Vineyard Wind Demersal Trawl Survey

Quarterly Report

Spring 2019 (April - June)

501 North Study Area

VINEYARD WIND DEMERSAL TRAWL SURVEY

Spring 2019 Seasonal Report

501 North Study Area

February 2020

Prepared for Vineyard Wind, LLC

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Vineyard Wind Demersal Trawl Survey Spring 2019 Seasonal Report

501 North Study Area

Progress Report #1

April 1 – June 30, 2019

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1. Introduction

In 2015, Vineyard Wind LLC leased a 675 km^2 area for renewable energy development on the Outer Continental Shelf, Lease Area OCS-A 0501, located approximately 14 miles south of Martha's Vineyard off the south coast of Massachusetts. Vineyard Wind is developing the northern portion of Lease Area OCS-A 0501 and fisheries studies are being conducted in a 250 km^2 area referred to as the "501 North (501N) Study Area," which is the focus of this report. Vineyard Wind is also conducting fisheries studies within the southern portion of Lease Area OCS-A 0501 (the "501 South Study Area") and within Lease Area OCS-A 0522 (the "522 Study Area"); these studies are reported separately.

The Bureau of Ocean Energy Management (BOEM) has statutory obligations under the National Environmental Policy Act (NEPA) to evaluate environmental, social and economic impacts of a potential project. Additionally, BOEM has statutory obligations under the Outer Continental Shelf Lands Act to ensure any on-lease activities "protect the environment, conserve natural resources, prevent interference with reasonable use of the U.S. Exclusive Economic Zone, and consider the use of the sea as a fishery."

To address the potential impacts, Vineyard Wind LLC, in collaboration with the University of Massachusetts Dartmouth's School for Marine Science and Technology (SMAST), has developed a monitoring plan to assess the potential environmental impacts of the proposed development. The impact of the development will be evaluated using the Before-After-Control-Impact (BACI) framework. This framework is commonly used to assess the environmental impact of an activity (i.e. wind farm development and operation). Under this framework, monitoring will occur prior to development (Before), and then during construction and operation (After). During these periods, changes in the ecosystem will be compared between the development site (Impact) and a control site (Control). The control site will be in the general vicinity with similar characteristics to the impact areas (i.e. depth, habitat type, seabed characteristics, etc.). The goal of the monitoring plan is to assess the impact that wind farm construction and operation has on the ecosystem within an everchanging ocean.

The current monitoring plan incorporates multiple surveys utilizing a range of survey methods to assess different facets of the regional ecology. The trawl survey is one component of the overall survey plan. A demersal otter trawl, further referred to as a trawl, is a net that is towed behind the vessel along the seafloor expanded horizontally by a pair of otter boards or trawl doors

(Figure 1). Trawls tend to be relatively indiscriminate in the fish and invertebrates they collect; hence trawls are a general tool for assessing the biological communities along the seafloor and are widely used by institutions worldwide for ecological monitoring. Since they are actively towed behind a vessel, they are less biased by fish activity and behavior like passive fishing gear (i.e. gillnets, longlines, traps, etc.), which rely on animals moving to the gear. As such, state and federal fisheries management agencies heavily rely on trawl surveys to evaluate ecosystem changes and to assess fishery resources. The current trawl survey closely emulates the Northeast Area Monitoring and Assessment Program (NEAMAP) survey protocol. In doing so, the goal was to ensure compatibility with other regional surveys, including the National Marine Fisheries Service (NMFS) annual spring and fall trawl survey, the annual NEAMAP spring and fall trawl survey, and state trawl surveys including the Massachusetts Division of Marine Fisheries (MADMF) trawl survey. The primary goal of this survey was to provide data related to fish abundance, distribution, and population structure in and around the Vineyard Wind's 501N Study Area. The data will serve as a baseline to be used in a future analysis under the Before-After-Control-Impact (BACI) framework. This progress report documents survey methodology, survey effort, and data collected during Spring 2019. This is the first season of the study.

2. Methodology

The methodology for the survey was adapted from the Atlantic States Marine Fisheries Commission's (ASMFC) NEAMAP nearshore trawl survey. Initiated in 2006, NEAMAP conducts annual spring and fall trawl surveys from Cape Hatteras to Cape Cod. The NEAMAP protocol has gone through extensive peer review and is currently implemented near the Lease Area using a commercial fishing vessel (Bonzek et al., 2008). The current NEAMAP protocol samples at a resolution of ~100 sq. kilometers, which is inadequate to provide scientific information related to potential changes on a smaller scale. Adapting existing methods with increased resolution (see Section 2.1) will enable the survey to fulfill the primary goal of evaluating the impact of windfarm development while improving the consistency between survey platforms, which should facilitate easier sharing and integration of the data with state and federal agencies and allow the data from this survey to be incorporated into existing datasets to enhance our understanding of the region's ecosystem dynamics. Additionally, this methodology is consistent with other ongoing surveys of nearby study areas (Vineyard Wind's 501S and 522 Study Area).

2.1 Survey Design

The current survey is designed to provide baseline data on catch rates, population structure, and community structure for a future environmental assessment using the BACI framework as recommended by BOEM (BOEM, 2013). Tow locations within the Vineyard Wind 501N Study Area were selected using a systematic random sampling design. The 501N Study Area (249.3 km^2) was sub-divided into 20 sub-areas (each ~12.5 km^2), and one trawl tow was made in each of the 20 sub-areas. This was designed to ensure adequate spatial coverage throughout the survey area. The starting location within each area was randomly selected (Figure 2).

An area located to the east of the 501N Study Area was established as a control region (306 km^2). The selected region has similar depth contours, bottom types, and benthic habitats to the 501N Study Area. An additional 20 tows were completed in the Control Area. Tow locations were selected in the same manner as the 501N Study Area.

The selection of 20 tows in each area was based on a preliminary power analysis conducted using catch data from a scoping survey (Stokesbury and Lowery, 2018). The results indicated that 20 tows within the 501N Study Area and a similar number in the Control Area would allow for a 95% chance of detecting a 25% change in the population of the most abundant species (i.e. scup, butterfish, silver hake, and summer flounder). When distributing the survey effort, randomly selecting multiple tow locations across the Study Area and Control Area accounts for spatial variations in fish populations. Alternatively, multiple tows could be sampled from a single tow track, which would assume that the tow track is representative of the larger ecosystem. The distributed approach, applied here, assumed that the catch characteristics across each area represents the ecosystem. Additionally, surveying each site seasonally accounts for temporal variations in fish populations. Accounting for spatial and temporal variations in fish assemblages reduces the assumptions of the population dynamics while increasing the power to detect changes due to the impacting activities. This methodology is commonly referred to in the scientific literature as the "beyond-BACI" approach (Underwood, 1991)

The survey will have a sampling density of 1 station per 12.5 km^2 (3.6 sq. nautical miles) in the 501N Study Area and 1 station per 15.3 km^2 (4.5 sq. nautical miles) in the Control Area. As previously mentioned, the NEAMAP nearshore survey samples at a density of one station per ~100 km^2 (30 sq. nautical miles).

2.2 Trawl Net

To ensure standardization and compatibility between these surveys and ongoing regional surveys and to take advantage of the well-established survey protocol, the otter trawl has an identical design to the trawl used for the NEAMAP surveys, including otter boards, ground cables and sweeps. This trawl was designed by the Mid-Atlantic and New England Fisheries Management Council's Trawl Advisory Panel (NTAP). As a result, the net design has been accepted by management authorities, the scientific community, and the commercial fishing industry in the region.

The survey trawl is a three-bridle four-seam bottom trawl (Figure 3). This net style allows for a high vertical opening (~5 m., 16.5 ft.) relative to the size of the net and consistent trawl geometry. These features make it a suitable net to sample a wide diversity of species with varying life history characteristics (i.e. demersal, pelagic, benthic, etc.). To effectively capture benthic organisms, a "flat sweep" was used (Figure 4). A "flat sweep" contains tightly packed rubber disk and lead weights, which ensures close contact with the substrate and minimizes the escape of fish under the net. This is permissible due to the soft bottom (i.e. sand, mud) in the survey area. To ensure the retention of small individuals, a 1" mesh size knotless liner was used within a 12 cm diamond mesh codend. Thyboron Type IV 66" trawl doors were used to horizontally open the net. The trawl doors were connected to the trawl by a series of steel wire bridles. See Figures 5 and 6 for a diagram of the trawl's rigging during the surveys. For a detailed description of the trawl design see Bonsek et al. (2008).

2.3 Trawl Geometry and Acoustic Monitoring Equipment

To ensure standardization between tows, the net geometry was required to be within pre-specified tolerances (±10%) for each of the geometry metrics (i.e. door spread, wing spread, and headline height). These metrics were developed by the NTAP and are part of the operational criteria in the NEAMAP survey protocol. Headline height was targeted to be between 5.0 and 5.5 m with acceptable deviations between 4.5 and 6.1 m. Wingspread was targeted between 13.0 and 14.0 meters (acceptable range: 11.7 – 15.4 m). Door spread was targeted between 32.0 and 33.0 meters (acceptable range: 28.8 – 37.4 m).

The Notus TrawlMaster net mensuration system (Notus Electronics, St. John's, Newfoundland, Canada) was used to monitor the net geometry. Two sensors were placed on the doors, one on each, to measure the distance between the doors, referred to as door spread. Two sensors placed on the sides of the net (center wingends) measured the horizontal spread of the net, commonly referred to as the wingspread. One sensor with a sonar transducer was placed on the top of the net (headrope) to measure the vertical net opening, referred to as headline height. A hydrophone mounted in the hull of the vessel was used to receive the acoustic signals from the net sensors. All sensor data was plotted and saved on a laptop located in the wheelhouse.

2.4 Survey Operations

The survey was conducted on F/V *Guardian*, an 80' stern trawler operating out of Boston, MA. F/V *Guardian* is a commercial groundfish vessel currently operating in the industry. All planned tows were completed during two seven-day trips to the survey area (Trip 1: June 10 – 16, 2019; Trip 2: June 22 – 28, 2019).

Surveys were alternated daily between the Control Area and 501N Study Area. Tows were only conducted during daylight hours. All tows started at least 30 minutes after sunrise and ended 30 minutes before sunset. This was intended to reduce the variability commonly observed during crepuscular periods. Tow duration was 20 minutes at a target tow speed of 3.0 knots (range: 2.8-3.2 knots). Timing of the tow duration was initiated when the wire drums were locked and ended at the beginning of the haulback (i.e. net retrieval). The trawl was towed behind the fishing vessel from steel wires, commonly referred to as trawl warp. Trawl warp was set at a ~5:1 wire to depth ratio in 25 fathom increments. In addition to monitoring the net geometry to ensure acceptable performance (as described in Section 2.3 above), the following environmental and operational data were collected:

- Cloud cover (i.e. clear, partly cloudy, overcast, fog, etc.)
- Wind speed (Beaufort scale)
- Wind direction
- Sea state (Douglas Sea Scale)
- Start and end position (Latitude and Longitude)
- Start and end depth
- Tow speed
- Bottom temperature

Tow paths and tow speed were continuously logged using the OpenCPN charting software (opencpn.org) running on a computer with a USB GPS unit (GlobalSat BU-353-S4).

2.5 Catch Processing

The catch from each tow was sorted by species. Aggregated weight from each species was weighed on a motion-compensated scale (M1100, Marel Corp., Gardabaer, Iceland). Individual fish length (to the nearest centimeter [cm]) and weight (to the nearest gram) were collected. Efforts were made to process all animals; however, during large catches sub-sampling was used for some abundant species. One of two sub-sampling strategies was employed during a tow: straight subsampling by weight, or mixed subsampling by weight.

> Straight subsampling by weight: When catch diversity was relatively low (5-10 species) straight sub-sampling was used. In this method the catch was sorted by species. An aggregated species weight was measured and then a sub-sample (50-100 individuals) was made for individual length and weight measurements. The ratio of the sub-sample weight to the total species weight was then used to extrapolate the length-frequency estimates. This was the predominate sub-sampling strategy employed during this survey.
>
> Mixed subsampling by weight: When catch diversity was high (10+ species) a mixed-subsampling strategy was used. With this strategy the catch of some large animals/species was "pre-sorted" to isolate these species and these individual species were measured separately. Subsequently, the unsorted catch, which usually contained smaller species, was placed into baskets and an aggregated tow weight was measured. A sub-sample from these baskets was sorted, and the relative proportions of each constituent species was used to extrapolate the total species weight from the unsorted catch. Individual lengths and weights of species were then collected. This sub-sampling strategy was used during several tows when the catch of silver hake, red hake, squid, and butterfish was high.

Lengths were collected during every tow. Individual fish weights were collected during every tow for low abundance species (<20 individuals/tow) or during alternating tows for abundant common species (>20 individuals/tow). The result from each tow was a measurement of aggregated weight, length-frequency curves, and length-weight curves for each species except dogfish, skates, crabs, lobsters, and some non-commercial species. For these species, aggregated weight and counts were collected. Collection of squid eggs were documented. All data was manually recorded and entered into a Microsoft Access database.

3. Results

3.1 Operational Data, Environmental Data and Trawl Performance

Twenty tows were successfully completed in both the 501N Study Area and the Control Area (Figure 2, Table 1). Operational parameters were similar between these two areas (Table 2). Tow durations averaged 20.7 ± 0.9 minutes (mean ± one standard error [SEM]) in the 501N Study Area and 20.9 ± 1.1 minutes in the Control Area. Tow distances averaged 0.99 ± 0.04 nautical miles in the 501N Study Area giving an average tow speed of 2.9 ± 0.1 knots. Similarly tow distance averaged 0.99 ± 0.06 nautical miles in the Control Area giving an average tow speed of 2.9 ± 0.1 knots.

The seafloor in both areas follows a northeast to southwest depth gradient with the shallowest tow along the northeast edge (~35 meters). Depth increased to a maximum of 50 meters along the southwest boundary. Bottom water temperature followed a similar gradient with warmer water observed during shallow tows (11.2^{o}C at 35 m) and colder water during deeper tows (8.9^{o}C at 50 m). Due to the changes in depth, trawl warp length was adjusted accordingly to keep the trawl from lifting off the bottom and maintain the tow geometry. Trawl warp was set to 100 fathoms (183 m.) for tows in 20 to 24 fathoms (36 to 44 m), and 125 fathoms (229 m) in depths between 25 and 27 fathoms (45 to 50 m).

The Notus TrawlMaster system was used during this survey to monitor trawl geometry. This was not the system proposed to conduct this survey; the new dedicated equipment was not available in time for this survey. Instead we acquired sensors and components from colleagues at SMAST, the Massachusetts Division of Marine Fisheries and FV *Guardian*. During the first trip some technical issues were experienced with this system. First, the trawl door sensors did not work. It was believed that there was an issue with the batteries in the sensors. Data was collected from the wing and headline sensors; however, readings were sporadic. This posed a challenge in tuning the trawl. Of the data collected, wingspread averaged 13.7 ± 1.7 m for tows in the 501N Study Area (11 tows collected) and 14.9 ± 0.8 m for tows in the Control Area (13 tows collected).

Headline height averaged 4.1 ± 0.4 m for tows in the 501N Study Area (11 tows collected) and 4.2 ± 0.5 m for tows in the Control Area (19 tows collected). While wingspread data indicated the net was within acceptable tolerances, the headline height was lower than expected. Additional testing and measurements are required to achieve the headline height within the acceptable range. Since the completion of this survey, a dedicated Simrad PX trawl monitor system has been acquired and tested. Our tests indicate that this system will be able to collect the required data as well as fine-tune the performance of the net. Additional details of the system and trawl performance measured with the system will be reported in the summer survey reports.

3.2 Catch Data

3.2.1 501N Study Area

In the 501N Study Area, a total of 31 species were caught over the duration of the survey (Table 3). Catch volume ranged from 148.4 kg/tow to 1760.5 kg/tow with an average of 556.0 kg/tow. The majority of the catch was primarily comprised of a small subset of the observed species. The five most abundant species (silver hake, red hake, winter skate, little skate and spiny dogfish) accounted for 73% of the total catch weight. Adding the next five most abundant species (alewife, butterfish, barndoor skate, smooth dogfish and monkfish) would encompass 93% of the total catch weight. Data collected from this area included the catch of both adults and juveniles of most species observed.

Silver hake (*Merluccius bilinearis*), also commonly referred to as whiting, was the predominate species observed. Silver hake was observed in every tow with an average catch rate of 107.1 ± 18.6 kg/tow (mean ± SE). Silver hake ranged in length from 11 to 47 cm with a bimodal size distribution consisting of peaks at 16 and 26 cm (Figure 7). Silver hake were caught throughout the 501N Study Area with catch highest to the south and east (Figure 8).

Red hake (*Urophycis chuss*) was the second most abundant species. Caught in every tow, the catch of red hake averaged 96.2 ± 29.1 kg/tow. Individuals ranged from 8 to 42 cm in length, with a bimodal size distribution peaking at 17 and 27 cm (Figure 9). Red hake distribution was similar to silver hake, with catch increasing along the depth gradient (i.e. higher catches in deeper water, Figure 10).

Elasmobranchs, including winter skate (*Leucoraja ocellata*), little skate (*Leucoraja erinacea*) and spiny dogfish (*Squalus acanthias*) were the third, fourth, and fifth most abundant species, respectively. Winter skates were caught in every tow with an average catch rate of 94.0 ± 15.8 kg/tow. Little skates were caught in 19 of the 20 tows with an average catch rate of 59.6 ± 8.3 kg/tow. Finally, spiny dogfish were caught in 18 of the 20 tows with an average catch rate of 48.5 ± 16.8 kg/tow. Winter and little skates were caught throughout the 501N Study Area without a discernable pattern to the distribution (Figure 11 and 12). Spiny dogfish were primarily observed along the southwest boundaries associated with the deeper water (Figure 13).

Additional common species included alewife (*Alosa pseidoharengus*), butterfish (*Peprilus triacanthus*), barndoor skate (*Dipturus laevis*), smooth dogfish (*Mustelus canis*), monkfish (*Lophius americanus),* and longfin squid (*Doryteuthis pealeii*). Alewife, butterfish, and barndoor skates were observed in every tow. Smooth dogfish were observed in 17 of the 20 tows.

Adult and juvenile alewife were both commonly observed in the catch. The population structure in the 501N Study Area was dominated by juveniles with a peak in abundance between 12 and 17 cm (Figure 14). This was largely due to three large catches (430.8, 183.3 and 93.6 kg) predominately containing juveniles. Adult alewife were commonly caught and represent a significant amount of the catch weight; however, due to the large number of juveniles caught (small individual size and large volume) the larger fish (20-25 cm) are not readily apparent in Figure 14. Catch rates averaged 43.1 ± 22.6 kg/tow (range: 0.5 - 430.8 kg/tow, Figure 15).

Butterfish had a bimodal distribution with peaks at 10 and 17 cm (Figure 16). Catch rates averaged 24.0 ± 7.3 kg/tow (range: 2.2 - 110.8 kg/tow, Figure 17). Catch rates of barndoor skates averaged 17.7 ± 3.3 kg/tow (range: 3.3 – 59.4 kg/tow, Figure 18). Smooth dogfish catches averaged 15.6 ± 6.5 kg/tow (range: 0 – 125.3 kg/tow, Figure 19). All four species had similar spatial distribution with higher catches observed along the southern and southeastern regions of the 501N Study Area (Figures 15, 17, 18, 19).

Monkfish, a commercially important species, had a wide size distribution (20 - 75 cm) with a peak between 30 and 35 cm (Figure 20). Catches averaged 10.6 ± 2.4 kg/tow with a range between 0.8 and 37 kg/tow. Monkfish were observed throughout the 501N Study Area (Figure 21). Similarly, longfin squid, another commercially important species in the region, had a unimodal distribution peaking at 10 cm mantle length (Figure 22). Longfin squid were observed throughout the 501N Study Area (Figure 23). Average catch rate was 9.4 ± 1.6 kg/tow (range: 0 – 27.2 kg/tow). No squid eggs (i.e. "squid mops") were observed during the survey.

Other commercially important species observed were haddock (*Melanogrammus aeglefinus*), shortfin squid (*Illex illecebrosus*), American lobster (*Homarus americanus*), and several flatfish species including winter flounder (*Pseudopleuronectes americanus*), summer flounder (*Paralichthys dentatus*), yellowtail flounder (*Limanda ferruginea*), and windowpane flounder (*Scophthalmus aquosus*). Winter flounder were primarily larger adults (> 25 cm, Figure 24). Winter flounder, despite having a relatively low catch rate (1.9 ± 0.8 kg/tow), were observed in 16 of the 20 tows (58 total individuals, Figure 25). Similarly, shortfin squid were observed in 15 of the 20 tows. Mantle length exhibited a unimodal distribution ranging from 5 to 21 cm (Figure 26). Catch rates averaged 1.4 ± 0.6 kg/tow (range: 0 - 10.7 kg/tow, Figure 27).

Twenty individuals of summer flounder were caught with a size range between 23 and 68 cm (Figure 28). Catch of summer flounder was predominately associated with the northern region of the 501N Study Area (Figure 29). The mean catch of yellowtail flounder was 0.6 ± 0.2 kg/tow (range: 0 – 2.9 kg/tow). Only 41 individuals were caught, with a size range between 15 and 46 cm (Figure 30 and 31). Haddock, which were all large adults, were only observed during one tow (Figures 32 and 33). Finally, only four individuals of windowpane flounder and one lobster were caught.

3.2.2 Control Area

Species composition in the Control Area were almost identical to that observed in the 501N Study Area. A total of 30 species were caught over the duration of the survey (Table 4). On average the catches were higher in the Control Area (862.8 kg/tow) ranging from 251 kg/tow to 2455.8 kg/tow. As with the 501N Study Area, the majority of the catch was comprised of a small subset of the observed species. The five most abundant species (silver hake, red hake, haddock, winter skate and spiny dogfish) accounted for 82% of the total catch weight. Including the next five most abundant species (little skate, barndoor skate, monkfish, butterfish and alewife) would encompass 98% of the total catch weight.

Silver hake was the predominate species observed. Silver hake was observed in every tow with an average catch rate of 231.4 ± 25.4 kg/tow (range: 84.1 – 472.9 kg/tow). Silver hake ranged in length from 7 to 49 cm with a bimodal size distribution consisting of peaks at 16 and 26 cm (Figure 7). Silver hake were caught throughout the Control Area (Figure 8).

Red hake was the second most abundant species. Caught in every tow, the average catch (227.5 ± 48.4 kg/tow) was considerably higher in the Control Area (range: 5.6 – 676 kg/tow). Individuals ranged from 5 to 40 cm with a bimodal size distribution (Figure 9). The highest catch of red hake was in the southern half of the Control Area (Figure 10).

Haddock, while only observed in 8 of the 20 tows, had the largest single catch with 1,180.9 kg in one tow. A second tow included an additional 764.2 kg. These two tows accounted for 95% of the total haddock catch. Almost all individuals were large adults (> 40 cm, Figure 32). These two large haddock tows were in the southwestern corner of the Control Area (Figure 33).

Elasmobranchs, including winter skate, spiny dogfish, little skate, and barndoor skate were the fourth, fifth, sixth, and seventh most abundant species, respectively. Winter skates were caught in every tow with an average catch rate of 77.1 ± 10.9 kg/tow (range: 17.8 – 224.9 kg/tow). Spiny dogfish were caught in 18 of the 20 tows with an average catch rate of 67.0 ± 20.1 kg/tow (range: 0 – 379.8 kg/tow). Little skates were caught in every tow with an average catch rate of 44.1 ± 4.2 kg/tow (range: 22.0 – 82.4 kg/tow). Finally, barndoor skates were observed in 19 of the 20 tows, with an average catch rate of 32.3 ± 6.8 kg/tow (range: 0 to 106 kg/tow). Winter, little, and barndoor skates were caught throughout the 501N Study Area without a discernable pattern to the distribution (Figures 11, 12 and 18). Spiny dogfish were primarily observed along the southwest boundaries associated with the deeper water (Figure 13).

Additional common species included monkfish, butterfish, alewife, longfin squid, and shortfin squid. Monkfish, butterfish, and alewife were observed in all 20 tows. Monkfish catch rates averaged 26.2 kg/tow (range: 1.4 – 75.0 kg/tow) with a wide size distribution (20 – 80 cm, Figure 20). Monkfish were observed throughout the Control Area (Figure 21). Butterfish had a bimodal distribution (Figure 16) with catch rates averaging 22.7 ± 8.1 kg/tow (range: 0.2 - 114.9 kg/tow). Higher catches of butterfish were observed in the southern and southwestern regions of the Control Area (Figure 17). Alewife observed in the Control Area were only adults (20-26 cm, Figure 14), as opposed to the 501N Study Area, which had juvenile fish. Catch rates averaged 13.7 ± 4.0 kg/tow (range: 0.2 - 58 kg/tow).

Other commercially important species observed included summer flounder, winter flounder, yellowtail flounder, American lobster, Atlantic cod, black sea bass, and scup. Twenty individuals of summer flounder ranging from 35 to 70 cm were caught, primarily in the northern and shallower region of the Control Area (Figures 28 and 29). Average catch rate of summer flounder was 13.7 ± 4.0 kg/tow (range: 0 - 8.4 kg/tow). Yellowtail flounder were caught in 9 of the 20 tows with catch rates averaging 0.2 ± 0.1 kg/tow (range: 0 - 0.9 kg/tow). All the other commercial species were caught sporadically. Only five lobsters and five winter flounder were caught. Atlantic cod (*Gadus morhua*), black sea bass (*Centropristis* striata), and scup (*Stenotomus chrysops*) were only caught in one tow, and one fish each in the tow.

4. Acknowledgements

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Table 1: Operational and environmental conditions for each survey tow.

Tow Number	Tow Area	Date	Sky Condition	Wind State (Knots)	Wind Direction	Sea State (m.)	Start Time	Start Latitude	Start Longitude	Start Depth (fm)	End Time	End Latitude	End Longitude	End Depth (fm)	Trawl Warp (fm)
1	501N	6/11/2019	Obscured	16-20	S	1.25-2.5	6:41	N 41° 06.919	W 70° 30.011	20	7:01	N 41° 06.619	W 70° 28.859	21	100
2	501N	6/11/2019	Overcast	11-15	S	1.25-2.5	8:16	N 41° 06.985	W 70° 28.225	20	8:36	N 41° 06.309	W 70° 27.281	20	100
3	501N	6/11/2019	Overcast	7-10	S	1.25-2.5	9:42	N 41° 06.359	W 70° 26.810	20	10:02	N 41° 07.273	W 70° 26.653	19	100
4	501N	6/11/2019	Rain	7-10	S	1.25-2.5	11:05	N 41° 05.676	W 70° 25.935	20	11:27	N 41° 04.878	W 70° 26.796	21	100
5	501N	6/11/2019	Overcast	7-10	S	1.25-2.5	12:47	N 41° 05.267	W 70° 25.599	21	13:07	N 41° 04.295	W 70° 25.820	22	100
6	501N	6/11/2019	Overcast	7-10	S	1.25-2.5	14:20	N 41° 02.662	W 70° 27.500	23	14:40	N 41° 03.321	W 70° 26.502	22	100
7	501N	6/11/2019	Clear	7-10	S	0.5-1.25	15:50	N 41° 03.582	W 70° 26.013	22	16:10	N 41° 02.617	W 70° 26.149	21	100
8	Control	6/12/2019	Clear	3-6	W	0.5-1.25	6:17	N 41° 01.111	W 70° 21.855	20	6:37	N 41° 00.192	W 70° 22.468	20	100
9	Control	6/12/2019	Clear	7-10	W	0.5-1.25	7:48	N 40° 58.904	W 70° 22.565	21	8:08	N 40° 59.989	W 70° 22.593	20	100
10	Control	6/12/2019	Clear	3-6	W	0.5-1.25	9:19	N 40° 59.884	W 70° 20.909	20	9:40	N 40° 59.164	W 70° 20.085	22	100
11	Control	6/12/2019	Clear	3-6	W	0.5-1.25	11:02	N 40° 58.982	W 70° 21.711	20	11:23	N 40° 58.034	W 70° 21.564	22	100
12	Control	6/12/2019	Clear	3-6	W	0.1-0.5	12:47	N 40° 56.360	W 70° 18.174	21	13:08	N 40° 57.414	W 70° 18.198	20	100
13	Control	6/12/2019	Clear	3-6	W	0.5-1.25	14:12	N 40° 58.804	W 70° 17.424	20	14:33	N 40° 57.832	W 70° 17.533	20	100
14	Control	6/12/2019	Clear	3-6	W	0.1-0.5	15:58	N 40° 56.619	W 70° 16.358	20	16:22	N 40° 55.906	W 70° 17.506	21	100
15	Control	6/12/2019	Partly Cloudy	3-6	W	0.1-0.5	17:22	N 40° 54.208	W 70° 17.949	22	17:43	N 40° 54.780	W 70° 18.972	22	100
16	501N	6/13/2019	Overcast	16-20	SE	1.25-2.5	6:57	N 41° 03.571	W 70° 30.502	22	7:17	N 41° 04.300	W 70° 31.355	22	100
17	501N	6/13/2019	Rain	16-20	SE	1.25-2.5	8:26	N 70° 32.277	W 70° 32.277	23	8:48	N 41° 03.806	W 70° 32.604	23	100
18	501N	6/13/2019	Rain	21-26	SE	1.25-2.5	10:16	N 41° 03.695	W 70° 33.540	22	10:38	N 41° 03.042	W 70° 34.591	23	100
19	501N	6/13/2019	Rain	27-33	SE	1.25-2.5	11:44	N 41° 02.894	W 70° 36.999	23	12:05	N 41° 02.257	W 70° 34.996	23	100
20	501N	6/14/2019	Clear	7-10	SW	1.25-2.5	6:09	N 41° 01.413	W 70° 32.249	24	6:30	N 41° 01.291	W 70° 31.023	25	125
21	501N	6/14/2019	Mostly Cloudy	7-10	SW	1.25-2.5	8:09	N 41° 00.865	W 70° 31.311	25	8:31	N 41° 00.491	W 70° 30.075	25	125
22	501N	6/14/2019	Mostly Cloudy	7-10	SW	1.25-2.5	9:53	N 40° 59.611	W 70° 26.764	22	10:12	N 41° 00.047	W 70° 25.745	22	125
23	501N	6/14/2019	Partly Cloudy	11-15	SW	1.25-2.5	11:10	N 41° 00.182	W 70° 24.396	21	11:29	N 41° 01.050	W 70° 24.072	21	100
24	501N	6/14/2019	Partly Cloudy	11-15	SW	1.25-2.5	12:21	N 41° 01.540	W 70° 23.045	21	12:41	N 41° 02.401	W 70° 23.613	21	100
25	501N	6/14/2019	Partly Cloudy	16-20	SW	1.25-2.5	13:49	N 41° 02.510	W 70° 22.261	20	14:09	N 41° 02.917	W 70° 23.483	20	100
26	Control	6/14/2019	Clear	16-20	SW	1.25-2.5	15:34	N 40° 57.280	W 70° 24.724	23	15:54	N 40° 57.963	W 70° 23.722	22	125
27	Control	6/15/2019	Clear	11-15	W	1.25-2.5	6:17	N 40° 56.145	W 70° 24.651	24	6:38	N 40° 55.295	W 70° 23.941	24	125
28	Control	6/15/2019	Clear	11-15	W	1.25-2.5	8:16	N 40° 53.832	W 70° 21.682	24	8:36	N 40° 53.753	W 70° 20.424	23	125
29	Control	6/15/2019	Clear	11-15	W	1.25-2.5	9:55	N 40° 53.985	W 70° 18.596	22	10:15	N 40° 53.193	W 70° 19.375	23	125
30	Control	6/15/2019	Clear	7-10	W	1.25-2.5	11:40	N 40° 51.533	W 70° 21.516	25	12:00	N 40° 50.932	W 70° 22.487	25	125
31	Control	6/15/2019	Clear	7-10	W	0.5-1.25	14:28	N 40° 51.048	W 70° 22.425	26	14:48	N 40° 50.169	W 70° 22.567	26	125
32	Control	6/15/2019	Clear	11-15	W	0.5-1.25	16:29	N 40° 51.400	W 70° 24.184	26	16:49	N 40° 52.371	W 70° 24.081	26	125
33	501N	6/23/2019	Clear	11-15	W	0.5-1.25	9:19	N 41° 01.093	W 70° 31.798	25	9:40	N 41° 00.466	W 70° 32.834	26	125
34	501N	6/23/2019	Clear	11-15	W	0.5-1.25	12:30	N 41° 00.424	W 70° 33.235	25	12:51	N 40° 59.622	W 70° 34.001	25	125
35	501N	6/23/2019	Clear	11-15	W	0.5-1.25	14:38	N 41° 00.642	W 70° 35.511	25	15:00	N 40° 59.630	W 70° 35.863	26	125
36	Control	6/23/2019	Clear	11-15	W	0.5-1.25	16:49	N 40° 56.316	W 70° 26.038	23	17:09	N 40° 56.144	W 70° 24.788	23	125
37	Control	6/23/2019	Clear	11-15	W	0.5-1.25	18:49	N 40° 55.999	W 70° 23.498	23	19:09	N 40° 55.455	W 70° 24.491	23	125
38	Control	6/24/2019	Clear	11-15	SW	0.5-1.25	7:07	N 40° 52.562	W 70° 23.117	25	7:27	N 40° 52.611	W 70° 25.311	26	125
39	Control	6/24/2019	Clear	11-15	SW	0.5-1.25	9:28	N 40° 52.194	W 70° 28.313	27	9:49	N 40° 53.260	W 70° 29.156	27	125
40	Control	6/24/2019	Clear	7-10	SW	0.5-1.25	11:30	N 40° 54.213	W 70° 29.649	26	11:51	N 40° 55.154	W 70° 29.184	26	125

Table 2: Tow parameters for each survey tow.

Tow Number	Tow Area	Tow Duration (min.)	Tow Speed (knots)	Tow Distance (nautical miles)	Bottom Temperature (^{o}C)	Headline Height (m.)	Wing Spread (m.)
1	501N	20.5	2.86	0.98	10.2		
2	501N	20.1	2.92	0.98	10.4		
3	501N	19.1	2.94	0.94	10.7		
4	501N	20.0	3.02	1.01	10.7		
5	501N	20.8	2.86	0.99	10.7		
6	501N	20.6	2.98	1.02	10.1		
7	501N	20.7	2.90	1.00	10.3		
8	Control	20.7	3.00	1.03	9.8	4.2	13.7
9	Control	21.9	3.04	1.11	9.8	3.9	14.7
10	Control	20.6	2.79	0.96	10.3	4.8	14.7
11	Control	20.6	2.84	0.97	10.0	5.0	15.9
12	Control	22.1	2.85	1.05	10.4	4.3	
13	Control	21.4	2.76	0.98	11.0	4.2	
14	Control	24.3	2.81	1.14	10.8	4.1	
15	Control	20.9	2.82	0.98	9.4	4.3	
16	501N	20.6	2.90	1.00	9.8	4.2	15.3
17	501N	21.6	2.77	1.00	9.6	4.0	
18	501N	22.1	2.82	1.04	9.6		15.6
19	501N	22.1	2.73	1.00	9.6	4.2	12.5
20	501N	20.5	2.78	0.95	9.4	4.0	
21	501N	21.5	2.86	1.03	9.3	4.5	12.5
22	501N	19.6	2.74	0.90	9.6	3.5	14.1
23	501N	19.2	2.86	0.91	10.2	5.1	12.9
24	501N	19.7	2.89	0.95	10.9		11.4
25	501N	20.1	3.02	1.01	11.2	3.5	11.3
26	Control	19.8	3.02	1.00	9.8	4.2	
27	Control	21.3	2.87	1.02	9.3	4.1	14.5
28	Control	20.2	2.85	0.96	9.4	4.2	15.8
29	Control	21.0	2.84	0.99	9.5	3.6	14.6
30	Control	20.3	2.84	0.96	9.1	3.7	
31	Control	19.0	2.81	0.89	9.2	4.4	16.2
32	Control	21.3	2.82	1.00	9.1	3.6	14.6
33	501N	20.8	2.84	0.98	9.1	4.0	15.5
34	501N	21.1	2.82	0.99	8.9	4.2	15.8
35	501N	22.4	2.81	1.05	9.0	4.1	14.1
36	Control	21.0	2.81	0.98	9.2	4.9	15.1
37	Control	20.2	2.78	0.93	9.6	5.1	15.4
38	Control	19.4	2.82	0.91	9.1		14.1
39	Control	21.1	2.79	0.98	9.0	4.0	15.8
40	Control	21.0	2.88	1.01	8.9	3.6	
Summary Statistics							
Control	Minimum	19.0	2.8	0.89	8.9	3.6	13.7
	Maximum	24.3	3.0	1.14	11.0	5.1	16.2
	Average	20.9	2.9	0.99	9.6	4.2	15.0
	St. Dev	1.1	0.1	0.06	0.6	0.5	0.8
501N	Minimum	19.1	2.7	0.90	8.9	3.5	11.3
	Maximum	22.4	3.0	1.05	11.2	5.1	15.8
	Average	20.7	2.9	0.99	10.0	4.1	13.7
	St. Dev.	0.9	0.1	0.04	0.7	0.4	1.7

Table 3: Total and average catch weights observed with the 501N Study Area.

Species Name	Scientific Name	Total Weight (Kg)	Catch/Tow (Kg) Mean	Catch/Tow (Kg) SEM	% of Total Catch	Tows with Species Present
Hake, Silver	*Merluccius bilinearis*	2141.4	107.1	18.6	19.3	20
Hake, Red	*Urophycis chuss*	1923.8	96.2	29.1	17.3	20
Skate, Winter	*Leucoraja ocellata*	1879.8	94.0	15.8	16.9	20
Skate, Little	*Leucoraja erinacea*	1191.7	59.6	8.3	10.7	19
Dogfish, Spiny	*Squalus acanthias*	969.5	48.5	16.8	8.7	18
Alewife	*Alosa pseudoharengus*	861.9	43.1	22.6	7.8	20
Butterfish	*Peprilus triacanthus*	479.4	24.0	7.3	4.3	20
Skate, Barndoor	*Dipturus laevis*	354.8	17.7	3.3	3.2	20
Dogfish, Smooth	*Mustelus canis*	312.3	15.6	6.5	2.8	17
Monkfish	*Lophius americanus*	212.7	10.6	2.4	1.9	20
Mackerel, Atlantic	*Scomber scombrus*	205.6	10.3	7.5	1.8	10
Squid, Atlantic Longfin	*Doryteuthis pealeii*	188.6	9.4	1.6	1.7	18
Haddock	*Melanogrammus aeglefinus*	77.3	3.9		0.7	1
Flounder, Fourspot	*Hippoglossina oblonga*	75.6	3.8	0.8	0.7	20
Crab, Cancer	*Cancer sp.*	48.6	2.4	1.0	0.4	15
Flounder, Winter	*Pseudopleuronectes americanus*	37.5	1.9	0.8	0.3	16
Flounder, Summer (Fluke)	*Paralichthys dentatus*	33.4	1.7	0.5	0.3	13
Menhaden, Atlantic	*Brevoortia tyrannus*	32.3	1.6	1.2	0.3	2
Ocean Pout	*Zoarces americanus*	29.1	1.5	0.5	0.3	12
Squid, Shortfin	*Illex illecebrosus*	28.7	1.4	0.6	0.3	5
Flounder, Yellowtail	*Limanda ferruginea*	11.1	0.6	0.2	0.1	6
Shad, American	*Alosa sapidissima*	8.0	0.4	0.2	0.1	9
Flounder, Gulfstream	*Citharichthys arctifrons*	7.6	0.4	0.1	0.1	15
Sculpin, Longhorn	*Myoxocephalus octodecemspinosus*	3.6	0.2	0.1	0.0	11
Flounder, Windowpane	*Scophthalmus aquosus*	2.0	0.1	0.0	0.0	8
Herring, Atlantic	*Clupea harengus*	1.1	0.1	0.0	0.0	4
Lobster, American	*Homarus americanus*	0.9	0.1		0.0	1
Northern Sea Robin	*Prionotus carolinus*	0.8	0.0	0.0	0.0	4
Cunner	*Tautogolabrus adspersus*	0.5	0.0		0.0	1
Hake, Spotted	*Urophycis regius*	0.5	0.0		0.0	1
American Eel	*Anguilla rostrata*	0.4	0.0		0.0	1
Total		**11120.3**				

Table 4: Total and average catch weights observed within the Control Area.

Species Name	Scientific Name	Total Weight (Kg)	Catch/Tow (Kg)		% of Total Catch	Tows with Species Present
			Mean	SEM		
Hake, Silver	*Merluccius bilinearis*	4627.8	231.4	25.4	26.8	20
Hake, Red	*Urophycis chuss*	4550.9	227.5	48.4	26.4	20
Haddock	*Melanogrammus aeglefinus*	2040.4	102.0	68.3	11.8	8
Skate, Winter	*Leucoraja ocellata*	1542.9	77.1	10.9	8.9	20
Dogfish, Spiny	*Squalus acanthias*	1340.3	67.0	20.1	7.8	18
Skate, Little	*Leucoraja erinacea*	882.9	44.1	4.2	5.1	20
Skate, Barndoor	*Dipturus laevis*	645.9	32.3	6.8	3.7	19
Monkfish	*Lophius americanus*	523.7	26.2	4.8	3.0	20
Butterfish	*Peprilus triacanthus*	454.3	22.7	8.1	2.6	20
Alewife	*Alosa pseudoharengus*	273.3	13.7	4.0	1.6	20
Squid, Atlantic Longfin	*Doryteuthis pealeii*	105.9	5.3	1.2	0.6	16
Squid, Shortfin	*Illex illecebrosus*	71.0	3.5	1.1	0.4	17
Flounder, Fourspot	*Hippoglossina oblonga*	58.9	2.9	0.7	0.3	20
Dogfish, Smooth	*Mustelus canis*	44.3	2.2	0.9	0.3	6
Flounder, Summer (Fluke)	*Paralichthys dentatus*	32.4	1.6	0.6	0.2	8
Crab, Cancer	*Cancer sp.*	15.5	0.8	0.3	0.1	9
Flounder, Gulfstream	*Citharichthys arctifrons*	10.1	0.5	0.1	0.1	15
Lobster, American	*Homarus americanus*	8.5	0.4	0.2	0.0	5
Ocean Pout	*Zoarces americanus*	6.4	0.3	0.1	0.0	9
Sculpin, Longhorn	*Myoxocephalus octodecemspinosus*	6.2	0.3	0.1	0.0	9
Flounder, Yellowtail	*Limanda ferruginea*	3.7	0.2	0.1	0.0	9
Shad, American	*Alosa sapidissima*	3.3	0.2	0.1	0.0	6
Mackerel, Atlantic	*Scomber scombrus*	2.0	0.1	0.0	0.0	6
Flounder, Winter	*Pseudopleuronectes americanus*	1.8	0.1	0.0	0.0	5
Atlantic Cod	*Gadus morhua*	1.6	0.1		0.0	1
Menhaden, Atlantic	*Brevoortia tyrannus*	1.0	0.1		0.0	1
Northern Sea Robin	*Prionotus carolinus*	0.3	0.0	0.0	0.0	2
Hake, Spotted	*Urophycis regius*	0.3	0.0		0.0	1
Black Sea bass	*Centropristis striata*	0.3	0.0		0.0	1
Scup	*Stenotomus chrysops*	0.2	0.0		0.0	1
Total		**17256.1**				

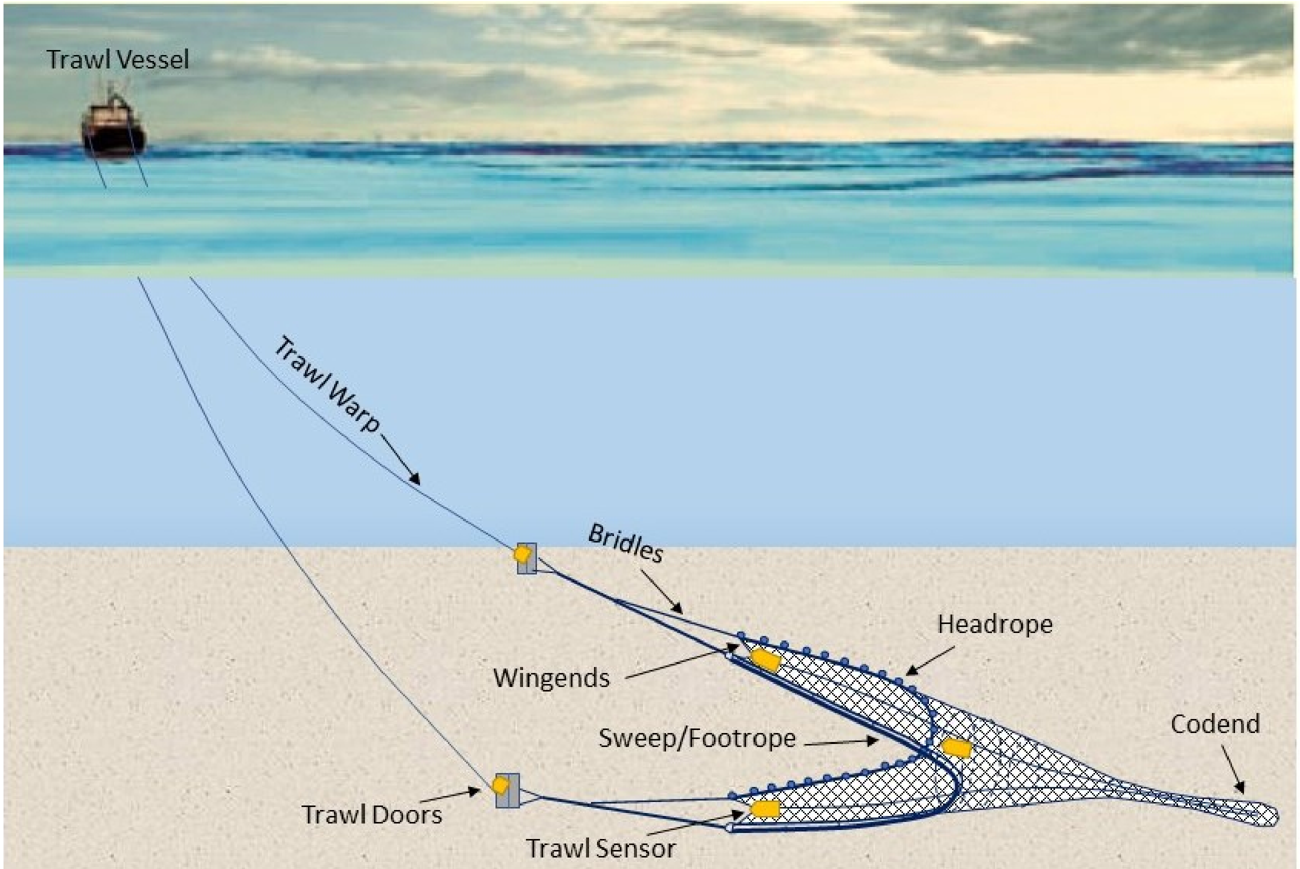


Figure 1: General schematic (not to scale) of a demersal otter trawl. Yellow rectangles indicate geometry sensors.

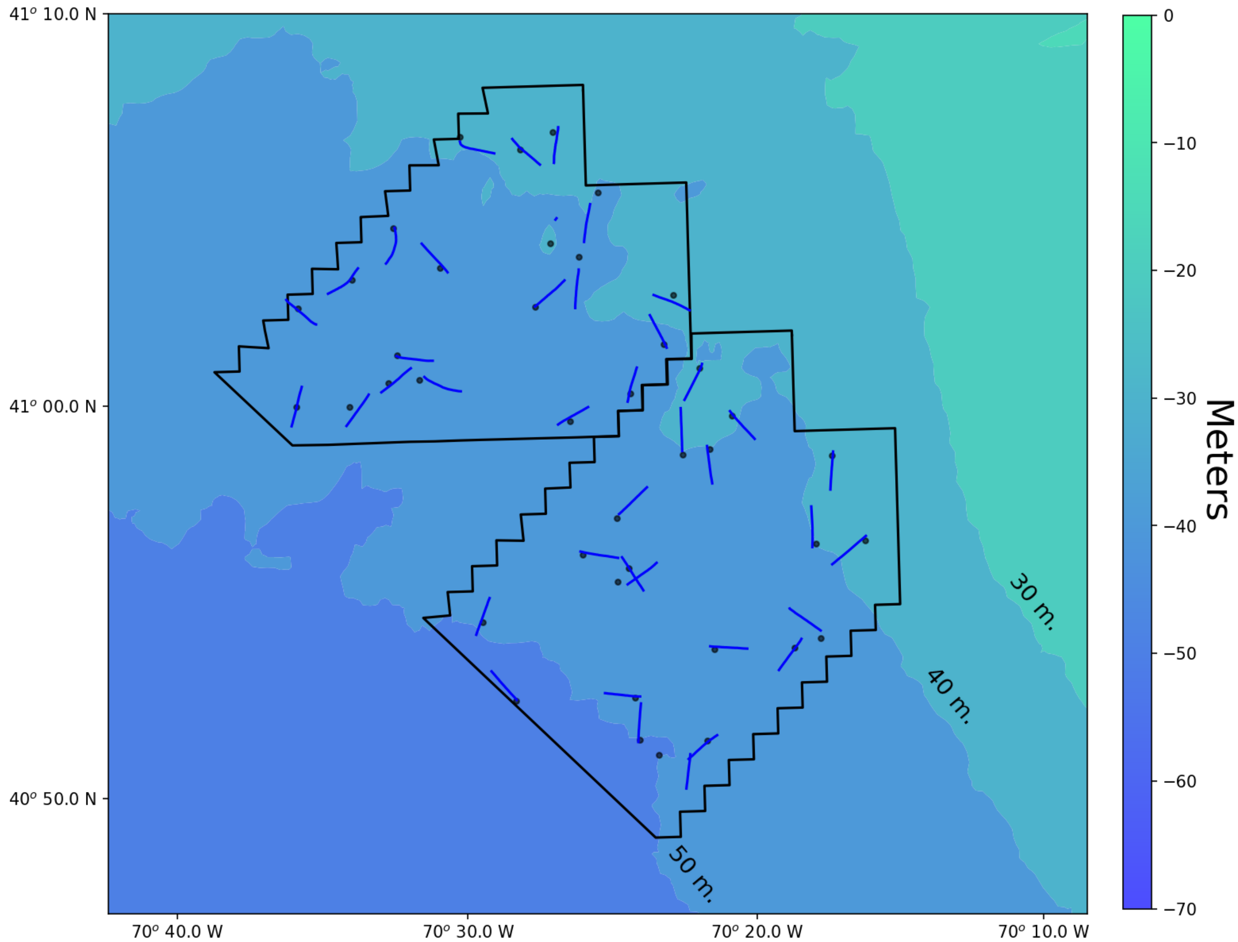


Figure 2: Tow locations (black dots) and trawl tracks (blue lines) from the 501N Study Area (left) and the Control Area (right)

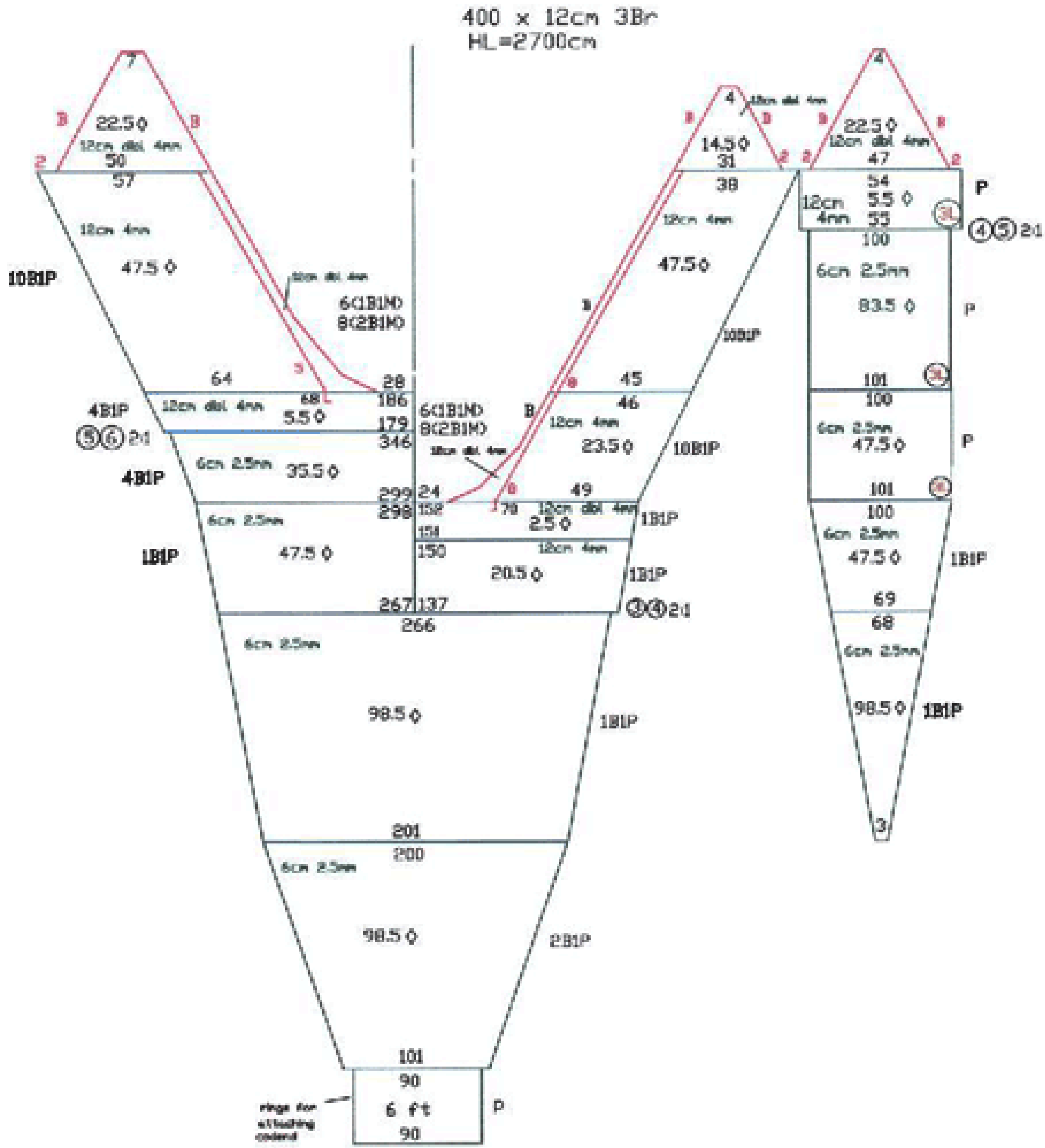


Figure 3: Schematic net plan for the NEAMAP trawl (Bonsek et al. 2008)

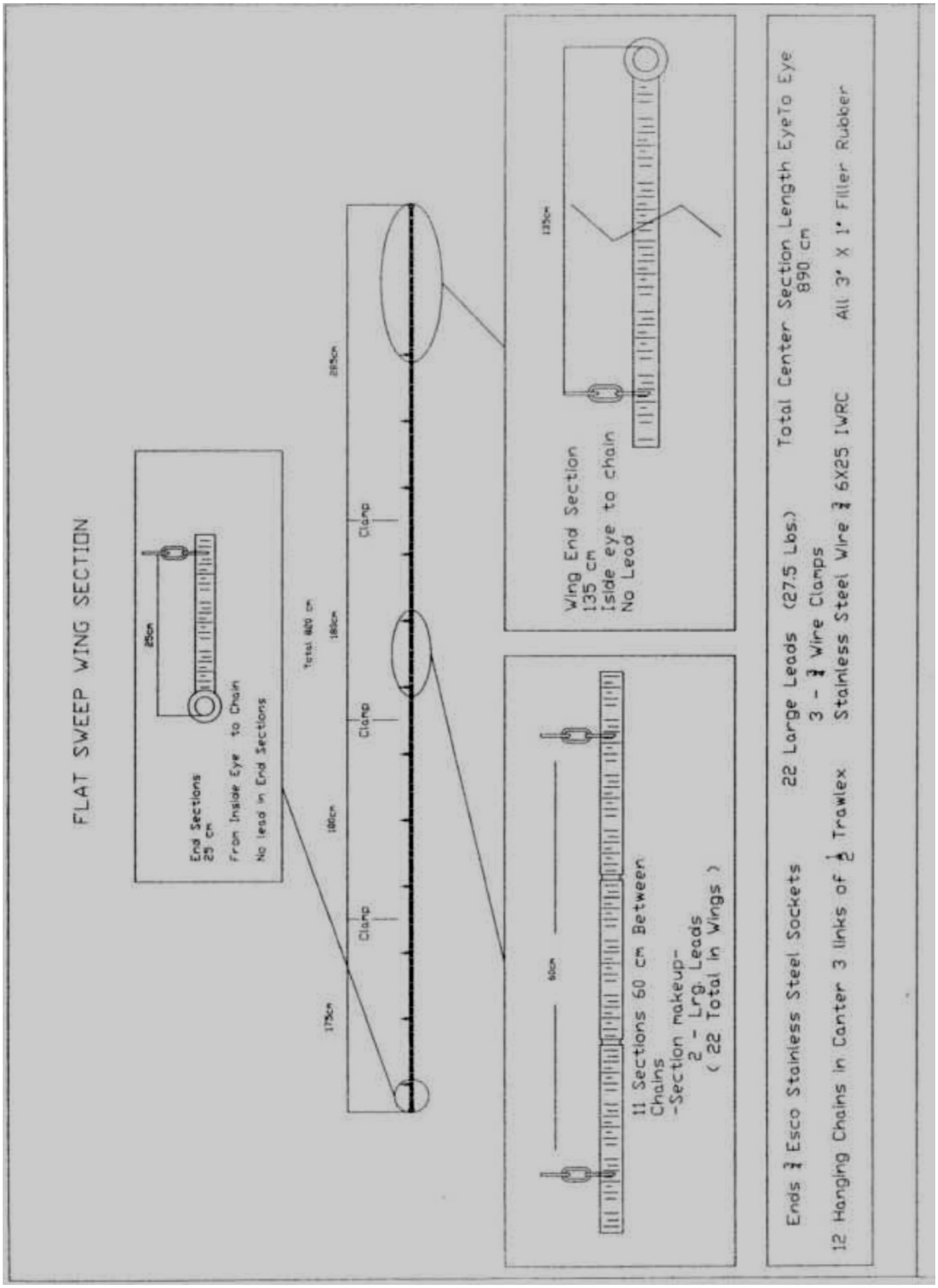


Figure 4: Sweep diagram for the survey trawl (Bonsek et al. 2008).

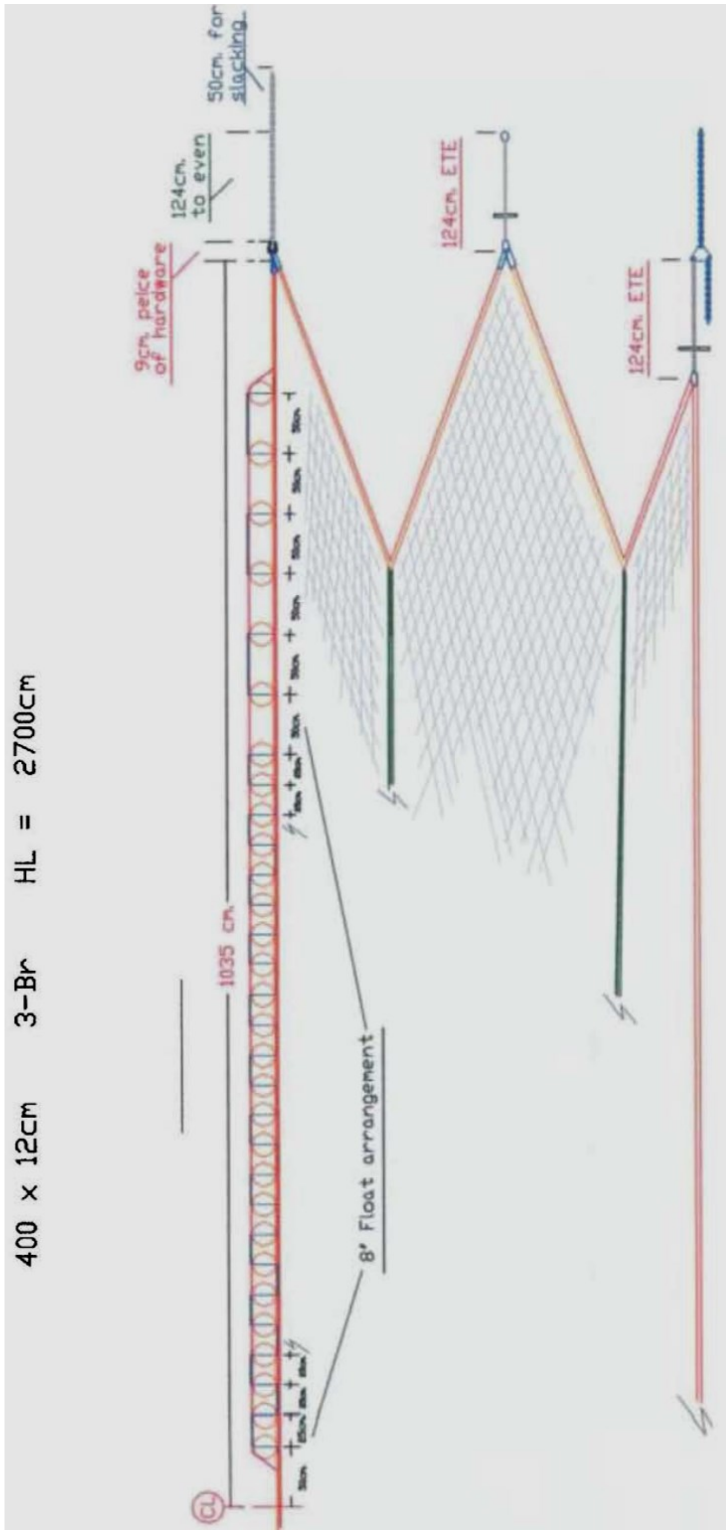


Figure 5: Headrope and rigging plan for the survey trawl (Bonsek et al. 2008)

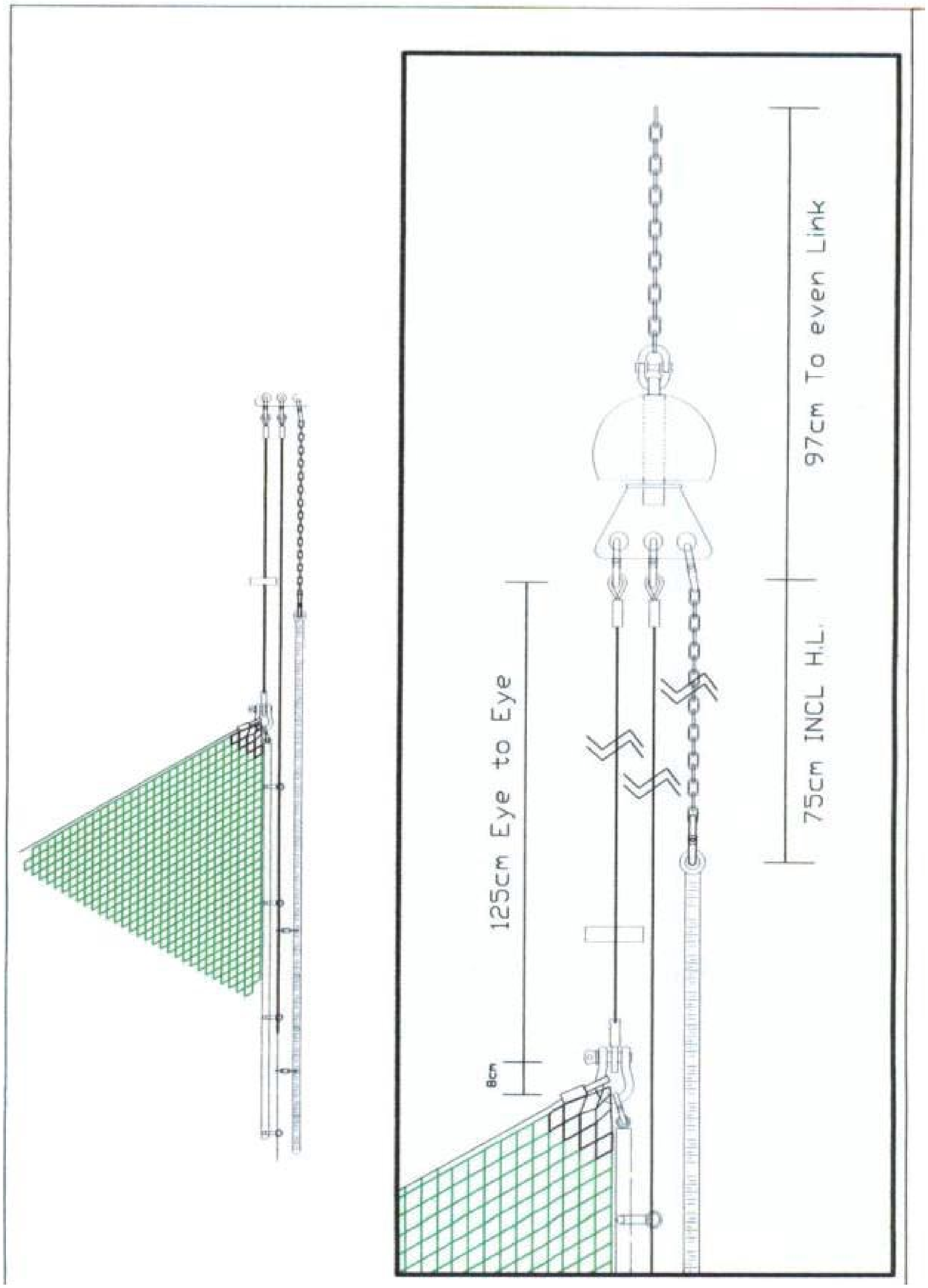


Figure 6: Lower wing and bobbin schematic for the survey trawl (Bonsek et al. 2008).

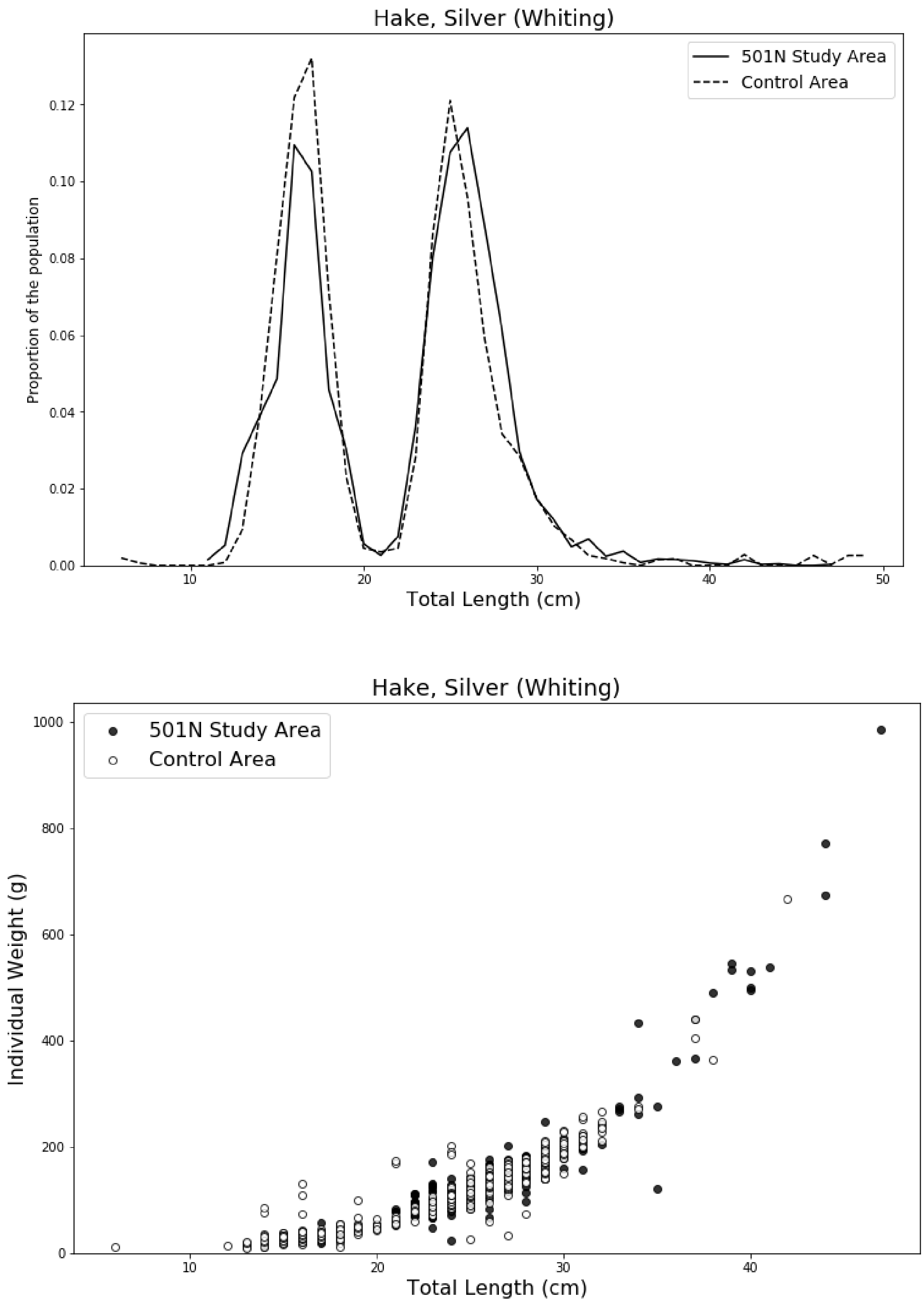


Figure 7: Population structure of silver hake in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

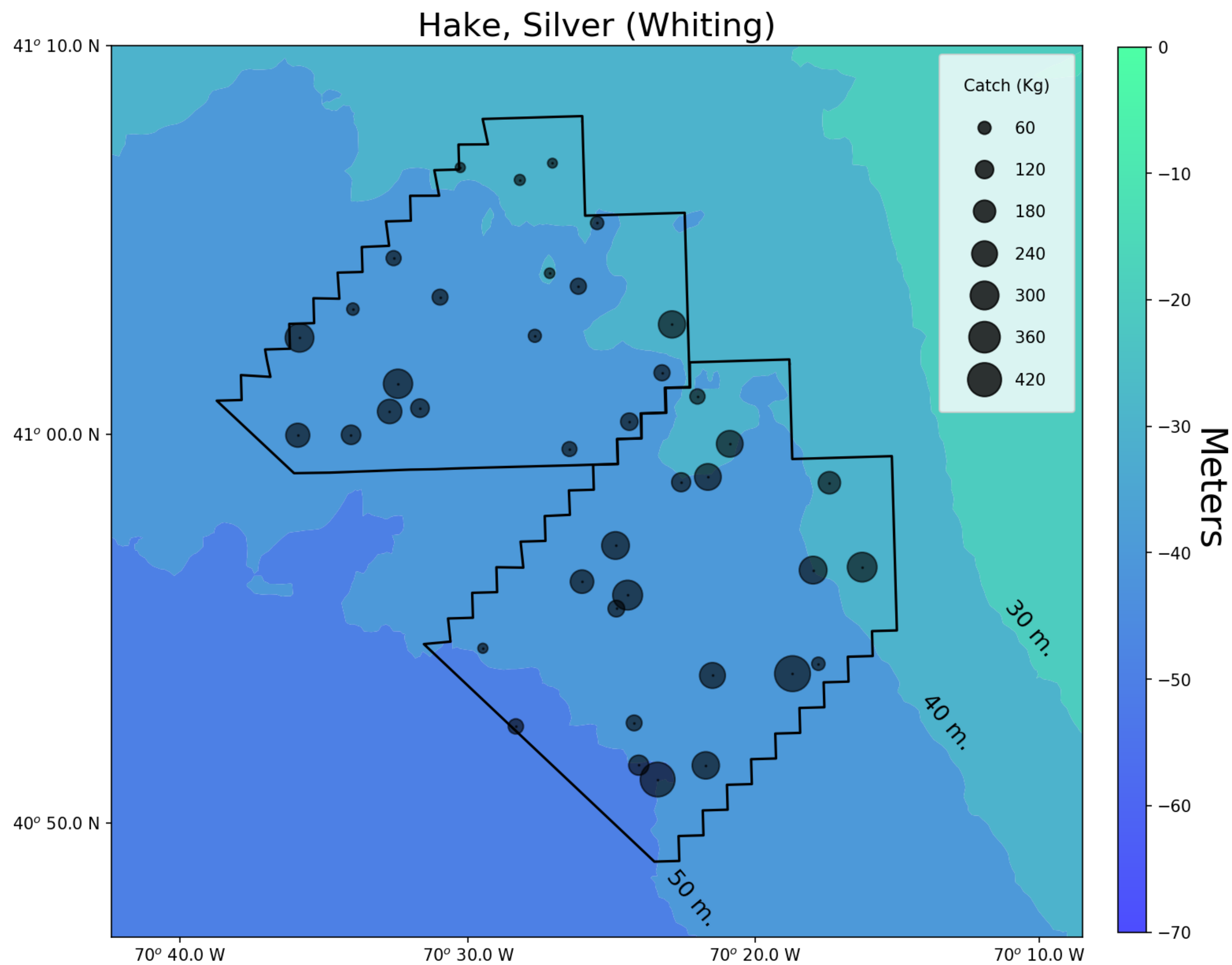
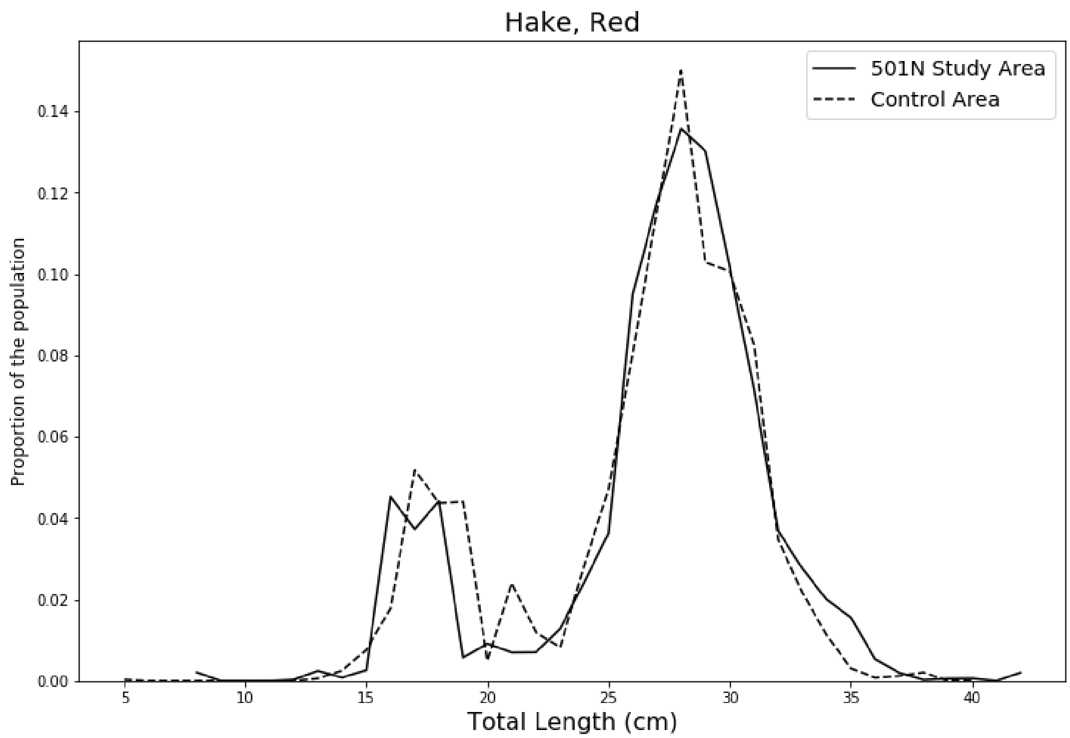


Figure 8: Distribution of the catch of silver hake in the 501N Study Area (left) and Control Area (right).



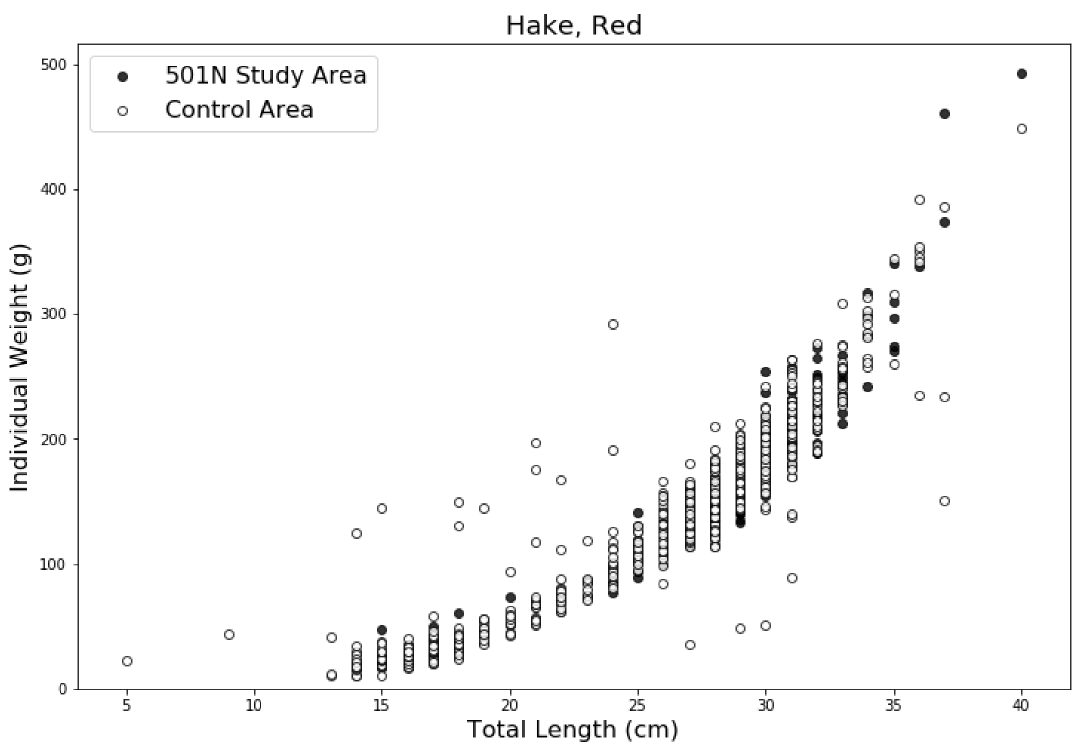


Figure 9: Population structure of red hake in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

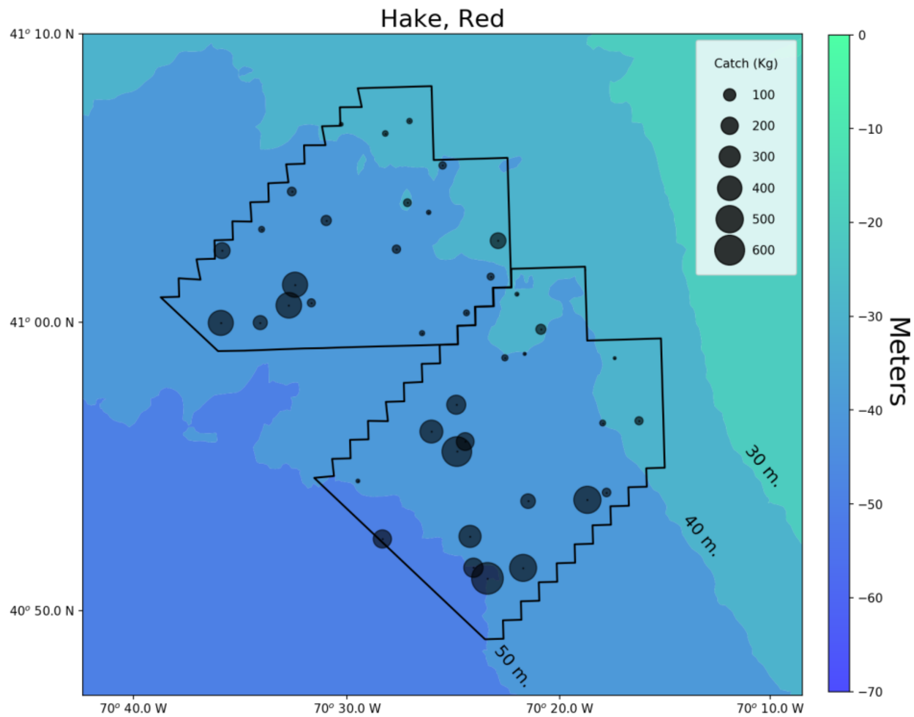


Figure 10: Distribution of the catch of red hake in the 501N Study Area (left) and Control Area (right).

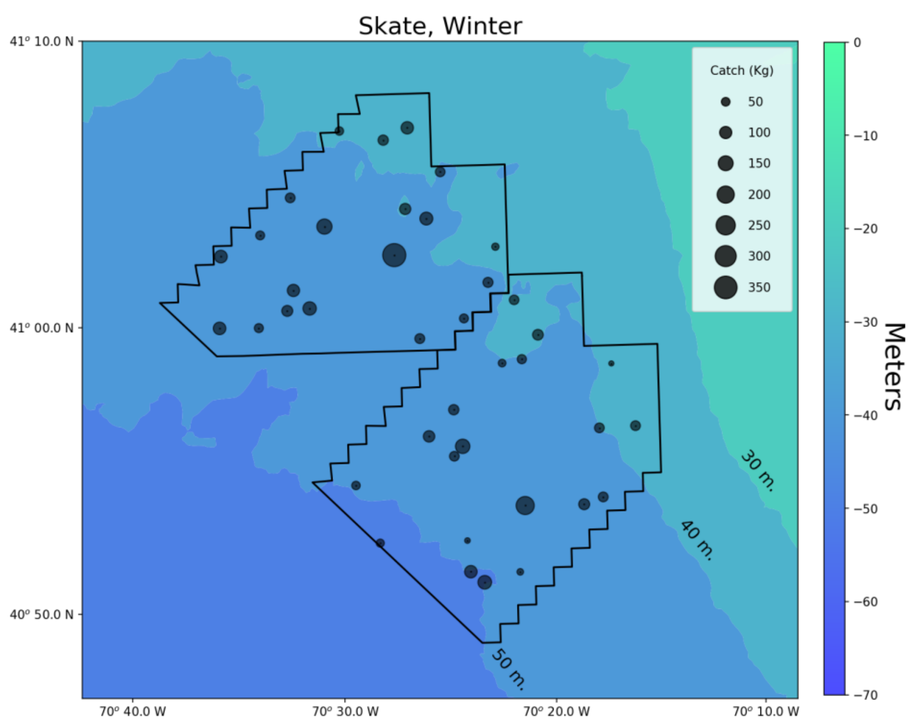


Figure 11: Distribution of the catch of winter skate in the 501N Study Area (left) and Control Area (right).

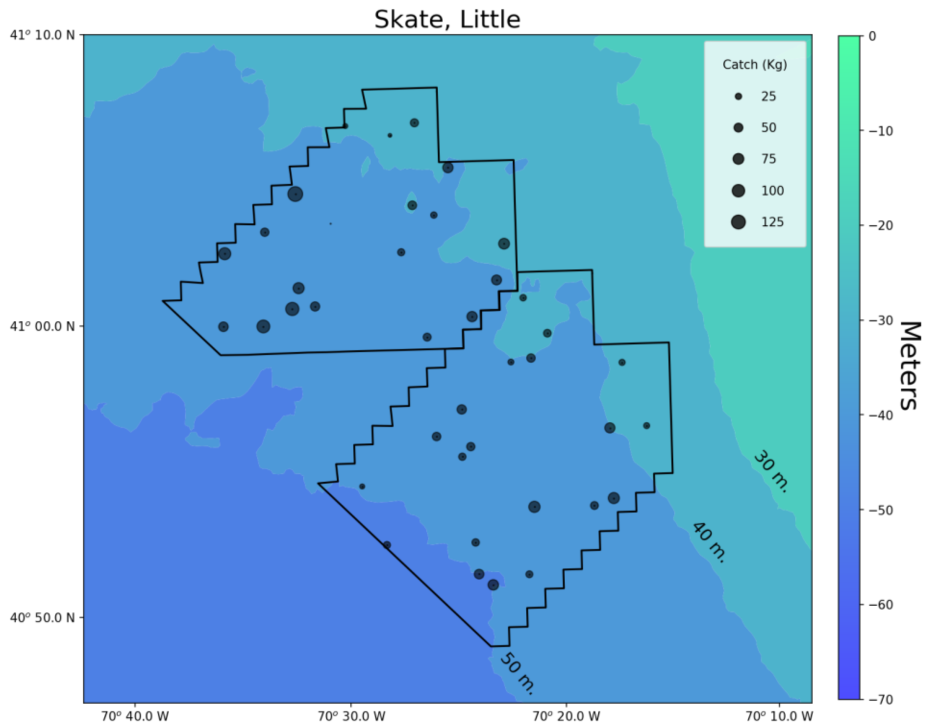


Figure 12: Distribution of the catch of little skate in the 501N Study Area (left) and Control Area (right).

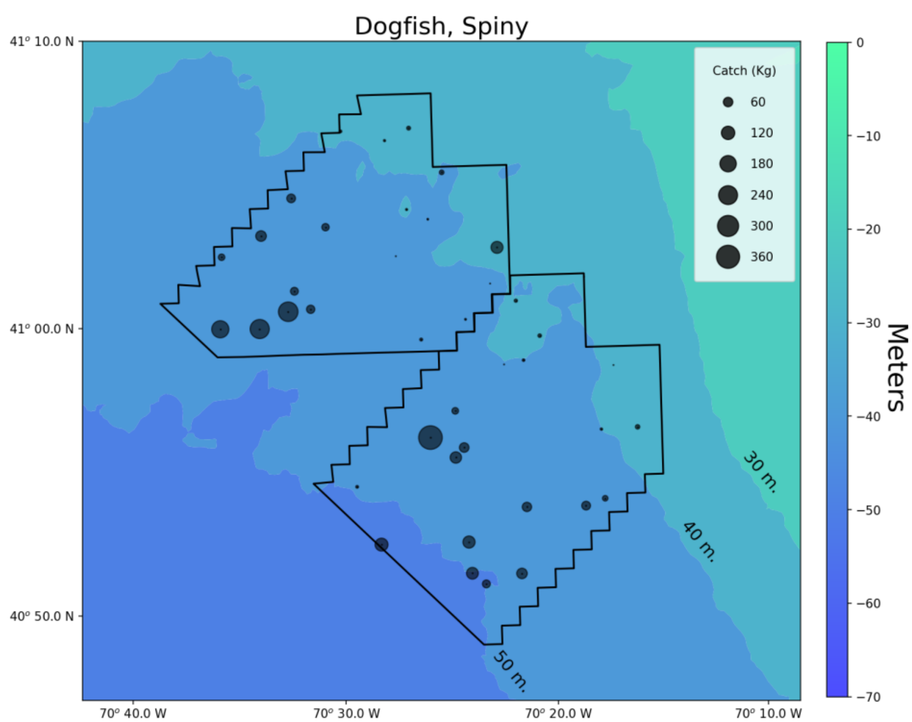
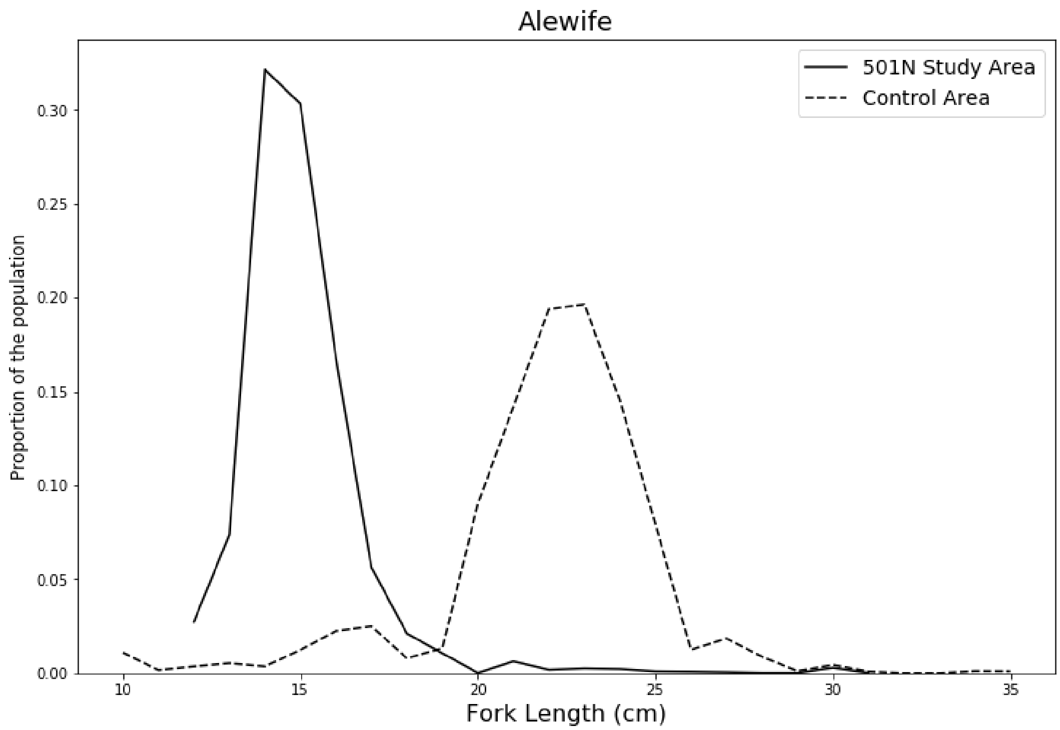


Figure 13: Distribution of the catch of spiny dogfish in the 501N Study Area (left) and Control Area (right).



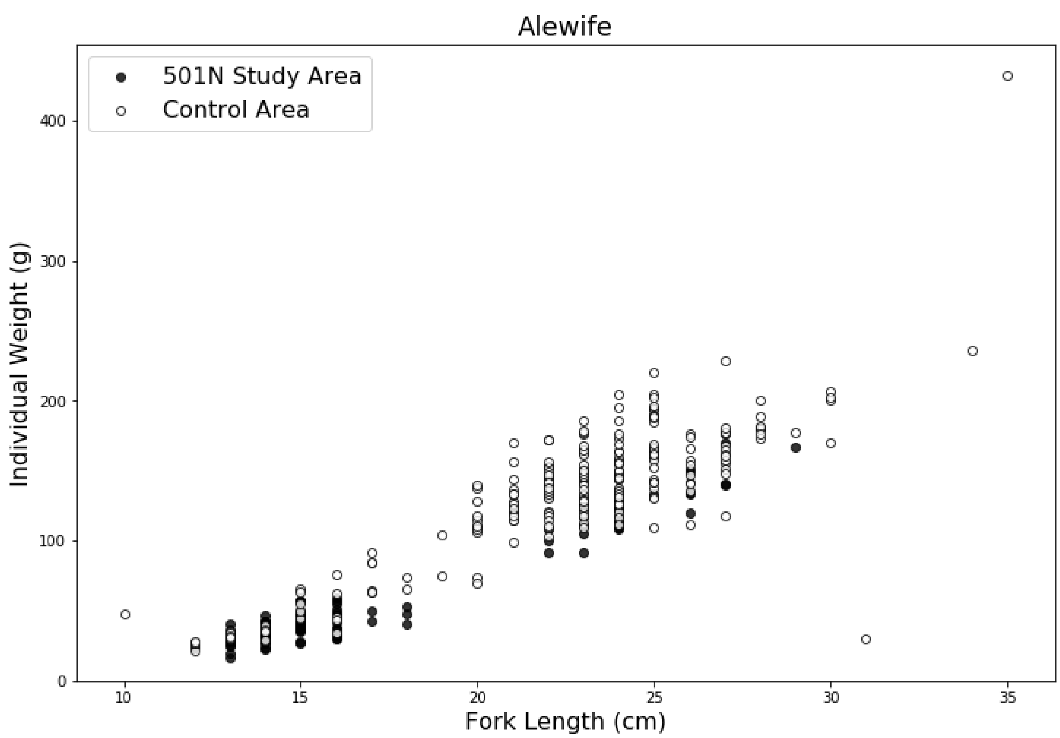


Figure 14: Population structure of alewife in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

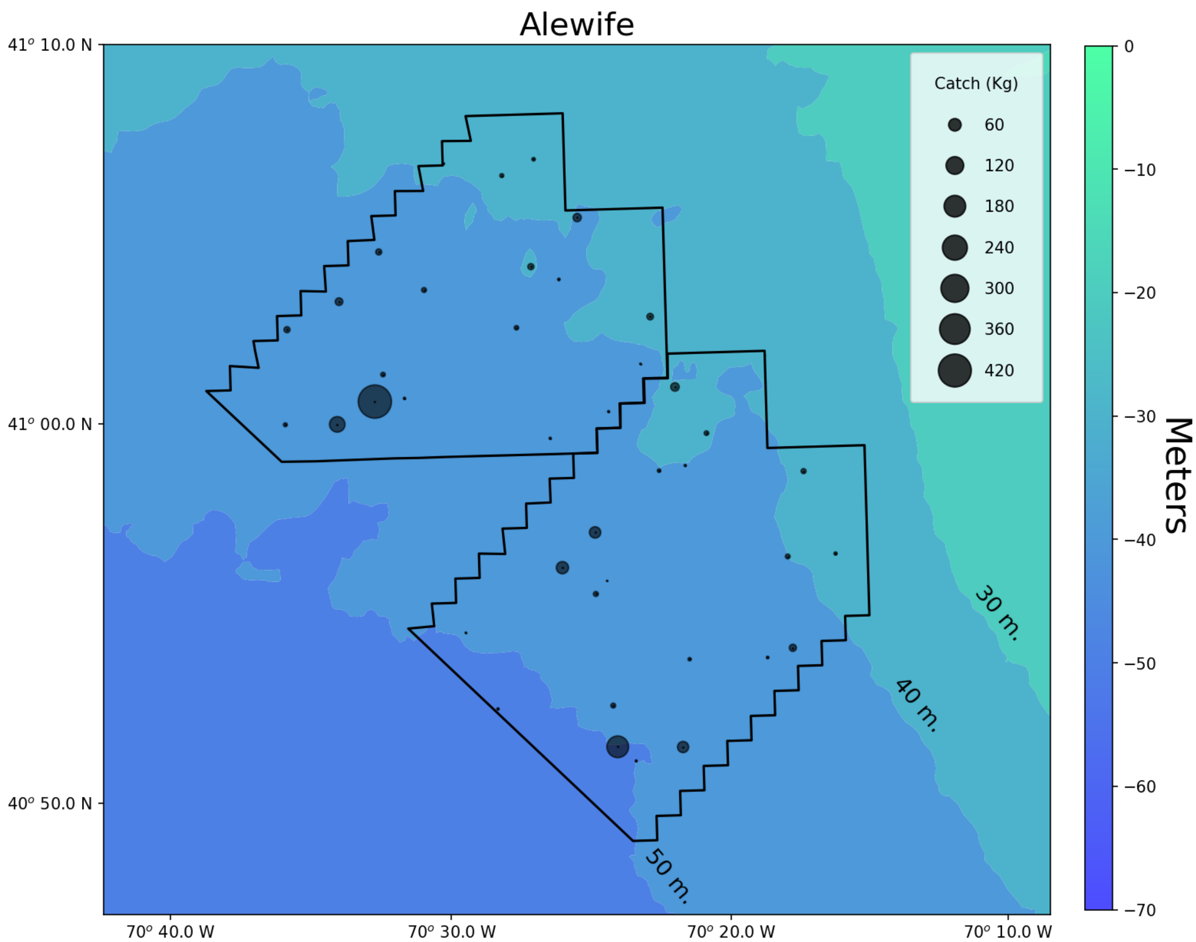
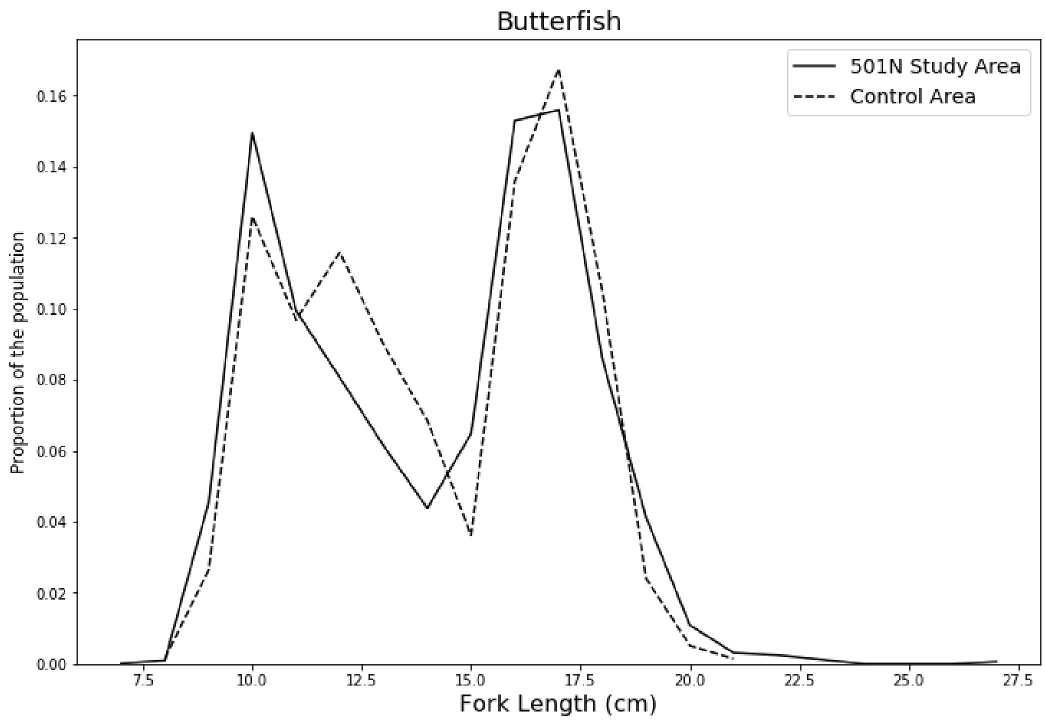


Figure 15: Distribution of the catch of alewife in the 501N Study Area (left) and Control Area (right).



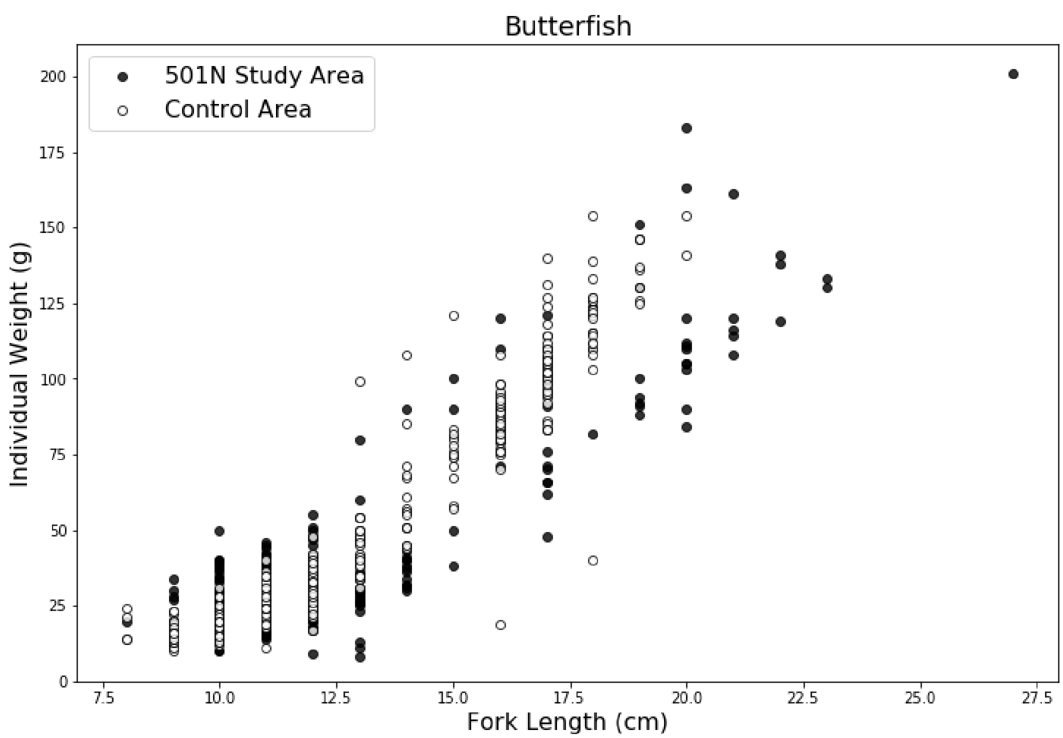


Figure 16: Population structure of butterfish in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

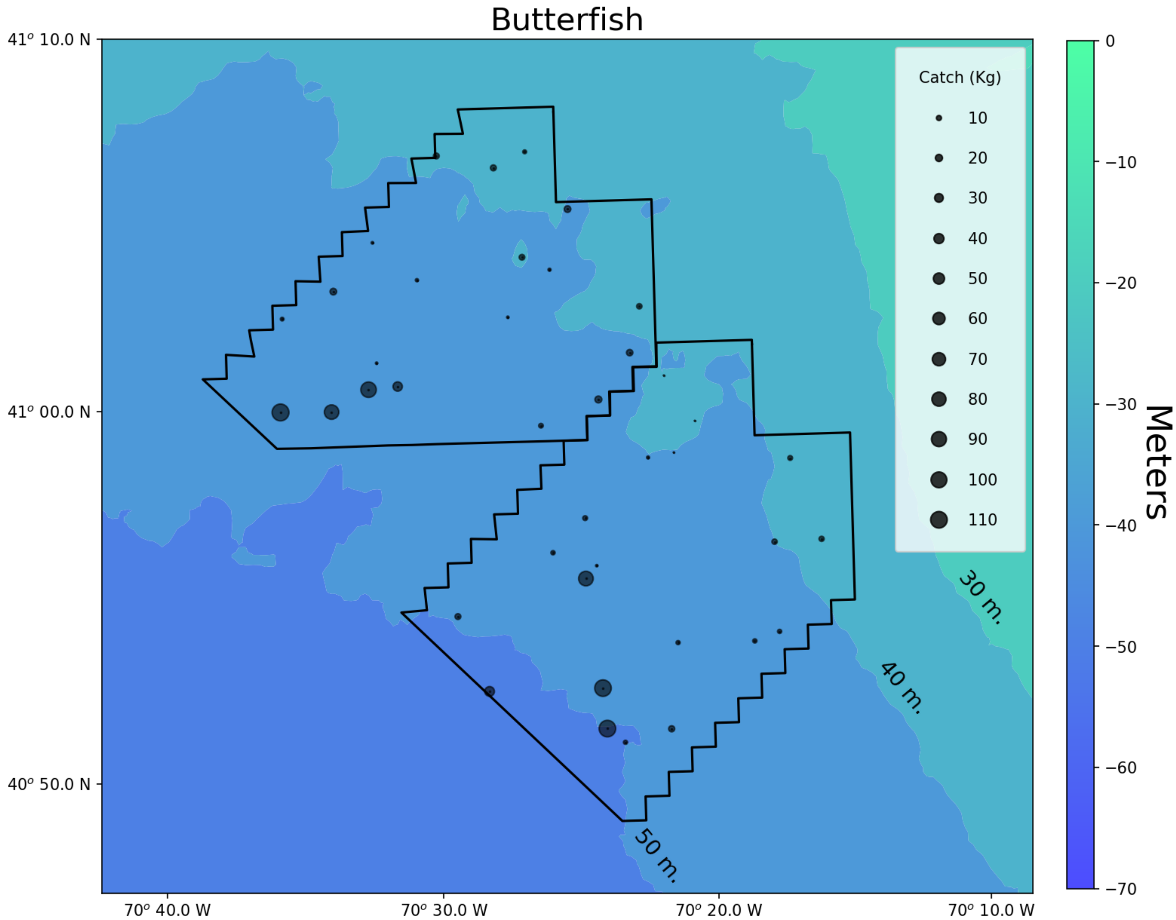


Figure 17: Distribution of the catch of butterfish in the 501N Study Area (left) and Control Area (right).

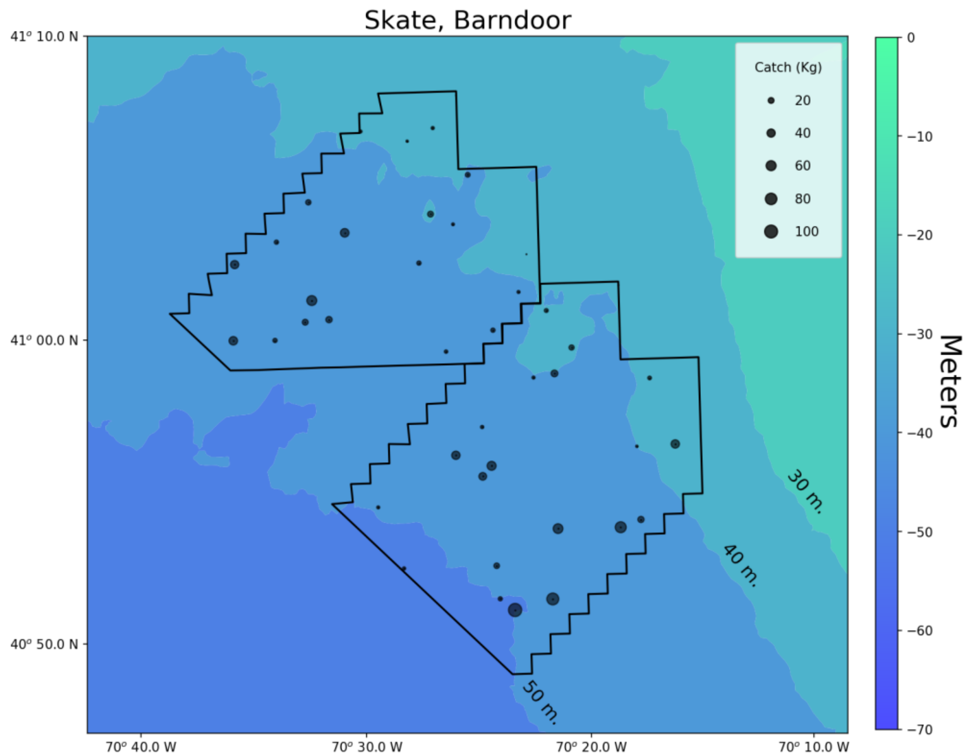


Figure 18: Distribution of the catch of barndoor skate in the 501N Study Area (left) and Control Area (right).

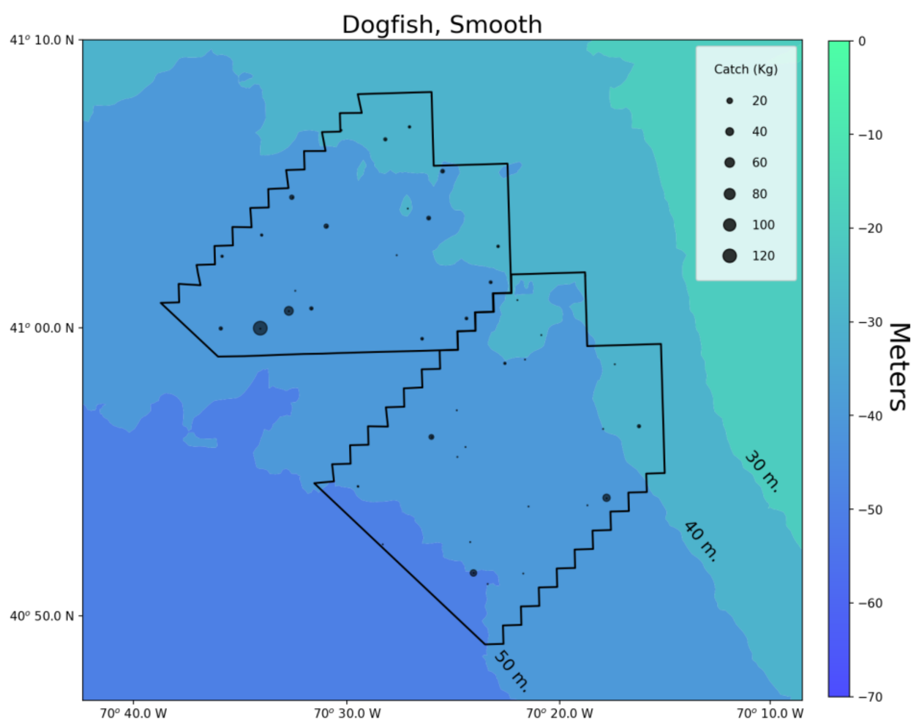
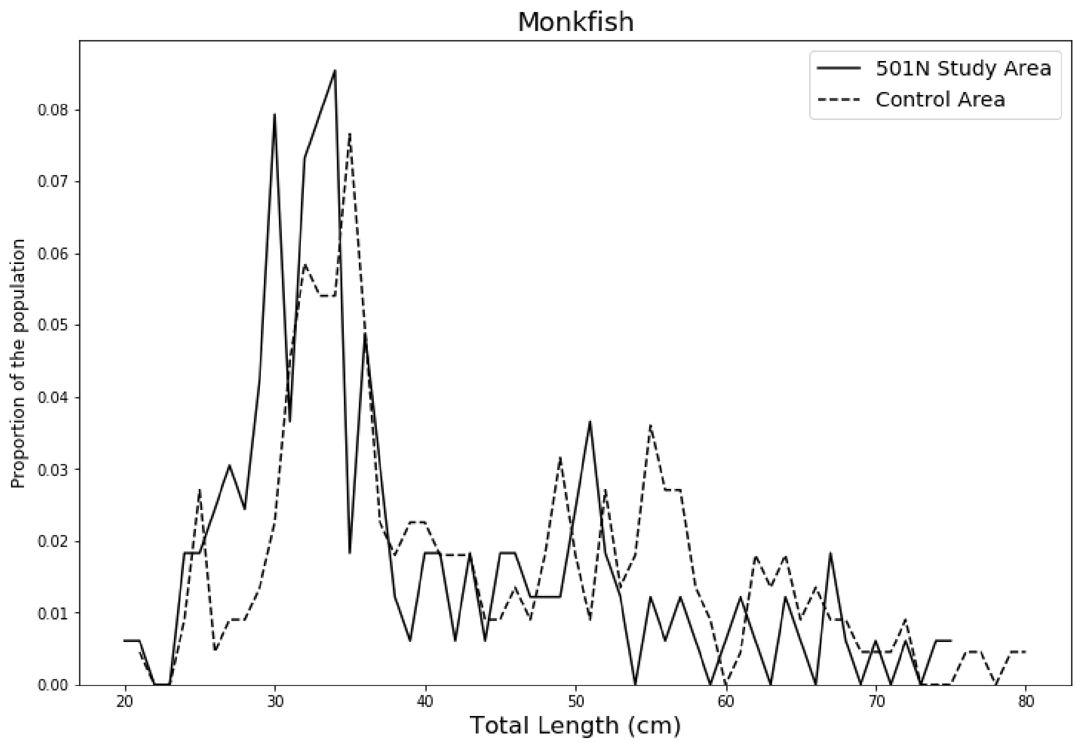


Figure 19: Distribution of the catch of smooth dogfish in the 501N Study Area (left) and Control Area (right).



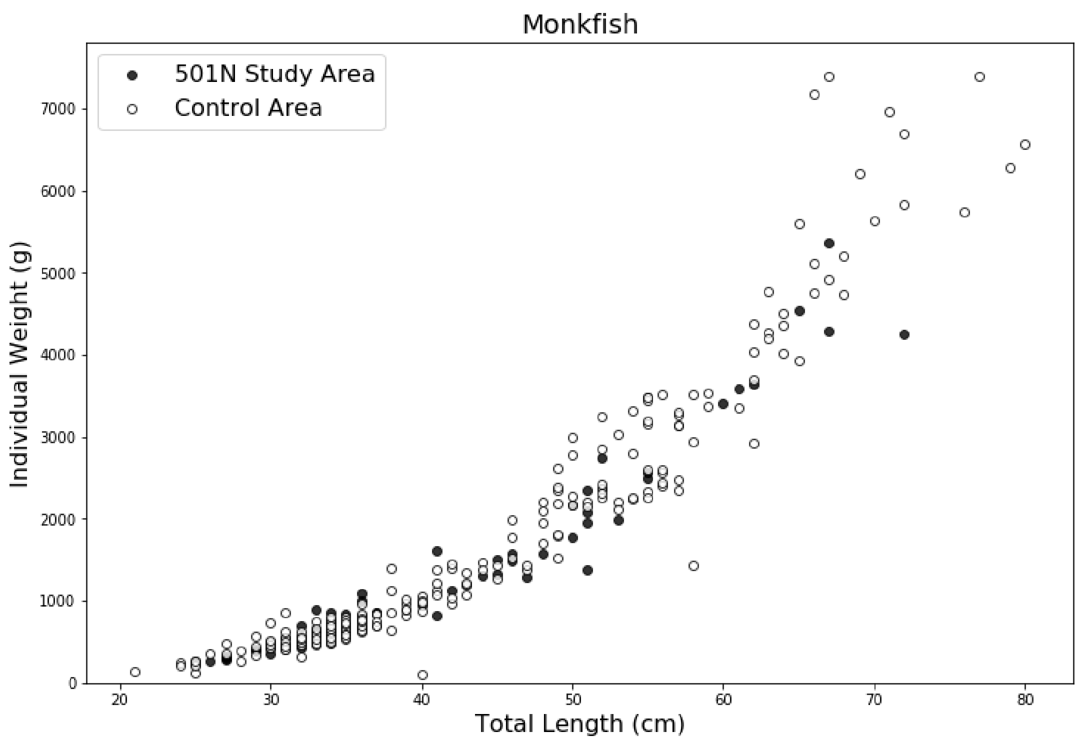


Figure 20: Population structure of monkfish in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

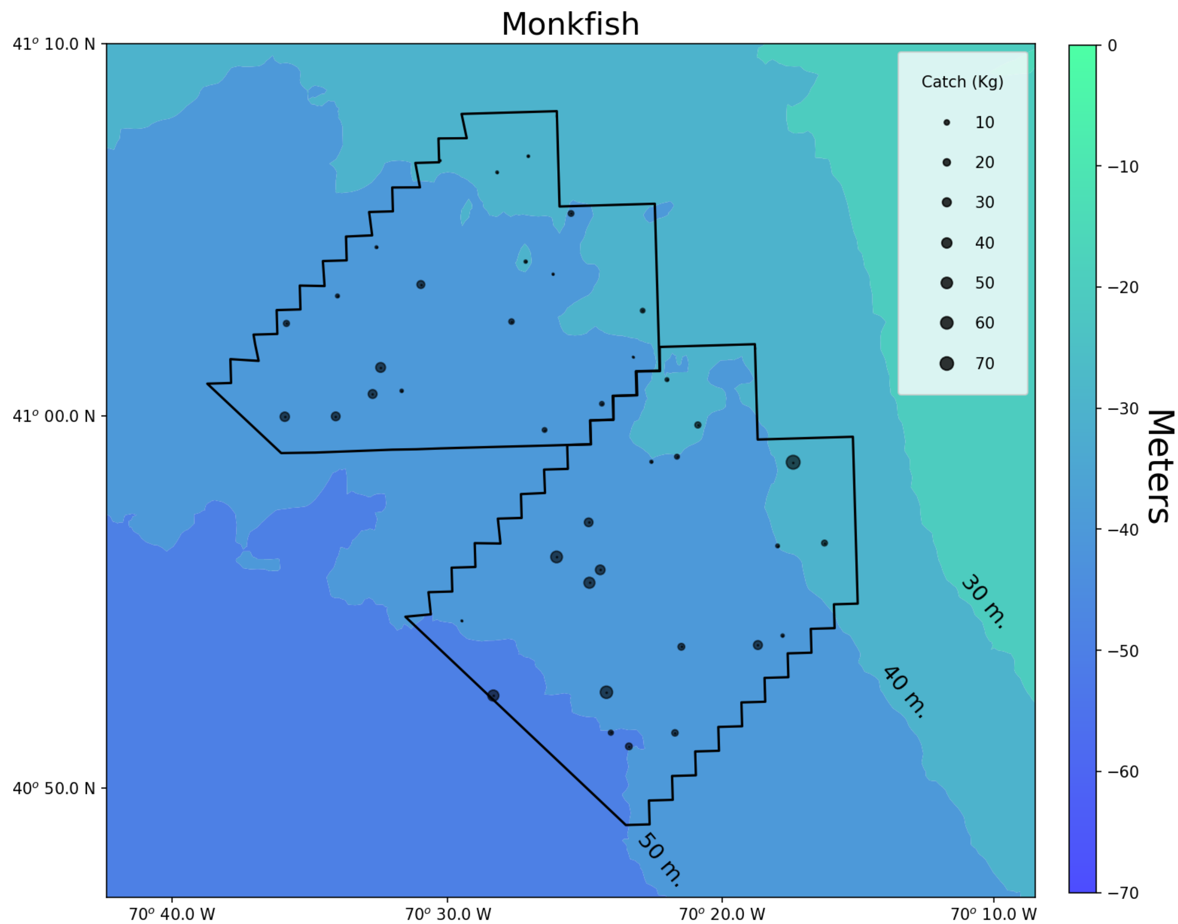
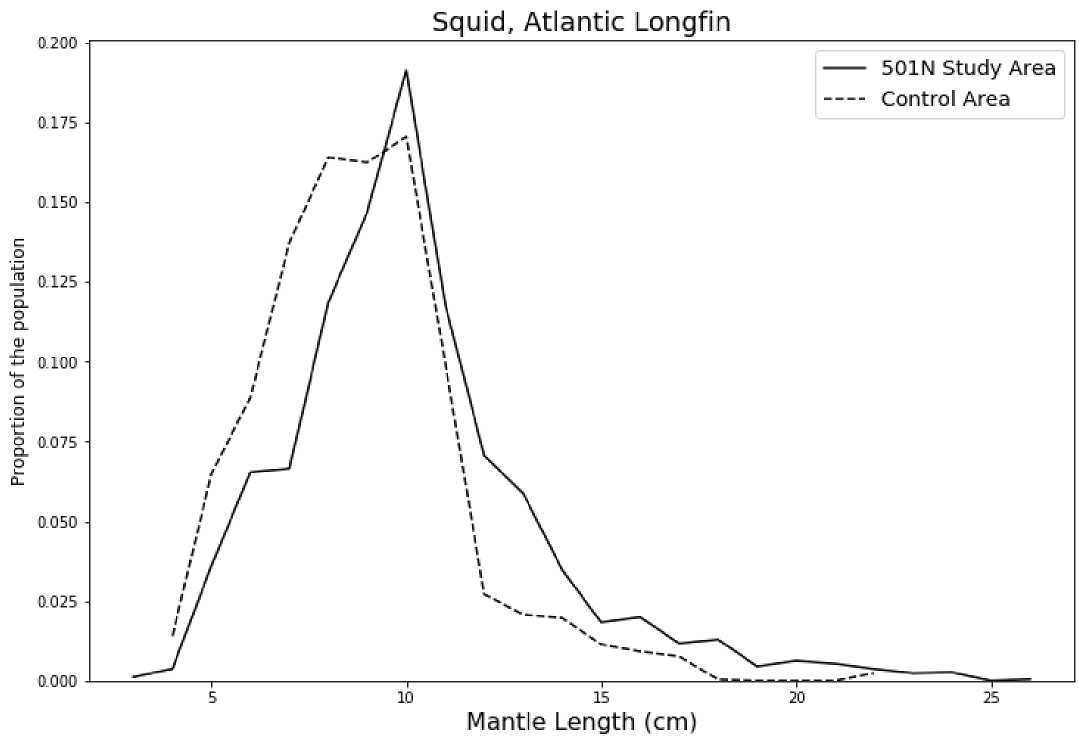


Figure 21: Distribution of the catch of monkfish in the 501N Study Area (left) and Control Area (right).



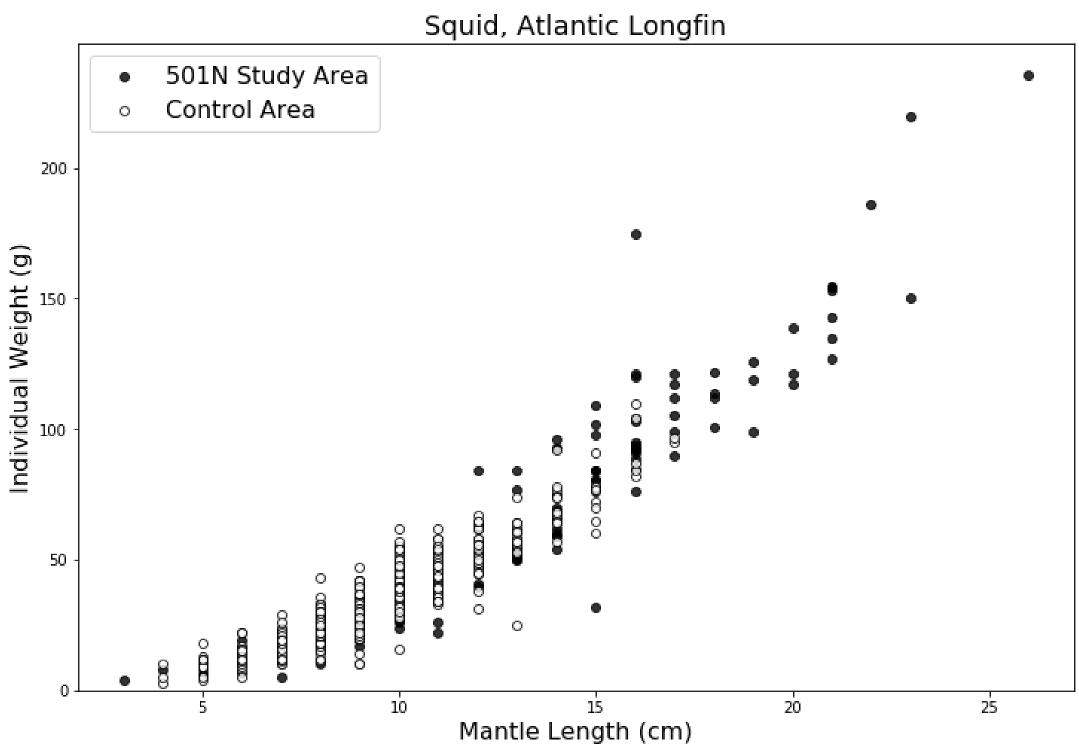


Figure 22: Population structure of longfin squid in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

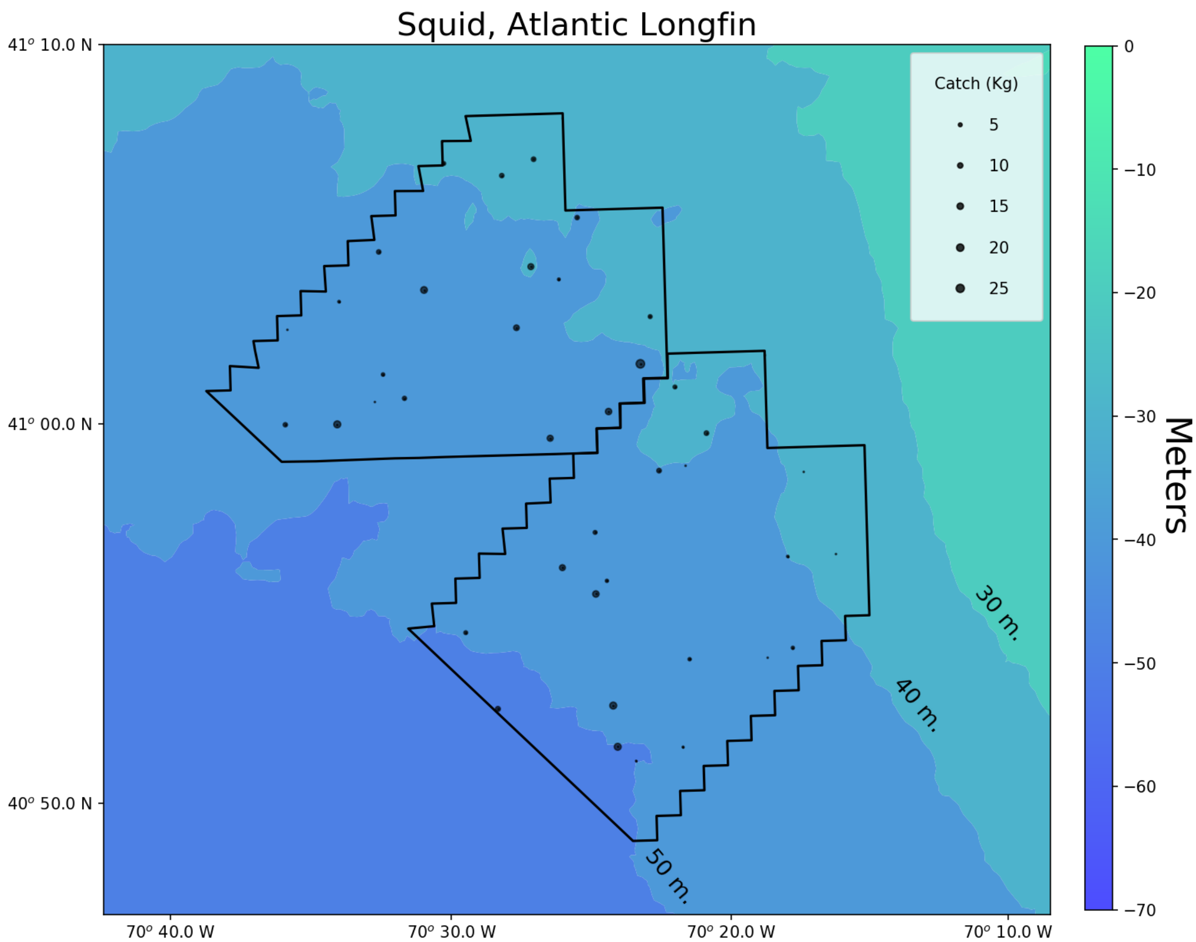
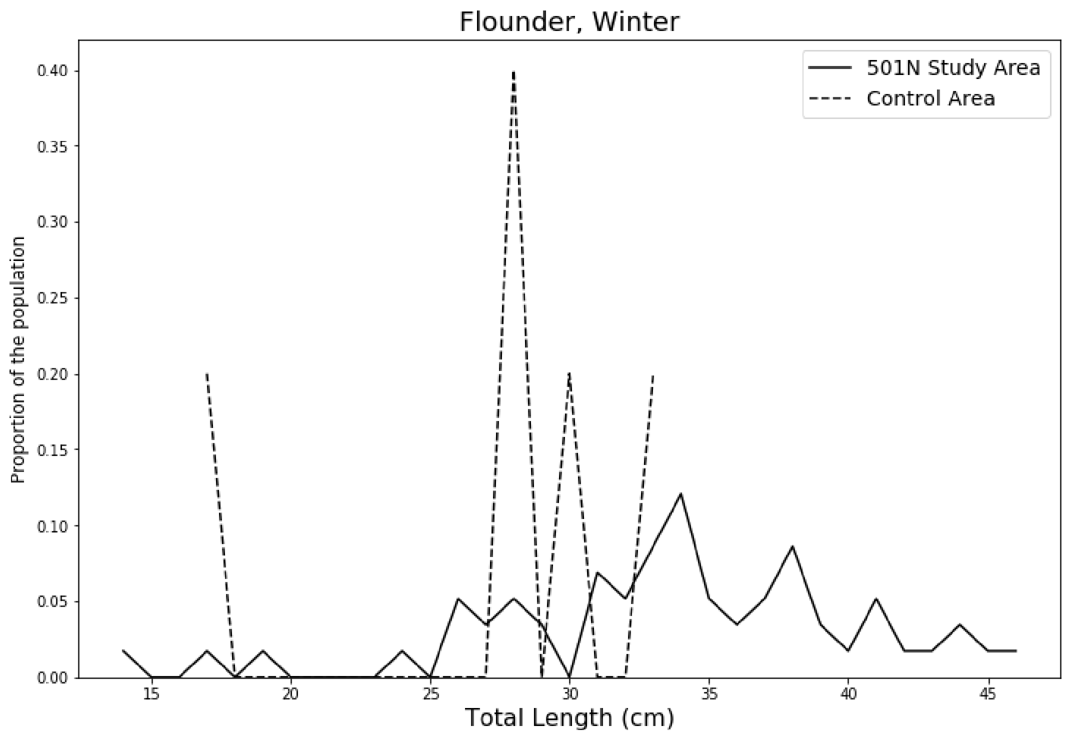


Figure 23: Distribution of the catch of longfin squid in the 501N Study Area (left) and Control Area (right).



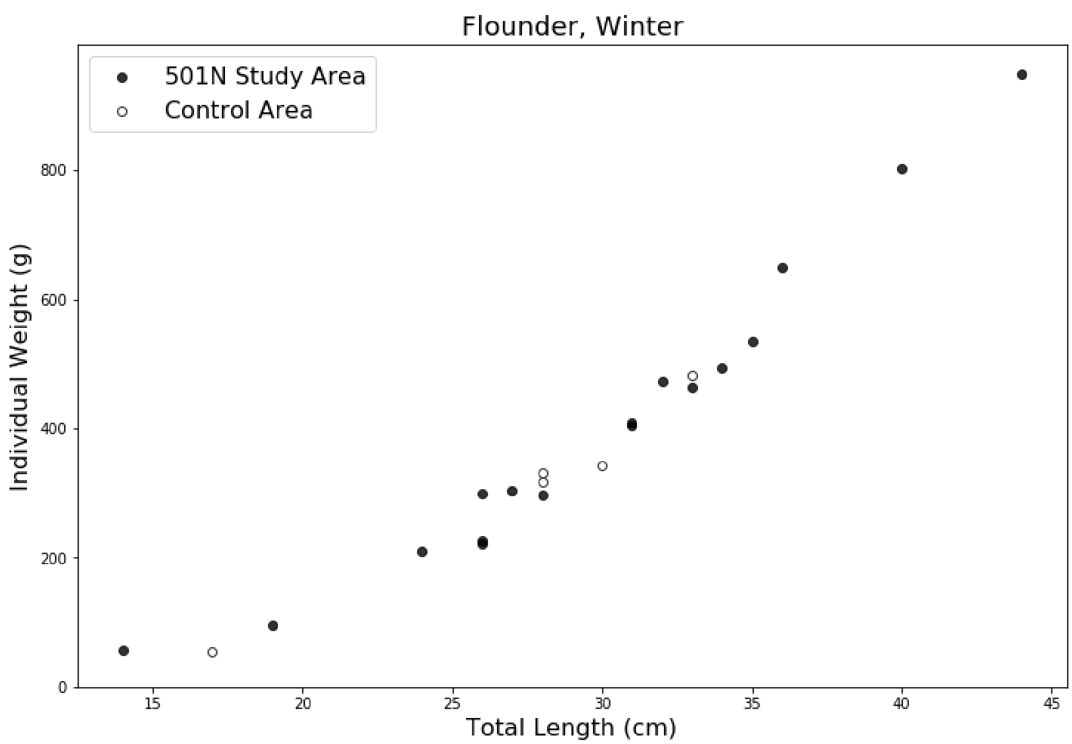


Figure 24: Population structure of winter flounder in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

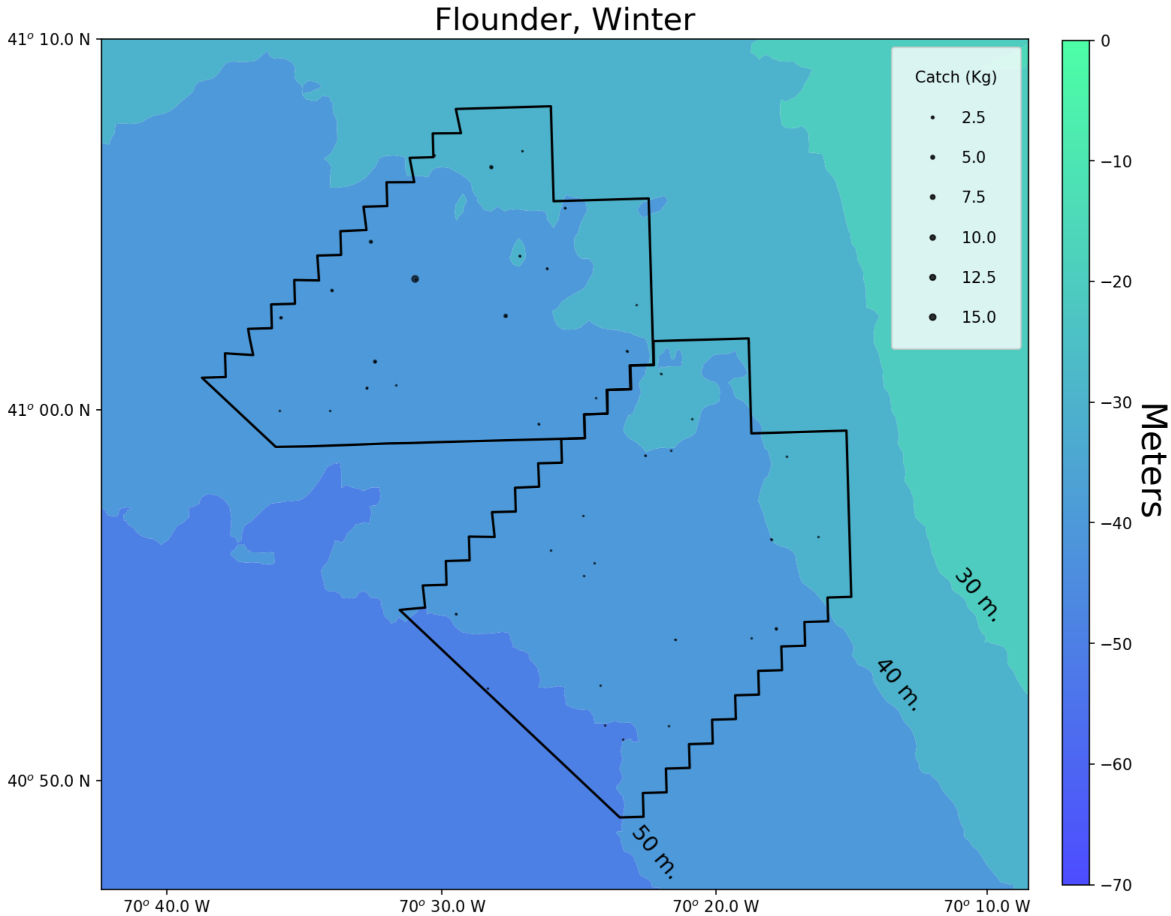


Figure 25: Distribution of the catch of winter flounder in the 501N Study Area (left) and Control Area (right).

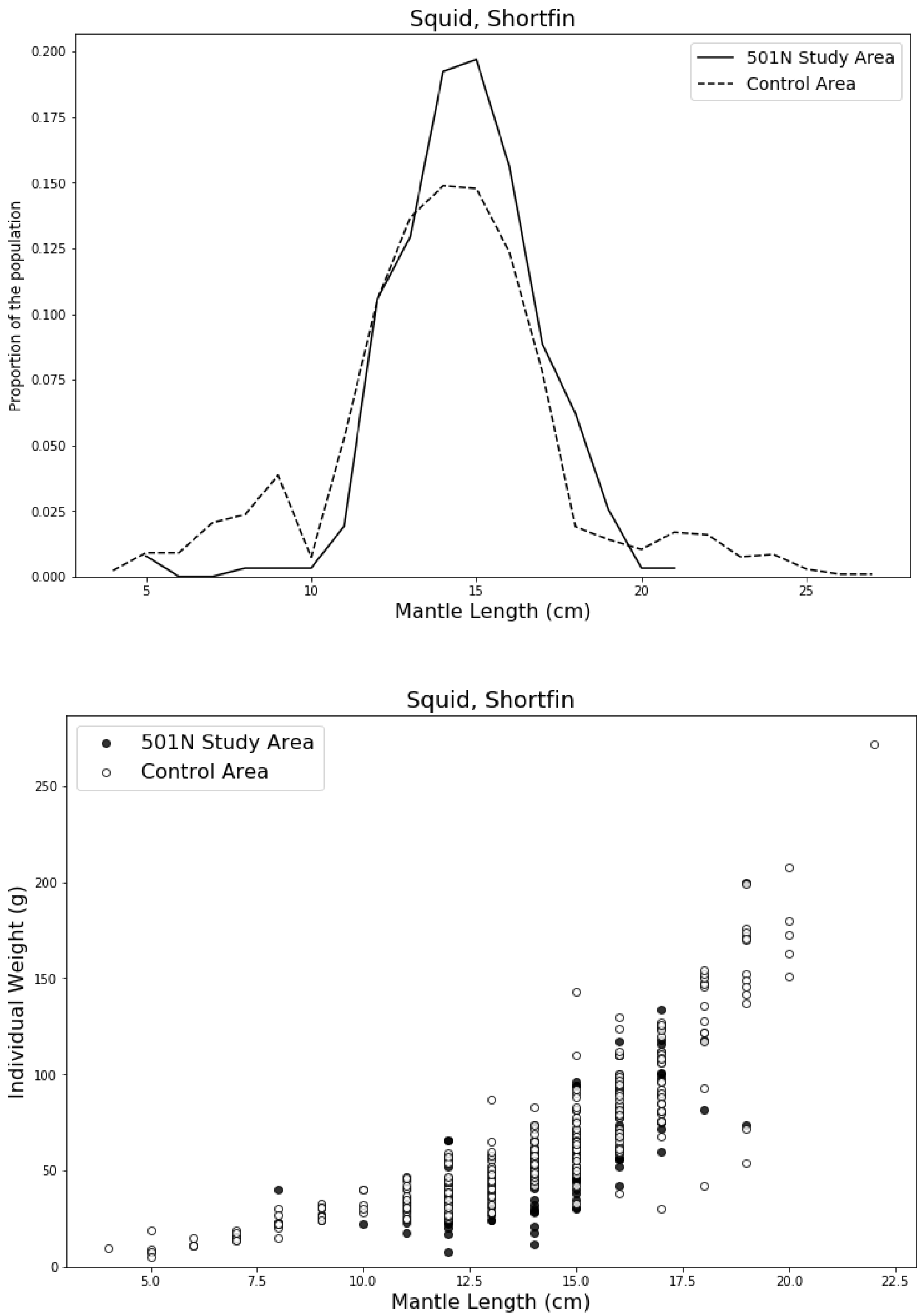


Figure 26: Population structure of shortfin squid in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

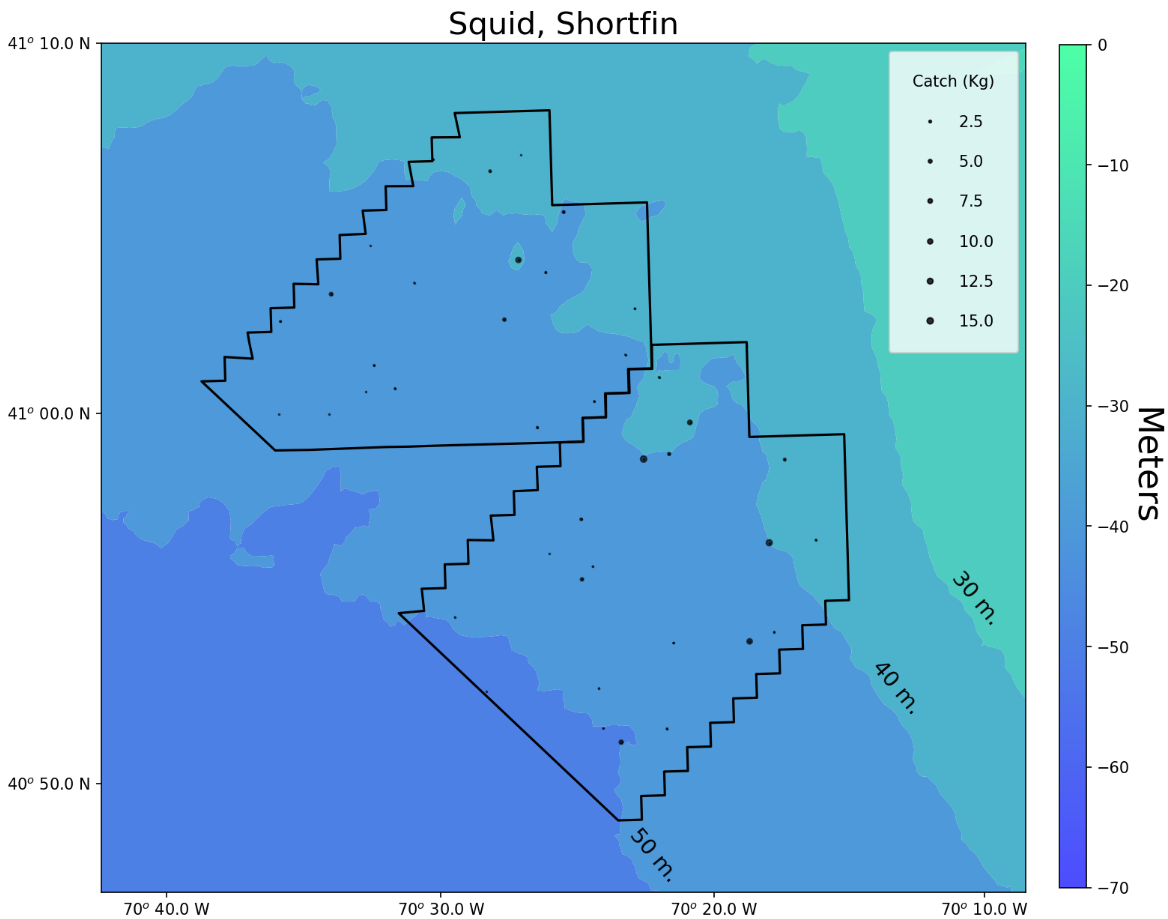
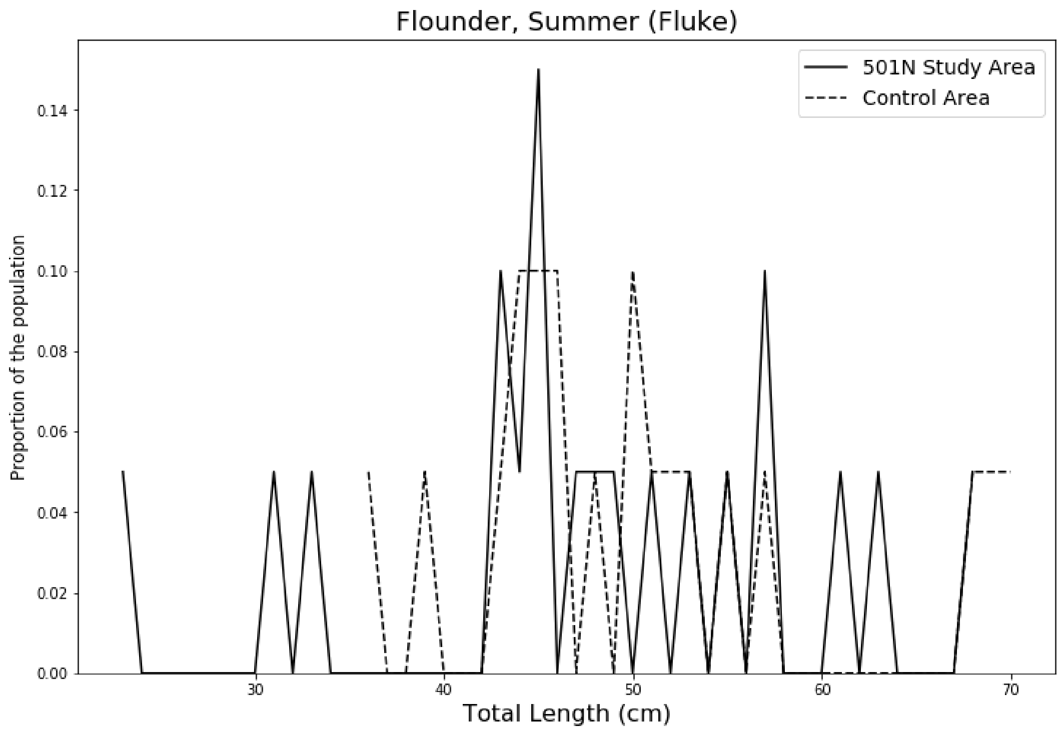


Figure 27: Distribution of the catch of shortfin squid in the 501N Study Area (left) and Control Area (right).



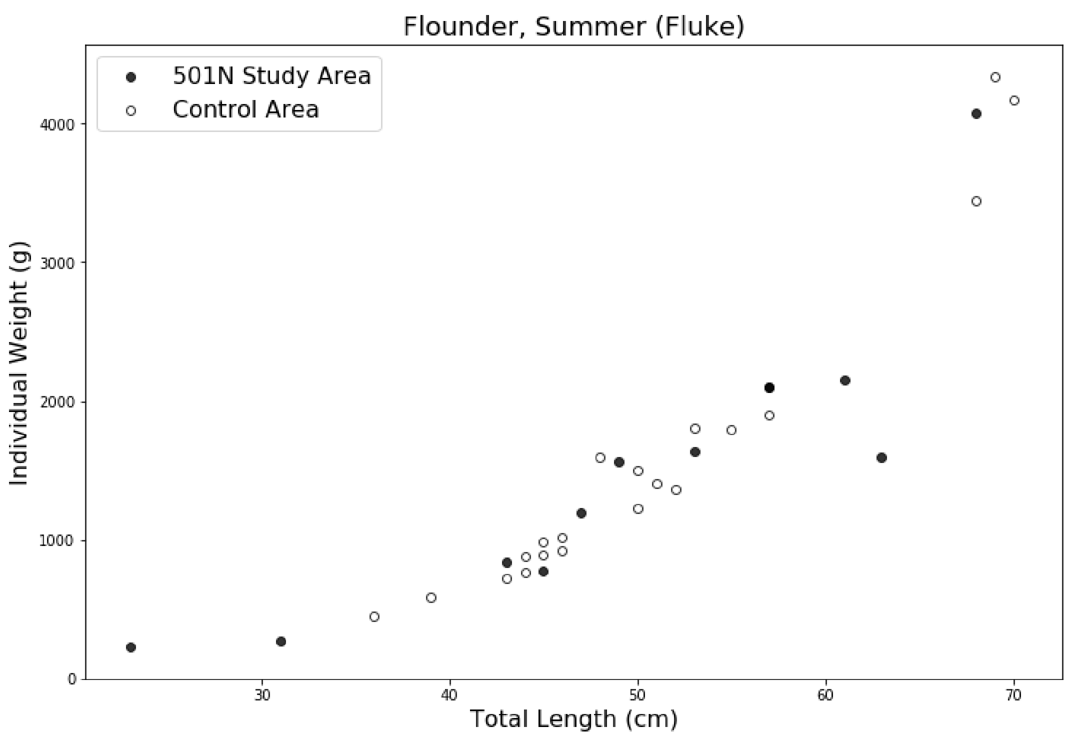


Figure 28: Population structure of summer flounder in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

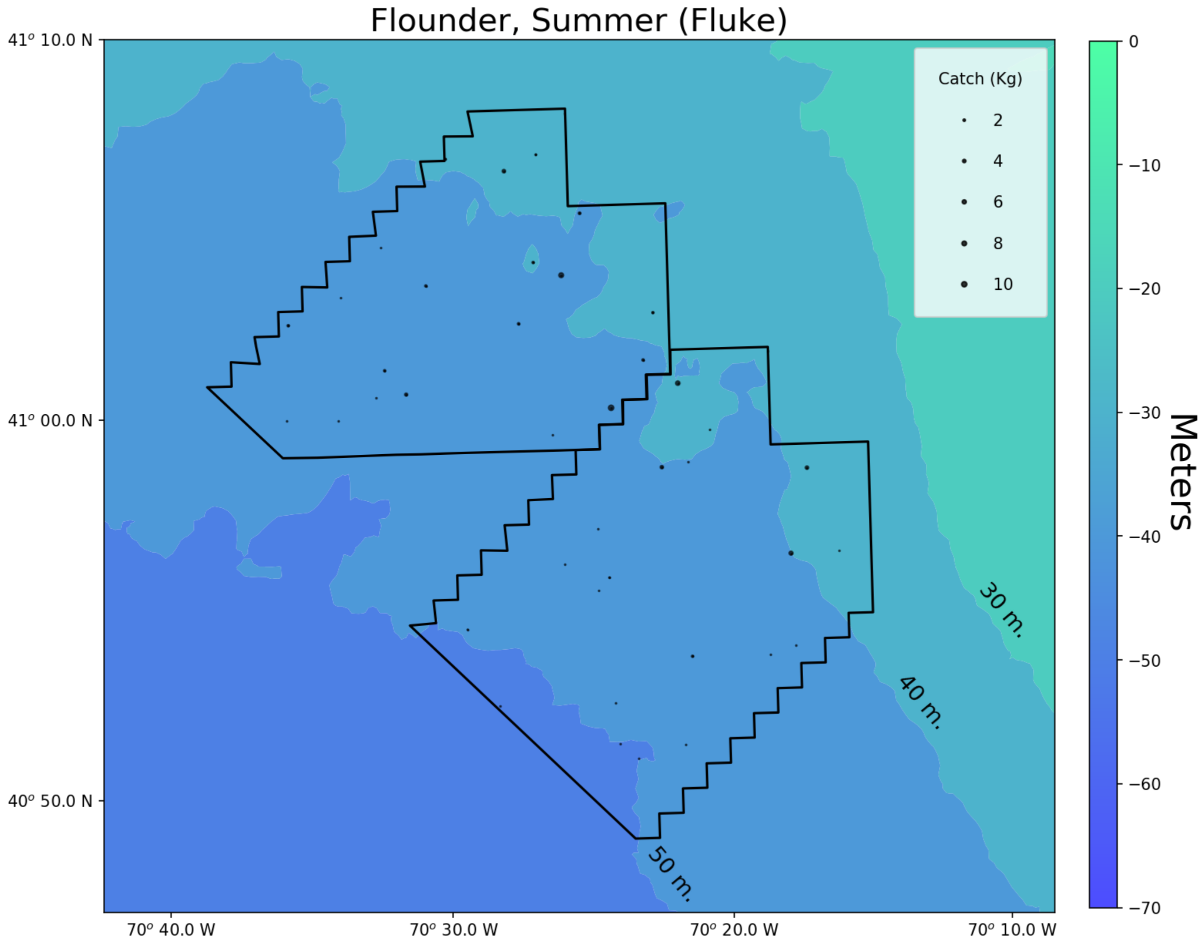
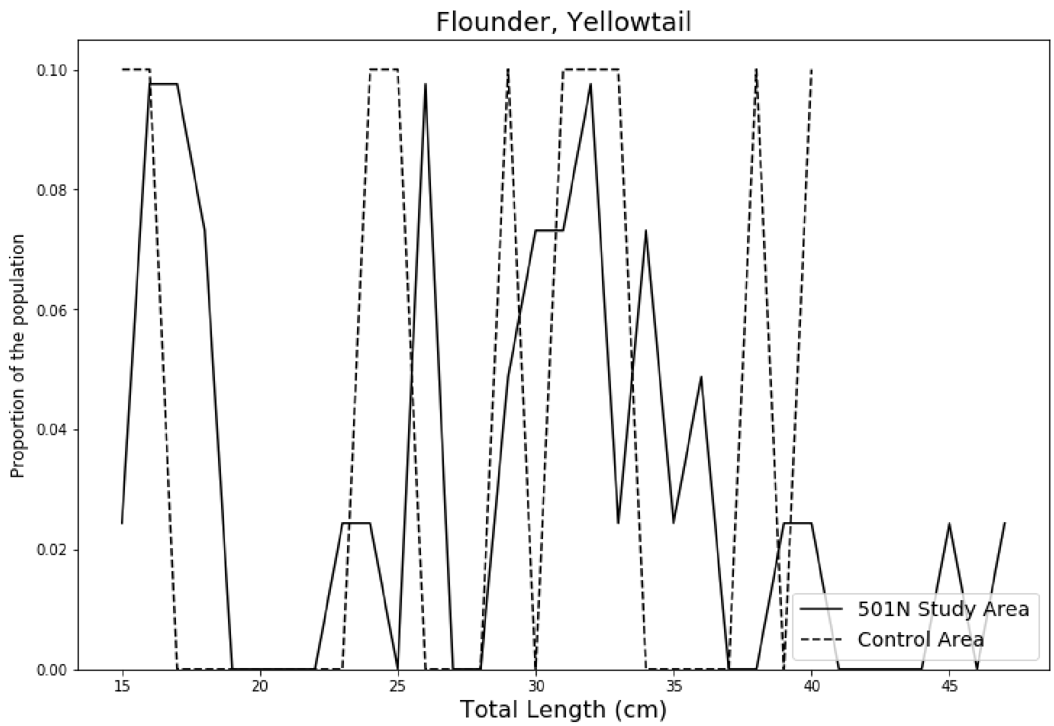


Figure 29: Distribution of the catch of summer flounder in the 501N Study Area (left) and Control Area (right).



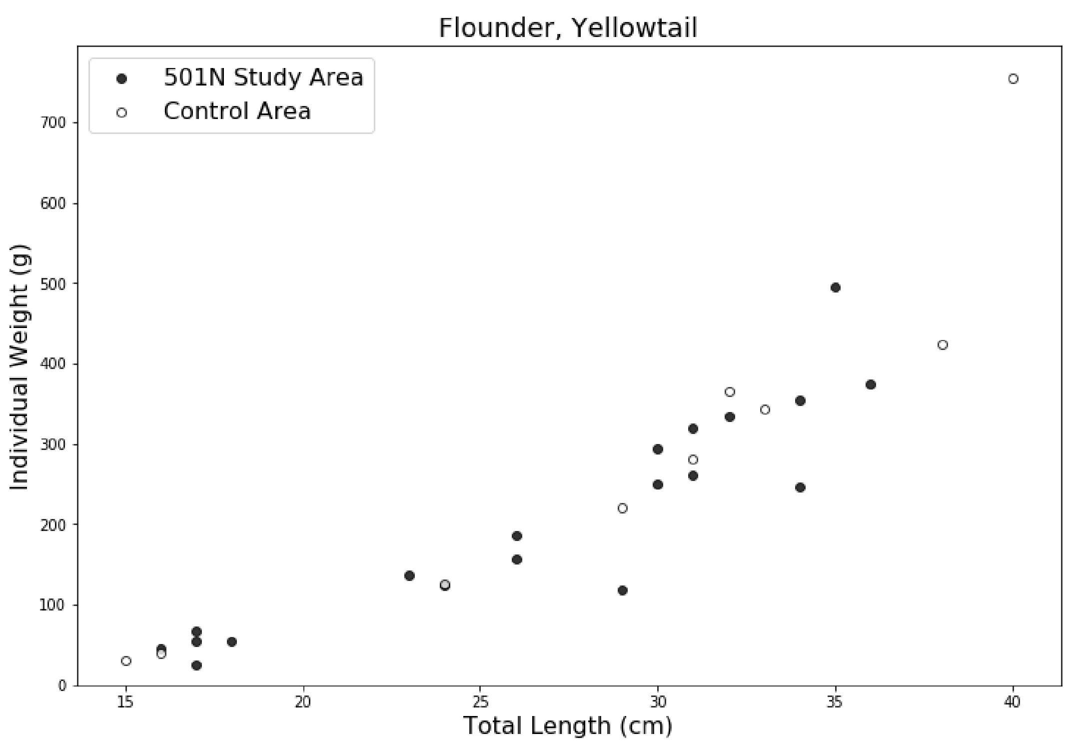


Figure 30: Population structure of yellowtail flounder in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

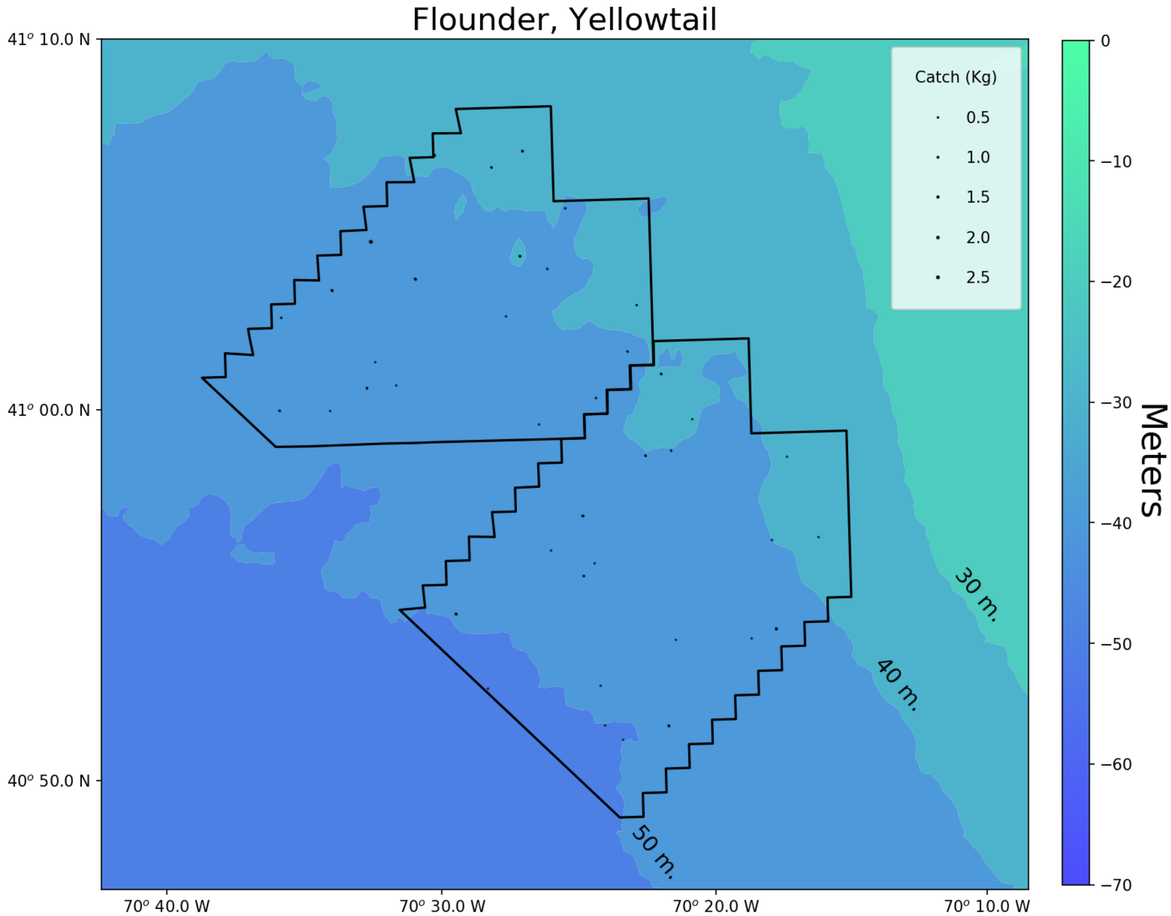
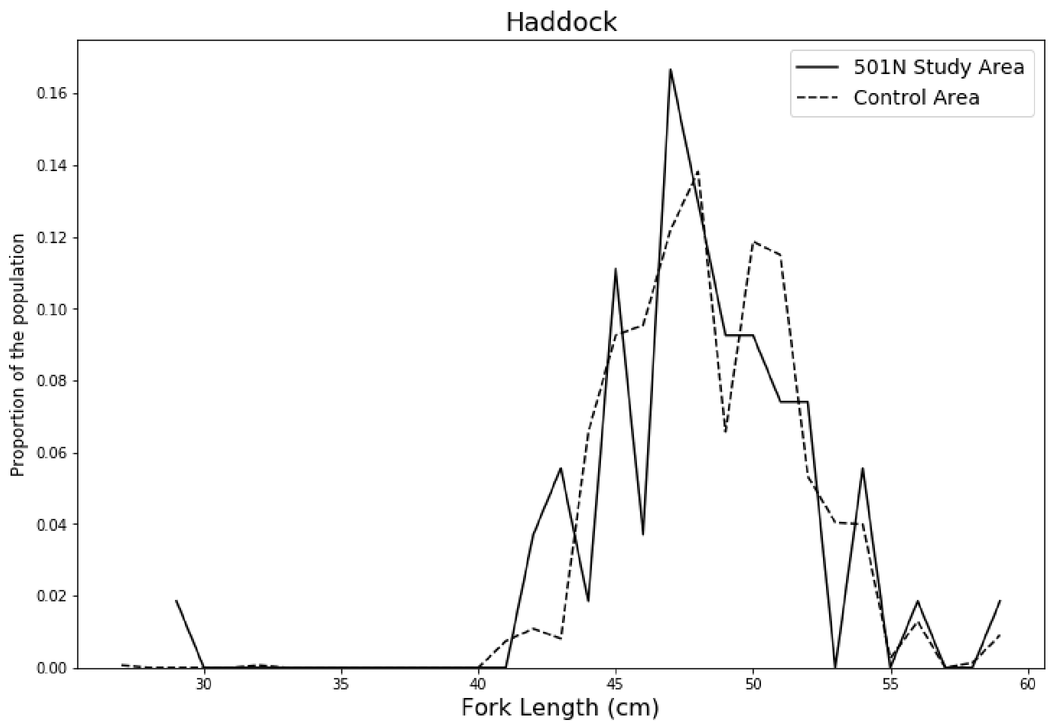


Figure 31: Distribution of the catch of yellowtail flounder in the 501N Study Area (left) and Control Area (right).



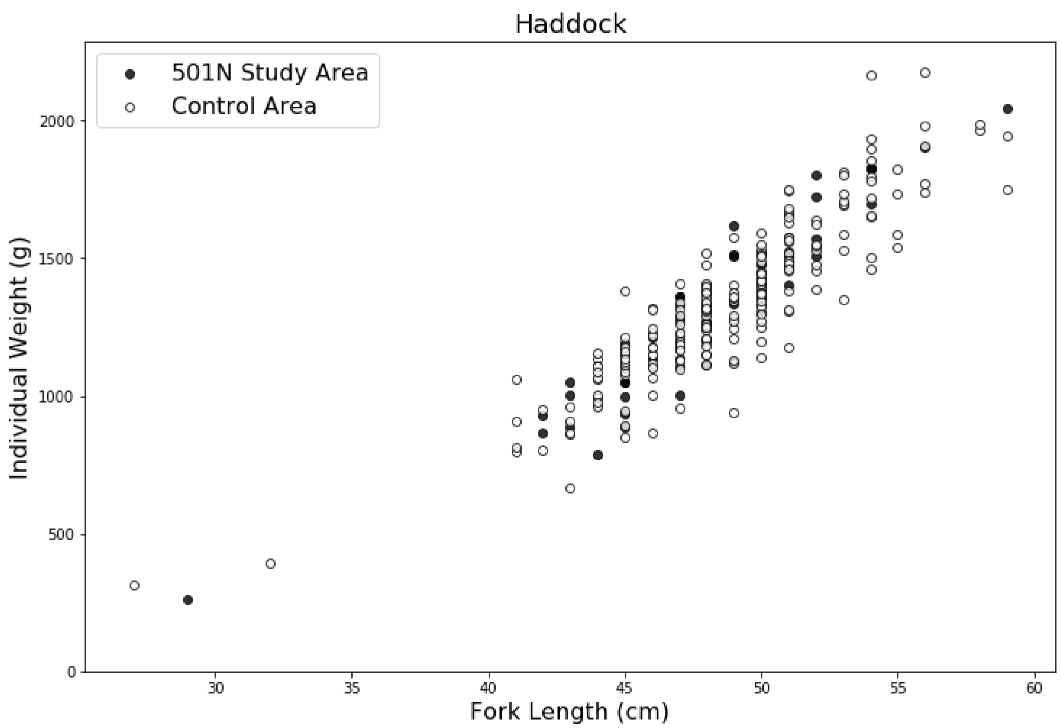


Figure 32: Population structure of haddock in the 501N Study Area and Control Area as determined by the length-frequency data (top) and length-weight relationships (bottom).

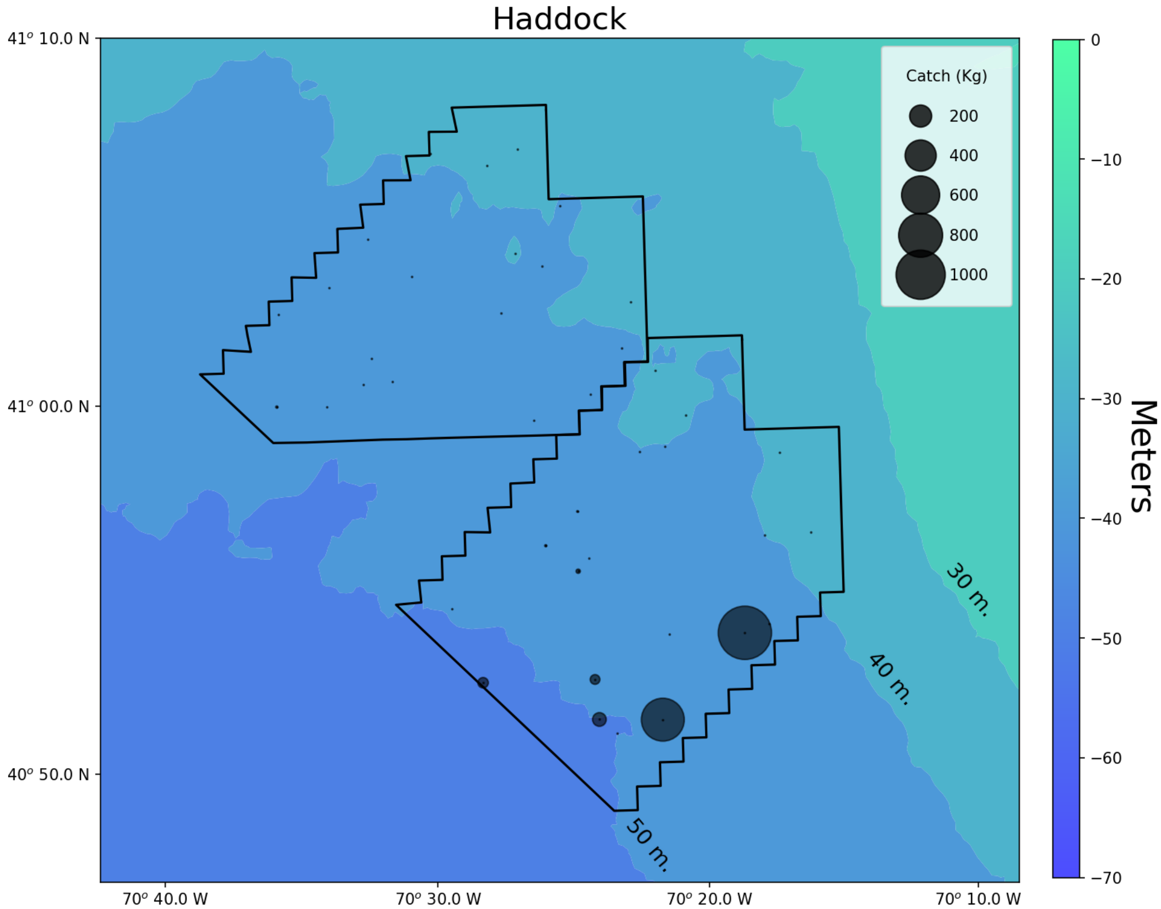


Figure 33: Distribution of the catch of haddock in the 501N Study Area (left) and Control Area (right).