



Fisheries and Oceans
Canada

Pêches et Océans
Canada

Ecosystems and
Oceans Science

Sciences des écosystèmes
et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2026/037

Quebec Region

Units 1 and 2 Redfish (*Sebastes mentella* and *Sebastes fasciatus*) Stock Status in 2024

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

[http://www.dfo-mpo.gc.ca/csas-sccs/
DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca/csas-sccs/DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca)



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ISSN 1919-5044

ISBN 978-0-660-99564-9 Cat. No. Fs70-5/2026-037E-PDF

Correct citation for this publication:

Senay, C. Poissant, D., Chavarria, C., Benoît, H.P., Bourdages, H., Blais, M., Bourret, A., and Parent, G.J. 2026. Units 1 and 2 Redfish (*Sebastes mentella* and *Sebastes fasciatus*) Stock Status in 2024. DFO Can. Sci. Advis. Sec. Res. Doc. 2026/037. xvii + 174 p.

Aussi disponible en français :

Senay, C. Poissant, D., Chavarria, C., Benoît, H.P., Bourdages, H., Blais, M., Bourret, A., et Parent, G.J. 2026. État des stocks des sébastes (Sebastes mentella et Sebastes fasciatus) de l'unité 1 et 2 en 2024. Secr. can. des avis sci. du MPO. Doc. de rech. 2026/037. xx + 187 p.

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ABSTRACT

Redfish (*Sebastes mentella* and *S. fasciatus*) biomass in Units 1 and 2 increased significantly in the past decade, supported by the strong cohorts of 2011-2013, mostly composed of *S. mentella*. Since then, no important recruitment has been observed. An update of fishery and survey data of *S. mentella* and *S. fasciatus* stocks from Units 1 and 2 are presented in this document.

In both Units, the total allowable catch (TAC) has not been fully harvested in the last decades. In 2024 (as of March 17th), Redfish landings corresponded to 2,964 tonnes (t) in Unit 1 for a TAC of 60,000 t with the opening of the commercial fishery, and 3,458 t in Unit 2 for a TAC of 8,500 t since 2006. From 2018 to 2024, total bycatch levels were estimated at 1.7% and 6.9% for Unit 1 and Unit 2, respectively. The most common bycatch species has been Atlantic Halibut (*Hippoglossus hippoglossus*) in both Units 1 and 2.

The results from the 2024 comparative survey between the industry vessel, the *Léry Charles*, carrying out the Unit 2 survey since 2020, and the CCGS *John Cabot* have shown important standardisation issues. Conversion factors could not be determined and therefore the 2020, 2022, and 2024 information collected on the *Léry Charles* cannot be used to assess *S. mentella* and *S. fasciatus* at this time. The information collected on the CCGS *John Cabot* in 2024 has been used to update trends in Unit 2.

In both Units, *S. mentella* was more abundant than *S. fasciatus* by a factor of approximately 10 in 2024. Redfish biomass in Unit 2 was about half of that of Unit 1 in 2024. No important recruitment and a reduction of growth has been observed in recent years. Even if the biomass of *S. mentella* has been significantly decreasing in Unit 1 since 2020, the estimates for that species in both Units are still among the highest of the time series. The situation is different for *S. fasciatus*, with a biomass that appears stable in the past three years and between 2018 and 2024 in Unit 1 and Unit 2, respectively.

The reference points of the Precautionary approach (PA) are based on the annual ecosystem bottom trawl survey of the Estuary and northern Gulf of St. Lawrence (nGSL) time series. In 2024, according to the adjusted Limit Reference Points (LRPs) and proposed Upper Stock References (USRs), the status of *S. mentella* stock in Units 1 and 2 was in the Healthy Zone. The estimate of *S. mentella* spawning stock biomass (SSB) decreased since 2020 and was estimated to 1,737 kilotonnes (kt) (1,386-2,089 kt, 95% confidence interval (CI)), which is still six times greater than the proposed USR. The estimated *S. fasciatus* SSB appeared stable since 2022 and slightly above the proposed USR, and was estimated to 190 kt (9-371 kt, 95% CI) in 2024. However, the status of the *S. fasciatus* stock relative to the PA is uncertain, owing to evidence suggesting it may currently be overestimated, but the magnitude of this overestimation is not quantified.

For *S. mentella*, the range of potential removals corresponded to 80 and 291 kt for Unit 1, and 36 and 131 kt for Unit 2. For *S. fasciatus*, given the uncertainty in biomass estimates and species identification, and the assumptions underlying the method used, it is not possible to provide a reliable range of potential removals. Directing fishing towards greater depths may reduce catches of *S. fasciatus* in all fishing areas except the Laurentian Fan, where this species is found at greater depths. Given the low levels of recruitment and growth observed in recent years, even in the absence of fishing, Redfish biomass is expected to decrease in upcoming years due to natural mortality.

In support of the Redfish stock assessments (*S. mentella* and *S. fasciatus*) of Units 1 and 2 in 2025, this document describes the data and methods used to characterize the fisheries,

analyses the status, and provides potential removals, which fall under the responsibility of the Science Branch of DFO Quebec Region.

1. INTRODUCTION

Three Redfish species are present in Units 1 and 2, the common Deepwater Redfish (*Sebastes mentella*) and Acadian Redfish (*Sebastes fasciatus*) and the Golden Redfish (*Sebastes norvegicus*) which are rare (Nozères et al. 2010) and hence are not discussed further in this document. The *S. mentella* and *S. fasciatus* are members of the Scorpenidae family, are difficult to differentiate morphologically, and are often referred to jointly as Redfish.

In the late 1950s, a fishery directed to Redfish was developed in the Gulf of St. Lawrence (GSL) and the Laurentian Channel outside the GSL (Cadigan et al. 2022). Prior to 1993, the Redfish fishery in the GSL and neighboring areas was managed as three management Units established by the Northwest Atlantic Fisheries Organization (NAFO): Divisions 4RST (GSL), Division 3P (southwest Newfoundland), and Divisions 4VWX (Scotian Shelf). In 1993, these management Units were redefined by taking various factors into account, including movement of Redfish from the GSL in summer to the Cabot Strait in winter (Kulka and Atkinson 2016), thus ensuring a stronger biological basis for management. The resulting management Units were defined as follows: Unit 1 included Divisions 4RST and, from January to May, Subdivisions 3Pn4Vn; Unit 2 included Subdivisions and Unit areas 3Ps4Vs4Wfgj, and from June to December, Subdivisions 3Pn4Vn; and Unit 3 included Unit areas 4WdehklX at any time of year (Figure 1).

In the 1990s, Redfish biomass decreased to particularly low levels and no important recruitment event contributed to replenishing the stocks in the years that followed. This resulted in a moratorium on Redfish-directed commercial fishing in Unit 1 from 1995 to 2024 and a decrease of the total allowable catch (TAC) for Unit 2 from 28,000 t in 1993 to 10,000 t in 1996. In 2010, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identified four Designable Units (DU) in the Atlantic Canadian waters for the two main *Sebastes* species, three of which are located in Unit 1 and Unit 2. The Deepwater Redfish of Gulf of St. Lawrence - Laurentian Channel Population (*S. mentella*), the Acadian Redfish Atlantic Population (*S. fasciatus*), and the Acadian Redfish Bonne Bay Population (*S. fasciatus*) were classified respectively as endangered, threatened, and of special concern (COSEWIC 2010, DFO 2011). The Bonne Bay population was considered of special concern because of its limited distribution and genetic particularities. Duplisea et al. (2012) established Limit Reference Points (LRPs) and Upper Stock references (USRs) and concluded that spawning stocks of *S. mentella* and *S. fasciatus* of Units 1 and 2 were in the Critical Zone of DFO's Precautionary Approach (PA) framework (DFO 2006), that is, under their respective LRPs.

Redfish recruitment success is highly variable and sporadic over time, with large year classes (cohorts) appearing at irregular intervals (Licandeo et al. 2020). For both species within Unit 1, the 1980 cohort was the last important cohort observed in Unit 1 prior to the arrival of the strong cohorts born in 2011, 2012, and 2013. These strong cohorts appeared dominated by *S. mentella* (Brassard et al. 2017). Subsequently, the biomass of these cohorts increased to unprecedented levels and has now reached the minimum regulatory size of 22 cm. Since 2020, Unit 1 Redfish growth has been negligible and recruitment low, resulting in a biomass decline, which is particularly apparent for *S. mentella* in Unit 1.

The main goals of the present document are to update Unit 1 and Unit 2 fishery and survey data, and stock status, and to propose a range of potential removals for the 2025-2026 fishing season in each Unit. The document also aims to provide most up to date information on the species composition of samples within the survey and fishery.

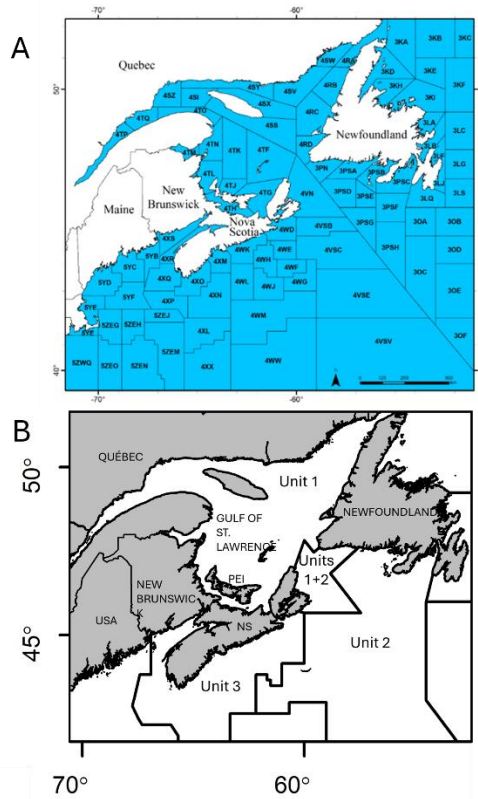


Figure 1. Northwest Atlantic Fishery Organization (NAFO) Divisions, Subdivisions, and Unit areas (A), and management Units 1, 2, and 3 (B). PEI = Prince Edward Island, NS = Nova Scotia, USA = United States of America.

2. BACKGROUND

2.1. STOCKS DEFINITION AND SPECIES IDENTIFICATION USING GENETICS AND GENOMICS

In the last two decades, analyses of population genetics highlighted reproductively isolated entities in both species of Redfish in Atlantic Canada. Genetic or genomic markers allowed for species identification at the individual level using either microsatellites or single-nucleotide polymorphisms (SNPs). A subset of 13 microsatellite markers suggested seven to eight different genetic groups or biological units along the Canadian coast, four of which were located in Unit 1 (Valentin et al. 2014). A single genetic group of *S. mentella*, characterized by introgression from *S. fasciatus*, was identified in both Units 1 and 2. For *S. fasciatus*, the results suggested the presence of three genetic groups in Unit 1. A first group was detected in both Units 1 and 2, and was characterized by introgression from *S. mentella*. A second genetic group was identified in both Units 1 and 2, and on the Scotian Shelf. A third genetic group was identified in the eastern inlet of the Bonne Bay fjord, on the west coast of Newfoundland (Division 4R in Unit 1).

Recently, a study based on thousands of genomic markers confirmed some genetic groups which previously had been identified with microsatellites and described new ones (Benestan et al. 2021). New SNPs confirmed the pronounced genetic distinction between *S. mentella* and *S. fasciatus*. This new method also identified high genetic differentiation between three genetic groups of *S. mentella*. The term ecotype was used to describe these genetically well-

differentiated groups due to their habitat specificity, as opposed to populations that are less differentiated. Two of these ecotypes are *S. mentella* shallow (light blue dots in Figure 2) and *S. mentella* deep (dark blue dots), which originated from specific depths along the continental slope in Eastern Canada between 300 m and 500 m and greater than 500 m, respectively (Figure 2). The *S. mentella* GSL (cyan dots) ecotype was the only one present in both Units 1 and 2. Five populations, which are less different of *S. fasciatus* were also identified, and three of these were located in Unit 1 (Figure 2). Sample sizes in the Laurentian Fan were deemed insufficient to confirm or refute previous hypotheses about a distinct population of *S. fasciatus* in that area. In summary, the Benestan et al. (2021) study highlighted that locations of specific ecotypes and populations do not generally correspond to fishery management units in Redfish.

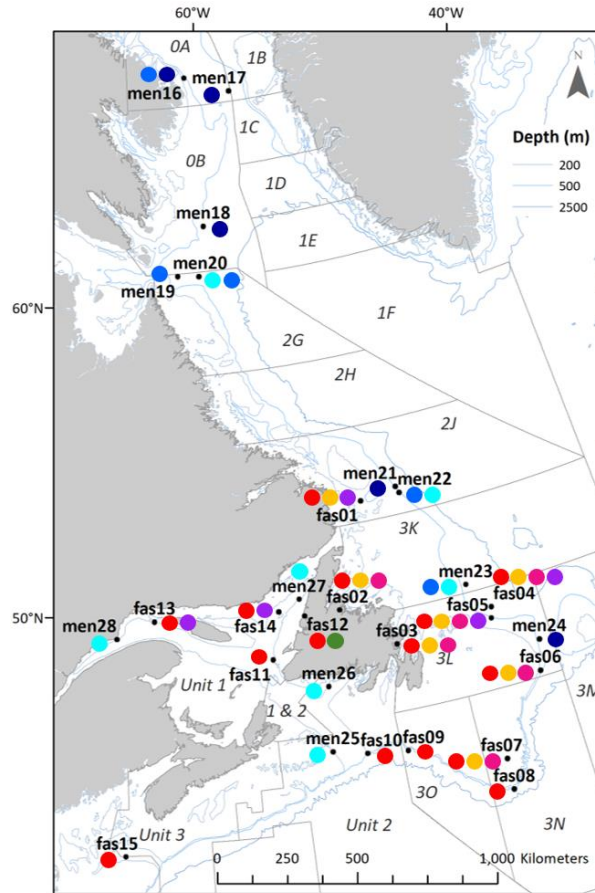


Figure 2. Map of the 28 sampling locations (black points) from 2001 to 2015 in the Northwest Atlantic (Benestan et al. 2021). The colored points next to each sampling point indicate the genetic clusters. A genetic cluster was indicated as present if one individual showed at least 50% associated ancestry in the sampling area. Three ecotypes were described for *S. mentella*: GSL (cyan), shallow (light blue), and deep (dark blue). Five populations were described for *S. fasciatus* and are indicated by color: red, yellow, green, pink, and purple.

2.2. SPECIES IDENTIFICATION IN RESEARCH SURVEYS AND THE COMMERCIAL FISHERY

The Redfish species considered in this assessment, *S. mentella* and *S. fasciatus*, are morphologically very similar and, therefore, often not distinguished in scientific surveys and fisheries catches.

2.2.1. Background

There are presently two approaches that can be implemented to estimate the species composition of Redfish catches in scientific surveys and fisheries. The first approach, which has yet to be implemented broadly, infers species composition directly from genetic analysis of a small number of individuals in a catch. Important reductions in the cost per sample now make a broader application of this approach feasible. The second and current approach uses the frequency distribution of anal fin ray (AFR) counts obtained from catch sampling to infer species composition indirectly from species and unit-specific count distributions across five possible AFR states: 6, 7, 8, 9, and 10. The assumed count distributions were those derived empirically from samples obtained between 1994 and 2001, based on the genetic methods available at the time and an undefined overall sampling scheme. Details of the analyses presented in Senay et al. (2022) assumed counts are treated as being known without error. Species composition in individual catches is inferred using a multinomial-mixture modelling approach. In its current implementation (current assumed AFR distributions and sample sizes of 30 individuals per tow and size category in scientific survey), the method was shown in simulations to have poor statistical properties, notably biases that increase as the proportion of one species tends to zero and large confidence intervals (Senay et al. 2022). Furthermore, the genetic approaches used to classify individuals by species for the original analyses (malate dehydrogenase locus) are less accurate than current methods (SNPs). All of these factors affect the reliability of the method for estimating Redfish species composition in catches.

The recent collection of data on the species identification and AFR count provides an opportunity to re-evaluate the species and unit-specific AFR count distributions and to estimate them probabilistically, such that associated uncertainty can be propagated to estimated catch proportions. Furthermore, these samples provide the opportunity to evaluate whether species composition could be estimated directly using covariates, for example, the water depth.

2.2.2. Methods

2.2.2.1. Sampling and genetic assignments

Redfish samples were collected from different sources. Samples for NAFO Divisions 4RST, which correspond to Unit 1, were obtained during the DFO annual ecosystem bottom trawl research survey in the Estuary and Northern Gulf of St. Lawrence (nGSL) in August 2018. From that survey, three to 50 individuals were randomly selected across 24 stations for a total of 906 individuals. Their fork length varied from 124 to 468 mm (mean \pm standard deviation, 269.2 \pm 58.4 mm). In 2020, NAFO Subdivisions 3Pn, 3Ps, 4Vn, and 4Vs were surveyed by the Atlantic Groundfish Council (AGC, formerly known as Groundfish Enterprise Allocation Council). Between one and 39 individuals were randomly selected within 39 stations, for a total of 694 specimens that ranged from 102 to 425 mm (250.3 \pm 37.0 mm). In 2021, to improve the spatial coverage of sampling in NAFO Subdivisions 3Ps and 4Vn, with the collaboration of AGC, between 50 and 52 individuals were randomly selected within five commercial fishing events for a total of 253 specimens, ranging in size from 174 to 395 mm (266.0 \pm 26.7 mm). In 2022, the Fédération régionale acadienne des pêcheurs professionnels (FRAPP), in collaboration with the Valores research institute, conducted some experiments in NAFO Divisions 4RST. Ten Redfish

were randomly collected in 44 locations and 30 in one location for a total of 470 specimens, ranging from 185 to 365 mm (244.5 ± 27.0 mm). Tissues (fin or muscle) from each specimen were sampled and preserved in 95% ethanol until genetic analysis. Fork length and AFR were recorded for all individuals.

We performed genetic assignments of all samples, except those collected by the FRAPP. To this end, we first generated a genetic dataset comprising 18,781 SNPs from double digest restriction-site-associated DNA (ddRAD) sequencing. Briefly, DNA was extracted with DNeasy Blood and Tissues or DNeasy 96 (Qiagen) and ddRAD libraries were prepared by the Plateforme d'Analyse Génomique (IBIS, Université Laval using *PstI* and *MspI* enzymes). Libraries also included reference samples from a previous genomic study (Benestan et al. 2021) with known identification (*S. mentella*, *S. fasciatus*, and *S. norvegicus*), and were sequenced on two lanes of NovaSeq 6000 S4 150 PE at Genome Quebec. Genotyping was performed using STACKS modules (v.2.55, Catchen et al. 2013; Rochette et al. 2019) and trimmed reads aligned on a *S. fasciatus* genome assembly (GeneBank accession: JBJQUQ000000000). SNPs panel was first determined using only high quality samples (minor allele frequency (MAF) > 0.05, missingness < 10% within the reference samples, N = 92), then all samples were genotyped using that panel.

Genetic assignments were performed using assignPOP (Chen et al. 2018). Three reference groups were used, *S. fasciatus* (N = 38), *S. mentella* (N = 43), and *S. norvegicus* (N = 11). Based on Markov chain Monte Carlo (MCMC) cross-validations results, we selected the support vector machine (SVM) model which had shown 100% assignment accuracy to reference groups using as few as 10% of SNPs. All samples were assigned to these reference groups. A few individuals with a missingness score deemed too high (> 90%, N = 14) or suspected being first or second generation hybrids were removed from the final dataset (N = 29). Another approach was used to identify the samples collected by the FRAPP. Species identification was performed using qPCR assays described in Brûlé et al. (2024).

2.2.2.2. Analyses

Each individual's AFR count was treated as a nominal response variable. Across the five possible AFR states, the AFR count constituted an unordered multinomial response. The baseline-category logits model is appropriate for modelling this type of data (Agresti 2002) and was therefore employed here. The probability of an outcome j (specific AFR count), is modelled with respect to a reference category, the choice of which does not affect model inferences. A mixed-effects baseline category logits model (bclm) for AFR counts, including both a fixed effect of intercepts and covariates and random effects, can be defined as follows:

$$y_i \in \{1, 2 \dots, J = 5\}$$

$$P(y_i = j | X_i, Z_i) = \frac{\exp(X_i \beta_j + Z_i \gamma_j)}{1 + \sum_{k=1}^{J-1} \exp(X_i \beta_k + Z_i \gamma_k)}$$

$$\sum_{j=1}^J P(y_i = j | X_i, Z_i) = 1$$

Where:

y_i is the AFR count for individual i ;

X_i is a vector of fixed explanatory variables for individual i ;

β_j is a vector of fixed-effect parameters for AFR count category j , where $\beta_j = 0$;

Z_i is a vector of random effects for individual i ; and,

γ_j is a vector of parameters for the random effects for count category j , which could vary across alternatives, and where $\gamma_j = 0$.

In the present application, we considered a single fixed-effect covariate, depth, which is known to relate to meristic characteristics (e.g. vertebral number, Swain and Frank 2000). Furthermore, we treated the NAFO unit area of origin as a random effect to account for spatial variability. Analyses were undertaken separately for Units 1 and 2 given that previous empirical estimates and preliminary analyses of the current data both indicated different species-specific count distributions between these units areas. The model was implemented using the R package `mclgit` (v. 0.9.6) with the option `catCov = "free"`, which excludes any restrictions on the covariance structure of random effects between logit equations for different values of j . In analyses for *S. fasciatus* in Unit 1, the `bclm` was fit only to data collected at depths ≤ 350 m (see below for explanation). Model predictions for subsequent analyses were also limited to depths ≤ 350 m, and the values at 350 m were assumed for depths greater than this.

Baseline category logits models are in effect a multinomial extension of the common binomial logit model (Agresti 2002). Assessing model fit using standard residuals is often difficult for both types of models. This problem is largely resolved for the binomial model when using quantile residuals, which are considerably more easily interpreted in the context of model validation (Dunn and Smyth 1996). However, we are not aware of any extension of quantile residuals to multinomial models and, therefore, had to rely on an examination of standard residuals.

The estimated parameter vector and covariance matrix from the model fitting were then (i) used in some limited simulation testing and (ii) applied to estimating the average proportion of *S. fasciatus* in the 2024 DFO nGSL bottom trawl survey for catches in Unit 1. In both cases, the proportion of *S. fasciatus* in a given simulated or observed (survey) sample was estimated using the multinomial mixture-distribution model described in Senay et al. (2022), based on the estimated multinomial probabilities from the `bclm` for Unit 1.

The simulation tests were limited to quantifying bias in the estimated proportion of *S. fasciatus* and, conversely, *S. mentella*. Given an estimated effect of depth on the multinomial probabilities for both species in Unit 1, we simulated 5,000 replicates for each combination of five possible depth categories (150, 250, 350, 450, and 550 m) and nine possible *S. fasciatus* fixed catch probabilities (0, 0.01, 0.1, 0.25, 0.5, 0.75, 0.9, 0.99, and 1), assuming a sample size of 30 fish, which is the target sample size for AFR counts in the survey. Other details of the simulations are as described in Senay et al. (2022). Here a larger dataset is being used.

The average proportion of *S. fasciatus* in the 2024 survey in Unit 1 was estimated according to two model variants. The first accounted only for variability in the estimated multinomial probabilities for each species from the `bclm`. This was achieved by drawing `bclm` parameters from species-specific multivariate normal distributions parameterized with the fixed effect parameter vectors and covariance matrices. The second variant additionally accounted for the uncertainty in the predicted probability of *S. fasciatus* for a given sample. This was achieved by first fitting the multinomial mixture-distribution model to the AFR counts in the sample, and then drawing a value of the logit probability from a normal distribution with a mean equal to the parameter estimate and a standard deviation equal to the parameter standard error. For both variants, the overall 2024 survey-level proportion of *S. fasciatus* was then estimated from the station-specific estimated values, weighted by station-specific Redfish catch numbers and the sampling weight for the station resulting from the stratified random survey design, accounting for size-fractionated subsampling (size categories) in stations where this was necessary.

Using the species identifications from genetics, we also evaluated whether the probability of capturing *S. fasciatus* in Redfish catches comprising both species could be predicted directly from fishing depth. We modelled the sample-specific number of *S. fasciatus*, conditional on the

total number of Redfish using mixed effects logistic regression. We tested both binomial and beta-binomial models, finding overwhelming evidence for the latter based on Akaike's Information Criteria (AIC). As for the bclm, we included depth as a fixed effect and NAFO unit area as a random effect. Models were implemented using the glmmTMB package (v 1.1.9). Model validation involved checking quantile residuals using the functionalities of the DHARMA package (v. 0.4.6). Exploratory analyses were undertaken using a polynomial function of depth as a fixed-effect predictor, as were generalized additive mixed effects models with a smoothed effect of depth. Neither produced substantial improvements in the explanatory power of depth, and they were therefore not pursued.

2.2.3. Results

The sampling locations for the data used for both the bclm and beta-binomial analyses are shown in Figure 3. Samples collected were widely spread across Units 1 and 2, although there was a cluster of samples in the eastern-most portion of the sampling area, which was in and around the Laurentian Fan. In contrast, the samples from Valores had been mainly obtained from the central portion of the GSL (Unit 1), with none from either the Estuary or Unit 2.

In Unit 1, the number of individuals sampled for AFR counts and later identified as *S. mentella* was roughly uniform across depths from about 150 to 475 m, although most samples originated from depths between 180 and 300 m (Figure 4). In contrast, almost all individuals identified as *S. fasciatus* originated from depths < 325 m. A relatively large sample of *S. fasciatus* ($n=23$; set # 83) collected at 365 m comprised individuals with AFR counts distribution that was fairly different from other samples and which had considerable leverage on the depth effect estimated in preliminary bclm analyses (results not shown). Furthermore, this sample was identified as an outlier in the beta-binomial modelling (see below). Given these findings, as well as the sparseness of samples at depths > 350 m and the observation that nearly all *S. fasciatus* were captured at shallower depths (Figure 4), we excluded samples collected at depths greater than 350 m from the bclm analyses for this species.

For the data from Unit 1, AIC values indicated more support, for both species, for models that included an effect of depth in addition to AFR-specific intercepts, with delta-AIC values of 29.1 and 41.2 for *S. fasciatus* and *S. mentella*, respectively. For *S. fasciatus*, AFR counts of 7 and 8 were most prevalent overall (Figure 5). At 150 m, a count of 7 was estimated to occur in about 77% of individuals, and a count of 8 in about 19%. At 350 m, the proportions of fish with 7 and 8 AFRs were respectively about 8 and 55%. The estimated proportion of individuals with 9 AFRs was essentially nil at shallower depths, and about 0.38% at 350 m, while individuals with 6 AFRs were relatively uncommon. No individual was observed with 10 AFRs. The estimated AFR count proportions generally corresponded with the currently assumed proportions, although the new analyses clearly indicated a need to account for depth. There was no evidence of significant issues with the fit of the model, including no notable difference in model residuals as a function of the data source, DFO or Valores (Figure 6). Parameter estimates for this and the other bclm analyses are presented in Table 1.

For *S. mentella* in Unit 1, an AFR count of 8 was most prevalent at all but the shallower depths, with other values largely dominated by counts of 7 and 9 (Figure 7). As observed for *S. fasciatus*, the prevalence of individuals with 8 AFRs increased with depth, while that of fish with 7 AFRs decreased. The prevalence of other AFR counts was less variable with depth. The estimated AFR count proportions generally corresponded with the currently assumed proportions. There was no evidence of significant issues with the fit of the model, such as differences in model residuals as a function of the data source and depth (Figure 8).

For the data from Unit 2, AIC values indicated for both species somewhat more support for intercept-only models compared to those with an additional effect of depth, with delta-AIC values of 4.1 and 3.4 for *S. fasciatus* and *S. mentella*, respectively. For *S. fasciatus*, AFR counts of 7 and 8 were most prevalent, with estimated relative proportions of 0.54 and 0.42, respectively (Figure 9). The estimated AFR count proportions are somewhat different from the currently assumed values, for which a count of 7 is about four times as prevalent as a count of 8. Overall, the model fit seemed adequate and no particular residual pattern was observed for samples collected in the Laurentian Fan area (deeper waters of NAFO unit areas 4Vsc and 3Psh) where *S. fasciatus* occur deeper than they do elsewhere in Units 1 and 2, and where a difference in AFR count might have been expected (Figure 10). For *S. mentella* in Unit 2, an AFR count of 8 was most prevalent, with an estimated proportion of 0.73, followed by AFR counts of 9 (estimated proportion 0.15) and 7 (estimated proportion 0.12) (Figure 11). Model fit also appeared to be adequate based on the examination of model residuals (Figure 12).

Biases for the multinomial mixture-distribution model estimated by the simulations varied as a function of depth and the simulated probability of *S. fasciatus* in the catch (Figure 13). The absolute magnitude of bias increased as the probability of *S. fasciatus* in the catch tended from 0.5 to either 0 or 1, and was greatest for a depth of 350 m. Senay et al. (2022) demonstrated that the absolute magnitude of bias for this model was positively related to the similarity in assumed or estimated AFR count distributions for the two species. A comparison of Figure 5 and Figure 7 showed that the estimated distributions are most similar around 350 m.

The maximum likelihood estimate (MLE) of the proportion of *S. fasciatus* in the 2024 nGSL survey in Unit 1 from the multinomial mixture-distribution model was 0.190. The 95% confidence interval for this value based on simulating only the variability from the bclms was 0.162 to 0.225. This variability is visualized in Figure 14, which shows predictions from the fitted bclms in individual simulation threads. Generally speaking, predictions were somewhat more variable for *S. fasciatus* compared to *S. mentella* at nearly all depths. The 95% confidence interval accounting for both this variability and the uncertainty of the multinomial mixture proportion estimates was 0.160 to 0.276. The asymmetry in the interval relative to the MLE value results from the logit transformation involved in estimating the mixture proportion.

Modelling the probability of catching *S. fasciatus* (as opposed to *S. mentella*) as a function of depth using the beta-binomial mixed-effects model and the data for the genetic identifications was particularly challenging. This is in large part because empirical proportions varied throughout the interval [0, 1] for samples collected at depths between about 180 and 250 m, and throughout the interval [0, 0.5] for depths between about 250 and 320 m (Figure 15). In other words, there is little to no depth-specificity to the proportion of *S. fasciatus* in catches made at these depths, which also happen to be the depth at which a large proportion of Redfish catches are made in the survey (Figure 16). The model fitted to all data except for catches in the Laurentian Fan produced significant patterns in quantile residuals (Figure 17). Excluding the data from Valores produced a significant change in model prediction (Figure 15) and only a modest improvement in residuals (Figure 18). Further excluding the data from set #81 which was also found to be an outlier in the bclm analyses, had a modest effect on model fit (Figure 15), yet further improved patterns in residuals, rendering them technically not statistically significant (Figure 19). Nonetheless, observed quantiles for the quantile residuals only partly matched expected quantiles, indicating a less than ideal model fit.

2.2.4. Discussion

Species identification based on AFR counts for Unit 1 is biased. While it was not explicitly evaluated, this is likely also the case for Unit 2. The bias results from the overlap in AFR counts distributions between the two species, and the magnitude of the bias in practice depends on the

relative true abundance of the two species, which is not known (Senay et al. 2022). There is a risk of overestimating the less abundant species and underestimating the more abundant one. In the present context, in which *S. fasciatus* is almost certainly less, potentially much less abundant, the risks are asymmetrical. Overestimating the abundance of *S. fasciatus* risks overstating its status and tolerance to different levels of fishing, while underestimating *S. mentella* is unlikely to result in foregone yield given the high level of biomass compared to *S. fasciatus*. Nonetheless, in the absence of other means to attribute survey and fishery catches to species, using the AFR-based method is probably better than disregarding species identification altogether. This is because current results clearly indicate that *S. fasciatus* is likely less abundant, and that information can be used in risk-based management.

The biases associated with AFR-based identification are relevant not only for estimating population scale measures such as mean survey abundance or total fishery catch, but they apply also to finer scale analyses, such as habitat associations and location specific predictions, which in turn, are used to describe spatial distribution. Our current understanding of these aspects of species-specific ecology in Units 1 and 2 needs to be viewed with some caution in light of the potential for bias.

The probability of catching *S. fasciatus* in Redfish catches in Units 1 and 2 cannot be reliably predicted from the depth of capture across most depths where Redfish occur. Although *S. fasciatus* tend to be less prevalent in waters deeper than 300 m, at least in the summer, sampling at one station (set #81) showed that catches comprising principally *S. fasciatus* at deeper depths may not be unusual.

Overall the results presented in this section indicate that a different, more direct means of estimating species composition should be considered for the assessment and management of Units 1 and 2 Redfish. Genetic sampling, for which the per individual costs have substantially been reduced, is almost certainly the most reliable (least biased, most precise) means of inferring the species composition of catches. Furthermore, additional sampling of both genetics and AFR counts will allow to improve the precision of AFR-based estimation, not necessarily for contemporary application, but importantly for application to survey and fishery data from the past when only AFR counts data are available for species identification.

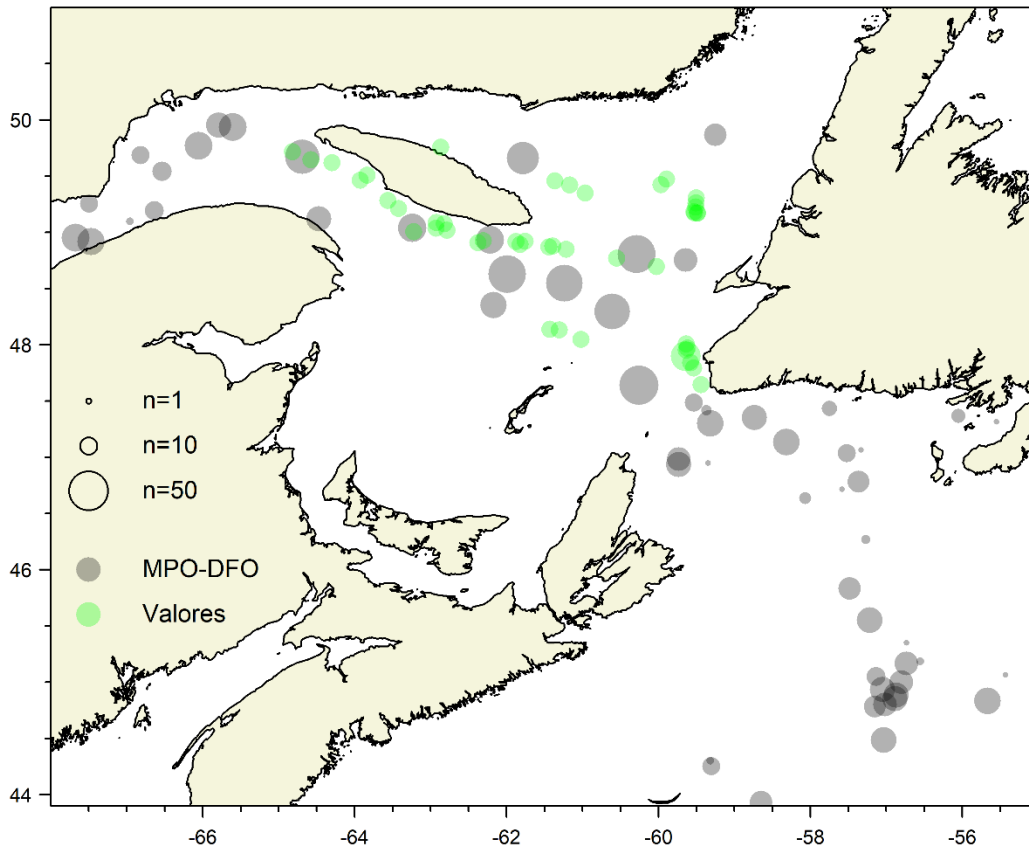


Figure 3. Spatial distribution of sampling locations for the data used for both the baseline-category logits modelling and beta-binomial analyses.

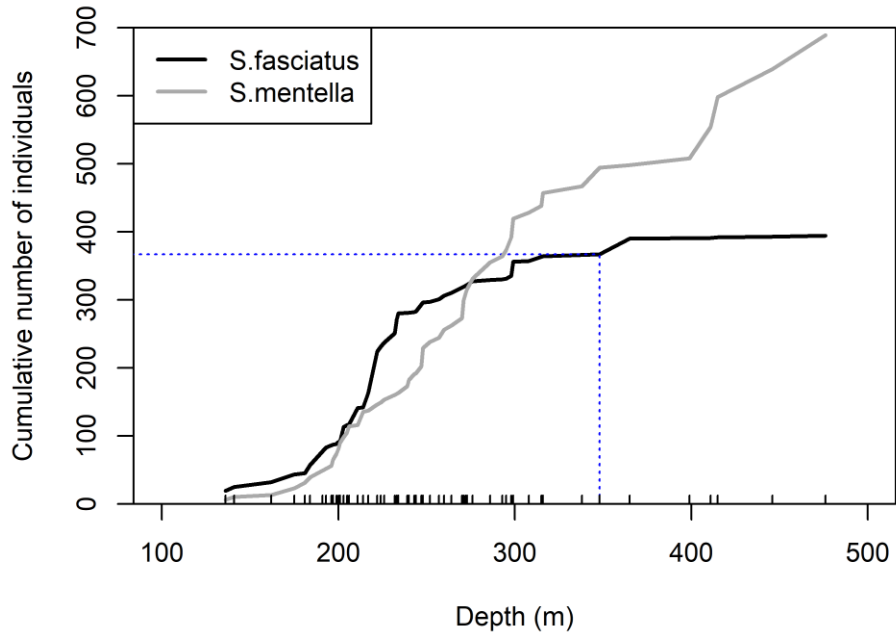


Figure 4. Cumulative number of individuals sampled for genetics and AFR count in Unit 1 as a function of depth, by Redfish species. Short bars along the x-axis indicate the depths for individual samples. The dotted blue line indicates the maximum depth of samples included in the baseline-category logits modelling for *S. fasciatus* in Unit 1.

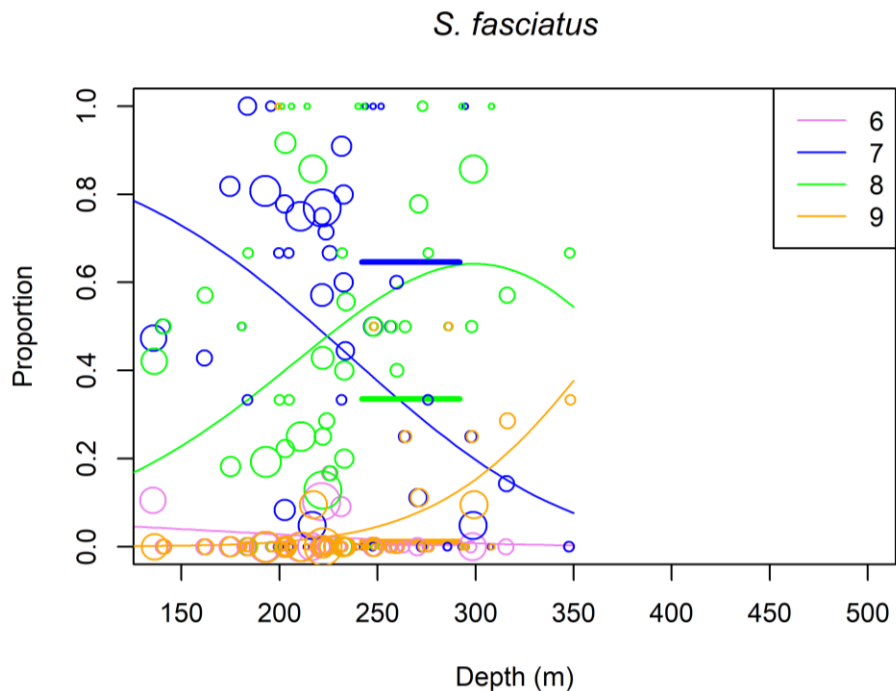


Figure 5. Observed (circles) and estimated (curved lines) proportions of different AFR counts for *S. fasciatus* from individual samples, as a function of depth in Unit 1. Colors distinguish AFR count categories, while circle size is proportional to the overall sample size from the individual samples. The thick horizontal bars near the center of the plot indicate the current assumed AFR count proportions, and are centered on the mean depth of capture for *S. fasciatus* across the samples used in this study.

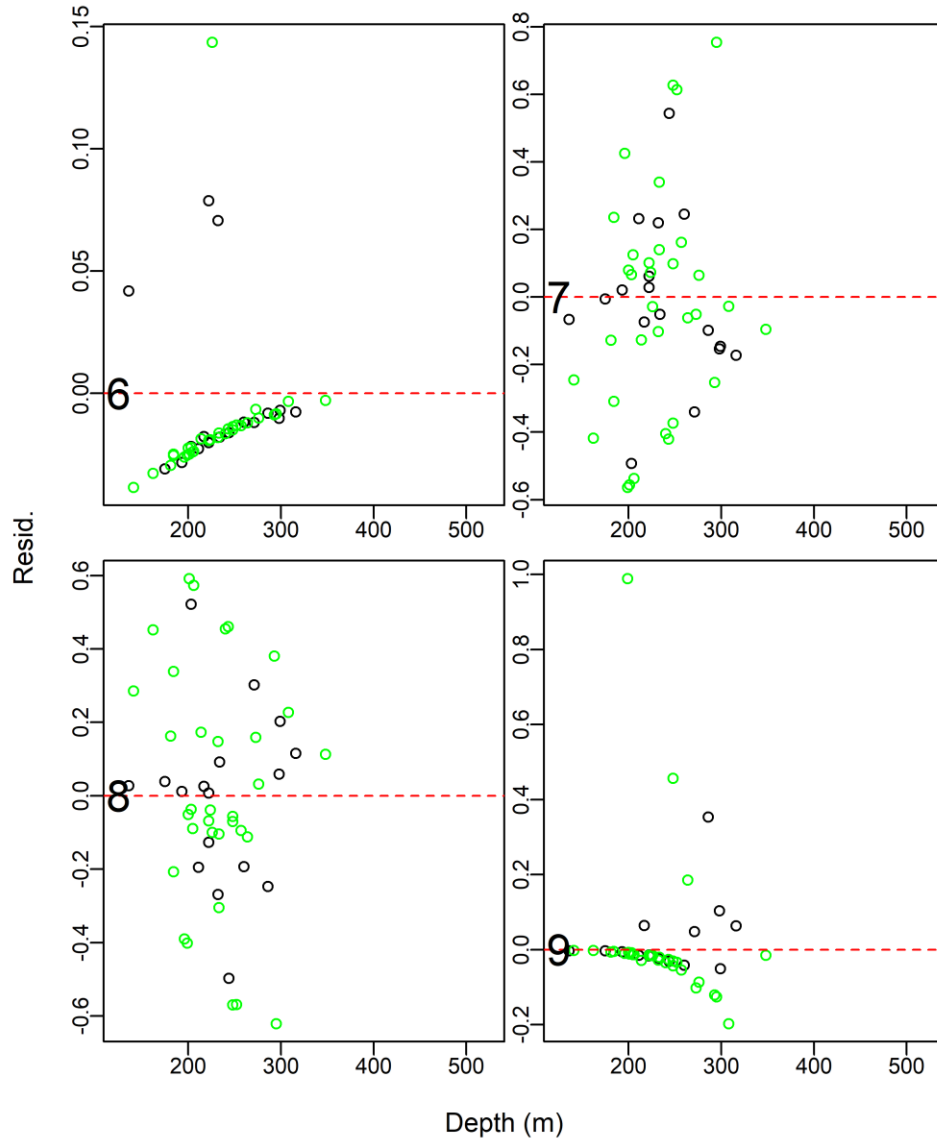


Figure 6. Residuals for the *bclm* for *S. fasciatus* in Unit 1, by AFR count (panels). Black circles indicate data collected by or for DFO, while green circles indicate data collected by Valores.

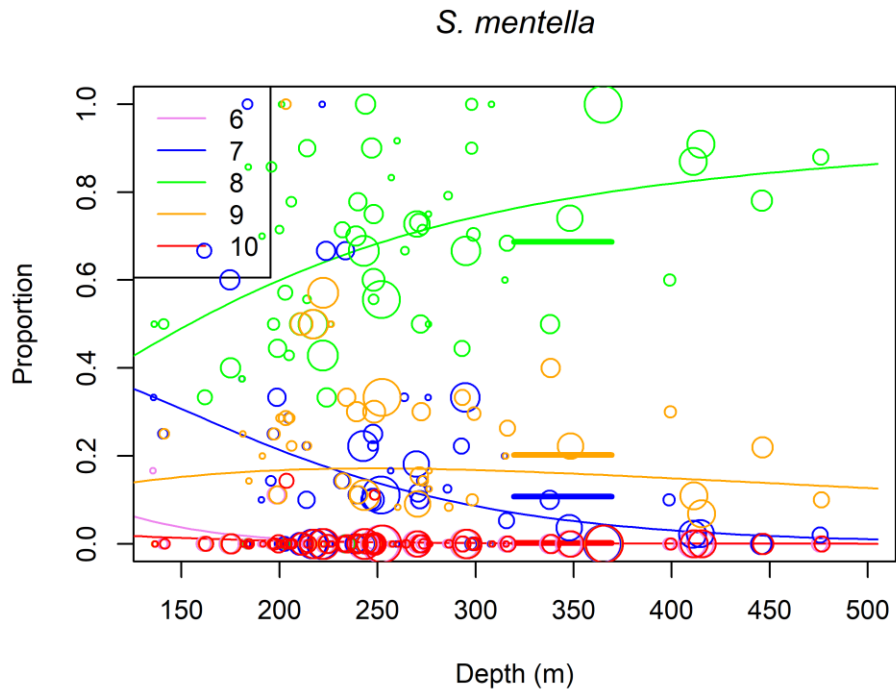


Figure 7. Observed (circles) and estimated (curved lines) proportions of different AFR counts for *S. mentella* from individual samples, as a function of depth in Unit 1. Colors distinguish AFR count categories, while circle size is proportional to the overall sample size from the individual samples. The thick horizontal bars near the center of the plot indicate the current assumed AFR count proportions, and are centered on the mean depth of capture for *S. mentella* across the samples used in this study.

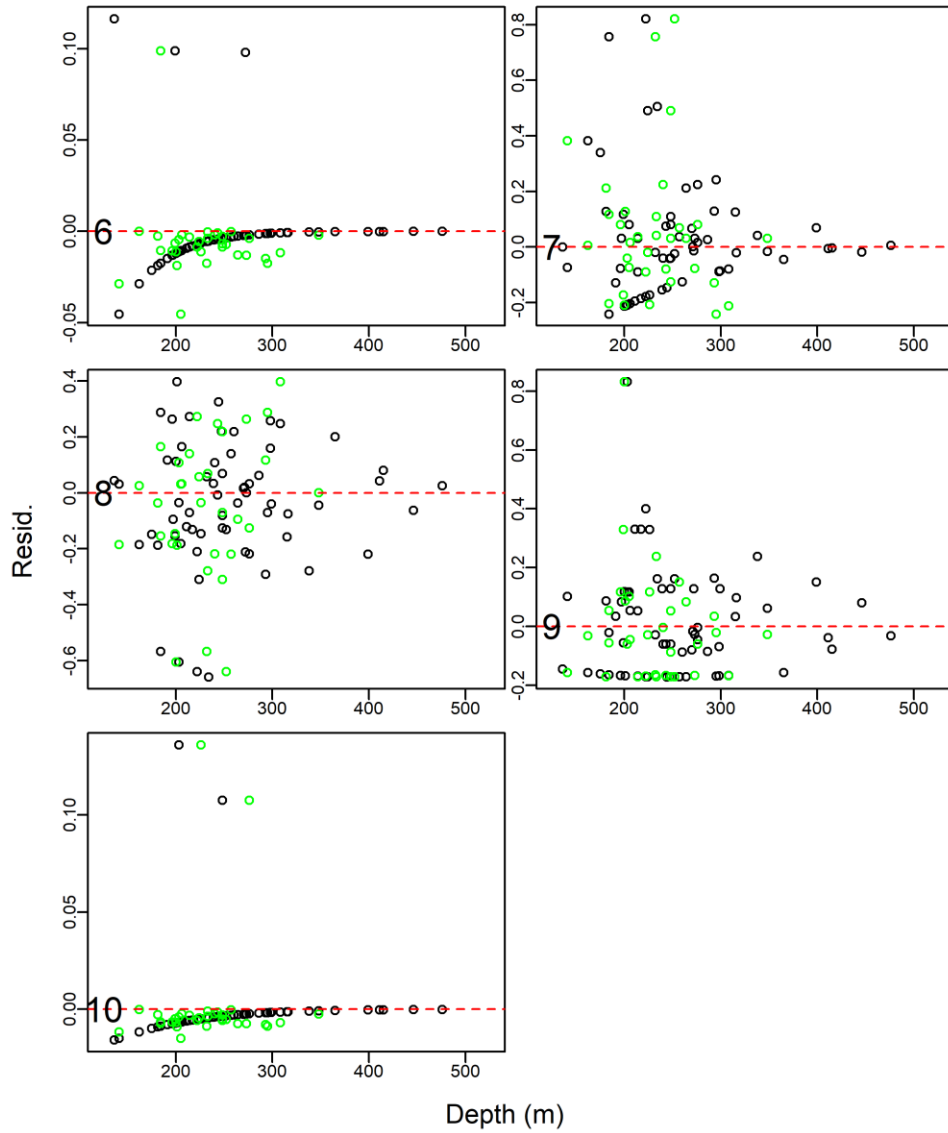


Figure 8. Residuals for the bclm for *S. mentella* in Unit 1, by AFR count (panels). Black circles indicate data collected by or for DFO, while green circles indicate data collected by Valores.

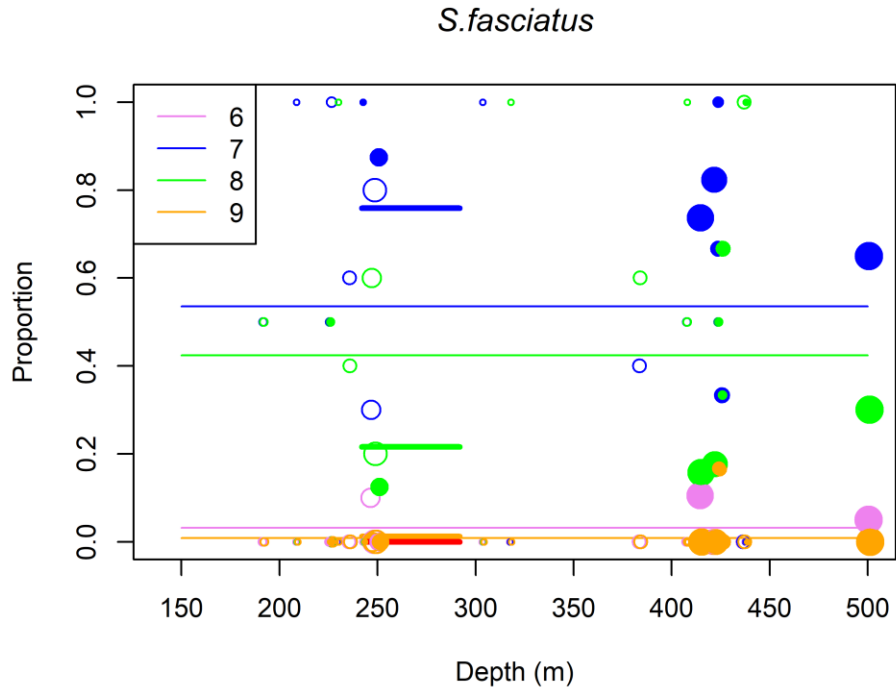


Figure 9. Observed (circles) and estimated (lines) proportions of different AFR counts for *S. fasciatus* from individual samples, as a function of depth in Unit 2. Colors distinguish AFR count categories, while circle size is proportional to the overall sample size from the individual samples. Filled circles indicate samples collected in NAFO unit areas 4Vsc and 3Psh, which include the Laurentian Fan area. The thick horizontal bars near the center of the plot indicate the current assumed AFR count proportions, and are centered on the mean depth of capture for *S. fasciatus* across the samples used in this study.

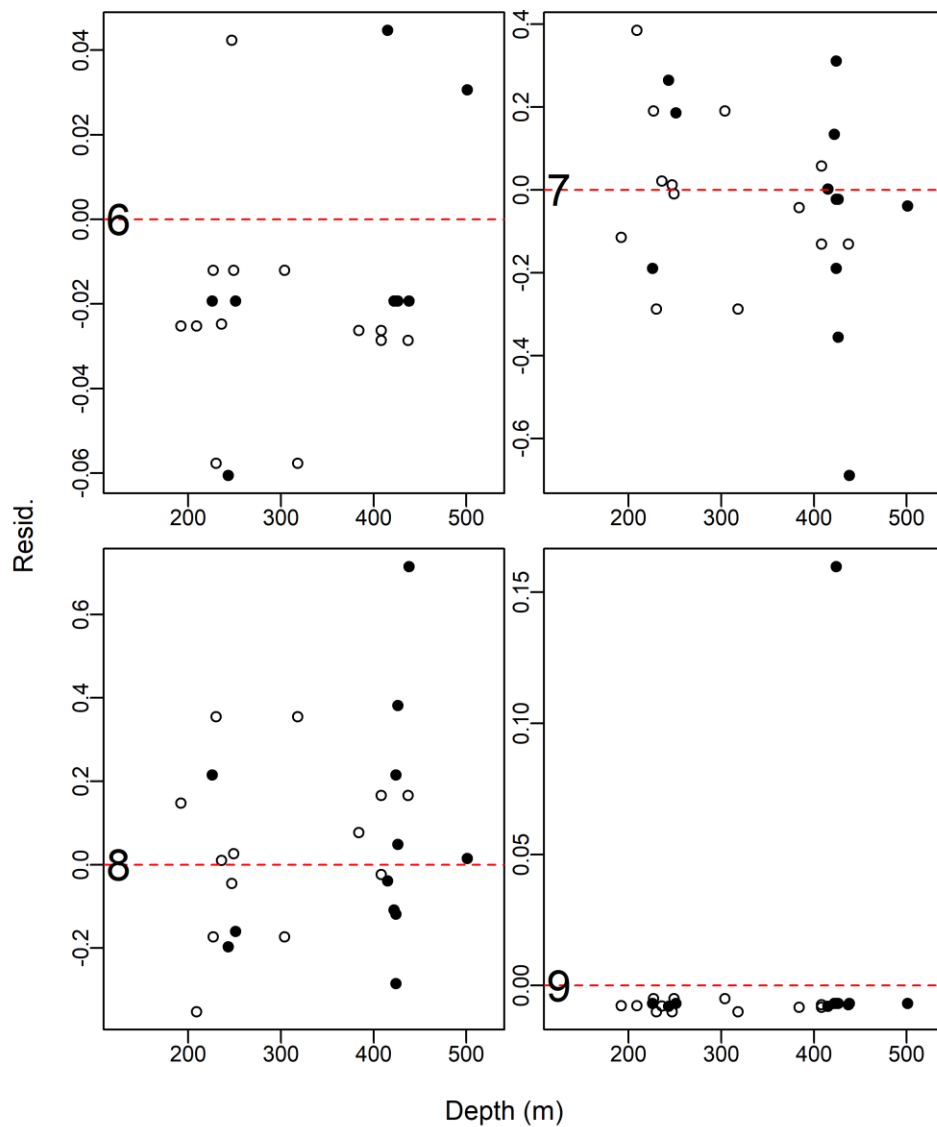


Figure 10. Residuals for the *bclm* for *S. fasciatus* in Unit 2, by AFR count (panels). Filled circles indicate samples from NAFO unit areas 4Vsc and 3Psh, for which the deeper depths occur in the Laurentian Fan.

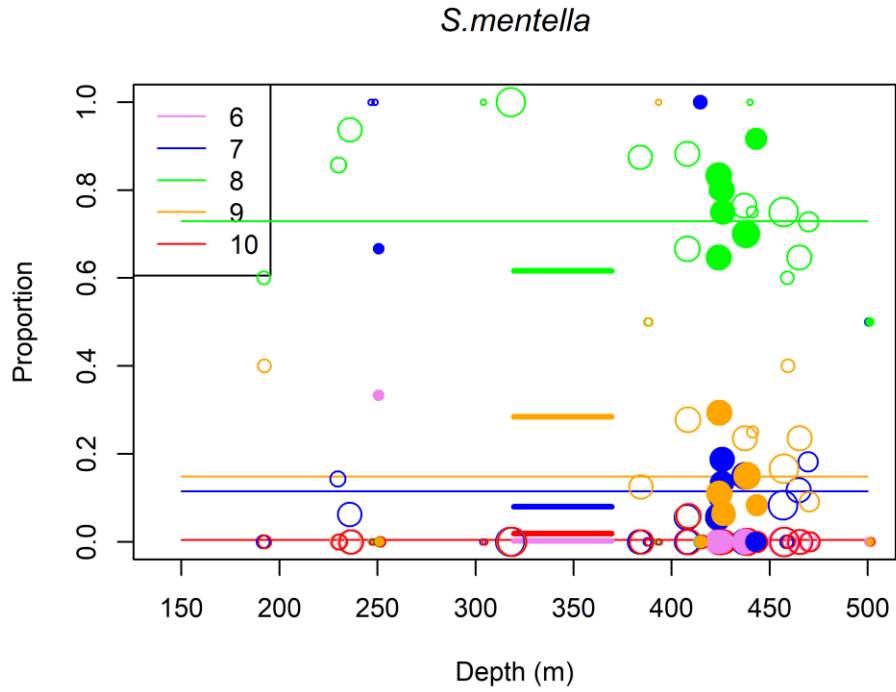


Figure 11. Observed (circles) and estimated (curved lines) proportions of different AFR counts for *S. mentella* from individual samples, as a function of depth in Unit 2. Colors distinguish AFR count categories, while circle size is proportional to the overall sample size from the individual samples. Filled circles indicate samples collected in NAFO unit areas 4Vsc and 3Psh, which include the Laurentian Fan area. The thick horizontal bars near the center of the plot indicate the current assumed AFR count proportions, and are centered on the mean depth of capture for *S. mentella* across the samples used in this study.

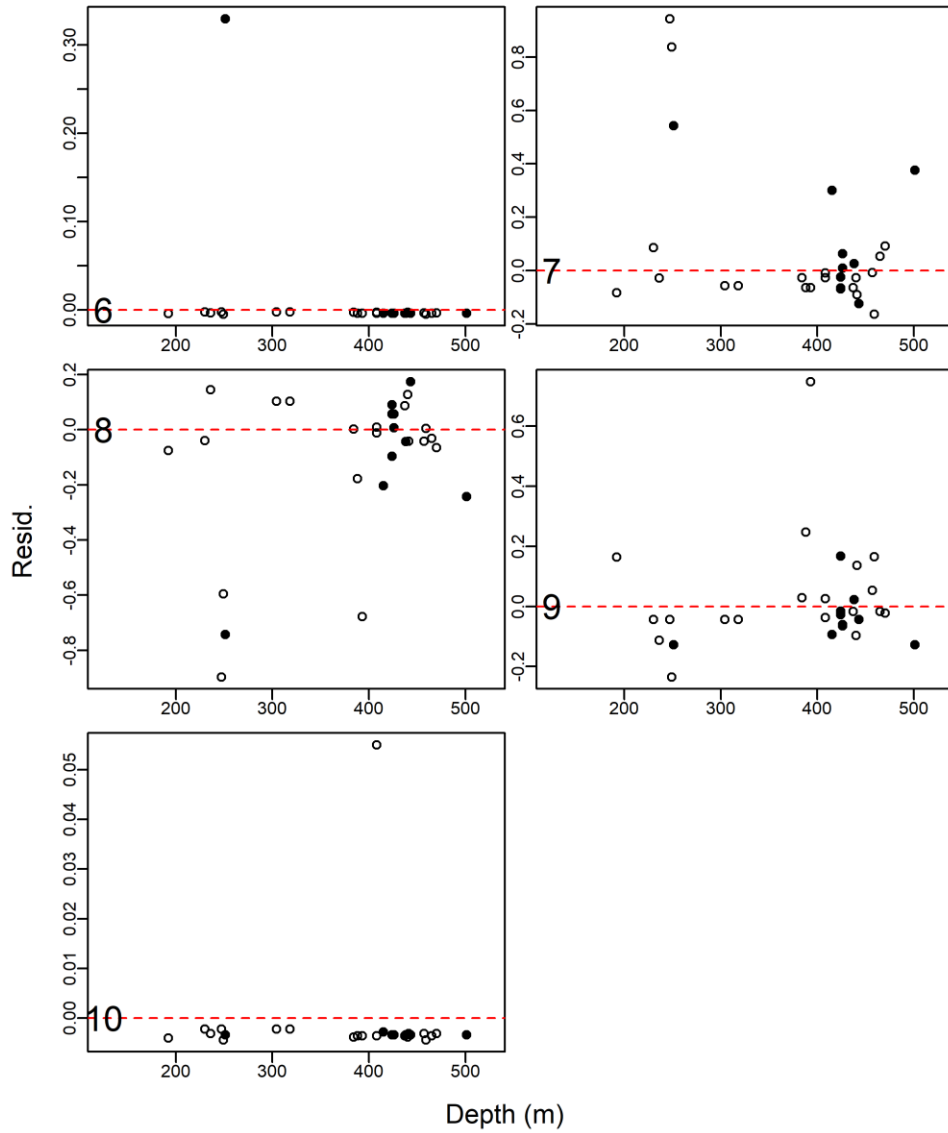


Figure 12. Residuals for the *bclm* for *S. mentella* in Unit 2, by AFR count (panels). Filled circles indicate samples from NAFO unit areas 4Vsc and 3Psh, for which the deeper depths occur in the Laurentian Fan.

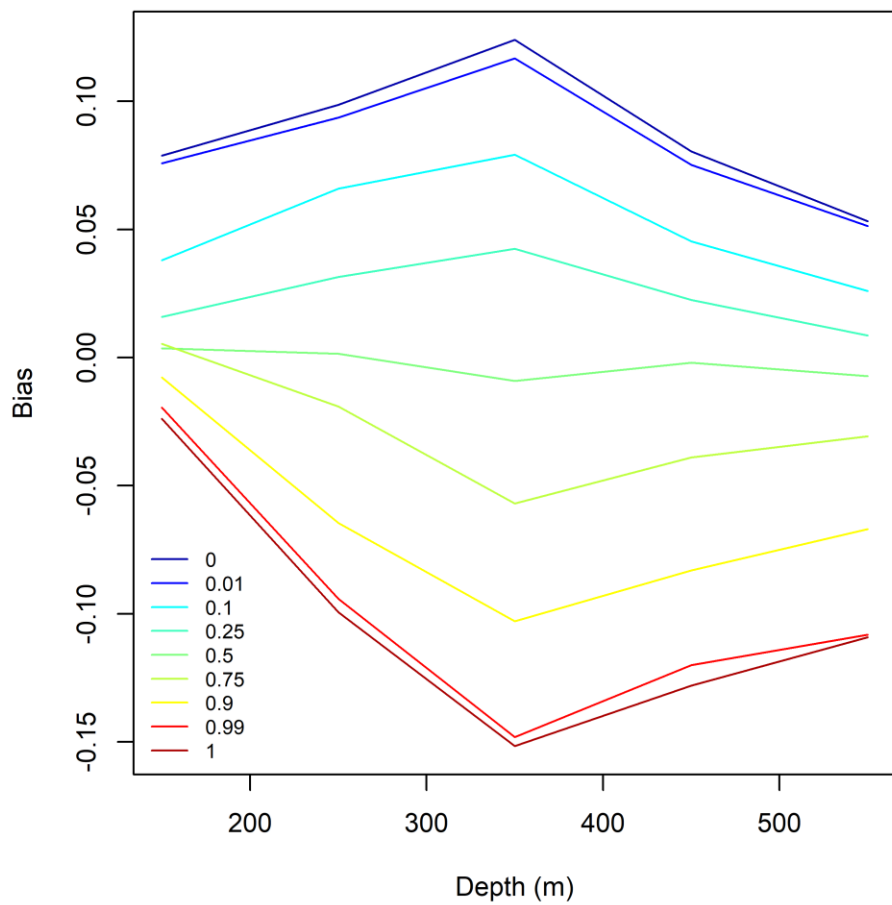


Figure 13. Biases for the multinomial mixture-distribution model estimated by the simulations, as a function of depth (x axis) and the simulated probability of *S. fasciatus* in the catch (colored lines).

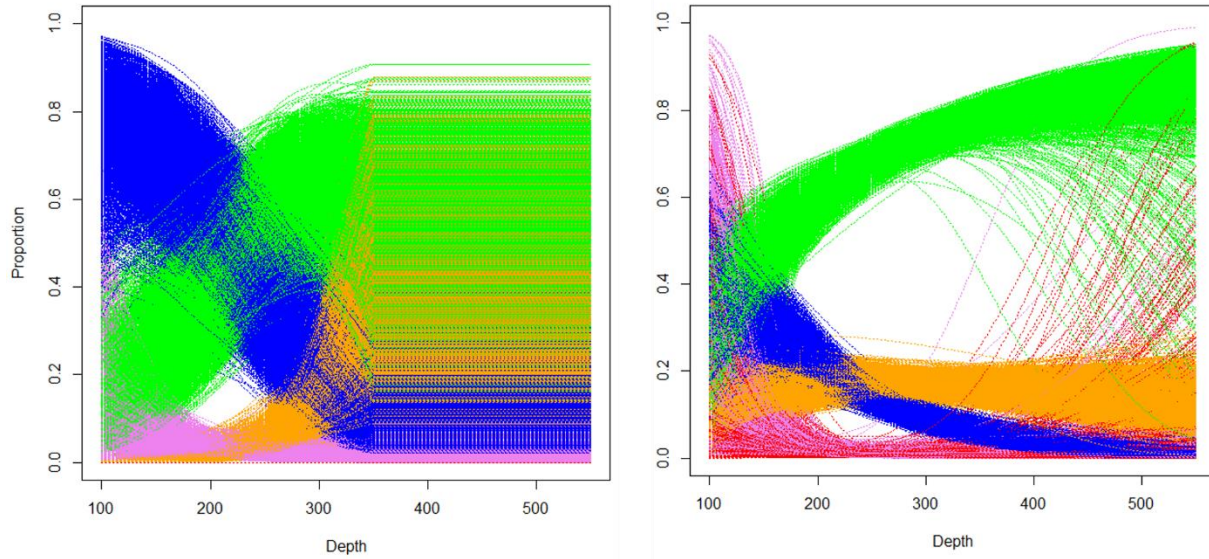


Figure 14. Predicted AFR proportions as a function of depth for *S. fasciatus* (left panel) and *S. mentella* (right panel) in Unit 1 for individual simulation threads from the parameter vector and covariance matrices of the bclm models. AFR counts are color coded in the same manner as in Figure 5 and Figure 7, that is: AFR 6 (purple), 7 (blue), 8 (green), 9 (orange), and 10 (red). Predictions for *S. fasciatus* at 350 m are assumed for depths greater than that value.

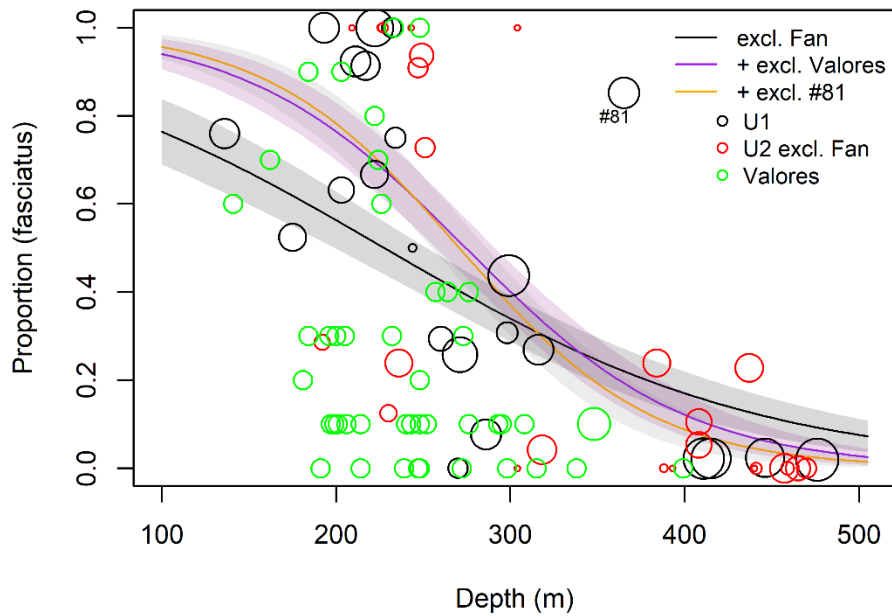


Figure 15. Empirical proportions of *S. fasciatus* as a function of depth in samples collected by or for DFO in Unit 1 (black circles) and Unit 2 (red circles; excluding the Laurentian Fan), or by Valores (green circles), and fits of three variants of the beta-binomial mixed-effects model (lines with standard error indicated by shading).

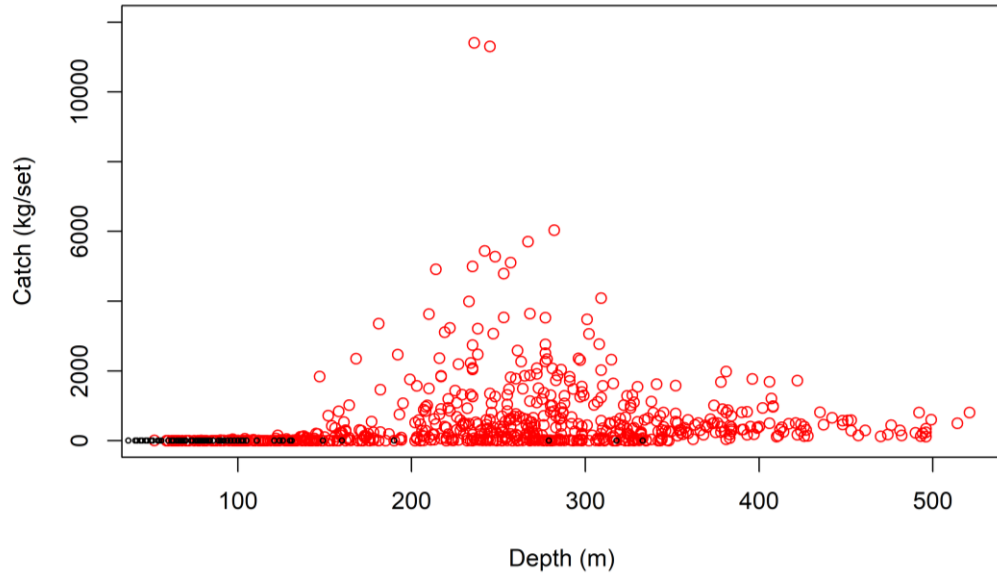


Figure 16. Relationship between overall Redfish catches (kg/set; irrespective of species) and depth (m) in the nGSL survey between 2020 and 2024. The presence (red) or absence (black) of Redfish in catches are shown.

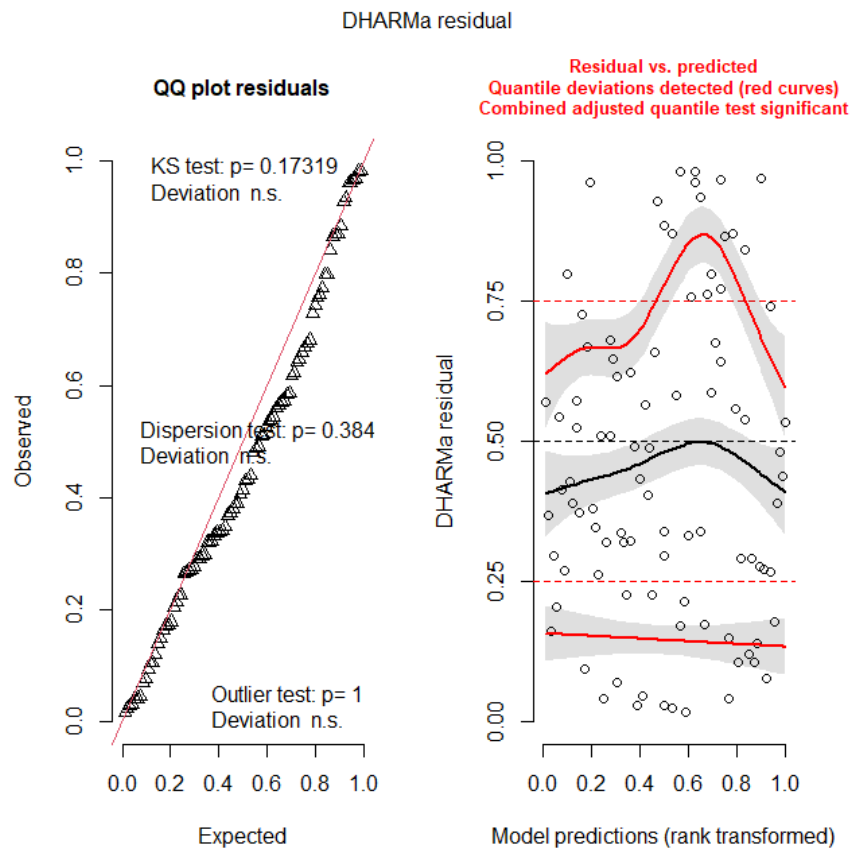


Figure 17. Quantile residuals diagnostics from the DHARMA package for the model fit to all data, except samples from the Laurentian Fan.

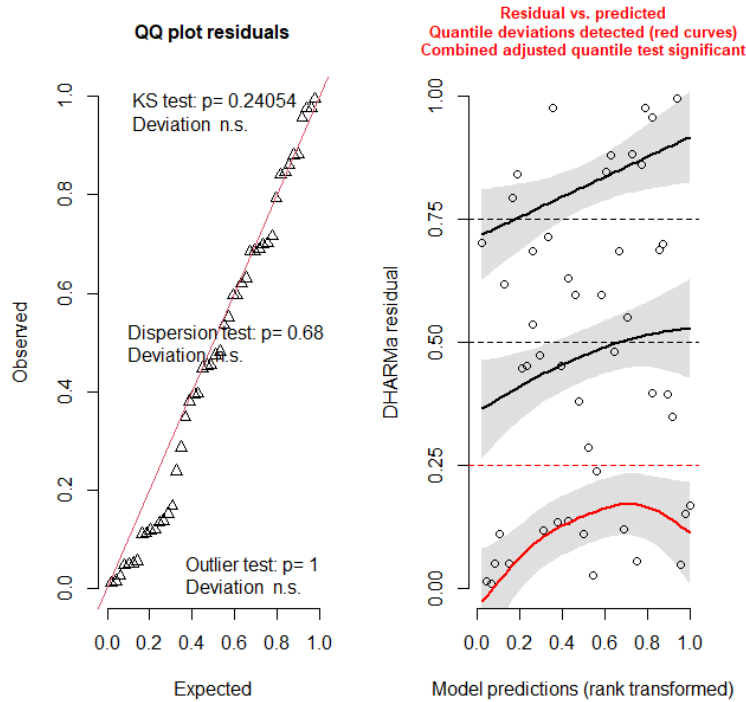


Figure 18. Quantile residuals diagnostics from the DHARMA package for the model fit to all data, excluding samples from the Laurentian Fan and those collected by Valores.

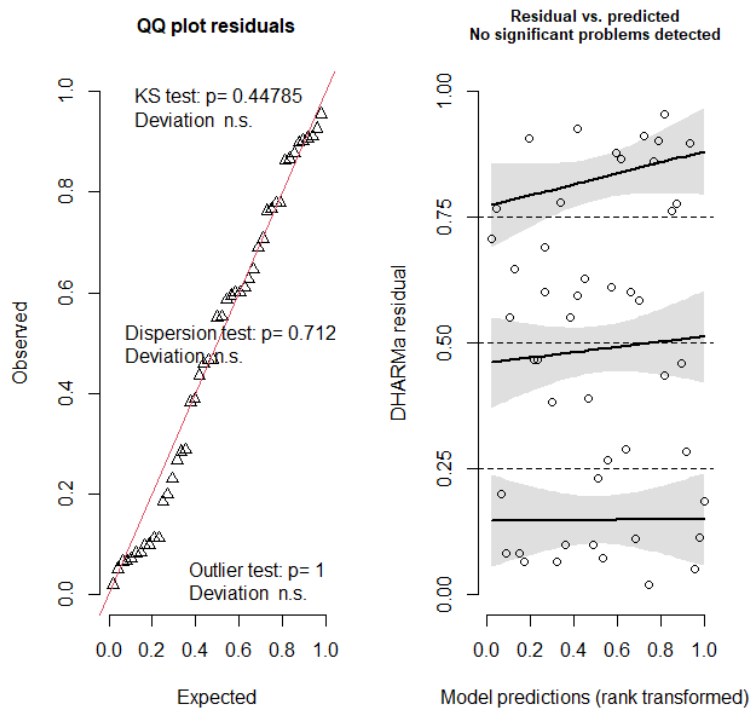


Figure 19. Quantile residuals diagnostics from the DHARMA package for the model fit to all data, excluding samples from the Laurentian Fan, those collected by Valores, and set #83.

Table 1. Parameter values (standard error) for *bclm* fits by Unit and species. Parameters are for individual AFR count categories as a function of the baseline AFR count of 6. Note that there were no AFR count of 10 for *S. fasciatus* and that selected models for Unit 2 did not include an effect of depth.

	AFR 7	AFR 8	AFR 9	AFR 10
Unit 1- <i>S. fasciatus</i>				
Intercept	4.633 (2.408)	1.090 (2.338)	-7.106 (3.000)	-
Depth	-0.0061 (0.0108)	0.0097 (0.0106)	0.0324 (0.0126)	-
Unit 1- <i>S. mentella</i>				
Intercept	-0.210 (2.755)	-1.431 (2.738)	-2.280 (2.752)	-2.487 (4.057)
Depth	0.0155 (0.0132)	0.0267 (0.0131)	0.0246 (0.0132)	0.0098 (0.0184)
Unit 2- <i>S. fasciatus</i>				
Intercept	2.822 (0.878)	2.589 (0.774)	-1.322 (1.196)	-
Unit 2- <i>S. mentella</i>				
Intercept	3.420 (1.089)	5.266 (1.053)	3.674 (1.055)	0.18 .442)

2.3. DISTRIBUTION AND HABITAT

In the northwest Atlantic, Redfish inhabit cold waters along the slopes of banks and deep channels at locations ranging in depth from 100 m to 700 m. *S. mentella* is typically found in deeper locations than *S. fasciatus*. In the main channels of the GSL and within the Laurentian Channel, *S. mentella* tends to predominate in the main channels at depths ranging from 350 m to 500 m. In contrast, *S. fasciatus* dominates at locations with depths less than 300 m, which mainly occur along the slopes of channels and banks, except at the entrance of the Laurentian Channel (Laurentian Fan) where it inhabits deeper waters. Redfish are demersal species given that they mainly occur near the seabed. These species undertake diel vertical migrations, leaving the sea floor at night to follow their preys migrating in the upper layers of the water column (Gascon 2003). Vertical migration appears to be a feeding strategy in which Redfish follow the migration of their preys.

2.4. DIET

Senay et al. (2023) described Redfish diet in Unit 1 according to individual length and between periods, and estimated predation on Northern Shrimp. Small Redfish are mainly zooplanktivorous. In contrast to individuals shorter than 20 cm, Redfish 20-30 cm long have a considerably greater intake of fishes and various species of shrimp. The importance of fishes and shrimp in the diet is even greater for Redfish ≥ 30 cm in length, which are uncommon in the GSL compared to smaller individuals. For larger preys such as fish and shrimp, results of the Senay et al. (2023) study were similar between periods. Pink Glass Shrimp (*Pasiphaea multidentata*) was the most important shrimp taxon consumed by Redfish, followed by the

Northern Shrimp (*Pandalus borealis*), regardless of the period considered. Similar results were also observed by Brown-Vuillemin et al. (2022) and additional prey have been identified by DNA metabarcoding, particularly zooplankton species (Brown-Vuillemin et al. 2025).

An update of Unit 1 diet and a comparison with Unit 2 as well as between summer and winter is available in Isabel et al. (2026).

2.5. MATURITY DETERMINATION

Redfish are ovoviviparous, meaning they fertilize eggs internally. Copulation generally takes place in fall, probably between September and December (Gascon 2003). Spermatozoa are maintained in a state of physiological dormancy inside females until their ovaries mature in February and March (Hamon 1972). Larval extrusion occurs from April to July, depending on the area and species (Ni and Templeman 1985). Absolute fecundity ranges from 3,330 to 107,000 larvae per female, a value which generally increases with female length (Gascon 2003). Mating and larval extrusion do not necessarily coincide in space and time for both species. In the GSL, *S. mentella* release larvae approximately three to four weeks earlier than *S. fasciatus*. Larvae are generally found in the water surface layers and juveniles gradually migrate deeper as they grow. Unit 1 Redfish are believed to move in the Cabot Strait area in winter and return to the GSL in spring. This migration out of the GSL could start as early as November and is linked to overwintering (Atkinson and Power 1991, Morin et al. 1994, Power 2003). Migration of Unit 2 Redfish is not documented.

Length at maturity relationships were first developed by Gascon (2003) based on 434 individuals from Unit 1 and 983 individuals from Unit 2 collected between 1996 and 1999. Species, age, maturity stage, and length were recorded. Species identification was based on AFR counts, genotype at the liver malate dehydrogenase locus (MDH-A), and extrinsic gasbladder muscle passage patterns. For each individual, maturity stage was determined from a macroscopic examination of the gonads appearance. Charts are available in Brûlé et al. (2024). The proportion mature as a function of length was modelled using a logistic regression model. For females of both species, the length at maturity was around 23-24 cm. In general, males reached sexual maturity one to two years before females. Ages (A_{50}) and lengths (L_{50}) at 50% maturity occurred at nine years and 22.8 cm for males *S. mentella*, ten years and 25.4 cm for females *S. mentella*, at seven years and 19.6 cm for males *S. fasciatus*, and nine years and 24.1 cm for females *S. fasciatus*.

Estimation of the proportion mature is based on the logistic equation as follows :

$$\text{Proportion mature} = e^{(a+b*L)} / (1 + e^{(a+b*L)})$$

The constants used from 1984 to 2010 are:

<i>S. fasciatus</i>	female	$a = -10.605$	$b = 0.441$	$L_{50} = 24.1$
<i>S. fasciatus</i>	male	$a = -10.687$	$b = 0.545$	$L_{50} = 19.6$
<i>S. mentella</i>	female	$a = -9.550$	$b = 0.377$	$L_{50} = 25.4$
<i>S. mentella</i>	male	$a = -7.521$	$b = 0.330$	$L_{50} = 22.8$

These equations allow the determination of the mature fraction of the stock based on the fork length (L) of each individual within the sample retained for maturity determination.

In 2018 and 2019, maturity ogives were updated based on 757 new specimens of Redfish collected within Units 1 and 2. Each individual was measured, genetically identified to species using a qPCR approach, and classified as immature or mature using gonad histology and macroscopic appearance. The revised species and sex-specific maturity ogives based on histological information were published in Brûlé et al. (2024).

Based on these new ogives, the constants used from 2011 to present are:

<i>S. fasciatus</i>	female	$a = -12.200$	$b = 0.750$	$L50 = 16.3$
<i>S. fasciatus</i>	male	$a = -15.445$	$b = 0.971$	$L50 = 16.0$
<i>S. mentella</i>	female	$a = -18.374$	$b = 1.070$	$L50 = 17.2$
<i>S. mentella</i>	male	$a = -18.701$	$b = 1.042$	$L50 = 18.0$

2.6. RECRUITMENT

Redfish are characterized by significant variability in recruitment. The main abundant cohorts in Unit 1 were born in 1946, 1956-1958, 1970, 1980, 1985, 1988, 2003, and 2011-2013. The 1985, 1988, and 2003 year classes were very abundant at ages 2 to 4 in research survey data, but were not detected at subsequent ages and never considerably contributed to the fishery (Licandeo et al. 2020). It was hypothesized that these cohorts had returned to the Grand Banks since they bore the genetic identity of that population based on microsatellites, although this population was not identified as distinct from other genetic groups based on SNPs. Ocean currents and age-based spatial and temporal abundance trends suggest that *S. fasciatus* may use the GSL as a nursery (Brassard et al. 2017).

Different factors may be linked to successful recruitment events, one of them being the correspondence between the timing of larvae extrusion and the bloom of their preys. Redfish larvae feed mainly on non-adult copepod, *Calanus finmarchicus* (Runge and De Lafontaine 1996; Burns et al. 2020). Larval growth was faster, and metamorphosis occurred earlier in 1980, when there was a close match between Redfish larval extrusion and *C. finmarchicus* reproduction, compared to 1981 when *C. finmarchicus* reproduction occurred seven weeks earlier than larval extrusion (Anderson 1994). More recently, it has been suggested that Redfish larvae that fed on a diet comprised of *C. finmarchicus* nauplii were in better condition and grew faster than those that fed on other prey items (e.g., *C. finmarchicus* eggs, Burns et al. 2021). Warming GSL waters have shifted the phenology of commonly consumed prey taxa earlier in the year, which may increase the overlap between Redfish and nauplii prey that drives fast growth, survival, and potentially recruitment success. Hence, the production of abundant Redfish cohorts was hypothesized to depend on a close co-occurrence between the predator and its preys (Burns et al. 2021).

2.7. ECOSYSTEM

DFO annually assesses the physical oceanographic conditions prevailing in the Canadian northwest Atlantic Shelf region including the GSL and Laurentian Channel with the Atlantic Zone Monitoring Program (AZMP) since 1998. The deep waters of the GSL originate from an inflow at the entrance of the Laurentian Channel which circulates towards the heads of the Laurentian, Anticosti, and Esquiman Channels in up to roughly three to four years at 300 m after reaching Cabot Strait, with limited exchanges with shallower upper layers. Conditions encountered in the GSL and Laurentian Channel in recent years were generally warmer than historical averages (Figure 20). Deep-water temperatures have been increasing in the GSL since 2009. In 2020, GSL-wide average temperature at 150 m was lower than the 2015 record highs but above normal at 3.7 °C (± 1.6 standard deviation [SD]). New series record highs (since 1915) were set at 200, 250 and 300 m, at 5.7 °C ($+1.2$ °C, ± 1.9 SD), 6.6 °C ($+1.1$ °C, ± 2.5 SD) and 6.8 °C ($+1.1$ °C, ± 2.7 SD), respectively. Bottom area covered by waters warmer than 6 °C was at a record high in the Northwest Gulf, the Northeast Gulf, and in Centre Gulf and Cabot Strait, and some 7-8 °C habitat appeared for the first time in the Northeast Gulf (Galbraith et al. 2025). In 2021, bottom temperature average in 3Ps in spring was the second warmest of time series after 2011 (Cyr et al. 2022). In 2022, bottom temperatures were substantially above normal across Units 1 and 2, and a new series record that was observed in the area deeper than 200 m of the

nGSL in August ($5.47\text{ }^{\circ}\text{C}$, $\pm 0.42\text{ SD}$), in 3Ps in spring ($2.39\text{ }^{\circ}\text{C}$, $\pm 0.46\text{ SD}$) and in 4W on the Scotian Shelf ($6.76\text{ }^{\circ}\text{C}$, $\pm 0.99\text{ SD}$). The Cabot Strait also hold a new series record at 300 m ($5.94\text{ }^{\circ}\text{C}$, $\pm 0.50\text{ SD}$). Those warm waters have propagated towards the heads of the channels and are still sustained by warm water inflows. The GSL average of the deep temperature maximum has slightly decreased from a record high of $7.0\text{ }^{\circ}\text{C}$ in 2022, down to $6.9\text{ }^{\circ}\text{C}$ in 2023, and to $6.7\text{ }^{\circ}\text{C}$ in 2024. This is an indication that deep water temperatures are stabilizing (Galbraith et al. 2025).

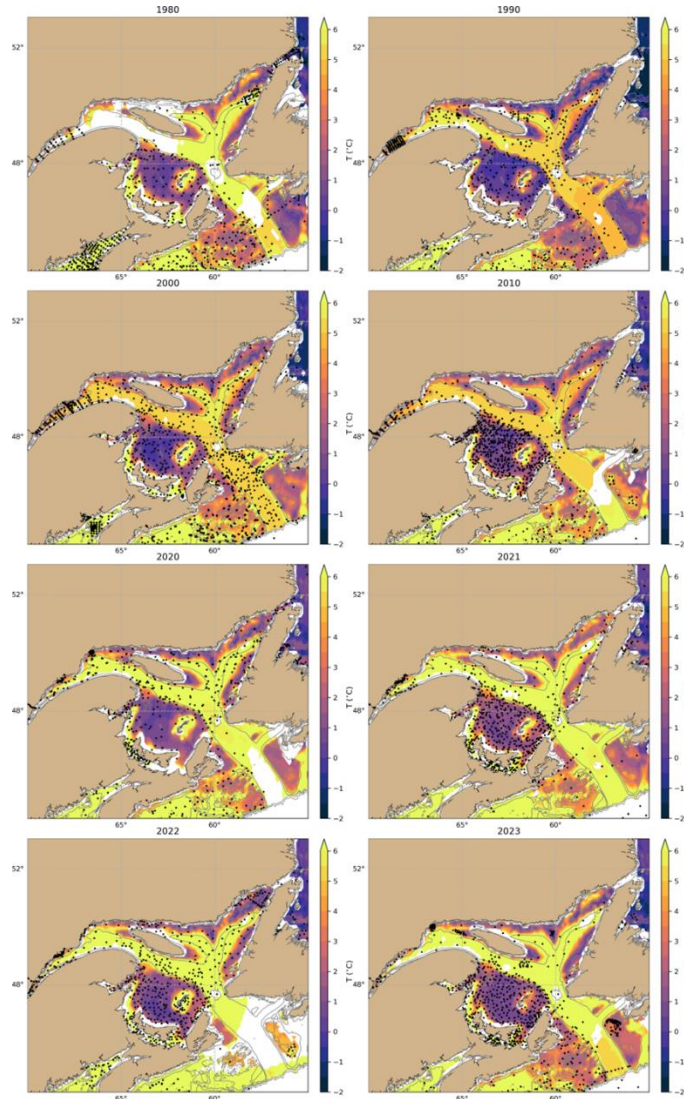


Figure 20. Bottom temperature in Unit 1 and 2 from 1980 to 2023. Black dots represent data locations available from July to September for each years (Coyne and Cyr 2025).

Oxygen concentration was measured using an oxygen probe (Sea-Bird SBE43) mounted on the CTD during AZMP campaigns and multidisciplinary surveys since the early 2000s. Starting in 2015 and across all Atlantic Regions, the probe was calibrated against seawater samples collected from most CTD casts, which were analyzed using Winkler titration (for the calibration procedure, see [Sea-Bird application notes 61-1, -2, -3](#)). Oxygen concentrations were converted to saturation levels using in situ temperature and salinity, according to the equation by Garcia and Gordon (1992), which was implemented in R Oxygen package (Chabot 2014). The hypoxic

condition threshold is set at 30% while severely hypoxic conditions are defined as below 20% saturation levels (Plante et al. 1998; Gilbert et al. 2005).

The oxygen profiles were seasonally interpolated over a $\sim 4 \text{ km}^2$ gridded field in the GSL and interpolated for each year using a $\sim 0.16 \text{ km}^2$ gridded field outside of the GSL, using the inverse distance weight approach (gstat package, (Gräler et al. 2016)). Gridded fields were computed at one-meter depth intervals within the GSL, and at ten-meter depth intervals outside the GSL, extending down to sea floor. Interpolation were limited to a distance of $\sim 50 \text{ km}$ from the closest vertical profile. Seasonal interpolations in the GSL were then averaged to produce annual maps. Quinquennial maps were finally produced by averaging annual maps over five-year periods.

The period from 2020 to 2024 shows the lowest oxygen levels in the bottom waters of the Laurentian Channel, with hypoxic conditions present in the northwest GSL, as well as at the heads of the Anticosti and Esquiman Channels. However, there is no evidence of oxygen depletion beyond 30% over the time series on the Newfoundland and Scotian Shelves (Figure 21).

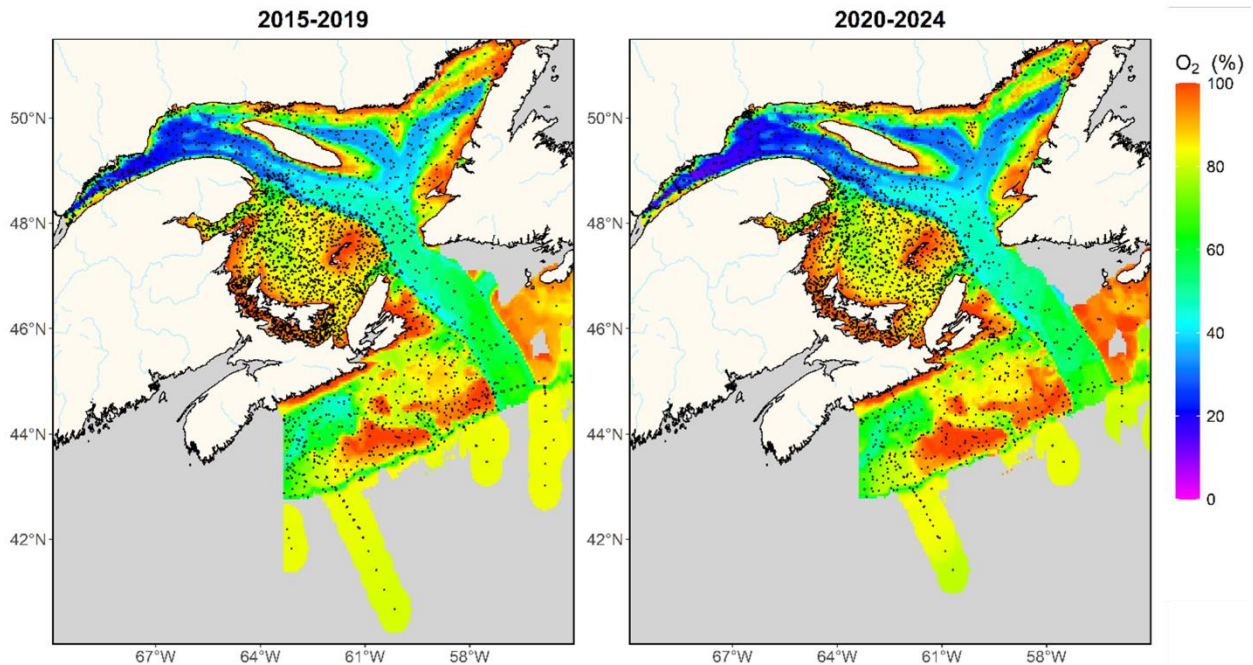


Figure 21. Oxygen saturation (%) found at the bottom of the water column in Units 1 and 2 per period from 2015 to 2024.

The GSL, the Laurentian Channel and the Scotian Shelf ecosystems are composed of diverse fish communities whose components vary in abundance over time and space. Many species can interact with Redfish as preys (e.g., Northern Shrimp), competitors (e.g., Greenland Halibut, *Reinhardtius hippoglossoides*) and/or predators (e.g., Atlantic Halibut). Other species also risk being caught as bycatch in the targeted Redfish fishery (e.g., Atlantic Cod, *Gadus morhua*). A brief description of various stocks known to interact with Redfish within Units 1 and 2 is presented below.

The Northern Shrimp stocks in the Estuary and GSL have been in the Healthy Zone for several years, but have been declining since the mid-2000s. Stocks have continued to decrease since then, and in 2023, the values were the lowest of the time series, except in the Estuary (DFO 2023a).

The biomass of 4RST Greenland Halibut generally has shown a downward trajectory since the end of the 2000s. Biomass indices increased slightly between 2019 and 2020, but reached levels well below the peaks observed in the 2000s (DFO 2021). In 2021, the indicator for Greenland Halibut increased and remained at a similar level in 2022, closer to the USR than in 2017-2020. The indicator dropped by 46% in 2023 compared to 2022, bringing it closer to the LRP defined in that assessment (DFO 2024a).

There is moderate but highly consistent evidence that the 4RST Atlantic Halibut stock has been at a historically high level in recent years (DFO 2023b). The Atlantic Halibut stock in 3NOPs4VWX5ZcO is in the Healthy Zone and has been increasing since 1991 (DFO 2023c).

The Atlantic Cod stock in the Southern GSL (4T and 4Vn from November to April) is at very low abundance and under moratorium since 2009 (DFO 2019). The nGSL (3Pn, 4RS) Atlantic Cod stock has been in the Critical Zone since 1990 and under moratorium in 1994-1996, 2003, as well as since 2022 (DFO 2024b). As for the 3Ps Atlantic Cod stock, it has been in the Critical Zone since 2000 and has not grown above its LRP since (DFO 2024c). In 4VsW and 4Vn (from May to October), it seems that the cod biomass index has been stabilizing since 2020 but it is still low compared to earlier in the time series (DFO 2024d).

White Hake (*Urophycis tenuis*) in 4T has been in the Critical Zone since 1992 and under moratorium since 1995 (DFO 2024e).

Haddock (*Melanogrammus aeglefinus*) biomass index in 4VW declined under the 40% long-term geometric mean in 2011 and the 2023 estimate was the fourth lowest value of the time series (DFO 2024d).

Since 2007, Silver Hake (*Merluccius bilinearis*) has been more frequently observed in the nGSL (DFO 2023d). In the Scotian Shelf (4VWX), the Silver Hake biomass index increased from 2009 to 2014 and then decreased. However, the population model showed indications of an increase in 2022 (DFO 2023d). Silver Hake is associated with warmer waters (Bourdages et al. 2023) and is a potential example of species distribution changes occurring in the GSL, Laurentian Channel and Scotian Shelf due to increased water temperatures.

3. COMMERCIAL FISHERY

3.1. LANDINGS AND MANAGEMENT HISTORY IN UNIT 1

The history of the Unit 1 Redfish commercial fishery is described based on data from the Zonal Interchange Format File (ZIFF) and at-sea-observers (ASO) databases. The TAC are established for each management cycle. Prior to 1999, the Redfish management cycle was from January 1st to December 31st of the same year. In 1999, the management cycle continued until May 14th, 2000 and subsequent management cycles have been from May 15th of the current year to May 14th of the following year.

3.1.1. Pre-moratorium period (1950-1994)

The Redfish fishery in Unit 1 has been characterized by three periods of high landings (1954-1956, 1965-1976, and 1987-1992, Table 2 and Figure 22). Average annual landings were 43,000, 79,000, and 59,000 t for each of these periods, respectively. The maximum annual landings value, 136,101 t, was observed in 1973. From 1953 to 1990, landings originated mainly from NAFO Divisions 4RS. Based on interviews with fishermen, Duplisea (2018) showed that reported landings in the 1980s and 1990s may have been underestimated by a factor of 2 or more. The quantity of small fish landed may have been underestimated by a factor of 150-200.

Before the Unit 1 moratorium in 1995, Redfish was landed year-round. From 1985 to 1993, there was an increase in the percentage of landings occurring in winter (January to March), from less than 5% in 1985 to 25% in 1992 (Figure 23). These landings came mainly from NAFO Subdivision 3Pn and Division 4R. From 1985 to 1994, Redfish were mainly caught using bottom and midwater trawls (Figure 24). Several fishing vessels used the Diamond 6 sides braided nylon midwater trawl equipped with Suberkrüb midwater doors. From 1985 to 1994, approximately 80% of the catches were made using large vessels over 30.5 m (100 feet) in length (Figure 25).

3.1.2. Moratorium (1995-2023) and the index fishery (1998-2023)

In 1995, a moratorium on the Unit 1 Redfish fishery was introduced due to low stock abundance and lack of sufficient recruitment. From 1995 to 1997, no fishery was directed to Redfish. Landings originated only from fisheries directed to other species (Table 2). An index fishery began in 1998 with a TAC of 1,000 t that increased to 2,000 t in 1999. From 1999 to 2023, the TAC for the index fishery remained at 2,000 t per management year. The index fishery took place between June 15th and October 31st. Redfish conservation measures for the index fishery in Unit 1 included the implementation of a protocol for protecting small fish (minimum regulatory size for Redfish was 22 cm, 100% dockside monitoring of landings, minimum mesh size of 90 mm for bottom and midwater trawls, mandatory hail reports upon departure and arrival, imposition of a minimum level of coverage by at-sea observers (ASO, 10-25%) and implementation of a bycatch protocol. Closure periods were also introduced 1) to protect Redfish copulation in the fall and larval extrusion in spring, 2) to minimize catches of Unit 1 Redfish moving in NAFO Subdivisions 3Pn4Vn at the end of fall and winter, and 3) to protect Atlantic Cod spawning. Fishing in the index fishery has only been allowed between longitudes 59°W and 65°W and deeper than 182 m (100 fathoms). In addition, in August 2009, an area has been closed in NAFO Division 4T3a to avoid large aggregations of Greenland Halibut (Figure 26).

Between 1999 and 2005 inclusively, most of the fishing effort directed to Redfish within the index fishery was located in NAFO Divisions 4RT (Figure 22). From 2006 to 2017, the majority of the index fishery landings originated from NAFO Division 4T. The Unit 1 TAC was not fully harvested in that period. On average, from 2010 to 2017, 440 t of Redfish were caught annually. From 1999 to 2017, the majority of Redfish were caught in June and July (Figure 23). From 1999 to 2006, the majority of landings were made using bottom trawls. The midwater trawl fleet was no longer active in the GSL after the moratorium. From 2007 to 2017, there was a sharp increase in the proportion of catches by Scottish seines (Figure 24). Vessels smaller than 19.8 m (65 feet) have generated most of the landings during the moratorium (Figure 25).

Following the Management Strategy Evaluation for Units 1 and 2 Redfish (DFO 2018a; Licandeo et al. 2020; McAllister et al. 2021), the 2018 Stock Assessment, and the Advisory Committee, in addition to the index fishery, an experimental fishery was established with an additional potential allocation of 2,500 t for the 2018-2019 fishing season, 3,950 t for 2019-2020, 3,681 t for 2020-2021, 5,463 t for 2021-2022, 5,944 t for 2022-2023, and 5,000 t for 2023-2024, which could be harvested year-round in Unit 1. Between 2018 and 2023 inclusively, in average 2,203 t of Redfish were landed (Figure 22). The objectives of the experimental fishery were to target *S. mentella*, currently more abundant than *S. fasciatus*, to investigate ways to limit bycatch of other species and capture of undersized Redfish (smaller than 22 cm), and to better understand the spatio-temporal distribution of Redfish and bycatch species. In 2018, research projects were initiated to reintroduce the midwater trawl in Unit 1 Redfish fishery. This gear is considered to be minimally impactful on benthic habitat, as there is no or little contact with the seabed during normal operations. Challenges associated to the performance of midwater trawl

were encountered. On average, since 2018, 5% of landings have been attributed to midwater trawl (Figure 24). Given that the experimental fishery was allowed year round, a greater proportion of the Redfish was landed from October to December (Figure 23). Vessels smaller than 19.8 m (65 feet) remained the dominant source of the landings (Figure 25).

3.1.3. Reopening of the commercial fishery (2024-present)

In 2024, the Redfish-directed commercial fishery resumed in Unit 1 with a TAC of 60,000 t per management year. NAFO Divisions 4RST were open for fishing from June 15th to December 31st, and Subdivisions 3Pn4Vn were open from January 1st to March 31st. From April 1st to June 14th, the Redfish fishery in Unit 1 was closed to protect larval extrusion. Initially, fishing at depths greater than 300 m was allowed between June 15th and October 31st, whereas fishing at depths greater than 182 m has been allowed from November 1st to March 31st. Midwater trawls have been mandatory from November 1st to March 31st. Observer-at-sea coverage was set to 25% from June 15th to October 31st for vessels shorter than 30.5 m (100 feet), and to 100% from November 1st to March 31st. Bycatch percentage limits per trip and overall caps were implemented.

In October 2024, the depth restriction was changed to a minimum of 240 m from June 15th to October 31st and the obligation to use of midwater trawl was limited to the period from January 1st to March 31st (Figure 27). Spatial closures (outside 59°W and 65°W, coral and sponges, and the 2009 closure in 4T3a) were maintained.

Given the highly preliminary nature of the 2024 ZIFF data, landings for the 2024-2025 fishing season will not be described in details here.

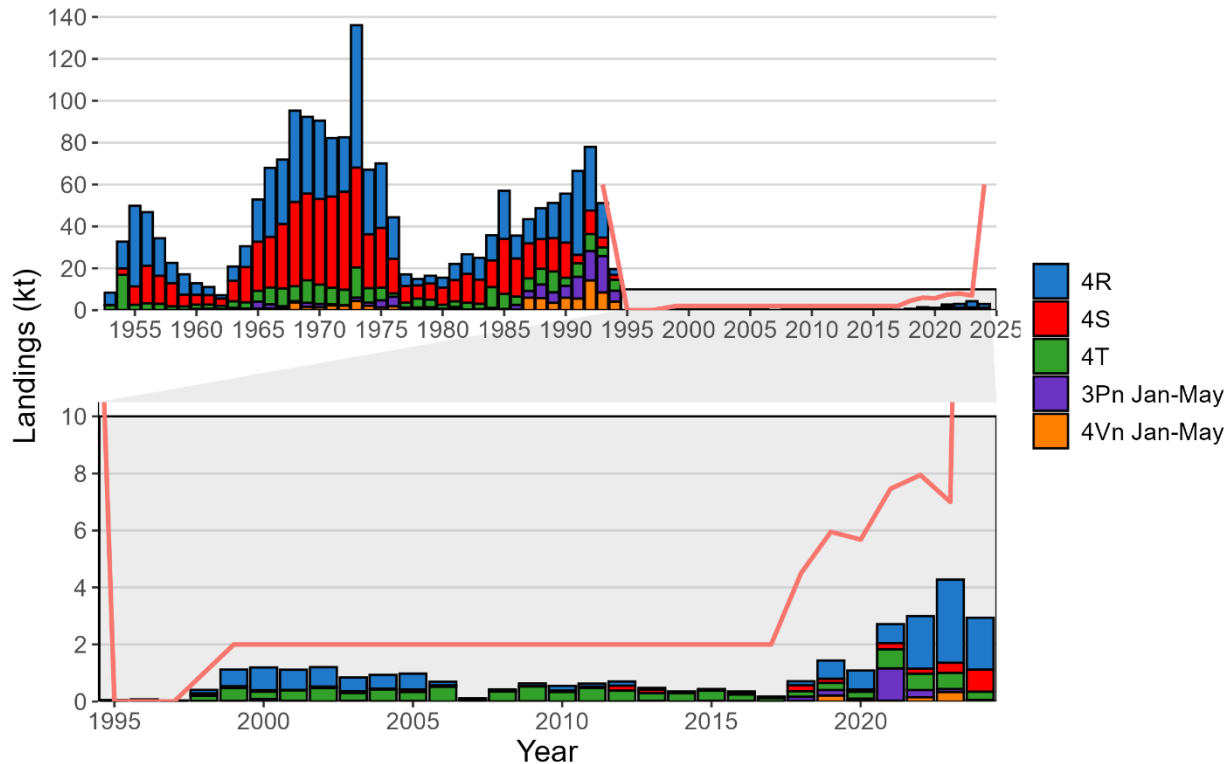


Figure 22. Fisheries annual Redfish landings in Unit 1 per NAFO Division or Subdivision from 1953 to 2024. Data include fisheries directed to all species. No Redfish-directed fishery took place from 1995 to 1997. The total allowable catch (TAC) is indicated by a solid orange line. The grey zone in the top panel is enlarged in the bottom panel. 2020 to 2024 values are preliminary.

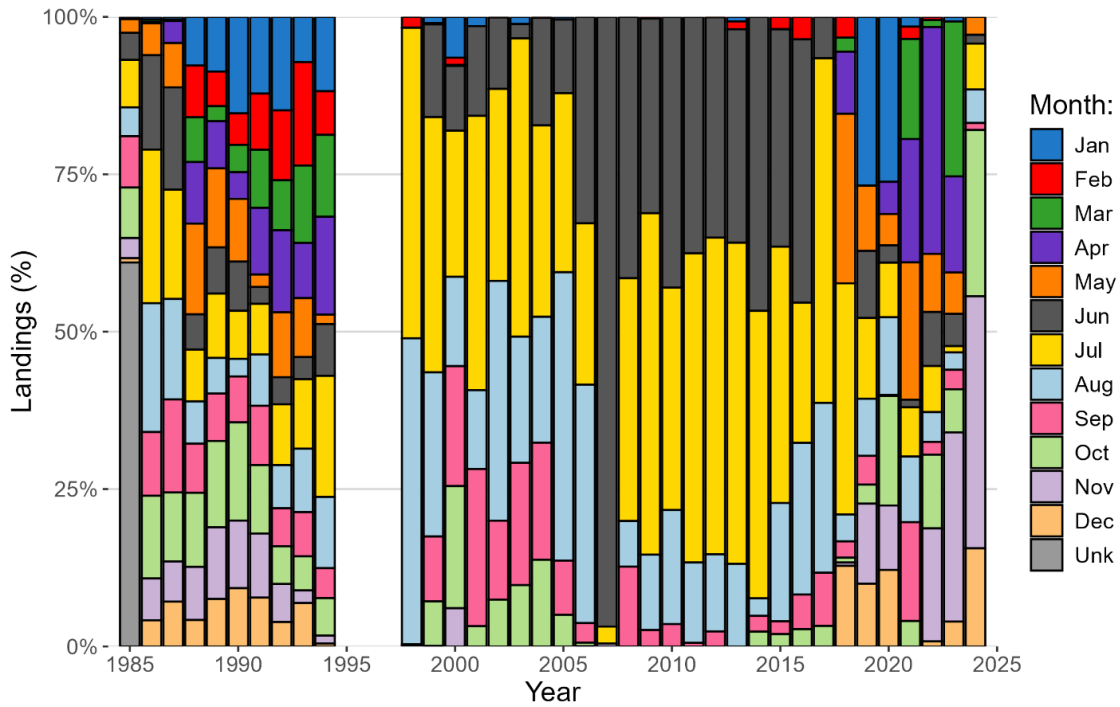


Figure 23. Redfish annual landings (biomass percentage) by month in Unit 1 from 1985 to 2024. Data include only landings from Redfish-directed fishery. No Redfish-directed fishery took place from 1995 to 1997. 2020 to 2024 values are preliminary. Unk: unknown.

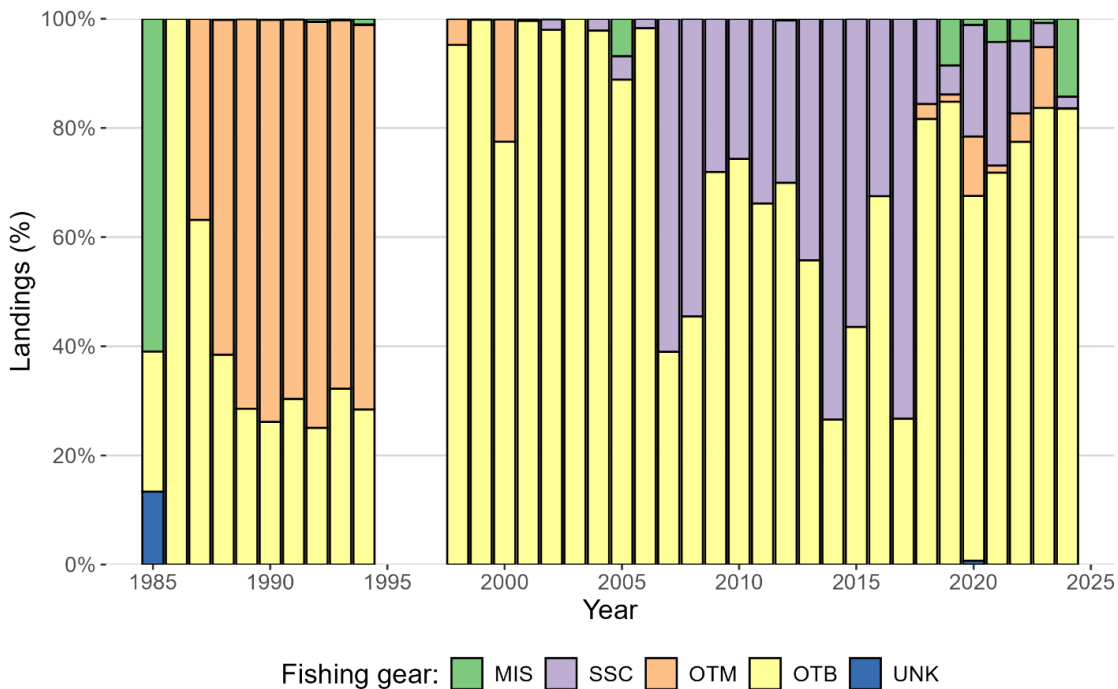


Figure 24. Redfish annual landings (biomass percentage) by gear in Unit 1 from 1985 to 2024. Data include only the Redfish-directed fishery. No Redfish-directed fishery took place from 1995 to 1997. 2020 to 2024 values are preliminary. MIS: miscellaneous, SSC: Scottish seine, OTM: midwater trawl, OTB: bottom trawl, and UNK: unknown.

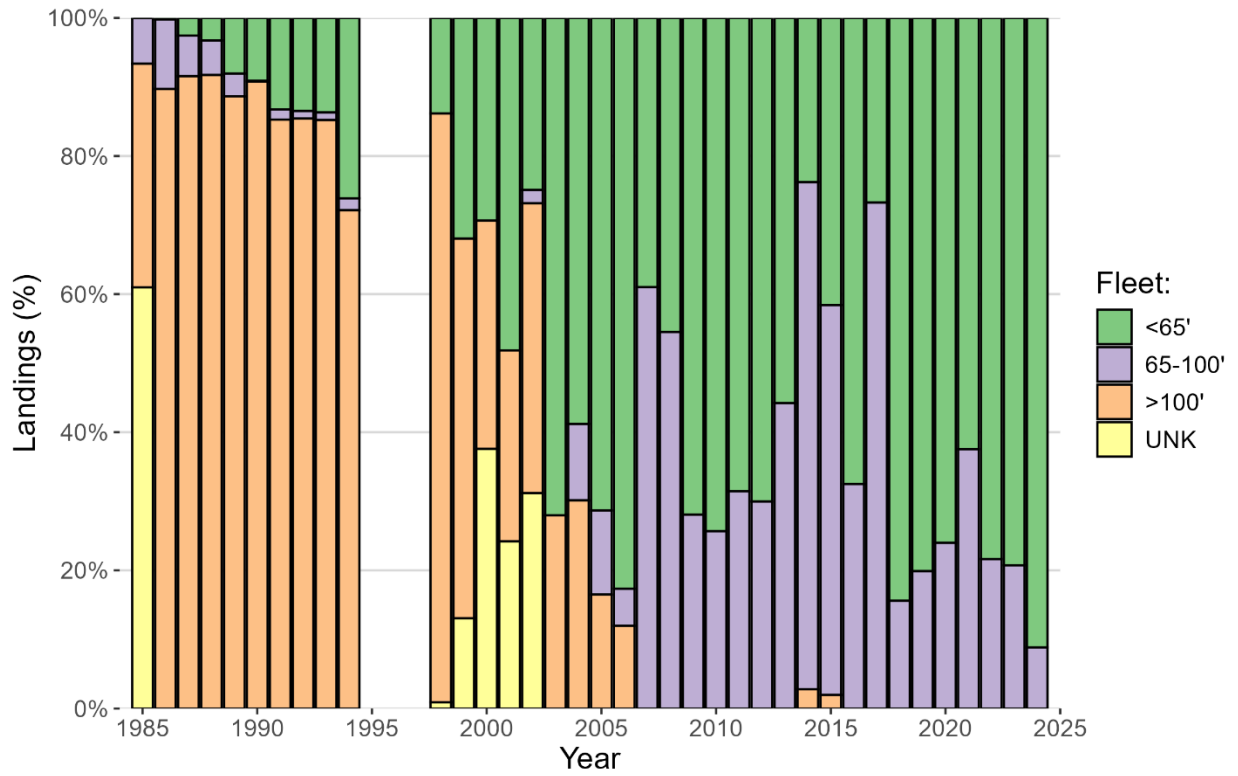


Figure 25. Redfish annual landings (biomass percentage) by boat size category (feet) in Unit 1 from 1985 to 2024. Data include only the Redfish-directed fishery. No Redfish-directed fishery took place from 1995 to 1997. 2020 to 2024 values are preliminary. UNK: unknown.

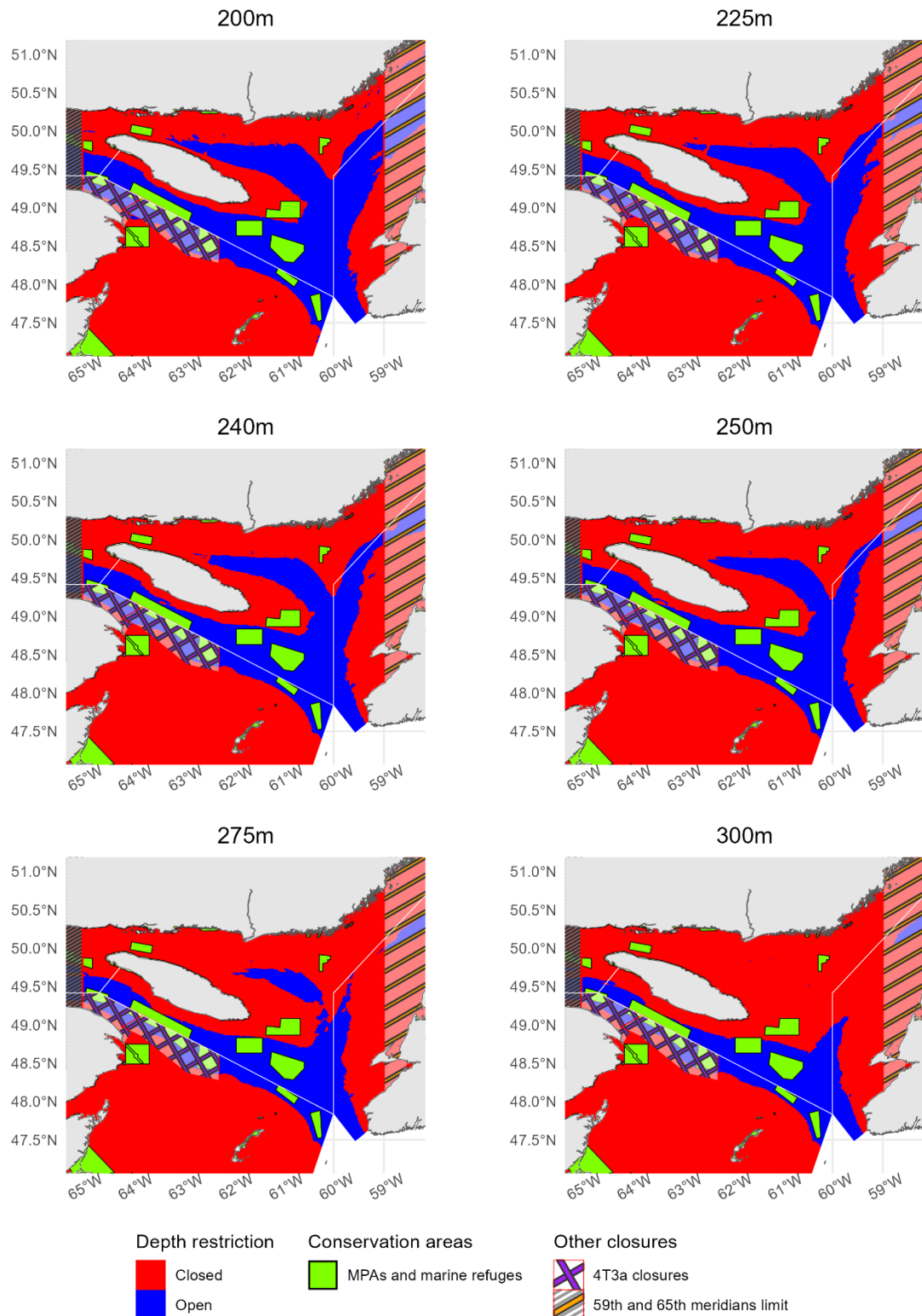


Figure 27. Closures and conservation areas in Unit (only 4RST). Different depth restrictions from 200 to 300 m are shown for information purposes. Since October 2024, the 240 m depth restriction is in place from June 15th to October 31st.

Table 2. Redfish annual landings (t) per NAFO Division or Subdivision and total allowable catches (TAC) per management cycle in Unit 1 from 1953 to 2024. Data include fisheries directed to all species. No Redfish-directed fishery took place from 1995 to 1997. 2020 to 2024 values are preliminary.

Year	Landings (t)					Total	TAC
	4R	4S	4T	3Pn Jan.-May	4Vn Jan.-May		
1953	5981	48	2337	0	0	8366	-
1954	12867	3048	16853	0	0	32768	-
1955	38520	8739	2598	0	0	49857	-
1956	25675	17900	3259	0	0	46834	-
1957	17977	13365	2989	0	0	34331	-
1958	9716	11076	1778	0	0	22570	-
1959	9744	5620	1614	0	135	17113	-
1960	5512	4678	2028	0	612	12830	-
1961	3927	4482	1982	2	669	11062	-
1962	1609	3444	1532	5	561	7151	-
1963	6908	9674	3212	443	580	20817	-
1964	9967	16843	2890	243	581	30524	-
1965	20115	23517	5195	3232	770	52829	-
1966	33057	24133	8025	1881	866	67962	-
1967	30855	30713	8468	995	874	71905	-
1968	43643	40228	7092	668	3633	95264	-
1969	36683	41352	10840	1912	1533	92320	-
1970	37419	40917	9252	1521	1394	90503	-
1971	27954	43540	7912	593	2190	82189	-
1972	26084	46788	7457	128	2135	82592	-
1973	68074	47594	14496	1521	4416	136101	-
1974	30896	25684	6909	1505	2087	67081	-
1975	30838	28499	6064	3378	1273	70052	-
1976	19963	16394	1626	4523	1872	44378	30000
1977	5620	7906	2314	772	460	17072	18000
1978	3084	6352	4155	1067	276	14934	18000
1979	3763	7629	3642	1185	206	16425	16000
1980	4809	8125	1898	527	180	15539	16000
1981	7685	10173	2691	973	523	22045	20000
1982 ¹	9410	13824	3222	63	212	26731	31000
1983 ¹	10463	11495	2547	322	147	24974	33000
1984	12123	12700	9988	936	80	35827	33000
1985	22976	26305	7153	427	125	56986	50600
1986	10964	18203	3954	2219	269	35609	55600
1987	11553	16774	5992	3221	5901	43441	50000
1988	14770	14169	7578	6440	5762	48719	56000
1989	16896	15838	10016	5052	3432	51234	57000
1990	23421	16771	3929	5650	5882	55653	57000

Year	Landings (t)					Total	TAC
	4R	4S	4T	3Pn Jan.-May	4Vn Jan.-May		
1991	40146	3991	6503	10345	5522	66507	57000
1992	30372	11193	8198	14001	14179	77943	57000
1993 ²	16475	4769	4132	17387	8392	51155	60000
1994	2745	2378	5173	5262	4014	19572	30689
1995 ³	27	8	13	0	2	50	0
1996	28	3	41	1	0	73	0
1997	6	10	20	0	1	37	0
1998 ⁴	127	87	190	0	5	409	1000
1999	589	63	457	10	3	1122	2000
2000	794	53	258	84	2	1191	2000
2001	710	17	370	13	5	1115	2000
2002	689	50	465	0	1	1205	2000
2003	484	65	288	0	10	847	2000
2004	486	34	413	0	2	935	2000
2005	562	87	325	0	5	979	2000
2006	126	52	512	0	0	690	2000
2007	5	22	78	0	0	105	2000
2008	62	9	348	0	1	420	2000
2009	95	16	524	0	2	637	2000
2010	164	53	330	0	0	547	2000
2011	113	42	475	0	1	631	2000
2012	148	173	378	0	1	700	2000
2013	65	121	280	0	9	475	2000
2014	37	33	286	0	0	356	2000
2015	8	55	366	0	9	438	2000
2016	65	47	231	11	0	354	2000
2017	30	34	113	0	0	177	2000
2018 ⁵	142	210	191	151	18	712	4500
2019	646	147	244	196	207	1440	5950
2020 ⁷	668	80	243	58	38	1087	5681
2021 ⁷	669	220	667	1139	19	2714	7463
2022 ⁷	1848	175	568	257	146	2993	7944
2023 ⁷	2920	356	563	110	327	4276	7000
2024 ^{6,7}	1820	776	289	0	54	2939	60000

¹ TAC changed during the year

² 1993: Beginning of Redfish management Unit 1

³ 1995: Beginning of the moratorium on directed commercial fishing

⁴ 1998: Beginning of the index fishery

⁵ 2018: Beginning of the experimental fishery

⁶ 2024: Reopening of the directed commercial fishery

⁷ Preliminary data as of February 2025

3.2. LANDINGS AND MANAGEMENT HISTORY IN UNIT 2

Unlike Unit 1, the Unit 2 management cycle has run from April 1st of the current to March 31st of the following year. A seasonal closure is in place from April 1st to June 30th to protect larval extrusion. The Unit 2 fishery operates from July 1st to October 31st (fixed gear), or July 1st to March 31st (mobile gear), and is subject to 100% dockside monitoring. Unit 2 Redfish is co-managed with France within Saint Pierre and Miquelon (NAFO Division 3Ps4Vs) for stocks listed under Annex I of the 1994 Procès-Verbal Applying the March 27, 1972 Agreement Between Canada and France on their Mutual Fishing Relations ([View treaty](#)).

The Unit 2 Redfish fishery bycatch measures are a complex set of regulations managed through different fleet Conservation Harvesting Plans and license conditions. Bycatch limits for non-individually managed quota stocks vary by fleet and bycatch species, with some managed through percentage-based limits and others through total quota caps. Most of the fleet caps are not specific to the Unit 2 Redfish fishery but apply at the fleet level or the broader multispecies fishery. Additionally, some bycatch species are controlled through fishery-wide caps, further adding to the regulatory complexity. Observer coverage varies from 5 to 20% depending on the fleet and Region (DFO 2016). A small fish protocol (Redfish minimum regulatory size is 22 cm, as in Unit 1), a minimum mesh size of 90 mm for bottom and midwater trawls and 140 mm for gill nets, and bycatch limits from 2 to 20% depending on the fleet and Region are in place. A depth restriction of 91.44 m is only present in NAFO Divisions 4VWX when using mesh sizes smaller than 130 mm. Fishing is prohibited in many areas, including different Marine Protected Areas (MPAs) such as the Laurentian Channel, St. Anns Bank, Gully, and Eastern Canyon, as well as other Ecological Reserves and Conservation Areas (Figure 28).

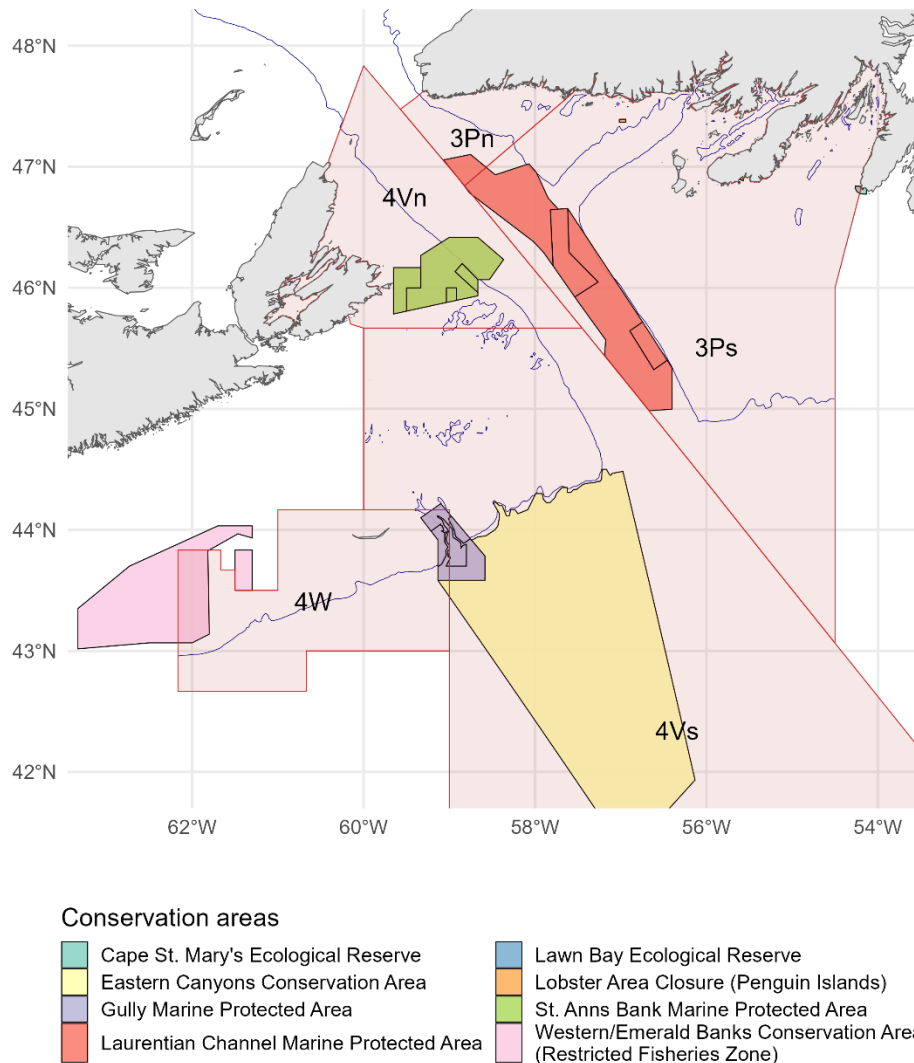


Figure 28. Location of Unit 2 and conservation areas. The 240 m isobath is shown in blue.

3.2.1. Comparison of Zonal Interchange File Format (ZIFF) and MARitimes Fisheries Information System (MARFIS)

The Redfish landings and bycatch percentages in Unit 2 Redfish fishery were derived from the landings and ASO data recorded across the Quebec, Gulf, Newfoundland and Labrador, and Maritimes Regions of the DFO. Accurate identification of landings associated to Redfish-directed activities is critical, as erroneously excluding or including sets could potentially bias estimated bycatch rates.

Typically, in the Quebec, Gulf, and Newfoundland and Labrador Regions, Redfish-directed fishing activities are discerned by analyzing a "species sought" code within the ZIFF which starts in 1985. However, this method proved to be challenging in the Maritimes Region due to inconsistent recording of sought species (Bowlby et al. 2024). Additionally, vessels may operate under a generic groundfish license, catching multiple groundfish species in a single trip (DFO 2018b). Conditional on the presence of an ASO, directed species may change within a single fishing trip.

An alternative method for identifying Redfish-directed fleet that was developed in the Maritimes Region involved using license conditions and related fishery characteristics as the main information. This method has been incorporated into a function, `fleet_redfish`, in the `Mar.fleets` package (McMahon and Bowlby 2021). This function uses license information, fishing gear, and NAFO Division to query the Maritimes Fishery Information System (MARFIS), the regional landings database which starts in 2003 (Table 3). Mesh size filters were applied post-extraction to ensure that identified sets effectively matched Redfish fishing management measures. However, mesh size information was missing for 32% of the `fleet_redfish` extractions; sets with missing mesh size information were excluded from the analysis.

In this section, landings were compared between the two extraction methods: the primary species sought within the ZIFF associated to the Maritimes Region and the `fleet_redfish` function to query MARFIS. The extractions were done on January 2025 and August 2024 for ZIFF and MARFIS, respectively. We classified the sets into those found in both extractions, and those exclusive to either ZIFF or MARFIS. To link the sets between the two databases, we created a key ID based on the date of landing, vessel registration number, species landed, quantity landed, and geographic coordinates of the set.

Between 2003 and 2022, the data extracted from ZIFF indicated total Redfish landings of 62,767 t in the Redfish-directed fishery, while the MARFIS data extraction suggested less landings with 45,253 t. The first year of implementation of MARFIS, 2003, was a notable exception, where no common sets were found between the extractions from the two databases, and higher Redfish landings were present in the ZIFF extraction. Moreover, 2020-2022 landings may not represent the fishery accurately given their preliminary nature in both the MARFIS and ZIFF databases.

As anticipated, the sets found in both extractions displayed almost identical quantities of annual Redfish landings (Figure 29). The Redfish-directed fishery identified within the ZIFF extraction consistently yielded a larger quantity of Redfish landings, with an average annual absolute difference of 756 t from 2004 to 2019 and a maximum annual difference of 1,839 t in 2006 (43.7% of ZIFF landings for that year). In terms of bycatch landings, yearly difference between both extractions varied greatly over the 2003-2022 time period (Figure 30). For the period from 2004 to 2019 inclusively, bycatch accounted for an average of 4.4% of annual Redfish landings according to the ZIFF extraction, while bycatch rose to 4.8% when using the `fleet_redfish` extraction method. The two extraction methods, main species caught in ZIFF and `fleet_redfish` in MARFIS, exhibited substantial differences in Redfish landings but overall similar bycatch percentages (Figure 29 and Figure 30). In both types of extraction, the main species caught were Redfish (Figure 31). The substantial negative difference in Redfish landings with the `fleet_redfish` extraction method is likely due to missing mesh size information. MARFIS fishing sets with missing mesh size information have Redfish proportion at both extremes (Figure 32). It is currently not feasible to definitively assert that Redfish was the target species in sets with missing mesh size information.

Estimating bycatch remains a complex issue within the context of an unspecified groundfish fishery in the Maritimes Region. Further analyses will use the ZIFF given that it describes a longer time period, starting in 1985 versus 2003, and that it covers all Regions involved in Units 1 and 2 Redfish fishery. However, particularities in the determination of directed fishery in the Maritimes Region may prevent direct comparison with other Regions, given that the ZIFF may underestimate bycatch percentages.

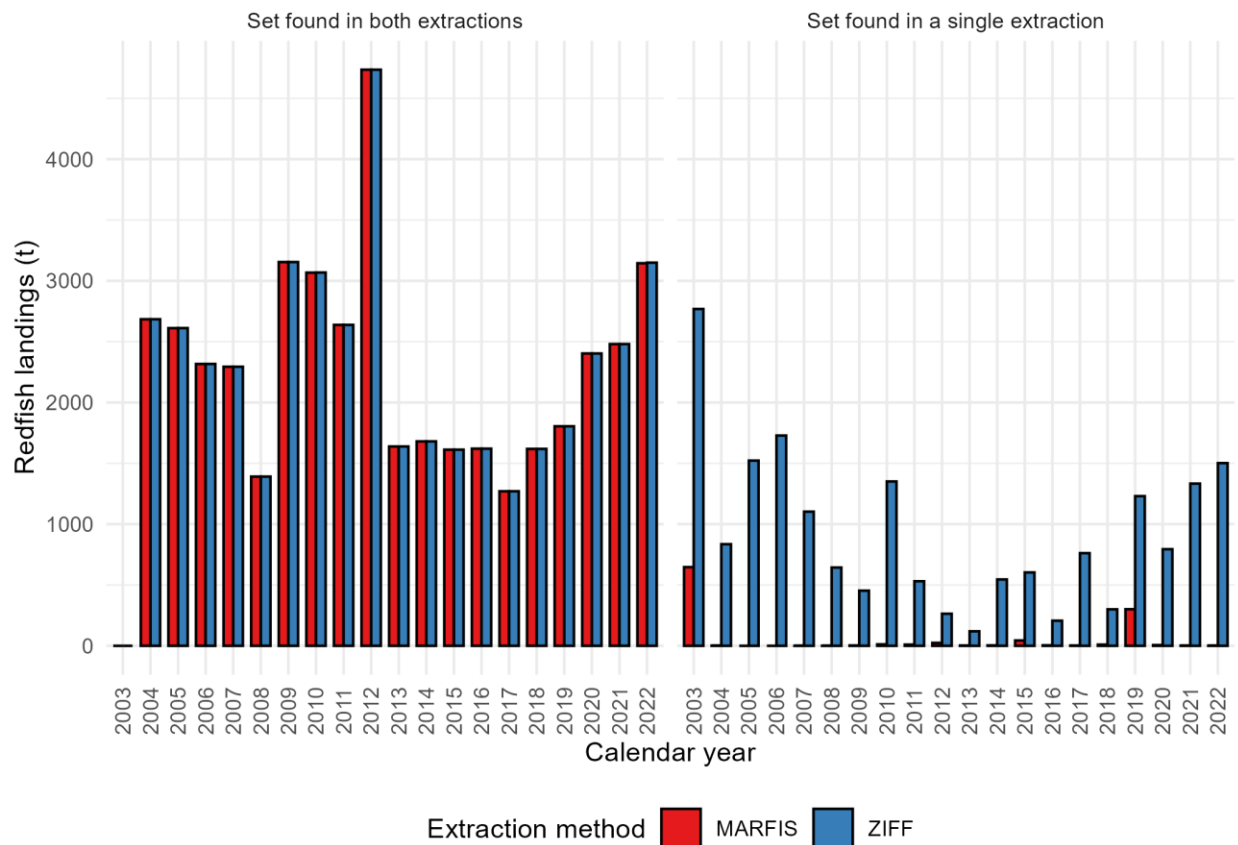


Figure 29. Redfish landings in the Redfish-directed fishery based on MARFIS and ZIFF extraction methods. The left panel corresponds to sets found in both extraction methods and the right panel corresponds to sets found in a single extraction method.

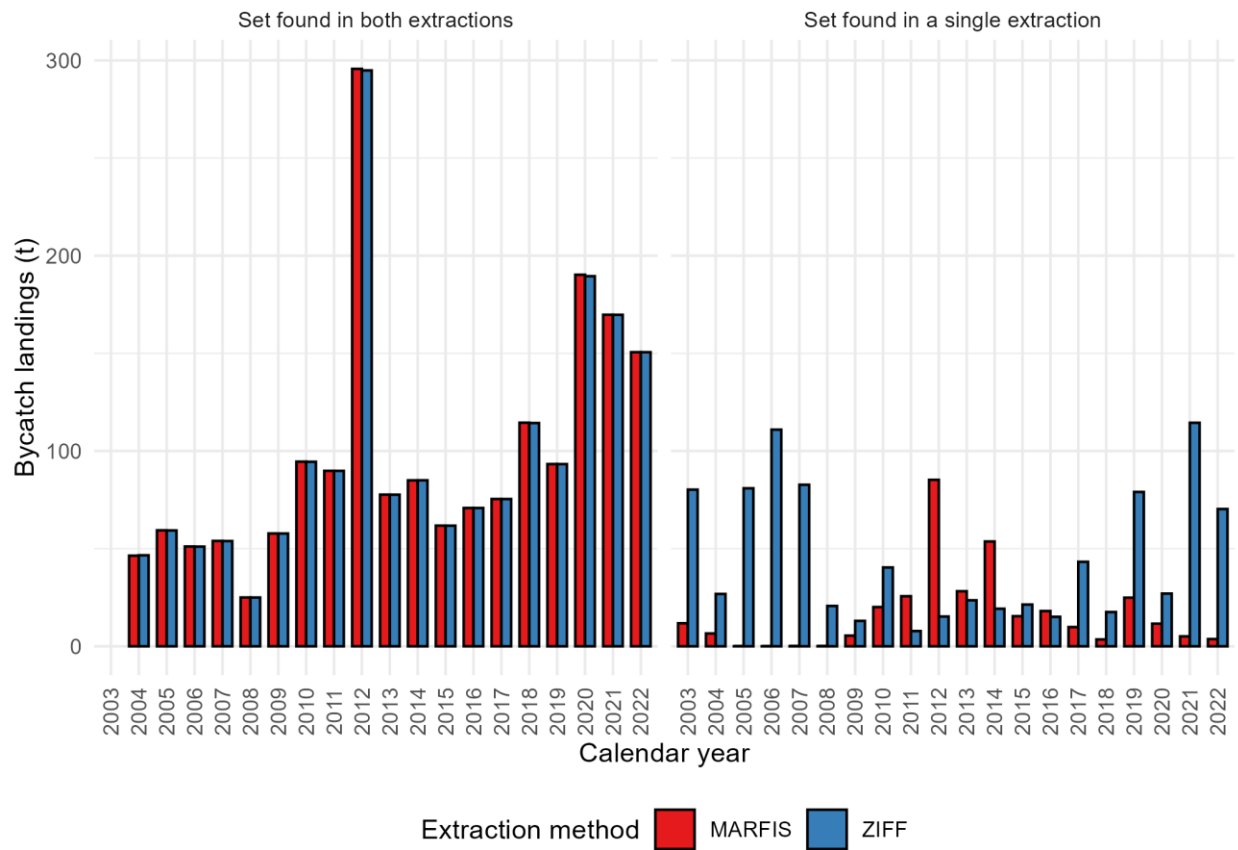


Figure 30. Bycatch landings in the Redfish-directed fishery based on MAFIS and ZIFF extraction methods. The left panel corresponds to sets found in both extraction methods and the right panel corresponds to sets found in a single extraction method.

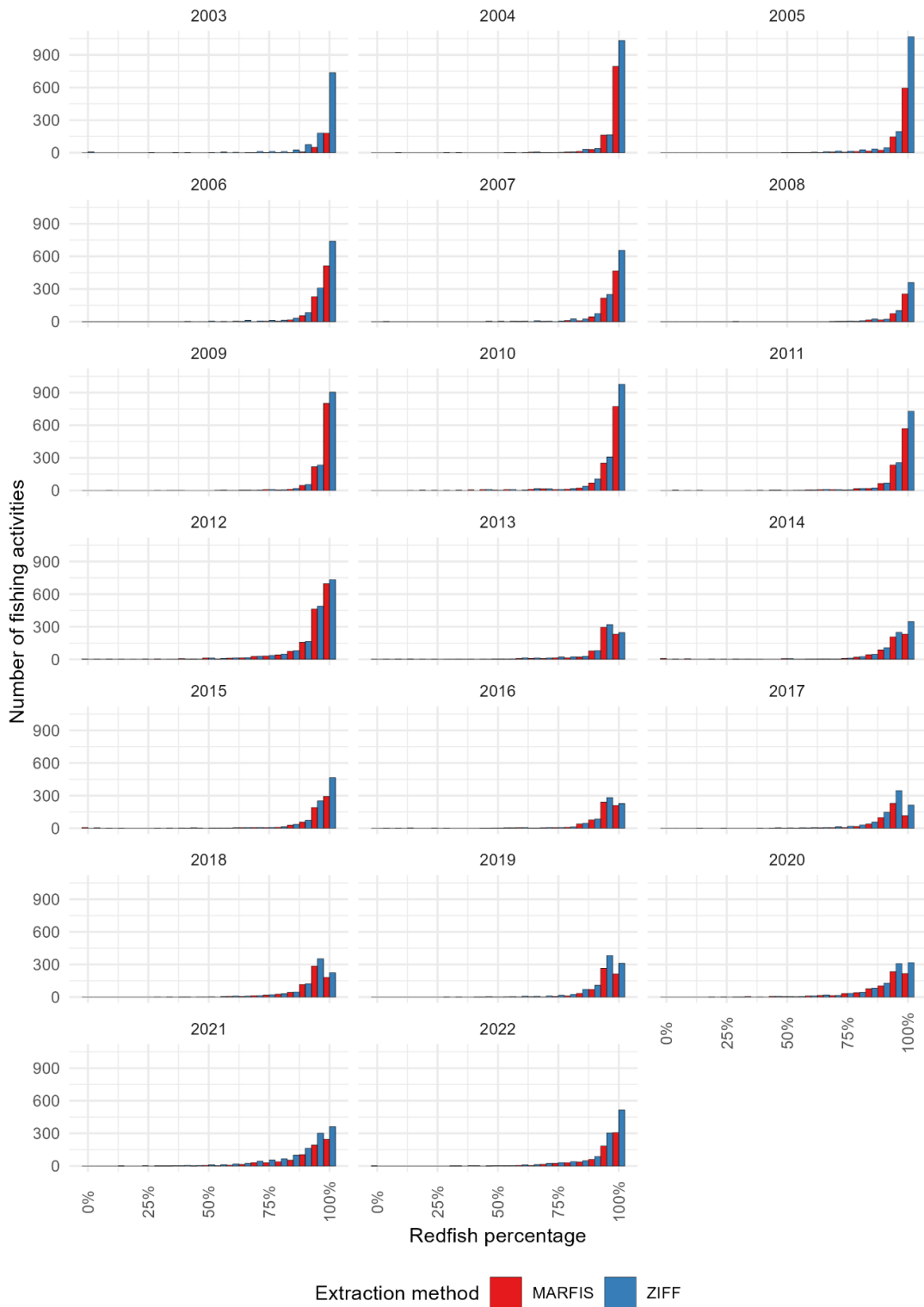


Figure 31. Number of fishing activities (sets) as a function of Redfish percentage per year based on MARFIS and ZIFF extraction methods.

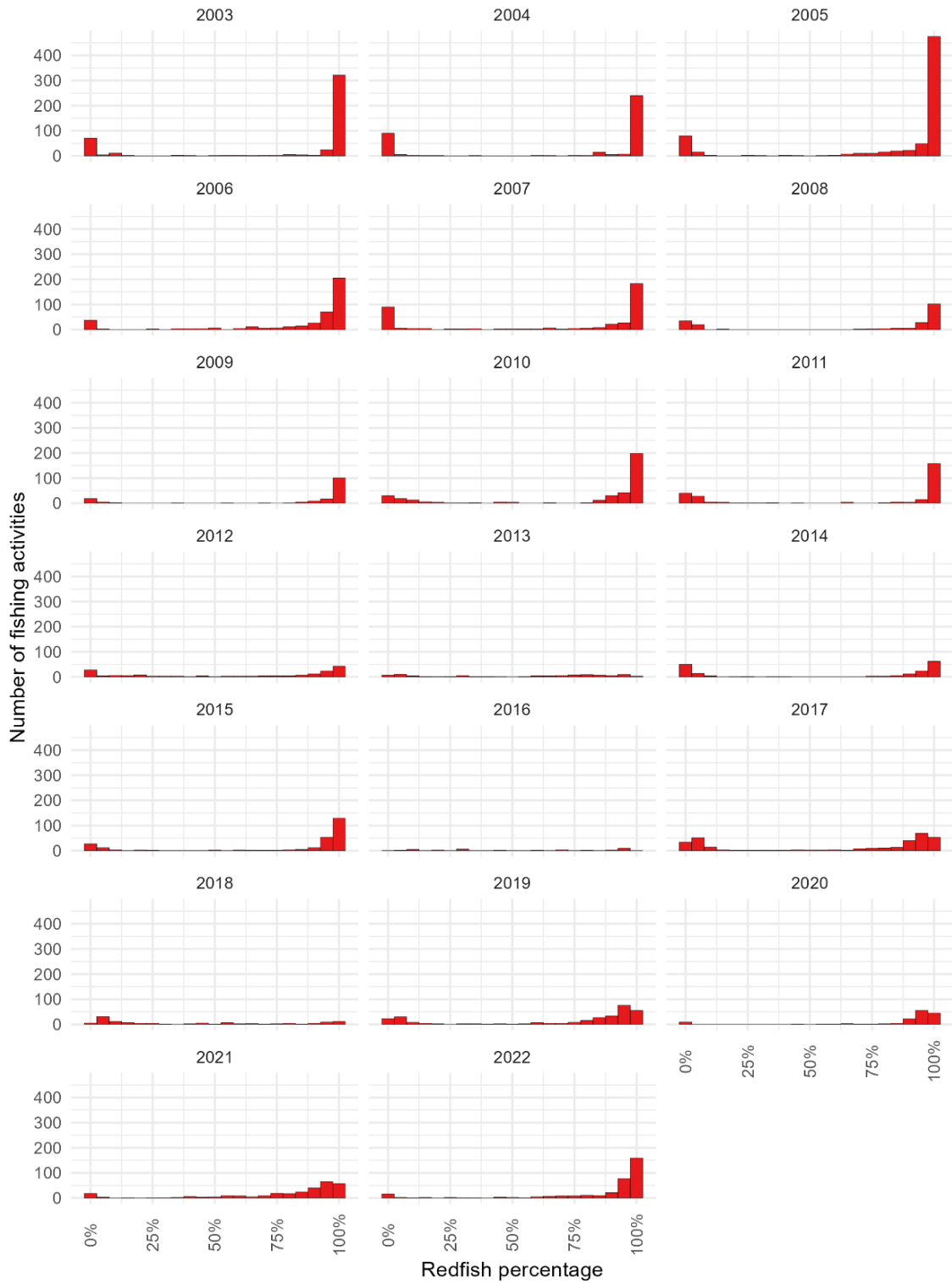


Figure 32. Number of fishing activities (sets) as a function of Redfish percentage per year for activities with unknown mesh size based on MARFIS.

Table 3. Variables and values used to query MARFIS with the *fleet_redfish* function from the *Mar.fleets* package.

Variable	Possible values	Complementary information
Licence type	0	Exempted vessel based
	1	Vessel based limited
	10	Enterprise allocation
	11	CC vessel based limited
License subtype	14	Midshore
	15	Offshore
	24	Fixed gear <50' – Groundfish
	28	Fixed gear <65' – Groundfish
	-99	NULL
License species	199	Groundfish, unspecified
NAFO areas	3Pn, 3Ps, 4Vn, 4Vs, 4Wf, 4Wg, 4Wj	
Gear	Otter trawl, stern	Mesh size between 90 and 130 mm*
	Otter trawl, side	Mesh size between 90 and 130 mm*
	Midwater trawl stern	Mesh size between 90 and 130 mm*
	Danish seine	Mesh size between 90 and 130 mm*
	Scottish seine	Mesh size between 90 and 130 mm*
	Gill net (set or fixed)	Minimal mesh size of 140 mm only in 3Ps*

*Mesh size restrictions were applied as filter after *fleet_redfish* extraction.

3.2.2. No quota period (1960-1992)

From 1960 to 1968, catches of Redfish in Unit 2 averaged around 20,000 t per year and increased to a time series high of 58,200 t in 1971, primarily due to increased catches by non-Canadian fleets. Since the declaration of the 200-mile Economic Exclusive Zone in 1977, Redfish have been primarily caught by Canadian fleets (DFO 2016). Subsequently, catches declined around 8,100 t in 1984 (Figure 33 and Table 4).

Landings were fairly evenly distributed across the seasons (Figure 34). Bottom trawls were generally the dominant gear used in the Redfish fishery, although there was an increase in the proportion of catch originating from midwater trawls from the mid-1980s to 2000, after which the proportion of midwater trawls continued to decline and has been essentially zero in recent years (Figure 35). This recent period is characterised by the dominance of vessels larger than 30.5 m (100 feet, Figure 36). The increase in catches in the late 1980s and early 1990s was driven primarily by depletion of other groundfish resources and increased interest in Redfish (DFO 2022).

3.2.3. Quota period (1993-present)

The first quota for Unit 2 was established in 1993 and was set at 28,000 t. After reaching slightly over 27,000 t in 1993, Redfish catches have overall declined and have remained well below the TAC since then. TACs were reduced to 10,000 t in 1996 and 1997, amid conservation concerns. The TAC was raised in 1998 and 1999 to 11,000 t and 12,000 t, respectively. The 1999 TAC was later adjusted in mid-1999 to 18,240 t, based on historical fishing patterns, to account for a

transition into the new management cycle that runs from April 1st of the current to March 31st of the following year. The 2000-2001 TAC was set at 10,000 t but was reduced to 8,000 t from 2001-2005. During the 2006-2007 fishing season, the TAC was raised to 8,500 t where it has remained since.

Overall, since 2002, landings have been well below the TAC (Figure 33 and Table 4). Landings increased from 5,890 t in 2020 to 7,750 t in 2022, and decreased to 4,867 t in 2023. Since 1995, most landings originated from Subdivisions 3Ps and 4Vs. Currently, Redfish are landed fairly uniformly across the fishing season (Figure 34), are driven primarily by bottom trawl (Figure 35), and vessels smaller than 30.5 m (100 feet) (Figure 36).

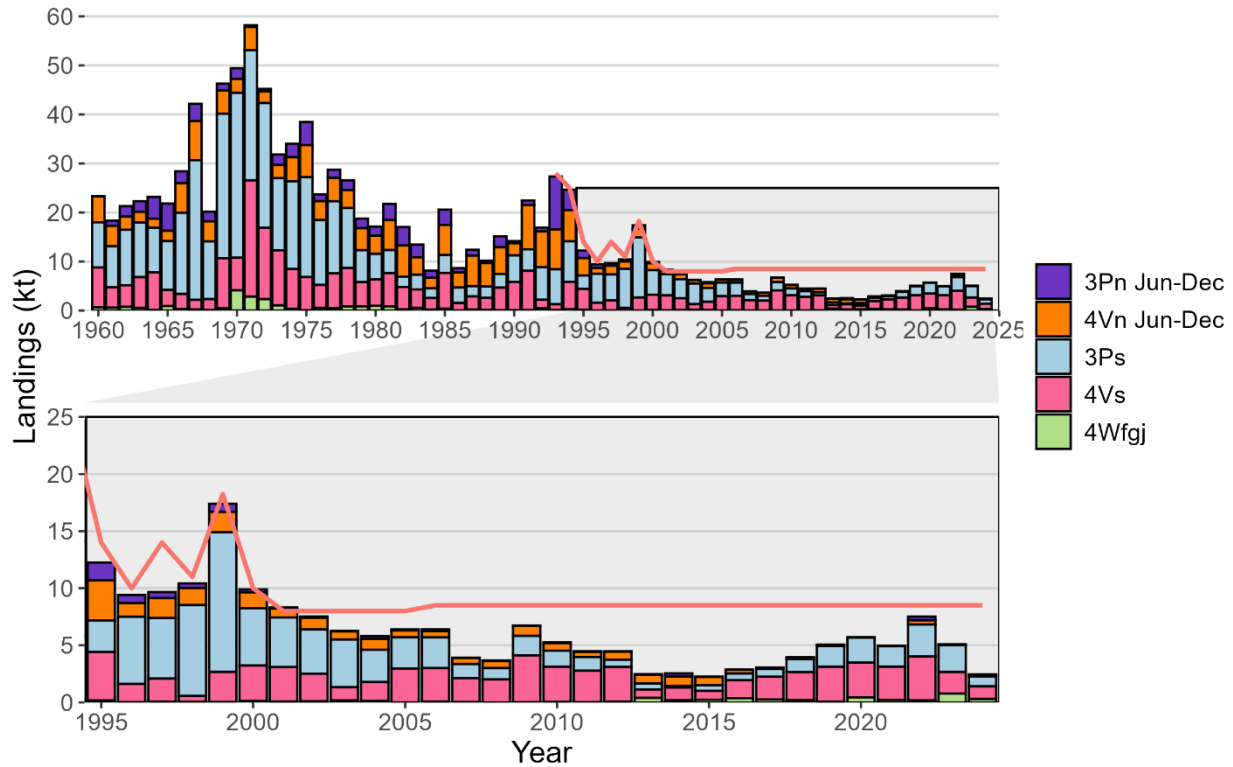


Figure 33. Commercial fishery annual Redfish landings in Unit 2 per NAFO Division or Subdivision from 1960 to 2024. Data include fisheries directed to all species. The total allowable catch (TAC) is indicated by a solid orange line. The grey zone in the top panel is enlarged in the bottom panel. 2020 to 2024 values are preliminary.

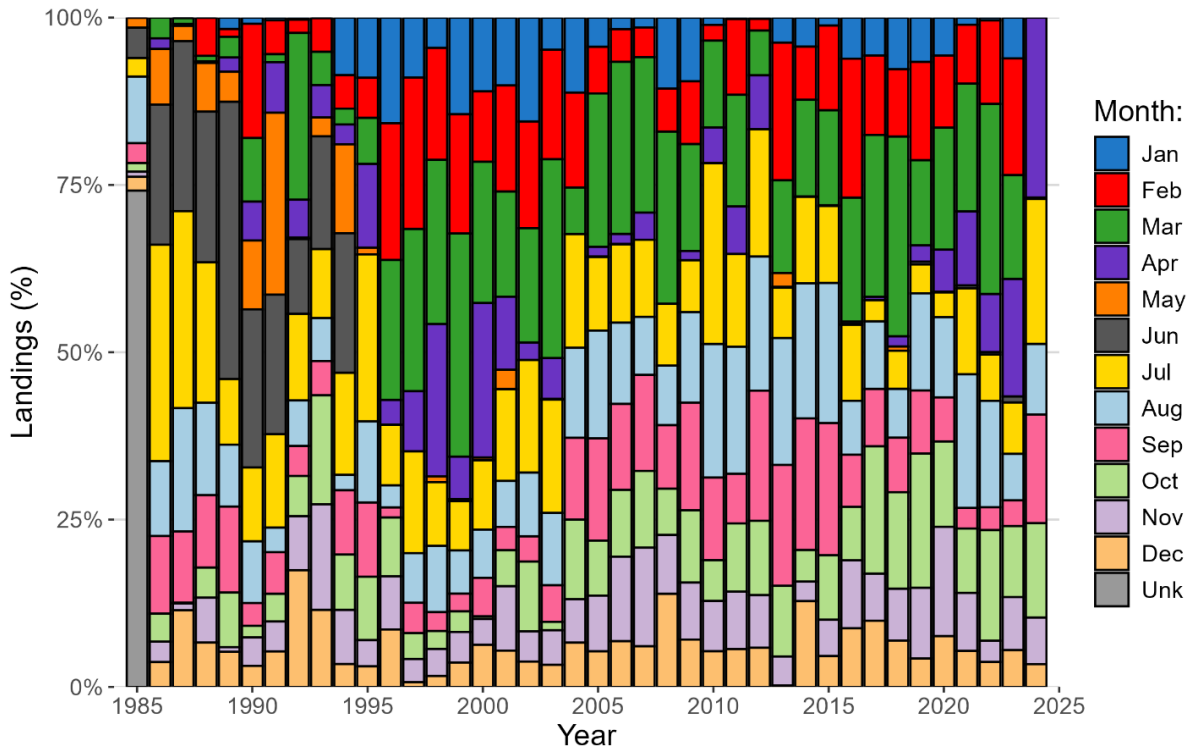


Figure 34. Redfish annual landings (biomass percentage) by month in Unit 2 from 1985 to 2024. 2020 to 2024 values are preliminary. Unk: unknown.

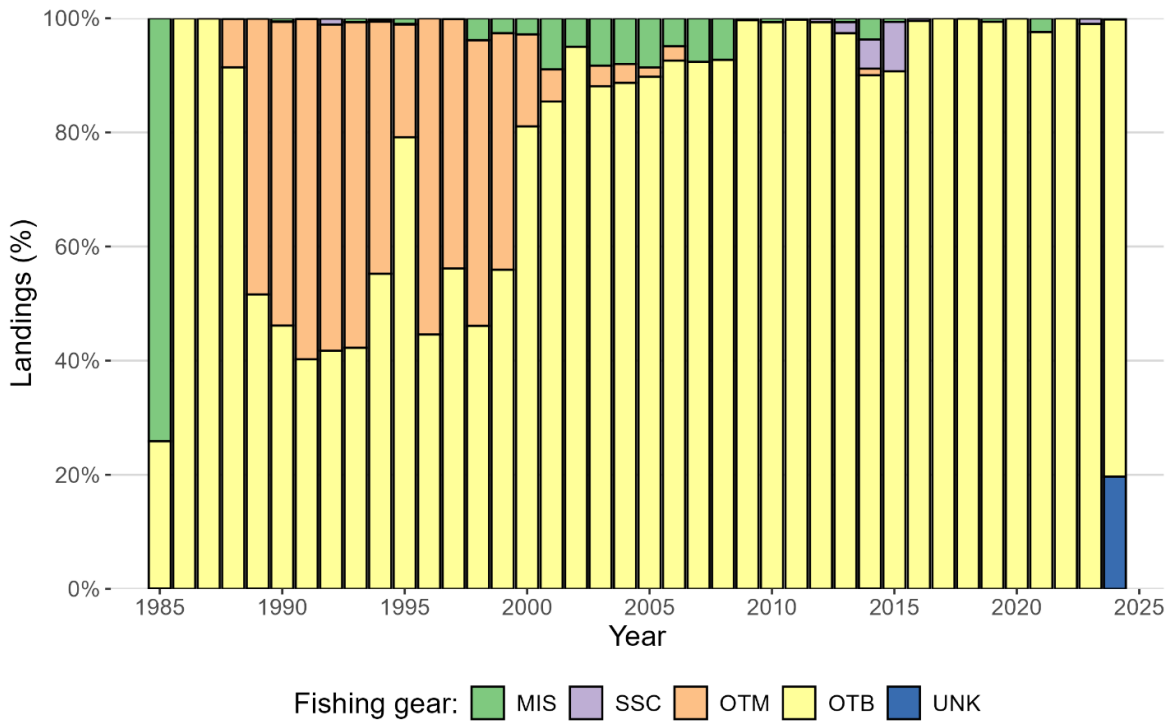


Figure 35. Redfish annual landings (biomass percentage) by gear in Unit 2 from 1985 to 2024. 2020 to 2024 values are preliminary. MIS: miscellaneous, SSC: Scottish seine, OTM: midwater trawl, OTB: bottom trawl, and UNK: unknown.

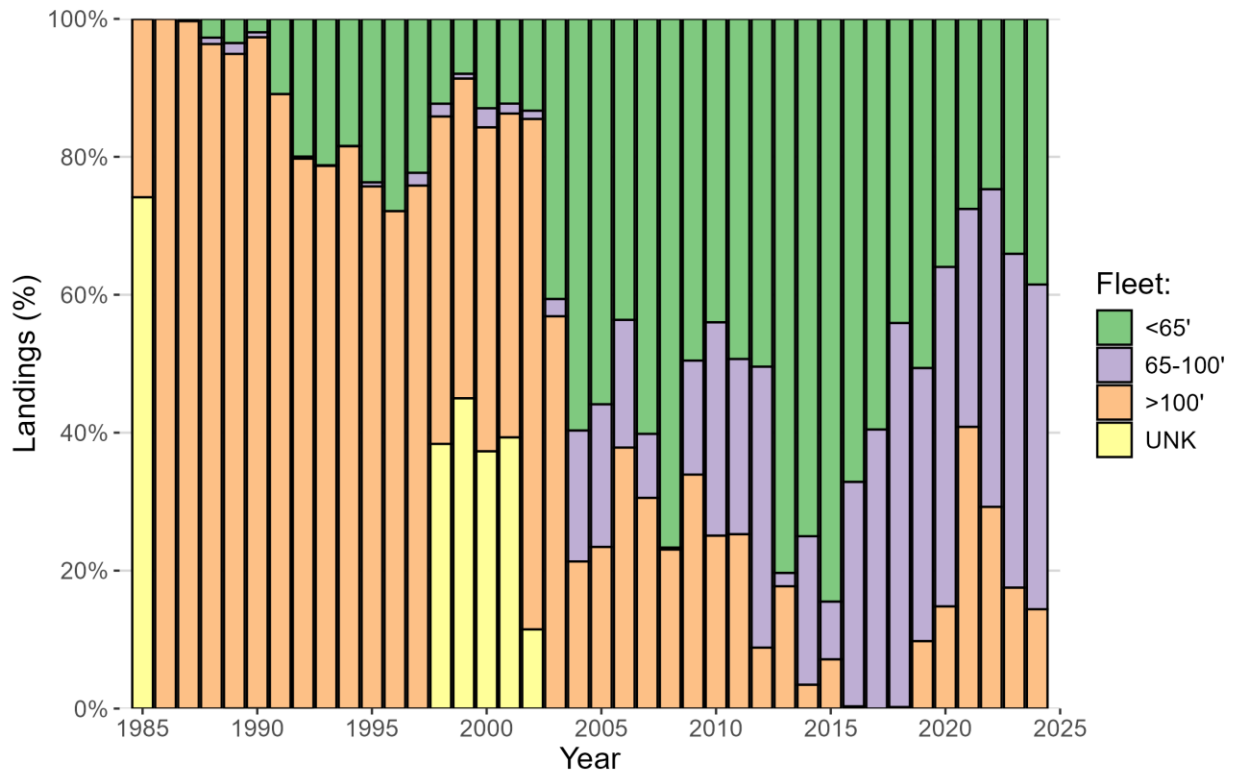


Figure 36. Redfish annual landings (biomass percentage) by boat size (feet) in Unit 2 from 1985 to 2024. 2020 to 2024 values are preliminary.

Table 4. Redfish annual landings (t) per NAFO areas and total allowable catches (TAC) per management cycle in Unit 2 from 1960 to 2024. Data include fisheries directed to all species. 2020 to 2024 values are preliminary.

Year	Landings (t)					Total	TAC
	3Pn	3Ps	4Vn	4Vs	4Wfgj		
1960	14	9211	5277	8122	663	23287	-
1961	1058	8340	4157	4170	604	18329	-
1962	2127	11306	2710	4372	780	21295	-
1963	2154	11150	2166	6270	550	22290	-
1964	4445	9119	1849	7629	150	23192	-
1965	5570	9931	2097	3319	917	21834	-
1966	2444	16543	6022	3067	316	28392	-
1967	3531	28465	7976	1989	209	42170	-
1968	1974	11764	4097	2222	112	20169	-
1969	1412	29460	4726	10241	437	46276	-
1970	2169	33581	2849	6694	4114	49407	-
1971	373	26534	4762	23698	2833	58200	-
1972	511	25398	2390	14580	2322	45201	-
1973	2133	14714	2709	11213	1058	31827	-
1974	2759	17894	4898	8112	375	34038	-
1975	4722	20345	6548	6791	65	38471	-
1976	1409	13235	3832	4718	515	23709	-
1977	1713	14678	4763	7123	473	28750	-
1978	1975	12203	3661	7856	853	26548	-
1979	1975	6459	4500	4979	858	18771	-
1980	1845	5192	3713	5431	948	17129	-
1981	3283	4685	6134	6789	860	21751	-
1982	3757	2090	6350	4585	243	17025	-
1983	2607	2996	3559	3758	553	13473	-
1984	1460	2005	2129	2367	180	8141	-
1985	3126	3656	6124	7298	388	20592	-
1986	888	3144	3054	1544	15	8645	-
1987	1215	2065	6225	2708	195	12408	-
1988	493	2283	4793	2444	156	10169	-
1989	2205	2802	5457	4590	81	15135	-
1990	424	5387	2489	5787	73	14160	-
1991	952	4364	9026	8026	98	22466	-
1992	792	6613	7318	1739	474	16936	-
1993	10798	7127	8102	1193	108	27328	28000
1994	4186	8241	6346	5604	267	24644	25000
1995	1547	2747	3535	4255	159	12243	14000
1996	709	5885	1202	1600	12	9408	10000
1997	523	5296	1758	2032	52	9661	10000
1998	396	7954	1507	532	31	10421	11000

Year	Landings (t)					Total	TAC
	3Pn	3Ps	4Vn	4Vs	4Wfgj		
1999	712	12232	1787	2651	21	17404	18240
2000	263	5009	1383	3119	120	9893	10000
2001	92	4356	791	3022	63	8324	8000
2002	109	3888	1013	2409	99	7518	8000
2003	34	4173	705	1172	163	6247	8000
2004	249	2823	942	1663	125	5802	8000
2005	92	2742	610	2951	1	6396	8000
2006	170	2675	541	2949	62	6397	8500
2007	20	1232	523	2111	19	3905	8500
2008	51	991	608	2015	1	3666	8500
2009	23	1723	869	4093	10	6717	8500
2010	66	1410	666	3085	30	5257	8500
2011	60	1187	454	2770	10	4481	8500
2012	29	632	706	3042	58	4468	8500
2013	76	536	740	737	388	2478	8500
2014	284	141	815	1113	189	2541	8500
2015	38	479	738	781	230	2267	8500
2016	4	590	325	1573	361	2854	8500
2017	25	678	109	2009	241	3062	8500
2018	21	1143	141	2446	206	3956	8500
2019	6	1827	107	3071	48	5060	8500
2020*	26	2345	10	3053	457	5890	8500
2021*	27	2178	12	2653	197	5066	8500
2022*	320	3016	373	3870	171	7750	8500
2023*	62	2014	36	1978	777	4867	8500
2024*	56	312	140	998	296	1801	8500

*Preliminary data as of February 2025.

3.3. LENGTH FREQUENCY IN UNIT 1

Fisheries catch length frequencies were determined from ASO data. Discarding of Redfish is illegal and is therefore not expected during trips covered by ASO (Benoit and Allard 2009). However, if discarding of small (undersize) Redfish occurs during trips not sampled by ASO, length frequencies may underrepresent the catches of small fish. From 1999 to 2018, catch length frequency has been more difficult to establish because fishing activities were scarce (especially since 2006). As a result, fewer Redfish were measured.

From 1999 to 2016, most Redfish caught by commercial fishing vessels were larger than 30 cm. The proportion of Redfish larger than 30 cm decrease from 2017 to 2024 with the arrival of the 2011-2013 cohorts. The somatic growth of individuals in these cohorts was apparent until 2021. Since then, their growth in length has appeared negligible (Figure 37 to Figure 39).

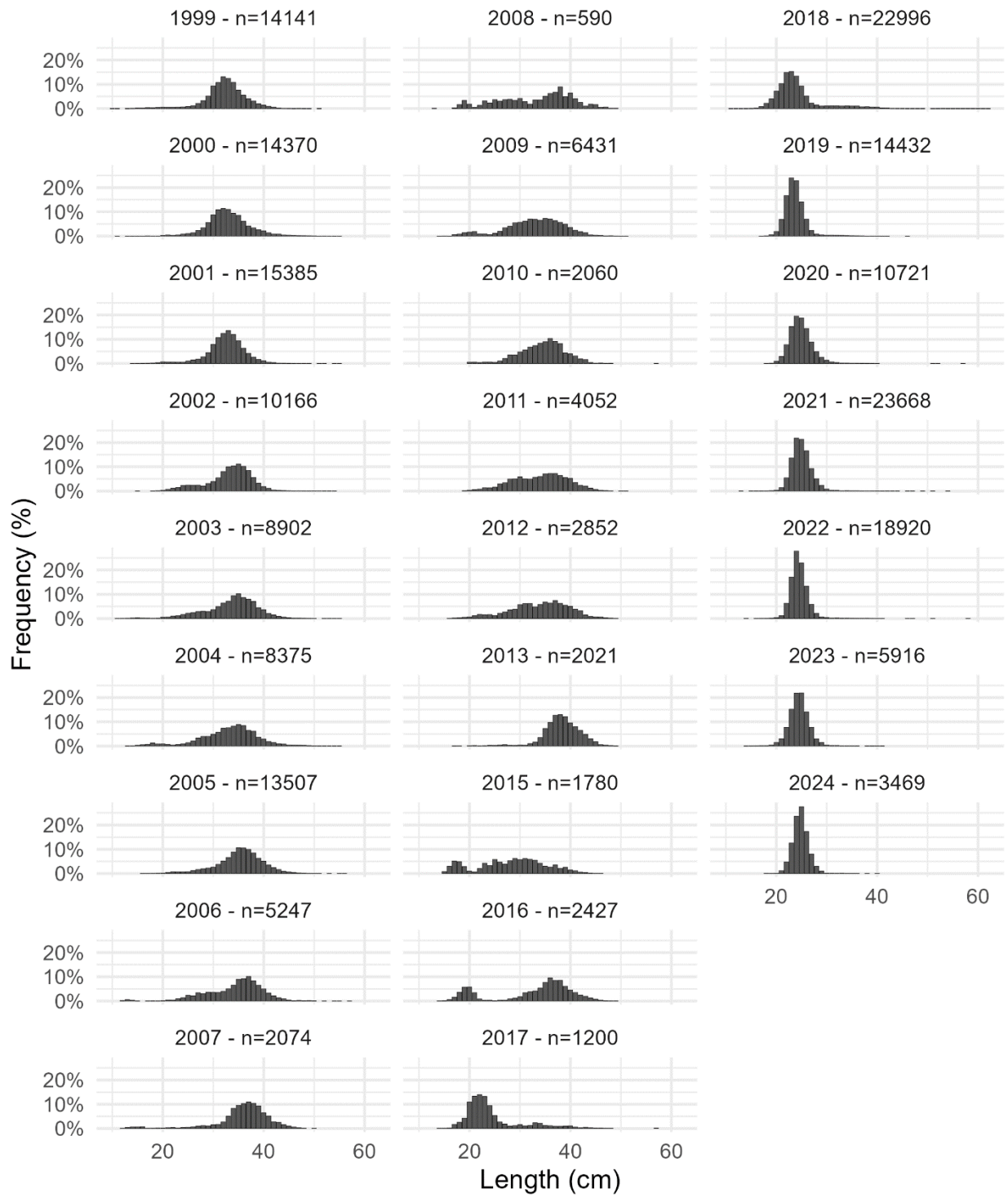


Figure 37. Redfish length frequency in percentage in Unit 1 from 1999 to 2024 based on at-sea-observer data. Numbers of fish measured are indicated (n). No fish were sampled in 2014. 2024 values are preliminary.

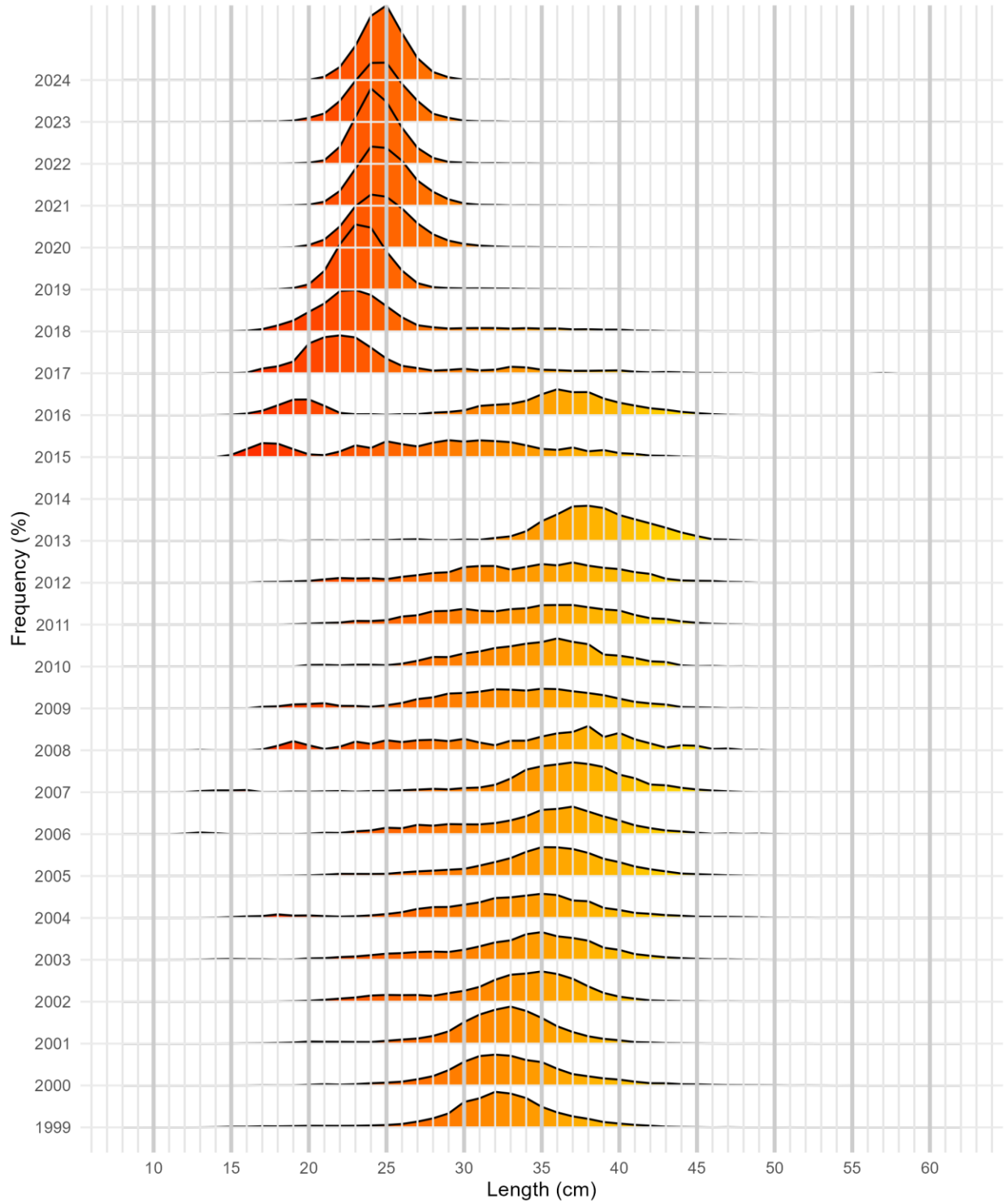


Figure 38. Redfish length frequency in percentage in Unit 1 from 1999 to 2024 based on at-sea-observer data. No fish were sampled in 2014. 2024 values are preliminary.

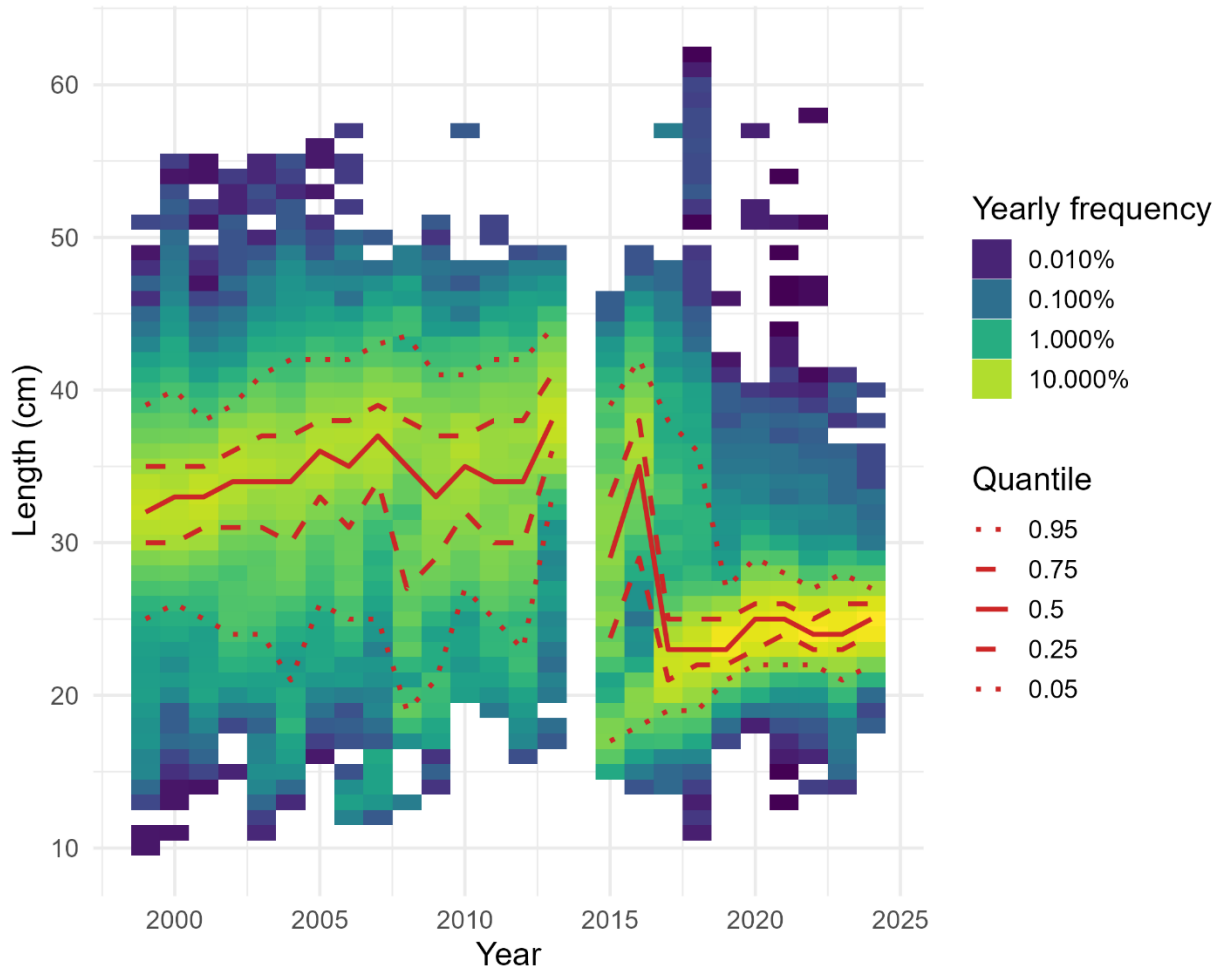


Figure 39. Redfish length frequency in percentage in Unit 1 from 1999 to 2024 based on at-sea-observer data. Fork length percentiles (0.05, 0.25, 0.5, 0.75, and 0.95) are shown for each year. No fish were sampled in 2014. 2024 values are preliminary.

3.4. LENGTH FREQUENCY IN UNIT 2

Length frequencies were derived from ASO data collected from 1999 to 2024. From 1999 to 2016, most Redfish caught were larger than 30 cm. Redfish larger than 30 cm were less frequent from 2017 to 2024. Compared to Unit 1, the arrival of the 2011-2013 cohorts was less apparent until the early 2020s and recent length frequencies were broader, suggesting that other cohorts had contributed more to the Redfish fishery in Unit 2 than in Unit 1 (Figure 40 to Figure 42).

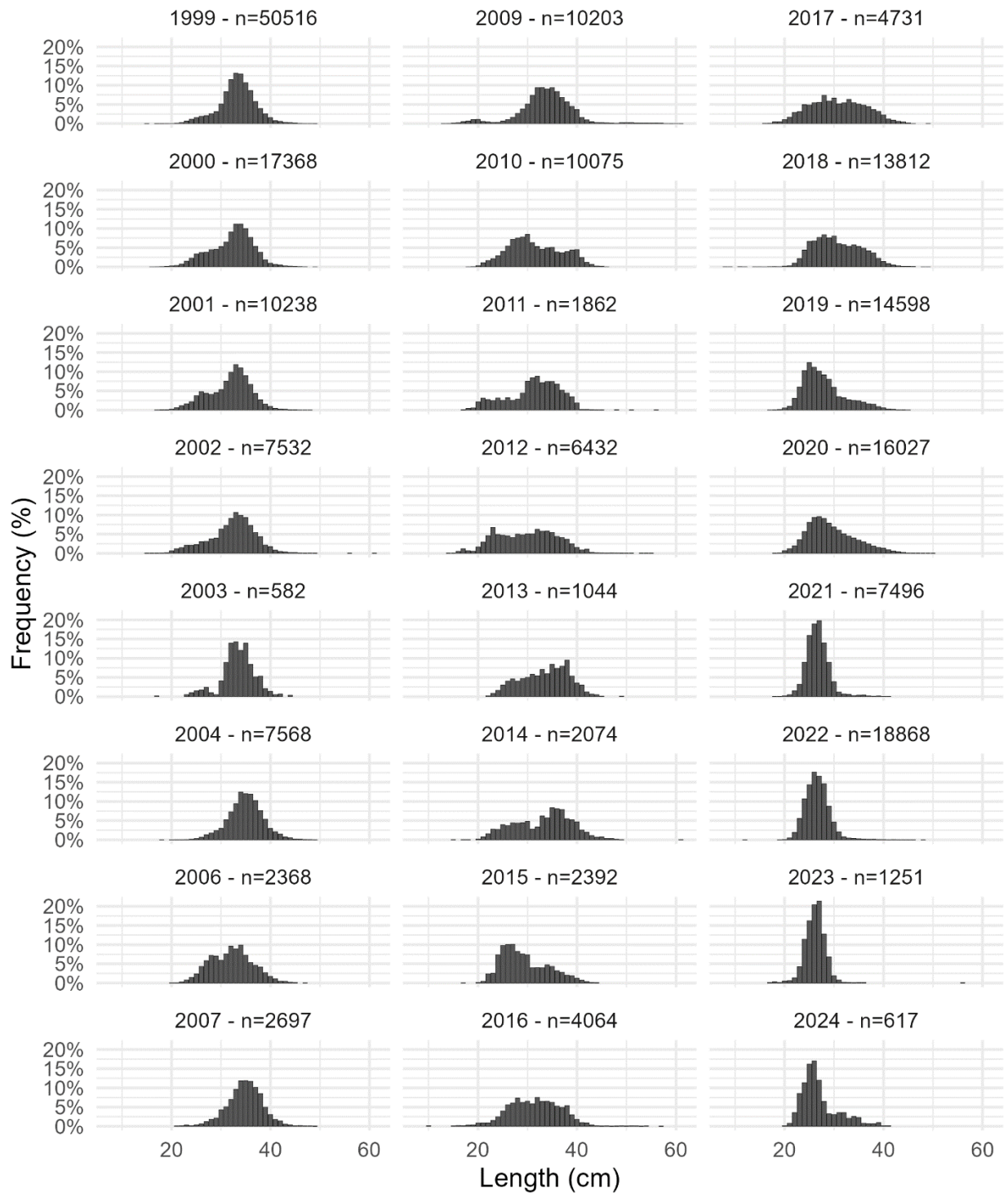


Figure 40. Redfish length frequency in percentage in Unit 2 from 1999 to 2024 based on at-sea-observer data. Numbers of fish measured are indicated (n). No Redfish was sampled in 2005 and 2008. 2024 values are preliminary.

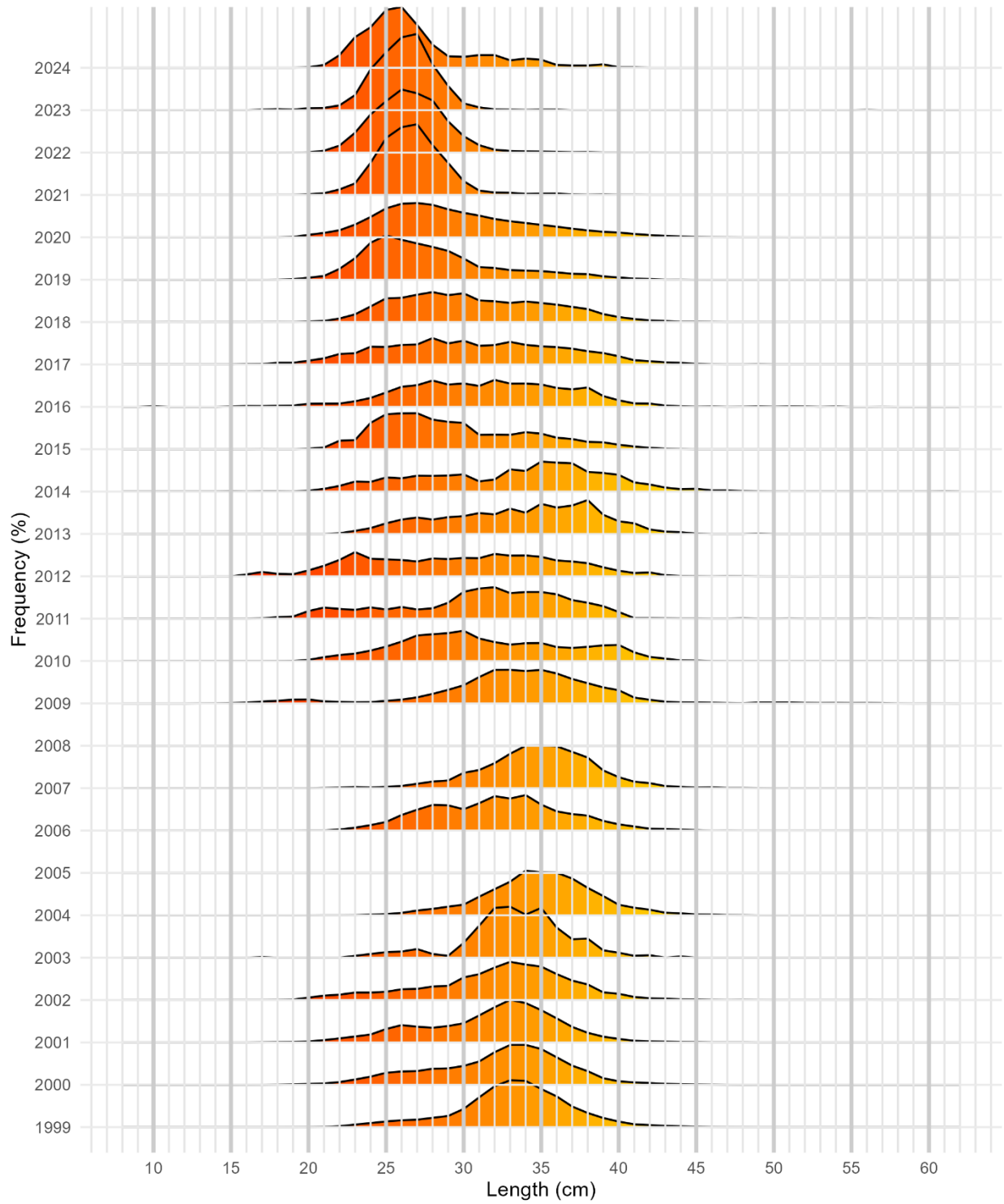


Figure 41. Redfish length frequency in percentage in Unit 2 from 1999 to 2024 based on at-sea-observer data. No fish were sampled in 2005 and 2008. 2024 values are preliminary.

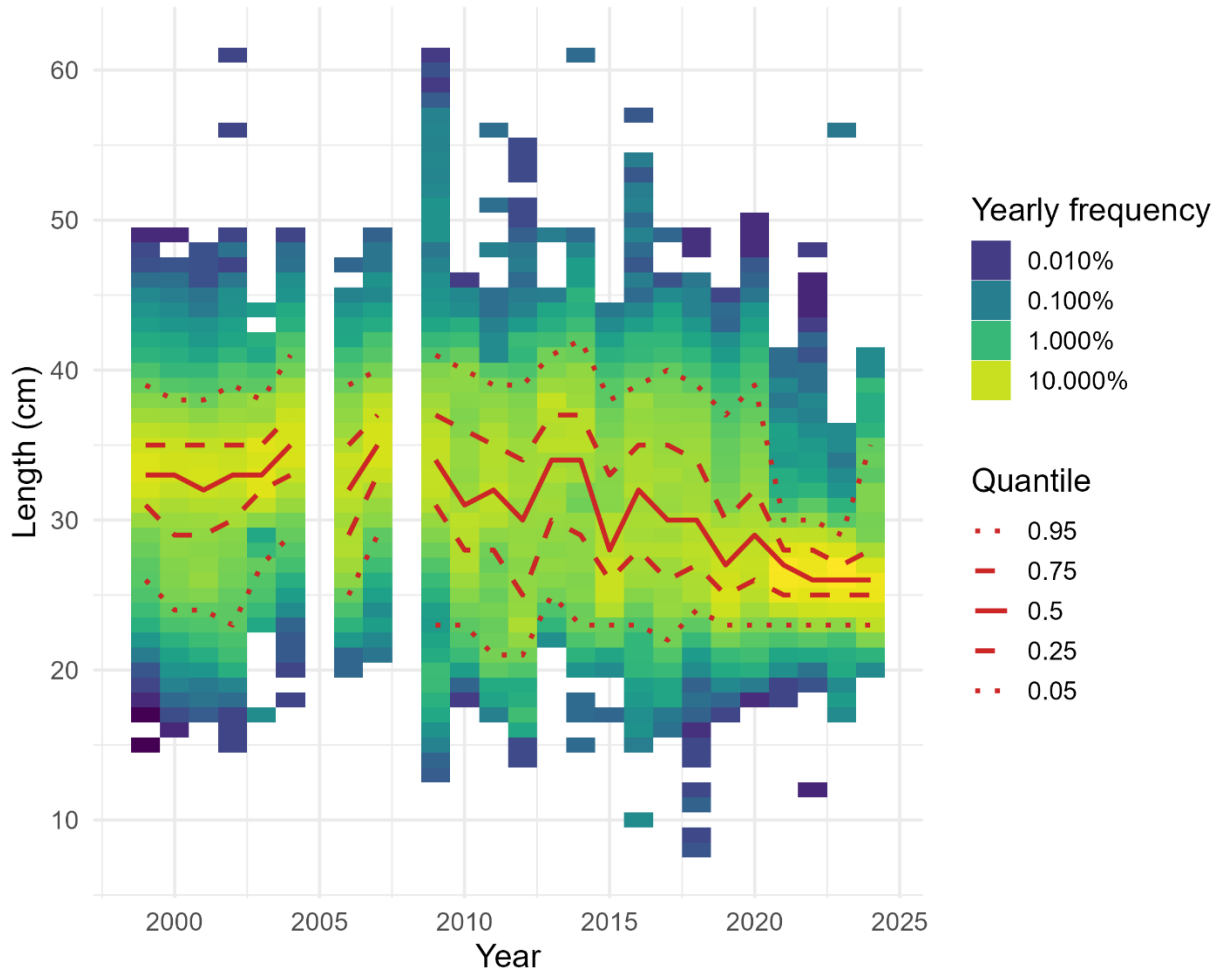


Figure 42. Redfish length frequency in percentage in Unit 2 from 1999 to 2024 based on at-sea-observer data. Fork length percentiles (0.05, 0.25, 0.5, 0.75 and 0.95) are shown for each year. No fish were sampled in 2005 and 2008. 2024 values are preliminary.

3.5. BYCATCH IN UNIT 1

Bycatch are common although commercial fishing attempts to minimize the capture of non-target species. Two data sources were combined to provide an overall picture of bycatch: the ZIFF and the ASO data. ZIFF data provided complete information on total reported landings. The ASO program covers a certain percentage of fishing trips. However, this program is the only source of data on at-sea discards and with GPS coordinates at the tow level.

3.5.1. ZIFF

Data from the dockside monitoring program recorded in ZIFF indicated that 93% of the reported Redfish catches from 2000 to 2024 came from the directed Redfish fisheries conducted in Unit 1, and 97% for the period from 2018 to the present (index, experimental and commercial fisheries combined). Fisheries targeting Greenland Halibut and Atlantic Cod were responsible for 3% and 2% of Redfish landings, respectively, on average for 2000 to 2024 (Figure 43). An elevated proportion of Redfish was landed by fishing activities targeting other species in 2007. This is likely due to the remarkably low levels of landings in the Redfish directed fishery that

year. In 2007, 27% of Redfish landed was caught in fishing activities with unknown targeted species.

Landings of species other than Redfish (i.e., bycatch species) have represented 5.1% of Redfish landings on average in the directed Redfish fishery since 2000, and 1.7% since 2018 (Figure 44). Since 2018, the most common bycatch were Atlantic Halibut (representing 33.0% of the bycatch biomass), Atlantic Cod (21.1%), White Hake (18.8%), and Greenland Halibut (10.4%, Figure 45 and Figure 46, Table 5 and Table 6). In recent years, the proportion of Greenland Halibut in the catches decreased while the proportion of Atlantic Halibut increased, most probably following stock trends (DFO 2023b).



Figure 43. Redfish annual landings (biomass percentage) in Unit 1 as a function of targeted species by the fishery from 2000 to 2024. 2020 to 2024 values are preliminary. Other may include unknown target species.

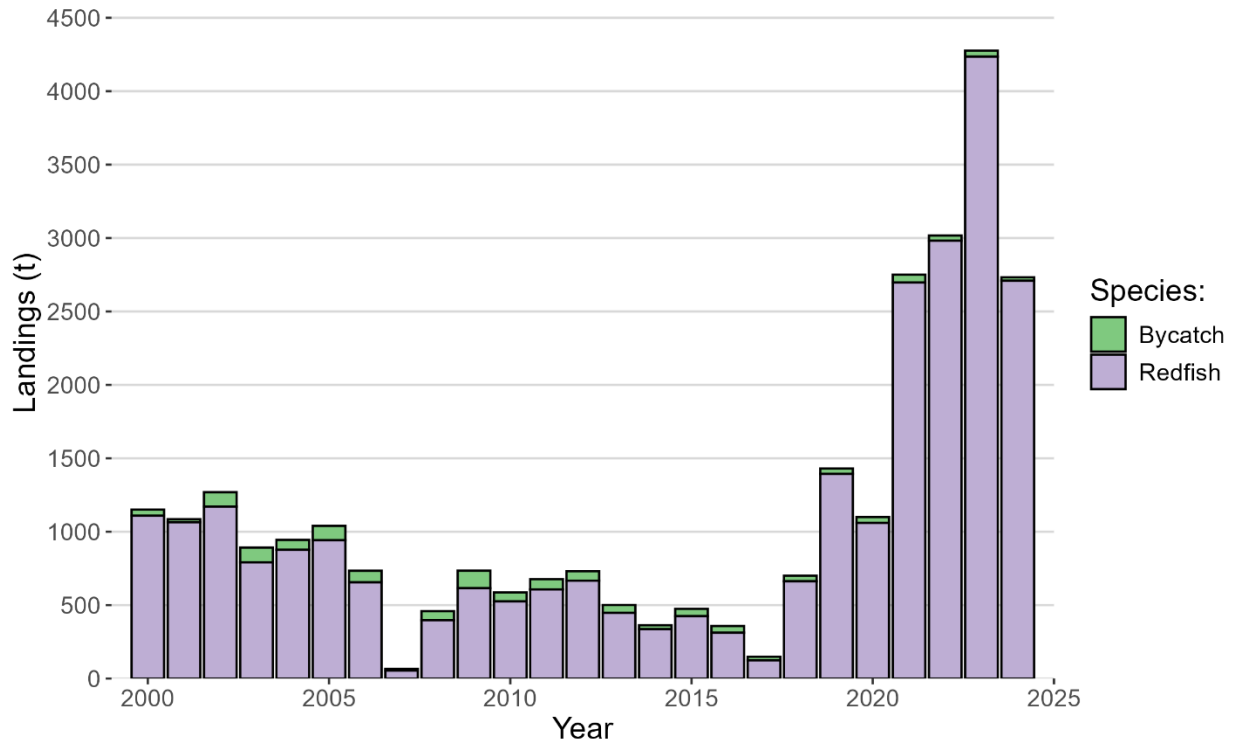


Figure 44. Annual landings of Redfish and bycatch (t) in the Redfish-directed fishery in Unit 1 from 2000 to 2024. 2020 to 2024 values are preliminary.

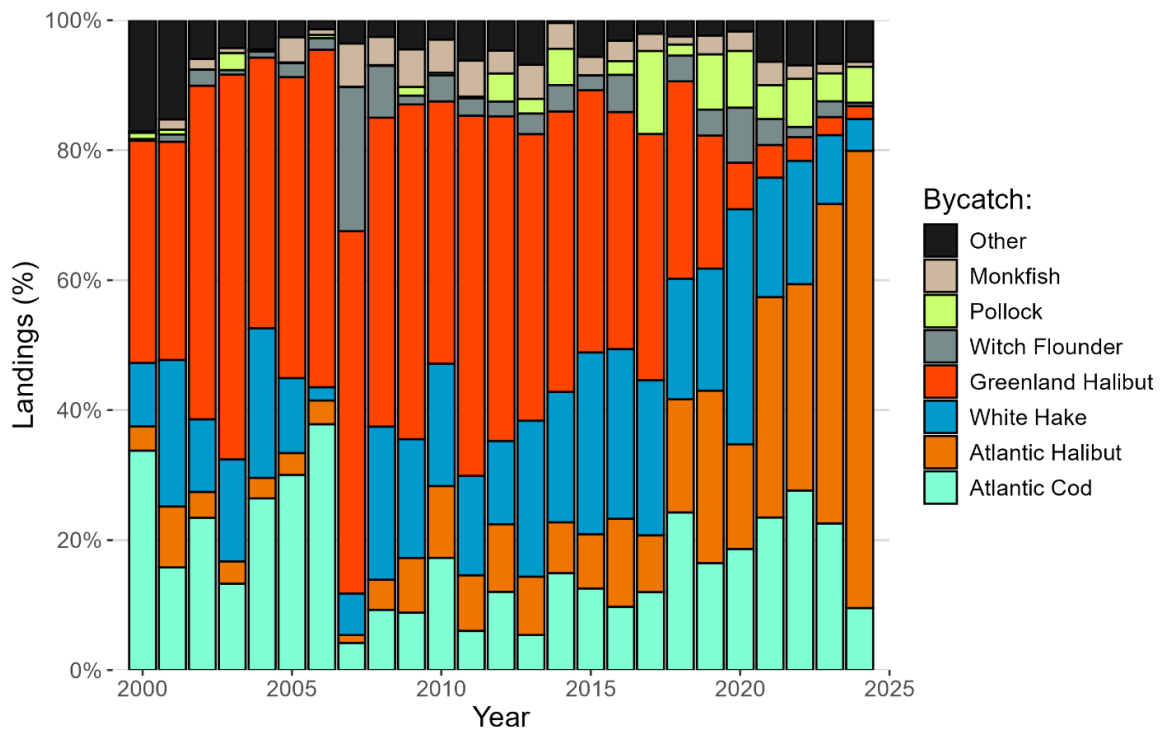


Figure 45. Annual bycatch landings (biomass percentage) by species captured in the Redfish-directed fishery in Unit 1 from 2000 to 2024. 2020 to 2024 values are preliminary.

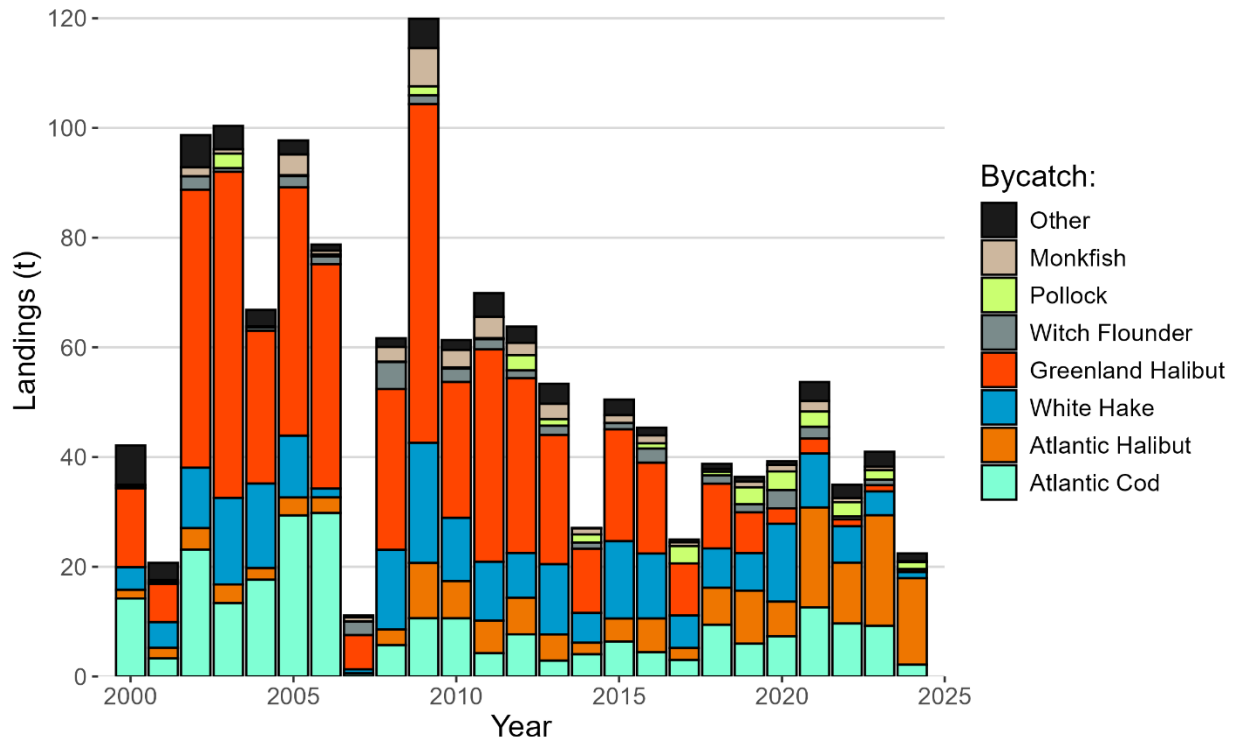


Figure 46. Annual bycatch landings (t) by species captured in the Redfish-directed fishery in Unit 1 from 2000 to 2024. 2020 to 2024 values are preliminary.

Table 5. Annual bycatch landings (biomass percentage) by species captured in the Redfish-directed fishery in Unit 1 from 2000 to 2024. 2020 to 2024 values are preliminary. Only species above 0.1% of annual landings for at least one year are shown.

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
American Plaice	1.1	0.5	1.9	1.0	0.5	0.3	0.1	2.4	0.9	1.9	2.0	4.1	1.8	5.0	0.0	5.6	2.0	0.0	2.0	0.8	1.5	1.8	3.0	0.6	0.9
Argentine	0.0	0.2	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	3.7	0.0	0.8
Atlantic Cod	33.8	15.8	23.4	13.3	26.4	30.0	37.8	4.2	9.3	8.9	17.3	6.0	12.1	5.4	14.9	12.6	9.7	12.0	24.3	16.5	18.6	23.5	27.6	22.5	9.5
Atlantic Halibut	3.7	9.4	4.0	3.4	3.2	3.4	3.7	1.2	4.6	8.4	11.0	8.5	10.4	9.0	7.8	8.3	13.6	8.7	17.4	26.5	16.1	33.9	31.8	49.2	70.4
Catfish	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Greenland Halibut	34.2	33.6	51.3	59.2	41.7	46.3	51.9	55.8	47.5	51.5	40.4	55.4	49.9	44.1	43.2	40.4	36.5	37.9	30.4	20.5	7.2	5.0	3.7	2.8	2.0
Haddock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.1	2.0	0.5	1.2	0.1	0.5	0.3	1.4	0.8
Herring	0.1	0.2	0.1	0.1	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mackerel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.2	0.0
Monkfish	0.2	1.6	1.7	0.8	0.2	3.9	0.9	6.7	4.4	5.8	5.1	5.6	3.5	5.3	4.0	2.9	3.2	2.7	1.3	2.9	3.0	3.6	2.1	1.5	0.8
Pollock	1.0	0.7	0.0	2.6	0.1	0.1	0.5	0.1	0.1	1.3	0.4	0.3	4.3	2.3	5.6	0.0	2.1	12.7	1.7	8.5	8.7	5.2	7.4	4.3	5.5
Porbeagle	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sculpins	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shortfin Mako	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silver Hake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.5	3.1
Skate	0.7	2.1	1.2	1.5	0.4	0.9	0.3	1.2	1.1	2.5	0.9	2.0	2.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Squalus Acanthias	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Squid	0.0	0.0	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
Unspecified Flounders	0.0	0.1	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified Groundfish	15.2	11.4	0.4	0.0	0.0	0.0	0.4	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
White Hake	9.7	22.5	11.2	15.7	23.0	11.5	2.0	6.4	23.5	18.2	18.8	15.3	12.8	24.0	20.0	28.0	26.1	23.8	18.5	18.8	36.1	18.4	18.9	10.6	4.9
Winter Flounder	0.0	0.0	0.0	1.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Witch Flounder	0.3	1.1	2.5	0.7	0.9	2.1	1.8	22.2	8.0	1.3	4.0	2.6	2.3	3.2	4.1	2.3	5.7	0.0	4.0	4.0	8.4	4.0	1.5	2.4	0.5
Yellowtail	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 1. Annual bycatch landings (kg) by species captured in the Redfish-directed fishery in Unit 1 from A) 2000-2012 and B) 2013-2024. 2020 to 2024 values are preliminary. Only species above 0.1% of annual landings for at least one year are shown.

A)

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
American Plaice	460	96	1916	1038	312	331	89	267	559	2246	1215	2876	1122
Argentine	0	48	163	168	93	0	56	0	0	0	0	0	0
Atlantic Cod	14230	3275	23125	13355	17656	29350	29788	466	5720	10619	10597	4224	7689
Atlantic Halibut	1573	1944	3933	3434	2112	3299	2875	135	2859	10087	6774	5967	6642
Catfish	11	118	219	28	18	0	0	0	0	0	0	0	0
Greenland Halibut	14412	6958	50653	59458	27844	45273	40888	6220	29313	61774	24756	38745	31869
Haddock	5	0	10	4	0	0	0	0	3	0	2	2	0
Herring	30	35	112	87	0	998	1	0	208	0	0	38	0
Mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0
Monkfish	98	333	1638	800	132	3801	677	743	2694	6955	3149	3881	2256
Pollock	409	153	9	2642	100	128	395	6	55	1615	236	178	2765
Porbeagle	0	0	0	0	36	0	0	0	0	0	0	0	126
Sculpins	0	0	0	0	763	0	0	0	0	0	0	0	0
Shortfin Mako	0	0	0	0	0	141	0	0	0	0	0	0	77
Silver Hake	0	0	0	0	0	0	0	0	0	0	0	0	0
Skate	287	442	1157	1517	239	858	257	133	699	3012	558	1419	1559
Squalus Acanthias	0	0	1845	0	22	0	0	0	0	0	0	0	0
Squid	0	0	3	0	194	0	359	0	6	0	0	0	42
Unspecified Flounders	0	17	24	5	165	79	0	0	0	0	0	0	0
Unspecified Groundfish	6402	2371	361	0	0	29	306	0	98	98	24	0	54
White Hake	4097	4674	11015	15749	15387	11245	1599	710	14514	21879	11546	10701	8160
Winter Flounder	0	0	0	1420	1086	0	0	0	0	0	0	20	0
Witch Flounder	106	230	2452	674	619	2066	1409	2473	4915	1604	2456	1848	1443
Yellowtail	0	22	0	0	0	0	0	0	0	0	0	0	0

B)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
American Plaice	2660	0	2816	924	11	769	287	589	940	1040	255	209
Argentine	0	7	0	0	0	0	0	0	617	1291	0	176
Atlantic Cod	2878	4041	6341	4415	3000	9410	5994	7311	12597	9653	9238	2140
Atlantic Halibut	4791	2119	4215	6150	2181	6751	9645	6335	18214	11097	20154	15790
Catfish	0	0	0	0	0	0	0	0	0	0	0	0
Greenland Halibut	23543	11698	20380	16554	9467	11781	7450	2819	2702	1283	1142	451
Haddock	0	108	0	498	508	198	420	21	269	96	571	190
Herring	0	0	0	0	0	0	0	0	0	0	0	0
Mackerel	0	0	0	0	0	0	0	0	1424	0	68	0
Monkfish	2803	1080	1453	1435	670	485	1058	1181	1934	728	621	174
Pollock	1203	1513	2	960	3182	655	3087	3425	2797	2587	1765	1242
Porbeagle	0	0	0	0	0	0	0	0	0	0	0	0
Sculpins	0	0	0	0	0	0	0	0	0	0	0	0
Shortfin Mako	0	0	0	0	0	0	0	0	0	0	0	0
Silver Hake	0	0	0	0	0	0	0	0	183	5	1834	696
Skate	557	0	0	2	0	0	0	0	0	0	5	2
Squalus Acanthias	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0	0	0	0	7	74	68	0	0	0	0
Unspecified Flounders	0	0	31	0	0	0	0	0	6	0	0	0
Unspecified Groundfish	0	0	0	0	0	0	0	0	0	0	0	159
White Hake	12799	5432	14122	11850	5956	7192	6831	14185	9852	6621	4330	1094
Winter Flounder	437	0	0	0	0	0	68	0	0	0	0	0
Witch Flounder	1690	1101	1138	2589	0	1537	1457	3317	2140	540	989	110
Yellowtail	0	0	0	0	0	0	0	0	0	0	0	0

3.5.2. At-sea observer

3.5.2.1. Bycatch levels

From 1999 to 2024, 3,506 sets sampled as part of the ASO program were retained for analysis (Figure 47). During the experimental and index fishery period (2018-2023), the most frequent bycatch species were White Hake (caught in 62% of fishing activities), Witch Flounder (*Glyptocephalus cynoglossus*, 50%), Atlantic Cod (49%), and Atlantic Halibut (48%, Table 7). The 2018-2024 period is also characterised by lower bycatch rates than previous years, with no bycatch species being above 1% overall. Bycatch rates for 2020-2024 must be interpreted with caution as these data are preliminary. Bycatch rates disaggregated by NAFO Division and period are presented in Table 8. Discarding of small quantities of groundfish is reported in recent years even if it is not authorized in most cases.

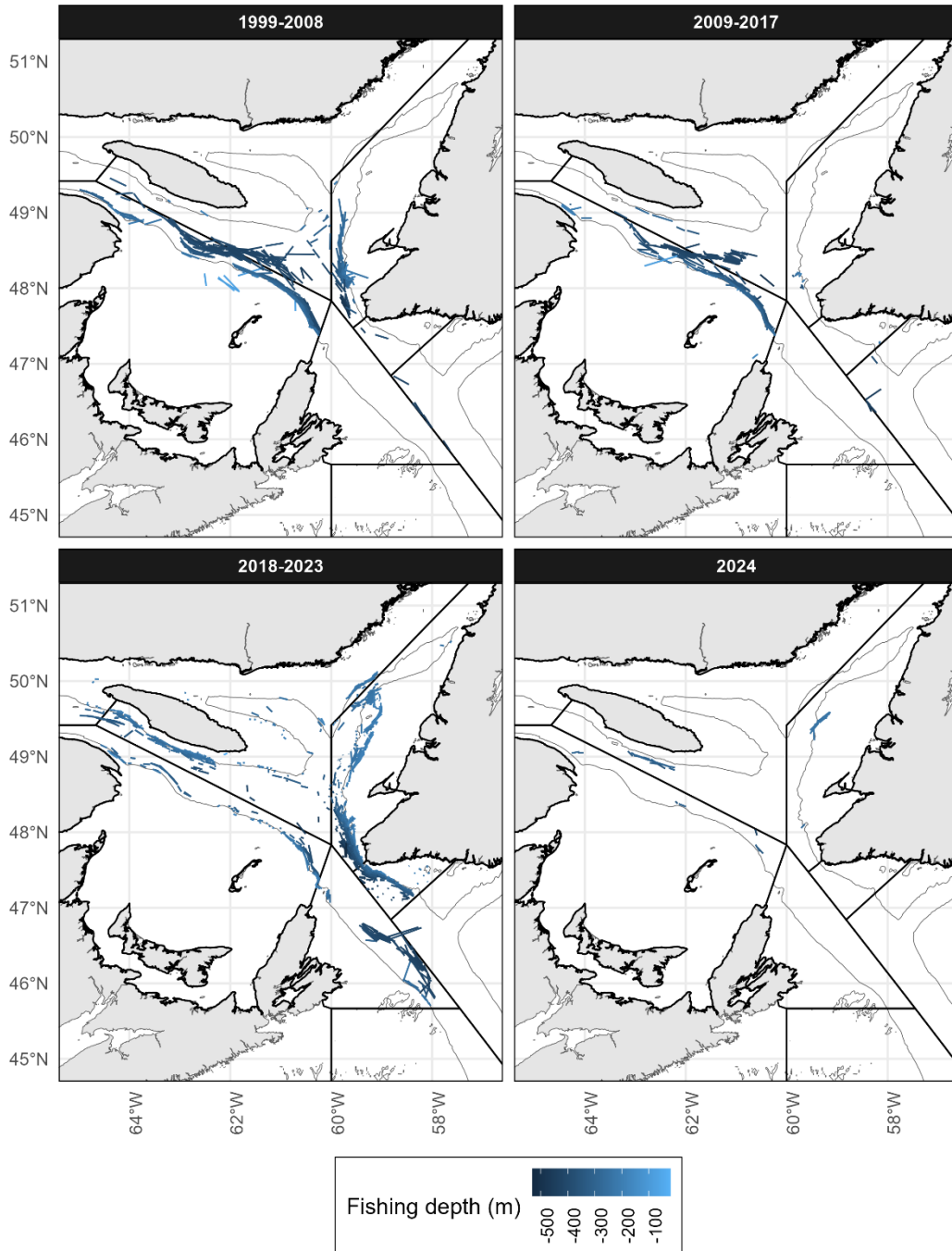


Figure 47. Start and end position of tows sampled by at-sea observers by period in Unit 1 from 1999 to 2024 in the Redfish-directed fishery. The grey line corresponds to the 240 m isobath. The color of the blue lines corresponds to depth. 2020 to 2024 values are preliminary.

Table 7. Occurrence percentage (%), biomass (kg), landed catches percentage (%), and percentage of each species biomass as a function Redfish biomass (%) based on at-sea observer data for the Redfish-directed fishery by periods from 1999 to 2024 in Unit 1. 2024 values are preliminary.

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
1999-2008				
Redfish	99.78	1211956	99.89	100.00
Greenland Halibut	66.97	47012	99.71	3.88
White Hake	45.58	10936	94.54	0.90
Witch Flounder	37.29	1823	99.45	0.15
Atlantic Cod	36.73	40524	100.00	3.34
Atlantic Halibut	16.13	2493	90.61	0.21
American Plaice	11.53	477	100.00	0.04
Pollock	8.29	1262	99.68	0.10
Haddock	1.01	124	100.00	0.01
Silver Hake	0.22	14	100.00	0.00
2009-2017				
Redfish	99.73	290088	99.09	100.00
Greenland Halibut	90.72	20259	99.89	6.98
White Hake	76.39	7652	63.07	2.64
Witch Flounder	58.62	1433	96.72	0.49
Atlantic Halibut	46.68	4637	80.05	1.60
Atlantic Cod	45.09	4592	97.63	1.58
American Plaice	14.85	171	96.49	0.06
Pollock	6.37	1849	6.27	0.64
Silver Hake	3.98	78	0.00	0.03
Haddock	1.06	12	16.67	0.00
2018-2023				
Redfish	99.45	5726419	99.46	100.00
White Hake	62.74	29232	62.05	0.51
Witch Flounder	49.77	23668	74.51	0.41
Atlantic Cod	48.99	33732	80.62	0.59
Atlantic Halibut	48.35	52158	69.21	0.91
Silver Hake	24.29	3962	42.86	0.07
Greenland Halibut	22.46	5627	84.56	0.10
Pollock	16.77	5602	80.76	0.10
American Plaice	9.44	1532	70.30	0.03
Haddock	3.02	434	36.87	0.01
2024				
Redfish	100.00	198240	99.91	100.00
White Hake	70.37	321	47.98	0.16
Atlantic Halibut	48.15	525	85.33	0.26
Silver Hake	18.52	10	20.00	0.01
Greenland Halibut	18.52	31	93.55	0.02
Witch Flounder	18.52	28	53.57	0.01
American Plaice	11.11	7	100.00	0.00
Atlantic Cod	3.70	2	100.00	0.00
Haddock	3.70	4	0.00	0.00

Table 8. Occurrence percentage (%), biomass (kg), landed catches percentage (%), and percentage of each species biomass as a function Redfish biomass (%) based on at-sea observer data for the Redfish-directed fishery from 1999 to 2024 in Unit 1 disaggregated by NAFO Divisions and Subdivisions, and periods. 2024 values are preliminary.

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
1999-2008 - 3Pn				
Redfish	100.00	206	100.00	100.00
White Hake	75.00	4	100.00	1.94
Atlantic Cod	25.00	3	100.00	1.46
Witch Flounder	25.00	1	100.00	0.49
1999-2008 - 4R				
Redfish	100.00	666350	100.00	100.00
White Hake	49.23	2305	98.79	0.35
Atlantic Cod	45.15	5924	100.00	0.89
Greenland Halibut	44.39	1153	99.22	0.17
Witch Flounder	29.85	422	100.00	0.06
American Plaice	16.07	73	100.00	0.01
Pollock	15.82	1225	99.67	0.18
Atlantic Halibut	15.56	1086	93.37	0.16
Haddock	1.79	122	100.00	0.02
Silver Hake	0.51	14	100.00	0.00
1999-2008 - 4S				
Redfish	100.00	60894	100.00	100.00
Greenland Halibut	92.65	6353	100.00	10.43
Witch Flounder	38.24	119	98.32	0.20
Atlantic Cod	29.41	1997	100.00	3.28
White Hake	17.65	143	100.00	0.23
Atlantic Halibut	13.24	225	96.00	0.37
American Plaice	5.88	19	100.00	0.03
Haddock	1.47	1	100.00	0.00
Pollock	1.47	1	100.00	0.00
1999-2008 - 4T				
Redfish	99.53	469892	99.71	100.00
Greenland Halibut	83.92	38052	99.67	8.10
White Hake	45.86	8274	93.12	1.76
Witch Flounder	43.50	1096	99.27	0.23
Atlantic Cod	30.02	32554	100.00	6.93
Atlantic Halibut	17.49	1182	87.06	0.25
American Plaice	7.80	360	100.00	0.08
Pollock	2.13	26	100.00	0.01
Haddock	0.24	1	100.00	0.00
1999-2008 - 4Vn				
Redfish	100.00	14614	100.00	100.00
Greenland Halibut	100.00	1454	100.00	9.95
White Hake	83.33	210	100.00	1.44
Witch Flounder	83.33	185	100.00	1.27
Atlantic Cod	50.00	46	100.00	0.31
American Plaice	50.00	25	100.00	0.17
Pollock	33.33	10	100.00	0.07
2009-2017 - 3Pn				

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
Redfish	100.00	581	99.48	100.00
Silver Hake	66.67	5	0.00	0.86
Atlantic Cod	33.33	10	100.00	1.72
White Hake	33.33	80	100.00	13.77
American Plaice	33.33	20	100.00	3.44
Witch Flounder	33.33	45	100.00	7.75
2009-2017 - 4R				
Redfish	100.00	10242	95.96	100.00
Greenland Halibut	76.47	157	98.73	1.53
Atlantic Cod	41.18	672	100.00	6.56
White Hake	41.18	44	100.00	0.43
Atlantic Halibut	41.18	231	75.76	2.26
Pollock	35.29	1735	3.69	16.94
Witch Flounder	29.41	16	100.00	0.16
American Plaice	23.53	4	75.00	0.04
Haddock	17.65	10	0.00	0.10
Silver Hake	5.88	5	0.00	0.05
2009-2017 - 4S				
Redfish	100.00	63167	99.17	100.00
Greenland Halibut	100.00	2799	99.93	4.43
White Hake	76.47	154	48.70	0.24
Witch Flounder	68.63	135	83.70	0.21
Atlantic Cod	58.82	48	64.58	0.08
Atlantic Halibut	39.22	595	98.32	0.94
Silver Hake	5.88	4	0.00	0.01
American Plaice	5.88	3	100.00	0.00
Pollock	3.92	14	0.00	0.02
2009-2017 - 4T				
Redfish	99.67	210048	99.19	100.00
Greenland Halibut	90.70	16033	99.88	7.63
White Hake	79.07	7367	62.71	3.51
Witch Flounder	58.14	1097	97.72	0.52
Atlantic Halibut	49.17	3789	77.51	1.80
Atlantic Cod	42.19	3795	97.58	1.81
American Plaice	15.95	144	96.53	0.07
Pollock	4.98	98	51.02	0.05
Silver Hake	2.99	64	0.00	0.03
Haddock	0.33	2	100.00	0.00
2009-2017 - 4Vn				
Redfish	100.00	6050	100.00	100.00
Atlantic Cod	100.00	67	100.00	1.11
Greenland Halibut	100.00	1270	100.00	20.99
Witch Flounder	100.00	140	100.00	2.31
White Hake	60.00	7	100.00	0.12
Pollock	20.00	2	100.00	0.03
Atlantic Halibut	20.00	22	68.18	0.36
2018-2023 - 3Pn				
Redfish	99.79	1538980	99.95	100.00
White Hake	71.16	7262	60.59	0.47

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
Atlantic Cod	57.05	14250	84.38	0.93
Silver Hake	45.64	1288	14.91	0.08
Atlantic Halibut	41.70	7644	14.95	0.50
Witch Flounder	31.74	821	59.07	0.05
Pollock	16.60	1005	89.65	0.07
Greenland Halibut	8.30	133	46.62	0.01
Haddock	3.94	89	67.42	0.01
American Plaice	3.11	24	33.33	0.00
2018-2023 - 4R				
Redfish	99.35	2876445	99.31	100.00
White Hake	55.46	14095	45.41	0.49
Witch Flounder	52.94	17888	71.11	0.62
Atlantic Cod	46.87	12837	75.53	0.45
Atlantic Halibut	44.72	29451	79.04	1.02
Silver Hake	19.70	1113	5.30	0.04
Pollock	17.55	2675	65.16	0.09
Greenland Halibut	10.83	760	31.97	0.03
American Plaice	5.60	1124	66.01	0.04
Haddock	3.08	317	22.71	0.01
2018-2023 - 4S				
Redfish	98.94	600608	98.39	100.00
White Hake	59.26	1847	79.48	0.31
Atlantic Halibut	55.29	7757	63.36	1.29
Witch Flounder	55.29	1291	69.95	0.21
Atlantic Cod	52.65	3954	73.70	0.66
Greenland Halibut	49.21	1607	86.81	0.27
American Plaice	26.98	172	69.77	0.03
Silver Hake	15.87	124	40.32	0.02
Pollock	12.43	874	95.77	0.15
Haddock	1.59	7	100.00	0.00
2018-2023 - 4T				
Redfish	100.00	213307	99.89	100.00
White Hake	74.63	1964	91.96	0.92
Atlantic Halibut	59.70	2296	78.05	1.08
Greenland Halibut	56.72	2217	97.20	1.04
Witch Flounder	49.25	913	86.20	0.43
Atlantic Cod	41.79	2415	94.58	1.13
Pollock	21.64	961	99.48	0.45
American Plaice	19.40	201	97.51	0.09
Silver Hake	8.21	51	64.71	0.02
Haddock	2.24	11	100.00	0.01
2018-2023 - 4Vn				
Redfish	100.00	497079	99.92	100.00
White Hake	92.31	4064	100.00	0.82
Witch Flounder	77.78	2755	99.49	0.55
Atlantic Halibut	73.50	5010	99.18	1.01
Greenland Halibut	61.54	910	99.23	0.18
Atlantic Cod	31.62	276	100.00	0.06
Silver Hake	23.93	1386	98.41	0.28
Pollock	18.80	87	100.00	0.02

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
Haddock	4.27	10	100.00	0.00
American Plaice	2.56	11	100.00	0.00
2024 - 4R				
Redfish	100.00	128489	99.95	100.00
White Hake	52.63	164	0.00	0.13
Atlantic Halibut	52.63	160	63.75	0.12
Haddock	10.53	4	0.00	0.00
Witch Flounder	10.53	12	0.00	0.01
2024 - 4S				
Redfish	100.00	57340	99.93	100.00
White Hake	85.71	147	100.00	0.26
Atlantic Halibut	42.86	268	92.91	0.47
Silver Hake	32.14	9	22.22	0.02
Greenland Halibut	21.43	6	100.00	0.01
Witch Flounder	17.86	5	80.00	0.01
American Plaice	10.71	3	100.00	0.01
Atlantic Cod	7.14	2	100.00	0.00
2024 - 4T				
Redfish	100.00	12411	99.45	100.00
White Hake	57.14	10	70.00	0.08
Atlantic Halibut	57.14	97	100.00	0.78
Greenland Halibut	57.14	25	92.00	0.20
American Plaice	42.86	4	100.00	0.03
Witch Flounder	42.86	11	100.00	0.09
Silver Hake	14.29	1	0.00	0.01

3.5.2.2. Spatial distribution

The spatial distribution of Redfish and most important bycatch species in the Redfish-directed fishery for different time periods from 1999 to 2024 were mapped (Figure 48 to Figure 52). Unfortunately, in the most recent time period, no specific location seemed to allow for high Redfish catches while minimizing catches of all other species. For instance, high Redfish catches were observed in 4Vn, while they were low for Atlantic Cod and high for White Hake.

Specific depths can be prescribed to target Redfish and avoid certain non-targeted species, which can vary among seasons. Before 2018, in the summer index fishery, White Hake and Atlantic Cod were caught at a shallower depth than Redfish (Figure 53 and Table 9). Species separation according to depth, however, appeared to be less contrasted in recent years (2018 to 2023) which coincide with the introduction of the experimental fishery all year round. Species depth preference may vary across seasons. For instance, Atlantic Cod depth distribution in the Redfish-directed fishery appears to follow closely that of Redfish. Additional analysis of species spatiotemporal distribution may be required to find appropriate measures to further reduce bycatch levels.

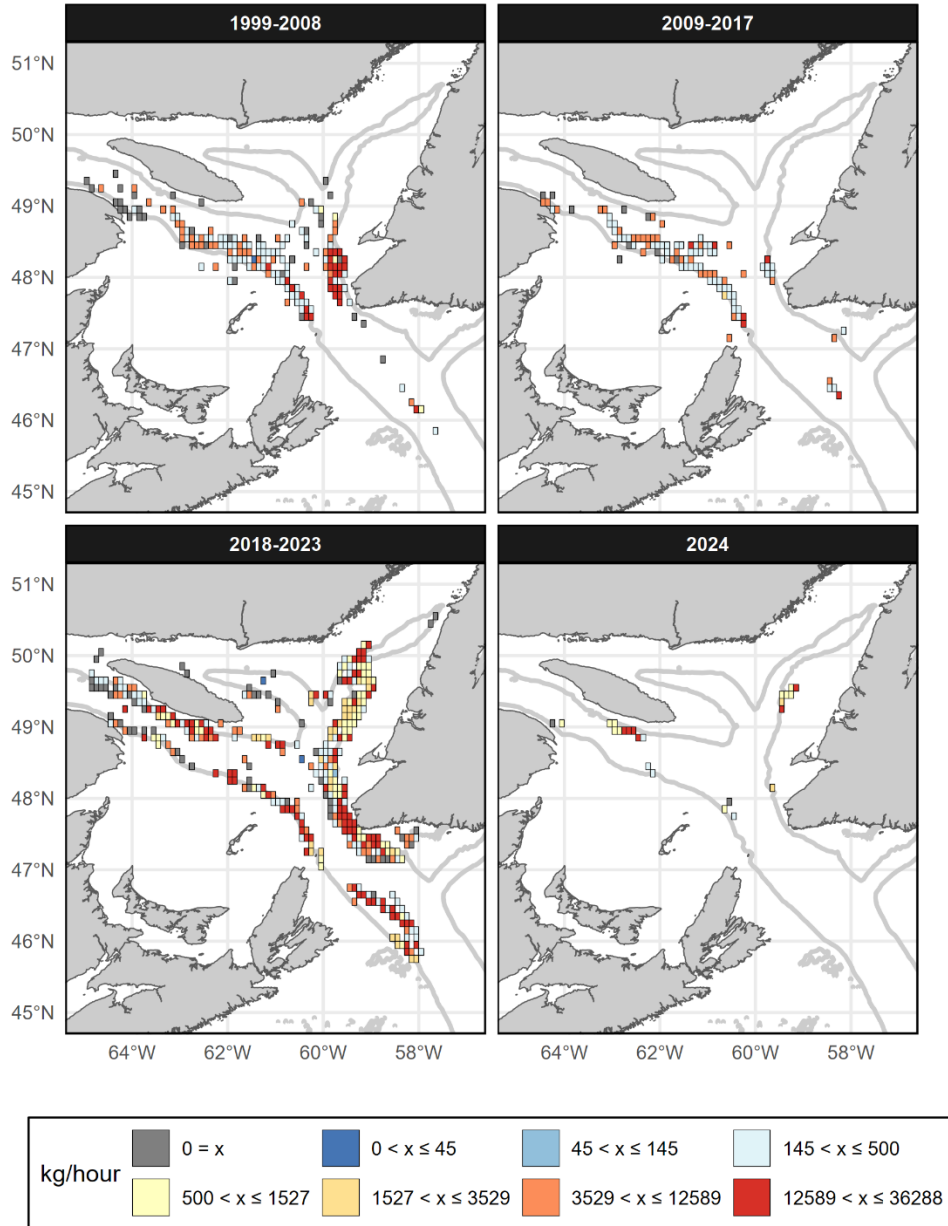


Figure 48. Catch rate (mean kg/hour) spatial distribution of Redfish based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 1. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

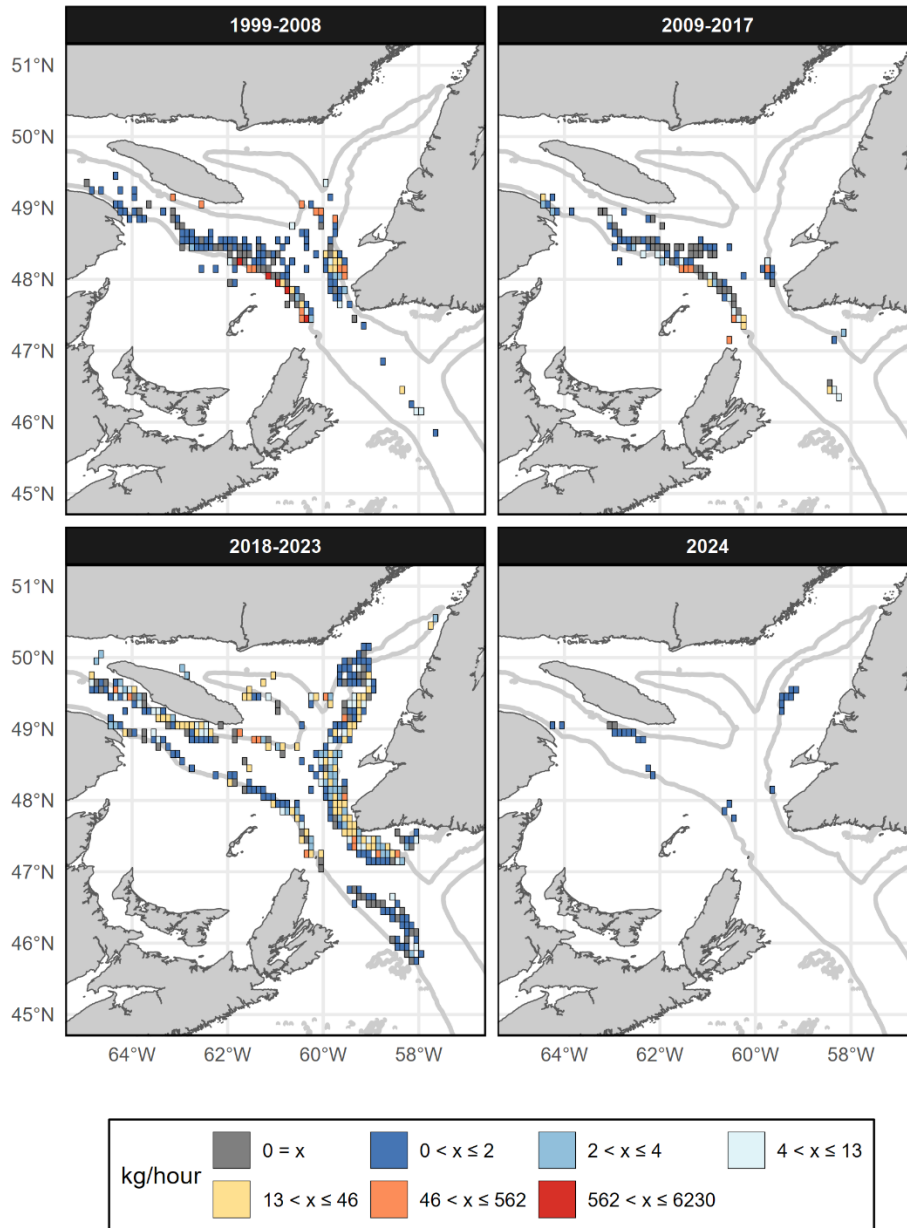


Figure 49. Catch rate (mean kg/hour) spatial distribution of Atlantic Cod based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 1. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

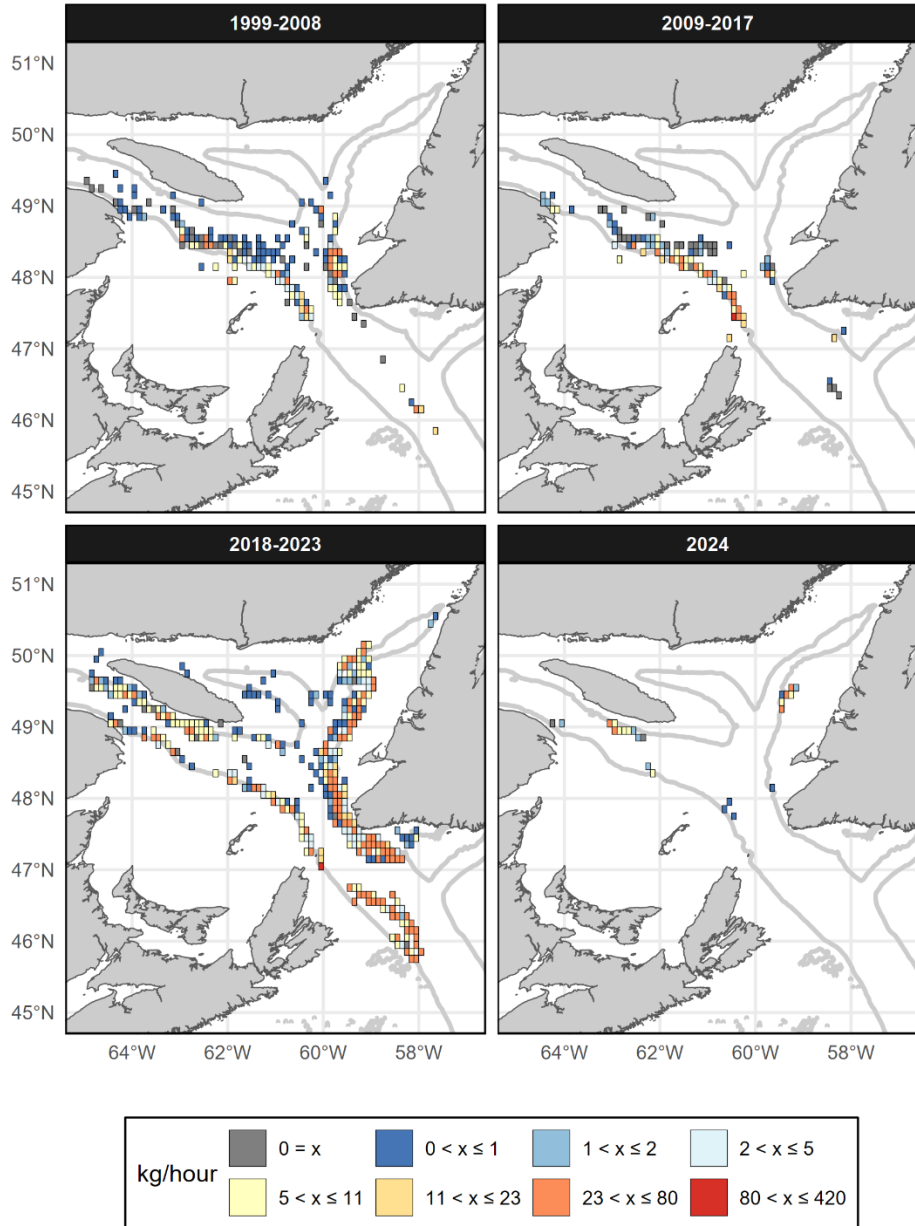


Figure 50. Catch rate (mean kg/hour) spatial distribution of White Hake based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 1. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

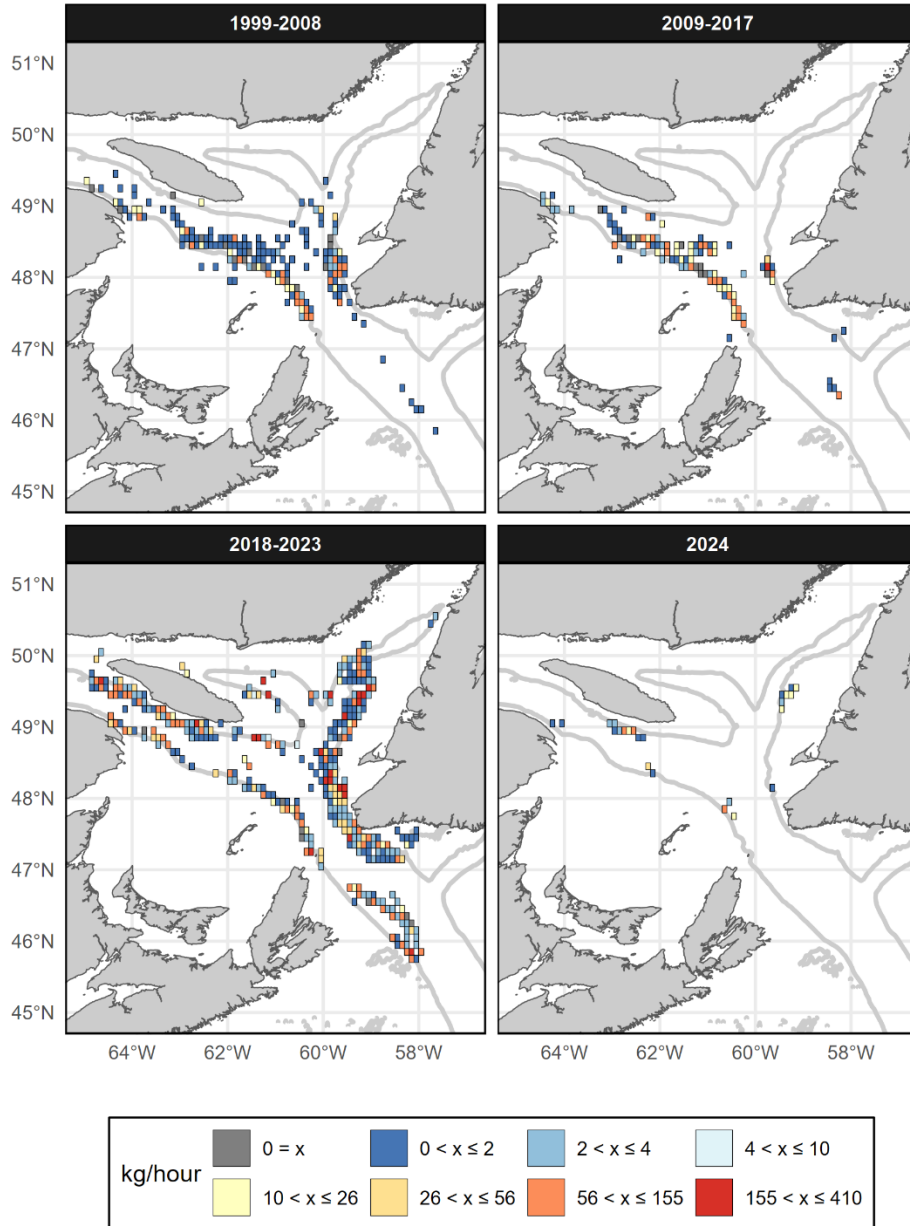


Figure 51. Catch rate (mean kg/hour) spatial distribution of Atlantic Halibut based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 1. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

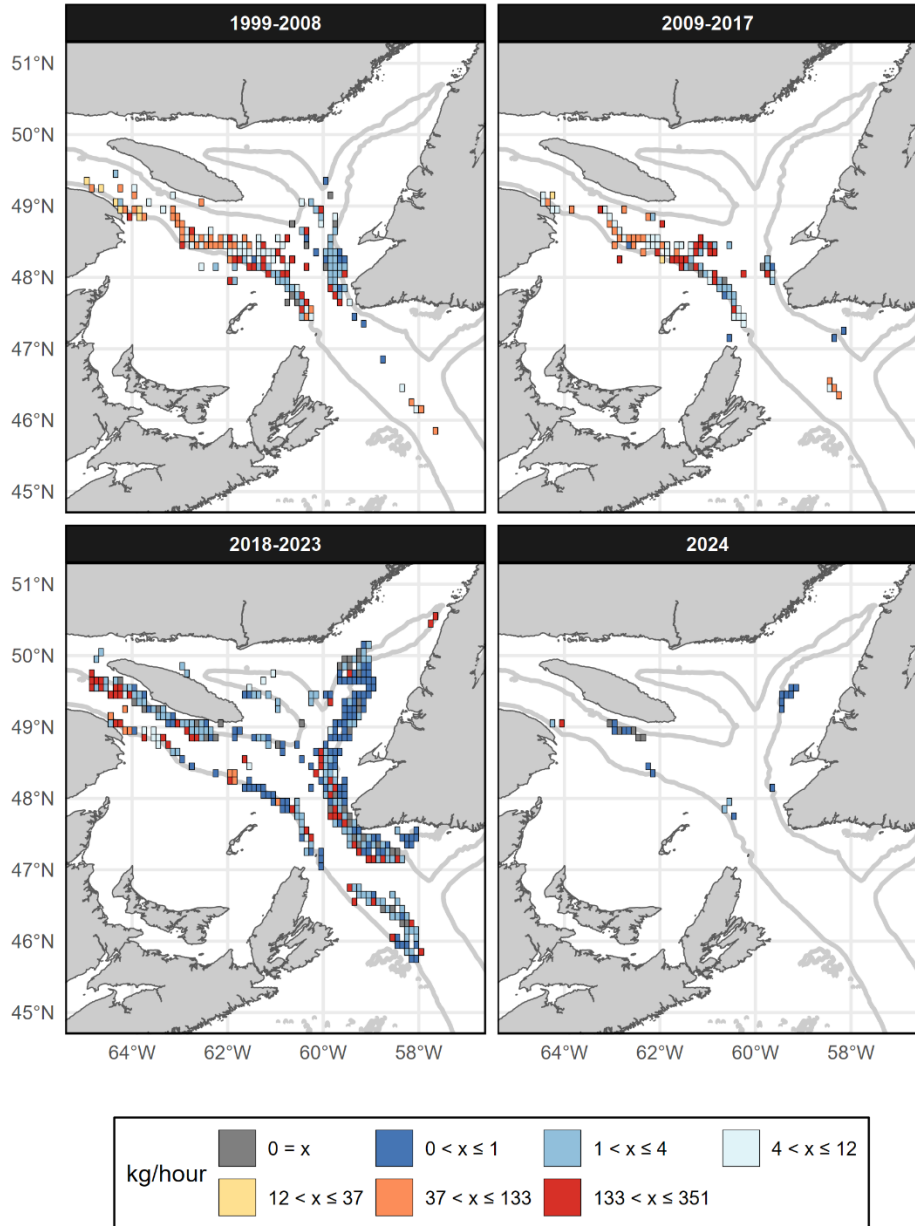


Figure 52. Catch rate (mean kg/hour) spatial distribution of Greenland Halibut based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 1. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

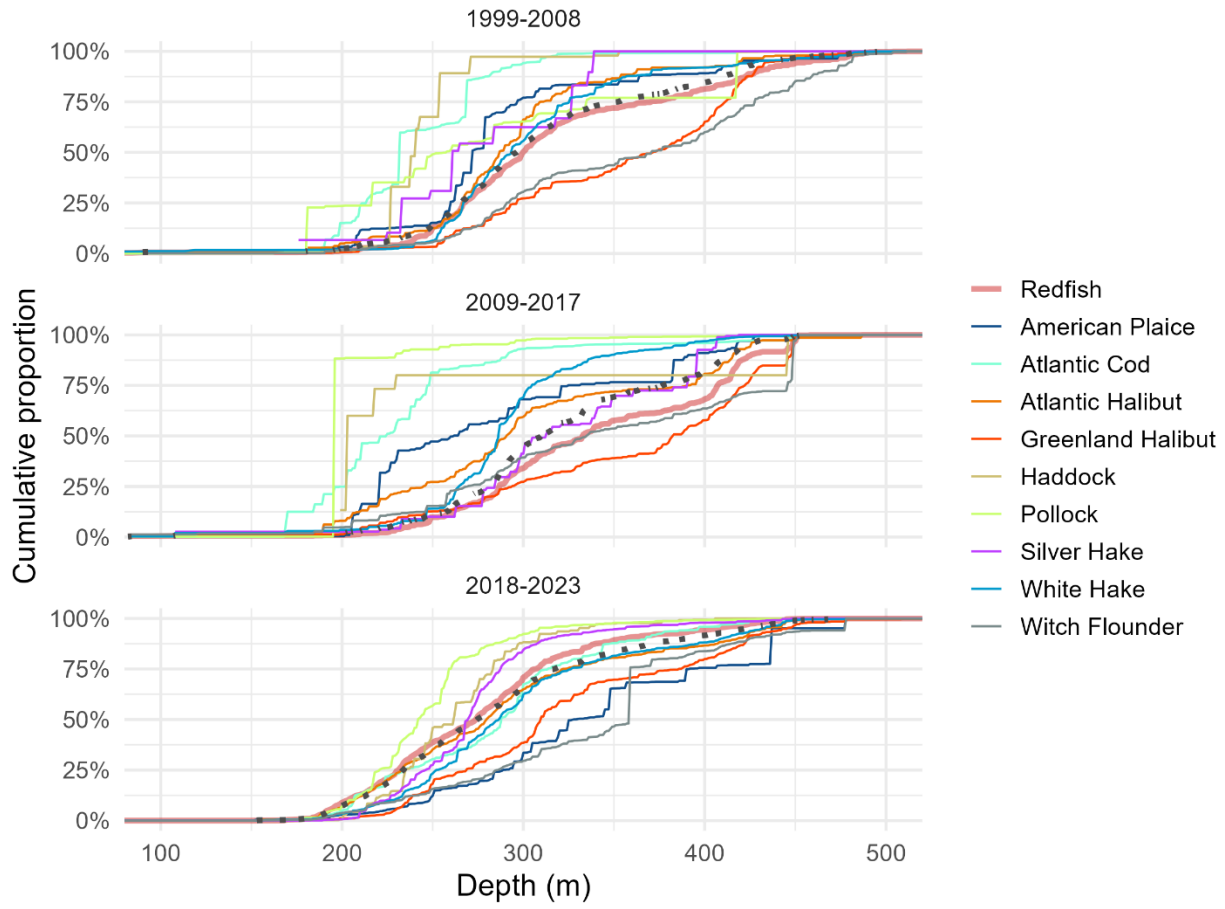


Figure 53. Cumulative proportion of Redfish, American Plaice, Atlantic Cod, Atlantic Halibut, Greenland Halibut, Haddock, Pollock, Silver Hake, White Hake, and Witch Flounder as a function of depth based on retained at-sea observer data in Redfish-directed fishery from 1999-2023 in Unit 1 by period. The dashed lines represent the depth distribution for all the sets done over that time period. 2024 values are not shown.

Table 9. Percentile describing depth (m) distribution of American Plaice, Atlantic Cod, Atlantic Halibut, Greenland Halibut, Haddock, Pollock, Redfish, Silver Hake, White Hake, and Witch Flounder based on at-sea observer data for the Redfish-directed fishery from 1999 to 2024 in Unit 1 by period. 2024 values are preliminary.

Species	5%	10%	25%	50%	75%	90%	95%
1999-2008							
American Plaice	206	209	260	272	297	405	420
Atlantic Cod	190	198	211	231	268	286	309
Atlantic Halibut	200	235	267	287	309	362	419
Greenland Halibut	253	262	296	371	411	428	438
Haddock	219	221	225	238	247	256	266
Pollock	171	174	211	256	334	409	414
Redfish	235	248	267	300	369	429	458
Silver Hake	176	221	232	261	322	336	338
White Hake	241	254	267	293	325	370	429
Witch Flounder	245	265	291	370	428	466	480
2009-2017							
American Plaice	205	206	221	261	324	391	417
Atlantic Cod	133	158	199	222	247	291	333
Atlantic Halibut	188	205	245	291	391	416	425
Greenland Halibut	212	234	294	382	422	447	449
Haddock	199	199	200	202	221	338	392
Pollock	88	95	114	146	179	228	261
Redfish	237	253	287	333	407	426	448
Silver Hake	228	245	281	307	384	395	406
White Hake	215	246	264	286	305	348	390
Witch Flounder	202	221	269	335	446	449	449
2018-2023							
American Plaice	224	248	289	328	391	436	437
Atlantic Cod	200	206	234	288	313	367	396
Atlantic Halibut	194	207	233	280	322	418	433
Greenland Halibut	229	237	269	309	385	424	444
Haddock	210	218	235	259	283	306	330
Pollock	195	204	221	242	259	292	309
Redfish	192	203	231	274	307	356	406
Silver Hake	213	224	246	269	287	314	355
White Hake	208	227	252	286	326	409	432
Witch Flounder	211	231	286	358	359	425	471

3.5.2.3. Bycatch length frequency

Bycatch length frequency were derived from ASO data and were not standardized for catch biomass. From 2018 to 2024, Atlantic Cod ranged from 5 to 118 cm (mode = 35 cm, median = 49 cm), White Hake from 12 to 101 cm (mode = 54 cm, median = 52 cm), Atlantic Halibut from 29 to 205 cm (mode = 92 cm, median = 104 cm), Greenland Halibut from 18 to 69 cm (mode = 41 cm, median = 43 cm), and Witch Flounder from 21 to 46 cm (mode = 22 cm, median = 34 cm) (Figure 54). Bycatch species length distribution in the Redfish-directed fishery remained overall similar over time, although larger specimens of Atlantic Cod were apparent in the 2018-2023 catches.

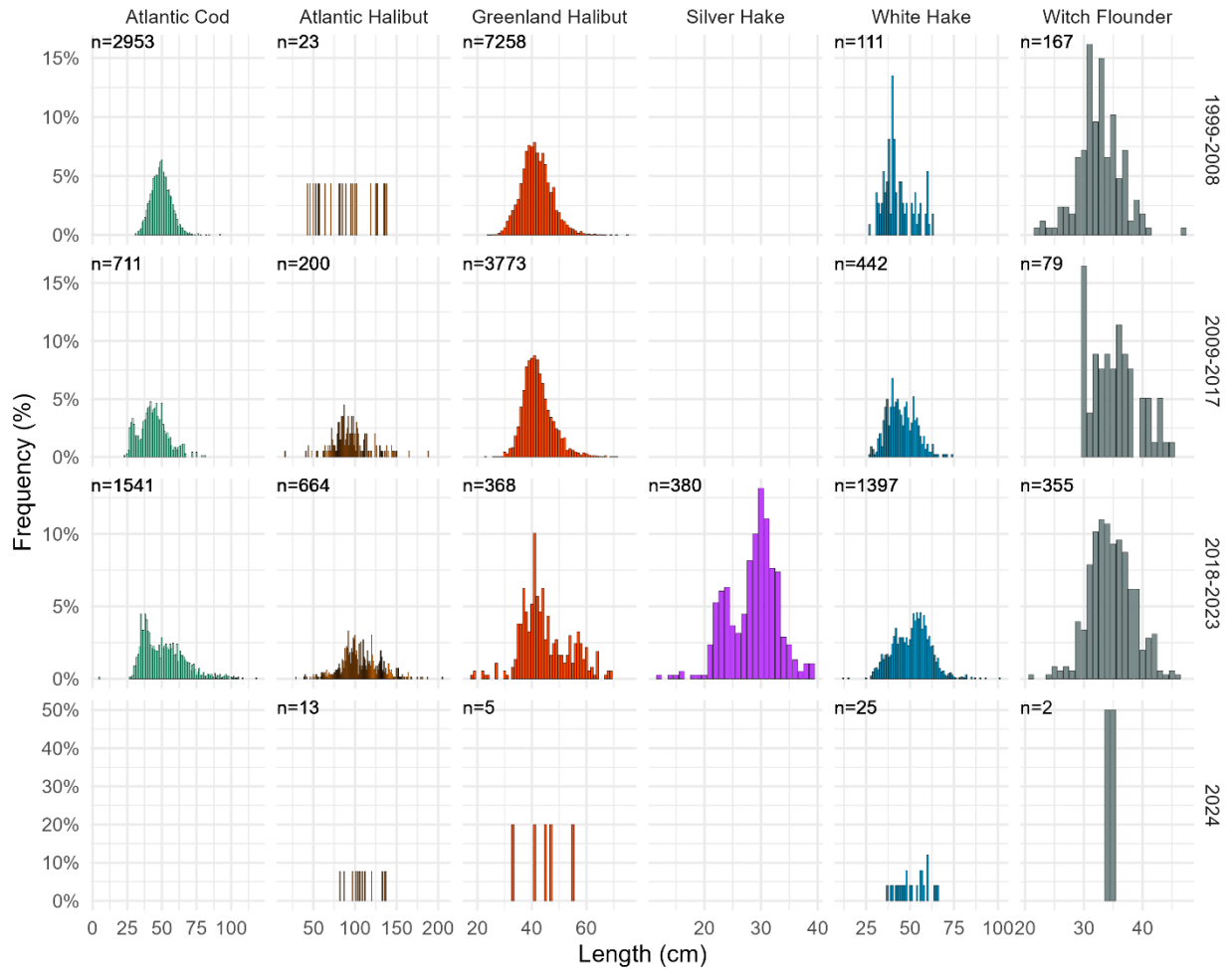


Figure 54. Bycatch species length frequency in percentage in Unit 1 from 1999 to 2024 based on at-sea-observer data in the Redfish-directed fishery. Numbers of fish measured by period are indicated (n). Frequency distributions were not standardised for catch weight. No fish were sampled in 2014. No Cod was measured in 2024 and Silver Hake was only measured in the 2018-2023 period. 2024 values are preliminary.

3.5.3. Northern Shrimp fishery

Redfish smaller than 20 cm are often caught as bycatch and discarded in the Northern Shrimp fishery. They are often dead because of decompression. Management measures for the Northern Shrimp fishery include mandatory 5% ASO coverage. The quantity, the location, and the length frequency of Redfish caught in the Northern Shrimp fishery were estimated for 2000 to 2024. The methods are presented in Savard et al. (2012) and Bourdages and Marquis (2019). In 2013, the amount of Redfish caught estimated for the whole Northern Shrimp fishery increased substantially, and continued to increase until 2016 (Figure 55). The amounts have since decreased as the lengths of 2011-2013 Redfish cohorts have increased, allowing them to avoid retention in the gear via the Nordmore grate (Figure 56). The ratio, expressed as a percentage, between the quantity of Redfish caught as bycatch divided by nGSL survey minimum trawlable biomass of Redfish smaller than 20 cm is used to estimate exploitation rates on fish of those lengths. The ratio has not exceeded 0.7% since 2000 (Figure 57). The decline in biomass of Redfish less than 20 cm in recent years caused the ratio to be above the average in 2021 and 2022. The ASO coverage in recent years was lower than usual (Figure 58),

especially for Esquiman in 2024, where about half of the landings took place. Therefore, the ASO data may not be representative of the whole fishery.

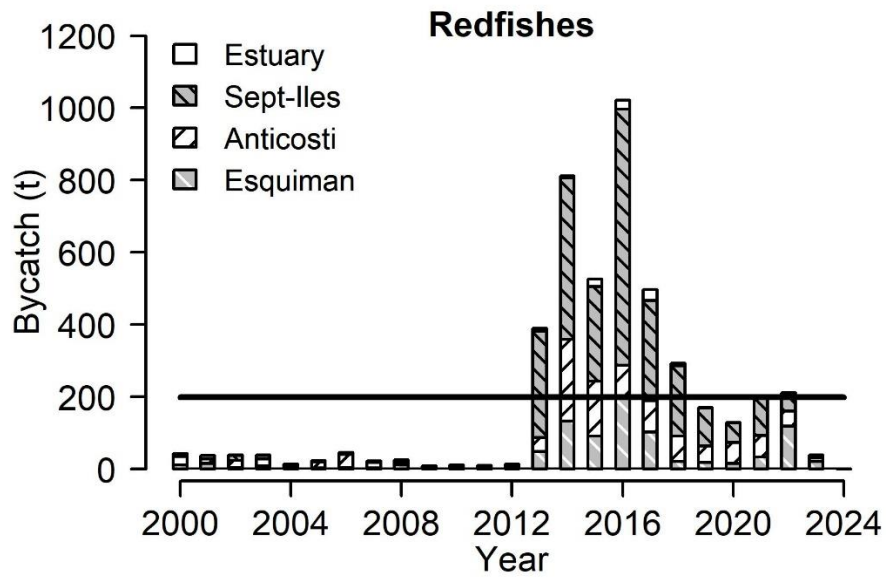


Figure 55. Annual estimated Redfish bycatch (t) in the Northern Shrimp fishery by shrimp fishing areas based on at-sea observer data. The solid horizontal line represents the 2000–2022 average. 2024 values are preliminary.

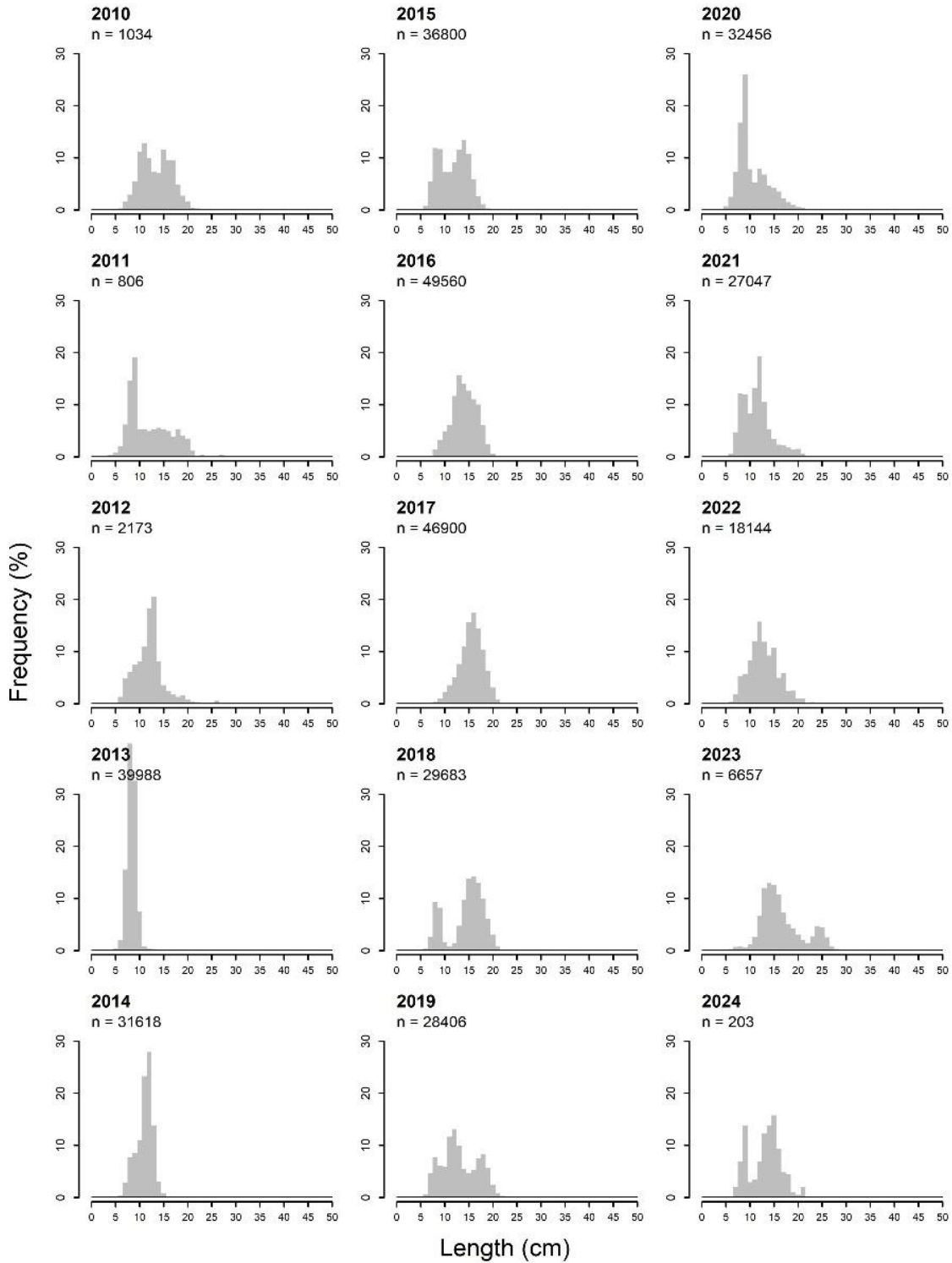


Figure 56. Length frequency of Redfish caught as bycatch in the Northern Shrimp fishery from 2010 to 2024. The numbers of fish measured are indicated (n). 2024 values are preliminary.

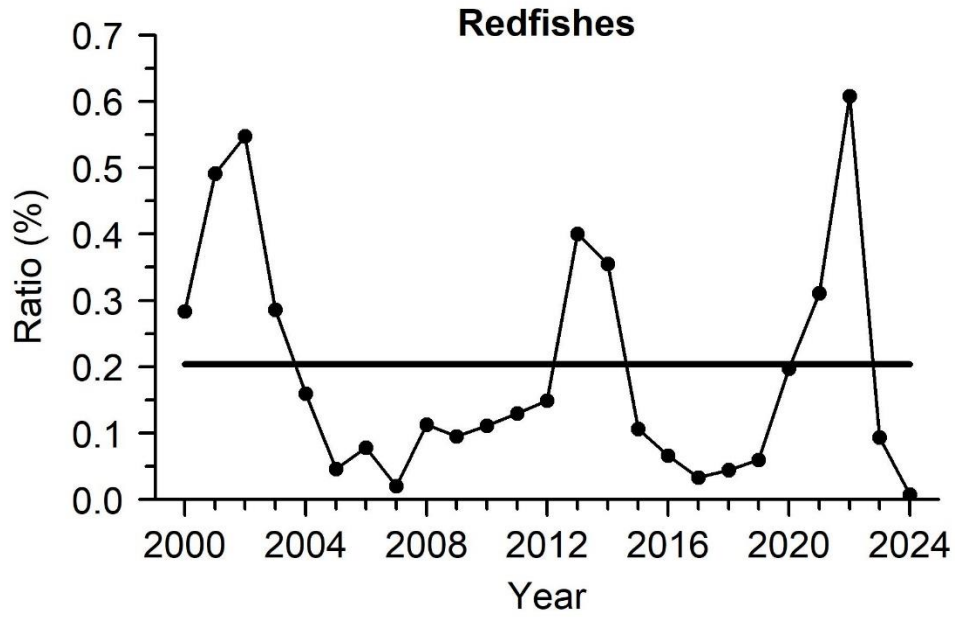


Figure 57. Ratio (%) between the quantity of Redfish caught as bycatch in the Northern Shrimp fishery and research survey minimum trawlable biomass of Redfish smaller than 20 cm from 2000-2024. Solid line indicates the average for the years 2000-2022. 2024 values are preliminary.

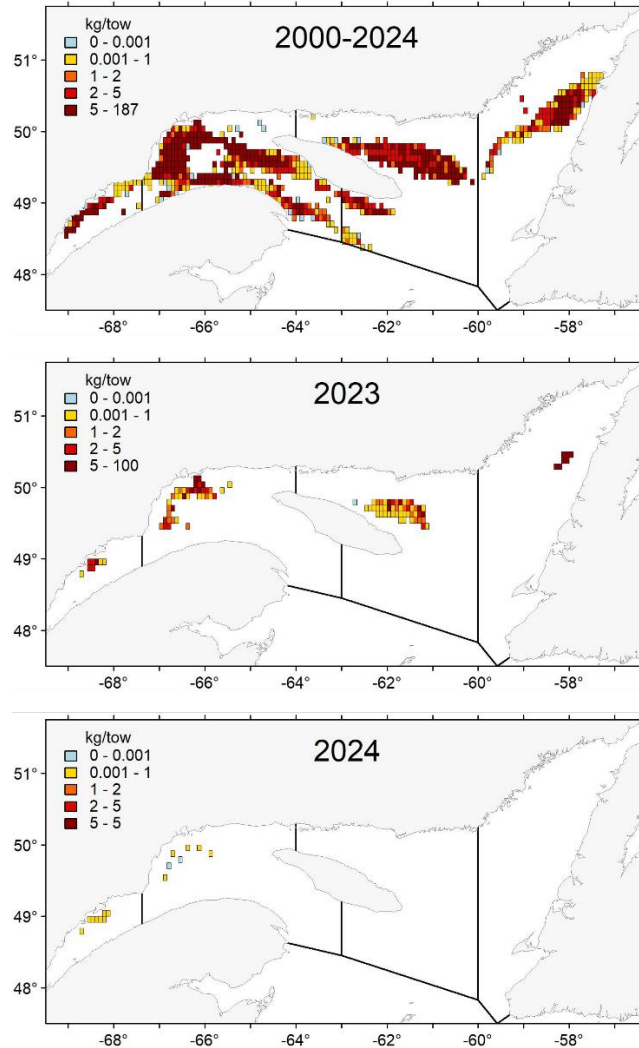


Figure 58. Redfish bycatch rate (kg/tow) distribution in the Northern Shrimp fishery from 2000-2024, 2023, and 2024. 2024 values are preliminary.

3.6. BYCATCH IN UNIT 2

3.6.1. ZIFF

Data from the dockside monitoring program recorded in ZIFF indicate that 97% of the reported Redfish catches from 2000 to 2024 came from the directed Redfish fisheries conducted in Unit 2, and 99% for 2018 to the present. Fisheries targeting Atlantic Cod were responsible for 2% of Redfish landings on average for 2000 to 2024 (Figure 59).

Bycatch species averaged 8.2% of Redfish landings in the directed Redfish fishery since 2000, and 6.9% since 2018 (Figure 60). Since 2018, the most common bycatch were Atlantic Halibut (41.9% of bycatch biomass), Atlantic Cod (16.2%) and White Hake (9.9%) (Figure 61 and Figure 62, Table 10 and Table 11). In recent years, the proportion of Atlantic Halibut in the catches increased.

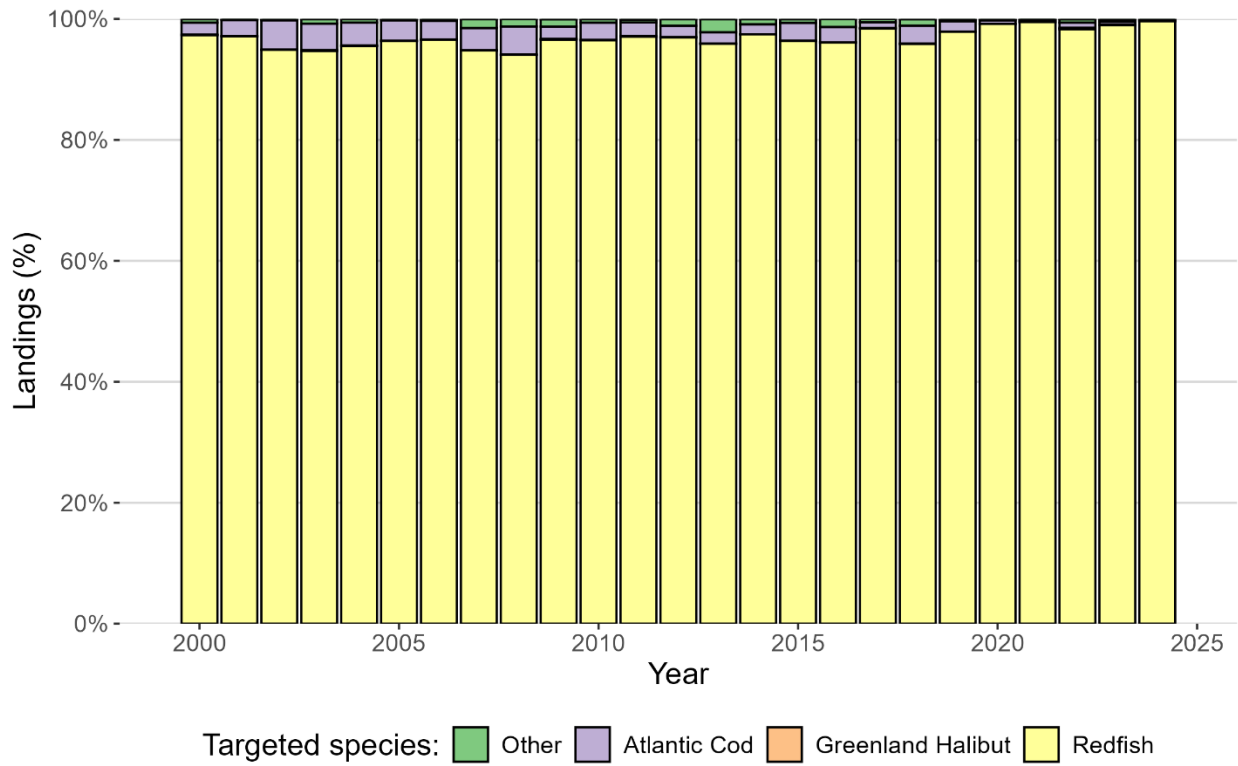


Figure 59. Redfish annual landings (biomass percentage) in Unit 2 as a function of targeted species by the fishery from 2000 to 2024. 2020 to 2024 values are preliminary. Other may include unknown target species.

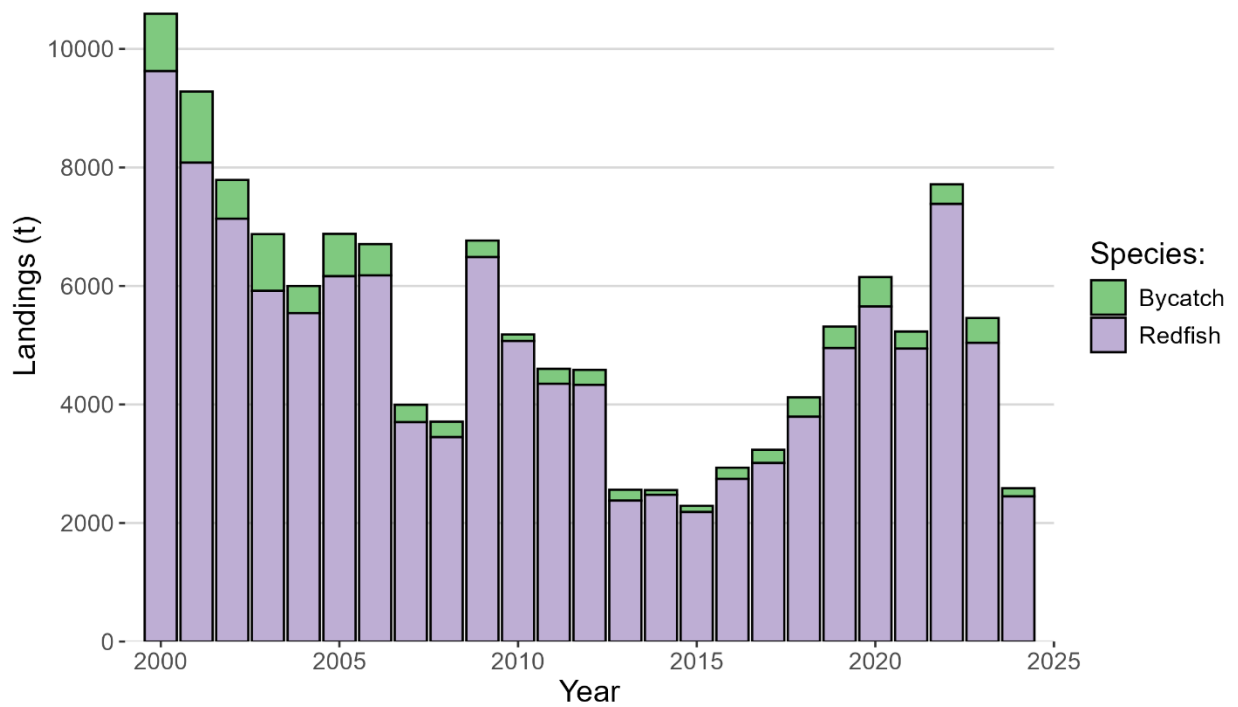


Figure 60. Annual landings of Redfish and bycatch (t) in the Redfish-directed fishery in Unit 2 from 2000 to 2024. 2020 to 2024 values are preliminary.

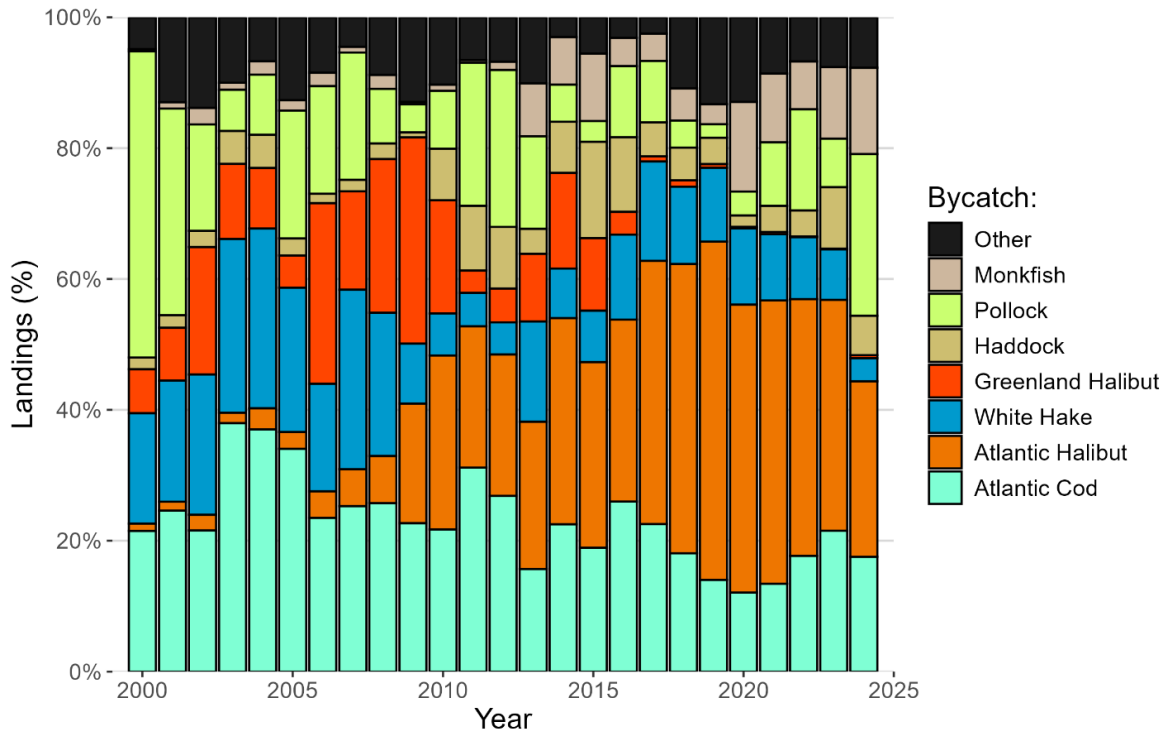


Figure 61. Annual bycatch landings (biomass percentage) by species captured in the Redfish-directed fishery in Unit 2 from 2000 to 2024. 2020 to 2024 values are preliminary.

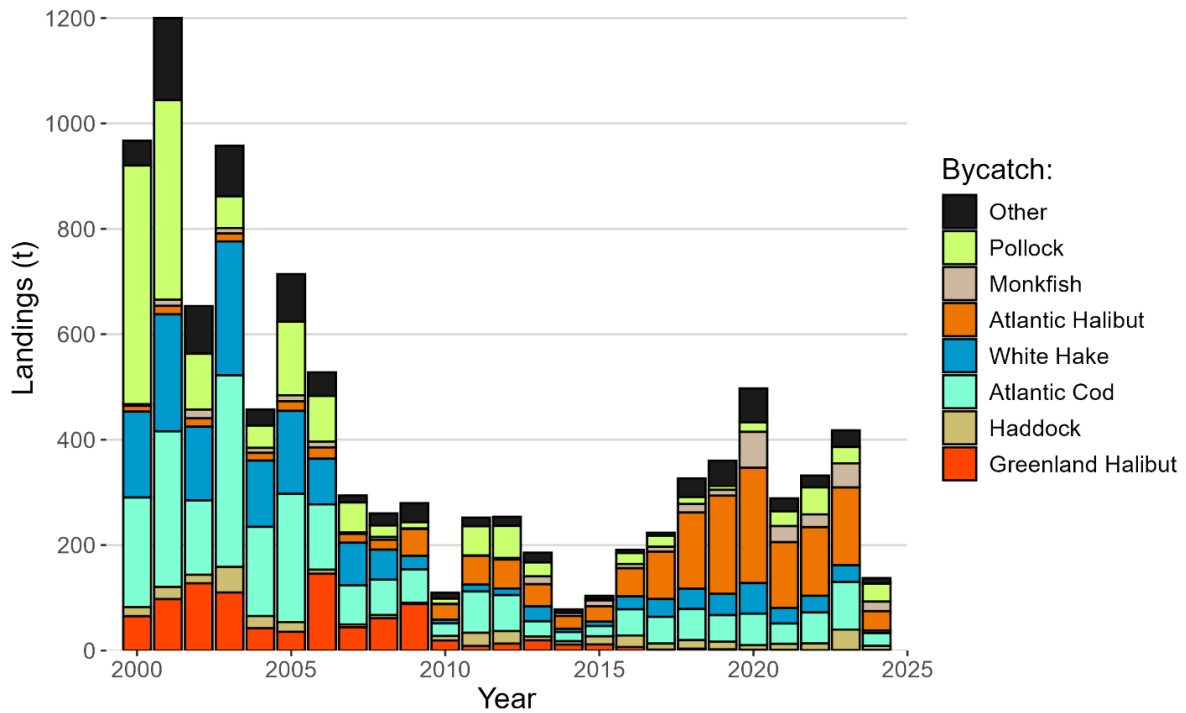


Figure 62. Annual bycatch landings (t) by species captured in the Redfish-directed fishery in Unit 2 from 2000 to 2024. 2020 to 2024 values are preliminary.

Table 10. Annual bycatch landings (biomass percentage) by species captured in the Redfish-directed fishery in Unit 2 from 2000 to 2024. 2020 to 2024 values are preliminary. Only species above 0.1% of annual landings for at least one year are shown.

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
American Plaice	0.8	0.6	1.3	0.8	1.8	8.5	3.3	0.6	1.4	0.5	3.9	1.1	0.1	1.9	1.6	2.4	0.6	0.4	2.8	2.4	1.9	1.4	0.1	0.4	0.3
Argentine	0.0	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	3.9	0.0	0.0
Atlantic Cod	21.5	24.6	21.6	38.0	37.0	34.0	23.5	25.3	25.8	22.7	21.7	31.2	26.9	15.7	22.5	18.9	26.0	22.6	18.1	14.0	12.1	13.4	17.7	21.5	17.6
Atlantic Halibut	1.1	1.3	2.4	1.6	3.2	2.6	4.0	5.7	7.2	18.3	26.6	21.6	21.6	22.5	31.5	28.4	27.8	40.2	44.2	51.7	44.0	43.3	39.2	35.3	26.8
Atlantic Wolffish	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blue Shark	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Catfish	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cusk	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.1	0.0	0.2	0.0	0.5	0.7	0.3	1.1	1.4	1.4	1.2	0.9	0.5	0.3	0.8	0.9	0.7
Greenland Halibut	6.7	8.1	19.5	11.5	9.3	5.0	27.6	15.0	23.5	31.5	17.3	3.4	5.2	10.3	14.6	11.1	3.5	0.8	1.0	0.6	0.2	0.4	0.1	0.1	0.5
Haddock	1.8	1.9	2.5	5.0	5.1	2.6	1.4	1.8	2.4	0.8	7.9	9.9	9.4	3.8	7.8	14.7	11.4	5.2	5.0	4.0	1.7	4.0	4.0	9.4	6.0
Herring	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Loligo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Mackerel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0
Monkfish	0.3	1.0	2.5	1.1	2.1	1.6	2.1	0.9	2.1	0.4	1.0	0.4	1.3	8.1	7.3	10.3	4.3	4.2	4.9	3.1	13.7	10.5	7.3	11.0	13.2
Pollock	46.8	31.5	16.2	6.3	9.2	19.5	16.4	19.4	8.3	4.3	8.8	21.9	24.0	14.1	5.7	3.2	10.9	9.4	4.1	2.0	3.6	9.7	15.4	7.4	24.7
Porbeagle	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red Hake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Shortfin Mako	0.0	0.1	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silver Hake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	3.3	2.9	0.4	1.9	1.5
Skate	0.2	0.7	1.1	1.0	0.9	1.3	0.5	0.8	0.5	0.0	2.6	0.1	0.0	3.2	0.0	0.0	0.2	0.2	0.2	0.0	0.9	0.2	0.0	2.0	0.0
Squalus Acanthias	0.0	8.4	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified Clams	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Unspecified Flounders	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	3.7	1.6	3.2	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Unspecified Groundfish	1.7	0.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified Shark	0.0	0.1	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified, Other Fish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
White Hake	16.9	18.5	21.4	26.5	27.5	22.0	16.4	27.4	21.9	9.2	6.4	5.1	4.9	15.3	7.6	7.9	13.0	15.2	11.8	11.3	11.6	10.1	9.5	7.7	3.5
Winter Flounder	0.0	0.0	0.1	0.0	0.1	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Witch Flounder	1.6	2.2	3.8	7.7	3.2	2.3	3.2	2.6	6.7	8.5	1.8	2.0	3.4	4.2	1.1	1.9	0.6	0.3	6.6	8.0	5.8	3.8	1.1	2.1	0.7
Yellowtail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.6

Table 11. Annual bycatch landings (kg) by species captured in the Redfish-directed fishery in Unit 2 from A) 2000 to 2012 and B) 2013 to 2024. 2020 to 2024 values are preliminary. Only species above 0.1% of annual landings for at least one year are shown.

A)

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
American Plaice	7335	7415	8654	7409	8391	60879	17647	1648	3603	1318	4310	2866	358
Argentine	461	2558	1908	3061	73	205	128	0	0	0	0	0	0
Atlantic Cod	207969	295448	141112	363702	169203	243125	124072	74390	67012	63455	23842	78621	68193
Atlantic Halibut	10846	16122	15563	15303	14857	18345	21329	16658	18737	51061	29219	54478	54878
Atlantic Wolffish	0	0	0	0	437	494	165	142	220	312	24	3	30
Blue Shark	0	73	1783	0	0	31	0	0	0	0	0	0	0
Catfish	1663	2605	1227	689	1	64	22	12	0	0	0	0	0
Cusk	182	341	661	461	1016	307	818	184	132	117	179	83	1207
Greenland Halibut	65136	97381	127444	110215	42295	35365	145668	44204	61152	88134	19017	8632	13131
Haddock	17149	23040	16195	48200	23242	18600	7558	5226	6176	2162	8641	24912	23876
Herring	13	0	60	48	181	0	0	0	0	0	0	0	0
Loligo	0	0	0	0	0	24	51	220	0	0	0	48	0
Mackerel	0	33	0	0	0	0	0	0	0	0	0	0	0
Monkfish	3183	11695	16579	10237	9393	11473	10844	2572	5582	988	1049	1055	3175
Pollock	452656	378601	106215	60076	41965	139316	86748	57210	21666	12005	9712	55188	60895
Porbeagle	0	197	499	0	0	0	9	51	0	0	161	86	0
Red Hake	0	0	0	0	0	0	0	0	0	0	0	0	0
Shortfin Mako	380	774	1321	20	192	1159	217	75	0	0	0	0	0
Silver Hake	33	143	183	0	0	0	147	0	0	5	0	0	0
Skate	1910	8413	6998	9728	4087	9096	2858	2470	1176	133	2823	315	3
Squalus Acanthias	0	100354	29638	0	143	0	218	74	18	0	0	0	0
Unspecified Clams	0	0	0	0	0	0	0	0	0	0	0	0	0
Unspecified Flounders	3162	0	54	721	585	0	0	0	0	10485	1810	7987	6793
Unspecified Groundfish	16212	5247	9435	0	22	0	0	11	0	0	0	0	0
Unspecified Shark	83	744	2317	0	130	1299	108	0	95	0	0	0	0
Unspecified, Other Fish	0	0	0	0	0	0	0	0	0	0	0	0	0
White Hake	163177	221890	140106	254034	125548	157422	86737	80720	56938	25683	7020	12807	12426
Winter Flounder	405	307	407	39	576	83	5215	634	113	2	35	0	272
Witch Flounder	15160	26220	24880	73775	14412	16536	16629	7753	17556	23788	1954	5059	8545
Yellowtail	131	177	213	0	72	236	62	3	0	0	0	0	0

B)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
American Plaice	3611	1254	2449	1114	912	9054	8703	9560	4036	486	1686	402
Argentine	0	28	0	0	0	0	0	561	0	13000	178	10
Atlantic Cod	29139	17577	19644	49629	50433	59147	50506	60132	38798	58775	89908	24114
Atlantic Halibut	41804	24580	29459	53100	89898	144457	186192	218763	125027	130208	147406	36855
Atlantic Wolffish	5	0	0	0	0	0	0	0	0	0	33	0
Blue Shark	0	0	0	0	0	0	0	0	0	0	0	0
Catfish	0	0	0	0	0	0	0	0	0	0	0	0
Cusk	1345	209	1154	2615	3112	3857	3352	2505	844	2774	3679	945
Greenland Halibut	19210	11406	11533	6650	1765	3179	2115	1182	1035	310	434	626
Haddock	7098	6099	15284	21783	11626	16371	14450	8680	11481	13282	39343	8270
Herring	0	0	2	0	0	0	0	0	0	0	0	327
Loligo	0	0	0	0	0	0	0	1527	0	0	11	0
Mackerel	0	0	0	0	0	0	973	15	0	0	571	50
Monkfish	15107	5678	10699	8256	9322	16153	11139	68168	30421	24337	45750	18111
Pollock	26212	4428	3284	20752	20927	13437	7377	18121	28033	51251	30844	33958
Porbeagle	0	0	0	0	0	0	0	0	0	0	0	0
Red Hake	0	0	73	0	0	0	0	0	0	0	0	4155
Shortfin Mako	0	0	79	0	0	0	0	0	0	0	0	0
Silver Hake	0	0	44	0	0	0	6033	16493	8395	1464	8066	2002
Skate	6035	0	0	403	368	741	83	4652	683	50	8377	28
Squalus Acanthias	0	0	0	0	0	0	0	0	0	0	0	11
Unspecified Clams	0	0	0	0	0	0	0	0	0	0	0	555
Unspecified Flounders	0	0	0	0	0	0	0	0	0	670	0	0
Unspecified Groundfish	0	0	0	0	0	0	0	0	0	42	26	0
Unspecified Shark	0	0	0	0	0	0	0	0	0	0	0	0
Unspecified, Other Fish	0	0	0	0	0	0	0	0	0	0	0	290
White Hake	28453	5914	8163	24837	33975	38550	40607	57856	29185	31413	32258	4840
Winter Flounder	0	0	0	29	64	0	0	0	0	2	0	0
Witch Flounder	7726	858	1958	1062	722	21516	28658	28963	10855	3816	8747	1009
Yellowtail	0	10	0	770	440	330	0	0	0	0	0	821

3.6.2. At-sea observers

3.6.2.1. Bycatch levels

From 1999 to 2024, 3,621 sampled tows by the ASO program were retained from the Unit 2 Redfish-directed fishery (Figure 63). During the recent period (2018-2023), the most frequent bycatch species were Atlantic Halibut (caught in 83% of fishing activities monitored by ASO), Silver Hake (42%), White Hake (40%), Witch Flounder (39%), and Atlantic Cod (36%, Table 12). The 2018-2023 period is also characterised by an important increase in Atlantic Halibut and Silver Hake proportions, the decline of Atlantic Cod and the more pronounced decline of Greenland Halibut bycatch compared to the previous decade (Table 12). Bycatch rates disaggregated by NAFO Division and Subdivision, and period are presented (Table 13).

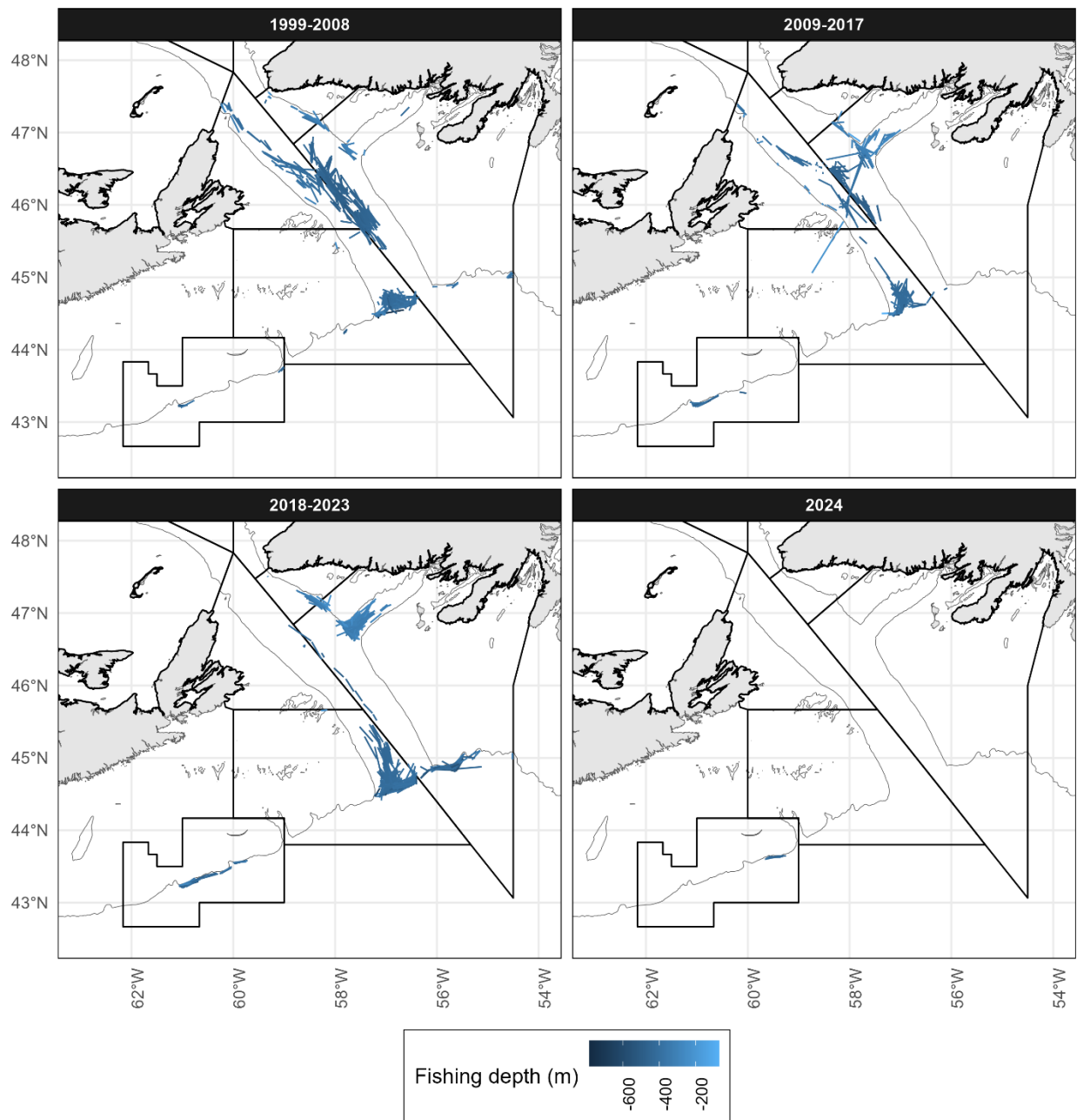


Figure 63. Start and end position of tows sampled by at-sea observers by period in Unit 2 from 1999 to 2024 in the Redfish-directed fishery. The grey line corresponds to the 240 m isobath. The color of the lines corresponds to depth. 2024 values are preliminary.

Table 12. Occurrence percentage (%), biomass (kg), landed catches percentage (%), and percentage of each species biomass as a function Redfish biomass (%) based on at-sea observer data for the Redfish-directed fishery by period from 1999 to 2024 in Unit 2. 2024 values are preliminary.

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
1999-2008				
Redfish	100.00	3963277	99.93	100.00
Greenland Halibut	56.98	26566	99.60	0.67
Atlantic Cod	48.93	18031	99.93	0.45
Witch Flounder	47.67	7313	98.33	0.18
White Hake	46.96	11038	99.81	0.28
Pollock	44.72	63405	99.99	1.60
Atlantic Halibut	27.01	7855	92.82	0.20
Haddock	15.30	7955	100.00	0.20
American Plaice	8.23	432	98.38	0.01
Silver Hake	6.71	453	47.02	0.01
2009-2017				
Redfish	99.57	1168661	99.94	100.00
Atlantic Cod	57.14	17973	96.82	1.54
Atlantic Halibut	53.09	10194	85.03	0.87
Greenland Halibut	39.45	18347	99.71	1.57
White Hake	38.17	3355	91.65	0.29
Witch Flounder	32.41	1662	94.34	0.14
Pollock	30.06	5368	100.00	0.46
Haddock	19.40	4156	99.64	0.36
Silver Hake	8.96	250	12.00	0.02
American Plaice	7.46	218	91.74	0.02
2018-2023				
Redfish	99.81	5444937	99.78	100.00
Atlantic Halibut	82.75	116568	97.49	2.14
Silver Hake	42.20	41478	86.44	0.76
White Hake	39.77	13274	92.38	0.24
Witch Flounder	38.60	25103	92.69	0.46
Atlantic Cod	35.67	38505	99.39	0.71
Pollock	22.42	10416	97.99	0.19
Greenland Halibut	9.16	908	62.44	0.02
Haddock	8.77	5342	98.52	0.10
American Plaice	8.19	5185	86.33	0.10
2024				
Redfish	100.00	13886	100.00	100.00
White Hake	100.00	60	100.00	0.43
Atlantic Halibut	100.00	1470	92.59	10.59
Witch Flounder	37.50	10	0.00	0.07
Silver Hake	12.50	6	100.00	0.04
American Plaice	12.50	3	0.00	0.02

Table 13. Occurrence percentage (%), biomass (kg), landed catches percentage (%), and percentage of each species biomass as a function Redfish biomass (%) based on at-sea observer data for the Redfish-directed fishery from 1999 to 2024 in Unit 2 disaggregated by NAFO areas, and periods. 2024 values are preliminary.

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
1999-2008 - 3Pn				
Redfish	100.00	71295	100.00	100.00
Greenland Halibut	75.00	271	100.00	0.38
White Hake	11.11	51	100.00	0.07
Atlantic Cod	2.78	10	100.00	0.01
Witch Flounder	2.78	2	100.00	0.00
1999-2008 - 3Ps				
Redfish	100.00	1427592	100.00	100.00
Greenland Halibut	54.14	16351	99.98	1.15
White Hake	50.59	4407	100.00	0.31
Witch Flounder	48.22	4033	99.33	0.28
Atlantic Cod	47.34	10621	100.00	0.74
Pollock	21.60	2048	100.00	0.14
American Plaice	13.61	293	100.00	0.02
Atlantic Halibut	6.51	876	90.98	0.06
Haddock	5.33	913	100.00	0.06
Silver Hake	2.96	18	22.22	0.00
1999-2008 - 4Vn				
Redfish	100.00	154164	100.00	100.00
Greenland Halibut	85.19	2938	99.39	1.91
Witch Flounder	72.84	770	100.00	0.50
White Hake	51.85	872	100.00	0.57
Atlantic Cod	20.99	100	90.00	0.06
Atlantic Halibut	13.58	395	100.00	0.26
Pollock	7.41	21	100.00	0.01
Silver Hake	4.94	30	0.00	0.02
American Plaice	4.94	26	100.00	0.02
1999-2008 - 4Vs				
Redfish	100.00	2285907	99.87	100.00
Pollock	64.91	61332	99.99	2.68
Atlantic Cod	57.03	7300	99.97	0.32
Greenland Halibut	55.18	6999	98.80	0.31
Witch Flounder	46.68	2478	96.17	0.11
White Hake	45.13	5475	99.62	0.24
Atlantic Halibut	40.34	6469	92.63	0.28
Haddock	23.49	7028	100.00	0.31
Silver Hake	7.73	249	21.29	0.01
American Plaice	6.49	113	93.81	0.00
1999-2008 - 4W				
Redfish	100.00	24319	100.00	100.00
White Hake	100.00	233	100.00	0.96
Silver Hake	68.75	156	100.00	0.64
Atlantic Halibut	50.00	115	93.04	0.47
Witch Flounder	50.00	30	100.00	0.12
Haddock	6.25	14	100.00	0.06

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
Pollock	6.25	4	100.00	0.02
Greenland Halibut	6.25	7	100.00	0.03
2009-2017 - 3Ps				
Redfish	99.53	549031	100.00	100.00
Atlantic Cod	64.19	14490	96.27	2.64
Greenland Halibut	46.98	16046	100.00	2.92
Atlantic Halibut	38.14	2238	73.91	0.41
Witch Flounder	32.56	1047	99.81	0.19
Pollock	29.30	2104	100.00	0.38
White Hake	24.65	774	99.35	0.14
Haddock	20.47	2498	99.44	0.45
American Plaice	12.09	175	100.00	0.03
Silver Hake	5.58	102	29.41	0.02
2009-2017 - 4Vn				
Redfish	98.53	111762	99.72	100.00
Greenland Halibut	80.88	1971	98.43	1.76
Atlantic Halibut	35.29	805	90.68	0.72
Witch Flounder	35.29	261	93.10	0.23
White Hake	29.41	139	100.00	0.12
Silver Hake	17.65	57	0.00	0.05
American Plaice	8.82	39	58.97	0.03
Atlantic Cod	5.88	169	100.00	0.15
Haddock	2.94	3	100.00	0.00
Pollock	2.94	183	100.00	0.16
2009-2017 - 4Vs				
Redfish	100.00	455090	99.98	100.00
Atlantic Cod	80.13	3312	99.09	0.73
Atlantic Halibut	75.00	5176	88.39	1.14
White Hake	49.36	1131	75.69	0.25
Pollock	48.72	3081	100.00	0.68
Witch Flounder	28.21	297	75.08	0.07
Haddock	27.56	1652	99.94	0.36
Greenland Halibut	14.74	156	85.26	0.03
Silver Hake	7.69	25	0.00	0.01
American Plaice	1.28	3	33.33	0.00
2009-2017 - 4W				
Redfish	100.00	52778	99.35	100.00
White Hake	96.67	1311	100.00	2.48
Atlantic Halibut	86.67	1975	86.53	3.74
Witch Flounder	46.67	57	100.00	0.11
Silver Hake	20.00	66	0.00	0.13
Greenland Halibut	20.00	174	100.00	0.33
Haddock	6.67	3	100.00	0.01
Atlantic Cod	3.33	2	100.00	0.00
American Plaice	3.33	1	100.00	0.00
2018-2023 - 3Pn				
Redfish	100.00	280865	99.82	100.00
White Hake	96.00	823	76.06	0.29
Witch Flounder	96.00	80	0.00	0.03

Species	Occurrence (%)	Biomass (kg)	Landed (%)	Bycatch / Redfish (%)
Silver Hake	84.00	119	0.00	0.04
Atlantic Halibut	80.00	2476	99.39	0.88
Atlantic Cod	68.00	43	41.86	0.02
Pollock	36.00	208	99.52	0.07
American Plaice	20.00	5	0.00	0.00
Greenland Halibut	16.00	21	85.71	0.01
2018-2023 - 3Ps				
Redfish	99.76	2780218	99.78	100.00
Atlantic Halibut	75.12	50596	97.39	1.82
Witch Flounder	48.82	23685	95.88	0.85
Silver Hake	45.26	34955	93.29	1.26
Atlantic Cod	43.60	34760	99.63	1.25
White Hake	38.15	8044	93.45	0.29
Pollock	17.54	3839	96.17	0.14
American Plaice	17.06	5029	86.28	0.18
Haddock	15.17	4842	98.49	0.17
Greenland Halibut	10.19	582	48.63	0.02
2018-2023 - 4Vn				
Redfish	100.00	477	100.00	100.00
Witch Flounder	100.00	6	0.00	1.26
White Hake	50.00	2	100.00	0.42
Greenland Halibut	50.00	3	100.00	0.63
2018-2023 - 4Vs				
Redfish	99.81	2318994	99.77	100.00
Atlantic Halibut	88.66	61891	97.87	2.67
Silver Hake	36.62	5599	57.94	0.24
White Hake	34.39	3412	91.56	0.15
Atlantic Cod	30.67	3702	97.84	0.16
Witch Flounder	29.00	1310	40.92	0.06
Pollock	27.14	6367	99.04	0.27
Greenland Halibut	5.76	123	68.29	0.01
Haddock	3.35	455	98.68	0.02
American Plaice	1.30	151	90.73	0.01
2018-2023 - 4W				
Redfish	100.00	64383	100.00	100.00
White Hake	94.87	993	100.00	1.54
Atlantic Halibut	89.74	1605	83.24	2.49
Silver Hake	61.54	805	0.00	1.25
Greenland Halibut	38.46	179	100.00	0.28
Haddock	20.51	45	100.00	0.07
Witch Flounder	20.51	22	100.00	0.03
Pollock	2.56	2	100.00	0.00
2024 - 4W				
Redfish	100.00	13886	100.00	100.00
White Hake	100.00	60	100.00	0.43
Atlantic Halibut	100.00	1470	92.59	10.59
Witch Flounder	37.50	10	0.00	0.07
Silver Hake	12.50	6	100.00	0.04
American Plaice	12.50	3	0.00	0.02

3.6.2.2. Spatial distribution

The spatial distribution of Redfish and bycatch species were mapped for different time periods from 1999 to 2024 (Figure 64 to Figure 72). Fishing location appeared to have shifted from the middle of the Laurentian Channel in the early 2000s to the Burgeo Bank and the Laurentian Fan in the most recent periods (Figure 64), potentially due to the implementation of the Laurentian Channel Marine protected area (MPA). In the most recent time period, the higher Redfish catches appear to overlay with the higher catches of Atlantic Cod, White Hake, Silver Hake, Atlantic Halibut, and Witch Flounder, suggesting that these species may be harder to avoid in the Redfish-directed fishery.

During 2018-2023, 80% of Redfish catches were concentrated between 305 m and 435 m (Figure 74 and Table 14). That range of depth corresponds to 75% of the biomass of Atlantic Halibut, 72% of Pollock, 71% of Silver Hake, 70% of White Hake, 69% of Haddock, and 62% of Atlantic Cod caught in the Redfish-directed fishery. Only American Plaice (*Hippoglossoides platessoides*), Greenland Halibut, and Witch Flounder were noticeably deeper than Redfish.

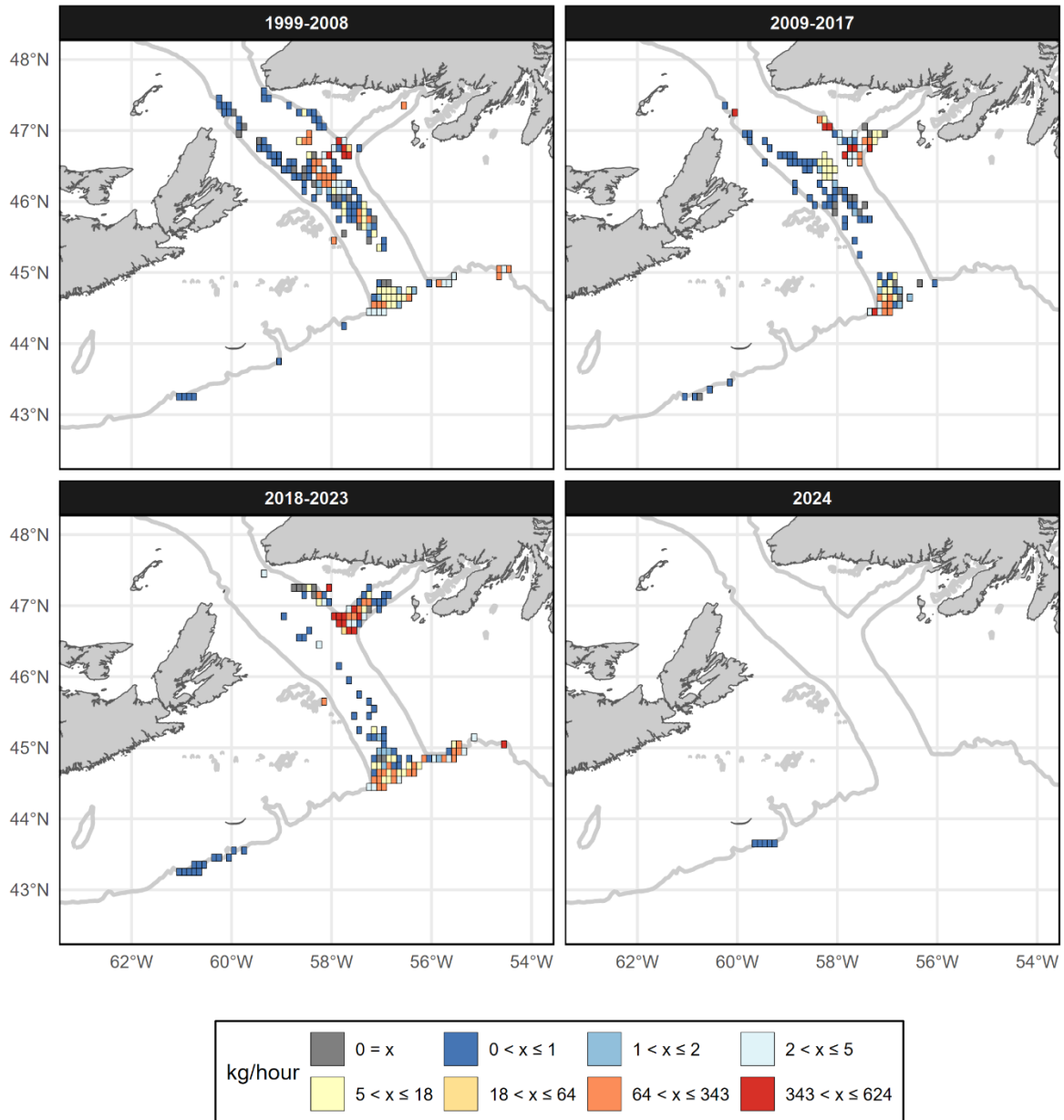


Figure 65. Catch rate (mean kg/hour) spatial distribution of Atlantic Cod based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 2. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

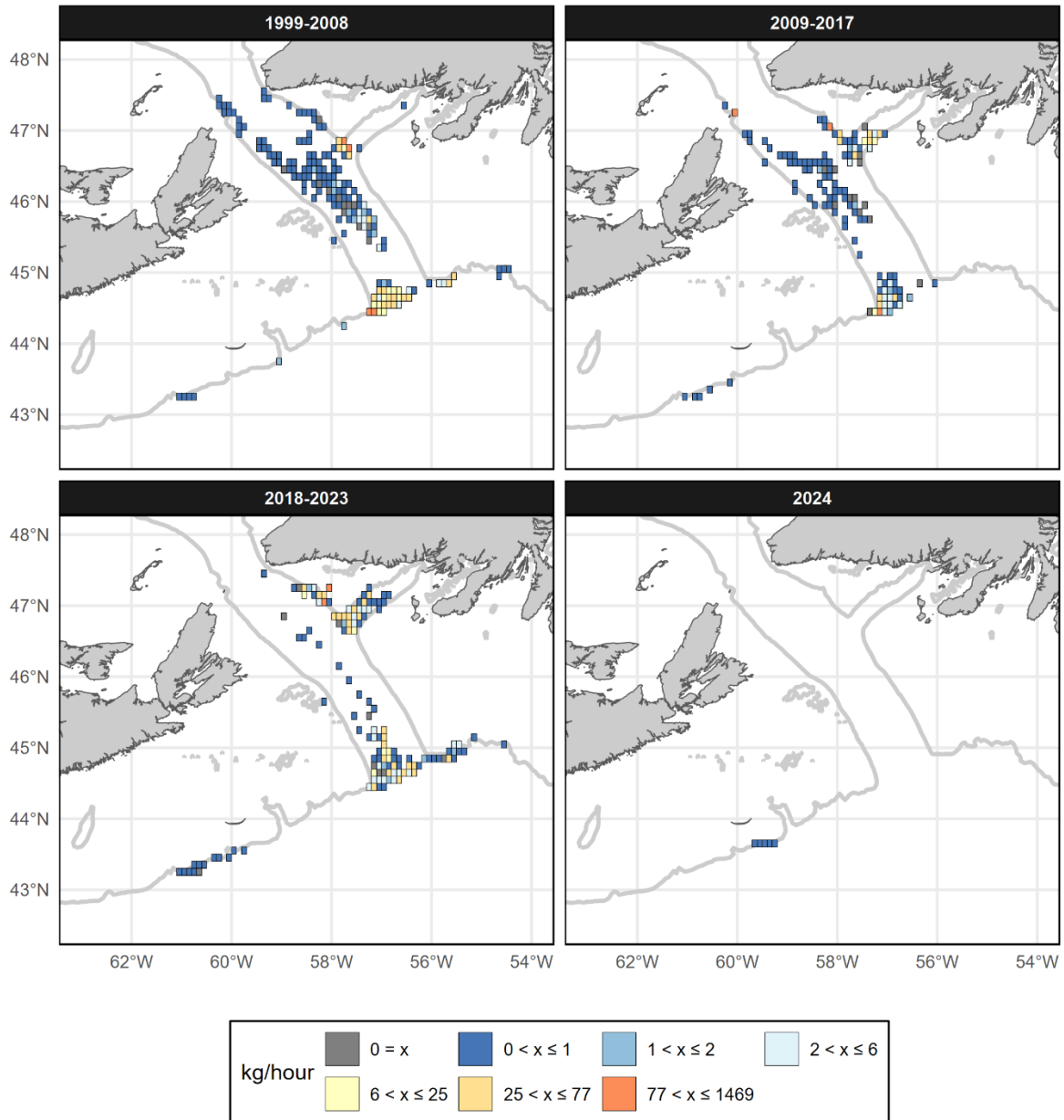


Figure 69. Catch rate (mean kg/hour) spatial distribution of Pollock based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 2. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

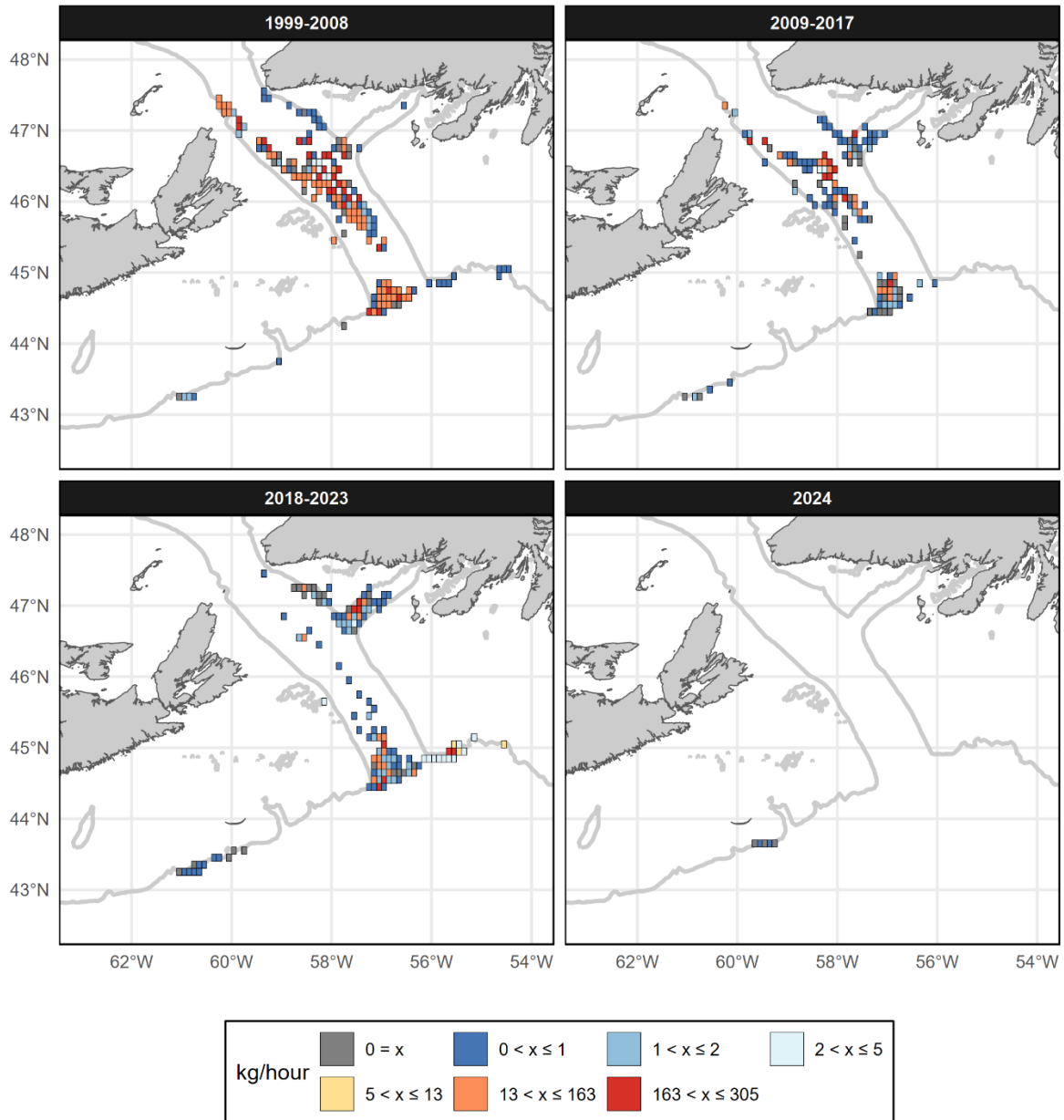


Figure 72. Catch rate (mean kg/hour) spatial distribution of Witch Flounder based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 2. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

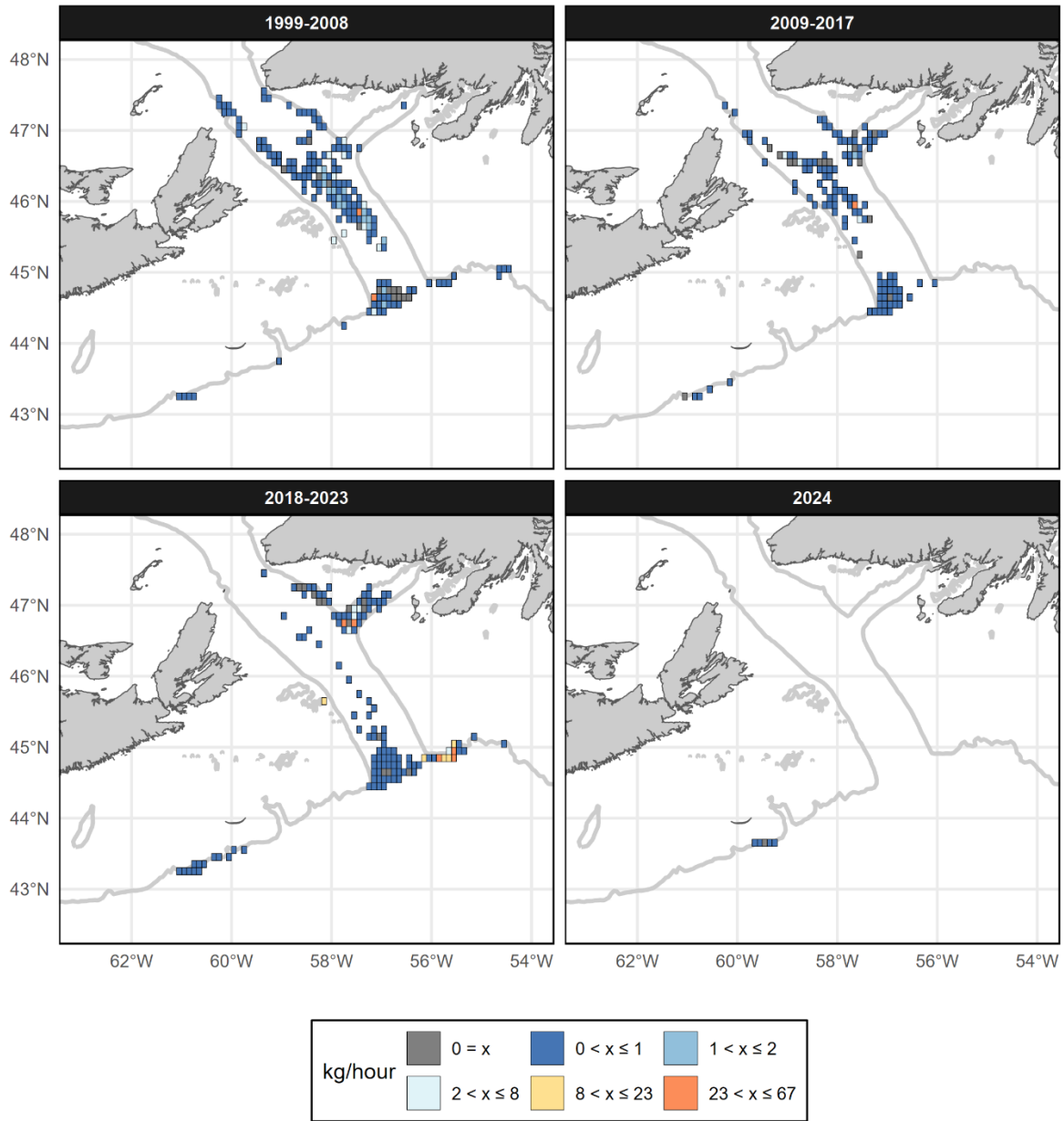


Figure 73. Catch rate (mean kg/hour) spatial distribution of American Plaice based on at-sea observer data in the Redfish-directed fishery from 1999-2024 in Unit 2. The grey line corresponds to the 240 m isobath. 2024 values are preliminary.

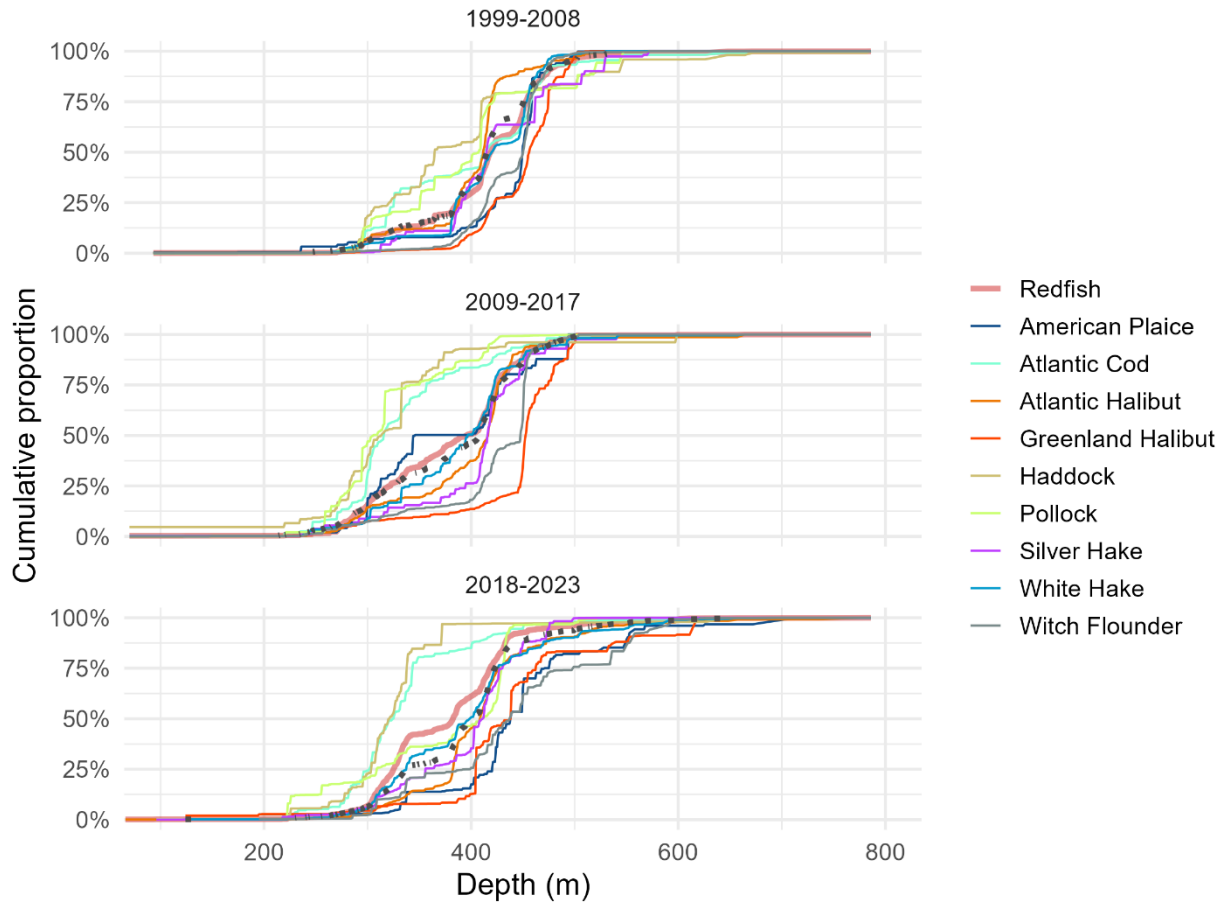


Figure 74. Cumulative proportion of Redfish, American Plaice, Atlantic Cod, Atlantic Halibut, Greenland Halibut, Haddock, Pollock, Silver Hake, White Hake, and Witch Flounder as a function of depth based on at-sea observer data in Redfish-directed fishery from 1999-2023 in Unit 2 by period. The dashed lines represent the depth distribution for all the sets done over that time period. 2024 values are not shown.

Table 14. Percentile describing depth (m) distribution of American Plaice, Atlantic Cod, Atlantic Halibut, Greenland Halibut, Haddock, Pollock, Redfish, Silver Hake, White Hake, and Witch Flounder based on at-sea observer data for the Redfish-directed fishery from 1999 to 2024 in Unit 2 by period. 2024 values are preliminary.

Species	5%	10%	25%	50%	75%	90%	95%
1999-2008							
American Plaice	280	386	423	450	458	471	488
Atlantic Cod	294	298	325	412	458	474	523
Atlantic Halibut	295	317	388	412	419	446	478
Greenland Halibut	389	402	422	456	474	490	497
Haddock	291	295	322	365	413	531	633
Pollock	292	296	347	407	421	519	525
Redfish	296	319	388	419	453	475	500
Silver Hake	317	334	390	415	461	510	529
White Hake	302	380	385	420	453	465	474
Witch Flounder	381	392	415	450	456	472	478
2009-2017							
American Plaice	276	298	311	345	426	469	481
Atlantic Cod	245	270	299	316	357	425	458
Atlantic Halibut	277	292	371	416	426	441	472
Greenland Halibut	278	357	447	453	472	493	498
Haddock	99	259	283	313	333	372	432
Pollock	250	256	285	305	345	411	417
Redfish	274	286	322	395	424	451	470
Silver Hake	256	314	392	416	435	454	481
White Hake	273	301	338	397	422	452	485
Witch Flounder	273	316	410	448	451	456	466
2018-2023							
American Plaice	330	337	417	438	471	550	562
Atlantic Cod	240	278	301	325	343	416	450
Atlantic Halibut	307	331	382	408	428	481	522
Greenland Halibut	305	387	404	438	461	553	607
Haddock	225	277	303	321	338	371	372
Pollock	221	225	309	410	429	434	438
Redfish	291	305	325	382	418	435	473
Silver Hake	288	309	356	411	430	469	474
White Hake	297	307	337	399	425	488	552
Witch Flounder	304	309	399	437	495	556	579

3.6.2.3. Bycatch length frequency

ASO also measured fish length in the Redfish-directed fishery (Figure 75). From 2018 to 2023, Atlantic Cod caught as bycatch ranged from 38 to 88 cm (mode = 45 cm, median = 47 cm), Haddock from 28 to 54 cm (mode=45 cm, median=47 cm), White Hake from 37 to 94 cm (mode=58 cm, median = 58 cm), Silver Hake from 27 to 52 (mode= 33 cm, median= 34 cm), Pollock from 38 to 70 cm (mode=45 cm, median = 49 cm), Atlantic Halibut from 56 to 185 cm (mode = 83 cm, median = 96 cm), Greenland Halibut from 39 to 64 cm (mode=42 cm, median=42 cm), and Witch Flounder from 36 to 44 cm (mode=36 cm, median=39 cm). Bycatch species length distribution in the Redfish-directed fishery remained overall similar over time, although larger specimens of the Gadidae family (i.e., Atlantic Cod, Pollock and Haddock) appear to have fallen in proportions in the 2018-2023 catches.

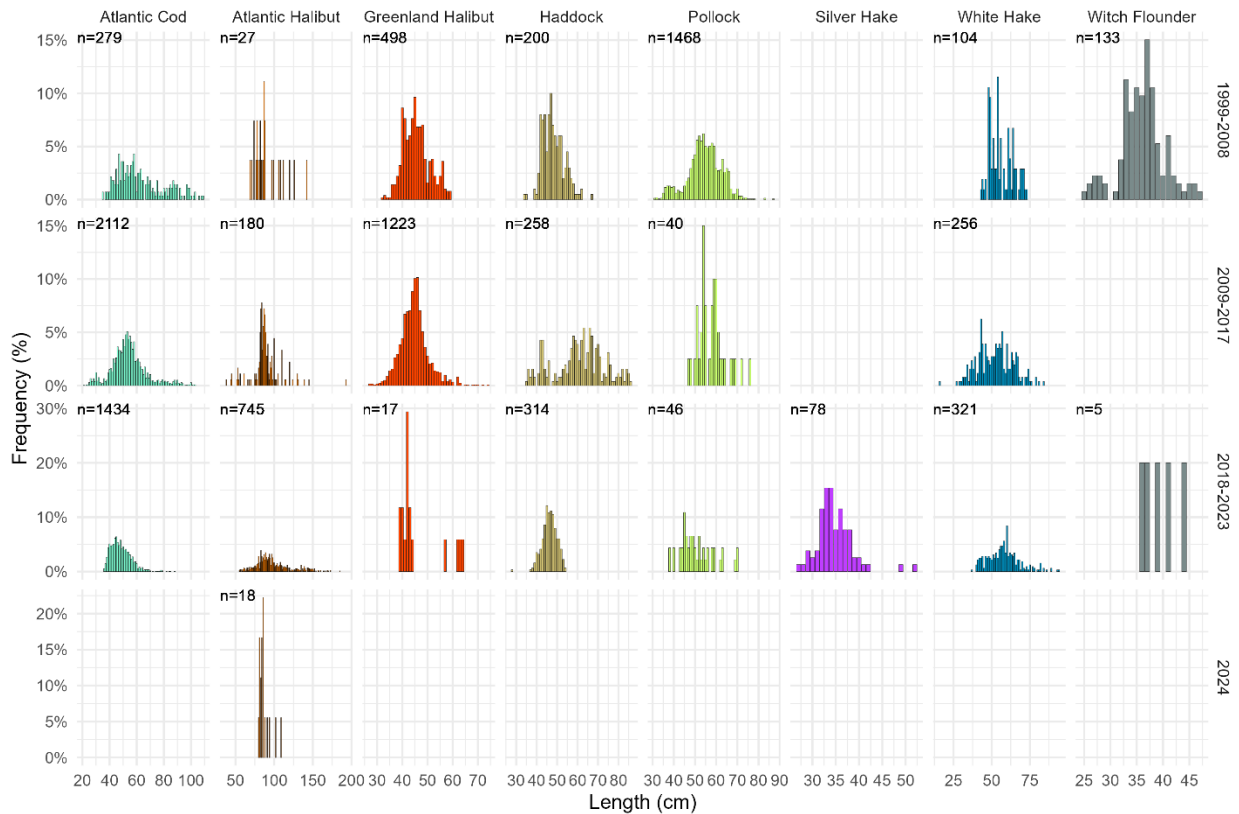


Figure 75. Bycatch species length frequency in percentage in Unit 2 from 1999 to 2024 based on at-sea-observer data in the Redfish-directed fishery. Numbers of fish measured by period are indicated (n). Frequency distributions were not standardised for catch weight.

4. SURVEYS

4.1. NGSL RESEARCH SURVEY

Since August 1984, DFO has conducted an annual ecosystem bottom trawl research survey of the Estuary and nGSL. The survey covers waters of the Laurentian Channel and north of it, from the Lower Estuary in the west to the Strait of Belle Isle and the Cabot Strait in the east, specifically NAFO Divisions 4RS, and the northern part of 4T (Chamberland et al. 2025, Figure 76). Over the years, different vessels and fishing gears have been used. From 1984 to 1990, the survey was conducted aboard the Lady Hammond using a Western IIA bottom trawl. From 1990 to 2005, the Canadian Coast Guard Ship (CCGS) *Alfred Needler* and an URI 81 '114' bottom trawl were used. Starting in 2004, the CCGS *Teleost* equipped with a Campelen 1800 bottom trawl has been used. In 2021, the CCGS *John Cabot* equipped with a modified Campelen 1800 bottom trawl started being used.

In 1990, comparative fishing was conducted between the Lady Hammond and the CCGS *Alfred Needler*, in 2004 and 2005, between the CCGS *Alfred Needler* and the CCGS *Teleost*, and in 2021 and 2022, between the CCGS *Teleost* and the CCGS *John Cabot*. Conversion factors were established to maintain continuity in the time series, providing a standardized Redfish abundance and biomass index series (Bourdages et al. 2007, Benoit et al. 2024).

This nGSL DFO survey uses a stratified random sampling design. Since 2008, the study area is divided into 56 strata (Figure 76) of which 52 have typically been sampled every year. Strata

were defined based on depth, NAFO Divisions, and substrate type. Trawling stations are allocated proportionately to strata surface area, with a minimum of two stations per stratum. The locations of the stations are determined randomly within each stratum. At each station, the catch is sorted and weighed by taxon and biological data are collected from subsamples of the catch. For Redfish, the following characteristics can be recorded or collected by individual: length, sex, AFR counts, stomach contents, otoliths, and tissue samples. The study area used for calculating Redfish indices encompassed the 52 strata surveyed each year, covering 116,115 km².

In 2024, 163 fishing stations were successfully fished, with 50 in 4R, 70 in 4S, and 43 in 4T. All strata were sampled with a minimum of two stations except for strata 414, 821, 824, and 841 for which the effort was one station.

When some strata were not sampled by a minimum of two successful stations, a multiplicative model was used to predict catch rates.

In such cases, a multiplicative model of the form:

$$\log(\text{catch rate} + 0.01) \sim \text{stratum} + \text{year}$$

was used to predict catch rate indices. This model provided a predicted value for strata with fewer than two tows based on the data of the current year and the previous three years, or from the current year and the three adjacent years for missing strata in the first three years of the series. A detailed description of the fishing and sampling protocol, and the calculation methods are presented in Chamberland et al. (2025).

The results of the nGSL survey are presented by species, *S. mentella* and *S. fasciatus*, for mature and immature individuals, or for different length classes in CCGS *John Cabot* equivalent. For the first time, catch rates for Units 1 and 2 used in the assessment are standardized to the catchability of the CCGS *John Cabot* fishing a modified Campelen trawl. This slightly modifies the biomass indices and reference points provided in previous assessments (Senay et al. 2023).

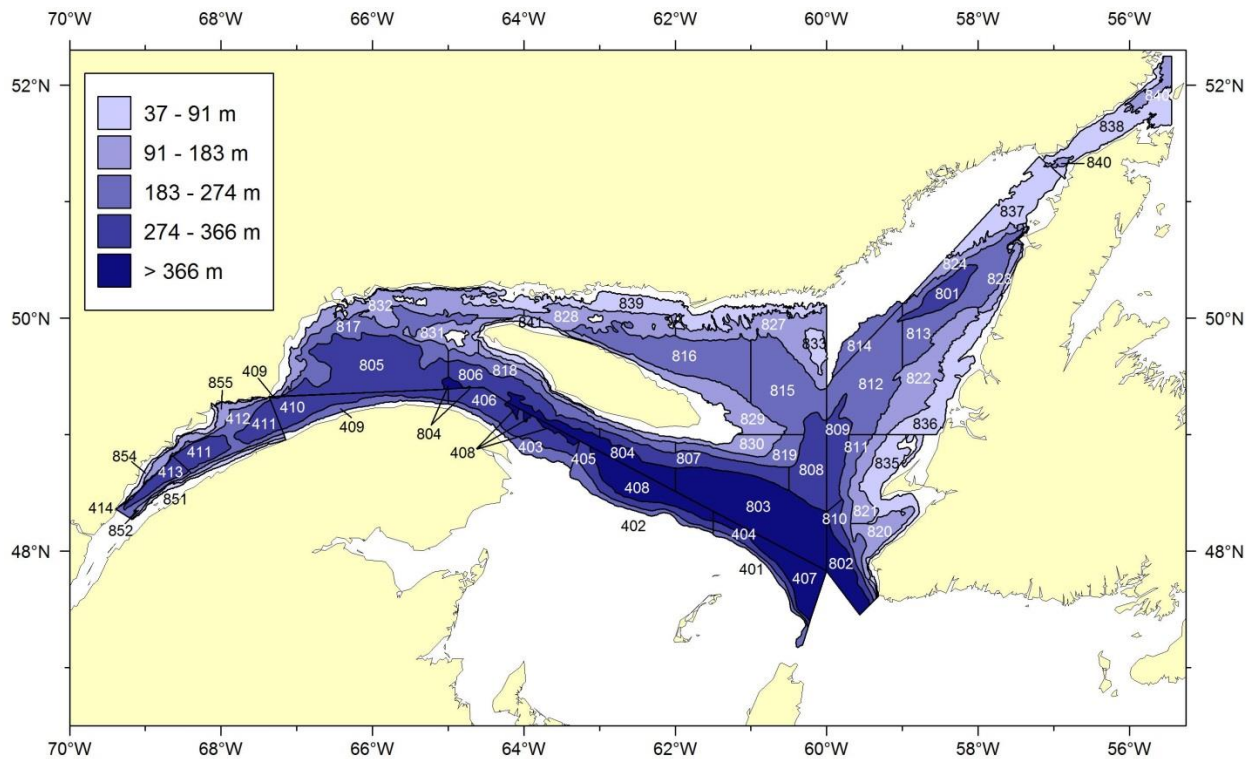


Figure 76. Stratification scheme used for the nGSL DFO survey.

4.2. SURVEYS COMPARISON IN UNIT 1

The southern GSL (sGSL) survey consists of a stratified random groundfish bottom trawl survey conducted annually in September since 1971 in NAFO Division 4T (Figure 77). Fishing was performed using the E.E. Prince equipped with a Yankee 36 trawl from 1971 to 1985, with the Lady Hammond using a Western IIA trawl from 1985 to 1991, and by the CCGS *Alfred Needler* using a Western IIA trawl from 1992 to 2002. In 2004 and 2005, comparative fishing was conducted between the CCGS *Alfred Needler* and the CCGS *Teleost* using a Western IIA trawl. Stratified abundance estimates for 2004 and 2005 were calculated by averaging catches of the two vessels for the corresponding tow. In 2021 and 2022, comparative fishing between the CCGS *Teleost* and the CCGS Captain Jacques Cartier using a NEST trawl was conducted. To maintain the consistency of the time series, comparative fishing experiments were conducted and conversion factors were applied where necessary to account for changes in vessel and gear (Nielsen 1994; Swain et al. 1995; Benoit and Swain 2003; Benoit 2006; Benoit and Yin 2023).

The mobile gear sentinel survey is carried out in NAFO Subdivision 3Pn and Divisions 4RST every July since 1995. The survey is performed by commercial fishermen and follows a depth-stratified random survey design similar to the nGSL DFO survey. The fishing gear used is a Star Balloon 300 bottom trawl mounted on a Rockhopper footgear. The trawl mesh size is 145 mm with a 40 mm mesh liner in the codend (Benoit et al. 2022).

Relative indices of Redfish biomass from nGSL, sGSL, and mobile sentinel surveys were scaled to their respective maximum value in order for values to be bounded between 0 and 1 and trends were compared across surveys and years. Similar trends can be observed across surveys, with high relative biomass values prior to the mid-1990s. Following this period, biomass decreased and stayed at low levels until the 2011-2013 cohorts started appearing in

the catch around 2013 and led to a rapid increase in overall redfish biomass thereafter (Figure 78). Both nGSL and sGSL surveys indicated a decline in Redfish biomass in recent years, with 2024 biomass corresponding to 45% of the maximum value obtained in 2019 in the nGSL and 58% of the maximum value obtained in 2018 in the sGSL survey. However, the 2024 estimate of the sentinel survey is the second highest value of that survey and similar to the maximum value of the time series. These differences may be explained by the heterogeneous distribution of Redfish, a species which forms large schools in specific locations; this can generate important spatiotemporal variations and large confidence intervals in the mean biomass indices. The nGSL survey is considered the most appropriate for assessing Redfish stocks in Unit 1 given that it covers the main Redfish aggregations. For this reason, the following sections will focus on the latter.

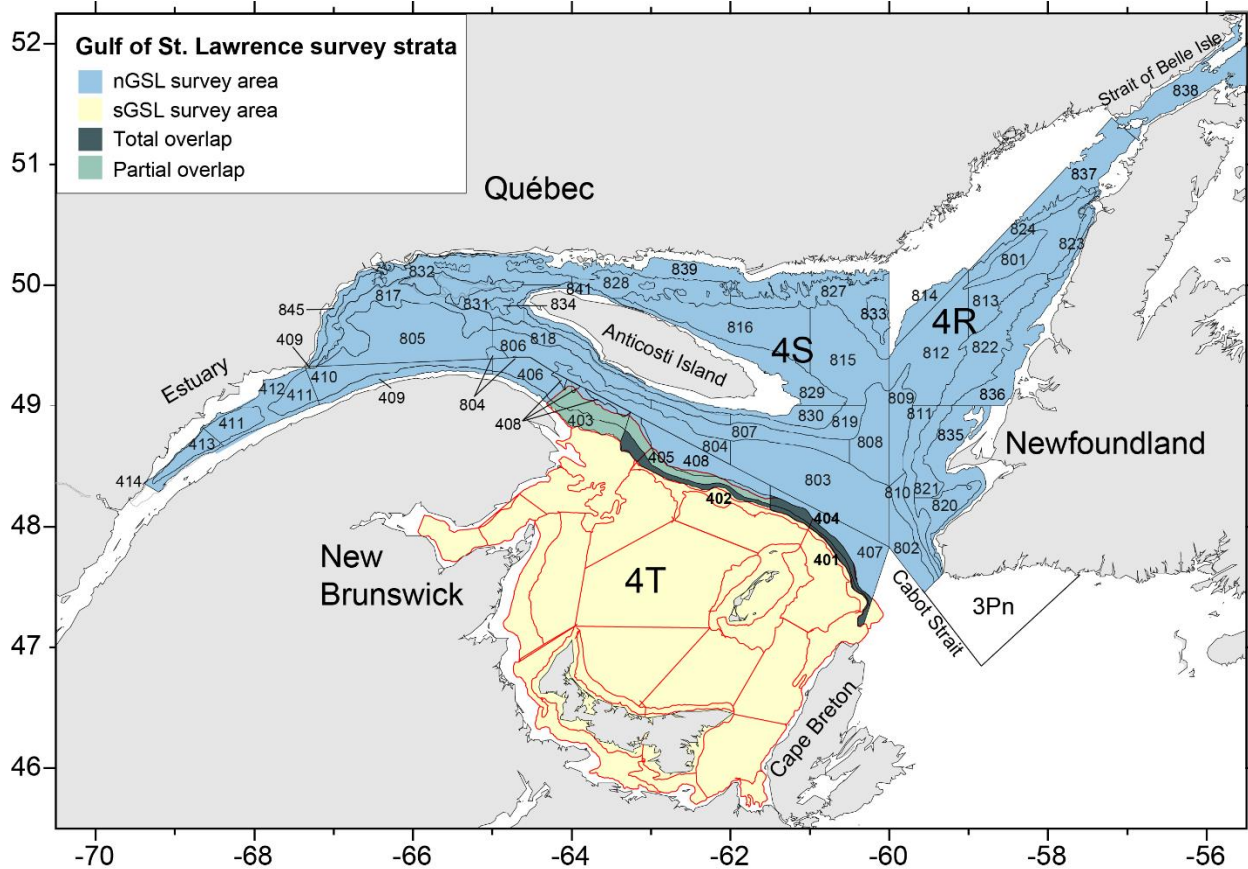


Figure 77. Map showing the area covered by the northern Gulf of St. Lawrence (nGSL) and the Southern Gulf of St. Lawrence (sGSL) DFO surveys and their overlap.

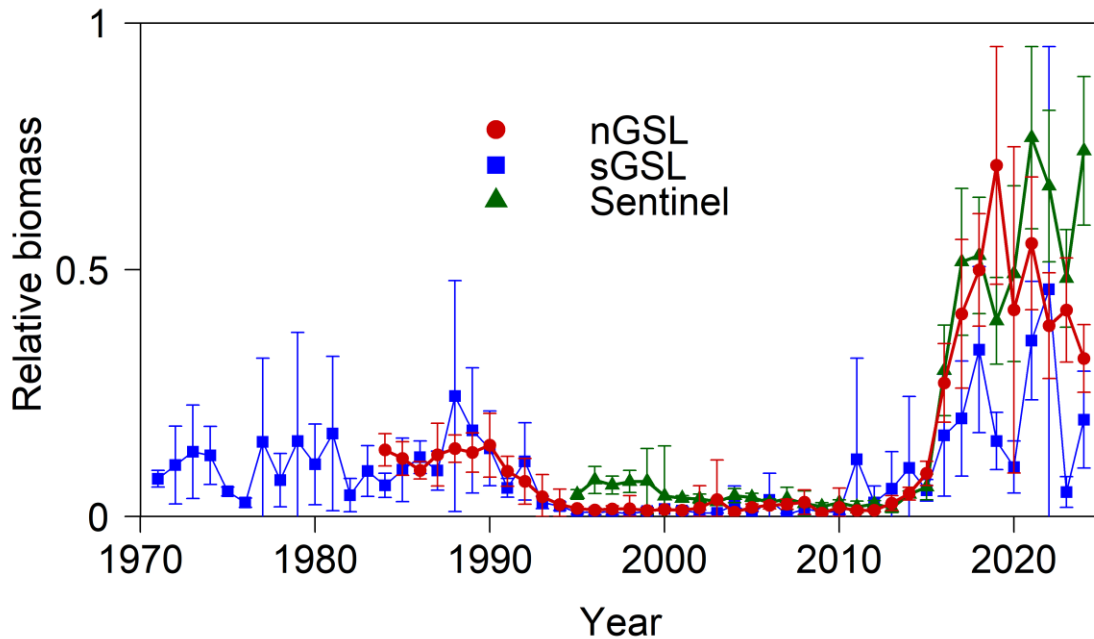


Figure 78. Comparison of relative indices of Redfish biomass with 95% confidence intervals from the DFO research survey in the nGSL (red line with circles) and sGSL (blue line with squares), and the Sentinel bottom trawl survey (green line with triangles).

4.3. SPATIAL DISTRIBUTION IN NGSL SURVEY

The spatial distribution of catch rates in the nGSL DFO survey, illustrated in maps created using inverse distance weighting, indicated that between 1984 and 1996, the Laurentian, Esquiman and Anticosti Channels were populated by both species (Figure 79 to Figure 82). Subsequently, there was a substantial decrease in the catch rate of mature individuals of both species, particularly west of Anticosti Island and north of Esquiman Channel (Figure 80 and Figure 82). Starting in 2013, catch rate of immature *S. mentella* increased in the Esquiman, Anticosti, and Laurentian Channels, and the southwestern edge of Cabot Strait (Figure 79). During the 2019-2024 period, the catch rate of immature fish decreased, while that of mature *S. mentella* increased to unprecedented levels. Matures *S. fasciatus* have also shown an increase in catch rate, albeit to a lesser extent than *S. mentella* (Figure 80 and Figure 82).

Stratified cumulative frequency distributions of catches (Perry and Smith 2011) indicated that between 2020 and 2024, *S. mentella* generally occurred at depths greater than 200 m, at temperatures between 6 and 7 °C, and at levels of dissolved oxygen between 20 and 40% (Figure 84). On the other hand, most *S. fasciatus* were caught at shallower depths (between 100 and 300 m), at temperatures between 2 and 7 °C, and at levels of dissolved oxygen between 20 and 60% (Figure 85). When considering size classes, *S. mentella* larger than 25 cm were found deeper than smaller individuals of that species, whereas size-based differences in spatial distribution were not observed for *S. fasciatus* (Figure 83). Depth distributions in 2024 were similar to those of previous years.

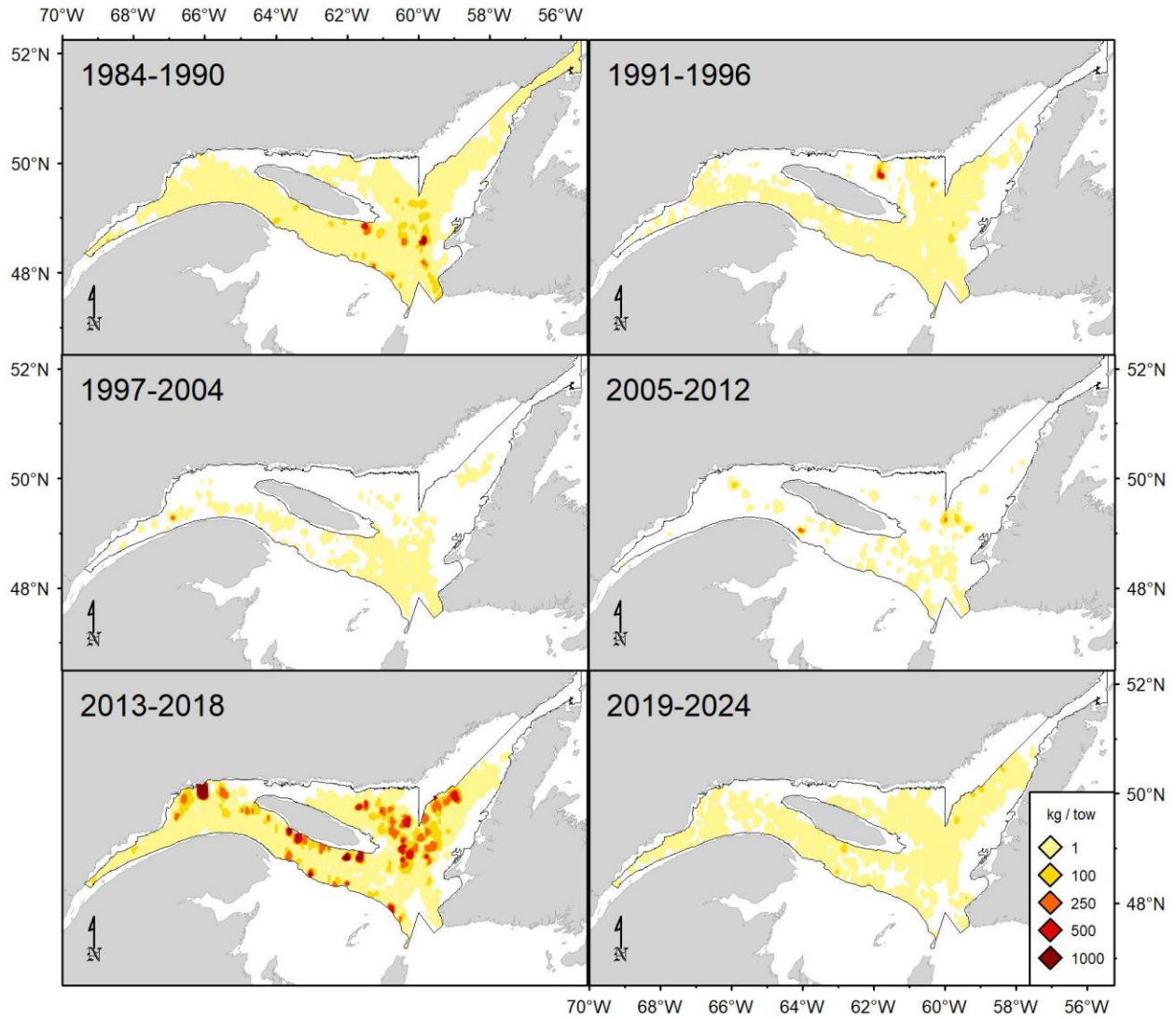


Figure 79. Catch rate distribution of immature *S. mentella* (kg/15-minute tow) in the nGSL DFO survey from 1984 to 2024.

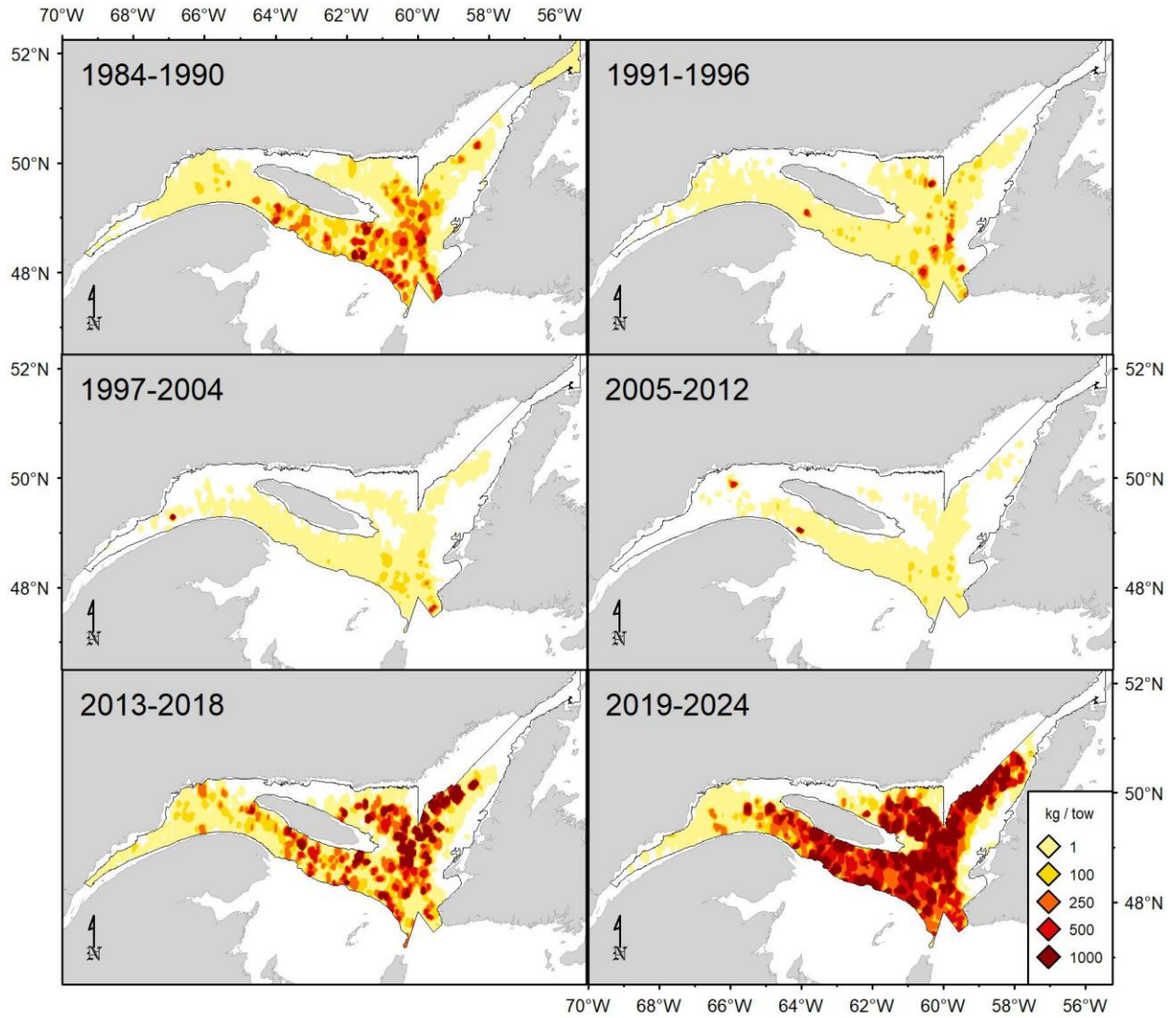


Figure 80. Catch rate distribution of mature *S. mentella* (kg/15-minute tow) in the nGSL DFO survey from 1984 to 2024.

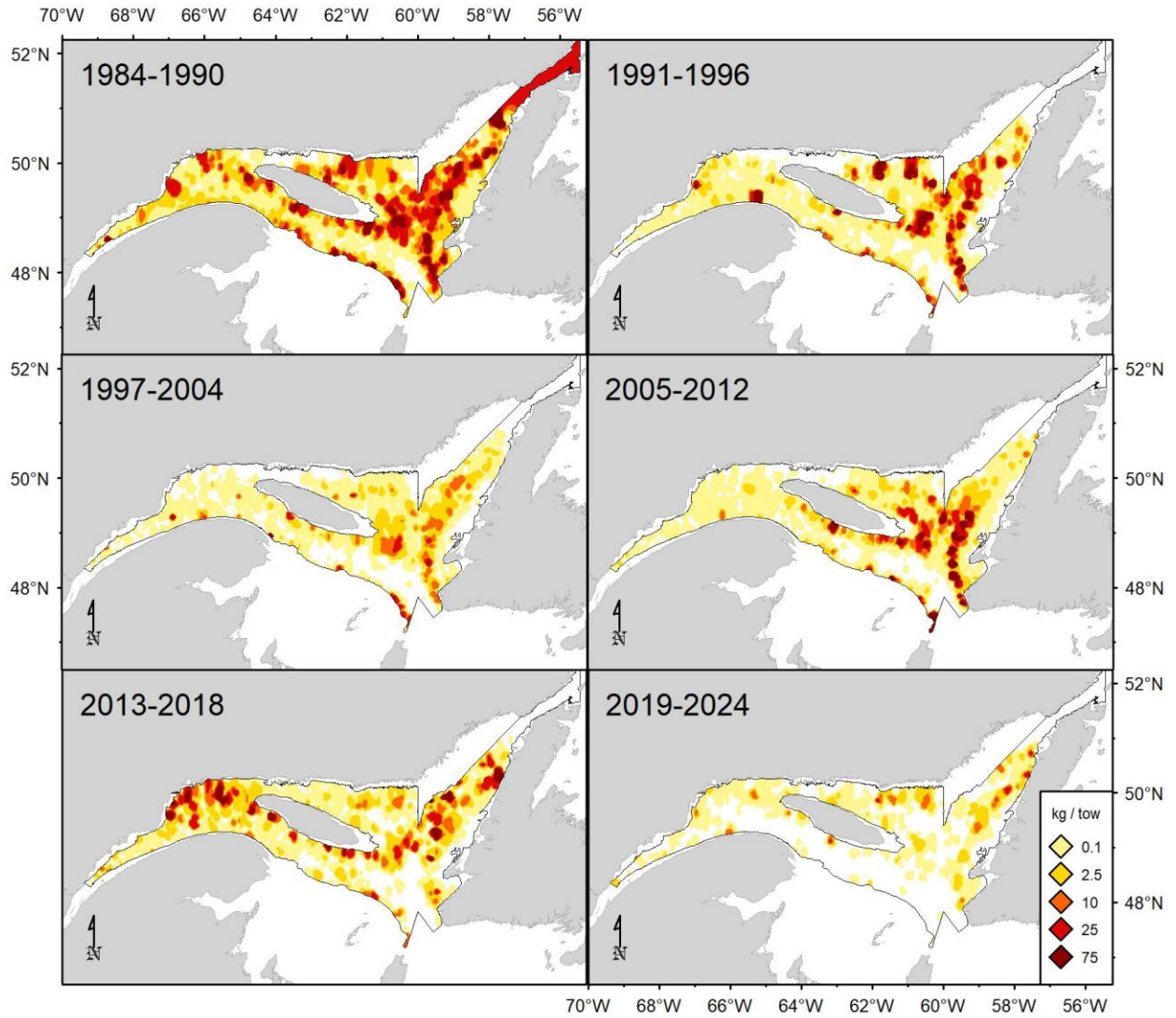


Figure 81. Catch rate distribution of immature *S. fasciatus* (kg/15-minute tow) in the nGSL DFO survey from 1984 to 2024.

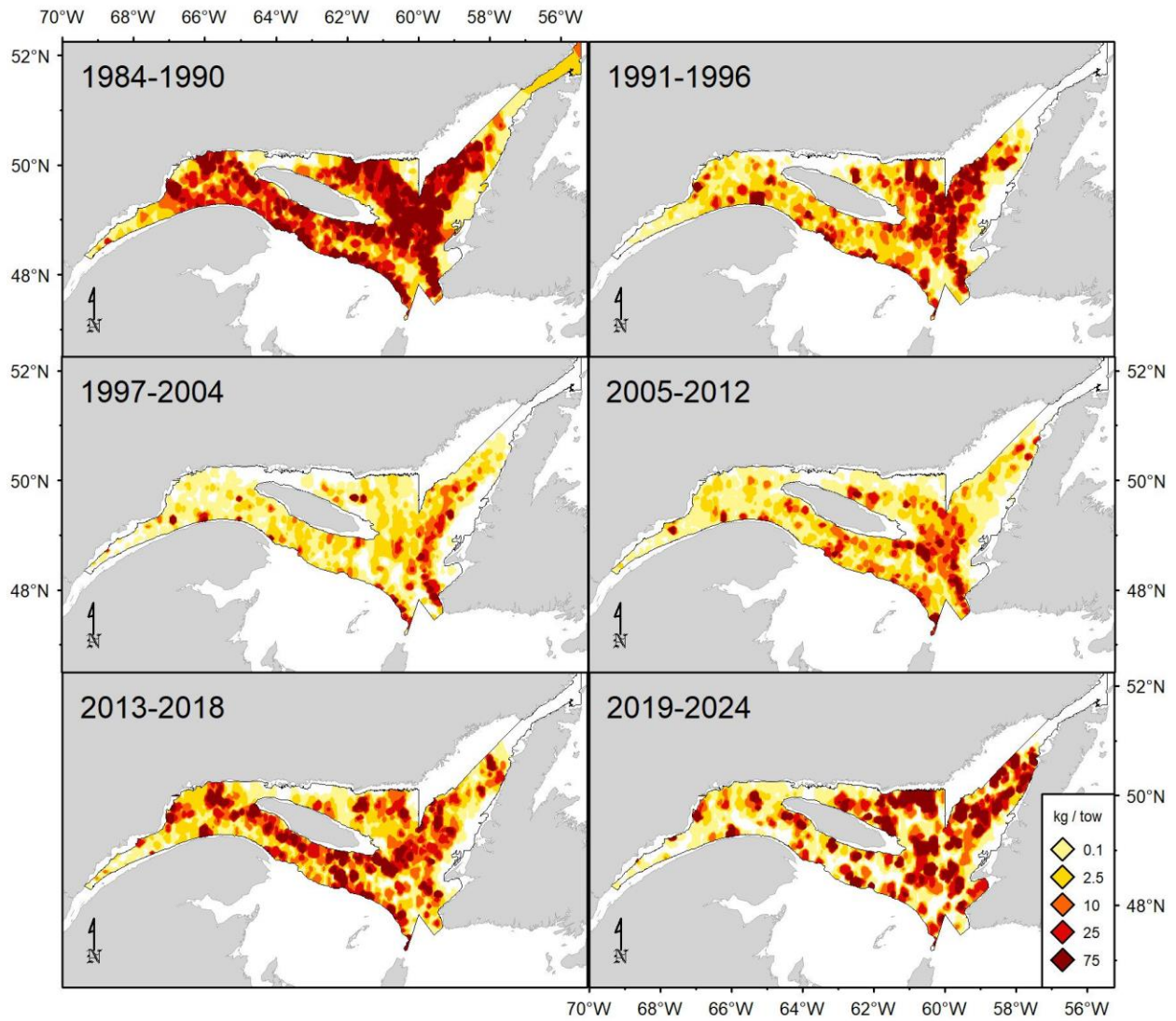


Figure 82. Catch rate distribution of mature *S. fasciatus* (kg/15-minute tow) in the nGSL DFO survey from 1984 to 2024.

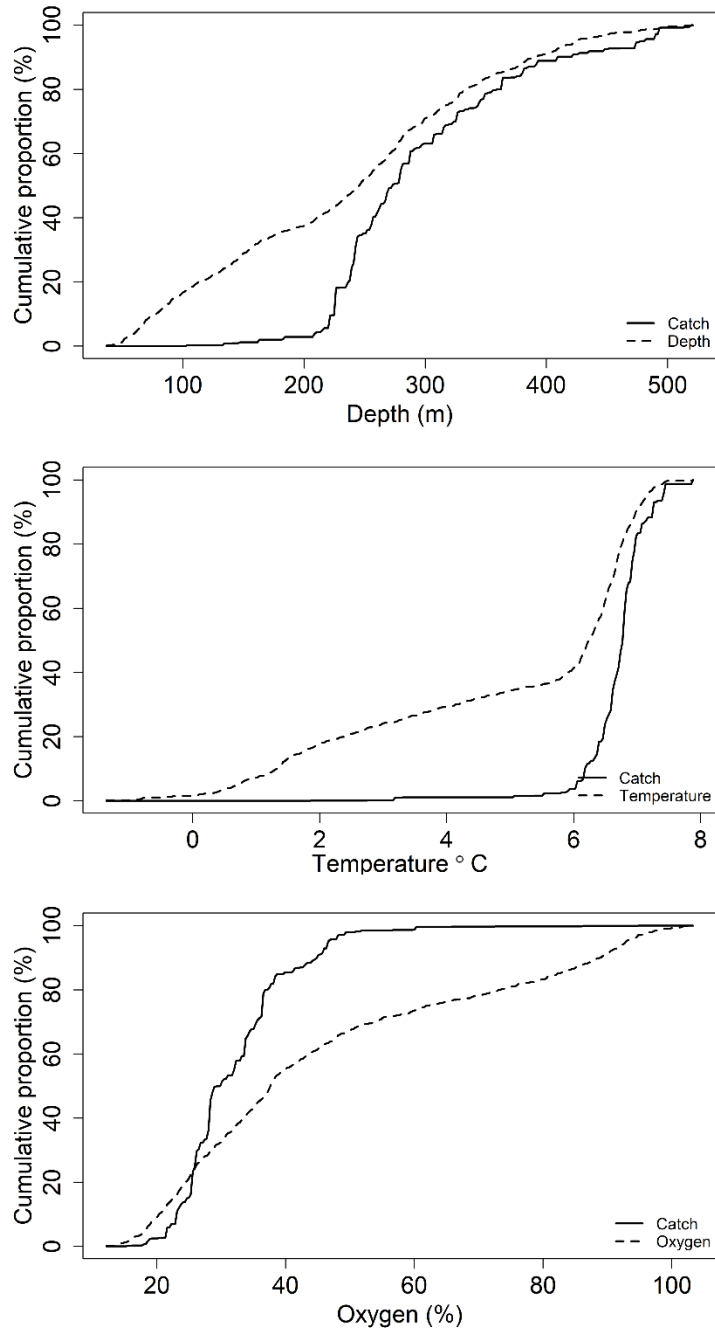


Figure 83. Stratified cumulative proportion of *S. mentella* in the nGSL DFO survey from 2020-2024. The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m), temperature (°C), and dissolved oxygen (saturation %).

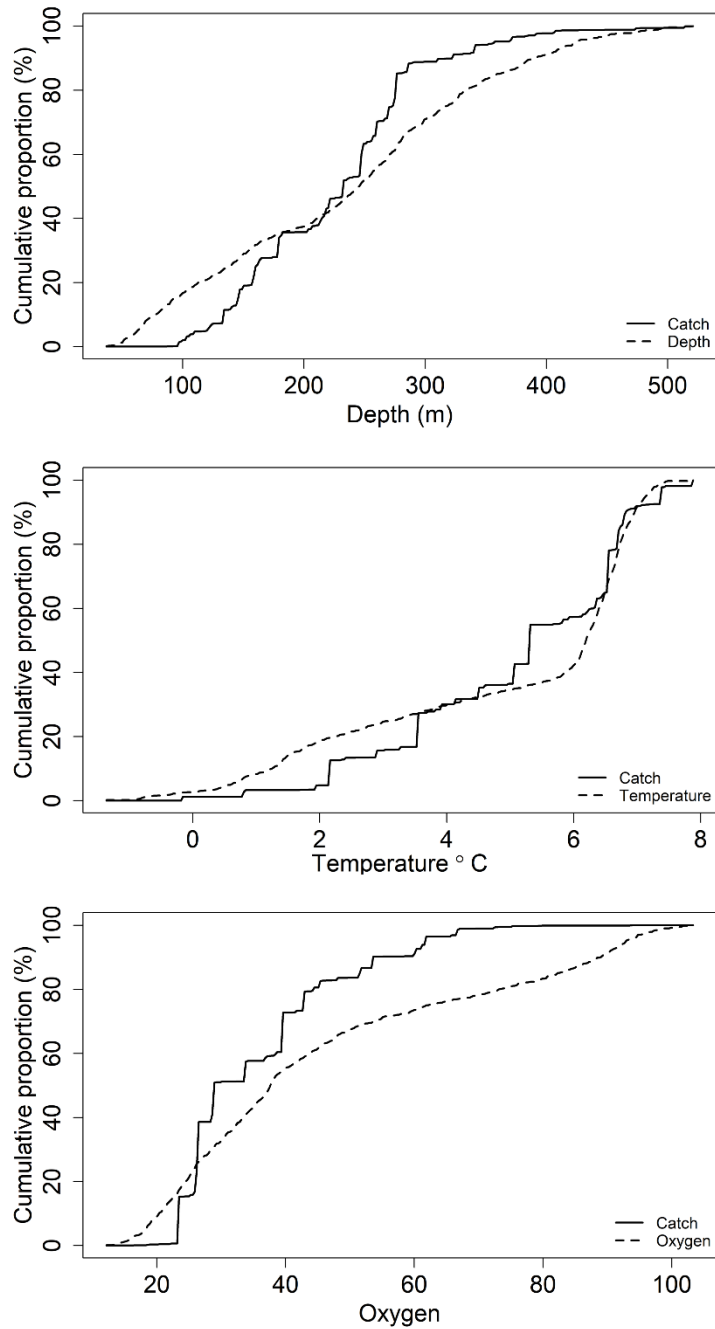


Figure 84. Stratified cumulative proportion of *S. fasciatus* in the nGSL DFO survey from 2020-2024. The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m), temperature (°C), and dissolved oxygen (saturation %).

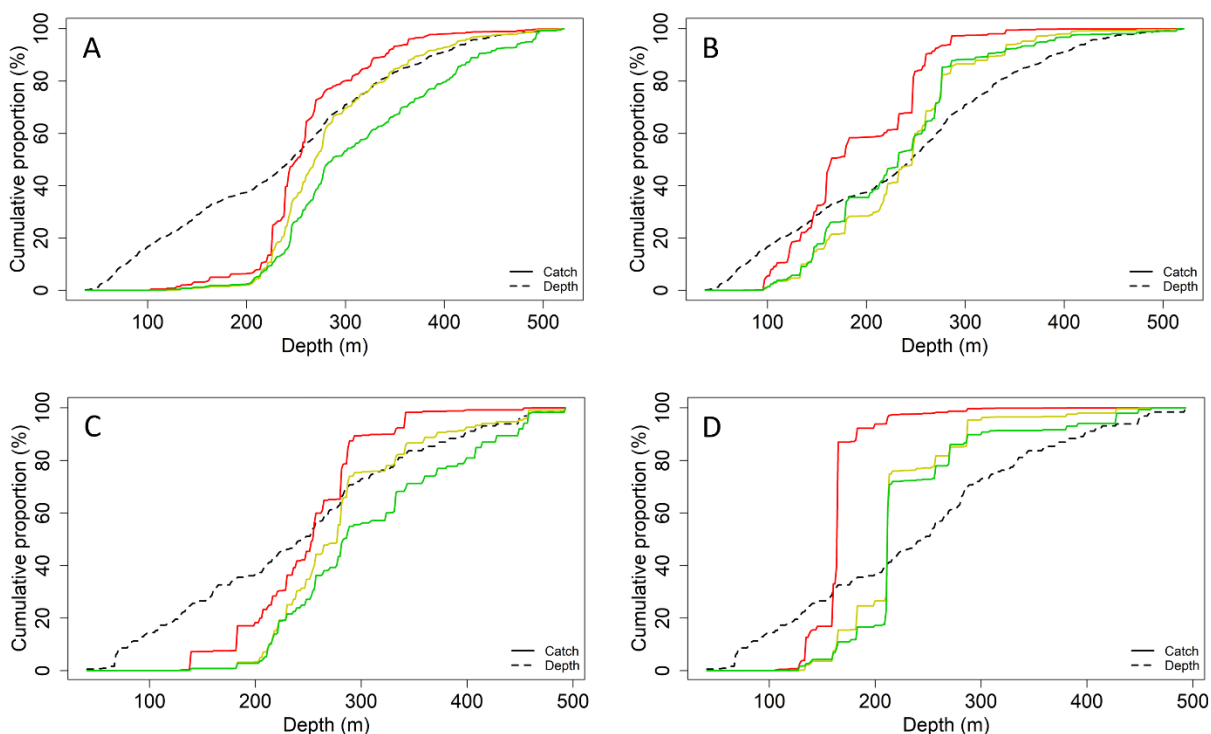


Figure 85. Stratified cumulative proportion of *S. mentella* (A and C) and *S. fasciatus* (B and D) in the nGSL DFO survey from 2020-2024 (A and B) and in 2024 only (C and D). The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m) and by length classes, 0-22 cm in red, 22-25 cm in yellow, and larger than 25 cm in green.

4.4. SURVEY INDICES AND LENGTH FREQUENCY IN NGSL SURVEY

Total minimum trawlable biomass indices for *S. mentella* and *S. fasciatus* declined sharply from the late 1980s to 1994 (Figure 86). Subsequently, the indices of Redfish of all sizes remained low and stable until the 2010s (Figure 87 and Table 15B). The 2011-2013 cohorts, mainly dominated by the 2011 year class, began appearing in the survey in 2013. These juveniles were mostly composed of *S. mentella*, with the genetic signature of the GSL ecotype (Brassard et al. 2017). The minimum trawlable biomass of small individuals increased as they were growing, until 2018 when it started decreasing as they reached the size of 22 cm (Figure 87A and B).

In 2024, the minimum trawlable biomass of both Redfish species combined was estimated at 1,933 kt which represented a decrease of 23% from the 2023 estimate, but was still among the highest values of the time series that started in 1984 (Table 15B). The minimum trawlable biomass of the two species combined accounted for 81% of the minimum trawlable biomass of all captured organisms in the survey (invertebrates, pelagic fish, demersal fish and groundfish), while it averaged 15% between 1995 and 2012 (Figure 88). *S. mentella* constituted alone 73% of the minimum trawlable made during the survey, indicating that it dominates the demersal ecosystem of the nGSL.

In 2024, total minimum trawlable biomass was estimated to be 1,741 kt for *S. mentella*, one of the highest values ever observed, despite a decrease of 25% from 2023. Total minimum trawlable biomass of *S. fasciatus* was estimated to be 192 kt, a value similar to 2022 and 2023 (Figure 86).

Minimum trawlable biomass of Redfish larger than 22 cm began to increase in 2017. In 2024, it was estimated at 1,722 kt for *S. mentella*, which is among the highest of the series even if it decreased by 24% compared to 2023 (Figure 87C). In 2024, minimum trawlable biomass was estimated at 179 kt for *S. fasciatus*, a value above the average of the time series, similar to 2022 and 2023 (Figure 87D).

Biomass of *S. mentella* greater than 25 cm (corresponding to larger fish that could be transformed as fillets) was estimated at 816 kt in 2024, a value similar to 2023, whereas biomass of *S. fasciatus* increased from 64 kt in 2023 to 104 kt in 2024 (Figure 87E and F, and Table 15B).

Overall in 2024, 1% of *S. mentella* biomass was under 22 cm, 52% between 22 and 25 cm, and 47% over 25 cm. For *S. fasciatus*, 7% of the biomass was under 22 cm, 39% between 22 and 25 cm, and 54% over 25 cm (Figure 89). In the summer 2024, Redfish modal length was 25 cm for both species, compared to 24 cm from 2021 to 2023 (Figure 90A and B). Since the 2011-2013 cohorts, no important recruitment event reached minimum regulatory size (Figure 90C and D).

In 2010, the COSEWIC designated the GSL and Laurentian Channel DU of *S. mentella* (equivalent to the Units 1 and 2 stock) as endangered, based on a 98% decline in mature fish abundance in the nGSL DFO survey (COSEWIC 2010). Since 2016, the abundance of mature *S. mentella* in the survey has exceeded the levels observed prior to the 1980s to mid-1990s decline, and abundance in 2024 was several folds higher than those levels (Figure 91A).

The Atlantic Population DU of *S. fasciatus* was designated as threatened by the COSEWIC in 2010, based on a 99% decline in mature fish abundance over two generations (COSEWIC 2010). Units 1 and 2 *S. fasciatus* were believed to constitute a majority of the DU, which also includes the Labrador, Newfoundland and Scotian Shelves. Abundance trends in the survey in Unit 1 were therefore influential in establishing the designation as threatened. The abundance of mature *S. fasciatus* was stable from 2022 to 2024 and at levels similar to those observed prior to the decline in the 1990s (Figure 91B).

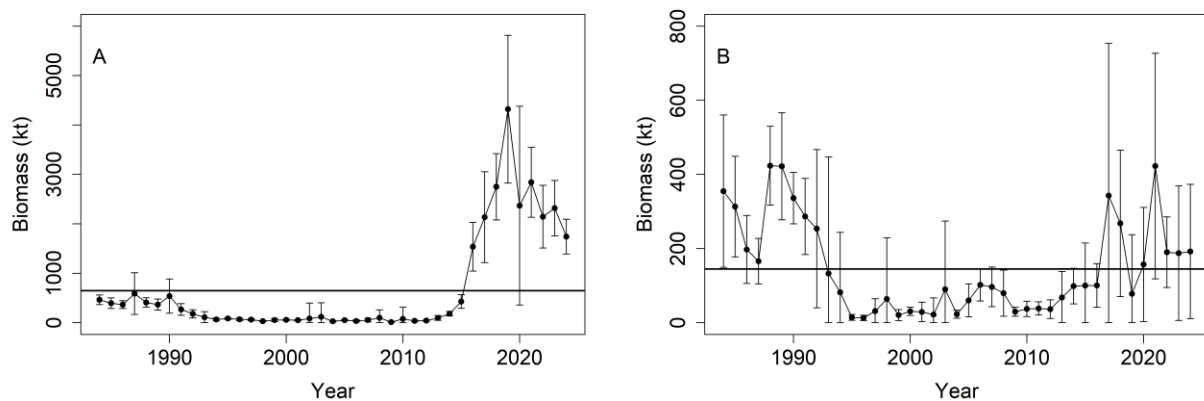


Figure 86. Minimum trawlable biomass in kilotonnes (kt) with 95% confidence intervals of *S. mentella* (A) and *S. fasciatus* (B) in the nGSL DFO survey from 1984 to 2024. The solid lines represent the 1984-2023 average. Note the different scales on the y-axis.

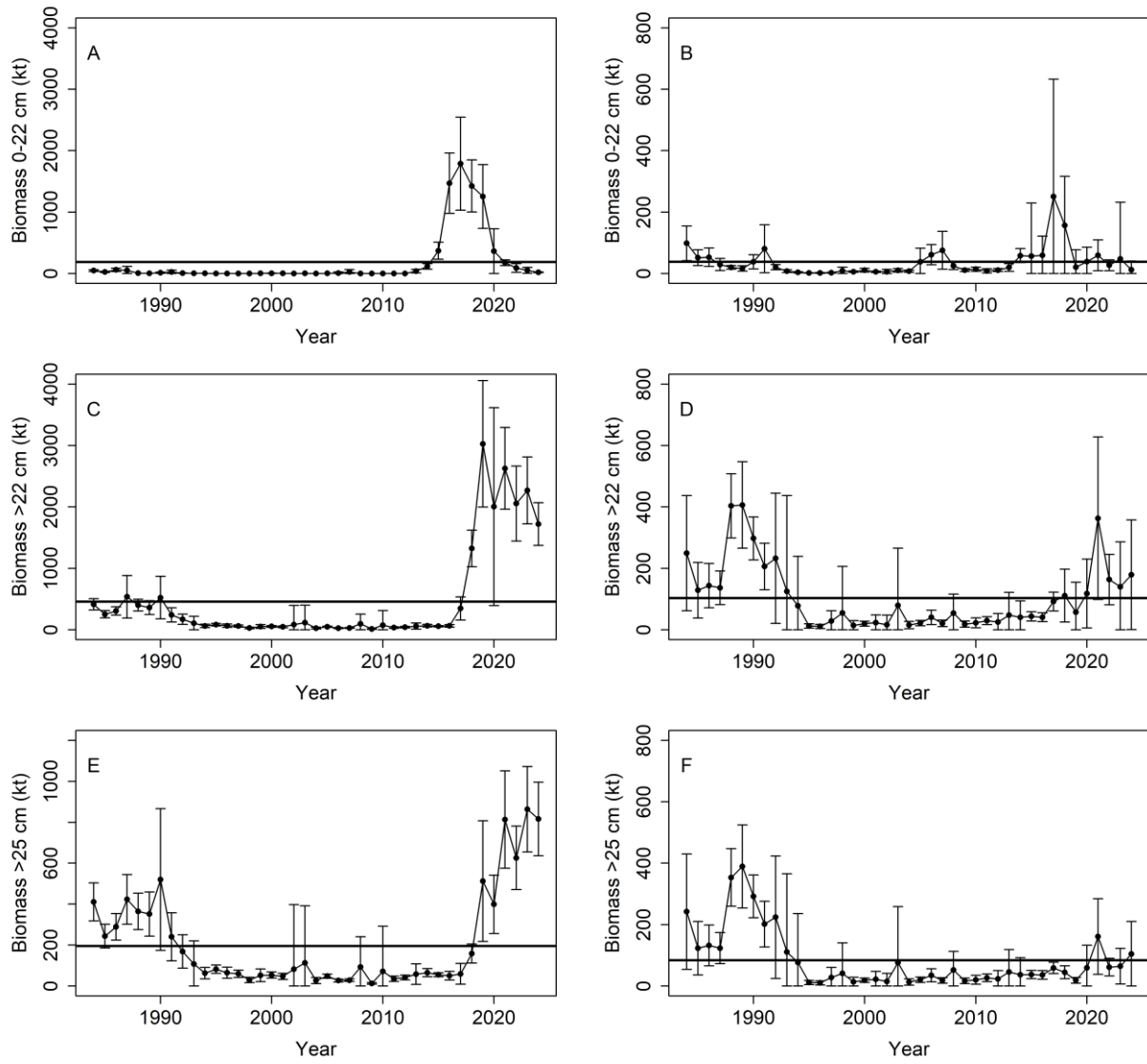


Figure 87. Minimum trawlable biomass in kilotonnes (kt, with 95% confidence intervals) of *S. mentella* (left column; panels A, C, and E) and *S. fasciatus* (right column; panels B, D, and F) in the nGSL DFO survey from 1984 to 2024, by length classes: 0–22 cm (A-B), > 22 cm (C-D), and > 25 cm (E-F). The solid lines represent the 1984–2023 average. Note the different scales on the y-axis.

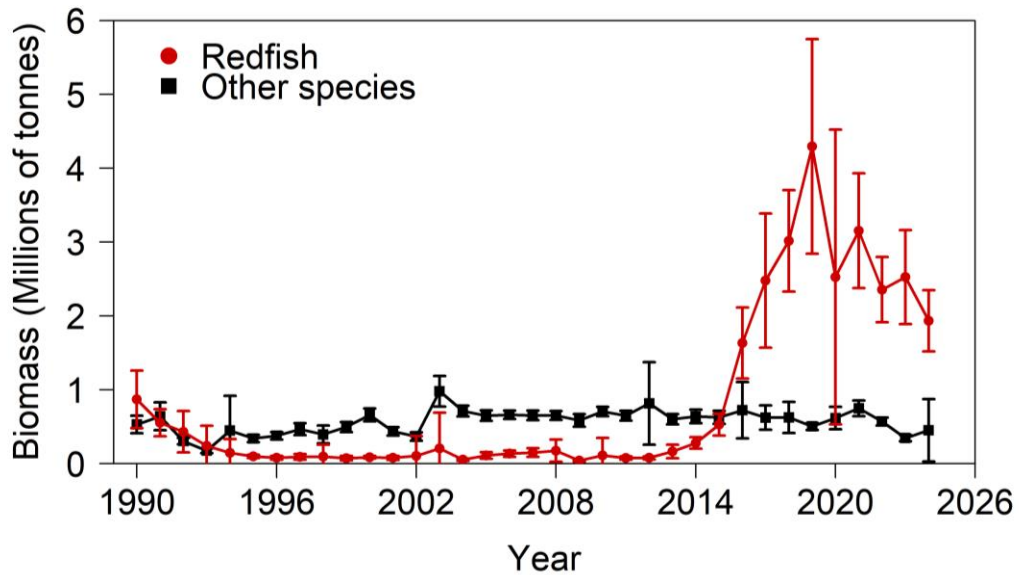


Figure 88. Minimum trawlable biomass (millions of t, with 95% confidence intervals) of Redfish (red circles) and all other species (black squares) sampled in the nGSL DFO survey from 1984 to 2024.

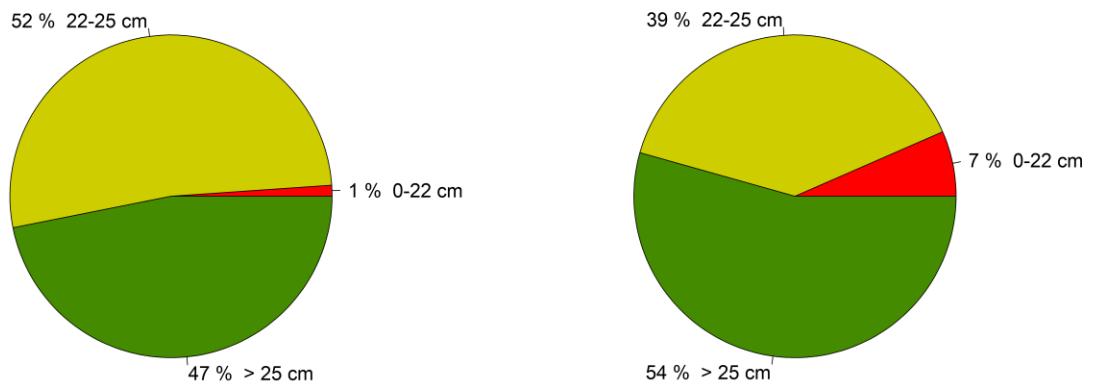


Figure 89. Percentage of minimum trawlable biomass of *S. mentella* (left) and *S. fasciatus* (right) in the nGSL DFO survey in 2024 by length classes, 0–22 cm in red, 22–25 cm in yellow, and larger than 25 cm in green.

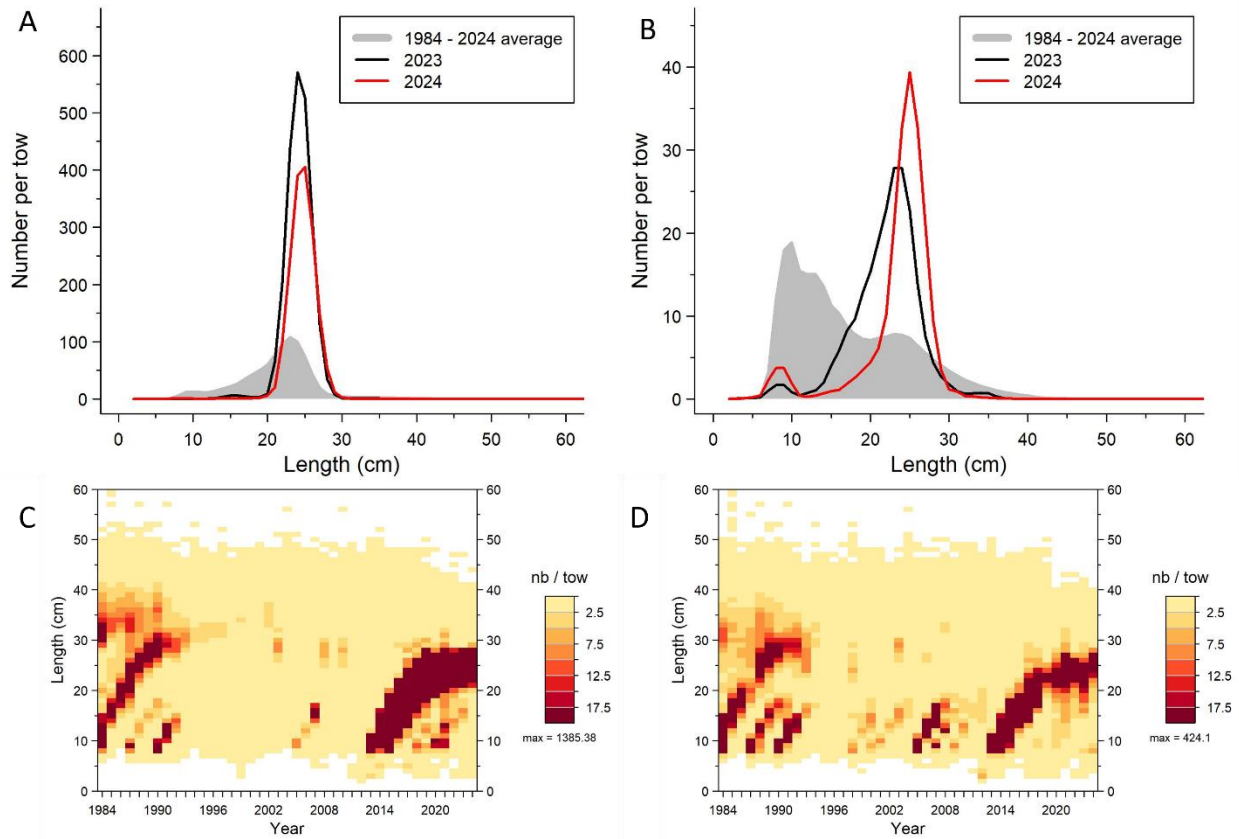


Figure 90. *S. mentella* (A and C) and *S. fasciatus* (B and D) length frequency in the nGSL DFO research survey for 2023, 2024, and the 1984 to 2024 average (A and B), and by length class and year (C and D).

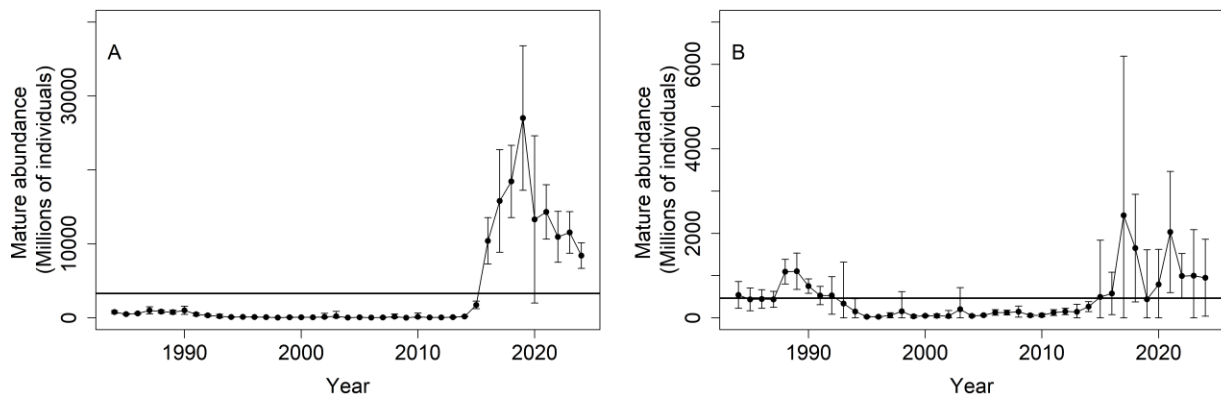


Figure 91. Minimum trawlable mature fish abundance (millions of individuals, with 95% confidence intervals) of *S. mentella* (A) and *S. fasciatus* (B) in the nGSL DFO survey from 1984 to 2024. The solid horizontal lines represent the 1984-2023 average. Note the different scales on the y-axis across panels.

Table 15. Abundance (1,000,000 individuals, A) and biomass (1,000 t, B) indices in nGSL DFO survey from 1984 to 2024 for *S. mentella*, *S. fasciatus*, and *Sebastes* spp. by length class.

A

Year	Abundance (1,000,000 individuals)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes</i> spp.			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
1984	1 523	808	791	2 331	3 286	501	464	3 787	4 810	1 308	1 255	6 118
1985	476	469	421	945	1 042	289	253	1 331	1 518	757	674	2 275
1986	672	599	488	1 272	686	359	288	1 045	1 359	958	776	2 317
1987	638	1 384	806	2 022	961	421	344	1 381	1 598	1 805	1 151	3 403
1988	166	1 147	931	1 312	548	1 230	939	1 778	714	2 377	1 870	3 090
1989	118	982	924	1 100	438	1 210	1 105	1 649	556	2 192	2 030	2 749
1990	585	1 179	1 159	1 764	2 080	781	749	2 861	2 665	1 960	1 909	4 625
1991	1 098	522	513	1 620	3 330	500	475	3 830	4 428	1 022	988	5 450
1992	190	392	376	582	570	553	509	1 123	760	945	885	1 706
1993	44	251	248	296	143	368	295	512	188	620	543	808
1994	37	122	120	160	66	151	145	217	103	273	265	376
1995	29	148	145	178	45	26	21	70	74	174	167	248
1996	32	116	112	148	46	23	20	69	78	139	131	217
1997	29	107	104	136	66	58	54	124	94	165	157	259
1998	38	51	49	88	202	164	97	366	239	215	146	454
1999	49	85	82	133	158	32	26	190	207	116	108	324
2000	71	87	84	158	269	38	32	307	340	126	116	466
2001	40	72	70	113	166	44	38	210	206	116	108	323
2002	27	130	126	158	125	36	29	161	153	167	155	319
2003	43	260	248	303	210	201	183	411	253	461	431	714
2004	16	42	39	58	119	39	29	158	135	81	68	216
2005	117	77	70	194	3 459	45	37	3 504	3 575	122	108	3 698
2006	72	37	35	109	1 491	110	82	1 601	1 563	147	117	1 710
2007	499	44	40	542	1 758	41	30	1 799	2 257	85	70	2 341
2008	16	215	197	231	445	121	110	566	461	336	307	797
2009	5	17	17	22	227	42	34	269	232	59	50	291
2010	15	184	165	199	218	46	36	265	234	231	200	464
2011	24	51	45	75	120	65	51	185	145	116	96	260
2012	16	57	53	73	226	61	47	286	241	118	100	359
2013	4 217	86	82	4 303	1 915	104	94	2 020	6 132	190	176	6 323
2014	4 263	94	89	4 356	2 495	99	78	2 595	6 758	193	167	6 951
2015	7 699	91	80	7 790	1 289	116	83	1 405	8 987	208	163	9 195
2016	20 503	182	98	20 685	1 027	110	84	1 137	21 530	292	182	21 821
2017	19 065	2 006	168	21 071	2 938	350	154	3 288	22 003	2 356	322	24 359
2018	12 611	7 417	529	20 028	1 372	492	125	1 864	13 983	7 909	654	21 892
2019	11 035	17 101	2 037	28 137	227	278	53	505	11 262	17 380	2 090	28 642
2020	3 043	10 674	1 630	13 717	424	496	180	921	3 467	11 170	1 810	14 637
2021	1 788	12 904	3 169	14 692	603	1 606	535	2 209	2 391	14 510	3 704	16 901

Year	Abundance (1,000,000 individuals)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes spp.</i>			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
2022	807	10 354	2 580	11 162	275	786	232	1 061	1 082	11 140	2 812	12 222
2023	460	11 226	3 604	11 687	475	629	220	1 104	935	11 856	3 824	12 791
2024	187	8 291	3 390	8 478	192	844	426	1 036	379	9 136	3 815	9 515

B

Year	Biomass (1,000 t)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes spp.</i>			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
1984	48	414	411	462	98	250	242	348	146	664	653	810
1985	27	252	244	279	51	129	123	180	78	381	367	459
1986	60	306	289	367	53	144	132	197	114	450	422	564
1987	51	538	423	589	29	137	123	166	80	674	547	755
1988	7	401	364	408	20	404	353	424	27	804	718	832
1989	5	361	352	366	16	406	389	423	21	767	741	789
1990	14	524	520	537	38	298	292	336	52	821	812	873
1991	27	242	240	269	80	206	201	286	107	448	442	555
1992	7	172	169	179	21	233	224	254	28	405	393	433
1993	2	108	107	110	8	125	111	133	10	233	218	243
1994	2	63	63	65	4	78	77	82	6	141	139	147
1995	2	83	82	85	2	12	11	14	4	95	94	99
1996	2	66	65	68	2	11	10	13	4	77	76	81
1997	1	60	60	62	3	29	28	31	4	89	88	93
1998	2	30	30	32	9	55	41	64	11	85	71	96
1999	2	53	52	55	6	14	13	21	8	67	66	76
2000	3	54	54	58	11	20	19	31	14	74	72	89
2001	3	48	47	50	6	23	22	29	8	71	69	79
2002	2	83	83	85	6	16	15	22	8	99	97	107
2003	2	116	113	118	10	79	76	90	12	195	189	207
2004	1	27	27	28	8	15	13	23	9	42	40	51
2005	2	49	48	51	38	22	20	60	41	71	68	112
2006	8	27	27	35	61	41	35	102	70	68	61	137
2007	26	29	29	55	76	21	18	97	101	50	47	151
2008	1	96	93	98	25	54	52	79	26	151	145	177
2009	0	13	13	13	11	18	17	30	12	31	29	43
2010	1	76	72	77	14	23	20	37	16	99	92	114
2011	2	36	35	38	9	30	27	38	10	66	62	76
2012	1	42	41	43	11	25	23	37	12	68	64	79
2013	38	59	58	97	20	48	46	68	58	107	104	165
2014	116	66	65	182	58	40	37	99	174	107	102	281
2015	371	57	55	429	57	44	38	100	428	101	93	529
2016	1 471	64	50	1 535	59	41	36	100	1 531	105	87	1 636

Year	Biomass (1,000 t)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes spp.</i>			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
2017	1 788	348	60	2 136	251	92	59	343	2 039	440	118	2 479
2018	1 426	1 324	159	2 750	157	111	45	268	1 583	1 435	203	3 018
2019	1 255	3 027	513	4 282	21	57	19	78	1 275	3 085	531	4 360
2020	364	2 005	399	2 369	39	118	60	157	403	2 123	459	2 526
2021	177	2 628	813	2 805	59	363	161	423	236	2 991	974	3 227
2022	90	2 055	626	2 145	27	163	62	190	117	2 218	688	2 335
2023	51	2 269	864	2 320	47	140	64	187	98	2 409	928	2 507
2024	19	1 722	816	1 741	13	179	104	192	32	1 901	920	1 933

4.5. GROWTH PROJECTION BASED ON NGSL SURVEY ESTIMATES

Redfish are slow-growing and long-lived species. Projections of growth for the length classes corresponding to the 2011-2013 cohorts were provided in previous stocks assessments (Senay et al. 2021). Growth parameters were estimated based on modal estimates of length for the 1980 *S. mentella* cohort and subjected to a constraint on L_{inf} , between 42 cm and 50 cm. Estimated modal size for recent cohorts have deviated from this growth curve, with the modal size remaining at 24 cm between 2021 and 2023, and corresponding to 25 cm in 2024 (Figure 92). Other curves were explored by using the same approach but with different data (1980 and/or 2011-2013 cohorts) and constraints (Figure 92 and Table 16).

When using the modal lengths of the 1980 and/or 2011-2013 cohorts with an L_{inf} constraint of 42-50 cm, similar curves were obtained, all suggesting higher growth than observed in recent years (Figure 92). Similarly, when no L_{inf} constraint was imposed on the 1980 cohort, and the combined 1980 and 2011-2013 cohorts, the curves suggested a higher growth than what is presently observed. The best fit to the observed recent modal lengths was obtained with the 2011-2013 cohorts without the L_{inf} constraint. This curve suggested an L_{inf} of 27 cm (Table 16). These results indicate that Redfish from the strong 2011-2013 cohorts are currently growing slower and are expected to reach smaller sizes compared to Redfish from the 1980 cohort. Generally, this could be explained by a maturation at smaller size, density-dependence, and/or environmental effects in the context of presently low exploitation rates. Coussau et al. (2024) found a strong correlation between growth and Redfish biomass, suggesting intense competition for food at high conspecific density.

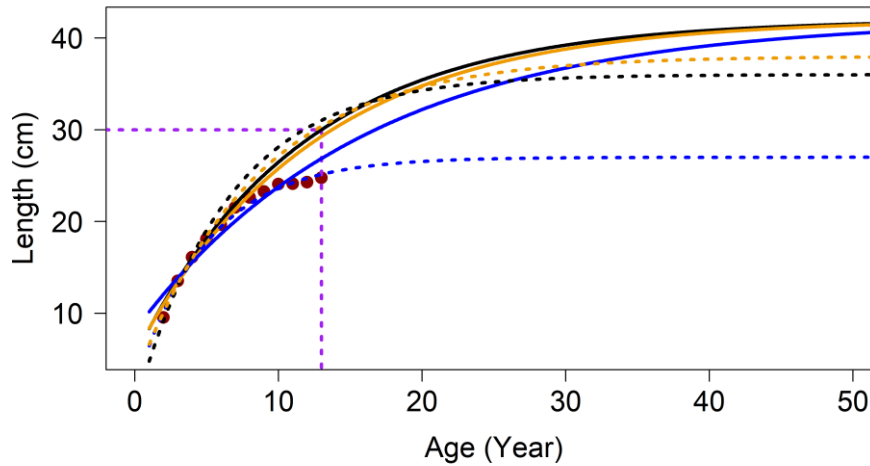


Figure 92. von Bertalanffy growth curves for specific cohorts of Redfish parameterized based on length-at-age data from the nGSL survey. The black lines correspond to curves developed for the 1980 cohort, the blue lines for the 2011-2013 cohorts, and the orange lines for both 1980 and 2011-2013 cohorts. Solid lines assume a L_{inf} constraint between 42-50 cm and dotted lines assume no constraint on L_{inf} . The dotted purple lines show that 13 years old individuals (2011 cohort in 2024) should measure 30 cm based on the 1980 cohort's constrained growth curve. The red dots indicate the observed annual modal sizes of the 2011-2013 cohorts since 2013.

Table 16. Parameters of different von Bertalanffy growth curves based on length-at-age data of the 1980 and/or 2011-2013 cohorts modal size, with or without a constraint on L_{inf} between 42-50 cm, as well as how they are illustrated in Figure 92. The curve with the best fit for the 2011-2013 cohorts is in bold.

Data	L_{inf} constraint	L_{inf}	K	t_0	Curve
1980	42-50 cm	42	0.086	-1.57	Black solid
2011-2013	42-50 cm	42	0.062	-3.466	Blue solid
1980 and 2011-2013	42-50 cm	42	0.081	-1.741	Orange solid
1980	Unconstrained	36	0.153	0.070	Black dotted
2011-2013	Unconstrained	27	0.200	-0.365	Blue dotted
1980 and 2011-2013	Unconstrained	38	0.116	-0.621	Orange dotted

4.6. FULTON CONDITION FACTOR IN NGSL SURVEY

Fulton condition factors ($K = \text{weight [g]} / \text{length}^3 \text{ [cm]}$) were estimated for Redfish of different size classes from 1990 to 2024 as in Chamberland and Benoît (2024). Condition factors are calculated based on the total weight of individual fish. Using somatic weight (fish total weight minus gonad and stomach content weights) would be preferable in order to eliminate the variability associated to feeding intensity and/or different degrees of gonad maturation (Dutil et al. 1995). However, since somatic weight was not available, total weight was deemed adequate for determining Redfish condition. It was also documented for the same period every year (August and outside of the spawning period, in spring).

An analysis of covariance (ANCOVA) was used to compare condition factors from year to year and by length class. Using ANCOVA allows the expected linear effect of fish length on condition factor to be accounted for and the year effect to be assessed. Condition factor was estimated by

the following size classes: 5-10 cm, 10-20 cm, 20-30 cm, and 30-40 cm (Redfish over 40 cm are not common). The model predicted condition factor for each year for length values corresponding to the middle of each size classes, namely 7.5, 15, 25, and 35 cm. These annual predictions were then examined for trends over time. Abnormally high and low values of condition factors that were deemed unreliable (inferior to 0.5 and superior to 1.6), corresponding to 6.6% of individuals, were removed prior to the analyses.

The condition factors associated with the smaller size classes, 5-10 and 10-20 cm, were generally higher than the average of their respective time series from 1990 to the early 2010s (Figure 93). Then, condition factors decreased under the average and started increasing in 2021 and 2020, for 5-10 and 10-20 cm Redfish respectively. Condition factors decreased again in 2023 and 2024, and in 2024 for Redfish 5-10 and 10-20 cm, respectively. The condition factors of larger size classes, 20-30 and 30-40 cm, were generally under the time series average in the early 1990s, increased above the average around 1995, and decreased below the average around 2015. These variations could be influenced by the density of Redfish present in the GSL and their impact on resources (Brown-Vuillemin et al. 2022). The arrival of new Redfish cohorts may have been favorable for individuals large enough to prey upon them. In recent years, lower condition factors were also observed for Greenland Halibut (Chamberland and Benoît 2024) and Atlantic Cod (DFO 2024f), potentially in part because of competition with Redfish.

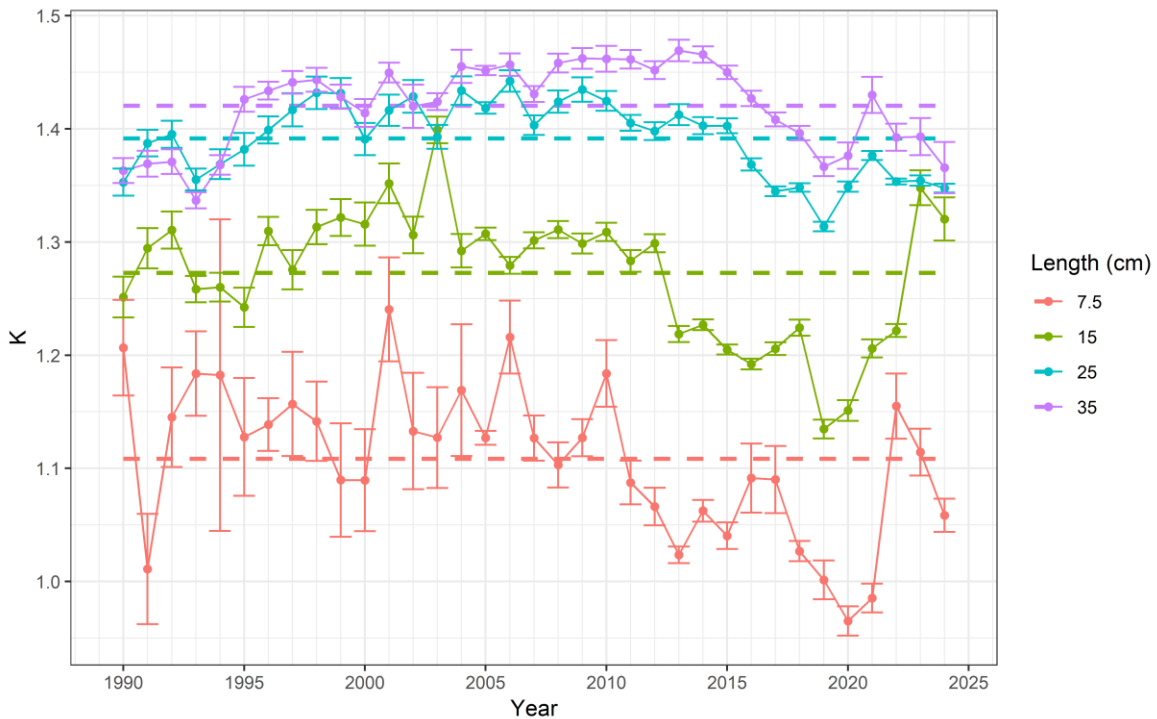


Figure 93. Annual Fulton condition factor (K) calculated from the DFO nGSL survey for different length classes illustrated by different colors. Dotted lines represent time series averages.

4.7. NEW COHORT SPECIES COMPOSITION AND MAGNITUDE

In the DFO nGSL survey, new cohorts of Redfish are monitored to determine recruitment strength and species composition based on genetics. For each station, when feasible, a sample

of Redfish smaller than 110 mm in fork length was frozen. This length corresponds to fish of ages 1+ and 2+.

A qPCR assay to discriminate *S. mentella* and *S. fasciatus* using the second intron of the nuclear S7 ribosomal gene was designed and described in Brûlé et al. (2024). DNA was extracted using QuickExtract™ DNA Extraction Solution (Lucigen). A specific region of 58–67 nucleotides in the targeted gene was then amplified using Quantstudio 3 and 5 Real-Time PCR Systems (Appliedbiosystems™). When designing the qPCR assay, we estimated accurate species identification based on SNPs of 247 Redfish. All 247 specimens were genotyped using 24,603 SNPs and classified as *S. mentella* or *S. fasciatus* using Admixture as described in Benestan et al. (2021). Species identification using the qPCR assay was deemed accurate for 96% of the 247 specimens tested. DNA extraction and qPCR based species identification for all the juveniles for 2022-2024 were processed as indicated in this section.

During the 2022-2024 surveys, 601 individuals from the 2021-2023 cohorts, ranging in length from 42 to 110 mm were collected (Table 17). The numbers of locations with samples in that length class was three, three and six for 2022, 2023 and 2024, respectively, for a total of 12 stations. There were substantially fewer individuals sampled for these three years compared to 2019-2021, for which there was a total of 2,086 fish (Senay et al. 2023). Following genetic analyses, 89 individuals were identified as *S. mentella* and 66 individuals as *S. fasciatus* in 2022. For 2023, no individuals were identified as *S. mentella* and 145 were identified as *S. fasciatus*. For 2024, 26 individuals were identified as *S. mentella* and 275 as *S. fasciatus*. In 2022, sample size for the three locations were between 41 and 62 individuals, and depth ranged from 125 to 252 m. In 2023, sample sizes for the three locations ranged from 21 to 75 individuals, while depths varied from 75 to 145 m. Finally, in 2024, sample sizes for the six locations ranged from 47 to 55 individuals, while depth varied from 105 to 178 m. For 2022, 2023 and 2024, Redfish fork lengths ranged respectively from 56 to 110 mm, with a mean of 96 mm, 63 to 110 mm with a mean of 75 mm, and 42 to 107 mm with a mean of 77 mm. Most locations were largely dominated by one species and, in general for those three years, *S. fasciatus* were more frequently observed than *S. mentella*. Figure 94 shows the geographical position of all 12 locations in the GSL overlaid with the species composition in a pie chart, where depth is indicated. The relationship between species composition and depth is also illustrated in Figure 95. Both a spatial gradient (Figure 94) and a certain depth gradient (Figure 95) are apparent. *S. mentella* was mainly collected in the estuary and north west of Anticosti and in general at greater depth than *S. fasciatus*. *S. fasciatus* was mostly collected on the west coast of Newfoundland and at depths lower than 180 m. Additionally in 2024, *S. fasciatus* was also collected northwest and west of Anticosti.

Based on the nGSL DFO survey, no important recruitment event occurred in recent years (Figure 96). No sample was collected for genetic analyses in Unit 2 given the low levels of small Redfish caught in 2024 (Figure 97). The highest values were observed in 2005 followed by 2001 for *S. mentella* and 2016 for *S. fasciatus*. The magnitude of these cohorts was lower than that of the 2011-2013 cohorts observed in Unit 1.

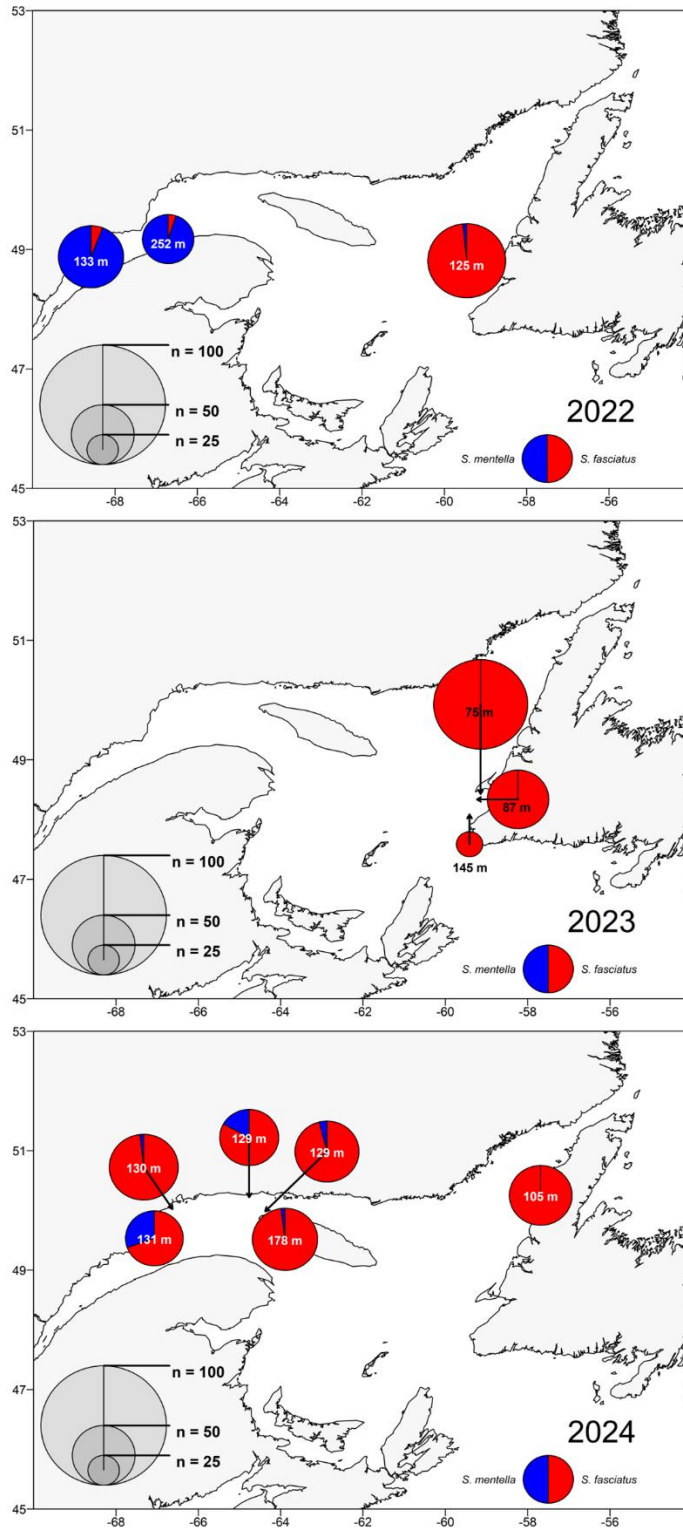


Figure 94. Map showing species composition (%) based on genetics between *S. mentella* in blue and *S. fasciatus* in red and location of genotyped juveniles sampled during the 2022–2024 nGSL DFO surveys. Size of the pie charts is relative to sample size and depth (m) is indicated in the circle.

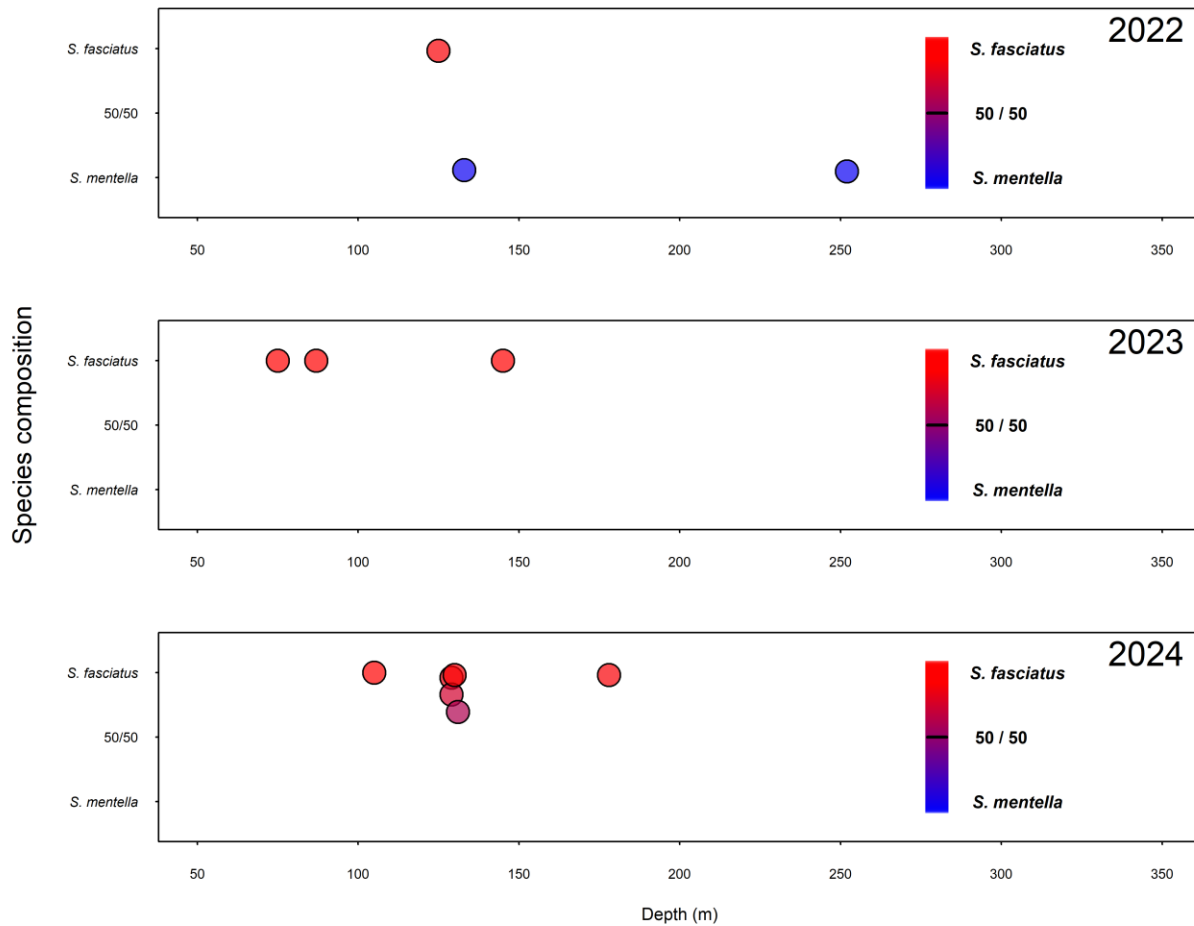


Figure 95. Relationship between species composition (%) based on genetics and depth (m) according to the genotyped juveniles from the locations sampled in 2022, 2023 and 2024, where 100% *S. fasciatus* is illustrated in red and 100% *S. mentella* in blue.

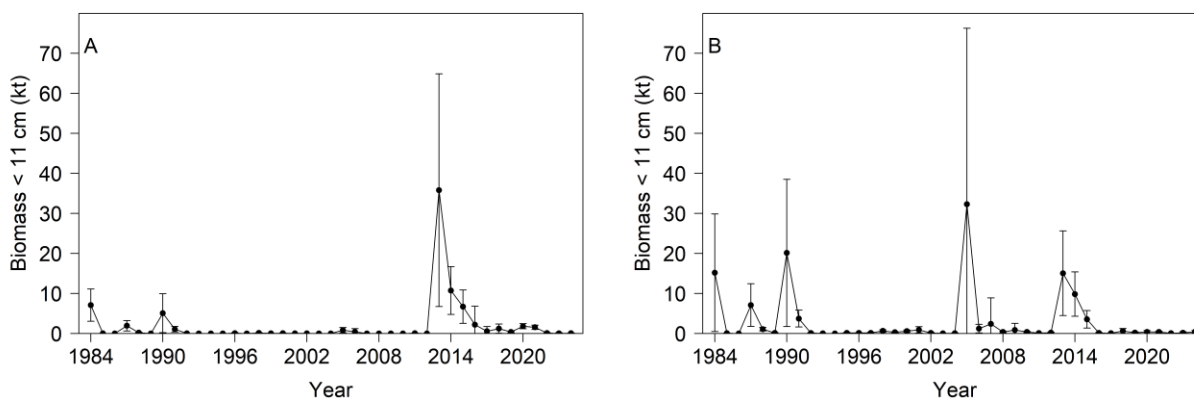


Figure 96. Minimum trawlable biomass in kilotonnes (kt) with 95% confidence intervals of *S. mentella* (A) and *S. fasciatus* (B) less than 11 cm based on AFR in the DFO nGSL survey from 1984 to 2024.

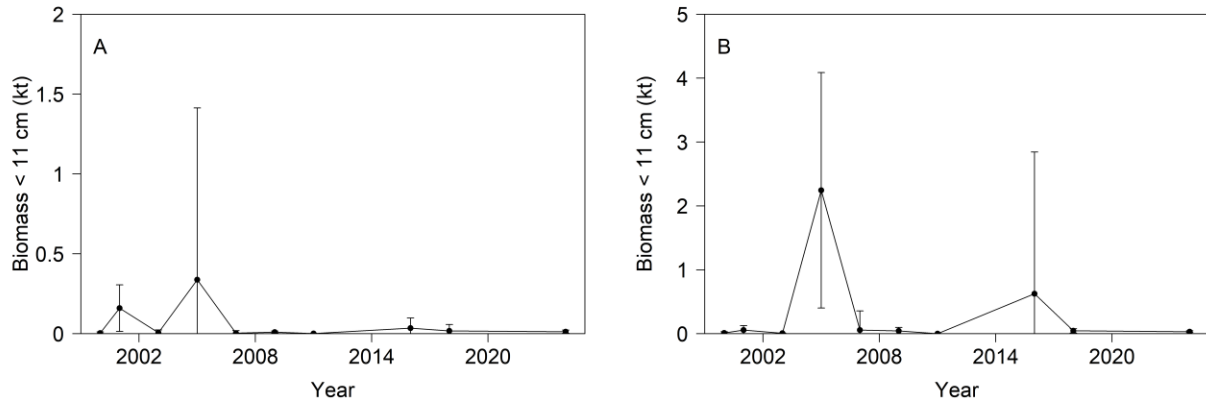


Figure 97. Minimum trawlable biomass in kilotonnes (kt) with 95% confidence intervals of *S. mentella* (A) and *S. fasciatus* (B) less than 11 cm based on AFR in the Unit 2 survey from 2000 to 2024.

Table 17. Species composition, mean depth (m), number of genotyped Redfish (n), mean fork length (mm), and geographical coordinates for each location used in the genetic analysis of juveniles Redfish sampled in 2022-2024.

Year	<i>S. mentella</i> (%)	<i>S. fasciatus</i> (%)	Mean depth (m)	n	Mean length (mm)	Latitude	Longitude
2022	2	98	125	62	90	48.81	-59.46
2022	95	5	252	41	104	49.17	-66.71
2022	94	6	133	52	96	48.88	-68.58
2023	0	100	145	21	78	48.09	-59.41
2023	0	100	87	49	74	48.34	-59.24
2023	0	100	75	75	76	48.43	-59.14
2024	0	100	105	50	74	50.25	-57.68
2024	4	96	129	51	74	49.99	-64.38
2024	17	83	129	47	70	50.22	-64.77
2024	2	98	130	55	81	50.03	-66.63
2024	30	70	131	46	84	49.53	-67.07
2024	2	98	178	52	78	49.52	-63.90

4.8. INDUSTRY SURVEY IN UNIT 2

Given that DFO ceased monitoring Unit 2 Redfish in 2002, AGC has funded a survey in Unit 2 (Kulka and Atkinson 2016). AGC has been conducting the survey in collaboration with DFO. Survey stratification design is illustrated in Figure 98. DFO has been responsible for data analyses and results presentations at stock assessments. The Science team from Newfoundland and Labrador Region was responsible of these tasks until they were transferred to Quebec Region in 2023.

In 1997, the survey was conducted in December. Following surveys took place between August and October for greater comparability with the nGSL survey in Unit 1. Different vessels and gears have been used throughout the years. In 1997-2001, 2003, 2005, 2007, 2009, and 2011, the Cape Ballard and the Cape Beaver, two sister ships, 50 m trawlers, surveyed Unit 2 Redfish with an Engel bottom trawl. In 2014, 2016, and 2018, the Nautical Legend, a 19 m vessel, was used and fished with a Campelen 1800 trawl. In 2020, 2022, and 2024, the Léry Charles, a

19 m trawler equipped with a modified Campelen 1800 trawl, conducted the survey. No liner was used until 2000, when a 30 mm liner was introduced. Mesh size was reduced to 12.7 mm in 2014. Tow duration was 30 min and speed 3.5 knots from 1997-2011. In 2014, tow duration was reduced to 15 min and speed to 2.8-3.2 knots. Walsh et al. (2016) describes the most recent version of the protocol used during Unit 2 Redfish survey. Stratum 295-300, 452, and 709 were added in 2007, and are included in the estimates presented in this document.

Comparative missions occurred to allow converting Unit 2 survey into “CCGS *Teleost* equivalents” so that comparisons can be made directly between Units 1 and 2 survey. In August 2000, 24 comparative stations were sampled between the Cape Ballard and the CCGS *Teleost* (Cadigan and Power 2011). Survey tows were monitored using Netmind™ and eSonar™ net monitoring equipment. The results indicated that there was no overall significant difference in catch rates, but that there was a significant length effect such that the CCGS *Teleost* will catch more small fish (< 30 cm) and the Cape Ballard will catch more large fish (> 30 cm). This study suggested two equations for specific size classes to obtain conversion factors. In April and May 2015, 55 comparative stations were fished by the Nautical Legend and the CCGS *Teleost*. Overall, the CCGS *Teleost* standardized catches were more than twice as much as the Nautical Legend and an effect of length was found (Christoph Konrad 2016, unpublished results). To convert data from “CCGS *Teleost* equivalents” into “CCGS *John Cabot* equivalents”, the conversion factors obtained in Unit 1 were used (Benoît et al. 2024).

Generally, these surveys have endeavored to split species via AFR counts. Unfortunately, information was not available by species for 2014. Hence, industry survey data are presented for both species combined, *Sebastes spp.*, from 2000 to 2024, when available, and by species, from 2000 to 2011, 2016, 2018 and 2024. In 2018, AFR samples were collected by AGC and sent to DFO Newfoundland and Labrador Region for validation. Unfortunately, some of these samples were lost and validation could not occur on 34 out of 129 samples. In order to ensure that all sets could be used in the estimation of biomass and abundance indices, a species-depth relationship was applied to the 34 sets to calculate proportions of *S. fasciatus* and *S. mentella* in the unvalidated sets.

The information presented in this publication follows on previous research documents for 1997-1999 (Power 1999), 2000 (McClintock 2000), 2001 (McClintock 2001), 2003 (McClintock 2005), 2005 (McClintock 2006), 2007 (McClintock and Teasdale 2009), and 2009-2014 (Kulka and Atkinson 2016).

Kulka and Atkinson (2016) listed a number of inconsistencies in the survey design which contributed to limiting the interpretation of the time series as a whole.

1. The initial survey in 1997 was conducted at a different time of year (december). This should not affect overall survey abundance estimates unless fish are moving into or outside of the survey area.
2. No trawl liner was used in 1997 to 1999 and, thus, primarily large fish would have been captured in those years; most fish smaller than about 19 cm would have had the potential to escape through the larger mesh. That would affect catch rate and length frequency.
3. Additional inshore strata in 3Ps (295, 296, 298, and 299) were added in 2007. In 2014, stratum 309 was not sampled. Also, stratum 452 was sampled only in certain years.

In this document, a multiplicative model is used as in Unit 1 and all strata were included to provide an overall view of Unit 2. The results of the comparative fishing between the Léry Charles and the CCGS *John Cabot* in 2024 are presented in the following section.

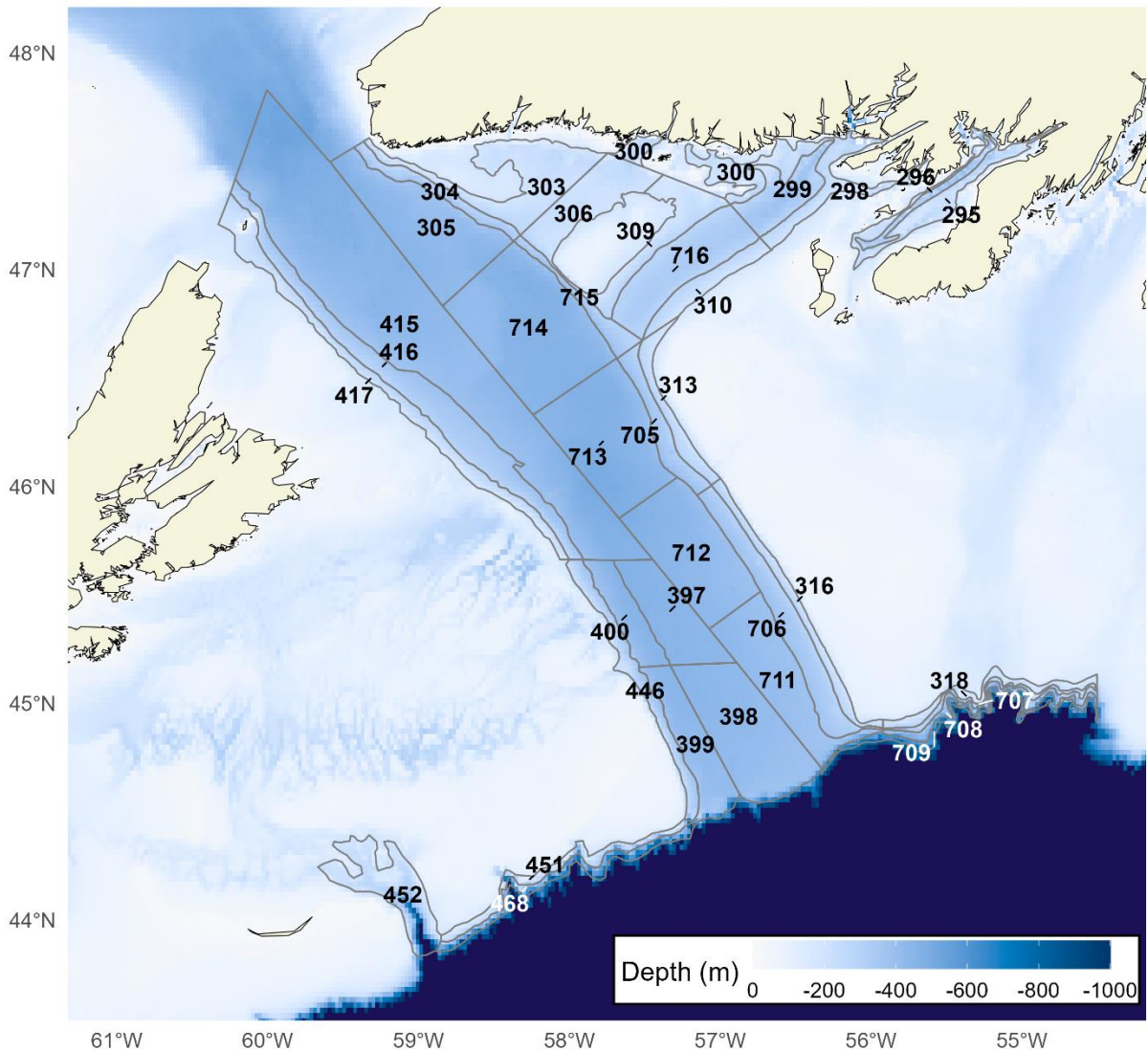


Figure 98. Stratum used in Unit 2 survey.

4.9. LÉRY CHARLES AND CCGS JOHN CABOT COMPARISON IN 2024

In 2024, comparative fishing occurred between the Léry Charles and the CCGS *John Cabot*. The goal was to establish conversion factors to convert the 2020, 2022, and 2024 Unit 2 survey data in CCGS *John Cabot* equivalents. The Léry Charles fished a total of 79 stations, 63 of which were also sampled by the CCGS *John Cabot* (within one nautical mile). Comparative fishing happened within 2h and 24h for 37% and 56% of the stations, respectively. However, because of logistical constraints, 44% of the stations were fished more than 24h apart (maximum = 16.3 days).

The protocol (Walsh et al. 2016) in place on the Léry Charles (e.g. warps ratio, trawling speed of 3 knots) and the Notus sensors that were used to monitor trawl depth, resulted in difficulties in ensuring trawl contact with the bottom and standardizing tow distance. For the purpose of comparative analyses, stations were categorized into three groups. The first group

corresponded to stations where the protocol was strictly adhered to, but did not yield a valid outcome (i.e., the moment when the trawl reached the bottom could not be determined and the trawl was hauled back 30 minutes after winch stop), which included 46 stations. The second group corresponded to eight stations in which the protocol was strictly adhered to and a valid outcome was achieved (i.e., the moment when the trawl reached the sea bottom could be determined). The third group included nine stations in which tests were conducted, such as increasing wraps and/or decreasing trawling speed, in order to obtain sensor reading indicating a contact with the bottom (Figure 99).

The Redfish biomass on the CCGS *John Cabot* and, for valid stations and sea trials, on the Léry Charles, were standardized by trawled distance. However, this could not be done for invalid stations. For two of the 63 comparative stations, Redfish were absent for both vessels. Of the remaining 61 stations, Redfish were present in all stations for the CCGS *John Cabot*, and in 82% of the stations for the Léry Charles. For the 50 stations where Redfish was present on both vessels, the Redfish biomass ratio (i.e., biomass captured by CCGS *John Cabot* divided by the biomass captured by the Léry Charles) had a median of 6.28, and ranged from 0.01 to 1,681.14.

To assess the relationship between catches on the CCGS *John Cabot* and the Léry Charles, we used robust linear regressions. Robust linear regression is a class of statistical methods that limits the effects of assumption violations in ordinary least square regression (in our case heteroskedasticity within residuals), and downweigh influential outliers on regression estimates (Alma 2011). More specifically, we used the *lm_robust* function from the *estimatr* package, with default “HC2” standard errors (Mackinnon and White 1983; Blair et al. 2018). Biomasses were transformed by applying a square root in order to overdispersion.

The linear regression slopes between Redfish biomass on the CCGS *John Cabot* and the Léry Charles were positive for all stations categories, although not significant for stations that were invalid (Figure 100 and Table 18). The linear model applied to invalid stations only accounted for only 10.1% (adjusted R^2) of the total variance. The weakness of this relationship can be explained by the inconsistency in trawl contact with the bottom and the inability to know tow duration. The relationship was significant when using only the eight valid stations and the explained variance was higher than for analyses conducted on other subsets of the data (adjusted $R^2 = 67.3\%$). These stations were in average shallower (mean = 216 m, standard deviation = 37 m) than invalid stations (mean = 341 m, standard deviation = 86 m), and sea trials (mean = 412 m, standard deviation = 102 m), for which trawl sensors signal was often lost.

Similarly to Redfish, the catches of flatfish (Atlantic Halibut, American Plaice, Greenland Halibut, and Witch flounder) were also compared between the Léry Charles and the CCGS *John Cabot* (Figure 101). For the 31 stations where flatfish were present in the catch of both vessels, the flatfish biomass ratio (i.e., biomass captured by CCGS *John Cabot* divided by the biomass captured by the Léry Charles) had a median of 1.99, and ranged from 0.05 to 63.3. For 65% of invalid stations, flatfish were not caught on the Léry Charles while they were on the CCGS *John Cabot*, corroborating a lack of contact of the trawl with the bottom on the Léry Charles. Flatfish biomass robust linear regressions were not significant for any single group of stations (Table 19).

Redfish length frequency was compared between the Léry Charles and the CCGS *John Cabot* by using all 52 stations that were fished by both vessels and considered invalid or valid. Sea trials were excluded, given that the usual protocol was not followed. The length frequency accounted for the Redfish biomass caught at the station and was standardised for trawled distance for CCGS *John Cabot*. This could not be done for catches by the Léry Charles given that trawling distance was unknown in many cases. The average Redfish length was significantly smaller (t-value = 3.23, p-value = 0.00128) by 1 cm on the Léry Charles compared

to the CCGS *John Cabot* (Figure 102). The modal length was also greater by 0.5 cm on the CCGS *John Cabot* (26.0 cm) compared to the Léry Charles (25.5 cm). The Léry Charles may have sampled smaller Redfish present higher in the water column and under sampled stations in deeper waters, where bigger Redfish are usually concentrated.

In 2024, a Star-Oddi sensor was attached to the trawl headline on the Léry Charles and provided fishing depth profiles for 36 stations, three of which were tried a second time, for a total of 39 depth profiles (31 invalid, seven valid, and one sea trial). Visualization of the distance between the trawl headline and the bottom confirmed inconsistent contact with the bottom, particularly for stations in deeper waters (Table 20 and Figure 103). For all valid station, the headline of the trawl reached below 10 m from the sea bottom at some point during the tow. No valid stations were fished deeper than 335 m. For invalid stations, the percentage of stations that appeared to touch the bottom at some point decreased from 83.3% at 103-260 m to 28.6% at 449-529 m.

An analysis of the sink rate data collected from field sheets in 2020 and 2022 on the Léry Charles showed that touchdown with the bottom was declared, on average, at 1:50 minutes for stations at 103-260 m, 2:30 minutes at 261-335 m, 3:04 minutes at 336-448 m, and 2:57 minutes at 449-529 m. Yearly averages of trawl sink rates regardless of tow depth were 3:08 minutes after the winch stopped in 2020, 1:44 minutes in 2022, and 14:25 minutes for valid stations in 2024. Therefore, it is likely that for most stations in 2020 and 2022, touchdown was not recorded properly, the estimated duration was incorrect, and that they should have been considered invalid. Consequently, standardization of tows from 2020 and 2022 is not feasible.

Issues with trawl bottom contact and poor headline sensor readings on the Léry Charles are reflected in Redfish catches time series (Table 21). Redfish was present in 87% and 45% of reported valid stations, as judged by ASO, in 2020 and 2022, respectively. These values are lower than historical values recorded on previous vessels. In 2024, Redfish was present in 79% of stations on the Léry Charles when the protocol was followed, compared to 95% on the CCGS *John Cabot*. Moreover, it appears that trawling speed also varied across surveys in Unit 2 (Figure 104). The higher trawling speed in 2020 and 2022 compared with other years may have prevented contact between the trawl and the sea bottom, thus possibly explaining the higher percentage of stations without Redfish for these years.

It appears that the implementation of the protocol developed by DFO and the industry for Unit 2 survey often prevented trawl bottom contact especially since 2020 for stations in deeper waters, and accurate and standardized monitoring of tow duration. This explains the poor relationships between biomass sampled by each vessel for Redfish and flatfish. Furthermore, it is likely that the observed differences in Redfish length frequency in 2024 are due to the data from the Léry Charles underrepresenting Redfish present in deeper areas and thus missing larger individuals. Therefore, the data collected on the Léry Charles in 2020, 2022, and 2024 is deemed unsuitable for a representative assessment of Redfish stocks in Unit 2 and conversion factors for the CCGS *John Cabot* cannot be provided. Suggested improvements for the industry survey conducted in Unit 2 include modifications to the gear (e.g., trawl, footgear, and doors), to the protocol (e.g., warp ratio and trawling speed), and to the trawl sensors to ensure consistent fishing on the bottom for a given duration. The acoustics data collected on the Léry Charles during the three survey years (2020, 2022 and 2024) have not yet been investigated.

In the following sections (i.e., 4.10 and 4.11), only the data collected on the CCGS *John Cabot* in 2024 are presented. A total of 110 stations were successfully completed. All strata were surveyed with a minimum of two stations using the same equipment and the main protocols as described in Chamberland et al. (2025).

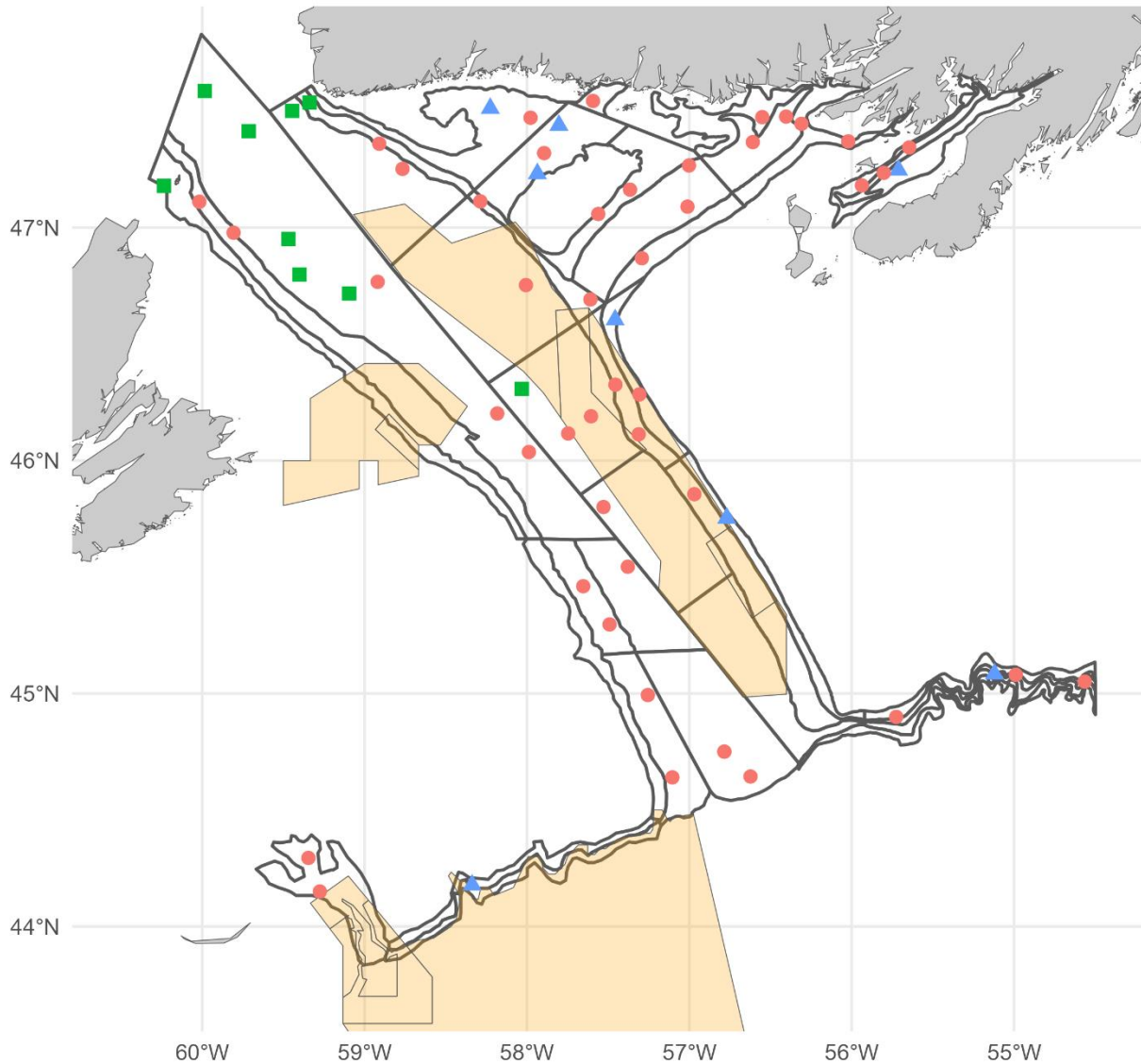


Figure 99. Geographic positions of the stations sampled by both the *Léry Charles* and the *CCGS John Cabot* in 2024 across Unit 2 strata. In red, the 46 stations that were considered invalid, in blue, the eight stations that were considered valid, and in green, the nine stations during which sea trials were conducted on the *Léry Charles*. Marine protected areas are indicated in beige.

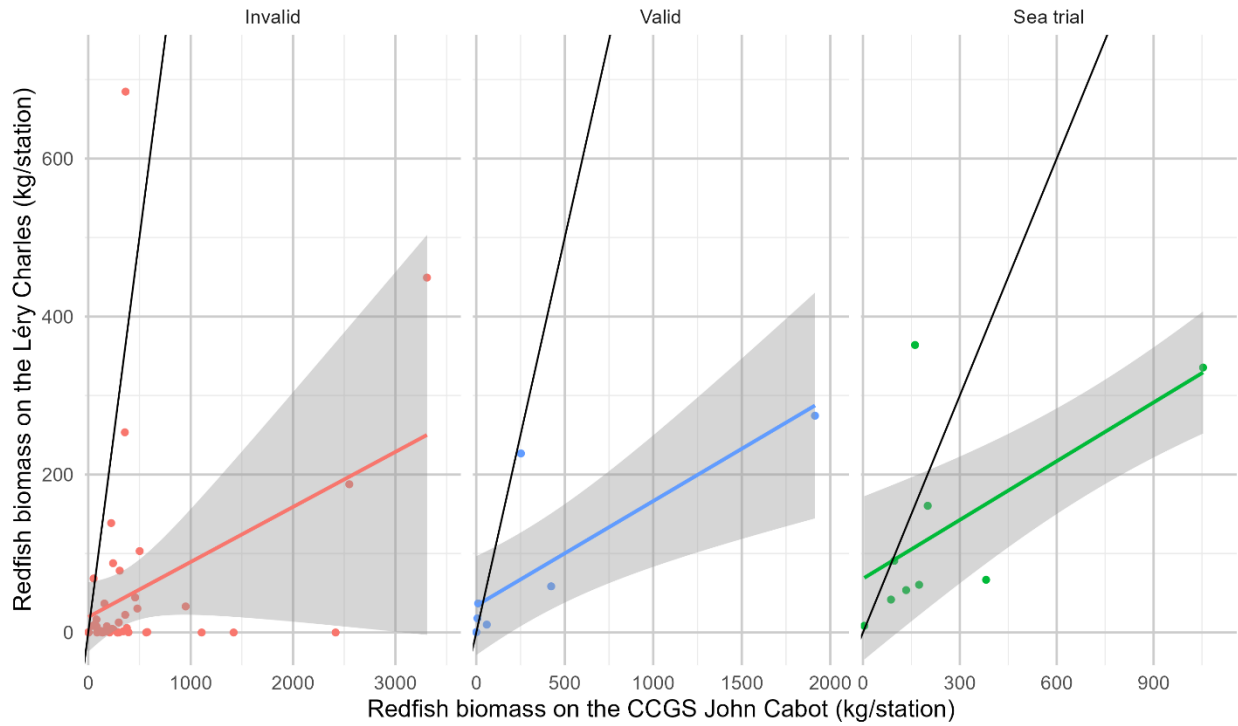


Figure 100. Robust linear regression between Redfish biomass caught on the Léry Charles and the CCGS John Cabot. In red, stations that were considered invalid, in blue, stations that were considered valid, and in green, stations during which sea trials were conducted on the Léry Charles. Shading areas represent 95% confidence intervals. The diagonal 1:1 black line corresponds to the null hypothesis that there is no difference between the Léry Charles and the CCGS John Cabot. Redfish biomass on the CCGS John Cabot, and for valid stations and sea trials on the Léry Charles were standardized by distance, however this could not be done for invalid stations. Untransformed data are presented.

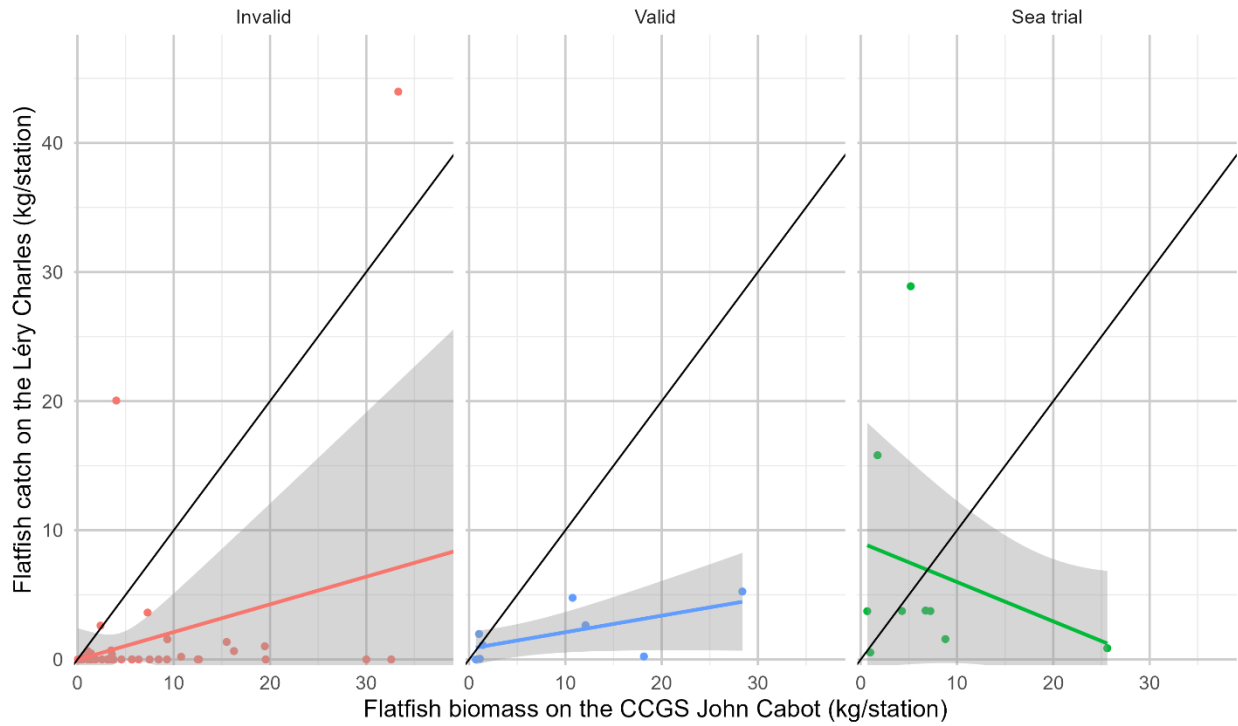


Figure 101. Robust linear regression between flatfish biomass caught on the Léry Charles and the CCGS John Cabot. In red, stations that were considered invalid, in blue, stations that were considered valid, and in green, stations during which sea trials were conducted on the Léry Charles. Shading areas represent 95% confidence intervals. The diagonal 1:1 black line corresponds to the null hypothesis that there is no difference between the Léry Charles and the CCGS John Cabot. Flatfish biomass on the CCGS John Cabot, and for valid stations and sea trials on the Léry Charles were standardized by distance, however this could not be done for invalid stations. Untransformed data are presented.

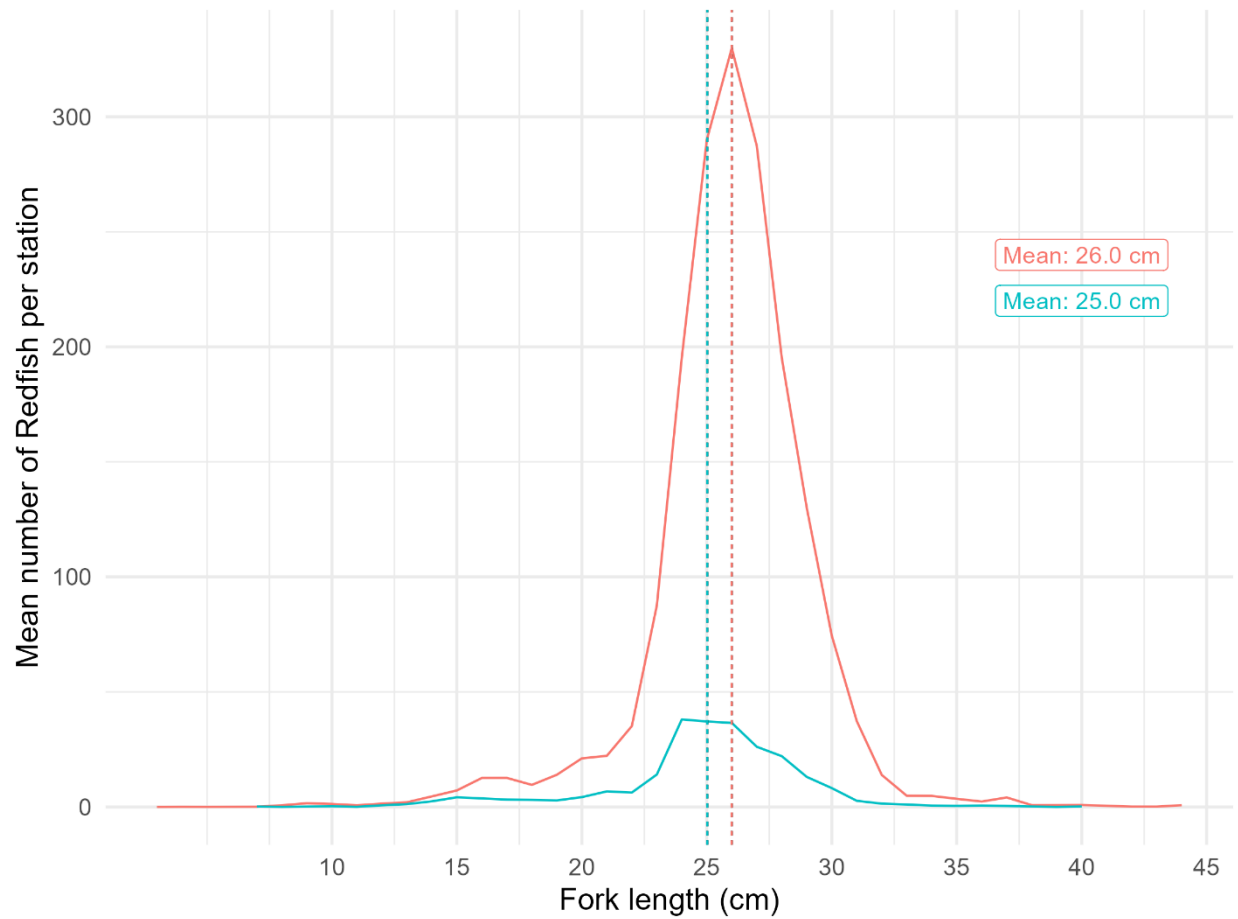


Figure 102. Comparison of length frequency (solid line) of Redfish caught on the Léry Charles in blue and the CCGS John Cabot in red. The mean Redfish length for each vessel are indicated by a dotted line.

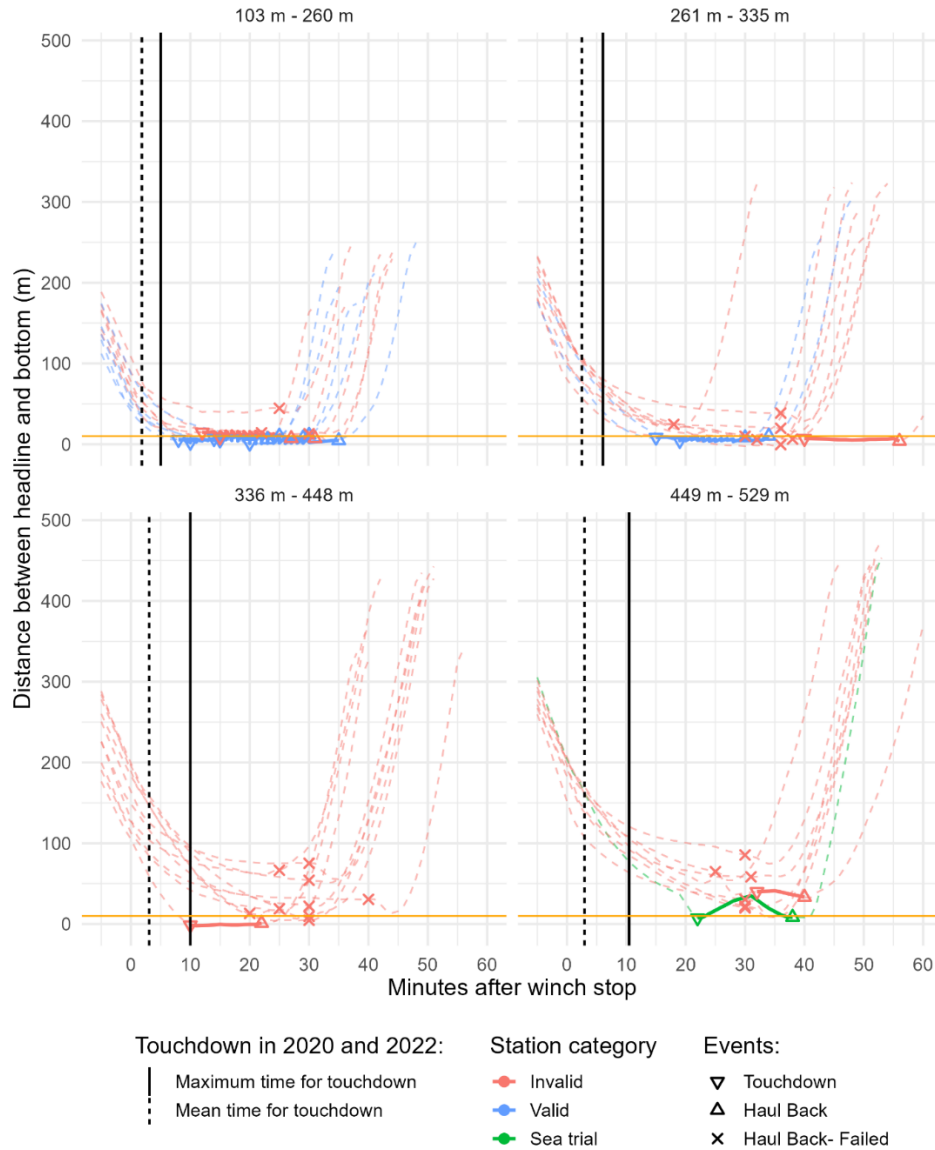


Figure 103. Fishing depth profiles for 39 stations on the Léry Charles by depth range. The moment that touchdown was declared is indicated by a downward triangle and haul back by a upward triangle for valid stations and sea trials, while haul back for stations that were considered invalid are illustrated by an X. Red lines represent depth profile of the trawl for invalid stations, blue lines valid stations, and green sea trial station. Black dotted and solid lines correspond to the maximum and mean time between winch stopped and declared touchdown for all stations in 2020 and 2022, by depth range. The orange horizontal line represent the 10 m from bottom mark.

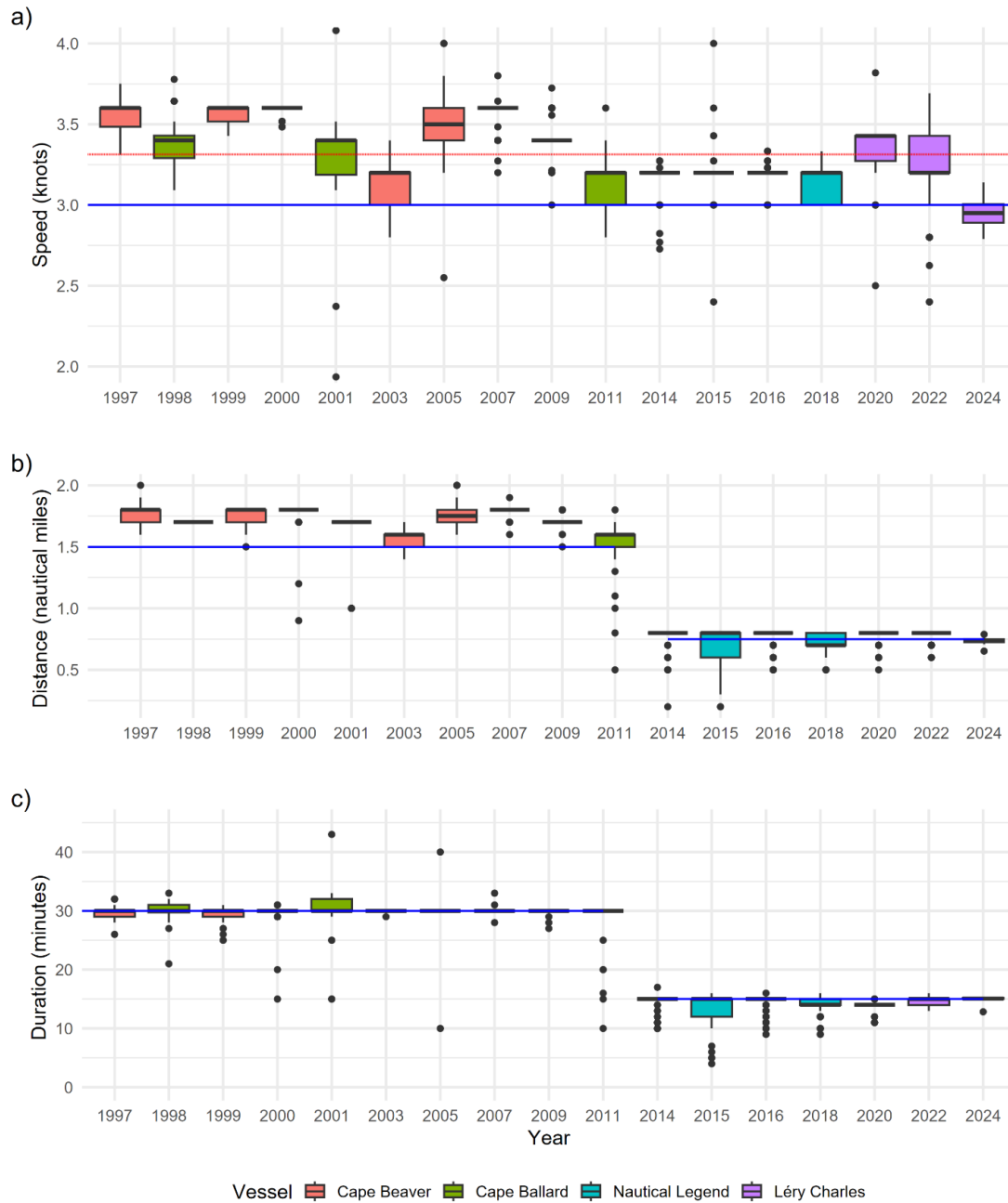


Figure 104. Comparison of trawling speed (knots), sampling distance (nautical miles), and duration (minutes) in Unit 2 survey from 1997 to 2024. The vessels are indicated by different colors, Cape Beaver in red, Cape Ballard in green, Nautical Legend in blue, and Léry Charles in purple. The blue horizontal lines in the three panels indicate the targeted values for speed, distance and duration of tows according to the protocol. In 2014, tow duration was changed from 30 to 15 minutes. The red horizontal line in panel a) indicates the average tow speed across survey history. Only valid stations were considered.

Table 18. Robust linear regression between Redfish biomass caught on the Léry Charles and the CCGS John Cabot for stations that were invalid, valid, and for sea trials. The estimate and confidence interval of the intercept and the slope, standard error (s.e.), t value, probability (p-value), number of observations, explained variance (R^2 and R^2 adjusted), AIC, BIC, and RMSE are indicated. Redfish biomass on the CCGS John Cabot, and for valid tows and sea trials on the Léry Charles were standardized by distance, however this could not be done for invalid stations on the Léry Charles.

	Invalid	Valid	Sea trial
Intercept	1.152	2.662	4.224
	95% C.I. = [-2.191, 4.495]	95% C.I. = [-0.325, 5.649]	95% C.I. = [-0.319, 8.766]
	s.e. = 1.657	s.e. = 1.221	s.e. = 1.921
	t = 0.695	t = 2.181	t = 2.199
	p.value = 0.491	p.value = 0.072	p.value = 0.064
Slope	0.173	0.347**	0.434**
	95% C.I. = [-0.035, 0.381]	95% C.I. = [0.181, 0.513]	95% C.I. = [0.241, 0.628]
	s.e. = 0.103	s.e. = 0.068	s.e. = 0.082
	t = 1.677	t = 5.112	t = 5.311
	p.value = 0.101	p.value = 0.002	p.value = 0.001
Num.Obs.	44	8	9
R^2	0.122	0.720	0.448
Adj. R^2	0.101	0.673	0.369
AIC	562.3	105.4	124.1
BIC	567.7	105.7	124.7
RMSE	134.69	121.07	171.23

Table 19. Robust linear regression between flatfish biomass caught on the Léry Charles and the CCGS John Cabot for stations that were invalid, valid, and for sea trials. The estimate and confidence interval of the intercept and the slope, standard error (s.e.), t value, probability (p-value), number of observations, explained variance (R^2 and R^2 adjusted), AIC, BIC, and RMSE are indicated. Flatfish biomass on the CCGS John Cabot, and for valid tows and sea trials on the Léry Charles were standardized by distance, however this could not be done for invalid stations on the Léry Charles.

	Invalid	Valid	Sea trial
Intercept	0.010	0.402	2.880
	95% C.I. = [-0.775, 0.795]	95% C.I. = [-0.650, 1.453]	95% C.I. = [0.381, 5.378]
	s.e. = 0.389	s.e. = 0.430	s.e. = 1.056
	t = 0.026	t = 0.935	t = 2.726
	p.value = 0.980	p.value = 0.386	p.value = 0.030
Slope	0.209	0.296	-0.283
	95% C.I. = [-0.209, 0.627]	95% C.I. = [-0.093, 0.685]	95% C.I. = [-1.059, 0.493]
	s.e. = 0.207	s.e. = 0.159	s.e. = 0.328
	t = 1.006	t = 1.863	t = -0.863
	p.value = 0.320	p.value = 0.112	p.value = 0.417
Num.Obs.	45	8	9
R2	0.070	0.352	0.058
R2 Adj.	0.048	0.244	-0.076
AIC	309.5	38.9	73.0
BIC	315.0	39.1	73.6
RMSE	7.06	1.89	10.01

Table 20. Number of stations for each category (i.e., invalid, valid, and sea trial) by depth range. Number and percentage of stations where the trawl headline reached below 10 m from the bottom are also presented.

Station category	Number of stations	Number of stations where headline reached below 10 m from bottom	Percentage of stations where headline reached below 10 m from bottom
103 m – 260 m			
Invalid	6	5	83.3
Valid	5	5	100.0
261 m – 335 m			
Invalid	8	5	62.5
Valid	2	2	100.0
336 m – 448 m			
Invalid	10	4	40.0
449 m – 529 m			
Invalid	7	2	28.6
Sea trial	1	1	100.0

Table 21. Number of valid stations, number of valid stations with Redfish, and percentage of valid stations with Redfish in Unit 2 survey from 1997 to 2024. The name of the vessel that conducted the surveys are also indicated.

Year	Total number of stations	Number of stations with Redfish	Percentage of stations with Redfish
Cape Beaver			
1997	69	67	97.1
1999	94	93	98.9
2000	94	94	100.0
2003	95	95	100.0
2005	92	92	100.0
Cape Ballard			
1998	64	64	100.0
2001	93	93	100.0
2007	134	133	99.3
2009	117	117	100.0
2011	138	138	100.0
Nautical Legend			
2014	113	111	98.2
2015	53	44	83.0
2016	121	119	98.3
2018	111	111	100.0
Léry Charles			
2020	115	100	87.0
2022	111	51	45.9
2024	12	12	100.0

4.10. SPATIAL DISTRIBUTION IN UNIT 2 SURVEY

The spatial distribution of catch rates in the Unit 2 survey, illustrated in maps created using inverse distance weighting (Figure 105 to Figure 108), indicated that from 2000 to 2007 immature individuals were common in Unit 2 and found especially around Burgeo Bank and in the Laurentian Fan for both species (Figure 105 and Figure 107). Between 2009 and 2016, immature individuals of *S. mentella* were mainly observed around Burgeo Bank and in the western portion of the Laurentian Channel. Immature *S. fasciatus* were also present on the eastern slope of the Laurentian Channel and Laurentian Fan. In 2018 and 2024, catch rate of immature individuals of both species decreased, especially in 2024.

Catch rates of mature *S. mentella* were relatively low from 2000 to 2016, and increased in 2018 and 2024, particularly in the Cabot strait and the center of the Laurentian Channel (Figure 106). On the contrary, catch rates of mature *S. fasciatus* were higher from 2000 to 2016 compared to 2018 and 2024 (Figure 108). The latter were mainly observed along the slopes of the Laurentian Fan and on Burgeo Bank.

Similarly to Unit 1, in September in Unit 2, *S. fasciatus* larger than 22 cm are generally found at shallower depths (250-400 m) than *S. mentella* (300-450 m), although they also occur within

the deeper Laurentian Fan. Moreover, Redfish smaller than 22 cm are found at shallower depths than larger individuals (Figure 109).

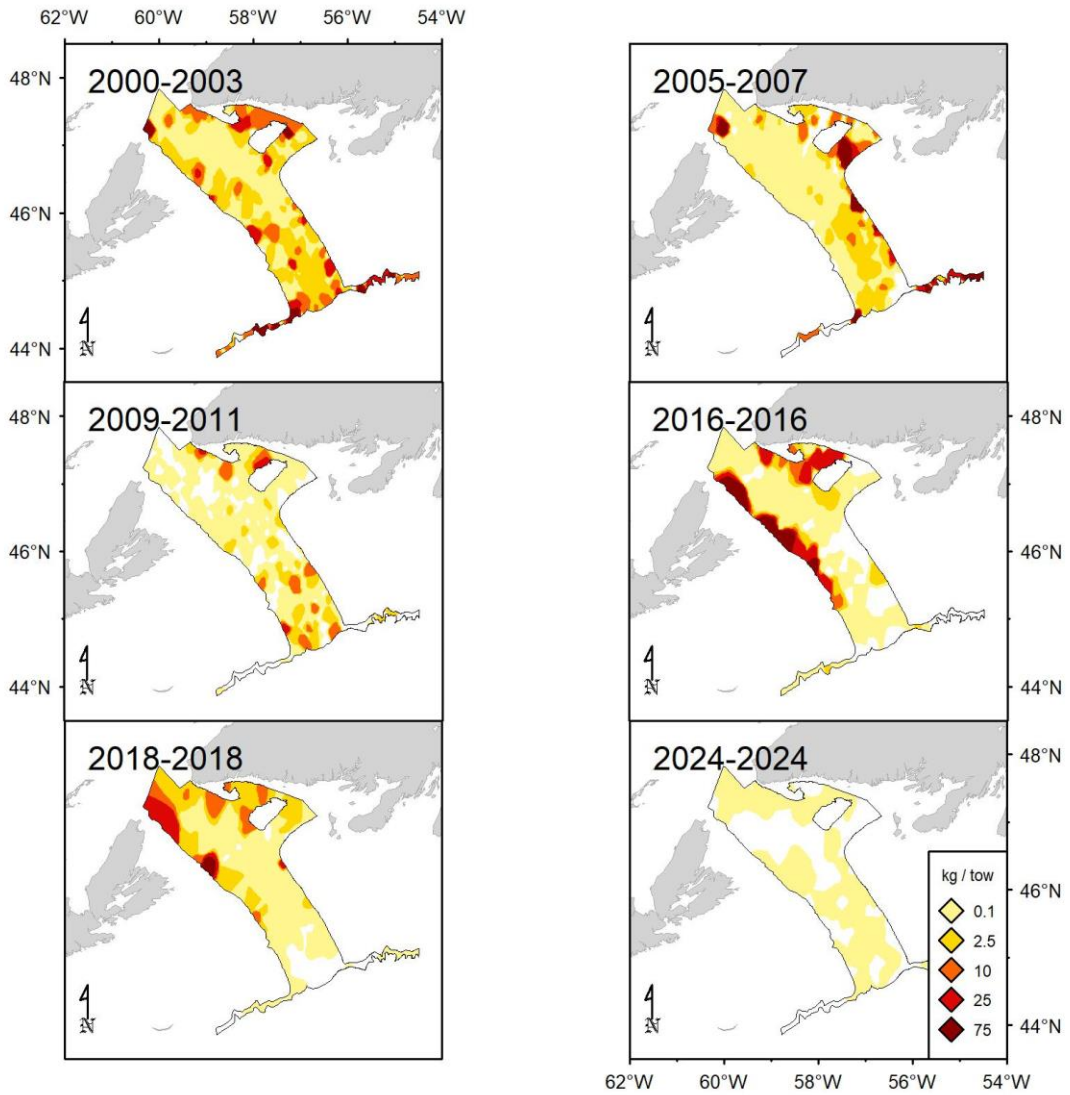


Figure 105. Catch rate distribution of immature *S. mentella la* (kg/15-minute tow) in the Unit 2 survey from 2000 to 2024.

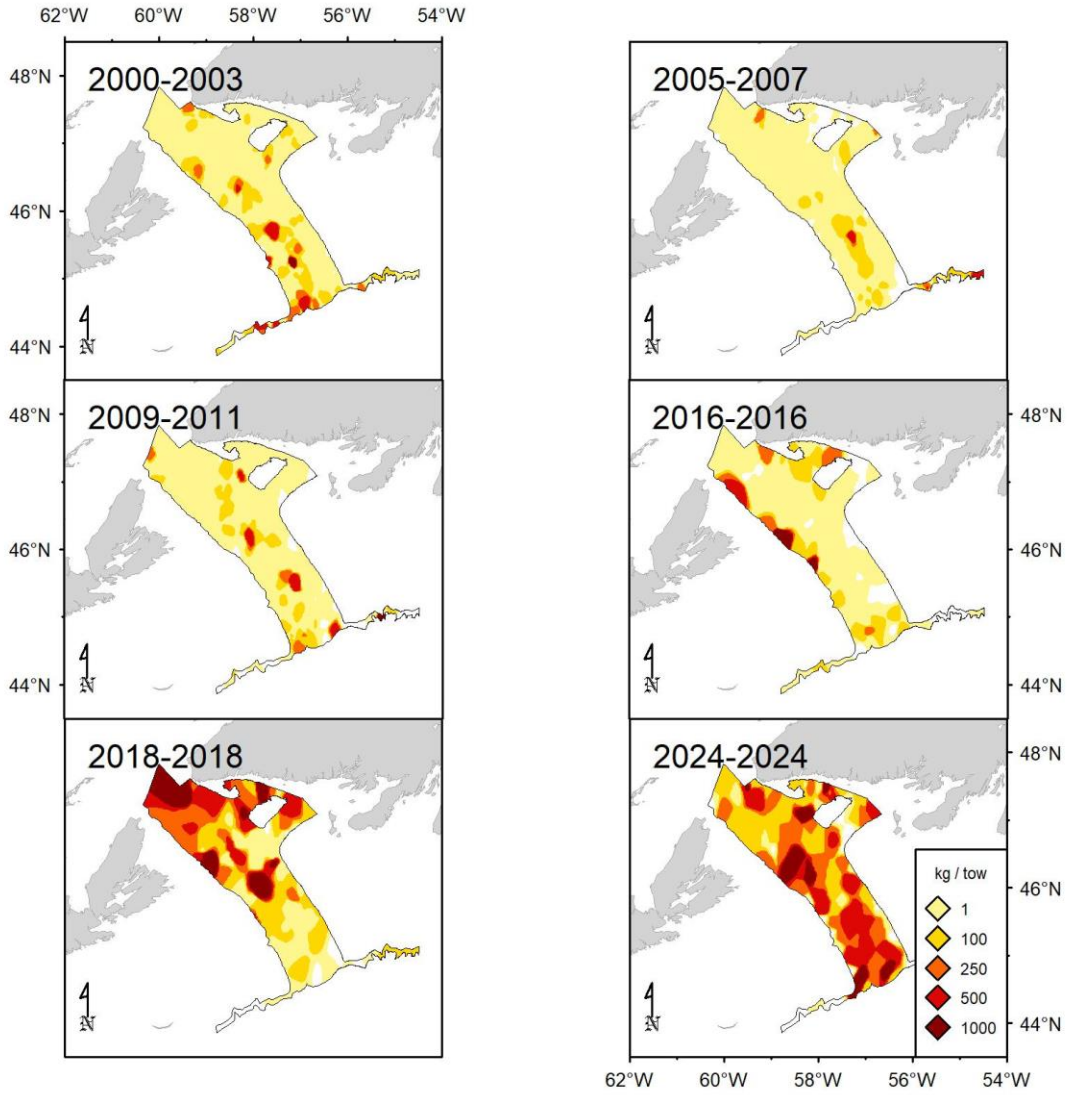


Figure 106. Catch rate distribution of mature *S. mentella la* (kg/15-minute tow) in the Unit 2 survey from 2000 to 2024.

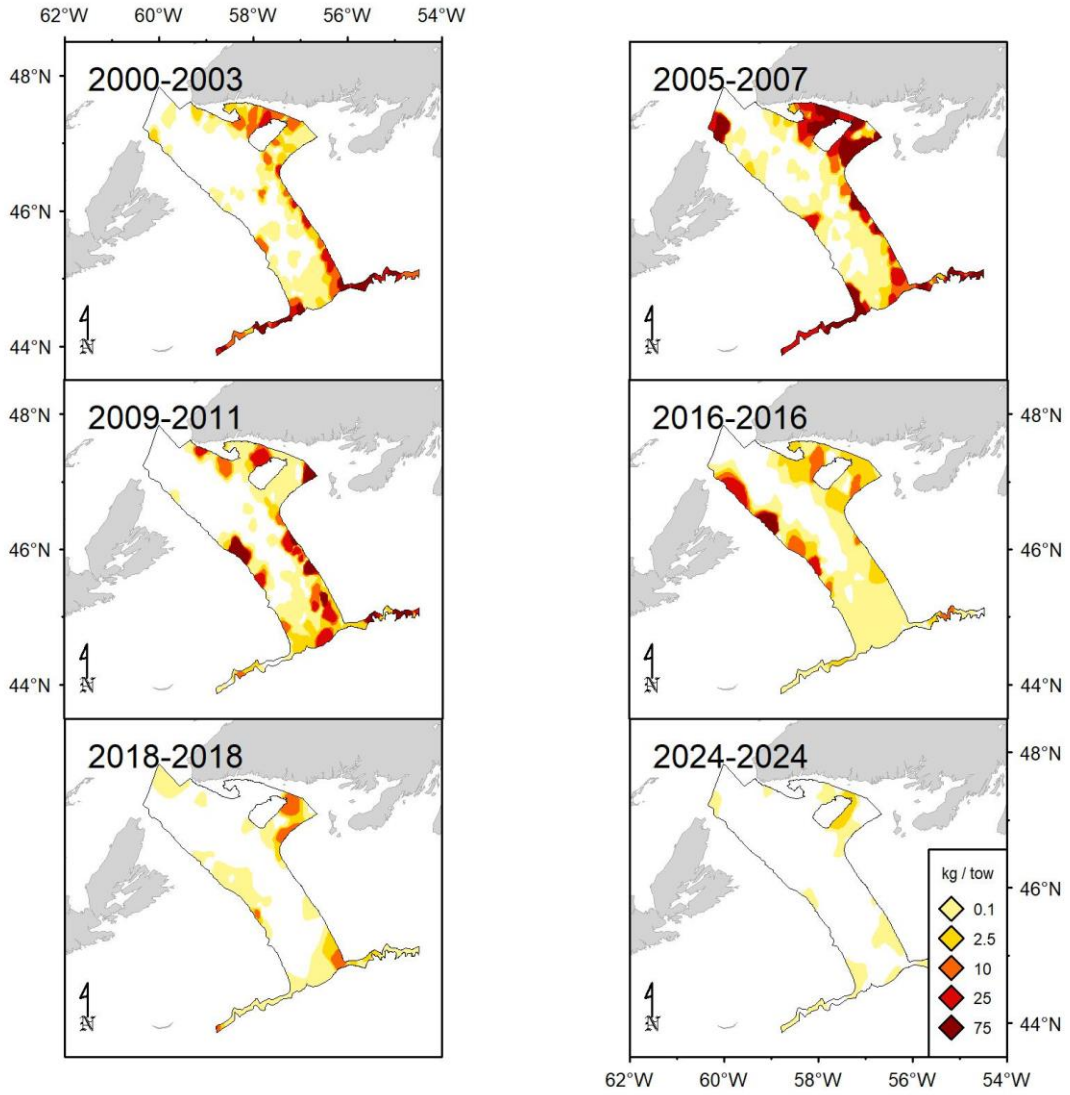


Figure 107. Catch rate distribution of immature *S. fasciatus la* (kg/15-minute tow) in the Unit 2 survey from 2000 to 2024.

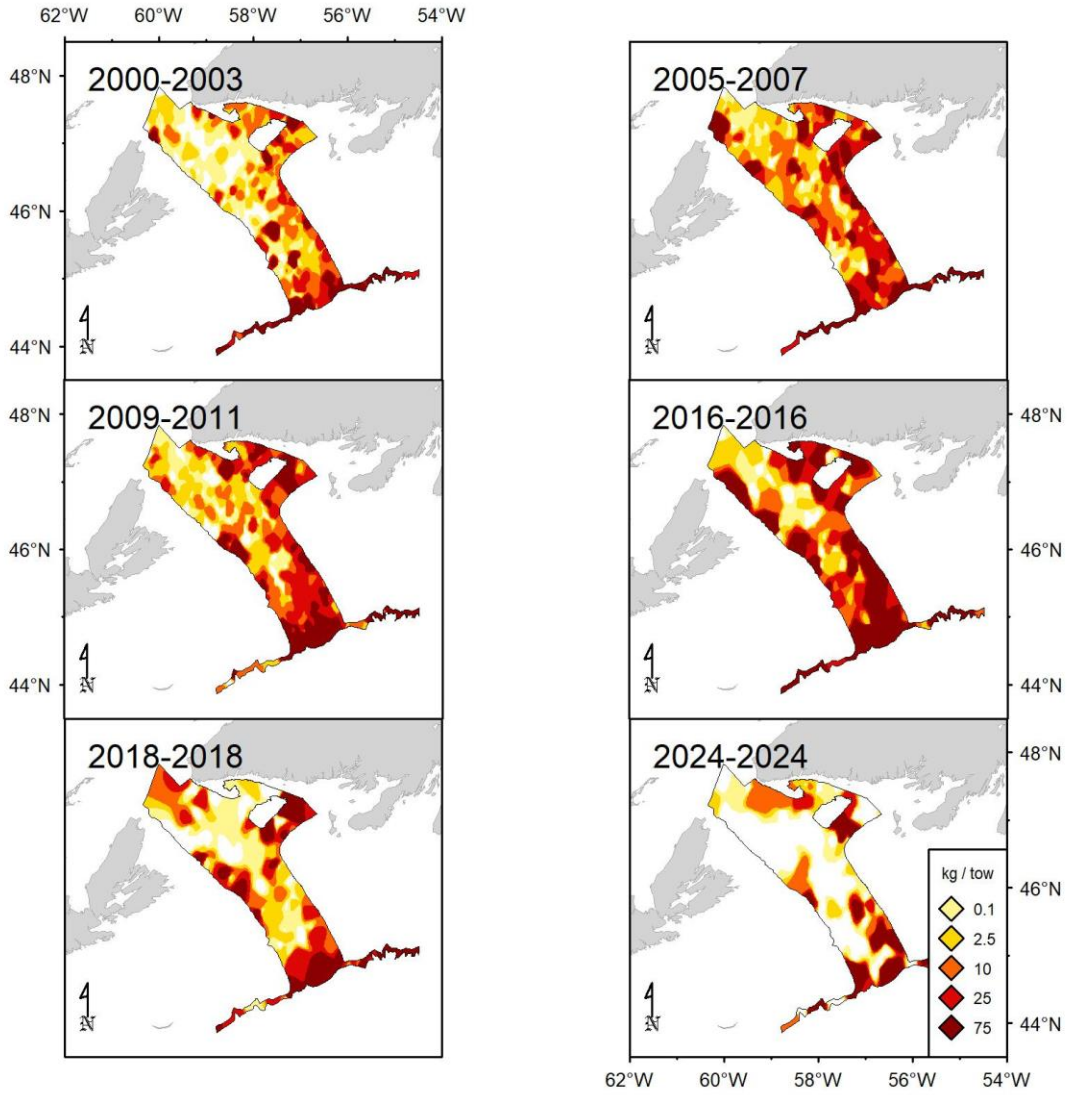


Figure 108. Catch rate distribution of mature *S. fasciatus la* (kg/15-minute tow) in the Unit 2 survey from 2000 to 2024.

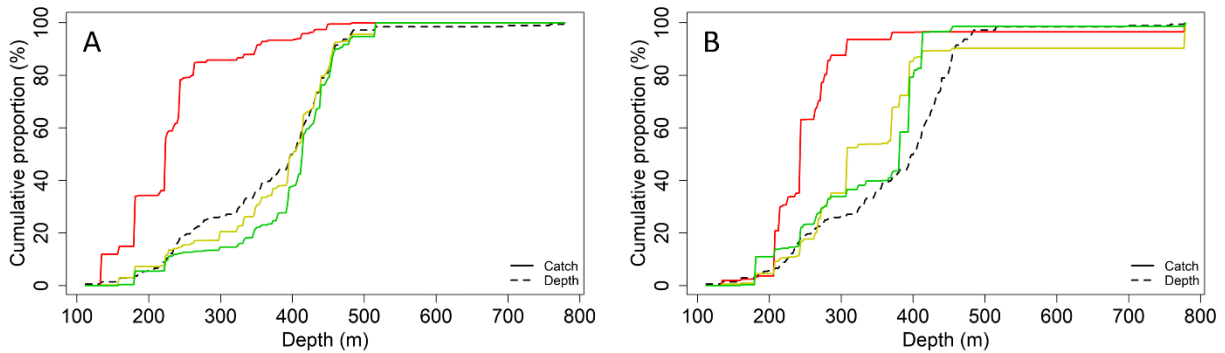


Figure 109. Stratified cumulative proportion of *S. mentella* (A) and *S. fasciatus* (B) in the Unit 2 survey in 2024. The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m) and by length classes, 0-22 cm in red, 22-25 cm in yellow, and larger than 25 cm in green.

4.11. SURVEY INDICES AND LENGTH FREQUENCY IN UNIT 2

Total minimum trawlable biomass of *S. mentella* was relatively stable and close to the average of the time series from 2000 to 2016 (Figure 110A). In 2018, total minimum trawlable biomass increased above the average. A slightly higher value was obtained in 2024, with an estimate of 894 kt, which is the highest value of the time series (Table 22B). Size classes estimates have shown a pulse of *S. mentella* smaller than 22 cm in 2016, which translated to an increase of larger fish in 2018 and 2024 (Figure 111A, C and E). In 2024, biomass of *S. mentella* larger than 22 cm and those larger than 25 cm were estimated at 891 and 776 kt, respectively, the largest values of the time series (Table 22B).

Total minimum trawlable biomass of *S. fasciatus* was more variable over time compared to *S. mentella* (Figure 110). The estimates were close or below the average at the beginning of the time series, close or above the average from 2005 to 2016, and decreased below the average in 2018 and 2024. In 2018 and 2024, the estimates of all size classes were below the average (Figure 111). *S. fasciatus* total biomass was estimated at 84 kt in 2024, the lowest value of the time series which began in 2000, from which 75 and 55 kt were larger than 22 and 25 cm, respectively (Table 22B). Similarly to Unit 1, Unit 2 estimated biomass of *S. fasciatus* was lower than that of *S. mentella* in recent years by a factor of 10. Total biomass of Redfish in Unit 2 is about half of that of Unit 1.

In 2024, less than 1% of the total biomass of *S. mentella* corresponded to individuals smaller than 22 cm, 13% between 22 and 25 cm, and 87% over 25 cm. For *S. fasciatus*, 10% of the biomass was under 22 cm, 24% between 22 and 25 cm, and 65% over 25 cm (Figure 112). For both species, the modal length was 18, 24, and 26 cm in 2016, 2018 and 2024, respectively, showing sizes similar to Unit 1 in recent years (Figure 113).

The abundance of mature *S. mentella* was stable under the average of the time series from 2000 to 2009 (Figure 114). Abundance of mature *S. mentella* started increasing in 2011 until it reached the highest value of the time series in 2018, before slightly decreasing in 2024. The 2024 estimate was the second highest value of the time series. *S. fasciatus* mature abundance was close or below the average of the time series from 2000 to 2009. It increased above the average in 2011 and 2016, and subsequently decreased below the average in 2018 and 2024. The 2024 estimate was the second lowest values of the time series (Table 22A).

Given the lack of reliable estimates between 2018 and 2024, recent trends in Unit 2 biomass and abundance are unknown.

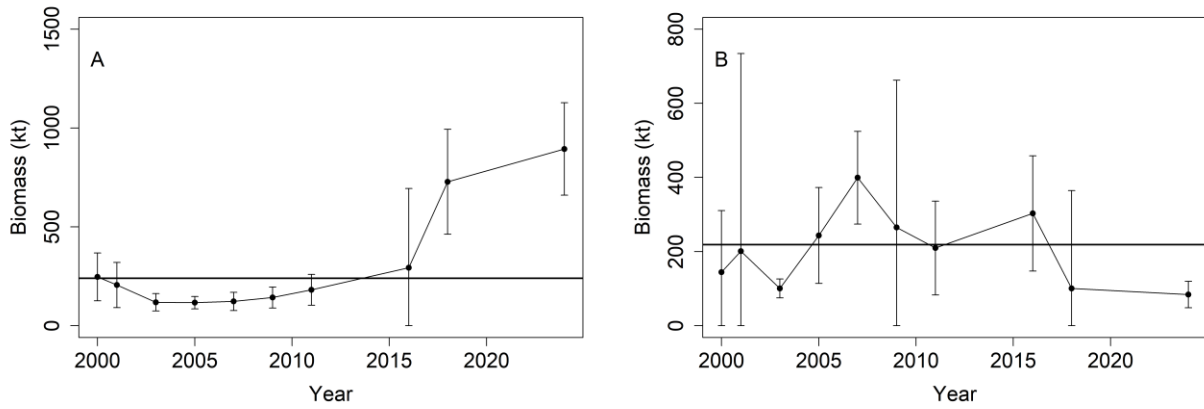


Figure 110. Minimum trawlable biomass in kilotonnes (kt) with 95% confidence intervals of *S. mentella* (A) and *S. fasciatus* (B) in the Unit 2 survey from 2000 to 2024. The solid lines represent the 2000-2018 average. Note the different scales on the y-axis.

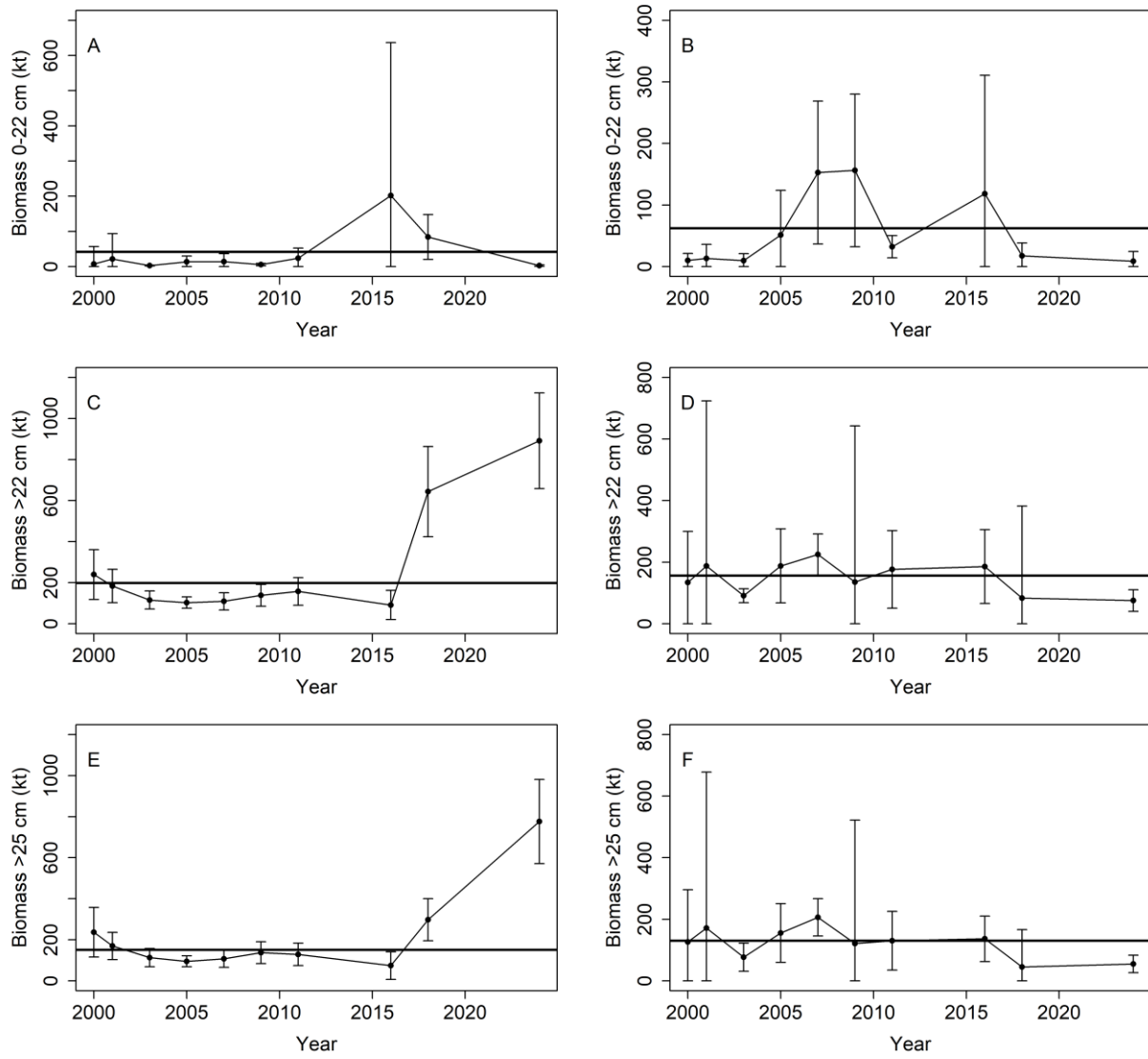


Figure 111. Minimum rawlable biomass in kilotonnes (kt, with 95% confidence intervals) of *S. mentella* (left column; panels A, C, and E) and *S. fasciatus* (right column; panels B, D, and F) in the Unit 2 survey from 2000 to 2024, by length classes: 0–22 cm (A-B), > 22 cm (C-D), and > 25 cm (E-F). The solid lines represent the 2000–2018 average. Note the different scales on the y-axis.



Figure 112. Percentage of minimum trawlable biomass of *S. mentella* (left) and *S. fasciatus* (right) in the Unit 2 survey in 2024 by length classes, 0-22 cm in red, 22-25 cm in yellow, and larger than 25 cm in green.

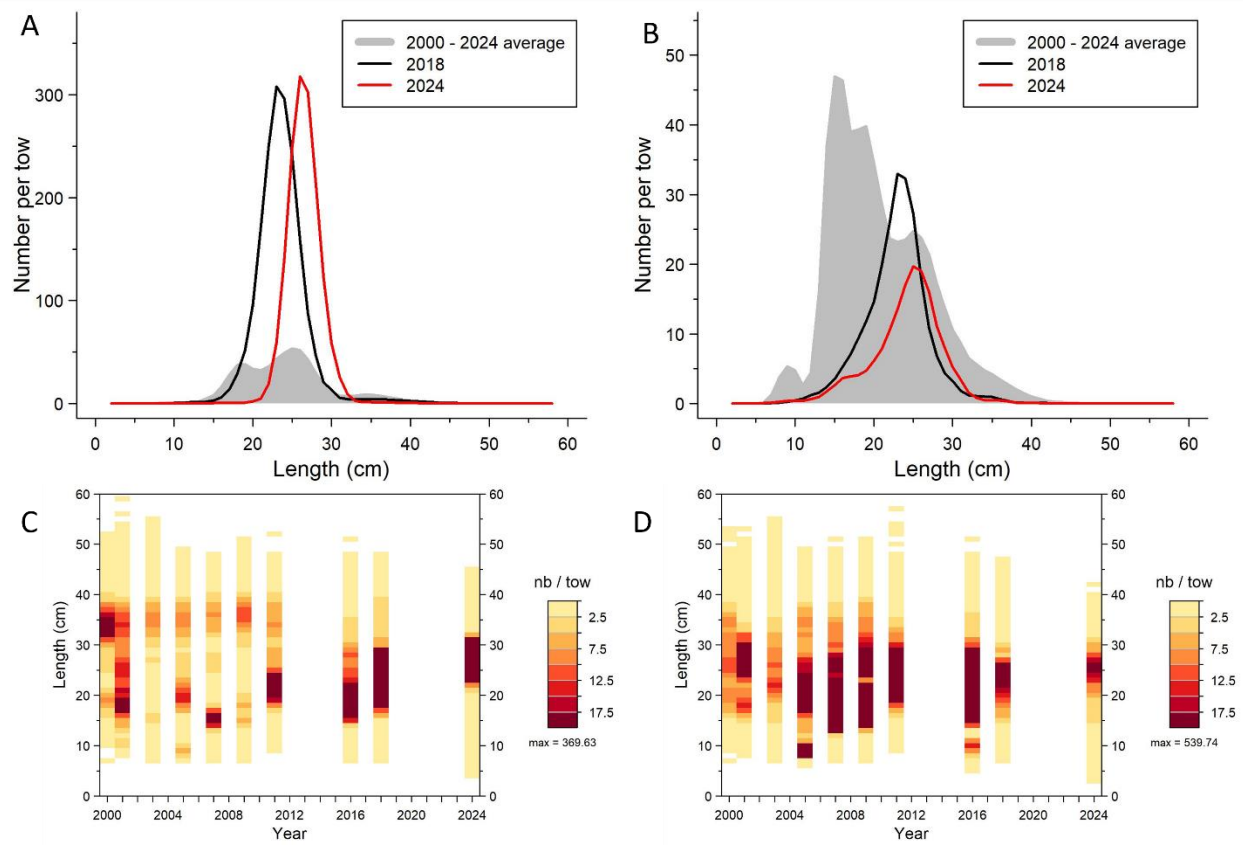


Figure 113. *S. mentella* (A and C) and *S. fasciatus* (B and D) length frequency in the Unit 2 survey for 2018, 2024, and the 2000 to 2024 average (A and B), and by length classes and years (C and D).

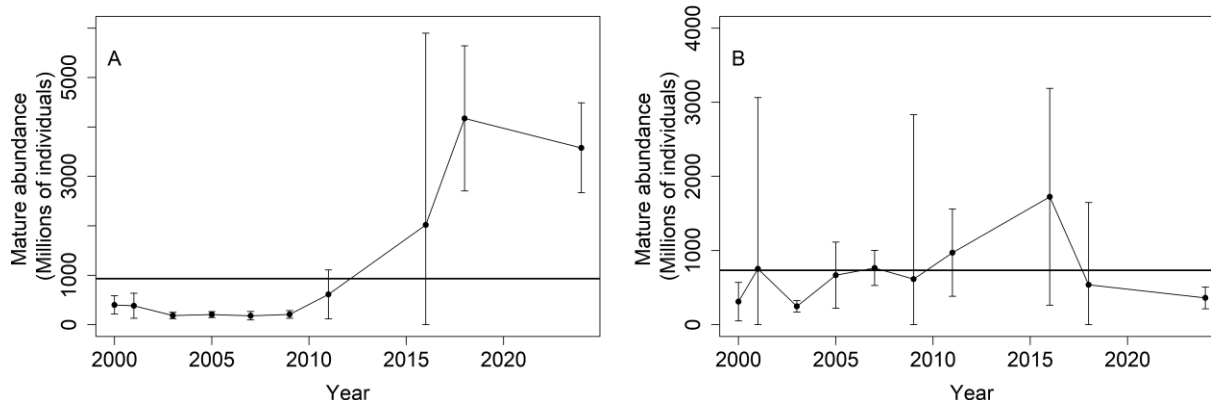


Figure 114. Trawlable mature fish abundance (millions of individuals, with 95% confidence intervals) of *S. mentella* (A) and *S. fasciatus* (B) in Unit 2 survey from 2000 to 2024. The solid lines represent the 2000-2018 average. Note the different scales on the y-axis.

Table 22. Abundance (1,000,000 individuals, A) and biomass (1,000 t, B) indices in Unit 2 industry survey from 2000 to 2024 for *S. mentella*, *S. fasciatus*, and *Sebastes* spp. by length class.

A

Year	Abundance (1,000,000 individuals)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes</i> spp.			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
2000	81	422	407	503	114	315	270	428	195	737	677	932
2001	300	438	356	738	167	791	687	958	466	1 229	1 043	1 696
2003	44	203	187	247	105	270	190	375	148	473	377	622
2005	186	220	174	406	798	580	396	1 377	983	800	570	1 783
2007	258	184	173	443	2 939	632	520	3 571	3 197	816	693	4 013
2009	85	207	204	292	1 938	419	331	2 357	2 023	626	535	2 649
2011	244	416	235	660	344	666	365	1 010	587	1 083	601	1 670
2014	NA	NA	NA	NA	NA	NA	NA	NA	884	678	458	1 562
2016	2 716	291	186	3 007	1 539	674	397	2 213	4 255	966	582	5 221
2018	787	3 507	1 351	4 294	174	404	173	578	961	3 911	1 524	4 872
2024	28	3 560	2 932	3 587	95	292	183	387	122	3 852	3 115	3 975

B

Year	Biomass (1,000 t)											
	<i>S. mentella</i>				<i>S. fasciatus</i>				<i>Sebastes spp.</i>			
	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total	0-22 cm	>22 cm	>25 cm	Total
2000	8	239	237	247	10	134	126	144	18	373	363	391
2001	22	184	170	206	13	188	172	201	35	372	342	407
2003	3	116	113	119	10	91	77	101	13	206	190	219
2005	14	103	95	116	51	188	155	239	65	291	251	355
2007	14	109	107	123	153	225	206	378	167	334	313	501
2009	6	138	138	144	156	136	121	292	162	274	259	436
2011	24	157	129	181	32	176	130	209	56	334	259	390
2014	NA	NA	NA	NA	NA	NA	NA	NA	57	225	189	282
2016	202	91	74	293	118	186	136	304	320	277	211	597
2018	84	644	298	728	18	83	45	101	102	727	343	829
2024	3	891	776	894	9	75	55	84	11	966	831	978

4.12. MARITIMES SUMMER ECOSYSTEM RESEARCH VESSEL SURVEY

Since 1970, DFO has conducted the Summer Ecosystem Research Vessel survey in the Maritimes Region using a standardized protocol (DFO 2024d). The stratification design of this survey partly covers Unit 2 (Figure 115). The data collected in strata 440-455, 457, 558 and 559, from 2014 (strata 558 and 559 were not sampled prior to 2014 with the exception of 1972) to 2024, were retained to assess trends in Redfish biomass and length frequency.

Redfish biomass increased from 2019 to 2023 and decreased in 2024 to a value similar to that recorded in 2020 (190 kt, Figure 116). The modal length of Redfish was 19 cm in 2017, 23 cm in 2019, 25 cm in 2020, and 26 cm in 2024 and 2023 (Figure 117), which could correspond to the 2011-2013 cohorts. Although this survey can be useful to understand Unit 2 Redfish dynamics, the small spatial coverage of Unit 2, the short duration of the time series starting in 2014, and the lack of Redfish species-specific estimates limit the conclusions that can be drawn from the Summer Ecosystem Research Vessel survey in the Maritimes Region.

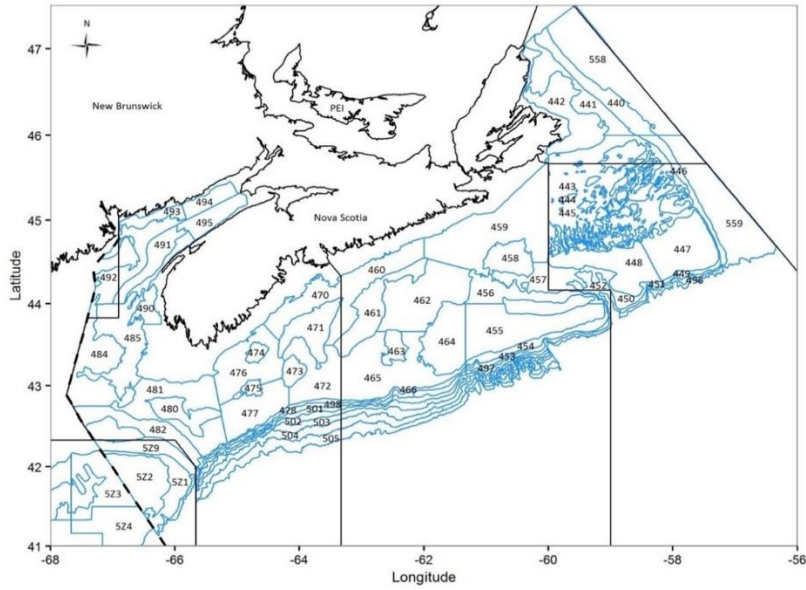


Figure 115. Stratification scheme used for the Maritimes Summer Ecosystem Research Vessel survey .

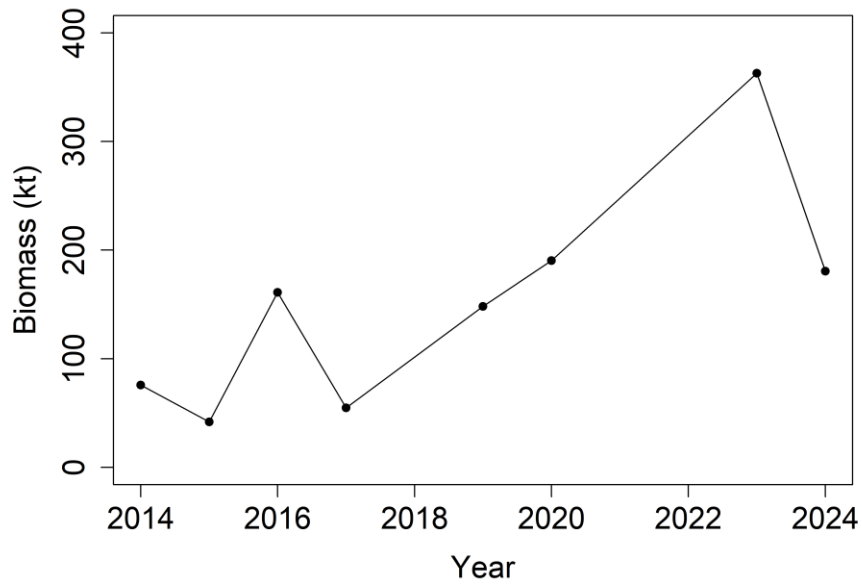


Figure 116. Minimum trawlable biomass in kilotonnes (kt) in the Maritimes Summer Ecosystem Research Vessel survey (strata 440-455, 457, 558 and 559) from 2014 to 2024.

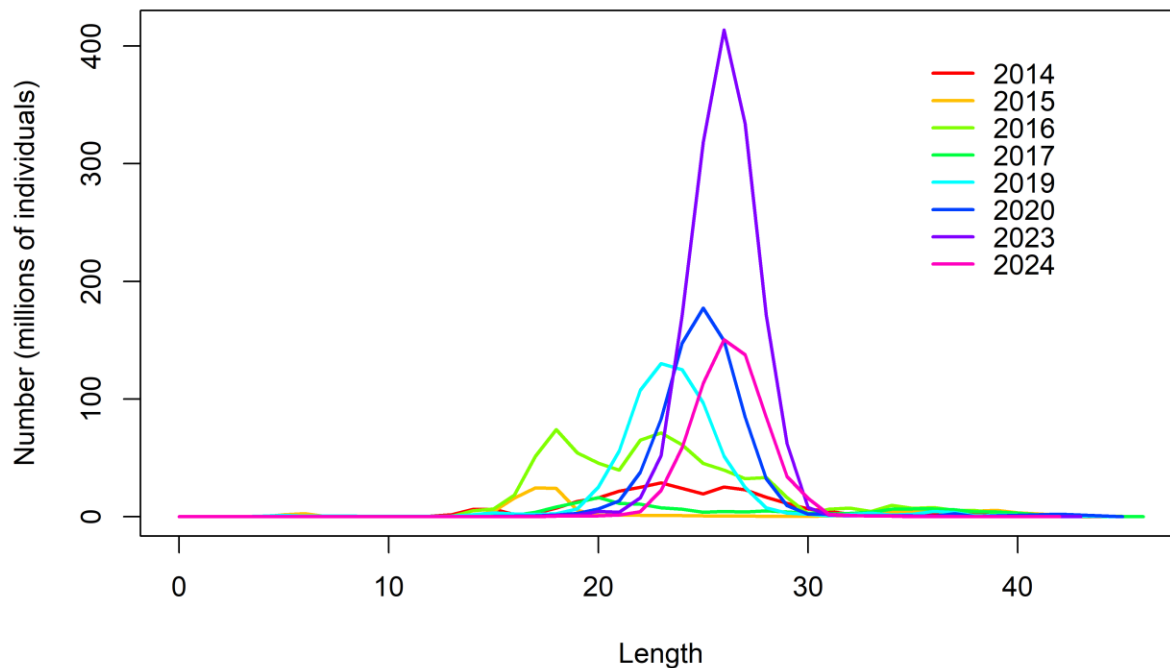


Figure 117. Length frequency (millions of individuals) in the Maritimes DFO survey (stratum 440-455, 457, 558 and 559) from 2014 to 2024. Each year is represented by a different color.

4.13. WINTER SURVEYS

From 1978 to 1994, DFO conducted a winter survey in January onboard the MV (Motor Vessel) *Gadus Atlantica* equipped with an Engel 145 Otter trawl (McCallum and Walsh 1997). This survey sampled NAFO Divisions 4RST and Subdivision 3Pn. Although a stratification scheme identical to that used in the nGSL survey was used (Fréchet 1986), the spatial coverage of the survey was highly variable from year to year, particularly in 4S, and the study area was never completely covered due to ice, which prevented the estimation of a standardised abundance index (Rivest et al. 2021). The survey was abandoned in 1995 mainly because nGSL cod were in 3Ps during the survey period and hence biomass estimates were considered biased (Fréchet and Schwab 1995). Another reason that was given was the retirement of the MV *Gadus Atlantica* (Fréchet and Schwab 1995).

From 2022 to 2024, a winter survey was conducted aboard the *Mersey Venture*, an industry vessel of identical length and width to the CCGS *Teleost* built the same year by the same shipyard (DFO 2020). The *Mersey Venture* fished with a modified Campelen 1800 trawl net with a 12.7 mm liner. The stations were determined according to an unaligned systematic sampling plan, which consists of gridifying the study area (in NAD83 Quebec Lambert), placing a station on each grid node and adding 1 random x component per line and 1 random y component per column (Ripley 1981).

For each survey, Redfish distribution maps and cumulative proportions according to depth are presented. During the MV *Gadus Atlantica* survey, the largest observed aggregations of Redfish in winter were located in the southern part of Esquiman Channel and in the Cabot Strait

(Figure 118). During the Mersey Venture survey, Redfish were more broadly distributed. They were present in 99% of sampled stations. The largest aggregations were observed around Anticosti Island, in 3Ps, and on the eastern side of the Laurentian Fan (Figure 119). Biomass estimates are not directly comparable between the MV Gadus Atlantica and the Mersey venture given the absence of conversion factors between the two vessels. Based on the MV Gadus Atlantica survey, 72% of observed Redfish biomass was located deeper than 300 m (Figure 120). A similar pattern was observed in recent years with the Mersey Venture, with 63% of Redfish biomass observed at depth greater than 300 m (Figure 121). The slight discrepancy in percentage between the two winter surveys may be explained by differences in sampling coverage and/or Redfish distribution over time.

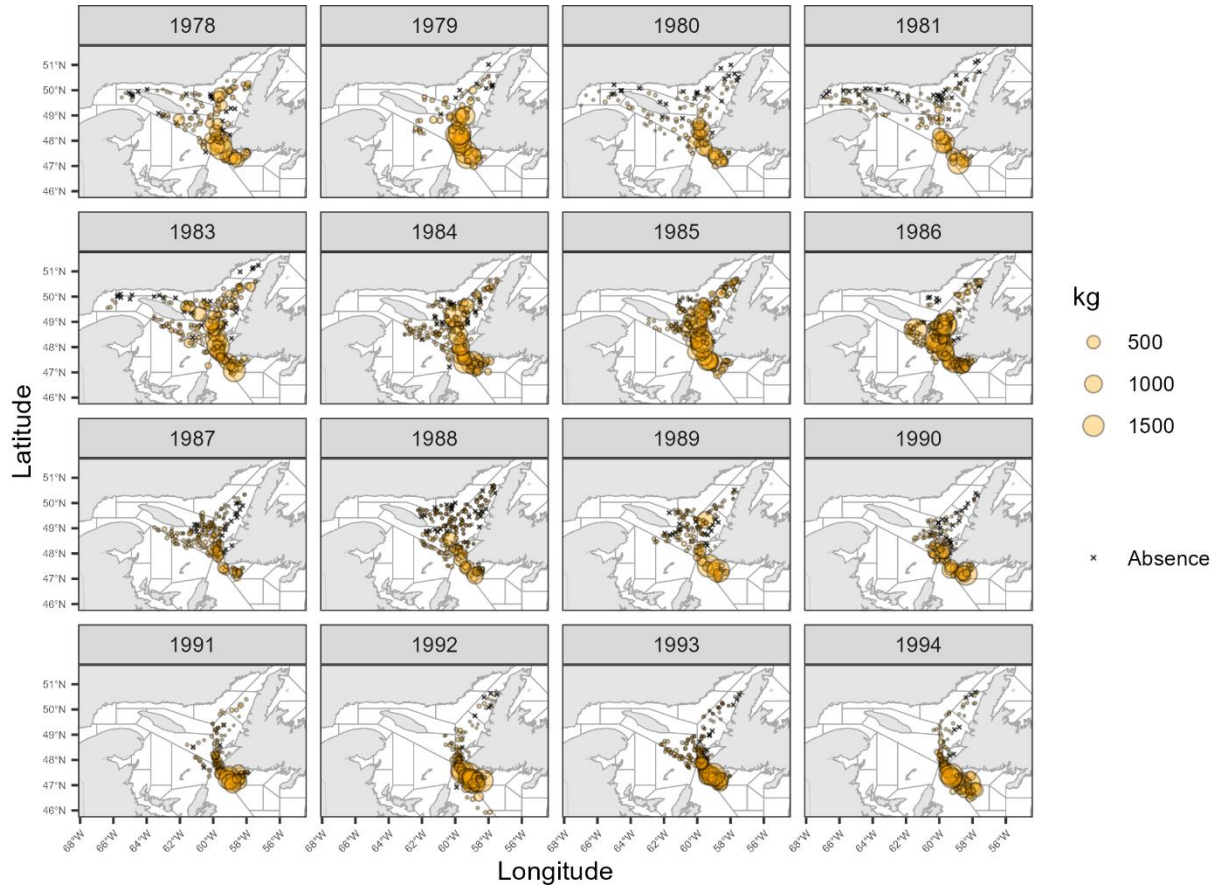


Figure 118. Redfish catch rate distribution during the MV Gadus Atlantica winter survey from 1978-1994. Values larger than the 99th percentile are illustrated as the 99th percentile for visualization. NAFO Subdivisions and Subunits are indicated by grey lines.

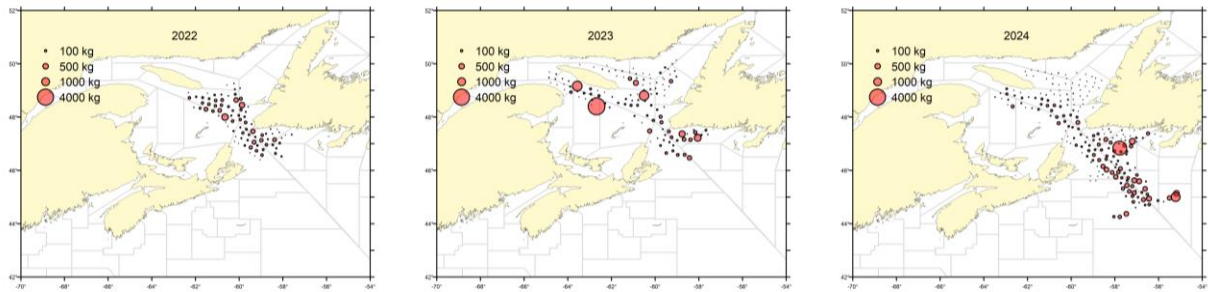


Figure 119. Redfish catch rate distribution during the Mersey Venture winter survey from 2022-2024. The size of the points is proportional to the square root of the catches for visualization, and NAFO Subdivisions and subunits are indicated by grey lines.

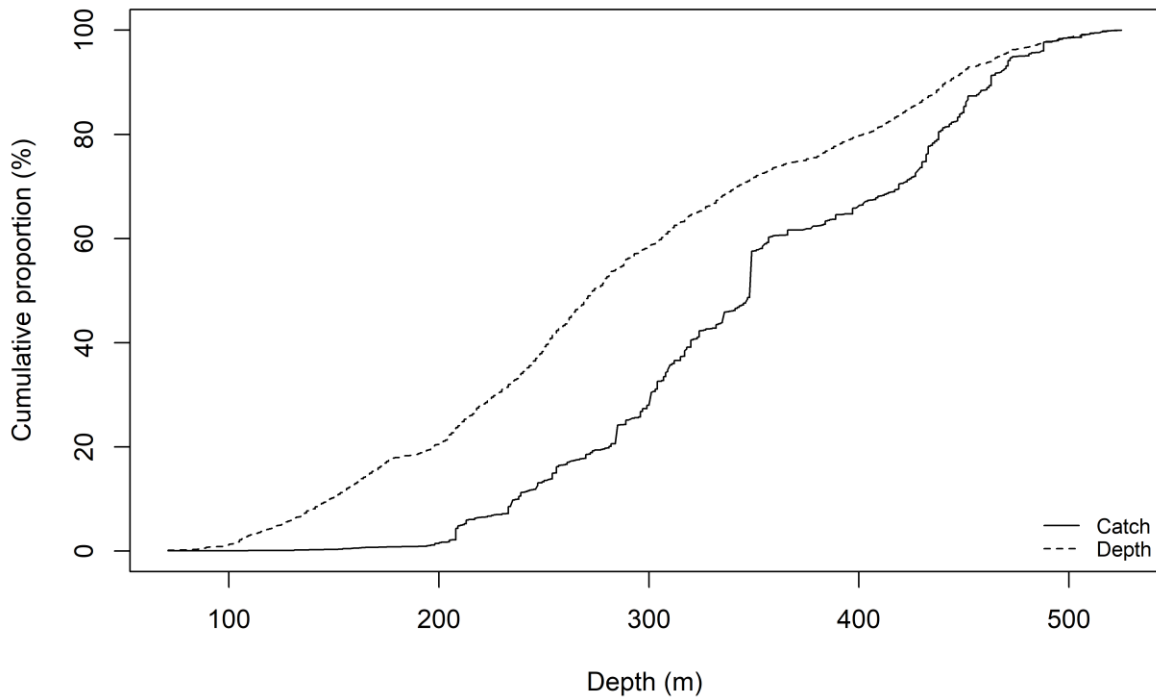


Figure 120. Cumulative proportion of Redfish during the MV Gadus Atlantica winter survey from 1978-1994. The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m).

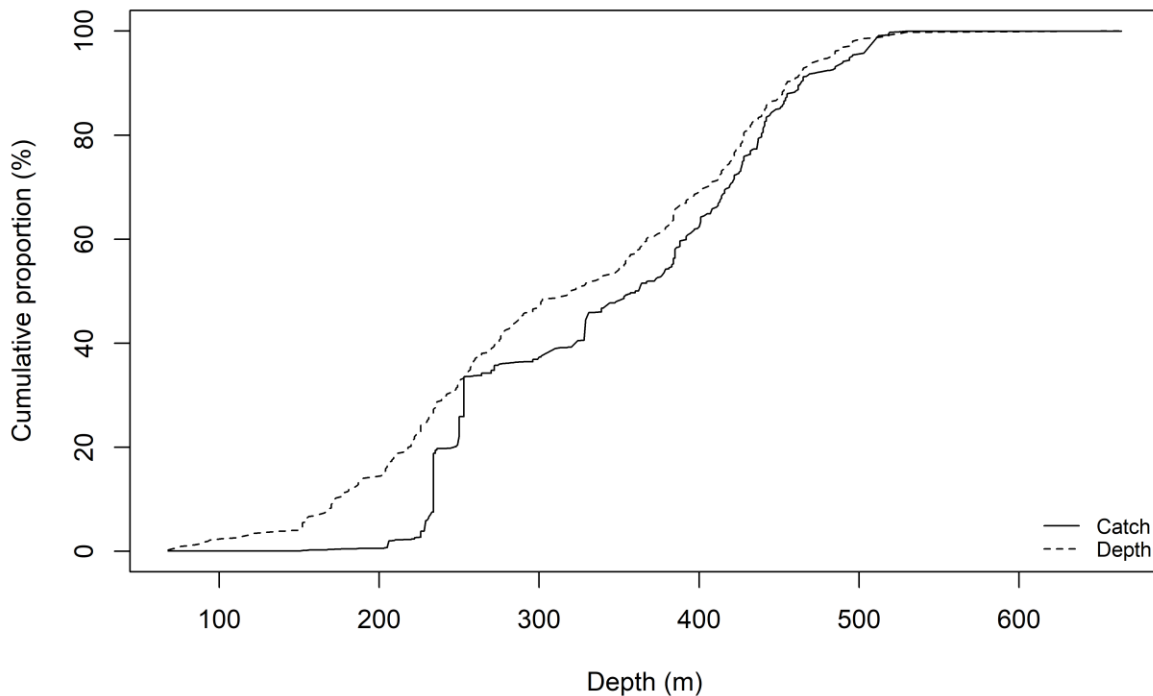


Figure 121. Cumulative proportion of Redfish during the Mersey Venture winter survey from 2022-2024. The solid and dotted lines represent the cumulative proportion of catches and survey stations, respectively, according to depth (m).

4.14. EMPIRICAL REFERENCE POINTS FOR UNITS 1 AND 2 STOCKS

The biomass that produces maximum sustainable yield (B_{msy}) is unknown for both Redfish species and the concept of B_{msy} may not apply for species producing such sporadic recruitment. Indeed, Units 1 and 2 Redfish do not display conventional stock-recruitment dynamics and the concept of recruitment over-fishing is difficult to infer based on the patterns observed. Throughout the stocks' histories, periods of high Redfish biomass have been sustained by a small number of large recruitment events. Redfish have also recovered from low levels of SSB. However, there are SSB levels from which recovery will be unlikely or impossible (Keith and Hutchings 2012).

In 2020, a Limit Reference Point (LRP) was empirically defined and estimated as the smallest SSB from which there has been a recovery (B_{rec}) for *S. mentella*, or in the case of *S. fasciatus*, the SSB that produced recruitment that would allow recovery in the absence of emigration. B_{rec} has been deemed an acceptable basis for the LRP for species with sporadic recruitment dynamics. For both stocks, B_{rec} was empirically estimated as the geometric mean of the 2010-2012 SSB in the Unit 1 survey, i.e. the SSB which produced the 2011-2013 cohorts. The resulting LRPs are based on a recent period of low SSB occurring in warm conditions that may not be unusual in the future.

An Upper Stock Reference (USR) was also proposed for each stock based on SSB information from the nGSL DFO research survey in Unit 1. A period of relatively high SSB and landings was considered as the basis for each species, specifically 1984-1990 for *S. mentella* and 1984-1992 for *S. fasciatus*. The proposed USRs were empirically estimated as 80% of the SSB geometric mean during these periods. While not founded in recruitment-overfishing concepts, the

proposed USRs provide a defensible baseline for what has previously been considered a “healthy” stock.

In 2022, the LRP were adjusted based on new species- and sex-specific maturity ogives for the 2011-2013 cohorts implemented from 2011 onwards to estimate the SSB in both stocks. This adjustment corresponded to a 1 kt increase in the LRP for *S. mentella* (from 43 kt to 44 kt) and a 5 kt increase in the LRP for *S. fasciatus* (from 25 kt to 30 kt). Since they were based on a period prior to the implementation of the new ogives, the proposed USRs remained unchanged, at 265 kt and 168 kt for *S. mentella* and *S. fasciatus*, respectively. In this document, LRP and USRs were calculated in CCGS *John Cabot* equivalents and corresponded respectively to 47 and 281 kt for *S. mentella* and 31 and 178 kt for *S. fasciatus*.

According to the adjusted LRP and proposed USRs, the status of the *S. mentella* stock in Units 1 and 2 in 2024 was in the Healthy Zone of the PA (Figure 122A). The estimate of *S. mentella* SSB has decreased since 2020 and was estimated at 1,737 kt (1,386-2,089 kt, 95% CI) in 2024. Nonetheless, the value was six times greater than the USR. The estimated *S. fasciatus* SSB has appeared stable at values slightly above the USR since 2022 and was estimated at 190 kt (9-371 kt, 95% CI) in 2024 (Figure 122B). The status of the *S. fasciatus* stock within the PA framework was deemed uncertain, owing to evidence suggesting it may currently be overestimated, but the magnitude of this overestimation is not quantified (Senay et al. 2022).

The proposed reference points for each species will need to be revised as soon as reliable information on the recruitment and dynamics of Redfish stocks in both Unit 1 and Unit 2 is available.

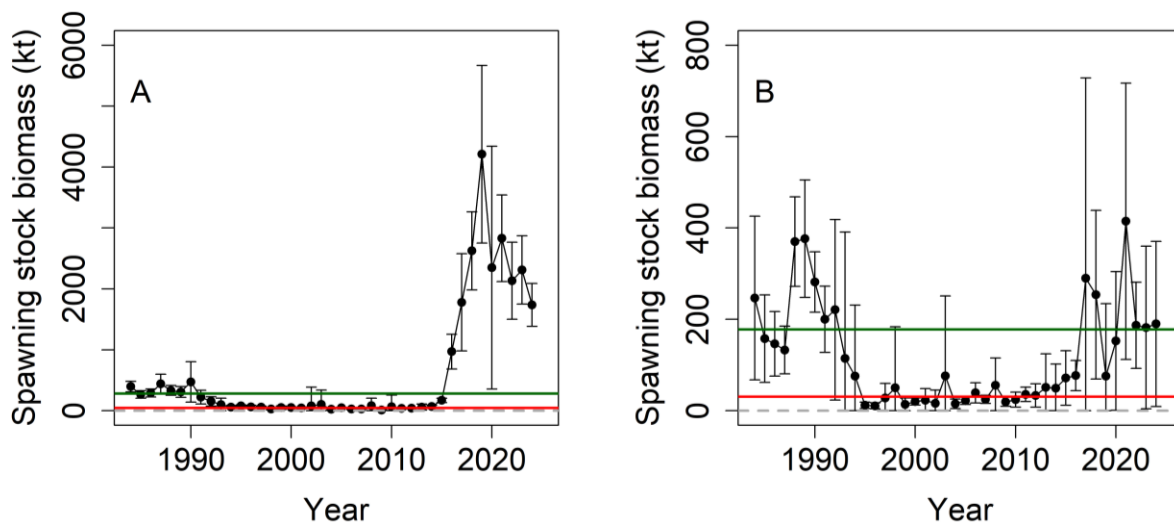


Figure 122. Spawning stock biomass (kilotonnes, with 95% confidence intervals) estimated from the nGSL DFO survey from 1984 to 2024. The proposed Upper Stock Reference (green line) and Limit Reference Point (red line) for *S. mentella* (A) and *S. fasciatus* (B) are shown. The 0 y-axis value is indicated by a gray dashed line. Note the different scales on the y-axis.

4.15. POTENTIAL REMOVALS AND DEPLETION RATE IN UNIT 1

A range of potential removals for the Unit 1 Redfish 2025-2026 fishing season was determined based on Froese et al. (2016). Their work argues for taking less from a stock than nature or ensuring that the fishing mortality rate (F) is lower than the natural mortality (M). They also

suggest that $F \sim 0.5 * M$ may be an adequate precautionary target when stock size is above half of their natural level and composed mostly of mature individuals. Other studies have supported that this range of F should be prudent (e.g., Patterson 1992; Zhou et al. 2012). The approach proposed by Froese et al. (2016) was applied to Unit 1 Redfish (Senay and Duplisea 2024), but is only meant to be used in the short-term (< 5 years).

Estimates of Redfish M were derived from available temperature and life history traits information using a [tool](#) developed by the National Oceanic and Atmospheric Administration (NOAA, Cope and Hamel 2022). A temperature of 7 °C (Galbraith et al. 2024), a longevity of 65 years (Campana et al. 1990), and growth parameters for the 2011-2013 cohorts (Table 16, $L_{inf} = 27$ cm, $k = 0.200$ y⁻¹, and $t_0 = -0.365$ y) were used as inputs, together with the average length-at-maturity recently updated for *S. mentella* and *S. fasciatus* from Unit 1 and 2 (Brûlé et al. 2024) and corresponding age-at-maturity based on the aforementioned growth curve ($A50 = 5.2$ years for *S. mentella* and 4.4 years for *S. fasciatus*). All outputs were set to describe fish over 13 years old and 22 cm in length (minimum regulatory size). Seventeen different methods using different input information and assumptions were applied to obtain 17 estimates of M for each species (Table 23). For both species, the median values of M across methods were 0.275 (annual rate of 24%), and included extreme values above 0.4 and below 0.01.

Extremes values of M seemed improbable, but were still reported and used to determine the complete range of potential removals with all 17 M estimates available in Cope and Hamel (2022). Some of these methods have been shown to be more or less appropriate for Redfish stocks in other areas (Sullivan et al. 2022). The two lowest values of M were derived from longevity, k and t_0 , while the highest value was derived from L_{inf} and k . The large differences in the estimates may be due to departures from generalized life history relationships. Some *Sebastes* species tend to approach L_{inf} quickly relative to their lifespans, and therefore, the standard cross-taxa relationship between k and M may be biased for some species like *Sebastes* (Beverton 1992). Longevity is often considered the most informative input to estimate M (Cope and Hamel 2022). However, no update of longevity for the 2011-2013 Redfish cohorts in the nGSL is yet available. Longevity is expected to be lower given other changes in life history traits, namely the growth parameters and length-at-maturity. Lower longevity would increase natural mortality and potential removals. Höffle and Planque (2023) estimated 48 different values of M for *S. mentella* in the Norwegian and Barents Seas which were also highly variable, ranging from 0.01 to 0.32 across the populations. They subsequently selected a subset of realistic estimates based on expert knowledge and values distribution. In the absence of recent information on Redfish longevity in Unit 1, and considering that limited information is currently available to inform the selection of specific M estimation methods over others, all 17 estimates of M were considered to derive potential removals for the 2024-2025 fishing season, and values corresponding to the 25th and 75th percentiles were retained as a realistic range for the present assessment.

Consistent with the precautionary target described above ($F \sim 0.5 * M$), all M estimates were halved and multiplied by the biomass of fish larger than 22 cm to determine a range of potential removals within the commercial fishery. To cope with annual variations in biomass estimates, the geometric mean of the last two years was calculated and used as the biomass value in the equation (1,976 kt for *S. mentella* and 158 kt for *S. fasciatus*). Potential removals were thus estimated as follows:

$$\text{Potential removal} = \text{Biomass} * (1 - \exp(-M * 0.5))$$

This equation provided a range of annual potential removals of 2 to 381 kt, with a median of 253 kt for *S. mentella* (Figure 123). For *S. fasciatus*, potential removals varied from 0.14 to 30 kt, with a median of 20 kt. Given that extreme values of M were deemed the most unlikely, a

realistic range of potential removals for the 2025-2026 fishing season was defined between the 25th and 75th percentiles of these estimates, corresponding to 80 and 291 kt for *S. mentella*, and 8 and 25 kt for *S. fasciatus*. *S. mentella* will very likely remain in the Healthy Zone in 2025 with this range of removals.

Given the uncertainty over the current status of the *S. fasciatus* stock, and the assumptions underlying the proposed method (namely the appropriateness of the precautionary target, $0.5 * M$, requiring stock biomass to be above half of its natural, unfished level), a range of potential removals could not be determined with certainty for the stock. A prudent approach is recommended for *S. fasciatus* given the large difference in biomass between the two species.

The estimated range of potential removals for *S. mentella* could be used in the short-term. Given that potential removals are based on current estimates of biomass, the first year of fishing would correspond to the largest removals in the absence of new production from recruitment and/or growth. Potential removals would have to be updated every year with annual values of biomass of fish larger than 22 cm. If some new production happens, it would be considered when determining subsequent potential removals.

The biomass depletion rate was determined assuming that no new production from either recruitment or growth and no new emigration or immigration occur after 2024. This is not a realistic situation, nevertheless it provides an approximation for how long the 2011-2013 cohorts might contribute to a fishery. First, the trajectories of the initial biomass (year 0 in Figure 124) of the 2011-2013 cohorts of *S. mentella* and *S. fasciatus* were subjected to the 17 different species-specific values of M , assuming no removals from fishing. For *S. mentella* and *S. fasciatus*, respectively 12 and 13 scenarios out of 17 resulted in values of biomass smaller than 10% of the initial biomass within 25 years or less. Within 15 years, initial biomass was estimated to decrease to 10% in 11 scenarios out of 17 for *S. mentella* and *S. fasciatus*. For both species, the two lowest values of M provided unrealistic scenarios, wherein biomass stayed at high level for a period longer than assumed Redfish longevity (> 100 years).

To illustrate the biomass trajectories for the 2011-2013 cohorts under various values of F , M was set as the median value of the 17 M values presented in Table 23 ($M=0.275$ for both species) and the 17 M were used to derive 17 F ($F = 0.5 * M$). The outcomes in the absence of fishing ($F = 0$), the 25th percentile of F (0.042 for *S. mentella* and 0.053 for *S. mentella*), the median F (0.138 for both species), and the 75th percentile of F (0.159 for *S. mentella* and 0.169 for *S. fasciatus*) were compared for insights into the impact of fishing (Figure 125). For both species, and in the absence of recruitment, growth, and emigration or immigration from and to Unit 1, the median and 75th percentile of F provided similar trajectories, with biomass decreasing to less than 10% of the initial biomass within six years, compared to eight years with the 25th percentile of F , and nine years without fishing. A decrease to 10% of initial biomass, corresponding to 198 kt for *S. mentella* and 16 kt for *S. fasciatus* would have different implications for each species relative to their precautionary approach.

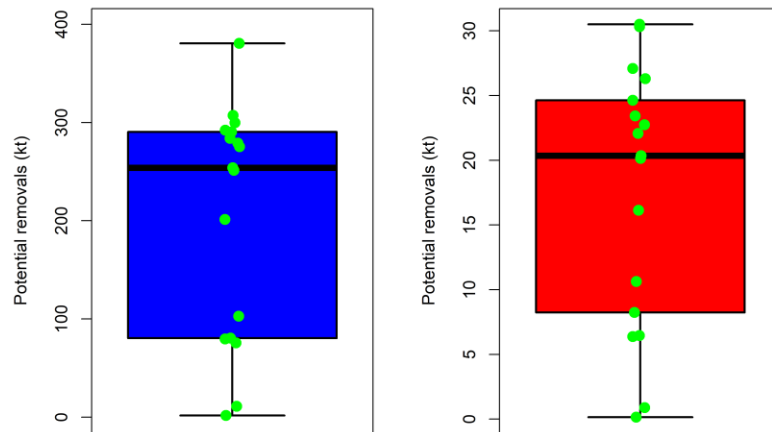


Figure 123. Boxplots representing annual potential removals for the Unit 1 2025-2026 fishing season in kilotonnes (kt) for *S. mentella* (left panel) and *S. fasciatus* (right panel). The different values derived from various estimates of M are indicated by green points. The blue and red boxes are delimited by the 25th and 75th percentiles and could be used as an acceptable range of potential removals. Note the different scales on the y-axis.

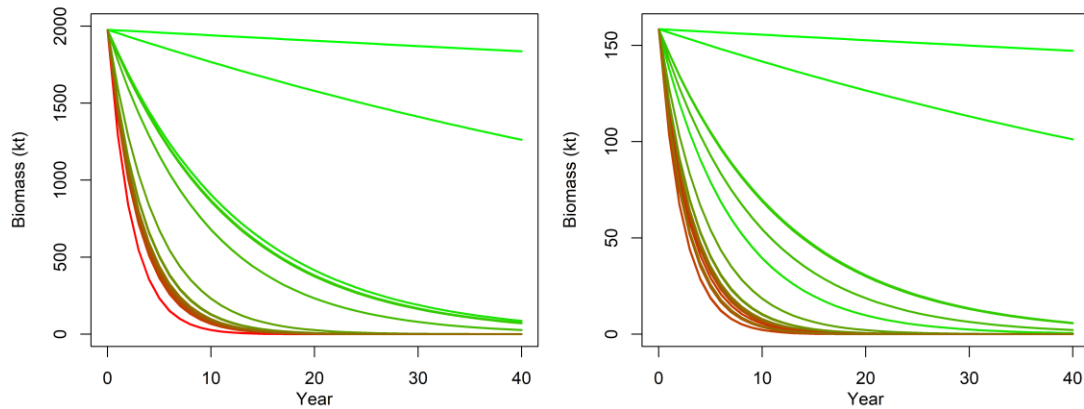


Figure 124. Impact of the 17 estimates of natural mortality rate (M) on the depletion of biomass for the 2011- 2013 cohorts of *S. mentella* (left panel) and *S. fasciatus* (right panel). The depletion assumes no new production. Small to large values of M are illustrated in a green to red gradient.

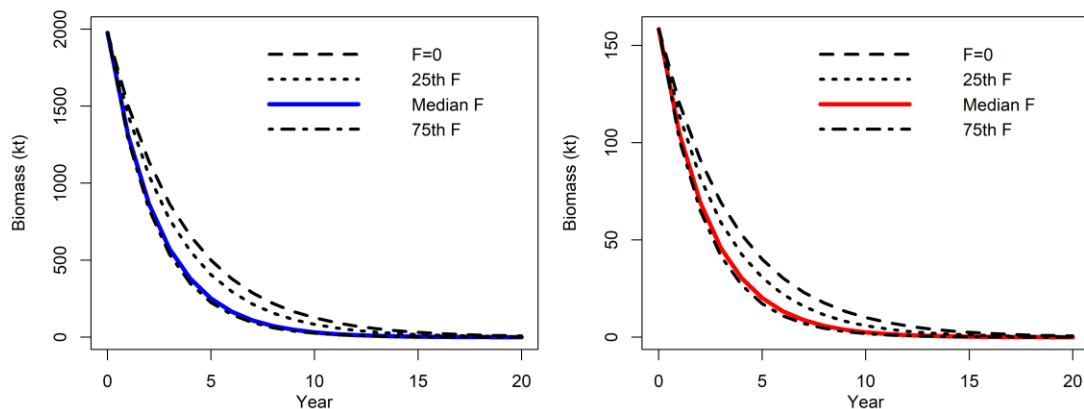


Figure 125. Impact of different fishing mortality (0, as well as 25th percentile, median, and 75th percentile of F) on the trajectories of 2011-2013 cohorts biomass for *S. mentella* (left panel) and *S. fasciatus* (right panel) without new production.

Table 23. Values of annual M derived for 17 methods based on temperature and life history traits for *S. mentella* and *S. fasciatus* (Cope and Hamel 2022).

Method	Input	<i>S. mentella</i>	<i>S. fasciatus</i>
FishLife	species name	0.078	0.139
Then_nls	longevity	0.107	0.107
Then_lm	longevity	0.082	0.082
Hamel_Amax	longevity	0.083	0.083
Chen-Wat	age, k , t_0	0.215	0.215
ZM_AC_pel	longevity, k , t_0	0.011	0.011
ZM_AC_dem	longevity, k , t_0	0.002	0.002
Then_VBGF	L_{inf} , k	0.428	0.428
Hamel_k	k	0.310	0.310
Jensen_k 1	k	0.300	0.300
Jensen_k 2	k	0.320	0.320
Gislason	L_{inf} , k , length	0.275	0.275
Charnov	L_{inf} , k , length	0.272	0.272
Pauly_lt	L_{inf} , k , temperature	0.338	0.338
Roff	k , age-at-maturity	0.329	0.425
Jensen_Amat	age-at-maturity	0.318	0.375
Ri_Ef_Amat	k , age-at-maturity	0.304	0.363

4.16. POTENTIAL REMOVALS AND DEPLETION RATE IN UNIT 2

A range of potential removals for the Unit 2 Redfish 2025-2026 fishing season was determined as in Unit 1. The same life history traits and natural mortality estimates were used, given that no information specific to Unit 2 Redfish (e.g., longevity, growth, length-at-maturity) was available. Instead of geometric means, only the estimates of biomass larger than 22 cm in 2024 were

used, 891 kt for *S. mentella* and 75 kt for *S. fasciatus*. The 2018 estimates were not considered recent enough to be included.

For *S. mentella*, the range of potential removals varied from 0.81 to 172 kt, with a median of 115 kt (Figure 126). The range of potential removals for *S. fasciatus* was from 0.07 to 15 kt, with a median of 10 kt. Given that extreme values of M are the most unlikely, a realistic range of potential removals for the 2025-2026 fishing season was defined as between the 25th and 75th percentiles of these estimates, corresponding to 36 and 131 kt for *S. mentella*, and 4 and 12 kt for *S. fasciatus*. This range of removal should not cause conservation concern for *S. mentella*.

As in Unit 1, given the uncertainty over the status of the *S. fasciatus* stock, and the assumptions underlying the proposed method, a range of potential removals could not be determined with certainty within Unit 2. A prudent approach is recommended for *S. fasciatus* given the large difference in biomass between the two species and that the estimate in Unit 2 is currently at the lowest value of the time series.

As in Unit 1, for *S. mentella* and *S. fasciatus*, respectively 12 and 13 scenarios out of 17 resulted in less than 10% of the initial biomass in 25 years or less (Figure 127). Within 15 years, initial biomass decreased to 10% in 11 scenarios out of 17 for *S. mentella* and *S. fasciatus*. For both species, the two lowest values of M provided unrealistic scenarios, where biomass stayed at high level for a period longer than assumed Redfish longevity (> 100 years). For both species, and in the absence of recruitment and growth, and emigration or immigration from Unit 2, the median and 75th percentile of F provided similar trajectories, with biomass decreasing to less than 10% of the initial biomass in six years, compared to eight years with the 25th percentile of F , and nine years without fishing (Figure 128). A decrease to 10% of the initial biomass, corresponding to 89 kt for *S. mentella* and 7.5 kt for *S. fasciatus* would have different implications for each species. Given the absence of survey every year and that Unit 2 survey is not included in the PA approach, caution is advised for Unit 2.

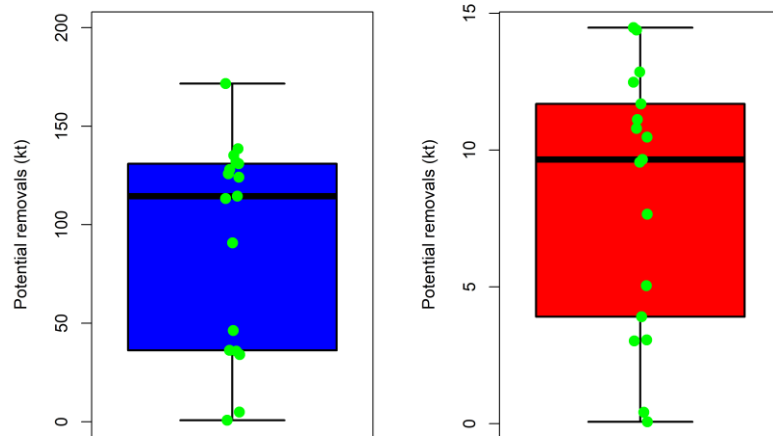


Figure 126. Boxplots representing annual potential removals for the 2025-2026 fishing season in Unit 2 in kilotonnes (kt) for *S. mentella* (left panel) and *S. fasciatus* (right panel). The different values derived from various estimates of M are indicated by green points. The blue and red boxes are delimited by the 25th and 75th percentiles and could be used as an acceptable range of potential removals. Note the different scales on the y-axis.

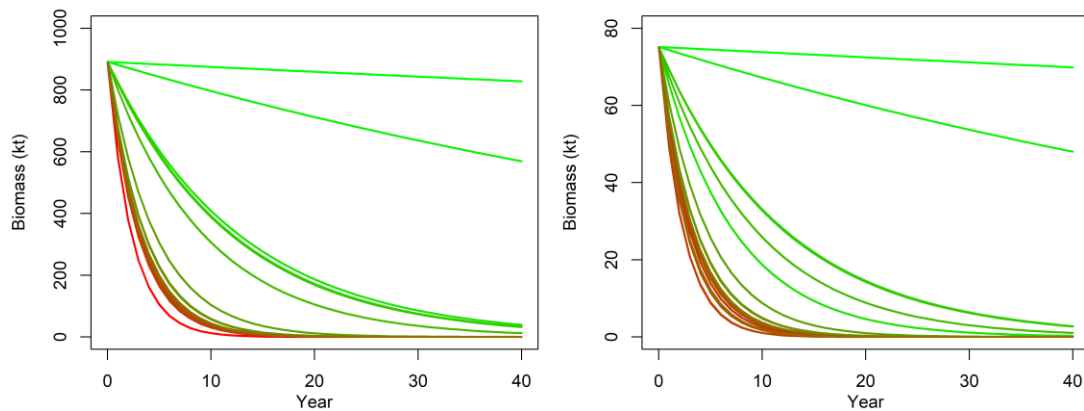


Figure 127. Impact of the 17 estimates of natural mortality rate (M) on the depletion of Unit 2 biomass for *S. mentella* (left panel) and *S. fasciatus* (right panel). The depletion assumes no new production. Small to large values of M are illustrated in a green to red gradient.

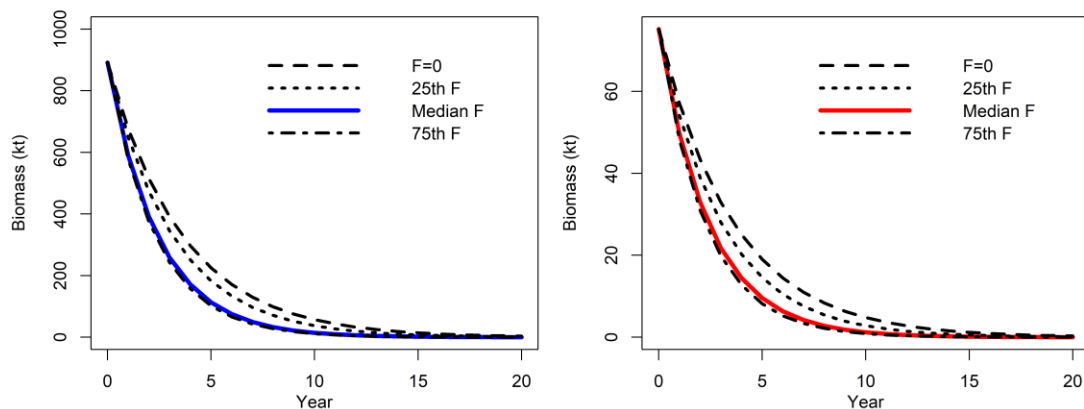


Figure 128. Impact of different fishing mortality (0, as well as 25th percentile, median, and 75th percentile of F) on the trajectories of Unit 2 biomass for *S. mentella* (left panel) and *S. fasciatus* (right panel) without new production.

5. SOURCES OF UNCERTAINTY

Species identification based on AFR counts implies the risk of overestimating the less abundant species, which currently is *S. fasciatus*. However, the extent of the overestimation has not been quantified. The biases associated with the AFR-based method could lead to overestimating the SSB, stock status, and tolerance to substantial removals of *S. fasciatus* within both management units. Given the uncertainty over biomass estimates and species identification, and the assumptions underlying the method used, it has not been possible to provide a reliable range of potential removals for *S. fasciatus*.

The uncertainties surrounding natural mortality lead to a wide range of potential removal rates, thus limiting our understanding of the rate at which biomass is likely to decline under any level of F in upcoming years.

Ensuring an appropriate survey in Unit 2 is a high priority. Issues with the implementation of the protocol developed by DFO and the industry for the Unit 2 survey in 2020, 2022, and 2024, precluded the use of the data from that survey, thereby limiting our understanding of stock trends and Redfish movements in recent years. The acoustics data collected during the survey should be investigated.

5.1. RESEARCH RECOMMENDATIONS

Genetic samples should be collected both in surveys and in the fishery to better determine biomass trends and species-specific harvest levels in the future. Such work should help improve the accuracy of species composition estimates based on the AFR counts for our comprehension of past trends.

More work is needed to better understand the effects of changing ecosystemic conditions on Redfish life-history traits and processes such as growth, mortality, recruitment, maturity, and longevity. Research initiatives aimed at understanding relationships between the increase in water temperature, decrease in dissolved oxygen and Redfish physiology (e.g., metabolism, growth), demographic rates (e.g., recruitment, mortality), and density-dependent processes, need to be maintained or initiated.

Given that the Redfish fishing effort may increase in upcoming years and that many co-occurring species are at historically low abundance, data collection and research aiming to better understand the factors affecting the quantities and composition of bycatch of other species are also a priority. This includes spatial and seasonal changes in fishing effort and the distribution of bycatch species, as well as the type and configuration of fishing gear, the selectivity of size and species, and fishing depth.

6. CONCLUSION

Prospects for fishing *S. mentella* in Unit 1 and Unit 2 are positive due to the large cohorts from 2011, 2012 and 2013 that are now mostly larger than the minimum regulatory size of 22 cm. This increase of *S. mentella* biomass may have important repercussions on other species, through bycatch risk, predation and competition interactions. The high biomass of *S. mentella* may allow higher catches up to 291 kt for Unit 1 and 131 kt for Unit 2 for the 2025-2026 fishing season. *S. mentella* will very likely remain in the Healthy Zone in 2025 given this range of removals.

A prudent approach is recommended for *S. fasciatus* given the large difference in biomass between the two species and uncertainty in species identification. The available evidence suggests that, except in the Laurentian Fan, fishing deeper than 300 m would target the more abundant species, *S. mentella*, and reduce catches of undersized Redfish of either species. Given the low recruitment and growth observed in recent years, and even in the absence of fishing, biomass of both species is expected to decrease in upcoming years.

There are concerns about impacts of an expanded Redfish fishery on depleted bycatch species which should be closely monitored within Units 1 and 2, particularly as regards vulnerable species. Nevertheless, a reduction in the biomass of Redfish could be favorable to certain species acting as preys or competitors. In Unit 1, high Redfish biomass has been identified as one of the potential causes of the decline of Northern Shrimp, through increased predation pressure, and the decline in the condition of Greenland Halibut and Atlantic Cod, through increased competition for food resources. Further research is needed to better understand the combined impacts of the increase in Redfish biomass, changes in environmental condition (warmer water temperature and low oxygen level), and fishing pressure on the ecosystem.

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