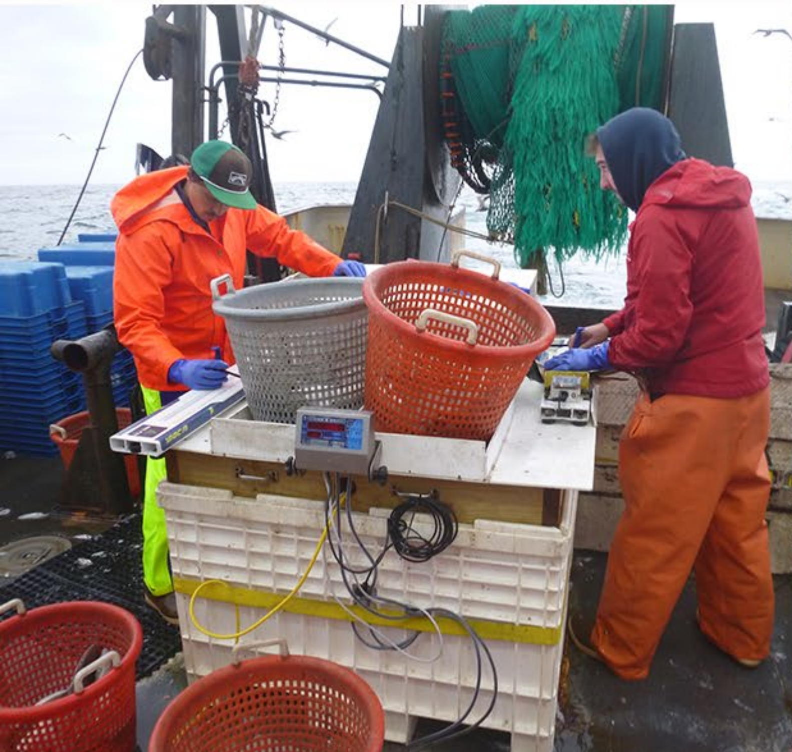
# New England Wind Demersal Trawl Survey



# Annual Report
2021-2022

## 534 Study Area

# NEW ENGLAND WIND DEMERSAL TRAWL SURVEY

## 2021/2022 Annual Report

## 534 Lease Area

**March 2022**

**Prepared for Avangrid Renewables, LLC**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**New England Wind**

**Demersal Trawl Survey**

**Annual Report**

**534 Lease Area**

**2021/2022 Annual Report**
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# 1. Summary

Avangrid 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 impact of future offshore renewable energy development on marine fish and invertebrate communities in the Lease Area OCS-A 0534. One component of the monitoring plan is a demersal trawl survey. The trawl survey is modeled after the Northeast Area Monitoring and Assessment Program (NEAMAP), a regional survey used to assess near-shore fish communities. The data collected from this survey is intended to provide baseline information on species abundance distribution, population structure and community composition to be used in a future impact analysis. Similar fisheries studies are being conducted within Lease Area OCS-A 0501 (the "Vineyard Wind 1 Study Area") and within Lease Area OCS-A 0522 (the "522 Study Area"); these studies are reported separately.

Two seasonal trawl surveys were conducted from the fall of 2021 through the winter of 2022 using a commercial fishing vessel. Ten tows were conducted each season in the 534 Study Area. Tow locations were randomly selected using a systematic unaligned sampling design. A standardized bottom trawl with a 1" knotless liner was towed behind the vessel for 20 minutes at 3 knots. Acoustic sensors were used to ensure the net's performance by monitoring the trawl geometry. The catch was sorted by species. Aggregated weight as well as individual fish lengths and weights were collected.

A total of 20 tows were completed throughout the year. The catch data obtained shows a dynamic area with a diversity of marine species. A total of 36 species were collected; however, the majority of the catch was comprised of a small subset of the observed species. The five most abundant species (spiny dogfish, scup, butterfish, little skate, and Atlantic longfin squid) accounted for 90.2% of the total catch weight in the 534 Study Area. All species caught displayed seasonal variations in distribution and abundance. The data indicate a unique assemblage of species and abundance in each season. The fall and winter surveys appeared to be relatively unique in the species assemblage.

Interannual changes in abundance varied amongst species and communities. For example, butterfish, Atlantic herring, Atlantic cod, scup, and Atlantic longfin squid exhibited increases in seasonal catch rates. Conversely, red hake, silver hake, monkfish, and little skate exhibited decreased annual catch rates. The seasonal changes were largely in line with those observed in 2019/2020 and 2020/2021. Winter tows were primarily associated with little skates, alewife, Atlantic herring, Atlantic mackerel, and blueback herring. Fall tows were associated with spiny dogfish, scup, butterfish, little skate, and longfin squid. The winter and fall surveys had similarity to the previous survey year. The interannual similarities may be due to consistent bottom water temperatures across the fall and winter surveys between survey years.

An updated power analysis was conducted using data aggregated from three survey years. The results indicate that the current bottom trawl survey effort would provide reasonable "power" to detect small to medium scales of change in abundance for the most common species, if changes in abundance do occur. Providing the additional year of survey data caused small changes to the CVs for most species, the changes observed serve to provide a more realistic assessment of the variability in the data and therefore a better understanding of the statistical power to detect changes.

# 2. Introduction

In 2015, Vineyard Wind LLC, a joint venture between Avangrid Renewables LLC (Avangrid) and Copenhagen Infrastructure Partners, leased a 675-square-kilometer ($km^2$) area for renewable energy development on the Outer Continental Shelf, Lease Area OCS-A 0501, which is located approximately 14 miles south of Martha's Vineyard off the south coast of Massachusetts. In June 2021, the Bureau of Ocean Energy Management (BOEM) segregated Lease Area OCS-A 0501 into two lease areas – OCS-A 0501 and OCS-A 0534. Lease Area OCS-A 0501 is assigned to an entity identified as Vineyard Wind 1 and OCS-A 0534 is assigned to New England Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC ("Avangrid"). Fisheries surveys are occurring within these areas – referred to as the "VW1 Study Area and "534 Study Area," respectively.[1] The latter is the focus of this report. The VW1 Study Area fisheries surveys are reported separately.

The Bureau of Ocean Energy Management (BOEM) has statutory obligations under the National Environmental Policy Act to evaluate the 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, Avangrid 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 on marine fish and invertebrate communities. 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

[1] The VW1 Study Area is referred to as the "501N Study Area" in SMAST fisheries survey reports compiled prior to the lease area segregation. Similarly, the 534 Study Area is referred to as the 501S Study Area in SMAST fisheries survey reports compiled prior to the lease area segregation. Park City Wind LLC became the sole holder of the OCS-A 0534 lease in late 2021.

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 ever-changing ocean.

The current monitoring plan incorporates multiple surveys utilizing a range of survey methods to assess different facets of the regional marine ecosystem. 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 a vessel along the seafloor and 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, bottom trawls are a generally accepted tool for assessing the biological communities along the seafloor and are widely used by institutions worldwide for ecosystem monitoring. Since they are actively towed behind a vessel, they are less biased by fish activity and behavior than passive fishing gear (i.e., gillnets, longlines, traps, etc.), which relies 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 the abundance of 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 annual spring and fall trawl surveys, the annual NEAMAP spring and fall trawl surveys, and state trawl surveys including the Massachusetts Division of Marine Fisheries trawl survey. The NEAMAP survey protocol has also been adopted by trawl surveys conducted in other offshore wind development areas in the northeast US by other institutions. The bottom trawl survey is complemented by the drop camera survey in the same area, also carried out by SMAST (reported separately).

The primary goal of this survey was to provide data related to seasonal fish abundance, distribution, population structure and community composition in and around the 534 Study Area. The data will serve as a baseline to be used to inform future fisheries monitoring efforts. This report documents the survey methodology, survey effort, and data collected during two seasonal surveys between the fall of 2021 and winter of 2022. Surveys planned for the spring and summer of 2022 were not conducted due to additional permitting requirements and associated delays. The 2019/2020 and 2020/2021 annual reports, as well as ten seasonal reports between 2019 to 2022, have been submitted to the sponsoring organization.

# 3. 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 3.1) will enable the survey to fulfill the primary goal of evaluating the impact of windfarm development while improving the consistency between survey platforms. This 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, the methodology is consistent with other ongoing surveys of nearby study areas (Vineyard Wind VW1 Study Area and the OCS-A 0522 Lease Area).

## 3.1 Survey Design

The current survey is designed to provide baseline data on species abundance, population structure, and community composition for a future environmental assessment. Four surveys were planned to be conducted to assess the seasonal variability in the resident populations, however due to changing regulatory and permitting requirements only two surveys were completed. The seasonal surveys consisted of a fall (October – December) and winter (January – March) survey. In temperate oceans the distribution of mobile marine species can fluctuate seasonally, typically coinciding with seasonal changes in water temperature. The timing of the seasonal surveys is intended to capture these generalized trends in the population dynamics. The timing of previous spring surveys coincides with the inshore movement of many species and is associated with increasing water temperature. The summer surveys are intended to characterize the resident summer species which occur during seasonal warm water. The fall surveys occur during decreasing water temperature which typically triggers the offshore movement of many coastal species. Finally, the winter surveys occur during stable cold temperatures in the region. Data collected during these surveys will be used to understand the population dynamics of the area while providing data related to the spatial and temporal variability of local fish communities. A power analysis of this data will ensure that an adequate sampling resolution is used when conducting a future environmental assessment using the BACI framework as recommended by BOEM (BOEM, 2013).

Tow locations within the 534 Study Area were selected using a spatially balanced sampling design. The 534 Study Area was modified from the 2020/2021 survey year for the winter survey due to boundary refinements of projects within Lease Area OCS-A 0501. The VW1 Study Area was increased from 369 $km^2$ to 411 $km^2$ by moving the southern boundary further south (Figure 2). The current 534 Study Area was sub-divided into 10 sub-areas (each ~41.1 $km^2$), and one trawl tow was made in each of the 10 sub-areas. This was designed to ensure adequate spatial coverage throughout the 534 Study Area. The starting location within each sub-area was randomly selected (Figure 2).

## 3.2 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 used in this survey 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.) 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 disks 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 Bonzek et al. (2008).

## 3.3 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 Simrad PX net mensuration system (Kongsberg Group, Kongsberg, Norway) was used to monitor the net geometry (Figure 1). Two sensors were placed in the doors, one in each, to measure the distance between the doors, referred to as door spread. Two sensors placed on the center wingends measured the horizontal spread of the net, commonly referred to as the wing spread. A 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. The headline sensor also measured bottom water temperature. To ensure the net was on the bottom a sensor was placed behind the footrope in the belly of the net. That sensor was equipped with a tilt sensor which reported the angle of the net belly. An angle around $0^{o}$ indicated the net was on the seafloor. A towed hydrophone was placed over the side of the vessel to receive the acoustic signals from the net sensors. A processing unit, located in the wheelhouse and running the TV80 software, was used to monitor and log the data during tows (Figure 7).

## 3.4 Survey Operations

Two surveys were conducted on the F/V *Heather Lynn*, an 84' stern trawler operating out of Point Judith, Rhode Island. The F/V *Heather Lynn* is a commercial fishing vessel currently operating in the industry. The seasonal surveys were completed between the following dates, during which all planned tows were completed:

- Fall Survey: November 16 – 21, 2021
- Winter Survey: February 2 – 4, 2022

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. 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. The trawl warp ratio (trawl warp: seafloor depth) was set to ~4:1. This decision was based on the net geometry data obtained from the 2019 surveys indicating that the 4:1 ratio provided the required geometry by constraining the horizontal spreading of the net and increasing the headline height.

In addition to monitoring the net geometry to ensure acceptable performance (as described in Section 3.3 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).

## 3.5 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) and weight (to the nearest gram) were collected. Length data was collected using a digital measuring board (DCS-5, Big Fin Scientific LLC., Austin, Texas) and individual weights were measured using a motion compensated digital scale (M1100, Marel Corp., Gardabaer, Iceland). An android tablet (Samsung Active Tab 2) running DCSLinkStream (Big Fin Scientific LLC., Austin, Texas) served as the data collection platform. Efforts were made to process all animals; however, during large catches sub-sampling was used for some abundant species. Two sub-sampling strategies were employed over the duration of the seasonal surveys: straight subsampling by weight and discard by count.

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 collected 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.

Discard by count: The discard by count method was used when a large catch of large-bodied fish was caught. For this method a sub-sample of the species (30-50 individuals) was collected to calculate a mean individual weight. The remaining individuals were counted and discarded. The aggregated weight for the species is the total number of individuals multiplied by the average individual weight. This method was primarily used during the fall survey when large volumes of spiny dogfish were caught.

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 crabs, lobsters, and some non-commercial species. For these species, aggregated weight and counts were collected. Any observation of squid eggs was documented. All the survey data was uploaded and stored in a Microsoft Access database.

The catch was standardized to account for small variations in the tow path. The area fished by the trawl, commonly referred to as the swept area, was calculated for each tow by multiplying the tow distance by the average wingspread. The data was then standardized to an ideal swept area (25,000 $m^2$) for each species, *i,* and tow, *j*, (Eq. 1). The ideal swept area assumes a tow distance of one nautical mile at a wing spread of 13.5 meters. The ideal wingspread was very close to the annual average swept area observed in the surveys (24,935 $m^2$). This standardization method is used by NEAMAP to create indices of abundance (Bonzek at al., 2017). If the swept area was higher or lower on a given tow the associated catch was respectively, and proportionately, scaled down or up. For example, if a tow had a swept area of 12,500 $m^2$, half of an ideal tow, then the respective catch would be doubled. Conversely, if a tow had double the swept area (50,000 $m^2$) then the catch would be halved. In this dataset most tows only required small adjustments (<±5%).

$$Standardized\ Catch_{ij} = \left(\frac{Catch_{ij}}{Swept\ Area_j / 25{,}000\ m^2}\right) \qquad Eq.1$$

## 3.6 Data Analysis

### 3.6.1 Community Structure Analysis

To assess the community dynamics in the 534 Lease Area a multivariate analysis was conducted using the Primer-E statistical software package (Primer 7, Quest Research Limited, Auckland, NZ). The goal of this analysis was to investigate changes in the community composition between seasons.

A resemblance matrix was created using Bray-Curtis dissimilarity coefficients of the square root transformed catch data. This resulted in a measurement of similarity between tows based on the species composition of the catch. The catch data was transformed to reduce the influence of numerically dominate species, ensuring a community-based assessment (Clarke and Gorley, 2015). A one-way Analysis of Similarities (ANOSIM) was conducted using season as a factor. The ANOSIM is a non-parametric, ANOVA-like, statistical test which compares the similarity between groups to the similarity within groups. The result is a statistic, R. A value of 0 indicates no difference between treatment groups and the maximum of 1 indicates a large separation between treatment groups. A permutation test (9999 permutation) was used to test against the null hypothesis where similarities within treatments are smaller or equal to the similarities between treatments. The permutation test randomly reassigns the treatment and calculates the test statistic. The result is a distribution of possible random outcomes, which is compared against the measured statistic.

To visualize the data, non-metric multidimensional scaling plots (nMDS) were created. These figures plot the similarity data in a low-dimensional space so that distances between points represent the relative similarity/dissimilarity between them. This analysis was conducted on the 2020-2021 dataset as well as the aggregated dataset (2019-2021). Pairwise comparison between surveys were used to investigate seasonal changes in species composition as well as annual variations within a season (e.g., winter 2020 vs winter 2022).

### 3.6.2 Power Analysis

To ensure the survey's ability to detect changes in fish populations, an updated power analysis was conducted using the data collected during the seasonal surveys. In statistics the term "power" refers to the probability of rejecting a false null hypothesis, otherwise known as a type 2 error or a false negative (Murphy, Myors and Wolach, 2014). In other words, it is a measure of the probability of detecting a change occurring in the environment. Studies with high statistical power have a high probability of detecting a change in the environment, given the environment is in fact changing.

The goal of a power analysis is to understand the balance between several variables including sample size, magnitude of change (expressed as percent of change, PC), type 1 error rate (α, the probability of a false positive) and type 2 error rate (β, the probability of a false negative). The power analysis conducted in this report is based on the equations in Van Belle (2011) as expressed in Equation 2.

$$n = \frac{2(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 (CV)^2}{[\ln{(1 - PC)}]^2} \qquad Eq. 2$$

Where PC = $(\mu_0 - \mu_1)/\mu_0$, with $\mu_0$ and $\mu_1$ being mean CPUEs of pre-development and post-development respectively. N is the total sample size (number of tows) required per treatment, z is the z-score given α (type-1 error rate) or β (type-2 error rate), CV is the coefficient of variation observed in the population and PC is the percent change in the population means. CVs were derived from the standardized catch rates observed throughout the four seasonal surveys. In many ecological analyses, α is usually set at 0.05, and β at 0.2 (Van Belle, 2011). β is the probably of not detecting the change when there is a change (false negative). The value (1- β) is called "power" – the power to detect a change when in fact there is a change. Fixing α, β and the CV demonstrates that the ability to detect a change is inversely related to the sample size. More samples are required to detect smaller changes. The equation can be reformulated to estimate any one of the parameters assuming the rest of the parameters are set.

The power analysis presented in this report is an updated analysis incorporating all seasonal survey data collected between 2019 and 2022.

# 4. Results

## 4.1 Operational Data

Ten tows were completed during each survey period in the 534 Lease Area for a total of 20 tows (Figure 2, Table 1). Tow duration, tow speed and tow distance were similar between seasons (Table 2). Tow durations were at the targeted 20 minutes averaging 20.0 ± 0.1 minutes (mean ± one standard deviation) and was maintained between seasons (Figure 8). Tow speed averaged 2.9 ± 0.1 knots with little variation between surveys (Figure 8). Tow distances averaged 1.0 ± 0.03 nautical miles. Similarly, the average tow distance showed little variation between surveys (Figure 8).

The seafloor in the 534 Study Area follows a north to south depth gradient with the shallowest tow along the northern edge (~48 m). Depth increased to a maximum of 60 m along the southeastern boundary. Tow depths ranged from 26 to 33 fathoms (47.5 – 60.4 m, Figure 9).

## 4.2 Environmental Data

Bottom water temperature followed seasonal trends in survey area (Figure 10). Bottom water temperature was highest during the fall survey and coldest during the winter survey. During the fall survey, water temperatures averaged 14.2 ± 0.3 °C. Fall bottom water temperature has shown little variation between survey years (Figure 10). Winter bottom temperatures averaged 4.3 ± 0.4 °C. Winter bottom water temperature was similar to that observed in 2021 and cooler then 2020 (Figure 10).

## 4.3 Trawl Performance

The trawl geometry data indicated that the trawl typically took about 2 to 3 minutes to open and stabilize. Once open, readings tended to be stable through the duration of the tow. Wingspread measurements were largely within the ideal range averaging 14.4 ± 0.6 m (range: 13.1 – 15.0 m). Wingspread is the most important trawl performance metric as it is used to measure the swept area. Wingspread readings were consistent across the surveys with all tows within the acceptable tolerance limits (Figure 11). Wingspread readings increased slightly with trawl warp and depth however this effect was small, and readings were relatively stable across the range of depths encountered within the surveys (Figure 12, 13).

Door spread averaged 36.4 ± 1.3 m (range: 34.8 – 38.3 m.). Door spread was relatively consistent across surveys (Figure 11). Similar to wingspread, door spread readings tended to increase with depth due to increased trawl warp (Figure 13). All tows were within the acceptable tolerance limit except for six tows, which were less then 1 meter higher then ideal. These tows occurred during the winter survey and were considered valid tows because the wing spread was well within the acceptable limits.

The headline height of the trawl averaged 4.7 ± 0.2 m (range: 4.3 – 5.0 m). Obtaining the desired headline height was a problem in the 2019-2020 surveys with the headline height frequently lower than the acceptable tolerance limit. Previous improvements to trawl operations have shown significant improvements. Three tow was below the acceptable tolerance limits by 0.1 – 0.2 meters. All subsequent tows were within the acceptable tolerance limits.

## 4.4 Catch Data

### 4.4.1 Overview

The data obtained from the two seasonal surveys conducted show that the study region is dynamic in its species composition and abundance. A total of 36 species were caught in at least one seasonal survey during the year; their common and scientific names, total catch (by weight), and mean catch per tow are provided in Table 3. Catch volume ranged from 11.7 kg/tow to 1630.6 kg/tow. The majority of the catch was primarily comprised of a small subset of the observed species. The five most abundant species (spiny dogfish, scup, butterfish, little skate, and Atlantic longfin squid) accounted for 90.2% of the total catch weight. The next five most abundant species (northern sea robin, winter skate, silver hake, red hake, and Atlantic herring) added an additional 7.1% of the catch. These ten species represented over 97.3% of catch weight. Data collected from the 534 Lease Area included the catch of both adults and juveniles of most species observed.

### 4.4.2 Spiny Dogfish

Spiny dogfish (*Squalus acanthias*) was the predominate species observed in the 534 Study Area accounting for 45.4% of the catch weight. Annually, the catch rate averaged 227.4 ± 63.2 kg/tow (mean ± Standard Error of the Mean (SEM), range: 0 – 905.6 kg/tow). While dogfish were the most abundant species by weight, there was a distinct seasonality to the catch. Spiny dogfish had the highest catches observed during the fall survey with lower catch observed in the winter. Catch rates in the fall of 2021 were similar to the fall of 2020 but lower then 2019 (Figure 14).

The catch rates of dogfish were the highest during the fall survey, including many of the largest aggregated tows of the year. The catch rate of dogfish averaged 453.6 ± 74.1 kg/tow (Figure 14). Dogfish were observed in all 10 tows in the 534 Study Area. The high seasonal average was largely driven by a several large tows (> 500 kg). The catch of dogfish was distributed across the study area (Figure 15). Individuals ranged in size from 53 to 80 cm with a unimodal distribution consisting of a peak at 66 cm (Figure 16).

During the winter survey, seasonal catch rates averaged 1.2 ± 0.8 kg/tow (Figure 14). Dogfish were observed in 2 of the 10 tows with catches observed in the southern extent of the study area (Figure 15). Six spiny dogfish were caught with sizes ranging from 62 to 76 cm (Figure 16).

#### 4.4.3 Scup

Scup (*Stenotomus chrysops*) was the second most abundant species by weight accounting for 28.3% of the total catch. Scup were abundant in the 534 Study Area during the fall survey (Figure 17). Seasonal and annual catch rates of scup have shown increasing trends throughout the duration of the study. Seasonal catch rates averaged 285.8 ± 83.3 kg/tow (range: 0 – 872.0 kg/tow). The high seasonal catch rate was driven by four large tows (> 400 kg). Scup were caught in 9 of the 10 tows with the catch distributed across the study area (Figure 18). Individuals ranged in size from 8 to 28 cm with bimodal peaks at 9 cm and 23 cm. (Figure 19).

Only two scup were caught during the winter survey.

#### 4.4.4 Butterfish

Butterfish (*Peprilus triacanthus*) were consistently caught in the 534 Study Area during the fall survey. The catch of butterfish in 2021 was higher then previously observed in the survey (Figure 20). Butterfish were only observed in the fall survey at an average catch rate of 87.2 ± 25.2 kg/tow. No butterfish were observed in the winter survey. Butterfish were observed in all 10 tows during the fall survey. The catch of butterfish was distributed across the 534 Lease Area (Figure 21). Individuals ranged from 6 to 17 cm with a unimodal distribution peaking at 9 cm (Figure 22).

### 4.4.5 Little Skate

Little skate (*Leucoraja erinacea*) were common throughout the year, being observed in all 20 tows. Annually, catch rates averaged 27.6 ± 4.4 kg/tow (range: 1.1 – 67.9 kg/tow). Annual and seasonal catch rates were lower than those observed in previous years (Figure 23).

The catch rates of little skate were the highest during the fall survey averaging 41.1 ± 5.0 kg/tow (Figure 23). Little skates were observed in all 10 tows in the 534 Study Area. The catch of little skate was distributed across the 534 Study Area (Figure 24). Individuals ranged in size from 12 to 32 cm with a unimodal peak at 26 cm (Figure 25).

Seasonal catch rates during the winter averaged 14.1 ± 4.0 kg/tow (Figure 23). Little skate were observed in all 10 tows with the catch distributed across the study area (Figure 24). Individuals similarly ranged in size from 12 to 33 cm with a unimodal peak at 26 cm (Figure 25).

### 4.4.6 Atlantic Longfin Squid

Atlantic longfin squid (*Doryteuthis pealei*), a commercially important species commonly called Loligo squid, were consistently caught in the survey area during the fall survey. Seasonally, catch rates during the fall survey averaged 20.7 ± 1.5 kg/tow (range: 10.9 – 26.2 kg/tow). Seasonal catch rates were higher in 2021 then observed in 2019 and 2020 (Figure 26). Longfin squid were caught in all 10 tows and distributed across the study area (Figure 27). Individuals ranged in size from 3 to 28 cm with unimodal peak at 6 cm (Figure 28).

No squid were caught in the winter survey. No squid eggs (i.e., "squid mops") were observed during any of the surveys.

### 4.4.7 Northern Sea Robin

Northern Sea Robin (*Prionotus carolinus*) were routinely caught during the fall survey. Seasonal catch rates during the fall survey averaged 19.9 ± 5.1 kg/tow (range: 4.8 – 58.5 kg/tow). The seasonal catch rate of northern sea robin has been observed to being increasing over the three-year duration of the study (Figure 29). Northern sea robin were caught in all 10 tows in the fall. The catch of sea robin was distributed across the study area (Figure 30). Individuals ranged in size from 11 to 32 cm with a unimodal peak at 25 cm (Figure 31).

No northern sea robins were observed in the winter survey.

### 4.4.8 Winter Skate

Winter skate (*Leucoraja ocellata*) were caught in the study area during fall survey with sporadic observations during the winter. Catch rates were relatively low during the fall survey compared to previous years. The seasonal catch rate averaged 16.0 ± 1.7 kg/tow in the fall survey (Figure 32). Winter skates were observed in all 10 tows in the fall with the catch distributed across the survey area (Figure 33). Winter skates had a wide size distribution ranging from 28 to 55 cm (Figure 34).

Only 2 individuals were collected during the winter survey. These were primarily located in the center of the 534 Study Area (Figure 34).

### 4.4.9 Silver Hake

Silver hake (*Merluccius bilinearis*), commonly referred to as whiting, is a commercially important species in the region. Silver hake were observed in all 20 tows in the 534 Study Area. Annually, catch rates averaged 7.0 ± 1.4 kg/tow (range: 0.3 – 19.1 kg/tow). In general, catch rates have been observed to be declining throughout the duration of the study (Figure 35).

The catch of silver hake was highest during the fall survey (12.4 ± 1.3 kg/tow). Low catch rates were observed in the winter (1.7 ± 0.6 kg/tow). Silver hake were caught in every tow in the both the fall and winter surveys. In both surveys the catch was distributed across the study area (Figure 36).

Individuals ranged in size from 23 to 46 cm with a unimodal peak at 26 cm during the fall survey (Figure 37). Only juvenile silver hake were observed in the winter survey with individuals ranging from 8 to 27 cm with a peak at 11 cm.

### 4.4.10 Red Hake

Red hake (*Urophycis chuss*) was one of the most consistent species during the 2019/2020 survey year with annual and seasonal catch rate declining throughout the study period (Figure 38). The catch of red hake was highest in the fall at an average catch rate of 11.8 ± 1.8 kg/tow. Low catch rates were observed during the winter (0.2 ± 0.1 kg/tow). Red hake were observed in all 10 tows during the fall survey and 6 of the 10 tows in the winter survey. The catch of red hake was observed to be distributed across the study area (Figure 39).

Red hake had a wide size distribution in the fall ranging from 19 to 36 cm with a peak at 30 cm (Figure 40). The size distribution of red hake was shifted to small individuals in the winter survey with a peak at 10 cm.

#### 4.4.11 Atlantic Herring

Atlantic herring (*Clupea harengus*) were caught during the winter survey. Atlantic herring have shown significant increases in the past two years of the survey (Figure 41). Seasonally, the catch rate of Atlantic herring in the winter averaged 8.5 ± 4.8 kg/tow. Herring were caught in all 10 tows with the catch distributed across the lease area (Figure 42). Individuals ranged in size from 18 to 24 cm with a unimodal peak at 20 cm (Figure 43).

Only two herring were caught during the fall survey.

#### 4.4.12 Alewife

Alewife (*Alosa pseudoharengus*) were commonly caught in the lease area during the winter survey. Seasonally, catch rates averaged 5.1 ± 1.4 kg/tow (range: 0.6 – 14.1 kg/tow) during the winter. The seasonal catch rate was higher than winter surveys in 2020 and 2021 (Figure 44). Alewife were caught in all 10 tows during the winter survey with the catch distributed across the study area (Figure 45). Individuals ranged from 13 to 29 cm with a unimodal distribution peaking at 20 cm (Figure 46).

No alewife were encountered during the fall survey.

#### 4.4.13 Summer Flounder

Summer flounder (*Paralichthys dentatus*), also known as fluke, is a commercially important flatfish caught during the fall survey. Seasonal catch rates averaged 3.8 ± 1.0 kg/tow (range: 0 – 9.4 kg/tow; Figure 47). Summer flounder were caught in 9 of the 10 tows in the fall. The catch of summer flounder was distributed across the lease area (Figure 48). Summer flounder had a wide size distribution ranging from 34 to 70 cm (Figure 49).

Only four individuals were observed in the winter survey. Individuals were relatively small, ranging from 28 to 34 cm (Figure 49).

### 4.4.14 Black Sea Bass

Black sea bass (*Centropristis striata*) is a commercially important species frequently caught during the fall surveys. Seasonally, catch rates averaged 2.3 ± 0.4 kg/tow (range: 0.8 – 5.3 kg/tow; Figure 50). The catch of black sea bass was similar to that observed in 2020/2021 (Figure 50). Black sea bass were caught in all 10 tows in the fall with the catch distributed across the study area (Figure 51). Individuals had a size range from 14 to 39 cm (Figure 52).

One black sea bass was caught during the winter survey.

### 4.4.15 Atlantic Cod

Atlantic cod (*Gadus morhua*), a commercially important species, was caught in the study area during the winter survey. Seasonally, catch rates averaged 1.3 ± 0.6 kg/tow (range: 0 – 6.1 kg/tow; Figure 53). The catch of cod has been observed to increase annually throughout the duration of the study (Figure 53). Cod were caught in 5 of the 10 tows with the catch primarily observed along the northern edge of the study area (Figure 54). Individuals had a size range from 41 to 58 cm (Figure 55).

No cod were caught during the fall survey.

### 4.4.16 Fourspot flounder

Fourspot flounder (*Paralichthys oblongus*) was a common flatfish species observed during the fall survey. Moderate catch rates were observed during the fall (0.9 ± 0.2 kg/tow; Figure 56). Fourspot flounder were caught in 9 of the 10 tows during the fall surveys with the catch distributed across the study area (Figure 57). Fourspot flounder ranged from 16 to 42 cm (Figure 58).

Eight fourspot flounder was caught in 3 tows during the winter survey.  All individuals were small ranging from 13 to 18 cm (Figure 58).

### 4.4.17 Windowpane Flounder

Windowpane flounder (*Scophtalmus aquosus*), also known as sand dab, is a federally regulated groundfish species.  Windowpane flounder were regularly observed in the fall and winter surveys. Annually, catch rates averaged 0.3 ± 0.1 kg/tow (range: 0 – 1.1 kg/tow; Figure 59).

The catch of windowpane flounder was highest in the winter at an average catch rate of 0.4 ± 0.1 kg/tow (Figure 59).  Lower catch rates of windowpane flounder were caught during the fall survey (0.2 ± 0.1 kg/tow).  Windowpane flounder were caught in 8 of the 10 tows in the winter survey and 4 of the 10 tows in the fall survey.  The catch observed to be scattered across the study area in both seasons (Figure 60).  Individuals ranged in size from 9 to 30 cm with a wide distribution in both surveys (Figure 61).

### 4.4.18 Other commercial species or species of interest

American lobster (*Homarus americanus*) is a commercially important crustacean that was occasionally caught in the fall and winter surveys.  Annually, the total catch of lobster was 1.5 kg which consisted of two individuals.

Atlantic sea scallop (*Placopecten magellanicus*) is a commercially important shellfish species that was caught in the study area.  Due to their sedentary life history, the catch is perceived to reflect the abundance on the seafloor as it should not change with the season.  Annually, the total catch of scallops was 1.4 kg, which consisted of 12 individuals.

Nine weakfish (*Cynoscion regalis*) were caught during the fall survey.  Individuals ranged in size from 33 to 38 cm.

Seven monkfish (*Lophius americanus*), a federally regulated and commercial species, were caught during the fall survey.  Individuals ranged in size from 26 to 52 cm.

Seven yellowtail flounder (*Pleuronectes ferrugineus*), a federally regulated and commercial species, were caught during the fall survey.  Individuals ranged in size from 19 to 26 cm.

Two bluefish (*Pomatomus saltatrix*) were caught during the fall survey. The individuals were 32 and 61 cm.

One winter flounder (*Pseudopleuronectes americnus*), also known as blackback flounder, was caught in the winter survey. Winter flounder are a federally regulated groundfish.

One haddock (*Melanogrammus aeglefinus*) was caught during the winter survey. The individual was 36 cm.

One porbeagle shark (*Lamna nasus*) was caught during the winter survey. The animal was estimated to be ~2.5 m long (fork length). The shark was immediately returned to the sea and was observed to swim away.

## 4.5 Community Structure

The community structure within the 534 Lease Area displayed changes in species composition between the two seasonal surveys. The analysis of similarities test (ANOSIM) yielded an R statistic of 0.772 when assessing the similarities between seasons. The R statistic can range from 0, indicating no difference in species composition, to 1, which would indicate a clear separation between seasons (Figure 62). The separation in seasons was very similar to that observed in the previous survey years.

Pairwise tests indicate that the winter had a clear difference in species composition compared to the fall survey (R = 1.0). Winter tows were primarily associated with little skates, alewife, Atlantic herring, Atlantic mackerel, and blueback herring. The winter 2022 survey showed moderate similarity to the 2021 survey but differences to the 2020 survey (R = 0.418 and 0.74, respectively, Figure 62).

Fall tows were associated with spiny dogfish, scup, butterfish, little skate, and longfin squid. Similar to the winter survey, the 2021 fall survey showed similarity to the 2019 and 2020 surveys (R = 0.581 and 0.398, respectively, Figure 62).

In summary, each season exhibits a distinct species assemblage. The winter and fall surveys appeared to be relatively unique in the species assemblage. The winter and fall surveys had moderate similarity to the previous survey year with decreasing similarity to the 2019/2020 survey year. The interannual similarities maybe due to consistent bottom water temperatures across the fall and winter surveys between survey years (Figure 10). Conversely, bottom water temperature during the summer surveys has varied annually. In 2020, summer bottom water temperature was 4ºC warmer than the 2019 survey. The species assemblage during 2020 was shifted toward heat-tolerant species (i.e., scup, butterfish, summer flounder) while species that prefer cooler water (i.e., silver hake, winter skate) appeared to move to deeper water.

### 4.6 Power Analysis

Catch data collected from the 2021/2022 seasonal surveys exhibited a high level of variability resulting in coefficients of variance (CVs) ranging from 0.88 (little skate) to 9.95 (American plaice, Table 4). The variability of the data is inversely related to the ability to detect a change in catch rates. This leads to decreased power or a need to increase the sample size (number of tows). The data from the 2021/2022 survey was used to update the power analysis presented in the previous annual report (Rillahan and He, 2020, Rillahan and He, 2021).

The results of the power analysis indicated that several species, including little skate, monkfish, and fourspot flounder had relatively low variability (CV = ~1) and therefore high probability of detecting a small to moderate change. Detecting a 25% change in the two areas with 80% confidence would require 145-342 tows per area. Detecting larger changes would require a smaller number of tows. To increase the ability to detect a smaller change (i.e., a 10% change), the sample size would have to be increased 8-fold (1087 – 2553 tows per area, Figure 63). Incorporating the 2021/2022 data into the power analysis resulted in negligible changes in the variability, and therefore effort required, in all these species.

Many of the common species observed, including Atlantic longfin squid, windowpane flounder, winter skate, summer flounder, butterfish, silver hake, red hake, and black sea bass had CVs between 1.5 and 2.1. These species would have a high probability of detecting a moderate change (i.e., 30-50% change). Detecting a 50% change in the two areas with 80% confidence would require 78-140 tows per area. To detect a 25% change, the sampling would have to be increased to 455 – 813 tows.

Scup, Atlantic cod, Atlantic herring, winter flounder, yellowtail flounder and winter flounder exhibited strong seasonality which led to high variability (CV's 2.3 – 3.4). These species would have a high probability of detecting moderate to large change (i.e., 50-75% change). Detecting a 75% change in the two areas with 80% confidence would require 42 - 92 tows per area. To detect a 50% change, the sampling would have to be increased to 169 – 369 tows. To detect a 25% change, the sampling would have to be increased to 986 – 2146 tows.

The current sampling effort has the statistical power to detect a complete disappearance of every species observed from either study area (100% change). The relationship between power and the sample size for abundant and commercially important species can be found in Figures 64 – 73.

## 5. Discussion

Two successful seasonal surveys were conducted during the 2021/2022 survey year. This work is a continuation of the effort started in 2019 and expands the existing data set. The commercial fishing vessel *F/V Heather Lynn* functioned well for the intended surveys. Overall, the surveys went smoothly and as planned. This bottom trawl survey employed the survey trawl and operational protocol consistent with the Northeast Area Monitoring and Assessment Program (NEAMAP) conducted by Virginia Institute of Marine Science (VIMS) over the last decade. The current survey methodology has proven to be effective in collecting high-quality data relevant to fish abundance, population structure, and community assemblages. The data from these surveys will provide baseline data for future surveys.

While the survey revealed high species diversity in the 534 Study Area, registering a total of 36 species, the majority of the catch was comprised of a small number of dominant species. The five most abundant species (spiny dogfish, scup, butterfish, little skate, and Atlantic longfin squid) accounted for 90% of the total catch weight, and together with the next five species (northern sea robin, winter skate, silver hake, red hake, and Atlantic herring), they contributed 97% of total catch weight in the lease area. However, less abundant species are just as important. These surveys provide baseline data on species diversity, and changes in species distribution with time and anthropogenic activities, including wind energy development. Southern New England is a borderline area for many species, which are prone to changes in distribution due to climate change. Interannual changes in abundance varied amongst species. For example, Atlantic cod, butterfish, scup, Atlantic herring, and longfin squid exhibited increases in seasonal catch rates.

Conversely, silver hake, red hake, monkfish, and little skate exhibited decreased seasonal catch rates.

This study area is dynamic with seasonal changes in species assemblages, abundances, and population structures. The seasonal changes were largely in line with those observed in 2019/2020 and 2020/2021. Winter tows were primarily associated with little skates, alewife, Atlantic herring, Atlantic mackerel, and blueback herring. Fall tows were associated with spiny dogfish, scup, butterfish, little skate, and longfin squid. The winter and fall surveys had similarity to previous survey years. The interannual similarities maybe due to consistent bottom water temperatures across the fall and winter surveys between survey years (Figure 10).

The updated power analysis, using the collected data for three years of survey effort, indicated that the current bottom trawl survey effort would provide reasonable "power" to detect small to medium scales of change in abundance for most common species, if changes in abundance do occur. Additional data only caused small changes to the CVs for most species. The changes observed serve to provide a more realistic assessment of the variability in the data and therefore a better understanding of the statistical power to detect changes.

## 6. Acknowledgements

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## 7. References

BOEM (U.S. Department of the Interior, Bureau of Ocean Energy Management). 2013. Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585

Bonzek, C. F., Gartland, J., Johnson, R. A., & Lange Jr, J. D. (2008). NEAMAP Near Shore Trawl Survey: Peer Review Documentation. *A report to the Atlantic States Marine Fisheries Commission by the Virginia Institute of Marine Science, Gloucester Point, Virginia*.

Bowman, A. W. and Azzalini, A. (2018). R package 'sm': nonparametric smoothing methods (version 2.2-5.6) URL http://www.stats.gla.ac.uk/~adrian/sm

Clarke, K.R., Gorley, R.N. 2015 PRIMER v7: User Manual/Tutorial PRIMER-E: Plymouth

Langlois, T.J., Fitzpatrick, B.R., Fairclough, D.V., Wakefield, C.B., Hesp, S.A., McLean, D.L., ... & Meeuwig, J.J. 2012. Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. *PLoS One,* 7(11), e45973.

Murphy, K. R., Myors, B., & Wolach, A. (2014). *Statistical power analysis: A simple and general model for traditional and modern hypothesis tests*. Routledge.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rillahan, C., He, P. (2020). Vineyard Wind Demersal Trawl Survey Annual Report – 501 South Stu dy Area. 2019/2020 Annual report. University of Massachusetts Dartmouth - SMAST, New Bedf ord, MA. SMAST-CE-REP-2020-089. 136 pp.

Rillahan, C., He, P. (2021). Vineyard Wind Demersal Trawl Survey Annual Report – 501 South Stu dy Area. 2019/2020 Annual report. University of Massachusetts Dartmouth - SMAST, New Bedf ord, MA. SMAST-CE-REP-2021-101. 136 pp.

Stokesbury, K.D.E. and Lowery, T. (2018). 2018 Vineyard Wind Groundfish Bottom Trawl Survey: Final Report.

Underwood, A. J. (1991). Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. *Marine and Freshwater Research*, *42*(5), 569-587.

Van Belle, G. (2011). *Statistical rules of thumb* (Vol. 699). John Wiley & Sons.

Matt Wand (2015). KernSmooth: Functions for Kernel Smoothing Supporting Wand & Jones (19 95). R package version 2.23-15. https://CRAN.R-project.org/package=KernSmooth

Zuur, A., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, G. M. (2009). *Mixed effects models and extensions in ecology with R*. Springer Science & Business Media.

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

| Tow Number | 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) | Bottom Temp. (°C) | Trawl Warp (fm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11/17/2021 | Clear | 11-15 | NW | 0.5-1.25 | 7:00 | N 40° 59.395 | W 70° 38.056 | 26 | 7:20 | N 40° 59.503 | W 70° 36.731 | 26 | | 100 |
| 2 | 11/17/2021 | Clear | 11-15 | NW | 0.5-1.25 | 8:16 | N 40° 57.186 | W 70° 37.556 | 29 | 8:36 | N 40° 56.351 | W 70° 37.993 | 28 | 14.4 | 120 |
| 3 | 11/17/2021 | Clear | 11-15 | NW | 0.5-1.25 | 9:27 | N 40° 54.596 | W 70° 42.287 | 30 | 9:47 | N 40° 54.153 | W 70° 43.348 | 29 | 14.4 | 125 |
| 4 | 11/17/2021 | Clear | 11-15 | NW | 0.5-1.25 | 10:42 | N 40° 53.044 | W 70° 44.345 | 30 | 11:02 | N 40° 52.291 | W 70° 45.077 | 29 | 14.3 | 125 |
| 5 | 11/17/2021 | Clear | 11-15 | NW | 0.5-1.25 | 12:10 | N 40° 50.197 | W 70° 44.888 | 29 | 12:30 | N 40° 49.236 | W 70° 44.809 | 30 | 14.4 | 125 |
| 6 | 11/17/2021 | Clear | 7-10 | NW | 0.5-1.25 | 13:28 | N 40° 46.420 | W 70° 44.295 | 33 | 13:48 | N 40° 45.575 | W 70° 43.990 | 33 | 14.3 | 125 |
| 7 | 11/17/2021 | Clear | 7-10 | NW | 0.5-1.25 | 14:39 | N 40° 49.871 | W 70° 42.874 | 31 | 14:59 | N 40° 50.692 | W 70° 42.284 | 30 | 14.2 | 125 |
| 8 | 11/17/2021 | Clear | 7-10 | NW | 0.5-1.25 | 15:46 | N 40° 51.574 | W 70° 39.792 | 29 | 16:06 | N 40° 51.809 | W 70° 38.619 | 30 | 14.2 | 125 |
| 9 | 11/20/2021 | Clear | 11-15 | N | 0.5-1.25 | 6:26 | N 40° 51.621 | W 70° 36.043 | 29 | 6:46 | N 40° 52.096 | W 70° 35.020 | 30 | 13.8 | 125 |
| 10 | 11/20/2021 | Clear | 11-15 | N | 0.5-1.25 | 7:51 | N 40° 54.604 | W 70° 33.199 | 28 | 8:11 | N 40° 54.609 | W 70° 34.401 | 28 | 13.7 | 125 |
| 1 | 2/3/2022 | Obscured | 1-2 | SW | 0.5-1.25 | 7:06 | N 40° 57.005 | W 70° 34.641 | 29 | 7:26 | N 40° 56.090 | W 70° 34.242 | 28 | 3.7 | 125 |
| 2 | 2/3/2022 | Obscured | 1-2 | SW | 0.5-1.25 | 8:04 | N 40° 54.251 | W 70° 33.684 | 29 | 8:24 | N 40° 53.357 | W 70° 33.126 | 30 | 4.4 | 125 |
| 3 | 2/3/2022 | Obscured | 1-2 | SW | 0.5-1.25 | 9:22 | N 40° 52.676 | W 70° 39.662 | 29 | 9:42 | N 40° 52.477 | W 70° 40.815 | 29 | 3.9 | 120 |
| 4 | 2/3/2022 | Mostly Clo | 1-2 | SW | 0.5-1.25 | 10:39 | N 40° 47.673 | W 70° 40.5662 | 32 | 10:59 | N 40° 47.673 | W 70° 41.833 | 32 | 4.4 | 125 |
| 5 | 2/3/2022 | Partly Clou | 1-2 | SW | 0.5-1.25 | 11:35 | N 40° 49.422 | W 70° 43.857 | 32 | 11:55 | N 40° 50.371 | W 70° 44.053 | 30 | 4.3 | 125 |
| 6 | 2/3/2022 | Partly Clou | 1-2 | SW | 0.5-1.25 | 12:31 | N 40° 50.713 | W 70° 43.273 | 30 | 12:51 | N 40° 51.590 | W 70° 43.918 | 30 | 3.9 | 120 |
| 7 | 2/3/2022 | Mostly Clo | 1-2 | SW | 0.5-1.25 | 13:33 | N 40° 54.862 | W 70° 44.894 | 29 | 13:53 | N 40° 55.829 | W 70° 45.296 | 29 | 5.0 | 120 |
| 8 | 2/3/2022 | Mostly Clo | 1-2 | SW | 0.5-1.25 | 14:23 | N 40° 55.681 | W 70° 43.556 | 29 | 14:43 | N 40° 55.668 | W 70° 42.301 | 31 | 5.0 | 120 |
| 9 | 2/3/2022 | Obscured | 1-2 | SW | 0.5-1.25 | 15:26 | N 40° 58.332 | W 70° 39.146 | 27 | 15:46 | N 40° 58.993 | W 70° 38.220 | 26 | 4.5 | 100 |
| 10 | 2/3/2022 | Obscured | 1-2 | SW | 0.5-1.25 | 16:10 | N 40° 59.999 | W 70° 38.484 | 26 | 16:30 | N 41° 00.790 | W 70° 39.349 | 26 | 4.4 | 100 |

Note: fm = fathom

**Table 2: Details of tows with operational, environmental and gear performance parameters for each survey tow.**

| Tow # | Survey | Tow Duration (min.) | Tow Distance (nm.) | Tow Speed (knots) | Start Depth (fm) | Bottom Temp. ($^oC$) | Trawl Warp (fm) | Headline Height (m.) | Wing Spread (m.) | Spread Door (m.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Fall | 20.1 | 1.0 | 3.0 | 26 | | 100 | | | |
| 2 | Fall | 20.4 | 0.9 | 2.7 | 29 | 14.4 | 120 | 4.7 | 13.9 | 35.3 |
| 3 | Fall | 20.0 | 0.9 | 2.8 | 30 | 14.4 | 125 | 4.6 | 14.2 | 36.2 |
| 4 | Fall | 19.9 | 0.9 | 2.9 | 30 | 14.3 | 125 | 4.7 | 14.0 | 35.9 |
| 5 | Fall | 20.1 | 1.0 | 2.9 | 29 | 14.4 | 125 | 5.0 | 13.9 | 34.8 |
| 6 | Fall | 20.1 | 0.9 | 2.8 | 33 | 14.3 | 125 | 4.9 | 14.0 | 35.7 |
| 7 | Fall | 20.0 | 0.9 | 2.8 | 31 | 14.2 | 125 | 4.8 | 13.8 | 34.9 |
| 8 | Fall | 20.0 | 0.9 | 2.7 | 29 | 14.2 | 125 | 4.6 | 14.1 | 35.4 |
| 9 | Fall | 20.0 | 0.9 | 2.8 | 29 | 13.8 | 125 | 4.9 | 13.8 | 34.9 |
| 10 | Fall | 20.0 | 0.9 | 2.7 | 28 | 13.7 | 125 | 4.7 | 14.3 | 35.5 |
| 1 | Winter | 20.1 | 0.9 | 2.8 | 29 | 3.7 | 125 | 4.5 | 15.0 | 38.1 |
| 2 | Winter | 20.0 | 1.0 | 3.0 | 29 | 4.4 | 125 | 4.3 | 15.0 | |
| 3 | Winter | 20.1 | 0.9 | 2.8 | 29 | 3.9 | 120 | 4.6 | 14.9 | 37.7 |
| 4 | Winter | 20.0 | 1.0 | 2.9 | 32 | 4.4 | 125 | 4.9 | 14.7 | 37.6 |
| 5 | Winter | 20.0 | 1.0 | 2.9 | 32 | 4.3 | 125 | 4.5 | 15.0 | 38.3 |
| 6 | Winter | 20.0 | 1.0 | 2.9 | 30 | 3.9 | 120 | 4.4 | 15.0 | 38.3 |
| 7 | Winter | 19.8 | 1.0 | 2.9 | 29 | 5.0 | 120 | 4.4 | 15.0 | 38.0 |
| 8 | Winter | 20.0 | 0.9 | 2.8 | 29 | 5.0 | 120 | 4.6 | 14.7 | 37.2 |
| 9 | Winter | 20.0 | 1.0 | 2.9 | 27 | 4.5 | 100 | 4.8 | 13.1 | 36.0 |
| 10 | Winter | 20.3 | 1.0 | 3.0 | 26 | 4.4 | 100 | 4.8 | 14.5 | 36.2 |
| Summary Statistics | | | | | | | | | | |
| | Minimum | 19.8 | 0.9 | 2.7 | 26.0 | 3.7 | 100 | 4.3 | 13.1 | 34.8 |
| | Maximum | 20.4 | 1.0 | 3.0 | 33.0 | 14.4 | 125 | 5.0 | 15.0 | 38.3 |
| | Average | 20.0 | 1.0 | 2.9 | 29.3 | 9.0 | 120 | 4.7 | 14.4 | 36.4 |
| | St. Dev | 0.1 | 0.03 | 0.1 | 1.8 | 5.1 | 8.9 | 0.2 | 0.6 | 1.3 |

**Table 3: Total and mean catch weight of species observed in the 534 Study Area.**

| Species Name | Scientific Name | Total Weight (Kg) | Catch/Tow (Kg) | | % of Total Catch | Tows with Species Present |
|---|---|---|---|---|---|---|
| | | | Mean | SEM* | | |
| Dogfish, Spiny | *Squalus acanthias* | 4416.8 | 227.4 | 63.2 | 45.4 | 12 |
| Scup | *Stenotomus chrysops* | 2758.0 | 142.9 | 52.1 | 28.3 | 11 |
| Butterfish | *Peprilus triacanthus* | 851.9 | 43.6 | 15.8 | 8.8 | 10 |
| Skate, Little | *Leucoraja erinacea* | 548.6 | 27.6 | 4.4 | 5.6 | 20 |
| Squid, Atlantic Longfin | *Dorytheuthis pealei* | 201.4 | 10.4 | 2.5 | 2.1 | 10 |
| Northern Sea Robin | *Prionotus carolinus* | 195.0 | 10.0 | 3.4 | 2.0 | 10 |
| Skate, Winter | *Leucoraja ocellata* | 157.3 | 8.1 | 2.0 | 1.6 | 12 |
| Hake, Silver | *Merluccius bilinearis* | 138.1 | 7.0 | 1.4 | 1.4 | 20 |
| Hake, Red | *Urophycis chuss* | 115.4 | 6.0 | 1.6 | 1.2 | 16 |
| Herring, Atlantic | *Clupea harengus* | 87.4 | 4.2 | 2.5 | 0.9 | 10 |
| Alewife | *Alosa pseudoharengus* | 53.1 | 2.6 | 0.9 | 0.5 | 10 |
| Flounder, Summer (Fluke) | *Paralichthys dentatus* | 38.6 | 2.0 | 0.7 | 0.4 | 12 |
| Herring, Blueback | *Alosa aestivalis* | 26.4 | 1.3 | 0.7 | 0.3 | 10 |
| Black Sea Bass | *Centropristis striata* | 22.7 | 1.2 | 0.3 | 0.2 | 11 |
| Mackeral, Atlantic | *Scomber scombrus* | 22.5 | 1.1 | 0.4 | 0.2 | 10 |
| Skate, Barndoor | *Dipturus laevis* | 14.1 | 0.7 | 0.6 | 0.1 | 8 |
| Atlantic Cod | *Gadus morhua* | 13.8 | 0.7 | 0.3 | 0.1 | 5 |
| Monkfish | *Lophius americanus* | 11.9 | 0.6 | 0.3 | 0.1 | 6 |
| Flounder, Fourspot | *Paralichthys oblongus* | 9.3 | 0.5 | 0.1 | 0.1 | 12 |
| Flounder, Gulfstream | *Citharichthys arctifrons* | 8.9 | 0.5 | 0.1 | 0.1 | 14 |
| Sculpin, Longhorn | *Myoxocephalus octodecimspinosus* | 6.9 | 0.3 | 0.1 | 0.1 | 8 |
| Flounder, Windowpane | *Scophtalmus aquosus* | 6.1 | 0.3 | 0.1 | 0.1 | 12 |
| Hake, Spotted | *Urophycis regia* | 5.5 | 0.3 | 0.1 | 0.1 | 4 |
| Weakfish | *Cynoscion regalis* | 4.2 | 0.2 | 0.2 | 0.04 | 2 |
| Bluefish | *Pomatomus saltatrix* | 3.6 | 0.2 | 0.2 | 0.04 | 1 |
| Shad, American | *Alosa sapidissima* | 3.5 | 0.2 | 0.1 | 0.04 | 8 |
| Sea Robin, Striped | *Prionotus evolans* | 3.4 | 0.2 | 0.1 | 0.03 | 4 |
| Lobster, American | *Homarus americanus* | 1.5 | 0.1 | 0.1 | 0.02 | 2 |
| Sea Scallop | *Placopecten magellanicus* | 1.4 | 0.1 | 0.03 | 0.01 | 7 |
| Shark, Porbeagle | *Lamna nasus* | 1.0 | 0.05 | 0.05 | 0.01 | 1 |
| Flounder, Yellowtail | *Pleuronectes ferrugineus* | 0.9 | 0.05 | 0.04 | 0.01 | 2 |
| Flounder, Winter | *Pleuronectes americanus* | 0.8 | 0.04 | 0.04 | 0.01 | 1 |
| Lizardfish | *Synodontidae* | 0.7 | 0.04 | 0.03 | 0.01 | 2 |
| Menhaden, Atlantic | *Brevoortia tyrannus* | 0.5 | 0.02 | 0.02 | 0.01 | 1 |
| Crab, Cancer | *Cancer irroratus* | 0.3 | 0.02 | 0.02 | 0.003 | 1 |
| Haddock | *Melanogrammus aeglefinus* | 0.3 | 0.01 | 0.01 | 0.003 | 1 |
| **Total** | | **5314.9** | | | | |

*SEM - Standard Error of the Mean

**Table 4: Coefficient of variance (CV) and the total number of tows required to detect certain percentage of change for each species in the lease area as calculated from power analysis, assuming type-1 error α=0.05 and type-2 error β=0.80.**

| | 2019-2022 | | | | | |
|---|---|---|---|---|---|---|
| | **CV** | **10%** | **25%** | **50%** | **75%** | **100%** |
| Skate, Little | 0.88 | 1087 | 145 | 25 | 6 | 0 |
| Flounder, Fourspot | 1.16 | 1911 | 256 | 44 | 11 | 0 |
| Monkfish | 1.34 | 2553 | 342 | 58 | 14 | 0 |
| Flounder, Gulfstream | 1.50 | 3175 | 425 | 73 | 18 | 0 |
| Squid, Atlantic Longfin | 1.55 | 3397 | 455 | 78 | 19 | 0 |
| Flounder, Summer (Fluke) | 1.67 | 3955 | 530 | 91 | 22 | 0 |
| Hake, Silver | 1.72 | 4198 | 563 | 97 | 24 | 0 |
| Flounder, Windowpane | 1.82 | 4660 | 625 | 107 | 26 | 1 |
| Hake, Red | 1.87 | 4968 | 666 | 114 | 28 | 1 |
| Black Sea Bass | 1.91 | 5140 | 689 | 118 | 29 | 1 |
| Crab, Cancer | 2.05 | 5946 | 797 | 137 | 34 | 1 |
| Skate, Winter | 2.07 | 6051 | 811 | 139 | 34 | 1 |
| Butterfish | 2.07 | 6067 | 813 | 140 | 35 | 1 |
| Skate, Barndoor | 2.08 | 6115 | 820 | 141 | 35 | 1 |
| Sculpin, Longhorn | 2.13 | 6385 | 856 | 147 | 36 | 1 |
| Sea Scallop | 2.15 | 6537 | 876 | 151 | 37 | 1 |
| Northern Sea Robin | 2.18 | 6740 | 904 | 155 | 38 | 1 |
| Scup | 2.28 | 7355 | 986 | 169 | 42 | 1 |
| Alewife | 2.64 | 9883 | 1325 | 228 | 57 | 2 |
| Ocean Pout | 2.67 | 10103 | 1355 | 233 | 58 | 2 |
| Flounder, Winter | 2.71 | 10353 | 1388 | 239 | 59 | 2 |
| Mackeral, Atlantic | 2.72 | 10449 | 1401 | 241 | 60 | 2 |
| Flounder, Yellowtail | 2.74 | 10591 | 1420 | 244 | 61 | 2 |
| Dogfish, Smooth | 2.83 | 11351 | 1522 | 262 | 65 | 2 |
| Lobster, American | 2.97 | 12497 | 1676 | 288 | 72 | 2 |
| Weakfish | 3.03 | 12963 | 1738 | 299 | 74 | 3 |
| Hake, Spotted | 3.06 | 13236 | 1775 | 305 | 76 | 3 |
| Bluefish | 3.10 | 13546 | 1817 | 312 | 78 | 3 |
| Atlantic Cod | 3.36 | 16001 | 2146 | 369 | 92 | 3 |
| Dogfish, Spiny | 3.40 | 16299 | 2186 | 376 | 94 | 3 |
| Sea Raven | 3.62 | 18490 | 2480 | 427 | 106 | 4 |
| Herring, Atlantic | 3.62 | 18564 | 2490 | 428 | 107 | 4 |
| Herring, Blueback | 4.58 | 29709 | 3985 | 686 | 171 | 6 |
| Shad, American | 4.87 | 33512 | 4495 | 774 | 193 | 7 |
| Squid, Shortfin | 5.12 | 37062 | 4971 | 856 | 214 | 8 |
| Menhaden, Atlantic | 7.07 | 70596 | 9469 | 1631 | 407 | 16 |
| Haddock | 9.73 | 133780 | 17944 | 3090 | 772 | 31 |
| Eel, Conger | 9.95 | 139996 | 18777 | 3234 | 808 | 32 |
| Flounder, American Plaice | 9.95 | 139996 | 18777 | 3234 | 808 | 32 |

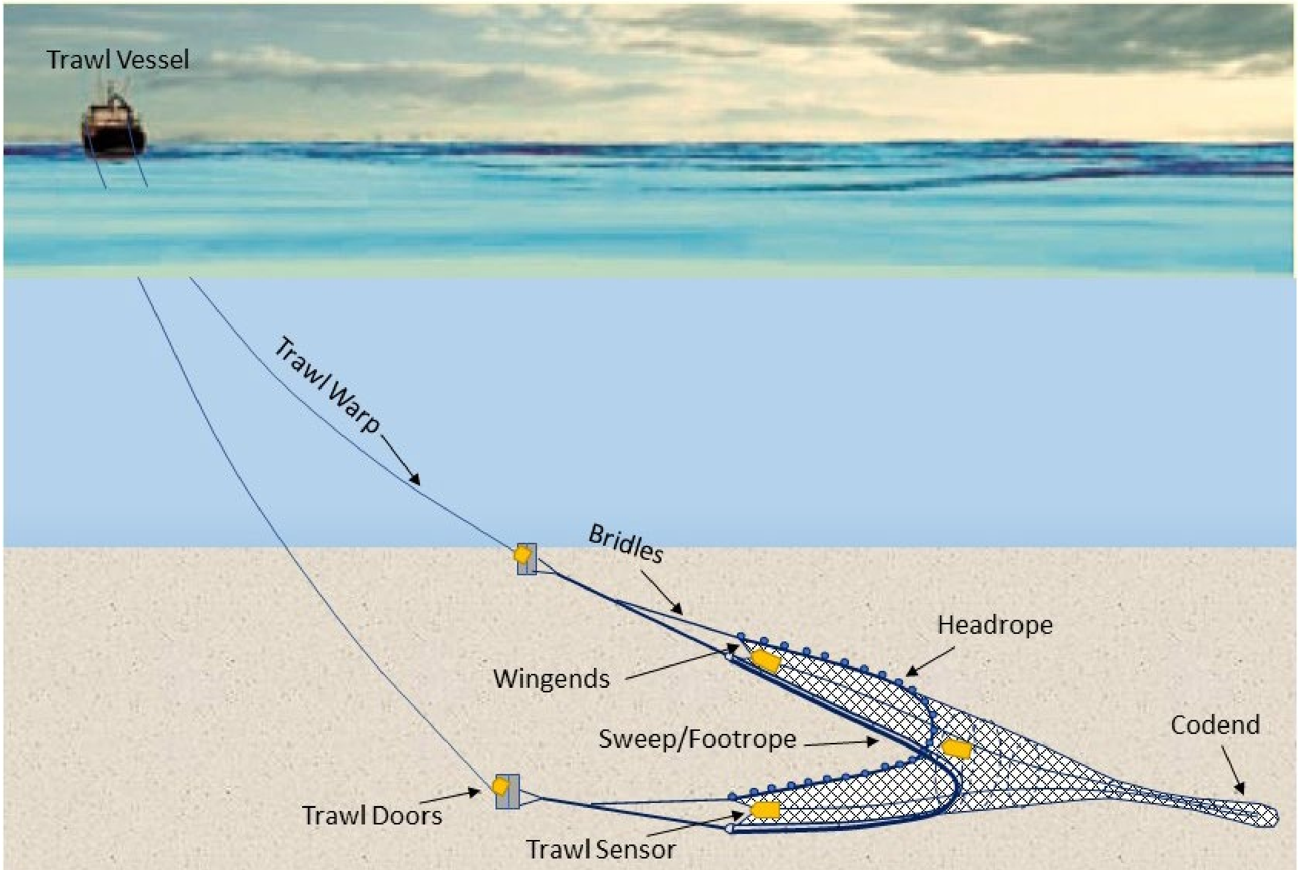



**Figure 1: General schematic (not to scale) of a demersal otter trawl. Yellow rectangles indicate geometry sensors.**

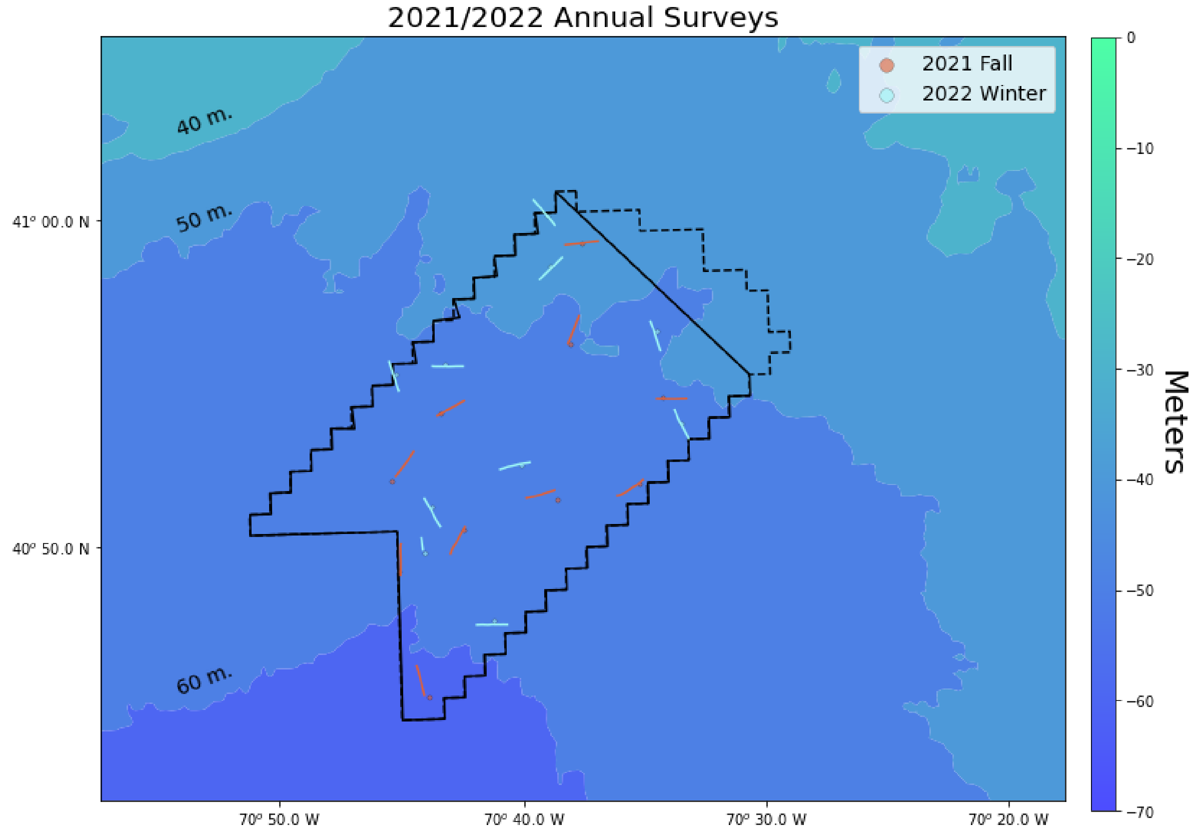



**Figure 2: Tow locations (dots) and trawl tracks (lines) from the 534 Study Area. The dashed line indicates the boundary refinement of the 534 Study Area. The 534 Study Area was increased from 369 km$^2$ (solid line) in 2020/2021 to 411 km$^2$ during 2021/2022 survey year (dashed line).**

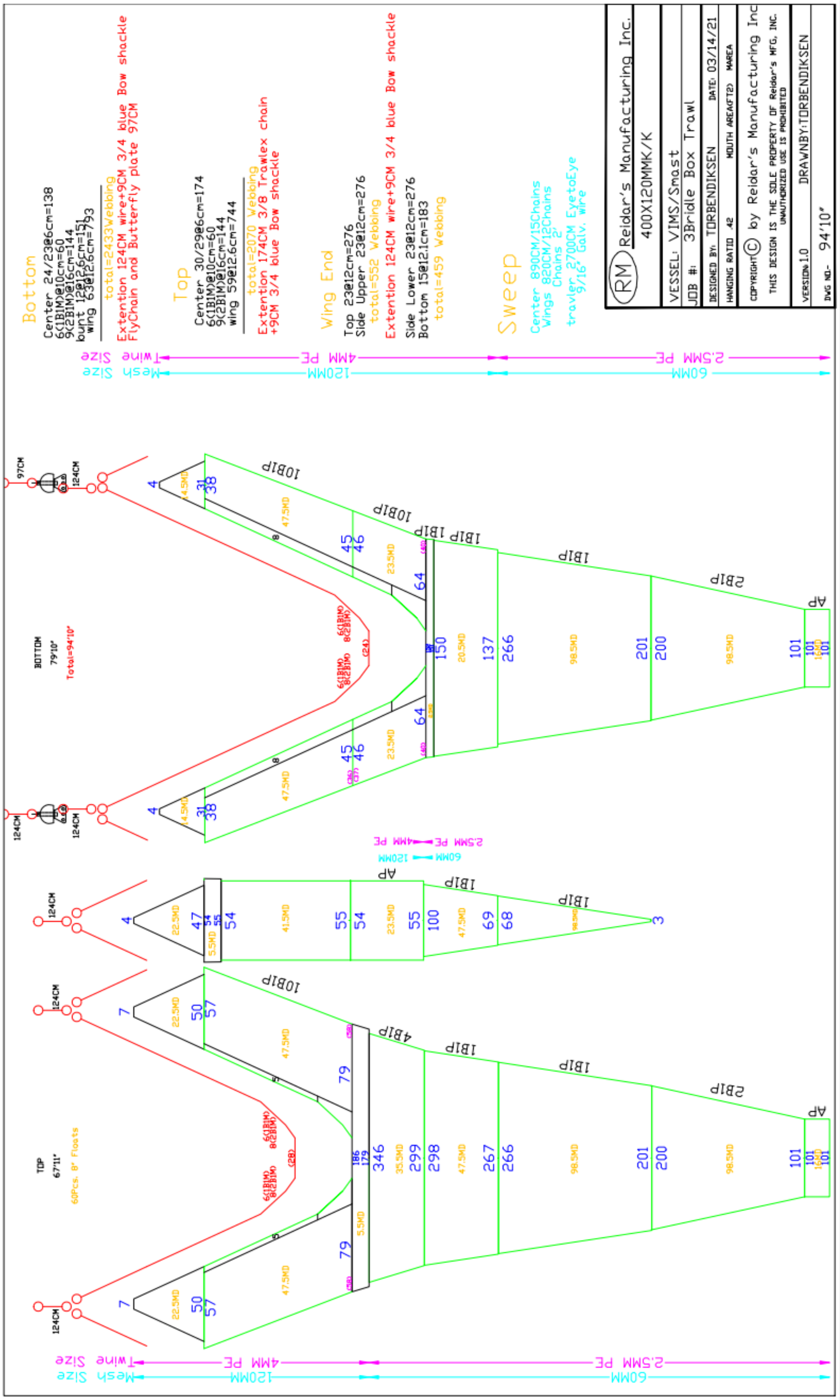



**Figure 3: Schematic net plan for the NEAMAP trawl (Courtesy of Reidar's Manufacturing Inc.).**

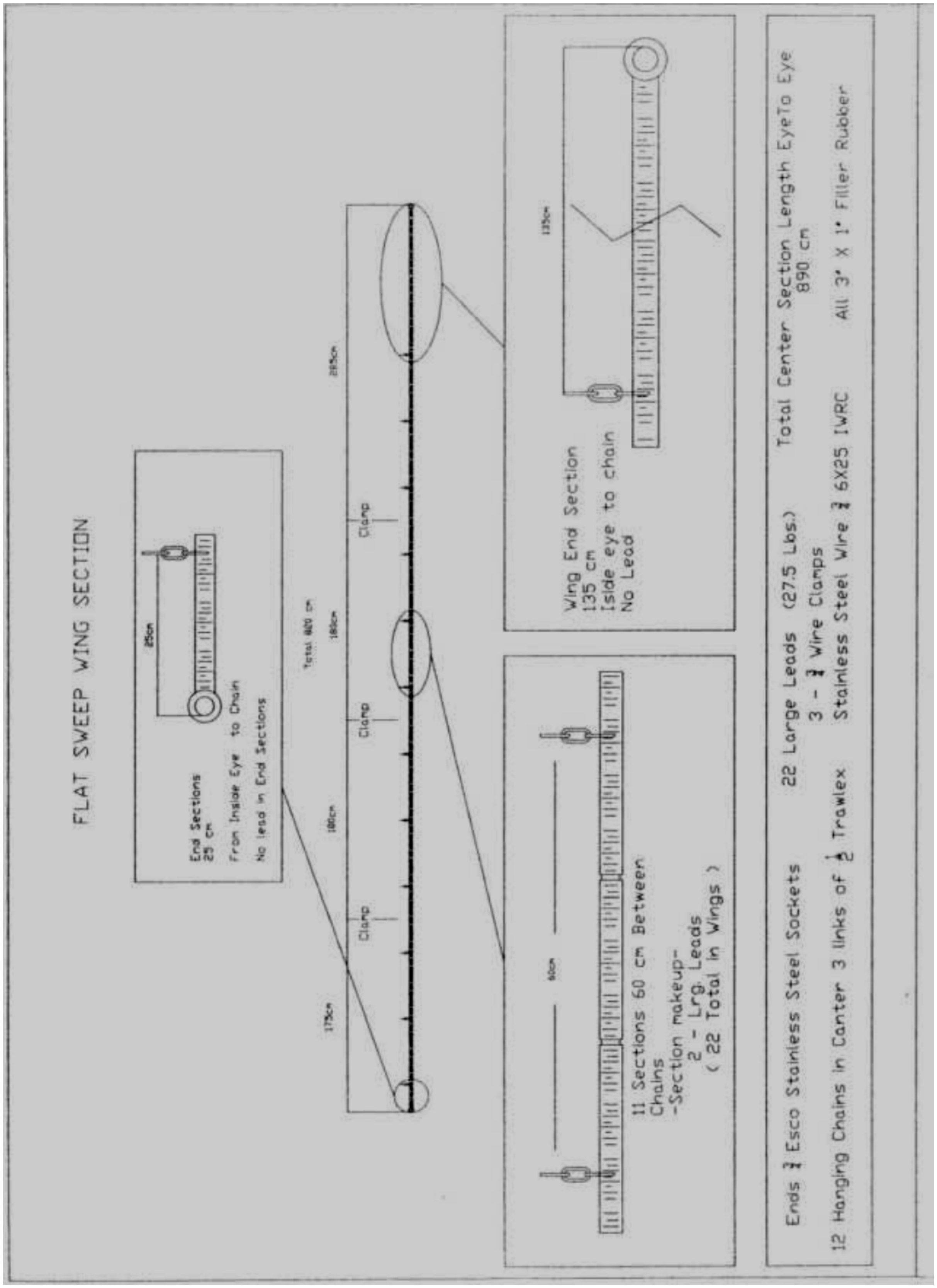



**Figure 4: Sweep diagram for the survey trawl (Bonzek et al. 2008).**

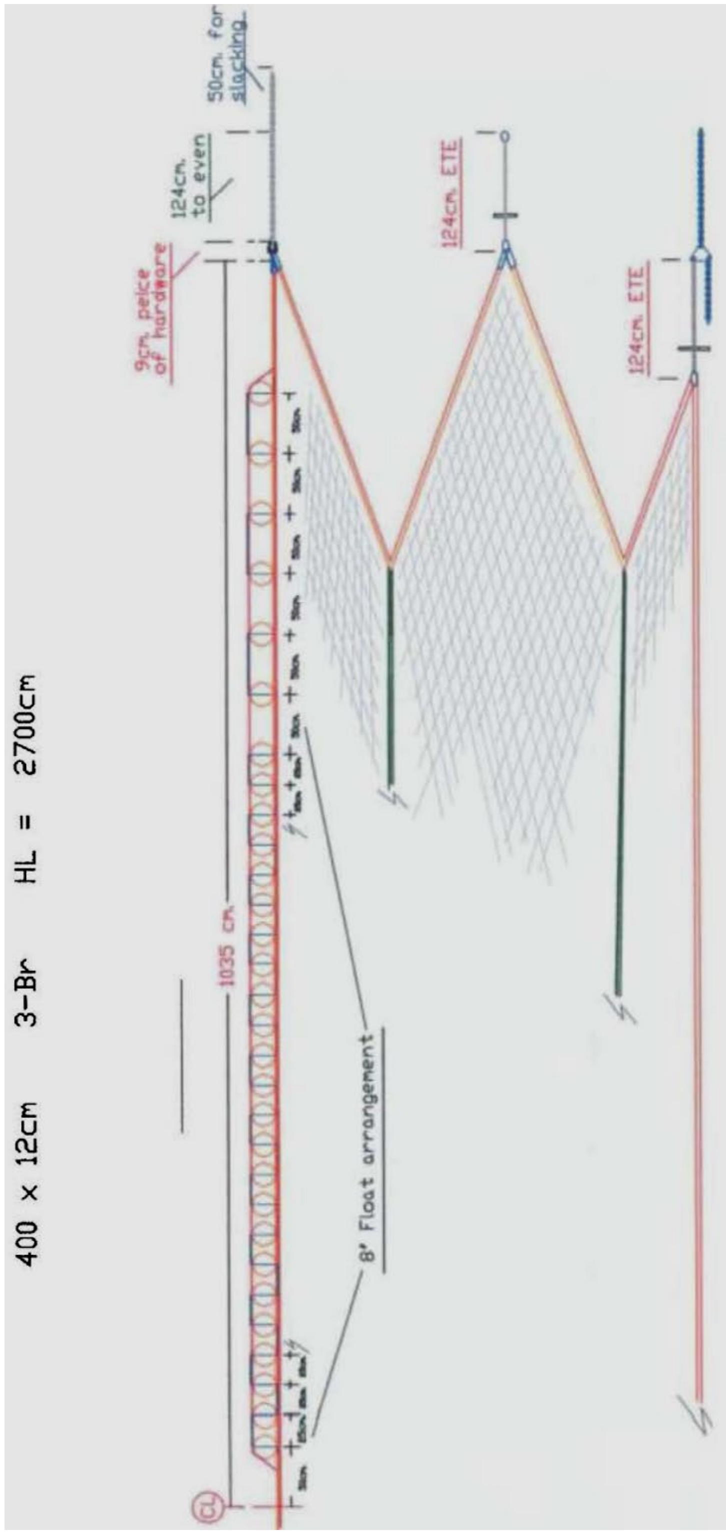



**Figure 5: Headrope and rigging plan for the survey trawl (Bonzek et al. 2008).**

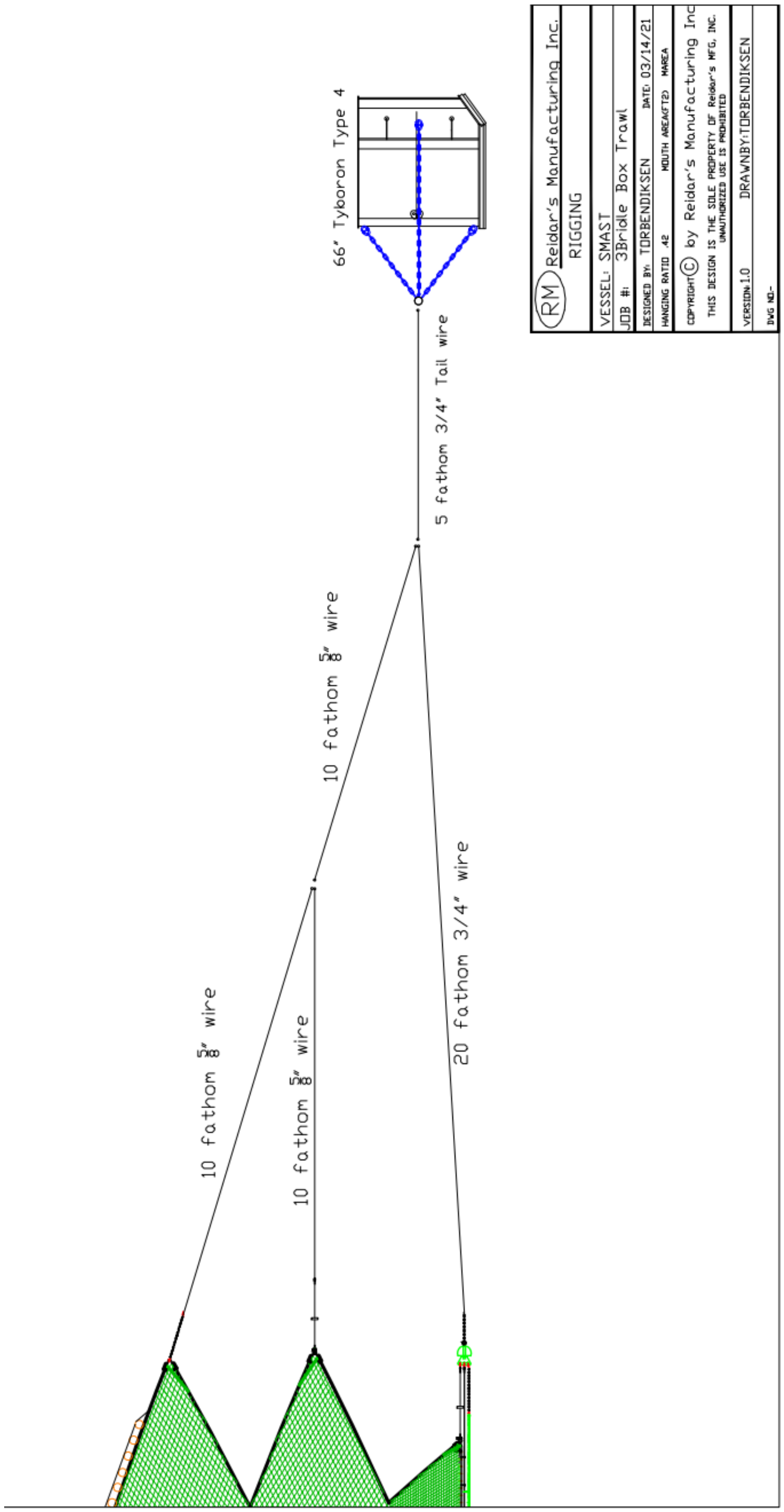



**Figure 6: Bridle and door rigging schematic for the survey trawl (Courtesy of Reidar's Manufacturing Inc.).**

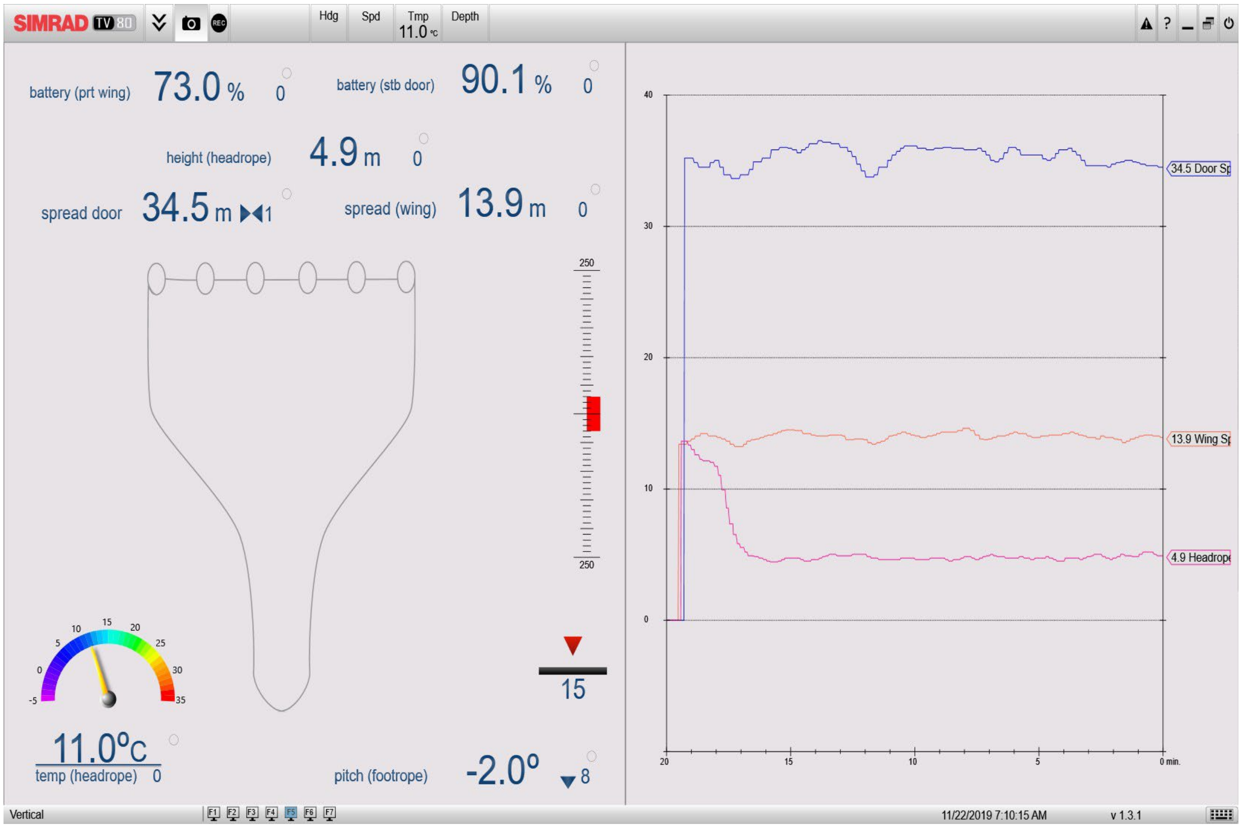



**Figure 7: Screenshot of the SIMRAD TV80 software monitoring the trawl parameters.**

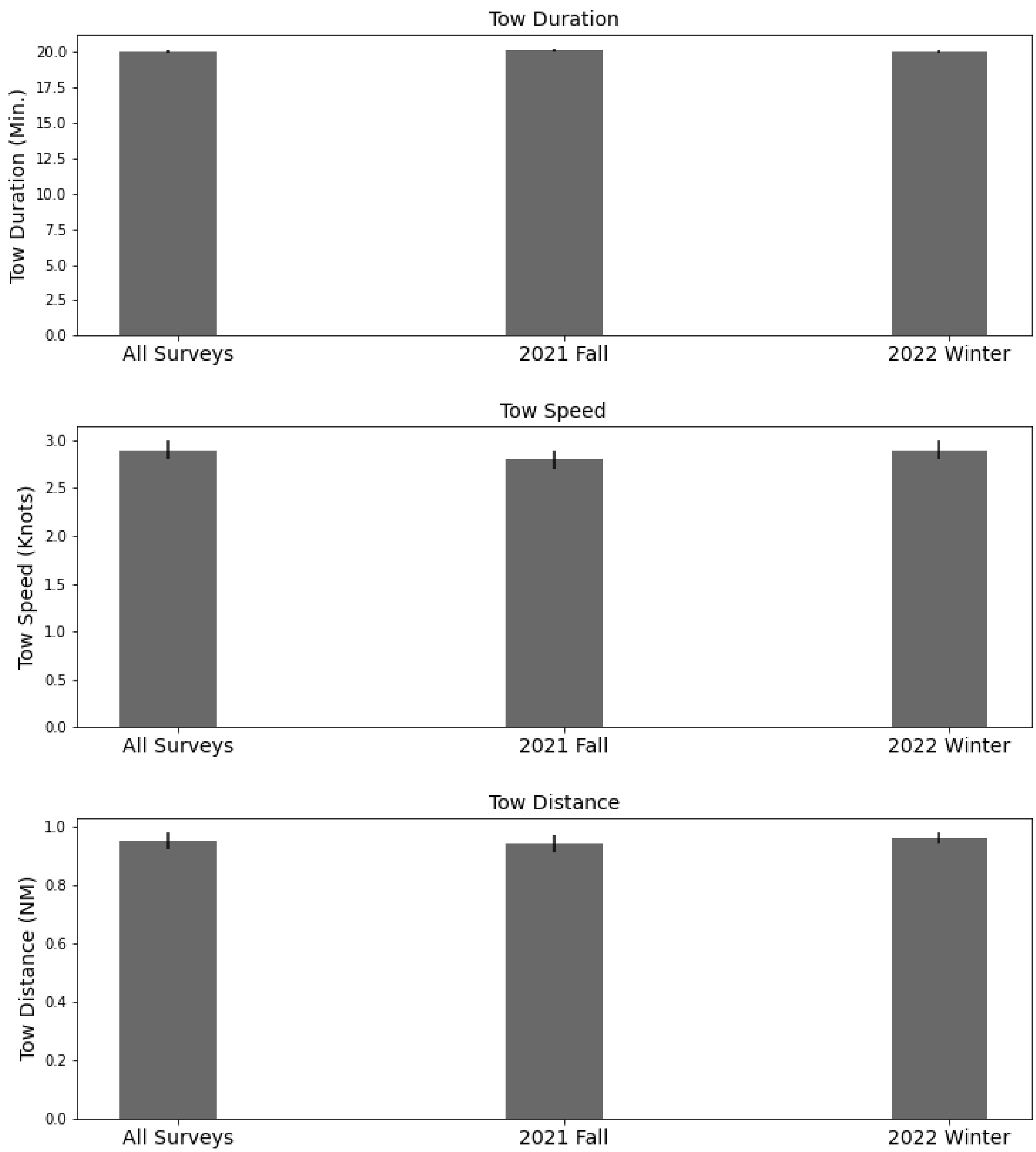



**Figure 8: Operational data from the seasonal surveys including tow duration, tow speed and tow distance.**

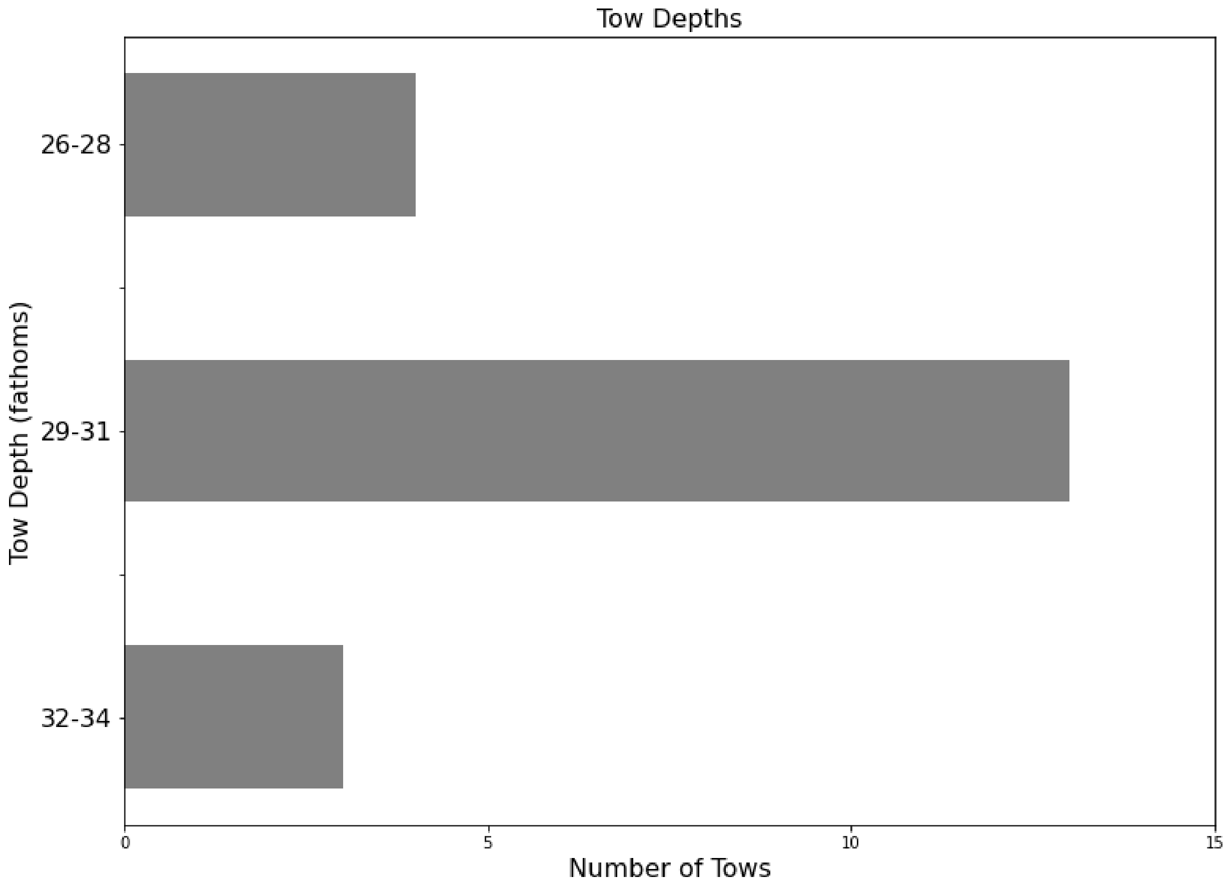



**Figure 9: Distribution of tow depths at the start of each tow.**

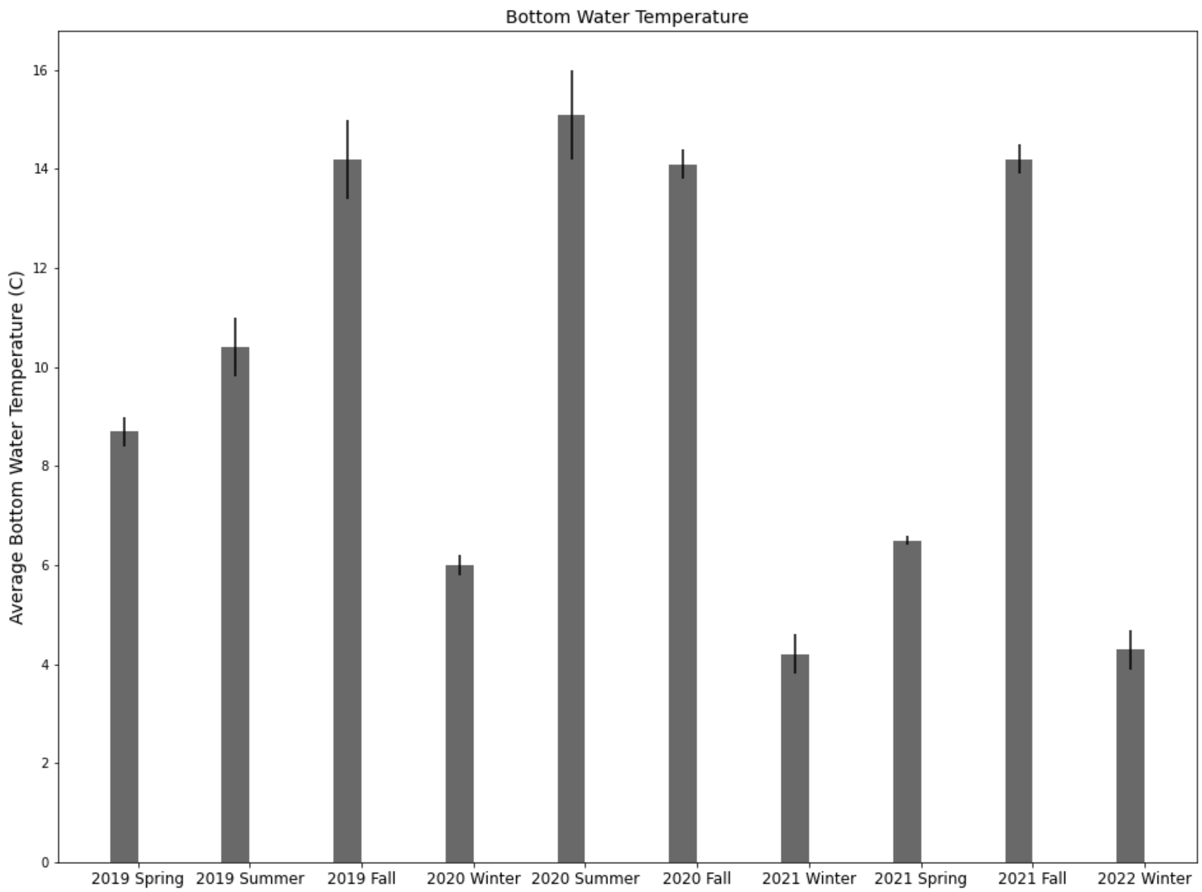



**Figure 10: Average seasonal bottom water temperature within the 534 Study Area between 2019-2022.**

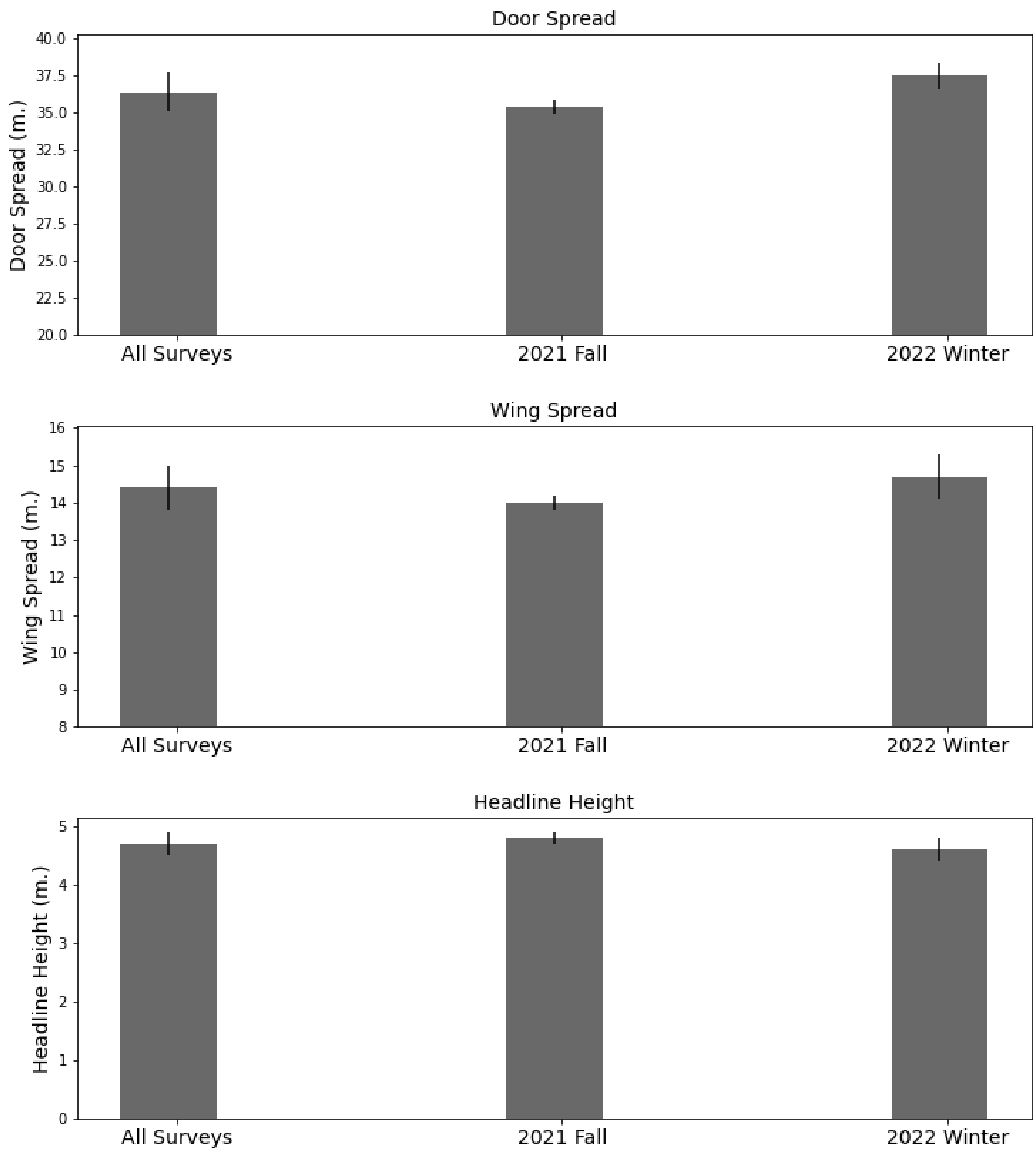



**Figure 11: Seasonal averages of the trawl parameters including door spread, wing spread and headline height.**

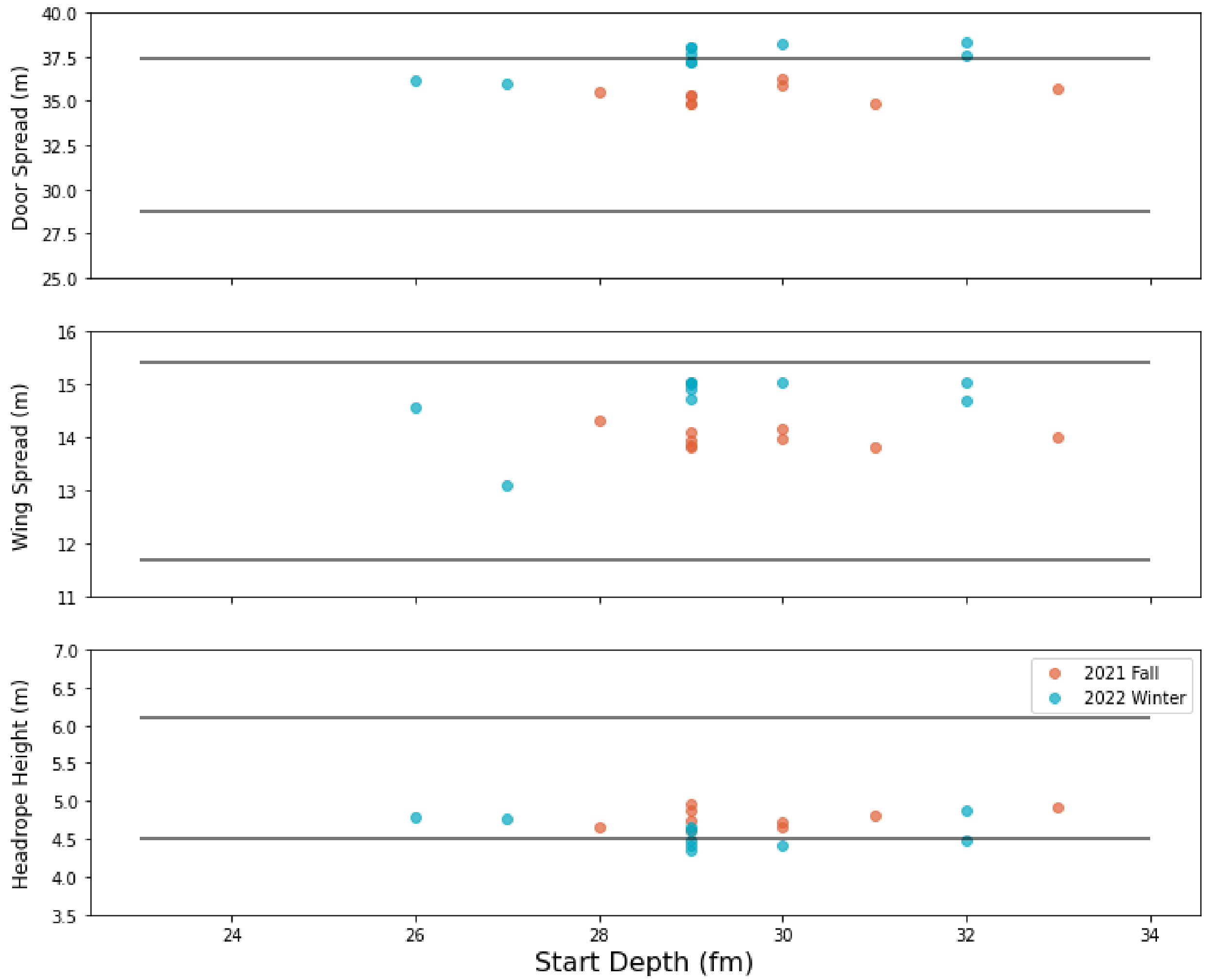



**Figure 12: Trawl parameters with respect to the tow starting depth.**

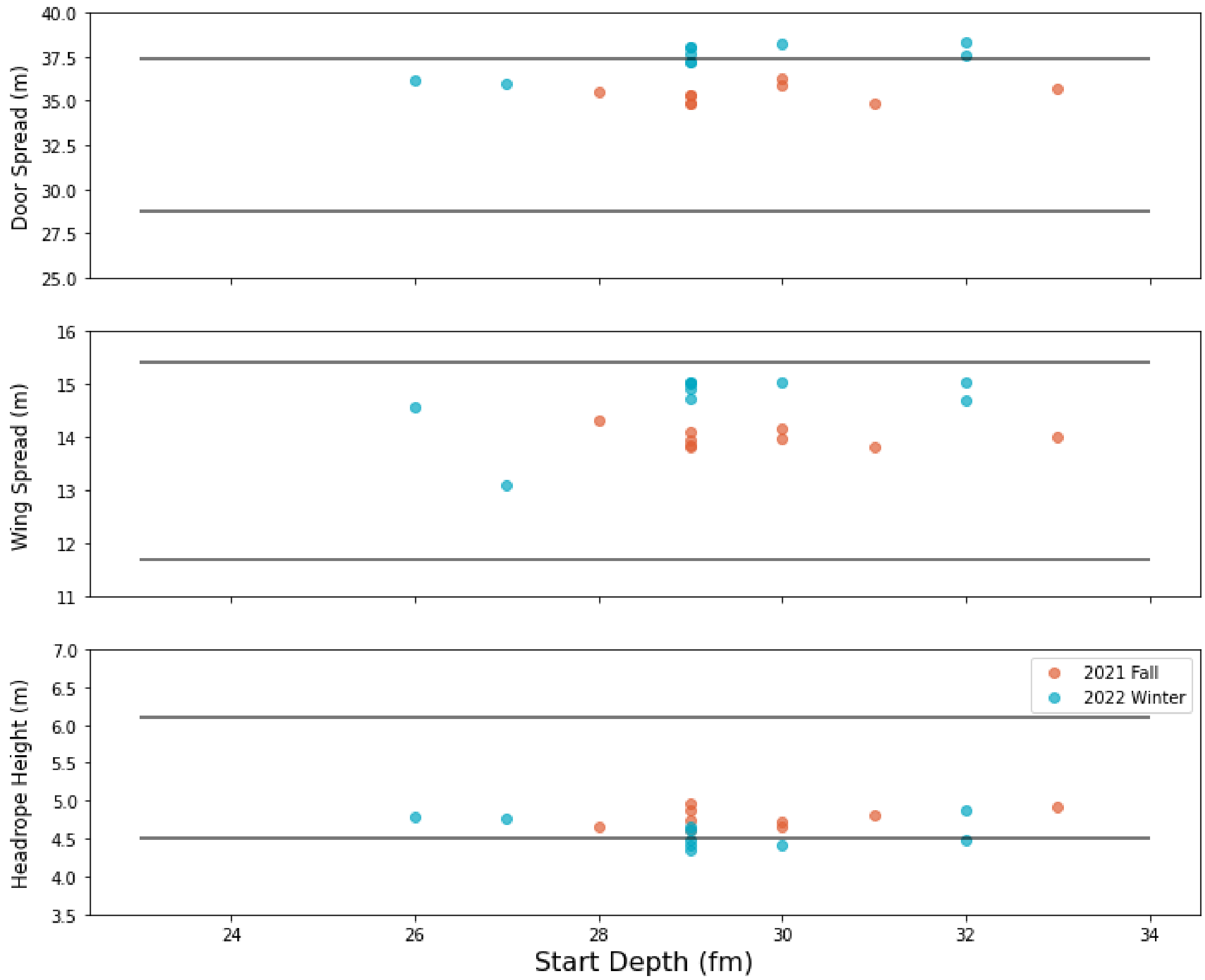



**Figure 13: Trawl parameters with respect to trawl warp.**

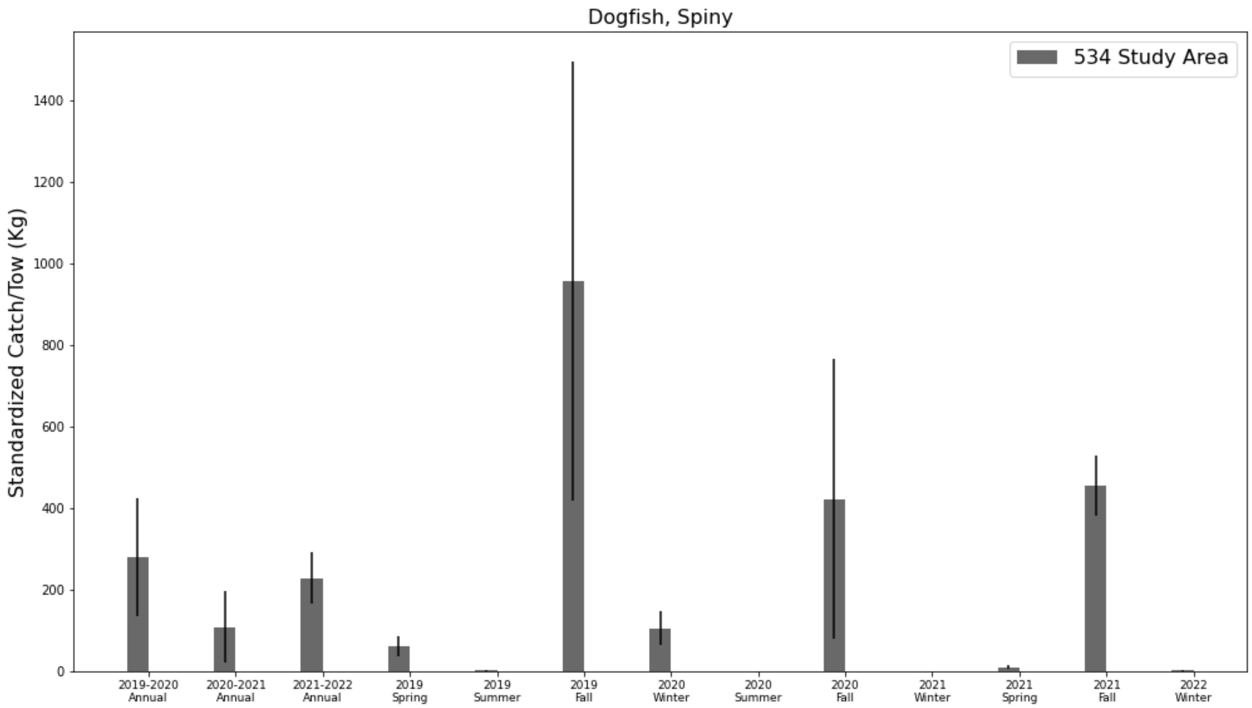



**Figure 14: Seasonal catch rates of spiny dogfish in the 534 Study Area.**

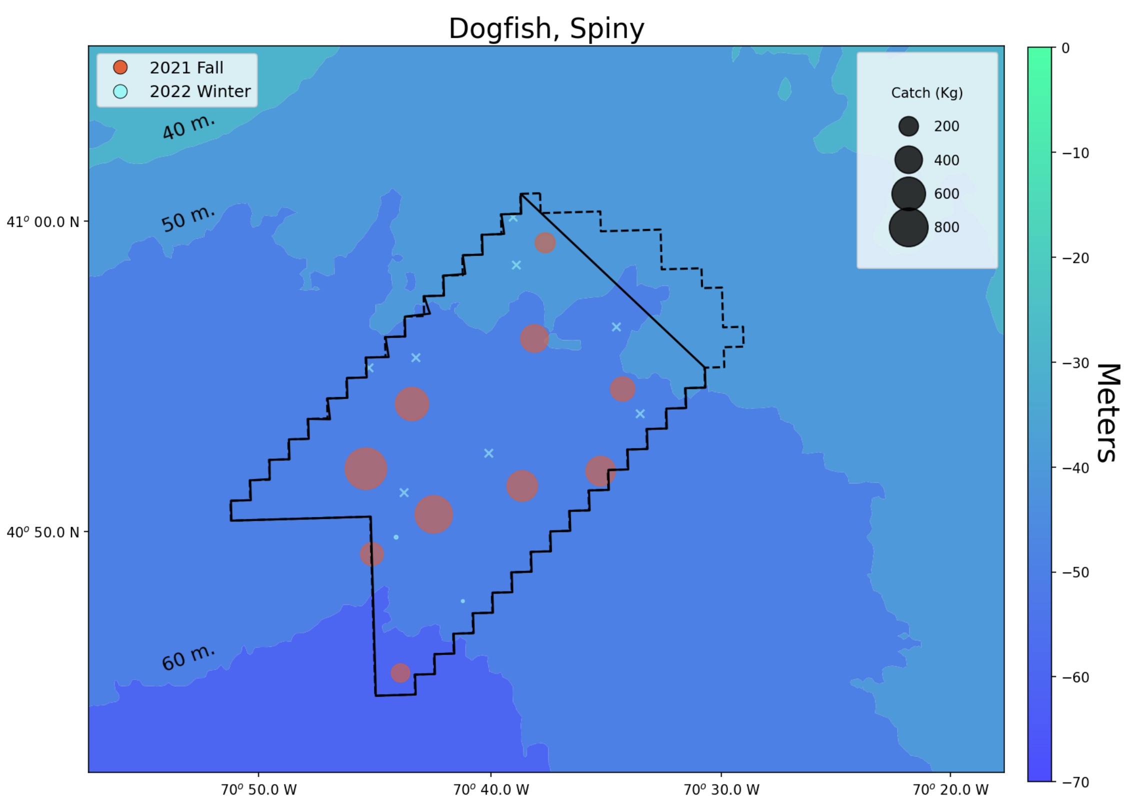



**Figure 15: Seasonal distribution of the spiny dogfish catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

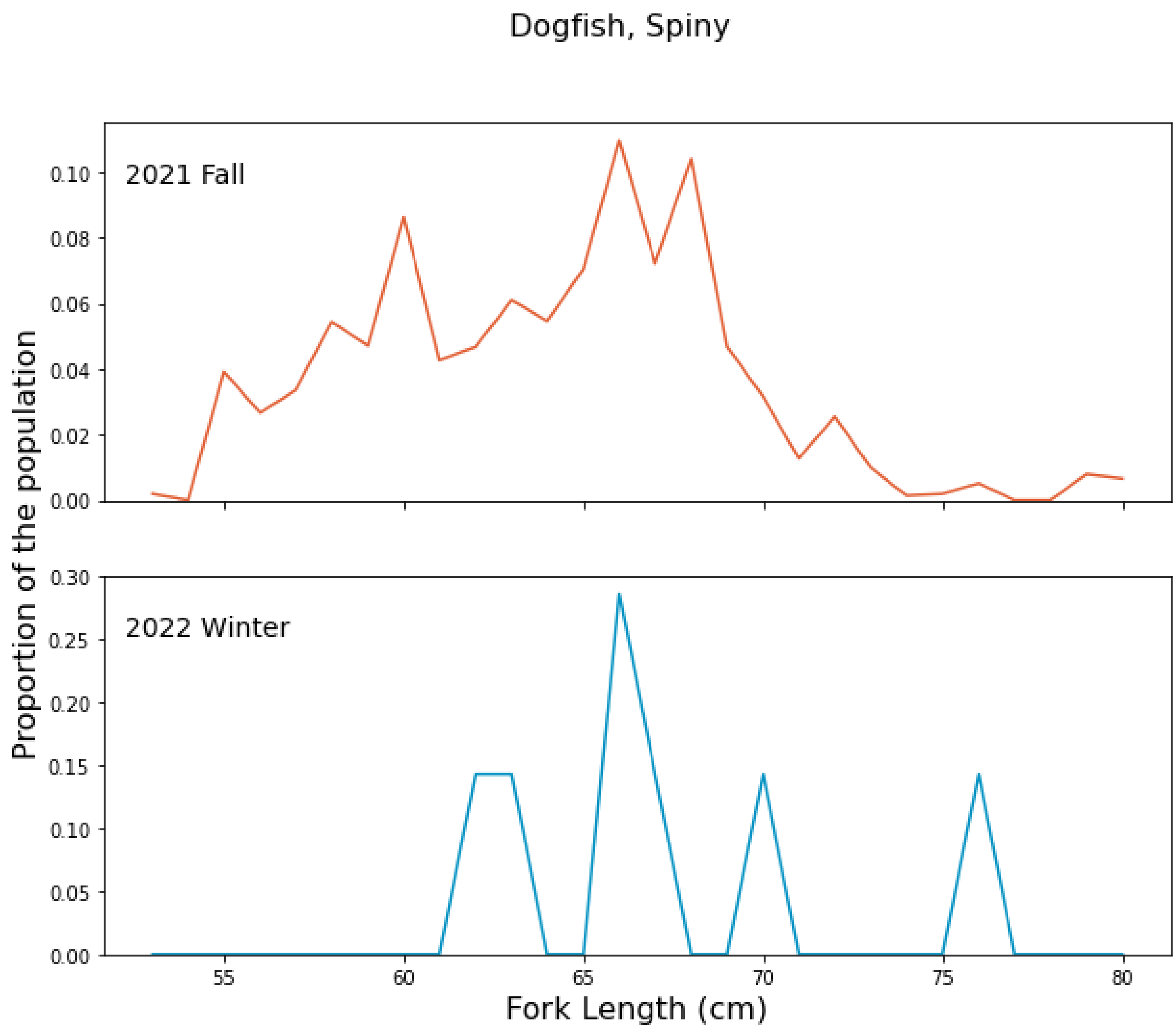



**Figure 16: The seasonal length distributions of spiny dogfish in the 534 Study Area.**

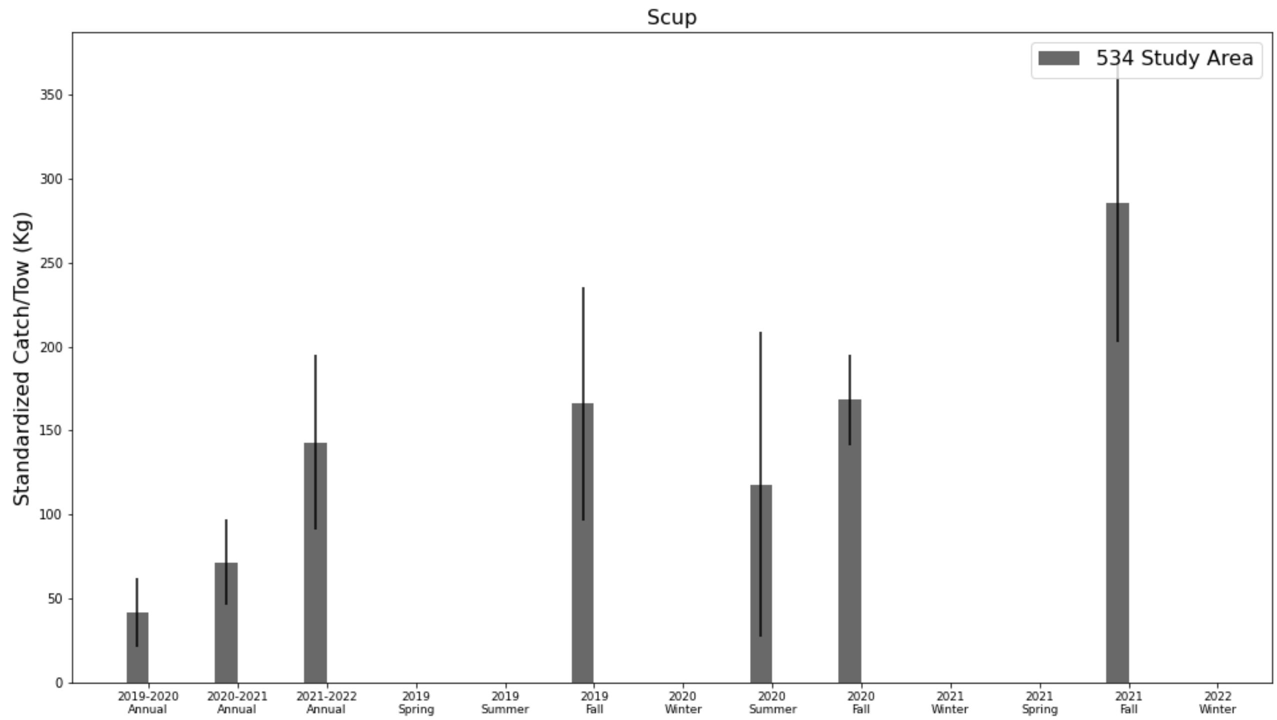



**Figure 17: Seasonal catch rates of scup in the 534 Study Area.**

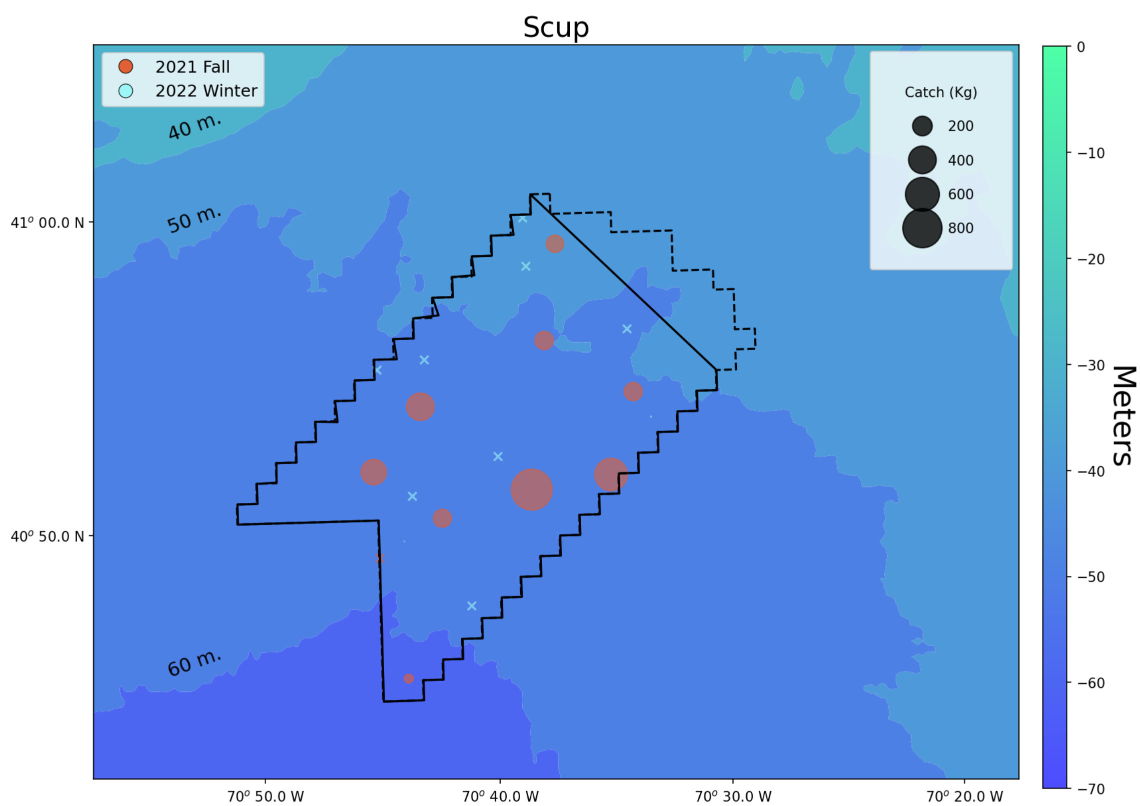



**Figure 18: Seasonal distribution of the scup catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

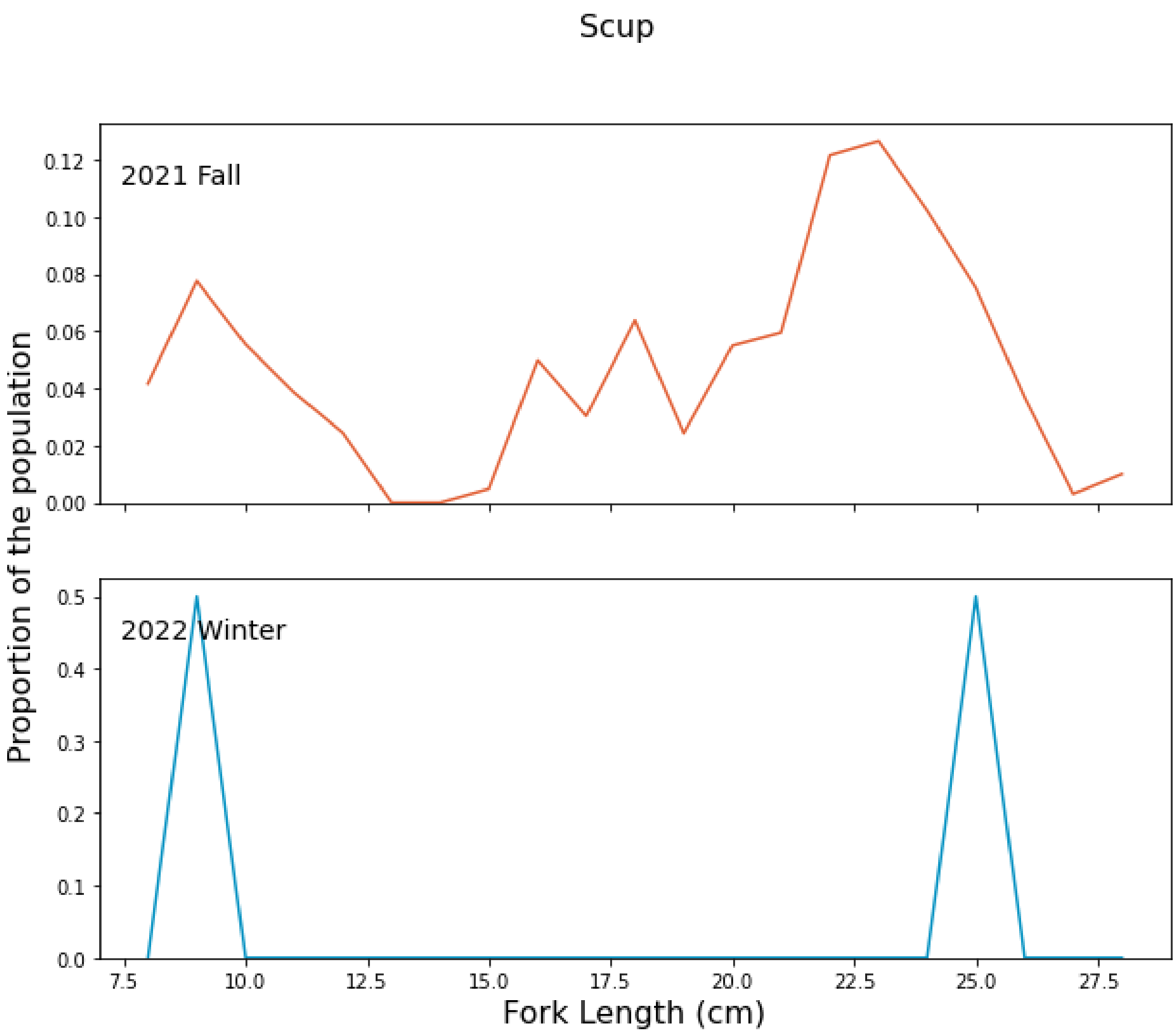



**Figure 19: The seasonal length distributions of scup in the 534 Study Area.**

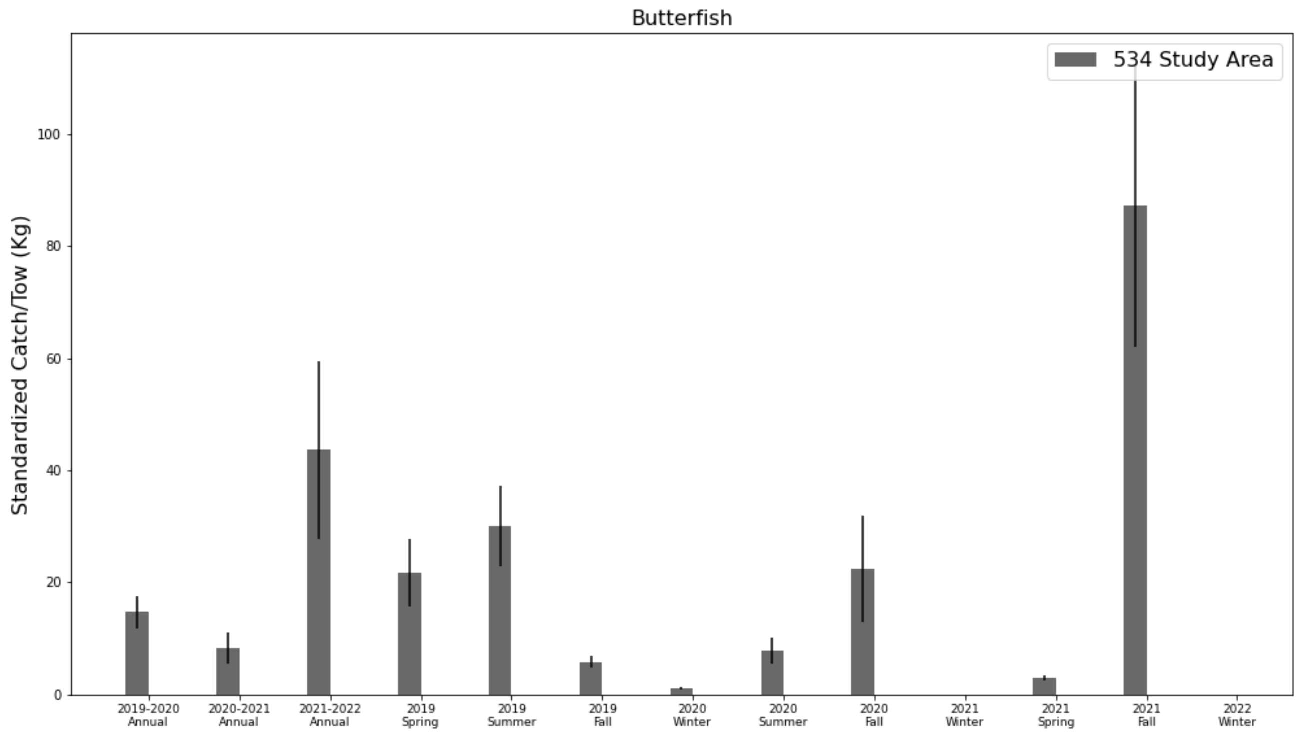



**Figure 20: Seasonal catch rates of butterfish in the 534 Study Area.**

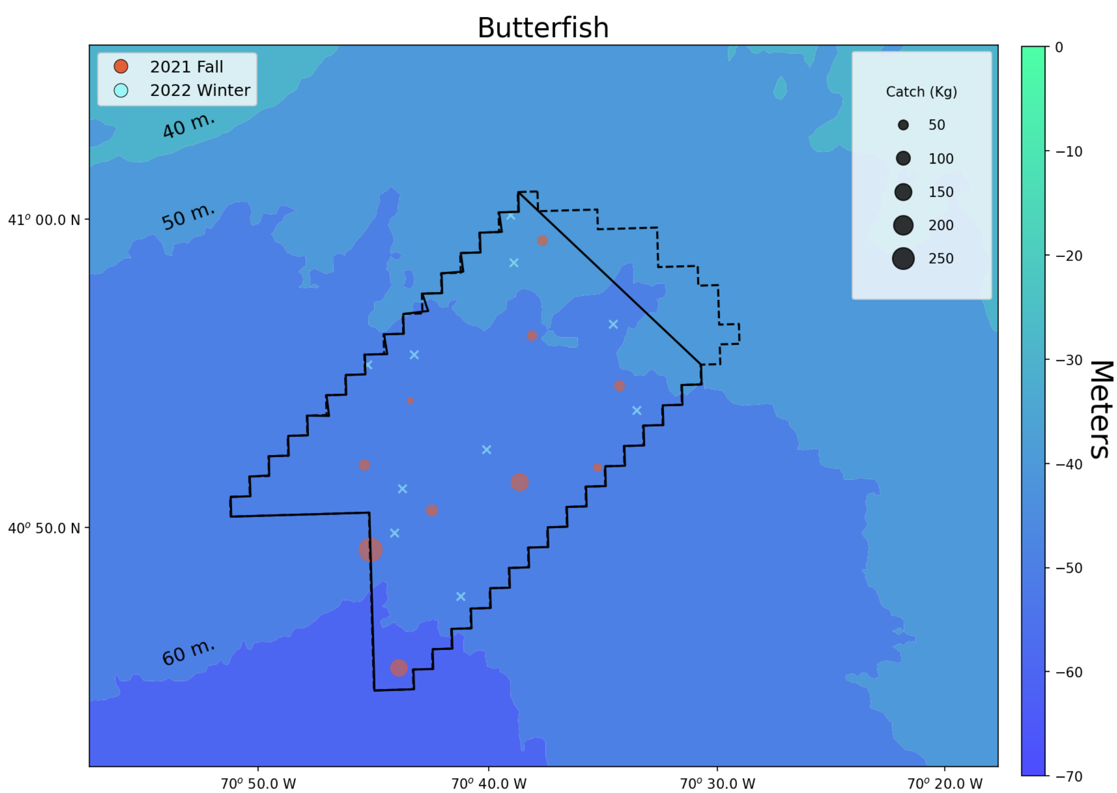



**Figure 21: Seasonal distribution of the butterfish catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

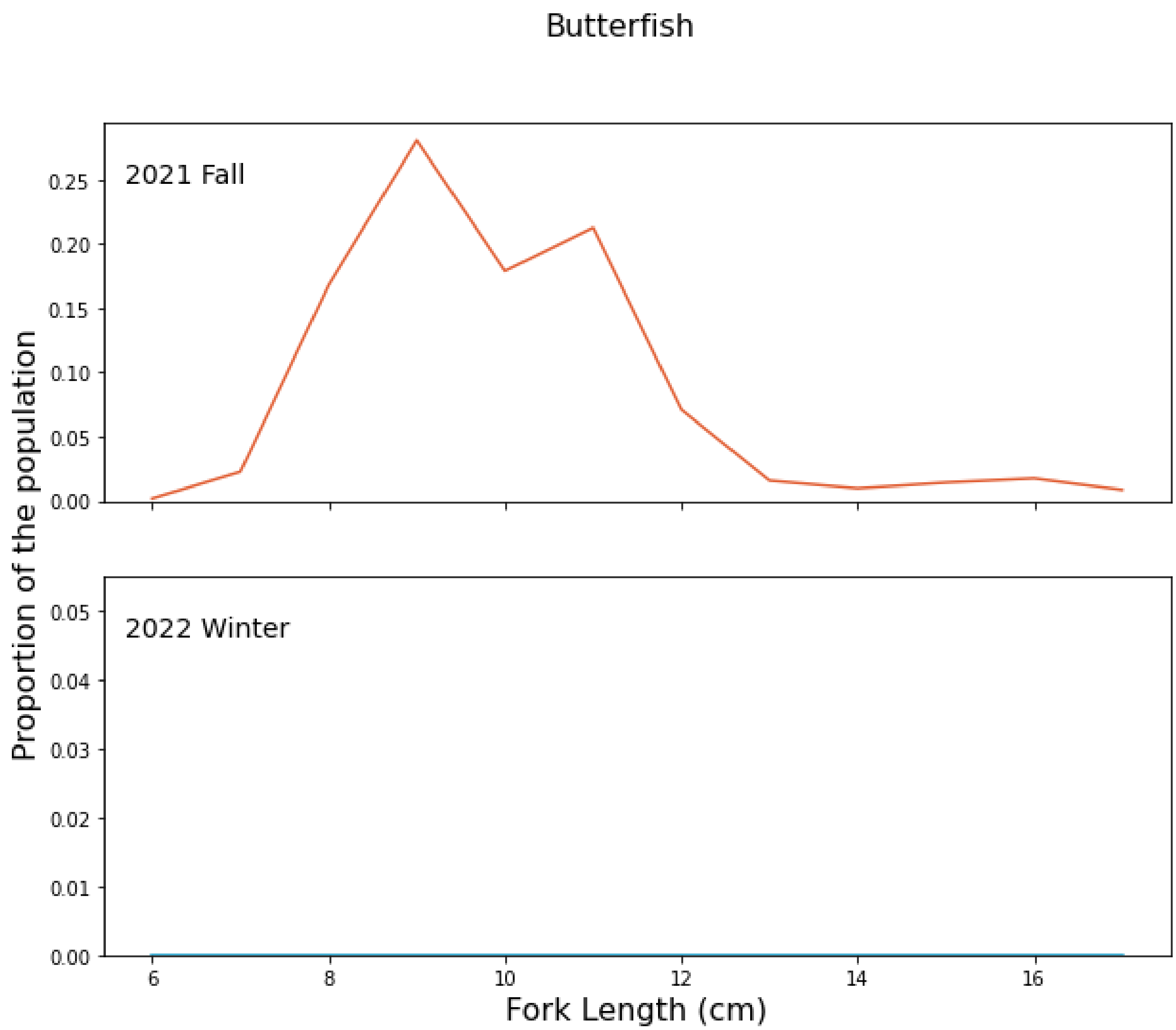



**Figure 22: The seasonal length distributions of butterfish in the 534 Study Area.**

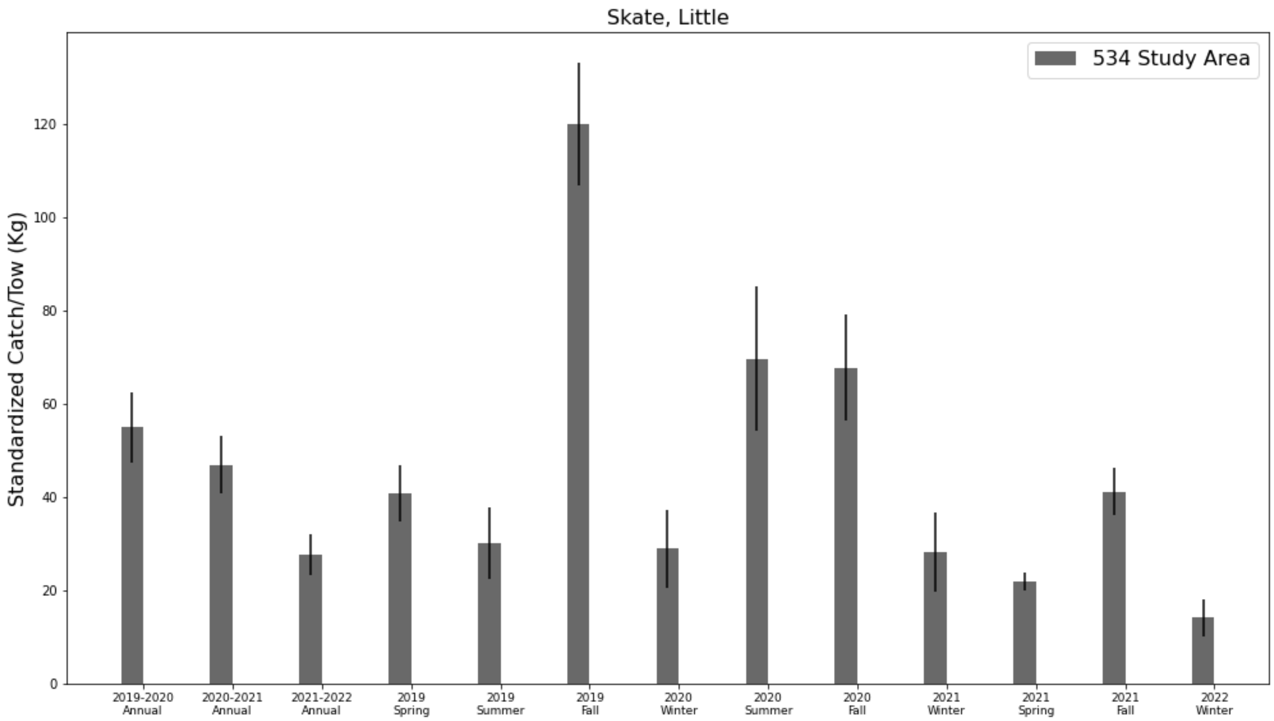



**Figure 23: Seasonal catch rates of little skate in the 534 Study Area.**

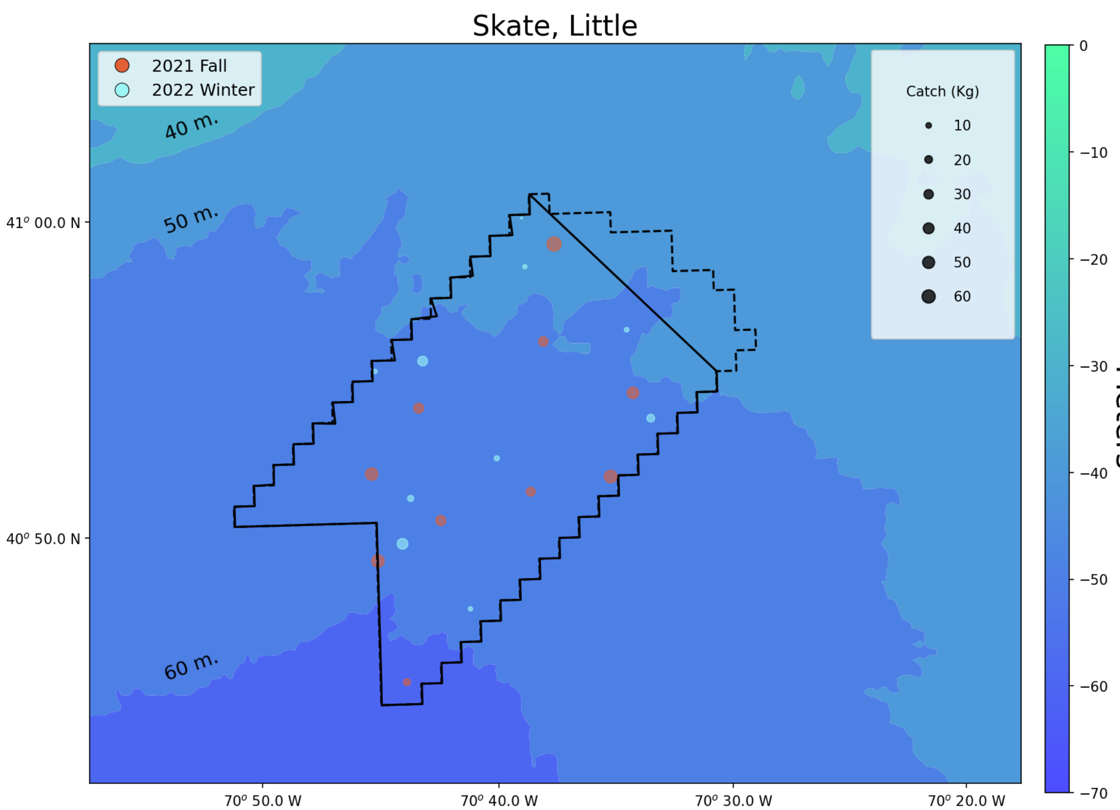



**Figure 24: Seasonal distribution of the little skate catch in the 534 Study Area.**

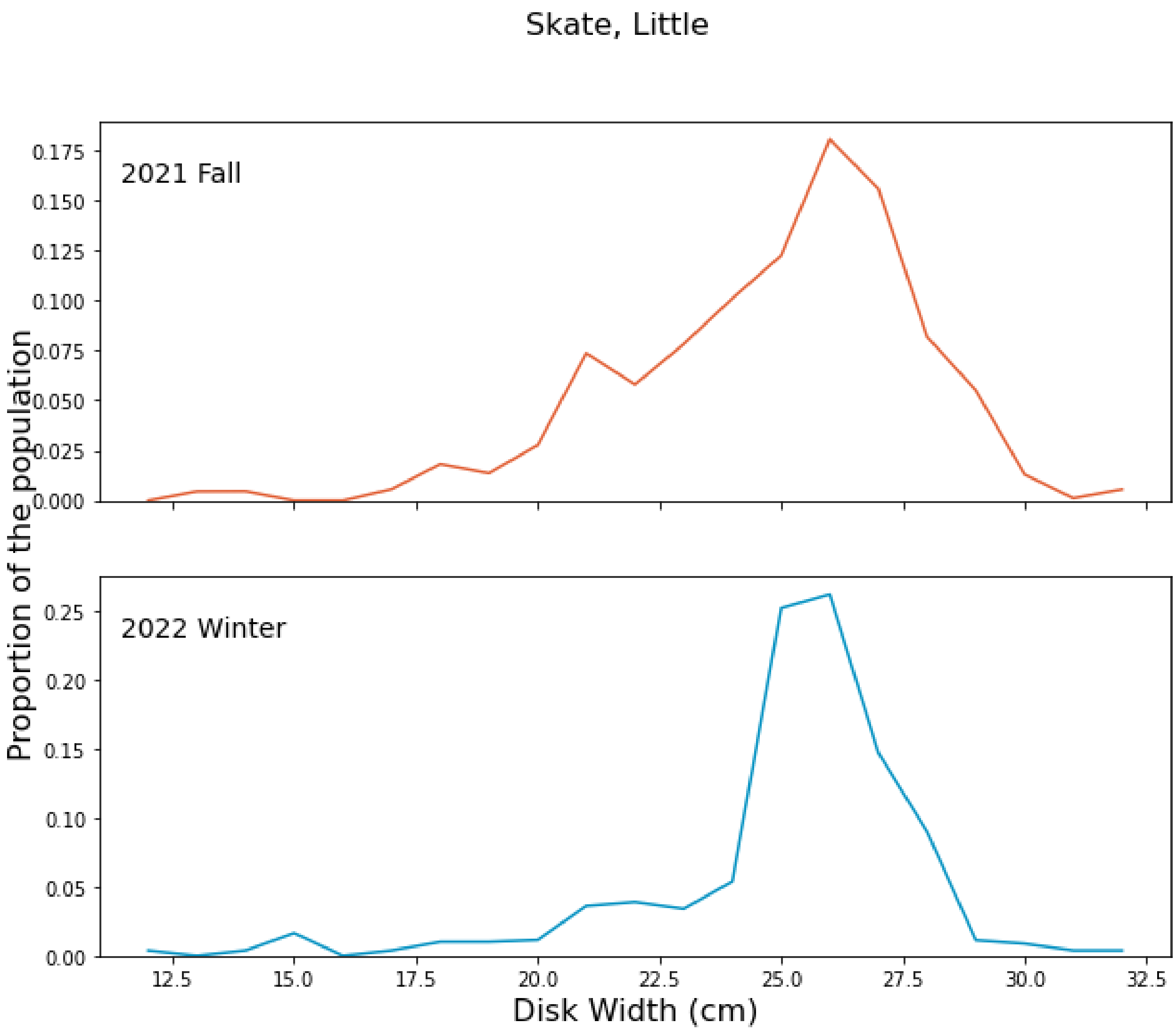



**Figure 25: The seasonal length distributions of little skate in the 534 Study Area.**

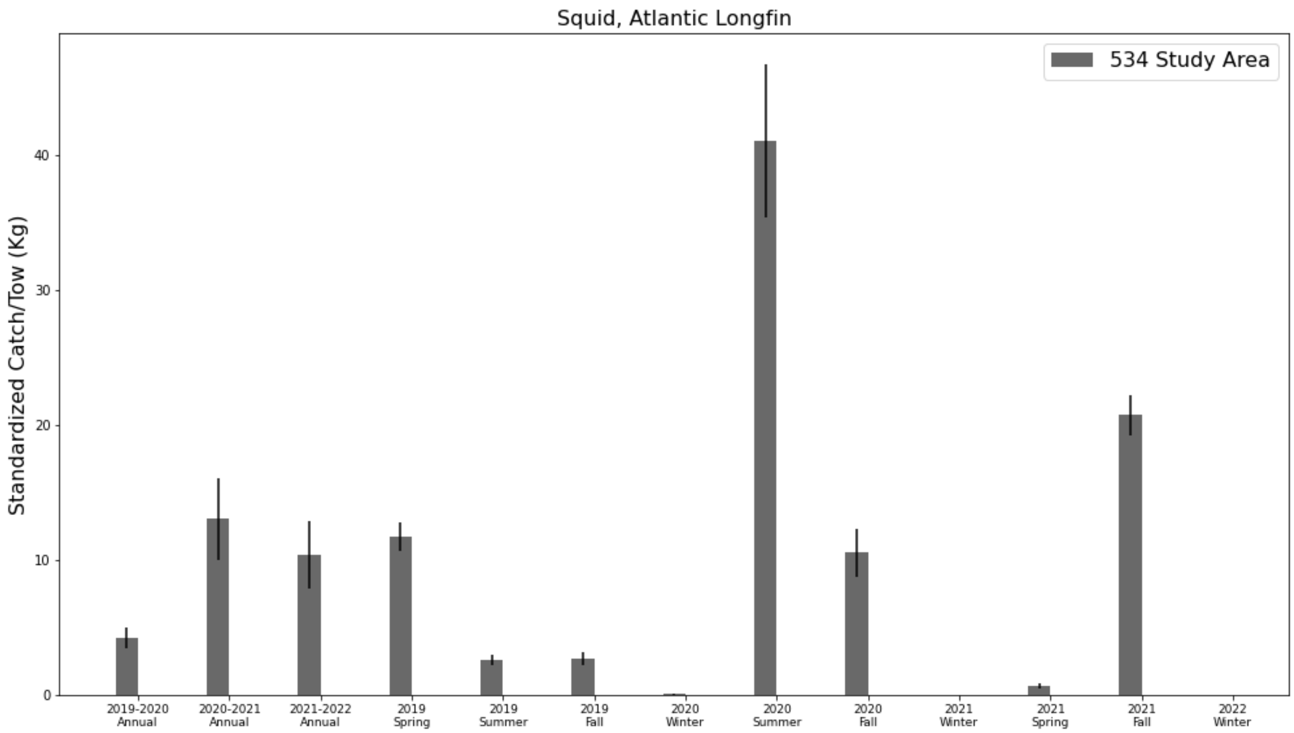



**Figure 26: Seasonal catch rates of Atlantic longfin squid in the 534 Study Area.**

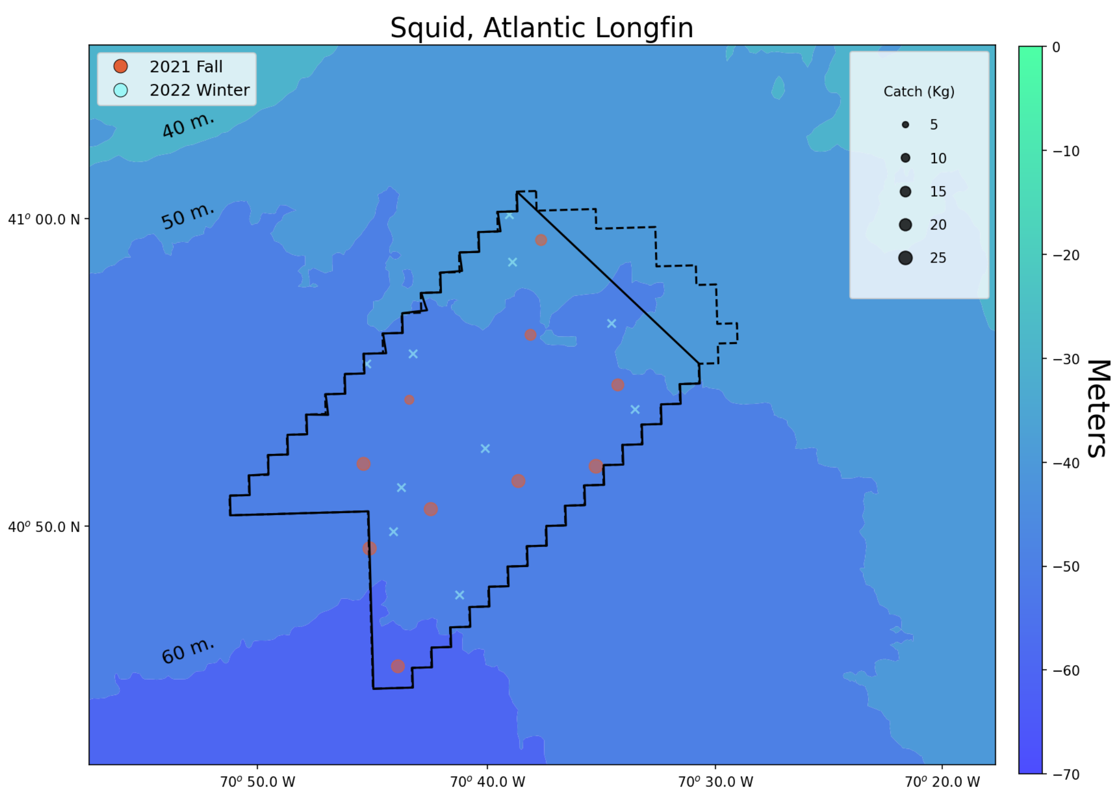



**Figure 27: Seasonal distribution of the Atlantic longfin squid catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

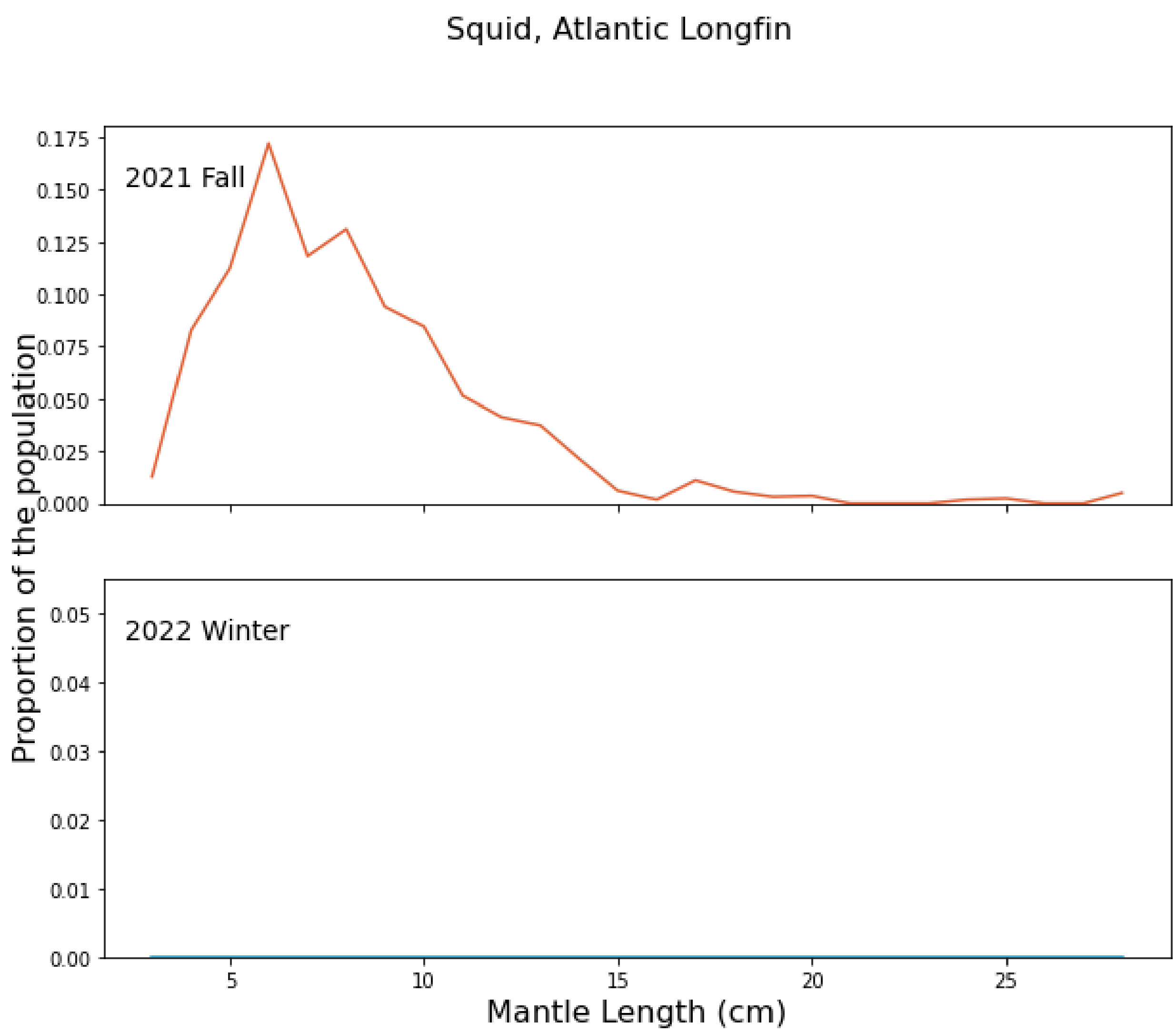



**Figure 28: The seasonal length distributions of Atlantic longfin squid in the 534 Study Area.**

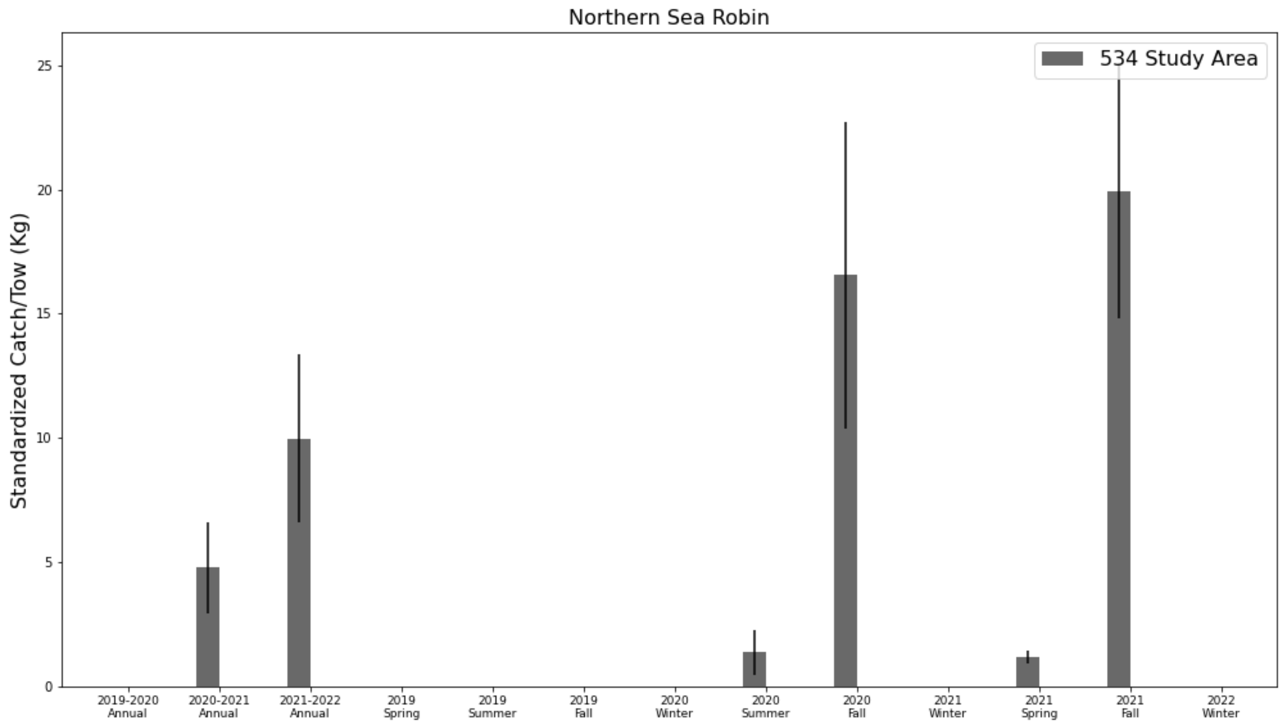



**Figure 29: Seasonal catch rates of northern sea robin in the 534 Study Area.**

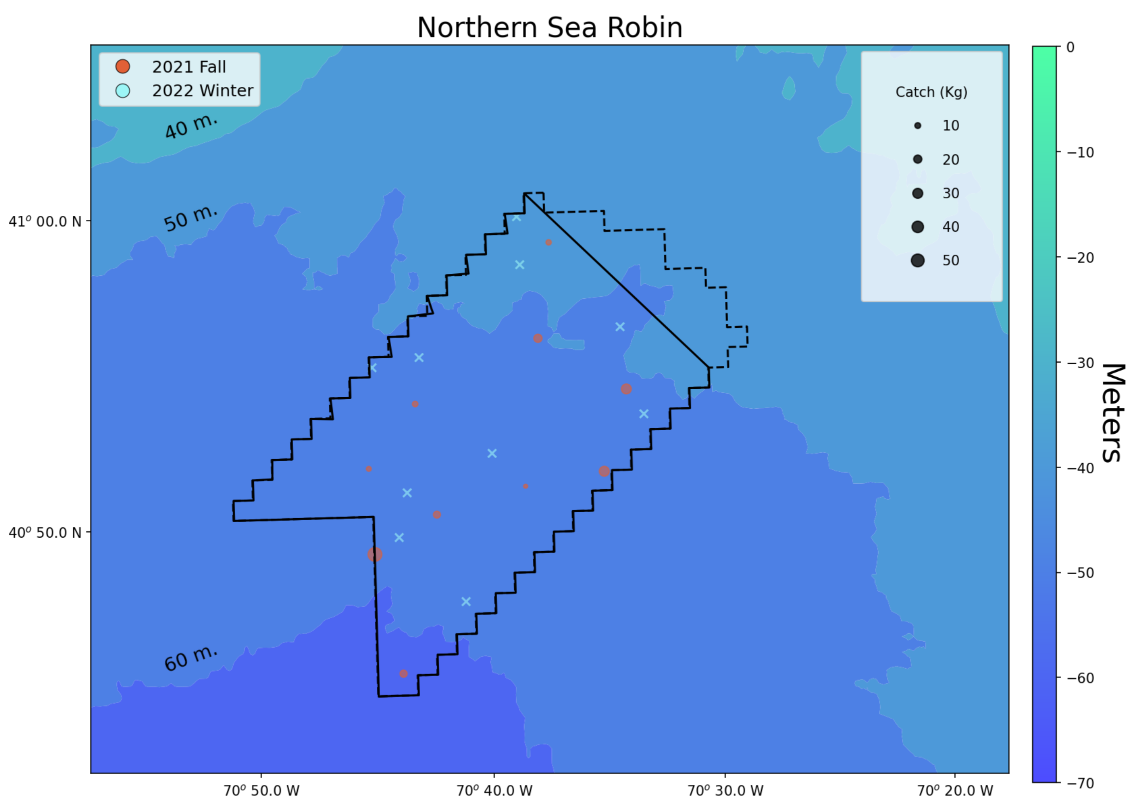



**Figure 30: Seasonal distribution of the northern sea robin catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

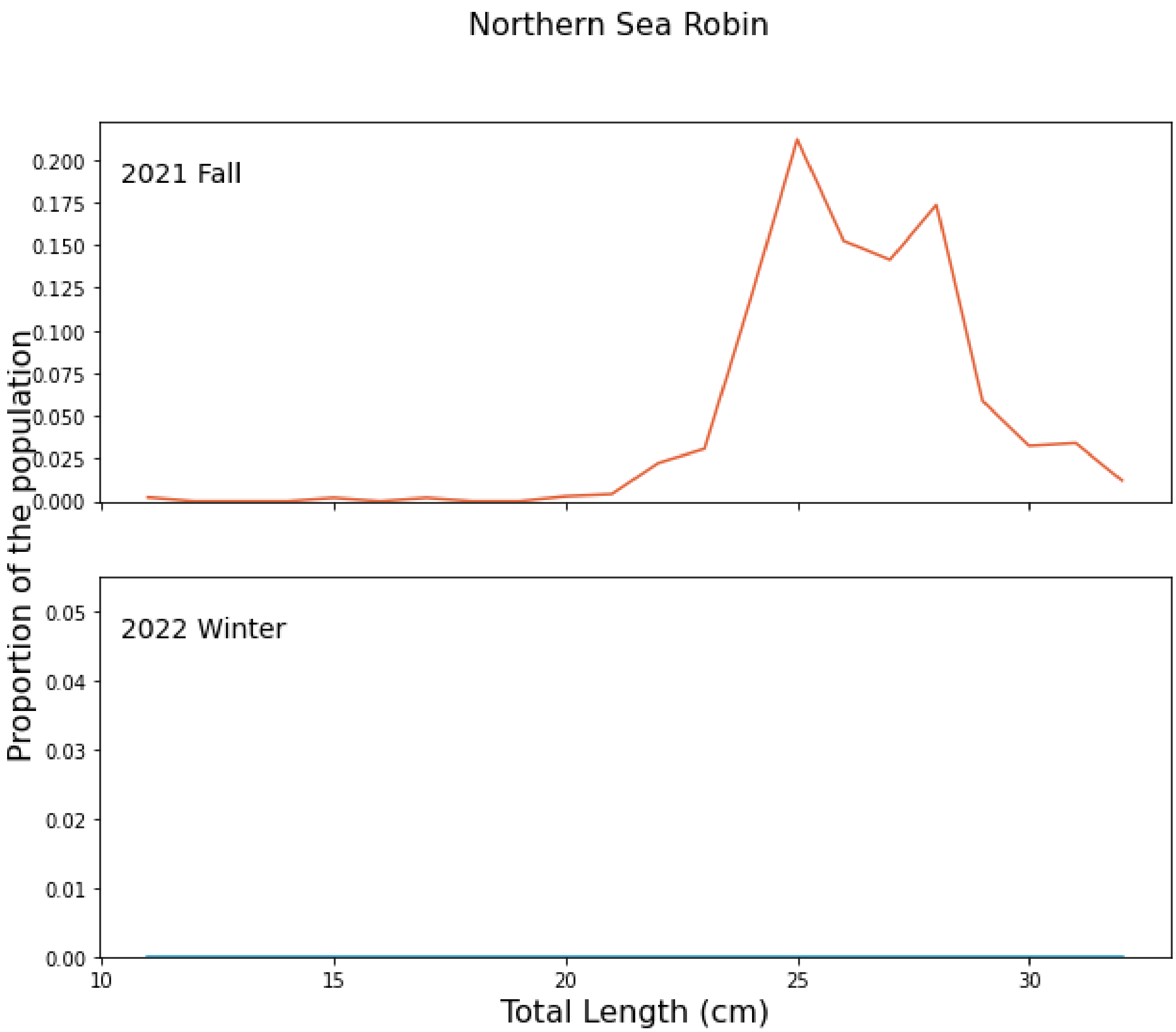



**Figure 31: The seasonal length distributions of northern sea robin in the 534 Study Area.**

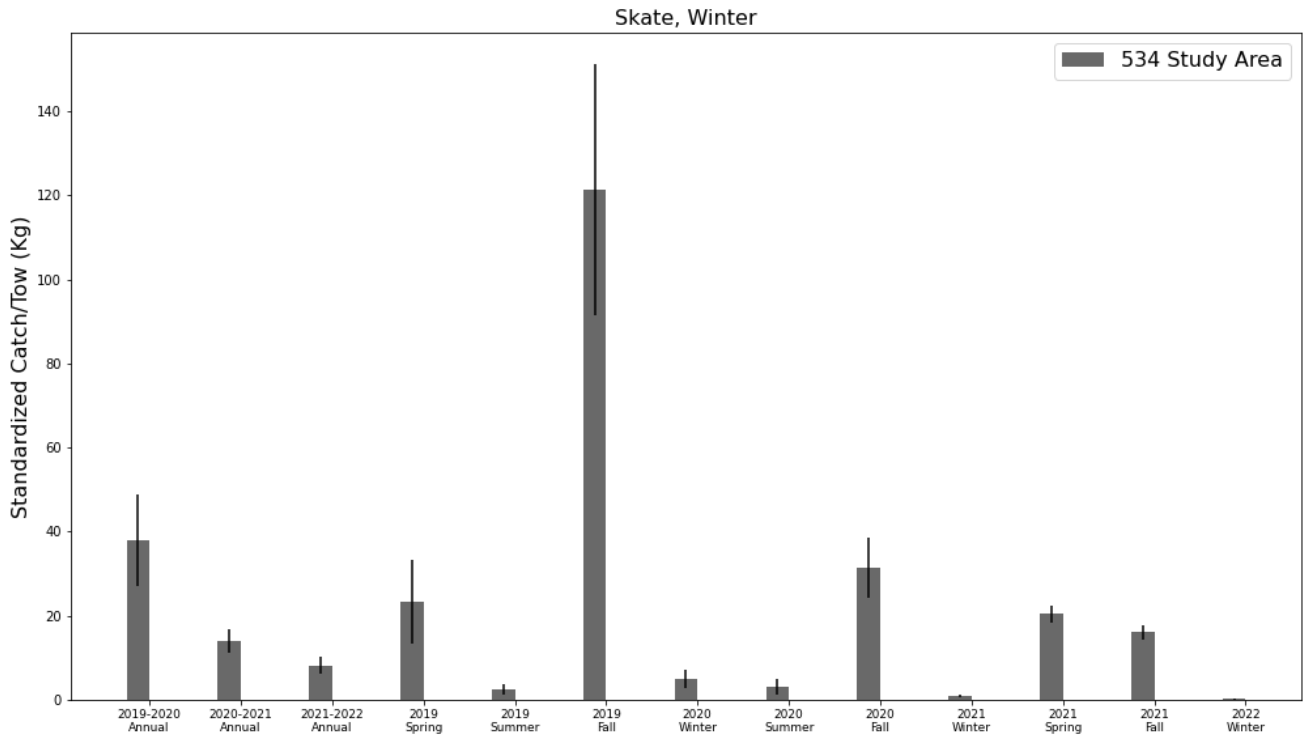



**Figure 32: Seasonal catch rates of winter skate in the 534 Study Area.**

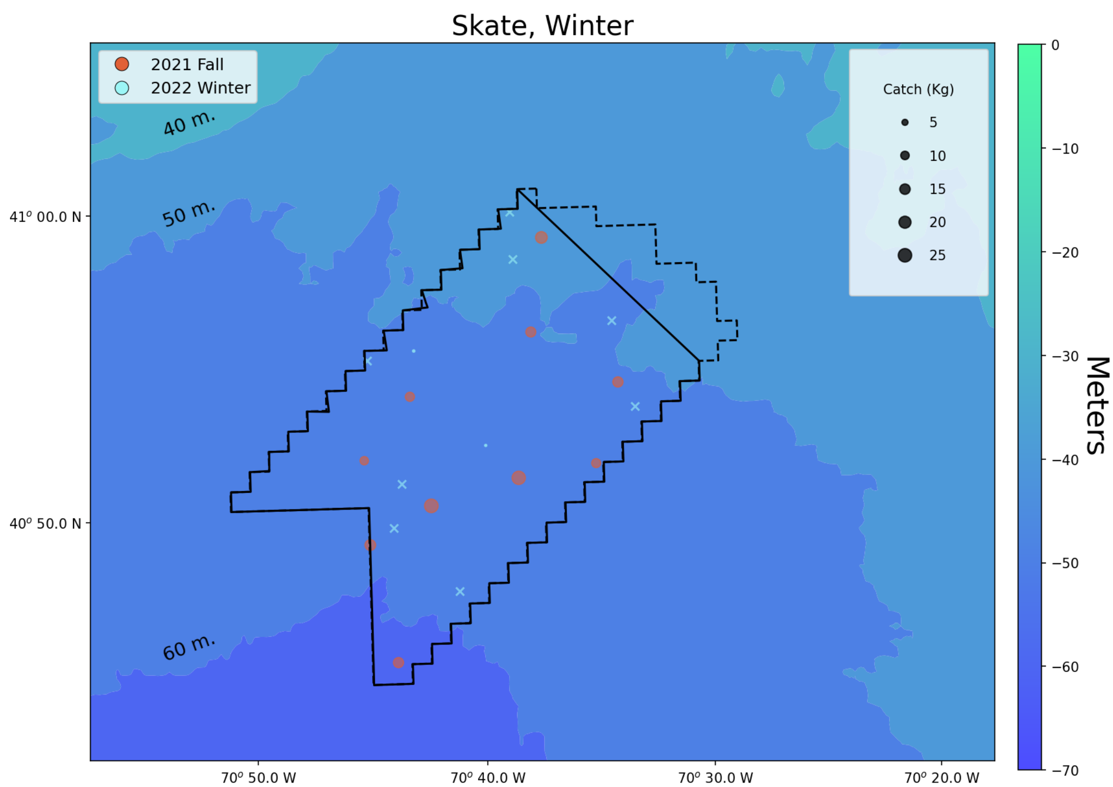



**Figure 33: Seasonal distribution of the winter skate catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

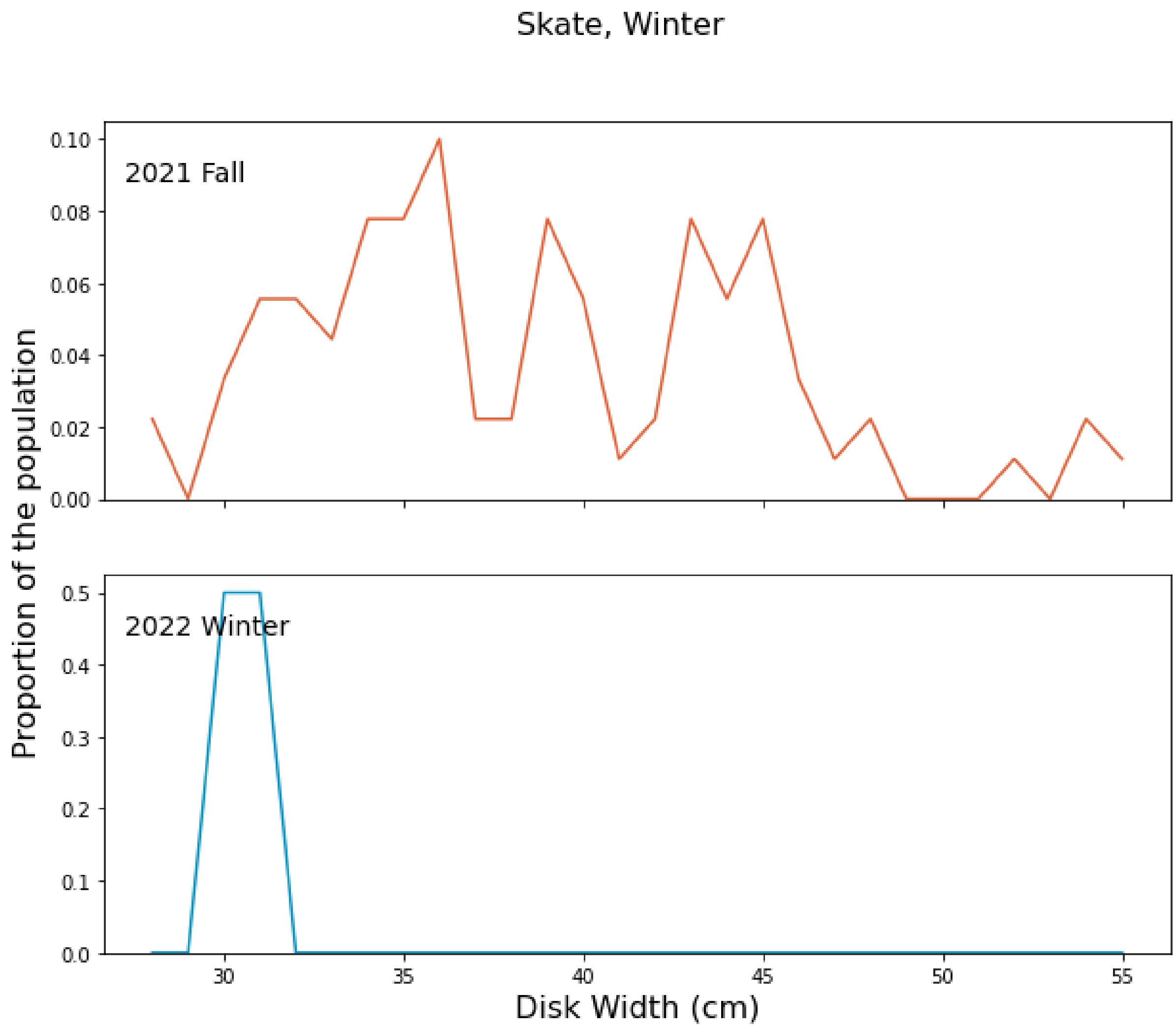



**Figure 34: The seasonal length distributions of winter skate in the 534 Study Area.**

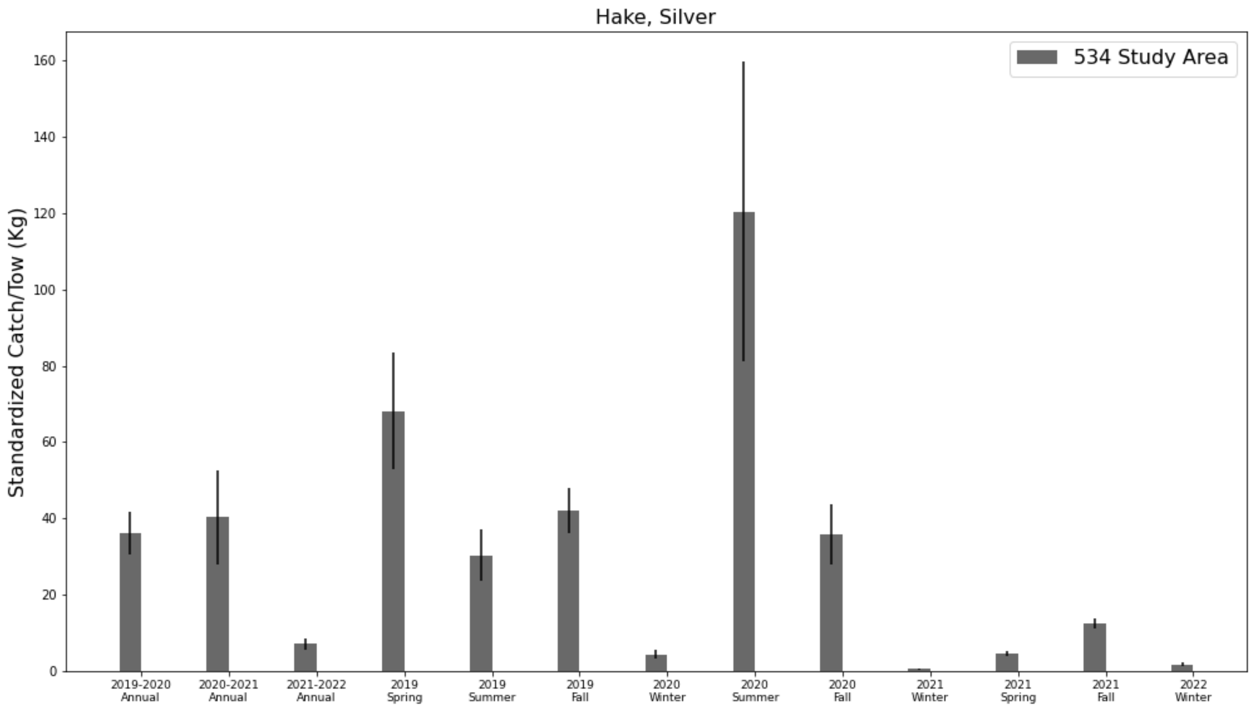



**Figure 35: Seasonal catch rates of silver hake in the 534 Study Area.**

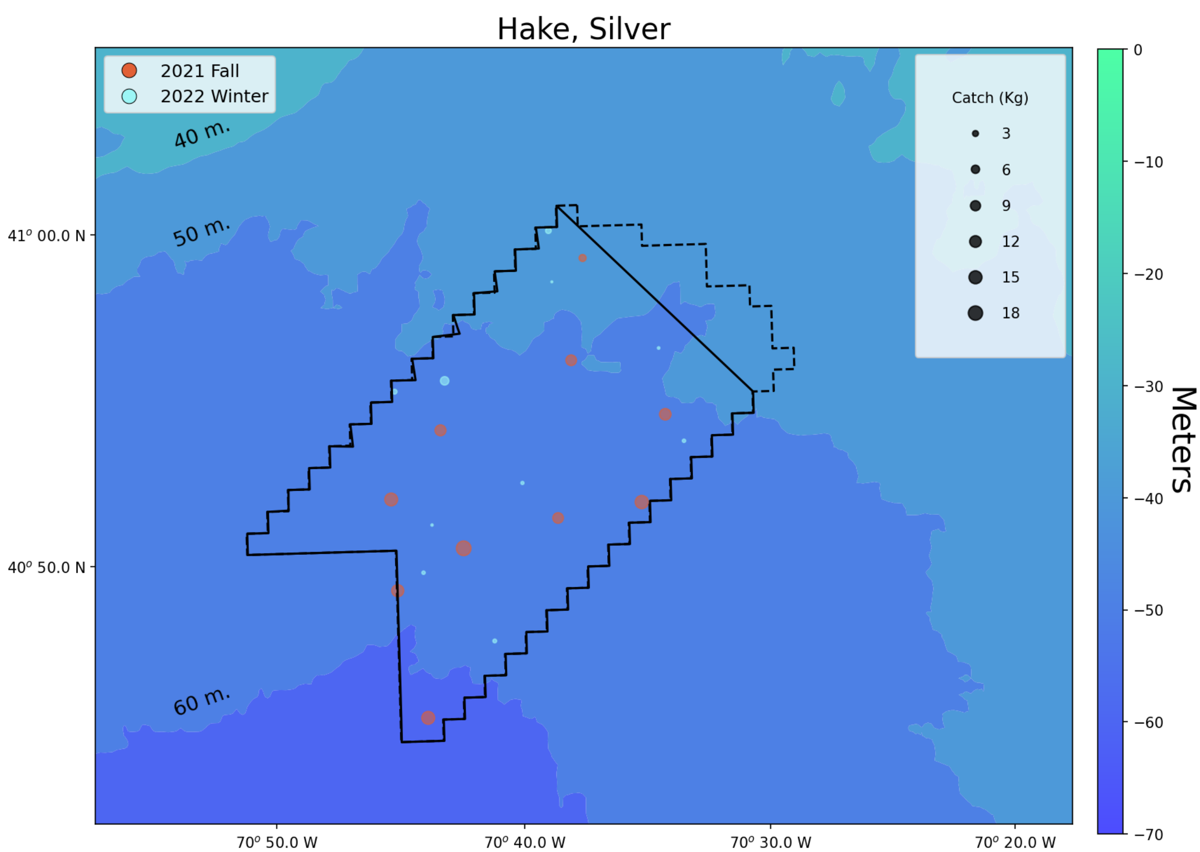



**Figure 36: Seasonal distribution of the silver hake in the 534 Study Area.**

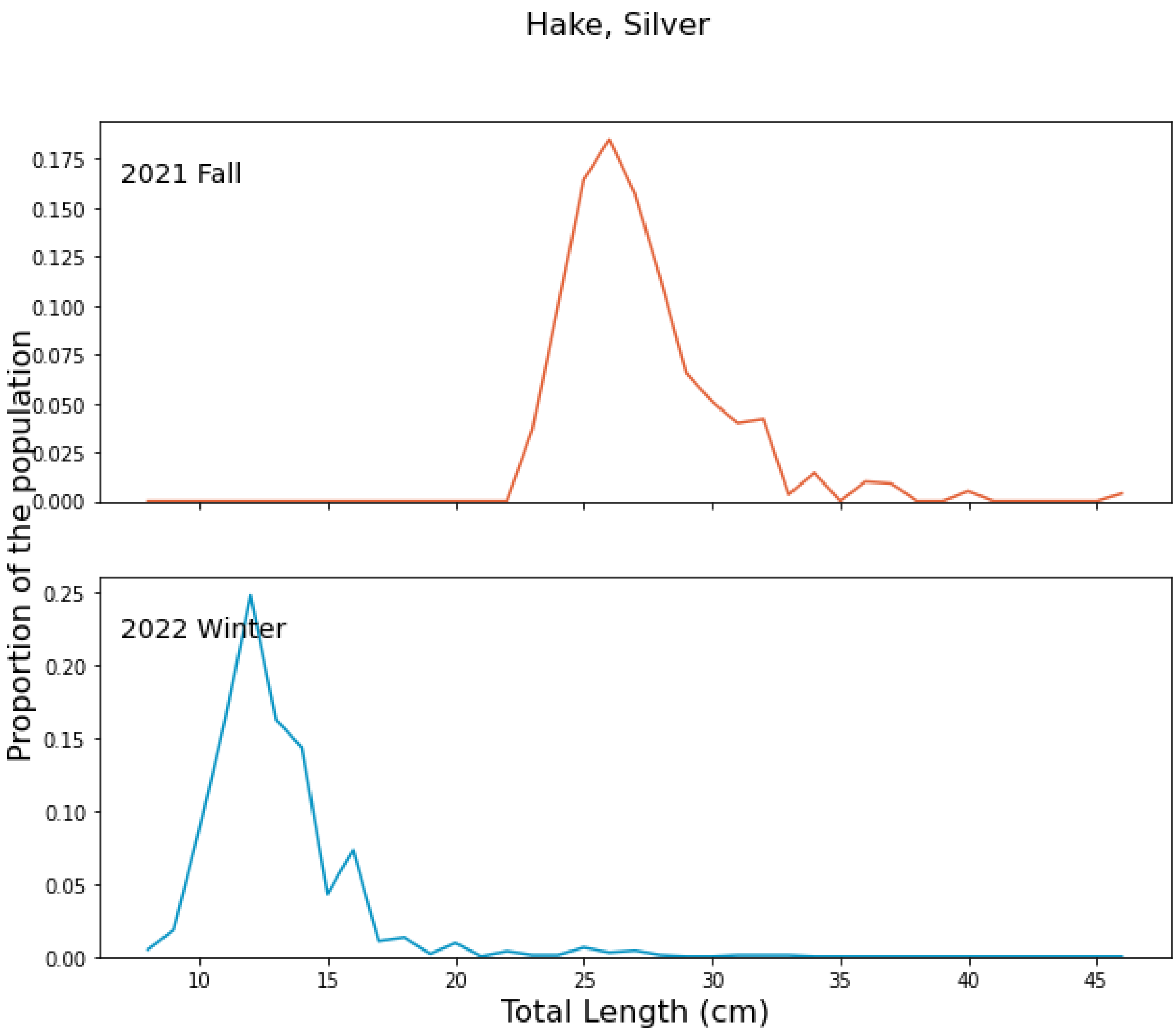



**Figure 37: The seasonal length distributions of silver hake in the 534 Study Area.**

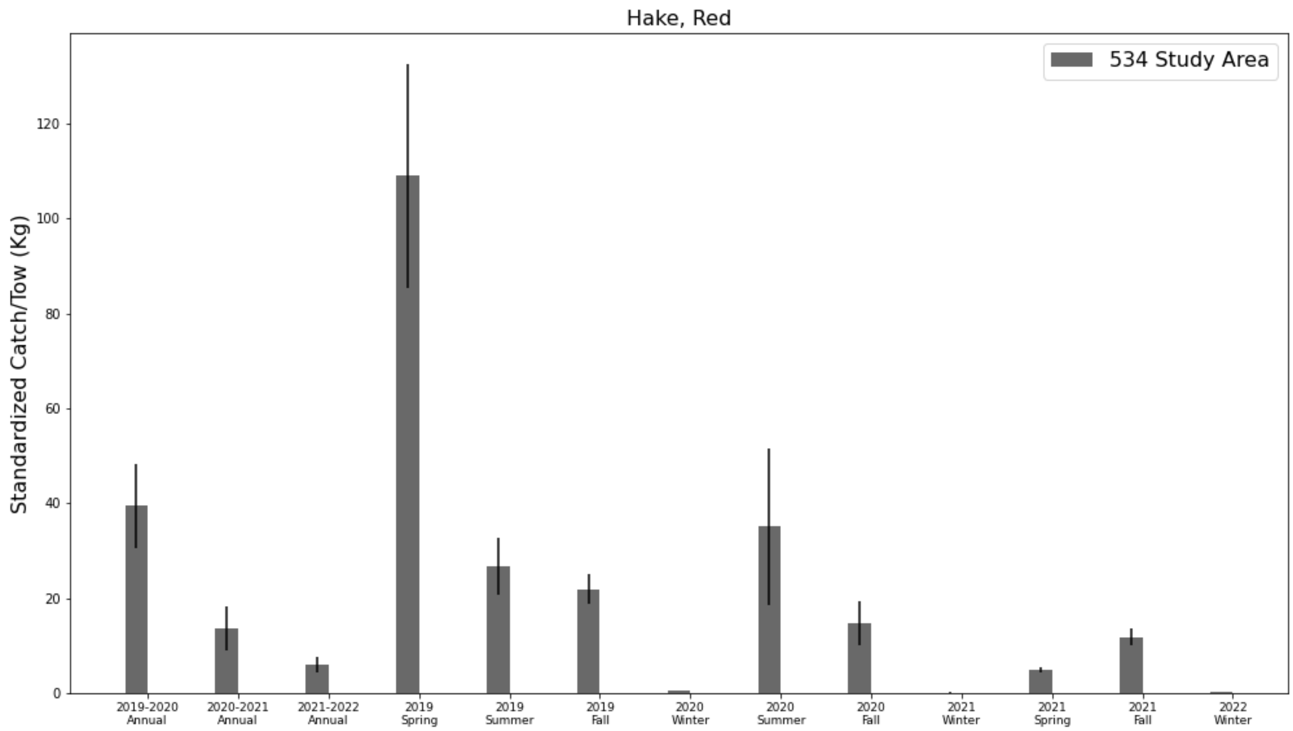



**Figure 38: Seasonal catch rates of red hake in the 534 Study Area.**

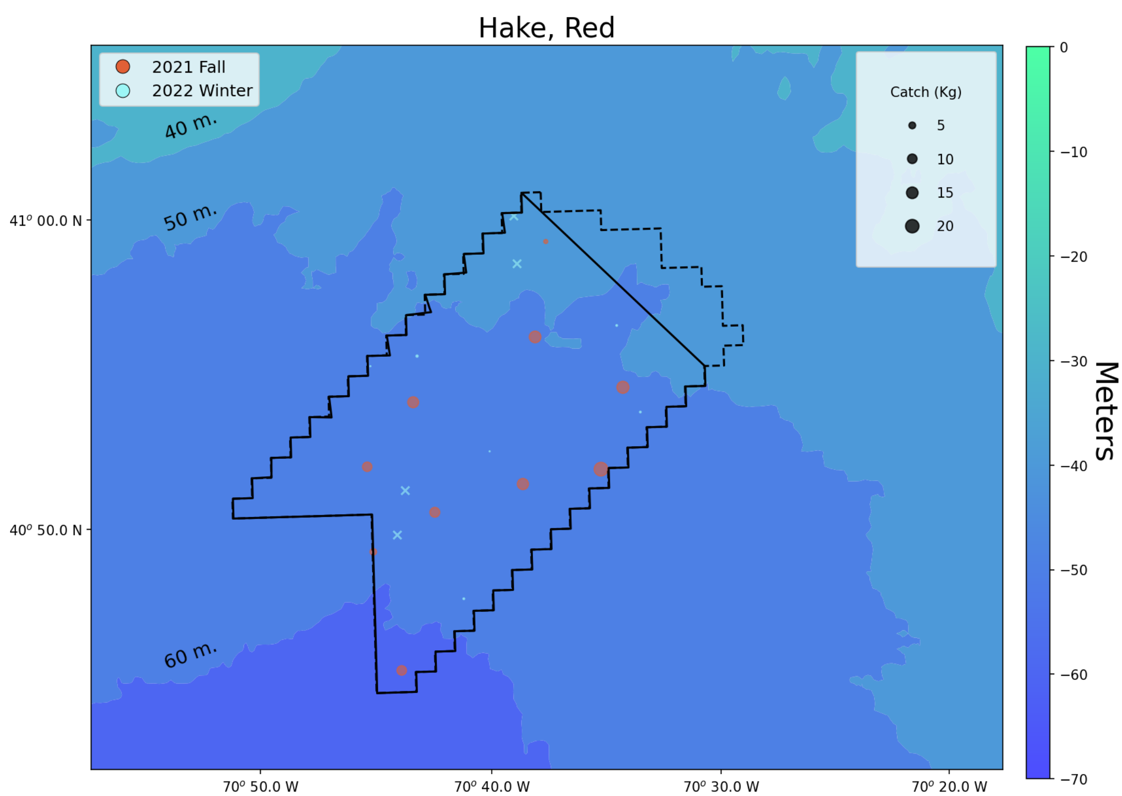



**Figure 39: Seasonal distribution of the red hake catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

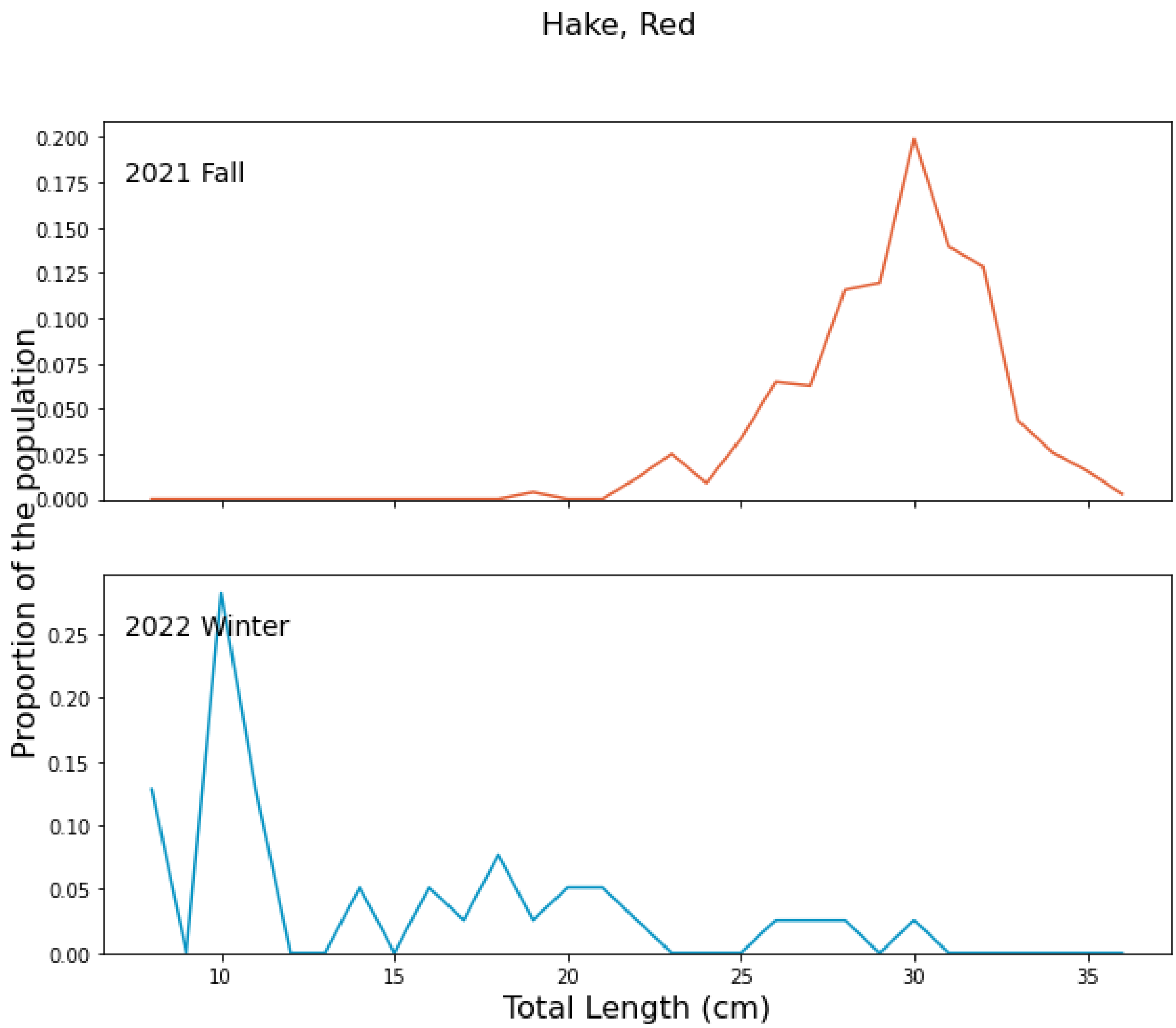



**Figure 40: The seasonal length distributions of red hake in the 534 Study Area.**

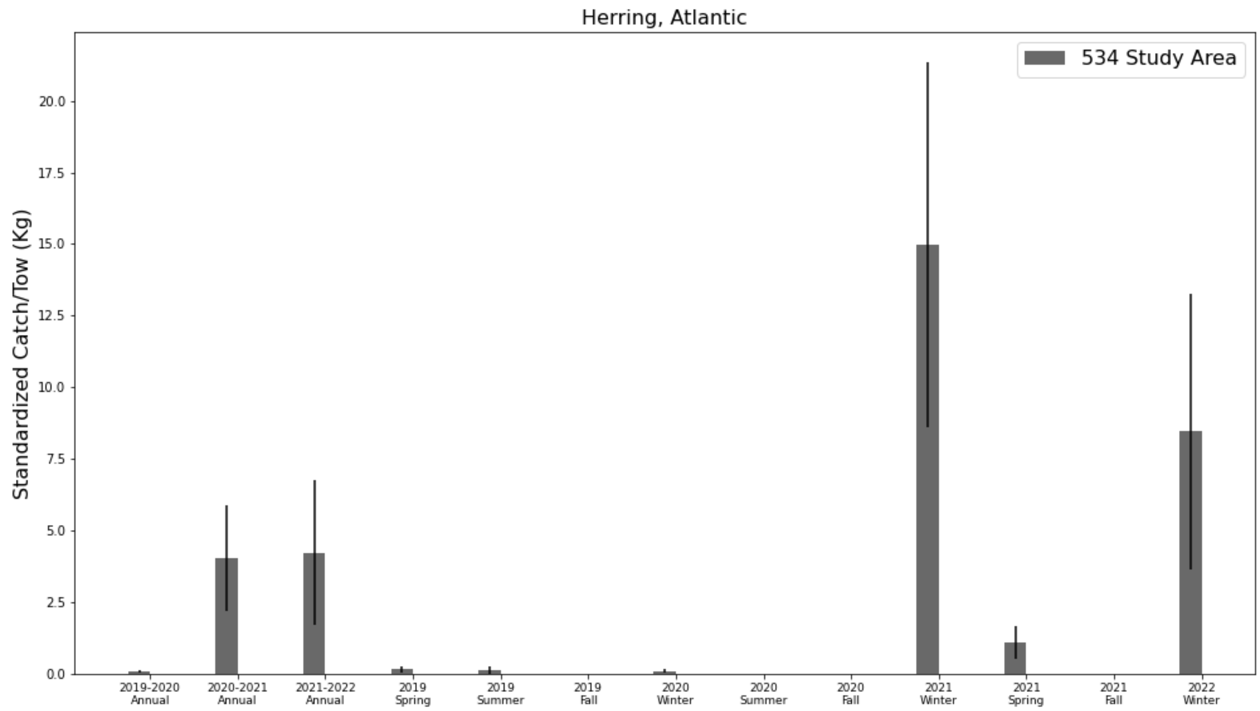



**Figure 41: Seasonal catch rates of Atlantic herring in the 534 Study Area.**

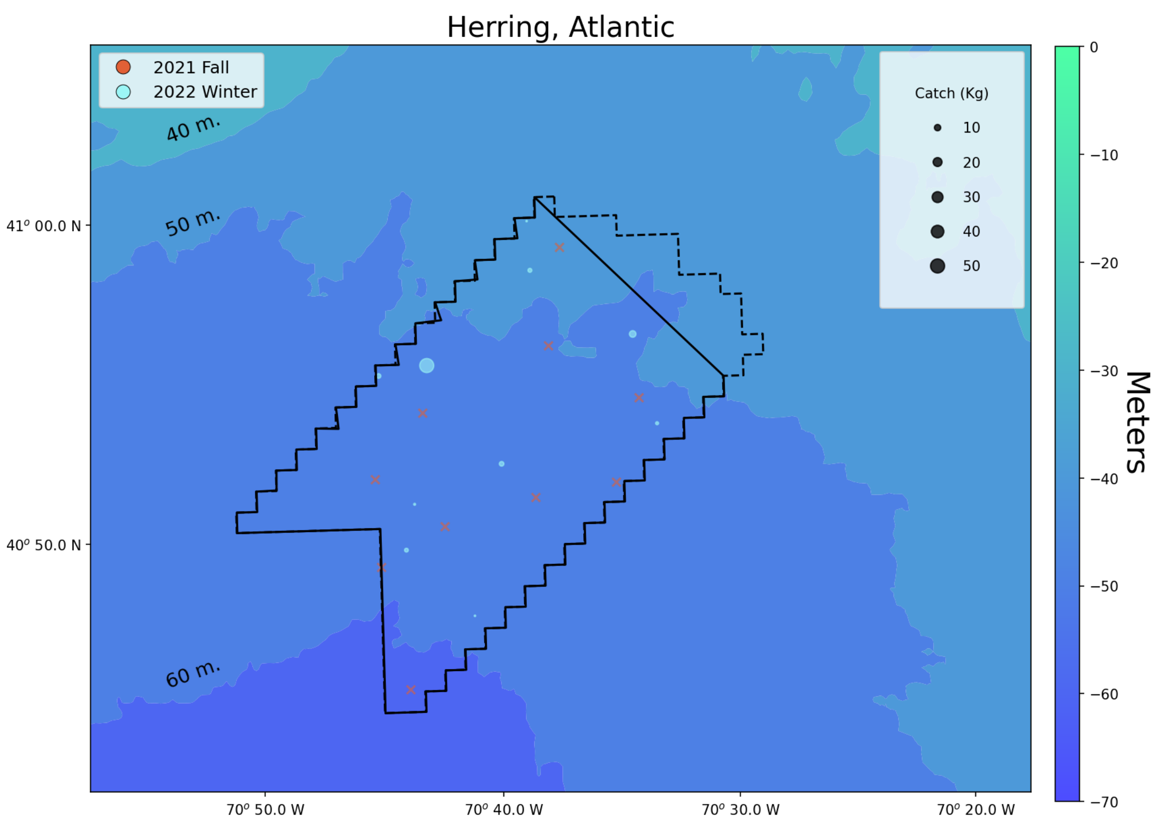



**Figure 42: Seasonal distribution of the Atlantic herring catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

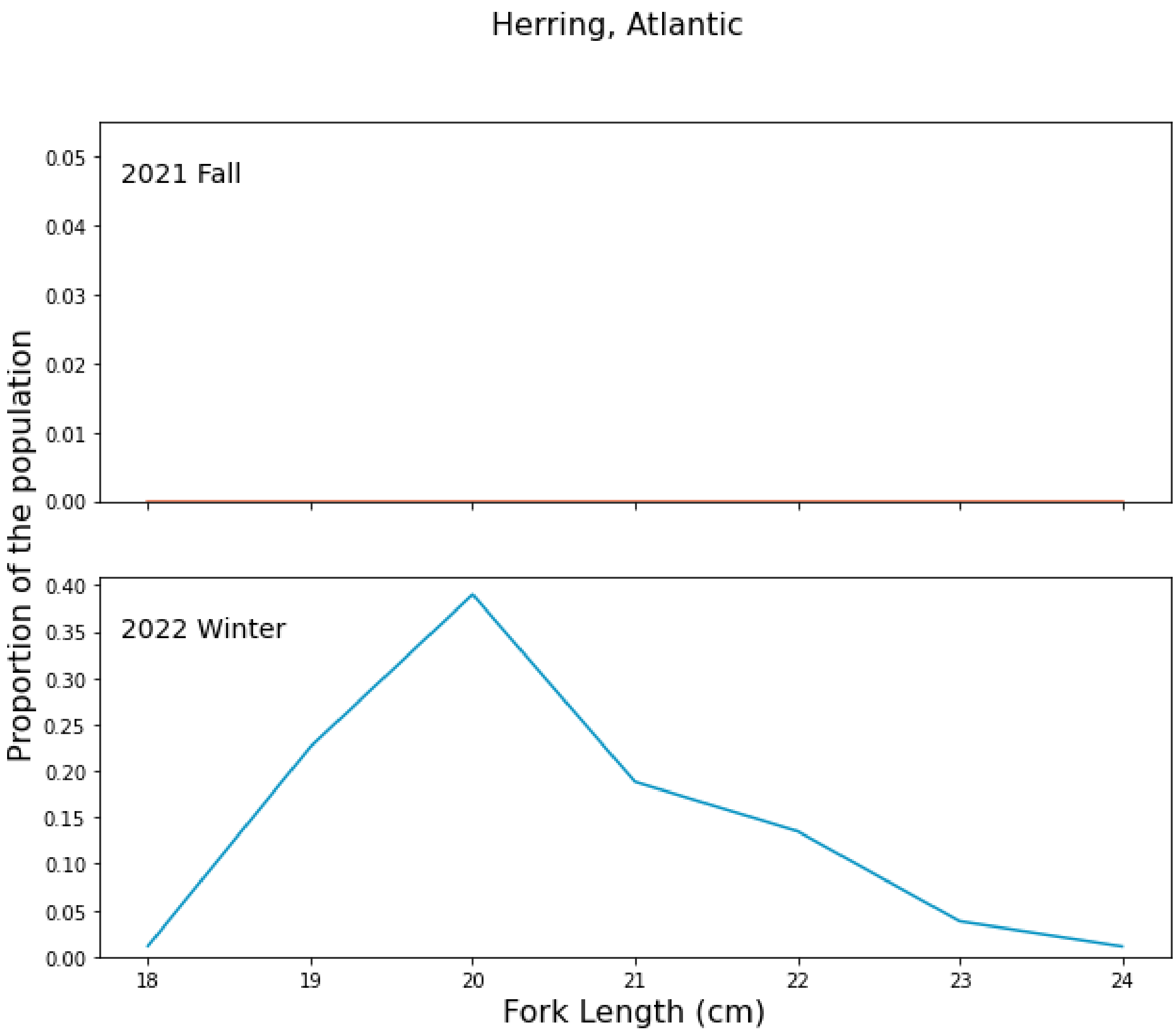



**Figure 43: The seasonal length distributions of Atlantic herring in the 534 Study Area.**

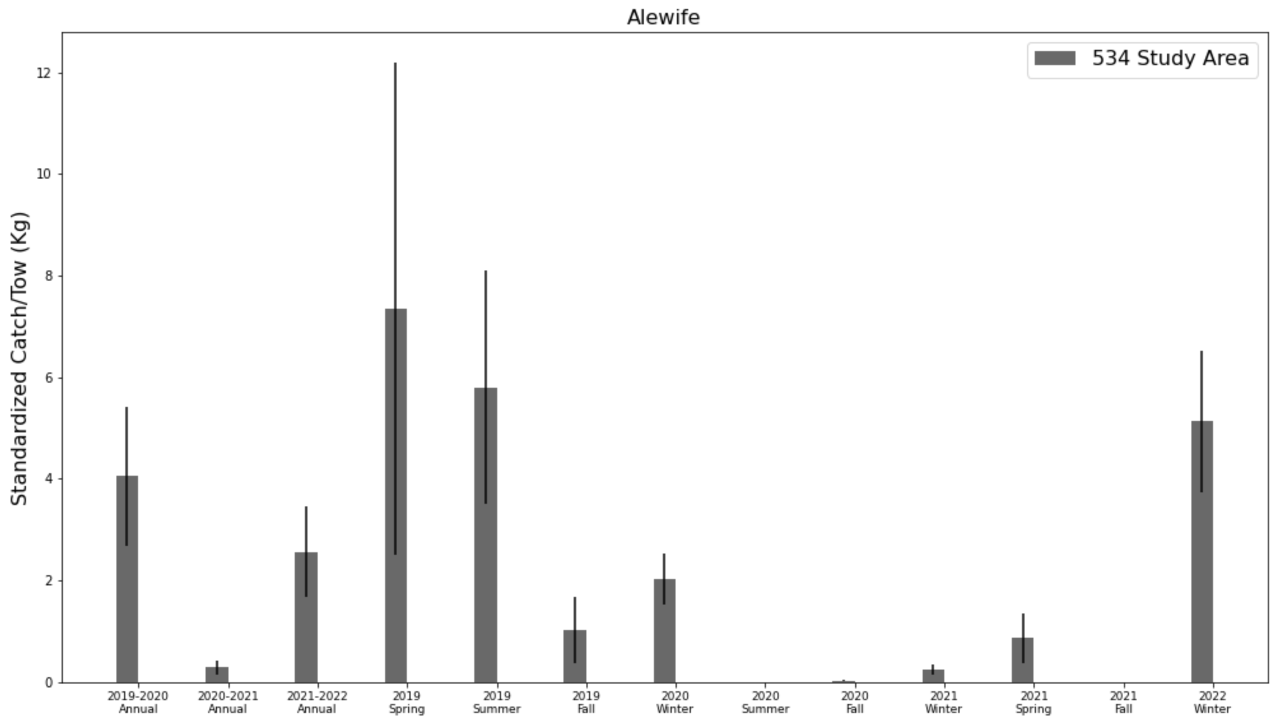



**Figure 44: Seasonal catch rates of alewife in the 534 Study Area.**

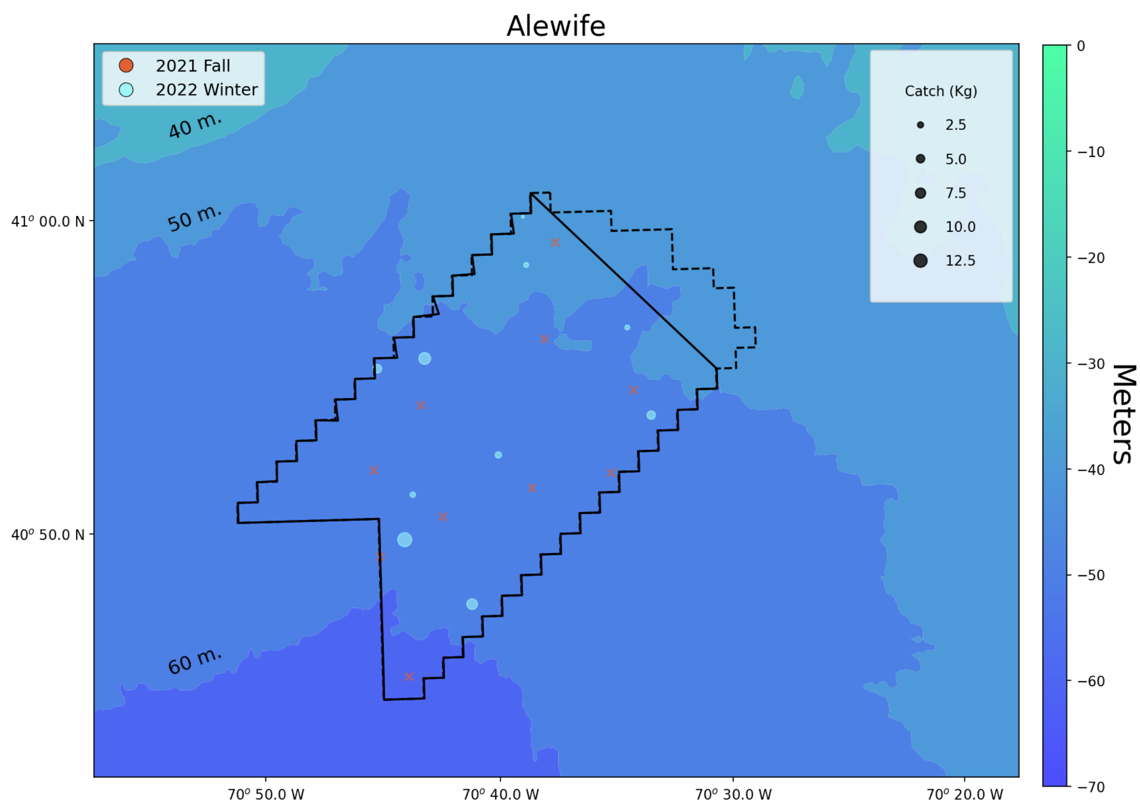



**Figure 45: Seasonal distribution of the alewife catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

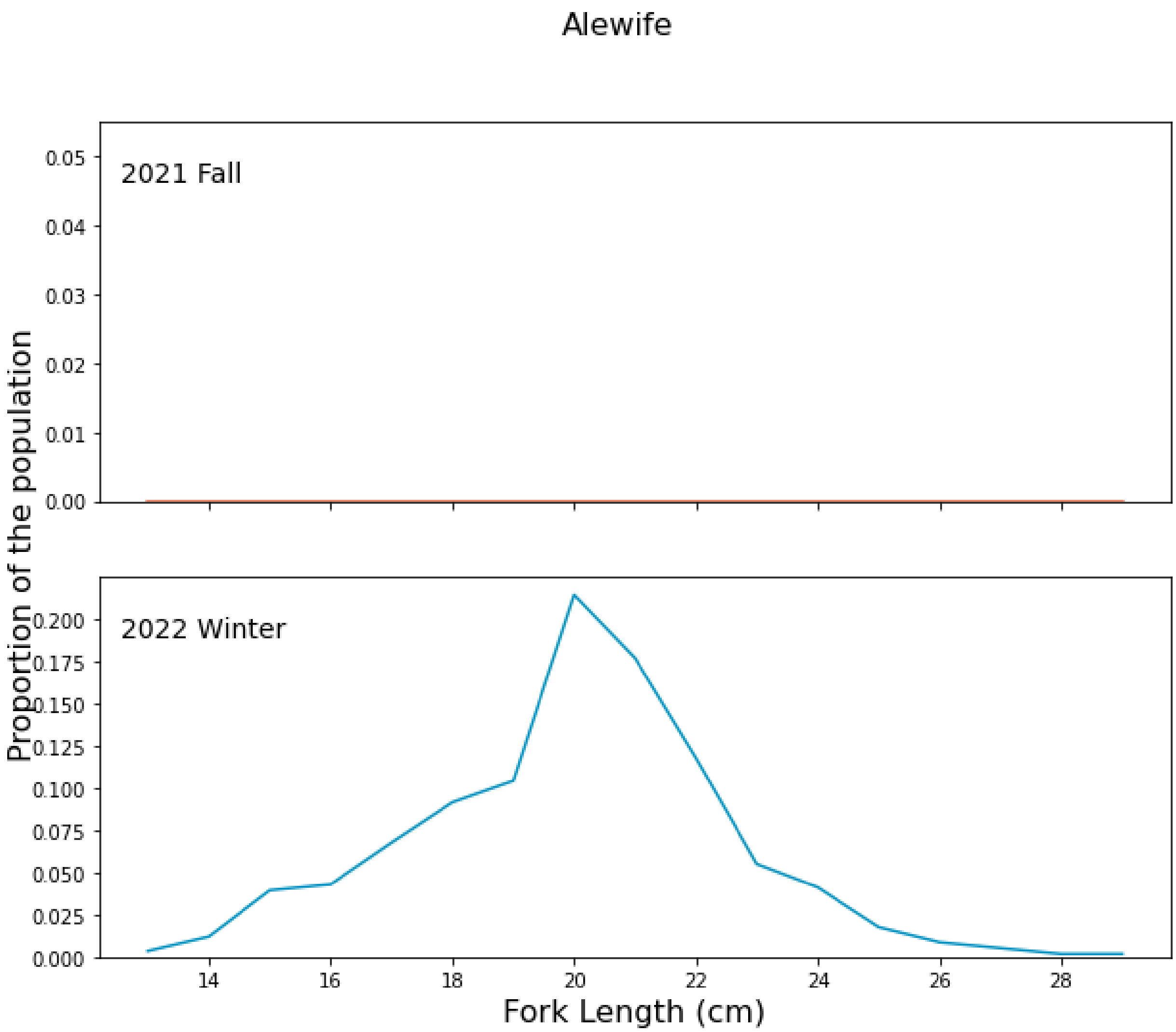



**Figure 46: The seasonal length distributions of alewife in the 534 Study Area.**

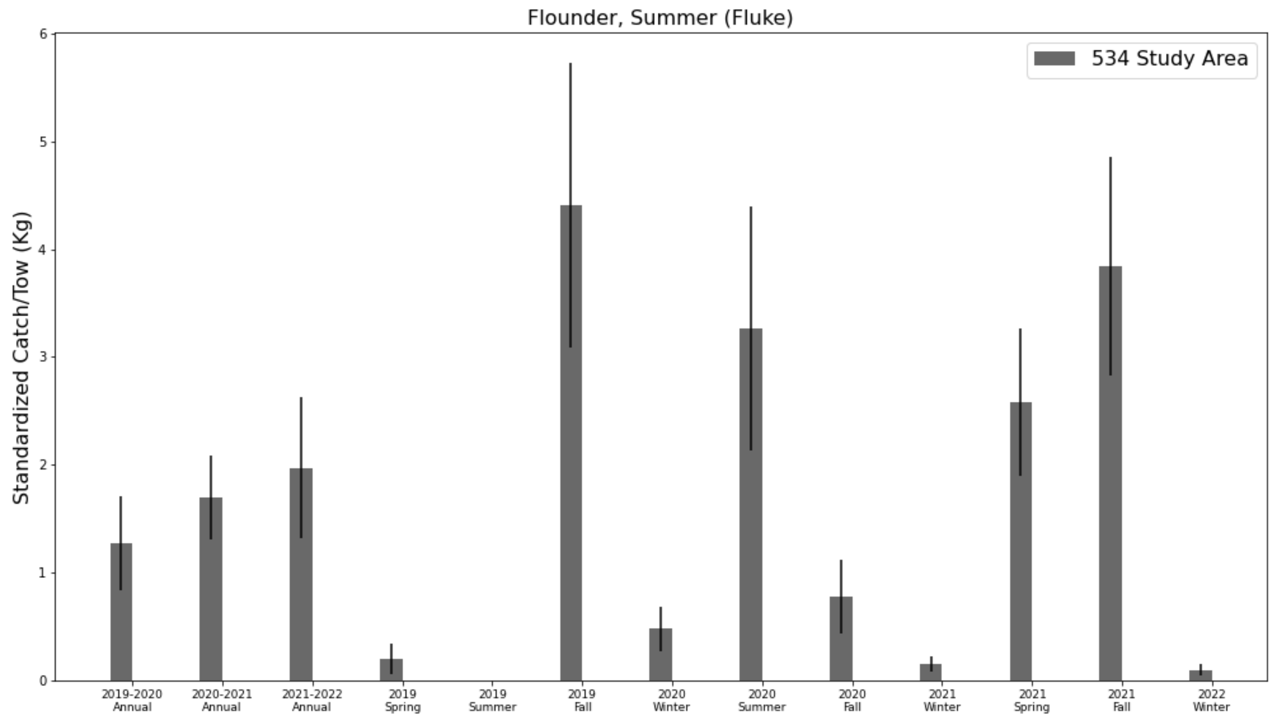



**Figure 47: Seasonal catch rates of summer flounder in the 534 Study Area.**

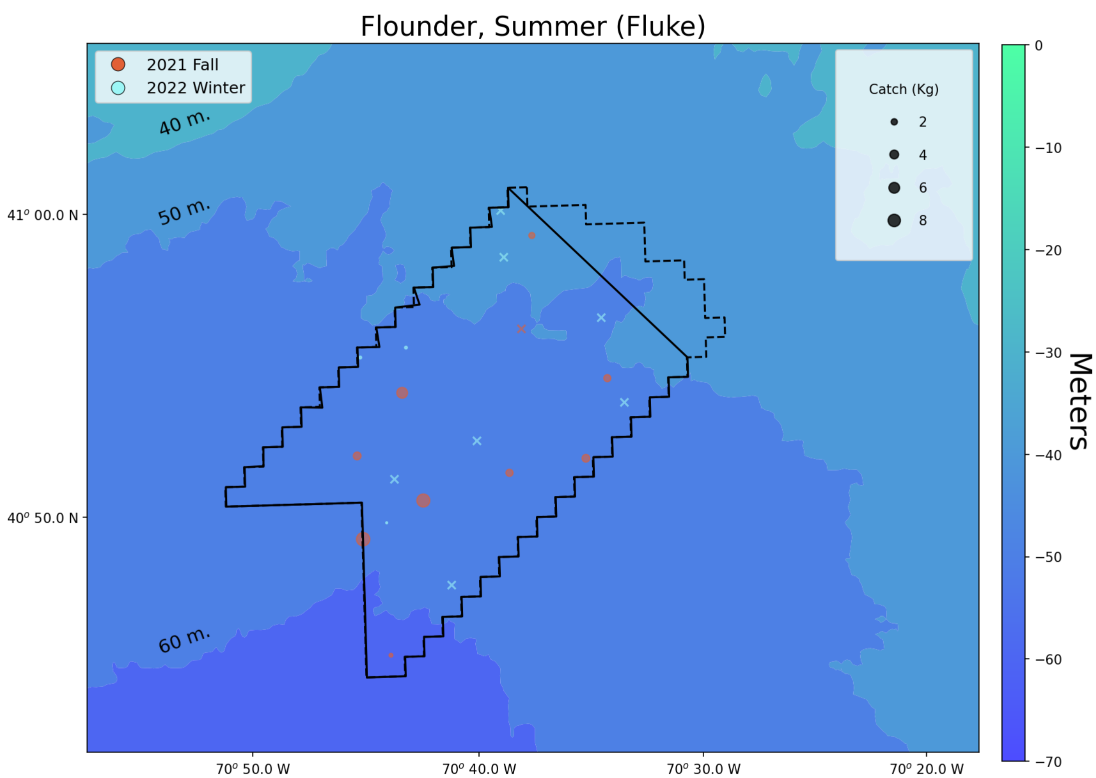



**Figure 48: Seasonal distribution of the summer flounder catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

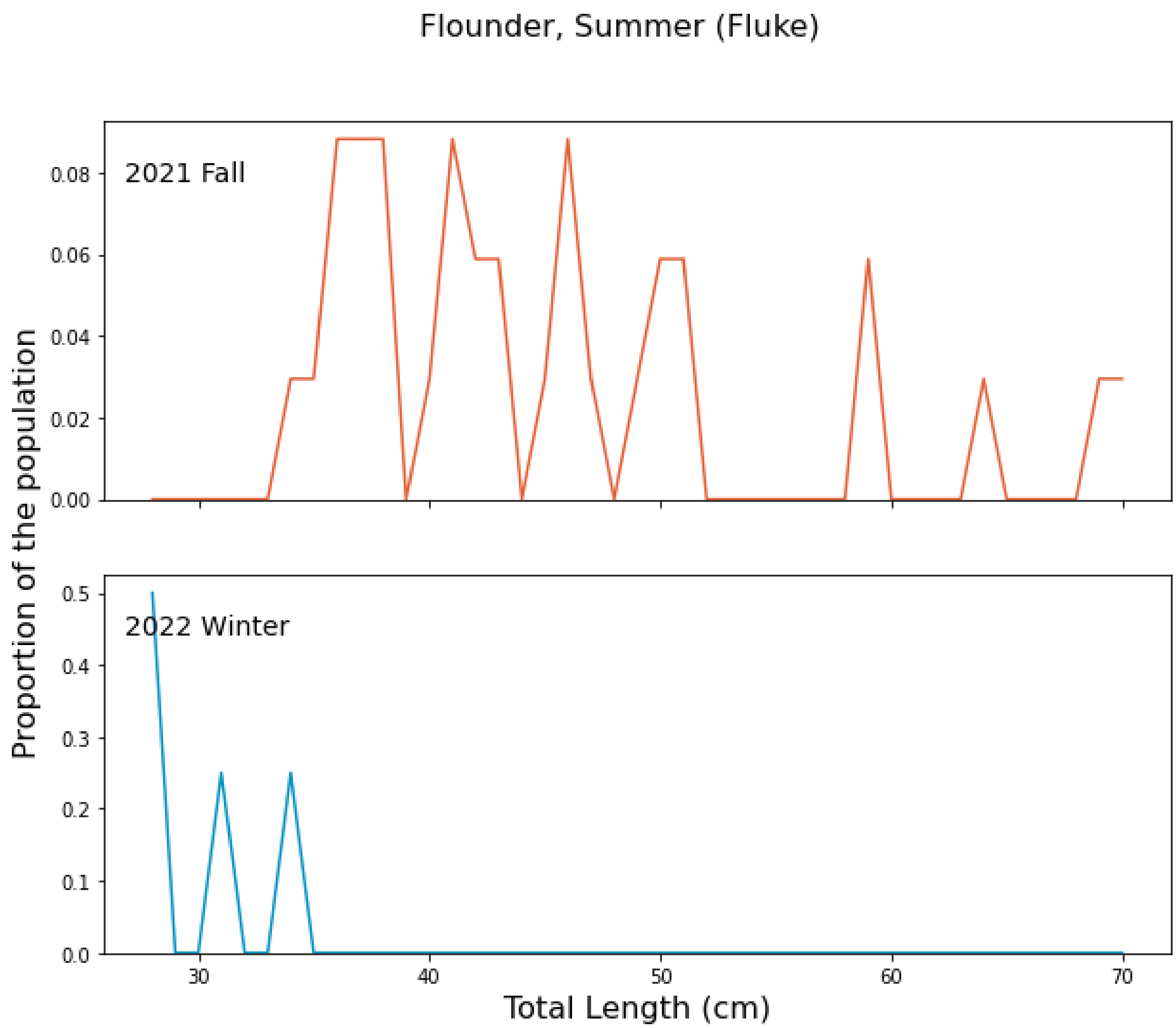



**Figure 49: The seasonal length distributions of summer flounder in the 534 Study Area.**

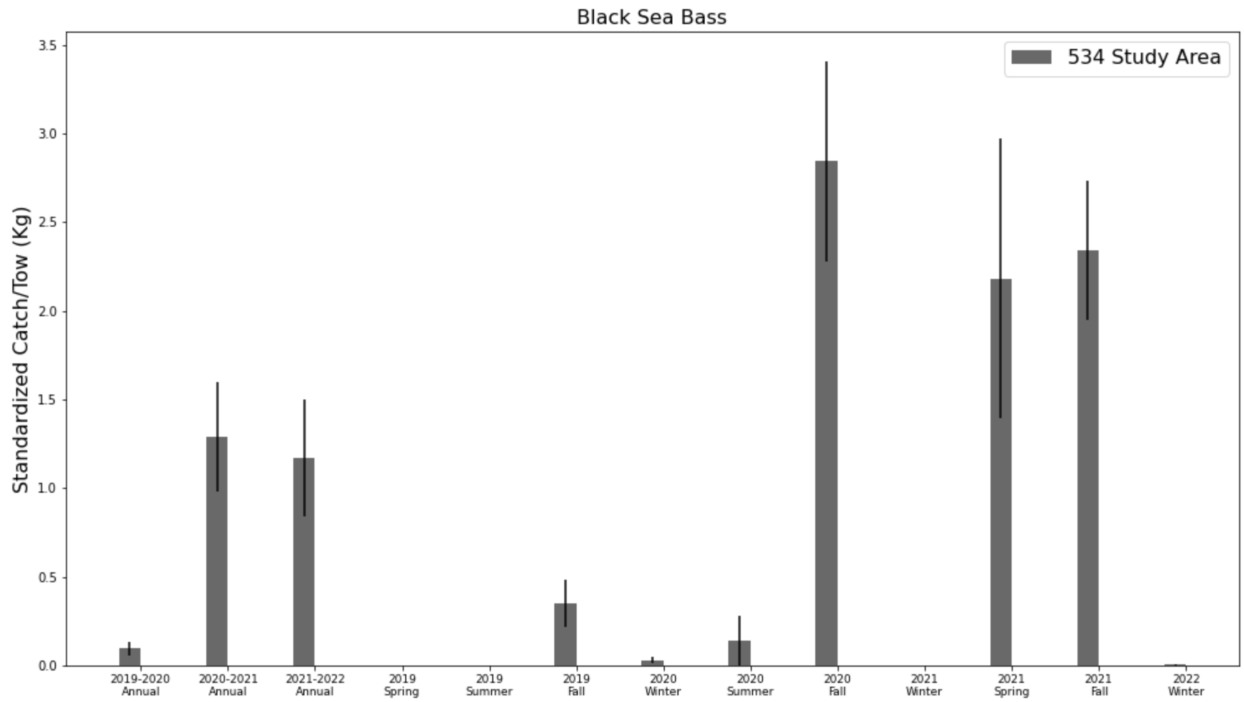



**Figure 50: Seasonal catch rates of black sea bass in the 534 Study Area.**

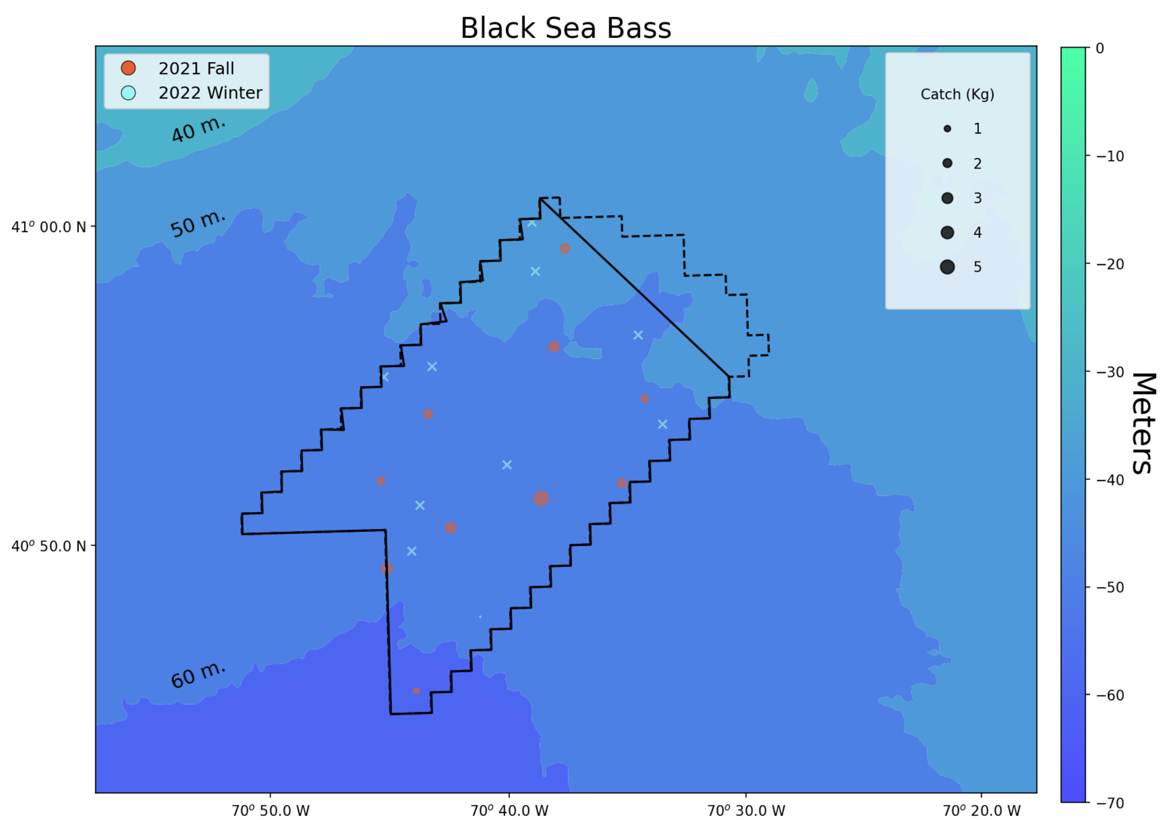



**Figure 51: Seasonal distribution of the black sea bass catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

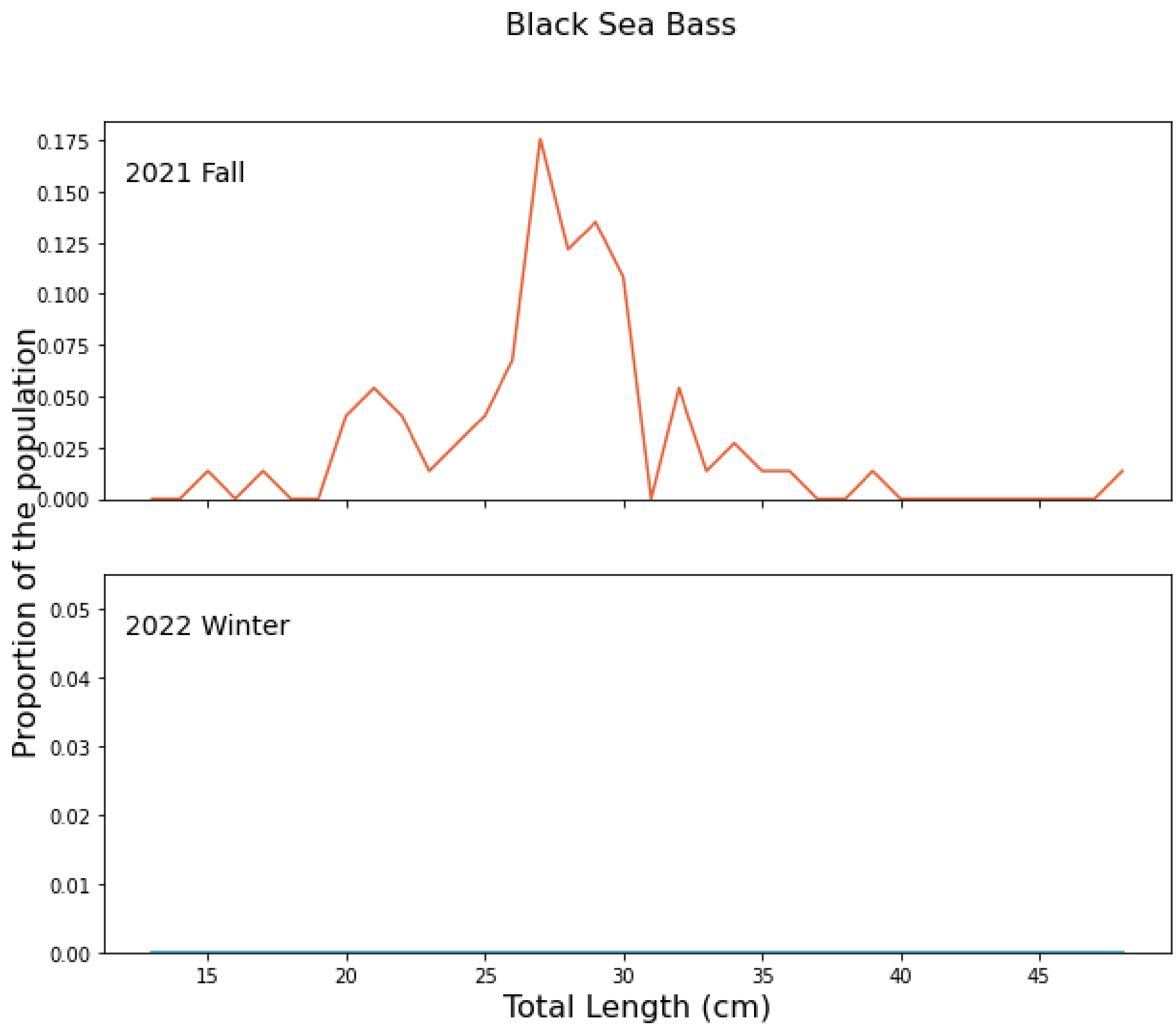



**Figure 52: The seasonal length distributions of black sea bass in the 534 Study Area.**

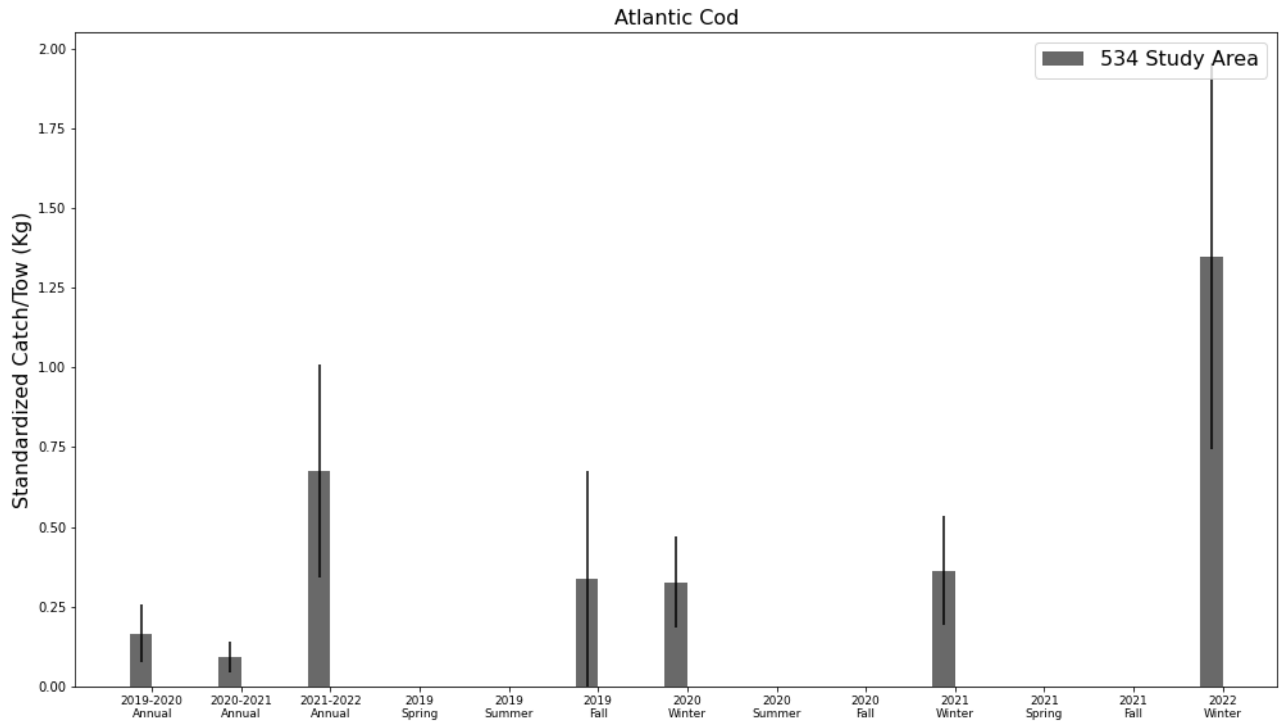



**Figure 53: Seasonal catch rates of Atlantic cod in the 534 Study Area.**

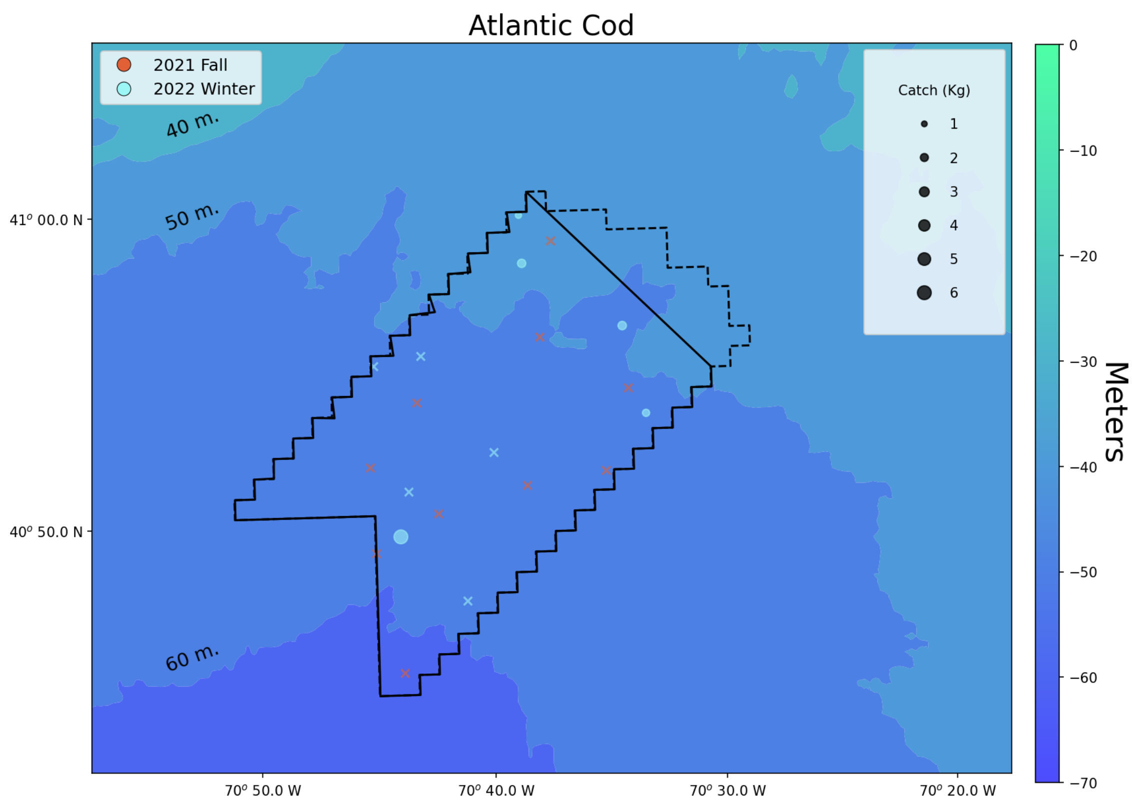



**Figure 54: Seasonal distribution of the Atlantic cod catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

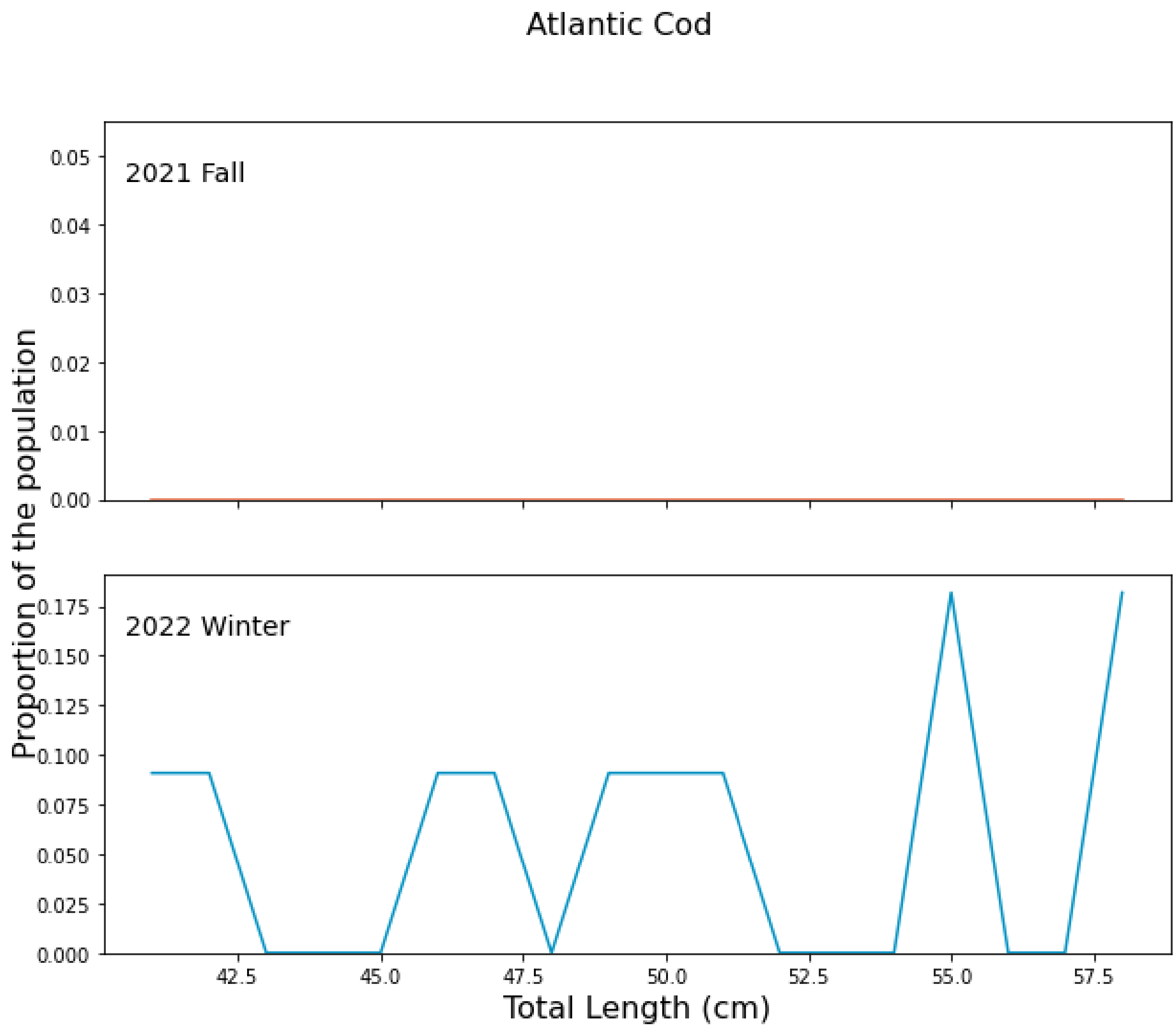



**Figure 55: The seasonal length distributions of Atlantic cod in the 534 Study Area.**

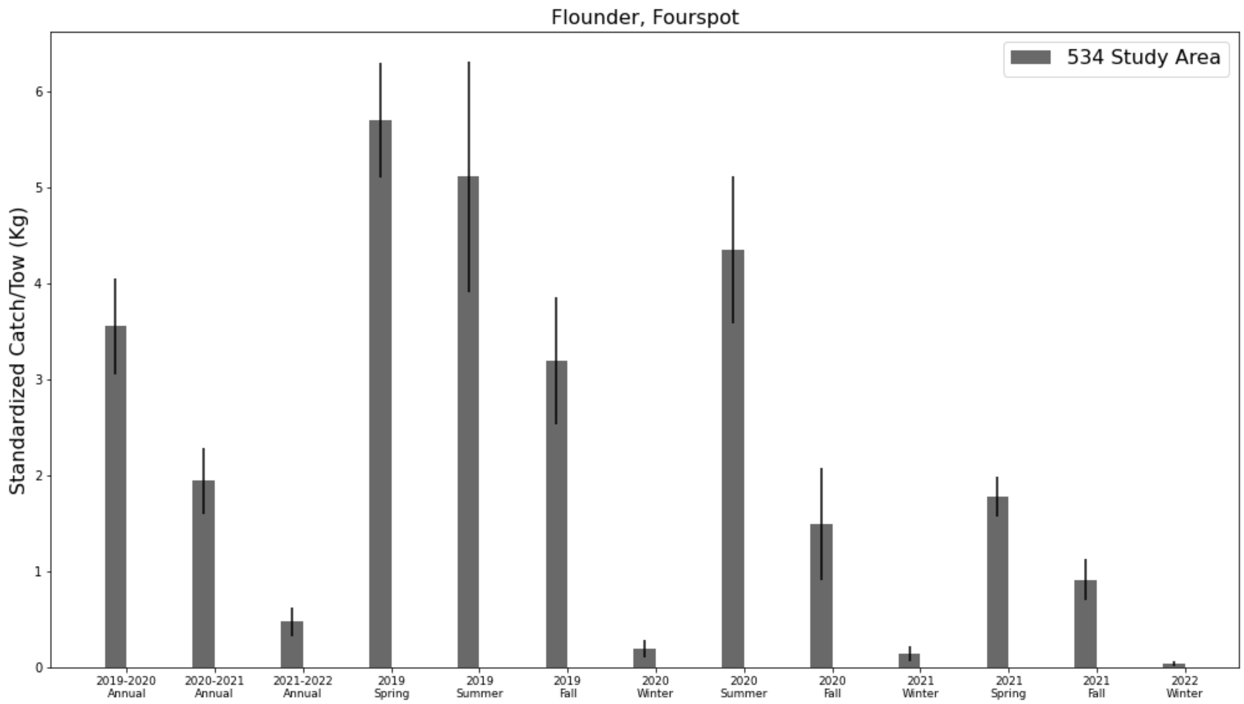



**Figure 56: Seasonal catch rates of fourspot flounder in the 534 Study Area.**

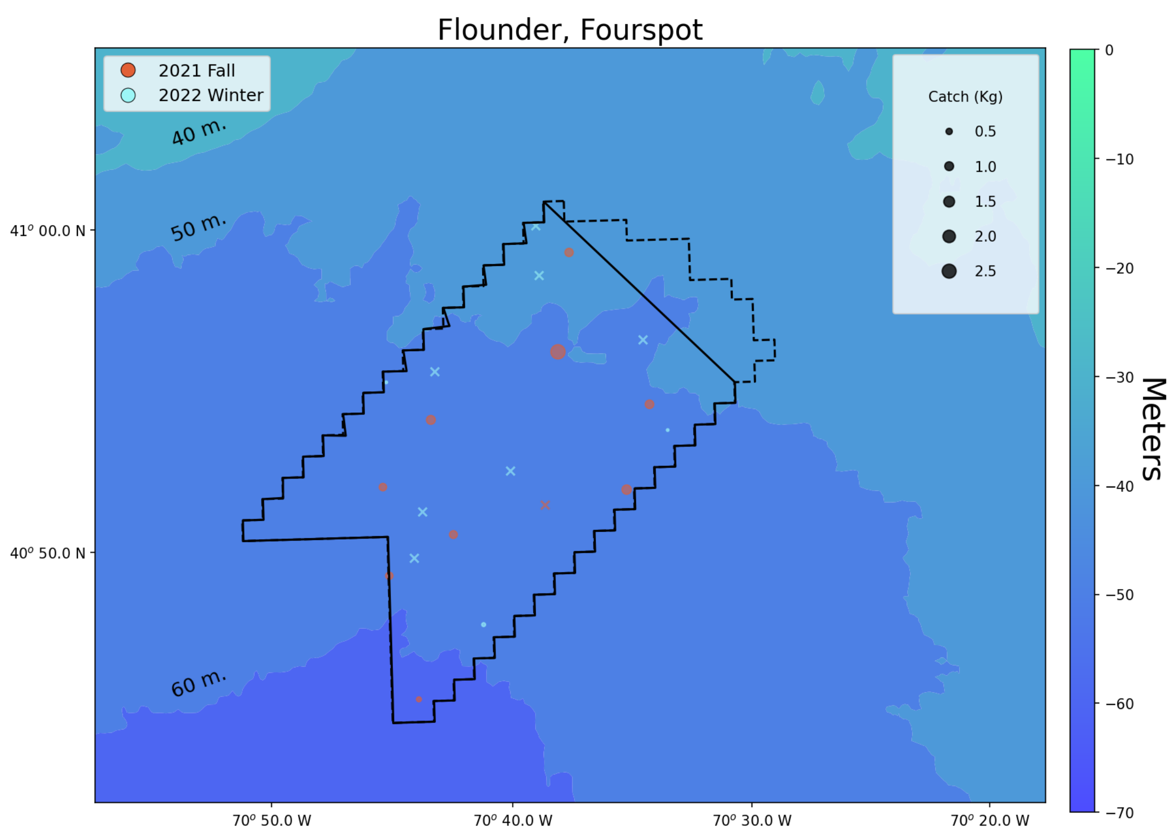



**Figure 57: Seasonal distribution of the fourspot flounder catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

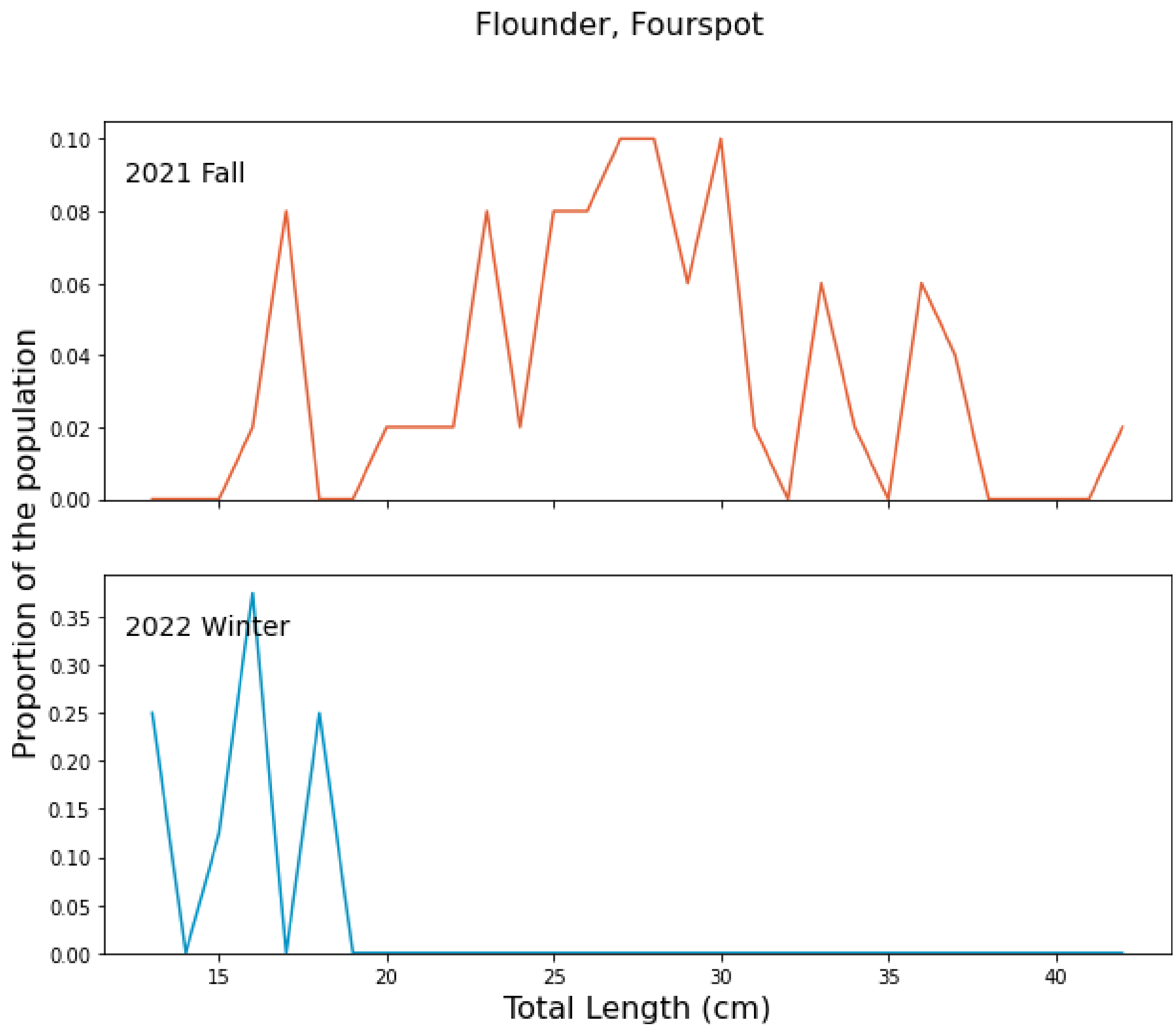



**Figure 58: The seasonal length distributions of fourspot flounder in the 534 Study Area.**

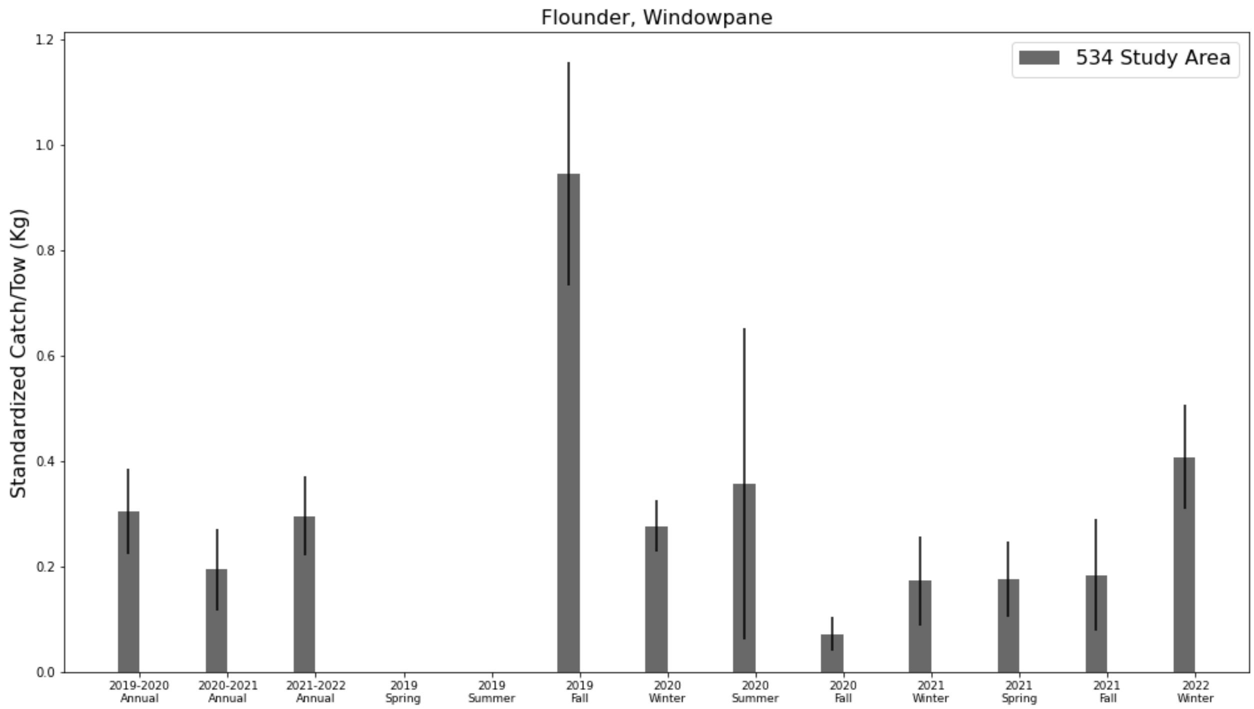



**Figure 59: Seasonal catch rates of windowpane flounder in the 534 Study Area.**

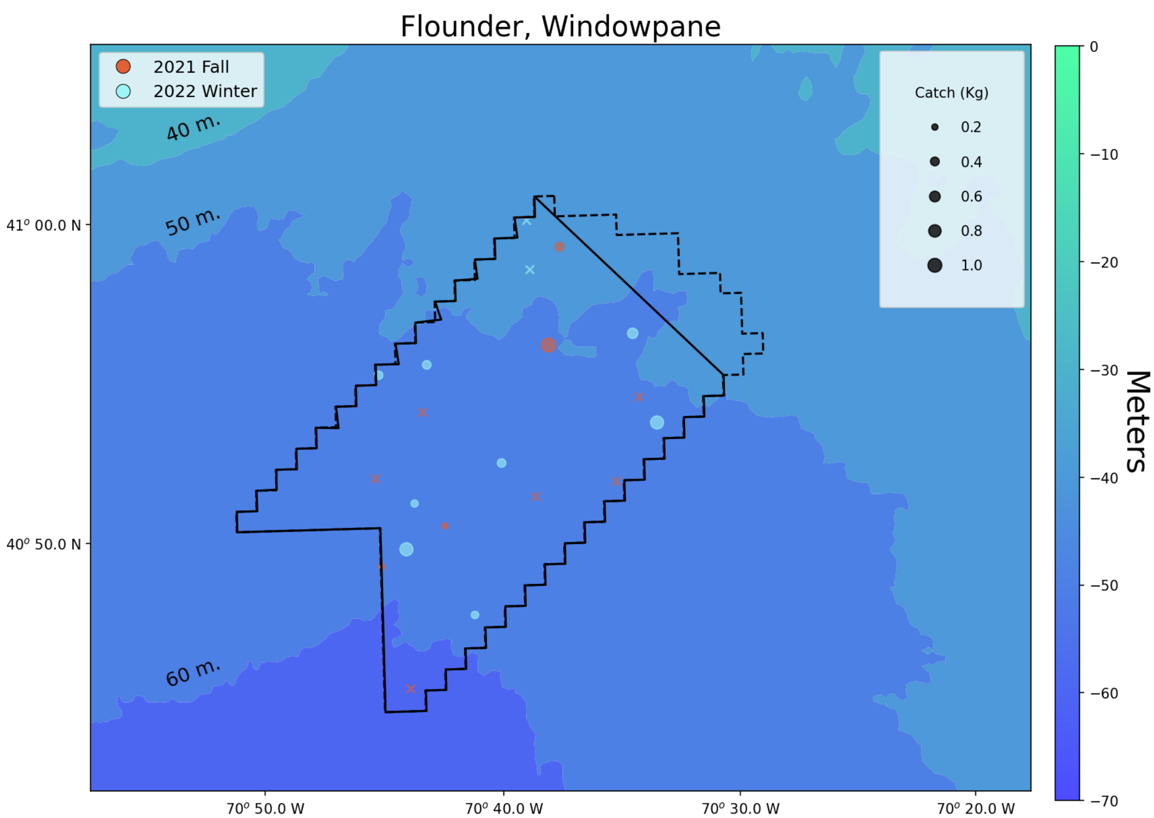



**Figure 60: Seasonal distribution of the windowpane flounder catch in the 534 Study Area. Tows with zero catch are denoted with an X.**

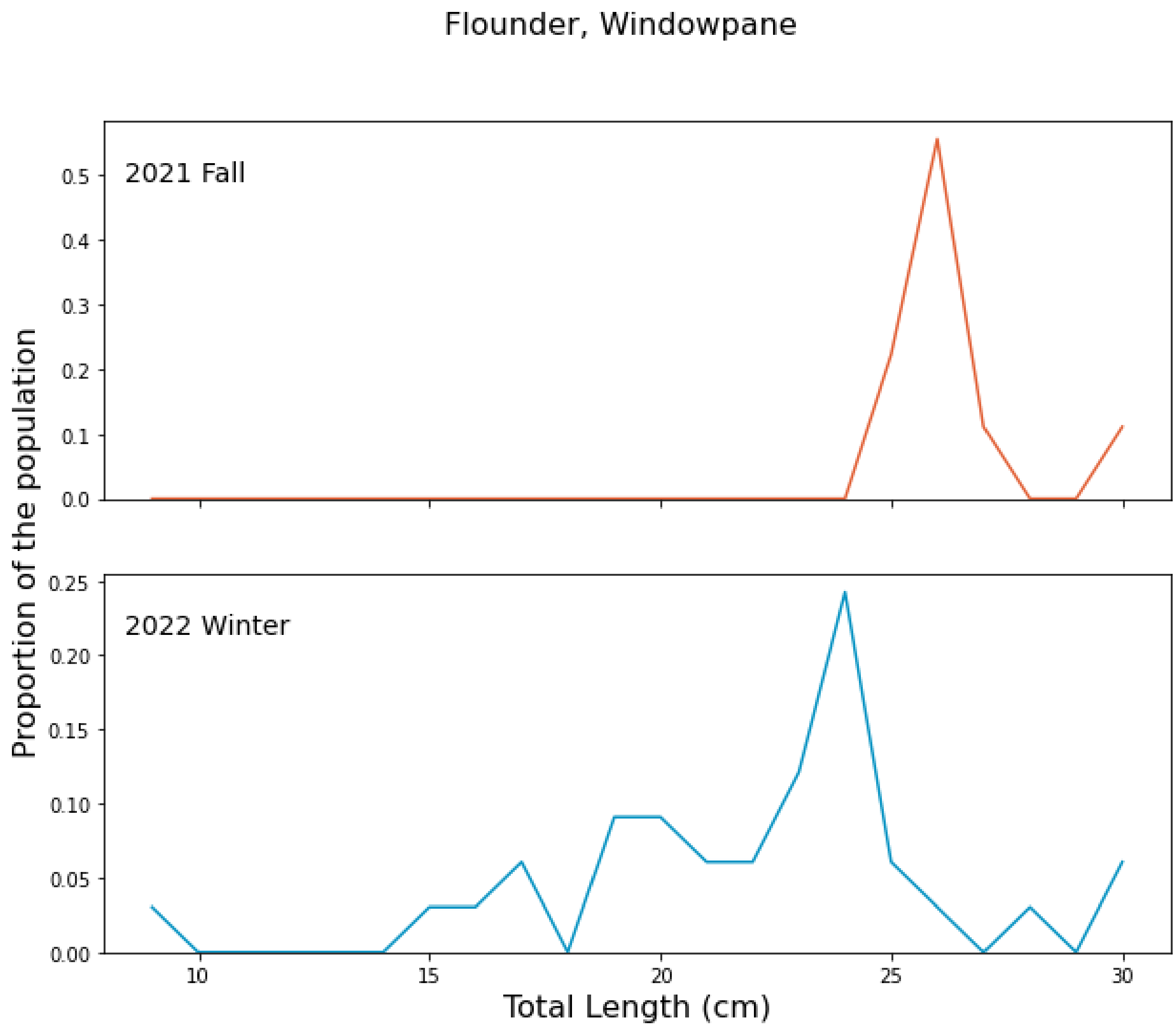
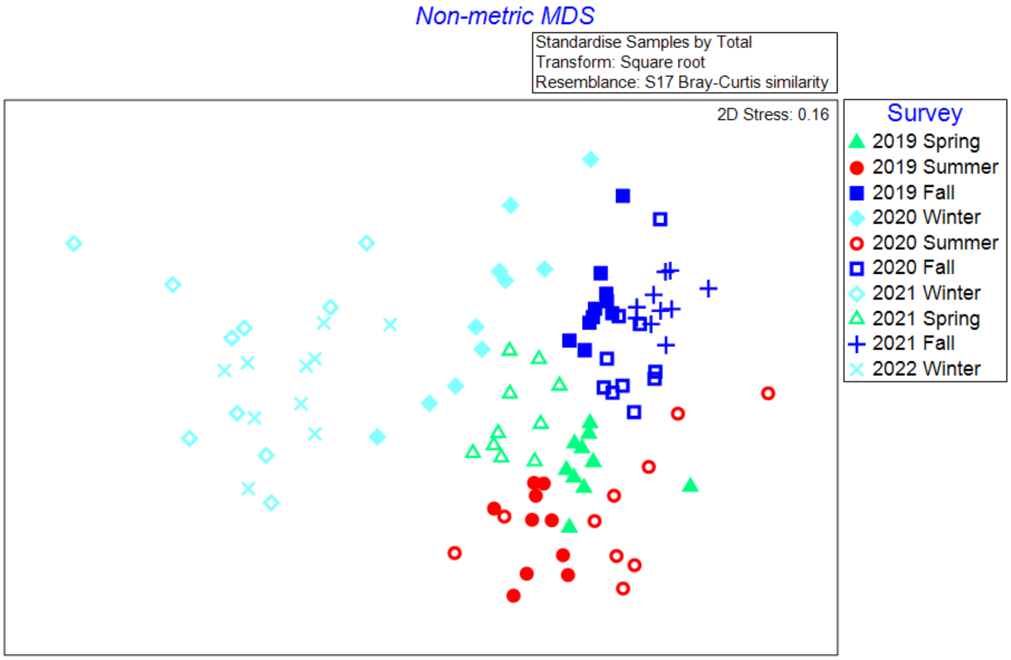



**Figure 61: The seasonal length distributions of windowpane flounder in the 534 Study Area.**



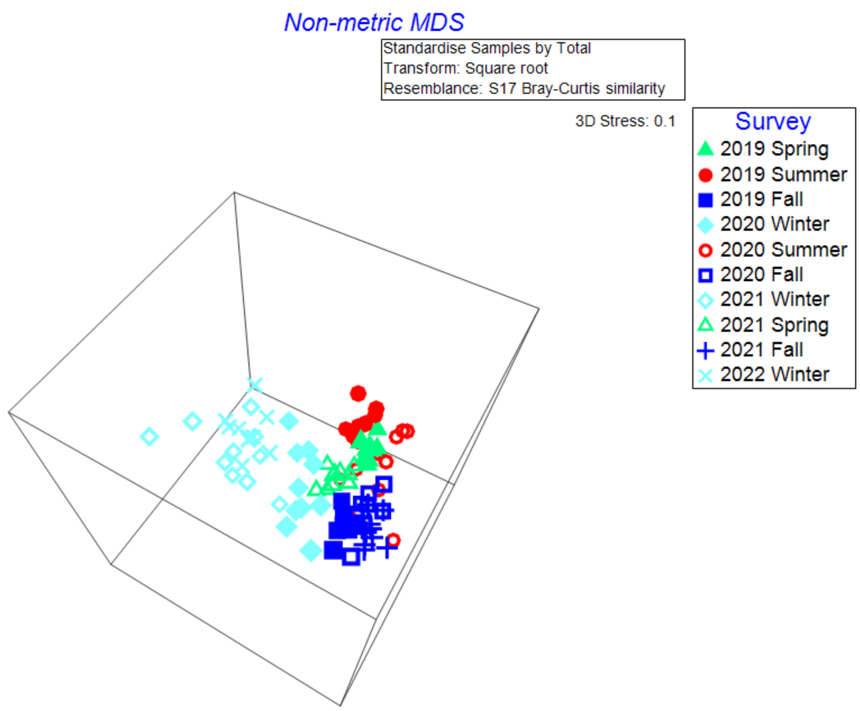




**Figure 62: 2D (top) and 3D (bottom) non-metric Multidimensional Scaling (nMDS) plots. The data was aggregated from all surveys with the lease area (2019-2022). The tow markers are colored by season to highlight the seasonal clusters in species similarity.**

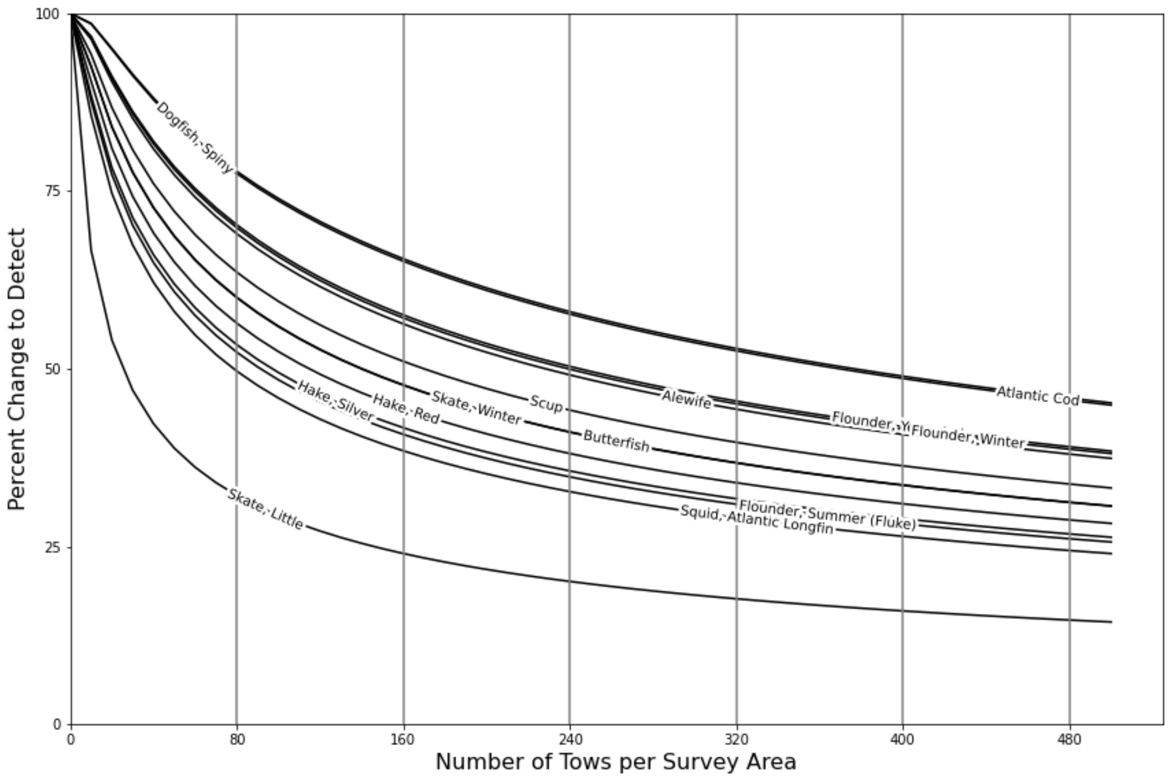



**Figure 63: The ability to detect the percent change in a species population size is a function of the variability in the catch and the sample size (i.e., number of tows). The current survey effort sampled 40 tows per year.**

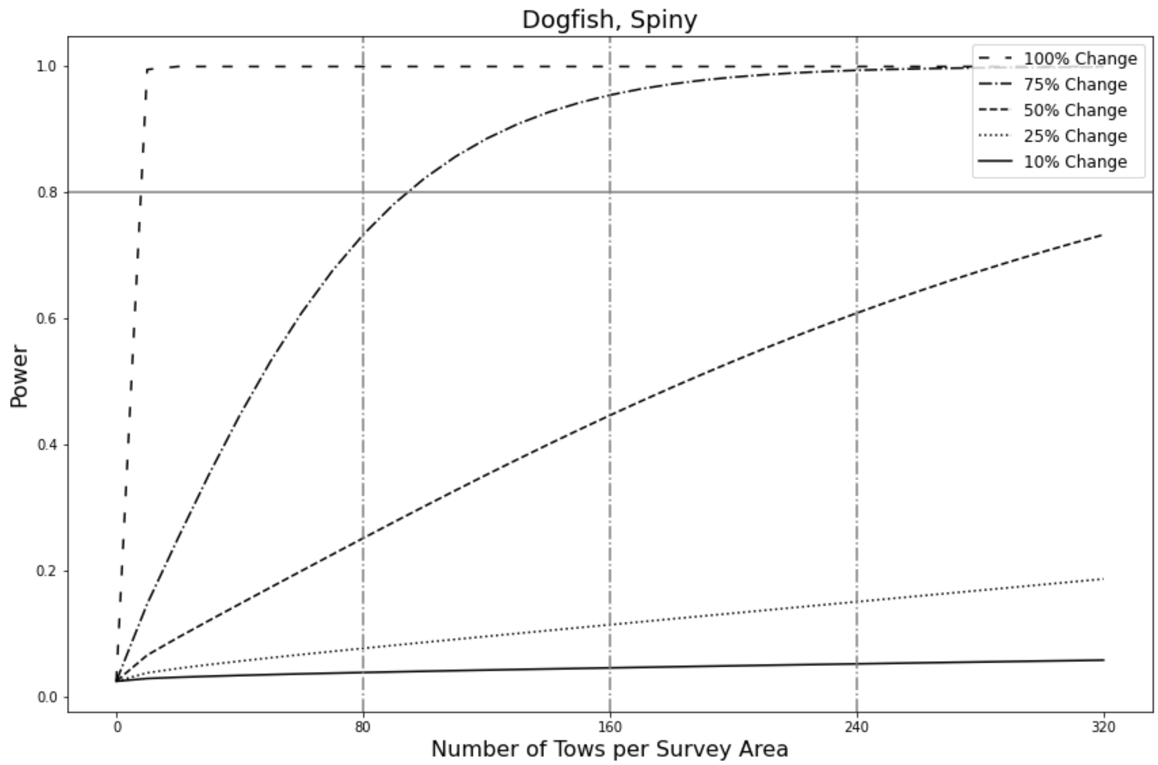



**Figure 64: Power analysis relationship between statistical power and sample size in spiny dogfish.**

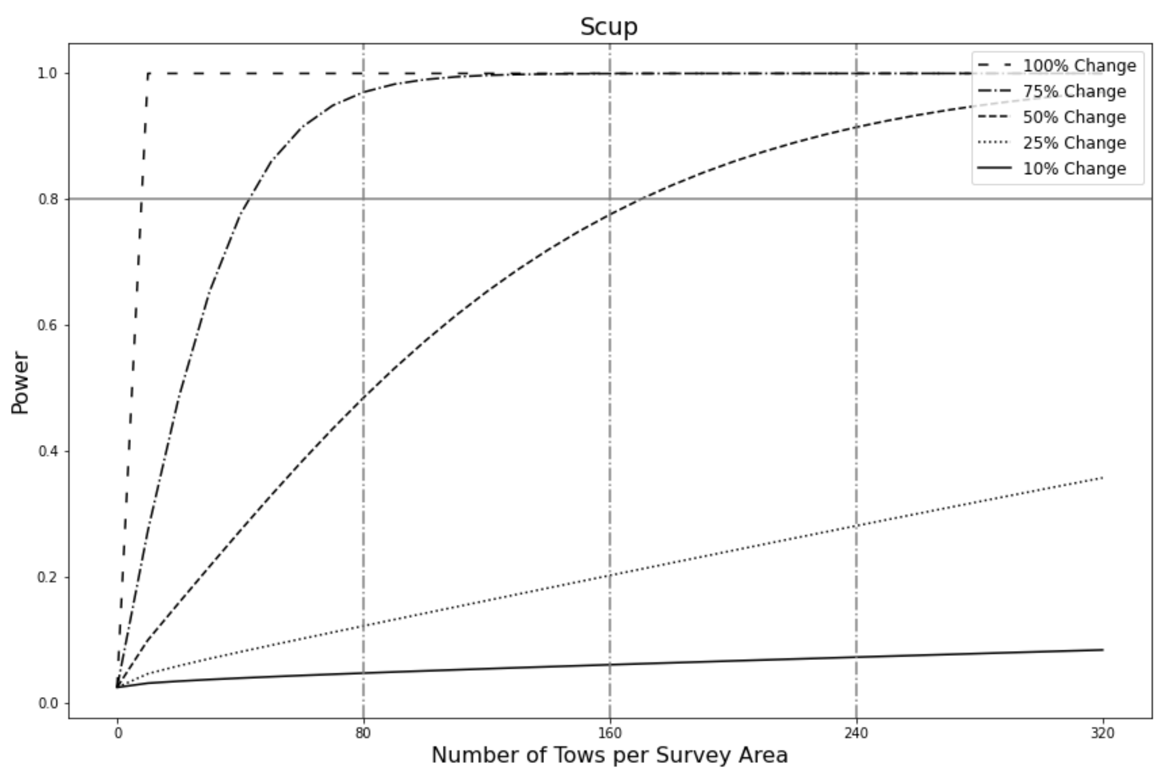



**Figure 65: Power analysis relationship between statistical power and sample size in scup.**

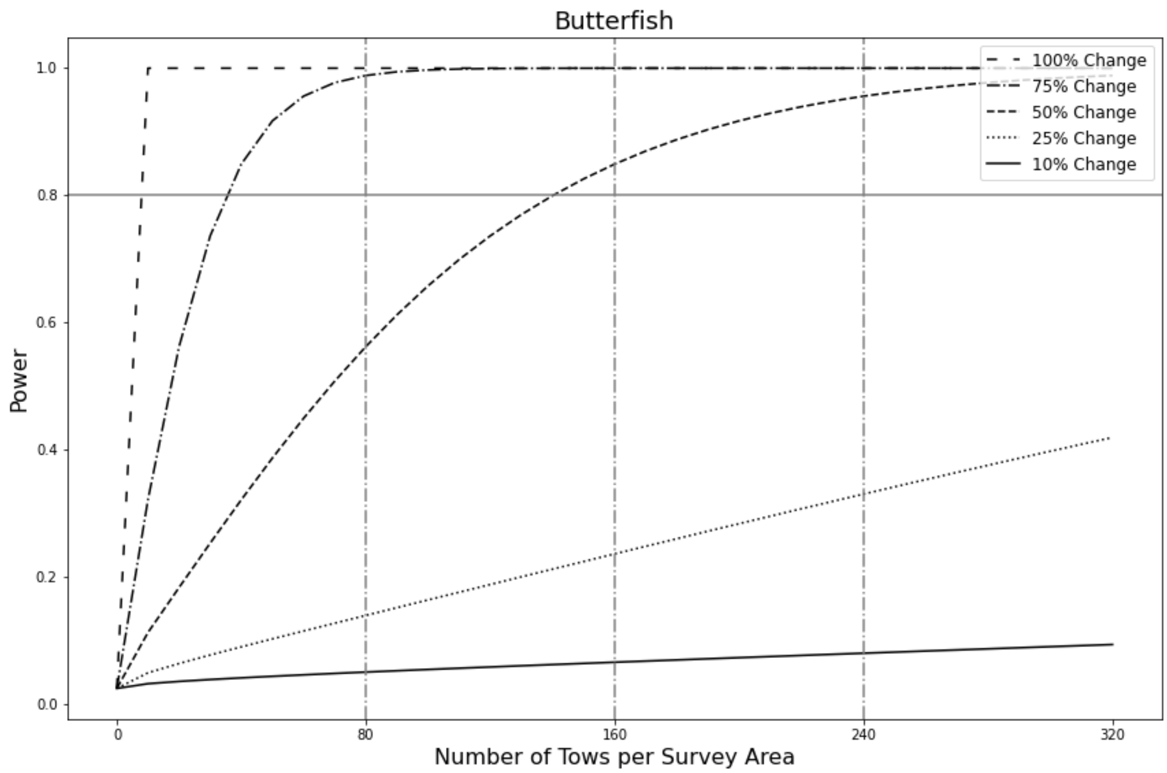



**Figure 66: Power analysis relationship between statistical power and sample size in butterfish.**

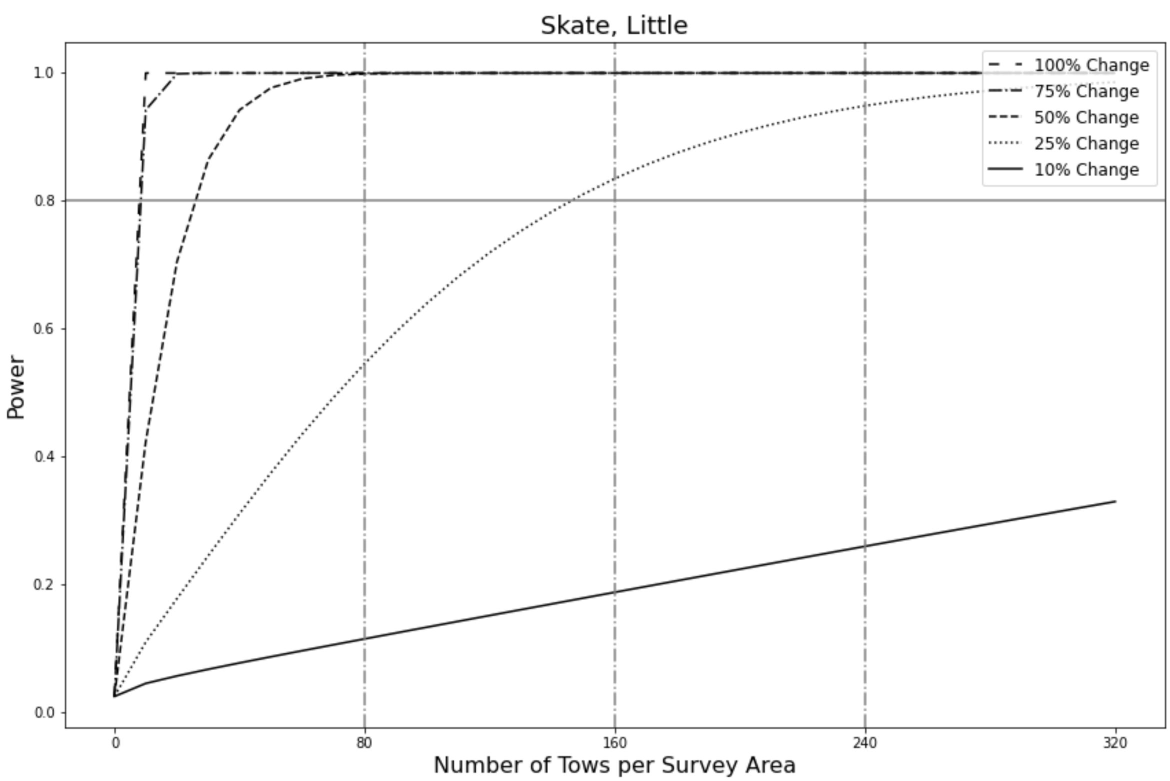



**Figure 67: Power analysis relationship between statistical power and sample size in little skate.**

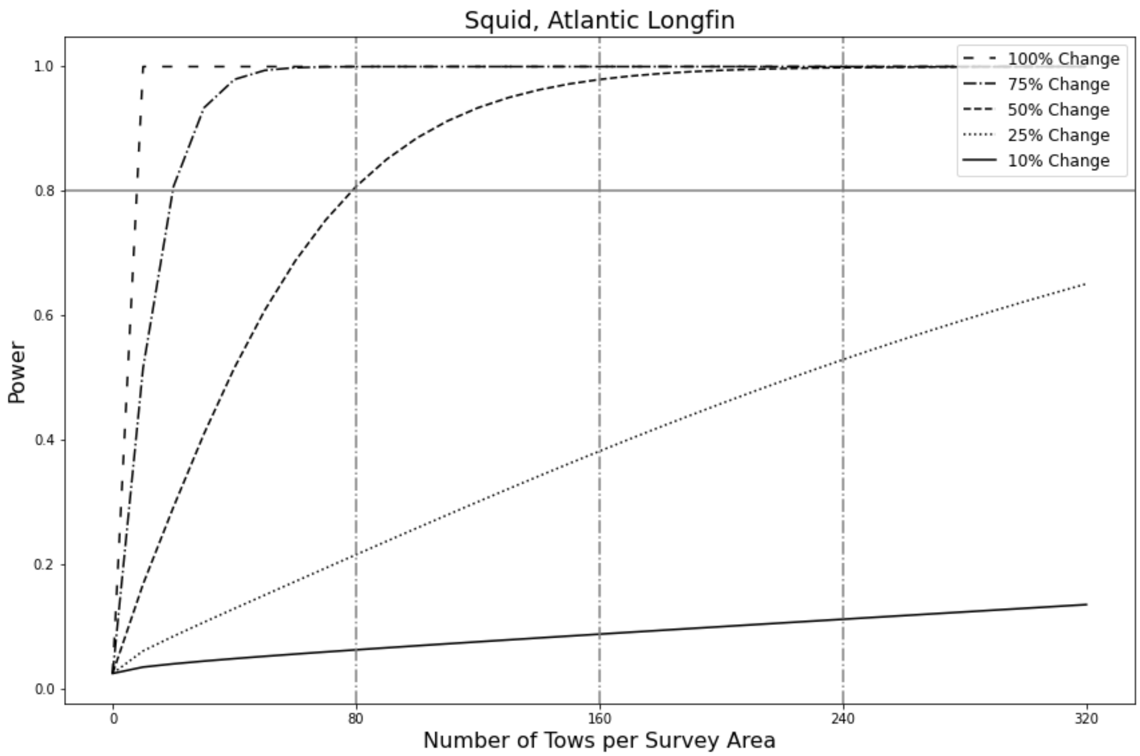



**Figure 68: Power analysis relationship between statistical power and sample size in Atlantic longfin squid.**

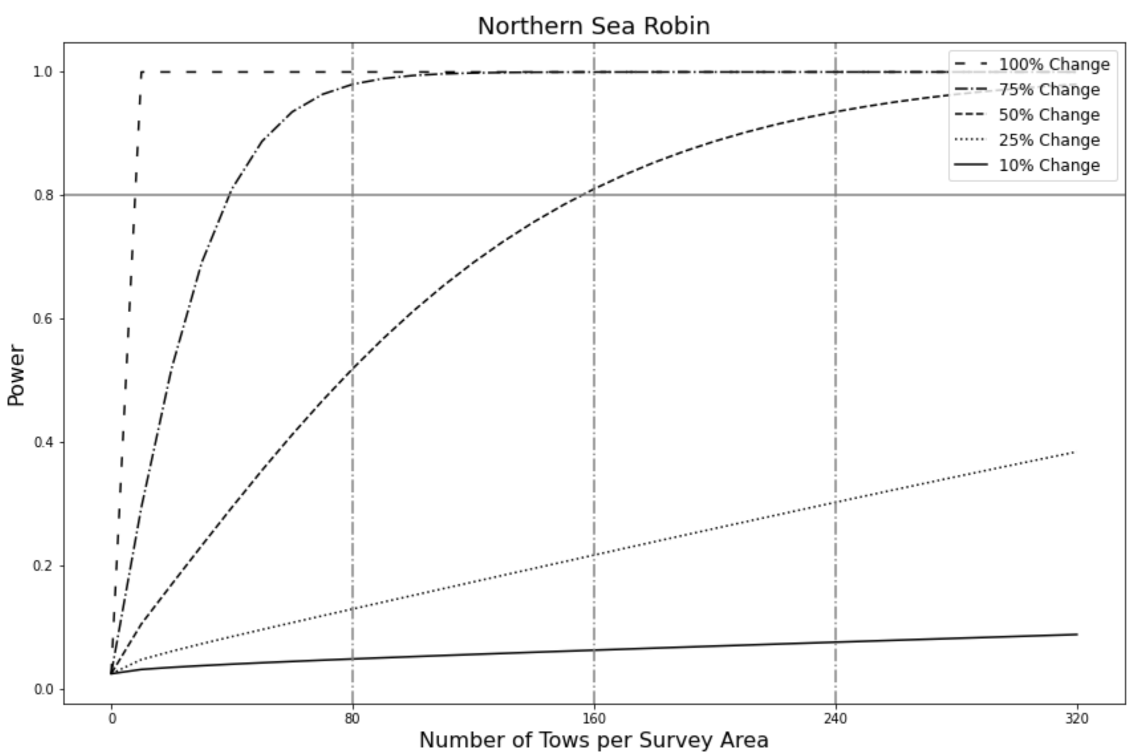



**Figure 69: Power analysis relationship between statistical power and sample size in northern sea robin.**

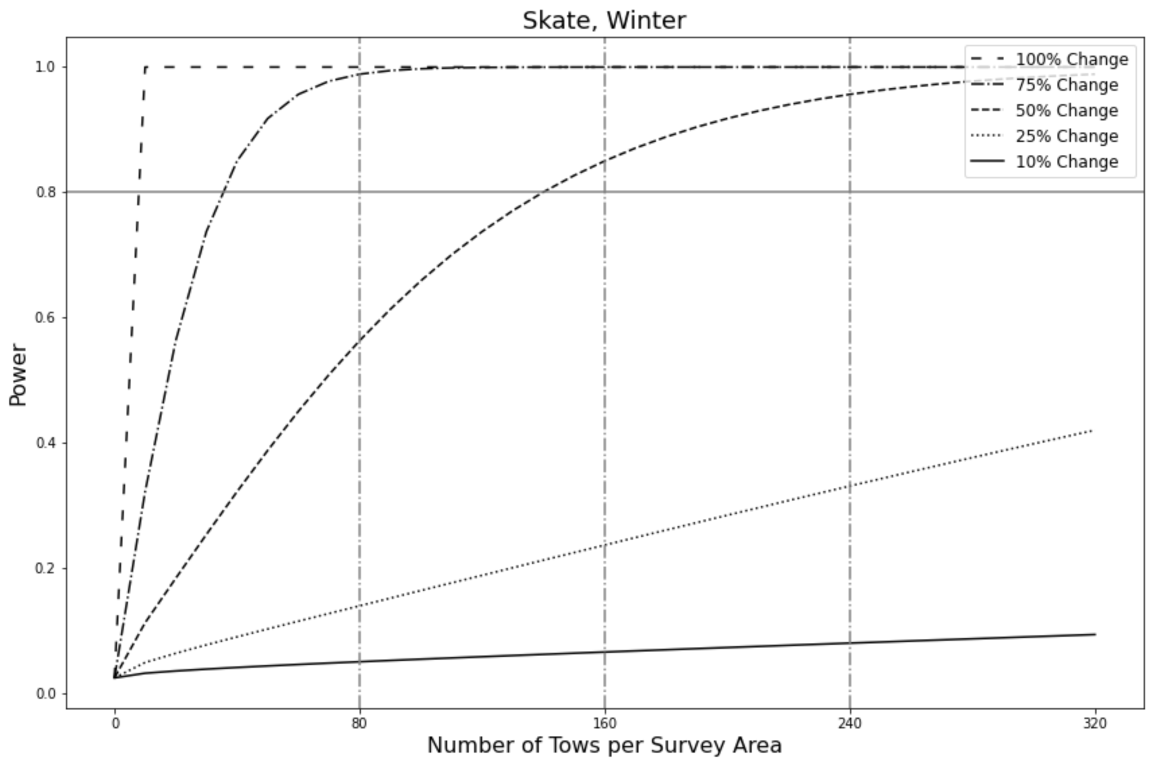



**Figure 70: Power analysis relationship between statistical power and sample size in winter skate.**

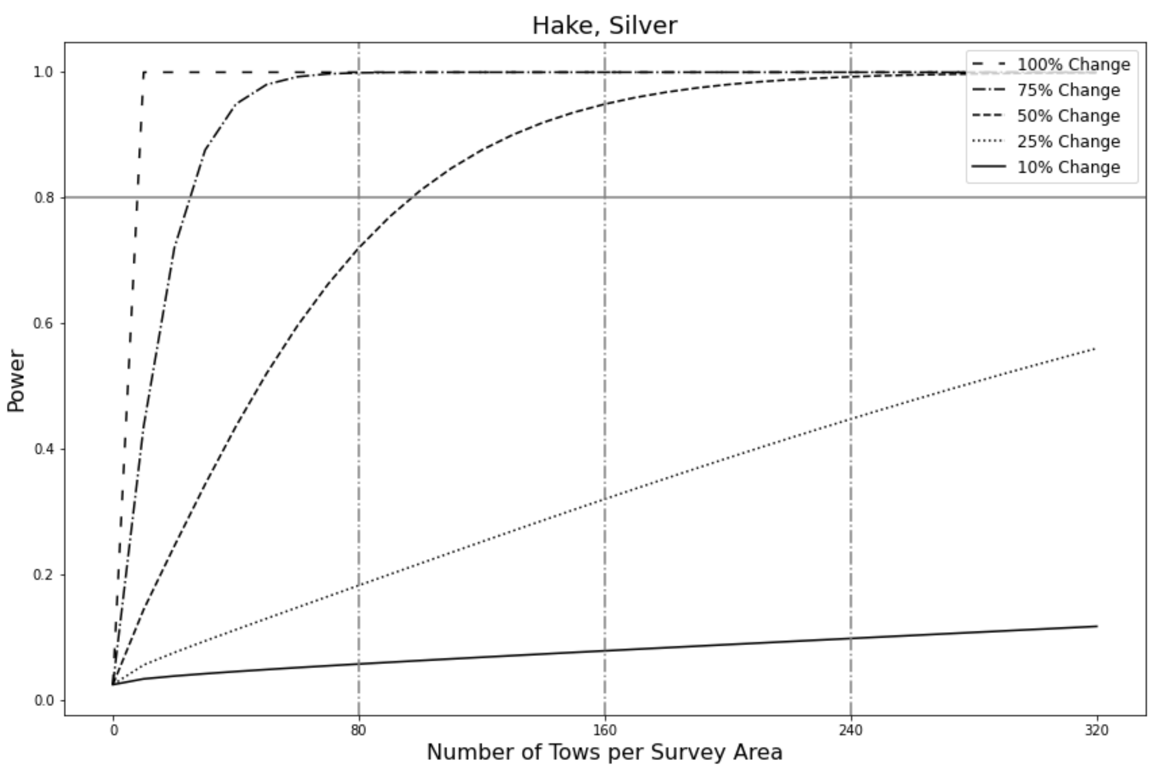



**Figure 71: Power analysis relationship between statistical power and sample size in silver hake.**

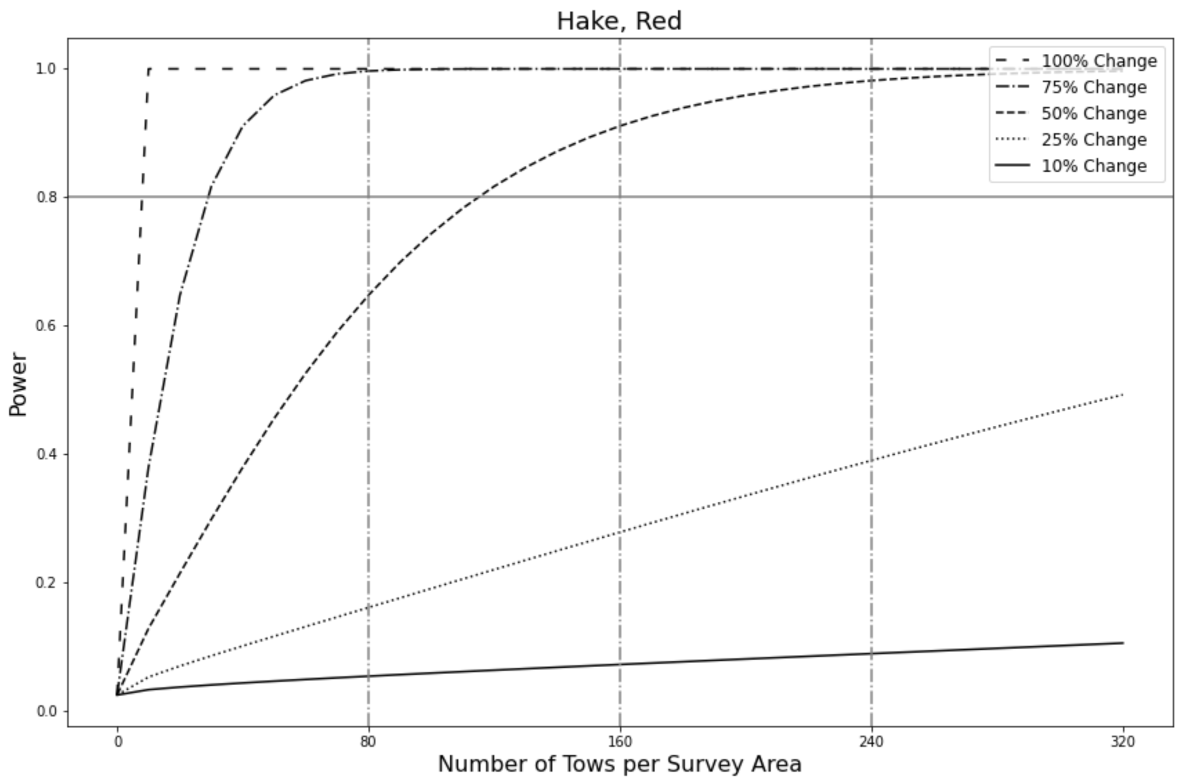



**Figure 72: Power analysis relationship between statistical power and sample size in red hake.**

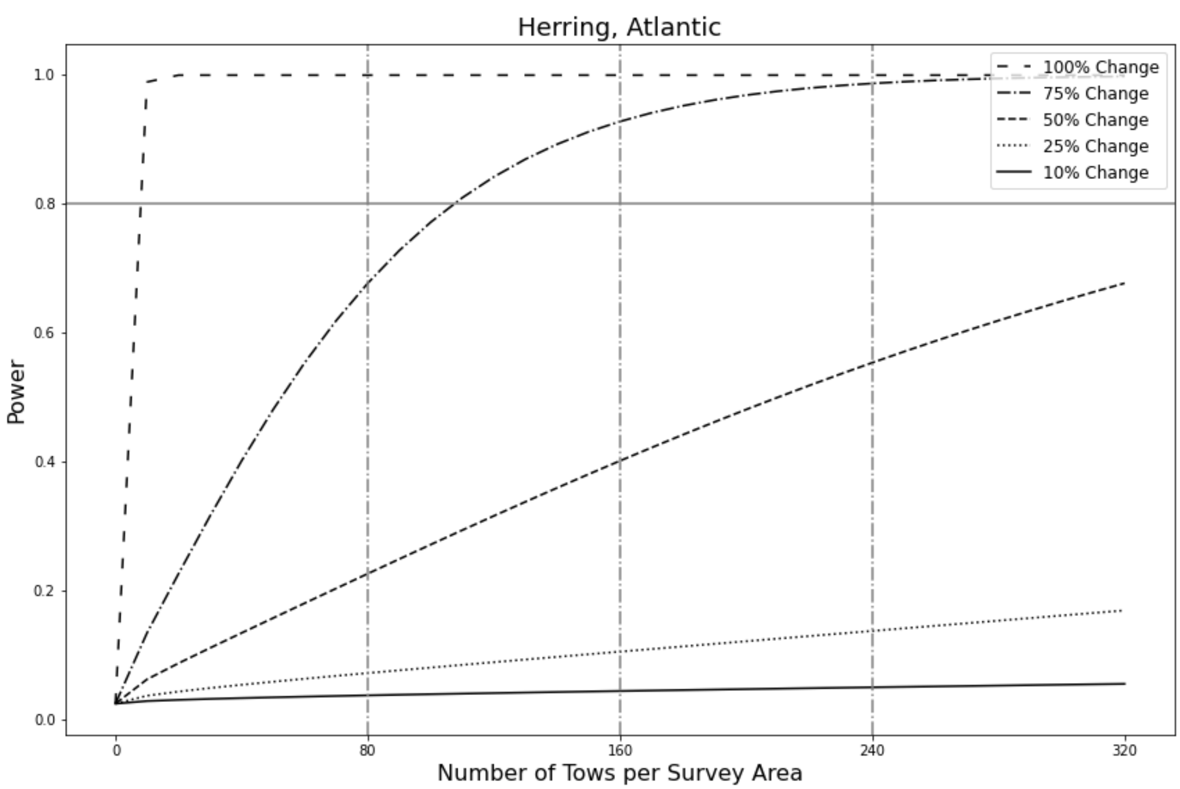



**Figure 73: Power analysis relationship between statistical power and sample size in Atlantic herring.**