At-Sea Catch Analysis of Inshore Scotian Shelf Lobster Fishery and 4VsW Commercial Index Groundfish Sentinel Fishery

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ABSTRACT

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The catch of 1 longline trip and 41 lobster fishing trips were sampled at-sea between November 2005 and July 2006. For both fisheries, more than 90% of the catch, by weight and number, was the target species.

Twelve species of fish and invertebrates, representing 4 phyla were caught by longline. Ninety percent of catch by weight was cod (*Gadus morhua*). Combined, cusk (*Brosme brosme*), pollock (*Pollachius virens*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*) composed 4.4%, by weight, of the catch.

Forty-four species from 9 phyla were caught in the commercial lobster traps sampled (n=2553). Most lobster traps caught 1 or 2 species but some caught as many as 6 species. The most commonly caught species in lobster traps were decapods. Twenty-three per cent of traps caught rock crab (*Cancer irroratus*), 10% Jonah crab (*Cancer borealis*), 2% hermit crabs (*Paguridae*) and 2% toad crabs (*Hyas sps*). Six per cent of traps caught sea urchins (*Strongylocentrotus*), 5% caught starfish (*Asterias sps.*), 5% caught whelks (*Buccinum sps.*) and 1% caught periwinkles (*Littorinidae*). Six per cent of traps caught shorthorn sculpin (*Myoxocephalus scorpius*), and almost 1% of traps caught cunner (*Tautogolabrus adspersus*), sea raven (*Hemitripterus americanus*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), cod (*Gadus morhua*) and winter flounder (*Pseudopleuronectes americanus*).

The species composition of lobster trap catch varied with both depth zone and geographic area. Species accumulation curves for each geographic zone plateau at roughly 200 traps. Overall diversity was greatest in Depth Zone 2 (10-30 m) and Zone 3, South Shore. In Cape Breton (Zone 1), the lower diversity of species in Depth Zone 1 (<10 m) may be attributed to disturbance from pack ice in the winter.

The design of lobster traps varied. The most commonly used trap designs were wire and bow. There was very little difference in the lobster and non-lobster by-catch in commercial lobster traps. Often more than one type of bait was used in a trap, but mackerel was used as bait in more than 70% of the traps sampled.

Commercial lobster fishing vessels may be used as a sampling platform for common by-catch species, such as other decapods. Monitoring of by-catch of commercially valuable or threatened species may also be important for fisheries management. The 41 trips sampled at sea as part of this project almost tripled the observer coverage in 2006, and extended the geographic range this coverage. The catches in the traps sampled at sea were expanded to the whole fishery using the proportion of lobster landings that were sampled at sea. Assuming survival of discards, the lobster fishery has the greatest impact on rock crab, Jonah crab, toad crab, green crab (*Carcinus maenus*), longhorn and shorthorn sculpins, sea raven, cunner and winter flounder, some of which may have been kept to use as bait.

This project benefited from the support of fishermen and the collaboration between Fisheries and Oceans Canada (DFO) and the Fishermen and Scientists Research Society (FSRS). In the long term, working more closely with fishermen to help collect this type of data could be a cost-effective way to monitor changes in distribution and abundance, collect data on species of interest and describe the fishing effort.

RÉSUMÉ

den Heyer, C.E., Bundy, A., et MacDonald, C. 2010. At-Sea Catch Analysis of Inshore Scotian Shelf Lobster Fishery and 4VsW Commercial Index Groundfish Sentinel Fishery. Rapp. tech. can. sci. halieut. aquat. 2890: viii + 39 p.

Les captures provenant d'une sortie de pêche à la palangre et de 41 sorties de pêche du homard ont été échantillonnées entre novembre 2005 et juillet 2006. Dans chacune des pêches, plus de 90 % des captures, en poids comme en nombre, étaient constituées de l'espèce ciblée.

Douze espèces de poissons et d'invertébrés, représentant 4 phylums, ont été capturées par la palangre. La morue (*Gadus morhua*) représentait 90 % du poids des captures et le brosme (*Brosme brosme*), la goberge (*Pollachius virens*) et le chaboisseau à dix-huit épines (*Myoxocephalus octodecemspinosus*) représentaient tous ensemble 4,4 % du poids des captures.

Quarante-quatre espèces, appartenant à 9 phylums, ont été capturées dans les casiers de pêche commerciale du homard échantillonnés (n = 2553). La plupart des casiers ont capturé une ou deux espèces, mais certains en comptaient jusqu'à six. Les espèces les plus courantes présentes dans les casiers à homard étaient les décapodes. Parmi tous les casiers échantillonnés, 23 % ont pris des crabes communs (*Cancer irroratus*), 10 % des crabes nordiques (*Cancer borealis*), 2 % des bernard l'ermite (*Paguridae*) et 2 % des crabes lyres (*Hyas sps*). Six pour cent d'entre eux ont pris des oursins (*Strongylocentrotus*), 5 % des étoiles de mer (*Asterias sps.*), 5 % des buccins (*Buccinum sps.*) et 1 % des bigorneaux (*Littorinidae*). On trouvait du chaboisseau à épines courtes (*Myoxocephalus scorpius*) dans 6 % des casiers et de la tanche-tautogue (*Tautogolabrus adspersus*), de l'hémitriptère atlantique (*Hemitripterus americanus*), du chaboisseau à dix-huit épines (*Myoxocephalus octodecemspinosus*), de la morue (*Gadus morhua*) ou de la plie rouge (*Pseudopleuronectes americanus*) dans près de 1% des casiers.

La composition spécifique des captures des casiers à homard variait à la fois selon la zone de profondeur et selon la zone géographique. Les courbes de cumul des espèces dans chaque zone géographique atteignaient un plateau à environ 200 casiers. Globalement, c'est dans les zones de profondeur 2 (10-30 m) et 3, sur la côte sud, que la diversité était la plus grande. Au Cap-Breton (zone 1), la plus basse diversité d'espèces observée dans la zone de profondeur 1 (< 10 m) peut être attribuée aux perturbations dues à la banquise en hiver.

Les modèles de casiers variaient, les plus courants étant ceux à armature arquée et à treillis métallique. Il y avait peu de différence dans les captures de homard et celles d'autres espèces parmi tous les casiers de pêche commerciale du homard. Souvent, un casier contenait plus d'une sorte d'appât, mais du maquereau était utilisé comme appât dans plus de 70 % des casiers échantillonnés.

Les bateaux de pêche commerciale du homard peuvent servir de plateforme d'échantillonnage des prises accessoires courantes, comme les autres décapodes. Il peut être important aussi pour la gestion des pêches de surveiller les prises accessoires d'espèces de valeur

commerciale ou d'espèces menacées. L'échantillonnage en mer des 41 sorties de pêche du homard a eu pour effet de tripler pratiquement tripler les sorties contrôlées par un observateur en 2006 et d'étendre la portée géographique des contrôles. Les captures des casiers échantillonnés en mer ont été extrapolées à toute la pêche, en fonction de la proportion des débarquements de homards échantillonnés. Si on tient pour acquis que les animaux remis à l'eau survivent, les plus fortes incidences de la pêche du homard portent sur le crabe commun, le crabe nordique, le crabe lyre, le crabe vert (*Carcinus maenus*), le chaboisseau à épines courtes, le chaboisseau à dix-huit épines, l'hémitriptère atlantique, la tanche-tautogue et la plie rouge, certains d'entre eux pouvant être gardés pour servir d'appât.

Ce projet a bénéficié de l'appui des pêcheurs et de la collaboration entre Pêches et Océans Canada (le MPO) et la Fishermen and Scientists Research Society (FSRS). À plus long terme, travailler en plus étroite collaboration avec les pêcheurs pour recueillir ce type de données pourrait se révéler un moyen rentable de surveiller les changements dans la répartition et l'abondance des ressources, de réunir des données sur les espèces qui nous intéressent et de connaître l'effort de pêche.

PREFACE

Fisheries and Oceans, Canada (DFO) is moving towards an Ecosystem Approach to Management (Canada 1997 *Oceans Act*). One element of this is the production of Ecosystem Overview and Assessment Reports (EOARs, DFO 2005) for five pilot Integrated Management areas, including the Eastern Scotian Shelf (ESS). The ESS EOAR published in 2006 did not include the inshore areas of the Scotian Shelf (Zwanenburg et al. 2006). Since then, the Eastern Scotian Shelf Integrated Management pilot project has been extended to include the inshore areas of the Scotian Shelf. In 2005, DFO and the Fishermen and Scientists Research Society (FSRS) established a collaborative project, the DFO-FSRS Inshore Ecosystem Project (IEP), to collect new data and synthesize existing information on the Inshore Scotian Shelf ecosystem (DFO 2006a, 2007) in support of an EOAR and the identification of Ecologically and Biologically Significant Areas (DFO 2004, 2006b).

The Inshore Ecosystem Project focused on waters within the 12 nautical mile limit of the Scotian Shelf, from Cape Sable to Cape North (Figure 1). Although inshore areas are recognized as nursery and feeding areas for many marine species, there is insufficient scientific data to meaningfully contribute to either Integrated Management of the inshore or to definitions of EBSAs. In order to address this data gap, the DFO-FSRS Inshore Ecosystem Project collected new baseline data. The new data was collected as part of eight research initiatives:

1. Workshop on Inshore Ecosystems and Significant Areas of the Scotian Shelf (DFO 2006a)
2. Analysis of DFO Databases and data archiving
3. Monitoring of Environmental and Oceanographic Data
4. Grey Seal Pup Survey
5. At-Sea Catch Analysis
6. Fishery-Independent Research
7. Video of bottom habitat using URCHIN (Underwater Reconnaissance and Coastal Habitat Inventory)
8. Local ecological knowledge (LEK) Survey of Commercial Fishermen

Here, we report on the at-sea catch analysis of inshore commercial fisheries.

INTRODUCTION

In the marine environment, basic data on distribution and abundance of species are collected on fisheries-independent surveys and from commercial fisheries. However, the long standing fisheries-independent research surveys that monitor the abundance and distribution of fish and invertebrates on the Scotian Shelf do not cover inshore areas, and the substantial and comprehensive source of data on the distribution and abundance of inshore species from commercial fisheries is not well utilized. Since the 1950s, catch statistics for commercially valuable target and non-target species have been systematically collected by DFO, but non-target species and size classes of target species that are not commercially valuable are not reported. Documenting this unreported by-catch could contribute to a better understanding of the abundance and distribution of both target and non-target species as well as species associations.

The at-sea analysis or monitoring of catch on fishing vessels could provide data on the distribution and abundance of the whole spectrum of species caught in commercial gear. Canada's At-Sea Observer Program records catches of target and non-target species at-sea during commercial fishing operations. This data have been used for stock assessment of target species (Showell et al. 1993, Showell and Bourbonnnai 1994, Gregoire and Showell 1994, Showell et al. 2005), ecosystem and environmental monitoring (Worm et al. 2003), and estimating the mortality of commercial species (O'Boyle et al. 1996, Orr et al. 2001) and species of conservation concern (Hooker et al. 1997, Hoey et al. 2002, Baum et al. 2003, Lewison et al. 2004, Miller and Skalski 2006). To date, the Observer Program coverage of the inshore fisheries has been limited (Gavaris 2010). Here, we modeled the sampling protocol for the at-sea catch analysis of inshore commercial fisheries after Canada's At-Sea Observer Program.

On the Scotian Shelf, there are several inshore fisheries including lobster, rock crab, sea urchin, eel, groundfish, gaspereau, herring, sea scallops, smelt clams, worms and marine plants. The lobster fishery is the single most valuable fishery in Nova Scotia, and the majority of the fishery is prosecuted inshore, broadly distributed along the entire coastline. This intense fishery provides an opportunity to collect data on abundance and distribution of species that are captured by lobster traps along the entire coast of Nova Scotia and over extended time periods corresponding to the lobster seasons. In addition, this shallow trap fishery may allow non-destructive sampling of fish and invertebrates as the survival of discarded by-catch is expected to be high.

Here, we explore the use of commercial fishing vessels as sampling platforms for the inshore ecosystem. We assess the potential of at-sea analysis of inshore commercial fisheries to (1) estimate by-catch of commercial and non-commercial species, (2) collect data on the distribution and abundance of commercial and non-commercial species, (3) collect morphometric data on individuals of commercial and non-commercial species and (4) monitor ecosystem metrics such as species diversity.

METHODS

The at-sea catch analysis began in the fall of 2005 and continued until July 2006. We focused on the lobster fishery since it is the most important fishery in the inshore and is broadly distributed. The other source of at-sea catch data was the 4VsW Sentinel Groundfish Survey. This longline survey of the eastern Scotian Shelf includes inshore stations.

The geographical scope of the DFO-FSRS Inshore Ecosystem Project was the inshore, defined as less than 92 m (50 fathoms) depth or less than 22 km (12 nautical miles) from shore, between Cape North and Cape Sable Island, Nova Scotia (Figure 1). The inshore area includes 7 Lobster Fishing Areas (LFAs), from LFA 27 to LFA 33. The inshore area was divided into three zones; Cape Breton (Zone 1), Eastern Shore (Zone 2) and South Shore (Zone 3), which encompass a variable number of LFAs (Figure 1). Data were collected by FSRS Community Technicians, situated in each zone (Sydney area, Halifax and Barrington).

DATA COLLECTION

The data collection protocols and data forms were modeled on the International Observer Program and the data were uploaded into the DFO Industry Surveys Database (ISDB). The data collected at sea included trip and vessel information, gear information, set information, catch data, and data on individuals of all target and non-target species caught during commercial fishing.

Trip and Vessel Information

Each trip was assigned a unique trip number. The trip number indicated the project (EC) the year (05 or 06), the geographic zone and the trip number (1-21). The three geographic zones were Zone 1 (Z1), Cape Breton, Zone 2 (Z2), Eastern Shore, and Zone 3 (Z3 or Z9), South Shore (Figure 1).

The vessel name and Commercial Fishing Vessel number were used to identify the boat and access information on length, gross tonnage, and break power. Boarding date, landing date and weather conditions, including wind speed and wind direction, on the day of the trip were recorded. Northwest Atlantic Fisheries Organization (NAFO) area and/or Lobster Fishing Area (LFA) was also recorded (Figure 1).

Gear Information

Data were collected to describe both the type of gear and the species sought. For the longline trip we recorded the size and number of hooks, length of the gear, duration of set and bait.

Inshore lobster fishermen use a variety of lobster traps. For each trip, the trap types were defined by the total length, wire spacing, the number of kitchens, parlours and bait spikes and the number, type and size of escape vents. We also recorded the number of traps per buoy or trawl.

Set Information

For each trap (set), we recorded the depth, position, number of soak days and bait type. Where depth was not recorded, position information was used to find depths from charts so that traps could be assigned to a depth zone. There were 5 depth zones: Depth Zone 1, 0-10 m, Depth Zone 2, 10-30 m, Depth Zone 3, 30-50 m, Depth Zone 4, 50-100 m, and Depth Zone 5, unknown.

Bait was identified by species or combination of species. By-products from processing plants such as frames or heads were not distinguished from whole fish.

Catch Data

Species Identification

When possible, species were identified while at sea by using field guides. For species that could not be identified while at sea, samples were frozen or digital photos were taken for identification.

Kept, Discarded and Estimated Total Weight

The weight (kg) of individuals in the catch that were used as bait, for personal use or landed was recorded as kept. Any catch that was returned to the sea or taken for identification by the ecosystem technicians was recorded as discarded. The estimated total weight of the catch was calculated by summing the kept and discarded weight by species.

When weights were not available because of failure of the digital scales or rough seas, length-weight relationships (Table 1) were used to estimate individual weights which were summed to estimate total catch. Published length-weight relationships were used when the range of length reported spanned the lengths to be estimated. Where there were no appropriate published length-weight relationships, the data collected in this study were used to estimate the weight from the length (or width).

Data on Individuals

Detailed Morphologies

The Observer Program protocols were followed for the measurement of individual length. Depending on the fish species either total length or fork length (cm) was measured; for lobster, carapace length (mm), and for crab, carapace width (mm) was measured with appropriate calipers. Whelks and whelk shells inhabited by hermit crabs were measured as the maximum shell height (mm) with crab calipers, and the maximum test diameter (mm) was measured for urchins and brittle stars. Maximum diameter (mm), end of arm to end of arm, was measured for starfish.

When sea state allowed, individual kept and discarded weights were recorded at sea using spring and electronic scales.

Sub-sampling

In some cases, when either the catch was too large, or time did not permit, only part of the catch was measured and weighed.

Data Management

DFO's ISDB was used to house the data collected from the at-sea catch analysis. The ISDB data forms were adapted for use with the longline and lobster fisheries. Although the forms worked well for the longline trip, in practice they were too cumbersome for the lobster trips as each lobster trap generated a separate catch and detailed morphology sheet. To reduce the amount of paper handled at-sea, the FSRS technicians developed a multitasking data sheet. This sheet allowed a technician to record data from a number of lobster traps on a single datasheet. The data from the multitasking data sheet was entered into EXCEL worksheets using a double entry system for quality control of data entry, and then uploaded to the ISDB using SQL scripts (Maritime Science Virtual Data Center (VDC)).

Temperature Data

Water temperature was not recorded during the at-sea catch analysis since it is available from the FSRS recruitment trap survey, which has been recording continuous bottom temperature with VEMCO minilog temperature recorders (0.1 °C resolution, +/-0.2 °C accuracy) attached to lobster recruitment traps along the Atlantic Coast since 1999 (Petrie and Pettipas 2004). Date and geography account for most of the variation in temperature along the coast, but depth can also be important. Each trap sampled was assigned the water temperature of the nearest FSRS recruitment trap on the day prior to at-sea sampling. There was a FSRS recruitment trap within 5 km for 85% of the traps sampled and within 70 km for all traps sampled (Figure 2A). For 82% of the traps, the difference between the depth of the trap and nearest FSRS minilog was less than 10 m (Figure 2B). All 135 traps sampled at depths greater than 30 m were in LFA 33. For these traps, the distance from a recruitment trap and the difference in depth was greater than for the other traps. However, these traps were sampled in late winter and very early spring, when water temperature was low and relatively constant along the depth profile (Coastal Time Series Temperature http://bluefin.mar.dfo-mpo.gc.ca/ctsqry/index-e.html, Appendix A).

Fishing Effort

In order to estimate the total by-catch (weight in tonnes) in each LFA, the proportion of the total lobster landings caught in the traps sampled was assumed to be equivalent to the proportion of total by-catch caught in the traps sampled. Landings data and the number of fishermen were estimated from the landings slips for each LFA (DFO MARFIS Landings database, Maritime Science Virtual Data Center (VDC), accessed April 2010).

STATISTICAL ANALYSES

Histograms, Wilcox rank sum tests and length-weight were completed with R 2.5.1 (R Development Core Team, 2007).

Species Accumulation Curves (SACs)

Species accumulation curves (SACs) of the fish and invertebrate catch were used to determine how well we had sampled the geographic and depth zones. The expected SACs and the unconditional standard deviation (Ugland et al. 2003, Colwell et al. 2004, Kindt et al. 2006) were calculated from random sampling of the data without replacement using the R package, vegan: Community Ecology Package version 1.8-6 (Oksanen et al. 2007).

Multidimensional Scaling

PRIMER v6 (Clarke and Warwick 2001, Clarke and Gorley 2006) was used to explore decapod distribution in the inshore Scotian Shelf with respect to geographic zone and depth with multidimensional scaling (MDS). The catch data was aggregated by trip and depth zone. Only those aggregated sampling units in which 5 traps or more were sampled were retained in the analysis. The mean number of traps in the filtered aggregated sampling units (n=77) was 32. The mean number of individuals per trap in each depth zone within trip was fourth root transformed to reduce the effect of species that were caught in high numbers. The MDS was based on the Bray-Curtis similarity matrix, which is most appropriate for data with high number of 0 values or joint absences. A 2-way paired Analysis of Similarities (ANOSIM) was used to compare the community composition in the geographic and depth zones.

RESULTS

EFFORT

Longline

One of 5 4VsW Commercial Index Sentinel Groundfish Survey longline trips was sampled (Figure 3a). A 2.2 km longline, with 1200 Mustad #10 circle hooks baited with squid was set for 11 hours in 50 m of water. The distance between the hooks was 1 m and the gangions, or connections from hook to line, were 0.5 m. Only cod (*Gadus morhua*), cusk (*Brosme brosme*), and pollock (*Pollachius virens*) were kept, all other species of fish and invertebrate caught were discarded (Table 2).

Lobster Traps

In total, 2553 lobster traps were sampled on 41 trips completed by 34 fishermen in LFAs 27, 29, 30, 31A, 31B, 32 and 33 (Figure 3b, Table 3). Forty-six per cent (n=1184) of the traps sampled were in Zone 1, Cape Breton (LFA 27, 29 and 30), 32 % (n=824) in Zone 2, Eastern Shore (LFA 31 and 32) and 21% (n=545) in Zone 3, South Shore (LFA 33). Less than 0.1 % of the total lobster fishing effort was sampled (Table 3).

There was a wide range of trap configurations (Table 4, Appendix B) and bait used (Table 5). Sixteen of the traps sampled were experimental FSRS recruitment traps. These traps have blocked escape vents and caught more by-catch than other traps (Table 6), and were not included in the analysis of community composition or extrapolation to total by-catch.

Lobster fishing seasons vary by LFA (Table 3), and the number of trips sampled varied from week to week (Table 7). For the most part traps were hauled after one day soak, but in Zone 3 (LFA 33) some traps were hauled 4 and 6 days after being set (Figure 4). In Zone 3 traps were also set at deeper depths than in Zones 1 and 2 (Figure 5).

Mackerel (*Scomber scombrus*) was the most commonly used bait in all three zones (Table 5). More than one type of bait was used in some traps. Bait was supplemented by rock crab (*Cancer irroratus*) and sculpin (*Myoxocephalus sp.*) caught in lobster traps, as well as cod waste (frames: head, tails, other pieces) from local processing plants.

SPECIES RICHNESS

Longline

On the one longline set, 12 species of fish and invertebrates, representing 4 phyla were caught. Ninety percent of catch by weight was cod (*Gadus morhua*) (Table 2). Combined, cusk (*Brosme brosme*), pollock (*Pollachius virens*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*) composed 4.4 %, by weight, of the catch.

Lobster Traps

Forty-four species from 9 phyla were caught in the commercial lobster traps sampled (Table 8, Appendix C). Most traps caught 1 or 2 species but some had as many as 6 species (Figure 6).

Lobster was the most common species caught by number and weight (Table 8). Of the 20 most common non-target species, 6 were decapods, 3 echinoderms, 3 molluscs, 6 fish and 2 algae.

Twenty-three percent of the traps sampled captured rock crab, 10% Jonah crab (*Cancer borealis*), 7% shorthorn sculpin (*Myoxocephalus scorpius*), 7% sea urchins (*Strongylocentrotus sp.*) and 1% caught cod (*Gadus morhua)*. Sea urchins were caught in high numbers around St. Margaret's Bay (Figure 7). Cod were caught on 9 trips. These trips were all east of St. Margaret's Bay, during spring (May, June and early July) fisheries (Figure 7).

Roughly 10% of the traps were empty. In traps that had no lobster, a greater number of species (other than lobster) were caught than in those that had caught one or more lobsters (mean number of species, traps without lobster = 0.9969, mean number of species, traps with lobster =0.5167, Wilcox rank sum test W=757149.5, $p < 0.001$).

Detailed Morphology

Data were collected on length and weight of all by-catch. Length-weight relationships were estimated for some of the more commonly caught species from the lobster traps (Table 9).

Species Accumulation Curves (SACs)

The height of the asymptote of the species accumulation curves (SACs) increased from east to west (Figure 10). In general, the SACs plateau at about 200 traps. Overall the South Shore has the highest diversity. In the shallowest depth zone (Depth Zone 1, <10 m), Cape Breton has lower diversity (asymptote is around 20) than the Eastern and South Shores. In Depth Zone 2 (10-30 m) species diversity is higher than Depth Zone 1 and more similar between Cape Breton and the Eastern Shore.

Species Distribution

The MDS plot of the average abundance per trap shows differences in decapod species composition associated with geographic zone and depth (Figure 8). The decapod species composition sampled by lobster traps in Cape Breton was different than those sampled to the west (Table 10). However, there was no detectable difference in the species composition sampled in the Eastern Shore and South Shore. There was no difference in species composition between the two shallowest zones (Table 11). Nor was there a detectable difference in the species composition between the two deepest zones. However, the decapod species composition in the shallow sites was different than that in the deeper sites. Bubble plots of the more common decapod species caught show associations with depth and geographic zone (Figure 9); crab species also have clear depth zonation, with toad crab in deeper waters and Jonah and rock crab in the more shallow waters. The plots of species composition along the coast also show geographic variation in the distribution of crabs, urchins and fish such as cod (Figure 7).

DISCUSSION

The lobster traps and longline trip sampled at sea caught a wide range of species, although both fisheries were highly selective. More than 90% of the catch by weight and number for both fisheries was the target species (Tables 2 and 8). Perhaps surprisingly, sea weeds were caught with both types of gear and benthic invertebrates such as sea potatoes (*Boltenia sp.*) and widgeon clams (*Pitar morrhuana*) were caught on the longline. More predictably, fish, whelks and starfish were caught in the lobster traps. Decapods were the most common by-catch in the lobster traps. More than 25% of the lobster traps sampled caught crabs. Echinoderms and molluscs were also caught in high numbers by lobster traps.

FISH MORPHOLOGY

For the more commonly caught species, commercial fishing vessels may be used as a sampling platform. At-sea sampling can provide information on the distribution and length-weight relationships of both target and non-target species. Currently, there is a very limited longline fishery but the inshore lobster fishery is intense. Here, we sampled 1 of 5 4VsW Commercial Index longline trips, but less than 0.1 % of the lobster landings along the coast (Table 3). As a proof of concept, we fit a simple regression to describe the length-weight relationships for more commonly caught species (Table 9). Since our sampling protocol used spring scales to measure individual weights, the movement of the boat may have introduced considerable error into individual weights of smaller organisms. For some species the size range susceptible to the lobster trap fishery is limited and may not be suitable for analysis for length-weight relationships. Modification of commercial traps to block escape vents could extend the size range of species caught. For commercial species, samples collected from the lobster fishery may extend data collection either geographically or seasonally. For non-commercial species this type of opportunistic sampling could contribute to the understanding of basic biology. Additionally, trap fisheries in shallow water provide the potential for low mortality sampling. With the assistance of commercial lobster fishermen it may be possible to sample a variety of species along the coast.

DISTRIBUTION AND ABUNDANCE

Lobster traps are passive gear. Trap design, such as the type of escape vent, wire spacing, hoop size and volume, can influence catch (Miller 1990). Further, bait type, soak time, water temperature and other factors correlated to the distribution and behaviour of fish and invertebrates may influence catches (Miller 1990, Drinkwater et al. 2006). For American lobster, catchability has been shown to be a function of size, sex, moult stage, ovigery, season, habitat (Tremblay and Smith 2001; Tremblay et al. 2006) and may also be related to population density (Tremblay et al. 2006). Notably, lobsters are thought to be socially dominant. American lobsters prey upon many of the species captured by lobster traps (Hanson 2009). Lobsters are also known to compete for space (Steneck 2006), be cannibalistic (Hanson 2009) and have been observed chasing smaller individuals out of traps (Jury et al. 2001). The presence of lobsters, particularly larger lobsters could reduce the catch of both lobsters and other species. Here we show that in traps with lobsters, fewer species were caught. A more detailed analysis of by-catch in lobster traps should consider the week in the fishery (Table 7), as larger lobsters are removed by the fishery (Claytor and Allard 2003).

There was considerable variation in the design of traps and the bait used. Overall, almost 75% of the traps were baited with mackerel (Table 5), but often more than one type of bait was used in a trap. Data collected during the commercial lobster fishery could be used to investigate relationships between bait and catch abundance and species composition. Further, data on bait is important in assessing the full ecological footprint of the lobster fishery (Harnish and Willison 2009).

The most common trap designs sampled were wire and traditional wooden bow, and there was very little difference in the lobster and non-lobster by-catch in these traps (Table 6). FSRS recruitment traps, which lack escape vents, caught more lobsters and more by-catch per trap than wire and bow commercial traps. More wood/wire combination traps were sampled on the Eastern Shore (Zone 2) and these caught more rock crab per trap than the other traps. Rock crab may be more susceptible to these traps, or these traps may have been set in areas with a higher abundance of rock crab.

Although individual lobster traps most commonly caught only 1 or 2 species (Figure 6), species accumulation curves (Figure 10) for each zone plateau at roughly 200 traps with 15 to 35 species. Overall diversity was greatest in Depth Zone 2 (10-30 m), which corresponds to the maximum depth for macrophyte growth in the clear Atlantic waters at about 20-25 m. In deeper water, the benthic ecosystem relies on detrital organic material. In shallow water, the species diversity in Cape Breton is lowest (Figure 10). Ice scour in this geographic zone can reduce diversity (Bergeron and Bourget 1986).

For the more commonly caught species, the lobster fishery provides an opportunity to document distribution and abundance. Here we have assigned our traps to 4 depth zones, which were used in the IEP Fishery-Independent survey Depth Zone 1, <10 m, Depth Zone 2, 10-30 m, Depth Zone 3, 30-50 m, and Depth Zone 4, >50 m. We also divided the study area into three geographic zones, Zone 1, Cape Breton, Zone 2, Eastern Shore, and Zone 3, South Shore. Species composition was related to both depth and location (Figure 8), with the differences between the geographic areas being more significant than those between depth zones (Tables 10 & 11). Unfortunately, the replication for depth zones within trips was uneven and small. As the number of species encountered increases with the number of traps sampled up until roughly 200 traps (Figure 10), the differences in species composition observed here could be associated with the number of traps sampled in each depth zone and trip. Despite this added variability, there is separation based on geography and depth zone.

A systematic exploration of the factors which describe the distribution of individual species would be useful. Differences can be detected in the species composition by geographic zone and depth zone (Figs. 8 and 9). While geographic zone incorporates both location and season, with exception of LFA 33 (Zone 3) all of the lobster fisheries were prosecuted in the spring. Bubble plots of the most commonly caught decapod species indicate difference in both geographic and depth distribution. Rock crab were most commonly caught in shallow waters along the entire coast, but in particularly high abundance in Cape Breton (Zone 1). This is consistent with the fishery-independent research vessel (RV) survey, which finds a preference of rock crab at depths less than 150 m (Tremblay et al. 2007). However, the current study documents a broader and more even geographic distribution probably because it is concentrated in more shallow waters. Similarly, the RV survey catches Jonah crab at very few stations east of the Gully, and in the lobster traps sampled no Jonah crab were caught in Cape Breton. Finally, the preference of toad crab for deeper colder water (Tremblay et al. 2007) is also seen in the by-catch of toad crab in the commercial lobster fishery.

BY-CATCH

Lobster traps catch commercially valuable species, as well as species which may be of conservation concern, such as Atlantic cod (*Gadus morhua*) or invasive species, such as green crab (*Carcinus maenas)*. Monitoring of by-catch of commercially valuable or threatened species may be important for fisheries management, particularly if the by-catch has a high mortality. For example almost 1% of the traps sampled in this survey caught cod, in total weighing 20 kg. However, none of the cod caught during the at-sea sampling were kept. Cod released from lobster traps may have good survivorship as the fishery is concentrated in shallow water (Figure 5). An experiment to estimate survival of cod released from lobster traps is required to assess the impact of lobster by-catch on the cod stocks.

Less than half of the fisheries in Atlantic Canada have any observer coverage and in 2006, less than 1% of the lobster trips were observed (Gavaris et al. 2010). The lobster fishery, in 2004, accounted for 46% of the landed value of all fisheries in Nova Scotia. Yet, prior to 2006, there had been no observer coverage of the lobster fishery in LFAs 27, 28, 29, 30, 31A, 31B and 32. In LFAs 33, 34, 40 and 41, 112 lobster fishing trips were observed between 1998 and 2006, and a further 28 trips were observed offshore in NAFO divisions 5ZEj and 5ZEm. Observer coverage has been increasing, with 26 of the observed trips occurring in 2006, but this still represents a very small portion of the total number of lobster fishing trips.

Landings slips were used to estimate the number of fishermen and the total landings by LFA (Table 3). We extrapolate the total by-catch for the 20 species that were most common (by weight) from the proportion of lobster landings that were caught in the traps that were sampled at sea (Table 12). In all LFAs, less than 0.1 % of the landings were sampled (Table 3). Thus, the conversion to total by-catch should be interpreted cautiously. Also, because lobsters are dominant, it is possible that the lack of sampling early in the fishing season contributes to an overestimation of by-catch. A more rigorous assessment of by-catch throughout the lobster fishing season is needed. Given the importance of depth in determining catch composition, extrapolation to the fishery incorporating depth distribution of the fishery, could also improve estimates of total by-catch.

FUTURE RESEARCH

The collection of biological data from commercial fishing platforms could be a cost-effective monitoring strategy of both distribution and abundance of species which are susceptible to the fishing gear. The extensive lobster fishery provides an opportunity to look at distribution and abundance of a range of species, particularly decapods, in the inshore.

Prior to the Inshore Ecosystem Project, 140 lobster trips had been observed by the Observer Program. The 41 trips sampled at-sea as part of this project almost triples the observer coverage in 2006, and extends coverage along the coast. Greater Observer coverage of the inshore lobster fishery is needed to assess by-catch and characterize the distribution of fishing effort. The data gathered here, as well as data from the FSRS recruitment trap survey, could be used to design a sampling strategy that would consider issues of catchability, replication throughout the fishery, and participation of many fishermen over a broad geographic area. A stratified design based on LFA, and depth, could also improve estimates of by-catch. Since the catch of commercial and non-commercial species in traps in close proximity may be very similar, increasing the number of trips sampled per LFA would improve the information gathered more than simply increasing the number of traps sampled per trip.

This project benefited from the support of fishermen and the collaboration between DFO and the FSRS. Working more closely with fishermen to help collect this type of data could be a cost-effective way to monitor changes in distribution and abundance, and collect data on species of interest, such as species of commercial value, conservation concern or understudied non-commercial species.

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TABLE 1. Length-weight relationships used to calculate Estimated Total Catch when individual weight data were missing. For each species, individual weight (W) is predicted from an equation based on length (L) or carapace length (CL) or width (CW) based on published work or the data collected during this study.

Species	Equation	Units	Source, Location
Lobster, *Homaus americanus*			
Male	$0.000566*CL^{3.078}$	mm to g	Campbell 1985 Bay of Fundy
Female	$0.001525*CL^{2.8612}$	mm to g	Campbell 1985 Bay of Fundy
Rock Crab, *Cancer irroratus*			
	$0.0004*CW^{2.82}$	mm to g	Krouse 1972, cited in Bigford 1979 Boothbay Harbour, Maine
Shorthorn Sculpin, *Myoxocephalus scorpius*			
	$0.0116*L^{2.991}$	cm to g	Data from present study, n=96, r^2=0.9599, p<0.001 Eastern Shore (Zone 2) only
Jonah Crab, *Cancer borealis*			
	$0.00006*CW^{3.217}$	mm to g	Data from present study, n=470, r^2=0.9017, p<0.001 Eastern Shore (Zone 2) only
Winter Flounder, *Pseudopleuronectes americanus*			
	L = 30 cm, W = 300 g	cm to g	Data from present study, Eastern Shore (Zone 2) only

TABLE 2. The total number of individuals caught and the estimated total and kept weight (kg) of fish and invertebrates caught in one longline set sampled at-sea. Fish lengths were only recorded for cod.

Species	Total N	Total weight, kg	Kept weight, kg	Min. length, cm	Max. length, cm
Chordata					
Gadus morhua	139	150	150	32	68
Brosme brosme	2	2.4	2.4		
Pollachius virens	1	2.5	2.5		
Myoxocephalus ctodecemspinosus	7	2			
Myoxocephalus scorpius	1	0.3			
Boltenia sps.	1	0.001			
Echinodermata					
Asterias rubens	7	0.5			
Strongylocentrotus sps.	5	0.005			
Ophiuroidea sps.	2	0.001			
Mollusca					
Buccinum sps.	15	0.3			
Pitar morrhuana	1	0.005			
Phaeophyta					
Phaeophyceae	5	0.005			
	186	158.017	154.9		

TABLE 3. At-sea catch analysis from lobster vessels was completed in 7 Lobster Fishing Areas (LFAs) along the Atlantic Coast of Nova Scotia. The start and end date of the 2006 lobster fisheries, the number of licenses, the number of traps per license, and the total landings are reported for each LFA. Also reported are the number of fishermen that participated and the number of traps (FSRS recruitment traps are excluded) sampled in each LFA. The proportion of the landings caught in the traps sampled (FSRS recruitment traps are excluded) was used a measure of sampling effort.

LFA	Start Date	End Date	Num. of licenses with landings	Trap limit	Landings of lobster, tonne	Num. of fishermen sampled	Num. of traps sampled	% of landings sampled
Zone 1, Cape Breton								
27	May 16	July 15	340	275	1848	11	900	0.018
29	May 1	June 30	48	250	658	2	125	0.019
30	May 20	July 20	14	250	187	1	148	0.054
Zone 2, Eastern Shore								
31A	April 30	June 30	67	250	672	1	168	0.011
31B	April 20	June 20	66	250	824	2	75	0.011
32	April 20	June 20	122	250	601	8	578	0.029
Zone 3, South Shore								
33	Nov 27, 2005	May 31	620	250	2515	9	543	0.006
Total			1277	250-275	7305	34	2537	0.014

TABLE 4. The number of traps of each trap configuration in each geographic zone.

Trap type	Zone 1, Cape Breton	Zone 2, Eastern Shore	Zone 3, South Shore	Grand Total
Wire	659	577	410	1646
Traditional Wooden Bow	307	226	132	665
Square wooden	203			203
Wood/wire combination		18	1	19
FSRS Lobster Recruitment Traps	11	3	2	16
Unknown	4			4
Grand Total	1184	824	545	2553

TABLE 5. The percent of commercial lobster traps (FSRS recruitment traps excluded) sampled with some of each bait type in Cape Breton (Zone 1), the Eastern Shore (Zone 2) and the South Shore (Zone 3). In some cases bait was supplemented with by-catch in the lobster traps or from waste from fish processing (e.g. cod frames).

Bait Code	Bait	Zone 1, Cape Breton	Zone 2, Eastern Shore	Zone 3, South Shore	Overall
125	Mackerel	72.2	82.1	66.3	74.1
132	Rock Crab	11.3	10.4	8.5	10.4
127	Herring	10.9	5.5	7.0	8.3
452	Flounder	5.4	8.0	11.6	7.6
134	Redfish	0	10.1	2.2	3.7
135	Sculpins	4.0	3.8	3.7	3.9
456	Capelin	7.4	0	0	3.4
451	Cunner	2.6	0	0.2	1.3
458	Smelt/Silversides	2.1	0	0	1.0
131	Gaspereau	0	2.3	0	0.7
457	Trout	1.4	0	0	0.6
117	Herring/Mackerel	0	0.5	1.3	0.4
453	Cod	0	0.2	1.7	0.4
450	Haddock	0	0	0.4	0.1
455	Silver Hake	0	0	0.2	0.0
129	Sea Raven	0.1	0	0.4	0.1
121	Non-specific	0	0	0.4	0.1

TABLE 6. Summary of the catch rate of lobster, non-lobster by-catch of fish and invertebrate, and rock crab in the different types of traps used by commercial fishermen along the Atlantic Coast of Nova Scotia.

Trap Type	Num. traps	Num. species	Total kg/trap	Lobster kg/trap	By-catch kg/trap	Rock crab kg/trap
Wire	1646	35	0.94	0.80	0.14	0.05
Traditional wooden bow	665	24	0.93	0.77	0.15	0.05
Square wooden	203	11	1.21	1.12	0.10	0.06
Wood/wire combination	19	10	0.79	0.41	0.38	0.13
FSRS Lobster Recruitment Traps	16	8	1.40	1.07	0.33	0.05
Grand Total	2549*	40	0.96	0.82	0.14	0.05

*4 traps were not described

TABLE 7. Number of traps sampled in the week of the fishery by zone.

Week	Zone 1, Cape Breton	Zone 2, Eastern Shore	Zone 3, South Shore	Grand Total
1	109			109
2	112	199		311
3		129	35	164
4	503	422		925
5	229	74	37	340
6	64		70	134
7	122			118
8	45			45
15			125	125
19			88	88
21			60	60
23			60	60
24			70	70
Grand Total	1184	824	545	2553

TABLE 8. Summary of species caught in commercial lobster traps (FSRS recruitment traps excluded) sampled at-sea. The total number caught, the number and percent of traps in which individuals were caught and the estimated total and kept weight (kg) and the minimum and maximum carapace length (fish length in cm, carapace length or width in mm) is reported by phyla and by species.

Order	Species	Total N	N traps	Per cent traps	Total weight, kg	Kept weight, kg	Min. width, mm	Max. width, mm	Min. length, cm	Max. length, cm
Arthropoda										
Decapoda	*Homarus americanus*	4467	1889	74.4	2064.83	1034.78	38	159		
	Cancer irroratus	1141	509	20.1	131.1	29.34	18	132		
	Cancer borealis	494	244	9.6	66.56	5.14	49	137		
	Paguridae	174	42	1.7	4.32	0	10	96		
	Hyas sps.	68	37	1.5	4.53	2.96	17	78		
	Carcinus maenas	68	11	0.4	3.1	0.06	45	70		
Echinodermata										
Echinoida	*Strongylocentrotus*	569	148	5.8	16.56	0.1	10	78		
Forcipulatida	*Asterias rubens*	311	111	4.4	5.62	0	6	288		
	Asterias sps.	16	12	0.5	0.35	0	28	149		
Mollusca										
Neogastropoda	*Buccinum undatum*	245	103	4.1	9.95	0	7	103		
	Buccinum sps.	38	21	0.8	1.12	0	24	75		
	Colus sps.	12	8	0.3	0.6	0	62	98		
	Littorinidae	70	35	1.4	0.3	0	13	33		
Chrodata										
Scorpaeniformes	*Myoxocephalus scorpius*	183	164	6.5	62.5	32.95			16	44
	Hemitripterus americanus	19	18	0.7	13.3	5.24			22	51
	Myoxocephalus octodecemspinosus	15	15	0.6	3.62	1.18			21	34
Gadiformes	*Gadus morhua*	22	20	0.8	19.65	0			31	58

TABLE 8. Continued.

Order	Species	Total N	N traps	Per cent traps	Total weight, kg	Kept weight, kg	Min. width, mm	Max. width, mm	Min. length, cm	Max. length, cm
Perciformes	*Tautogolabrus adspersus*	45	35	1.4	4.77	1.27			10	29
	Pholis gunnellus	6	6	0.2	0.08	0			13	15
Pleuronectiformes	*Pseudopleuronectes americanus*	15	15	0.6	3.92	0.39			21	36
Phaeophyta										
	Thallophyta C.	7	6	0.2	0.18	0				
	Fucus sps.	16	16	0.6	1.96	0			30	73
	Phaeophyceae	11	11	0.4	0.72	0			33	162

TABLE 9. Weight (kg) as a function of length for the most commonly caught (n > 20) by-catch species in the at-sea analysis of lobster catch. For fish, length is reported in cm, and for invertebrates length is reported in mm.

Species	Sex	Df	Min length	Max length	A	β	r^2	P
Arthropoda								
Cancer borealis	M	316	49	137	-10.066	3.2812	0.8936	<0.001
	F	161	54	121	-9.3177	3.1066	0.8726	<0.001
Cancer irroratus	M	918	24	132	-7.511	2.7049	0.7921	<0.001
	F	97	53	101	-7.3553	2.6603	0.7397	<0.001
Hyas	M	22	20	67	-5.2596	2.2724	0.5515	<0.001
Carcinus maenas	M	63	46	70	-8.6256	3.0468	0.6896	<0.001
Paguridae		79	10	96	-4.5184	1.9757	0.7471	<0.001
Mollusca								
Buccinum		36	24	75	-7.2891	2.6564	0.8209	<0.001
Buccinum undatum		241	7	103	-4.5938	2.0021	0.5881	<0.001
Littorinidae		63	13	33	-6.2069	2.3842	0.476	<0.001
Echinodermata								
Asterias rubens		273	30	288	-9.279	2.6546	0.7546	<0.001
Strongylocentrotus		465	10	78	-5.9351	2.5017	0.8127	<0.001
Chordata								
Gadus morhua		19	31	58	-5.1789	3.1449	0.8581	<0.001
Tautogolabrus adspersus		47	10	29	-4.5548	3.1027	0.9231	<0.001
Myoxocephalus scorpius		166	16	44	-4.2383	3.0192	0.7833	<0.001

TABLE 10. Pairwise tests for differences between geographic zones in the 2-way crossed ANOSIM of the Bray-Curtis Similarity Matrix of fourth root transformed average abundance of decapods per depth zone per trip. Zone 1, Cape Breton; Zone 2, Eastern Shore; and Zone 3, South Shore.

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥ Observed
Zone 1, Zone 2	0.56	0.1	Very large	999	0
Zone 3, Zone 1	0.784	0.1	Very large	999	0
Zone 3, Zone 2	-0.002	45.9	43439760	999	458
Overall	0.55	0.1	Very large	999	0

TABLE 11. Pairwise tests for differences between depth zones in the 2-way crossed ANOSIM of the Bray-Curtis Similarity Matrix of fourth root transformed average abundance of decapods per depth zone per trip. Depth Zone 1, z < 10 m; Depth Zone 2, 10m > z < 30m; Depth Zone 3, 30 m > z < 50 m; Depth Zone 4, z > 50 m.

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥ Observed
Depth Zone 1, Depth Zone 2	-0.021	75.5	Very large	999	754
Depth Zone 2, Depth Zone 3	0.611	2.9	35	35	1
Depth Zone 2, Depth Zone 4	0.76	2.9	35	35	1
Depth Zone 1, Depth Zone 3	0.607	1.7	120	120	2
Depth Zone 1, Depth Zone 4	0.735	0.6	330	330	2
Depth Zone 3, Depth Zone 4	0	45.7	35	35	16
Overall	0.035	12.4	Very large	999	123

TABLE 12. Estimation of total by-catch for the most commonly caught species in the lobster fisheries in LFAs 27, 29, 30, 31A, 31B, 32 and 33. The bycatch is extrapolated from the proportion of lobster landings observed in each LFA (FSRS recruitment traps are excluded) per LFA.

Order	Species	Total weight, tonne	Kept weight, tonne
Arthropoda			
Decapoda	*Homarus americanus*	14333.40	7305.00
	Cancer irroratus	890.50	222.81
	Cancer borealis	487.22	17.82
	Paguridae	59.89	0
	Hyas	74.15	52.05
	Carcinus maenas	10.75	0.21
Echinodermata			
Echinoida	*Strongylocentrotus*	214.82	1.76
Forcipulatida	*Asterias rubens*	45.08	0
	Asterias	4.74	0
Mollusca			
Neogastropoda	*Buccinum undatum*	147.98	0
	Buccinum	8.26	0
	Colus	10.55	0
	Littorinidae	2.10	0
Chordata			
Scorpaeniformes	*Myoxocephalus scorpius*	399.86	251.25
	Hemitripterus americanus	115.07	57.52
	Myoxocephalus octodecemspinosus	45.24	17.16
Gadiformes	*Gadus morhua*	145.85	0
Perciformes	*Tautogolabrus adspersus*	25.05	7.12
	Pholis gunnellus	0.33	0
Pleuronectiformes	*Pseudopleuronectes americanus*	24.14	3.58

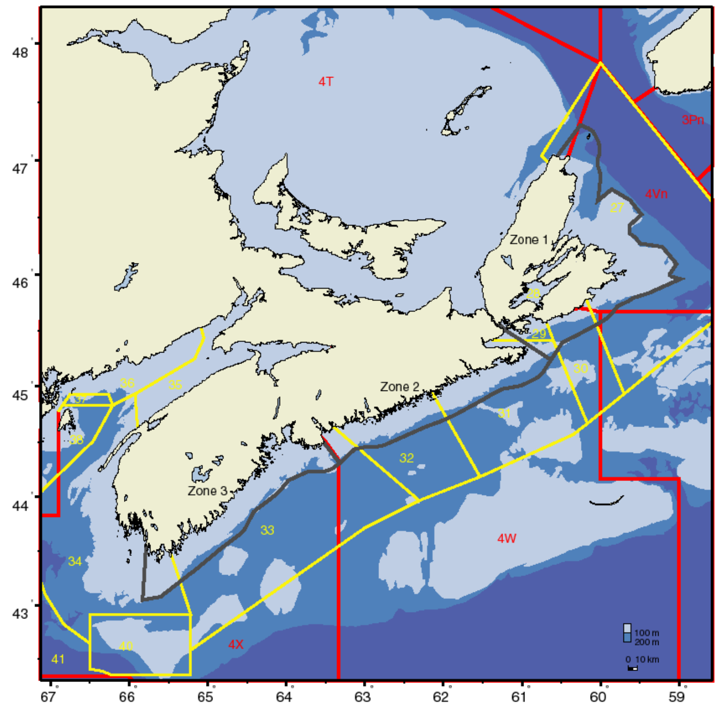

FIGURE 1. Bathymetric map of the DFO-FSRS Inshore Ecosystem Project and the Lobster Fishing Areas (LFAs) .The red lines indicate NAFO boundaries, the yellow lines demarcate the LFA boundaries and the boundary describing the Inshore Ecosystem Study area is in dark green. The three geographic zones are Zone 1 (Cape Breton), Zone 2 (Eastern Shore) and Zone 3 (South Shore).

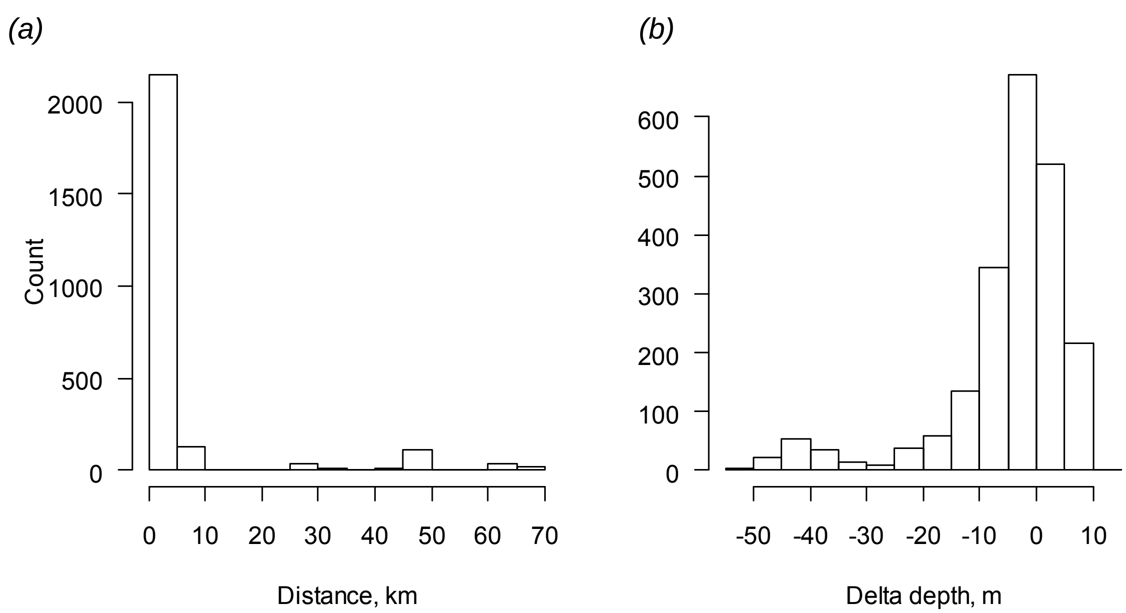

FIGURE 2. Histograms of the (a) the distance between the traps sampled at sea and the nearest temperature gauge and (b) the difference in depth (delta depth) between the nearest temperature gauge and the traps sampled.

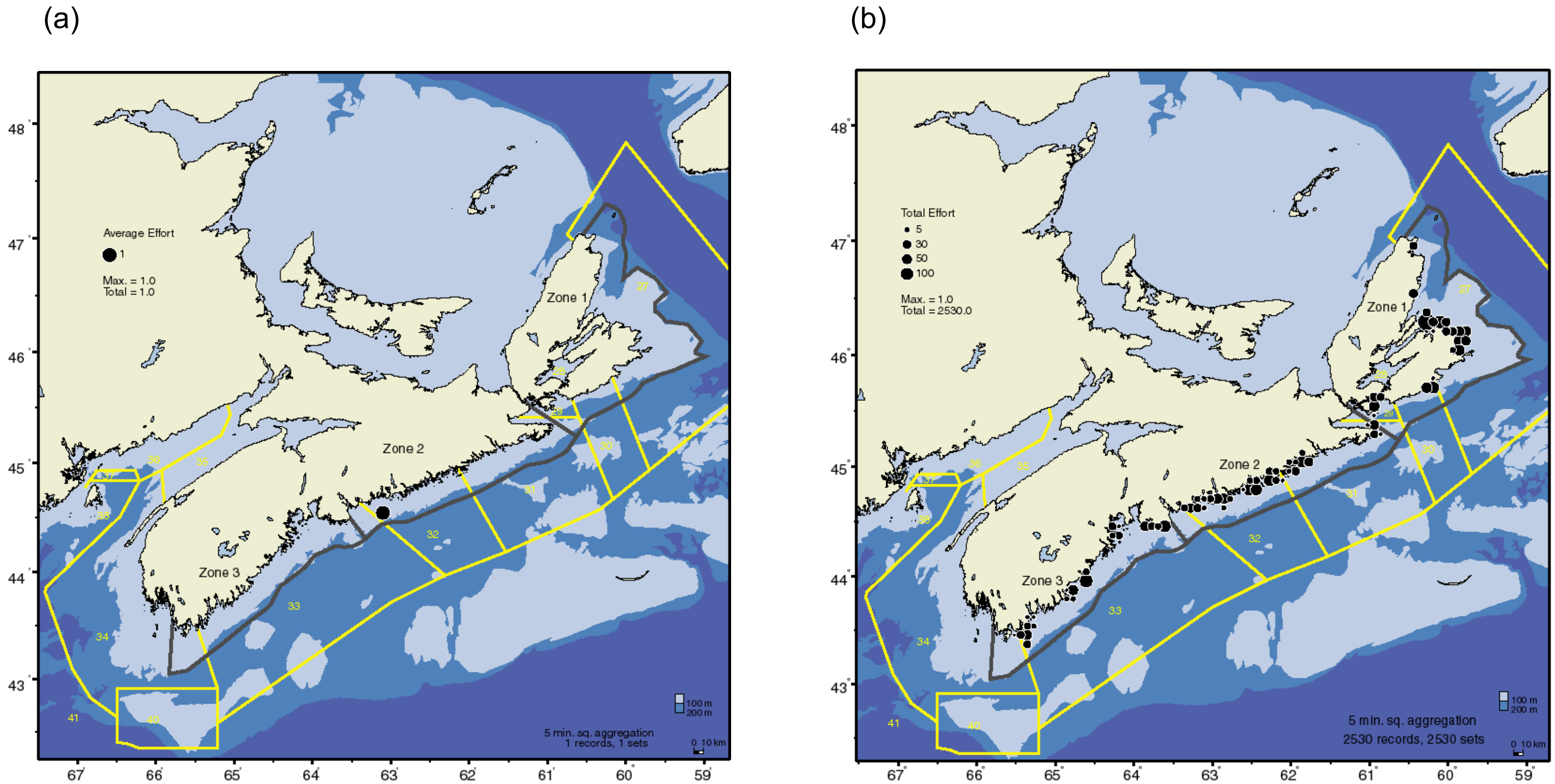

FIGURE 3. Map of the distribution of at-sea catch sampling effort for a) longline and b) lobster traps. The size of the circles indicates the number of traps sampled per 5 minute grid.

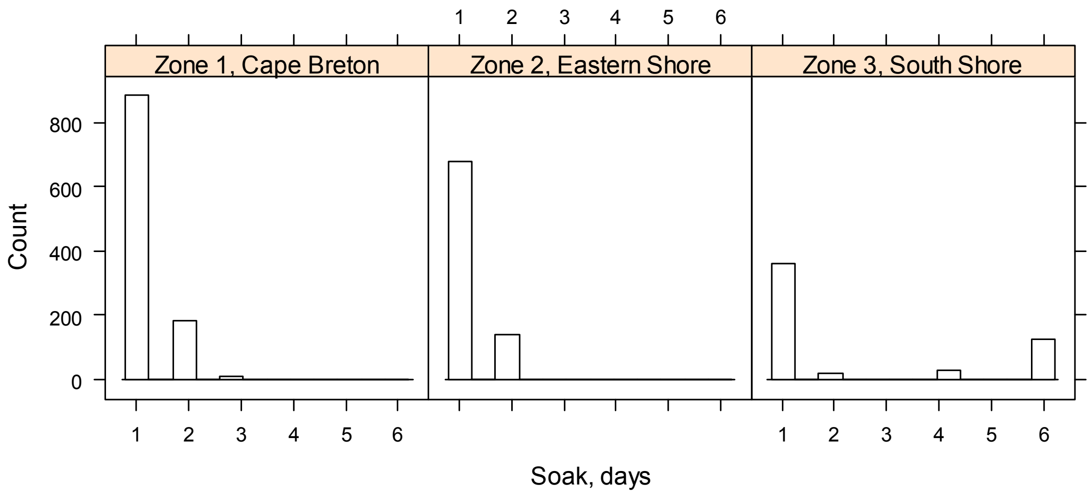

FIGURE 4. Histograms of soak days for traps sampled (n=2422) in Cape Breton (Zone 1), the Eastern Shore (Zone 2) and the South Shore (Zone 3).

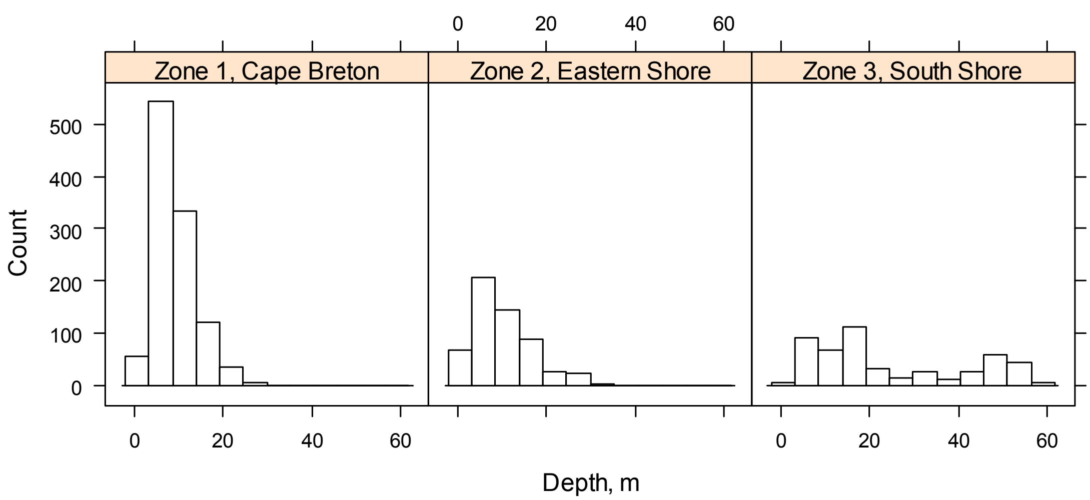

FIGURE 5. Histograms of depth of traps sampled (n=2139) in Cape Breton (Zone 1), the Eastern Shore (Zone 2) and the South Shore (Zone 3).

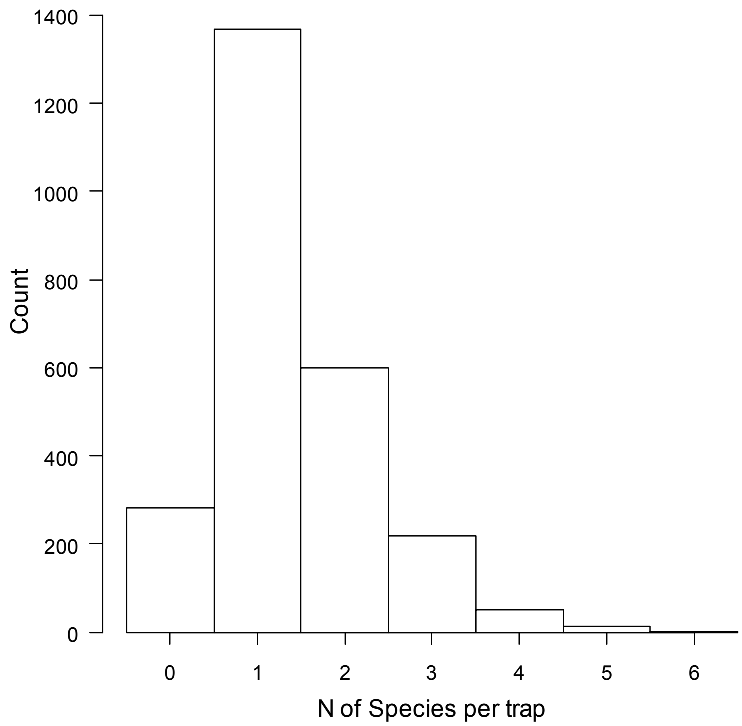

FIGURE 6. Histogram of the number of species caught per commercial lobster trap (FSRS recruitment traps excluded).

(a)

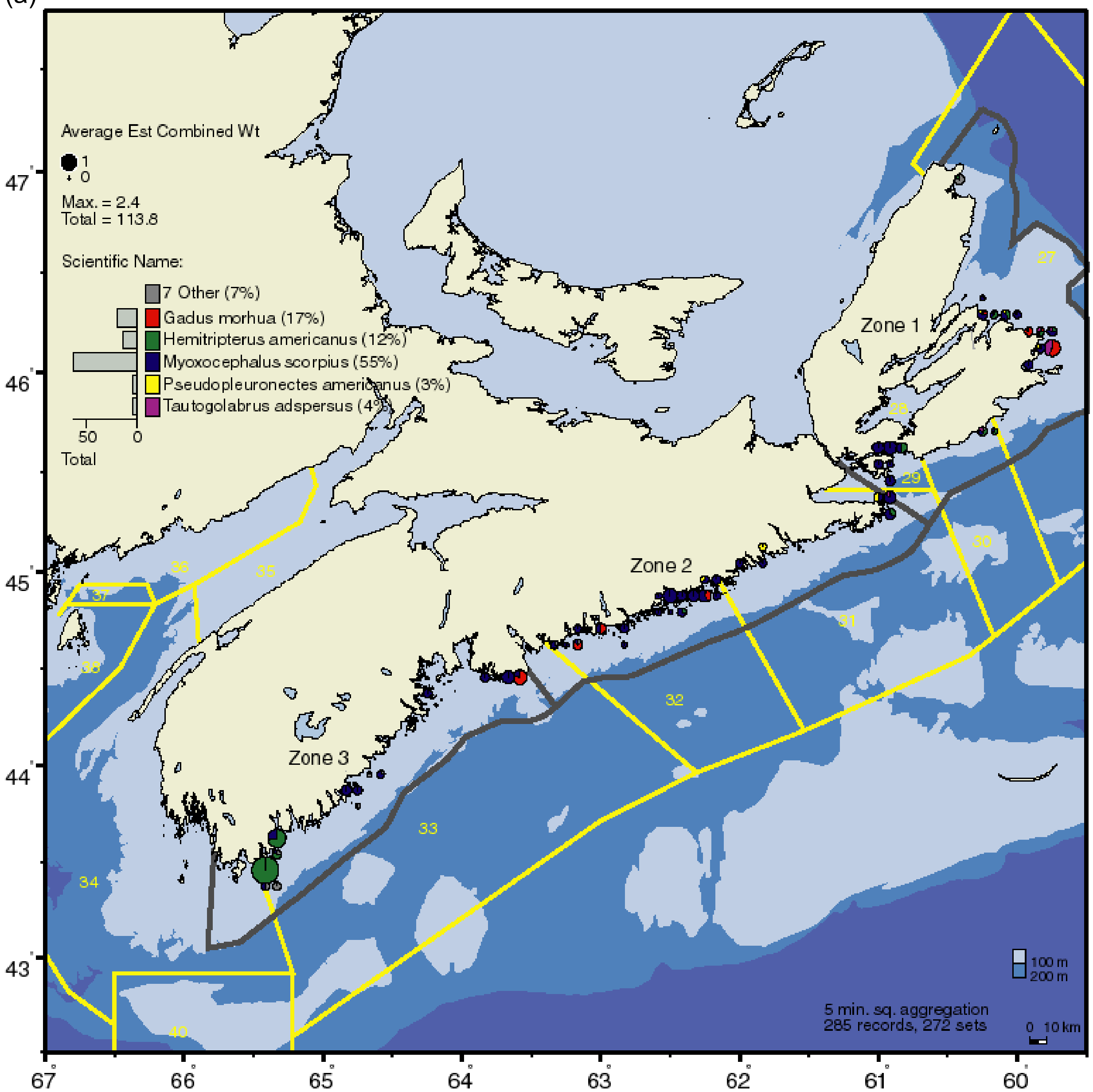

FIGURE 7. Maps of pie charts showing the composition by weight of the (a) decapods, (b) molluscs and echinoderms and (c) fish sampled at-sea during commercial lobster fishing on the Atlantic Coast of Nova Scotia.

(b)

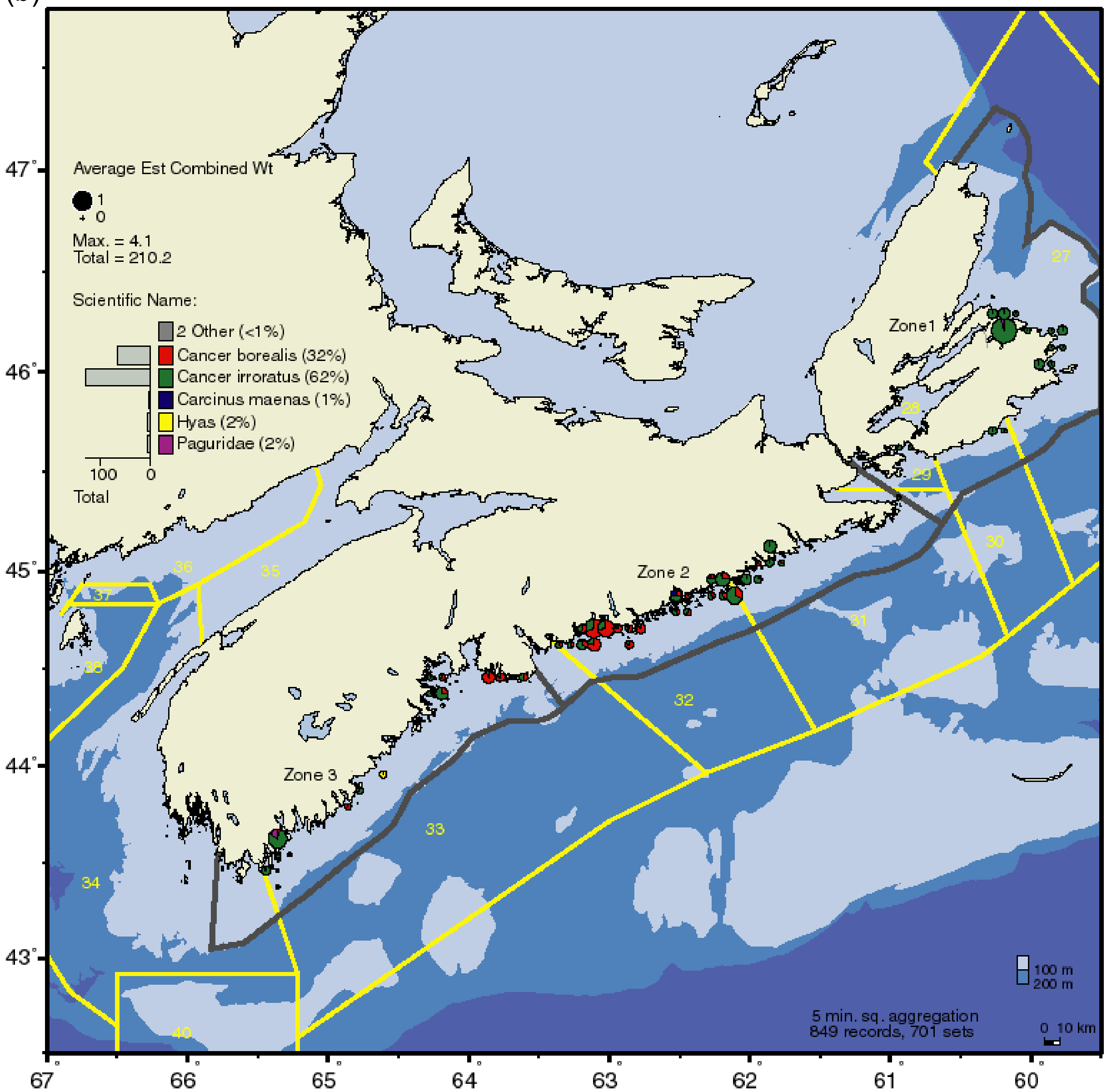

FIGURE 7. Continued.

(c)

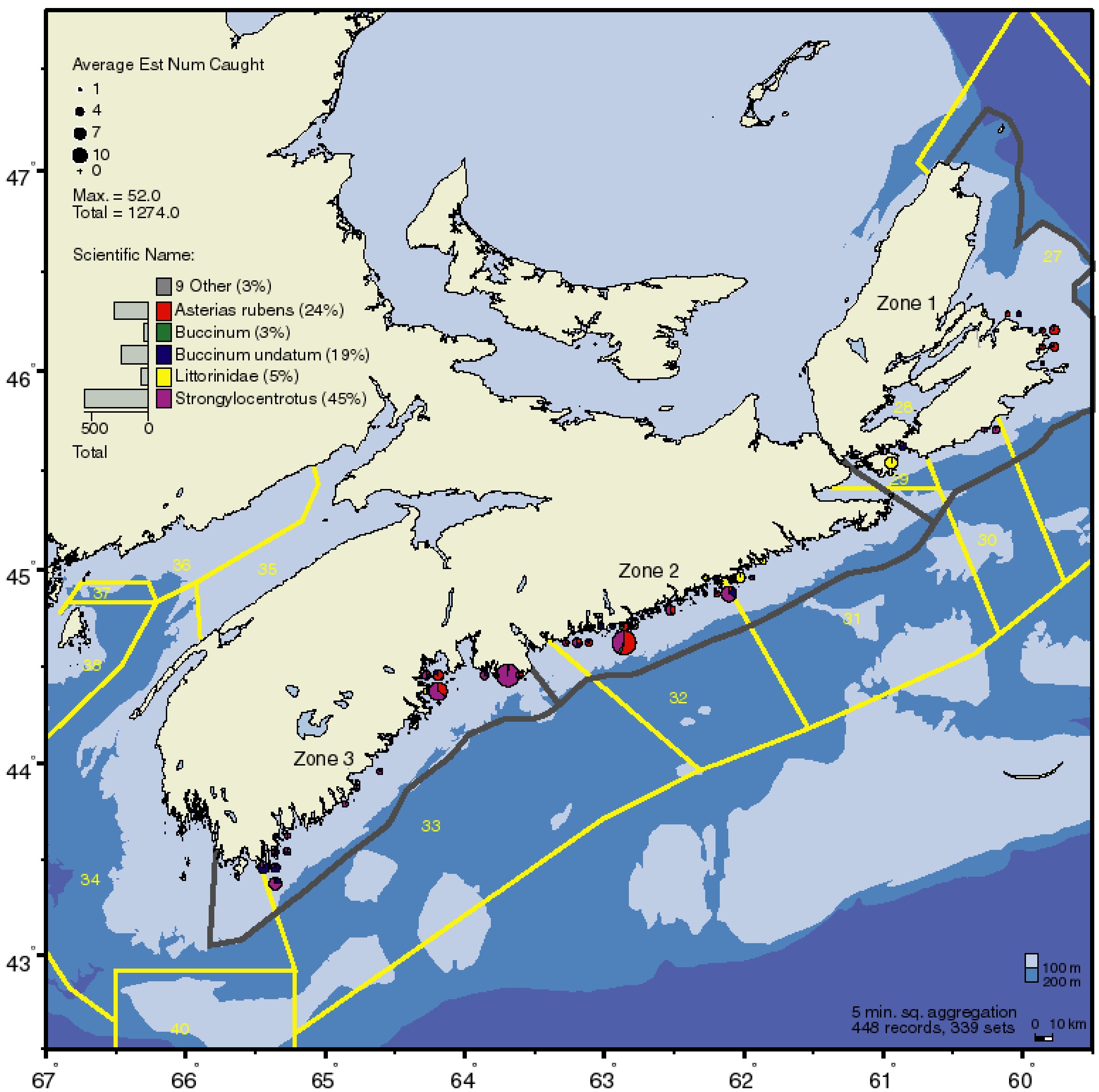

FIGURE 7. Continued.

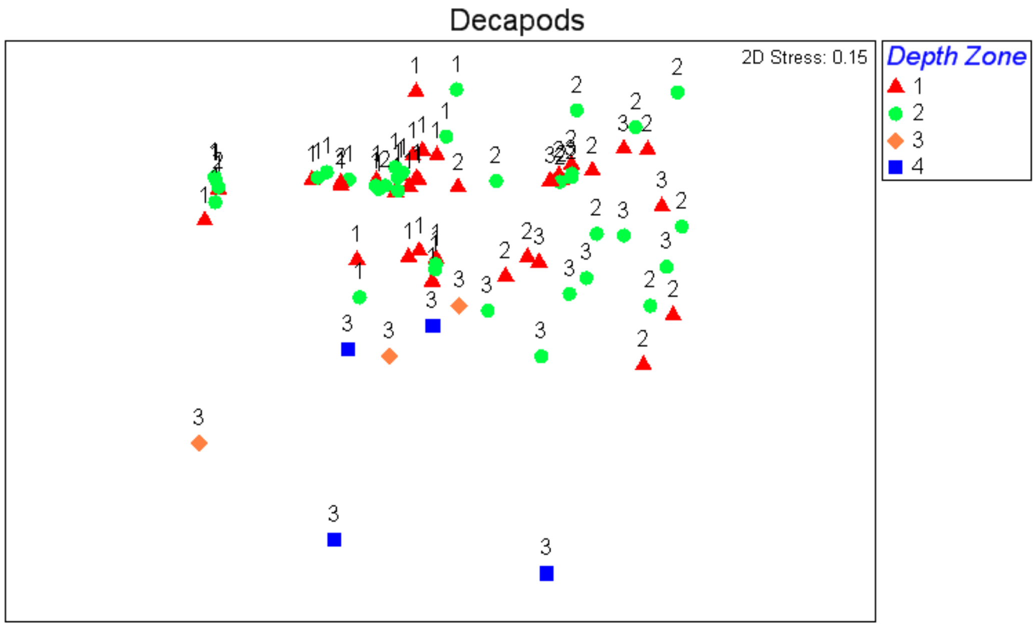

FIGURE 8. MDS plot of the Bray-Curtis similarity matrix of fourth root transformed decapod catch per depth zone per trip. The depth zones are coded by the symbol and color and the numeric labels indicate the geographic zones: Zone 1, Cape Breton (1), Zone 2, Eastern Shore (2), Zone 3, South Shore (3), Depth Zone 1, x <10m (red triangles), Depth Zone 2, 10m>x<30m (green circles), Depth Zone 3, 30m>x< 50m (orange diamonds), and Depth Zone 4, x>50m (blue square).

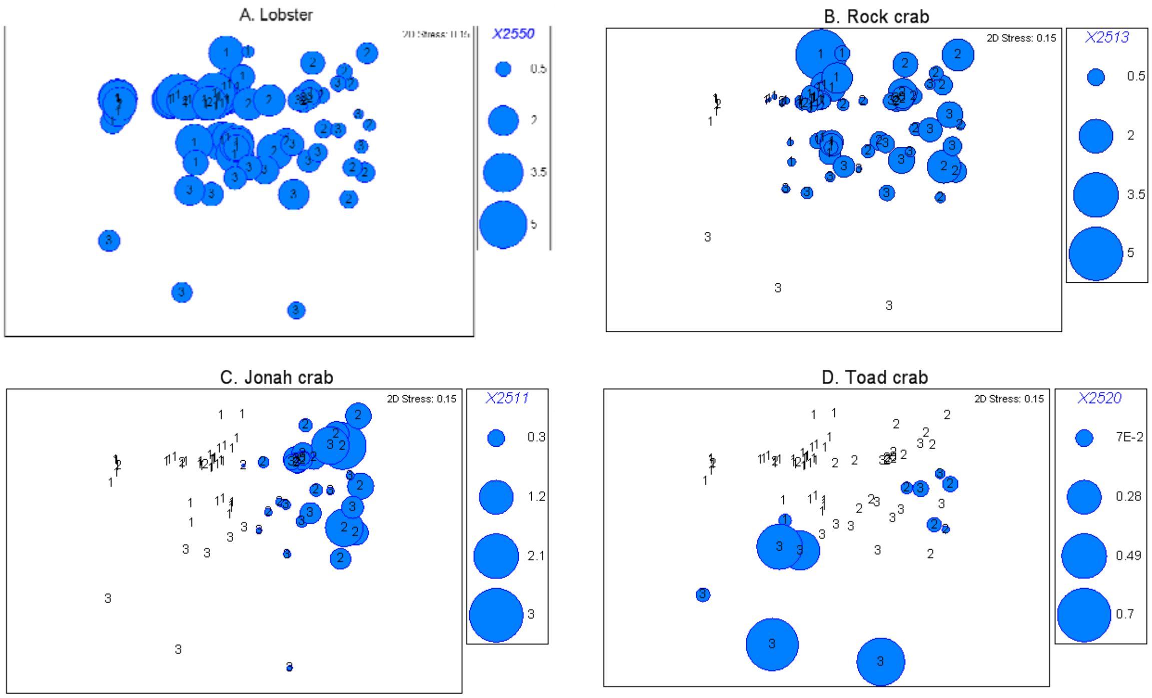

FIGURE 9. Bubble plots of A) lobster, B) rock crab, C) Jonah crab and D) Toad crab, unidentified, overlayed on the MDS plot of the Bray-Curstis similarity matrix of the fourth root transformed average decapod catch per depth zone per trip (Figure 8).

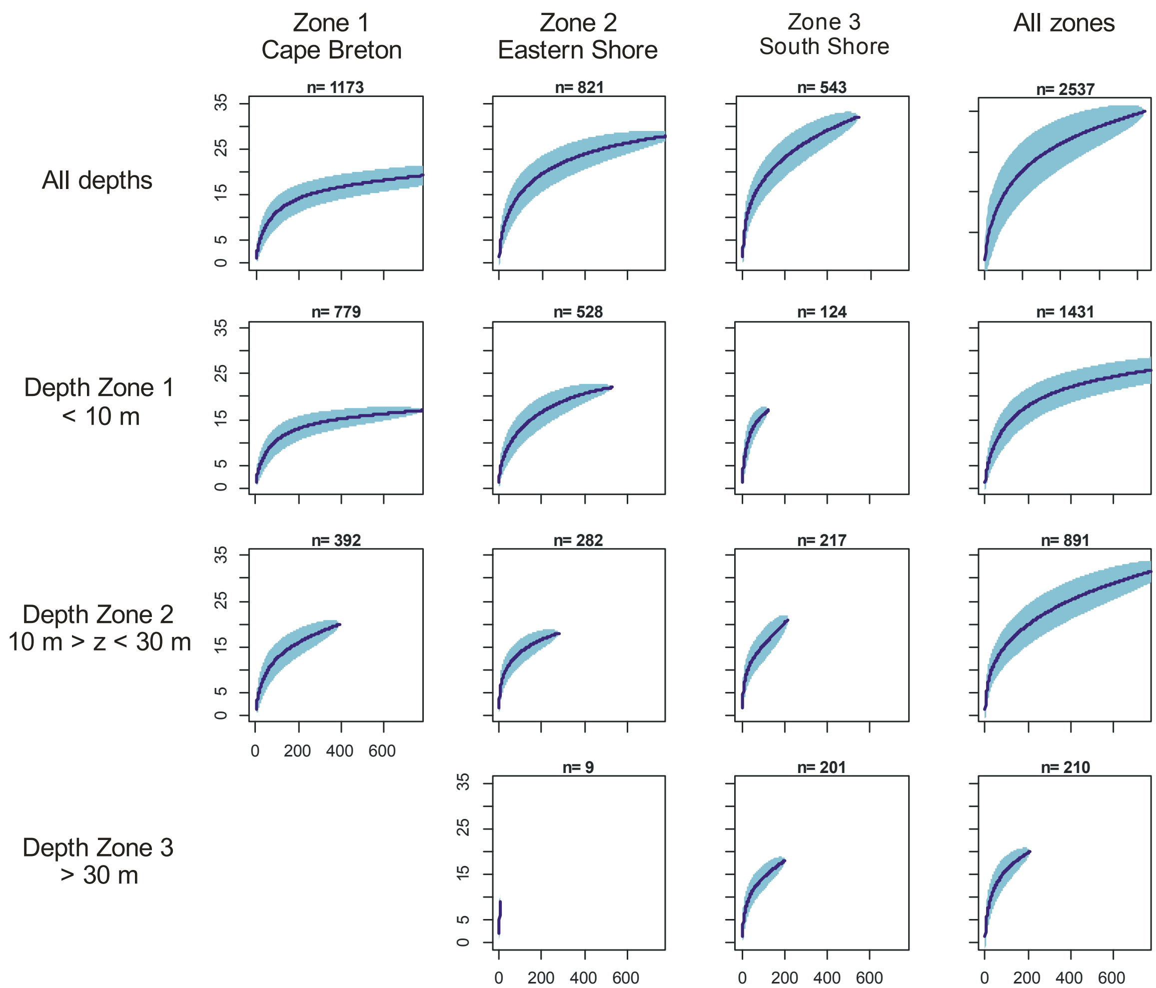

FIGURE 10. Species Accumulation Curves (SACs) in the three geographic zones broken down by depth zone, where n is the number of traps sampled at sea.

Appendix A. LFA 33 FSRS Recruitment Trap and CTS temperature on the days prior to at-sea sampling and location data for trips with traps sampled deeper than 30 m.

Trip	Date temp. data	Lat, deg.dec	Long, deg.dec	Depth, m	CTS Temp, °C	FSRS Temp, °C
EC06Z3-01	Jan 5, 2006	43.4486	-65.4253	22.1	4.1	
Jan 6, 2006		44.6824	-63.6137	1.8	1.92	
		44.4667	-63.5583	12	3.07	
		43.4667	-65.4150	27		4.05
EC06Z3-03	Mar 17, 2006	44.6824	-63.6137	1.8	2.71	
Mar 18, 2006		44.4667	-63.5583	12	1.74	
		44.6478	-63.5695	2	2.61	
		44.6478	-63.5695	2	2.66	
		44.3090	-64.2535	8		2.26
EC06Z3-04	Apr 10, 2006	44.6824	-63.6137	1.8	4.74	
Apr 11, 2006		44.4667	-63.5583	12	2.43	
		44.6478	-63.5695	2	3.85	
		44.6478	-63.5695	2	3.86	
		43.5483	-65.3333	14		2.90
EC06Z3-05	May 2, 2006	44.6824	-63.6137	1.8	5.97	
May 3, 2006		44.4667	-63.5583	12	4.26	
		44.6478	-63.5695	2	4.8	
		44.6478	-63.5695	2	4.77	
		43.6500	-65.1500	14		4.6

Appendix B. Description of the fishing effort sampled at-sea by trip. Several different types of bait were used: 117 herring / mackerel, 121 non-specific, 125 mackerel, 127 herring, 129 sea raven, 131 gaspereau, 132 rock crab, 134 redfish, 135 sculpins, 450 haddock, 451 cunner, 452 flounder, 453 cod, 455 silver hake, 456 capelin, 457 trout, 458 smelt.

	LFA	Date	Num. Traps Sampled	Bait	Soak d	Min. Depth m	Max. Depth m
Zone 1							
EC06Z1-01	27	May 16	44	125	1	3.6	13.1
EC06Z1-02	27	May 17	65	125	1	3.5	15
EC06Z1-03	27	May 25	63	125, 132	1	3	14
EC06Z1-04	27	May 26	48	125, 132, 135	1	6.9	24
EC06Z1-05	29	May 31	60	125, 127, 132, 135, 452	1	1.4	10.5
EC06Z1-06	29	Jun 2	65	127, 132, 135, 451, 457	1	1.5	13.7
EC06Z1-07	27	Jun 6	79	125, 127, 132, 135, 452	1, 3	1.6	11.3
EC06Z1-08	27	Jun 12	51	125, 129, 135	2	9.1	24.9
EC06Z1-09	27	Jun 16	33	125, 451, 456, 458	1, 3	6	26
EC06Z1-10	27	Jun 15	61	456	1	2	15.2
EC06Z1-11	27	Jun 20	90	125, 132	1	2.4	23.5
EC06Z1-12	27	Jun 22	72	125, 132, 135	1, 2	2.5	11.4
EC06Z1-13	27	Jun 23	67	125, 132, 135	1	3.4	14.1
EC06Z1-14	27	Jun 28	28	125	1	4.9	17.4
EC06Z1-15	27	Jun 30	36	125	1	2	8
EC06Z1-16	27	Jul 5	77	125, 132, 135, 451, 452	1	3.1	23.4
EC06Z1-17	27	Jul 7	45	125, 132, 135	2	3.7	18.3
EC06Z1-18	30	Jul 11	56	125, 127, 132, 451	1	3.2	12
EC06Z1-19	27	Jul 12	45	125, 135	2	9	25.6
EC06Z1-20	30	Jul 18	46	125, 132	1	6.6	19.8
EC06Z1-21	30	Jul 19	52	125, 132	1	2.8	12.1
Zone 2							
EC06Z2-05	32	May 8	59	125, 132, 134, 135	1	3.7	27.4
EC06Z2-07	32	May 18	50	125, 134, 135	2	5.5	32
EC06Z2-08	32	May 24	76	125, 131, 132	1, 3	3.7	24.3

Appendix B. Continued.

	LFA	Date	Num. Traps Sampled	Bait	Soak d	Min. Depth m	Max. Depth m
EC06Z2-09	32	May 25	74	125	1	4.6	32.9
EC06Z2-10	32	May 30	91	117, 125, 127, 134, 452	1	0.3	5.5
EC06Z2-11	32	Jun 2	108	125, 127, 134, 135, 452	1, 2	2.6	19.4
EC06Z2-12	32	Jun 6	70	125, 132, 134, 135, 452, 453	1	2	18.8
EC06Z2-13	32	Jun 12	53	125, 132, 135	1	1.8	27.4
EC06Z2-14	31B	Jun 14	119	125, 135, 452	1	1.8	27.4
EC06Z2-15	31B	Jun 17	49	125	1	13	13
EC06Z2-16	31A	Jun 22	75	125, 135, 452	2	-	-
Zone 3							
EC05Z9-02	33	Dec 13	35	125	1, 4	4.8	28.9
EC06Z3-01	33	Jan 6	37	125	1	-	-
EC06Z3-02	33	Jan 13	70	125	1	2.9	3.1
EC06Z3-03	33	Mar 18	125	125	1, 4	27.2	59.4
EC06Z3-04	33	Apr 11	34	125	1	5.4	55.8
EC06Z3-05	33	Apr 22	54	117, 121, 125, 132, 135	1	14.4	54
EC06Z9-03	33	Apr 25	60	125, 127, 132, 135, 450, 453, 455	1, 2	1.5	21
EC06Z9-04	33	May 5	60	125, 127, 135, 452, 453	1, 2	2.2	21.2
EC06Z9-06	33	May 15	70	125, 127, 129, 132, 134, 135, 450, 451, 452	1	3.5	34.6

Appendix C. Number of individuals caught in lobster traps in LFAs 27, 29, 30, 31A, 31B, 32 and 33.

Phylum Order	Scientific name	Common name	27	29	30	31A	31B	32	33
Annelida									
Aciculata	*Harmothoe*	HARMOTHOE SP.							1
Arthropoda									
Decapoda	*Cancer borealis*	JONAH CRAB					5	378	113
	Cancer irroratus	ATLANTIC ROCK CRAB	401	5	45	4	42	437	215
	Homarus americanus	AMERICAN LOBSTER	2015	376	398	230	413	554	527
	Chionoecetes opilio	SNOW CRAB (QUEEN)							
	Hyas	TOAD CRAB,UNIDENT.	1					7	60
	Hyas araneus	TOAD CRAB						3	1
	Paguridae	HERMIT CRABS	8	1			2	45	119
	Carcinus maenas	GREEN CRAB						68	
Chordata									
Gadiformes	*Macrozoarces americanus*	OCEAN POUT	5		1				
	Gadus morhua	COD(ATLANTIC)	7					10	5
Lophiiformes	*Lophius americanus*	MONKFISH,GOOSEFISH,ANGLER							1
Perciformes	*Tautogolabrus adspersus*	CUNNER	40		7	1		1	
	Pholis gunnellus	ROCK GUNNEL(EEL)	4		1			1	
(blank)	*Blennioidei s.o.*	BLENNIES,SHANNIES,GUNNELS			1				
Pleuronectiformes	*Pseudopleuronectes americanus*	WINTER FLOUNDER	10			1	2	2	
Scorpaeniformes	*Myoxocephalus*	SCULPIN						1	
	Myoxocephalus octodecemspinosus	LONGHORN SCULPIN	1					3	11

Appendix C. Continued

Phylum Order	Scientific name	Common name	27	29	30	31A	31B	32	33
	Myoxocephalus scorpius	SHORTHORN SCULPIN	49	12	4	6	10	84	20
	Cyclopterus lumpus	LUMPFISH						1	
	Eumicrotremus spinosus	ATLANTIC SPINY LUMPSUCKER							1
	Hemitripterus americanus	SEA RAVEN	12	1	3	1		1	3
Cnidaria									
(blank)	*Hydrozoa*	HYDROZOA C.					2		
Semaeostomeae	*Pelagia noctiluca*	JELLYFISH					1		
Echinodermata									
Forcipulatida	*Asterias*	ASTERIAS SP.				1		10	5
	Asterias rubens	PURPLE STARFISH	85					149	77
Spinulosida	*Henricia sanguinolenta*	BLOOD STAR							4
Clypeasteroida	*Clypeasteroida*	SAND DOLLARS							1
Echinoida	*Strongylocentrotus*	SEA URCHINS	17	1	50		3	132	366
(blank)	*Ophiuroidea*	BRITTLE STAR							1
Mollusca									
Mytiloida	*Mytilidae*	MUSSELS (NS)	1						
Archaeogastropoda	*Archaeogastropoda*	LIMPET (NS)							3
Neogastropoda	*Buccinum*	WHELKS						25	13
	Buccinum undatum	WAVE WHELK,COMMON EDIBLE	9	5	4		2	42	183
	Colus	SPINDLE SHELL							12
	Neptunea lyrata	NEW ENGLAND NEPTUNE							1

Appendix C. Continued

Phylum Order	Scientific name	Common name	27	29	30	31A	31B	32	33
	NASSARIIDAE OR THAISIDAE F.	DOG WHELKS	1						
Neotaenioglossa	*Littorinidae*	PERIWINKLES	28	7			11	17	7
	Euspira heros	NORTHERN MOONSNAIL	4						1
Phaeophyta									
Fucales	*Fucus*	BROWN ROCKWEED	●	●			●	●	●
(blank)	*Phaeophyceae*	BROWN SEAWEEDS					●		●
	THALLOPHYTA C.	SEAWEED,(ALGAE),KELP					●		●
Porifera									
(blank)	*Porifera*	SPONGES							●
Rhodophyta									
(blank)	*Rhodophyceae*	RED SEAWEEDS							●