are expressed on an annual basis for 2006 and 2007 to reflect the majority of the fishery.

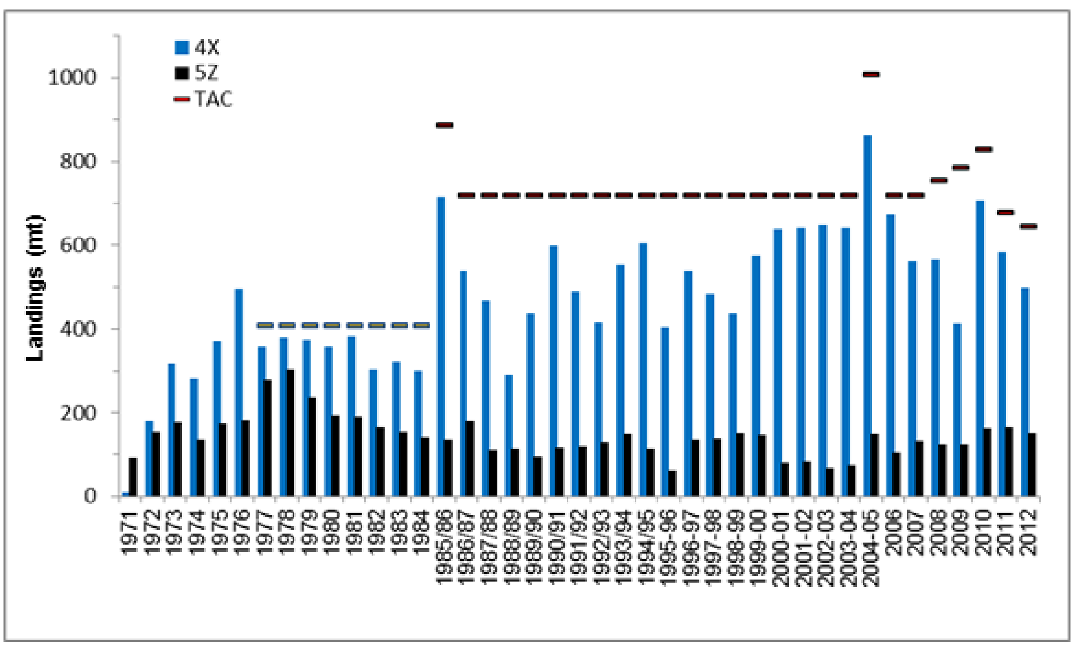

Figure 13b. LFA 41 landings (bars) in metric tonnes (mt) from 1971 to 2012 showing adjusted total allowable catch (TAC) (dashed line) for the quota period by NAFO divisions 4X and 5Ze.

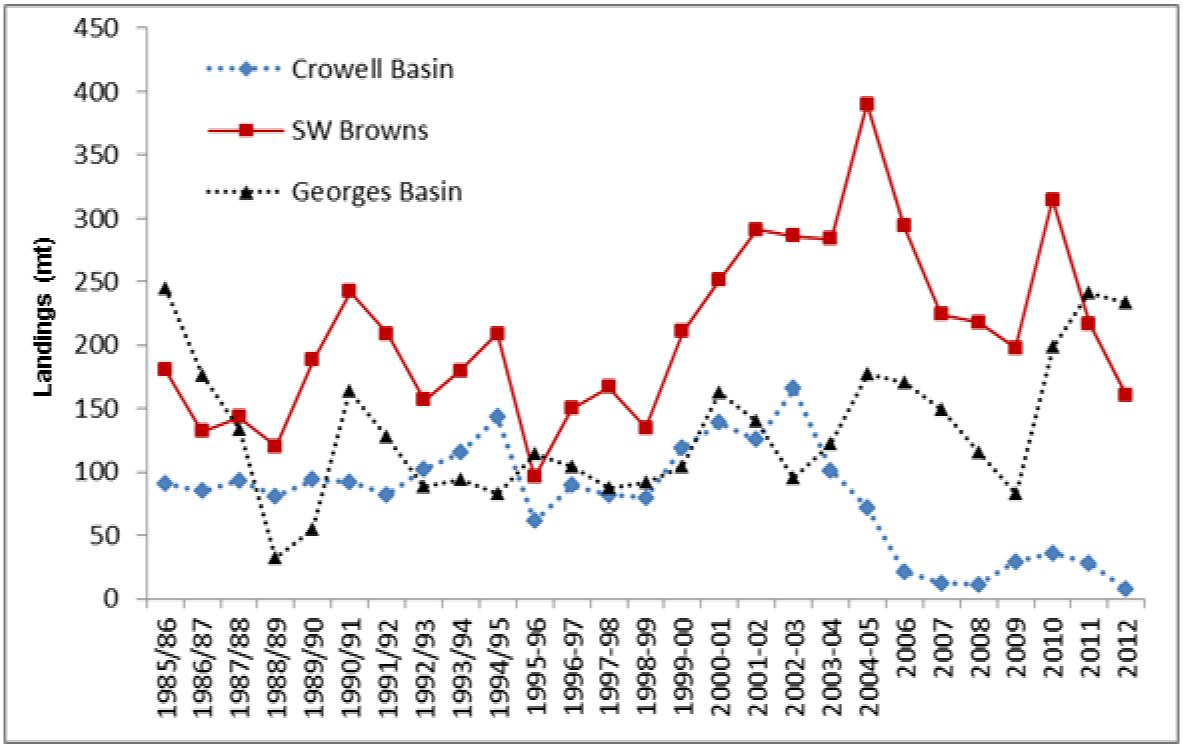

Figure 14a. Lobster landings in metric tonnes (mt) from 1985 to 2012 for the quota season for the Crowell Basin, Georges Basin and SW Browns assessment areas.

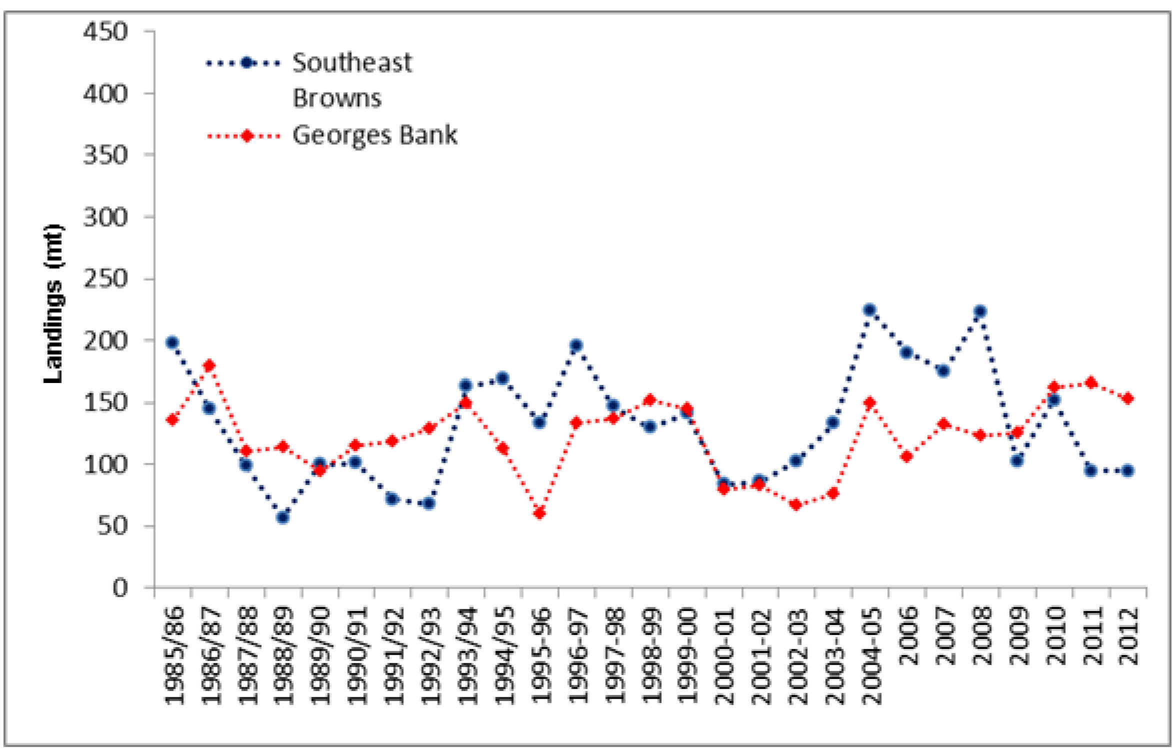

Figure 14b. Lobster landings in metric tonnes (mt) from 1985 to 2012 for the quota season for the SE Browns and Georges Bank assessment areas.

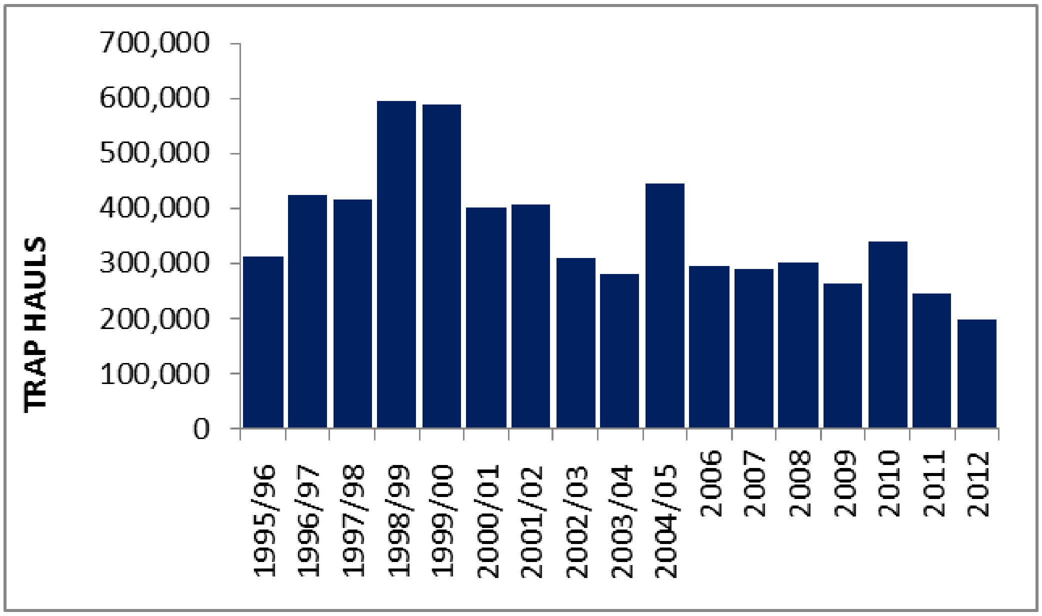

Figure 15. Total LFA 41 reported trap hauls for the quota season 1995-2012.

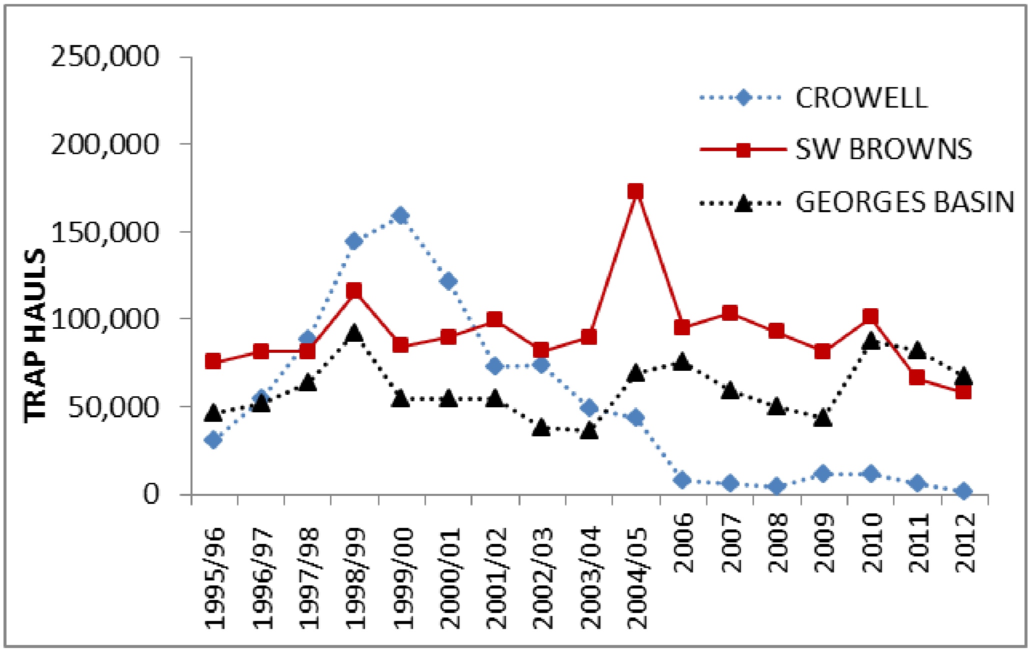

Figure 16a. Reported trap hauls for the quota season for Crowell Basin, Georges Basin and SW Browns assessment areas from 1995 to 2012.

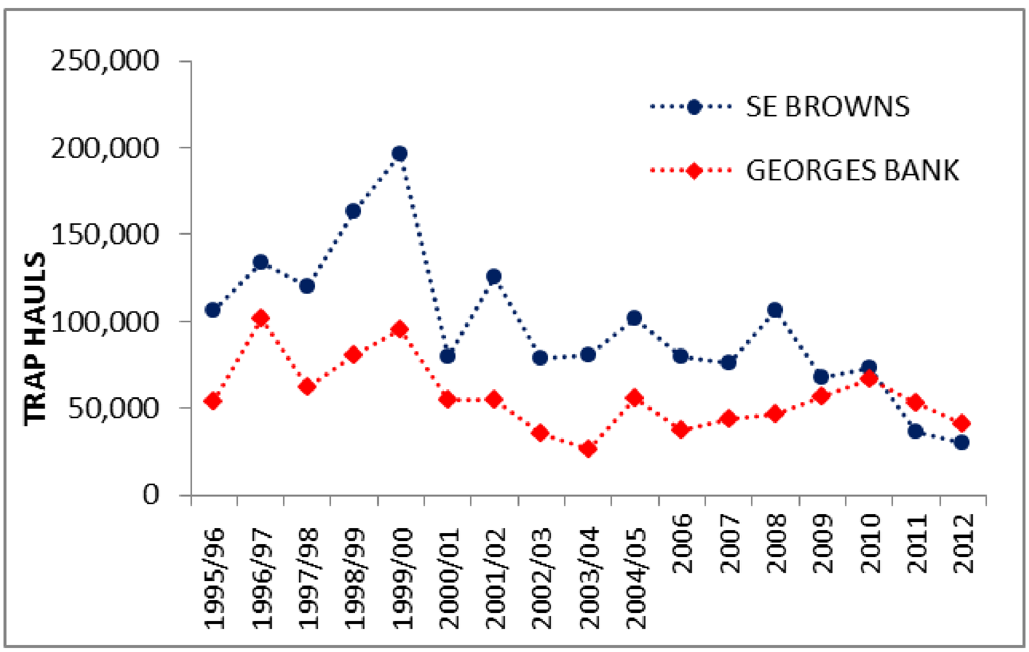

Figure 16b. Reported trap hauls for the quota season for SE Browns and Georges Bank assessment areas from 1995 to 2012.

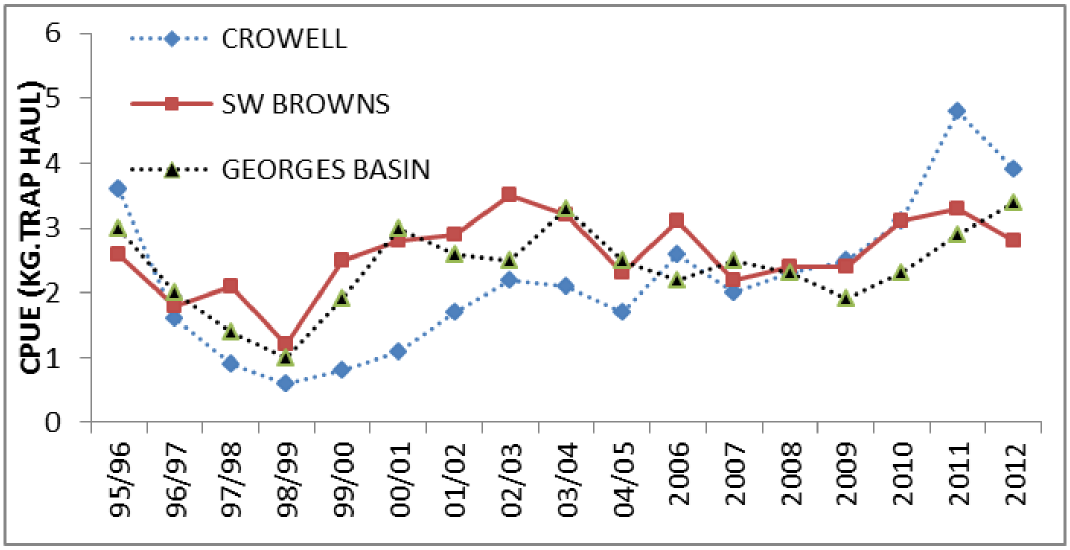

Figure 17a. Overall uncorrected lobster Catch per Unit Effort (CPUE) in kilograms per trap hauled (kg/TH) from 1995/1996 to 2012 for Crowell Basin and SW Browns assessment areas and fishing season.

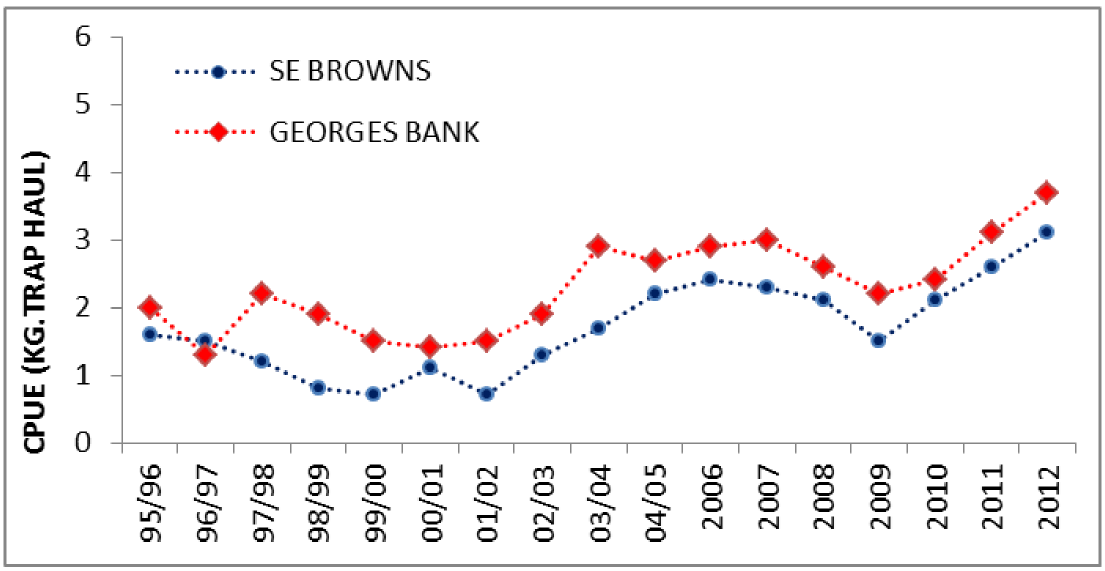

Figure 17b. Overall uncorrected lobster Catch per Unit Effort (CPUE) in kilograms per trap hauled (kg/TH) from 1995/1996 to 2012 for SE Browns and Georges Bank assessment areas and fishing season).

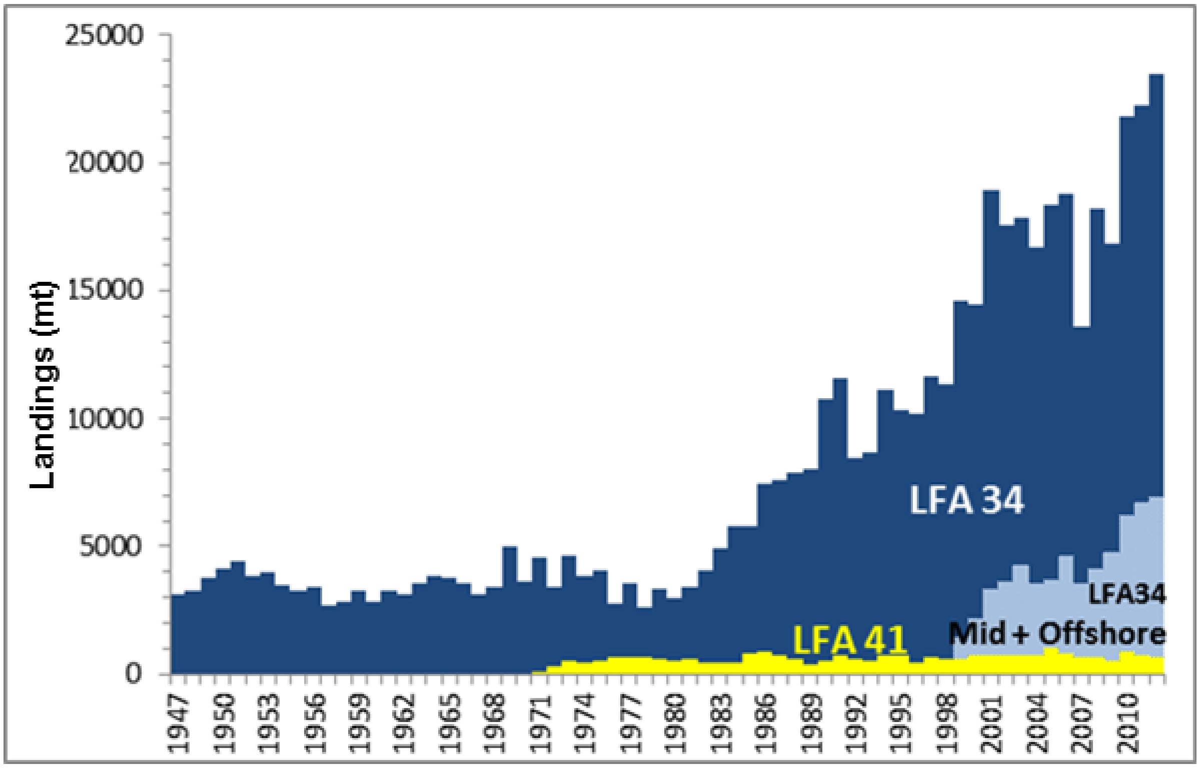

Figure 18. Lobster landings in metric tonnes (mt) from 1947 to 2012 for LFA 41 and LFA 34 (total and portion from the mid and offshore areas (Grid Groups 4, 5, and 6) since 1998).

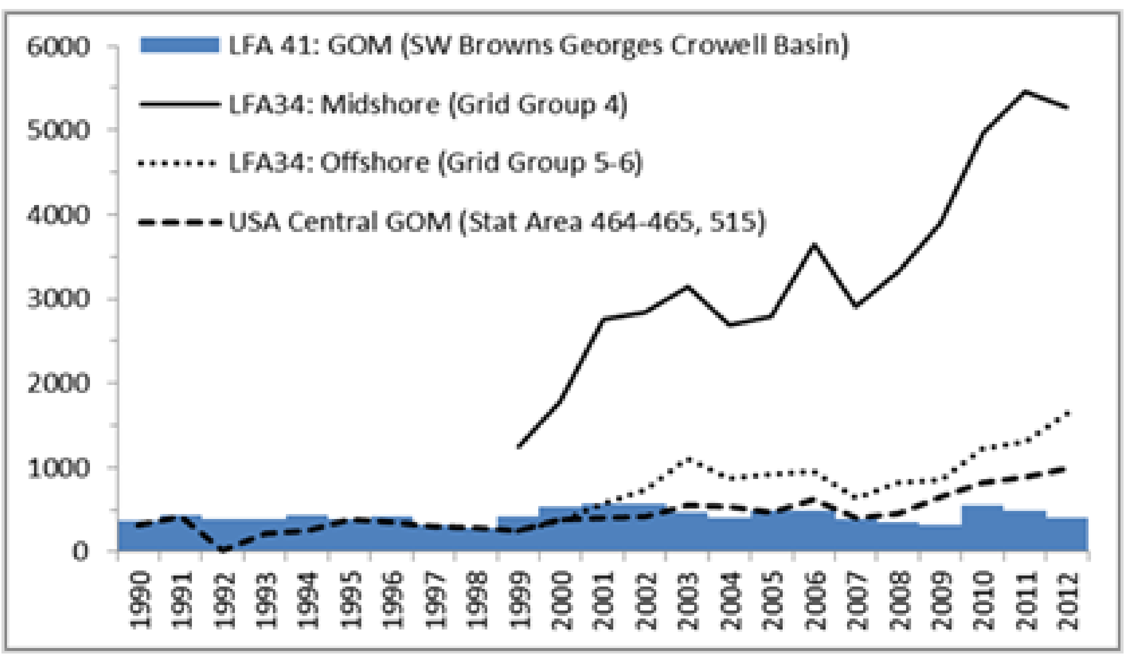

Figure 19. Lobster landings in metric tonnes (mt) from 1990 to 2012 in the Gulf of Maine portion of LFA 41 and LFA 34 midshore (Grid Group 4) and offshore (Grid Group 5-6) subareas and U.S. central Gulf of Maine area (Statistical Area 464, 465 and 515).

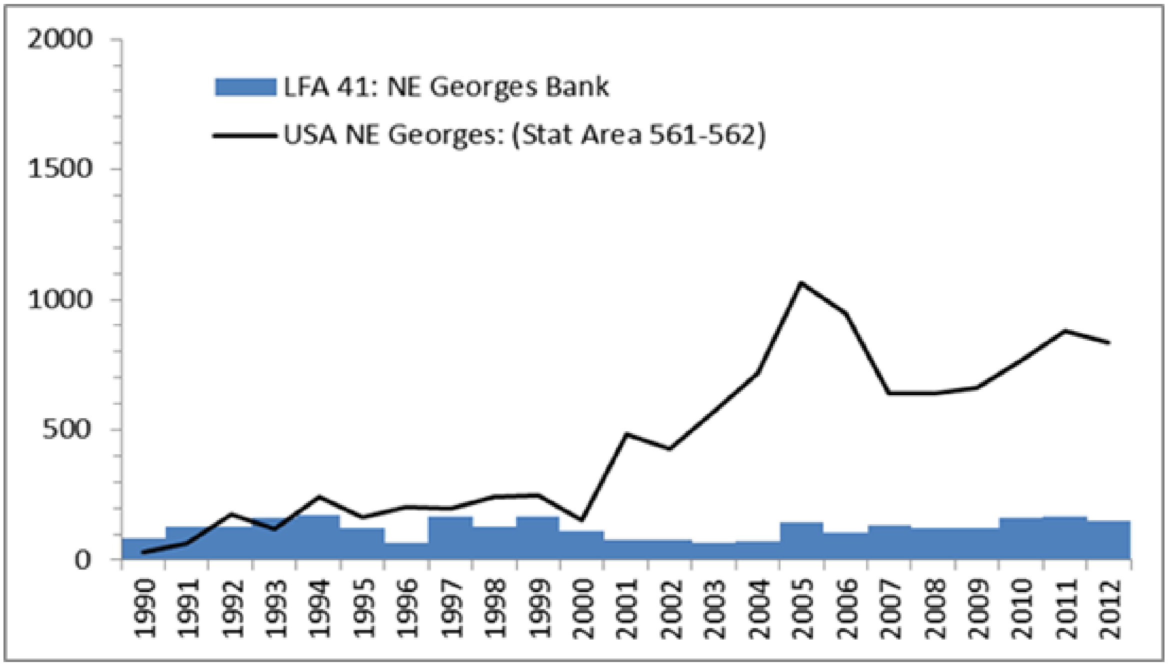

Figure 20. Lobster landings in metric tonnes (mt) from 1990 to 2012 on the Canadian portion of northeast Georges Bank and U.S. portion of northeast Georges Bank (Statistical Area 561-562).

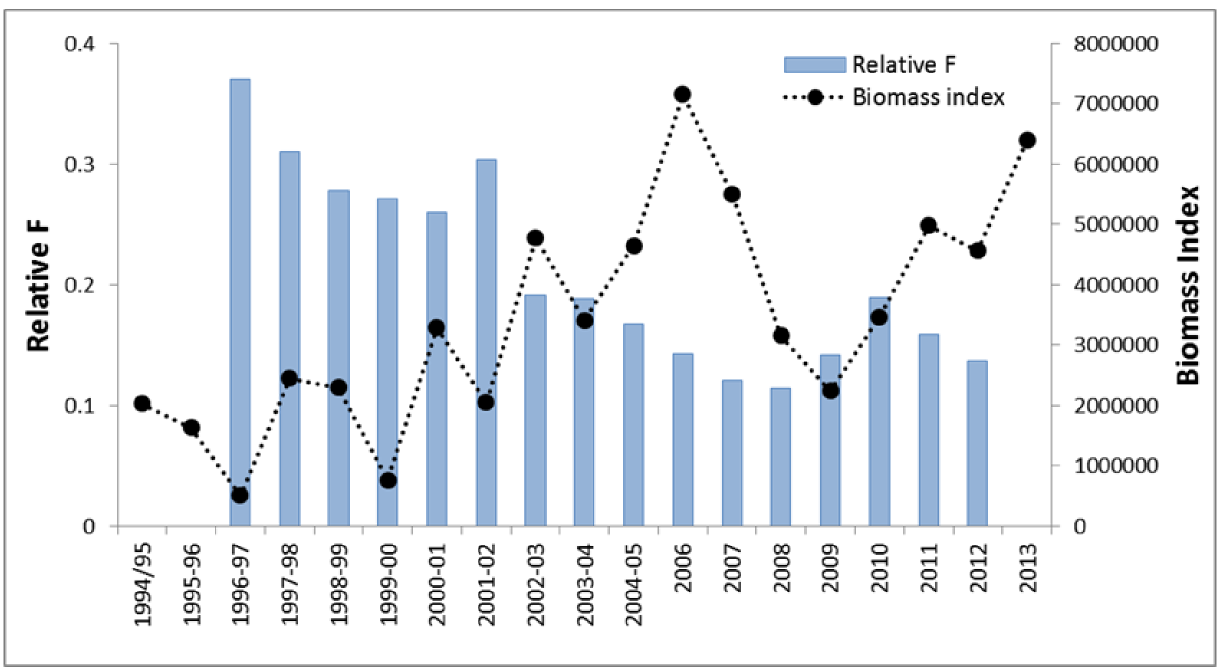

Figure 21. Relative F (bars) and biomass index (dashed line) of the LFA 41 NAFO division 4X lobster fishery from the DFO Maritime Region Summer RV survey.

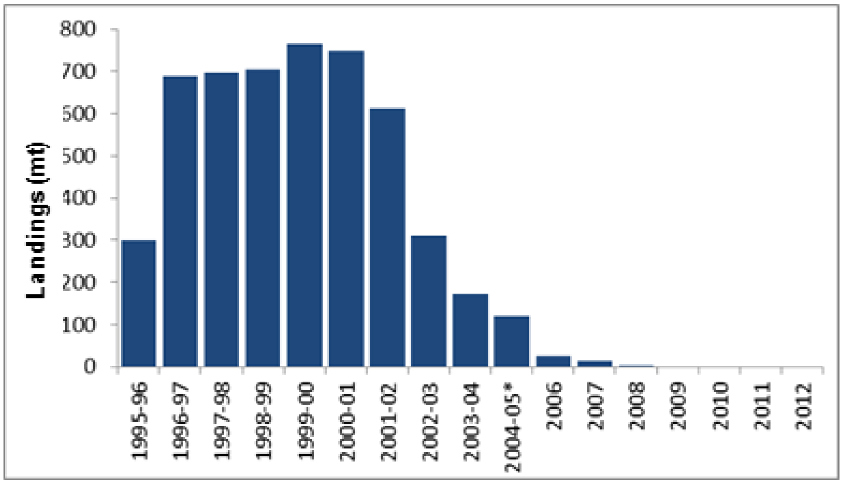

Figure 22. Total LFA 41 Jonah Crab landings in metric tonnes (mt) for the quota season.

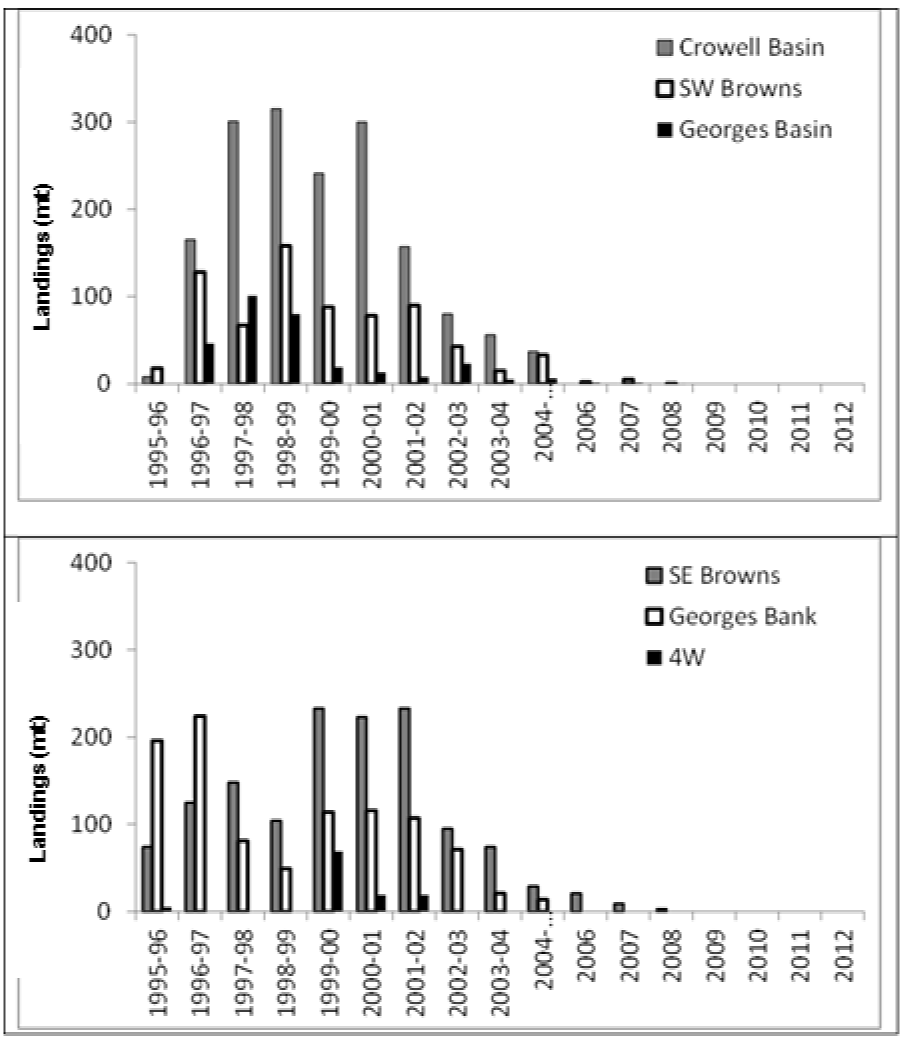

Figure 23. LFA 41 Jonah Crab landings in metric tonnes (mt) by assessment area (upper panel) and quota season (lower panel).

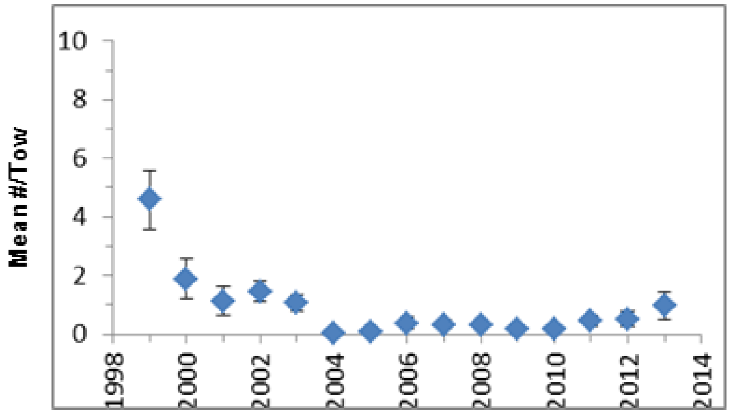

Figure 24. Jonah Crab in mean number per tow (#/Tow) with standard error. Data from the DFO Maritimes Summer RV survey Strata 477, 478 and 480-484.

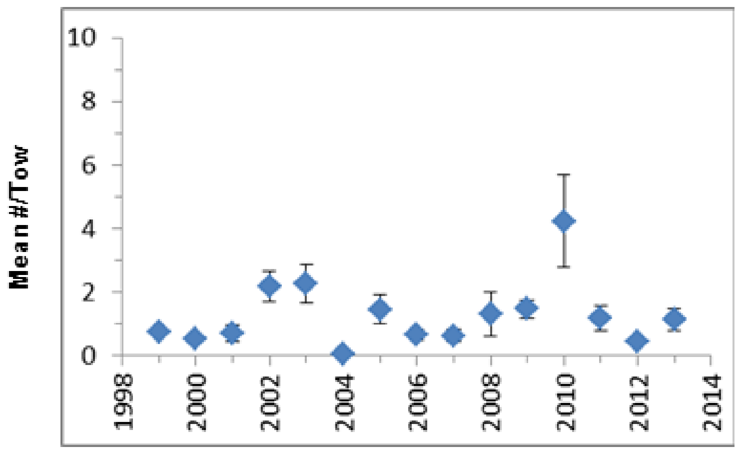

Figure 25. Jonah Crab in mean number per tow (#/Tow) with standard error for NAFO division 4X. Data from the DFO Maritimes Summer RV survey.

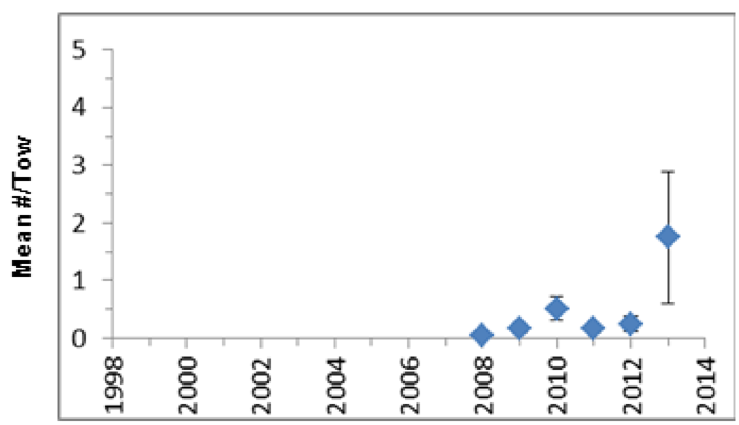

Figure 26. Jonah Crab in mean number per tow (#/Tow) with standard error for Georges Bank. Data from the DFO Maritimes Winter RV survey (Strata 5Z1+5Z2+5Z3+5Z4).

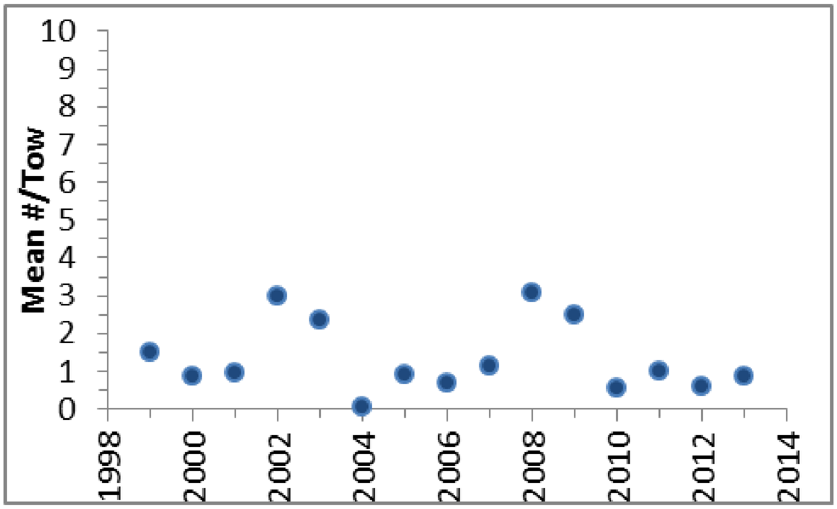

Figure 27. Jonah Crab in mean number per tow (#/Tow) in inshore LFA 32-33. Data from the DFO Maritimes Summer RV survey (Strata 460+461+462+470+471+474+476).

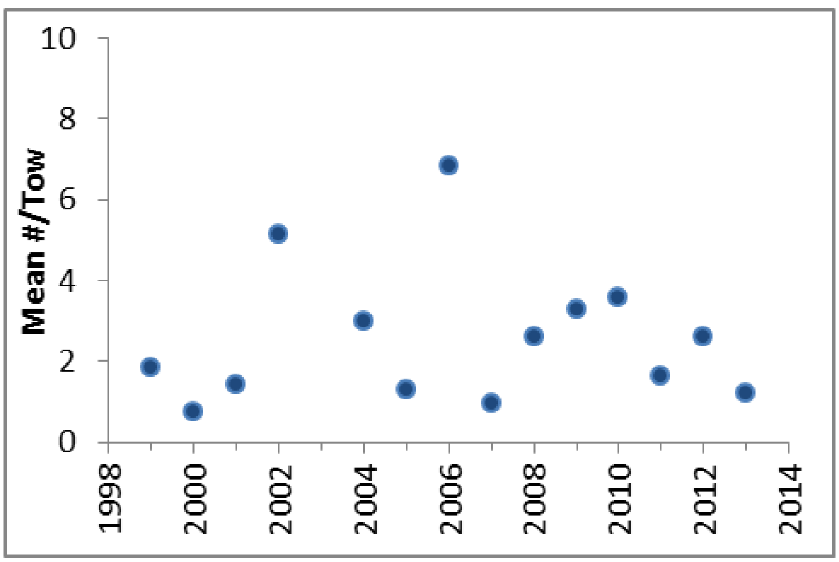

Figure 28. Jonah Crab in mean number per tow (#/Tow) in the Bay of Fundy. Data from the DFO Maritimes Summer RV survey (Strata 490-495).

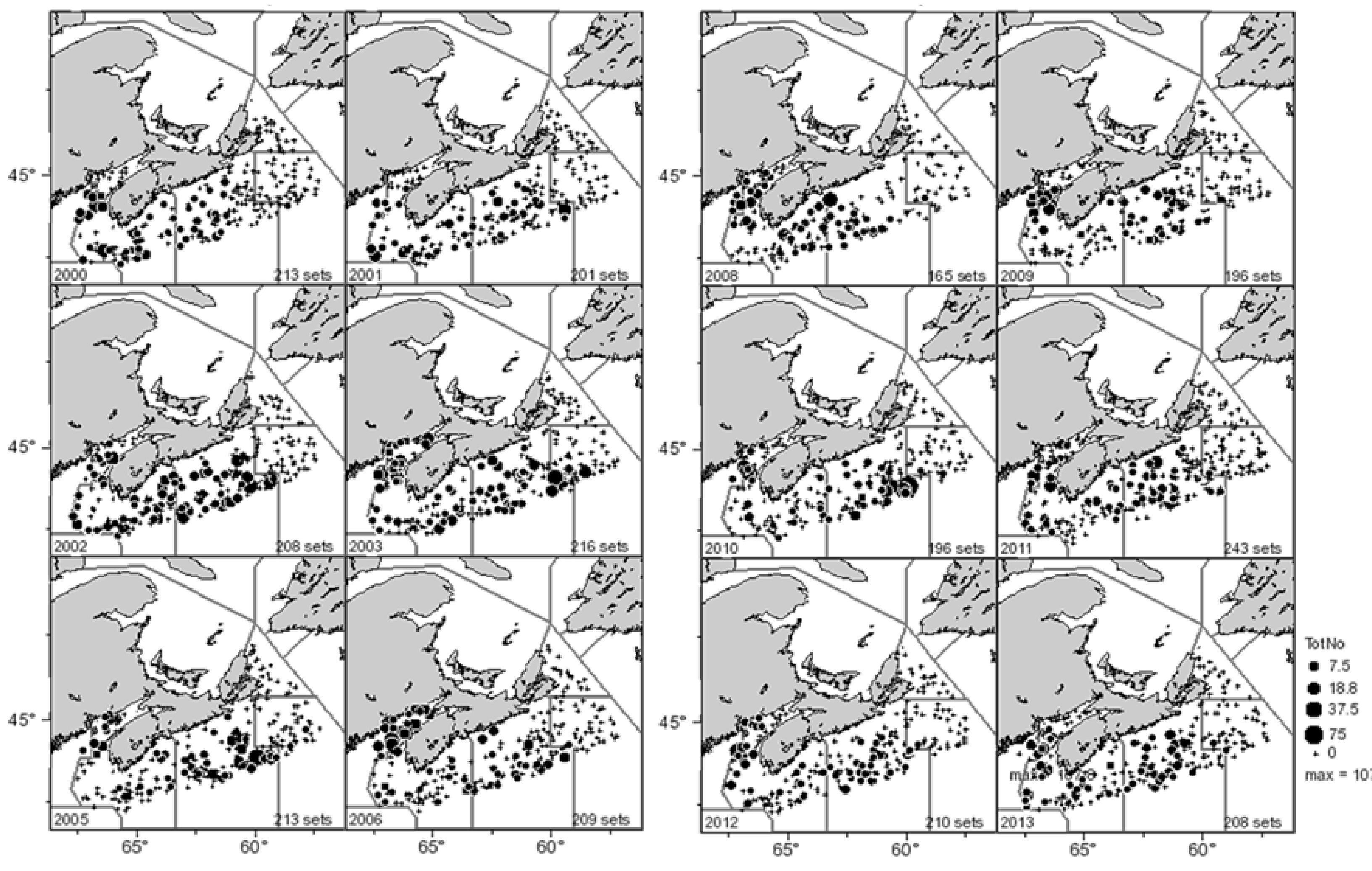

Figure 29. Maps of the DFO Maritimes Region Summer RV survey in catch in numbers per tow (#/Tow) from 2000 to 2013.

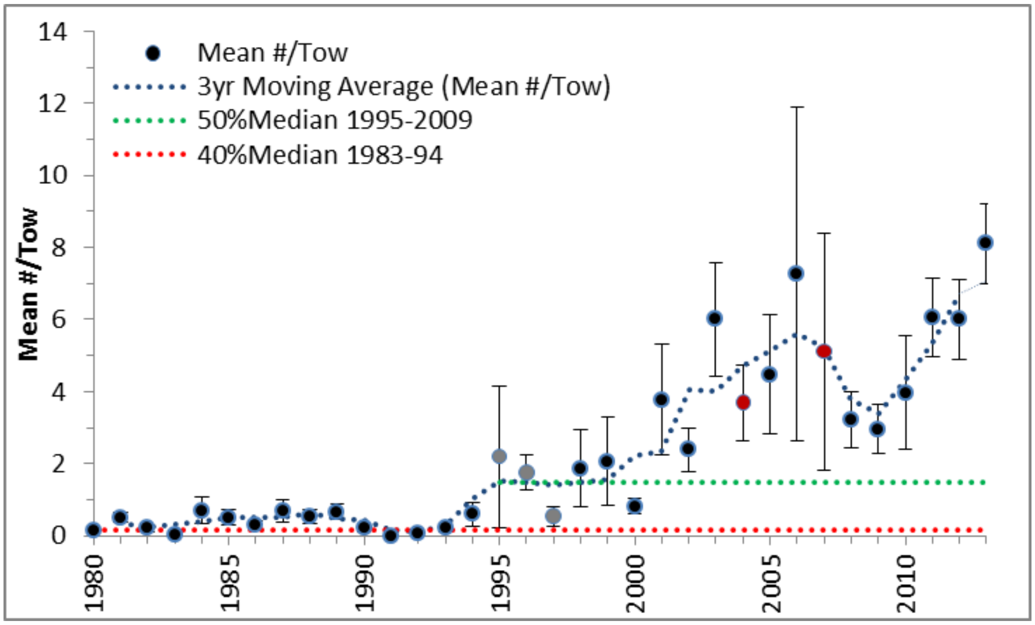

Figure 30. DFO Maritimes Region Summer RV survey (Strata 477-484 – NAFO division 4X) mean number per tow with standard errors and a 3-year moving average (red symbols 2004 and 2007 represent surveys with a different vessel, the Teleost, and grey symbols (1995-1997 represent period when count is estimated from the mean weight per tow as count not recorded). Upper Boundary (green dashed line) set as 50% of the median value 1995-2009 and Lower Boundary as 40% (red dashed line) of the median value 1983-1994.

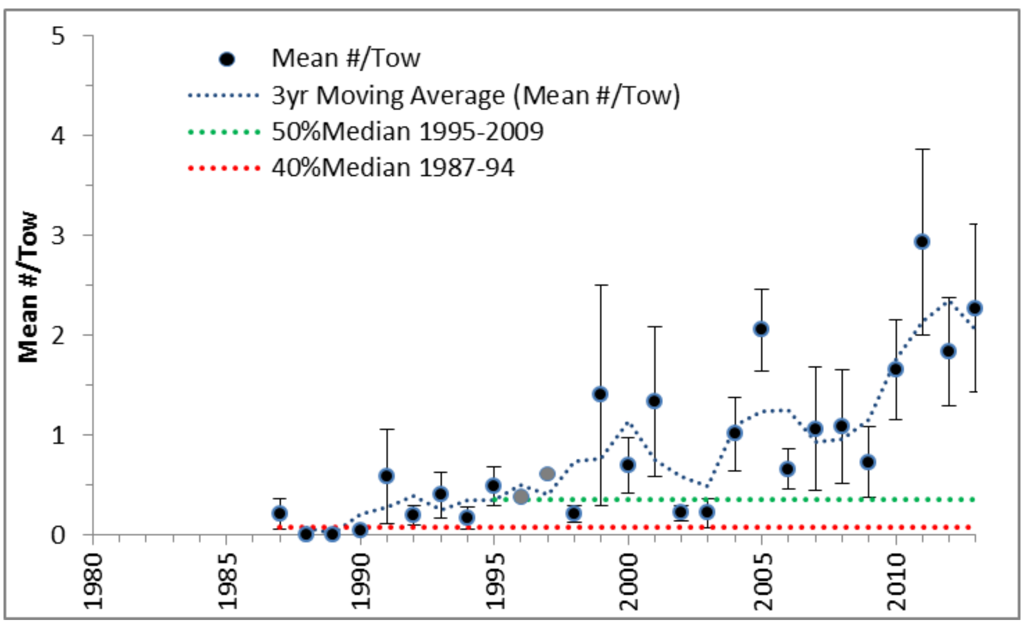

Figure 31. DFO Maritimes Region Winter RV survey (Strata Z1-Z4 – Georges Bank) mean number per tow with standard errors and a 3-year moving average (grey symbols (1996-1997) represent period when count is estimated from the mean weight per tow as count not recorded). Upper Boundary (green dashed line) set as 50% of the median value 1995-2009 and Lower Boundary as 40% (red dashed line) of the median value 1987-1994.

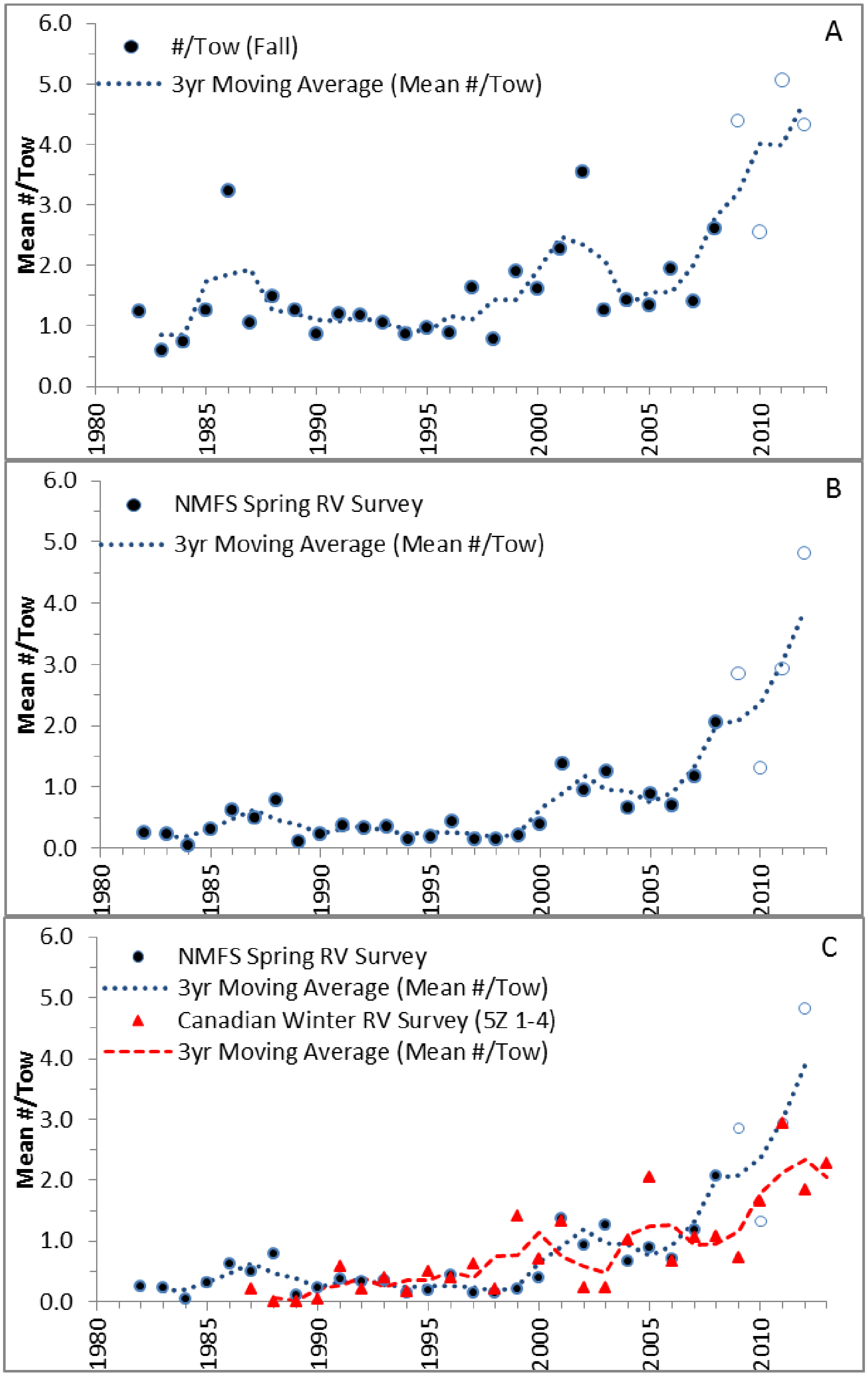

Figure 32. U.S. NMFS Northeast Fisheries Center RV Survey (Strata 16-18, 21) mean number per tow and a 3-year moving average (open symbols (2009-2012) represent new vessel and trawl design): A) Fall Survey (upper panel); B) Spring Trawl Survey (middle panel); and C) Spring Trawl survey (lower panel) compared with the DFO Maritimes Region Winter RV survey.

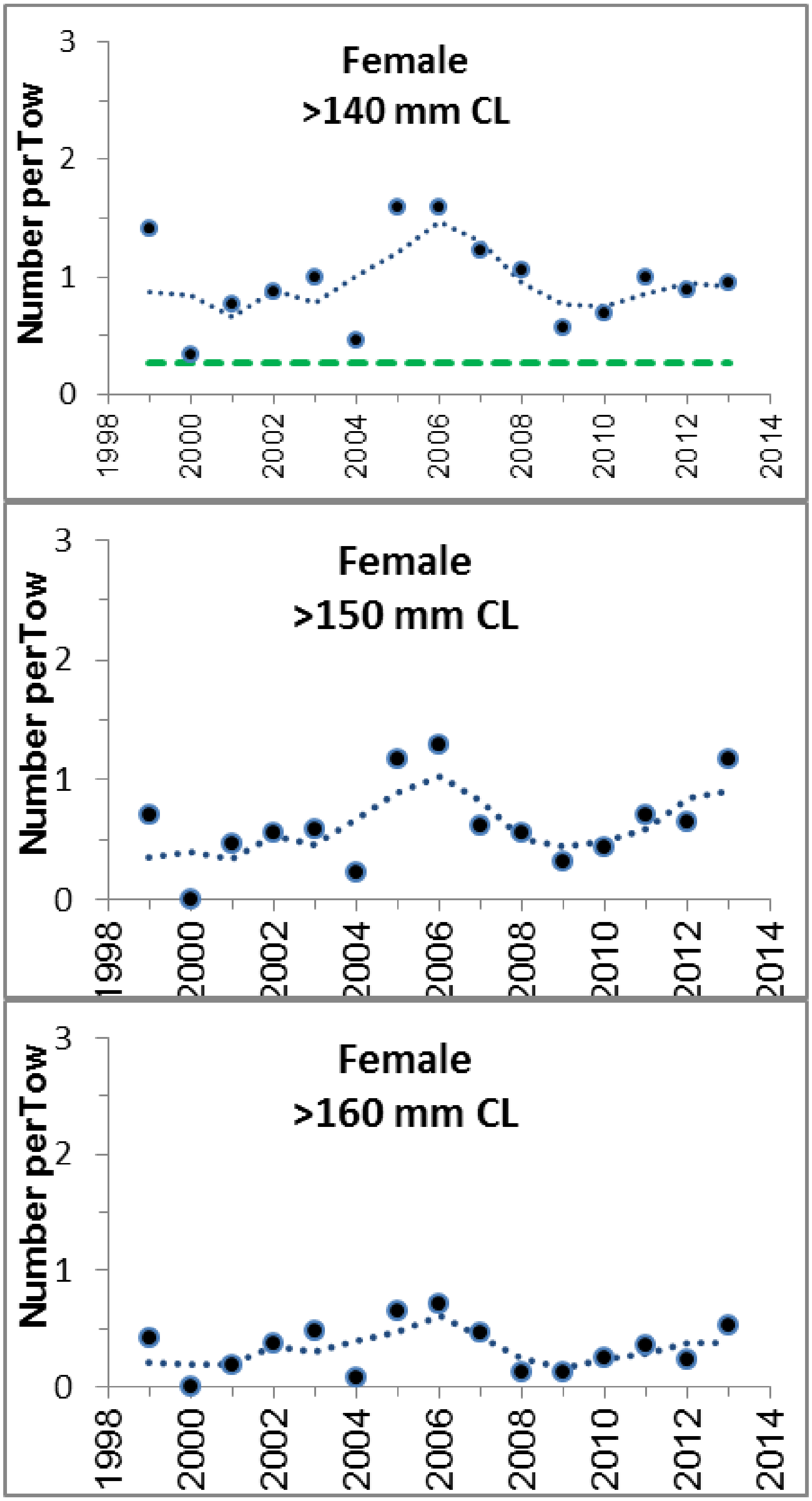

Figure 33. Number per tow of females >140 (upper panel), 150 (middle panel) and 160 mm lower panel) CL from NAFO division 4X, with Upper Boundary of 80% (green dashed line) of the minimum value. Data from the DFO Maritimes Summer RV survey.

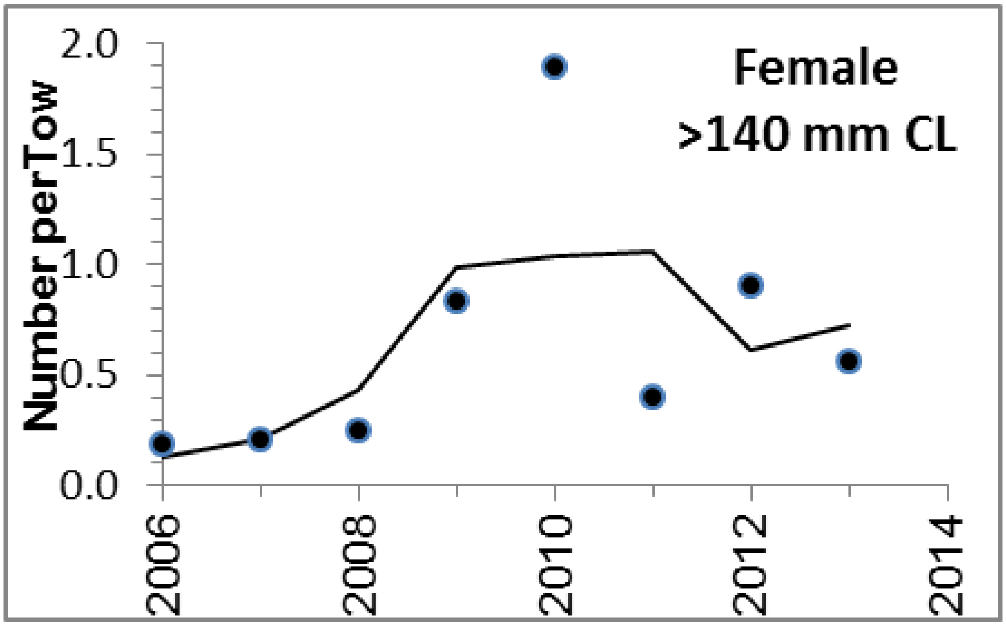

Figure 34. Number per tow of females >140mm CL from 5Z. Data from the DFO Maritimes RV Winter survey.

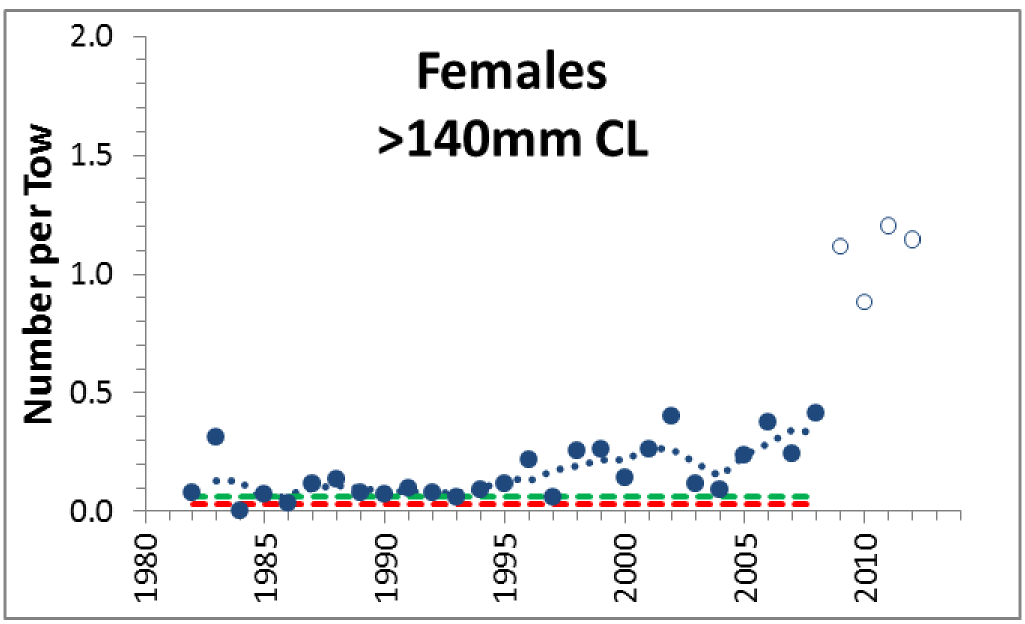

Figure 35. U.S. NMFS Northeast Fisheries Center Fall RV survey in NAFO division 5Z. Number per tow of females >140mm CL with female Upper Boundary of 80% (green dashed line) of the median value 1983-1994 and Lower Boundary is 40% (red dashed line) of the median value 1983-1994. Note: a change in the survey design in 2009 has resulted in higher catch rates of many species, and the effect on size selectivity is at this time not known.

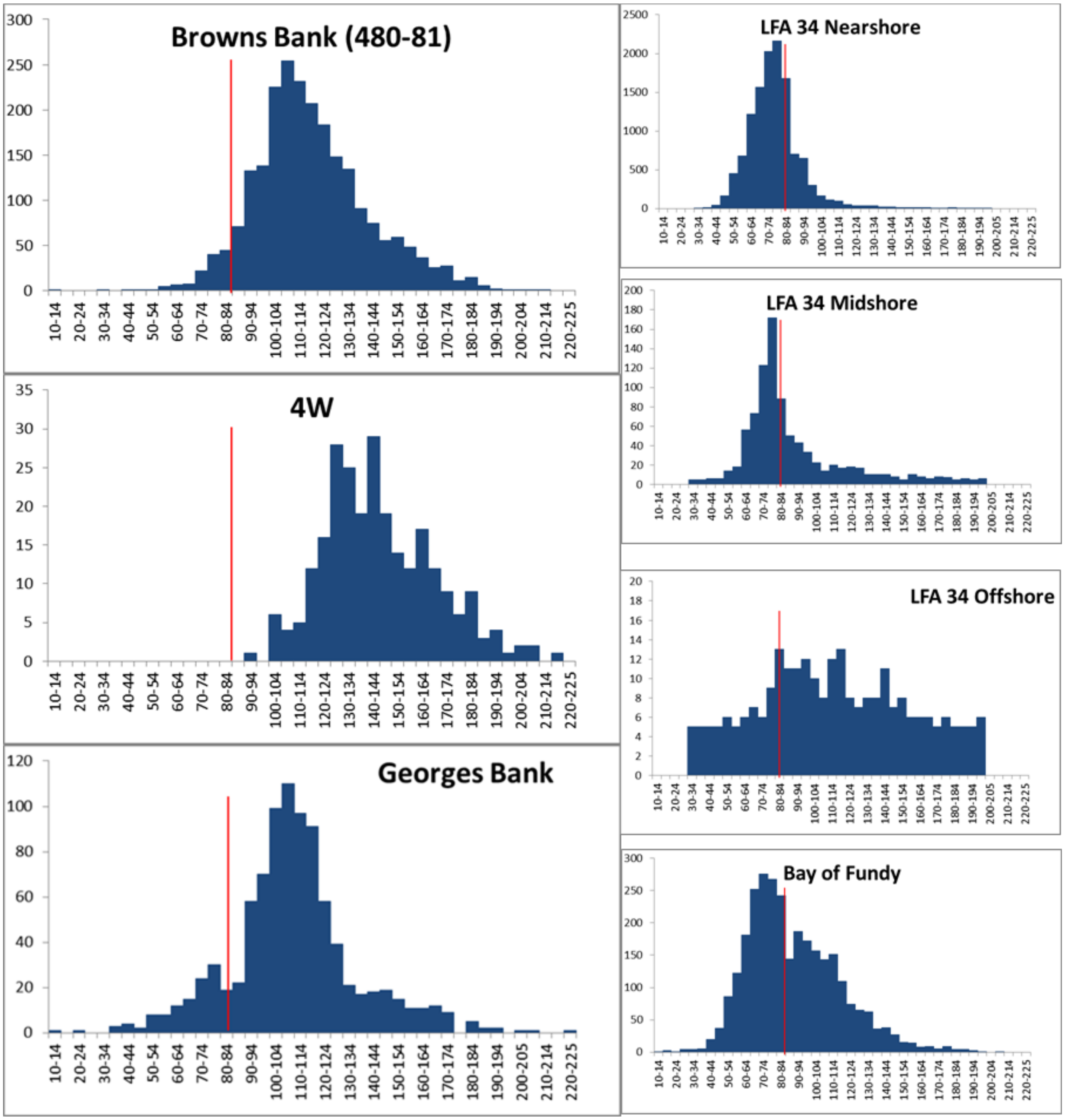

Figure 36. Comparison of overall size frequency expressed as numbers per 5-mm CL increments in the Browns Bank area and offshore NAFO division 4W, which is an unfished area to the east of the LFA 41 fishery (both based on DFO Maritime Region Summer RV survey); Georges Bank (NAFO division 5Zc DFO Maritimes Region Winter RV survey) and the Nearshore, Midshore, and Offshore portions of LFA 34 (ITQ summer trawl survey); and the Bay of Fundy (DFO Maritime Region Summer RV survey). The red vertical line represents minimum legal size. Note: all inshore size frequencies are immediately post fishery and prior to the moulting season.

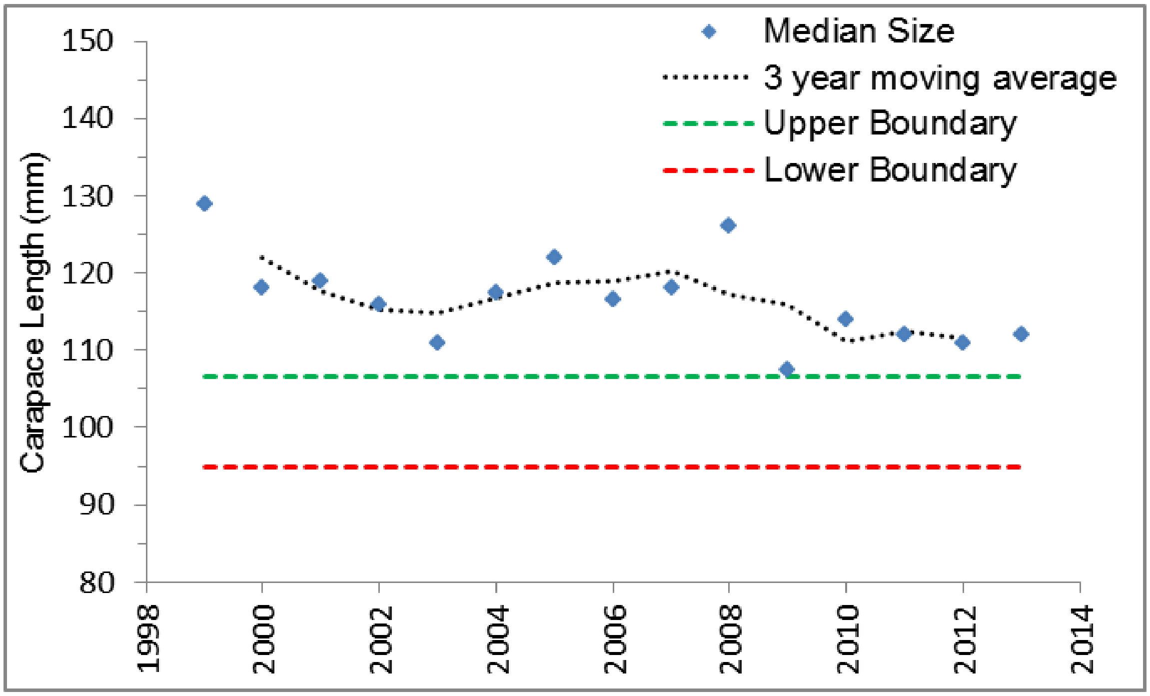

Figure 37. Median size of females from the DFO Maritime Region RV Summer survey (NAFO division 4X) with 3-year moving average and Upper Boundary (green dashed line) and Lower Boundary (red dashed line) limits.

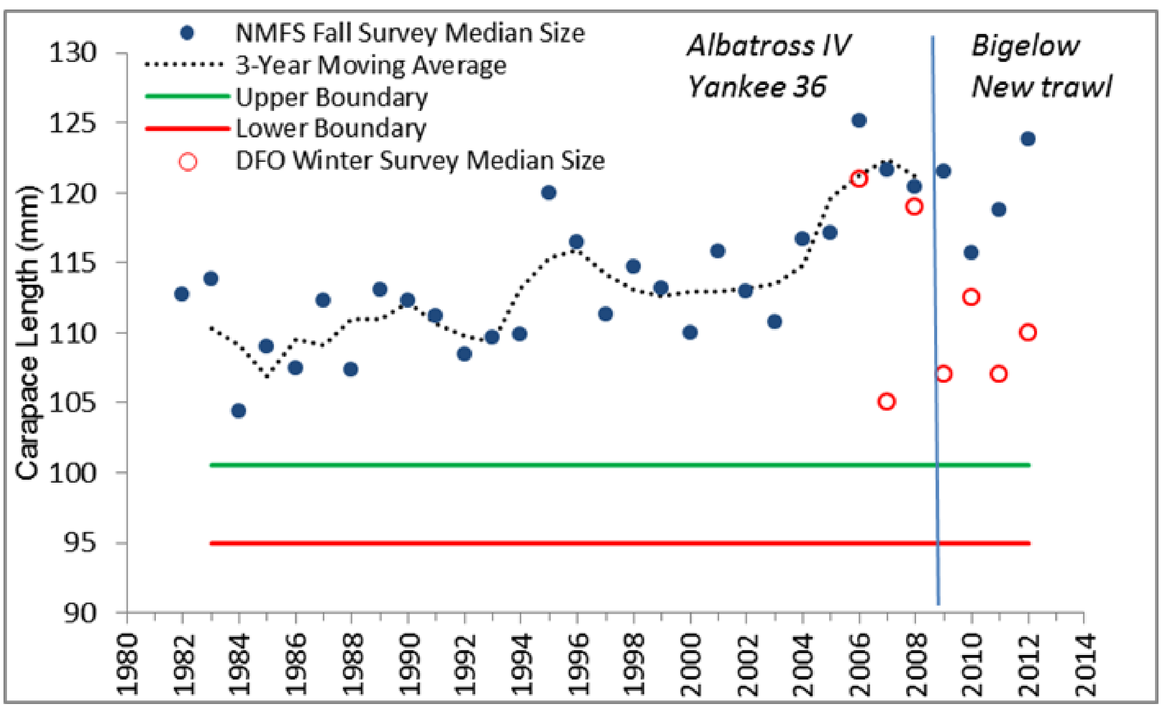

Figure 38. Median size of females from the U.S. NMFS Fall RV survey in NAFO division 5Z, with 3-year moving average and Upper Boundary (green line) and Lower Boundary (red line) limits, as well as Median size of females from the DFO Maritimes Region RV Winter survey. Prior to 2009, the U.S. surveys conducted by the NOAA FSV Albatross IV used a Yankee 36 trawl. Since 2009, surveys conducted by the FSV Henry B. Bigelow are using a new trawl design.

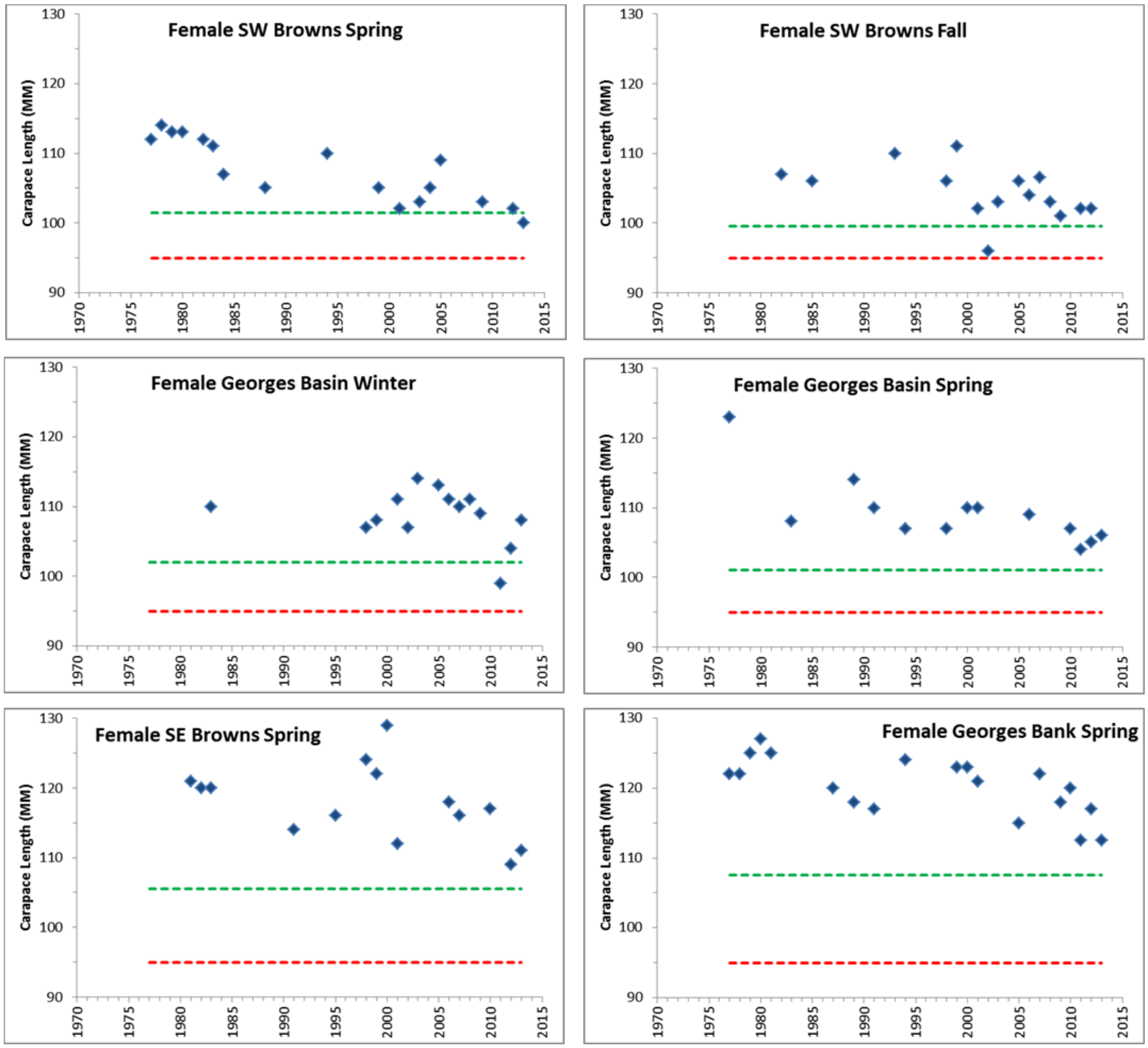

Figure 39. Median size of females from at-sea samples compared to Upper Boundary (green dashed line) and Lower Boundary (red dashed line) limits.

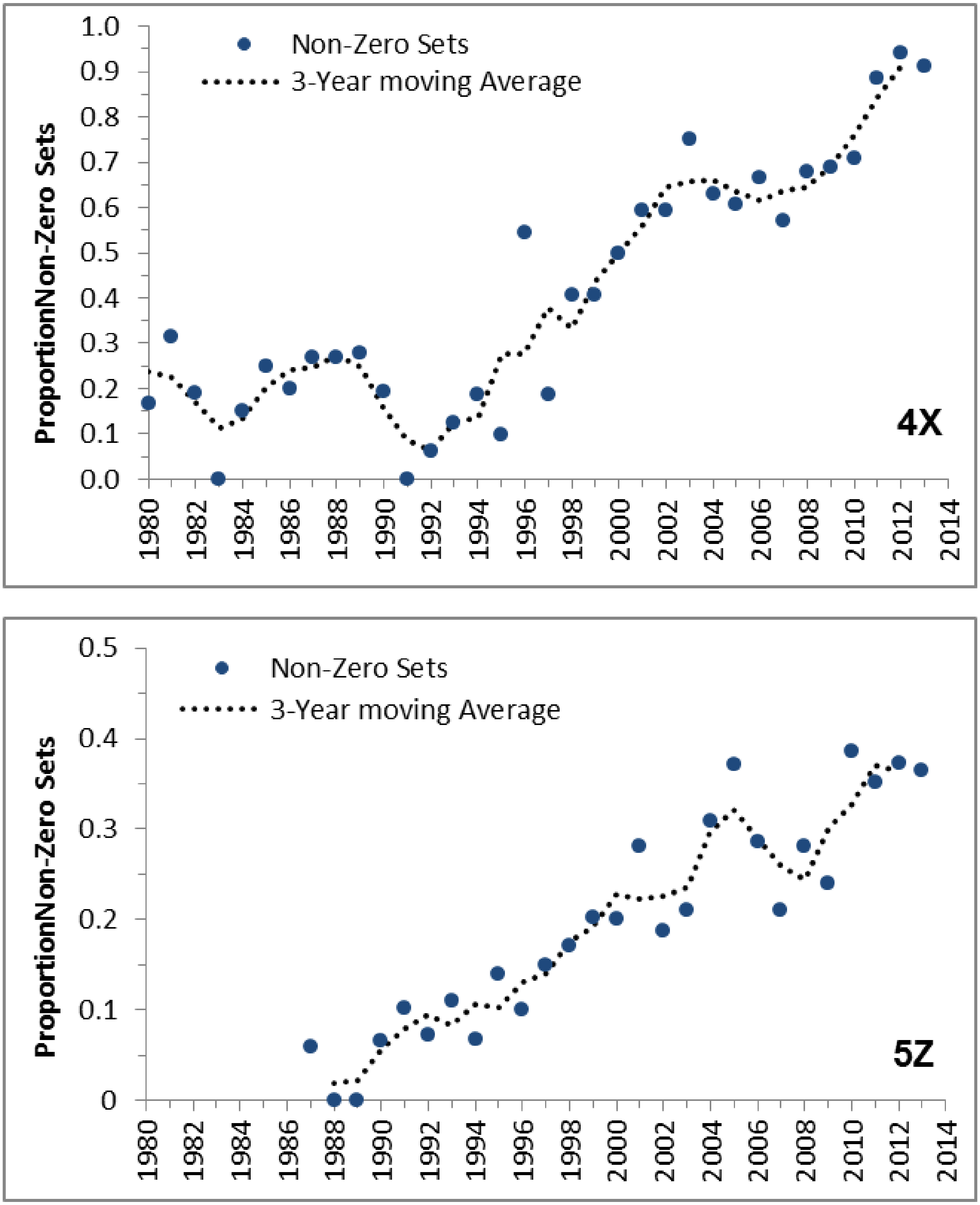

Figure 40. Proportion of non-zero sets in the DFO Maritime Region Summer RV trawl survey (upper panel) and Winter RV trawl survey (lower panel).

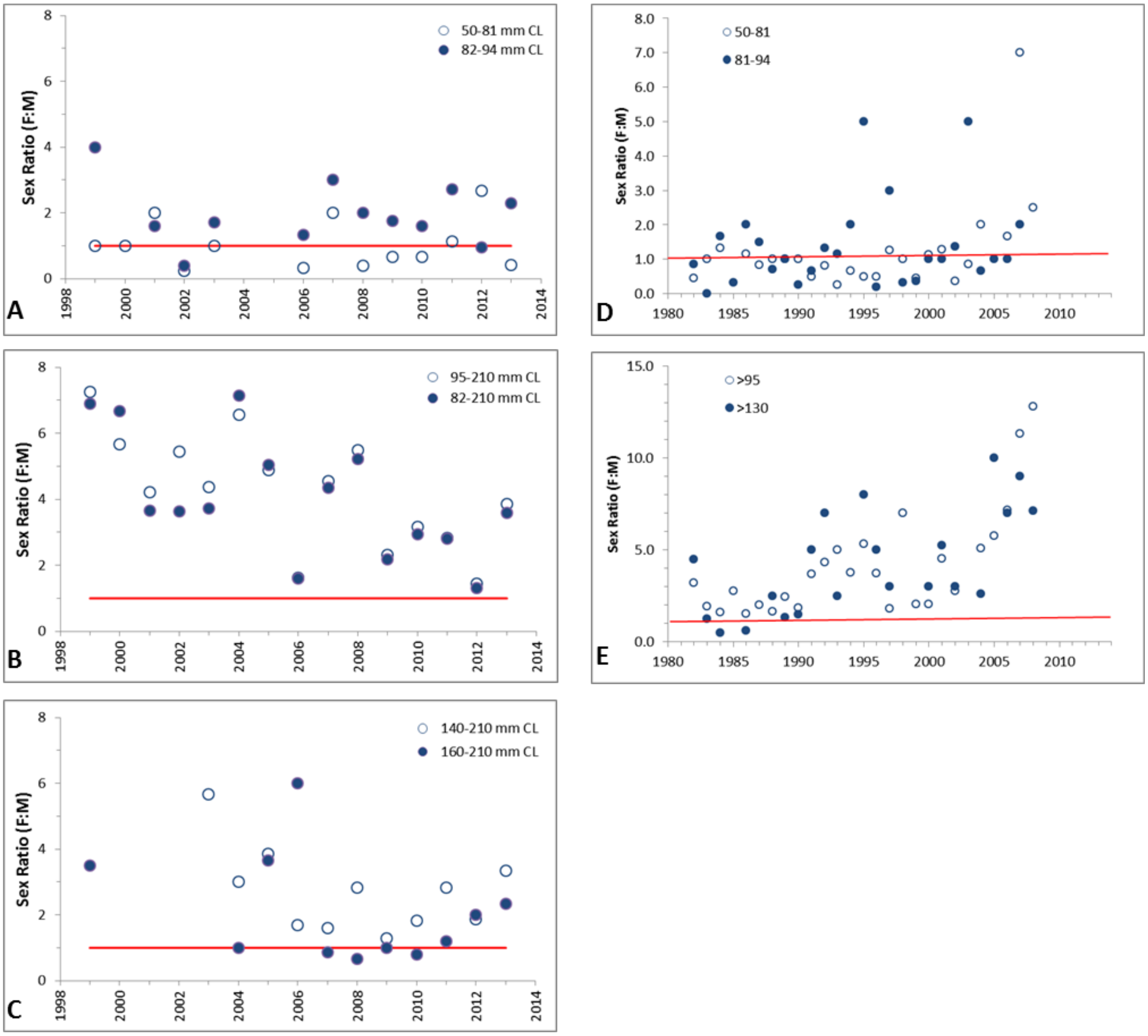

Figure 41. Sex Ratio (Female-to-Male) by size groups from the DFO Maritime Region RV Summer trawl survey (NAFO division 4X: A, B and C) and the U.S. NMFS Northeast Fisheries Center Fall RV Survey (NAFO division 5Z: D and E). Panels A and D (top two panels) depict the ratios for pre-recruits and newly-recruited sizes for NAFO divisions 4X and 5Z, respectively. Panel B represents the mature and legal sizes for NAFO division 4X (middle left panel), Panel C the large sizes for NAFO division 4X (lower left panel), and Panel E the mature and large sizes for NAFO division 5Z (middle right panel). The red line represents a 1:1 ratio.

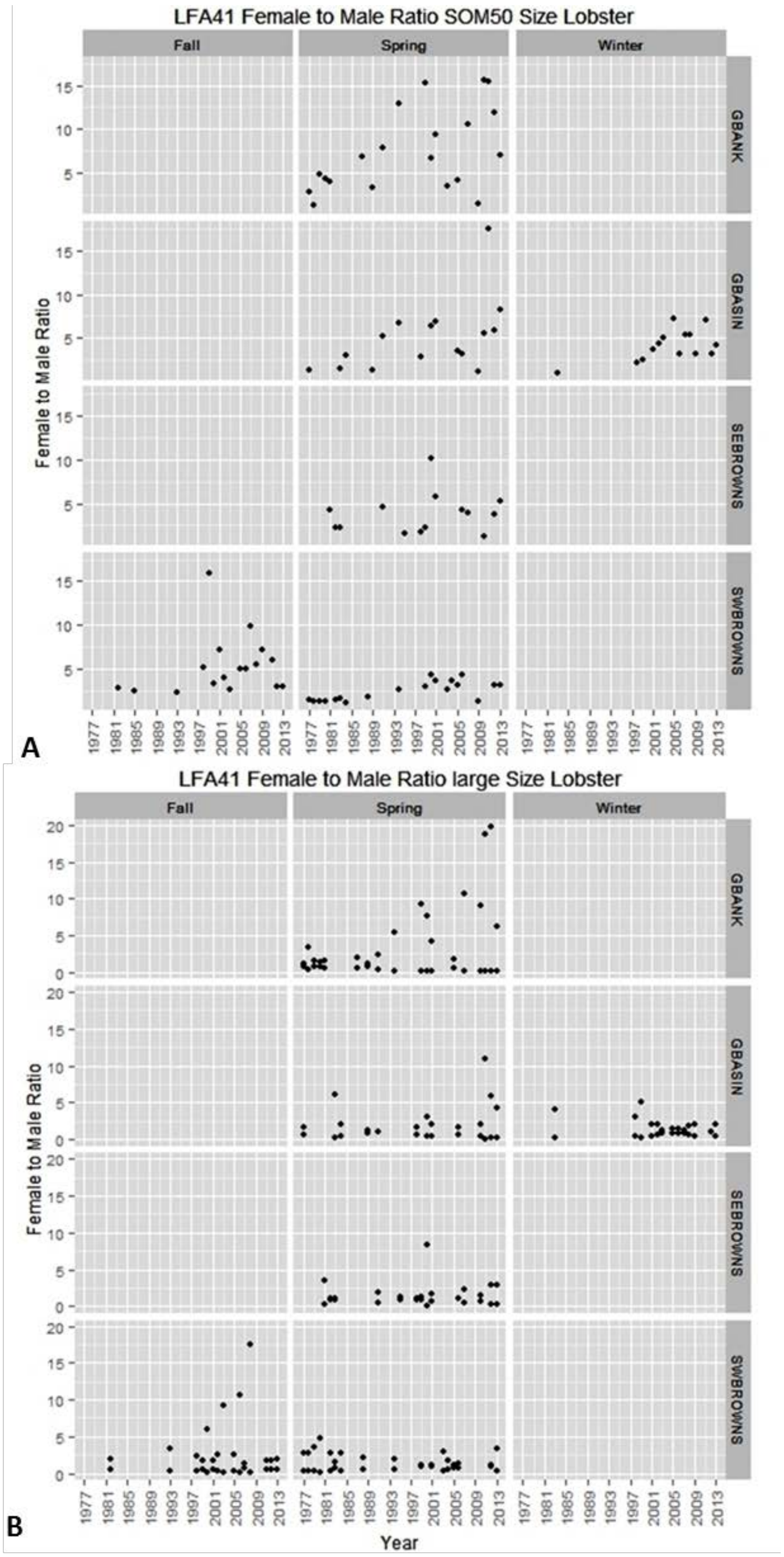

Figure 42. Sex Ratio (Female-to-Male) from at-sea samples by season and assessment areas: A) mature sizes >95 mm CL (upper panel); and B) large sizes >140mm CL (lower panel).

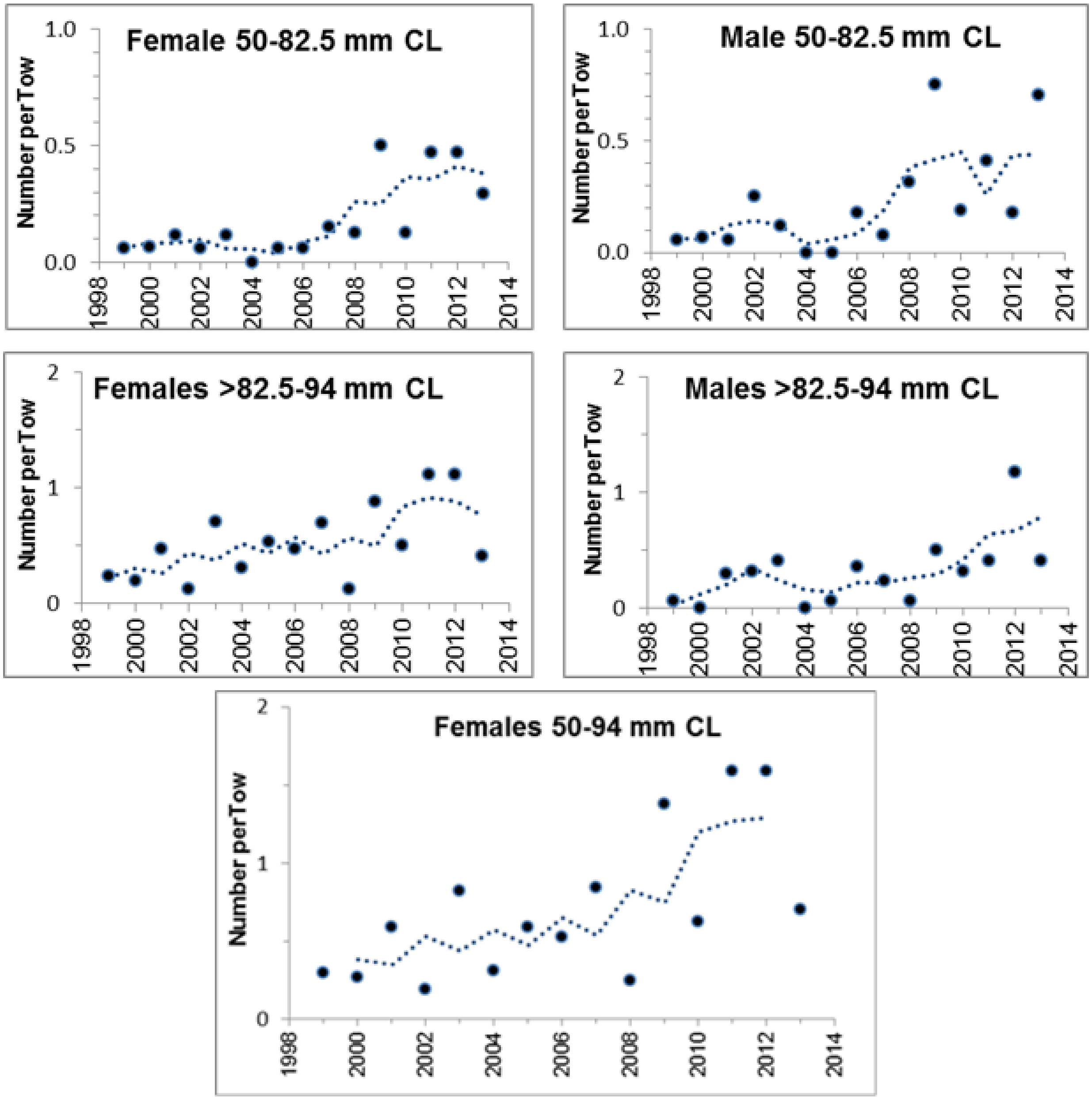

Figure 43. Number per tow of pre-recruits (50-82.5 mm CL) and newly recruited (>82.5-94 mm CL) females and males in the LFA 41 portion of 4X in the DFO Maritimes Region RV Summer trawl survey. Also shown is the number per tow for the sum of pre-recruit and recruit females (50-94 mm CL). Dotted line in each panel is the central moving average.

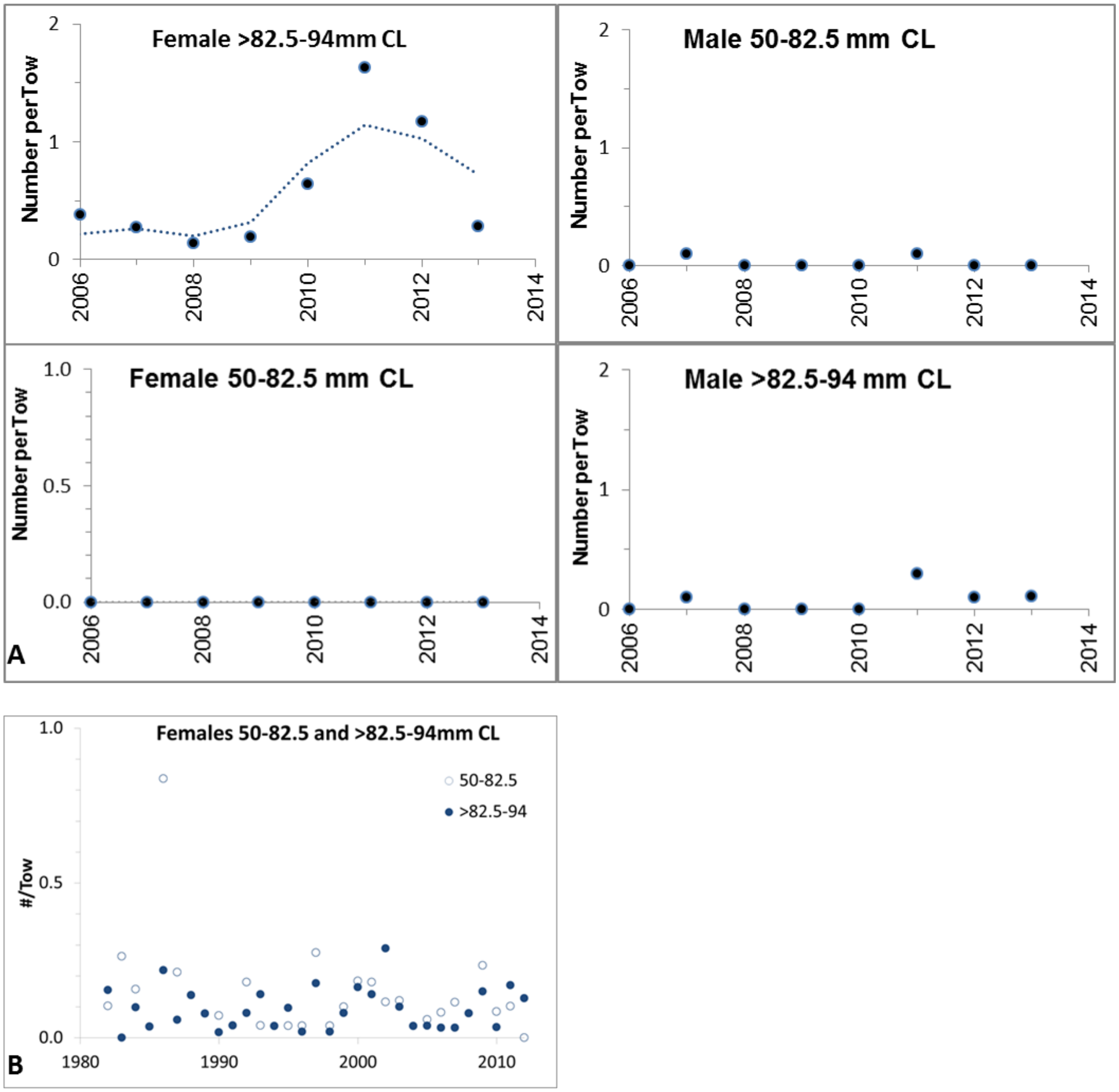

Figure 44. Number per tow of pre-recruits (50-82.5 mm CL) and newly recruited (>82.5-94 mm CL) females and males in the LFA 41 portion of 5Z from: A) the DFO Maritimes Region Winter RV trawl survey (upper four panels); and B) fall NMFS Northeast Fisheries Center RV survey in 5Z (Females only) (bottom panel). Dotted line is the central moving average.

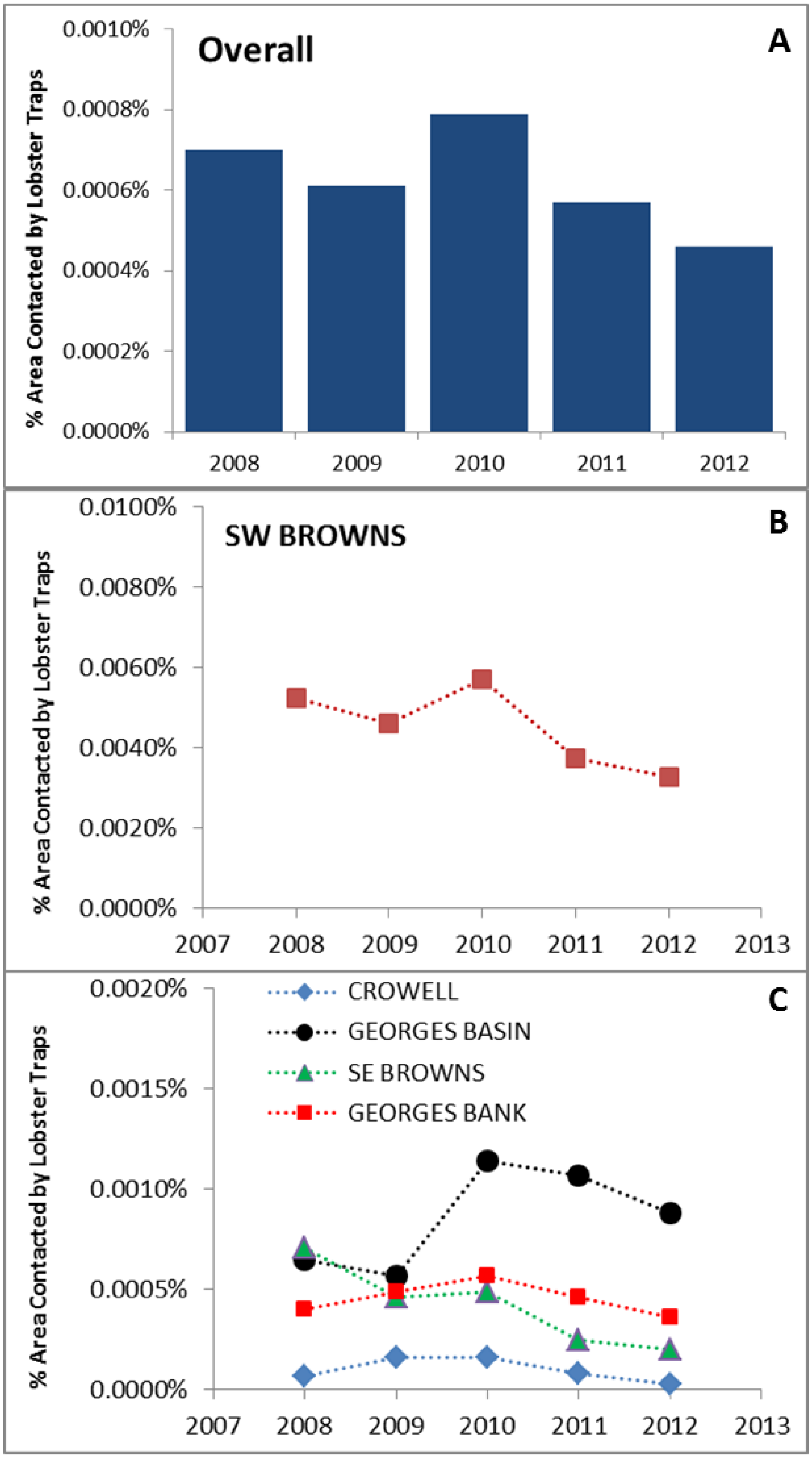

Figure 45. Estimated percentage area of LFA 41 contacted by lobster traps during a fishing year: A) Total (top panel); B) SW Browns (middle panel); and C) Crowell basin, Georges basin, SE Browns and Georges Bank (bottom panel).

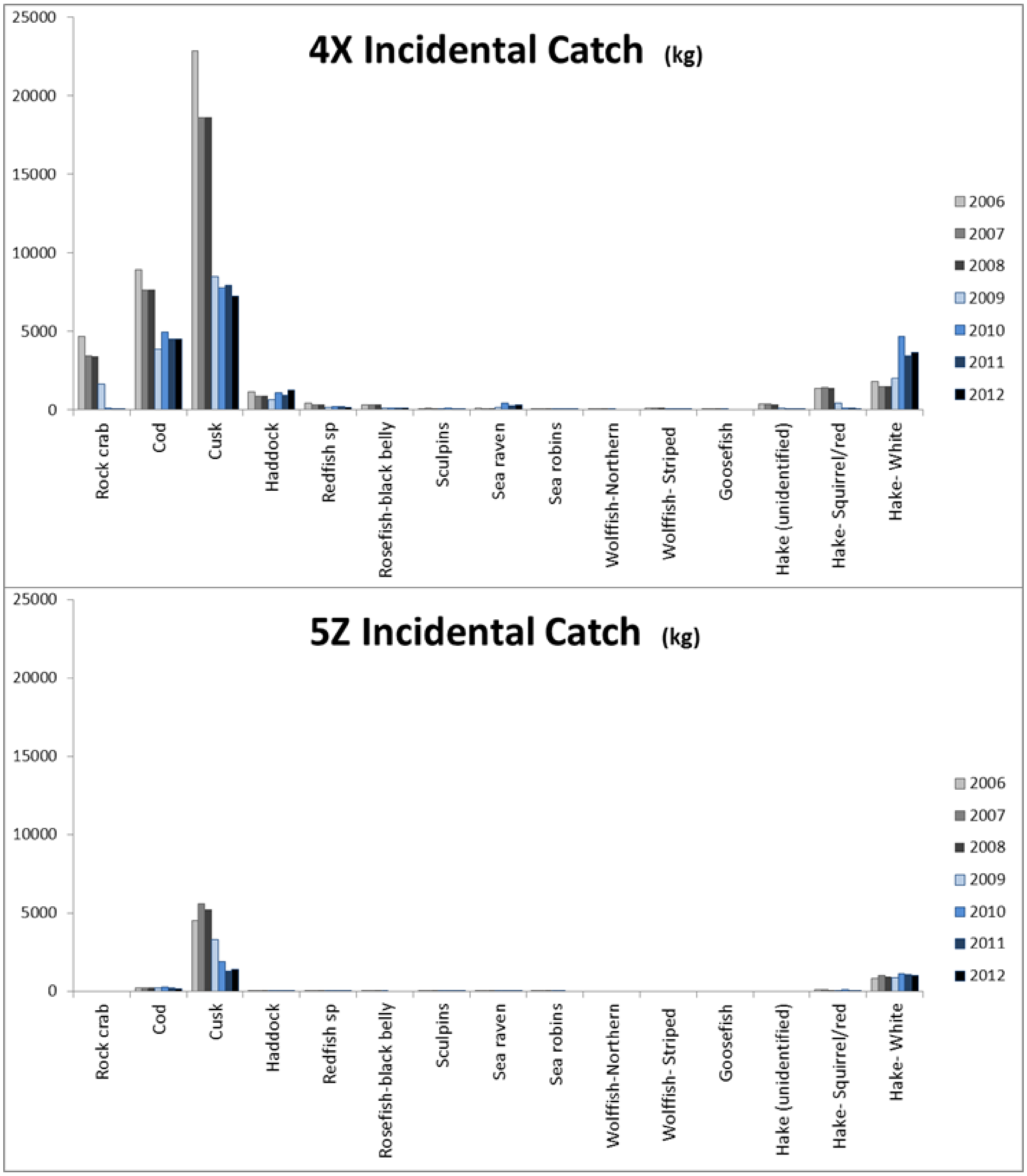

Figure 46. Estimated total incidental catch per year (kg) of all species from 2006 to 2012 (excluding Lobsters and Jonah Crab).

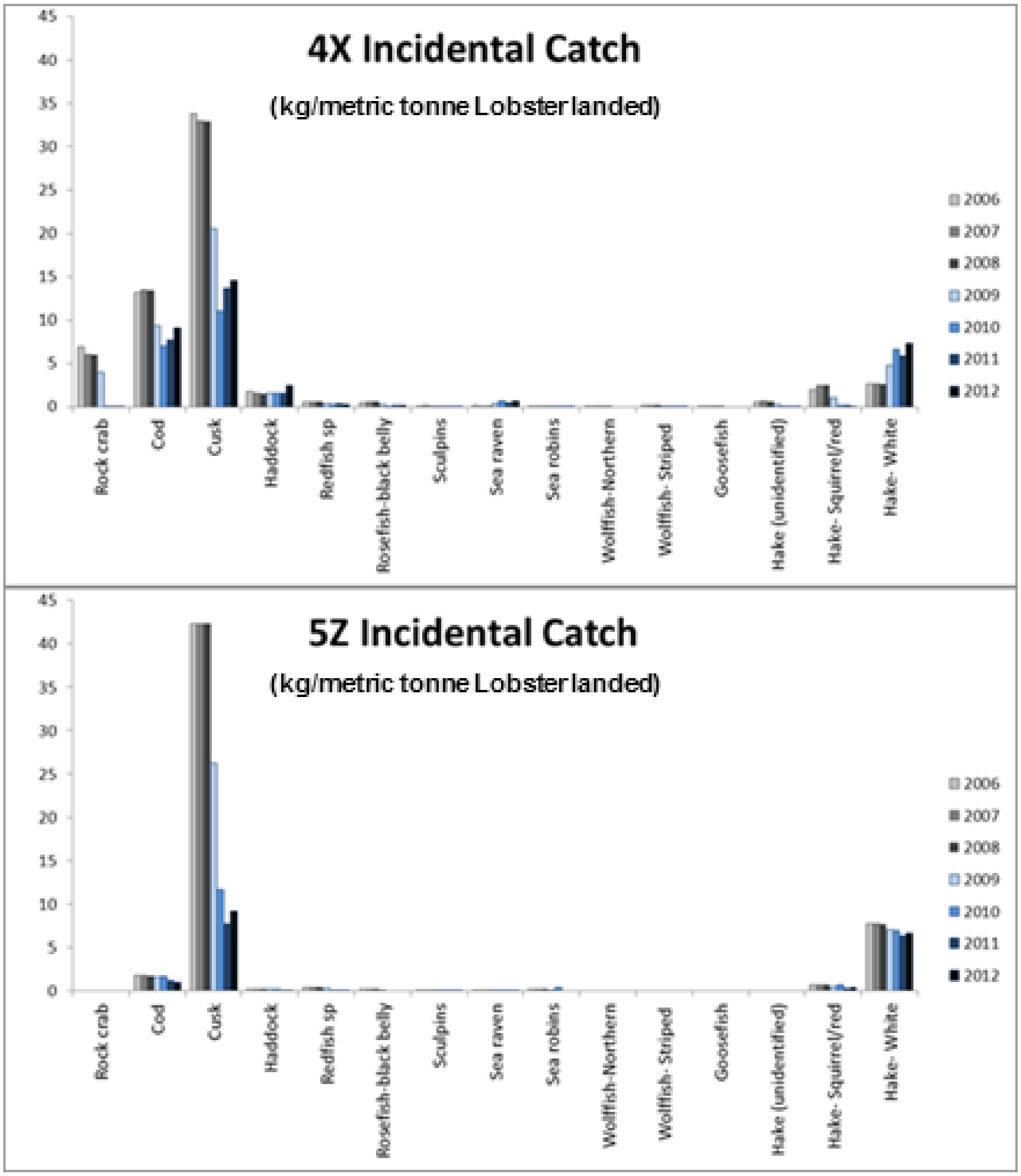

Figure 47. Estimated incidental catch rate (kg per metric tonne of lobsters landed) of all species from 2006 to 2012 (excluding lobsters and Jonah Crab).

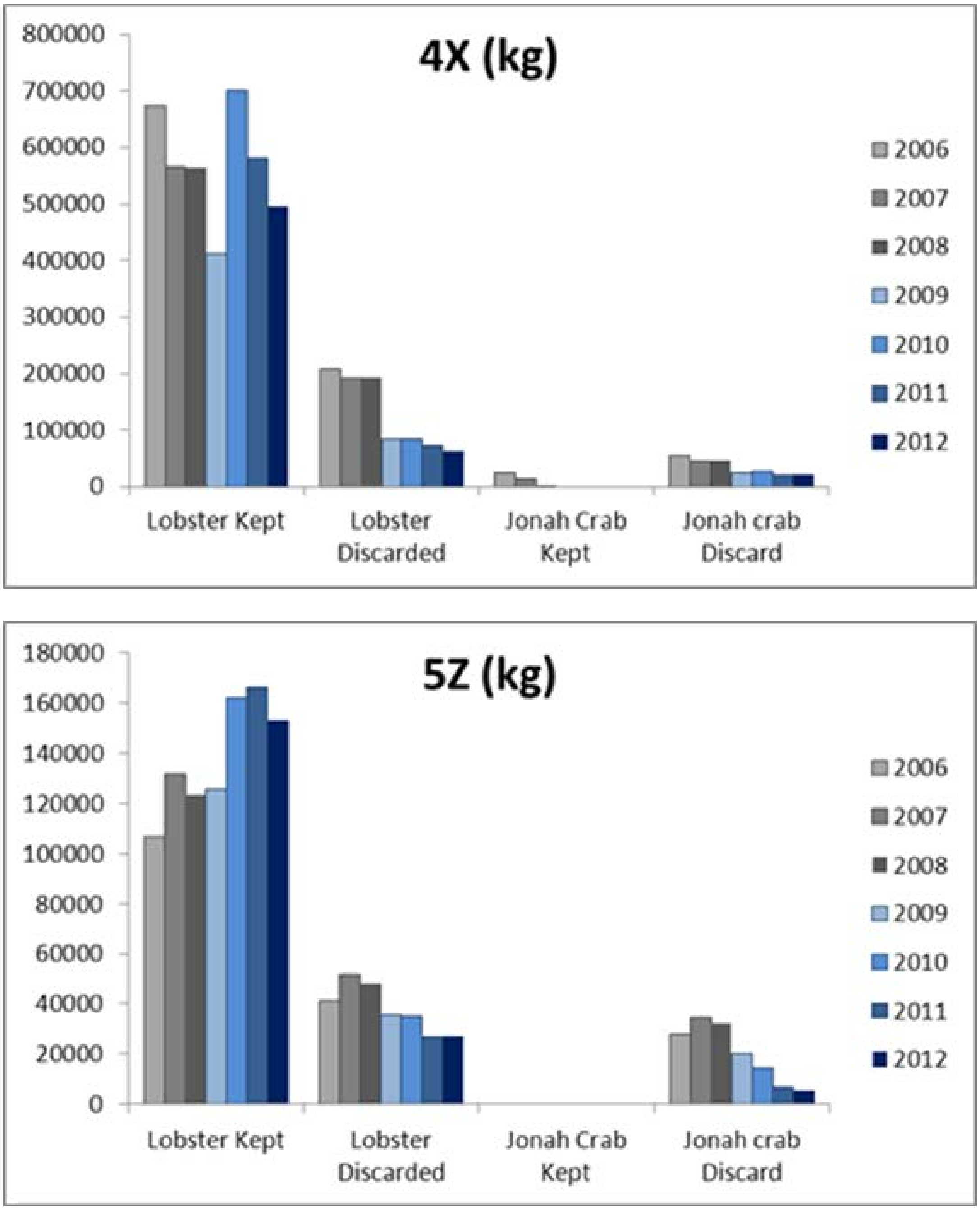

Figure 48. Estimated total catch (kg) of lobsters and Jonah Crab from 2006 to 2012 divided into those kept and those discarded.

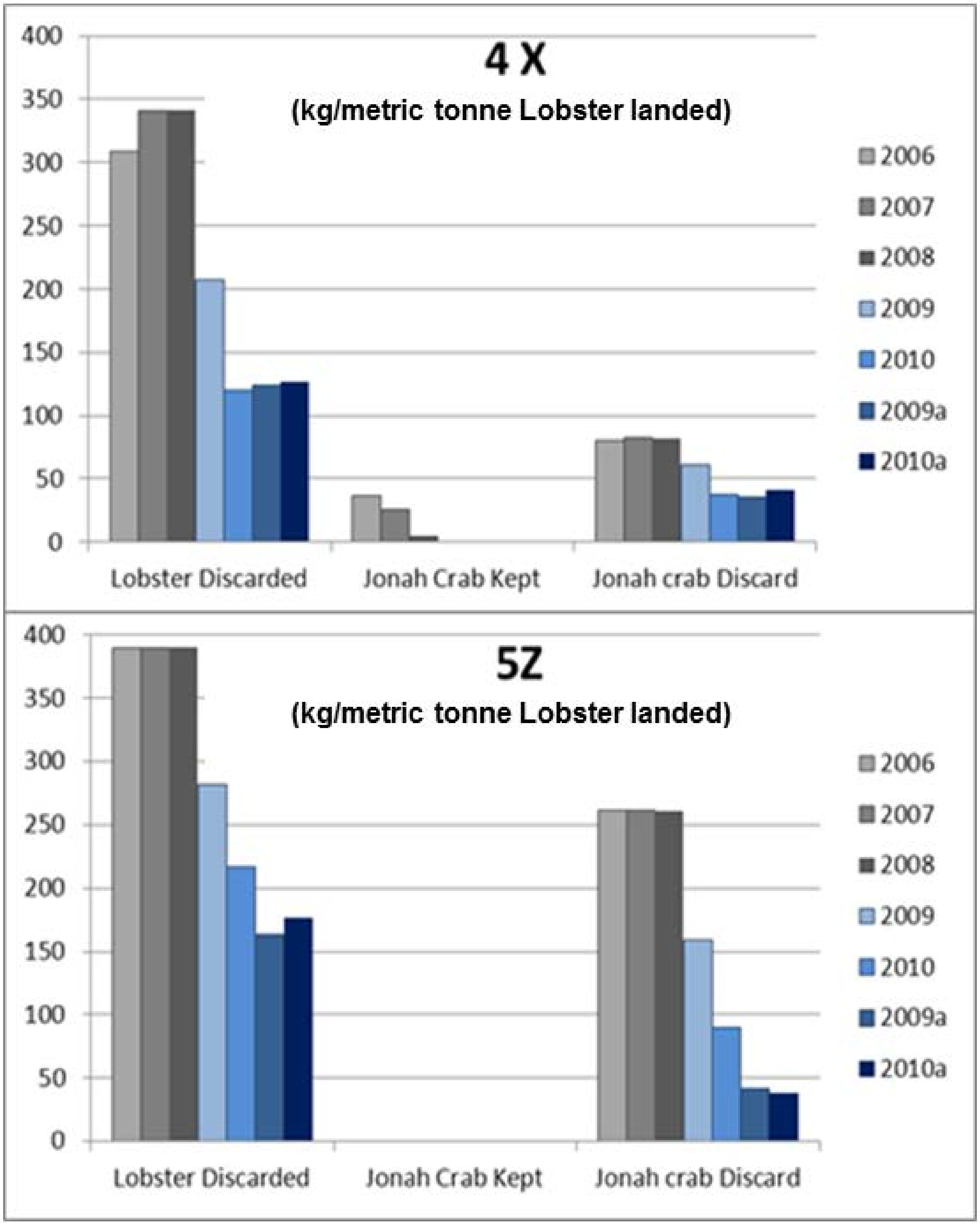

Figure 49. Estimated catch rate (kg per metric tonne of lobsters landed) of lobsters and Jonah Crab from 2006 to 2012, including those kept and those discards.

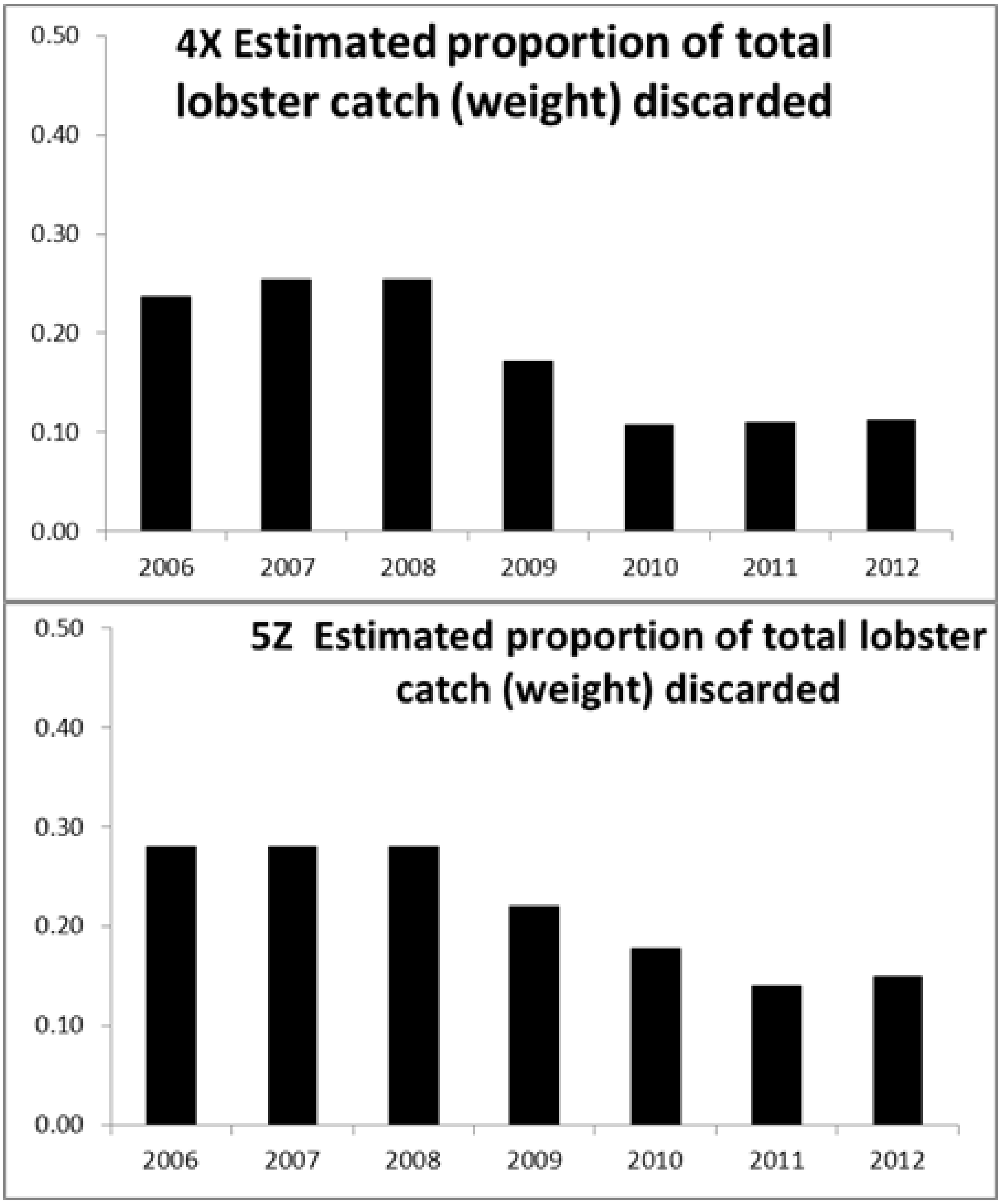

Figure 50. Estimated proportion of lobster catch discarded from 2006 to 2012.

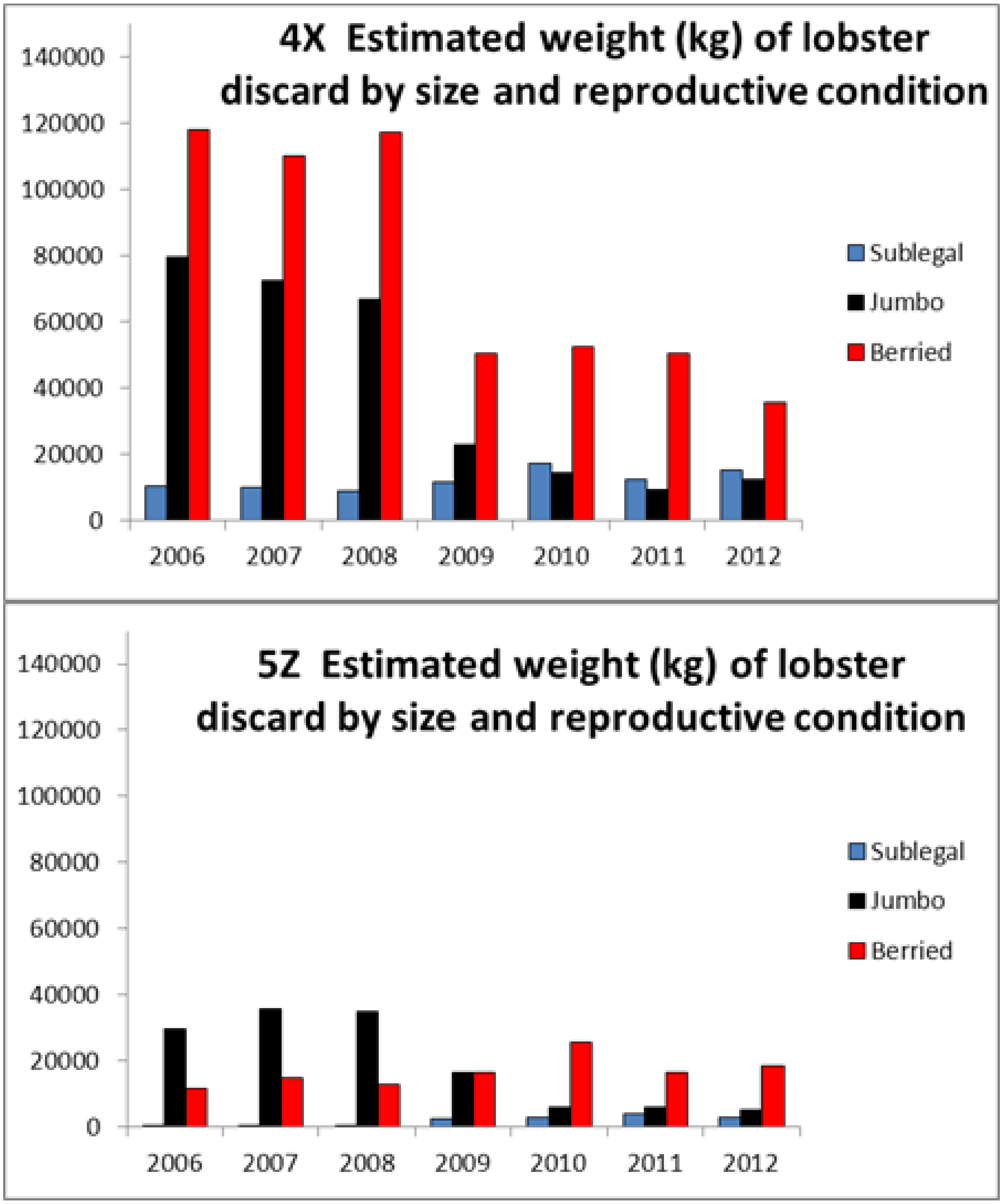

Figure 51. Estimated weight of lobsters discarded by size and reproductive condition from 2006 to 2012.

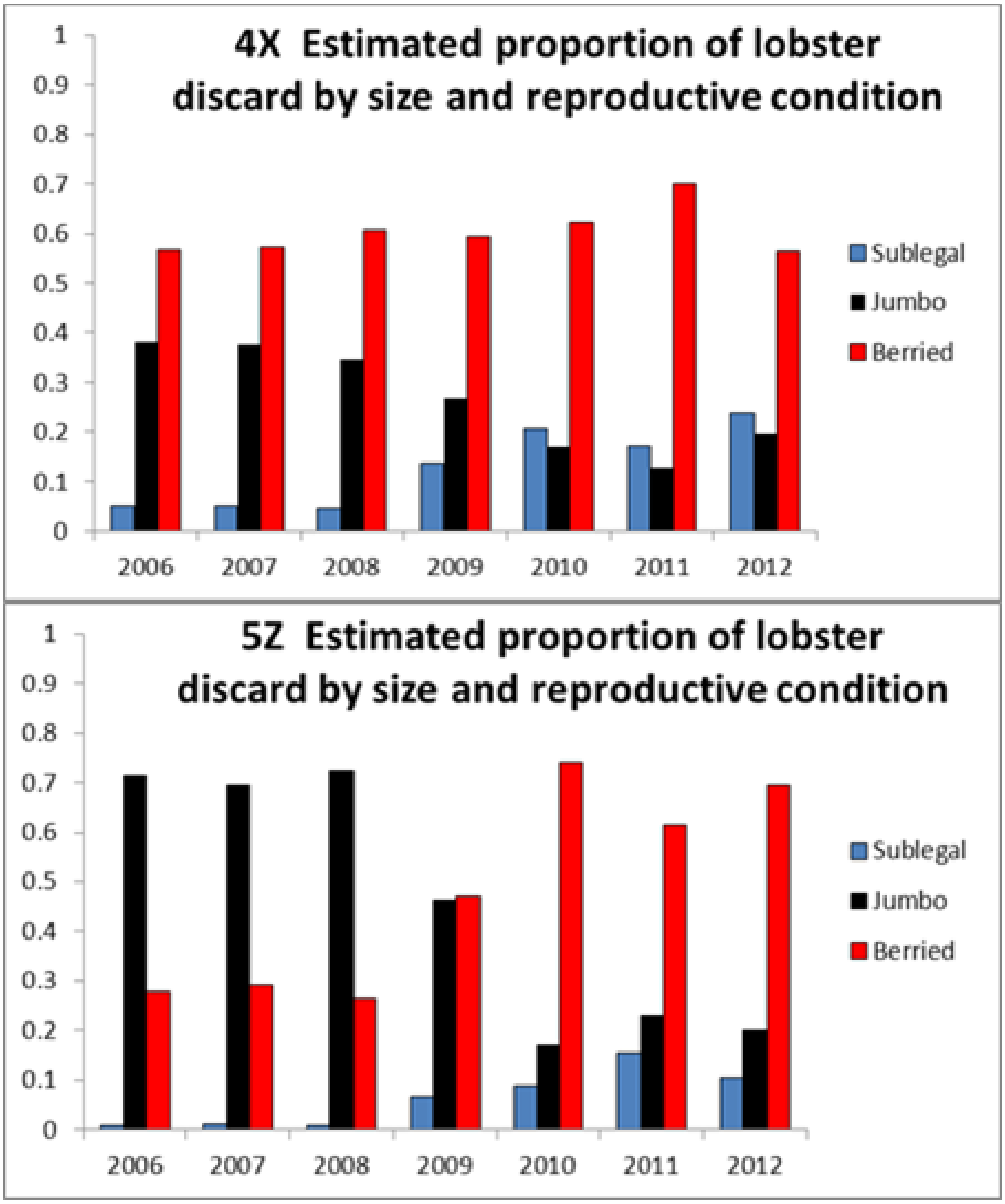

Figure 52. Estimated proportion of lobsters discarded by size and reproductive condition from 2006 to 2012.

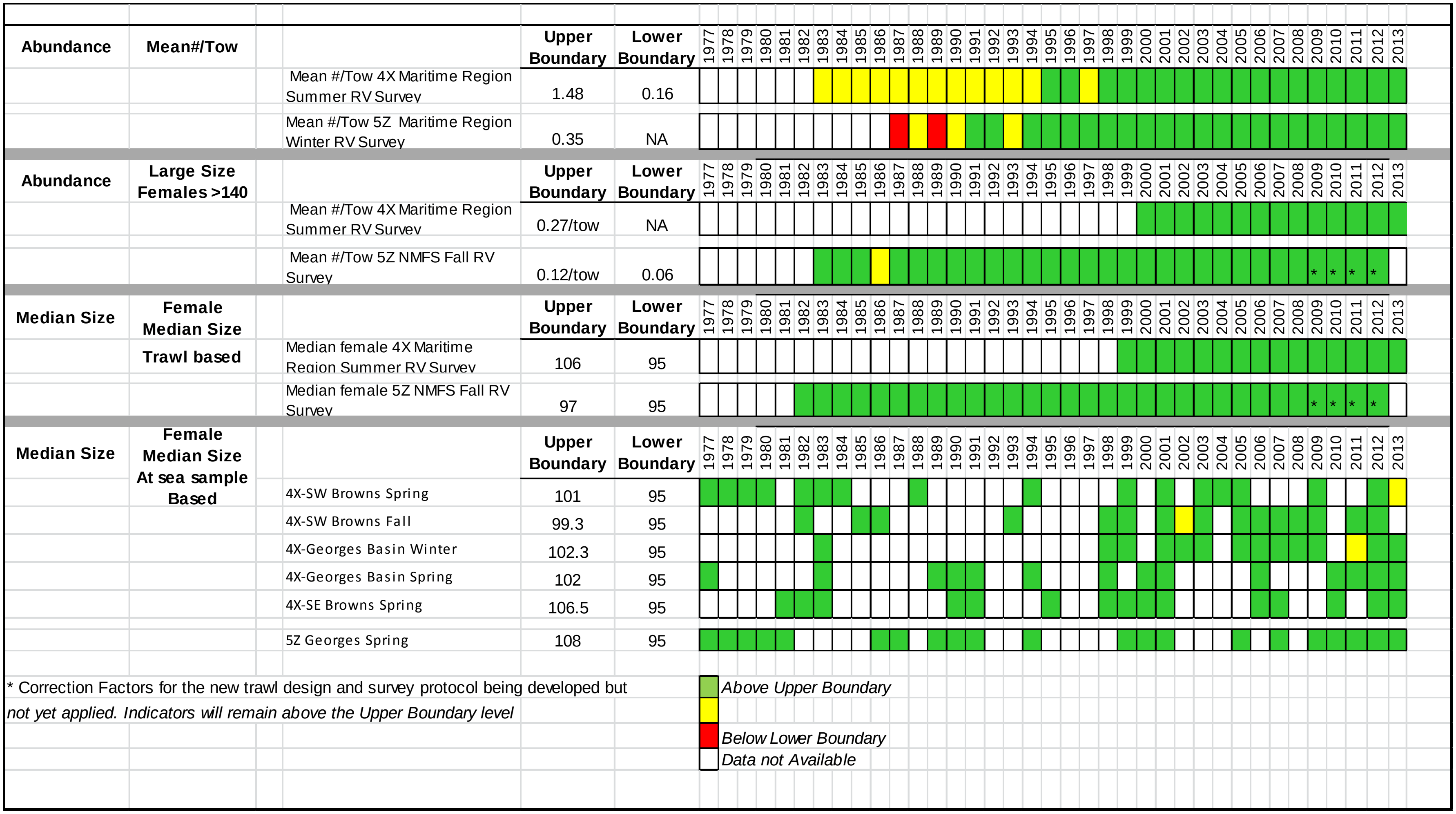

Figure 53. Traffic light display of the levels of the LFA 41 primary indicators relative to the boundary levels (green=above Upper Boundary; yellow=between Upper and Lower Boundaries; red= below Lower Boundary).