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Assessment of lobster (*Homarus americanus*) off southwest Nova Scotia and in the Bay of Fundy (Lobster Fishing Areas 34-38)

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Foreword

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

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ABSTRACT

Lobster Fishing Area (LFA) 34 is located off the southwest coast of Nova Scotia, while LFAs 35-38 are in the Bay of Fundy. The status of LFAs 34-38 was assessed by a two-part framework assessment held in 2012 (July 10-12) and 2013 (February 12-14). This assessment includes data on the fishing seasons ending in spring 2012.

This document provides review and analysis for the assessment of LFAs 34-38. It reviews lobster population biology and ecology and stock structure. Based on the degree of spatial and temporal integrity of population characteristics, two assessment units are warranted: LFA 34 and LFAs 35-38. Data analyzed in detail in the current document are landings and effort geo-referenced to 10 by 10 minute grids, size frequency from samples of the catch, and size and catch rates from Fishermen and Scientists Research Society (FSRS) recruitment traps. In addition to the above, data from other sources on fishery independent surveys are accessed for discussion of ecosystem considerations and for reference points.

In LFA 34, landings for 2011-12 (23,292 t) were an all-time high and about one third higher than the last time LFA 34 was assessed (2006). Within LFA 34 there has been a spatial shift in landings since 1998-99, with an increased percentage of landings in the mid- and offshore (37% of the total in 2010-11 and 2011-12 versus 11-15% in 1998-99 and 1999-00). This is largely due to a spatial shift in effort. Total fishing effort in LFA 34 has either varied without trend or declined since 1998-99. The adjusted annual number of trap hauls ranged from 19.9-23.4 million; 2011-12 effort (21,181,579 trap hauls) was just below the mean for 1999-2012. The catch per unit effort (CPUE) of the whole LFA in the last two years (1.1 kg/trap haul) is 1.7 times that of 1998-99 and 1999-00. Changes in size structure in commercial traps since 1990 in LFA 34 were most evident at the larger sizes. The 95th percentile of female size became smaller in traps set in the nearshore Grid Groups and in two of the midshore Grid Groups. In the offshore Grid Groups there was no consistent trend.

In LFAs 35-38, landings in 2011-12 (8,467 t) were an all-time high, and are about double the landings the last time LFAs 35-38 was assessed (2007). Fishing effort has increased in LFAs 35-38, but is still lower than in LFA 34 on an area basis. In terms of total annual trap hauls, reported levels in 2011-12 (4,539,140 trap hauls) for LFAs 35-38 were 1.2 times those estimated for 2005-06. CPUE in the Bay of Fundy increased in all LFAs since 2005-06. In LFAs 35-38 as a whole, CPUE in 2011-12 (1.9 kg/trap haul) was 1.8 times that of 2005-06. The size structure in commercial traps in the Bay of Fundy showed some reductions in large sizes since the early 1990s.

Data from standardized traps designed to retain more sublegal lobsters, maintained by the FSRS, were used to evaluate abundance trends of sublegal lobsters in some portions of the stock assessment units. Most available data were for LFA 34. A standardized CPUE model and a Temperature Corrected Abundance Index (TCAI) for LFA 34 nearshore indicate that sublegal abundance in the last 2 years was higher than all previous years in the 13 year time series. The standardized CPUE of sublegals in LFA 35 is available only for 6 years, but the last 2 years were the highest in the time series.

Exploitation rates (ER) were estimated for the nearshore portion of LFA 34 for the period 1999-00 to 2011-12 using Continuous Change in Ratio (CCIR). A different method (Length composition analysis, or LCA), was used to estimate ER for all of LFA 34, and for nearshore, midshore and offshore portions for selected seasons. LCA estimates of ER for LFA 34 as a whole ranged from 0.71 to 0.77. CCIR estimates for the nearshore portion of LFA 34 ranged from 0.63-0.94 with an overall mean above 0.80. LCA estimates for the nearshore fell within this range, and indicate that ER is lower in the midshore and offshore (mean of 0.36 for 2006-07 and 2009-10). Evidence for an upward shift in ER in LFA 34 since 1999 is mixed. ER in LFA 34

have been high for many years based on the long-term consistency in size distribution in the nearshore. High ER in the nearshore portion of LFA 34 have not inhibited the substantial increases in lobster abundance in the last 10-12 years. Given that environmental conditions remain favorable for lobster, the current levels of fishing effort do not appear to threaten the sustainability of lobster stocks in LFA 34.

For LFAs 35-38, there are inadequate data for estimating ER. Partial results for a few years for a portion of LFA 35 suggest a lower ER in the upper Bay of Fundy than in the outer Bay and in LFA 34.

A precautionary approach proposed for lobster in LFA 34 and LFAs 35-38 utilizes reference points for the abundance of legal sizes based on both fishery dependent indicators (landings and commercial catch rate) and fishery independent indicators. The fishery independent indicator for LFA 34 comes from an industry groundfish survey that recorded lobsters in the catch; for LFAs 35-38 the number of lobsters per tow in the DFO Summer Research Vessel survey provides a fishery independent indicator. Both sources have shortcomings but provide a view of lobster abundance independent of the commercial trap fishery. All of the indicators for LFA 34 and LFAs 35-38 are above their proposed Upper Stock References (USR).

The biomass trends of potential predators of lobster indicate most are at low levels relative to the long-term mean and median. Given the current low biomass levels of most of these potential lobster predators, a near-term increase in the natural mortality of lobsters due to these species is not expected.

The estimated percentage of the area of the LFAs contacted by lobster traps was low (<0.1%). In the nearshore portion of LFA 34, the total area in contact is higher but still less than 0.2% of the total area. The fishery footprint was lower in the Bay of Fundy LFAs (0.02-0.03%). These estimates do not account for any movement of the traps either due to storms or while hauling.

Évaluation des homards (*Homarus americanus*) au large du sud-ouest de la Nouvelle-Écosse et dans la baie de Fundy (zones de pêche du homard 34 à 38)

RÉSUMÉ

La zone de pêche du homard (ZPH) 34 est située au large des côtes sud-ouest de la Nouvelle-Écosse, tandis que les ZPH 35 à 38 sont situées dans la baie de Fundy. L'état des ZPH 34 à 38 a été étudié dans un cadre d'évaluation en deux parties, en 2012 (du 10 au 12 juillet) et en 2013 (du 12 au 14 février). Cette évaluation comprend des données sur les saisons de pêche se terminant au printemps 2012.

Le présent document fournit un examen et une analyse de l'évaluation des ZPH 34 à 38. Il examine la biologie et l'écologie des populations de homard ainsi que la structure du stock. En fonction du degré d'intégrité spatiale et temporelle des caractéristiques de la population, deux unités d'évaluation sont justifiées : la ZPH 34 et les ZPH 35 à 38. Les données analysées en détail dans le présent document sont les débarquements et l'effort géoréférencé par grilles de 10 minutes par 10 minutes, la fréquence des tailles estimée à partir d'échantillons des prises ainsi que les tailles et les taux de prise à partir des casiers de recrutement de la Fishermen and Scientists Research Society (FSRS). En outre, des données provenant d'autres sources sur des relevés indépendants de la pêche sont évaluées afin de discuter de considérations écosystémiques et de servir de points de référence.

Dans la ZPH 34, les débarquements pour 2011-2012 (23 292 t) ont atteint un sommet historique et étaient supérieurs d'un tiers par rapport à la dernière évaluation effectuée dans la zone en 2006. Depuis 1998-1999, on a assisté à une évolution de la répartition spatiale des débarquements à l'intérieur de la ZPH 34, avec une augmentation du pourcentage des débarquements hauturiers et semi-hauturiers (37 % du total en 2010-2011 et 2011-2012, contre 11 à 15 % en 1998-1999 et 1999-2000). Cela est grandement dû à une évolution de la répartition spatiale de l'effort. Depuis 1998-1999, l'effort de pêche total dans la ZPH 34 a soit varié sans suivre une tendance précise, soit diminué. Le nombre total annuel ajusté de casiers levés a varié de 19,9 à 23,4 millions; en 2011-2012, l'effort (21 181 579 casiers levés) était juste sous la moyenne des années 1999-2012. Les prises par unité d'effort (CPUE) dans l'ensemble de la ZPH pour les deux dernières années (1,1 kg par casier levé) sont 1,7 fois plus élevées qu'en 1998-1999 et en 1999-2000. Depuis 1990, les changements dans la structure des tailles de homards pris dans les casiers de la pêche commerciale dans la ZPH 34 étaient les plus évidents aux tailles supérieures. Le 95e centile de la taille des femelles est devenu plus petit dans les casiers mouillés dans les groupes de grilles des secteurs côtiers et dans deux des groupes de grilles des secteurs semi-hauturiers. En ce qui concerne les groupes de grilles des secteurs hauturiers, il n'y avait pas de tendance constante.

Dans les ZPH 35 à 38, les débarquements pour 2011-2012 (8 467 t) ont atteint un sommet historique ayant presque doublé par rapport à la dernière évaluation effectuée dans ces zones en 2007. L'effort de pêche a augmenté dans les ZPH 35 à 38, mais il reste néanmoins inférieur à celui dans la ZPH 34 sur une base géographique. En termes de nombre total de casiers levés annuellement, les niveaux déclarés en 2011-2012 (4 539 140 casiers levés) pour les ZPH 35 à 38 étaient 1,2 fois plus élevés que les niveaux estimés pour 2005-2006. Depuis 2005-2006, les CPUE dans la baie de Fundy ont augmenté dans toutes les ZPH. En 2011-2012, les CPUE dans les ZPH 35 à 38 considérées dans leur ensemble (1,9 kg par casier levé) ont été 1,8 fois plus élevées qu'en 2005 2006. La structure des tailles de homards pris dans les casiers de la pêche commerciale dans la baie de Fundy a montré quelques réductions dans les tailles supérieures depuis le début des années 1990.

Les données des casiers standards conçus pour retenir plus de homards de taille inférieure à la taille normale, tenues à jour par la FSRS, ont été utilisées pour évaluer les tendances relatives à l'abondance des homards de taille inférieure à la taille normale dans certaines parties des unités d'évaluation des stocks. Les données les plus disponibles étaient celles concernant la ZPH 34. Un modèle de CPUE normalisé et un indice d'abondance corrigé en fonction de la température pour le secteur côtier de la ZPH 34 montrent que l'abondance des homards de taille inférieure à la taille réglementaire durant les deux dernières années était plus élevée que durant les années précédentes de la série chronologique de 13 ans. On ne dispose de CPUE normalisées de homards de taille inférieure à la taille réglementaire dans la ZPH 35 que pour six années, mais l'abondance des deux dernières années a été la plus élevée de la série chronologique.

Les taux d'exploitation ont été estimés pour le secteur côtier de la ZPH 34 pour la période allant de 1999-2000 à 2011-2012 en utilisant la méthode du changement de proportions en continu. On a utilisé une méthode différente (analyse de la distribution des longueurs) afin d'évaluer les taux d'exploitation pour toute la ZPH 34, et ceux pour certains secteurs côtiers, semi-hauturiers et hauturiers pour des saisons précises. Les estimations des analyses de la distribution des longueurs du taux d'exploitation pour l'ensemble de la ZPH 34 variaient de 0,71 à 0,77. Les estimations de changements de proportions en continu pour le secteur côtier de la ZPH 34 variaient de 0,63 à 0,94, avec une moyenne globale supérieure à 0,80. Les estimations des analyses de la distribution des longueurs pour le secteur côtier correspondaient à cet éventail et elles indiquaient que le taux d'exploitation était moins élevé dans les secteurs semi-hauturiers et hauturiers (moyenne de 0,36 pour 2006-2007 et pour 2009-2010). Les éléments de preuve d'une augmentation du taux d'exploitation dans la ZPH 34 depuis 1999 ne concordent pas toujours. Les taux d'exploitation dans la ZPH 34 ont été élevés pendant de nombreuses années en raison de la cohérence à long terme dans la répartition des tailles dans le secteur côtier. Les taux d'exploitation élevés dans le secteur côtier de la ZPH 34 n'ont pas freiné les augmentations considérables au chapitre de l'abondance au cours des dix à douze dernières années. Puisque les conditions environnementales demeurent favorables pour le homard, les niveaux actuels des efforts de pêche ne semblent pas avoir menacé la durabilité des stocks de homards dans la ZPH 34.

En ce qui concerne les ZPH 35 à 38, nous ne disposons que de données insuffisantes pour estimer les taux d'exploitation. Les résultats partiels pendant quelques années pour une partie de la ZPH 35 laissent à penser que les taux d'exploitation sont inférieurs dans la partie supérieure de la baie de Fundy par rapport à ceux de l'avant-baie et de la ZPH 34.

L'approche de précaution proposée pour les homards dans la ZPH 34 et les ZPH 35 à 38 utilise des points de référence pour l'abondance des homards de taille réglementaire basés sur des indicateurs dépendants de la pêche (débarquements et prises par unité d'effort de la pêche commerciale) et des indicateurs indépendants de la pêche. L'indicateur indépendant de la pêche pour la ZPH 34 provient d'un relevé sur le poisson de fond effectué par l'industrie qui avait consigné des homards parmi les prises. En ce qui concerne les ZPH 35 à 38, cet indicateur est fourni par le nombre de homards par trait indiqué dans le relevé d'été du navire de recherche de Pêches et Océans Canada (MPO). Les deux sources ont des lacunes, mais elles fournissent une indication de l'abondance des homards indépendante de la pêche commerciale aux casiers. Tous les indicateurs concernant la ZPH 34 et les ZPH 35 à 38 sont supérieurs aux points de référence supérieurs du stock proposés.

Les tendances de la biomasse des prédateurs potentiels des homards montrent que la plupart sont à un bas niveau comparé à la moyenne et au taux médian à long terme. Étant donné les faibles niveaux actuels de la biomasse de la plupart de ces prédateurs potentiels du homard, une augmentation à court terme de la mortalité naturelle des homards dans la ZPH 34 en raison de ces espèces n'est pas prévue.

Le pourcentage estimé de la superficie des ZPH touchée par les casiers à homards était bas (<0,1 %). Dans le secteur côtier de la ZPH 34, la superficie totale touchée est plus élevée, mais elle représente moins de 0,2 % de la superficie totale. L'empreinte de la pêche était inférieure dans les ZPH de la baie de Fundy (de 0,02 % à 0,03 %). Ces estimations ne tiennent toutefois pas compte des déplacements de casiers dus aux tempêtes ou des casiers déplacés lors des opérations de levage.

1. INTRODUCTION

1.1. CONTEXT FOR THE ASSESSMENT

The landed value of the lobster fishery in Atlantic Canada ($396 million in 2010) is the highest of any fishery in Canada. Landings in Lobster Fishing Areas (LFAs) 34-38 (Gulf of Maine and the Bay of Fundy) comprise a significant portion of the Atlantic Canada total (44% in 2010). Landings in LFAs 34-38 are currently near all-time highs.

Fisheries and Ocean Canada's (DFO's) Fisheries and Aquaculture Management Branch requested updated information on the status of the LFA 34-38 lobster stocks. The status of the lobster resources in LFA 34 was last assessed in 2006 (Pezzack et al. 2006); LFAs 35-38 were last assessed in 2007 (Robichaud and Pezzack 2007). Since 2006, there have also been two Science Responses, one on the likely causes of damaged lobsters (DFO 2008a) in LFAs 33 and 34, and one on the conservation benefits of large lobsters (DFO 2008b).

The advisory process for the assessment entailed two parts. Part I was a Framework meeting (July 10-12, 2012, in Digby, Nova Scotia) that covered the following topics:

- Describe basis of the management units in context of stock structure.
- Identify strengths and weaknesses of fishery and survey data inputs for providing indicators of abundance, size structure, recruitment, effort, and spatial distribution of catch using:
  - Port and at-sea sampling protocols
  - Observer sampling
  - Logbooks
  - Fishermen and Scientists Research Society (FSRS) information
  - Trawl survey data
  - Out of season trap surveys
  - Data on young-of-the-year (settlement)
- Present preliminary analyses of indicators of the following characteristics to assess whether changes have occurred in the last decade:
  - Fishery performance (landings, unstandardized CPUE, effort).
  - Abundance (legal sizes) (CPUE; available fishery independent).
  - Abundance of prerecruits and settlers (CPUE; available fishery independent).
  - Reproduction (spawners, egg production proxies).
  - Fishing Pressure (effort quantity and spatial distribution, exploitation estimates from change-in-ratio; size-based).
- Review relevant biological and ecological information:
  - Life history, molting, recruitment, etc.
  - Present preliminary results of size at maturity studies: LFA 34, LFA 38.
  - Incidental catch; fishery footprint.
  - Environmental data, e.g. temperature.
- Present rationale for current landings-based reference points; present potential alternative.
- Develop assessment schedule, including guidelines for the monitoring of the indicators and other events that would trigger earlier than scheduled assessment.

Part 1 is documented in a Proceedings (DFO 2013).

Part 2 of the advisory process was the assessment meeting with the following objectives:

- Address key issues identified during Part 1.

- Assess the stock status of the LFA 34-38 lobster stocks as of the end of the 2011-2012 seasons:
    - Report indicator trends.
    - Estimate relative exploitation rate (ER) over the last 10 years and evaluate the consequences of maintaining the current harvest levels.
    - Evaluate stocks status in relation to landings-based reference points and any new reference points identified in Part 1.
    - Estimate the level of incidental catch (including lobster) and the retention of non-lobster species, and report on information available on the survival of discarded species.
    - Provide implications for fishery management of the current estimates of the 50% size at onset of maturity for females, and other indicators of stock reproduction.

1.2. OVERVIEW OF DOCUMENTATION

The current document was prepared for Part 2 of this assessment process, held in February 2013. The current document provides the overall assessment for LFAs 34 and 35-38, as well as the background for material covered in Part 1. Four topics will be treated in companion documents because of their importance to the overall assessment: fishery independent surveys, size at maturity, incidental catch, and a reproductive index (D. Pezzack, unpublished; A. Silva, unpublished; and J. Gaudette, unpublished). Some of these unpublished results are referenced in the current document as appropriate.

1.3. BRIEF DESCRIPTION OF THE FISHERIES

The fisheries in LFAs 34 and 35-38 are managed by input controls including limited entry, fishing seasons, and trap limits, as well as technical measures including a minimum legal size and prohibition on landing berried females (Table 1.1). These fisheries have a long history stretching back to the 1800s. While historically the fishing effort was close to shore, fishing grounds have expanded to deeper water in the last 20-30 years (Pezzack et al. 2006, Robichaud and Pezzack 2007).

Table 1.1. Main regulations for fisheries in LFAs 34 to 38.

Season, Licences and Traps	Lobster Fishing Area (LFAs)			
	LFA 34	**LFA 35**	**LFA 36**	**LFA 38**
Fishing Season	**The last Monday in November to May 31st**	**October 14 to December 31 February 28th to July 31st**	**2nd Tuesday in November to January 14th March 31st to June 29th**	**2nd Tuesday in November to June 29th**
Number of Licences (as of January 28, 2013)				
Category A	861	75	135	65
Category A Partnership	89	2	26	54
Category B	0	3	1	1
Commercial Communal Category A	27	13	13	12
Commercial Communal Partnership	2	2	2	4
Number of traps – Category A	375 until Mar. 31; 400 from Apr 1-May 31	300	300	375
Number of traps Partnership	1.5 times Category A			
Number of Traps Category B	NA	90	90	113
Escape Vents	IN THE EXTERIOR WALLS OF EACH PARLOUR IN THE TRAP AND NOT MORE THAN 250MM FROM THE FLOOR OF EACH TRAP AT LEAST: (A) TWO UNOBSTRUCTED CIRCULAR OPENINGS THE DIAMETER OF EACH OF WHICH IS NOT LESS THAN 57.2MM; OR (B) ONE UNOBSTRUCTED RECTANGULAR OPENING THE HEIGHT AND WIDTH OF WHICH IS NOT LESS THAN 44MM. (HEIGHT) BY 127 MM (WIDTH)			
Biodegradable Trap Mechanism	NO PERSON SHALL FISH WITH, OR HAVE ON BOARD A VESSEL, A LOBSTER TRAP UNLESS THE TRAP (A) HAS IN ONE EXTERIOR WALL OF EACH PARLOUR AN ESCAPE PANEL THAT PROVIDES, WHEN REMOVED, AN UNOBSTRUCTED OPENING NOT LESS THAN 89 MM IN HEIGHT AND 152 MM IN WIDTH AND THAT IS FASTENED TO THE LOBSTER TRAP WITH (I) UNTREATED COTTON OR SISAL TWINE THAT DOES NOT EXCEED 4.8 MM IN DIAMETER, OR (II) UNCOATED FERROUS METAL WIRE, OTHER THAN OF STAINLESS STEEL, THAT DOES NOT EXCEED 1.6 MM IN DIAMETER; OR (B) IS A WOODEN LOBSTER TRAP THAT HAS IN ONE EXTERIOR WALL OF EACH PARLOUR TWO SOFTWOOD LATHS THAT ARE ADJACENT TO EACH OTHER AND THAT ARE NOT TREATED WITH A WOOD PRESERVATIVE.			
Biological Measures				
Minimum Carapace Length (mm)	82.5	82.5	82.5	82.5
Landing of egg bearing females or female with egg cement or glue on its swimmerets prohibited	Common to all LFAs			
Landing of V-notch females prohibited	Common to all LFAs			

2. REVIEW OF LOBSTER POPULATION BIOLOGY AND ECOLOGY

2.1. EARLY LIFE HISTORY

Lobsters have a planktonic larval period that takes a few weeks to a month or more depending on temperature. The larvae are chiefly in the surface waters, although they undergo a daily vertical migration. There are 3 larval stages followed by a postlarval stage ("Stage 4") that is planktonic for a few days to weeks until it begins diving to the bottom to search for shelter providing habitat. Growth studies in the laboratory indicate stages 1-3 take 35 days at 12°C and 22 d at 15°C (MacKenzie 1988). Field estimates of larval duration suggest development in the plankton can be substantially faster (Annis et al. 2007).

Halfway through the postlarval stage, lobsters leave the surface waters, and after some trial and error, settle preferentially on substrates that provide shelter, in particular hard bottom with cobbles. There have been some observations of settlers in eel grass and in areas with hard clay or mud sediment that is conducive to burrowing. Once the post larvae find suitable shelter on the bottom they tend to remain in or near the shelter to avoid predation. As post larvae grow, they increase the time spent outside the shelter (Lavalli and Lawton 1996).

In the Bay of Fundy, DFO has some long-standing sites where settlement has been monitored (Lawton et al. 2001). Since 2005, settlement has also been monitored in different locations in coastal N.S (Tremblay et al. 2012a, Wahle et al. 2013). This work is ongoing and settlement density may form the basis of a future reference point.

2.2. AGE AND GROWTH

At legal size, lobsters weigh approximately 0.45 kg (one pound) and generally moult once a year. Larger lobsters moult less often, with a 1.4 kg (three pound) lobster moulting every two to three years. The largest recorded lobster was 20.1 kg (44.4 lb) (Guinness Book of Records). The maximum age of lobsters is unknown but based on growth information and long-term holding studies, it is believed to be in the range of 50 years. Growth increments are dependent upon size, sex and maturity with the mean growth increment for males and immature females between 12-16%, while mature females exhibit a declining percentage increase with size (more constant growth increment) as more energy is invested in egg production.

In the Maritimes Region, lobsters are thought to take approximately 8-10 years on average to reach the legal size of 82.5 mm carapace length (CL) (81 mm in LFA 27 as of 2009). This is based on growth studies in adjacent regions (Gendron and Sainte-Marie 2006) and tagging studies of prerecruit lobsters in the region which indicate annual moults by most individuals (Miller et al. 1989, Tremblay and Eagles 1997). Lobster age at size may be quite variable based on results from analyses of the "age pigment", lipofuscin. Studies of lipofuscin in *Homarus gammarus* indicate that lobsters 85 mm CL may comprise up to 7 year classes (Sheehy et al. 1999). Lipofuscin accumulation is; however, affected by ambient temperature and challenges remain for applying the technique to wild-caught lobsters and other decapods such as blue crab because of the potentially variable temperature history of individuals (Wahle and Fogarty 2006, Puckett et al. 2008).

The assumption that no hard parts are retained through crustacean molts has prevented direct aging of lobsters. A recent paper (Kilada et al. 2012) challenges this assumption and suggests that some hard parts are retained. Chemical tags in the lobster cuticle were retained through one or two molts that occurred over the duration of their experiment. The eyestalk and gastric mill of lobsters had growth bands that appear to form annually, thus providing a potential method for direct aging of lobsters.

2.3. LOBSTER DIET

Little is known about the diet of larval lobster, but stomach contents include algae, larval crustacean parts, copepods, and insect parts (Herrick 1895a and b, Juinio and Cobb 1992).

Benthic stage lobsters are omnivorous, being mostly predators, but scavenging prey items when available. Newly settled lobsters feed on small organisms in the substrate including amphipods, crabs (Carter and Steele 1982), shellfish spat (Wickins 1986) and they may filter feed on plankton (Lavalli and Barshaw 1989). Stomach content work has found that juvenile and adult lobsters prey upon a wide variety of benthic organisms, including gastropods, bivalves (scallops, clams, mussels), chitons, crustaceans (shrimp, crab), starfish and brittle stars, sea urchins, various marine worms (polychaetes) fish, and occasionally plant material (Carter and Steele 1982, Elner and Campbell 1987, Gendron et al. 2001, Hanson 2009, Jones and Shulman 2008, Lawton 1987). Lobsters also catch fast moving animals like shrimp, amphipods and small fish. Lobsters are also opportunistic feeders on fish eggs, discarded lobster shells and dead animals including fish, marine mammals and bait in lobster traps.

Lobsters have a wide range of diet items and are usually considered as generalist predators with population sizes that are not limited by food availability (Childress and Jury 2006, Wahle 2003). However, lobsters do rely heavily on some species that are important for growth and reproduction (Gendron et al. 2001) and the availability of natural prey may limit lobster growth in some areas (Grabowski et al. 2009, 2010).

2.4. REPRODUCTIVE POTENTIAL

The usual reproductive pattern is for the mature female to mate in late summer while in a soft shell condition immediately after moulting. The male transfers a spermatophore into the seminal receptacle at the base of the female's tail. Over the next, year the eggs develop in the female's ovaries and following summer the mature eggs are extruded, fertilized and then attached to the underside of the tail. The eggs are then carried for 10-12 months and hatch the following July or August. Lobsters mature at varying sizes depending upon local water temperatures (Aiken and Waddy 1980, Campbell and Robinson 1983, Aiken and Waddy 1986, Waddy and Aiken 1991, Comeau and Savoie 2002a, Comeau 2003, Waddy and Aiken 2005), maturing at smaller sizes in regions with warm summer temperatures (Gulf of St. Lawrence, southern New England) and at larger sizes in regions with cooler summer temperatures (Bay of Fundy, northeastern Maine).

2.4.1. Size at Onset of Maturity (SOM) Estimates

Maturity estimates for eastern Cape Breton were recently completed (Reeves et al. 2011). The 50% SOM (SOM50) estimates ranged from 71.5 mm CL to 75.8 mm CL and were lowest in the northern most sampling site, closest to the Southern Gulf of St. Lawrence (Dingwall, LFA 27). The estimates of SOM50 were variable across the three sites, across years from 2005 to 2007, and across weeks within years. The results indicate that for accurate estimates of SOM50, there is a need for standardized, replicated seasonal sampling over the period prior to extrusion and hatching.

Maturity estimates for the Scotia-Fundy area are provided below (Figure 2.1); these are currently under evaluation in several areas and the results will be documented elsewhere (A. Silva, unpublished).

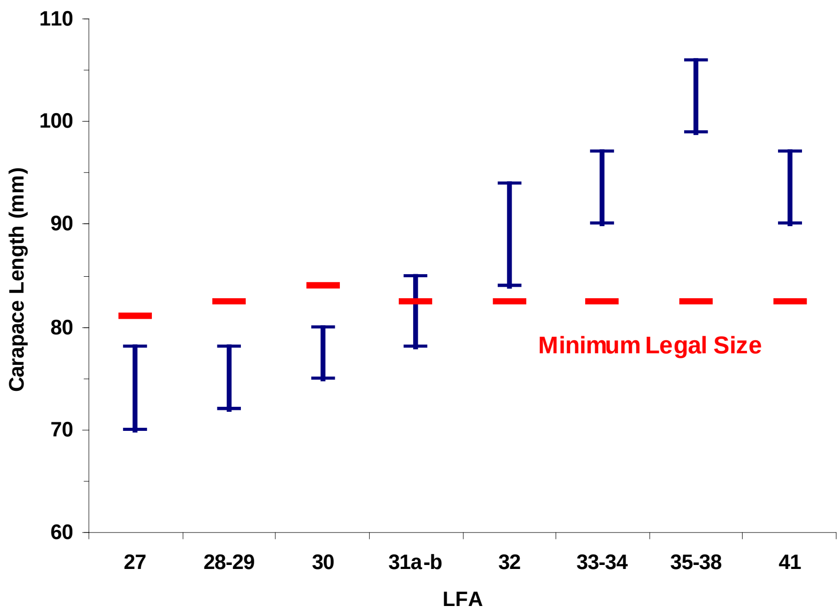


Figure 2.1. Best estimates available in 2009 of size ranges at which 50% of female lobsters have reached onset of maturity (SOM50) by LFA, together with the Minimum Legal Size (MLS). Some of the values were taken from Campbell and Robinson (1983) and Miller and Watson (1991). Estimates by Reeves et al. (2011) for LFAs 27 and 29 are within the above ranges. Estimates for LFAs 33, 34 and 38 are being evaluated (A. Silva, unpublished).

At maturity, lobsters generally produce eggs every second year. Based on laboratory studies using ambient inshore Bay of Fundy water temperatures, female lobsters appear able to spawn twice without an intervening moult (consecutive spawning) at some size greater than 120 mm CL (Waddy and Aiken 1990) though this size may vary in nature (Campbell 1983, Comeau and Savoie 2001, 2002a). Consecutive spawning occurs in two forms: successive-year (spawning in two successive summers, a moult in the first and fourth years) and alternate-year (spawning in alternate summers). In both types, females often are able to fertilize the two successive broods with the sperm from a single insemination (multiple fertilizations). Intermoult mating has also been observed in laboratory conditions (Waddy and Aiken 1990). Consecutive spawning and multiple fertilizations enable large lobsters to spawn more frequently over the long-term than their smaller counterparts. This combined with the logarithmic relationship between body size and numbers of eggs produced means that very large lobsters have a much greater relative fecundity (Campbell and Robinson 1983, Estrella and Cadrin 1995). Protection of large females that are multiple breeders results in increased egg production and a greater diversity of breeders that should lead to more successful egg production under a variety of environmental conditions (DFO 2008b).

A relatively recent concern about the effects of fishing on lobster population biology systems is the possibility of sperm limitation. Density, sex ratio and size structure influence sexual competition and mating success in decapods and lobsters (MacDiarmid and Sainte-Marie 2006, Robertson and Butler 2013). In some situations, reproductive females may go unmated due to an insufficient number of the sufficiently large males. Multiple matings in more highly exploited areas provide evidence for sperm limitation (Gosselin et al. 2005) as does an ongoing study of mating success that is finding smaller mature females that are unmated (no sperm plugs) (J. Gaudette, unpublished).

2.5. DISTRIBUTION

The North American lobster (*Homarus americanus*) is widely distributed in coastal waters from the southern tip of Labrador to Maryland (Figure 2.2), with the major fisheries concentrated in the Gulf of St. Lawrence and the Gulf of Maine.

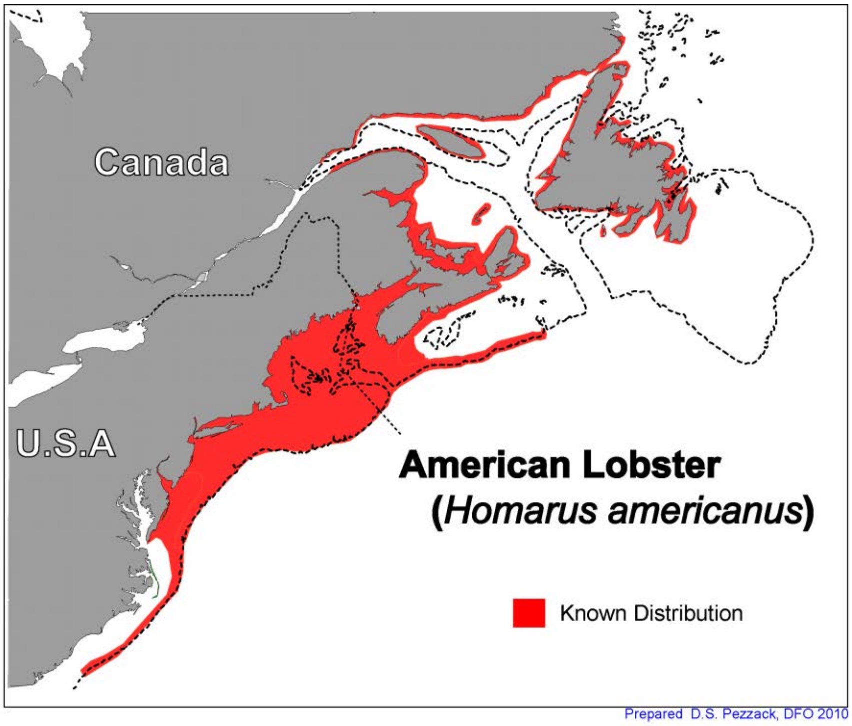


Figure 2.2. Lobster distribution based on known fishing areas and DFO and NMFS bottom trawl surveys.

Lobsters are also found in deeper waters (down to 750 m) in the Gulf of Maine and along the outer edge of the continental shelf from Sable Island to off North Carolina. This deep water distribution is due to the presence of the warm slope water that keeps the slope and deep basins in the Gulf of Maine warm year-round. This warm deep water is not found on the eastern Scotian Shelf, in the Gulf of St Lawrence, or off Newfoundland.

Lobsters are a temperate species that requires sufficiently warm summer temperatures to grow and produce and hatch their eggs. Juvenile and adult lobsters can exist in waters from less than 0°C to approximately 25°C. Larval lobsters occur in surface waters between 6°C and 25°C, though a minimum temperature of approximately 10-12°C appears to be required for successful development to the settlement phase (stage IV). Larval development is temperature dependent and takes just 10 days at 22-24°C, but over 2 months at 10°C.

At the northern limit of their range (northern Newfoundland), summer temperatures remain too cold for ovary and egg development, while at the southern limit of their range (Maryland coastal and off Cape Hatteras along the slope edge) winter temperatures remain too warm and the moulting and reproductive cycles are not coordinated.

Juvenile and adult lobsters can tolerate a wide range of salinities from 15 to 32 ppt (parts per thousand), but can be affected by low salinities associated with spring melts or heavy runoffs in shallow estuaries. Larval lobsters are sensitive to salinities below 20 ppt, and alter their depth by actively swimming to avoid low-salinity surface waters. Moulting lobsters are less resistant to low salinities than are hard-shelled lobsters due to the osmotic permeability of their skeletons.

Lobsters are found on many different bottom types from mud and sand to cobble and boulders (Lawton and Lavalli 1995). Young lobsters require shelter to avoid predators so are more restricted in their habitat than larger lobsters. Newly settled and juvenile lobsters are most common in complex habitats such as cobble or gravel bottoms, or eel grass. They are also capable of burrowing so can also be found in areas with compact clays or peat reefs which can be burrowed into. As they grow and become less susceptible to predators they are found in more varied bottoms including open mud and sand bottoms.

2.6. MIGRATIONS AND DEPTH PREFERENCES

Knowledge of movement of lobsters comes chiefly from tagging studies, but also from observations of changes in seasonal distribution of lobster trap catches. Tagging studies have been restricted mainly to lobsters greater than about 70 mm CL. Adult lobsters make seasonal migrations to shallower waters in summer and deeper waters in winter (Cooper and Uzmann 1971, Cooper et al. 1975, Fogarty et al. 1980, Campbell et al. 1984, Ennis 1984, Campbell and Stasko 1986, Pezzack and Duggan 1986, Estrella and Morrissey 1997, Tremblay et al. 1998, Comeau and Savoie 2002b, Bowlby et al. 2007, Cowan et al. 2007). Migrations may be undertaken to optimize the temperature to which lobsters and their eggs are exposed, to avoid shallow water during stormier winter periods, and to migrate to areas optimal for hatching eggs and either retention or export of larvae. The triggers for these migrations are not well understood.

Mature-sized lobsters on average move significantly greater distances then immature-sized animals (Campbell 1986, Campbell and Stasko 1986). Over most of their range, these movements vary from a few kilometres to 20 km. However, in the Gulf of Maine and on the outer continental shelf, some lobsters undertake long distance migrations of tens to hundreds of kilometres. Tagging studies have shown that at least some of these lobsters exhibit “homing” behavior by returning to the same area each year (Campbell 1986, Pezzack and Duggan 1986). Tagging within the Bay of Fundy indicates potential for movement throughout the Bay (Robichaud and Lawton 1997).

In general, lobsters appear to move less in eastern Nova Scotia than in the Gulf of Maine. On the outer coast of Nova Scotia, lobsters with Sphyrion tags were released at one location in both 1978 and 1979 and at seven locations in 1982. Among 698 lobsters recaptured in this study after 1-6 years at liberty, only 3 were recovered greater than 12 km from their release point. Other published reports representing many areas in Atlantic Canada and Maine that recruit sized lobsters are usually recovered within less than 12 km of release sites (Miller et al. 1989). Off northeastern Cape Breton, a total of 3,684 lobsters were tagged between 1993 and 1995 (Tremblay et al. 1998). Greater than 80% of lobsters were recaptured less than 6 km from their release site after 1-2 seasons at large.

Quantitative estimates of exchange rates between areas would improve our understanding of stock relationships but such estimates are a challenge. The mark-recapture approach used in historical studies does not permit discrimination between non migrants and return migrants after lengthy periods at large, except where intervening recaptures of the same individual lobster are involved. The origin of the animals that are tagged in any one location is unknown. Determining the proportion of animals in the population that make long distance movements is confounded by regional differences in the reporting rate of recaptures, and the fact that where local fisheries are intense, there is a low probability that legal-sized animals survive to move long distances. The closed season in inshore fisheries also poses a problem in that summer movements would not have been detected in these earlier studies.

2.7. NATURAL MORTALITY

2.7.1. Estimates of Annual Mortality

Natural mortality (M) has been estimated for some nearshore populations and is generally assumed to be between 10-15% for legal-sized lobsters, and constant over the legal size range and over time (Fogarty and Idoine 1988, Gendron and Gagnon 2001, Idoine et al. 2001, Gendron 2005). In reality, natural mortality likely varies greatly depending upon habitat, predator abundance, and lobster size. A constant M is usually chosen using life history criteria such as longevity, growth rate, and age at maturity. American lobsters have a relatively long life span and slow reproduction and are thus classified by biologists as "k-selected" with low natural mortality after the larval stage. The uncertainty around lobster natural mortality is in part due to the lack of an accurate ageing method.

2.7.2. Lobster Predators

Larval lobsters are likely preyed upon by larger zooplankton, jellyfish and ctenophores, and fish, including mackerel and herring (Ennis 1995). During the transition from the neuston to benthos the postlarval lobsters are exposed to a large number of predators as they descend to the bottom and seek shelter. These would include small visual predators such as shrimp, crabs, cunners, and sculpins, and passive predators such as sea anemones. During their first three to four years, lobsters remain in or near their chosen shelter to avoid predation from small fish and crabs (Lavalli and Lawton 1996, Palma et al. 1998) such as sculpin, cunners and skate, and by crabs and other opportunistic feeders. As the lobster increases in size, the suite of predators changes and larger lobsters are safer from all but the largest predators.

Predation rates are highly size-specific (Wahle 1992) with predation rates declining with body size (Steneck 1997, Wahle and Steneck 1992). This is particularly true in the present regime where large predator species have been reduced by commercial fishing leaving the smaller non-commercial species such as cunners and sculpins as the most abundant predators (Butler et al. 2006).

Known and suspected predators include (L - larval stage; J - Juveniles, R - newly recruited legal sizes; M - larger mature sizes):

- Cunners - L/J (Barshaw et al. 1994, Barshaw and Lavalli 1988, Hanson and Lanteigne 2000)
- Sculpins - J/R (Hanson and Lanteigne 2000, van der Meeren 2000)
- Skates - J/R (Hanson and Lanteigne 2000, Templeman 1982)
- Cod - J/R/M (Davis et al. 2004, Hanson and Lanteigne 2000, Herrick 1911, Sherwood and Grabowski 2010, van der Meeren 2000)
- Spiny Dogfish - J/R/M (Davis et al. 2004, Hanson and Lanteigne 2000, van der Meeren 2000)
- Sea Ravens - J/R/M (Cooper 1977, Cooper and Uzmann 1980)
- Wolffish - J/R/M (Nelson and Ross 1992)
- Cancer Crabs - J (van der Meeren 2000)
- Striped Bass - J/R/M (Nelson et al. 2003, Nelson et al. 2006)

The Maritimes Region Science Branch has done stomach content analyses for a portion of the fish captured in the research vessel trawl surveys and the following data come from this source (A. Cook, DFO Science Branch, unpublished data). Lobsters have only rarely been observed in the stomachs. The consumed lobsters are identifiable for up to several days post consumption, depending on predator species, water temperature, size and stage of molt. For the summer surveys from 1999-2009, lobsters were in fish stomachs as follows (A. Cook, unpublished data):

Fish species	NAFO Division	No. of stomachs examined	No. of stomachs with lobster	Percentage
Haddock	4X	16553	8	0.05%
Longhorn sculpin	4X	576	3	0.52%
Cod	4X	6760	2	0.03%
White hake	4X	1913	2	0.10%
Dogfish	4X	1198	2	0.17%
Red hake	4X	718	1	0.14%
Atlantic wolffish	4X	162	1	0.62%
Barndoor skate	4X	117	1	0.85%

The mean CL for the consumed lobsters was 4.4 cm with a range of 1 - 8.4 cm. It is important to remember that these came from the offshore areas where predator communities and size composition differ from the nearshore. Also they came only from the July and August time period.

2.7.3. Shell Disease

Shell disease has been a significant source of mortality in southern New England (Castro and Somers 2012, Gomez-Chiarri and Cobb 2012). There the prevalence has been highest in the south, in Long Island Sound. There shell disease levels have been elevated since 1999, reaching 35% in 2002. In 2009, prevalence was 22% (Castro and Somers 2012). Incidence in Maine has been substantially lower. Shell disease was noted for the first time in Maine in 2003. From 2005 to 2010, prevalence was 0.02-0.11%; a high of 0.2% was reached in 2011 (Castro and Somers 2012). In Atlantic Canada, shell disease in wild populations has not been systematically documented, but to date has been rare in the Canadian Gulf of Maine based on tens of thousands of lobsters measured dockside and at-sea.

3. STOCK STRUCTURE AND ASSESSMENT UNITS

3.1. DEFINITIONS

Stocks and populations are terms that fishery biologists use frequently, but they are not always defined and rarely quantified. Some have proposed limiting the term stock to denote the unit of commercially fished animals in a particular geographic area without any implication of biological meaning, e.g. the LFA 34 lobster stock. However, most fisheries biologists use the term "stock" as synonymous with "population" (Jennings et al. 2001) or with the related terms of "sub-population" and "meta-population" (Waldman 2005). In general, there is an intuitive understanding that a stock in the fisheries sense is group of fish or invertebrates of the same species that have some degree of cohesion and can be distinguished from adjacent groups. Waldman (2005) suggested using the term "harvest stock" when referring to a group of fish defined only by the fishery and reserving the term "unit stock" or just stock for the term that implies a cohesive group of fish.

The concepts of stocks and populations have evolved over the last century and have been reviewed extensively (e.g. Berst and Simon 1981 and references therein, McQuinn 1997, Booke 1999, Waldman 2005, Waples and Gaggiotti 2006, NMFS 2008). Waples and Gaggiotti, for example, list 18 population definitions extracted from the literature and grouped them into four paradigms: Ecological, Evolutionary, Statistical, and Variations. Under the ecological paradigm, demographic cohesion is emphasized; under the evolutionary paradigm, genetic cohesion is most important. A related and relatively new term is that of evolutionarily significant unit (ESU), which emerged in the species conservation literature (Ryder 1986) and also has had multiple interpretations (Fraser and Bernatchez 2001). With regard to the terms stock and population, if there is a consensus, it is that there is no single best definition for either term and that definitions should be tailored to the objective.

Some important concepts related to whatever definition is used are the scales of intraspecific variation and the degree of connectivity. Differentiation within a species occurs at a wide range of scales from subspecies right down to brood. Figure 3.1 illustrates this range of scales.

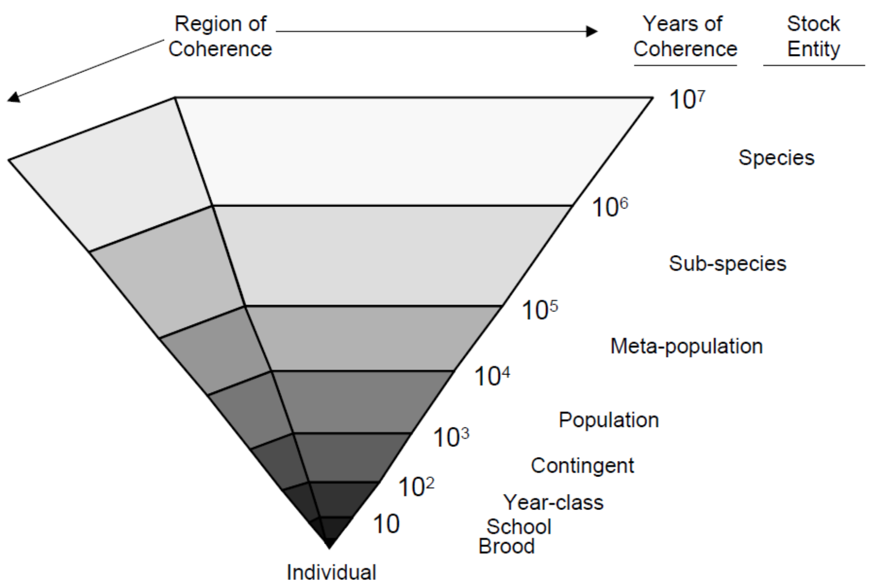


Figure 3.1 Temporal and spatial domains and levels of biological organization relevant to the unit stock. From NMFS (2008) after Secor (2005).

Figure 3.2 shows the varying degree to which subpopulations might interact:

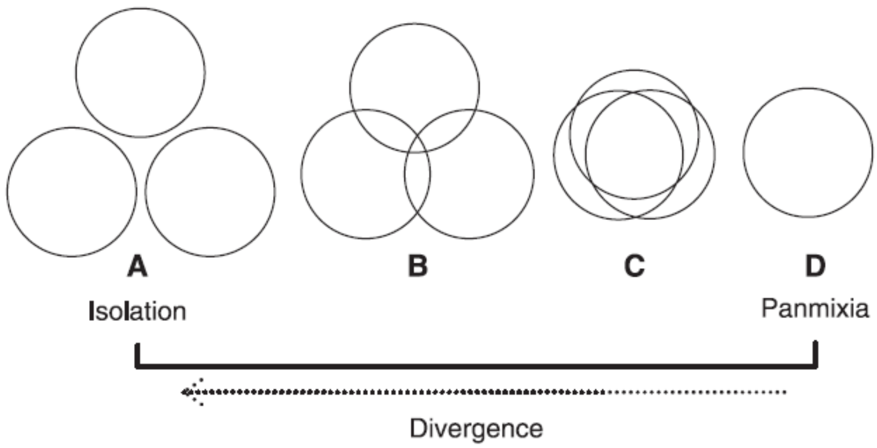


Figure 3.2 The continuum of population differentiation. Each group of circles represents a group of subpopulations with varying degrees of connectivity (geographical overlap and/or migration). (A) Complete independence. (B) Modest connectivity. (C) Substantial connectivity. (D) Panmixia; 'subpopulations' are completely congruent. From Waples and Gaggiotti (2006).

For the purposes of the current document the following definition from Ihssen et al. (1981) is used:

> "… we define a stock as an intraspecific group of randomly mating individuals with temporal or spatial integrity. This definition characterizes an ideal or model stock that is, in practice, only approximated by intraspecific groups of fish that are commonly referred to as stocks. For example, production or management units of fish, differentiated on the basis of population parameters are included as stocks under the definition even though the degree to which the conditions of random mating and temporal and spatial genetic integrity are satisfied is usually unknown…"

This definition incorporates both ecological and evolutionary aspects and, given that population genetic studies of lobster are ongoing, recognizes uncertainty.

Understanding stock structure is important from a management perspective for a variety of reasons:

- To prevent excessive fishing mortality on any one portion of the stock because the rate of replenishment from adjacent stocks is uncertain.
- To devise management measures that are appropriate for any demographic characteristics that are unique to the stock, e.g. size at maturity, growth.
- To devise management measures that are matched to the scale of the response of such measures.
- To conserve genetic diversity if stocks are locally adapted to their environment.

"Assessment units" are defined here as those subdivisions that are sufficiently large that they can be practically assessed, and are cohesive enough that unique management rules make sense, or are deemed important for socio-economic reasons. For reasons related to management and data availability, stocks and assessment units may or may not match up.

3.2. APPLICATION TO LOBSTER IN LFAS 34 TO 38

Studies of American lobster stock structure report some differences among widely separate areas. In LFAs 34 and 38, temporal or spatial integrity can be recognized at some scales, but there is considerable evidence for exchange across LFA boundaries.

The last available research documents for LFAs 35 to 38 considered Bay of Fundy lobsters to be one population and part of the larger Gulf of Maine lobster population which is viewed as a stock complex.

Here is considered the different types of evidence relevant to the issue of stock structure in the Bay of Fundy and the Gulf of Maine.

3.2.1. Morphometric Studies

Some studies of lobster morphometrics have indicated discrimination of [phenotypic] stocks is possible on the basis of morphometrics (Harding et al. 1993, Cadrin 1995). Harding et al. (1993) reported that morphological characteristics of the first larval stage separated the southern Gulf of St. Lawrence (and its outflow around Cape Breton Island) from the large area represented by the Atlantic inshore region of Nova Scotia and the offshore banks bordering the Gulf of Maine. In a study of inshore and offshore lobsters in the Gulf of Maine, Cadrin (1995) demonstrated that males could be distinguished on the basis of relative claw size.

3.2.2. Movement of Adult Lobsters

This topic is reviewed in Section 2.6. To summarize, in the Gulf of Maine and Bay of Fundy, lobsters undertake seasonal movements; a subset of tagged lobsters has undertaken migrations of 10s to 100s of kilometers in distance. There is ample opportunity for movement of adults throughout the Bay Fundy. Some lobsters will also move between the Bay of Fundy and the Gulf of Maine, including the LFA 34 portion.

3.2.3. Genetics

Most studies to date of lobster stock structure using genetic tools have found limited genetic differentiation (Tracey et al. 1975, Harding et al. 1997, Crivello et al. 2005a, Crivello et al. 2005b, Kenchington et al. 2009). An early study of eight populations of lobsters found low levels of genetic variability and that interpopulation differences were small (Tracey et al. 1975). Differentiation between populations supported the suggestion that *H. americanus* is subdivided into a number of more or less geographically isolated inshore and offshore populations, but that these local populations are nonetheless genetically similar. Some non-adjacent areas have been found to be more genetically distant than adjacent areas (e.g. the southern Gulf of St. Lawrence compared with the Gulf of Maine - Harding et al. 1997), but overall the results suggest extensive mixing among areas in the northwest Atlantic.

Recently, Kenchington et al. (2009) used microsatellite DNA markers to examine the large-scale population structure of lobsters throughout eastern North America. This paper documents a north/south separation with a relatively homogenous population to the north (centered in the Gulf of St. Lawrence and extending down the coast of Nova Scotia to Shelburne County west of Halifax) and more heterogeneous populations in the south (centered in the Gulf of Maine and the Mid-Atlantic Bight region). At smaller geographical scales, the analyses identified areas of low gene flow between some areas, which are likely to be shaped by ocean currents and lobster migration patterns. These areas of restricted gene flow were limited to the Gulf of Maine and areas south of it. It should be noted that these areas of lower gene flow were not different from adjacent sites, but from some sites to the north (e.g. some, but not all sites, in Newfoundland, the Gulf of St. Lawrence, or off Cape Breton).

Some more general papers on the connectivity within species with planktonic larvae have reviewed the literature on population genetics and report population structuring. They highlight studies that have examined non-neutral genetic markers and report high levels of structure even in populations thought to be well-mixed. Conover et al. (2006) examined the temporal and spatial scales of adaptive divergence with emphasis on marine species with large, open populations that lack obvious barriers to gene flow. They report that recent studies challenge assumptions of low adaptive variation among these types of species.

> "First, there is strong evidence of geographically structured local adaptation in physiological and morphological traits. Second, the proportion of quantitative trait variation at the among-population level (QST) is much higher than it is for neutral markers (FST) and these two metrics of genetic variation are poorly correlated. Third, evidence that selection is a potent evolutionary force capable of sustaining adaptive divergence on contemporary time scales is summarized. The differing spatial and temporal scales of adaptive v. neutral genetic divergence call for a new paradigm in thinking about the relationship between phenogeography (the geography of phenotypic variation) and phylogeography (the geography of lineages) in marine species."

Hauser and Carvalho (2008) conclude that the notion that genetic and evolutionary processes are only important on a time-scale irrelevant to fisheries management, is no longer tenable: major phenotypic shifts and genetic change may occur in decades. It appears there is still much to be learned about the population genetics of lobsters, and the implications for connectivity.

3.2.4. Biophysical Models of the Drift of Planktonic Larvae

Incze et al. (2010) used a biophysical model to predict the drift of lobster larvae from various source locations in the Gulf of Maine. The spatial pattern of egg production in the Canadian Gulf of Maine and Bay of Fundy was extrapolated from data in coastal Maine on the relationship between depth and egg production. They found that connectivity depended on many factors, including patterns of egg production and transport, and the location and size of the receiving zones.

The Incze et al. (2010) model estimates of self-recruitment were just 1% for the Lower Bay of Fundy, but 39% for Grand Manan Island, and 83% for the Upper Bay of Fundy. LFA 34 includes the zones termed "Digby" and southwest Nova Scotia ("SWNS") by Incze et al. (2010); Digby received 83% of its larvae from SWNS, while SWNS was 100% self-seeding. The latter result is to some extent an artifact since the model did not include potential upstream sources for SWNS. The model used by Incze et al. 2010 indicated that the upper Bay of Fundy, the lower Bay of Fundy, and Grand Manan were not sources of larvae for Digby or SWNS. They also reported that most of the competent post-larvae in a zone originated within one to two zones in the prevailing "up-stream" direction, forming shorter connections along the coast than the energetic currents might otherwise suggest. These findings support the reports of an unexpected structuring in populations with planktonic larvae (Conover et al. 2006, Hauser and Carvalho 2008).

New biophysical models are being applied by the Natural Sciences and Engineering Research Council of Canada (NSERC) Lobster Node to ask the same questions as those posed by Inzce et al. 2010. This project differs in that the model includes all of Altantic Canada, and will have ground-truthed data for spatial patterns of egg production throughout this large region.

3.2.5. Environment and Life History

The Fisheries Resource Conservation Council (FRCC) (1995, 2007) advocated a move towards "Lobster Production Areas" (LPAs) within which conservation strategies could be applied. These LPAs should have similar biological characteristics and environmental characteristics, e.g. bottom temperature, substrate, currents and lobster size at maturity. For example, LPA 5 (Gaspé, Baie des Chaleurs, S. Gulf of St. Lawrence, E. Cape Breton, and Chedabucto Bay) was characterized by warm summer temperatures, bottom temperatures that limit offshore movement, relatively rapid lobster growth and lower sizes at maturity. Within the Scotia-Fundy area, FRCC recognized two other LPAs: LPA 6 from Canso to Yarmouth in LFA 34, and LPA 7 for the Canadian Gulf of Maine (most of LFA 34) and the Bay of Fundy. LPA 7 was characterized by relatively cold water, but with some relatively warm offshore temperatures permitting the existence of offshore and midshore lobster populations and movement of adult lobsters over relatively long distances in the area. Lobster growth was characterized as relatively slow and sizes of maturity large.

The LPAs can be thought of as “phenotypic stocks”. Although they were never formally adopted, they provided a useful classification of lobster populations in Atlantic Canada.

3.2.6. Temporal Patterns in Production

Another characteristic that can be examined to indicate stock structure is the patterns in annual lobster landings. If different areas have the same patterns, it may be that they are responding in the same way to environment and/or fishing pressure.

In the 1980s and early 1990s, there were several papers that used lobster landings trends to identify lobster “stocks” or identify linkages among areas (Campbell and Mohn 1983, Harding et al. 1983, Pezzack 1992, Hudon 1994). The most recent of these uses landings data only up until 1991. These analyses are predicated on the assumption that landings bear some relationship with abundance. Three stock areas can be recognized based on the earlier papers: northeastern Cape Breton (LFA 27); southeast Cape Breton and eastern shore (LFAs 29-32) and south shore (LFA 33). LFA 28 (Bras d’Or Lake) was not part of these analyses as historically landings were not kept separate for this LFA.

Potential stock assessment units were evaluated based on landings trends in statistical districts (the smallest geographic units with landings) from 1947-2009 in Tremblay et al. 2011 (Figure 3.3). The results support some of the earlier papers in identifying 3 major groups and several subgroups. The 3 major groups were (i) Cape Breton, the south shore of Nova Scotia and much of SWNS, (ii) eastern Cape Breton and the eastern shore of Nova Scotia, and (iii) the Bay of Fundy.

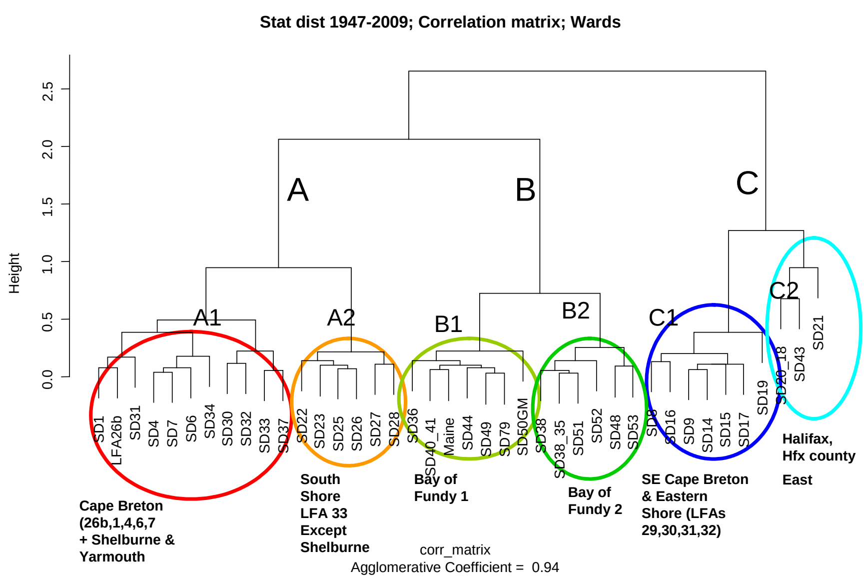


Figure 3.3 Results of cluster analysis of statistical district landings data, 1947-2009.

3.3. CONCLUSION REGARDING STOCK STRUCTURE AND ASSESSMENT UNITS FOR LFAS 34-38

It is important to note that the picture of lobster stock structure in Atlantic Canada is currently being evaluated through a variety of approaches. The Lobster Node of the Canadian Fisheries Research Network is using genetic tools, as well as biophysical models of larval drift to examine connectivity. While there may not be substantial changes to the current perspective of stock structure, more will be learned about levels of differentiation at different scales, and there will be a strong test of the findings from previous studies on larval exchange rates.

Based on what is available now, and the definition of stocks as identifiable based on some degree of spatial and temporal integrity, it is concluded that two stocks and two assessment units are appropriate for assessing LFAs 34, 35, 36, and 38. The bulk of studies indicate that there is exchange among the Bay of Fundy LFAs at various life history stages and that the landings in the different LFAs have trended in a similar manner. As such LFAs 35-38 will be considered as one assessment unit. As the fishery-dependent data on catch rate are not readily combined because of different seasons, there will continue to be reporting of some data on an LFA basis (“assessment subunits”). Indicators from these subunits will be considered as secondary.

There is some exchange of lobsters at the benthic stage between LFA 34 and the Bay of Fundy, but LFA 34 is large, has some genetic structure, and appears to receive a limited portion of its larvae from the Bay of Fundy. In addition, LFA 34 landings trends have differed from those of the Bay of Fundy. As such, LFA 34 will be considered a stock and an assessment unit for our purposes. Subunits of LFA 34 based on different patterns in size and catch rate (Pezzack et al. 2006) will be referred to as appropriate.

Some of the available assessment data are best tabled on a Gulf of Maine-Bay of Fundy basis. For example, the summer trawl survey data are spatially extensive but relatively low density. These data are highly variable across years and, where appropriate, the data are aggregated across the assessment units to obtain the best representation of annual trends. This has the advantage of recognizing the potential linkages between LFA 34 and LFAs 35-38. By tracking metrics at various scales (subunit, stock or assessment unit, and stock complex) changes to stock health within LFAs 34-38 are more likely to be captured.

4. DATA DESCRIPTION

A note on terminology related to fishing seasons is in order. Data are tabulated by fishing season (see Table 1.1 for dates) or by calendar year (e.g. older landings data). All table and figure captions specify how the data were aggregated. Sometimes it is necessary or efficient to reference fishing seasons by a single year. The second year of the fall/winter/spring fishing seasons is used (e.g. 2012 for 2011-12 fishing season), which is most appropriate when comparing landings from these fisheries with landings from spring fisheries (all LFAs east of Halifax).

Sometimes the fall, winter and spring portions of a given fishing season are referenced in regard to data on catch rate and from port samples.

4.1. LANDINGS DATA

The landings data presented here differ slightly from those presented in Tremblay et al. (2012b). The changes result from a systematic review of the original data sources, as described below. Considering the fishing seasons from 1984-85 to 2008-09 for LFAs 34-38, the individual season changes averaged just 0.4% but were as high as 8.7% (LFA 35 in 1994-95).

The LFA 34-38 landings data reported here were derived from multiple sources:

- 1893-1974 – Williamson, 1992
- 1975-1996 – Legacy Data Oracle Tables
- 1997-2001 - Zonal Interchange File Format (ZIFF) Oracle Tables
- 2002-present – Maritime Fishery Information System (MARFIS) Oracle Tables

How the data were originally tabulated has changed over the years. From 1892 to 1946, landings were tabulated by calendar year and county. From 1947 to 1996, landings were tabulated by Statistical District (Figure 4.1). Only in 1975 were landings available both on the basis of calendar year and fishing season (which spans two calendar years). The mandatory catch reporting system changed in 1995 from a system based on dealer sales slips to one based on individual fishermen sending in monthly catch settlement reports. The catch settlement report provided information on daily catch by port and date of landing (Figure 4.2). Thus, landings data were reported by LFA or Statistical District. In November 1998, as part of a lobster conservation plan, LFA 34 fishermen adopted an expanded catch settlement reporting system, called the Lobster Catch and Settlement Report (Figure 4.3) which required them to provide estimates of daily catch and effort by reference to a 10 minute x 10 minute grid system (Figure 4.4). The actual weight of lobsters landed is reported on the weighout slip portion of these logs. The grid-referenced catch and effort on these logs provided the first picture of landings and effort distribution on the LFA 34 fishing grounds. This system was later implemented in LFAs 35-38 and was in full use by 2005.

For this assessment, all landings data prior to 1975 were obtained from a manuscript report (Williamson 1992). The data from 1975 to 1996 were obtained from Legacy Data Oracle tables by port and Lobster District. Data from 1997-2001 was obtained from the ZIFF (Zonal Interchange File Format) weighout slip and estimate Oracle tables by Lobster District. Data from 2002 to present was accessed from the current DFO MARFIS (Maritime Fishery Information System) Oracle database.

Changes in reporting systems in 1996 and 1998-2005 may influence accuracy and completeness of landings. Landings prior to 1996, based on sales slips, may have missed a portion of the catch sold directly to consumers or sold directly in the USA. The size of the underestimate is not known. Post 1996 landings, reported by fishermen directly, should be more complete; however, no analysis has been done to determine completeness or accuracy of reports. Thus, changes observed since 1996 must be viewed in light of the change in reporting methods.

Removals of lobster by means other than the commercial fishery are partially documented or undocumented, but are thought to be low relative to the commercial fishery. The reported landings by the commercial fishery in LFAs 34-38 in 2011-12 totalled over 31,000 t as the result of some 20 million trap hauls. DFO receives some reports from First Nations on the removals for purposes of Food, Social and Ceremonial (FSC) from LFAs 34-38; the total removed is not known but given the effort deployed, would reach a maximum of 0.1 to 0.5% of the commercial landings in recent years. Removals by illegal means (e.g. poaching) cannot be estimated here, but are thought to be low relative to the commercial fishery given the number of commercial trap hauls. Removals of lobsters outside of the commercial fishery are not considered further in this document.

4.1.1. Weighout Slip Landings versus Log Landings

With the Lobster Catch and Settlement Report, the most accurate landings data for an entire LFA are from the weighout slip portion. The weighout slip weight is the actual weight of lobster sold. This can provide landings only on a fishing season and LFA basis due to the uncertainty in the timing of when the lobster is landed versus when it is sold. As well, the only geographical information provided with a sale is the port landed.

When summarizing or analyzing landings on any finer temporal and spatial scale, the log portion of the report is used. The log includes a daily estimate of catch and effort by fishing location (a series of ten minute grid squares).

A comparison of the total weight sold versus a total of the estimates of weight found that these two measures were close, and usually differed by less than 5% per season for LFAs 34-38.

For LFA 34, the 10-minute grids were grouped into a total of 9 Grid Groups, as in Pezzack et al. (2006) (Figure 4.5). Nearshore, midshore and offshore areas were identified based on depth of water and distance from shore. These were further divided into northern and southern components. Additional subdivisions (A and B) of Grid Groups 2 and 4 were based on known size differences and the history of fishery. For some analyses, these subgroups are combined. For LFAs 35, 36, and 38, the grids were aggregated into 7 Grid Groups as in Robichaud and Pezzack (2007) (Figure 4.6).

4.1.2. Reporting Levels

In general, the reporting levels have improved over time, with most measures indicating levels of reporting on the order of 70-90% or more. Estimates of reporting levels were completed on the previous self-reporting system and the currently used Lobster Catch and Settlement Reports for 1998 to the end of the 2011-12 for LFA 34, and for the period 2002 to the end of the 2011-12 for LFAs 35-38 (Table 4.1). The percentage of licence holders reporting was calculated by counting the number of licence holders reporting per month and dividing that by the total number of licences in that LFA. Even if a licence holder only reported once within a month (one day fished), it was counted as a reporting licence for that month. The licence numbers used for this were: 980 for LFA 34, 97 for LFA 35, 177 for LFA 36, and 136 for LFA 38.

To estimate reporting levels of effort, the percentage of logs jointly reporting trap hauls and landings information was calculated (Table 4.2). This was done by dividing the total number of records reporting weight and effort by the total number of records reporting a weight. This excludes records with no weight and no trap hauls, which is valid for a month where there was no fishing activity by a licence holder.

In LFAs 35-38, the percentage of licence holders reporting effort increased significantly between 2004 and 2005, reflecting the phasing in of the current logbook system which requires the reporting of effort.

To estimate the levels and accuracy of grid location reporting, the total number of records reporting weight and a valid grid number was divided by the total number of records reporting a weight (Table 4.3). A valid grid number is one which is within that licence holder's LFA according to the grid map provided with the Lobster Catch and Settlement Report. Again, only the records with a weight reported were used as the denominator to exclude nil fishing activities.

4.2. AT-SEA SAMPLES OF THE COMMERCIAL CATCH

At-sea samples (or "sea samples") collect information from fishermen's catch during normal commercial fishing operations. The data collected includes: CL measured to the nearest millimetre (from the back of eye socket to the end of the carapace), sex, egg presence and stage, shell hardness, occurrence of culls and v-notches, and number, location and depth of traps. Since 1988, all data is geo-referenced with latitude and longitude.

Sea sampling provides detailed information on lobster size-structure in the traps (including sublegal, berried, and soft-shelled lobsters). As all lobsters retained in each trap haul are measured, the numbers caught can be converted into estimates of the catch rate of legal-sized animals by weight from known length-weight relationships.

Sea sample data resides in the CRIS (Crustacean Research information System) database and the ISDB (Industry Survey Database). Sea samples in these databases fall within the following time periods (Figure 4.7) and locations (Figure 4.8):

- LFA 34 – 1981 to 2012 (15 tagging trips prior to this)
- LFA 35 – 1977 to 2012
- LFA 36 – 1978 to 2010
- LFA 38 – 1976 to 2010

In 2008, a *Species at Risk Act (SARA)* initiative began to collect bycatch data from lobster fishing activities. During these sampling trips, all bycatch was evaluated. In addition, all lobsters and crabs were measured and sampled. The *SARA* data was entered into the ISDB which is a Department of Fisheries and Oceans database that includes at-sea catch observations from commercial fishing vessels. Queries on the ISDB tables were developed to produce outputs similar to that from the CRIS database allowing integration of the two datasets. During 2008-2010, approximately 300 *SARA* samples were completed in the LFA 34 lobster fishery.

No *SARA* sampling was completed in LFAs 35, 36 or 38, but there is additional bycatch data available from all LFAs from observers trips conducted for other purposes (e.g. trap tag replacements). This data is available at the catch summary level (estimated weights by species and set), but not at the individual fish level.

The at-sea data set used in this assessment includes only targeted lobster trips.

4.3. PORT SAMPLING OF THE COMMERCIAL CATCH

During port sampling, a fisherman's landed catch is measured (carapace length), and sexed. On average, each sample includes up to 6 crates of lobster, or the fisherman's catch for the day. This information is captured on a voice recorded and later transcribed onto paper for data entry into the Lobster Fishery Catch and Length Composition database. The CRIS database cannot be used since the data are not collected on a per trap basis. In the past, location of the port samples was available only at the level or port landed. However, in more recent years, whenever possible the fishing grid from the Lobster Catch and Settlement Report is associated with the sample. A summary of the numbers of port samples completed by year in LFA 34 is available in Table 4.4. Typically these samples were taken in both the fall and spring portions of the fishing seasons.

4.4. FSRS RECRUITMENT TRAPS

The FSRS recruitment trap project involves volunteer fishermen keeping track of the lobsters caught in project traps (Claytor and Allard 2003). Fishermen participants use standard traps and a standard gauge to assign each lobster captured to a size group. Participants in the project are distributed along the Atlantic coast of Nova Scotia (Figure 4.9). The number of participants in LFAs 34 was 3 in 1998-99, but increased steadily to 49 in 2005-06. The number of participants was 25 in 2011-12 (Table 4.5). The number of participants in LFA 35 was 6 in 2006-07, and 13 in 2011-12.

Participants record size, sex and presence of external eggs for all lobsters collected in standard traps on each day of commercial fishing. Soak times were usually one day except during the winter period. Compared with commercial traps, the FSRS wire traps have features that lead to greater retention of prerecruit lobsters: smaller mesh size (2.5 cm), smaller entrance rings (12.5 cm), and no slots to allow sublegal-sized lobsters to escape. As such, the FSRS traps provide a better indication of the abundance of prerecruit lobsters than commercial traps. Since the traps are the same throughout the study area, they allow for a better comparison between areas that may have several different designs of commercial traps. Lobster measurements were made with an FSRS gauge that facilitates data collection in the field by fishermen.

Fishermen were asked to set the traps in one location throughout the season. Most were able to comply, but as commercial traps in some fishing areas are moved substantial distances over the course of the season, sometimes standard traps were moved as well so that fishermen did not have to travel as far to service the standard traps. In these instances, fishermen noted the location changes and these were later recorded in the database. The standard traps were equipped with temperature recorders that provided data on nearshore bottom temperatures (Tremblay et al. 2007).

Size groups (as of fall 2003) are listed below:

Size 1 (less than 11 mm)
Size 2 (11 mm – 20.9 mm)
Size 3 (21 mm – 30.9 mm)
Size 4 (31 mm – 40.9 mm)
Size 5 (41 mm – 50.9 mm)
Size 6 (51 mm – 60.9 mm)
Size 7 (61 mm – 70.9 mm)
Size 8 (71 mm – 75.9 mm)
Size 9 (76 mm – 80.9 mm)
Size 10 (81 mm – 90.9 mm)
Size 11 (91 mm – 100.9 mm)
Size 12 (101 mm – 110.9 mm)
Size 13 (111 mm – 120.9 mm)
Size 14 (121 mm – 130.9 mm)
Size 15 (greater than 131 mm)

Size groups 8 and 9 are in 5 mm increments to give a clear indication of the number of lobsters just under the legal size limit. As the legal sizes in within the above size classes, fishermen also recorded whether or not the lobster was legal-sized.

Prior to 2003, the size groups ran from size 1 (less than 51 mm) to size 8 (101 mm and greater). Fishermen participants use standard traps and a standard gauge to assign each lobster captured to a size group.

Size groups are listed below:

Size 1 (less than 51 mm)
Size 2 (51 mm – 60.9 mm)
Size 3 (61 mm – 70.9 mm)
Size 4 (71 mm – 75.9 mm)
Size 4.1 (sublegal lobsters 71 mm – 75.9 mm)
Size 4.0 (legal lobsters 71 mm – 75.9 mm)
Size 5 (76 mm – 80.9 mm)
Size 6 (81 mm – 90.9 mm)
Size 6.1 (sublegal lobsters 81 – 90.9 mm)
Size 6.0 (legal lobsters 81-90.9 mm)
Size 7 (91 mm – 100.9 mm)
Size 8 (101 mm and greater)

4.5. OTHER DATA SOURCES – FISHERY INDEPENDENT

Fishery independent data sources are available and are accessed from reports prepared for the 2013 lobster assessment (Pezzack, unpublished). Fishery independent data sources for LFAs 34-38 include surveys directed at other species that routinely sample lobsters in addition to the targeted species. These include (i) DFOs ecosystem trawl survey, completed annually in summer since 1970; (ii) an industry trawl survey (the ITQ survey) designed to obtain information on the groundfish abundance, completed annually since 1996; and (iii) annual surveys for scallops that use scallop drags.

Data have been collected on the numbers of newly settled lobsters ("young-of-the-year") in the Bay of Fundy for over 20 years. In coastal Nova Scotia, the time series is shorter (4-7 years depending on area (Tremblay et al. 2012a, Wahle et al. 2013).

Table 4.1. Number of licences reporting and the percentage of the total number of licences reporting by LFA, year, and month. Year refers to the second year of the fall-winter-spring fishing season.

LFA 34

YEAR	JAN		FEB		MAR		APR		MAY		NOV		DEC	
	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%
1998											5	1%	925	94%
1999	848	87%	617	63%	828	84%	923	94%	924	94%	845	86%	936	96%
2000	864	88%	659	67%	853	87%	925	94%	917	94%	930	95%	947	97%
2001	898	92%	678	69%	860	88%	940	96%	929	95%	928	95%	925	94%
2002	898	92%	824	84%	879	90%	880	90%	866	88%	913	93%	911	93%
2003	896	91%	846	86%	887	91%	896	91%	896	91%	906	92%	906	92%
2004	896	91%	830	85%	892	91%	912	93%	913	93%	126	13%	952	97%
2005	946	97%	889	91%	949	97%	951	97%	944	96%	961	98%	954	97%
2006	937	96%	876	89%	931	95%	936	96%	924	94%	923	94%	920	94%
2007	905	92%	810	83%	872	89%	897	92%	896	91%	960	98%	959	98%
2008	956	98%	886	90%	951	97%	961	98%	958	98%	970	99%	969	99%
2009	950	97%	871	89%	960	98%	963	98%	953	97%	400	41%	965	98%
2010	954	97%	841	86%	918	94%	954	97%	952	97%	943	96%	947	97%
2011	944	96%	858	88%	918	94%	938	96%	933	95%	937	96%	940	96%
2012	925	94%	852	87%	921	94%	918	94%	913	93%				

LFA 35

YEAR	MAR		APR		MAY		JUN		JUL		OCT		NOV		DEC	
	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%
2002	75	77%	83	86%	87	90%	87	90%	88	91%	84	87%	79	81%	67	69%
2003	64	66%	66	68%	79	81%	82	85%	84	87%	83	86%	80	82%	66	68%
2004	58	60%	62	64%	77	79%	82	85%	83	86%	77	79%	78	80%	62	64%
2005	66	68%	72	74%	76	78%	87	90%	87	90%	88	91%	89	92%	76	78%
2006	71	73%	73	75%	75	77%	86	89%	86	89%	82	85%	83	86%	64	66%
2007	55	57%	61	63%	66	68%	70	72%	69	71%	93	96%	93	96%	72	74%
2008	64	66%	70	72%	76	78%	93	96%	94	97%	91	94%	91	94%	72	74%
2009	58	60%	71	73%	79	81%	93	96%	93	96%	94	97%	91	94%	70	72%
2010	66	68%	68	70%	72	74%	92	95%	93	96%	92	95%	91	94%	68	70%
2011	65	67%	69	71%	72	74%	92	95%	93	96%	93	96%	92	95%	72	74%
2012	69	71%	72	74%	78	80%	90	93%	90	93%						

Table 4.1. Continued.

LFA 36

YEAR	JAN		APR		MAY		JUN		NOV		DEC	
	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%
2002	124	70%	109	62%	124	70%	124	70%	135	76%	134	76%
2003	112	63%	98	55%	118	67%	117	66%	118	67%	115	65%
2004	100	56%	89	50%	109	62%	111	63%	110	62%	112	63%
2005	132	75%	138	78%	137	77%	141	80%	140	79%	140	79%
2006	137	77%	136	77%	136	77%	137	77%	143	81%	139	79%
2007	118	67%	116	66%	123	69%	123	69%	162	92%	158	89%
2008	158	89%	158	89%	162	92%	160	90%	163	92%	162	92%
2009	158	89%	161	91%	163	92%	159	90%	161	91%	160	90%
2010	161	91%	147	83%	159	90%	160	90%	164	93%	163	92%
2011	161	91%	161	91%	161	91%	162	92%	160	90%	161	91%
2012	160	90%	157	89%	159	90%	163	92%				

LFA 38

YEAR	JAN		FEB		MAR		APR		MAY		JUN		NOV		DEC	
	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%	# of licences reporting	%
2002	83	61%	74	54%	74	54%	73	54%	75	55%	74	54%	77	57%	76	56%
2003	70	51%	64	47%	59	43%	60	44%	66	49%	64	47%	71	52%	68	50%
2004	65	48%	63	46%	58	43%	63	46%	68	50%	68	50%	68	50%	64	47%
2005	90	66%	89	65%	87	64%	92	68%	94	69%	91	67%	103	76%	103	76%
2006	99	73%	89	65%	88	65%	97	71%	101	74%	100	74%	89	65%	88	65%
2007	75	55%	72	53%	74	54%	76	56%	79	58%	77	57%	117	86%	117	86%
2008	117	86%	114	84%	114	84%	116	85%	116	85%	120	88%	118	87%	118	87%
2009	118	87%	116	85%	117	86%	116	85%	115	85%	113	83%	111	82%	110	81%
2010	110	81%	108	79%	109	80%	109	80%	110	81%	109	80%	108	79%	108	79%
2011	105	77%	104	76%	104	78%	104	76%	104	76%	104	76%	105	77%	105	77%
2012	105	77%	105	77%	105	76%	106	78%	104	76%	108	79%	-	-	-	-

Table 4.2. Numbers of Lobster Catch and Settlement Reports with a reported weight, a reported weight and effort (TH), and the percentage of records with effort by LFA, year, and month. Year refers to the second year of the fall-winter-spring fishing season.

LFA 34

YEAR	JAN			FEB			MAR			APR			MAY			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%
1998																30	24	80%	17,068	15,724	92%
1999	4,690	4,177	89%	3,802	3,422	90%	6,392	5,784	90%	15,582	14,087	90%	17,562	15,744	90%	885	821	93%	14,615	13,428	92%
2000	3,506	3,166	90%	2,604	2,324	89%	9,212	8,170	89%	12,318	10,730	87%	17,011	15,014	88%	2,730	2,540	93%	12,268	11,353	93%
2001	6,827	6,386	94%	2,061	1,863	90%	6,428	5,847	91%	15,865	14,394	91%	19,705	17,841	91%	3,643	3,364	92%	14,348	13,377	93%
2002	5,371	4,963	92%	2,317	2,155	93%	6,531	5,964	91%	13,939	12,722	91%	16,198	14,645	90%	3,375	3,134	93%	11,223	10,487	93%
2003	3,967	3,694	93%	1,366	1,259	92%	5,216	4,733	91%	14,689	13,132	89%	19,286	17,183	89%	3,672	3,370	92%	10,905	9,890	91%
2004	3,944	3,528	89%	1,734	1,519	88%	4,834	4,357	90%	12,739	11,368	89%	18,470	16,182	88%	37	35	95%	14,181	13,071	92%
2005	4,816	4,313	90%	1,894	1,699	90%	6,064	5,308	88%	16,394	14,574	89%	17,810	15,719	88%	1,892	1,656	88%	15,462	13,857	90%
2006	5,605	4,954	88%	2,445	2,179	89%	6,849	5,999	88%	12,303	10,640	86%	16,455	14,430	88%	2,700	2,334	86%	15,979	14,134	88%
2007	4,848	4,242	88%	1,355	1,204	89%	2,609	2,281	87%	11,351	9,949	88%	17,652	15,512	88%	966	917	95%	14,164	13,697	97%
2008	6,412	6,200	97%	2,704	2,618	97%	6,517	6,290	97%	13,754	13,134	95%	16,953	16,265	96%	4,274	4,011	94%	11,439	10,995	96%
2009	4,080	3,922	96%	1,697	1,602	94%	7,185	6,784	94%	14,259	13,684	96%	17,754	17,069	96%	9	9	100%	14,972	14,292	95%
2010	5,446	5,232	96%	1,829	1,733	95%	6,344	6,043	95%	15,229	14,678	96%	17,632	16,964	96%	1,272	1,155	91%	14,908	14,200	95%
2011	6,905	6,649	96%	1,830	1,745	95%	4,884	4,648	95%	11,438	10,847	95%	16,005	15,271	95%	1,219	1,063	87%	16,253	15,514	95%
2012	5,447	5,221	96%	2,830	2,720	96%	8,242	7,870	95%	11,189	10,524	94%	14,870	14,067	95%						

LFA 35

YEAR	MAR			APR			MAY			JUN			JUL			OCT			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%
2004	13		0%	100		0%	612		0%	1,116		0%	1,251		0%	955		0%	863		0%	139		0%
2005	1		0%	103	28	27%	611	130	21%	1,249	266	21%	1,320	347	26%	993	459	46%	1,128	780	69%	121	85	70%
2006	14	5	36%	92	55	60%	700	538	77%	1,150	854	74%	1,232	923	75%	867	673	78%	1,059	798	75%	111	80	72%
2007	2	2	100%	59	42	71%	558	454	81%	980	755	77%	1,025	826	81%	1,194	1,159	97%	941	919	98%	106	103	97%
2008				72	69	96%	638	637	100%	1,205	1,193	99%	1,357	1,345	99%	1,102	1,101	100%	936	916	98%	74	72	97%
2009	6	6	100%	63	56	89%	652	646	99%	1,182	1,177	100%	1,378	1,376	100%	1,134	1,094	96%	1,122	1,099	98%	106	106	100%
2010	2	2	100%	104	104	100%	692	673	97%	1,221	1,186	97%	1,413	1,346	95%	1,157	1,117	97%	1,068	1,043	98%	199	187	94%
2011	1		0%	106	101	95%	691	677	98%	1,278	1,246	97%	1,479	1,463	99%	1,188	1,142	96%	1,150	1,123	98%	230	228	99%
2012	4	4	100%	236	228	97%	843	830	98%	1189	1168	98%	1403	1366	97%									

Table 4.2. Continued.

LFA 36

YEAR	JAN			APR			MAY			JUN			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGH T	# RECS WITH WEIGHT & TH	%
2004	91		0%	65		0%	950	4	0%	1,733	6	0%	1,418	31	2%	1,040	36	3%
2005	72	8	11%	102	9	9%	1,116	377	34%	2,138	646	30%	1,707	1,234	72%	1,246	910	73%
2006	88	65	74%	83	57	69%	1,052	802	76%	2,045	1,563	76%	1,303	1,003	77%	1,415	1,057	75%
2007	113	92	81%	64	60	94%	922	680	74%	1,846	1,430	77%	1,554	1,505	97%	1,254	1,172	93%
2008	81	69	85%	103	103	100%	1,247	1,174	94%	2,469	2,312	94%	1,657	1,604	97%	1,040	975	94%
2009	55	54	98%	84	84	100%	1,362	1,338	98%	2,503	2,449	98%	1,997	1,907	95%	1,167	1,123	96%
2010	65	59	91%	138	138	100%	1,402	1,364	97%	2,563	2,472	96%	1,926	1,850	96%	1,435	1,382	96%
2011	89	86	97%	207	200	97%	1,544	1,512	98%	2,605	2,481	95%	2,116	2,031	96%	1,457	1,405	96%
2012	84	78	93%	412	407	99%	1,708	1,657	97%	2,562	2,449	96%	-	-	-	-	-	-

LFA 38

YEAR	JAN			FEB			MAR			APR			MAY			JUN			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & TH	%
2004	271		0%	137		0%	150		0%	427		0%	881		0%	1,160		0%	926	37	4%	688	32	5%
2005	297	83	28%	177	51	29%	146	53	36%	636	159	25%	1,140	404	35%	1,496	566	38%	1,360	986	73%	928	629	68%
2006	312	220	71%	158	102	65%	230	163	71%	549	393	72%	1,215	799	66%	1,484	961	65%	953	655	69%	1,037	694	67%
2007	337	214	64%	105	73	70%	121	91	75%	454	312	69%	1,119	705	63%	1,219	790	65%	1,206	1,174	97%	1,093	1,071	98%
2008	431	406	94%	177	174	98%	189	182	96%	657	627	95%	1,459	1,387	95%	1,800	1,717	95%	1,197	1,153	96%	779	758	97%
2009	263	259	98%	96	87	91%	126	117	93%	618	595	96%	1,392	1,344	97%	1,620	1,558	96%	1,441	1,411	98%	970	952	98%
2010	330	317	96%	101	96	95%	138	137	99%	610	596	98%	1,391	1,368	98%	1,594	1,577	99%	1,279	1,217	95%	926	913	99%
2011	423	406	96%	103	100	97%	125	113	90%	485	455	94%	1,237	1,202	97%	1,542	1,511	98%	1,366	1,245	91%	960	896	93%
2012	333	311	93%	216	206	95%	221	213	96%	665	625	94%	1,299	1,247	96%	1,536	1,451	94%	-	-	-	-	-	-

Table 4.3. Numbers of Lobster Catch and Settlement Reports with a reported weight, a reported weight and valid grid and the percentage of records with valid grid by LFA, year, and month. Year refers to the second year of the fall-winter-spring fishing season.

LFA 34

YEAR	JAN			FEB			MAR			APR			MAY			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%
1998																30	24	80%	17,068	15,074	88%
1999	4,690	4,035	86%	3,802	3,319	87%	6,392	5,577	87%	15,582	13,605	87%	17,562	15,135	86%	885	758	86%	14,615	12,662	87%
2000	3,506	3,035	87%	2,604	2,330	89%	9,212	7,782	84%	12,318	10,530	85%	17,011	14,474	85%	2,730	2,447	90%	12,268	10,853	88%
2001	6,827	6,165	90%	2,061	1,794	87%	6,428	5,698	89%	15,865	14,031	88%	19,705	17,209	87%	3,643	3,332	91%	14,348	12,891	90%
2002	5,371	4,845	90%	2,317	2,121	92%	6,531	5,884	90%	13,939	12,559	90%	16,198	14,464	89%	3,375	3,026	90%	11,223	9,910	88%
2003	3,967	3,537	89%	1,366	1,221	89%	5,216	4,693	90%	14,689	13,082	89%	19,286	16,903	88%	3,672	3,368	92%	10,905	9,932	91%
2004	3,944	3,504	89%	1,734	1,551	89%	4,834	4,369	90%	12,739	11,313	89%	18,470	16,316	88%	37	30	81%	14,181	12,927	91%
2005	4,816	4,291	89%	1,894	1,677	89%	6,064	5,373	89%	16,394	14,655	89%	17,810	15,842	89%	1,892	1,673	88%	15,462	13,798	89%
2006	5,605	4,957	88%	2,445	2,149	88%	6,849	6,142	90%	12,303	11,041	90%	16,455	14,787	90%	2,700	2,376	88%	15,979	14,343	90%
2007	4,848	4,267	88%	1,355	1,183	87%	2,609	2,296	88%	11,351	10,157	89%	17,652	15,692	89%	966	930	96%	14,164	13,644	96%
2008	6,412	6,138	96%	2,704	2,591	96%	6,517	6,202	95%	13,754	13,132	95%	16,953	16,172	95%	4,274	3,965	93%	11,439	10,664	93%
2009	4,080	3,703	91%	1,697	1,508	89%	7,185	6,549	91%	14,259	13,226	93%	17,754	16,489	93%	9	2	22%	14,972	13,650	91%
2010	5,446	4,833	89%	1,829	1,644	90%	6,344	5,669	89%	15,229	13,708	90%	17,632	15,737	89%	1,272	1,109	87%	14,908	13,492	91%
2011	6,905	6,283	91%	1,830	1,627	89%	4,884	4,352	89%	11,438	10,305	90%	16,005	14,303	89%	1,219	1,058	87%	16,253	14,733	91%
2012	5,447	4,964	91%	2,830	2,576	91%	8,242	7,565	92%	11,189	10,066	90%	14,870	13,450	90%	-	-	-	-	-	-

LFA 35

YEAR	MAR			APR			MAY			JUN			JUL			OCT			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%
2004	13		0%	100		0%	612		0%	1,116		0%	1,251		0%	955		0%	863		0%	139		0%
2005	1		0%	103	28	27%	611	130	21%	1,249	266	21%	1,320	385	29%	993	414	42%	1,128	786	70%	121	85	70%
2006	14	2	14%	92	75	82%	700	582	83%	1,150	898	78%	1,232	999	81%	867	725	84%	1,059	885	84%	111	87	78%
2007	2	2	100%	59	48	81%	558	443	79%	980	809	83%	1,025	778	76%	1,194	1,145	96%	941	911	97%	106	93	88%
2008				72	67	93%	638	616	97%	1,205	1,118	93%	1,357	1,238	91%	1,102	1,015	92%	936	840	90%	74	55	74%
2009	6	6	100%	63	63	100%	652	642	98%	1,182	1,127	95%	1,378	1,295	94%	1,134	1,039	92%	1,122	1,019	91%	106	95	90%
2010	2	2	100%	104	99	95%	692	654	95%	1,221	1,145	94%	1,413	1,311	93%	1,157	993	86%	1,068	947	89%	199	174	87%
2011	1	1	100%	106	97	92%	691	647	94%	1,278	1,135	89%	1,479	1,261	85%	1,188	1,046	88%	1,150	1,045	91%	230	210	91%
2012	4	2	50%	236	216	92%	843	743	88%	1,189	1,067	90%	1,403	1,235	88%	-	-	-	-	-	-	-	-	-

Table 4.3. Continued.

LFA 36

YEAR	JAN			APR			MAY			JUN			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%
2004	91		0%	65		0%	950	14	1%	1,733	6	0%	1,418	20	1%	1,040	26	3%
2005	72	8	11%	102	8	8%	1,116	344	31%	2,138	601	28%	1,707	1,237	72%	1,246	923	74%
2006	88	73	83%	83	54	65%	1,052	776	74%	2,045	1,523	74%	1,303	963	74%	1,415	1,064	75%
2007	113	88	78%	64	54	84%	922	656	71%	1,846	1,397	76%	1,554	1,496	96%	1,254	1,184	94%
2008	81	79	98%	103	99	96%	1,247	1,175	94%	2,469	2,359	96%	1,657	1,581	95%	1,040	976	94%
2009	55	49	89%	84	84	100%	1,362	1,297	95%	2,503	2,376	95%	1,997	1,875	94%	1,167	1,091	93%
2010	65	60	92%	138	138	100%	1,402	1,307	93%	2,563	2,317	90%	1,926	1,758	91%	1,435	1,294	90%
2011	89	81	91%	207	193	93%	1,544	1,512	98%	2,605	2,481	95%	2,116	2,031	96%	1,457	1,405	96%
2012	84	78	93%	412	372	90%	1,708	1,657	97%	2,562	2,449	96%						

LFA 38

YEAR	JAN			FEB			MAR			APR			MAY			JUN			NOV			DEC		
	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%	# RECS WITH WEIGHT	# RECS WITH WEIGHT & GRID	%
2004	271		0%	137		0%	150		0%	427		0%	881		0%	1,160		0%	926	37	4%	688	32	5%
2005	297	84	28%	177	52	29%	146	62	42%	636	200	31%	1,140	461	40%	1,496	627	42%	1,360	1,088	80%	928	698	75%
2006	312	251	80%	158	116	73%	230	195	85%	549	463	84%	1,215	969	80%	1,484	1,158	78%	953	730	77%	1,037	760	73%
2007	337	243	72%	105	71	68%	121	103	85%	454	359	79%	1,119	853	76%	1,219	955	78%	1,206	1,133	94%	1,093	1,008	92%
2008	431	396	92%	177	162	92%	189	182	96%	657	635	97%	1,459	1,393	95%	1,800	1,728	96%	1,197	1,099	92%	779	713	92%
2009	263	243	92%	96	89	93%	126	116	92%	618	573	93%	1,392	1,238	89%	1,620	1,462	90%	1,441	1,253	87%	970	845	87%
2010	330	309	94%	101	95	94%	138	131	95%	610	574	94%	1,391	1,297	93%	1,594	1,487	93%	1,279	1,139	89%	926	848	92%
2011	423	399	94%	103	94	91%	125	115	92%	485	462	95%	1,237	1,202	97%	1,542	1,511	98%	1,366	1,245	91%	960	846	88%
2012	333	292	88%	216	191	88%	221	205	93%	665	641	96%	1,299	1,247	96%	1,536	1,451	94%	-	-	-	-	-	-

Table 4.4. Number of LFA 34 Port Samples completed. Year refers to the second year of the fall-winter-spring fishing season.

Year	No. Port Samples
2006	32
2007	37
2008	42
2009	38
2010	41
2011	41
2012	42

Table 4.5. Number of participants in FSRS Recruitment Trap project by fishing season. Numbers are based on entries in the FSRS database as of January 10, 2013.

LFA 34

Fishing season	Number of Participants
1998/1999	3
1999/2000	24
2000/2001	37
2001/2002	38
2002/2003	42
2003/2004	41
2004/2005	46
2005/2006	49
2006/2007	39
2007/2008	34
2008/2009	32
2009/2010	31
2010/2011	30
2011/2012	25

LFA 35

Fishing season	Number of Participants
2006/2007	6
2007/2008	4
2008/2009	13
2009/2010	14
2010/2011	14
2011/2012	13

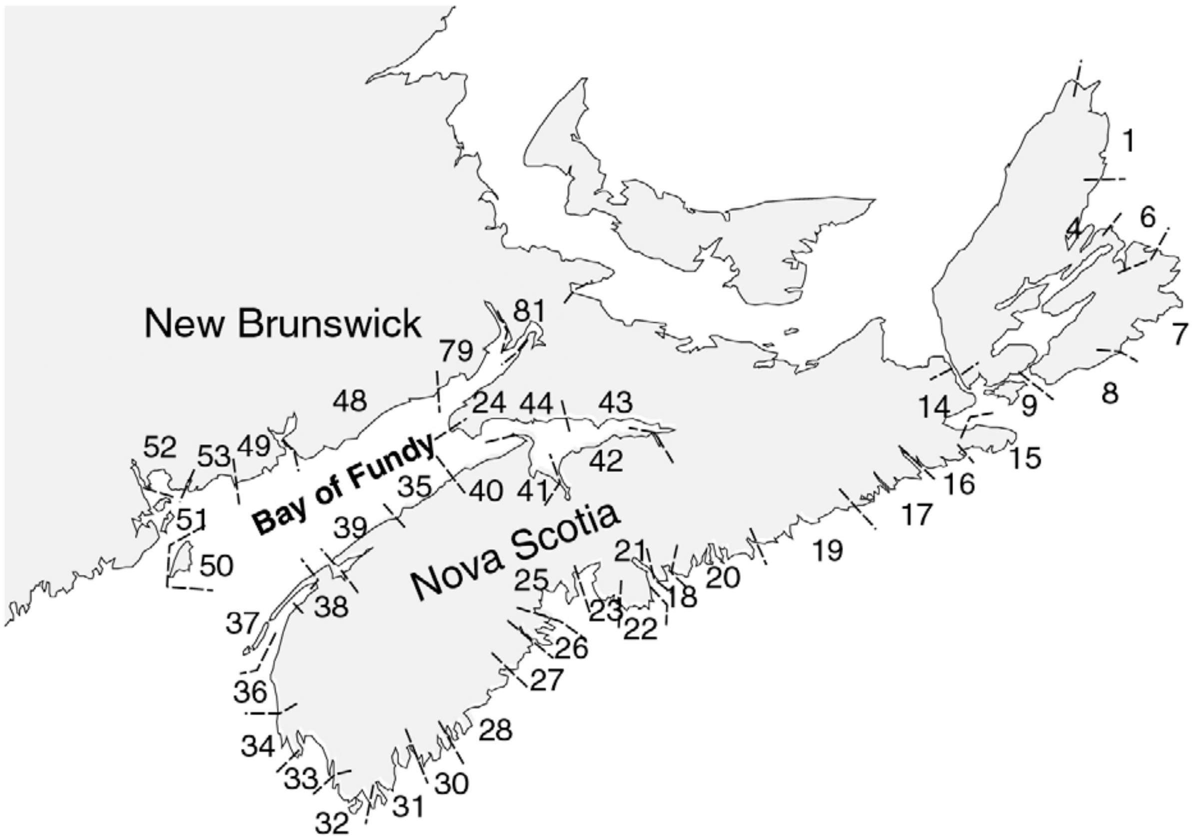
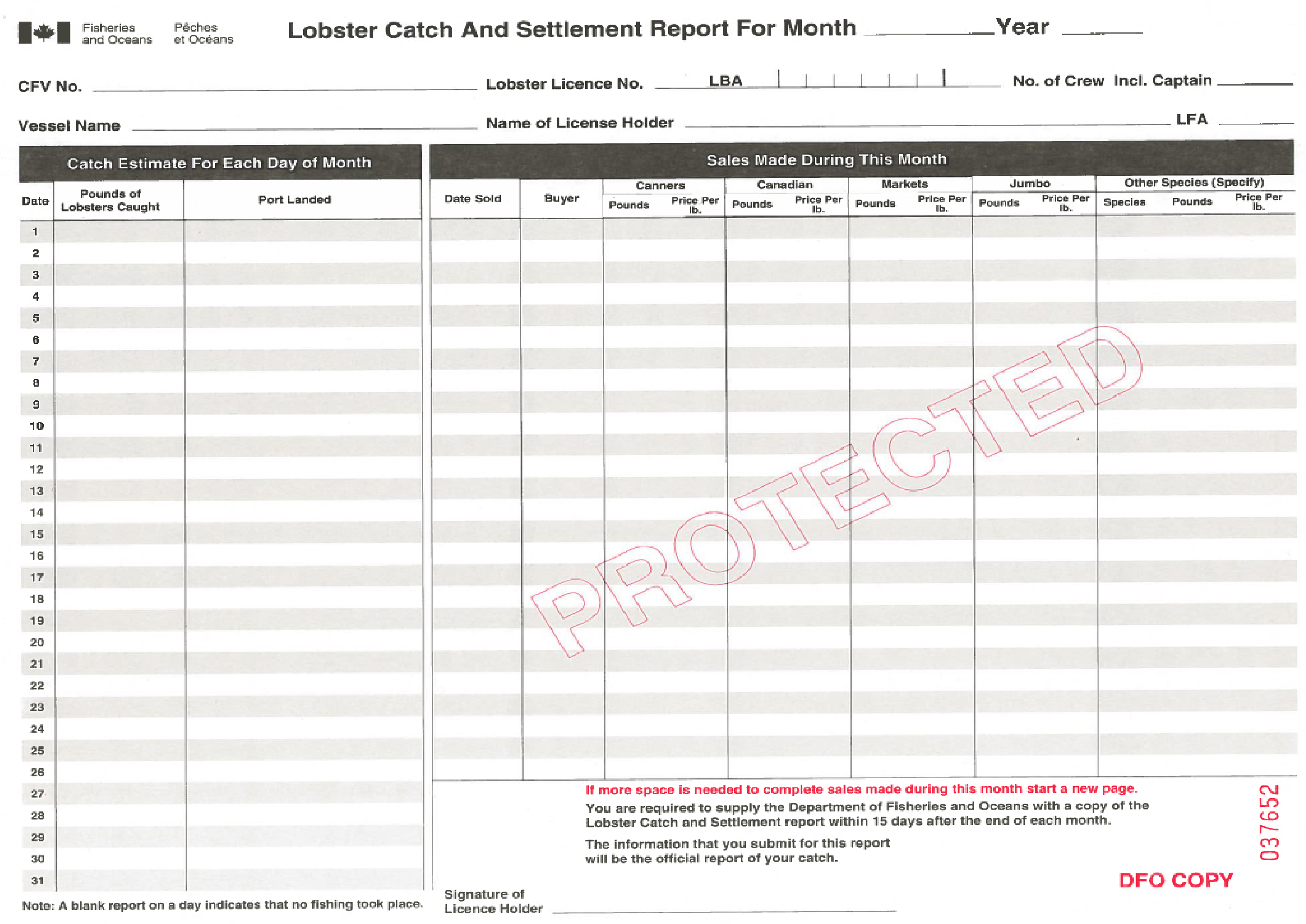


Figure 4.1. Map of fisheries statistical district boundaries.



Fisheries and Oceans / Pêches et Océans

Lobster Catch And Settlement Report For Month ________ Year ______

CFV No. ____________ Lobster Licence No. LBA ________ No. of Crew Incl. Captain ______

Vessel Name ____________ Name of License Holder ____________ LFA ______

Catch Estimate For Each Day of Month		
Date	Pounds of Lobsters Caught	Port Landed
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
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22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

Note: A blank report on a day indicates that no fishing took place.

Sales Made During This Month													
Date Sold	Buyer	Canners		Canadian		Markets		Jumbo		Other Species (Specify)		
		Pounds	Price Per lb.	Pounds	Price Per lb.	Pounds	Price Per lb.	Pounds	Price Per lb.	Species	Pounds	Price Per lb.

If more space is needed to complete sales made during this month start a new page.

You are required to supply the Department of Fisheries and Oceans with a copy of the Lobster Catch and Settlement report within 15 days after the end of each month.

The information that you submit for this report will be the official report of your catch.

PROTECTED

037652

DFO COPY

Signature of Licence Holder ____________

Figure 4.2. Example of Lobster Catch and Settlement Report implemented in 1995.

Fisheries and Oceans Canada / Pêches et Océans Canada

CONFIDENTIAL
CONFIDENTIEL

For DFO use only / À l'usage du MPO

000760

SERIAL NUMBER / NUMÉRO DE SERIE

LFA 27-38 Lobster Catch and Settlement Report for Month / Rapport de prises et de transactions concernant la pêche du homard dans les ZPH 27 à 38 pour le mois de ______________ Year/Annee ________ LFA/ZPH ________

Vessel Registration No. / N° d'immatriculation du bateau ______________ *No. of Crew Including Captain / N° de membres d'équipage, y compris le capitaine* ______________ *Lobster Licence Control No. / N° du permis de pêche du homard* ______________

Vessel Name / Nom du bateau ______________ *Name of License Holder/Operator / Nom du titulaire de permis* ______________

Day of Month / Jour	Estimated Lobster Landings / Débarquements de homard estimés — First Grid / Premier secteur de quadrillage			Second Grid / Deuxième secteur de quadrillage			Third Grid / Troisième secteur de quadrillage			Lbs of Crab for Bait / Poids (livres) du crabe utilisé comme appât ☐ YES/OUI ☐ NO/NON		Port Landed / Port de débarquement	At-Sea Observer Trip No. / N° de la sortie en mer avec observateur	Weighout Information / Données de pesage — NO SALES IN MONTH / PAS DE VENTE DANS LE MOIS ☐			
	Grid # on Map / N° de quadrillage sur la carte	Pounds Landed / Livres débarquées	Trap Hauls / Casiers levés	Grid # on Map / N° de quadrillage sur la carte	Pounds Landed / Livres débarquées	Trap Hauls / Casiers levés	Grid # on Map / N° de quadrillage sur la carte	Pounds Landed / Livres débarquées	Trap Hauls / Casiers levés	Jonah / Crabe nordique	Rock / Crabe commun			Date Sold / Date de la vente	Buyer / Acheteur	Market / Homard de marche	Price / Prix
1																	
2																	
3																	
4																	
5																	
6																	
7																	
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30																	
31																	

Note: A blank report on a day indicates that no fishing took place. If more space is needed to complete sales made during this month, start a new page. You are required to supply a Dockside Monitoring Company that has been designated by DFO with a copy of the Catch and Settlement Report within 15 days of the end of each month. The information you submit for this report will be the official report of your catch.

Remarque: Une ligne laissée en blanc pour un jour quelconque signifie qu'il n'y a pas eu de pêche le jour en question. Si vous avez besoin de plus d'espace pour rendre compte des transactions du mois, veuillez commencer une nouvelle page. Vous devez remettre à ministère des une entreprise de vérification à quai (EVQ) désignée par le MPO un exemplaire du Rapport de prises et de transactions concernant la pêche du homard dans les 15 jours de la fin de chaque mois. Les renseignements contenus dans ce rapport constitueront l'information officielle sur vos prises.

Signature of License Holder / Operator
Signature du titulaire de permis ______________

White - DMC Copy / Exemplaire blanc - EVQ

Yellow - Fisher Copy / Exemplaire jaune - Pêcheur

Figure 4.3. Example of current Lobster Catch and Settlement Report.

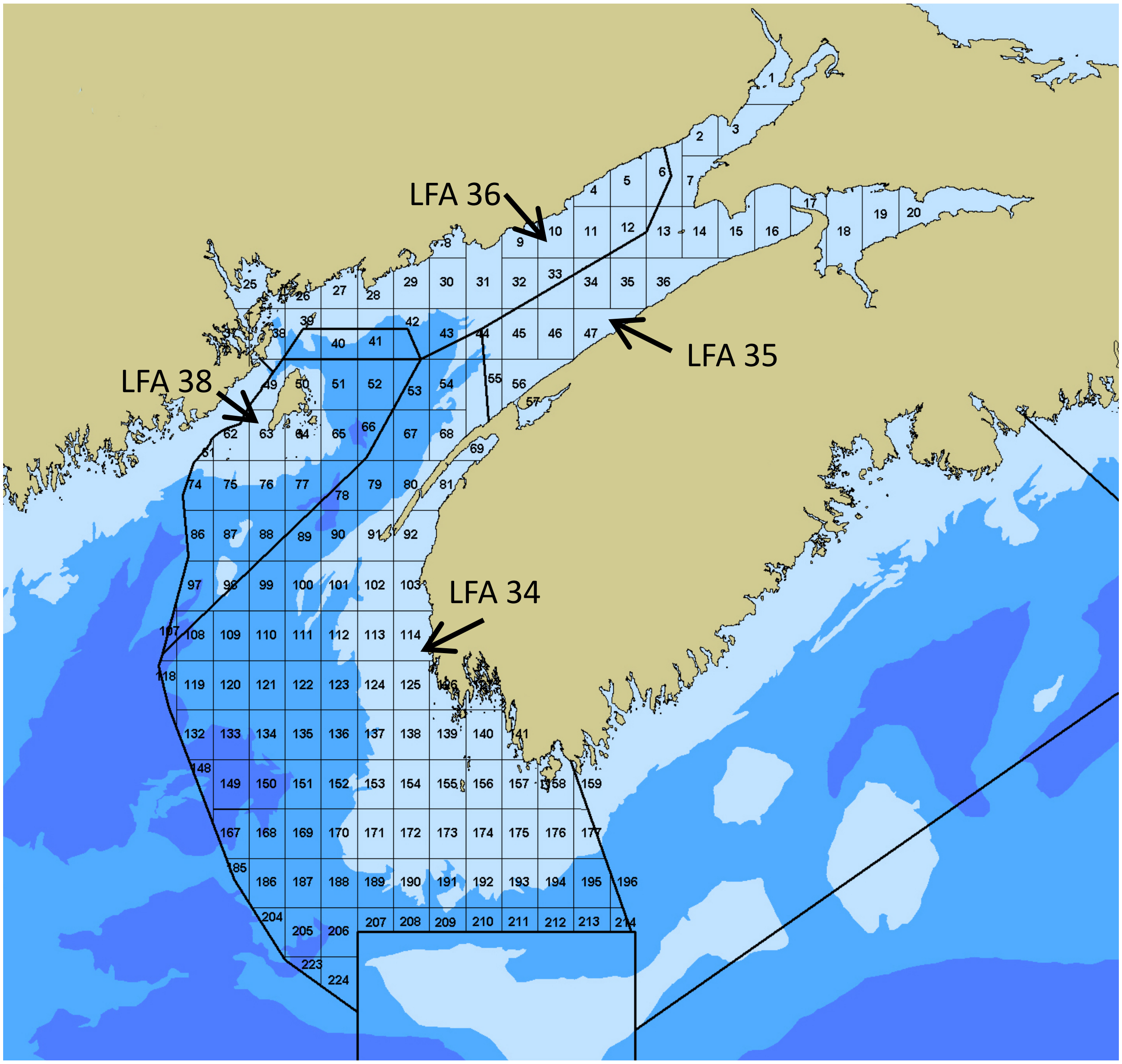


Figure 4.4. LFAs 34-38 logbook grids and corresponding LFAs.

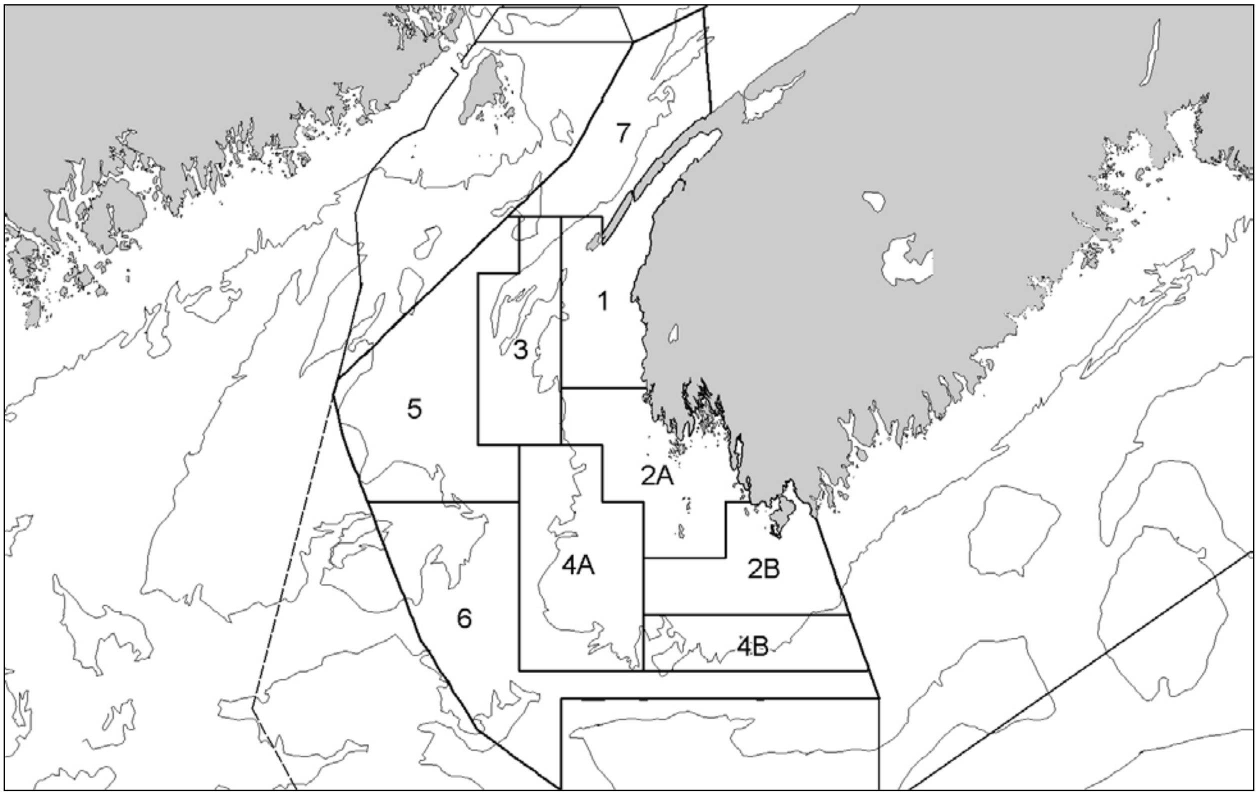


Figure 4.5. LFA 34 Grid Groups.

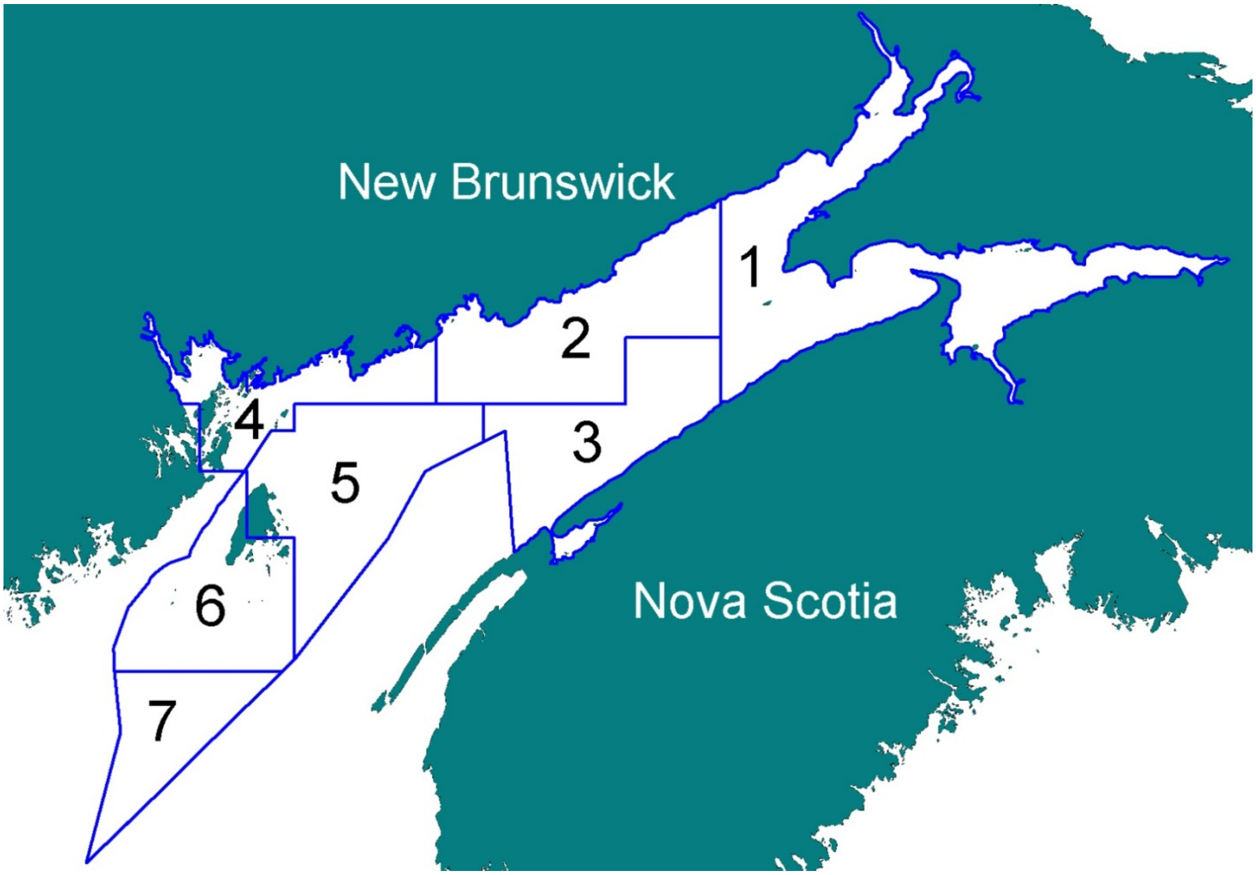


Figure 4.6. LFA 35-38 Grid Groups (see Figure 4.4 for corresponding LFAs).

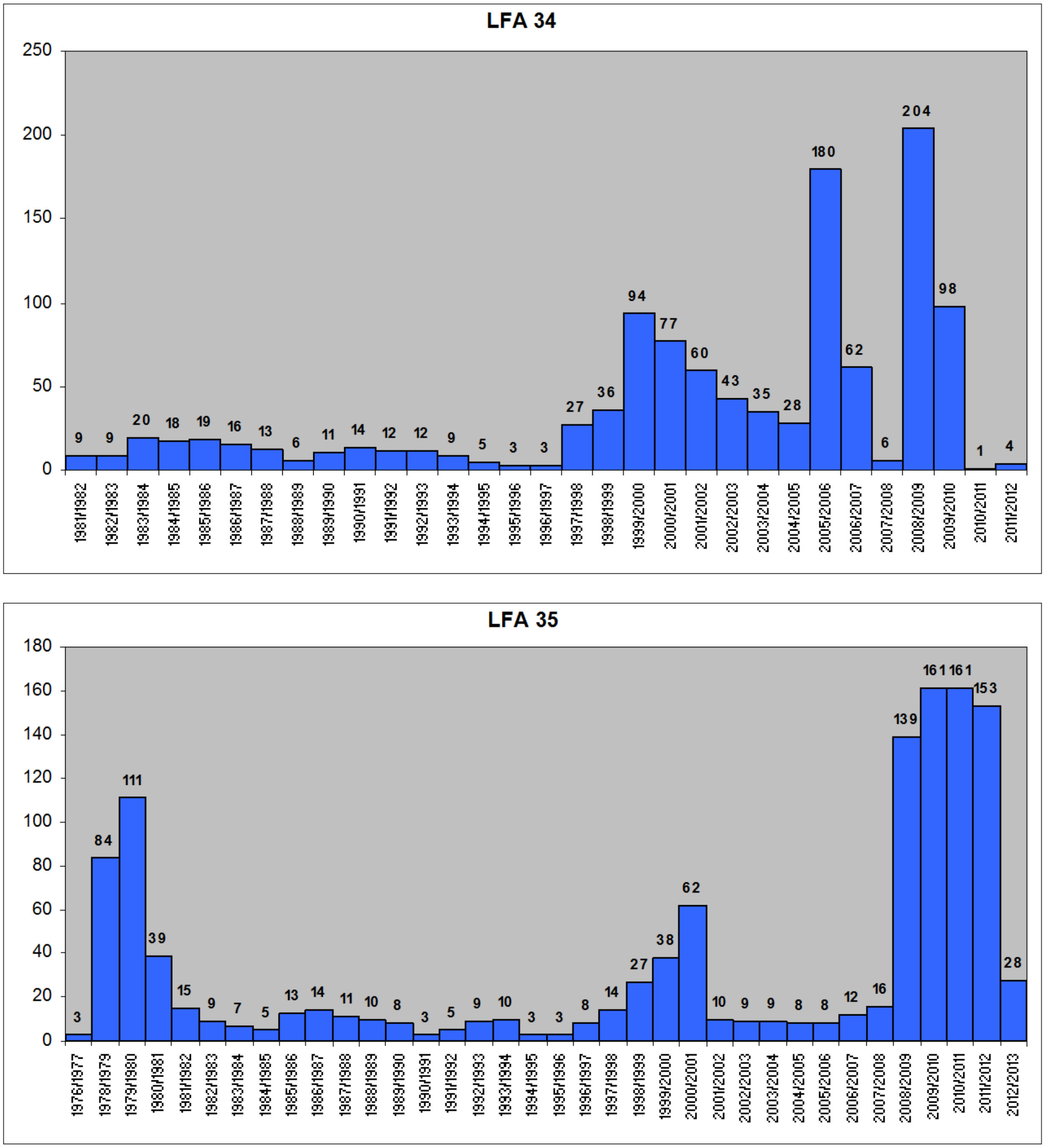
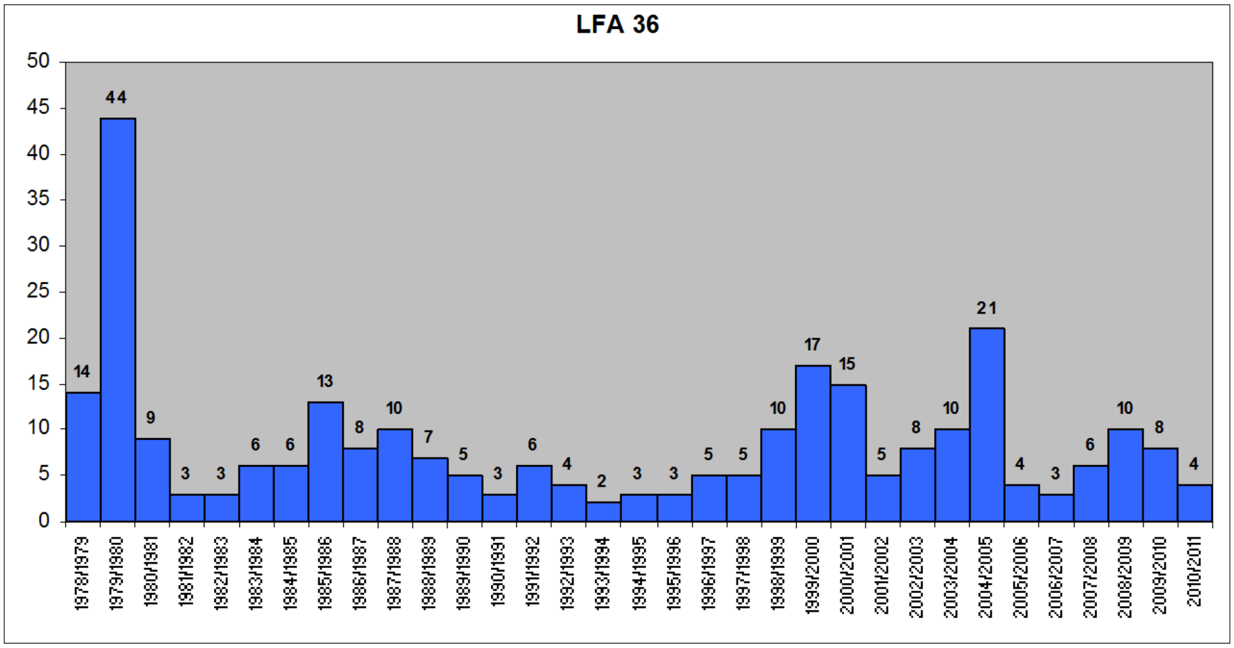


Figure 4.7. Number of at-sea samples per fishing season in LFA 34-38 (see Table 1.1 for season opening and closing dates).



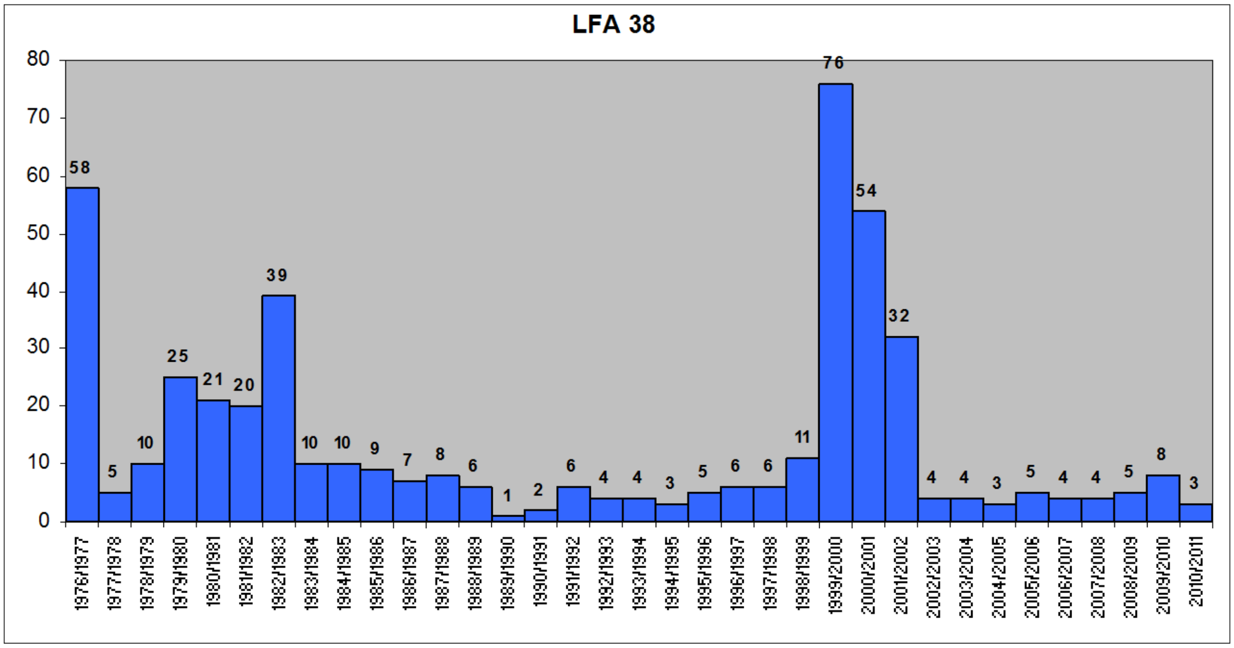


Figure 4.7. Continued.

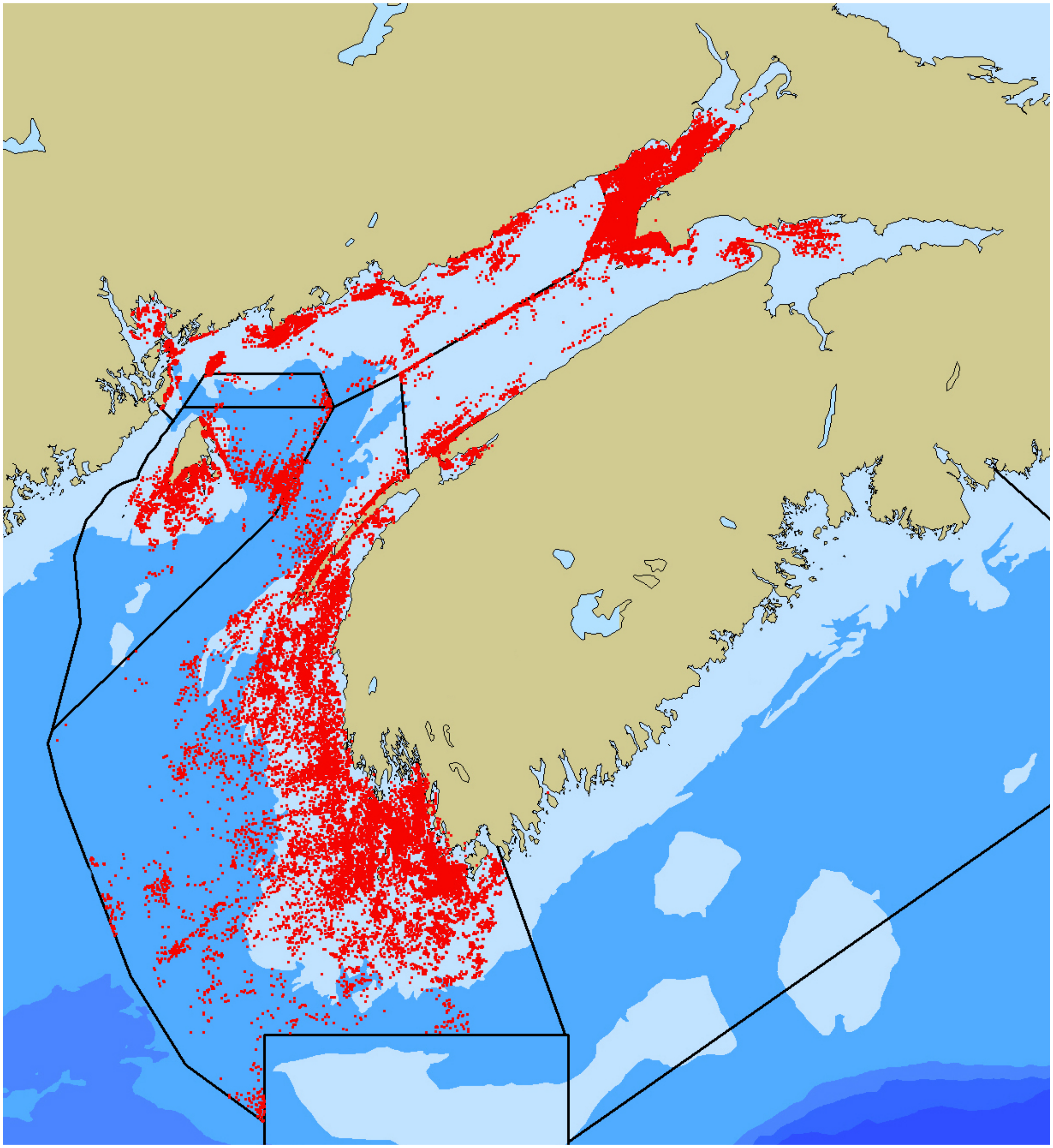


Figure 4.8. At-sea sample locations, 1976 to present.

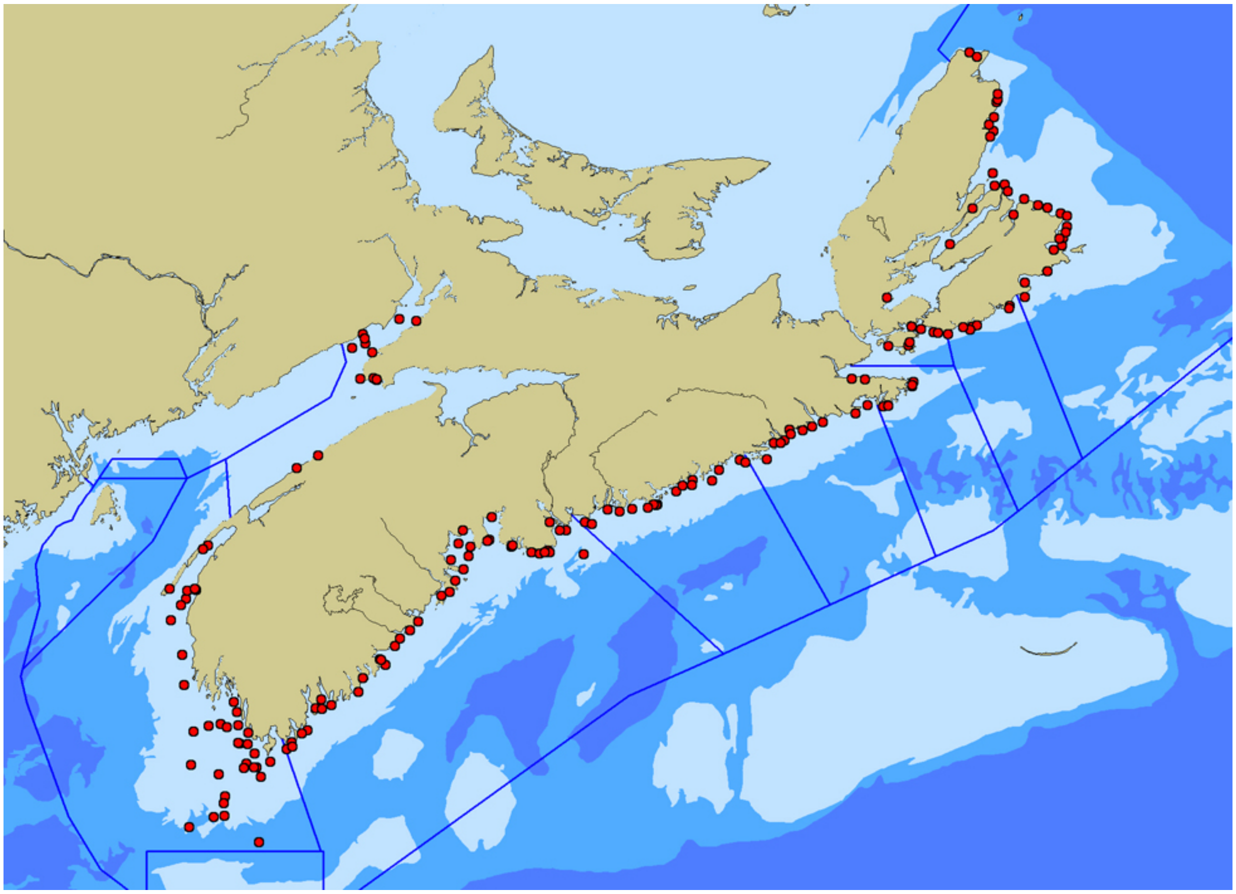


Figure 4.9. Locations of traps in FSRS recruitment trap project (as of spring 2012).

5. FISHERY PERFORMANCE INDICATORS

All data presented in this section originate from the landings databases, the Lobster Catch and Length Settlement Reports, or samples of the commercial catch. In addition to the analyses done for this assessment, supplemental reference is made to maps produced by Oceans as part of their Resource Mapping Project (Appendix 1).

5.1. LANDINGS

5.1.1. Methods

Landings were derived for the various time periods and spatial units as described in Section 4 from the Lobster Catch and Settlement Reports ("logs"). For LFAs as a whole, the weighout portion of the logs provided the best estimate of total landings. For the fishing seasons 1974-75 to 2011-12, landings within each year and LFA were characterized as within the lower quartile (lowest 25%), middle two quartiles (25-75%), or upper quartile (upper 25%).

For any measure requiring effort or location, the estimate portion of the log was used. For LFA totals (effort and estimated landings), location (grid cell) was not needed. If a fisherman reported on more than one grid in a day, the landings and effort were summed across these grids. An analysis indicated most fishermen (85%) report just one grid per day. For estimates of landings, effort and CPUE by Grid Group, additional constraints were applied (Table 5.1).

5.1.2. Results and Discussion

5.1.2.1. LFA 34

Commercial lobster fishing began in the mid-1800s and annual lobster landings in the Gulf of Maine were first recorded in 1893. Landings peaked in 1898 at 15,995 metric tons (t) [reported in error as 12,995 in Pezzack et al. 2006], and were followed by a decline in landings, dropping to 1,600 t in the early 1930s (Figure 5.1). The landings remained low (1,600-3,000 t) during the 1930s and early 1940s. Landings rose following World War II (WW II), varying between 2,200 and 4,500 t (averaging 3,334 t) until the 1980s. Landings increased throughout the 1980s as part of a pattern that extended over the entire range of the lobster in the western Atlantic.

Current and recent landings are very high by any measure (Figure 5.1,Tables 5.2, 5.3). They are 2.6 times the 50-year mean (1961-2010), and the last three years are the highest on record. Considering the period from 1975-76 to 2011-12, eight of the last ten years are in the upper quartile, the other two years were in the 3rd quartile (Table 5.2).

Within the LFA 34 Grid Groups, spatial shifts in landings are evident (Figure 5.2). Most Grid Groups have trended upwards, but Grid Group 2A (Lobster Bay area) has trended downward since 2001-02. Landings in Grid Groups 2B and 4B have increased.

Considered from the perspective of nearshore (Grid Groups 1, 2A, 2B, 7), midshore (Grid Groups 3, 4A, 4B) and offshore (Grid Groups 5,6) the importance of the midshore and offshore has increased substantially (Table 5.4). Landings in the nearshore Grid Group still comprise the bulk of the landings (63%), but have increased by a factor of just 1.2 since the first two seasons on record (1998-99 and 1999-00). Increases relative to the first two seasons were much greater in the midshore (4.6) and the offshore (5.8).

5.1.2.2. LFAs 35-38

In the Bay of Fundy, the landings peak in 1896 (2,791 t) was followed by a decline to 53 t in the early 1900s (Figure 5.3). Landings rose again until 1909 (900 t) and then trended downwards until the late 1930s. As in LFA 34, annual landings rose following WW II and were relatively stable for 20 years before declining to a low point in 1976. From 1986-87 to 1993-94, seasonal landings were stable (Table 5.2) with a mean of 994 t. From 1994-95 to the present, landings increased more than 6-fold. Even since 2005-06, when the Lobster Catch and Settlement Records were in widespread use, landings have more than doubled (Figure 5.4, Table 5.5).

To an even greater extent than in LFA 34, current landings are very high in the Bay of Fundy as a whole and in the individual LFAs (Table 5.2). Landings in 2011-12 were almost 5 times the 50-year mean (1961-2010), and the last three years are the highest on record. Considering the period from 1975-76 to 2011-12, nine of the last ten years are in the upper quartile, the other year was in the 3rd quartile (Table 5.2).

Within the Bay of Fundy LFAs, the landings increase since 2005-06 has been widespread, but somewhat greater in LFA 35 (about 3-fold) compared to LFAs 36 (doubled) and LFA 38 (almost doubled).

5.2. FISHING EFFORT

5.2.1. Methods

The Lobster Catch and Settlement Reports from LFA 34 and LFAs 35-38 were used to estimate (i) the annual number of trap hauls, (ii) the average number of days fished per fisherman, and (iii) the average number of grids fished per fisherman. The average number of days fished could be estimated from both versions of the Lobster Catch and Settlement Report (Figures 4.2 and 4.3), while annual trap hauls and grids fished could only be estimated from the version that includes daily effort.

5.2.2. Results and Discussion

5.2.2.1. LFA 34

The total annual trap hauls reported for LFA 34 (Table 5.3, Figure 5.5) shows no trend over the period since the Lobster Catch and Settlement Reports were introduced (1997-98). If anything, there is a declining trend in the adjusted effort since 2007-08. In terms of average days fished, there is a downward trend since 1997-98 (Figure 5.6). In terms of the average number of grids fished (Figure 5.7), there is slight downward trend in the seasonal measure; the average per day was slightly higher in the last 5 years (1.17-1.22) compared to the first 9 years (1.10-1.16). It is concluded that total fishing effort in LFA 34 as measured by these indicators has not increased over the last 14 years.

Within the LFA 34 Grid Groups, there have been spatial shifts in effort that explain the spatial shift in landings (Figure 5.8). Effort within Grid Group 2A has declined, whereas effort in all other Grid Groups has increased or remained stable. In terms of nearshore, midshore, and offshore portions of LFA 34, effort in the nearshore portion of LFA 34 in the last two years is about 80% that of the 1998-99 and 1999-00 seasons (Table 5.4). Effort in the midshore and offshore has increased by 2.7 times over the same time period. Most of the fishing effort (73%) is still in the nearshore.

5.2.2.2. LFAs 35-38

The total annual trap hauls reported in 2011-12 for LFAs 35-38, adjusted for reporting, were 1.2 times those reported for 2005-06 (Table 5.5, Figure 5.9). Reported effort in terms of average days fished has also increased since 1997-98 in all Bay of Fundy LFAs (Figure 5.6). In terms of average number of grids fished (Figure 5.7), there is an increase in the daily average in LFA 35, but overall the data are variable with no consistent trend. Variation in the first 3-4 years might be attributed to reporting issues. The trends in the annual number of trap hauls, and in the average number of days fished provide evidence for a gradual increase in fishing effort in the Bay of Fundy over the last 6 years and since 1997-98.

It is noted that, even though the average number of days fished has increased within the Bay of Fundy, overall it is still lower than LFA 34 (Figure 5.6). Total number of days fished is also lower in LFAs 35-38, as is the total number of trap hauls on an area basis (Appendix 1-Figures 4 and 6).

5.3. CPUE FROM COMMERCIAL LOGS

5.3.1. Methods

CPUE (kg/trap haul) was calculated from those records that provided daily weight landed, (estimated) daily effort, and a grid (Table 5.1). Annual CPUE for the spatial unit of interest was calculated simply as the total weight landed per year/total number of trap hauls per year.

5.3.2. Results and Discussion

5.3.2.1. LFA 34

CPUE in LFA 34 as a whole was lowest from 1998-99 to 2000-01 (0.6-0.7 kg/trap/haul), intermediate from 2001-02 to 2007-08, and highest for the last 3 years (0.9-1.1 kg/trap haul – Table 5.3, Figure 5.10). The average CPUE of the last two years (1.1 kg/trap haul) is 1.7 times that of 1998-99 and 1999-00. This increase in CPUE accounts for the increased landings over the same time period.

Within the LFA 34 Grid Groups, there was a general increase in CPUE in all Grid Groups, particularly in the last 3-5 years (Figure 5.11). The relative increase in CPUE (Figure 5.12) was highest in the midshore and offshore Grid Groups. In terms of absolute values, the CPUE has been higher in the midshore and offshore Grid Groups throughout the time period.

The higher CPUEs in the midshore and offshore portions of LFA 34 provide an explanation for the shift in effort away from the nearshore Grid Groups.

5.3.2.2. LFAs 35-38

CPUE in the Bay of Fundy has increased in all LFAs since 2005-06 (Table 5.5, Figure 5.13). In the Bay of Fundy as a whole, the 2011-12 CPUE (1.9 kg /trap haul) was 1.8 times that of 2005-06. This increase in CPUE, coupled with increased fishing effort, explains the doubling of landings in the Bay of Fundy since 2005-06.

In terms of the Grid Groups, the CPUE in the Bay of Fundy has increased in Grid Groups 1 to 5, but has shown no trend in Grid Groups 6 and 7, east of Grand Manan (Figure 5.14).

5.4. SIZE IN COMMERCIAL TRAPS

5.4.1. Methods

Sizes were obtained from at-sea samples from 1990 to the present and from port samples since 2005-06 (LFA 34 only). Trends over time were examined by inspection of box-whisker plots and plots of median size and large sizes (females, 95th percentile).

5.4.2. Results and Discussion

5.4.2.1. LFA 34

Trends in the size of males are presented in box-whisker plots in Figure 5.15; those for females are in Figure 5.16. The overall impression is that the size distributions of both sexes have not changed much over time, and that there is interannual variability. In the Grid Groups sampled best (1, 2A, 2B, 4A) a slight downward shift in sizes from the early 1990s to the present is evident.

The 50th percentiles (median) of female size (Figure 5.17a) indicate a downward trend in some of the nearshore (2B) and midshore Grid Groups (3 and 4A). The 95th percentiles of female size (Figure 5.17b) indicate a decline in the representation of large females in all of the nearshore

Grid Groups (1, 2A, 2B, 7), and in two of the midshore Grid Groups (3, 4A). Declines in the offshore Grid Groups (5, 6) were not evident, but sampling effort was low there.

Another source of data for sizes in the commercial catch is the port samples in LFA 34. The 95th percentiles of female sizes for port samples indicate a decline in the largest females in most nearshore and midshore Grid Groups (Figure 5.18). Plotting the nearshore, midshore and offshore Grid Groups together (Figure 5.19) indicates a decline in large female representation everywhere. Firm conclusions on this shift cannot be made given that the first year (2005-06) determines much of the trend over the last 7 years.

5.4.2.2. LFAs 35-38

Trends in the size of males in the Bay of Fundy are presented in box-whisker plots in Figure 5.20; those for females are in Figure 5.21. As for LFA 34, the overall impression is that the size distributions of both sexes has not changed much over time, and that there is interannual variability. The longer tails of distribution in Grid Group 1 in LFA 35 in the last 5 years likely reflect increased sampling there due to the Petticodiac project. The two Grid Groups in LFA 38 (5 and 6) show markedly different distributions, with lobsters in Grid Group 5 being much larger.

The 50th percentiles of female size (Figure 5.22) indicate a downward trend in some of the LFA-Grid Groups, but they are not consistent across LFAs. Grid group 2 in LFA 35 shows a steep decline since 2000, but Grid Group 2 in LFA 36 shows little change. The 95th percentiles of female size (Figure 5.23) show a pattern similar to the medians. Declines with time are evident in the 95th percentile in LFA 35 Grid Groups 1 and 2, but not in Grid Group 2 of LFA 36. There is an indication of a decline in the 95th percentile in one of the Grid Groups in LFA 36 (4). The 95th percentile of females in LFA 38 did not decline between 1997 and 2010.

5.5. ISSUES AND UNCERTAINTIES

Fishery-derived data can reflect changes in stock health and fishing pressure, but may change for a variety of reasons unrelated to stock health. Tremblay et al. (2012b) identified uncertainties with respect to the use of fishery data for biomass proxies and indicators of fishing pressure. Those most relevant to the current assessment are summarized below.

- Landing levels are a function of abundance and a wide range of other factors, such as number of trap hauls, soak days, fishing strategy, catchability (affected by environmental factors, such as temperature and storms, as well as gear efficiency), and management rules. Changes in any of these can affect the relationship between landings and abundance.
- Fishing efficiency has increased due to larger boats, improvements to navigation and traps and fishing strategy, but this increase has not been quantified. For example, in LFA 34, overall vessel length increased by about 20% from 1985 to 2003 and the percent of vessels with brake horsepower >300 increased from about 15% in 1998 to over 40% in 2005 (Michael Campbell, DFO Policy and Economics Branch, pers. comm., 2012).
- Accurate landings are dependent on accurate records from industry. If the willingness to provide accurate data decreases, the use of landings as a biomass proxy is not tenable.

Given these uncertainties, conclusions about abundance and fishing pressure from fishery data are possible only if the signals are strong and/or if they are supported by fishery independent data.

The size data will be affected by the seasonal timing of the samples, the location, and the fishing strategy (trap type, bait, etc.).

5.6. SUMMARY OF FISHERY PERFORMANCE INDICATORS

5.6.1. LFA 34

- Landings have increased and current landings (2011-12: 23,292 t) are at an all-time high. They are 2.6 times the 50-yearr mean (1961-2010), and are about 1/3 higher than the last time LFA 34 was assessed (2006).
- Within LFA 34 there has been a spatial shift in landings since 1998-99, with an increased percentage of landings in the mid- and offshore (37% of the total in 2010-11 and 2011-12 versus 11-15% in 1998-99 and 1999-00). Landings increases relative to 1998-99 and 1999-00 were greater in the midshore (4.6 times) and the offshore (5.8 times).
- Total fishing effort (trap hauls, average days fished, and grids fished) in LFA 34 has either varied without trend or declined since 1998-99.
- The adjusted annual number of trap hauls has ranged from 19.9-23.4 million; 2011-12 effort (21.2 million) was just below the mean for 1999-2012.
- Within LFA 34, there has been a spatial shift in effort with an increased percentage of effort in the mid- and offshore (27-28% in last 2 years compared to 10-11% in 1998-99 and 1999-00).
- The CPUE of the whole LFA in the last two years (1.1) is 1.7 times that of 1998-99 and 1999-00. This increase in CPUE accounts for the increased landings over the same time period.
- Within LFA 34, there was a general increase in CPUE in all Grid Groups, particularly in the last 3-5 years. The increase was highest in the midshore and offshore.
- The CPUE has been higher in the midshore and offshore since 1998-99; these higher CPUEs provide an explanation for the shift in effort away from the nearshore Grid Groups.
- Changes in size structure in commercial traps since 1990 in LFA 34 were most evident at the larger sizes. The 95th percentile of female size became smaller in traps set in the nearshore Grid Groups and in two of the midshore Grid Groups. In the offshore Grid Groups there was no consistent trend.

5.6.2. LFAs 35-38

- Landings have increased and current landings (2011-12: 8467 t for LFAs 35-38) are at an all-time high. They are almost 5 times the 50-year mean (1961-2010), and are about double the landings the last time LFAs 35-38 was assessed (2007).
- Within the Bay of Fundy LFAs, the landings increase since 2005-06 has been widespread but somewhat greater in LFA 35 (about 3-fold) compared to LFAs 36 (doubled) and LFA 38 (almost doubled).
- Fishing effort has increased in LFAs 35-38. In terms of average days fished, effort has increased since 1997-98 in all Bay of Fundy LFAs. In terms of total annual trap hauls adjusted for reporting, levels in 2011-12 for LFAs 35-38 were 1.2 times those reported for 2005-06.
- Fishing effort in the Bay of Fundy is still lower than in the adjacent LFA 34.
- CPUE in the Bay of Fundy has increased in all LFAs since 2005-06. In LFAs 35-38 as a whole, CPUE in 2011-12 (1.9 kg/trap haul) was 1.8 times that of 2005-06.
- This increase in CPUE, coupled with increased fishing effort of about 16%, explains the doubling of landings in the Bay of Fundy since 2005-06.
- The size structure in commercial traps in the Bay of Fundy showed some reductions in large sizes since the early 1990s. Of the two best sampled Grid Groups in LFA 36, one showed a decline in the 95th percentile of female size. Similarly, this measure declined in two of three Grid Groups in LFA 35. There was no such trend in LFA 38.

Table 5.1. Description of constraints applied and number of resultant records during analysis of data from Lobster Catch and Settlement Reports. Two different sets of constraints were applied depending on the level and type of analysis (A and B below). Records were defined as follows: A - At the LFA level, one record was defined as one day's landings or effort by one fisherman summed over the locations (grids) fished, regardless of whether a grid(s) was supplied. This is referred to as a day record. B – At the level of the Grid Group, and for CPUE calculations at the LFA and Grid Group level, one record was defined as one day's landings or effort by one fisherman in one grid. This is referred to as a day-grid record.

A. Landings and Effort at LFA level.

Constraint (Con) Description	Con No.	Data set	Number of day-records by LFA				
			34	35	36	38	35-38
Landings or effort within fishing season	1		927,952	86,827	98,643	86,940	272,410
Within fishing season and Wt <30,000 lb/day	2	Landings (Con 1,2)	927,944	86,826	98,643	86,940	272,409
Within fishing season and no. traps hauled per day <1127	3	Effort (Con 1,3)	862,786	47,221	63,003	51,175	161,399

B. Landings and Effort at Grid Group level and CPUE at LFA and Grid Group level.

Constraint (Con) Description	Con No.	Data set	Number of day-grid records by LFA				
			34	35	36	38	35-38
Valid LFA and grid	1		890,527	45,608	53,688	46,292	145,588
Within fishing season	2		890,032	45,559	53,562	46,284	145,405
and trap hauls <1127	3	Effort (Con 1,2,3)	889,925	45,559	53,562	46,284	145,405
and weight <30,000 lb	4	Landings (Con 1,2,4)	889,917	45,559	53,562	46,284	145,405
and traps and weight NOT null or zero	5	CPUE (Con 1-5)	831,730	43,201	50,719	42,492	136,412

Table 5.2. LFAs 34, 35, 36 and 38 landings for 1975-76 to 2011-12 fishing seasons, as of January 1, 2013. Sources as described in the methods. Values less than the 25th percentile of the time series were classified as "negative" (black cells), values between the 25th and 75th percentile were classified as "neutral" (grey cells), and values greater than the 75th percentile were classified as "positive" (white cells). Values include commercial communal removals. Food, Social and Ceremonial (FSC) are not included but given the effort deployed, are expected to be no more than 0.1-0.5% of the totals in recent years. Note that some of the landings data have been corrected from those presented in Tremblay et al. 2012b.

FISHING SEASON	LFA34	LFA35	LFA36	LFA38	LFA 35-38
1975/1976	3,829	132	115	294	541
1976/1977	3,525	120	58	170	348
1977/1978	2,668	157	47	351	555
1978/1979	2,963	137	176	302	615
1979/1980	3,203	75	126	347	548
1980/1981	3,086	132	156	236	524
1981/1982	3,649	133	195	390	718
1982/1983	4,546	135	225	378	738
1983/1984	5,140	164	211	365	740
1984/1985	5,937	226	266	334	826
1985/1986	6,892	246	281	316	843
1986/1987	7,672	330	327	329	986
1987/1988	8,478	265	340	384	989
1988/1989	8,200	271	310	468	1,049
1989/1990	9,449	255	221	467	943
1990/1991	11,084	227	271	495	993
1991/1992	8,888	261	260	512	1,033
1992/1993	8,902	239	257	472	968
1993/1994	10,334	241	274	523	1,038
1994/1995	9,683	338	318	661	1,317
1995/1996	10,339	546	427	600	1,573
1996/1997	10,646	738	680	551	1,969
1997/1998	12,064	837	788	701	2,326
1998/1999	13,074	923	826	809	2,558
1999/2000	13,444	910	879	826	2,615
2000/2001	16,198	1,074	1,032	984	3,090
2001/2002	19,058	1,219	1,261	1,145	3,625
2002/2003	17,613	1,234	1,155	1,073	3,462
2003/2004	17,801	1,337	1,169	1,133	3,639
2004/2005	17,250	1,172	1,143	1,363	3,678
2005/2006	17,009	1,235	1,295	1,595	4,125
2006/2007	16,583	1,191	1,138	1,413	3,742
2007/2008	17,145	1,488	1,477	1,855	4,820
2008/2009	17,262	1,617	1,596	1,638	4,851
2009/2010	19,749	1,898	1,594	2,035	5,527
2010/2011	20,401	2,546	1,916	2,352	6,814
2011/2012	23,292	3,245	2,481	2,741	8,467
1st Quartile	5,937	226	225	365	826
3rd Quartile	17,009	1,191	1,143	1,133	3,625

Table 5.3. Landings, effort, and CPUE in LFA 34 from fishermen logs (Lobster Catch and Settlement Records) by fishing season. CPUE is calculated only from those records that have data for landings, effort, and location. Adjusted Effort = Weighout slip landings/CPUE.

	Weigh-out slips	Records with landings or effort data		Records with entries for landings, effort and grid cell			
Fishing season	Landings (t)	Landings (t)	Effort (no trap hauls)	Landings (t)	Effort (no trap hauls)	CPUE (kg/trap haul)	Adjusted Effort
1998-99	13,074	13,071	20,683,053	11199	19,192,056	0.58	22,404,536
1999-00	13,444	13,597	18,818,488	11322	17,305,377	0.65	20,548,322
2000-01	16,198	16,876	21,295,210	14328	19,776,211	0.72	22,357,697
2001-02	19,058	19,156	20,268,448	16328	18,824,906	0.87	21,972,228
2002-03	17,613	17,832	19,418,891	15072	17,995,743	0.84	21,029,062
2003-04	17,801	18,120	18,271,825	15195	17,042,730	0.89	19,965,001
2004-05	17,250	17,102	20,928,521	14441	19,567,499	0.74	23,374,304
2005-06	17,009	17,017	19,489,952	14059	18,132,832	0.78	21,937,043
2006-07	16,583	16,773	18,047,385	13854	16,945,250	0.82	20,282,835
2007-08	17,145	16,607	21,125,251	15576	20,384,603	0.76	22,438,285
2008-09	17,262	17,711	20,870,661	15929	19,535,246	0.82	21,170,678
2009-10	19,749	20,690	21,392,960	18044	19,479,295	0.93	21,320,374
2010-11	20,401	21,170	19,740,950	18460	18,036,776	1.02	19,933,722
2011-12	23,292	24,083	20,668,177	20942	19,044,401	1.10	21,181,579

Table 5.4. LFA 34 landings and effort by fishing season for nearshore Grid Groups (1, 2A, 2B, 7), midshore Grid Groups (3, 4A, 4B), and offshore Grid Groups (5, 6).

		Landings (t)			Effort (no trap hauls)		
Year	Season	Nearshore	Midshore	Offshore	Nearshore	Midshore	Offshore
1999	1998-99	10,492	1,140	193	17,625,128	1,599,246	264,058
2000	1999-00	10,225	1,612	267	15,585,435	1,581,669	337,431
2001	2000-01	11,963	2,805	376	16,854,597	2,664,052	326,870
2002	2001-02	13,118	3,528	664	15,704,978	2,711,238	497,379
2003	2002-03	11,643	3,544	724	14,711,306	2,903,055	502,583
2004	2003-04	11,012	4,109	1,343	13,365,064	2,974,154	790,781
2005	2004-05	11,397	3,304	758	15,955,750	3,040,938	684,187
2006	2005-06	10,807	3,560	937	14,668,594	2,846,984	750,733
2007	2006-07	9,947	4,254	787	13,436,048	2,993,134	582,202
2008	2007-08	10,726	4,438	918	16,108,410	3,734,339	720,947
2009	2008-09	11,804	4,197	594	15,593,154	3,569,628	528,926
2010	2009-10	12,266	5,480	1,041	15,139,841	3,786,354	675,250
2011	2010-11	11,943	6,079	1,159	13,137,913	4,334,120	705,496
2012	2011-12	13,735	6,600	1,526	13,977,463	4,289,090	901,397
Ratio 2011/2012: 1999/2000		1.2	4.6	5.8	0.8	2.7	2.7

Table 5.5. Landings, effort, and CPUE by fishing season for LFAs 35-38 from the estimate portion of fishermen logs (Lobster Catch and Settlement Records). CPUE is calculated only from those records that have data for landings, effort, and location.

LFA	Fishing Season	Weighout Slip landings (t)	Records with landings or effort data		Records with landings, effort and location (grid)			Adjusted Effort (no. trap hauls)
			Landings (t)	Effort (no. trap hauls)	Landings (t)	Effort (no. trap hauls)	CPUE (kg/th)	
35	2005-06	1,235	1,220	799,558	707	736,986	0.96	1,286,663
	2006-07	1,191	1,191	770,500	839	719,351	1.17	1,020,923
	2007-08	1,488	1,458	1,185,804	1,385	1,126,189	1.23	1,210,317
	2008-09	1,617	1,681	1,215,644	1,542	1,132,433	1.36	1,187,128
	2009-10	1,898	1,996	1,274,617	1,793	1,161,987	1.54	1,229,841
	2010-11	2,546	2,782	1,361,352	2,389	1,190,569	2.01	1,268,854
	2011-12	3,245	3,618	1,471,667	3,137	1,319,638	2.38	1,364,860
Ratio 2011-12: 2005-06		2.6	-	0	-	-	2.5	1.1
36	2005-06	1,295	1,232	792,037	816	708,501	1.15	1,123,838
	2006-07	1,138	1,122	725,816	765	666,551	1.15	991,943
	2007-08	1,477	1,432	1,060,996	1,333	1,041,201	1.28	1,153,823
	2008-09	1,596	1,523	1,078,437	1,395	1,029,394	1.36	1,177,831
	2009-10	1,594	1,611	1,202,730	1,445	1,112,384	1.30	1,227,214
	2010-11	1,916	1,921	1,292,233	1,703	1,188,572	1.43	1,337,349
	2011-12	2,481	2,587	1,419,790	2,219	1,274,447	1.74	1,425,035
Ratio 2011-12: 2005-06		1.9	-	-	-	-	1.5	1.3
38	2005-06	1,595	1,550	1,078,747	1,059	1,015,729	1.04	1,530,259
	2006-07	1,413	1,410	841,430	907	809,024	1.12	1,260,724
	2007-08	1,855	1,805	1,650,193	1,704	1,605,781	1.06	1,748,087
	2008-09	1,638	1,593	1,443,874	1,424	1,338,779	1.06	1,539,497
	2009-10	2,035	2,001	1,626,506	1,808	1,510,269	1.20	1,699,866
	2010-11	2,352	2,272	1,532,987	2,064	1,447,913	1.43	1,650,122
	2011-12	2,741	2,725	1,670,693	2,315	1,518,713	1.52	1,797,855
Ratio 2011-12: 2005-06		1.7	-	-	-	-	1.5	1.2
35-38	2005-06	4,125	4,002	2,670,342	2,583	2,461,216	1.05	3,931,270
	2006-07	3,742	3,723	2,337,746	2,511	2,194,926	1.14	3,271,459
	2007-08	4,820	4,695	3,896,993	4,421	3,773,171	1.17	4,113,337
	2008-09	4,851	4,797	3,737,955	4,362	3,500,606	1.25	3,893,217
	2009-10	5,527	5,608	4,103,853	5,046	3,784,640	1.33	4,145,276
	2010-11	6,814	6,975	4,186,572	6,156	3,827,054	1.61	4,236,428
	2011-12	8,467	8,930	4,562,150	7,672	4,112,798	1.87	4,539,140
Ratio 2011-12: 2005-06		2.1	-	-	-	-	1.8	1.2

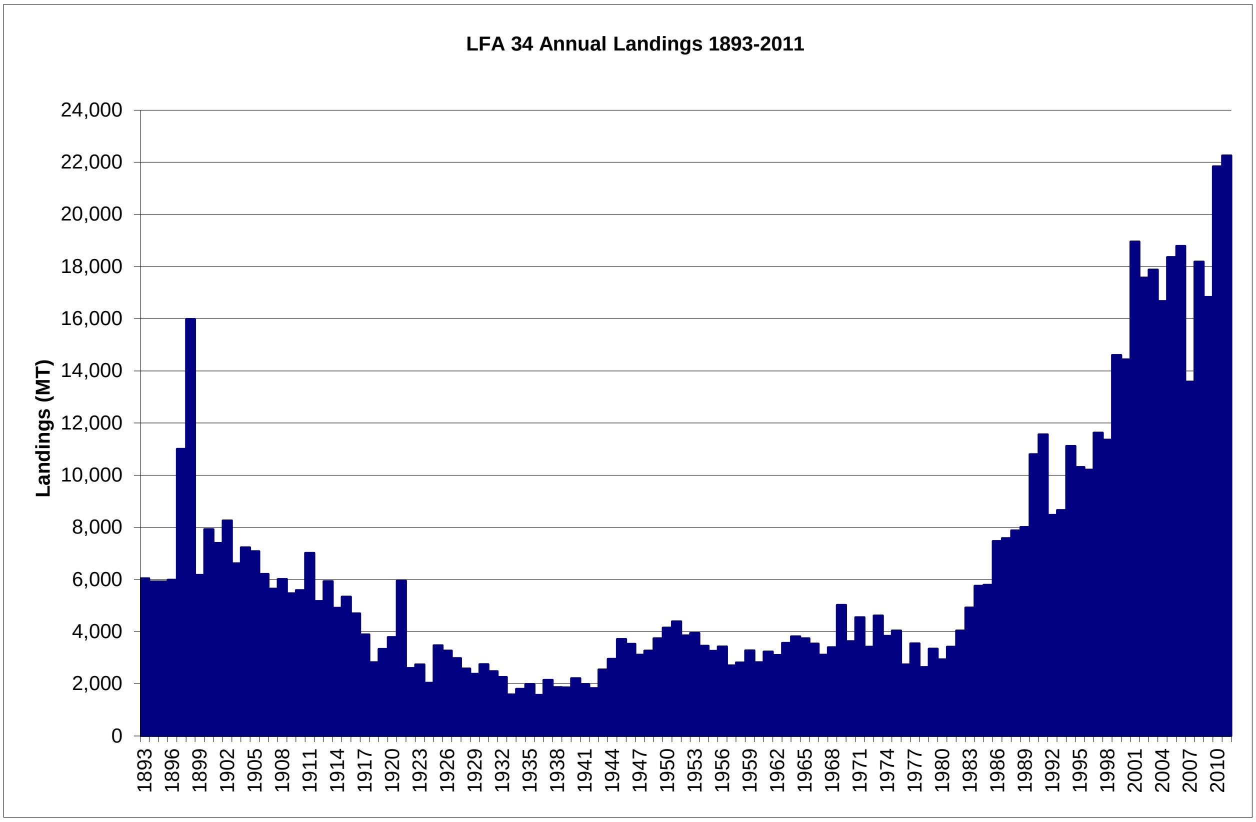


Figure 5.1. Lobster landings (mt) for LFA 34 by calendar year, 1893-2011. Methods and sources described in Section 4 (Data Sources).

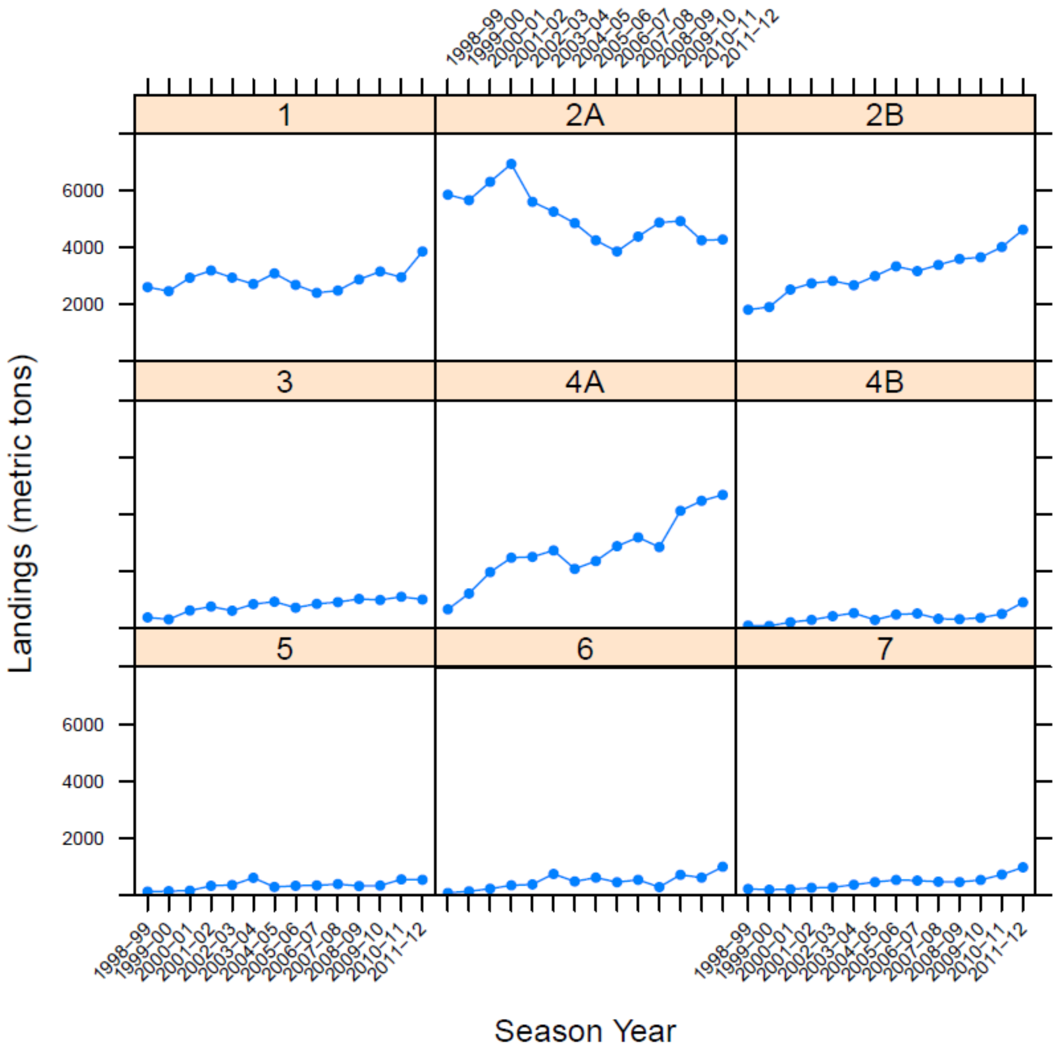


Figure 5.2. LFA 34 landings (mt) for 1998-99 to 2011-12 fishing seasons by Grid Group. Data are from the estimate portion of lobster catch and settlement reports.

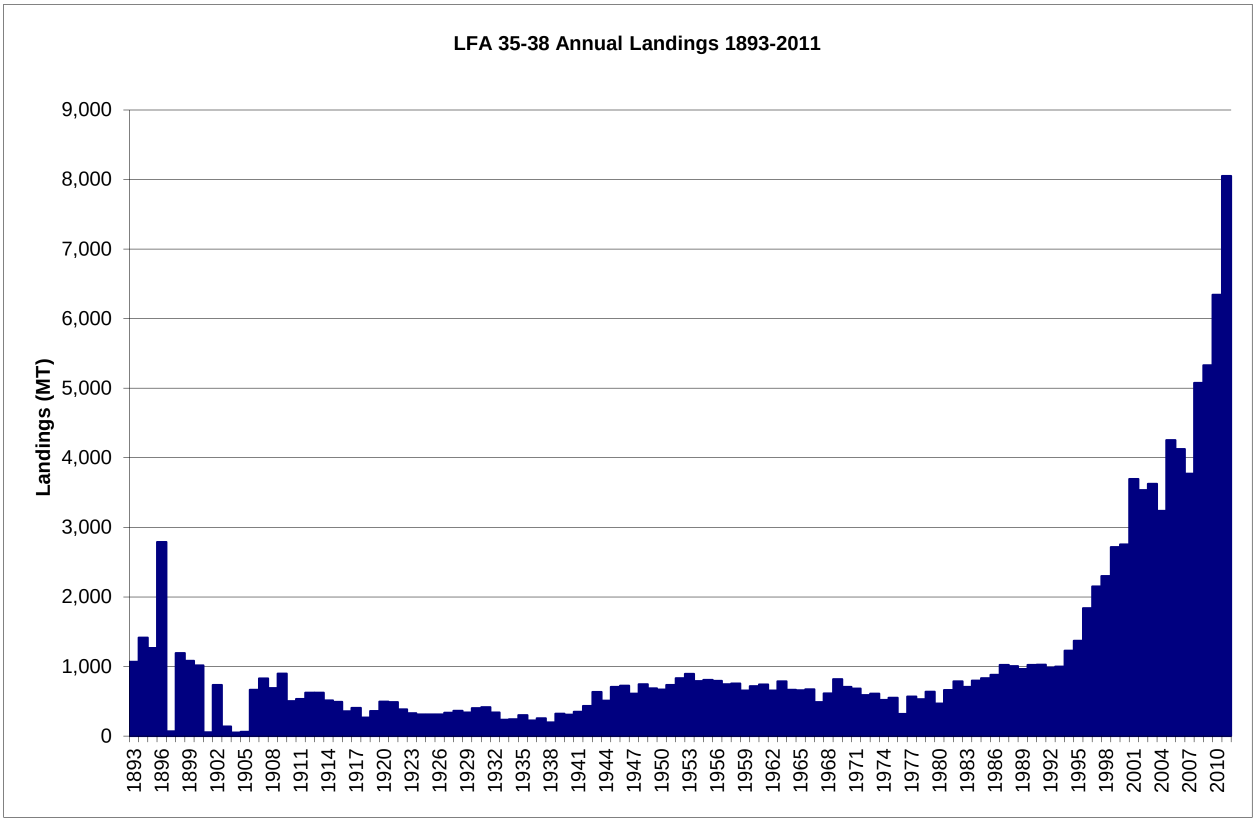


Figure 5.3. Lobster landings (mt) for LFAs 35-38 by calendar year, 1893 to 2011. Methods and sources described in Section 4 (Data Sources).

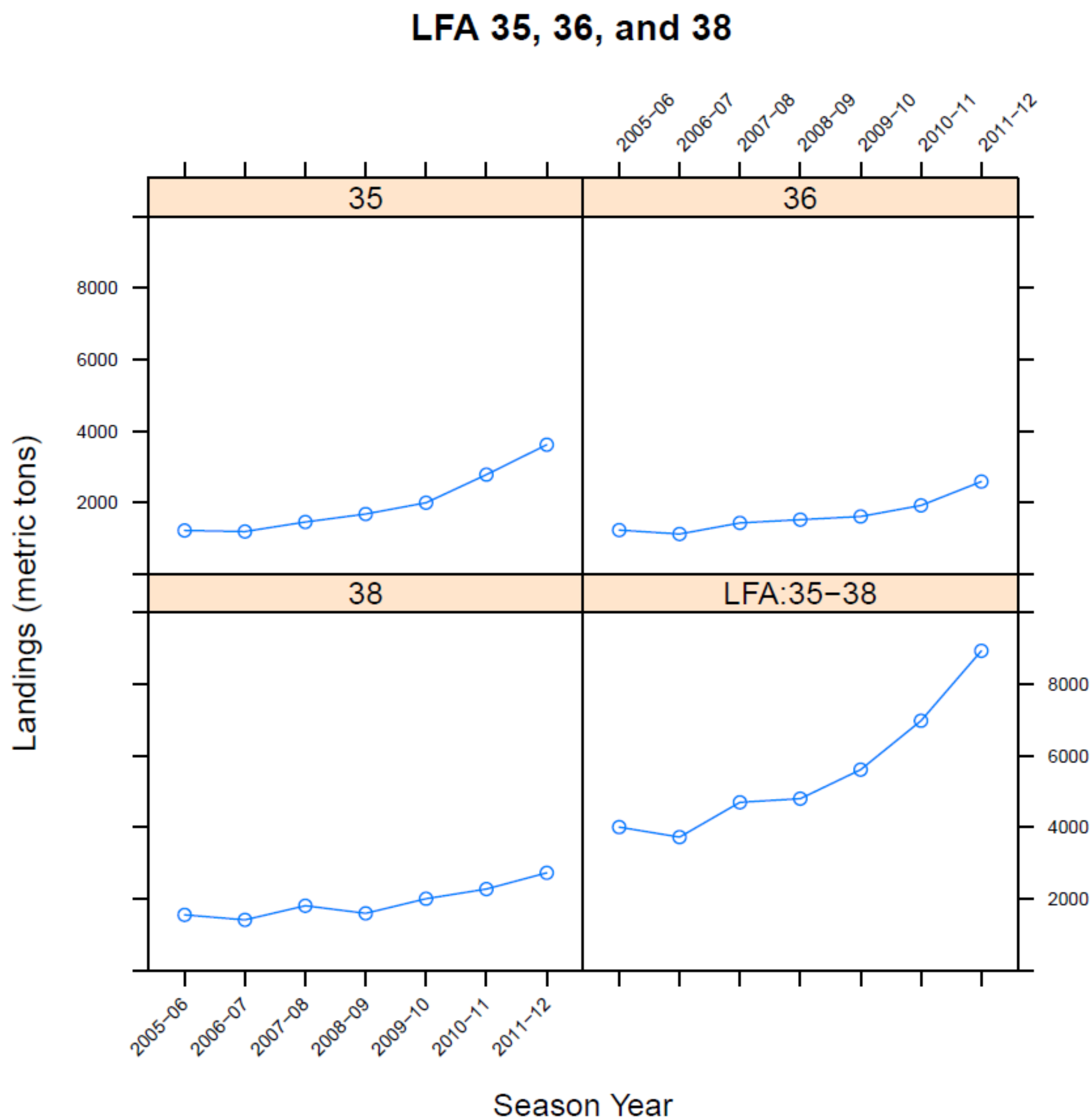


Figure 5.4. LFA 35-38 landings (mt) for fishing seasons from 2005-06 to 2011-12. Data are from the estimate portion of Lobster Catch and Settlement Reports.

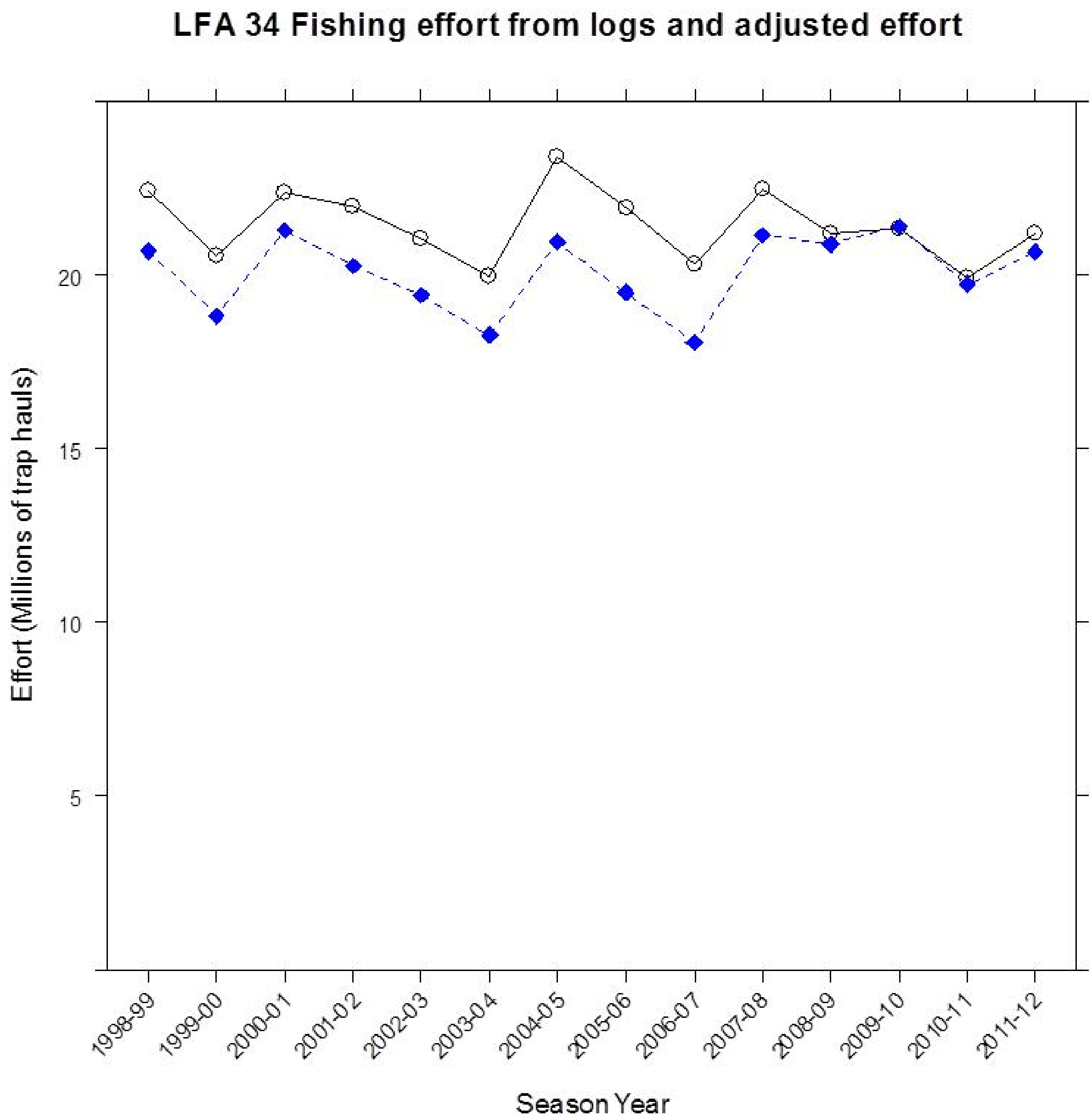


Figure 5.5. Annual fishing effort in LFA 34 for fishing seasons 1998-99 to 2011-12 in terms of total annual trap hauls (in millions). Data are from the estimate portion of Lobster Catch and Settlement Reports. Blue dashed line is total from logs; solid line is adjusted effort (weighout slip landings/CPUE)

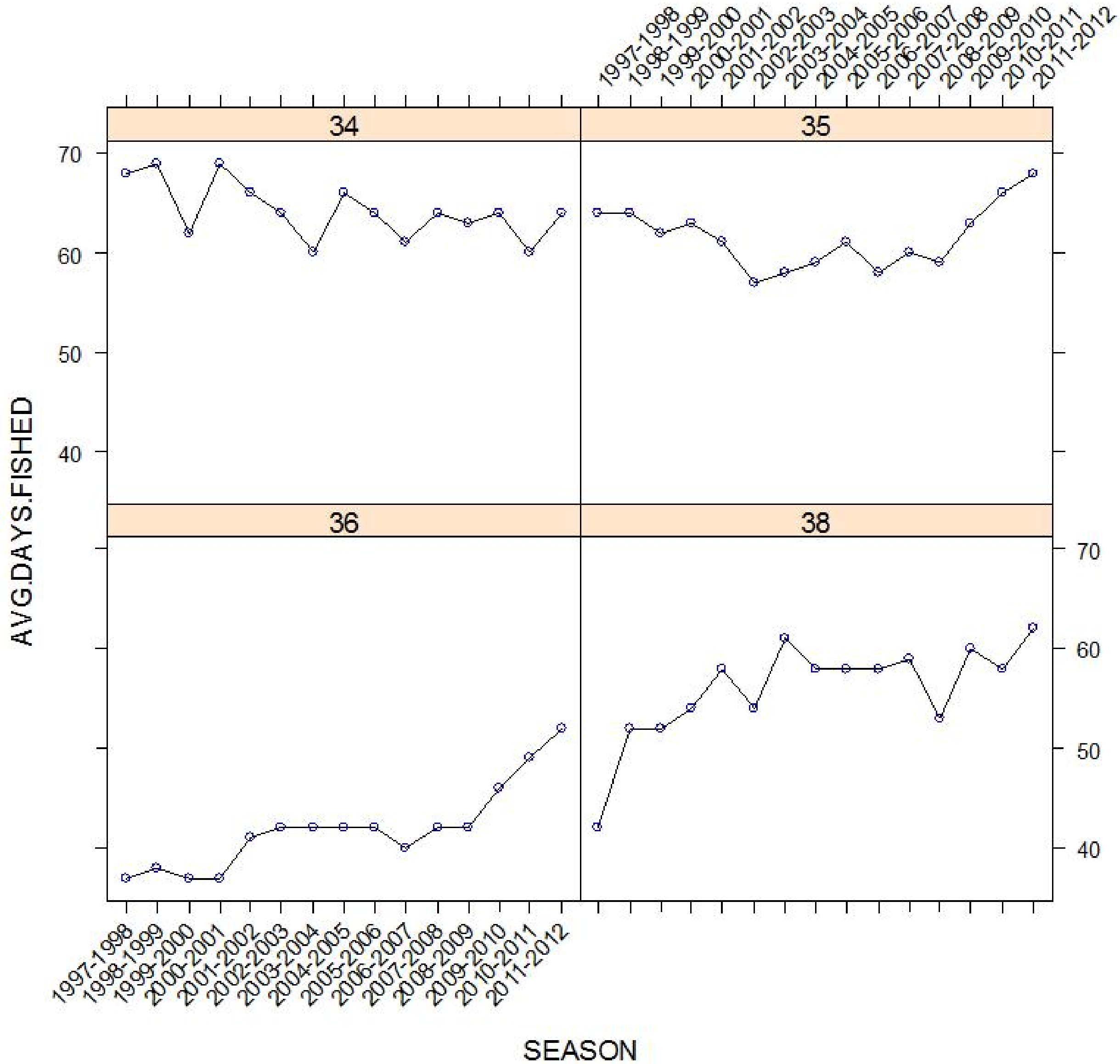


Figure 5.6. Average number of days fished in LFAs 34 and 35-38 for fishing seasons 1997-98 to 2011-12.

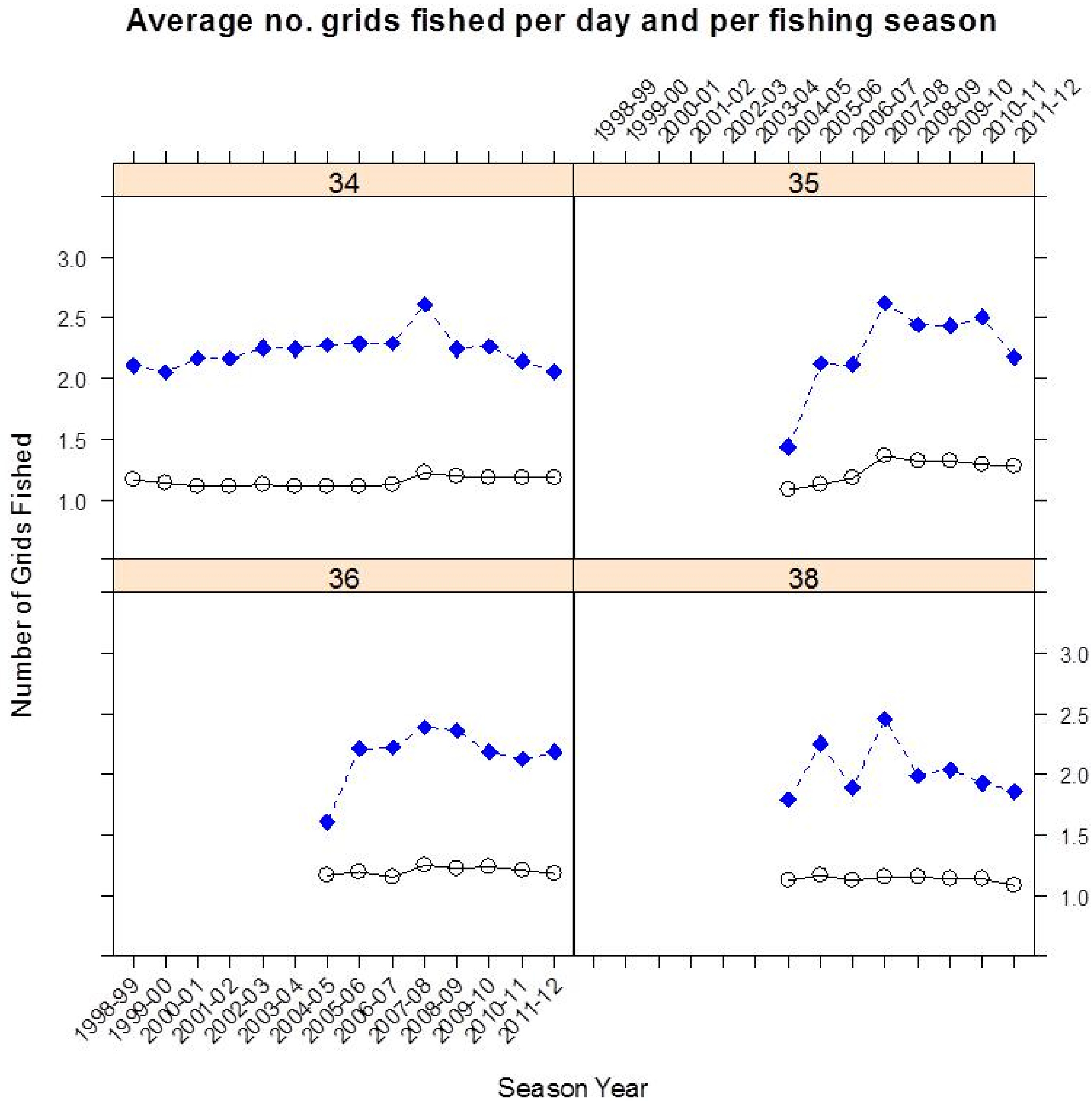


Figure 5.7. Average number of grids fished per day (open circles, solid line) and per fishing season (closed diamonds, dashed line) per fisherman by LFA for fishing seasons 1998-99 to 2011-12 (LFA 34) and 2004-05 to 2011-12 (LFAs 35-38).

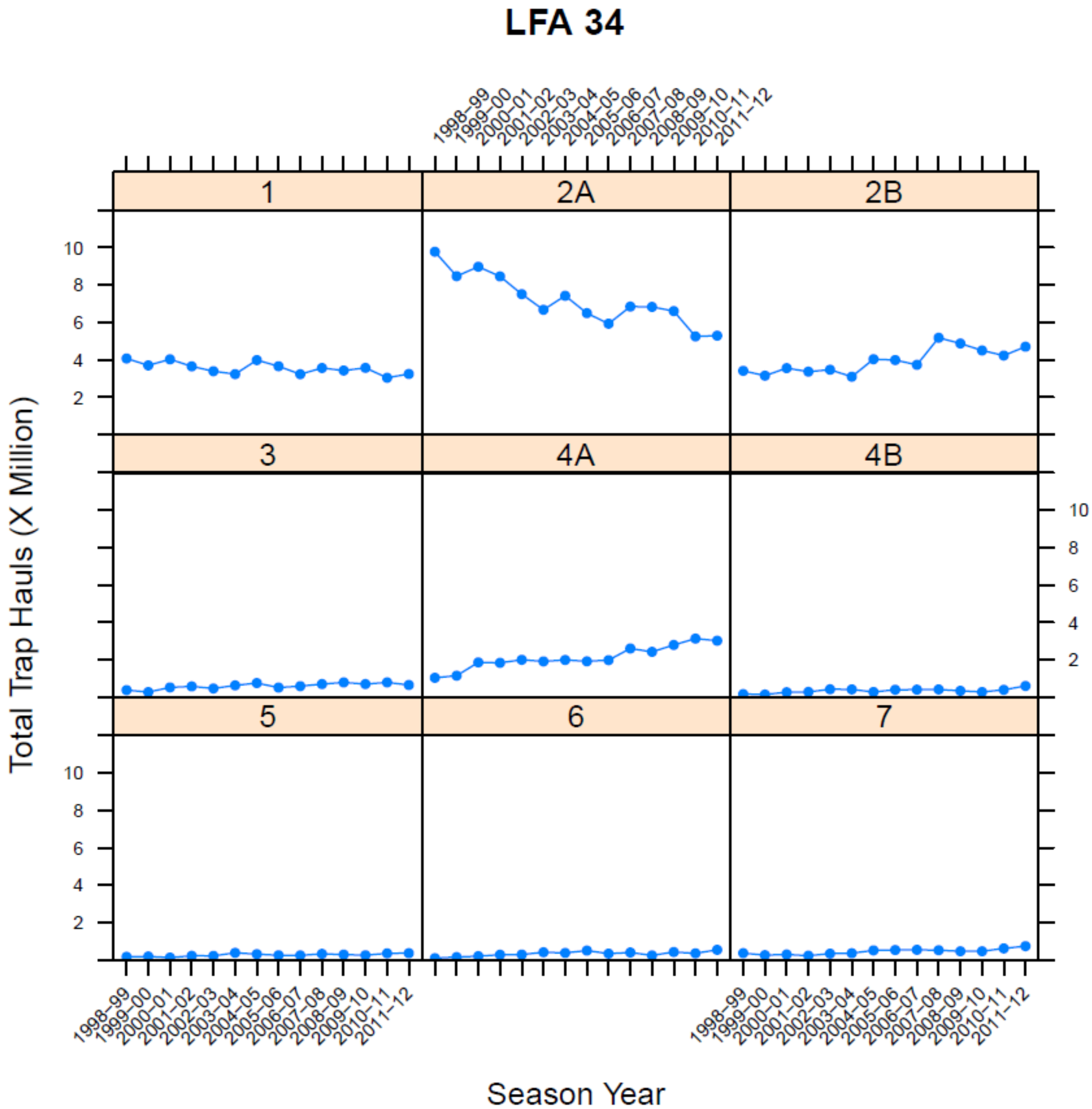


Figure 5.8. LFA 34 effort (number of trap hauls) by Grid Group for fishing seasons 1998-99 to 2011-12. Data are from the estimate portion of Lobster Catch and Settlement Reports.

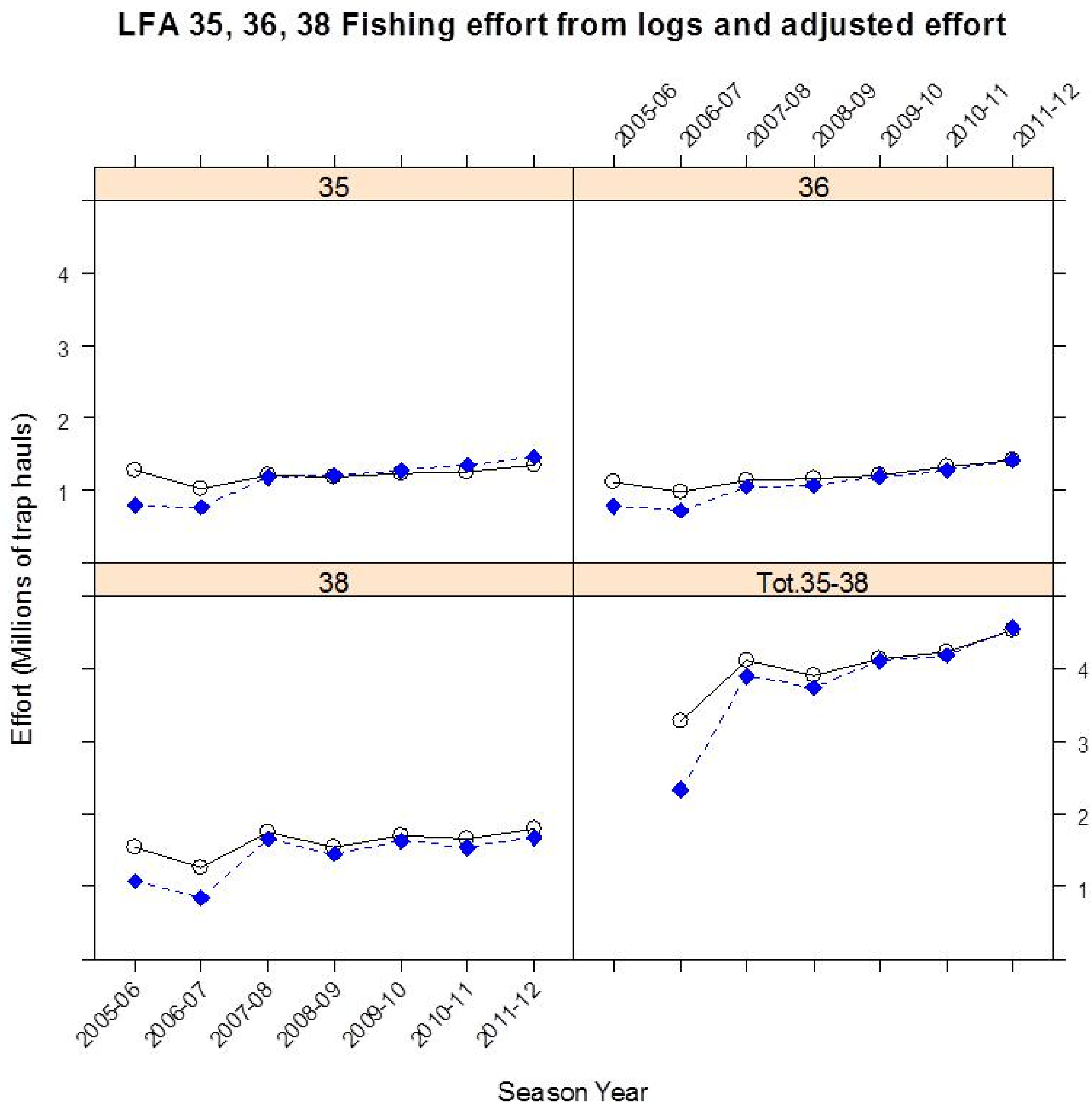


Figure 5.9. LFA 35-38 effort (number of trap hauls) for fishing seasons 2005-06 to 2011-12. Data are from the estimate portion of Lobster Catch and Settlement Reports. Blue dashed line is total from logs; solid line is adjusted effort (weighout slip landings/CPUE).

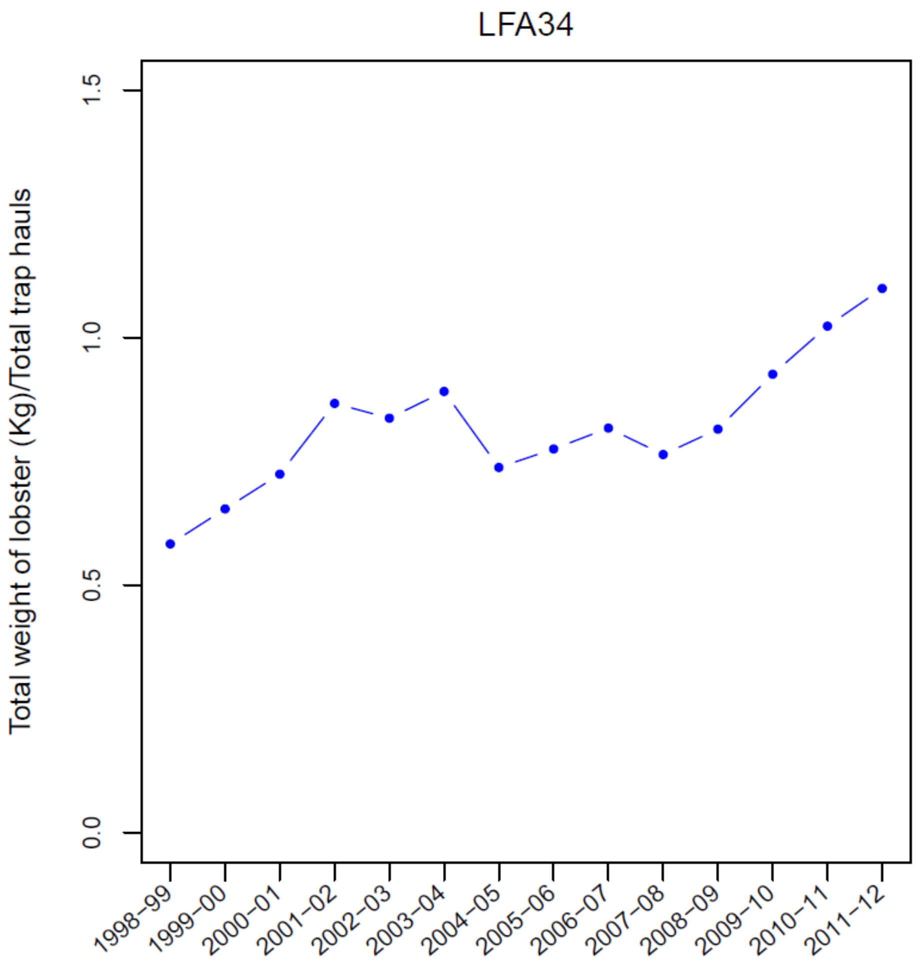


Figure 5.10. CPUE in LFA 34 as a whole for fishing seasons 1998-99 to 2011-12.

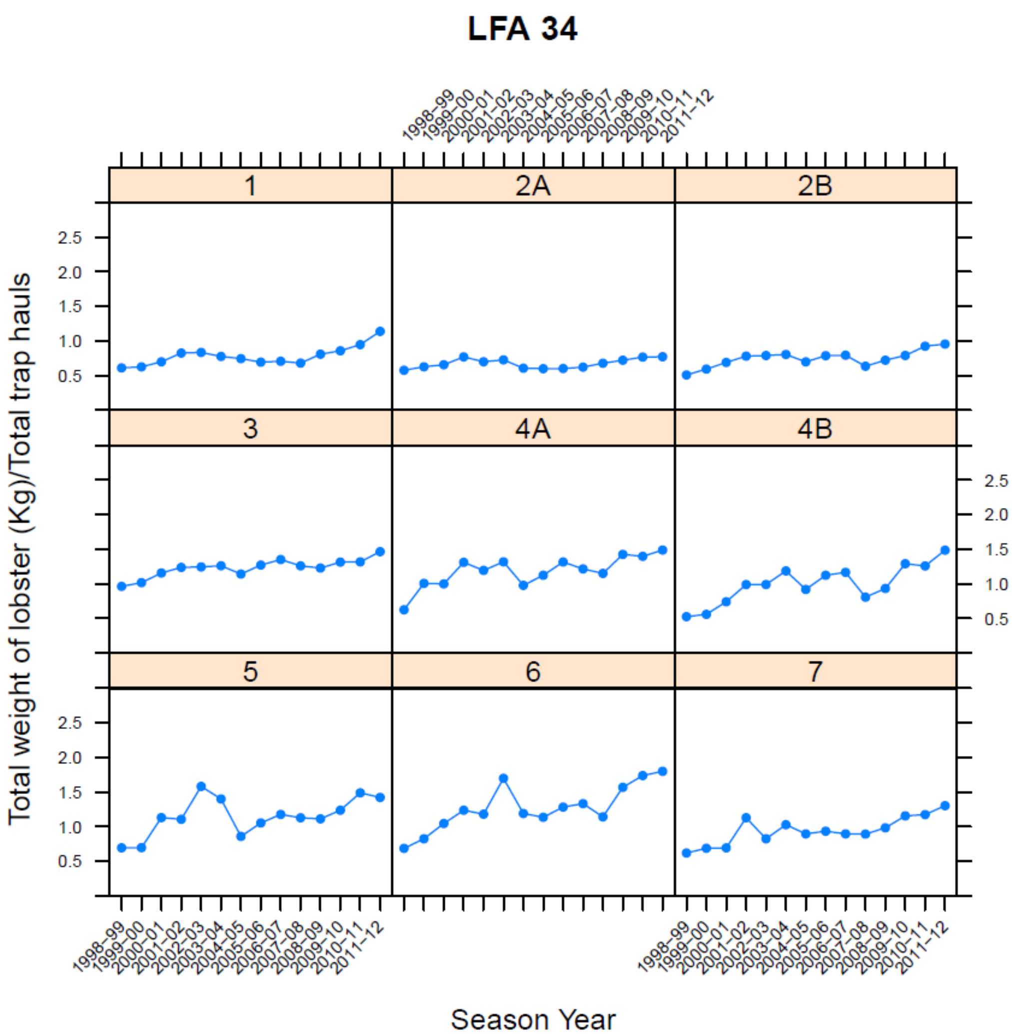


Figure 5.11. Commercial CPUE in LFA 34 by Grid Group for fishing seasons 1998-99 to 2011-12.

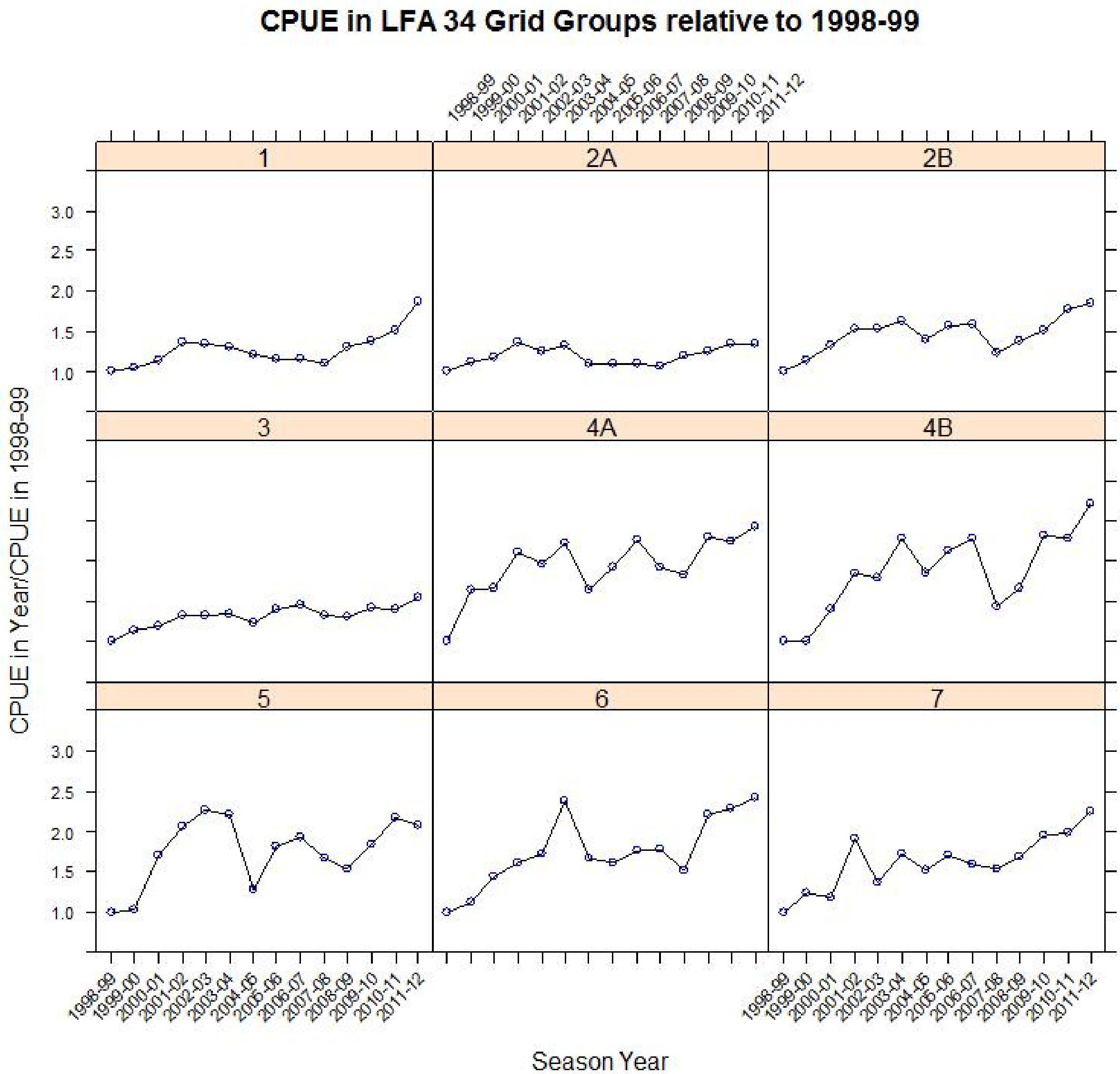


Figure 5.12. Commercial CPUE in LFA 34 Grid Groups for fishing seasons 1998-99 to 2011-12, relative to 1998-99 (1998-99 = 1.0).

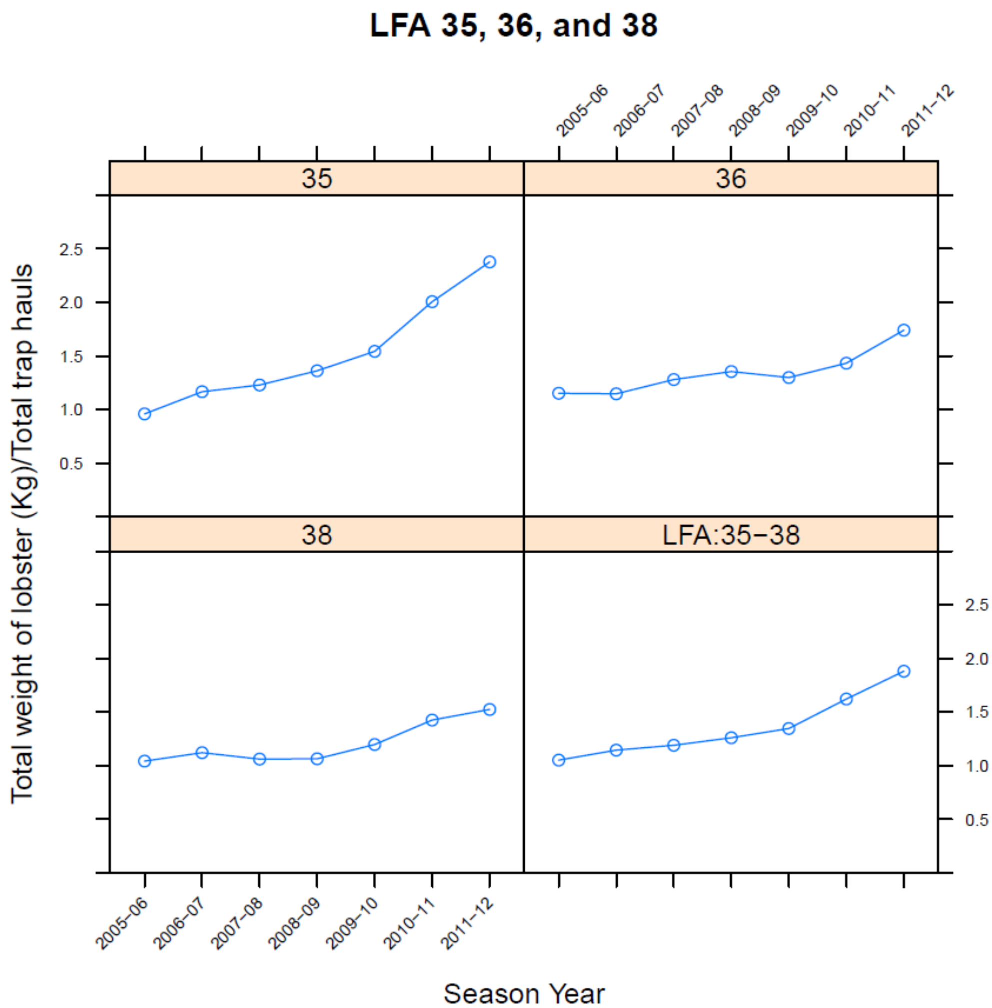


Figure 5.13. Commercial CPUE in LFAs 35-38 for fishing seasons 2005-06 to 2011-12.

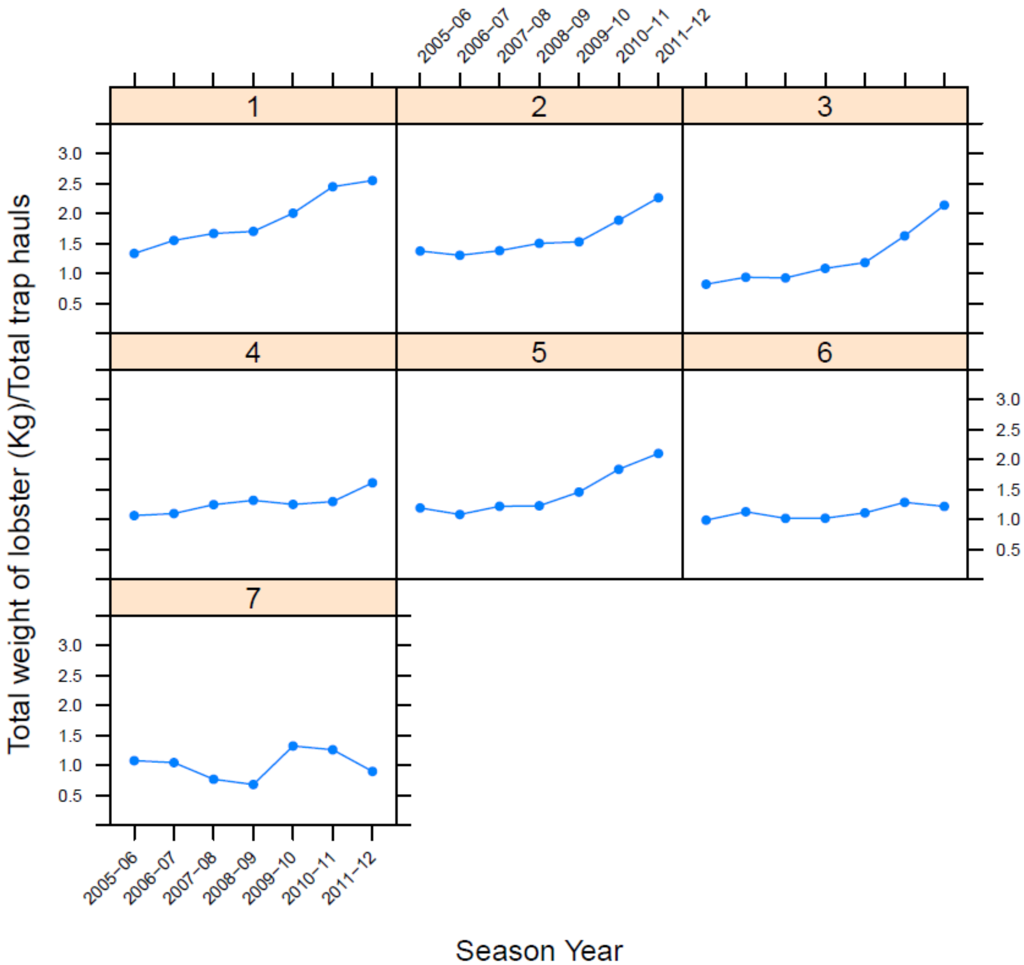


Figure 5.14. Commercial CPUE in Grid Groups within the Bay of Fundy for fishing seasons 2005-06 to 2011-12.

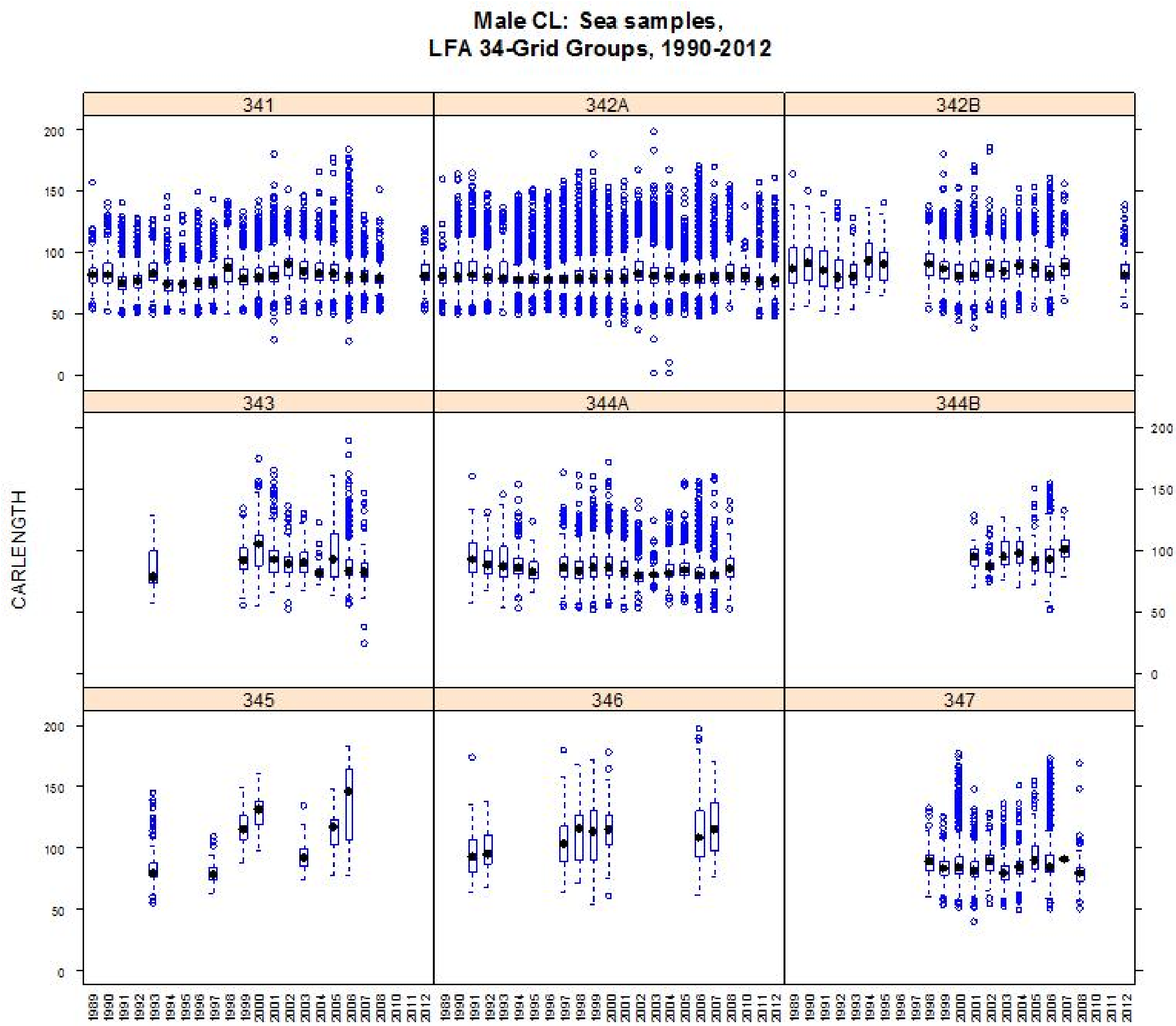


Figure 5.15. Box-whisker plot of male sizes by calendar year, 1990-2012, within LFA 34 Grid Groups. All data are from at-sea samples during the commercial fishing season.

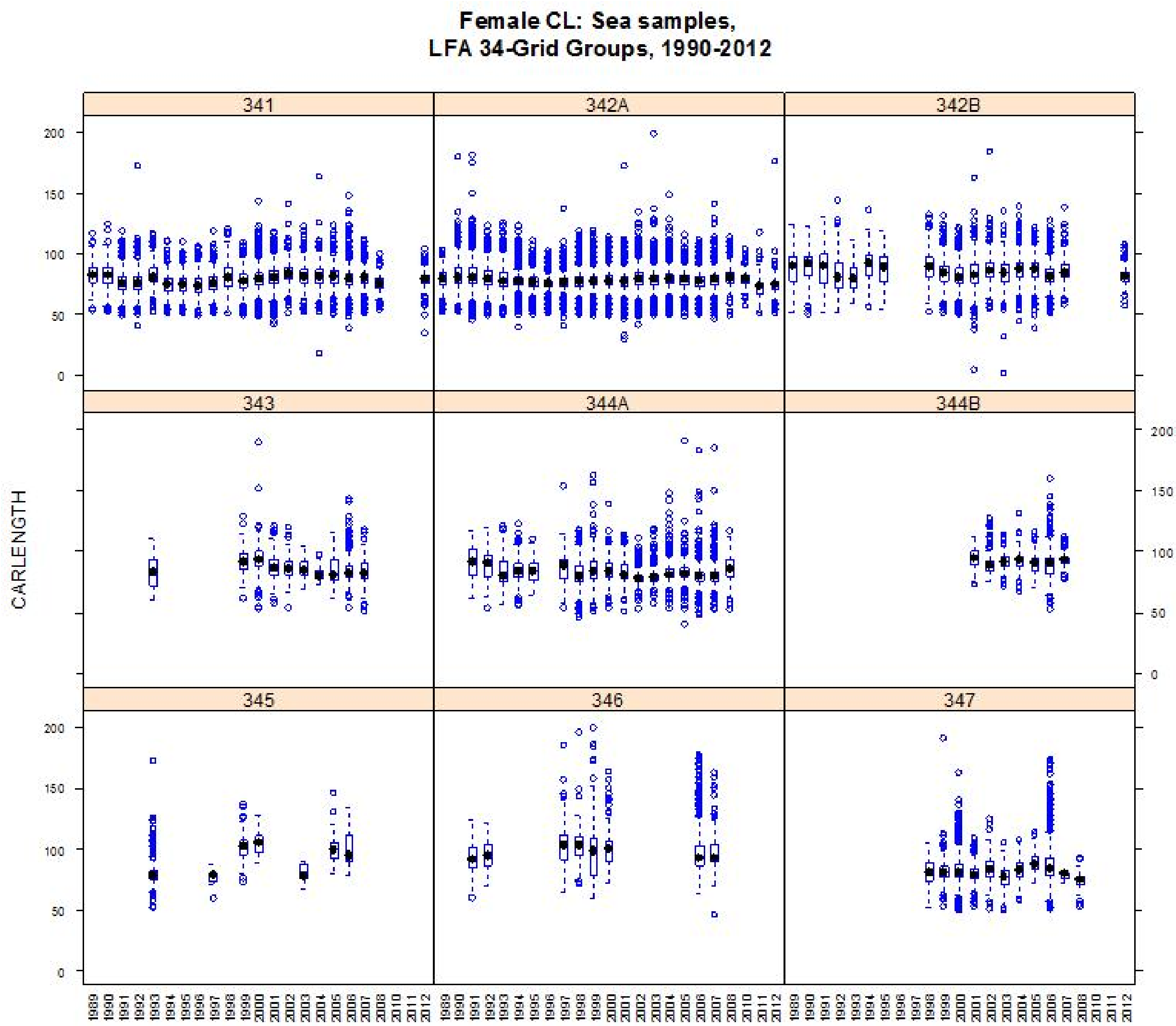


Figure 5.16. Box-whisker plot of female sizes by calendar year, 1990-2012, within LFA 34 Grid Groups. All data are from at-sea samples during the commercial fishing season.

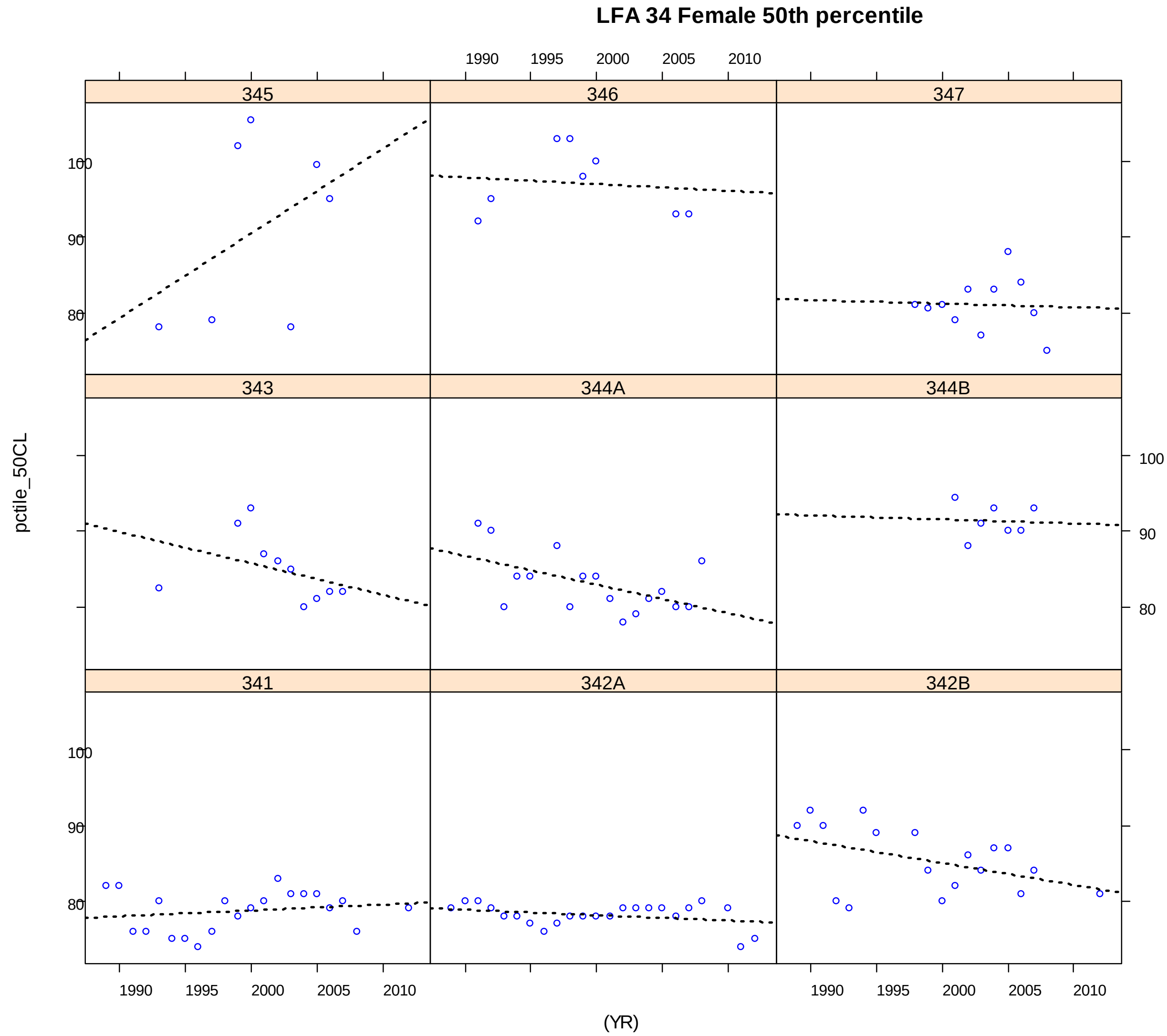


Figure 5.17a. Female median size by calendar year, 1990-2012, within LFA 34 Grid Groups. All data are from at-sea samples during the commercial fishing season. Dotted line is linear fit.

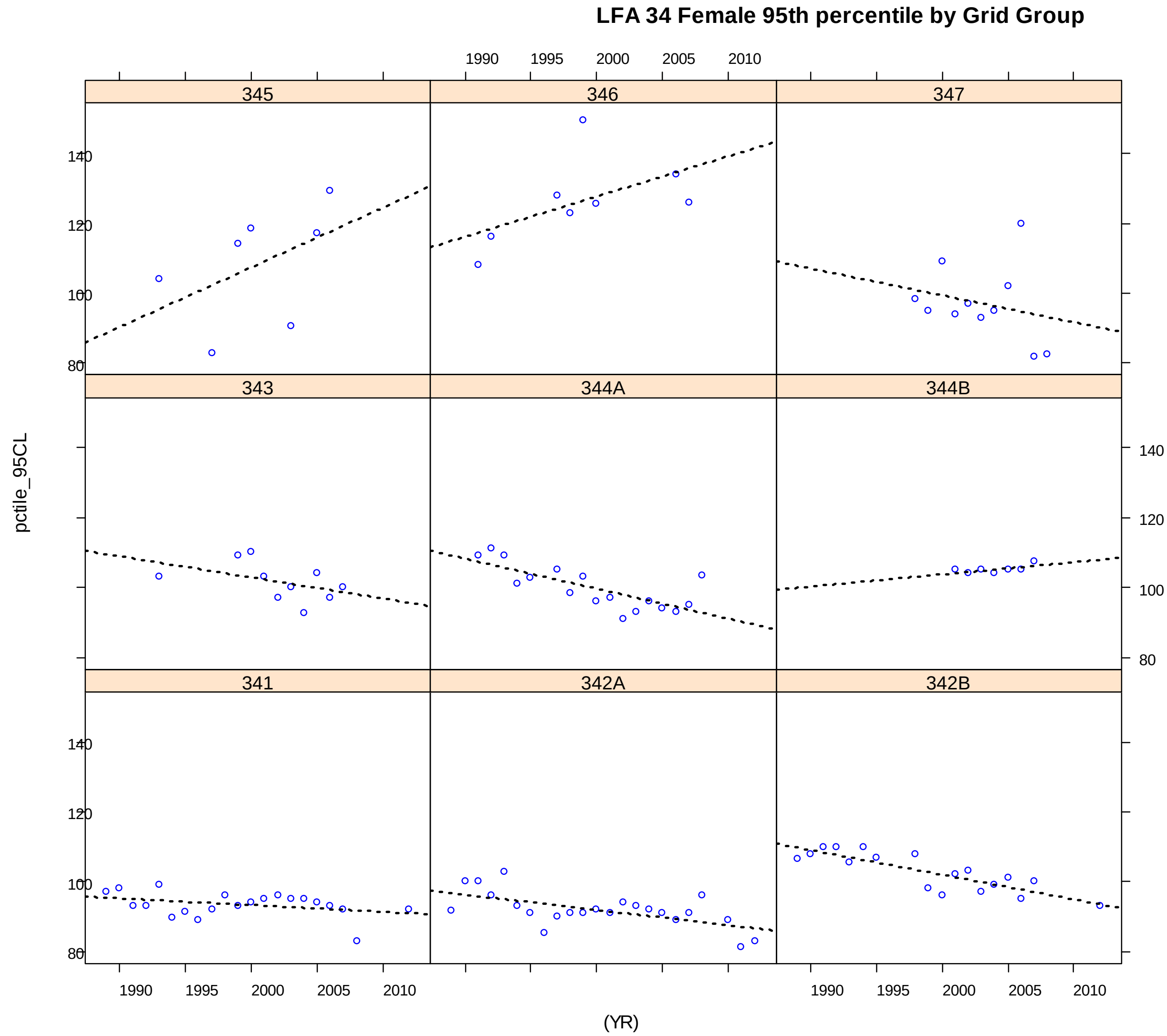


Figure 5.17b. Large female size (95th percentile) by calendar year, 1990-2012, within LFA 34 Grid Groups. All data are from at-sea samples during the commercial fishing season. Dotted line is linear fit.

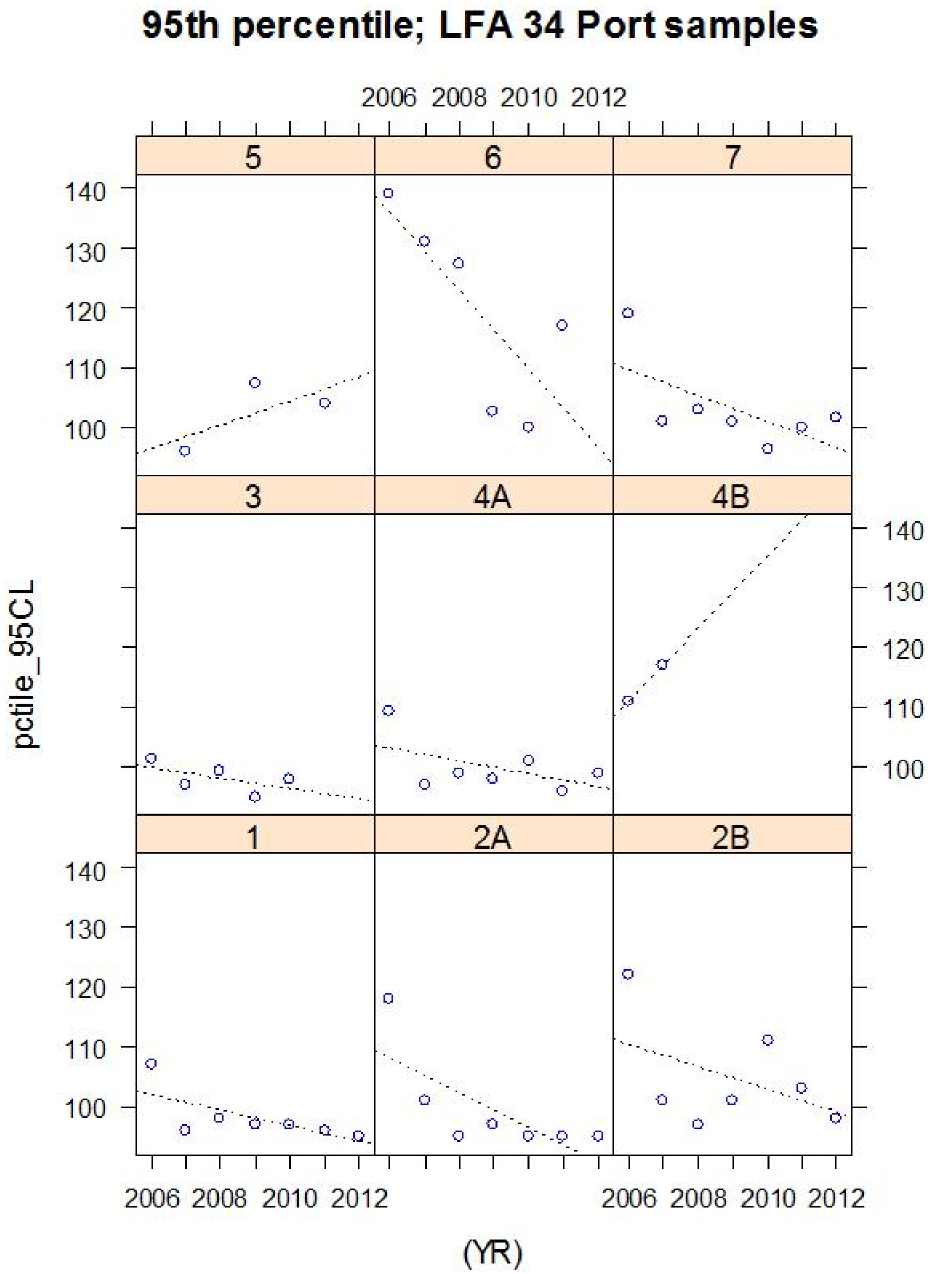


Figure 5.18. Large female size trends from port samples of lobster catch during commercial fishery. Shown is 95th percentile by calendar year, 2006-2012, within LFA 34 Grid Groups. Dotted line is linear fit. Note short time series compared to at-sea samples.

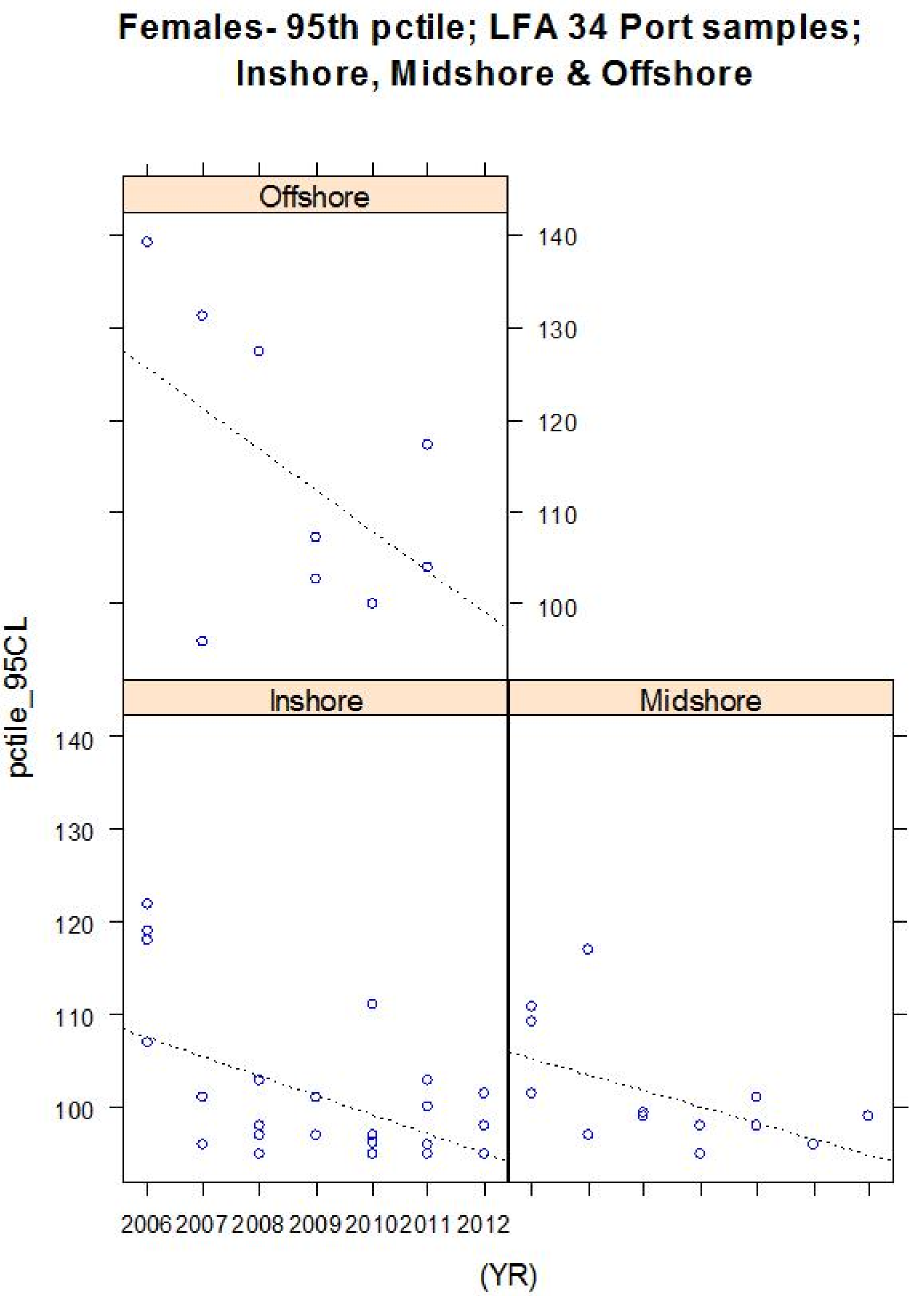


Figure 5.19. Large female size trends from port samples by calendar year, 2006-2012. Grid groups grouped as Nearshore (1, 2A, 2B, 7) (= Inshore in figure), Midshore (3, 4A, 4B), and Offshore (5,6). Each point represents 95th percentile within a Grid Group. Dotted line is linear fit. Note short time series compared to at-sea samples.

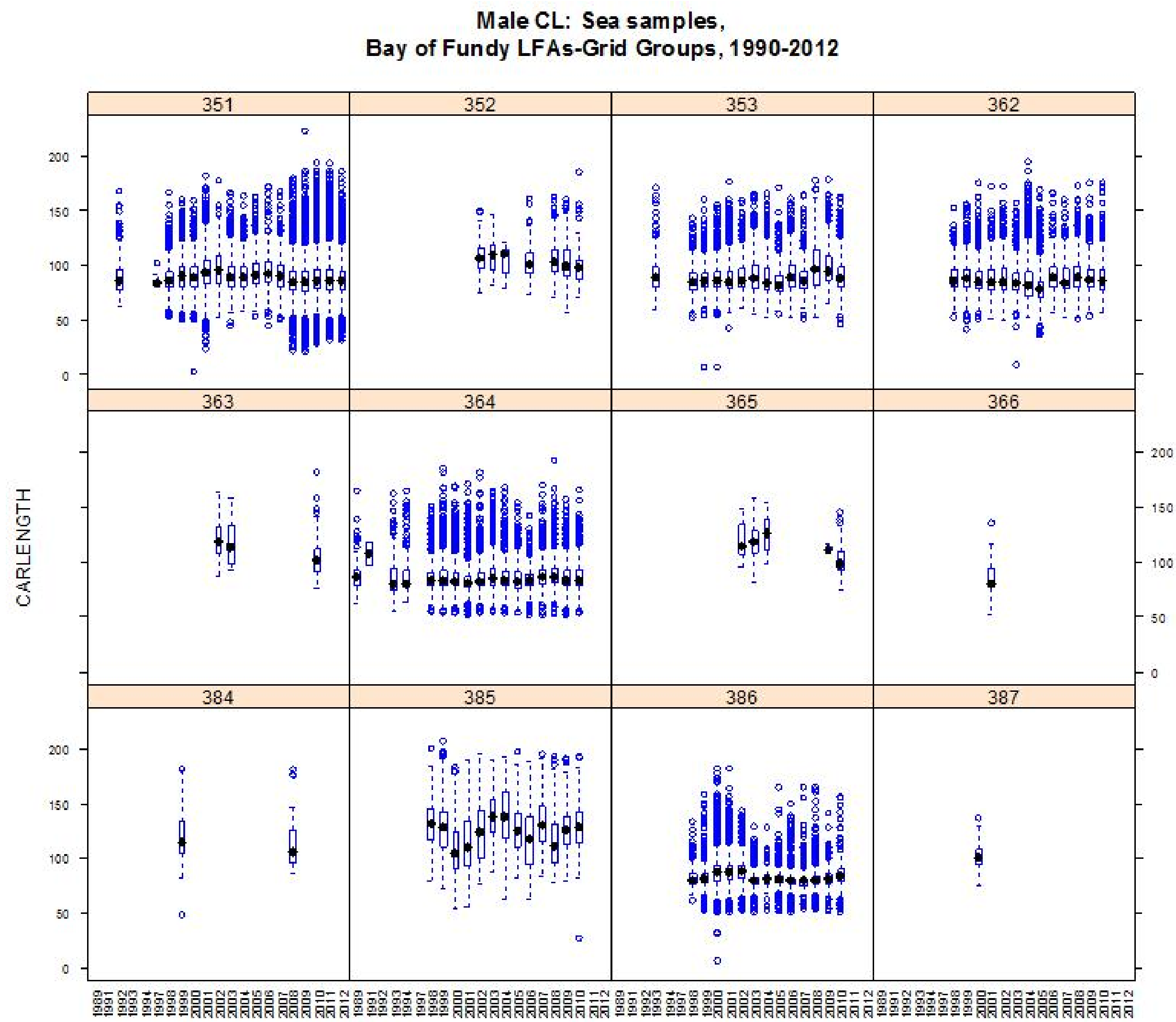


Figure 5.20. Box-whisker plot of male sizes from at-sea samples by calendar year. 1990-2012, within LFAs 35-38 Grid Groups. "351" = LFA 35, Grid Group 1; "384" = LFA 38, Grid Group 4, etc.

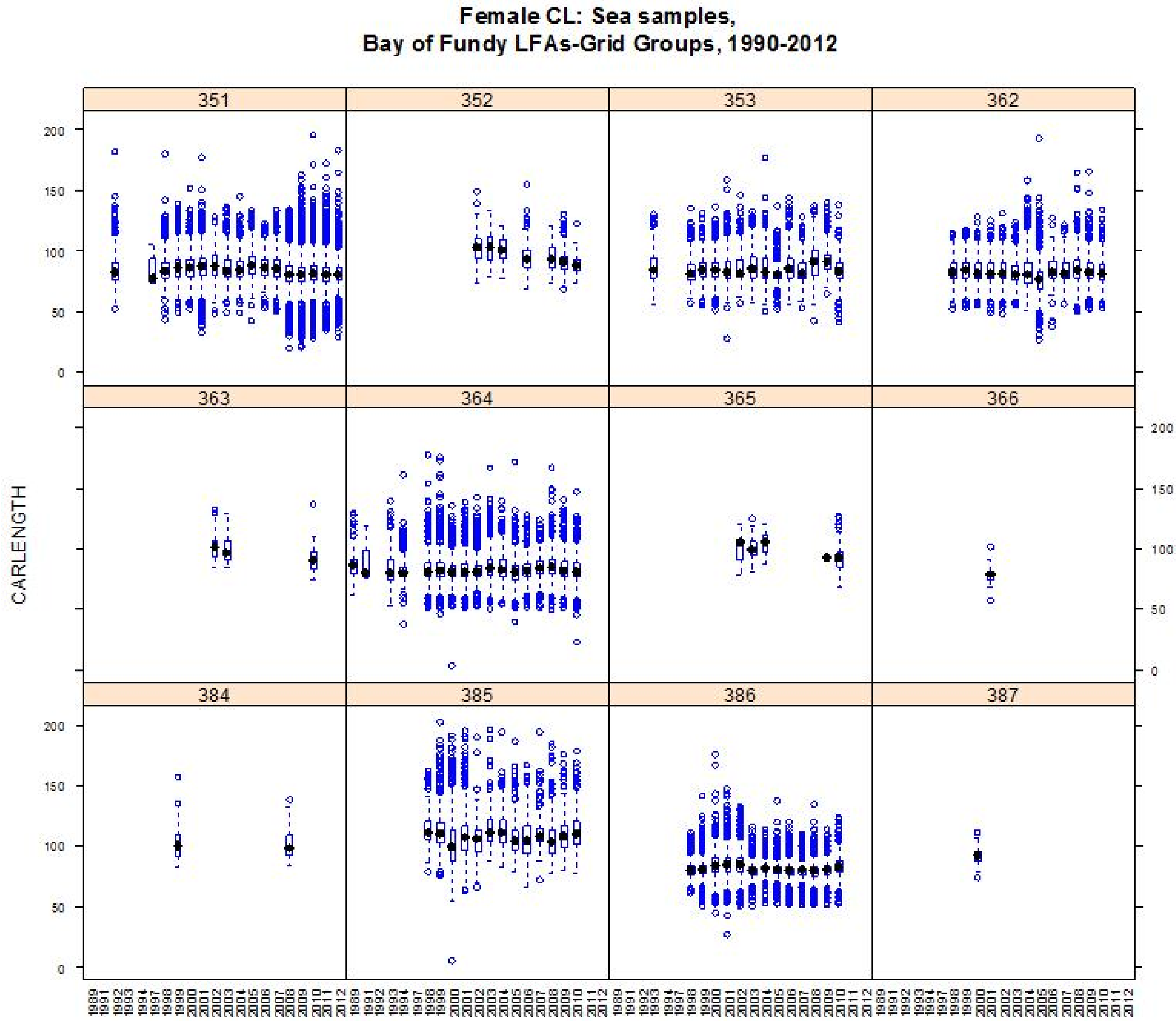


Figure 5.21. Box-whisker plot of female sizes from at-sea samples by calendar year, 1990-2012, within LFAs 35-38 Grid Groups. "351" = LFA 35, Grid Group 1; "384" = LFA 38, Grid Group 4, etc.

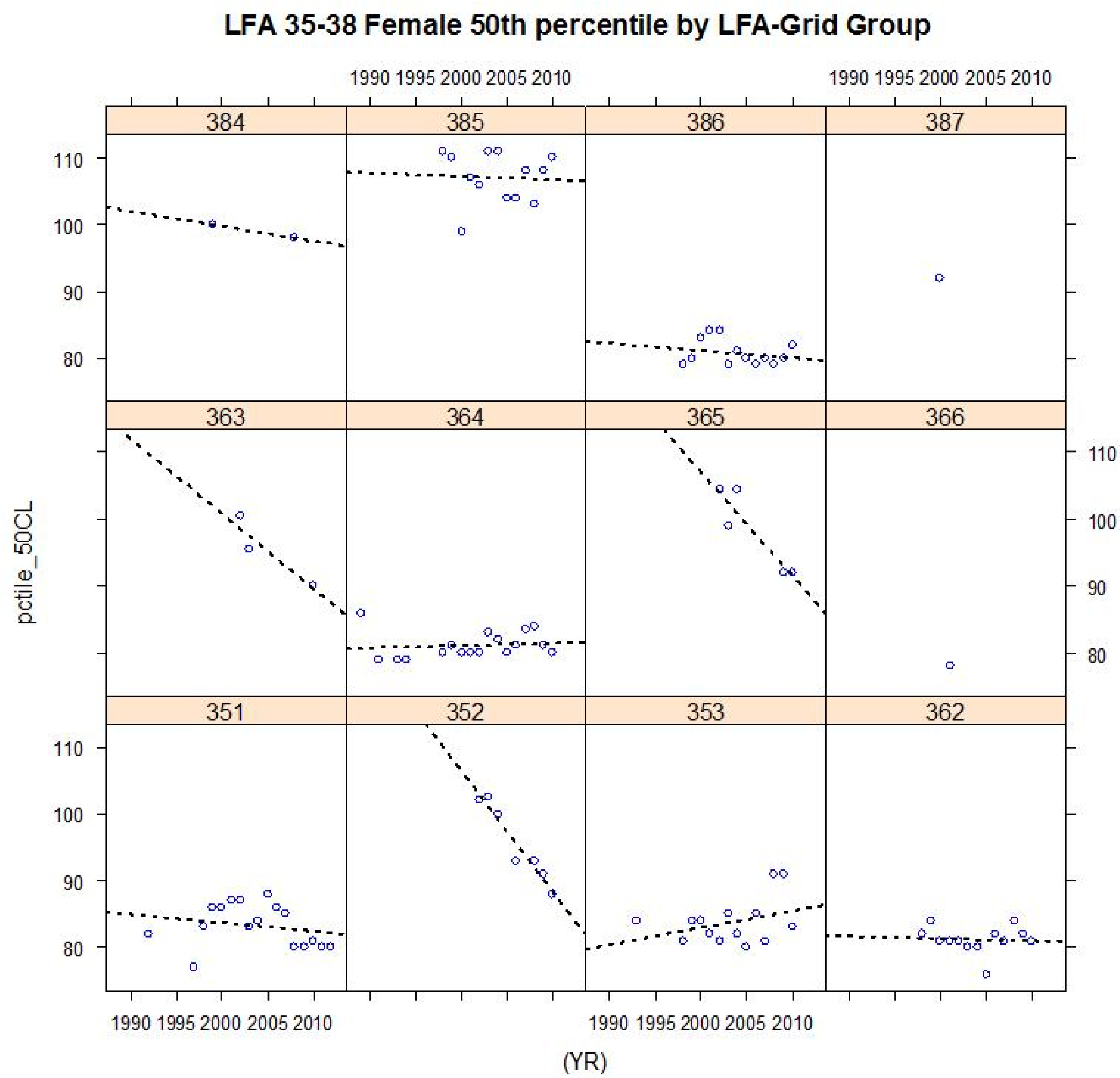


Figure 5.22. Female median size from at-sea samples by calendar year, 1990-2012, within Bay of Fundy Grid Groups. Dotted line is linear fit.

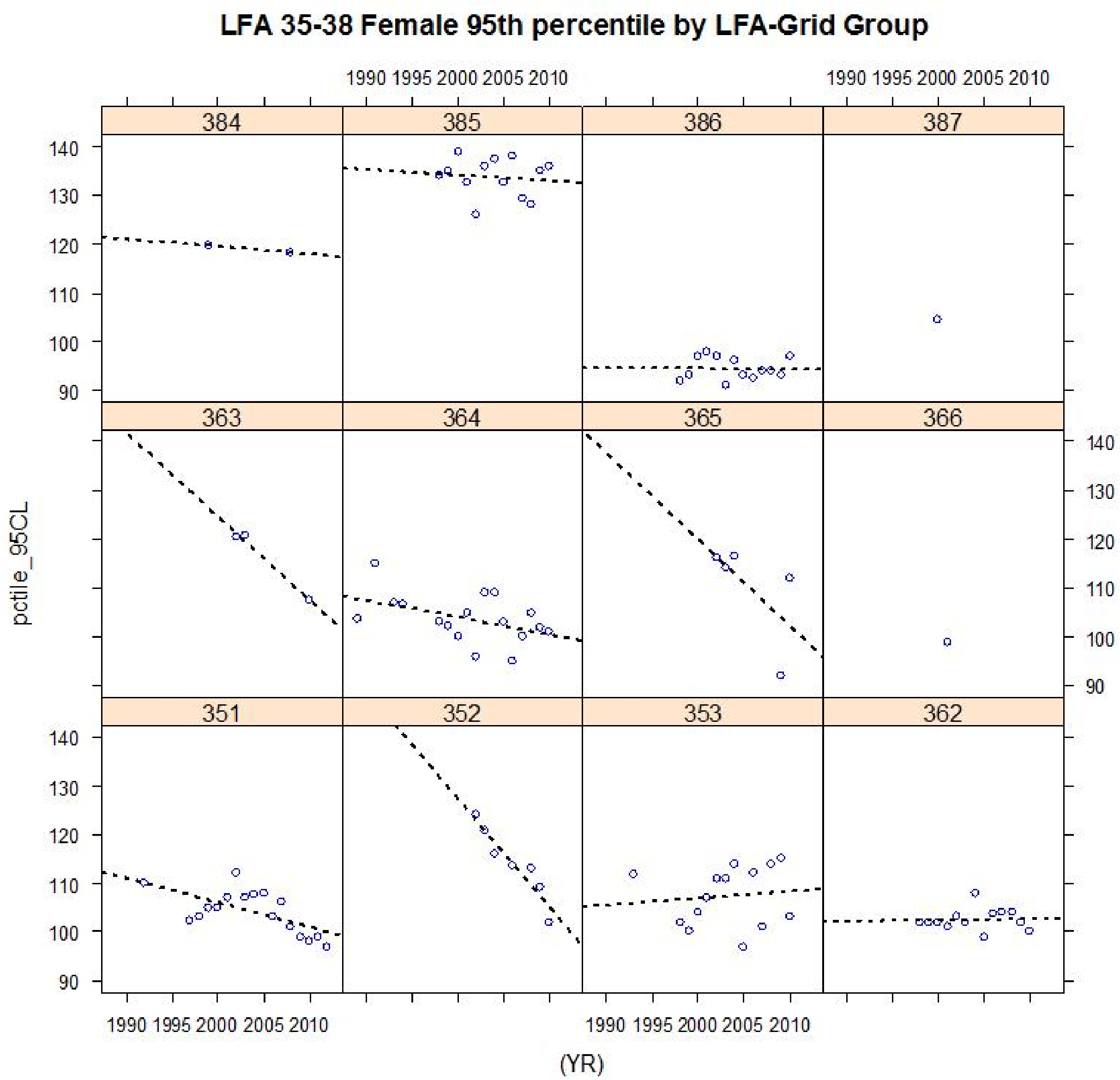


Figure 5.23. Large female size trends in the Bay of Fundy by calendar year, 1990-2012, from at-sea samples. Shown is 95th percentile by year within LFAs 35-38 Grid Groups. Dotted line is linear fit.

6. CATCH RATES IN STANDARD TRAPS AS INDICATORS OF ABUNDANCE

6.1. METHODS

All data come from the FSRS recruitment trap project, described in the Data Inputs section. Some features of this data are listed below.

- The time series for this dataset is from 1999/00 to 2011/12. The first season year, 1998-99, only has records for the spring portion of the fishing season, and is excluded in CPUE and model analyses.
- FSRS recruitment traps are designed to capture more sublegal lobster sizes than commercial traps: they lack escape vents, have smaller mesh openings, and smaller entrance hoops.
- The recruitment trap project protocol calls for fishing at a single location during a fishing season although some have moved to different locations within a fishing year. These trap movements have been noted to be within Grid Groups and between adjacent Grid Groups. In the case of some participants, catch and effort is split between 2 or 3 different Grid Groups within a fishing season.
- The data has been edited to remove any records that are outside the LFA of interest. Additionally, the data excludes soak days that are <1 day and >5 days, and berried females. For the temperature corrected model, only soak days of 1 day were used.
- Lobster catch is recorded in number not weight.
- Each participant is given 2-5 recruitment traps to monitor while in the project.

Two modeling approaches are used: (1) a standardized CPUE model for both sublegal and legal sizes, and (2) temperature corrected model for prerecruits only (Allard et al. 2012).

6.1.1. Methods - Standardized CPUE Model

This approach builds on what was developed for LFAs 27-33 in Tremblay et al. 2012c. Here we use a Generalized Additive Mixed Modeling (GAMM) to obtain catch rate estimates from the FSRS traps. In the development of this approach, a Poisson-GAMM was compared to a Poisson Generalized Linear Model (GLM). The GAMM was a better fit based on the residuals. There are 3 components to a GAMM. The first component is the GLM. The second part of the approach is the use of an additive component for one or more covariates. Additive models are a form of smoothing; this is used to account for the predictable decrease in CPUE in winter followed by an increase in CPUE in the spring. The third component is the mixed effects -- the mixing of random and fixed effects. In our model, fishing season year and week of the fishing season are fixed effects, and FSRS vessel (=fisherman) is treated as a random effect. This GAMM has the following characteristics:

- Poisson distribution (for count data).
- Inclusion of zero catches.
- A smoother for seasonal variation in catch.
- Catch (number of lobsters) is modeled with effort as an offset. This not only avoids the problem of modeling a ratio, but observations with a higher number of trap hauls receive more weight in the model than those with a lower number of trap hauls.
- Grid group level of resolution.

Only Grid Groups 1, 2A and 2B are included in the LFA 34 analysis (the main “nearshore” Grid Groups) as the other Grid Groups were only partially sampled over the time period. Table 6.1 shows the number of annual FSRS project participants by Grid Group. In LFA 34, participation was the highest and most continuous across years in Grid Groups 1, 2A, and 2B. In LFA 35, participation was most consistent in Grid Group 1 and 3. The results are presented for both sublegal and legal sizes, but the emphasis is on the model for sublegal sizes. In comparison with the commercial traps, the FSRS traps are less effective at capturing large lobsters.

Data removals are shown in Table 6.2.

Two models were compared, one without Grid Group as a factor (1) and one with Grid Group as a factor (2):

$$Catch \sim S.Year, s(wos), (1|Vessel.Code), offset(tot.traps) \quad (1)$$

$$Catch \sim S.Year, s(wos), gridgroup, (1|Vessel.Code), offset(tot.traps) \quad (2)$$

where *S.Year* is Season year (= fishing year); *wos* is week of fishing season, and *tot.traps* is the total number of trap hauls.

6.1.2. Methods - Temperature Corrected Abundance Index (TCAI) Model

This approach develops a TCAI based on a probabilistic model of the catch from a single sampling event as a function of the number of lobsters available at the sampling location, the current temperature, and the catchability-temperature relationship (Allard et al. 2012). The parameters of the model, including the TCAI, are estimated by maximum likelihood and standard errors are obtained using Wald's method.

The TCAI model begins with a size class of non-exploited animals for a fished population for which a single abundance index is desired. The main model assumptions are the following: such a population is defined by an ecological or administrative area where all the population is subject to the same natural and man-made conditions. It is assumed that, within each fishing season, the target class is locally closed in the sense that migration, moulting into or out of the class, and mortality are negligible at each sampling location. It is also assumed that the same temperature catchability relationship for the target class applies within each fishing season, across the fishing seasons, and across locations.

The input data for the TCAI differs from standardized CPUE analysis in that soak days were restricted to one day, and the sizes examined were subsets of the total sublegals. FSRS sizes 7 to 9 and a portion of size class 10 were used in the model. Size classes 7 and 8 represent 61-70.9 mm and 71-75.9 mm CL; FSRS size class 9 represents 76-80.9 mm CL. The sublegal portion (81-82.4 mm CL) of FSRS size class 10 (81-90.9 mm CL) was also included.

6.2. RESULTS AND DISCUSSION

6.2.1. Standardized CPUE Model

6.2.1.1. LFA 34

The analysis of deviance table is shown in Table 6.3. Grid Group was found to be significant. The estimates by individual Grid Group are provided in Figures 6.1 to 6.3; the sublegal CPUE for all Grid Groups increased in the last year, with Grid Groups 2A and 2B having the highest CPUE for the series in the last 3 years. Grid Group 1 also increased in 2011-12, but only to the 3rd highest in the series. CPUE of legals has not shown a consistent trend. For both the sublegal and legal sizes there was close agreement between the trends in unstandardized CPUE and model CPUE.

Given that one goal of the analysis is to get a single abundance index for the nearshore areas of LFA 34, one approach is to ignore the Grid Group effect, and use the model predictions without Grid Group as a factor. This result is shown in Figure 6.4. The sublegal size model CPUEs were variable with no trend over the first 10 years, but the last 3 years had 2 out of the 3 highest CPUEs in the time series.

A second approach to dealing with the finding that Grid Group was significant, is to run the models for the individual Grid Groups and then combine the predicted CPUEs into a single index by weighting the individual Grid Group CPUEs by Grid Group area (Table 6.4) as was done for a CPUE model for LFA 27 (Tremblay et al. 2012c). This approach is shown in Figure 6.5. The weighted index shows a trend similar to that for Grid Groups 2A and 2B, with the last 3 years having the highest CPUE on record. This approach recognizes that Grid Groups 2A and 2B make up a larger portion of the nearshore of LFA 34.

6.2.1.2. LFA 35

For LFA 35, the analysis of deviance indicated Grid Group was not a significant factor. The time series for LFA 35 is only half as long as that for LFA 34, but for the overlapping period, the CPUEs for LFA 35 are considerably higher (Figure 6.6).

6.2.2. Temperature Corrected Abundance Index (TCAI) Model

The temperature corrected model was run for LFA 34 only. The predictions for individual Grid Groups for the 76-82.5 mm CL sizes are shown in Figure 6.7; the predictions for all Grid Groups combined for sizes 76-82.5 mm CL and for sizes 61-82.5 mm CL are shown in Figure 6.8. Overall, the trends are similar to the GAMM modeled CPUEs but there were some differences. Most of these are thought to be due to the temperature correction, but the fact that only data with one-day soaks were included in the TCAI model may have some influence. For example, from 2002-03 to 2005-06 seasons, the TCAI indicates the abundance was higher than the unstandardized CPUE (Figure 6.8). In the most recent year, TCAI indicates that the abundance of sublegals 76-82.5 mm CL did not increase as much as the unstandardized CPUE (except Grid Group 1), but was the highest on record for Grid Groups 2A and 2B. The TCAI indicates that the abundance in Grid Group 2A in the last 2 years was the highest in the series, rather than the last 3 years in the GAMM standardized CPUE models for Grid Group 2A. In Grid Group 1, the TCAI indicates the last year was the highest abundance in the series, differing from that predicted by the GAMM standardized CPUE model (3rd highest abundance). For Grid Group 2B, the TCAI and the GAMM standardized CPUE indicate that abundance was highest in the 2011-12 season (Figure 6.8).

6.3. SUMMARY - CATCH RATES IN STANDARD TRAPS AS INDICATORS OF ABUNDANCE

- Data from standardized traps designed to retain more sublegal lobsters were used to evaluate abundance trends of sublegal lobsters. This model was also applied to legal sizes.
- The model is a GAMM allowing the incorporation of zeros and uses the number of traps hauled as an offset.
- The same data were used in a different approach to estimate a TCAI for sublegal sizes. This approach uses a probabilistic model and uses temperature-catchability relationships to correct for the effect of temperature on CPUE.
- The standardized CPUE models indicated that Grid Group had a significant effect on CPUE.
- Both the standardized CPUE models and the TCAI for LFA 34 nearshore indicate that sublegal abundance in the last 2 years was higher than all previous years in the 13 year time series.
- Trends in standardized CPUE for individual Grid Groups and for a single index weighted by Grid Group area indicate increases in sublegal abundance over the last 1-3 years. The weighted index indicates CPUE in the nearshore of LFA 34 has been higher in the last 3 seasons (2009-10, 2010-11 and 2011-12) than in the previous 10 seasons.
- The TCAI index indicates the abundance of sublegal lobsters has been higher in the last 2 seasons (2010-11 and 2011-12) than the previous 11 seasons.

- The standardized CPUE of sublegals in LFA 35 is available only for 6 years, but the last 2 years were the highest in the time series.

Table 6.1. FSRS project participation by fishing season.

Year Series	LFA 34	Grid Group									LFA 35	Grid Group		
		1	**2A**	**2B**	**3**	**4A**	**4B**	**5**	**6**	**7**		**1**	**3**	**5**
1998-99	3			3										
1999-00	24	4	7	12						1				
2000-01	37	10	16	12			2			2				
2001-02	38	9	16	14		1	2			3				
2002-03	42	9	20	14		6	4	1	2	3				
2003-04	41	8	19	15		6	5	1	4	3				
2004-05	46	12	16	17		5	4	1	2	3				
2005-06	49	15	15	18		7	6	1	4	4				
2006-07	39	12	13	15		8	4	1	4	1	6	2	4	
2007-08	34	10	11	13		5	4		4	1	4	2	2	
2008-09	32	10	10	12		3	3		2	1	13	11	2	
2009-10	31	9	10	11		5	2		3	1	14	12	2	
2010-11	30	7	8	12	1	7	3		5		14	12	2	
2011-12	24	6	7	8		4			2		13	11	2	1

Note: If a participant fishes 2 or more Grid Groups, his participation in each is accounted for.

Table 6.2. FSRS data record counts.

***Number of Daily Records 1998/99-2011/12:**	**LFA34 (All 9 Grid Groups)**	**Grid Groups 1,2A,2b**	**Grid Group 1**	**Grid Group 2A**	**Grid Group 2B**
Before removals -	279,300	250,958	83,414	100,902	66,642
After removals -	257,328	233,111	76,704	93,303	63,104
****For modeling 1999/00-2011/12:**					
# Weekly Records:	7,859	6,800	2,106	2,248	2,446

*4 records are removed from the daily because they are outside of LFA 34.

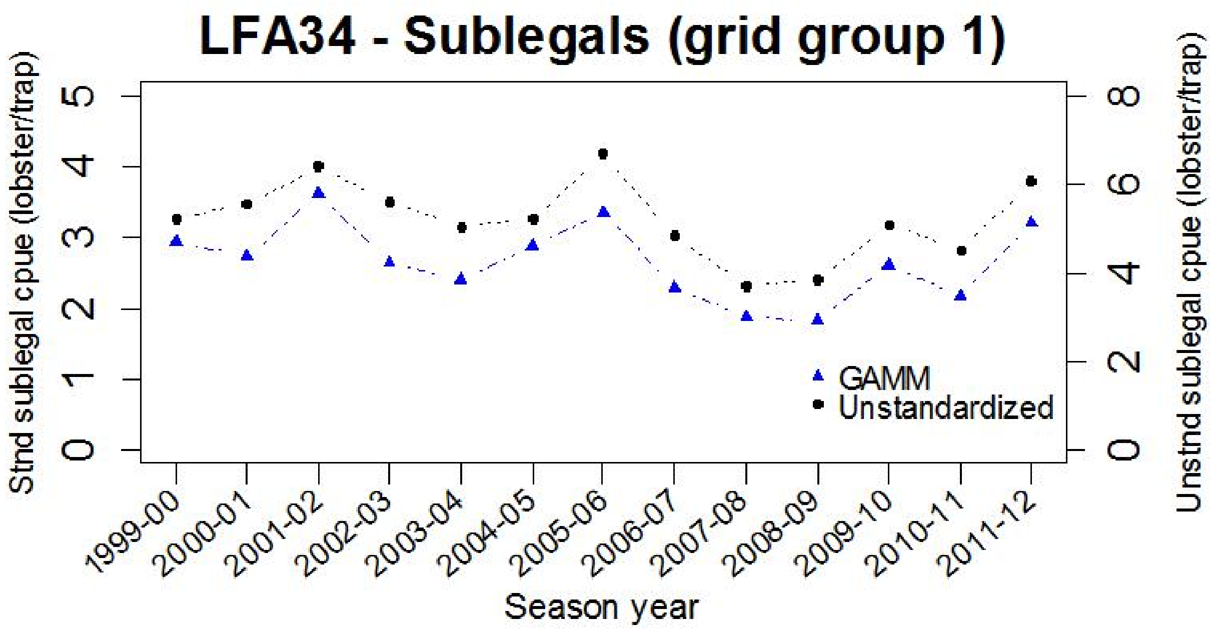
**18 records are removed to exclude 1998/99 season.

Table 6.3. Analysis of deviance table for standardized CPUE model fit for sublegal lobsters. In model 1, the 3 Grid Groups are combined; in model 2, Grid Group is included as a factor. wos = Week of season.

Model Trials	Parametric Terms	df	F	p-value	AIC
1	Season Year	12	52.88	<2e-16	14907.8
	s(wos)		325.7	<2e-16	
2	Season Year	12	55.84	<2e-16	14775.8
	Grid Group	8	27.50	<2e-16	
	s(wos)		327.7	<2e-16	

Table 6.4. Areas (Km^2) of Grid Groups.

Grid Number	Grid Group		
	1	2A	2B
69	84		
81	175		
91	235		
92	248		
102	247		
103	221		
113	248		
114	258		
124		249	
125		249	
126		118	
127		173	
138		249	
139		249	
140		249	
141		103	
155		250	
156		250	
157			248
158			243
159			37
173			251
174			251
175			251
176			251
177			156
Total Area (Km2)	**1717**	**2141**	**1687**



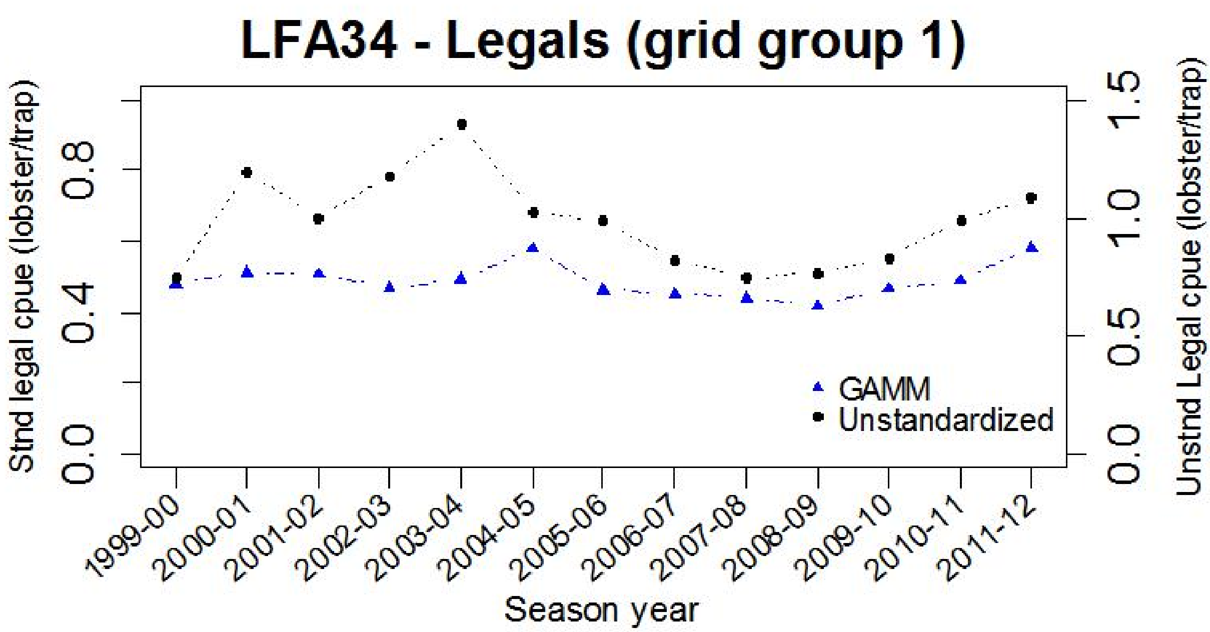


Figure 6.1. Predicted model CPUE for sublegals (upper panel) and legals (lower panel), together with unstandardized CPUE for Grid Group 1,1999-00 to 2011-12.

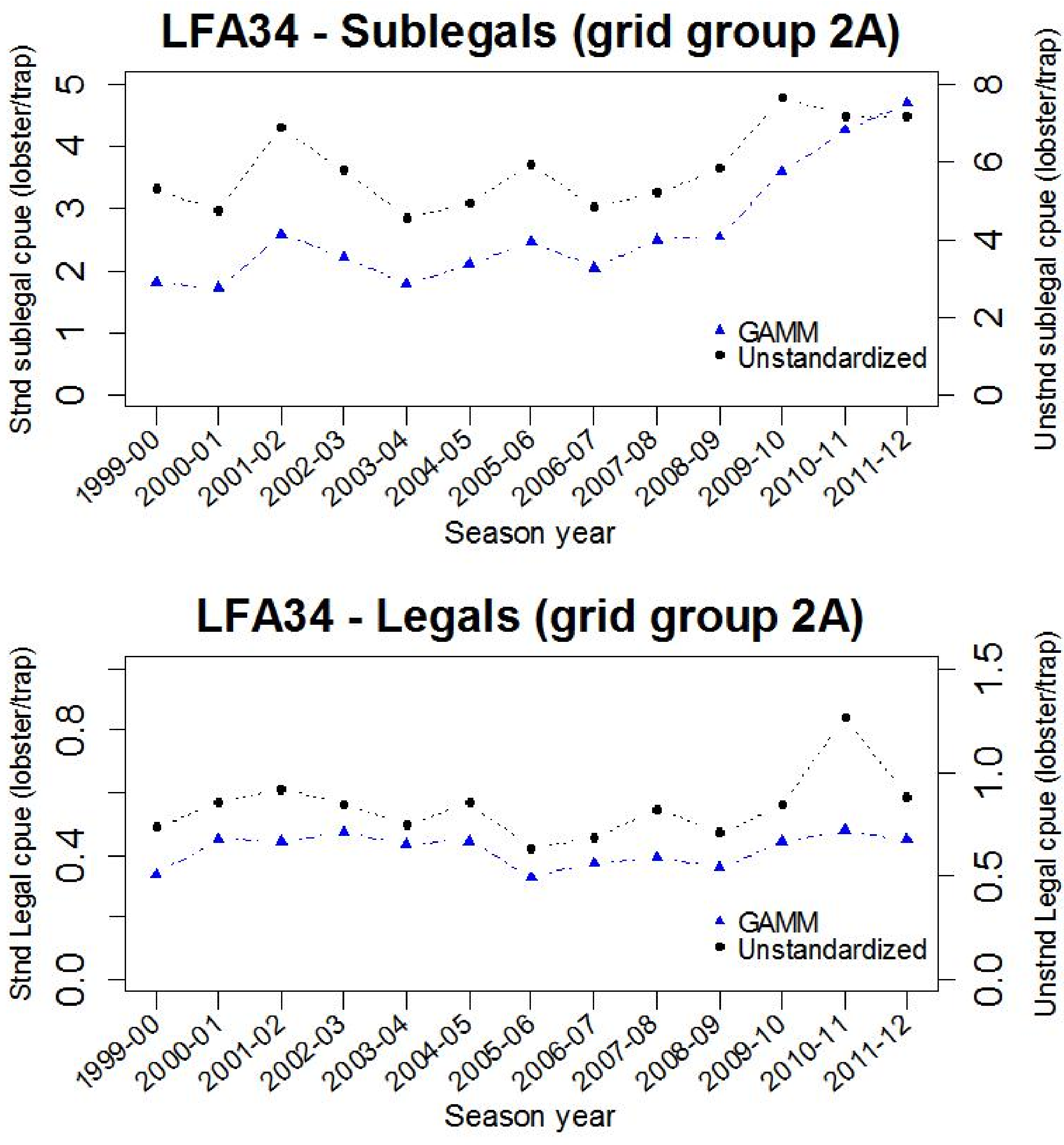


Figure 6.2. Predicted model CPUE for sublegals (upper) and legals (lower), together with unstandardized CPUE for Grid Group 2A,1999-00 to 2011-12.

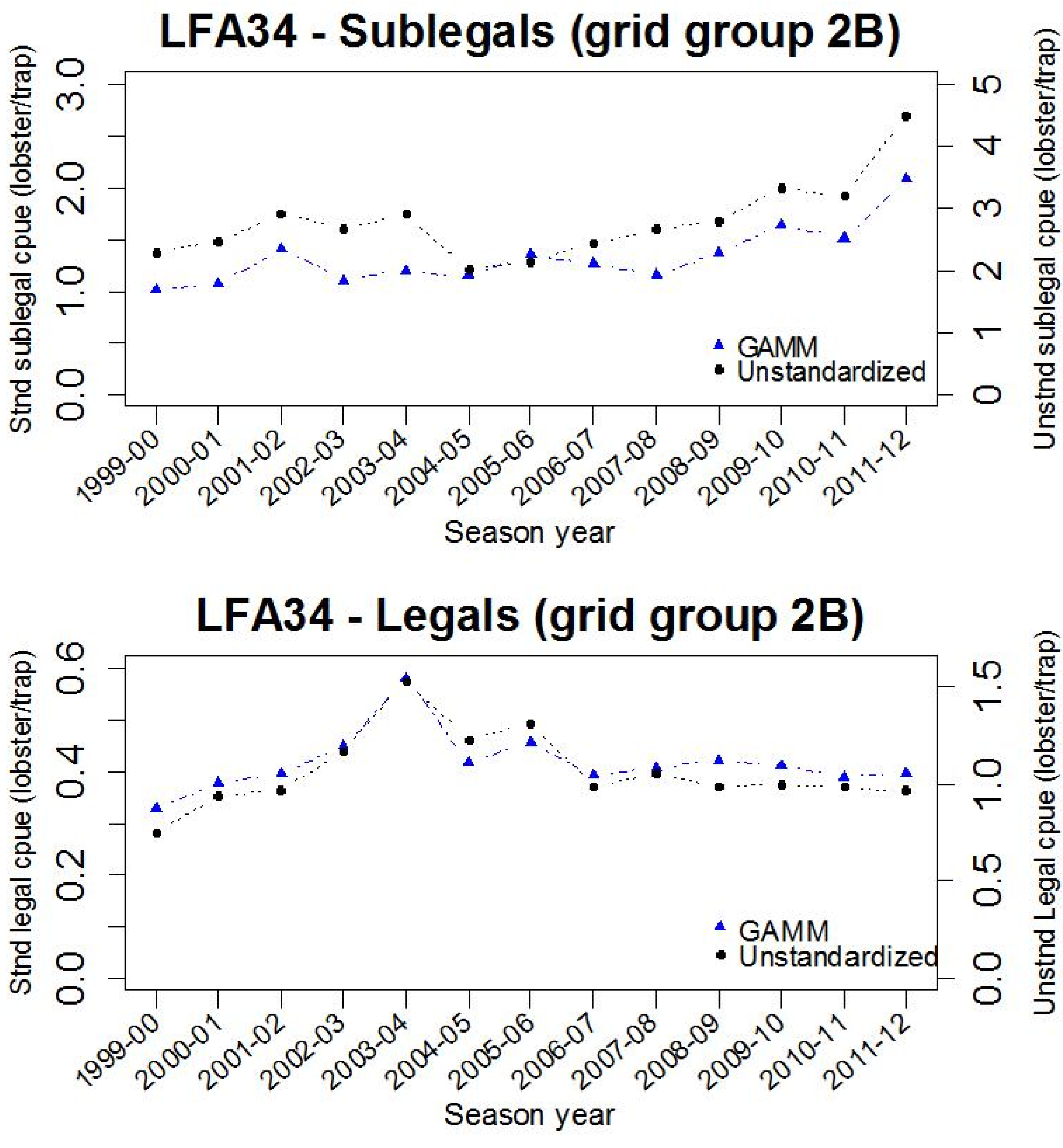


Figure 6.3. Predicted model CPUE for sublegals (upper) and legals (lower), together with unstandardized CPUE for Grid Group 2B,1999-00 to 2011-12.

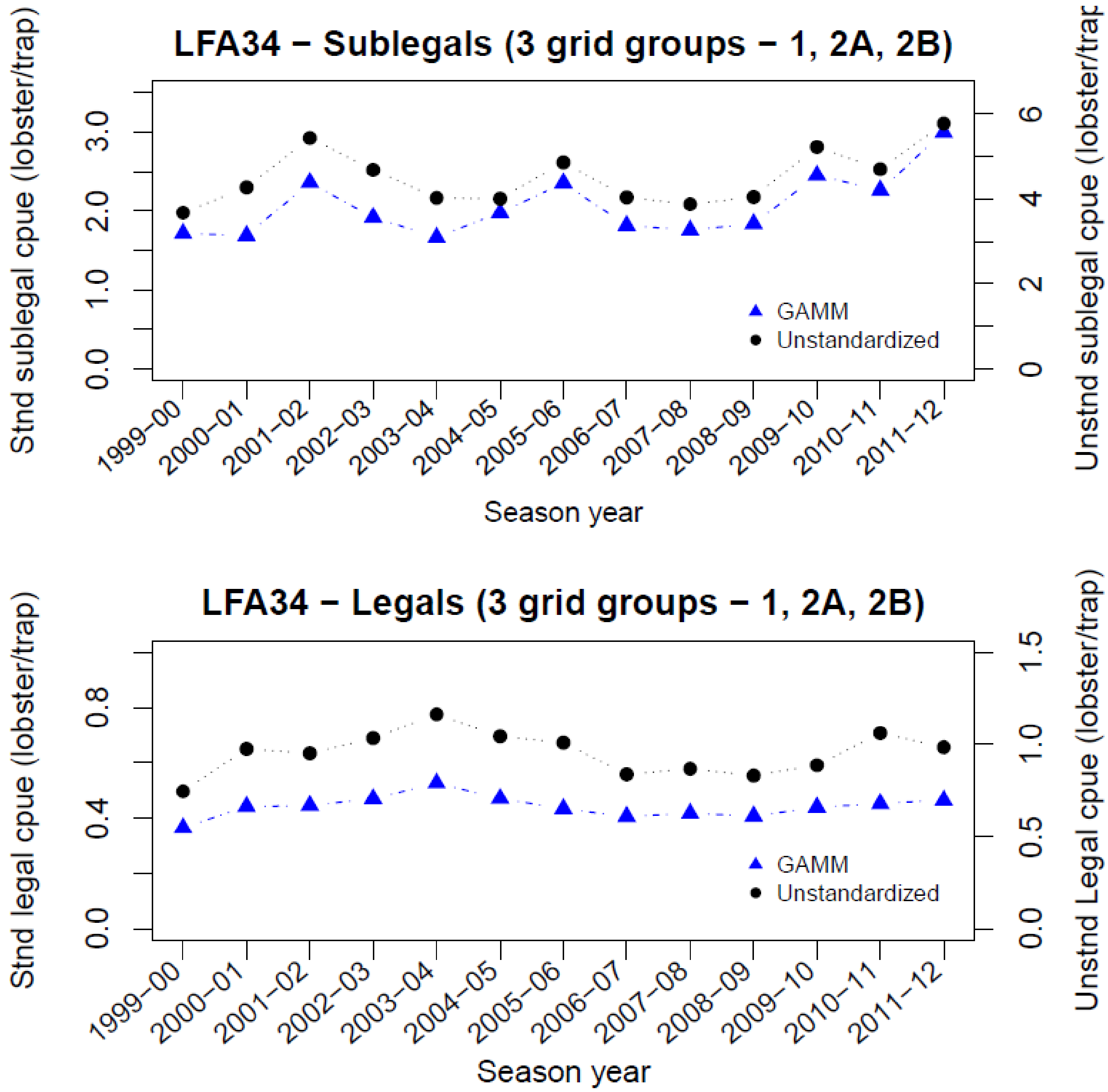


Figure 6.4. Predicted model CPUE for sublegals (upper) and legals (lower), for the 3 Grid Groups combined ignoring the effect of Grid Group,1999-00 to 2011-12. Also shown is unstandardized CPUE.

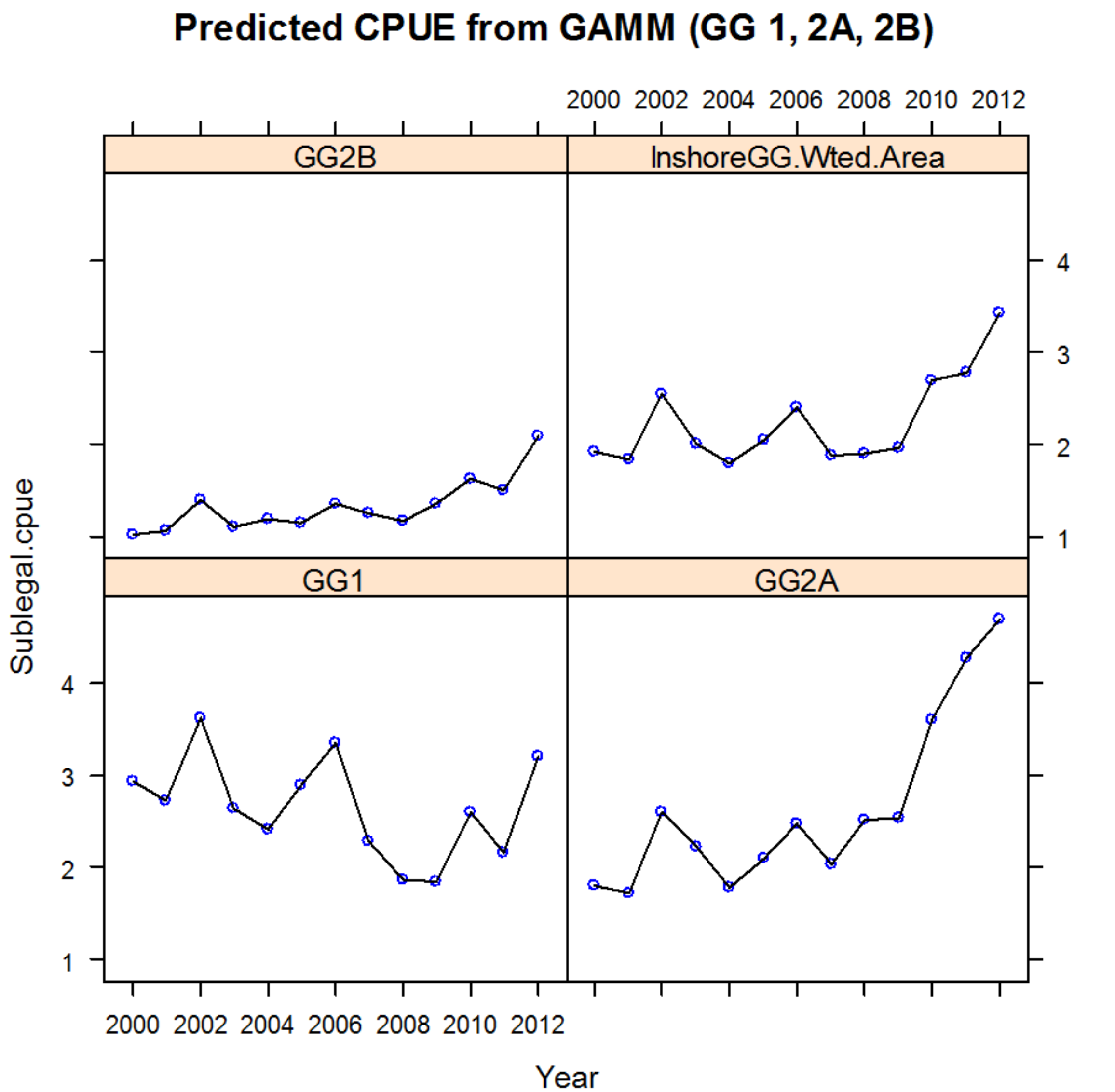


Figure 6.5. Model predictions for sublegal CPUE in Grid group (GG) 1, 2A and 2B together with a single weighted index. Data in GG1, GG2A and GG2B plots are the sublegal data plotted in Figures 6.1, 6.2 and 6.3. "InshoreGG.Wted.Area" plot is a single index based on weighting the predictions for individual Grid Groups by their area (provided in Table 6.4) by fishing season, 2000-2012 (year is 2^{nd} year of the fishing season, e.g. 2012 represents the 2011-12 fishing season).

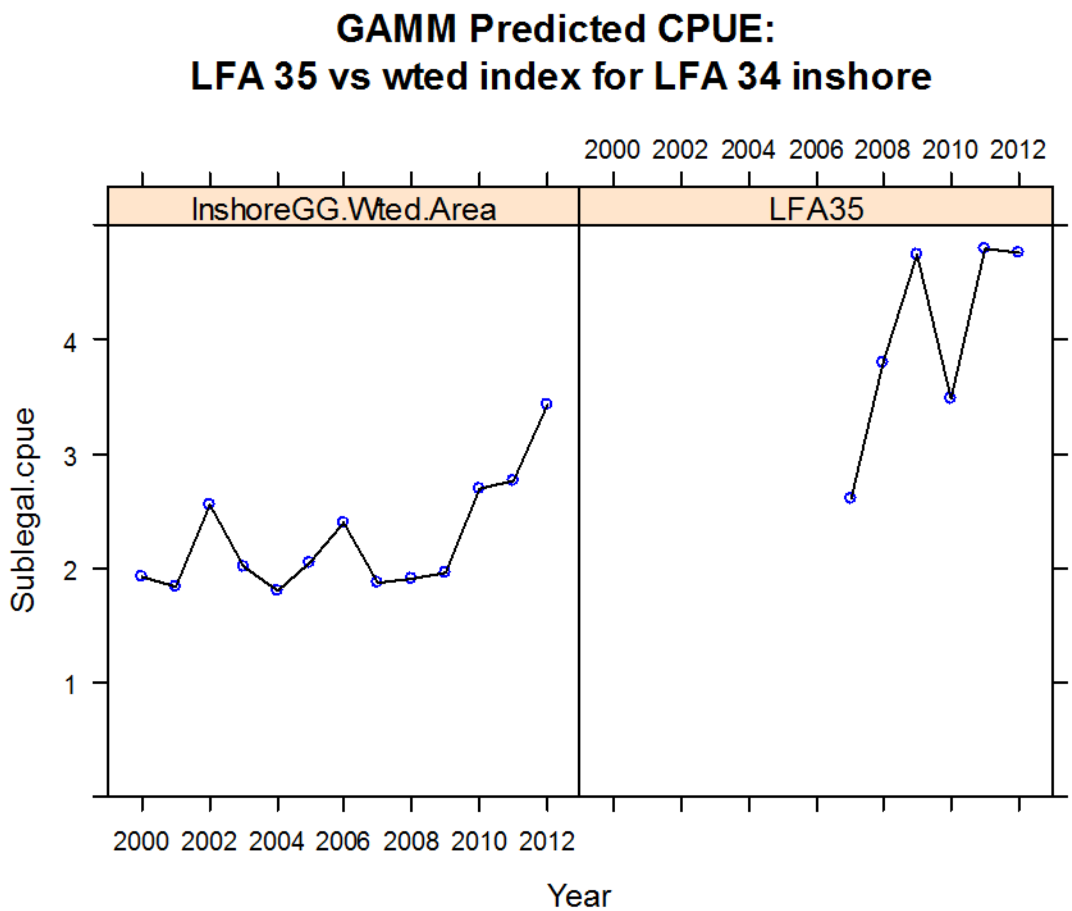


Figure 6.6. CPUE predictions for LFA 35 vs the weighted index for LFA 34 nearshore Grid Groups (same as that depicted in Figure 6.5) by fishing season, 2000-2012 (year is 2nd year of the fishing season e.g. 2012 represents the 2011-12 fishing season). InshoreGG = Nearshore Grid Groups.

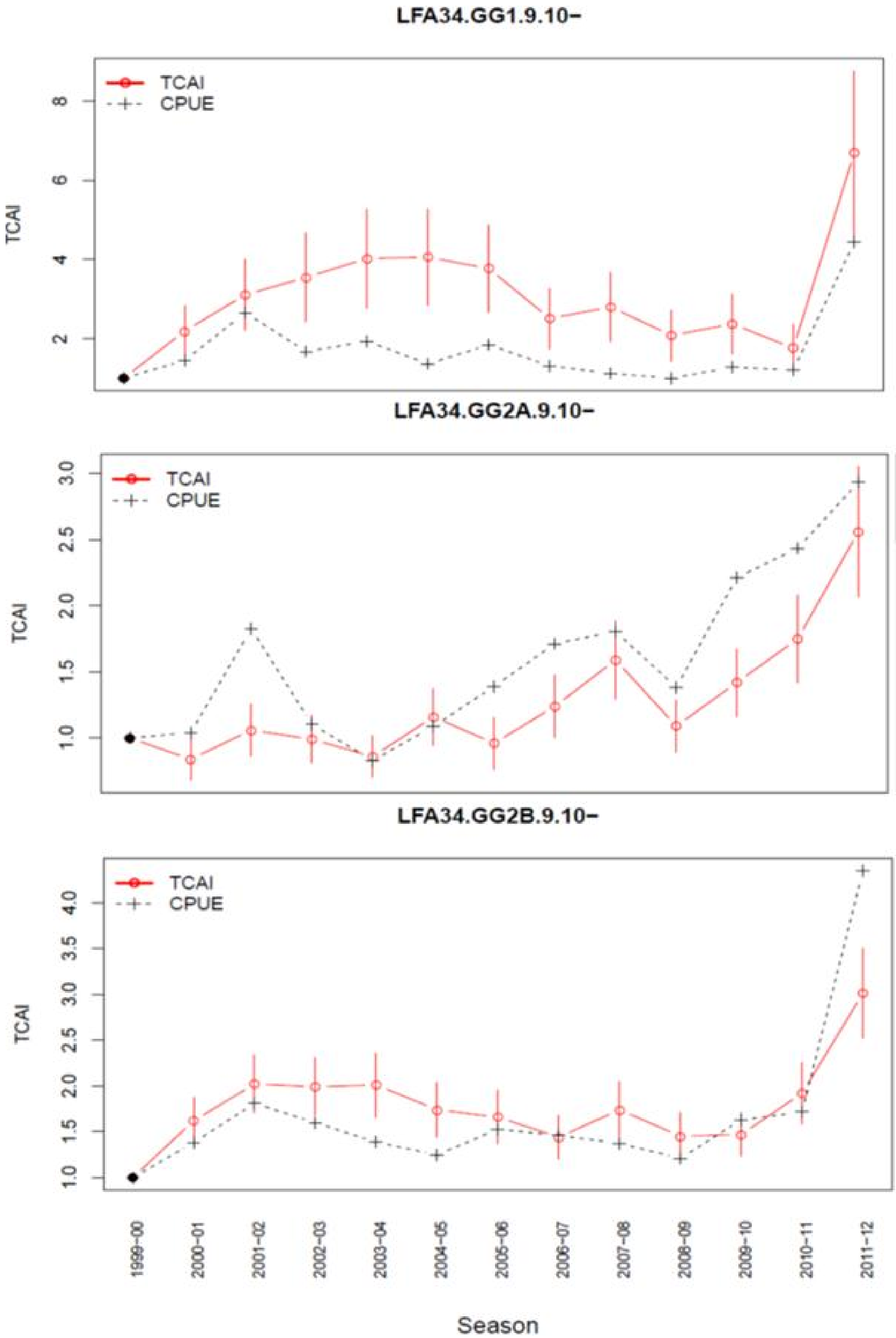
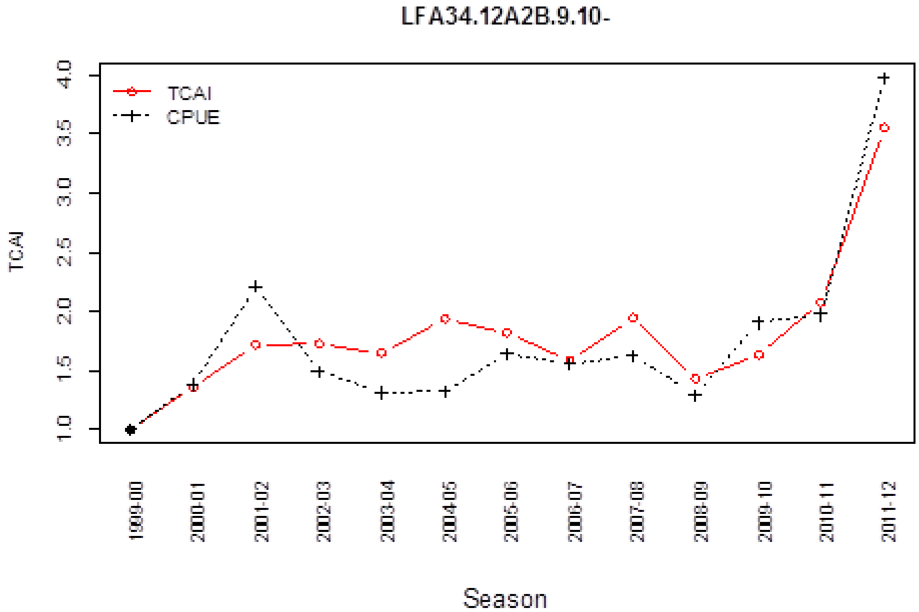


Figure 6.7. TCAI by fishing season (1999-00 to 2011-12) for sublegal lobsters in individual Grid groups 1, 2A and 2B. Index is for sublegal lobsters 76-82.5 mm CL (FSRS size classes 9 and sublegal portion of 10). Also shown is unstandardized CPUE.



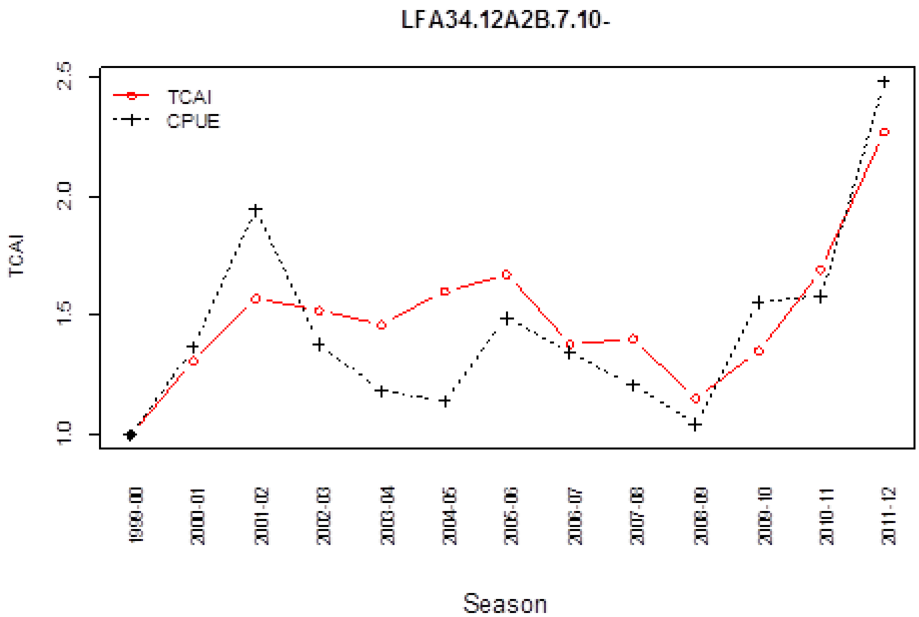


Figure 6.8. TCAI by fishing season (1999-00 to 2011-12) for sublegal lobsters for combined Grid groups 1, 2A and 2B. Upper panel is index is for sublegal lobsters 76-82.5 mm CL (FSRS size classes 9 and sublegal portion of 10). Lower panel is for sublegal lobsters 61-82.5 mm CL (FSRS size classes 7-9 and sublegal portion of 10). Also shown is unstandardized CPUE.

7. EXPLOITATION RATE INDICATORS

7.1. METHODS

To estimate Exploitation rate (ER), the CCIR (Continuous Change in Ratio) method (Claytor and Allard 2003) is used, together with a size based method (Length Cohort Analysis or LCA).

7.1.1. Continuous Change in Ratio (CCIR)

The CCIR method (Claytor and Allard 2003) is used as described in Tremblay et al. (2011). The ER estimates (also known as "removal rate") should be considered an index since CCIR does not generate absolute estimates of exploitation because ovigerous females are not accounted for by the method. The year to year trends in the ER of the exploitable population are captured by CCIR.

CCIR estimates ER for a size fraction of the exploitable stock based on the change in ratio of the harvested fraction to an unharvested ("reference") fraction. To avoid potential problems with differential catchability, it is best to limit the exploitable sizes to those close to the reference size class. As such, the ER estimates provided here are for lobsters between 82.5 and 90 mm CL, a size fraction that makes up a high proportion of the catch throughout LFAs 34 and 35. This size fraction is highly relevant but it is important to recognize that the CCIR estimates do not include the larger size fractions.

The data used come from FSRS traps, as participants record all sizes in the traps on a daily basis. These data are limited mainly to nearshore Grid Groups in LFA 34, and to LFA 35 within the Bay of Fundy.

The assumptions of CCIR are that (1) the population is closed, (2) that the ratio of catchability between the classes is constant throughout the season for all traps, (3) that the ratio of catchability by the monitoring traps and by the commercial traps is constant over the season for all classes, and (4) that the ratio of the fleet effort to the monitoring trap effort is either constant over the season or can be estimated up to a constant factor.

With regard to the assumption of a closed population (assumption 1), this may be problematic if lobsters are moving in and out of the area covered by the FSRS traps. The largest lobster movements are usually associated with lobsters at sizes that should be mature, which in SWNS and the Bay of Fundy are mainly larger than 95 mm CL. CCIR would yield estimates biased upward if the harvestable sizes left the area fished by the FSRS traps earlier than the prerecruit sizes.

Assumption 2 is also potentially problematic as changes in catchability with size and agonistic interactions around traps suggest larger lobsters may inhibit smaller lobsters from entry (Miller 1990, Frusher and Hoenig 2001, Watson and Jury 2013). As long as the catchability ratio remains constant this is not a problem for the method, but if the decline in legal sizes over the fishing season causes increased catchability of sublegal lobsters, this would bias the CCIR estimates upwards. If the presence of legal-sized lobsters did inhibit the entry of sublegal lobsters, a negative correlation between sublegal and legal sizes would be expected in the FSRS data. Examination of FSRS data from spring fisheries (Tremblay et al. 2011) did not find a negative relationship. As such, available evidence indicates the size-related behavioral interaction between lobsters is not important for the sizes considered by CCIR (Tremblay et al. 2011).

Assumption 3 is reasonable in that some sizes no doubt have a different catchability in FSRS traps than commercial traps, but there is no expectation that the ratio of the two should change over the season. If, however, Assumption 2 is violated, there could be a seasonal change in the ratio of the catchability of the monitoring traps to that in the commercial traps as legal sizes are removed due to fishing. It is not expected that the ratio of the number of FSRS trap hauls to the number of commercial trap hauls should change over the season (Assumption 4).

All assumptions will be better satisfied if the reference and exploited classes are adjacent and narrow as is the case in the current analysis. Claytor and Allard (2003) showed that the method has some robustness relative to departures from these assumptions, particularly if the true exploitation rate is high.

For LFA 34, exploitation rate was estimated for males and females for each year within Grid Groups 1, 2A and 2B and 4AB for the fishing seasons 1999-00 to 2011-12. The exploited size group was the minimum legal size (MLS, 82.5 mm) to 90 mm CL, the reference size group 76 mm CL to MLS.

For LFA 35, exploitation rate was estimated in the same manner as for LFA 34. Data were limited to the fishing seasons 2007-08 to 2011-12, and to two Bay of Fundy Grid Groups: Grid Group 1 in the upper Bay, and Grid Group 3 on the Nova Scotia side of the lower Bay.

Sample size affects the precision of the exploitation estimates. Claytor and Allard (2003) recommended that for best results (narrower confidence intervals), sample sizes for both reference and exploited classes should exceed 200. While this was achieved in most cases, the results are presented for all samples in tabular form. Only those exploitation estimates that have both upper and lower confidence intervals that are within 0.3 units (30%) of the estimate are plotted and included in the calculation of overall means.

7.1.2. Length Cohort Analysis (LCA)

LCA was developed by Jones (Jones 1974, 1981) based on Pope's (1972) cohort analysis which assumes that abundance at the end of year *i* can be estimated by the initial abundance, a half year of natural mortality, a midyear catch, and natural mortality for the remainder of the year. See Pezzack et al. (2006) for more on the method.

The size distribution used for the method is that of the landed catch. This was developed from available at-sea samples, but as the method requires, only the legal sizes and legally retained animals were included. This size distribution was used to estimate the catch for the sequence of time intervals and von Bertalanffy growth parameters were applied to estimate the delta *t* (time duration of each size interval). Since this method does not follow a single cohort over time, but instead assumes that the size frequency represents the abundance of a cohort over time, the method assumes constant recruitment. In practice, however, this is not the case and estimates are generally based on the size distribution aggregated over several years.

In conditions where the recruitment is dramatically changing year to year, such values should be used with caution. Similarly where fishing patterns change resulting in changes in the mix of sizes in the catch, estimates of exploitation rate will be effected. For example an increase in fishing effort in deeper water areas with a large mean size could result in lower estimate of exploitation rate.

The input parameters were as used in Pezzack et al. (2006). Natural mortality was set at 0.10. The time of catch (Tc) is the period in the year when the catch is taken. The year begins in August following the molt and Tc is set as the month in which cumulative landings reach 50% of the total. For LFA 34, this occurs in December. Sizes were grouped into 5 mm or 10 mm CL intervals. The 10 mm intervals were used at larger sizes when numbers in any size interval were small or absent. The smaller intervals were most critical at the smaller sizes where delta *t* has the greatest effect. The delta t's were the same as those used in Pezzack (2006), when they were calculated from the output of an egg-per-recruit model.

The analysis was done on the weighted catch at size for the season 2000-01, 2003-04, 2006-07 and 2009-10. The size frequencies for the above seasons were based primarily on sizes measured during the above season, but where Grid Groups were not sampled in that season, seasons before or after were used to fill in the gaps.

7.2. RESULTS AND DISCUSSION

7.2.1. Continuous Change in Ratio (CCIR)

The results for LFA 34 Grid Groups are displayed in Table 7.1 and Figure 7.1. Estimates with wide confidence intervals (upper or lower limit >0.3 from estimate) are indicated by a “FALSE” in the last column; these were not included in calculation of means or in Figure 7.1. By Grid Groups the means for 2006-2012 (males and females averaged within year) were 0.87 (Grid Group 1), 0.92 (Grid Group 2A), 0.80 (Grid Group 2B) and 0.87 (Grid Group 4AB). The means for 2000-2005 were lower in Grid Group 1 (0.79) and Grid Group 2A (0.86). Recent estimates are in the upper quartile for the times series for 2 of the 4 Grid Groups but there was considerable interannual variability over the 13 year time series (Table 7.2). The apparent increase in exploitation rate in Grid Group 2A is surprising given the decline in effort there (Figure 5.8).

All of the exploitation rate estimates for these Grid Groups are high relative to LFAs 27-33. CCIR estimates of exploitation for LFAs 29-32 for the period 2006-2010 averaged 0.57-0.67 (weighted by landings: 0.63). For the western part of LFA 33, they averaged 0.72 for the period 2006-2010 (Table 5.2 in Tremblay et al. 2012c). Effort is high in LFA 34 relative to the most LFAs (Appendix 1 – Figures 4, 5), indicating a link between effort and overall exploitation rate.

Partial results for a few years for two Grid Groups within LFA 35 are displayed in Table 7.3 and Figure 7.2. The CCIR method applied here resulted in a high proportion of estimates with wide confidence intervals, so partial results for just 4 years are displayed in Figure 7.2. Of the available estimates with confidence intervals less than +/- 0.3, the average was 0.67 for Grid Group 1 in the upper Bay, and 0.88 for Grid Group 3 in the lower Bay. These estimates suggest a lower exploitation rate in the upper Bay of Fundy than in the outer Bay and in LFA 34.

7.2.2. Length Cohort Analysis (LCA)

The LCA results for the four seasons in LFA 34 are shown in Table 7.4 and Figure 7.3. Size data were available for the whole of LFA 34, so estimates were done for nearshore, midshore, and offshore areas. The results indicate differences between males and females and between nearshore, midshore and offshore, but there is no indication from LCA of an increase in exploitation rate over the time period considered.

Estimates for males were consistently lower than those for females. This may be the result of two factors:

(i) The inputs to the model were based on females rather than males and although there is not expected to be much difference in growth between males and females until the size at maturity (current 50% size at maturity estimates of 95-100 mm CL), not accounting for growth differences may affect the male estimates. In the previous document using the method (Pezzack et al. 2006), only female exploitation rates were provided.

(ii) The method does not account for the fact that ovigerous females are protected and thus do not show up in the landed catch. This could inflate the estimates of exploitation for females.

Estimates of exploitation were highest in the nearshore (females=0.84), almost as high in the midshore (females=0.76-0.80), and lowest in the offshore (0.47-0.49). For LFA 34, the overall estimates were 0.80 for females and 0.68 for males.

The consistency of highly truncated size distributions in the nearshore of LFA 34 over many years (e.g. Figure 5.15) indicates that the high exploitation rates estimated here are not new. Looking at the long-term there does appear to be a reduction in the size of the largest females in the trap catch (Figure 5.18), suggesting exploitation in the nearshore and midshore may be higher in recent years.

7.2.3. Other Considerations - Yield per Recruit

Although current exploitation rates are unlikely to threaten sustainability of lobsters in any of the assessment units through "recruitment overfishing", lower exploitation rates would very likely increase yield per recruit. Previous estimates of yield per recruit for some of these LFAs (Miller et al. 1987, Idoine et al. 2001) indicated yield per recruit would increase with decreased effort or increased minimum legal size.

A yield per recruit analysis was outside the scope of this assessment and would have to account for changes since the last analysis, such as updated values for size at maturity. Potential density dependent effects on growth and maturity would also need consideration. Economic considerations could also be built into the analysis.

7.3. SUMMARY

7.3.1. LFA 34

- Exploitation rates (ER) were estimated for the nearshore portion of LFA 34 for the period 1999-00 to 2011-12 using CCIR.
- A different method (LCA), was used to estimate exploitation rates for all of LFA 34, and for nearshore, midshore, and offshore portions for the seasons 2000-01, 2003-04, 2006-07 and 2009-10.
- LCA estimates of ER for LFA 34 as a whole ranged from 0.71 in 2009-10 to 0.77 in 2006-07.
- In the nearshore portion of LFA 34, CCIR estimates for individual Grid Groups for the seasons 2005-06 to 2011-12 ranged from 0.63-0.94 with an overall mean above 0.80. LCA estimates for the nearshore for a similar time period fell within this range (ER = 0.78 and 0.79 for 2 seasons, males and females combined).
- LCA indicates that compared to the nearshore, ER is lower in the midshore (mean of 0.70 for 2006-07 and 2009-10) and offshore (mean of 0.36 for 2006-07 and 2009-10).
- Exploitation rates in LFA 34 have been high for many years based on the long-term consistency in size distribution in the nearshore.
- Evidence for an upward shift in ER in LFA 34 since 1999 is mixed. An upward trend in ER in the nearshore was detected by one method (CCIR), and the size of the largest females (95^{th} percentile) has declined since 1990. However, LCA detected no upward trend in exploitation rate over the time period considered for LFA 34 as a whole, or for the nearshore, midshore and offshore portions.

7.3.2. LFA 35

- The data are inadequate for estimating even relative exploitation rates in LFAs 35-38.
- Partial results for a few years for two Grid Groups within LFA 35 suggest a lower exploitation rate in the upper Bay of Fundy than in the outer Bay and in LFA 34.

Table 7.1. Annual CCIR exploitation rate estimates by year and Grid Group within LFA 34. Estimates are for size group 82.5-90 mm CL. Reference class was 76-82.4 mm CL. Dates are earliest and latest sample dates. N days samp = N of days of FSRS data (any number of records). Ref = reference; Expl = exploited. SE = standard error. CI = confidence interval. Wide CI is logical test to identify confidence intervals where either upper or lower limit is more than 0.25 from estimate.

Grid Group 1

Grid Group	Year	Sex	Date Start	Date End	N days total	N days samp	N in Ref class	N in Expl class	Exploit rate	SE	Lower CI	Upper CI	Wide CI
1	2000	1	30/11/99	27/05/00	180	77	182	118	0.841	0.0769	0.738	1.043	FALSE
1	2000	2	30/11/99	29/05/00	182	71	183	94	0.957	0.0417	0.902	1.068	FALSE
1	2001	1	28/11/00	30/05/01	184	111	747	393	0.734	0.0598	0.638	0.873	FALSE
1	2001	2	28/11/00	30/05/01	184	112	805	336	0.603	0.0887	0.462	0.806	FALSE
1	2002	1	27/11/01	29/05/02	184	125	864	349	0.865	0.0382	0.804	0.956	FALSE
1	2002	2	27/11/01	30/05/02	185	124	853	312	0.826	0.044	0.761	0.932	FALSE
1	2003	1	27/11/02	31/05/03	186	103	631	369	0.720	0.0648	0.620	0.873	FALSE
1	2003	2	27/11/02	31/05/03	186	94	570	208	0.707	0.0937	0.575	0.939	FALSE
1	2004	1	25/11/03	31/05/04	189	89	413	250	-0.304	0.3826	-0.836	0.605	TRUE
1	2004	2	25/11/03	30/05/04	188	90	298	161	-0.458	0.5438	-1.159	0.925	TRUE
1	2005	1	01/12/04	04/06/05	186	132	1224	617	0.825	0.0324	0.771	0.897	FALSE
1	2005	2	01/12/04	04/06/05	186	128	1020	373	0.819	0.0447	0.754	0.925	FALSE
1	2006	1	29/11/05	31/05/06	184	136	1600	632	0.852	0.0266	0.806	0.909	FALSE
1	2006	2	29/11/05	29/05/06	182	140	1345	380	0.912	0.0227	0.874	0.963	FALSE
1	2007	1	28/11/06	31/05/07	185	107	962	446	0.847	0.0365	0.788	0.932	FALSE
1	2007	2	28/11/06	30/05/07	184	109	902	257	0.925	0.0312	0.875	0.996	FALSE
1	2008	1	30/11/07	31/05/08	184	113	726	315	0.709	0.0727	0.598	0.884	FALSE
1	2008	2	30/11/07	31/05/08	184	108	620	160	0.753	0.0943	0.629	0.994	FALSE
1	2009	1	25/11/08	30/05/09	187	100	621	317	0.860	0.0423	0.798	0.958	FALSE
1	2009	2	25/11/08	27/05/09	184	101	520	160	0.945	0.0303	0.899	1.016	FALSE
1	2010	1	01/12/09	31/05/10	182	115	847	344	0.940	0.0219	0.908	0.994	FALSE
1	2010	2	01/12/09	29/05/10	180	107	684	160	0.884	0.0565	0.803	1.026	FALSE
1	2011	1	30/11/10	30/05/11	182	109	523	253	0.909	0.0294	0.863	0.978	FALSE
1	2011	2	30/11/10	28/05/11	180	100	428	132	0.921	0.0392	0.865	1.017	FALSE
1	2012	1	30/11/11	30/05/12	183	122	734	334	0.851	0.0442	0.782	0.955	FALSE
1	2012	2	30/11/11	28/05/12	181	115	599	171	0.889	0.0416	0.827	0.989	FALSE

Table 7.1. Continued.

Grid Group 2A

Grid Group	Year	Sex	Date Start	Date End	N days total	N days samp	N in Ref class	N in Expl class	Exploit rate	SE	Lower CI	Upper CI	Wide CI
2A	2000	1	30/11/99	27/05/00	180	97	435	211	NA	NA	NA	NA	NA
2A	2000	2	30/11/99	31/05/00	184	93	357	177	0.809	0.0625	0.720	0.957	FALSE
2A	2001	1	28/11/00	30/05/01	184	118	1139	546	0.765	0.049	0.685	0.878	FALSE
2A	2001	2	28/11/00	29/05/01	183	121	1115	402	0.759	0.059	0.666	0.899	FALSE
2A	2002	1	27/11/01	31/05/02	186	129	1961	606	0.908	0.021	0.873	0.956	FALSE
2A	2002	2	27/11/01	31/05/02	186	136	2040	401	0.874	0.0348	0.821	0.959	FALSE
2A	2003	1	27/11/02	31/05/03	186	104	1726	580	0.949	0.0167	0.922	0.988	FALSE
2A	2003	2	27/11/02	31/05/03	186	100	1560	434	0.899	0.0312	0.850	0.972	FALSE
2A	2004	1	25/11/03	31/05/04	189	96	766	298	0.737	0.0706	0.633	0.908	FALSE
2A	2004	2	25/11/03	31/05/04	189	94	706	217	0.788	0.0714	0.685	0.969	FALSE
2A	2005	1	01/12/04	04/06/05	186	97	1110	387	0.897	0.0249	0.856	0.956	FALSE
2A	2005	2	01/12/04	02/06/05	184	98	1047	266	0.898	0.03	0.849	0.964	FALSE
2A	2006	1	29/11/05	30/05/06	183	115	1447	275	0.903	0.035	0.852	0.989	FALSE
2A	2006	2	29/11/05	30/05/06	183	111	1348	226	0.954	0.0394	0.900	1.054	FALSE
2A	2007	1	27/11/06	31/05/07	186	97	983	308	0.922	0.0284	0.881	0.992	FALSE
2A	2007	2	27/11/06	29/05/07	184	97	927	208	0.853	0.0587	0.766	1.003	FALSE
2A	2008	1	29/11/07	28/05/08	182	121	1389	321	0.948	0.0174	0.918	0.989	FALSE
2A	2008	2	29/11/07	28/05/08	182	115	1132	223	0.963	0.0197	0.931	1.007	FALSE
2A	2009	1	25/11/08	30/05/09	187	89	1119	286	0.904	0.0312	0.857	0.979	FALSE
2A	2009	2	25/11/08	30/05/09	187	88	838	187	0.939	0.0413	0.885	1.042	FALSE
2A	2010	1	30/11/09	30/05/10	182	100	1174	222	0.964	0.028	0.920	1.031	FALSE
2A	2010	2	30/11/09	31/05/10	183	97	1052	206	0.856	0.0538	0.779	0.989	FALSE
2A	2011	1	30/11/10	31/05/11	183	96	1191	273	0.952	0.0231	0.918	1.010	FALSE
2A	2011	2	30/11/10	30/05/11	182	94	990	185	0.855	0.0579	0.774	1.000	FALSE
2A	2012	1	30/11/11	25/05/12	178	91	1141	184	0.955	0.0254	0.913	1.015	FALSE
2A	2012	2	30/11/11	28/05/12	181	95	891	130	0.939	0.0398	0.880	1.035	FALSE

Table 7.1. Continued.

Grid Group 2B

Grid Group	Year	Sex	Date Start	Date End	N days total	N days samp	N in Ref class	N in Expl class	Exploit rate	SE	Lower CI	Upper CI	Wide CI
2B	2000	1	30/11/99	31/05/00	184	94	459	323	0.757	0.0656	0.658	0.911	FALSE
2B	2000	2	30/11/99	31/05/00	184	88	449	294	0.846	0.0461	0.777	0.954	FALSE
2B	2001	1	28/11/00	31/05/01	185	106	634	301	0.858	0.0437	0.792	0.959	FALSE
2B	2001	2	28/11/00	31/05/01	185	99	637	301	0.727	0.072	0.618	0.902	FALSE
2B	2002	1	27/11/01	30/05/02	185	99	792	322	0.838	0.0447	0.771	0.945	FALSE
2B	2002	2	27/11/01	29/05/02	184	100	873	335	0.816	0.0445	0.744	0.918	FALSE
2B	2003	1	27/11/02	31/05/03	186	104	734	461	0.728	0.0597	0.639	0.872	FALSE
2B	2003	2	27/11/02	31/05/03	186	100	867	516	0.683	0.0637	0.583	0.822	FALSE
2B	2004	1	25/11/03	31/05/04	189	88	544	388	0.870	0.0354	0.816	0.953	FALSE
2B	2004	2	25/11/03	31/05/04	189	84	619	421	0.729	0.0641	0.627	0.874	FALSE
2B	2005	1	01/12/04	04/06/05	186	94	558	348	0.726	0.0698	0.623	0.894	FALSE
2B	2005	2	01/12/04	04/06/05	186	101	637	371	0.923	0.0232	0.887	0.978	FALSE
2B	2006	1	29/11/05	31/05/06	184	113	790	460	0.664	0.0695	0.549	0.815	FALSE
2B	2006	2	29/11/05	31/05/06	184	116	864	574	0.592	0.0792	0.467	0.775	FALSE
2B	2007	1	28/11/06	31/05/07	185	85	634	349	0.963	0.0161	0.939	1.002	FALSE
2B	2007	2	28/11/06	31/05/07	185	86	567	335	0.914	0.0261	0.874	0.979	FALSE
2B	2008	1	30/11/07	31/05/08	184	91	428	281	0.753	0.0684	0.654	0.919	FALSE
2B	2008	2	30/11/07	31/05/08	184	87	489	239	0.830	0.0603	0.743	0.984	FALSE
2B	2009	1	25/11/08	28/05/09	185	82	430	254	0.701	0.0894	0.569	0.917	FALSE
2B	2009	2	25/11/08	30/05/09	187	92	556	317	0.739	0.0675	0.637	0.901	FALSE
2B	2010	1	01/12/09	29/05/10	180	91	553	299	0.841	0.0505	0.764	0.957	FALSE
2B	2010	2	01/12/09	29/05/10	180	91	610	368	0.785	0.0558	0.693	0.914	FALSE
2B	2011	1	30/11/10	31/05/11	183	86	572	328	0.762	0.0657	0.663	0.921	FALSE
2B	2011	2	30/11/10	31/05/11	183	93	618	249	0.721	0.0813	0.607	0.922	FALSE
2B	2012	1	29/11/11	31/05/12	185	105	733	273	0.832	0.0491	0.755	0.952	FALSE
2B	2012	2	29/11/11	31/05/12	185	106	717	230	0.794	0.0684	0.699	0.959	FALSE

Table 7.1. Continued.

Grid Group 4AB

Grid Group	Year	Sex	Date Start	Date End	N days total	N days samp	N in Ref class	N in Expl class	Exploit rate	SE	Lower CI	Upper CI	Wide CI
4AB	2003	1	27/11/02	25/05/03	180	46	196	138	0.669	0.1399	0.489	1.041	TRUE
4AB	2003	2	27/11/02	22/05/03	177	50	244	198	0.620	0.1422	0.428	0.980	TRUE
4AB	2004	1	25/11/03	31/05/04	189	53	290	199	0.721	0.0962	0.591	0.966	FALSE
4AB	2004	2	25/11/03	31/05/04	189	51	423	254	0.738	0.0778	0.618	0.917	FALSE
4AB	2005	1	01/12/04	29/05/05	180	60	180	99	0.911	0.0606	0.835	1.065	FALSE
4AB	2005	2	01/12/04	01/06/05	183	63	240	99	0.820	0.1124	0.686	1.109	FALSE
4AB	2006	1	29/11/05	29/05/06	182	80	371	214	0.955	0.0196	0.924	1.001	FALSE
4AB	2006	2	29/11/05	29/05/06	182	81	568	294	0.931	0.0261	0.891	0.996	FALSE
4AB	2007	1	28/11/06	21/05/07	175	47	260	156	0.870	0.0552	0.792	1.001	FALSE
4AB	2007	2	28/11/06	31/05/07	185	47	385	217	0.837	0.0562	0.760	0.981	FALSE
4AB	2008	1	30/11/07	21/05/08	174	40	80	34	1.020	0.0271	0.957	1.064	FALSE
4AB	2008	2	30/11/07	23/05/08	176	58	125	56	0.875	0.123	0.753	1.221	TRUE
4AB	2009	1	25/11/08	27/05/09	184	44	53	60	0.866	0.1317	0.759	1.247	TRUE
4AB	2009	2	25/11/08	26/05/09	183	50	78	89	0.957	0.0304	0.916	1.029	FALSE
4AB	2010	1	01/12/09	29/05/10	180	45	131	93	0.842	0.0935	0.739	1.102	FALSE
4AB	2010	2	01/12/09	29/05/10	180	46	112	114	0.851	0.0739	0.754	1.044	FALSE
4AB	2011	1	30/11/10	29/05/11	181	65	158	130	0.665	0.1481	0.470	1.056	TRUE
4AB	2011	2	30/11/10	29/05/11	181	68	213	148	0.358	0.273	0.012	1.042	TRUE
4AB	2012	1	30/11/11	27/05/12	180	45	111	68	0.955	0.0442	0.901	1.069	FALSE
4AB	2012	2	30/11/11	23/05/12	176	46	133	77	0.922	0.0698	0.839	1.101	FALSE

Table 7.2. Summary of CCIR exploitation rates for LFA 34. Shown for each year is mean of male and female estimates for Grid Groups 1, 2A, 2B and 4AB. Each cell is coloured depending on whether it is below the 25th percentile (white), between the 25th and 75th percentiles (grey), or above the 75th percentile (black).

Year	GG 1	GG 2A	GG 2B	GB 4AB
2000	0.90	0.81	0.80	NA
2001	0.67	0.76	0.79	NA
2002	0.85	0.89	0.83	NA
2003	0.71	0.92	0.71	NA
2004	NA	NA	NA	NA
2005	0.82	0.90	0.82	0.861
2006	0.88	0.93	0.63	0.778
2007	0.89	0.89	0.94	0.91
2008	0.73	0.96	0.79	0.873
2009	0.90	0.92	0.72	0.821
2010	0.91	0.91	0.81	0.86
2011	0.91	0.90	0.74	NA
2012	0.87	0.95	0.81	0.88
25th percentile	0.80	0.89	0.74	0.84
75th percentile	0.89	0.93	0.82	0.88
Mean 2000-2005	0.79	0.86	0.79	0.86
Mean 2006-2012	0.87	0.92	0.80	0.87

Table 7.3. Annual CCIR exploitation rate estimates for LFA 35. Year is second year of fishing season, e.g. 2012 represents 2011-12 fishing season. Estimates are for size group 82.5-90 mm CL. Reference class was 76-82.4 mm CL. Dates are earliest and latest sample dates. N days samp = N of days of FSRS data (any number of records). Ref = reference; Expl = exploited. SE = standard error.

LFA/GG	YR	Sex	Date Start	Date End	N days total	N days samp	N in Ref class	N in Expl class	Exploit rate	SE	Lower CI	Upper CI	Wide CI
35.GG1	2007	1	15/10/2006	27/07/2007	286	58	218	116	NA	NA	NA	NA	NA
35.GG1	2007	2	15/10/2006	31/07/2007	290	57	201	86	0.892	0.066	0.8157	1.0708	FALSE
35.GG1	2008	1	22/10/2007	30/07/2008	283	43	122	67	0.78	0.151	0.6157	1.1773	TRUE
35.GG1	2008	2	22/10/2007	30/07/2008	283	41	138	51	0.529	0.415	0.1904	1.7309	TRUE
35.GG1	2009	1	15/10/2008	31/07/2009	290	88	716	443	0.36	0.136	0.1465	0.6704	TRUE
35.GG1	2009	2	15/10/2008	31/07/2009	290	88	585	334	0.388	0.146	0.1567	0.7206	TRUE
35.GG1	2010	1	15/10/2009	31/07/2010	290	95	717	604	0.643	0.073	0.5259	0.8124	FALSE
35.GG1	2010	2	15/10/2009	31/07/2010	290	91	503	353	0.513	0.124	0.3232	0.8283	TRUE
35.GG1	2011	1	14/10/2010	31/07/2011	291	89	775	512	0.633	0.075	0.5161	0.8052	FALSE
35.GG1	2011	2	14/10/2010	31/07/2011	291	93	671	338	0.583	0.104	0.4289	0.8293	FALSE
35.GG1	2012	1	15/10/2011	31/07/2012	291	116	901	578	0.541	0.088	0.3938	0.7363	FALSE
35.GG1	2012	2	15/10/2011	31/07/2012	291	116	805	356	0.286	0.17	0.0258	0.6865	TRUE
35.GG3	2007	1	15/10/2006	28/07/2007	287	73	229	125	0.372	0.259	0.0381	1.049	TRUE
35.GG3	2007	2	15/10/2006	28/07/2007	287	71	216	104	0.503	0.252	0.2164	1.1924	TRUE
35.GG3	2008	1	02/06/2008	02/06/2008	1	3	4	1	NA	NA	NA	NA	NA
35.GG3	2008	2	17/05/2008	02/06/2008	17	3	8	2	NA	NA	NA	NA	NA
35.GG3	2009	1	15/10/2008	24/07/2009	283	69	165	89	0.32	0.358	-0.083	1.3127	TRUE
35.GG3	2009	2	15/10/2008	27/07/2009	286	69	154	80	0.109	0.484	-0.434	1.4168	TRUE
35.GG3	2010	1	18/10/2009	30/07/2010	286	73	125	140	0.486	0.203	0.2166	0.9922	TRUE
35.GG3	2010	2	20/10/2009	30/07/2010	284	67	118	81	0.44	0.331	0.0917	1.3159	TRUE
35.GG3	2011	1	15/10/2010	31/07/2011	290	68	177	101	0.913	0.05	0.852	1.0476	FALSE
35.GG3	2011	2	15/10/2010	31/07/2011	290	63	159	76	0.586	0.278	0.3024	1.2844	TRUE
35.GG3	2012	1	15/10/2011	31/07/2012	291	73	330	148	0.662	0.138	0.478	1.0087	TRUE
35.GG3	2012	2	15/10/2011	31/07/2012	291	71	316	97	0.838	0.087	0.7348	1.0679	FALSE

Table 7.4. Annual exploitation rate estimates from Length Composition Analysis (LCA) for LFA 34 by fishing season. Nearshore includes Grid Groups 1, 2A, 2B and 7; Midshore includes Grid Groups 3, 4A and 4B; Offshore includes Grid Groups 5 and 6.

A. Males and Females separately.

Fishing Season	Nearshore		Midshore		Offshore		All of LFA 34	
	Male	Female	Male	Female	Male	Female	Male	Female
2000-01	0.69	0.83	0.61	0.79	0.21	0.47	0.67	0.81
2003-04	0.68	0.85	0.65	0.81	0.22	0.47	0.64	0.79
2006-07	0.72	0.85	0.70	0.84	0.18	0.44	0.70	0.83
2009-10	0.72	0.84	0.56	0.67	0.25	0.54	0.65	0.77
Mean 06-10	0.69	0.84	0.63	0.80	0.22	0.47	0.66	0.80
Mean 00-04	0.72	0.85	0.63	0.76	0.22	0.49	0.68	0.80

B. Mean of Males and Females.

Fishing Season	Nearshore	Midshore	Offshore	LFA 34
2000-01	0.76	0.70	0.34	0.74
2003-04	0.77	0.73	0.35	0.72
2006-07	0.79	0.77	0.31	0.77
2009-10	0.78	0.62	0.40	0.71

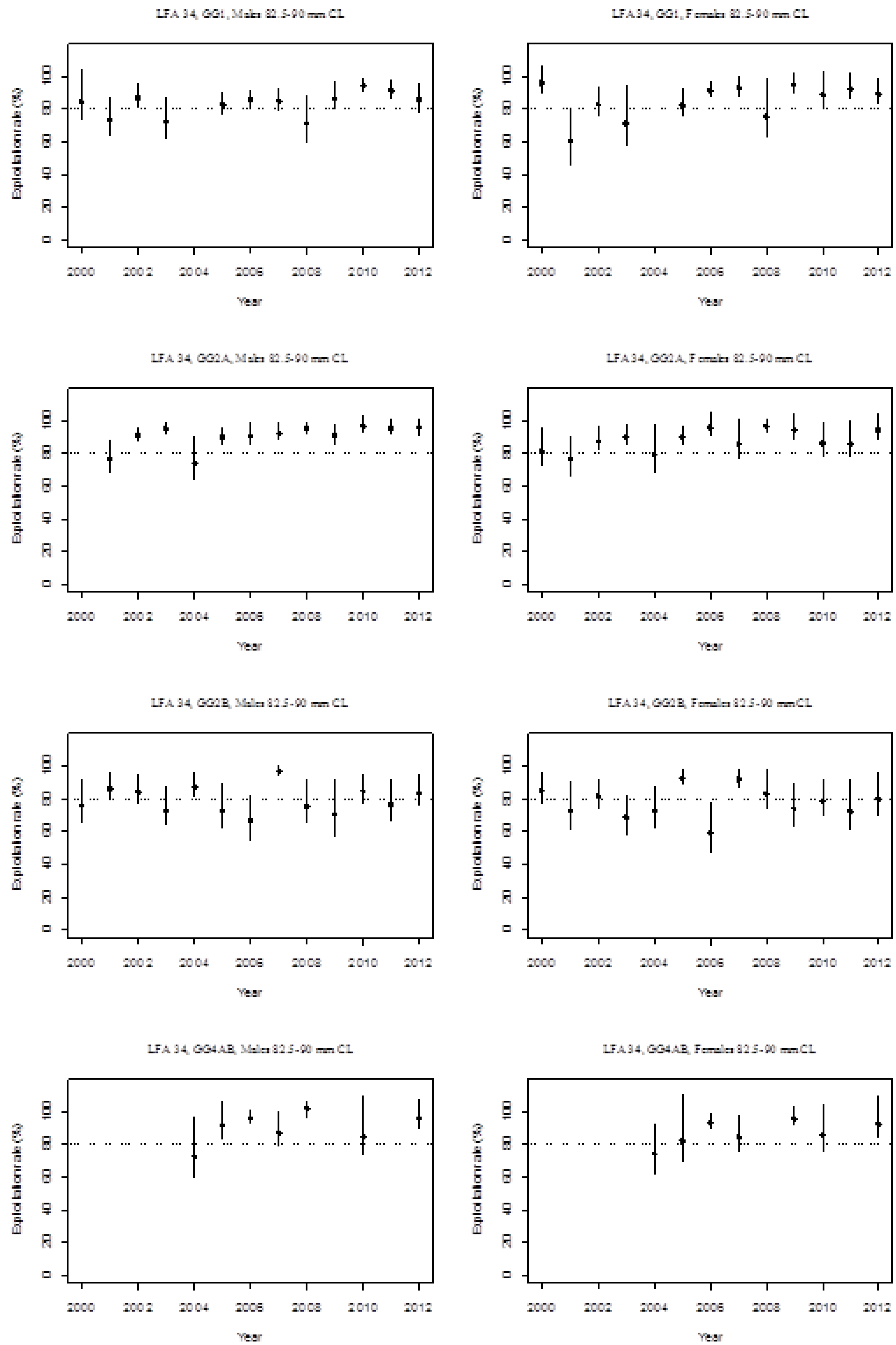


Figure 7.1. Annual CCIR exploitation rate estimates by Grid Group (GG) within LFA 34. Year is second year of fishing season (from 2000-2012), e.g. 2012 represents 2011-12 fishing season. Sex 1 = males; Sex 2 = females. See Table 7.1 for values. Dashed line at Exploitation = 80% is for reference only.

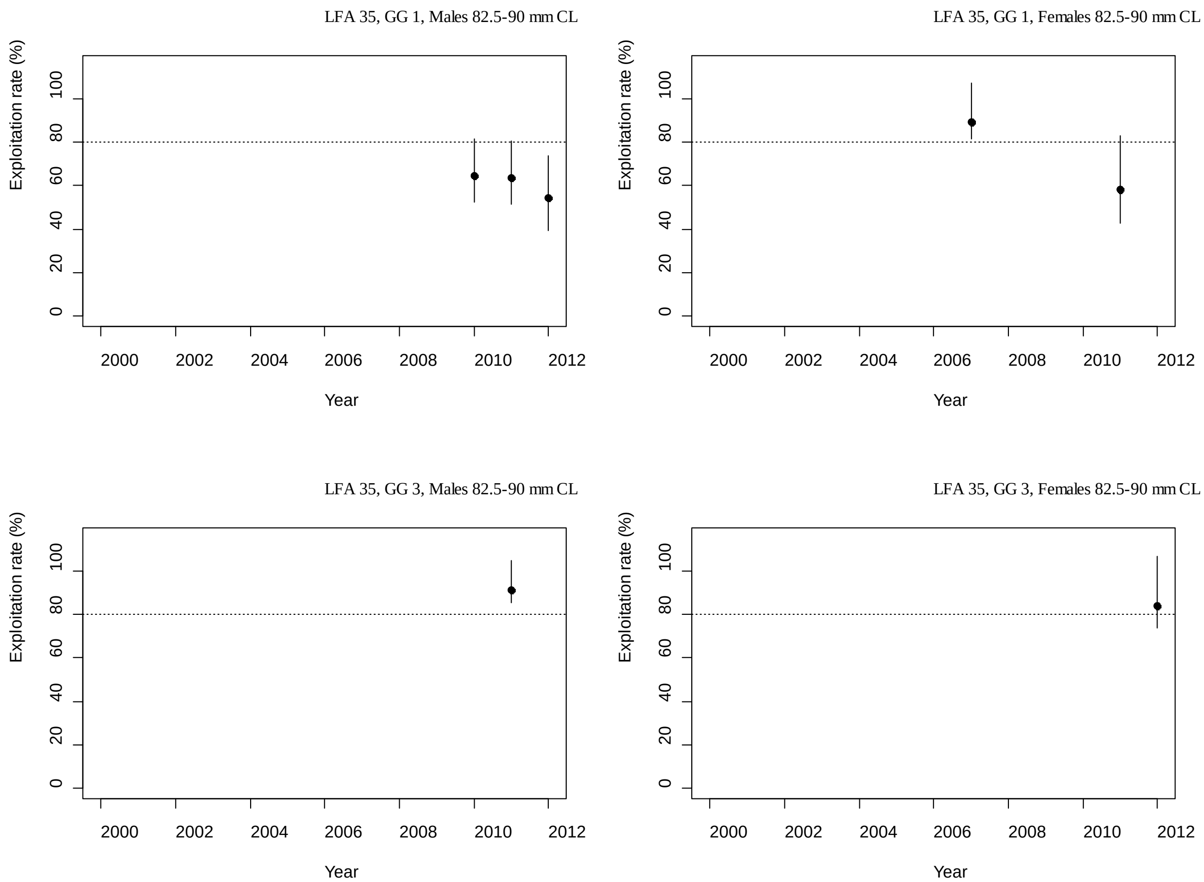


Figure 7.2. Annual CCIR exploitation rate estimates by Grid Group within LFA 35. Year is second year of fishing season (from 2000-2012), e.g. 2012 represents 2011-12 fishing season. Data were available only from 2007 onwards. Sex 1 = males; Sex 2 = females. See Table 7.2 for values. Dashed line at Exploitation = 80% is for reference only.

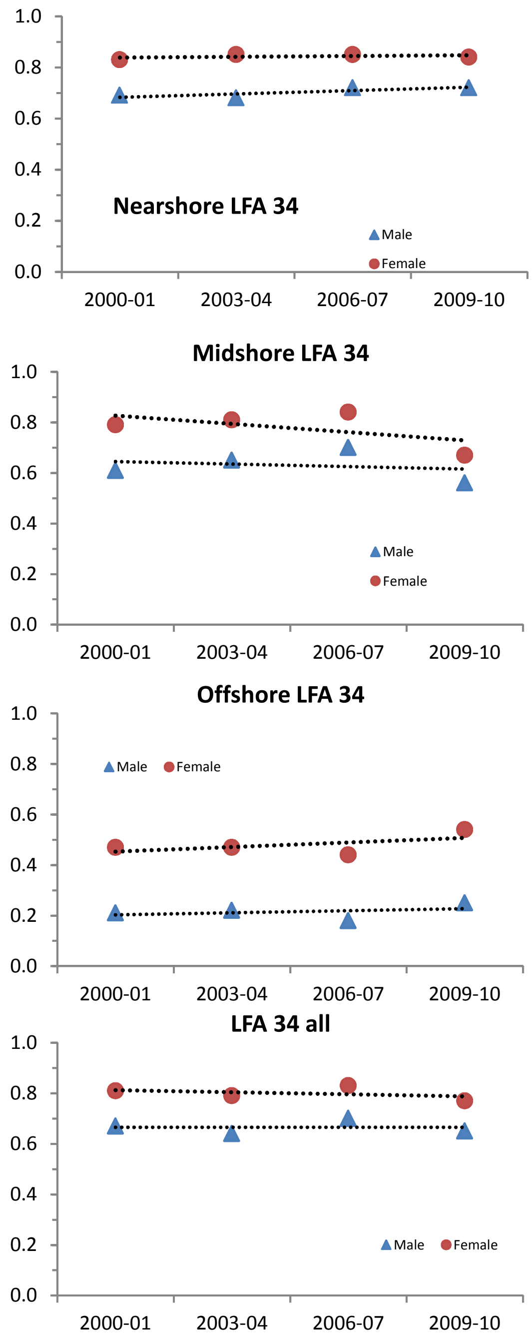


Figure 7.3. Annual LCA estimates for selected fishing seasons, 2000-01 to 2009-10, in LFA 34.

8. ECOSYSTEM CONSIDERATIONS

The increase in lobster abundance in the Gulf of Maine has been hypothesized to be a release from predation by groundfish (Boudreau and Worm 2010, Steneck et al. 2011) and/or a shift to a more favorable climate.

The release from predation explanation is plausible in the Gulf of Maine given the sharp decline in the abundance of some key groundfish, but the data to support it are correlative in nature. For the Canadian side of the Gulf of Maine, there is spatial mismatch in that much of the stomach content data are from outside the main lobster grounds.

Temperature or climatic shifts have also been put forward as potential causes of increased lobster abundance. Drinkwater et al. (1996) could find no link between the increase in lobster catches in the 1980s and changes in ocean temperatures. Boudreau on the other hand (unpublished thesis, 2012) reported a positive relationship between the North Atlantic Oscillation Index (NAOI) and indicators of lobster abundance at lags of several years. In addition, Pershing et al. (2012) point to atmospheric temperature as an important explanatory variable in patterns of lobster settlement. Temperature data were tabled by D. Hebert (Oceans Science, B.I.O.) at the Assessment Meeting and are described in a draft research document entitled "Meteorological, Sea Ice and Physical Oceanographic Conditions on the Scotian Shelf and in the Gulf of Maine during 2012".

Here are tabled some of the available data on predators to identify any large changes that may have implications for lobster production.

Also tabled are data on the "fishery footprint", defined here as the proportion of the bottom that lobster traps cover.

8.1. METHODS

8.1.1. Potential Predators of Lobster

Biomass trends of fish species were obtained from the DFO summer research trawl surveys. The species chosen were those that have records of lobster consumption (not necessarily in LFAs 34-38 - see section 2). In alphabetical order, these species are Atlantic Wolffish, Cod, Cusk, Haddock, Longhorn Sculpin, Sea Raven, Spiny Dogfish, and White Hake. The area selected was and the Bay of Fundy (4Xopqrs, Figure 8.1). All data were obtained from DFO's Virtual Data Centre (VDC).

8.1.2. Fishery Footprint

The numbers of annual trap hauls (from Section 5) were expanded to an estimate of the total area of the bottom contacted by lobster traps using the dimensions of a typical trap. The number of trap hauls used was that for 2011-12. The trap size used was 21 inches by 48 inches, which covers an area of 0.63 m^2.

The total area contacted by traps was expressed as a percentage of the total area (Km^2) of the LFAs. Total areas of grid cell and of LFAs were estimated for Coffen-Smout et al. (2013). Areas of grid cells were estimated using ARCGIS software based on the Universal Transverse Mercator projection (NAD 1983 CSRS UTM zone 20).

8.2. RESULTS AND DISCUSSION

8.2.1. Potential Predators of Lobster

The biomass trends of potential predators of lobster indicate most are at low levels relative to the long-term mean and median (Table 8.1, Figure 8.2). The exception is Sea Raven, which is well above long-term means. Atlantic wolffish and cod are at the lowest points relative to the long-term with recent means only 5% and 17% of the mean for 1970-2009. Recent biomass estimates for haddock are closer to the long-term mean, but still below. Recent estimates for Cusk, Spiny Dogfish, White Hake, and Longhorn Sculpin, are 30-64% of the long-term means.

Given the current low biomass levels of most of these potential lobster predators, a near-term increase in the natural mortality of lobsters due to these species is not expected. Although the research trawl survey does not cover much of the nearshore grounds where lobsters are most abundant, trends in the biomass of some of these species in the ITQ survey are similar.

8.2.2. Fishery Footprint

The percentage of the area of the LFAs contacted by lobster traps was quite low, with estimates less than 0.1% (Table 8.2). In the nearshore Grid Groups of LFA 34, the total area contacted is higher but still less than 0.2% of the total area. As expected, the footprint was larger in LFA 34 than in any of the Bay of Fundy LFAs (0.02-0.03%). These estimates do not account for any movement of the traps either due to storms or while hauling. In addition, the analysis assumes that traps are dropped in a new location each time, which does not account for the expected overlap in trap footprints over time. The estimates assume traps are evenly distributed over the entire LFAs but we know that is not the case, so some portions of the LFAs will have higher footprints, while others will be lower.

8.3. SUMMARY

Given the low biomass levels of seven of eight potential predators of lobster (Atlantic Wolffish, Cod, Cusk, Haddock, Longhorn Sculpin, Sea Raven, Spiny Dogfish, and White Hake) in LFAs 34-38 (approximated by NAFO Division 4Xopqrs), it is not expected that lobster predation mortality due to these species will increase in the near future.

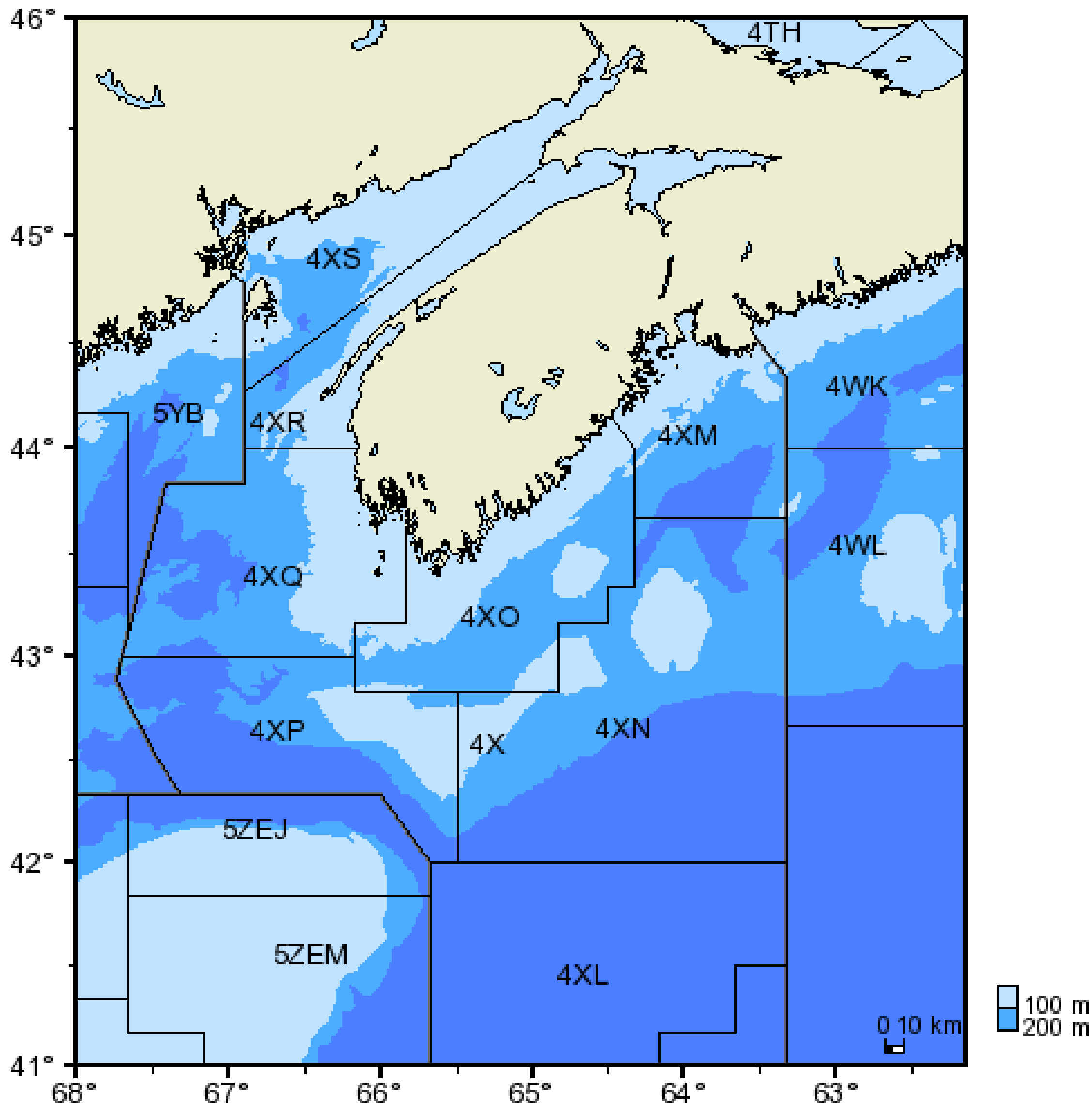
The area contacted by lobster traps (fishery footprint) in any given year in LFAs 34 as a whole is calculated to be less than 0.1% of the total area; for LFAs 35-38 it is calculated at 0.02-0.03%.

Table 8.1. Biomass (t) of potential predators of lobster. Shown are the long-term mean estimates, and the estimates for recent years as a percentage of long-term values. Data are from DFO's July trawl survey. Estimates are the stratified annual totals obtained from DFO's Virtual Data Centre. Area for biomass estimates was NAFO 4Xopqrs.

Species	Long-term mean 1970-2009	Long-term median 1970-2009	Recent mean 2010-2012	Recent mean as % of long-term mean	Recent median as % of long-term median
Atlantic Wolffish	861	644	33	4%	5%
Cod	13410	12016	1718	13%	14%
Cusk	2166	1546	464	21%	30%
Haddock	21240	16380	15141	71%	92%
Longhorn Sculpin	1195	904	759	64%	84%
Sea Raven	1468	1356	1916	131%	141%
Spiny Dogfish	79821	51995	28291	35%	54%
White Hake	16437	12677	8966	55%	71%

Table 8.2. Percentage of area contacted by lobster traps in 2011-12 by LFA.

LFA	Total Km^2	Number of trap hauls	Area of trap (m2)	Area affected (m^2)	Area affected (Km^2)	**% of area contacted by lobster traps**
34	20346	21,181,579	0.63	13,344,395	13.34	**0.07%**
35	5406	1,364,860	0.63	859,862	0.86	**0.02%**
36	4258	1,425,035	0.63	897,772	0.90	**0.02%**
38	4050	1,797,855	0.63	1,132,649	1.13	**0.03%**



DFO Science Virtual Data Centre Jan 08 2013

Figure 8.1. North Atlantic Fisheries Organization (NAFO) divisions and unit areas. Biomass estimates for fish species are for 4Xopqrs.

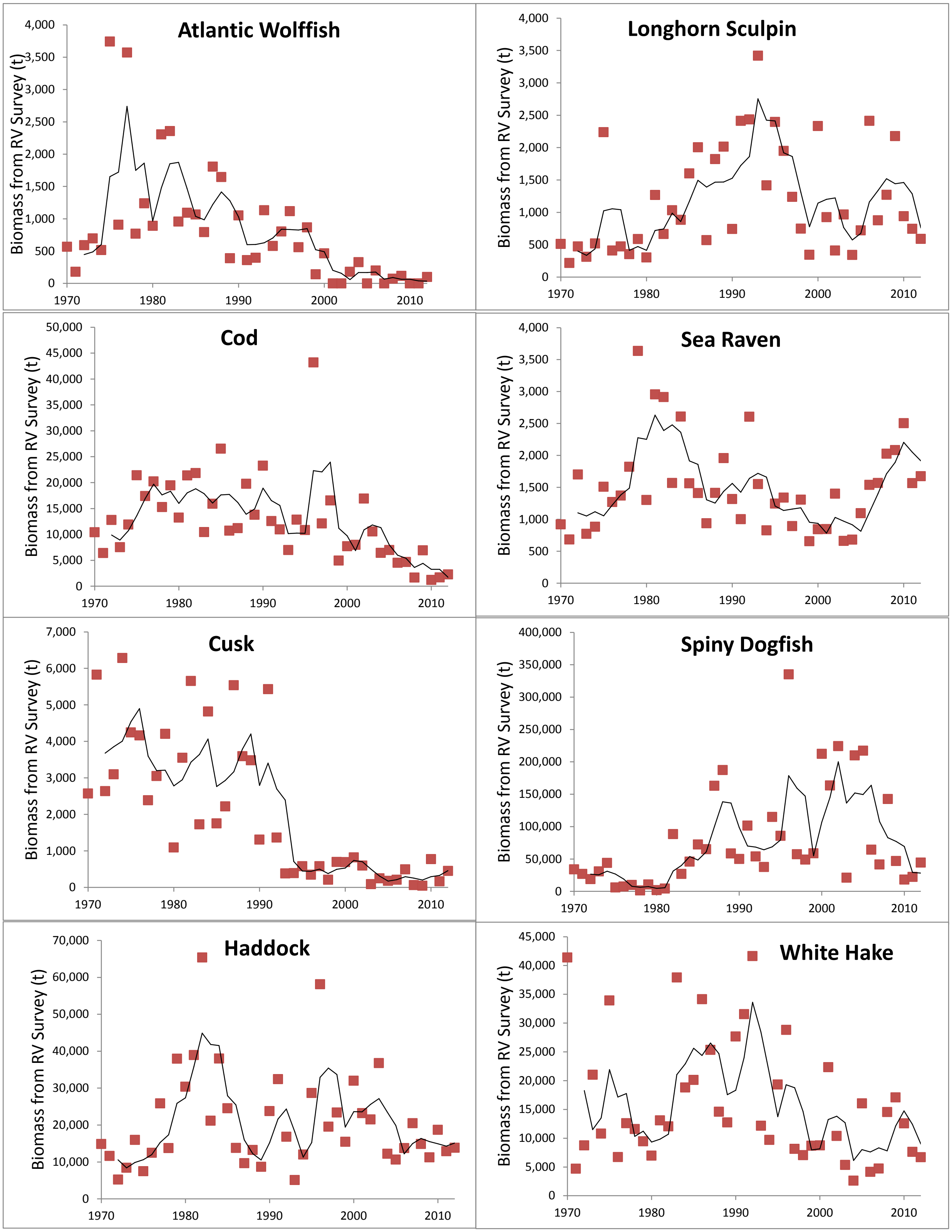


Figure 8.2. Annual biomass estimates for potential predators of lobster (Atlantic Wolffish, Cod, Cusk, Haddock, Longhorn Sculpin, Sea Raven, Spiny Dogfish, White Hake) - 1970-2012. Data are from DFO's July trawl survey. Estimates are stratified totals obtained from DFO's Virtual Data Centre. Area for biomass estimates was NAFO 4Xopqrs. Line is 3-year running mean.

9. REFERENCE POINTS

Progress in the development of Reference Points (RPs) for lobster in the Maritimes Region is described in Tremblay et al. (2012b). The rationale for using empirical (or “trend-based”) RPs for lobsters, and for using landings as a proxy for biomass in the near to medium term, is related to the available data and the assessment tools available. Although there are clearly uncertainties in using landings as a proxy for biomass, evidence was presented that increased landings since the 1980s are primarily the result of increased lobster abundance. Here landings-based reference points are restated and new reference points are proposed based on catch rate in the fishery and on the catch rate of lobsters in some fishery independent surveys (Pezzack, unpublished).

9.1. LANDINGS-BASED REFERENCE POINTS - ABUNDANCE OF LEGAL SIZES

The median of the lobster landings from 1985-2009 is used as a proxy for Biomass at Maximum Sustainable Yield (BMSY) (Tremblay et al. 2012b). Landings are displayed in Table 9.1. For the Upper Stock Reference USR and Limit Reference Point (LRP), the values of 80% and 40% are proposed, as is suggested in the DFO guidance document on application of the Precautionary Approach. These values are set out for each LFA; for the Bay of Fundy, summing the landings for the Bay of Fundy LFAs is proposed (Table 9.2). Where there were observations of lower landings from 1985-2009 from which the fishery recovered, the lowest point of a 3-year running average was used as the LRP. The mean of the last 3 years is taken as the metric to assess whether landings have dropped below the USR. Based on this metric, LFA 34 and LFAs 35-38 are well above the proposed USRs.

9.2. CPUE-BASED REFERENCE POINTS – ABUNDANCE OF LEGAL SIZES

9.2.1. LFA 34

For LFA 34, there are now 14 seasons of log data. The commercial CPUE has increased substantially since 1998-99 (almost double). How long this high productivity regime will last is uncertain but there are no indications of an imminent change. An USR is proposed based on the CPUE for LFA 34 as a whole. While there have been spatial differences in CPUE trends within LFA 34, all Grid Groups have trended upwards in the last 14 years and we expect the trend in bulk CPUE will reflect the trend in most Grid Groups.

It is proposed to use the median CPUE for the period 1998-99 to 2008-09 (= 0.78 kg/trap haul) as a proxy for BMSY as suggested in the DFO Guidance document. This period covers much of the available time series but does not include the last 3 record-breaking seasons. Ending at 2008-09 allows for meaningful comparison of a 3-year running mean of recent CPUE’s with an 11-year period. Stopping at 2008-09 is also consistent with the landings-based reference point.

A USR equal to 80% of the median (= 0.62 kg/trap haul) is proposed. Recognizing the uncertainty in CPUE levels prior to 1999, a second option is a USR equal to 70% of the median (=0.54 kg/trap haul). Both of these USRs are close to the CPUE measured at the start of the time series (1998-99, CPUE = 0.58 kg/trap haul). If CPUE drops below this level it would be an indication of a substantial reduction in the current productivity. These USRs are more precautionary than the landing-based reference point, and recognize that if productivity declines to that of the late 1990s, adjustments to the management plan should be considered.

To avoid anomalous years triggering a response, it is proposed that the mean of the last 3 years be taken as the metric to assess whether CPUE has dropped below the USR. The current 3-year mean (1.02 kg/trap haul) is well above the proposed USR.

9.2.2. LFAs 35-38

For LFAs 35-38, the time series of reliable catch and effort data is only 7 years, making the delineation of reference points more difficult. A USR equal to an estimate of CPUE for the period 1995-96 to 1997-98 is proposed. This is a similar approach to LFA 34, accounting for the shorter time series of CPUE data. The median CPUE from the start of the CPUE series (2005-06) to 2008-09 is 1.16 kg/ trap haul. The CPUE for the period 1995-96 to 1997-98 is not available, but can be estimated by the ratio of the median landings from 1995-96 to 1997-98 to the median landings for the period 2005-06 to 2008-09 with an adjustment for higher effort in the more recent period (approximately 10%). With a downward adjustment of 10%, the median landings for the more recent period is 3,946 t, compared 1,969 t for the period 1995-96 to 1997-98. Applying the ratio of 1,969:3,946 (= 0.50) to the CPUE of 1.16 kg/trap haul, the proposed USR is 0.58 kg/trap haul.

As for LFA 34, it is proposed that the mean of the last 3 years be taken as the metric to assess whether CPUE has dropped below the USR. The current 3-year mean (1.6 kg/trap haul) is well above the proposed USR.

9.3. CPUE OF LOBSTERS IN FISHERY INDEPENDENT SURVEYS – ABUNDANCE OF SUBLEGAL AND LEGAL SIZES

The catch rate of lobsters in surveys directed at other species, such as groundfish and scallops, are proving to provide meaningful indicators of lobster biomass and abundance (Pezzack, unpublished).

9.3.1. LFA 34

For LFA 34, it is proposed that the lobster catch rate in the ITQ survey be used to provide an upper stock reference point (Figure 9.3). The ITQ survey began in 1995. We propose to use the period 1996 to 2009 to avoid the initial year that involved protocol development. The end year (2009) is consistent with the landings-based reference point. We propose to use the median of the above period (23.7 lobster per tow) as the BMSY proxy and propose a USR of 80% (19.0 lobsters per tow) (Figure 9.3).

9.3.2. LFAs 35-38

For the Bay of Fundy LFAs, it is proposed to use the lobster catch rate in the annual research vessel (RV) surveys in strata 490-495. It is proposed to use the period 1985-2009. The median for this period is 2.4 lobsters per tow, the proposed USR is 80% of this, or 1.9 lobsters per tow (Figure 9.4).

9.4. CPUE IN STANDARD TRAPS - ABUNDANCE OF SUBLEGAL SIZES

FSRS data for sublegal sizes for LFA 34 is available since 1999-00. It is proposed to use a USR based on these data using the same approach as commercial CPUE. The median of the period 1999-00 to 2008-00 for LFA 34 nearshore sublegal CPUE, weighted by Grid Group area (section 6) is 1.9 lobsters per trap haul. A USR at 80% of this figure is 1.55 lobsters per trap haul (Figure 9.5).

A USR for sublegal lobsters based on the FSRS trap data for LFAs 35-38 is not proposed due to the short time series.

9.5. SECONDARY INDICATORS

Secondary indicators may both (i) change the perception of stock status, and (ii) inform the type of response to a stock that has entered the cautious zone (Tremblay et al. 2012b). The primary indicators need to be interpreted in the light of secondary indicators related to

Abundance/biomass (commercial sizes), Production (recruitment, reproduction), Demography (size structure, sex ratio), Fishing Pressure (effort, exploitation) and the Environment. Spatial changes in distribution should also be considered. For example, if the overall CPUE in LFA 34 declines, the changes within Grid Group should be examined. While these secondary indicators will not necessarily be evaluated on an annual basis, they will be evaluated should the primary indicators change substantially.

The contribution of larger lobsters to reproduction has been identified as an important aspect that needs to be monitored at the level of the secondary indicators. In the future, a reference point based on a reproductive index is needed.

9.6. FUTURE

- To reduce uncertainty assessing changes in stock status, need to have fishery independent surveys.
- These could be enhanced existing surveys or new surveys. If any surveys are discontinued there will be greater uncertainty in stock status.
- These surveys should provide not only an index of abundance, but the data on lobster sizes and reproductive success.
- There is a need to incorporate reference points for (i) large lobsters and (ii) a reproductive index.
- The proposed Upper Stock Reference Points should be revisited during the next assessment.

Table 9.1. Landings for fishing seasons from 1975-76 season to 2011-12 season for LFAs 34, 35, 36 and 38. Values less than the 25th percentile of the time series were classified as "negative" (black), values between the 25th and 75th percentile were classified as "neutral"(grey) and values greater than the 75th percentile were classified as "positive" (white). Note that some of the landings data have been corrected from those presented in Tremblay et al. (2012b).

FISHING SEASON	LFA34	LFA35	LFA36	LFA38	LFA 35-38
1975/1976	3,829	132	115	294	541
1976/1977	3,525	120	58	170	348
1977/1978	2,668	157	47	351	555
1978/1979	2,963	137	176	302	615
1979/1980	3,203	75	126	347	548
1980/1981	3,086	132	156	236	524
1981/1982	3,649	133	195	390	718
1982/1983	4,546	135	225	378	738
1983/1984	5,140	164	211	365	740
1984/1985	5,937	226	266	334	826
1985/1986	6,892	246	281	316	843
1986/1987	7,672	330	327	329	986
1987/1988	8,478	265	340	384	989
1988/1989	8,200	271	310	468	1,049
1989/1990	9,449	255	221	467	943
1990/1991	11,084	227	271	495	993
1991/1992	8,888	261	260	512	1,033
1992/1993	8,902	239	257	472	968
1993/1994	10,334	241	274	523	1,038
1994/1995	9,683	338	318	661	1,317
1995/1996	10,339	546	427	600	1,573
1996/1997	10,646	738	680	551	1,969
1997/1998	12,064	837	788	701	2,326
1998/1999	13,074	923	826	809	2,558
1999/2000	13,444	910	879	826	2,615
2000/2001	16,198	1,074	1,032	984	3,090
2001/2002	19,058	1,219	1,261	1,145	3,625
2002/2003	17,613	1,234	1,155	1,073	3,462
2003/2004	17,801	1,337	1,169	1,133	3,639
2004/2005	17,250	1,172	1,143	1,363	3,678
2005/2006	17,009	1,235	1,295	1,595	4,125
2006/2007	16,583	1,191	1,138	1,413	3,742
2007/2008	17,145	1,488	1,477	1,855	4,820
2008/2009	17,262	1,617	1,596	1,638	4,851
2009/2010	19,749	1,898	1,594	2,035	5,527
2010/2011	20,401	2,546	1,916	2,352	6,814
2011/2012	23,292	3,245	2,481	2,741	8,467

Table 9.2. Landings-based reference points for LFAs 34, 35, 36 and 38.

	LFA34	LFA35	LFA36	LFA38	LFA 35-38
BMSY proxy - Median 1984-85 to 2008-09	11,084	738	680	661	1,969
Upper Stock Reference	8867	590	544	529	1575
Lower Stock Reference	4434	295	272	264	788
3-year Running Mean	21,147	2,563	1,997	2,376	6,936

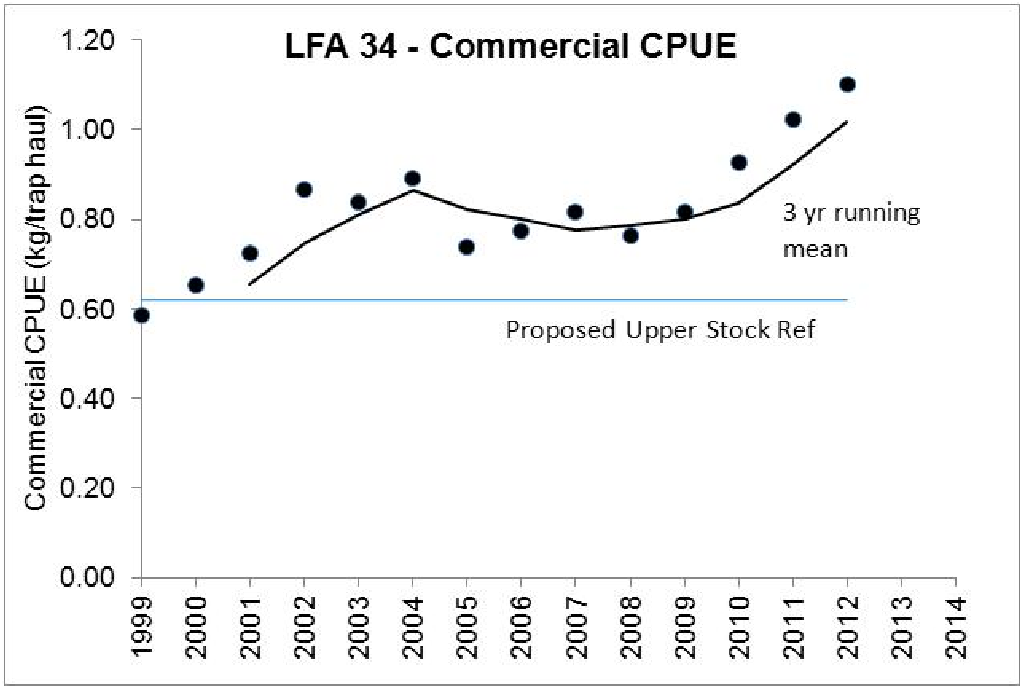


Figure 9.1. Proposed Upper Stock Reference (USR) (horizontal line) based on commercial CPUE for LFA 34. Shown is annual commercial CPUE (total weight landed/total trap hauls), with USR based on 80% of the median CPUE for fishing season from 1998-99 to 2008-09 (= 0.62 kg/trap haul). Also shown is the 3-year running mean (= 1.0 after 2011-12 season).

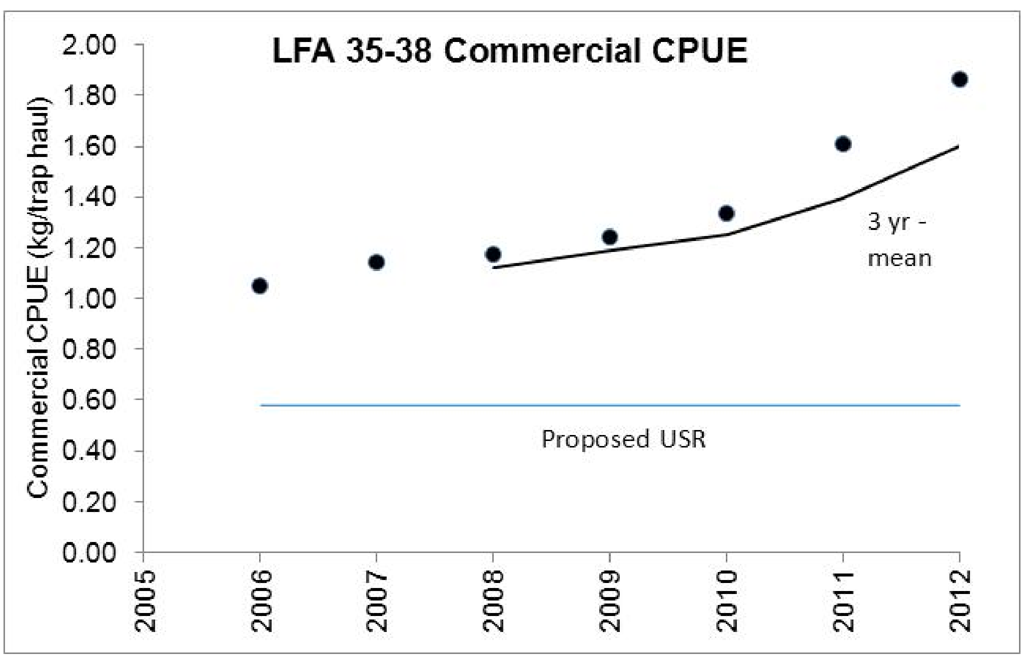


Figure 9.2. Proposed Upper Stock Reference (USR) based on CPUE for LFAs 35-38. Shown is the annual commercial CPUE (total weight landed/total trap hauls) for fishing seasons 2005-06 to 2011-12. Proposed USR (0.58 kg/trap haul) is 50% of the median CPUE for the period 2005-06 to 2008-09 (1.16 kg/trap haul). Also shown is the 3-year running mean (= 1.6 after 2011-12 season).

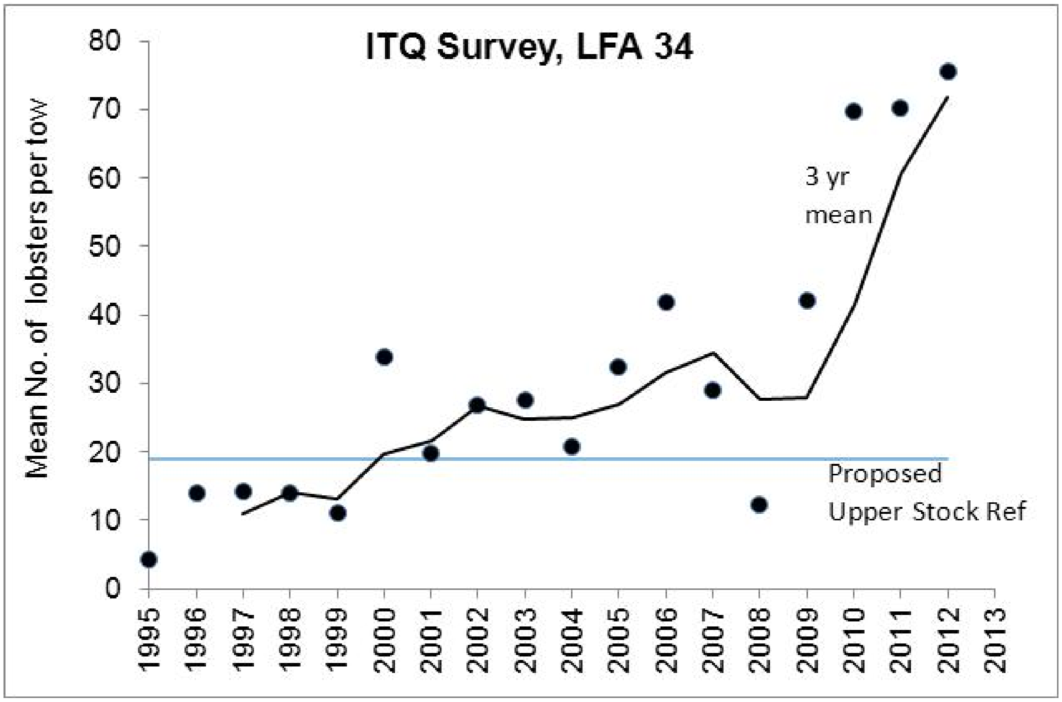


Figure 9.3. Proposed Upper Stock Reference (USR) for lobster abundance in LFA 34 based on ITQ survey. The median for 1996 to 2009 (23.7 lobsters/tow) is used as the BMSY proxy, with the USR proposed as 80% of the median (19.0 lobsters/tow, dashed line). The solid line is the 3-year running mean.

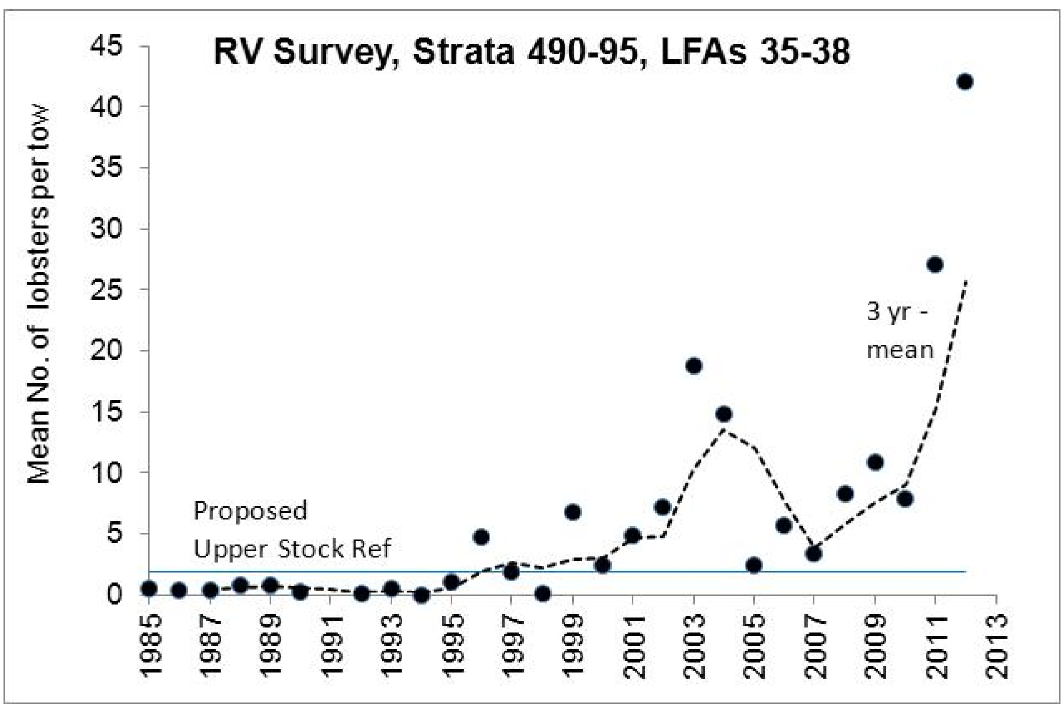


Figure 9.4. Proposed reference point for lobster abundance in LFA 35-38 based on summer RV survey. The median for 1985 to 2009 (2.4 lobsters/tow) is used as the BMSY proxy. Proposed Upper Stock Reference is 80% of the median (1.9 lobsters/tow). Solid line is 3-year running mean.

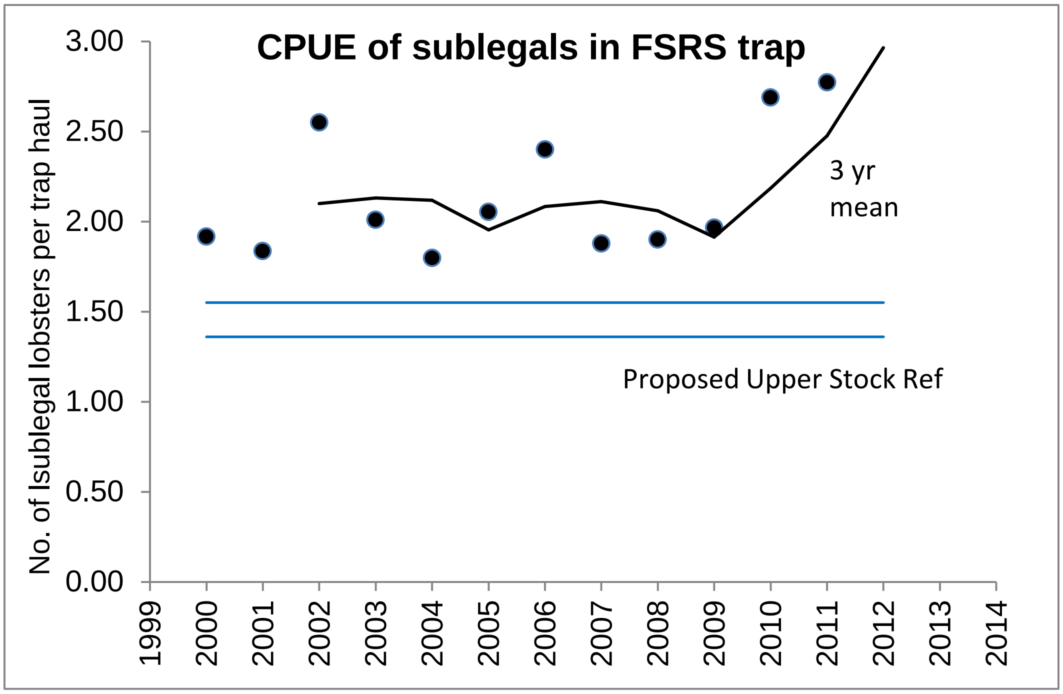


Figure 9.5. Proposed reference point for sublegal lobster abundance in LFA 34 based on CPUE (no. lobsters per trap haul) in FSRS traps. Median for period of 1999-00 to 2008-09 is 1.94 lobsters per trap haul. Proposed USR is 80% of this (= 1.55 lobsters per trap haul). A second possible USR is 70% of the median (= 1.36 lobsters per trap haul).

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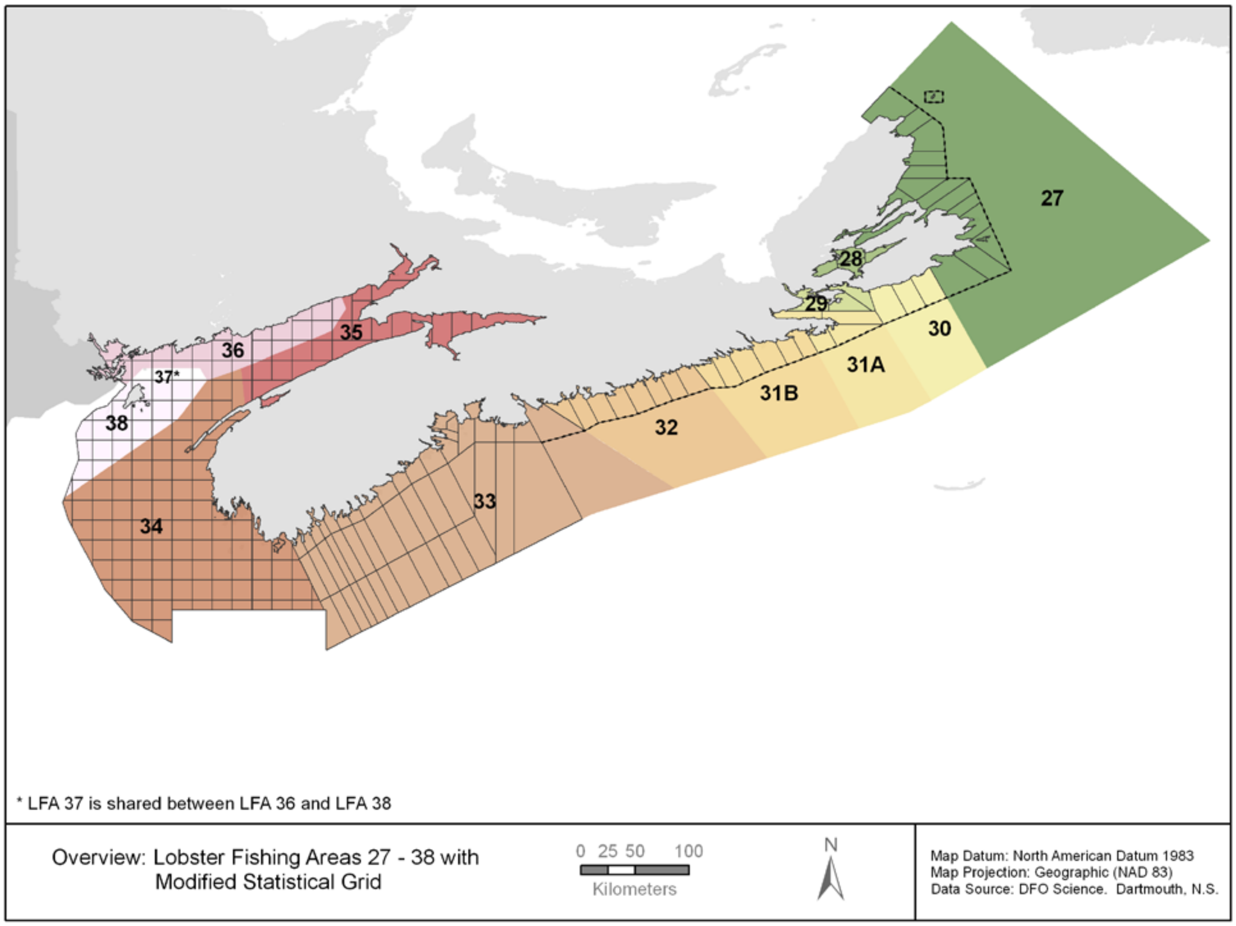
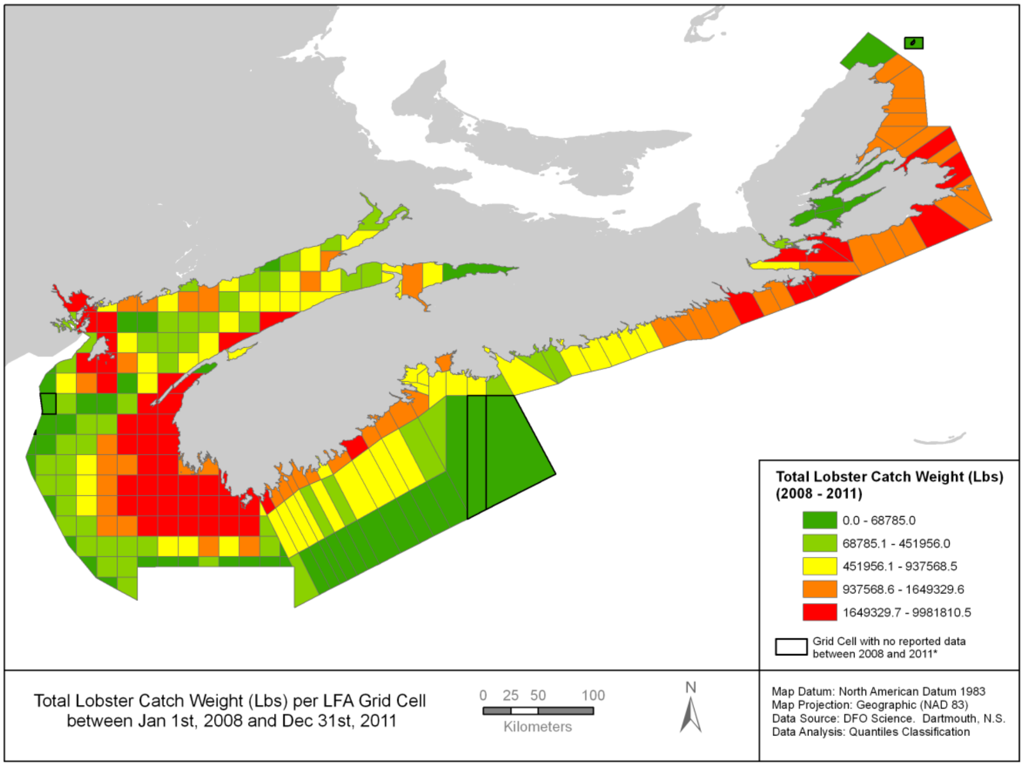
11. APPENDIX 1 – MAPS OF FISHERY DATA FROM LOGBOOKS, LFAS 27-38

11.1. INTRODUCTION

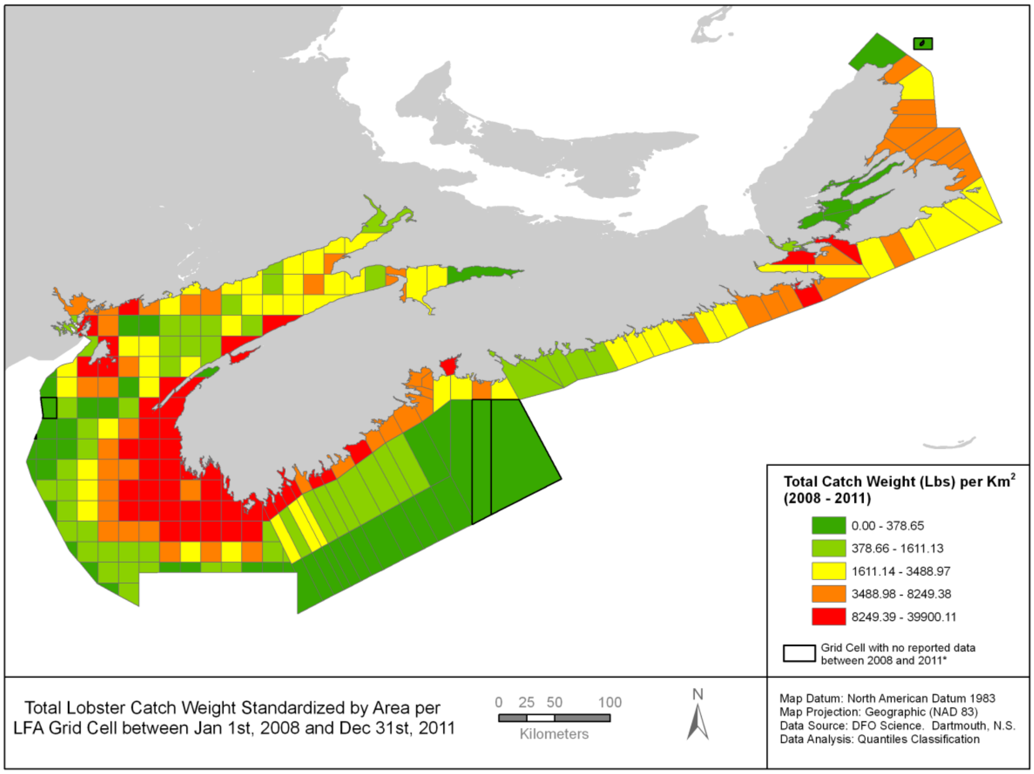
Maps produced here are from an analysis of Lobster Catch and Settlement Reports ("Logbooks") by DFO Maritimes, Oceans Branch as part of their Resource Mapping Project. All figures are from a draft of the following technical report: S. Coffen-Smout, D. Shervill, D. Sam, C. Denton, and J. Tremblay. 2013. Mapping Inshore Lobster Landings and Fishing Effort on a Maritimes Region Modified Grid System. Canadian Technical Report of Fisheries and Aquatic Sciences 3024: 33 p.



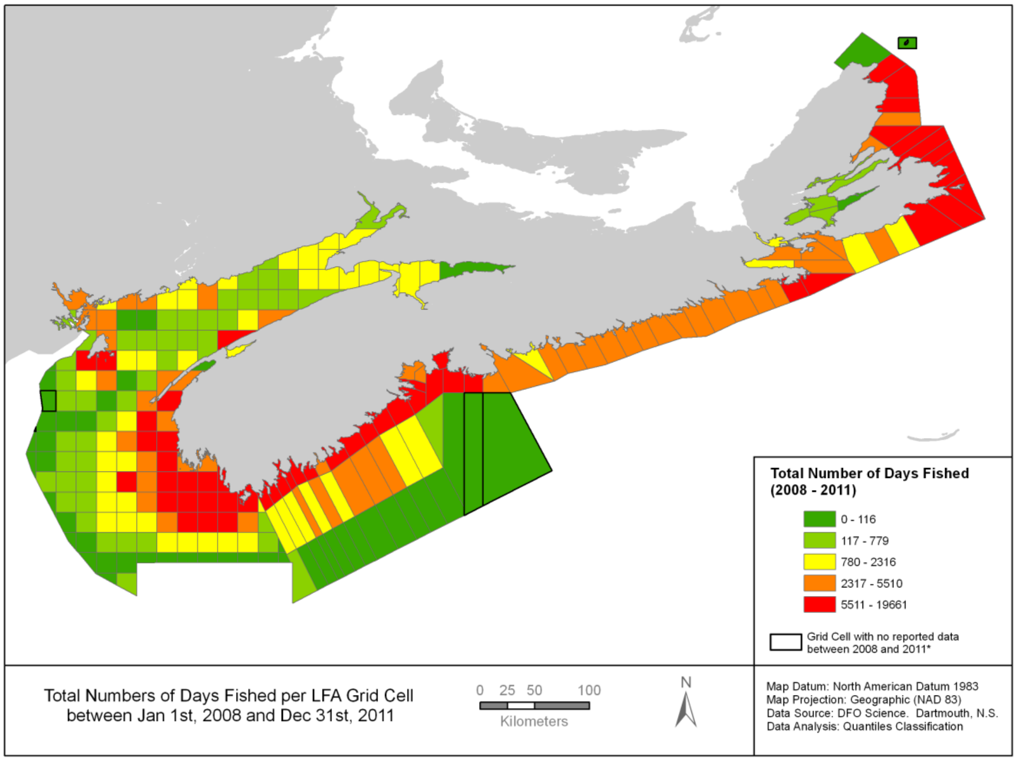
Appendix 1, Figure 1. Overview of LFAs with grid cells.



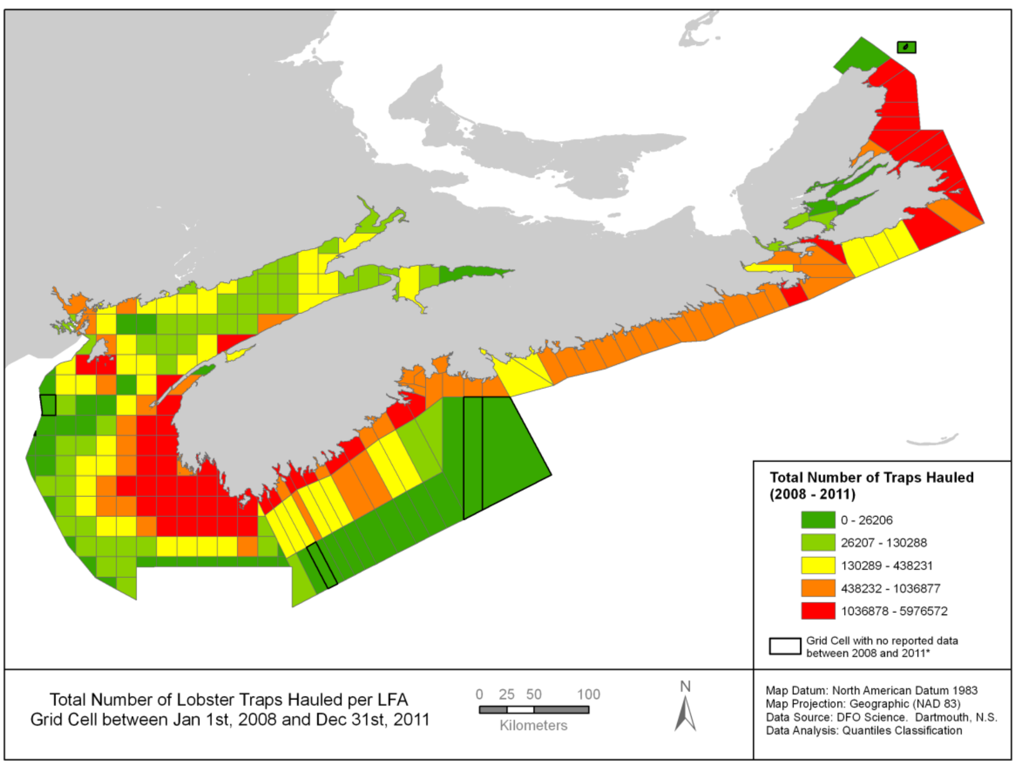
Appendix 1, Figure 2. Total landings (lbs) per grid cell, 2008-2011.



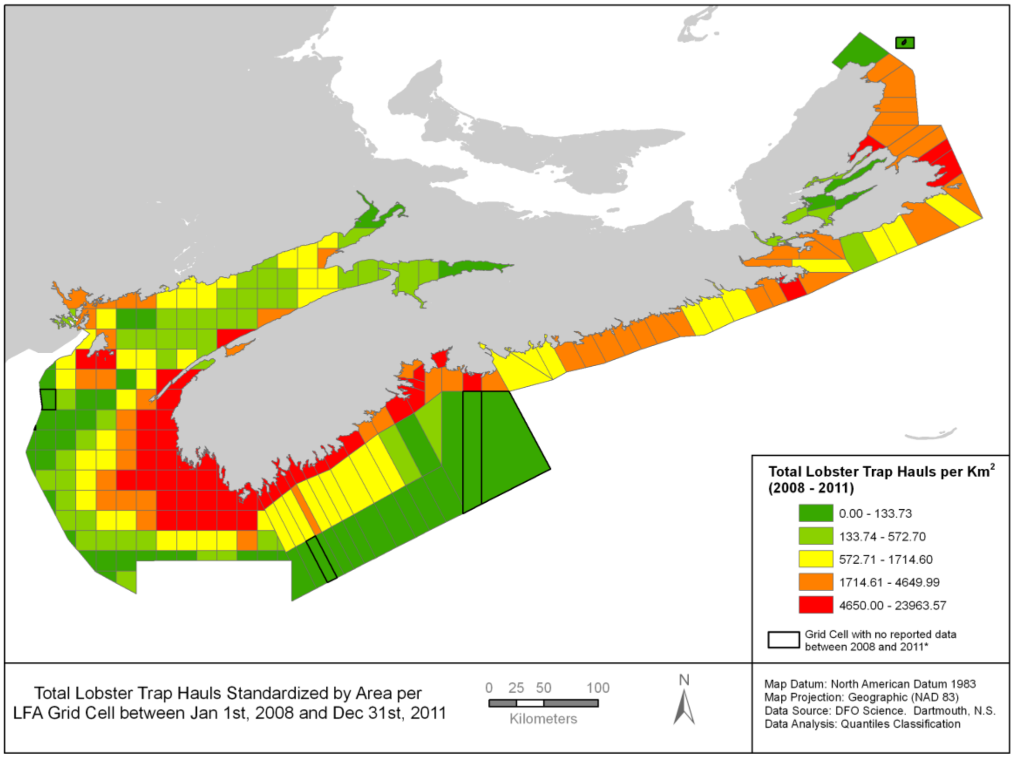
Appendix 1, Figure 3. Total landings (lbs) per Km^2 per grid cell, 2008-2011.



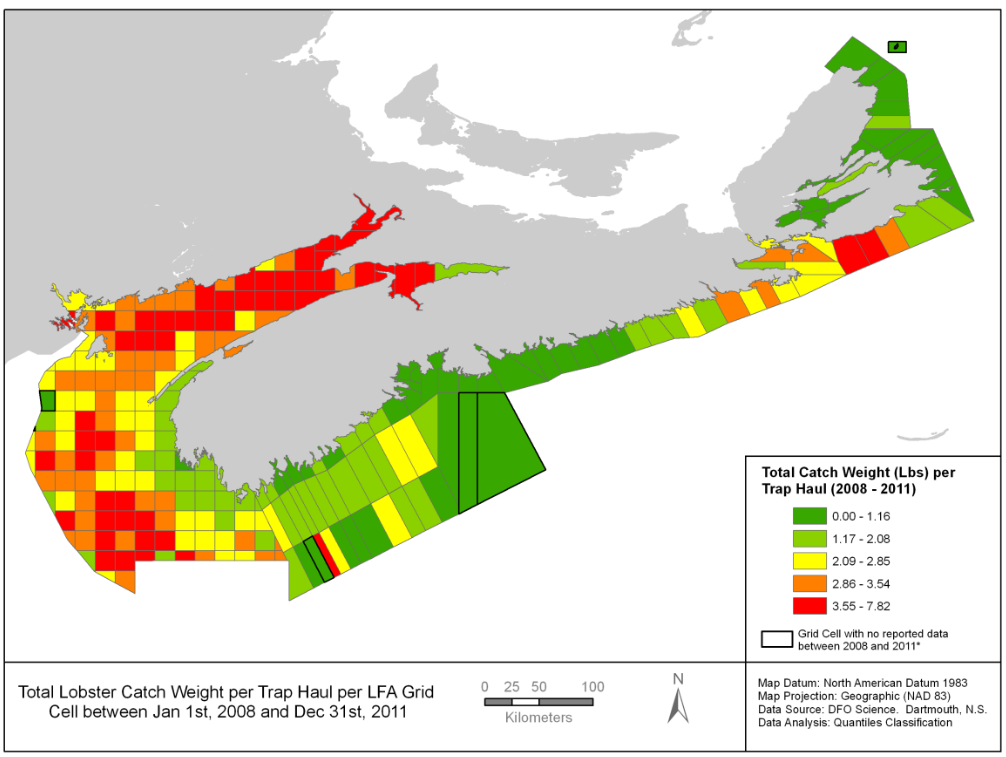
Appendix 1, Figure 4. Total days fished per LFA grid cell, 2008-2011.



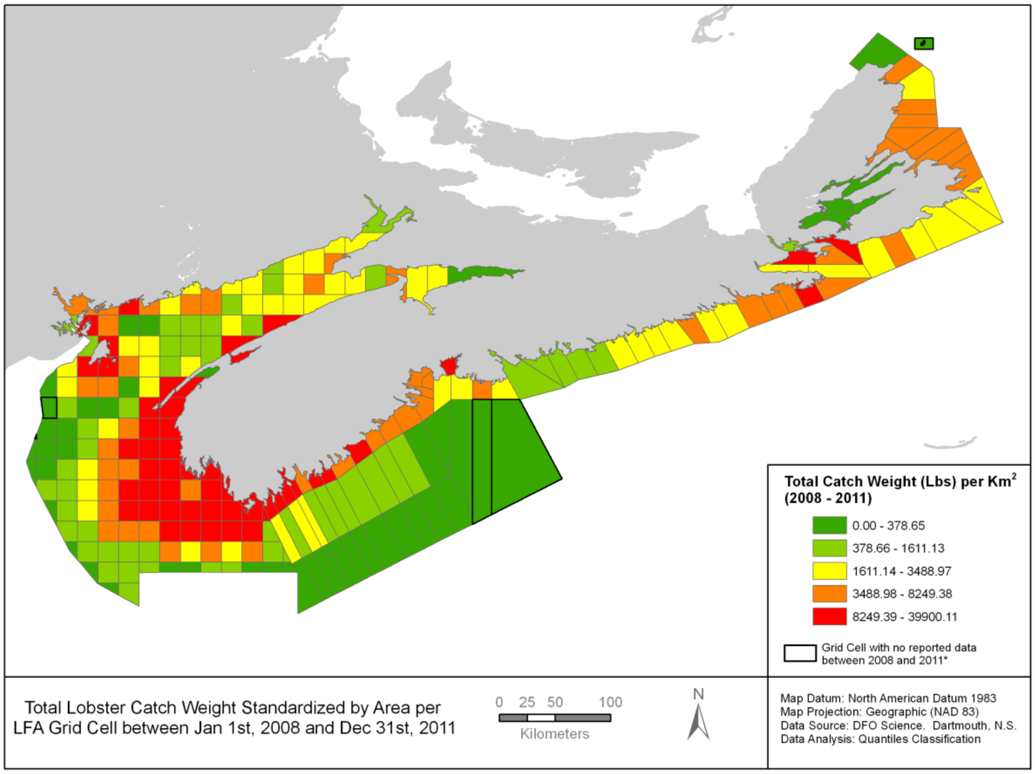
Appendix 1, Figure 5. Total number of trap hauls per grid cell, 2008-2011.



Appendix 1, Figure 6. Total number of trap hauls per Km^2 per grid cell, 2008-2011.



Appendix 1, Figure 7. CPUE (lb per trap haul) per grid cell, 2008-2011.



Appendix 1, Figure 8. CPUE (lb per trap haul) per Km^2, 2008-2011.