Patterns of Fishing Gear in Areas of the Bay of Fundy and Southwest Scotian Shelf Frequented by North Atlantic Right Whales

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by

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TABLE OF CONTENTS

ABSTRACT

Johnston, T.L., Smedbol, R.K., Serdynska, A., Vanderlaan, A., Helcl, N., Harris, L., and Taggart, C.T. 2007. Patterns of fishing gear in areas of the Fay of Fundy and southwest Scotian Shelf frequented by North Atlantic right whales. Can. Tech. Rep. Fish. Aquat. Sci. 2745: v + 52 p.

North Atlantic right whales (*Eubalaena glacialis*) are among the most critically endangered cetacean species in the world. Despite having protected status, both internationally and in Canadian waters, the right whale population that frequents Canadian waters remains at low abundance, with an estimated population of around 325 individuals (EC 2006). It has been estimated that at least thirty percent of right whale deaths result from their interaction with human activities, and entanglement in fishing gear is a significant cause for known injury and mortality (Knowlton and Kraus 2001).

This report has identified the different gear types and fisheries that right whales encounter in Scotia-Fundy region, as well as the potential they pose for entanglement. Commercial landings data for the time series between 1999 and 2005 inclusive were used to assess the spatial and temporal distribution of fishing activity. These fishery distributions were compared to the patterns of right whale aggregation in Scotia-Fundy waters in order to estimate the potential for right whale/gear interaction among the different gear types/fisheries over time and space.

Of all the gears that right whales encounter in their summer habitat, the groundfish gillnet, groundfish hook and line, and crab trap fisheries pose the greatest potential for entanglement. These gear types are relatively more likely to lead to entanglement because (1) these are the most active fisheries in Scotia-Fundy during the period of right whale aggregation, and (2) the design of the gears and their methods of deployment lend themselves to possible entanglements.

The results of this study may be used to advise industry and management on actions that would minimize the risk of entanglement to right whales, while correspondingly minimizing any disruption of the commercial fisheries in the Scotia-Fundy region.

RÈSUMÈ

Johnston, T.L., Smedbol, R.K., Serdynska, A., Vanderlaan, A., Helcl, N., Harris, L., and Taggart, C.T. 2007. Patterns of fishing gear in areas of the Fay of Fundy and southwest Scotian Shelf frequented by North Atlantic right whales. Can. Tech. Rep. Fish. Aquat. Sci. 2745: v + 52 p.

La baleine noire de l'Atlantique Nord (*Eubalaena glacialis*) compte parmi les espèces de cétacés les plus menacées de disparition au monde. En dépit de son statut d'espèce protégée, autant dans les eaux internationales que dans les eaux canadiennes, la population de baleines noires qui fréquente les eaux canadiennes demeure très clairsemée. Elle est évaluée à environ 325 individus (EC 2006). On estime qu'au moins trente pour cent des mortalités de baleines noires sont dues à leurs interactions avec des activités humaines. Les engins de pêche notamment blessent ou tuent un nombre élevé de baleines noires qui s'y empêtrent (Knowlton et Kraus, 2001).

Les auteurs du présent rapport ont identifié les divers types d'engins et de pêches avec lesquels les baleines noires interagissent dans le secteur de Scotia-Fundy, ainsi que les risques d'empêtrement connexes. On a utilisé les données sur les débarquements de la pêche commerciale provenant de l'analyse chronologique des années 1999 à 2005 inclusivement pour évaluer la répartition spatiale et temporelle de l'activité halieutique. Ensuite, on a comparé ces mouvements halieutiques avec les habitudes de rassemblement des baleines noires dans les eaux de Scotia-Fundy afin d'évaluer les risques d'interaction spatiale et temporelle entre ce cétacé et les divers types d'engins pour chaque pêche exploitée.

De tous les engins de pêche qui se retrouvent sur le chemin de la baleine noire dans son habitat estival, ce sont le filet maillant et la ligne avec hameçons utilisés pour la pêche du poisson de fond ainsi que les casiers de crabe qui posent les plus graves risques d'empêtrement. Il y a deux raisons à cela : premièrement, il s'agit des pêches les plus actives du secteur de Scotia-Fundy durant la période de concentration des baleines noires; deuxièmement, la conception de ces engins et la façon de les installer dans la zone en question augmentent les risques d'empêtrement.

Les résultats de cette étude pourraient être utilisés pour présenter des conseils à l'industrie halieutique et aux gestionnaires des pêches quant aux mesures à prendre pour diminuer dans la mesure du possible les risques d'empêtrement des baleines noires de même que les risques de perturbation des pêches commerciales dans le secteur Scotia-Fundy.

INTRODUCTION

North Atlantic right whales (*Eubalaena glacialis*) are among the most critically endangered cetaceans in the world, with an estimated population of fewer than 325 individuals (COSEWIC 2004). The species is classified as endangered on the IUCN (World Conservation Union) Red List of Threatened Animals and has been protected under the International Convention for the Regulation of Whaling (International Whaling Commission) since 1949. In Canada, the western North Atlantic right whale has been listed as Endangered under the federal Species at Risk Act since the Act was passed into law in 2003, and is also protected under the Marine Mammal Regulations of the Fisheries Act (Environment Canada 2006). In spite of their protected status, right whale abundance has not rebounded, for reasons that remain unclear (IWC 2001). It has been estimated, however, that at least 30% of right whale deaths are caused by their interaction with human activities, such as collisions with ships and entanglement in fishing gear (Knowlton and Kraus 2001).

Entanglement in fishing gear is a leading cause for known injury and mortality in the North Atlantic right whale population (Knowlton and Kraus 2001; Johnson et al. 2005). More than 60% of right whales bear scars from entanglements (Knowlton et al. 2005). Gear entanglement debilitates the animal, and severe cases can result in death from drowning, infection, exhaustion, vulnerability to further entanglement, increased susceptibility to ship strike, or starvation (COSEWIC 2004).

Each year, from June through October as many as two-thirds of the North Atlantic right whale population migrate into Canadian waters and take up residence in the southwestern Scotian Shelf and the Bay of Fundy (IWC 2001). This region of Canadian waters also supports substantial commercial fisheries for a variety of vertebrate and invertebrate species. As a result, right whales may encounter several types of fishing gear during their seasonal habitation of Scotia-Fundy waters. The demonstrated susceptibility of right whales to entanglement generates a need for evaluation of the degree of interaction that may occur between right whales and the different types of fishing gear used in the region. Some gears pose a greater threat to right whales than others, and the degree of interaction may vary due to design or deployment of the gear, or to spatial or seasonal distribution of fishing effort.

This report provides a summary of spatial patterns exhibited by each major gear type. Gear types that pose the greatest entanglement risk have been identified, along with the fisheries in which these gears are used. Commercial fishing effort data for the period of 1999-2005, inclusive, were selected for analysis, with the purpose of providing a quantitative description of the spatial and temporal distribution of fishing activity in the Scotia-Fundy region that may be of relevance to entanglement. Limitations of the available fisheries data were also revealed, and discussed in the context of this analysis and the degree of confidence in its results. The geo-referenced patterns of fishing effort provided in this report will be used in future analyses to determine the potential spatio-temporal overlap of right whales and fishing gear in the Bay of Fundy and along the Southwest Scotian Shelf, and quantify the relative risk of right whale/gear interaction among the different gear types/fisheries over time and space. The results of this study may be used to advise industry and management on actions that would minimize the risk

of entanglement to right whales, while correspondingly minimizing any disruption of the commercial fisheries in the Scotia-Fundy region.

METHODS

SELECTION OF FISHERIES DATA

The period of 1999-2005, inclusive, was selected for analysis in this paper. Geo-referenced fishery effort data for the Bay of Fundy and southwest Scotian Shelf were extracted from databases housed by Fisheries and Oceans Canada (DFO), Maritimes Region. Two databases contained data for the period in question; the Zonal Interface File Format (ZIFF) database for 1999-2001, and the MARine FISh (MARFIS) database for 2002-05. Both databases were queried for a list of the distinct gear types used in the study area (which included sections of North Atlantic Fishery Organization (NAFO) divisions 4X, 5Y, 5Ze), along with the species caught by each gear type. Gear types could be further subdivided into "fisheries" (fishery and fleet sectors), based on the different species types that were caught by the gear (i.e. groundfish, large pelagics, crustaceans, etc.). Consultation with DFO fisheries experts also provided information on the species typically caught in each fishery. The target species of each fishery are listed in Table 1.

All substantial fisheries known to be prosecuted in the study area were evaluated for their potential for entangling a right whale. Each identified fishery was rated arbitrarily according to their perceived potential risk for entanglement, based on characteristics of the gear used in each fishery (e.g. number and length of vertical lines deployed, breadth of the gear, deployment depth, the existence of nets or hooks, etc.), the method of deployment, the area where fishing effort occurred, and the season. Information pertaining to gear specifications and use were provided by DFO fisheries experts. The fisheries/gears that were considered as medium to high relative risk, and thus selected for analysis in this paper, were: (1) groundfish fixed gillnet, (2) herring fixed gillnet, (3) groundfish fixed longline, (4) pelagic longline, (5) hagfish trap, (6) lobster pot, and (7) crab pot. These fisheries are discussed below. All other fisheries considered to constitute low risk for entanglement are discussed in Appendix A, and were excluded from further analysis. Note that this study does not take into account gear which is not recovered from the water or is lost.

DATA EXTRACTION

Commercial fishing data were extracted from the ZIFF (1999-2001) and MARFIS (2002-2005) databases for fisheries that were identified as medium to high risk for entanglement. The two databases differ somewhat in structure and organization, resulting in a need for construction of separate queries. In ZIFF, each fishing set contains a unique combination of log code ID number, date fished, and coordinates. In MARFIS, each set is assigned a unique log code ID number upon entry into the database. A fishing set is designated to a given fishery based on whether the catch contains more than 45.36 kg (100 lbs) of any species targeted by that fishery. The lobster and crab fisheries are the

exception, where the designation is based on which species had the highest proportion of catch.

Fishing sets were extracted for the period June to October inclusive, and within a study area bounded by 64^{o} 30' and 68^{o} 00' W longitude, and 40^{o} 00' and 45^{o} 12' N latitude. (This study area lies within NAFO areas 4X, 5Y, 5ZE.) This temporal and spatial extent of the study area was selected to encompass the main temporal and spatial seasonal distribution of right whales in the Scotia-Fundy region. Data extracted for each set included the date fished, the coordinates, soak time (duration of set deployment), the number of gear units deployed (i.e. hooks, nets, traps), the types of species caught and their total weight.

Only geo-referenced fishing sets were extracted for the analysis. To date, reporting of coordinates for individual fishing sets is not mandatory for all fisheries; however, the NAFO statistical area is generally recorded. Since the study area lies within NAFO areas 4X, 5Y, 5ZE, a count of sets with and without corresponding coordinates in these statistical areas allowed estimation of both the proportion of geo-referenced sets within the defined study area, and the number of sets that were excluded from the analysis for right whale interactions of each relevant fishery (Table 2). In general, the majority of set records for each fishery had included set coordinates.

RANKING AND EDITING OF FISHERY DATA

For all fisheries and gear, set records with identical log code IDs but with different h or gear unit values were assumed to be duplicates and thus reflect a data entry error. In these cases only the maximum value for h or gear units was assigned to the record, and the duplicate was deleted. A substantial portion of geo-referenced records contained either (1) a zero value for h deployed and a nonzero number of gear units, (2) a nonzero value for h deployed and a zero value for the number of gear units, or (3) both fields contained zero values. In all these cases these records the zero values were assumed to represent missing values rather than actual zeroes and these records were omitted from the subsequent analyses. The number of sets used is listed in Table 2.

Gillnet Fishing

Fixed gillnets: description The gill net is a large wall of netting that fish become entangled in as they attempt to swim through the net webbing (Sainsbury 1986). Individual nets ("panels") are strung together, and are anchored to the seabed at each end to keep the gear stationary (Sainsbury 1986). Surface buoys also float on each end, to indicate the location and ownership of the gear, and to provide a line from which the gear can be raised to the surface. Strings may be set at a variety of depths, depending on the target species, using buoy lines at intervals along the string to maintain depth (Sainsbury 1986). Ideally, gear is set in parallel with currents in order for the gear to stay taut and to avoid snags (S. Smith, DFO, St. Andrews, pers. comm.).

In this report, all fisheries described in this section that deploy fixed gillnets (see below) are considered to present a relatively HIGH risk for right whale entanglement, due to the areas fished, type of gear used, and method of deployment.

Groundfish Gillnet: Primary species sought and captured by fixed gillnets in Scotia-Fundy region include cod, pollock, haddock, and white hake (D. Clark, DFO St. Andrews, pers. comm.). A spring cod fishery (March/April) is located around Tusket Basin. A summer fishery between Jordan Basin and Crowell Basin catches cod, haddock and pollock. From July to September, there is a cod/pollock fishery south of Grand Manan, and a cod/pollock fishery located between northern Grand Manan and the Wolves Islands. A pollock fishery did exist on Roseway Basin approximately ten years ago, but has since ceased (Stone et al. 2006).

Typically, four to five strings of netting are deployed per groundfish trip, with each string holding three to four panels end-to-end (D. Clark, DFO St. Andrews, pers. comm.). Each panel is approximately 100 m long and 3 m wide, with minimal spacing between each panel (Trippel et al. 1996). Therefore, a gillnet string is approximately 300 to 400 m long (Trippel et al. 1996). A lead line and buoy line are attached to the end of each string, fixing the strings in place near the sea floor, and buoy lines are attached along the net to maintain the desired depth. The gear is set overnight, and allowed to soak for approximately 12 h (D. Clark, DFO St. Andrews, pers. comm.).

The licenses held by most fishers allow the use of a maximum of 40 nets. As a result, any records that list a number of nets fished greater than 40 were considered to be erroneous and were adjusted to a null value. Anecdotal reports suggest fishers may record the number of nets permitted (40) rather than the number of nets that were actually deployed, or individual fishers may record either the number of strings or number of nets deployed. These differences in data logging can cause discrepancies in fishing effort recorded in the database. As a result, in an unknown number of sets, the number of nets fished may be biased upward. In 2005, the number of nets fished was not entered in the database, and subsequently this field is no longer used.

The length of soak times recorded in the database exhibited substantial variation, and were adjusted to represent known fishing practices. In discussions with DFO science staff and fishery representatives, it was determined that in general, groundfish gillnet gear is set on one day and retrieved on the following day. Longer soak times are usually avoided by fishers as they often lead to lost or degraded catch. As a result of this general fishing practice, deployments of 24 h duration were assumed to be the upper limit of standard practice. Set records that contained soak times differing from this standard practice were adjusted as follows. If a database set record contained a soak time of between 1 h and 24 h, the recorded soak time was retained as this duration falls within the standard period. Reported soak times of less than 1 h were considered to be erroneous, and soak time was set to a null value (no data, rather than a value of zero). Soak times greater than 24 h were also set to null values. It should be noted that a substantial number of set records contained soak time entries of 48, 72, and 96 h. While sets of such length may occur, the consensus among those knowledgeable of the fishery is that such entries likely indicate the number of net strings multiplied by soak times of 12 or 24 h. For instance, three strings deployed for 24 h provides an (erroneous) soak time of 72 h. Given that it was impossible to determine correct entries of soak times greater than 24 h from incorrect entries, all soak times greater than 24 h were adjusted to a null value.

The data quality and reporting rate of particular fields with the set data has changed through the time series. As an example, in 2004 and 2005, over 1000 total h of fishing was recorded, but for the years 1999-2003 very few records contain information on soak time. This is consistent in amendments to fishery reporting requirements, wherein recording the number of h fished was changed from optional to mandatory.

Herring Gillnet: The fixed gillnet herring fishery is a relatively small fishery, and very few sets occur in the study area (Power et al. 2005). Herring are captured by fixed gillnet gear along the eastern shore of Nova Scotia, predominantly east of Halifax (Power et al. 2005). The gear is deployed in a manner similar to that seen in groundfish gillnet fisheries, but the depth of deployment ranges from the surface to the sea floor, depending on the location of the herring school. A lead line and buoy line are attached to the end of each string, fixing the strings in place near the sea floor, and buoy lines are attached along the net to maintain the desired depth. Each string holds from 1-10 panels end-to-end. The gear is allowed to soak for 1-4 h.

Soak time in this fishery is relatively short, usually ranging from 2-24 h. As a result, in sets where soak time was recorded as greater than 24 h, the soak time was replaced with a null value. In 2005, the number of nets deployed per set was not recorded, but was available for all other years. The accuracy of this field was considered suspect, and the field is no longer recorded (D. Clark, DFO St. Andrews, pers. comm.).

Hook and Line Fishing

Fixed longline fishing: description In longline fishing, a length of line on which a series of baited hooks is attached, is set out and spread along the ocean (Sainsbury 1986). The main line is typically several kilometres long (Sainsbury 1986). Anchors, or lead lines, are placed at each end to keep the gear stationary. Surface buoys are attached at each end, to indicate the location and ownership of the gear. A mid-water set requires buoy lines at intervals along the line to maintain depth. Gear is set in parallel with tidal currents, in order for the gear to remain taut and to avoid snags (S. Smith, DFO St. Andrews, pers. comm.).

The groundfish and midwater longline fisheries (described below) are considered a HIGH risk for right whale entanglement, due to the timing and location of the fishery.

Groundfish hook and line: Longline fishing for groundfish is undertaken mainly in offshore areas and along the Atlantic coast of Nova Scotia. From July to October a relatively large fishery occurs between Georges Bank and Brown's Bank, where cod, haddock and pollock are sought (Clark and Perley 2006; DFO 2006; Stone et al. 2006). There is also an inshore fishery along the eastern coast of Nova Scotia and around (not within) Roseway Basin, where cod, haddock, and pollock are caught. A summer fishery occurs between Brier Island and Lurcher Shoals in search of halibut, white hake, cod and haddock. Little effort occurs in the Bay of Fundy, where the only fishery is an inshore cod fishery in April between Maces Bay and Saint John.

In the Scotia-Fundy region, the main line of the fixed groundfish longline gear may contain 5 000-10 000 hooks, with hooks placed approximately 2 m apart (D. Clark, DFO,

St. Andrews, pers. comm.). Lead lines at each end of the string anchor the gear along the sea floor. The gear is usually allowed to soak overnight. In the Georges Bank/Browns Bank fishery, total annual fishing effort usually encompasses several thousand fishing days, where 300 boats each deploy approximately 10 000 hooks nightly (D. Clark, DFO St. Andrews, pers. comm.). In the Brier Island fishery, 1-2 strings of 5 000 hooks are typically set per trawl.

Deployments of greater than 10 000 hooks are unlikely due to gear handling issues (D. Clark, DFO St. Andrews, pers. comm.). As a result, any set records wherein the recorded number of hooks exceeded 10 000 the number of hooks was replaced with a null value. Only a subset of records for the years 1999-2004 contain information concerning set number of hooks fished. Records from 2005 did not contain entries for hooks. Fishers are not obligated to record depth for non-trawl gear, so data concerning depth of set is not available. However, since the gear is usually set just off bottom, bottom depth at the set coordinates can be used as a proxy for set depth.

Similar to groundfish gillnet fishing, longline gear typically is set on one day and retrieved on the following day. Longer soak times are usually avoided by fishers as they often lead to lost or degraded catch (D. Clark, DFO St. Andrews, pers. comm.). As a result of this general fishing practice, deployments of 24 h duration were assumed to be standard practice. Therefore, in set records that contained soak times greater than 24 h and less than 1 h, the soak time entry was replaced with a null value.

Pelagic hook and line: In Scotia-Fundy, the mid-water longline fishery targets large pelagics such as swordfish and tunas. The tuna fishery occurs from April to mid July, then again from September to December, where fishing is concentrated southeast of Georges Bank. The swordfish fishery is larger, takes place in July and August, and is concentrated along the edge of the Scotian Shelf and in Emerald and LaHave Basins. A small fishery for porbeagle shark also operates in Emerald and LaHave Basins, and along the continental shelf.

The gear is typically set at dusk, allowed to soak overnight and hauled back the next morning. Hooks are spaced approximately 35 to 40 m apart on a fishing line that typically spans around 50 km or more (S. Smith, DFO, St. Andrews, pers. comm.), resulting in about 1500 hooks per line. Float lines attached to the rope control the fishing depth, and there are typically 3-4 hooks between each float.

Fishermen may record the maximum number of hooks that they are allowed to fish per set, rather than the actual number of hooks that were deployed, which causes a discrepancy in recorded effort in the database. Any number of hooks greater than 2000 per line would be very difficult to manage, and thus any entries exceeding this amount were set to a null value. Entries are frequently missing for the number of hooks, hours, and coordinates, which represents missing effort information. Fishers are not obligated to record depth for non-trawl gear, so data concerning depth of set is not available.

Soak times in this fishery exceeding 24 h are usually avoided by fishers as they often lead to lost or degraded catch (D. Clark, DFO St. Andrews, pers. comm.). Therefore, deployments of up to 24 h duration were assumed to be standard practice. In set records

that contained soak times greater than 24 h and less than 1 h, the soak time entry was replaced with a null value.

Trap and Pot Fishing

In trap or pot fishing, the gear is baited to induce fish to enter, then relies on the gear's effectiveness to prevent fish from escaping (Sainsbury 1986). This gear type is applicable for capturing species that are active predators or scavengers (Sainsbury 1986). Gear may be set singly, or in strings of multiple traps. Traps are set with a surface buoy line (or in the case of trap strings, one line on each end of the string).

All types of trap and pot fishing discussed below are considered to present a HIGH risk for right whale entanglement when fishing effort overlaps right whale distribution in the Scotia-Fundy region. The risk arises from the use of vertical lines and the possibility of slack lines between traps on trap strings.

Lobster trap: In the Lobster Fishing Areas 33-38 in Scotia-Fundy region (Fig. 1) is a very large fishery, with approximately 1500 licences and almost 600 000 pots in use (DFO 1998). Fishing takes place from October to July, with specific open/closure dates dependent on the area fished (DFO 2001). There is also a summer fishery in LFA 38b from June to October (Fig. 1). LFA 38b is located southwest of Grand Manan, near Machias Seal Island. The United States also conducts a year round lobster fishery in this area using approximately 15 000 traps. An offshore lobster fishery is conducted in LFA 41 (Fig. 1), largely during the summer months.

Pots may be fished singularly or strung together in trawls, depending on the time of year, area fished and preference. Trawls are typically used, particularly at depths greater than 72 m (40 fathoms) and during the winter fishing season when lobster move offshore (L. Murison, Grand Manan Whale and Seabird Research Station, North Head, pers. comm.). Single pots may be used in less than 72 m (40 fathoms), early in the winter fishing season, and in the spring season when lobster are inshore (L. Murison, Grand Manan Whale and Seabird Research Station, North Head, pers. comm.). The contours of the sea floor, proximity to shore, and crowding from other fishermen may also dictate whether single pots are deployed rather than trawls.

The numbers of pots per trawl ranges from 12-50, and the basic configuration may be altered depending on the season and area fished. Pots are placed between (37-55 m) (20-30 fathoms) apart on the trawl, but typically 46 m (25 fathoms). However the distance between pots may be shortened to allow more pots in a particular area, and concentrating fishing effort by a number of fishermen. Mini-trawls of 5-6 pots may also be deployed. Floating rope is used between pots to prevent tangling on the ocean bottom.

Trawls are ideally set along the tidal axis. Exceptions occur when fishing effort is heavy and it is not always possible for the ideal deployment. Pots that are set from October to December and from April to July generally soak for 1-4 days. Pots set from January through March soak longer, from 3-21 days, largely due to winter weather conditions and the reduced activity levels of lobsters in cold-water temperatures.

The coordinates of all fishing sets were examined to ensure that sets were located within geographical areas specified in licence conditions. Sets recorded as occurring outside these areas were considered to be erroneous and discarded. As a condition of licence, crab caught in traps set under a lobster licence can be retained and landed, but lobster cannot be landed from traps set for crab. Therefore, no inshore lobster should be caught outside Lobster Fishing Area 38b (referred to as the "Grey Zone"; Fig. 1) from mid-June to mid-October. Any sets found in this area at other times of the year were considered erroneous and discarded. In the lobster fishery, fishermen are required to log daily catch, but not effort or location. Therefore, values are frequently missing for depth, h, number of pots, and location coordinates.

Crab trap: The directed fishery for crab in Scotia-Fundy is a relatively small fishery, catching Jonah crab, snow crab and rock crab. A Jonah fishery takes place in LFA 36 (Fig. 1), with 22 licenses and 8250 traps. The Jonah season runs from mid June to mid November to avoid the lobster season. The snow crab fishery occurs in Roseway Basin and LaHave Basin from November to June, with 4 licenses in 2005. There is also an inshore rock crab and Jonah crab fishery in the Gulf of Maine. Crab is caught as a bycatch of the lobster fishery.

Crabs are fished using 20 to 30 pots on one string, set on the sea floor (D. Robichaud, DFO, St. Andrews, pers. comm.). Trawls are generally laid out with the current so that the rope between each trap is as tight as possible, ensuring the greatest distance between traps and maximizing the bait attraction of each trap. Traps are spaced approximately 47.4 m (25 fathoms) apart. Traps typically soak for 2-3 days before retrieval.

The coordinates of all fishing sets were examined to ensure that sets were located within geographical areas specified in licence conditions. Sets recorded as occurring outside these areas were considered to be erroneous and discarded. In recent years the DFO databases have not included information concerning the number of traps or soak time for sets. The reason for this change is that in previous years individual fishers may have recorded the maximum number of pots that they were allowed to fish per set, rather than the actual number of pots that were deployed, which may have caused discrepancies in recorded effort in the database. Also, fishers are not required to record depth of non-trawl gear, so data concerning depth of set is not available. However, since the gear is usually set on bottom, bottom depth at the set coordinates can be used as a proxy for set depth.

Subsets of annual crab fishery data for the years 2000-05 have been compiled separately by DFO researchers. In order to minimize the potential impact of the data gap in the ZIFF and MAFIS databases, these additional data subsets were included for analysis in this study. In these subsets the proportion of sets that recorded the number of traps fished is higher, except for 2005 when effort was not recorded. Soak time was recorded very rarely, and is not a required field, as soak time can vary substantially (D. Robichaud, DFO, St. Andrews, pers. comm.). However, these subsets only include fishing areas in the Bay of Fundy (licensed lobster fishing areas 35, 36, 37, and 38). Data from the remaining areas within the study area (areas 33, 34, and 41) are still based on extractions from the ZIFF and MAFIS databases. The inclusion of the extra data from the Bay of Fundy may result in some unknown bias. Statistical comparisons of the few sets from the Fundy subsets and the ZIFF/MARFIS data that overlap in time and space did not identify

a significant difference in effort, although these tests had low power due to very low number of matching set records in the databases. Despite the caveats about using the extra Fundy data, these data were included because the potential value of additional geo-referenced data. All the available data was combined and all analyses presented in this report were conducted on the pooled data.

In discussions with DFO science staff, it was determined to be unlikely that fishers would deploy more than 1000 traps in a set, given vessel sizes and concomitant gear handling issues. Trap counts in excess of 1000 traps per set may have resulted from misinterpretation of original fishing logbook entries during data entry. Therefore, if set records contained entries greater than 1000 traps fished per set, the entry was changed to a null value.

Hagfish trap: Hagfish are common around southern Nova Scotia and New Brunswick, particularly in Passamoquoddy Bay (DFA 2004). Hagfish are typically fished in summer months (DFO 1998), and they prefer deep, cool waters and soft muddy bottoms. Hagfish are harvested using plastic barrel traps with holes drilled into them. The numbers of traps set vary according to harvester. The gear is set on the sea floor at a variety of depths. The optimal fishing time is during the evening and night, with soak times of 12-24 h. Surface buoys are attached to the traps, and float at the surface to indicate the location and ownership of the gear, and to provide a line from which the gear can be raised to the surface.

The experimental hagfish fishery began in 1999. Since this is a new fishery, requirements for data logging have evolved quickly during the fishery's short history. The number of traps used was recorded only in 2002 and 2003, with an entry of one trap per set. Soak time was recorded only in 2004. Optimum soak times are considered to be 12 or 24 h. Since the gear is set on the bottom, bottom depth at the set coordinates can be used as a proxy for set depth.

DATA ANALYSIS

Descriptive statistical analyses were performed on each fishery. Box plots were created for nets per set and h per set for each year, and weight per species for all years combined. Histograms were produced for the number of sets per year and sets per month for all years combined. Bar charts were created for species caught per year.
ANOVA tests performed on the number of gear units recorded for each fishery showed no significant difference in annual mean values, and comparison tests showed no temporal trend for any of the fisheries analyzed. Therefore, one mean could be calculated across years and the time series (1999-2005) could be aggregated and plotted as one grouping for each fishery.

The defined area of study (64^{o} 30' and 68^{o} 00' W longitude, and 40^{o} 00' and 45^{o} 12' N latitude) was divided into 3-min W latitudinal and 3-min N longitudinal cells, resulting in a 104 by 70 cell grid, with 7280 cells. The grid layout is the limiting resolution used for later analyses. This region included two areas in which right whales are known to aggregate seasonally; east of Grand Manan and Roseway Basin (Fig. 1).

Each set within a fishery was assigned to its overlapping grid cell, and the total number of sets and total numbers of gear units were calculated for all years combined. Scaled symbol frequency distribution plots and contour frequency distribution plots were created in SURFER, Version 8 (Golden Software), for (1) the total number of sets and (2) total number of gear units and for all years combined (1999-2005). Two different gridding methods were used in the creation of contour plots: Inverse Distance to a Power (IDP) and Natural Neighbour (NN). A weighting power parameter value (β) of 1.5 was used for contour plots generated using IDP. All other parameters for both IDP and NN methods were set to their default values. In all contour plots contouring was undertaken on a finer-scale grid of size of 208 by 140.

Several gear types are deployed with vertical lines ranging from the gear to the surface. New quantities were created to incorporate added risk that such vertical lines contribute to potential for entanglement. As stated earlier, water column depth was used to estimate the amount of vertical rope in the water column. Bathymetry data was used to define the water column depth (bottom depth) of each grid cell. If multiple sets occurred in a grid cell, it was necessary to estimate the total amount of vertical rope present in the cell. In these cases, bottom depth was multiplied by the total number of sets or total number of gear units in each grid cell. Contour frequency distribution plots of these new, "rope-weighted" quantities were created for each applicable gear type for each year and using the pooled time series (1999-2005), are noted as either "sets*depth" or "nets*depth".

Right whale sightings per unit effort (SPUE) data were provided by the New England Aquarium Right Whale Consortium for the Scotia-Fundy region (Fig. 2). The data contained annual survey effort (km of linear survey track) and sightings (number of whales) from 1987 to 2000 inclusive, which were used to estimate SPUE (number of whales/1000 km). It was necessary to aggregate the annual data, as annual SPUE estimates are too limited in time and space. The SPUE data represent cell-specific SPUE estimates across the study grid. Portions of the overall grid were isolated that covered the general location of the right whale Conservation Zones; Grand Manan, bound by 44^{o} 00' to 45^{o} 00' N latitude and 66^{o} 00' to 67^{o} 00' W longitude (20 by 20 grid, or 400 grid cells), and Roseway Basin, bound by 42^{o} 30' to 43^{o} 30' N latitude and 64^{o} 45' to 66^{o} 00' W longitude (20 by 25 grid, or 500 grid cells).

RESULTS

GEO-REFERENCED DATA RECORDS

Generally, record-keeping of set locations in NAFO fishing areas 4X, 5Y and 5ZE has improved for all fisheries over time (Table 2). The groundfish gillnet fishery has 76.3% recorded sets with coordinates overall, with 65.7-92.9% recorded annually throughout the time series. The proportion of sets with coordinates has increased over the time series. The herring gillnet fishery recorded 56.6% of sets with coordinates overall, and has been increasing annually, with 26-87.8% geo-referenced sets. The groundfish hook and line fishery has 75.2% geo-referenced sets recorded throughout the time series, with 65.9-92.3% recorded annually and is increasing over time. The pelagics hook and line fishery has 75.9% of recorded sets with coordinates overall, with 68.9% early in the time series

to 98.9% recorded later. The crab trap fishery has 96.5% recorded coordinates throughout the time series, with 93-99.1% recorded annually. The proportion of sets in the crab trap fishery with coordinates was augmented by the inclusion of the data subset supplied by DFO researchers. All (100%) of the fishing sets recorded from the lobster trap fishery included set coordinates each year of the time series. However, these recorded sets represent a very small proportion of total effort. The hagfish trap fishery has 94.2% geo-referenced sets overall, with 80.2-100% recorded annually. Record-keeping of coordinates has increased over the time in this small fishery.

DISTRIBUTION OF FISHING GEAR

Gillnet Fishing

Groundfish gillnet: Table 2 provides the annual number of total and geo-referenced sets in NAFO fishing areas 4X, 5Y and 5ZE. Within the smaller study area, a mean number of 1361 geo-referenced sets per year were recorded in the DFO databases (ranging from 1157 in 2001, to 1611 in 1999), and the majority of sets were fished in June, July and August (July maximum) (Fig. 3). Soak time recorded per set is 24 h, and the mean number of nets per set is 29. The main species caught in this fishery were cod, pollock, and white hake (Fig. 3). This fishery occurred throughout the study area, but with the greatest intensity north of Grand Manan and in the lower Bay of Fundy (Fig. 4-6). Fishing within the Grand Manan Conservation Zone was greatest in the southwest and northeast corners of the zone. Fishing also occurred in Roseway Conservation Zone, but the greatest intensity was just north of the zone.

Herring gillnet: There was a dramatic decline in the number of recorded sets in NAFO fishing areas 4X, 5Y and 5ZE midway through the time series, from 281 sets in 2001 to 19 sets in 2002 (Table 2). Most sets within the smaller study area were fished in September and October (Fig. 7). Records of nets per sets only existed for 1999, 2000, and 2001, with a mean of 4.8 nets per set for these years. Recorded soak times per set varied greatly from less than 1 h to 24 h. Fishing mainly occurred along the coast of Digby Neck and along the south shore of Nova Scotia near Liverpool (Fig. 8-10). Some effort took place in the southern portion of the Grand Manan Conservation Zone. There was no discernable overlap of right whales and herring gillnets within the Roseway Conservation Zone (Fig. 2, 8-10).

Hook and Line Fishing

Groundfish Hook and Line: The mean number of geo-referenced sets per year recorded was 2940 in NAFO areas 4X, 5Y and 5ZE (Table 2) and 2576 in the smaller study area (Fig. 11). The majority of sets in the study area were fished during July and August (Fig. 11). The average recorded soak time per set was 24 h, with an average of 4232 hooks per set (Fig. 11). The main species caught in this fishery were cod, haddock, dogfish, white hake and cusk (Fig. 11). Fishing effort occurred throughout the study area, with the greatest intensity located in the lower Bay of Fundy, Browns Bank, Roseway Basin, and north of Georges Bank, with a substantial number of sets in the Conservation Zones (Fig. 12-14).

Pelagic Hook and Line: The mean number of geo-referenced sets per year recorded in NAFO areas 4X, 5Y and 5ZE was 366 (Table 2), where the majority of sets within the smaller study area occurred in July and August (Fig. 15). Soak time and hooks per set were only available for 1999, 2000, and 2001. Soak times varied greatly for the years recorded. The mean number of hooks per set for the available years was 901 (Fig. 15). The species caught in this fishery was predominantly swordfish and bigeye tuna. Fishing occurred mainly offshore, far south of Roseway Basin (Fig. 16-18).

Trap and Pot Fishing

Crab Trap: On average, 2074 geo-referenced crab sets occurred annually within NAFO fishing areas 4X, 5Y and 5ZE (Table 2). Within the smaller study area, a mean number of 1412 geo-referenced sets per year were fished, where the majority of sets occurred in July, August and September (Fig. 19). The main species caught was Jonah crab. Soak time per set usually varied from one to several days, with some sets deployed for a considerably longer period (Fig. 19). The mean number of traps per set was 128. Fishing was mainly prosecuted south of Grand Manan and in the lower Bay of Fundy, north of Georges Bank (Fig. 20-22). Substantial crab fishing effort occurred in the Bay of Fundy Conservation Zone (Fig. 2, 20-22).

Lobster Trap: The mean number of 723 geo-referenced sets per year were recorded in NAFO fishing areas 4X, 5Y and 5ZE (Table 2) and 236 in the smaller study area (Fig. 23). The majority of sets in the study area were fished in June and October (Fig. 23). The mean number of traps per set was 420. Records for h per set were available for 1999, 2000, and 2001, with a mean of 255 h per set (Fig. 23). Fishing was confined to the areas southwest of Grand Manan (LFA 38b) and offshore of the Scotian Shelf (Fig. 24-26). There was no indication of potential overlap of right whales and lobster trap gear in the vicinity of either right whale Conservation Zone (Fig. 2, 24-26).

Hagfish Trap: An average of 104 geo-referenced sets per year were recorded within NAFO fishing areas 4X, 5Y and 5ZE (Table 2), within the smaller study area, a mean number of 49 geo-referenced sets were recorded per year, and the majority of sets were fished in June and July (Fig. 27). Soak time was only recorded in 2000 and 2001, with a mean of 16 h per set. Records of traps per set were only available for 2002 and 2003, with a mean of one trap per set. Most fishing occurs in the areas outside Passamaquoddy Bay (southwest Bay of Fundy) and north of Roseway Basin (Fig. 28-30).

DISCUSSION

POTENTIAL FOR RIGHT WHALE ENTANGLEMENT

The groundfish gillnet and groundfish hook and line fisheries likely pose the greatest risk for right whale entanglements. These fisheries made up the bulk of fishing effort in Scotia-Fundy between the months of June and October when the highest densities of right whales occur, and sets were widely distributed throughout the region. The design and deployment of the gears also increases the potential for entanglement, with lengths of netting strung end-to-end, or long strings of hooks that remain unattended in the water for

up to 24 h. Both fisheries place substantial effort in both right whale Conservation Zones during the summer months.

Herring gillnet gear may also pose a threat, since the design specifications are essentially the same as those for groundfish. However, soak times are unusually less than 10 h, and fewer nets are cast on a string. Although some fishing occurs near the Grand Manan Conservation Zone, most fishing effort is concentrated near Digby Neck and south of Halifax, where right whales are less likely to aggregate.

The hook and line gear in the large pelagic fishery could entangle a whale since the lengths of string and hooks are left unattended for several h. While the vast majority of fishing occurs offshore and away from the coastal habitat of right whales, the amount of fishing effort in the Conservation Zones is not trivial. Also, it is likely that right whales may migrate through offshore areas to reach feeding/nursing ground; however, the persistent large aggregations as seen in Bay of Fundy and Roseway Basin have not been recorded in the areas of high hook and line fishing effort. Due to lack of SPUE data in these offshore areas, the risk of overlap cannot be assessed. Risk of overlap in the Conservation Zones may be substantial given the amount of fishing effort within the Zones.

The lobster trap fishery was thought to pose substantial risk to right whales because of the design of the gear. While lobster fishing occurs year-round in the American waters of Fundy region, the Canadian fishery moves offshore during the summer months and there is no overlap evident in the available data between lobster gear and regional coastal waters frequented by right whales. The only inshore fishing that is permitted during right whale season is in LFA 38b (the "grey zone"; Fig. 1). This fishery appears to have a relatively low likelihood of interaction between Canadian lobster gear and right whale population, due to the low number of right whale sightings from that area. Again, survey effort is low in the "grey zone" and LFA 41.

In contrast, the crab trap fishery does occur inshore during whale season and likely poses a risk to right whales, especially due to the relatively small amount of effort that is prosecuted in the right whale Conservation Zones.

The gear in the hagfish fishery may cause entanglements, where vertical lengths of rope remain unattended in the water for a period of time, especially given that fishing occurs within the Roseway Basin Conservation Zone. However, this was a very small fishery at the time of this study and the likelihood of entanglements may be relatively low and limited to the Roseway area.

The likelihood of right whale/gear overlap is concentrated in the right whale Conservation Zones, despite the fact that most fishing effort occurs elsewhere in the study area. The main reason for this is that the vast majority of available right whale sightings occur in the Zones, and strongly influence the interpretation of relative risk of entanglement. To date, most sightings effort is concentrated in the Conservation Zones, and as a result our knowledge of right whale distribution in Canadian waters is substantially biased. It should be noted that right whales move into and out of the Conservation Zones during their annual migration, and do not stay in these areas year-round. It follows logically that right whales may be susceptible to entanglement in

fishing gear that is set in their (currently unknown) migration corridors. If further, broader-scales information existed concerning right whale migration patterns, additional areas in Canadian waters might be identified as areas of enhanced entanglement risk.

SOAK TIME

The number of h that gear remains in the water obviously affects the probability that a right whale will encounter the gear, and should be included in the calculation of any probability indices. Unfortunately, it is currently not mandatory that fishing log books contain records of soak time, and the vast majority of records within the gear time series were left blank. Those records that were not blank often contained erroneous or inexplicable data, which consequently were removed from the investigation.

Soak time for all fisheries in the analysis was assumed to be a constant value, since fishing practices tend to be routine; the gear is set in the afternoon, retrieved the next morning, and then re-released in the afternoon. Also, soak time for each set in the gillnet and hook and line fisheries could safely be assumed to be 24 h, as any longer would result in damaged or lost catch. A constant value could be excluded from analysis, since it would have no effect when calculated into the probability indices. However, this was a major weakness in the analysis of the crab and lobster trap fisheries, where soak times could vary from 1 d to 1 mo.

FISHING EFFORT

Overall, 80% of all reported sets fished in the Scotia-Fundy region were geo-referenced during the period under investigation, and were therefore used to determine the potential for right whale/gear interactions. This is a remarkably high value and the Scotia-Fundy region is one of the few areas where the analyses presented in this report can be undertaken. Despite this overall high proportion of geo-referenced sets, fishing effort for several fisheries in this study was likely underestimated due to the limitations of available data. A conservative approach was used in data selection, in that sets lacking coordinates were omitted. An alternative to this approach would have been to assume that sets lacking coordinates conformed to a particular spatial distribution (e.g. spatially distributed in the same manner as the geo-referenced sets), and then to assign set coordinates according to this assumed distribution. This method was not adopted due to the lack of evidence for a candidate distribution. As a result of this underestimate of effort, it is possible that (1) additional areas with potential for right whale/gear interaction may not have been detected, and (2) the total effort within the Conservation Zones was underestimated, assuming a constant proportion by area of sets without coordinates.

The greatest potential for error is found in the indices calculated for the groundfish gillnet and groundfish hook and line fisheries, where several thousand sets were excluded from the analysis. These were the most active fisheries in Scotia-Fundy during the seasonal period of right whale occupancy, and effort was distributed throughout the region. There is also potential for inaccuracies in the crab trap data, but to a lesser overall degree because of the relative size of the fishery. The potential for error in the crab fishery was

partially ameliorated though the inclusion of the enhanced subset of fishery data for the Bay of Fundy.

Sets in the pelagic hook and line and lobster fisheries that lack coordinate data would likely occur offshore, due to the nature of the species targeted. In the case of lobster, fishing was legally restricted to offshore areas and LFA 38b between the months of June and October. For both fisheries, any sets without coordinate data would have likely occurred at a distance from either right whale Conservation Zones.

The herring gillnet fishery is fairly small, and the ideal fishing locations are a distance from where right whales tend to aggregate. The hagfish fishery is also very small.

DATA INTEGRITY

The fishing records presented here are drawn from DFO's commercial landings databases. The main purpose of these databases is to track the weights of commercial species captured and landed in Canadian waters, which is then used in fisheries management decisions. Along with vessel information, the data required for fishing activities include the species caught, landed weight and the date of the fishing trip. Data that may aid an ecological study (e.g. actual latitude and longitude of a fishing set, soak time) may not be required from fishers, as in the past the information was not collected with such uses in mind. It should be noted that the quality and quantity of recorded set information has continued to improve most fisheries.

The accuracy of the data that has been recorded in many log book fields was dependent on the fisher's understanding of the meaning of that field, as this is often not clearly explained. For example, one fishing set is defined by DFO as any number of gear units that are deployed at a certain location and at a certain time. However, some fishers have interpreted one set as being the fishing activities that occur in one trip. Also, each individual gear unit that is deployed has been recorded as a set. The extent of these misunderstandings and the frequency in which inaccurate set data has been recorded in the databases are unknown. For the purposes of this study, a set was any record that contained a unique log code ID number in the databases. Given the misinterpretation of the definition of a fishing set, it is logical to assume that some portion of the data relating to a particular set, such as soak time *per set* and gear units *per set*, may also contain errors.

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Table 1: The species targeted by each fishery and their species codes in the DFO commercial landings databases (ZIFF and MARFIS).

Fishery	Species Name	ZIFF Code	MARFIS Code
Groundfish	Cod	100	100
	Rock cod	101	101
	Arctic cod	102	102
	Ling cod	103	103
	Pacific cod	105	
	Haddock	110	110
	Redfish	120	120
	Cunners	121	121
	Alfonsino	122	
	Halibut	130	130
	Plaice	140	140
	Yellowtail	141	141
	Greysole	142	142
	Winter flounder	143	143
	Turbot	144	144
	Windowpane flounder		145
	Unspecified flounder	149	149
	Skate	356	160
	Dogfish	362	161
	Butterfish		166
	Pollock	170	170
	White hake	171	171
	Silver hake	172	172
	Cusk	173	173
	Catfish	174	174
	Tomcod	175	175
	Lumpfish	176	176
	Monkfish	177	177
	Sand eel	178	178
	Roundnose grenadier	179	179
	Red hake	180	180
	Sculpin	181,188	181
	Roughhead grenadier	182	182
	Sand lance	183	178
	Eelpout	184	183
	Catfish, striped	185	192
	Catfish, spotted	186	
	Catfish, northern	187	187
	Chimaera		184
	Wrymouth		185
	Snakebleny		186
	Blue hake		188
	Tilefish	190	190
	Hagfish	953	197
	Scalefish	198	198
	Unspecified groundfish	199	199

Table 1 (continued): The species targeted by each fishery and their species codes in the DFO commercial landings databases (ZIFF and MARFIS).

Fishery	Species Name	ZIFF Code	MARFIS Code
Large Pelagics	Swordfish	251	251
	Albacore tuna	252	252
	Bigeye tuna	253	253
	Bluefin tuna	254	254
	Tuna, skipjack	255	255
	Yellowfin tuna	256	256
	Unspecified tuna	259	259
	Billfish	260	260
	Blue marlin	261	261
	White marlin	262	262
	Mahi mahi		263
	Escolar		270
	Pelagic unknown	299	299
Herring	Herring	200	200
	Mackerel	250	250
Crab	Jonah crab	703	703
	Rock crab	704	704
	Snow crab (queen)	705	705
	Red crab	706	706
	Unspecified crab	707	707
	Stone crab	708	708
	Spiny crab	709	709
	Spider crab	710	
	Porcupine crab		710
Lobster	Lobster	700	700
Hagfish	Hagfish	953	197

Table 2: Total number of fishing sets and number of geo-referenced sets in NAFO areas 4X, 5Y, 5ZE. *NAFO area is not recorded for most sets in the pelagics fishery.

Fishery	Year	Total Sets	Geo-referenced Sets	Percent (%)	Fishery	Year	Total Sets	Geo-referenced Sets	Percent (%)
Groundfish Gillnet	1999	3333	2190	65.7	Crab Traps	1999	1746	1623	93
	2000	2280	1588	69.6		2000	2060	1961	95.2
	2001	2115	1486	70.3		2001	2679	2597	96.9
	2002	2072	1543	74.5		2002	3079	2960	96.1
	2003	2086	1756	84.2		2003	2502	2479	99.1
	2004	1712	1591	92.9		2004	1865	1819	97.5
	2005	1558	1417	90.9		2005	1120	1081	96.5
	All years	15156	11571	76.3		All years	15051	14520	96.5
	Mean	**2165**	**1653**	**78.3**		**Mean**	**2150**	**2074**	**96.3**
Herring Gillnet	1999	543	287	52.9	Lobster Traps	1999	300	300	100
	2000	404	105	26		2000	369	369	100
	2001	631	340	53.9		2001	793	793	100
	2002	197	154	78.2		2002	465	465	100
	2003	84	62	73.8		2003	870	870	100
	2004	229	201	87.8		2004	907	907	100
	2005	115	97	84.3		2005	1354	1354	100
	All years	2203	1246	56.6		All years	5058	5058	100
	Mean	**315**	**178**	**65.3**		**Mean**	**723**	**723**	**100**
Groundfish Hook and Line	1999	4238	2864	67.6	Hagfish Traps	1999	86	74	86
	2000	4449	3003	67.4		2000	101	81	80.2
	2001	4550	2997	65.9		2001	156	152	97.4
	2002	4421	3261	73.8		2002	111	107	96.4
	2003	3927	3128	79.7		2003	150	145	96.7
	2004	2945	2718	92.3		2004	110	110	100
	2005	2858	2611	91.4		2005	58	58	100
	All years	27382	20582	75.2		All years	772	727	94.2
	Mean	**3913**	**2940**	**76.9**		**Mean**	**110**	**104**	**93.8**
Pelagics Hook and Line	1999	501	367	73.3					
	2000	991	683	68.9					
	2001	1148	799	69.6					
	2002*	216	208	96.3					
	2003*	135	128	94.8					
	2004*	207	201	97.1					
	2005*	181	179	98.9					
	All years	3379	2565	75.9					
	Mean	**483**	**366**	**85.6**					

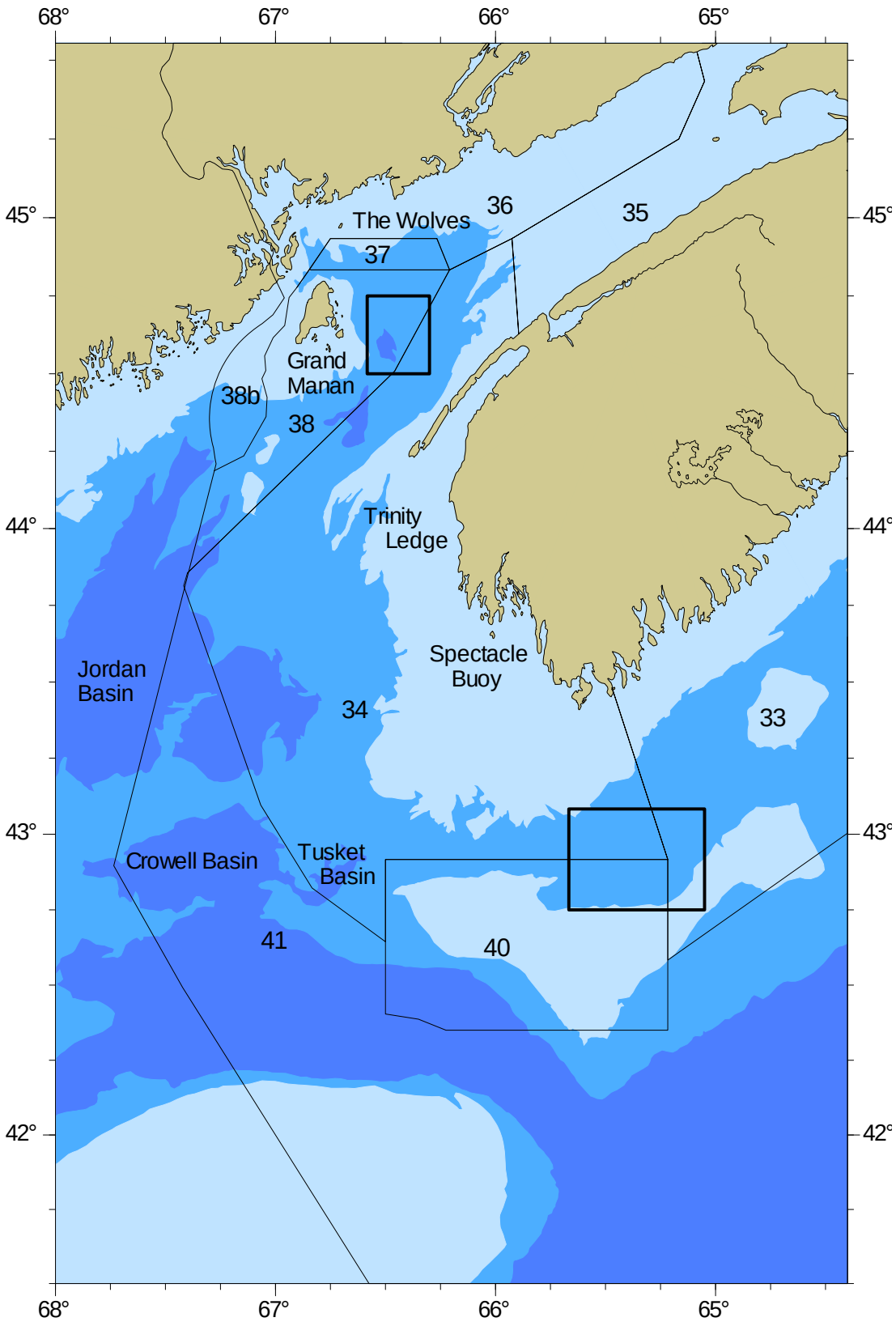

Fig. 1: Study area within the Scotia-Fundy region. The Bay of Fundy and Roseway Basin right whale Conservation Zones Boxes identified with bold lines. Lobster fishing areas (LFAs) discussed in the text and labelled as 33-41, and the Exclusive Economic Zone (200 mile limit) are delineated with thin, solid lines.

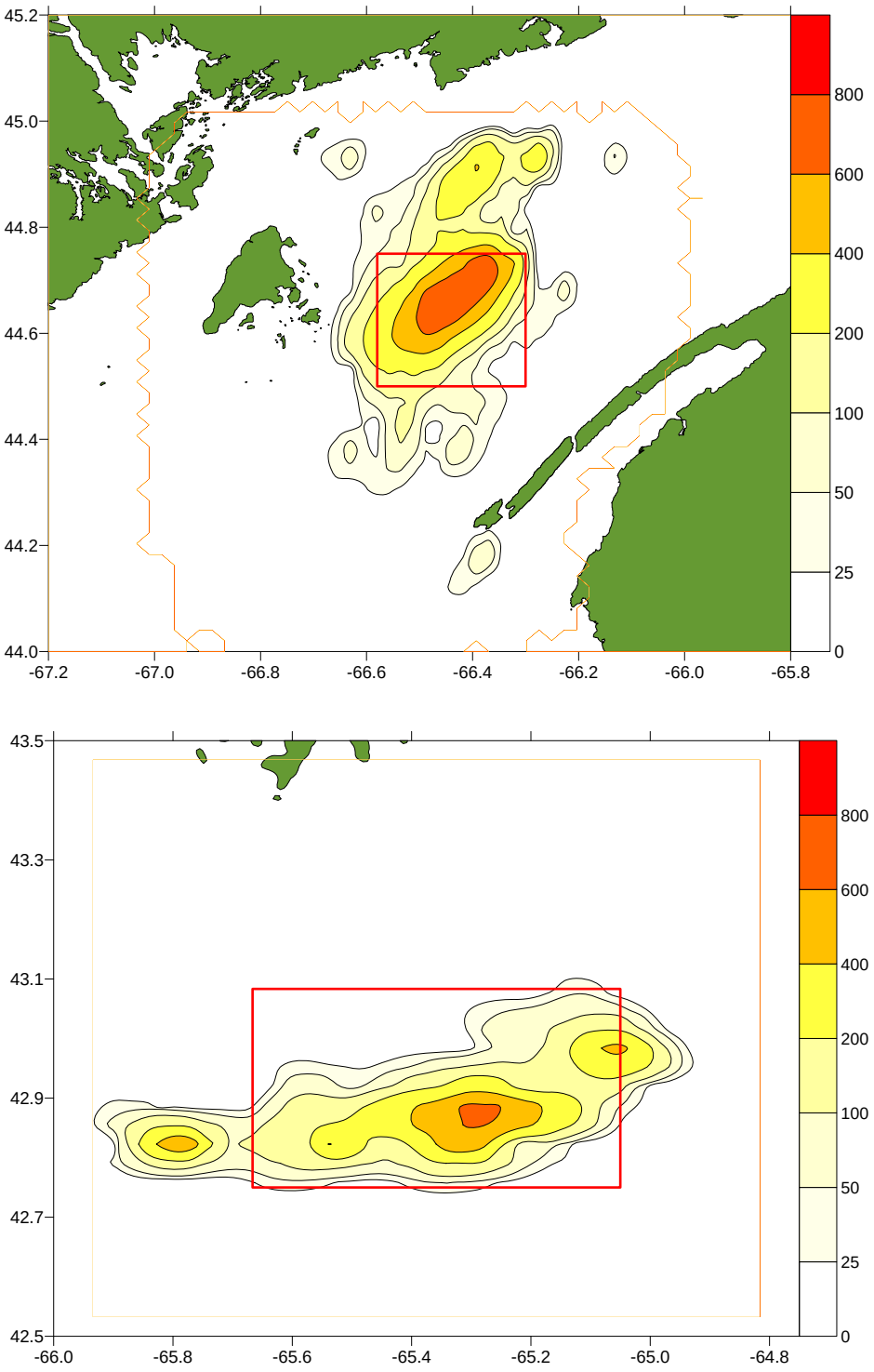

Fig. 2: Contour plots of sightings per unit effort (SPUE) of right whales in Grand Manan Basin (top) and Roseway Basin (bottom). The North Atlantic Right Whale Conservation Zones are identified with solid lines.

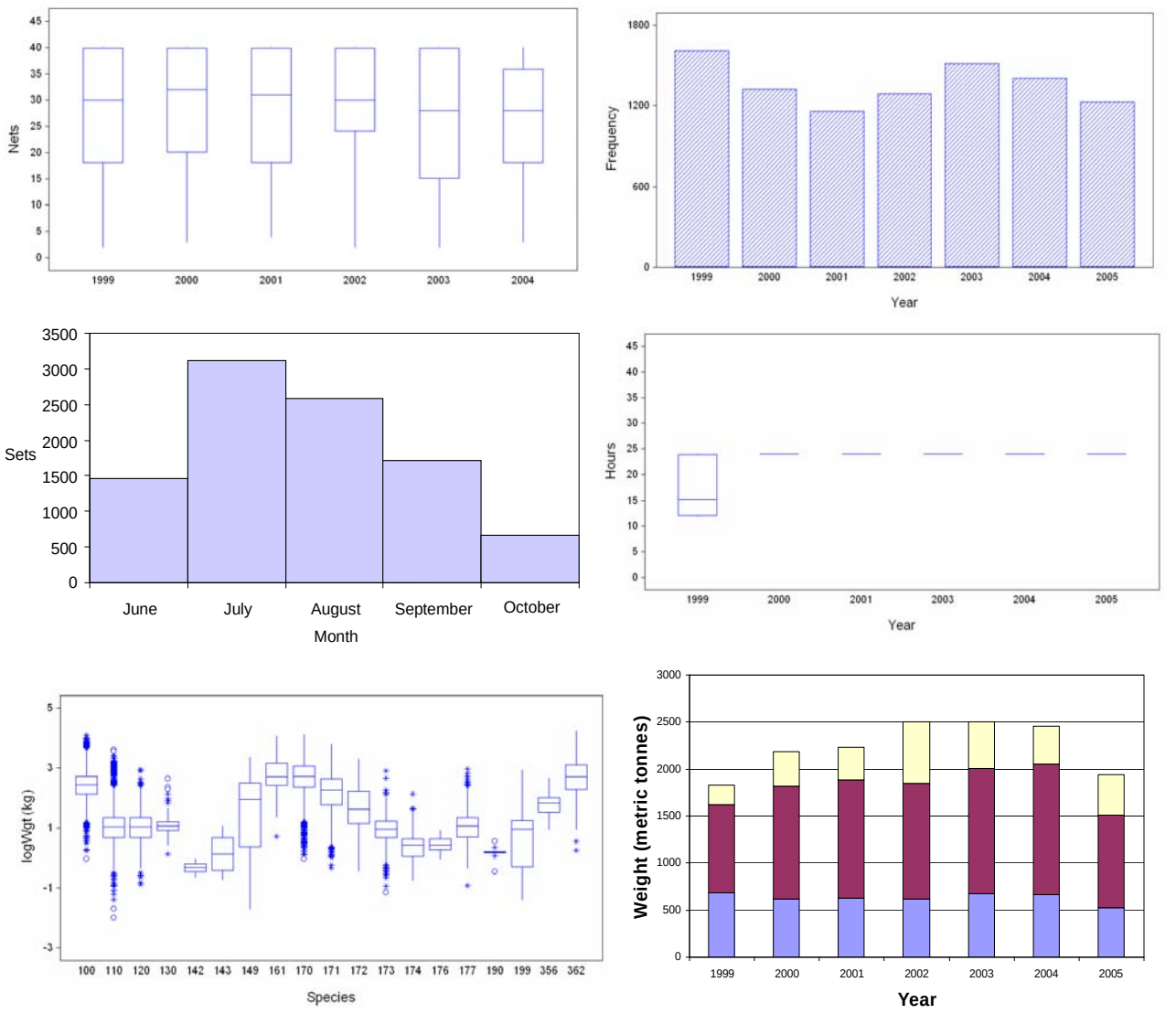

Fig. 3: Descriptive statistics of the groundfish gillnet fishery data, for years 1999-2005 located in the study area. Nets per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom right). Species codes are provided in Table 1. Most commonly caught species: white hake (top), pollock (middle), and haddock (bottom).

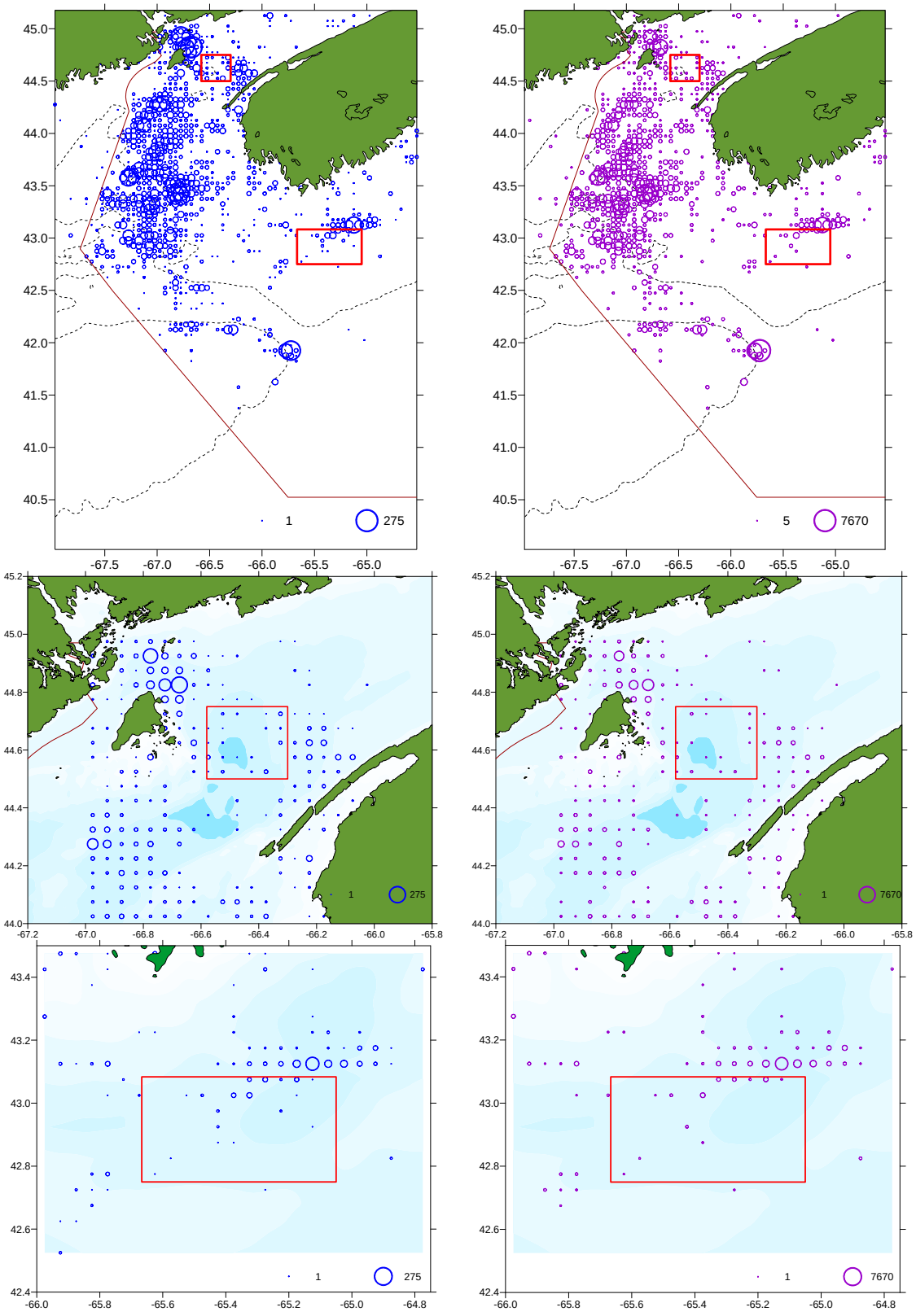

Fig. 4: Spatial distribution of effort density in the groundfish gillnet fishery from 1999-2005. Scaled symbol plots (3 minute aggregation) of sets (left column) and nets (right column) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom). The solid line is the Exclusive Economic Zone (200 mile limit).

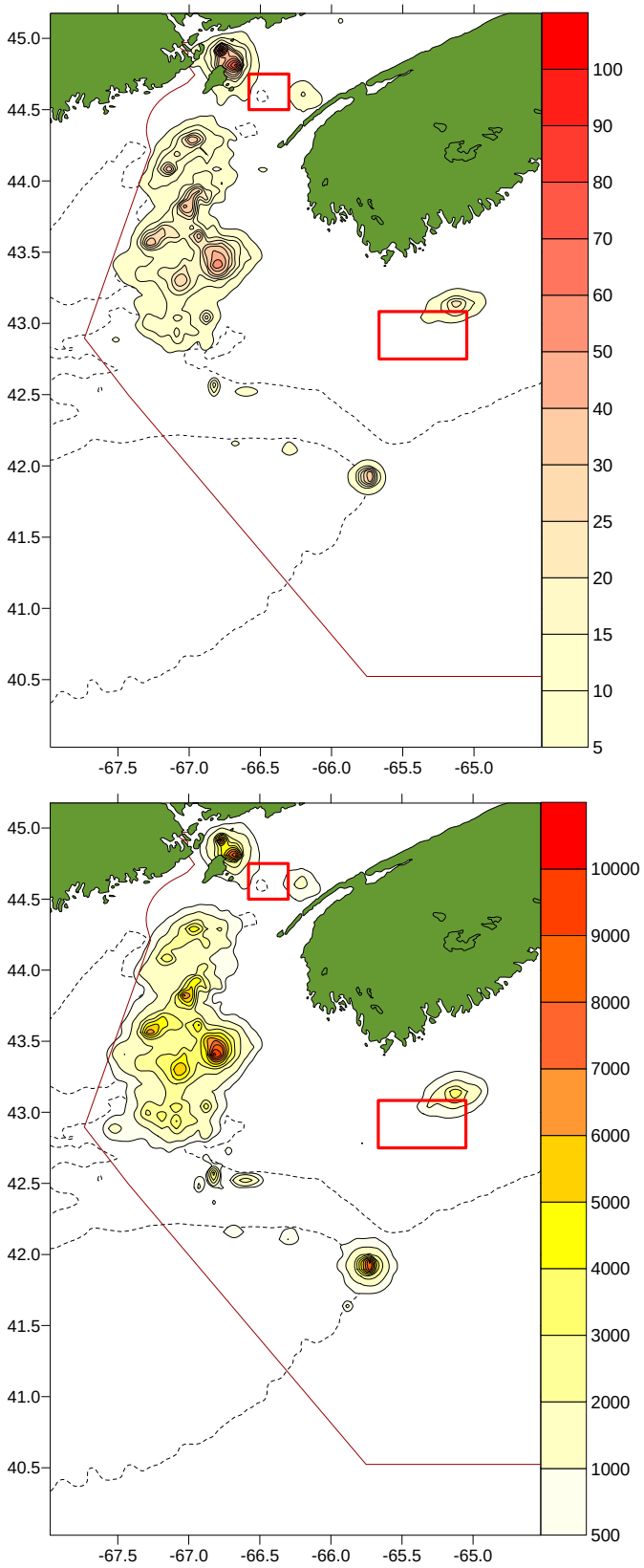

Fig. 5: Contour frequency distribution plots of sets (above) and sets*depth (below) for the groundfish gillnet fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

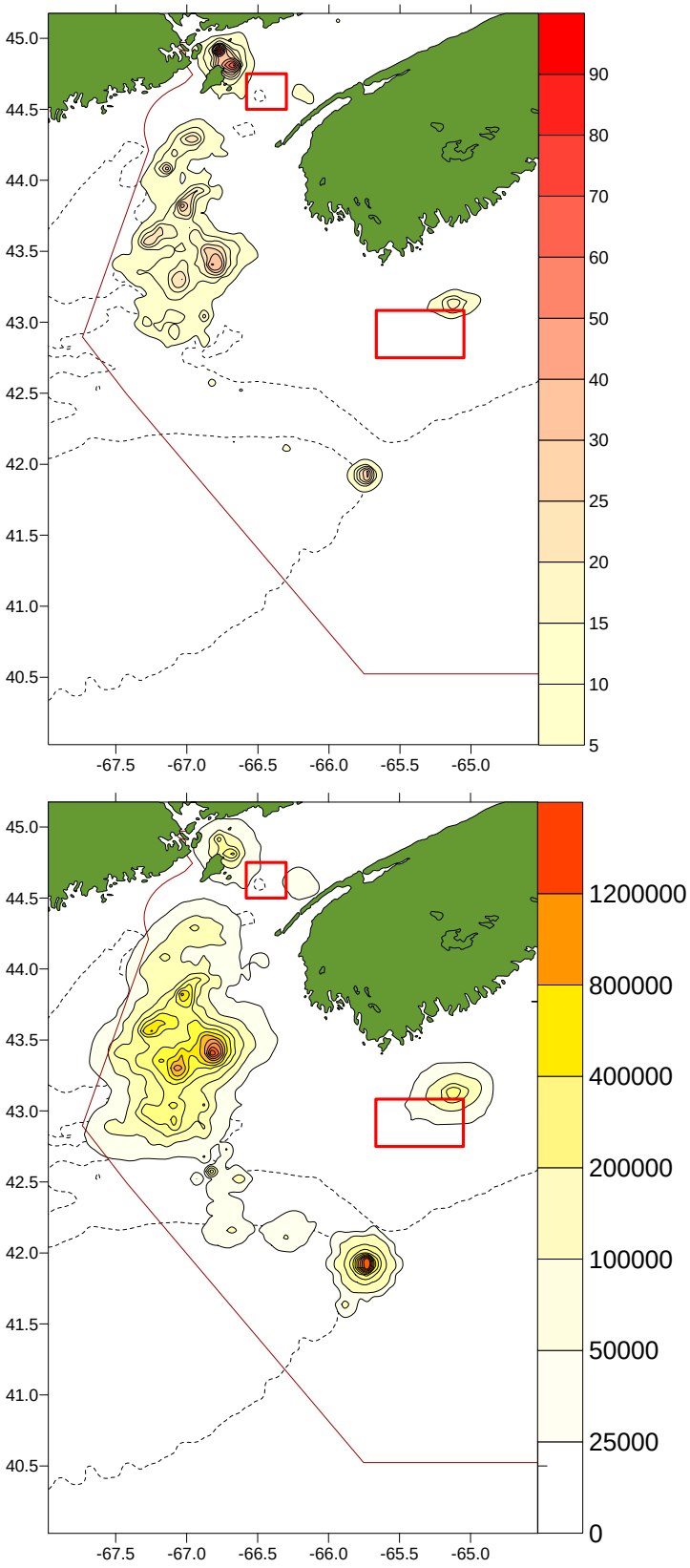

Fig. 6: Contour frequency distribution plots of nets (above) and nets*depth (below) for the groundfish gillnet fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

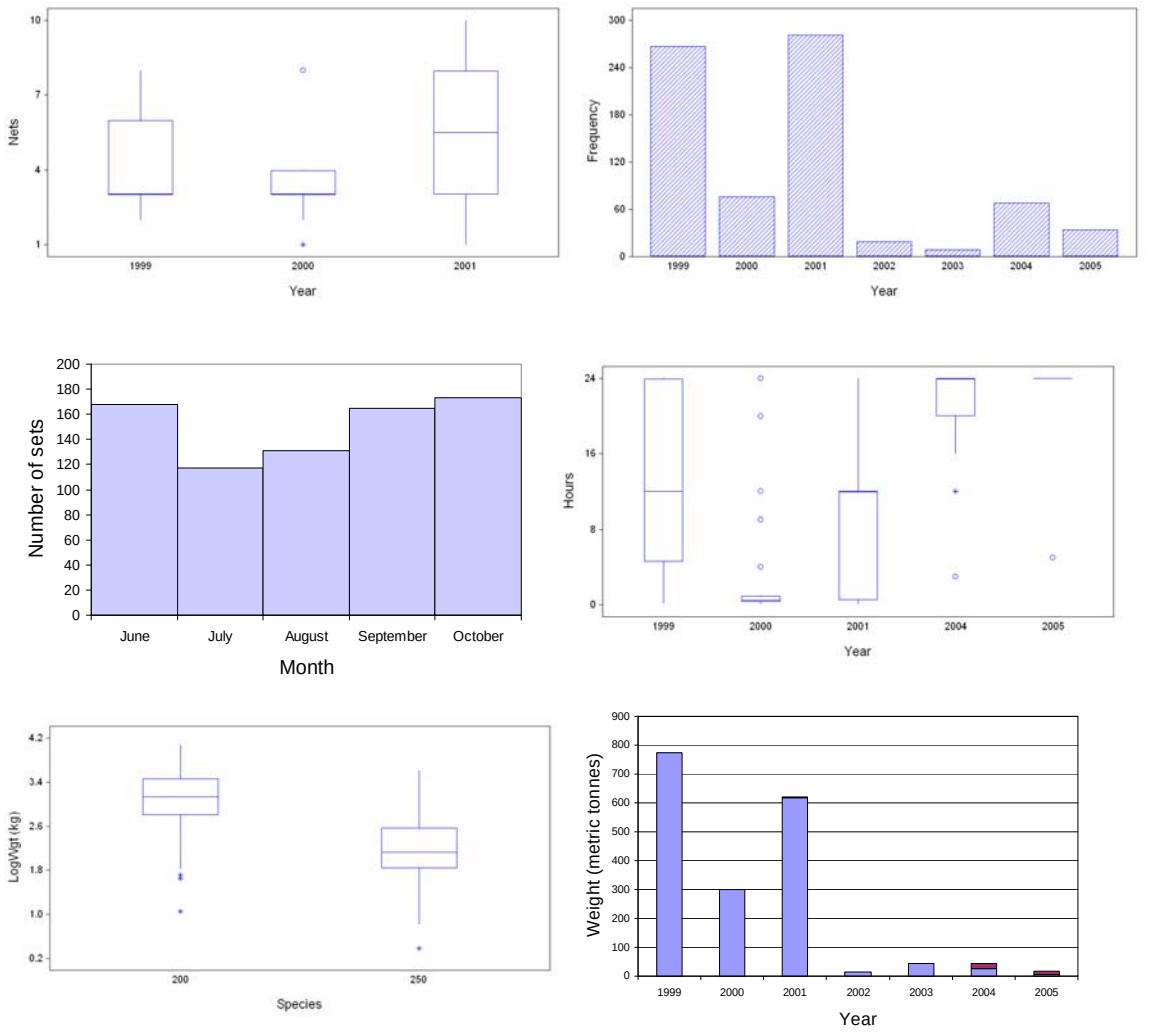

Fig. 7: Descriptive statistics for the herring gillnet fishery. Nets per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom right). Most commonly caught species: herring (bottom; large bars) and mackerel (top).

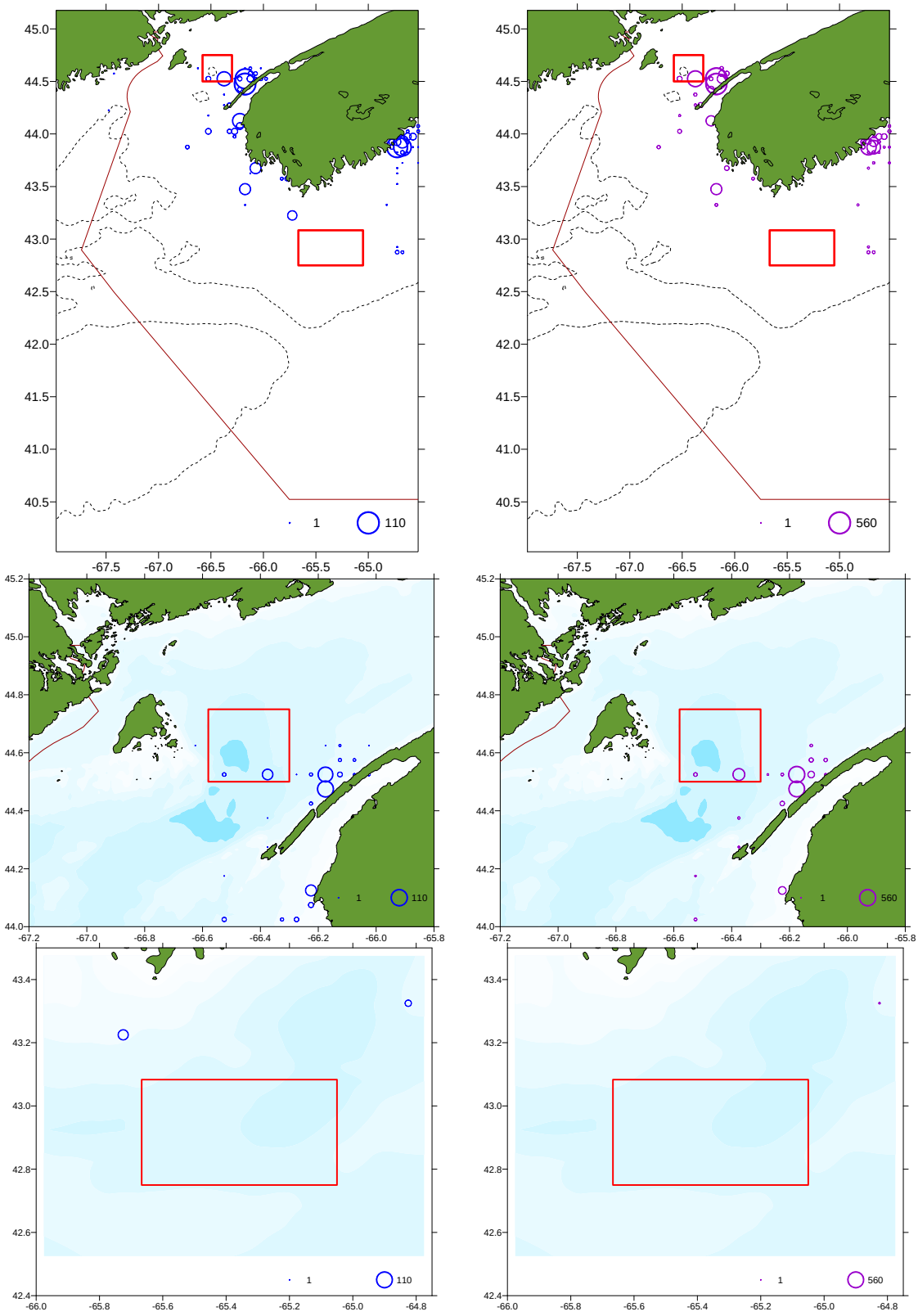

Fig. 8: Frequency distribution analysis of effort in the herring gillnet fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and nets (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom).

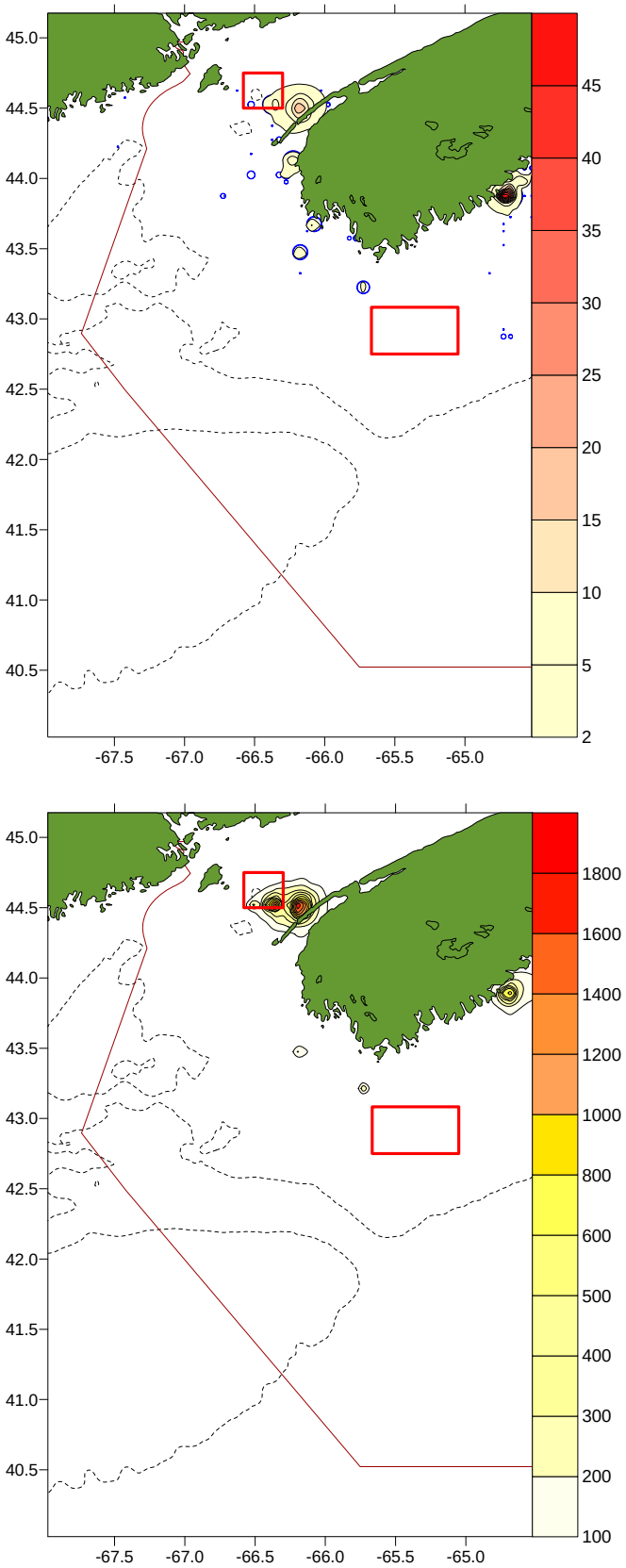

Fig. 9: Contour frequency distribution plots of sets (above) and sets*depth (below) for the herring gillnet fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

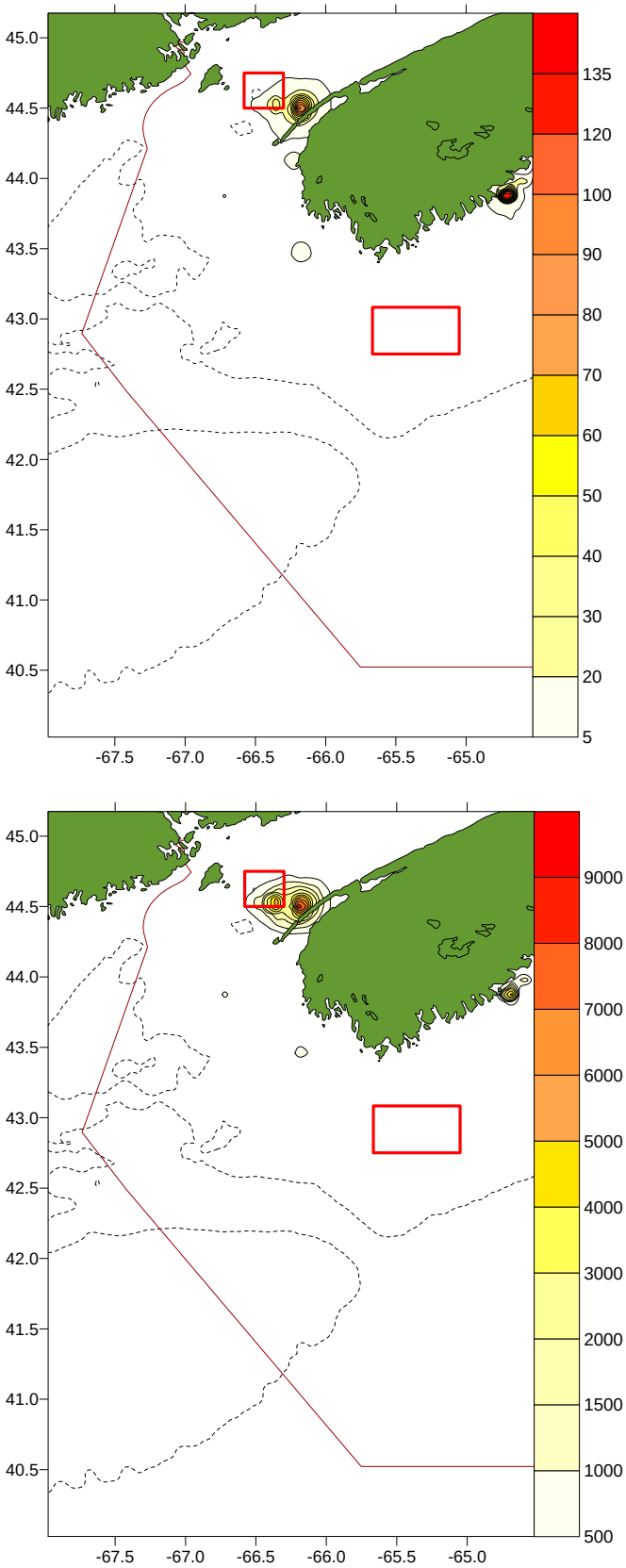

Fig. 10: Contour frequency distribution plots of nets (above) and nets*depth (below) for the herring gillnet fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

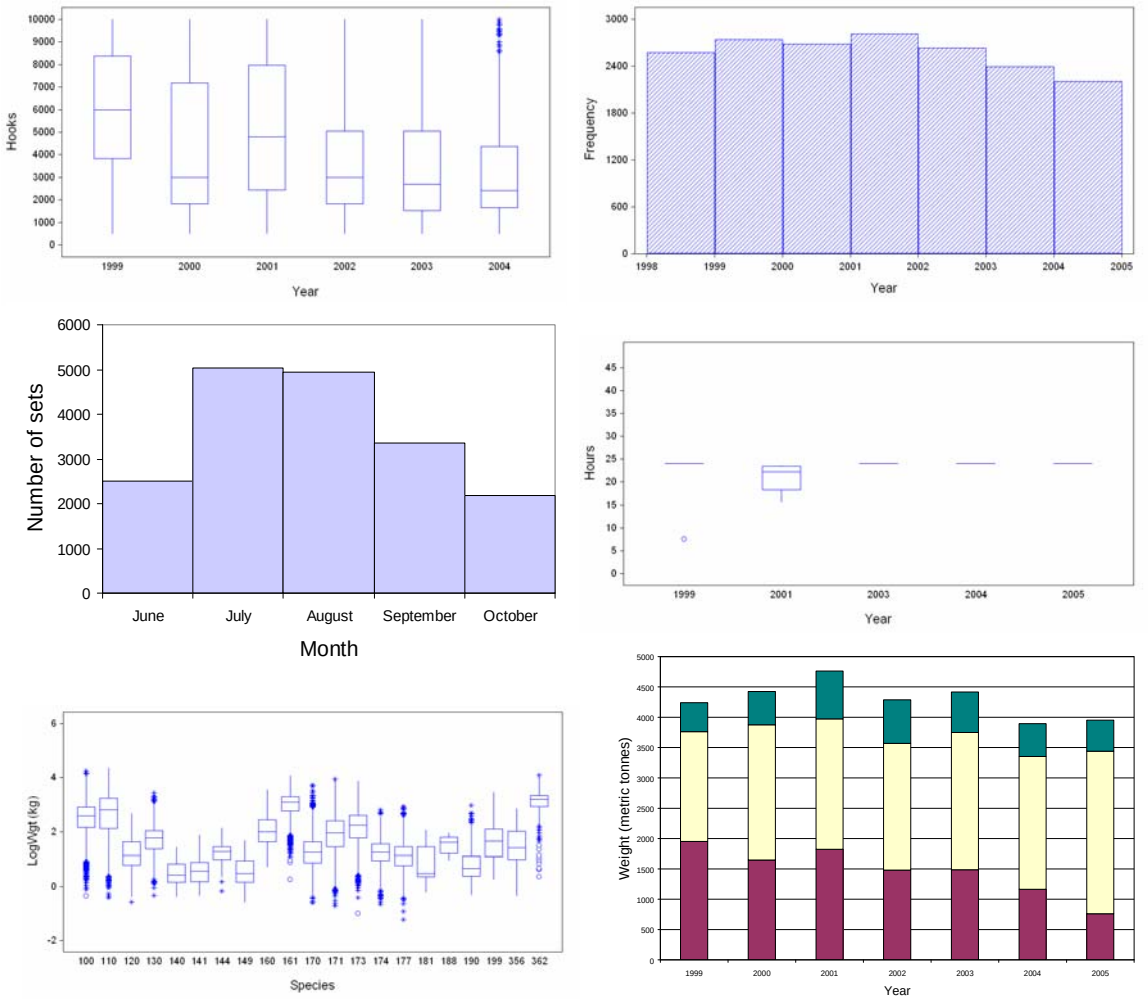

Fig. 11: Descriptive statistics for the groundfish hook and line fishery. Hooks per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom right). Most commonly caught species: cusk (top), haddock (middle), and cod (bottom).

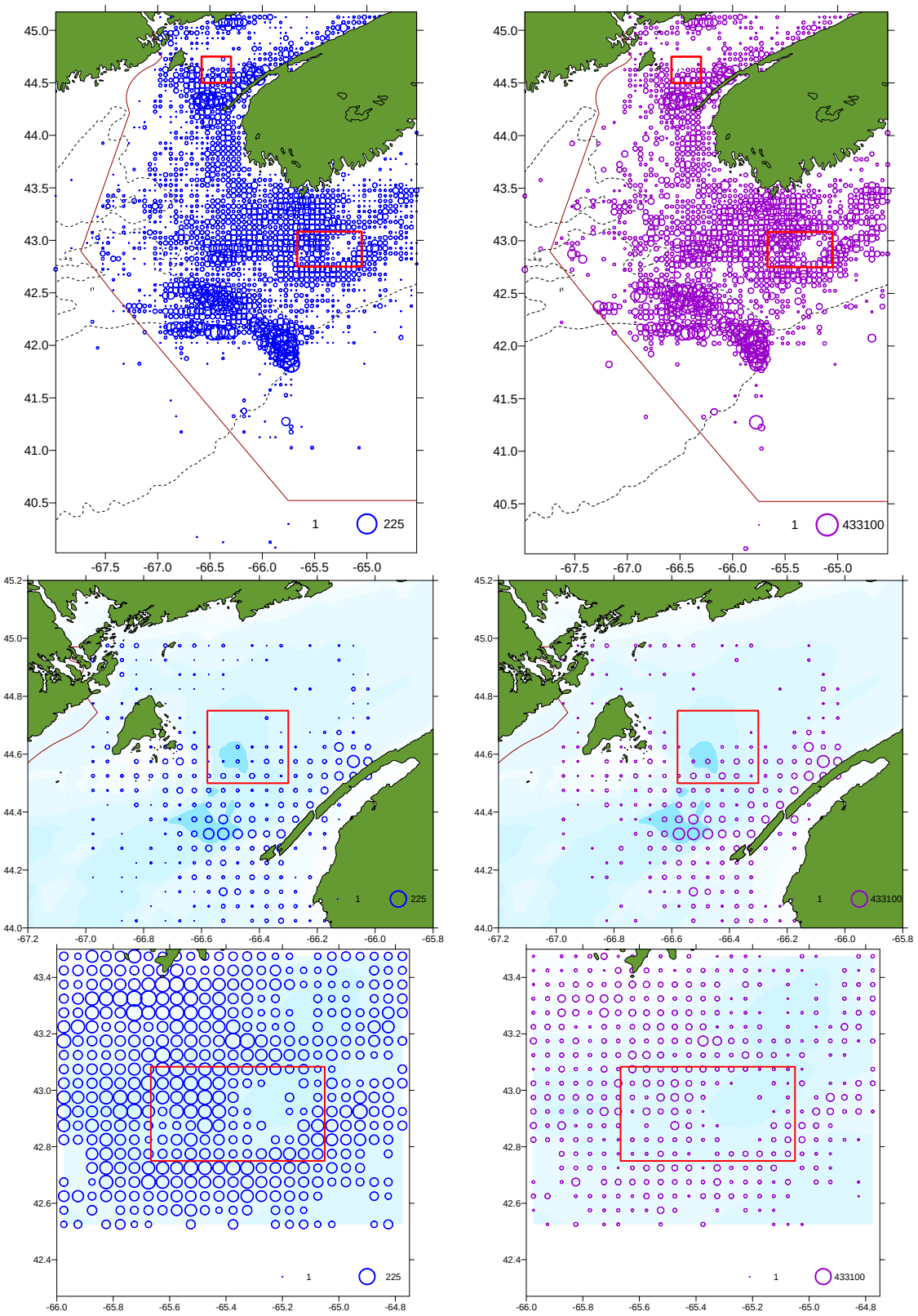

Fig. 12: Frequency distribution analysis of effort in the groundfish hook and line fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and hooks (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom).

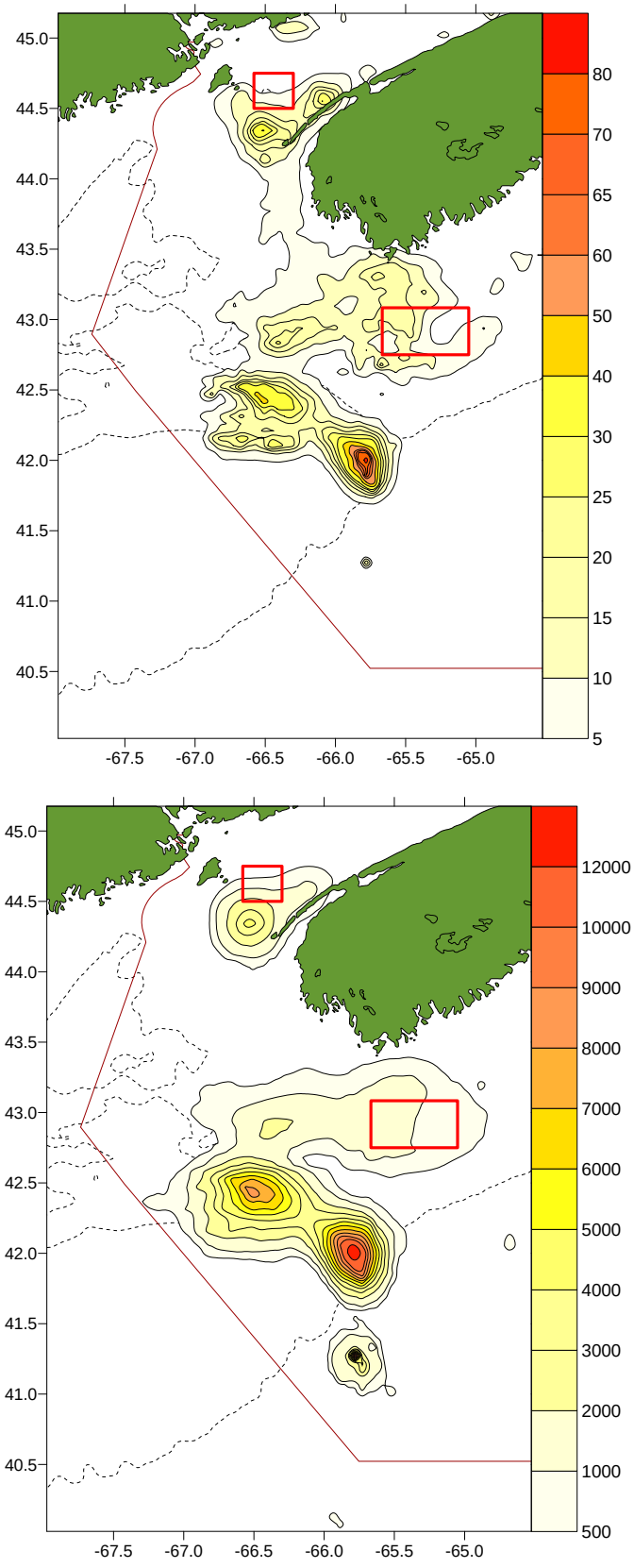

Fig. 13: Contour frequency distribution plots of sets (above) and sets*depth (below) for the groundfish hook and line fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

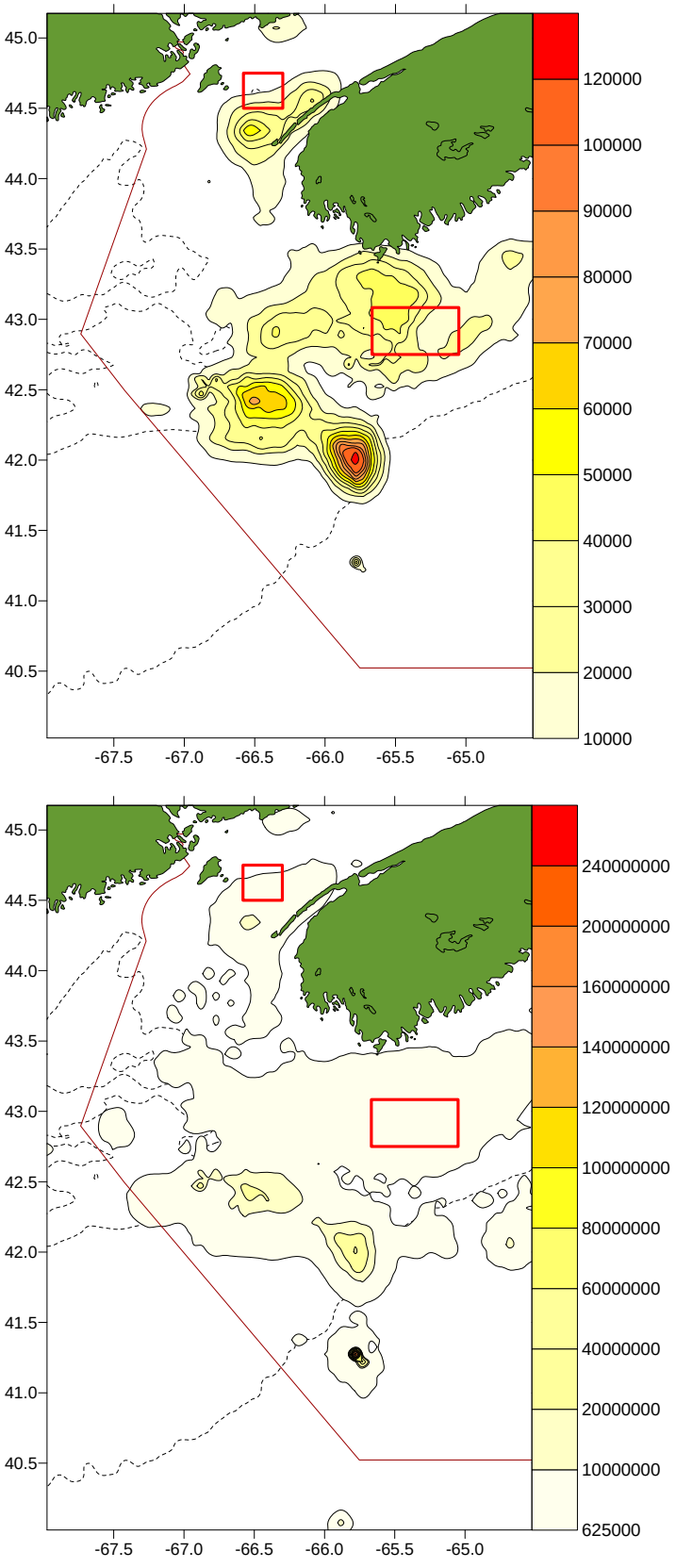

Fig. 14: Contour frequency distribution plots of hooks (above) and hooks*depth (below) for the groundfish hook and line fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

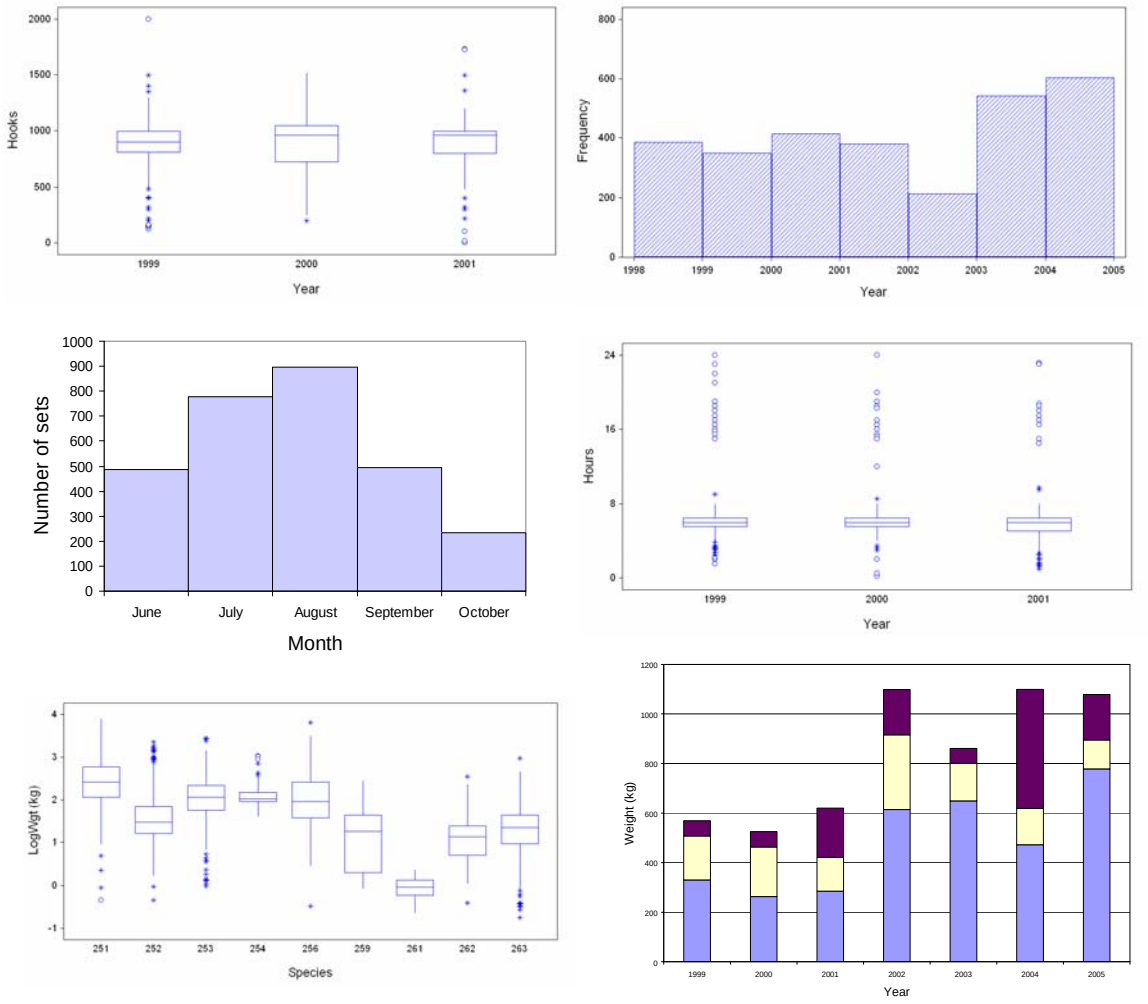

Fig. 15: Descriptive statistics for the pelagics hook and line fishery. Hooks per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom right). Most commonly caught species: yellowfin tuna (top), bigeye tuna (middle), and swordfish (bottom).

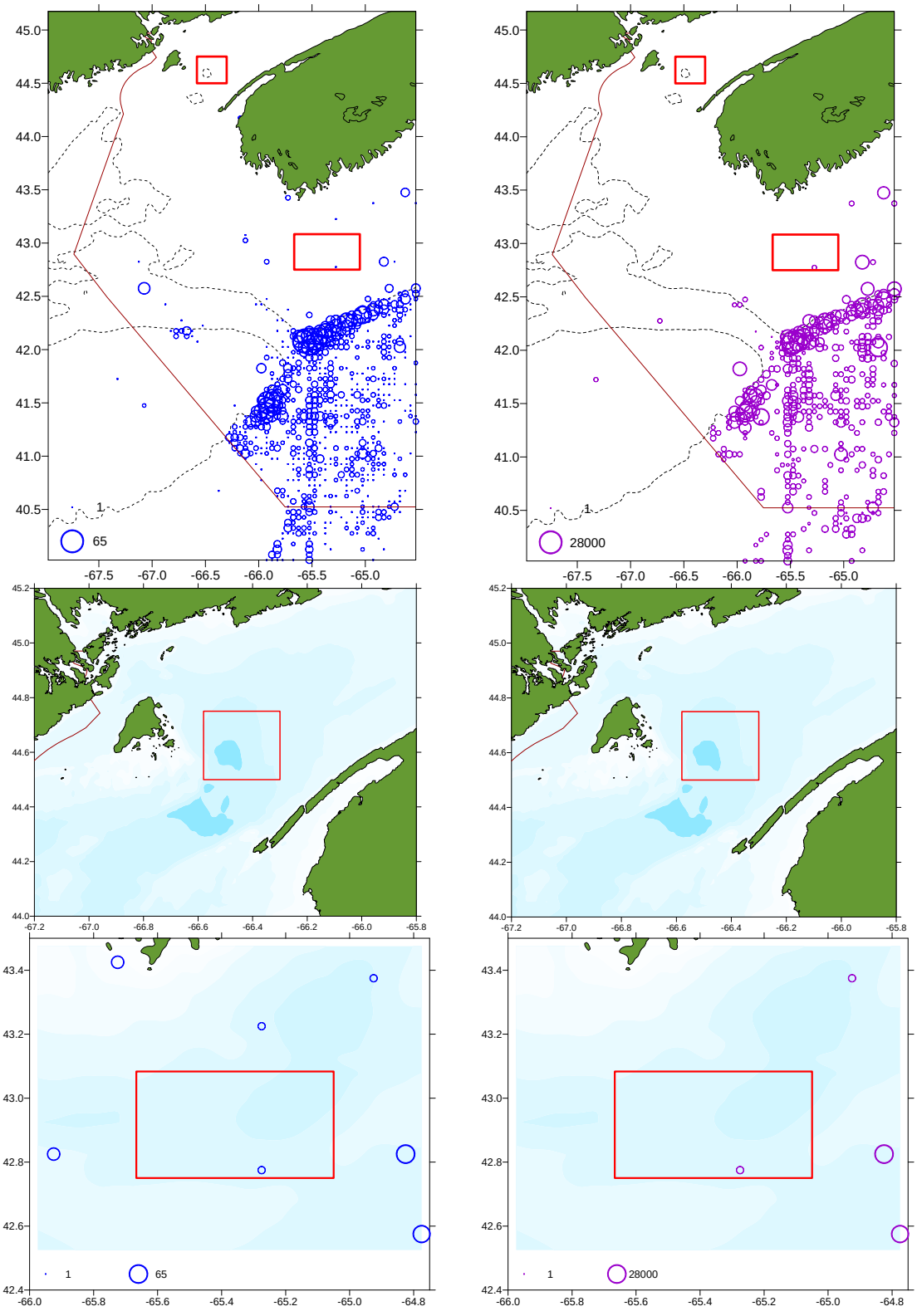

Fig. 16: Frequency distribution analysis of effort in the pelagic hook and line fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and hooks (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom).

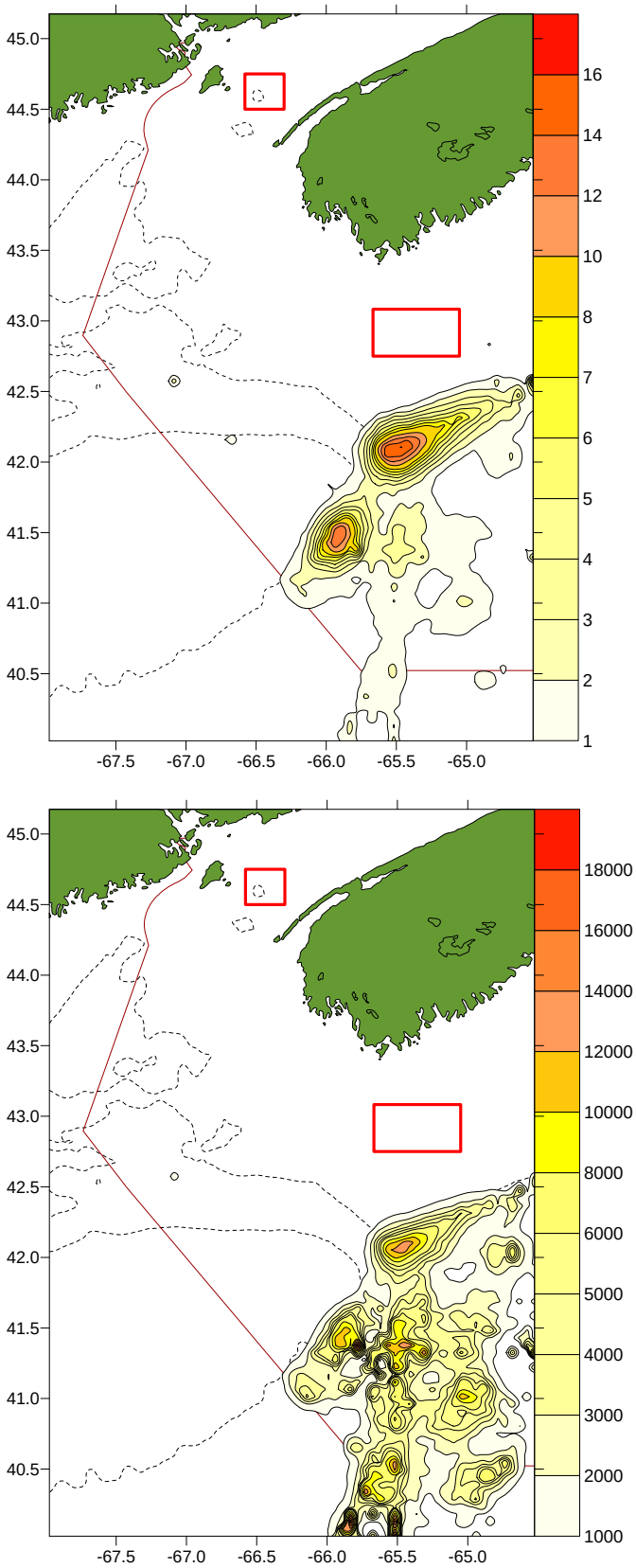

Fig. 17: Contour frequency distribution plots of sets (above) and sets*depth (below) for the pelagics hook and line fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

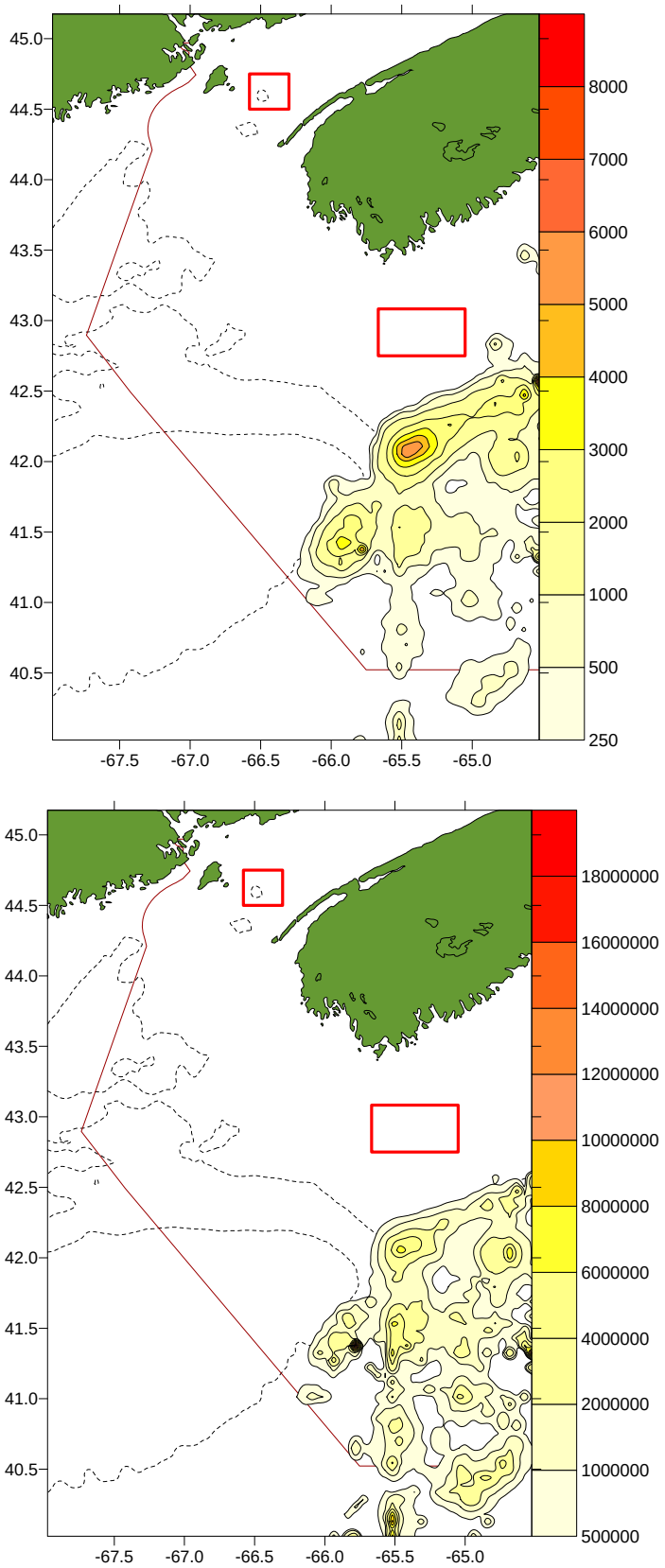

Fig. 18: Contour frequency distribution plots of hooks (above) and hooks*depth (below) for the pelagics hook and line fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

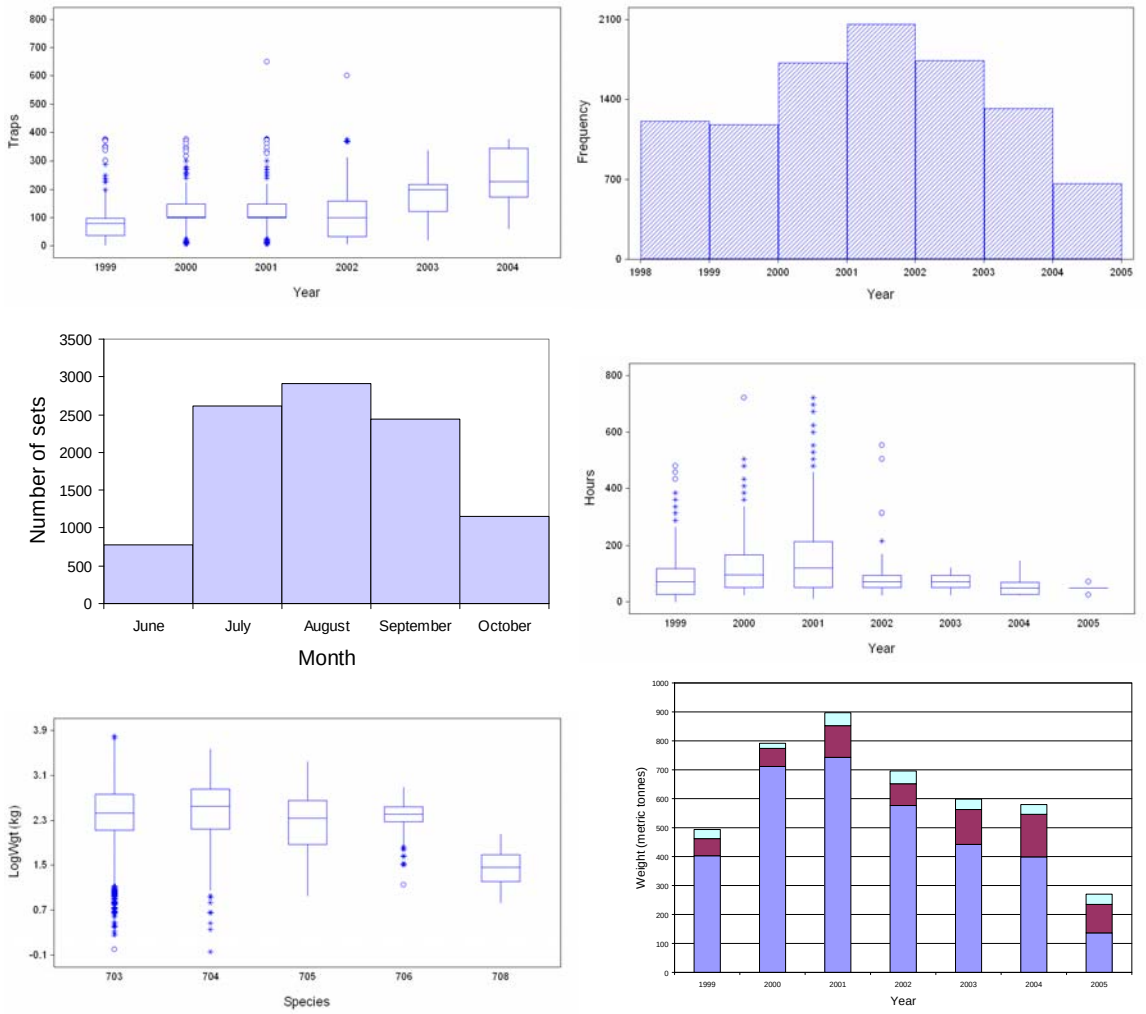

Fig. 19: Descriptive statistics for the crab trap fishery. Traps per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom right). Most commonly caught species: red crag (top), rock crab (middle), and Jonah crab (bottom).

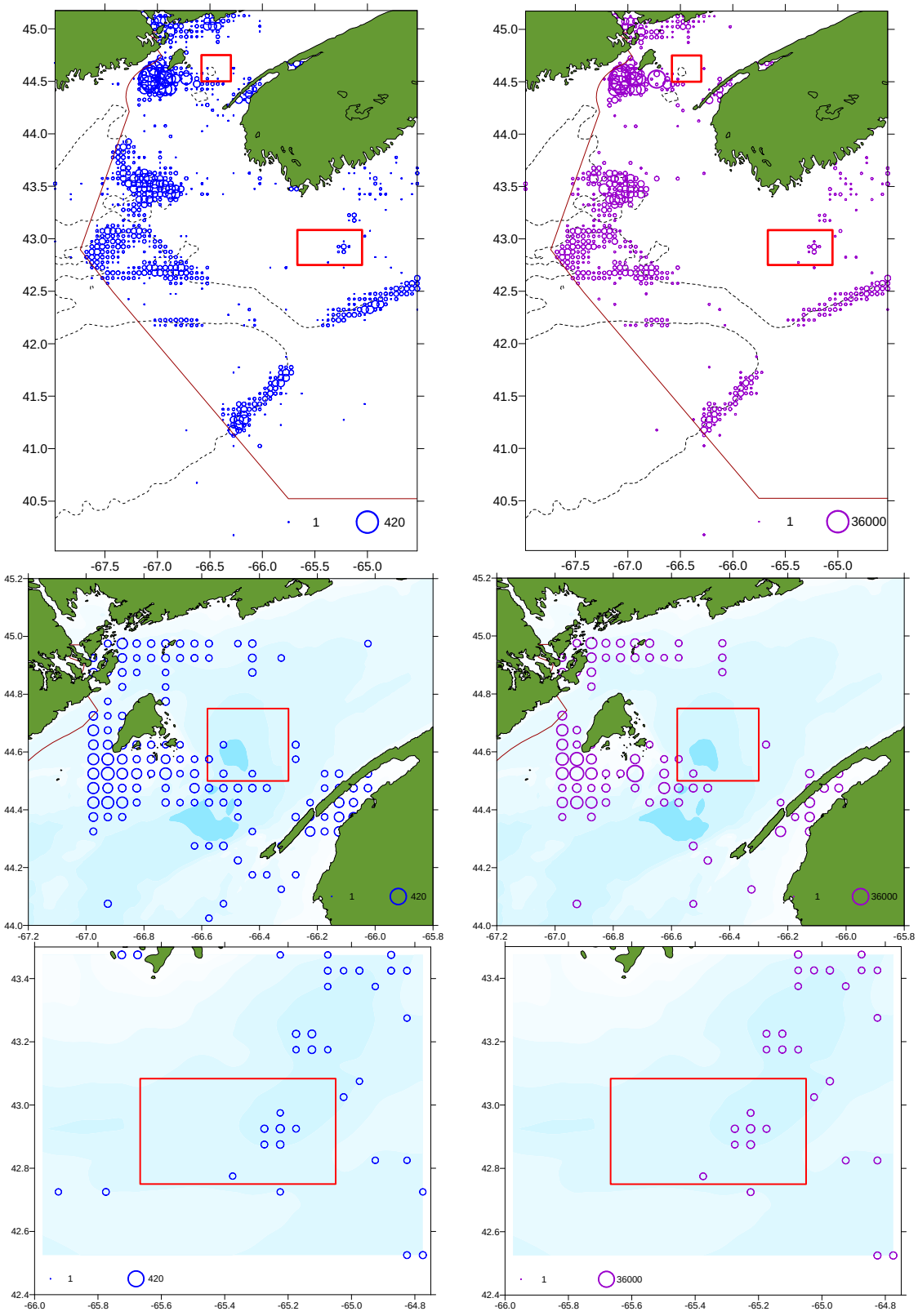

Fig. 20: Frequency distribution analysis of effort in the crab trap fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and traps (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom).

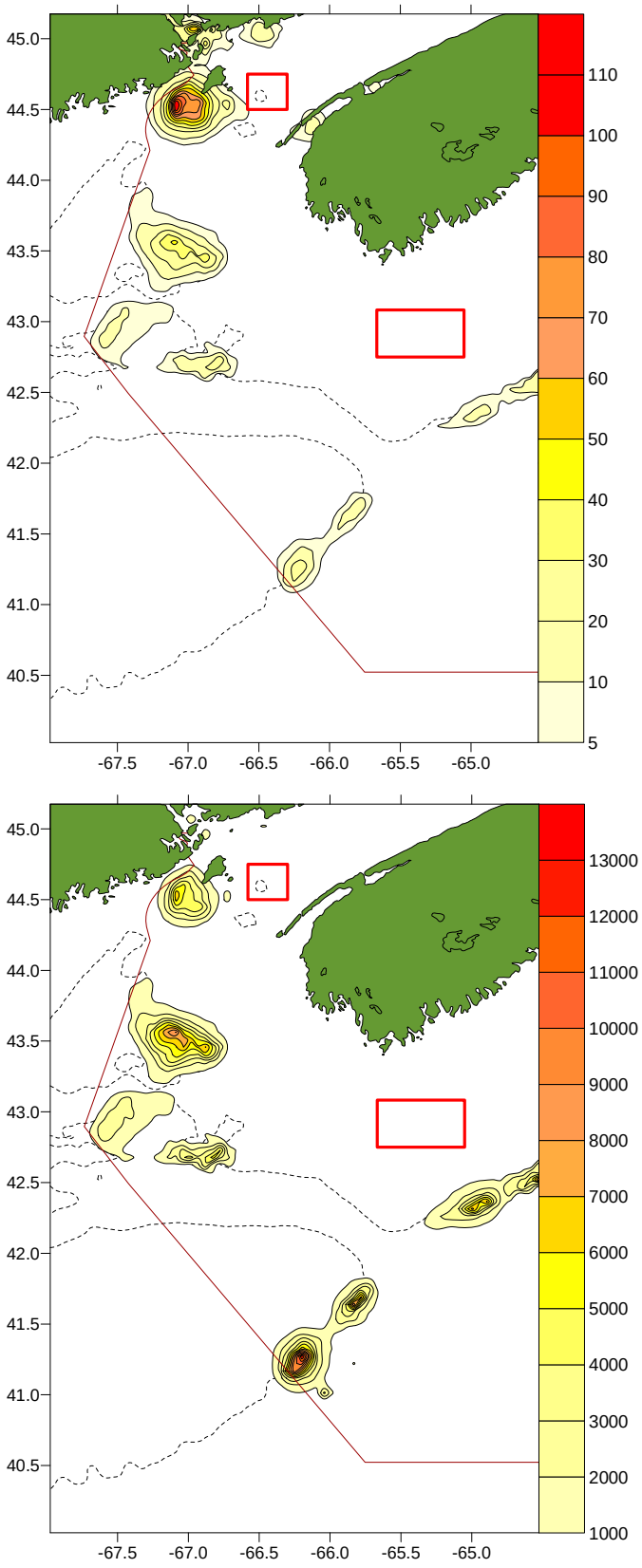

Fig. 21: Contour frequency distribution plots of sets (above) and sets*depth (below) for the crab trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

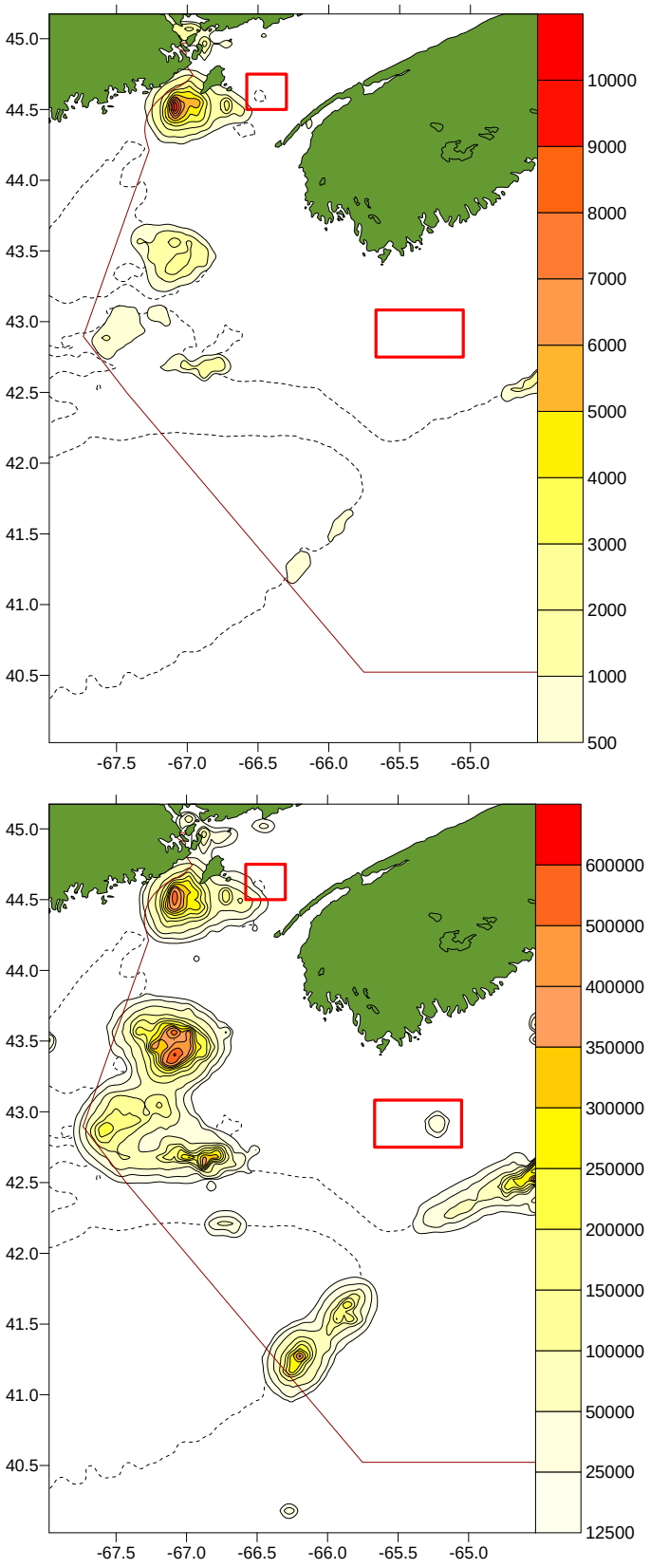

Fig. 22: Contour frequency distribution plots of traps (above) and traps*depth (below) for the crab trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

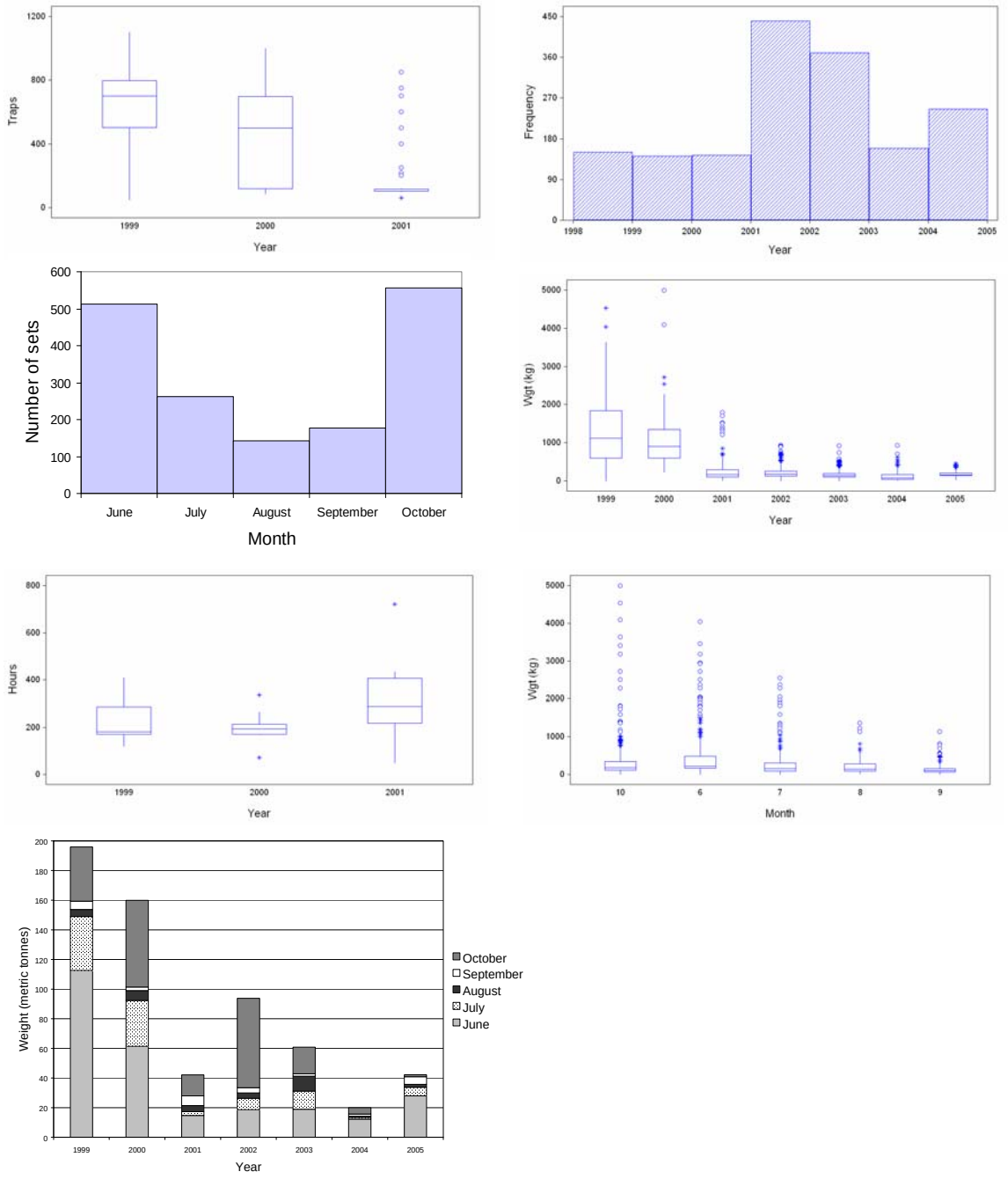

Fig. 23: Descriptive statistics for the lobster trap fishery. Traps per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set by year (mid left), weight per set by month (mid right), total weight per year (bottom left).

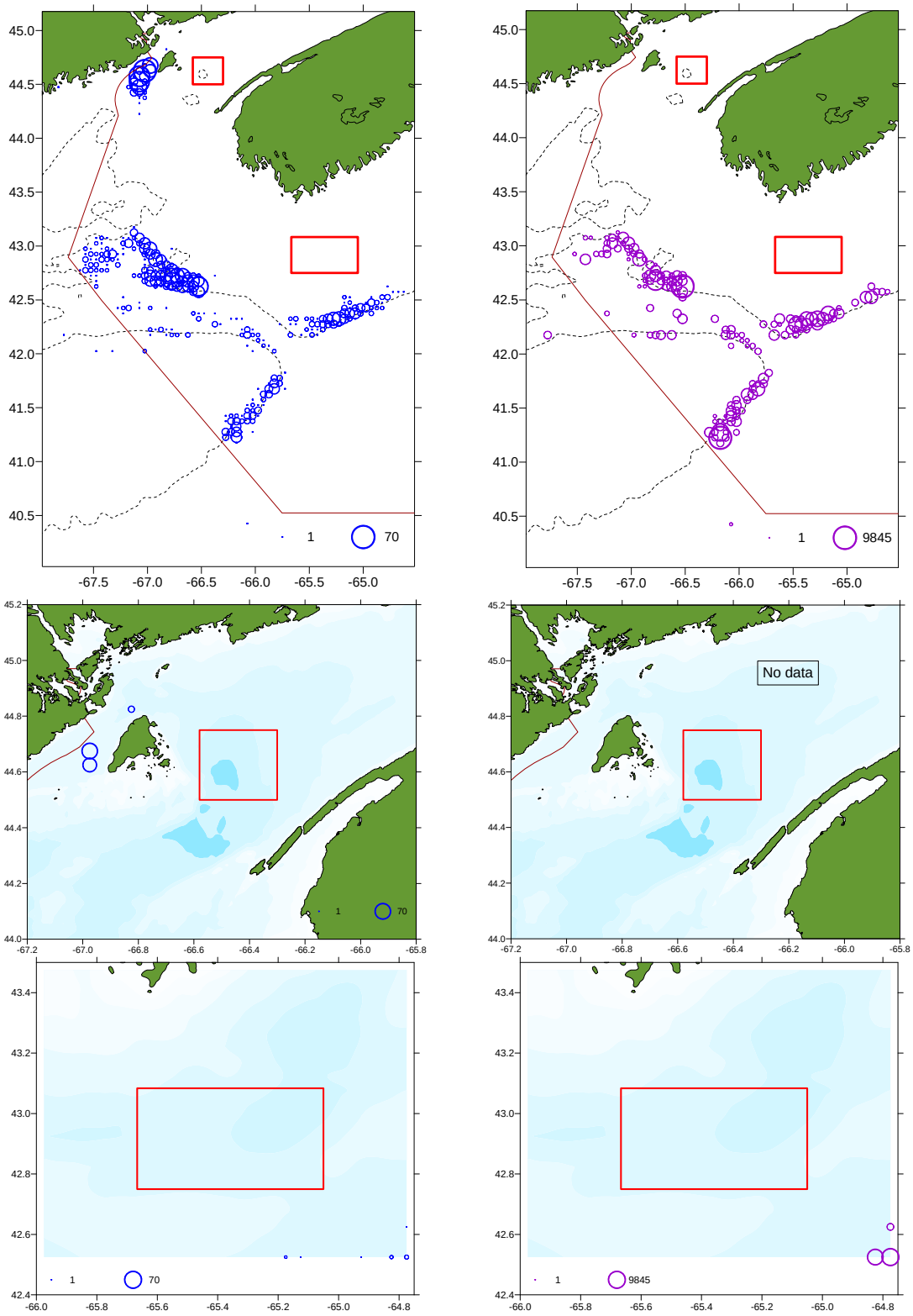

Fig. 24: Frequency distribution analysis of effort in the lobster trap fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and traps (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom). Note that information concerning the number of traps fished is unavailable for the Bay of Fundy region.

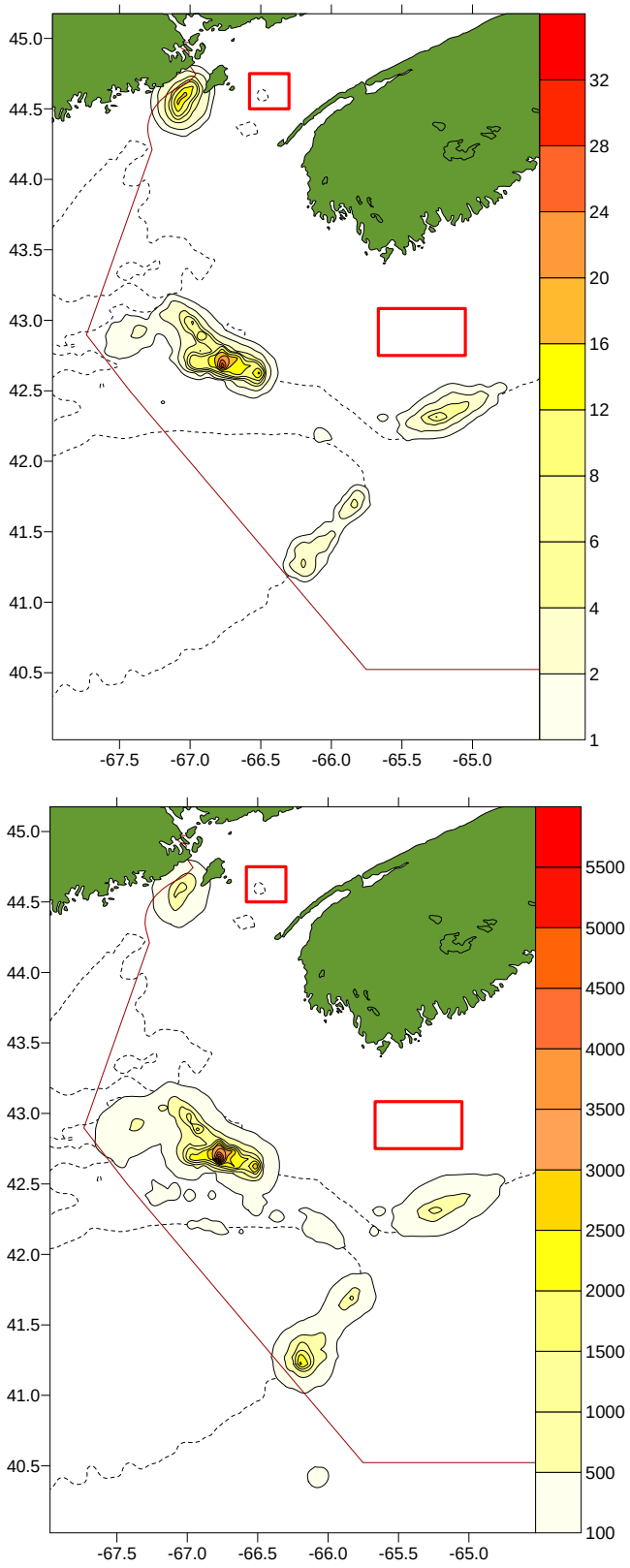

Fig. 25: Contour frequency distribution plots of sets (above) and sets*depth (below) for the lobster trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

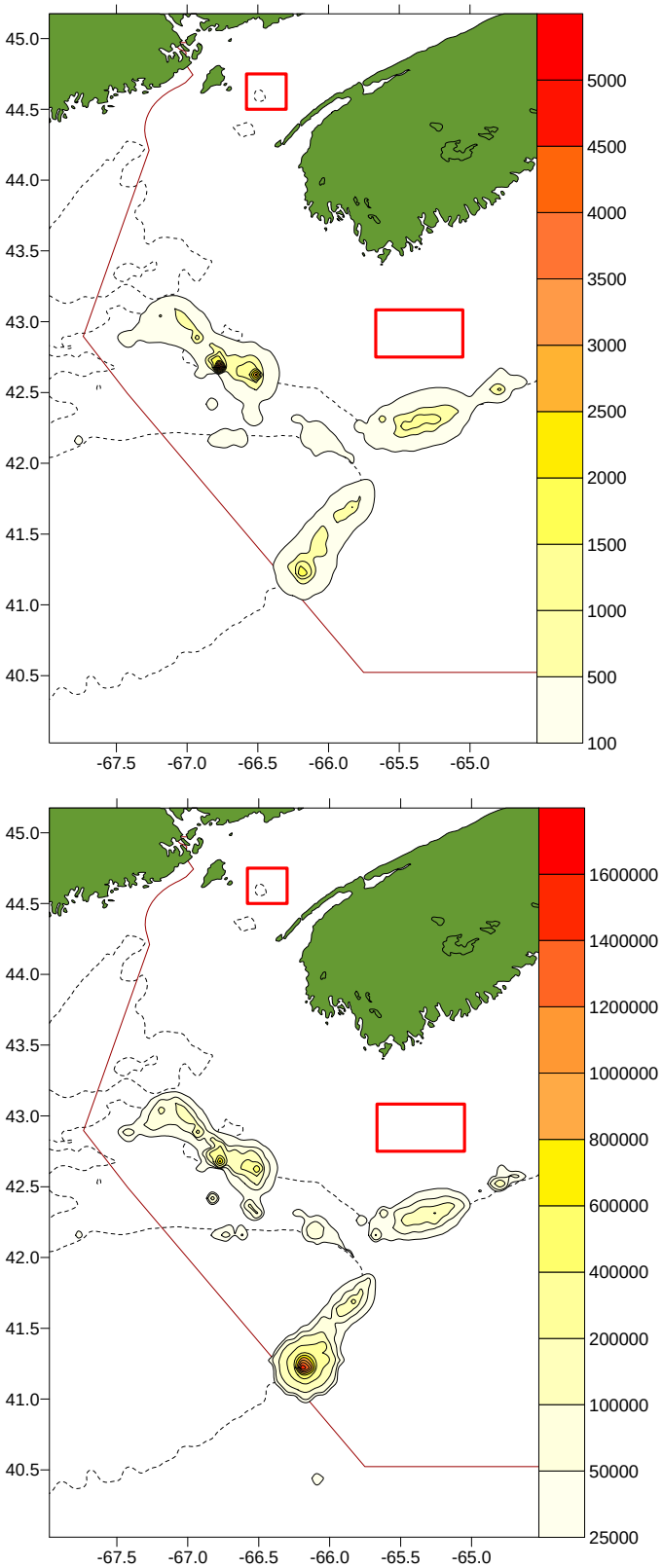

Fig. 26: Contour frequency distribution plots of traps (above) and traps*depth (below) for the lobster trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

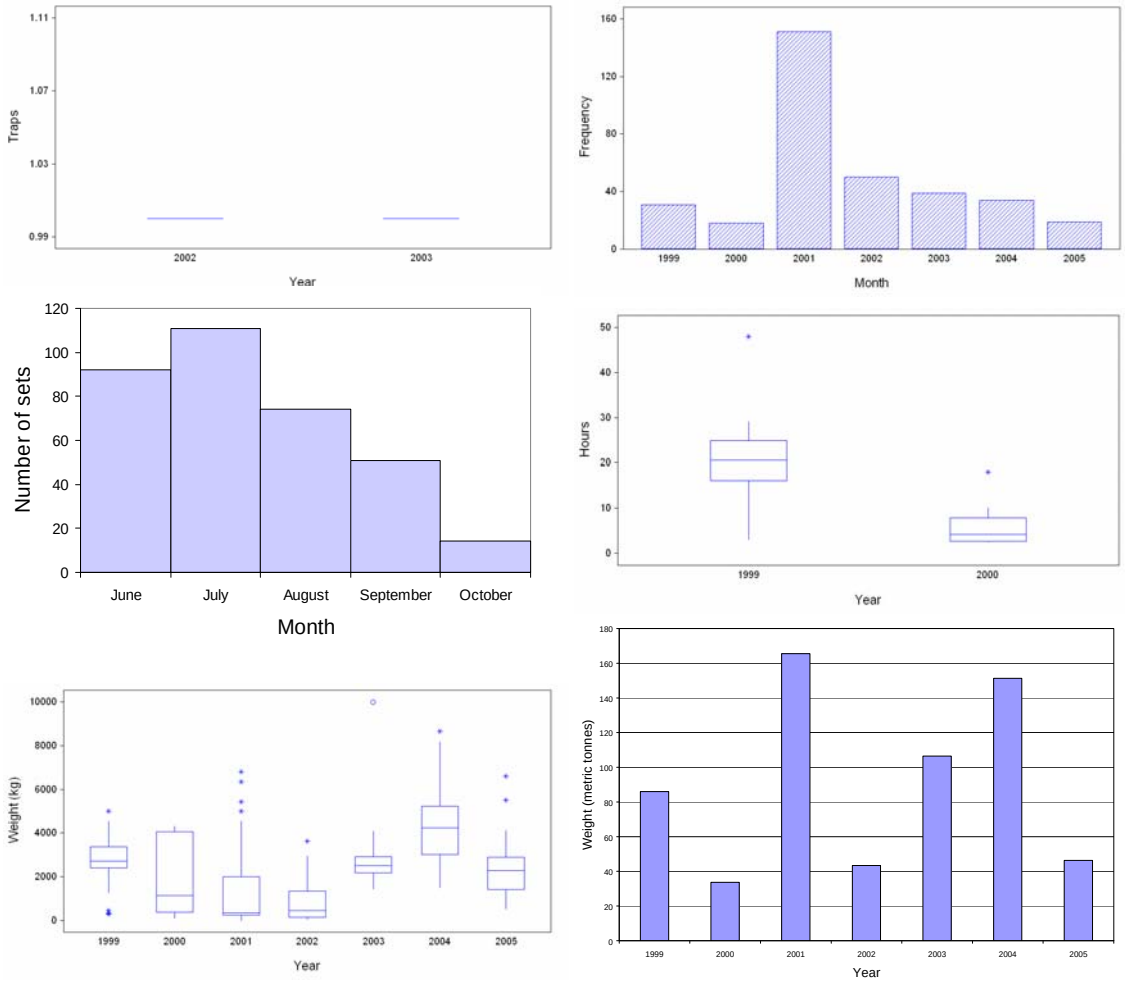

Fig. 27: Descriptive statistics for the hagfish trap fishery. Traps per set (top left), sets per year (top right), sets per month (mid left), h per set (mid right), weight per set (bottom left), total weight per year (bottom left).

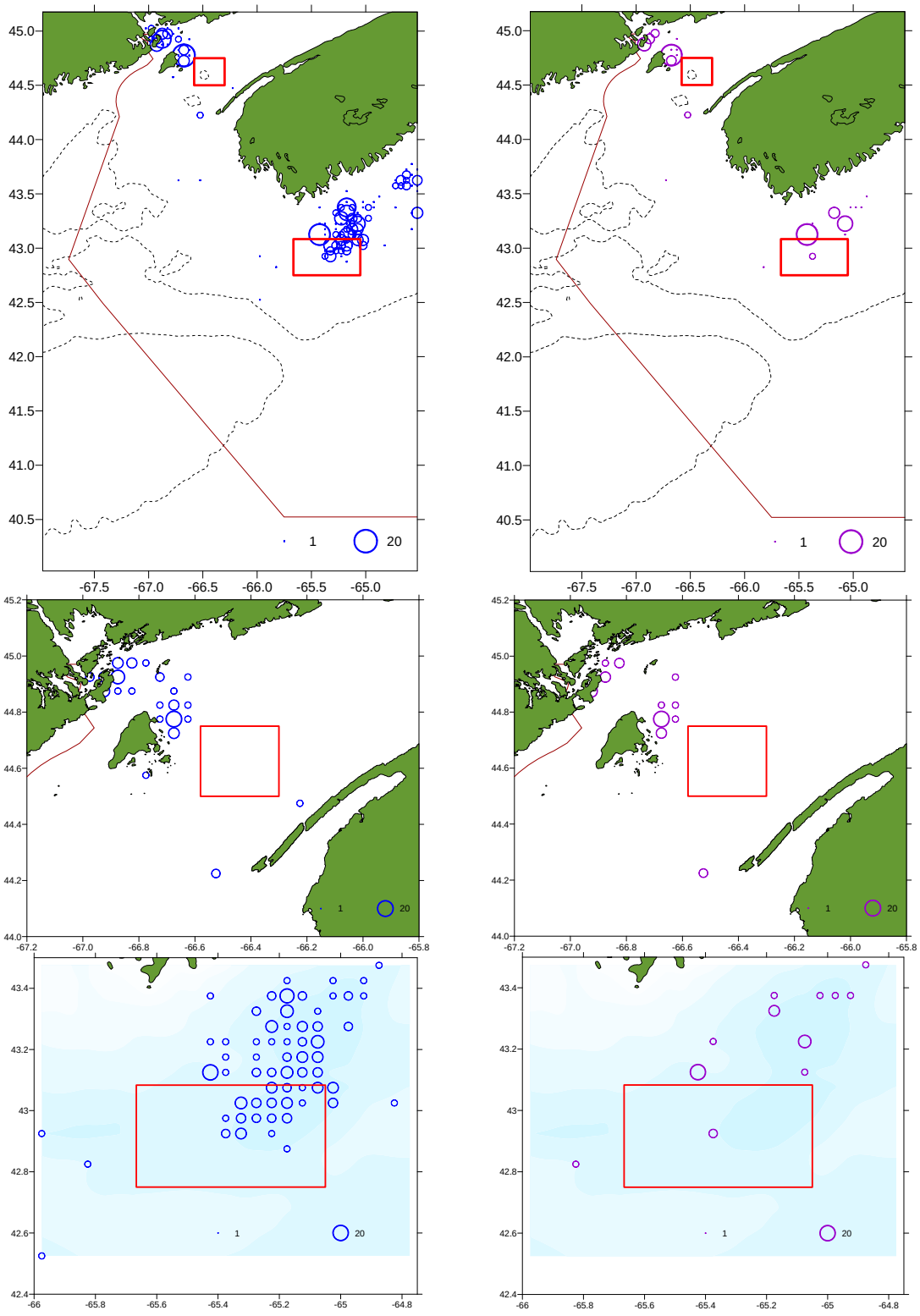

Fig. 28: Frequency distribution analysis of effort in the hagfish trap fishery. Scaled symbol plots (3 minute aggregation) of sets (left) and traps (right) for the entire study area (top), Grand Manan Basin (middle), and Roseway Basin (bottom).

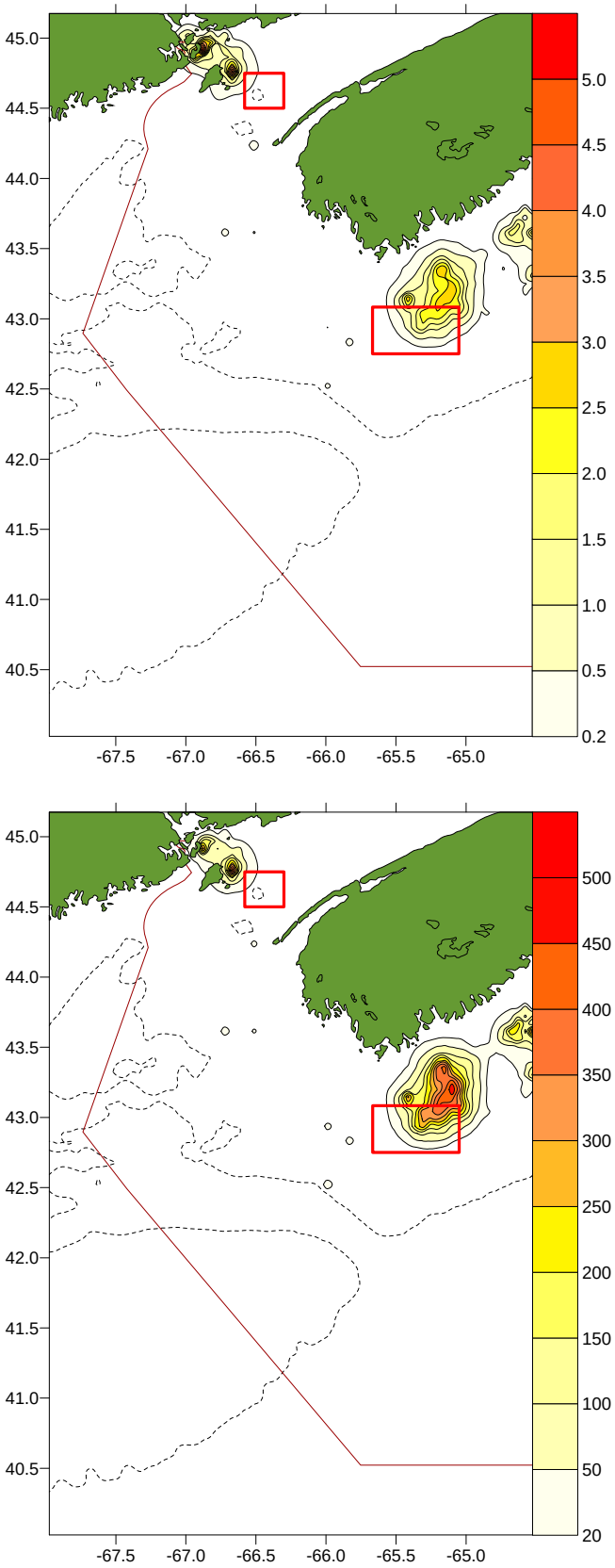

Fig. 29: Contour frequency distribution plots of sets (above) and sets*depth (below) for the hagfish trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

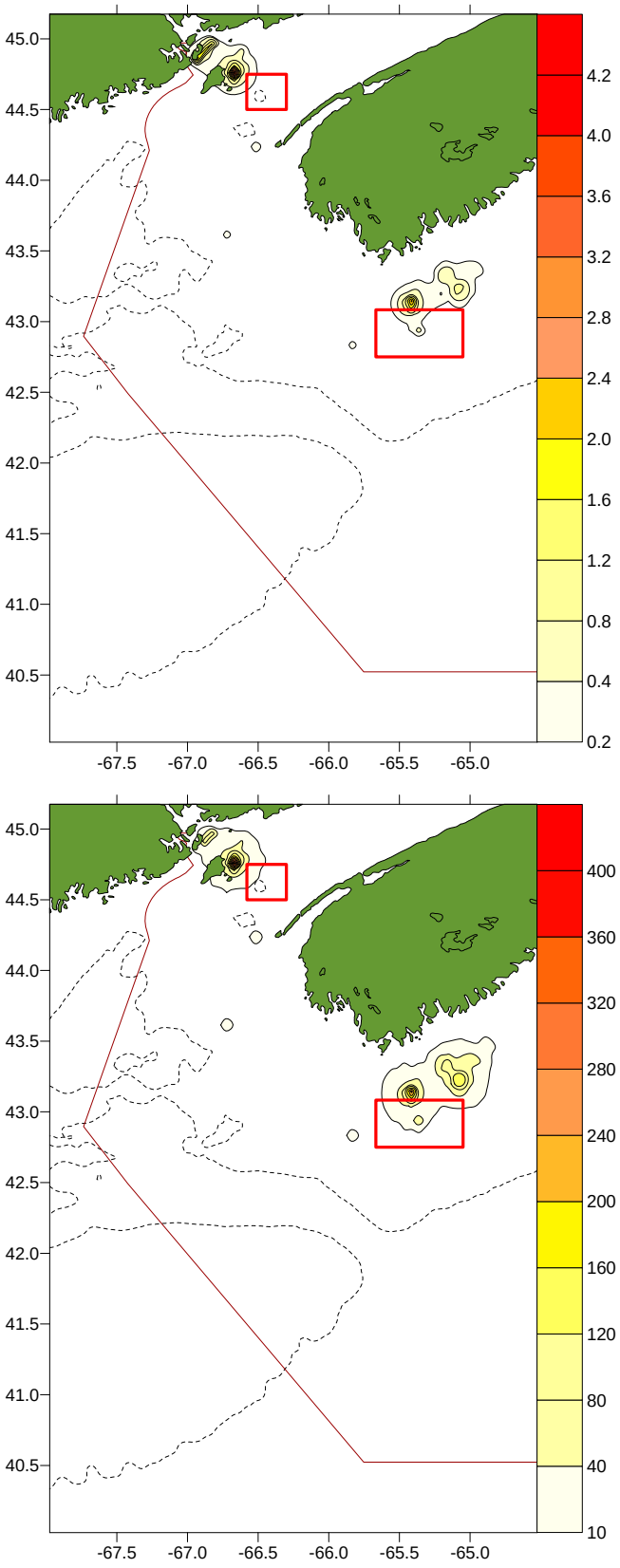

Fig. 30: Contour frequency distribution plots of traps (above) and traps*depth (below) for the hagfish trap fishery from 1999-2005. The dotted line is the 200 m isobath. The solid line is the Exclusive Economic Zone (200 mile limit).

APPENDIX A: EXCLUDED FISHING METHODS

This is a description of the types of fishing practices in use in the Scotia-Fundy region (specifically NAFO divisions 4X, 5Y, and 5ZE).

HOOK AND LINE FISHING

Mobile Trawler Lines

In this fishery 1 to 3 baited lines of approximately 6 m length are deployed. During fishing, the lines are towed behind the vessel. This method targets swordfish and tuna, and is used in an area in 4Xp, 4Xo between Georges Bank and Browns Bank termed the 'hell hole' (S. Smith DFO, St. Andrews, pers. comm.). This is a tended fishery wherein set during is relatively short. Due to the nature of this fishery, it is considered to be of low risk of entanglement for right whales.

Fixed, Baited Handline

In this fishery baited lines are deployed from the vessel. This is an inshore fishery targeting dogfish, groundfish, and mackerel. It is a tended fishery, and is considered to be of low risk for right whale entanglement.

TRAP AND LIFT NET FISHING

In trap fishing, the gear is baited to induce fish to enter, then relies on the gear's effectiveness to prevent fish from escaping (Sainsbury 1986). This gear type is applicable for capturing species that are active predators or scavengers (Sainsbury 1986).

Inshore

Traps are set inshore to catch eel and mackerel, but also smelt and alewife and any other inshore scavenger species (R. Stephenson, DFO, St. Andrews, pers. comm.). This fishery is of minimal risk to right whales.

Weirs

Weirs are constructed from poles and nets that are set in inshore mud, which are configured in such a pattern that fish are drawn inside the net but become too disoriented to escape (MUN 2004). The weir fishery captures herring in 4X. The very shallow depths at which this gear is deployed make it of little consequence to right whale entanglement.

TRAWL FISHING

Large, cone-shaped nets are towed along the ocean. Fish that enter through the mouth of the net are contained at its bag-like base, or cod end (Sainsbury 1986).

The Bottom, Stern Otter Trawl takes its name from the rectangular "otterboards" that are attached to cables between the boat and the net, which serve to keep the mouth of the net horizontally open while the net is making its tow (MUN 2004). Otter trawls are typically towed along the ocean bottom to catch demersal species.

In Bottom Pair Trawling two vessels draw one net along the sea floor. The mouth of the net is kept open by maintaining the relative speed and distance of the vessels (Sainsbury 1986). This method of fishing also targets demersal species.

Midwater Trawling and Shrimp Trawling also occur in 4X, but are very small fisheries.

Trawl fishing is a minimal risk to right whale entanglement, because the gear is tended to while in use and it remains in the water for only a short period of time.

SEINE FISHING

In seine fishing, the gear is used to encircle and capture the fish. Seining is most effective in catching schooling fish (Sainsbury 1986).

In Purse Seining one end of the net is held stationary, while the other end is taken by the vessel, and drawn around to encircle the school (Sainsbury 1986). A wire rope that passes through rings on the bottom of the net is winched to form a bag that entraps the fish (MUN 2004). This fishery is used to capture herring in 4X.

The Danish Seine is generally suited for catching groundfish species (Sainsbury 1986). Nets and ropes are spread out in a pear-shaped form along the ocean floor. The vessel remains in a fixed position while the gear is hauled along the bottom, and the action of the ropes stirs up the substrate and herds the fish into the path of the net (MUN 2004). In 4X, this is a very small fishery that captures monkfish in 4Xm.

Beach Seining involves the use of small handheld nets to encircle shoreline species. It is used to capture herring in 4Xs.

Seine fishing is a minimal risk to right whale entanglement, because the gear is tended to while in use and it remains in the water for only a short period of time.

OTHER FISHING METHODS

Other fishing methods that take place in 4X, 5Y, 5ZE include Harpooning and Dredging. Both fisheries are small in the areas of our concern, and are of little risk to right whales.

REFERENCE

Sainsbury, J.C. 1986. Commercial Fishing Methods: an introduction to vessels and gears. 2nd edition. Fishing News Books Ltd, Farnham, Surrey, England. 207 pp.