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Assessment of the American Lobster (*Homarus americanus*) Stock Status in the Southern Gulf of St. Lawrence (LFA 23, 24, 25, 26A and 26B)

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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.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

This document describes data and analyses used to produce the 2013 science advisory report on American lobster stock status for the southern Gulf of St. Lawrence (Lobster Fishing Areas 23, 24, 25, 26A and 26B) (DFO 2013). The assessment is based on indicators of stock abundance, fishing pressure, and stock productivity, which are compared with past values. Overall abundance of lobster in the southern Gulf of St. Lawrence remains at high levels with recent landings either well-above the long-term median values or at their peak in the time series. Only the central portion of the Northumberland Strait had low indicators of abundance and productivity. Catch-per-unit of effort (CPUE) for commercial-sized lobsters increased in most sub-regions. Trawl survey data shows increases in the distribution and abundance of commercial-sized lobsters in most areas, though the prevalence of null or small catches indicates low abundance in some areas of the Northumberland Strait. SCUBA survey data suggests that overall lobster abundance has steadily increased between 2000 and 2012 but this contrasts with trends within the central Northumberland Strait. Productivity indicators are generally positive or stable though uncertainty remains as no recent data are available for some areas. Except for the central Northumberland Strait, berried female CPUEs from at-sea sampling data increased in 2012 compared to the 2007 assessment. SCUBA data from Caraquet (NB) show a similar increase. These may be the result of increases in the minimum legal size (MLS) over the last few years. Pre-recruit lobsters (those below the MLS) increased except for the central Northumberland Strait. Data from both the recruitment index program and the bottom trawl survey confirms the low abundance of pre-recruit lobsters in the central Northumberland Strait. The indicator for one-year-old lobsters is also low in the central Northumberland Strait compared to other regions surveyed. The lobster stock status is positive in most Lobster Fishing Areas of the southern Gulf. The central Northumberland Strait presents a special concern due to its very low annual recruitment and high fishing pressure. Additional conservation measures aimed at increasing egg production and lowering fishing effort could be considered.

Évaluation de l'état des stocks de homard (*Homarus americanus*) pour le sud du golfe du Saint-Laurent : ZPH 23, 24, 25, 26A et 26B

RÉSUMÉ

Le présent document décrit les données et analyses ayant servi à produire l'avis de 2013 sur l'état des stocks du homard pour le sud du golfe du Saint-Laurent (Zones de pêches du homards 23, 24, 25, 26A et 26B) (MPO 2013). L'évaluation de l'état des stocks repose sur des indicateurs relatifs à l'abondance du homard, la pression de pêche et la productivité des stocks qui sont comparés à des données existantes. De façon générale, l'abondance du homard dans sud du golfe du Saint-Laurent continue d'être à des niveaux élevés. Les débarquements récents sont soit bien au-dessus des valeurs médianes à long terme ou bien les plus élevés de la série de données. Seule la région centrale du détroit de Northumberland (Détroit) démontre des indicateurs d'abondance et de productivité négatifs. Les prises par unité d'effort (PUE) des homards commerciaux ont augmenté dans la majorité des sous-régions. Les données provenant du relevé au chalut montrent une augmentation de la distribution et de l'abondance des homards de taille commerciale dans certains endroits du Détroit. Cependant, une faible abondance de homard dans certaines régions du Détroit est mise en évidence par une répétition de captures quasi nulles au fil des ans. Les données des relevés en plongée sous-marine suggèrent que l'abondance du homard a progressivement augmentée entre 2000 et 2012 ce qui contraste avec les observations du centre du Détroit. Les indicateurs de productivité démontrent une situation globalement positive ou stable mais dans certaines sous-régions l'incertitude persiste faute de données. Exception faite du centre du Détroit, les PUE de femelles œuvées basées sur l'échantillonnage en mer ont augmentées en 2012 par rapport à l'évaluation de 2007. Les données des relevés en plongée sous-marine dans la région de Caraquet (N.-B.) confirment cette augmentation. Ces observations pourraient découler des différents accroissements de la taille minimale légale (TML) ces dernières années. L'abondance des homards prérecrues (sous la TML) a aussi augmenté sauf dans le centre du Détroit. À cet endroit, les données du programme d'indice de recrutement et des relevés au chalut confirment la faible abondance des homards prérecrues. L'indicateur d'abondance des homards d'un an est aussi négatif dans le centre du Détroit alors qu'il est positif dans les autres régions examinées. Dans l'ensemble, la situation du homard est positive dans la plupart des zones de pêche au homard du sud du golfe. La situation préoccupante du centre du détroit de Northumberland résulte vraisemblablement d'un faible recrutement annuel et d'une pression de pêche élevée. Des mesures additionnelles visant à favoriser la production d'œufs et réduire l'effort de pêche pourraient être envisagées.

1 INTRODUCTION

The last assessment of the American lobster (*Homarus americanus*) stock for the southern Gulf of St. Lawrence (Lobster Fishing Areas 23, 24, 25, 26A, and 26B) took place in 2007 (DFO 2007; Comeau et al. 2008). The present research document updates management measures and catches for the lobster stock since the last assessment. Indicators of stock status to the 2012 fishing year are provided and the associated science advice is provided in DFO (2013a).

Similar to other regions in Atlantic Canada, the lobster assessment in the southern Gulf of St. Lawrence (sGSL) relies on a suite of fishery-dependent (landing statistics, logbooks, and at-sea sampling programs) and independent (trawling, SCUBA surveys, and bio-collectors) indicators. Information on abundance, population dynamics, and productivity of the stock as well as on fishing pressure is derived from these indicators. Also, environmental data (e.g., temperature) are used to obtain better knowledge of the ecosystem-based parameters that could affect the lobster stock.

1.1 FISHERY MANAGEMENT

The lobster fishery in the sGSL has developed over more than a century as a near-shore small-boat fishery, involving a large number of harvesters using only lobster traps as fishing gear (DeWolf 1974). The lobster fishery is presently the most important resource in Eastern Canada with total landings of 66,500 t in 2011 (preliminary data) valued at around $620 million (DFO 2012). The total value of this resource, however, peaked in 2005 at over $684 million for landings of 50,721 t (DFO 2012).The DFO-Gulf Region is responsible for lobster fisheries that operate in all three Maritimes Provinces (i.e. New Brunswick (NB), Nova Scotia (NS), and Prince Edward Island (PEI)). The lobster fishery in the sGSL is managed entirely by effort control (input fishery; Table 1). The four most important measures in controlling effort are the limited entry of lobster fishing licences, individual trap allocation, restrictions on gear characteristics, and a fixed fishing season. Starting in 1934, the fishing activities were also limited by Lobster Fishing Area (LFA; (Figure 1). In addition to those management controls, other measures were implemented to protect key components of the lobster population. Lobsters can only be retained if they comply with a minimum legal size (MLS) designed to allow some females to reach sexual maturity before being harvested. Egg-bearing female lobsters must also be released.

In the last two decades, increases in MLS have been aimed at supporting egg production as recommended in two reports by the Fisheries Resource Conservation Council (FRCC 1995; 2007). In the second report, the FRCC recommended setting the MLS at the size corresponding to the onset of sexual maturity for females (i.e., size at which 50% of females are mature; SOM_{50}) allowing for more primiparous females (i.e., first time spawners) to reproduce before becoming available to the fishery (FRCC 2007). The objective of reaching SOM_{50} has already been met in some LFAs or will be by the 2013 fishing season for the entire sGSL. Another measure to increase egg production implemented in 2003 was the mandatory release of window-size (115-129 mm) females. In 2004, the window-size female regulation was replaced by a maximum legal size of 114 mm of carapace length (CL) for females in LFA 25 (Comeau et al. 2008).

In both reports, the FRCC also concluded that exploitation levels were too high and that fishing effort needed to be reduced. Proposed measures for reducing exploitation rates included reducing the number of licences, the number of traps per licence, the total number of trap hauls or the length of the fishing season (FRCC 1995). In contrast to other measures which were implemented in two multi-year conservation plans (1998-2001, 2003-2005) by fisheries managers after extensive consultations with the fishing industry to increase egg production (Comeau et al. 2008), no significant measures were put in place to reduce effort.

In June 2009, DFO announced the Atlantic Lobster Sustainability Measures contribution program (ALSM) to provide financial aid ($50M) for the Canadian lobster industry, mainly harvesters (DFO 2009a). The establishment of the ALSM was motivated by substantial price declines in 2008 (18%) compared with 2007 (the decline from 2008 to 2009 was a further 17%; DFO 2012) caused by the global economic and financial crisis. The objective of the ALSM was to provide support for the development and implementation of lobster sustainability plans to help the industry make changes which would enhance its economic prosperity (through self-rationalization) and long-term sustainability. To access funding, harvester associations had to first submit an LFA-wide sustainability plan that would:

- improve biological productivity (MLS at or above SOM_{50} or an equivalent),
- provide reliable reporting of landing data, and
- reduce ecosystem impacts.

Upon approval of the sustainability plan by DFO, harvester associations within the LFA applied for the second stage of the program, by submitting a request to DFO for partial funding (between 20%-50% depending on incomes and landings) for specific projects, which mainly consisted of effort reduction through buyback (reducing the number of harvesters) or reduction of the number of traps.

1.1.1 Lobster Fishing Areas (LFAs)

From 1934 to 1985, the sGSL lobster fishery was partitioned in four zones: 7B, 7B1, 7C, and 8. These zones were then renamed in the mid-1980s to LFAs 24, 26, 23, and 25 respectively. LFAs were established to support management of the lobster resource within specific geographic areas. In 1987, LFA 26 was further divided into 26A and 26B. Starting in 1995, harvester groups within LFA 26A wanted to implement different management measures within their lobster fishery and so “sub-areas” were created. By 2008, LFA 26A had one sub-LFA, 26A-2, and two management zones, 26A-1 and 26A-3 (Fig. 1). A sub-LFA defines a portion of a LFA where lobster fishing activities must occur, where the number of lobster licences is capped to a maximum, and has licence conditions which are specific to that sub-LFA. A regulatory amendment is required to redefine the LFAs and in the interim, licence conditions are to be used. Conversely, a management zone accommodates differences in management measures and no licence conditions are required. Starting in 2008, changes were made to other LFAs. LFA 23 was divided into three sub-LFAs, 23A and 23B within Baie des Chaleurs, and 23C on the Gulf-side. The following year, sub-LFA 23C was further divided in two, with the southern part becoming sub-LFA 23D (Fig. 1). LFA 26B was also divided in two management zones, 26B north and 26B south, in 2008. Different management measures are implemented within each of these sub-LFAs and management zones (Table 1).

Since LFAs were not established based on biological characteristics of lobster populations but rather for management, they often encompass different habitats and oceanographic regimes. Assessing the lobster fishery based solely on existing management divisions might not adequately reflect the status of the lobster populations and/or the fishery itself. Therefore, for the purpose of this assessment and as per the previous stock assessment (Comeau et al. 2008), LFAs were divided in nine sub-regions (Fig. 2) to better reflect either lobster biological characteristics or fishery aspects. LFA 23 was sub-divided in two zones; LFA 23BC that encompasses all of Chaleurs Bay and corresponding to the new sub-LFAs 23A and 23B (Fig. 1) and LFA 23G corresponding to sub-LFAs 23C and 23D, outside the bay. LFA 25 has also been divided in two sub-regions as was the case in the last assessment (Comeau et al. 2004). LFA 25N refers to the northern part west of the Northumberland Strait neck (narrowest part of the western Strait near West Point) and LFA 25S is the southern part. LFA 26A was divided in three distinctive sub-regions. LFA 26AD refers to the part of LFA 26A located in the Northumberland

Strait west of Pictou Island: LFA 26APEI includes all wharves from the eastern side of PEI, and LFA 26ANS includes mainland NS east of Pictou Island.

1.1.2 Number of fishing licences

There are two types of licence holders in the Gulf region: individual (bona fide) and communal (assigned to Aboriginal groups). There are three sub-types of bona fide licences. Type-A bona fide licences have a full trap allocation (similar for communal). Type-B bona fide licences have approximately one-third of the trap allocation for a given LFA and partnership. Partnerships consist of the combination of two active licences and 75% of the total trap allocation from the two licences, fished from a single vessel. In contrast to type-A bona fide or communal licenses, type-B licences are non-transferable and are removed permanently when the licence holder ceases fishing.

Following the introduction of limited access to the lobster fishery in 1967, the number of licences remained fairly stable until 2006 (Comeau et al. 2008). The number of licences for the sGSL (DFO Gulf Region) has decreased by 9.1% from 3,248 licences in 2006 to 2,953 licences in 2012 (Table 2). Based on the last management plan, an additional 12 licences will be removed in 2013. The reduction of licences between 2006 and September 2009 was accomplished through industry-funded retirement initiatives, while the second stage of withdrawal came from the ALSM program under the restructuring and rationalization category (DFO 2009a). The change in the number of licences is used as a fishing pressure indicator.

1.1.3 Trap allocation

The number of traps allowed per type-A fishing licence in the sGSL was stable until 2006, except in LFA 23 where the number of traps was reduced from 375 to 300 between 1998 and 2000 (Comeau et al. 2008). For spring fisheries, a trap reduction was observed in LFAs 26A and 26B while the allocation remained at 300 traps per licence in LFAs 23 and 24 (Table 3). Prior to the announcement of the ALSM program in September 2009, harvester groups from sub-LFA 26A-2 and management zones 26B north and south voluntarily reduced the trap allocation for bona fide licences from 300 to 275 (Table 3) in an attempt to reduce fishing effort. Later, with funding from the ALSM program, other trap reductions were implemented for the 2011 fishing season. In management zone 26A-1, the allocation was reduced by 20 traps and then by a further 7 traps for the PEI side in 2012 (Table 3). Trap allocations were set at 250 traps in management zones 26A-3, 26B-north, and 26B south in 2011. In LFA 25, the trap allocation was decreased by ten traps, from 250 to 240, but only by PEI harvesters.

Trap allocations for type-B licences did not change with 90 traps in all LFAs except LFA 25 at 75 traps. Trap allocations for partnership licences equal 75% of the combined allocations for the two type-A licences (e.g., 450 traps would be allocated for a partnership licence in LFA 23).

1.1.4 Fishing gear restrictions

The only gear for fishing lobster in eastern Canada is the lobster trap. Trap dimensions and design have changed and evolved through time and the arrival of hydraulic haulers on fishing vessels allowed the use of larger lobster traps. However, the majority of traps currently in use are still under the maximum allowable dimensions of 125 x 90 x 50 cm (length, width, height). Building material (wood, metal, or a combination of both) and trap's shape (rectangular or bow) have changed over time as well as the number of entrances and parlours, the offsetting and inclination of the entrances, and the increase of the entrance's hoop ring diameter. A maximum hoop ring diameter (152 mm) was implemented in LFA 23 in 1995 followed by LFA 25 in 2006. In 2009, sub-LFA 26A-2 adopted the same hoop ring diameter and management zone 26B north followed in 2011 (Table 1).

Conservation measures were implemented to minimize indirect fishing mortality and waste by allowing sub-legal animals to avoid capture and ensuring that lost traps will not keep fishing. These regulations stipulate that each trap must be fitted with both escape vents and biodegradable mechanisms. The escape vent consists of an opening, near the base of the trap, allowing sub-legal size lobsters to exit the trap before it is hauled to the surface. These vents are installed in the parlour section of the traps (section with no entrance from the outside). Since 1996, all traps must be equipped with a rectangular escape mechanism and the dimensions of its opening are regulated according to the MLS in each LFA/sub-LFA/management zone. Changes in MLS were followed by adjustments to the escape vent dimensions in subsequent years (Comeau et al. 2008). The biodegradable mechanism consists of a portion of the trap wall that can detach or decompose if the trap is lost at sea, leaving an unobstructed opening of at least 89 mm high and 148 mm wide. Because roughly 3% of the traps in use in the sGSL are lost at sea annually (Lanteigne 1999), the purpose of this measure is to reduce the unwanted mortality through ghost fishing on marine animals including lobsters. The biodegradable mechanism conservation measure was implemented in 1995 and modified in 2012 to increase its efficiency. Only untreated cotton twine with a diameter < 1.5 mm can now be used for biodegradable mechanism.

1.1.5 Fishing seasons

There are two distinct lobster fishing seasons in the sGSL; the spring fishery (LFAs 23, 24, 26A and 26B) that take place mostly during the months of May and June, and the summer fishery (LFA 25) generally operating from August 10^{th} to October 10^{th}. The later season is often referred to as the “fall” fishery despite most of the lobster being caught before mid-September. Generally, the spring season start and end dates are the same from year to year (from May 1^{st} to June 30^{th}; harvesters set their traps on April 30^{th}) but a change was brought about in management zone 26B north since 2009. Harvesters decided to start their season the first Saturday of May (except on April 30^{th} in 2011). Also, harvesters from LFA 23 requested and were authorized, for 2010 only, to shift their fishing season a few days earlier but for the same total duration (from April 26^{th} to June 27^{th}).

1.1.6 Minimum legal size (MLS)

Numerous changes in MLS were implemented since the 1900s in sGSL. The most prominent one was the MLS of 63.5 mm imposed in 1957 (Table 4). Between 1987 and 2012, the MLS increased in the sGSL at different rates among LFAs, either from voluntary initiatives or as conservation measures. The MLS is fixed primarily to allow a sufficient number of mature animals to spawn at least once and produce offspring to ensure a sustainable recruitment (i.e., egg production). The minimum level of protection for primiparous (first time spawning) females has been chosen to be the size at 50% maturity (SOM_{50}). For most LFAs, that size corresponds to a carapace length (CL) of 72 mm, while it is 75 mm in LFA 26B. Since the last assessment, some LFAs, sub-LFAs and management zones have reached that target or above. In the announced management plan for 2013 (Table 4), as part of the ALSM program, all remaining areas will require a MLS at SOM_{50} or above, meaning that LFAs 24 and 25, sub-LFAs 23D and management area 26A-1 will move from 71 mm to 72 mm.

1.1.7 Window-size and maximum size females

The overall steady decline of lobster landings in the sGSL after the historical highs of the late 1980s - early 1990s prompted the implementation in 2003 of a new conservation measure aimed at protecting the larger brood stock to enhance egg production. At that time, egg production was considered to be low since females were harvested at a size smaller than the SOM_{50}. As a counter measure, all female lobsters with a CL between 115 and 129 mm (window-size) were to be returned to the water. This conservation measure still applies in all spring fisheries except in

LFA 26B where the MLS is at least 79 mm of CL (Table 4), a size at which almost all primiparous females are protected and should participate in egg production. As a result, the requirement to return window-size females to the water was dropped in 2010 and 2011 in management zones LFA 26B north and 26B south respectively. In LFA 25, instead of a window-size requirement, a maximum-size was implemented and all females >114 mm CL have to be returned to the water (Table 1). Between 2003 and 2005, male lobsters >129 mm CL also had to be released in LFA 25.

1.2 HISTORICAL LOBSTER LANDINGS

Records of lobster landings for the sGSL date to the 1890s (Fig. 3). High lobster landings reported at the turn of the 20th century were rapidly followed by an overall decline in the early 1900s. Annual catches decreased from 15,000 t in 1895 to around 8,000 t between 1915 and 1975. Starting in the mid-1970s, lobster landings in the sGSL increased sharply (>2.5-fold) and reached a record reported catch of 22,000 t in 1990 (Fig. 3). Although part of this increase in landings could be attributed to an increase in fishing power, favourable environmental factors are thought to be responsible for strong lobster recruitment success over its entire range, from Labrador to North Carolina. At the last assessment, lobster landings in the sGSL had declined from their peak in the early 1990s to reach 15,472 t in 2005 (DFO 2007). Since then, landings have increased again to 20,816 t and 18,964 t in 2010 and 2011 (preliminary landing data for 2011) respectively. Landings in 2011 for the sGSL were 73% above the long-term median (10,933 t) over the period 1947 to 2011.

Since the last assessment (up to the 2005 preliminary landing data), landings have generally increased in all LFAs, except LFA 26B where reported catches have remained rather stable since 1994 (Fig. 4). Landings from 2011 are slightly lower compared to 2010 in all LFAs but are still preliminary. Also, the beginning of the 2011 spring fishing season was characterized by adverse weather conditions that might have negatively impacted landings in some LFAs. Variation in the timing of peaks and the pattern of declines across LFAs reflects the heterogeneity of the spatial distribution and the temporal variability of the lobster resource in the sGSL. The exception to the pattern seen in the other LFAs is LFA 24, where no marked peak or decline has been observed; landings have increased steadily since 1947 (Fig. 4).

2 DATA SOURCES

2.1 FISHERY RELATED DATA

2.1.1 Official statistics

Official lobster catch statistics were obtained from the Policy and Economics Branch of DFO. The database consists of a compilation of sale transactions conducted between registered lobster buyers and harvesters. Although this information essentially documents monetary transactions, it is assumed that the volume sold to registered lobster buyers closely tracks the quantity of lobster caught by commercial harvesters. Furthermore, because the actual fishing location is not available, it was decided that landings would be separated by statistical district (SD), and assumed that the SD where lobsters were landed generally represents the geographical area in which lobsters were caught. These SD were then regrouped into the nine sub-regions (Fig. 2) which were used in the assessment. Landings from 1947 to 1968 on a LFA basis are only available from Williamson (1992).

Information on licences issued and individual trap allocations were also obtained from the Fisheries and Aquaculture Management Branch of DFO. Since the last stock assessment (Comeau et al. 2008), reductions in both the number of fishing licences issued and the number of traps allowed per harvester occurred and these are examined in terms of nominal fishing effort reduction.

2.1.2 At-sea sampling program

In the last assessment, information on lobster size structure, catch rate, and empty traps were obtained from the DFO at-sea sampling program, which was in place from 1982 to 2003 in all LFAs (Mallet et al. 2006). Following the termination of that program, the PEI provincial government decided to initiate their own program using the same protocol for lobster harvesters operating out of their province (i.e., LFA 24, 25, and 26A). Data collected by the PEI provincial government are archived by DFO Science and shared. Thus, continuous information from the at-sea sampling program between 2004 and 2012 around PEI was available for analysis. For the other provinces, at-sea sampling programs, funded mainly through the ALSM and managed by various harvesters' associations, were carried out during the 2012 fishing season (Table 5). At-sea sampling activities were conducted by lobster industry personnel, trained by DFO technicians, aboard commercial fishing vessels. One sample was defined as one day at-sea with one harvester from a given port. Sampling personnel recorded information on lobster size (CL to the lowest mm), sex, and carapace condition (egg stage of berried females), in addition to trap types and characteristics. Other information recorded include the trap's position on the line of traps (where applicable), precise geographic position of the line using a GPS, and water depth.

For LFA 25 (summer fishery), only at-sea sampling data collected in August were used for the analyses since almost 60% of all catches occur in the first three weeks of the fishery. Later in the season, fishing patterns vary daily and from one harvester to another. For all other LFAs, at-sea sampling data of the entire fishing season were used. Data were grouped into nine identified sub-regions (23BC, 23G, 24, 25N, 25S, 26AD, 26APEI, 26ANS and 26B).

2.1.3 Recruitment-index program

The recruitment-index program is a harvester-based at-sea sampling program that collects information on lobster size and catch-per-unit-effort (CPUE) throughout the fishing season. It contrasts with traditional at-sea sampling with the latter being more intensive (i.e., precise measurements with a calliper of all lobsters caught in traps) but covering only a few days within the fishing season. Advantages of the recruitment-index versus the at-sea sampling program are an improved temporal coverage and efficiency, which reduces data variability (Comeau et al. 2009), and importantly, harvesters' involvement. Hence, an extended temporal coverage can address issues/biases that occur throughout the fishing season including variability in events (e.g., biological and meteorological) and fishing strategies that can be missed by less intense sampling activities.

This program was put in place in 1999 to monitor the relative abundance of pre-recruits and their relative CPUE. In addition to filling a daily logbook of their catch and number of traps hauled, harvesters participating in this voluntary program recorded size and sex of all lobsters caught in six identified traps, three of which had the escape vent blocked. It was assumed that traps with blocked escape vents would retain more animals below the MLS. Lobster CL was measured with a gauge graduated in 13 size classes (Fig. 5). Class size 1 represented lobsters at least 20 mm smaller than the MLS and class size 13 referred to lobsters 50 mm above the MLS. Except for size classes 2, 11 and 12, which are 10-mm group sizes, all other size classes are in 5-mm groupings. Lobsters of group size 4 and below are sub-legal lobsters whereas size groups 5 and 6 always represented animals from the first molting group into the fishery because the gauge was adjusted to the applicable MLS for a given area.

Between 2007 and 2011, only LFAs around PEI were covered as the program had been maintained by the PEI provincial government following the termination of the program managed by DFO. In 2012, harvester groups from LFAs 26A and 26B participated in the recruitment-index program and shared the data with DFO Science for this assessment. Data were also collected around PEI in 2012, but were not yet available for this assessment. Details of the activities and the data collected can be found in Table 6.

2.2 FISHERY INDEPENDENT DATA

2.2.1 Trawl surveys in LFAs 25 and 26A, 2001 to 2009, 2012

In 2001, a trawl survey was initiated to monitor abundance and distribution of lobster in LFA 25 (Comeau et al. 2004) but was expanded over the years to cover most of LFA 26A as well (Comeau et al. 2008). The survey used a random-block experimental design with an overlaying grid of 2 X 2 nautical miles. Primary and alternate stations were randomly selected within each block. The survey net was a number 286 bottom trawl equipped with rubber “rock-hopper” footgear that has been used to sample demersal fishes and large crustaceans in the survey area since 1990 (Hanson 1996; Hanson and Lanteigne 2000; Voutier and Hanson 2008). After each tow, the catch was sorted to species, each taxon weighed and numbers recorded. For all lobster, CL (to the lowest mm) and sex were recorded, as well as the presence of eggs for berried females. A complete description of the survey design can be find in Comeau et al. (2008) and Voutier and Hanson (2008).

The sampling intensity varied from 100 to 235 stations between 2001 and 2009 and in 2012 but the survey protocol remained consistent. However, in 2010 and 2011, the survey design was changed. In those two years, a Bigouden trawl with a smaller footgear was used along with a different fishing protocol to sample rock crab (*Cancer irroratus*) and sand shrimp (*Crangon septemspinosa*) more efficiently (Conan et al. 1994). The number of stations was also reduced from over 200 stations in 2009 to about 110 in 2010 and 2011. In 2012, the original survey design and trawl (#286 bottom trawl with “rockhopper” footgear) were used, but the number of stations was kept at 110 (Fig. 6). The geographical coverage of the survey was gradually increased in 2008-2009 to include the eastern portion of LFA 26A that was not covered before. Given different lobster catchability between the two types of trawl, data from the 2010 and 2011 surveys were not considered in this stock assessment but are presented in the rock crab stock assessment (Rondeau et al. 2014).

2.2.2 SCUBA surveys

Visual line-transect surveys using SCUBA divers were performed on lobster habitat during 2000 to 2012 to assess lobster density at various sites in the sGSL (Table 7; Fig. 7). The longest time series of uninterrupted surveys were carried out in Caraquet (2003-2012), located in sub-region 23BC, and Shediac (2005-2012), located in sub-region 25S. Other sites were added in more recent years from Pointe-Verte to Pictou Island to cover LFAs 23, 25 and 26A in the central Northumberland Strait.

The main objective of the SCUBA survey was to measure local lobster density and length-frequency characteristics at various sites as well as monitor temporal changes.

The survey design has three components. First, a selective design was used to define a survey region, i.e., identification of lobster reefs, within the site. Then, line-transects within the survey region were spread-out across the region using a haphazard design and finally, transects were systematically sampled on a yearly basis.

At each site, the general location of lobster reefs was first determined through interviews of local harvesters. They were asked to identify on a map their fishing locations, especially those with rocky habitat characterized by gravel, cobbles and small boulders, at depths ranging from 4.5 to 10.0 m. Sites with soft sediment were excluded as suitable survey sites. The seafloor was then mapped by remote sensing using an OLEX™ system, which analyzes acoustic echo-sounder signals and classifies the seafloor according to various physical characteristics (e.g., hardness, coarseness, and presence of algae). A single-beam (Simrad™ CM 60 and ES 60 complete system) was used between 2004 and 2007, and a multi-beam (WASP™ system) is now being used. Small-scale topographic maps of bottom-type were generated real time. Validation of maps produced by the OLEX™ system was done via a suspended underwater camera or by direct observation by SCUBA divers. The formal boundaries of the survey region were defined using observed abiotic (e.g., sand, gravel, cobble, boulders) and biotic (i.e., lobster, other benthic species and algal growth) habitat characteristics. Areas with dense algae cover (mainly kelp), large immovable boulders, stacks of smaller boulders, soft sediment bottom (i.e., mud and/or sand), or layers of unbroken granite or sandstone were deemed unsuitable.

Once the survey region was defined within a site, leaded line-transects were spread-out haphazardly over the region, running generally parallel to the coastline in order to be aligned with the prevailing currents. Divers surveyed against the current to avoid decreased visibility from disturbed sediments. Start and finish positions of all line-transects were entered into the on-board GPS chart plotter and systematically sampled every year. The number of line-transects per site was a function of the reef size and the pre-approved diving time allowed for the site. Weather permitting, at least three line-transects per year on selected sites were sampled.

A 100-m leaded transect line, marked at 5-m intervals, was used to survey all sites. Two divers descended and each sampled two meters on either side of the line-transect, for a total swept area of 400 m^2. The SCUBA survey was designed to meet underlying assumptions identified by Burnham et al. (1980) to achieve reliable estimates of population abundance from the line-transect sampling model. These four assumptions are:

- lobsters directly on the line will always be detected and sampled;
- lobsters are fixed at the initial sighting position (i.e., they do not move before being detected and none are counted twice);
- distances are measured exactly, thus, neither measurement errors nor rounding errors occur; and
- sightings are independent events.

Divers attempted to capture every lobster observed within the line-transect. All captured lobsters were measured (CL) and the sex was determined. Divers also recorded the seafloor characteristics (i.e., size, type and aggregation of rocks and other features). Information from each diver was recorded on underwater sampling sheets at each 5-m interval. To standardize the information collected by divers, the sediment size classification scheme developed by Wentworth (1922) and later modified by Pettijohn (1949) was used. Sampling complexity refers to the ability of a diver to efficiently sample (i.e., detect all lobsters) a 10 m^2 quadrat. Habitat complexity was generally due to the particular assemblage of large immovable boulders or stacks of smaller boulders, or macro-algae within the quadrat. Some five-meter sections within each transect were removed from the analysis if the habitat was deemed unsuitable lobster habitat (soft or hard-bare substrate) or too complex for sampling. SCUBA data were analyzed to derive both abundance and production indicators.

2.2.3 Bio-collectors

Passive, vessel-deployed bio-collectors have been developed and used as a tool for assessing patterns of post-larval settlement of lobster (Wahle et al. 2009, 2013). These bio-collectors were made with 10-gauge vinyl-coated wire (38 mm mesh) filled with rocks to mimic lobster habitat. Their dimensions were 61.0 cm x 91.5 cm x 15.0 cm in height, for a surface area of 0.55 m^2. The inside of the bio-collector was lined with 2-mm rugged plastic mesh (PetMesh™) to retain lobsters, crabs and other small organisms during retrieval. More details of their design are provided in Wahle et al. (2009). The inside bottom of the bio-collectors was filled with gravel (10-20 mm) and then by cobble (10 to 15 cm) acquired at a local quarry. Each collector was fitted with a bridle to permit lifting in a horizontal position, which is important for retaining collections during retrieval as demonstrated by Wahle et al. (2009). Bio-collectors filled with rocks weigh approximately 80 kg.

In 2008, the bio-collectors project was carried out by DFO at six sites (Fig. 7). At each site, 30 bio-collectors were deployed by boat at depths ranging from 5 to 7 m (9 m in Neguac, NB) in late-May and early-June (Table 8). Divers were sent down to verify the positioning on appropriate lobster habitat of each bio-collector on the seafloor. No surface buoy was used that year to mark the location of the bio-collectors and, hence, divers were also sent down to attach a rope and buoy to the bio-collectors for retrieval at the end of the submersion period in October-November. Bio-collectors were lifted to the surface with the boat's trap hauler with no pause during the lift to maintain constant water pressure on the contents of the collector. In collaboration with the Prince Edward Island Fishermen's Association, six sites were done between 2009 and 2012 in PEI, with an additional site in Arisaig NS (Table 8; Fig. 7). Each year, 30 bio-collectors were deployed by boat at depths ranging from 5 to 9 m in early-July and retrieved by late-September and early-October. In contrast with the 2008 project, a surface buoy was used to mark the location and retrieve the bio-collectors. In Fortune, five bio-collectors were deployed at 22 m between 2010 and 2012. Sites at Covehead and Arisaig (NS) have five years of uninterrupted data. Finally, a Vemco™ probe was used at each site to record bottom temperature during the immersion period.

After retrieval at the end of the submersion period, the wire mesh covers were removed from the bio-collectors and the rocks were rinsed and removed to inspect for lobsters. Occasionally, collectors became swamped with soft sediments (i.e., sand or mud) over the course of the submersion period and these collectors were excluded from the analyses. All lobsters were measured and their sex determined when possible.

3 DETERMINATION OF INDICATORS

3.1 ABUNDANCE INDICATORS

3.1.1 Landings

The preliminary 2011 landings were compared to the median landings of the long-term (65 years), mid-term (1968-2011), and short-term (2005-2011; since the last stock assessment) (Comeau et al. 2008). Landing indicators were defined as follows:

- if the 2011 landings were within ±15% of the median landings, they were considered as stable (⇔),
- if the 2011 landings were higher than 15% or lower than 15% of the median landings, they scored as increased (🡅) or decreased (🡇), respectively.

Another indicator used to assess annual landing trends was based on a ranking system. Landings were ranked compared to the 1968-2011 median landings for each statistical district. For this indicator, landings were ranked as being 1 for values greater than 75% above the median, 2 for values ranging between 26% and 75% above the median, 3 for values ranging between 25% below and 25% above the median (values within the median value), 4 for values ranging between 26% and 75% below the median, and 5 for values below 75% of the median.

3.1.2 CPUE – At-sea sampling and recruitment-index programs

Data collected through the at-sea sampling program was categorized into berried female lobsters (hereafter identified as B) and male and non-berried female lobsters (identified as M&F). As per the last assessment, berried females were treated separately in the analysis as they could be above the MLS but cannot be retained in the fishery. A description of the activities and the data used can be found in Table 5.

Size distributions and CPUE at size were based on 2-mm carapace length (CL) size groups and calculated as:

$$CPUE_{id} = \frac{\text{total number of lobsters in size class } i \text{ and zone } d}{\text{Number of traps sampled in zone } d} \quad .$$

Average CPUEs in kg/trap by year for the M&F group were calculated using length-weight relationships applied to the observed length-frequency data and divided by the total number of traps sampled. The following length-weight relationships for the sGSL (based on DFO Gulf Region data; female n = 1,166, size range 52-154 mm CL and male n = 1,277, size range 53-127 mm CL) were used:

Female: weight = 0.0013x $CL^{2.8822}$

Male: weight = 0.0006x $CL^{3.0782}$

Average CPUEs of male and non-berried female were also calculated from the recruitment-index program in units of numbers per trap. For those data, length frequencies could not be transformed into weight since CL measurements were grouped by 5 or 10 mm size bins. Only data from regular traps were used. CPUEs for sub-regions 23BC and 23G were not calculated as the recruitment-index program ended in 2004 in those areas.

3.1.3 Spatial analysis and length-frequency distribution – Trawl survey

Interpolated densities over the survey area were produced using a delta-lognormal model (Zuur et al. 2012). Catch data were first partitioned into a presence-absence component and a non-zero catch component. Generalized Additive Models (GAMs), as formulated in the “mgcv” package in R (Wood 2006) were then applied to each component.

A logistic-regression model, applied to the presence-absence data, estimated the probability of observing a non-zero catch while a log-normal regression model estimated the quantity which was observed. Additive smoothing terms based on water depth (i.e. smoothing spline) plus a spatial term (i.e. thin-plate spline) were included for both model components. Coordinate data for the spatial term were transformed to km (via a UTM projection). Predictions from the two component models were combined to obtain a predicted mean catch over an interpolated grid (square cells of 0.016 degrees) over most of the survey area for each year. The interpolation area was adjusted to the survey area coverage for 2006-2008 and to an extended area for 2009 and 2012 as the survey coverage increased in those years. The two size-classes, sub-legal lobsters (<MLS) and commercial lobsters (≥ MLS), were analyzed separately. MLS for LFA 25 and 26A were 70 mm in 2006-2009, and 71 mm in 2012. Catch weights (in kg) were calculated using length-weight relationships applied to the observed length-frequency data. These were standardized to a tow length of 0.625 nm. For each year, the proportion of the estimated densities over 400 kg per km^2 within LFA 25 was calculated. Density (mean number) and biomass (mean weight) annual indices for all sizes of lobsters were calculated from the trawl survey data for each sub-region. The 2012 indices were then compared to the time series averages. Mean length-frequencies by year were calculated for LFA 25 and LFA 26A without adjustment for spatial coverage variations of the survey (mainly in LFA 26A).

Data from the trawl survey were previously presented based on strata segregation and general zones (Western-central, central, and Eastern; Comeau et al. 2008), but since the recent coverage of the survey includes all LFA 25 and nearly the entire LFA 26A, data are presented by either LFA or sub-region. However, because of inconsistencies in the spatial coverage of the survey in LFA 26A, some data are only presented for LFA 25.

3.1.4 Lobster abundance – SCUBA

The goal of the this analysis is to provide a synthesis of SCUBA data collected since 2000 in various sites in the sGSL, with special focus on general spatial and temporal trends in abundance and relative scaling between cohorts. For each transect (*n* = 725), counts of observed lobster by cohort, using size intervals based on Hudon (1987) and Gendron and Sainte-Marie (2006) (Table 9), were tabulated and analyzed.

A generalized linear mixed model (GLMM) was used, which assumes that observed counts are realizations from a Poisson distribution whose conditional mean is defined by a log-linear three factor (year, site and cohort) additive model with full interactions (Jiang 2007).

Formally, the model may be written as:

$$\ln(\mu_{ijkl}) = \eta_{ijkl} = \alpha + \beta_j + \gamma_k + \delta_l + (\beta\gamma)_{jk} + (\beta\delta)_{jl} + (\gamma\delta)_{kl} + (\beta\gamma\delta)_{jkl} + \varepsilon_{ijkl}$$

$$x_{ijkl} \sim \text{Pois}(\mu_{ijkl})$$

where x_{ijkl} is the observed count for transect *i*, year *j*, site *k* and cohort *l*, μ_{ijkl} the Poisson mean, α is a global intercept term, β_j are year effects, γ_k are site effects, δ_l are cohort effects, $(\beta\gamma)_{jk}$ are year-site interaction effects, $(\beta\delta)_{jl}$ are year-cohort interaction effects, $(\gamma\delta)_{kl}$ are site-cohort interaction effects, $(\beta\gamma\delta)_{jkl}$ is a year-site-cohort three-way interaction effect and ε_{ijkl} is an observation-level random effect to account for over-dispersion. We formulated a full Bayesian model (Gelman, 2004) by specifying priors for each model parameter. The intercept term was assigned an uninformative prior ($\alpha \sim N(0,10^4)$). Random effects were drawn from normal distributions with zero mean and variances drawn from an uninformative gamma prior, one for each additive and interaction term ($Gam(10^{-4}, 10^{-4})$). An offset term $z_{ijkl} = \ln(a_{ijkl} / 100)$ was included in the linear term, where a_{ijkl} is the surface area of each transect, in order to standardize the means to a standard transect surface area of 100 m^2. Inference on posterior distributions was performed via MCMC sampling using OpenBUGS (Lunn et al. 2000, 2009).

The hierarchical structure of the model provides a relatively simple way of pooling information between years, sites and cohorts. Interaction terms allow for variation between temporal, spatial and cohort trends to be incorporated in the model. This combination of hierarchical pooling and model flexibility allows us to make reasonable inferences on missing data observations, while taking uncertainty into account.

With the set of inferred mean densities, a set of R values is calculated, defined as the relative differences between cohort means from adjacent years:

$$R_{jkl} = \ln \mu_{\bullet jkl} - \ln \mu_{\bullet j-1,k,l-1}$$

where $\mu_{\bullet jkl}$ is the marginal mean for year *j*, site *k* and cohort *l*, and $\mu_{\bullet j-1,k,l-1}$ is the marginal mean for the previous cohort in the previous year. On the regular scale, this relative change corresponds to the ratio between cohort means and is given by $R^*_{jkl} = \exp(R_{jkl})$. A value of R^*_{jkl} of one (i.e., R_{jkl} of zero) corresponds to no change between cohorts from adjacent years. A value of R^*_{jkl} greater than one implies an increase while a value of R^*_{jkl} less than one implies a decrease. Marginal posterior values for R were obtained by averaging over the appropriate dimensions (i.e., over years, sites or cohorts). Given that R is defined as a log-difference between terms, we could have formulated our model as a cohort-structured population model, expressing cohort means as a function of R values rather than its reciprocal. However, here the focus is to explore the structure of R values rather than impose some a priori structural constraints. Future versions of the model, within which constraints on R may be applied, could be expressed in a cohort-structured form more familiar to population biologists and discussions from the present analysis will form the basis for future development of a population model.

3.2 FISHING PRESSURE INDICATORS

3.2.1 Exploitation rates – Fishery related data

For this assessment, two different estimators were used to calculate the exploitation rate from the male recruitment-index data. Males were used to avoid the bias associated with the female's reproductive cycle, i.e. females have a 2-year reproductive cycle alternating from molting to spawning (Comeau and Savoie 2002) while males molt on a yearly basis at sizes close to the MLS (Comeau and Savoie 2001).

The first estimator is based on the Miller et al. (1987) method by comparing the abundance of the first molt class recruited to the fishery to the second molt class a year later (hereafter designated as the molt class method). The equation used to calculate the instantaneous mortality rate (Z) for the first molt class is the following:

$$Z = -\ln(N_2 / N_1)$$

where N_1 is the number of lobsters in the first molt class and N_2 is the number of lobsters in the second molt class. The number of lobsters by molt class was adjusted to the number of traps sampled. The first molt class includes lobsters from the MLS but less than MLS+10 mm (bin sizes 5-6 for the recruitment-index data), while the second molt class consists of lobsters from MLS+10 mm but less than MLS+20 mm (bin sizes 7-8 for the recruitment-index data, regular traps). The MLS for the second molt class at year+1 was always similar to the one used for the first molt class at year 1. The first molt class was adjusted to changes in MLS but not for the second molt class as recruitment-index data are recorded by bin sizes and not to the lowest mm. For this estimator, we assumed the underlying assumption that the catchability is comparable for different sizes of lobster and also from year to year (Tremblay et al. 1998). The exploitation rate (U) was estimated using the Ricker (1980) equation based on the estimated Z:

$$U = F/Z\ (1-e^{-Z})$$

assuming that natural mortality $M = 0.1$, so that $F = Z - 0.1$. Samples with <200 lobsters for the first cohort were not considered.

The second estimator used was the "change-in-ratio" (hereafter CIR). This method has already been used for lobster and other crustaceans (Dawe et al. 1993; Chen and Montgomery 1999; Gendron and Savard 2003; Tremblay et al. 2012), and basically monitors the change in the abundance ratio of commercial and sub-legal size lobsters between the beginning and the end of a fishing season. Data from the modified traps of the recruitment-index program were used in order to have a good representation of sub-legal animals. Commercial sizes were considered as ranging from the MLS to less than MLS+20 mm (size bins 5 to 8), i.e., about two molt classes. Sub-legal lobsters considered were from MLS-10 mm to less than the MLS (size bins 3-4). Classes were adjusted to MLS changes accordingly. The exploitation rate (U) was calculated with the following equation:

$$U = (P_1-P_2) / (P_1 * (1-P_2))$$

where $P = X / N$ with X = the number of commercial size lobsters and N = the number of commercial plus sub-legal size lobsters. The indices (1 and 2) represent the beginning and the end of the fishing season. The first weekly data group with >200 animals was considered as the beginning of the fishing season, and the last data group with >100 was considered as the end of the fishing season. Sub-regions that did not meet that criteria, or had less than three weeks between the data representing the beginning and the end of the fishing season were not considered.

The usual underlying assumptions for these estimators are:

- the population is closed,
- the catchability of all size classes considered is equal,
- the ratio of catchability by the monitored traps and the commercial traps is constant over the season, and
- the fishing effort is either constant over the season or can be estimated up to a constant factor.

3.2.2 Empty traps

An indicator of fishing pressure can be derived from the percentage of empty traps seen during commercial activities. Traps were considered "empty" when no commercial lobster (thus excluding lobsters smaller than the MLS, berried females, and window/maximum size females) was caught. Yearly data from the at-sea sampling and recruitment-index programs (regular traps only) were used for each sub-region and the number of empty traps was divided by the total number of traps sampled. However, data from the recruitment-index program were slightly biased because window/maximum size females could not be separated from "commercial females" in the dataset. For example, traps with only window-size/maximum size females would not be considered "empty" although it is prohibited to land these females. That situation will most likely decrease the percentage of empty traps.

3.3 PRODUCTION INDICATORS

3.3.1 Berried females in the catch – At-sea sampling

At-sea sampling data were analyzed to provide an abundance indicator of berried females in the catch. Size distributions and CPUE at size were based on 2 mm carapace length (CL) size groups with the following equation:

$$CPUE_{id} = \frac{\text{total number of lobsters in size class } i \text{ and zone } d}{\text{Number of traps sampled in zone } d} \quad .$$

A description of the activities and the data used can be found in Table 5. When the data series from the last assessment (2006) was not continuous, the last year of data was kept for comparison with the 2012 data.

Yearly averages of CPUE in number per trap of berried females were calculated from the at-sea sampling data for 2000 to 2012. Catch rates could not be compiled in kg per trap as no CL to weight relationship exists for berried female lobster. Years with less than 100 berried females sampled within a sub-region were not considered.

3.3.2 Pre-recruit CPUE - Recruitment-index program

Yearly information collected in the six traps was grouped according to the nine sub-regions and the trap types (regular or modified traps). The number of lobsters (excluding berried females) per trap at size ($CPUE_n$) was calculated using the gauge's bin sizes and the equation given in section 3.1.2 ($CPUE_{id}$). For the pre-recruit indicator, CPUEs for bin sizes <5 were summed. No results are presented for sub-regions 23BC and 23G because the program has not been carried out in those areas since 2000.

3.3.3 Pre-recruit density and sex ratio - Trawl survey

Contours of sub-legal lobster distribution in Northumberland Strait and area of abundance > 400 kg of sub-legal lobsters per km^2 were calculated (see section 3.1.3 for details). Density (mean number) and biomass (mean weight) annual indices for sub-legal lobsters were calculated from the trawl survey data for each sub-region spatially covered. The 2012 indices were then compared to the time series averages. Yearly sex ratios between males and females of legal and sub-legal sizes were calculated by LFAs and adjusted to the MLS. For LFA 26A, the MLS used was the one for the management zone 26A1 (Table 4). Pearson's Chi-squared test was applied to the data by LFA and size group to identify sex ratio differences between years.

3.3.4 SCUBA and lobster settlement index

Three production indicators were derived from data collected from SCUBA surveys and bio-collectors. The first index is the empirical density of berried females observed at the Caraquet, NB SCUBA site. In addition, the proportions of berried females in the 70 to 75 mm CL size range were calculated from 2007 and 2012. This is a measure of the potential contribution of MLS increases to egg production, as the MLS was incremented by 1 mm per year in sub-LFA 23B over this period (Table 4). The second index reflects benthic recruitment, defined as the density of cohort 1 lobsters derived from both the SCUBA GLMM (3.1.4) and empirical data from various SCUBA sites (Fig. 7).

The third production index is a measure of lobster settlement, derived from size-frequency analysis of bio-collector data. Lobsters observed in bio-collectors may be grouped into two categories; smaller-sized young-of-year (yoy) lobsters (the category of interest) and larger-sized lobster called walk-ins. The former consists of stage IV larvae settling directly into the bio-collector, while the latter are older individuals (not newly settlers) that roamed into the bio-collectors from the surrounding substrate. Size-frequency distributions of lobsters sampled from these bio-collectors generally have a perceptible gap at around 14 mm CL (Fig. 8) which can be explained by the molt schedule and the timing of the observations. Lobsters that settled the previous year reach sizes >14 mm CL by September of the following year, but yoy individuals settle at a size around 5 mm CL and by September have not reached a size >14 mm CL (Hudon 1987; Gendron and Sainte-Marie 2006).

This feature of size-frequency distributions was used to derive a classification rule, which can be used for separating individuals for each year and site. To this end, a mixture of two log-normal distributions was fit for each unique combination of year and sampling site. Using a Bayesian approach, hierarchical priors were placed on the mixture proportions as well as the means. This allowed for pooling of parameter information between sites and years. Component variances were assumed to have common values. Formally, the model is:

$$x_{ijk} \mid z_{ijk} = 0 \sim LN\left(\mu_{ij}^{0}, \sigma_0^2\right)$$

$$x_{ijk} \mid z_{ijk} = 1 \sim LN(\mu_{ij}^{1}, \sigma_1^2)$$

$$z_{ijk} \sim Bern(\pi_{ij})$$

where i, j, and k are indices for year, site and lobster, respectively. The latent variable z_{ijk} indicates the group to which the observed size x_{ijk} belongs, μ_{ij}^0 and μ_{ij}^1 are the means of the yoy and walk-in groups, and the corresponding variances are σ_0^2 and σ_1^2, respectively. Assigned variance priors were $\sigma_0^2 \sim Gam(10^{-3}, 10^{-3})$ and $\sigma_1^2 \sim Gam(10^{-3}, 10^{-3})$, mean priors were $\mu_{ij}^0 \sim N(\mu_h, \sigma_{h0}^2)$ and $\mu_{ij}^1 \sim N(\mu_h + \theta, \sigma_{h1}^2)$, where $\sigma_{h0}^2 \sim Gam(10^{-3}, 10^{-3})$, $\sigma_{h0}^2 \sim Gam(10^{-3}, 10^{-3})$

and $\theta \sim U(0, 100)$, and the group proportion priors $\pi_{ij} \sim Beta(a, b)$, where $a \sim Exp(1)$ and $b \sim Exp(1)$.

Once the model was fit, a classification rule was defined as the size at which the probability densities of each component were equal, under the assumption that each component had the same proportion. Lobsters smaller than this size were classified as being yoy. Posterior samples of quantities of interest were drawn using MCMC sampling using OpenBUGS (Lunn et al. 2000; 2009). Posterior predictions of the yoy classification size are presented in Table 8.

Once the yoy were estimated, the third production index, defined as the number of yoy per bio-collector was estimated using a Poisson model for each site and year. Estimates and confidence intervals were obtained from the *predict* function from the *stats* package in R (R Core Team, 2012). Means were scaled to a standard surface area of one square meter.

For all sites, the yearly accumulated degree-days (ADD) was calculated using the following equation (Dobson and Petrie 1985):

$$\text{ADD} = \sum_{i=1}^{t} \left(T_i - T_{ref}\right)$$

where T_{ref} is the reference temperature of 12°C, which provides information on the level of thermal energy required for lobster settlement (Annis 2005), T_i is the mean daily temperature for each day, indexed by i, which spans the period from July 15th ($i = 1$) to September 20th ($i = t$) for each of the yearly temperature profiles available.

4 RESULTS

4.1 ABUNDANCE INDICATORS

4.1.1 Landings

4.1.1.1 LFA 23

Commercial lobster catches in LFA 23 showed small fluctuations between 1947 and 1974 with a median landing of 1,175 t. This was followed by a sharp increase and a major fluctuation, from 759 t in 1974 to the highest recorded landing of 4,602 t in 2010, representing a six-fold increase in 36 years (Fig. 4). The previous highest landings were observed in 1989-90 (Fig. 4). Between 1993 and 2005, landings in LFA 23 declined, representing a 35% reduction from the peak landings observed in 1989. Since 2005, landings for the entire LFA 23 increased steadily to reach 4,576 t in 2011, a value which is 164% above the long-term median landings (1,732 t) (Table 10).

Comeau et al. (2008) reported that until 1990, landing trends within LFA 23 were somewhat different between fisheries operating inside Chaleurs Bay (sub-region 23BC) and the Gulf side (sub-region 23G). A two-step increase was observed in sub-region 23BC between 1971 and 1989, while a steady increase (6.5-fold) was observed in sub-region 23G between 1974 and 1990 (Fig. 9). Following their respective highs, declines were observed for both sub-regions 23BC (47%) and 23G (33%) until 2005. Based on 2011 data, landings in both sub-regions 23BC and 23G increased by 67% (936 t) and 55% (3640 t) respectively since 2005 (Table 11; Fig. 9). It represents values 46% and 33% above the mid- (640 t) and short- (703 t) term median landings for sub-region 23BC, and 52% and 33% above the mid- (2401 t) and short- (2743 t) term median landings for sub-region 23G (Table 11).

4.1.1.2 LFA 24

Commercial lobster catches in LFA 24 showed a steady increase from 1947 to 2010 with few minor fluctuations (Fig. 4). Landings observed in 2011 were 5,469 t, 17% lower than the 2010 level of 6,550 t (highest landings since 1947). However, unofficial landings of around 7,300 t have been reported from provincial sources, which would make 2012 landings the highest in recent years with an increase of approximately 11% from the 2010 record landings. The lower landings of 2011 could be partially due to bad weather and colder water temperature (Chassé et al. 2014). Overall, a 13-fold increase was observed from the lowest landings recorded in 1947 (497 t) to the peak in 2010 (6,550 t). Landings in 2010 were 2.5 times above the long-term median landing (2,657 t) observed between 1947 and 2011. In contrast to other areas, LFA 24 is still steadily recording record-high landings based on information dating back to 1947 (Fig. 4). Landings reported in 2011 were 106% and 32% above the long- (2,657 t; Table 10) and mid- (4,151 t) term median landings, while it was 13% below the short-term (6,288 t) median landing (Table 11). However, landings in 2010 (last official landings) were 4.2% above the short-term median landing.

4.1.1.3 LFA 25

The landing trend in LFA 25 was characterized by wide fluctuations with no stable period since 1947 (Fig. 4). Commercial lobster catches in LFA 25 showed a sharp increase from 1,622 t in 1973 to the highest recorded landings of 6,323 t in 1985, representing an almost four-fold increase in 12 years (Fig. 4). Within the sGSL, LFA 25 was the first area to reach its record high landings in the 1980s. Since 1947, three major increases were observed, the first (1947 to 1950) was 2.4-fold, the second (1954 to 1960) was 3.3-fold and the last one (1973 to 1985) was 3.9-fold. These large fluctuations (in terms of amplitude) were not observed in the other LFAs (Fig. 4). Between 1985 and 2004, however, landings in LFA 25 declined steadily (Fig. 4). This 20-year decline is the longest and largest one observed in the sGSL. According to Comeau et al. (2008), 2,422 t were landed in 2004 which represented a 62% reduction from the peak landings observed in 1985, and a 22% reduction from the long-term median landing (3,106 t) observed between 1947 and 2004. Conversely, a positive trend has been observed for LFA 25 since 2004 (Fig. 4). Landings reached 4,015 t in 2011 which was 27% above the long-term median landings (3,155 t) (Table 10).

As opposed to the situation observed in 2005 (Comeau et al., 2008), the latest landing trends within LFA 25 were more similar between sub-regions 25N and 25S (Fig. 9). The landings trend for sub-region 25N has been previously described as being more similar to that from LFA 23, whereas sub-region 25S experienced the widest landings fluctuations within the sGSL between 1968 and 2005 (Comeau et al., 2008). In general, the steady decline observed in both sub-regions 25N and 25S changed to a positive trend between 2004 and 2011 (Table 11; Fig. 9). In sub-region 25N, the 2011 landings of 2,947 t were 20% and 17% above the mid- (2,458 t) and the short- (2,510 t) term median landings, respectively (Table 11). For sub-region 25S, the lowest recorded annual landing since 1968 was observed in 2004 (533 t). The 2011 landings (1,068 t) were close to the mid-term median landing value (1,084 t), and 25% above the short-term median landing (856 t) (Table 11).

4.1.1.4 LFA 26A

Commercial lobster catches in LFA 26A showed a median of 2,484 t between 1947 and 1974 (Fig. 4). After the lowest recorded landings of 1,372 t in 1974, there was a sharp increase to the highest recorded landing of 6,691 t in 1988, representing more than a four-fold increase (Fig. 4). Following this peak, a rapid decline to 3,480 t in 1994 was observed. Since then, landings remained somewhat stable. In 2011, 3,866 t were landed which is 34% above the long-term median landings (2,893 t) observed between 1947 and 2011 (Table 10).

Within LFA 26A, landing trends in sub-region 26AD were different from the other two sub-regions (26ANS, 26APEI; Fig. 9). The landing trend in sub-region 26AD has fluctuated since 1968 with a peak at 2067 t in 1987 (Comeau et al. 2008). The median for the 1968 to 1982 period was 427 t. An increase in landings was observed from 1982 (539 t) to 1987 (2,067 t) followed by an equally rapid decline to 710 t in 1994 (Fig. 9). Between 1994 and 2005, landings increase to 995 t by 2000 followed by a decline reaching 500 t in 2005. Since 2005 a positive trend was observed (Fig. 9). The 2011 landings (678 t) were at the short-term median landings value and 7% below the mid-term median landings (729 t; Table 11).

The landing trend in sub-region 26A PEI could be characterized as fairly stable between 1968 and 1985 with a median landing of 1,346 t, followed by a sharp landing increase between 1985 and 1994 (historical high of 3,575 t in 1990), and since, fairly stable landings with minor fluctuations (Fig. 9). Landings in 2011 were 2,022 t, which was the short-term median landing and 19% above the mid-term median landing (1,706 t) (Table 11). Landings were fairly stable since 1988 in sub-region 26ANS (Fig. 9). After a slight decrease in landings from 1968 (513 t) to 1974 (325 t, the lowest recorded landings of the time series), a 3.8-fold increase was observed until 1991 (1,221 t; Fig. 9). Landings in 2011 were 1,167 t, which was, as for the rest of the sub-regions, the short-term median value, and 17% above the mid-term median landings of 1,003 t (Table 11).

4.1.1.5 LFA 26B

Commercial lobster catches in LFA 26B showed a relatively stable pattern between 1947 and 1977 with a median landing of 495 t (Fig. 4). A 3.8-fold increase in landings was observed between 1974 (406 t) and 1991 (1,543 t). Landings then dropped 28% in four years to 1,110 t in 1994. However, this sharp decline was followed by stable landings (Fig. 4). A median landing of 1,102 t has been observed for the past 18 years, representing a 2.2-fold increase from the previous median observed between 1947 and 1977 (i.e., prior to the large increase in landings in the 1980s). The fishery in LFA 26B was stable with recorded landings of 1,037 t in 2011, which was still 48% above the long-term median landing (700 t) observed in the past 65 years (Table 10), and within the mid- (1,074 t) and short- (1,083 t) term median landing values (Table 11).

4.1.2 Landing trends based on ranking

The landing trends ranking approach show that the 2011 landings were among the best since 1968 (Fig. 10). Based on the mid-term median landings (1968 to 2011), 75% of the reported landings between 1968 and 1982 (first 15 years) ranked below 25% of the median, compared to 14% between 2005 and 2011. In general, all statistical districts ranked higher or within the median in 2011 compared to 2005 (LFA 23, 24, 25N, 26ANS, 26APEI, 26B), except for three statistical districts (45, 46, 10) in central Northumberland Strait (Fig. 10). Those statistical districts are located at the boundary between sub-regions 25S (DS 45) and 26AD (DS 10 and 46) and they ranked the lowest, below 25% of the mid-term median (Fig. 10). LFA 23 ranked above the median with one statistical district (SD 68) being at its historical high (Fig. 10).

4.1.3 CPUE – At-sea sampling and recruitment-index programs

Many factors independent from lobster's abundance will affect CPUE calculated from fishery dependent data (e. g. gradual implementation of escape vents, increase in MLS, decrease in the trap allocation, weather conditions, etc.). The CPUE distributions based on at-sea sampling data showed different patterns between areas (Figs. 11 to 17), and also between the two groups considered (M&F and B). In some sub-regions or LFA (23BC, 23G, 26ANS, 26B), it was difficult to characterize trends because no at-sea sampling activities were carried out for many years. For those areas, the last year of available data presented in the last assessment are shown for comparison.

One general observation for the M&F group is that CPUE in the most recent years seemed higher, or at least of a similar level, compared with values examined in the last assessment. In sub-regions 23BC, 23G (Fig. 11), and LFA 26B (Fig. 17), a 2 to 3-fold increase of the 2012 CPUE was observed compared with values observed in either 2003 or 2004. Furthermore, the obvious shift to larger-sized lobsters (M&F) between 2003 and 2012 in LFA 26B (Fig. 17) probably reflects in part the numerous increases in the MLS in that LFA, going from 76 mm in 2003 to 79 mm or more in 2012 (Table 4) as well as adjustments of escape vents. LFA 24 shows very stable CPUE both in terms of magnitude and size distribution (Fig. 12) from 2006 to 2012, with peaks ranging between 0.29 and 0.45 lobster per trap. The lack of a shift in the distribution could be explained by minor increases of the MLS in that LFA (Table 4). In sub-region 25N, a greater abundance of 70-80 mm CL lobsters was observed in 2009 and 2012 compared to the other years with CPUE reaching up to 0.81 lobster per trap in 2012 (Fig. 13). That magnitude in the CPUE for M&F is the highest of the sub-regions or LFAs. Sub-region 25S is characterized by a 10-fold increase in the CPUE of M&F between 2006 and 2012 (from 0.04 to 0.43 lobster/trap) with a peak in 2011 at 0.73 lobster per trap (Fig. 14). The CPUEs in 26AD have continued to be low in 2006 and 2007, but increased in 2008 (0.05 lobster/trap) and 2009 (0.06 lobster/trap) and then stabilized at around 0.05 lobster per trap in 2010-2012 (Fig. 15). A peak CPUE has been observed in 2011 at 0.06 lobster per trap with sizes close to 70-72 mm CL, the same year the MLS has gone from 70 to 71 mm CL (Table 4). Also, the largest size range and proportion of larger animals can be observed in sub-region 26AD. While most lobster caught in other regions are between 60 and 90 mm CL, in 26AD lobsters bigger than 100 mm CL seem more frequent (Fig. 15). However, this extension of the size distribution is probably due to the low number of lobsters in smaller sizes and not to an increase in the amount of large-sized lobsters. In sub-region 26APEI, CPUE for M&F were stable for 2006-2008 (Fig. 16), but an increase in magnitude has been seen since 2009 with peaks in 2011 and 2012 at about 0.27 lobster per trap for 70 mm CL lobsters.

Average CPUE (in kg/trap) from the at-sea sampling program are showing a substantial increase in 2012 in 6 of the 9 sub-regions (Table 12) when compared to 2006 or the last year with data available. In sub-regions 24, 26AD, and 26ANS average CPUE are similar to those observed in 2006 or earlier. In sub-regions 25N and 25S the 2012 CPUE for the month of August only have increased by 3.4 and 5.3-fold respectively compared to 2006. In sub-regions 23BC, 23G, 26APEI, and 26B the increase in CPUE in 2012 ranged from 2.2 to 3.9-fold (Table 12) compared to 2006 or to the last data available.

For sub-regions where data were available, fluctuations in average CPUE (in number/trap) calculated from the recruitment-index program showed the same trend than those from the at-sea sampling program. Hence, an increase in CPUE was observed for sub-regions 25N, 25S, 26AD, 26APEI, and 26B ranging from 1.3 to 3.1-fold (Table 13), with the most recent data comparable to either 2006 or an earlier year with data available. The only difference from the at-sea sampling data is for sub-region 26AD where a 1.6-fold increase is seen in the data from the recruitment-index program while no increase was observed from the other data source. The greater increases were seen for sub-regions 25N and 25S (Table 13). Average CPUE showed no trend in LFA 24 while very little data were available for sub-region 26ANS.

The implementation of various increases of the MLS and/or changes in escape vent dimensions at different time and in different LFAs, sub-LFAs and management zones most likely affected CPUE estimates as well as the observed size ranges. While changes in MLS are documented (Table 4), escape vents characteristics were not recorded during at-sea sampling activities.

4.1.4 Density and length-frequency distribution – Trawl survey

Legal-sized lobsters were concentrated mainly along the east coast of NB, from Shediac up to Escuminac, the west coast of PEI, and around Pictou Island in NS (Fig. 18). In 2009 and 2012, when the survey's coverage increased over the eastern part of LFA 26A, concentrations of legal size lobsters were also found along the East coast of PEI. The distribution pattern of commercial lobsters has remained quite stable since 2006, perhaps with a weaker signal in 2009 along the east coast of NB. Concentrations were higher and covered a larger area in 2012 around Pictou Island and in the northwestern portion of LFA 25 compared to other years. Year after year, legal-sized lobsters seem to be almost totally absent from the area east of Cape Tormentine to River John, NS (Fig. 18). The trawl survey is conducted just prior the fishery in LFA 25 and about one month after the fishery's end in LFA 26A. The great concentrations of commercial-sized lobsters in LFA 26A, after the 2012 fishery and the annual molt, may suggest that the 2013 landings will be relatively strong in the area covered by this survey if no emigration or mortality occurred.

The spatial proportion of high density areas (>400 kg of legal size lobsters per km^2) in LFA 25 has fluctuated between 2001 and 2012 but is greater in 2012 compared to the last few years (Fig. 19).

Mean annual indices of density (number per tow) and biomass (kg per tow) were calculated for all sizes of lobster in sub-regions 25N, 25S, and 26AD from the trawl survey data. For 2012, the biomass index value of 17.0 kg per tow in sub-region 25N was 76% above the 2001-2012 series average of 9.7 kg per tow (Fig. 20). It is the highest index value of the time series except for 2001; for that year, three exceptional tows had such quantities of lobster caught that the mean was greatly influenced resulting in wide confidence intervals. In sub-regions 25S and 26AD (central Northumberland Strait) biomass indices in 2012 were lower than in 25N but still respectively 14 and 27% above the series averages (Fig. 20). Another biomass index was estimated for the entire LFA 25 based on the delta log-normal model (see section 3.1.3) and mean annual values follow very closely those of the mean annual index (Fig. 21).

Because of variations in the survey spatial coverage of sub-region 26AD, only data from 2005 to 2012 were examined. Density indices mirrored those of biomass for all three sub-regions.

The length-frequency distributions of lobsters in LFA 25 were similar between 2006 and 2009 with an increase in 2012 for almost all sizes of lobsters (Fig. 22). There is no evidence of an influx of smaller individuals in any year or the accumulation of bigger size lobsters even with the recent implementation (2003) of a management measure prohibiting the landing of large females (>114 mm CL).

In LFA 26A, length-frequency distributions fluctuated between years with no clear pattern, with 2008 showing the least amount of lobster while distributions in years 2006, 2009, and 2012 being similar in shape and magnitude (Fig. 22). Note that the data for this LFA were collected just after the fishery, while those of LFA 25 were taken just before the fishery, and that the spatial coverage of LFA 26A was not the same in 2006-2008 compared to 2009 and 2012. Those details might have an effect on the results presented here. Also, catchability of small lobsters might have been affected by the trawl mesh size.

4.1.5 Lobster abundance – SCUBA surveys

Based on the SCUBA-survey GLMM, lobster densities (number per 100 m^2) from all cohorts and regions combined in the sGSL increased more than 5-fold from 0.6 to 3.9 between 2000 and 2012 (Fig. 23). Spatially, differences were observed among sites along the north to south axis, reflecting a contrast in the population dynamics between the outside and central Northumberland Strait. Higher densities (2.1 - 4.2) were observed in LFA 23 and sub-region 25N, while densities in sub-regions 25S and 26AD ranged between 0.1 and 1.3 (Fig. 24). Fox Harbour (at the LFA 25-26A boundary in central Northumberland Strait) had the lowest estimated density at 0.1. Generally, small lobsters were the main group driving both the temporal and spatial trends. Density levels of cohorts 1 and 2 were significantly higher (Fig. 25) compared to those of cohorts 3 to 6+ (cohort 0 will be discussed later).

Useful insight into spatio-temporal dynamics may also be gained by comparing trends in relative changes between cohort densities, i.e., *R* or *R**. Given that *R** is a ratio, a value of *R** > 1 indicates an increase in inter-annual cohort density, while a value of *R** < 1 indicates a decrease. The *R** values are not simply the result of mortality between cohorts, being a confounding of sampling detection, natural mortality, fishing mortality as well as spatial dynamics. However, meaningful inferences on individual processes of *R** may often be made, given that some are cohort-specific. For example, Figure 26 shows the variation in *R** ratios between cohorts averaged over years and sites. The high *R** value of 2.3 between the smallest cohorts (0 and 1), which are sedentary and cryptic, indicates a significant detection problem during SCUBA surveys for cohort 0. Hence, although cohort 0 represent lobsters <19 mm CL (first benthic year-class) it should not be used as a recruitment index, because it violates an important underlying assumption for line transect sampling (Burnham et al. 1980), i.e., varying detectability. In contrast, the *R** value of 0.82 between cohorts 1 and 2 (Fig. 26) is consistent with what one would expect under assumptions of mortality and spatial dynamics.

By separating the sample sites into northern and southern components, it becomes clear that the higher values of *R** by cohort, when averaged over years and sites, is driven by sites within the central Northumberland Strait (Fig. 27), with an *R** value of 1.3 between cohorts 1 and 2. In comparison, sites outside the central Strait have an *R** value between cohorts 1 and 2 of 0.8 (Fig. 28). This implies either some differential detectability issue or some influx of cohort 2 lobsters within the central Strait. Nevertheless, in general cohort 1 (Fig. 25) could be used within the sGSL as the index of recruitment to the benthic habitat (one of the production indicators).

Within LFA 23 and sub-region 25N, *R** ratios lie below 1 for larger cohorts (Fig. 28), while those from the central Northumberland Strait all have corresponding values which are larger and are often centred or exceed 1 (Fig. 27). Similarly, *R** values by site averaged over years and cohorts indicated that northern sites and Cocagne had values which were significantly smaller than 1, while the remaining southernmost sites (i.e., the central Strait) either had values which exceeded 1 (i.e., Shediac, Robichaud and Fox Harbour) or equalled 1 (Toney River) (see Fig. 29). Barring a detection issue (improbable for cohorts larger than 1), *R** values larger than 1 imply a marked inflow of lobster onto sampling sites within central Northumberland Strait. Otherwise stated, levels of larger cohorts within the central Strait are at variance with the consistently low recruitment levels which are observed. Such is not the case for the Caraquet site, for example, where population dynamics are strikingly different (Fig. 30).

Because larger cohorts within the central Strait do not seem to stem from recruitment, we describe results from the Bayesian estimation model for sites in LFA 23 and sub-region 25N (Fig. 28) separately. The *R** value of 0.5 from cohort 2 to 3 shows a large decrease in abundance (Fig. 28). This drop is likely due to ethological considerations, as there is an important change in the mobility behaviour of lobster at these sizes. While cohorts 0 and 1 (lobsters <33 mm CL) are considered cryptic, i.e., generally hiding in burrows, at cohort 2 lobsters begin to roam and are fully vagile by cohort 3, making them more vulnerable to predators with an expected increase in natural mortality. For cohorts 3 and 4, with their larger size and few putative predators, natural mortality is correspondingly lower and the observed *R** value of 0.8 lends support to this hypothesis (Fig. 28). Note that these cohorts are not affected by fishing mortality. The *R** values for the remaining cohorts 4, 5 and 6+ show a decreasing trend. If one assumes that natural mortality and migration are constant for cohorts 3 to 6+, one may interpret this decrease as the effect of fishing, as the MLS lies within the size bounds of cohort 5. Under these assumptions the *R** values should reflect the exploitation rate.

Finally, there is no significant trend in the *R** values by year, averaged over regions and cohorts, which tend to fluctuate at about 1 (Fig. 31).

4.2 FISHING PRESSURE INDICATORS

4.2.1 Exploitation rates – Fishery data

The representativeness of exploitation rate values obtained from the different estimators was questionable because of the limited data available which reduces the number of years with values. Generally for both estimators, realistic exploitation rate values were calculated in a data-rich situation in terms of a high sampling intensity and lobster abundance. In LFA 24, average exploitation rate from the CIR method for the entire data series (1999-2011) was higher at 81% (Table 15) than from the molt class method that averaged 65% (Table 14). Average exploitation rates between 1999 and 2003-2004 for sub-region 23G were 61% and 66% based on the molt class and the CIR methods respectively (Tables 14 and 15). No data were available to calculate exploitation rates for that region after 2004. Also, too few data were available to calculate exploitation rates for sub-region 23BC. In sub-region 25N, average exploitation rates fluctuated between 63% and 68% depending on the method (Tables 14 and 15). Exploitation rates in sub-region 25S averaged 47% (Table 14) for the period between 1999 and 2010 but values for years 2004 to 2009 did not meet the minimum criteria of 200 individuals in the first size class and are therefore not presented. Data limitation also prevented calculation of exploitation rates in sub-region 25S with the CIR method. In sub-region 26APEI, average exploitation rates were 51% (Table 14) and 67% (Table 15) depending on the method and data used. For LFA 26B, exploitation rates could only be estimated prior to 2003 and average values ranged between 61% and 67% (Tables 14 and 15). Too few data were available to calculate exploitation rates in sub-region 26ANS with any method.

Data from the recruitment-index program seem adequate for calculating exploitation rate estimates when and where their availability was sufficient. In some cases, there is concern that the underlying assumptions were violated (e.g., constant catchability between lobster size classes and “closed” populations). It is well known that lobster abundance in the central portion of Northumberland Strait (sub-regions 25S, 26AD, and 26ANS) is influenced to a certain extent by the influx of lobsters from outside the Strait. Also, during the recent years, changes in temperature regimes have been observed in that area with probable effects on catchability, especially between years. Furthermore, even if calculations were adjusted to changes in MLS, those changes in the definition of the exploited population might have had an effect on the exploitation rates obtained and/or their fluctuations.

4.2.2 Empty traps

Proportions of empty traps recorded during at-sea sampling activities have generally decreased in all LFAs since the last assessment, except for sub-regions 26AD and 26ANS with levels comparable to 2000-2006 (Table 16). LFA 24 and sub-region 26APEI showed a gradual decrease in the proportion of empty traps, from 24% and 47% in the 2000-2006 period to 17% and 25%, respectively, in 2012 (Table 16). In both sub-regions of LFA 25, percentages of empty traps have fluctuated between 2007 and 2012, but many years had limited data, except in 2012 (Table 5). When comparing the 2000-2006 period and 2012, a decrease in proportion can be observed (Table 16). These lower percentages of empty traps in LFA 25 could be partly explained when one considers that only the data from the first weeks of the fishing season were used. When we included fishing activities from September and October, higher percentages were obtained. In this assessment, only at-sea sampling data from August were considered. The highest proportion of empty traps (58%) was observed in sub-region 26AD (Table 16). Since 2000, the percentage of empty traps in that region has always been high and has not shown any notable decrease over the recent years.

Empty trap percentages from the recruitment-index program are comparable to those from the at-sea sampling program and show the same trends per sub-region. In general, there was a decrease in the proportion of empty traps in recent years compared to the 2000-2006 levels (Table 17) except for 26ANS. In that sub-region, data were only available in 2000 and in 2012 but for both years, the percentage of empty traps is the same at 30% (Table 17). Sub-regions with the least empty traps in 2011 were 24, 25N, and 25S with 20%, 21%, and 24%, respectively (Table 7), a decrease compared to the 2000-2006 levels. However for LFA 25, data from the entire season were considered (because of their continuity) and percentages were similar to those from at-sea sampling data (Table 16). LFA 26B also showed a decrease in empty traps in 2012 and percentages between both datasets were very similar. Proportions of empty traps have also decreased in recent years in sub-regions 26AD and 26APEI but with some fluctuations (Table 17). No data from the recruitment-index program were available to calculate empty trap proportions in LFA 23 in the recent years.

4.2.3 Nominal effort reduction

The recent reduction in nominal effort was assessed based on the number of available licences and the total number of traps allocated from 2006 to 2012 in each area. Detailed information on licences and trap allocations were obtained from the Fisheries and Aquaculture Management Branch of DFO. Information were verified and validated following a thorough process as data were not consolidated within a single database. Temporary licences (4 in 2012) were not considered in the nominal effort reduction analysis.

From 2006 to 2012, the number of available lobster fishing licences (all types combined) was reduced by 9.1% from 3,248 to 2,953 (Table 2). Overall, 48 type-B licences were renewed in 2012, 16 less than in 2006. A total of 279 type-A licences have been removed from the fishery. The effort reduction in terms of licence removals was not equally distributed in all LFAs. The majority of the licence reduction was done through the ALSM program with a total of 270 licences retired between 2010 (before the fishery) and 2012. The reduction was mainly observed in LFAs 25 (NB and PEI only) and 23 (Table 2). Management zone 26A-3 had the highest proportion of licences removed with 26%. Licence reductions in management zones 26A-1, 26B north, and 26B south ranged between 7.6% and 9.3%. No type-A licences were removed from LFA 24, sub-LFA 26A-2 and LFA 25 NS side. Additional licence retirements are expected for 2013 in LFA 25 NS side (2), in management zone 26A-1 PEI side (2) and sub-LFA 26A-2 (7).

Nominal effort in terms of the maximum trap allowed per year and region was estimated by multiplying the number of licences by their trap allocation. There was an overall reduction in nominal effort of 12.3% (112,594 traps) from 2006 to 2012 for all LFAs combined (Table 18) but most of the reduction (10.5%) was observed following the announcement of the ALSM program in September 2009. For areas where the breakdown in sub-LFA and management zones is not possible, the earliest year available was used for comparison. Management zones 26A-3 and 26B south had their nominal effort for type-A licences decreased by 37.5% and 23.9% respectively (Table 18). In management zone 26A-1 the reduction was 16.7% and 13.8% for PEI and NB respectively. In LFA 23, the reduction varied from 2.2% to 15.8% depending on the sub-LFA, while in LFA 25 it was 17.6% and 13.9% for NB and PEI respectively. Nominal effort in 26B north dropped by 18.5% from 2008 to 2012 and in sub-LFA 26A-2 there was a reduction of 9.2% from 2006 to 2012. The overall reduction in nominal effort from 2006 to 2012 for the type-A licence alone was 111,154 traps, which would represent about 370 licences based on an allotment of 300 traps. There was no change in the nominal effort of type-A licence for LFAs 24, 25 NS, and in sub-LFA 26A-2.

Nominal effort reductions from type-B licences did not result from active initiatives but are still accounted for in the global picture and are detailed in Table 18.

4.3 PRODUCTION INDICATORS

4.3.1 Berried females in the catch – At-sea sampling

In general, berried female CPUEs have increased or remained stable since the last assessment (Table 19; Figs. 11 to 17). In sub-regions 23BC, 23G, 26ANS and LFA 26B, the increase in CPUE appears substantial (Table 19; Figs. 11 to 17) because data from 2012 can only be compared to those of 2003 given the available data. Also, the shift in the size distribution of berried female in LFA 26B could be attributed to the MLS increase from 73 mm in 2003 to a minimum of 79 mm (Table 4) in 2012. At this size, the proportion of females that can now reproduce before being exposed to the fishery is larger. In LFA 24, the size distributions of B were similar between 2003 and 2012 (Fig. 12) and yearly CPUE averages did not reveal any trend (Table 19). Yearly CPUE average values in 2012 were the highest of the 2000 to 2012 period for sub-regions 25N and 25S (Table 19) at 0.67 and 0.80 B per trap respectively and with overall high values in the last three years. An increase in berried female CPUE was also observed in the recent years for sub-region 26APEI with highest values of 0.40 and 0.39 B per trap in the last two years (Table 19). Berried female CPUE in 26AD increased since the last assessment up until 2010 when it reached a maximum at 0.34 B per trap (Table 19). CPUE has since decreased by about 38% to reach 0.21 B per trap in 2012, the lowest value of all sub-regions. While other sub-regions showed a narrow size range for B, between 65-95 mm CL, in 26AD larger females (>95 mm CL) were observed in the catch (21% in 2012; Fig. 15). For example, the percentage of B >95 mm CL observed in 2012 was only 5% in LFA 26B and 4% in LFA 24.

4.3.2 Pre-recruit CPUE - Recruitment-index program

For all sub-regions examined there was a clear signal of the presence of pre-recruitment size lobsters (M&F only, bin sizes <5) into the fishery based on the modified traps data (Figs. 32 and 33). Pre-recruit CPUEs have been increasing considerably for the last few years in both sub-regions of LFA 25 (Fig. 32) and the signal was noticeable both in the modified and in the regular traps. An increase has also been observed in sub-region 26ANS, and LFA 26B but many years of data are missing (Fig. 33). For LFA 26B, the increase in CPUE could most likely be attributed to the 8 mm increase of the MLS from 73 mm in 2004 to 81 mm in 2012, which would have left more sub-legal size lobsters in the water over the years. No trend in pre-recruit CPUEs from modified or regular traps was detectable in LFA 24 and in sub-regions 26AD, and 26APEI (Figs. 32 and 33). Sub-region 26AD was characterized by the lowest CPUE of all sub-regions at less than 0.4 lobster per trap (Fig. 33).

4.3.3 Pre-recruit density and sex ratio - Trawl survey

Sub-legal lobsters in the trawl survey area seemed to have been highly concentrated along the eastern coast of NB, within sub-region 25N, from Caissie Cape to Escuminac from 2006 to 2009, and again in 2012 (Fig. 34). Also, with the increase coverage of the trawling survey in 2009 and 2012 concentrations of sub-legal lobsters have been observed on the east coast of PEI (sub-region 26APEI), mainly between Murray Harbour and Souris. In 2006, 2009, and 2012 a concentration was also observed around Pictou Island and in 2007 and 2012 on the west coast of PEI. No sub-legal lobster concentration was observed for the entire central portion of Northumberland Strait, from Shediac (NB) to Toney River (NS) (Fig. 34). As for commercial-sized lobsters, higher concentrations of sub-legal in 2012 were observed in the northwestern portion of LFA 25 and around Pictou Island (junction area of sub-regions 26AD, 26ANS, and 26APEI) compared to previous years. The spatial proportion of high densities areas (>400 kg of sub-legal size lobsters per km^2) in LFA 25 remained low between 2001 and 2009 but increased in 2012 by 3.1-fold from the 2001-2009 series average (Fig. 19).

Biomass indices of sub-legal lobster derived from the survey data emphasized the differences between the northern section of the survey area and central Northumberland Strait. At a mean weight of 7.42 kg per tow in 2012 (Fig. 35), the biomass index of sub-legal lobsters in sub-region 25N is 1.9-fold higher than the 2001-2012 series average (3.93 kg/tow). In sub-regions 25S and 26AD, even though the 2012 biomass indices are much lower than in 25N (1.04 and 0.84 kg per tow respectively), they were still higher than the series averages (0.82 and 0.59 kg per tow respectively).

The operational sex ratio calculated represents the number of males available for mating with each female. In LFA 25, the sex ratio of legal-sized lobsters significantly increased between 2007 and 2012 ($p < 0.01$) and always favours males, being slightly over 1 (Table 20). For sub-legal lobsters in LFA 25, sex ratios were near parity, with 3 years out of 4 slightly favouring females (Table 20), with significant differences between years ($p < 0.01$). In LFA 26A, ratios for legal size lobsters did not vary much from 1 without significant difference between years ($p = 0.3057$). For sub-legal lobsters, ratios favour females 3 years out of 4 with a significant difference ($p < 0.001$) between years (Table 20).

4.3.4 Berried female and one-year old abundance – SCUBA

The mean density of berried females per 100 m^2 from SCUBA surveys (i.e., the SCUBA production index) from Caraquet fluctuated from 0.1 to 1.0 between 2003 and 2012 (Fig. 36). Starting in 2009, the mean density of berried females more than doubled every year to reach 1.0 in 2012 (Fig. 36). The contribution of females ranging from 70 to 75 mm CL to egg production increased from 10% in 2007 to 44% in 2012 (a peak was observed at 53% in 2011; Fig. 36). During that time the MLS was increased from 70 to 75 mm CL at a rate of 1 mm per year (Table 4) in that area (sub-LFAs 23A-B).

The mean density per 100 m^2 for cohort 1 lobsters (i.e., recruitment to the benthic habitat index) from Caraquet indicated a dramatic increase in recruitment between 2003 and 2012 (Fig. 37). Caraquet was presented because it had the longest uninterrupted time series and large samples. There has been a 5-fold increase from the 2006 values (3.0) presented at the last stock assessment (Comeau et al. 2008). However, no such increases were observed for sites within central Northumberland Strait (Fig. 37). The mean densities for sites outside Northumberland Strait increased from about 1.0 in the early 2000s to values of about 1.5 in 2012 (Fig. 38). In contrast, mean densities for sites within the central Northumberland Strait were much lower and showed different trends (Figs. 37 and 39). In sub-region 25S, a 3.1-fold increase was observed in Shediac (0.9 to 2.8 between 2006 and 2012) and a 1.5-fold increase in Cocagne (2.8 to 4.3 between 2008 and 2012). This type of trend was not observed in sub-region 26AD for both Fox Harbour and Toney River with the lowest abundances in the sGSL at 0.0 and 0.9, respectively in 2012 (Fig. 39). Although positive trends were observed for cohort 1 densities in Shediac and Cocagne, their values were much lower than sites outside central Northumberland Strait.

Linear trends of the log-transformed mean densities of cohort 1 versus time for Caraquet (Fig. 40) imply exponential population growth through time. There is a direct relation between the slope of a fitted linear model and the exponential growth rate parameter r, the slope being the logarithm of the growth rate plus 1. There appears to be two such linear phases in the data. The first (2003-2009) showed a strong exponential increase of about 72% per year, followed by a discontinuity between 2009 and 2010 leading to the second phase (2010-12) also showing a strong, but lower population growth of 51% (Fig. 40). The abundance of cohort 1 dropped by 42% between 2009 and 2010 (from 13.1 to 7.6 lobster per 100 m^2), which indicates a decrease in the number of lobster settling in 2008 compared to 2007.

4.3.5 Lobster settlement index – Bio-collectors

The abundance of yoy (per m^2) varied between sub-regions (Table 8; Fig. 41). Except for a single yoy observed in Nine Mile Creek in 2009, none were observed in bio-collectors in sub-regions 25S or 26AD. Also, none were observed in Caraquet in 2008. This was quite surprising because of the sizeable cohort 1 abundance observed in the 2010 SCUBA survey (Fig. 38). The highest yoy abundance in 2008 at 0.5 was observed in Neguac (Fig. 41) located in sub-region 23G. A positive trend was observed in Skinner's Pond (sub-region 25N) between 2009 and 2012 with a steady increase from 0.1 to 0.6 (Fig. 41). Yoy abundances in Arisaig (sub-region 26ANS) were on a downward trend since the peak value (0.2) in 2009 with a value of 0.1 in 2012 (Fig. 41). The sub-region with the widest variations was 26APEI. For both Murray Harbour and Fortune, low values were observed in 2009 and 2011, and high values in 2010 and 2012 (Fig. 41). In Murray Harbour, the variations were quite dramatic (could be described as boom and bust) with high yoy abundances of 1.0 and 0.7 in 2010 and 2012, respectively, that followed a year with no observed yoys. Similarly, the yoy abundance in Fortune1 (site at 8.3 m) increased by 10-fold (0.2 to 1.9), followed by a drop of 75% (1.9 to 0.5) and a final 3.6-fold increase (0.5 to 2.0) between 2009 and 2012 (Table 8; Fig. 41). The yoy abundance of 2.0 was the second highest in 2012. Fluctuations with a 0.0 value in 2011 were also observed in Fortune2 (site at 22.0 m). The highest yoy abundance values were observed in LFA 24 (Fig. 41). The positive trend observed in Alberton also showed the highest yoy abundance in the last three years with a peak at 2.7 in 2012 (Fig. 41). A positive trend was also observed in Covehead peaking at 1.1 yoy per m^2 in 2011 (Fig. 41).

Yoy abundance does not seem to be related to the accumulated degree days (ADD) or a particular threshold, but for sites located in the sub-region 26APEI, the ADD could explain some of the inter-annual variations. In Murray Harbour and both sites in Fortune (sites at 8.3 and 22.0 m) low ADD values correlated with low yoy abundance (Table 8; Fig. 41). Except for Nine Mile Creek, the lowest ADD values were observed in 2011, and the second lowest in 2009 (Table 8). During those two years, yoy abundances in Murray Harbour were at 0.0 and the lowest between 2009 and 2012 for Fortune1 (Fig. 41). As observed in Murray Harbour, bio-collectors deployed at 22.0 m in Fortune had an abundance of 0.0 in 2010. Also, and not surprisingly because of the depth, the lowest recorded ADD values were observed at the Fortune2 site (Table 8).

5 SOURCES OF UNCERTAINTY

There is continued concern regarding the accuracy of the catch data derived from the official catch system and the delay in the availability of these data (Comeau et al. 2008). There are uncertainties in the amount of non-recorded lobster catches corresponding to other sales, personal consumption and illegal fishing. The time delay is obvious from the present stock status assessment, as the analysis of landing trends could only be done on 2011 data, fourteen months after the end of the 2011 summer fishing season. Furthermore, in terms of stock assessment, the current system has yet to collect any information relevant to fishing effort, despite the lobster fishery being managed based on effort control.

In 2006, a 3-year pilot-project was initiated by a harvester group from LFA26B and DFO-Science to electronically collect accurate lobster landings with fishing effort information in a timely fashion. Lobster landings, fishing effort data, and other fishery related information were recorded at the wharf by lobster buyers using a handheld computer. Data were then sent daily to a DFO server and became readily available to DFO staff. In 2008, the lobster fishing activities of 296 harvesters from NS and PEI were effectively recorded through the pilot project, representing almost 10% of all the lobster licence holders in DFO-Gulf Region. Although the pilot-project ended in 2008, some harvester groups and/or buyers decided to continue with the electronic system until 2011 when DFO officially terminated this electronic system. More information on the project can be found in Rondeau and Comeau (2011).

Data on the spatial distribution of landings and effort is not collected. This information is needed to monitor the extent and changes in the distribution of fishing effort and to map the overlap of fishing gear. Information on catch, effort, and fishing location from all users is imperative to properly assess lobster stocks especially in the context of climate change.

Landings and information gathered from recruitment-index and at-sea sampling programs are a function of abundance, the level of fishing effort (trap hauls, soak-days, timing of effort and fishing strategy) and catchability. Catchability in turn is affected by environmental conditions (Drinkwater et al. 2006), gear efficiency (including trap design and bait), and other factors (Krouse 1989; Miller 1989, 1990). Changes in any of these parameters can affect landings and catch rates. Thus, indicators derived from these sources would not necessarily reflect changes in abundance, fishing pressure, or production.

None of the fishery independent indicators of stock status are available for all LFAs and only landings data provide an index of abundance for the entire sGSL, which makes an assessment of the status of the resource difficult.

Exploitation rate estimates derived from the change in abundance of the first molt class or the change in ratio estimator could potentially be biased if the underlying assumptions of these methods (similar catchability among size groups and among years) are violated or if there is inadequate sampling. Additional or alternate approaches (e.g. modelling) may address these uncertainties.

There is no estimate of total lobster biomass for the sGSL, neither the biomass available to the fishery nor the biomass of reproductive females. In the absence of such measures, landings are used as a proxy of biomass and the berried female index is derived from at-sea sampling as a measure of reproductive potential. The validity of these proxies has not been demonstrated.

Localized movements of benthic stages of lobster within the sGSL related to Northumberland Strait are not well understood.

The contribution of larval settling versus benthic movements to the recruitment of lobster into Northumberland Strait fisheries (sub-regions 25S, 26AD) is not well understood. Particle drift modelling indicates that there is limited larval exchange between this area and the rest of the sGSL. From SCUBA survey indices of abundance, recruitment to the fishery in this area cannot be explained by *in situ* larval settlement. Initial results from industry-led monitoring activities with bio-collectors, used to estimate the settling success of lobsters in several sub-regions, suggest higher settling densities in LFA 24 compared to those in Northumberland Strait, although the time series is short (2008-2012). Such data may be useful in the future regarding the lobster recruitment dynamics.

From previous assessments, the SOM_{50} from various locations has not changed between 1984 and 2006. It would be appropriate to re-estimate the SOM_{50} considering the changes in fishery regulations (mainly MLS increases) and environmental conditions observed in the past decade, and those anticipated in the future.

The general effects of changes in temperature on lobster larvae survival, benthic stages, recruitment, growth, and behaviour is also not understood.

6 CONCLUSION

The stock status of the five LFAs located in the Gulf Region has been assessed using a suite of indicators from trawl and SCUBA surveys, DFO official catch statistics, at-sea sampling and recruitment-index data, and biological sampling. Globally, lobsters in the sGSL continue to be in high abundance with recent landings above long-term medians or the highest of the time series.

The only area with weak or negative trends remains the central Northumberland Strait (i.e., sub-regions 25S and 26AD). Abundance indicators based on landings showed that the weakest landing trends are those of the Strait and those based on CPUE and the fishery-independent trawl survey have shown no improvement since the last assessment. Also, the fishery-independent SCUBA abundance index shows that the abundance of small animals (<50 mm CL) is low and a viable commercial fishery in the central Strait cannot be explained by *in situ* larval settlement, but rather by relying on benthic movement (i.e., immigration) of larger animals.

The decrease in proportions of empty traps during the fishery in almost every LFA corroborates the positive landing indicators, but the fishing pressure on the lobster stock might still be elevated because empty trap percentages in some areas are still above 20%. Exploitation rate estimates were highly variable between LFAs and among years, and should be interpreted with caution as fishing pressure indicators. Nevertheless, the lobster fishery in the sGSL continues to have high exploitation rates and to be heavily dependent on new recruits.

The two multi-year management plans aimed at increasing the MLS and the protection of large females to raise egg production seem to have had an overall positive effect on lobster production in the five LFAs within the DFO Gulf Region. The recent reduction in nominal effort, both in licence numbers and in maximum trap allocations, from industry-funded retirement programs or via the ALSM program, will most likely release some fishing pressure on lobster stocks but its full benefit at the moment is still unknown.

The only area that systematically shows negative indicators for the abundance of cohort 1, pre-recruits into the fishery and berried females is central Northumberland Strait. Conclusions from the last assessment regarding the female reproductive condition in LFA 25 are still relevant today with the timing of the fishery being detrimental to the reproductive potential of the stock.

The trends of the lobster stock from different indicators are presented in more detail in Tables 22 to 24.

6.1 ABUNDANCE INDICATORS

Landings are used as a proxy for the lobster abundance for all the fisheries in eastern Canada. No estimate of the fishable biomass is provided in the present document.

Abundance indicators based on landings of legal-sized lobsters from all LFAs are above the long-term median (1947-2011; Table 22). Since the last assessment (Comeau et al. 2008), only landings in LFAs 23 and 25 have continued to increase while elsewhere they stabilized. No decrease in the mid- (1968-2011) or short-term (2005-2011) abundance indicators has been seen in any LFA (Table 22). While landings have generally increased since 1947 (73.5% overall), the timing of the peaks differed as did the pattern of declining landings following peaks. This reflects the heterogeneity of the spatial distribution and the temporal variability of the lobster resource in the sGSL. The exception is LFA 24 where landings have generally shown a steady increase since 1975.

For long-term comparisons, it seems that increasing trends have been more pronounced in the spring fisheries and those outside of central Northumberland Strait (Table 22). In LFA 23, landings have generally increased since 2005 and by 2011 they were 164% above the long-term median. The short-term indicator for LFA 23 was also positive with an increase of 33%. Landings in 2010 and 2011 for LFA 23 were the highest of the entire time-series, mainly because of high landings in sub-region 23G. In LFA 24, the 2011 landings were 106% above the long-term median and 32% above the mid-term median but when compared to the 2005-2011 period, there was a slight decrease (13%). However, that decrease might not be representative of the actual situation as landings for 2011 need to be updated. The trend in LFA 25 has improved since the last assessment with an increase of 21%, notably driven by sub-region 25N. In LFA 26A, the 2011 landings were 34% above the long-term median. However, landing trends within LFA 26A varied spatially (Table 22). Landings from the Northumberland Strait portion of the LFA (sub-region 26AD) are still much lower (67%) compared to their highest peak landing in 1987, and neither the mid- nor the short-term comparison are showing improvement. For sub-region 26ANS, landings in 2011 were almost identical to those of 2005 with very little variation in the last 22 years. Stability in landings was also noted for the PEI sector of LFA 26A over the last 18 years. However, landings for 2011 are still 19% above the mid-term median. Landings in LFA 26B have also varied little for the last 18 years, but the 2011 landings were still 48% above the long-term median.

Landing trends in both sub-regions 25S and 26AD are typical of a boom and bust fishery (Acheson and Steneck 1997). Recent positive indicators suggest that conversely to what was seen during the last assessment, central Northumberland Strait might be in a “bust” to a “boom” transition based on historical landings information. This area might continue to experience increases in landings but to an unknown extent.

The lack of effort and fishing location information from harvesters combined with uncertainties about catch data makes it difficult to understand and analyze landing fluctuations. This problematic situation is symptomatic for most of the Canadian lobster fisheries, and has been raised on several occasions by biologists responsible for lobster stock assessments in eastern Canada (Comeau et al. 2008). Although harvesters in communities within the sGSL are indicating important changes in their catches, it is impossible to clearly determine where they are occurring, to quantify these changes and to determine if they are the result of shift in effort. These issues can only be fully understood with timely accurate temporal and spatial data supplied directly from the users, i.e. harvesters.

Recent trends in average CPUE from the at-sea sampling (in kg/trap) and the recruitment-index programs (in number/trap) are similar with increasing values in most sub-regions (Table 24). Between 2006 and 2012 no increase in CPUE was observed in LFA 24 and very limited data were available in sub-region 26ANS to define an indicator (Tables 12 and 13). The highest increase in CPUE was observed in sub-regions 25N and 25S with up to a 5-fold increase in 2012 compared to 2006 (Table 12). Those 2 sub-regions also had the best catch rates in the sGSL in kg per trap. Based on the at-sea sampling program, increases of the 2012 CPUE values were observed for sub-regions 23BC, 23G, and LFA 26B compared to 2003 (Table 12). An increase was also observed in LFA 26B between 2004 and 2012 based on the recruitment-index programs (Table 13). The lowest CPUE values both from the recruitment-index (2011) and the at-sea sampling (2012) programs were observed in sub-region 26AD (Tables 12 and 13). The wide size distribution in that sub-region is probably due to a low number of lobsters in smaller sizes rather than an increase in the number of large-sized lobsters. The implementation of various increases of the MLS and/or escape vents dimensions at different times and in different LFAs, sub-LFAs and management zones most likely affected CPUE estimates as well as the observed size ranges. However, CPUE distribution can still be used as a practical indicator of stock abundance and trends since the size structure was standardized to effort.

Positive trends in abundance were also observed in the fishery-independent trawl surveys. The distribution of commercial-sized lobsters has spread with highest concentrations around Pictou Island and east of PEI and increasing abundance in the northern part of LFA 25. The area east of Cape Tormentine to River John (sub-region 26AD) is still flagged as a barren ground with almost no lobster catch (Fig. 18). In 2012, sub-region 25N had its highest biomass index for all sizes lobster (Fig. 20) of the time series (2001-2009, 2012) putting aside the 2001 biased estimate. For sub-regions 25S and 26AD, the 2012 biomass indices were also above their respective time series averages but at a lower level compared to sub-region 25N. The proportion of the area of LFA 25 with a high lobster density (more than 400 kg per km^2) was estimated to be the highest in 2012 when compared to the last few years (Fig. 19).

Length frequency analysis from the trawl surveys show an increased abundance of lobsters of all sizes in 2012 for LFA 25 but no such signal was observed in LFA 26A where the survey is conducted just after the fishery. Furthermore, there is no evidence in LFA 25 of an inflow of recruitment-size animals or an accumulation of larger lobsters, even though landing big size females is prohibited since 2003.

Fishery-independent data from the lobster SCUBA survey was analyzed using a GLMM to estimate abundance trends. Results indicated that global lobster abundance in the sGSL increased steadily and significantly between 2000 and 2012. Also, similar to landing trends, spatial differences were observed for lobster abundances within and outside central Northumberland Strait; higher abundances were observed in LFAs 23 and 25N, while low abundances, reaching almost 0 lobster per 100 m^2 at Fox Harbour, were observed in LFAs 25S and 26AD (Table 22). Results from the model showed that inferred increases in abundance from fishery-based indices were consistent with actual observed increases in abundance, inconsistent with the idea that the variations were the result of an increase in effort or a modification of fishing practices. Results from the model for LFAs 25 and 26A are also consistent with indices derived from the trawl surveys.

Future versions of the model should account for changes in MLS. Changes in cohort abundance only partly susceptible to the fishery could provide a meaningful interpretation of the overall changes in *R* over time. Specifically, at the start of the time series in 2000, cohort 5 was fully affected by the fishery, but as the MLS was successively increased, a smaller and smaller proportion of cohort 5 was being fished prior to sampling. If group trends are informative enough (i.e., *R* has some meaningful spatial and temporal trends), it might be possible to tease out estimates of *F* or an exploitation rate.

6.2 FISHING PRESSURE INDICATORS

While knowing precise exploitation rates by year and LFA would be of great value for managing the lobster fishery, only pooled estimates in data-rich areas were derived from our methods. In the last FRCC report (FRCC 2007), exploitation rates for the Gulf-Region LFAs were estimated at between 70% and 75% for 2003 compared to 70% to 85% in 1995. Estimates from previous stock status reports (Lanteigne et al. 1998, 2004) indicated that they varied from 63% to 87%. For this assessment, exploitation rates ranged from 47% to 81% but these estimates only represent a few years (1999-2011) and areas. By year, rate estimates were highly variable and comparison of estimates with those from the period of the last assessment (2005-2006) was not possible. Therefore, exploitation rates will not be used in the present assessment as a fishing pressure indicator. Exploitation rates can be calculated a number of ways, but none seem fully applicable given the available data. Furthermore, possible violations in the underlying assumptions of the methods used undermine our ability to make meaningful comparisons between years and areas. For example, the assumption of a closed population for areas within the Strait seems tenuous given the known periodic influx of lobsters in these areas. Equal catchability throughout the sampling period for all size classes considered could also be questioned. Catchability could vary because harvesters are targeting specific size ranges, or larger animals may not be physiologically active (e.g., staying in their shelters) compared to smaller lobsters. Inconsistent fishing effort throughout the season could also affect data availability with a reduced fishing intensity at the end of the season.

The empty trap indicators from at-sea sampling and the recruitment-index program revealed similar trends. The proportion of empty traps has decreased almost everywhere since the last assessment (Table 23) and aside from sub-region LFA 26AD, no area showed more than 50% of empty traps over the course of the season (August only for at-sea sampling data for LFA 25). Also, the percentages of empty traps were lower compared to the 1980s and the 1990s, where data were available and for regions outside Northumberland Strait. In some areas the reduction in the percentage of empty traps may be explained by reductions in trap allocations.

The reduction in nominal effort is presented in the assessment for the first time because no significant changes in the number of fishing licences or trap allocations had occurred prior to 2006. The number of licences in the sGSL was reduced by 9.1% between 2006 and 2012, but most of the reduction (7.5%) was observed after the announcement of the ALSM program (DFO 2009a). However, the reduction was not equal among LFAs, with no type-A licences retired in LFA 24, 25 NS-side and in sub-LFA 26A-2 (sub-region 26ANS in Table 23). In the other areas, the reduction ranged from 2.1% to 26.5%, but those values for sub-LFA 23B and management zone 26A-3, respectively, are the extremes. In the remaining areas, the reduction averaged 10.7%. Additional licence reductions are expected for 2013 but on a smaller scale. The effect of that reduction in number of harvesters is still unknown but in areas where a higher proportion of licences were removed a release in fishing pressure is expected.

The nominal effort reduction in terms of maximum trap allocation was 12.2% between 2006 and 2012 (Table 23). The reduction is directly linked to decreases in the number of fishing licences and trap allocations. As for licence retirements, most changes occurred after the implementation of the ALSM program (DFO 2009a). The largest decrease in nominal effort was observed in management zones 26A-3 (37.5%) and 26B south (23.9%) for type-A licences and is the result of reduction in both the number of fishing licences and trap allocations. In LFA 24 and 25 (NS), no change in nominal effort occurred over the last 7 years for type-A licences (Table 18). For other areas, the reduction in nominal effort averaged 14.2%. Based on the number of trap, the global reduction in nominal effort corresponds to 111,154 traps, and multiplied by a theoretical season of 60 days, it represents a reduction of about 6.6 million trap hauls within a season. Similar to the reduction in licence numbers, the effect of such a reduction in nominal effort on lobster stocks and the fishery is unknown. Adequate monitoring of abundance and stock status indicators in the upcoming years will be necessary to understand the effect of the recent reductions in nominal effort.

In the last assessment, one indicator used to evaluate fishing pressure was the percentage of first molt group (FMG) into the fishery. However, the interpretation of data related to FMG was complex and needed to be combined with other indicators to be meaningful. Also, because of several changes in MLS over the years, the size range for the FMG would have to be adjusted and comparison between years would be even more complicated. For those reasons, the FMG in the fishery is no longer used as a fishing pressure indicator.

Overall, the fishing pressure indicators examined are positive.

6.3 PRODUCTION INDICATORS

Since the last assessment, CPUE indices of berried females in the at-sea samples have generally increased or remained stable (Table 24). In sub-regions 23BC, 23G, 26ANS, and 26B, where only data dating back to 2003 were available, the increase in CPUE is most likely due to changes in MLS that have occurred since 2003. High CPUE indices for berried females were observed in sub-regions 25N and 25S with a significant increase in 2012 compared to 2006. In 2012, the peak index value observed in sub-region 25S was the highest ever recorded (Comeau et al. 2008). In sub-region 26A PEI, CPUE of berried females has generally increased over the last seven years while no change was observed in LFA 24 (the area with the smallest increases in MLS). CPUE indices of berried females increased in sub-region 26AD from 2006 to 2010 but then dropped to a level close to those observed in 2006-2007(Table 24). Despite having the lowest CPUE indices of berried females of all sub-regions, the proportion of large females (>95 mm CL) in 26AD was higher in 2012, at 21%, than anywhere else. By comparison, only 5% of females were >95 mm CL in LFA 26B where the MLS protects 100% of primiparous females.

An increase in the abundance of berried females was also observed in the SCUBA data. A steady increase was observed between 2009 and 2012 in Caraquet, corresponding to gradual changes in the MLS which eventually reached the size corresponding to SOM_{50} in sub-LFAs 23A and 23B. Although the increased abundance of berried females could be attributed to an overall increase in the lobster biomass, there is a strong indication that it could also be directly attributed to the increase in MLS. The best indication is that the contribution of females between 70 and 75 mm CL (now fully protected from the fishery) to the berried female abundance increased from 10% to 53% between 2003 and 2011.

Based on the modified traps data of the recruitment-index program, lobsters within one molt from recruiting into the fishery were observed in all sub-regions. CPUE indices of fishery recruits have increased in the last few years in many areas while in others (LFA 24 and sub-region 26APEI), no trend was observed (Table 24). As for the CPUE of berried females, the increase in CPUE of fishery recruits in LFA 26B is most likely the result of recent MLS increases, from 73 to 81 mm CL between 2004 and 2012. Sub-region 26AD was characterized by the lowest CPUE of fishery recruits with very little difference between modified and regular trap data (Table 24). This situation is alarming and could indicate very low fishery recruitment in that sub-region. This observation corroborates the low level of recruitment in central Northumberland Strait observed from other indicators, both fishery-dependent and independent.

Concentrations of sub-legal lobsters along the eastern coast of NB were detected in the trawl survey, and most recently around Pictou Island and on the east coast of PEI as the spatial coverage of the survey was increased. Distribution patterns of sub-legal lobsters reflected those of legal size lobsters over the years. Biomass indices of sub-legal lobsters were more than two times higher in 2012 compared to the 2001-09 series averages in the three sub-regions covered by the survey (Table 24). In LFA 25, the spatial proportion of high density areas also increased in 2012. No concentration of sub-legal lobsters was observed in central Northumberland Strait during the surveys.

Male-to-female sex ratios of legal size lobsters caught in the trawl surveys were generally above 1.0 both for LFA 25 and 26A which represents an adequate situation to ensure mating success (Table 24). For sub-legal animals, sex ratios fluctuated more, especially in LFA 26A. While they remained close to 1.0 in LFA 25 (0.90-1.16), in recent years sex ratios in LFA 26A were unbalanced towards females in 2008, 2009, and 2012 (0.68-0.89). However, that situation should not raise an immediate concern because few females smaller than the MLS (71 mm CL in 2012) are sexually mature and do contribute to the reproductive potential of the stock.

Cohort 1 from the SCUBA survey should be used as a recruitment index (to the benthic habitat) instead of cohort 0 because of a detection problem. For all the sites and years, the observed R* values were high (~3). This is most easily explained by the practical limits of divers to locate and capture animals in cohort 0 due to their small size. A further issue was detected in the central Northumberland Strait, which had relatively high *R** values between cohorts 1 and 2, but this should not be interpreted as a detection problem. It is rather part of a larger pattern of influx of lobster from adjacent sites. Since these cohorts have very low abundances within central Strait, small amounts of incoming lobster would easily increase the corresponding *R** values.

The abundance of cohort 1 lobsters was assessed by SCUBA diving surveys in sub-regions 23BC, 23G, 25N, 25S, and 26AD between 2003 and 2012 (Table 24). Empirical mean abundance for the longest uninterrupted dataset in Caraquet (LFA 23B) showed a 16.5-fold increase for cohort 1 lobsters between 2003 and 2012. Similar values and trends were observed for another site in LFA 23B (Grande-Anse), sites in LFAs 23A and 23D, as well as sub-region 25N (i.e., outside central Northumberland Strait). Abundances observed in both sub-regions of the central Northumberland Strait (i.e., LFAs 25S and 26AD) were much lower. A slight improvement was noted in the sites located in LFA 25S in 2012, but values are well below those observed in Caraquet (by a factor of 2.6). No cohort 1 lobster was observed in Fox Harbour located in sub-region 26AD. The large increase in cohort 1 lobster abundances in sites outside of

Northumberland Strait since 2003 is indicative of very good recruitment. These large increases of cryptic lobsters were not observed in central Northumberland Strait where the estimated abundances were the lowest. Recruitment is still lacking in the Northumberland Strait area.

Implementation of conservation measures since 2003 to increase egg production could, at least partially, be responsible for the increasing abundance of cohort 1 lobsters. The abundances of cohort 1 lobsters have increased dramatically in the sGSL from stable (low) levels in the 1990s (Michel Comeau, DFO, Moncton, unpublished data) and early 2000s (Comeau et al. 2008). Increasing the MLS, to protect females from exploitation until they reach the SOM_{50}, and the protection of large and fecund window-sized females (maximum size in LFA 25) seems to have resulted in higher recruitment. The increasing trends observed in the mid-2000s correlate with the implementation of these new measures. The widespread effect in the sGSL could be attributed to connectivity from the larval drift (from west to east). The exception is the central Northumberland Strait. In contrast to the rest of the sGSL, the Northumberland Strait is an isolated system (relying on itself for recruitment) in terms of summer water movement (Comeau et al. 2008; Chassé et al. 2014), hence, recruitment should be self-sufficient. Thus, there might still be a high risk of adverse effects in the Strait from the present regulatory conservation measures.

7 MANAGEMENT CONSIDERATIONS

Information on catch, effort and fishing location from all harvesters is imperative for proper assessment of lobster stocks. At present there are no direct data on the spatial distribution of landings and effort. This information would permit a monitoring of the extent and changes in the distribution of fishing effort and mapping of the overlap of fishing gear. Reliance on volunteer programs to provide this level of information has been inadequate to date.

In order to properly assess lobster stock status, emphasis should be put on fishery independent indicators. In the context of a Precautionary Approach (PA), stock status indicators that are derived from fishery dependent data sources would become unusable if changes in the fishery are implemented. Existing fishery-independent monitoring programs provide valuable information on some portions of the sGSL lobster stock and should at least be secured if not expanded.

Abundance, fishing pressure and production indicators all suggest that the weak landing trends observed in central Northumberland Strait are probably caused by weak annual recruitment and high fishing capacity. Some of the corrective measures to reduce the fishing effort and enhance the egg production that were implemented recently seemed to have been beneficial, but further measures as suggested in the last two assessments related to LFA 25 (Comeau et al. 2004, 2008) could be considered.

Recent reductions in the number of participants in the lobster fishery and in the number of traps will most likely have a positive effect on fishing pressure. However, the presumed effects on lobster stocks will only become noticeable in future years. With the current high abundance of lobster stocks and positive indicators, the decrease in nominal effort might have been overshadowed by the increase in abundance.

8 OTHER CONSIDERATIONS

There are currently no biomass indicators for lobster in the sGSL. Data from LFAs 24, 26A, and 26B from 1949 to 2010 were used with a Schaefer surplus-production model to try to obtain biomass estimates. A number of issues were encountered when the model was applied to the available data which prevented fitting the model adequately. A population model developed by the University of Maine has been applied to lobster stocks and fisheries in the United States (US) (Chen et al. 2005). However, the adaptation of the US model to Canadian stocks would require considerable work as there are many differences between the US and Canadian lobster stocks and fisheries.

Very little information is available on lobster by-catch from other fisheries in the sGSL but no landing of lobster from these fisheries is permitted. Lobster by-catch during the scallop fishery has been evaluated to represent a very small fraction of the total lobster population. From 24 sampling trips done between 2006 and 2008 only 51 lobsters were caught (mean of 1.7 lobsters per fishing trip) and most animals were in good to excellent condition when returned to the water. Buffer zones are in place in the scallop fishery to reduce or avoid dragging on lobster grounds.

Rock crab, cunner, and sculpin are allowed to be landed during the lobster fishery operating in the Gulf Region. While the amount of rock crab landed as by-catch is recorded and incorporated in the assessment of that species, no information is available for rock crab used as bait. Removals of cunner and sculpin are undocumented with unknown consequences to their populations or the ecosystem.

The trophic link between lobster and rock crab is well documented (DFO 2013b; Rondeau et al. 2014). The directed rock crab fishery is restricted to large males which are very little preyed upon by lobsters. There is presently no MLS or harvest limit on removals of male rock crabs in the by-catch and the bait fisheries during the lobster season. The extent of rock crab catches in lobster gear may be decreasing with the use of larger escape mechanisms in lobster traps adjusted to the lobster MLS which would reduce the retention of small rock crab.

The gear impact or “footprint” from the lobster fishery on the benthic habitat has not been formally assessed. However, using regulatory maximum traps dimensions, the surface area of each LFA and a full 60-day fishing season, the contact area between traps and the benthic habitat is estimated to be around 1% in each LFA. This estimate should be considered as an overestimate because no harvesters fish with maximum-sized traps for 60 consecutive days. However, the impact associated with the movement of traps along the bottom (i.e., dragging) is not taken into account.

9 REFERENCES CITED

Acheson, J.M., and Steneck, R.S. 1997. Bust and boom in the marine industry: perspectives of fishers and biologists. North Am. J. Fish. Manag. 17: 826-846.

Annis, E.R. 2005. Temperature effects on the vertical distribution of lobster postlarvae (*Homarus americanus*). Limnol. Oceanogr. 50: 1972-1982.

Burnham, K.P., Anderson, D.R., and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72: 202 p.

Chassé, J., Lambert, N., Comeau, M., Galbraith, P.S., and Pettipas, R.G. 2014. Environmental conditions in the southern Gulf of St. Lawrence relevant to lobster. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/031. v + 25 p.

Chen, Y., and Montgomery, S. 1999. Modelling the dynamics of rock lobster, *Jasus verreauxi*, stock in New South Wales, Australia. Fish. Bull. 97: 25-38.

Chen, Y., Kanaiwa, M., and Wilson, C. 2005. Developing and evaluating a size-structured stock assessment model for the American lobster, *Homarus americanus*, fishery. N.Z. J. Mar. Freshwater Res. 39: 645-660.

Comeau, M., and Savoie, F. 2001. Growth increment and molt frequency of the American lobster (*Homarus americanus*) in the southwestern Gulf of St. Lawrence. J. Crust. Biol. 21: 923-936.

Comeau, M., and Savoie, F. 2002. Maturity and reproduction cycle of the female American lobster, *Homarus americanus*, in the southwestern Gulf of St. Lawrence, Canada. J. Crust. Biol. 22: 762-774.

Comeau, M., Smith, M.D., and Mallet, M. 2009. Variability in trap catches for an American lobster, *Homarus americanus*, spring fishery. N.Z. J. Mar. Freshwater Res. 43: 401-410.

Comeau, M., Hanson, J.M., Mallet, M., and Savoie, F. 2004. Stock status of the American lobster, *Homarus americanus*, in the Lobster Fishing Area 25. DFO Can. Sci. Adv. Sec. Res. Doc. 2004/054. 70 p.

Comeau, M., Hanson, J.M., Rondeau, A., Mallet, M., and Chassé, J. 2008. Framework and assessment for American lobster, *Homarus americanus*, fisheries in the southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/054. 111 p.

Conan, G.Y., Comeau, M., Robichaud, G., Gosset, C., and Garaicoechea, C. 1994. The Bigouden *Nephrops* trawl, and the Devismes trawl, two otter trawls efficiently catching benthic stages of snow crab, and of American lobster. Can. Tech. Rep. Fish. Aquat. Sci. 1992. 27 p.

Dawe, E.G., Hoenig, J.M., and Xu, X. 1993. Change-in-ratio and index-removal methods for population assessment and their application to snow crab (*Chionoecetes opilio*). Can. J. Fish Aquat. Sci. 50: 1467-1476.

DeWolf, A.G. 1974. The lobster fishery of the Maritime Provinces: economic effects of regulations. Bull. Fish. Res. Board Can. 187: 59 p.

DFO. 2007. Framework and Assessment for Lobster (*Homarus americanus*) in the Southern Gulf of St. Lawrence Lobster Fishing Areas 23, 24, 25, 26A and 26B. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/035. 12 p.

DFO. 2009a. Atlantic lobster sustainability measures (accessed 12 May 2015).

DFO. 2009b. A fishery decision-making framework incorporating the precautionary approach (accessed 12 May 2015).

DFO. 2012. Commercial fisheries (accessed 12 May 2015).

DFO. 2013a. American lobster, *Homarus americanus*, stock status in the southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/029.

DFO. 2013b. Assessment of the Rock Crab (*Cancer irroratus*) fishery in the southern Gulf of St. Lawrence for 2006 to 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/030.

Dobson, D., and Petrie, B. 1985. Long-term temperature monitoring program, 1984, Scotia-Fundy, Gulf Regions. Can. Data Rep. Hydrogr. Ocean Sci. 35: 691 p.

Drinkwater, K.F., Tremblay, M.J., and Comeau, M. 2006. The influence of wind and temperature on the catch rate of the American lobster (*Homarus americanus*) during spring fisheries off eastern Canada. Fish. Oceanogr. 15: 150-165.

FRCC (Fishery Resource Conservation Council). 1995. A conservation framework for Atlantic lobster. Report to the Minister of Fisheries and Oceans. Nov. 1995. 49 p.

FRCC (Fishery Resource Conservation Council). 2007. Sustainability framework for Atlantic lobster. Report to the Minister of Fisheries and Oceans. July 2007. 54 p.

Gelman, A., Carlin, J.B., Stern, H.S., and Rubin, D.B. (eds). 2004. Bayesian Data Analysis. Chapman & Hall/CRC. New York. 668 p.

Gendron, L., and Sainte-Marie, B. 2006. Growth of juvenile lobster *Homarus americanus* off the Magdalen Islands (Quebec, Canada) and projection of instar and age at commercial size. Mar. Ecol. Prog. Ser. 326: 221-233.

Gendron, L., and Savard, G. 2003. Lobster stock status in the Magdalen Islands (LFA 22) in 2002. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/058. viii + 55 p.

Hanson, J.M. 1996. Seasonal distribution of juvenile Atlantic cod in the southern Gulf of St. Lawrence. J. Fish. Biol. 49:1138-1152.

Hanson, J.M., and Lanteigne, M. 2000. Evaluation of Atlantic cod predation on American lobster in the southern Gulf of St. Lawrence, with comments on other potential fish predators. Trans. Am. Fish. Soc. 129: 13-29.

Hudon, C. 1987. Ecology and growth of postlarval and juvenile lobster, *Homarus americanus*, off Îles de la Madeleine (Quebec). Can. J. Fish. Aquat. Sci. 44: 1855-1869.

Jiang, J. 2007. Linear and Generalized Linear Mixed Models and their Applications. Springer, New York. 257 p.

Krouse, J.S. 1989. Performance and selectivity of trap fisheries for crustaceans. *In*: Marine invertebrate fisheries: their assessment and management. Edited by J.F. Caddy. Willey, New York. pp. 307-325.

Lanteigne, M., Comeau, M., and Mallet, M. 2004. Stock and fishery status of the American lobster, *Homarus americanus*, in the southern Gulf of St. Lawrence, for the 2001 (Lobster Fishing Areas 23, 24, 25, 26A and 26B). DFO Can. Sci. Adv. Sec. Res. Doc. 2004/048. 60 p.

Lanteigne, M., Comeau, M., Mallet, M., Robichaud, G., and Savoie, F. 1998. The American lobster, *Homarus americanus*, in the southern Gulf of St. Lawrence. DFO Can. Stock Assess. Sec. Res. Doc. 98/123. 29 p.

Lunn, D.J., Thomas, A., Best, N., and Spiegelhalter, D. 2000. WinBUGS - a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing, 10: 325-337.

Lunn, D.J., Spiegelhalter, D., Thomas, A. and Best, N., 2009. The BUGS project: Evolution, critique and future directions (with discussion), Statistics in Medicine, 28: 3049-3082.

Mallet, M., Comeau, B., Gagnon, D., and Comeau, M. 2006. At-sea sampling data collection and fishery regulations for the southern Gulf of St. Lawrence lobster (*Homarus americanus*) fishery – 1982-2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2769. 105 p.

Miller, R.J. 1989. Catchability of American lobsters (*Homarus americanus*) and rock crabs (*Cancer irroratus*) by traps. Can. J. Fish. Aquat. Sci. 46: 1652-1657.

Miller, R.J. 1990. Effectiveness of crab and lobster traps. Can. J. Fish. Aquat. Sci. 47: 1228-1251.

Miller, R.J., Moore, D.S., and Pringle, J.D. 1987. Overview of the inshore lobster resources in the Scotia-Fundy Region. CAFSAC Res. Doc. 87/85. 20 p.

Pettijohn, F.J. (ed.). 1949. Sedimentary rocks. Harper & Row, New York, 718 p.

R Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. R: The R Project for Statistical Computing. (accessed 12 May 2015).

Rondeau, A., and Comeau, M. (eds). 2011. Workshop on the Lobster (*Homarus americanus*) fishery data collection pilot project and general data collection issues held in Moncton, New Brunswick, 16-17 February 2009: Abstracts and proceedings. Can. Manuscr. Rep. Fish. Aquat. Sci. 2961: vi + 21 p.

Rondeau, A., Hanson, J.M., and Comeau, M. 2014. Rock crab, *Cancer irroratus*, fishery and stock status in the southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/032. vi + 55 p.

Tremblay, M.J., and Eagles, M.D. 1998. Eastern Cape Breton Lobster (LFA27-30): stock status and eggs-per-recruit estimates. DFO Can. Sci.Advis. Sec. Res. Doc. 1998/124. 28 p.

Tremblay, M.J., Pezzack, D.S., Denton, C., Cassista-Da Ros, M., Smith, S.J., Reeves, A.R., Silva, A., and Armsworthy, S. 2012. Assessment of lobster off the coast of eastern Cape Breton and the eastern and south shores of Nova Scotia (LFAs 27-33). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/022. iv + 114 p.

Voutier, J.L., and Hanson, J.M. 2008. Distribution, abundance, and feeding of a disjunct population of lady crab in the southern Gulf of St. Lawrence, Canada. Aquat. Ecol. 42: 43-60.

Wahle, R.A., Bergeron, C., Tremblay, J., Wilson, C., Burdett-Coutts, V., Comeau, M., Rochette, R., Lawton, P., Glenn, R., and Gibson, M. 2013. The geography and bathymetry of American lobster benthic recruitment as measured by diver-based suction sampling and passive collectors. Mar. Biol. Res. 9: 42-58.

Wahle, R.A., Wilson, C., Parkhurst, M., and Bergeron, C.E. 2009. A vessel-deployed passive postlarval collector to assess settlement of the American lobster *Homarus americanus*. N.Z. J. Mar. Freshwater Res. 43: 465-474.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. J. Geol. 30: 377-392.

Williamson, A.M. 1992. Historical lobster landings for the Atlantic Canada, 1892-1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2164: 110 p.

Wood, S.N. (ed.). 2006. Generalized Additive Models: An Introduction with R. Chapman & Hall/CRC. New York. 410 p.

Zuur, A., Saveliev, A.A., and Ieno, E.N. (eds). 2012. Zero Inflated Models and Generalized Linear Mixed Models with R. Highland Statistics Ltd. 324 p.

TABLES

Table 1. Key management measures in place during the 2012 lobster fishery in the southern Gulf of St. Lawrence by lobster fishing area (LFA), sub-LFA, and management zone.

Characteristic	23A	23B	23C	23D	24	25	26A1	26A2	26A3	26B-North	26B-South
Fishing season	May 1 to June 30				May 1 to June 30	Aug. 13 to Oct. 14	May 1 to June 30[1]			May 2 to June 30	May 1 to June 30
Number of licences											
Category A	636				635	708	703			223	
Category B	33				1	6	5			3	
Number of traps per licence	300				300	250 (PEI 240)	280 (PEI 273)	275	250	250	
Number of traps per line	na	na	3 (portion)		na	na	6 (part of PEI) 5 (Gulf NS)	6	2	5	na
Maximum size entrance (mm diameter)	152				na	152	na	152	na	152	na
Minimum legal carapace size (mm)	75	75	72	71	71	71	71	73	76	81	79
Female size restriction (mm)	115-129				115-129	>= 114	115-129			na	

[1] Fishing season for the portion of LFA26A from Point Prim to Victoria was May 7 to July 8, 2012

Table 2. Number of renewed lobster licences per lobster fishing area (LFA), sub-LFA or management zone from 2006 to 2012. Numbers in parentheses are the total number of licences before LFAs were subdivided.

	Sub LFA				LFA		LFA		Management zone			Sub LFA	Management zone		
	23A	23B	23C	23D	24		25		26A-1		26A-3	26A-2	26B N	26B S	
Year	NB				PE	NB	NS	PE	NS	PE	NS	NS	NS		Total
2006	(754)				639	573	18	251	147	404	49	166	(247)		3,248
2007	(753)				639	568	18	251	146	403	49	166	(247)		3,240
2008	127	95	(526)		639	567	18	252	146	403	49	166	118	129	3,235
2009	126	95	336	186	639	561	18	252	147	403	47	166	118	129	3,223
2010	125	95	336	186	639	560	18	226	145	403	48	166	118	128	3,193
2011	124	95	336	186	637	560	18	226	134	378	36	166	109	118	3,123
2012	109	93	298	169	636	471	18	225	134	372	36	166	109	117	2,953

Table 3. Trap allocations for type-A licences per lobster fishing area (LFA), sub-LFA or management zone from 2006 to 2012. Numbers in parentheses are the trap allocations before the LFA was subdivided.

	LFA	LFA		LFA		Management zone			Sub-LFA	Management zone	
	23	24		25		26A-1		26A-3	26A-2	26B N	26B S
Year	NB	PE	NB	NS	PE	NS	PE	NS	NS	NS	
2006	300	300	250	250	250	300	300	300	300	(300)	
2007	300	300	250	250	250	300	300	300	300	(300)	
2008	300	300	250	250	250	300	300	300	275	275	300
2009	300	300	250	250	250	300	300	300	275	275	275
2010	300	300	250	250	250	300	300	300	275	275	275
2011	300	300	250	250	240	280	280	250	275	250	250
2012	300	300	250	250	240	280	273	250	275	250	250

*Table 4. Lobster minimum legal carapace size (MLS, in mm) in effect by lobster fishing area (*LFA), sub-LFA or management zone *for the management of the lobster fisheries of the southern Gulf of St. Lawrence, 1957 to 2013. For 2013, the MLS has been defined in the harvesting plan.*

	LFA 23				LFA		LFA 26A			LFA 26B	
Year	23A	23B	23C	23D	24	LFA 25	26A3	26A1	26A2	North	South
1957-1986	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	
1987	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	65.1	
1988	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	66.7	
1989	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	68.3	
1990	65.1	65.1	65.1	65.1	63.5	65.1	63.5	63.5	63.5	70.0	
1991-1996	66.7	66.7	66.7	66.7	63.5	66.7	65.1	65.1	65.1	70.0	
1997	66.7	66.7	66.7	66.7	63.5	66.7	70	65.1	66.7	70.0	
1998	67.5	67.5	67.5	67.5	65.1	67.5	70	65.9	68.3	70.0	
1999	67.5	67.5	67.5	67.5	65.9	67.5	70	65.9	70	70.0	
2000	67.5	67.5	67.5	67.5	66.7	67.5	70	66.7	70	70.0	
2001-2002	67.5	67.5	67.5	67.5	67.5	67.5	70	67.5	70	70.0	
2003	68.5	68.5	68.5	68.5	68.5	68.5	70	68.5	70	72	
2004	70.0	70.0	70.0	70.0	69.5	70.0	70	69.5	71.5	73	
2005	70.0	70.0	70.0	70.0	70.0	70.0	73	70.0	71.5	74	
2006	70.0	70.0	70.0	70.0	70.0	70.0	76	70.0	71.5	75	
2007	70.0	70.0	70.0	70.0	70.0	70.0	76	70.0	71.5	76	
2008	71	71	71	70	70.0	70.0	76	70.0	73	77	76
2009	72	72	72	70	70.0	70.0	76	70	73	78	76
2010	73	73	72	70	70.0	70.0	76	70	73	79	77
2011	74	74	72	71	71	71	76	71	73	80	79
2012	75	75	73	71	71	71	76	71	73	81	79
2013	76	76	73	72	72	72	76	72	73	81	79

Table 5. At sea sampling activities descriptions (number of berried female (B) and number of male and non-berried female (M&F) lobsters measured, number of ports sampled, number of samples collected, and number of traps sampled by sub-regions, 1983 to 2012. For sub-regions 25N and 25S, data are from the month of August only.

	23BC					23G					24				
Year	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps
1983	11	504	1	1	171	47	1008	3	5	609	85	1602	3	5	471
1984	5	253	2	3	158	104	4801	3	26	3056	76	4276	2	15	1031
1985	139	2402	3	35	985	133	3658	2	20	2364	134	10145	3	29	2764
1986	10	233	1	4	93	46	825	2	5	383	358	8954	6	28	3055
1987	48	1255	1	3	573	21	551	1	4	311	61	1209	3	6	391
1988	126	2476	2	6	1423	7	409	1	4	517	14	1532	3	7	570
1989	29	790	1	3	643	65	1409	1	3	951	341	10026	3	26	3518
1990	210	3031	3	9	1877	45	1925	2	6	889	97	2819	3	10	846
1991	227	5463	3	11	2624	93	3549	2	8	1747	266	6760	5	15	1770
1992	405	3680	3	8	2089	127	1540	2	4	1041	428	11627	9	23	3295
1993	200	2658	3	6	1759	94	1640	2	4	1418	465	12105	9	24	3052
1994	91	951	3	6	669	14	730	2	4	388	154	3316	4	4	989
1995	209	1581	3	7	1244	42	713	2	4	661	254	5330	4	8	1218
1996	119	1267	3	6	925	36	1215	2	4	1086	422	6256	5	10	2472
1997	339	1859	4	10	1262	33	710	2	4	672	331	2520	4	8	1616
1998	205	977	3	6	938	76	986	2	4	960	3540	22413	13	85	12364
1999	1034	5454	3	24	3926	892	12252	3	37	9609	2597	42148	13	126	18226
2000	3273	16593	5	50	11455	233	2693	1	7	1633	4240	39934	14	115	15273
2001	994	4255	2	18	4055	1074	23827	1	36	10524	2034	31876	7	64	9135
2002	450	2189	1	10	2934	25	378	1	1	293	1496	17090	8	34	6495
2003	532	2463	2	7	2037	102	1491	1	4	1167	1697	17374	12	30	5865
2004	36	207	1	1	297	na	na	na	na	na	1492	15486	9	24	4843
2005	na	na	na	na	na	na	na	na	na	na	1451	17339	10	28	6374
2006	na	na	na	na	na	na	na	na	na	na	2987	23523	10	30	7321
2007	na	na	na	na	na	na	na	na	na	na	1694	17925	9	25	6617
2008	na	na	na	na	na	na	na	na	na	na	2590	17189	9	25	6266
2009	na	na	na	na	na	na	na	na	na	na	3178	24562	10	30	8049
2010	na	na	na	na	na	na	na	na	na	na	1230	14799	9	22	5927
2011	na	na	na	na	na	na	na	na	na	na	2398	18982	9	25	6465
2012	3751	23948	3	26	7549	2265	19856	3	26	7750	2557	22986	9	28	7363

Table 5 (continued). At sea sampling activities descriptions (number of berried female (B) and number of male and non-berried female (M&F) lobsters measured, number of ports sampled, number of samples collected, and number of traps sampled by sub-regions, 1983 to 2012. For sub-regions 25N and 25S, data are from the month of August only.

	26AD					26ANS					26APEI				
Year	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps
1983	202	2023	1	6	390	199	1557	1	10	1080	60	1300	2	4	429
1984	683	5673	8	19	3277	452	4558	6	20	2865	125	1999	4	14	1294
1985	353	4010	11	20	2127	33	738	3	5	499	167	7091	5	32	3456
1986	250	2614	5	7	1000	107	1033	3	3	552	87	1475	3	5	553
1987	224	1390	1	3	660	63	662	1	3	567	96	920	2	6	309
1988	772	4566	2	14	1862	28	1332	1	3	639	28	1647	3	6	316
1989	1068	3430	2	14	1873	9	636	1	2	429	218	3698	2	6	1262
1990	510	2704	2	8	1249	103	1269	1	3	671	267	3811	2	6	1467
1991	817	3494	4	12	2703	69	1411	1	3	481	590	8531	5	15	2331
1992	802	4350	4	23	4905	179	1877	1	3	826	518	7543	6	19	3213
1993	173	1094	3	7	1457	119	1277	1	2	470	414	5045	4	13	1927
1994	132	216	1	2	282	39	382	1	2	187	57	284	1	1	294
1995	58	408	2	4	470	17	369	1	3	387	66	1906	2	4	855
1996	85	299	2	4	457	24	272	1	2	154	89	1457	2	4	1088
1997	134	256	2	4	468	36	378	1	1	141	35	838	2	4	635
1998	1062	4779	5	25	4263	136	910	1	2	440	2590	12739	8	58	10811
1999	1694	8180	5	46	7441	738	5295	2	12	3202	2201	19507	8	75	20142
2000	2507	6871	5	34	6401	1621	7437	1	13	3687	3381	18951	8	71	14170
2001	181	283	2	3	379	na	na	na	na	na	1207	11751	3	44	10774
2002	733	1538	2	10	2716	na	na	na	na	na	2061	12342	4	39	9975
2003	1681	3678	10	27	7172	1916	10926	3	22	5995	1361	9668	6	27	6392
2004	464	1571	5	16	3581	na	na	na	na	na	724	5877	5	15	3738
2005	281	1155	5	12	2716	na	na	na	na	na	822	7117	5	19	5012
2006	560	1575	4	14	3250	na	na	na	na	na	1082	6117	5	20	5126
2007	477	1195	4	11	2682	na	na	na	na	na	812	5148	5	17	4969
2008	482	1684	3	8	2211	na	na	na	na	na	814	5618	5	17	5204
2009	765	2507	4	11	2894	na	na	na	na	na	1754	8416	5	17	5396
2010	1084	2436	4	12	3199	na	na	na	na	na	1288	8033	5	16	5056
2011	409	1398	3	9	1888	na	na	na	na	na	1966	9187	5	18	4920
2012	1138	3930	5	24	5465	3132	9681	3	20	5015	1804	10443	5	17	4592

Table 5 (continued). At sea sampling activities descriptions (number of berried female (B) and number of male and non-berried female (M&F) lobsters measured, number of ports sampled, number of samples collected, and number of traps sampled by sub-regions, 1983 to 2012. For sub-regions 25N and 25S, data are from the month of August only.

	25N					25S					26B				
Year	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps	B	M&F	Port	Samples	Traps
1983	57	1185	4	5	265	60	1851	2	3	310	270	5723	4	15	3399
1984	76	3806	3	10	999	132	6312	4	9	964	15	889	1	2	580
1985	289	3637	2	9	602	417	4896	5	14	1011	194	7254	5	23	3259
1986	22	704	2	2	120	5	826	2	3	143	455	10021	6	27	3869
1987	40	582	2	2	136	133	1981	3	4	587	215	3673	3	18	1937
1988	19	549	1	1	105	124	1193	3	3	429	205	4869	3	18	1489
1989	114	1209	1	1	177	375	1479	3	3	535	331	6313	5	16	1844
1990	401	3478	4	4	689	319	1950	4	4	803	913	15592	4	46	5124
1991	190	3203	6	6	537	189	2884	5	5	964	1010	9634	5	25	2903
1992	189	5510	5	8	1148	504	4848	5	7	1607	598	6987	5	23	3230
1993	256	3403	6	7	598	154	2222	4	4	714	780	8875	4	24	4689
1994	76	709	2	2	150	26	225	2	2	131	668	7219	5	50	4251
1995	166	1570	2	2	271	332	1495	4	4	681	351	3367	4	18	2019
1996	153	954	2	2	396	220	500	4	4	705	181	1155	3	6	672
1997	10	656	2	2	298	152	721	4	4	590	184	1062	3	6	748
1998	335	3044	5	9	1213	747	3091	8	18	2793	279	1577	3	6	1027
1999	656	3920	5	10	1553	942	2997	8	16	3029	1099	6831	4	24	5601
2000	1018	5942	6	17	3207	467	1738	7	16	2216	1834	8192	4	27	6710
2001	na	na	na	na	na	502	2767	4	13	2583	2324	12511	1	28	8047
2002	157	1504	2	3	609	57	446	2	2	497	922	3742	1	11	3013
2003	364	2389	5	7	1619	192	1380	4	8	1641	596	2385	2	11	2231
2004	252	2314	4	4	852	38	259	2	2	428	na	na	na	na	na
2005	299	1459	3	4	899	152	831	3	5	1148	na	na	na	na	na
2006	284	1714	4	4	916	127	258	3	3	610	na	na	na	na	na
2007	190	1501	2	2	419	108	491	3	3	515	na	na	na	na	na
2008	248	4075	4	6	1236	137	1346	3	3	704	na	na	na	na	na
2009	165	2736	3	3	506	86	406	1	1	240	na	na	na	na	na
2010	377	2308	2	3	633	257	1371	2	2	367	na	na	na	na	na
2011	677	5781	3	6	1328	195	1238	2	2	375	na	na	na	na	na
2012	783	7233	4	6	1166	1504	5932	4	8	1878	2827	16148	6	32	7609

Table 6. Details of the sampling activities within the recruitment-index program by sub-regions, 2006 to 2012. Modified refers to modified traps with escape vents blocked. Regular refers to lobster traps with functioning escape vents. Data from 2012 were not available for sub-regions 24, 25N, 25S, 26AD, and 26APEI but activities were conducted.

LFA or Sub-Region	Year	Number of participants	Lobsters measured – modified traps	Modified traps sampled	Lobsters measured – regular traps	Regular traps sampled	Total lobsters measured
24	2006	51	48606	7347	31062	7347	79668
	2007	51	37927	7131	26362	7131	64289
	2008	50	41133	6953	28235	6952	69368
	2009	54	44421	7170	30397	7172	74818
	2010	52	41650	6876	27652	6879	69302
	2011	51	37321	6675	25556	6675	62877
25N	2006	7	5540	1231	2892	1231	8432
	2007	6	5041	783	1847	783	6888
	2008	9	6760	1144	3108	1144	9868
	2009	10	10569	1247	4617	1247	15186
	2010	13	15443	1657	7699	1656	23142
	2011	13	14605	1574	7172	1574	21777
25S	2006	3	520	364	417	364	937
	2007	3	812	392	679	392	1491
	2008	3	989	361	707	361	1696
	2009	3	1172	360	972	360	2144
	2010	3	1293	340	1062	340	2355
	2011	3	1549	360	1240	360	2789
26AD	2006	6	546	786	545	786	1091
	2007	6	627	722	605	726	1232
	2008	6	881	735	813	735	1694
	2009	7	1204	875	1191	876	2395
	2010	7	1237	864	1146	863	2383
	2011	7	1012	897	960	898	1972
26ANS	2000	9	2545	1114	1916	1113	4461
	2012	8	3053	1122	2498	1122	5551
26APEI	2006	16	7143	2563	4957	2563	12100
	2007	17	5691	2575	4319	2576	10010
	2008	20	7140	2667	5176	2667	12316
	2009	20	8474	2589	5728	2589	14202
	2010	20	8318	2441	5386	2441	13704
	2011	17	7776	2376	5522	2375	13298
26B	2004	9	2616	1029	2138	1028	4754
	2012	5	2915	645	1893	641	4808

Table 7. Number of line transects (400 m^2 area) sampled by SCUBA diving at various sites, 2000 to 2012.

	Year												
Site	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pointe-Verte	na	na	na	na	na	na	na	na	na	6	11	11	3
Grande-Anse	11	17	15	na	16	16	na	9	na	na	11	na	na
Caraquet	na	na	na	32	32	34	32	28	28	28	28	26	25
Neguac	na	na	na	na	na	na	2	2	na	1	3	na	3
Richibucto	na	na	na	na	na	na	na	na	9	8	na	9	9
Cocagne	na	na	na	na	na	na	na	na	10	7	12	12	12
Shediac	na	na	na	na	na	3	5	7	11	11	11	11	11
Robichaud	na	na	na	na	na	na	12	13	na	na	na	na	na
Murray Corner	na	na	na	na	na	na	na	na	na	na	na	na	3
Fox Harbour	na	na	na	na	na	39	24	19	na	na	12	na	5
Toney’s River	na	na	na	na	na	na	na	na	na	3	6	na	3

Table 8. Sampling information for bio-collectors sampled in the southern Gulf of St. Lawrence during 2008 to 2012. The depth, date of deployment and retrieval of collectors, the maximum carapace length (mm) and density (lobster per m^2) for the young-of-the-year (yoy) sampled in collectors and the yearly accumulated degree-days adjusted at 12°C (ADD) per site are indicated.

Year	Site	Depth (m)	Date in	Date out	Number sampled	Yoy maximum size	Yoy density	ADD
2008	Arisaig	6.8	5-June	10-Oct	29	13.8	0.1	331
	Bedeque	7.6	9-June	13-Nov	30	na	0.0	498
	Caraquet	5.2	22-May	18-Oct	28	na	0.0	308
	Covehead	6.7	10-June	16-Oct	29	14.5	0.4	237
	Neguac	9.1	5-June	20-Oct	30	14.1	0.5	202
	Shediac	6.1	2-June	25-Oct	30	-	0.0	376
2009	Alberton	8.9	8-June	22-Sep	30	15.1	0.7	267
	Arisaig	6.8	2-July	16-Oct	25	14.6	0.2	391
	Covehead	6.7	2-July	1-Oct	30	14.5	0.5	365
	Fortune1	8.3	3-July	21-Sep	29	14.4	0.2	300
	Murray Harbour	7.1	9-July	2-Oct	26	14.1	0.0	317
	Nine Mile Creek	6.5	3-July	25-Sep	29	na	0.1	315
	Skinner's Pond	7.1	17-July	5-Nov	25	14.1	0.1	343
2010	Alberton	8.9	2-July	20-Sep	30	13.6	1.9	320
	Arisaig	6.8	2-July	28-Sep	30	14.2	0.1	435
	Covehead	6.7	2-July	22-Sep	27	15.1	0.5	489
	Fortune1	8.3	2-July	21-Sep	24	15.3	1.9	378
	Fortune2	22.0	2-July	21-Sep	5	15.3	0.4	104
	Murray Harbour	7.1	2-July	24-Sep	30	14.4	1.0	329
	Nine Mile Creek	6.5	2-July	13-Oct	30	na	0.0	357
	Skinner's Pond	7.1	2-July	29-Sep	30	15.0	0.4	378
2011	Alberton	8.9	6-July	26-Sep	30	14.1	2.3	212
	Arisaig	6.8	6-June	28-Sep	28	14.4	0.1	316
	Covehead	6,7	5-July	30-Sep	30	14.1	1.2	301
	Fortune1	8.3	5-July	29-Sep	30	14.2	0.5	274
	Fortune2	22.0	5-July	29-Sep	5	14.2	0.0	57
	Murray Harbour	7.1	18-July	21-Oct	26	14.1	0.0	250
	Nine Mile Creek	6.5	13-July	11-Oct	27	na	0.0	334
	Skinner's Pond	7.1	14-July	12-Oct	26	14.2	0.6	311
2012	Alberton	8.9	12-July	2-Oct	29	14.0	2.7	349
	Arisaig	6.8	30-June	4-Oct	30	14.2	0.1	439
	Covehead	6.7	3-July	25-Sep	29	14.1	1.1	436
	Fortune1	8.3	3-July	24-Sep	29	15.2	2.0	388
	Fortune2	22.0	3-July	24-Sep	5	15.2	0.4	134
	Murray Harbour	7.1	9-July	17-Oct	22	14.9	0.7	401
	Nine Mile Creek	6.5	10-July	10-Oct	29	na	0.0	344
	Skinner's Pond	7.1	16-July	15-Oct	28	15.1	0.6	na

Table 9. Range of carapace lengths (mm) for corresponding lobster cohorts used for analyzing SCUBA data. Small annual variations were observed. Also, an additional instar was added for corresponding cohort 0 to 3 from sites in central Northumberland Strait (Zone B, i.e., sub-regions 25S and 26AD; while sites within LFA 23 and sub-region 25N are Zone A) to account for different growth patterns.

Zone	Year	Cohort 0	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Cohort 5	Cohort 6+
A	2000	<19	19-33	34-48	49-59	60-69	70-80	81+
	2001	<18	18-33	34-48	49-59	60-69	70-80	81+
	2002	<18	18-33	34-48	49-59	60-69	70-80	81+
	2003	<17	17-30	31-48	50-59	60-69	70-80	81+
	2004	<18	18-31	32-49	50-59	60-69	70-80	81+
	2005	<19	19-33	34-49	50-59	60-69	70-80	81+
	2006	<19	19-33	34-49	50-59	60-69	70-80	81+
	2007	<19	19-32	33-49	50-59	60-69	70-80	81+
	2008	<20	20-31	32-49	50-58	59-69	70-80	81+
	2009	<19	19-31	32-47	48-59	60-69	70-80	81+
	2010	<20	20-31	32-47	48-59	60-69	70-80	81+
	2011	<19	19-31	32-47	48-59	60-69	70-80	81+
	2012	<20	20-33	34-49	50-59	60-69	70-80	81+
B	2005	<26	26-38	39-49	50-59	60-69	70-80	81+
	2006	<26	26-38	39-49	50-59	60-69	70-80	81+
	2007	<26	26-38	39-49	50-59	60-69	70-80	81+
	2008	<27	27-38	39-49	50-59	60-69	70-80	81+
	2009	<26	26-36	37-49	50-59	60-69	70-80	81+
	2010	<25	25-36	37-49	50-59	60-69	70-80	81+
	2011	<27	27-38	39-49	50-59	60-69	70-80	81+
	2012	<27	27-38	39-49	50-59	60-69	70-80	81+

Table 10. Long-term lobster landings (median of 1947 to 2011, last 65 years) compared to the 2011 landings (t) as an abundance indicator for the five lobster fishing areas (LFA) located in the southern Gulf of St. Lawrence. Data for 2011 are preliminary. 🡅 positive; ⇔ indicates that there is no change; 🡇 negative.

Value	LFA 23	LFA 24	LFA 25	LFA 26A	LFA 26B
Median landings (t)	1,732	2,657	3,155	2,893	700
2011	4,576	5,469	4,015	3,866	1,037
Indicator	🡅	🡅	🡅	🡅	🡅

Table 11. Mid-term lobster landings (median of 1968 to 2011, last 44 years) and short-term landings (median of 2005-2011) in tons compared to the 2011 landings as an abundance indicator for the five lobster fishing areas (LFA) located in the southern Gulf of St. Lawrence divided into nine sub-regions. Data for 2011 are preliminary. 🡅 positive; ⇔ indicates that there is no change; 🡇 negative.

Value	LFA 23BC	LFA 23G	LFA 24	LFA 25N	LFA 25S	LFA 26AD	LFA 26APEI	LFA 26ANS	LFA 26B
2011	936	3,640	5,469	2,947	1,068	678	2,022	1,167	1,037
Mid-Term	640	2,401	4,151	2,458	1,084	729	1,706	1,003	1,074
Indicator	🡅	🡅	🡅	🡅	⇔	⇔	🡅	🡅	⇔
Short-Term	703	2,743	6,288	2,510	856	678	2,022	1,170	1,083
Indicator	🡅	🡅	⇔	🡅	🡅	⇔	⇔	⇔	⇔

Table 12. Average CPUE in kg per trap of male and non-berried female lobsters from the at-sea sampling program between 2000 and 2012. For sub-regions 25N and 25S, data are from the month of August only.

Year	23BC	23G	24	25N	25S	26AD	26ANS	26APEI	26B
2000	0.46	0.49	0.76	0.57	0.33	0.55	0.74	0.43	0.44
2001	0.33	0.68	1.01	na	0.39	0.45	na	0.39	0.51
2002	0.24	0.40	0.78	0.90	0.32	0.41	na	0.41	0.39
2003	0.44	0.39	0.91	0.48	0.48	0.32	0.75	0.51	0.39
2004	0.31	na	0.97	0.84	0.36	0.32	na	0.50	na
2005	na	na	0.84	0.63	0.43	0.27	na	0.46	na
2006	na	na	1.05	0.64	0.24	0.37	na	0.40	na
2007	na	na	0.89	1.05	0.59	0.33	na	0.35	na
2008	na	na	0.89	1.05	0.70	0.47	na	0.37	na
2009	na	na	1.01	1.81	0.70	0.52	na	0.54	na
2010	na	na	0.83	1.20	1.41	0.53	na	0.52	na
2011	na	na	0.96	1.28	1.14	0.43	na	0.62	na
2012	1.22	0.92	1.08	2.19	1.27	0.42	0.78	0.86	1.00

Table 13. Average CPUE in number per trap of male and non-berried female lobsters from the recruitment-index program between 2000 and 2012 (regular traps) by sub-region. No data were available for sub-regions 23BC and 23G.

Year	24	25N	25S	26AD	26ANS	26APEI	26B
2000	3.17	1.96	1.37	0.86	1.42	1.62	1.67
2001	3.36	2.05	1.15	0.82	na	1.47	1.93
2002	3.12	1.67	0.98	0.81	na	1.68	1.81
2003	3.47	1.47	0.93	0.63	na	1.79	1.63
2004	4.09	1.93	0.76	0.59	na	1.57	1.71
2005	4.03	1.70	0.88	0.58	na	1.64	na
2006	3.74	2.03	0.94	0.55	na	1.59	na
2007	3.32	2.15	1.49	0.71	na	1.42	na
2008	3.60	2.48	1.66	0.92	na	1.73	na
2009	3.82	3.39	2.21	1.09	na	1.89	na
2010	3.63	4.16	2.34	0.97	na	1.91	na
2011	3.36	4.12	2.88	0.86	na	1.99	na
2012	na	na	na	na	1.78	na	2.43

Table 14. Estimated exploitation rates based on the change in abundance of the first molt class recruited to the fishery to the second molt class a year later with data from the recruitment-index program (regular traps).

Year	23G	24	25N	25S	26APEI	26B
1999	33%	61%	77%	43%	32%	63%
2000	68%	68%	65%	51%	61%	63%
2001	64%	66%	58%	58%	44%	58%
2002	68%	64%	68%	44%	60%	74%
2003	71%	67%	53%	43%	63%	79%
2004	na	71%	58%	na	58%	na
2005	na	66%	58%	na	53%	na
2006	na	68%	65%	na	61%	na
2007	na	59%	64%	na	30%	na
2008	na	66%	54%	na	57%	na
2009	na	62%	57%	na	43%	na
2010	na	66%	73%	41%	47%	na
Average	61%	65%	63%	47%	51%	67%

Table 15. Estimated exploitation rates based on the change-in-ratio method with data from the recruitment-index program (modified traps).

Year	23G	24	25N	26APEI	26B
1999	78%	78%	65%	na	63%
2000	55%	87%	73%	55%	81%
2001	78%	84%	49%	63%	46%
2002	63%	81%	70%	81%	55%
2003	50%	86%	60%	63%	na
2004	73%	87%	52%	55%	na
2005	na	74%	66%	69%	na
2006	na	86%	86%	81%	na
2007	na	80%	59%	43%	na
2008	na	84%	59%	68%	na
2009	na	81%	81%	76%	na
2010	na	77%	78%	78%	na
2011	na	71%	84%	70%	na
Average	66%	81%	68%	67%	61%

Table 16. Average percentages of empty (without commercial lobster) traps in the nine sub-regions based on data from the at-sea sampling program. Sub-regions 25N and 25S only include data from the month of August.

Year	23BC	23G	24	25N	25S	26AD	26ANS	26APEI	26B
1980's	36%	30%	24%	12%	13%	17%	38%	23%	42%
1990's	44%	50%	28%	18%	33%	47%	26%	44%	41%
2000-2006	54%[1]	39%[2]	24%	34%	57%	61%	26%[3]	47%	51%[2]
2007	na	na	20%	14%	49%	69%	na	54%	na
2008	na	na	23%	20%	36%	53%	na	55%	na
2009	na	na	22%	4%	30%	49%	na	45%	na
2010	na	na	24%	14%	10%	52%	na	43%	na
2011	na	na	21%	25%	22%	52%	na	39%	na
2012	26%	22%	17%	7%	13%	58%	30%	25%	32%

[1] for years 2000 to 2004
[2] for years 2000 to 2003
[3] for years 2000 and 2003

Table 17. Average percentages of empty (without sub-legal size and berried female lobsters) traps in the nine sub-regions based on data from the recruitment-index program (regular traps).

Year	23BC	23G	24	25N	25S	26AD	26ANS	26APEI	26B
1999	48%	52%	30%	27%	43%	43%	27%	49%	45%
2000-2006	46%[1]	47%[2]	28%	46%	65%	62%	30%[1]	47%	54%[2]
2007	na	na	18%	33%	43%	56%	na	49%	na
2008	na	na	18%	30%	37%	50%	na	40%	na
2009	na	na	17%	20%	28%	42%	na	37%	na
2010	na	na	15%	18%	23%	43%	na	36%	na
2011	na	na	20%	21%	24%	47%	na	34%	na
2012	na	na	na	na	na	na	30%	na	33%

[1] for year 2000
[2] for years 2000 to 2004

Table 18. Nominal effort expressed as total number of traps by licence type (A or B) and province per LFA, sub-LFA or management zone for 2006 to 2012.

LFA (Sub-LFA)	Prov-ince	Licence type	2006	2007	2008	2009	2010	2011	2012
23A	NB	A	na	na	28,500	28,200	28,050	28,200	24,000
	NB	B	na	na	2,880	2,880	2,790	2,700	2,610
23B	NB	A	na	na	27,900	27,900	27,900	27,900	27,300
	NB	B	na	na	180	180	180	180	180
23C&D	NB	A	na	na	157,050	155,550	155,850	155,850	139,200
	NB	B	na	na	180	180	180	180	180
23C	NB	A	na	na	na	100,350	100,800	100,800	89,250
	NB	B	na	na	na	0	0	0	0
23D	NB	A	na	na	na	55,200	55,050	55,050	49,950
	NB	B	na	na	na	180	180	180	180
23	Total	A	213,900	214,050	213,450	211,650	211,800	211,950	190,500
	Total	B	3,690	3,510	3,240	3,240	3,150	3,060	2,970
24	PE	A	190,500	190,500	190,500	190,500	190,500	190,500	190,500
	PE	B	360	360	360	360	360	180	90
25	NB	A	141,000	139,625	139,750	137,250	137,125	138,000	116,125
	NB	B	375	375	375	375	375	375	375
	NS	A	4,250	4,250	4,250	4,250	4,250	4,250	4,250
	NS	B	75	75	75	75	75	75	75
	PE	A	62,750	62,750	63,000	62,875	56,375	54,240	54,000
	PE	B	0	0	0	0	0	0	0
	Total	A	208,000	206,625	207,000	204,375	197,750	196,490	174,375
	Total	B	450	450	450	450	450	450	450
26A-1	NS	A	43,200	43,200	43,200	43,350	43,200	37,240	37,240
	NS	B	270	180	180	180	90	90	90
	PE	A	120,600	120,300	120,300	120,000	119,400	104,580	100,467
	PE	B	180	90	90	90	90	90	90
26A-2	NS	A	48,900	48,900	44,688	44,688	44,688	44,551	44,414
	NS	B	270	270	270	270	270	270	270
26A-3	NS	A	14,400	14,400	14,400	14,100	14,400	9,000	9,000
	NS	B	90	90	90	0	0	0	0
26B	NS	A	72,900	72,750	69,700	66,414	66,140	55,125	54,750
	NS	B	360	360	360	360	270	270	270
26B-North	NS	A	na	na	31,900	31,764	31,490	26,125	26,000
	NS	B	na	na	90	90	90	90	90
26B-South	NS	A	na	na	37,800	34,650	34,650	29,000	28,750
	NS	B	na	na	270	270	180	180	180
26	Total	A	300,000	299,550	292,288	288,552	287,828	250,496	245,871
	Total	B	1,170	990	990	900	720	720	720
All areas	Total	Total	918,070	916,035	908,278	900,027	892,558	853,846	805,476

Table 19. Average CPUE expressed as number per trap of berried female lobsters by sub-region from the at-sea sampling program between 2000 and 2012. For sub-regions 25N and 25S, data are from the month of August only. Years with less than 100 berried females sampled (identified with a dash) were omitted from calculations. Years with no sampling are indicated as na.

Year	23BC	23G	24	25N	25S	26AD	26ANS	26APEI	26B
2000	0.29	0.14	0.28	0.32	0.21	0.39	0.44	0.24	0.27
2001	0.25	0.10	0.22	na	0.19	0.48	na	0.11	0.29
2002	0.15	–	0.23	0.26	–	0.27	na	0.21	0.31
2003	0.26	0.09	0.29	0.22	0.12	0.23	0.32	0.21	0.27
2004	–	na	0.31	0.30	–	0.13	na	0.19	na
2005	na	na	0.23	0.33	0.13	0.10	na	0.16	na
2006	na	na	0.41	0.31	0.21	0.17	na	0.21	na
2007	na	na	0.26	0.45	0.21	0.18	na	0.16	na
2008	na	na	0.41	0.20	0.19	0.22	na	0.16	na
2009	na	na	0.39	0.33	–	0.26	na	0.33	na
2010	na	na	0.21	0.60	0.70	0.34	na	0.25	na
2011	na	na	0.37	0.51	0.52	0.22	na	0.40	na
2012	0.50	0.29	0.35	0.67	0.80	0.21	0.62	0.39	0.37

Table 20. Sex ratios (males: females) of legal size and sub-legal size lobsters from the Northumberland trawl survey grouped by lobster fishing area (LFA).

LFA	Year	Males legal	Females legal	M:F legal	Males sub-legal	Females sub-legal	M:F sub-legal
LFA 25	2007	836	797	1.05	727	795	0.91
	2008	824	706	1.17	1015	1123	0.90
	2009	481	410	1.17	781	673	1.16
	2012	474	318	1.49	506	545	0.93
LFA 26A	2007	398	398	1.00	192	152	1.26
	2008	330	314	1.05	143	162	0.88
	2009	549	601	0.91	244	359	0.68
	2012	327	303	1.08	167	187	0.89

Table 21. The accumulated degree-day values adjusted to 12°C for all the sites where bio-collectors were deployed between 2008 and 2012. The temperature data from Skinner's Pond in 2012 was lost.

Site	Year				
	2008	2009	2010	2011	2012
Alberton	na	267	320	212	349
Arisaig	331	391	435	316	439
Bedeque	498	na	na	na	na
Caraquet	308	na	na	na	na
Covehead	237	365	489	301	436
Fortune 1	na	300	378	274	388
Fortune 2	na	na	104	57	134
Murray Harbour	na	317	329	250	401
Neguac	202	na	na	na	na
Nime Mile Creek	na	315	357	334	344
Shediac	376	na	na	na	na
Skinner's Pond	na	343	378	311	na

Table 22. Summary of abundance indicators based on landings and SCUBA surveys used to assess the changes in status of lobster by LFA and overall for the southern Gulf of St. Lawrence. ↑ positive; ⇔ indicates that there is no change; ↓ negative. LFAs were divided into nine sub-regions.

		23			25		26A			
Indicator	Gulf	23BC	23G	24	25N	25S	26AD	26APEI	26ANS	26B
2011 landings relative to										
Median 1947 to 2011	↑	↑		↑	↑			↑		↑
Median 1968 to 2011	↑	↑	↑	↑	↑	⇔	⇔	↑	↑	⇔
Median 2005 to 2011	↑	↑	↑	⇔	↑	↑	⇔	⇔	⇔	⇔
SCUBA surveys		↑	↑	na	↑	⇔	↓	na	na	na

Table 23. Summary of trends or levels for the fishing pressure indicators used to assess changes since 2006 in the status of the lobster stocks for LFAs 23, 24, 25, 26A and 26B of the southern Gulf of St. Lawrence. ↓ positive; ⇔ indicates that there is no change; ↑ negative. LFAs were divided into nine sub-regions.

		23			25		26A			
Indicator	Gulf	23BC	23G	24	25N	25S	26AD	26APEI	26ANS	26B
Empty traps	↓	↓	↓	↓	↓	↓	⇔	↓	⇔	↓
Nominal effort – licence	↓	↓	↓	⇔	↓		↓		⇔	↓
Nominal effort - traps	↓	↓	↓	⇔	↓		↓		↓	↓

Table 24. Summary of production indicators used to assess the changes in status of lobster by LFA and overall for the southern Gulf of St. Lawrence. ↑ positive; ⇔ indicates that there is no change; ↓ negative. LFAs were divided into nine sub-regions.

		23			25		26A			
Indicator	Gulf	23BC	23G	24	25N	25S	26AD	26APEI	26ANS	26B
Berried females – at-sea sampling	↑	↑	↑	⇔	↑	↑	↓	↑	↑	↑
Pre-recruit CPUE – recruitment index	na	na	na	⇔	↑	↑	↓	⇔	↑	↑
Pre-recruit density – trawl survey	na	na	na	na	↑	↑	na	↑	↑	na
Sex ratio – trawl survey	na	na	na	na	⇔			⇔		na
Cohort 1 abundance - SCUBA surveys	na	↑	↑	na	↑	⇔	↓	na	na	na

FIGURES

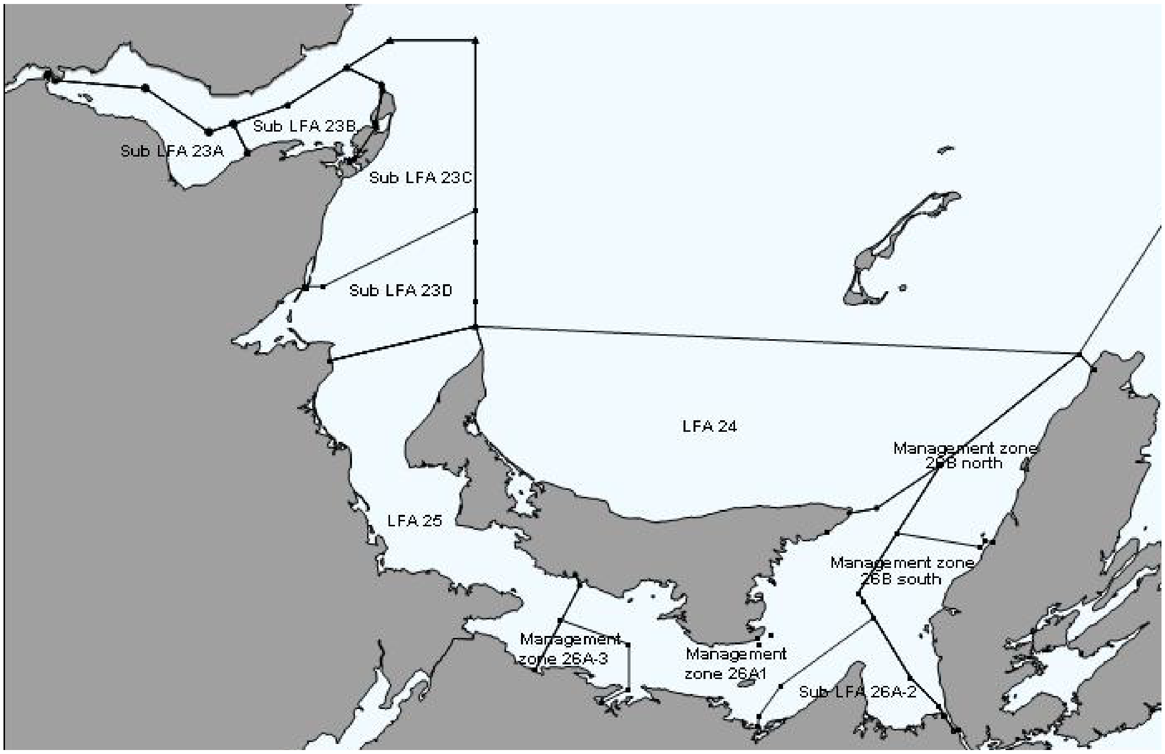

Figure 1. Lobster fishing areas (LFA), sub-areas, and management zones in the southern Gulf of St. Lawrence under the management of the DFO Gulf Region.

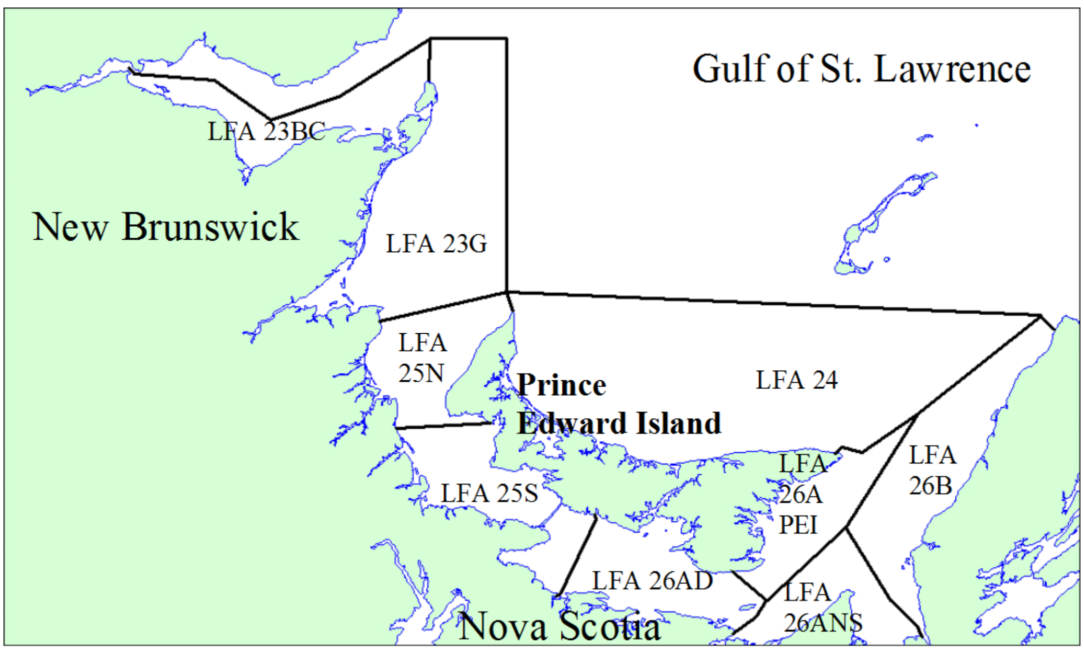

Figure 2. Map of the nine sub-regions used by DFO Science in the context of the lobster assessment in the southern Gulf of St. Lawrence.

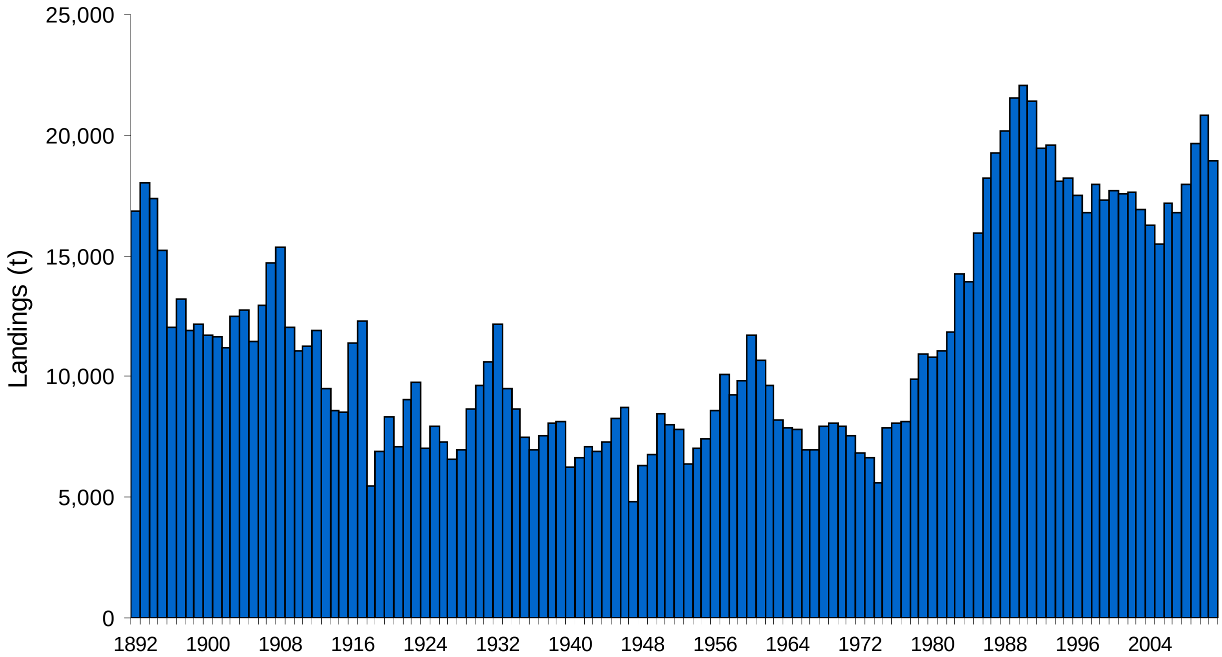

Figure 3. Historical lobster (Homarus americanus) landings in the southern Gulf of St. Lawrence (DFO, Gulf Region) from 1892 to 2011. Data for 2011 are preliminary.

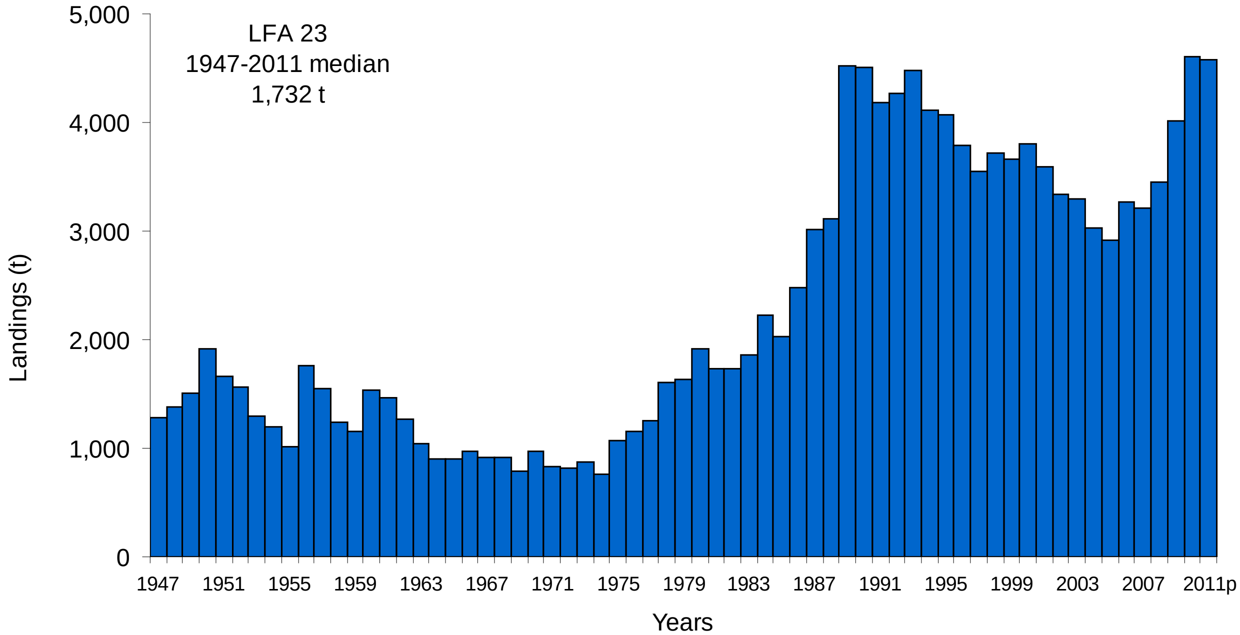

Figure 4a. Historical lobster (Homarus americanus) landings in lobster fishing area (LFA) 23 for 1947 to 2011. Data for 2011 are preliminary.

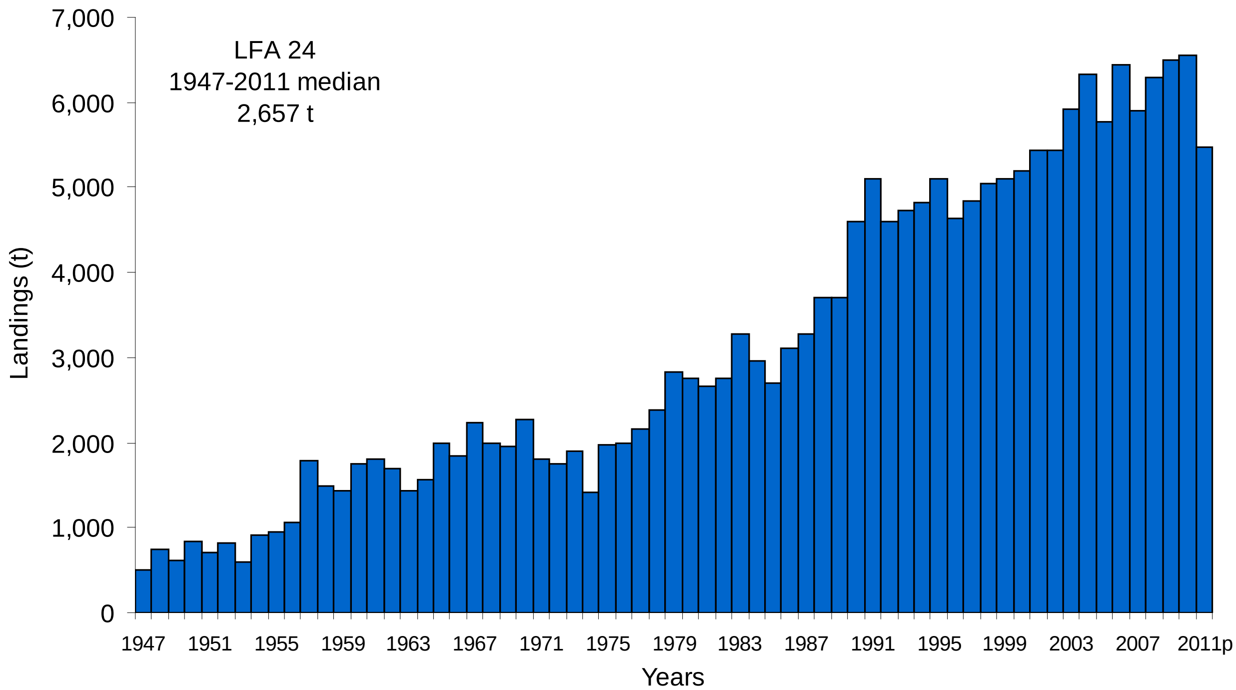

Figure 4b. Historical lobster (Homarus americanus) landings in lobster fishing area (LFA) 24 for 1947 to 2011. Data for 2011 are preliminary.

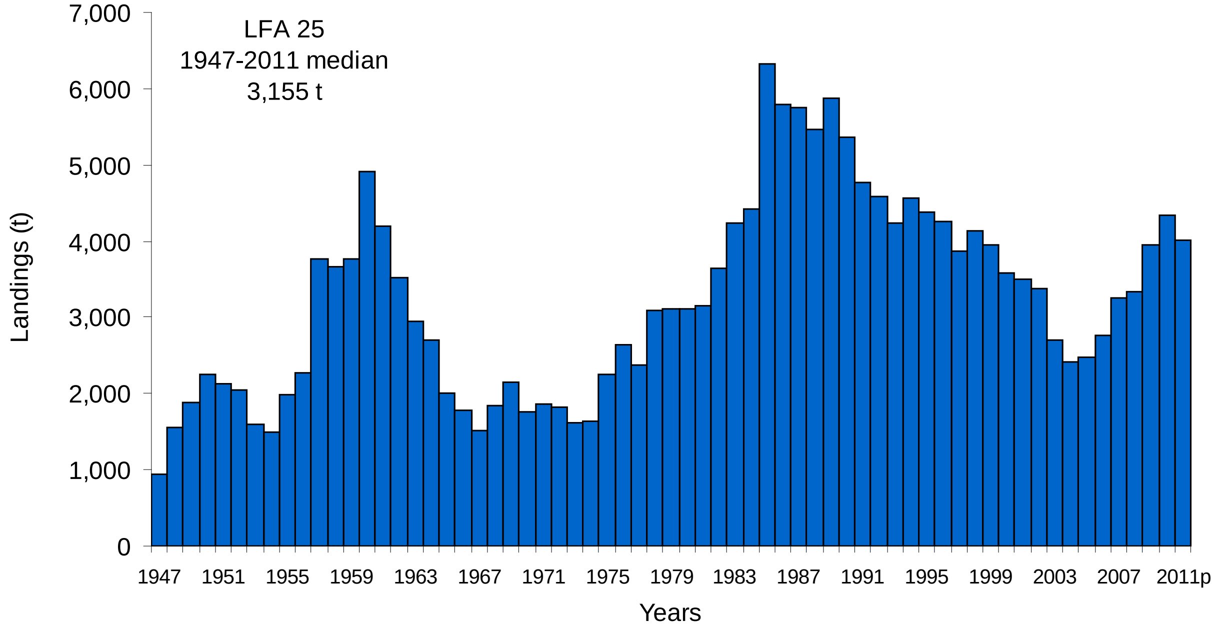

Figure 4c. Historical lobster (Homarus americanus) landings in lobster fishing area (LFA) 25 for 1947 to 2011. Data for 2011 are preliminary.

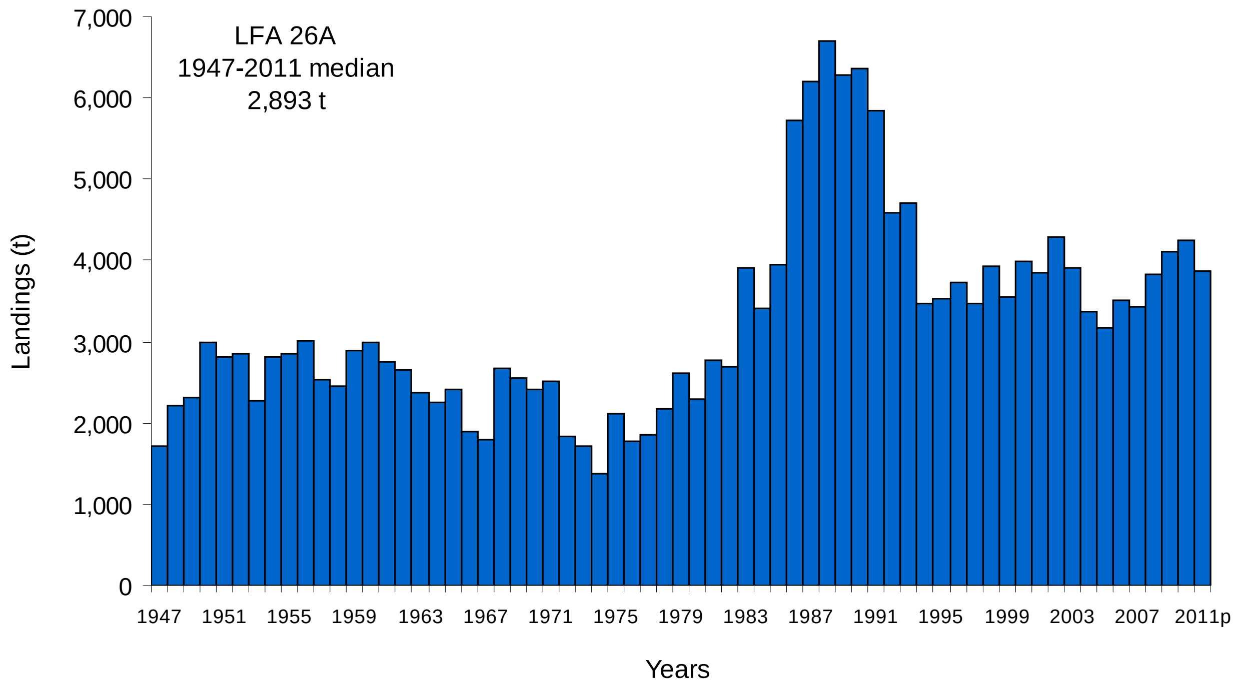

Figure 4d. Historical lobster (Homarus americanus) landings in lobster fishing area (LFA) 26A for 1947 to 2011. Data for 2011 are preliminary.

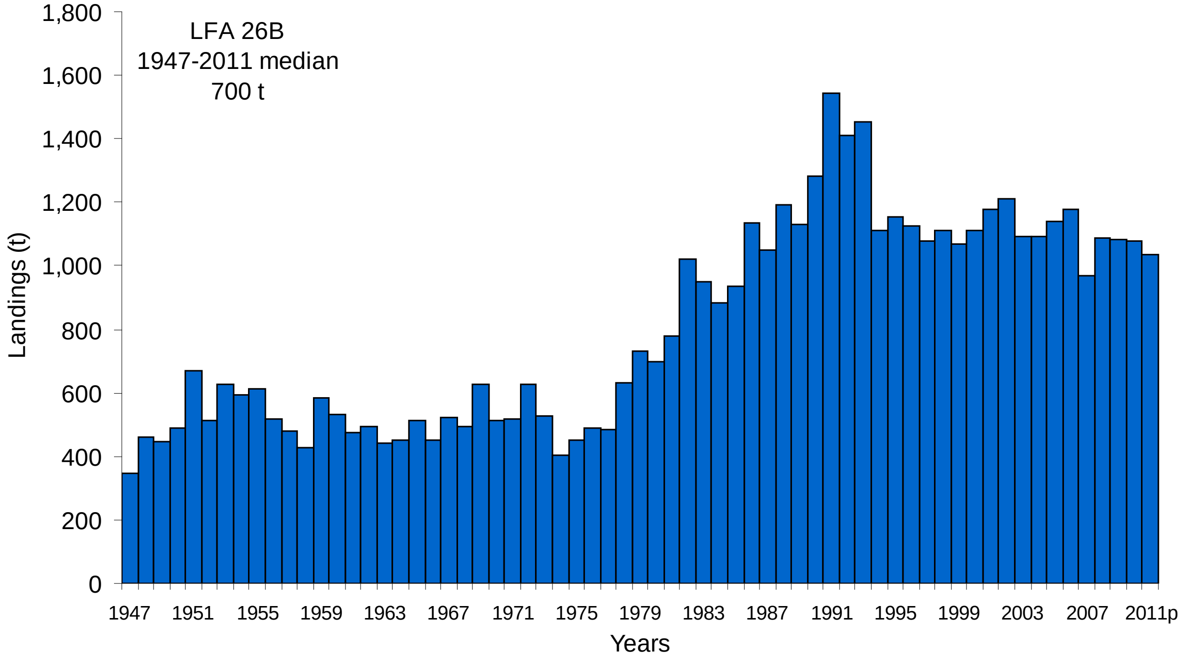

Figure 4e. Historical lobster (Homarus americanus) landings in lobster fishing area (LFA) 26B for 1947 to 2011. Data for 2011 are preliminary.

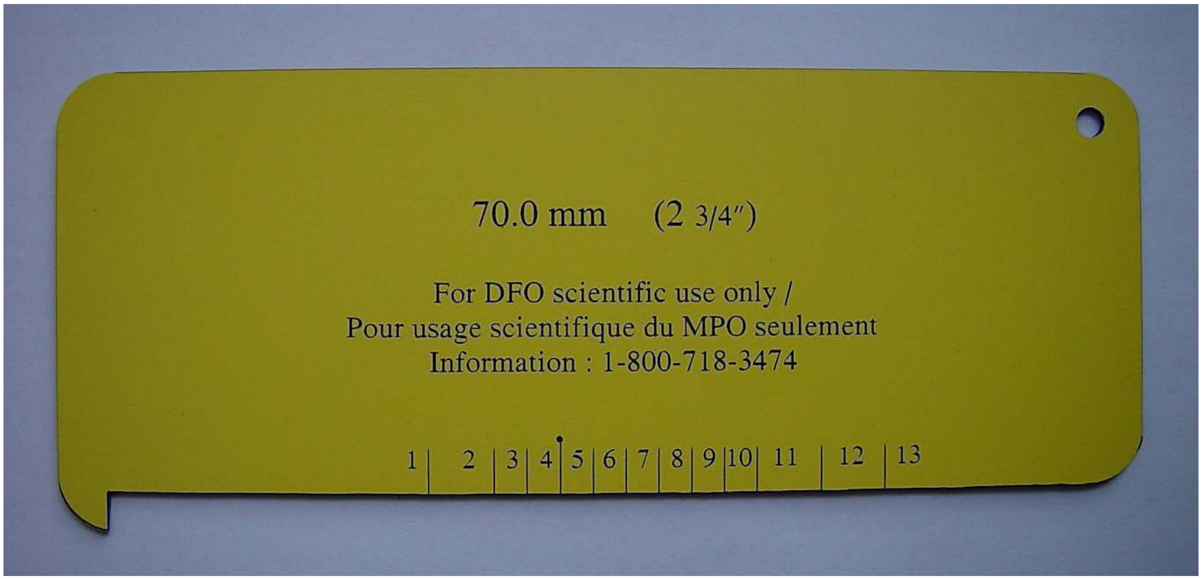

Figure 5. Gauge used by harvesters participating in the recruitment-index program. Size class 5 lower value was adjusted to the minimum legal size each year. Size classes 3 to 10 are 5-mm size intervals while size classes 2, 11 and 12 are 10-mm wide intervals.

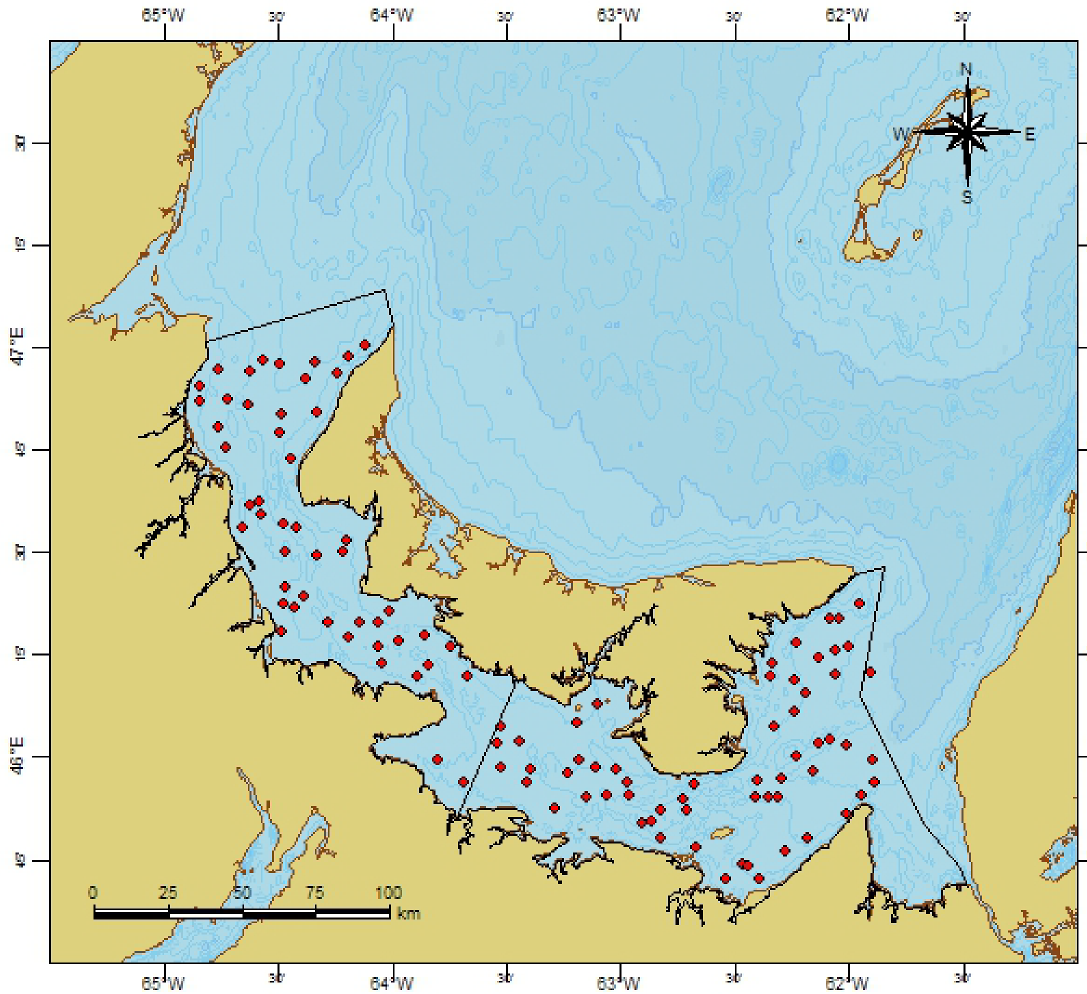

Figure 6. Map of stations sampled in 2012 during the Northumberland Strait trawl survey with delimitations of LFA 25 and 26A.

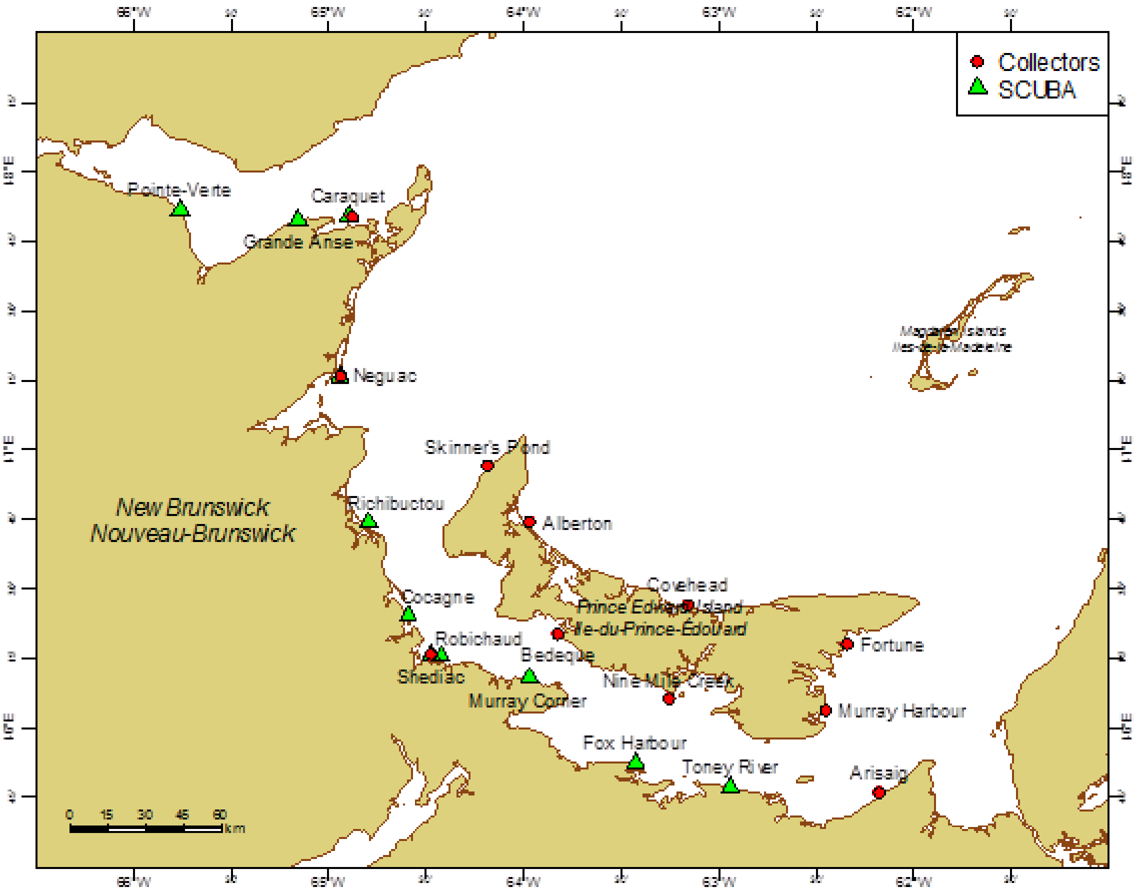

Figure 7. Map of the bio-collector (red circle) and SCUBA diving (green triangle) sites sampled in the southern Gulf of St. Lawrence.

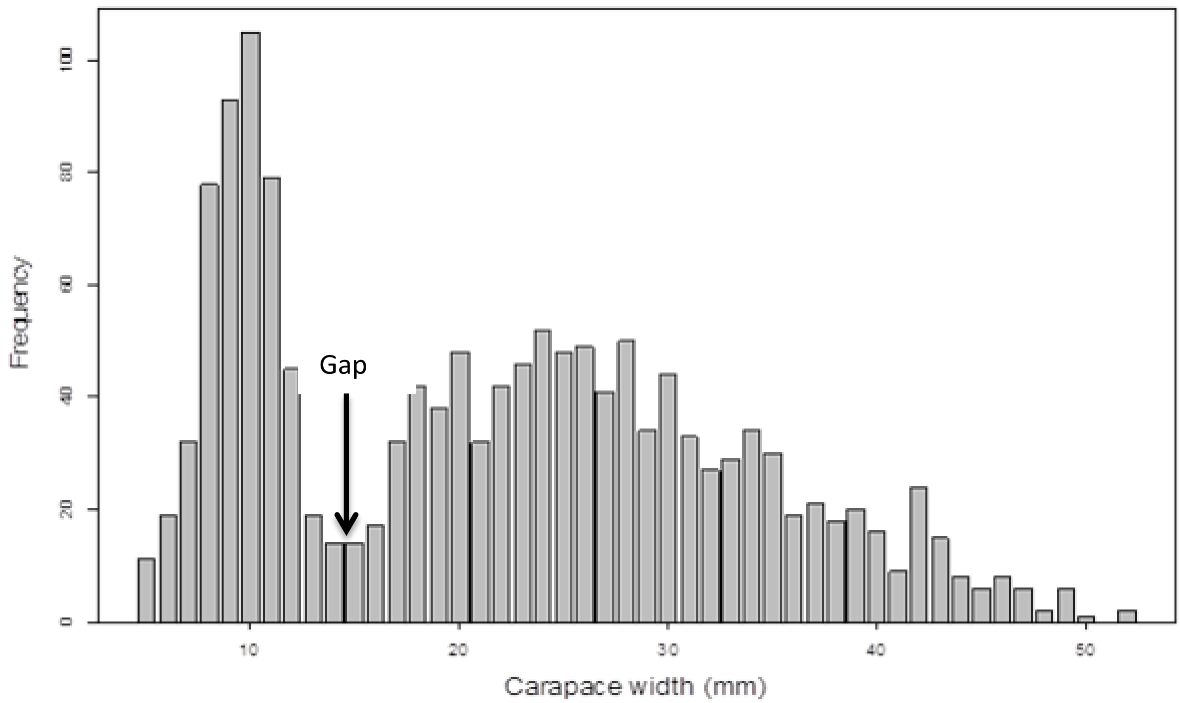

Figure 8. Length frequency distribution of lobsters (Homarus americanus) sampled with bio-collectors at various sites in the southern Gulf of St. Lawrence between 2008 and 2012. The arrow indicates the gap between young-of-the-year and walk-in lobsters.

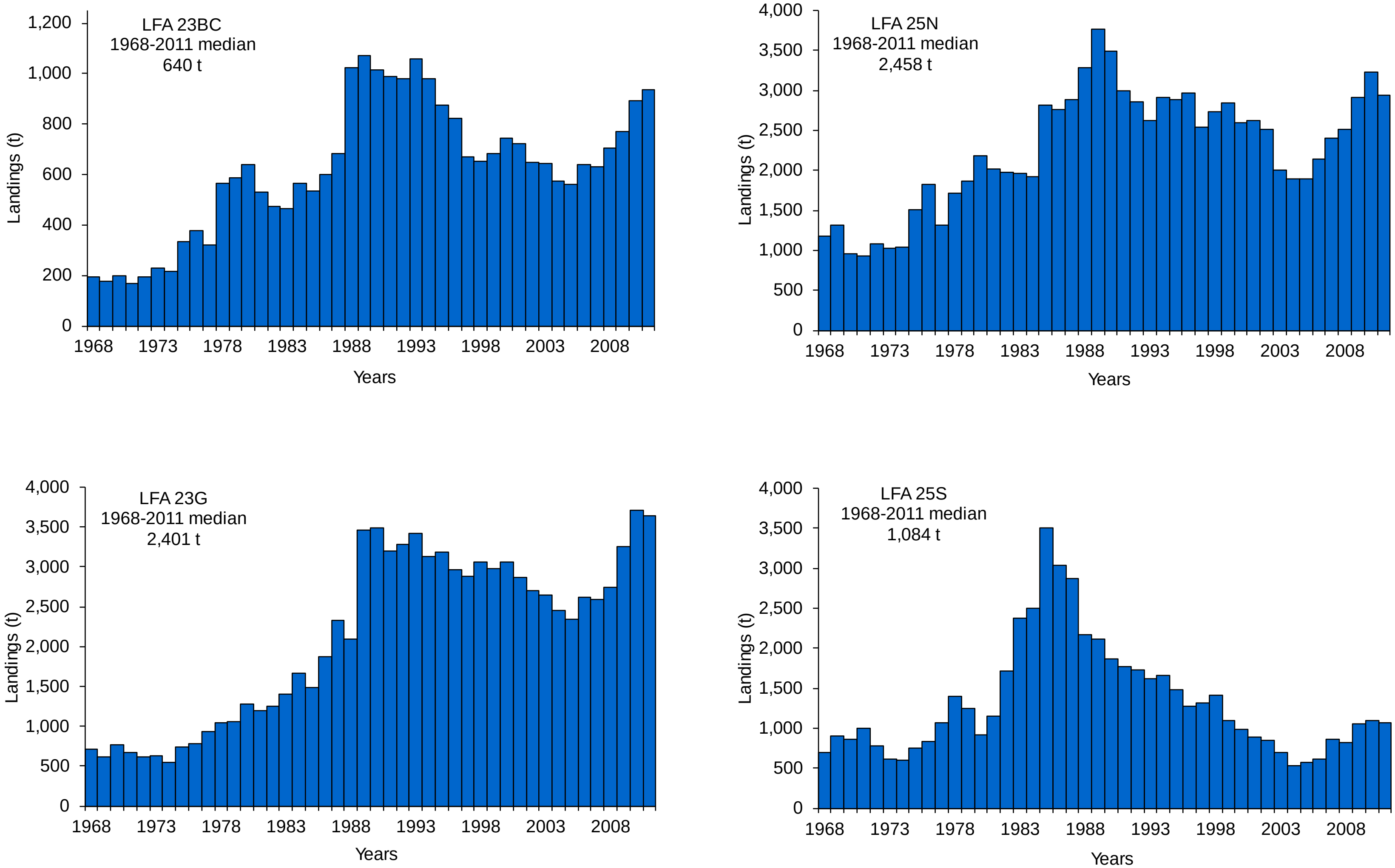

Figure 9. Lobster landings by sub-region between 1968 and 2011. The mid-term median landings value is shown on each panel. Data for 2011 are preliminary.

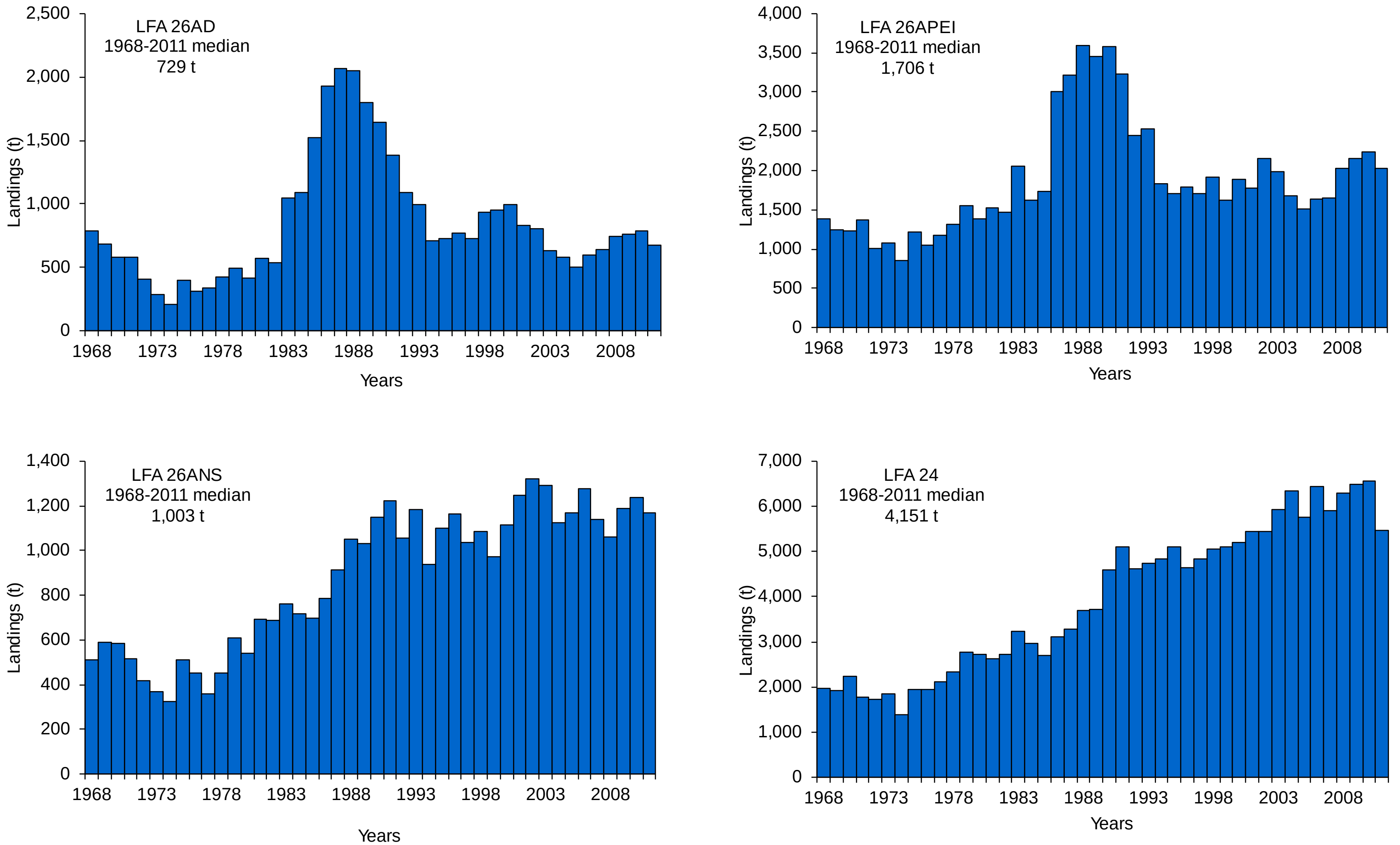

Figure 9 (continued).

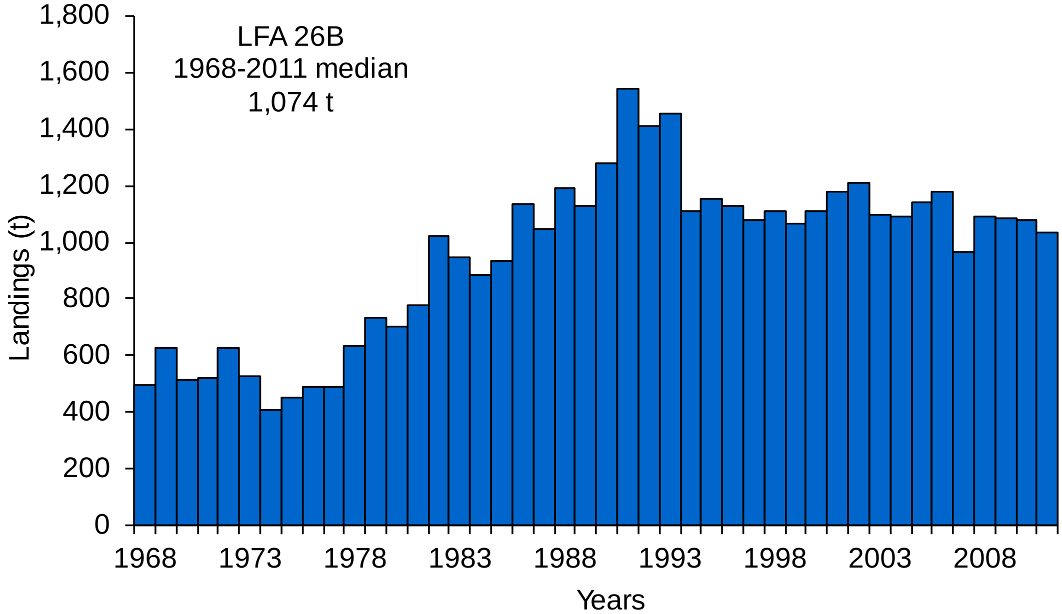

Figure 9 (continued).

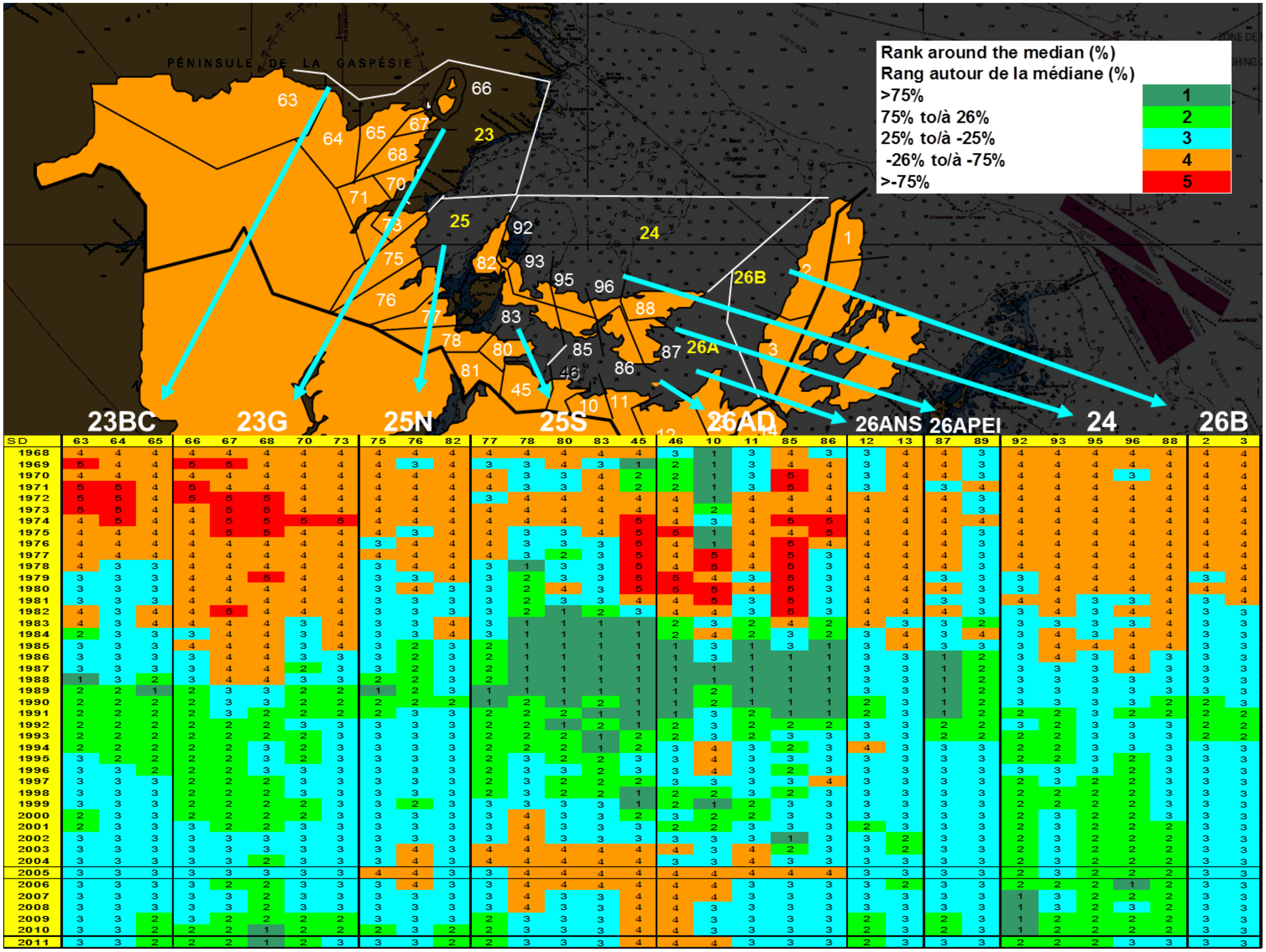

Figure 10. Summary of lobster abundance indicators based on a ranks of landings relative to the median landings of 1968 to 2011 by statistical district (SD) located in the nine sub-regions. Data for 2011 are preliminary.

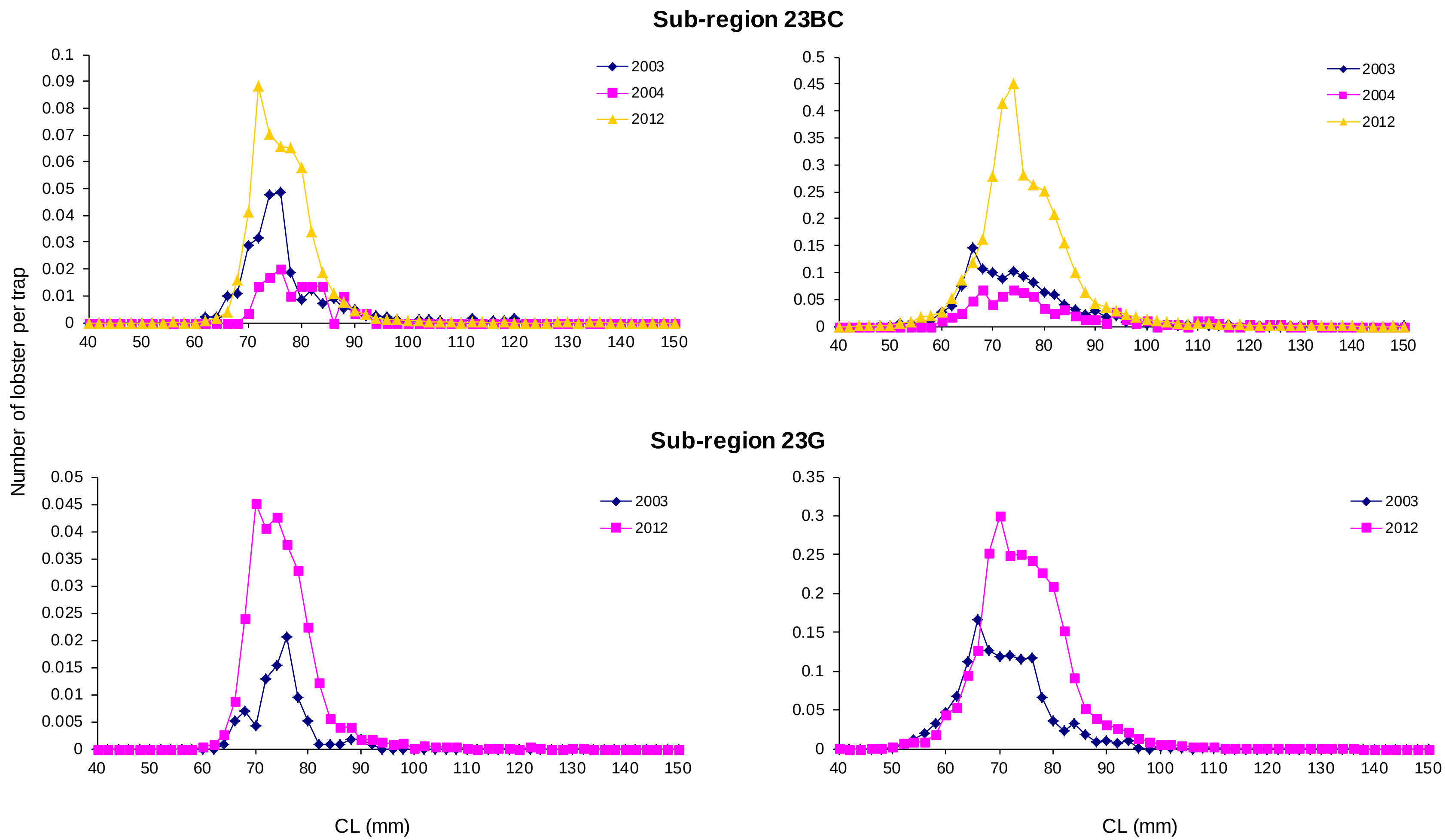

Figure 11. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-regions 23BC and 23G in the southern Gulf of St. Lawrence during 2003, 2004 and 2012.

LFA 24

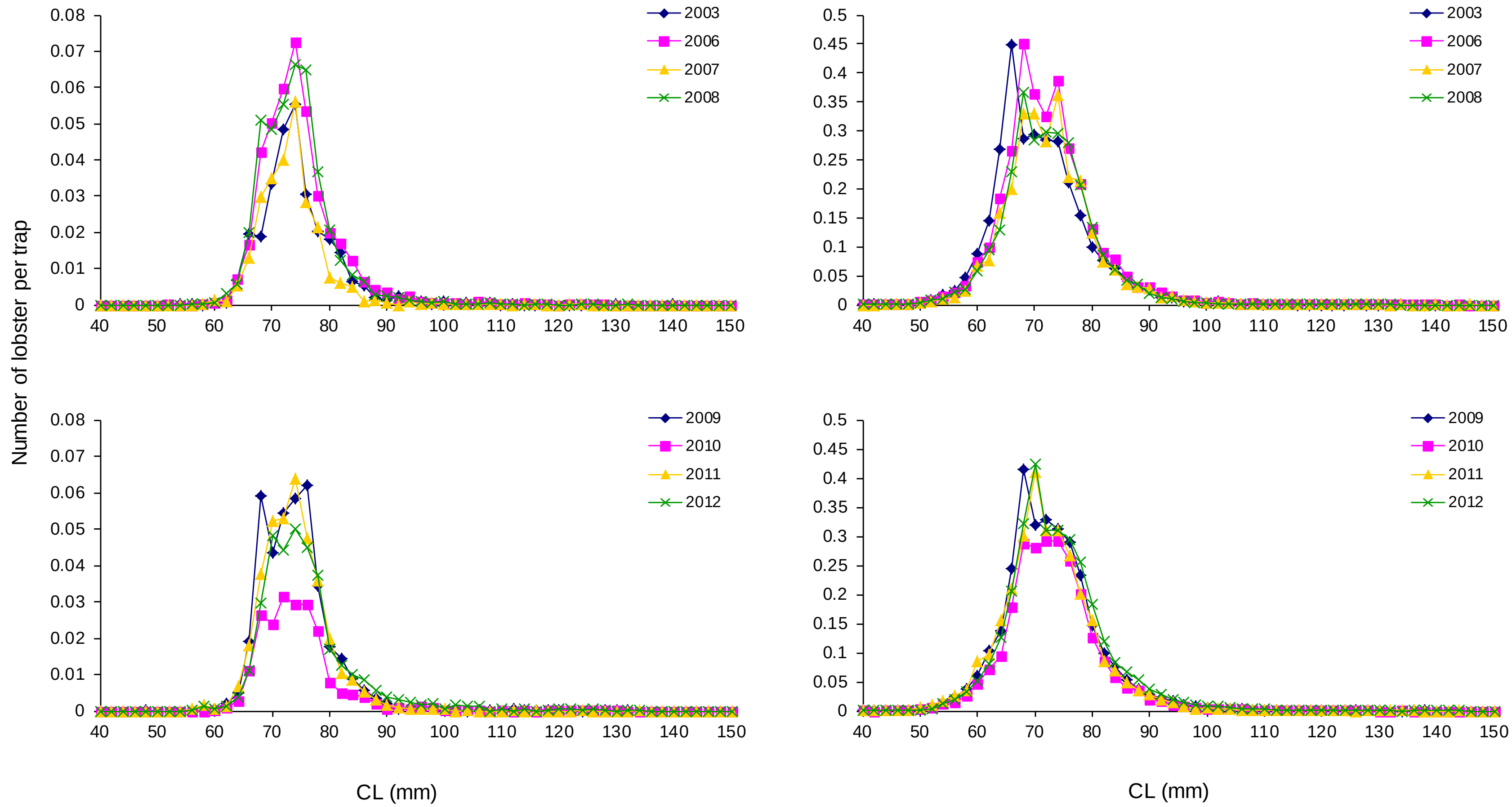

Figure 12. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for LFA 24 in the southern Gulf of St. Lawrence during 2003 and 2006 to 2012.

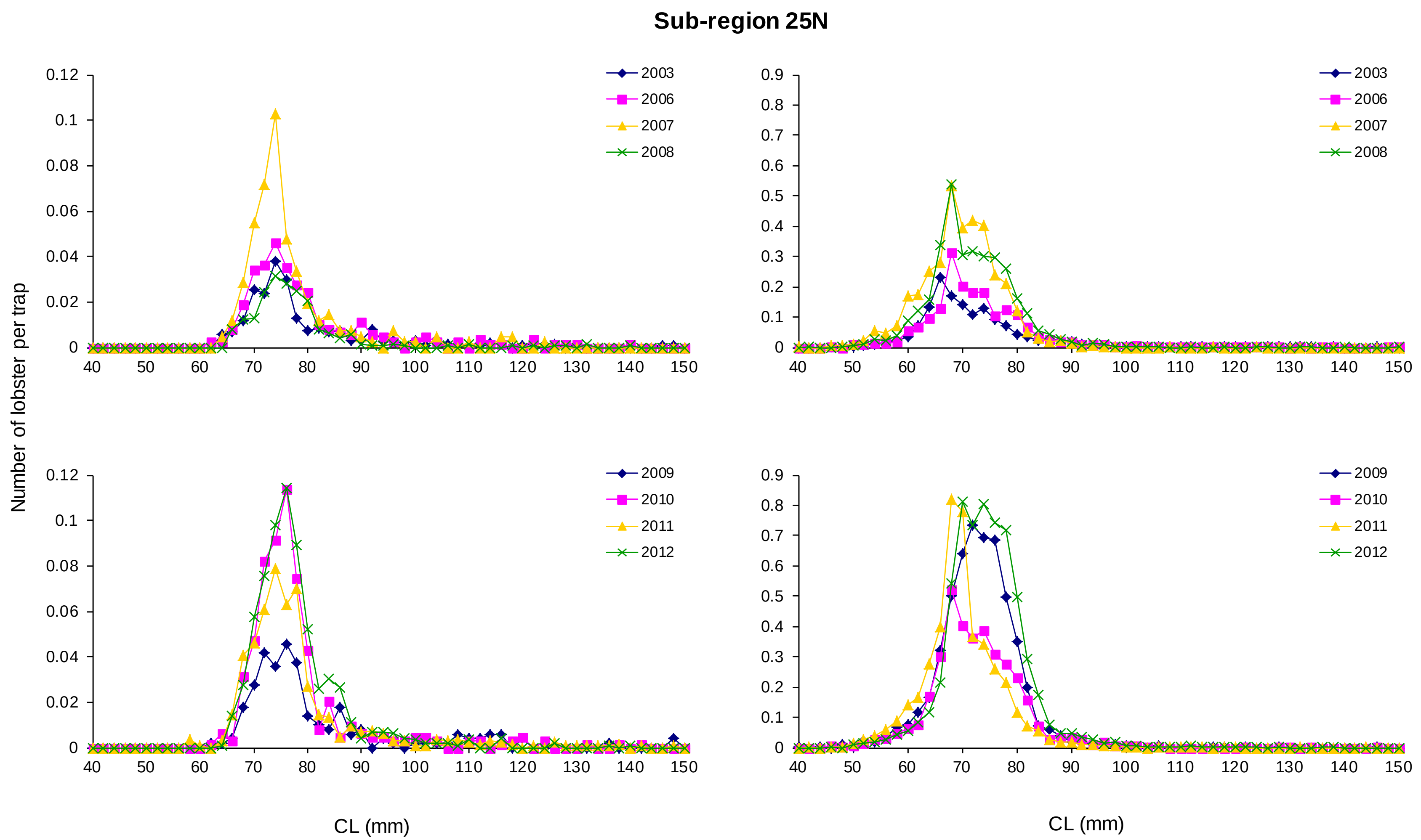

Figure 13. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-region 25N in the southern Gulf of St. Lawrence during 2003 and 2006 to 2012.

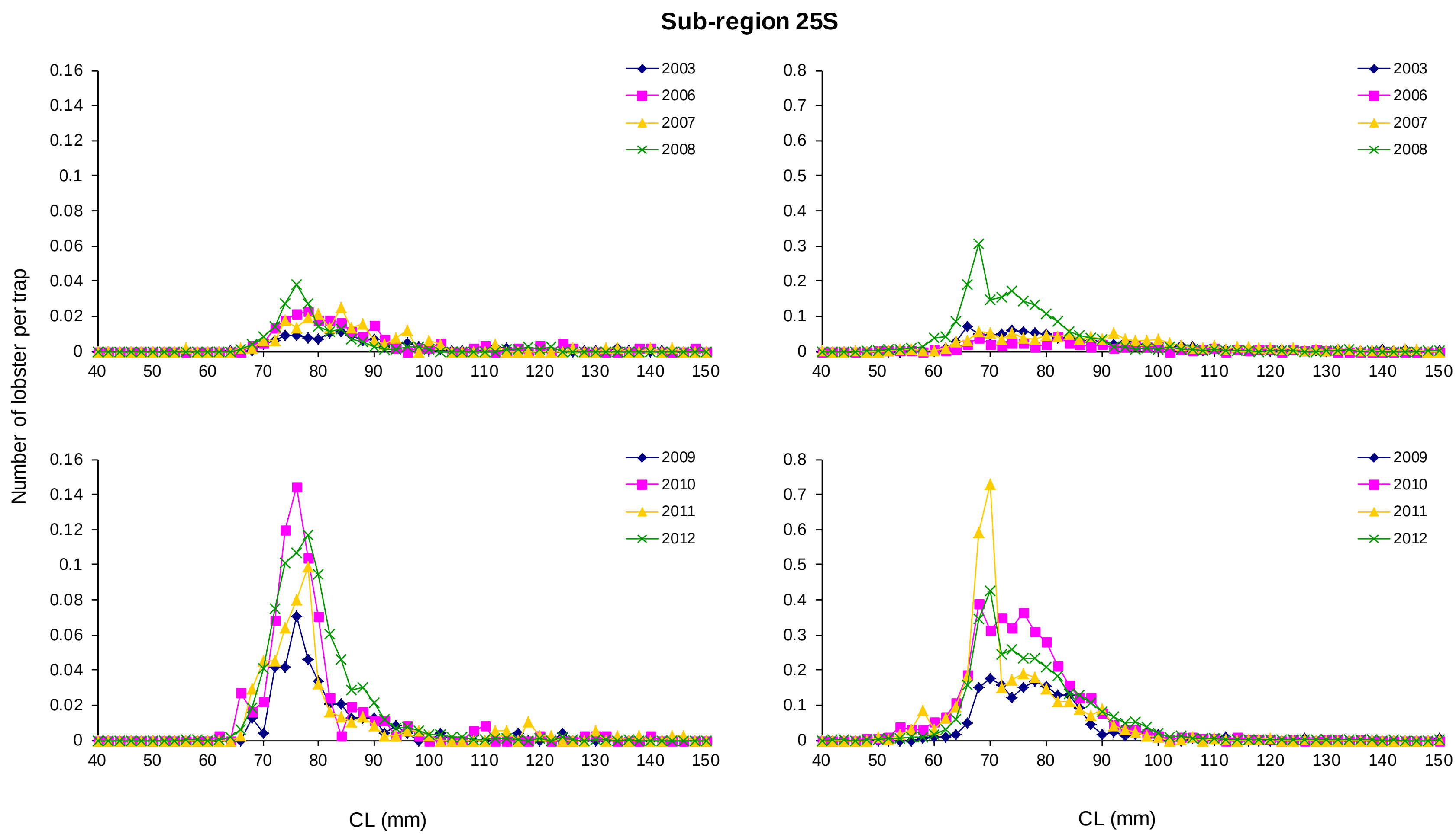

Figure 14. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-region 25S in the southern Gulf of St. Lawrence during 2003 and 2006 to 2012.

Sub-region 26AD

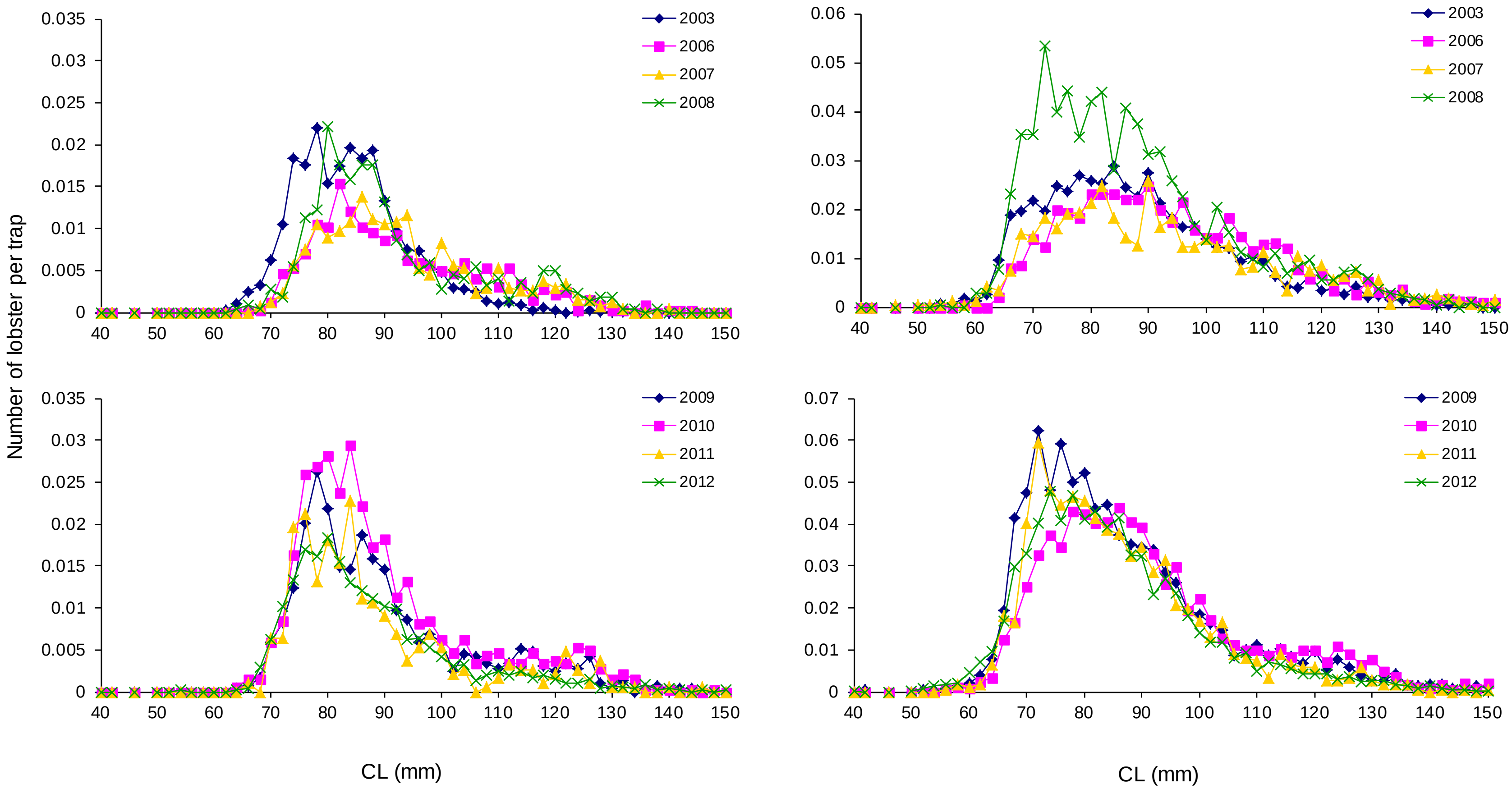

Figure 15. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-region 26AD in the southern Gulf of St. Lawrence during 2003 and 2006 to 2012.

Sub-region 26APEI

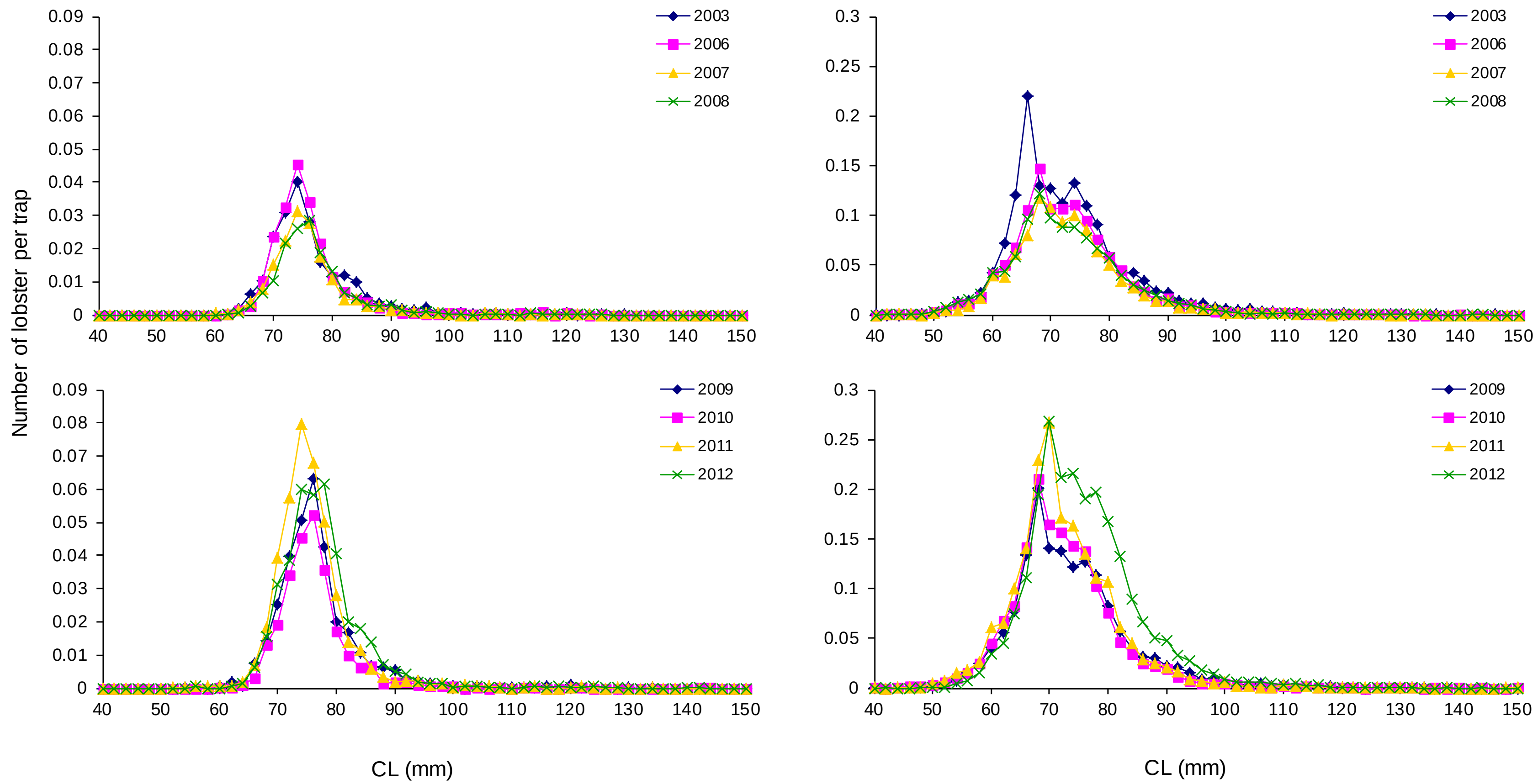

Figure 16. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-region 26APEI in the southern Gulf of St. Lawrence during 2003 and 2006 to 2012.

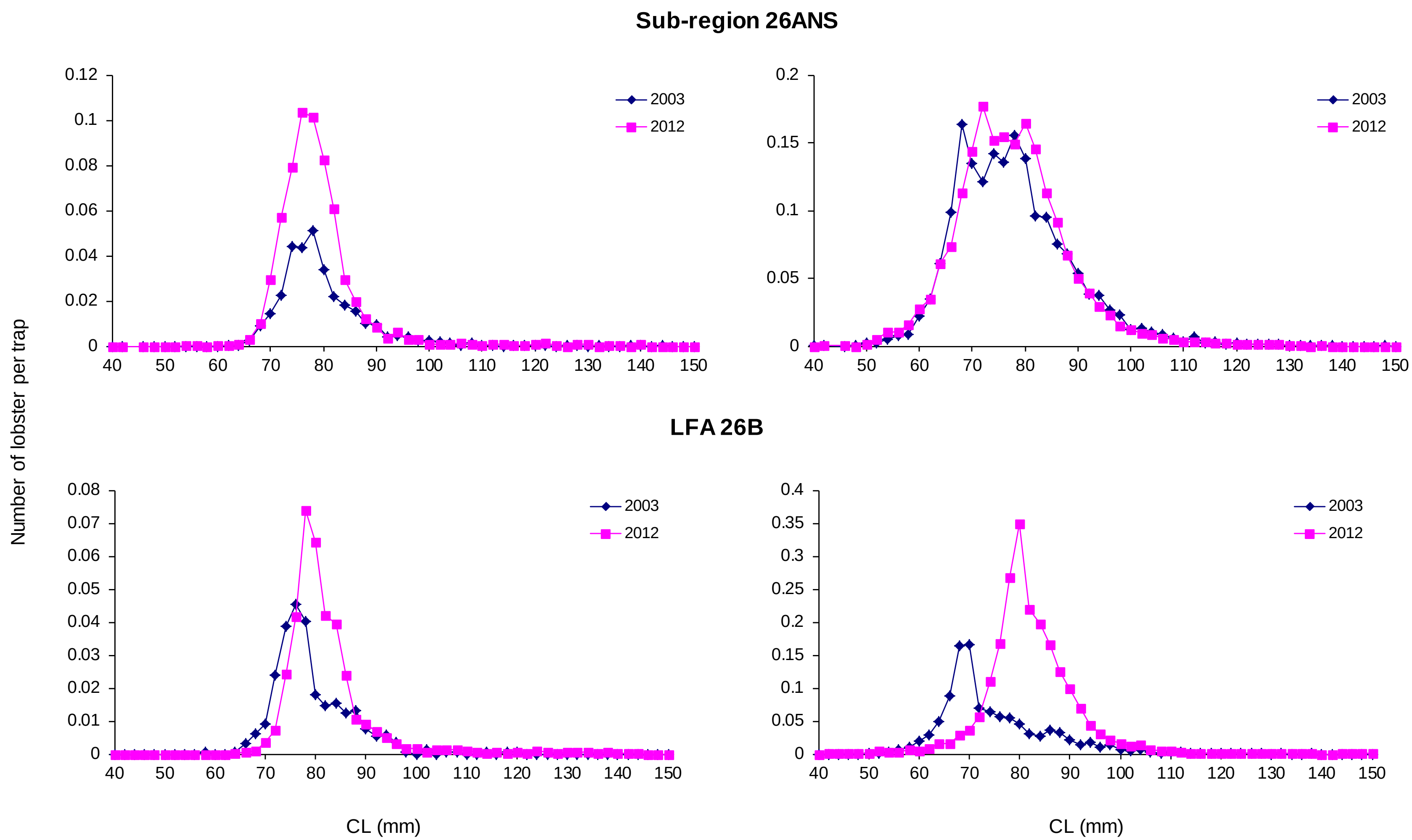

Figure 17. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm carapace length (CL) size interval based on data from the at-sea sampling program for sub-region 26ANS (top panels) and LFA 26B (bottom panels) in the southern Gulf of St. Lawrence during 2003 and 2012.

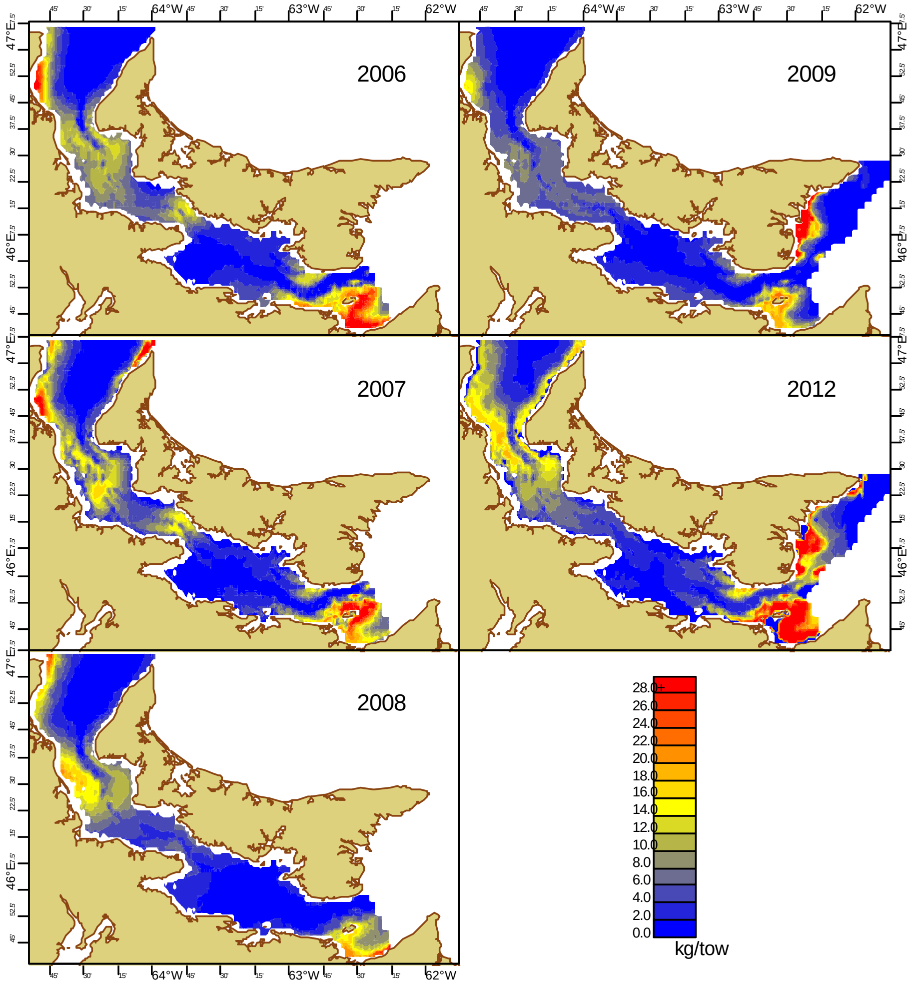

Figure 18. Distribution of legal-size lobster caught during the Northumberland Strait survey for 2006 to 2009 (≥70 mm CL) and 2012 (≥71 mm CL), interpolated using the GAM model.

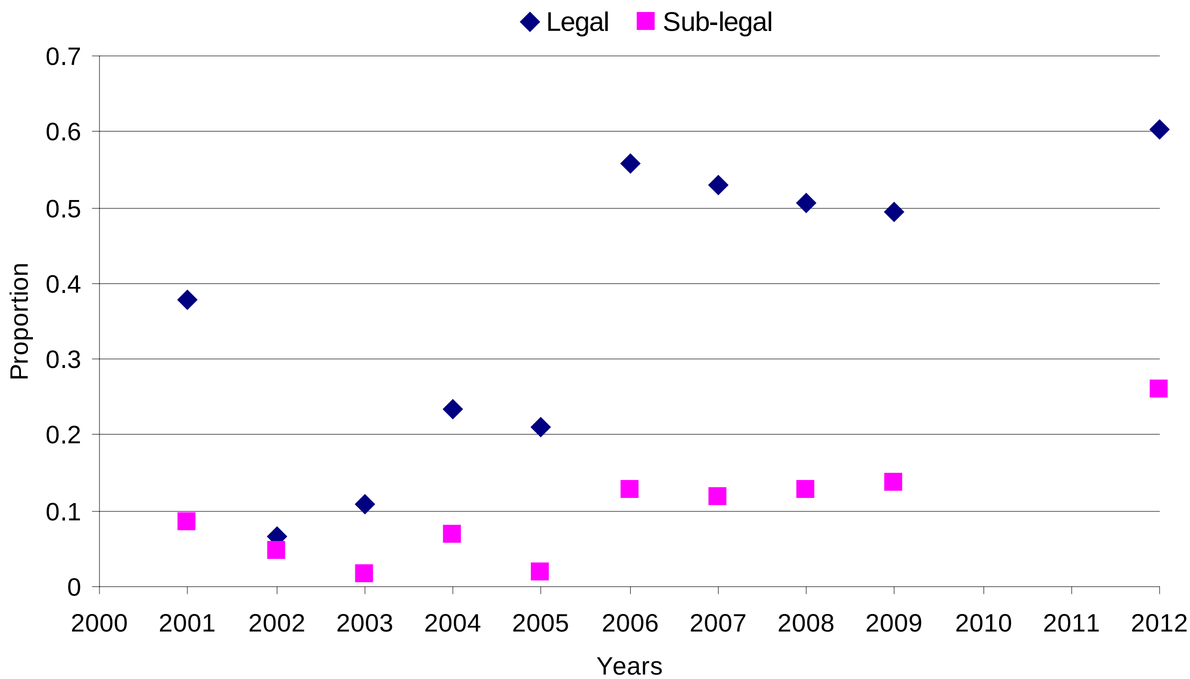

Figure 19. Estimates of the proportion of the survey area in LFA 25 where the biomass of legal and sub-legal size lobsters was greater than 400 kg per km^2.

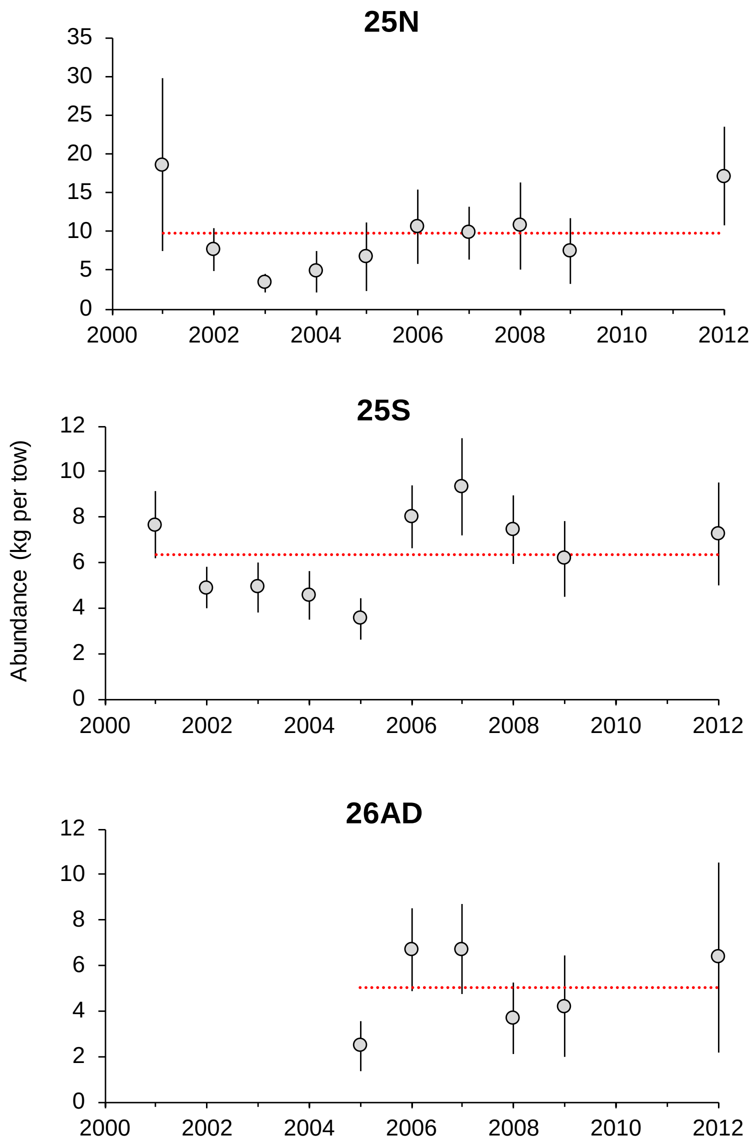

Figure 20. Biomass indices (kg per tow, mean and 95% confidence interval range) of all sizes of lobster in sub-regions 25N (upper panel), 25S (middle panel), and 26AD (bottom panel) as estimated from the bottom trawl survey, 2001 to 2009 and 2012. The horizontal lines are the mean values for the time series, 2001 to 2012 except for sub-region 26AD where the mean is calculated for the years 2005 to 2012.

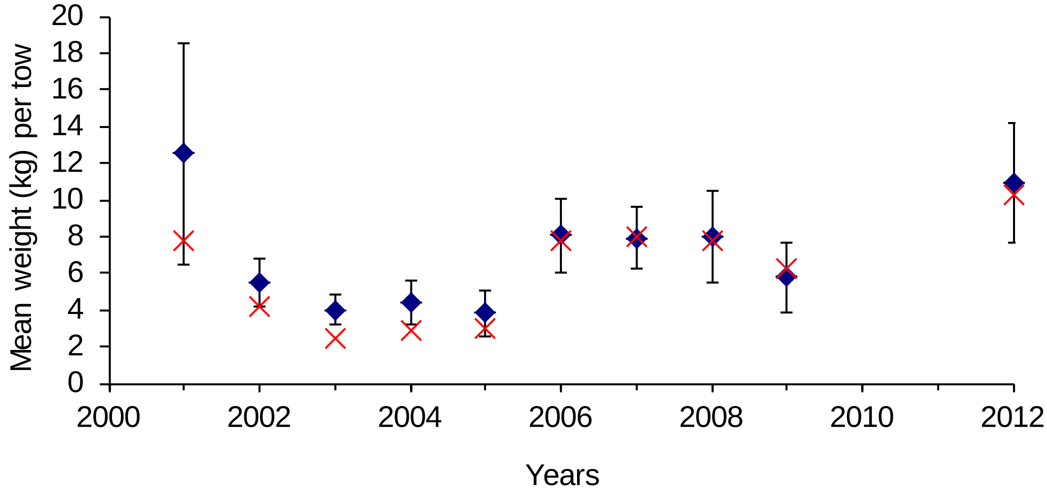

Figure 21. Annual indices (average ± 95% CI) of biomass (kg per tow) of lobsters caught during the trawl survey in LFA 25. Red "X" symbols represent biomass index values calculated with the GAM model.

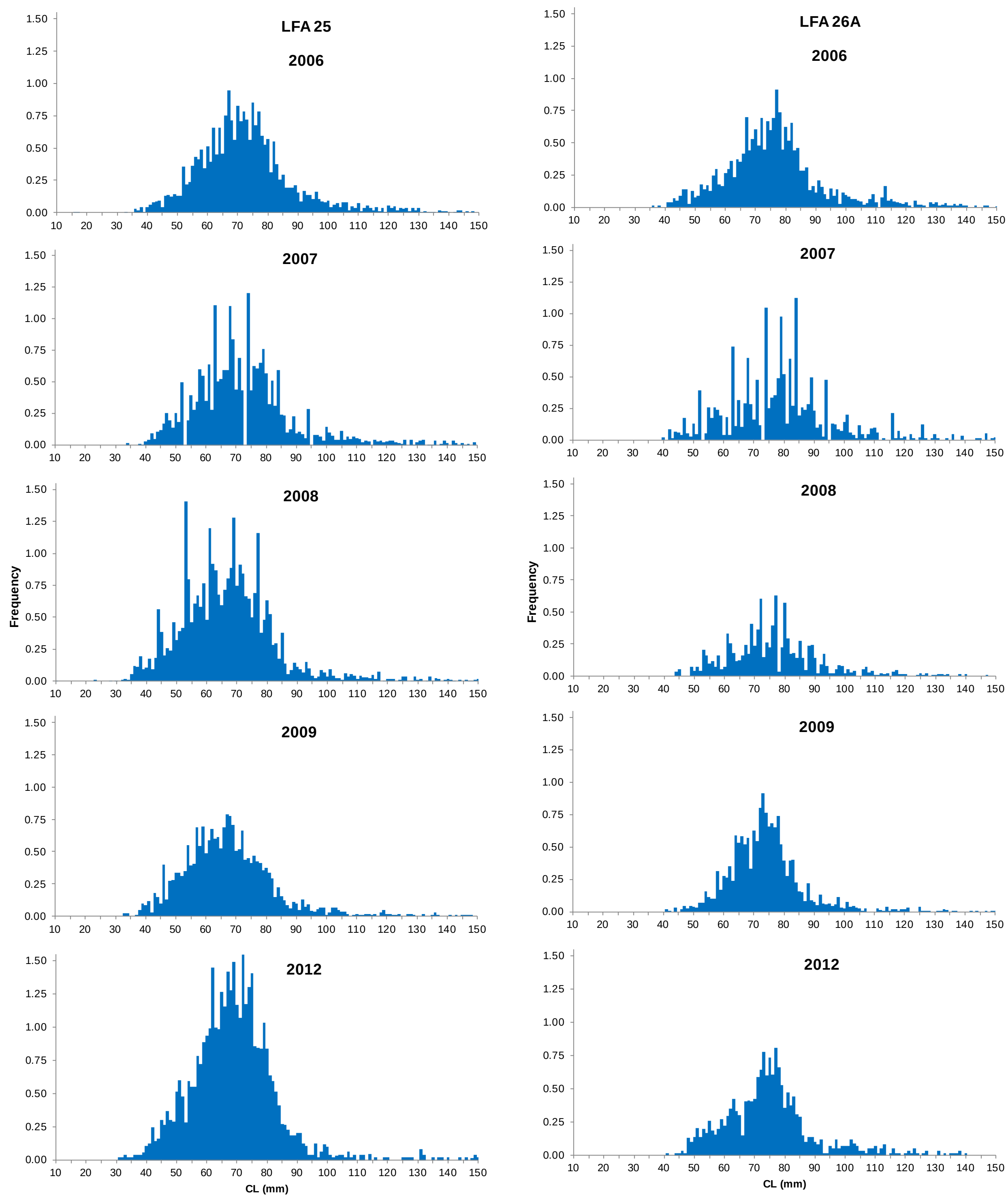

Figure 22. Size (carapace length in mm) distributions of lobster caught during Northumberland Strait surveys in LFA 25 (left panels) and LFA 26A (right panels) for 2006 to 2009 and 2012.

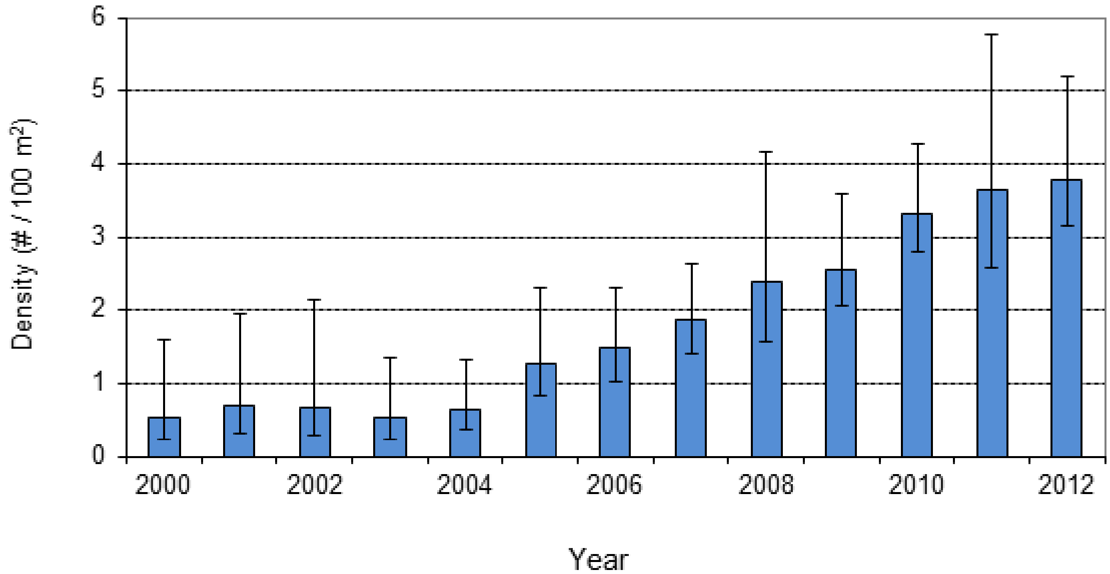

Figure 23. Mean density (number per 100 m²) of lobsters from 2000 to 2012, averaged over sites and cohorts from the SCUBA generalized linear mixed model. Error bars show 95% credibility intervals.

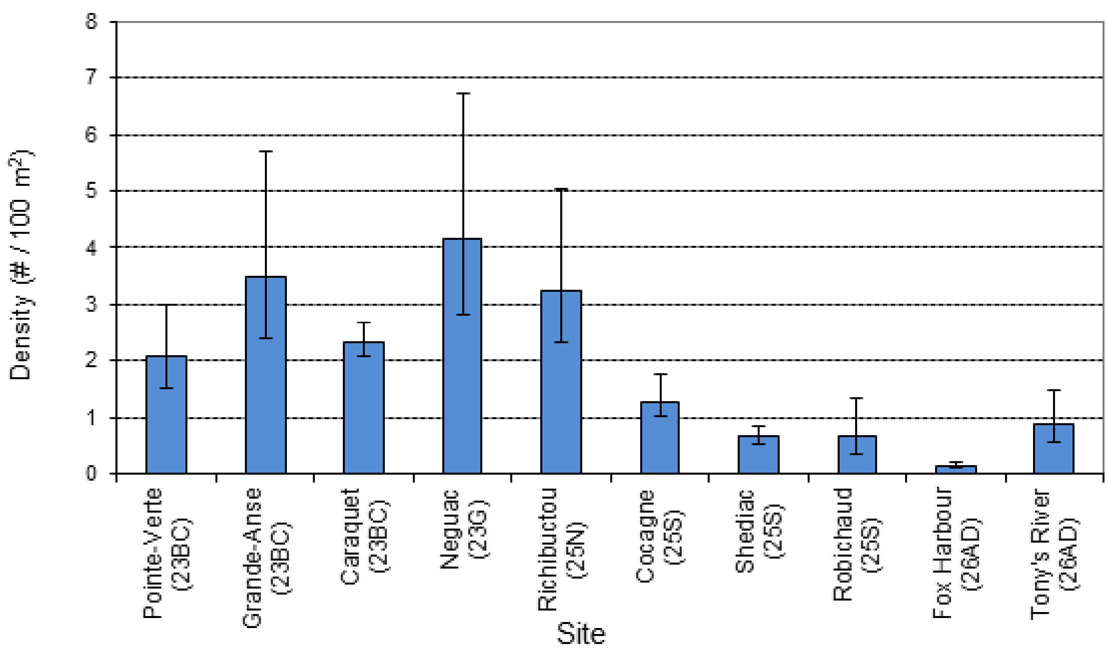

Figure 24. Mean density (number per 100 m²) of lobster by site, averaged over years and cohorts from the SCUBA generalized linear mixed model. Error bars show 95% credibility intervals.

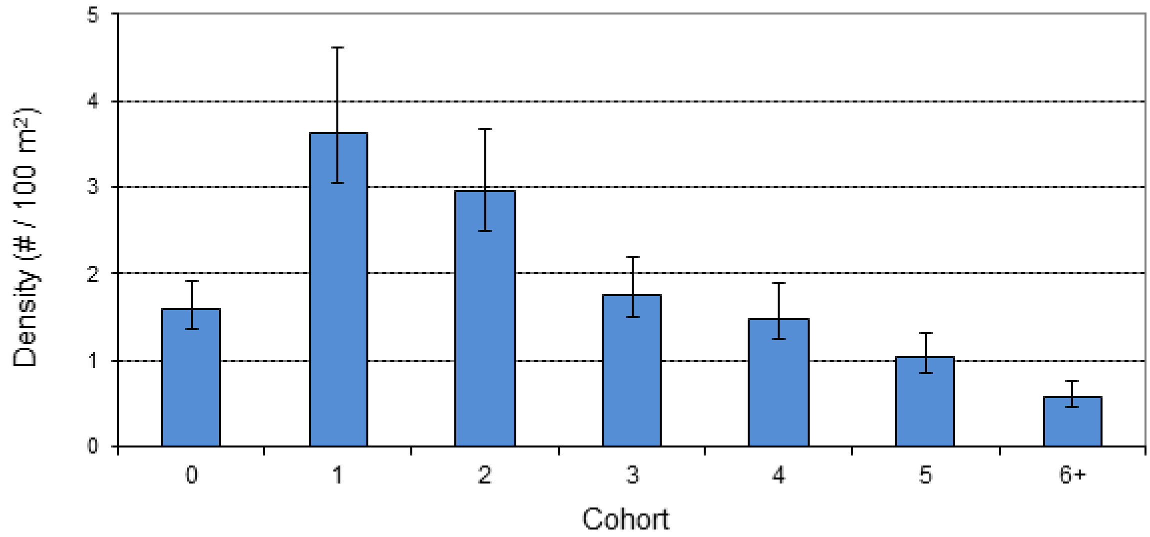

Figure 25. Mean density (number per 100 m²) of lobster by cohort, averaged over years and sites from the SCUBA generalized linear mixed model. Error bars show 95% credibility intervals.

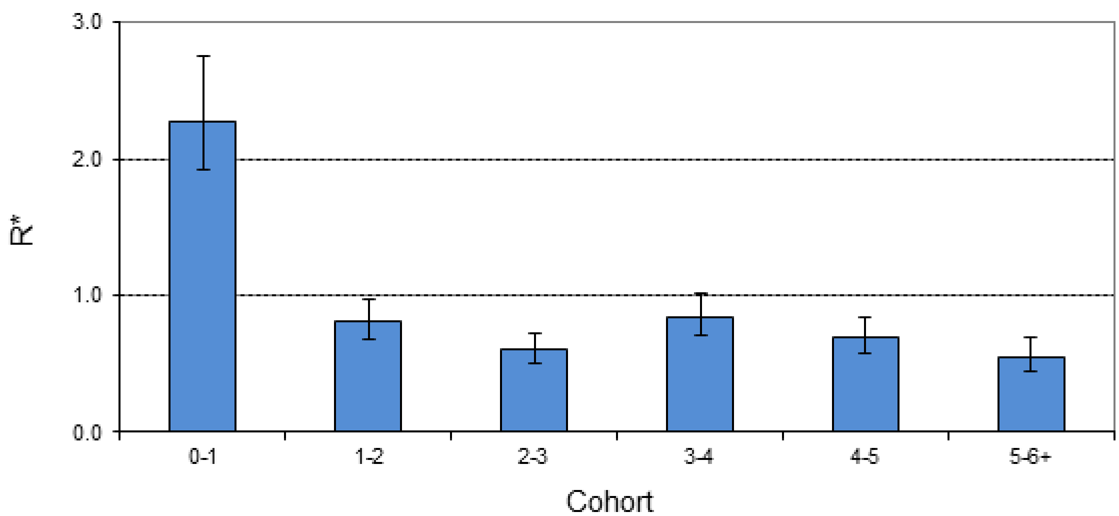

Figure 26. Ratios (R) between cohorts by cohort, averaged over years and all sites. Also shown are 95% credibility intervals from MCMC sampling from the posterior distributions.*

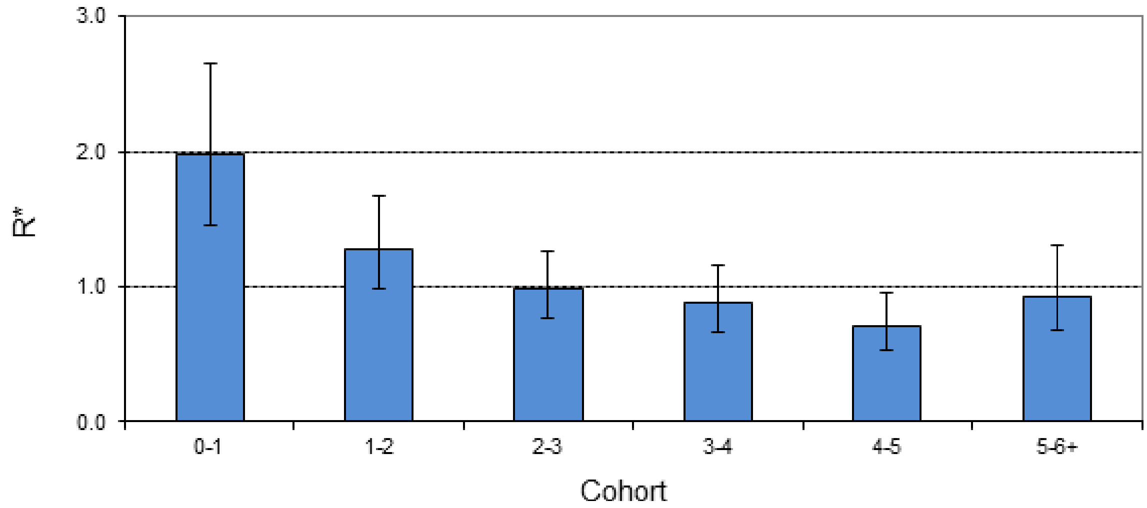

Figure 27. Cohort ratios (R), averaged over years and sites from central Northumberland Strait (i.e., sub-region 25S and 26AD). Error bars show 95% credibility intervals.*

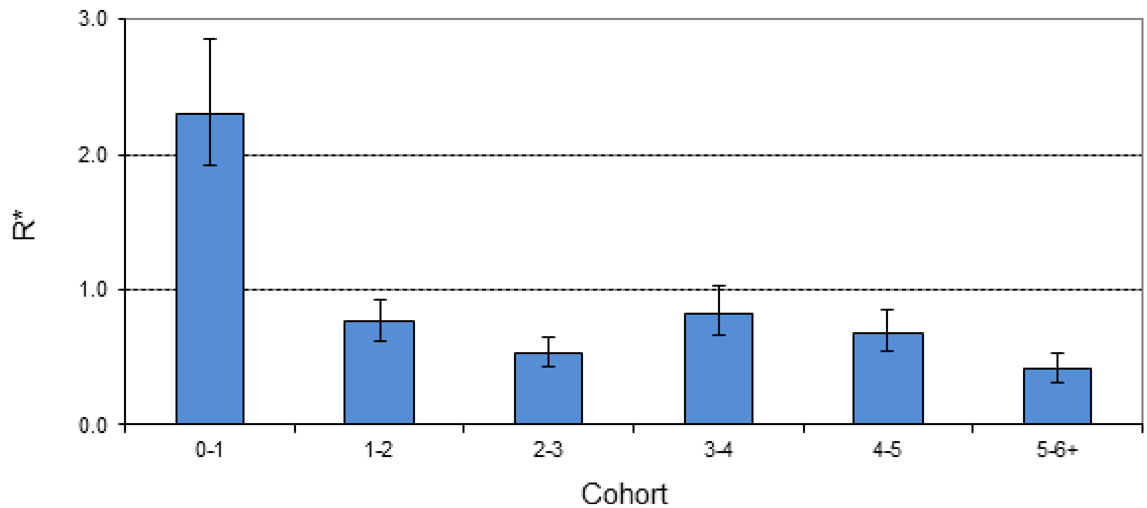

Figure 28. Cohort ratios (R) averaged over years and sites located in the Lobster Fishing Area 23 and sub-region 25N. Error bars show 95% credibility intervals.*

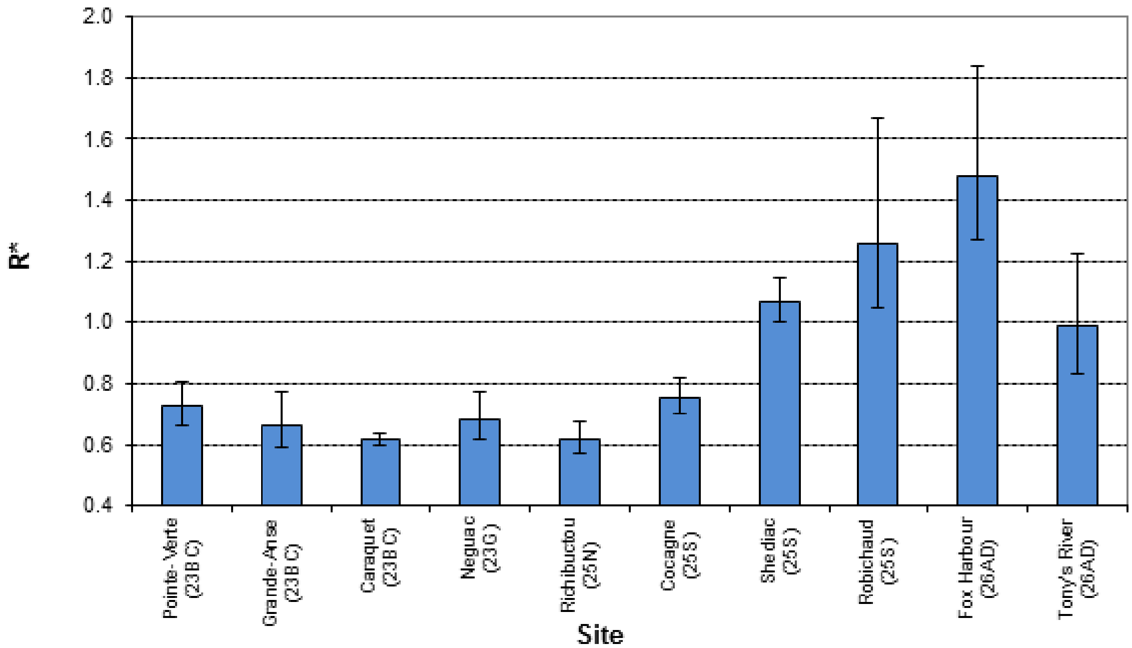

Figure 29. Cohort ratios (R) by site, averaged over years and cohorts 1 through 6+. Error bars show 95% credibility intervals.*

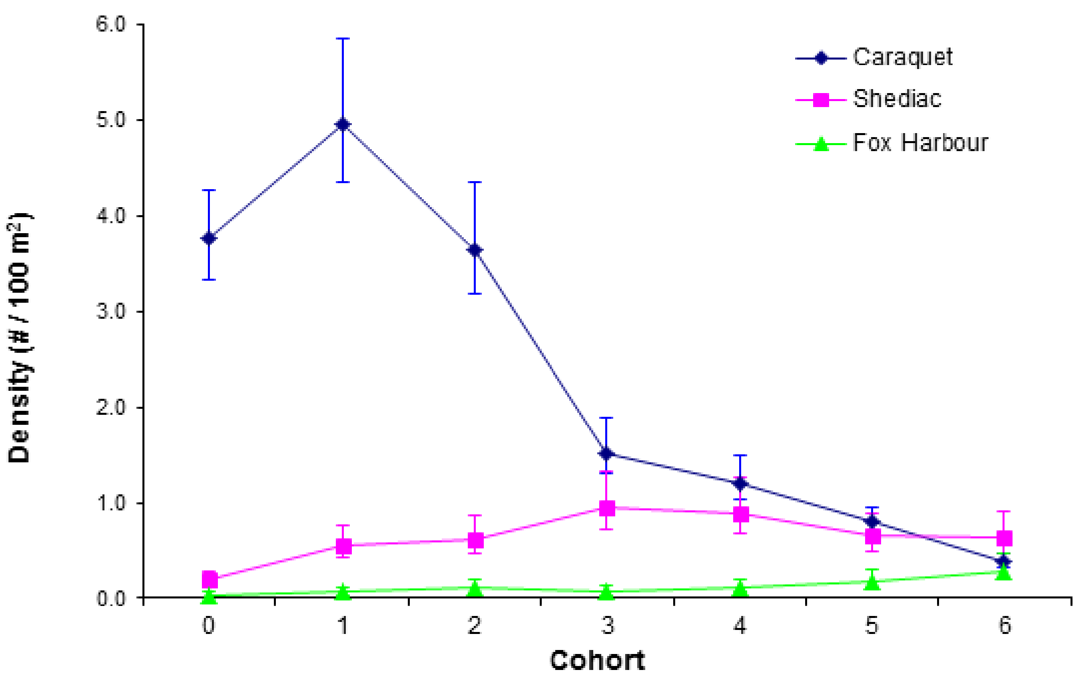

Figure 30. Mean density (number per 100 m²) by cohort for Caraquet, Shediac and Fox Harbour sampling sites from the SCUBA generalized linear mixed model. Error bars show 95% credibility intervals.

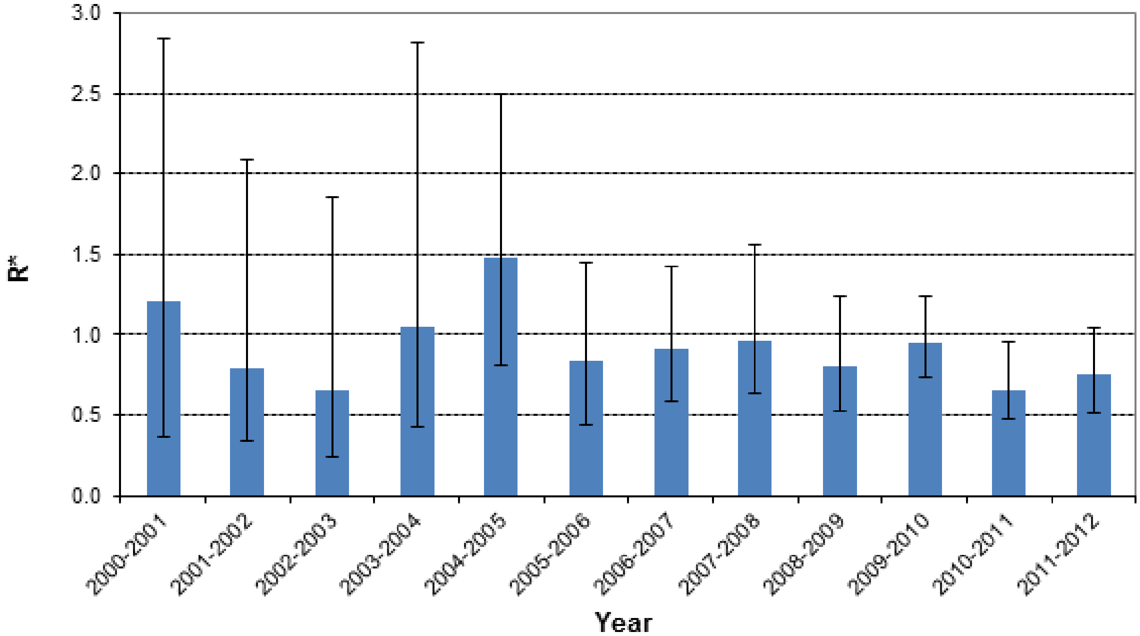

Figure 31. Cohort ratios (R) by site, averaged over years and cohorts 1 through 6+. Error bars show 95% credibility intervals.*

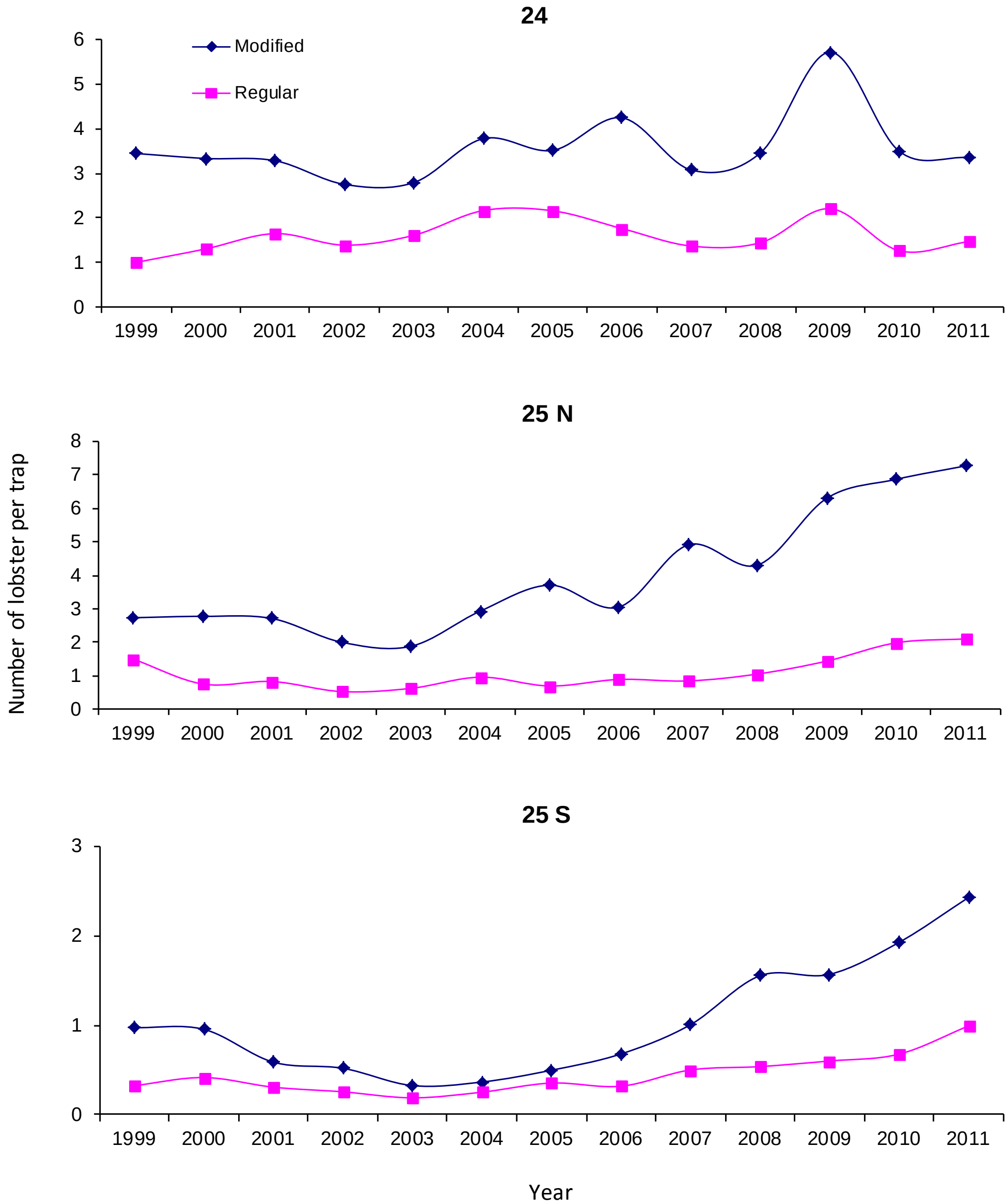

Figure 32. Annual catch per unit effort (number of lobster per trap) for recruitment size (bin sizes <5) male and non-berried-female lobsters in regular (square symbols) and modified (diamond symbols) traps from the recruitment-index program in sub-regions 24, 25N and 25S during 1999 to 2011.

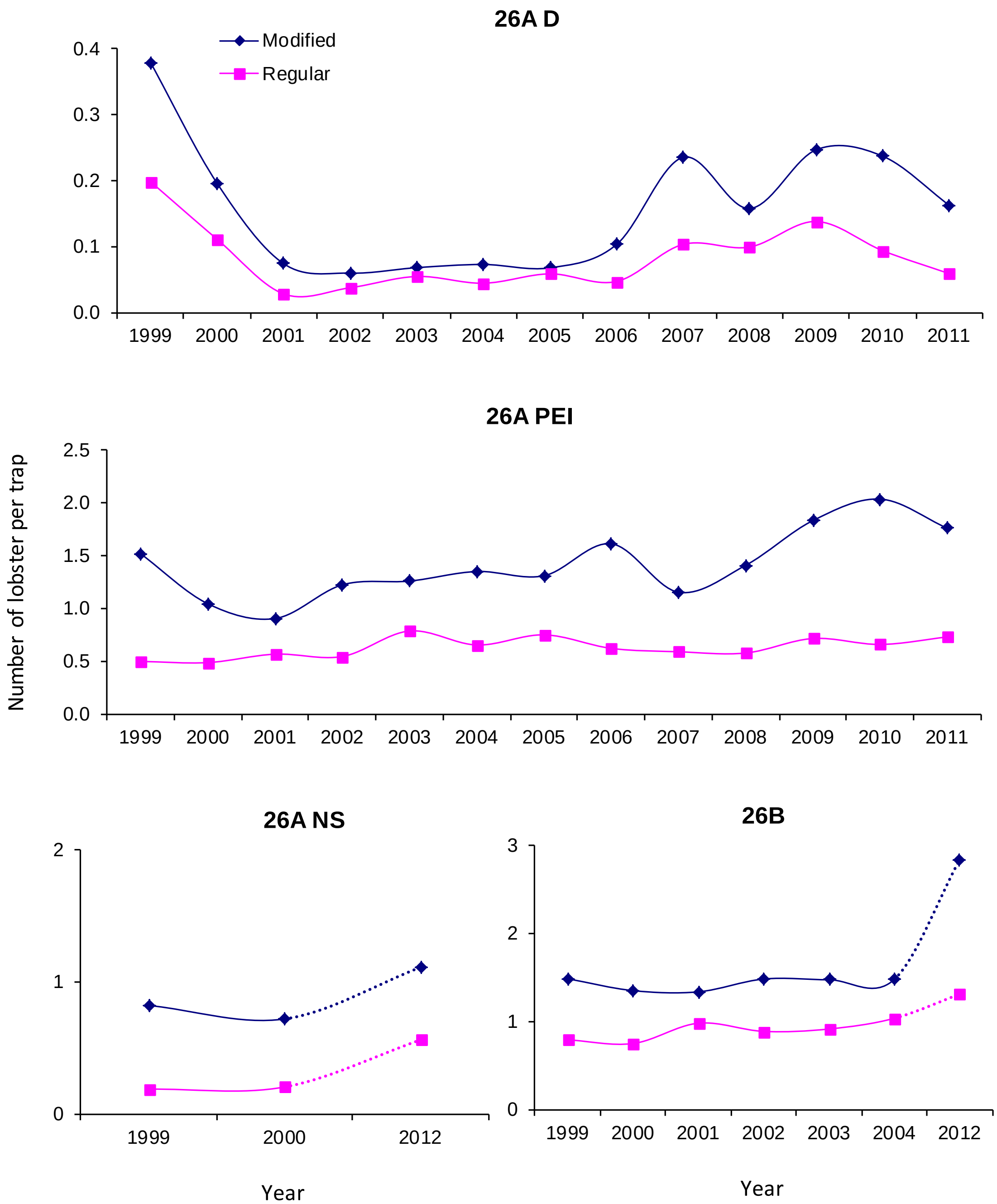

Figure 33. Annual catch per unit effort (number of lobsters per trap) for recruitment size (bin sizes <5) male and non-berried-female lobsters in regular (square symbols) and modified (diamond symbols) traps from the recruitment-index program in sub-regions 26AD, 26APEI, 26ANS, and 26B, 1999 to 2012.

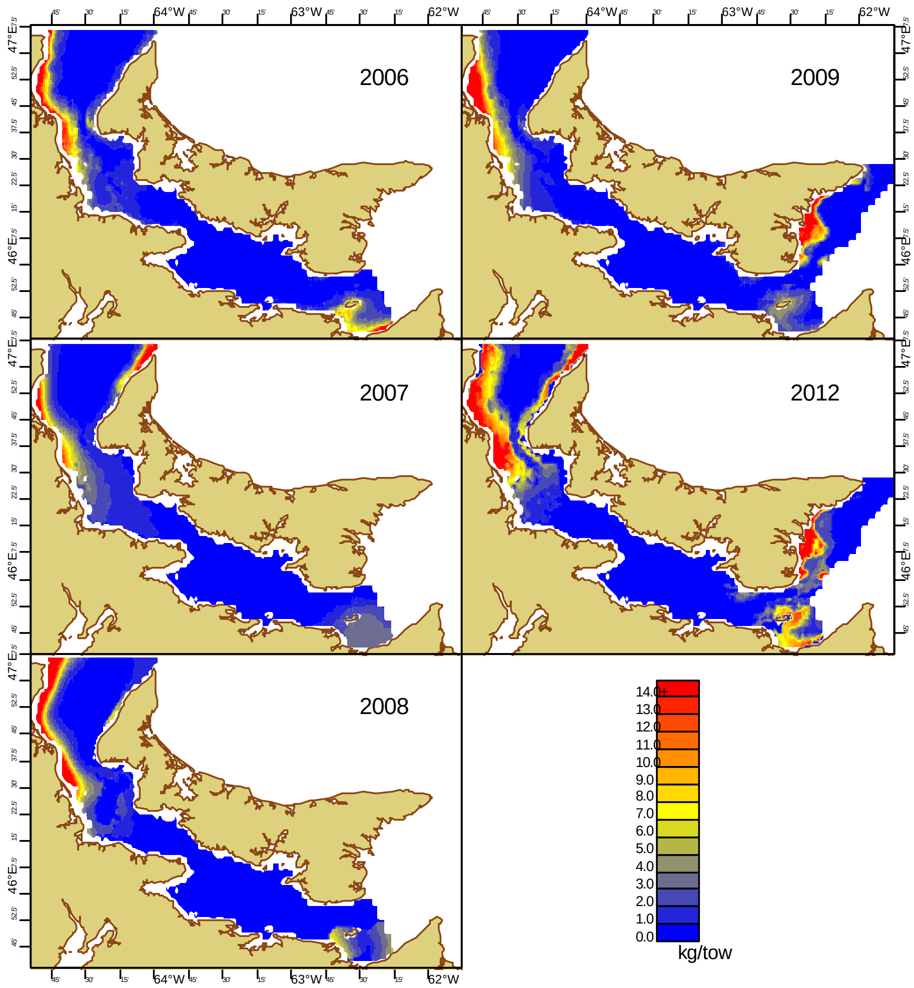

Figure 34. Distribution of sublegal-size lobster caught during the Northumberland Strait survey for 2006 to 2009 (<70 mm CL) and 2012 (<71 mm CL) as interpolated using the GAM model.

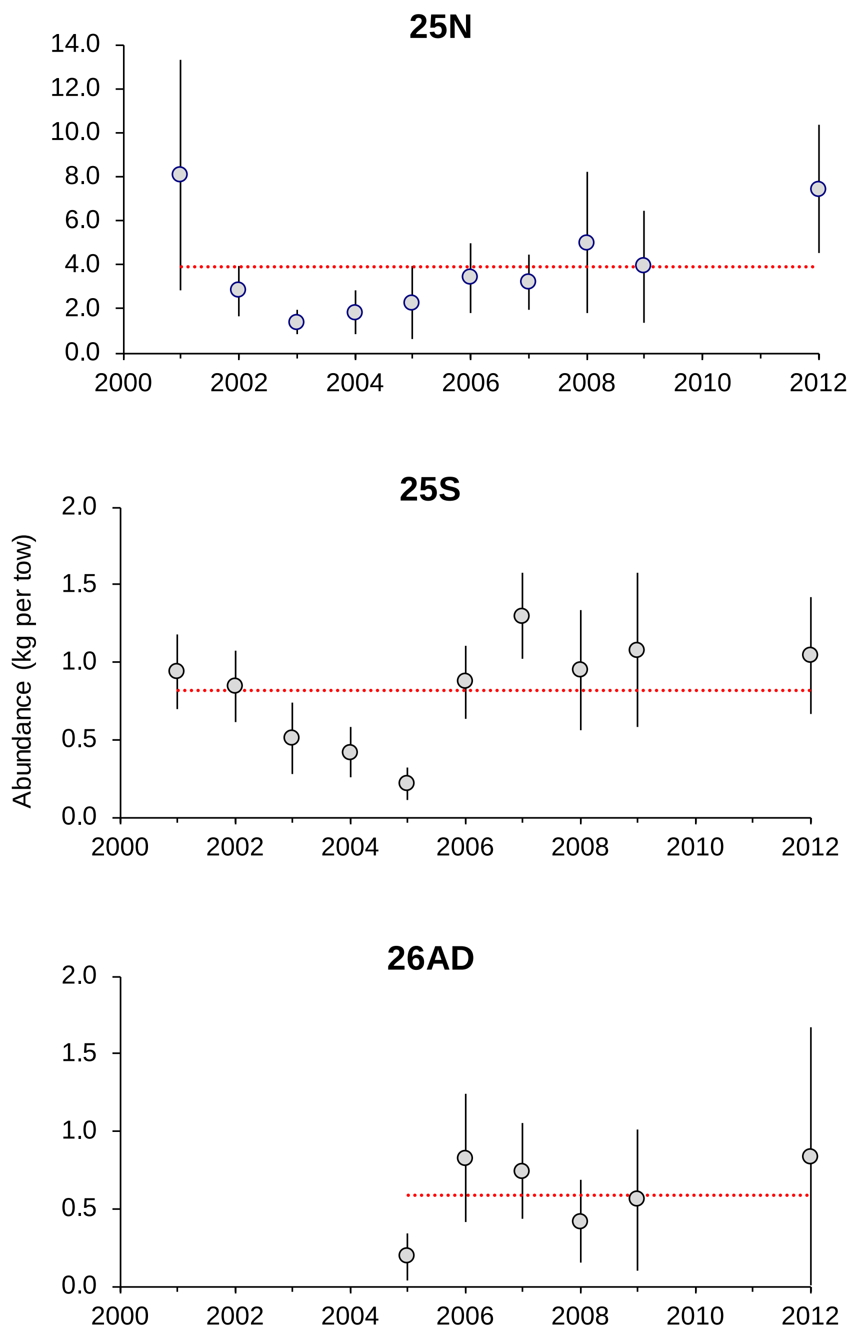

Figure 35. Trends in abundance (kg per tow, mean and 95% confidence interval range) of sub-legal size lobsters in sub-regions 25N (upper panel), 25S (middle panel), and 26AD (bottom panel) as estimated from the bottom trawl survey, 2001 to 2009 and 2012. The horizontal lines are the mean values for the time series, 2001 to 2012 except for sub-region 26AD where the mean is calculated for the years 2005 to 2012.

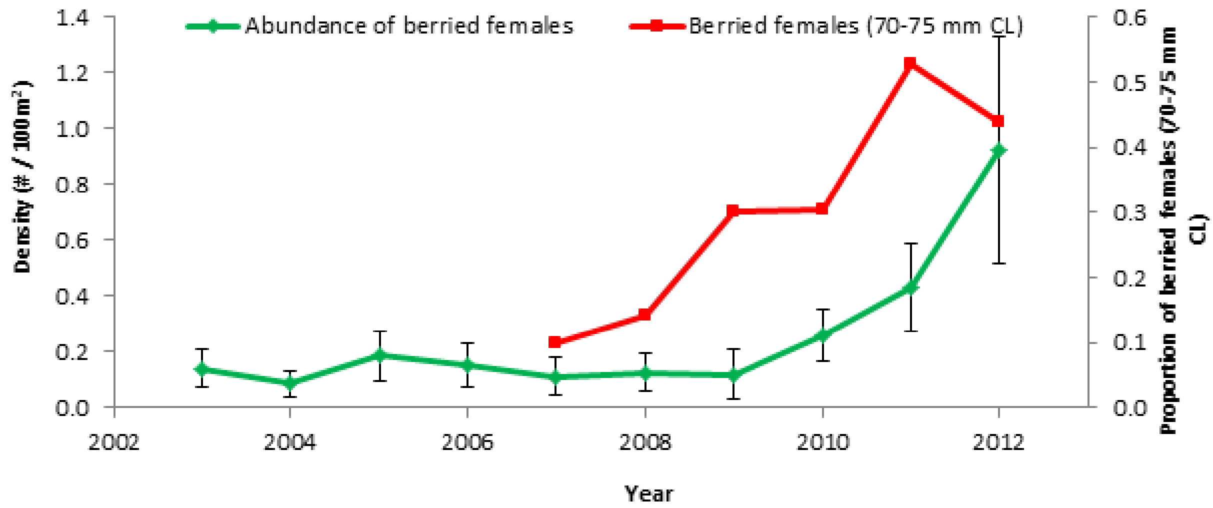

Figure 36. Mean density (number per 100 m²) of berried females observed from SCUBA surveys in Caraquet between 2003 and 2012. Confidence intervals shown as vertical lines are the 95% level. The proportion of berried females ranging from 70 to 75 mm of carapace length (CL) between 2007 and 2012 is also shown.

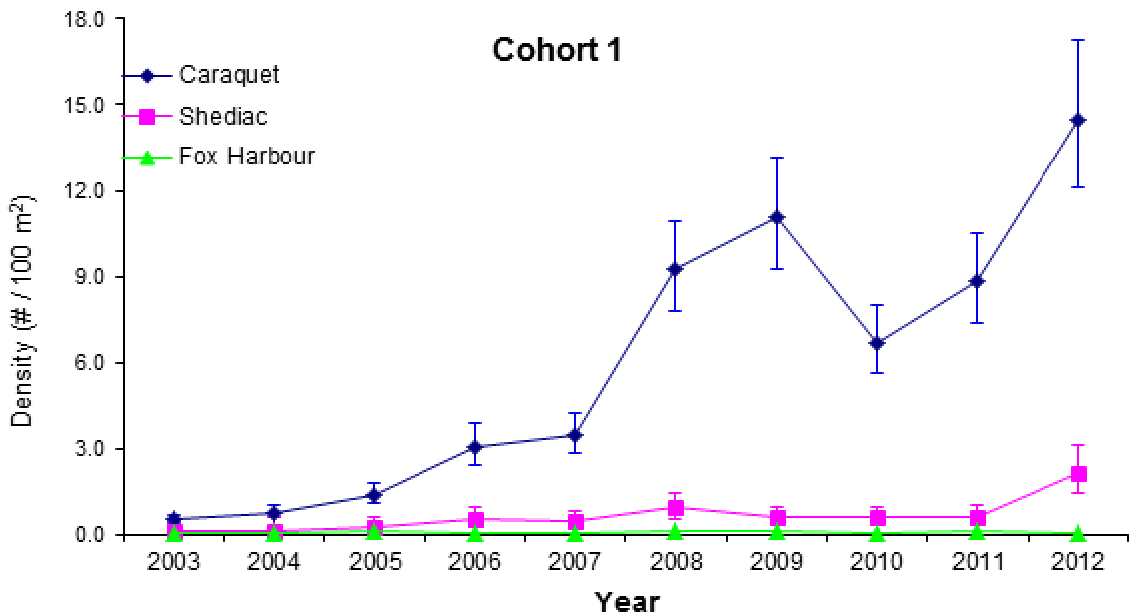

Figure 37. Mean density (number per 100 m²) by year for cohort 1 lobsters for Caraquet, Shediac and Fox Harbour from the SCUBA generalized linear mixed model. Error bars shown are 95% credibility intervals.

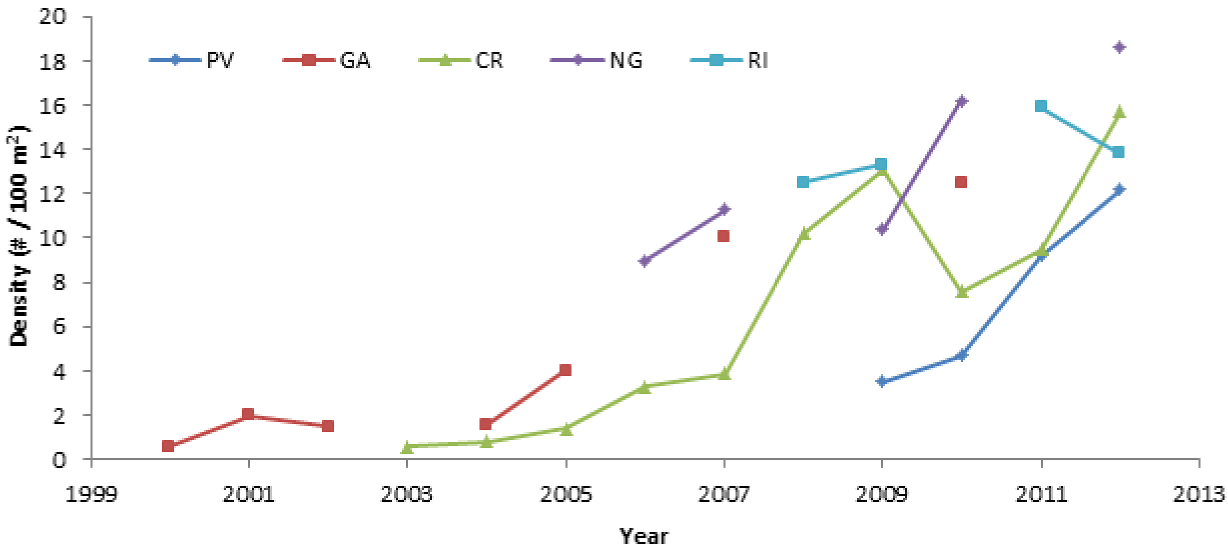

Figure 38. Mean density (number per 100 m^2) for cohort 1 lobsters based on SCUBA data for sites outside central Northumberland Strait from sub-region 23BC (Pointe-Verte; PV: Grande-Anse; GA: Caraquet; CR), sub-region 23G (Neguac; NG), and sub-region 25N (Richibucto; RI), 200o to 2012.

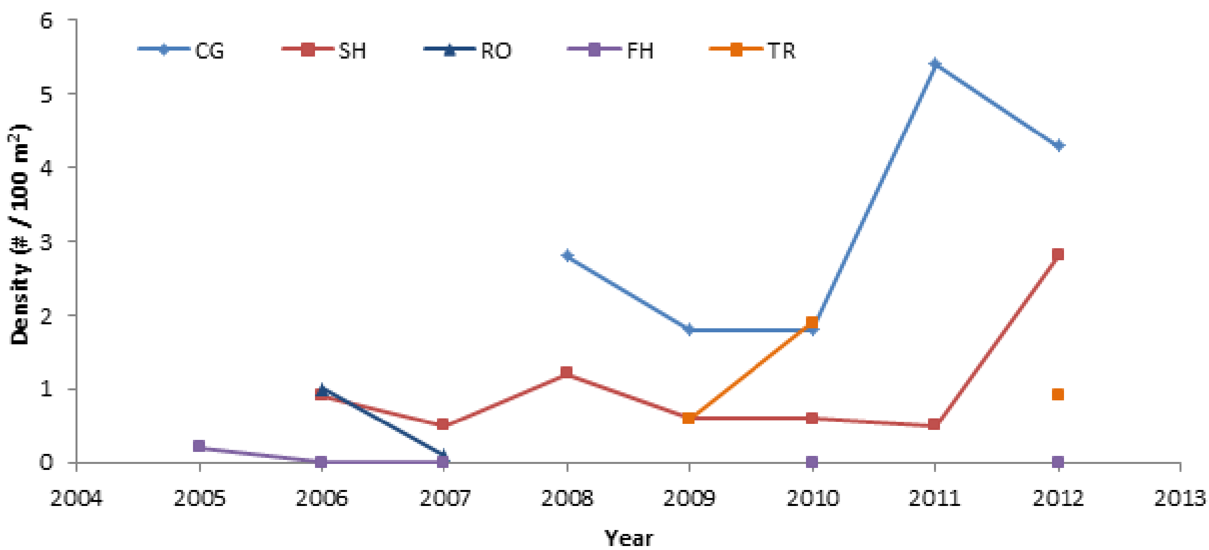

Figure 39. Mean density (number per 100 m^2) for cohort 1 lobsters based on SCUBA data for sites inside central Northumberland Strait from sub-region 25S (Cocagne; CG: Shediac; SH: Robichaud; RO), and sub-region 26ANS (Fox Harbour; FH: Toney River; TR), 2005 to 2012.

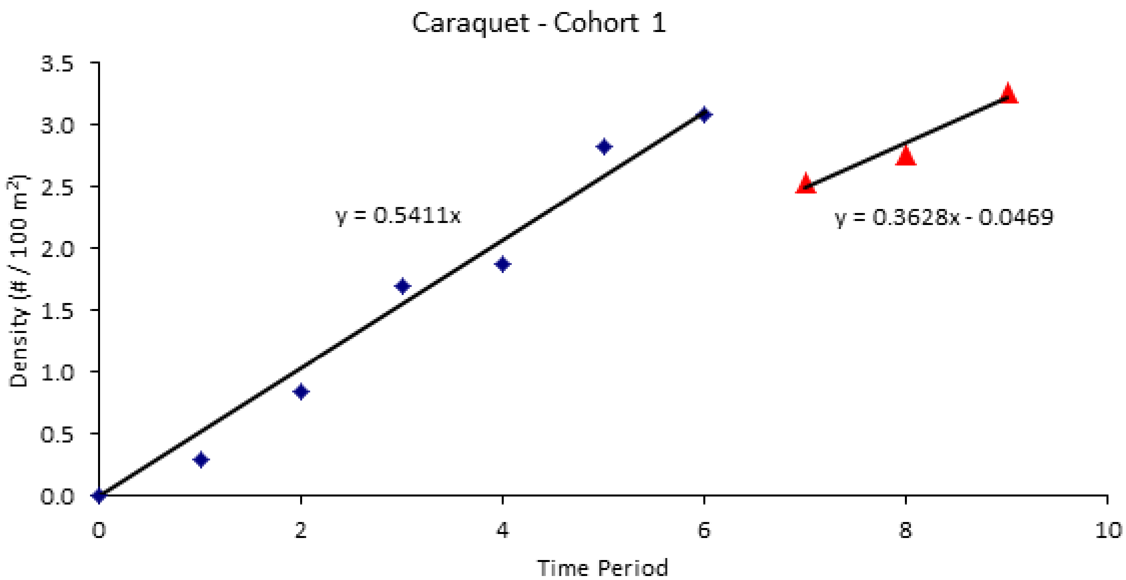

Figure 40. Mean density (number per 100 m^2) for cohort 1 lobsters from SCUBA surveys carried out in Caraquet between 2003 and 2012 (time period 0-9) showing the significant increase in recruitment with a discontinuity between 2009 and 2010. Linear relationships of the logarithmically transformed densities as a function of time are presented.

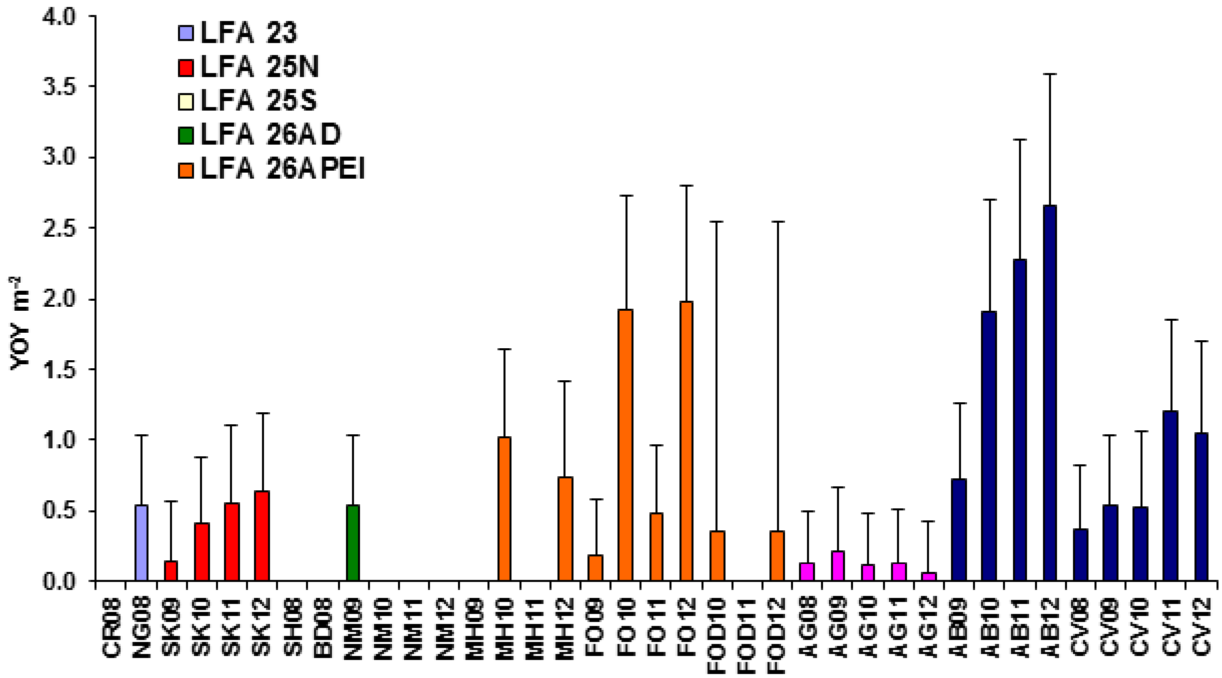

Figure 41. Mean density (number per m²) of young-of-year lobsters (yoy) from bio-collectors at various sites in the southern Gulf of St. Lawrence between 2008 and 2012. Site labels are: AB=Alberton; AG=Arisaig; BD=Bedeque; CR=Caraquet; CV=Covehead; FO=Fortune; FOD=Fortune (22 m); MH=Murray Harbour; NG=Neguac; NM=Nine Mile Creek; SH=Shediac; SK=Skinner's Pond.