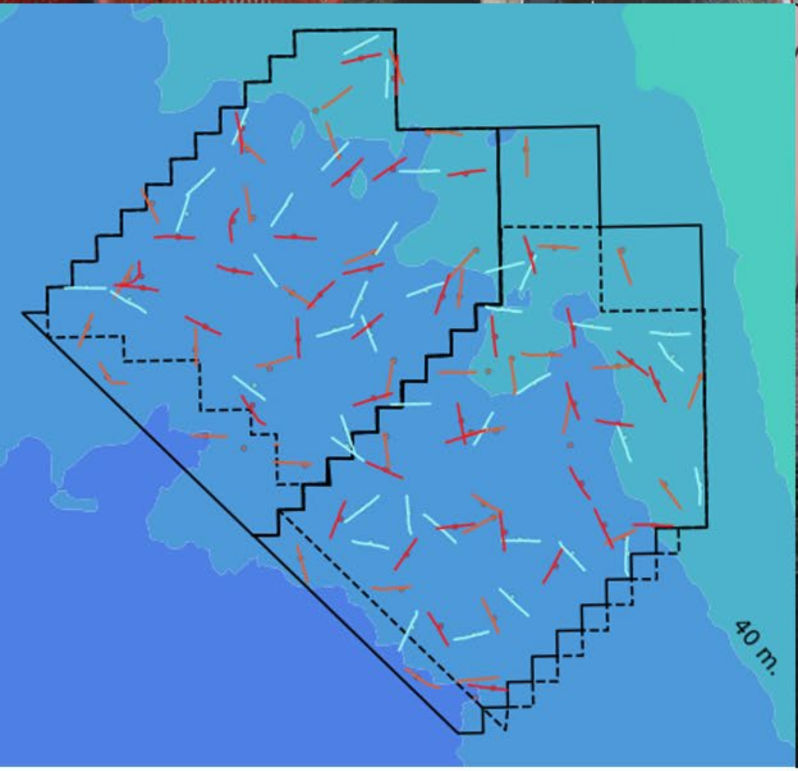
VINEYARD
WIND

Vineyard Wind 1
Demersal Trawl Survey



Vineyard Wind 1 Study Area

Annual Report
2021-2022

VINEYARD WIND 1 DEMERSAL TRAWL SURVEY

2021/2022 Annual Report

Vineyard Wind 1 Study Area

March 2023

Prepared for Vineyard Wind 1 LLC

VINEYARD
WIND

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Vineyard Wind 1 Demersal Trawl Survey Annual Report

Vineyard Wind 1 Study Area

UMass
Dartmouth

2021/2022 Annual Report

June 1, 2021 – September 31, 2022

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1. Summary

Vineyard Wind 1 LLC (Vineyard Wind), 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 the proposed offshore renewable energy development on marine fish and invertebrate communities in Lease Area OCS-A 0501 (the "VW1 Study Area). 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 nearshore 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. Pre-construction monitoring started in 2019. The data provided in this report is the third and final year of pre-construction monitoring, which included three seasonal surveys. Similar fisheries studies are being conducted within Lease Area OCS-A 0534 (the "534 Study Area") and within Lease Area OCS-A 0522 (the "522 Study Area"); these studies are reported separately.

Three seasonal trawl surveys were conducted using a commercial fishing vessel in the fall of 2021, winter of 2022, and summer of 2022. Twenty tows were conducted each season in the VW1 Study Area. An additional 20 tows were collected in a neighboring region, which served as a control (Control Area). Tow locations were randomly selected using a spatially balanced 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 weights, as well as individual fish lengths and weights, were collected.

A total of 120 tows were completed throughout the year split equally between the VW1 Study Area and the Control Area, and among the three seasons. In general, the data were similar to that observed during the previous survey years. The catch data obtained shows a dynamic area with a diversity of marine species. A total of 40 species were collected; however, the majority of the catch was comprised of a small subset of the observed species. The five most abundant species (butterfish, scup, little skate, Atlantic herring, and spiny dogfish) accounted for 87% of the catch weight in the Control Area and 81% of the catch weight in the VW1 Study Area. Interannual changes in abundance varied amongst species. All species caught displayed seasonal variations in distribution and abundance. The data indicated a unique assemblage of species and abundance in each season. Species composition during the fall and winter surveys showed strong similarity to that observed in the same surveys in 2019/2020 and 2020/2021. The summer survey exhibited variations in the community composition compared to the same seasons in 2019 and 2020. The changes in species composition may be linked to changing seasonal water temperatures. Bottom water temperature has remained relatively consistent across the fall and winter surveys between survey years. Conversely, bottom water temperature during the summer surveys has varied annually. In 2020, the summer bottom water temperature was 5°C warmer than in the 2019 survey. The species assemblage during 2020 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. Summer bottom water temperature in 2022 was intermediate to the two previous surveys (2019 & 2020). No differences in species assemblages were observed between the VW1 Study Area and Control Area.

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. Additional data only caused small changes to the Coefficients of Variation (CVs) for most species. Common species (i.e., species frequently observed regardless of abundance), including little skate and Atlantic longfin squid, exhibited low variability resulting in the projected ability to detect a 25% change in abundance or greater. Most commercial species, including summer flounder, black sea bass, and silver hake, exhibited modest variability. The current sampling effort should be able to detect 30 – 40% changes in abundance.

2. Introduction

In 2015, Vineyard Wind leased a 675 square kilometer (km^2; 197 square nautical miles [nmi^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. Vineyard Wind is conducting fisheries studies in a 306 km^2 (89 nmi^2) area referred to as the "VW1 Study Area," which is the focus of this report. Fisheries studies are also being conducted in Vineyard Wind shareholder company lease areas. This includes Lease Area OCS-A 0534 (the "534 Study Area") and Lease Area OCS-A 0522 (the "522 Study Area"); these studies are reported separately.[1]

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 United States (US) Exclusive Economic Zone, and consider the use of the sea as a fishery."

To address the potential impacts, Vineyard Wind, in collaboration with 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) to assess if there is any impact due to the development of wind farms. The control site will be in the general vicinity with similar characteristics to the study 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 may have on the ecosystem within an ever-changing ocean.

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[1] The Bureau of Ocean Energy Management (BOEM) segregated Lease Area OCS-A 0501 into two lease areas – OCS-A 0501 and OCS-A 0534 – in June 2021. The VW1 Study Area, which is located in the area designated as Lease Area OCS-A 0501, 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, which is designated as Lease Area OCS-A 0534, is referred to as the 501S Study Area in SMAST fisheries survey reports compiled prior to the lease area segregation.

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 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 NEAMP 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 and the lobster trap 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 VW1 Study Area. The data will serve as a baseline to be used in a future analysis under the BACI framework. This report documents the survey methodology, survey effort, and data collected during three seasonal surveys between the fall of 2021 and the summer of 2022. The 2019/2020 and 2020/2021 annual reports, as well as eleven 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 NEAMAP nearshore trawl survey. Initiated in 2006, NEAMAP conducts annual spring and fall trawl surveys from Cape Hatteras to Cape Cod. The NEAMAP survey protocol has gone through extensive peer review and is currently implemented near Lease Area OCS-A 0501 using a commercial fishing vessel (Bonzek et al., 2008). The current NEAMAP survey protocol samples at a resolution of ~100 km^2 (29 nmi^2), 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 wind farm 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 (i.e., the 534 Study Area and 522 Study 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 using the BACI framework as recommended by BOEM (BOEM, 2019). Three surveys were conducted to assess the seasonal variability in the resident populations. The seasonal surveys consisted of summer (July – September), fall (October – December), and winter (January – March) surveys. 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 was intended to capture these generalized trends in the population dynamics. The timing of the summer survey is intended to characterize the resident summer species that occur during seasonally warm water temperatures. The fall survey occurs during decreasing water temperatures, which typically triggers the offshore movement of many coastal species. Finally, the winter survey occurs during stable cold temperatures in the region. Additionally, the fall survey is intended to coincide with ongoing state and federal fisheries surveys.

Tow locations within the VW1 Study Area were selected using a spatially balanced sampling design. The VW1 Study Area was modified from the 2020/2021 survey year for the winter and summer surveys due to boundary refinements and segregation of the lease area into OCS-A 0501 and OCS-A 0534. The VW1 Study Area was decreased from 306 km^2 in the 2020/2021 survey year to 265 km^2 (89 to 77 nmi^2) in the 2021/2022 survey year by moving the southern boundary north (Figure 2). The current VW1 Study Area was sub-divided into 20 sub-areas (each ~13.25 km^2 [4 nmi^2]), and one trawl tow was made in each of the 20 sub-areas. This was designed to ensure adequate spatial coverage throughout the VW1 Study Area. The starting location within each sub-area was randomly selected (Figure 3).

An area located to the east of the VW1 Study Area was established as a control region, further referred to as the Control Area. The selected region has similar depth contours, bottom types, and benthic habitats to the VW1 Study Area. The Control Area was modified from the 2020/2021 survey year for the winter and summer surveys to align with the aforementioned changes to the VW1 Study Area. To align the northern and southern boundaries with the VW1 Study Area, areas to the north and south were removed from the Control Area. Additionally, the eastern boundary was slightly extended to match the width and area of the VW1 Study Area (Figure 2). These changes decreased the Control Area from 324 to 269.5 km^2 (94.5 to 78.6 nmi^2). The Control Area was sub-divided into 20 sub-areas (each ~13.5 km^2 [4 nmi^2]). An additional 20 tows, one per sub-area, were completed in the Control Area. The tow locations were selected in the same manner as the VW1 Study Area, using the spatially balanced sampling design.

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). This information was updated based on catch data from the 2019/2020 survey year (Rillahan and He, 2020). The results of the updated power analysis indicated that several species, including little skate (*Leucoraja erinacea*) Atlantic longfin squid (*Dorytheuthis pealei*), silver hake (*Merluccius bilinearis*), and fourspot flounder (*Paralichthys oblongus*), had relatively low variability and therefore a high probability of detecting small to moderate effects (~25% change) under the current monitoring effort. Many of the common species observed, including winter skate (*Leucoraja ocellata*), red hake (*Urophycis chuss*), windowpane flounder (*Scophtalmus aquosus*), monkfish (*Lophius americanus)*, summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), yellowtail flounder (*Pleironectes ferrugineus*), winter flounder (*Pleuronectes americanus),* and butterfish (*Peprilus triacanthus*), had higher variability (CV: 1.5 – 2.3). For these species, the current monitoring would have a high probability of detecting moderate effects (i.e., 30 – 50% change). For species exhibiting strong seasonality and high variability (CV: 2.5 – 4), large effects (i.e., 50 – 75% change) can be detected with a high probability under the current monitoring plan. For all species collected during the surveys, the current monitoring plan has the statistical power to detect a complete disappearance from either the VW1 Study Area or Control Area (i.e., 100% change). The updated power analysis showed that increasing the survey effort would only result in small improvements in detectability (Table 7).

When distributing the survey effort, randomly selecting multiple tow locations across the VW1 Study Area and Control Area accounts for spatial variations in fish populations. The distributed approach, applied here, assumes that the catch characteristics across each survey area represent 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 one station per 13.25 km^2 (3.86 nmi^2) in the VW1 Study Area and one station per 13.5 km^2 (3.94 nmi^2) in the Control Area. As previously mentioned, the NEAMAP nearshore survey samples at a density of one station per ~100 km^2 (29 nmi^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 4). This net style allows for a high vertical opening (~5 meters [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 5). 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 areas. To ensure the retention of small individuals, a 1" mesh size knotless liner was used within a 12-centimeter (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

6 and 7 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 (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. Wing spread was targeted between 13.0 and 14.0 m (acceptable range: 11.7 to 15.4 m). Door spread was targeted between 32.0 and 33.0 m (acceptable range: 28.8 to 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° 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 8).

3.4 Survey Operations

All three 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 8 – 23, 2021
- Winter Survey: January 31 – February 9, 2022

- Summer Survey: August 10 – 15, 2022

Surveys were alternated daily between the VW1 Study Area and Control 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. 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 a 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 were 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 three seasonal surveys: straight sub-sampling by weight and discard by count.

Straight sub-sampling by weight: When catch diversity was relatively low (five to 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 predominant 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 (*Squalus acanthias*) 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 survey data were uploaded and stored in a Microsoft Access database.

3.6 Data Analysis

3.6.1 Catch Per Unit Effort Analysis

To assess the influence of season and area (i.e., VW1 Study Area versus Control Area) on the observed catch, a catch per unit effort (CPUE) analysis was conducted. 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 wing spread. The data were then standardized to an ideal swept area (25,000 square meters [m^2]) for each species, i, and tow, j, (Equation [Eq.] 1). The ideal swept area assumes a tow distance of one nautical mile at a wing spread of 13.5 m. The ideal swept area was very close to the annual average swept area observed in the surveys (24,885 m^2). This standardization method is used by NEAMAP to create indices of abundance (Bonzek et 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%).

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

The generalized linear modeling (GLM) framework was used to model the observed catch as a function of season and area. Models were produced for each species. The full model had two explanatory variables, season and area. Season was a categorical variable with three levels to account for the three seasonal surveys (summer, fall, and winter). Area was a categorical variable with two levels (VW1 Study Area and Control Area) to examine catch differences between the two survey areas.

The response (standardized catch) was therefore modeled as:

$$\log(standardized\ catch)_i = \beta_0 + \beta_{survey} + \beta_{area} + \varepsilon_i \qquad Eq. 2$$

β_0 is an intercept term, β_{survey} and β_{area} are the two explanatory variables, and ε_i is the error term. A Gaussian error distribution was used with a log link function. To evaluate the importance of each explanatory variable on the model fit, two nested models were subsequently created with only one of the two explanatory variables. A likelihood ratio test was used to compare each nested model to the full model (Zuur et al., 2009). P-values less than 0.05 indicated that removing the explanatory variable significantly reduced the model's fit, while p-values greater than 0.05 indicated that removing the explanatory variable did not significantly impact the model. Additionally, Akaike Information Criterion values were used to examine the relative goodness of fit between the candidate models. Residual analysis was used to validate each model and ensure the residuals were normally distributed with no heteroscedasticity.

The models were fit using the ‘glm’ function in the Stats package in the R programming language (version 3.6.2, R Core Team, 2018). Only data from the 2021 – 2022 surveys were used in this analysis. The previous annual report had shown a significant area-effect for many species (i.e., the VW1 Study Area and Control Area had significantly different catch rates). As a result, we did not aggregate all the survey data (2019 – 2022) so as not to confound this effect. The goal of this analysis was to reassess these impacts given the modifications of the two areas.

3.6.2 Fish Size Structure Analysis

To assess potential differences in the size structures of fish populations between the VW1 Study Area and the Control Area, kernel density estimation (KDE) was used. This process uses the length-frequency data collected from the surveys to estimate a probability density function for each survey area using a kernel function. Each probability density function is effectively a smooth curve representing the observed size-frequency of each species in each survey area. The similarity between the two curves is then measured using the Jensen-Shannon divergence statistic. A permutation test is used to assess statistically significant differences between the two areas. During the permutation test, the survey area is randomly reassigned for each data point and KDEs are fit to each data set. Measurements of curve similarity are calculated for each permutation. One thousand permutations of the data are used to create a robust, “random” dataset. The observed data is then compared to the randomized dataset. Statistically, significant differences (i.e., values in the top or bottom 2.5% of observations) would indicate that the differences observed in the data were highly unlikely to be collected randomly thereby indicating a different size structure between the two survey areas. This method is outlined by Langlois et al. (2012) and used by Bond et al. (2018) to look at the size structure of fish populations around, and away from, a subsea pipeline.

KDEs were created for each species and season. Bandwidths were selected using the ‘dpik’ function in the ‘KernSmooth’ package in the R programming language (Wand, 2015). This method uses the ‘plug-in’ style, which does not make assumptions about the distribution of the data. The statistical test compared the area between the two KDEs to the results of 1,000 permutations of the data. The permutation test randomly reassigned the survey area and compared the random pairs using the ‘sm.density.compare’ function in R’s ‘sm’ package (Bowman and Azzalini, 2018). The result is a null model assuming no difference between areas. Data outside of one standard error, above or below the null model, indicates significant differences between the two survey areas. As with the CPUE analysis, only data from 2021 – 2022 were evaluated to reassess the impacts of the survey area on the catch.

3.6.3 Condition Index Analysis

The condition of fish was compared between seasons and the two survey areas. Fish condition is a general metric comparing the weight of a fish at a given length and is typically an indication of fish well-being (Blackwell et al., 2000). Fish with a high condition (i.e., plump fish) may indicate favorable environmental conditions, including adequate prey availability, which may lead to increased survival or fecundity. Fish with a low condition (i.e., lean fish) may indicate the opposite (Blackwell et al., 2000). Fish condition was evaluated using a relative condition factor (Eq. 3; LeCren, 1951). The relative condition factor (Kn) is derived from the weight of the fish (W) compared to the predicted length-specific mean weight for the population (W’).

$$K_n = \frac{W}{W'} \qquad Eq.3$$

A value of 1 indicates that a fish is of average condition. K_n values greater than 1 indicate that the fish is heavier given its length, or of better condition than average, while values less than 1 indicate a fish with a below-average condition.

To calculate the predicted length-specific mean weight, weight-length curves for each species were fit for the population of animals in and around the development area. Individual length and weight data were aggregated between surveys and areas, including additional data collected in the 534 Study Area and 522 Study Area. The weight-length curves were fit using the exponential relationship defined in Eq. 4 converted to logarithmic form (Eq. 5).

$$W = aL^b \qquad Eq.4$$

$$\log W = \log a + b \log L \qquad Eq.5$$

A regression model was used to estimate the model parameters (a and b) using the ordinary least squares method in the statsmodels package (version 0.11.1) in the Python programming language. Relative condition factors for each fish were calculated using Eq. 3 where W is the measured weight and W’ is the length-specific model estimated weight, derived from Equation 5. A generalized linear model, the same as used in the CPUE analysis, was used to assess the influence of season and survey area on fish condition.

3.6.4 Community Structure Analysis

To assess the community dynamics in the VW1 Study Area and Control Area a multivariate analysis was conducted using the Primer-E statistical software package (Primer 7, Quest Research Limited, Auckland, New Zealand). The goal of this analysis was to investigate changes in the community composition between seasons and survey areas.

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 were transformed to reduce the influence of numerically dominant species, ensuring a community-based assessment (Clarke and Gorley, 2015). A two-way nested Analysis of Similarities (ANOSIM) was conducted with tow area nested with season as factors. The ANOSIM is a non-parametric, ANOVA-like, statistical test that 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 a maximum of 1 indicates a large separation between treatment groups. A permutation test (9,999 permutations) was used to test against the null hypothesis where similarities within treatments were 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 aggregated dataset (2019 – 2022). Pairwise comparisons between surveys were used to investigate seasonal changes in species composition as well as annual variations within a season (e.g., fall 2019 versus fall 2022).

3.6.5 Power Analysis

To ensure the survey’s ability to detect changes in fish populations, a 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 a 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 Eq. 6.

$$n = \frac{2(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 (CV)^2}{[\ln{(1 - PC)}]^2} \qquad Eq. 6$$

Where 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. PC = (μ_0 - μ_1)/μ_0, with μ_0 and μ_1 being mean CPUEs of pre-development and post-development respectively. CVs were derived from the standardized catch rates observed throughout the seasonal surveys. In many ecological analyses, α is usually set at 0.05 and β at 0.2 (Van Belle, 2011). β is the probability 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

Twenty tows were completed during each survey period in both the VW1 Study Area and the Control Area for a total of 120 tows (Figure 3, Tables 1 through 4). Tow duration, tow speed, and tow distance were similar between survey areas and seasons (Table 4). Tow durations were close to the targeted 20 minutes, averaging 20.1 ± 0.4 minutes (mean ± one standard deviation) in the VW1 Study Area and 20.1 ± 0.2 minutes in the Control Area ($p = 0.4404$, unpaired t-test). The targeted tow duration was maintained between seasons (Figure 9). Tow speed averaged 2.89 ± 0.13 knots in the VW1 Study Area and 2.92 ± 0.13 knots in the Control Area ($p = 0.2341$). The average tow speed showed little variation between surveys or survey areas (Figure 9). Tow distances averaged 0.97 ± 0.04 nmi in the VW1 Study Area and 0.98 ± 0.05 nmi in Control Area ($p = 0.3444$). The average tow distance showed little variation between survey seasons or survey areas (Figure 9).

The seafloor in both areas follows a northeast-to-southwest depth gradient with the shallowest tow along the northeast edge (18 fathoms [33 m]). Depth increases to a maximum of 28 fathoms (51 m) along the southwest boundary. Tow depths ranged from 20 to 27 fathoms (36.6 – 49.4 m) in the VW1 Study Area and 18 to 28 fathoms (32.9 – 51.2 m) in the Control Area. The distribution of starting depths was wider in the Control Area (range: 17 – 28 fathoms) compared to the VW1 Study Area in which a majority of the tows occurred between 21 and 26 fathoms (Figure 10). This is similar to the 2020/2021 survey data and in contrast to the 2019/2020 survey data. In 2019/2020, it was observed that the distribution of tows was significantly deeper in the Control Area. These results were part of the reason for adjusting the Control Area boundaries. The updated data show improved similarity in the depth distributions between the two survey areas. The average starting depth in the VW1 Study Area was 23.6 ± 1.7 fathoms and 23.3 ± 2.4 fathoms in the Control Area (p-value = 0.4530).

4.2 Environmental Data

Bottom water temperature followed seasonal trends in both survey areas (Figure 11). The bottom water temperature was highest during the fall and summer surveys and lowest during the winter survey. During the fall survey, water temperatures averaged 14.4 ± 0.6°C in the VW1 Study Area and 13.9 ± 0.5°C in the Control Area. The bottom temperature was similar to that observed in 2019 and 2020. Similarly, bottom water temperature during the winter has been relatively consistent throughout the survey duration (Figure 11). In 2022, bottom water temperature during the winter survey averaged 3.7 ± 0.6°C in the VW1 Study Area and 4.5 ± 0.8°C in the Control Area. Conversely, bottom water temperature during the summer surveys has varied. In 2022, bottom water temperature averaged 13.9 ± 0.5°C in the VW1 Study Area and 14.1 ± 1.1°C in the Control Area. Summer bottom water temperature was observed to be warmer in 2020, averaging 15.9 ± 1.1°C in the VW1 Study Area and 16.5 ± 1.2°C in the Control Area. Conversely, summer bottom water temperature was observed to be cooler in 2019, averaging 11.4 ± 0.8°C in the VW1 Study Area and 12.0 ± 0.6°C in the Control Area.

Within each seasonal survey, the bottom temperature tended to follow the depth gradient. Shallow tows were warmer than deeper tows in the summer surveys. Conversely, deeper tows were cooler in the winter survey. During the fall survey, the bottom temperature was relatively uniform throughout the survey areas.

4.3 Trawl Performance

The trawl geometry data indicated that the trawl typically took about two to three minutes to open and stabilize. Once open, readings tended to be stable through the duration of the tow. Wing spread measurements were largely within the ideal range of 13.0 to 14.0 m, averaging 13.7 ± 0.4 m for tows in the VW1 Study Area (range: 12.8 – 14.6 m) and 13.7 ± 0.6 m for tows in the Control Area (range: 11.2 – 14.9 m; $p = 0.8549$). Wing spread is the most important trawl performance metric as it is used to measure the swept area. Wing spread readings were consistent across the surveys with all tows within the acceptable tolerance limits (Figure 12). Wing spread readings increased slightly with trawl warp; however, this effect was small, and readings were relatively stable across the range of depths encountered within the surveys (Figures 13, 14).

Door spread averaged 34.3 ± 1.3 m (range: 31.6 – 37.6 m) for tows in the VW1 Study Area and 34.4 ± 1.6 (range: 30.8 – 37.8 m; $p = 0.8518$) in the Control Area. Door spread was relatively consistent across surveys (Figure 12). Similar to wing spread, door spread readings tended to increase with depth due to increased trawl warp (Figure 14). All tows were within the acceptable tolerance limit except for three tows, which were 0.2 to 0.4 m higher than 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 4.8 ± 0.2 m for tows in the VW1 Study Area (range: 4.5 – 5.8 m) and 4.9 ± 0.3 m for tows in the Control Area (range: 4.4 – 6.1 m, p = 0.5843). 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 resulted in significant improvements overall. Only one tow was below the acceptable tolerance limits by 0.1 m. All subsequent tows were within the acceptable tolerance limits.

4.4 Catch Data

4.4.1 Overview

The data obtained from the three seasonal surveys conducted show that the two survey areas are dynamic in their species composition and abundance. A total of 40 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 5 for the VW1 Study Area and Table 6 for the Control Area. Thirty-five species were caught in the VW1 Study Area, and 40 species were caught in the Control Area, with 35 species shared between the two regions. Catch volume ranged from 7.5 to 2,668.5 kilograms per tow (kg/tow). The majority of the catch was primarily comprised of a small subset of the observed species. The five most abundant species (butterfish, scup, little skate, Atlantic herring, and spiny dogfish) were shared between the two regions and accounted for 81.4% and 87.4% of the total catch weight in the VW1 Study Area and Control Area, respectively. The next five most abundant species (red hake, silver hake, Atlantic longfin squid, winter skate, and northern sea robin [*Prionotus carolinus*]) were similarly shared between regions and comprised 15.9% and 9.6% of the catch in the VW1 Study Area and Control Area, respectively. These ten species represented around 97% of catch weight. Data collected from both areas included the catch of both adults and juveniles of most species observed.

4.4.2 Butterfish

Butterfish (*Peprilus triacanthus*) was the most abundant species by weight in both the VW1 Study Area (27.0% of the catch) and the Control Area (31.3% of the catch). Butterfish were consistently caught in both survey areas. Butterfish were observed in every tow during the fall and summer surveys with no butterfish observed in the winter surveys. Annually, catch rates averaged 56.3 ± 12.9 kg/tow (mean ± Standard Error of the Mean [SEM], range: 0 – 459.2 kg/tow) in the VW1 Study Area and 101.9 ± 37.0 kg/tow (range: 0 – 1,803.2 kg/tow) in the Control Area. The GLM analysis indicated a significant seasonal and survey area effect with the Control Area exhibiting higher catches (season: $p < 0.0001$; area: $p = 0.0064$). In general, the annual catch rate was higher than observed in previous survey years (Figure 15). Seasonal catch rates were higher in both the summer and fall, compared to 2019 and 2020.

The catch rate of butterfish was highest in the summer survey with catch rates averaging 110.5 ± 30.5 kg/tow in the VW1 Study Area and 285.3 ± 100.2 kg/tow in the Control Area (Figure 15). Butterfish were observed in all 20 tows in the VW1 Study Area and the Control Area. The catch of butterfish was observed to be higher in the northern half of the survey areas associated with shallower waters (Figure 16). Individuals ranged from 10 to 14 cm in length with a unimodal size distribution peaking at 12 cm (Figure 17). Fish in both survey areas exhibited a similar narrow size distribution ($p = 0.1$; Figure 18).

Catch rates in the fall survey were lower than in the summer survey. Seasonal catch rates averaged 58.5 ± 17.1 kg/tow in the VW1 Study Area and 20.5 ± 7.1 kg/tow in the Control Area (Figure 15). Butterfish were observed in all 20 tows in the VW1 Study Area and 19 of the 20 tows in the Control Area. The butterfish catch was evenly distributed across both survey areas (Figure 16). Individuals ranged in length from 4 to 17 cm with a wide unimodal size distribution peaking between 7 and 8 cm (Figure 17). The length distribution in the VW1 Study Area was concentrated in a narrow range between 6 and 11 cm while individuals in the Control Area exhibited a wider distribution of sizes ($p = 0.0001$; Figure 18).

No butterfish were observed during the winter survey.

Butterfish displayed seasonal and area differences in condition ($p = 0.0019$ and 0.0001, respectively; Figure 19). The condition was highest in the fall survey in the Control Area (VW1 Study Area: 0.92 ± 0.26, Control 1.16 ± 0.35). In general, the condition was higher in the Control Area compared to the VW1 Study Area.

4.4.3 Scup

Scup (*Stenotomus chrysops*) was the second most abundant species in both survey areas despite the catch being limited to the summer and fall surveys. In general, the catch was high during the summer and fall surveys. The annual catch rate averaged 48.6 ± 9.7 kg/tow (range: 0 – 262.7 kg/tow) in the VW1 Study Area and 81.6 ± 17.8 kg/tow (range: 0 – 758.7 kg/tow) in the Control Area. The GLM analysis indicated that season and survey area were significant predictors of the catch (season: $p < 0.0001$; area: $p < 0.0001$). The annual average catch rate has exhibited an increasing trend in the Control Area during the three years of surveying. The annual average catch rate in the VW1 Study Area was similar to 2020/2021 and higher than 2019/2020 (Figure 20).

The catch of scup was highest during the fall survey. Catch rates of scup averaged 113.9 ± 18.8 kg/tow in the VW1 Study Area and 158.7 ± 26.9 kg/tow in the Control Area (Figure 20). Scup were caught in every tow in both survey areas. The catch of scup was distributed throughout both survey areas (Figure 21). Individuals ranged in size from 7 to 29 cm with a unimodal peak at 24 cm (Figure 22). The shape of the distributions was similar between survey areas with the Control Area, shifting slightly toward larger fish ($p = 0.0001$; Figure 23).

The summer catch of scup averaged 32.0 ± 12.8 kg/tow in the VW1 Study Area and 86.0 ± 39.4 kg/tow in the Control Area (Figure 20). The summer catches were varied, ranging from 0 to 758.7 kilograms (kg). Several large tows (>200 kg) served to boost the seasonal average in the Control Area but were not observed in the VW1 Study Area. Scup were caught in 10 of the 20 tows in the VW1 Study Area and 16 of the 20 tows in the Control Area. The catch of scup was primarily focused on the northern half of the survey areas, with the catch extending further south in the Control Area (Figure 21). Scup ranged in size from 19 to 28 cm with a unimodal peak around 22 cm in the VW1 Study Area and 24 cm in the Control Area (Figure 22). The shape of the distributions was similar between survey areas with the Control Area shifted toward larger fish ($p = 0.0001$; Figure 23).

Only two scup were collected in the winter survey. Both individuals were small (10 to 11 cm) and collected in the VW1 Study Area.

The condition of scup was not significantly different between survey areas ($p = 0.1808$; Figure 24). Generally, the condition was higher in the fall survey (VW1 Study Area: 1.02 ± 0.1; Control

Area: 1.05 ± 0.11) and lower in the summer survey (VW1 Study Area: 0.97 ± 0.08; Control Area: 0.97 ± 0.08).

4.4.4 Little Skate

Little skate (*Leucoraja erinacea*) was the third most abundant species by weight in both the VW1 Study Area (15.8% of the catch) and the Control Area (13.3% of the catch). Little skates were common throughout the year, being observed in 58 of the 60 tows in the VW1 Study Area and all 60 tows in the Control Area. Annually, catch rates averaged 33.8 ± 4.7 kg/tow (range: 0 – 119.9 kg/tow) in the VW1 Study Area and 43.0 ± 6.4 kg/tow (range: 0.3 – 175.0 kg/tow) in the Control Area ($p < 0.0001$). In general, the catch was highest in the fall survey, moderate in the summer survey, and low in the winter survey ($p = 0.0001$; Figure 25). Catch rates and trends appeared lower than those observed in previous survey years (Figure 25).

The catch rate of little skate was the highest during the fall survey with catch rates averaging 71.9 ± 6.3 kg/tow in the VW1 Study Area and 103.7 ± 8.5 kg/tow in the Control Area (Figure 25). Little skates were observed in all 20 tows in both survey areas. The catch was observed to be distributed throughout both survey areas in the fall survey (Figure 26). Individuals ranged in size from 12 to 35 cm (disk width; Figure 27). The KDE analysis indicated that the distribution of little skates was slightly larger in the VW1 Study Area with a peak at 25 cm compared to the Control Area with a peak at 24 cm ($p = 0.0001$; Figure 28).

The catch rate of little skate in the summer survey averaged 27.9 ± 5.7 kg/tow in the VW1 Study Area and 22.6 ± 3.4 kg/tow in the Control Area (Figure 25). Little skates were observed in all 20 tows in both survey areas. During the summer survey, the catch was distributed throughout the survey areas (Figure 26). Individuals ranged in size from 11 to 31 cm (Figure 27). The KDE analysis indicated that the distribution of skates was similar between the two areas with a peak at 26 cm compared to the Control Area with a peak at 24 cm ($p = 0.1$; Figure 28).

Little skate abundance was low during the winter survey (VW1 Study Area: 1.6 ± 0.3; Control Area: 2.7 ± 0.6); however, they were still observed in 18 of the 20 tows in the VW1 Study Area and all 20 tows in the Control Area. Similar to other seasons, the catch was distributed throughout both survey areas (Figure 26). Individuals ranged in size from 6 to 34 cm (disk width) in the winter survey with a broad size distribution (Figure 27). The size distribution in the VW1 Study Area was shifted slightly toward larger individuals, compared to the Control Area ($p < 0.0001$; Figure 28)

The condition of little skates was ~1.0 (i.e., average) during all seasons. No significant difference was observed between survey areas ($p = 0.1861$; Figure 29).

4.4.5 Atlantic Herring

Atlantic herring (*Clupea harengus*) were abundant during the winter survey. Catch rates during the winter survey averaged 56.7 ± 12.6 kg/tow in the VW1 Study Area and 82.4 ± 14.1 kg/tow in the Control Area ($p = 0.0177$; Figure 30). Atlantic herring were caught in all 20 tows in both the VW1 Study Area and the Control Area. The catch appeared to be distributed throughout both survey areas (Figure 31). Individuals ranged in length from 18 to 26 cm with a unimodal peak at 20 cm (Figure 32). The Atlantic herring population in the VW1 Study Area and Control Area appear to be very similar ($p = 0.228$; Figure 33).

The condition of Atlantic herring was not significantly different between survey areas ($p = 0.2685$). During the winter survey condition was ~1 (VW1 Study Area: 1.0 ± 0.08; Control Area: 1.01 ± 0.08; Figure 34).

4.4.6 Spiny Dogfish

Spiny dogfish (*Squalus acanthias*) was the fifth most abundant species observed in both the VW1 Study Area and Control Area accounting for 5.9% and 8.8% of the catch weight, respectively. Annually, catch rates averaged 12.5 ± 4.2 kg/tow (range: 0 – 225.7 kg/tow) in the VW1 Study Area and 27.8 ± 12.9 kg/tow (range: 0 – 698.5 kg/tow) in the Control Area ($p = 0.0328$). While spiny dogfish were an abundant species, there was a distinct seasonality to the catch ($p < 0.0001$). Spiny dogfish were primarily only observed during the fall survey. Annual catch rates were similar to 2020/2021 and lower than 2019/2020 (Figure 35).

The spiny dogfish catch rates were the highest during the fall survey, which included many of the largest aggregated tows of the year. The catch rate of spiny dogfish averaged 37.4 ± 10.7 kg/tow in the VW1 Study Area and 83.5 ± 36.2 kg/tow in the Control Area (Figure 35). Spiny dogfish were observed in all 20 tows in the VW1 Study Area and 19 of the 20 tows in the Control Area. The highest catches in the fall survey were observed in deeper waters along the southern boundary in both survey areas (Figure 36). Individuals ranged in length from 39 to 88 cm with a unimodal distribution consisting of a peak at 66 cm (Figure 37). The KDE analysis indicated that the size distribution in the VW1 Study Area was wider including larger individuals ($p < 0.0001$; Figure 38).

Only one spiny dogfish was caught during the summer survey in the VW1 Study Area. Five spiny dogfish were caught in the Control Area. No spiny dogfish were collected during the winter survey in either survey area.

The condition of spiny dogfish was not statistically different between survey areas ($p = 0.2112$) or seasons ($p = 0.9976$; Figure 39).

4.4.7 Red Hake

Red hake (*Urophycis chuss*) were consistently caught in the fall and summer surveys. Annually, catch rates averaged 11.2 ± 3.5 kg/tow (range: 0 – 167.0 kg/tow) in the VW1 Study Area and 8.5 ± 1.7 kg/tow (range: 0 – 57.9 kg/tow) in the Control Area. On average, annual and seasonal catch rates were lower than 2019/2020 but similar to the 2020-2021 survey year (Figure 40). The GLM analysis indicated season was a significant predictor of the catch with no significant survey area effect (season: $p = 0.0002$; area: $p < 0.1221$).

The catch of red hake exhibited a significant disparity between the two survey areas in the fall survey (VW1 Study Area: 6.7 ± 1.6 kg/tow; Control Area: 19.5 ± 3.7 kg/tow; Figure 40). Red hake were observed in 19 of the 20 tows in the VW1 Study Area and 18 of the 20 tows in the Control Area. The catch of red hake was distributed throughout both survey areas (Figure 41). Individuals ranged in length from 20 to 39 cm with a wide unimodal size distribution peaking between 28 and 30 cm (Figure 42). The population structure within the VW1 Study Area was shifted slightly toward larger individuals compared to the Control Area ($p < 0.0001$; Figure 43).

The catch of red hake exhibited the opposite disparity between the two survey areas in the summer survey (VW1 Study Area: 26.9 ± 9.5 kg/tow; Control Area: 6.1 ± 1.4 kg/tow; Figure 40). Red hake were observed in all 20 tows in the VW1 Study Area and 17 of the 20 tows in the Control Area. The catch of red hake was distributed throughout both survey areas with high catches observed in the center of the VW1 Study Area (Figure 41). Red hake had a broad size distribution ranging from 18 to 40 cm in length (Figure 42). The two survey areas had bimodal peaks at 24 cm and 30 cm with differing proportions between the two modes (p < 0.0001; Figure 43). The VW1 Study Area had a larger proportion of individuals at the smaller mode while the Control Area had more individuals at the larger mode.

During the winter survey, only 49 individuals were caught between five tows in the VW1 Study Area. One individual was caught in the Control Area.

Red hake displayed significant seasonal differences in condition (p = 0.0001; Figure 44). The condition was highest in the summer survey (VW1 Study Area: 1.04 ± 0.09; Control Area: 1.05 ± 0.10). The condition of fish was lower in the fall survey (VW1 Study Area: 0.99 ± 0.09; Control Area: 0.99 ± 0.08). No difference in fish condition was observed between the two survey areas (p = 0.1918).

4.4.8 Atlantic Longfin Squid

Atlantic longfin squid (*Doryteuthis pealei*), a commercially important species commonly called Loligo squid, was consistently caught in both survey areas during the summer and fall surveys. Annually, catch rates averaged 8.9 ± 1.3 kg/tow (range: 0 – 46.4 kg/tow) in the VW1 Study Area and 8.4 ± 2.1 kg/tow (range: 0 – 116.6 kg/tow) in the Control Area. The GLM analysis indicated that season was a significant predictor of catch rate (p = 0.0001) but not survey area (p = 0.9081). In general, the catch of Atlantic longfin squid was similar to the 2020/2021 survey year. Seasonally, the catch rates were similar between the fall of 2020 and 2021. Catch rates were lower in the summer 2022 survey compared to 2021 (Figure 45). No squid eggs (i.e., "squid mops") were observed during any of the surveys.

The catch of Atlantic longfin squid was highest during the summer survey. The seasonal catch averaged 12.3 ± 2.7 kg/tow in the VW1 Study Area and 16.0 ± 2.3 kg/tow in the Control Area (Figure 45). Atlantic longfin squid were caught in all 20 tows in the VW1 Study Area and 19 of the 20 tows in the Control Area. The catch was observed to be evenly distributed across both survey areas (Figure 46). Individuals ranged in length from 3 to 30 cm (mantle length) with a unimodal distribution peaking at 13 cm (Figure 47). The size structure of the VW1 Study Area was narrower than the Control Area (p = 0.0001; Figure 48).

The seasonal catch of longfin squid during the fall averaged 14.3 ± 1.3 kg/tow in the VW1 Study Area and 9.2 ± 2.0 kg/tow in the Control Area (Figure 45). Atlantic longfin squid were caught in all 20 tows in both the VW1 Study Area and the Control Area. The catch was distributed throughout both survey areas (Figure 46). Individuals ranged in length from 3 to 34 cm with a wide unimodal size distribution peak between 4 and 13 cm (Figure 47). The size distribution in the VW1 Study Area was observed to be shifted slightly toward smaller individuals compared to the Control Area ($p < 0.0001$; Figure 48)

Only two Atlantic longfin squid were caught during the winter survey.

Atlantic longfin squid displayed seasonal variations in condition ($p = 0.0001$; Figure 49). The condition was highest in the fall survey (VW1 Study Area: 1.08 ± 0.31; Control Area: 1.3 ± 0.24) and lowest in the summer survey (VW1 Study Area: 0.92 ± 0.17; Control Area: 0.96 ± 0.21). Atlantic longfin squid in the Control Area appeared to be in improved condition compared to the VW1 Study Area ($p = 0.0001$).

4.4.9 Silver Hake

Silver hake (*Merluccius bilinearis*), commonly referred to as whiting, is a commercially important species in the region. Annual catch rates averaged 8.2 ± 1.3 kg/tow (range: 0 – 37.0 kg/tow) in the VW1 Study Area and 8.9 ± 1.6 kg/tow (range: 0 – 68.3 kg/tow) in the Control Area. The GLM analysis indicated that the season was significant a predictor of the catch ($p < 0.0001$). No significant area effect was detected ($p = 0.8841$). During the 2019/2020 survey season, silver hake was the most consistent species caught in the survey with individuals present in 159 of the 160 tows conducted. The 2020/2021 survey season exhibited significantly lower catches with the average annual catch rate reduced 80% compared to 2019/2020 (Figure 50). The 2021/2022 data indicated further reductions, primarily associated with a reduced catch in the fall (Figure 50).

The silver hake catch was highest in the summer survey. Catch rates averaged 18.4 ± 2.4 kg/tow in the VW1 Study Area and 15.3 ± 4.1 kg/tow in the Control Area (Figure 50). Silver hake were observed in all 20 tows in the VW1 Study Area and the Control Area. The catch of silver hake was distributed throughout both survey areas (Figure 51). Individuals ranged in length from 14 to 40 cm with a unimodal peak at 22 and 20 cm in the VW1 Study Area and Control Area, respectively (Figure 52). The length distribution of silver hake was shifted slightly towards larger fish in the VW1 Study Area ($p = 0.0001$; Figure 53).

Significant amounts of silver hake were also caught during the fall survey. The catch of silver hake averaged 5.8 ± 0.9 kg/tow in the VW1 Study Area and 11.0 ± 1.4 kg/tow in the Control Area (Figure 50). Silver hake were observed in all 20 tows in both survey areas. The catch of silver hake was evenly distributed across both survey areas (Figure 51). Individuals ranged in length from 15 to 40 cm with unimodal peaks at 25 cm in both survey areas (Figure 52). The distribution of the catch was similar between survey areas with the VW1 Study Area catching slightly larger fish ($p = 0.0001$; Figure 53).

Low catches were observed in the winter survey, averaging 0.4 ± 0.1 kg/tow in the VW1 Study Area and 0.3 ± 0.1 kg/tow in the Control Area (Figure 50). Silver hake were observed in 19 of the 20 tows in the VW1 Study Area and 13 of the 20 tows in the Control Area. The catch of silver hake scattered across both survey areas (Figure 51). Silver hake caught in the winter survey were primarily small (Figure 52). Individuals ranged in length from 7 to 17 cm with peaks at 12 and 11 cm in the VW1 Study Area and Control Area, respectively. The population in the Control Area had a narrower distribution, and smaller size, compared to the VW1 Study Area ($p < 0.0001$; Figure 53).

Silver hake displayed significant seasonal and area differences in condition ($p = 0.0009$ and $p = 0.0001$, respectively; Figure 54). The condition of fish in the VW1 Study Area was ~1 during all the seasonal surveys. In the Control Area, the condition was highest in the winter (1.18 ± 0.2) and fall surveys (1.05 ± 0.1). The condition of fish in the Control Area during the summer survey was ~1.

4.4.10 Winter Skate

Winter skate (*Leucoraja ocellata*) were consistently caught during the fall survey. The seasonal catch rate averaging 8.6 ± 1.5 kg/tow in the VW1 Study Area and 6.9 ± 1.7 kg/tow in the Control Area (Figure 55). Winter skates were caught in 16 of the 20 tows in the VW1 Study Area and 14 of the 20 tows in the Control Area. The catch of winter skate was distributed throughout both survey areas (Figure 56). Winter skates had a wide size distribution ranging from 21 to 60 cm in length (disk width; Figure 57). The size distribution of winter skates was slightly larger in the VW1 Study Area compared to the Control Area ($p = 0.0001$; Figure 58).

No winter skates were caught in the winter survey. Two winter skates were caught in the summer survey, one in the VW1 Study Area and one in the Control Area.

There was no significant difference in the condition of winter skates between the two survey areas (p = 0.1351; Figure 59).

4.4.11 Northern Sea Robin

Northern sea robin (*Prionotus carolinus*) were commonly caught during the fall survey. Seasonally, catch rates averaged 6.0 ± 1.2 kg/tow in the VW1 Study Area and 7.7 ± 1.8 kg/tow in the Control Area (Figure 60). Northern sea robins were observed in all 20 tows in the VW1 Study Area and 19 of the 20 tows in the Control Area. The catch of northern sea robins appeared to correlate with depth as the catch increased toward the southern boundary (Figure 61). Individuals ranged in length from 8 to 34 cm with the majority of individuals between 20 to 30 cm (Figure 62). Smaller sea robins were observed in the Control Area (p = 0.0001; Figure 63).

The catch of northern sea robin in the Control Area during the summer survey was 0.7 ± 0.3 kg/tow. This contrasts with a relatively low catch in the VW1 Study Area (0.1 ± 0.006 kg/tow; Figure 60). Only eight individuals were caught in the VW1 Study Area in three tows. Northern sea robin were observed in 7 of the 20 tows in the Control Area. The catch in the Control Area was primarily observed in the center of the study area (Figure 61). Individuals ranged in length from 20 to 31 cm with a unimodal peak around 27 cm (Figure 62). The population of northern sea robin was similar between the two survey areas ($p < 0.096$; Figure 63).

No northern sea robins were collected during the winter survey.

Northern sea robins in the Control Area appeared to be in slightly higher condition than those in the VW1 Study Area during the fall survey (VW1 Study Area: 0.97 ± 0.1; Control Area: 1.03 ± 0.1; p = 0.0001; Figure 64).

4.4.12 Fourspot flounder

Fourspot flounder (*Paralichthys oblongus*) was the most common flatfish species observed during the survey. Fourspot flounder were frequently observed in the summer and fall surveys. Annually, catch rates averaged 0.9 ± 0.2 kg/tow (range: 0 – 5.1 kg/tow) in the VW1 Study Area and 1.4 ±

0.2 kg/tow (range: 0 – 7.1 kg/tow) in the Control Area. The GLM analysis indicated that season and survey area were significant predictors of catch rate (season: p = 0.0001; area: p = 0.0226; Figure 65). Catch rates were similar between 2021/2022 and 2020/2021. However, the 2020/2021 catch rates were ~30% lower compared to the 2019/2020 survey year (Figure 65).

The catch rate of fourspot flounder during the summer survey was 2.1 ± 0.3 kg/tow in the VW1 Study Area and 1.9 ± 0.4 kg/tow in the Control Area (Figure 65). Fourspot flounder were caught in every tow in both survey areas. The catch was observed to be distributed throughout both survey areas (Figure 66). Individuals ranged in length from 17 to 38 cm with unimodal peaks at 28 cm (Figure 67). The size structure of the population was nearly identical between survey areas (p = 0.841; Figure 68).

Significant disparities in the catch rate of fourspot flounder between survey areas were observed in the fall survey. Seasonally, catch rates averaged 0.6 ± 0.1 kg/tow in the VW1 Study Area and 2.3 ± 0.4 kg/tow in the Control Area (Figure 65). Fourspot flounder were caught in 14 of the 20 tows in the VW1 Study Area and 19 of the 20 tows in the Control Area. The catch was distributed across the survey areas (Figure 66). Individuals ranged in length from 12 to 42 cm (Figure 67). The population structure in the VW1 Study Area was comprised of more small fish, compared to the Control Area, however, due to the variation in the data this was not statistically different (p = 0.112; Figure 68).

No fourspot flounder were collected during the winter survey.

Fourspot flounder exhibited seasonal variations in condition (p = 0.0001; Figure 69). The condition of fourspot flounder was highest in Control Area during the fall survey (VW1 Study Area: 0.99 ± 0.1; Control Area: 1.07 ± 0.1). The condition of fish was ~1 during the summer survey. No significant difference was observed between areas (p = 0.1029).

4.4.13 Summer Flounder

Summer flounder (*Paralichthys dentatus*), also known as fluke, is a commercially important flatfish that was commonly observed during the surveys. Summer flounder were frequently observed during the fall survey. The catch of summer flounder was significantly lower than in previous survey years, primarily due to the low catches observed in the summer survey (Figure 70). Catch rates during the fall and winter surveys were similar to previous years.

The highest catch rates of summer flounder were observed during the fall survey (VW1 Study Area: 1.8 ± 0.3 kg/tow; Control Area: 1.8 ± 0.3 kg/tow; Figure 70). Summer flounder were observed in 16 of the 20 tows in the VW1 Study Area and 18 of the 20 tows in the Control Area. The catch of summer flounder appeared to be distributed across both survey areas (Figure 71). Individuals ranged in size from 29 to 68 cm with a broad size distribution (Figure 72). No significant difference was observed in the size distribution between survey areas ($p = 0.662$; Figure 73).

Two summer flounder were caught during the summer survey, one in the VW1 Study Area and one in the Control Area. Only one summer flounder was observed in the winter survey, occurring in the VW1 Study Area.

The condition of summer flounder was observed to be close to 1 during the fall survey with no significant difference between survey areas ($p = 0.4691$; Figure 74).

4.4.14 Windowpane Flounder

Windowpane flounder (*Scophtalmus aquosus*), also known as sand dab, is a federally regulated groundfish. Windowpane flounder were observed in low abundances in all surveys and both survey areas. Annually, catch rates averaged 0.6 ± 0.1 kg/tow (range: 0 – 4.7 kg/tow) in the VW1 Study Area and 2.4 ± 0.7 kg/tow (range: 0 – 21.7 kg/tow) in the Control Area. The GLM analysis indicated that season and survey area were significant predictors of catch rate (season: $p = 0.0001$; area: $p = 0.0005$). Seasonal trends were similar between the 2020/2021 and 2021/2022 survey years with the highest catches observed in the fall survey, followed by the summer survey. Catch rates were low in the winter surveys.

The highest catch rates of windowpane flounder were observed during the fall survey (VW1 Study Area: 1.7 ± 0.3 kg/tow; Control Area: 6.8 ± 1.6 kg/tow; Figure 75). Windowpane flounder were observed in all 20 tows in both survey areas with higher catches collected in the northern half of the Control Area (Figure 76). Windowpane flounder ranged in length from 12 to 31 cm with a unimodal peak at around 24 cm (Figure 77). The population of windowpane flounder in the VW1

Study Area primarily consisted of larger individuals, 20 – 30 cm, compared to a wider distribution in the Control Area (Figure 78).

Catch rates during the summer survey averaged 0.1 ± 0.04 kg/tow in the VW1 Study Area and 0.2 ± 0.1 kg/tow in the Control Area (Figure 75). Nine individuals were collected in 5 of the 20 tows in the VW1 Study Area. Twenty-five individuals were collected in 5 of the 20 tows in the Control Area. All individuals were caught in the northern half of the survey areas (Figure 76). Windowpane flounder ranged in length from 11 to 30 cm (Figure 77). The populations in the two survey areas were not significantly different (p = 0.714; Figure 78).

Catch rates were low during the winter survey, averaging 0.07 ± 0.02 kg/tow in the VW1 Study Area and 0.08 ± 0.02 kg/tow in the Control Area (Figure 75). Thirteen individuals were collected in 9 of the 20 tows in the VW1 Study Area. Eighteen individuals were collected in 10 of the 20 tows in the Control Area. The catch of windowpane flounder was scattered across both development areas (Figure 76). Windowpane flounder ranged in length from 12 to 28 cm with a broad size distribution (Figure 77). The size structure within the two survey areas was not significantly different (p = 0.686; Figure 78).

Windowpane flounder exhibited seasonal and survey area variations in condition (p = 0.0366 and 0.0057, respectively; Figure 79). The condition of windowpane flounder was variable between seasons and survey areas. In general, the condition of windowpane flounder was higher in the Control Area (1.02 ± 0.1) compared to the VW1 Study Area (1.0 ± 0.1; p = 0.0057; Figure 79).

4.4.15 Atlantic Cod

Atlantic cod (*Gadus morhua*) were caught during the winter survey. The seasonal catch rate in the winter survey averaged 1.3 ± 0.4 kg/tow (range: 0 – 6.6 kg/tow) in the VW1 Study Area and 2.0 ± 0.5 kg/tow (range: 0 – 9.1 kg/tow) in the Control Area (Figure 80). Twenty-eight individuals were caught in 13 of the 20 tows in the VW1 Study Area. Forty-three individuals were caught in 18 of the 20 tows in the Control Area. Cod were caught throughout the survey areas (Figure 81). Individuals ranged in size from 19 to 63 cm with a wide size distribution (Figure 82). No significant differences in the population structure were observed between the survey areas (p = 0.938; Figure 83). No significant differences were observed in the condition of fish between the survey areas (p = 0.1852; Figure 84).

4.4.16 Alewife

Alewife (*Alosa pseudoharengus*) were consistently caught in both survey areas in the winter surveys with sporadic captures in the summer and fall surveys. Annually, catch rates averaged 0.4 ± 0.1 kg/tow (range: 0 – 4.0 kg/tow) in the VW1 Study Area and 0.6 ± 0.2 kg/tow (range: 0 – 8.1 kg/tow) in the Control Area. Catch rates have varied between years with higher catch rates observed in the winter of 2022 compared to the winter of 2021, but lower than in the winter 2020 survey (Figure 85). The GLM analysis indicated that season was a significant predictor of catch rate with a moderate survey area effect (season: p = 0.0001; area: p = 0.0702).

The catch rate of alewife was highest in the winter survey. Seasonally, catch rates averaged 1.2 ± 0.3 kg/tow in the VW1 Study Area and 1.8 ± 0.5 kg/tow in the Control Area (Figure 85). Alewife were caught in 19 of the 20 tows in the VW1 Study Area and 18 of the 20 tows in the Control Area. The catch of alewife was distributed across both survey areas (Figure 86). Individuals ranged in size from 12 to 28 cm (Figure 87). No significant differences were observed in the population structure between the survey areas (p = 0.461; Figure 88).

One alewife was caught in the VW1 Study Area during the summer survey. No alewife were collected in the VW1 Study Area during the fall survey. In the Control Area, four alewife were caught in two tows in during the fall survey. An additional three alewife were caught in the Control Area during the summer survey.

The condition of alewife was observed to be higher in the Control Area (1.06 ± 0.1) compared to the VW1 Study Area for the winter survey (0.98 ± 0.13; p = 0.0005; Figure 89).

4.4.17 Black Sea Bass

Black sea bass (*Centropristis striata*) is another commercially important species in the region. Black sea bass were commonly observed during the fall survey. During the fall survey, catch rates of black sea bass averaged 1.3 ± 0.2 kg/tow in the VW1 Study Area and 0.9 ± 0.3 kg/tow in the Control Area (p = 0.0748; Figure 90). Black sea bass were observed in 19 of the 20 tows in the VW1 Study Area and 15 of the 20 tows in the Control Area. The catch was observed to be scattered across the survey areas (Figure 91). Individuals ranged in length from 5 to 34 cm with a broad size distribution (Figure 92). The population structure in the survey areas was significantly different (p = 0.0001; Figure 93). Individuals in the VW1 Study Area were primarily associated with a unimodal peak around 26 cm. The population in the Control Area exhibited a bimodal distribution with peaks 5 cm and 25 cm (Figure 93).

Only one black sea bass was caught during the summer survey, which occurred in the VW1 Study Area. No black sea bass were caught during the winter survey.

The condition of black sea bass was observed to be higher in the Control Area (1.06 ± 0.2) compared to the VW1 Study Area (1.0 ± 0.08; p = 0.0129; Figure 94).

4.4.18 Winter Flounder

Winter flounder (*Pseudopleuronectes americanus*), also known as blackback flounder, is a federally regulated groundfish commonly caught at low levels during the summer and fall surveys. Annually, catch rates average 0.3 ± 0.1 kg/tow (range: 0 – 2.2 kg/tow) in the VW1 Study Area and 0.4 ± 0.1 kg/tow (range: 0 – 3.4 kg/tow) in the Control Area (Figure 95). The GLM analysis indicated that season was significant a predictor of catch rate and with no significant difference between survey areas (season: p = 0.0001; area: p = 0.4567).

Catch rates were highest during the fall survey, averaging 0.8 ± 0.2 kg/tow in the VW1 Study Area and 0.9 ± 0.2 kg/tow in the Control Area (Figure 95). Winter flounder were caught in 14 of the 20 tows in the VW1 Study Area and 16 of the 20 tows in the Control Area. The catch was distributed throughout the two survey areas with the highest catches located in the northern half of the survey areas (Figure 96). Winter flounder ranged in length from 20 to 48 cm (Figure 97). Individuals in the VW1 Study Area were generally smaller with a concentration of length around 23 cm (p = 0.0001; Figure 98). Individuals in the Control Area were generally larger with a wider distribution (Figure 98).

Catch rates during the summer survey averaged 0.2 ± 0.1 kg/tow in the VW1 Study Area and 0.4 ± 0.1 kg/tow in the Control Area (Figure 95). Winter flounder were observed in 13 of the 20 tows in the VW1 Study Area and 10 of the 20 tows in the Control Area. The catch was primarily concentrated in the northern half of the survey areas (Figure 96). Individuals ranged from 14 to 39 cm in length (Figure 97). No significant difference in the population structure was observed between the two survey areas (p = 0.197; Figure 98).

Three individuals were caught during the winter survey. Two individuals were caught in the VW1 Study Area, and one individual was caught in the Control Area.

No significant differences were observed in fish condition between seasons or areas (p = 0.1066 and p = 0.4326, respectively; Figure 99).

4.4.19 Other Commercial Species or Species of Interest

Eight yellowtail flounder (*Pleuronectes ferrugineus*) were caught over the duration of the survey year. Yellowtail flounder is a federally regulated groundfish. Seven individuals were caught in the VW1 Study Area. One yellowtail flounder were caught in the Control Area. Individuals ranged in length from 20 to 27 cm.

Seven monkfish (*Lophius americanus*) were caught over the duration of the survey year. Monkfish are a commercially important, and federally regulated groundfish. Three individuals were caught in the VW1 Study Area. Four monkfish were caught in the Control Area. Individuals ranged in length from 26 to 76 cm.

Two bluefish (*Pomatomus saltatrix*) were caught during the summer and fall surveys. One individual during the fall survey in the VW1 Study Area (22 cm). One individual was caught during the summer survey in the Control Area (66 cm).

American lobster (*Homarus americanus*) is a commercially important crustacean that was occasionally caught in the summer survey in both survey areas. Annually, the total catch of lobster was 0.6 kg in the VW1 Study Area, which consisted of two individuals. The total catch of lobster in the Control Area was 1.1 kg, which consisted of four individuals.

Atlantic sea scallop (*Placopecten magellanicus*) is a commercially important shellfish species that was caught in both survey areas. 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 1.9 kg in the VW1 Study Area, which consisted of 12 individuals. The total catch of scallops in the Control Area was 0.8 kg, which consisted of seven individuals.

Eleven northern kingfish (*Menticirrhus saxatilis*) were caught during the fall survey. Five individuals were caught in the VW1 Study Area, and six individuals were caught in the Control Area. Individuals ranged in length from 24 to 35 cm.

Eleven weakfish (*Cynoscion regalis*) were caught during the fall survey. One individual was caught in the VW1 Study Area, and 10 individuals were caught in the Control Area. Individuals ranged in length from 18 to 44 cm.

Two haddock (*Melanogrammus aeglefinus*) were caught in the Control Area during the fall survey. Individuals were 14 and 20 cm.

Two roughtail stingrays (*Dasyatis cantroura*) were caught in the Control Area during the summer survey. The animals were estimated to be ~1.5 m long (disk width). The stingrays were immediately returned to the sea and were observed to swim away.

4.5 Community Structure

The community structure within the VW1 Study Area and Control Area displayed seasonal changes in species composition throughout the 2021/2022 survey year. The ANOSIM test yielded an R statistic of 0.779 when assessing the similarities between seasons (Figure 100). The R statistic can range from 0, indicating no difference in species composition, to 1, which would indicate a clear separation between seasons. The separation in seasons was very similar to that observed in the previous survey years (Figure 101).

Pairwise tests indicate that the winter survey had a clear difference in species composition compared to the summer and fall surveys (R = 0.999 and 1.0, respectively). Winter tows were primarily associated with Atlantic herring, little skate, and alewife. The winter 2022 survey showed a strong similarity to the winter 2020 and 2021 surveys (R = 0.469 and 0.184, respectively; Figure 101).

In general, the summer and fall surveys exhibited more similarities between each other (R = 0.69; Figure 100). The fall survey exhibited the highest similarity between tows and was associated with scup, little skate, spiny dogfish, butterfish, and Atlantic longfin squid. The fall 2021 survey showed a strong similarity to the fall 2019 and 2020 surveys (R = 0.4 and 0.161, respectively; Figure 101).

Conversely, summer survey tows had the highest dissimilarities between individual tows and were associated with butterfish, little skate, silver hake, and Atlantic longfin squid. The summer 2022 survey was moderately distinct from the summer 2019 and 2020 surveys (R = 0.534 and 0.768; Figure 101) indicating annual variations in catch composition. While the timing of the surveys has been similar between years, the bottom water temperature during the summer surveys was shown to exhibit significant interannual variations which may alter the species composition (Figure 11).

The community structure between the two survey areas was observed to be very similar, yielding an R statistic of 0.141 (Figure 102). The species with the highest similarities between survey areas were little skate, silver hake, butterfish, red hake, Atlantic herring, scup, and Atlantic longfin squid. The nMDS plot shows no distinct clustering of points related to the survey areas (Figure 102).

In summary, each season exhibits a distinct species assemblage. The winter survey is the most distinct but exhibited strong similarity between survey years. The fall survey, while distinct, showed some similarities to the summer survey and previous spring surveys. The fall survey also exhibited strong consistency between survey years. The summer survey and previous spring surveys were unique and exhibited significant inter-annual differences.

4.6 Power Analysis

Catch data collected over multiple survey years (2019 – 2022) exhibited a high level of variability resulting in CVs ranging from 1.15 (little skate) to 20.95 (American plaice [*Hippoglossoides platessoides*]; Table 7). 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 year was used to update the power analysis presented in the previous annual reports (Rillahan and He, 2020; Rillahan and He, 2021).

The results of the power analysis indicated that several species, including little skate, Atlantic longfin squid, and fourspot flounder, had relatively low variability (CV: ~1) and therefore a high probability of detecting a small to moderate change. Detecting a 25% change in the two areas, with 80% confidence, would require 149 – 425 tows per area, which under the current sampling intensity (80 tows/area/year) would require about three years of sampling before and after impact. 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 tenfold (1,863 – 3,175 tows per area; Figure 103). Incorporating the 2021/2022 survey year data into the power analysis resulted in slight changes to the variability depending on individual species.

Many of the common species observed, including winter skate, silver hake, red hake, windowpane flounder, monkfish, summer flounder, scup, winter flounder, and butterfish, had CVs between 1.8 and 3.0. These species would have a high probability of detecting a moderate change (i.e., 30 – 50% change). Detecting a 50% change in the two survey areas, with 80% confidence, would require 109 – 288 tows per area, which under the current sampling intensity (80 tows/area/year) would require two to three years of sampling before and after impact. To detect a 25% change, sampling would have to be increased to 634 – 1,673 tows. Incorporating an additional year of data had mixed effects on this group with most changes in the CVs being moderate.

Spiny dogfish, Atlantic herring, Atlantic cod, alewife, blueback herring, and yellowtail flounder exhibited strong seasonality, which led to high variability (CVs: 3.0 – 6). These species would have a high probability of detecting moderate to large changes (i.e., 50 – 75% change). Detecting a 75% change in the two survey areas, with 80% confidence, would require 77 – 284 tows per area, which under the current sampling intensity (80 tows/area/year) would require one to two years of sampling before and after impact. To detect a 50% change, sampling would have to be increased to 311 – 1,136 tows. To detect a 25% change, sampling would have to be increased to 1,810 – 6,599 tows.

The current sampling effort has the statistical power to detect a complete disappearance of every species observed from either survey area (i.e., 100% change). The relationship between power and the sample size for the 10 most abundant species, by weight, can be found in Figures 104 – 113.

5. Discussion

Three 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. This collection of surveys will serve as the third and final year of pre-construction baseline data that will be used in the BACI analysis. The current survey methodology has proven to be effective in collecting high-quality data relevant to fish abundance, population structure, and community assemblages. Modification to this year's survey methodology included the reduction of the VW1 Study Area after the fall survey from 306 to 265 km^2 (89 to 77 nmi^2) due to boundary refinements and segregation of the lease areas into OCS-A 0501 and OCS-A 0534. Additionally, the Control Area was similarly modified from the 2020/2021 survey year for the winter and summer surveys to align with the aforementioned changes to the VW1 Study Area. These changes decreased the Control Area from 324 to 269.5 km^2 (94.5 to 269.5 nmi^2).

In general, the data collected during the 2021/2022 survey year were similar to that in the previous survey years. While the surveys revealed high species diversity in both survey areas, documenting a total of 40 species, the majority of the catch was comprised of a small number of dominant species. Butterfish, scup, little skate, Atlantic herring, and spiny dogfish were the five most abundant species in the VW1 Study Area and Control Area accounting for 81.4% and 87.4% of the total catch weight, respectively. Interannual changes in abundance varied amongst species. For example, butterfish, scup, and Atlantic herring exhibited increases in annual average catch rates. Conversely, spiny dogfish, winter skate, summer flounder, and little skate exhibited decreased annual catch rates. Atlantic longfin squid and silver hake remained similar between years.

These survey areas are dynamic with seasonal changes in species assemblages, abundances, and population structures. The seasonal changes were largely in line with those observed in the previous survey year. Species composition during the fall and winter surveys showed strong similarity to that observed in the same surveys in 2019/2020 and 2020/2021. The summer survey exhibited significant variations in the community composition compared to the same seasons in 2019 and 2020. The changes in species composition may be linked to changing seasonal water temperatures. Bottom water temperature has remained relatively consistent annually across the fall and winter surveys (Figure 11). Conversely, bottom water temperature during the summer surveys has varied several degrees annually. In 2020, the summer bottom water temperature was 5^{o}C 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. Summer bottom water temperature in 2022 was intermediate to the two previous surveys.

The updated power analysis, using the collected data from two 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. Common species, including little skate and Atlantic longfin squid, exhibited low variability resulting in the projected ability to detect a 25% change in abundance or greater. Most commercial species, including summer flounder, black sea bass, and silver hake, exhibited modest variability. The current sampling effort should be able to detect 30 – 40% changes in abundance.

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

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)	Bottom Temp. (°C)	Trawl Warp (fm)
1	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	7:05	N 41° 04.205	W 70° 34.408	23	7:25	N 41° 03.409	W 70° 33.873	23	14.8	100
2	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	8:25	N 41° 02.248	W 70° 34.735	24	8:45	N 41° 01.462	W 70° 35.333	25	15.1	100
3	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	9:31	N 41° 01.007	W 70° 36.101	25	9:51	N 41° 00.180	W 70° 36.543	26	14.8	100
4	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	10:36	N 40° 59.881	W 70° 35.938	26	10:56	N 40° 59.261	W 70° 34.929	27	15.1	100
5	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	12:08	N 40° 57.655	W 70° 31.175	27	12:28	N 40° 57.664	W 70° 29.803	26		100
6	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	13:27	N 40° 57.865	W 70° 31.532	26	13:50	N 40° 57.892	W 70° 32.705	27	14.8	100
7	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	14:38	N 40° 59.721	W 70° 32.573	27	14:58	N 41° 00.644	W 70° 32.597	27	15.0	100
8	VW1	11/9/2021	Clear	7-10	WSW	0.5-1.25	15:49	N 40° 59.682	W 70° 30.477	26	16:09	N 40° 59.925	W 70° 29.303	24	14.9	100
9	VW1	11/10/2021	Partly Cloudy	7-10	WSW	0.5-1.25	6:40	N 40° 57.154	W 70° 28.681	25	7:00	N 40° 57.216	W 70° 29.924	25	14.2	100
10	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	7:52	N 40° 55.039	W 70° 29.121	26	8:12	N 40° 54.136	W 70° 28.799	27	14.5	120
11	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	9:30	N 40° 51.940	W 70° 25.523	28	9:50	N 40° 51.397	W 70° 24.312	28	14.4	120
12	Control	11/10/2021	Partly Cloudy	7-10	w	0.5-1.25	10:45	N 40° 51.563	W 70° 23.732	28	11:05	N 40° 51.652	W 70° 22.339	27	14.5	120
13	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	12:00	N 40° 52.788	W 70° 22.313	26	12:21	N 40° 53.679	W 70° 22.854	26	14.4	100
14	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	13:03	N 40° 55.053	W 70° 18.800	23	13:23	N 40° 55.434	W 70° 17.665	22	14.4	100
15	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	14:10	N 40° 55.944	W 70° 16.071	21	14:30	N 40° 56.708	W 70° 16.797	21	14.0	100
16	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	15:17	N 40° 58.620	W 70° 15.812	19	15:37	N 40° 59.460	W 70° 15.404	18	13.7	100
17	Control	11/10/2021	Partly Cloudy	7-10	W	0.5-1.25	16:30	N 40° 59.667	W 70° 17.866	21	16:50	N 40° 59.621	W 70° 19.083	22	14.5	100
18	Control	11/11/2021	Clear	7-10	N	0.5-1.25	6:40	N 41° 01.791	W 70° 17.909	20	7:00	N 41° 02.676	W 70° 18.221	19	14.2	100
19	Control	11/11/2021	Clear	7-10	N	0.5-1.25	8:01	N 41° 02.703	W 70° 19.635	20	8:21	N 41° 02.757	W 70° 20.907	21	14.5	100
20	Control	11/11/2021	Clear	7-10	N	0.5-1.25	9:10	N 41° 04.584	W 70° 21.308	22	9:30	N 41° 05.562	W 70° 21.338	22	14.0	100
21	VW1	11/11/2021	Clear	7-10	N	0.5-1.25	10:12	N 41° 05.636	W 70° 23.566	21	10:32	N 41° 05.725	W 70° 24.735	22	14.5	95
22	VW1	11/11/2021	Clear	7-10	N	0.5-1.25	11:20	N 41° 06.973	W 70° 25.534	22	11:40	N 41° 07.803	W 70° 25.963	21	14.6	95
23	VW1	11/11/2021	Clear	3-6	N	0.5-1.25	12:24	N 41° 6.861	W 70° 23.297	21	12:44	N 41° 06.337	W 70° 28.270	22	14.6	95
24	VW1	11/11/2021	Clear	3-6	N	0.5-1.25	13:27	N 41° 05.921	W 70° 28.116	22	13:47	N 41° 05.025	W 70° 27.698	22	14.9	100
25	VW1	11/11/2021	Clear	3-6	N	0.5-1.25	14:40	N 41° 04.919	W 70° 30.265	23	15:00	N 41° 05.554	W 70° 31.177	23	15.0	100
26	VW1	11/11/2021	Clear	3-6	N	0.5-1.25	15:49	N 41° 04.291	W 70° 30.891	23	16:09	N 41° 03.385	W 70° 30.726	23	14.9	100
27	Control	11/20/2021	Clear	11-15	N	0.5-1.25	9:13	N 40° 53.965	W 70° 27.594	27	9:33	N 40° 53.491	W 70° 25.310	26	13.6	120
28	Control	11/20/2021	Partly Cloudy	7-10	N	0.5-1.25	10:17	N 40° 56.085	W 70° 25.021	25	10:37	N 40° 57.949	W 70° 26.199	23	13.4	100
29	VW1	11/20/2021	Partly Cloudy	7-10	N	0.5-1.25	11:21	N 40° 58.849	W 70° 26.115	24	11:41	N 40° 59.802	W 70° 25.898	23	13.6	100
30	VW1	11/20/2021	Clear	7-10	N	0.5-1.25	12:26	N 41° 01.220	W 70° 28.581	23	12:46	N 41° 01.704	W 70° 29.581	24	13.5	100
31	VW1	11/20/2021	Clear	3-6	N	0.5-1.25	13:25	N 41° 02.330	W 70° 27.487	22	13:45	N 41° 02.693	W 70° 26.344	21	13.4	100
32	VW1	11/20/2021	Clear	3-6	N	0.5-1.25	14:16	N 41° 01.950	W 70° 23.931	22	14:36	N 41° 02.647	W 70° 23.103	21	13.3	100
33	VW1	11/20/2021	Partly Cloudy	3-6	N	0.5-1.25	15:08	N 41° 02.154	W 70° 23.494	22	15:28	N 41° 01.198	W 70° 23.675	22	13.3	95
34	Control	11/20/2021	Partly Cloudy	3-6	N	0.5-1.25	16:04	N 40° 59.512	W 70° 24.276	23	16:24	N 40° 59.515	W 70° 23.057	21	13.5	100
35	Control	11/22/2021	Overcast	11-15	S	1.25-2.5	6:34	N 40° 55.395	W 70° 23.478	24	6:54	N 40° 55.807	W 70° 22.355	24	13.4	100
36	Control	11/22/2021	Mostly Cloudy	16-20	S	1.25-2.5	7:45	N 40° 55.887	W 70° 22.152	24	8:05	N 40° 56.361	W 70° 23.169	25	13.4	100
37	Control	11/22/2021	Overcast	16-20	S	1.25-2.5	8:47	N 40° 57.909	W 70° 23.425	24	9:07	N 40° 58.084	W 70° 22.096	24	13.3	100
38	Control	11/22/2021	Overcast	16-20	S	1.25-2.5	9:44	N 40° 58.942	W 70° 21.758	23	10:04	N 40° 59.866	W 70° 21.884	21	13.4	100
39	Control	11/22/2021	Overcast	11-15	S	1.25-2.5	10:42	N 41° 00.000	W 70° 21.475	21	11:02	N 40° 59.945	W 70° 20.172	22	13.4	95
40	Control	11/22/2021	Overcast	11-15	S	1.25-2.5	11:38	N 40° 58.851	W 70° 19.856	23	11:58	N 40° 58.953	W 70° 20.095	23	13.3	100

Note: fm = fathom

Table 2: Operational and environmental conditions for each tow during the winter survey.

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)	Bottom Temp. (°C)	Trawl Warp (fm)
1	VW1	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	7:15	N 41° 01.691	W 70° 36.987	26	7:35	N 41° 01.685	W 70° 35.652	25	5.0	100
2	VW1	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	8:23	N 41° 01.598	W 70° 35.436	26	8:43	N 41° 01.066	W 70° 34.288	25	4.9	100
3	VW1	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	9:27	N 40° 59.404	W 70° 31.259	27	9:47	N 40° 58.819	W 70° 30.241	25	3.4	100
4	VW1	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	10:21	N 40° 57.826	W 70° 28.931	25	10:41	N 40° 57.262	W 70° 26.896	24	3.5	100
5	VW1	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	11:03	N 40° 57.477	W 70° 27.204	24	11:23	N 40° 58.398	W 70° 27.630	25	3.4	100
6	Control	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	12:01	N 40° 56.322	W 70° 26.404	25	12:21	N 40° 55.679	W 70° 27.487	26	3.5	100
7	Control	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	12:51	N 40° 55.171	W 70° 27.228	26	13:11	N 40° 54.982	W 70° 26.044	26	3.5	100
8	Control	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	13:44	N 40° 55.376	W 70° 25.281	25	14:04	N 40° 56.337	W 70° 25.416	25	3.6	100
9	Control	2/1/2022	Partly Cloudy	16-20	NE	1.25-2.5	14:36	N 40° 55.765	W 70° 24.667	25	14:56	N 40° 55.156	W 70° 23.776	25	3.8	100
10	Control	2/1/2022	Partly Cloudy	16-20	NE	1.25-2.5	15:26	N 40° 53.365	W 70° 25.077	26	15:46	N 40° 52.362	W 70° 25.715	27	3.9	100
11	Control	2/1/2022	Mostly Cloudy	16-20	NE	1.25-2.5	16:26	N 40° 52.639	W 70° 23.789	27	16:46	N 40° 52.835	W 70° 22.661	26	7.1	100
12	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	7:07	N 40° 53.253	W 70° 21.321	25	7:27	N 40° 53.932	W 70° 22.265	26	5.0	100
13	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	8:18	N 40° 55.181	W 70° 22.151	24	8:38	N 40° 55.158	W 70° 20.908	24	4.9	100
14	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	9:08	N 40° 55.120	W 70° 20.212	24	9:28	N 40° 54.416	W 70° 19.380	24	4.9	100
15	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	9:57	N 40° 54.300	W 70° 17.925	24	10:17	N 40° 55.252	W 70° 17.924	22	4.7	100
16	Control	2/2/2022	Rain	7-10	E	1.25-2.5	10:46	N 40° 56.111	W 70° 15.467	21	11:06	N 40° 57.017	W 70° 15.603	20	4.7	100
17	Control	2/2/2022	Rain	7-10	E	1.25-2.5	11:31	N 40° 57.226	W 70° 17.810	21	11:51	N 40° 58.118	W 70° 18.248	22	5.2	100
18	Control	2/2/2022	Overcast	7-10	E	1.25-2.5	12:31	N 40° 59.552	W 70° 16.036	19	12:51	N 41° 00.244	W 70° 16.834	19		95
19	Control	2/2/2022	Overcast	7-10	E	1.25-2.5	13:26	N 41° 00.495	W 70° 15.818	18	13:46	N 41° 00.531	W 70° 17.122	20	4.0	95
20	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	14:13	N 41° 00.619	W 70° 18.478	21	14:33	N 41° 00.766	W 70° 19.853	22	4.0	100
21	Control	2/2/2022	Mostly Cloudy	7-10	E	1.25-2.5	15:05	N 41° 01.205	W 70° 22.693	22	15:25	N 41° 01.075	W 70° 21.518	22	3.8	100
22	Control	2/2/2022	Overcast	7-10	E	1.25-2.5	15:53	N 41° 01.659	W 70° 21.538	22	16:13	N 41° 02.519	W 70° 21.032	22	3.8	100
23	VW1	2/6/2022	Clear	11-15	N	1.25-2.5	7:28	N 41° 04.066	W 70° 32.826	24	7:48	N 41° 03.165	W 70° 33.222	25		100
24	VW1	2/6/2022	Clear	11-15	N	1.25-2.5	8:23	N 41° 04.109	W 70° 12.855	24	8:43	N 41° 04.746	W 70° 31.966	24	2.9	100
25	VW1	2/6/2022	Clear	11-15	N	1.25-2.5	9:17	N 41° 05.419	W 70° 31.306	23	9:37	N 41° 06.294	W 70° 30.815	23	2.7	100
26	VW1	2/6/2022	Partly Cloudy	7-10	N	0.5-1.25	10:15	N 41° 07.725	W 70° 27.494	21	10:35	N 41° 08.174	W 70° 26.394	21	2.9	95
27	VW1	2/6/2022	Clear	7-10	N	0.5-1.25	11:01	N 41° 07.563	W 70° 26.053	21	11:21	N 41° 06.601	W 70° 26.086	23	3.2	95
28	VW1	2/6/2022	Clear	3-6	N	0.5-1.25	11:50	N 41° 05.421	W 70° 27.421	22	12:10	N 41° 04.751	W 70° 28.267	22	3.2	100
29	VW1	2/6/2022	Partly Cloudy	3-6	N	0.5-1.25	12:37	N 41° 04.694	W 70° 25.607	23	12:57	N 41° 04.709	W 70° 24.331	22	3.7	100
30	VW1	2/6/2022	Partly Cloudy	3-6	N	0.5-1.25	13:36	N 41° 03.362	W 70° 25.751	24	13:56	N 41° 02.576	W 70° 26.439	22	3.9	100
31	VW1	2/6/2022	Partly Cloudy	3-6	N	0.5-1.25	14:24	N 41° 01.836	W 70° 26.776	22	14:44	N 41° 00.950	W 70° 27.293	23	3.7	100
32	VW1	2/6/2022	Partly Cloudy	7-10	N	0.5-1.25	15:18	N 41° 01.483	W 70° 25.381	23	15:38	N 41° 01.811	W 70° 24.158	23	3.8	100
33	VW1	2/6/2022	Partly Cloudy	7-10	E	0.5-1.25	16:09	N 41° 02.090	W 70° 22.683	22	16:29	N 41° 02.339	W 70° 21.438	22	4.0	100
34	Control	2/8/2022	Rain	7-10	NE	0.5-1.25	7:04	N 40° 59.465	W 70° 20.552	23	7:24	N 40° 58.972	W 70° 21.649	23	4.8	100
35	Control	2/8/2022	Overcast	7-10	NE	0.5-1.25	7:53	N 41° 05.419	W 70° 23.190	24	8:13	N 40° 58.464	W 70° 22.500	23	4.8	100
36	Control	2/8/2022	Obscured	11-15	NE	0.5-1.25	8:51	N 40° 58.709	W 70° 24.629	24	9:11	N 40° 58.688	W 70° 25.939	24	4.7	100
37	VW1	2/8/2022	Overcast	11-15	NE	0.5-1.25	9:38	N 41° 00.087	W 70° 26.464	24	9:58	N 41° 00.915	W 70° 26.920	24	4.4	100
38	VW1	2/8/2022	Overcast	11-15	NE	1.25-2.5	10:21	N 41° 00.745	W 70° 26.227	24	10:41	N 41° 00.452	W 70° 28.449	24	4.3	100
39	VW1	2/8/2022	Mostly Cloudy	11-15	E	1.25-2.5	11:10	N 41° 01.746	W 70° 29.848	25	11:30	N 41° 02.534	W 70° 30.574	25	3.9	100
40	VW1	2/8/2022	Mostly Cloudy	11-15	E	1.25-2.5	11:54	N 41° 03.301	W 70° 30.998	25	12:14	N 41° 04.108	W 70° 29.306	24	4.0	100

Note: fm = fathom

Table 3: Operational and environmental conditions for each tow during the summer survey.

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)	Bottom Temp. (°C)	Trawl Warp (fm)
1	VW1	8/11/2022	Mostly Cloudy	3-6	S	0.5-1.25	6:59	N 41° 06.190	W 70° 13.280	22	7:19	N 41° 05.173	W 70° 13.015	23	14.3	100
2	VW1	8/11/2022	Mostly Cloudy	7-10	s	0.5-1.25	8:29	N 41° 03.700	W 70° 31.165	24	8:49	N 41° 02.761	W 70° 31.302	24	13.8	100
3	VW1	8/11/2022	Overcast	7-10	S	0.5-1.25	9:29	N 41° 03.010	W 70° 29.818	24	9:49	N 41° 02.962	W 70° 28.516	23	13.8	100
4	VW1	8/11/2022	Overcast	7-10	S	0.5-1.25	10:41	N 41° 02.050	W 70° 30.586	25	11:01	N 41° 02.257	W 70° 31.838	24	14.0	100
5	VW1	8/11/2022	Rain	3-6	S	0.5-1.25	12:29	N 41° 02.980	W 70° 32.666	25	12:44	N 41° 02.995	W 70° 33.964	23	13.6	100
6	VW1	8/11/2022	Rain	7-10	S	0.5-1.25	13:24	N 41° 02.230	W 70° 34.506	23	13:44	N 40° 01.765	W 70° 35.325	24	13.5	100
7	VW1	8/11/2022	Rain	7-10	S	0.5-1.25	14:30	N 41° 01.750	W 70° 35.109	24	14:50	N 40° 01.629	W 70° 33.871	24	13.3	100
8	VW1	8/11/2022	Mostly Cloudy	7-10	S	0.5-1.25	15:29	N 41° 00.940	W 70° 32.899	26	15:49	N 41° 00.572	W 70° 31.750	26	13.7	100
9	VW1	8/11/2022	Partly Cloudy	7-10	S	0.5-1.25	16:28	N 40° 58.900	W 70° 30.995	26	16:48	N 40° 58.185	W 70° 30.219	25	13.8	100
10	VW1	8/11/2022	Mostly Cloudy	3-6	S	0.5-1.25	17:30	N 40° 58.680	W 70° 27.178	24	17:50	N 40° 58.977	W 70° 25.928	24	13.6	100
11	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	6:27	N 40° 55.280	W 70° 28.997	26	6:47	N 40° 56.186	W 70° 27.275	25	13.3	100
12	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	7:33	N 40° 57.190	W 70° 26.731	25	7:53	N 40° 56.799	W 70° 25.571	25	11.5	100
13	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	8:35	N 40° 57.690	W 70° 23.437	24	8:55	N 40° 58.695	W 70° 23.683	23	13.6	100
14	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	9:37	N 40° 59.950	W 70° 22.371	21	9:57	N 41° 00.951	W 70° 22.511	22	14.4	100
15	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	10:33	N 41° 02.990	W 70° 21.395	21	10:53	N 41° 02.075	W 70° 21.046	21	15.0	95
16	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	11:47	N 41° 01.130	W 70° 19.934	22	12:07	N 41° 00.176	W 70° 19.696	22	16.6	100
17	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	14:06	N 40° 59.210	W 70° 19.968	23	14:26	N 40° 58.311	W 70° 19.573	23	14.8	100
18	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	15:16	N 40° 58.270	W 70° 19.918	23	15:36	N 40° 58.129	W 70° 17.770	21	14.7	100
19	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	16:20	N 40° 59.440	W 70° 17.233	20	16:40	N 41° 00.035	W 70° 18.237	21	12.6	95
20	Control	8/12/2022	Mostly Cloudy	1-2	E	0.1-0.5	17:36	N 40° 59.640	W 70° 17.142	20	17:56	N 40° 58.514	W 70° 16.631	20	15.9	95
21	Control	8/13/2022	Mostly Cloudy	7-10	W	0.5-1.25	6:18	N 40° 55.550	W 70° 16.437	21	6:38	N 40° 55.577	W 70° 17.699	22	15.2	100
22	Control	8/13/2022	Mostly Cloudy	7-10	W	0.5-1.25	7:28	N 40° 55.000	W 70° 18.440	23	7:48	N 40° 55.975	W 70° 19.031	23	14.3	100
23	Control	8/13/2022	Mostly Cloudy	11-15	NW	0.5-1.25	8:37	N 40° 57.040	W 70° 19.858	23	8:57	N 40° 56.264	W 70° 19.218	23	14.3	100
24	Control	8/13/2022	Mostly Cloudy	11-15	NW	0.5-1.25	9:41	N 40° 54.930	W 70° 20.174	23	10:01	N 40° 54.091	W 70° 20.780	24	13.4	100
25	Control	8/13/2022	Partly Cloudy	11-15	NW	0.5-1.25	10:51	N 40° 51.330	W 70° 22.049	27	11:11	N 40° 51.461	W 70° 23.318	27	14.5	120
26	Control	8/13/2022	Partly Cloudy	11-15	NW	0.5-1.25	11:52	N 40° 52.500	W 70° 24.043	27	12:12	N 40° 53.315	W 70° 24.685	26	13.7	120
27	Control	8/13/2022	Clear	16-20	NW	0.5-1.25	12:59	N 40° 54.460	W 70° 25.795	26	13:19	N 40° 55.225	W 70° 25.091	25	13.4	100
28	Control	8/13/2022	Clear	16-20	NW	0.5-1.25	13:56	N 40° 55.510	W 70° 24.374	24	14:16	N 40° 55.611	W 70° 23.129	24	13.7	100
29	Control	8/13/2022	Clear	16-20	NW	0.5-1.25	14:55	N 40° 54.930	W 70° 22.106	23	15:15	N 40° 55.877	W 70° 22.258	24	13.5	100
30	Control	8/13/2022	Clear	11-15	NW	0.5-1.25	16:18	N 40° 58.010	W 70° 22.805	23	16:38	N 40° 57.708	W 70° 24.068	23	13.9	100
31	VW1	8/13/2022	Clear	7-10	NW	0.5-1.25	17:31	N 41° 00.040	W 70° 27.231	23	17:51	N 41° 01.001	W 70° 26.255	23	13.5	100
32	VW1	8/14/2022	Clear	1-2	E	0.1-0.5	6:24	N 40° 59.900	W 70° 29.068	24	6:44	N 41° 00.887	W 70° 29.131	24	13.4	100
33	VW1	8/14/2022	Clear	1-2	E	0.1-0.5	7:24	N 41° 01.180	W 70° 28.761	24	7:44	N 41° 01.843	W 70° 27.888	23	13.6	100
34	VW1	8/14/2022	Clear	1-2	E	0.1-0.5	8:22	N 41° 02.070	W 70° 27.530	22	8:42	N 41° 02.304	W 70° 26.213	22	13.8	100
35	VW1	8/14/2022	Clear	1-2	E	0.1-0.5	9:22	N 41° 01.050	W 70° 24.415	23	9:42	N 41° 02.029	W 70° 23.956	23	14.1	100
36	VW1	8/14/2022	Clear	1-2	E	0.1-0.5	10:25	N 41° 04720	W 70° 22.761	22	10:45	N 41° 04.591	W 70° 23.984	21	14.8	100
37	VW1	8/14/2022	Partly Cloudy	1-2	E	0.1-0.5	11:25	N 41° 05.030	W 70° 25.458	22	11:45	N 41° 04.472	W 70° 26.538	22	14.0	100
38	VW1	8/14/2022	Partly Cloudy	1-2	E	0.1-0.5	12:24	N 41° 04.340	W 70° 27.908	23	12:44	N 41° 05.013	W 70° 26.917	22	13.7	100
39	VW1	8/14/2022	Partly Cloudy	1-2	E	0.1-0.5	13:25	N 41° 06.690	W 70° 25.751	21	13:45	N 41° 07.671	W 70° 25.715	20	14.5	100
40	VW1	8/14/2022	Mostly Cloudy	1-2	E	0.1-0.5	14:20	N 41° 07.710	W 70° 26.305	20	14:40	N 41° 07.488	W 70° 27.584	21	15.3	95

Note: fm = fathom

Table 4: Details of tows with operational, environmental, and gear performance parameters for each survey tow.

Tow #	Survey	Tow Area	Tow Duration (min.)	Tow Distance (nmi.)	Tow Speed (knots)	Start Depth (fm)	Bottom Temp. (^{0}C)	Trawl Warp (fm)	Headline Height (m.)	Wing Spread (m.)	Spread Door (m.)
1	Fall	VW1	20.2	0.9	2.7	23	14.8	100	5.0	13.5	33.1
2	Fall	VW1	20.2	0.9	2.7	24	15.1	100	4.8	13.8	33.6
3	Fall	VW1	20.0	0.9	2.7	25	14.8	100	4.9	13.9	33.3
4	Fall	VW1	19.9	1.0	2.9	26	15.1	100	4.9	13.5	32.8
5	Fall	VW1	20.0	1.0	2.9	27		100			
6	Fall	VW1	22.7	0.9	2.3	26	14.8	100	5.3	13.2	32.2
7	Fall	VW1	20.0	0.9	2.8	27	15.0	100	4.8	13.7	33.6
8	Fall	VW1	20.2	0.9	2.8	26	14.9	100	4.8	13.5	33.6
9	Fall	VW1	20.2	1.0	2.8	25	14.2	100	5.0	13.8	33.0
10	Fall	Control	20.0	1.0	2.9	26	14.5	120	4.5	14.0	34.0
11	Fall	Control	19.7	1.0	3.0	28	14.4	120	4.6	14.0	35.5
12	Fall	Control	21.2	1.0	3.0	28	14.5	120	4.9	13.6	34.1
13	Fall	Control	20.2	1.0	2.9	26	14.4	100	4.9	13.6	33.5
14	Fall	Control	20.0	1.0	2.9	23	14.4	100	5.2	12.9	31.8
15	Fall	Control	20.3	0.9	2.6	21	14.0	100	4.9	11.2	32.9
16	Fall	Control	19.9	0.9	2.8	19	13.7	100	4.8		32.4
17	Fall	Control	19.8	0.9	2.8	21	14.5	100	5.1		32.4
18	Fall	Control	19.9	0.9	2.9	20	14.2	100	4.7	13.6	33.2
19	Fall	Control	20.1	1.0	3.0	20	14.5	100	4.9		33.0
20	Fall	Control	20.0	1.0	3.0	22	14.0	100	4.6	13.9	33.8
21	Fall	VW1	20.1	0.9	2.7	21	14.5	95	5.2	13.3	32.1
22	Fall	VW1	20.4	0.9	2.7	22	14.6	95	5.1	12.9	31.6
23	Fall	VW1	20.1	0.9	2.7	21	14.6	95	4.8	13.6	33.2
24	Fall	VW1	20.2	1.0	2.9	22	14.9	100	4.9	13.5	33.1
25	Fall	VW1	20.2	0.9	2.8	23	15.0	100	4.7	13.4	34.1
26	Fall	VW1	19.8	0.9	2.8	23	14.9	100	5.0	13.2	32.5
27	Fall	Control	20.1	1.0	2.9	27	13.6	120	4.9	13.4	33.5
28	Fall	Control	20.0	0.9	2.7	25	13.4	100	4.8	13.5	33.8
29	Fall	VW1	20.1	1.0	2.9	24	13.6	100	4.7	14.0	34.9
30	Fall	VW1	20.2	0.9	2.7	23	13.5	100	4.8	13.6	33.7
31	Fall	VW1	20.2	0.9	2.8	22	13.4	100	4.7	13.8	34.7
32	Fall	VW1	20.1	0.9	2.8	22	13.3	100	4.6	14.1	35.3
33	Fall	VW1	19.9	1.0	2.9	22	13.3	95	4.9	13.0	32.6
34	Fall	Control	20.2	0.9	2.7	23	13.5	100	4.8	13.9	35.1
35	Fall	Control	20.1	1.0	2.9	24	13.4	100	4.8	13.9	34.3
36	Fall	Control	20.1	0.9	2.7	24	13.4	100	4.8	13.9	33.8
37	Fall	Control	20.0	1.0	3.1	24	13.3	100	4.8	14.0	33.1
38	Fall	Control	20.1	0.9	2.8	23	13.4	100	5.0	13.2	32.7
39	Fall	Control	20.0	1.0	3.0	21	13.4	95	5.2	12.9	32.2
40	Fall	Control	20.1	0.9	2.8	23	13.3	100	4.7	13.8	34.9

Table 4 (Cont.): Details of tows with operational, environmental, and gear performance parameters for each survey tow.

Tow #	Survey	Tow Area	Tow Duration (min.)	Tow Distance (nmi.)	Tow Speed (knots)	Start Depth (fm)	Bottom Temp. (^oC)	Trawl Warp (fm)	Headline Height (m.)	Wing Spread (m.)	Spread Door (m.)
1	Winter	VW1	20.2	1.0	3.1	26	5.0	100	4.7	14.4	36.7
2	Winter	VW1	20.2	1.0	3.1	26	4.9	100	4.9	14.4	36.3
3	Winter	VW1	20.1	1.0	2.9	27	3.4	100	4.9	14.5	36.4
4	Winter	VW1	20.0	1.0	3.0	25	3.5	100	5.1	14.3	36.1
5	Winter	VW1	20.0	1.0	3.0	24	3.4	100	4.5	14.1	37.6
6	Winter	Control	20.1	1.1	3.2	25	3.5	100	4.8	13.7	36.4
7	Winter	Control	20.0	1.0	2.9	26	3.5	100	6.1		
8	Winter	Control	20.1	1.0	3.0	25	3.6	100	4.7	14.5	37.6
9	Winter	Control	20.0	1.0	2.9	25	3.8	100	4.9	14.6	37.8
10	Winter	Control	20.7	1.1	3.3	26	3.9	100	4.7	14.7	36.8
11	Winter	Control	20.2	0.9	2.7	27	7.1	100	5.4	13.8	36.9
12	Winter	Control	20.1	1.0	3.0	25	5.0	100	4.8	14.5	36.3
13	Winter	Control	19.8	1.0	3.0	24	4.9	100	5.3	13.8	35.3
14	Winter	Control	20.0	1.0	2.9	24	4.9	100	5.1	13.8	34.3
15	Winter	Control	20.0	1.0	3.0	24	4.7	100	4.8	14.2	35.5
16	Winter	Control	20.0	0.9	2.8	21	4.7	100	4.8	13.9	34.9
17	Winter	Control	20.1	1.0	2.9	21	5.2	100	4.5	14.6	37.1
18	Winter	Control	20.0	0.9	2.8	19		95	4.6	13.8	34.5
19	Winter	Control	20.0	1.0	3.1	18	4.0	95	5.1	13.4	34.7
20	Winter	Control	20.1	1.1	3.2	21	4.0	100	5.0	13.9	35.0
21	Winter	Control	20.1	1.0	2.9	22	3.8	100	4.5	14.9	
22	Winter	Control	20.1	1.0	2.8	22	3.8	100	4.4	14.6	37.2
23	Winter	VW1	20.0	1.0	2.9	24		100	5.8	14.1	36.0
24	Winter	VW1	19.9	1.0	2.9	24	2.9	100	4.6	14.6	37.2
25	Winter	VW1	20.0	1.0	2.9	23	2.7	100	4.8	14.2	35.6
26	Winter	VW1	20.0	1.0	2.9	21	2.9	95	5.0	14.0	35.2
27	Winter	VW1	20.0	0.9	2.8	21	3.2	95	4.8	14.0	34.9
28	Winter	VW1	20.0	0.9	2.8	22	3.2	100	4.8	14.3	34.8
29	Winter	VW1	20.0	1.0	3.0	23	3.7	100	5.2	13.7	34.0
30	Winter	VW1	20.0	0.9	2.8	24	3.9	100	4.8	14.1	35.9
31	Winter	VW1	20.2	1.0	2.9	22	3.7	100	4.9	13.9	35.1
32	Winter	VW1	20.1	1.0	2.9	23	3.8	100	4.7	14.3	
33	Winter	VW1	20.1	1.0	2.9	22	4.0	100	4.5	14.4	36.5
34	Winter	Control	20.0	1.0	2.9	23	4.8	100	5.2	13.7	33.8
35	Winter	Control	20.0	0.9	2.8	24	4.8	100	4.6	14.4	
36	Winter	Control	20.0	1.0	3.0	24	4.7	100	5.0	14.0	34.7
37	Winter	VW1	20.0	1.0	2.9	24	4.4	100	5.1	13.8	
38	Winter	VW1	20.0	1.0	2.9	24	4.3	100	4.9	14.2	35.3
39	Winter	VW1	20.0	1.0	2.9	25	3.9	100	5.0	14.0	35.4
40	Winter	VW1	20.1	1.0	2.9	25	4	100	5.1	13.8	34.7

Table 4 (Cont.): Details of tows with operational, environmental, and gear performance parameters for each survey tow.

Tow #	Survey	Tow Area	Tow Duration (min.)	Tow Distance (nmi.)	Tow Speed (knots)	Start Depth (fm)	Bottom Temp. (^oC)	Trawl Warp (fm)	Headline Height (m.)	Wing Spread (m.)	Spread Door (m.)
1	Summer	VW1	20.5	1.0	3.0	22	14.3	100		13.7	34.4
2	Summer	VW1	20.0	1.0	3.0	24	13.8	100	4.7	13.5	33.8
3	Summer	VW1	20.7	1.0	3.0	24	13.8	100	4.8	13.8	34.4
4	Summer	VW1	18.5	0.9	2.9	25	14.0	100	4.6	13.7	35.1
5	Summer	VW1	20.2	1.0	3.0	25	13.6	100	4.8	13.8	33.9
6	Summer	VW1	19.8	1.1	3.2	23	13.5	100	4.7	13.5	33.9
7	Summer	VW1	20.1	0.9	2.8	24	13.3	100	4.5	14.0	35.2
8	Summer	VW1	20.5	1.0	2.9	26	13.7	100	4.7	13.7	35.1
9	Summer	VW1	20.0	1.0	2.9	26	13.8	100	4.9	13.6	34.9
10	Summer	VW1	20.6	1.0	3.0	24	13.6	100	4.7	13.5	34.4
11	Summer	Control	20.2	1.0	3.0	26	13.3	100	5.0	13.5	33.8
12	Summer	Control	20.1	1.0	2.9	25	11.5	100	4.8	13.7	34.4
13	Summer	Control	20.2	1.0	3.1	24	13.6	100	4.6	13.8	34.9
14	Summer	Control	20.4	1.0	3.0	21	14.4	100	4.5	13.5	34.3
15	Summer	Control	19.5	1.0	3.0	21	15.0	95	4.9	13.1	32.6
16	Summer	Control	20.2	1.0	2.9	22	16.6	100	4.9	13.0	31.6
17	Summer	Control	20.2	1.0	2.9	23	14.8	100	4.8	13.5	34.2
18	Summer	Control	20.0	0.9	2.8	23	14.7	100	4.9	13.5	34.3
19	Summer	Control	19.5	1.0	3.0	20	12.6	95	5.1	12.9	30.8
20	Summer	Control	20.2	1.0	2.8	20	15.9	95	5.1	13.0	34.0
21	Summer	Control	20.0	1.0	3.0	21	15.2	100	4.8	13.5	34.3
22	Summer	Control	20.2	1.1	3.2	23	14.3	100	4.7	13.7	34.6
23	Summer	Control	20.0	0.9	2.8	23	14.3	100	4.8	12.9	32.7
24	Summer	Control	20.1	1.0	2.9	23	13.4	100	5.2	13.0	33.5
25	Summer	Control	20.0	1.0	3.0	27	14.5	120	4.5	14.4	37.4
26	Summer	Control	20.3	1.0	2.8	27	13.7	120	4.5	14.3	36.4
27	Summer	Control	20.0	0.9	2.8	26	13.4	100	4.8	13.4	34.6
28	Summer	Control	20.0	1.0	2.9	24	13.7	100	4.7	13.2	34.2
29	Summer	Control	20.0	1.0	2.9	23	13.5	100			
30	Summer	Control	20.1	1.0	3.0	23	13.9	100	4.9	13.4	33.7
31	Summer	VW1	20.0	1.0	2.9	23	13.5	100	4.6	13.4	34.5
32	Summer	VW1	20.1	1.0	3.0	24	13.4	100	4.7	13.5	33.9
33	Summer	VW1	20.1	0.9	2.8	24	13.6	100	4.9	13.1	32.7
34	Summer	VW1	20.3	1.0	3.0	22	13.8	100	4.7	13.3	33.4
35	Summer	VW1	20.2	1.0	3.1	23	14.1	100	4.6	13.6	34.4
36	Summer	VW1	20.2	0.9	2.8	22	14.8	100	4.7	13.0	33.1
37	Summer	VW1	20.1	1.0	2.9	22	14.0	100	4.6	13.2	33.2
38	Summer	VW1	20.2	1.0	3.0	23	13.7	100	4.6	13.2	33.5
39	Summer	VW1	20.0	1.0	3.0	21	14.5	100	4.6	13.2	33.8
40	Summer	VW1	20.0	1.0	3.0	20	15.3	95	4.9	12.8	32.5
Summary Statistics											
	Control	**Minimum**	19.5	0.9	2.6	18.0	3.5	95	4.4	11.2	30.8
		Maximum	21.2	1.1	3.3	28.0	16.6	120	6.1	14.9	37.8
		Average	20.1	0.98	2.92	23.3	10.9	101.5	4.9	13.7	34.4
		St. Dev	0.2	0.05	0.13	2.4	4.6	6.4	0.3	0.6	1.6
	VW1	**Minimum**	18.5	0.9	2.3	20.0	2.7	95	4.5	12.8	31.6
		Maximum	22.7	1.1	3.2	27.0	15.3	100	5.8	14.6	37.6
		Average	20.1	0.97	2.89	23.6	10.7	99.4	4.8	13.7	34.3
		St. Dev.	0.4	0.04	0.13	1.7	5.0	1.6	0.2	0.4	1.3
		T-Test	0.4371	0.4617	0.3222	0.4116	0.7236	0.0155	0.5784	0.8552	0.9552

Table 5: Total and mean catch weight of species observed in the VW1 Study Area.

Species Name	Scientific Name	Total Weight (kg)	Catch/Tow (kg)		% of Total Catch	Tows with Species Present
			Mean	SEM*		
Butterfish	*Peprilus triacanthus*	3273.4	56.3	12.9	27.0	40
Scup	*Stenotomus chrysops*	2790.7	48.6	9.7	23.1	32
Skate, Little	*Leucoraja erinacea*	1917.8	33.8	4.7	15.8	58
Herring, Atlantic	*Clupea harengus*	1155.3	18.9	5.4	9.5	20
Dogfish, Spiny	*Squalus acanthias*	710.7	12.5	4.2	5.9	21
Hake, Red	*Urophycis chuss*	652.8	11.2	3.5	5.4	44
Squid, Atlantic Longfin	*Dorytheuthis pealei*	518.6	8.9	1.3	4.3	41
Hake, Silver	*Merluccius bilinearis*	481.8	8.2	1.3	4.0	59
Skate, Winter	*Leucoraja ocellata*	162.3	2.9	0.7	1.3	17
Northern Sea Robin	*Prionotus carolinus*	114.5	2.0	0.5	0.9	23
Flounder, Fourspot	*Paralichthys oblongus*	52.7	0.9	0.2	0.4	34
Flounder, Summer (Fluke)	*Paralichthys dentatus*	34.7	0.6	0.1	0.3	18
Flounder, Windowpane	*Scophtalmus aquosus*	34.4	0.6	0.1	0.3	34
Crab, Cancer	*Cancer irroratus*	27.7	0.5	0.1	0.2	21
Atlantic Cod	*Gadus morhua*	26.3	0.4	0.1	0.2	13
Alewife	*Alosa pseudoharengus*	25.7	0.4	0.1	0.2	20
Black Sea Bass	*Centropristis striata*	24.8	0.4	0.1	0.2	20
Sculpin, Longhorn	*Myoxocephalus octodecimspinosus*	22.7	0.4	0.1	0.2	21
Flounder, Winter	*Pleuronectes americanus*	19.9	0.3	0.1	0.2	29
Herring, Blueback	*Alosa aestivalis*	11.4	0.2	0.1	0.1	22
Dogfish, Smooth	*Mustelus canis*	8.7	0.2	0.1	0.1	4
Skate, Barndoor	*Dipturus laevis*	8.1	0.1	0.1	0.1	11
Hake, Spotted	*Urophycis regia*	5.7	0.1	0.0	0.0	14
Sea Robin, Striped	*Prionotus evolans*	4.5	0.1	0.03	0.04	7
Monkfish	*Lophius americanus*	3.6	0.1	0.04	0.03	3
Flounder, Gulfstream	*Citharichthys arctifrons*	3.1	0.1	0.02	0.03	14
Sea Raven	*Hemitripterus americanus*	2.6	0.04	0.03	0.02	3
Shad, American	*Alosa sapidissima*	1.9	0.03	0.01	0.02	12
Sea Scallop	*Placopecten magellanicus*	1.9	0.03	0.02	0.02	7
Flounder, Yellowtail	*Pleuronectes ferrugineus*	0.7	0.01	0.01	0.01	5
Lobster, American	*Homarus americanus*	0.6	0.01	0.01	0.005	2
Mackeral, Atlantic	*Scomber scombrus*	0.5	0.01	0.01	0.004	2
Weakfish	*Cynoscion regalis*	0.4	0.01	0.01	0.003	1
Kingfish, Northern	*Menticirrhus saxatilis*	0.4	0.01	0.005	0.003	2
Bluefish	*Pomatomus saltatrix*	0.2	0.003	0.003	0.001	1
Total		12101.2				

*SEM - Standard Error of the Mean

Table 6: Total and mean catch weight of species observed in the Control Area.

Species Name	Scientific Name	Total Weight (kg)	Catch/Tow (kg) Mean	Catch/Tow (kg) SEM*	% of Total Catch	Tows with Species Present
Butterfish	*Peprilus triacanthus*	5903.0	101.9	37.0	31.3	39
Scup	*Stenotomus chrysops*	4698.0	81.6	17.8	24.9	36
Skate, Little	*Leucoraja erinacea*	2519.7	43.0	6.4	13.3	60
Herring, Atlantic	*Clupea harengus*	1713.2	27.5	6.9	9.1	21
Dogfish, Spiny	*Squalus acanthias*	1666.0	27.8	12.9	8.8	24
Hake, Silver	*Merluccius bilinearis*	518.3	8.9	1.6	2.7	53
Hake, Red	*Urophycis chuss*	503.5	8.5	1.7	2.7	36
Squid, Atlantic Longfin	*Dorytheuthis pealei*	486.5	8.4	2.1	2.6	40
Northern Sea Robin	*Prionotus carolinus*	163.6	2.8	0.7	0.9	27
Skate, Winter	*Leucoraja ocellata*	139.0	2.3	0.7	0.7	15
Flounder, Windowpane	*Scophtalmus aquosus*	136.0	2.4	0.7	0.7	35
Flounder, Fourspot	*Paralichthys oblongus*	82.9	1.4	0.2	0.4	39
Hake, Spotted	*Urophycis regia*	51.9	0.9	0.4	0.3	17
Herring, Blueback	*Alosa aestivalis*	51.0	0.8	0.5	0.3	20
Atlantic Cod	*Gadus morhua*	43.8	0.7	0.2	0.2	18
Alewife	*Alosa pseudoharengus*	37.4	0.6	0.2	0.2	23
Flounder, Summer (Fluke)	*Paralichthys dentatus*	36.3	0.6	0.1	0.2	19
Flounder, Winter	*Pleuronectes americanus*	25.5	0.4	0.1	0.1	25
Sculpin, Longhorn	*Myoxocephalus octodecimspinosus*	22.4	0.4	0.1	0.1	28
Black Sea Bass	*Centropristis striata*	17.8	0.3	0.1	0.1	15
Crab, Cancer	*Cancer irroratus*	17.3	0.3	0.1	0.1	24
Monkfish	*Lophius americanus*	14.5	0.2	0.2	0.1	4
Dogfish, Smooth	*Mustelus canis*	6.2	0.1	0.1	0.03	4
Mackeral, Atlantic	*Scomber scombrus*	5.3	0.1	0.1	0.03	8
Skate, Barndoor	*Dipturus laevis*	5.1	0.1	0.0	0.03	9
Weakfish	*Cynoscion regalis*	4.7	0.1	0.0	0.03	11
Shad, American	*Alosa sapidissima*	4.4	0.1	0.0	0.02	20
Bluefish	*Pomatomus saltatrix*	3.3	0.1	0.1	0.02	1
Sea Raven	*Hemitripterus americanus*	2.7	0.04	0.02	0.01	5
Kingfish, Northern	*Menticirrhus saxatilis*	2.2	0.04	0.02	0.01	4
Stingray, Roughtail	*Dasyatis cantroura*	2.0	0.03	0.02	0.01	2
Sea Robin, Striped	*Prionotus evolans*	1.6	0.03	0.02	0.01	2
Flounder, Gulfstream	*Citharichthys arctifrons*	1.4	0.02	0.01	0.01	11
Lobster, American	*Homarus americanus*	1.1	0.02	0.01	0.01	4
Sea Scallop	*Placopecten magellanicus*	0.8	0.01	0.01	0.004	7
Haddock	*Melanogrammus aeglefinus*	0.2	0.003	0.003	0.001	2
Cusk-Eel, Fawn	*Lepophidium profundorum*	0.2	0.003	0.003	0.001	2
Flounder, Yellowtail	*Pleuronectes ferrugineus*	0.1	0.002	0.002	0.001	1
Crab, Horseshoe	*Limulus polyphemus*	0.1	0.002	0.002	0.001	1
Lizardfish	*Synodontidae*	0.1	0.002	0.002	0.001	1
Total		12985.9				

*SEM - Standard Error of the Mean

Table 7: Coefficient of variance (CV) and the total number of tows required to detect a certain percentage of change for each species in two survey areas 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	1.15	1863	249	43	10	0
Flounder, Fourspot	1.29	2340	313	54	13	0
Squid, Atlantic Longfin	1.50	3175	425	73	18	0
Hake, Silver	1.83	4730	634	109	27	1
Skate, Winter	1.87	4956	664	114	28	1
Crab, Cancer	2.02	5756	772	132	33	1
Flounder, Summer (Fluke)	2.12	6367	854	147	36	1
Black Sea Bass	2.20	6840	917	158	39	1
Scup	2.22	6966	934	160	40	1
Flounder, Winter	2.32	7631	1023	176	44	1
Flounder, Windowpane	2.48	8689	1165	200	50	2
Hake, Red	2.54	9115	1222	210	52	2
Sea Scallop	2.65	9923	1331	229	57	2
Monkfish	2.97	12475	1673	288	72	2
Herring, Atlantic	3.09	13499	1810	311	77	3
Flounder, Gulfstream	3.13	13812	1852	319	79	3
Flounder, Yellowtail	3.24	14841	1990	342	85	3
Atlantic Cod	3.30	15410	2067	356	89	3
Sculpin, Longhorn	3.37	16092	2158	371	92	3
Butterfish	3.43	16665	2235	385	96	3
Ocean Pout	3.97	22240	2983	513	128	5
Lobster, American	4.03	22936	3076	529	132	5
Bluefish	4.04	23106	3099	533	133	5
Skate, Barndoor	4.06	23304	3125	538	134	5
Dogfish, Smooth	4.14	24249	3252	560	140	5
Weakfish	4.21	25016	3355	578	144	5
Hake, Spotted	4.55	29228	3920	675	168	6
Dogfish, Spiny	4.77	32236	4323	744	186	7
Herring, Blueback	5.26	39089	5243	903	225	9
Northern Sea Robin	5.55	43559	5842	1006	251	10
Sea Raven	5.57	43841	5880	1012	253	10
Alewife	5.90	49205	6599	1136	284	11
Sea Robin, Striped	6.32	56523	7581	1305	326	13
Squid, Shortfin	6.51	60006	8048	1386	346	13
Shad, American	8.88	111394	14941	2573	643	25
Menhaden, Atlantic	10.69	161605	21676	3733	933	37
Kingfish, Northern	13.52	258583	34684	5974	1493	60
Haddock	13.88	272622	36567	6298	1574	63
Mackeral, Atlantic	14.05	279171	37445	6450	1612	64
Eel, Conger	15.13	323752	43425	7480	1870	75
Cunner	15.42	336052	45075	7764	1941	78
Flounder, American Plaice	20.95	620792	83267	14343	3585	144

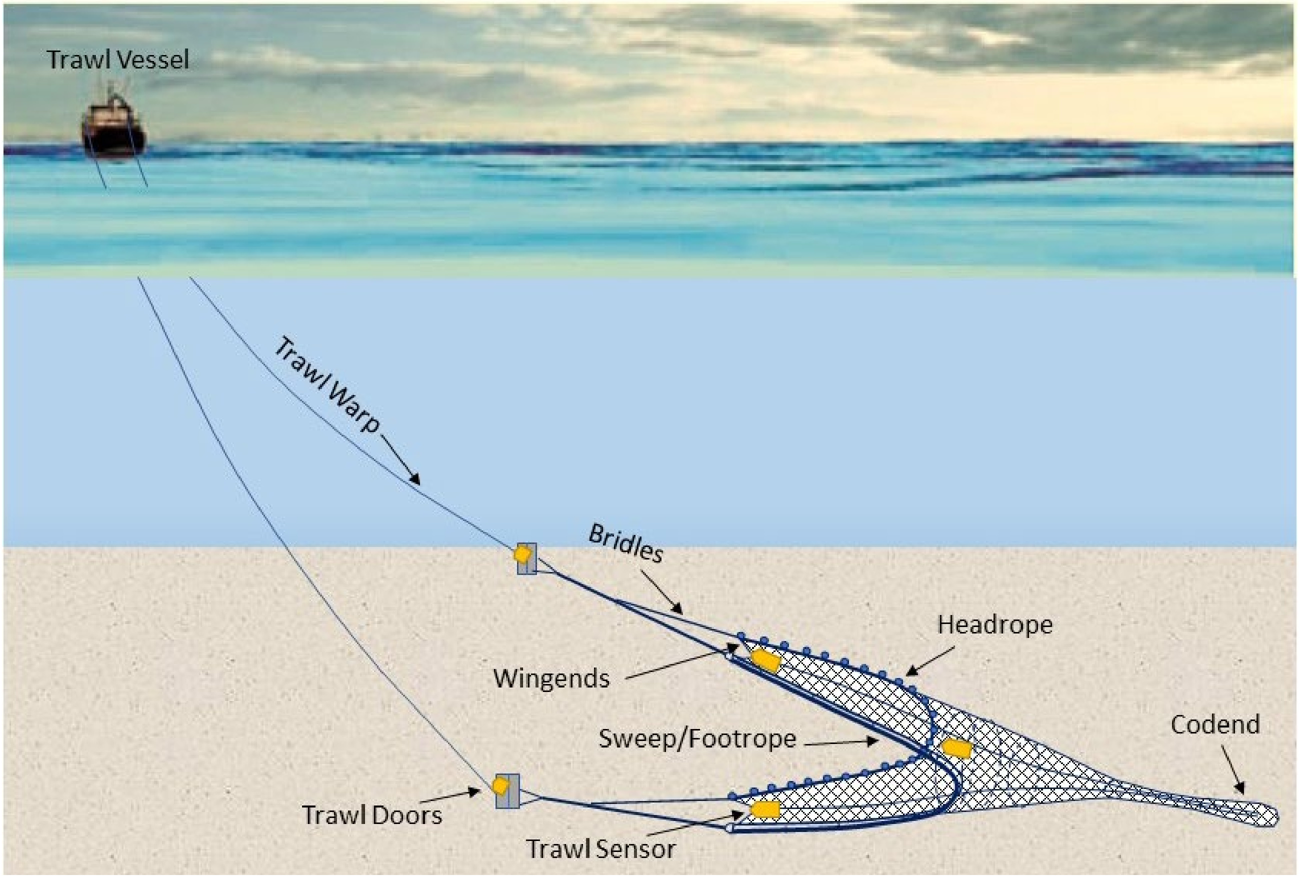


Figure 1: General schematic (not to scale) of a demersal otter trawl. Yellow rectangles indicate geometry sensors.

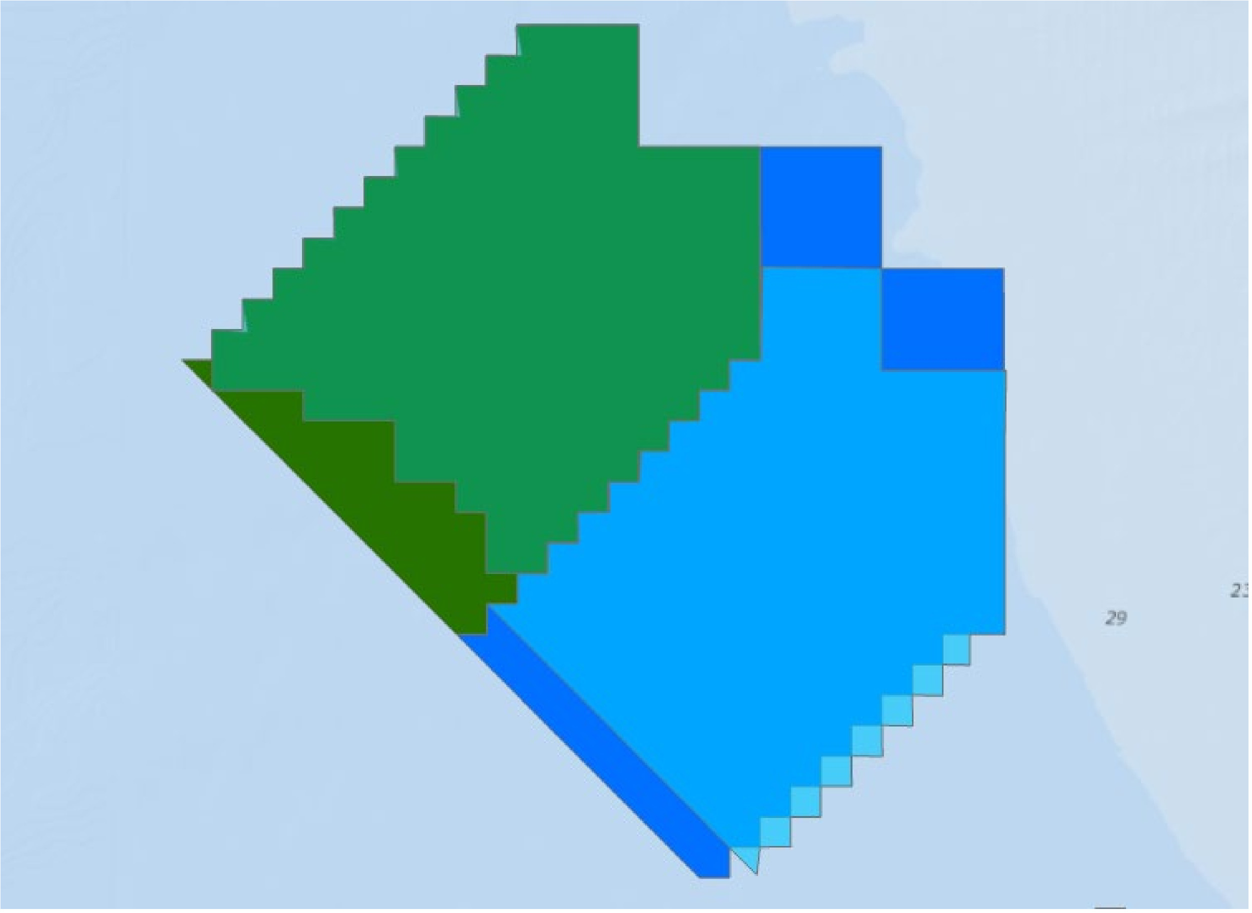


Figure 2: Boundary refinements of the VW1 Study Area and Control Area. The VW1 Study Area was reduced from 306 km^2 (89 nmi^2; dark green) in 2020/2021 to 265 km^2 (77 nmi^2; light green) in 2021/2022. The Control Area was similarly reduced from 324 km^2 (94.5 nmi^2; dark blue) to 269.5 km^2 (78.6 nmi^2; light blue).

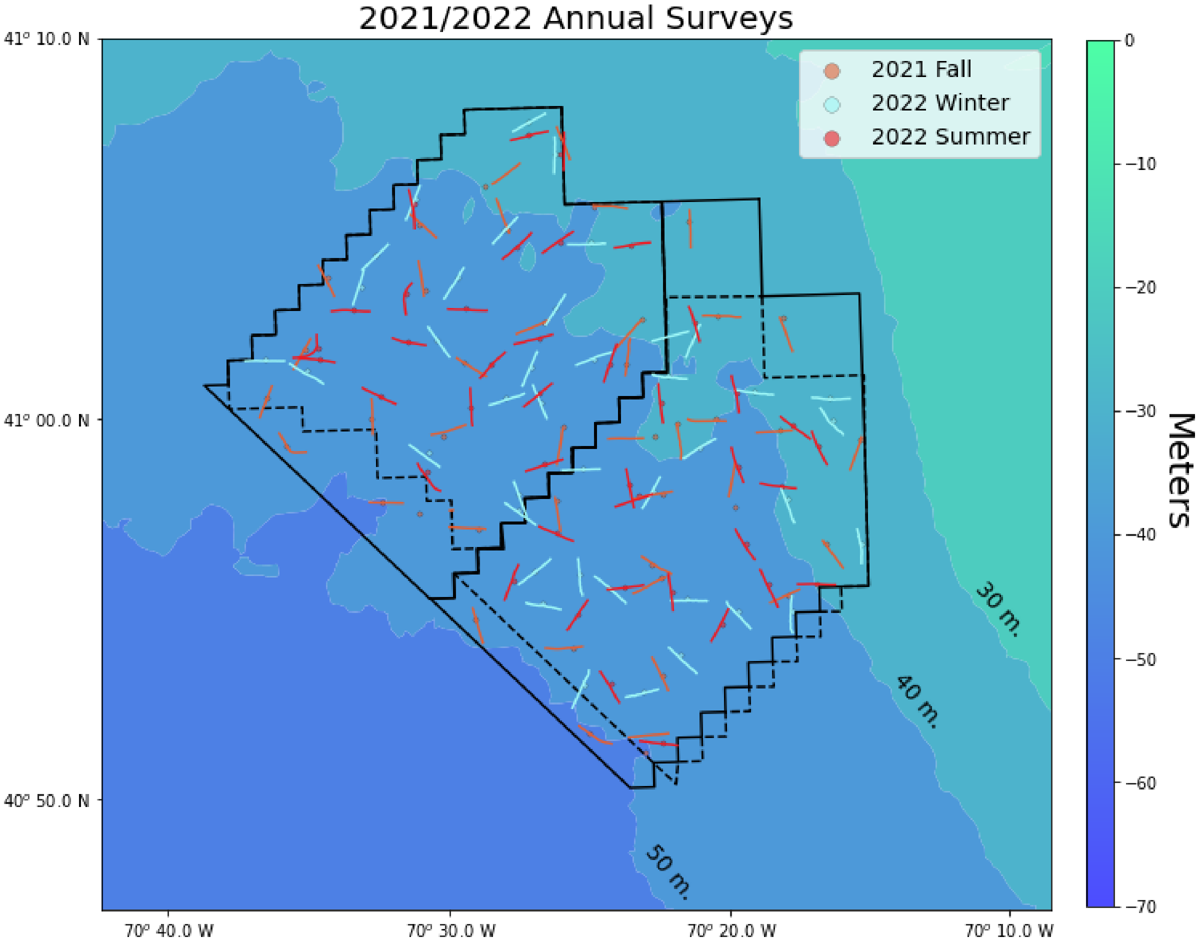


Figure 3: Tow locations (dots) and trawl tracks (lines) from the VW1 Study Area (left) and the Control Area (right). Solid area boundaries represent the survey area during the fall survey while the dashed lines represent the refined survey area for the winter and summer surveys.

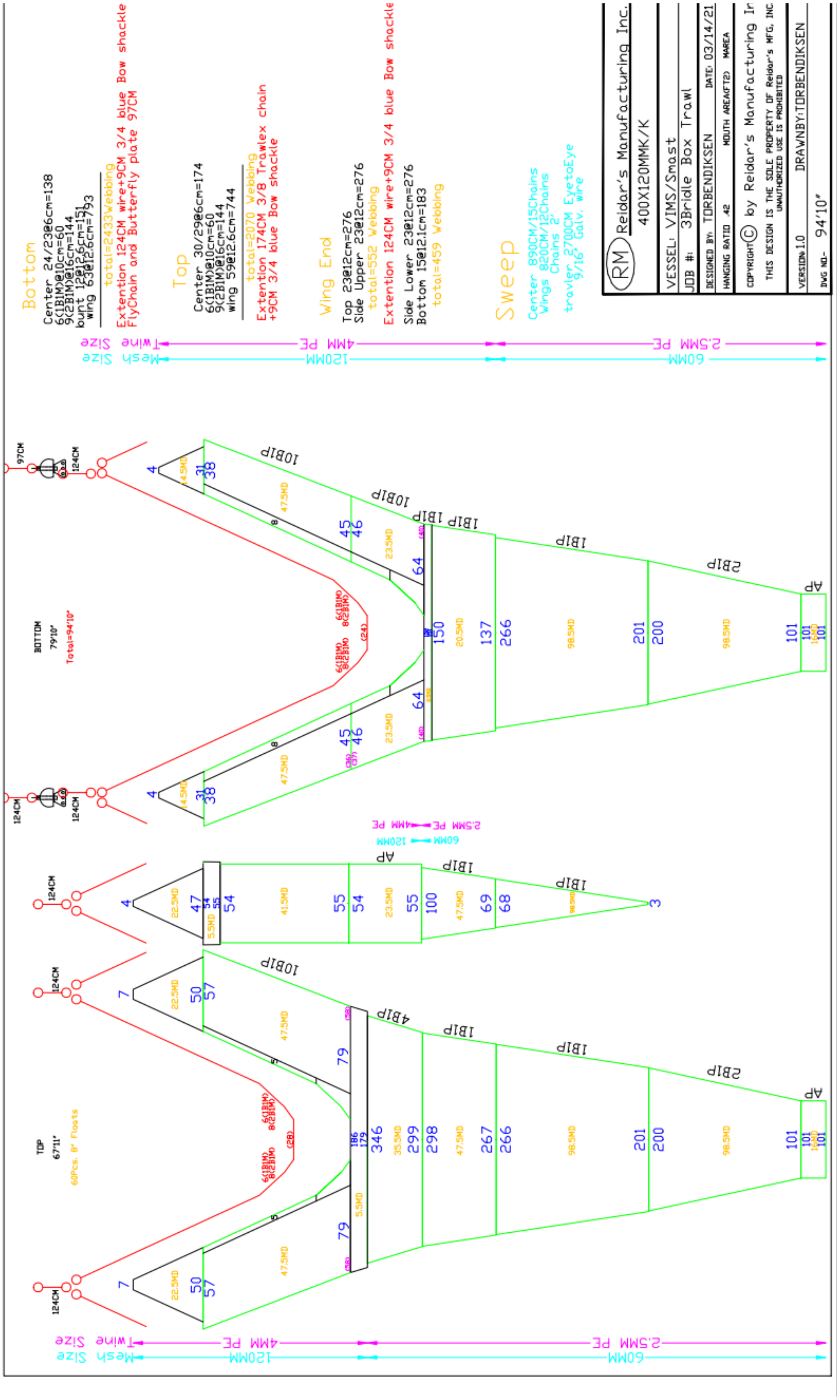


Figure 4: Schematic net plan for the NEAMAP trawl (Courtesy of Reidar's Manufacturing Inc.).

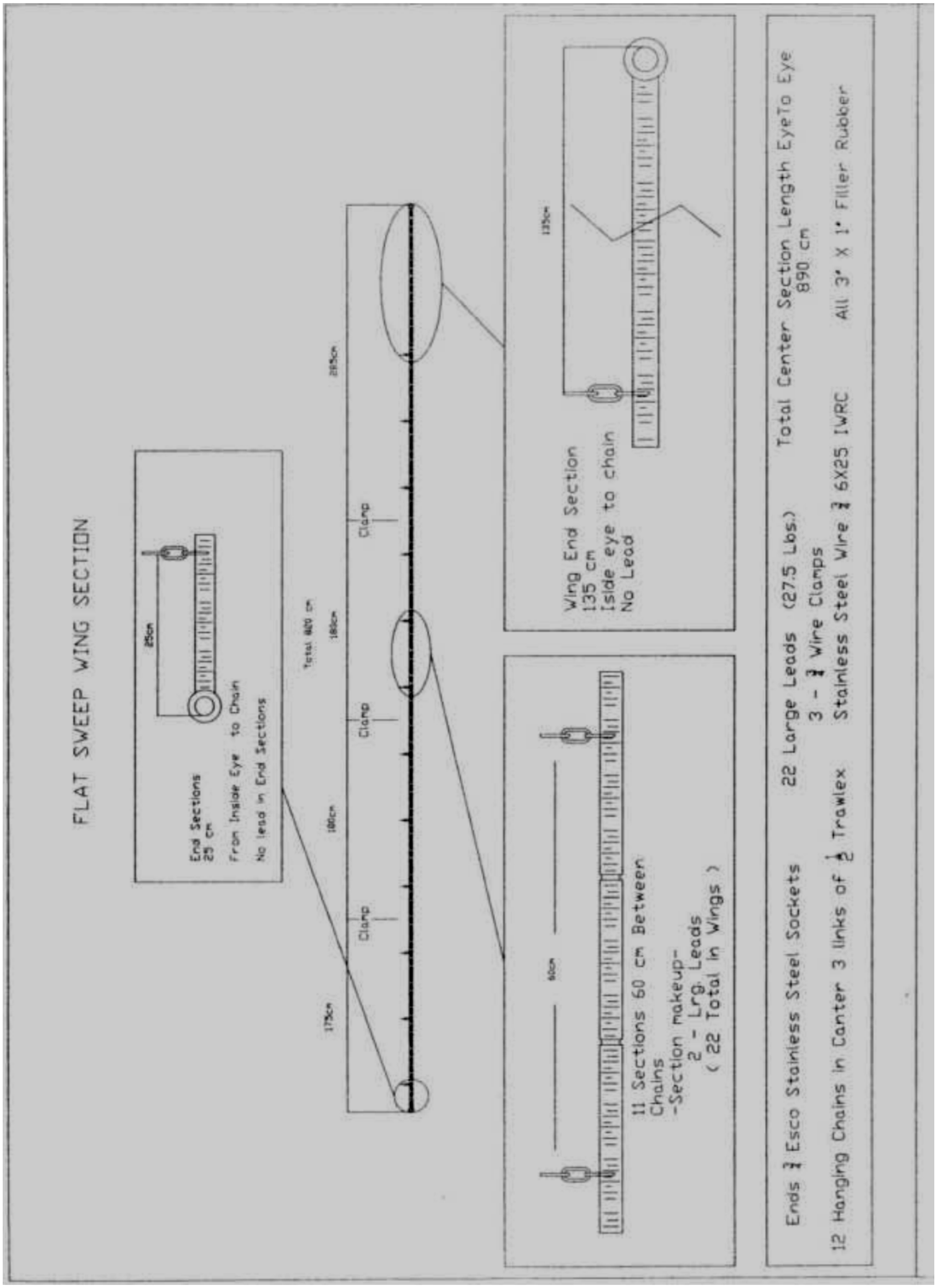


Figure 5: Sweep diagram for the survey trawl (Bonzek et al., 2008).

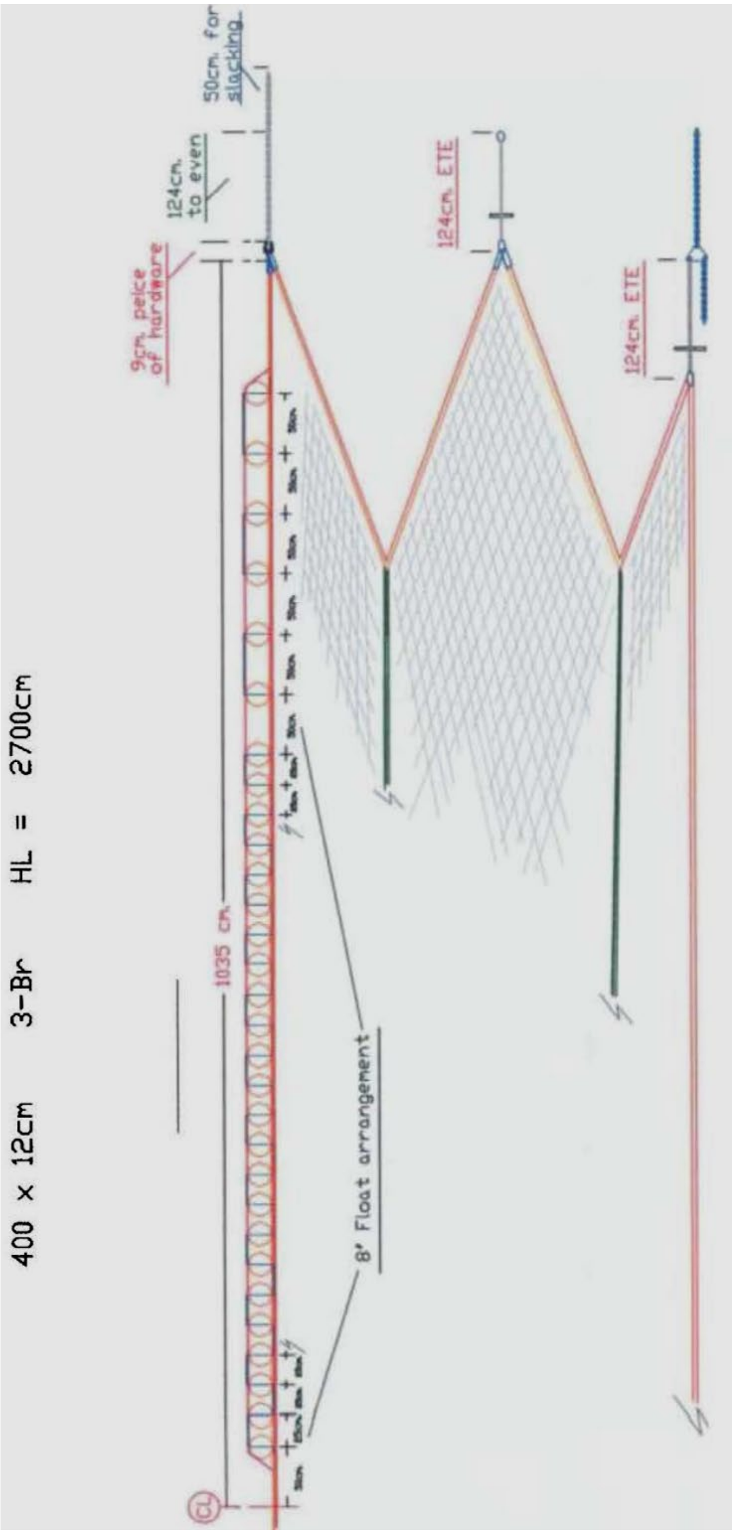


Figure 6: Headrope and rigging plan for the survey trawl (Bonzek et al., 2008).

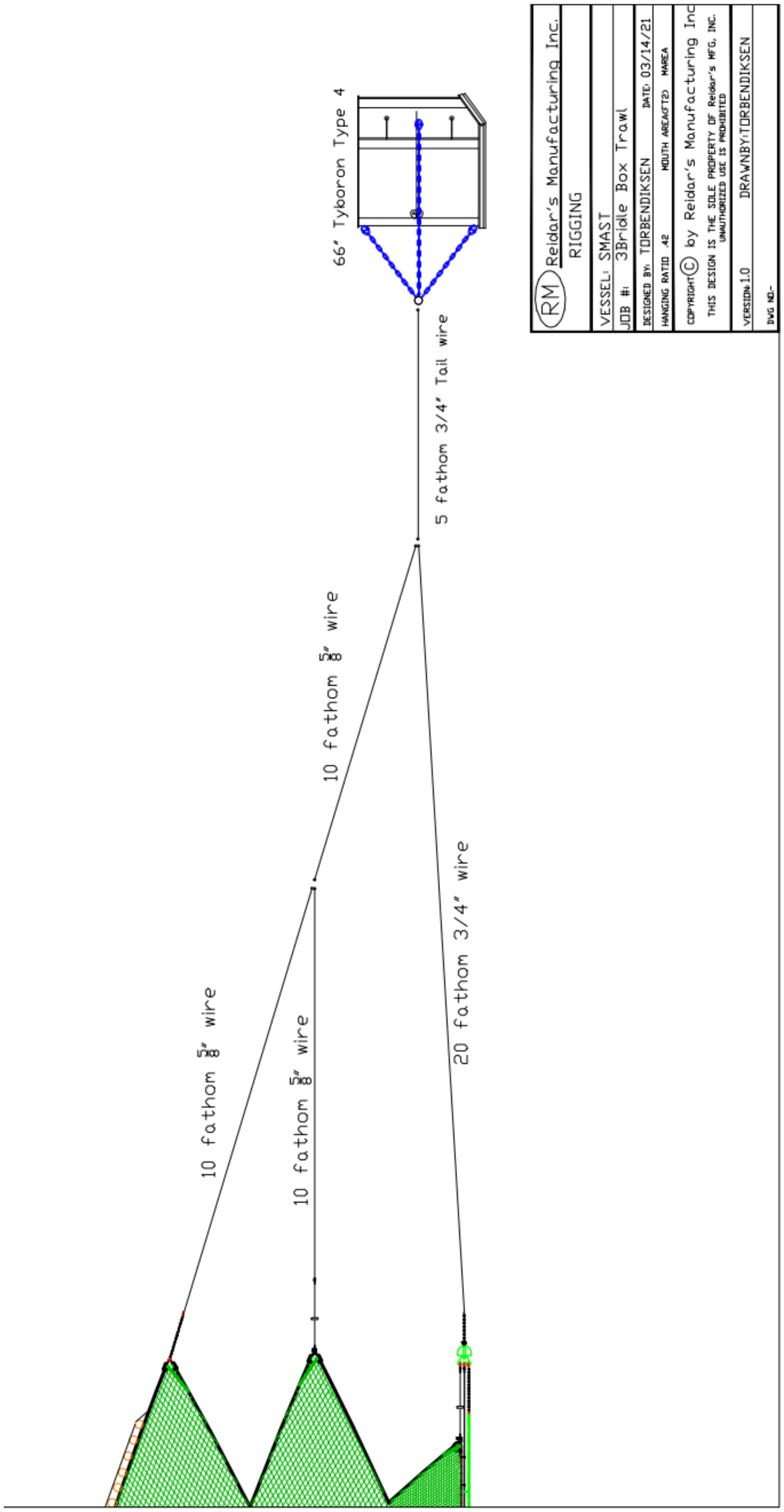


Figure 7: Bridle and door rigging schematic for the survey trawl (Courtesy of Reidar's Manufacturing Inc.).

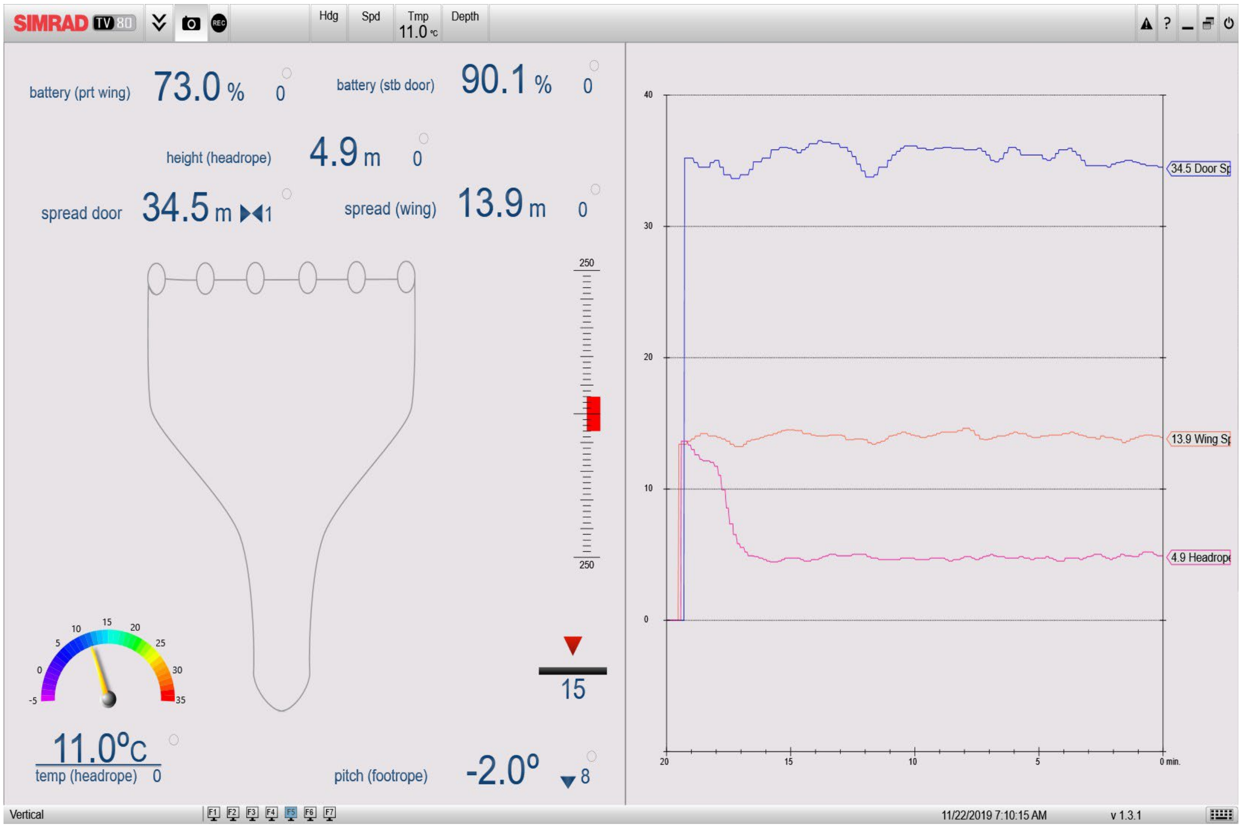


Figure 8: Screenshot of the SIMRAD TV80 software monitoring the trawl parameters.

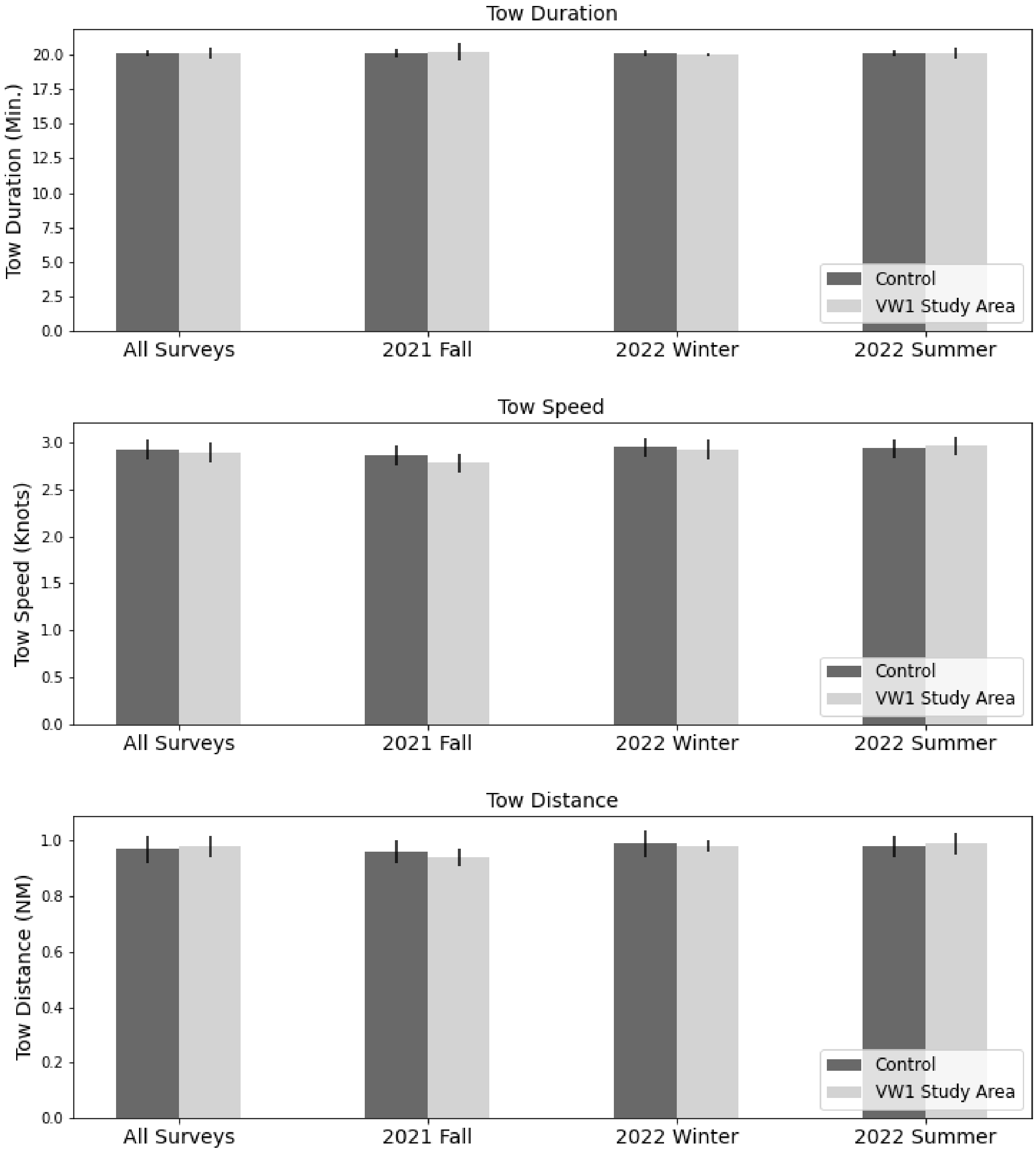


Figure 9: Operational data from the seasonal surveys including tow duration, tow speed, and tow distance.

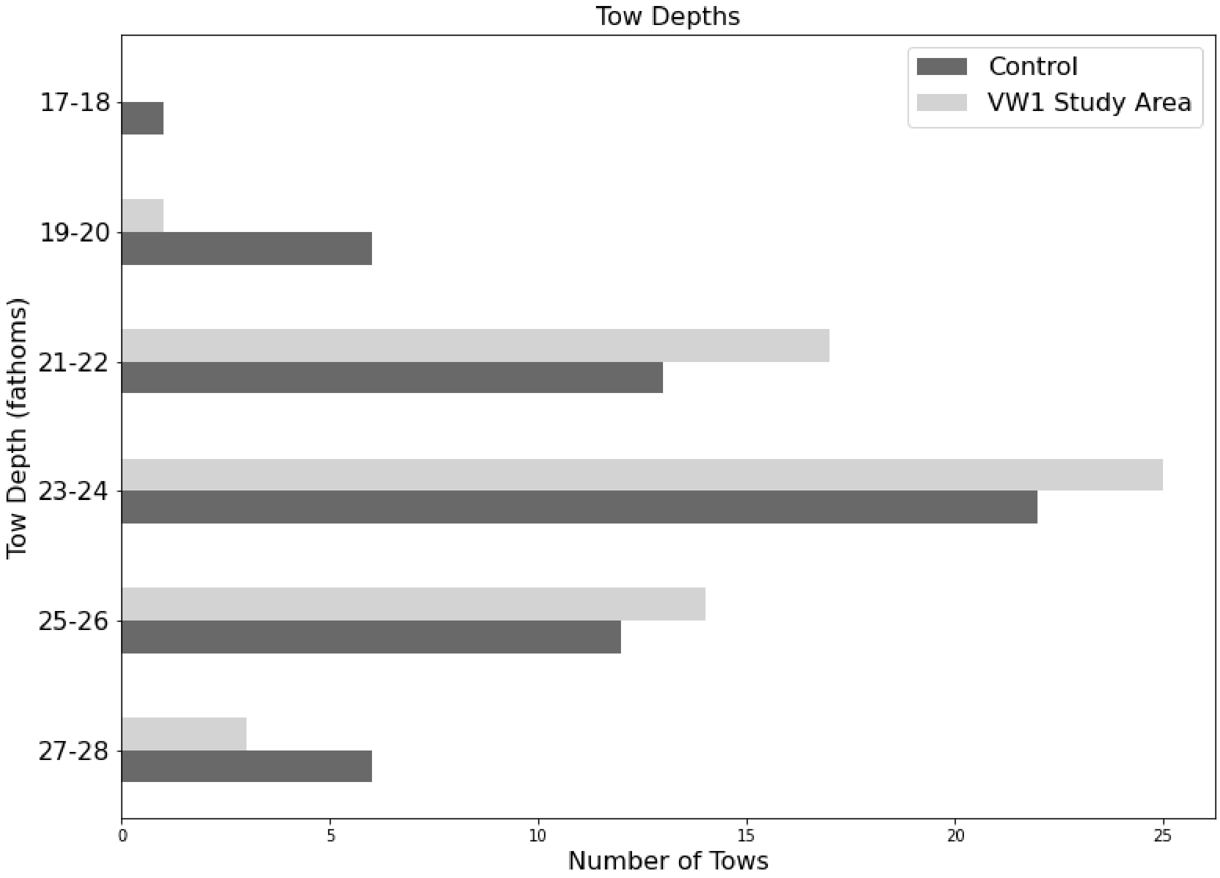


Figure 10: Distribution of tow depths at the start of each tow.

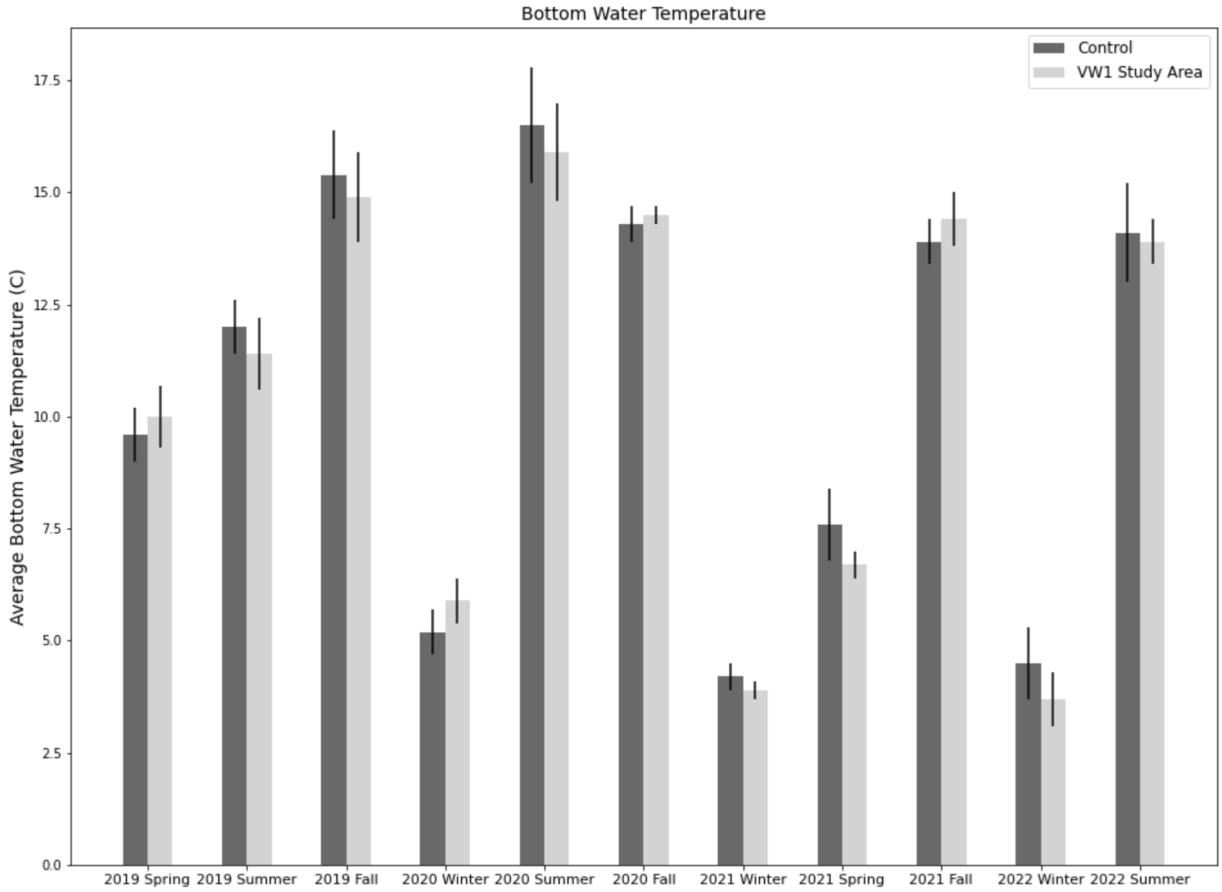


Figure 11: Average seasonal bottom water temperature within the VW1 Study Area and Control Area between 2019 – 2022.

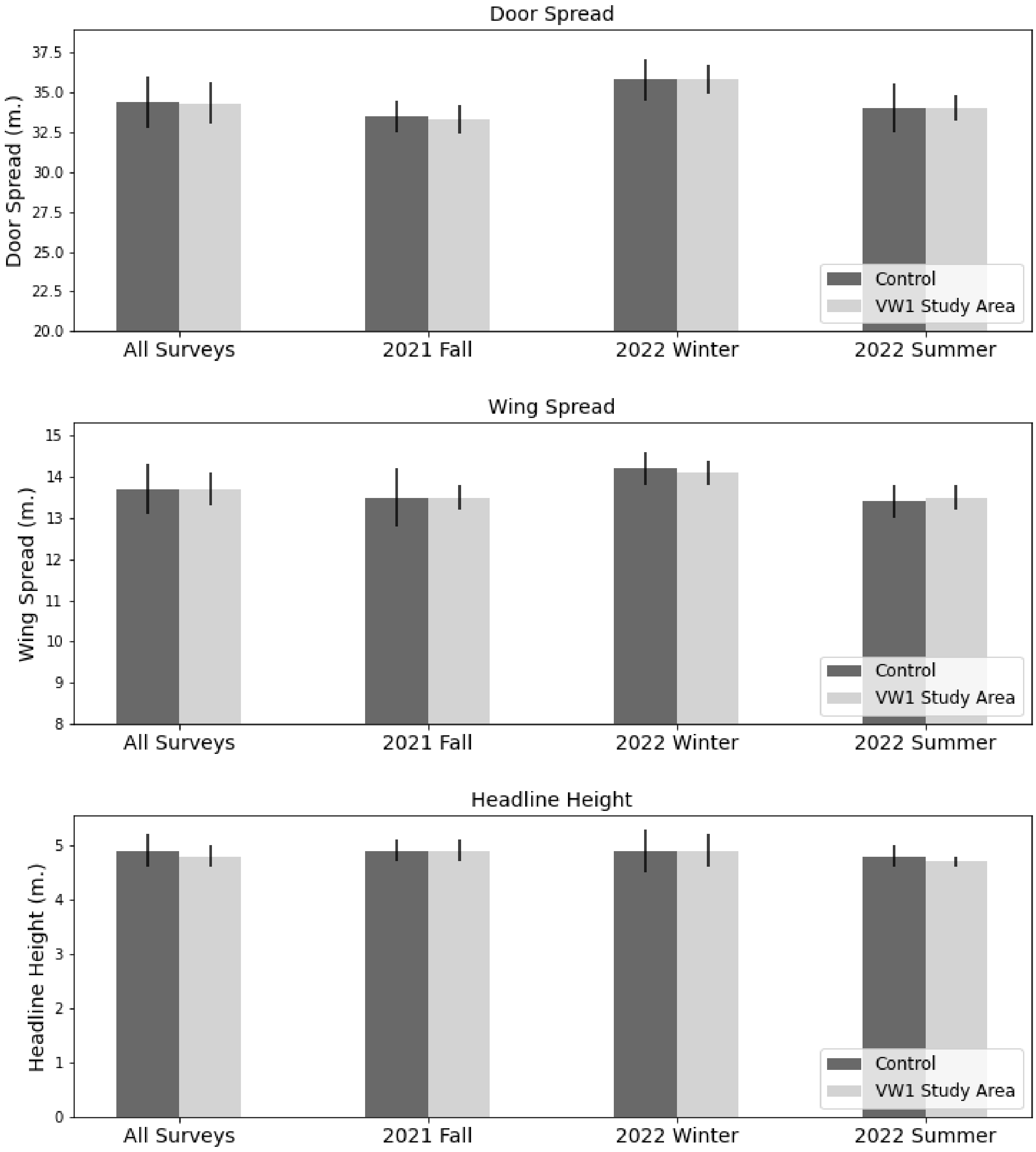


Figure 12: Seasonal averages of the trawl parameters including door spread, wing spread, and headline height.

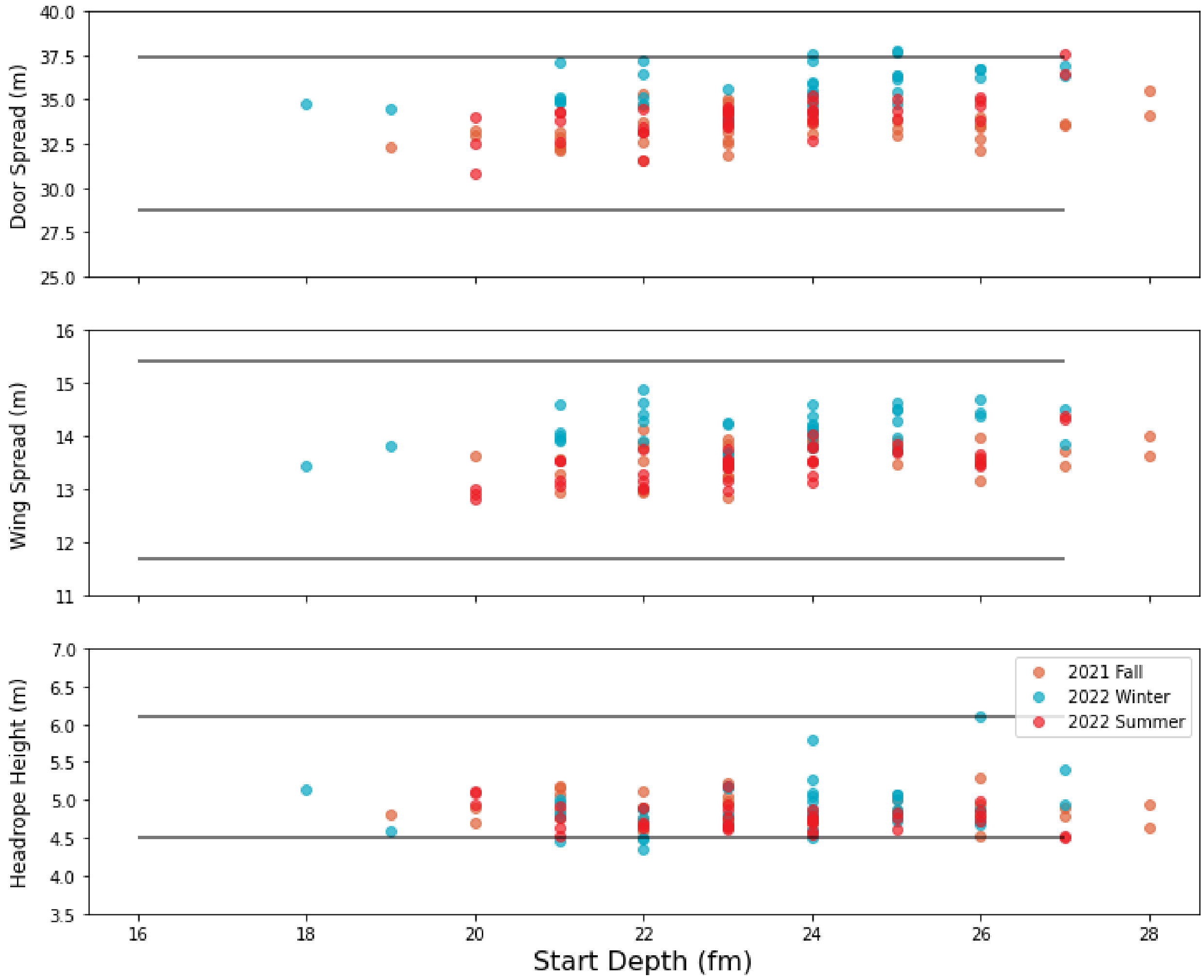


Figure 13: Trawl parameters with respect to the starting depth.

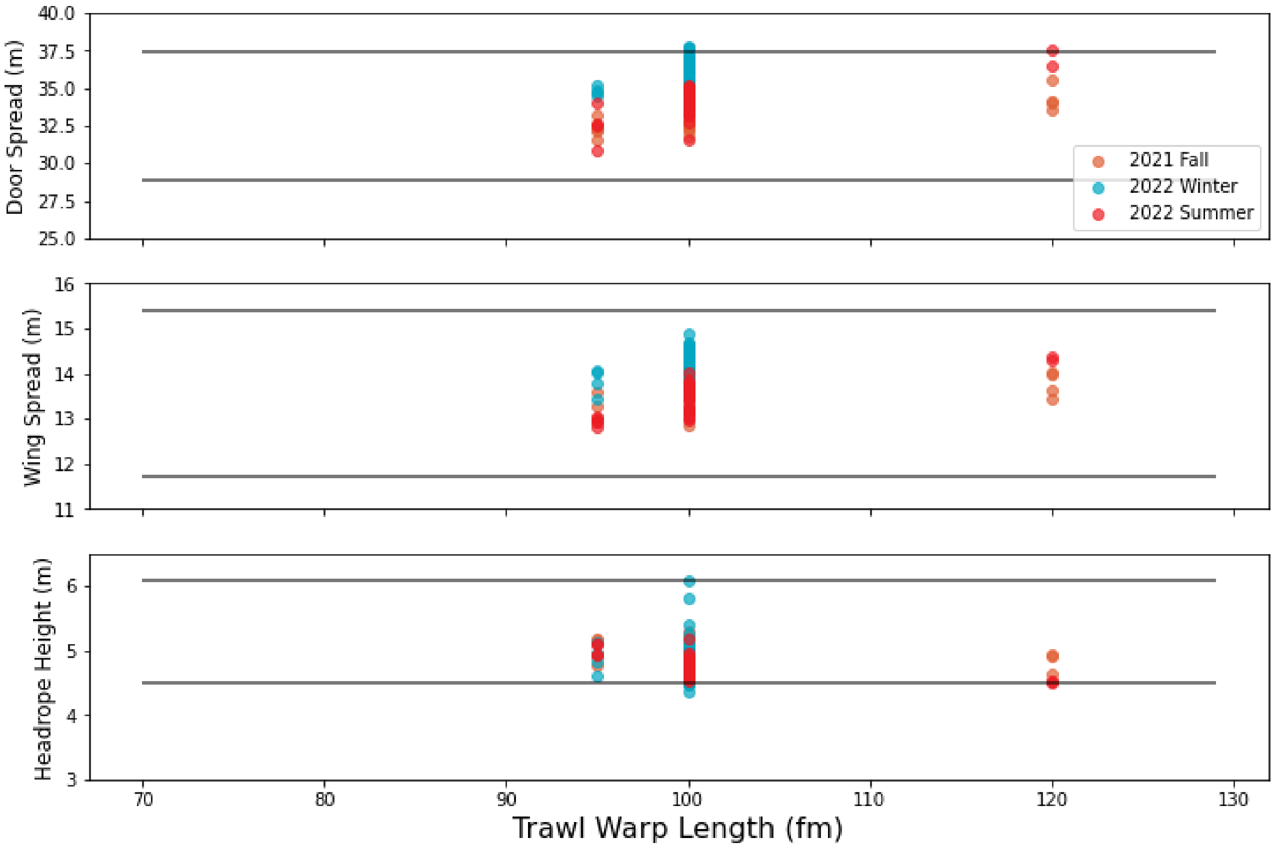


Figure 14: Trawl parameters with respect to the trawl warp.

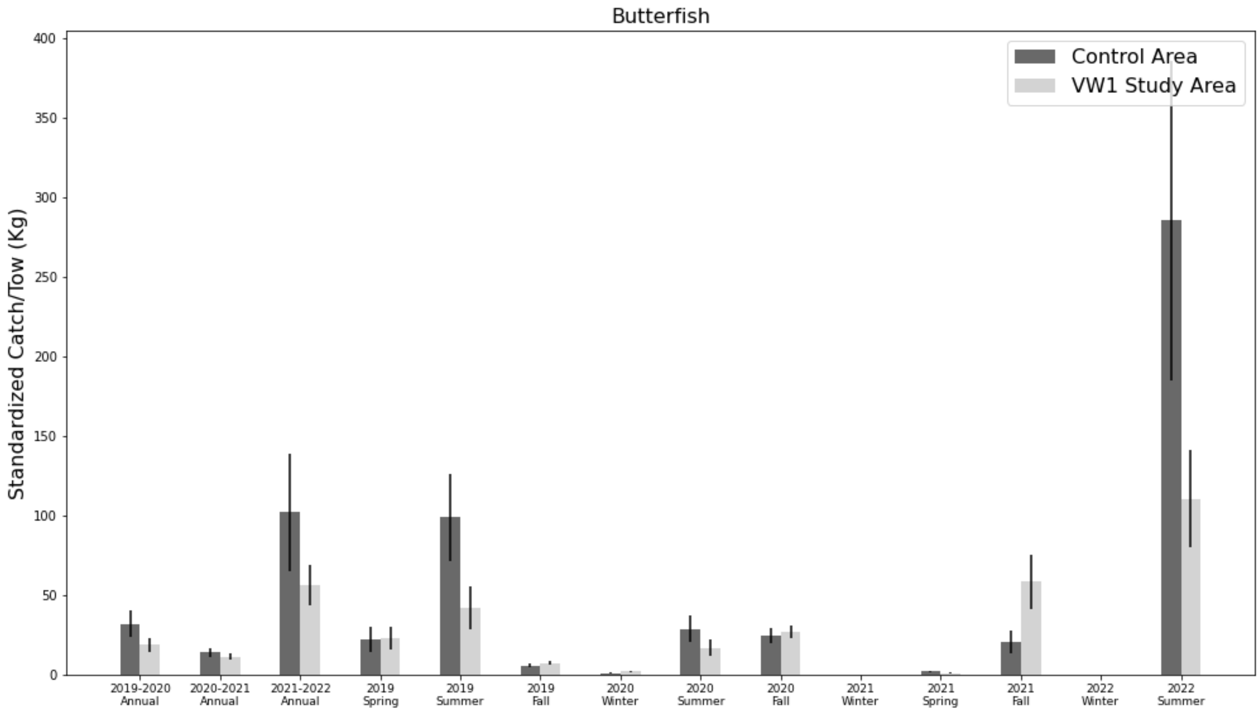


Figure 15: Seasonal catch rates of butterfish in the VW1 Study Area and Control Area.

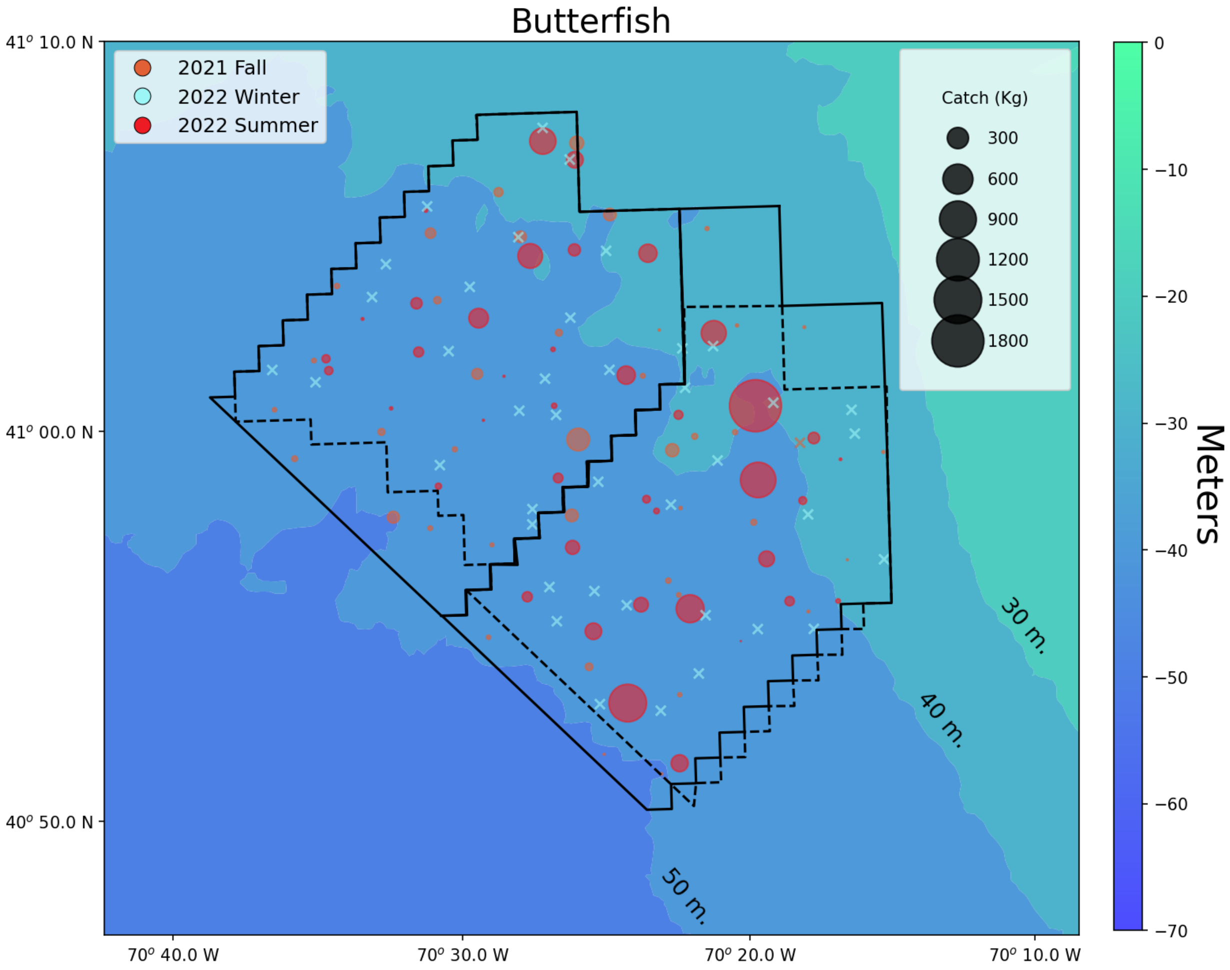


Figure 16: Seasonal distribution of the butterfish catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an x.

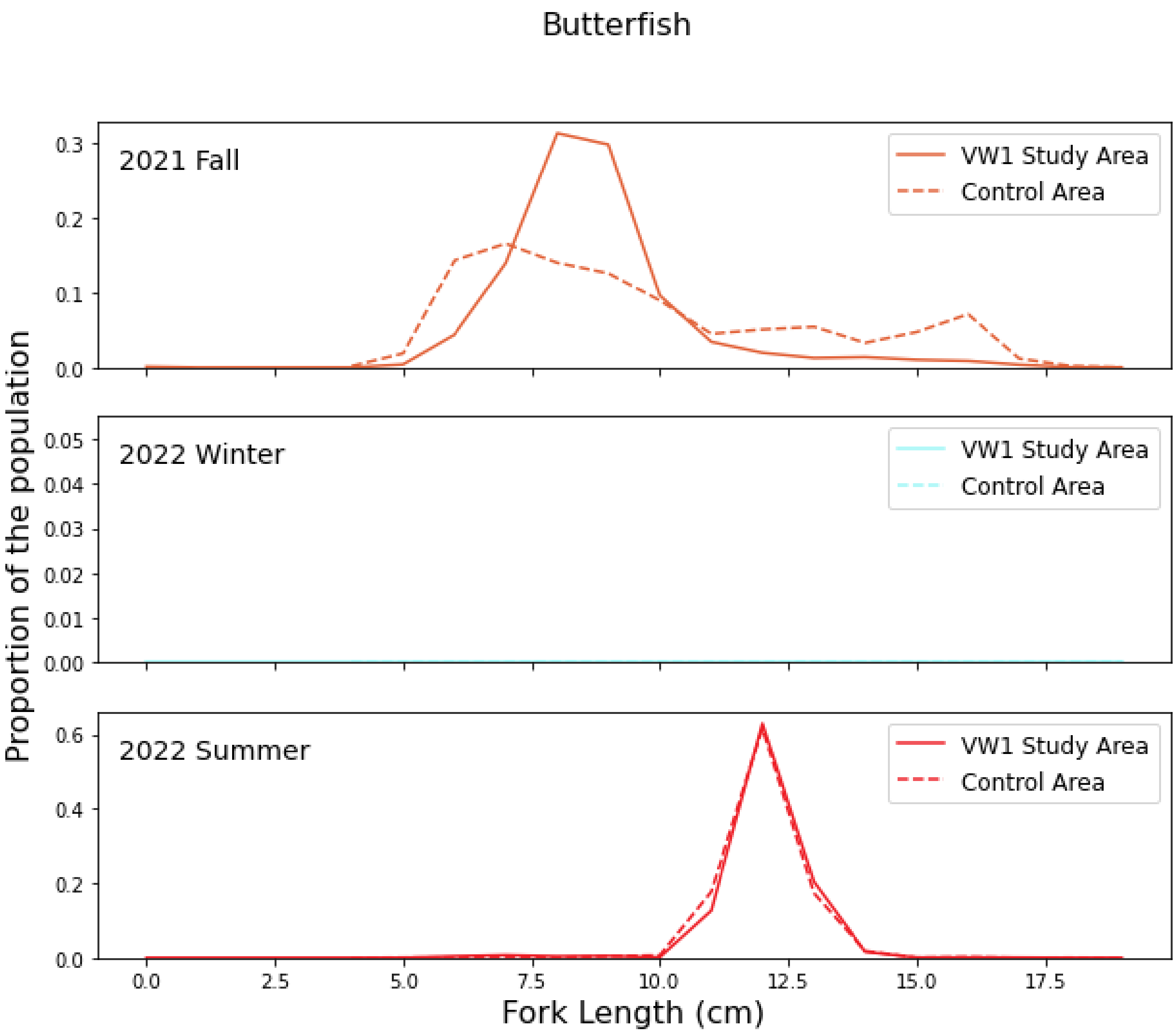


Figure 17: The seasonal length distributions of butterfish in the VW1 Study Area and Control Area.

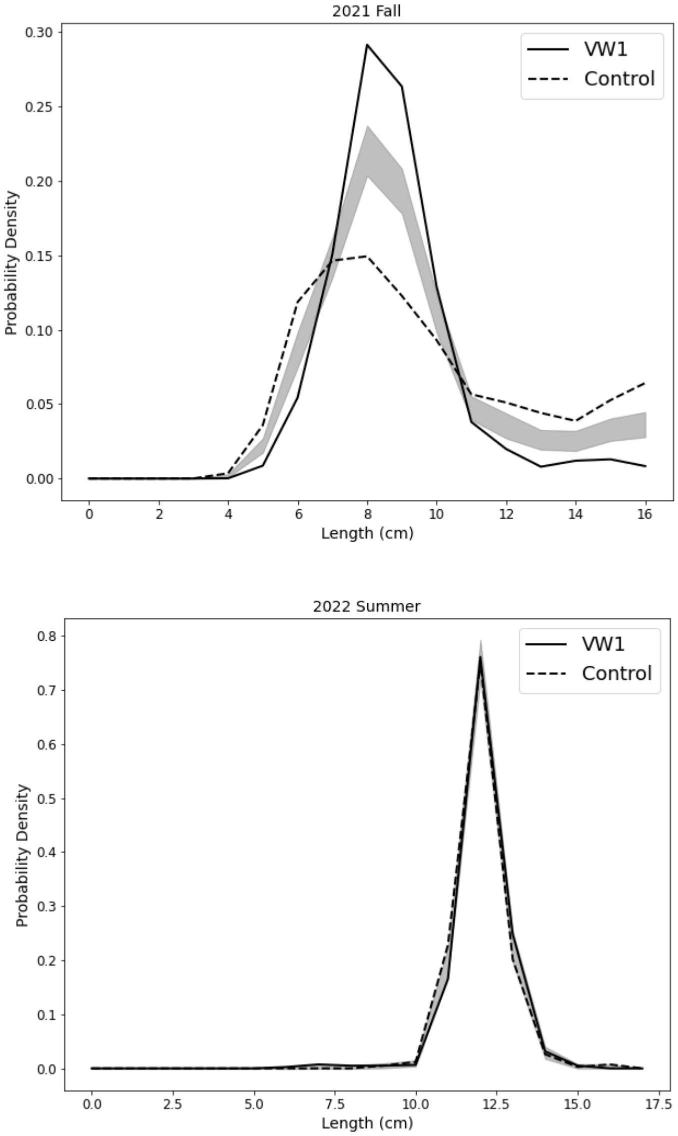


Figure 18: The population structure of butterfish in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

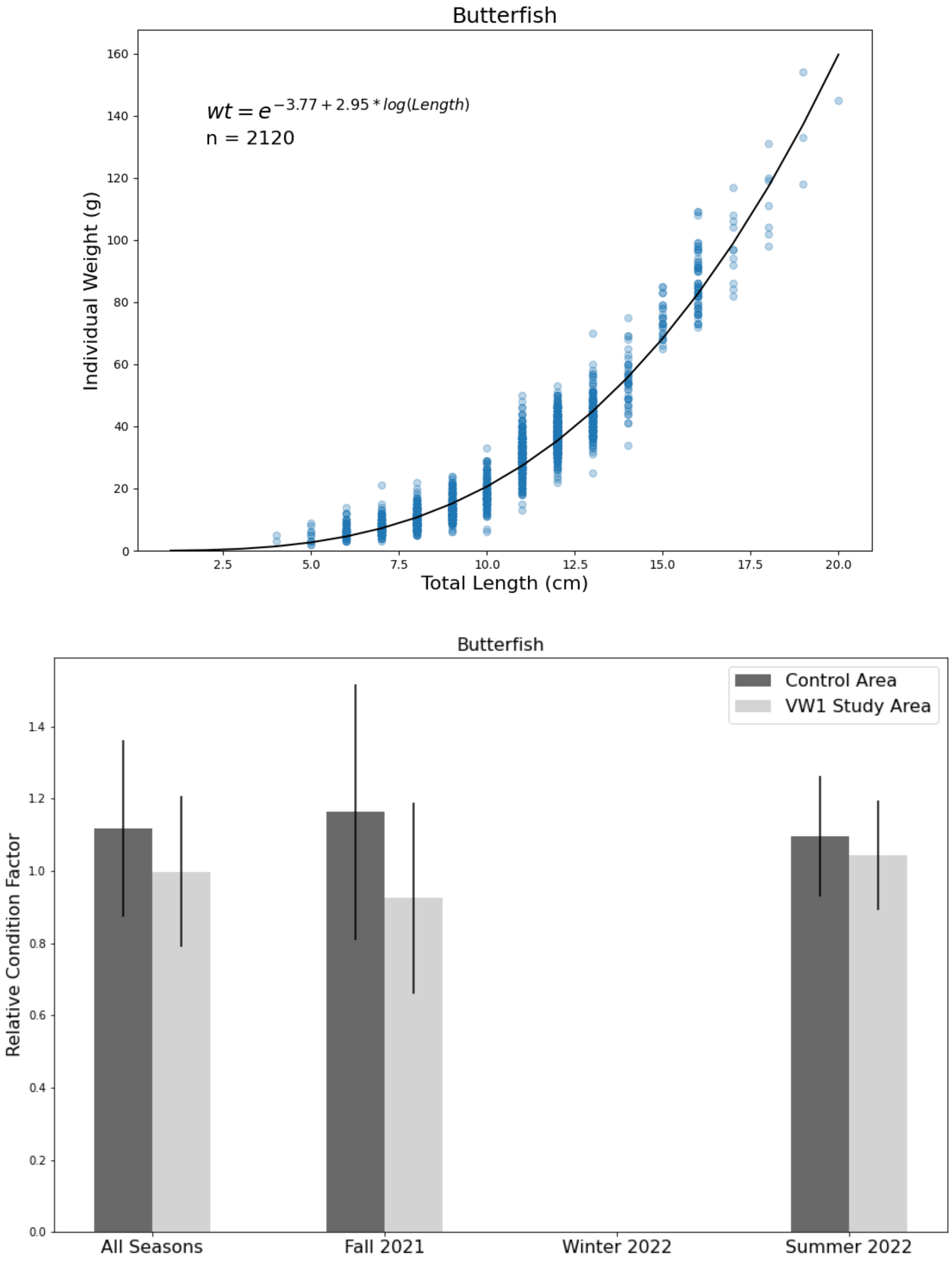


Figure 19: The seasonal condition of butterfish (bottom) as derived from the length-weight relationship (top).

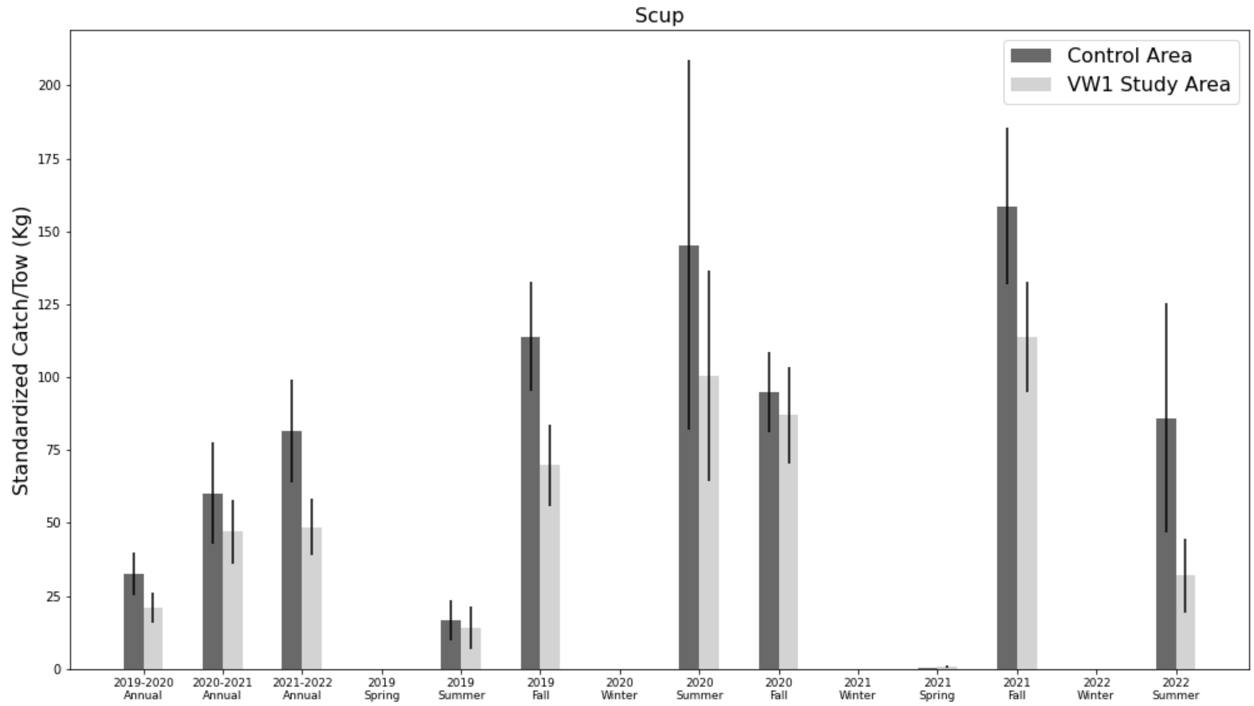


Figure 20: Seasonal catch rates of scup in the VW1 Study Area and Control Area.

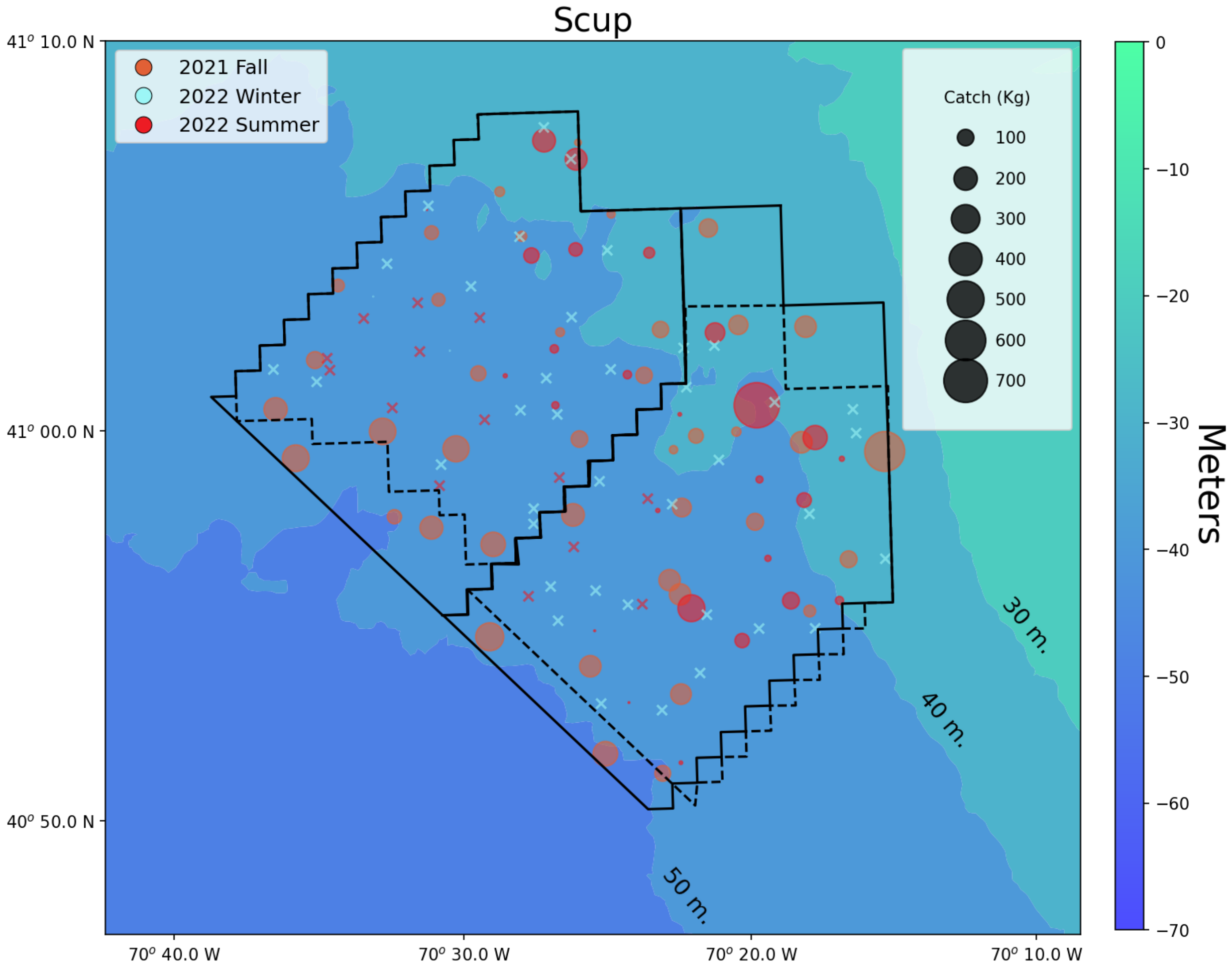


Figure 21: Seasonal distribution of the scup catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

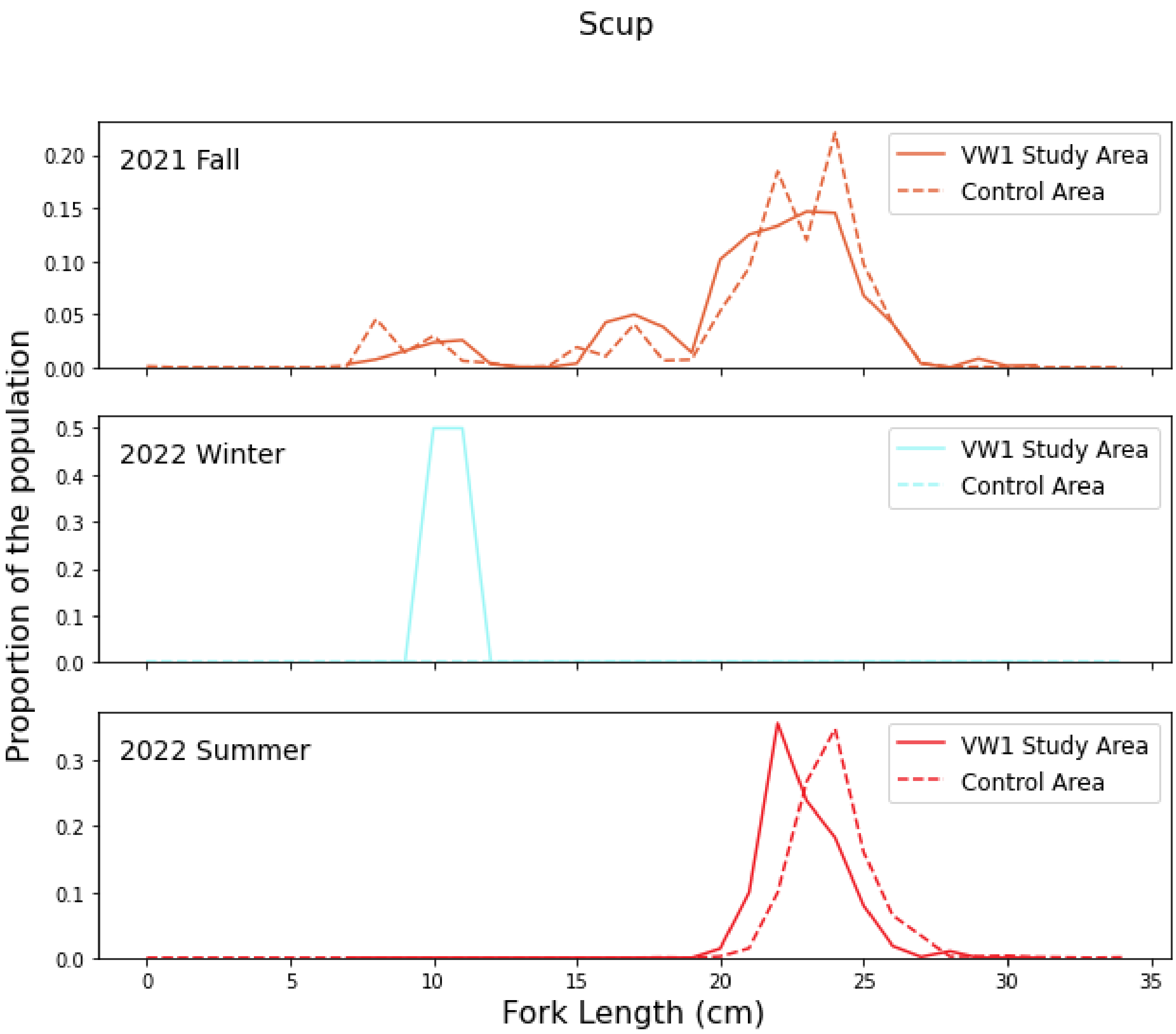
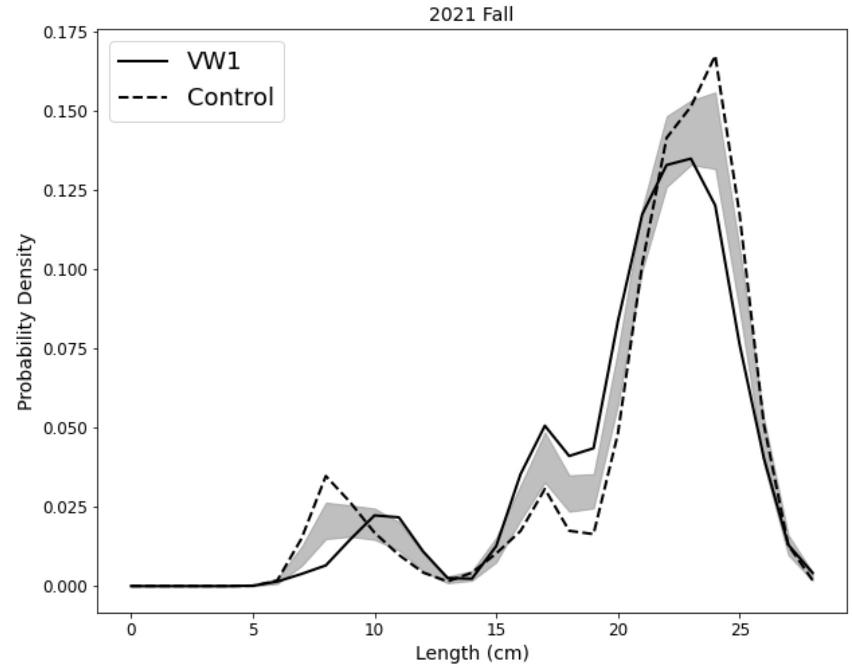


Figure 22: The seasonal length distributions of scup in the VW1 Study Area and Control Area.



2022 Summer

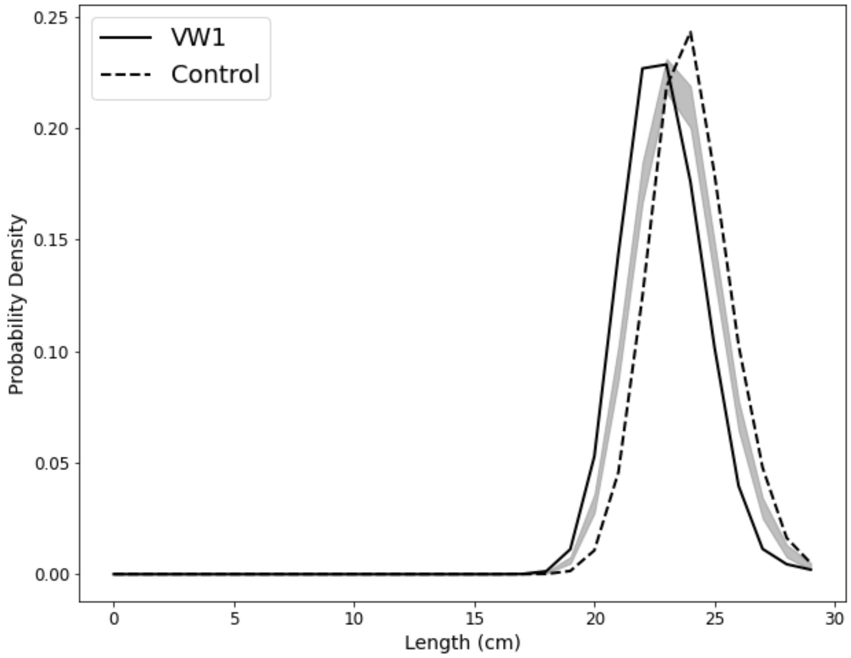


Figure 23: The population structure of scup in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

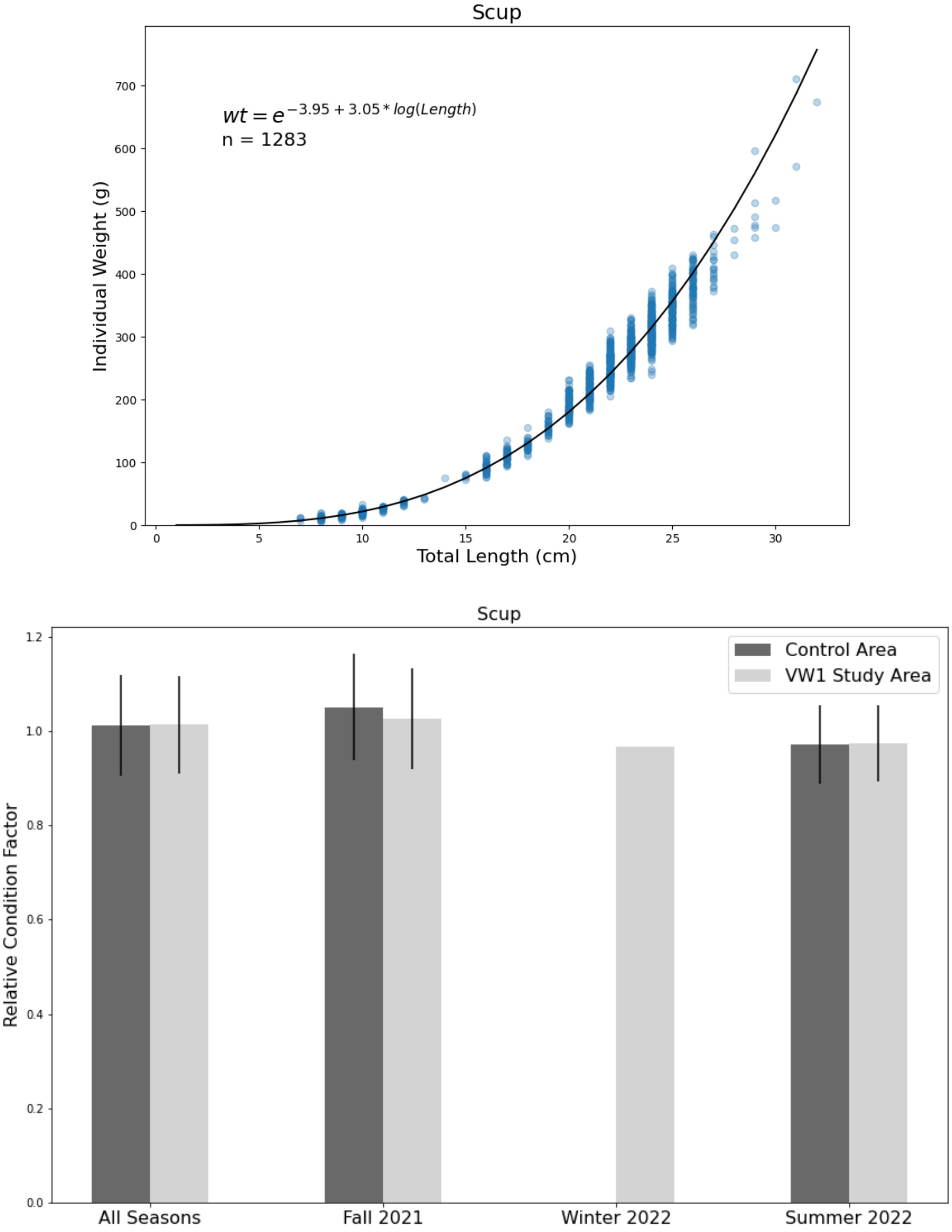


Figure 24: The seasonal condition of scup (bottom) as derived from the length-weight relationship (top).

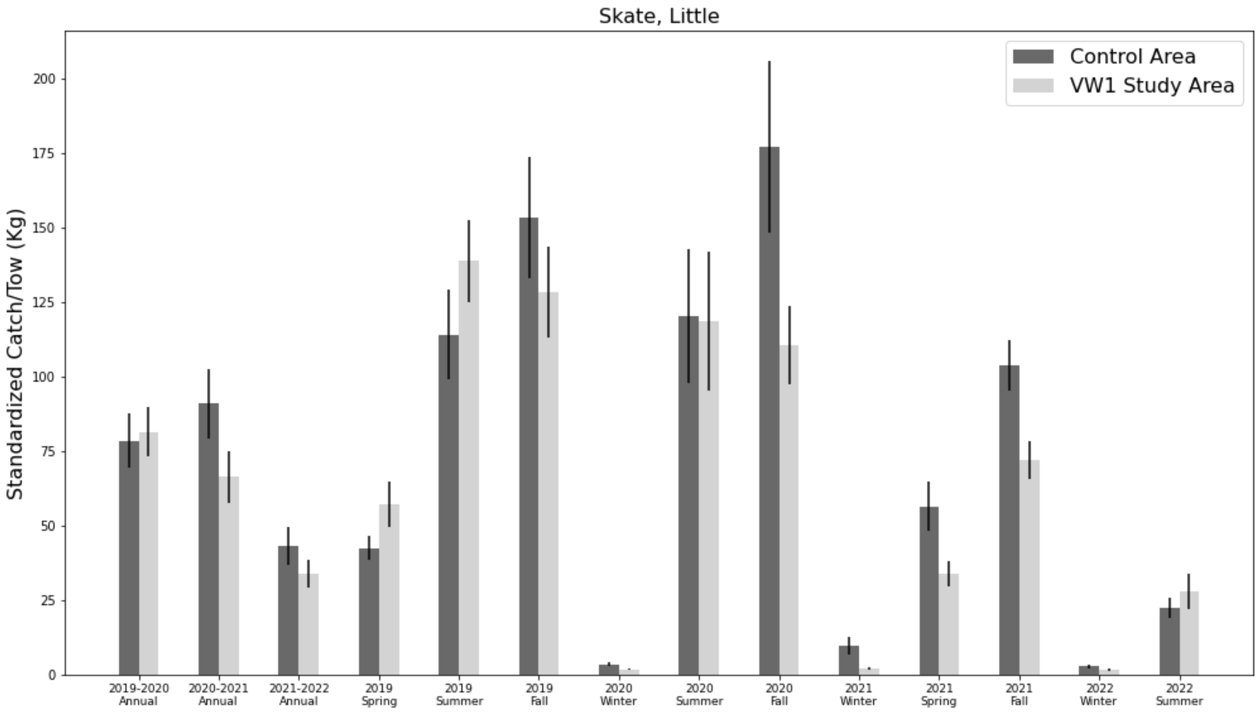


Figure 25: Seasonal catch rates of little skate in the VW1 Study Area and Control Area.

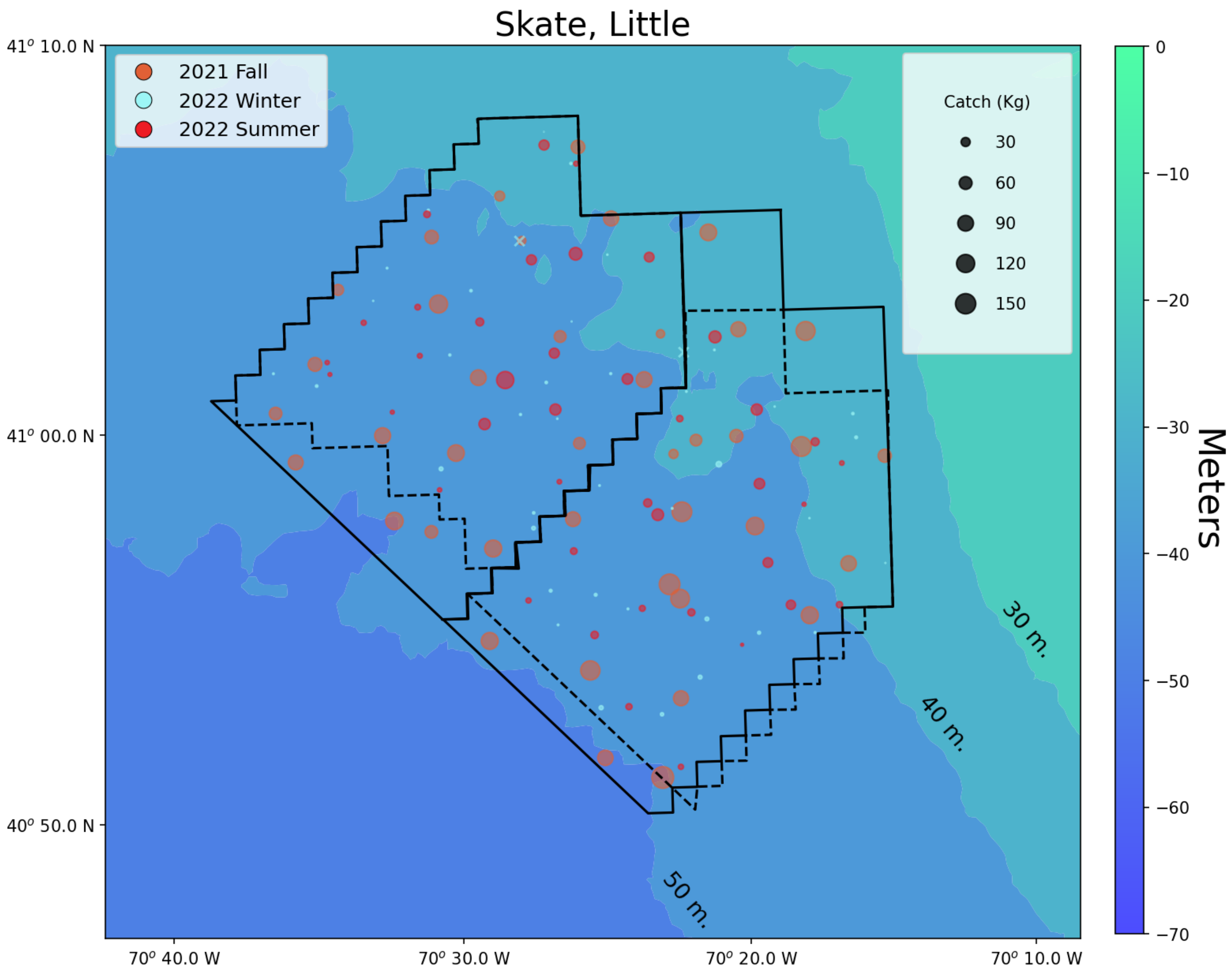


Figure 26: Seasonal distribution of the little skate catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

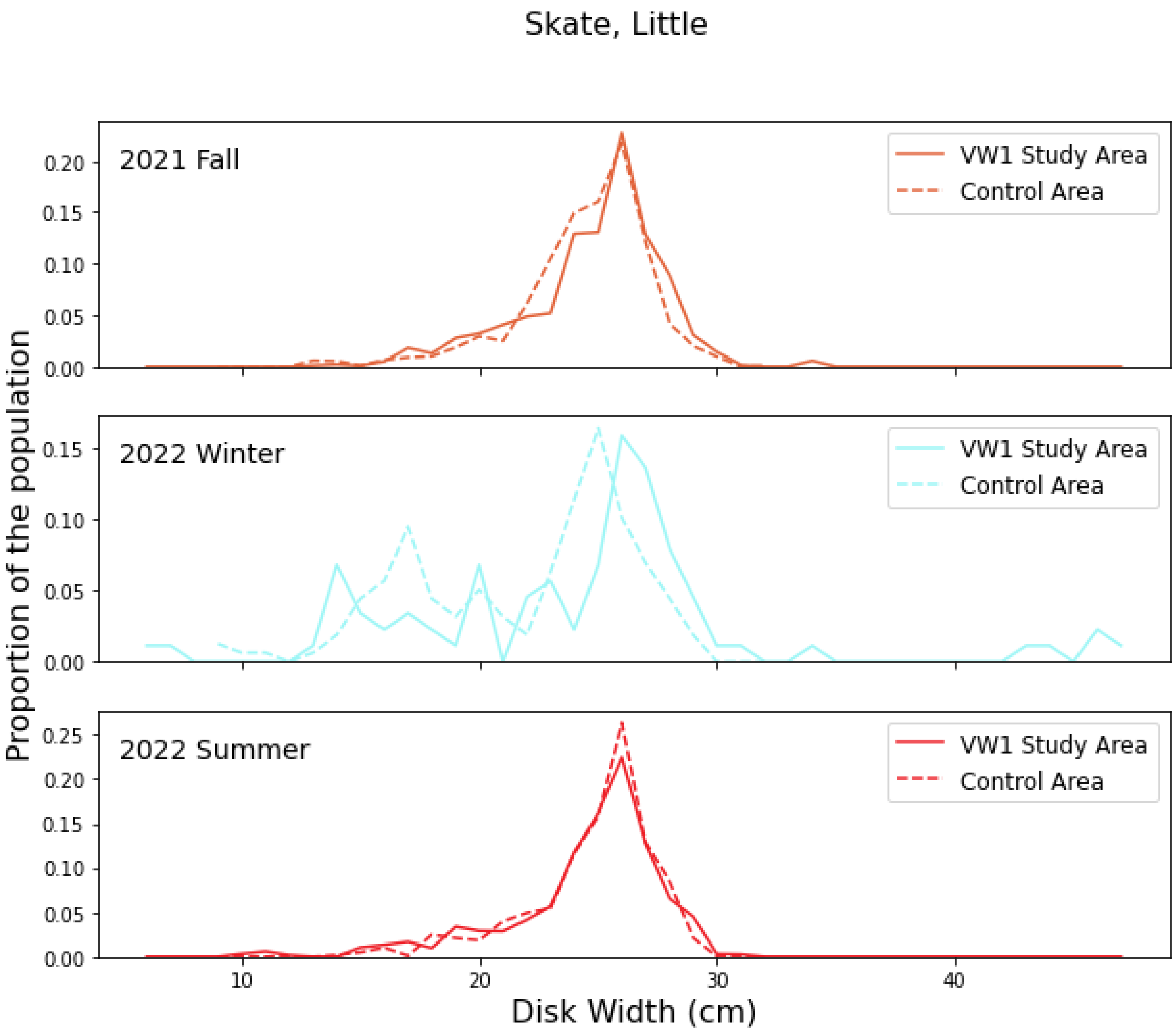


Figure 27: The seasonal length distributions of little skate in the VW1 Study Area and Control Area.

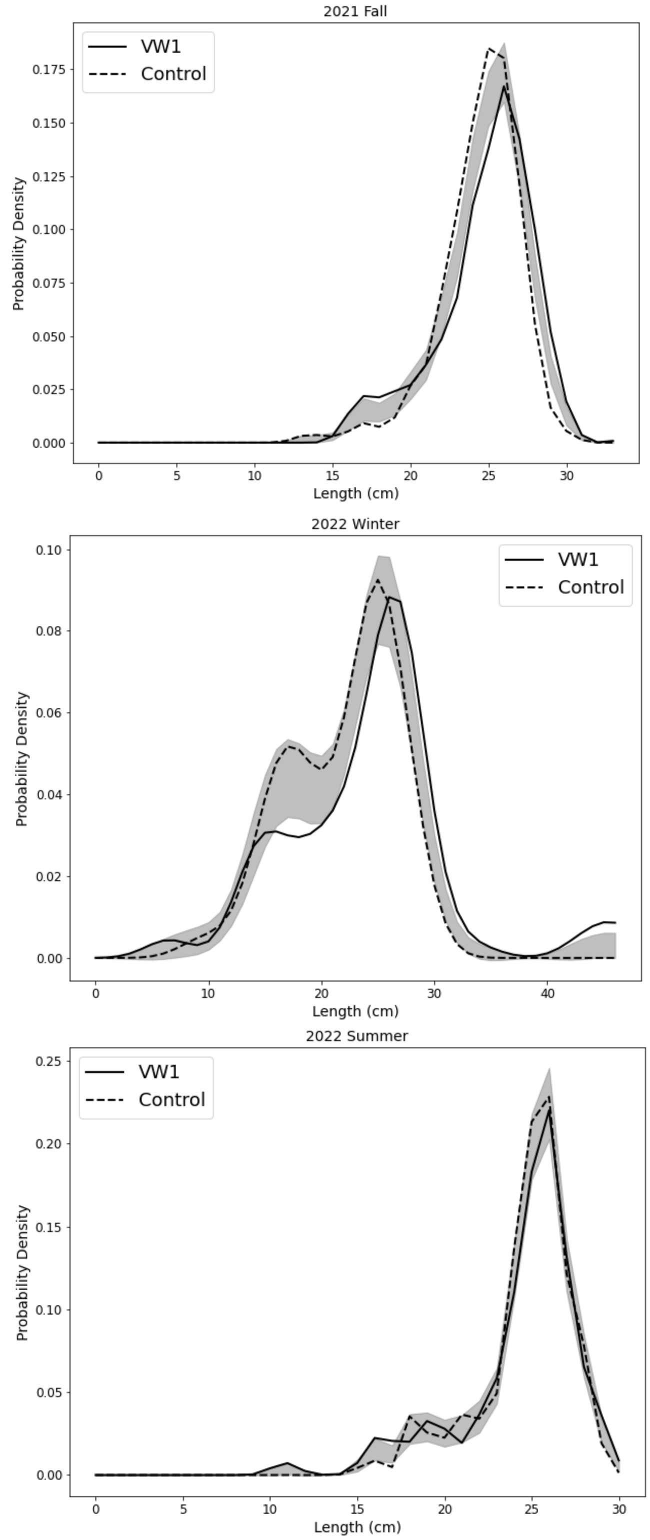
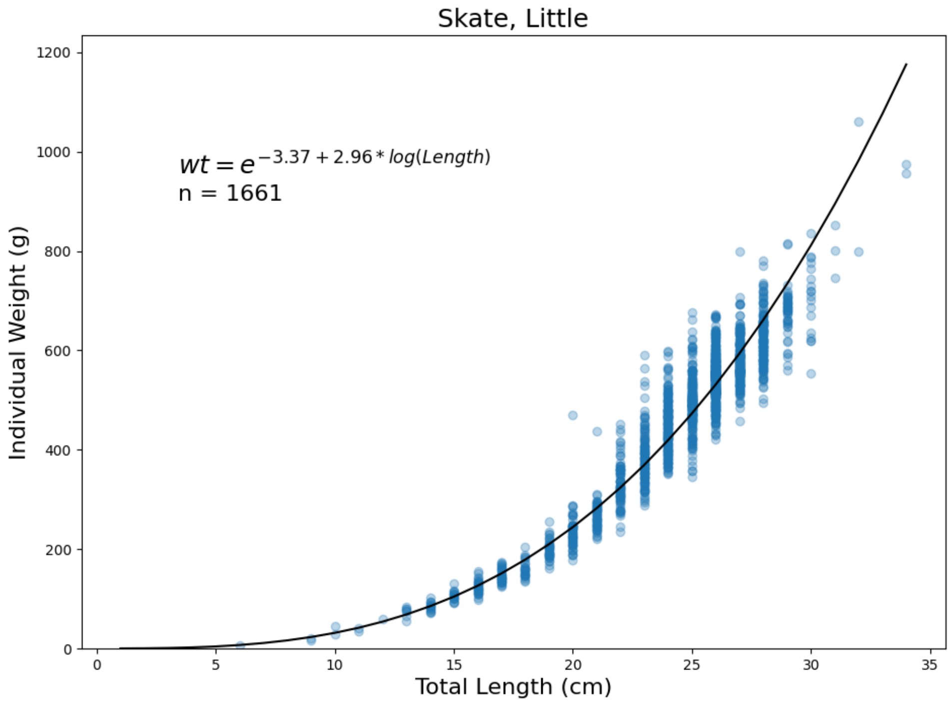


Figure 28: The population structure of little skate in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



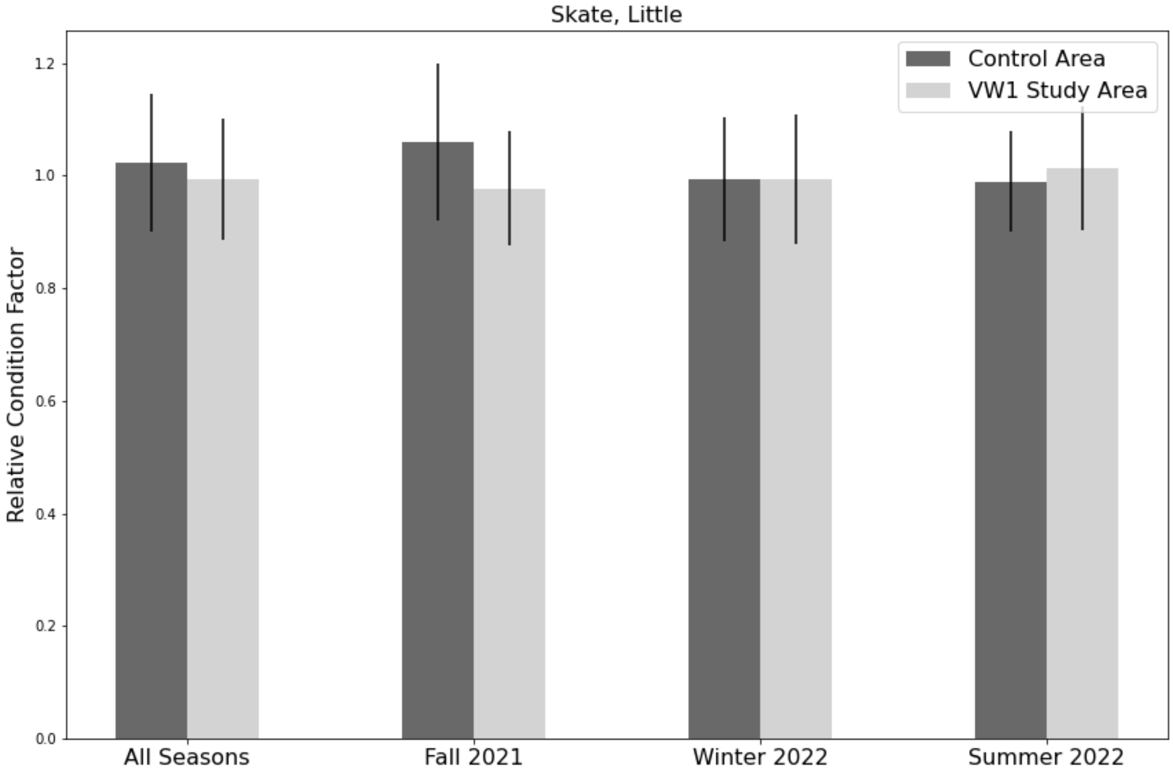


Figure 29: The seasonal condition of little skate (bottom) as derived from the length-weight relationship (top).

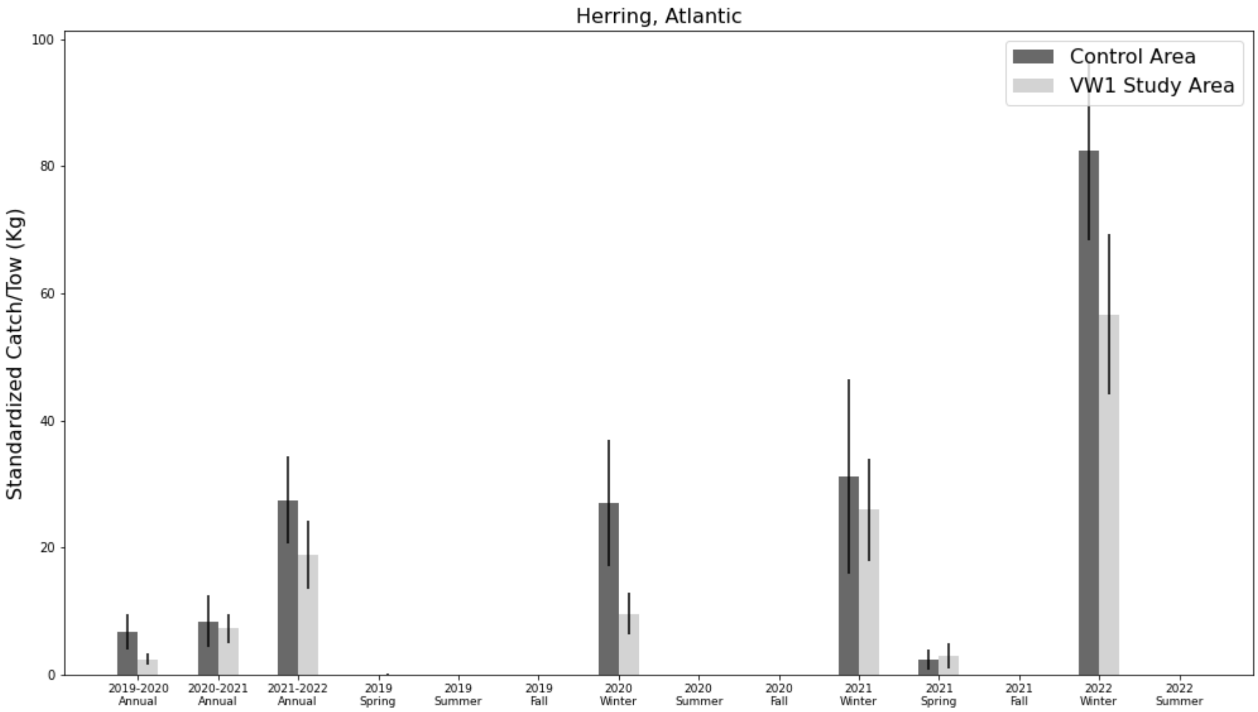


Figure 30: Seasonal catch rates of Atlantic herring in the VW1 Study Area and Control Area.

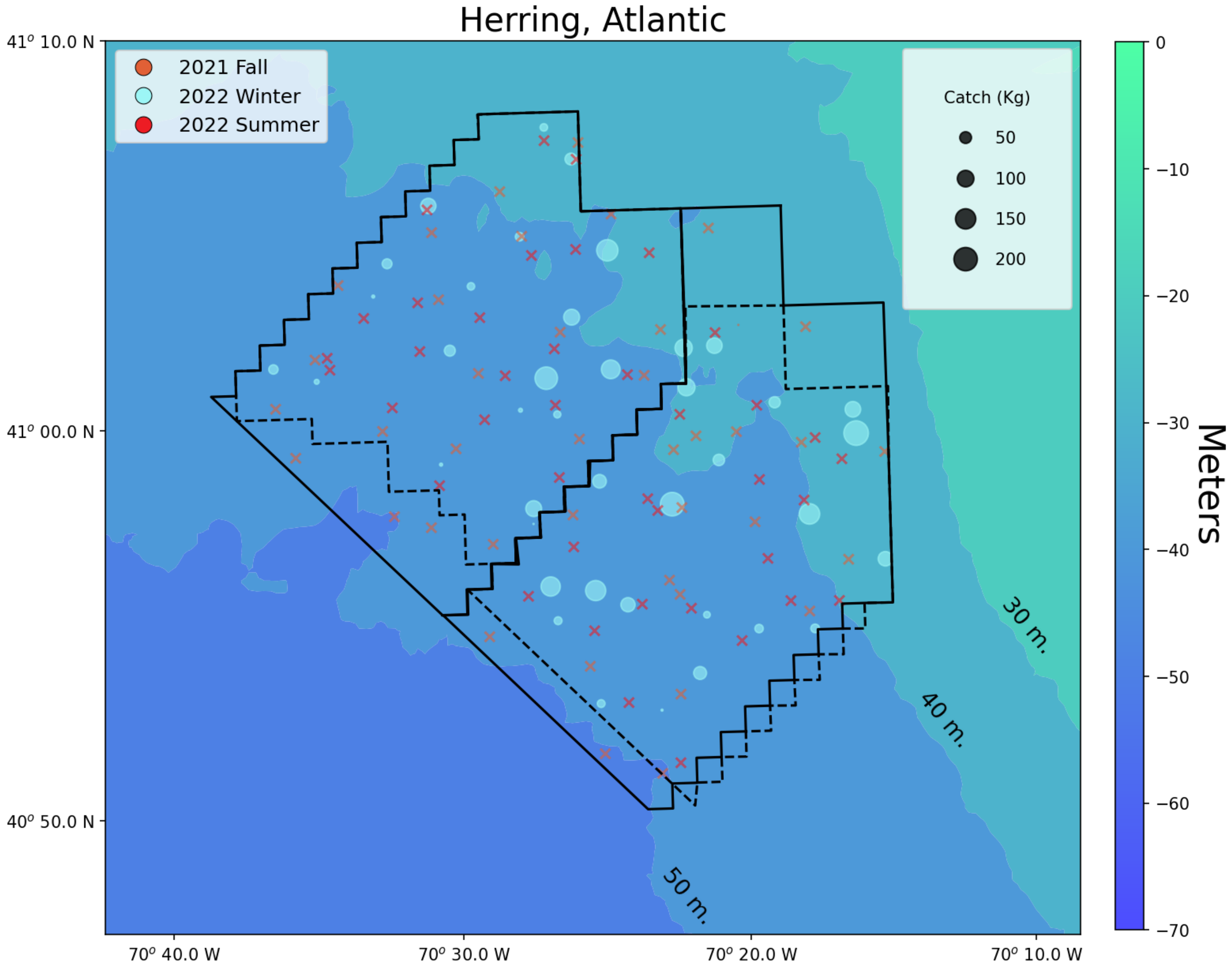


Figure 31: Seasonal distribution of the Atlantic herring catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

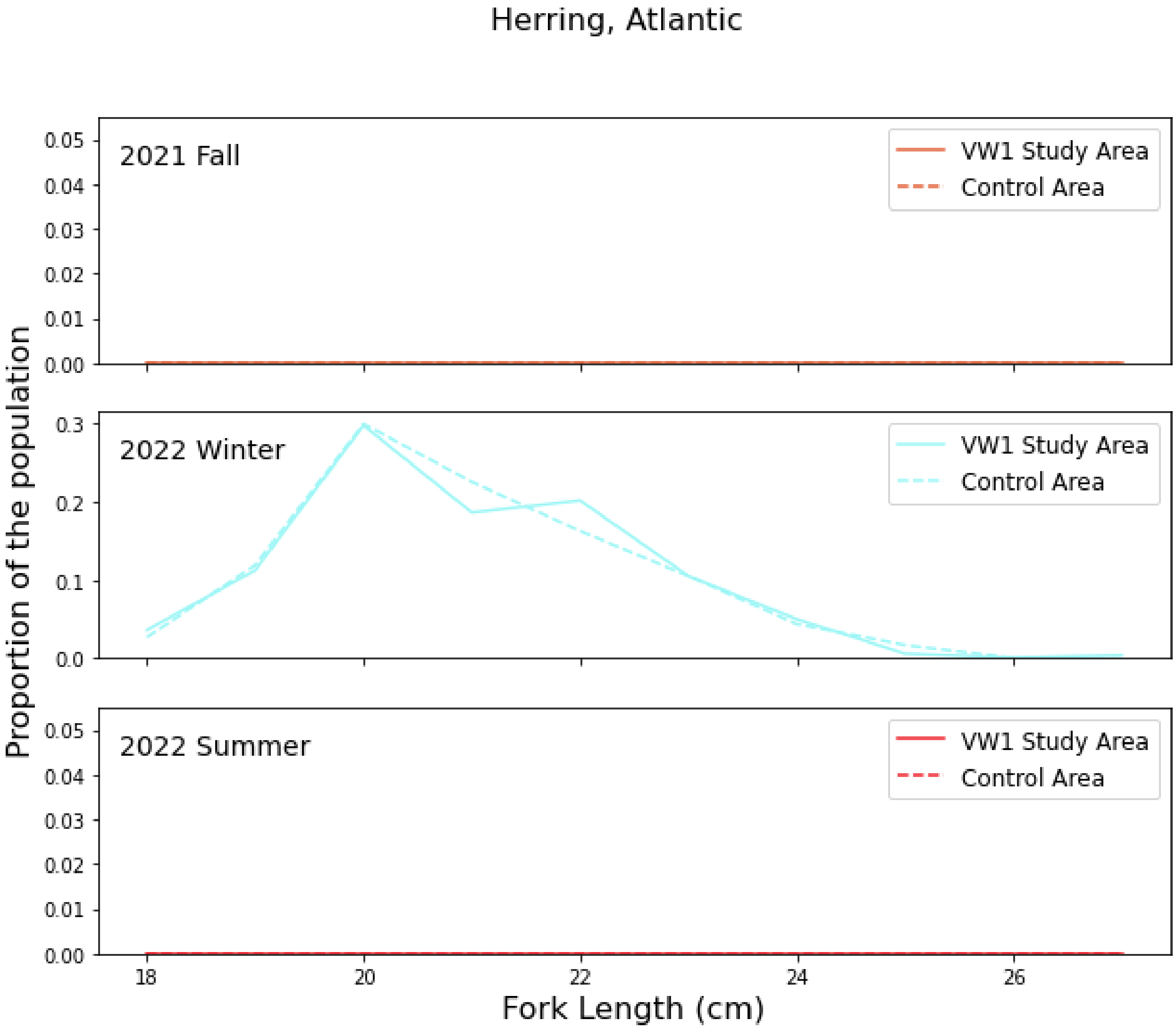


Figure 32: The seasonal length distributions of Atlantic herring in the VW1 Study Area and Control Area.

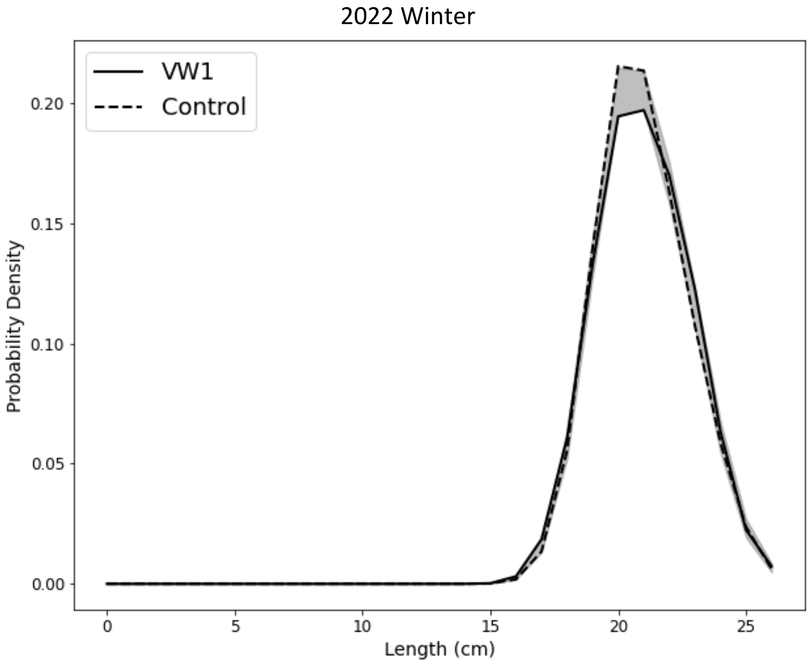
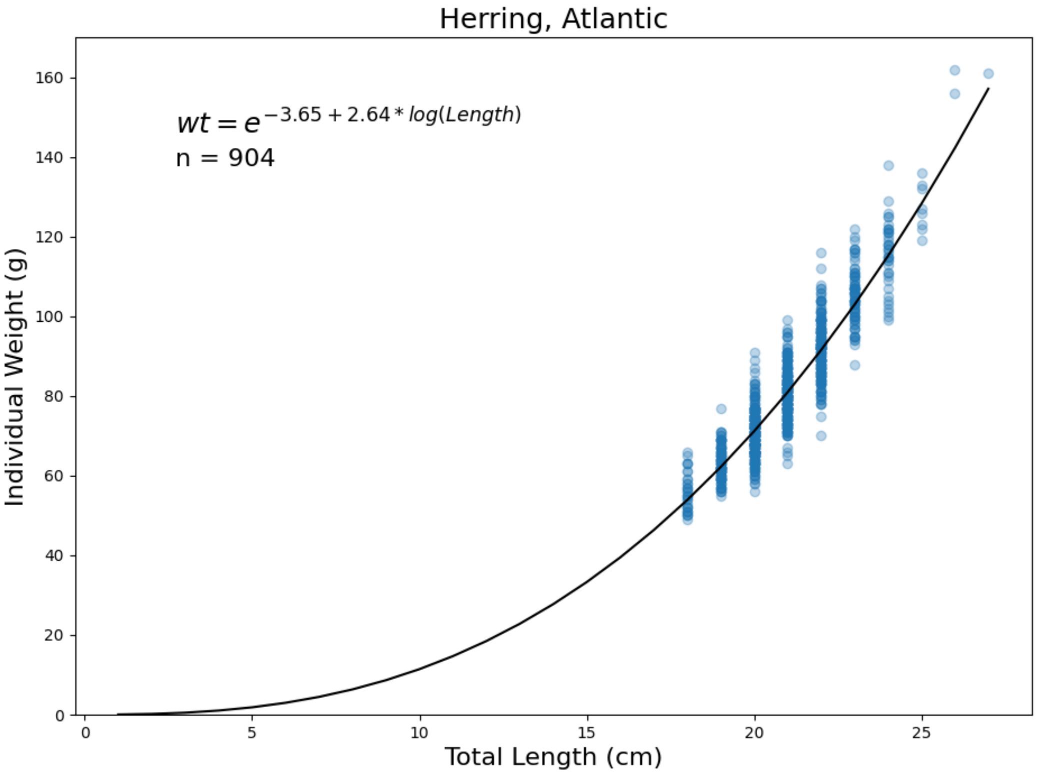


Figure 33: The population structure of Atlantic herring in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



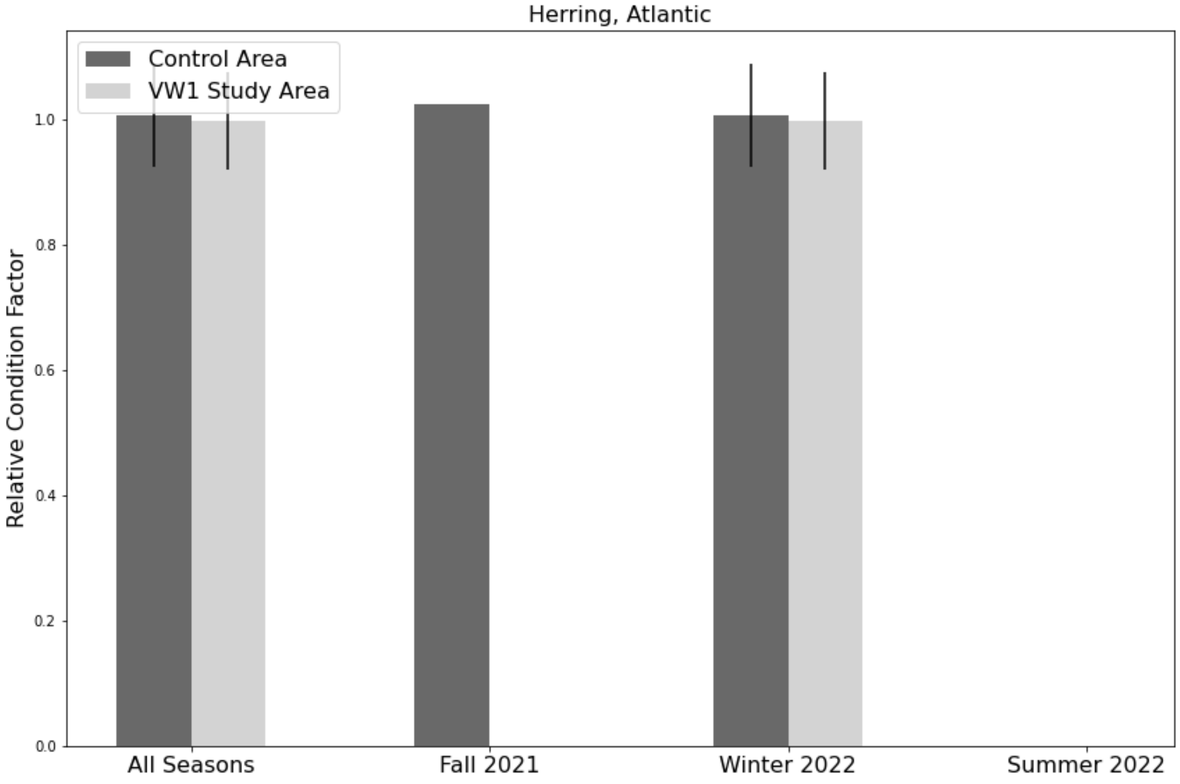


Figure 34: The seasonal condition of Atlantic herring (bottom) as derived from the length-weight relationship (top).

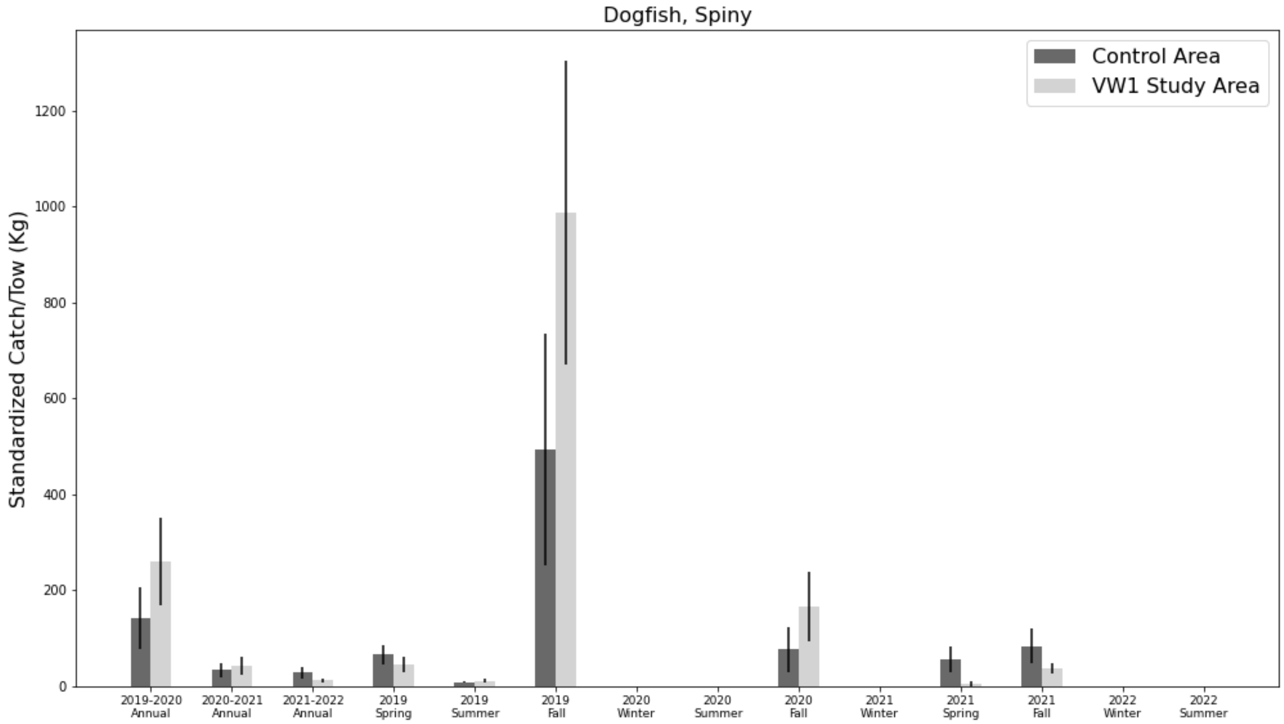


Figure 35: Seasonal catch rates of spiny dogfish in the VW1 Study Area and Control Area.

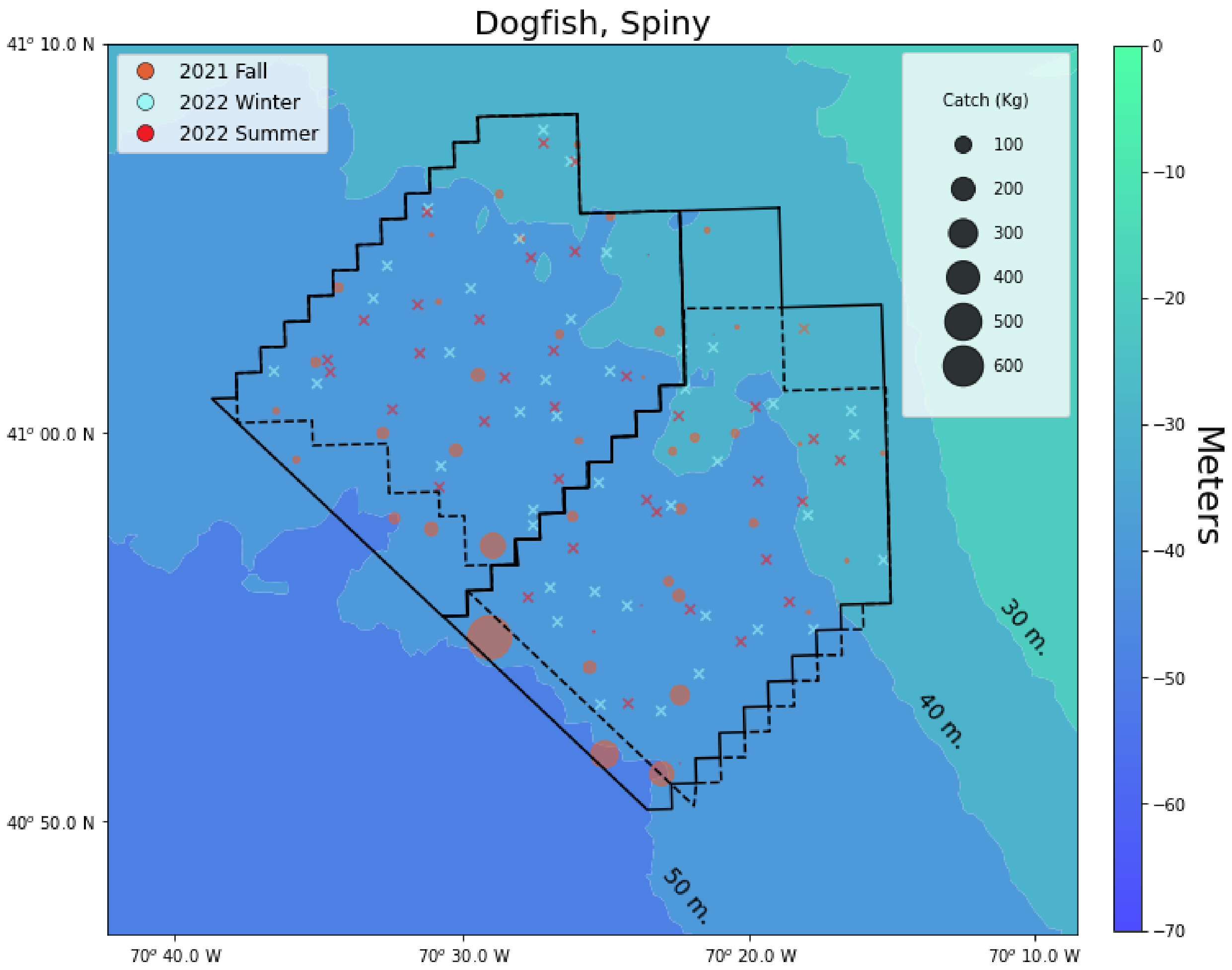


Figure 36: Seasonal distribution of the spiny dogfish catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

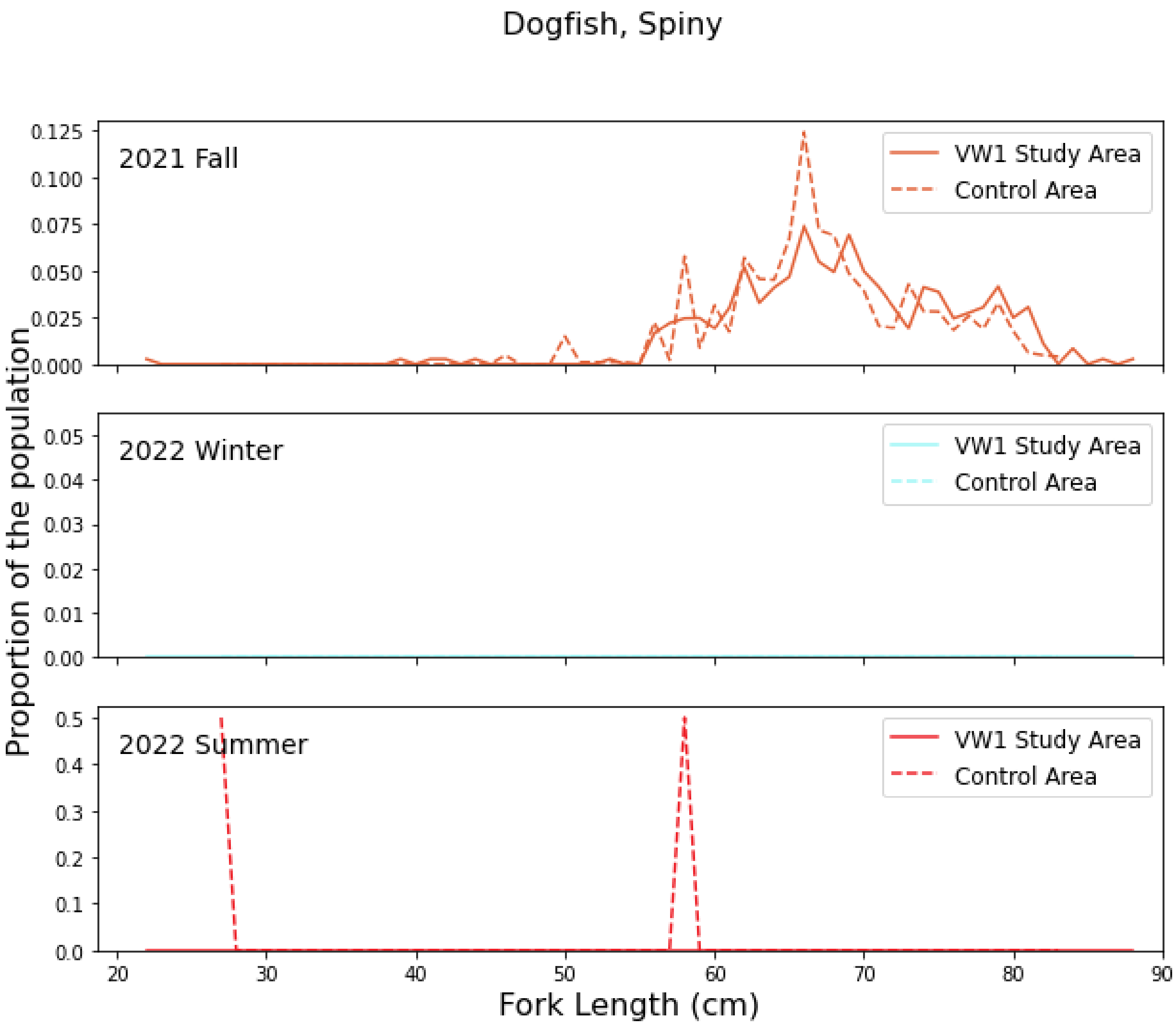


Figure 37: The seasonal length distributions of spiny dogfish in the VW1 Study Area and Control Area.

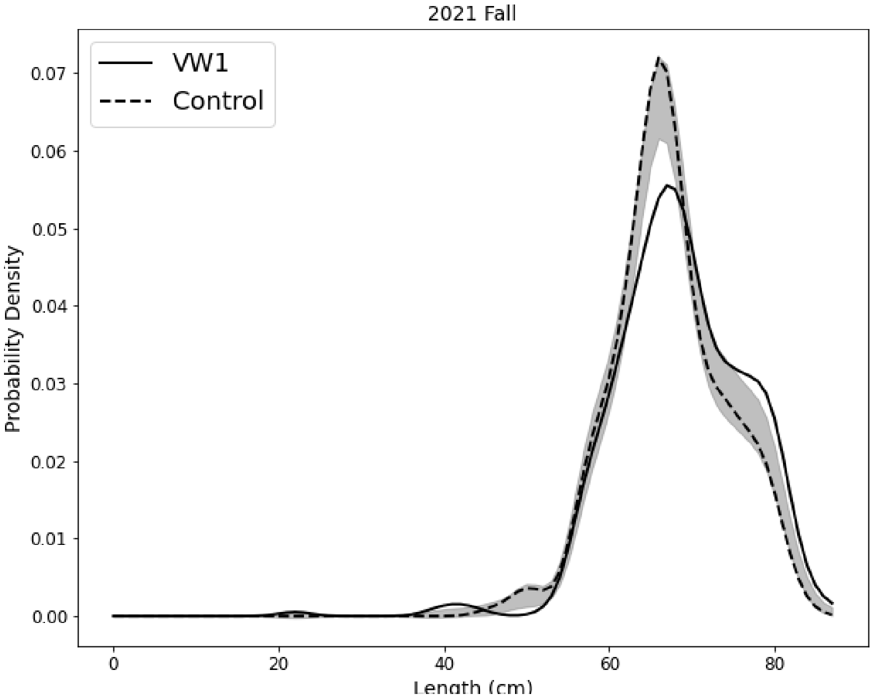
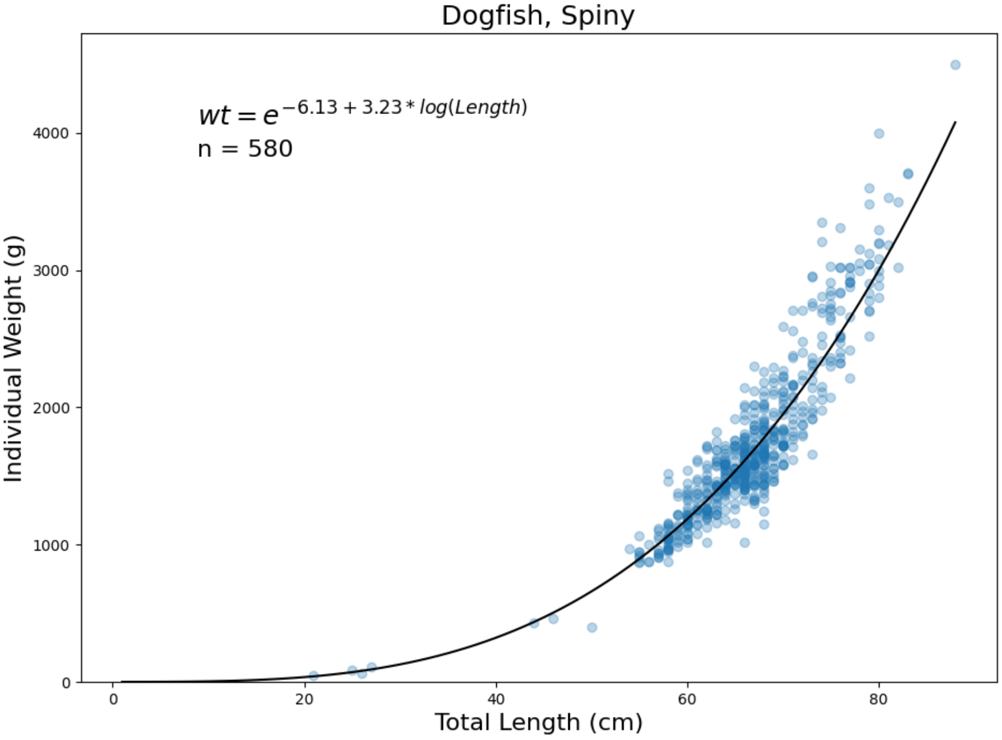


Figure 38: The population structure of spiny dogfish in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



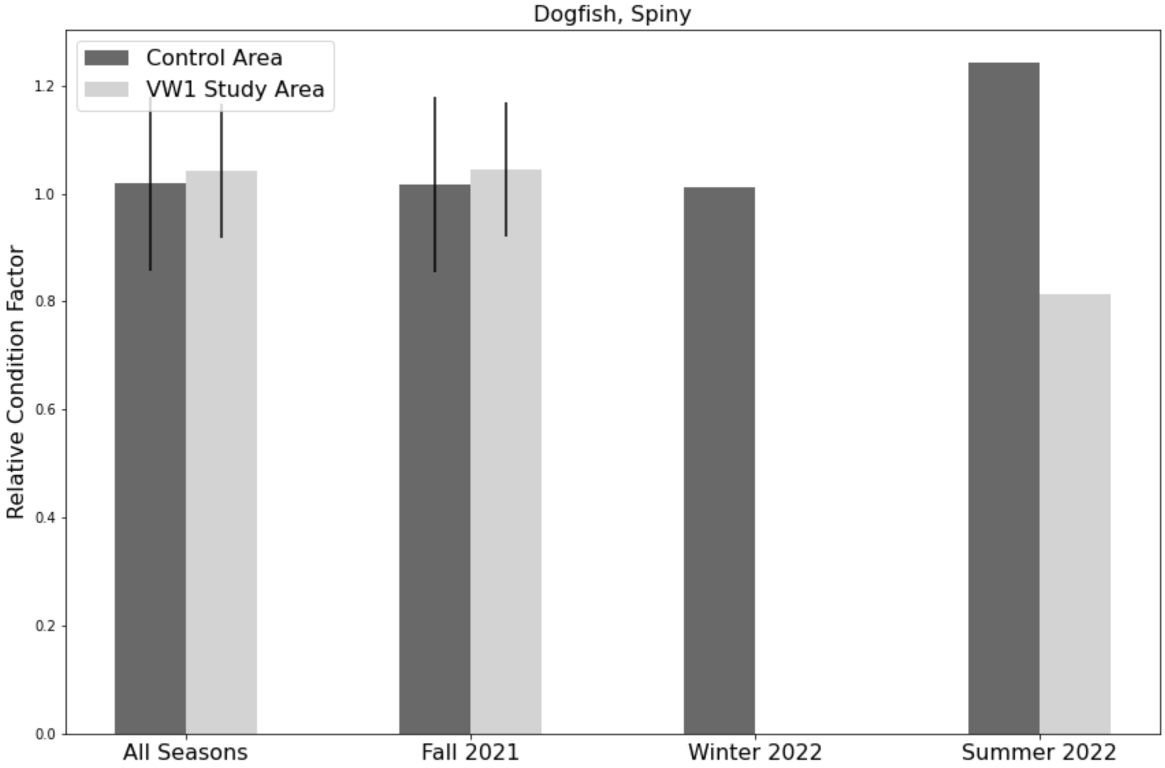


Figure 39: The seasonal condition of spiny dogfish (bottom) as derived from the length-weight relationship (top).

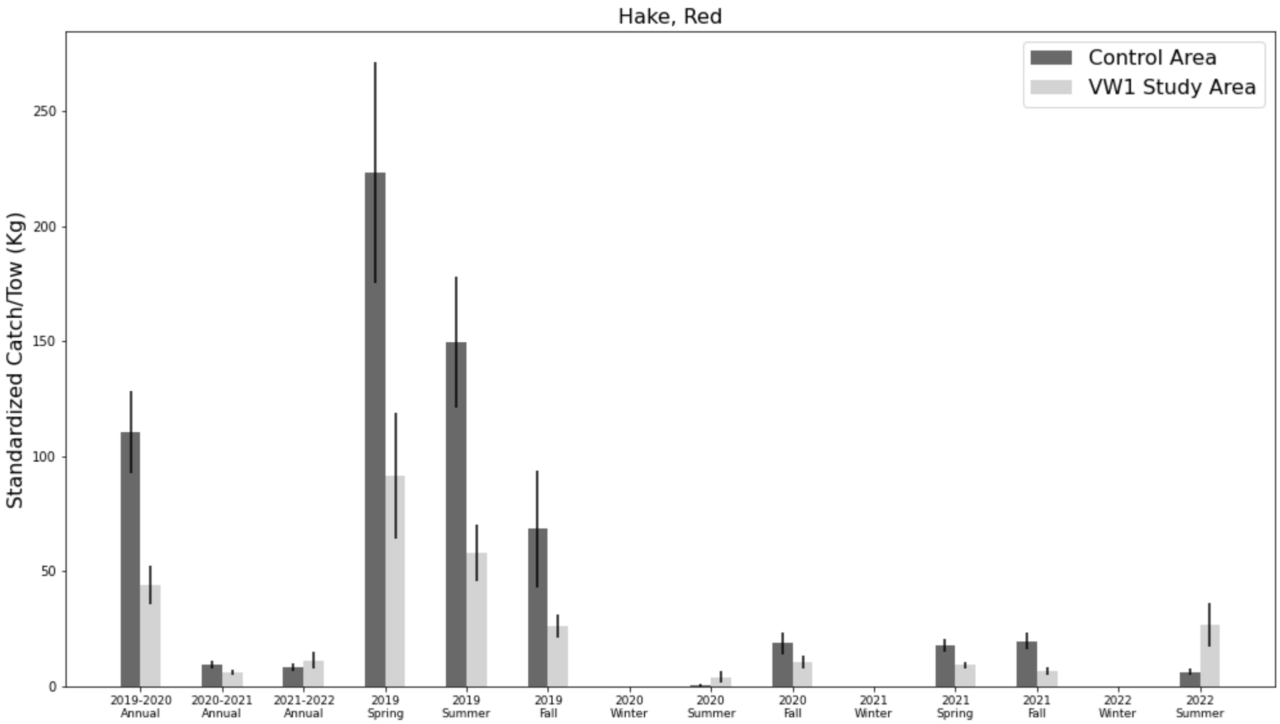


Figure 40: Seasonal catch rates of red hake in the VW1 Study Area and Control Area.

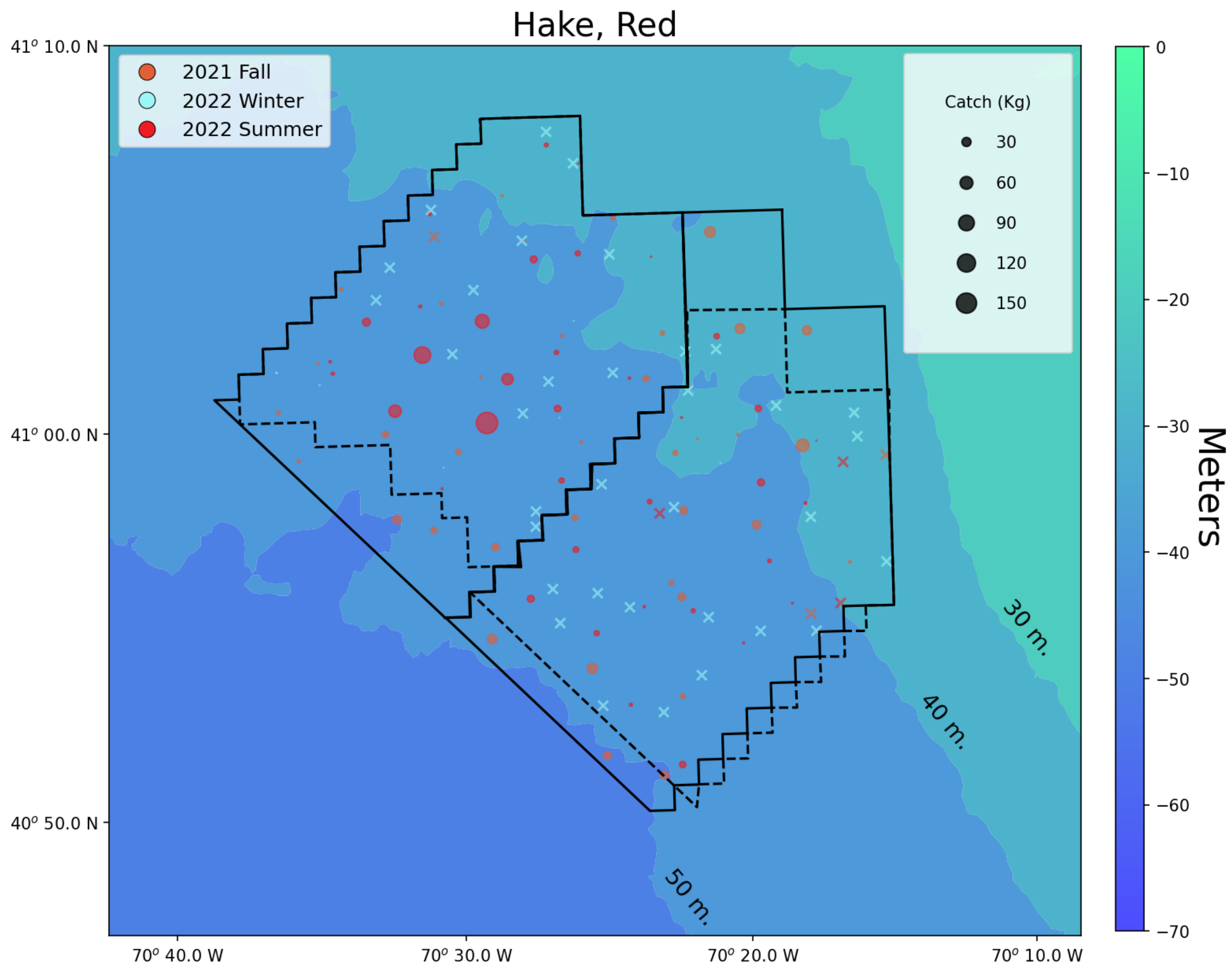


Figure 41: Seasonal distribution of the red hake catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

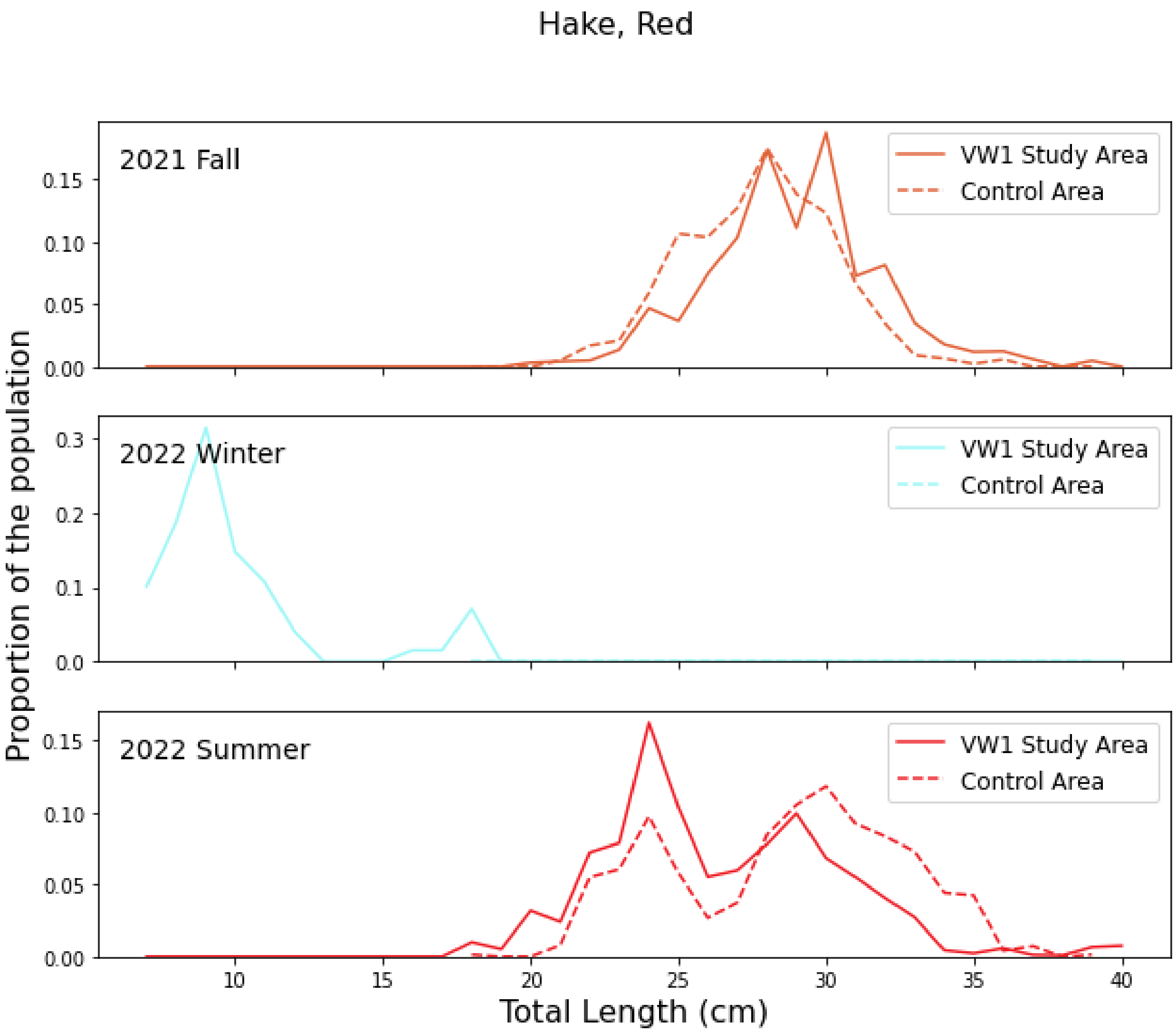


Figure 42: The seasonal length distributions of red hake in the VW1 Study Area and Control Area.

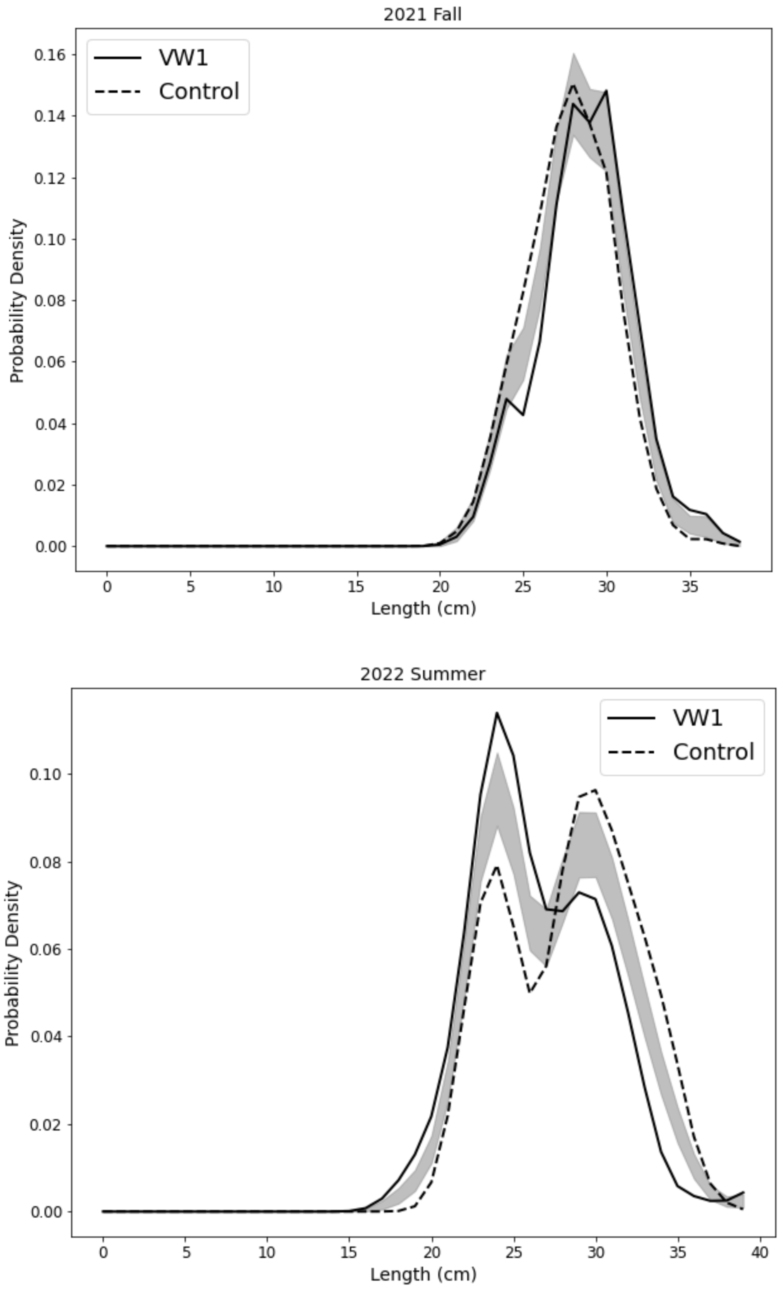


Figure 43: The population structure of red hake in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

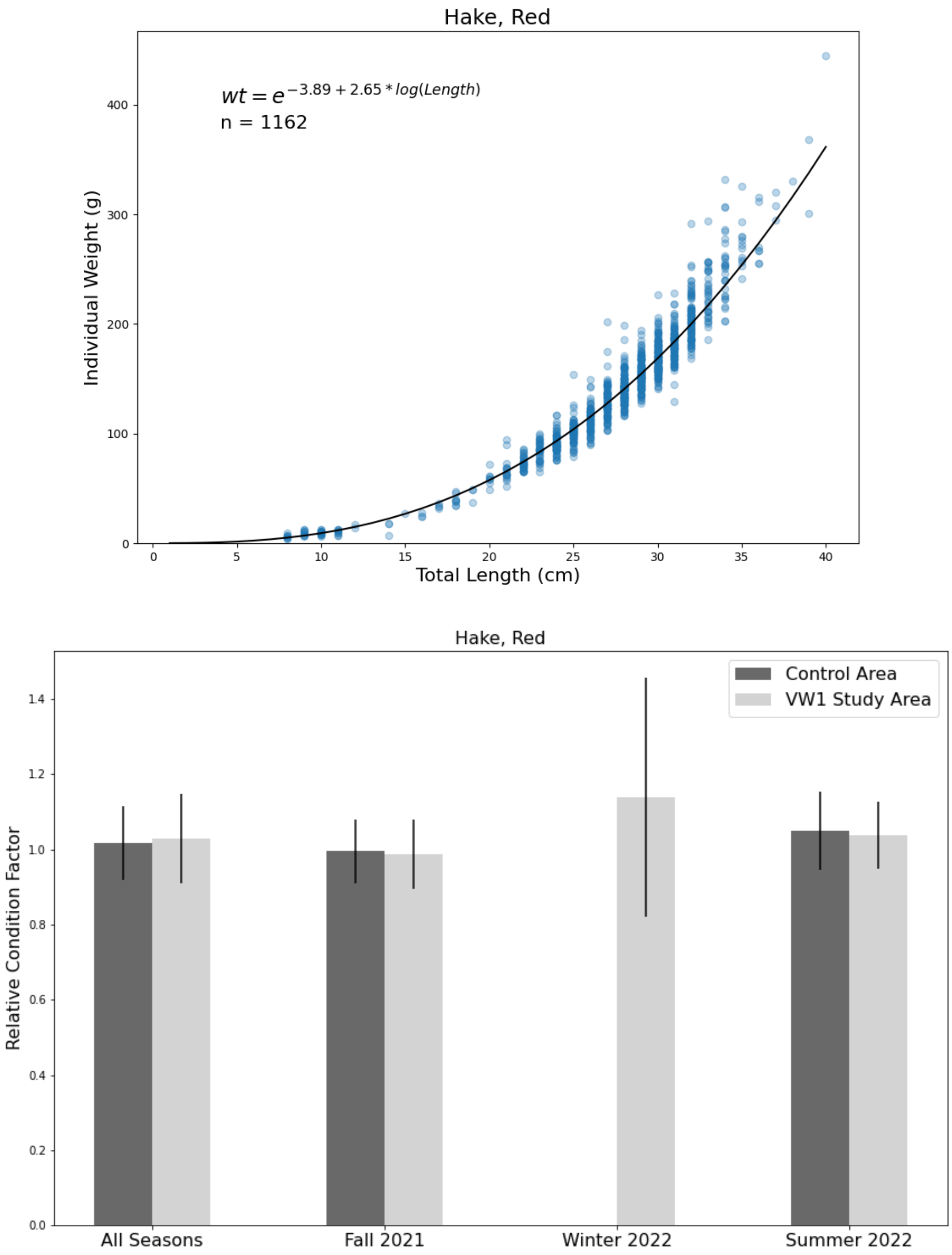


Figure 44: The seasonal condition of red hake (bottom) as derived from the length-weight relationship (top).

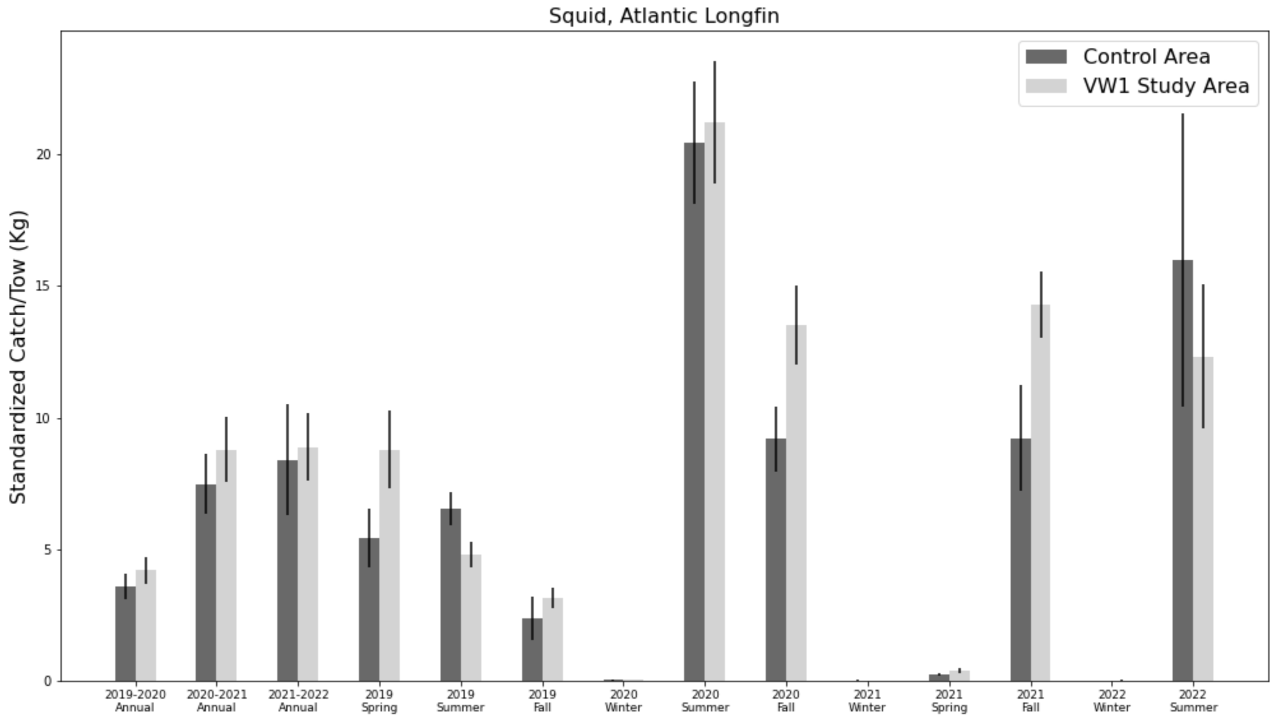


Figure 45: Seasonal catch rates of Atlantic longfin squid in the VW1 Study Area and Control Area.

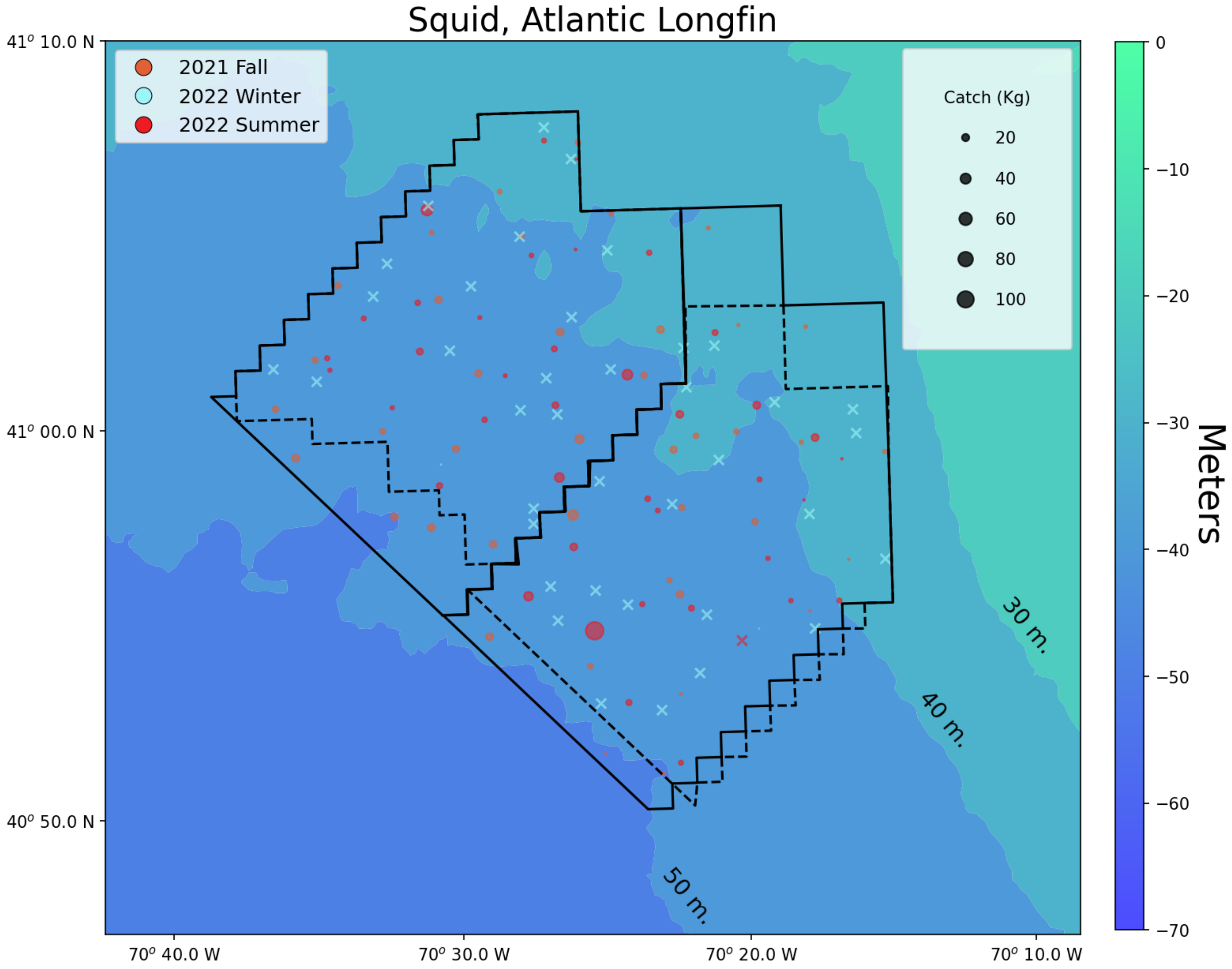


Figure 46: Seasonal distribution of the Atlantic longfin squid catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

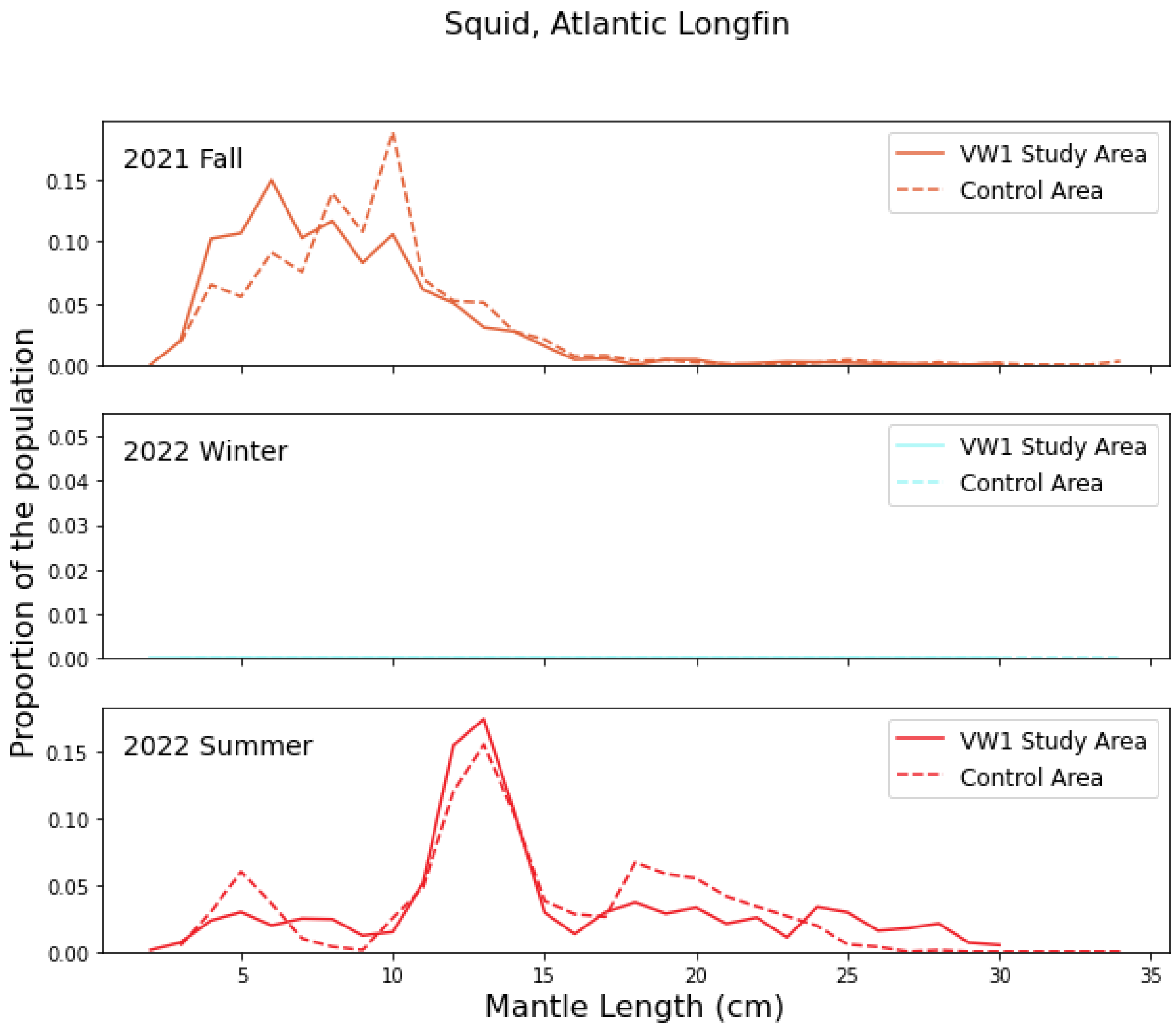


Figure 47: The seasonal length distributions of Atlantic longfin squid in the VW1 Study Area and Control Area.

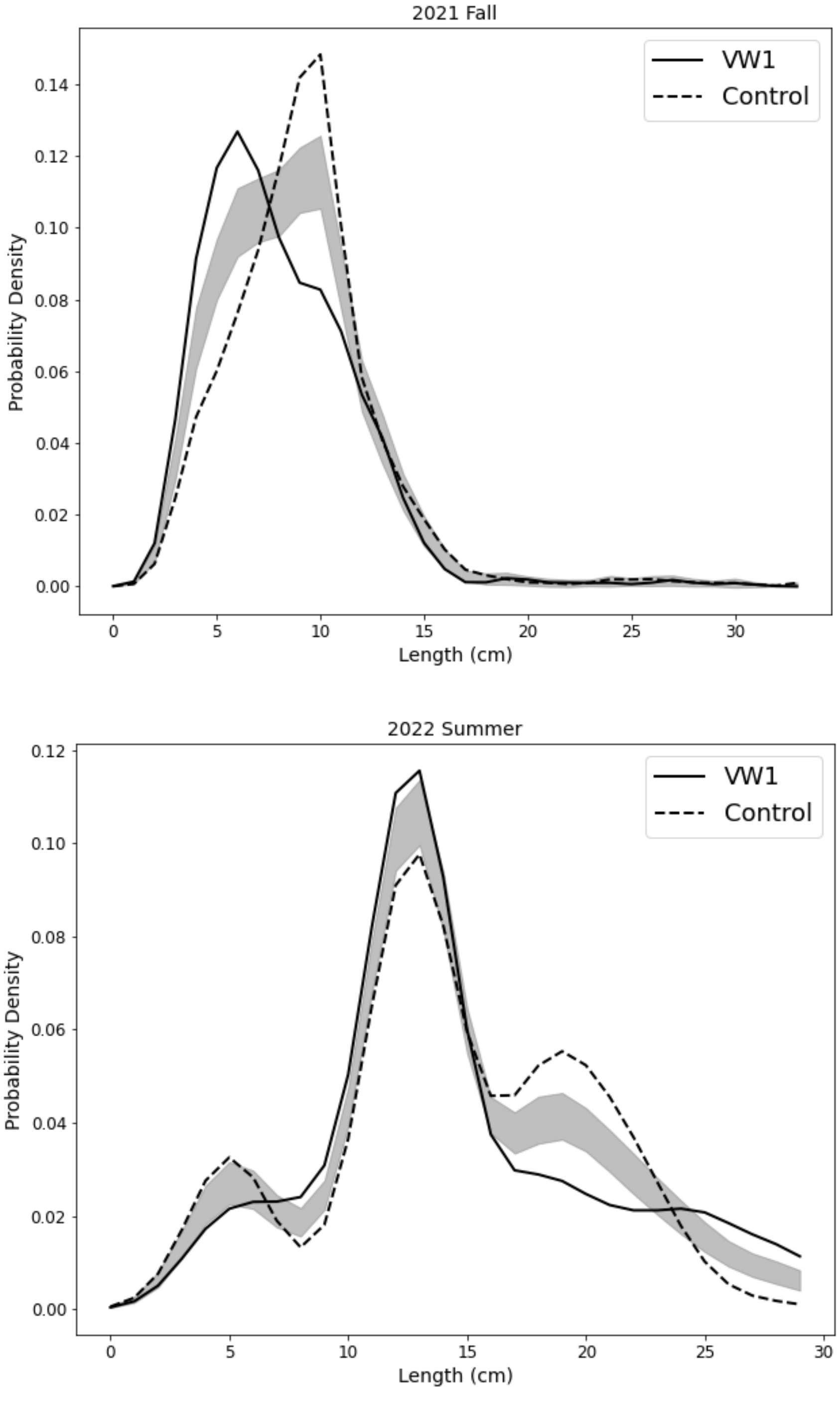
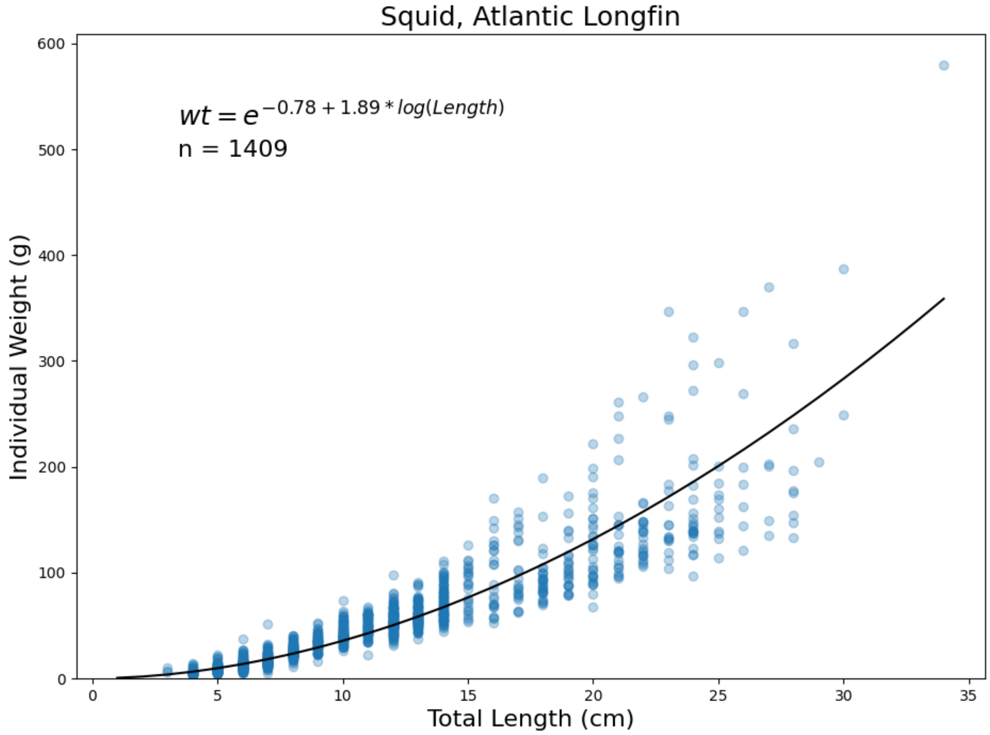


Figure 48: The population structure of Atlantic longfin squid in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



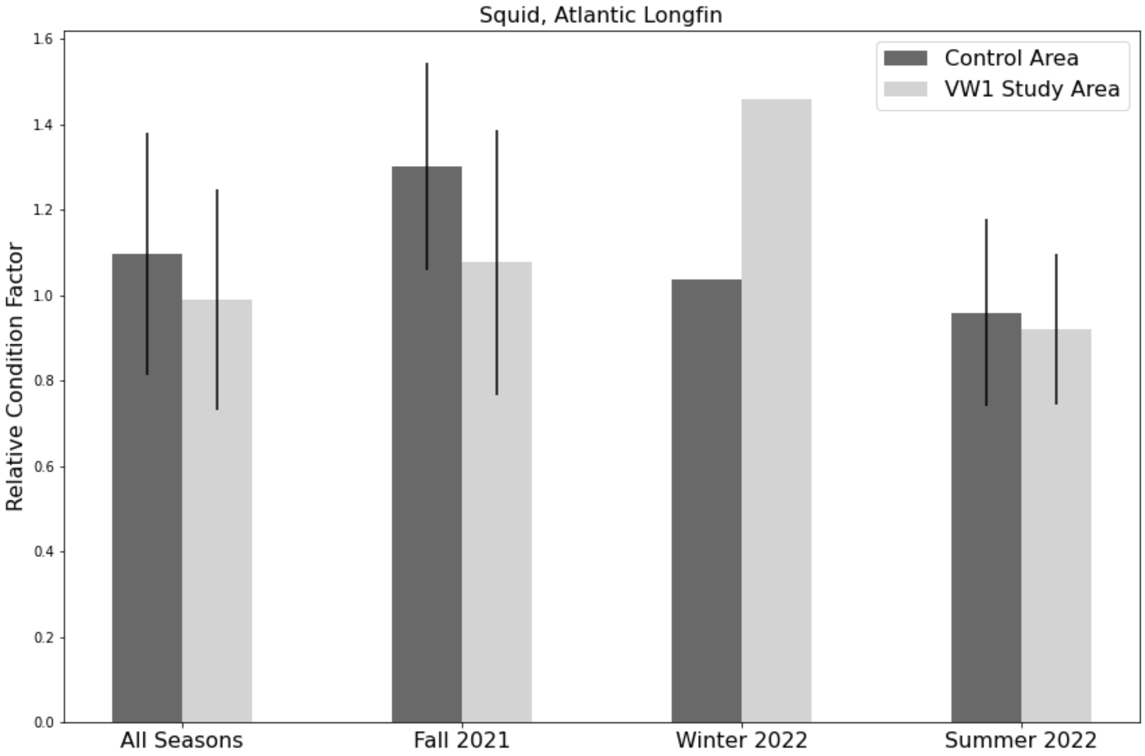


Figure 49: The seasonal condition of Atlantic longfin squid (bottom) as derived from the length-weight relationship (top).

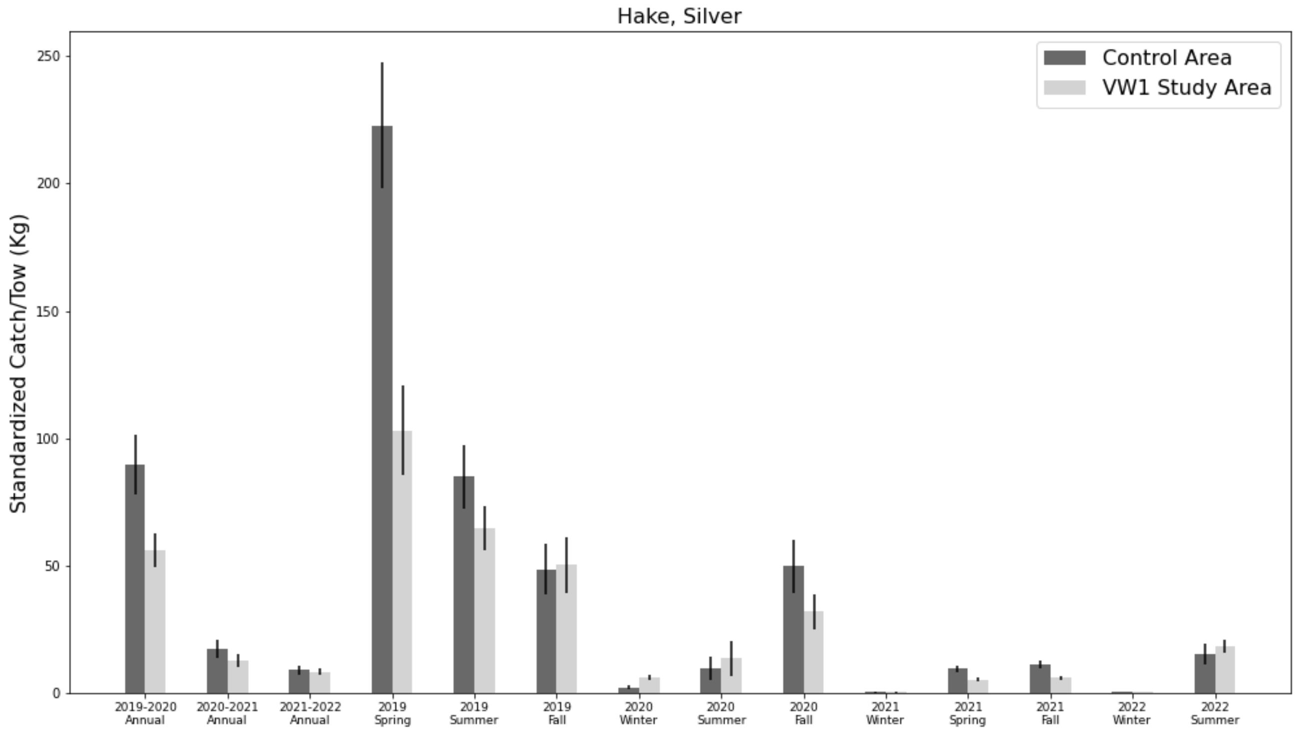


Figure 50: Seasonal catch rates of silver hake in the VW1 Study Area and Control Area.

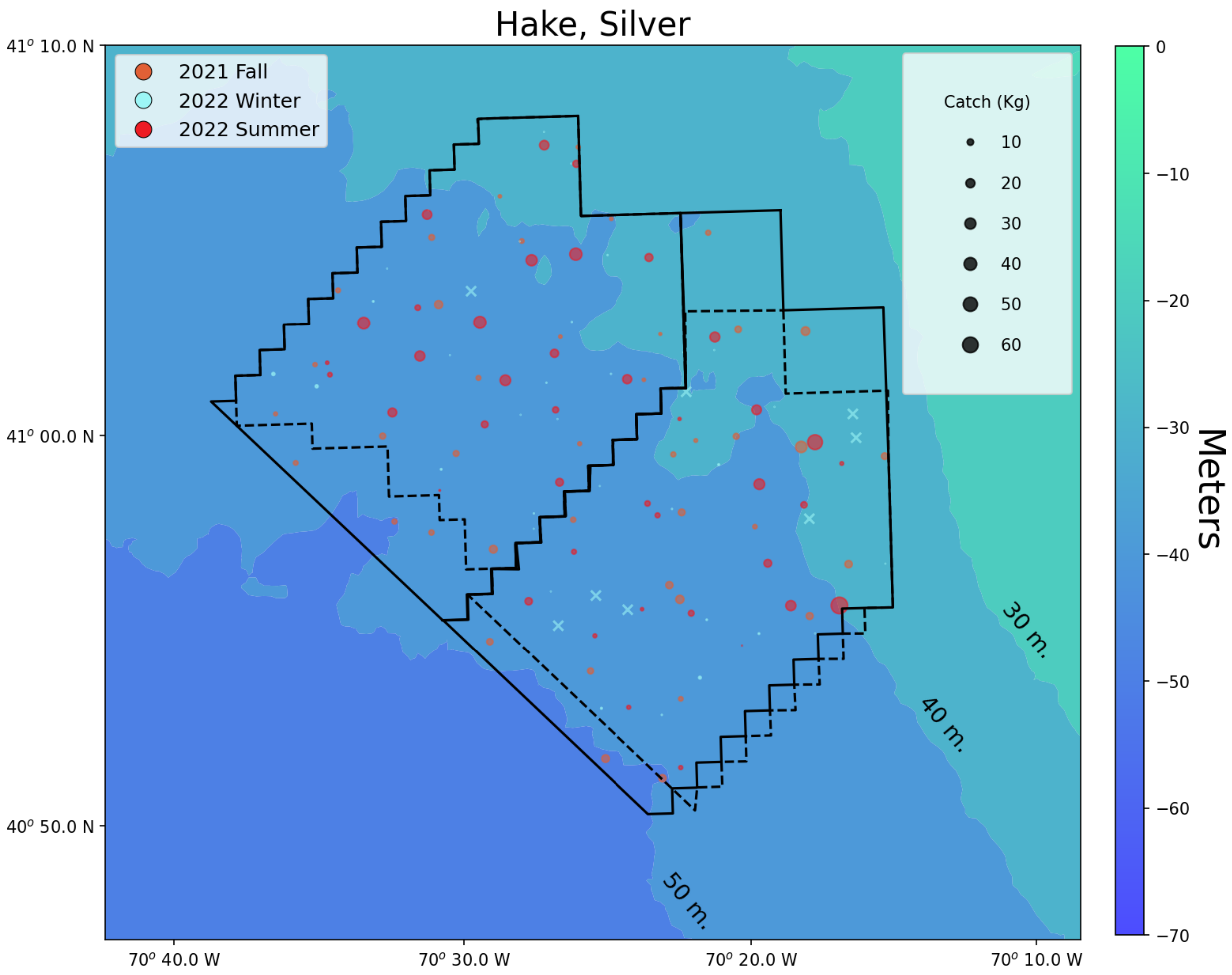


Figure 51: Seasonal distribution of the silver hake catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

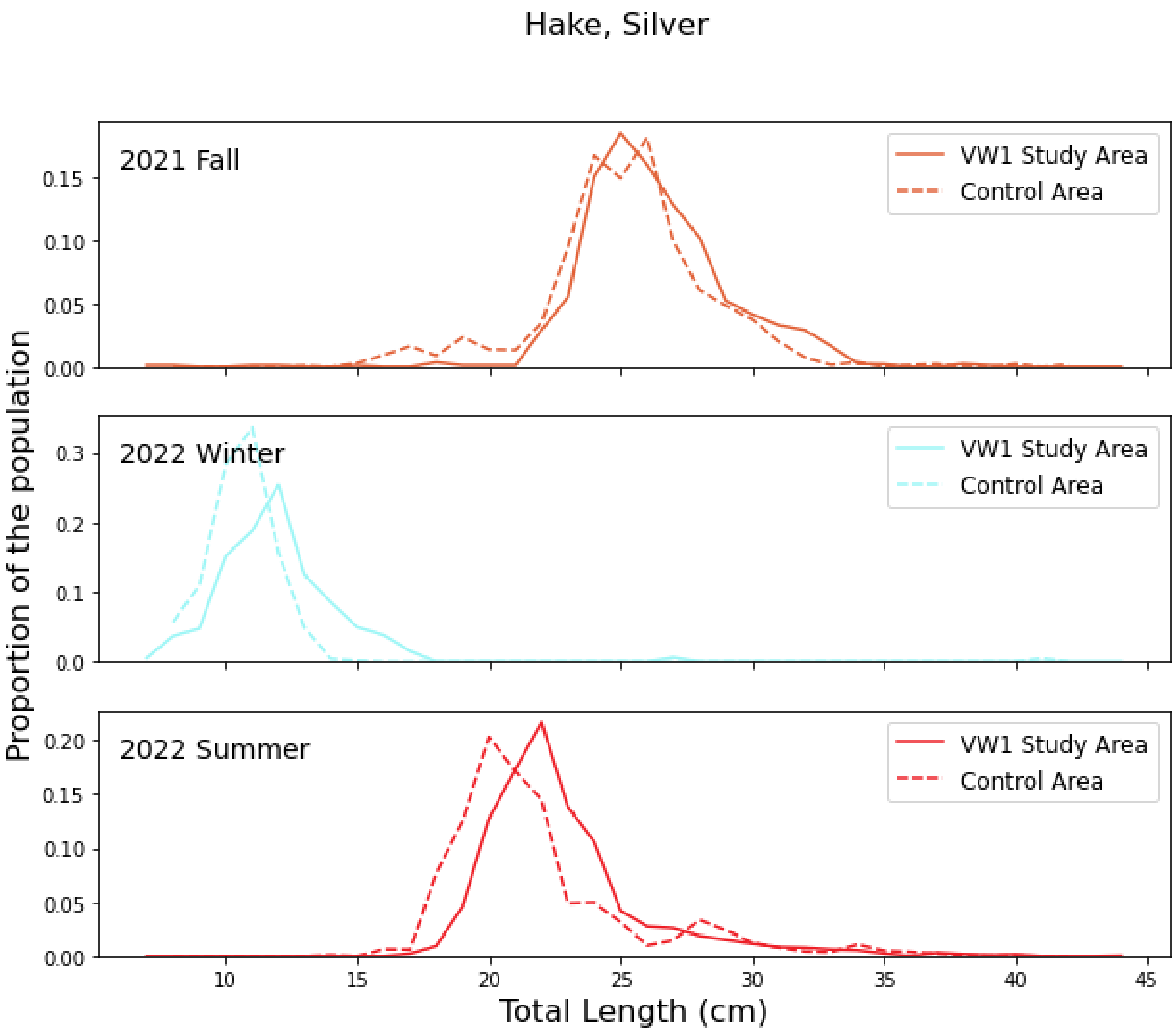


Figure 52: The seasonal length distributions of silver hake in the VW1 Study Area and Control Area.

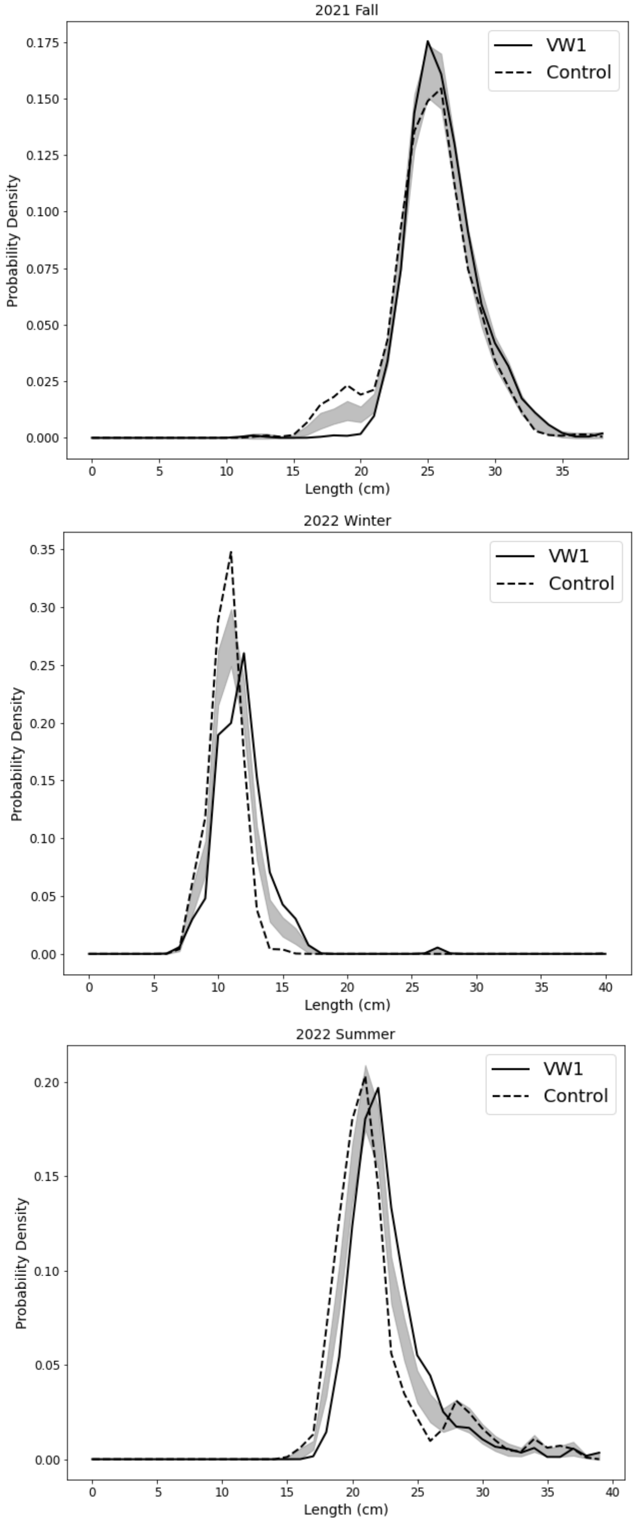


Figure 53: The population structure of silver hake in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

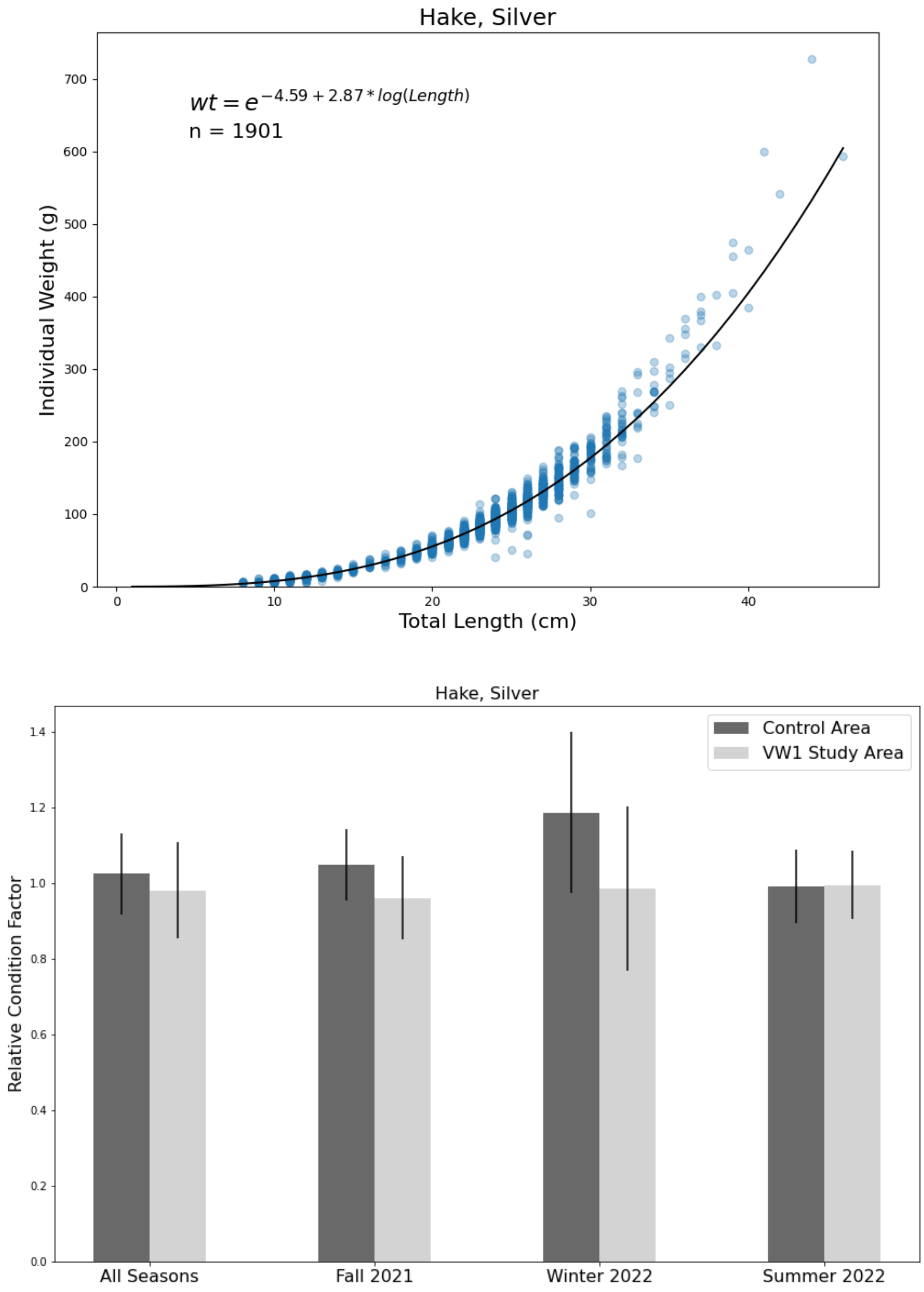


Figure 54: The seasonal condition of silver hake (bottom) as derived from the length-weight relationship (top).

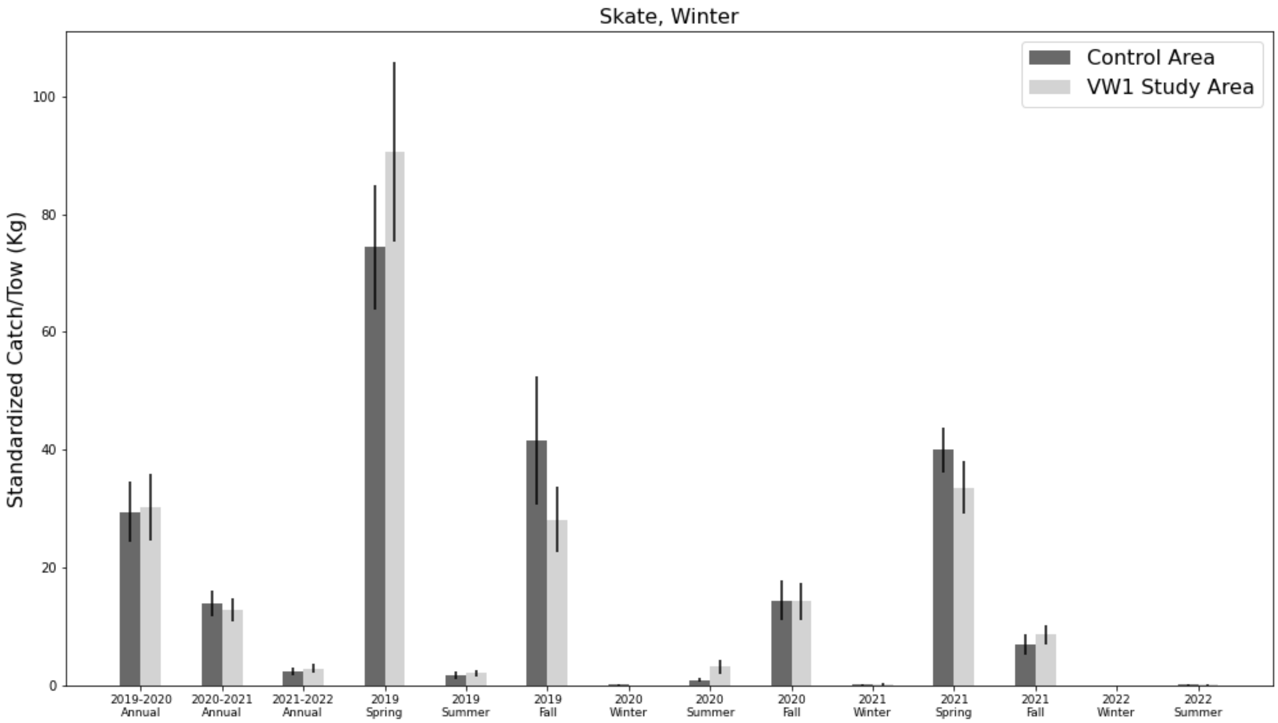


Figure 55: Seasonal catch rates of winter skate in the VW1 Study Area and Control Area.

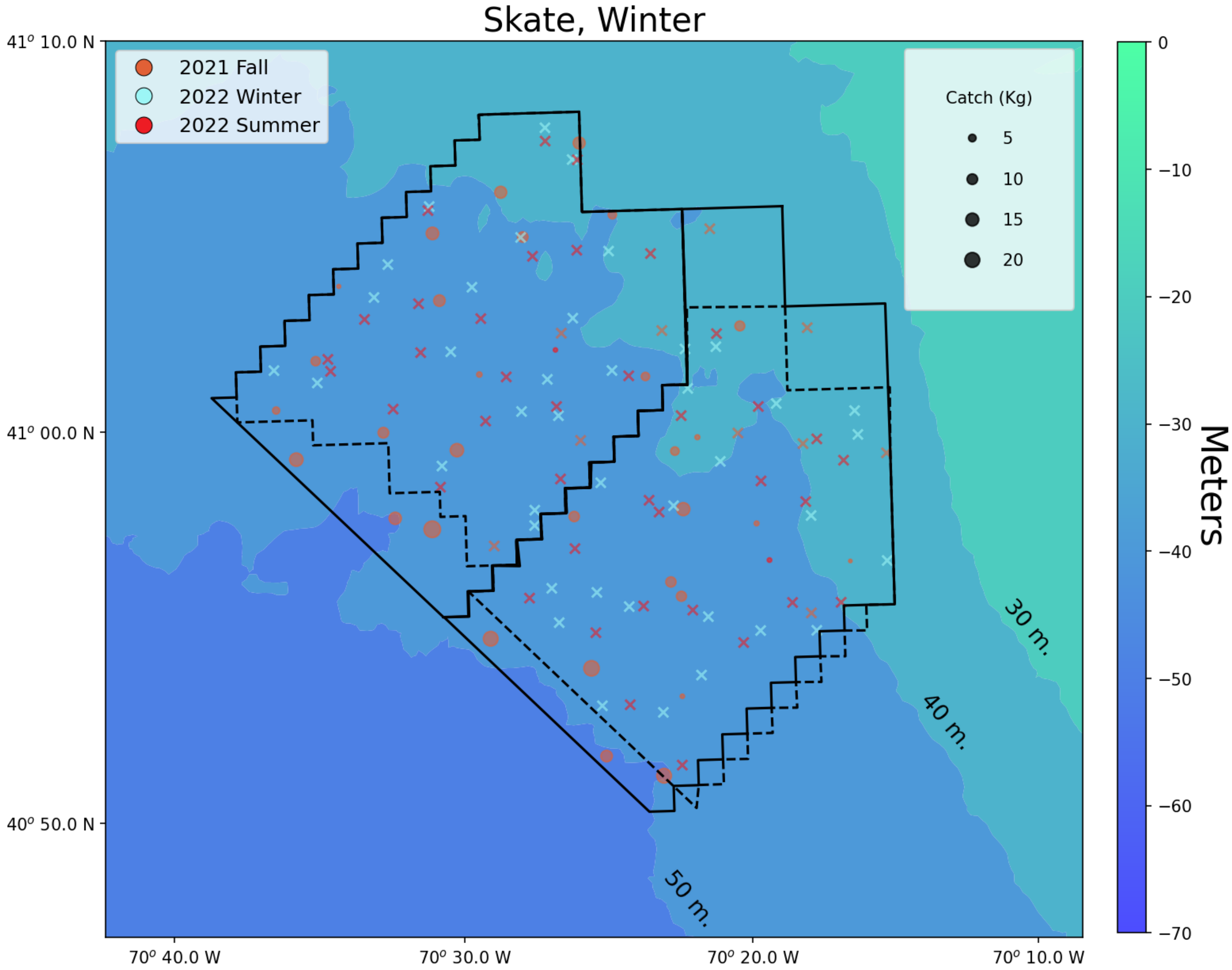


Figure 56: Seasonal distribution of the winter skate catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

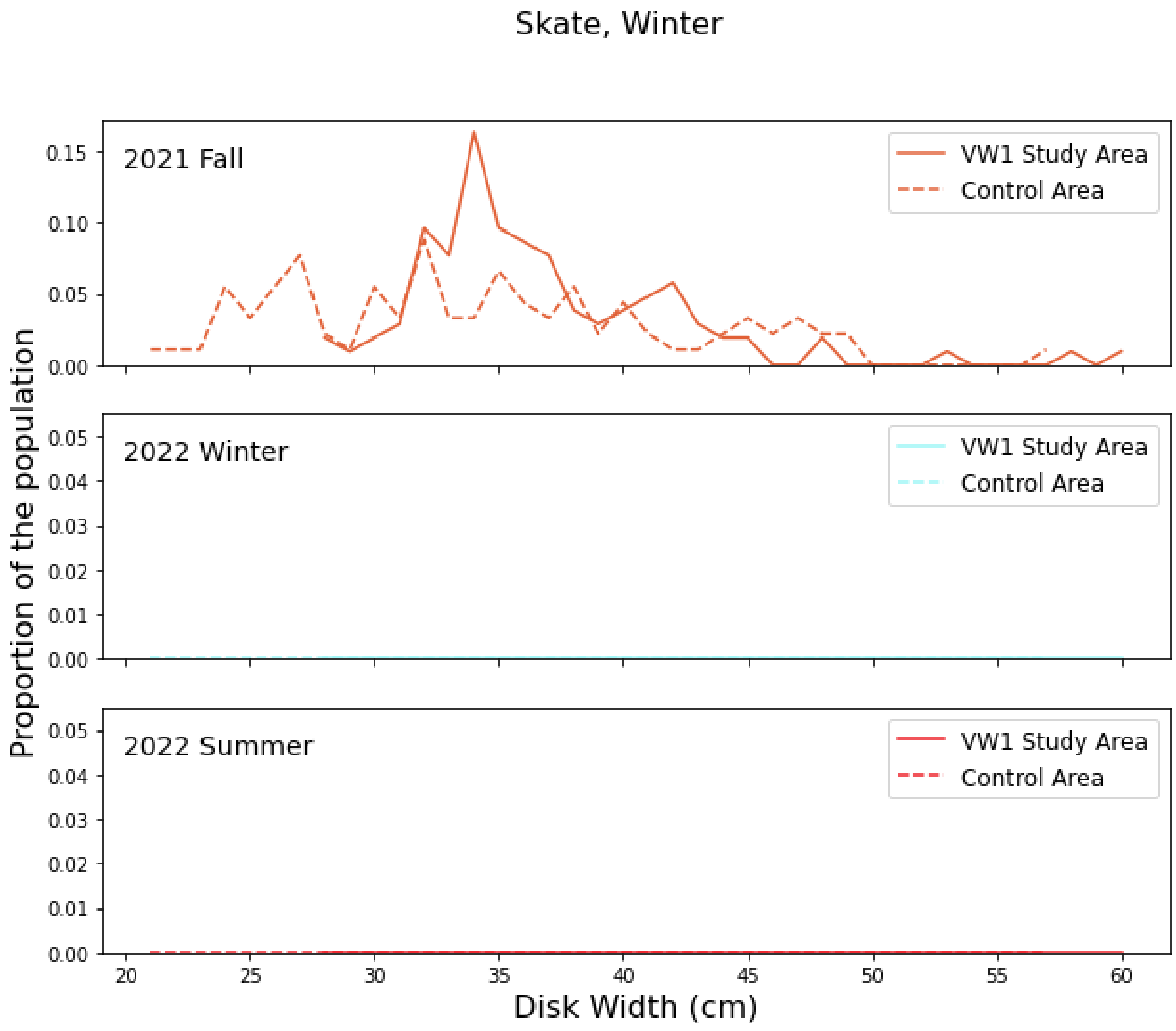


Figure 57: The seasonal length distributions of winter skate in the VW1 Study Area and Control Area.

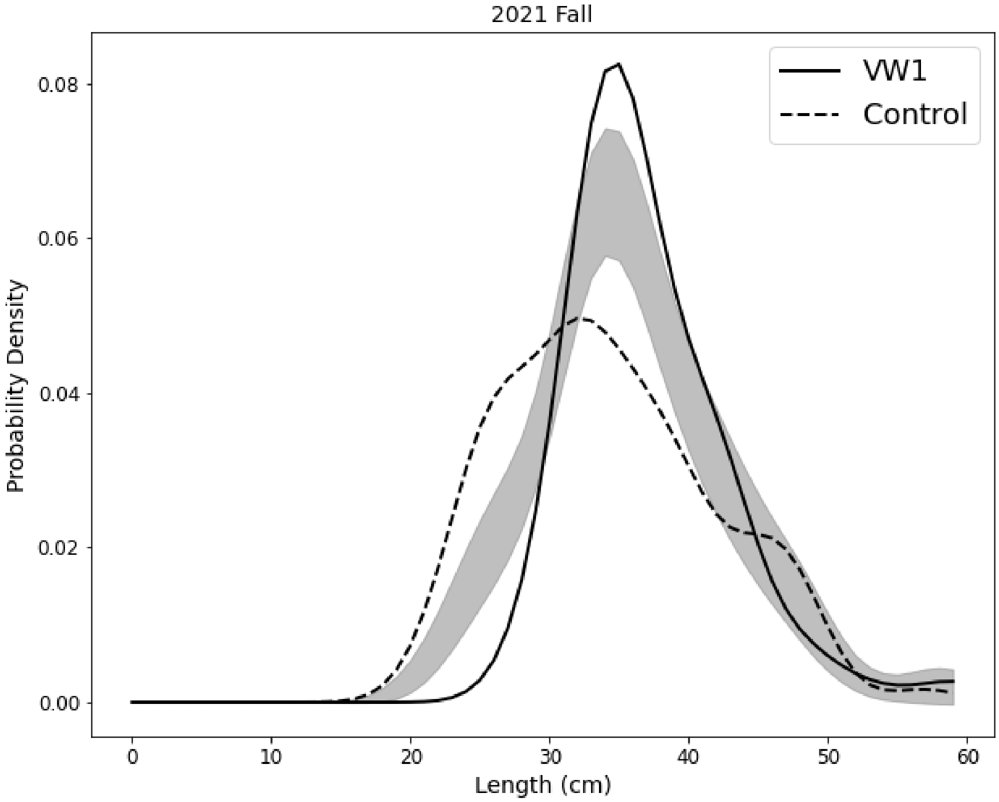


Figure 58: The population structure of winter skate in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

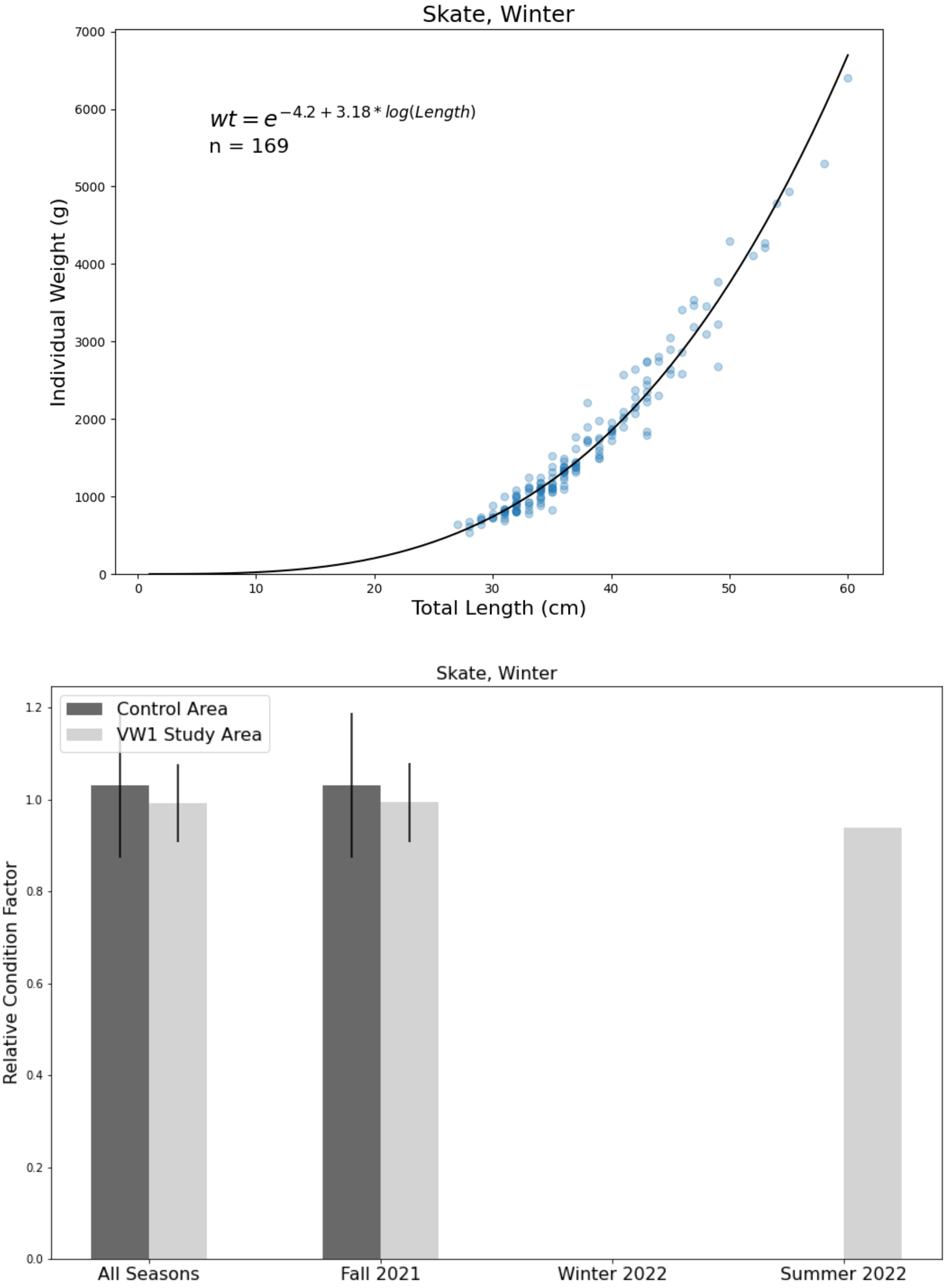


Figure 59: The seasonal condition of winter skate (bottom) as derived from the length-weight relationship (top).

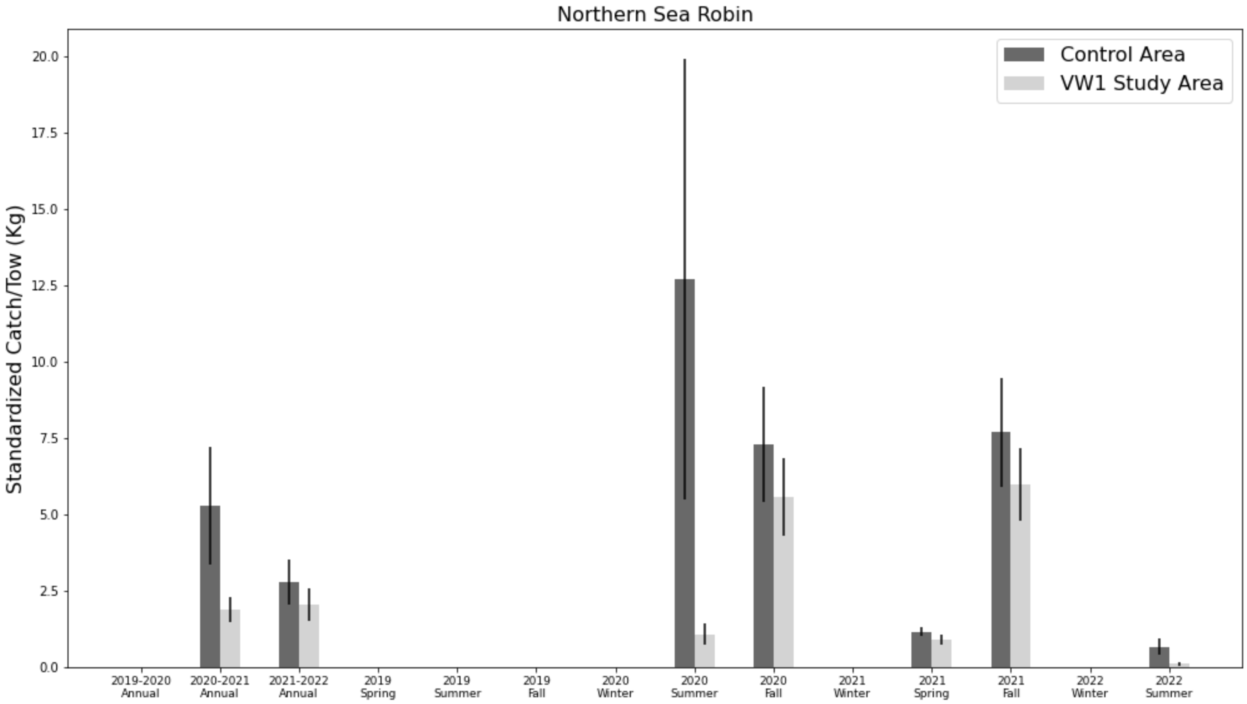


Figure 60: Seasonal catch rates of northern sea robin in the VW1 Study Area and Control Area.

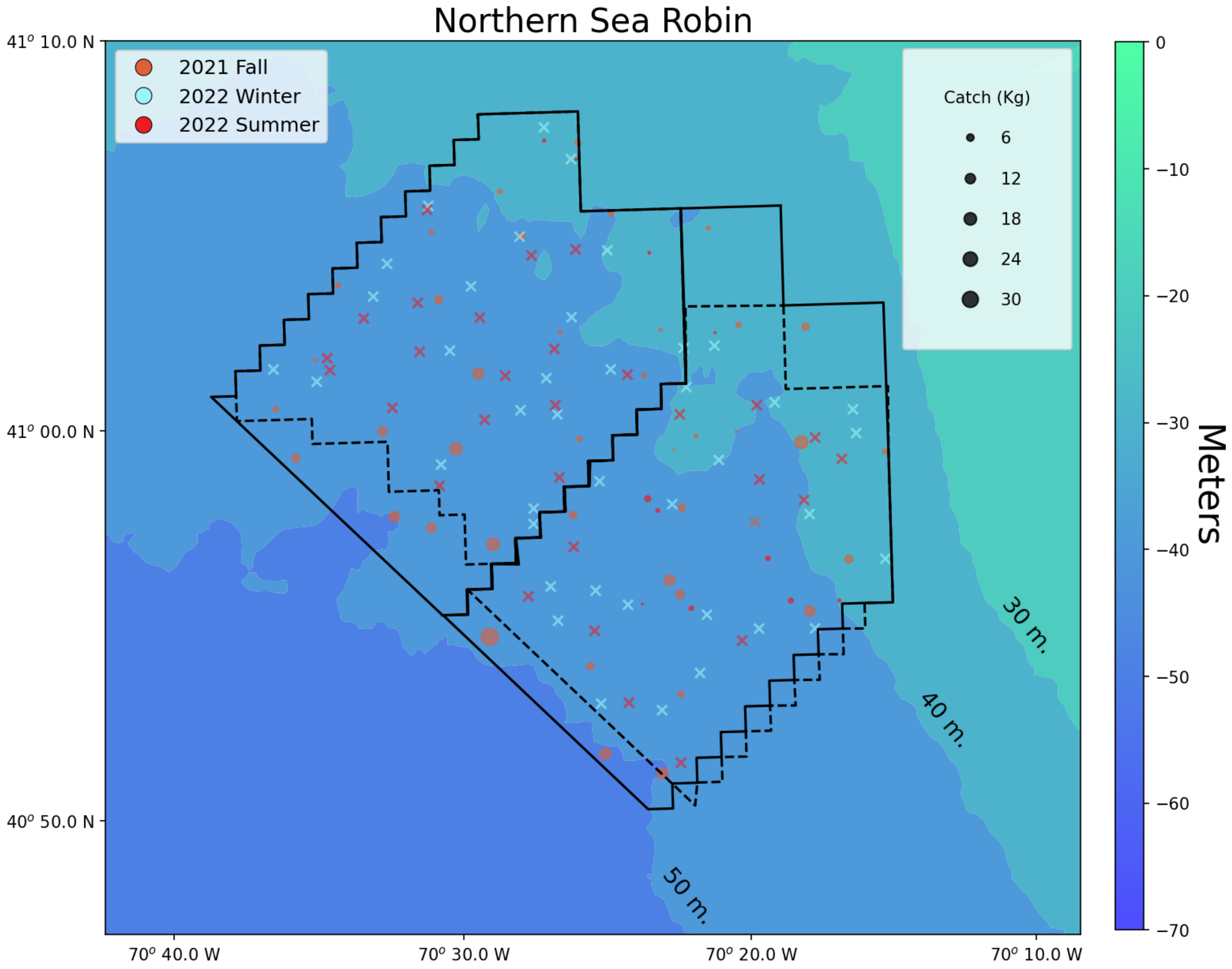


Figure 61: Seasonal distribution of the northern sea robin catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

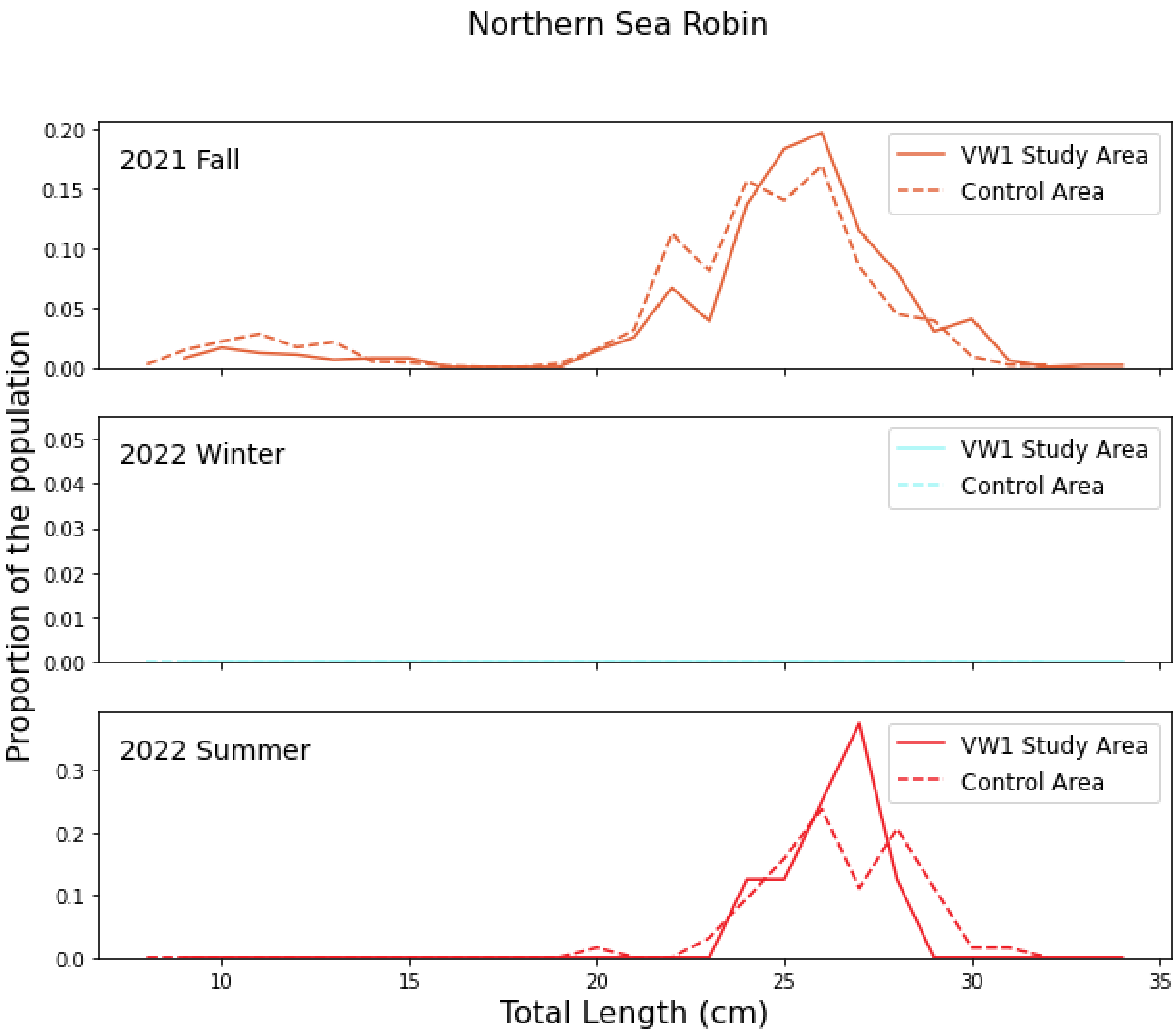


Figure 62: The seasonal length distributions of northern sea robin in the VW1 Study Area and Control Area.

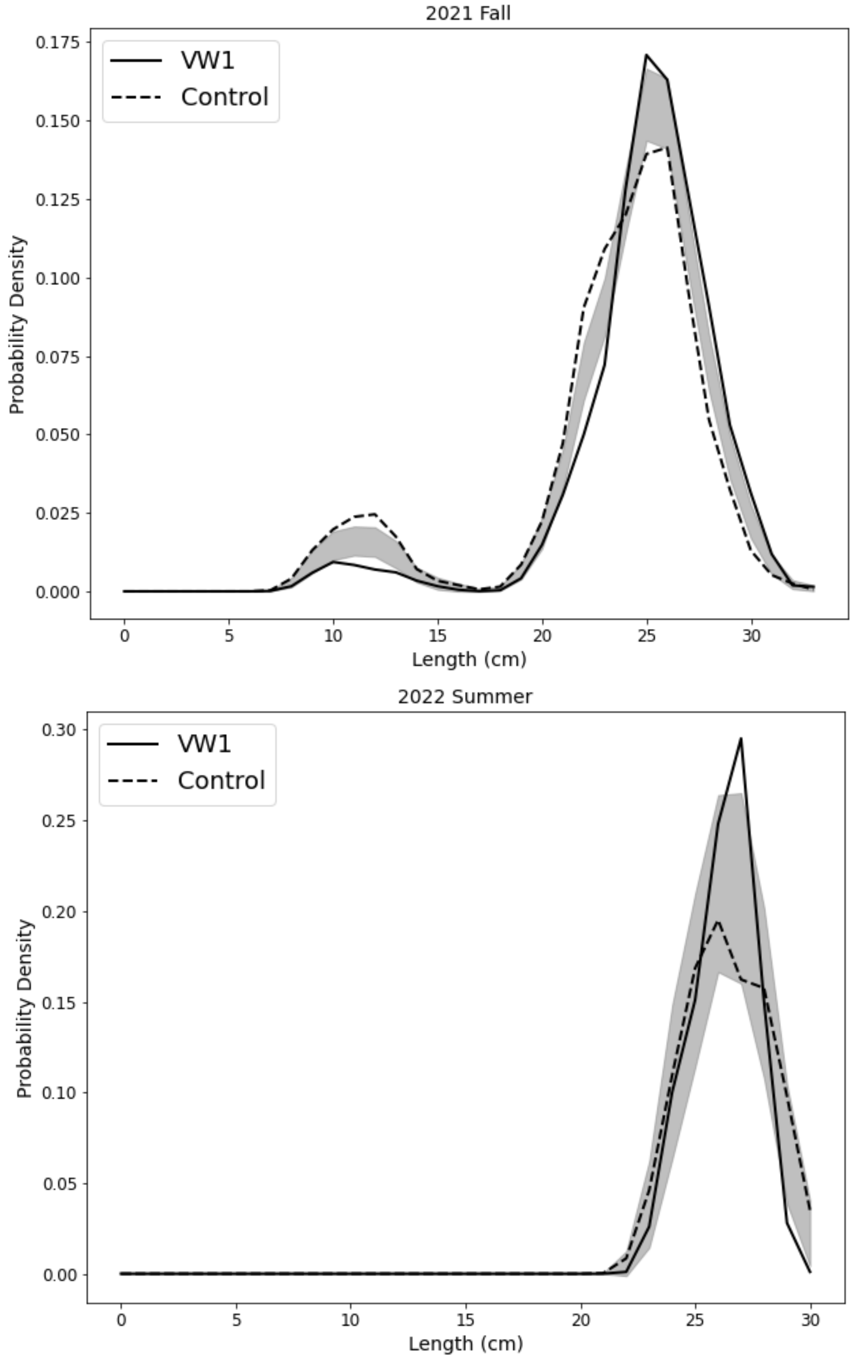
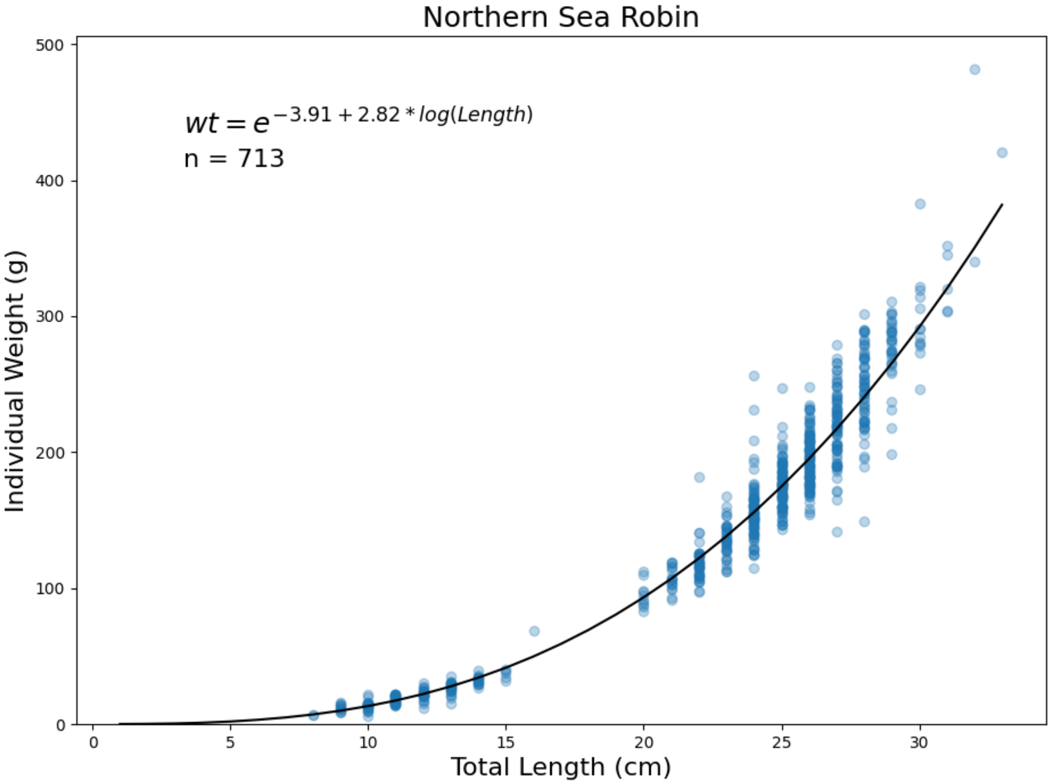


Figure 63: The population structure of northern sea robin in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



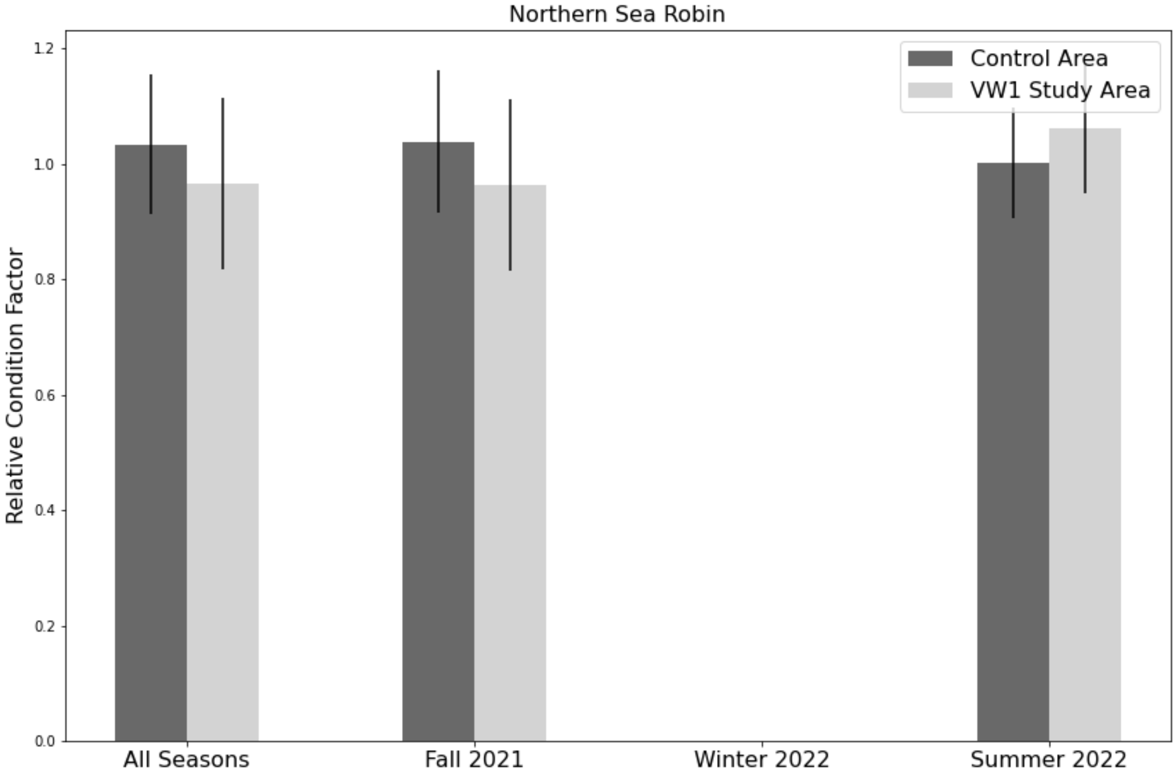


Figure 64: The seasonal condition of northern sea robin (bottom) as derived from the length-weight relationship (top).

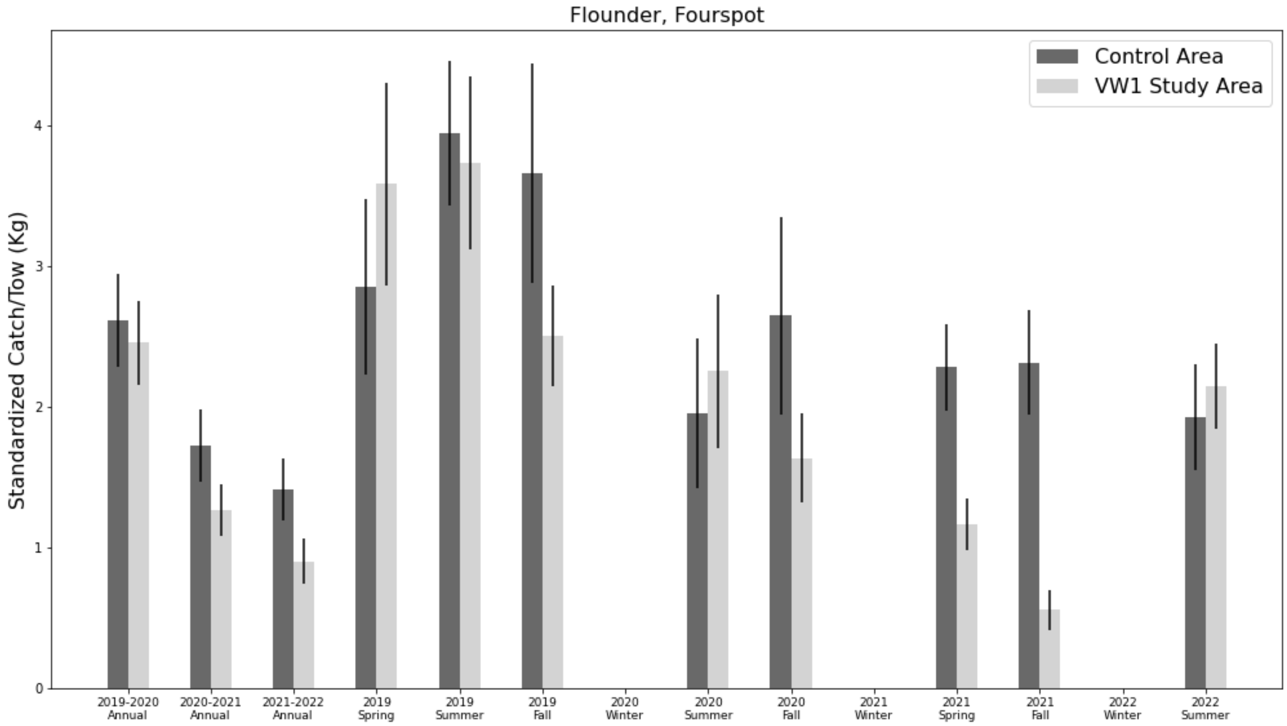


Figure 65: Seasonal catch rates of fourspot flounder in the VW1 Study Area and Control Area.

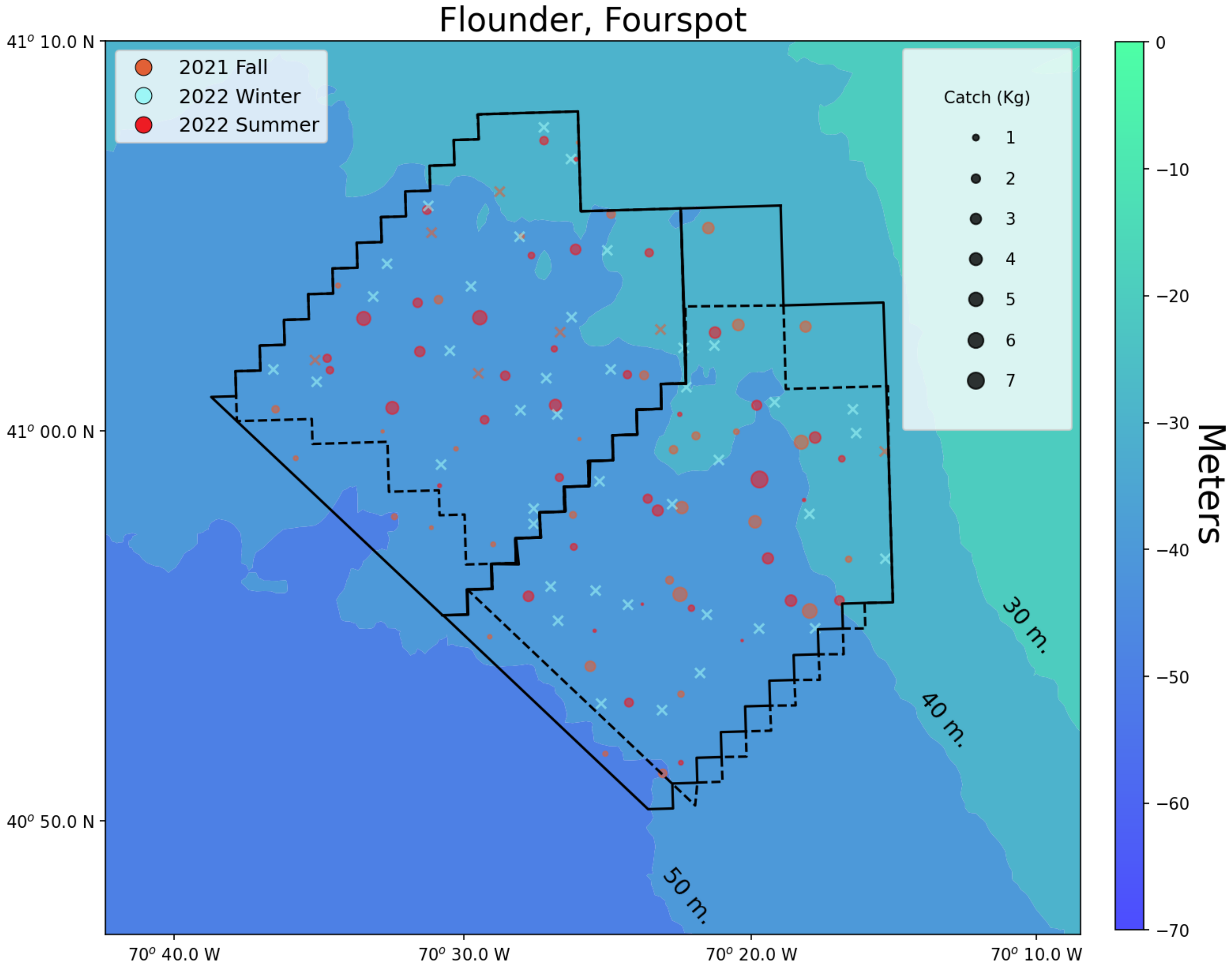


Figure 66: Seasonal distribution of the fourspot flounder catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

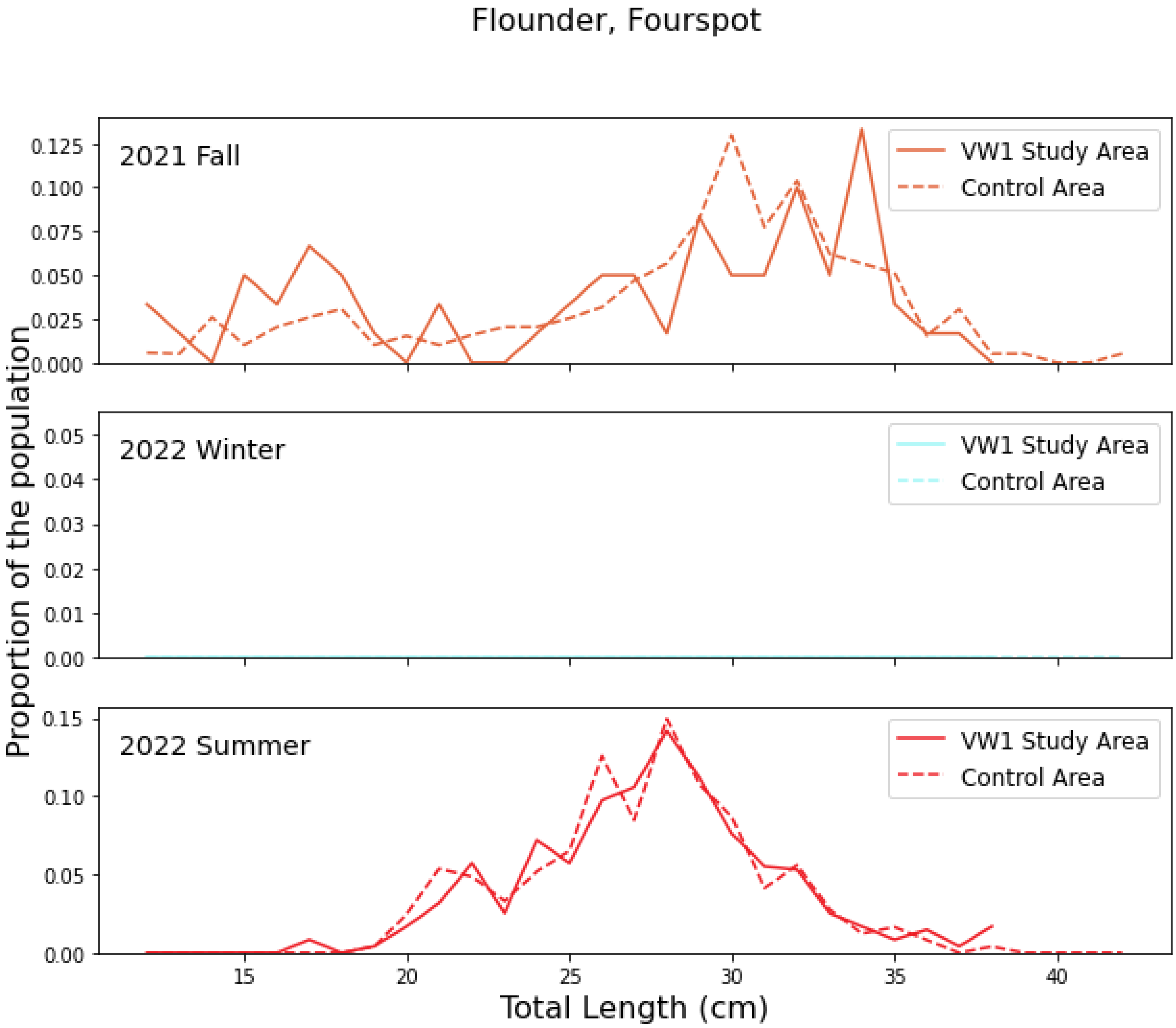


Figure 67: The seasonal length distributions of fourspot flounder in the VW1 Study Area and Control Area.

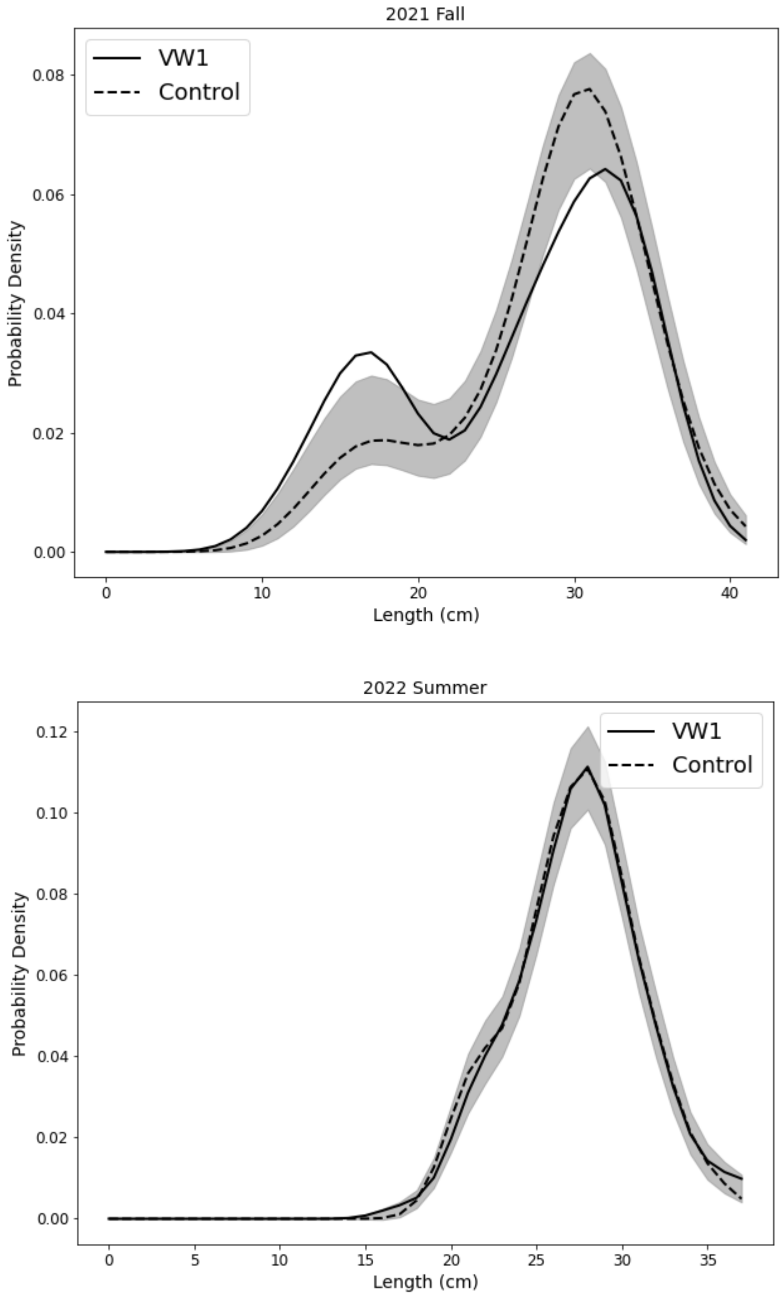
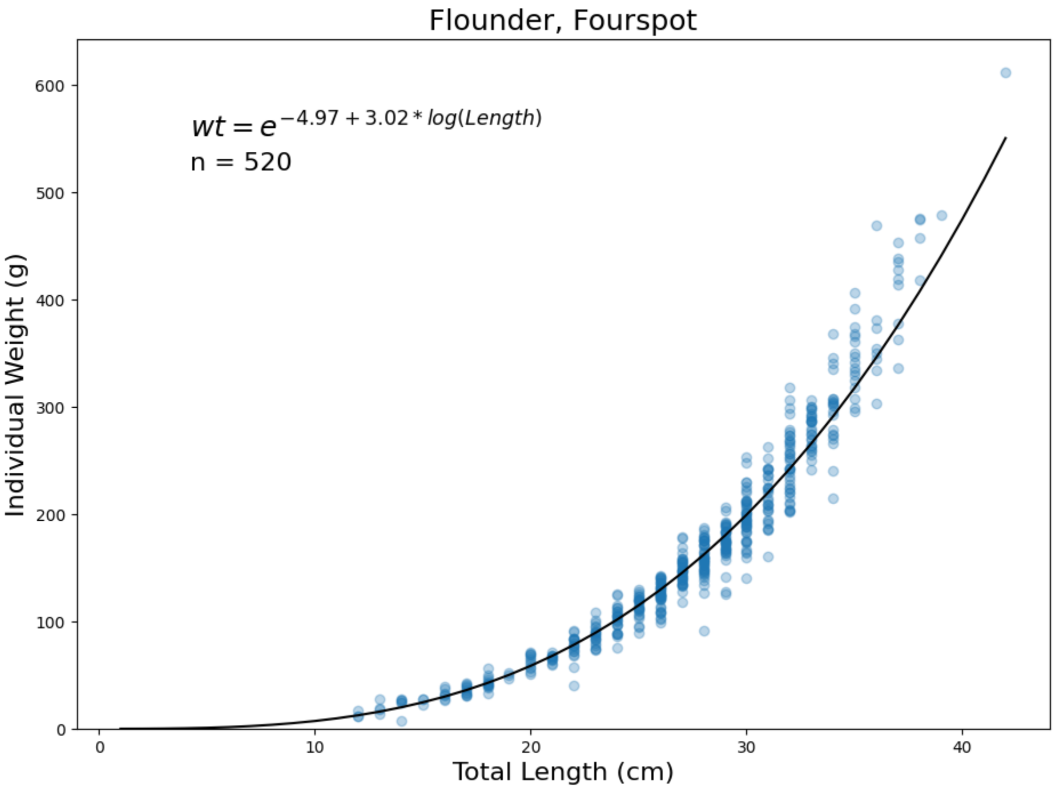


Figure 68: The population structure of fourspot flounder in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



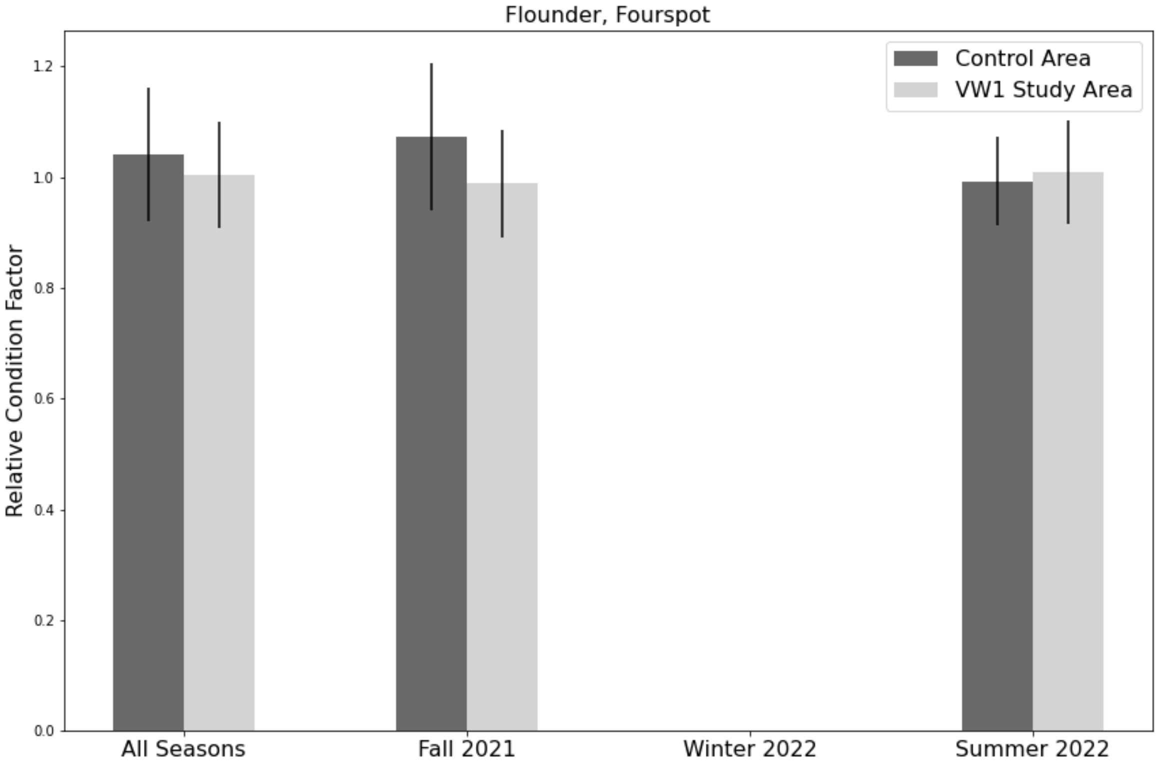


Figure 69: The seasonal condition of fourspot flounder (bottom) as derived from the length-weight relationship (top).

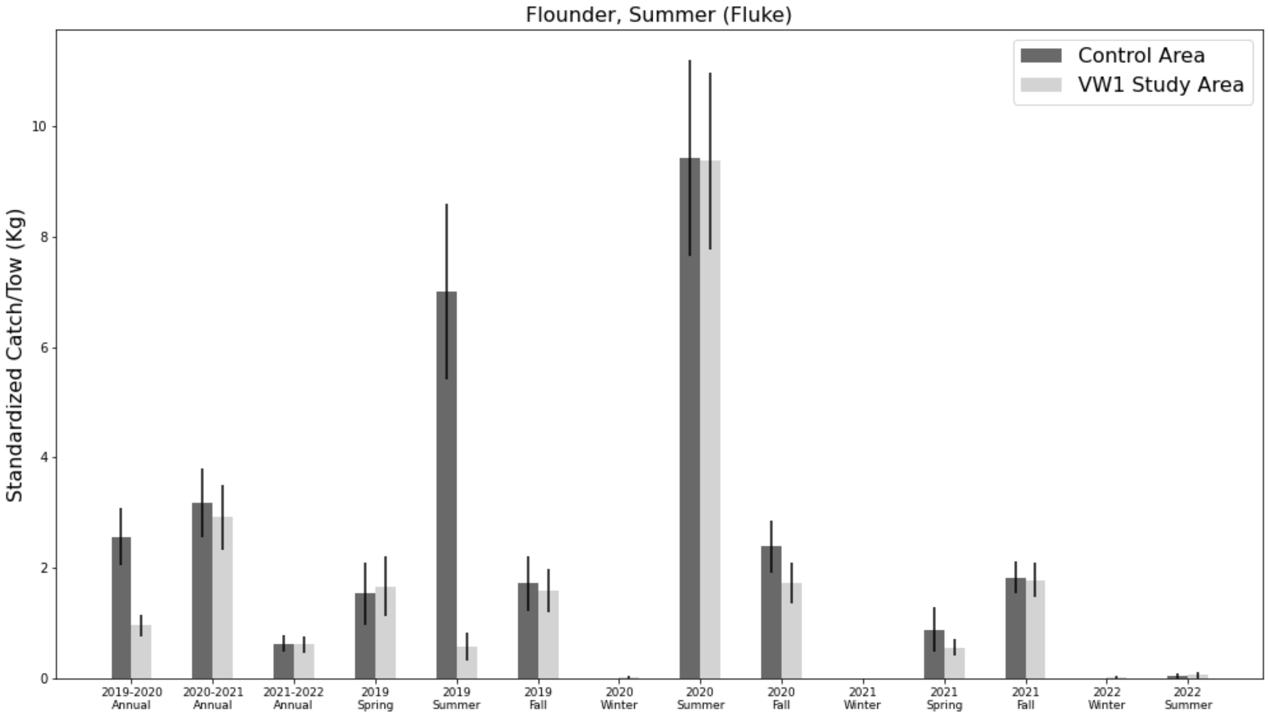


Figure 70: Seasonal catch rates of summer flounder in the VW1 Study Area and Control Area.

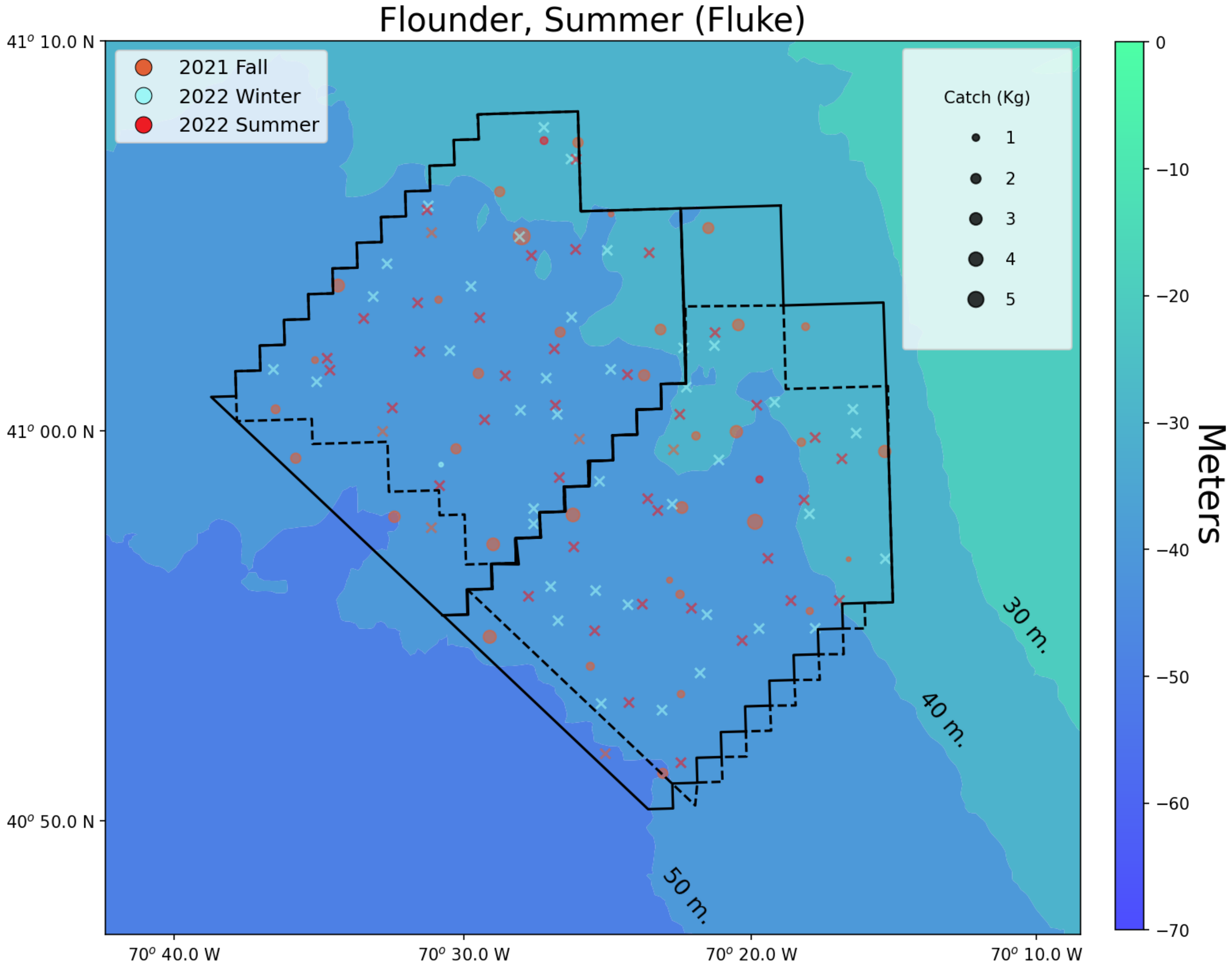


Figure 71: Seasonal distribution of the summer flounder catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

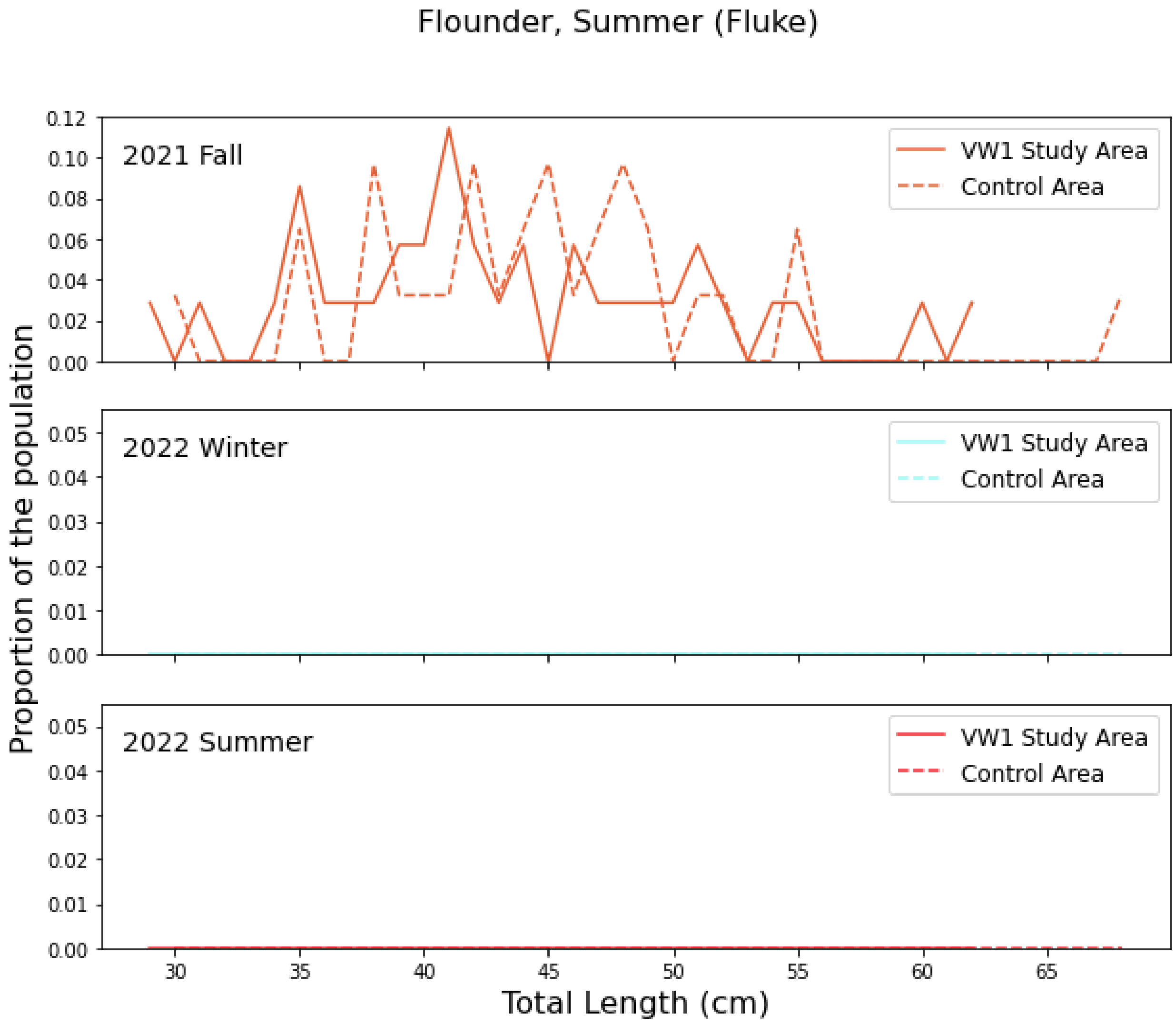


Figure 72: The seasonal length distributions of summer flounder in the VW1 Study Area and Control Area.

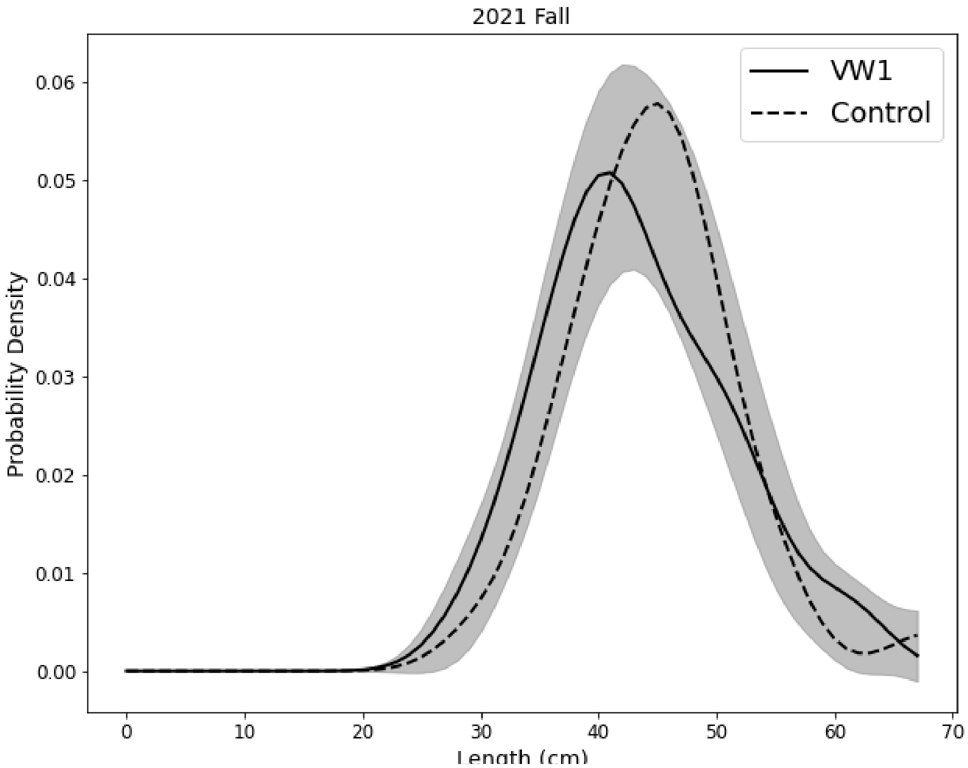
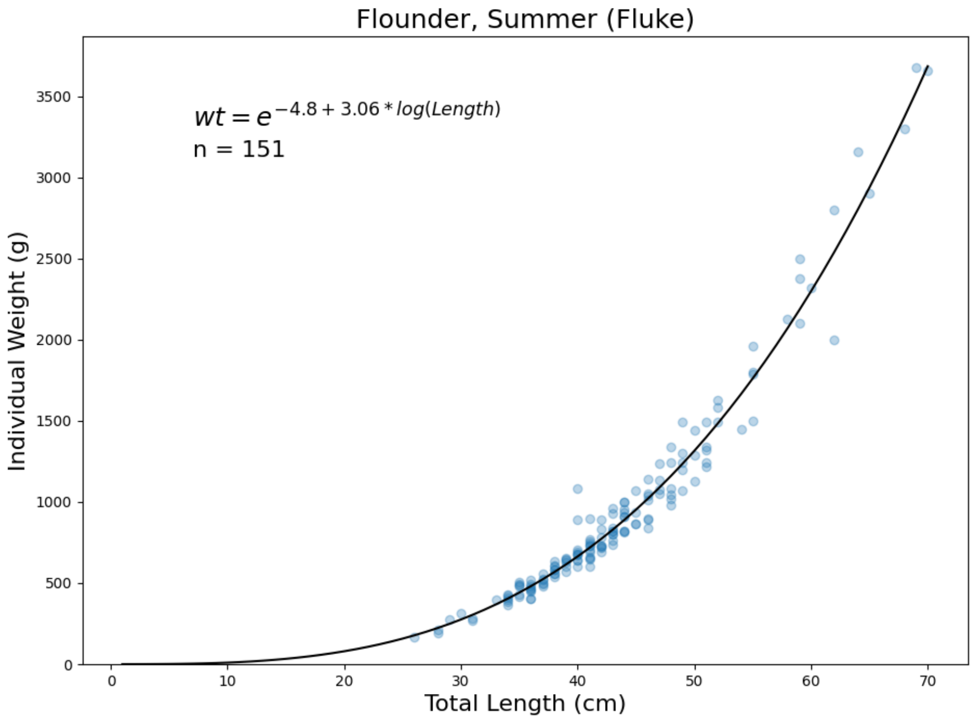


Figure 73: The population structure of summer flounder in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



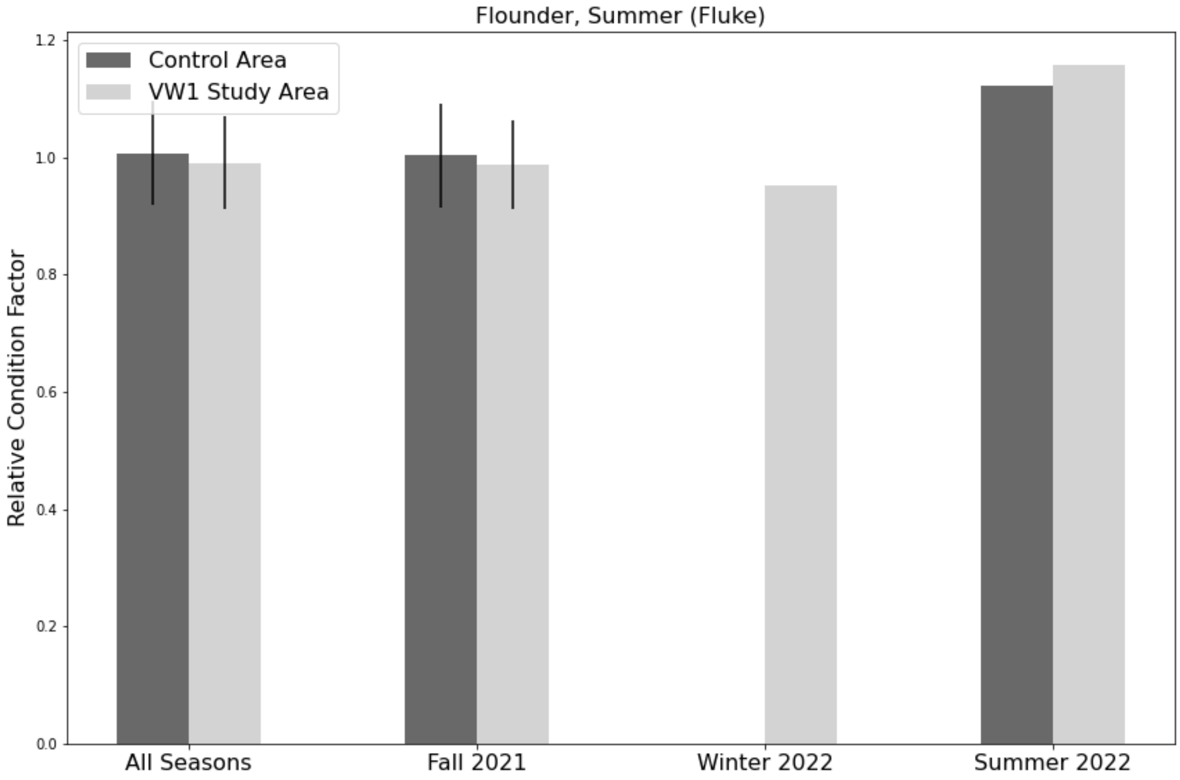


Figure 74: The seasonal condition of summer flounder (bottom) as derived from the length-weight relationship (top).

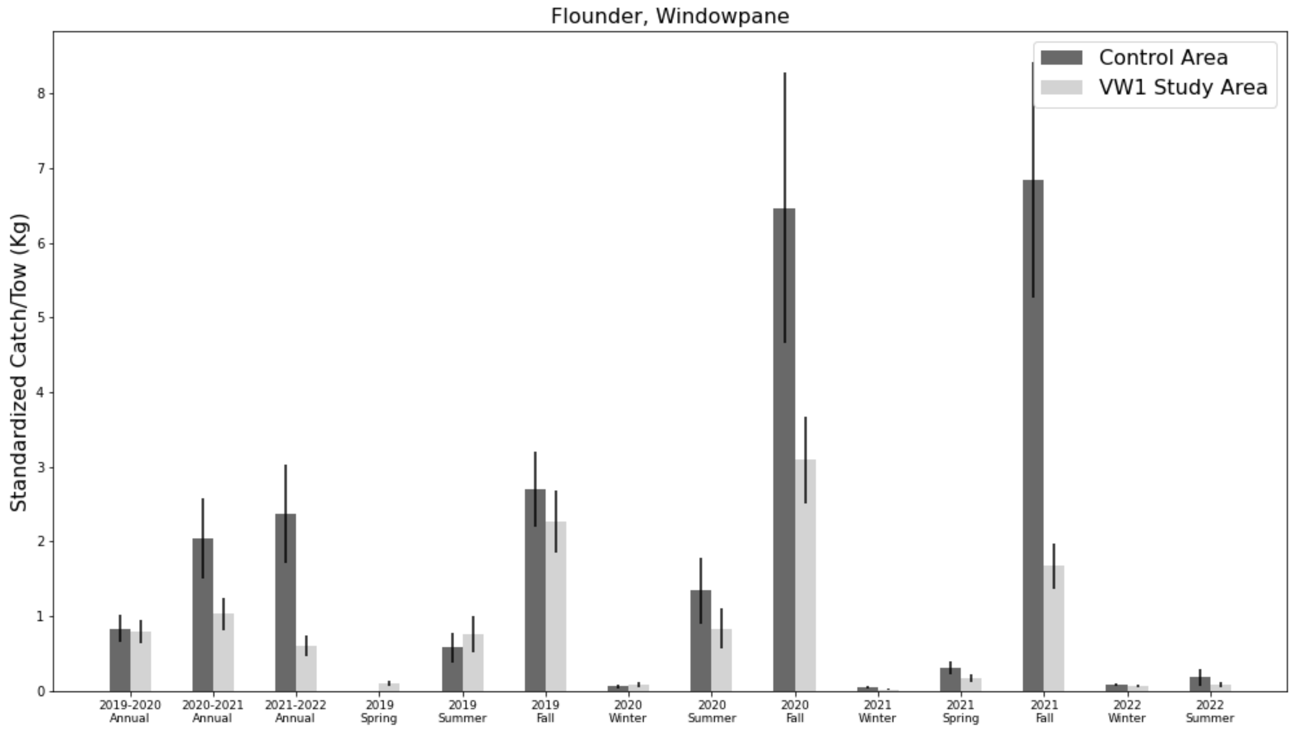


Figure 75: Seasonal catch rates of windowpane flounder in the VW1 Study Area and Control Area.

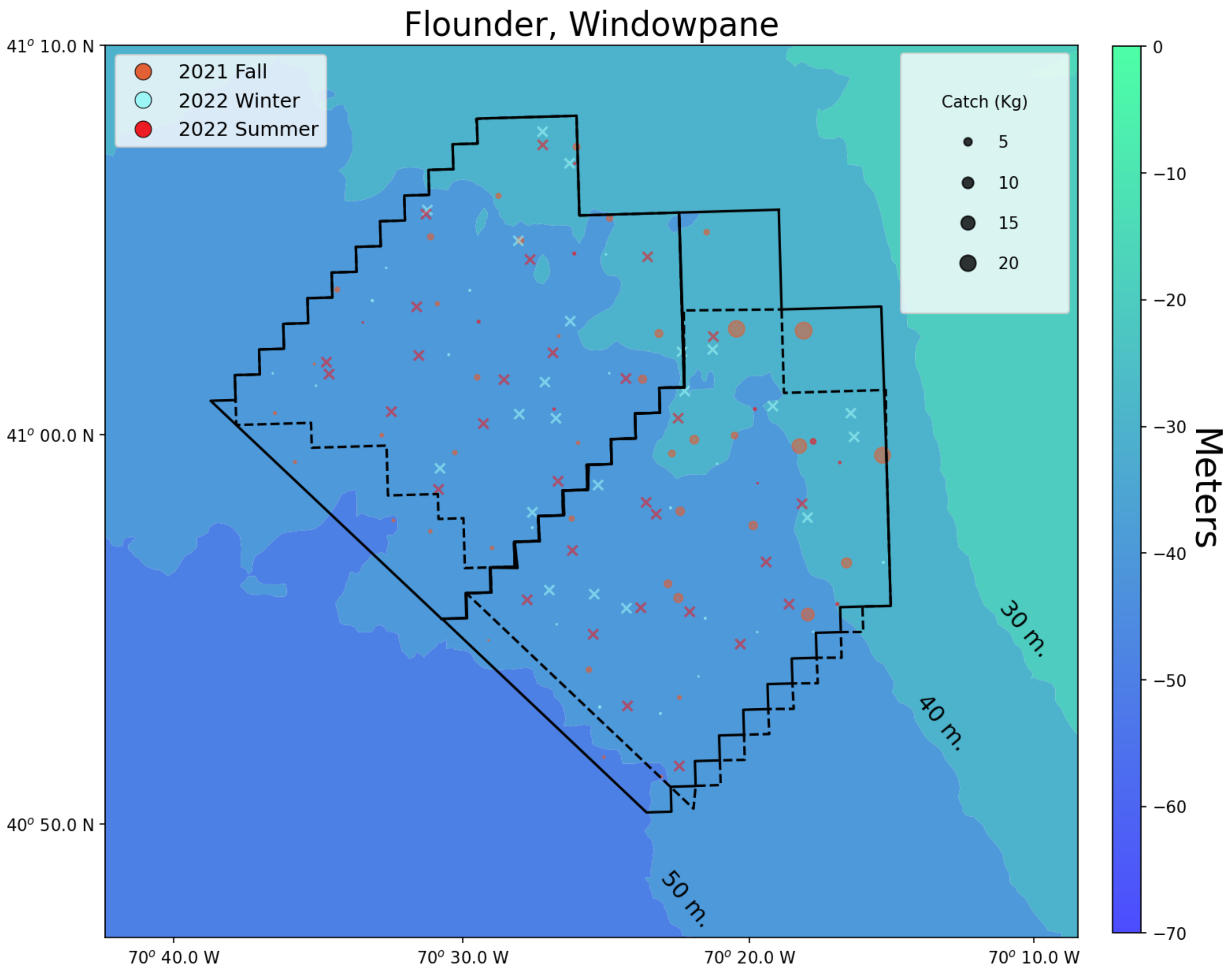


Figure 76: Seasonal distribution of the windowpane flounder catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

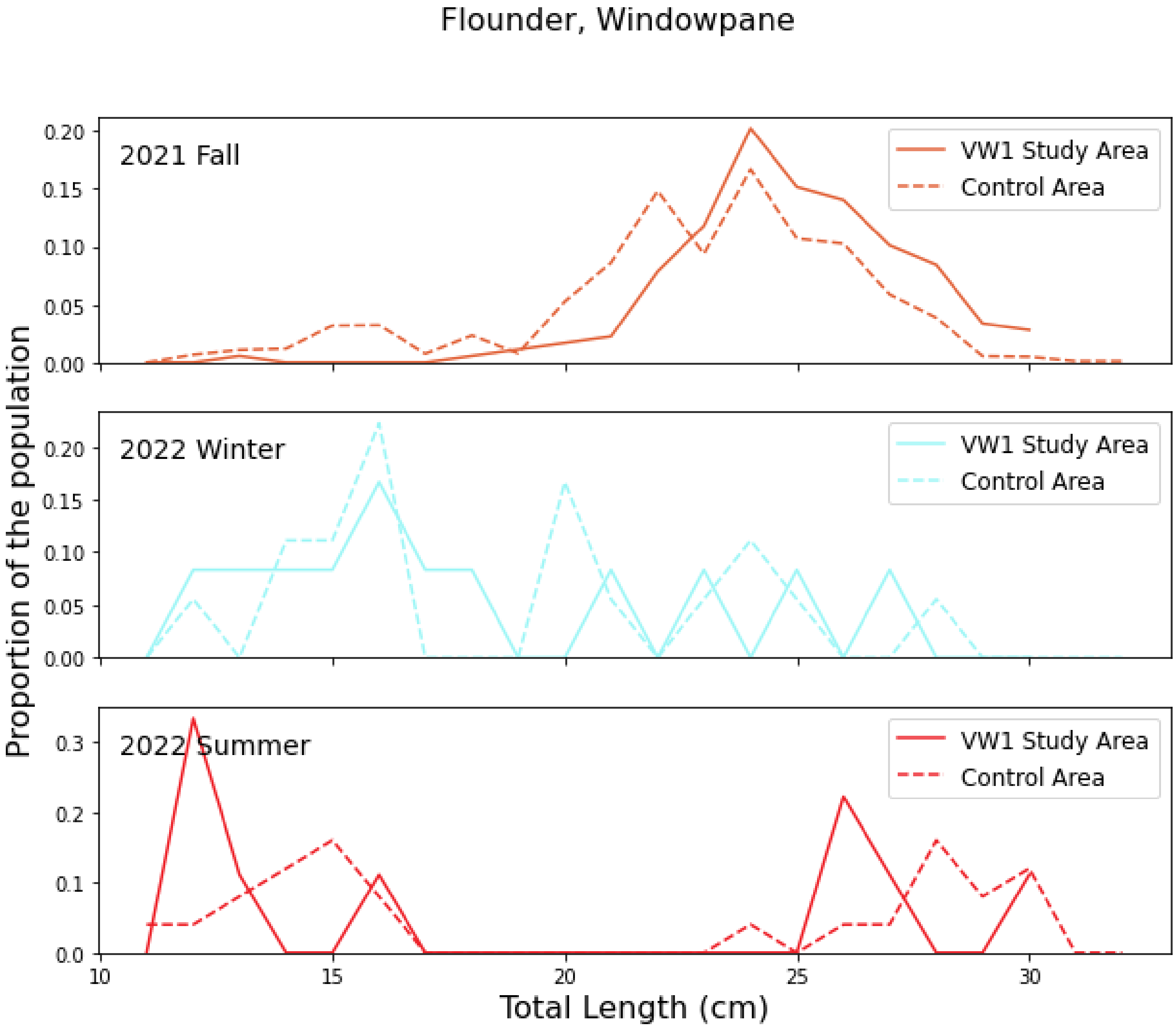


Figure 77: The seasonal length distributions of windowpane flounder in the VW1 Study Area and Control Area.

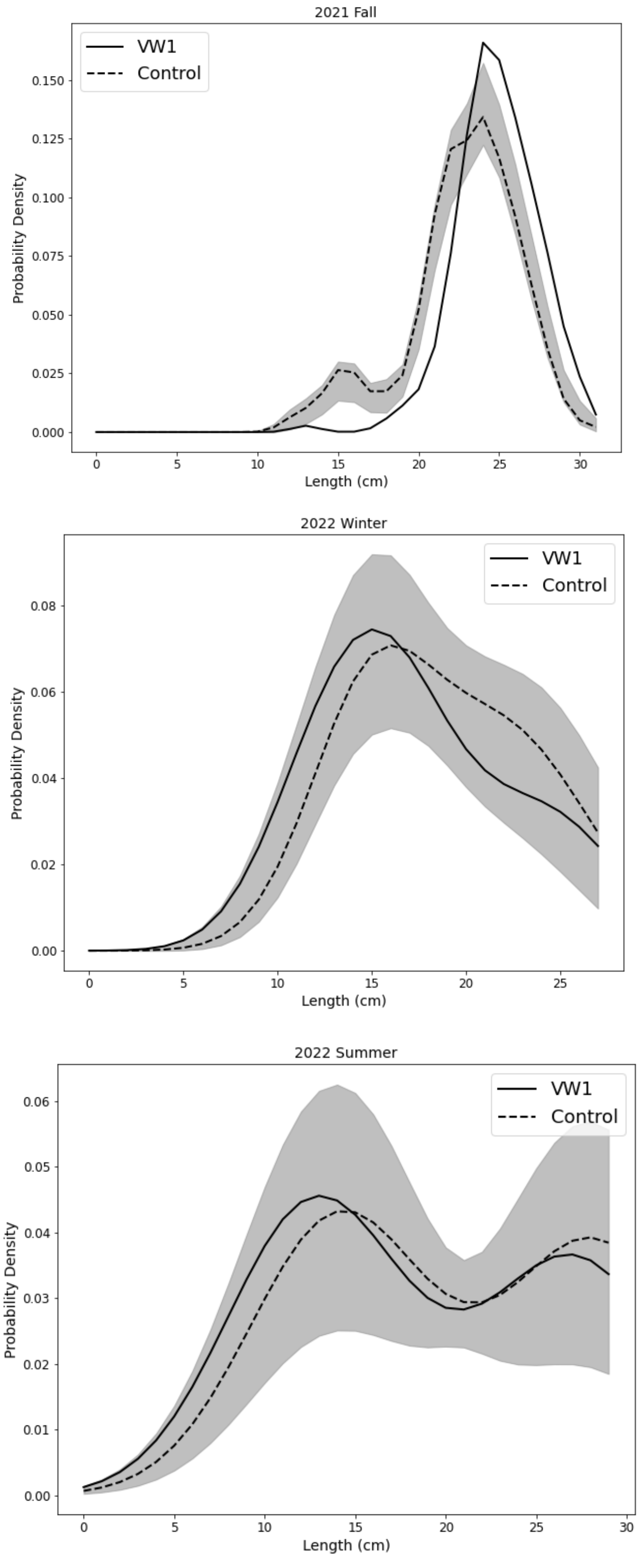
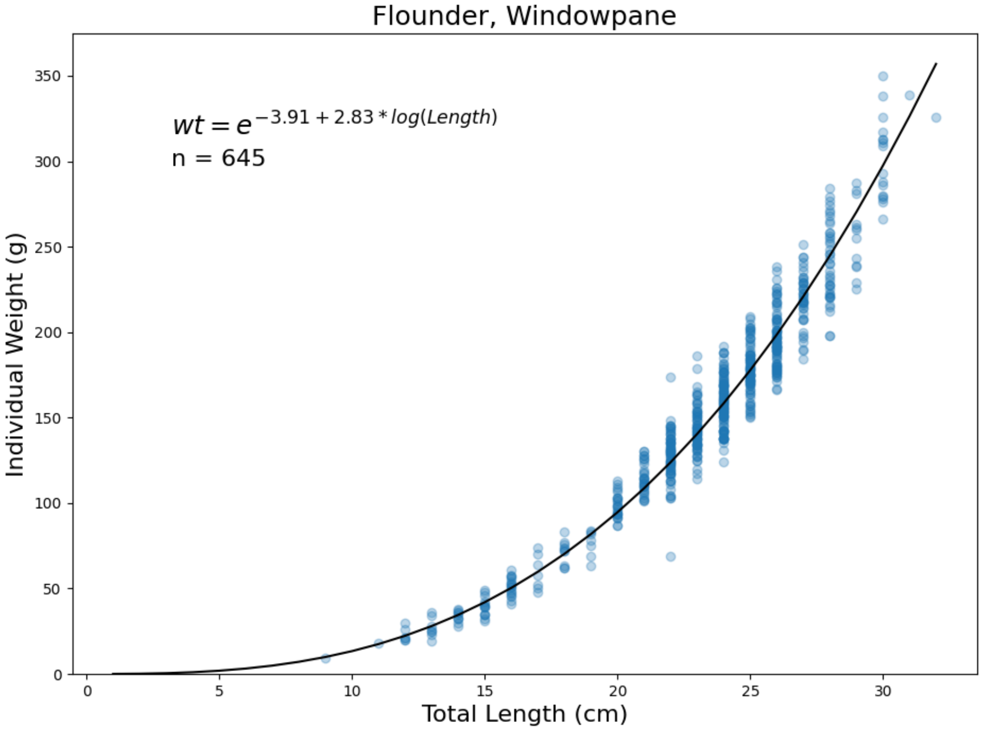


Figure 78: The population structure of windowpane flounder in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



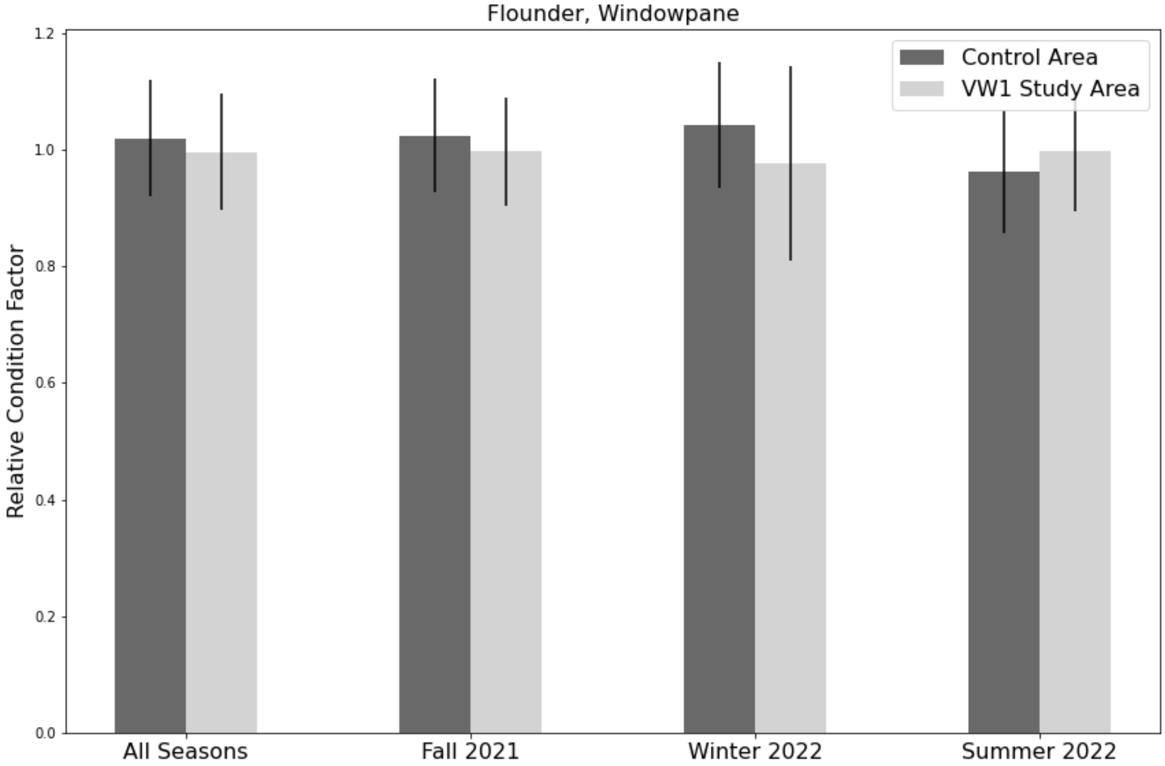


Figure 79: The seasonal condition of windowpane flounder (bottom) as derived from the length-weight relationship (top).

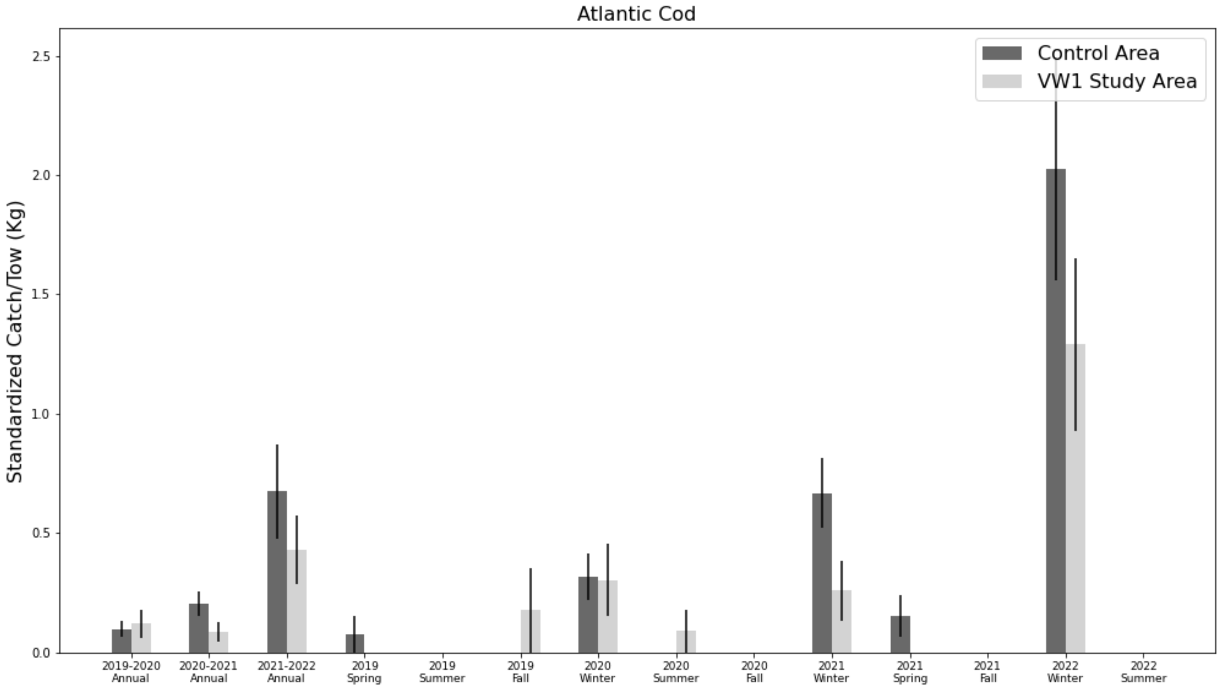


Figure 80: Seasonal catch rates of Atlantic cod in the VW1 Study Area and Control Area.

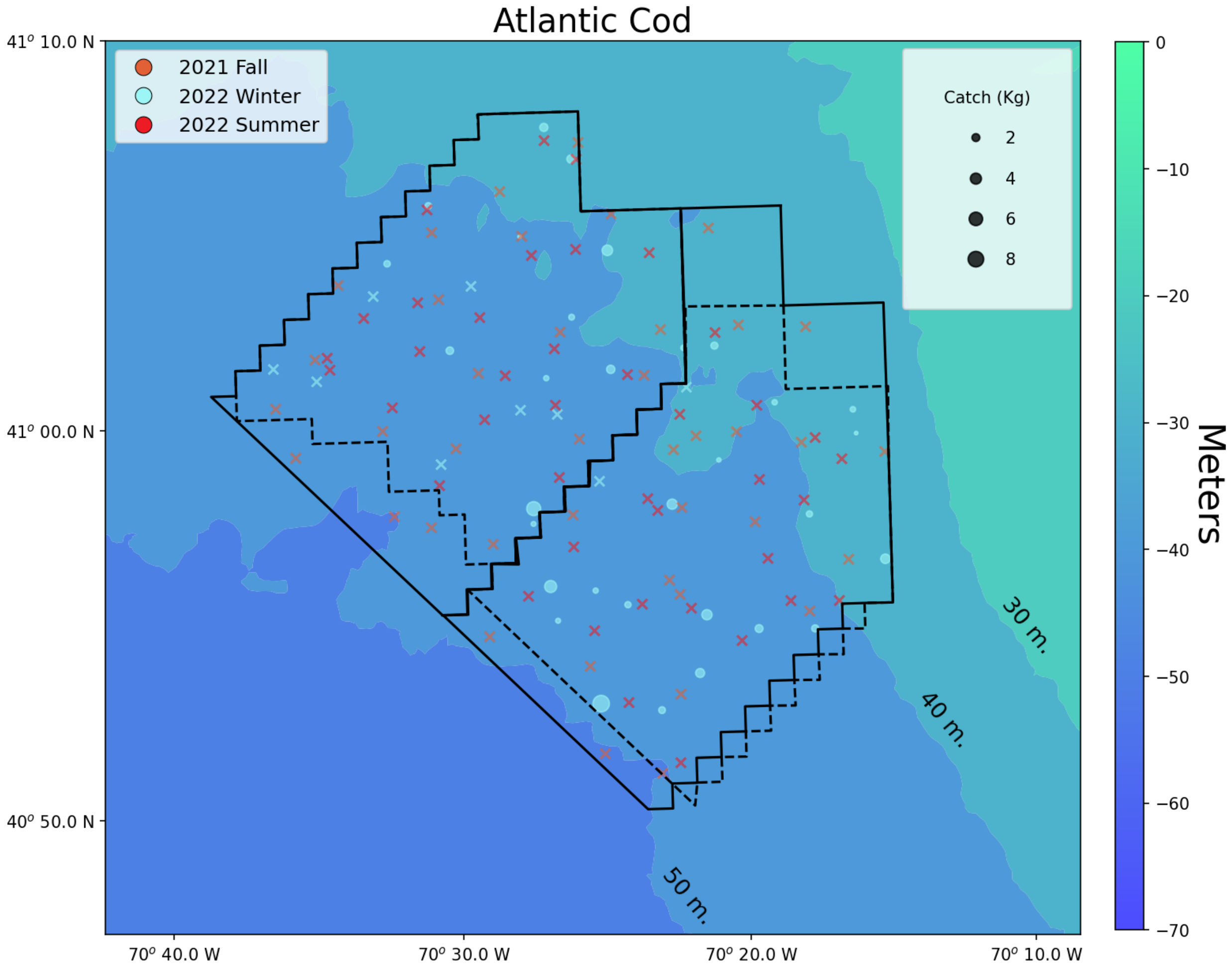


Figure 81: Seasonal distribution of the Atlantic cod catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

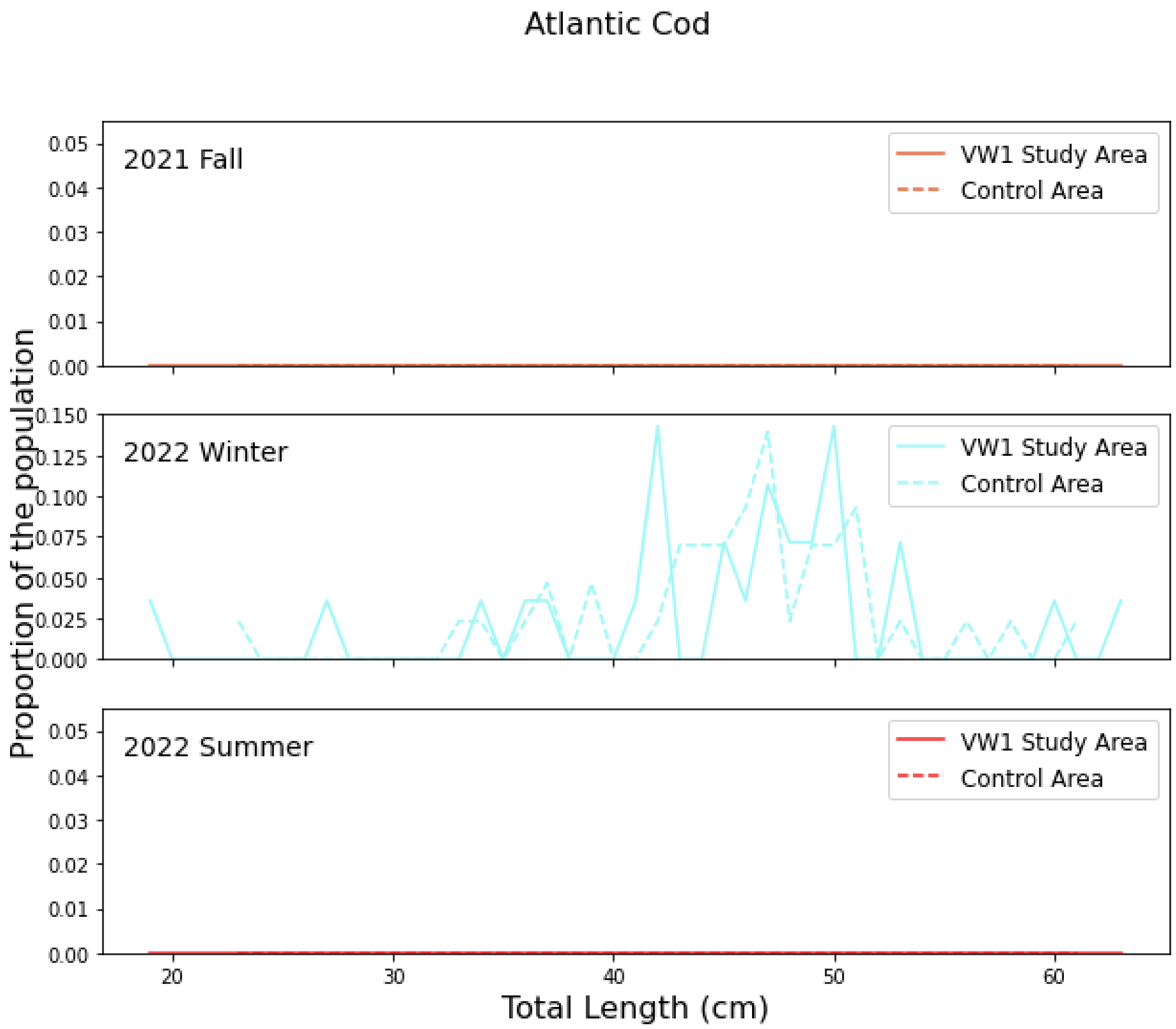


Figure 82: The seasonal length distributions of Atlantic cod in the VW1 Study Area and Control Area.

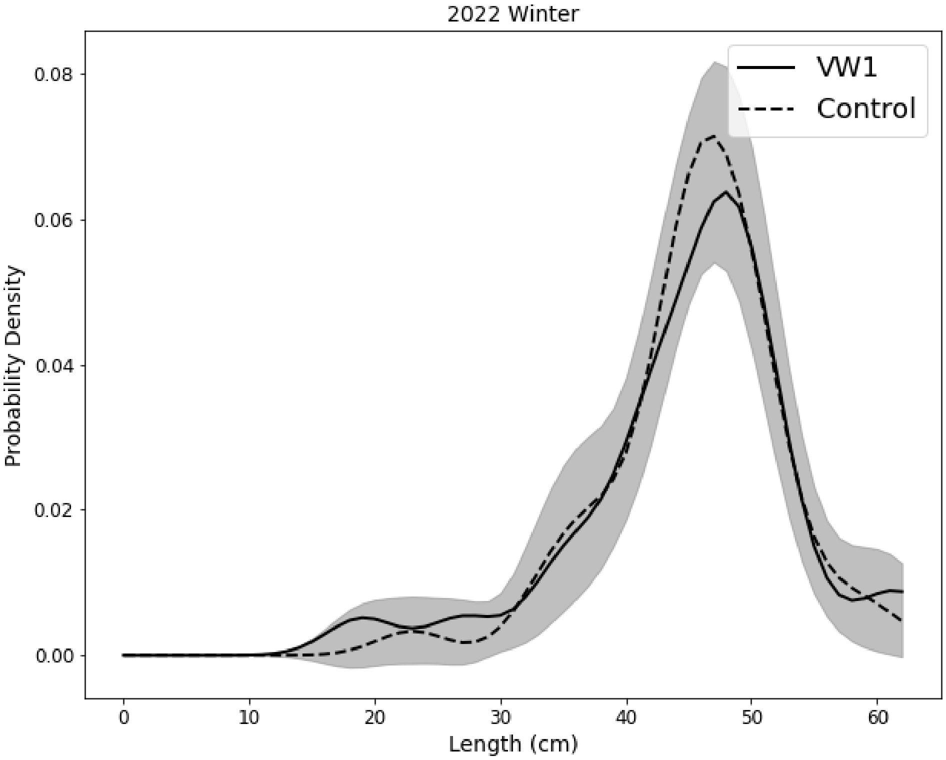


Figure 83: The population structure of Atlantic cod in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.

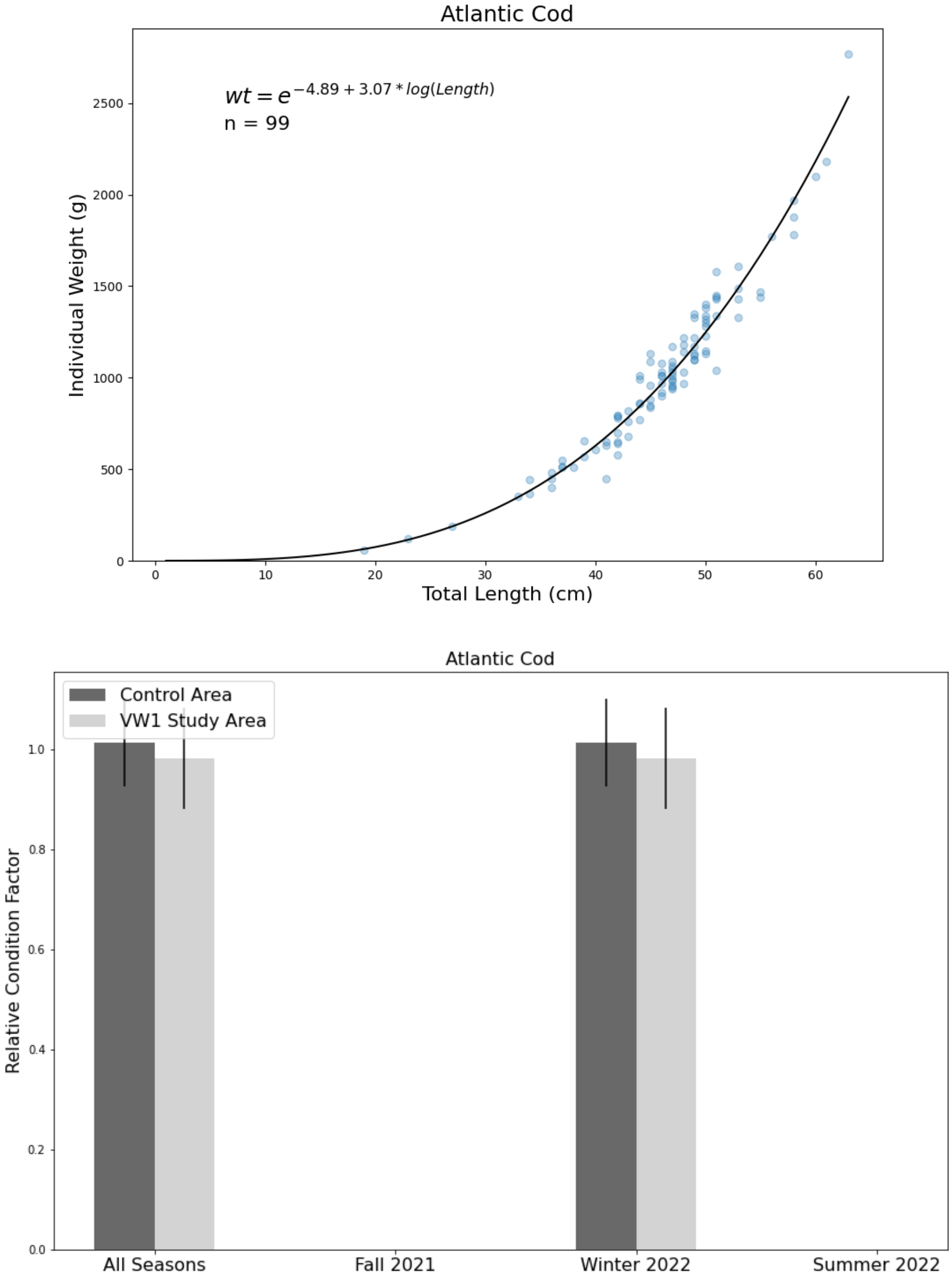


Figure 84: The seasonal condition of Atlantic cod (bottom) as derived from the length-weight relationship (top).

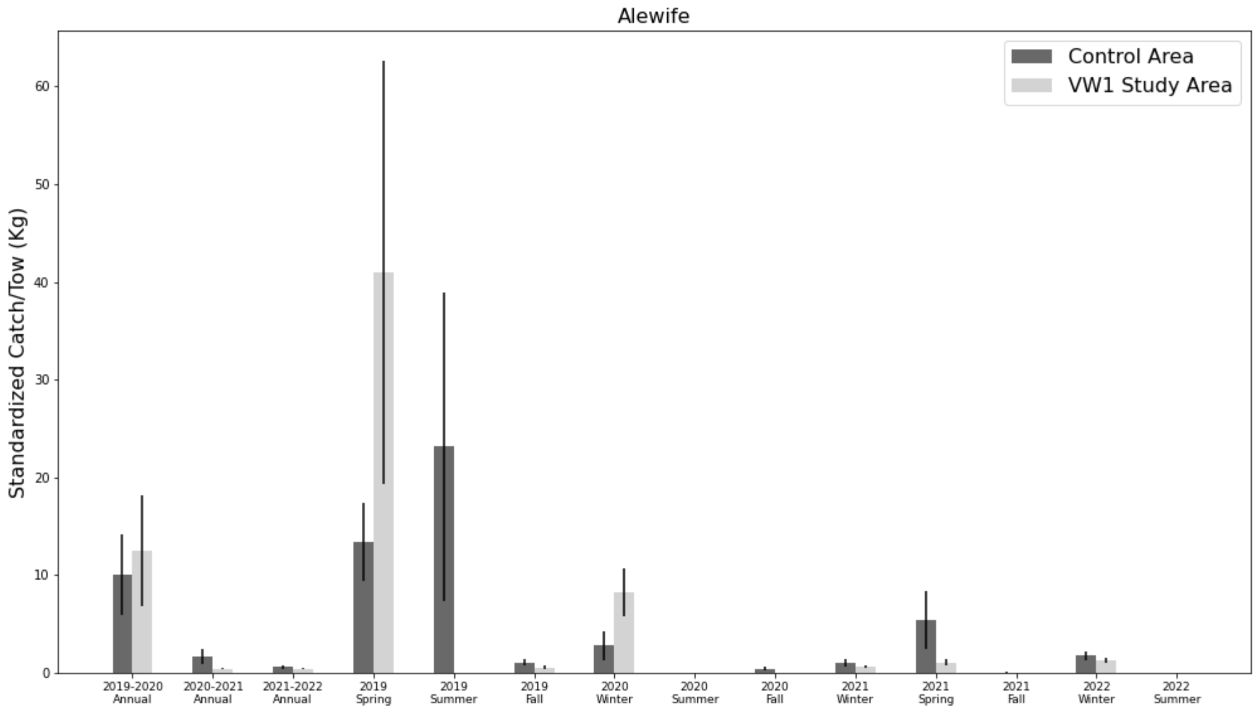


Figure 85: Seasonal catch rates of alewife in the VW1 Study Area and Control Area.

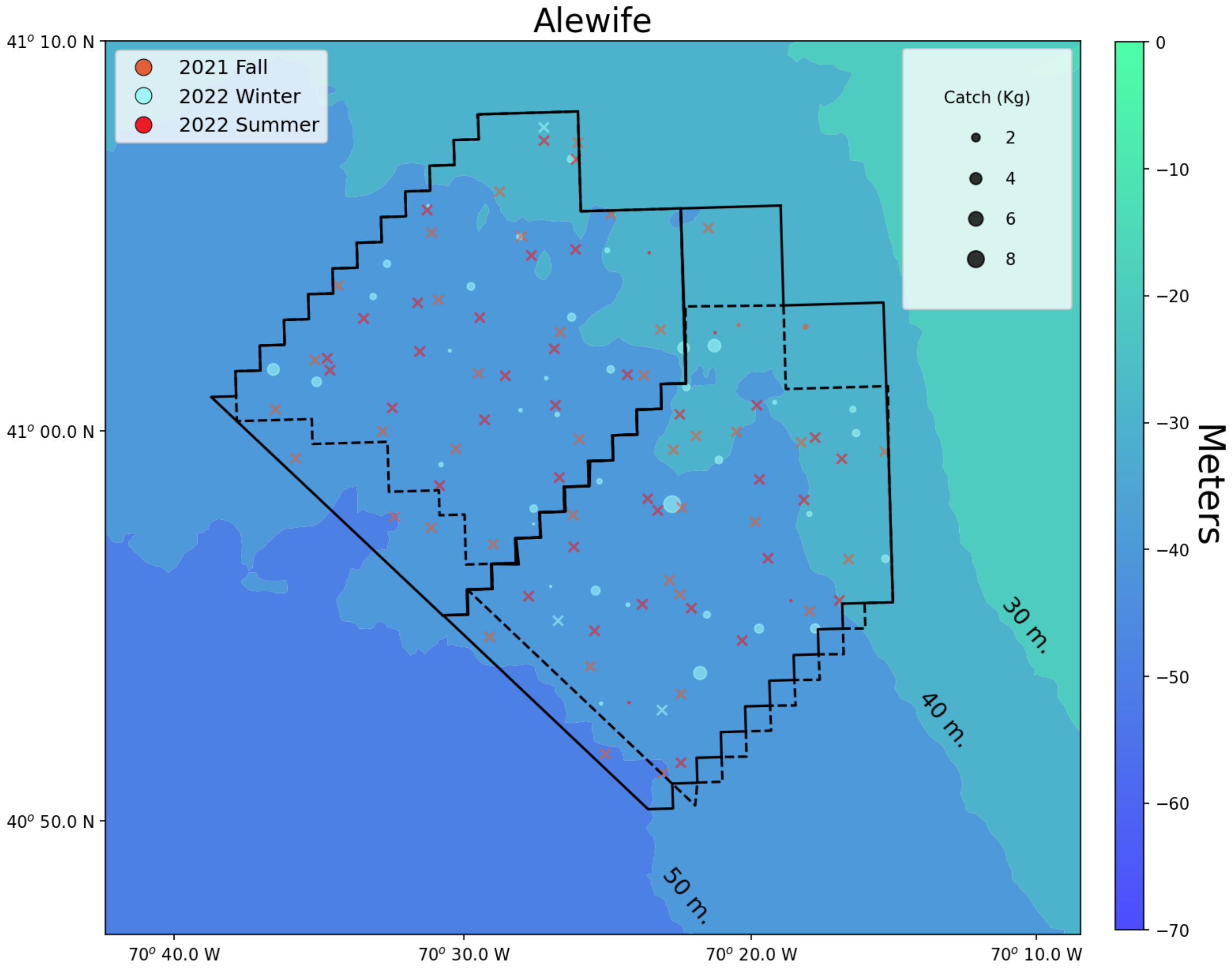


Figure 86: Seasonal distribution of the alewife catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

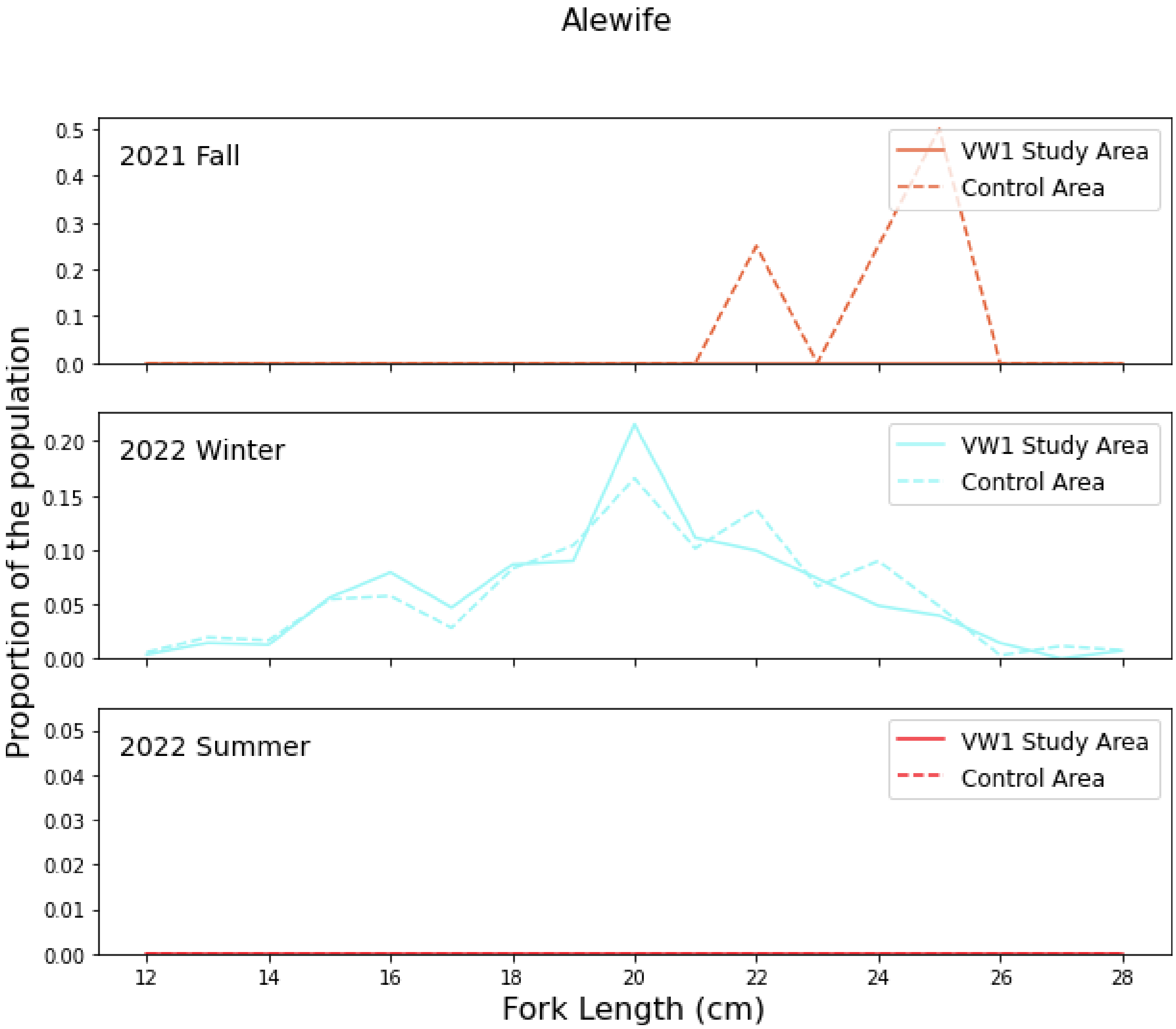


Figure 87: The seasonal length distributions of alewife in the VW1 Study Area and Control Area.

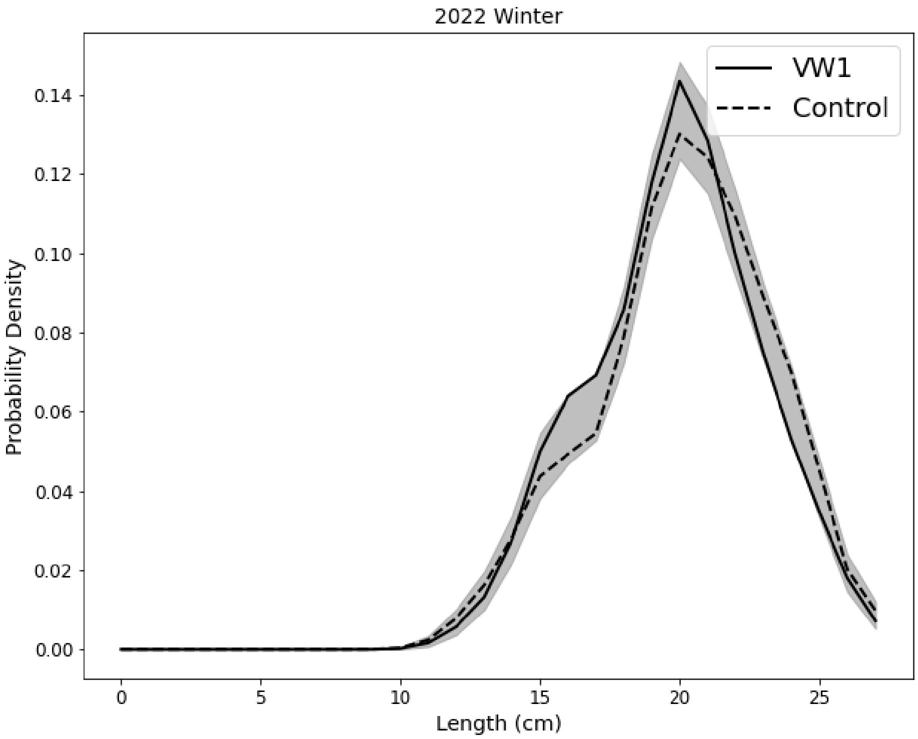
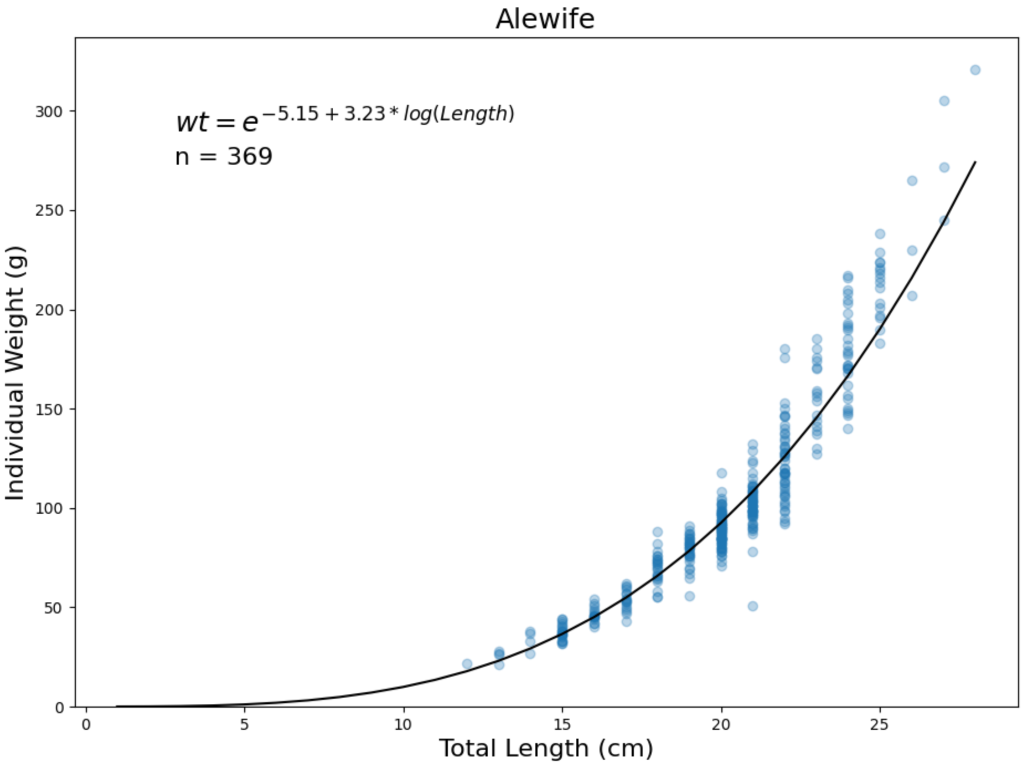


Figure 88: The population structure of alewife in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



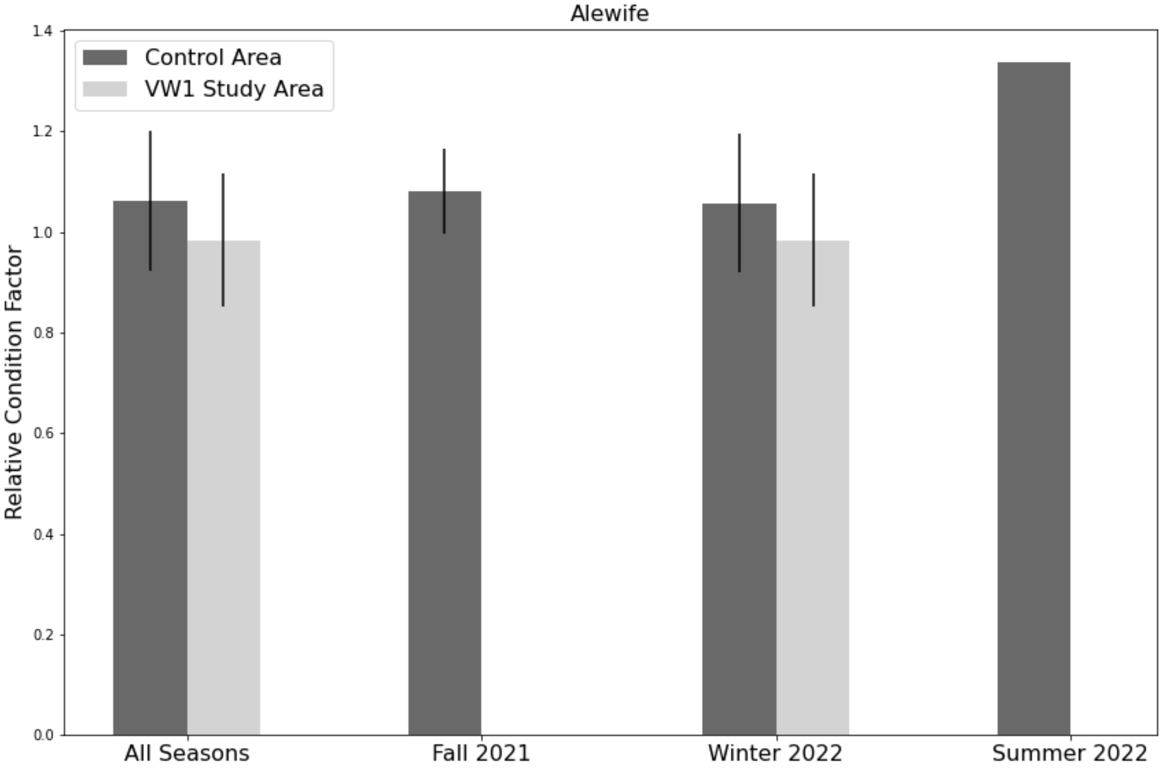


Figure 89: The seasonal condition of alewife (bottom) as derived from the length-weight relationship (top).

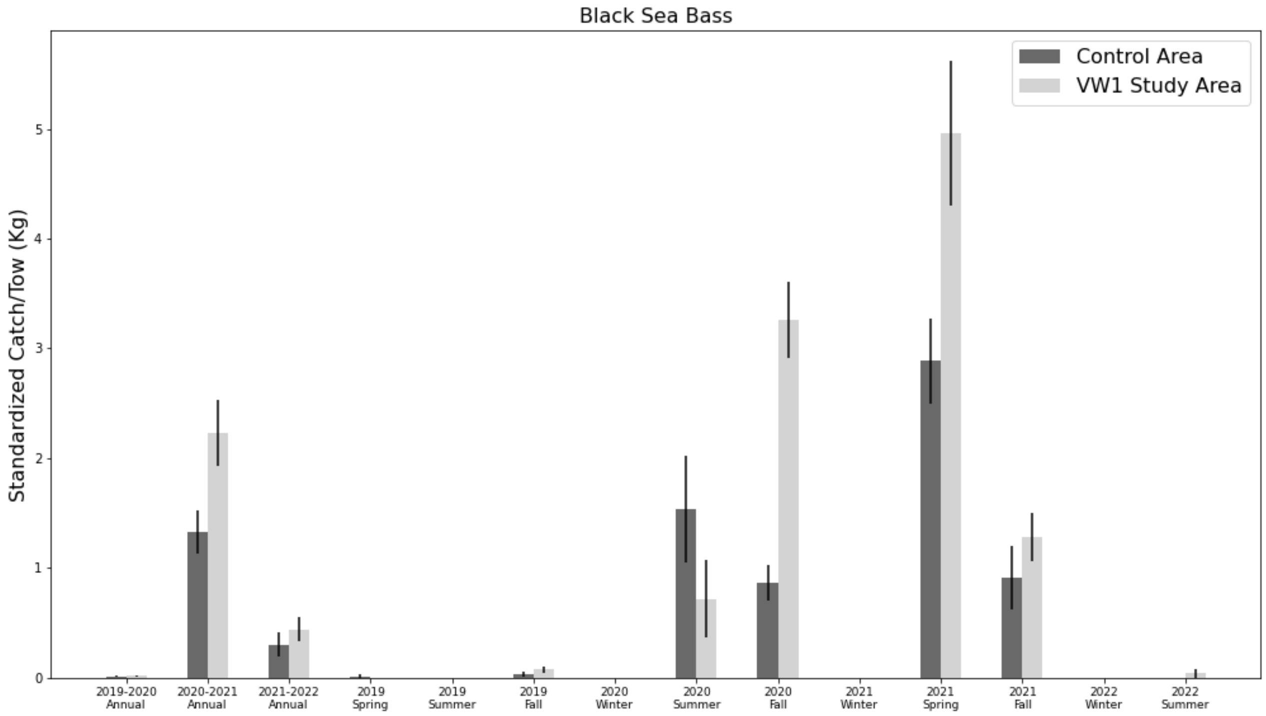


Figure 90: Seasonal catch rates of black sea bass in the VW1 Study Area and Control Area.

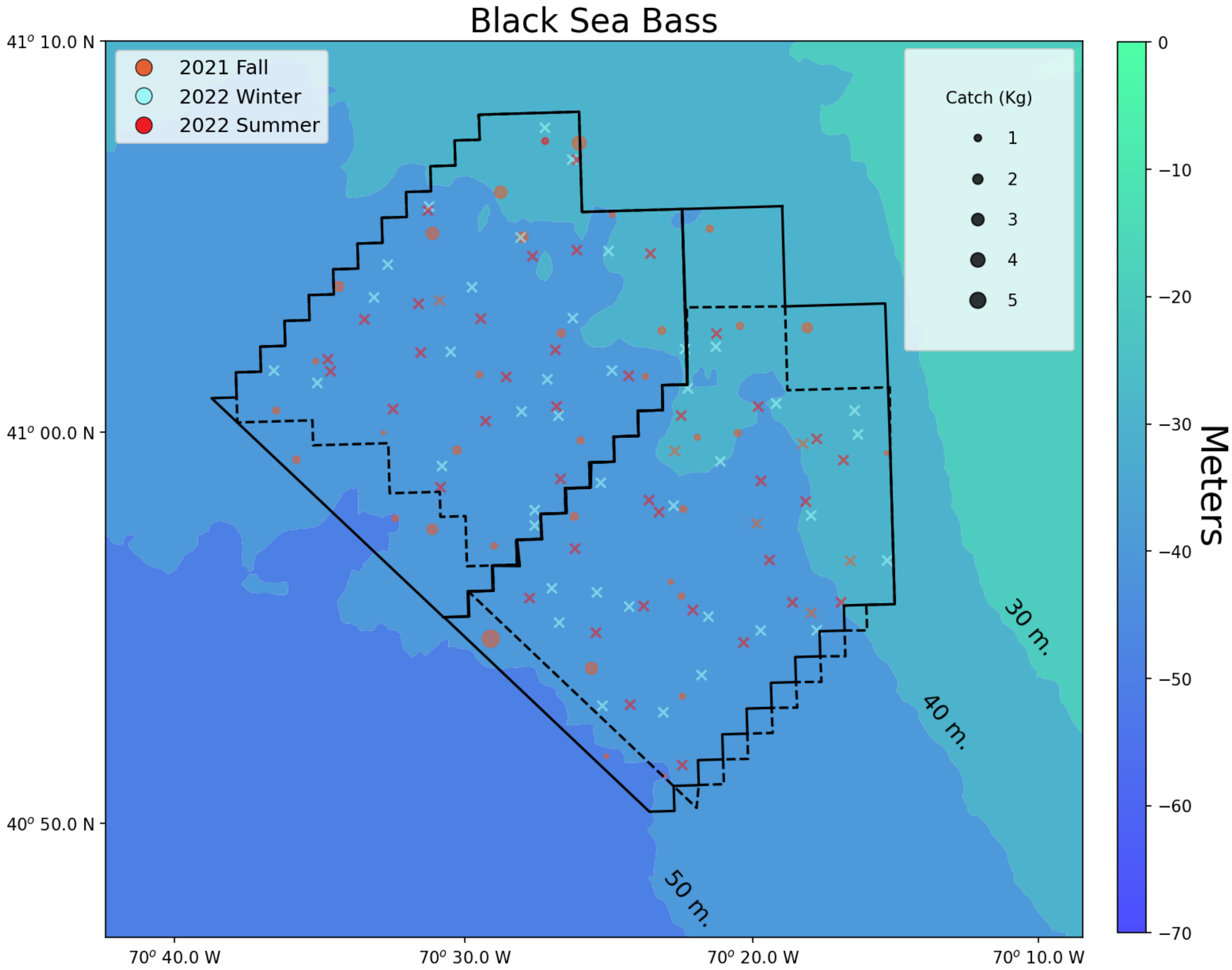


Figure 91: Seasonal distribution of the black sea bass catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

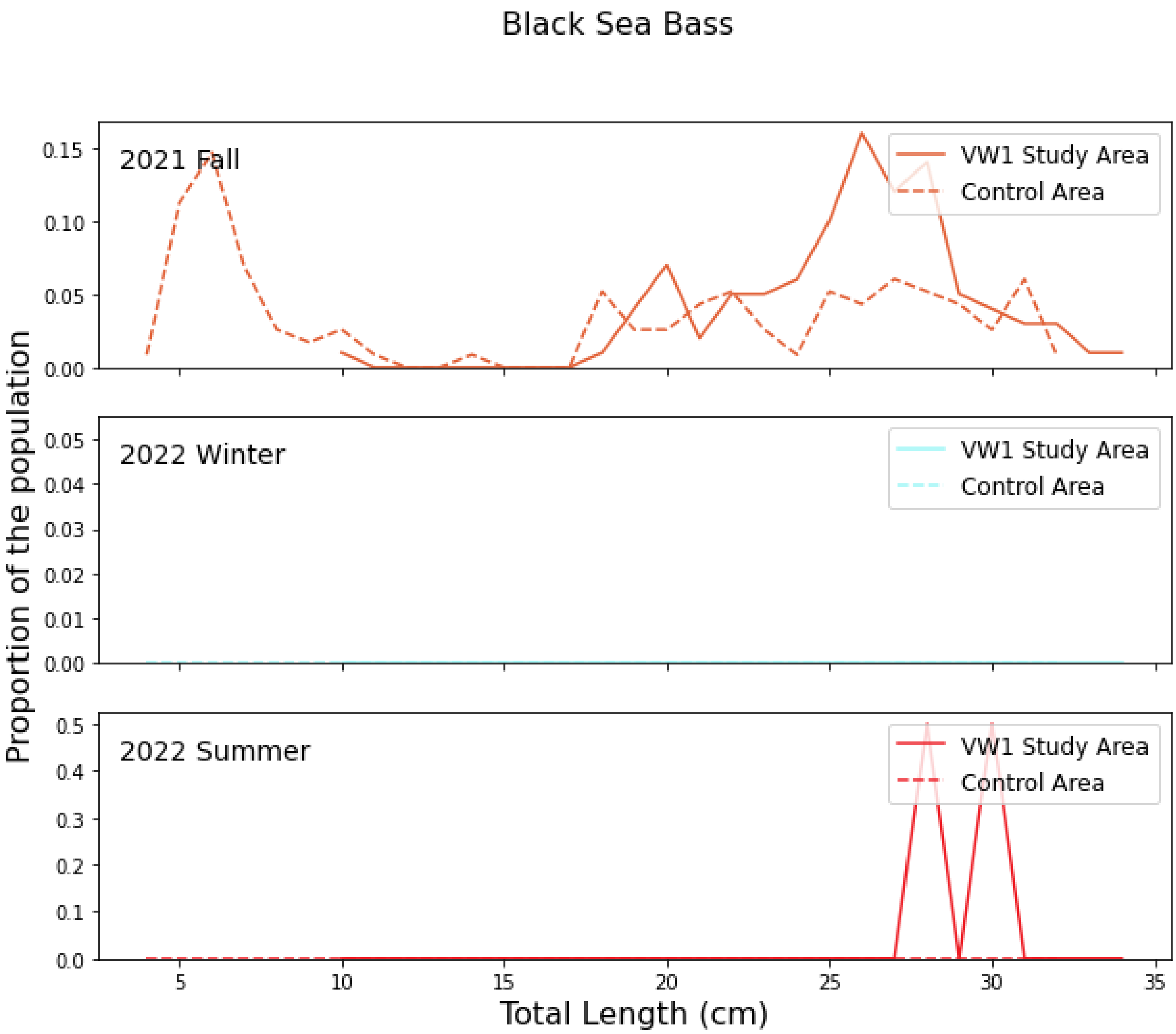


Figure 92: The seasonal length distributions of black sea bass in the VW1 Study Area and Control Area.

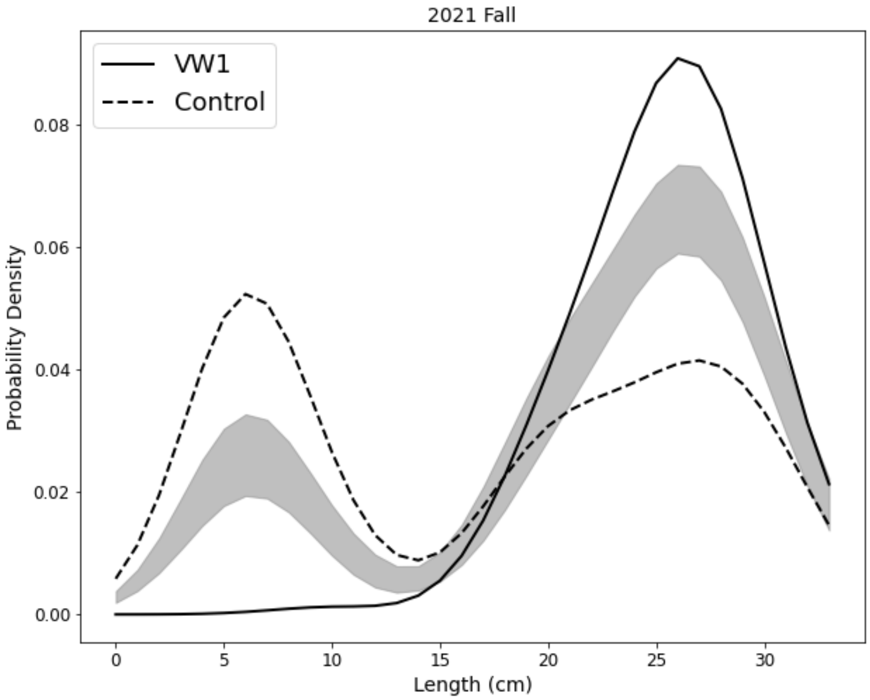
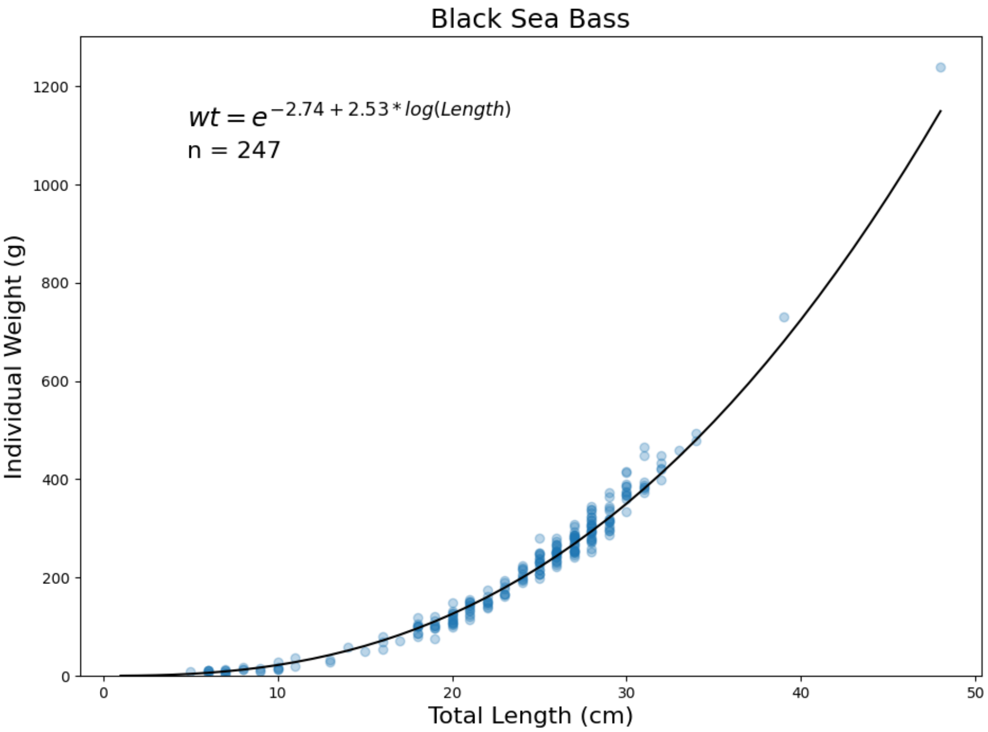


Figure 93: The population structure of black sea bass in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



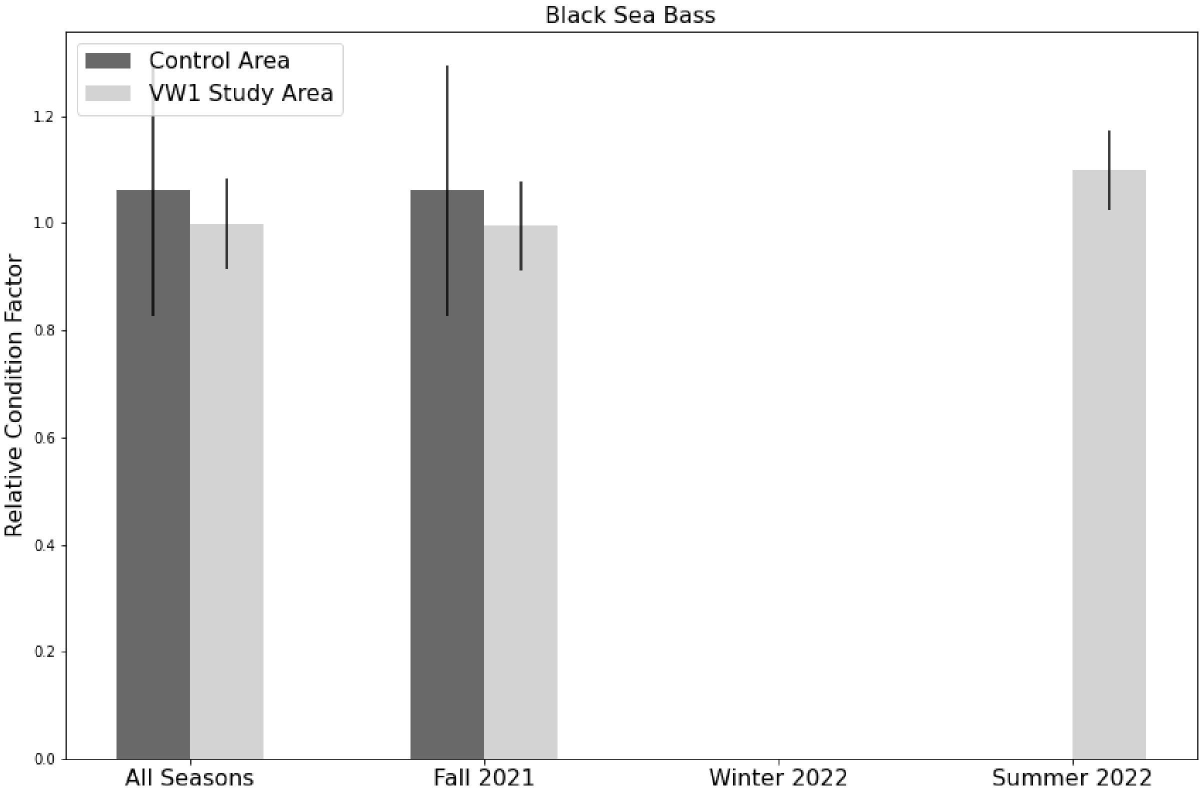


Figure 94: The seasonal condition of black sea bass (bottom) as derived from the length-weight relationship (top).

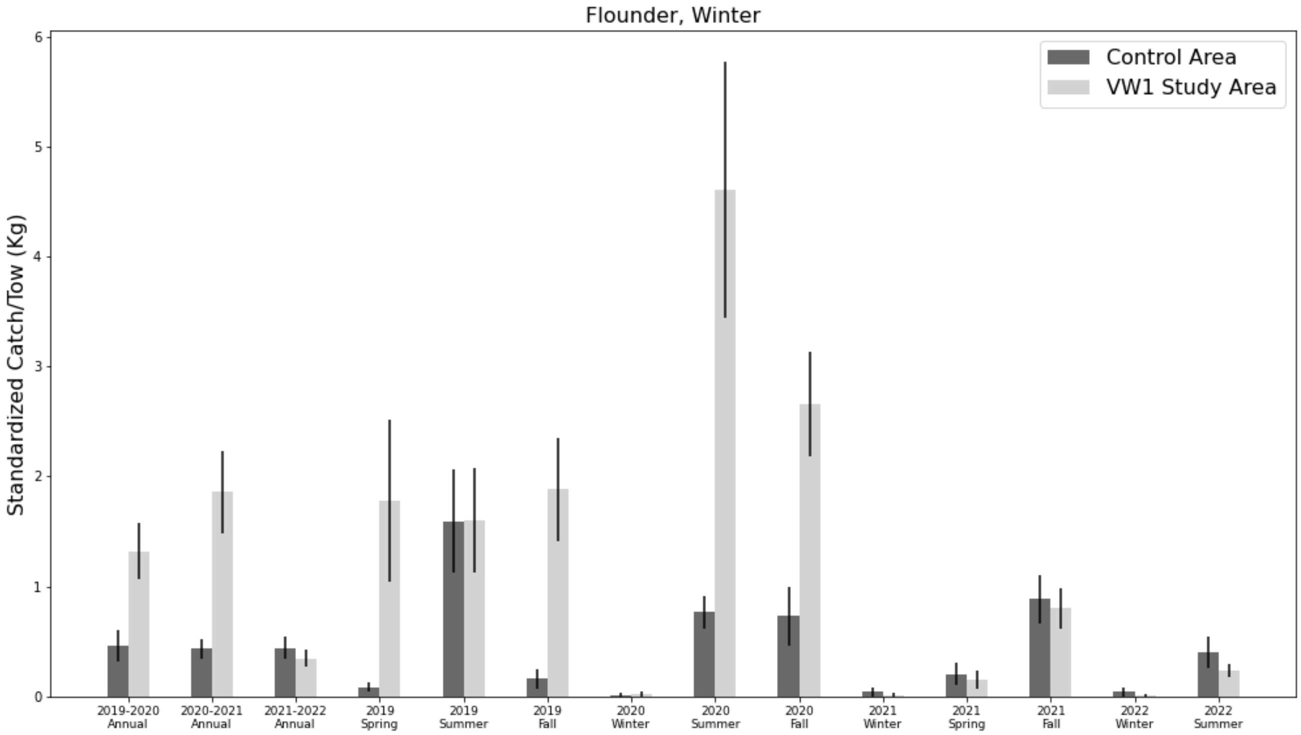


Figure 95: Seasonal catch rates of winter flounder in the VW1 Study Area and Control Area.

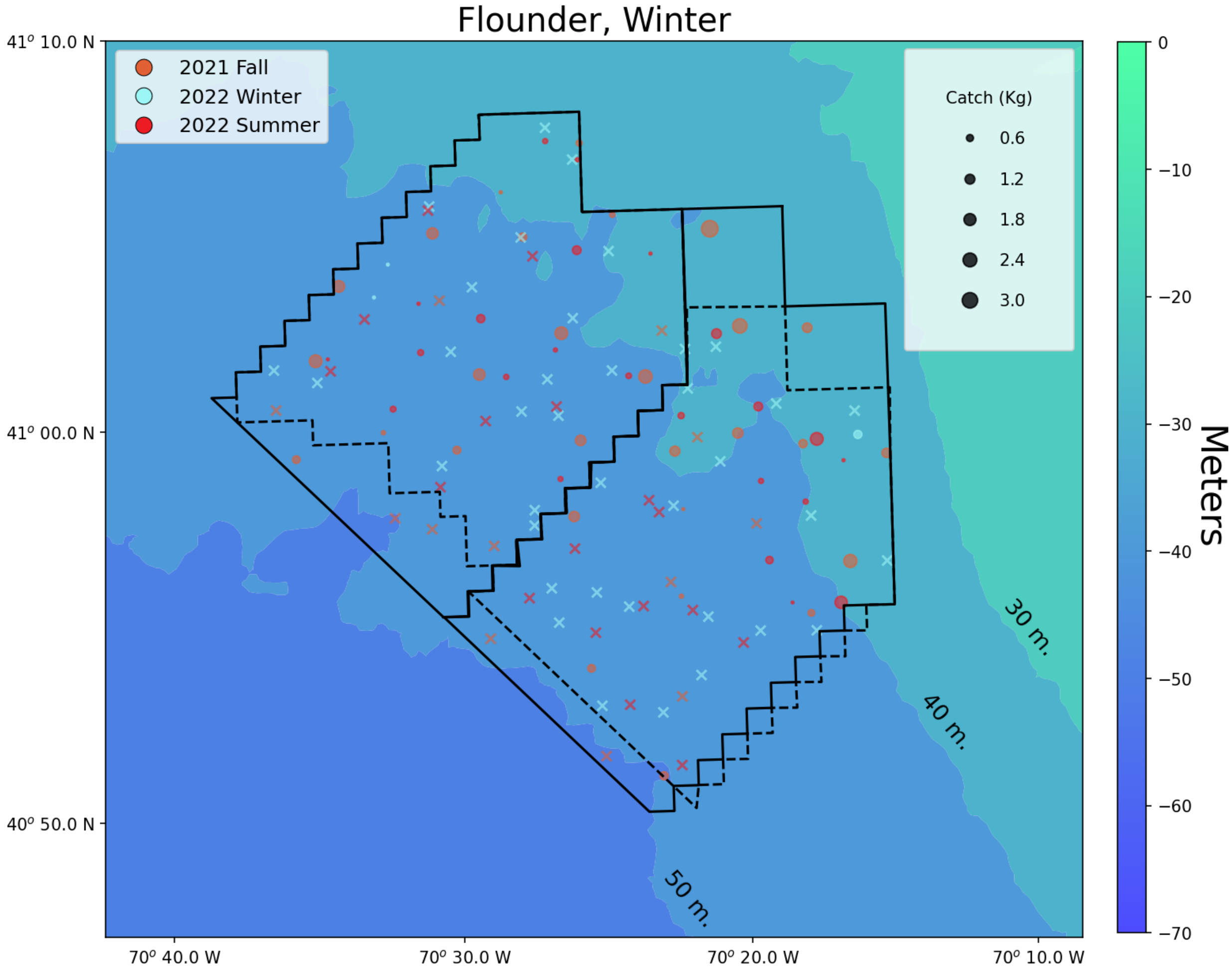


Figure 96: Seasonal distribution of the winter flounder catch in the VW1 Study Area (left) and Control Area (right). Tows with zero catch are denoted with an X.

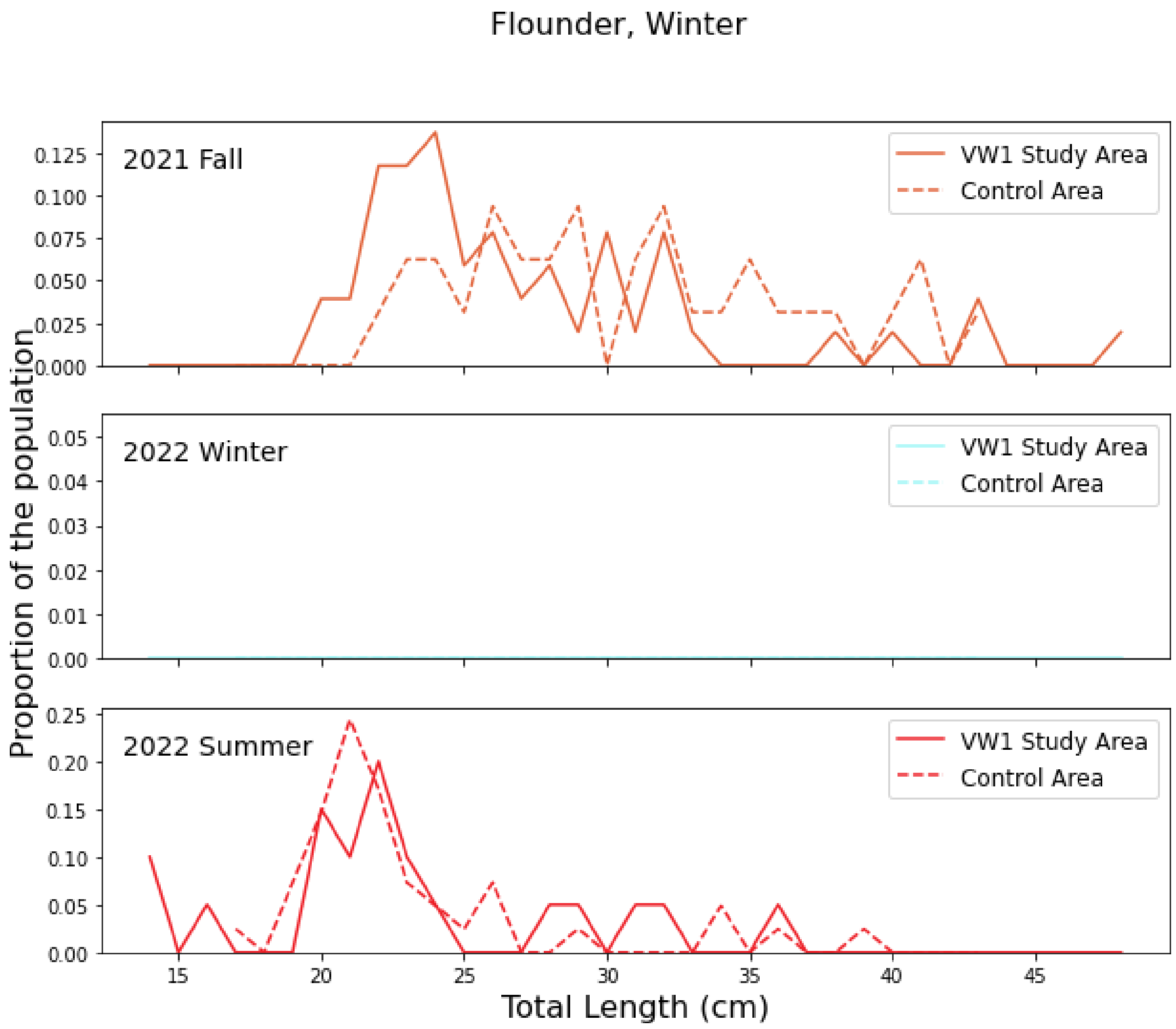


Figure 97: The seasonal length distributions of winter flounder in the VW1 Study Area and Control Area.

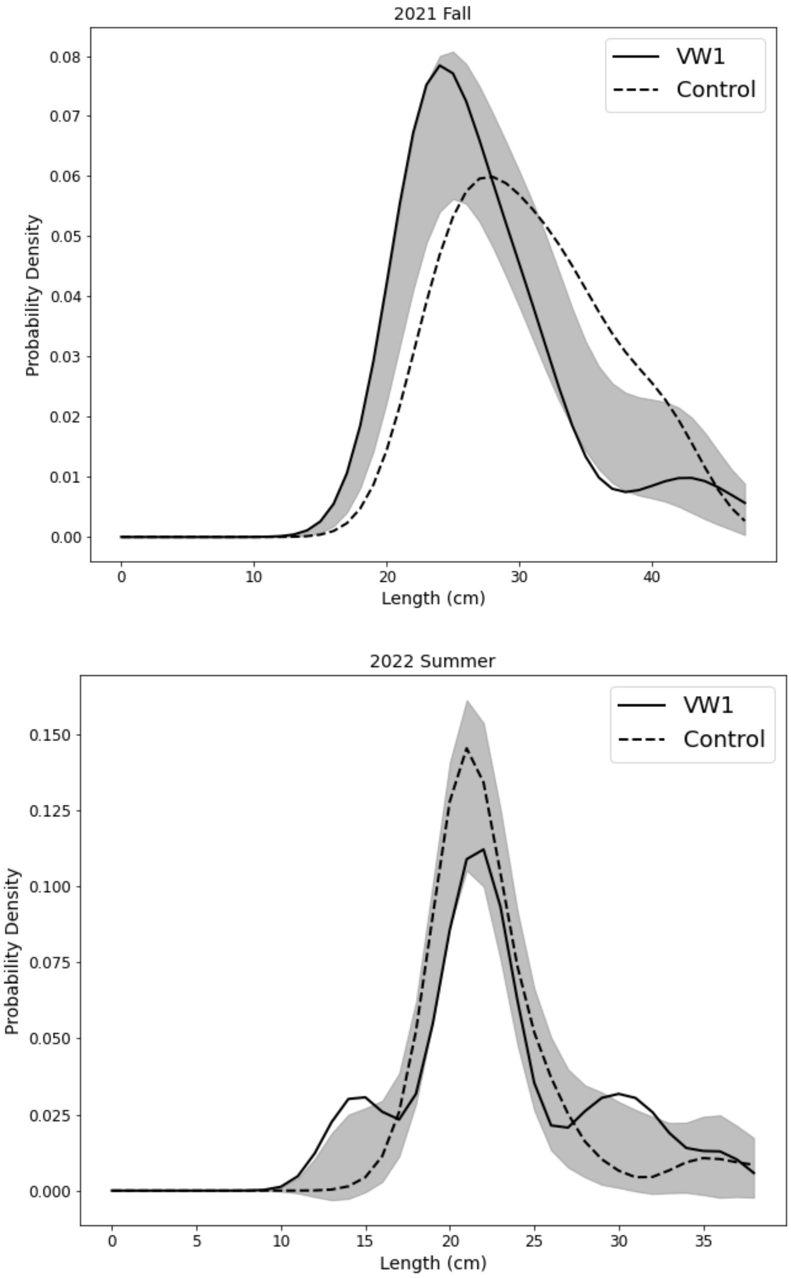
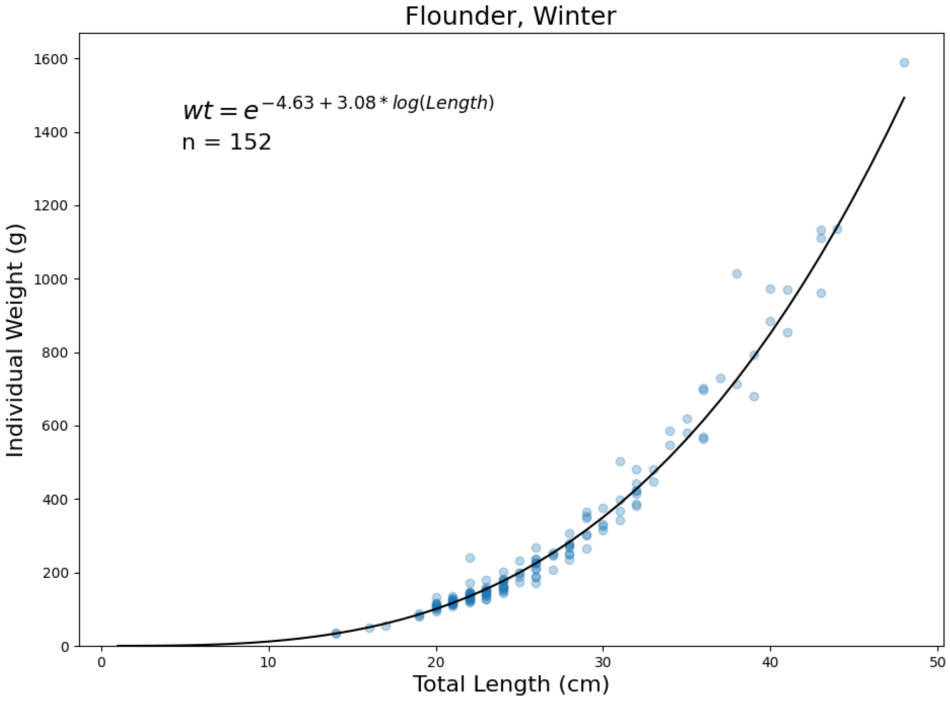


Figure 98: The population structure of winter flounder in the VW1 Study Area and Control Area assessed through kernel density estimates. The gray band represents the null hypothesis of no significant difference between treatments.



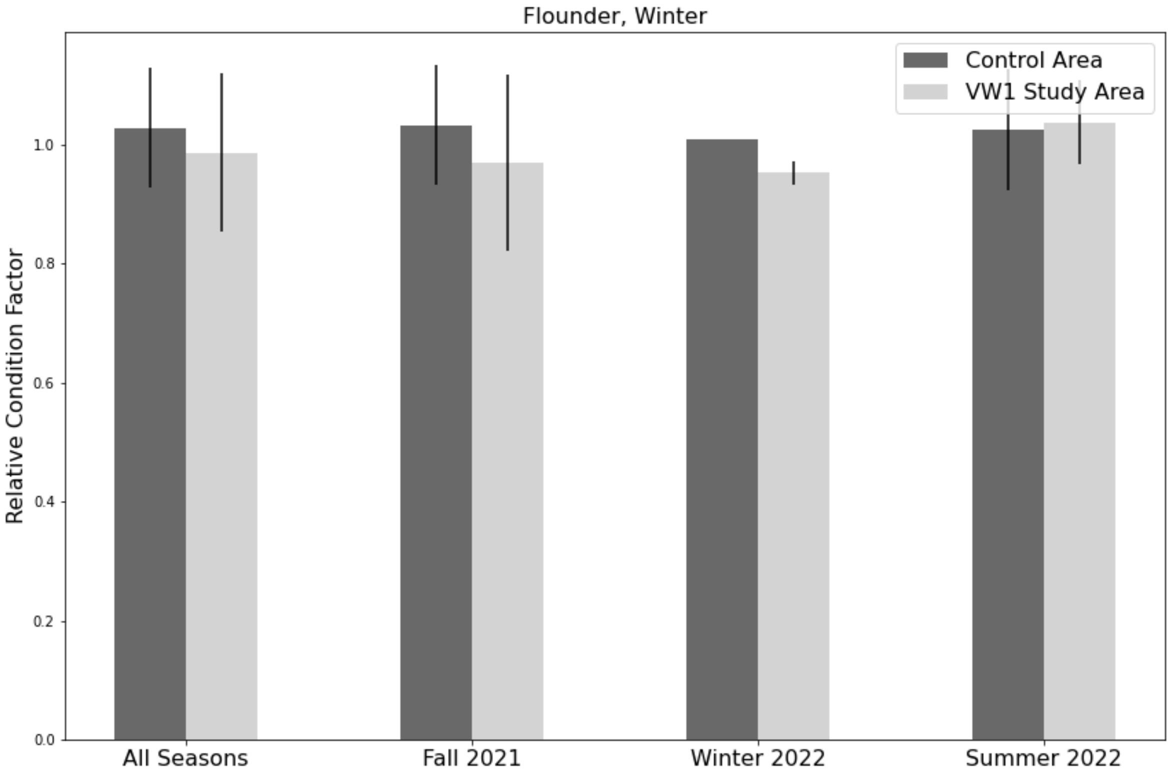


Figure 99: The seasonal condition of winter flounder (bottom) as derived from the length-weight relationship (top).

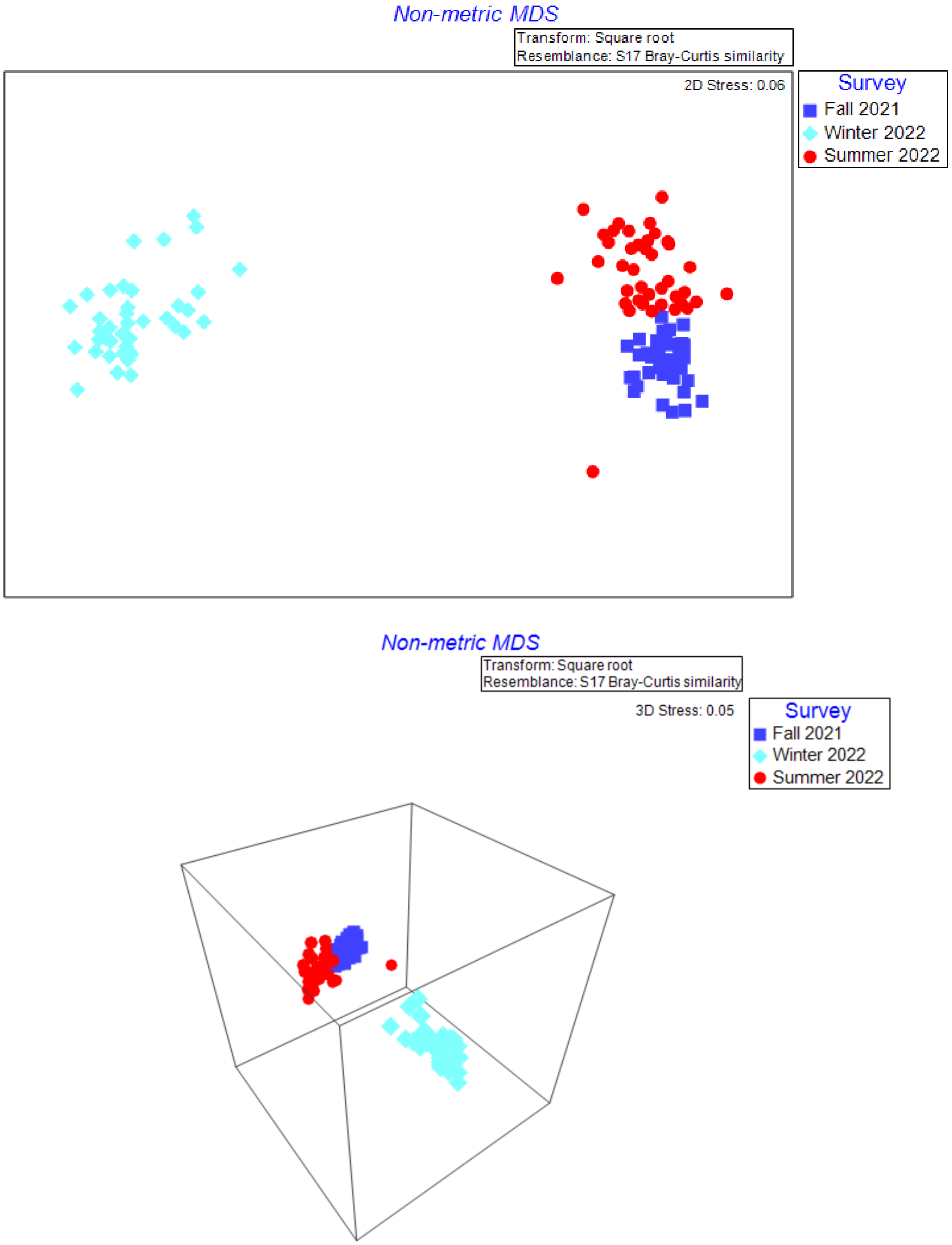


Figure 100: 2D (top) and 3D (bottom) nMDS plots. Data from the 2021/2022 seasons and survey areas is aggregated with the tow markers colored by season to highlight the seasonal clusters in species similarity.

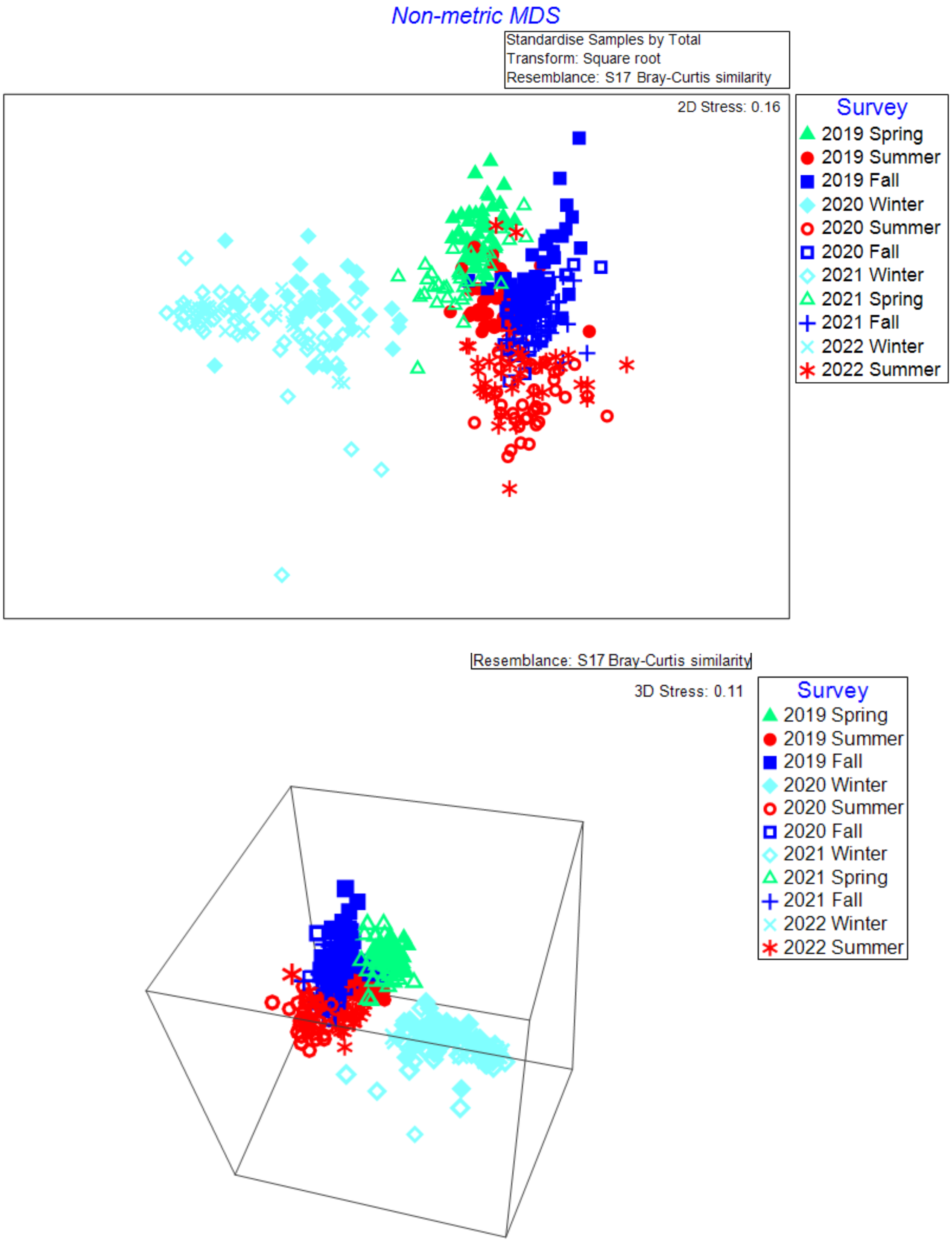


Figure 101: 2D (top) and 3D (bottom) nMDS plots. The data were aggregated from all surveys (2019 – 2022), including all seasons and both survey areas. The tow markers are colored by season to highlight the seasonal clusters in species similarity.

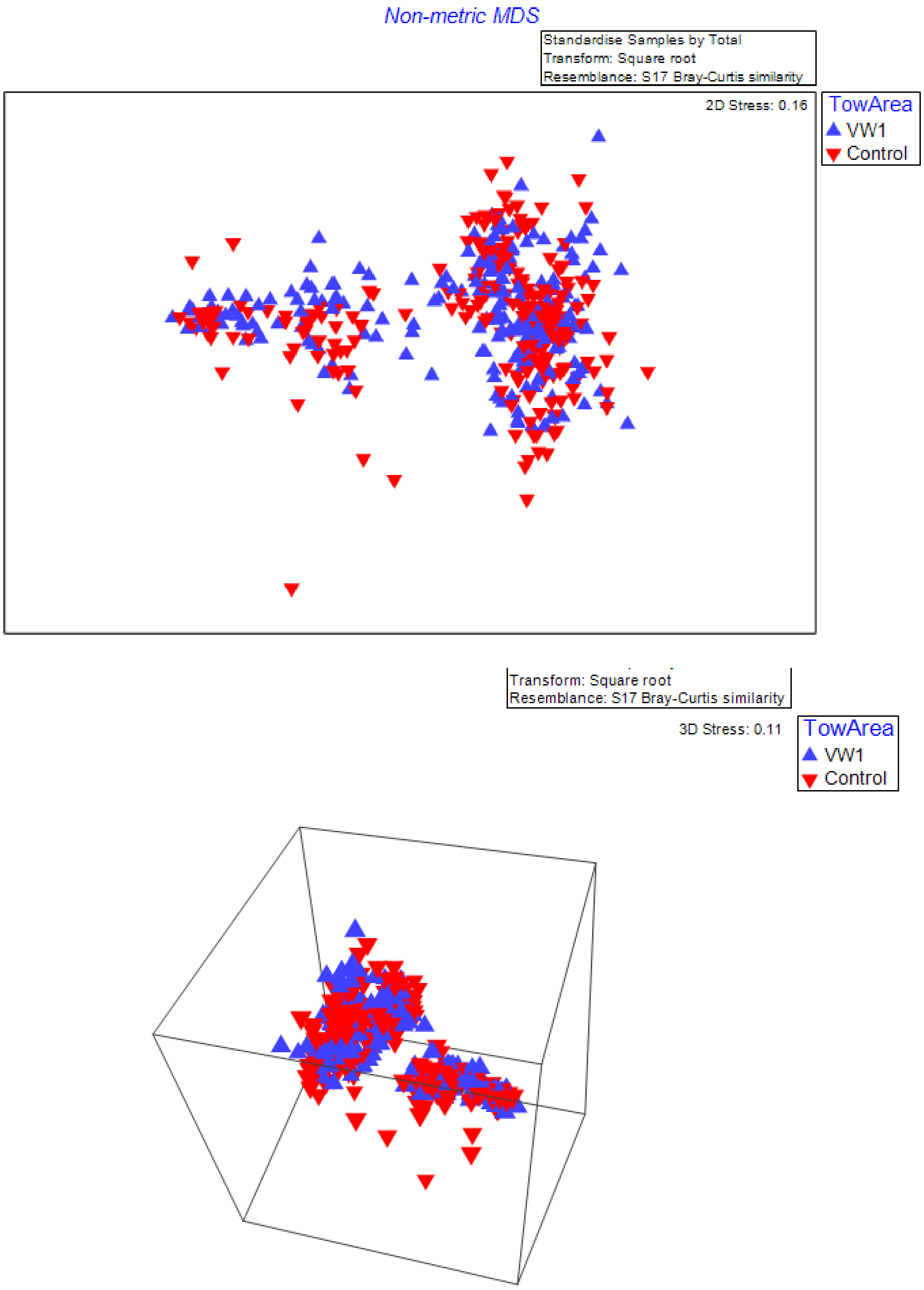


Figure 102: 2D (top) and 3D (bottom) nMDS plots. Data from all seasons and survey areas (2019 – 2022) is aggregated with the tow markers colored by survey area to highlight the lack of clustering between survey areas.

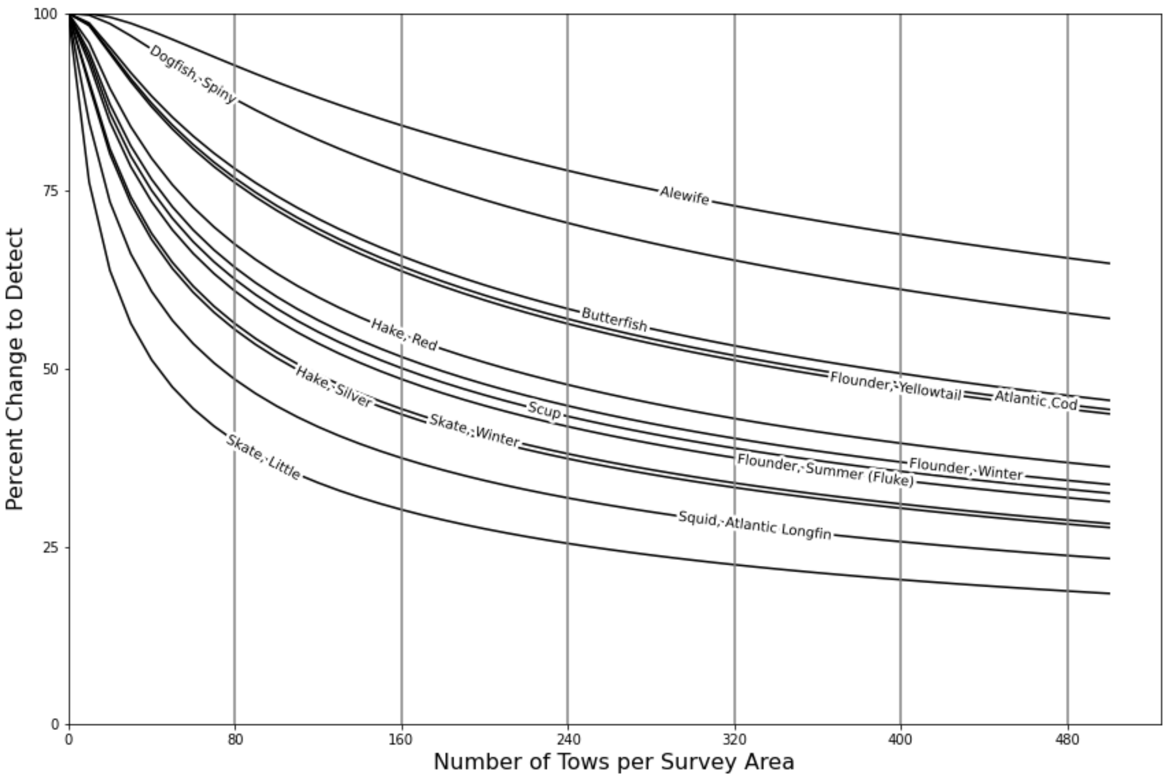


Figure 103: Relationship between survey effort and detectable magnitude of change for several species of commercial interest. The ability to detect the percent change in a species population size is a function of the variability in the catch and the sample size (i.e., number of tows). The current survey effort samples 80 tows per survey area per year.

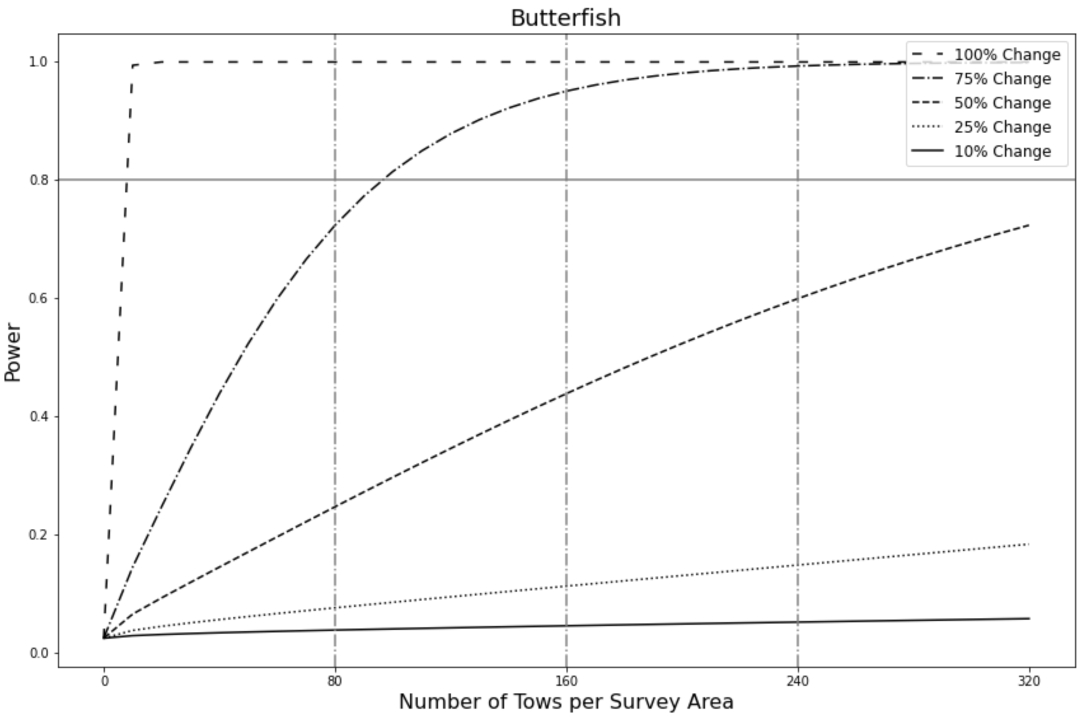


Figure 104: Power analysis relationship between statistical power and sample size in butterfish. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

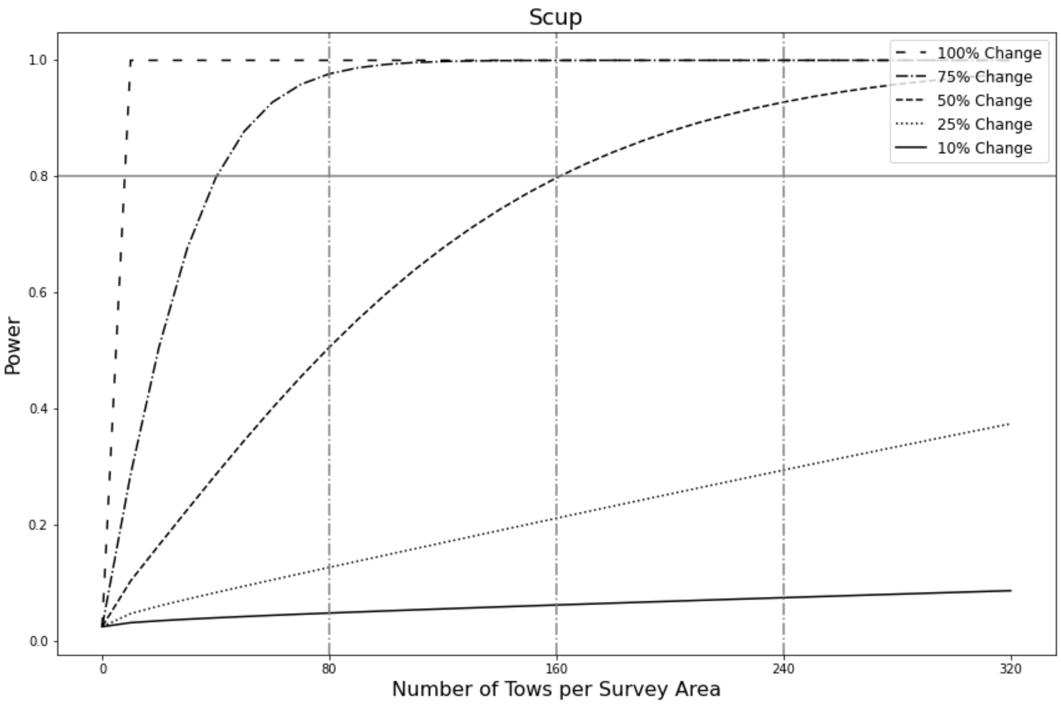


Figure 105: Power analysis relationship between statistical power and sample size in scup. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

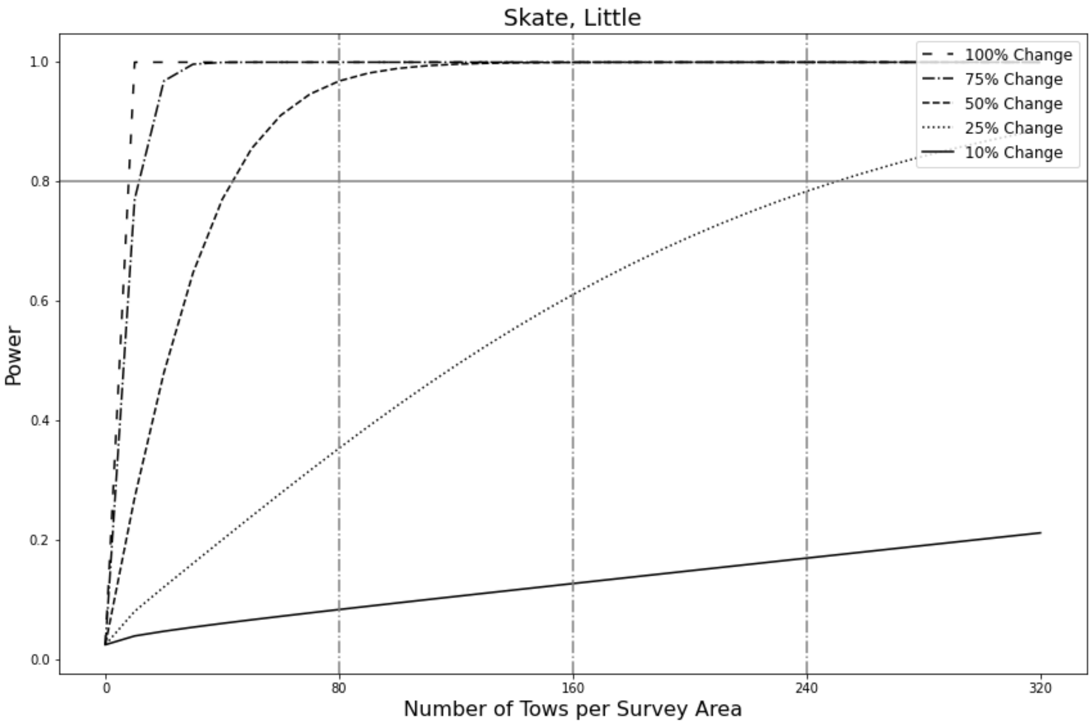


Figure 106: Power analysis relationship between statistical power and sample size in little skate. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

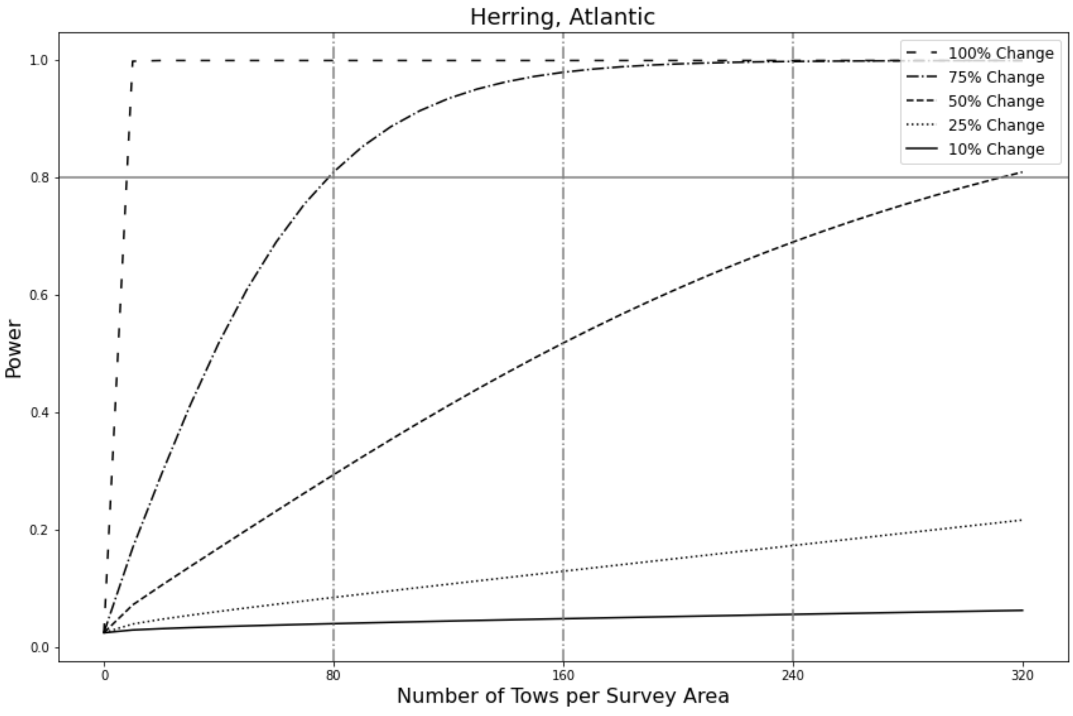


Figure 107: Power analysis relationship between statistical power and sample size in Atlantic herring. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

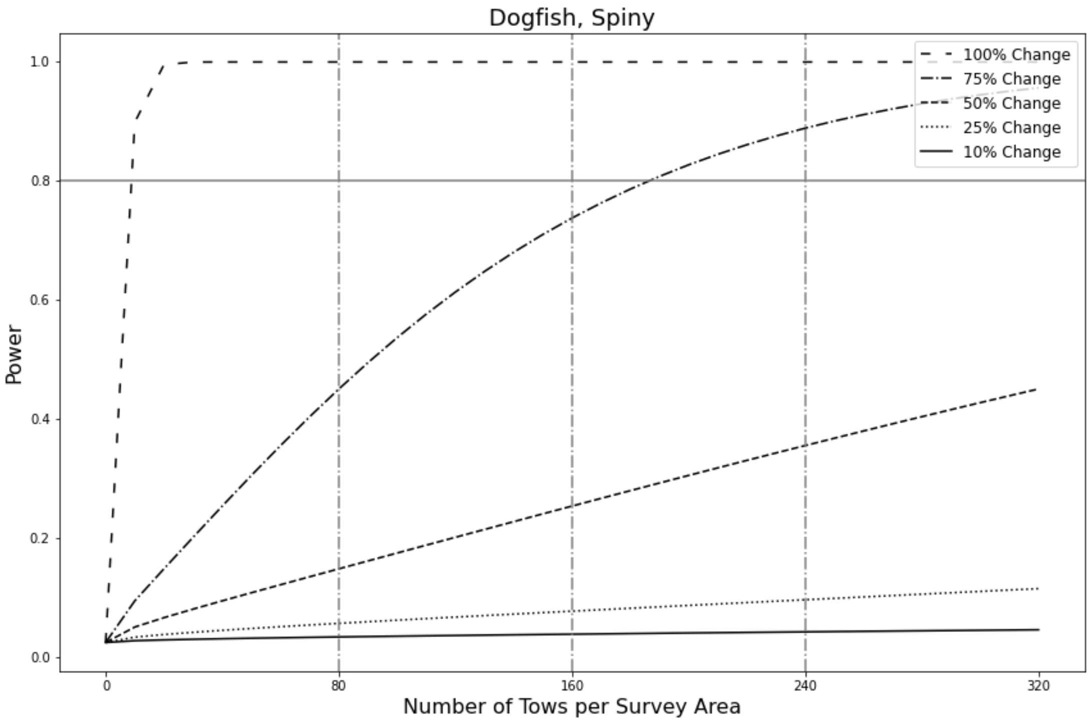


Figure 108: Power analysis relationship between statistical power and sample size in spiny dogfish. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

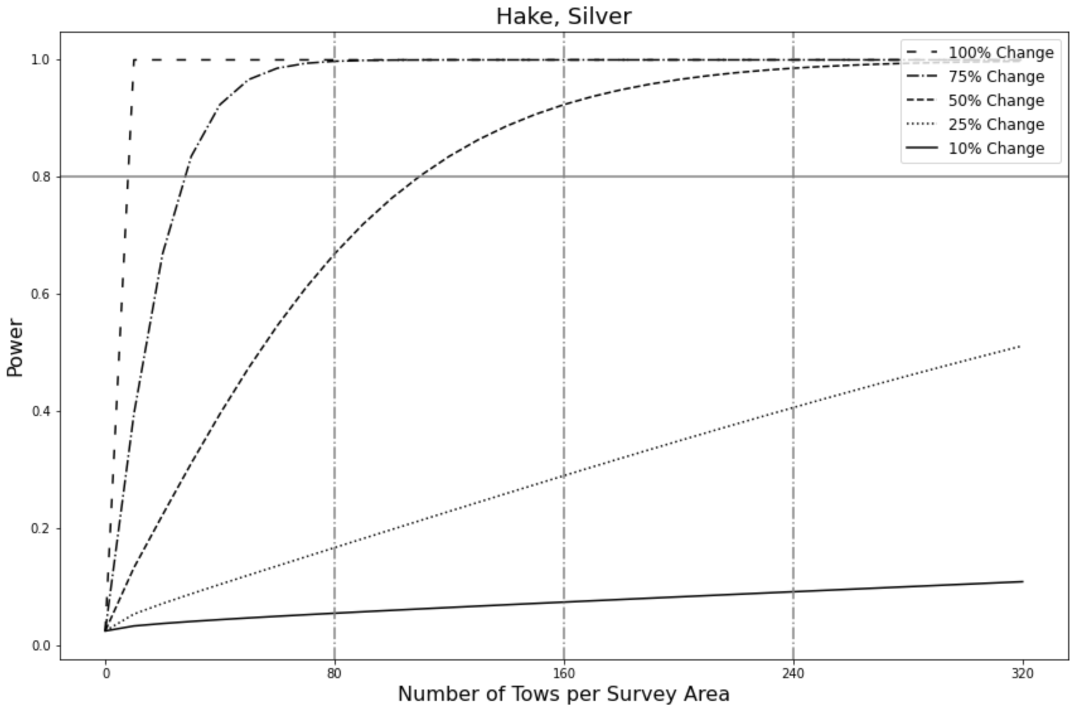


Figure 109: Power analysis relationship between statistical power and sample size in silver hake. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

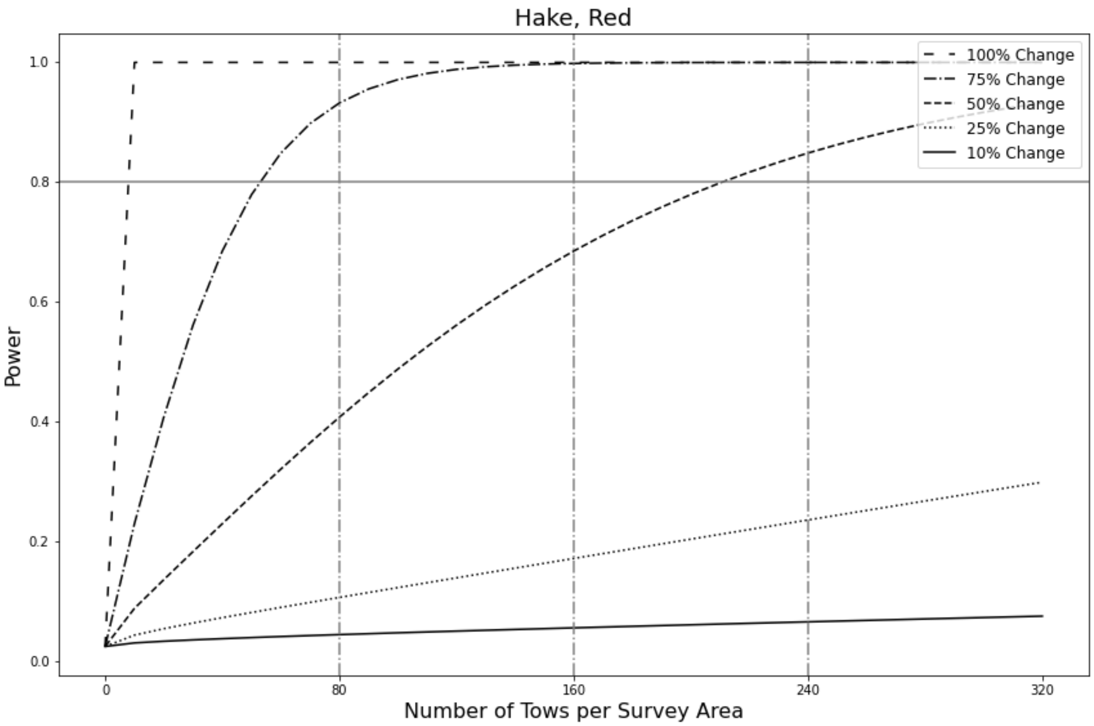


Figure 110: Power analysis relationship between statistical power and sample size in red hake. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

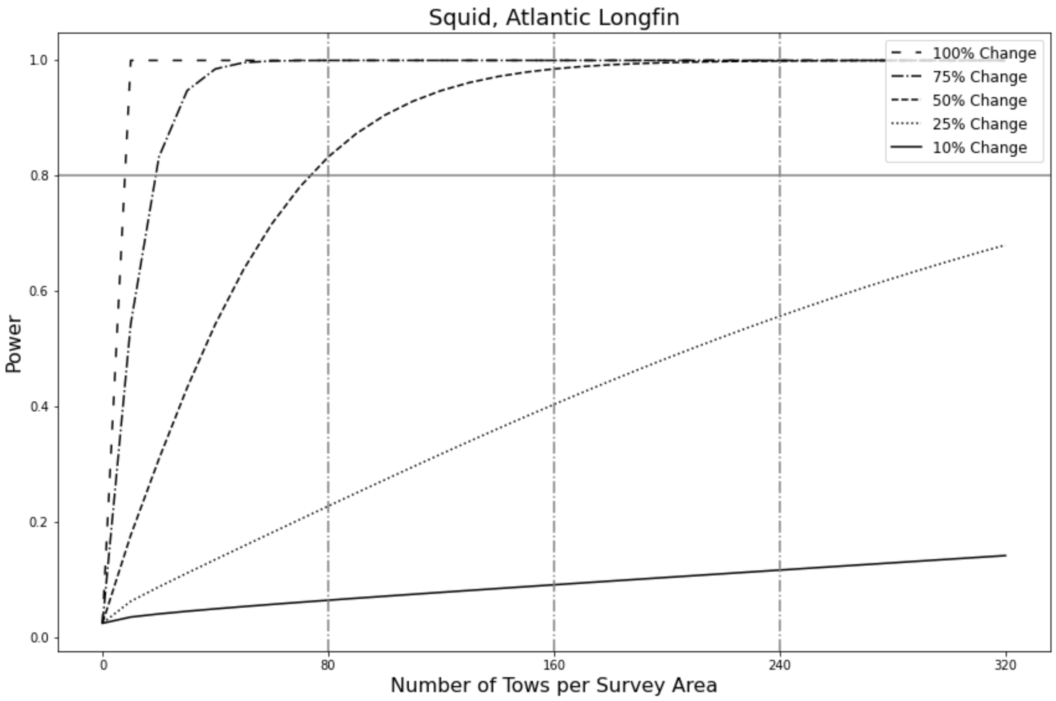


Figure 111: Power analysis relationship between statistical power and sample size in Atlantic longfin squid. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

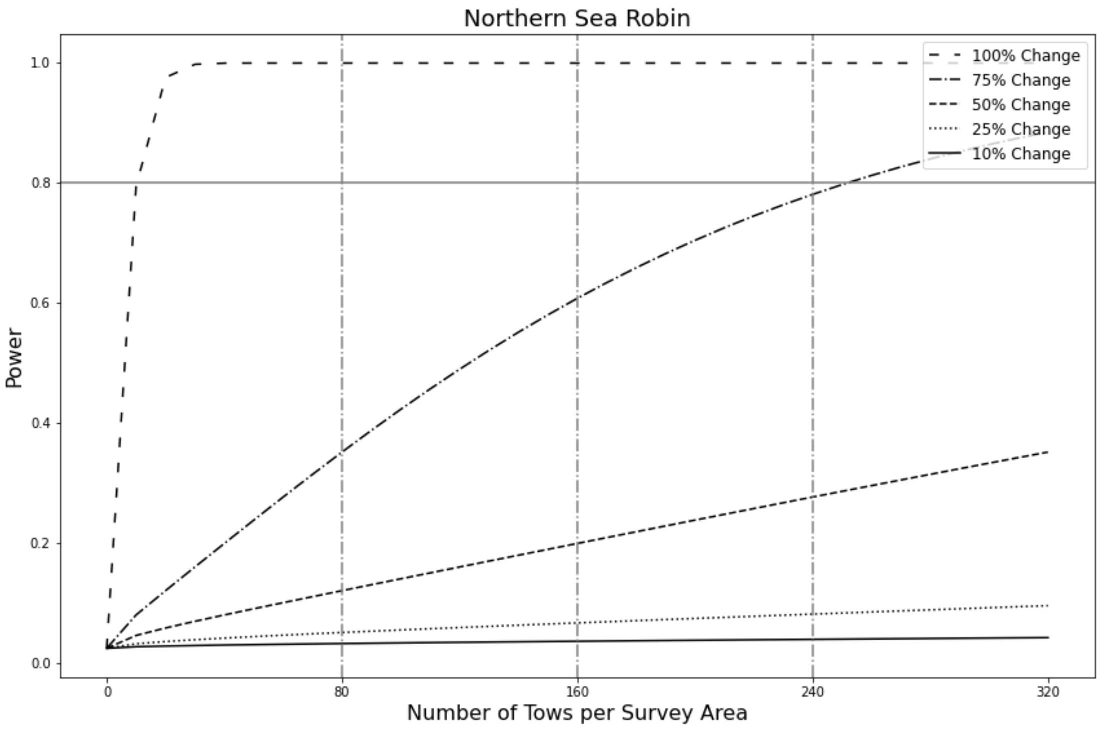


Figure 112: Power analysis relationship between statistical power and sample size in northern sea robin. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.

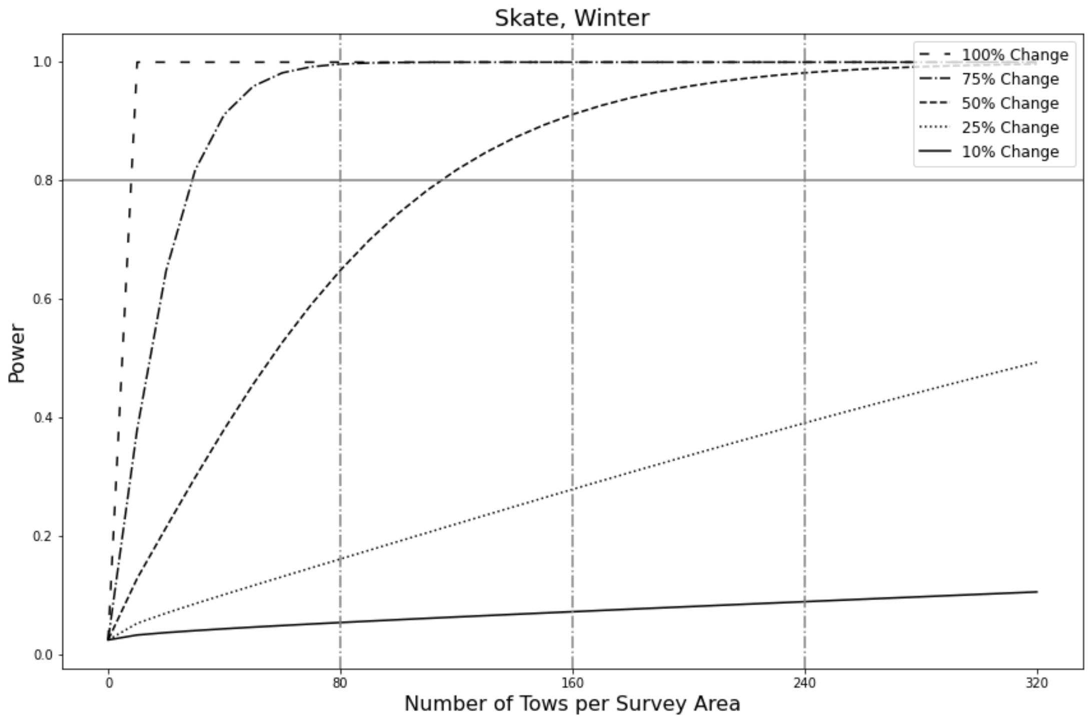


Figure 113: Power analysis relationship between statistical power and sample size in winter skate. Dashed vertical gray lines align with years of survey effort. Gray horizontal line highlights an 80% probability of positive detection.