Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

Canadian Science Advisory Secretariat (CSAS)

Research Document 2014/032

Gulf Region

Rock crab, *Cancer irroratus*, Fishery and Stock Status in the Southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B

A. Rondeau, J.M. Hanson, and M. Comeau

Fisheries and Oceans Canada
Gulf Fisheries Centre
P.O. Box 5030, 343 Université Avenue
Moncton N.B. E1C 9B6

August 2014

Foreword

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

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

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Rondeau, A., Hanson, J.M., and Comeau, M. 2014. Rock crab, *Cancer irroratus*, fishery and stock status in the southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/032. vi + 52 p.

TABLE OF CONTENTS

ABSTRACT

The rock crab (*Cancer irroratus*) fishery began during the 1960's as a bycatch in the lobster fishery, some of which was used as bait. A directed exploratory fishery began in 1974 on a small-scale until the late 1980's, when expanding markets and increased value resulted in substantial increase in effort. While the directed fishery is conducted with defined management measures, the bycatch and bait fisheries taking place during the lobster fishery are only restricted to harvesting male rock crab. The present research document describes the data and analysis in support of the most recent Science Advisory Report on the assessment of the rock crab fishery in the southern Gulf of St. Lawrence (DFO 2013). The majority of the indicators presented are fishery dependent. New fishery independent indicators are presented. The assessment is based primarily on the examination of abundance, fishing pressure, and production indicators. When possible, temporal fluctuations in the indicators were assessed relative to the previous assessment (DFO 2008). Ecosystem considerations were included in the document mainly to emphasize the importance of rock crab within coastal ecosystems, especially as a prey for several species of fish and for lobster.

État de la pêche et des stocks de crabe commun, *Cancer irroratus*, dans le sud du golfe du Saint-Laurent : ZPH 23, 24, 25, 26A et 26B

RÉSUMÉ

L'exploitation du crabe commun (*Cancer irroratus*) a débuté dans les années soixante à titre de prises accidentelles lors de la pêche au homard où une certaine quantité était utilisée comme appât. Une pêche dirigée exploratoire à petite échelle a été mise en place en 1974 mais ce n'est qu'à la fin des années 1980s qu'il y a eu une augmentation substantielle de l'effort de pêche en réponse au développement des marchés et à l'augmentation de la valeur du produit. La pêche dirigée au crabe commun est encadrée par des mesures de gestion bien définies alors que les pêches accessoire et pour l'appât, qui ont lieu durant la pêche au homard, ne sont assujetties qu'à la restriction de récolter des crabes mâles. Le présent document de recherche décrit les données et les analyses ayant servies à l'élaboration du plus récent avis scientifique sur l'évaluation de la pêche au crabe commun dans le sud du golfe du Saint-Laurent (MPO 2013). Bien que la plupart des indicateurs présentés soient issus de données liées à la pêche, de nouveaux indicateurs indépendants de la pêche sont présentés. L'évaluation repose principalement sur l'examen d'indicateurs d'abondance, de pression de pêche et de production. Les variations temporelles des récents indicateurs par rapport à ceux présentés lors de la dernière évaluation (MPO 2008) ont été examinées dans certains cas. Des considérations écosystémiques ont été incluses dans le document afin de souligner l'importance du crabe commun au sein des écosystèmes côtiers, particulièrement en tant que proie pour de nombreuses espèces de poisson et pour le homard.

INTRODUCTION

Rock crab (*Cancer irroratus*) is distributed along the Atlantic coast of North America, from South Carolina to Labrador, from the intertidal zone to depth up to 575 meters. Rock crabs concentrate in shallow waters and seem to prefer sandy bottoms, although they can be observed on all types of substrate. They are widespread and abundant in the southern Gulf of St. Lawrence (sGSL) (Caddy and Chandler 1976).

In the sGSL, rock crab has been exploited since the early 1960's, initially as a bycatch of the lobster (*Homarus americanus*) fishery and, since 1974, as a directed fishery. During the lobster fishery, harvesters can use the rock crab caught in their lobster traps as bait, or sell the bycatch. Since the late 1980's, the directed fishery has been expanding and over 200 harvesters currently participate in this fishery. Rock crabs are fished in coastal waters using modified lobster traps, conical or pyramidal crab traps. All traps are equipped with escape vents to minimize the bycatch of lobsters and have biodegradable mechanisms to reduce ghost fishing if traps are lost at sea. Traps are usually hauled daily using the same boats and equipment as those of the lobster fishery.

This document is a review of the rock crab fishery managed by DFO-Gulf Region in the sGSL from 2006 to 2011. The last assessment was completed in 2008 (DFO 2008). The stock assessment is based mainly on fishery dependent indicators such as landings and catch rates derived from mandatory logbook reports and from dockside monitoring of the catches. Indicator trends were evaluated. Biomass estimates and other fishery-independent indicators were derived from a bottom trawl survey conducted in 2010 and 2011 in the Northumberland Strait of the sGSL. No biological reference points have been established for this species. Finally, ecosystem considerations are discussed in the context of stock productivity and relative to the trophic links between rock crab and lobster.

FISHERY MANAGEMENT

DFO Gulf Region is responsible for rock crab fisheries that operate in the sGSL (i.e., New Brunswick (NB), Nova Scotia (NS), and Prince Edward Island (PEI)) excluding those in Quebec waters (i.e. Magdalen Islands and Gaspé area). Five fishing areas are defined for the rock crab fishery, corresponding to the Lobster Fishing Areas (LFAs): 23, 24, 25, 26A and 26B (Figure 1). These areas were not created based on the biology of the species, but for management purposes.

The directed fishery follows defined management measures including a minimum legal size (MLS), a prohibition to land females, individual allocations (except in LFA 24), limited access to fishing licences, and catch-monitoring with a mandatory dockside monitoring program and logbooks (Table 1). The number of rock crab licences issued (including 24 temporary licences in 2011) in recent years was stable, at around 250, but not all licence holders were active in the fishery. Individual allocations have not changed since 2000 but they vary among LFAs (Table 1) and licence type. Most licences are classified either as commercial or commercial communal (Aboriginal Groups). In 2011, there were only two partnership licences in LFA 25 and seven community licences (one maximum allocation divided among a group of harvesters) in LFA 25 NB-side. Partnerships consist of a combination of two commercial licences that provides double the individual allocation but the allocation must be fished from a single vessel with 150% (rather than twice) of the trap allocation in effect in the LFA. Even though partnership and community licences represent a very small number of the available licences, they were still considered in the estimates related to attainment of individual allocation (i.e., quota).

The bycatch and bait fisheries operate based on section 55 of the Atlantic Fishery Regulations (1985) that states: "Where a person is fishing for lobster in accordance with these Regulations, that person may, without a licence for crab fishing, retain any male rock crabs caught in his lobster traps". Rock crab bycatches sold to registered buyers were used in this assessment, but no information was available on rock crab removals in the bait fishery. With about 3,000 lobster harvesters in the sGSL, potential markets for rock crab and fluctuations in the availability of bait during the lobster fishery, rock crab catches outside the directed fishery may be important. Ninety-five percent of rock crab licence holders also had a lobster fishing licence in 2011.

DATA SOURCES

FISHERY RELATED DATA

Official statistics

Landings data from the directed rock crab fishery were collected from the mandatory harvesters' logbook filled on a daily basis and verified by the dockside monitoring company. Fishing effort information of the daily activities (number of traps hauled, number of soak days, fishing positions, etc.) was also recorded in the logbook but entered into DFO Policy and Economics Branch database at a later time by the dockside monitoring companies. Matching up the information on rock crab landings and fishing effort was difficult and may had led to gaps in the data when no reconciliation was possible, i.e., when matching variables were missing. No significant effort was made to verify logbook compliance.

Data on bycatch of rock crab during the lobster fishery were compiled from sales transactions, not from logbook or dockside monitoring companies' reports. When sales slips for lobster transactions reach DFO, the data are entered into DFO Policy and Economics Branch database. Data on bycatch removals were obtained by querying the database for rock crab landings where at least one pound of lobster was recorded; rock crab sold independently from lobster (a different buyer or separate sale slip) were not accounted for, and were a source of uncertainty in the data. Changes to the official data recording system at DFO had also revealed some discrepancies in the data. Landings were reported in 2011 but the data are considered preliminary.

Other statistics were also obtained from the Fisheries and Aquaculture Management Branch of DFO, namely on the different type of licences, to calculate percentages of individual quotas that were reached.

Scientific trap survey

Biological information on rock crab is very limited and, given the presumed importance of this species in the coastal ecosystem, it was deemed relevant to collect some information even if on a sporadic basis. In 2011, trap sampling activities were conducted to collect information on biological characteristics of rock crab such as population size distribution, sex ratios, allometric relationships, etc. Between 10 and 15 small conical rock crab traps with blocked escape vents and a liner (mesh size of 25 mm knot-to-knot) were set at three locations: Egmont Bay (PEI), Toney River (NS), and Cocagne Bay (NB) (Figure 2) and hauled the next day with the assistance of local harvesters. The traps were modified to capture small individuals, in particular females. The sampling was done once per location in June (before the fishery) and a second time in late October-early November (toward the end of the fishing season) when more than 85% of the fishing activities were done in both LFAs.

All rock crab from the catches were sampled at minimum for sex and number captured. For selected traps in an area and period, all the crabs from that trap were sampled. For each sample, sex was determined for all crabs, they were then measured to the nearest millimeter (maximum carapace width, from spine to spine; CW), and the carapace condition was categorized as either: clean and soft (newly molted), clean and hard (inter-molt), and hard and dirty (old carapace). Claw height (CH) for males was measured at its highest point with vernier calipers (to 1 mm).

FISHERY INDEPENDENT DATA

Trawl surveys in LFAs 25 and 26A

A trawl survey, using a No. 286 rockhopper trawl, was initiated in 2001 to monitor abundance and distribution of lobster in LFA 25. The survey was later expanded to cover most of LFA 26A and converted to a full ecosystem trawl survey in 2005 (Hanson 2009, Bosman et al. 2011, Kelly and Hanson 2013). In 2010 and 2011, the survey trawl was changed because the No. 286 rockhopper trawl was considered to have a low efficiency at capturing rock crab (Hanson 2009). In those two years, a *Nephrops* trawl was used; this trawl is designed to dig into the bottom and is efficient at capturing crabs (Conan et al. 1994). However, because of this, the *Nephrops* trawl cannot be used on cobble, boulder, and rock substrates.

The 20 m *Nephrops* trawl used in 2010 and 2011 had a 28 m footrope, 80 mm stretch-measure diamond mesh in the body of the net, 60 mm stretch-measure diamond mesh in the extension piece, and 40 mm stretch-measure diamond mesh in the codend. A lattice of 2x2 nautical-mile grids was overlaid over the survey area. As the survey area is irregular, grids falling on the boundaries had smaller surface areas than those lying within the area. To avoid a spatial sampling bias, the expected number of survey sampling stations within each grid was selected as proportional to the available survey area. The locations of survey stations were randomly selected from a set of nine regularly-spaced points within each grid. For boundary grids, only points lying within the survey area were considered. A set of alternate sampling stations were also generated in a similar manner. Tows were done during daytime at a target speed of 2 knots for only 5 minutes, as large amounts of sediment and debris are retained by the trawl, which usually required washing the net with a hose to remove as much sediment from the net as possible before sorting the catch. In 2010 and 2011, 101 and 103 valid tows were done respectively in LFAs 25 and 26A (Figure 3).

The catch was sorted down to species, with each taxon weighed and numbers recorded. CW to the nearest mm, CH for male only with a precision of 0.1 mm, sex, carapace condition, and individual weight for intact specimens only were recorded for all rock crabs, as well as the presence of eggs for berried females. Sexual maturity was determined for males based on the presence/absence of spermatophores in the vas deferens. Rock crabs were retained (frozen) for stomach content analysis from the 2010 survey.

Stomach samples of fish and decapods used in the diet analysis mostly came from the 2000-2009 surveys conducted in Northumberland Strait (Voutier and Hanson 2008; Hanson 2009; Bosman et al. 2011; Hanson 2011; Kelly and Hanson 2013). Intact fish or crustaceans were retained from an arbitrary subset of stations, frozen, taken to the laboratory, and stomach contents examined. Samples could not be collected concurrently for all species due to freezer-space limitations on the survey ship. In the laboratory, the organism was thawed in cold water, its length or width recorded (in mm), and the stomach was excised. Stomach contents were identified to the lowest practical taxonomic level, the number of individuals recorded (when possible), and the weight of all organisms in a taxa measured to the nearest mg (blotted wet weight). The importance of rock crab and lobster to the various fish and crustacean species was expressed as % by weight because it is much less subjective than visual estimation of volume or point estimate methods that are frequently used when reporting diets. Also, % biomass is a critical input variable to mass-balance type ecosystem models. Whenever possible, the CW of the rock crab consumed by fishes was measured to the nearest mm. It was not possible to estimate the size of rock crab eaten by decapod predators. Decapod remains were classified as fresh prey if muscle or gills were still attached to the exoskeleton; otherwise, the remains were classified as molted carapaces (exuvia).

Bio-collectors

Data from passive vessel-deployed bio-collectors developed as a lobster postlarval settlement indicator (Wahle et al. 2009, 2013) were examined to assess patterns of postlarval settlement of rock crab. The bio-collectors were made with 10-gauge vinyl-coated wire (38 mm mesh), with dimensions of 61.0 cm x 91.5 cm x 15.0 cm in height, for a surface area of 0.55 m^2, and the structures were filled with rocks to mimic lobster habitat. The inside of the bio-collector was lined with 2-mm rugged plastic mesh (PetMesh™) to retain lobsters, crabs and other small organisms during retrieval. Details of their design are provided in Wahle et al. (2009). The inside bottom of the bio-collectors was filled with gravel (10-20 mm) and then by cobble (10 to 15 cm) acquired at a local quarry. Each collector was fitted with a bridle to permit lifting in a horizontal position, which is important to retain collections during retrieval (Wahle et al. 2009). Bio-collectors filled with rocks weighted approximately 80 kg.

In 2008, the bio-collectors project was carried-out by DFO-Science at six sites (Table 2). At each site, 30 bio-collectors were deployed by boat at depths ranging between 5 to 7 m (9 m in Neguac) in late-May and early-June (Table 2). Divers were sent down to verify positioning on the seafloor. No surface buoy was used that year to mark the location of the bio-collectors and, hence, divers were also sent down to attach a rope and buoy to the bio-collectors for retrieval at the end of the submersion period in October-November. Bio-collectors were lifted to the surface with the boat's trap hauler with no pause during the lift to keep constant water pressure on the content of the bio-collector.

In collaboration with the Prince-Edward-Island Fishermen's Association, bio-collectors were deployed at six sites between 2009 and 2012, with an additional site in Arisaig, NS (Table 2). Each year, 30 bio-collectors were deployed by boat at depths ranging between 5 to 9 m in early-July and retrieved by late-September and early-October. In contrast with the 2008 project, a surface buoy was used to mark the location and to facilitate retrieval of the bio-collectors. In Fortune (PEI), five bio-collectors were deployed at 22 m between 2010 and 2012. Sites at Covehead (PEI) and Arisaig (NS) have five years of uninterrupted data. Finally, a Vemco™ probe was used at each site to record bottom temperature during the immersion period.

After retrieval and once on deck of the boat, the wire mesh covers were removed from the bio-collectors, and rocks were rinsed and removed to inspect for crustaceans and/or fish. Occasionally, collectors had become filled with soft sediments (i.e., sand or mud) over the course of the submersion period; these collectors were excluded from the analysis. All rock crabs collected were measured and their sex was determined. For large samples of small rock crabs (i.e., rock crab settlers), the content of the bio-collectors were brought to the laboratory for processing.

DATA ANALYSIS

BIOLOGICAL PARAMETERS

Data collected from the trap and trawl surveys were used to study relationships between selected biological characteristics of rock crabs in the sGSL. Relationships were either established or updated. Data were log-transformed and the *lm* function in R© (R Core Team, 2012, version 2.15.0) was used to fit the regressions between the CW and the weight. The relationship between

CW and body weight was examined using combined data from both years of the trawl survey, but separately for males and females because an analysis of co-variance (ANCOVA) indicated that there were significant differences in the slopes ($F_{1189, 1076}$ = 2.29, P<0.0001) and intercepts ($F_{1,2266}$ = 297.2, P<0.0001) between sexes. A t-test was used to determine whether the slope differed significantly from 3.0 (symmetrical growth).

A linear regression was applied to log-transformed CW and CH (males only) based on combined data from the trap and trawl surveys. A t-test was used to determine whether the slope differed significantly from 1.0 (symmetrical growth).

A logistic regression was fitted to male maturity data in 3-mm CW intervals using R© (R Core Team, 2012, version 2.15.0) *glm* model. The regression equation and CW at 50% of maturity were determined.

ABUNDANCE INDICATORS

Landings

Total landings from the directed fishery were compiled on a yearly basis and by LFA. Landings cannot be used as an indicator of the stock abundance as the fishery is limited by individual quotas (except in LFA 24). A global allocation was calculated by LFA, by year, using the number of licences issued times their individual quota. Landings were related to their theoretical allocations so that yearly trends could be interpreted.

Rock crabs landed as a bycatch were compiled separately and the proportion of those removals was calculated in relation to the recorded landings. Temporal trends in these proportions were assessed by LFA.

Catch rates

Average catch rates (CPUE kg/trap) by year and LFA were calculated from the logbook data. Daily CPUEs were estimated by harvester and the average for the LFA was calculated with a 95% confidence interval. Trend analysis of the CPUE was done by comparing the yearly average for the LFA to the average for the reference period (2000-2010) for which data have been finalised.

Several trap types were used in the directed fishery. The most common type was the conical trap. However, catch rates were not standardized by trap type since the information was not reliable. Variation of CPUE in relation to soak time was not considered. In 2011, fishing time recorded in logbooks were 24 and 48 hours for more than 80% of the fishing trips.

Individual allocation

The percentage of licence holders which reached their maximum individual allocation was estimated per year and LFA, except for LFA 24 where there was no allocation. The allocation for a given licence was considered to be reached when the total landings at the end of the season was ≥ 90% of the allocation. The estimates were done on active licences only and the cut off at 90% allowed for some flexibility since harvesters generally would not run the risk overrunning their allocation with an additional trip. All licence types were considered and annual percentages were compiled by licence categories (commercial or commercial communal).

CPUE and spatial, size, and depth distributions – Trawl surveys

Trawlable biomass estimates for LFAs 25 and 26A were derived using the catch weights, estimated from observed size-frequencies and length-weight relationships. Individual catches were standardized to weights per square kilometer using the estimated swept area of the tow, calculated from the observed tow distance times an assumed width of 5.9 m. The means and confidence intervals of the biomass estimates were derived by year (2010 and 2011), LFA, and crab category (total and commercial-sized males). These estimates were then scaled using the respective surface areas of LFA 25 and 26A to obtain the final biomass estimates.

Survey abundance estimates were calculated from CPUE (number or weight per standardized tow of 0.125 nautical miles in length) for rock crab and lobster in each stratum (Figure 4) for the 2010 and 2011 surveys (combined data).

The catch per standard tow from the 2010 and 2011 surveys were used to describe the spatial distributions of rock crab and lobster for both years combined. A chi-square test was used to test whether there was a difference in occurrence of rock crab and lobster (percentages of stations) in the surveys.

Spatial distributions of legal-sized rock crab catches (kg per tow) from the 2010 and 2011 surveys are presented with expendable circles. The MLS used for LFA 25 was 102 mm of CW and 108 mm for LFA 26A.

For the combined 2010 and 2011 data, random distributions of rock crab and lobster over depth were assessed by comparing the estimates of the number of rock crabs, number of lobsters, and number of sets sampled by 1 m depth intervals using Kolmogorov-Smirnov (K-S) tests (Voutier and Hanson 2008; Hanson 2009, 2011; Kelly and Hanson 2013). The 50^{th} and 90^{th} percentiles at depth were also calculated for both species.

Size frequency distributions were generated by sex and by LFA for each of the 2010 and 2011 surveys. Individual CW measurements were grouped in 5 mm bins. The CW medians were calculated from the original data. The median was chosen instead of the mean because differences were detected in the shape of the size frequency distributions between LFAs. Kolmogorov-Smirnov tests were used to compare distributions for males and females between LFAs with years combined and separately. Only animals ≥40 mm in CW were included in the calculation of the median CW and the K-S tests because of uncertainty in the trawl retention efficiency for crabs below that size.

Size-frequency distributions – Trap survey

Size frequency distributions were generated by sex for each sample (site, sampling period). Individual CW measurements were combined in 3 mm bins but CW means (±95% CI) were calculated on the original data. Kolmogorov-Smirnov tests were done to compare distributions for males and females between sampling sites, the two sites within LFA 25 were combined. Proportions of commercial size males (≥102 mm for Egmont Bay and Cocagne Bay samples and ≥108 mm for Toney River samples) in the catches were also calculated.

FISHING PRESSURE INDICATORS

The fishing effort deployed during the directed fishery was quantified as the average number of traps hauled per day during the season, i.e., the total traps hauled divided by the number of trips and then multiplied by the number of active licences. The actual fishing effort being deployed during the fishing season was compared to the maximum number of traps allowed per day based on management measures. However, the number of traps hauled was often biased (underestimated) as the information was not always available from the logbooks, representing in some cases up to 10% of the fishing trips (mainly in LFA 23) without information on traps hauled. Fishing pressure is also represented over the years by LFAs using the actual number of fishing trips reported. Recorded fishing positions in the logbooks for 2006-2011 were mapped. Many positions had to be transformed from *Loran C* to latitude-longitude coordinates even though harvesters were requested to use GPS coordinates.

PRODUCTION INDICATORS

Rock crab settlement index – Bio-collectors

For the rock crab settlement index, observed young-of-year (yoy) rock crab (i.e., <16 mm CW) counts per bio-collector were modeled as a negative binomial distribution to account for extra Poisson variance. Estimated means and confidence intervals (95%) were calculated by site and year. Estimations were performed using the *predict* function in the *stats* package in R© (R Core Team, 2012, version 2.15.0). Means were scaled to a standard surface area of one square meter. For all sites, the accumulated degree-days (ADD) adjusted to 0°C were calculated from the temperature data using the following equation (Dobson and Petrie 1985):

$$AAD=\Sigma((T) \times Time),$$

where T is the mean daily temperature, and Time is time period in days. For each site, the ADDs were calculated from 15 July to 20 September for each of the annual temperature profiles available.

Sex ratio –Trawl surveys

Male:female sex ratios were calculated by LFA from the 2010 and 2011 trawl survey data. In the context of a male only fishery, a balanced sex ratio would be looked-for as this should maintain the reproductive potential of the stock.

DIET ANALYSIS

The diet of rock crab was quantified in the same manner as for previous studies of diets of northern lady crab and lobster in the Northumberland Strait (Voutier and Hanson 2008, Hanson 2009). From 1999 to 2006, lobster and small numbers of rock crab were retained, frozen on board the ship, taken to the laboratory, and kept frozen for later analysis. For lobster, the target was 15 animals per tow for 10 randomly chosen stations in each survey stratum per year. Rock crabs were retained haphazardly; however, the numbers retained often represented every specimen captured in the survey. During the 2010 Nephrops trawl survey, rock crabs were retained at a rate of 50 animals (randomly selected) from any 5 tows per survey unit area (strata 1 and 2, stratum 3, stratum 5 plus part of 6, rest of stratum 6 and strata 7 and 10).

Intact lobsters or rock crabs were processed by first thawing the animal in cold water and excising the foregut. The foregut was opened and the contents examined under a stereo-microscope. The contents were identified to the lowest practical taxonomic level, blotted, and weighed (nearest 0.1 mg). Diet importance was expressed as % mass. Each survey was treated as a sample; however, the data were separated into mainly sand or sandy-gravel habitats (strata 1-3) versus mainly mud or sandy-mud substrate (strata 5-7 and 10). Mean diet (± SE) was calculated for each species and substrate combination using survey year as the sample. The data were not separated by size-class for either lobster or rock crab.

Diet similarity between rock crab and lobster was evaluated separately for western strata (1-3; mainly sand and gravel substrate) and eastern strata (5-7 and 10; mainly mud and sandy-mud substrate). Each year was treated as a separate sample. Diet overlap was evaluated using cluster analysis (Bray-Curtis similarity index, square root transformation) and followed by two-dimensional multi-dimensional scaling (MDS) (Clarke and Gorley 2006). The stress value (a measure of goodness-of-fit) was low (stress = 0.11), indicating that higher-level solutions (e.g., three dimensional MDS) were not necessary (Clarke and Warwick 2001). Analysis of similarity

(ANOSIM) was used to test whether there were differences in diet between species, and similarity of percentages (SIMPER) analysis was used for identifying which taxa contributed most to the observed differences in diet between rock crab and lobster. A separate SIMPER analysis was used to evaluate diet differences between rock crab caught on mainly sand *versus* mainly mud habitat.

RESULTS

BIOLOGICAL PARAMETERS

Relations between rock crab body weight (g) and carapace width (CW in mm) were:

(1) Male weight = 1.4840×10^{-4} $CW^{2.9955}$, r^2=0.97, n=1,191

(2) Female weight = 1.3548×10^{-4} $CW^{3.0360}$, r^2=0.97, n=1,078

The exponents of the two regressions did not differ significantly from 3.0 (t-tests, P>0.05), which indicated growth was symmetrical (Figure 5). Male body weight and CW equations from 1984 data (Moriyasu unpublished data) at various sites within LFA 25 suggested that crabs were heavier then. However, the equation presented here is derived from trawl samples while the one from 1984 used crabs caught in baited traps. The CW-weight relationships for rock crabs derived from Northumberland Strait surveys of 2010 and 2011are to be used in this and future work.

The relationship between CH and CW (both in mm) for males was:

(3) CH = 0.1101 $CW^{1.1457}$, r^2=0.94, n=5,473

The exponent was significantly greater than 1.0 (t-test, t=37.9, P<0.0001) indicating larger males had proportionately larger claws (Figure 6).

The size at maturity curve, based on 547 male rock crabs (Figure 7) was:

(4) % mature = $1/(1+e^{(-0.1208\ CW\ +\ 5.9053)})$, n=35 intervals

Based on this relationship, the size at 50% maturity was estimated to be 48.8 mm CW for male rock crab in the Northumberland Strait. Full maturity (≥ 95%) is reached at 73 mm CW, well below the minimum legal size in the directed fishery. The smallest male with spermatophores in the vas deferens was 36 mm CW. Physiological maturity based on the presence/absence of spermatophores in the vas deferens might not be equivalent to the functional maturity, defined as the ability of a male to mate. Further studies on rock crab maturity would be needed.

ABUNDANCE INDICATORS

Landings

Total landings in the fishery increased sharply between 1992 and 1995 and then leveled (Figure 8). Prior to 2000, rock crab landings were not partitioned by fishery type (directed or bycatch). Total landings from the directed fishery have remained stable since 2000 with a mean of 4,301 t (range 3,685-4,727 t; Table 3). Preliminary landings of 4,197 t for 2011 were slightly lower than the 2000-2010 average. Most landings (36-41%) come from LFAs 25 and 26A, respectively, followed by LFA 23 at 18% and LFA 24 at 4%. Only small amounts of rock crab were caught in the directed fishery in LFA 26B. The number of active licences in LFA 26B decreased from 8 in 2006 to 2 in 2011 with a corresponding reduction in fishing trips, from 83 to 7 in 2006 and 2011 respectively (Table 4). Compared to 2006, total landings in 2011 were similar; however, the number of fishing trips declined by 23%, from 4,105 to 3,153 (Table 4). Landings from the various

LFAs have fluctuated in the recent years without distinct trends (Figure 9), except for LFA 26B where the directed fishing activity is very small.

When landings were compared to the sum of individual allocations for all licences issued, it is clear that there is the potential for increased fishing pressure. In 2011, only 76% of the maximum removal of crabs was landed in both LFAs 25 and 26A (Table 5), leaving approximately 1,000 t of potential harvest not fished. In LFAs 23 and 26B, only 40% and 1%, respectively, of the maximum removals were landed which left 1,464 t of potential catch not fished in the directed fishery. Overall, the directed fishery on rock crab in 2011 only landed 62% of the total allocation (Table 5).

Recent and updated data on rock crab bycatches from 2003 to 2011 have been obtained from DFO Policy and Economics Branch. Since the last Science Advisory Report (DFO 2008), verification and adjustment were made to the bycatch data and therefore, only the more recent numbers will be considered in the present assessment. Rock crab removals during the lobster fishery declined in all LFAs in 2011 compared to 2006 (Table 6, Figure 9). Bycatches in LFA 26B are negligible with 0.6 t recorded in 2011 (numbers in table were rounded to the nearest t). While total bycatches from 2000-2006 represented about 18% of the directed fishery landings, they were about 10% during 2007 to 2011. This reduction is consistent with the decline in the number of lobster harvesters landing rock crab as a bycatch, 705 in 2006 compared to 387 in 2011.

Catch rates

Catch rates in 2011 were above the average of the reference period (2000-2010) for each LFA and, except for LFA 24, they were all higher than those observed in 2006 (Table 7). Catch rates were highest in LFAs 25 (14.5 kg/trap) and 26A (16.2 kg/trap), an increase (compared to 2006) of 28% and 33%, respectively. This was not, however, part of an increasing trend as there were lower values in some years. In LFA 23, the average catch rate (12.2 kg/trap) was 23% higher than in 2006 however, catch rates have been stable at about 12 kg/trap for the last three years. Catch rates in LFAs 24 and 26B have fluctuated over the years with no clear trend in either LFA. Catch rates in LFA 26B used to be the lowest in the sGSL but they rose slightly above those of LFA 24 in 2011. However, variation in the data can be seen from the confidence interval that reflects the very few data available that year (only seven fishing trips) for that LFA.

Individual allocations

Percentages of harvesters reaching at least 90% of their individual allocation for 2011 were 19%, 51%, and 71% for LFAs 23, 25, and 26A, respectively (Table 8). From 2006 to 2011, percentages were variable and without any trend, but LFA 26A consistently had the highest levels. In LFA 26B, only two licences were active in 2011 and neither reached their individual allocation. When data were separated by the type of licences (commercial or commercial communal), some peculiarities were observed. Active commercial communal licences were fished with lower intensity than commercial ones (Figure 10); in most years <50% reached their allocation and, in some years, none reached their full allocation. There are fewer commercial communal licences per LFA than commercial ones, but they still represent 30%, 20%, and 7% of all active licences in LFAs 23, 25, and 26A, respectively. There are no commercial communal licences in LFA 26B.

Abundance and spatial distributions of rock crab and lobster – Trawl survey

Biomass estimates of rock crab, all sizes and sexes, from the surveys indicate that in terms of weight rock crabs were slightly more abundant in LFA 26A than in LFA 25 (Table 10). An increase of ~2000 t in total biomass was observed in LFA 26A between 2010 and 2011, while a decline of 645 t was observed in LFA 25. Commercial-size male biomass was slightly higher in LFA 26A than in LFA 25. Biomass declined slightly between 2010 and 2011 in LFA 26A whereas it increased over the same time period in LFA 25 (Table 10). However, such trends are difficult to interpret given the rather large uncertainty in the estimates and only two years of observations.

Survey abundance estimates reflected the relative body size differences of rock crab and lobster (Table 11). Mean lobster catches ranged from a low 0.3 kg/tow in stratum 5 (mainly mud bottom) to 8.2 kg/tow in stratum 1 and were greater than that of rock crab in 4 of 7 survey strata. Mean rock crab catches varied between 1.1 and 3.8 kg/tow. Due to their smaller size, rock crab exceeded lobster in terms of numerical abundance in every stratum but stratum 1 – where lobster biomass was five times higher than rock crab.

Both rock crab and lobster were widely distributed in Northumberland Strait. However, rock crab occurred in 94% of the 204 stations fished (Figure 11), which was significantly greater (χ^2 = 60.72, df=1, P<0.001) than the occurrence of lobster (62% of stations). Consistent with earlier work (Hanson 2009), lobster largely avoided the muddy substrates that were typical of much of stratum 5, the deeper parts of strata 6 and 7, and most of 10 (Figure 12).

Legal-sized (≥MLS) male rock crabs were most abundant in the northern portion of LFA 25 (western PEI) and generally distributed throughout LFA 26A (Figure 13).

Rock crab and lobster differed with respect to their depth distribution (Figure 14); rock crab occupied deeper waters than lobster (K-S statistic=-0.37, P<0.001), and their distribution reflected the depth distribution of the stations fished (K-S statistic=0.07, P=0.307). In contrast, lobster were distributed disproportionately with respect to depth (K-S=-0.32, P<0.001), being most abundant in shallow waters. The depth at 50% and 90% occurrence of lobster was 14.3 and 22.0 m, respectively. The depth at 50% and 90% occurrence of rock crab was 20.6 and 36.0 m, respectively.

Size-frequency distributions – Trawl survey

When both survey years were combined, there were proportionally more large males in LFA 26A (n=959) than in LFA 25 (n=1,159) (K-S=0.22, P<0.0001). When examined by years, males in LFA 26A had a different size distribution than those in LFA 25 (Figure 15). They were larger in 2010 (median CW=100 mm, K-S=0.34, P<0.0001) and in 2011 they had proportionately more small animals (K-S=0.08, P=0.0213) and more large animals (K-S=0.13, P=0.0001) than in LFA 25. Male median CW were 82 and 90 mm in LFA 25 and 100 and 95 mm in LFA 26A for 2010 and 2011, respectively.

There were significantly (K-S=0.20, P<0.0001) more large females in LFA 26A (n=989) than in LFA 25 (n=1,142) when both years were combined. When data were analyzed by year, there were still more large females in LFA 26A than in LFA 25 in 2010 (K-S=0.30, P<0.0001) but a reverse situation was observed in 2011 with proportionately more large females in LFA 25 than in 26A (K-S=0.15, P<0.0001) (Figure 15). Female median CW were 75 and 78 mm in LFA 25 and 81 and 80 mm in LFA 26A for 2010 and 2011 respectively. The maximum size recorded for females in both LFAs was 101 mm.

The size distributions (Figure 15) showed that small animals might not have been well retained by the net, which is consistent with the 70 mm mesh used in the trawl.

Size-frequency distributions – Trap survey

Size distributions of males and females were similar for the Egmont Bay and Cocagne Bay sites, for the two sampling periods (Figures 16 and 17) as both sites were relatively near each other (LFA 25; Figure 2). Consistent with the results of the two trawl surveys, in Toney River (LFA 26A), there were proportionately more large crabs of both sexes (K-S=0.34, P<0.0001 and K-S=0.70, P<0.0001 for males and females respectively) than the two combined sites in LFA 25

(Figures 16 and 17). Average CW for males varied from 97.3 mm to 111.2 mm and from 75.9 mm to 90.4 mm for females (Table 12).

In LFA 25, where the MLS is 102 mm, the proportion of commercial-size males in the samples dropped from 40.9% before the fishery to 25.3% towards the end of the fishing season in Cocagne Bay. Similarly, in Egmont Bay, the proportion of commercial-size males dropped from 39.3% to 29.0% between the beginning and near the end of the fishery. In contrast, the proportion of commercial-size males actually increased from 25.0% to 65.5% between the two sampling periods in Toney River (LFA 26A; MLS 108 mm). One possible explanation for the pattern in Toney River is that the sampling site was moved and may have been relocated in an area of local concentration of large-sized crabs. The Toney River site also differed from the LFA 25 sites at having high proportions of females >90 mm CW (56% to 58%) during both sampling periods (Figure 17), the largest one was 104 mm. In LFA 25, <4% of females were above 90 mm CW and none was observed over 99 mm.

FISHING PRESSURE INDICATORS

LFAs 25 and 26A had the highest proportion of effective fishing effort deployed in one day with respect to the nominal effort, 92% and 84%, respectively, in 2011 (Figure 18). However, effective effort for the entire season is necessarily much less than nominal effort because licences are not active every day of the season. In the other LFAs, effort deployed (in number of traps) on any given day in 2011 was far from the maximum allowed leaving significant potential for effort increases, as it has been the case in previous years.

The overall number of fishing trips recorded in 2011 was 23% less than in 2006 (Table 4). The number of trips decreased compared to 2006 in all LFAs but the most significant reductions were observed in LFAs 23 and 26B where the number of trips dropped by 35% and 91%, respectively. As mentioned previously, the directed rock crab fishery in LFA 26B is very small with only 2 of 11 licences active. A reduction in fishing trips of 17% was observed for both LFAs 25 and 26A between 2006 and 2011 (Table 4).

The fishing position information was available for 65% of all trips in the study area, a slight increase from the 59% in 2006. Based on those data, fishing effort was concentrated in Northumberland Strait and on the eastern coast of New-Brunswick in LFA 23 (Figure 19) for all the years examined, consistent with an earlier report (DFO 2008). No contraction or expansion of fishing grounds has been observed that could suggest a change in rock crab abundance in the recent years. However, one small area in central Northumberland Strait (Figure 20) was not fished for all years observed. This might represent an unfavorable rock crab habitat or unfavorable environmental conditions. Trawl surveys data confirmed low rock crab abundance in that area (Figure 11). Deeper waters of the Shediac Valley and east of PEI did not show much fishing activity (Figure 20), which is somewhat inconsistent with the spatial distribution of rock crab described from the research surveys (Figure 11).

PRODUCTION INDICATORS

Sex ratio –Trawl surveys

Rock crab sex ratios calculated from the 2010 and 2011 trawl surveys provide the first quantitative baseline for future comparison, assuming the *Nephrops* trawl survey would be repeated. In LFA 25, the male: female ratio was 1:1 for both years (481:474, 694:680), but different values were observed in LFA 26A with a male-favored ratio of 1.6:1 in 2010 (480:301) and a female favored ratio of 0.7:1 in 2011 (515:703). Even in the context of a male-only fishery, sex ratios were expected to be >1:1 because males grow to larger sizes than females, which hypothetically would mean that more males could be retained by the trawl. However, previous studies reported that rock crab sex ratios could vary by season, location, carapace size, and reproductive status (Krouse 1972; Scaratt and Lowe 1972; Haefner 1976).

Rock crab settlement index – Bio-collectors

The abundance of young-of-the-year (yoy) rock crab varied between LFAs and years (Figure 21). Since 2008, none, or very low yoy (<= 1.0 yoy m^{-2}), abundance values were observed in bio-collectors in the Northumberland Strait portion of LFAs 25 and 26A. The highest yoy abundance in 2008 was observed in Neguac (LFA 23 gulf-side) at 41.9 yoy m^{-2}, with all the other sites falling below 9.2 yoy m^{-2}. From 2009 to 2012 in LFA 25, the abundance of yoy ranged between 4.5 and 17.5 yoy m^{-2} with the highest values observed at Skinner's Pond, located outside Northumberland Strait. Yearly fluctuations were also observed for yoy abundances in LFA 26A for sites located outside of Northumberland Strait. Yoy abundance values in Arisaig (LFA 26A NS-side) ranged from 1.0 to 3.8 yoy m^{-2} between 2008 and 2011, and reached a significantly higher value of 8.0 yoy m^{-2} in 2012. Sites with steady yearly variations of abundance values were located in LFA 26A PEI-side. For both Murray Harbour and Fortune, low values observed in 2009 and 2011, contrasted with significantly higher values in 2010 and 2012. The very highest yoy abundance values were observed in LFA 24 (Figure 21). In Alberton, values >82.0 yoy m^{-2} were observed, except in 2011 (37.0 yoy m^{-2}). For Covehead, significantly lower abundance values were observed in 2008 (9.2 yoy m^{-2}) and 2011 (20.7 yoy m^{-2}), otherwise values >60.0 yoy m^{-2}.

In general, fluctuations in yoy abundance do not seem to be linked to an ADD threshold, but rather to ADD inter-annual variations. For all the sites with multiyear information, years with low ADD values correspond to low yoy abundance (Table 9; Figure 21). Except for Nine Mile Creek and Covehead, the lowest ADD values were observed in 2011, and the second lowest in 2009 for sites outside of LFA 24 (Table 9). During those two years, yoy abundance values in Skinner's Pond, Murray Harbour and Fortune were the lowest (Figure 21). Although ADD values were much lower for the Fortune site at 22 m compared to the site at 9 m, the abundance value in 2010 was the only one that was significantly lower. The lowest ADD values were observed in 2008 for Covehead and in 2011 for the majority of the sites, which correlates with low yoy abundance values (Table 9; Figure 21).

ECOSYSTEM INDICATORS

Rock crab and lobster as prey

Evaluation of potential consumption of demersal stages of rock crab and lobster by fishes in Northumberland Strait was based on examination of 20,450 stomachs collected during summer months over multiple years. Demersal stages of rock crab were an important prey (>5% prey biomass) of four fish species and of all three species of large decapod crustaceans that occur in Northumberland Strait (Table 13; Hanson 2009). While lobster (intact individuals) was an important component of the shorthorn sculpin diet, rock crab actually comprised a much larger fraction, by four times, of this predator's diet. Rock crabs were swallowed whole by longhorn sculpin and shorthorn sculpin and swallowed whole but partially crushed by cunner and winter skate. Rock crab was a minor prey item of Atlantic cod and winter flounder and only very small (CW <20 mm) rock crabs were consumed (Figure 22). Longhorn sculpin and winter skate ate individuals up to about 35 mm CW, while shorthorn sculpin ate rock crab up to 80 mm CW. All of the rock crab >35 mm CW consumed by winter skate were newly molted individuals (Kelly and Hanson 2013). Most of the rock crab >50 mm CW consumed by shorthorn sculpin also had just molted.

Evaluation of potential consumption of demersal stages of rock crab and lobster by large decapod crustaceans in Northumberland Strait was based on examination of 4,031 foreguts collected during summer months. In the case of decapod predators, the rock crabs were broken into small pieces; consequently, it was impossible to determine which sizes were being eaten. As reported earlier (Hanson 2009), rock crab was the single-most important prey of lobster; however, rock crab were strongly cannibalistic with fresh remains comprising 13.8% of total prey biomass. Rock crab were an important prey (5% of prey biomass) of lady crab while only trace amounts of fresh lobster were detected, and only during summer months (Voutier and Hanson 2008). Fresh lobster remains represented about 8% of prey biomass of lobster (Table 13). Only trace amounts of old lobster exuvia, and no fresh material, were detected in the rock crab diet.

Evaluation of potential consumption of pelagic stages of rock crab and lobster by planktivorous fishes in Northumberland Strait was based on examination of 8,693 stomachs collected during July and August. Pelagic stages of rock crab were eaten by all planktivorous fish species examined while lobster larvae were but a trace prey item. Larval rock crab were particularly important (>18% of prey biomass) prey for gaspereau (*Alosa* sp.). While windowpane flounder typically do not eat planktonic prey, small (<15 cm TL) windowpane consumed rock crab megalop larvae, presumably as the megalops were settling to the bottom.

Rock crab diet and diet overlap with lobster

With an 70 mm mesh size and need to wash the mud from the catch, the *Nephrops* trawl simply did not retain many rock crab <40 mm CW; therefore, the diet analysis that follows was only representative of animals 40 to 125 mm CW.

When averaged over the four survey years, rock crabs were primarily carnivorous with plant material representing <2.5% of the diet (Table 14). Regardless of habitat type, crustaceans were the most important prey eaten by rock crab followed by fish, mollusks, and polychaetes or detritus. With respect to mollusks, gastropods were seldom eaten and unidentified bivalve remains were predominant. Identifiable bivalves included razor clams (*Siliqua costata*) and *Macoma* sp. The importance of polychaetes in the rock crab diet may have been underestimated because setae were almost always found among the material designated “detritus” and this detritus could, in part, have been left behind when polychaetes bodies were digested.

Prey consumption by rock crab was highly variable between years within a habitat as shown by the wide standard errors of the mean diets (Table 14) and the wide scatter in the MDS plot (Figure 23). While the ANOSIM test did not show significant differences between habitats (Global R=0.229; P=0.14) likely due to the very wide between-year variation, there were obvious differences in the average diet between habitat types. SIMPER analysis identified *Crangon* shrimp (on mud), rock crab (on sand), and fish remains (especially herring on sand as opposed to unidentified remains, cunner, 3-spine stickleback, and sandlance on mud) explained about 60% of the observed dissimilarity between diets of rock crab caught on sand versus mud substrates. There were significantly more empty stomachs observed for rock crab collected on sand than on mud (Table 14, χ^2=55.23, df=1,P< 0.001).

Lobster had a narrow diet comprised mainly of rock crab, lobster, and sea stars (Figure 24). Rock crab had a broader diet and consumed more fish and shrimp and less rock crab, lobster, and echinoderms compared to lobster. Despite rock crab diets showing substantial between-year and between-habitat variation, the diets of rock crab and lobster separated clearly on the MDS plot (Figure 23). Overall, lobster diets were >55% similar regardless of sampling year or location and showed only moderate (34%) similarity to rock crab diets. The diets of lobster and rock crab (Figure 24) were significantly different (ANOSIM, Global R=0.723, P=0.001). Based on SIMPER analysis, the largest differences in diet were due to between-predator differences in consumption of rock crab, *Crangon*, lobster, sea star, fish remains, detritus, clams, herring, and polychaetes (together comprising >60% of the observed diet dissimilarity).

SOURCES OF UNCERTAINTY

The rock crab stock assessment relies on a very limited number of indicators that are mostly fishery dependent. Fishery data are obtained through several unconnected processes that result in duplication of data entry work, which increase the chance of data errors and results in substantial delays. Only preliminary data for 2011 were available for this assessment.

Total removals of rock crab are not known since no data are available for removals as bait during the lobster fishery. In certain areas, this practice is common and could lead to significant catches, even more so if or when the access to more traditional bait species (herring, mackerel, etc.) is difficult or if markets expand.

Catch rates and fishing effort indicators derived from logbook data are uncertain given that not all information is recorded. Most of the unreported information was either the number of traps hauled or the fishing positions. However, over the years, the quality and completeness of logbook data have increased.

Uncertainties are also present in the interpretation of catch rates (CPUE) given that in most LFAs removals are subject to a maximum individual allocation. Fishing strategies might also come into play to maintain high catches leading to ultra-stable CPUE which could mask fluctuations in stock abundance. In addition, catch rates could be affected by environmental factors, such as water temperature, socio-economic context (fluctuating markets, access to other fisheries, etc.), and changes in fishing technology.

Stock structure and rock crab movements in the sGSL are not well understood. Rock crab larvae are the most abundant component in the plankton where such samples have been collected in the sGSL. Combined with information on currents, larval drift over large areas is expected.

Effects of changes in temperatures on rock crab larvae survival, benthic stages, recruitment, growth etc., and indicators of environmental stress are not known for rock crab.

Stock and recruitment dynamics are not well understood for rock crab which precludes estimates of traditional biomass or exploitation rate reference points. Alternate indicators such as those based on CPUE indicators or size frequency distributions require further considerations.

CONCLUSION

ABUNDANCE INDICATORS

Total landings from the directed fishery have remained stable since 2000 with a mean of 4,301 t from which 77% came from LFAs 25 and 26A. Preliminary landings in 2011 were slightly lower than the 2000-2010 average but comparable to those presented in the last assessment. Landings in the different LFAs have fluctuated over time without any distinctive trend. Overall, the directed fishery in 2011 only landed 62% of its total allocation which left a significant amount of unused allocation and room for effort increase. No trend was observed in the percentages of licence holders reaching their individual allocation but LFA 25 and 26A had the highest values at 51% and 71% respectively. Trivial amounts of rock crab were caught in the directed fishery in LFA 26B and no individual allocation has ever been reached. That situation might be either a consequence of low rock crab abundance or limited interest in the fishery.

Bycatches during the lobster fishery have decreased in all LFAs since 2004, and reached the lowest value of 295 t in 2011. The proportion of bycatch removals on the directed fishery landings was about 10% from 2007 to 2011 and around 18% prior to that. Reduction in bycatch removals is consistent with the reduced number of lobster licence holders landing rock crab. However, the completeness of the bycatch data is in question and a complete data set might change these statistics. Also, the extent of rock crab bycatches may be decreasing along with the increase of escape mechanism's dimension (i.e. height or width) in lobster traps, which would reduce the retention of rock crab.

Catch rates in the 2011 directed fishery were above the 2000-2010 average in all LFAs but there is no clear trend. Also, aside from LFA 24, CPUEs in 2011 were higher than those in 2006. The highest CPUEs were seen in LFAs 25 and 26A in 2011 and these were among the highest of the time series.

Present effort limits allow for an increase in fishing pressure from either the directed or the bycatch and bait fisheries. The stock's response to such an increase remains unknown. Further, there is no control over rock crab removals during the lobster fishery.

Trawl survey data indicated that rock crabs in LFAs 25 and 26A occurred in almost all stations and were widely distributed throughout the whole Northumberland Strait. Overall, males were larger in LFA 26A compared to LFA 25 but in both cases, median CWs were below the MLS. Similarly, there were more large females in LFA 26A compared to LFA 25. Biomass estimates from the 2010-2011 trawl surveys were highly variable. For LFA 25, biomass estimates of commercial-size male rock crabs for both years were very close to the annual reported landings, resulting in unrealistic exploitation rate estimates of ~100%. This suggests that the catchability of the *Nephrops* trawl is less than one over certain portions of the survey area (e.g. rocky substrate) or less probably that significant crab densities occur in shallow coastal areas which lie outside the survey area.

Comparisons of length frequency distributions from the trap samples were consistent with those of the trawl surveys with more large animals in the LFA 26A site than in those located in LFA 25. Male length frequency distributions were not truncated in the "pre-fishery" samples but proportions of large males were lesser in the "post-fishery" samples of both sites within LFA 25.

FISHING PRESSURE INDICATORS

Even though preliminary landings in 2011 were similar to those of 2006, the number of fishing trips recorded in the 2011 directed fishery was 23% less which partially explains the observed increase in CPUE. A gradual decreasing trend in number of fishing trips was observed in all LFAs since 2006. The general daily effort deployed in terms of trap hauls is close to what is allowed by the management plan only in LFAs 25 and 26A; in the other LFAs, only a small proportion of the allowed effort is deployed leaving room for significant increase in fishing effort.

Fishing positions from logbook entries were not recorded for all fishing trips but based on the available data, no contraction or expansion of fishing grounds was seen that would suggest recent changes in rock crab distribution. The central portion of Northumberland Strait seemed unfavorable to fishing activities which is consistent with the distribution pattern from the trawl survey. However, less fished areas discerned from the logbook data in Shediac Valley and East of PEI do not correspond to what was seen in the trawl surveys and might be an artifact of missing data.

PRODUCTION INDICATORS

Production indicators for the rock crab stock were limited as very few data were available. Also, with male-only fisheries (bait, bycatch, and directed) it is expected that the reproductive potential of the stock will be maintained as females are not landed. Ensuring mating success is important but very limited information on rock crab reproductive biology is available. Assuming that a balanced sex ratio should be close to 1, values observed from the trawl surveys in LFA 25 were exactly that but in LFA 26A the 2010 sex ratio favored males and then was bias toward females in 2011. Those data represent the first quantitative baseline for future comparison.

Concentrations of rock crab settlers do not correlate with high fishing concentrations. The highest abundance values were observed in LFA 24 which has the second lowest rock crab fishing activity level. Conversely, the lowest abundances of settlers were observed in the high fishing concentrations in central Northumberland Strait. The abundance values estimated for rock crab settlers are much higher compared to lobster settlers (A. Rondeau, unpublished data). The highest abundance for lobster settlers was around 3 yoy m^{-2}, compared to values of 127 yoy m^{-2} for rock crab (Figure 21); a 42-fold difference. Interestingly, the highest abundance values for both species were observed in Alberton (LFA 24) in 2012.

ECOSYSTEM INDICATORS

Rock crab plays a much greater role than lobster in ecosystem structure and functioning. Rock crabs are more widely distributed (occur in more habitats) with both larvae and demersal stages being important prey of a wide variety of organisms and they eat a wide variety of prey according to their availability in the habitat. Additionally, rock crab is a critical prey for lobster molt processes and maturation (Gendron et al. 2001) while lobster is critical prey to no other species.

Rock crab occurred over a wider range of depths and habitat types than lobster. While rock crab were numerous on both mud-dominated and sandy substrates, lobster largely avoid muddy habitat (Hanson 2009, this study) and both are common on rock and cobble substrates studied elsewhere (Hudon and Lamarche 1989; Ojeda and Dearborn 1991; Wells et al. 2010). Rock crab occurred at greater depths than lobster in Northumberland Strait. Unlike lobster, rock crab also occur well up into small, very warm, estuaries adjacent to the study area where there are pronounced seasonal migrations in and out of these small estuaries (Comeau et al. 2012).

The predator-prey interaction between rock crab and lobster was uni-directional. Rock crab was an important prey of lobster in Northumberland Strait while lobster is almost never detected in rock crab stomach contents (Miller et al. 1971; Scarratt and Lowe 1972; this study). Elsewhere, lobster has not been detected in appreciable amounts in rock crab stomachs (Drummond-Davis et al. 1987; Hudon and Lamarche 1989; Ojeda and Dearborn 1991; Stehlik 1993; Stehlik et al. 2004) while rock crab, or some other crab species, usually are a major prey of lobster (Miller et al. 1971; Ennis 1973; Elner and Campbell 1987; Hudon and Lamarche 1989; Ojeda and Dearborn 1991; Steimle et al. 1994; Sainte-Marie and Chabot 2001; Jones and Shulman 2008). Indeed, the strong preference of lobster for rock crab has been confirmed in laboratory studies where lobster selected rock crab over bivalves and echinoderms under controlled experimental conditions (Evans and Mann 1977; Carter and Steele 1982; Ojeda and Dearborn 1991). Furthermore, a laboratory study by Gendron et al. (2001) indicates that rock crab consumption is required for normal growth and development of lobster although the authors pointed out that other crabs eaten by lobster (e.g., *Hyas* spp., *Ovalipes ocellatus*, and *Carcinus maenas*) could perform the same role.

Rock crab was an important prey for shorthorn sculpin, winter skate, longhorn sculpin, and cunner. As was seen for lobster (Hanson and Lanteigne 2000; Davis et al. 2004; Hanson 2009), large gadoids (Atlantic cod and white hake) and flatfishes (Pleuronectidae and Bothidae) were not important predators of rock crab in sGSL. While the proportion of rock crab in the diet of shorthorn sculpin was very high, the low abundance of this sculpin likely meant it was a minor source of natural mortality for rock crab. In contrast, with their relatively high abundances, longhorn sculpin and cunner were likely a major source of natural mortality for rock crab while consumption by winter skate was largely localized to the sandy areas of the central Strait, - the only area of the sGSL where winter skate remain relatively common, (Kelly and Hanson 2013). In a similar analysis of potential predators of lobster (Hanson and Lanteigne 2002; Comeau et al. 2008; Hanson 2009) it was found that only shorthorn sculpin consumed substantial numbers of intact lobsters. However, due to the low abundance of shorthorn sculpin in the sGSL, cannibalism was likely the greatest source of natural mortality for lobster (Hanson 2009). In this study, cannibalism was a significant source of rock crab mortality, especially on sandy substrate, and was somewhat higher than levels of cannibalism reported for studies conducted in US waters (Stehlik 1993; Ojeda and Dearborn 1991) suggesting it is a widespread characteristic of rock crab populations.

The extent of predation on rock crab by seals, particularly grey seals, in the sGSL is not known.

Rock crab larvae, unlike lobster larvae, are an important prey of most of the planktivorous fishes in Northumberland Strait. This is likely more a reflection of the very low abundance of lobster larvae versus rock crab larvae in the zooplankton community of the Strait. In 2008 and 2009, in plankton tows taken concurrent with the pelagic fishes analyzed for diet analysis, lobster larvae occurred at a maximum of a few individuals per 100 m^3 while rock crab larvae numbers were over 1000-times higher at between 25 to 200 per m^3 (A.J. Debertin, J.M. Hanson, S.C. Courtenay, unpublished data). The only shrimp species widespread in the Strait is the sevenspine bay shrimp *Crangon septemspinosa* (also called sand shrimp) but we have yet to conduct a detailed analysis of this species' diet. Elsewhere, *Crangon* shrimps are major predators of megalops of crab and larval flatfishes settling to the bottom, sometimes even a factor controlling year-class strength (Olmi and Lipcius 1991; Witting and Able 1993; Wennhage 2002; Taylor and Collie 2003).

Rock crab diets are highly variable and site dependent (Stehlik et al. 2004; Quijon and Snelgrove 2005); therefore, it is not surprising that findings from this study in Northumberland Strait differ from published studies. Very little plant material was observed in any study. In Northumberland Strait, although the percentage compositions varied between habitats, the order of the principle prey groups (>10% of prey biomass) of rock crab stayed the same: crustaceans, fish, mollusks (almost exclusively bivalves), and polychaetes. Bivalve consumption (~13% of prey biomass) was lower than in other areas; however, highest consumption of bivalves occurs where mussels are present (Evans and Mann 1977; Carter and Steele 1982; Ojeda and Dearborn 1991), which is not the case on soft sediments characterizing most of the Strait. While rock crabs were thought to be a threat to juvenile sea scallop *Placopecten magellanicus* (Elner and Jamieson 1979; Nadeau and Cliché 1998; Wong et al. 2005), no sea scallop remains were detected during the present study. The relatively low consumption of bivalves by both rock crab and lobster in the present study is not an indication of low abundance because the other large crab species, northern lady crab (*Ovalipes ocellatus*), consumes large numbers of bivalves (Voutier and Hanson 2008). In New York Bight, the principal prey groups of rock crabs were polychaetes, detritus, and bivalves (Stehlik 1993). In a rocky site in the Gulf Maine, the principal prey groups were bivalves (mainly mussels), rock crabs, sea urchins, and fish remains (Ojeda and Dearborn 1991; Donahue et al. 2009). In an earlier study in a small rocky area in Northumberland Strait (near Richibucto Cape), the principal prey groups were detritus, polychaetes, and crustacean remains (Scarratt and Lowe 1972). Sea urchin was not found in rock crabs sampled in the present study; however, they were prominent in studies where sea urchin were common (e.g., Drummond-Davis et al. 1982; Ojeda and Dearborn 1991).

It was difficult to ascertain how much of the rock crab diet in Northumberland represented active predation and how much was scavenging. The main complicating factor was the ongoing or recently completed rock crab fishery at time of survey because the rock crab could have been eating bait and rock crabs damaged or killed as discards. However, most of the identifiable fish eaten in muddy areas were not species typically used for bait. Further directed sampling of all sizes of rock crab, both during and outside of the fishery, is needed to better understand spatial and temporal variation in the diet of rock crab in Northumberland Strait.

Based on limited diet information, Hudon and Lamarche (1989) suggested there could be moderate competition for food between lobster and rock crab. While a moderate level of diet overlap was detected in this study, a large part was due to consumption of rock crab by both lobster and rock crab, representing predation and cannibalism, respectively. In any study to assess the strength of competitive interactions, it is necessary, however, to demonstrate that there is actually a resource in short supply (in this case food and shelters) – a daunting task when studying mobile species in marine ecosystems.

Due to their high biomass (second only to lobster), carnivorous feeding habits, and use as prey by many predators, rock crab is likely a critical component of the demersal community in sGSL coastal ecosystems. Unlike lobster, rock crab is an important prey to a wide variety of demersal and pelagic fish species and to large decapods. This means rock crab may have a key role in the trophic structure and functioning of the sGSL coastal ecosystem. In contrast, lobster largely represents a large-bodied energy sink. Other than the now rare shorthorn sculpin (which eats four times more rock crab), no species consumes substantial numbers of lobster. Indeed, at assumed exploitation rates of > 65% per year, the fishery is by far the main source of mortality for lobster. Moreover, rock crab is critical prey for lobster. Were lobster to disappear from the sGSL ecosystem, there is sufficient ecosystem redundancy to replace the role of lobster as a predator and no organism depends on lobster to survive. In contrast, loss of rock crab would be a major disruption in the functioning of the coastal ecosystem (unless perhaps the alien invasive green crab expanded out of the estuaries), and lobster would also largely disappear due to their reliance on rock crab for molting and reproductive processes (Gendron et al. 2001).

OTHER CONSIDERATIONS

No estimate of fishing mortality rate was calculated for rock crab because of the limited data available to apply estimation methods such as change-in-ratio or change in abundance of molt classes. Also, population models could not be developed for rock crab because of too many unknowns on biological characteristics such as natural mortality, growth, productivity, and carrying capacity.

The development of reference points for the rock crab directed fishery in the Gulf Region was not done given the uncertainties related to the short time series, two years, of biomass estimates from the Northumberland Strait area and the absence of reliable exploitation rate estimates. Total removals of rock crab should be accounted for in the development of reference points for that species.

The proportion of rock crab removals as bycatch during the lobster fishery has decreased since 2006 and represented less than 10% of the directed fishery landings in the last three years. Rock crab removals used as bait during the lobster fishery is unknown. The latent potential for an increase in fishing pressure on rock crab is significant with unknown consequences on the stock's health.

The trophic link between lobster and rock crab is well documented but no regulation is focusing on controlling rock crab removals to ensure lobster population health. In the directed fishery however the high MLS mitigates the fishing impact on the lobster diet as usually lobster does not prey on large size crabs. If rock crab removals were to impede the population's reproductive potential and recruitment, many predator species would need to shift their diet with unknown consequences.

Based on a study of bycatch during the scallop fishery (Benoît 2011), rock crab was the second most common incidentally captured species, after starfish. From 24 sampling trips done from 2006 to 2008, 4,311 rock crabs were caught (average of 209 crabs per fishing trip) and most animals were in good to excellent condition when returned to the water suggesting high survival rate. The direct impact of that fishery on rock crab populations is therefore expected to be minimal.

The gear impact "footprint" from the directed rock crab fishery on benthic habitat has not been assessed but is deemed to be minimal based on the limited number of participants and trap allocations.

ACKOWLEDGMENT

The authors would like to thank both crews of the CCGS *Opilio* as well as the scientific staff that conducted the scientific surveys. Thanks to the harvesters involved in the trap sampling and the bio-collector projects and the organizations they belong to for their assistance. A special thanks to Tobie Surette who processed the Northumberland Strait trawl survey data and derived the estimates of trawlable biomass of rock crab for 2010 and 2011.

REFERENCES

Benoît, H.P. 2011. Estimated amounts, species composition and pre-discard condition of marine taxa captured incidentally in the southern Gulf of St. Lawrence scallop fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/031. iv + 20 p.

Bosman, S.H., Methven, D.A., Courtenay, S.C., and Hanson, J.M. 2011. Fish assemblages in a north Atlantic coastal ecosystem: Spatial patterns and environmental correlates. Est. Coast. Shelf Sci. 92: 232-45.

Caddy, J.F., and Chandler, R.A. 1976. Historical statistics of landings of inshore species in the Maritime provinces 1947-73. DFO Tech. Rep. 639. 240 p.

Carter, J.A., and Steele, D.H. 1982. Attraction to and selection of prey by immature lobsters (*Homarus americanus*). Can. J. Zool. 60: 326-336.

Clarke, K.R., and Gorley, R.N. 2006. PRIMER v6: User manual/tutorial. PRIMER-E, Plymouth, 192 p.

Clarke, K.R., and Warwick, R.M. 2001. Changes in marine communities: an approach to statistical analysis and interpretation. 2nd edition. PRIMER-E: Plymouth, U.K.

Comeau, L.A., Sonier, R., and Hanson, J.M. 2012. Seasonal movements of Atlantic Rock Crab (*Cancer irroratus* Say) transplanted into a mussel aquaculture site. Aquac. Res. 43: 509-517.

Comeau, M., Hanson, J.M., Rondeau, A., and Mallet, M. 2008. Framework and assessment for American lobster, *Homarus americanus*, fisheries in the southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A, and 26B. DFO Can. Sci. Advis. Secr. Res. Doc. 2008/054. 120 p.

Conan, G.Y., Comeau, M., Gosset, C., Robichaud, G., and Garaicoechea, C. 1994. The Bigouden Nephrops trawl, and the Devismes trawl, two otter trawls efficiently catching benthic stages of snow crab (*Chionoecetes opilio*) and American lobster (*Homarus americanus*). DFO Can. Tech. Rep. Fish Aquat. Sci. No. 1992. 27p.

Davis, A., Hanson, J.M., Watts, H., and MacPherson, H. 2004. Local ecological knowledge and marine fisheries research: the case of white hake predation on juvenile American lobster. Can. J. Fish. Aquat. Sci. 61: 1191-1201.

DFO. 2008. Assessment of the rock crab (*Cancer irroratus*) fishery in the southern Gulf of St. Lawrence Lobster Fishing Areas (LFA's) 23, 24, 25, 26A and 26B for 2000 to 2006. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/022. 9 p.

DFO. 2013. Assessment of the Rock Crab (*Cancer irroratus*) fishery in the southern Gulf of St. Lawrence for 2006 to 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/030. 17 p.

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

Donahue, M.J., Nichols, A., Santamaria, C.A., League-Pike, P., Krediet, C.J., Perez, K.O., and Shulman, M.J. 2009. Predation risk, prey abundance, and the vertical distribution of three brachyuran crabs on Gulf of Maine shores. J. Crustac. Biol. 29: 523-531.

Drummond-Davis, N.C., Mann, K.H., and Pottle, R.A. 1987. Some estimates of population density and feeding habits of the rock crab, *Cancer irroratus*, in a kelp bed in Nova Scotia. Can. J. Fish. Aqua. Sci. 39: 636-639.

Elner, R.W., and Campbell, A. 1987. Natural diets of lobster *Homarus americanus* from barren ground and macroalgal habitats off southwestern Nova Scotia, Canada. Mar. Ecol. Progr. Ser. Oldendorf 37: 131-140.

Elner, R.W., and Jamieson, G.S. 1979. Predation of sea scallops, *Placopecten magellanicus*, by the rock crab, *Cancer irroratus*, and the American lobster, *Homarus americanus*. J. Fish. Res. Board Can. 36: 537-543.

Ennis, G.P. 1973. Food, feeding, and condition of lobsters, *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay, Newfoundland. J. Fish. Res. Board Can. 30: 1905-1909.

Evans, P.D., and Mann, K.H. 1977. Selection of prey by American lobsters (*Homarus americanus*) when offered a choice between sea urchins and crabs. J. Fish. Res. Board Can. 34: 2203-2207.

Gendron, L., Fradette, P., and Godbout, G. 2001. The importance of rock crab (*Cancer irroratus*) for growth, condition and ovary development of adult American lobster (*Homarus americanus*). J. Exp. Mar. Biol. Ecol. 262: 221-241.

Haefner, P.A. 1976. Distribution, reproduction and moulting of the rock crab, *Cancer irroratus* Say, 1917, in the mid-Atlantic Bight. J. Nat. Hist. 10: 377-397.

Hanson, J.M. 2009. Predator-prey interactions of American lobster (*Homarus americanus*) in the southern Gulf of St. Lawrence, Canada. N. Z. J. Mar. Freshw. Res. 43: 69-88.

Hanson, J.M. 2011. Ontogenetic diet comparison of Atlantic cod and white hake occurring at historically low population abundances. Trans. Am. Fish. Soc. 140: 1070-1077.

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

Hudon, C., and Lamarche, G. 1989. Niche segregation between American lobster *Homarus americanus* and rock crab *Cancer irroratus*. Mar. Ecol. Prog. Ser. 52: 155-168.

Jones, P.L., and Shulman, M.J. 2008. Subtidal-intertidal trophic links: American lobsters (*Homarus americanus* Milne-Edwards) forage in the intertidal zone on nocturnal high tides. J. Exp. Mar. Biol. Ecol. 361: 98-103.

Kelly, J.T., and Hanson, J.M. 2013. Maturity, size at age and predator-prey relationships of winter skate *Leucoraja ocellata* in the southern Gulf of St. Lawrence: potentially an undescribed endemic facing extirpation. J. Fish. Biol. 82: 959-978.

Krouse, J.S. 1972. Some life history aspects of the rock crab, *Cancer irroratus*, in the Gulf of Maine. J. Fish. Res. Board Can. 29: 1479-1482.

Miller, R.J., Mann, K.H., and Scarratt, D.J. 1971. Production potential of a seaweed lobster community in eastern Canada. J. Fish. Res. Board Can. 28: 1733-1738.

Nadeau, M., and Cliché, G. 1998. Predation of juvenile sea scallops (*Placopecten magellanicus*) by crabs (*Cancer irroratus* and *Hyas* sp.) and starfish (*Asterias vulgaris*, *Leptasterias polaris*, and *Crossaster papposus*). J. Shellfish Res. 17: 905-910.

Ojeda, P.F., and Dearborn, J.H. 1991. Feeding ecology of benthic mobile predators: experimental analysis of their influence in rocky subtidal communities of the Gulf of Maine. J. Exp. Mar. Biol. Ecol. 149: 13-44.

Olmi, E.J., and Lipcius, R.N. 1991. Predation on postlarvae of the blue crab *Callinectes sapidus* Rathbun by sand shrimp *Crangon septemspinosa* Say and grass shrimp *Palaemonetes pugio* Holthius. J. Exp. Mar. Biol. Ecol. 151: 169-183.

Quijon, P.A., and Snelgrove, P.V.R. 2005. Differential regulatory roles of crustacean predators in a sub-arctic, soft-sediment system. Mar. Ecol. Prog. Ser. 285: 137-149.

R Development Core Team 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0.

Sainte-Marie, B., and Chabot, D. 2001. Ontogenetic shifts in natural diet during benthic stages of American lobster (*Homarus americanus*) off the Magdalen Islands. Fish. Bull. 100: 106-116.

Scarratt, D.J., and Lowe, R. 1972. Biology of the rock crab (*Cancer irroratus*) in Northumberland Strait. J. Fish. Res. Board Can. 29: 161-166.

Stehlik, L.L. 1993. Diets of the brachyuran crabs *Cancer irroratus*, *C. borealis*, and *Ovalipes ocellatus* in the New York Bight. J. Crust. Biol. 13: 723-735.

Stehlik, L.L., Pikanowski, R.A., and McMillan, D.G. 2004. The Hudson-Raritan Estuary as a crossroads for distribution of blue (*Callinectes sapidus*), lady (*Ovalipes ocellatus*), and Atlantic rock (*Cancer irroratus*) crabs. Fish. Bull. 102: 693-710.

Steimle, F.W., Jeffress, D., Fromm, S.A., Reid, R.N., Vitaliano, J.J., and Frame, A. 1994. Predator-prey relationships of winter flounder, *Pleuronectes americanus*, in the New York Bight apex. Fish. Bull. 92: 608-619.

Taylor, D.L., and Collie, J.S. 2003. A temperature- and size-dependent model of sand shrimp (*Crangon septemspinosa*) predation on juvenile winter flounder (*Psuedopleuronectes americanus*). Can. J. Fish. Aquat. Sci. 60: 1133-1148.

Voutier, J.L., and Hanson, J.M. 2008. Abundance, distribution, and feeding of lady crab in the southern Gulf of St. Lawrence. Aquatic Ecology 42: 43-60.

Wahle, R.A., Wilson, C., Parkhurst, M., and Bergeron, C.E. 2009. A vessel-deployed passive postlarval collector to assess settlement of the American lobster *Homarus americanus*. N. Z. J. Mar. Freshw. Res. 43: 467–474.

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

Wells, R., Steneck, R.S., and Palma, A.T. 2010. Three-dimensional resource partitioning between American lobster (*Homarus americanus*) and rock crab (*Cancer irroratus*) in a subtidal kelp forest. J. Exp. Mar. Biol. Ecol. 384: 1-6.

Wennhage, H. 2002. Vulnerability of newly settled plaice (*Pleuronectes platessa* L.) to predation: effects of habitat structure and predator functional response. J. Exp. Mar. Biol. Ecol. 269: 129-145.

Witting, D.D., and Able, K.W. 1993. Effects of body size on probability of predation for juvenile summer and winter flounder based on laboratory experiments. Fish. Bull. 91: 577-581.

Wong, M.C., Barbeau, M.A., Hennigar, A.W., and Robinson, S.M.C. 2005. Protective refuges for seeded juvenile scallops (*Placopecten magellanicus*) from sea star (*Asterias* spp.) and crab (*Cancer irroratus* and *Carcinus maenas*) predation. Can. J. Fish. Aquat. Sci. 62: 1766-1781.

TABLES

Table 1. Summary of management measures in place during the 2011 rock crab directed fishery in the southern Gulf of St. Lawrence by LFAs.

LFA	Minimum legal size (mm)	Individual trap allocation	Fishing season	Individual allocation (kg)	Issued licences	Active licences
23	102	100	Aug. 1 - Oct. 16	35,000	55	42
24	102	150	Jul. 5 - Oct. 29	n/a	16	9
25	102	100	June 27 - Jul. 23 Oct. 20 - Nov. 30	25,000 [1]	71	68
26A	108	90	Aug. 1 - Nov. 26	23,913	95	83
26B	108	100	Aug. 15 - Nov. 11	27,216	11	2

[1] Individual allocation for communal licences is 35,000 kg

Table 2. Number of bio-collectors sampled at various sites in the southern Gulf of St. Lawrence between 2008 and 2012. Each year about 30 bio-collectors were deployed per site, but because some were either lost or filled with mud or sand the number of bio-collectors sampled varied.

Year	Site	Depth (m)	Date deployed	Date retrieved	Number sampled
2008	Arisaig	6.8	5-June	10-Octobre	29
	Bedeque	7.6	9-June	13-November	30
	Caraquet	5.2	22-May	18-October	28
	Covehead	6.7	10-June	16-October	29
	Neguac	9.1	5-June	20-October	30
	Shediac	6.1	2-June	25-October	30
2009	Alberton	8.9	8-July	22-September	30
	Arisaig	6.8	2-July	16-October	25
	Covehead	6.7	2-July	1-October	30
	Fortune1	8.3	3-July	21-September	29
	Murray Harbour	7.1	9-July	2-October	26
	Nine Mile Creek	6.5	3-July	25-September	29
	Skinner's Pond	7.1	17-July	5-November	25
2010	Alberton	8.9	2-July	20-September	30
	Arisaig	6.8	2-July	28-September	30
	Covehead	6,7	2-July	22-September	27
	Fortune1	8.3	2-July	21-September	24
	Fortune2	22.0	2-July	21-September	5
	Murray Harbour	7.1	2-July	24-September	30
	Nine Mile Creek	6.5	2-July	13-October	30
	Skinner's Pond	7.1	2-July	29-September	30
2011	Alberton	8.9	6-July	26-September	30
	Arisaig	6.8	6-June	28-September	28
	Covehead	6,7	5-July	30-September	30
	Fortune1	8.3	5-July	29-September	30
	Fortune2	22.0	5-July	29-September	5
	Murray Harbour	7.1	18-July	21-October	26
	Nine Mile Creek	6.5	13-July	11-October	27
	Skinner's Pond	7.1	14-July	12-October	26
2012	Alberton	8.9	12-July	2-October	29
	Arisaig	6.8	30-June	4-October	30
	Covehead	6,7	3-July	25-September	29
	Fortune1	8.3	3-July	24-September	29
	Fortune2	22.0	3-July	24-September	5
	Murray Harbour	7.1	9-July	17-October	22
	Nine Mile Creek	6.5	10-July	10-October	29
	Skinner's Pond	7.1	16-July	15-October	28

Table 3. Rock crab landings (t) by LFA from the directed fishery. Data for 2011 are preliminary.

Year	23	24	25	26A	26B	Total
2000	995	237	1,186	1,917	24	4,360
2001	1,128	211	1,300	2,063	25	4,727
2002	1,007	177	1,378	1,769	18	4,349
2003	665	136	1,284	1,592	8	3,685
2004	956	183	1,290	1,591	21	4,041
2005	1,028	159	1,469	1,867	29	4,552
2006	982	212	1,361	1,574	43	4,172
2007	957	221	1,551	1,796	24	4,550
2008	846	181	1,687	1,685	18	4,417
2009	1,051	162	1,568	1,477	17	4,274
2010	817	167	1,578	1,624	1	4,187
2011	766	187	1,507	1,734	4	4,197

Table 4. Number of fishing trips reported during the directed fishery. Data for 2011 are preliminary.

Year	23	24	25	26A	26B	Total
2000	1,497	400	1,100	1,795	68	4,860
2001	1,556	335	1,355	2,159	82	5,487
2002	1,397	257	1,173	1,633	47	4,507
2003	637	178	1,102	1,341	19	3,277
2004	1,018	139	1,176	1,612	38	3,983
2005	1,063	166	1,138	1,276	49	3,692
2006	1,015	220	1,305	1,482	83	4,105
2007	993	211	1,277	1,349	66	3,896
2008	927	137	1,266	1,294	29	3,653
2009	924	167	1,256	1,422	30	3,799
2010	747	140	1,145	1,255	2	3,289
2011	663	161	1,089	1,233	7	3,153

Table 5. Percentages per LFA of the total allocation of rock crab landed in the directed fishery, 2006 to 2011. Data for 2011 are preliminary.

Year	23	25	26A	26B	Total
2006	51%	69%	69%	13%	61%
2007	50%	80%	79%	7%	67%
2008	44%	85%	74%	6%	65%
2009	55%	79%	65%	6%	63%
2010	42%	80%	72%	1%	62%
2011	40%	76%	76%	1%	62%

Table 6. Rock crab landings (t) by LFA as bycatch during the lobster fishery. Numbers are rounded to the nearest ton. Data for 2011 are preliminary.

Year	23	24	25	26A	26B	Total
2000	284	18	230	223	0	755
2001	244	22	278	370	0	914
2002	352	17	272	344	0	985
2003	227	16	191	302	0	736
2004	261	20	203	492	0	976
2005	194	37	172	293	0	696
2006	170	21	101	227	0	519
2007	121	30	141	239	0	531
2008	85	11	143	266	0	505
2009	68	39	84	227	0	419
2010	71	13	66	186	0	335
2011	29	12	42	211	1	295

Table 7. Mean (± 95% confidence interval range in parentheses) catch rates (kg/trap) in the directed rock crab fishery by year and LFA for 2000 to 2011. Data for 2011 are preliminary.

Year	23	24	25	26A	26B
2000	7.5 (0.3)	6.1 (0.5)	11.2 (0.4)	13.2 (0.3)	4.4 (0.6)
2001	7.8 (0.3)	5.8 (0.5)	10.6 (0.7)	11.6 (0.3)	4.3 (0.8)
2002	8.0 (0.3)	6.7 (0.5)	12.2 (0.4)	13.7 (1.4)	5.5 (1.0)
2003	12.5 (0.5)	7.8 (0.6)	12.7 (0.4)	14.1 (0.4)	5.4 (1.2)
2004	10.8 (0.3)	10.2 (0.7)	12.1 (0.4)	11.6 (0.2)	9.5 (1.1)
2005	10.6 (0.3)	10.1 (0.8)	14.1 (0.6)	17.3 (0.6)	9.8 (1.2)
2006	9.9 (0.3)	10.6 (0.7)	11.3 (0.3)	12.2 (0.3)	6.1 (0.6)
2007	10.3 (0.4)	8.3 (0.6)	12.6 (0.3)	15.0 (0.4)	4.6 (0.6)
2008	10.8 (0.7)	9.5 (0.6)	13.9 (0.4)	15.4 (0.6)	7.3 (1.1)
2009	12.5 (0.4)	7.8 (0.5)	12.5 (0.3)	11.9 (0.2)	6.5 (0.7)
2010	11.9 (0.4)	9.8 (0.9)	14.3 (0.5)	15.1 (0.4)	8.4 (0.7)
2011	12.2 (0.5)	9.2 (0.5)	14.5 (0.5)	16.2 (0.4)	10.6 (4.0)
2000-2010 Average	10.2 (1.1)	8.4 (1.0)	12.5 (0.7)	13.7 (1.1)	6.5 (1.2)

Table 8. Percentages of active licences in the directed fishery for which at least 90% of the individual allocation was landed. There is no individual allocation in LFA 24. Data for 2011 are preliminary.

Year	23	25	26A	26B
2006	30%	40%	59%	0%
2007	23%	64%	73%	0%
2008	21%	64%	69%	0%
2009	33%	51%	40%	0%
2010	26%	58%	60%	0%
2011	19%	51%	71%	0%

Table 9. The accumulated degree-days (ADD) adjusted to 0ºC for all sites where bio-collectors were deployed between 2008 and 2012. The temperature probe from Skinner's Pond was lost in 2012. Lowest ADD values observed for multiyear dataset per sites are in bold.

Site	Year				
	2008	2009	2010	2011	2012
Alberton	na	1,073	1,136	**1,024**	1,164
Arisaig	1,146	1,207	1,251	**1,132**	1,255
Bedeque	1,314	na	na	na	na
Caraquet	1,111	na	na	na	na
Covehead	**1,024**	1,167	1,305	1,105	1,252
Fortune1	na	1,098	1,192	**1,088**	1,204
Fortune2	na	na	876	**750**	896
Murray Harbour	na	1,123	1,144	**1,066**	1,217
Neguac	988	na	na	na	na
Nine Mile Creek	na	**1,131**	1,173	1,150	1,160
Shediac	1,192	na	na	na	na
Skinner's Pond	na	1,151	1,194	**1,126**	na

Table 10. Swept area biomass estimates (t) (mean and 95% confidence intervals) of rock crab, all sizes and sexes combined and for commercial size male rock crab in LFAs 25 and 26A from the 2010 and 2011 trawl surveys. Also shown are the annual reported landings (t) by LFA for 2010 and 2011.

LFA (surface area km²)	Year	Sizes and Sexes Combined	Commercial-Size Male Rock Crab	Total Annual Reported Landings (t)
25 (5,482)	2010	7,165 (4,361 to 18,039)	1,506 (639 to 4,187)	1,644
	2011	6,520 (4,435 to 16,508)	1,890 (1,023 to 5,255)	1,549
26A (6,443)	2010	7,419 (5,073 to 17,699)	2,721 (1,892 to 6,450)	1,810
	2011	9,397 (6,629 to 21,812)	2,293 (1,522 to 5,440)	1,945

Table 11. Mean (± 95% confidence interval range in parentheses) catch rates (number or weight (kg) per standardized tow) of rock crab and lobster by stratum in trawl surveys (2010 and 2011 combined). For each stratum, the number of stations sampled is shown.

Stratum	Number of rock crab	Kg of rock crab	Number of lobster	Kg of lobster
1 (*n* = 22)	16.0 (5.9)	1.5 (0.5)	42.5 (26.8)	8.2 (4.7)
2 (*n* = 18)	36.5 (16.5)	3.8 (1.5)	11.1 (10.3)	2.9 (2.6)
3 (*n* = 51)	14.3 (4.2)	1.1 (0.3)	8.6 (2.9)	2.4 (0.6)
5 (*n* = 32)	21.8 (9.6)	2.4 (0.9)	0.3 (0.2)	0.3 (0.3)
6 (*n* = 32)	22.4 (5.7)	2.2 (0.6)	8.6 (3.7)	3.2 (1.4)
7 (*n* = 24)	11.5 (7.1)	1.5 (0.9)	10.9 (10.8)	2.8 (2.6)
10 (*n* = 25)	10.5 (7.0)	1.6 (1.2)	5.3 (6.2)	1.4 (1.5)

Table 12. Details of the 2011 trap sampling activities in the Northumberland Strait area. The total number of crabs includes those that were sampled.

Location	Date hauled	Number of traps set	Number of traps sampled	Total number of rock crabs captured	Total number of males	Total number of females	Rock crabs sampled	Males	Females	Average carapace width of males (mm)	Average carapace width of females (mm)
Cocagne Bay	22-Jun-11	10	9	3,947	1,041	2,906	968	264	704	99.3	77.0
	28-Oct-11	10	8	1,994	429	1,565	912	178	734	98.3	80.5
Toney River	14-Jun-11	15	12	3,969	2,873	1,096	926	687	239	99.2	89.9
	24-Oct-11	10	10	1,222	1,124	98	1,016	935	81	111.1	90.4
Egmont Bay	17-Jun-11	15	13	4,710	3,885	825	1,019	844	175	97.3	75.9
	03-Nov-11	10	10	1,252	632	620	947	479	468	98.0	81.0

*Table 13. Number (N) of fish and large crustacean stomachs collected in Northumberland Strait and percentages by weight of stomach contents comprised of rock crab and American lobster, during 1999 to 2010. * megalop larvae only; ** legs only. For consumption by crustaceans, the number in brackets indicates the percentage of diet comprised of exuvia.*

Species	N	Rock crab	Lobster
Planktivores			
Atlantic herring	2,128	3.9	<0.01
Alewife	1,170	18.3	<0.01
American shad	400	1.0	0.06
Atlantic mackerel	1,034	5.0	<0.01
Rainbow smelt	3,808	1.0	0.02
Sand lance	153	1.2	0.0
Windowpane flounder	489	0.2*	0.0
Demersal fishes			
Longhorn sculpin	1,300	11.5	0.04**
Shorthorn sculpin	134	44.1	10.6
Sea raven	166	0.3	0.0
Cunner	751	11.4	1.2**
Atlantic cod	11,477	0.3	<0.01
White hake	3,462	0.1	<0.01
Winter skate	978	16.7	0.0
American plaice	571	0.0	0.0
Windowpane flounder	489	0.0	0.0
Yellowtail flounder	241	0.0	0.0
Winter flounder	881	1.3	0.0
Large invertebrates			
Lady crab	934	5.1	<0.01
Rock crab	1,166	15.1 (1.3)	0.1 (0.1)
Lobster	1,931	60.5 (16.5)	10.9 (3.1)

Table 14. Mean diet (% by weight) of rock crab sampled from mainly sand habitat (1999, 2001, 2006, and 2010) and mainly mud habitat (1999, 2001, 2006, and 2010).

	Substrate - sand		Substrate - mud	
Prey species	Mean	SE	Mean	SE
Rock crab - fresh	24.79	13.949	3.00	2.461
Rock crab - carapace	2.03	1.688	0.48	0.479
Lobster - fresh	0.00	0.000	0.00	0.000
Lobster - carapace	0.00	0.000	0.10	0.101
Lady crab	0.00	0.000	0.35	0.351
Hermit crab	0.21	0.208	0.01	0.013
Crangon septemspinosa	3.02	2.615	27.02	13.990
Other shrimp remains	0.45	0.448	6.14	6.126
Mysids	0.00	0.000	1.74	1.682
Gammarids	4.29	3.962	0.37	0.211
Crustacean remains	0.05	0.051	2.41	2.152
Clam - *Macoma*	0.73	0.419	0.25	0.239
Clam - razor	1.35	1.167	0.00	0.000
Clam remains - meat	7.71	5.721	6.07	4.063
Bivalve shell fragments	6.20	3.510	3.74	2.199
Gastropods	1.03	0.982	0.25	0.243
Polychaetes	9.71	3.210	6.58	3.602
Brittle stars	0.08	0.083	0.00	0.000
Sea stars	0.02	0.017	0.05	0.052
Tunicates	0.11	0.082	0.70	0.635
Bryozoans	0.02	0.016	0.00	0.000
Sponges	0.00	0.000	0.00	0.000
Other invertebrates	0.00	0.000	0.00	0.000
Sand lance	0.60	0.604	6.60	6.597
Three-spine stickleback	1.16	0.883	2.11	1.303
Herring	16.99	16.992	2.22	2.222
Cunner	0.00	0.000	6.74	6.739
Fish remains - other	1.69	0.975	14.98	3.811
Flatfish remains	0.43	0.314	0.66	0.659
Fish bones	2.33	2.206	0.94	0.745
Algae	2.48	2.443	0.03	0.022
Zostera	0.03	0.026	0.01	0.009
Plants	0.01	0.013	0.00	0.000
Detritus	12.48	5.119	6.46	2.069
Number sampled	582		587	
% empty	42.30		23.00	

FIGURES

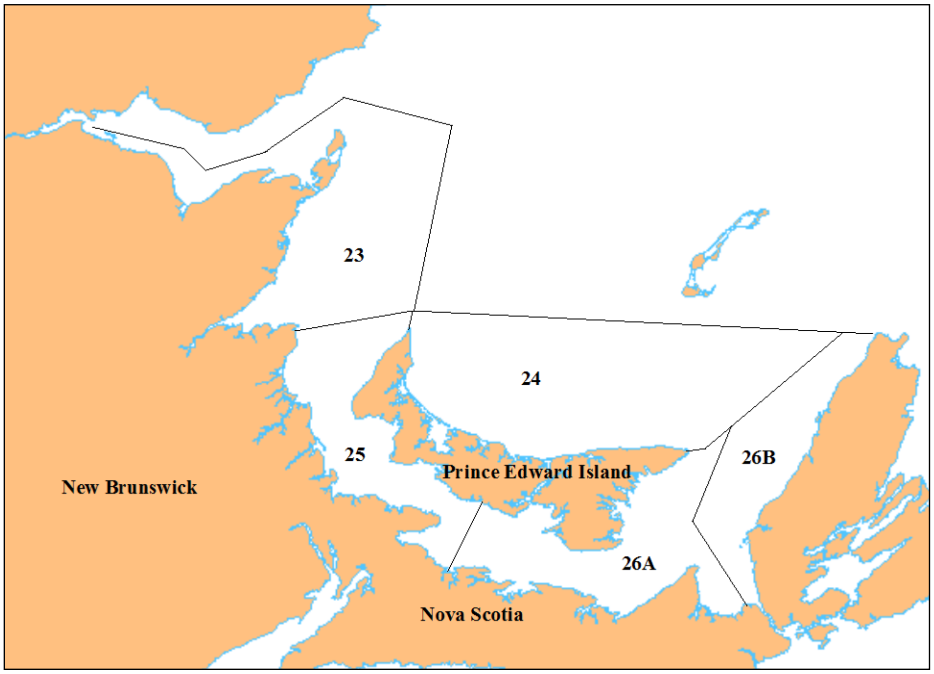


Figure 1. Lobster Fishing Areas (LFAs) used in the management of the rock crab directed fishery in the southern Gulf of St. Lawrence.

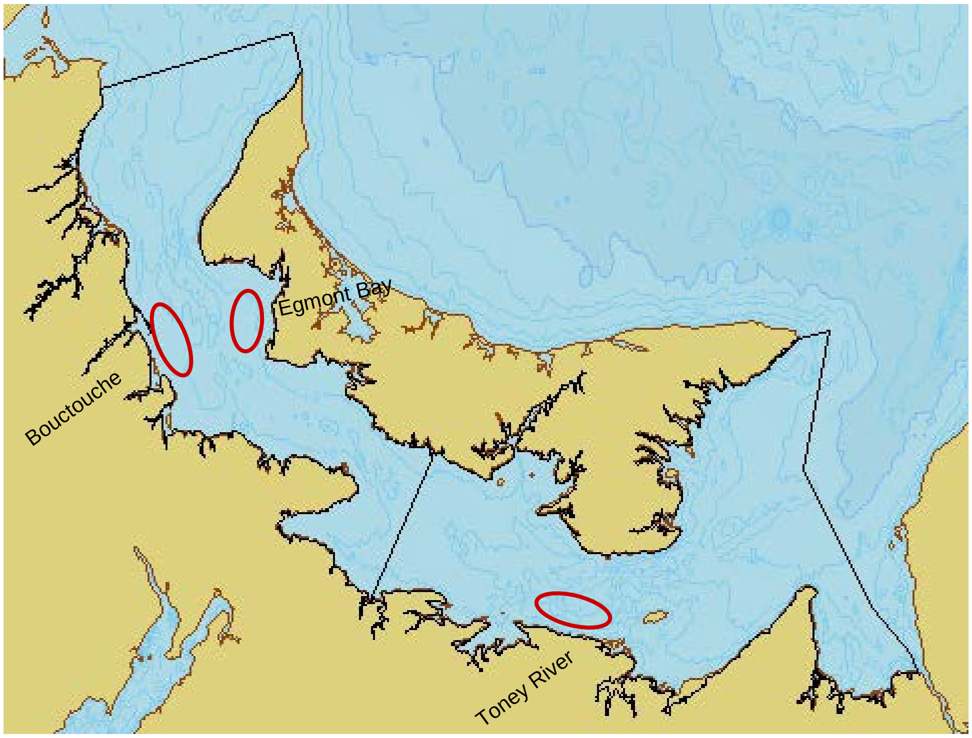
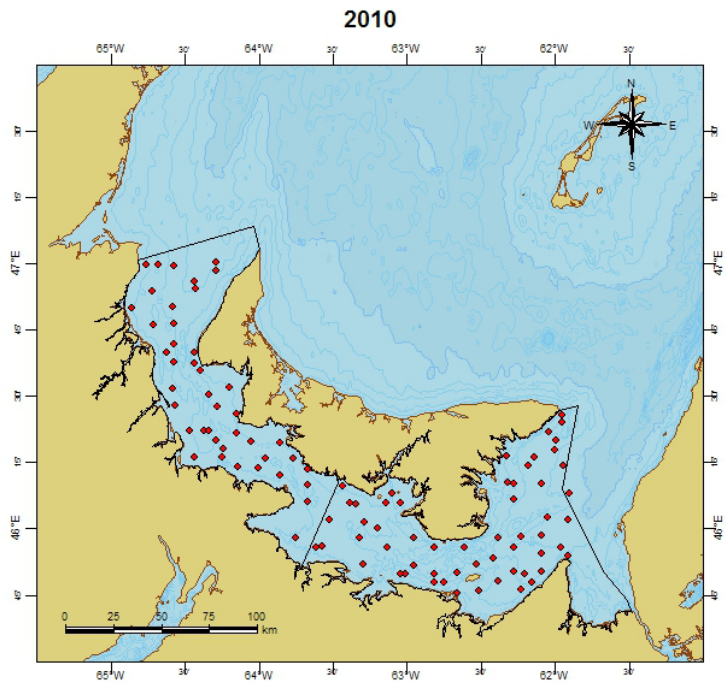


Figure 2. Sites of the 2011 trap sampling activities.



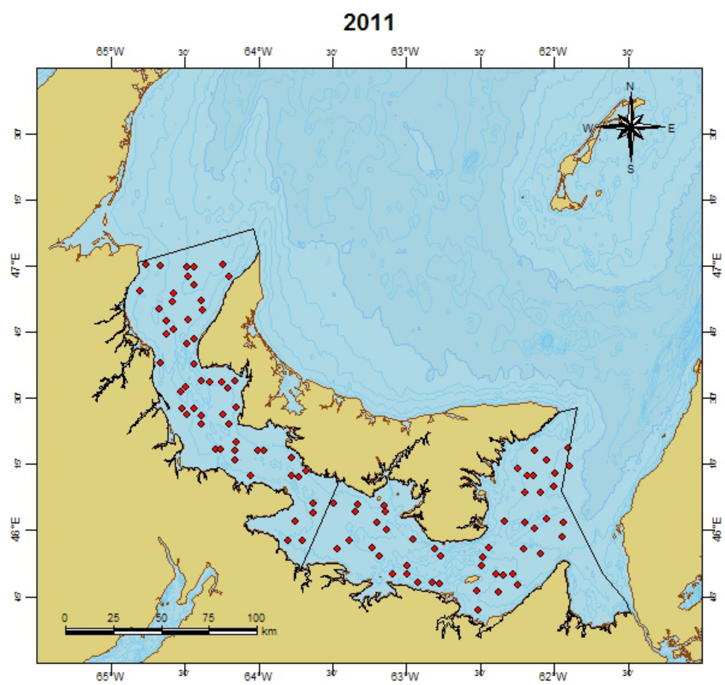


Figure 3. Location of stations sampled in 2010 (top) and 2011 (bottom) during the Northumberland Strait trawl surveys. The lines demarcate LFAs 25 and 26A as shown in Figure 1.

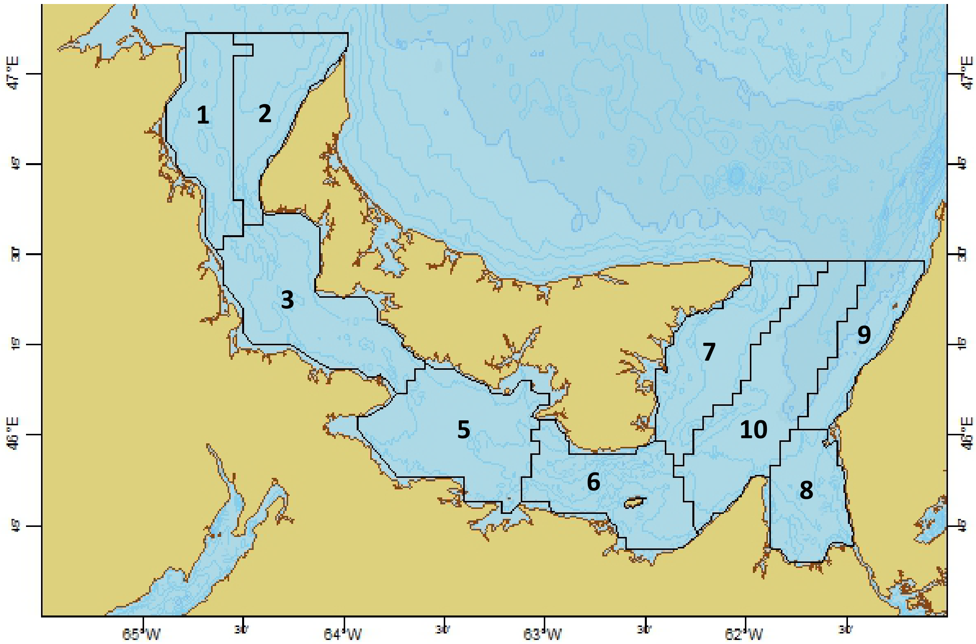
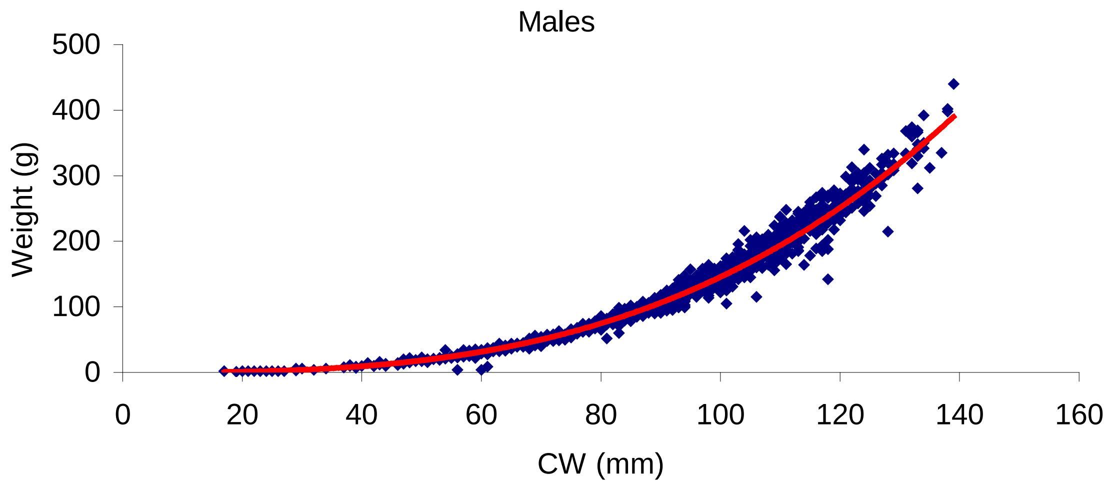


Figure 4. Location of strata used in the analysis of the Northumberland Strait trawl survey data.



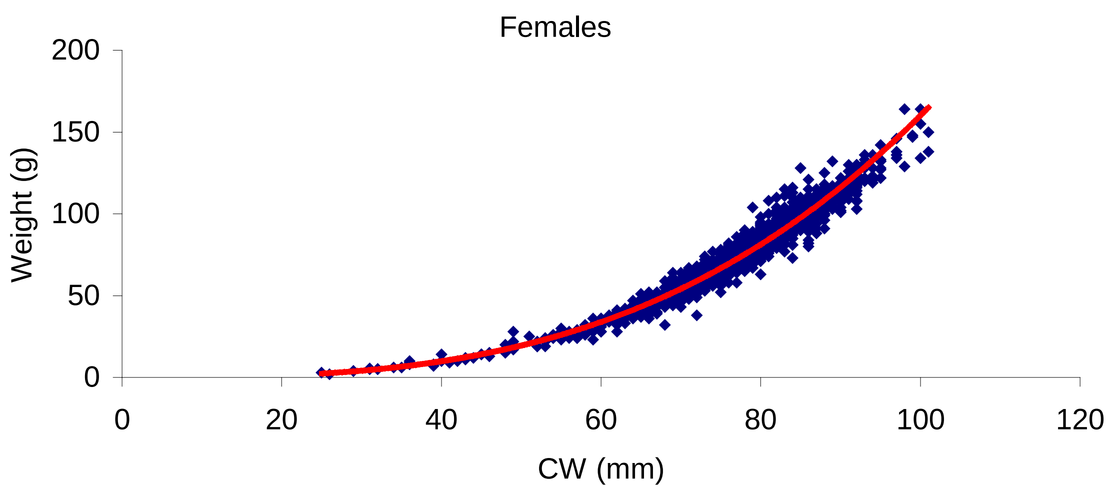


Figure 5. Scatterplot of body weight (g) and carapace width (mm) of male (top) and female (bottom) rock crabs from the 2010-2011 Northumberland Strait trawl surveys.

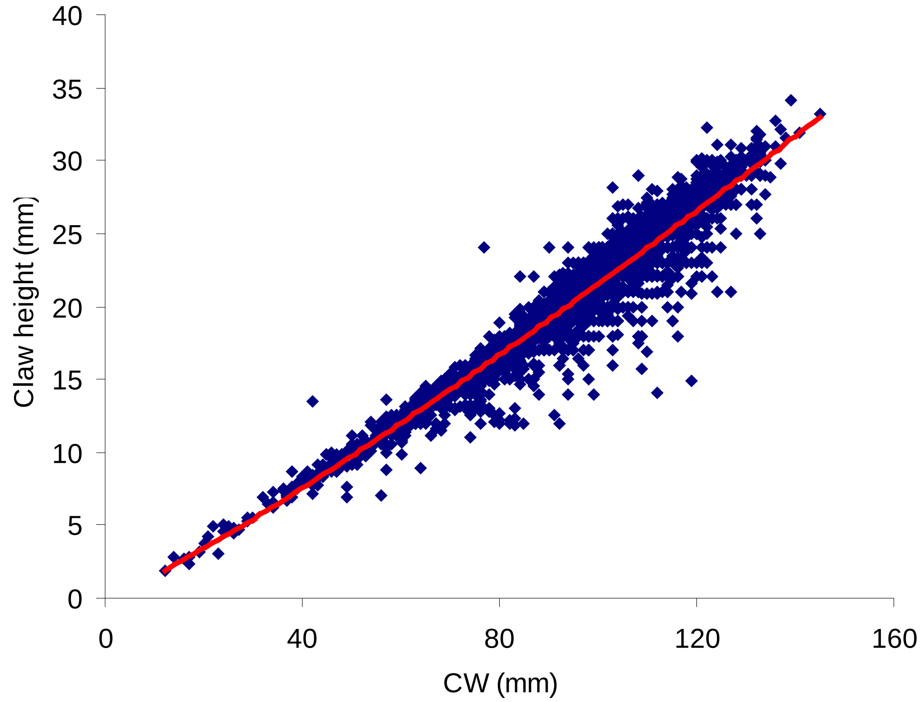


Figure 6. Scatterplot of claw height and carapace width of male rock crabs sampled from traps and from the 2010-2011 trawl surveys.

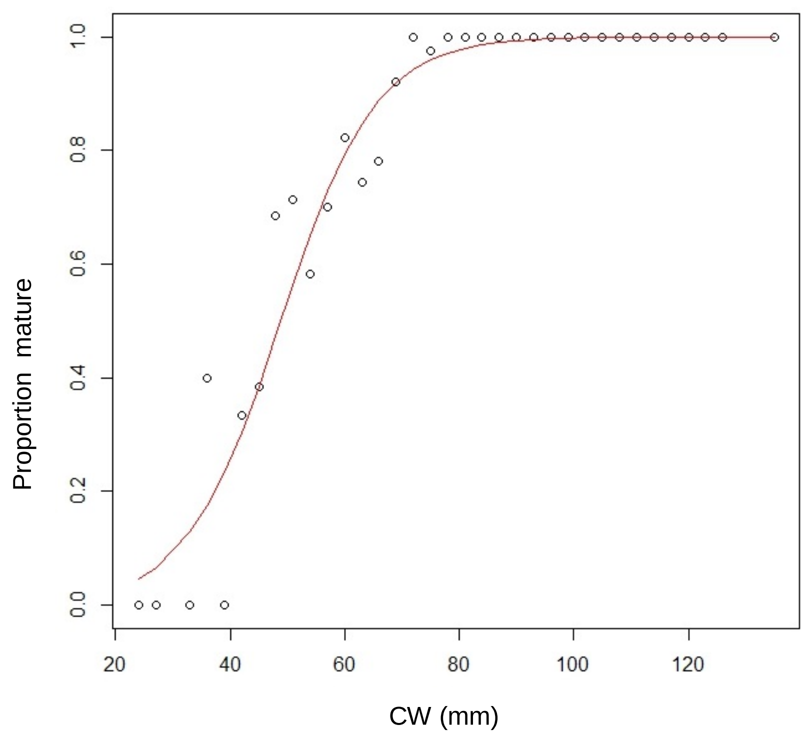


Figure 7. Male rock crabs maturity curve with fitted logistic curve.

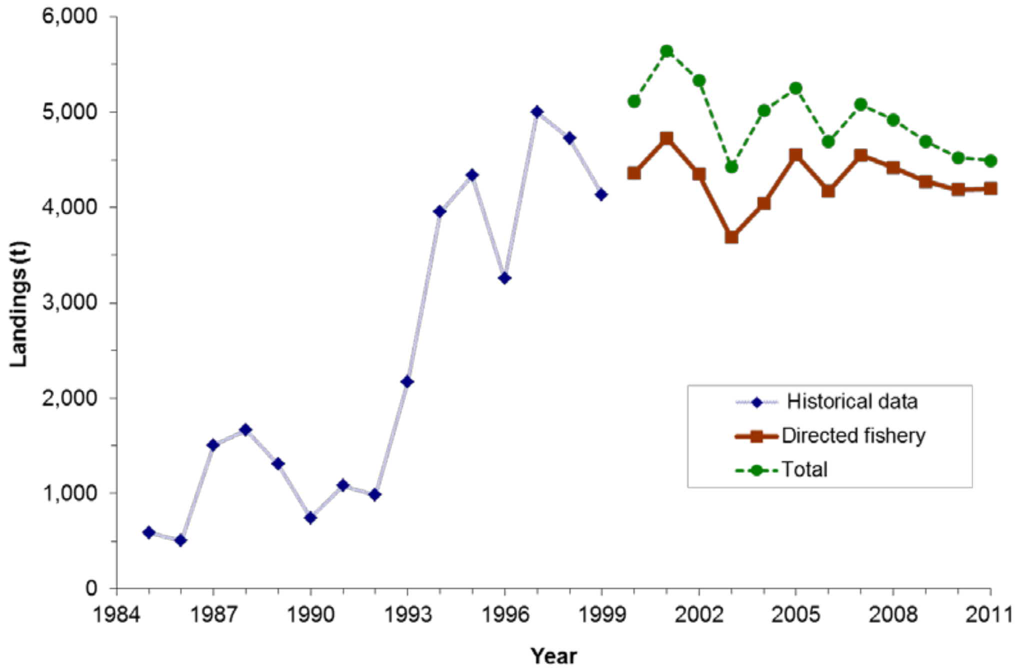


Figure 8. Total (directed and bycatch) recorded rock crab landings (t) in the southern Gulf of St. Lawrence between 1985 to 2011, with landings from the directed fishery shown separately for 2000 to 2011. Data for 2011 are preliminary.

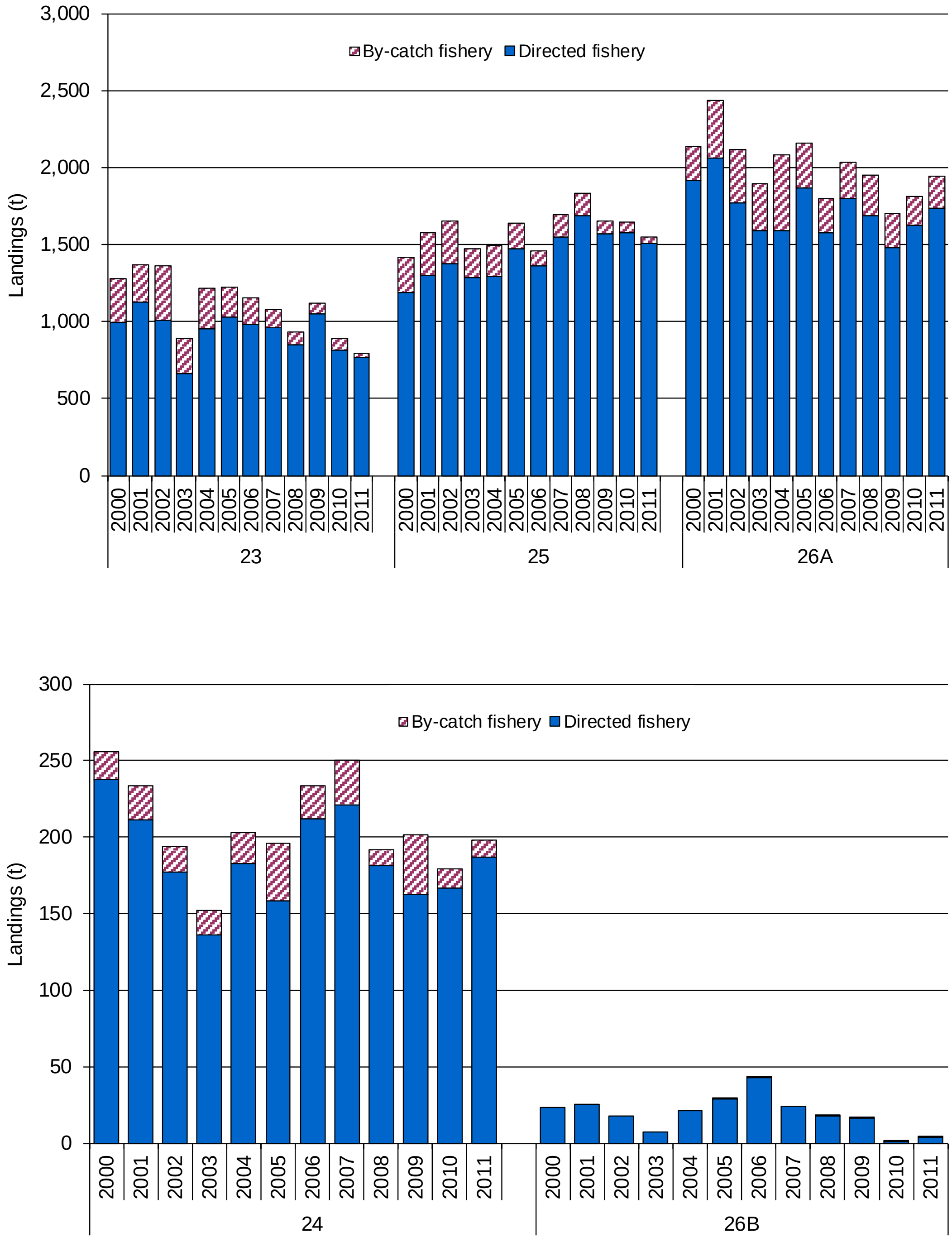


Figure 9. Recorded rock crab landings (t) in the directed and bycatch fisheries by LFA from 2000 to 2011. Data for 2011 are preliminary.

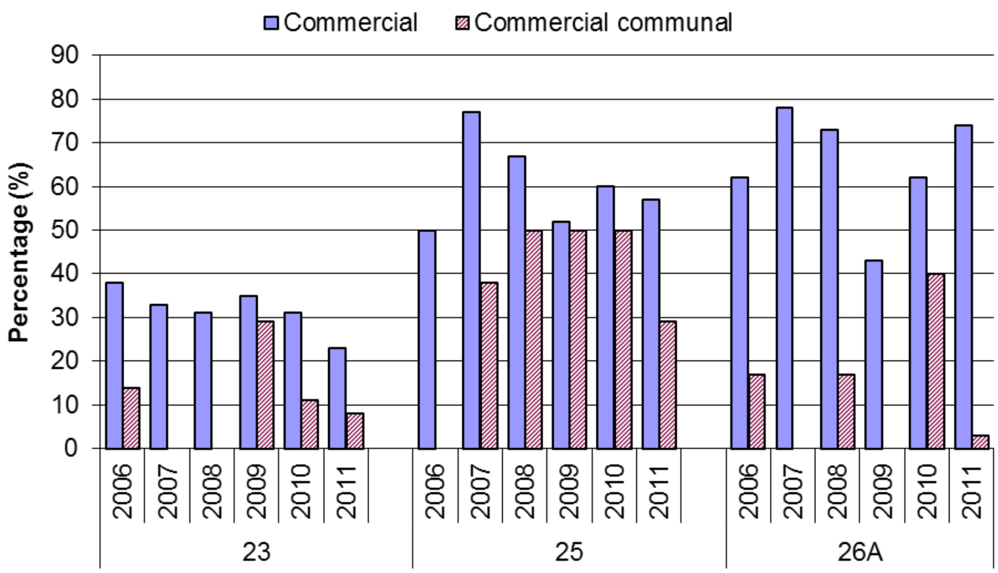


Figure 10. Percentages of active licences (commercial or commercial communal) for which >=90% of the individual allocation was reached during 2006 to 2011. There is no individual allocation in LFA 24 and no commercial communal licence in LFA 26B. Data for 2011 are preliminary.

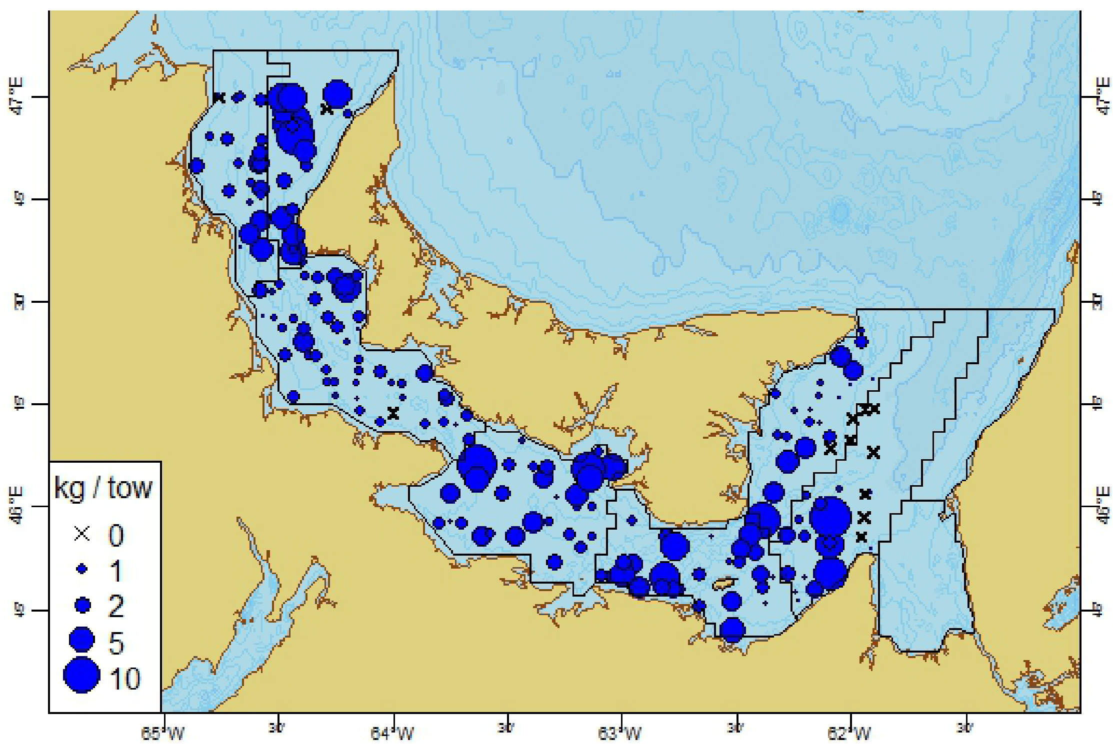


Figure 11. Distribution and relative abundance (kg/tow) of all sizes rock crab in the 2010-2011 combined trawl surveys of Northumberland Strait.

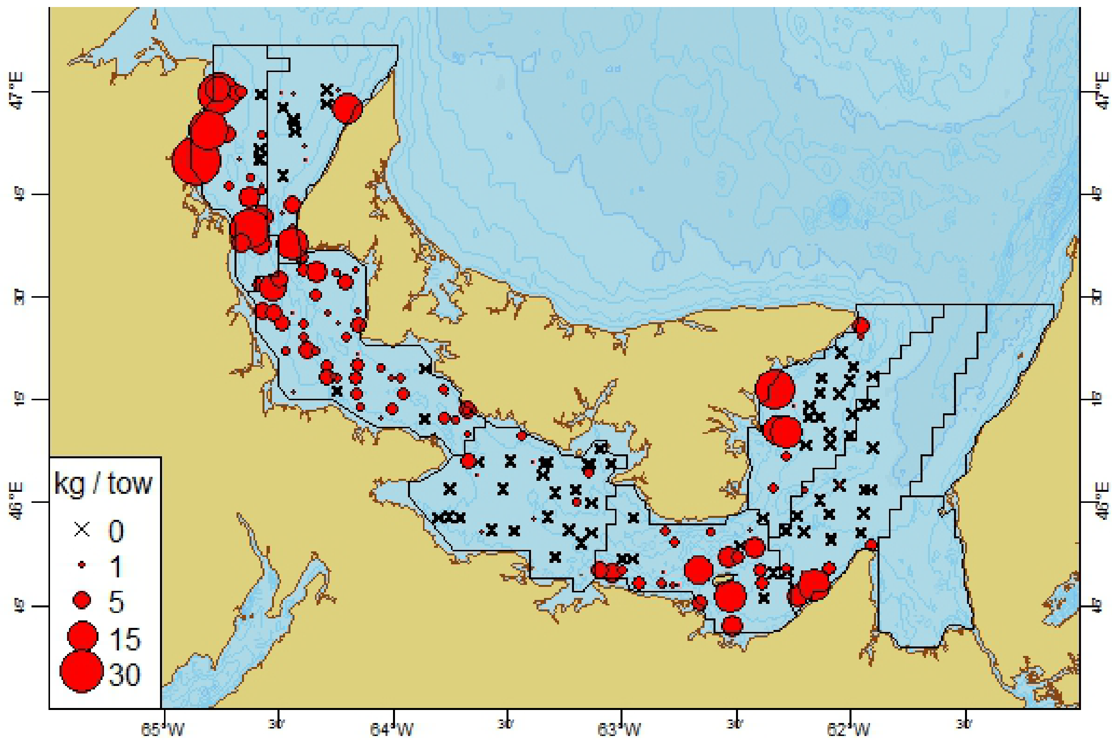


Figure 12. Distribution and relative abundance (kg per tow) of all sizes of American lobster in the 2010-2011 combined trawl surveys of Northumberland Strait.

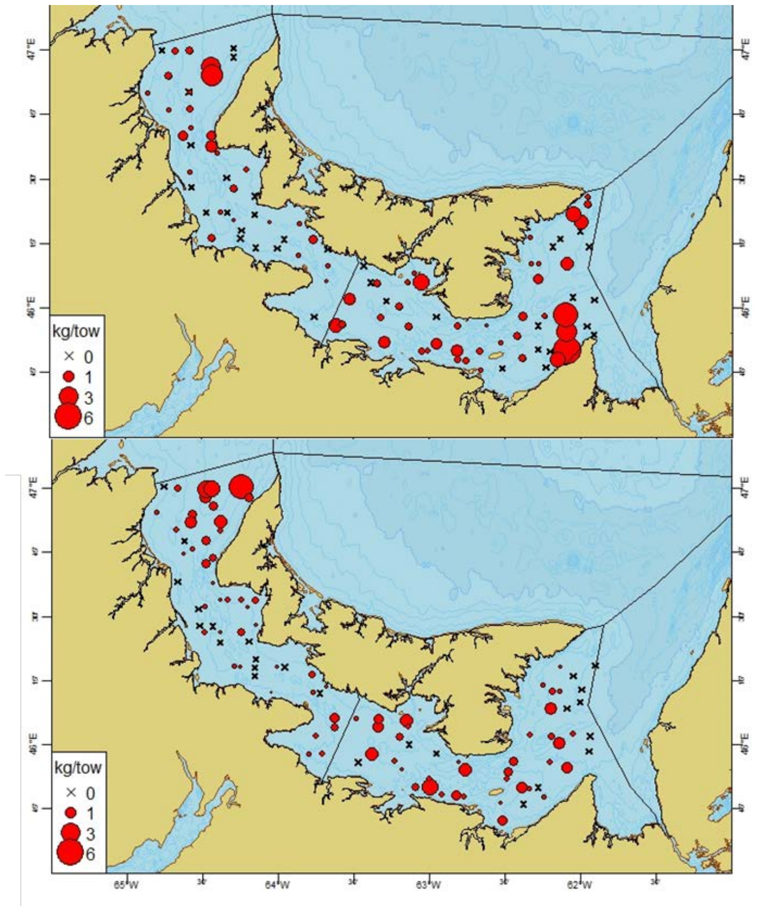


Figure 13. Distribution and relative abundance (kg per tow) of legal-sized male rock crab from the Northumberland Strait Nephrops trawl survey for 2010 (top) and 2011 (bottom). The minimum legal size used for LFA 25 is 102 mm and 108 mm for LFA 26A.

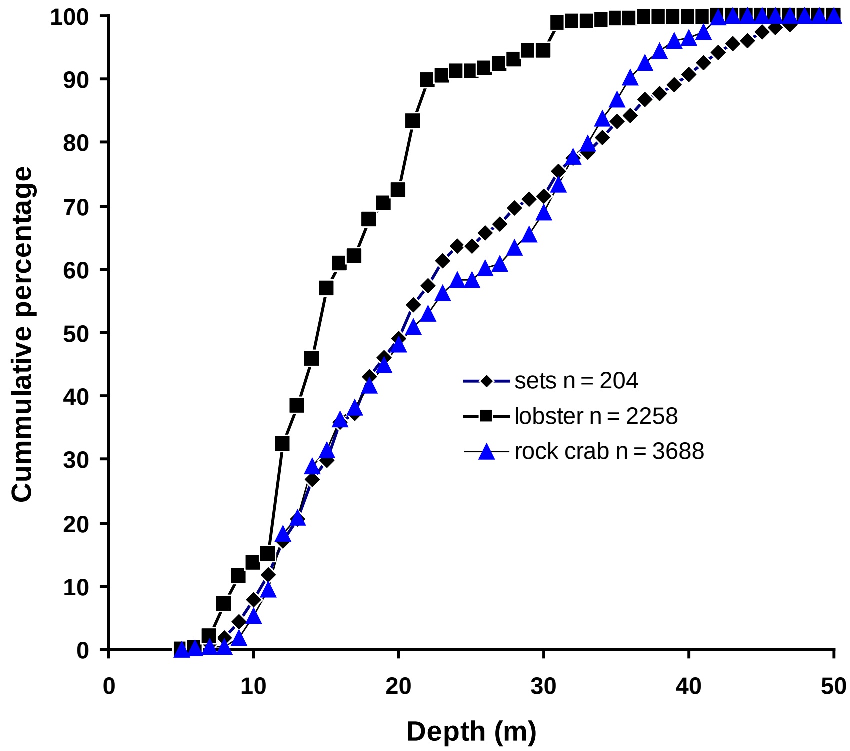


Figure 14. Cumulative depth distribution of rock crab and American lobster in trawl surveys of Northumberland Strait, July-August, 2010 and 2011 combined.

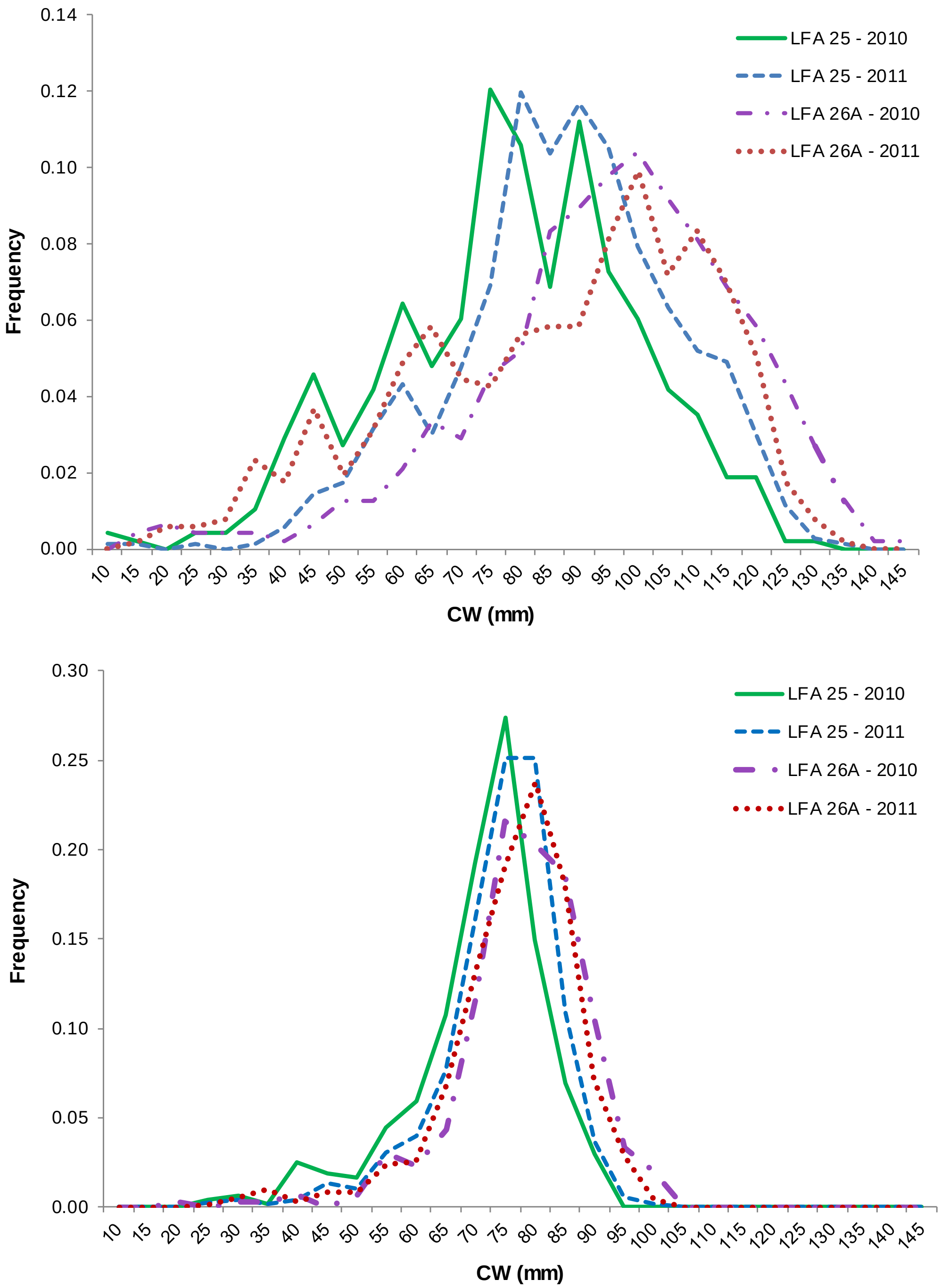


Figure 15. Relative size frequency distributions (by 5 mm bins of CW) of males (top) and females (bottom) caught during the 2010 and 2011 trawl surveys in LFAs 25 and 26A.

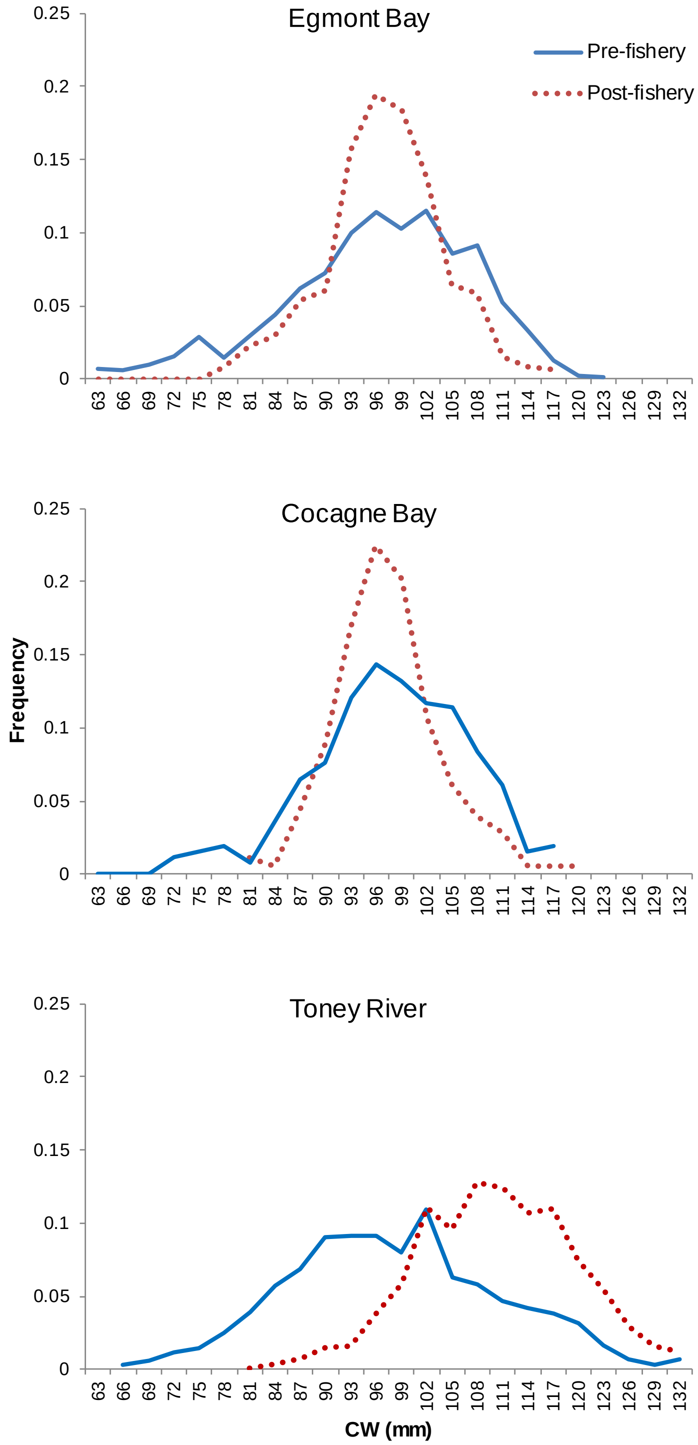


Figure 16. Relative size frequency distributions (by 3 mm bins of CW) of male rock crabs caught during the 2011 trap sampling activities in three locations, before and toward the end of the fishing season.

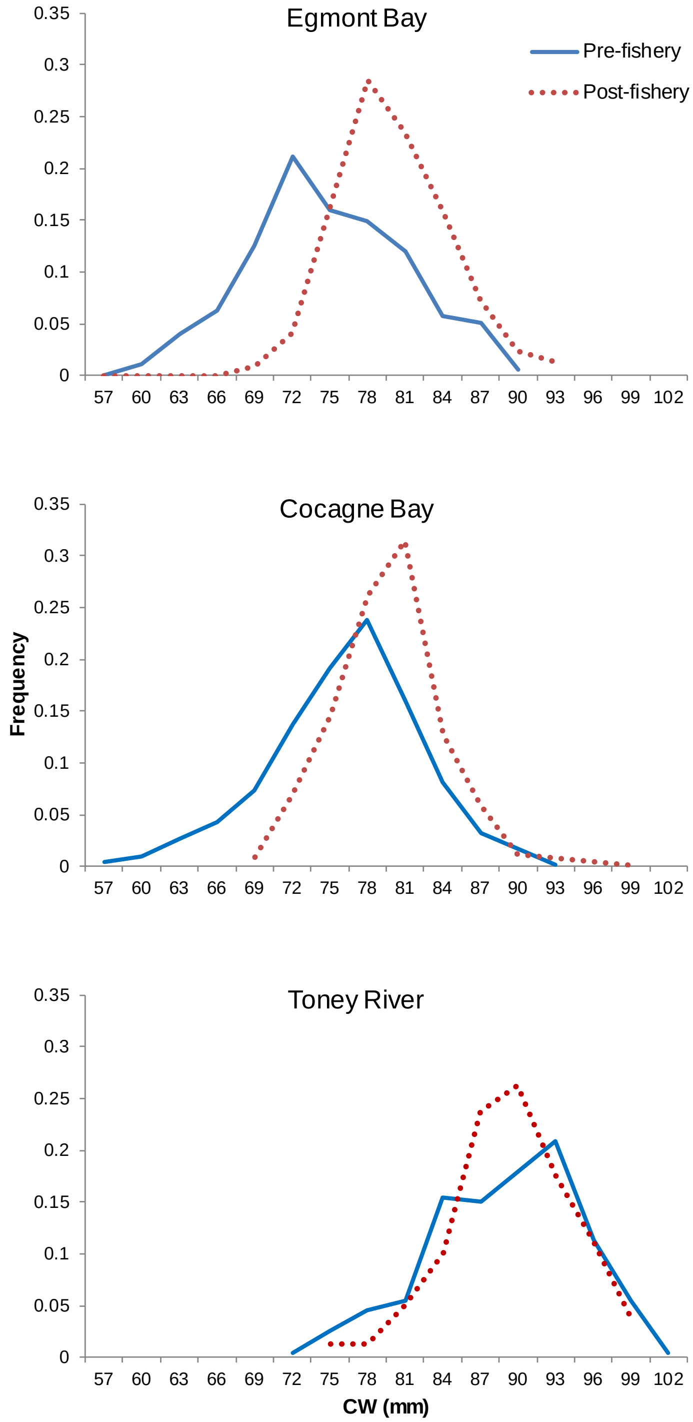


Figure 17. Relative size frequency distributions (by 3 mm bins of CW) of female rock crabs caught during the 2011 trap sampling activities in three locations, before and toward the end of the fishing season

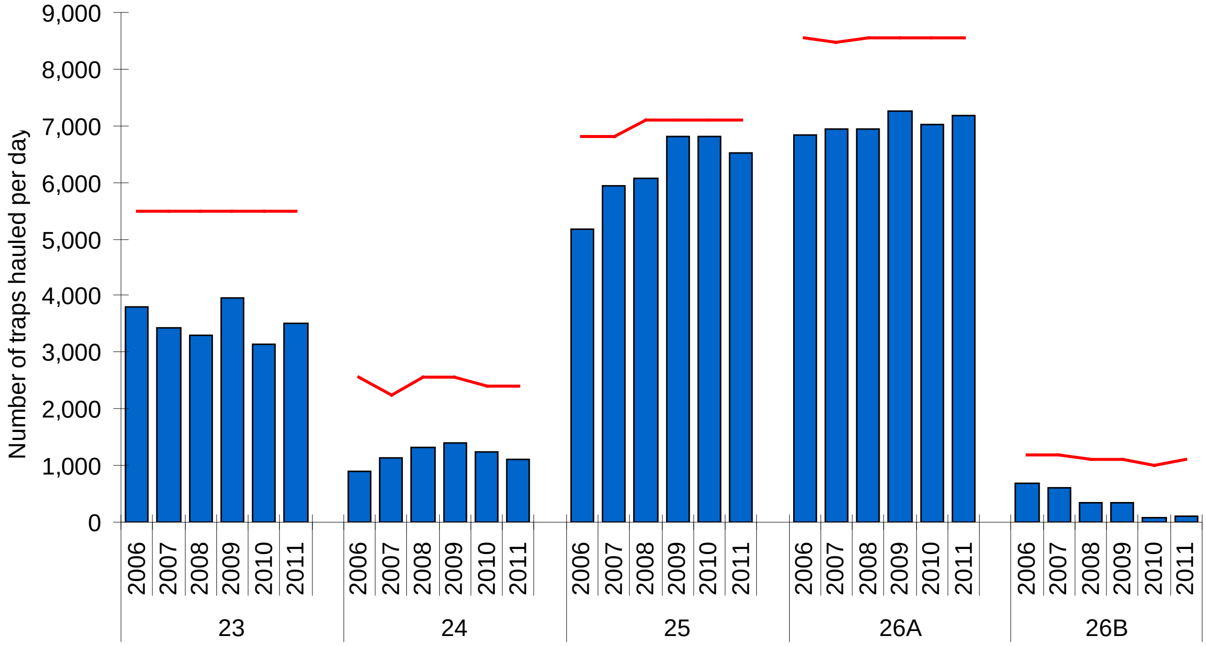


Figure 18. Average number of traps hauled in a day (solid bars) and nominal number of traps allowed to be fished according to the management measures in effect (red line) for the directed rock crab fishery by LFA for 2006 to 2011.

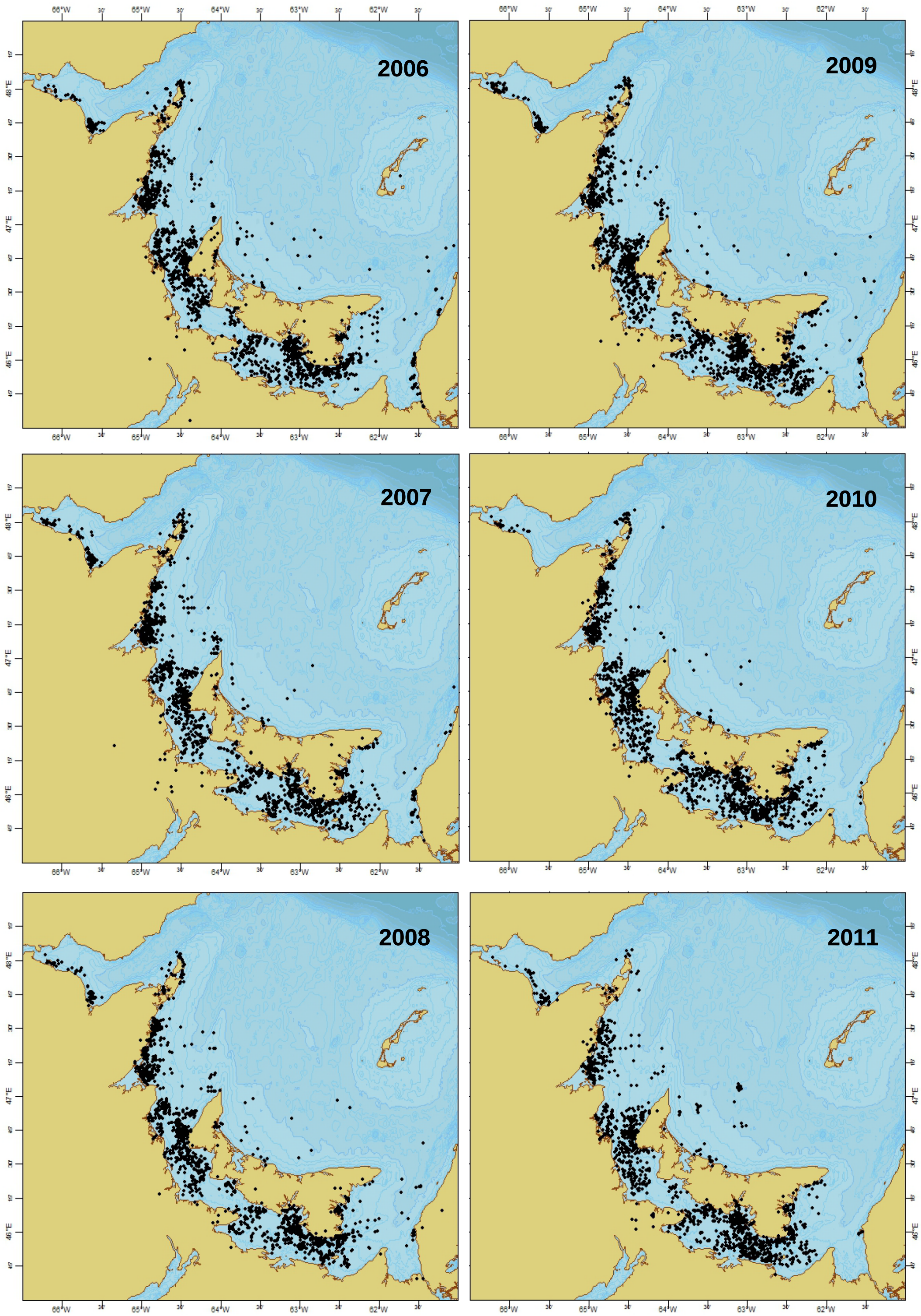


Figure 19. Fishing positions of the directed rock crab fishery as recorded in the mandatory logbooks from 2006 to 2011.

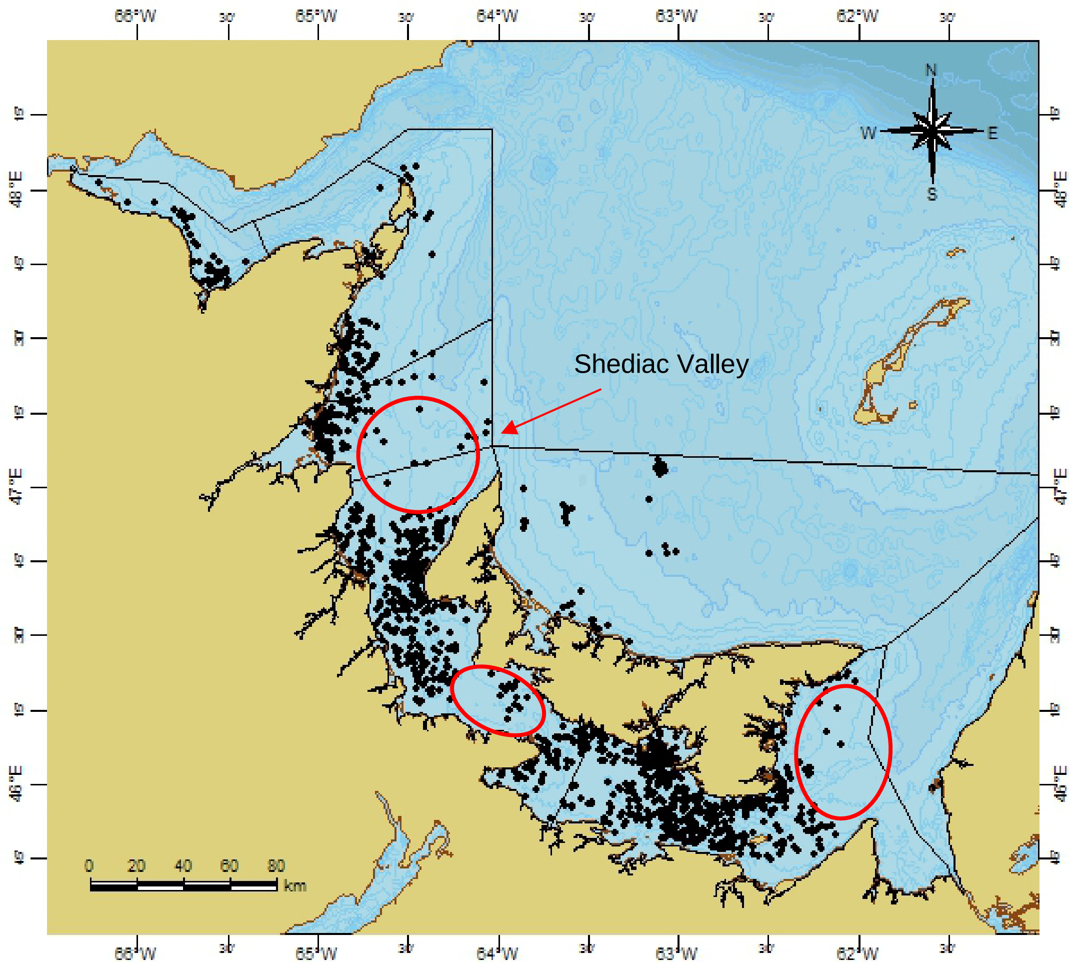


Figure 20. Fishing positions of the directed rock crab fishery as recorded in mandatory logbooks in 2011 with identification of less fished areas in red ellipses.

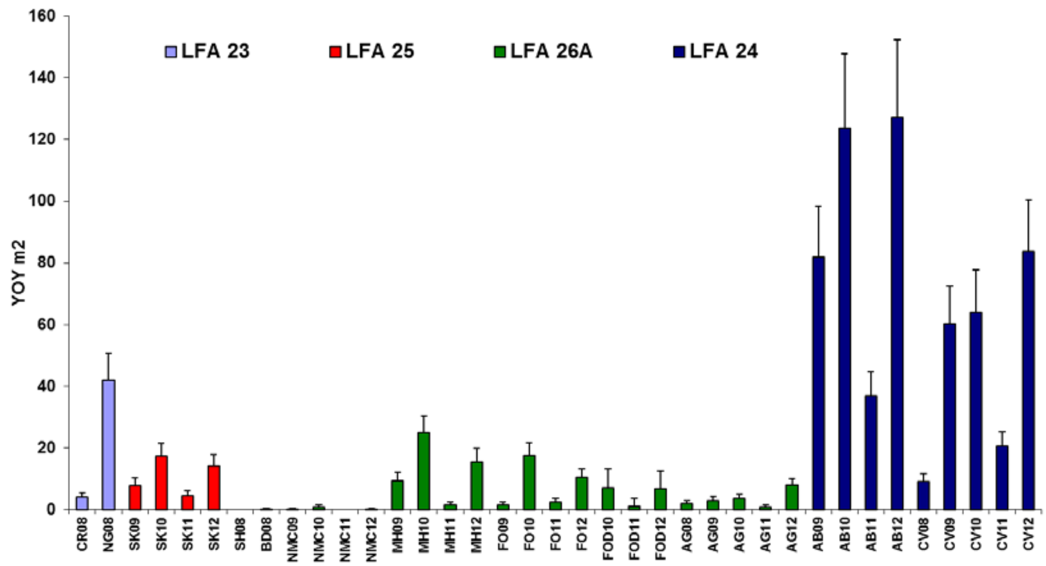


Figure 21. Mean number of young-of-year rock crab per square meter measured from bio-collectors at various sites in the southern Gulf of St. Lawrence between 2008 and 2012. Sites abbreviations are as follows: AB=Alberton; AG=Arisaig; BD=Bedeque; CR=Caraquet; CV=Covehead; FO=Fortune; FOD=Fortune (22 m); MH=Murray Harbour; NG=Neguac; NMC=Nine Mile Creek; SH=Shediac; SK=Skinner's Pond.

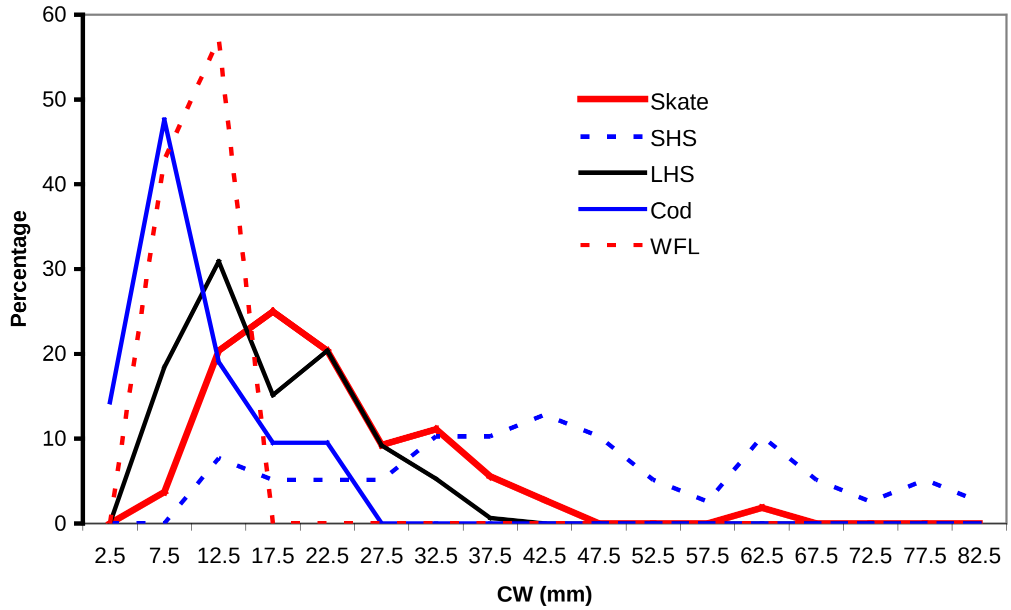


Figure 22. Carapace width (mm) of rock crab sampled from stomachs of winter skate (skate), shorthorn sculpin (SHS), longhorn sculpin (LHS), Atlantic cod (Cod), and winter flounder (WFL) from Northumberland Strait.

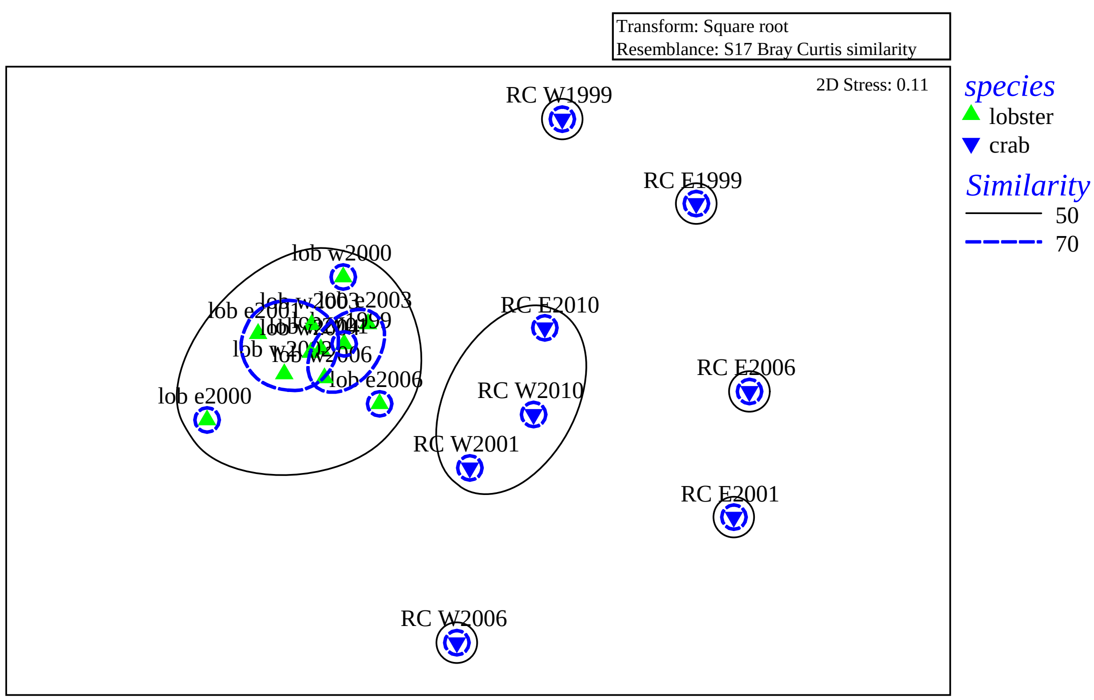


Figure 23. Multidimensional Scaling plot of diet overlap between rock crab and American lobster captured from sandy (W) or muddy (E) habitats during 1999 to 2010.

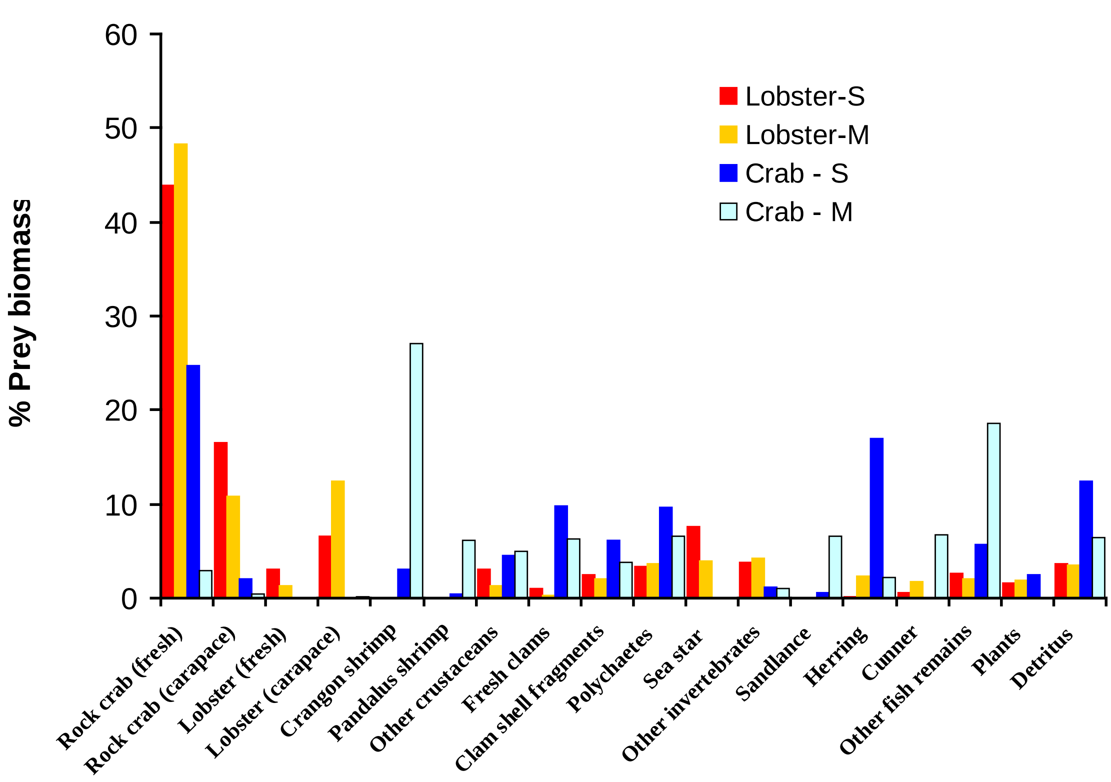


Figure 24. Comparison of average diets expressed as the percentage by weight of prey items of rock crab and American lobster separated by sandy habitat (S) and muddy habitat (M) types of the samples collected during the bottom trawl surveys of Northumberland Strait.