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Offshore Lobster in Lobster Fishing Area 41 (4X and 5Zc)

La pêche hauturière du homard de la zone de pêche du homard 41 (4X et 5Zc)

D.S. Pezzack, C.M. Frail, A. Reeves, and M.J. Tremblay

Population Ecology Division, Maritimes Region
Bedford Institute of Oceanography
P.O. Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2

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ABSTRACT

The offshore lobster (*Homarus americanus*) fishery (Lobster Fishing Area [LFA] 41), established in 1972, fishes from the 50 nautical mile line (92km) to the upper continental slope of the Scotian Shelf and on northeast Georges Bank. While LFA 41 includes parts of the Northwest Atlantic Fisheries Organization (NAFO) divisions 4Vs, 4W, 4X and 5Z, lobster fishing is authorized only in 4X and 5Zc. The fishery is managed by input and output controls including a 82.5mm minimum size carapace length (CL), prohibition on landing berried or v-notched female lobsters, limited entry (8 licences) and a 720t Total Allowable Catch (TAC). In this assessment, indicators of abundance, fishing pressure and production are evaluated for 5 subareas (Georges Bank, Southeast Browns, Southwest Browns, Georges Basin and Crowell Basin). Based on these indicators, the current TAC of 720t (in place since 1985) does not appear to have had negative impacts on the lobster in LFA 41 (4X and 5Zc) overall, and is considered to represent an acceptable harvest strategy at this time.

Abundance indicators (trap catch rate, catch rate in Department of Fisheries and Oceans (DFO) summer bottom trawl surveys) for commercial sized lobsters in the different subareas suggest that lobster abundance has been either stable without trend or has trended higher since 1999. Fishing pressure was evaluated in terms of total trap hauls, size structure and sex ratio. Total trap hauls in 2007 (288,000) returned to levels observed in 1995 (228,000), down from the peak of 593,000 in the 1998-1999 season, presumably because of reduced fishing for Jonah crab. The size structure has remained stable except for apparent decreases in median size in Crowell Basin. A decrease in the proportion of males occurred during the first 10 years of the fishery, with the largest change on Georges Bank. The sex ratio is skewed towards more females as conservation rules protecting berried females result in lower fishing mortality on females. Exploitation rate has not been directly estimated but is inferred to be low. Landings in the larger adjacent fisheries (USA, LFA 34) increased significantly during the last 10 years, indicating additional pressure on the lobster resources in these areas. Production indicators show that there is a high proportion of females above the estimated size of 50% maturity of 97mm carapace length (CL) and above 115mm CL (most females are multiparous or multiple breeders above this size) in the LFA 41 fishery, indicating a high level of potential egg production relative to the inshore fisheries. Four assessment areas have shown no trend in this proportion over time. Indicators of lobster recruitment in LFA 41 are not currently available since the fishery is conducted primarily in deeper areas where recruitment is not expected to occur.

Potential ecosystem interactions include impacts of traps on bottom habitat, impacts of lost gear, bycatch and interactions with other species. Bycatch species that occur most frequently in the LFA 41 lobster fishery include Jonah crab, cusk, hake (red and white), cod, rock crab and redfish. Other than Jonah crab, all animals are released. High survival is assumed for invertebrates, but survival may be lower for some fish species. The effect of fishing on bottom habitat has not been evaluated but is expected to be low relative to other bottom contact gear types. This expectation is based on the small size of the gear footprint and the relatively low density of traps in this large fishing area.

RÉSUMÉ

La pêche hauturière du homard (*Homarus americanus*) dans la zone de pêche du homard [ZPH] 41 a débuté en 1972. Elle porte sur les eaux allant de la limite des 50 milles marins (92 km) à la partie supérieure du talus continental du plateau néo-écossais et sur la partie nord-est du banc Georges. Quoique la ZPH 41 englobe des parties de la subdivision et des divisions 4Vs, 4W, 4X et 5Z de l'OPANO, la pêche du homard n'est autorisée que dans 4X et dans 5Zc. Cette pêche est gérée à l'aide de mesures régissant les intrants et les extrants, dont une longueur de carapace (LC) minimale de 82,5 mm, l'interdiction de débarquer des femelles œuvées ou porteuses d'une encoche en V, un accès limité (8 permis) et un TAC de 720 t. Le présent document évalue les indicateurs d'abondance, de pression de pêche et de production concernant cinq sous-zones (le banc Georges, le sud-est du banc de Brown, le sud-ouest du banc de Brown, le bassin Georges et le bassin Crowell). Si on se fie sur ces indicateurs, l'actuel TAC de 720 t (adopté en 1985) ne semble pas avoir eu d'incidences négatives sur le homard dans la ZPH 41 (4X et 5Zc) en général et on estime qu'il représente une stratégie de capture acceptable pour le moment.

Les indicateurs d'abondance (taux de prises au casier et taux de prises dans les relevés d'été du MPO au chalut de fond) des homards de taille commerciale dans les différentes sous-zones portent à croire que l'abondance du homard a été soit stable sans présenter de tendance, soit en hausse depuis 1999. La pression de pêche a été évaluée d'après le nombre total de casiers levés, la structure de tailles et les proportions de chacun des sexes. En 2007, le nombre total de casiers levés (288 000) est redescendu à des niveaux comparables à ceux de 1995 (228 000), après avoir culminé à 593 000 en 1998-1999, probablement à cause de la diminution de la pêche du crabe nordique. La structure de tailles est restée stable, sauf pour ce qui est de baisses apparentes de la taille médiane dans le bassin Crowell. On a observé une baisse de la proportion de mâles dans les 10 premières années de la pêche, le changement le plus important se produisant sur le banc Georges. S'agissant de la proportion des sexes, les pourcentages dénotent plus de femelles, car les mesures de conservation qui protègent les femelles œuvées se traduisent par une baisse de la mortalité par pêche chez les femelles. Il n'y a pas eu d'estimation directe du taux d'exploitation, mais on le tient pour faible. Les débarquements dans les plus grandes pêches de homard des zones contiguës (États-Unis, ZPH 34) ont considérablement augmenté dans les dix dernières années, ce qui reflète une pression supplémentaire sur les stocks de homard de ces zones. Les indicateurs de production dénotent la présence d'une forte proportion de femelles dont la LC est supérieure à 97 mm (qui est la taille estimée à la maturité 50 %) et également de femelles de plus de 115 mm (femelles multipares) dans les prises de la pêche dans la ZPH 41, reflétant une forte production d'œufs possible comparativement à celle des zones de pêche côtière. Aucune tendance n'a été observée dans cette proportion au fil du temps dans quatre zones d'évaluation. On ne dispose pas d'indicateurs du recrutement du homard dans la ZPH 41, étant donné que la pêche se déroule surtout dans des zones où aucun recrutement n'est attendu.

Au nombre des interactions possibles avec l'écosystème, il faut citer les effets des casiers sur l'habitat offert par le fond marin, les effets des engins perdus, les prises accessoires et les interactions avec d'autres espèces. Les prises accessoires les plus fréquentes dans la pêche du homard pratiquée dans la ZPH 41 comprennent le crabe nordique, le brosme, la merluche rouge, la merluche blanche, la morue, le crabe commun et le sébaste. Hormis celles de crabe nordique, toutes les prises accessoires sont remises à l'eau. On pense que le taux de survie des prises renvoyées à la mer est élevé pour ce qui est des invertébrés, mais qu'il pourrait être plus bas chez certains poissons. L'effet de la pêche sur l'habitat qu'est le fond marin devrait être faible comparativement à celui d'autres engins qui entrent en contact avec le fond, compte tenu de la petite taille de l'empreinte laissée par chacun des casiers et de la densité relativement basse de ces derniers dans cette vaste zone de pêche.

1.0 INTRODUCTION

1.1. Overview of the Fishery

The offshore lobster fishery (LFA 41), established in 1972, fishes from the 50 nautical mile line (92km) off Nova Scotia to the upper continental slope (Figures 1.1.1 and 1.1.2). The status of lobster in LFA 41 was last assessed in 2000. The fishery operates under the 2006-2010 Integrated Harvesting Plan with 8 licences and a Total Allowable Catch (TAC) of 720t lobster and 720t Jonah crab. While LFA 41 includes parts of the Northwest Atlantic Fisheries Organization (NAFO) divisions 4Vs, 4W, 4X and 5Z, lobster fishing is authorized only in 4X and 5Zc. LFA 41 is the only lobster fishery in Canada that is managed with a TAC.

The fishery is managed by input and output controls including a minimum size carapace length (CL), prohibition on landing berried or v-notched female lobsters, limited entry and a TAC. An area encompassing all parts of Browns Bank <50 fathoms (91.4m) was closed to lobster fishing in 1979, though other fishing activity still occurs within it. This is referred to as the Browns Bank closed area or LFA 40 (Figure 1.1.2).

Season:	Year round Quota year Jan. 1 - Dec. 31
Minimum Legal Size:	82.5mm CL
Landings of Berried and V-Notched Females:	Prohibited
Trap Limit:	None
Number of Licences:	8
TAC:	720t

A more detailed history is found in Appendix 1 and the Integrated Fisheries Management Plan (IFMP) (Fisheries and Oceans Canada 2006) for LFA 41.

1.2. Lobster Biology

Biology

Nova Scotia lobsters take 8-10 years to reach the legal size of 82.5mm CL. At that size they weigh approximately 0.45kg (1lb) and molt once a year. Larger lobsters molt less often, with a 1.4kg (3lb) lobster molting every two to three years. Off southwestern Nova Scotia, most lobsters mature between 95 and 100mm CL at an average weight of 0.7kg (1.5lb). The mature female mates after molting in late summer and the following summer produce eggs that attach to the underside of the tail. The eggs are carried for 10-12 months and hatch in July or August. The larvae spend 30-60 days feeding and growing near the surface before settling to the bottom and seeking shelter. For the first few years, lobsters remain in or near their shelter to avoid predation, spending more time outside the shelter as they grow (Lavalli and Lawton 1996).

Distribution

The American lobster (*Homarus americanus*) is widely distributed in coastal waters from southern Labrador to Maryland, with the major fisheries concentrated in the Gulf of St. Lawrence and the Gulf of Maine (Figure 1.2.1). Though lobsters are most common in coastal waters, they are also found in deeper, warm water areas of the Gulf of Maine and along the outer edge of the continental shelf from Sable Island to off North Carolina. Lobsters are found in the offshore areas of the western Scotian Shelf and Georges Bank due to the presence of the warm slope water that keeps the slope and deep basins in the Gulf of Maine warm year-round. This warm deep water is not found on the eastern Scotian Shelf, in the Gulf of St. Lawrence or off Newfoundland.

Various lobster populations have been investigated using morphometrics (Cadrin 1995, Harding et al. 1993, Saila and Flowers 1969) and genetics (Crivello et al. 2005a, 2005b, Gosselin et al. 2005, Harding et al. 1997, Hedgecock et al. 1975, Jørstad et al. 2004, 2005, Tam 1997, Tam and Kornfield 1996, Tracey et al. 1975, Triantafyllidis et al. 2005, Ulrich et al. 2001) with no conclusive picture on stock structures.

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

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

Lobster concentrations are highest in coastal regions with lower concentrations associated with the offshore banks of Browns and Georges. Lobsters are known to migrate on to the banks in summer and to deeper water in winter. The international boundary, LFA divisions and the 50 mile offshore lobster boundary line created artificial boundaries that divide the lobsters between different management units with different management measures. The 50 mile line bisects Browns Bank and divides the lobsters that migrate to the bank between LFA 34 and 41.

Circulation models (Drinkwater et al. 2001) indicate strong retention of larvae on Georges Bank. Browns Bank shows weaker retention, with potential exchange of larvae from Browns to German Bank or to the Bay of Fundy. No potential exchange has been observed from Browns to the nearshore areas of southwestern Nova Scotia or the south shore inside the 50m isobath (Drinkwater et al. 2001). A recent paper by (Xue et al. 2008) indicated that there is little exchange of larvae from Browns Bank to coastal Maine, but that there is potential for larvae from Maine to settle in the Browns Bank region.

Larvae and adults are exchanged between areas within the Gulf of Maine, but this does not necessarily imply a dependency of one area on another. Information available at present is insufficient to either support or to disprove the existence of individual stocks or a dependency linkage between lobsters in the Gulf of Maine.

In the past, it was often assumed that recruitment was restricted to shallow coastal regions, but the presence of late stage 4 larvae over the banks and basin areas (Harding et al. 2005), small juvenile lobsters in scientific trawl surveys (Canadian Research Vessel (RV) stratified random bottom trawl survey, USA National Marine Fisheries Service (NMFS) bottom trawl survey), and in at-sea samples from trap catches, indicate the presence of small juvenile lobsters in these areas. This suggests that successful larval settlement likely occurs in the deep water basins of the Gulf of Maine and on the shallow areas of Georges Banks. The scale and importance of larval settlement in these regions is not known at this time.

Migrations and Depth Preferences

Adult lobsters make seasonal migrations to shallower waters in summer and deeper waters in winter (Bowlby et al. 2007, Campbell et al. 1984, Campbell and Stasko 1986, Comeau and Savoie 2002b, Cooper et al. 1975, Cooper and Uzmann 1971, Cowan et al. 2007, Ennis 1984, Estrella and Morrissey 1997, Fogarty et al. 1980, Pezzack and Duggan 1986, Tremblay et al. 1998). Mature lobsters on average move significantly greater distances then immature animals (Campbell 1986b, Campbell and Stasko 1986). Over most of their range, these movements vary from a few kilometres to 20km. However, in the Gulf of Maine and on the outer continental shelf lobsters undertake long distance migrations of tens to hundreds of kilometres. Tagging studies have shown that at least some of these lobsters return to the same area each year (Campbell 1986a, Pezzack and Duggan 1986).

Offshore lobster tagging shows seasonal migrations from the upper continental slope and outer basins of the Gulf of Maine onto the outer edge of the shelf to the shoals of Browns and Georges Bank. 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 move to areas optimal for hatching eggs and either retention or export of larvae. The triggers for these migrations are not certain.

Tagging studies provide evidence for along-shore movement of lobster in the nearshore, as well as for dispersal from nearshore and midshore release sites off Southwest Nova Scotia, and from the Bay of Fundy to offshore and USA fishing grounds (Campbell 1982, 1989, Campbell and Stasko 1986). Although one USA tagging study (Northeast Fisheries Center 1985) showed significant movement occurred from Jordan Basin, but not Crowell Basin, into nearshore areas, there is generally little evidence for return movement to the nearshore following offshore dispersal. Seasonal movements between the tops of offshore banks and deeper slope and basin areas occur, including indications of long-distance return movement within the offshore area. (Campbell 1986a, Pezzack and Duggan 1986).

Quantitative estimates of exchange rates between different parts of the Gulf of Maine cannot be given at this time. The mark-recapture approach used in historical studies does not permit discrimination between residences and return migrations 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 LFA 34 from June to November poses a problem in that summer movement into nearshore areas would not have been detected in these earlier studies.

Reproductive Potential

Lobsters mature at varying sizes depending upon local water temperatures (Aiken and Waddy 1980, 1986, Campbell and Robinson 1983, Comeau 2003, Comeau and Savoie 2002a, Waddy and Aiken 1991, 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). Size at maturity in offshore areas varies from 82mm CL on the slope off New England, 92mm CL for Georges Bank and Gulf of Maine (Little and Watson 2005) and approximately 97mm CL for Northeast Georges and Browns Bank (Pezzack and Duggan 1989).

The median size of lobsters in the Canadian offshore catch is greater than the size at which 50% of the females mature (95mm CL) and, thus, a high proportion of the females caught have had the opportunity to breed. This contrast with the coastal inshore fisheries where the median size in the catch is below the size of 50% maturity (95mm, FRCC 2007) and only a small percentage of females have had the opportunity to breed (Pezzack et al. 2006).

At maturity, lobsters produce eggs every second year. Based on laboratory studies using ambient inshore Bay of Fundy water temperatures, female lobsters appear able to spawn twice without an intervening molt (consecutive spawning) at some size greater than 120mm CL (Waddy and Aiken 1986, 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 molt in the first and fourth years) and alternate-year (spawning in alternate summers). In both types, females often are able to fertilize the two successive broods with the sperm from a single insemination (multiple fertilizations). Intermolt mating have 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 (Campbell and Robinson 1983, Estrella and Cadrin 1995) means that very large lobsters have a much greater relative fecundity.

Natural Mortality

Natural mortality (M) has been estimated for some nearshore populations and is generally assumed to be between 10-15% for all fully recruited legal sized lobsters and, in most models, (Fogarty and Idoine 1988, Gendron 2005, Gendron and Gagnon 2001, Idoine et al. 2001) is assumed to be the same over time and for all size groups. However, in reality, this could vary greatly depending upon habitat, predator abundance, and lobster size.

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

1.3. Management

The international boundary, LFA divisions and the 50 mile offshore lobster boundary line created artificial boundaries that divide the lobsters between different management units with different management measures. The 50 mile line bisects Browns Bank and divides the lobsters that migrate to the bank between LFA 34 and 41.

Due to the uncertainty of stock structure within the Gulf of Maine, the management plan and past assessments have looked at maintaining the high reproductive potential in this area by preserving its size structure dominated by mature animals. This has been done through a limited number of licences, a TAC and the closed area of Browns Bank. Prior to this assessment, the key indicator of the health of the stock was the size composition of the catch (Fisheries and Oceans Canada 2006, Pezzack and Duggan 1988, 1995a).

In general, exploitation of a previously unfished or lightly fished population results in a reduction of larger sizes and a truncation of the size frequency. This has been observed in the southern Georges Bank offshore fishery (1956-1967) (Skud 1970, Skud and Perkins 1970) and in the early years of the coastal fisheries (Herrick 1911a, b, Rathbun 1884, Rathbun 1887, Wakeham 1909). The lobster growth and reproduction model (Idoine et al. 2001) indicates that at moderate or high exploitation a shift in the offshore size frequency should also occur. As this has not occurred within the population, the assumption was made that exploitation rates were low, with the model suggesting an exploitation rate of less than 30%, which is less than half that of the inshore fisheries of LFA 34.

A major conservation management program was initiated in Atlantic Canada in light of the October 1995 review of the Atlantic lobster fishery by the Fisheries Resource Conservation Council (FRCC 1995). In their report, the FRCC concluded, that under the current management regimes, lobster fishermen generally were "taking too much, and leaving too little". Based on the scientific data available to the Council, they concluded that Atlantic lobster fisheries had a high exploitation rate and harvested primarily immature animals, resulting in very low levels of eggs-per-recruit (estimated to be as low as one to two percent of that expected in an unfished population). While they accepted that lobster stocks have traditionally been quite resilient, the FRCC concluded that the risk of recruitment failure was unacceptably high and suggested a need to increase egg production in all inshore regions.

The management changes introduced from 1998 to 2002 to improve conservation were:

- Voluntary v-notching with landing of v-notched animals forbidden (1998).
- Minimum size increase from 81mm CL to 82.5mm CL (2000).
- Requirement to release one and no clawed females (cull) (2002, but removed in 2007).

In recent years, an industry set voluntary maximum weight has been in place for the majority of the fleet. The maximum weight is set by the licence holder and may vary according to market demand and prices, but is generally in the area of 6lb (150mm-155mm CL).

2.0 METHODS / DATA DESCRIPTION

Sources of Information

1. Lobster log books (1981-2008) that provide daily records (1982-2000), and string by string records of catch, effort and location (2001-2008).
2. At-sea samples of the commercial catch (1972-2008).
3. Canadian RV stratified random trawl survey: Scotian Shelf, summer (1999-2008) and Georges Bank, winter (2007-2008) trawl survey.
4. NMFS data on USA landings and the Georges Bank portion of the fall Northeast Fisheries Science Center (NEFSC) bottom trawl survey (1980-2007).

Indicators

In the absence of direct estimates of population abundance or biomass, lobster assessments develop a number of indicators that can provide knowledge on trends in the stock and assist in determining appropriate management and harvest strategies. The Maritimes Region's Lobster Conservation Strategy (2004-2008) requires that, within each LFA, easy to measure and easy to understand "indicators" be developed that have the support of a broad representation of stakeholders. These indicators are to be used to evaluate the status of the lobster stock and that can be used to develop decision rules that will influence management actions based on analytical results from appropriate, accurate and timely data sources.

The purpose of the 2009 Science Advisory meeting (DFO 2009) was to evaluate the status of lobster in LFA 41 (4X + 5Zc) based on indicators. This assessment evaluates the current stock status of the lobster population in LFA 41 compared to the last assessment in 2000 and conditions at the beginning of the fishery in the 1970s.

Four general categories of indicators are developed here and within each category, a number of indicators are proposed and evaluated. The criteria for each will include the long term and short term trends.

<u>Abundance (legal sizes):</u>
- Landings
- Commercial CPUE (weight per trap haul)
- Catch rate in RV stratified random trawl surveys

<u>Fishing pressure:</u>
- Fishing effort
- Exploitation rates
- Changes in size frequencies
- Sex ratios

<u>Production/recruitment:</u>
- Levels of prerecruits
- Proportion of mature and multiparous females

<u>Ecosystem/environment:</u>
- Interactions with other species, habitat and the ecosystem
- Bycatch in fishery
- Environmental conditions

In this assessment, indicators are categorized as positive (“+”) if values or trends were positive compared to the period of the last assessment (1995-1999) and to early period of the fishery prior to 1985 before the present TAC, EA and the ICJ Canada/USA boundary settlement; negative (“--”) if values were less or trends were negative in this period; and neutral (“o”) if otherwise.

2.1. Landings and Effort Data

Catch, effort and location information is available for the LFA 41 fishery since 1972. In 1996, this fishery became fully dockside monitored. These data have been compiled and stored in various databases over time.

Lobster landings data from 1981 to 1994 were accessed from Oracle database tables previously maintained by the DFO Science Branch. Data from 1995 to 2001 were accessed from Oracle database tables created by DFO’s Marine Fisheries Division from data compiled by the DFO Statistics Branch into the ZIFF (Zonal Interchange File Format) database. As of 2002, lobster landings were accessed from archived and production components of the MARFIS (Maritime Fishery Information System) database.

Offshore log books have changed over the history of the fishery, but they have provided the same basic information including: date, location and depth fished, as well as traps hauled, soak days and estimated catch. Log book information is generally provided on a string by string basis, but it was only provided on a daily basis in the earlier years of the fishery. In 2001, the log was modified to capture both lobster and Jonah crab fishing activity occurring during a fishing trip (Appendix 2 - current fishing log). Upon landing, the catch was weighed, verified by a dockside monitor and recorded on the log in the weight out section. This weigh out was used to prorate the estimated catches for a trip.

RATIO = landed catch/total estimated catch

ADJUSTED DAILY CATCH = RATIO * estimated catch

Log data is reported by fishing season that was based on the calendar year up to 1985, the TAC year (Oct. 16-Oct. 15) from 1985/86 to 2004/05 and calendar year since 2006. During the transition, in 1985, there was a seven month season (Jan-August) and in 1985/96 and 2004/05 a fourteen and a half month season with a prorated TAC for that period.

The change in the quota year in 2005 resulted in seven of the eight licences having an extended season during the transition in 2004-2005, and an annual TAC (Jan.-Dec.) during 2006 to 2007, while one licence continued under the Oct. 16-Oct. 15 TAC during those years. The remaining licence switched to an annual quota year in 2007. For simplicity in this report, the landings and TAC are expressed on an annual basis for 2006 and 2007 to reflect the majority of the fishery.

Analyses of log data were traditionally conducted by assigning catches and effort to five areas. These areas were: (1) Crowell Basin, (2) Southwest (SW) Browns, (3) Georges Basin, (4) Southeast (SE) Browns and (5) Georges Bank (Figure 2.1.1). The five areas represent the traditional lobster grounds used in past assessments (Pezzack and Duggan 1985, Pezzack and Duggan 1987, Pezzack and Duggan 1988, 1995a, Robichaud et al. 2000). While these areas still reflect the general pattern of the fishery, changes over time has resulted in the need for more detailed mapping of effort and landings. For this assessment, the above areas were redefined by 10 minute grid square groupings (Figure 2.1.2) that are slightly different from the traditional offshore areas.

Landings from other regions in Canada and USA landings are based on data provided by regional biologists and landings posted on Government web sites.

Data Editing

Locations:
In some cases, latitude and longitude where entered into the ZIFF database in the incorrect format (decimal degrees vs. degrees, minutes, decimal minutes). These errors were fixed in the extracted data file. As well, the data were mapped and obvious location errors were identified and fixed by referring to log records or by reviewing previous or post fishing trips by the vessel in question.

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

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

<u>Expanding symbol plots of landings, effort and CPUE:</u>
Expanding symbol plots were completed on log data for the 1985/86 season to 2007. For lobster landings and effort, all trips were plotted regardless of the quantity of crab landed. For lobster CPUE, only data where lobster landings were not zero and trap hauls numbers were recorded were used (89% of records), regardless of the associated crab landings. CPUE was calculated for each season and 10 minute grid square by dividing the sum of all landings in a particular grid for a particular season by the sum of the corresponding trap hauls.

<u>Within-year fishing periods:</u>
Data is summarized by three month periods or quarters based on the TAC reporting period: fall (October-December), winter (January-March), spring (April-June), summer (July-September).

For the CPUE modelling, the data is grouped into two periods: winter (October 16 to April 1) and summer (April 2 to October 15).

2.2. At-sea Samples of the Commercial Catch

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

Frequency and distribution of sampling (Figure 2.2.1) has varied over the history of the fishery, with several trips within the first year of fishing (1972-1973), periodic sampling from 1977-1983 and reduced sampling in the late 1980s and early 1990s due to reduced resources and the lack of observed changes in the size frequencies over time (Appendix 3 - summary of size data). Since 1995, offshore license holders have funded sampling and, in 1997, a plan to obtain one sample per grid grouping per quarter was initiated. This often was not obtained due to vessels not fishing the areas during the specified time periods or other logistical problems. Changes in the implementation of the plan have been made over time to better reach these goals. Prior to 2000, sampling was done by DFO or Javitech (a company that provided at-sea observer coverage) and other private contractors. Since 2000, Javitech has conducted all of the at-sea sampling in LFA 41. Part of the Javitech protocol is to estimate weights and species composition of all bycatch. This bycatch data is stored in the observer program database, ISDB (Industry Surveys Data Base) and is available for this fishery since 1988.

At-sea sampling data is stored in the Crustacean Research Information System (CRIS), an Oracle database. Data were extracted from 1977 to present and grouped by the offshore 10 minute grid groupings (Figure 2.1.2). In all, 291 at-sea sampling trips were included in the dataset.

2.3. Trawl Survey Data

Canadian Research Vessel Stratified Random Bottom Trawl Survey

Beginning in 1999, select invertebrates began to be systematically recorded in annual summer (July) ecosystem trawl surveys of the Scotian Shelf (Figure 2.3.1). Originally designed for groundfish, the surveys from 1999 to present have provided very useful data on a number of important benthic invertebrates (Tremblay et al. 2007). Beginning in 2007, selected invertebrates began to be systematically recorded in annual winter ecosystem trawl surveys of Georges Bank (Figure 2.3.2).

The ecosystem survey is a stratified random design with strata defined on the basis of depth. Samples of fish and invertebrates were obtained with a Western IIA bottom trawl towed for 30 minutes at a speed of 3.5 knots. Beginning in 1999, all crabs and lobsters were measured to the nearest millimetre (carapace width/length) and sexed. As well, a total catch weight was recorded for each species.

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

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

USA National Marine Fisheries Service Trawl Survey

The NEFSC bottom trawl survey began in 1967. This survey is generally conducted in September and October. Lobster data used in this assessment are from the autumn survey since 1982.

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

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

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

Modelled Catch Rates

The datasets used for the following analyses are outlined in Section 2.1 (Landings and Effort Data). The selected time series ran from October 1996 to April 2008. All records that did not contain trap haul and/or lobster catch information were removed (<14% of total records; note original dataset contained both lobster and Jonah crab catch information). Records with lobster catch rates of zero were removed due to the unlikelihood of zero catch in an entire string of traps (50 to 100 traps, which is the resolution of the data) even when the target species may have been Jonah crab. A modification to the log record indicating the directed species for each string would be greatly beneficial to these analyses.

A total of 10 data subsets (5 grid groupings and 2 seasonal periods - spring/summer and fall/winter) were created prior to modelling to reduce the potential complications of area and period interactions (Claytor et al. 2001). Catch rate was defined as the total weight divided by the total number of trap hauls per trap string where a trap string most frequently had 100 traps. In some cases individual strings were not distinguished on a log record, and these groups of strings were treated as one for the purposes of the analysis.

A total of 10 data subsets were individually modelled. This strategy was adopted to follow previous analyses (Claytor et al. 2001). Catch rates were log-transformed and became the response variable for multiplicative model catch rate analyses (Claytor et al. 2001). A linear regression was fitted to each subset of area/period using the “lm” (linear model) function in R, with the main effects of fishing season, two week period (2wk period) and vessel (as factors). The general form of the model is given by:

$$\mathbf{log(cpue)_{ijk} \sim 2wk.period_i + fishing.season_j + vessel_k}$$

Model runs were made for each area/period group iteratively. Criteria for selecting the best fitting model for each area/period group included: AIC (akaike information criterion) scores, the significance of each term (ANOVA), the adjusted R-squared values and the residual plots. Annual and seasonal changes in catch rate indices were visualized using effects plots of the fishing season and 2wk period.

3.0 ABUNDANCE

3.1. Landings

LFA 41 landings are summarized in the following tables and figures:

- Table 3.1.1 Landings 1981-2008 by LFA 41 subareas and fishing year; TAC and vessel number.
- Table 3.1.2 Landings by NAFO divisions 4X and 5Zc, 1971- 1985.
- Figure 3.1.1 Lobster landings LFA 34 and 41, 1946-2007.
- Figure 3.1.2 Landings total and Gulf of Maine portion, Georges Bank and SE Browns.
- Figure 3.1.3 Landings in the Gulf of Maine Portion of LFA 41.

Landings in lobster fisheries are a function not only of abundance, but also of the level of fishing effort (trap hauls), soak over days (SOD), timing of effort and fishing strategy, catchability (affected by environmental factors, physiology, migrations, gear type and other factors) and the distribution of lobsters. Under a TAC, the absolute landings are not an indicator of abundance because the TAC sets an upper limit; however, a failure to catch the TAC could reflect lower abundance and, thus, serve as an indicator of low abundance. In using this indicator, the other factors controlling landings would also have to be accounted for.

Total Allowable Catch

Landings are limited by the TAC but have fluctuated over the years, with the TAC not caught in some years during the late 1980s and 1990s. Since 1999-2000, over 95% of the TAC has been caught each year, and in seven of the nine years over 99% of the TAC was taken.

Reasons given for past failures to catch the TAC included the cold water event 1998-1999 that saw cold slope water invade much of the bottom water of the Gulf of Maine reducing catch rates (Claytor et al. 2001), the introduction of the Jonah crab fishery in 1995 and a redirection of effort to that fishery, and the inability of some licences to meet the TAC due to age and size of the vessels. While the 1998-1999 temperature event is well documented (Drinkwater et al. 1999), it is impossible to quantify the other possible causes related to vessel and fishing strategy.

Seasonal Trends in Landings

Monthly landings vary with area and over time, but there are persistent annual trends in landings (Figures 3.1.4, 3.1.5, 3.1.8) and effort (Figures 3.1.4 and 3.1.6) within an area.

Fishermen state that they target the seasonal movements of lobsters on and off the banks, and the timing of such movements determine their locations and landings. These seasonal movements are documented in numerous tagging studies.

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

Distribution of Landings

The distribution of landings, effort and CPUE by 10 minute grids groupings are given in Figure 3.1.9. The spatial distribution of landings has varied over time with expansion and contraction of areas fished around core areas that have not changed significantly. The small size of the fishery with four to six vessels in recent years means that a change in fishing by a single vessel can result in a large shift of landings from one area to another. Therefore, year to year changes in landings within an area do not necessarily reflect changes in abundance.

Georges Bank (Corsair Canyon and the slope east of it) has the largest median size lobsters and is the furthest fishing area from port. It has been fished since the fishery began in 1972. The fishery has its highest landings in spring and early summer during the shoalward movement of lobsters (Figure 3.1.8). There is little area for expansion on Georges Bank as the USA lobster fishery lies to the south; once lobsters move onto the banks, they disperse. In addition, this is an area with significant mobile gear activity. Landings on Georges Bank declined in 2000, but have increased again since 2005.

SE Browns has been fished since 1973. The median size of lobsters is similar to those on Georges Bank. During the late 1990s, fishing effort on SE Browns expanded eastward in part due to the expansion of the Jonah crab effort into these areas. With the decline of the Jonah crab catch in 2003, lobster landings shifted back to more traditional grounds. The fishery has its highest landings in spring and early summer during the shoalward movement of lobster (Figure 3.1.8). Since 2000, landings from SE Browns have been relatively stable with an increase in annual CPUE.

In the Gulf of Maine portion of LFA 41, SW Browns has had persistent effort, while Georges Basin and Crowell Basin have varied over the time series. SW Browns is a small area bordered by the closed area of Browns Bank to the east and LFA 34 to the north. SW Browns accounts for 32-40% of LFA 41 landings. The fishery has its highest landings in the late fall during the movement of lobsters to deeper water (Figure 3.1.8).

Georges Basin was first fished heavily in 1985 following the International Court of Justice (ICJ) Canada/USA boundary settlement that removed USA effort from the area. The fishery has its highest landings in winter and spring (Figure 3.1.8).

Crowell Basin is one of the grounds closest to port and has the smallest median sized lobsters. The fishery has its highest landings in the late fall and winter (Figure 3.1.8). Landings increased from 1995 to 2003 then declined, though CPUE did not. A major shift in effort and landings out of Crowell Basin began in 2004, with little or no fishing in the basin in 2006 and 2007 (Figure 3.1.3). Industry representatives and vessel captains indicate this shift was the result of vessels no longer targeting Jonah crab, which had made up an important portion of the catch. The recent removal of the vessel that previously fished this area was part of the industries fleet reduction.

Number of Grids Fished

The number of grids fished to catch 75% of the TAC (Table 3.1.3, Figure 3.1.10) is a measure of changes in the spatial expanse of the fishery that can indicate changes in population distribution and densities. However, this measure could also represent changes in fishing strategy related to economics or targeting of the Jonah crab bycatch allowed since 1995, rather than changes in abundance. The total number of grids fished has remained relatively constant since 2000-2001. The number of grids fished to catch 75% of the TAC shows a similar pattern but with a slight decline over the last three years. The increase in the number grids fished to catch 75% of the TAC in the late 1990s is believed to have occurred as a result of the introduction of the Jonah crab bycatch in 1995-1996 that led to an expansion of effort to parts of the grounds not previously fished to any great extent.

3.2. Trawl Surveys Trends

With the formalization of measuring and recording all lobsters (and other selected invertebrates) in 1999, the possibility of using the annual DFO RV summer bottom trawl survey as an indicator of lobster abundance became possible. The survey was not designed to survey lobsters nor is the gear designed to catch them. Complications in the interpretation of data also arise as there have been changes in survey vessels over time, with three vessels used over the time series (Table 3.2.1). Data are available for the Scotian Shelf and Bay of Fundy from the July surveys 1999-2008. The 2004 data are not included due to problems with the net configuration that year. Catch rate data are not presented from Georges Bank as the survey only began recording lobsters in 2007.

The distribution of lobster catches on the Scotian Shelf in Figure 3.2.1 shows that catches are centred in the Browns Bank area, off of the mouth of St. Mary's Bay and in the Bay of Fundy. As shown in Figure 3.2.2, this corresponds to the areas with warmer bottom temperatures. Lobsters are also found at lower numbers along the slope as far as the Gully east of Sable Island. The area immediately north of Browns Bank is not surveyed because of large areas of untrawlable bottom.

The adjusted stratified mean number of lobsters per tow in 4X (LFA 41) has increased since 2000 (Figure 3.2.3a). The short time series should be interpreted in terms of general trends rather than focussing on year to year changes, as catches in these surveys show yearly variability with wide variance. Due to the short time series, it is not possible to say how the present levels compare with past abundance. A longer time series and more study of catchability may provide a measure of the total or relative abundance of lobster in LFA 41 in future assessments.

The DFO RV stratified random trawl survey on Georges Bank (winter) has only included detailed information on lobster catches since 2007, so trends in lobster abundance from this index are not reported here. NEFSC RV fall bottom trawl survey on the USA portion of Georges Bank indicates that relative lobster abundance increased from 2000 to 2003 and then declined again to 2007 (Figure 3.2.3b).

3.3. Non-standardized Catch Rates (Annual)

Non-standardized catch rates from the commercial fishery (CPUE, landed kg/trap haul) vary spatially (Figure 3.1.9) and throughout the year (Figures 3.1.4 and 3.1.7), and are influenced by many environmental, fishery and biological factors, but the annual CPUE values are provided as a picture of the general trend in CPUE over time. Overall annual CPUE has increased since the lows of 1998-2000 (0.9-1.2kg/TH), and have levelled off in the past three to four years (2.3-2.7kg/TH). The CPUE values of the individual areas (Figure 3.3.1, Table 3.3.1) are variable, but have also trended upward since 1999. CPUE in the outer slope area of SE Browns and Georges Bank have been stable or increasing over the previous five seasons. Areas in the Gulf of Maine are more variable, with SW Browns increasing to 2002-2003, then trending downward.

The low CPUE values in the Gulf of Maine and on SE Browns in 1998-1999 were in part the result of a cold water event where cold slope waters filled the Northeast Channel and the deep basins of the Gulf of Maine. Georges Bank was not strongly affected and CPUEs remained higher.

Fishing activity in the adjacent LFA 34 and USA fisheries with increase landings over this time period could be a factor influencing CPUE in SW Browns, Crowell Basin and Georges Bank.

3.4. Modelled Catch Rate Index

Many factors influence lobster catch rates, on both short and long temporal scales. These factors include lobster abundance, temperature, molt state and a host of other factors (Miller 1990, Tremblay and Smith 2001). By using a model, at least some of the fishing related factors can be controlled to better interpret annual trends in CPUE. Here, the annual and seasonal changes in catch rates are described using the main effects of fishing season (October to October), biweekly interval (2wk) and vessel (3-way factorial ANOVA). Interactions between these terms were not explored due to limited degrees of freedom. For the purposes of this analysis, the assumption is made that there are no significant interactions. This analysis of variance model, applied for the previous catch rate analyses used for this fishery (Claytor et al. 2001), assumes that the factors affecting CPUE were multiplicative and as such, log transformed data were used. This provides standardized catch rate indices as described in (Gavaris 1980).

The ultimate objective of this analysis is to use catch rate (or CPUE) as an index of abundance. With such an index, a lower level of CPUE could be identified that would act as a “trigger” for a further analysis to identify whether the lower CPUE is likely reflecting a decrease in abundance or a change in other factors that affect it. It is understood that any such index must be interpreted in light of other factors. The model is considered to be at the exploratory stage. All analyses were done in R version 2.7.0.

Preliminary Data Visualization

The total 2wk CPUE for each area/seasonal period group is presented annually in panel plots (Figures 3.4.1 and 3.4.2). Some of the fishing seasons for each group indicate a general decrease in CPUE seasonally following the first three to four 2wk periods (e.g., Crowell Basin, winter, 2000-2001; Georges Bank, summer, 2004-2005), while others are variable. The annual averages (indicated by the horizontal line in each panel) appear to be generally higher in recent years for all areas during both the winter and summer periods, but there are large variances around these means.

CPUE histograms were produced for each area/period group (all fishing seasons combined) to visualize the distributions and indicate anomalies in the catch rates. The histograms generally indicated a positive (right) skewed, lognormal distribution of CPUE for each group (Figure 3.4.3, for example). Box-plots (biweekly across all fishing seasons and by fishing season across all 2wk periods) were also produced for each area/period group as a preliminary visualization of trends in mean CPUE and variability (Figure 3.4.3, for example).

Model Trials

The three main effects were consistently significant for all area/period groups. The AIC score, adjusted R-squared value and degrees of freedom for the model run for each area/period group are provided in Table 3.4.1. The residual plots for all models show few trends across the predicted values (Appendix 4.1).

The coefficients and ANOVA tables for each model can be found in Appendix 4.2. The low adjusted R-squared values indicate that a considerable amount of the variation in CPUE is not accounted for by the selected model. Model trials with a subset of vessels with consistent effort across fishing seasons and 2wk intervals should be conducted in the future.

Within Season and Annual Patterns

Annual and seasonal changes in CPUE for each area/seasonal period group were visualized using effects plots of the predicted CPUE indices referenced to mean levels of the other co-variates (Figures 3.4.4 to 3.4.7). It is important to note that these are static mean indices and the significance of each effect simply indicates that one or more levels are different than the other levels. Transformations of these CPUE indices back to the original CPUE scale (kg/trap haul) has not been completed at this time.

<u>Within Season (Biweekly Period)</u>

Winter
All area/seasonal period groups show consistent peaks between 2wk intervals 3 to 6 with lower CPUE indices for early and late season. The large confidence intervals for Crowell Basin and SW Browns for 2wk interval 13 are most likely due to limited data for that 2wk interval (Figure 3.4.4).

Summer
As with the winter seasonal period, all groups except Georges Basin show consistent peaks mid way through the season (between 2wk intervals 5 to 7 for the summer). Georges Basin indicates higher levels for the 2wk intervals 1 to 7 (Figure 3.4.5).

<u>Annual (1996-1997 to 2007-2008)</u>

Winter
SW Browns, Georges Basin and Crowell Basin show lowest CPUE indices for fishing seasons 1997-1998 or 1998-1999. SE Browns and Georges Basin indicate the period since 2002-2003 has higher CPUE indices than the previous fishing seasons in the time series (Figure 3.4.6).

Summer
SE Browns and Georges Bank indicate a low point in CPUE indices for 2000-2001, and recent (since 2003-2004) indices are the highest in the time series. All areas shows the fishing season 2003-2004 to have higher indices than the previous fishing season for the summer period (Figure 3.4.7).

Model Interpretation and Conclusions

Alternative approaches to modelling the catch rates for the LFA 41 lobster fishery, such as using Generalised Linear, Additive models or various Mixed Effects of Time-series models may provide better resolution. These approaches should be considered in future analyses.

A better picture of short and long term trends in lobster catch rates may be provided by adding covariates to the models that are known to influence catch rates and may account for some of the remaining variability. These covariates may include, but are not limited to: measures of bottom temperature, measures of dominant weather patterns, information on migration timing, estimates of abundance and estimates of exploitation. These data are not consistently available at this time for the LFA 41 fishery. The coincidental Jonah crab fishery, specifically the partitioning of effort, further confounds these analyses.

- CPUE indices in the LFA 41 fishery are influenced by (i) the time of year fishing takes place in an individual area and seasonal period (summer vs. winter; significant 2wk interval effect), (ii) the vessels fishing and (iii) the fishing season.
- The model accounts for effects of fishing season, biweekly period and vessel with a strong assumption that there are no interaction terms.
- With the current model and data set, interaction effects cannot be evaluated because few vessels fished any one area consistently over the time period.
- Other factors potentially affecting CPUE (temperature, molt state, movement) were not evaluated.
- Within season differences in CPUE, indices seem to be the most consistent, generally indicating higher levels in the early to mid portion of the season, with lower levels toward the end.
- The annual differences in CPUE indices by area and seasonal period (summer vs. winter) must be interpreted with caution, but in recent years do not show levels below the indices for the entire time series for any area or seasonal period.
- A CPUE model has the potential to be used to evaluate whether CPUE thresholds in the LFA 41 fishery are reached on an annual and potentially on a seasonal basis; the development of such a model is ongoing.

3.5. Abundance Indicators Summary

Indicators were categorized as positive ("+") if values or trends were positive compared to the period of the last assessment (1995-1999) and to early period of the fishery prior to present TAC, EA and the ICJ Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise. Empty cells means no data is available or the indicator cannot be applied on that scale or time period.

			2000-2007 period compared to previous periods in the fishery						
			Pre EA and ICJ 1972-1985	**Previous assessment period 1995-1999**					
Data Source	**Indicator**		**Overall**	**Overall**	**Georges Bank**	**SE Browns**	**SW Browns**	**Crowell Basin**	**Georges Basin**
Landings	**90% TAC**	TAC reached in 8 of last 10 years and 5 of last 5 years.	+	+					
	# of grids fished to obtain TAC	Stable number of grids fished in recent years. The number of grids fished does not vary greatly and thus the utility of this indicator is not clear under present fishing patterns.		o					
Trawl surveys	**Mean # / tow Canada**	The trawl surveys show a general increasing trend in the mean # per tow from 1999-2007 but given the variability and the short time series this indicator is still in development.		+		+	+	+	+
Catch Rate	**Annual Catch rate**	Stable or increasing in 4 areas. SW Browns levels high but decreased last 2 years.		+	+	+	–	+	+
	Catch rate Model			+	+	+	o	o	+

4.0 FISHING PRESSURE

4.1. Effort

Vessel Number

Vessel numbers have varied in recent years (Table 3.1.1), but originally a share of the quota was assigned to each of the eight vessels. Following the introduction of the Enterprise Allocation (EA) in the mid 1980s, vessel numbers were reduced as companies matched vessel's cost with the TAC. Vessel numbers increased again in the late 1990s, with the introduction of the Jonah crab fishery late in 1995, and some vessels began to target this species. With the decline in Jonah crab effort in recent years and purchase of the Donna Rae license by Clearwater Seafoods LP, the number of vessels has decline to four in 2007 and 2008.

Number of Trap Hauls

Total trap hauls by area are given in Figure 4.1.1 and Table 4.1.1. Overall trap hauls have declined since 1999-2000 and are at levels similar to the mid 1990s. The largest changes were in Crowell Basin in which effort has dropped to near zero in 2008.

There is no trap limit, but information from Clearwater Seafoods indicates that vessels traditionally fished 2,500 traps each. The fleet presently fishes approximately 12,000 traps split between four vessels in 2008.

Information on changes in trap efficiency, fishing strategy or increased knowledge by the captains is not captured in the log books. Fishermen are continually experimenting with trap designs and bait to optimize their catch and, over time, the effectiveness of traps will increase. DFO's inability to track these changes is an important deficiency in the data.

Grids Fished

The number of grids fished initially increased with the introduction of the Jonah crab bycatch beginning in 1995-1996 as effort expanded to the east. The number of grids fished to reach 75% of the TAC is a measure of the spatial expanse of the fishery and can serve as an indicator of changes in the distribution and density. It could also represent changes in fishing strategy related to economics and not abundance. The number of grids has remained relatively constant since 2000-2001, with a slight decline.

Adjacent Fisheries

Trends in adjacent fisheries can serve as an indication of additional pressure on the common stocks exploited by both fisheries. While LFA 41 has been capped by the TAC, adjacent fisheries have continued to expand putting additional pressure on lobsters.

Landings from adjacent LFA 34 (Figure 4.1.2) and USA (Figure 4.1.3) are given in Table 4.1.2 and Figure 4.1.4- 4.1.5.

Gulf of Maine

The adjacent fisheries in LFA 34 and the USA are not quota limited and have shown increases over this same time period. The deep water fishery in LFA 34 began in the early 1980s, and has expanded with vessels fishing adjacent to the 50 mile offshore lobster boundary. The deep water area can be divided into two areas, one directly adjacent to LFA 41 (LFA 34 offshore/grid groups 5-6) and a second further inshore that includes German Bank (LFA 34 midshore/grid groups 3-4) (Figure 4.1.2). The landings of the LFA 34 offshore exceeded the total LFA 41 and are three times larger than the adjacent GOM portion of LFA 41 (SW Browns, Crowell Basin and Georges Basin) (Figure 4.1.4). The LFA 34 offshore and midshore fisheries produce landings close to 10 times the Gulf of Maine portion of LFA 41. LFA 41 represented the equivalent of 15% of entire LFA 34 in 1976, but it represented only 4% in 2004. (Figure 3.1.1).

USA landings in the adjacent statistical areas (Figure 4.1.4) show a similar pattern to those in LFA 41. The decline in USA landings in 1987-1988 was likely a result of the displacement of effort that resulted from the ICJ boundary settlement. Similarly, Canadian landings increased at this time.

Georges Bank

USA landings from NE Georges Bank have increased dramatically in recent years, while Canadian landings have declined slightly. During the 1990s, Canadian and USA landings were similar, but the USA portion averaged over six times that of Canada during the 2000-2007 period. USA landings on the southern portion Georges Bank have increased slightly over the last 10 years (Figure 4.1.5).

4.2. Exploitation Rates

Exploitation rate has not been directly estimated, but is inferred to be low relative to other lobster fisheries. Inferences are made based on size structure relative to lobster populations modelled with the Idoine lobster growth and fishery model, expected changes in sizes at various levels of exploitation and the estimates of F from the USA NMFS Georges Bank surveys.

In past Canadian lobsters assessments, exploitation rates have been estimated using various length based methods including Change in Ratio (Claytor and Allard 2003, Pezzack et al. 2006), comparing numbers in the first two molt groups, and Length Based Cohort analysis (Pezzack et al. 2006). However, these methods are not applicable, because of the dome shaped size structure in LFA 41 with the mode three to four molt groups above legal size.

Estimates of exploitation rates presented to the FRCC reports (FRCC 1995, 2007) were based on modelling expected size structure using a growth and mortality model (ASMFC 2006) and estimates of trap selectivity (Pezzack and Duggan 1995b). The modelled size structure of females was then compared to the observed size structure of the trap catch. Close agreement between the modelled and observed size structures was obtained at low exploitation rates (at or below 30%). At higher exploitation rates, the model indicated a size structure that was shifted towards smaller sizes than has been observed in the fishery.

Based on other fisheries, the exploitation of a previously unfished or lightly fished population should result in a reduction of larger sizes and a truncation of the size frequency even at moderate exploitation rates. This was observed in the southern Georges Bank offshore fishery (1956-1967) (Skud 1970) and in the early years of the coastal fisheries (Rathbun 1884, Wakeham 1909, Herrick 1911a, b), but has not been observed in the LFA 41 fishery.

The LFA 41 size structure has remained stable except for an apparent recent decrease in sizes in the Crowell Basin area. This suggests a low exploitation level similar to that measured in the USA 2006 assessment of Georges Bank (F=0.3) (ASMFC 2006). Estimation of exploitation using the DFO RV survey data should be investigated for future assessments.

Size structure can be affected by a number of factors, including changes in recruitment, gear selectivity, area and depths of fishing, targeting of sizes through fishing strategy and spatial segregation of sizes. The observed stability in size structure could also represent stability in the pattern of ontogenetic migrations with the fishery targeting the adult areas. The size structures of the lobsters on Browns and Georges banks in trawl surveys suggest this could explain some of the stability.

The USA assessment makes use of the Collie-Sissenwine model (ASMFC 2006) based on trawl survey data. Estimates of Georges Bank fishing mortality in the 2006 assessment were F=0.29 for male/female combined and 0.17 for females only.

Exploitation rates in the nearshore LFA 34 lobster fisheries are higher with estimates ranging from 75-87% (Pezzack et al. 2006).

4.3. Size Structure

At-sea samples collect information from fishermen's catches during normal commercial fishing operations. The data were looked at by grid grouping and broken into 3-month quarters (Oct.-Dec., Jan.-Mar., Apr.-June, and July-Sept.). The numbers of lobsters measured in at-sea samples are given in Appendix 3.

For long term comparison of sizes, quarters were chosen that had both early and recent samples of sufficient numbers of individual lobsters measured for both sexes (values excluded from comparison where numbers for one sex <100 individuals). Figure 4.3.1 provides an overview of the changes in the proportion of animals at size by sex over time. Data were chosen to represent earliest, middle and most recent samples. Figure 4.3.2 presents the data as box plots (SPlus 7.0) showing the median size with the box defining the upper and lower quartiles.

When evaluating trends, it must be remembered that gear types have changed over time as has fishing strategy, including changes in depth and bait used. This variation could affect the median sizes and the upper and lower sizes of lobsters caught by the fishery; as well, the fleet targets specific sizes with higher market values and avoids the very large jumbo size lobsters. Fishermen also avoid times and areas where the catch has a high proportion of berried females. During one of the earliest fishing trips to Georges Bank in 1972, a large percentage of the traps fished were top entry conical crab traps with 10" openings. Analysis of the sample indicated that these traps selected for larger sizes (Pezzack and Duggan 1995b). Wooden traps were also replaced by wire traps in the late 1980s, and small design changes have occurred over time to maximize the catch of the more desired sizes.

Georges Bank / SE Browns

Georges Bank and SE Browns were the first areas fished and provide the earliest samples from the first years of the fishery. Little change has been observed in the size structure or median sizes of females on Georges Bank or SE Browns since the fishery began in 1972. A wider size range has been observed at both extremes (larger and smaller lobsters) in recent samples from SE Browns and to a lesser extent on Georges Bank.

Comparing size structure within the male population is made more difficult due to the smaller sample sizes. The median size on Georges dropped during the 1980s, and remains lower than it was during the first 10 years of the fishery, with smaller size representing a great proportion of the catch. The median sizes on SE Browns have remained the same or increased.

SW Browns/Georges Basin/Crowell Basin

SW Browns, Georges Basin, and Crowell Basin were first fished in the mid 1970s. There was limited sampling during the early years of the fishery, but these grounds have always shown a smaller median size than the two outer shelf fisheries of Georges and SE Browns.

The median size of females in SW Browns is slightly lower in recent samples with higher proportion of the catch in smaller and larger sizes (<85mm and >135mm CL).

Median sizes in Georges Basin are higher in recent years and, as in SW Browns, have a wider size range with a higher proportion in the larger and smaller sizes.

The median size in Crowell Basin is lower and the shape of the distribution in recent samples is shifted to the right with an increased proportion of the catch falling below <100mm CL. This same shift is seen in the males.

Trawl Survey Size Data

Size frequencies from at-sea samples are compared to the catch of the Georges Bank winter trawl surveys in Figure 4.3.3. The sizes caught in the trawl survey correspond well with the sizes in the traps along the outer slope of Georges Bank. The shallower portions of Georges Bank are not commercially fished due to other fishing activity in the area, and the trawl survey of this area found a size structure containing many more smaller sized lobsters with a high proportion of the catch under the minimum legal size. While larger mature lobsters migrate to this area in summer, they return to the slope region in winter (Uzmann et al. 1977). The presence of smaller immature sizes in the shallower portions on Georges Bank suggests the possibility that it is a source of recruitment for Georges Bank.

Unlike Georges Bank, the summer trawl survey of the Browns Bank area showed no sign of a large number of the smaller sizes. The sizes of lobsters in the trawl survey were similar to those obtained in the trap fishery.

It has been hypothesised that the shallow areas of Browns could represent one of the sources of offshore recruitment, based in part on larval distribution and early sampling and tagging conducted in the shoal areas of Browns. However, the present data does not show this. Further sampling, particularly in the more complex bottom on the northwest portion of the bank, is suggested to better determine the population structure in the shallow areas of the bank.

Discussion

Interpretation of size data requires caution due to the number of variables that can influence it. Increased proportion in smaller sizes can indicate recruitment increases, changes in gear design, depth of fishing, phase of the migration sampled and possible bait used. Given these confounding factors, small changes and shifts in size frequency should not be over emphasised.

The size structure of lobster in the commercial catch has been relatively stable over the 35 years of fishing with minor shifts to smaller sizes in some areas. The most significant changes in the sizes were observed in Crowell Basin, where the shape of the distribution and median sizes shifted towards smaller sizes. Crowell Basin is adjacent to the offshore grids of LFA 34 that has much higher landings (958t in 2005) and a similar size structure in recent years (Figure 4.4.2 d, f). Some caution is also needed in interpreting the sizes changes in Crowell

Basin, as the two most recent at-sea samples correspond to the period in which Jonah Crab were targeted on many of the trips in this area, and this would affect the areas chosen for fishing.

4.4. Sex Ratio

The sex ratio of immature lobsters (<83mm CL) before entering the fishery is approximately 1:1 (M:F). However, at maturity, the lobster fishery gives greater protection to females through protection of berried females and v-notch protection (Saila and Flowers 1965). A mature female will carry eggs for 10-12 months every second year, or at larger sizes (>120-30mm CL), two out of every three years. Thus, females have lower overall fishing mortality than males. As the offshore fishery targets mostly mature sizes, this difference should be evident in the sex ratios.

Figure 4.4.1 and Table 4.4.1 gives the sex ratio (M:F) of legal sized lobsters (≥83mm CL) in the at-sea samples, over the history of the fishery. Figure 4.4.2 presents plots of the proportion of the catch that is male and female at size. Together, these results show that the proportion of males in the catch have declined since the early years of the fishery.

On Georges Bank, the change from a 1:1 ratio (M:F) occurred in the mid-late 1970s, and has averaged 0.09:1 to 0.27:1 depending upon the season. All other areas have also seen a decline in the proportion of males, though not to the same extent as on Georges Bank. Of note is the seasonal trend in the means for 1998-2008. Males appear to be found in higher proportions during spring and summer period. This could be due to difference in migration and distribution over the year, avoidance of areas of high numbers of berried females by fishermen and to seasonal differences in catchability (Tremblay and Smith 2001).

The sex ratio of lobsters in the commercial fishery in LFA 41 is currently skewed towards more females. The decrease in the proportion of males occurred during the first 10 years of the fishery, with the largest change on Georges Bank. The skewed sex ratio suggests that fishing pressure has had an impact on the population, since an unfished population is expected to have a sex ratio closer to 1:1. However, the shift to this skewed sex ratio occurred early in the fishery has been evident for the last 20-30 years, and there are no indications of negative impacts.

Males are able to mate with a large number of females each year and, with only 50% of the females available (33% at sizes greater than 120-130mm CL) to mate each year, the present skewed distribution may have little impact on breeding success as long as the wide range of sizes is maintained. Whether the current sex ratio is a concern for population productivity should be investigated further.

4.5. Fishing Pressure Indicators Summary

Indicators were categorized as positive ("+") if values or trends were positive compared to the period of the last assessment (1995-1999) and to early period of the fishery prior to present TAC, EA and the ICJ Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise. Empty cells means no data is available or the indicator cannot be applied on that scale or time period.

			2000-2007 period compared to previous periods in the fishery						
			Pre EA and ICJ 1972-1985	Previous assessment period 1995-1999					
Data Source	Indicator		Overall	Overall	Georges Bank	SE Browns	SW Browns	Crowell Basin	Georges Basin
Effort	Trap Hauls	Total trap hauls have declined. No data on trap efficiency changes.		o					
	# of grids fished to obtain TAC	Stable number of grids fished in recent years.		o					
	Landings in adjacent fisheries	Landings increased significantly during last 10 years in areas adjacent to Georges Bank, Crowell and SW Browns.	–	–	–	o	–	–	o
Size Distribution	Median size	Small shifts to smaller sizes in some areas, stable sizes in others. A lack of change in median size is considered positive Most significant changes noted in Crowell Basin.	+	+	+	+	o	–	+
	Size Structure	General shape of distribution changed little, a though wider size range noted in some areas. Significant change in the shape of the distribution in Crowell Basin.	+	+	+	+	o	–	+
Sex Ratio	Sex Ratio	The decrease in the proportion of males during the first 10 years of the fishery. Acceptable levels are not known.	–	o	o	o	o	o	o

5.0 PRODUCTION/RECRUITMENT

5.1. Egg Production

As in most lobster fisheries, there are no direct measurements of egg production, but the abundance indicators for mature females in the LFA 41 fishery, relative to most other lobster fisheries, suggest a high level of potential egg production. One estimate of the health of a stock is the proportion of the population in mature sizes. The proportion of mature females gives a better indication of egg production than numbers of berried females in the catch (Figure 5.1.1, Table 5.1.1), because the fishing fleet actively avoids areas with large numbers of berried females, and berried females may have a different catchability and distribution.

The presence of multiparous females is another indication of the health of the breeding population as they provide increased egg production and reduce the dependency on first time breeders adding great stability to the population. Mature females can reproduce every second year with larger sizes (>120 or 130mm CL) producing multiple broods from a single mating and, thus, two sets of eggs in a three year period.

Figure 5.1.2 and Table 5.1.2 shows the proportion of females greater than the size of 50% maturity (97mm CL) and greater than 115mm CL, a size at which all females are believed to be multiparous (females that have bred at least once before).

Over the last 10 years, the percentage of mature females was highest on the outer shelf fisheries of Georges and SE Browns, with mean percentages of 98% and 96%, respectively. In the Gulf of Maine area, SW Browns, Georges Basin and Crowell Basin mean percentages were 77%, 91% and 63%, respectively.

Percentage multiparous were similarly high for these regions (Georges Bank 72%, SE Browns 63%, SW Browns 25%, Georges Basin 33% and Crowell Basin (based on summer rather than spring samples) 11%). At the median size found in the various grid groupings, the females would have bred 2-3 times (110mm CL) or 3-4 times (120mm CL).

Size at maturity is not monitored, so it is not possible to say precisely if there has been any change over the history of the fishery. Figure 5.1.3 shows the minimum size of berried females in each at-sea sample, as well as the mean and maximum size. The data shows that the smallest size of the smallest berried females has remained relatively constant, suggesting that large changes in the size of maturity have not occurred.

5.2. Recruitment

Indicators of prerecruits are not currently available from the lobster fishery in LFA 41, as the fishery is not conducted in areas where recruitment is expected to occur. This is reflected in the size frequencies of the commercial catch, in which there are few animals under legal size. Median sized lobsters in LFA 41 are five-seven years beyond the minimum legal size, and identifying short term changes in recruitment from at-sea sampling size data is unlikely.

This differs from LFA 34 and most other coastal fisheries that are recruitment based fisheries, with up to 90% of the landings in the first molt group and a large number of lobsters caught under the legal size.

DFO RV trawl surveys offer an opportunity to identify recruitment to the fishery by sampling shallower areas on the banks not commercially fished where recruitment may occur. The

NEFSC trawl survey has been used to track recruit abundance and, as the time series develops, a similar approach will be applied to the Canadian data. The 2006 USA assessment (ASMFC 2006), concluded stable abundance for the Georges Bank stock and much of the Gulf of Maine stock, with very little variability in abundance in recruit and post-recruit size classes over the time series (1982-2003) on Georges Bank.

5.3. Production/ recruitment indicators summary

Indicators were categorized as positive ("+") if values or trends were positive compared to the period of the last assessment (1995-99) and to early period of the fishery prior to present TAC, EA and the ICJ Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise. Empty cells means no data is available or the indicator cannot be applied on that scale or time period.

			2000-2007 period compared to previous periods in the fishery						
			Pre EA and ICJ 1972-1985	Previous assessment period 1995-99					
Data Source	**Indicator**		**Overall**	**Overall**	**Georges Bank**	**SE Browns**	**SW Browns**	**Crowell Basin**	**Georges Basin**
Egg Production	Proportion of females mature (last 10 years)	Georges Bank 98%, SE Browns 96, SW Browns 77%, Georges Basin 91%, Crowell Basin 63%.	+	+	+	+	+	+	+
	Proportion of females multiparous (Mean last 10 years)	Georges Bank 72%, SE Browns 63%, SW Browns 25%, Georges Basin 33% Crowell Basin 11%.	+	+	+	+	+	+	+
Sex Ratio	Sex Ratio	Decrease in the proportion of males occurred during the first 10 years of the fishery. Skewed sex ratio present the last 20-30 years with no indications of negative effect	—	o	o	o	o	o	o

6.0 ENVIRONMENT/ECOSYSTEM

6.1. Predation on Offshore Lobsters

During their first three to four years, lobsters remain in or near their chosen shelter to avoid predation from predators including many fish species such as sculpin, cunners and skate, and by crabs and other opportunistic feeders (Lavalli and Lawton 1996, Palma et al. 1998). There is evidence that natural mortality may vary inversely with body size, with larger lobsters safer from all but the largest predators; however, all lobsters are most vulnerable immediately following the moult when their shell is still soft (Nelson et al. 2003). Known and suspected predators are shown in Table 6.1.1.

6.2. Food Sources for Lobsters Offshore

Lobsters are both active and opportunistic feeders. They catch and feed upon live fish, crabs, clams, mussels, scallop, various gastropods, marine worms, sea urchins, starfish and small amounts of marine plants, and scavenge on dead fish and other organisms (Carter and Steele 1982, Elner and Campbell 1987, Gendron et al. 2001, Jones and Shulman 2008).

6.3. Species Interactions and Interactions with Other Fisheries

Other Crustaceans

Lobsters co-occur with other crustaceans of commercial value, most notably Jonah crab (*Cancer borealis*), rock crab (*Cancer irroratus*) and deep-sea red crab (*Chaceon quinquedens*). While Jonah crab co-occur in shallower waters and are caught either as a directed fishery or as a bycatch of lobster fisheries, red crab generally exist in greater water depths than commercial lobster distributions and rarely make up a significant portion of bycatch.

Other Lobster Fisheries

The LFA 34 deeper water midshore fishery developed in the early 1980s and its landings exceed that of LFA 41. Landings for grid groups 4 a and b exceed 2100t and the outer grid groups (5 and 6) exceed 700t (Pezzack et al. 2006). Lobsters in this outer region have similar size frequency to LFA 41, and portions of it may represent the same animals that migrate onto Browns Bank in the summer.

Other Fisheries

While lobsters cannot legally be landed by other fisheries, there is potential interaction with mobile bottom gear. Observer data indicates their presence in scallop dredges (Smith et al. 2008), otter trawls, and gill nets set on the bottom. No qualitative information is available as to survival of lobsters returned to the water, but the weight of lobsters brought on deck by the inshore scallop fishery in SFA 29 is a small proportion of what is captured by the directed lobster fishery. Data from SFA 29 showed that 3% of lobsters seen in the drags were dead and 13% damaged. Levels of damage or mortality on the bottom are unknown.

6.4. Impacts of the Fishery on the Ecosystem in which it Operates

Gear Impact

The offshore habitat is varied with fishing activity on sand, hard gravel bottoms, soft clay/silt slope areas, within actively eroding canyons, in high energy areas with active movement of bottom sediments, in moraine areas and in softer sediment (Fader et al. 1977, Kostylev and Hannah 2005, Kostylev et al. 2001, Kostylev et al. 2005, McCall et al. 2004, Todd 2005, Todd et al. 1999, Valentine et al. 1984). The potential for local impact will vary considerably. One area of known coral concentration is closed to fishing.

A risk assessment of lobster trap impact on the bottom has not been conducted, but reviews of trap impacts have concluded that the potential for impact is small, though could increase with density and frequency of the traps being hauled (Anonymous 2004, Chiappone et al. 2005, Chiarella et al. 2005, Eno et al. 2001, Fogarty 2005, Hill et al. 2005, Morgan and Chuenpagdee 2003, Sheridan et al. 2005).

A study by Eno (Eno et al. 2001) found that lobster traps (*Homarus gammarus*) that landed on, or were hauled through, beds of the foliose bryozoans *Pentapora foliacea* caused physical damage to the colonies. However, contrary to expectations, sea pens, *Pennatula phosphorea*, *Virgularia mirabilis* and *Funiculina quadrangularis* bent in response to the pressure wave created by the descending trap and lay flat on the seabed. The study of Eno et al. (2001) suggests that the direct contact of fishing gears with fauna may not be the primary cause of mortality and the frequency and intensity of physical contact is more likely to be important. Traps location will vary according to season and, thus, it is highly unlikely that one particular area will continue to be impacted.

Based on available literature, it is expected that the impact of traps on bottom habitat is restricted to area immediately around the trap footprint; however, few studies have been conducted on this issue. The type of bottom fished is varied (e.g., mud, sand, gravel), and includes the sides of banks, basins and offshore canyons with some high energy areas with large natural sediment movements.

In LFA 41, lobster traps (dimensions of 1.22m x 0.51m x 0.35m) are set in strings of 100 traps separated by approximately 27.5m (15 fathoms) at depths of 100-400m and on varied bottom types (e.g., mud, sand, gravel, till, compacted clay), offshore canyons and other high energy areas with large natural sediment movements. Density of lobster gear in LFA 41 is considered to be low (approximately 12,000 traps over roughly 32,000km^2) relative to the inshore fisheries (LFA 34 - approximately 386,800 traps over roughly 21,000km^2).

The trap foot print is small, and traps are usually heavy enough to avoid movement with currents on the sea bottom. The traps are thus static on the bottom and the area affected is limited to the trap foot print area (0.62m^2). Proper hauling does not include significant dragging on the bottom, though this can occur especially in rough weather. As a result, the area of potential damage is likely to be insignificant compared with the widespread effects of mobile fishing gears.

At high trap densities, the seafloor could be significantly affected, but affect is believed to be small in LFA 41 due to the low trap densities, the seasonal movement of the traps and the relatively high energy areas (due to tidal action) in which the traps are placed.

Gear Loss and Ghost Fishing

Gear loss is believed to be low as strings of gear are valuable and efforts are made to recover them through grappling. Gear lost would remain intact for considerable periods of time unless disturbed by mobile gear. However, all traps are fitted with a ghost fishing panel that will open after a period of time.

The traps would be colonised by encrusting marine organisms, and the resulting habitat could provide shelter to smaller mobile fish and invertebrates. Observations from submersibles on the open slope area of Georges Bank suggest that traps with open doors or biodegradable panels form habitat for small fish, crabs and lobsters in an otherwise open bottom. In time, the traps would corrode and disappear.

Non Retained Bycatch

Pressure from this fishery is not thought to exert a direct impact upon ecological system structure or functioning (including specific prey or predator species, but no specific or systematic studies have been done).

Bycatch species that occur most frequently in the LFA 41 lobster fishery include cusk, rock crab, hake (red and white), cod and spiny dogfish. These non target species are not retained and are returned to the water. Female and undersized Jonah crab and berried and undersized lobsters are also returned to the water. Survival of discarded species is unknown, but is believed to be high for most invertebrates. Fish species with a swim bladder likely have a lower survival rate (DFO 2008).

The number of observer trips with recorded bycatch are given in Table 6.5.1 and the species and estimated weight in Table 6.5.2. The estimated weight is based on the observers' visual estimates and with the minimum weight recorded being 1 kg. As a result, the weight is not an absolute value and will overestimate the weight of the less common and smaller species.

Interaction with Whales

Right whales are present on the Scotian Shelf in summer, and the mouth of the Bay of Fundy, and Roseway Basin have been identified as summer feeding habitat. While there is potential for interaction between lobster gear and whales, lobster fishing grounds in LFA 41 do not overlap with areas of known whale concentrations (e.g., Roseway Basin) and overall trap densities are low. However, little is know of whale migration routes between the summer and winter grounds. There is also potential for interaction with sea turtles. There have been no reported interactions between whales and lobster gear or turtles and lobster gear in LFA 41.

Gear density is considered low over the grounds with 12,000 traps set in stings of 100-150 traps, attached to the groundline every 27.5m for a total length of approximately 4000m, with approximately 160 vertical lines (one on each end).

The ground line is a ¾ inch (18mm) Polysteel brand polypropylene. Captains indicate that the rope lies flat on the bottom due to the configuration of the gear where the groundline are set such that there is not slack in the line. There are no direct observations of the gear on the bottom, though a single observation made in the late 1980s by the author from a submersible on Georges Bank did observe the groundline was tight with little or no slack, and the 2002 Massachusetts (McKiernan et al. 2002) study of groundline indicates that this rope lies flat on the bottom.

6.5. Environment/ Ecosystem Indicators Summary

Indicators were categorized as positive ("+") if values or trends were positive compared to the period of the last assessment (1995-1999) and to early period of the fishery prior to present TAC, EA and the ICJ Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise. Empty cells means no data is available or the indicator cannot be applied on that scale or time period.

		2000-2007 period compared to previous periods in the fishery						
		Pre EA and ICJ 1972-1985	Previous assessment period 1995-1999					
Data Source	Indicators	Overall	Overall	Georges Bank	SE Browns	SW Browns	Crowell Basin	Georges Basin
Predators	Unable to quantify but reduced groundfish populations may have reduced predation of some sizes of lobsters.		o					
Food Sources	Unable to quantify, lobsters are able to feed on a wide range of prey	o	o					
Impact of traps on bottom	Gear density is low and impact believed to be restricted to area immediately around the trap footprint. Many of the areas fished are high energy areas with large natural sediment movements. Areas of known coral areas are closed.	o	o					
Lost gear	Gear loss is believed minimal and all traps equipped with Ghost fishing devices		o					
Bycatch	All animals are released with high survival believed in invertebrates but lower survival in fish species		o					
Interaction with whales	Gear density is low and fishing grounds are not in areas of know whale concentrations but little is know of their migration routes between the summer and winter grounds		o					

7.0 ENVIRONMENT/ECOSYSTEM INDICATORS SUMMARY

Indicators were categorized as positive ("+") if values or trends were positive compared to the period of the last assessment (1995-1999) and to early period of the fishery prior to present TAC, EA and the ICJ Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise. Empty cells means no data is available or the indicator cannot be applied on that scale or time period.

			2000-2007 period compared to previous periods in the fishery						
			Pre EA/ICJ 1972-1985	Previous assessment period 1995-1999					
	Data Source	**Indicator**	**Overall**	**Overall**	**Georges Bank**	**SE Browns**	**SW Browns**	**Crowell Basin**	**Georges Basin**
Abundance	Landings	90% TAC	+	+					
		# of grids fished to obtain TAC		o					
	Trawl surveys	Mean # / tow Canada				+	+	+	+
	Catch Rate	Annual Catch rate		+	+	+	–	+	+
		Catch rate Model		+	+	+	o	o	+
Fishing Pressure	Effort	Trap Hauls		o					
		# of grids fished to obtain TAC		o					
	Exploitation Rate								
		Landings in adjacent fisheries	–	–	–	o	–	–	o
	Size Distribution	Median size	+	+	+	+	o	–	+
		Size Structure	+	+	+	+	o	–	+
	Sex Ratio		–	o	o	o	o	o	o
Production/ Recruitment	Egg Production	Proportion of females mature	+	+	+	+	+	+	+
		Proportion of females multiparous	+	+	+	+	+	+	+
	Sex Ratio	Sex Ratio	–	o	o	o	o	o	o
Environment/ Ecosystem	Predators			o					
	Food Sources		o	o					
	Impact of traps on bottom		o	o					
	Lost gear			o					
	Bycatch			o					
	Interaction with whales			o					

8.0 CONCLUSIONS

Abundance

Abundance indicators for commercial sized lobsters in different subareas of LFA 41 suggest that lobster abundance has been either stable without trend or has trended higher since 1999. Annual fishery catch rates (non-standardized) are stable or increasing in four of five areas. The multiplicative catch rate model indicates catch rates have trended inconsistently or increased in different areas of LFA 41. The DFO RV summer bottom trawl survey shows an increase in mean number per tow, but the time series is short (1999-2008), and further development of the analytical approach is recommended. The NMFS fall trawl survey indicates that on the USA side of Georges Bank, lobster abundance increased from 2000 to 2003 and then declined to 2007.

Uncertainties

The waters of outer shelf and basins of the Gulf of Maine are influenced by water mass movements caused by larger scale oceanographic events. Fishery-based indicators of abundance in LFA 41 may be influenced by these oceanographic events that could mask short term changes in population size. Long term trends in these indices may be more reliable.

In a small fishery with only four vessels fishing, a migratory stock and subjected to changing oceanographic events, fluctuations in catch and CPUE are expected, and concern would arise with longer term trends that cannot be explained by environment or fishery related issues.

The definition of the stock fished is uncertain. Georges Bank is considered a separate stock which is shared between Canada and the USA, while the lobsters in the SW Browns, Crowell Basin area are shared with the LFA 34 fishery fishing beyond German Bank, and management differs between these areas.

Fishing Pressure

Fishing pressure was evaluated in terms of total trap hauls, size structure and sex ratio. Total trap hauls in 2007 (288,000) returned to levels observed in 1995 (228,000), down from the peak of 593,000 in the 1998-1999 season, presumably because of reduced fishing for Jonah crab. The size structure has remained stable except for apparent decreases in median size in Crowell Basin. A decrease in the proportion of males occurred during the first 10 years of the fishery, with the largest change on Georges Bank. Whether the female biased sex ratio is a concern for population productivity needs to be investigated further. Males are able to mate with several females each year, and with only 50% of the females available (33% at sizes greater than 120-130mm CL) to mate each year, the present skewed distribution may have little impact on breeding success as long as the wide size range of males is maintained. Exploitation rate has not been directly estimated, but based on the size structure and estimates from the American fishery on Georges Bank, it is inferred to be low. Further investigation into approaches for estimating exploitation (including DFO RV summer bottom trawl survey data) is recommended.

Landings in adjacent fisheries increased significantly during the last 10 years, indicating additional pressure on the lobster resources in these areas. Landings by the deeper water (>100m) LFA 34 fishery directly adjacent to LFA 41 now exceed the total LFA 41 landings and are three times higher than the adjacent Gulf of Maine portion of LFA 41 (SW Browns, Crowell Basin and Georges Basin). Over the last five years (2003-2007), landings from the USA portion of NE Georges Bank averaged 7.9 times that of the Canadian landings on Georges Bank.

Uncertainties

The uncertainties in exploitation rates are a reason for caution and for maintaining the goals of preserving a population with high reproductive capacity. The uncertainties show the need for developing reference points and triggers to protect the population. Development of fishing mortality estimates from the Canadian trawl surveys should be pursued, as well as additional modelling.

Caution is needed in interpreting the observed stability in the size frequency distributions. The lack of change in the sizes over the history of the fishery could be the result of a number of factors including low fishing mortality; trap selectivity that could mask some changes in the population size frequency; stability in the pattern of ontogenetic migrations with the fishery targeting the adult areas. The size structures of the lobsters on Browns and Georges banks in trawl surveys suggest this could explain some of the stability.

Caution is needed in interpreting the observed changes in size and sex ratio over time because gear design has changed over the history of the fishery, and the samples being compared do not necessary represent the same exact location or bottom as they are grouped by the general area, nor are they necessarily from the same phase in the migration period. Size changes in the fishery could also be the result of natural changes in lobster distribution or changes in lobster catchability related to environmental or ecosystem changes. Additional caution is needed in interpreting the sizes changes in Crowell Basin, as the most recent at-sea samples correspond to the period during which Jonah Crab were targeted on many of the trips, and this would affect the areas chosen for fishing.

Production and Recruitment

Indicators of recruitment are currently unavailable. DFO RV trawl surveys may offer an opportunity to identify recruitment by sampling in shallower areas on the banks and by having broader size selectivity. The NMFS fall trawl survey indicates low variability in abundance of recruit and post-recruit size classes over the time series (1982-2003) on Georges Bank. The size structure in LFA 41 has been maintained with little variation over the history of the fishery, and the high proportion of females above 97mm CL (the estimated size of 50% maturity) and 115mm CL (multiparous females) in the LFA 41 fishery indicates a high level of potential egg production in this area relative to the inshore. Four grid groupings have shown no trend in this proportion over time; the Crowell Basin grid grouping has shown a decrease in the proportion of mature females.

Uncertainties

There is uncertainty as to the source of recruitment to the fishery. Trawl surveys indicate prerecruits in the offshore, and tagging also shows some out migration of mature animals from coastal areas. The importance of these two sources may vary with location and time depending on larval settlement and relative densities of lobsters on the different grounds.

Ecosystem and Environment

Potential ecosystem interactions include impacts of traps on bottom habitat, impacts of lost gear, bycatch and interactions with other species. Bycatch species that occur most frequently in the LFA 41 lobster fishery include Jonah crab, cusk, hake (red and white), cod, rock crab and redfish. Other than Jonah crab, all animals are released. High survival is assumed for invertebrates, but survival may be lower for some fish species. The effect of fishing on bottom habitat has not been evaluated. but is expected to be low relative to other bottom contact gear types. This expectation is based on the small size of the gear footprint and the relatively low density of traps in this large fishing area. There have been no reports of interactions with whales or sea turtles from this fishery.

9.0 MANAGEMENT CONSIDERATIONS

Based on the current indicators of abundance, fishing pressure and production, the current TAC of 720mt (in place since 1985) does not appear to have had negative impacts on the lobster in LFA 41 overall, and is considered to represent an acceptable harvest strategy at this time. Better estimates of lobster abundance and exploitation rate would provide a more robust way of evaluating harvest strategies in the future.

Decline in median size in Crowell Basin (the only grid grouping of 5 to show this decline) is cause for further investigation. This decline may reflect the influence of fisheries in adjacent areas. Increasing catches in adjacent areas may affect LFA 41 (4X + 5Zc) overall.

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11.0 TABLES

Table 3.1.1. LFA 41 lobster landings 1981-2008, by subareas and fishing season; with TAC and vessel number. The fishing season is defined as the period for catching the TAC and this has varied over time:

Jan. 1-Dec. 31 for 1981-1985,
Aug. 1, 1985 to Oct. 15, 1986,
Oct. 16-Oct. 15 for 1986-87-2003-04,
Oct. 16, 2004 to Dec. 31, 2005 (7 of 8 licences with 1 licence retaining Oct. 16-Oct. 15), and
Jan. 1-Dec 31 for 2006-2008 (7 of 8 licences with 1 licence retaining Oct. 16-Oct. 15 year until 2007).

Landings (MT)	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W experimental	Total	TAC	Vessel Number
1981		122	14	245	191		572	408 (4X)	8
1982	31	112	8	152	166		469	408 (4X)	8
1983	65	140	4	114	154		477	408 (4X)	8
1984	50	94	28	127	140		439	408 (4X)	7
1985	66	142	267	192	111		778	408 (4X)	8
1985/86*	91	181	245	198	136		851	888	8
1986/87	85	132	176	145	179		717	720	8
1987/88	93	143	133	99	110		578	720	7
1988/89	81	120	32	57	114		404	720	6
1989/90	94	188	55	100	94		531	720	6
1990/91	92	242	164	101	115		714	720	5
1991/92	82	209	128	72	118		609	720	5
1992/93	102	157	88	68	129		544	720	5
1993/94	115	180	94	163	150		702	720	7
1994/95	143	209	83	169	113		717	720	6
1995-96	61	96	114	133	60	0.1	464	720	7
1996-97	89	150	104	196	134		673	720	7
1997-98	82	167	87	147	137		620	720	8
1998-99	80	135	92	130	152		589	720	8
1999-00	119	211	104	141	145	9.4	730	720	9
2000-01	139	252	163	84	79		717	720	8
2001-02	125	291	140	86	83	0.5	726	720	9
2002-03	166	286	95	103	67		718	720	8
2003-04	101	284	122	133	76		717	720	8
2004-05**	72	390	177	224	150		1013	1008	7
2006-06	21	294	170	190	106		780	720	6
2007-07	12	224	149	175	132		691	720	4
2008-08	11	216	117	223	123		692	720	4

** 1985/86 SEASON Aug. 1, 1985 to Oct. 15, 1986.*
*** 2004/2005 SEASON Oct. 16, 2004 to Dec. 31, 2005.*

Table 3.1.2. LFA 41 lobster landings by NAFO divisions 1971-1985. No TAC 1972-1976, TAC applied to 4X only 1977-1984.

Year	No. of Vessels	Browns Bank (4X)	Georges Bank (5Zc)	Total (Jan.-Dec.)	TAC
1971	5	8	92	100	
1972	6	180	154	334	
1973	7	317	176	493	
1974	6	281	135	416	
1975	8	372	173	545	
1976	7	496	182	678	
1977	8	358	277	635	408 (4X)
1978	8	381	303	684	408 (4X)
1979	8	373	236	609	408 (4X)
1980	8	357	192	549	408 (4X)
1981	7	382	190	572	408 (4X)
1982	8	303	166	469	408 (4X)
1983	8	323	154	477	408 (4X)
1984	7	299	140	439	408 (4X)
1985	8	664	114	778	

Table 3.1.3. Number of grids fished to obtain 75% of TAC, 75% landings and total grids fished.

Year	Grids for 450mt 75% TAC	Grids for 75% Landings	Total Grids (>0.5mt)	Landings
1986/87	95	94	215	718
1987/88	206	116	235	578
1988/89		95	189	403
1989/90		117	251	532
1990/91	108	106	225	713
1991/92	149	97	212	609
1992/93	216	100	211	544
1993/94	111	104	232	701
1994/95	91	90	216	717
1995/96	81	82	196	725
1996/97	135	115	236	672
1997/98	149	101	215	620
1998/99	195	109	228	590
1999/00	98	102	233	730
2000/01	152	151	274	718
2001/02	146	149	277	726
2002/03	150	149	281	718
2003/04	153	154	293	721
2004/05*	137	172	329	800
2005/06*	132	158	303	780
2006/07*	132	144	288	750
Mean	139	119	245	670

** Based on Oct. 16-Oct. 15 season.*

Table 3.2.1. DFO RV summer trawl survey vessels and the total number of lobsters caught during the survey.

	Vessel			
Year	**Needler**	**Teleost**	**Templeman**	**Total**
1999	85			85
2000	33			33
2001	132			132
2002	92			92
2003	195			195
2004		96		96
2005	172	191		363
2006	263			263
2007		154		154
2008			158	158

Table 3.3.1. Annual non-standardized CPUE (total landings/total trap hauls) by subarea 1995-2008 and by fishing season (TAC period).

	Lobster Kg per Trap Haul					
Fishing Season	**Crowell Basin**	**SW Browns**	**Georges Basin**	**SE Browns**	**Georges Bank**	**4W experimental**
1995-96	2.7	2.0	2.8	1.7	1.6	0.15
1996-97	1.6	1.8	2.0	1.5	1.3	
1997-98	0.9	2.1	1.4	1.2	2.2	
1998-99	0.6	1.2	1.0	0.8	1.9	
1999-00	0.8	2.5	1.9	0.7	1.5	0.37
2000-01	1.1	2.8	3.0	1.1	1.4	
2001-02	1.7	2.9	2.6	0.7	1.5	0.04
2002-03	2.2	3.5	2.5	1.3	1.9	
2003-04	2.1	3.2	3.3	1.7	2.9	
2004-05	1.7	2.3	2.5	2.2	2.7	
2006-06	2.6	3.1	2.2	2.4	2.9	
2007-07	2.0	2.2	2.5	2.3	3.0	
2008-08	2.6	1.9	2.3	2.2	2.6	

Table 3.4.1. AIC, adjusted R-squared value and degrees of freedom for each area/seasonal model.

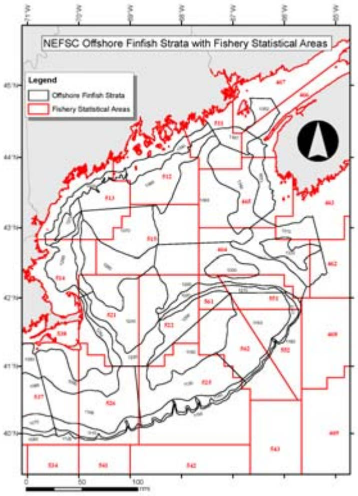
Data subset	**AIC***	**Adj. R-sqr**	**DF**
Crowell Basin- winter	5012	0.49	2183
Crowell Basin- summer	3444	0.47	1452
SW Browns - winter	7530	0.55	4617
SW Browns - summer	4390	0.27	2369
SE Browns - winter	7368	0.30	2682
SE Browns - summer	9861	0.45	3842
Georges Bank - winter	1287	0.55	987
Georges Bank - summer	3398	0.61	2114
Georges Basin - winter	2641	0.38	1887
Georges Basin - summer	2840	0.53	2021

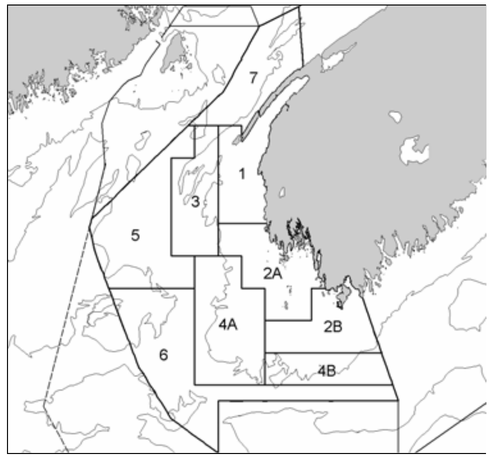
** Note: AIC are not directly comparable across groups due to differing degrees of freedom.*

Table 4.1.1. Total trap hauls by subarea and by fishing season (TAC period) 1995-2008.

	Sum of TRAP_HAULS						
Fishing season	**Crowell Basin**	**SW Browns**	**Georges Basin**	**SE Browns**	**Georges Bank**	**4W experimental**	**Total**
1995-96	22050	48880	41000	77668	38250	625	228473
1996-97	54650	81470	52225	134150	101445		423940
1997-98	88787	81472	64063	119623	62200		416145
1998-99	143750	115939	91115	161372	80665		592841
1999-00	158845	84484	54787	195518	94840	25160	613634
2000-01	121828	89777	54846	79544	55228	7700	408923
2001-02	73258	99170	54320	125582	54912	12300	419542
2002-03	74097	81563	38394	78550	35590		308194
2003-04	48630	89505	36450	80050	26300		280935
2004-05	43845	173022	69615	101820	55800		444102
2006-06	8070	95034	75982	77770	37180		294036
2007-07	5930	103500	58792	76370	43370		287962
2008-08	400	35190	48780	102210	47170		233750

Table 4.1.2. Lobster landings in adjacent lobster fisheries with maps showing LFA 34 grids and USA statistical areas.





Year	NE Georges LFA 41	GOM LFA 41 SW Browns Georges Crowell Basin	LFA34 Grid Group 5-6	LFA34 Grid Group4	NE Georges Stat Area 561-562 (USA)	Central GOM Stat Area 464-465, 515 (USA)	South Georges Stat Area 522, 525 (USA)
1981	190	136			220	95	517
1982	166	150			111	98	693
1983	154	210			161	179	983
1984	140	173			142	252	663
1985	114	456			292	228	504
1986	161	477			222	172	334
1987	145	351			298	35	274
1988	140	289			275	16	352
1989	84	307			318	15	212
1990	85	373			31	321	424
1991	129	435			66	416	486
1992	130	382			177	23	463
1993	164	393			120	222	506
1994	171	433			242	250	368
1995	121	387			163	386	324
1996	66	423			202	353	337
1997	168	326			197	308	397
1998	128	282	179	727	242	282	399
1999	168	412	251	1228	251	251	537
2000	111	532	349	2051	152	379	499
2001	79	573	582	2685	483	401	399
2002	78	569	672	2781	425	412	458
2003	68	477	1343	3264	573	550	552
2004	75	410	764	2381	720	530	502
2005	143	489	958	2848	1062	476	627
2006	106	484	798	3404	949	626	594
2007	132	384	935	3516	643	436	536
Mean 81-89	144	283			277	121	503
Mean 90-99	133	385			169	281	424
Mean 00-07	99	490	800	2866	626	476	521

*Table 4.4.1. Male:Female sex ratio (number of males per female) of legal sized lobsters from at-sea samples (**F**all, **W**inter, **S**pring, **S**ummer).*

	Georges Bank				SE Browns				SW Browns				Georges Basin				Crowell Basin			
Year	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**
1972			1.36																	
1973							0.96													
1974																				
1975																				
1976																				
1977	1.11		0.58	0.27							0.72	0.68							0.86	0.64
1978	0.88		0.77						1.37		0.76	1.20					0.91			0.87
1979	0.53		0.21					1.23			0.75	0.77								0.77
1980			0.24					0.35				0.67								
1981			0.26					0.31												
1982								0.46			0.69	0.74					0.45			
1983							0.48	0.47			0.60	0.65			0.82					
1984								0.74			0.76	0.90								
1985																	0.46			
1986																				
1987			0.15																	
1988												0.58								
1989		0.41	0.26												0.70					
1990																				
1991			0.14	0.13				0.23				0.53			0.20	0.46				0.56
1992									0.44											
1993	0.29												0.31							0.38
1994			0.09								0.41					0.16				0.23
1995							0.64													
1996																				
1997														0.46						
1998	0.11	0.19	0.10	0.23		0.15		0.45	0.25	0.21		0.63		0.44	0.31	0.50	0.24	0.45	0.25	
1999	0.09				0.38		0.46		0.06		0.88							0.32		
2000			0.09	0.31			0.10	0.30	0.32						0.13		0.21	0.61	0.13	
2001		0.29	0.11		0.28		0.22		0.14		0.26			0.26	0.14		0.12	0.17		0.43
2002		0.23	0.15				0.50		0.20					0.32	0.20		0.13	0.58	0.16	
2003		0.18			0.21				0.36		0.38				0.29		0.35		0.15	
2004										0.28	0.29							0.41		
2005	0.09		0.12	0.27			0.32		0.20	0.20	0.29	0.41	0.17	0.17	0.14		0.18		0.38	
2006		0.11	0.13		0.18	0.17	0.24		0.19	0.40		0.97		0.31	0.30		0.28			
2007		0.07	0.10			0.18	0.22		0.10					0.18	0.32					
2008						0.37								0.50						
Mean 1998-2008	0.09	0.18	0.11	0.27	0.26	0.21	0.30	0.37	0.20	0.27	0.42	0.67	0.17	0.31	0.23	0.50	0.22	0.42	0.21	0.43

Table 5.1.1. Percentage of females >97mm CL (approximate size at 50% maturity) that are berried in spring (Apr.-Jun.) at-sea samples (Crowell Basin 1998-2006 are summer (Jul.-Sept.) samples).

Year	Georges Bank %berried >97	SE Browns %berried >97	SW Browns %berried >97	Georges Basin %berried >97	Crowell Basin %berried >97
1972	13%				
1973		21%			
1974					
1975					
1976					
1977	21%		9%		9%
1978	16%		14%		30%
1979	30%		12%		30%
1980	16%				
1981	29%				
1982			7%		
1983		8%	11%	5%	
1984			5%		
1985					
1986					
1987	18%				
1988					
1989	26%			41%	
1990					
1991	19%			2%	15%
1992					
1993					18%
1994	16%		15%		5%
1995		30%			
1996					
1997					
1998	2%			3%	3%
1999		6%	7%		
2000		8%		3%	6%
2001	9%		8%		
2002		14%		1%	
2003	31%		10%	8%	3%
2004			23%		
2005		18%	6%	4%	3%
2006	3%	28%	36%	12%	
2007	4%	20%		3%	
2008	23%				

Table 5.1.2. Percentage of legal sized females >97mm CL (approximate size at 50% maturity) and >115mm CL (approximate size at which all females have reproduced at least once) in spring (Apr.-Jun.) at-sea samples (Crowell Basin 1998-2006 are summer (Jul.-Sept.) samples).

	Georges Bank		SE Browns		SW Browns		Georges Basin		Crowell Basin	
Year	**>97**	**>115**	**>97**	**>115**	**>97**	**>115**	**>97**	**>115**	**>97**	**>115**
1972	99%	79%								
1973			98%	51%						
1974										
1975										
1976										
1977	100%	73%			95%	38%			86%	22%
1978	99%	73%			96%	46%			84%	25%
1979	99%	76%			97%	41%			87%	33%
1980	100%	84%								
1981	99%	77%								
1982					91%	41%				
1983			99%	67%	87%	32%	84%	26%		
1984					87%	33%				
1985										
1986										
1987	98%	65%								
1988										
1989	94%	49%					90%	42%		
1990										
1991	98%	62%					95%	27%	79%	13%
1992										
1993									85%	19%
1994	98%	73%			87%	33%			87%	29%
1995			93%	51%						
1996										
1997										
1998	99%	82%					88%	22%	65%	9%
1999			96%	72%	78%	24%				
2000			98%	82%			89%	28%	70%	9%
2001	99%	81%			80%	14%				
2002	96%	65%	96%	42%			89%	19%		
2003	96%	62%			70%	18%	94%	47%	49%	7%
2004					76%	26%				
2005			98%	67%	83%	33%	96%	41%	68%	19%
2006	99%	71%	96%	54%	78%	32%	88%	33%		
2007	99%	79%	93%	57%			91%	37%		
2008	98%	67%								
Mean 1998-2008	98%	73%	96%	62%	78%	24%	91%	33%	63%	11%

Table 6.1.1. Known and suspected predators on lobsters.

Common Name	Lobster Life Cycle Stage	Reference Source
Cunners	Larval, postlarvae, juveniles	(Barshaw and Lavalli 1988; Barshaw et al. 1994; Hanson and Lanteigne 2000)
Sculpins	Juveniles, recruits	(Hanson and Lanteigne 2000; van der Meeren 2000)
Skates	Juveniles, recruits	(Templeman 1982; Hanson and Lanteigne 2000)
Cod	Juveniles, recruits, mature	(Herrick 1911; Hanson and Lanteigne 2000; van der Meeren 2000; Davis et al. 2004)
Spiny Dogfish	Juveniles, recruits,	(Hanson and Lanteigne 2000; van der Meeren 2000; Davis et al. 2004)
Sea Ravens	Juveniles, recruits,	(Cooper 1977; Cooper and Uzmann 1980)
Wolfish	Juveniles, recruits, mature	(Nelson and Ross 1992)
Cancer Crabs	Postlarvae, juveniles	(van der Meeren 2000)
Striped Bass	Juveniles, recruits, mature	(Nelson et al. 2003; Nelson et al. 2006))

Table 6.5.1. Number of observed at-sea trips with bycatch recorded.

Year	No. observed trips
1988	9
1989	8
1996	5
1999	2
2000	7
2001	7
2002	6
2003	7
2004	3
2005	9
2006	8
2007	5
2008	2
Total	78

Table 6.5.2. Bycatch (excluding lobster and crab discards). Based on 81 observed trips form 1988 to 2008. Shown for each taxon is the total estimated weight (kg) for all trips. Note that the weight is estimated and the minimum weight recorded is 1 kg.

Group	Taxon	Total wt (kg)	%
Invertebrates			
Crab	ATLANTIC ROCK CRAB	15410	33.2%
	RED DEEPSEA CRAB	136	0.3%
	NORTHERN STONE CRAB	63	0.1%
	BRACHIURAN CRABS	19	<0.1%
	CALAPPA MEGALOPS	10	<0.1%
	TOAD CRAB,UNIDENT.	7	<0.1%
	SNOW CRAB (QUEEN)	5	<0.1%
	PORTUNIDAE F.	1	<0.1%
Shrimp	PANDALUS SP.	4	<0.1%
Echinoderms	ASTEROIDEA S.C.	60	0.1%
	SEA ANEMONE	7	<0.1%
	SEA URCHINS	1	<0.1%
Molluscs	SEA SNAILS,SEA BUTTERFLIES, PTEROPODA	11	<0.1%
	OCTOPUS	1	<0.1%
	SEA CORN	1	<0.1%
Jellies	JELLYFISHES	3	<0.1%
Vertebrates			
	CUSK	20392	43.9%
	COD(ATLANTIC)	2809	6.0%
	SQUIRREL OR RED HAKE	2321	5.0%
	HAKE (NS)	1914	4.1%
	WHITE HAKE	1631	3.5%
	SPINY DOGFISH	631	1.4%
	HADDOCK	251	0.5%
	REDFISH UNSEPARATED	234	0.5%
	ROSEFISH(BLACK BELLY)	127	0.3%
	STRIPED ATLANTIC WOLFFISH	107	0.2%
	SCULPINS	49	0.1%
	LANTERNFISH PATCHWORK	41	0.1%
	SEA RAVEN	41	0.1%
	OCEAN POUT(COMMON)	29	0.1%
	MONKFISH,GOOSEFISH,ANGLER	25	0.1%
	LONGHORN SCULPIN	20	<0.1%
	SHORTHORN SCULPIN	20	<0.1%
	POLLOCK	19	<0.1%
	NORTHERN WOLFFISH	13	<0.1%
	FINFISHES (NS)	12	<0.1%
	WOLFFISH,UNIDENT.	11	<0.1%
	SCULPIN UNIDENTIFIED	10	<0.1%
	DOGFISHES (NS)	7	<0.1%
	EELPOUTS (NS)	7	<0.1%
	AMERICAN EEL	4	<0.1%
	CUNNER	2	<0.1%
	FOURHORN SCULPIN	2	<0.1%
	SCULPIN (NS)	2	<0.1%
	SMOOTH SKATE	2	<0.1%
	ARGENTINE(ATLANTIC)	1	<0.1%
	NORTHERN HAGFISH	1	<0.1%
	SILVER HAKE	1	<0.1%
	SPOTTED WOLFFISH	1	<0.1%
Total		**46476**	**100%**

12.0 FIGURES

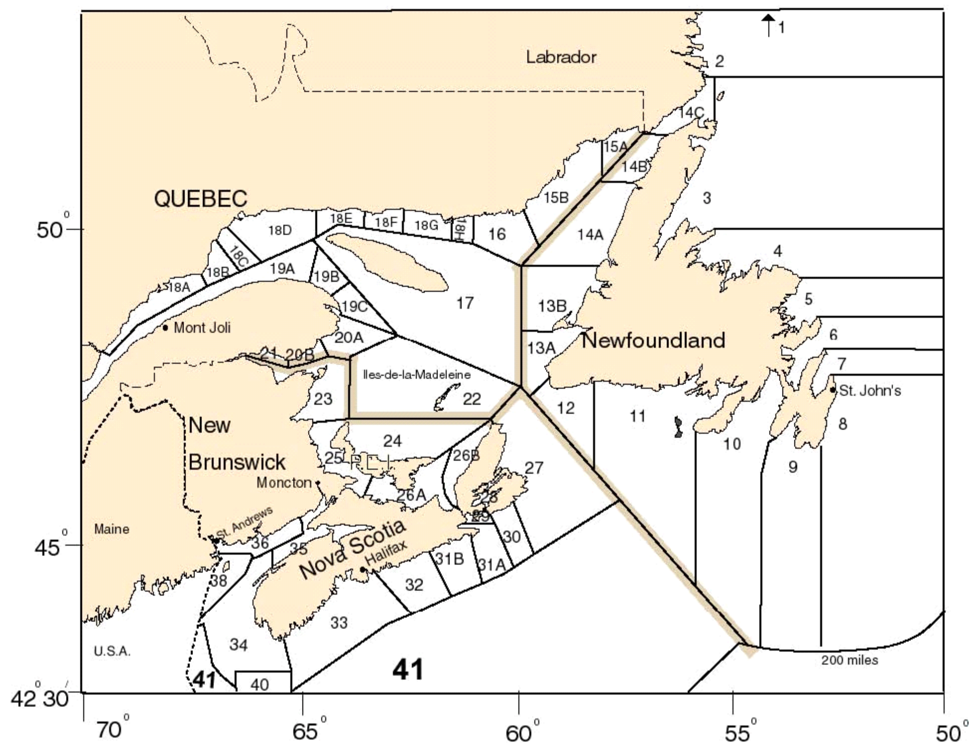


Figure 1.1.1. Canadian Lobster Fishing Areas (LFAs).

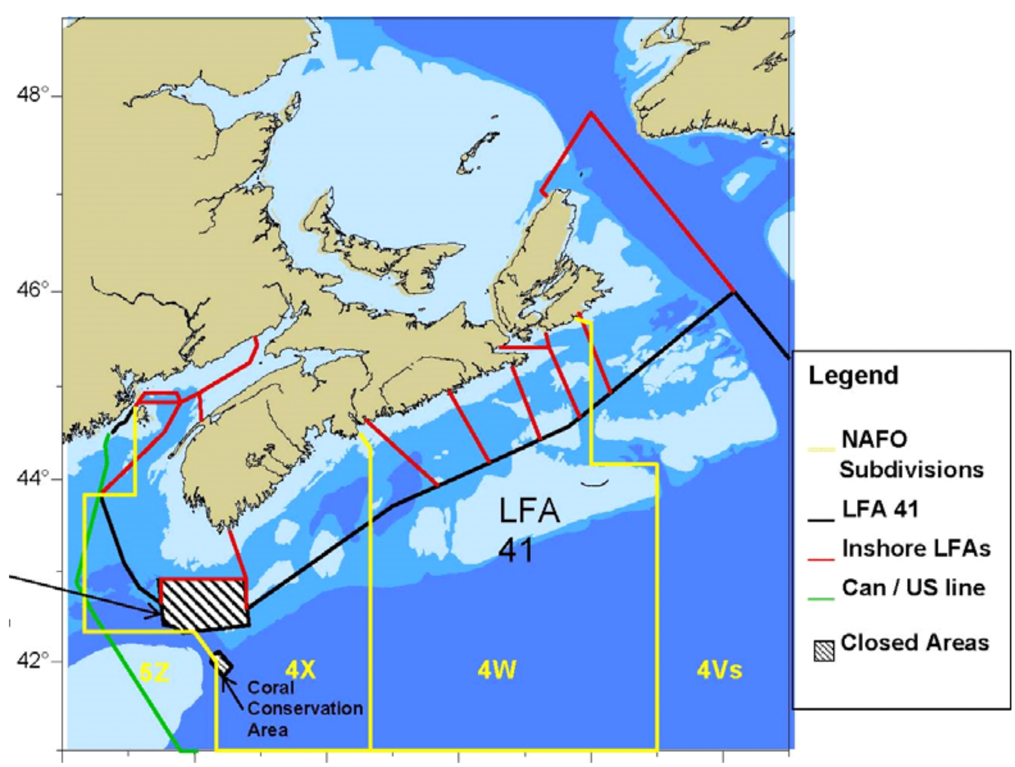


Figure 1.1.2. NAFO divisions, LFA 41, LFA 40 (Browns Bank closed area) and Coral Conservation Area.

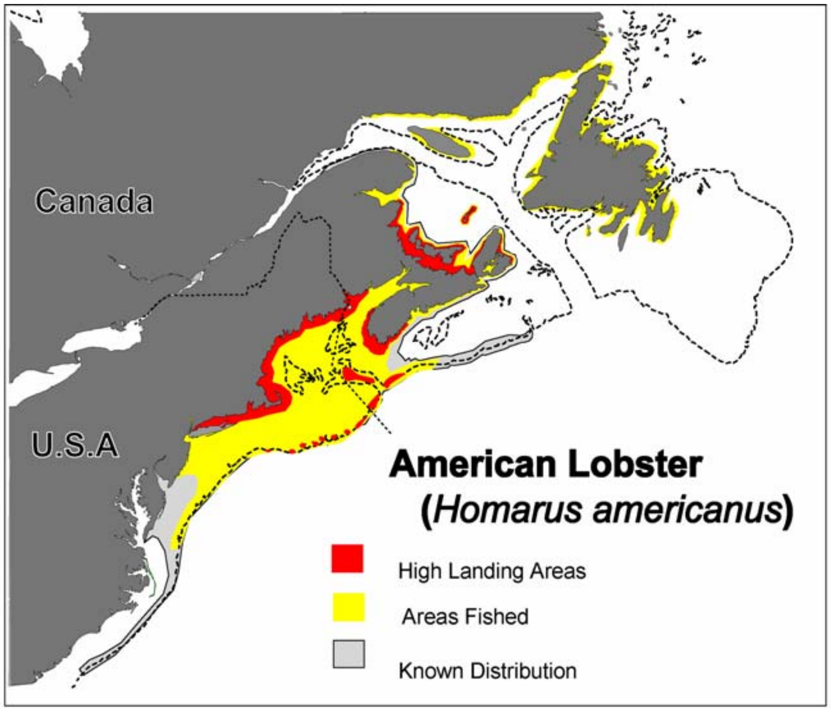


Figure 1.2.1. American LOBSTER distribution range and areas fished based on fishery data and DFO and NMFS bottom trawl surveys.

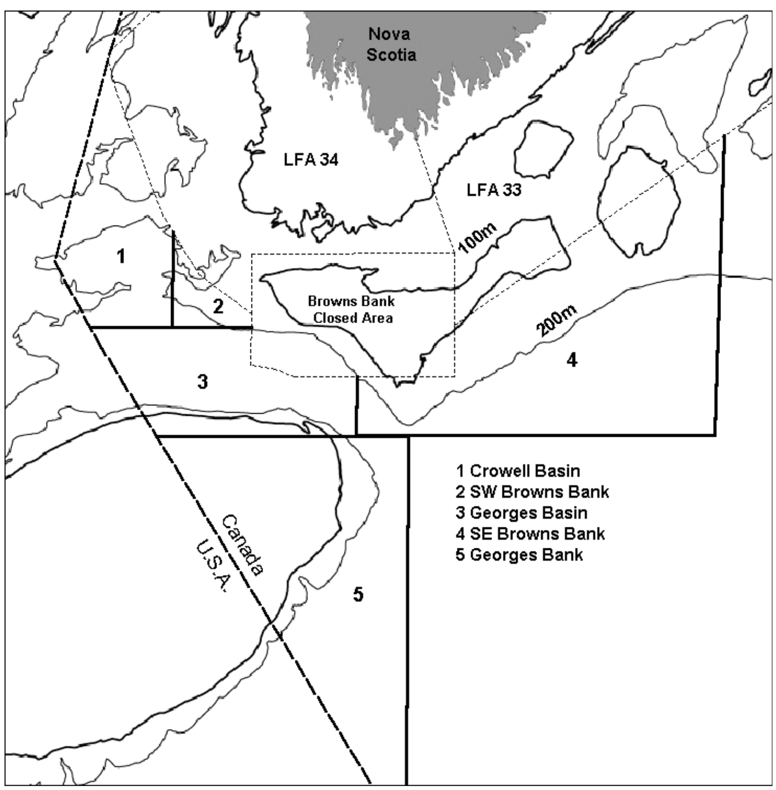


Figure 2.1.1. Traditional offshore subareas used in past assessments.

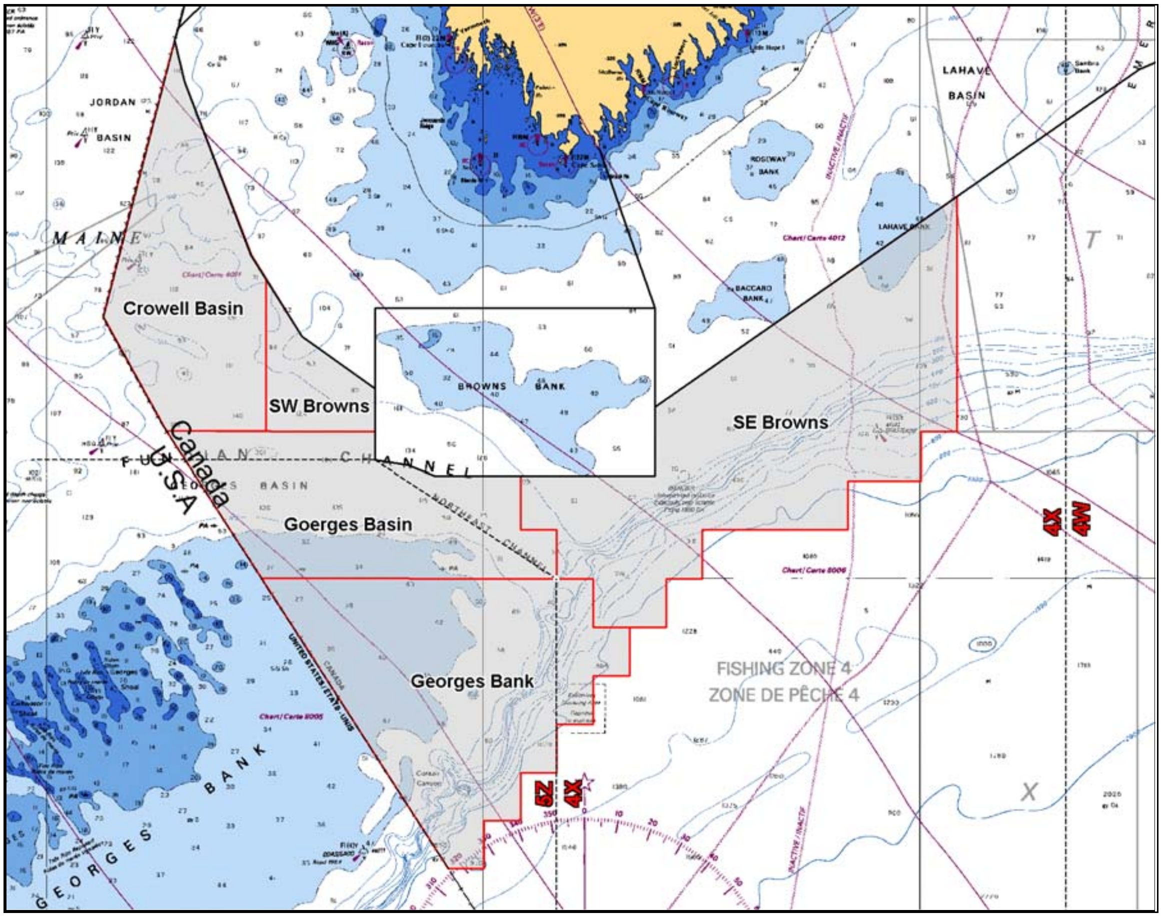


Figure 2.1.2. New offshore subareas based on grid grouping.

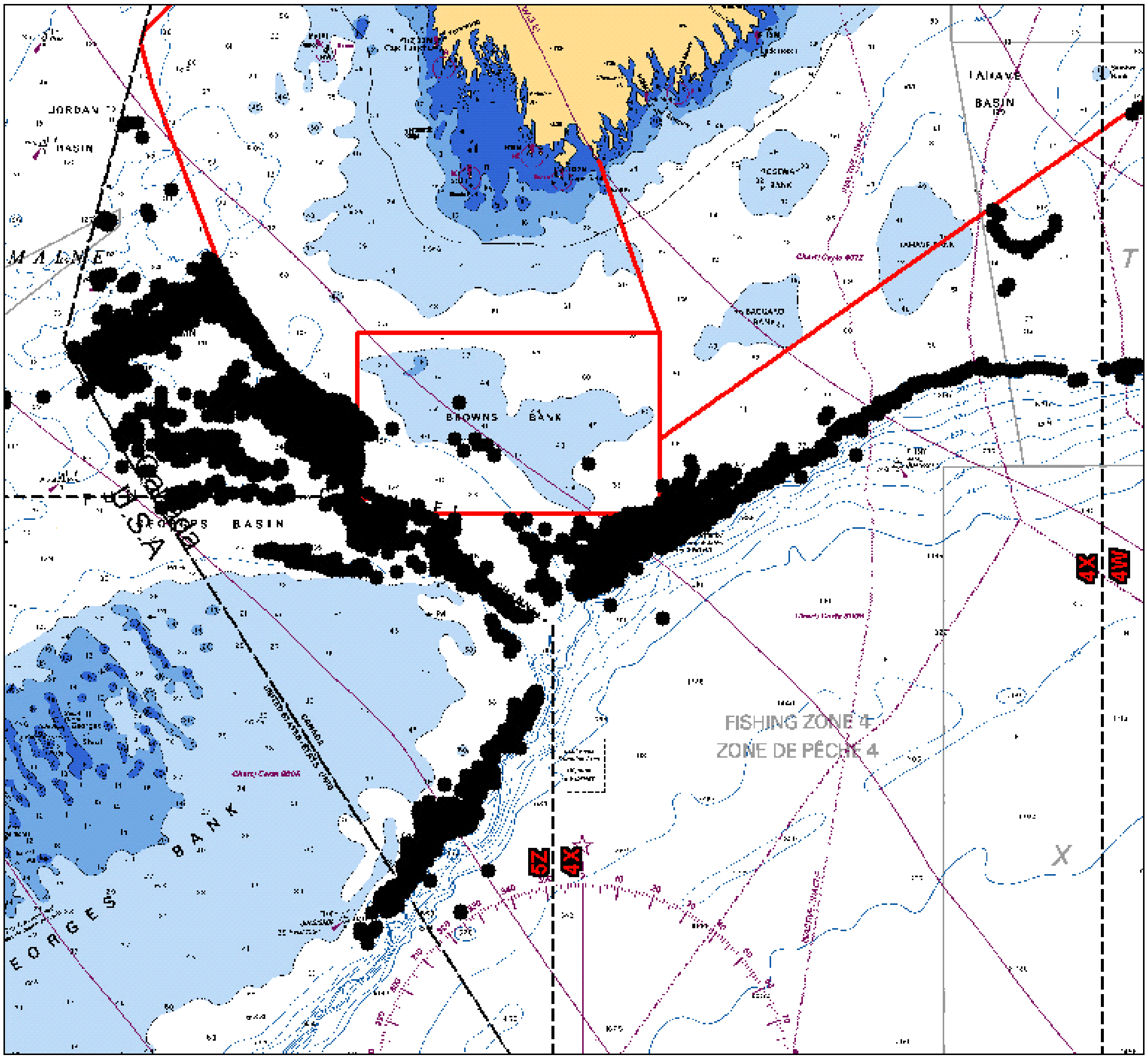


Figure 2.2.1. LFA 41 at-sea sampling locations 1977 to 2007 (note locations in the Browns Bank closed area were part of a DFO trapping survey).

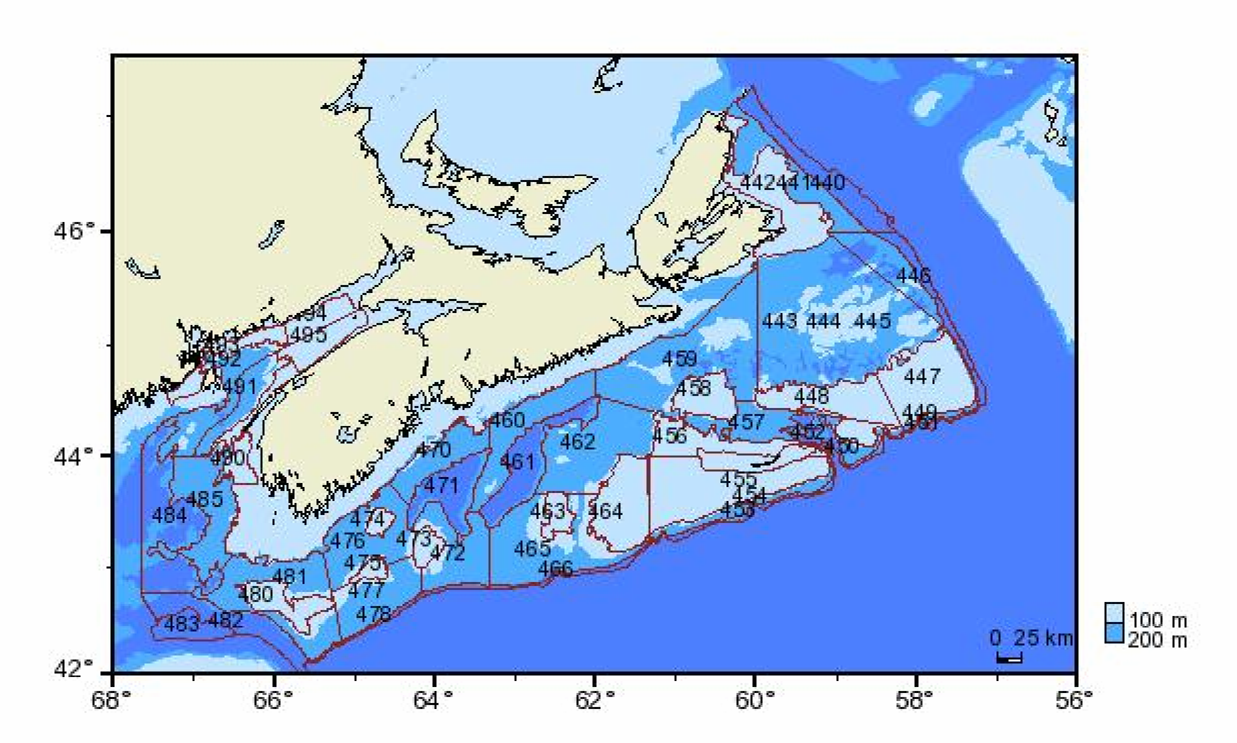


Figure 2.3.1. Sampling strata RV stratified random summer trawl on the Scotian Shelf and Bay of Fundy.

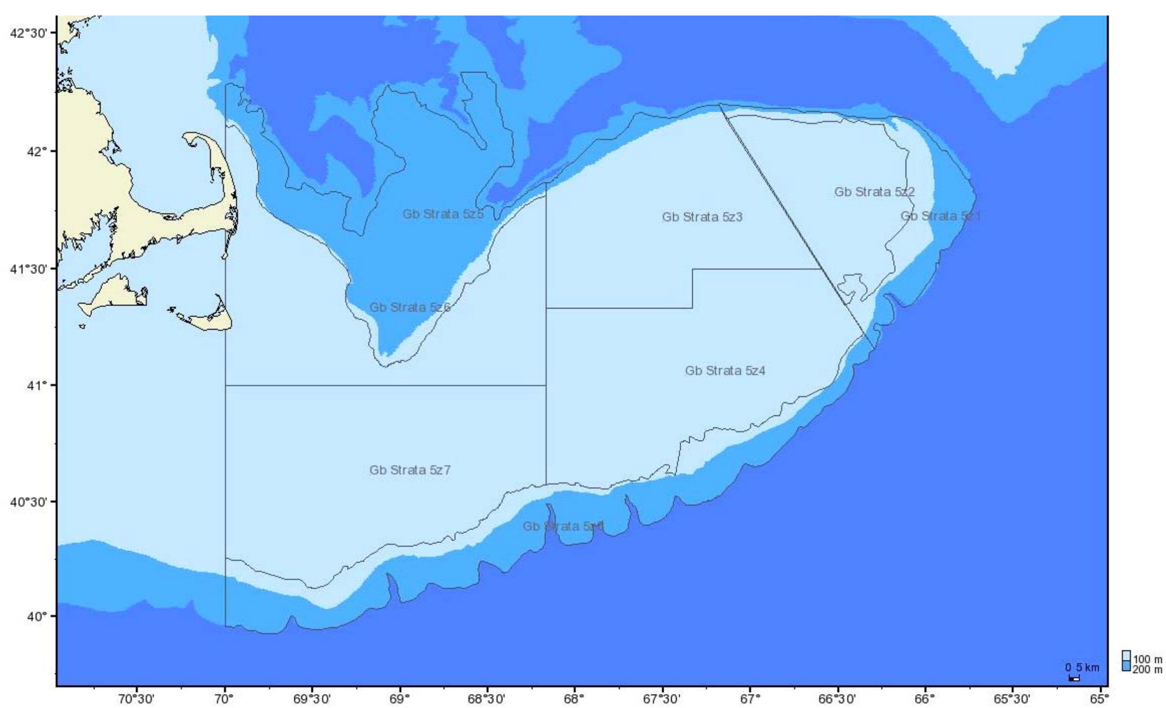


Figure 2.3.2. Sampling strata for the RV stratified random winter trawl survey on Georges Bank.

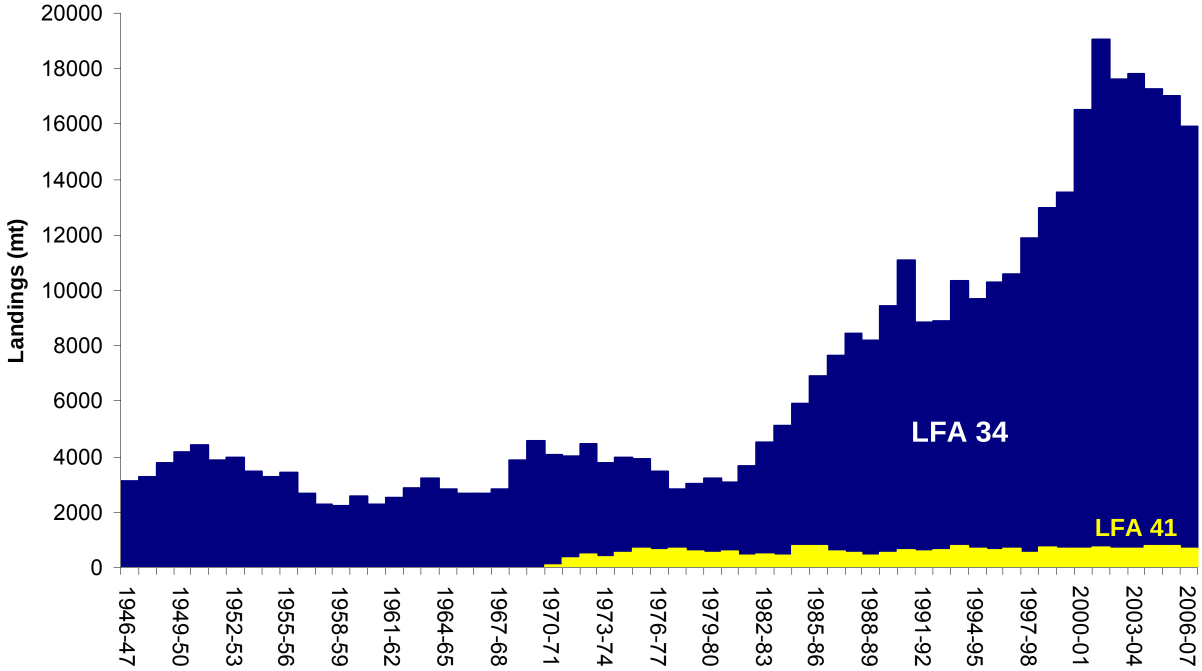


Figure 3.1.1. Lobster landings LFA 34 and 41, 1946-2007 (by fishing season LFA 34 Nov.-May, LFA 41 Oct. 16-Oct. 15).

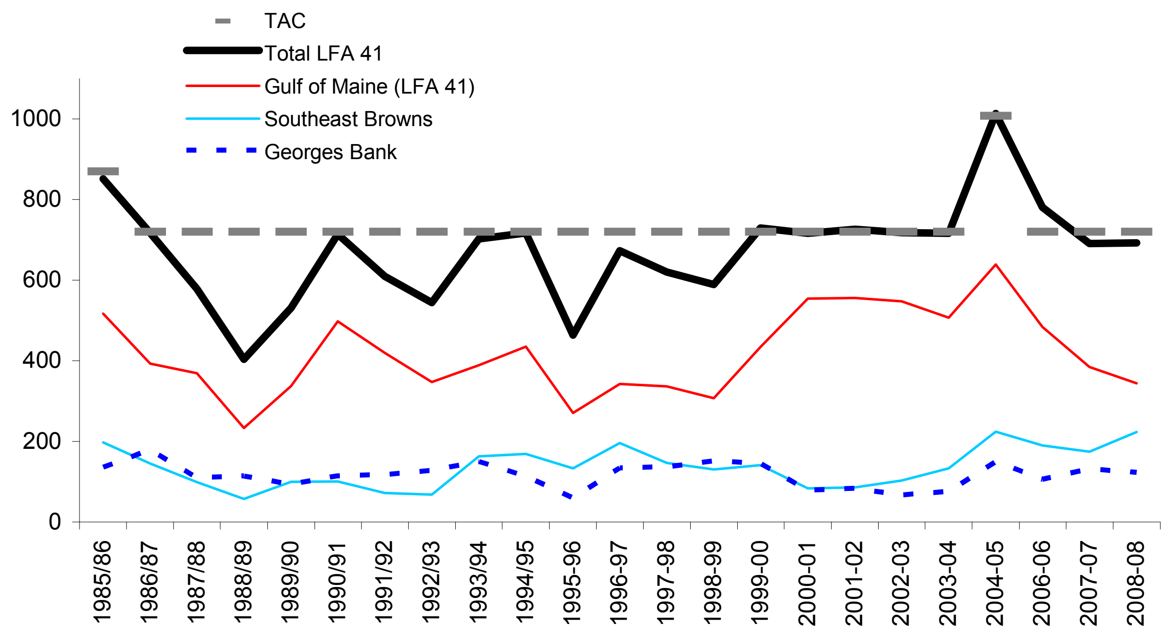


Figure 3.1.2 Total landings and landings from Gulf of Maine portion, Georges Bank and SE Browns.

Author note: The change in the quota year resulted in seven of the eight licences having an extended season during the transition in 2004-2005, and an annual TAC (Jan.-Dec.) during 2006 to 2007, while one licence continued under the Oct. 16-Oct. 15 TAC during those years. The remaining licence switched to an annual quota year in 2007. For simplicity in this report, the landings and TAC are expressed on an annual basis for 2006 and 2007 to reflect the majority of the fishery.

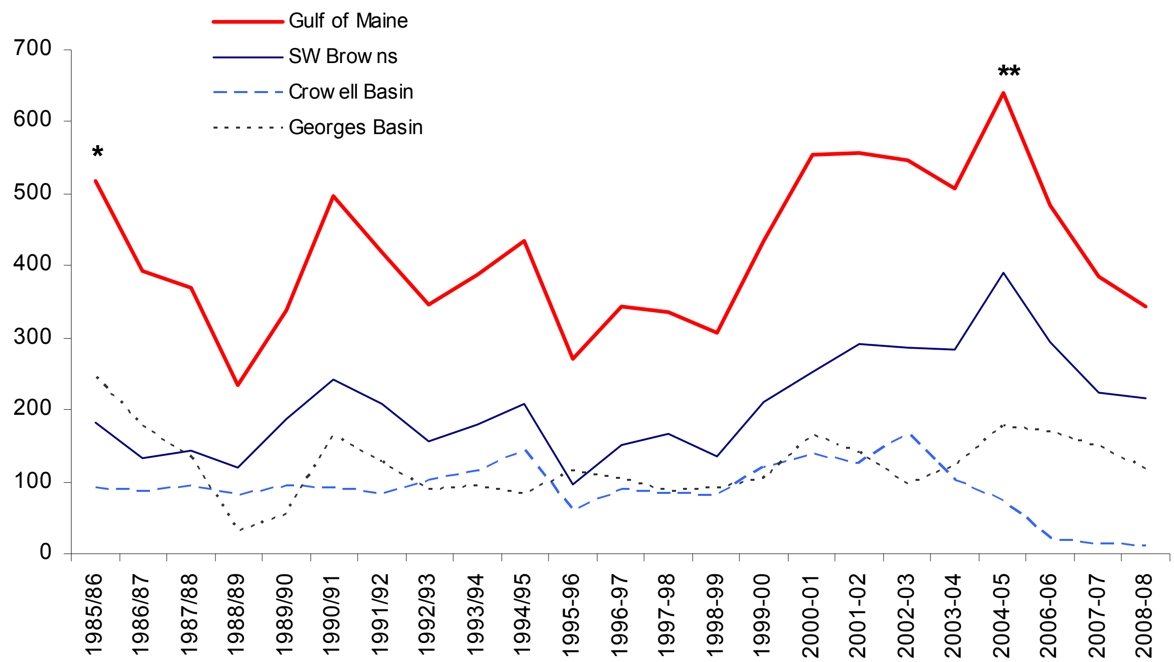
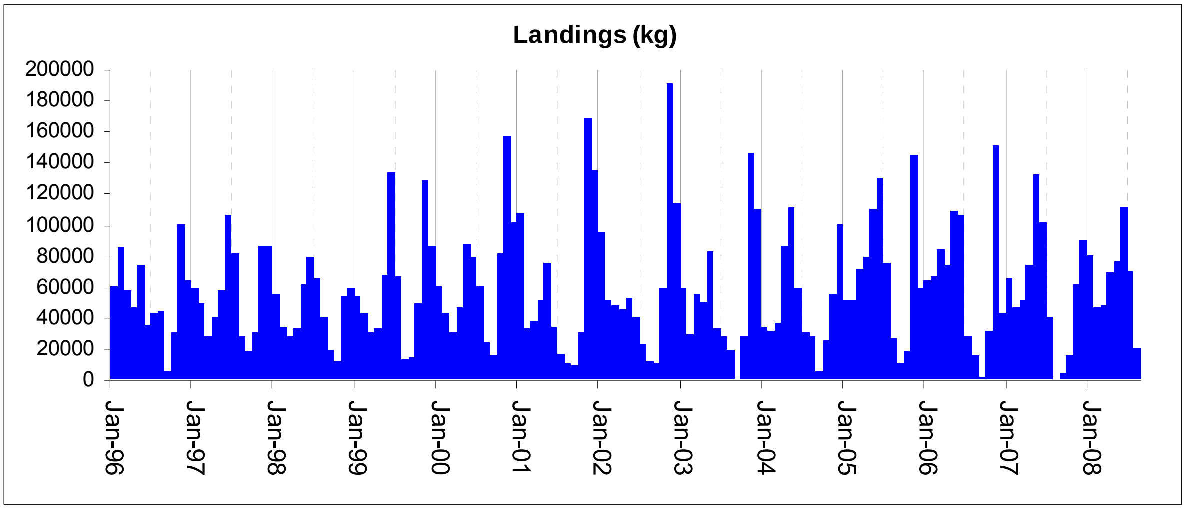
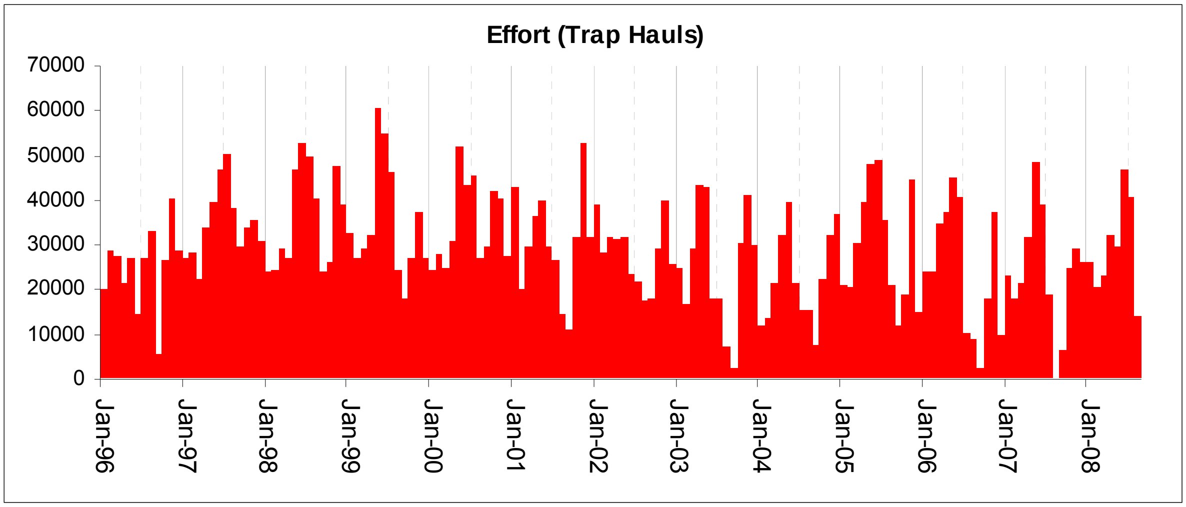


Figure 3.1.3. Landings in the Gulf of Maine portion of LFA 41.

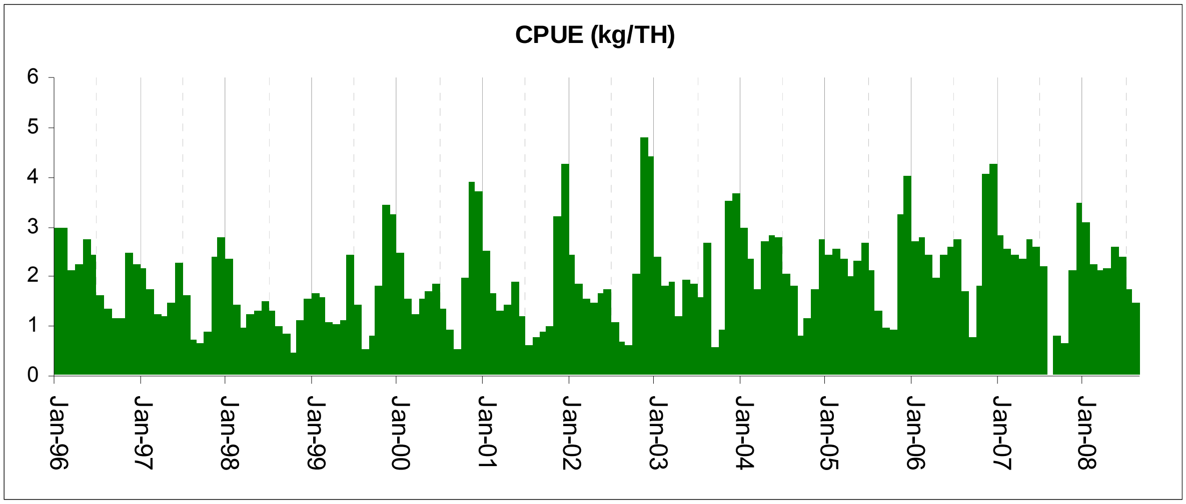
** Extended season 1985-1986.*
*** Extended season 2004-2005.*



Monthly landings (kg)



Monthly trap hauls



Monthly CPUE(Kg/TH)

Figure 3.1.4. Monthly patterns of landings, effort and CPUE Jan. 1986-Sept. 2008.

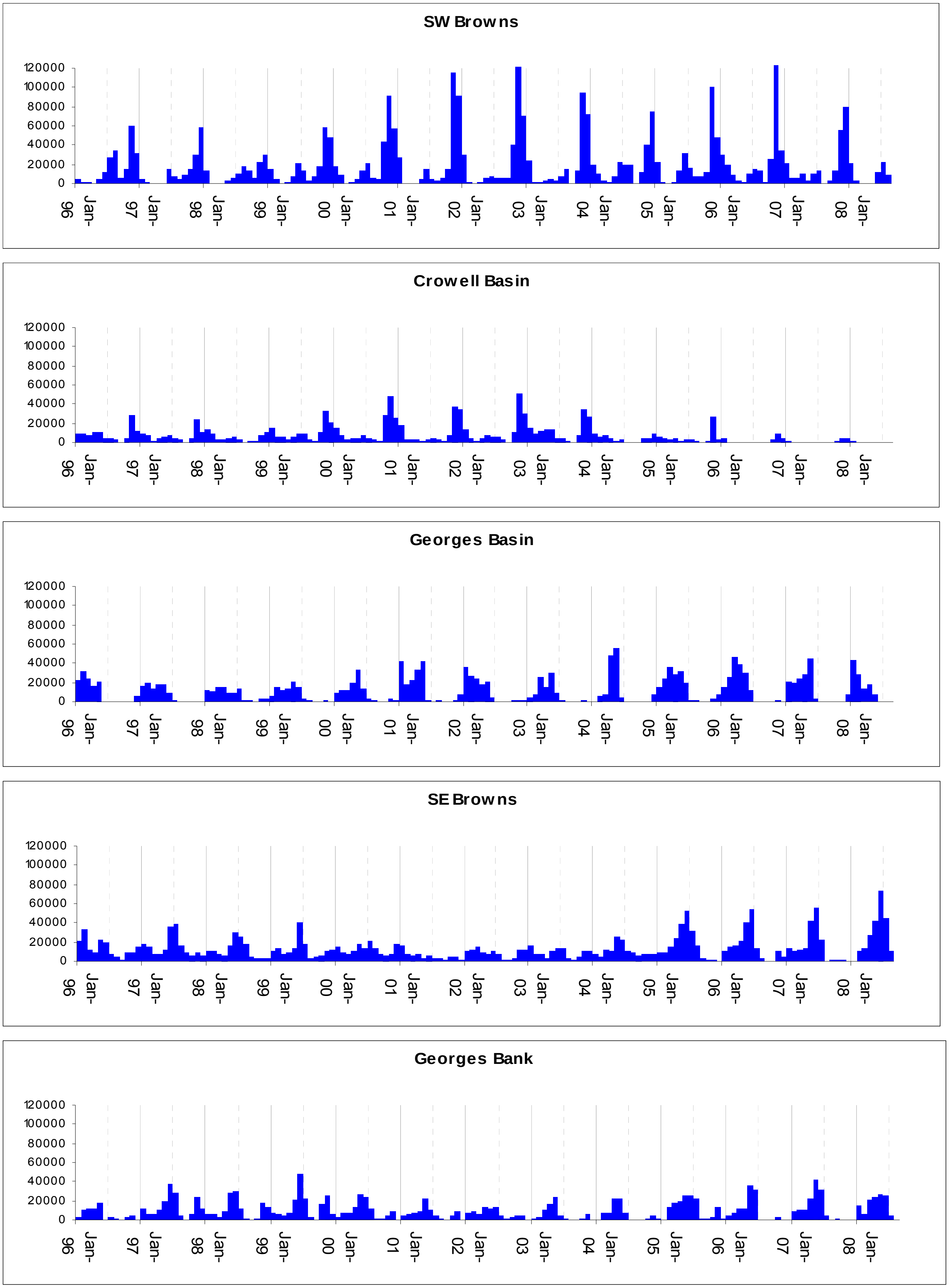


Figure 3.1.5. Monthly lobster landings (kgs) by LFA 41 subareas Jan. 1986-Sept. 2008.

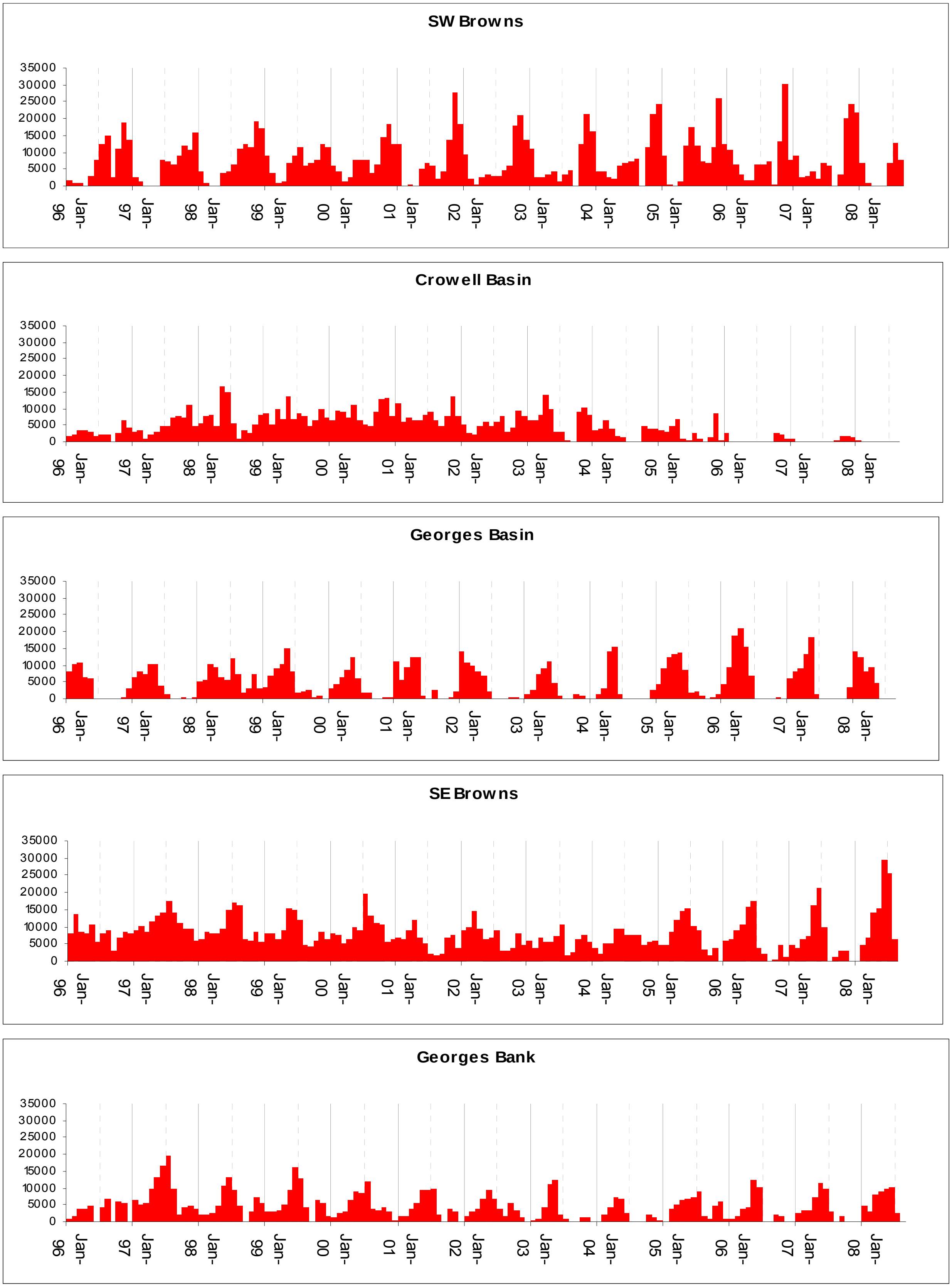
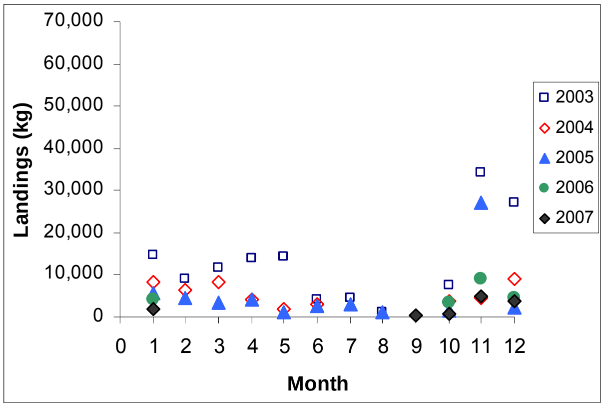
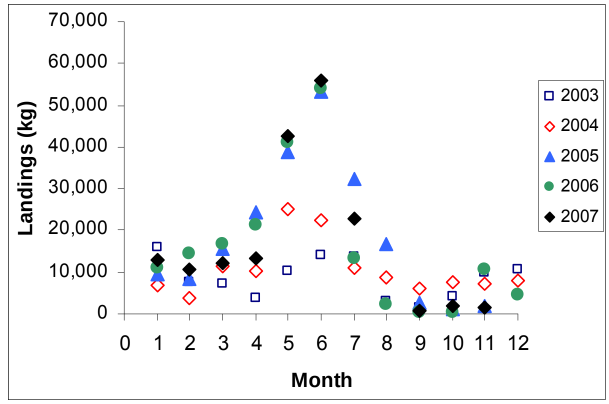


Figure 3.1.6. Monthly lobster effort (trap hauls) LFA 41 subareas Jan. 1986-Sept. 2008.

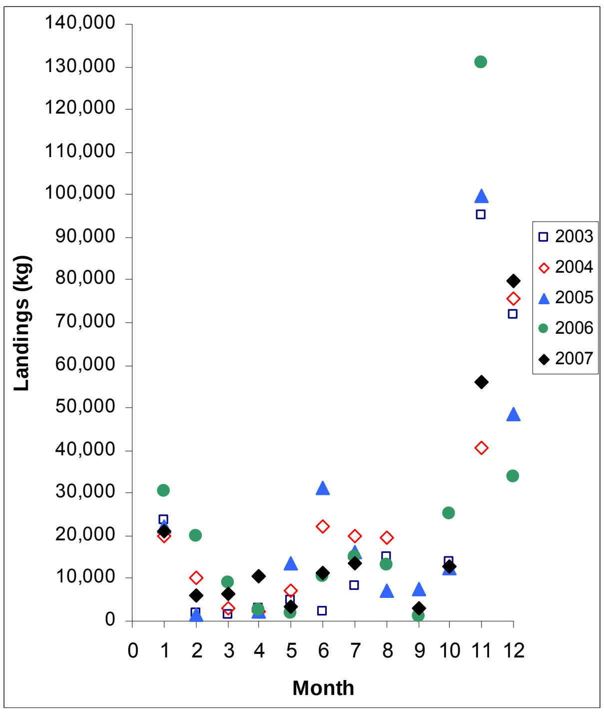
Figure 3.1.7. Monthly lobster CPUE (kg/trap haul) by LFA 41 subareas Jan. 1986-Sept. 2008.



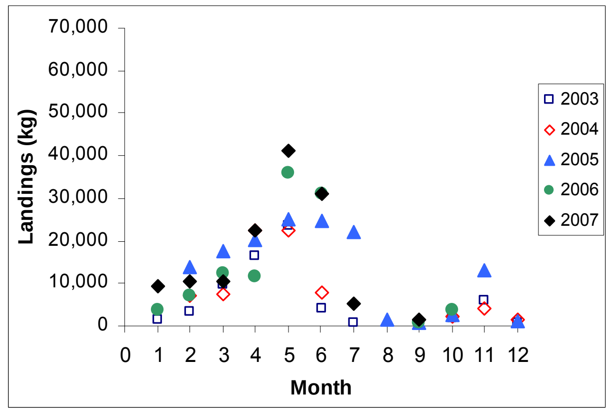
Crowell Basin



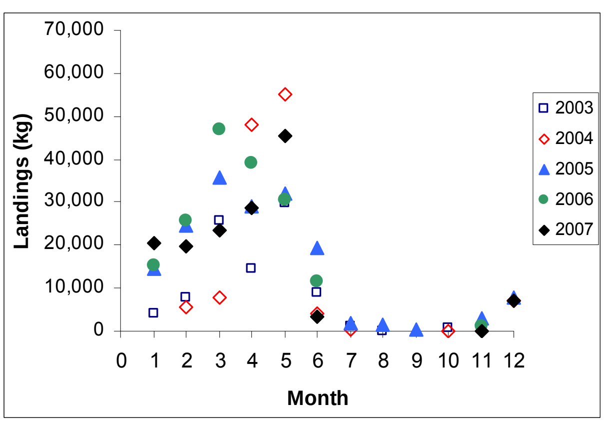
SE Browns



SW Browns



Georges Bank



Georges Basin

Figure 3.1.8. Monthly landings by area 2003-2007.

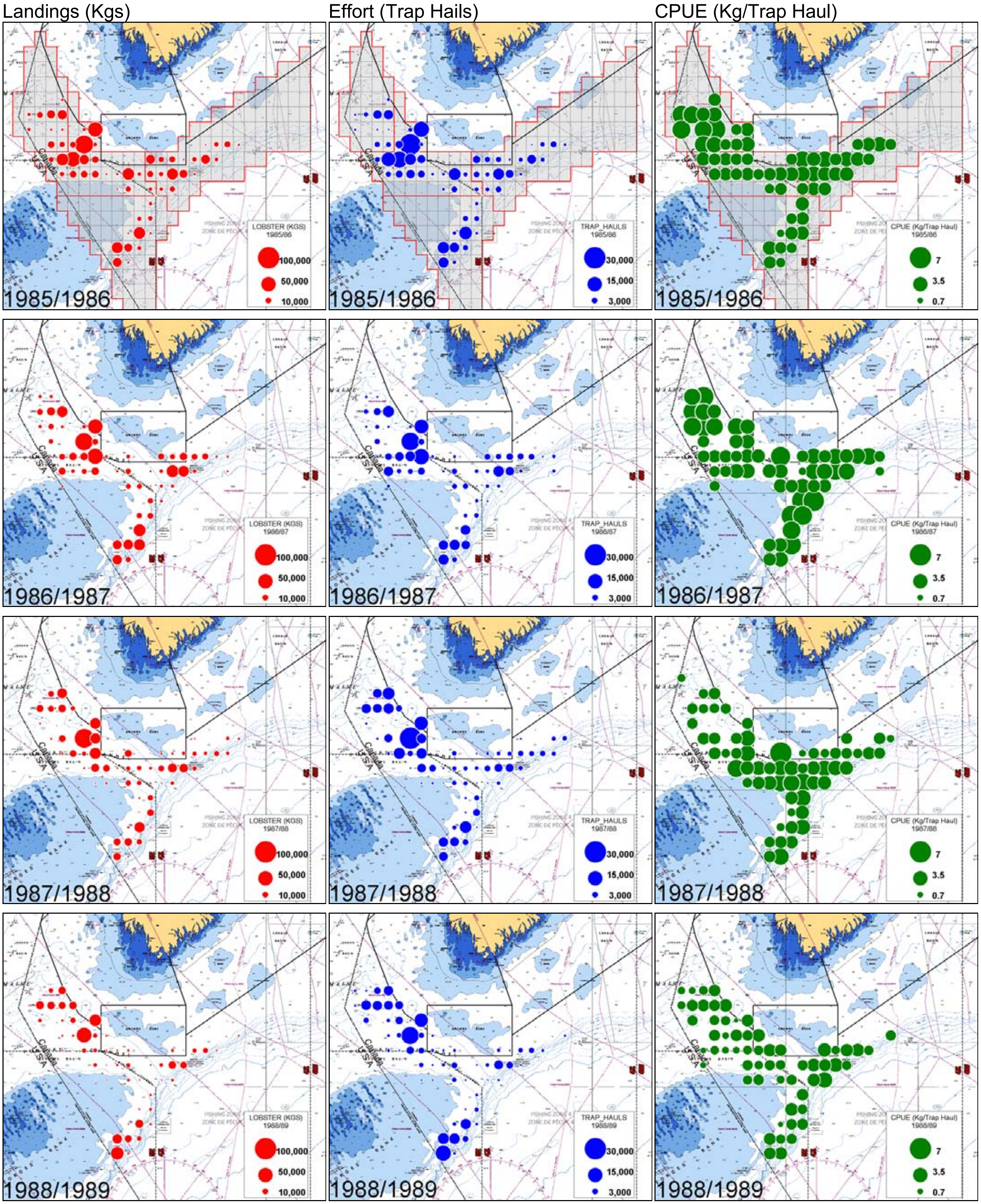


Figure 3.1.9 Graduated lobster landings, effort and CPUE by 10 minute grids 1985/86 to 1988/89 (Oct. 16 to Oct. 15).

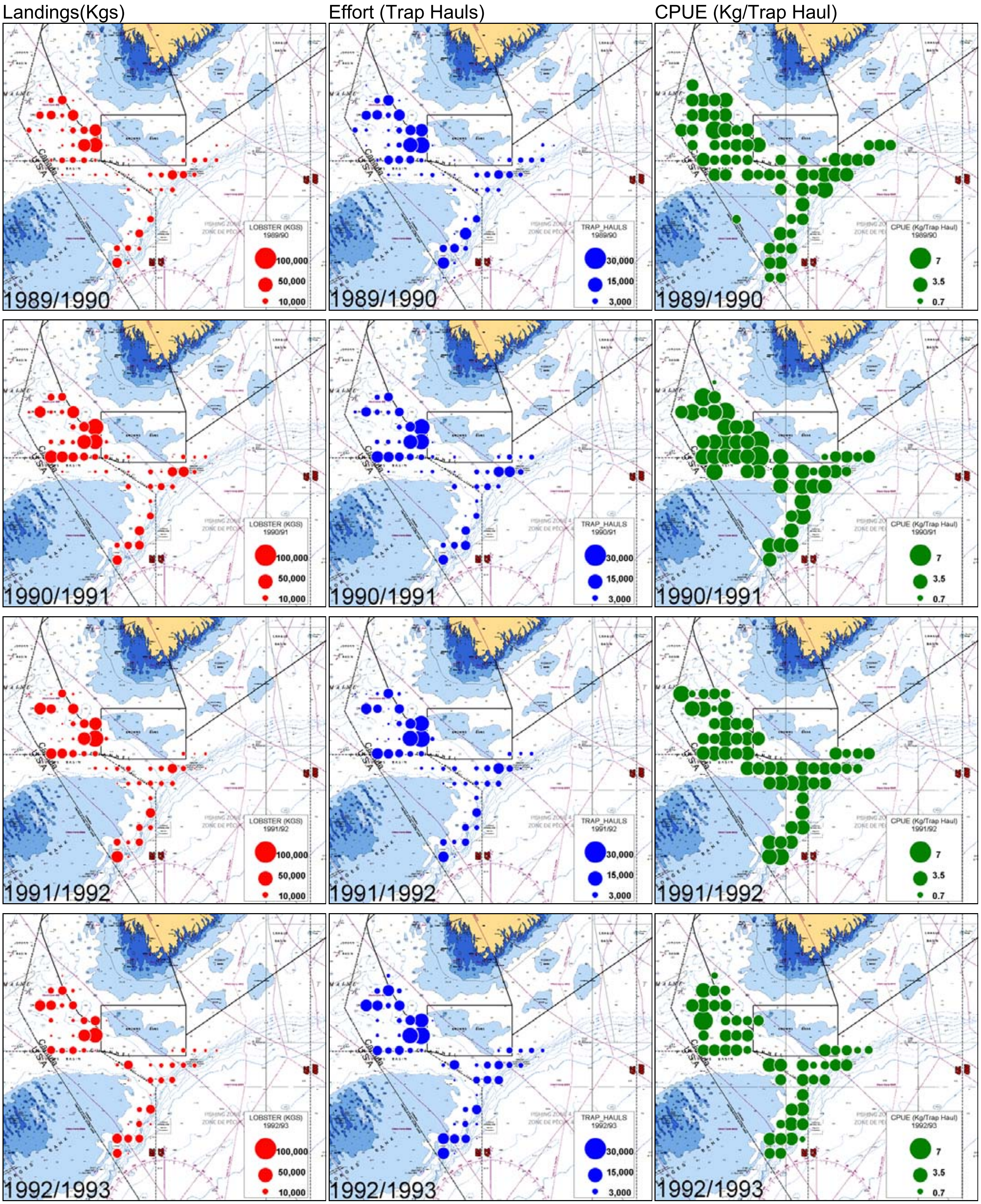


Figure 3.1.9 cont'd. Graduated lobster landings, effort and CPUE by 10 minute grids 1989/90 to 1992/93 (Oct. 16 to Oct 15).

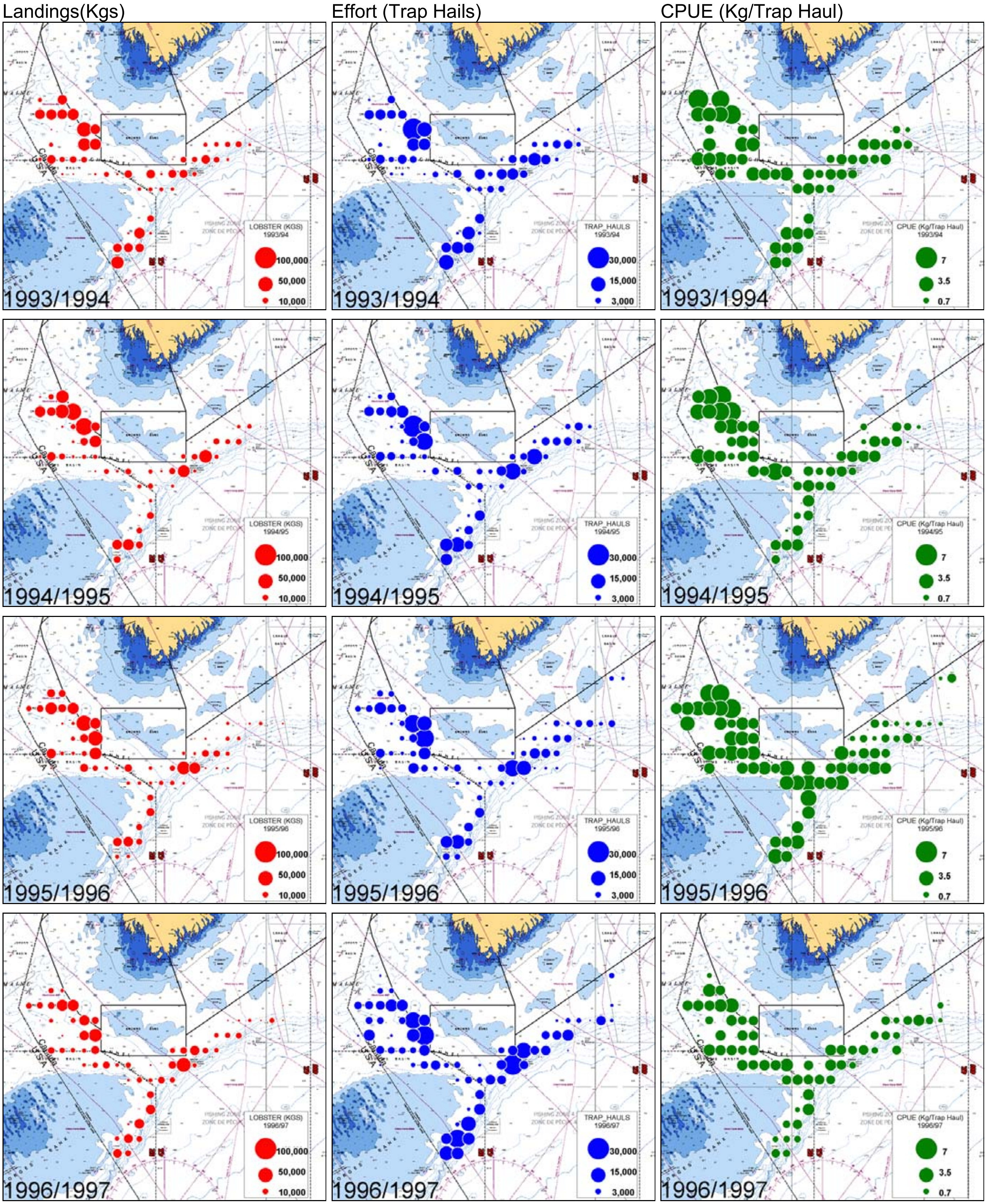


Figure 3.1.9 cont'd. Graduated lobster landings, effort and CPUE by 10 min grids 1993/94 to 1996/97 (Oct. 16 to Oct. 15).

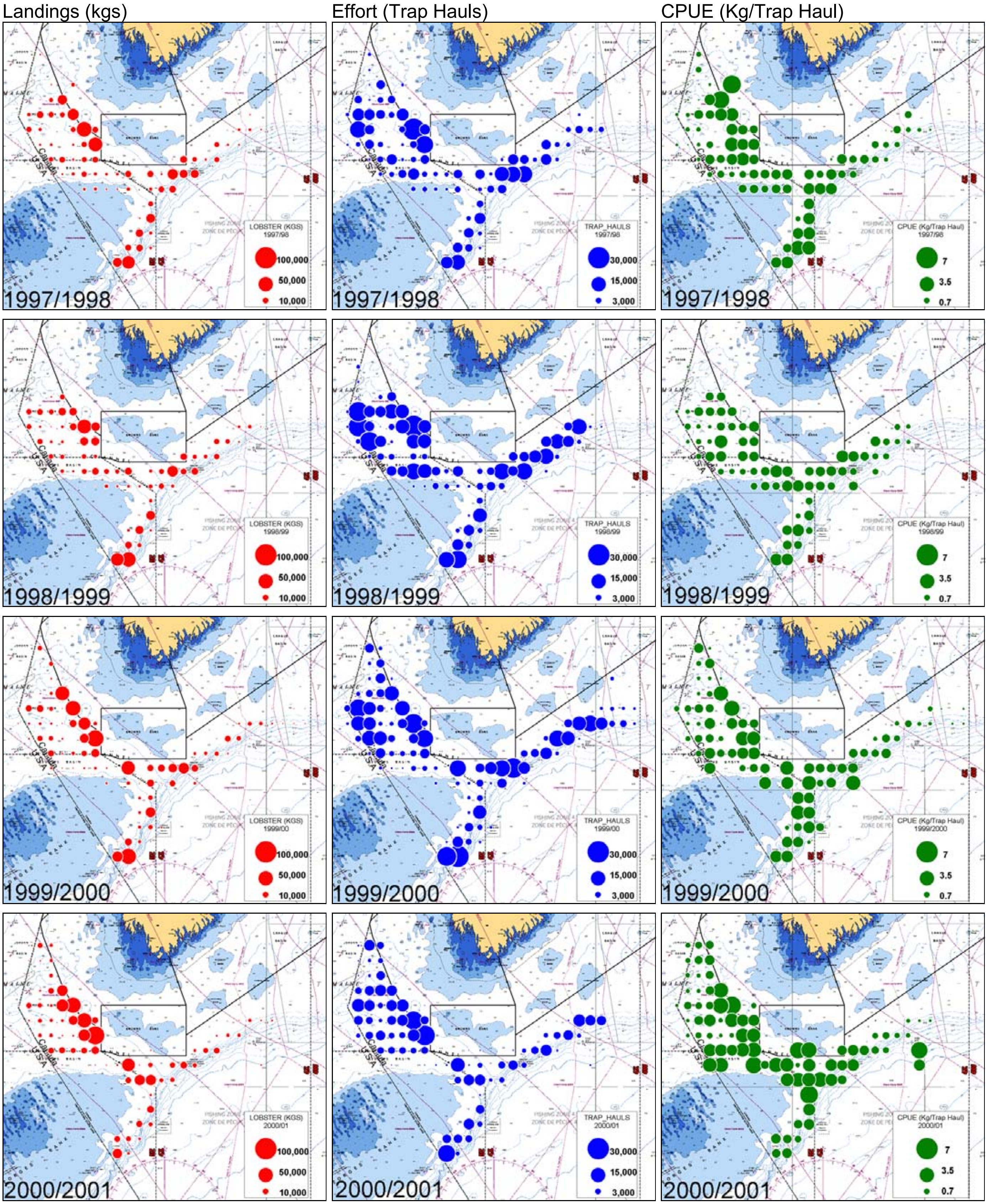


Figure 3.1.9 cont'd. Graduated lobster landings, effort and CPUE by 10 minute grids 1997/99 to 2000/01 (Oct. 16 to Oct 15).

Landings (Kgs) Effort (Trap Hauls) CPUE (Kg/Trap Haul)

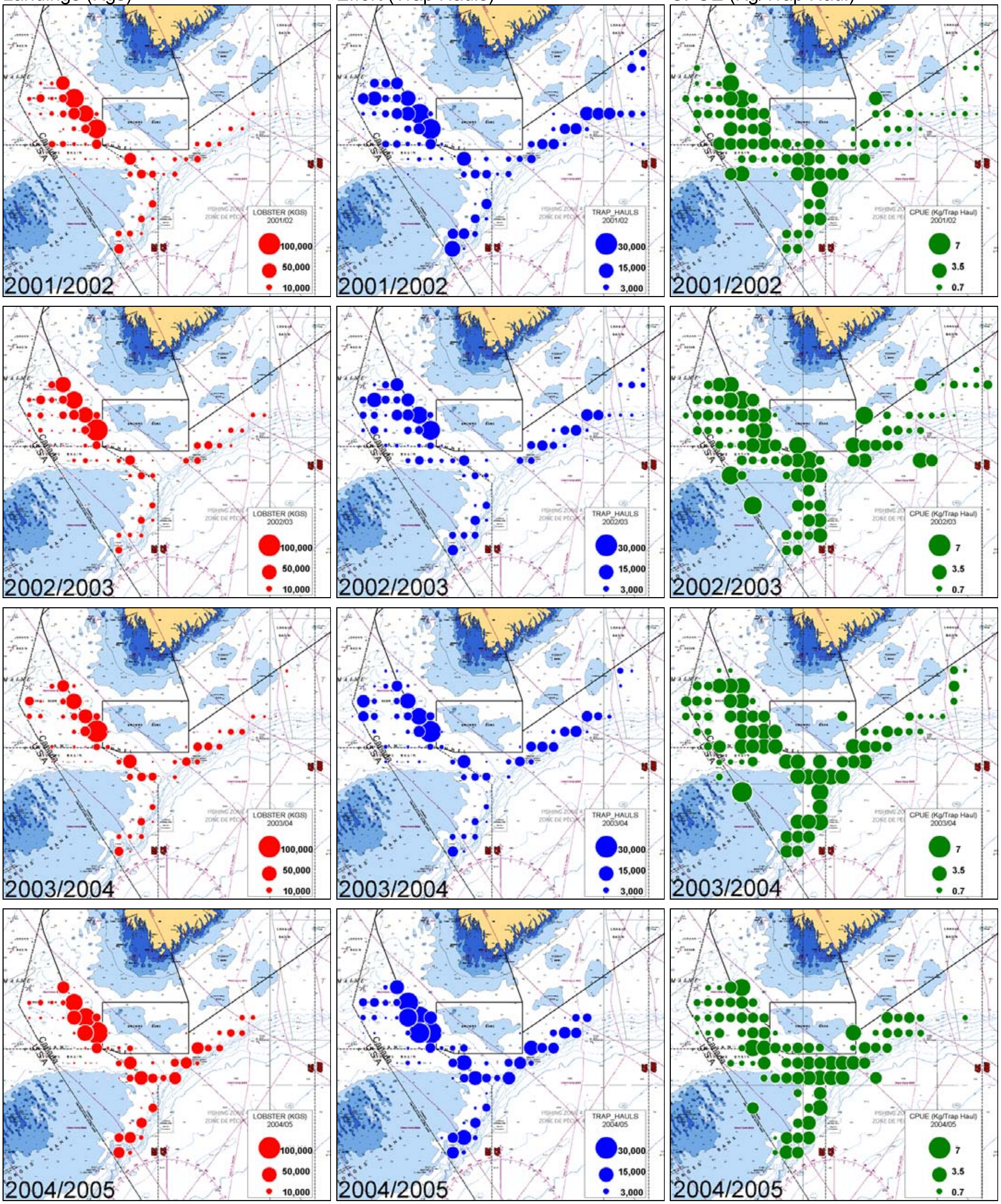


*Figure 3.1.9 cont'd. Graduated lobster landings, effort and CPUE by 10 minute grids 2001/02 to 2004/05. *Note: 2004/2005 season is from Oct. 16, 2004 to Dec. 31, 2005.*

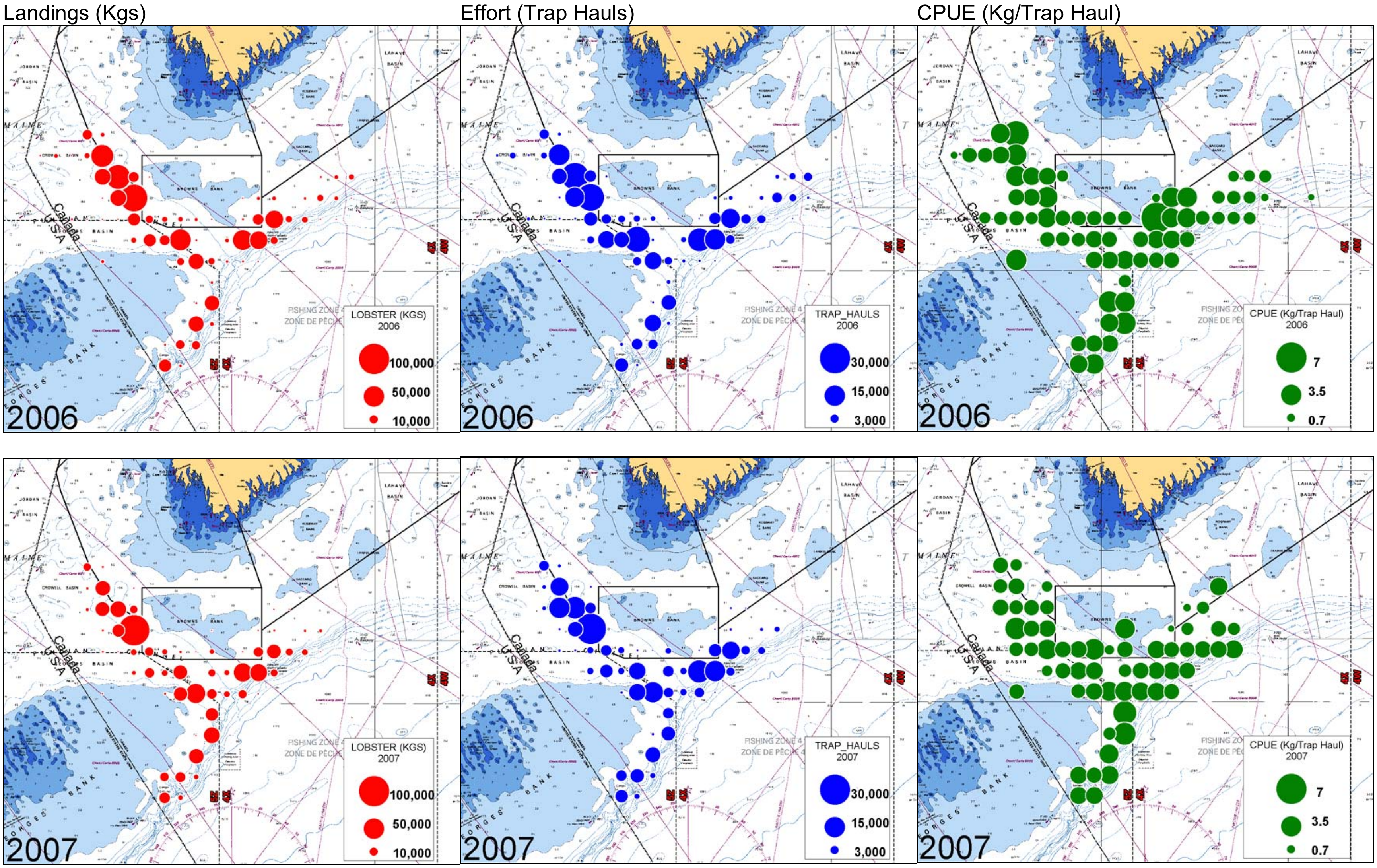


Figure 3.1.9 cont'd. Graduated lobster landings, effort and CPUE by 10 minute grids 2006 and 2007 (Jan. 1 to Dec. 31).

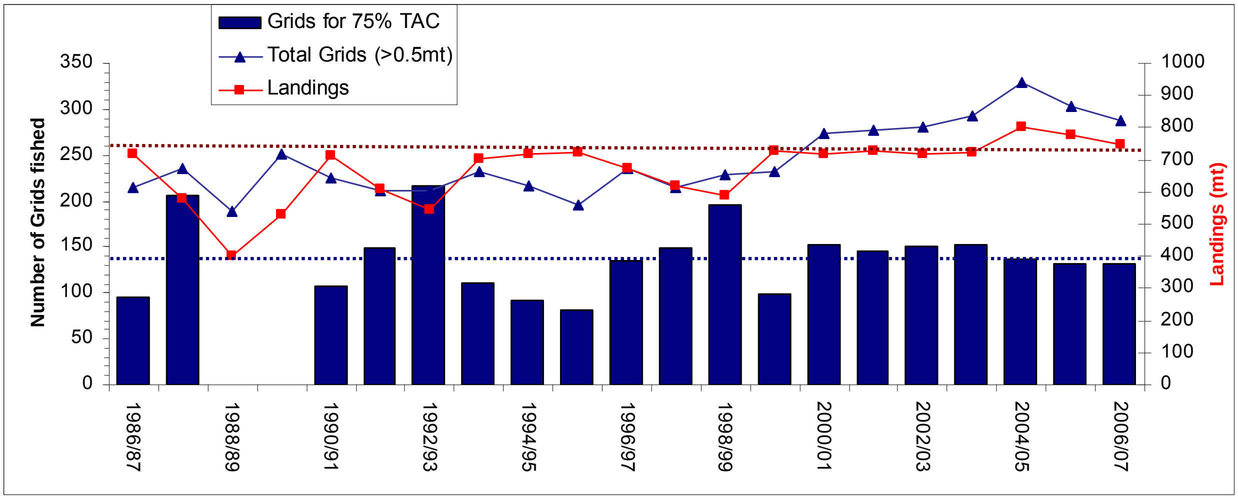


Figure 3.1.10. Total number of grids fished, the number of grids fished to catch 75% of TAC (mean blue dot line) and landings (TAC red dot line).

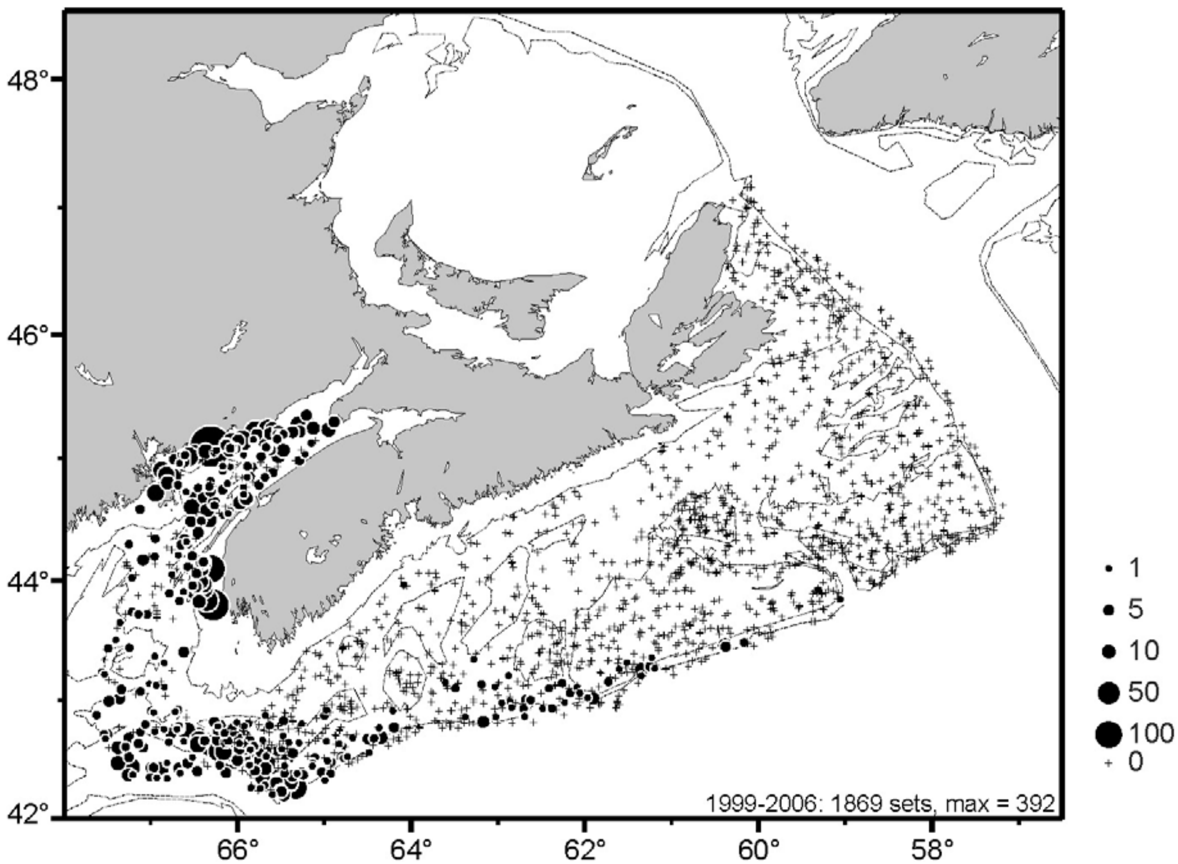


Figure 3.2.1. Number of American lobsters per tow from the 1999-2006 RV stratified random summer trawl survey.

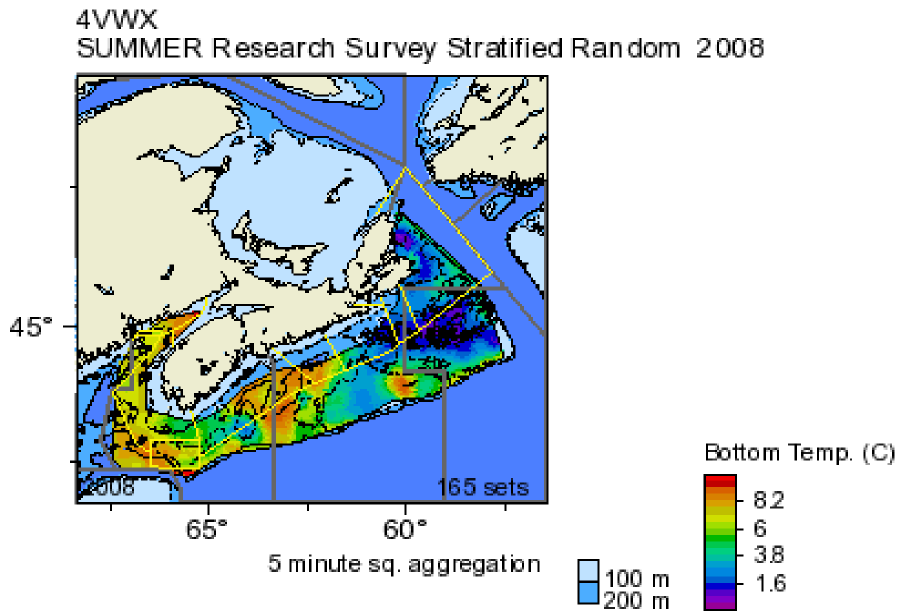
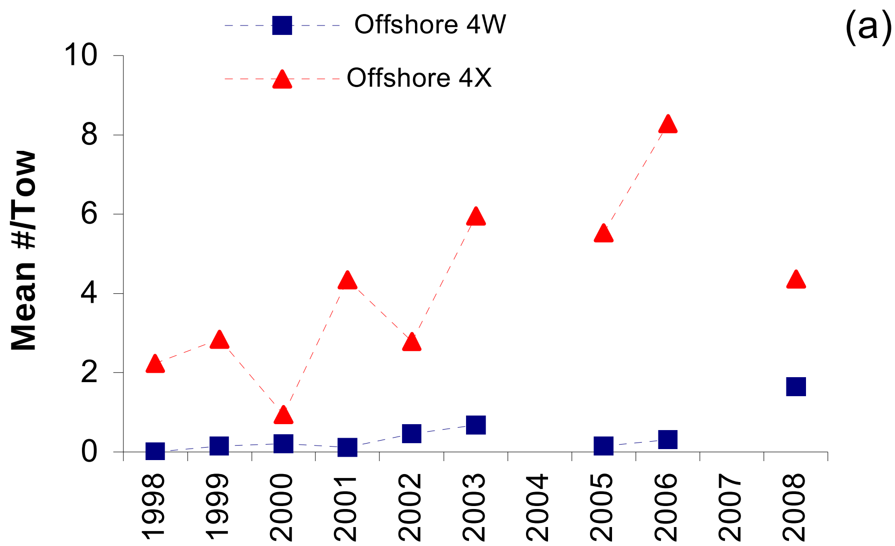


Figure 3.2.2. Bottom water temperatures during the 2008 RV stratified random summer trawl survey.



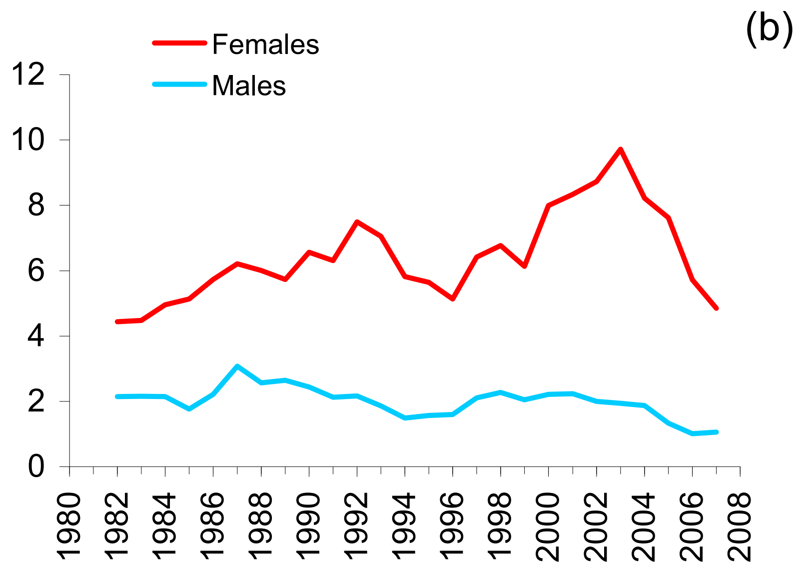


Figure 3.2.3. Mean numbers per tow from RV stratified random summer trawl survey. (a) Canadian survey: overall mean for LFA 41 portion of 4X and 4W; (b) USA NMFS survey: abundance estimates from fall bottom trawl survey for USA side of Georges Bank (1982-2007).

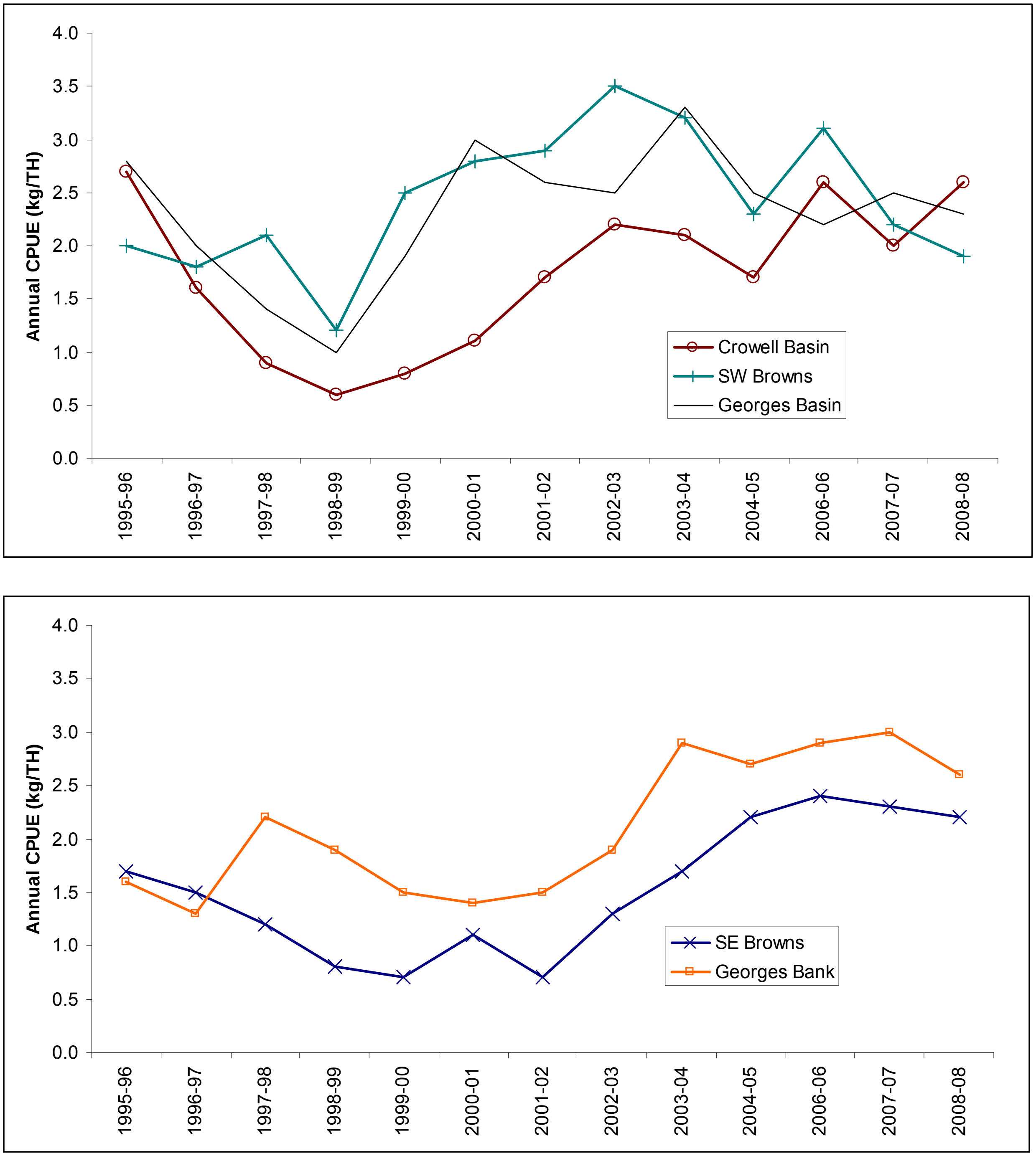


Figure 3.3.1. Annual CPUE (kg/TH) by area. CPUE is total landings by total effort.

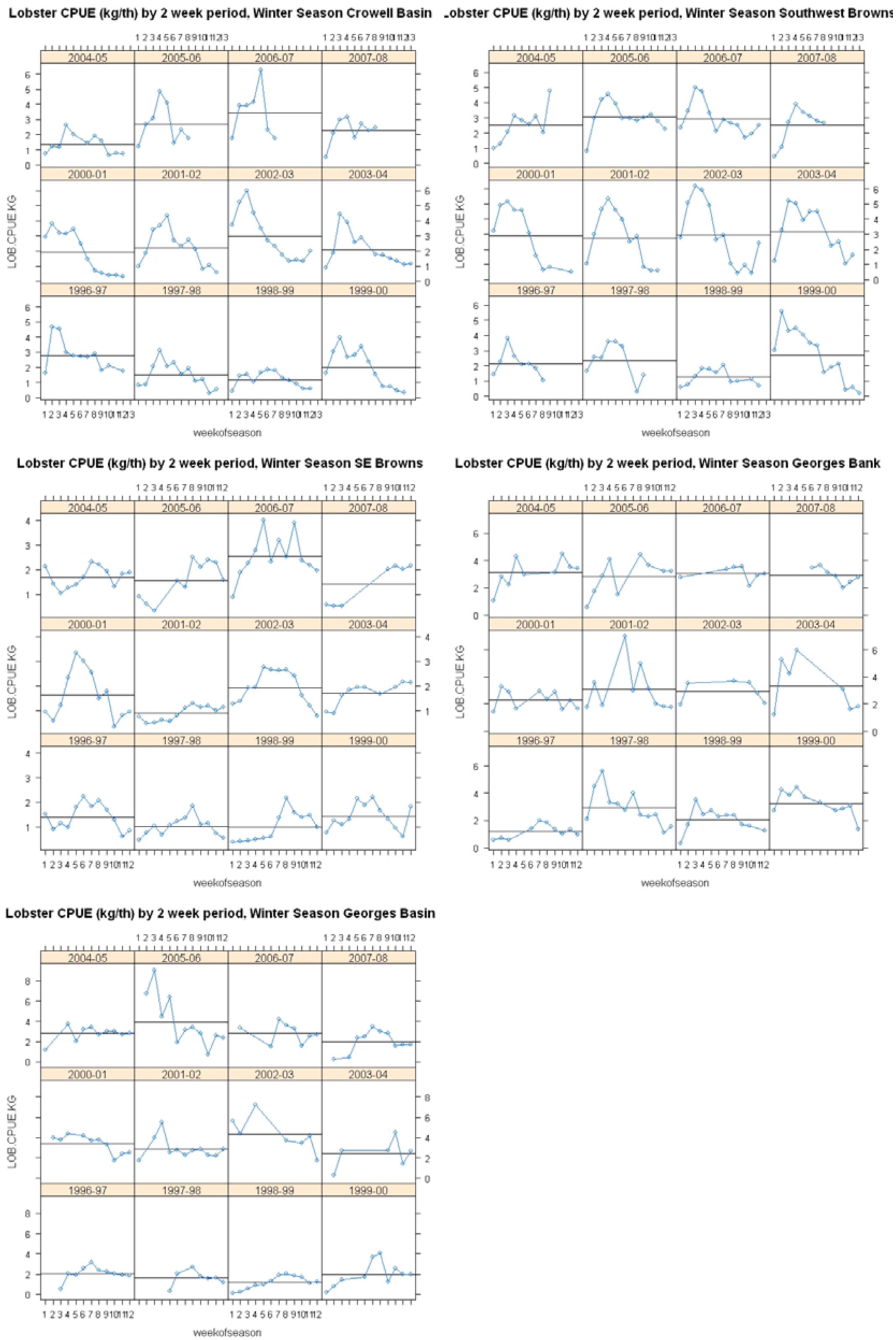


Figure 3.4.1. Total biweekly catch rates (kg/trap haul) for each area during the winter period. Each panel indicates a fishing season (for winter: October to April). The horizontal line in each panel represents the mean catch rate for that season.

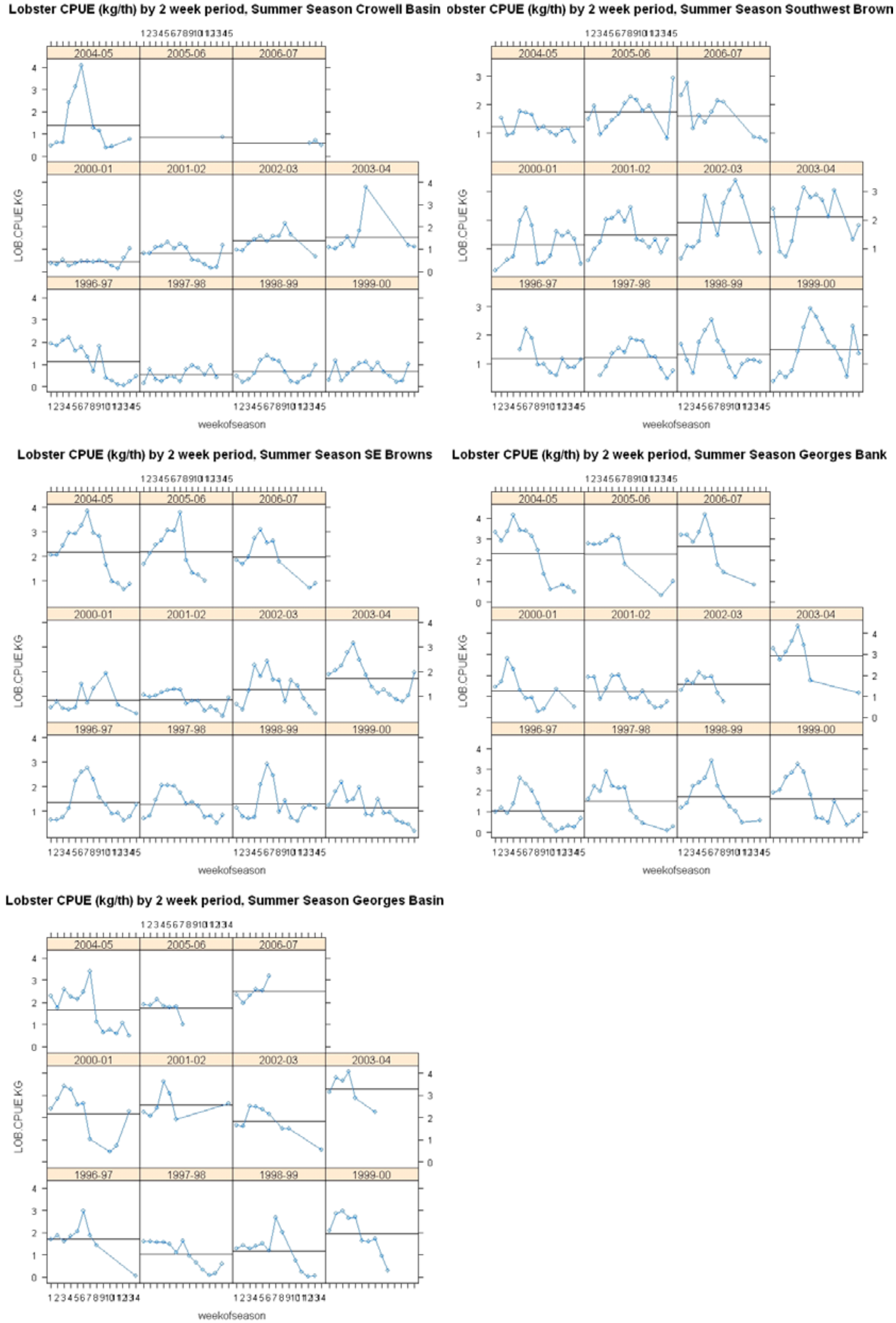
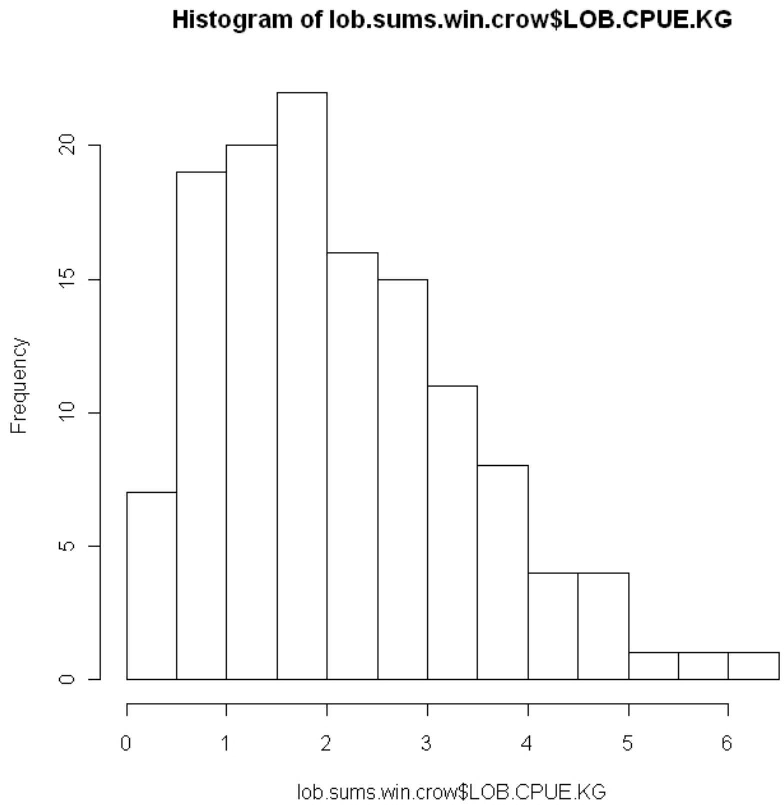


Figure 3.4.2. Total biweekly catch rates (kg/trap haul) for each area during the summer period. Each panel indicates a fishing season (for summer: April to October; 1997-98 would represent summer 1998). The horizontal line in each panel represents the mean catch rate for that season.



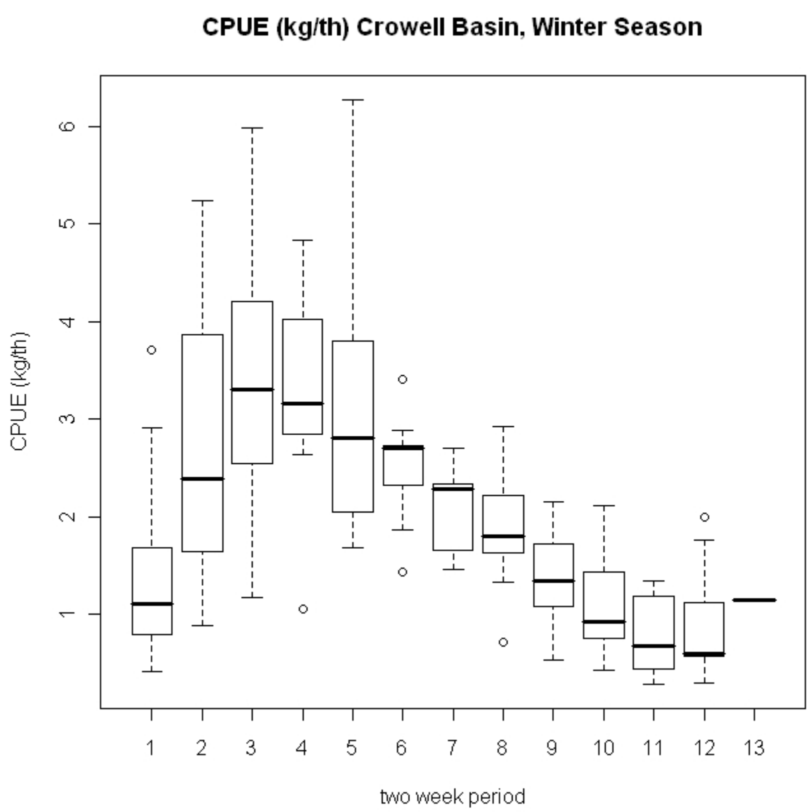
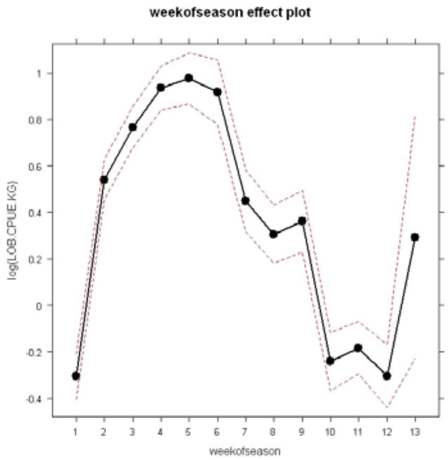


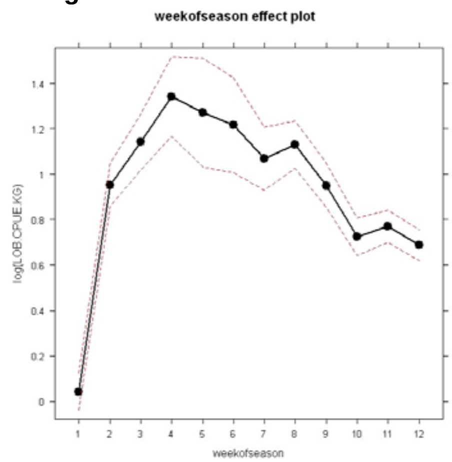
Figure 3.4.3. Example histogram and box-plot of biweekly CPUE for Crowell Basin, winter (all fishing seasons combined).

.
Winter

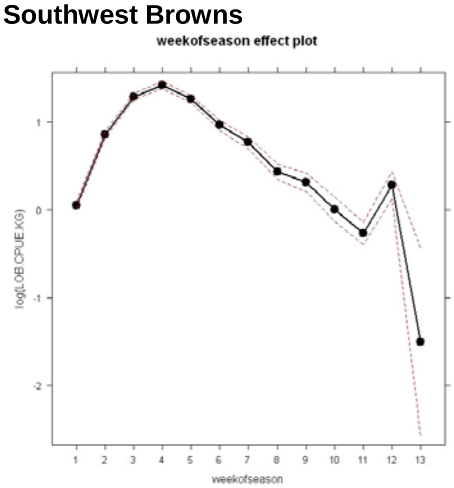
Crowell Basin



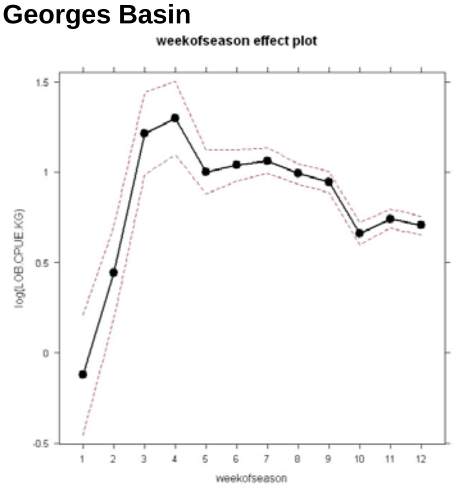
Georges Bank



Southwest Browns



Georges Basin



Southeast Browns

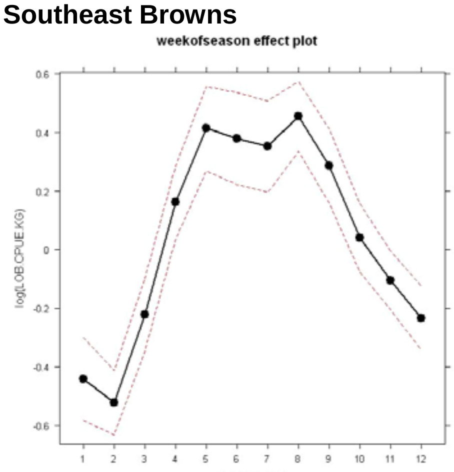
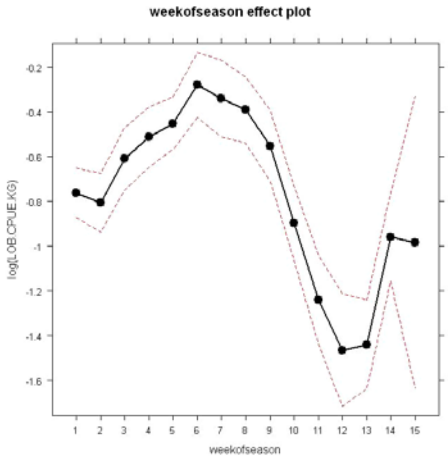


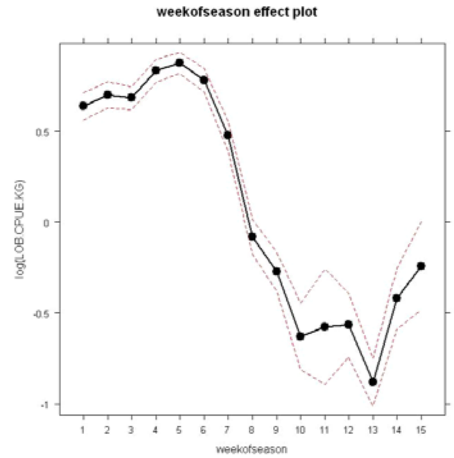
Figure 3.4.4. Effects plots of fitted values for the main effect of 2 week period for each area, winter period. The dashed lines indicate 95% confidence levels.

Summer

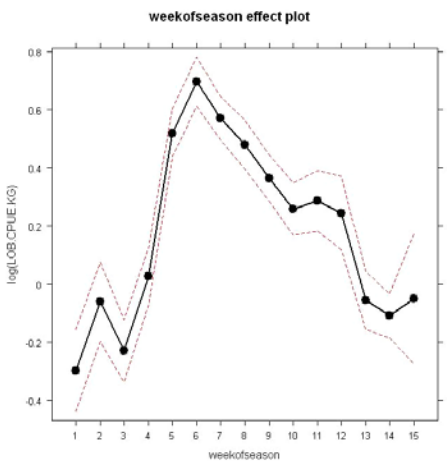
Crowell Basin



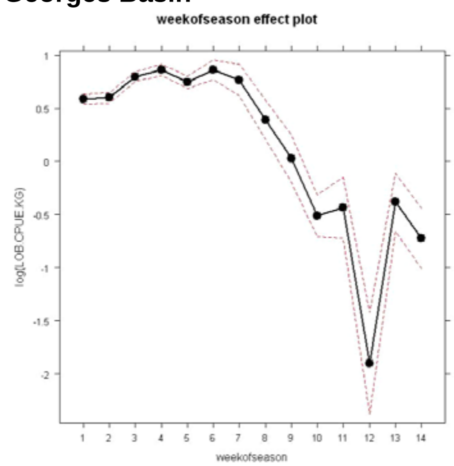
Georges Bank



Southwest Browns



Georges Basin



Southeast Browns

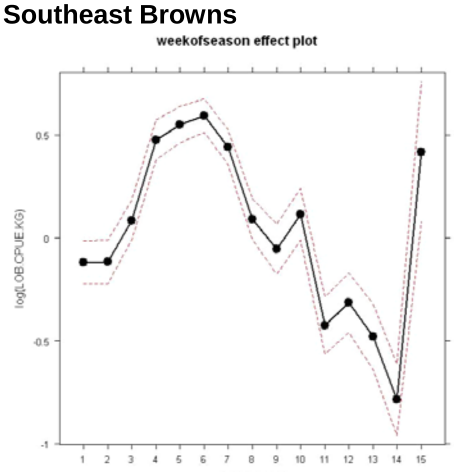
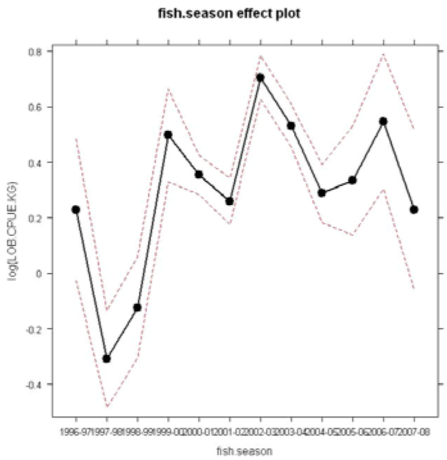


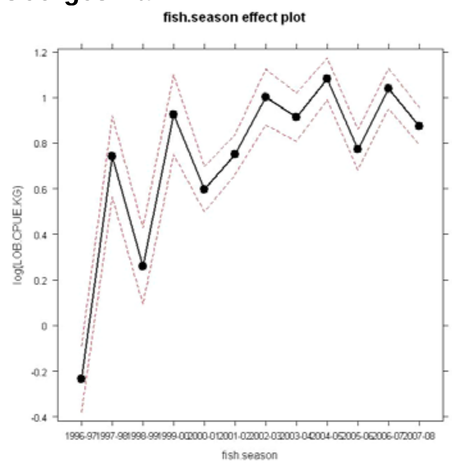
Figure 3.4.5. Effects plots of fitted values for the main effect of 2 week period for each area, summer period. The dashed lines indicate 95% confidence levels.

Winter

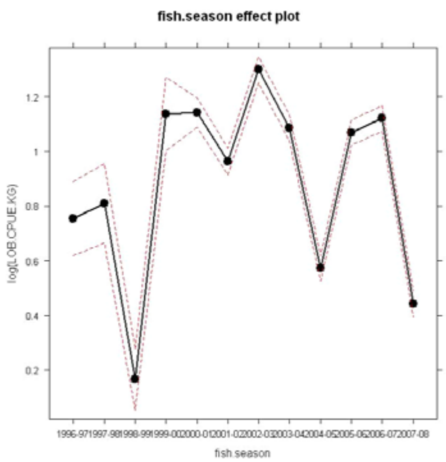
Crowell Basin



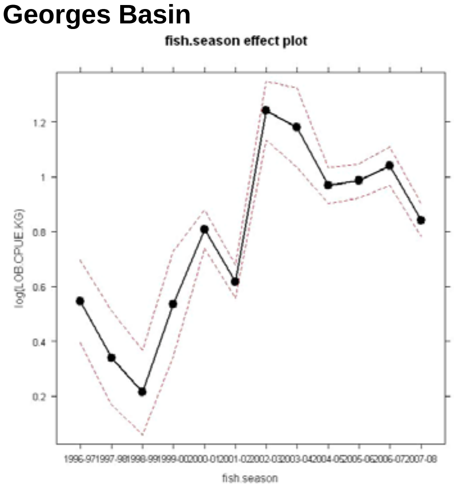
Georges Bank



Southwest Browns



Georges Basin



Southeast Browns

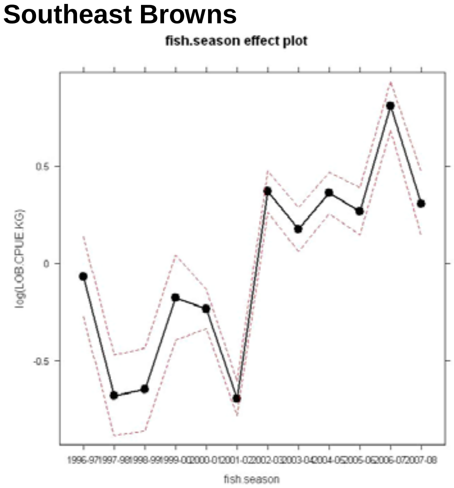
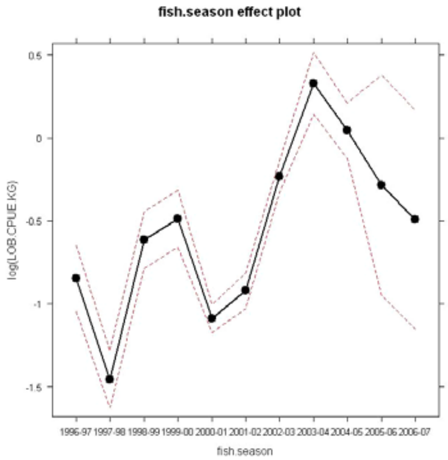


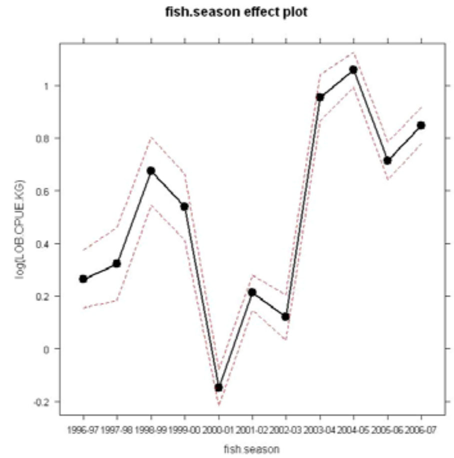
Figure 3.4.6. Effects plots of fitted values for the main effect of fishing season for each area, winter period. The dashed lines indicate 95% confidence levels.

Summer

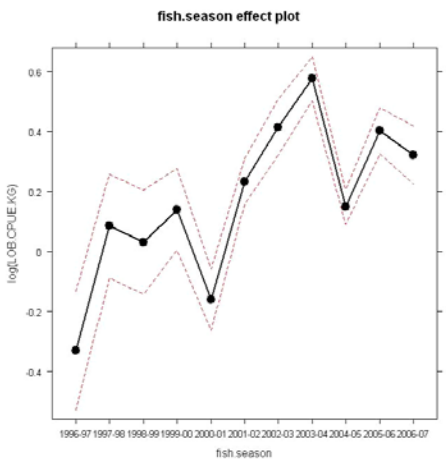
Crowell Basin



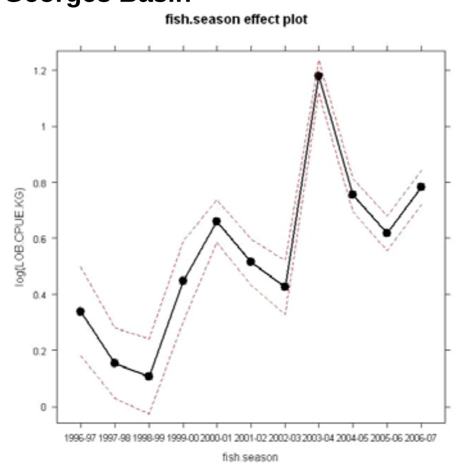
Georges Bank



Southwest Browns



Georges Basin



Southeast Browns

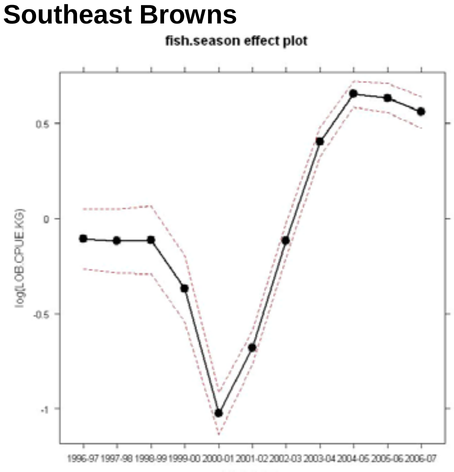


Figure 3.4.7. Effects plots of fitted values for the main effect of fishing season for each area, summer period. The dashed lines indicate 95% confidence levels.

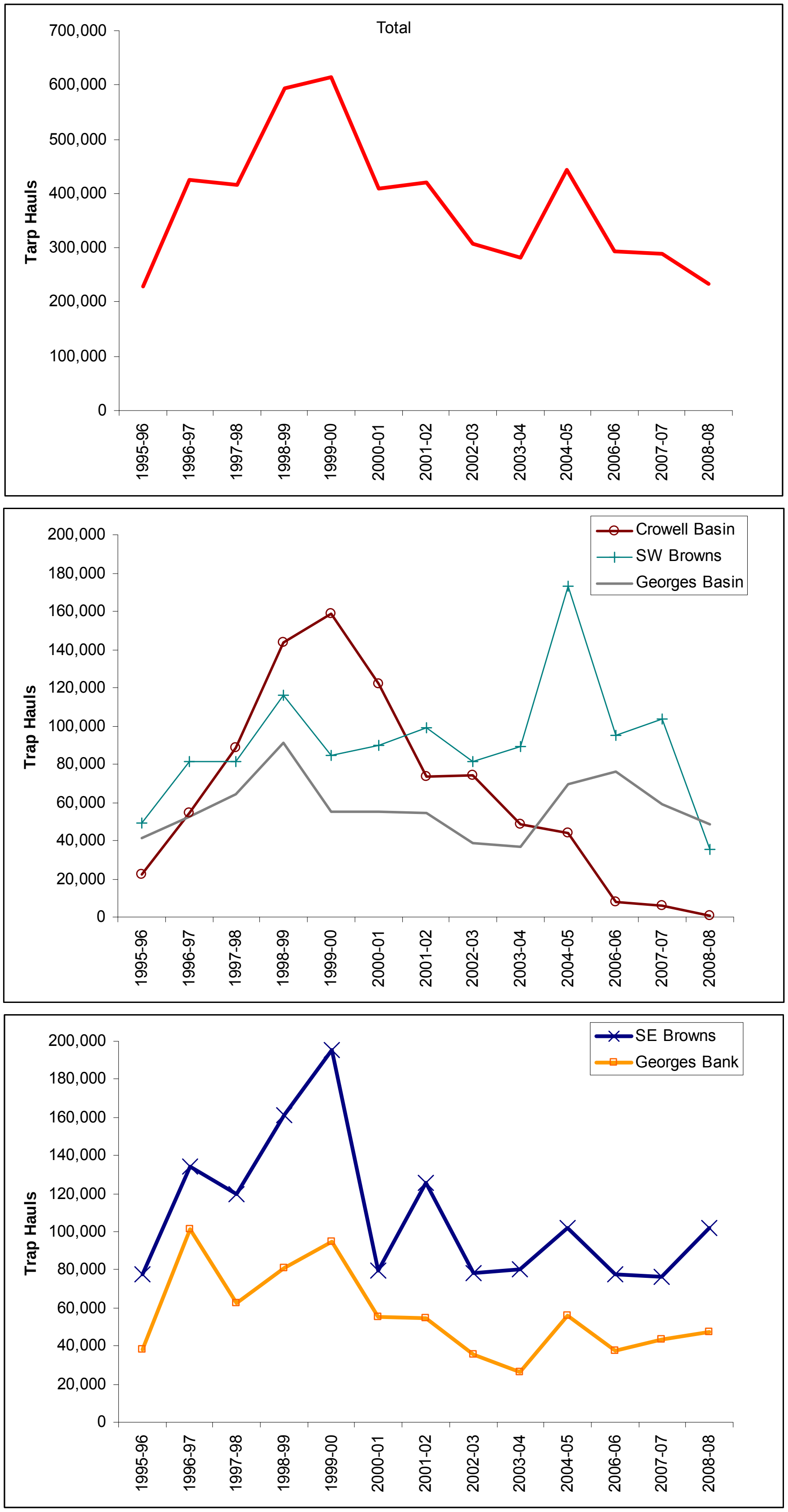


Figure 4.1.1. Annual trap hauls by area based on logbooks.

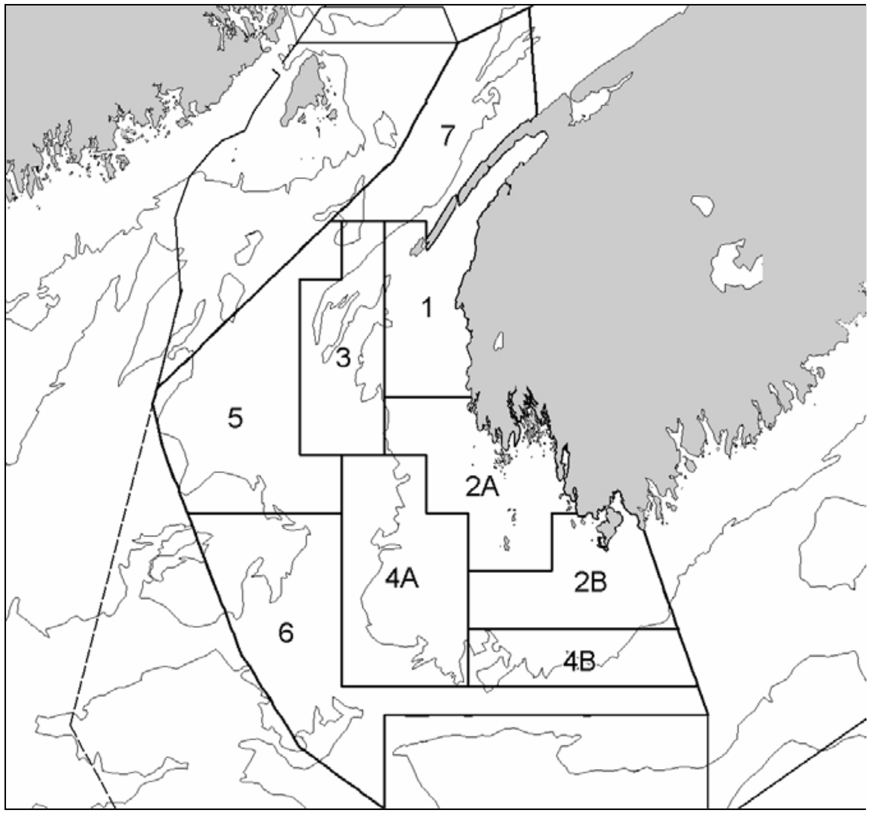


Figure 4.1.2 Grid groups from LFA 34 log book grids.

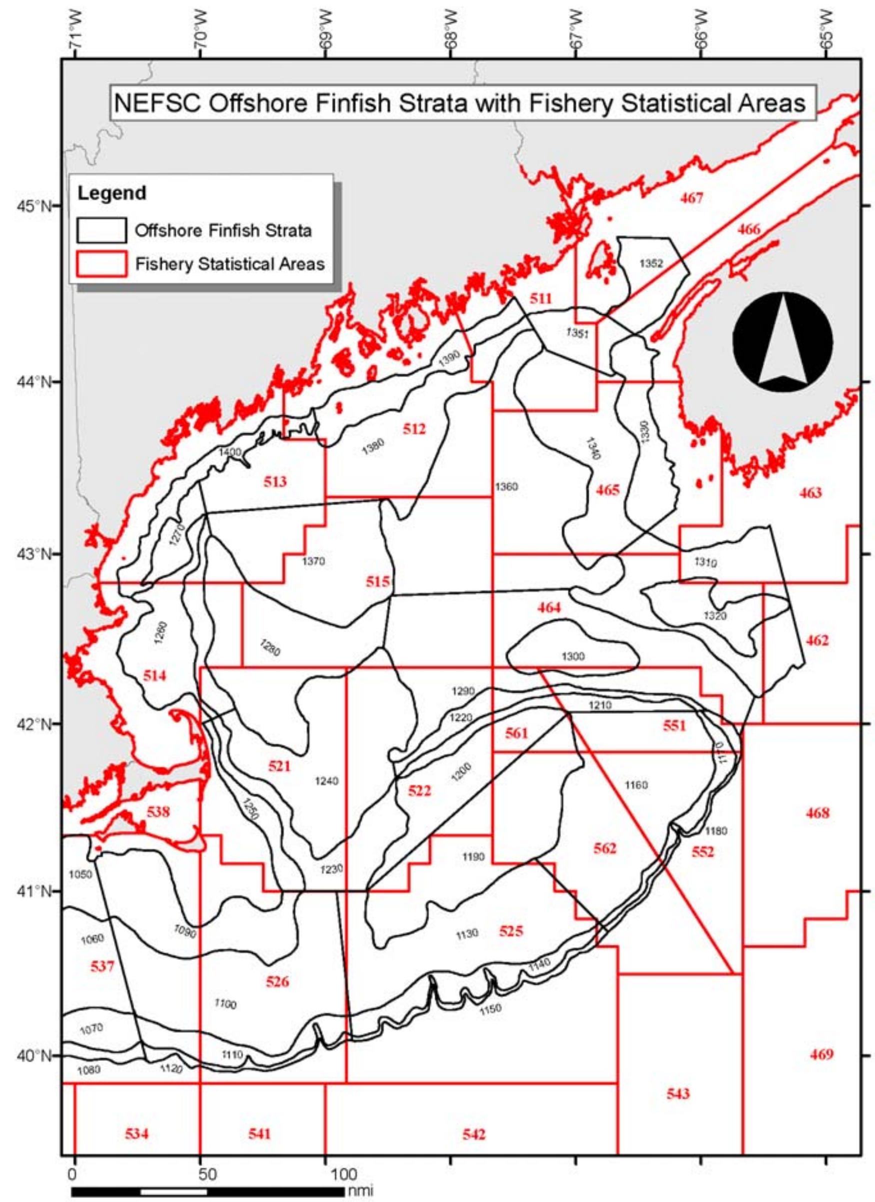


Figure 4.1.3. USA statistical areas (red) and trawl survey strata (black).

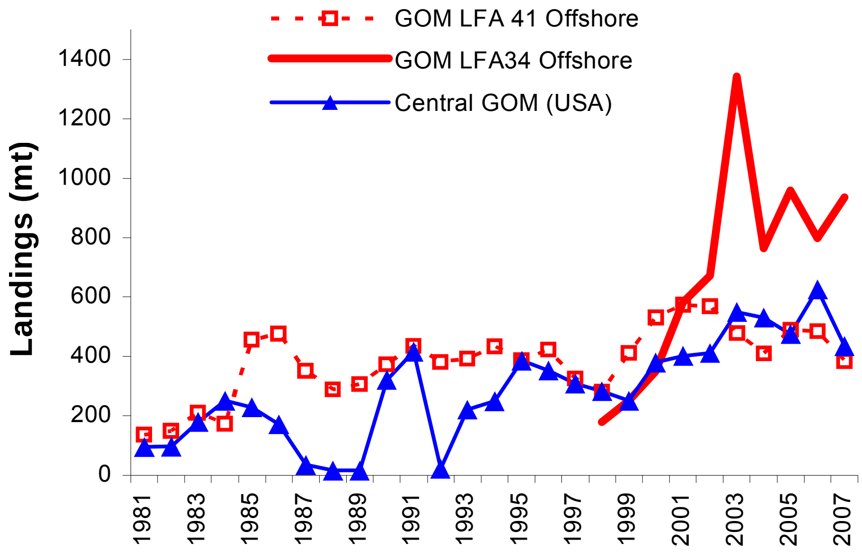


Figure 4.1.4. Gulf of Maine lobster landings from LFA 41 (SW Browns, Crowell Basin, Georges Basin), LFA 34 (grid groups 5-6), USA (statistical areas 464-465, 515).

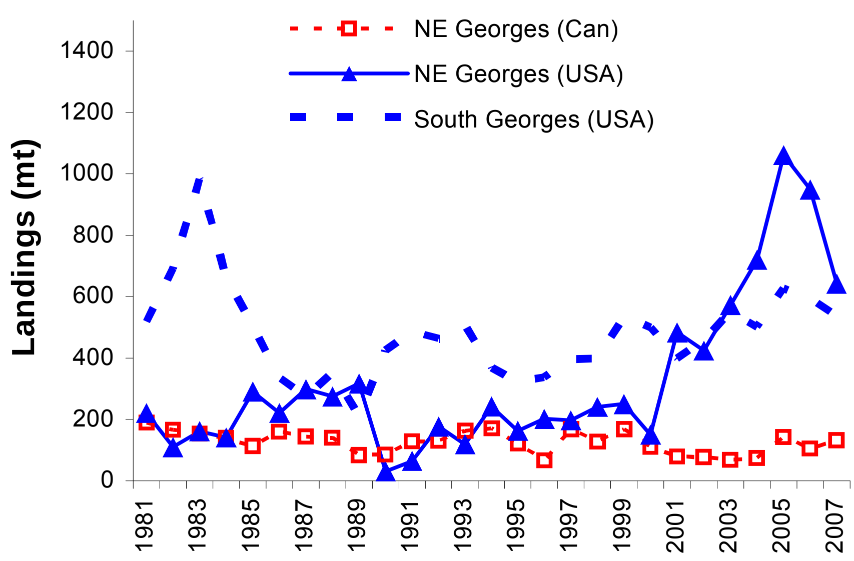
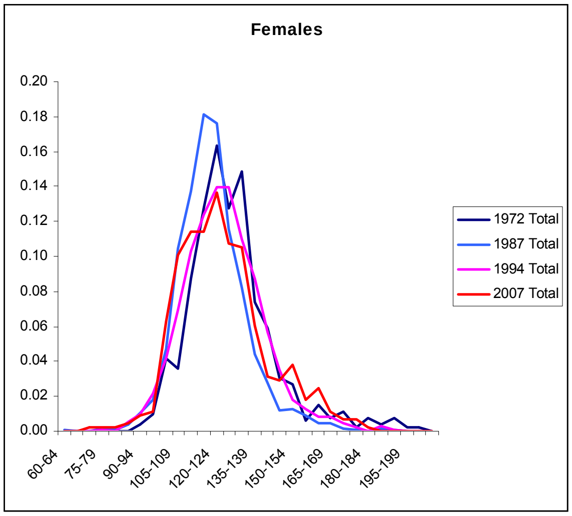
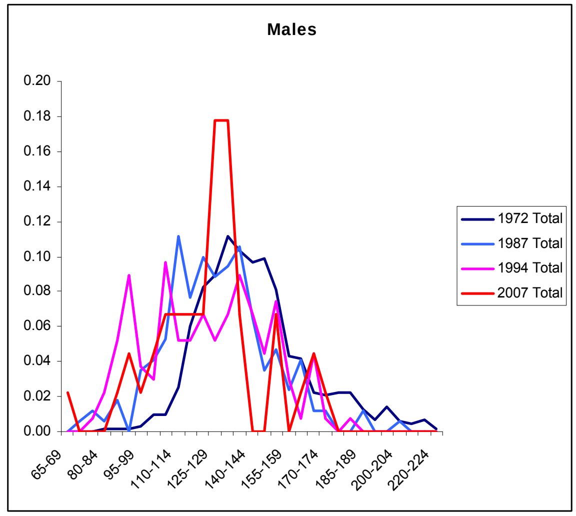


Figure 4.1.5. Georges Bank lobster landings from LFA 41, USA NE Georges (stat. areas 561-562), Southern Georges (statistical area 522, 525).

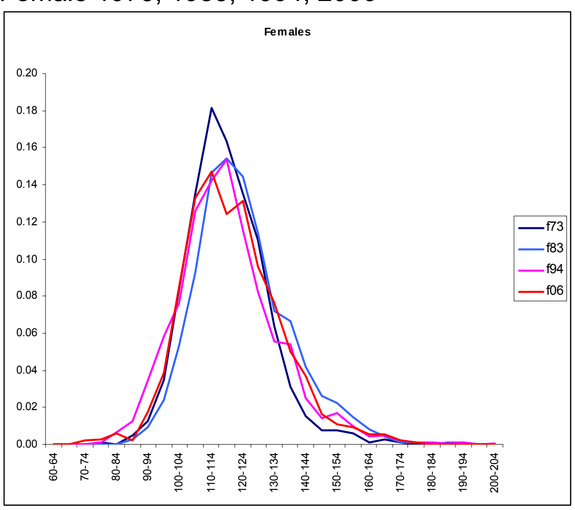
Georges Bank
Females 1972, 1987, 1994, 2007



Georges Bank
Males 1972, 1987, 1994, 2007



SE Browns
Female 1973, 1983, 1994, 2006



SE Browns
Male 1973, 1983, 1994, 2006

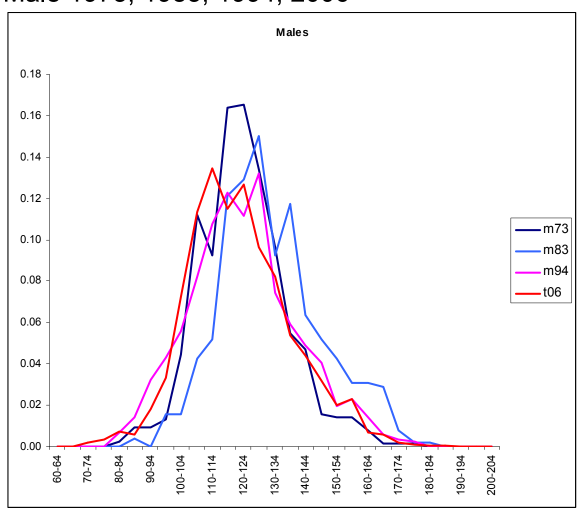
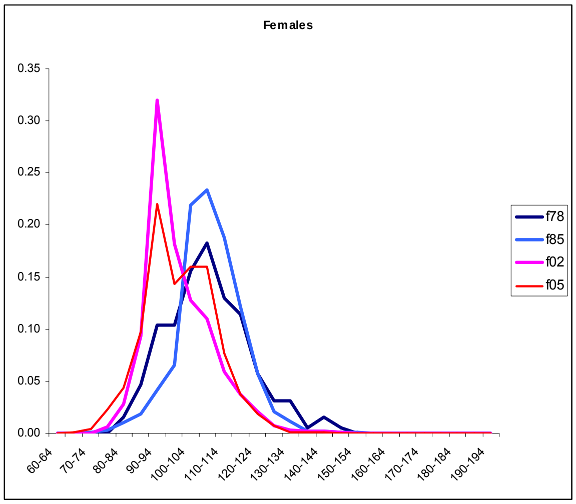
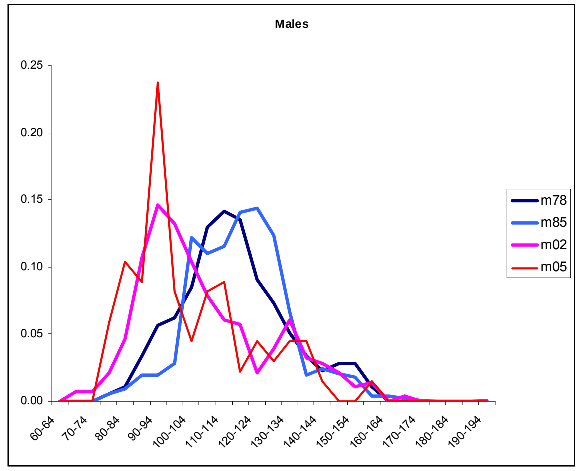


Figure 4.3.1(a). Representative frequencies sizes by area over the history of the fishery. Proportion of lobsters in 5mm groups for males and females.

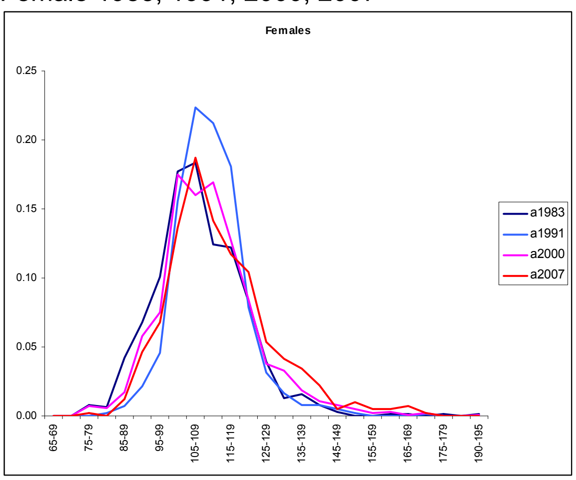
Crowell Basin
Females 1978, 1985, 2002, 2005



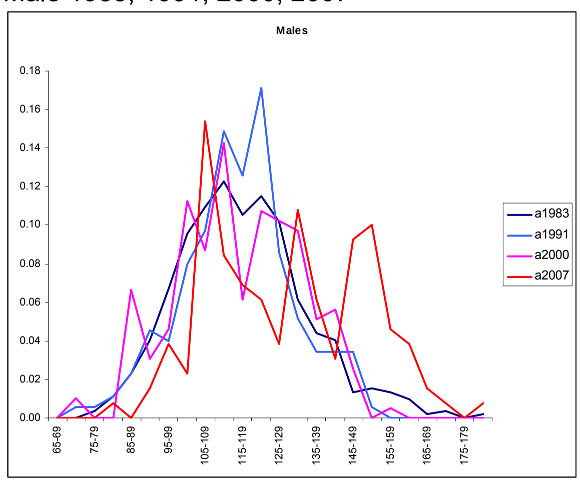
Crowell Basin
Males 1978, 1985, 2002, 2005



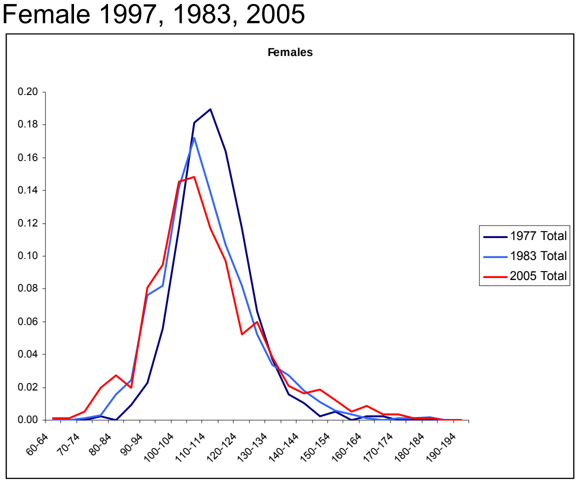
Georges Basin
Female 1983, 1991, 2000, 2007



Georges Basin
Male 1983, 1991, 2000, 2007



SW Browns
Female 1997, 1983, 2005



SW Browns
Male 1997, 1983, 2005

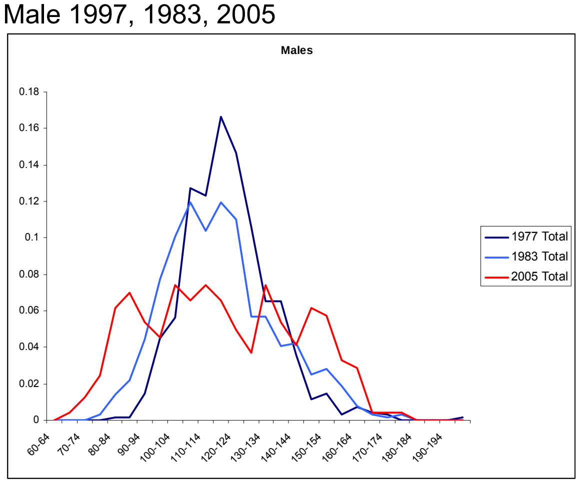
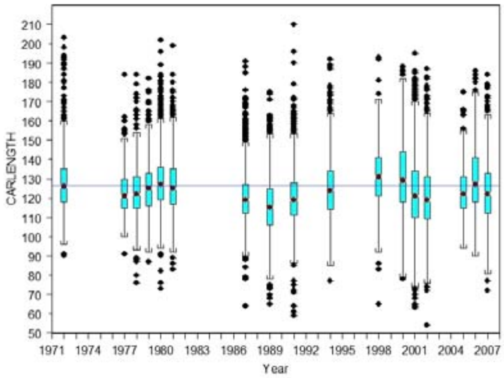


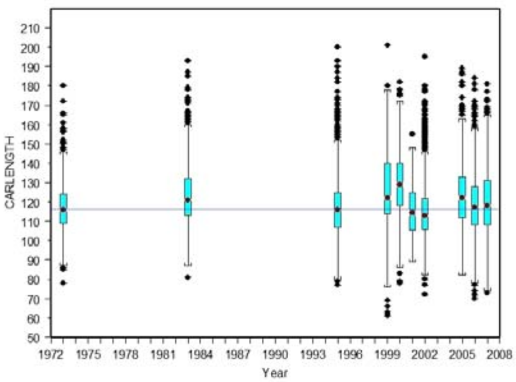
Figure 4.3.1(b). Representative frequencies sizes by area over the history of the fishery. Proportion of lobsters in 5mm groups for males and females.

Females

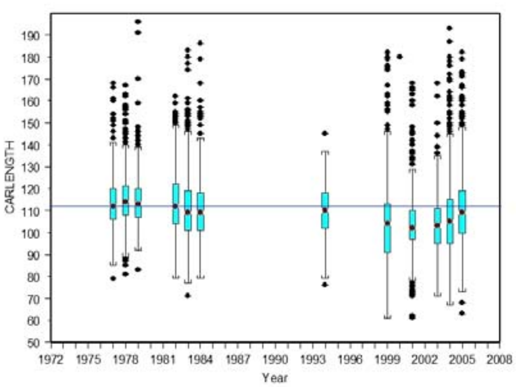
Georges Bank Spring



SE Brown Spring

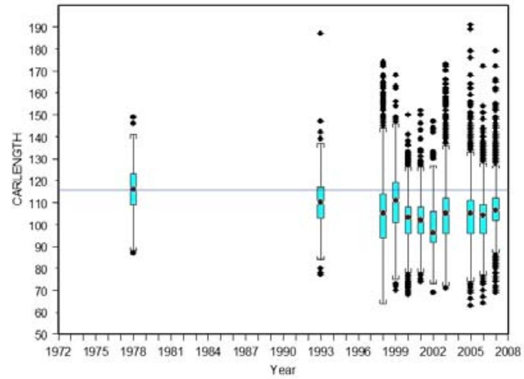


SW Browns Spring

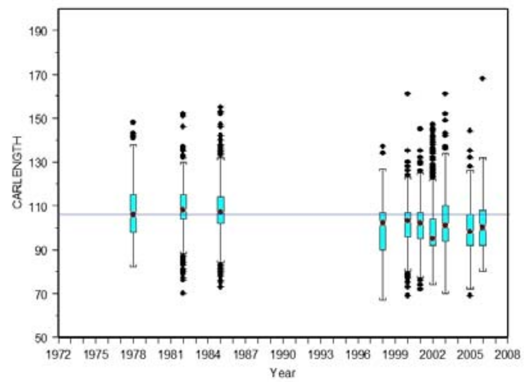


Females

SW Browns Fall



Crowell Basin Fall



Georges Basin Spring

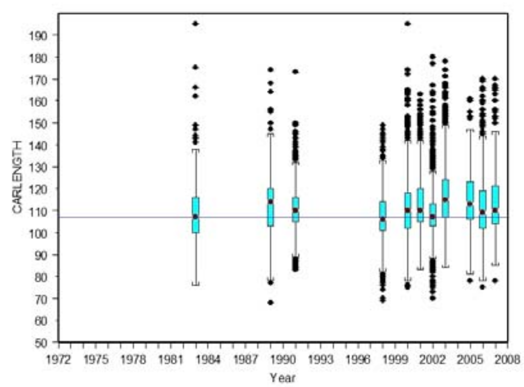
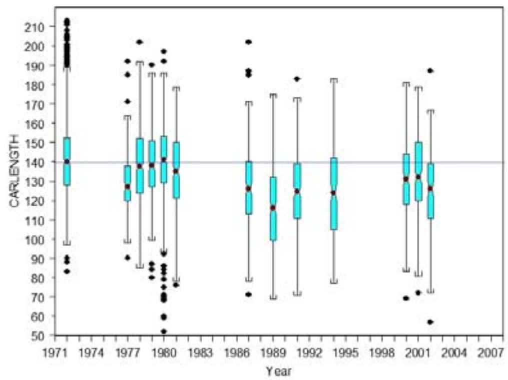


Figure 4.3.2(a). Box plots of female sizes from at-sea samples of the catch showing median size with the box defining the upper and lower quartiles.

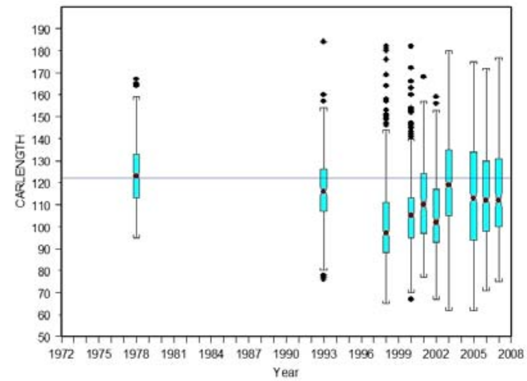
Males

Georges Bank Spring

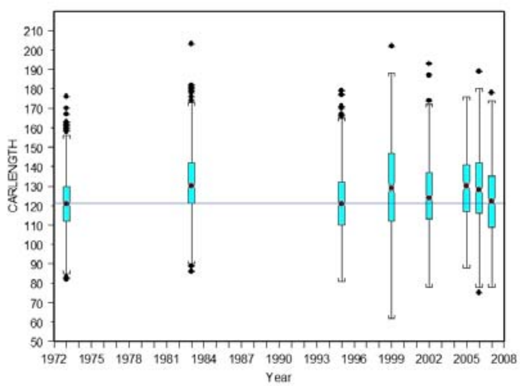


Males

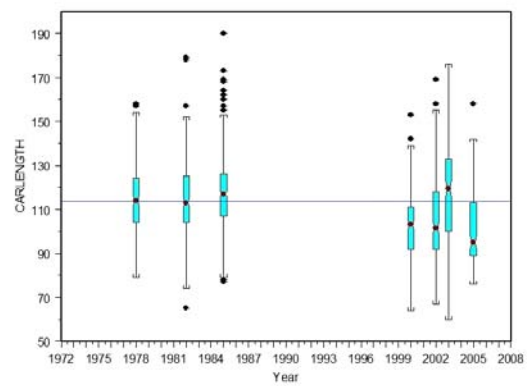
SW Browns Fall



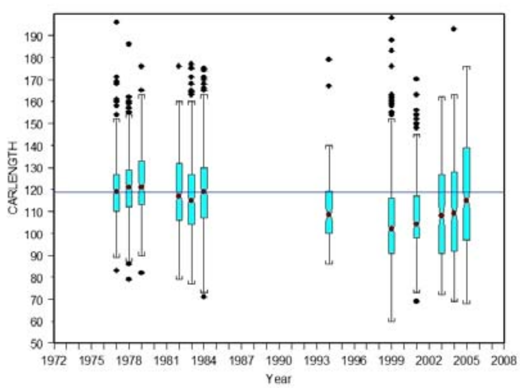
SE Browns Spring



Crowell Basin Fall



SW Browns Spring



Georges Basin Spring

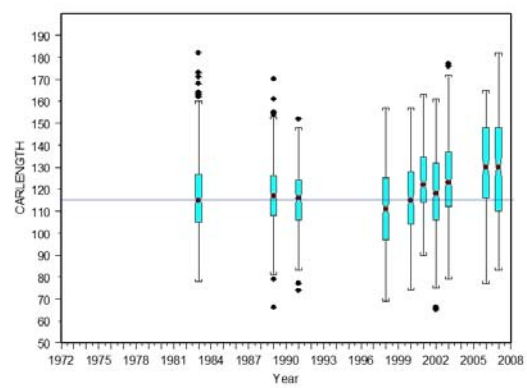
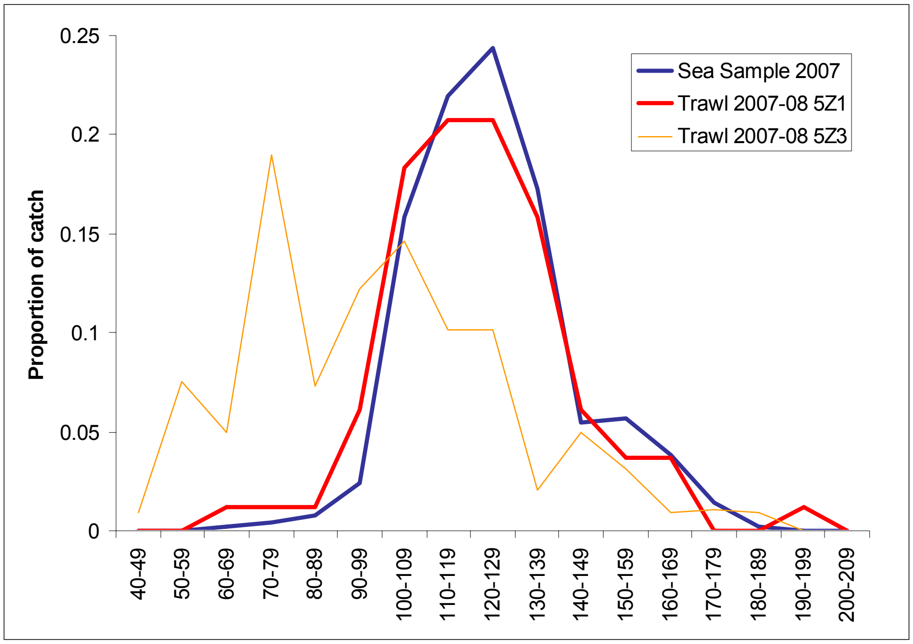
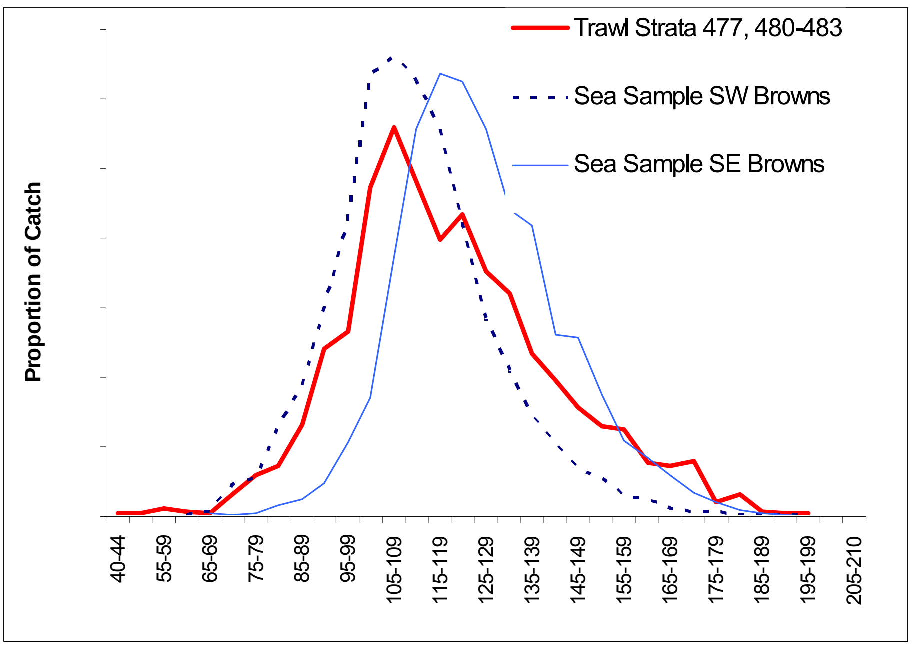


Figure 4.3.2(b). Box plots of male sizes from at-sea samples of the catch showing median size with the box defining the upper and lower quartiles.



a

Georges Bank



b

Browns Bank

Figure 4.3.3. Comparison of trap (at-sea sample) and trawl (DFO RV stratified random trawl survey) caught size frequencies for (a) Georges Bank (winter) and (b) Browns Bank (summer).

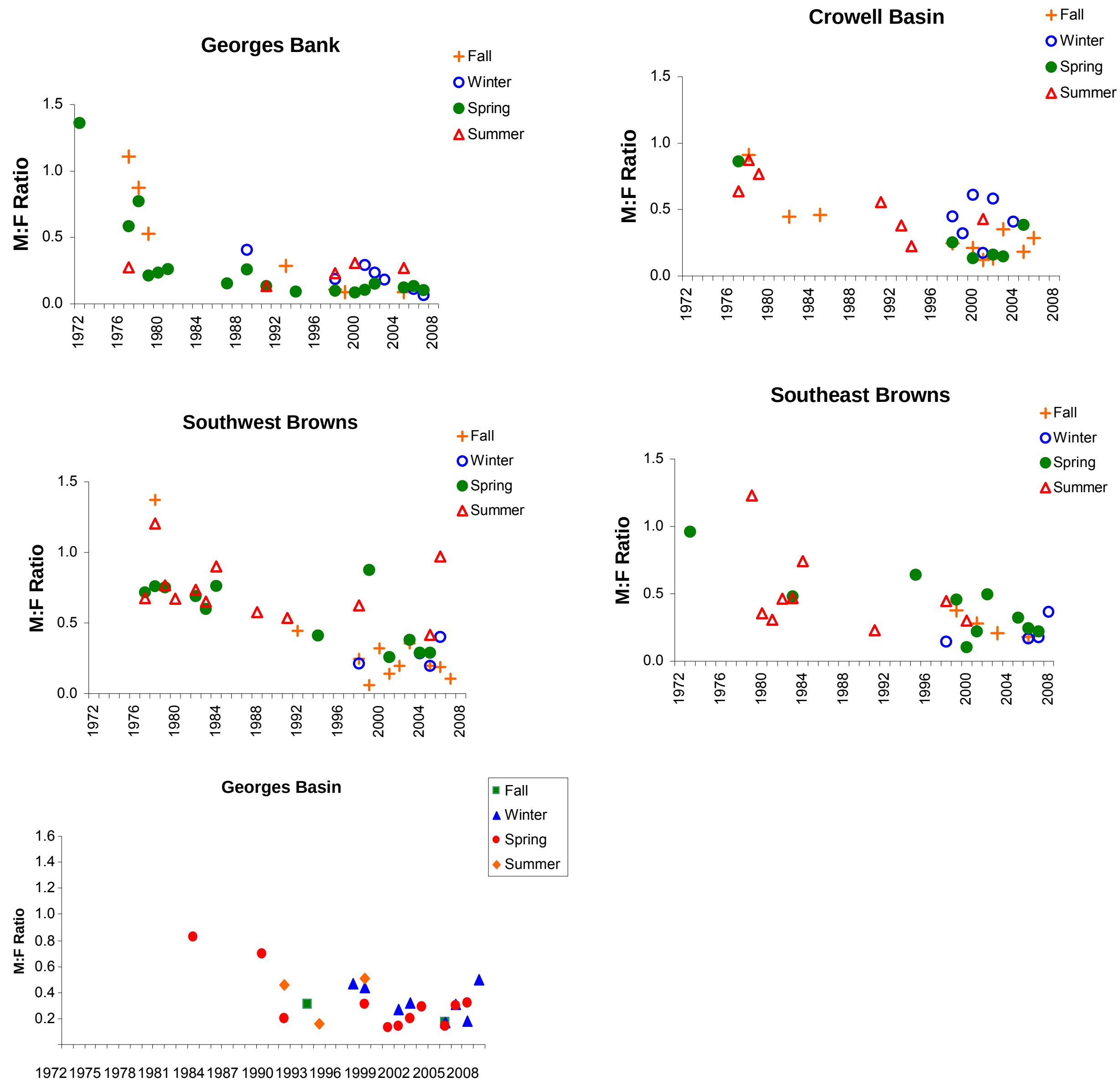


Figure 4.4.1. Sex ratio (Male:Female) from at-sea samples.

Georges Bank

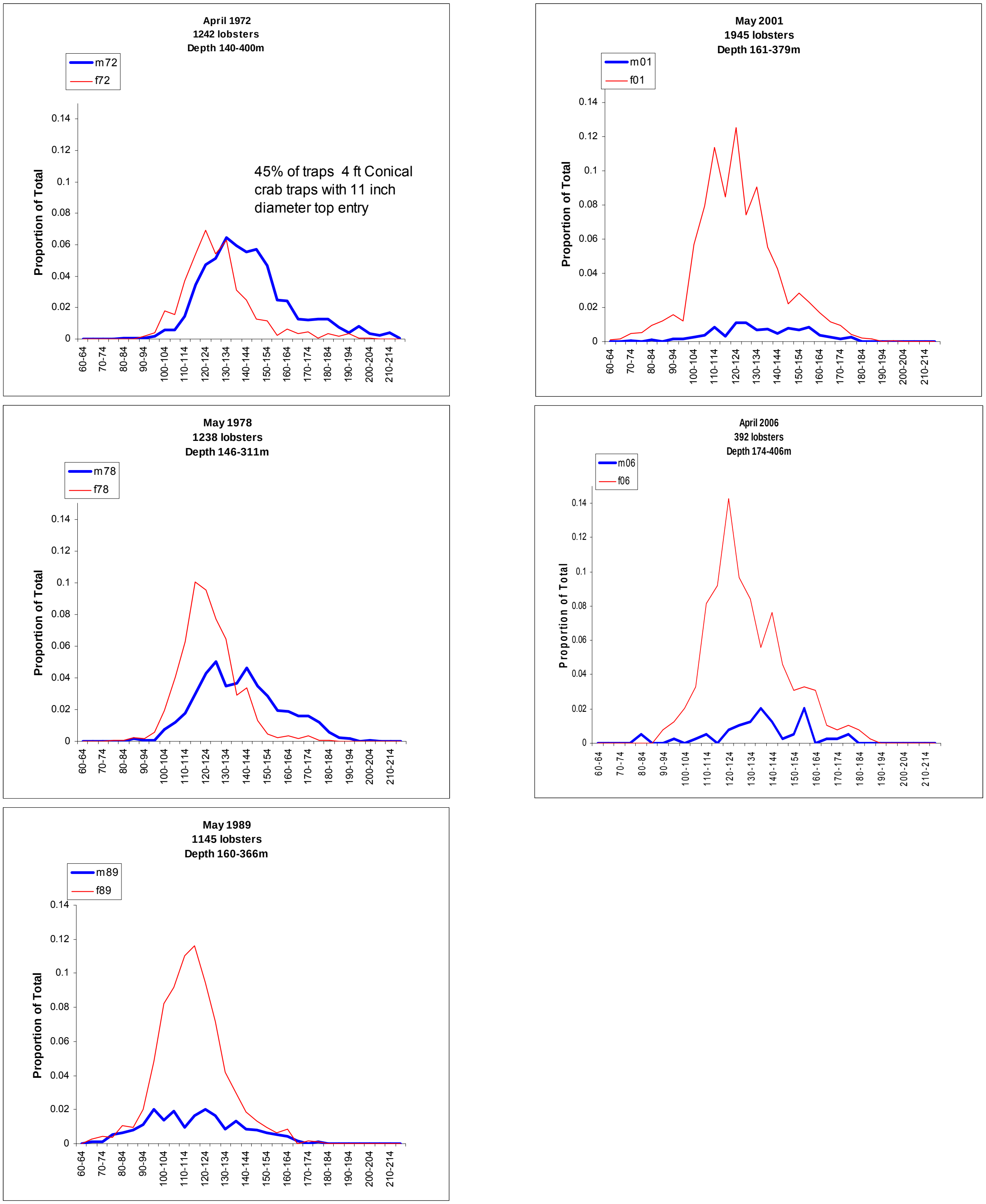
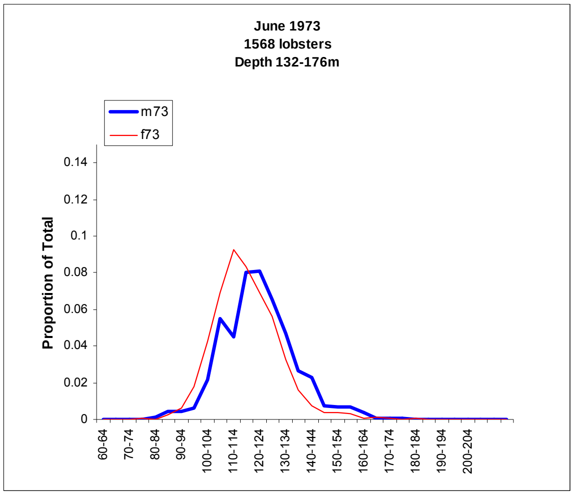
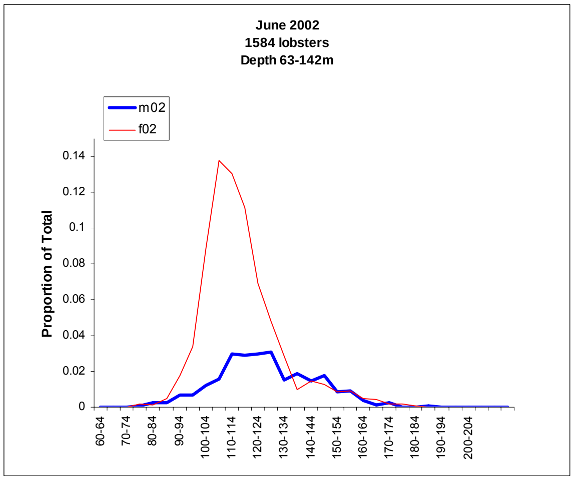
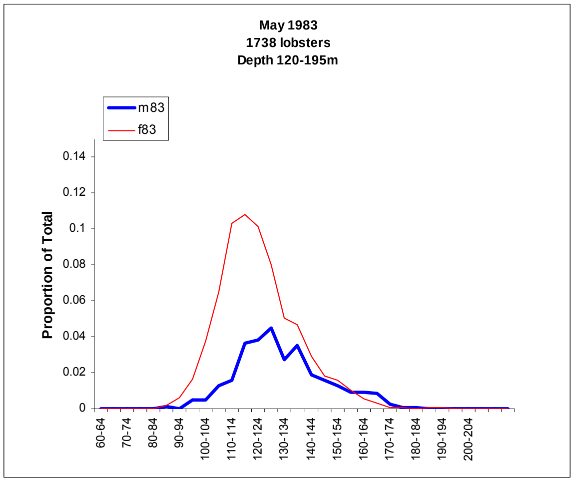


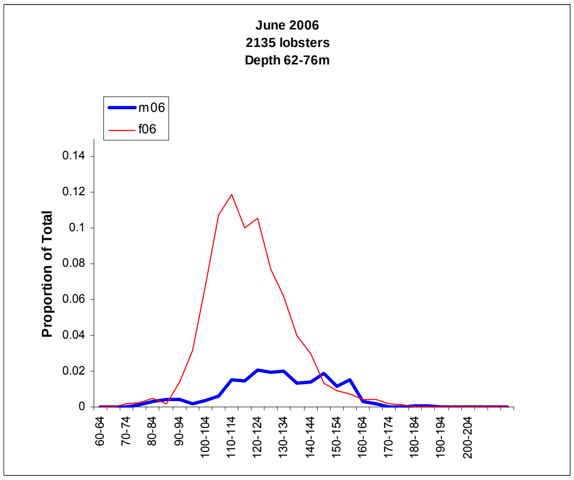
Figure 4.4.2(a). Proportion of male and females in the catch at size, Georges Bank.

SE Browns









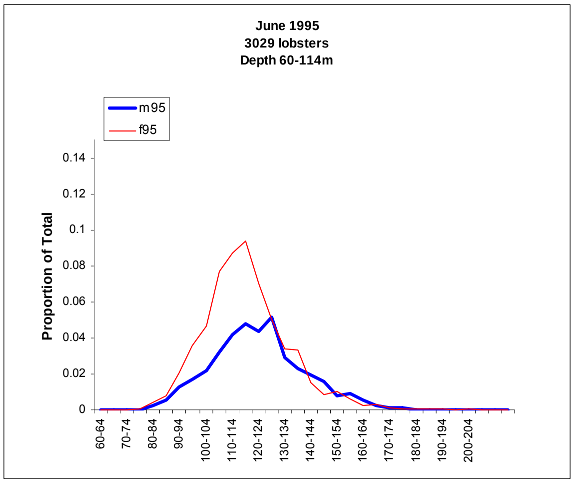


Figure 4.4.2(b). Proportion of male and females in the catch at size, SE Browns.

SW Browns

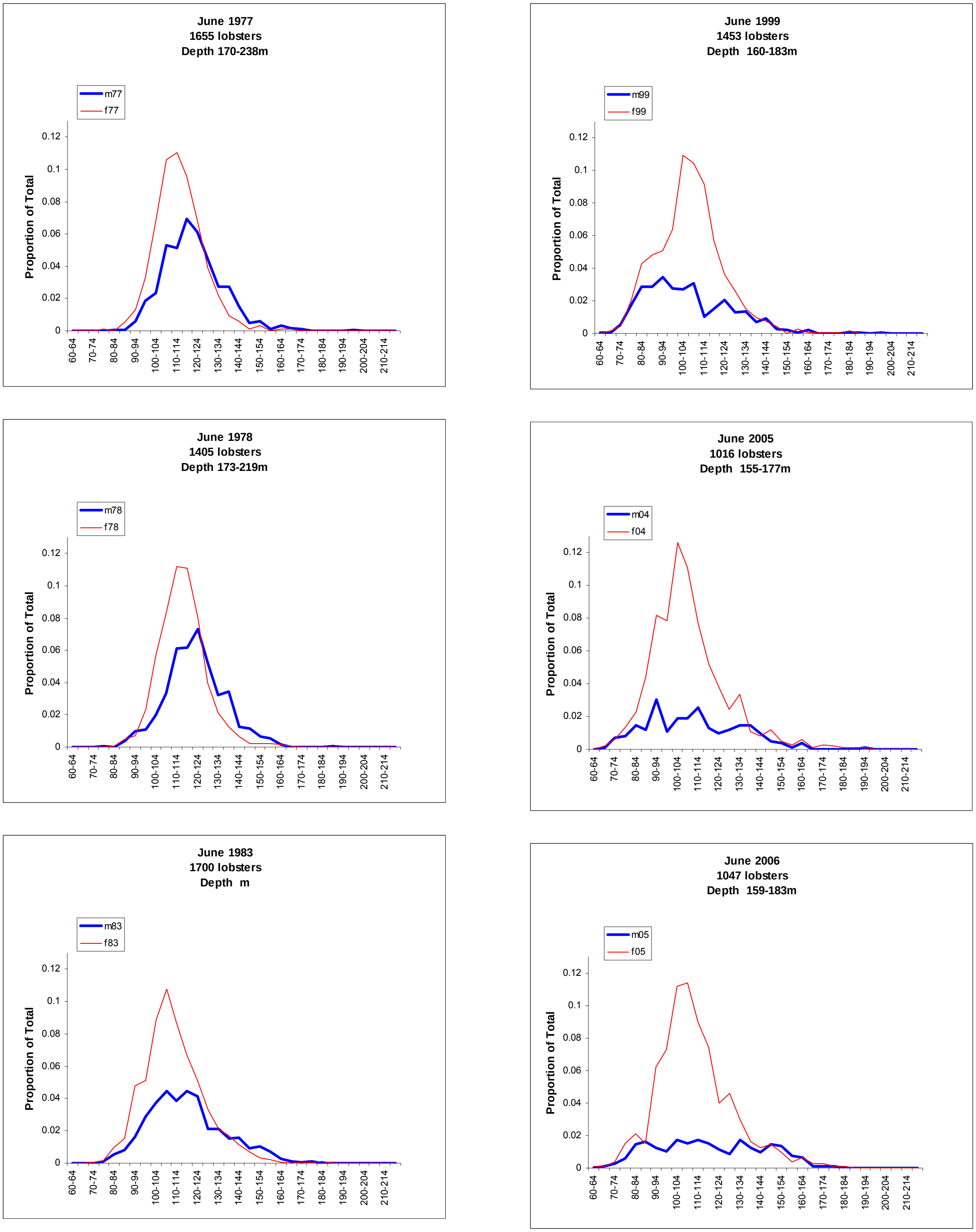


Figure 4.4.2(c). Proportion of male and females in the catch at size, SW Browns.

Crowell Basin

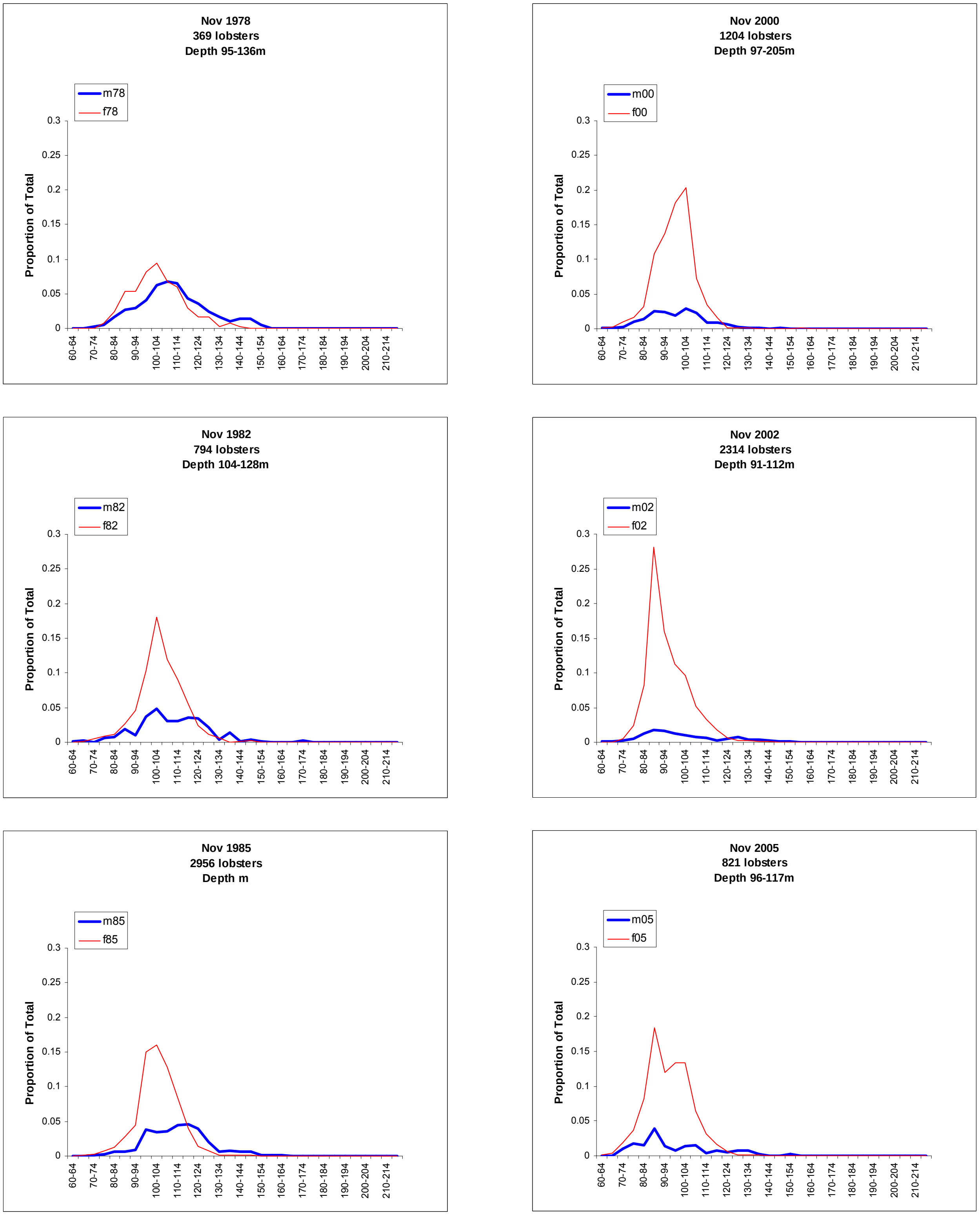


Figure 4.4.2(d). Proportion of male and females in the catch at size, Crowell Basin.

Georges Basin

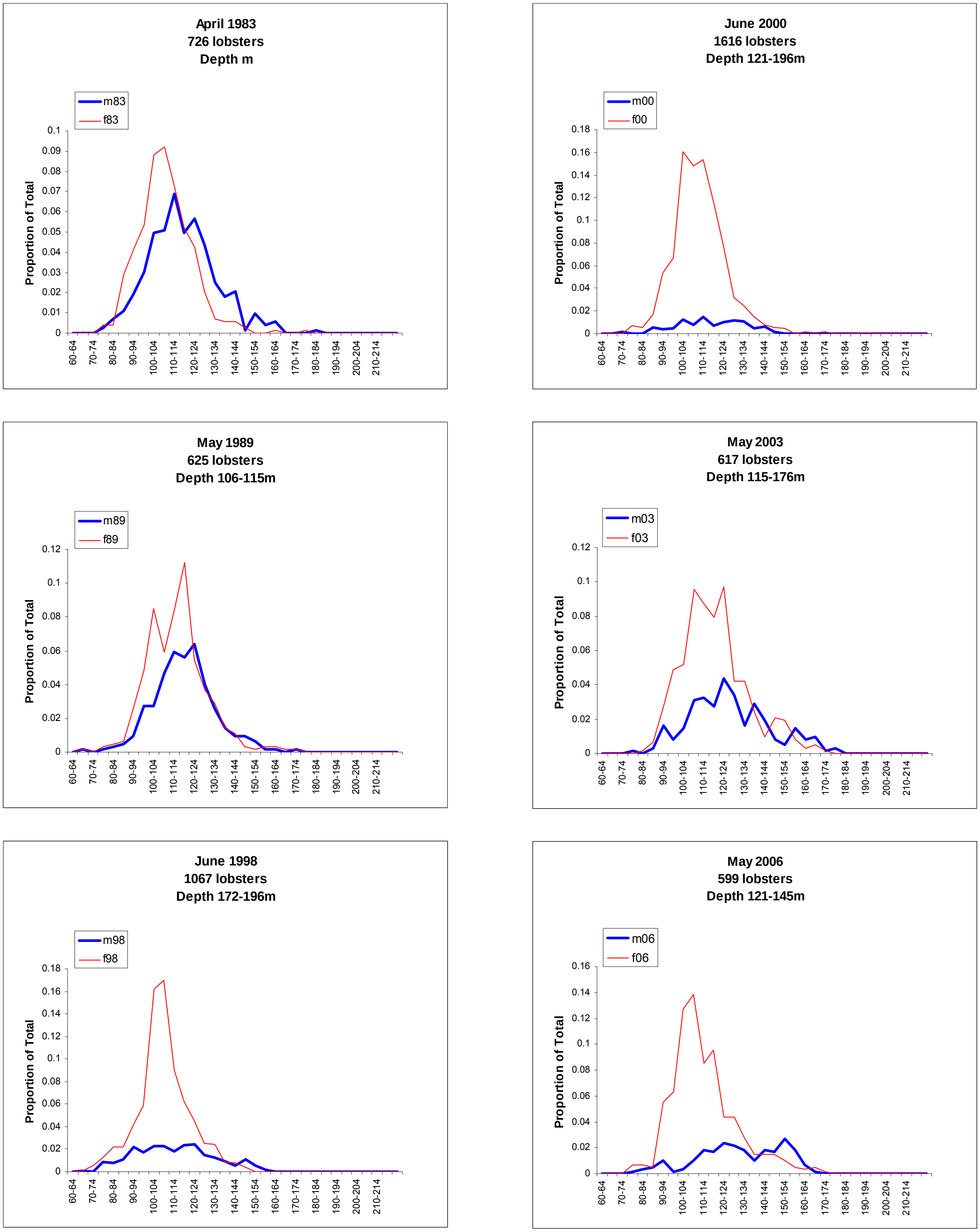


Figure 4.4.2(e). Proportion of male and females in the catch at size, Georges Basin.

LFA 34 Offshore

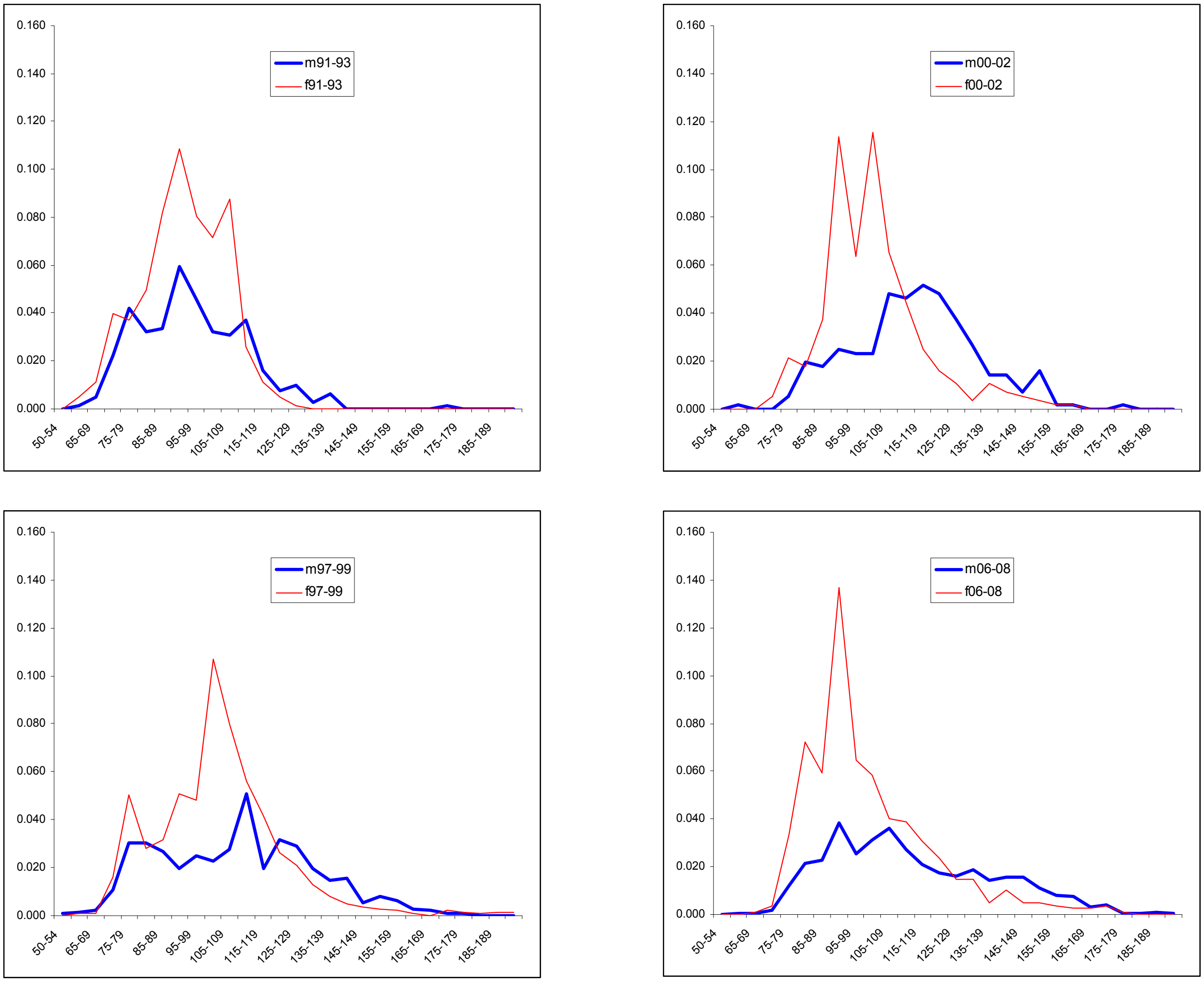


Figure 4.4.2(f). Proportion of male and females in the catch at size, LFA 34 offshore.

Browns Bank (from RV stratified random summer trawl survey)

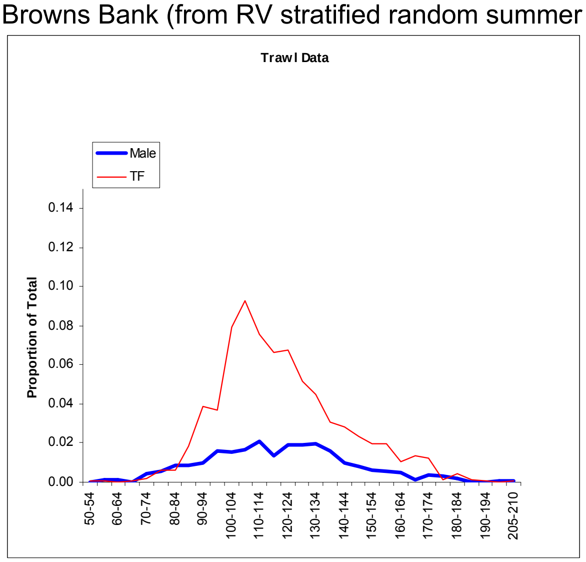


Figure 4.4.2(g). Proportion of male and females in the catch at size, Browns Bank from RV stratified random summer trawl survey.

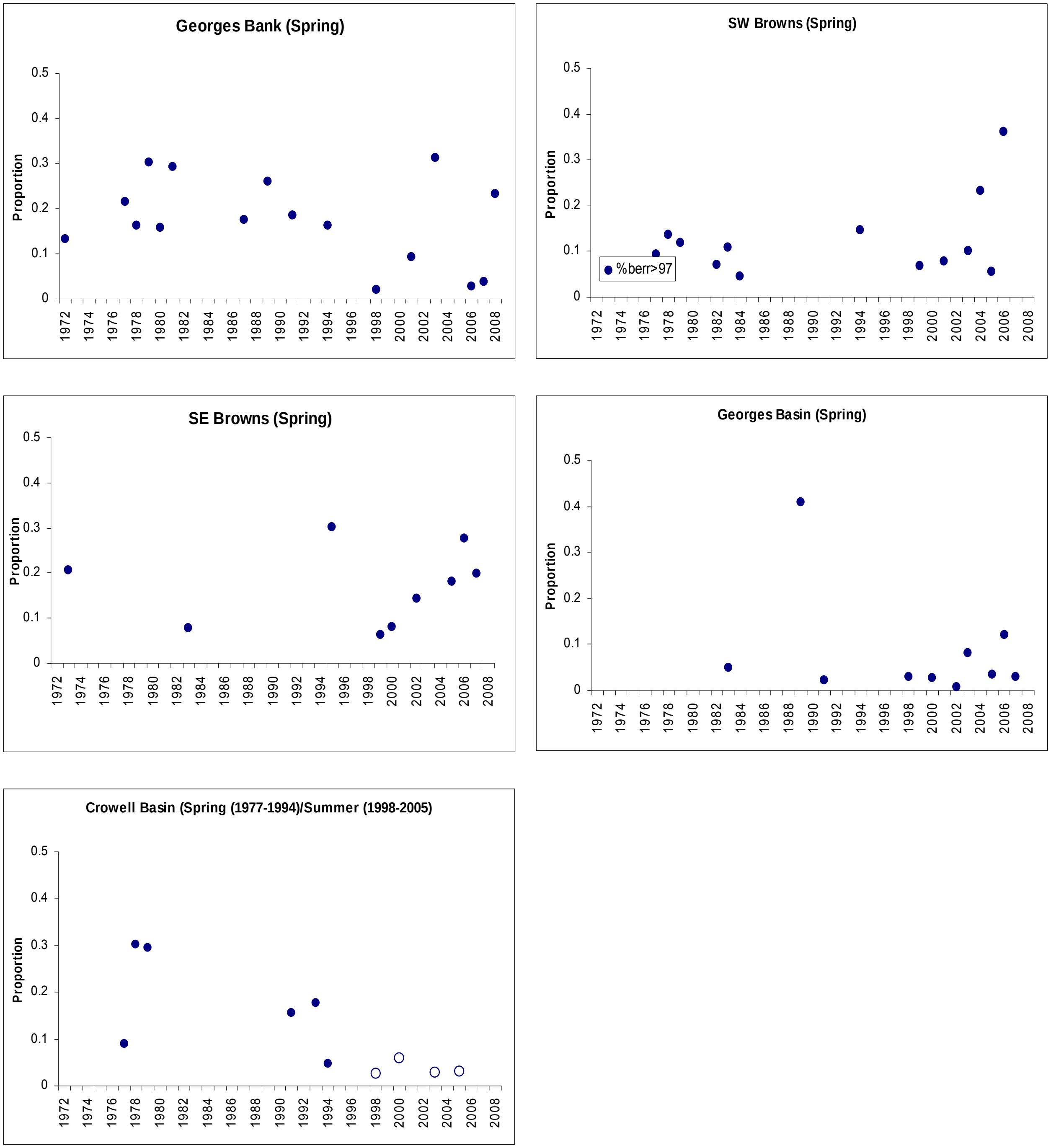


Figure 5.1.1 Proportion of females >97mm CL in at-sea sample that are berried.

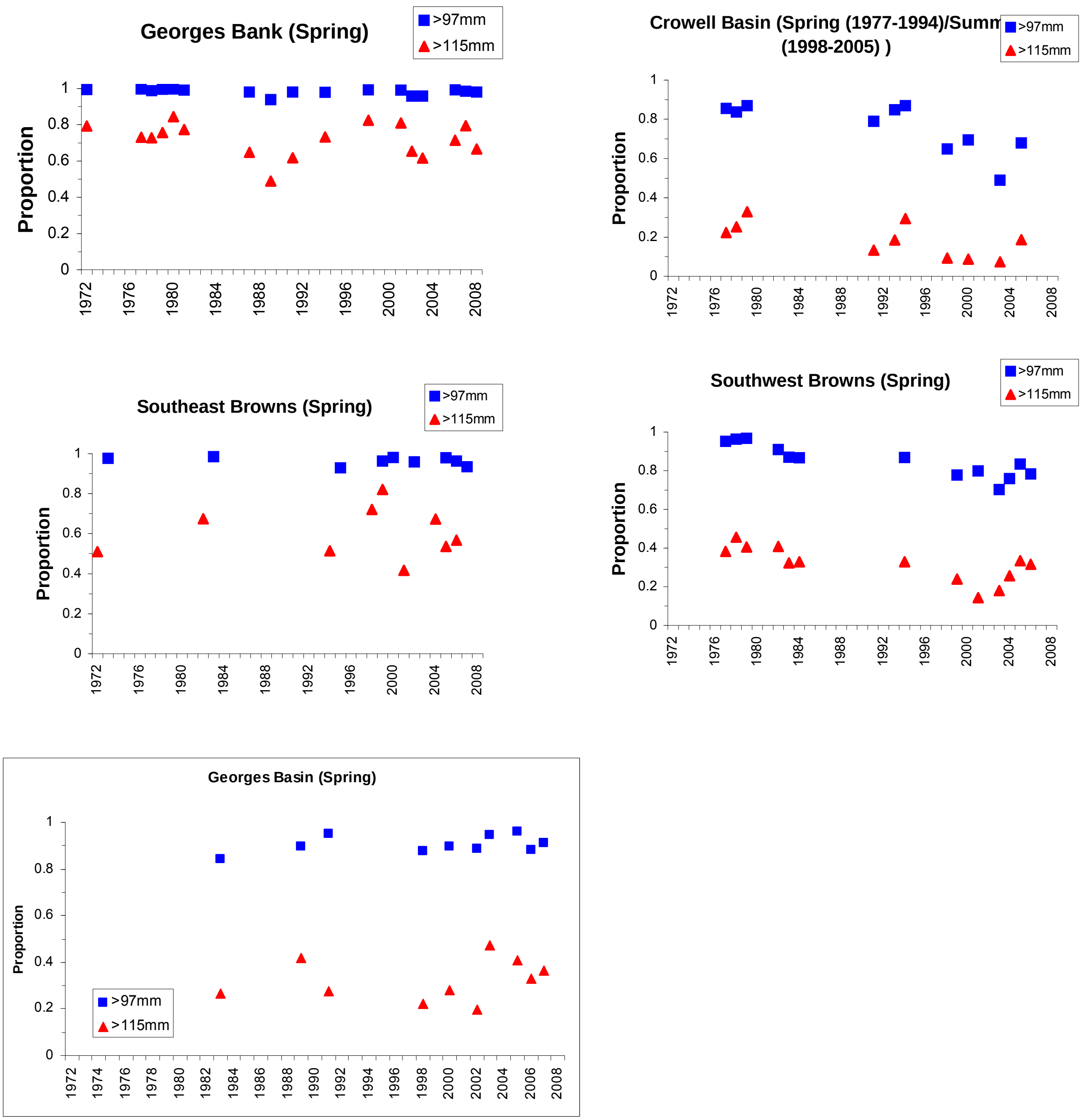
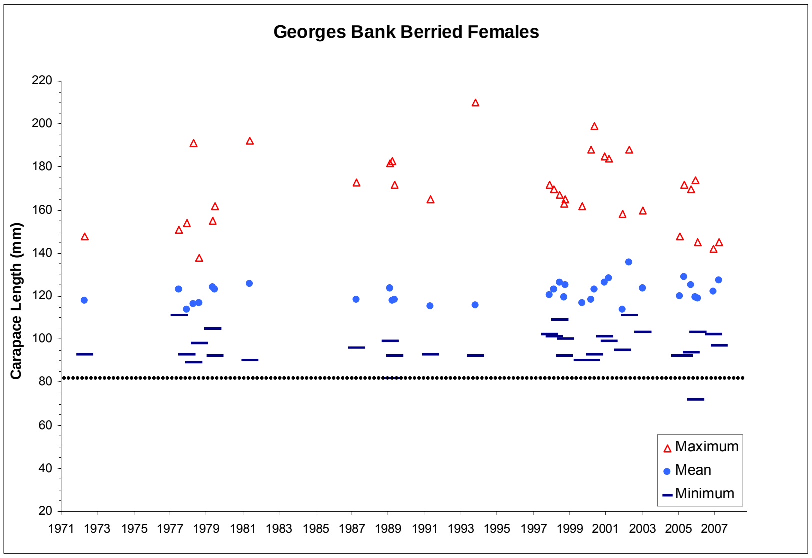
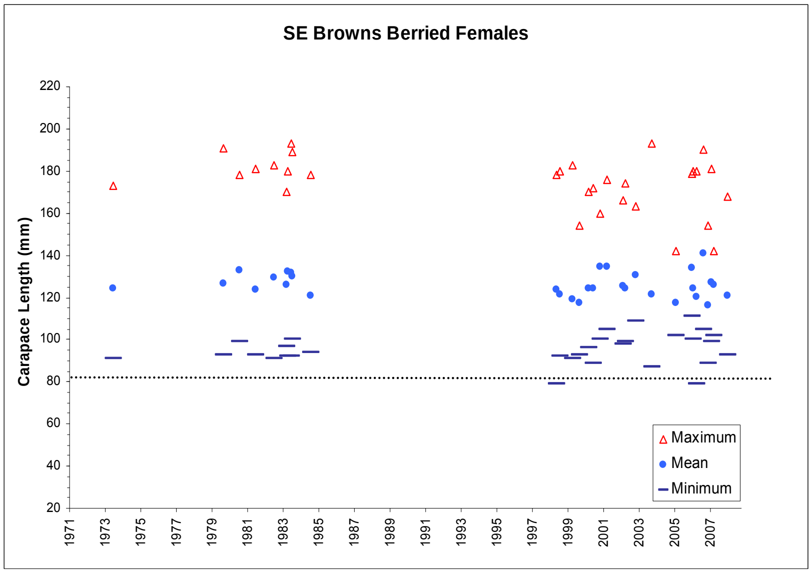


Figure 5.1.2. Proportion of females in at-sea samples >97mm CL (size at 50% maturity) and >115mm CL (multiparous).





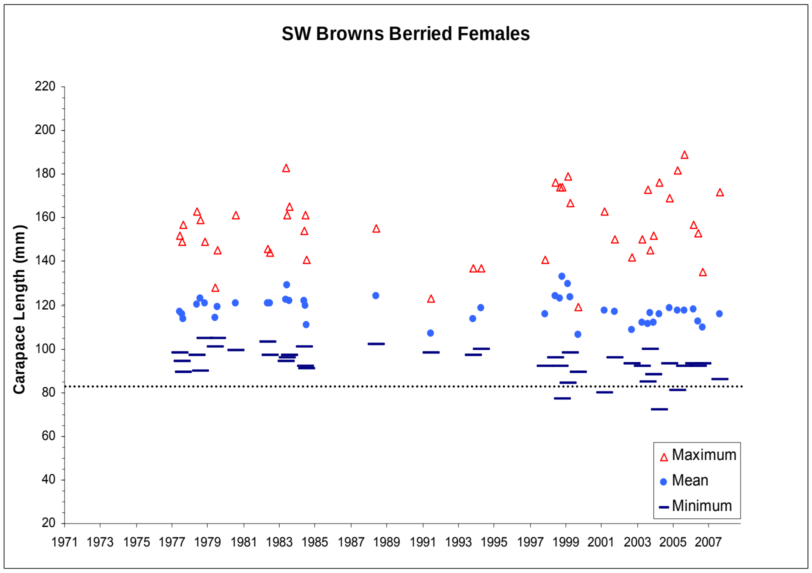


Figure 5.1.3. Minimum, mean and maximum size of berried females in at-sea samples. Horizontal line represents minimum legal size.

13.0 APPENDICES

Appendix 1. History

History Beginnings: 1971-1975 Licences and Area

As a result of the growth of an offshore lobster fishery in the United States (US) during the latter part of the 1960s, similar Canadian interest in an offshore lobster fishery on Georges Bank began. In July 1971, the Minister of Fisheries and Oceans Canada (DFO) announced the opening of a Canadian offshore lobster fishery. The fishery was authorized for a geographical area termed "Lobster District A", which is the area seaward from the offshore lobster boundary line - 50 nautical miles from the geographical base line for the 12 mile limit. This district extended along the entire outer portion of the Scotian Shelf.

In 1970, the US government imposed restrictions on the importation of swordfish due to increasing consumer standards on mercury levels in food products. This approach negatively affected the Canadian swordfish longline fishery, which exported the majority of its landings to the US market. In an effort to provide an alternative fishery option to the Canadian swordfish longline fleet, the Canadian government offered an opportunity to the 56 swordfish longline licence holders, predominantly based in Southwest Nova Scotia (SWNS) to fish offshore lobsters. However, few of the swordfish vessel licence holders opted to acquire an offshore lobster licence and, by 1972, only six swordfish vessels had entered the new fishery, with two additional licences entering the fishery in 1976. The awarding of the two additional licences caused serious reservations among the SWNS inshore lobster industry as concerns were expressed that the offshore effort may negatively impact the viability of the inshore lobster fishery.

The Canadian offshore lobster fishery initially occurred on the known lobster grounds of southern Georges Bank. This provided an obvious geographical separation between the inshore and offshore fleet activity. Exploratory efforts indicated concentrations of lobster along the eastern and southwestern portion of Browns Bank which contributed to offshore catches from all areas increasing to 678 tonnes (t) by 1976. Since many inshore fishermen believed that the offshore harvesting effort could be disrupting the migration of lobsters to the inshore grounds, they expressed serious concerns on the impact that this new offshore lobster effort may have on their established fishery. The average landings for inshore SWNS lobster decreased from 4036t during 1970-1976 to 3120t for the period of 1976-1980.

Restrictions: 1976

While the inshore lobster fleet's concerns of the potential impact of the offshore lobster fleet on lobster migrations could not be supported with the data available at the time, DFO responded by applying additional restrictions on the offshore lobster fishery. These restrictions included: (1) freezing the number of offshore lobster licences at eight (8), (2) limiting the number of traps at 1000 traps/vessel, (3) applying a 10 month season (to be chosen by the vessel owner) and (4) a 408t Total Allowable Catch (TAC) on the 4X portion of Lobster Fishing Area (LFA) 41, which included the area closest to the inshore fleet, Browns Bank area. Only six of the eight licences were permitted to fish in this part of the offshore area, with the remaining two licences restricted to Georges Bank.

All eight licences had fishing access to Georges Bank, including 5Ze, with no quota limits.

Closed Area: 1979

In 1979, DFO established a rectangular regulatory “closed” area on Browns Bank, identified as LFA 40, to protect lobster brood stock (Pezzack and Duggan 1985, 1987). The closure continues to remain in effect, encompassing all portions of the Bank shallower than 50 fathoms and straddles the inshore/offshore line with approximately 57% of its area in LFA 34 and 43% in LFA 41. This closure does not affect other gear sectors.

The “Hague” Line Affects the Fishery: 1984

During the period of 1977-1984, the 408t TAC remained in effect. In October 1984, an International Court of Justice (ICJ) decision established the official boundary between Canada and the US in the Gulf of Maine known as “the Hague Line”.

The ICJ ruling subsequently displaced the American offshore lobster effort from areas now defined as Canadian waters, principally in Crowell Basin and Georges Basin. Average annual American catches from these two combined areas were estimated at 200 t. The Canadian offshore lobster allocations were based on: (1) the 4X 408t TAC; (2) the average annual Canadian 5Z (Georges Bank, Georges Basin and part of the Northeast Channel) lobster catches and (3) 100t from the estimated American catch from Crowell and Georges Basins and Georges Bank.

Enterprise Allocation Program Introduced: 1985/86

The combination of: (1) a small marginally profitable offshore lobster fleet, (2) a major trans-boundary ruling by the ICJ in 1984 and (3) increasing conservation and economic concerns from the inshore fleet relating to impact of this fishery on their own fishery, generated an environment requiring a collaborative conservation strategy involving DFO and the offshore lobster fleet. In response, the Offshore Lobster Advisory Committee (OLAC) was formed in 1985. This Committee was originally comprised of the offshore lobster licence holders, the Nova Scotia Department of Agriculture and Fisheries and DFO.

In 1986, OLAC recommended an initial three-year trial Enterprise Allocation (EA) Offshore Lobster Management Plan for this fishery, which provided licence holders with the equivalent of transferable quotas. During this period, the TAC was established at 720t and a DFO economic analysis indicated that an allocation of 12.5% of the TAC (90t) to each of the eight vessel licences was sufficient to support a vessel replacement program.

The effort control measures adopted at this time included: (1) a TAC of 720t, (2) the number of licences limited to 8, with an individual vessel licence quota of 90t, (3) specific vessel trap limits, and (4) an October 16th – October 15th season for optimizing market quality requirements. In 1995 the trap limit was removed.

Through the years, the Offshore Lobster industry periodically landed some Jonah crab as a bycatch to the lobster fishery. In the latter part of 1995, a proposal from the Offshore Lobster industry to land Jonah crab on a regular basis was approved, licences were issued, and a TAC of 720t set. The fleet is limited to a male only Jonah crab fishery with a minimum size limit of 130mm carapace width (CW). The gear type in use is an offshore lobster trap. A program funded by industry provides samplers for the collection of at-sea biological samples. The industry also provides fishery data through completion of logbooks detailing catch and effort information.

In 2006 the Department approved the transfer of one licence from Donna Rae Ltd to Clearwater Seafoods Limited Partnership (CSLP), resulting in all eight offshore lobster licences and 100% of the quota being held by CSLP.

In 2005, CSLP was authorized a change in fishing season to a calendar quota year (January 1 to December 31). This change enabled CSLP to focus effort during the winter period of high quality lobster, which optimizes dry-land storage of inventory. Donna Rae Ltd. elected to remain with the October 16th to October 15th quota year at this time. Upon transfer of the Donna Rae licence to CSLP and subsequent approval by DFO, the quota season was changed on this licence so that all eight licences operate under a harmonized fishing season.

Clearwater obtained permission from DFO to change the quota season on the final licence in early 2007.

Appendix 2. Offshore Lobster and Crab Monitoring Document

Offshore Lobster and Crab Monitoring Document

Vessel Registration # ______ Vessel Name ______ Port Sailed ______ Time Sailed (HH:MM) ______

Gear Type ______ # of Crew ______ Bait ______ Lobster Confirmation # ______

Crab Confirmation # ______

Date Sailed (Year Month Day) ______ Date Landed (Year Month Day) ______

Licence # ______ Licence # ______

Port Landed ______ Time Landed (HH:MM) ______

Date Hauled (Year Month Day)	String Number	Latitude/Longitude		Depth (fathoms)	Soak days	# Traps hauled	CRAB	LOBSTER		Remarks
		Degrees Minutes	Degrees Minutes				Estimated Catch (lbs)	Estimated Catch (lbs)	# V-notch Observed	

Buyer ______

Address ______

NAFO Division ______

Lobster Weighout

Units (pounds)	Size	Price
	Total	

Jonah Crab Weighout

Units (pounds)		Price
	Live	
	Dead	
	Total	

Captain's Name ______

Captain's Signature ______

Observer ID# ______

Observer's Name ______

Observer's Signature ______

Buyer's Name ______

Buyer's Signature ______

Appendix 3. Summary of Number of Lobsters (Male and Female) Measured Each Year, in Each Area, and Season (Fall: October-December, Winter: January-March, Spring: April-June, Summer: July-September)

SW Browns

	Fall			Winter			Spring			Summer			Total
Year	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	
1977							690	965	1655	1281	1897	3178	4833
1978	328	239	567				607	798	1405	448	369	817	2789
1979							163	217	380	118	154	272	652
1980										1045	1559	2604	2604
1982							229	332	561	402	545	947	1508
1983							635	1065	1700	1145	1746	2891	4591
1984							374	487	861	821	920	1741	2602
1988										364	605	969	969
1991										114	210	324	324
1993	259	576	835										835
1994							90	221	311				311
1998	705	2731	3436	477	2134	2611				370	596	966	7013
1999	69	1136	1205				918	1131	2049				3254
2000	743	2261	3004				19	71	90				3094
2001	149	1034	1183	25	32	57	251	964	1215				2455
2002	300	1493	1793	74	46	120							1913
2003	614	1708	2322	38	84	122	104	273	377				2821
2004				295	1018	1313	239	777	1016				2329
2005	673	3275	3948	404	2049	2453	243	804	1047	86	197	283	7731
2006	593	3128	3721	67	172	239	25	95	120	375	371	746	4826
2007	167	1544	1711										1711
2008				21	26	47							47
Total	4600	19125	23725	1401	5561	6962	4587	8200	12787	6569	9169	15738	59212

Georges Bank

	Fall			Winter			Spring			Summer			Total
Year	**m**	**f**	**total**	**m**	**f**	**total**	**m**	**f**	**total**	**m**	**f**	**total**	
1972							716	526	1242				1242
1977	328	296	624				159	272	431	49	179	228	1283
1978	63	72	135				540	698	1238	39	63	102	1475
1979	344	652	996				162	761	923				1919
1980							534	2262	2796				2796
1981							241	924	1165				1165
1987							171	1113	1284				1284
1989				250	617	867	235	910	1145				2012
1991							312	2311	2623	455	3391	3846	6469
1993	361	1266	1627										1627
1994							134	1460	1594				1594
1998	238	2233	2471	104	558	662	51	519	570	37	160	197	3900
1999	126	1435	1561										1561
2000							107	1257	1364	248	804	1052	2416
2001				135	461	596	185	1760	1945				2541
2002				66	282	348	116	762	878				1226
2003				68	373	441	7	30	37				478
2005	83	939	1022				35	287	322	85	315	400	1744
2006				180	1602	1782	46	346	392				2174
2007				22	331	353	46	447	493				846
Total	1543	6893	8436	825	4224	5049	3797	16645	20442	913	4912	5825	39752

SE Browns

	Fall			Winter			Spring			Summer			Total
Year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	
1973							768	800	1568				1568
1979										365	297	662	662
1980										467	1313	1780	1780
1981										250	805	1055	1055
1982										503	1081	1584	1584
1983							997	2073	3070	888	1897	2785	5855
1984										758	1018	1776	1776
1991										508	2165	2673	2673
1995							1182	1848	3030				3030
1998				281	1930	2211				1168	2616	3784	5995
1999	122	317	439				351	722	1073				1512
2000							29	269	298	245	799	1044	1342
2001	74	171	245	152	630	782	31	140	171				1198
2002				5	12	17	893	1806	2699				2716
2003	419	1456	1875	113	1060	1173							3048
2005							151	483	634	45	97	142	776
2006	75	399	474	220	1289	1509	601	2456	3057				5040
2007				50	283	333	423	1915	2338				2671
2008				179	489	668							668
Total	690	2343	3033	1000	5693	6693	5426	12512	17938	5197	12088	17285	44949

Crowell Basin

	Fall			Winter			Spring			Summer			Total
Year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	
1977							50	58	108	1192	1871	3063	3171
1978	177	192	369							266	303	569	938
1979							16	21	37	394	513	907	944
1982	245	549	794										794
1983							97	72	169				169
1985	929	2027	2956										2956
1991										877	1575	2452	2452
1993										838	2188	3026	3026
1994										232	1031	1263	1263
1998	68	278	346	1079	2440	3519	414	1654	2068				5933
1999				586	1731	2317							2317
2000	216	988	1204	727	1172	1899	99	667	766	9	27	36	3905
2001	55	442	497	141	802	943	7	24	31	44	97	141	1612
2002	280	2033	2313	67	113	180	26	164	190				2683
2003	144	401	545	47	40	87	72	432	504				1136
2004				83	199	282							282
2005	133	683	816				100	260	360	31	80	111	1287
2006	36	124	160										160
2008				20	23	43							43
Total	2283	7717	10000	2750	6520	9270	881	3352	4233	3883	7685	11568	35071

Georges Basin

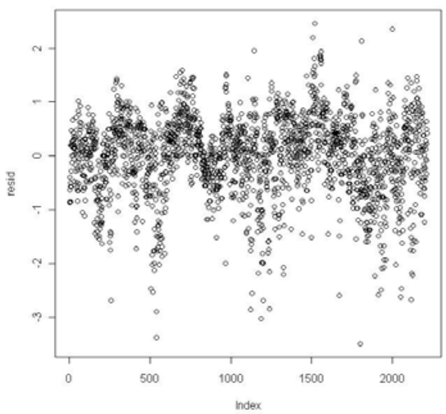
	Fall			Winter			Spring			Summer			Total
Year	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	
1977										5	25	30	30
1979				109	55	164							164
1983							522	637	1159				1159
1984							11	35	46				46
1989							257	368	625				625
1991							175	853	1028	198	427	625	1653
1993	43	139	182										182
1994										37	228	265	265
1998				893	1930	2823	254	814	1068	230	456	686	4577
1999				44	96	140							140
2000							196	1551	1747	14	88	102	1849
2001				240	905	1145	152	1077	1229				2374
2002				271	844	1115	524	2576	3100				4215
2003							373	1302	1675				1675
2005	40	236	276	81	470	551	57	411	468	25	73	98	1393
2006				602	1972	2574	139	460	599				3173
2007				58	321	379	130	411	541				920
2008				80	161	241							241
Total	83	375	458	2378	6754	9132	2790	10495	13285	509	1297	1806	24681

Appendix 4. Modelled Catch Rate

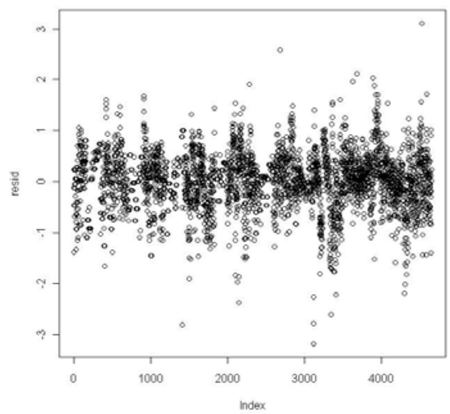
Appendix 4.1. Modelled Catch Rate Residual Plots

Winter

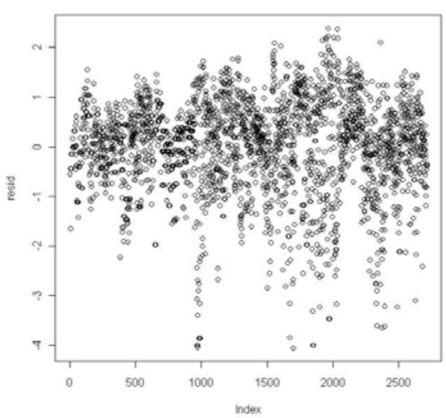
Crowell Basin



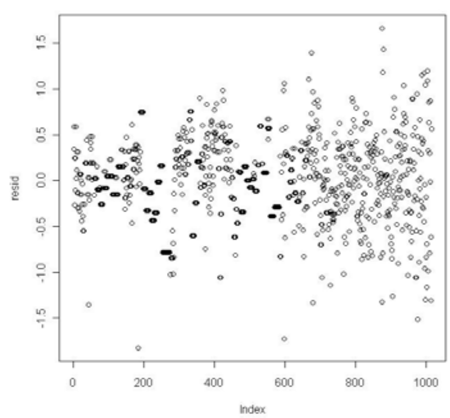
Southwest Browns



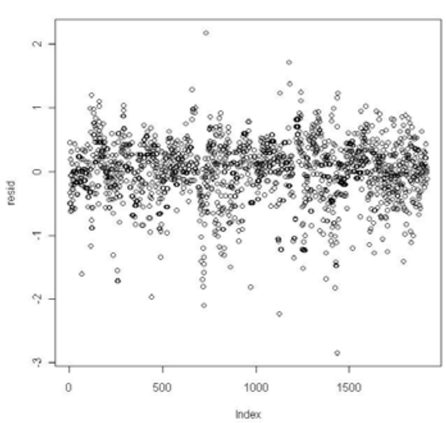
Southeast Browns



Georges Bank

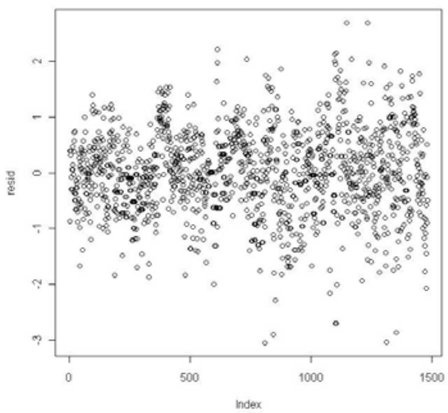


Georges Basin

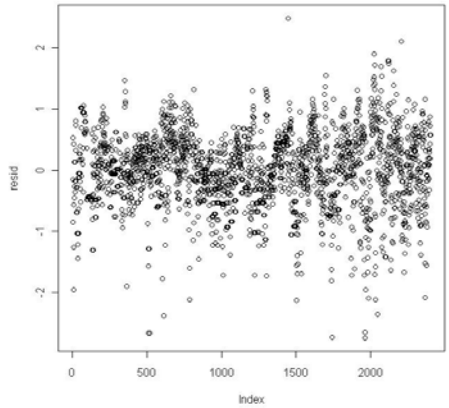


Summer

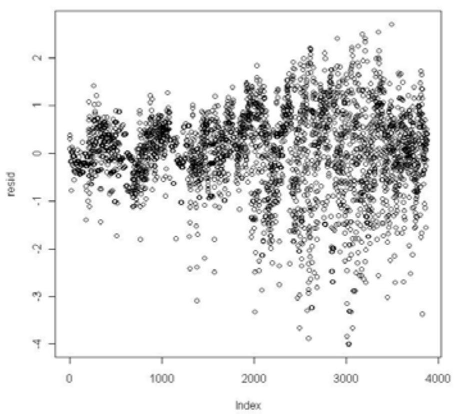
Crowell Basin



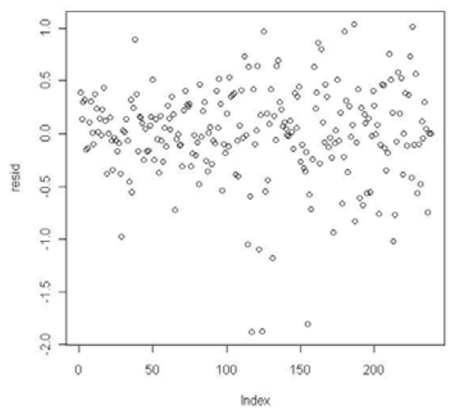
Southwest Browns



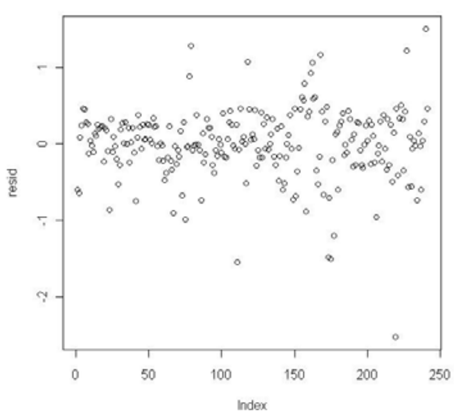
Southeast Browns



Georges Bank



Georges Basin



Appendix 4.2. Modelled Catch Rate: Coefficients and ANOVA Tables for each Model

Crowell Basin, Winter

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> crow.win.w.y.cfv = lm( lobcpue.model, data=lob.data.win.crow)
> summary(crow.win.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.win.crow)

Residuals:
    Min          1Q          Median      3Q         Max
-3.49483     -0.40834     0.08849     0.48403     2.46769

Coefficients:
                     Estimate    Std. Error   t value   Pr(>|t|)
(Intercept)          0.1457724   0.1374969    1.060     0.289177
weekofseason2        0.8468863   0.0669715    12.645    < 2e-16 ***
weekofseason3        1.0736658   0.0668984    16.049    < 2e-16 ***
weekofseason4        1.2405652   0.0691827    17.932    < 2e-16 ***
weekofseason5        1.2828848   0.0755340    16.984    < 2e-16 ***
weekofseason6        1.2242342   0.0871181    14.053    < 2e-16 ***
weekofseason7        0.7552192   0.0850175    8.883     < 2e-16 ***
weekofseason8        0.6123662   0.0828365    7.392     2.04e-13 ***
weekofseason9        0.6679220   0.0852841    7.832     7.45e-15 ***
weekofseason10       0.0641322   0.0825154    0.777     0.437116
weekofseason11       0.1228964   0.0770360    1.595     0.110787
weekofseason12       0.0004939   0.0860285    0.006     0.995420
weekofseason13       0.5981395   0.2705648    2.211     0.027159 *
fish.season1997-98   -0.5379182  0.1577022    -3.411    0.000659 ***
fish.season1998-99   -0.3519025  0.1591660    -2.211    0.027145 *
fish.season1999-00   0.2683744   0.1562553    1.718     0.086023 .
fish.season2000-01   0.1257615   0.1351943    0.930     0.352356
fish.season2001-02   0.0309118   0.1365580    0.226     0.820940
fish.season2002-03   0.4771731   0.1351305    3.531     0.000422 ***
fish.season2003-04   0.3036311   0.1373637    2.210     0.027180 *
fish.season2004-05   0.0598340   0.1420217    0.421     0.673576
fish.season2005-06   0.1063485   0.1659551    0.641     0.521703
fish.season2006-07   0.3184436   0.1815383    1.754     0.079547 .
fish.season2007-08   0.0004426   0.1986138    0.002     0.998222
CFV_NO1532           0.0636273   0.2416270    0.263     0.792322
CFV_NO1578           -0.3215814  0.0814465    -3.948    8.12e-05 ***
CFV_NO4005           -0.3756540  0.1096794    -3.425    0.000626 ***
CFV_NO4034           -0.9898383  0.0406780    -24.334   < 2e-16 ***
CFV_NO4056           0.1952301   0.1145465    1.704     0.088453 .
CFV_NO100989         -0.5634562  0.2502633    -2.251    0.024456 *
CFV_NO101315         -1.3049368  0.0763540    -17.091   < 2e-16 ***
CFV_NO129902         -0.8259270  0.1075379    -7.680    2.38e-14 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7444 on 2183 degrees of freedom
Multiple R-squared: 0.498,      Adjusted R-squared: 0.4908
F-statistic: 69.85 on 31 and 2183 DF,  p-value: < 2.2e-16

> Anova(crow.win.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
               Sum Sq     Df     F value    Pr(>F)
weekofseason   450.73     12     67.787     < 2.2e-16 ***
fish.season    104.77     11     17.190     < 2.2e-16 ***
CFV_NO         412.73     8      93.108     < 2.2e-16 ***
Residuals      1209.60    2183
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Crowell Basin, Summer

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> crow.sum.w.y.cfv = lm( lobcpue.model, data=lob.data.sum.crow)
> summary(crow.sum.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.sum.crow)

Residuals:
      Min        1Q    Median        3Q       Max
-3.052850 -0.448926 -0.008242  0.494207  2.692255

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      -0.42825    0.12084  -3.544 0.000407 ***
weekofseason2    -0.04464    0.08490  -0.526 0.599082
weekofseason3     0.15071    0.08876   1.698 0.089737 .
weekofseason4     0.24914    0.08883   2.805 0.005106 **
weekofseason5     0.30897    0.08107   3.811 0.000144 ***
weekofseason6     0.48258    0.09422   5.122 3.43e-07 ***
weekofseason7     0.42026    0.10638   3.951 8.17e-05 ***
weekofseason8     0.36938    0.09550   3.868 0.000115 ***
weekofseason9     0.20911    0.09963   2.099 0.035998 *
weekofseason10   -0.13713    0.10382  -1.321 0.186771
weekofseason11   -0.47864    0.11800  -4.056 5.25e-05 ***
weekofseason12   -0.70425    0.14164  -4.972 7.41e-07 ***
weekofseason13   -0.67851    0.11815  -5.743 1.13e-08 ***
weekofseason14   -0.19677    0.11664  -1.687 0.091825 .
weekofseason15   -0.22233    0.33790  -0.658 0.510658
fish.season1997-98 -0.60885    0.13530  -4.500 7.34e-06 ***
fish.season1998-99  0.23079    0.13280   1.738 0.082460 .
fish.season1999-00  0.36076    0.13277   2.717 0.006662 **
fish.season2000-01 -0.24257    0.11064  -2.192 0.028514 *
fish.season2001-02 -0.07483    0.11482  -0.652 0.514702
fish.season2002-03  0.61096    0.11357   5.380 8.69e-08 ***
fish.season2003-04  1.17525    0.14056   8.361  < 2e-16 ***
fish.season2004-05  0.89072    0.13416   6.639 4.44e-11 ***
fish.season2005-06  0.56189    0.35413   1.587 0.112802
fish.season2006-07  0.35570    0.35153   1.012 0.311773
CFV_NO1578       -0.15254    0.22702  -0.672 0.501747
CFV_NO4005       -0.30071    0.18106  -1.661 0.096958 .
CFV_NO4034       -0.94427    0.05920 -15.951  < 2e-16 ***
CFV_NO4056        0.33107    0.25961   1.275 0.202417
CFV_NO101315     -1.10781    0.08278 -13.383  < 2e-16 ***
CFV_NO129902     -0.02833    0.06577  -0.431 0.666674
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7643 on 1452 degrees of freedom
Multiple R-squared: 0.485,      Adjusted R-squared: 0.4743
F-statistic: 45.58 on 30 and 1452 DF,  p-value: < 2.2e-16

> Anova(crow.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason 128.24   14  15.682 < 2.2e-16 ***
fish.season  258.32   10  44.224 < 2.2e-16 ***
CFV_NO       195.34    6  55.736 < 2.2e-16 ***
Residuals    848.14 1452
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Southwest Browns, Winter

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> swbrns.win.w.y.cfv = lm( lobcpue.model, data=lob.data.win.swbrns)
> summary(swbrns.win.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.win.swbrns)

Residuals:
     Min       1Q   Median       3Q      Max 
-3.18666 -0.29514  0.04322  0.33818  3.11051 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)       -0.68839    0.10056  -6.845 8.63e-12 ***
weekofseason2      0.80589    0.02990  26.951  < 2e-16 ***
weekofseason3      1.23755    0.02870  43.116  < 2e-16 ***
weekofseason4      1.37298    0.02986  45.980  < 2e-16 ***
weekofseason5      1.20965    0.03101  39.007  < 2e-16 ***
weekofseason6      0.91263    0.03806  23.980  < 2e-16 ***
weekofseason7      0.71582    0.04152  17.239  < 2e-16 ***
weekofseason8      0.38355    0.05083   7.546 5.38e-14 ***
weekofseason9      0.26496    0.05722   4.631 3.74e-06 ***
weekofseason10    -0.04575    0.07479  -0.612 0.540728    
weekofseason11    -0.32196    0.06787  -4.744 2.16e-06 ***
weekofseason12     0.22685    0.08393   2.703 0.006896 ** 
weekofseason13    -1.55518    0.54786  -2.839 0.004551 ** 
fish.season1997-98  0.05663    0.09481   0.597 0.550372    
fish.season1998-99 -0.58782    0.08779  -6.696 2.40e-11 ***
fish.season1999-00  0.38342    0.09715   3.947 8.04e-05 ***
fish.season2000-01  0.38788    0.07377   5.258 1.52e-07 ***
fish.season2001-02  0.20938    0.07250   2.888 0.003895 ** 
fish.season2002-03  0.54553    0.07395   7.377 1.91e-13 ***
fish.season2003-04  0.33332    0.07366   4.525 6.19e-06 ***
fish.season2004-05 -0.18017    0.07423  -2.427 0.015257 *  
fish.season2005-06  0.31541    0.07421   4.250 2.18e-05 ***
fish.season2006-07  0.36707    0.07461   4.920 8.96e-07 ***
fish.season2007-08 -0.31125    0.07472  -4.166 3.16e-05 ***
CFV_NO1530         0.74646    0.10052   7.426 1.33e-13 ***
CFV_NO1532         0.82593    0.09977   8.278  < 2e-16 ***
CFV_NO1578         0.58789    0.10373   5.667 1.54e-08 ***
CFV_NO4005         0.41135    0.10134   4.059 5.00e-05 ***
CFV_NO4034         0.05070    0.10343   0.490 0.624017    
CFV_NO4056         0.73886    0.10235   7.219 6.10e-13 ***
CFV_NO100989       0.39520    0.10728   3.684 0.000232 ***
CFV_NO101315       0.14609    0.11188   1.306 0.191676    
CFV_NO129902       0.25307    0.10167   2.489 0.012844 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.5417 on 4617 degrees of freedom
Multiple R-squared: 0.5553,     Adjusted R-squared: 0.5523 
F-statistic: 180.2 on 32 and 4617 DF,  p-value: < 2.2e-16 

> Anova(swbrns.win.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
              Sum Sq   Df F value    Pr(>F)    
weekofseason 1074.14   12  305.01 < 2.2e-16 ***
fish.season   368.87   11  114.27 < 2.2e-16 ***
CFV_NO        322.91    9  122.26 < 2.2e-16 ***
Residuals    1354.96 4617                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
```

Southwest Browns, Summer

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> swbrns.sum.w.y.cfv = lm( lobcpue.model, data=lob.data.sum.swbrns)
> summary(swbrns.sum.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.sum.swbrns)

Residuals:
     Min       1Q   Median       3Q      Max 
-2.74567 -0.35317  0.02584  0.38956  2.80035 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)       -0.69294    0.10934  -6.338 2.78e-10 ***
weekofseason2      0.23674    0.09827   2.409 0.016069 *  
weekofseason3      0.06670    0.09038   0.738 0.460586    
weekofseason4      0.32237    0.08766   3.678 0.000241 ***
weekofseason5      0.81690    0.08489   9.623  < 2e-16 ***
weekofseason6      0.99412    0.08541  11.640  < 2e-16 ***
weekofseason7      0.86837    0.08200  10.590  < 2e-16 ***
weekofseason8      0.77696    0.08462   9.182  < 2e-16 ***
weekofseason9      0.66279    0.08338   7.949 2.88e-15 ***
weekofseason10     0.55712    0.08614   6.468 1.20e-10 ***
weekofseason11     0.60192    0.08955   6.721 2.25e-11 ***
weekofseason12     0.54106    0.09823   5.508 4.02e-08 ***
weekofseason13     0.24155    0.08883   2.719 0.006590 ** 
weekofseason14     0.18918    0.08125   2.328 0.019973 *  
weekofseason15     0.24669    0.13350   1.848 0.064744 .  
fish.season1997-98  0.41900    0.10425   4.019 6.02e-05 ***
fish.season1998-99  0.36667    0.10235   3.583 0.000347 ***
fish.season1999-00  0.50016    0.12234   4.088 4.49e-05 ***
fish.season2000-01  0.16877    0.11179   1.510 0.131243    
fish.season2001-02  0.56153    0.11120   5.050 4.77e-07 ***
fish.season2002-03  0.74158    0.11710   6.333 2.87e-10 ***
fish.season2003-04  0.90325    0.11361   7.951 2.84e-15 ***
fish.season2004-05  0.47662    0.11169   4.267 2.06e-05 ***
fish.season2005-06  0.72819    0.11402   6.387 2.03e-10 ***
fish.season2006-07  0.65011    0.11511   5.648 1.82e-08 ***
CFV_NO1530        -0.25854    0.10493  -2.464 0.013811 *  
CFV_NO1532         0.10950    0.10240   1.069 0.285027    
CFV_NO1578        -0.33679    0.10825  -3.111 0.001886 ** 
CFV_NO4005        -0.10107    0.12737  -0.793 0.427585    
CFV_NO4034        -0.43602    0.10469  -4.165 3.23e-05 ***
CFV_NO4056        -0.32701    0.12428  -2.631 0.008561 ** 
CFV_NO100989      -0.17908    0.14848  -1.206 0.227883    
CFV_NO101315      -0.28108    0.08487  -3.312 0.000941 ***
CFV_NO129902      -0.12282    0.09857  -1.246 0.212906    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 0.6015 on 2369 degrees of freedom
Multiple R-squared: 0.2838,     Adjusted R-squared: 0.2739 
F-statistic: 28.45 on 33 and 2369 DF,  p-value: < 2.2e-16 

> Anova(swbrns.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)    
weekofseason 186.16   14  36.755 < 2.2e-16 ***
fish.season   69.24   10  19.140 < 2.2e-16 ***
CFV_NO        41.33    9  12.695 < 2.2e-16 ***
Residuals    857.04 2369                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Southeast Browns, Winter

```
> # model with week and year  and cfv
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> sebrns.win.w.y.cfv = lm( lobcpue.model, data=lob.data.win.sebrns)
> summary(sebrns.win.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.win.sebrns)

Residuals:
    Min      1Q  Median      3Q     Max 
-4.0540 -0.4518  0.1249  0.6032  2.3916 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)         0.65275    0.48825   1.337 0.181368    
weekofseason2      -0.08036    0.09119  -0.881 0.378254    
weekofseason3       0.21940    0.09498   2.310 0.020962 *  
weekofseason4       0.60312    0.09657   6.245 4.90e-10 ***
weekofseason5       0.85583    0.10264   8.339  < 2e-16 ***
weekofseason6       0.82104    0.10766   7.626 3.34e-14 ***
weekofseason7       0.79396    0.10797   7.354 2.55e-13 ***
weekofseason8       0.89730    0.09513   9.432  < 2e-16 ***
weekofseason9       0.72799    0.09717   7.492 9.19e-14 ***
weekofseason10      0.48132    0.09357   5.144 2.88e-07 ***
weekofseason11      0.33661    0.08857   3.800 0.000148 ***
weekofseason12      0.20764    0.09162   2.266 0.023518 *  
fish.season1997-98 -0.61131    0.14662  -4.169 3.15e-05 ***
fish.season1998-99 -0.57930    0.14909  -3.885 0.000105 ***
fish.season1999-00 -0.10917    0.15075  -0.724 0.468999    
fish.season2000-01 -0.16581    0.11612  -1.428 0.153442    
fish.season2001-02 -0.62671    0.11410  -5.493 4.33e-08 ***
fish.season2002-03  0.43805    0.11940   3.669 0.000249 ***
fish.season2003-04  0.24392    0.12095   2.017 0.043832 *  
fish.season2004-05  0.43049    0.11991   3.590 0.000336 ***
fish.season2005-06  0.33587    0.12332   2.724 0.006498 ** 
fish.season2006-07  0.87968    0.12455   7.063 2.07e-12 ***
fish.season2007-08  0.37464    0.13480   2.779 0.005486 ** 
CFV_NO1532         -0.64027    0.47798  -1.340 0.180513    
CFV_NO1578         -0.92604    0.55880  -1.657 0.097594 .  
CFV_NO2735         -1.16252    0.57177  -2.033 0.042130 *  
CFV_NO4005         -0.38294    0.47651  -0.804 0.421680    
CFV_NO4034         -1.63441    0.48230  -3.389 0.000712 ***
CFV_NO4056         -0.16921    0.66694  -0.254 0.799734    
CFV_NO100989       -1.25799    0.47179  -2.666 0.007712 ** 
CFV_NO101315       -2.95835    0.55948  -5.288 1.34e-07 ***
CFV_NO129902       -0.60013    0.81278  -0.738 0.460352    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Southeast Browns, Summer

```
> # model with week and year  and cfv
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> sebrns.sum.w.y.cfv = lm( lobcpue.model, data=lob.data.sum.sebrns)
> summary(sebrns.sum.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.sum.sebrns)

Residuals:
     Min       1Q   Median       3Q      Max 
-4.00009 -0.38310  0.06147  0.52921  2.70972 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)        1.201360   0.220754   5.442 5.60e-08 ***
weekofseason2      0.002687   0.071262   0.038 0.969925    
weekofseason3      0.205782   0.069071   2.979 0.002907 ** 
weekofseason4      0.597135   0.069389   8.606  < 2e-16 ***
weekofseason5      0.673318   0.066982  10.052  < 2e-16 ***
weekofseason6      0.718391   0.065036  11.046  < 2e-16 ***
weekofseason7      0.594271   0.066498   8.937  < 2e-16 ***
weekofseason8      0.213094   0.071646   2.974 0.002955 ** 
weekofseason9      0.067122   0.080950   0.829 0.407054    
weekofseason10     0.241141   0.082483   2.924 0.003481 ** 
weekofseason11    -0.298435   0.088310  -3.379 0.000734 ***
weekofseason12    -0.187944   0.089462  -2.101 0.035720 *  
weekofseason13    -0.356310   0.094831  -3.757 0.000174 ***
weekofseason14    -0.663213   0.100660  -6.589 5.04e-11 ***
weekofseason15     0.532224   0.176987   3.007 0.002654 ** 
fish.season1997-98 -0.014779   0.107942  -0.137 0.891108    
fish.season1998-99 -0.006320   0.112015  -0.056 0.955010    
fish.season1999-00 -0.263919   0.108685  -2.428 0.015215 *  
fish.season2000-01 -0.915199   0.092293  -9.916  < 2e-16 ***
fish.season2001-02 -0.542981   0.090856  -5.976 2.49e-09 ***
fish.season2002-03 -0.009719   0.092001  -0.106 0.915877    
fish.season2003-04  0.510199   0.088752   5.749 9.70e-09 ***
fish.season2004-05  0.754250   0.087489   8.621  < 2e-16 ***
fish.season2005-06  0.735986   0.089888   8.188 3.58e-16 ***
fish.season2006-07  0.653898   0.090341   7.238 5.47e-13 ***
CFV_NO1532        -1.140541   0.211730  -5.387 7.60e-08 ***
CFV_NO1578        -1.870297   0.241768  -7.736 1.30e-14 ***
CFV_NO2735        -1.618693   0.214217  -7.556 5.15e-14 ***
CFV_NO4005        -0.880239   0.218985  -4.020 5.94e-05 ***
CFV_NO4034        -1.922366   0.215541  -8.919  < 2e-16 ***
CFV_NO4056        -1.154325   0.483865  -2.386 0.017098 *  
CFV_NO100989      -1.765107   0.209092  -8.442  < 2e-16 ***
CFV_NO101315      -2.336684   0.336160  -6.951 4.24e-12 ***
CFV_NO129902      -1.615459   0.886766  -1.822 0.068572 .  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.8594 on 3842 degrees of freedom
Multiple R-squared: 0.4547,     Adjusted R-squared:  0.45 
F-statistic: 97.07 on 33 and 3842 DF,  p-value: < 2.2e-16 

> Anova(sebrns.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
              Sum Sq   Df F value    Pr(>F)    
weekofseason  470.57   14  45.507 < 2.2e-16 ***
fish.season   938.01   10 126.997 < 2.2e-16 ***
CFV_NO        359.61    9  54.097 < 2.2e-16 ***
Residuals    2837.72 3842                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Georges Bank, Winter

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> gbank.win.w.y.cfv = lm( lobcpue.model, data=lob.data.win.gbank)
> summary(gbank.win.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.win.gbank)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.82651 -0.26263  0.02384  0.27534  1.66679 

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)    
(Intercept)      -0.86513    0.09024  -9.587  < 2e-16 ***
weekofseason2     0.90902    0.06135  14.818  < 2e-16 ***
weekofseason3     1.10003    0.07545  14.579  < 2e-16 ***
weekofseason4     1.29951    0.09801  13.260  < 2e-16 ***
weekofseason5     1.22819    0.12933   9.496  < 2e-16 ***
weekofseason6     1.17327    0.11564  10.146  < 2e-16 ***
weekofseason7     1.02575    0.08346  12.290  < 2e-16 ***
weekofseason8     1.08568    0.06792  15.986  < 2e-16 ***
weekofseason9     0.90609    0.06528  13.881  < 2e-16 ***
weekofseason10    0.68059    0.06085  11.185  < 2e-16 ***
weekofseason11    0.72742    0.05578  13.040  < 2e-16 ***
weekofseason12    0.64378    0.05481  11.745  < 2e-16 ***
fish.season1997-98  0.97648    0.11914   8.196 7.67e-16 ***
fish.season1998-99  0.49568    0.11500   4.310 1.79e-05 ***
fish.season1999-00  1.15877    0.11711   9.895  < 2e-16 ***
fish.season2000-01  0.83323    0.09298   8.961  < 2e-16 ***
fish.season2001-02  0.98361    0.08721  11.279  < 2e-16 ***
fish.season2002-03  1.23681    0.09921  12.467  < 2e-16 ***
fish.season2003-04  1.14871    0.09466  12.135  < 2e-16 ***
fish.season2004-05  1.31650    0.09122  14.433  < 2e-16 ***
fish.season2005-06  1.00642    0.07839  12.839  < 2e-16 ***
fish.season2006-07  1.27439    0.08887  14.341  < 2e-16 ***
fish.season2007-08  1.10868    0.08674  12.782  < 2e-16 ***
CFV_NO1532       -0.12570    0.04336  -2.899  0.00383 ** 
CFV_NO1578       -0.78430    0.46330  -1.693  0.09080 .  
CFV_NO4005       -0.03164    0.13731  -0.230  0.81781    
CFV_NO4034       -0.59543    0.07407  -8.039 2.58e-15 ***
CFV_NO4056        0.12849    0.06530   1.968  0.04939 *  
CFV_NO100989     -1.32485    0.16245  -8.155 1.05e-15 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 0.449 on 987 degrees of freedom
Multiple R-squared: 0.5624,     Adjusted R-squared:  0.55 
F-statistic: 45.31 on 28 and 987 DF,  p-value: < 2.2e-16 

> Anova(gbank.win.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
              Sum Sq  Df F value    Pr(>F)    
weekofseason 101.962  11  45.971 < 2.2e-16 ***
fish.season   63.325  11  28.551 < 2.2e-16 ***
CFV_NO        29.059   6  24.020 < 2.2e-16 ***
Residuals    199.010 987                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Georges Bank, Summer

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> gbank.sum.w.y.cfv = lm( lobcpue.model, data=lob.data.sum.gbank)
> summary(gbank.sum.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.sum.gbank)

Residuals:
     Min       1Q   Median       3Q      Max
-3.30591 -0.24008  0.01748  0.30001  2.16649

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         0.44642    0.07681   5.812 7.11e-09 ***
weekofseason2       0.06198    0.05299   1.170 0.242277
weekofseason3       0.04575    0.04955   0.923 0.355911
weekofseason4       0.19591    0.04980   3.934 8.62e-05 ***
weekofseason5       0.23954    0.04896   4.893 1.07e-06 ***
weekofseason6       0.14225    0.05215   2.728 0.006434 **
weekofseason7      -0.16125    0.05805  -2.778 0.005520 **
weekofseason8      -0.71900    0.06286 -11.439  < 2e-16 ***
weekofseason9      -0.91047    0.06753 -13.482  < 2e-16 ***
weekofseason10     -1.26653    0.10161 -12.465  < 2e-16 ***
weekofseason11     -1.21215    0.16638  -7.285 4.50e-13 ***
weekofseason12     -1.20320    0.09755 -12.334  < 2e-16 ***
weekofseason13     -1.51719    0.07773 -19.518  < 2e-16 ***
weekofseason14     -1.05633    0.09412 -11.224  < 2e-16 ***
weekofseason15     -0.87899    0.12947  -6.789 1.46e-11 ***
fish.season1997-98  0.05732    0.08790   0.652 0.514357
fish.season1998-99  0.40944    0.08468   4.835 1.43e-06 ***
fish.season1999-00  0.27461    0.08438   3.255 0.001154 **
fish.season2000-01 -0.41262    0.06492  -6.356 2.53e-10 ***
fish.season2001-02 -0.05103    0.06409  -0.796 0.426056
fish.season2002-03 -0.14464    0.07337  -1.971 0.048820 *
fish.season2003-04  0.68971    0.07456   9.251  < 2e-16 ***
fish.season2004-05  0.79632    0.06501  12.248  < 2e-16 ***
fish.season2005-06  0.45020    0.07057   6.379 2.18e-10 ***
fish.season2006-07  0.58397    0.06963   8.387  < 2e-16 ***
CFV_NO1532         -0.10159    0.03543  -2.867 0.004180 **
CFV_NO1578         -0.60577    0.17003  -3.563 0.000375 ***
CFV_NO4005          0.32826    0.07952   4.128 3.81e-05 ***
CFV_NO4034         -0.70599    0.08068  -8.751  < 2e-16 ***
CFV_NO4056          0.05425    0.04997   1.086 0.277820
CFV_NO100989       -1.81083    0.38247  -4.735 2.34e-06 ***
CFV_NO101315       -1.30603    0.37871  -3.449 0.000575 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5299 on 2114 degrees of freedom
Multiple R-squared: 0.6183,     Adjusted R-squared: 0.6127
F-statistic: 110.5 on 31 and 2114 DF,  p-value: < 2.2e-16

> Anova(gbank.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason 433.07   14 110.174 < 2.2e-16 ***
fish.season  217.43   10  77.440 < 2.2e-16 ***
CFV_NO        49.47    7  25.171 < 2.2e-16 ***
Residuals    593.55 2114
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Georges Basin, Winter

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> gbasin.win.w.y.cfv = lm( lobcpue.model, data=lob.data.win.gbasin)
> summary(gbasin.win.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.win.gbasin)

Residuals:
    Min      1Q  Median      3Q     Max
-2.8448 -0.2334  0.0445  0.2958  2.1790

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       -0.197748   0.188078  -1.051 0.293203
weekofseason2      0.565956   0.204462   2.768 0.005695 **
weekofseason3      1.334929   0.195573   6.826 1.18e-11 ***
weekofseason4      1.422029   0.195022   7.292 4.48e-13 ***
weekofseason5      1.124335   0.178606   6.295 3.81e-10 ***
weekofseason6      1.159702   0.174250   6.655 3.69e-11 ***
weekofseason7      1.185379   0.173347   6.838 1.08e-11 ***
weekofseason8      1.113477   0.172414   6.458 1.34e-10 ***
weekofseason9      1.068655   0.172618   6.191 7.32e-10 ***
weekofseason10     0.782764   0.172802   4.530 6.27e-06 ***
weekofseason11     0.865285   0.172130   5.027 5.46e-07 ***
weekofseason12     0.828287   0.172218   4.810 1.63e-06 ***
fish.season1997-98 -0.206169   0.113303  -1.820 0.068975 .
fish.season1998-99 -0.331906   0.107728  -3.081 0.002093 **
fish.season1999-00 -0.009345   0.122305  -0.076 0.939106
fish.season2000-01  0.263712   0.081997   3.216 0.001321 **
fish.season2001-02  0.072743   0.079414   0.916 0.359786
fish.season2002-03  0.696411   0.091771   7.589 5.05e-14 ***
fish.season2003-04  0.635725   0.104762   6.068 1.56e-09 ***
fish.season2004-05  0.422847   0.084125   5.026 5.47e-07 ***
fish.season2005-06  0.441272   0.084569   5.218 2.01e-07 ***
fish.season2006-07  0.494200   0.086817   5.692 1.45e-08 ***
fish.season2007-08  0.297433   0.085184   3.492 0.000491 ***
CFV_NO1532        -0.187935   0.036196  -5.192 2.30e-07 ***
CFV_NO1578        -0.438633   0.034005 -12.899  < 2e-16 ***
CFV_NO4005        -0.744094   0.094764  -7.852 6.81e-15 ***
CFV_NO4034        -1.264204   0.087676 -14.419  < 2e-16 ***
CFV_NO4056         0.159696   0.045396   3.518 0.000445 ***
CFV_NO100989      -0.539171   0.044704 -12.061  < 2e-16 ***
CFV_NO129902      -0.633210   0.089430  -7.081 2.02e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4779 on 1887 degrees of freedom
Multiple R-squared: 0.3907,     Adjusted R-squared: 0.3813
F-statistic: 41.72 on 29 and 1887 DF,  p-value: < 2.2e-16

> Anova(gbasin.win.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason  53.63   11  21.348 < 2.2e-16 ***
fish.season   63.22   11  25.168 < 2.2e-16 ***
CFV_NO       126.29    7  79.002 < 2.2e-16 ***
Residuals    430.92 1887
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Georges Basin, Summer

```
> lobcpue.model = as.formula( "log(LOB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> gbasin.sum.w.y.cfv = lm( lobcpue.model, data=lob.data.sum.gbasin)
> summary(gbasin.sum.w.y.cfv)

Call:
lm(formula = lobcpue.model, data = lob.data.sum.gbasin)

Residuals:
     Min       1Q   Median       3Q      Max 
-2.82828 -0.20068  0.05926  0.29626  2.05685 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)        0.296755   0.193421   1.534  0.12513    
weekofseason2      0.009083   0.035225   0.258  0.79654    
weekofseason3      0.207341   0.032705   6.340 2.83e-10 ***
weekofseason4      0.277999   0.035668   7.794 1.03e-14 ***
weekofseason5      0.158233   0.038908   4.067 4.95e-05 ***
weekofseason6      0.275628   0.053281   5.173 2.53e-07 ***
weekofseason7      0.178291   0.080035   2.228  0.02601 *  
weekofseason8     -0.199378   0.098317  -2.028  0.04270 *  
weekofseason9     -0.564275   0.115913  -4.868 1.21e-06 ***
weekofseason10    -1.102522   0.103948 -10.607  < 2e-16 ***
weekofseason11    -1.025513   0.147529  -6.951 4.87e-12 ***
weekofseason12    -2.489412   0.244665 -10.175  < 2e-16 ***
weekofseason13    -0.972489   0.141614  -6.867 8.68e-12 ***
weekofseason14    -1.314648   0.146822  -8.954  < 2e-16 ***
fish.season1997-98 -0.183962   0.101259  -1.817  0.06940 .  
fish.season1998-99 -0.231561   0.103660  -2.234  0.02560 *  
fish.season1999-00  0.108364   0.106897   1.014  0.31083    
fish.season2000-01  0.321943   0.086104   3.739  0.00019 ***
fish.season2001-02  0.176095   0.087789   2.006  0.04500 *  
fish.season2002-03  0.086378   0.094867   0.911  0.36266    
fish.season2003-04  0.839759   0.086732   9.682  < 2e-16 ***
fish.season2004-05  0.415331   0.087262   4.760 2.08e-06 ***
fish.season2005-06  0.278638   0.088069   3.164  0.00158 ** 
fish.season2006-07  0.442591   0.088536   4.999 6.26e-07 ***
CFV_NO1530          0.205475   0.175501   1.171  0.24182    
CFV_NO1532          0.010793   0.178342   0.061  0.95175    
CFV_NO1578         -0.267284   0.177442  -1.506  0.13214    
CFV_NO4005          0.587374   0.187078   3.140  0.00172 ** 
CFV_NO4034         -0.585183   0.178063  -3.286  0.00103 ** 
CFV_NO4056          0.414461   0.178493   2.322  0.02033 *  
CFV_NO100989       -0.196946   0.186839  -1.054  0.29196    
CFV_NO101315       -0.639506   0.230636  -2.773  0.00561 ** 
CFV_NO129902       -0.221928   0.183503  -1.209  0.22665    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.479 on 2021 degrees of freedom
Multiple R-squared: 0.5339,     Adjusted R-squared: 0.5266 
F-statistic: 72.35 on 32 and 2021 DF,  p-value: < 2.2e-16 

> Anova(gbasin.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(LOB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)    
weekofseason 135.80   13  45.526 < 2.2e-16 ***
fish.season   98.17   10  42.783 < 2.2e-16 ***
CFV_NO       150.02    9  72.647 < 2.2e-16 ***
Residuals    463.72 2021                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
```