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Assessment of the LFA 41 Offshore Jonah Crab (*Cancer borealis*) (NAFO 4X and 5Zc)

Évaluation des stocks de crabe nordique (*Cancer borealis*) extracôtiers de la ZPH 41 (division 4X et sous-division 5Zc de l'OPANO)

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ABSTRACT

The offshore Jonah crab fishery began in 1995 when a 720t Total Allowable Catch (TAC) was established for the Lobster Fishing Area (LFA) 41 lobster fishery. The species is fished as a by-catch in the lobster fishery and by vessels targeting the crab. The offshore lobster fishery (LFA 41), established in 1972, fishes from the 50 nautical mile line (92 km) out to the upper continental slope. While LFA 41 includes parts of NAFO areas 4Vs, 4W, 4X and 5Z, historically fishing only occurs in 4X and 5Zc.

The status of the Jonah crab stocks in LFA 41 was last assessed in 2000, and the Jonah crab fishery presently operates under the 2006-2010 Integrated Harvesting Plan as a male only fishery with a minimum size of 130mm Carapace Width (CW) fished by 8 licences and a TAC of 720t. Since the 1960s, Jonah crab stocks have been exploited as a trap by-catch to inshore and offshore lobster fisheries. Accurate landings are not available from these early fisheries. In the early 1980s, an experimental Jonah crab fishery concentrating in LaHave and Emerald basins on the Scotian Shelf lasted only two years, before poor economic conditions resulted in the fishery closure.

The development of the LFA 41 Jonah crab by-catch fishery in 1995 resulted in more widespread fishing activity within the traditional offshore area as vessels fished further east where crab concentrations were present. An experimental Jonah crab fishery took place in 4W between 1999 and 2002. Inshore Jonah crab fisheries also developed in LFAs 33 and 34. After initial high landings these fisheries have declined since 2000 with little or no activity in 2007 or 2008.

The 720t Jonah crab TAC was obtained or nearly obtained between the 1996-1997 and 2000-2001 seasons. Landings then declined sharply with 14t landed in 2007. At present there is no directed fishery.

The abundance indicators (standardized and non-standardized Catch Per Unit Effort (CPUE)), suggest that Jonah crab abundance in LFA 41 has declined since the fishery began in 1995. Adjusted mean stratified number per tow in the DFO Research Vessel (RV) bottom trawl surveys also show a general declining trend in all the strata fished in LFA 41. This is in contrast to the lack of a declining trend in areas adjacent to LFA 41. The decline is sharpest in the 1999-2002 period in the strata corresponding to Crowell Basin and Georges Basin. The time series of the trawl surveys is short (1999-present) and issues of catchability, trawlable bottom and the variance around the mean values needs to be further evaluated.

The time series of at-sea samples and DFO RV surveys are too short to evaluate production or recruitment trends for Jonah crab in LFA 41

The causes of the decline in Jonah crab abundance indicators cannot be given with certainty, but it appears that low (relative to most fisheries) fishing pressure has contributed to a substantial reduction in the biomass that was present at the start of the fishery and the TAC of 720t set in 1995 does not appear to have been sustainable. Future Jonah crab fisheries will

have to rely on annual recruitment and growth. Females are not allowed to be retained regardless of size and, therefore, the potential reproductive capacity of females is protected as long as there are sufficient males available and discards are low. At present there is no directed fishery, and the abundance indices from the DFO RV survey will be used to follow the recovery. Other information sources may also be examined, including by-catch recorded in the offshore lobster fishery and water temperature over the shelf.

RÉSUMÉ

La pêche hauturière du crabe nordique a commencé en 1995, lorsqu'un total autorisé de captures (TAC) de 720 t a été établi pour cette espèce dans le cadre de la pêche du homard dans la zone de pêche du homard (ZPH) 41. L'espèce est capturée accessoirement dans la pêche du homard et aussi dans la pêche dirigée du crabe. La pêche hauturière du homard (ZPH 41), créée en 1972, est pratiquée à partir de la limite des 50 milles marins (92 km) jusqu'au haut du talus continental. Bien que la ZPH 41 englobe des parties des divisions et sous-divisions 4Vs, 4W, 4X et 5Z de l'OPANO, cette pêche s'est toujours limitée à 4X et 5Zc.

La dernière évaluation de l'état des stocks de crabe nordique de la ZPH 41 remonte à 2000 et la pêche de ce crabe se limite actuellement, en vertu du Plan de pêche intégrée de 2006-2010, aux crabes mâles dont la largeur de carapace (LC) est d'au moins 130 mm; cette pêche est pratiquée par 8 titulaires de permis, qui exploitent un TAC de 720 t. Depuis les années 1960, les stocks de crabe nordique ont été exploités sous forme de captures accessoires dans la pêche côtière et la pêche hauturière du homard. On n'a pas de données exactes sur les débarquements de ces premières pêches. Au début des années 1980, une pêche expérimentale du crabe nordique, concentrée sur les bassins LaHave et Émeraude du plateau néo-écossais, a été amorcée, mais elle n'a duré que deux ans et les piètres conditions économiques ont entraîné sa fermeture.

Le développement de la pêche accessoire du crabe nordique dans la ZPH 41 en 1995 s'est traduit par une activité plus étendue au sein des zones de pêche traditionnelles, les navires allant pêcher plus à l'est, là où le crabe était concentré. Une pêche expérimentale du crabe nordique a été entreprise dans 4W entre 1999 et 2002. Par ailleurs, des pêches côtières du crabe nordique ont également vu le jour dans les ZPH 33 et 34. Après avoir connu de forts débarquements au début, ces pêches ont décliné à partir de 2000 et l'activité y était faible ou inexistante en 2007 ou 2008.

Le TAC de crabe nordique de 720 t a été pêché intégralement ou presque entre les saisons 1996-1997 et 2000-2001. Les débarquements ont ensuite diminué brusquement, ne dépassant pas 14 t en 2007. Actuellement, il n'y a pas de pêche dirigée de ce crabe.

Les indicateurs d'abondance (captures, standardisées et non standardisées, par unité d'effort [CPUE]) laissent croire que l'abondance de crabe nordique dans la ZPH 41 a diminué depuis le début de la pêche, en 1995. Le nombre moyen stratifié et rajusté de crabes nordiques par trait dans les relevés par navire scientifique (NS) dénote aussi une baisse générale dans toutes les strates exploitées dans la ZPH 41. Cela contraste avec l'absence de baisse apparente dans les secteurs adjacents à la ZPH 41. Le déclin le plus marqué est celui qui a été observé de 1999 à 2002 dans la strate correspondant au bassin Crowell et au bassin Georges. La série chronologique des relevés au chalut est courte (de 1999 à nos jours) et il y a lieu d'étudier plus à fond les questions de capturabilité, de fonds chalutables et d'écart par rapport aux valeurs moyennes.

Les séries chronologiques d'échantillonnages en mer et de relevés NS du MPO sont trop courtes pour qu'on puisse évaluer les tendances de la production ou du recrutement du crabe nordique dans la ZPH 41.

Les causes du déclin des indicateurs de l'abondance du crabe nordique ne peuvent être établies avec certitude, mais il semble que la faible pression de pêche (par rapport à la plupart des autres pêches) ait contribué à une réduction notable de la biomasse qui était présente au début de la pêche et le TAC de 720 t fixé en 2005 ne semble pas être viable. Les futures

pêches du crabe nordique devront dépendre de la croissance et du recrutement annuels. Indépendamment de leur taille, les femelles doivent être remises à l’eau; par conséquent, leur capacité de reproduction éventuelle est protégée, pour autant que les mâles soient en nombre suffisant et les rejets faibles. Actuellement, il n’y a pas de pêche dirigée de l’espèce et les indices d’abondance provenant du relevé NS du MPO serviront à surveiller le rétablissement des stocks. D’autres sources d’information pourront aussi être utilisées, comme les captures accessoires enregistrées dans la pêche hauturière du homard et les températures de l’eau sur le plateau néo écossais.

INTRODUCTION

Overview of the Fishery

The offshore lobster fishery (LFA 41) established in 1972, fishes from the 50 nautical mile line (92km) to the upper continental slope. A unique feature of the Gulf of Maine lobster fisheries is the presence of a deepwater component due to the warm year-round bottom temperatures in the basins of the Gulf of Maine and along the upper continental slope. While LFA 41 includes parts of NAFO areas 4Vs, 4W, 4X and 5Z, historically fishing only occurs in 4X and 5Zc.

Since the 1960s, Jonah crab stocks have been exploited as a trap by-catch to inshore and offshore lobster fisheries (Robichaud et al. 2000; Robichaud and Frail 2006). Accurate landing figures are not available from these early fisheries. In the early 1980s, an experimental Jonah crab fishery concentrating in LaHave and Emerald basins on the Scotian Shelf lasted only two years. Average catch rates were 6.6 Kg/trap haul (TH) in 1983 and 13.3 Kg/TH in 1984, before poor economic conditions resulted in the fishery closure. The last directed research trapping surveys for Jonah crab were conducted in 1981 prior to the establishment of the Jonah crab fishery.

The offshore Jonah crab fishery began in 1995 when a 720t TAC was established for Jonah crab in the LFA 41 fishery. The species is fished as a by-catch in the lobster fishery and by vessels targeting the crab. The development of the LFA 41 Jonah crab by-catch fishery in 1995 resulted in more widespread fishing activity within the traditional offshore area as vessels fished further east where crab concentrations were present. An experimental Jonah crab fishery took place in 4W between 1999 and 2002.

Lobster Fishing Area (LFA) 41, off Southwest Nova Scotia (Figure 1) is conducted by 8 licenses fished under a Total Allowable Catch (TAC) of 720t lobster and 720t Jonah crab. The fishery is managed by input and output controls including a minimum size carapace width (CW), prohibition on landing females, limited entry, and a TAC.

Season:	Year-round quota year Jan1st - Dec 31st
Minimum Legal Size:	130mm carapace length (CL) male only
Trap Limit:	None
No. Licences:	8

The development of the LFA 41 Jonah crab by-catch fishery in 1995 resulted in more widespread fishing activity within the traditional offshore area as vessels fished further east where crab were present. An experimental Jonah crab fishery took place in 4W between 1999 and 2002. Inshore Jonah crab fisheries also developed in LFA 33 and 34.

The last assessment of the offshore Jonah crab fishery was in 2000 (SSR C3-68 (2000)).

Biology

The habitat preferred by Jonah crab varies from rocky substrates in Narragansett Bay (Jeffries 1966) and the coast of Maine (Krouse 1980), to silt and clay bottom on the continental slope (Musick and McEachran 1972; Wenner et al. 1992). Jonah crab (*Cancer borealis*) can be found from Newfoundland to Florida, and in the Bermudas, at depths ranging from the intertidal to 800m (Haefner 1977; Stehlik et al. 1991; Wenner et al. 1992) Off Nova Scotia, they are found primarily at depths of 50-300m and temperatures of 8-14 ºC. Inshore movement from spring through fall, followed in winter by emigration to deeper, warmer waters have been reported off

Rhode Island. Size and sexual segregation with depth were reported in Norfolk Canyon where smaller-sized (<30mm CW) females were dominant at depths less than 150m, and males were most abundant at depths over 150m (Carpenter 1978).

Very little biological information exists for Jonah crab in waters off Nova Scotia. Knowledge of life history is geographically limited to waters off New England and Chesapeake Bay. In Norfolk Canyon, off the mouth of Chesapeake Bay, Virginia, males mature at 90-100mm CW, and female Jonah crabs mature at 85mm CW (Carpenter 1978; Wenner et al. 1992) (Carpenter 1978). Preliminary analysis of Jonah crab maturity on the Scotian Shelf have shown that the size at 50% morphometric maturity (or functional maturity) for males occurred at 128mm CW and the size of 50% gonadal maturity occurred at 69mm CW. (Moriyasu et al. 2002). This size at maturity is much larger than the previous assumption of 110mm CW. The estimated size of 50% maturity for females occurred at 92mm CW (Mikio Moriyasu, unpublished data).

Males can reach a maximum CW of 222mm (Robichaud et al. 2000; Robichaud et al. 2000). Females usually do not exceed 150mm CW. Ovigerous females as small as 65mm CW have been reported on the Scotian Shelf. Ovigerous females have been found during August and September in Maine and in mid-July in Narragansett Bay. The spawning period in the Middle Atlantic Bight is suggested to be during late winter to early spring.

METHODS / DATA DESCRIPTION

Sources of Information

1. Lobster log books (1995-2008) that provide daily records (1995-2000), and string by string records of catch, effort and location (2001-2008).
2. At-sea samples of the commercial catch (1995-2008).
3. Canadian Research Vessel (RV) stratified random trawl survey: Scotian Shelf, summer (1999-2008).

Indicators

The Jonah crab assessment makes use of indicators used in recent lobster assessments. 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 used to evaluate the status of the lobster stock and 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 Peer Review 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.

Abundance (legal sizes):

- Landings
- Commercial Catch Per Unit Effort (CPUE) (weight per trap haul)
- Catch rate in RV stratified random trawl surveys

Fishing pressure:

- Fishing effort
- Exploitation rates
- Changes in size frequencies
- Sex ratios

Production/recruitment:

- Levels of prerecruits
- Proportion of mature and multiparous females

Ecosystem/environment:

- Interactions with other species, habitat and the ecosystem
- By-catch 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 (Total Allowable Catch), EA (Enterprise Allocation) and the International Court of Justice (ICJ) Canada/USA boundary settlement; negative ("--") if values were less or trends were negative in this period; and neutral ("o") if otherwise.

Landings and Effort Data

Catch, effort and location information has been provided from the LFA 41 Jonah crab fishery since it began in 1995. This fishery has been under 100% dockside monitoring for its entirety.

Jonah crab catch and effort data from 1995 to 2001 were accessed from Oracle database tables created by DFO's Marine Fisheries Division from data compiled by DFO Statistics Branch into the ZIFF (Zonal Interchange File Format) database. As of 2002, Jonah crab data 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 have provided the same basic information. This includes date, location, and depth fished as well as traps hauled, soak days and estimated catch. This information is generally provided on a string by string basis, but was only provided on a daily basis in the earlier years of the fishery. In 2001, the log was modified to capture both the lobster and Jonah crab fishing activity occurring during a fishing trip (Appendix1, current fishing log). Upon landing, the catch was weighed and 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 which was based on TAC year, (Oct. 16th -Oct. 15th) from 1995/96 to 2004/2005 and calendar year since 2006. During the transition from TAC year to calendar year in 2004/2005, there was a 14.5 month season with a prorated TAC for that period.

The logbooks do not identify if the string of traps is targeting lobster or crab; therefore, any strings with crab landings reported are used in determining the number of trap hauls. This may over estimate effort levels.

Analyses of log data were traditionally conducted by assigning catches and effort to 5 areas. These areas were: (1) Crowell Basin, (2) Southwest Browns, (3) Georges Basin, (4) Southeast Browns, and (5) Georges Bank (Figure 2). The five areas represent the traditional lobster grounds and have been used in the past (Pezzack and Duggan 1985; Pezzack and Duggan 1987; Pezzack and Duggan 1988; Pezzack and Duggan 1995; 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 these areas have been redefined by 10-minute grid square groupings (Figure 3) which are slightly different from the traditional offshore areas.

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 was mapped and obvious location errors were identified and fixed by referring to log records or looking and previous or post fishing trips by that vessel.

Effort

For certain vessels, trap hauls were not recorded consistently. By looking at the fishing history of these vessels, it was decided to fill in 100 trap hauls per string for these cases.

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

All records were flagged in the extracted data file where corrections where made.

Expanding Symbol Plots of Landings, Effort and CPUE

Expanding symbol plots were completed of the log data for the 1995/96 season to 2007. For crab landings and effort, all trips were plotted regardless of the amount of lobster landed. For crab CPUE, only data where crab landings were not zero and trap hauls were not zero were used (48% of records), regardless of the associated lobster 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.

Within-Year Fishing Periods: Winter, Summer

There are two distinct periods of fishing effort in LFA 41. To account for this, each fishing season was divided into two periods. These fishing periods are used in the CPUE modeling.

Winter – October 16th to April 1st

Summer – April 2nd to October 15th

Modeled CPUE

The datasets used for the following analyses are outlined previously in Landings and Effort Data section of the **METHODS / DATA DESCRIPTION**. The selected time series ran from October 1996 to April 2008. All records that did not contain trap haul and/or Jonah crab catch information were removed (approximately 46% of total records; note original dataset contained both lobster and Jonah crab catch information). Records with Jonah crab 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 how the data is collected) when Jonah crab was the directed species. A modification to the log record indicating the directed species for each string would be greatly beneficial to these analyses by clearly identifying directed activity versus retained by-catch of crab.

Subsets by area (five in total) and seasonal period (spring/summer and fall/winter) were created prior to modeling 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 50 traps. In some cases individual strings were not distinguished on a log record and we had to treat these groups of strings as one for the purposes of the analysis.

A total of 10 data subsets were individually modeled. This strategy was adopted to follow previous analyses (Claytor et al. 2001). These catch rates were log-transformed and became the response variable for multiplicative model catch rate analyses (see 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 and vessel (as factors). The general form of the model is given by:

$$log(cpue)ijk \sim 2wk.periodi+fishing.seasonj+vesselk$$

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 2-week period.

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) for lobsters; carapace width for crab; sex; egg presence and stage; shell hardness; occurrence of culls (lobster only) and v-notches (lobster only); and number, location and depth of traps.

At-sea sampling provides detailed information on lobster and crab size-structure in the traps (including sub-legal, berried, and soft-shelled animals).

Since 1995 the offshore license holders have funded sampling and in 1997 a plan to obtain one sample per assessment subarea per quarter was initiated. The first at-sea sampling for Jonah crab was in 1999. At this time, the samples were dedicated to one species only, so during these trips, only crabs were measured (10 trips, 15,834 crabs). From 2001 to present, to increase efficiency of the sampling trips, both lobster and crabs were measured during the same trip. This resulted in 95 trips where Jonah crabs were measured with a total of 47,705 crab measurements (Appendix 2). Figure 4 shows the overall distribution of these samples. At-sea sampling data is stored in the Crustacean Research Information System (CRIS), an Oracle database. This data was extracted from 1972 to present (lobster) and 1999 to present (Jonah crab) and grouped by the offshore 10-minute grid groupings (Figure 3)

DFO Research Vessel (RV) Bottom Trawl Surveys

Beginning in 1999 select invertebrates began to be systematically recorded in annual summer (July) bottom trawl surveys (also known as Ecosystem Surveys) of the Scotian Shelf (Figure 5). 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).

The ecosystem survey design is stratified random 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 Jonah crab and lobsters where 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 Center (VDC). Data corresponding to LFA 41 and parts of LFA 34 were extracted and summarized.

Bottom trawl survey indices are the sum of mean numbers per tow for all length groups.

ABUNDANCE

Landings

Crab landings are presented in Table 1 and Figure 6 (Gulf of Maine/SE Browns/ Georges Bank) and Figure 7 (by subareas). Monthly landings a presented in Figure 8 (total) and Figure 9 (assessment subareas).

Crab landings rose rapidly at the start of the fishery in 1995-1996 and from the 1996-1997 to 2000-2001 seasons the TAC was reached or nearly reached (Figure 2). Overall landings then declined to 14t in 2007. While overall landings were high, landings from individual areas rose and fell at different times (Figure 2). Initial landings for Georges Bank dropped in 1997-1998 while landings from areas in the Gulf of Maine increased, especially Crowell Basin which remained high until 2000-2001 then declined. Southeast (SE) Browns increased in importance in 1999-2000 and maintained landings until 2001-2002 when it also declined.

The maps in Figure 12 show the evolution of landings 1995-96 to 2008.

Non-Standardized Catch Rates (Annual)

Crab CPUE (Kg/TH) is presented in Table 1 and Figure 6 (Gulf of Maine/SE Browns/ Georges Bank) and Figure 7 (assessment subareas). Monthly CPUE are presented in Figure 8 (total) and Figure 9 (assessment sub areas). The maps in Figure 12 show the evolution of CPUE 1995-96 to 2008.

Non-standardized catch rates from the commercial fishery (CPUE, landed kg/trap haul) vary spatially (Figure 12) and throughout the year (Figure 11), 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.

Catch rates for individual areas were initially high catch rates followed by a declining trend since the 2000-2001 fishing season.

Modeled Catch Rate Index

Jonah crab catch rates are influenced by abundance, temperature, molt state and a host of other factors. Direct data for these factors as they are associated with the LFA 41 Jonah crab fishery are often unavailable. Here we describe the annual and seasonal changes in catch rates using the main effects of fishing season (October to October), bi-weekly interval (2wk) and vessel, (3-way factorial ANOVA). Interactions of these terms were not explored due to limited degrees of freedom. For the purposes of this analysis we make the strong assumption that there are no significant interactions.

The ultimate objective is to use catch rate (or catch per unit effort; 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 CPUE. It is understood that any such index must be interpreted in light of other influences. This model is considered to be at the exploratory stage. All analyses were done in R version 2.7.0.

<u>Preliminary Data Visualization</u>

The total 2-week CPUE for each area/seasonal period group is presented annually in panel plots (figures 13 and 14). There was very little or no fishing activity for Crowell Basin, Southwest Browns, Georges Bank, and Georges Basin since 2005-06. All area/seasonal period groups show generally lower CPUE for the most recent years in the time series. Well above average catch rates are in seen several 2-week intervals for each area during both the winter and summer seasonal periods.

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 (see Figure 15 for example). Box-plots (2-weeks across all fishing seasons and by fishing season across all 2-week periods) were also produced for each area/period group as a preliminary visualization of trends in mean cpue and variability (see Figure 15 for example).

<u>Model Trials</u>

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. The residual plots for all models show few trends across the predicted values (see Appendix 3).

The coefficients and ANOVA tables for each model can be found in Appendix 3. The low adjusted R-squared values for most of the area/seasonal period groups 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 2-week intervals should be conducted in the future.

<u>Within Season and Annual Patterns</u>

Annual and seasonal changes in Jonah crab 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 16 to 19). 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. The large confidence intervals around some indices are most likely due limited data.

<u>Annual (1996-97 to 2007-08)</u>

The most recent fishing seasons in each time series have consistently lower CPUE indices than the those for the beginning of each time series, for almost all areas during both the winter and summer seasonal periods. The exceptions are Georges Basin (inconsistent) and Georges Bank- winter 2003-04, summer 2004-05.

<u>Within Season (Bi-Weekly Period)</u>

The Jonah crab CPUE indices for the 2wk interval are variable within season. Several area/seasonal period groups indicate lower indices for the mid 2-week intervals.

Alternative approaches to modeling the catch rates for the LFA 41 Jonah crab fishery, such as using Generalized Linear or 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 crab catch rates may be provided by adding covariates to the models which 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 partitioning of effort directly for Jonah crab and lobster further confounds these analyses.

<u>Model Interpretation and Conclusions</u>

- CPUE indices in the LFA 41 Jonah crab fishery are influenced by; (i) 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, bi-weekly period and commercial fishing vessel (CFV) 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.
- Annual differences are apparent, with the most recent fishing seasons in each time series having consistently lower CPUE indices.
- Within season differences in CPUE indices are variable.
- A CPUE model has the potential to be used to evaluate whether CPUE thresholds in the LFA 41 Jonah crab fishery are reached on an annual and potentially on a seasonal basis; the development of such a model is ongoing.

Trawl Survey Trends

With the formalization of measuring and recording all lobsters and crabs (and other selected invertebrates) in 1999, the possibility of using the annual DFO RV summer bottom trawl survey as an indicator of abundance became possible. The survey was not designed to survey crab 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. 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 Jonah crab in 2007.

Adjusted mean stratified numbers per tow are given in Figure 20 for the strata in LFA 41 and for comparison those in LFAs 34 and 33 and 4W.

Adjusted mean stratified number per tow in the DFO RV surveys show a general declining trend in all the strata fished in LFA 41, while areas outside of LFA 41 (e.g. Western/Emerald Bank and South Shore) show no downward trend. The decline is sharpest in the 1999-2002 period in the strata corresponding to Crowell Basin and Georges Basin (Figure 5).

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 Jonah crab in LFA 41 in future assessments.

Indicators

Data Source	Indicator	Observed	Overall	Georges Bank	SE Browns	SW Browns	Crowell Basin	Georges Basin
Trawl Surveys	Mean #/Tow Canada	The trawl surveys show a general declining trend in tow 1999-2007 in all the offshore areas while areas outside of LFA 41 show no downward trend.	--		--	--	--	--
Catch Rate	Annual Catch Rate	General decline after initial high levels.		--	--	--	--	--
	Catch Rate Model	Annual differences are apparent, with the most recent fishing seasons in each time series having consistently lower cpue indices.	--	--	--	--	--	--

+ Indicator is positive
o Indicator is neutral or showing no trend
-- Indicator is negative

FISHING PRESSURE

Effort

There is no trap limit, but information from Clearwater Seafoods indicates that vessels traditionally fished 2,500 traps each. The fleet presently fish approximately 12,000 traps split between four vessels in 2008; however, the logbooks do not identify if the string of traps is targeting lobster or crab; therefore, any strings with crab landings reported are used in determining the number of trap hauls. This may over estimate effort levels.

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.

Trends in trap hauls (TH) are presented in Table 1 and Figure 6 (Gulf of Maine/SE Browns/ Georges Bank) and Figure 7 (assessment subareas). Monthly effort is presented in Figure 8 (total) and Figure 9 (assessment subareas). The maps in Figure 12 show the evolution of effort 1995-96 to 2008.

Total effort increased rapidly between 1995 and 1998-99, but steadily declined after 1999-2000 and effectively stopped in 2008.

Size Frequency

Size frequencies of male crab are presented in Figure 21.

Size frequencies of male crab in Crowell Basin (1999, 2001, 2003, 2005) and SE Browns (2001, 2002, and 2005) in spring show indications of a shift to smaller sizes, but this is not seen in winter in SE Browns (2001, 2002, 2003, 2006, and 2007). Other plots show no consistent trend in the proportion of the catch at size.

The length of time series and intensity of sampling is insufficient to draw firm conclusions on changes in the size structure.

Exploitation Rate

Estimates of exploitation rates are not available.

Indicators

Data Source	Indicator	Observed	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.						
Size Frequency	**Male Size Structure**	Spring Crowell Basin and SE Browns show indications of a shift to smaller sizes, but this is not seen in winter in SE Browns. Other plots show no consistent trend in the proportion of the catch at size.			--		--	o

\+ Indicator is positive
o Indicator is neutral or showing no trend
-- Indicator is negative

PRODUCTION / RECRUITMENT

There is insufficient data in the time series to evaluate production or recruitment.

ECOSYSTEM

Species Interactions and Interactions with Other Fisheries

There is currently no directed fishery for Jonah crab in LFA 41. Jonah crab is caught primarily within the lobster fishery, and ecosystem interactions including by-catch, whale interaction, gear loss and ghost fishing and gear impact are expected to be similar to those described for that fishery (Pezzack et al. 2009).

<u>Other Crustaceans</u>

Jonah crab co-occurs with other crustaceans of commercial value, most notably lobster, with some overlap with deep-sea red crab and snow crab. Deep-sea red crabs generally occur in waters deeper than commercial Jonah crab distributions and rarely make up a significant by-catch.

<u>Predation on Jonah Crab</u>

Little is know about predators of Jonah crabs. At small sizes they are preyed upon on by many fish species including sculpin, cunners, skate, lobsters, other crabs and other opportunistic feeders. Larger crabs would have fewer predators. At all sizes they are most vulnerable immediately following the moult while their shell is still soft.

<u>Food Sources for Jonah Crab</u>

The Jonah crab mainly feeds on shellfish such as mussels, snails and barnacles, whose shells are easily crushed by the claws, echinoderms and polychaetes. They will also scavenge on dead fish or leftovers from lobsters or other predators.

<u>Sources of Uncertainty</u>

Growth rates, reproductive biology, stock structure and migration of Jonah crab are poorly understood. The linkages between Jonah crab in LFA 41 and adjacent areas are uncertain, including sources of recruitment.

The logbooks do not identify if the string of traps is targeting lobster or crab; therefore, any strings with crab landings reported are used in determining the number of trap hauls. This may over estimate effort levels.

The short time series for the Jonah crab fishery and the lack of information on some aspects of its biology on the Scotian Shelf limit the ability to assess the stock. 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.

CONCLUSIONS

After only a few years of directed fishing landings, CPUE and catch/tow in the RV survey declined indicating that the TAC of 720t set in 1995 does not appear to have been sustainable.

The exact causes of the decline in Jonah crab abundance indicators cannot be given with certainty, but the data suggest that low (relative to most fisheries) fishing pressure contributed to a substantial reduction in the population.

The fishing down of the stock is reason for concern, and indicates that any future fishery be limited by very low fishing effort. Future Jonah crab fisheries will have to rely on annual recruitment and growth. Females are not allowed to be retained regardless of size and therefore, the potential reproductive capacity of females is protected as long as there are sufficient males available and discards are low.

At present there is no directed fishery and given the low $/lb value relative to lobsters, economics will restrict the lower catch rate that the fleet can fish. So while crabs are still present the fishery is no longer active.

The recovery of the population will be monitored using the abundance indices from the DFO RV survey, and the by-catch of Jonah crabs observed in the offshore lobster fishery. The behaviour of the Jonah crab is not known and their catchability and ability to redistribute themselves over the fishing grounds is unclear. While lobsters are known to undertake seasonal migrations, the movement patterns of Jonah crab off Nova Scotia are unknown.

Other Jonah crab fisheries in the inshore areas have also experienced recent declines in landings and fishing activity. A broad review of rock and Jonah crab in the Maritimes Region may be helpful in providing a better understanding of population dynamics and contribute to improved guidelines for these fisheries

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TABLES

Table 1. LFA 41 lobster landings 1995-2008, by subareas and fishing season; with TAC and total trap hauls. The fishing season is defined as the period for catching the TAC and this has varied over time:

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

	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W	Total	TAC	Total Trap Hauls
1995-96	8	18	0	74	196	5	300	720	150,773
1996-97	165	128	46	125	224		688	720	423,940
1997-98	301	67	101	148	81		697	720	416,145
1998-99	315	158	80	104	49		705	720	592,841
1999-00	241	88	19	233	114	69	765	720	613,634
2000-01	300	78	13	223	116	19	750	720	408,923
2001-02	157	90	8	233	107	19	614	720	419,542
2002-03	80	43	23	95	71		312	720	308,194
2003-04	56	15	5	74	21		171	720	280,935
2004-05*	37	33	6	29	14		119	720	444,102
2006-06	0	2	1	21	0		25	720	294,036
2007-07	0	5	1	9	0		14	720	287,962
2008-08	0	0	0	0	0		0	720	69,980

Table 2. Annual non-standardized CPUE (total landings/total trap hauls) by subarea 1995-2008 and by fishing season (TAC period).

	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W
1995-96	0.53	0.39	0.00	1.60	6.15	7.26
1996-97	3.02	1.57	0.88	0.93	2.21	
1997-98	3.39	0.82	1.57	1.23	1.30	
1998-99	2.19	1.36	0.87	0.64	0.60	
1999-00	1.52	1.04	0.35	1.19	1.20	2.75
2000-01	2.47	0.87	0.25	2.80	2.09	2.48
2001-02	2.15	0.90	0.14	1.86	1.95	1.53
2002-03	1.08	0.53	0.59	1.21	1.99	
2003-04	1.14	0.16	0.15	0.93	0.82	
2004-05	0.84	0.19	0.09	0.28	0.26	
2006-06	0.00	0.02	0.02	0.28	0.00	
2007-07	0.02	0.05	0.02	0.11	0.00	
2008-08	0.00	0.01	0.00	0.02	0.00	

Table 3. AIC, adjusted R-squared value and degrees of freedom for each area/seasonal model.

Data Subset	AIC*	Adj. R-sqr	DF
Crowell Basin- winter	3412.6	0.40	1869
Crowell Basin- summer	2652.0	0.56	2008
SW Browns - winter	2619.0	0.48	1186
SW Browns - summer	2524.5	0.58	1226
SE Browns - winter	5159.3	0.45	2382
SE Browns - summer	6725.0	0.41	3086
Georges Bank - winter	555.1	0.61	245
Georges Bank - summer	1819.6	0.52	1080
Georges Basin - winter	495.3	0.72	231
Georges Basin - summer	1323.2	0.55	506

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

Table 4. Total trap hauls by subarea and by fishing season (TAC period) 1995-2008.

	Sum of Trap Hauls						
	Crowell Basin	SW Browns	Georges Basin	SE Browns	Georges Bank	4W	Total
1995-96	14,550	45,380	12,000	46,368	31,850	625	150,773
1996-97	54,650	81,470	52,225	134,150	101,445		423,940
1997-98	88,787	81,472	64,063	119,623	62,200		416,145
1998-99	143,750	115,939	91,115	161,372	80,665		592,841
1999-00	158,845	84,484	54,787	195,518	94,840	25,160	613,634
2000-01	121,828	89,777	54,846	79,544	55,228	7,700	408,923
2001-02	73,258	99,170	54,320	125,582	54,912	12,300	419,542
2002-03	74,097	81,563	38,394	78,550	35,590		308,194
2003-04	48,630	89,505	36,450	80,050	26,300		280,935
2004-05	43,845	173,022	69,615	101,820	55,800		444,102
2006-06	8,070	95,034	75,982	77,770	37,180		294,036
2007-07	5,930	103,500	58,792	76,370	43,370		287,962
2008-08	400	7,940	34,600	11,350	15,690		69,980

FIGURES

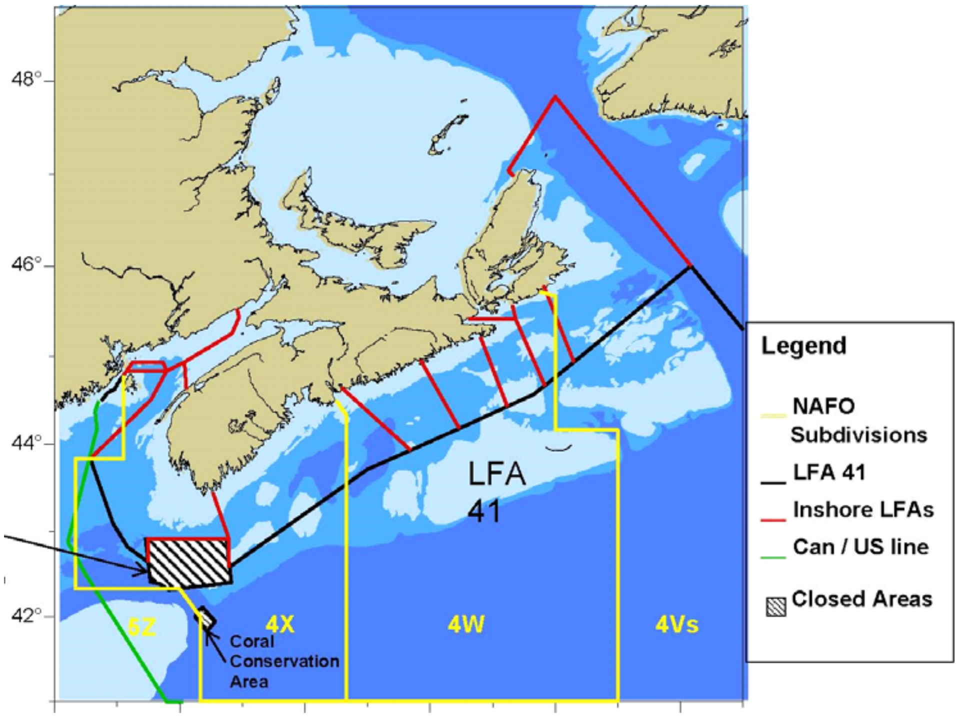


Figure 1. NAFO divisions, LFA 41, LFA 40 (Browns Bank closed area) and Coral Conservation Area.

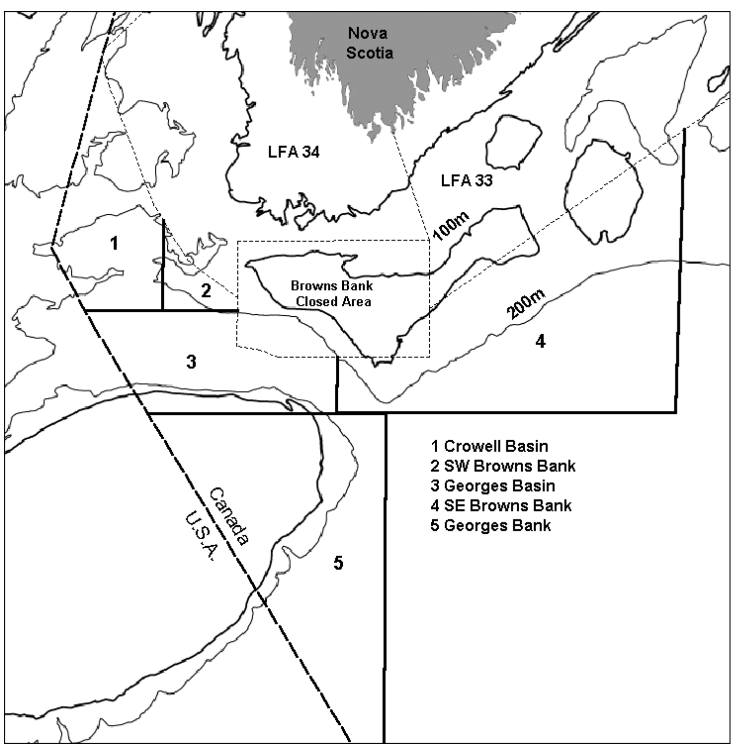


Figure 2. Traditional offshore subareas used in past assessments.

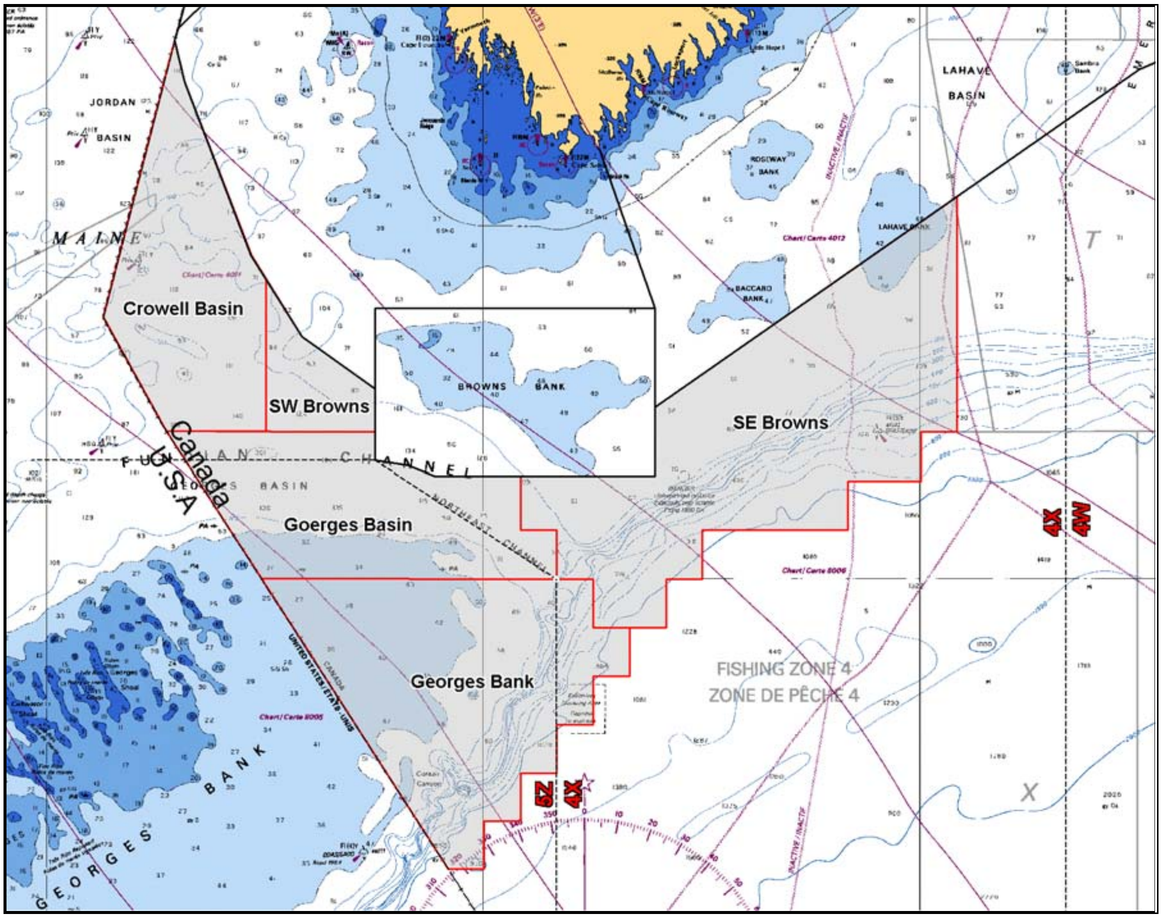


Figure 3. New offshore subareas based on grid grouping.

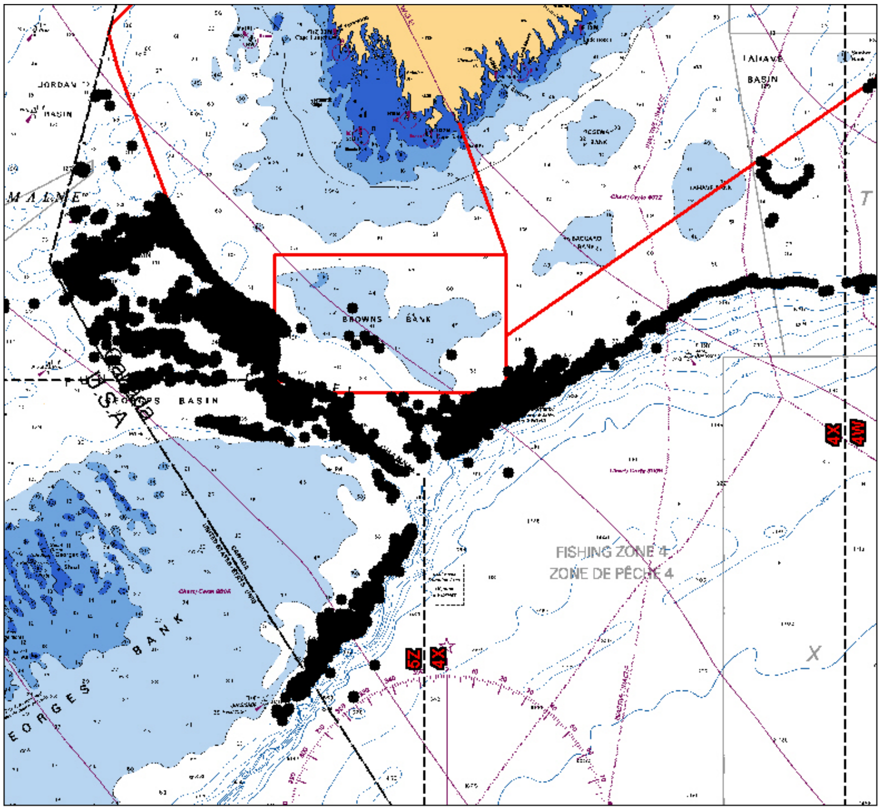


Figure 4. LFA 41 at-sea sampling locations 1977 to 2007 (note locations in the Browns Bank closed area were part of a DFO trapping survey).

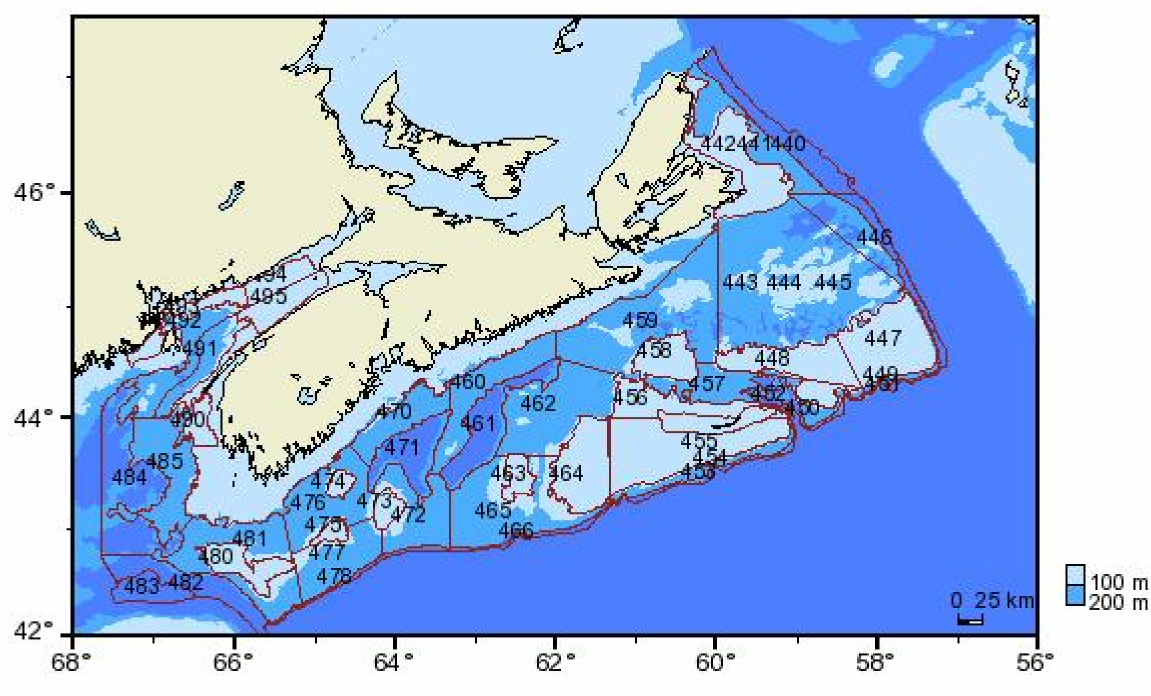


Figure 5. Sampling strata RV stratified random summer trawl on the Scotian Shelf and Bay of Fundy.

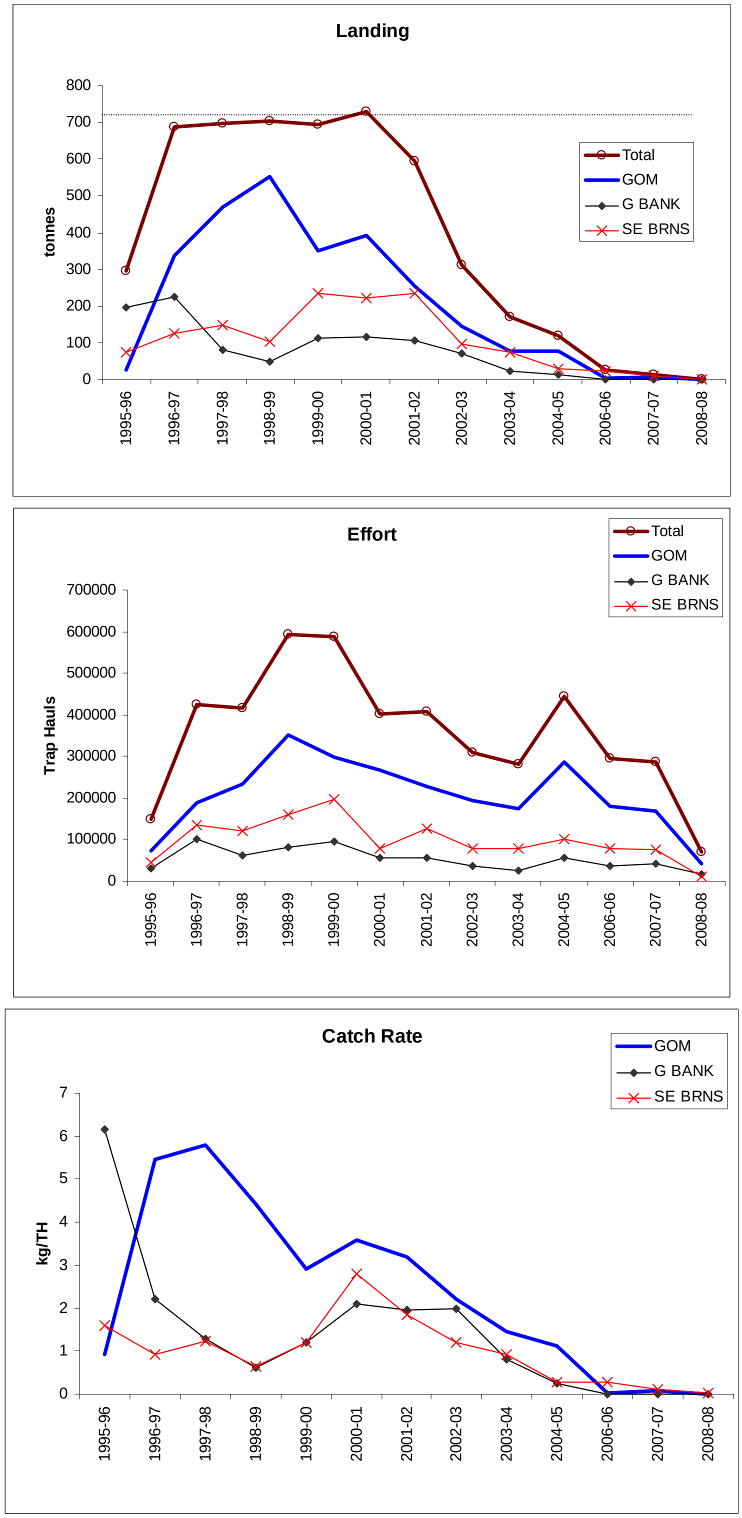


Figure 6. Total landings, trap hauls and CPUE (Kg/TH) and for GOM, SE Browns and Georges Bank.

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.

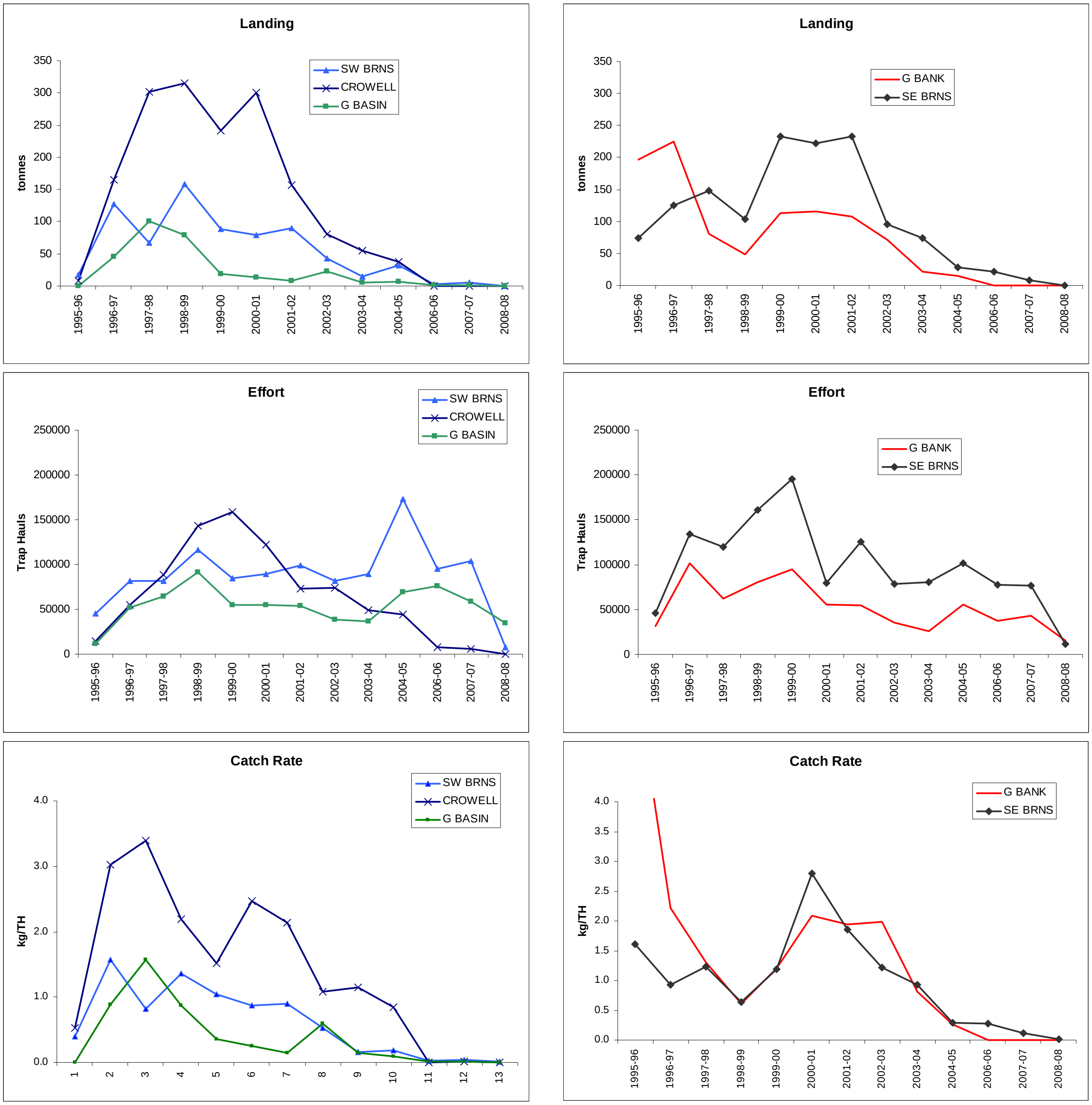
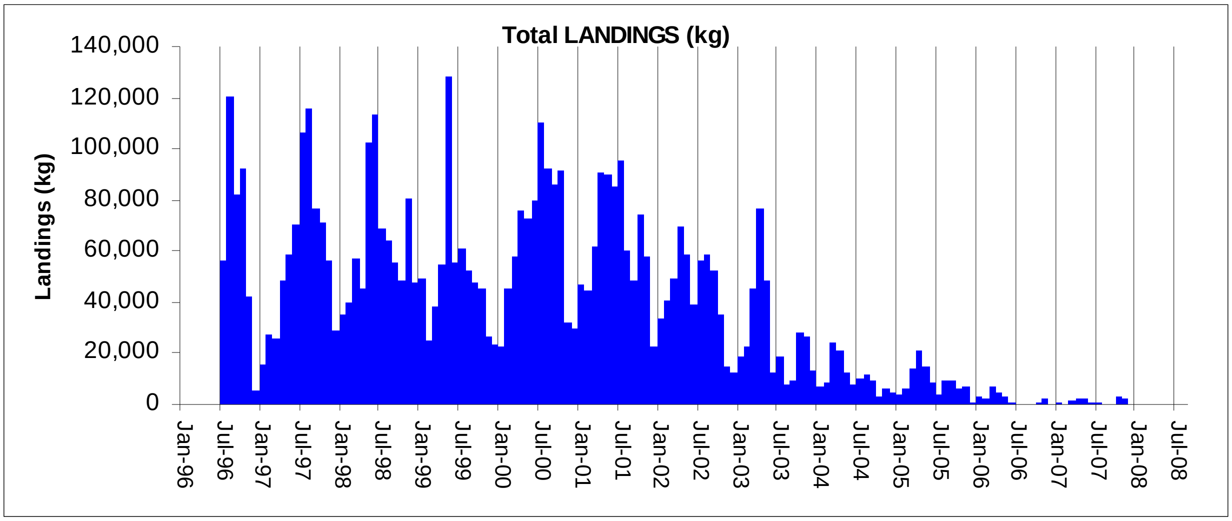
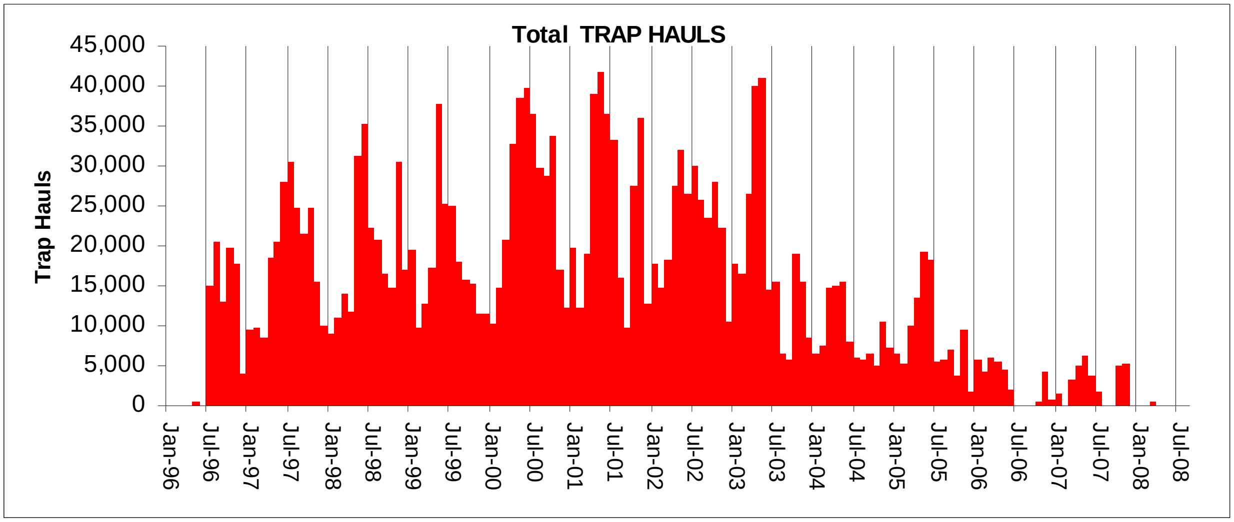


Figure 7. Landings, trap hauls and CPUE (Kg/TH) by assessment subarea.

LANDINGS Kg



TRAP HAULS



CPUE Kg/TH

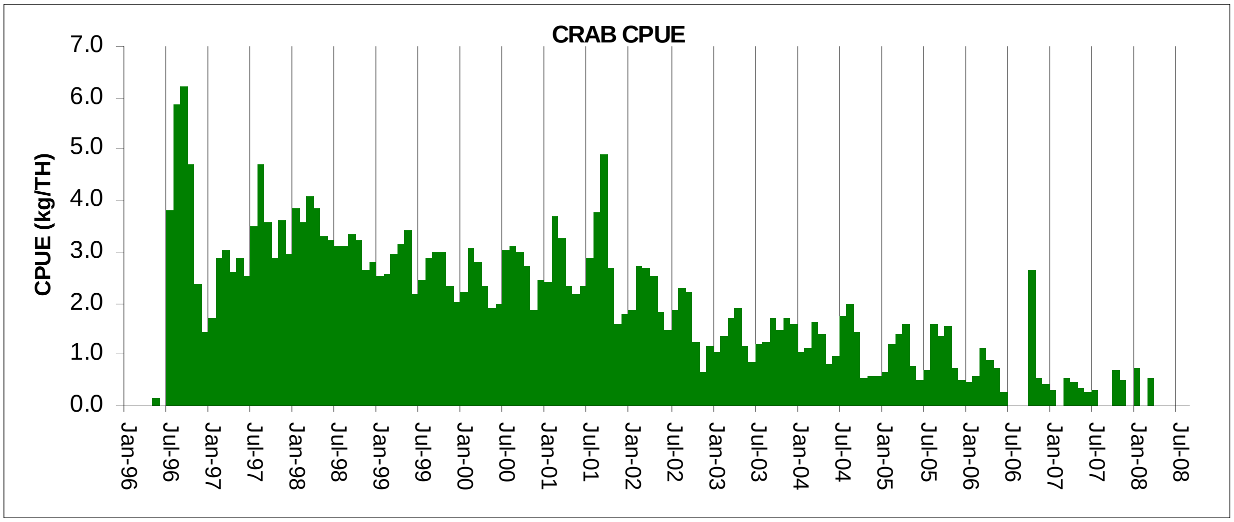


Figure 8. Monthly crab landings, effort and CPUE Jan. 1986-Sept. 2008.

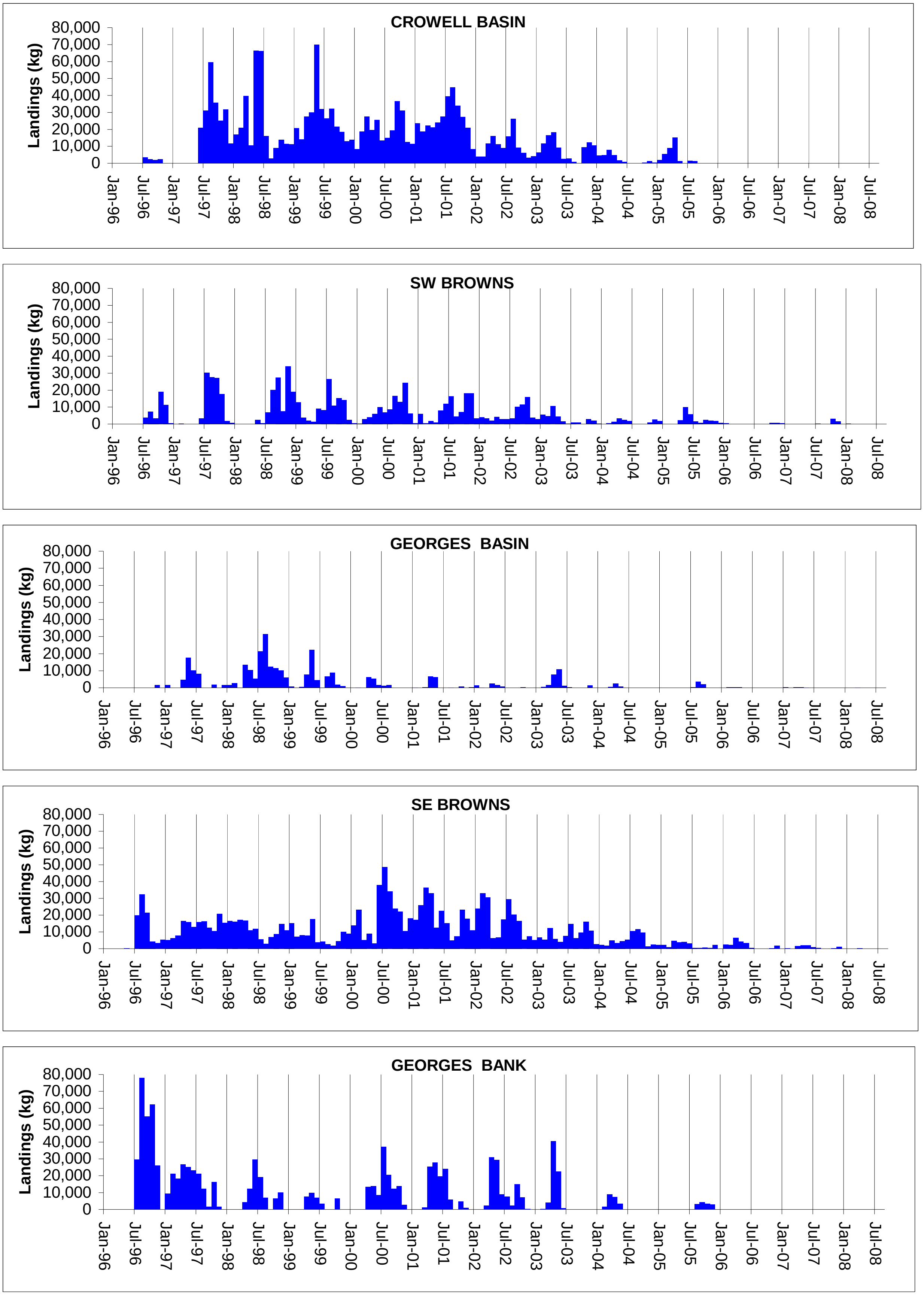


Figure 9. Monthly crab landings (Kgs) by LFA 41 subareas Jan. 1986-Sept. 2008.

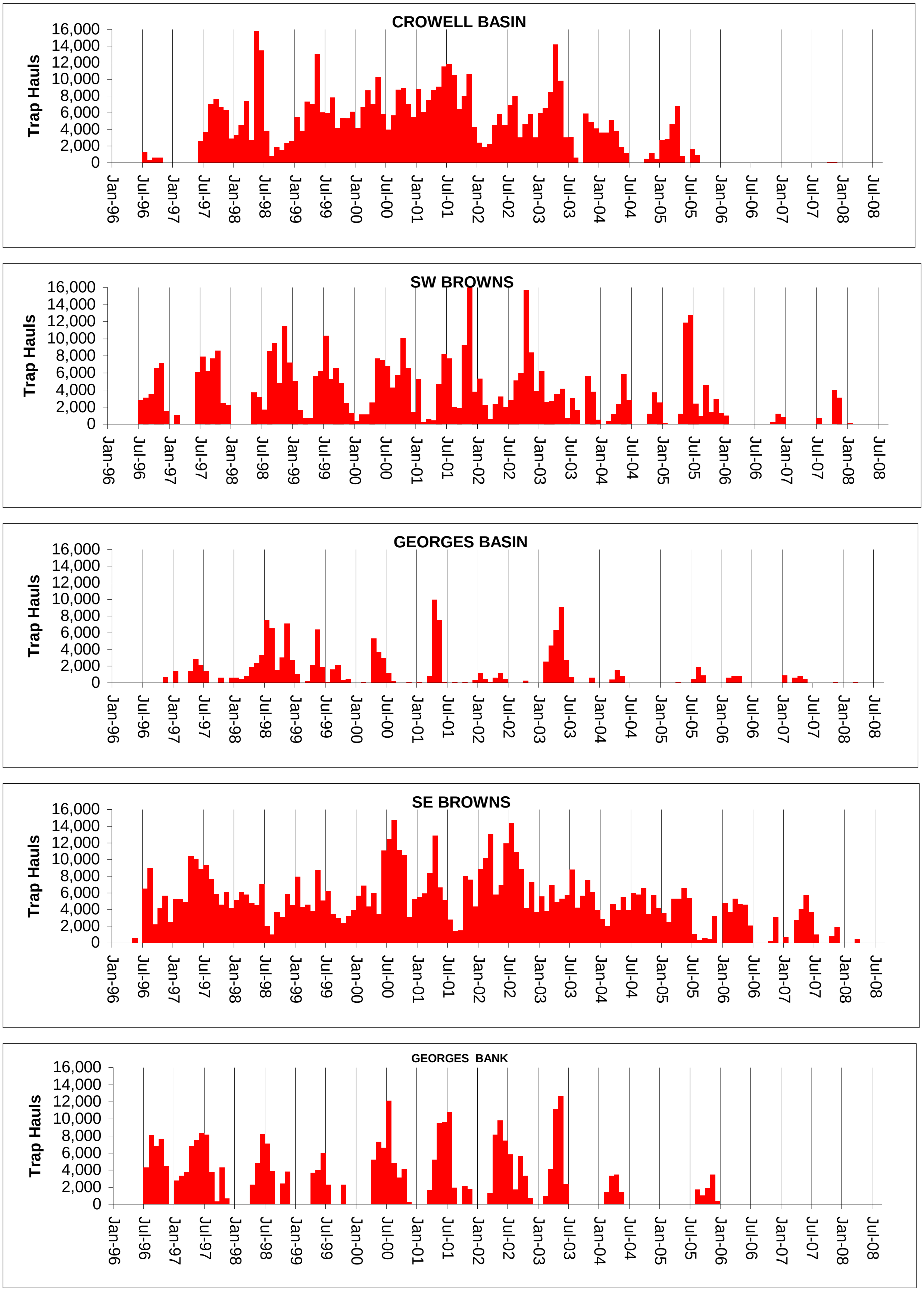


Figure 10. Monthly crab effort (trap hauls) by LFA 41 subareas Jan. 1986-Sept. 2008.

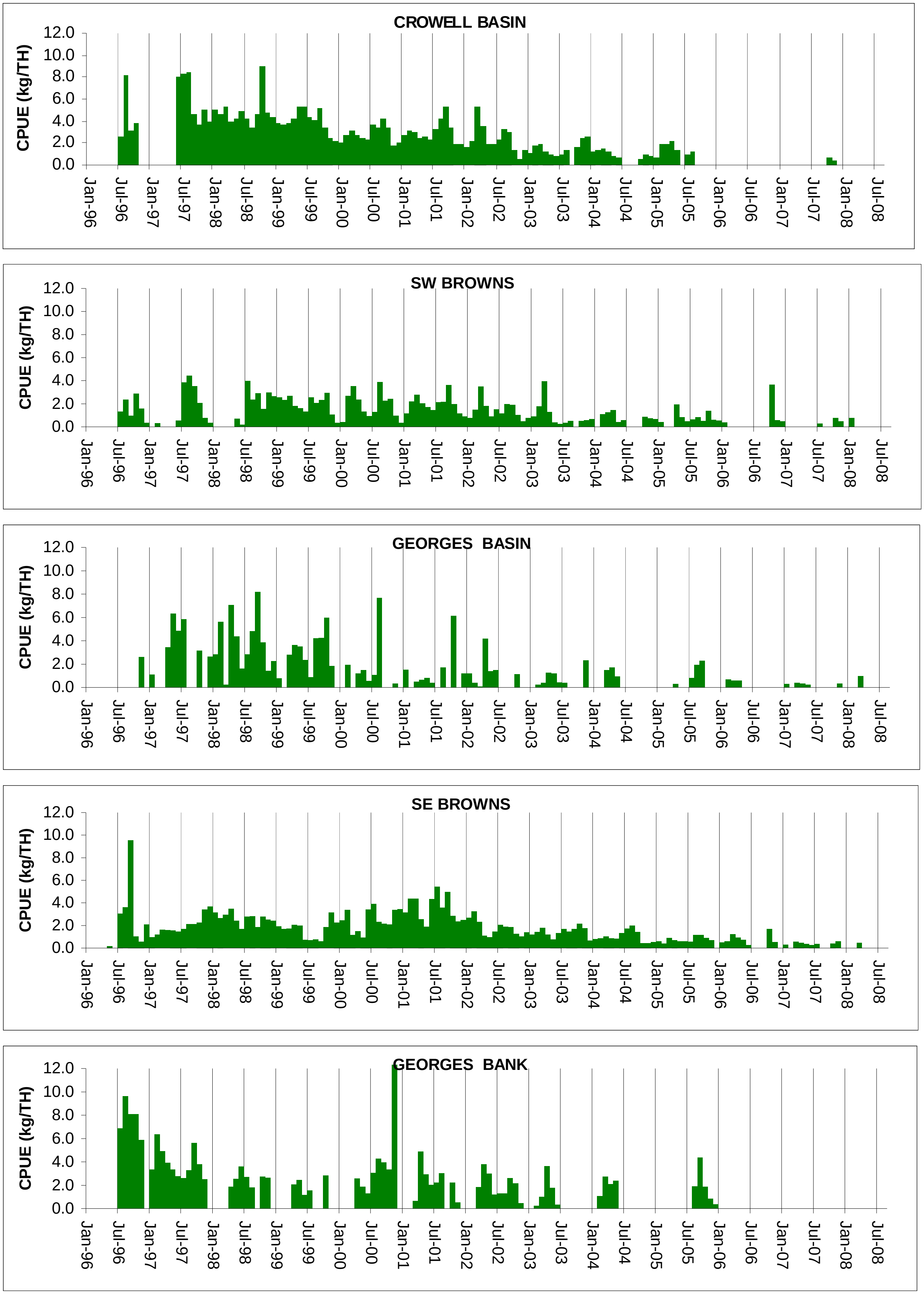


Figure 11. Monthly crab CPUE (Kg/trap haul) by LFA 41 subareas Jan. 1986-Sept. 2008.

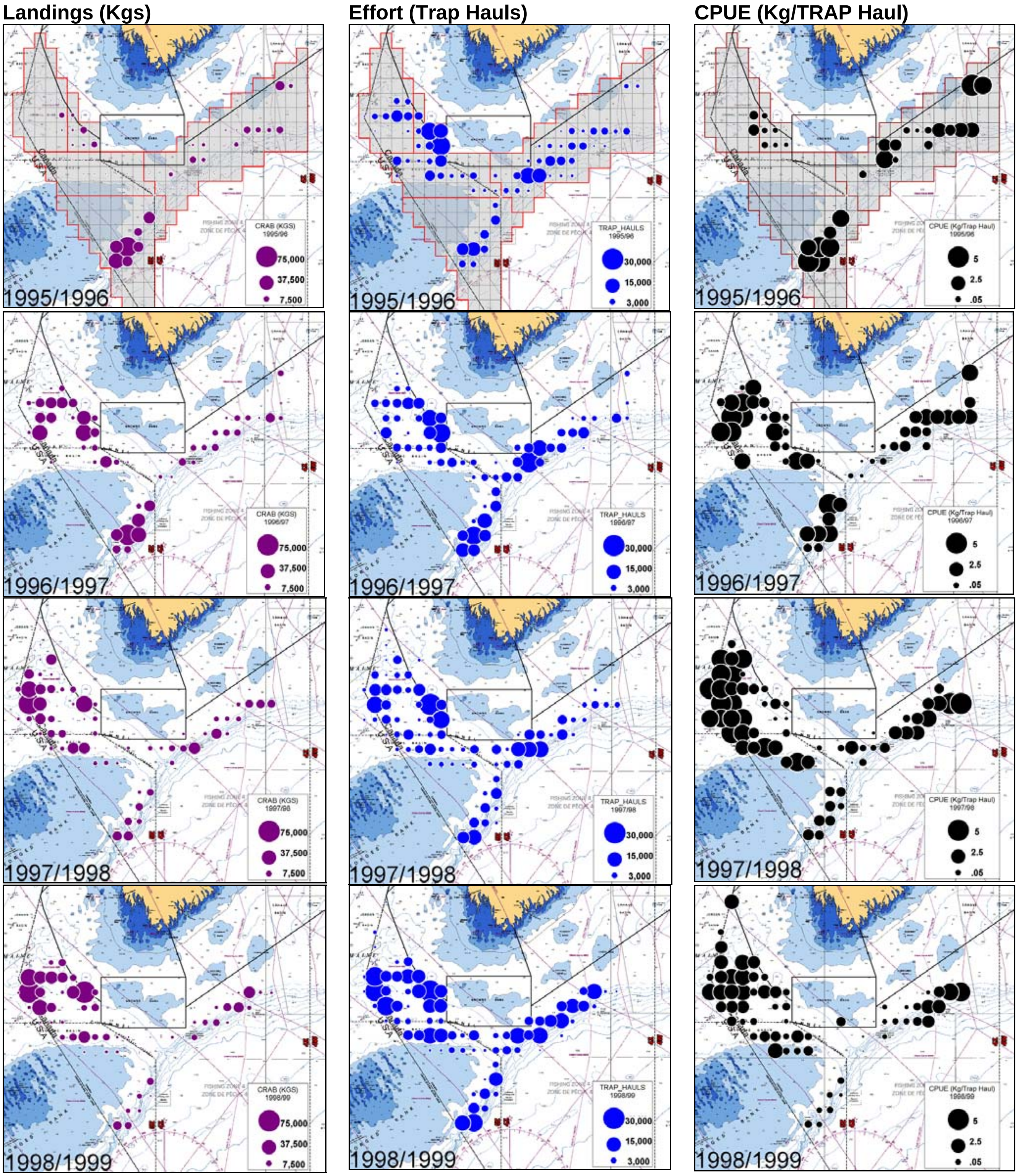


Figure 12. Graduated Jonah crab landings, effort, and CPUE by 10-minute grids 1995/96-1998/99 (Oct. 16th to Oct. 15th).

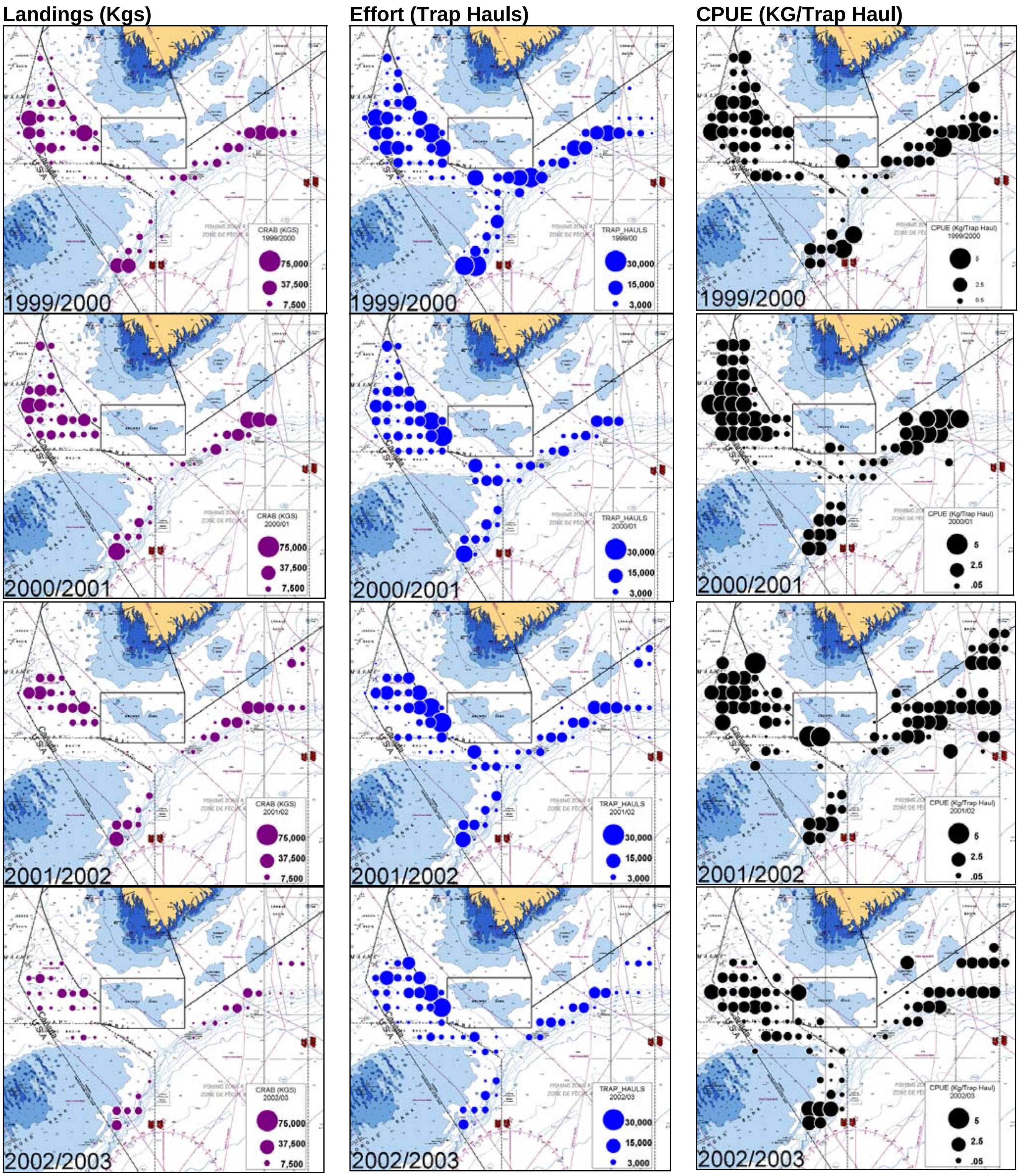


Figure 12 (cont'd.) Graduated Jonah crab landings, effort, and CPUE by 10-minute grids 1999/00-2002/03 (Oct. 16th – Oct. 15th).

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

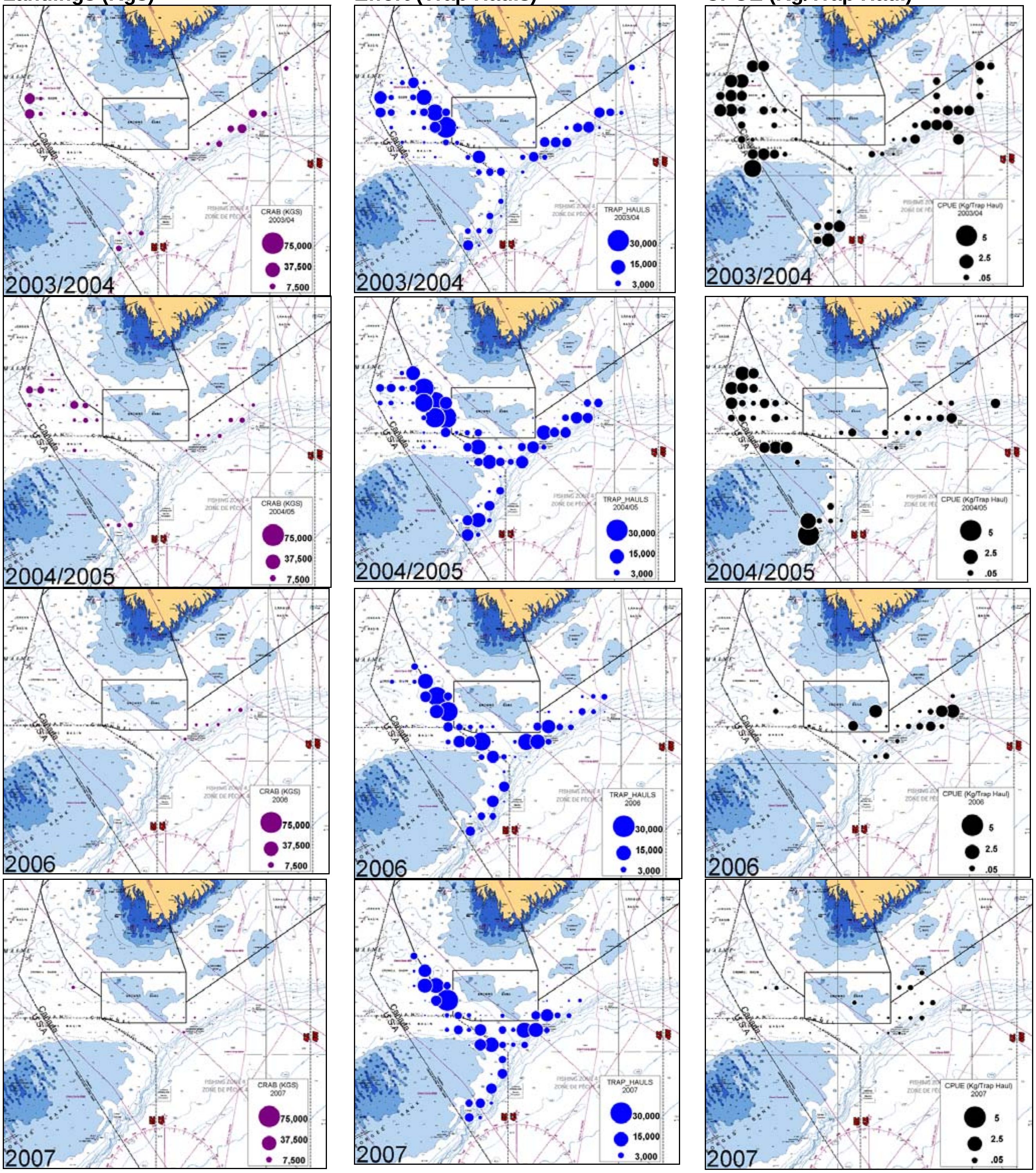


Figure 12 (cont'd.) Graduated Jonah crab landings, effort, and CPUE by 10-minute grids 2003/04(Oct. 16th to Oct. 15th), 2004/2005 (Oct. 16, 2004, to Dec. 31, 2005) and 2006, 2007 (Jan 1st to Dec 31st).

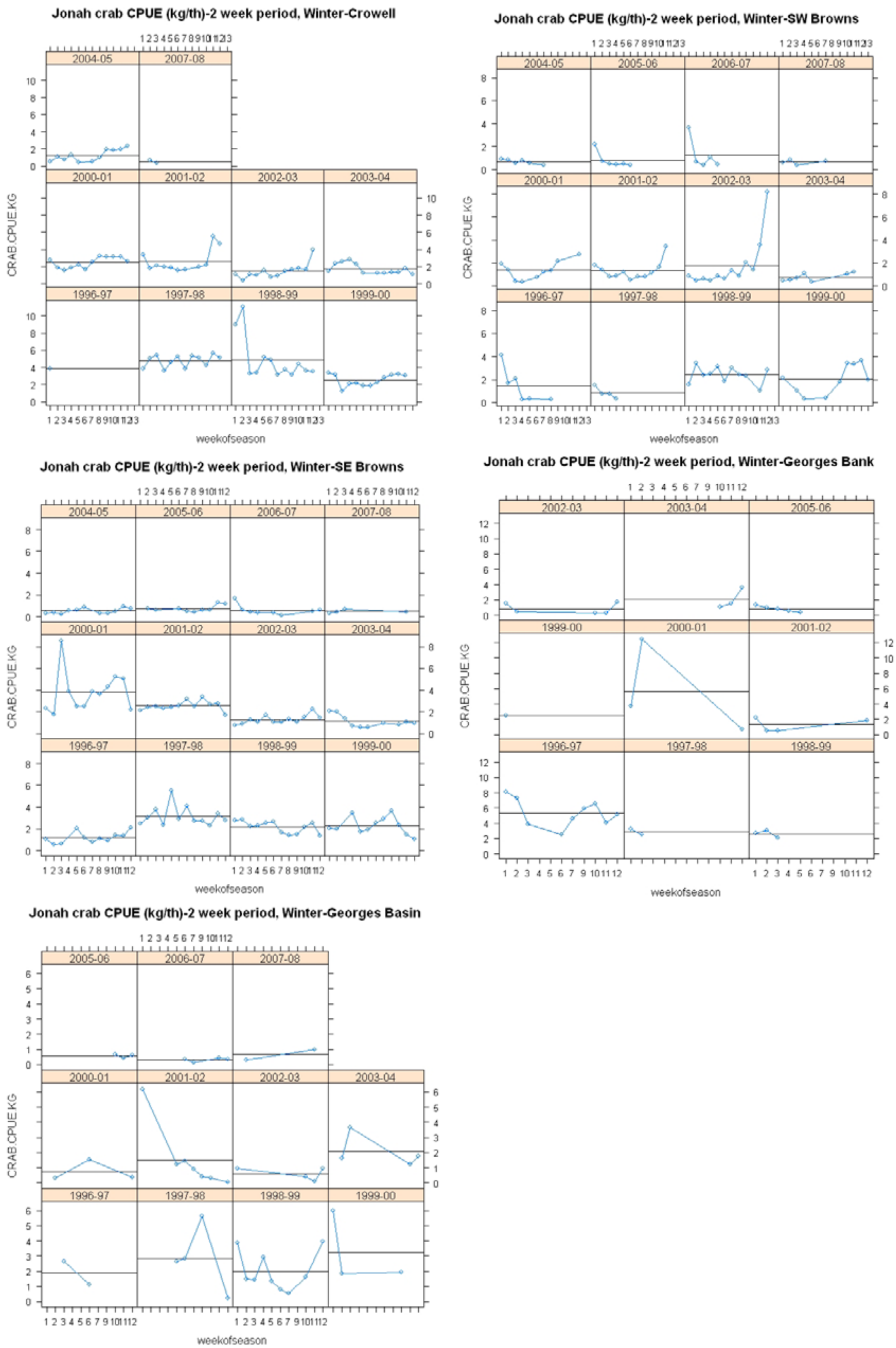


Figure 13. Total biweekly Jonah crab catch rates (Kg/trap haul) for each area during the winter period. Each panel indicates a fishing season (for winter October to April). The horizontal line in each panel represents the mean catch rate for that season.

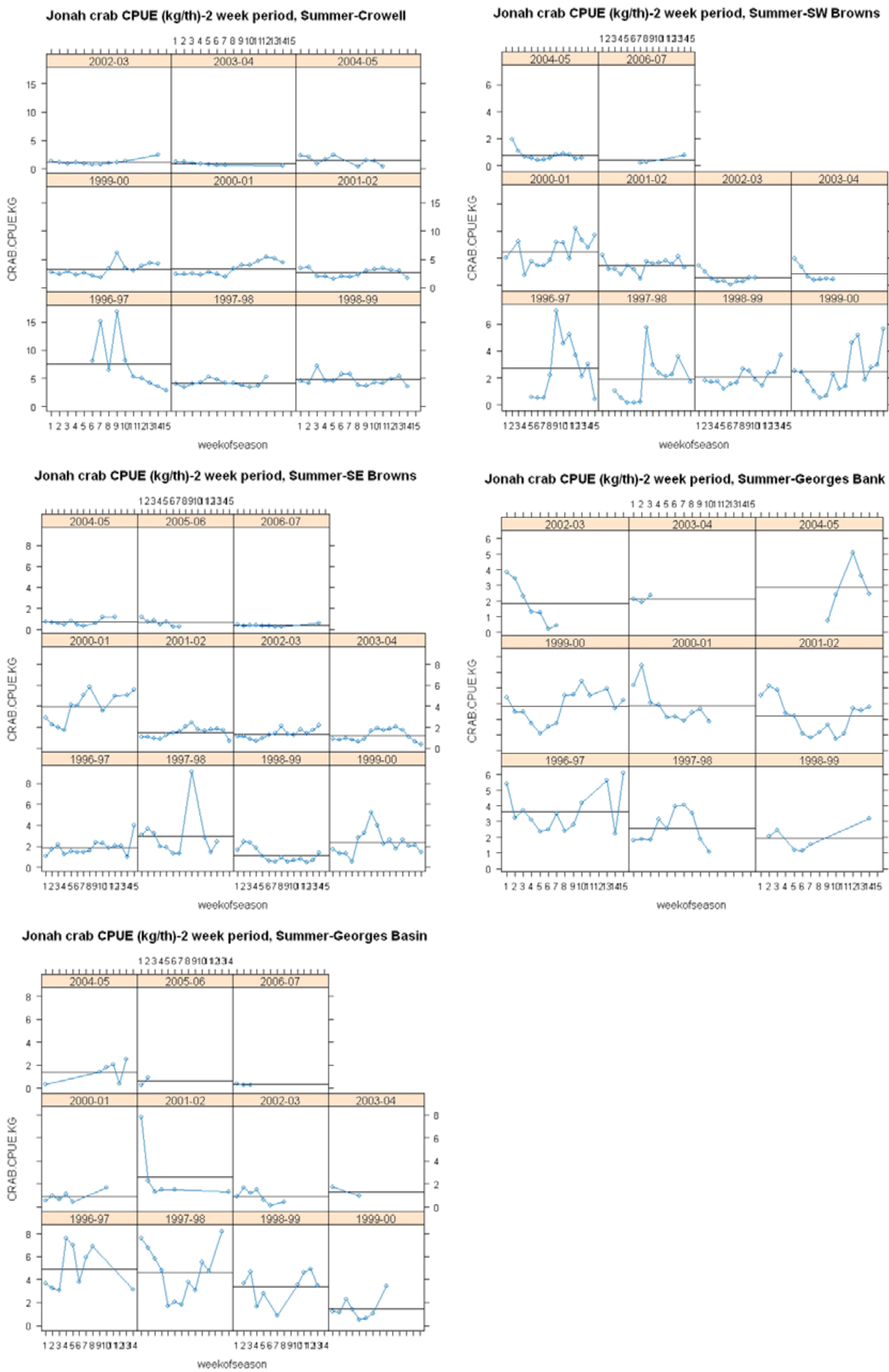
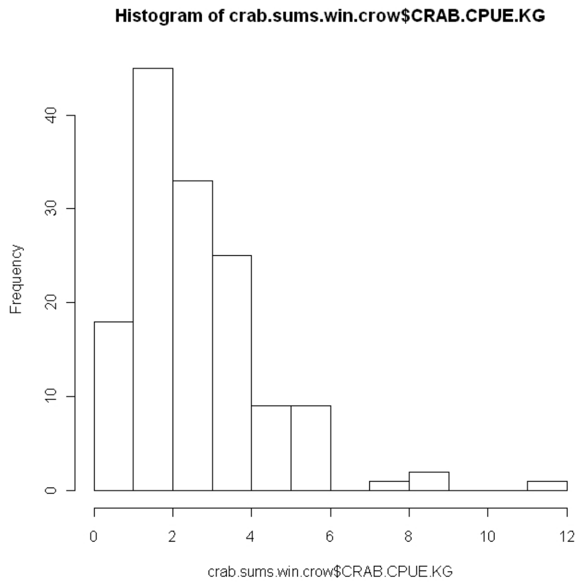


Figure 14. Total biweekly Jonah crab catch rates (Kg/trap haul) for each area during the summer period. Each panel indicates a fishing season (for summer April to October; 1997-98 would represent summer 1998). The horizontal line in each panel represents the mean catch rate for that season.



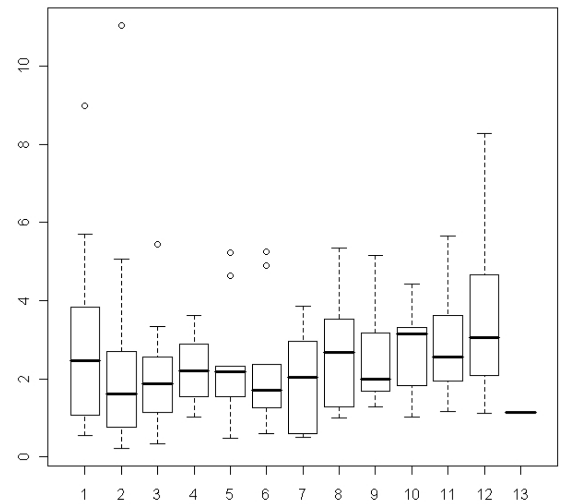
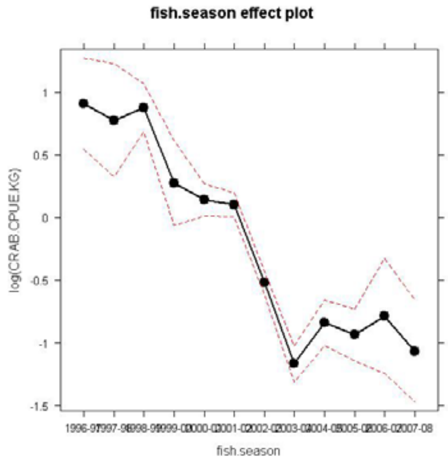


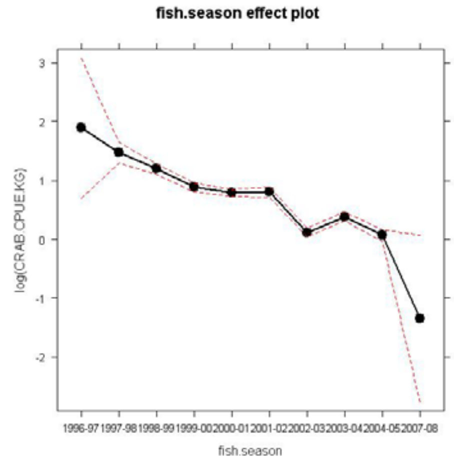
Figure 15. Example histogram and box-plot of biweekly Jonah crab CPUE for Crowell Basin, winter (all fishing seasons combined).

Winter

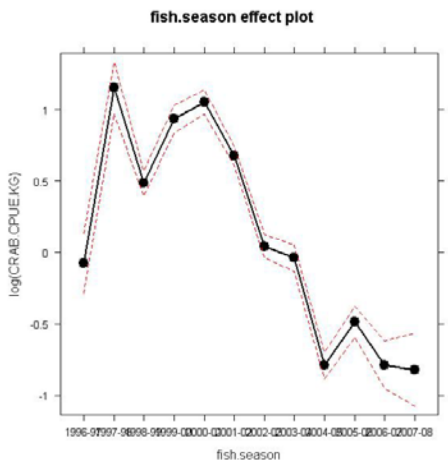
Crowell Basin



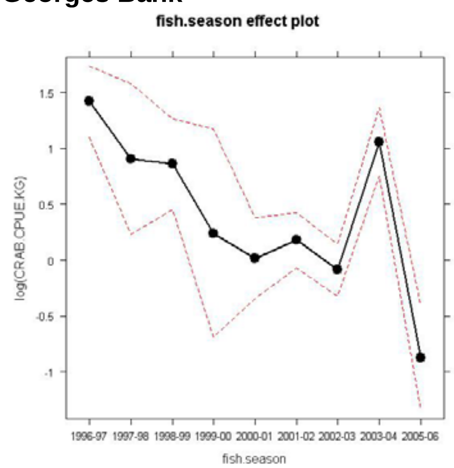
Southwest Browns



Southeast Browns



Georges Bank



Georges Basin

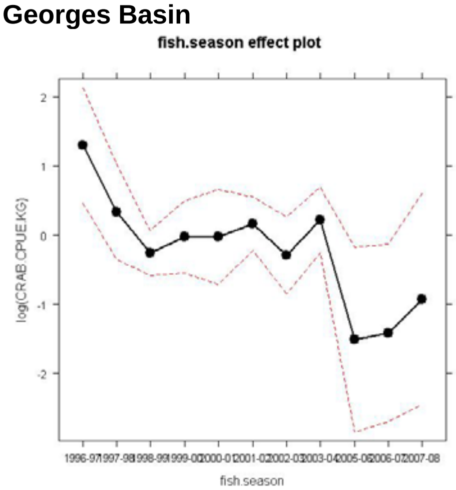
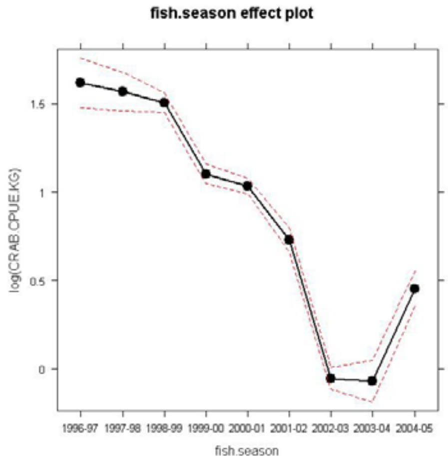
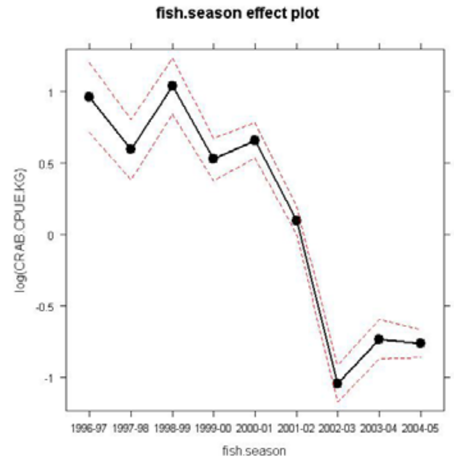


Figure 16. Effects plots of fitted values for the main effect of fishing season for each area, winter period. The dashed lines indicate 95% confidence levels.

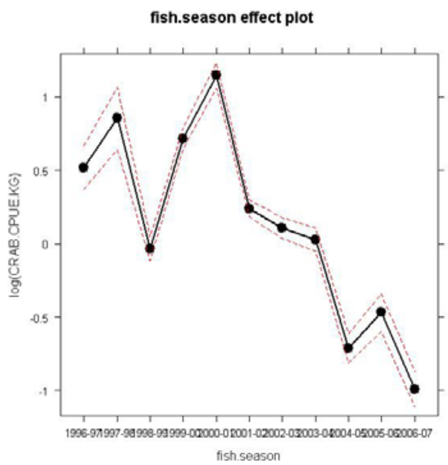
Summer
Crowell Basin



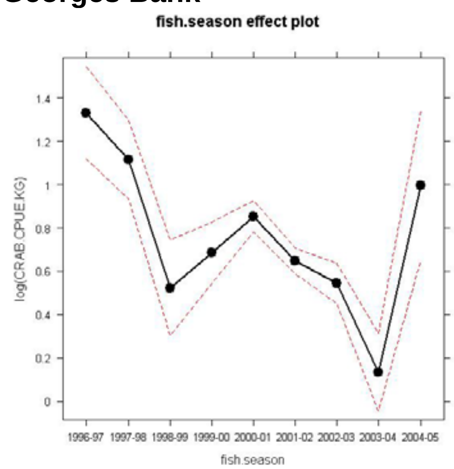
Southwest Browns



Southwest Browns



Georges Bank



Georges Basin

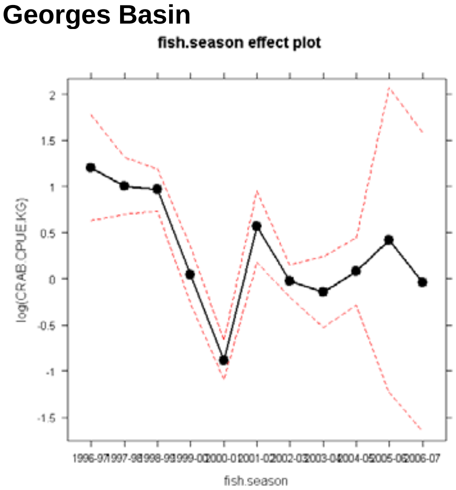
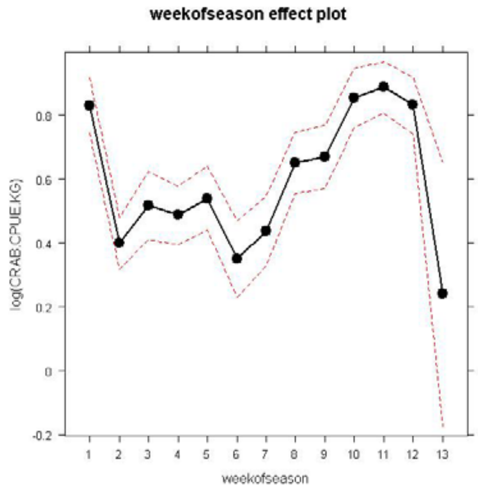


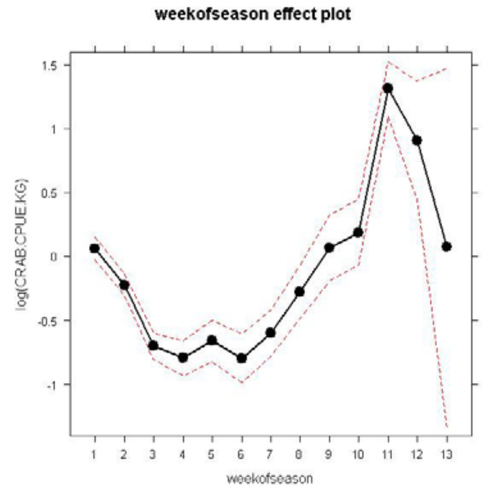
Figure 17. Effects plots of fitted values for the main effect of fishing season for each area, summer period. The dashed lines indicate 95% confidence levels.

Winter

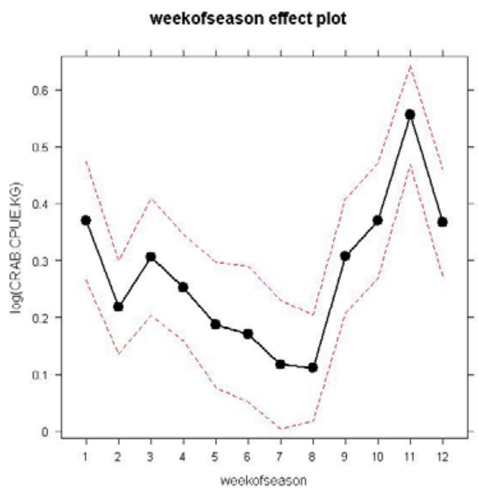
Crowell Basin



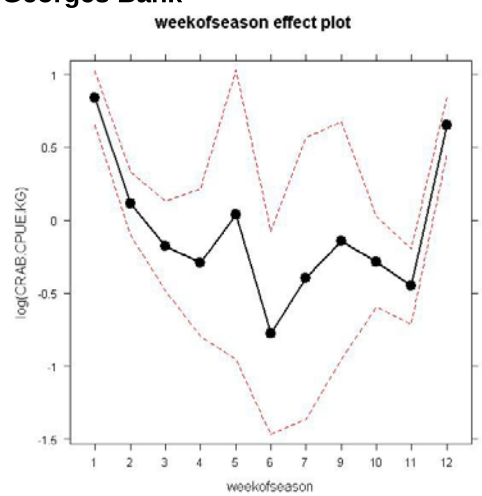
Southwest Browns



Southeast Browns



Georges Bank



Georges Basin

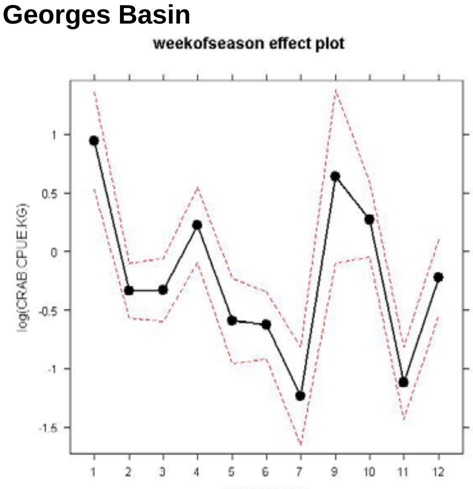
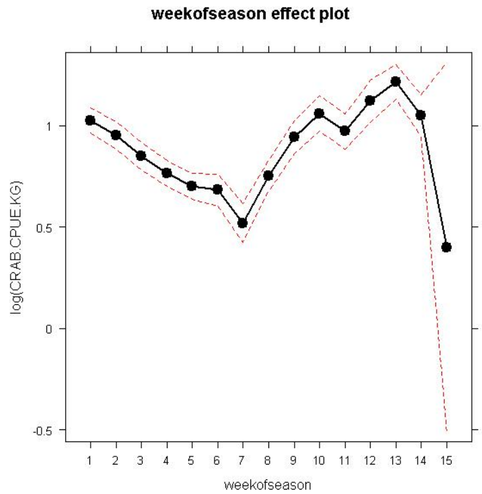


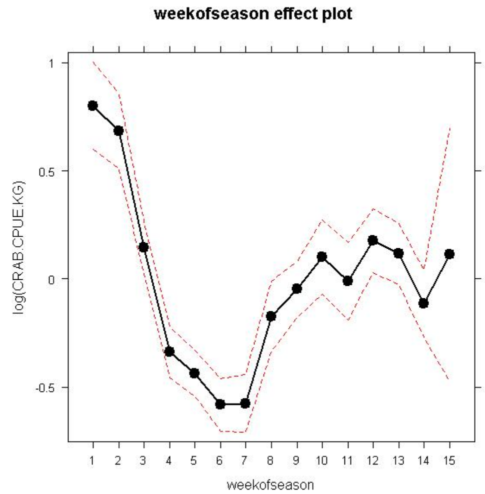
Figure 18. Effects plots of fitted values for the main effect of 2-week period for each area, winter period. The dashed lines indicate 95% confidence levels.

Summer

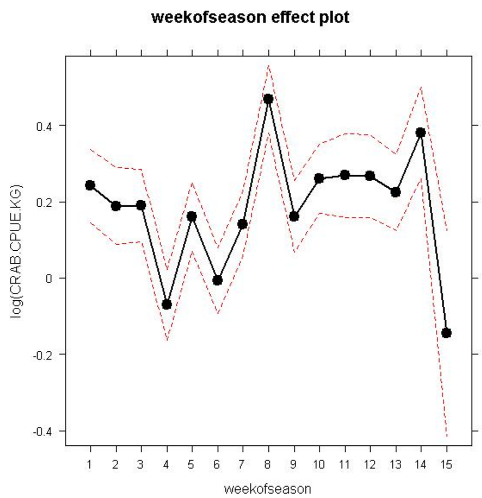
Crowell Basin



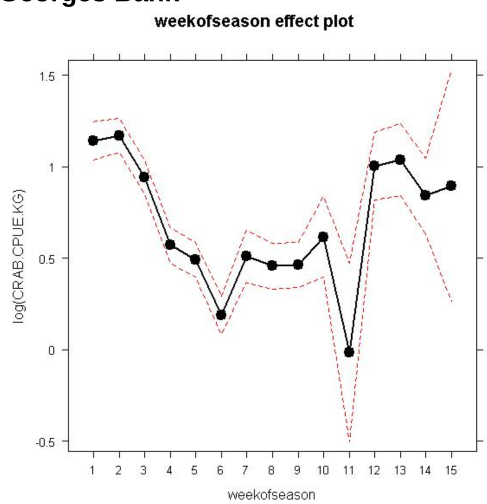
Southwest Browns



Southeast Browns



Georges Bank



Georges Basin

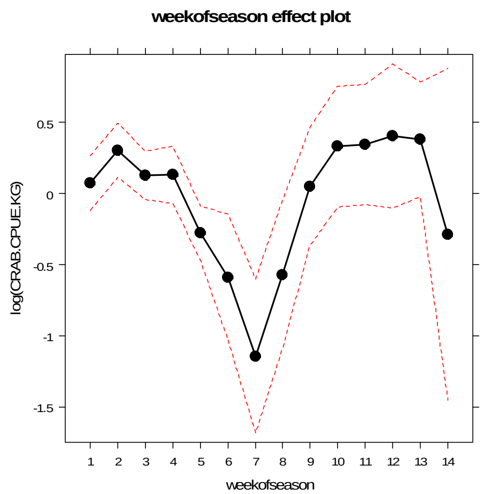


Figure 19. Effects plots of fitted values for the main effect of 2-week period for each area, summer period. The dashed lines indicate 95% confidence levels.

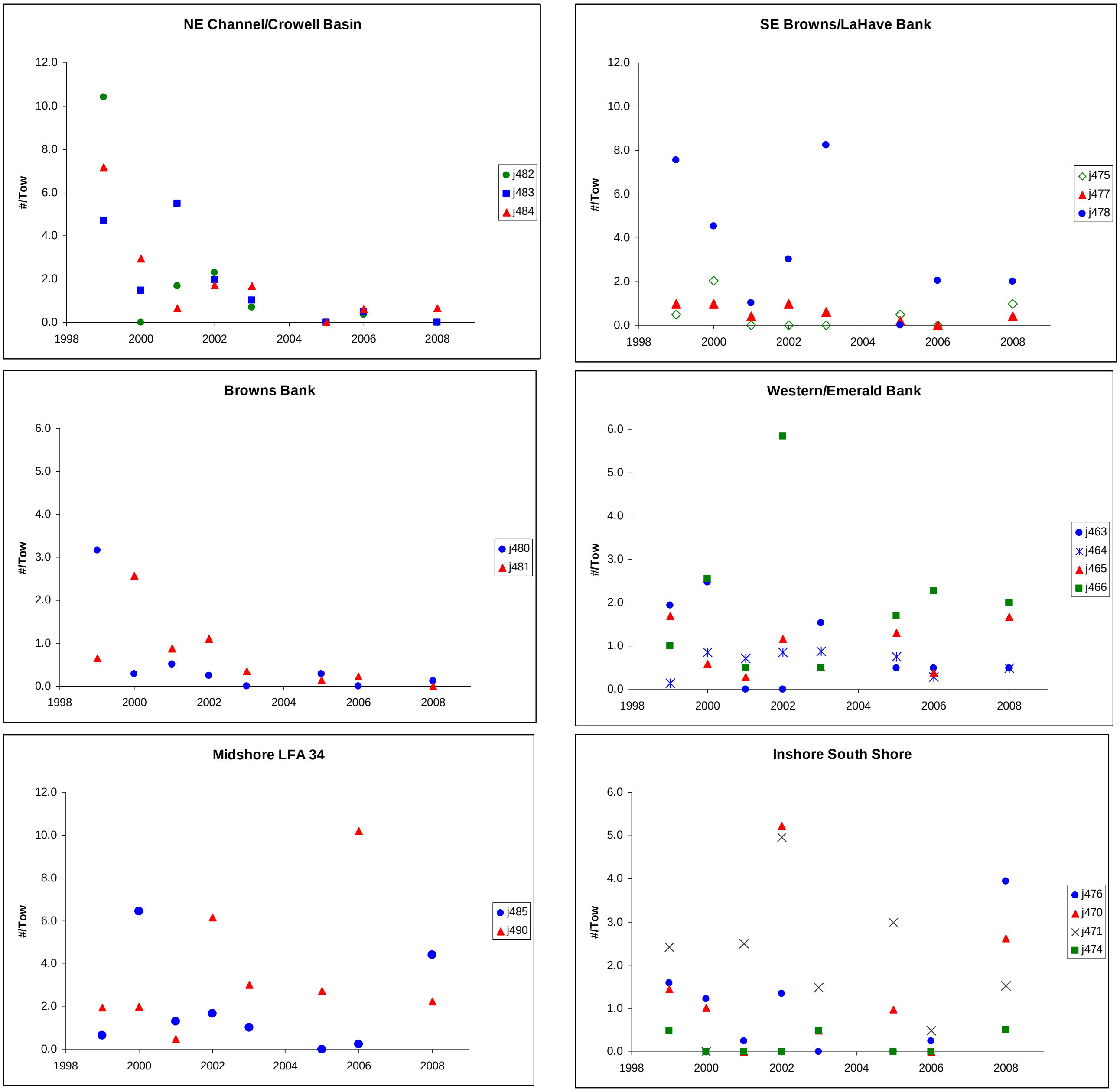
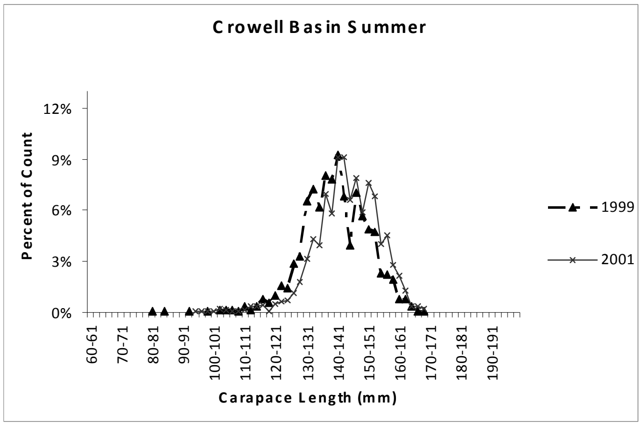
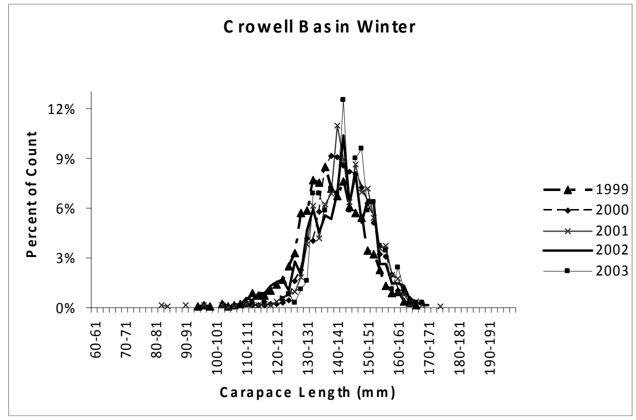
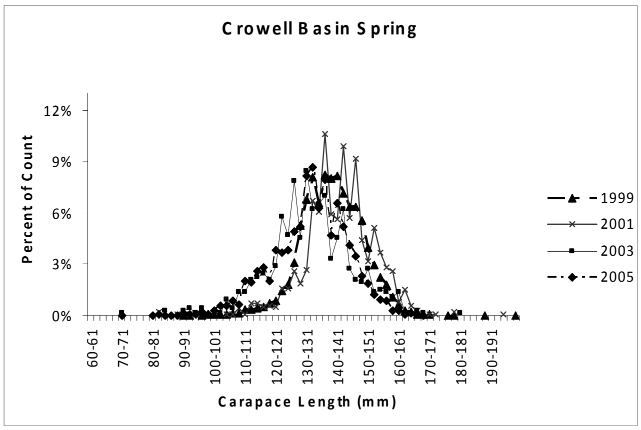
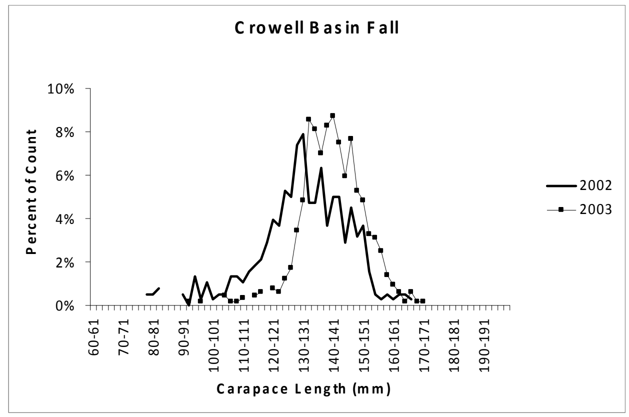


Figure 20. Mean number per tow by Strata, from RV stratified random summer ecosystem trawl survey.

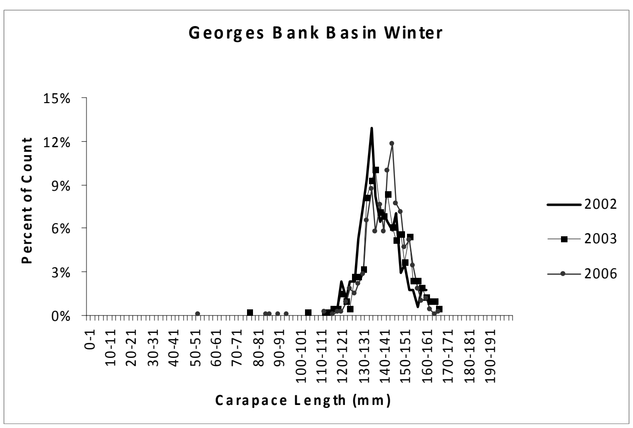


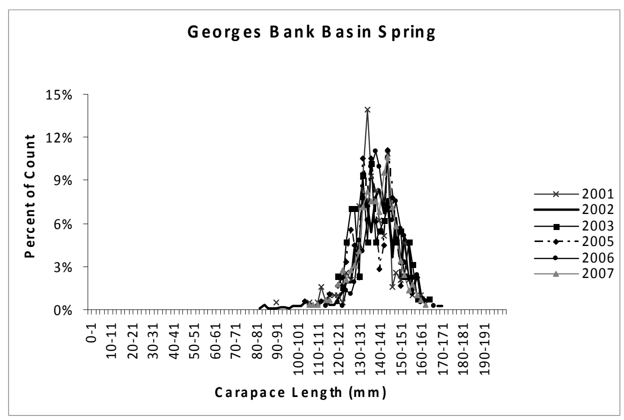






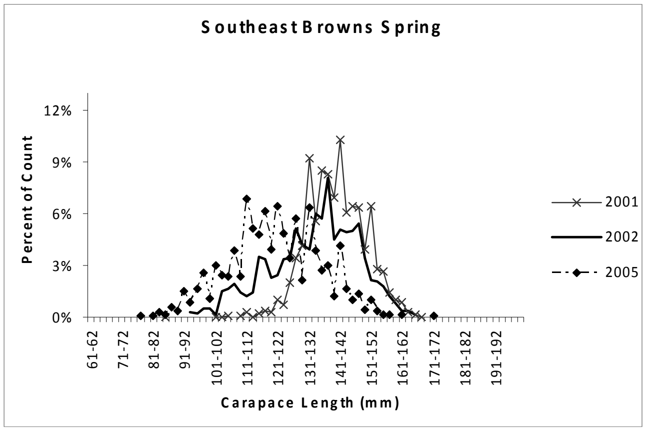
Crowell Basin Males

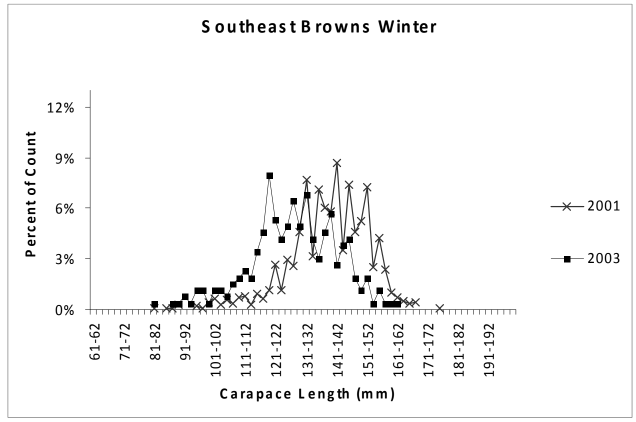


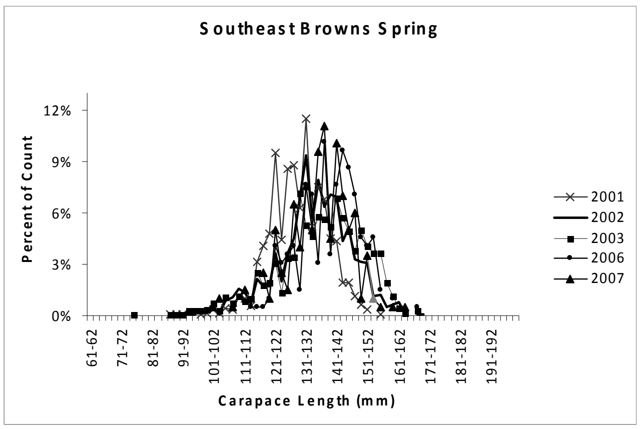


Georges Basin Males

Figure 21. Size frequencies of male Jonah crab.







Southeast Browns Males

Figure 21 (cont'd). Size frequencies of male Jonah crab.

APPENDIX 1

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 Degrees Minutes	 Degrees Minutes	Depth (fathoms)	Soak days	# Traps hauled	CRAB Estimated Catch (lbs)	LOBSTER Estimated Catch (lbs)	 # V-notch Observed	Remarks

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 2

Summary of number of Jonah crab (Male and Female) measured each year and season (Fall: Oct-Dec, Winter: Jan-March, Spring: April-June, Summer: July-Sept).

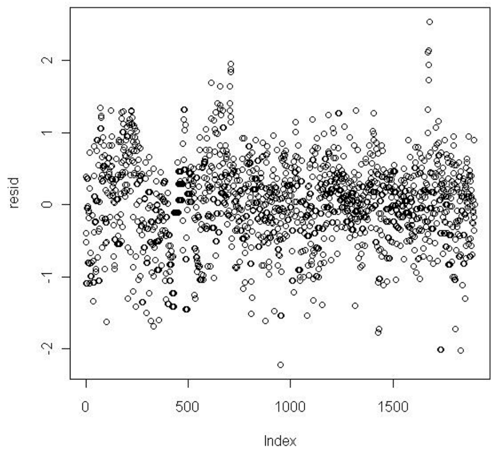
Year	Fall			Winter			Spring			Summer			Grand Total
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	
1999				3,509	103	3,612	6,196	335	6,531	2,061	1,126	3,187	13,330
2000				2,061	440	2,501							2,501
2001	1,710	2,788	4,498	3,557	466	4,023	4,071	458	4,529	2,109	1,704	3,813	16,863
2002	684	569	1,253	4,185	409	4,594	2,558	1,397	3,955				9,802
2003	1,201	814	2,015	3,932	499	4,431	1,895	78	1,973				8,419
2004				302	12	314	128	16	144				458
2005	30	4	34	113	4	117	4,851	430	5,281	1,573	604	2,177	7,609
2006	249	90	339	1,650	47	1,697	767	20	787	377	421	798	3,621
2007	212	44	256	291	8	299	330	4	334				889
2008				20		20							20

APPENDIX 3

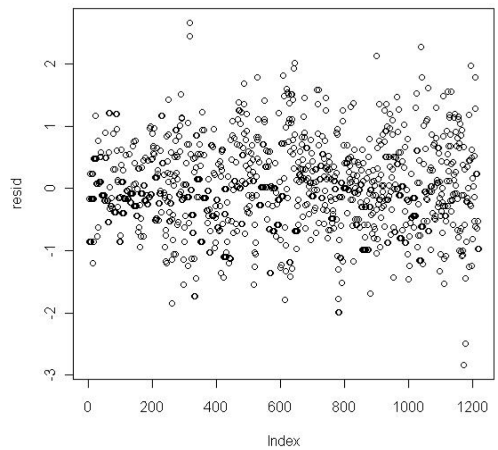
Residual Plots, Jonah Crab Models

Winter

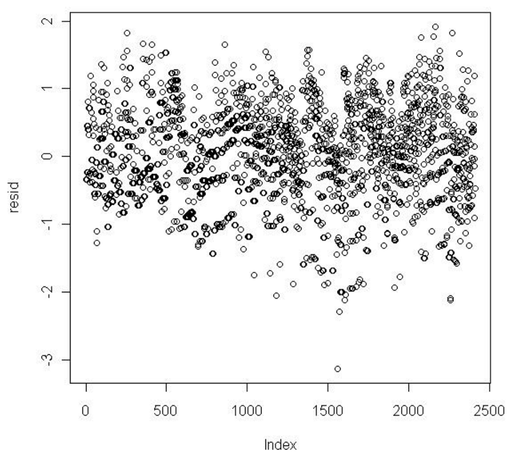
Crowell Basin



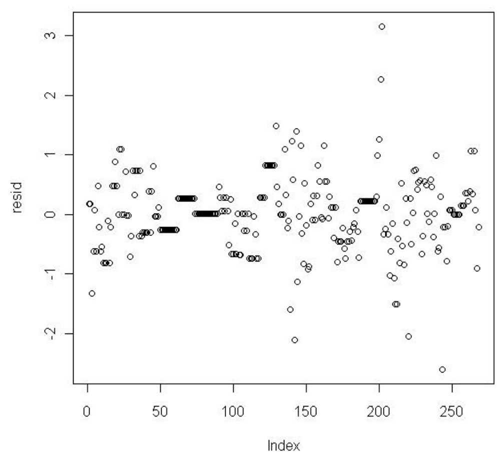
Southwest Browns



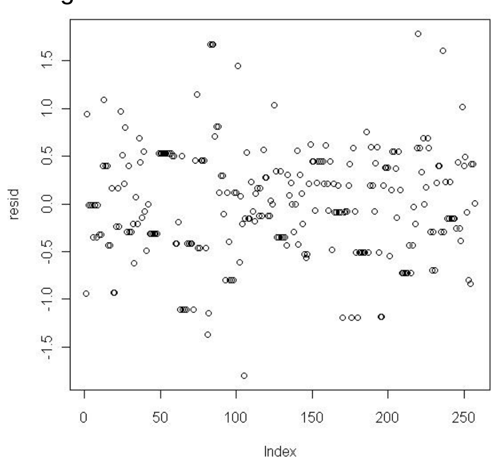
Southeast Browns



Georges Bank

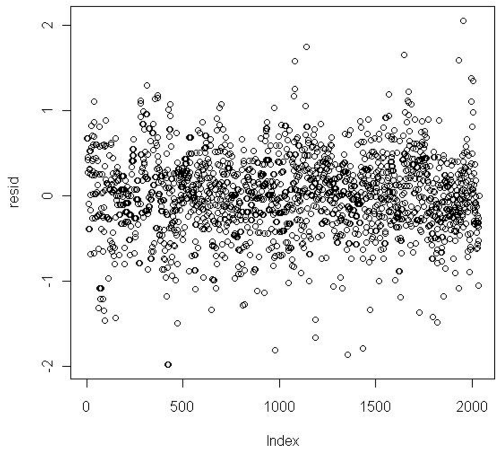


Georges Basin

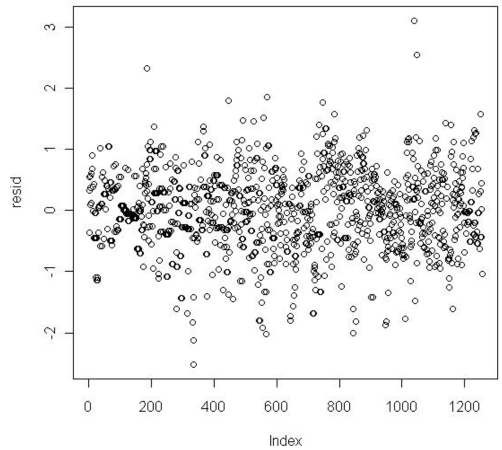


Summer

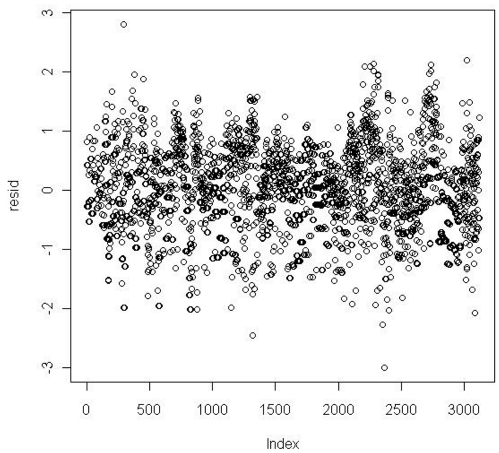
Crowell Basin



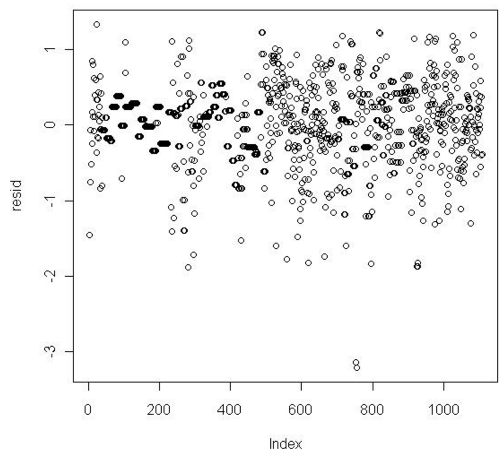
Southwest Browns



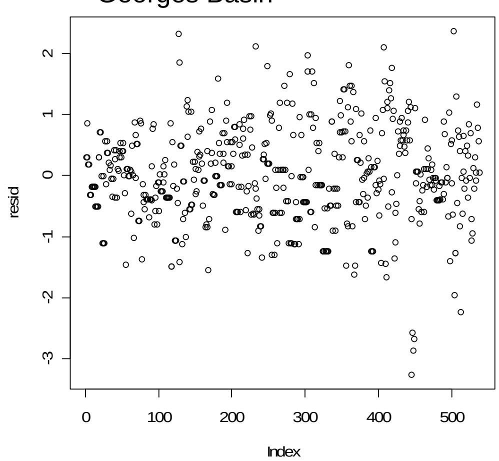
Southeast Browns



Georges Bank



Georges Basin



APPENDIX 4

COEFFICIENTS AND ANOVA TABLES FOR EACH MODEL, JONAH CRAB

Crowell Basin, winter

```
> crabcpue.model = as.formula( "log(CRAB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> crow.win.w.y.cfv = lm( crabcpue.model, data=crab.data.win.crow)
> summary(crow.win.w.y.cfv)
Call:
lm(formula = crabcpue.model, data = crab.data.win.crow)

Residuals:
     Min       1Q   Median       3Q      Max
-2.22626 -0.33409  0.04314  0.36170  2.54638

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)        1.5557154  0.6097126   2.552 0.010803 *
weekofseason2     -0.4309359  0.0598679  -7.198 8.80e-13 ***
weekofseason3     -0.3122141  0.0706131  -4.421 1.04e-05 ***
weekofseason4     -0.3429702  0.0654852  -5.237 1.81e-07 ***
weekofseason5     -0.2903871  0.0682040  -4.258 2.17e-05 ***
weekofseason6     -0.4809530  0.0758724  -6.339 2.89e-10 ***
weekofseason7     -0.3923937  0.0717857  -5.466 5.22e-08 ***
weekofseason8     -0.1792201  0.0672311  -2.666 0.007748 **
weekofseason9     -0.1605776  0.0674746  -2.380 0.017421 *
weekofseason10     0.0229885  0.0654242   0.351 0.725346
weekofseason11     0.0566027  0.0609163   0.929 0.352912
weekofseason12     0.0006205  0.0647466   0.010 0.992354
weekofseason13    -0.5906111  0.2158773  -2.736 0.006280 **
fish.season1997-98 -0.4138293  0.6154193  -0.672 0.501390
fish.season1998-99 -0.6960317  0.6104964  -1.140 0.254387
fish.season1999-00 -1.0099924  0.6098068  -1.656 0.097839 .
fish.season2000-01 -1.1033261  0.6090951  -1.811 0.070237 .
fish.season2001-02 -1.0919195  0.6080763  -1.796 0.072705 .
fish.season2002-03 -1.7763046  0.6101584  -2.911 0.003643 **
fish.season2003-04 -1.5055263  0.6098607  -2.469 0.013652 *
fish.season2004-05 -1.8264471  0.6113357  -2.988 0.002848 **
fish.season2007-08 -3.2391313  0.9472315  -3.420 0.000641 ***
CFV_NO4005        -0.3180126  0.1655838  -1.921 0.054940 .
CFV_NO4034         0.5906195  0.0600551   9.835  < 2e-16 ***
CFV_NO4056        -0.2151470  0.1530523  -1.406 0.159977
CFV_NO100989       1.3108614  0.5950922   2.203 0.027731 *
CFV_NO101315       0.4425698  0.0809909   5.464 5.27e-08 ***
CFV_NO129902       0.8715685  0.0937557   9.296  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5902 on 1869 degrees of freedom
Multiple R-squared: 0.4132,     Adjusted R-squared: 0.4048
F-statistic: 48.75 on 27 and 1869 DF,  p-value: < 2.2e-16

> Anova(crow.win.w.y.cfv)
Anova Table (Type II tests)
Response: log(CRAB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason  60.12   12  14.382 < 2.2e-16 ***
fish.season  233.64    9  74.529 < 2.2e-16 ***
CFV_NO        65.61    6  31.392 < 2.2e-16 ***
Residuals    651.02 1869
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Crowell Basin, Summer

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

Call:
lm(formula = crabcpue.model, data = crab.data.sum.crow)

Residuals:
     Min       1Q    Median       3Q      Max
-1.983504 -0.264508  0.006883  0.283245  2.060537

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)       1.84542    0.08291  22.257  < 2e-16 ***
weekofseason2    -0.07498    0.04544  -1.650 0.099092 .
weekofseason3    -0.17472    0.04572  -3.821 0.000137 ***
weekofseason4    -0.26020    0.04525  -5.750 1.03e-08 ***
weekofseason5    -0.32526    0.04467  -7.282 4.71e-13 ***
weekofseason6    -0.34354    0.05050  -6.802 1.35e-11 ***
weekofseason7    -0.50737    0.05878  -8.631  < 2e-16 ***
weekofseason8    -0.27434    0.05093  -5.387 8.02e-08 ***
weekofseason9    -0.08182    0.05317  -1.539 0.124005
weekofseason10    0.03459    0.05479   0.631 0.527920
weekofseason11   -0.05393    0.05570  -0.968 0.332984
weekofseason12    0.09504    0.06201   1.533 0.125489
weekofseason13    0.19002    0.05399   3.520 0.000442 ***
weekofseason14    0.02364    0.06102   0.387 0.698469
weekofseason15   -0.62487    0.46732  -1.337 0.181334
fish.season1997-98 -0.04745    0.09265  -0.512 0.608624
fish.season1998-99 -0.11203    0.07670  -1.461 0.144260
fish.season1999-00 -0.51647    0.07670  -6.733 2.16e-11 ***
fish.season2000-01 -0.58353    0.07569  -7.710 1.97e-14 ***
fish.season2001-02 -0.88970    0.08024 -11.088  < 2e-16 ***
fish.season2002-03 -1.67128    0.07941 -21.046  < 2e-16 ***
fish.season2003-04 -1.68696    0.09531 -17.699  < 2e-16 ***
fish.season2004-05 -1.16620    0.08906 -13.095  < 2e-16 ***
CFV_NO4005        -0.10389    0.08665  -1.199 0.230673
CFV_NO4034        -0.17724    0.03399  -5.214 2.04e-07 ***
CFV_NO4056        -0.80781    0.23508  -3.436 0.000602 ***
CFV_NO100989       0.47658    0.46362   1.028 0.304093
CFV_NO101315      -0.07576    0.04588  -1.651 0.098825 .
CFV_NO129902       0.11760    0.03886   3.026 0.002510 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4605 on 2008 degrees of freedom
Multiple R-squared: 0.5655,     Adjusted R-squared: 0.5594
F-statistic: 93.32 on 28 and 2008 DF,  p-value: < 2.2e-16

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

Response: log(CRAB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason  55.93   14  18.841 < 2.2e-16 ***
fish.season  388.75    8 229.192 < 2.2e-16 ***
CFV_NO        14.04    6  11.040 3.866e-12 ***
Residuals    425.74 2008
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Southwest Browns, Winter

```
> crabcpue.model = as.formula( "log(CRAB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> swbrns.win.w.y.cfv = lm( crabcpue.model, data=crab.data.win.swbrns)
> summary(swbrns.win.w.y.cfv)
Call:
lm(formula = crabcpue.model, data = crab.data.win.swbrns)

Residuals:
    Min      1Q  Median      3Q     Max
-2.8430 -0.4400 -0.0368  0.4270  2.6663

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)        0.144879   0.166077   0.872 0.383191
weekofseason2     -0.285734   0.061939  -4.613 4.40e-06 ***
weekofseason3     -0.762765   0.071278 -10.701  < 2e-16 ***
weekofseason4     -0.856209   0.086964  -9.845  < 2e-16 ***
weekofseason5     -0.721881   0.099178  -7.279 6.12e-13 ***
weekofseason6     -0.857529   0.111805  -7.670 3.57e-14 ***
weekofseason7     -0.661193   0.102743  -6.435 1.78e-10 ***
weekofseason8     -0.341162   0.116589  -2.926 0.003497 **
weekofseason9      0.002578   0.141396   0.018 0.985458
weekofseason10     0.128113   0.137902   0.929 0.353070
weekofseason11     1.248077   0.120908  10.323  < 2e-16 ***
weekofseason12     0.847041   0.242283   3.496 0.000490 ***
weekofseason13     0.009777   0.717367   0.014 0.989128
fish.season1997-98 -0.134152   0.232805  -0.576 0.564561
fish.season1998-99 -0.034421   0.198686  -0.173 0.862492
fish.season1999-00 -0.634705   0.247927  -2.560 0.010589 *
fish.season2000-01 -0.767780   0.197967  -3.878 0.000111 ***
fish.season2001-02 -0.808180   0.191201  -4.227 2.55e-05 ***
fish.season2002-03 -1.430666   0.194394  -7.360 3.44e-13 ***
fish.season2003-04 -2.077234   0.202365 -10.265  < 2e-16 ***
fish.season2004-05 -1.750976   0.212932  -8.223 5.16e-16 ***
fish.season2005-06 -1.847057   0.223963  -8.247 4.27e-16 ***
fish.season2006-07 -1.694205   0.312028  -5.430 6.84e-08 ***
fish.season2007-08 -1.976501   0.294213  -6.718 2.85e-11 ***
CFV_NO1530         0.535574   0.209159   2.561 0.010572 *
CFV_NO1532         0.718761   0.202815   3.544 0.000410 ***
CFV_NO4005         1.111756   0.198667   5.596 2.72e-08 ***
CFV_NO4034         1.780851   0.198927   8.952  < 2e-16 ***
CFV_NO4056         0.651602   0.199546   3.265 0.001124 **
CFV_NO100989       1.632234   0.279100   5.848 6.42e-09 ***
CFV_NO101315       1.170460   0.200892   5.826 7.29e-09 ***
CFV_NO129902       0.566143   0.197756   2.863 0.004273 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.6994 on 1186 degrees of freedom
Multiple R-squared: 0.4966,     Adjusted R-squared: 0.4834
F-statistic: 37.74 on 31 and 1186 DF,  p-value: < 2.2e-16

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

Response: log(CRAB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason 224.59   12  38.265 < 2.2e-16 ***
fish.season  215.56   11  40.067 < 2.2e-16 ***
CFV_NO       205.76    8  52.588 < 2.2e-16 ***
Residuals    580.07 1186
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Southwest Browns, Summer

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

Call:
lm(formula = crabcpue.model, data = crab.data.sum.swbrns)

Residuals:
      Min        1Q    Median        3Q       Max
-2.524721 -0.394361  0.008822  0.394834  3.109254

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.85017    0.14034   6.058 1.83e-09 ***
weekofseason2   -0.11867    0.13371  -0.887 0.374989
weekofseason3   -0.65496    0.12100  -5.413 7.46e-08 ***
weekofseason4   -1.13989    0.11857  -9.613  < 2e-16 ***
weekofseason5   -1.23811    0.11909 -10.396  < 2e-16 ***
weekofseason6   -1.38452    0.12285 -11.270  < 2e-16 ***
weekofseason7   -1.37766    0.12372 -11.136  < 2e-16 ***
weekofseason8   -0.97412    0.13119  -7.425 2.10e-13 ***
weekofseason9   -0.84909    0.12215  -6.951 5.87e-12 ***
weekofseason10  -0.69941    0.13581  -5.150 3.04e-07 ***
weekofseason11  -0.81259    0.13901  -5.845 6.47e-09 ***
weekofseason12  -0.62393    0.13003  -4.799 1.79e-06 ***
weekofseason13  -0.68516    0.12720  -5.386 8.61e-08 ***
weekofseason14  -0.91516    0.13105  -6.983 4.72e-12 ***
weekofseason15  -0.68965    0.31725  -2.174 0.029906 *
fish.season1997-98 -0.36520    0.13259  -2.754 0.005969 **
fish.season1998-99  0.08088    0.12133   0.667 0.505131
fish.season1999-00 -0.43277    0.14850  -2.914 0.003630 **
fish.season2000-01 -0.30106    0.13597  -2.214 0.026993 *
fish.season2001-02 -0.86268    0.13923  -6.196 7.89e-10 ***
fish.season2002-03 -2.00411    0.15077 -13.292  < 2e-16 ***
fish.season2003-04 -1.69264    0.15488 -10.929  < 2e-16 ***
fish.season2004-05 -1.72300    0.14656 -11.756  < 2e-16 ***
CFV_NO1530       1.40202    0.14317   9.793  < 2e-16 ***
CFV_NO1532       1.44715    0.14953   9.678  < 2e-16 ***
CFV_NO4005       0.84633    0.21726   3.896 0.000103 ***
CFV_NO4034       1.59359    0.13055  12.207  < 2e-16 ***
CFV_NO4056       0.93577    0.15343   6.099 1.43e-09 ***
CFV_NO101315     1.17113    0.10343  11.323  < 2e-16 ***
CFV_NO129902     0.85809    0.12299   6.977 4.93e-12 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6528 on 1226 degrees of freedom
Multiple R-squared: 0.5892,     Adjusted R-squared: 0.5795
F-statistic: 60.63 on 29 and 1226 DF,  p-value: < 2.2e-16

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

Response: log(CRAB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)
weekofseason 150.14   14  25.169 < 2.2e-16 ***
fish.season  258.05    8  75.700 < 2.2e-16 ***
CFV_NO       141.36    7  47.392 < 2.2e-16 ***
Residuals    522.40 1226
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Southeast Browns, Winter

```
> crabcpue.model = as.formula( "log(CRAB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> sebrns.win.w.y.cfv = lm( crabcpue.model, data=crab.data.win.sebrns)
> summary(sebrns.win.w.y.cfv)

Call:
lm(formula = crabcpue.model, data = crab.data.win.sebrns)

Residuals:
     Min       1Q   Median       3Q      Max 
-3.13785 -0.42684  0.01569  0.47814  1.92054 

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)    
(Intercept)       -3.244e+00  3.746e-01  -8.661  < 2e-16 ***
weekofseason2     -1.518e-01  6.778e-02  -2.240 0.025171 *  
weekofseason3     -6.432e-02  7.431e-02  -0.866 0.386813    
weekofseason4     -1.174e-01  7.183e-02  -1.635 0.102206    
weekofseason5     -1.834e-01  7.713e-02  -2.378 0.017477 *  
weekofseason6     -1.992e-01  8.066e-02  -2.469 0.013614 *  
weekofseason7     -2.530e-01  7.897e-02  -3.204 0.001373 ** 
weekofseason8     -2.592e-01  7.199e-02  -3.600 0.000325 ***
weekofseason9     -6.244e-02  7.465e-02  -0.836 0.402972    
weekofseason10    -4.788e-05  7.410e-02  -0.001 0.999485    
weekofseason11     1.855e-01  6.956e-02   2.666 0.007727 ** 
weekofseason12    -3.396e-03  7.253e-02  -0.047 0.962665    
fish.season1997-98  1.225e+00  1.418e-01   8.644  < 2e-16 ***
fish.season1998-99  5.577e-01  1.149e-01   4.855 1.28e-06 ***
fish.season1999-00  1.007e+00  1.177e-01   8.559  < 2e-16 ***
fish.season2000-01  1.126e+00  1.149e-01   9.805  < 2e-16 ***
fish.season2001-02  7.484e-01  1.110e-01   6.739 1.99e-11 ***
fish.season2002-03  1.188e-01  1.143e-01   1.039 0.298797    
fish.season2003-04  3.719e-02  1.161e-01   0.320 0.748707    
fish.season2004-05 -7.170e-01  1.162e-01  -6.168 8.08e-10 ***
fish.season2005-06 -4.089e-01  1.196e-01  -3.419 0.000640 ***
fish.season2006-07 -7.118e-01  1.354e-01  -5.258 1.59e-07 ***
fish.season2007-08 -7.461e-01  1.677e-01  -4.449 9.00e-06 ***
CFV_NO4005         2.489e+00  3.633e-01   6.850 9.37e-12 ***
CFV_NO4034         3.530e+00  3.592e-01   9.829  < 2e-16 ***
CFV_NO100989       3.271e+00  3.559e-01   9.193  < 2e-16 ***
CFV_NO101315       3.300e+00  4.040e-01   8.168 5.04e-16 ***
CFV_NO129902       1.752e+00  7.875e-01   2.224 0.026228 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.7014 on 2382 degrees of freedom
Multiple R-squared: 0.4552,     Adjusted R-squared: 0.449 
F-statistic: 73.71 on 27 and 2382 DF,  p-value: < 2.2e-16 

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

Response: log(CRAB.CPUE.KG)
              Sum Sq   Df  F value    Pr(>F)    
weekofseason   36.86   11   6.8124 2.182e-11 ***
fish.season   826.98   11 152.8285 < 2.2e-16 ***
CFV_NO         97.57    5  39.6696 < 2.2e-16 ***
Residuals    1171.76 2382                       
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Southeast Browns, Summer

```
> crabcpue.model = as.formula( "log(CRAB.CPUE.KG) ~ weekofseason+fish.season+CFV_NO" )
> sebrns.sum.w.y.cfv = lm( crabcpue.model, data=crab.data.sum.sebrns)
> summary(sebrns.sum.w.y.cfv)

Call:
lm(formula = crabcpue.model, data = crab.data.sum.sebrns)

Residuals:
     Min       1Q   Median       3Q      Max 
-3.00193 -0.44070  0.02458  0.47839  2.80959 

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)    
(Intercept)         -0.64747    0.42337  -1.529 0.126289    
weekofseason2       -0.05223    0.06834  -0.764 0.444812    
weekofseason3       -0.05105    0.06698  -0.762 0.446057    
weekofseason4       -0.31135    0.06652  -4.681 2.98e-06 ***
weekofseason5       -0.08014    0.06640  -1.207 0.227523    
weekofseason6       -0.24844    0.06566  -3.784 0.000158 ***
weekofseason7       -0.09987    0.06661  -1.499 0.133882    
weekofseason8        0.22758    0.06806   3.344 0.000837 ***
weekofseason9       -0.07942    0.06999  -1.135 0.256565    
weekofseason10       0.01987    0.06917   0.287 0.773985    
weekofseason11       0.02790    0.07624   0.366 0.714457    
weekofseason12       0.02495    0.07504   0.333 0.739518    
weekofseason13      -0.01659    0.07214  -0.230 0.818145    
weekofseason14       0.13977    0.07879   1.774 0.076154 .  
weekofseason15      -0.38629    0.14521  -2.660 0.007849 ** 
fish.season1997-98   0.33849    0.13025   2.599 0.009401 ** 
fish.season1998-99  -0.55295    0.08512  -6.496 9.55e-11 ***
fish.season1999-00   0.19780    0.08277   2.390 0.016924 *  
fish.season2000-01   0.62945    0.08649   7.278 4.28e-13 ***
fish.season2001-02  -0.27626    0.08139  -3.394 0.000697 ***
fish.season2002-03  -0.41107    0.08382  -4.904 9.87e-07 ***
fish.season2003-04  -0.48990    0.08496  -5.766 8.90e-09 ***
fish.season2004-05  -1.23116    0.09110 -13.515  < 2e-16 ***
fish.season2005-06  -0.98686    0.09995  -9.873  < 2e-16 ***
fish.season2006-07  -1.50944    0.09690 -15.577  < 2e-16 ***
CFV_NO1532           0.39919    0.45544   0.876 0.380832    
CFV_NO2735           0.96502    0.41701   2.314 0.020725 *  
CFV_NO4005           0.55659    0.42136   1.321 0.186618    
CFV_NO4034           1.48591    0.41516   3.579 0.000350 ***
CFV_NO100989         1.19173    0.41329   2.883 0.003960 ** 
CFV_NO101315         0.59870    0.44390   1.349 0.177521    
CFV_NO129902        -0.34759    0.82165  -0.423 0.672299    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.7076 on 3086 degrees of freedom
Multiple R-squared: 0.4212,     Adjusted R-squared: 0.4154 
F-statistic: 72.45 on 31 and 3086 DF,  p-value: < 2.2e-16 
> Anova(sebrns.sum.w.y.cfv)
Anova Table (Type II tests)

Response: log(CRAB.CPUE.KG)
              Sum Sq   Df  F value    Pr(>F)    
weekofseason   55.18   14   7.8732 < 2.2e-16 ***
fish.season   737.29   10 147.2737 < 2.2e-16 ***
CFV_NO        104.62    7  29.8527 < 2.2e-16 ***
Residuals    1544.94 3086                       
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
```

Georges Bank, Winter

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

Call:
lm(formula = crabcpue.model, data = crab.data.win.gbank)

Residuals:
      Min        1Q    Median        3Q       Max 
-2.608372 -0.312606  0.002698  0.284511  3.156178 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)         1.8299     0.2336   7.834 1.43e-13 ***
weekofseason2      -0.7233     0.1375  -5.259 3.15e-07 ***
weekofseason3      -1.0166     0.1770  -5.742 2.76e-08 ***
weekofseason4      -1.1286     0.2704  -4.174 4.15e-05 ***
weekofseason5      -0.7996     0.5177  -1.544  0.12379    
weekofseason6      -1.6133     0.3687  -4.376 1.79e-05 ***
weekofseason7      -1.2363     0.5055  -2.446  0.01516 *  
weekofseason9      -0.9772     0.4298  -2.274  0.02384 *  
weekofseason10     -1.1238     0.2026  -5.548 7.48e-08 ***
weekofseason11     -1.2902     0.1714  -7.528 9.83e-13 ***
weekofseason12     -0.1873     0.1468  -1.275  0.20347    
fish.season1997-98 -0.5148     0.3906  -1.318  0.18876    
fish.season1998-99 -0.5576     0.2872  -1.942  0.05333 .  
fish.season1999-00 -1.1779     0.5168  -2.279  0.02350 *  
fish.season2000-01 -1.4002     0.2754  -5.083 7.37e-07 ***
fish.season2001-02 -1.2401     0.2399  -5.169 4.89e-07 ***
fish.season2002-03 -1.5055     0.2376  -6.337 1.11e-09 ***
fish.season2003-04 -0.3614     0.2598  -1.391  0.16547    
fish.season2005-06 -2.2939     0.2186 -10.494  < 2e-16 ***
CFV_NO4005         -0.8718     0.2156  -4.044 7.06e-05 ***
CFV_NO4034          0.9371     0.2816   3.328  0.00101 ** 
CFV_NO4056         -0.1520     0.1507  -1.009  0.31417    
CFV_NO100989        0.2794     0.4041   0.691  0.49002    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6519 on 245 degrees of freedom
Multiple R-squared: 0.6465,     Adjusted R-squared: 0.6148 
F-statistic: 20.37 on 22 and 245 DF,  p-value: < 2.2e-16 

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

Response: log(CRAB.CPUE.KG)
              Sum Sq  Df F value    Pr(>F)    
weekofseason  52.488  10 12.3512 < 2.2e-16 ***
fish.season   81.876   8 24.0833 < 2.2e-16 ***
CFV_NO        14.843   4  8.7319 1.323e-06 ***
Residuals    104.116 245                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Georges Bank, Summer

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

Call:
lm(formula = crabcpue.model, data = crab.data.sum.gbank)

Residuals:
     Min       1Q   Median       3Q      Max 
-3.21142 -0.27759  0.05609  0.31918  1.33255 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)         2.28740    0.21947  10.422  < 2e-16 ***
weekofseason2       0.03060    0.07104   0.431 0.666755    
weekofseason3      -0.19689    0.06803  -2.894 0.003880 ** 
weekofseason4      -0.56919    0.07160  -7.950 4.68e-15 ***
weekofseason5      -0.65027    0.07407  -8.780  < 2e-16 ***
weekofseason6      -0.95207    0.07719 -12.335  < 2e-16 ***
weekofseason7      -0.63173    0.09310  -6.785 1.91e-11 ***
weekofseason8      -0.68480    0.08533  -8.025 2.63e-15 ***
weekofseason9      -0.67698    0.08527  -7.939 5.08e-15 ***
weekofseason10     -0.52416    0.12782  -4.101 4.43e-05 ***
weekofseason11     -1.15617    0.25642  -4.509 7.23e-06 ***
weekofseason12     -0.13670    0.10952  -1.248 0.212261    
weekofseason13     -0.10340    0.11591  -0.892 0.372579    
weekofseason14     -0.30011    0.11991  -2.503 0.012469 *  
weekofseason15     -0.24437    0.32818  -0.745 0.456653    
fish.season1997-98 -0.21755    0.14546  -1.496 0.135052    
fish.season1998-99 -0.80846    0.16060  -5.034 5.62e-07 ***
fish.season1999-00 -0.64657    0.13517  -4.783 1.96e-06 ***
fish.season2000-01 -0.47918    0.12175  -3.936 8.82e-05 ***
fish.season2001-02 -0.68386    0.11942  -5.727 1.33e-08 ***
fish.season2002-03 -0.78853    0.12952  -6.088 1.58e-09 ***
fish.season2003-04 -1.19752    0.15130  -7.915 6.10e-15 ***
fish.season2004-05 -0.33513    0.13952  -2.402 0.016470 *  
CFV_NO1532         -0.26001    0.17644  -1.474 0.140852    
CFV_NO4005         -1.96759    0.19201 -10.248  < 2e-16 ***
CFV_NO4034         -0.79541    0.23058  -3.450 0.000583 ***
CFV_NO4056         -0.68310    0.17839  -3.829 0.000136 ***
CFV_NO100989       -0.90572    0.44169  -2.051 0.040548 *  
CFV_NO101315       -0.82987    0.32557  -2.549 0.010941 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.5421 on 1080 degrees of freedom
Multiple R-squared: 0.5355,     Adjusted R-squared: 0.5235 
F-statistic: 44.47 on 28 and 1080 DF,  p-value: < 2.2e-16 

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

Response: log(CRAB.CPUE.KG)
             Sum Sq   Df F value    Pr(>F)    
weekofseason  99.73   14  24.242 < 2.2e-16 ***
fish.season   33.81    8  14.384 < 2.2e-16 ***
CFV_NO       172.29    6  97.724 < 2.2e-16 ***
Residuals    317.35 1080                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
```

Georges Basin, Winter

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

Call:
lm(formula = crabcpue.model, data = crab.data.win.gbasin)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.80313 -0.35088 -0.01365  0.41345  1.78822 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)          1.5386     0.8136   1.891 0.059881 .  
weekofseason2       -1.2785     0.2179  -5.868 1.52e-08 ***
weekofseason3       -1.2720     0.2329  -5.461 1.22e-07 ***
weekofseason4       -0.7214     0.2478  -2.911 0.003954 ** 
weekofseason5       -1.5356     0.2691  -5.707 3.51e-08 ***
weekofseason6       -1.5730     0.2566  -6.130 3.77e-09 ***
weekofseason7       -2.1763     0.2989  -7.281 5.16e-12 ***
weekofseason9       -0.3058     0.4269  -0.716 0.474436    
weekofseason10      -0.6704     0.2950  -2.273 0.023963 *  
weekofseason11      -2.0677     0.2870  -7.204 8.22e-12 ***
weekofseason12      -1.1663     0.2888  -4.038 7.35e-05 ***
fish.season1997-98  -0.9584     0.5094  -1.881 0.061192 .  
fish.season1998-99  -1.5508     0.4562  -3.399 0.000795 ***
fish.season1999-00  -1.3189     0.5110  -2.581 0.010462 *  
fish.season2000-01  -1.3251     0.4097  -3.234 0.001398 ** 
fish.season2001-02  -1.1339     0.4690  -2.418 0.016399 *  
fish.season2002-03  -1.5886     0.5470  -2.904 0.004040 ** 
fish.season2003-04  -1.0779     0.5117  -2.107 0.036233 *  
fish.season2005-06  -2.8098     0.8176  -3.436 0.000699 ***
fish.season2006-07  -2.7136     0.7694  -3.527 0.000507 ***
fish.season2007-08  -2.2228     0.8848  -2.512 0.012685 *  
CFV_NO1532          -0.0358     0.6668  -0.054 0.957229    
CFV_NO4005          -1.0771     0.6899  -1.561 0.119824    
CFV_NO4034           1.5372     0.7497   2.050 0.041465 *  
CFV_NO4056          -0.1149     0.8429  -0.136 0.891705    
CFV_NO100989         1.7947     1.0305   1.742 0.082927 .  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.6023 on 231 degrees of freedom
Multiple R-squared: 0.7505,     Adjusted R-squared: 0.7235 
F-statistic:  27.8 on 25 and 231 DF,  p-value: < 2.2e-16 

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

Response: log(CRAB.CPUE.KG)
             Sum Sq  Df F value    Pr(>F)    
weekofseason 50.212  10 13.8404 < 2.2e-16 ***
fish.season  11.611  10  3.2003 0.0007138 ***
CFV_NO       25.688   5 14.1609 4.363e-12 ***
Residuals    83.806 231                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
```

Georges Basin, Summer

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

Call:
lm(formula = crabcpue.model, data = crab.data.sum.gbasin)

Residuals:
     Min       1Q   Median       3Q      Max
-3.26792 -0.45255 -0.04027  0.52747  2.37178
Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)         -0.40636    0.48988  -0.829 0.407213
weekofseason2        0.23047    0.13175   1.749 0.080839 .
weekofseason3        0.05497    0.12465   0.441 0.659414
weekofseason4        0.05886    0.14134   0.416 0.677252
weekofseason5       -0.35295    0.13901  -2.539 0.011415 *
weekofseason6       -0.66255    0.24988  -2.651 0.008267 **
weekofseason7       -1.21718    0.30065  -4.048 5.96e-05 ***
weekofseason8       -0.64424    0.28591  -2.253 0.024671 *
weekofseason9       -0.02616    0.24855  -0.105 0.916223
weekofseason10       0.25711    0.25316   1.016 0.310320
weekofseason11       0.27009    0.25213   1.071 0.284566
weekofseason12       0.33133    0.28883   1.147 0.251870
weekofseason13       0.30604    0.24543   1.247 0.212996
weekofseason14      -0.35967    0.60732  -0.592 0.553969
fish.season1997-98 -0.19494    0.31591  -0.617 0.537458
fish.season1998-99 -0.23745    0.31118  -0.763 0.445783
fish.season1999-00 -1.15436    0.33036  -3.494 0.000517 ***
fish.season2000-01 -2.08488    0.31823  -6.551 1.40e-10 ***
fish.season2001-02 -0.63775    0.34483  -1.849 0.064972 .
fish.season2002-03 -1.22506    0.30993  -3.953 8.83e-05 ***
fish.season2003-04 -1.34918    0.33592  -4.016 6.81e-05 ***
fish.season2004-05 -1.12102    0.34890  -3.213 0.001397 **
fish.season2005-06 -0.78189    0.92245  -0.848 0.397048
fish.season2006-07 -1.24248    0.90577  -1.372 0.170751
CFV_NO1530           1.74382    0.39189   4.450 1.06e-05 ***
CFV_NO1532           2.41400    0.40985   5.890 7.05e-09 ***
CFV_NO4005           0.14767    0.41620   0.355 0.722876
CFV_NO4034           1.86240    0.38524   4.834 1.77e-06 ***
CFV_NO4056           1.46910    0.41389   3.549 0.000422 ***
CFV_NO100989         0.35958    0.90777   0.396 0.692185
CFV_NO101315         1.07760    0.50093   2.151 0.031932 *
CFV_NO129902         0.56366    0.53910   1.046 0.296267
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.8026 on 506 degrees of freedom
Multiple R-squared: 0.5785,     Adjusted R-squared: 0.5527
F-statistic:  22.4 on 31 and 506 DF,  p-value: < 2.2e-16

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

Response: log(CRAB.CPUE.KG)
              Sum Sq  Df F value    Pr(>F)
weekofseason  36.92  13   4.408 4.262e-07 ***
fish.season  123.87  10  19.227 < 2.2e-16 ***
CFV_NO       111.94   8  21.721 < 2.2e-16 ***
Residuals    325.98 506
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```