Analysis of Atlantic Cod, Greenland Halibut, Redfish, and Skate Stomach Contents from the 2018 NSRF-DFO Summer Shrimp Survey in Hudson Strait, Davis Strait and Labrador Sea

Hannah Polaczek, Sheila Atchison, David Deslauriers, Katherine Skanes, Olivia Lacasse, Virginie Roy, Wojciech Walkusz

Fisheries and Oceans Canada
Ontario and Prairie Region, Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
Canada R3T 2N6

2023

Canadian Data Report of
Fisheries and Aquatic Sciences 1338

Fisheries and Oceans Canada
Pêches et Océans Canada

Canada

Canadian Data Report of Fisheries and Aquatic Sciences

Data reports provide a medium for filing and archiving data compilations where little or no analysis is included. Such compilations commonly will have been prepared in support of other journal publications or reports. The subject matter of the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Data reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-25 in this series were issued as Fisheries and Marine Service Data Records. Numbers 26-160 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Data Reports. The current series name was changed with report number 161.

Rapport statistique canadien des sciences halieutiques et aquatiques

Les rapports statistiques servent de base à la compilation des données de classement et d'archives pour lesquelles il y a peu ou point d'analyse. Cette compilation aura d'ordinaire été préparée pour appuyer d'autres publications ou rapports. Les sujets des rapports statistiques reflètent la vaste gamme des intérêts et politiques de Pêches et Océans Canada, notamment la gestion des pêches, la technologie et le développement, les sciences océaniques et l'environnement aquatique, au Canada.

Le titre exact figure au haut du résumé de chaque rapport. Les rapports à l'industrie sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports statistiques sont produits à l'échelon régional, mais numérotés à l'échelon national. Lesdemandes de rapports seront satisfaites par l'établissement d'origine dont le nom figure sur la couvertureet la page du titre.

Les numéros 1 à 25 de cette série ont été publiés à titre de Records statistiques, Service des pêcheset de la mer. Les numéros 26-160 ont été publiés à titre de Rapports statistiques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 161.

Canadian Data Report
of Fisheries and Aquatic Sciences 1338

2023

ANALYSIS OF ATLANTIC COD, GREENLAND HALIBUT, REDFISH, AND SKATE STOMACH CONTENTS FROM THE 2018 NSRF-DFO SUMMER SHRIMP SURVEY IN HUDSON STRAIT, DAVIS STRAIT AND LABRADOR SEA

by

Hannah Polaczek[1], Sheila Atchison[1], David Deslauriers[1], Katherine Skanes[2], Olivia Lacasse[3],
Virginie Roy[3], Wojciech Walkusz[1]

[1] Fisheries and Oceans Canada
Ontario and Prairie Region, Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
Canada R3T 2N6

[2] Fisheries and Oceans Canada
Newfoundland and Labrador Region, Northwest Atlantic Fisheries Centre
80 E White Hills Road
St. John's, Newfoundland and Labrador
Canada A1A 5J7

[3] Fisheries and Oceans Canada
Quebec Region, Maurice Lamontagne Institute
850 Route de la Mer
Mont-Joli, Québec
Canada G5H 3Z4

Cat. No. Fs 97-13/1338E-PDF ISBN: 978-0-660-38221-0 ISSN 1488-5395

Correct citation for this publication:

Polaczek, H., Atchison, S., Deslauriers, D., Skanes, K., Lacasse, O., Roy, V., and Walkusz, W. 2023. Analysis of Atlantic Cod, Greenland Halibut, Redfish, and Skate Stomach Contents from the 2018 NSRF-DFO Summer Shrimp Survey in Hudson Strait, Davis Strait and Labrador Sea. Can. Data. Rep. Fish. Aquat. Sci. 1338: vi + 20 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Polaczek, H., Atchison, S., Deslauriers, D., Skanes, K., Lacasse, O., Roy, V., and Walkusz, W. 2023. Analysis of Atlantic Cod, Greenland Halibut, Redfish, and Skate Stomach Contents from the 2018 NSRF-DFO Summer Shrimp Survey in Hudson Strait, Davis Strait and Labrador Sea. Can. Data. Rep. Fish. Aquat. Sci. 1338: vi + 20 p.

The stomach contents of Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), redfishes (unidentifiable *Sebastes* sp.), and skates (unidentifiable Rajidae) sampled during the 2018 Northern Shrimp Research Foundation and Fisheries and Oceans Canada (NSRF-DFO) summer shrimp survey in the Eastern Assessment Zone (EAZ), Western Assessment Zone (WAZ), and Shrimp Fishing Area 4 (SFA 4) were analyzed. This work was done to help determine the potential predation pressure of these fishes on the regions' populations of Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*Pandalus montagui*) in the context of stock assessment for the commercial Northern Shrimp fishery. The results of these analyses found the relative contribution by percent weight (%W) and percent number (%N) of Pandalid prey in comparison to all other taxonomic categories of prey to be highest within the stomachs of Atlantic Cod (n = 27), with %W and %N values of 87.1% and 92.7%, respectively. The %W values were 23.4% and 14.0%, while the %N values were 15.5% and 30.6% for the stomachs of Greenland Halibut (n = 633) and skates (n = 168), respectively. There was no Pandalid prey observed in redfish stomachs (n = 186).

RÉSUMÉ

Polaczek, H., Atchison, S., Deslauriers, D., Skanes, K., Lacasse, O., Roy, V., and Walkusz, W. 2023. Analysis of Atlantic Cod, Greenland Halibut, Redfish, and Skate Stomach Contents from the 2018 NSRF-DFO Summer Shrimp Survey in Hudson Strait, Davis Strait and Labrador Sea. Can. Data. Rep. Fish. Aquat. Sci. 1338: vi + 20 p.

Les contenus stomacaux de morues franches (*Gadus morhua*), de flétans du Groenland (*Reinhardtius hippoglossoides*), de sébastes (espèces non identifiables de la famille *Sebastes*) et de raies (espèces non identifiables de la famille *Rajidae*) prélevés lors du relevé d'été de la crevette effectué en 2018 par la Northern Shrimp Research Foundation (NSRF) et Pêches et Océans Canada (MPO) dans la zone d'évaluation Est (ZEE), la zone d'évaluation Ouest (ZOA) et la zone de pêche à la crevette 4 (ZPC 4), ont été analysés. Ce travail a été effectué pour évaluer la pression de prédation qu'exercent potentiellement ces poissons sur les populations de crevettes nordiques (*Pandalus borealis*) et de crevettes ésope (*Pandalus montagui*) de la région, dans le contexte de l'évaluation des stocks de crevettes nordiques pour la pêche commerciale. Les résultats de ces analyses ont révélé que la proportion relative (soit le pourcentage en poids [%P] et le pourcentage en nombre [%N]) des proies de la famille des pandalidés, par rapport à toutes les autres catégories taxonomiques de proies, était la plus élevée dans les estomacs de morues franches (n = 27), avec des valeurs de %P et de %N de 87,1 % et 92,7 %, respectivement. Les valeurs de %P étaient de 23,4 % et de 14,0 %, tandis que les valeurs de %N étaient de 15,5 % et 30,6 % dans les estomacs de flétans du Groenland (n = 633) et de raies (n = 168), respectivement. Aucune proie de la famille des pandalidés n'a été observée dans les estomacs de sébastes (n = 186).

1.0 INTRODUCTION

Stomach content analysis has been a fundamental tool in the understanding of predator-prey dynamics and the underlying trophic structure of ecosystems (King et al. 2018). The types and quantities of prey found in a predator can be used to make inferences about prey availability and selectivity, predation pressure, and local biomass, as well as a predator's energetic requirements and standing within the trophic system (Hyslop 1980). Variation in these measures can be used as indices for spatial and temporal shifts in predator size or life stage (Young et al. 2015). More recently there has been an emphasis on using stomach content analysis in an ecosystem- and multispecies-based approach for the long-term management of commercial marine fisheries (King et al. 2018). With a more comprehensive understanding of an ecosystem's trophic structure we are able to make better predictions on how changing environmental conditions and fishing mortalities will impact both the ecosystem as a whole and the sustainability status of the fishery (Babcock et al. 2005).

Since the 1970's, Fisheries and Oceans Canada (DFO) has monitored the stock species of the commercial Northern Shrimp fishery: Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*P. montagui*) (DFO 2018). The Northern Shrimp fishery in Canada spans from the Flemish Cap and the northern edge of the Grand Banks to Baffin Bay. Resource status of the two species in the Eastern Assessment Zone (EAZ), Western Assessment zone (WAZ) and Shrimp Fishing Area (SFA) 4 (Figure 1) is assessed regionally based on total abundance, fishable biomass, and spawning biomass indices. These indices are possible due to data provided by fishery-independent surveys conducted by the Northern Shrimp Research Foundation (NSRF) with scientific input from DFO (DFO 2018). The NSRF was formed under the auspices of the Federal Government in 2004 for the purpose of conducting annual Northern and Striped Shrimp stock assessment surveys in the fishery's WAZ, EAZ, and SFA 4.

Pandalus borealis and *P. montagui* co-occur in the same geographical range, with *P. borealis* found in the Northwest Atlantic from Baffin Bay to the Gulf of Maine and *P. montagui* found in Davis Strait southward to the Bay of Fundy (Fisheries and Oceans Canada 2019). Despite their geographical overlap, each species has a preferred depth, temperature range, and substrate (Hudon 1990). While *P. borealis* is found most abundantly in relatively warmer (0–4°C), deeper (300–500 m) water with soft bottom substrates, *P. montagui* tends to be found in cooler (-1–2°C), shallower water (200–500 m) with harder bottom substrates (DFO 2018). *Pandalus borealis* and *P. montagui* are protandrous hermaphrodites, maturing as male then changing sex and spending the rest of their lives as female. Eggs are spawned in late summer and fall and carried by mature females for up to 10 months until they hatch in the spring. The newly hatched shrimp spend 3 to 4 months as pelagic larvae before moving to the ocean floor and transitioning into adult males. Most male shrimp will reach sexual maturity during their second or third year of life, when they will then mate as males for several years before transitioning to mature females. It is thought that both Pandalids live between 6 to 8 years, with shrimp in more Northern areas living longer than those in more Southern regions. Both *P. borealis* and *P. montagui* can grow to a maximum total length of approximately 160 mm, although the average size is about half of this (Bergström 2000). They are considered harvestable once their carapace length exceeds 17 mm, which occurs most often when they are female and approximately 3 years of age (DFO 2018).

In addition to being of commercial significance, *P. borealis* serves as an important prey for several commercially-relevant species, including Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossides*), redfishes (*Sebastes* sp.), and skates (Rajidae) (DFO 2018). A study conducted by Pérez-Rodríguez et al. (2011) found *P. borealis* to be a key prey species at varying life stages among the core fish species on the Flemish Cap. Through stomach content analyses, the authors found that *P. borealis* was an increasingly dominant prey species in the diets of redfishes as they grew, and was also an important prey species for smaller Atlantic Cod and Greenland Halibut. Stomach content analysis of skate stomachs found that *P. borealis* remained a key prey species throughout all size classes (Pérez-Rodríguez et al. 2011). In addition, Pérez-Rodríguez et al. (2011) found a generalized trend towards increasing *P. borealis* predation by these predator species on the Flemish Cap from 1993 to 2008. Dawe et al. (2012) found similar results, noting an increased occurrence of *P. borealis* in the gut contents of Atlantic Cod and Greenland Halibut from the Newfoundland and Labrador shelf and the northern Gulf of St. Lawrence from 1978 to 2008 and 1993 to 2008, respectively. Less is known about the historical predation pressure on *P. borealis* by redfishes due to the tendency of their stomachs to be everted when brought up from depth. A review by Parsons (2005) noted that several studies have found *P. borealis* to be an important prey species of redfishes in the North Atlantic.

While there has been more research done on the predation of *P. borealis* by Atlantic Cod, Greenland Halibut, skates, and to a lesser degree, redfishes, less is known about the predation of these predators on *P. montagui.*

In this report we summarize the stomach content analysis results of Atlantic Cod, Greenland Halibut, redfish, and skate stomachs collected during the 2018 NSRF-DFO summer shrimp survey in the EAZ, WAZ, and SFA 4. The main objective of this work is to help quantify the potential impact these predator species have on the natural mortality of *P. borealis* and *P. montagui* in these three areas.

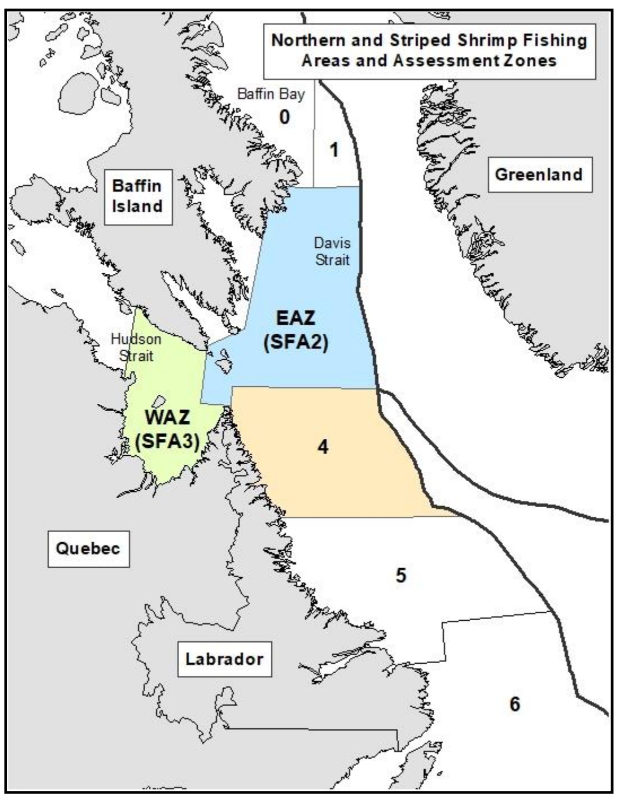

Figure 1. Location of the Northern and Striped Shrimp Fishing Areas (SFAs) 0 – 6, with the Western Assessment Zone (WAZ corresponding roughly to SFA 3) and Eastern Assessment Zone (EAZ corresponding roughly to SFA 2) highlighted in green and blue, respectively. The 2018 NSRF-DFO survey areas are highlighted in blue, green, and orange.

2.0 METHODS

2.1 COLLECTION OF STOMACH SAMPLES

The data presented in this report were obtained from the 2018 NSRF-DFO Northern and Striped Shrimp survey that took place between July 21st and September 4th, 2018 onboard the *f/v Aqviq*. Three assessment areas of the Northern and Striped Shrimp fishery were surveyed: the WAZ, EAZ, and SFA 4 (Figure 2). The WAZ and EAZ, formerly known as SFA 3 and SFA 2, respectively, are under the jurisdiction of DFO's Ontario and Prairie Region, while SFA 4 falls under the jurisdiction of DFO Newfoundland and Labrador Region. The survey was conducted using a stratified buffered random sampling design. Consequently, each assessment area was divided into depth strata as follows: 100–200 m, 200–300 m, 300–400 m, 400–500 m, and 500–750 m. Sampling locations were chosen at random, with the number of locations within a depth stratum being proportional to the area of that depth stratum within the assessment area. Samples were collected during 15 minute tows using a standard Campelen 1800 shrimp trawl (12.8 mm codend mesh) in SFA 4 and Modified Campelen shrimp trawl in the WAZ and EAZ. A more detailed description of the survey can be found in Walkusz and Atchison (2020).

In addition to direct quantification of the target species (*i.e.*, Northern and Striped Shrimp), stomach samples were collected from four predator fishes for diet analysis: Atlantic Cod, Greenland Halibut, redfishes, and skates. Stomach samples were collected from a total of 38 locations within the survey areas (Figure 2). Stations were selected to maximize geographic coverage while considering available human resources for onboard processing. Table 1 outlines the number of stomachs that were sampled within each depth stratum and assessment area. Up to 10 stomachs from each predator taxon per size class and depth stratum were collected from each of the three assessment areas. In the case of redfishes, their stomachs were randomly selected, without selecting for non-everted ones. That suggests there was an unknown proportion of everted stomachs, thus these results should be taken with caution. Size classes were set in 5 cm increments based on total length for all four predators. Following dissection onboard the vessel, stomachs were frozen (-20 °C) and stored for later content analysis.

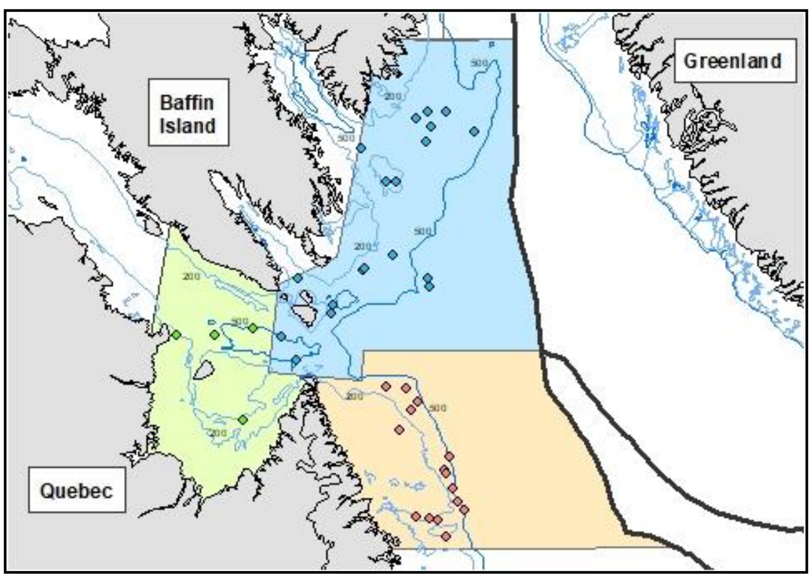

Figure 2. Stomach sampling locations in the Western Assessment Zone (green), Eastern Assessment Zone (blue), and Shrimp Fishing Area 4 (orange) including the 200 and 500 m isobaths.

Table 1. Number of stomach sampling locations within each depth stratum of the Eastern Assessment Zone (EAZ), Western Assessment Zone (WAZ), and Shrimp Fishing Area 4 (SFA 4).

Depth Stratum (m)	Assessment Area		
	EAZ	WAZ	SFA 4
100–200	2	1	1
200–300	7	0	8
300–400	5	1	2
400–500	2	1	2
500–750	3	1	2

2.2 STOMACH CONTENT ANALYSIS

Stomach content analysis followed a modified version of DFO's Quebec Region stomach content analysis protocol (Denis Chabot, DFO, pers. comm.). Once thawed in the laboratory, the weight of the whole stomach, stomach lining, and stomach contents were determined using a fine-point balance (0.001 g). When possible, globules of mucous were separated from prey items. Mucous, if present, was mechanically removed to the best extent and was not included in the weight of either the stomach lining or stomach contents. Contents were identified to the lowest possible taxonomic level that could be achieved with a high degree of certainty. Prey items were identified using a dissecting microscope and through the utilization of an abundance of taxonomic guides and literature, online identification websites (e.g., WoRMS), guidance from in-house experts, as-well-as other Regional expertise. Each identified taxonomic category was then further categorized based on its digestive state. Three stages of digestion were defined: 1 – no-to-minimal signs of digestion, 2 – some signs of digestion but still identifiable, and 3 – highly digested material precluding identification other than by key features (*e.g.,* characteristic body parts such as telson, rostrum). Items of the same digestive stage and taxonomic category were weighed together (0.001 g). The number of individuals within each taxonomic category and digestive stage were recorded, with an 'individual' defined as any specimen that had more than half of its body intact. Specimens that had less than half their body intact were described as 'partial' individuals and not counted towards the number of individuals for a given taxonomic category and digestive stage. The lengths of up to 10 individuals within each taxonomic category and digestive stage were measured using digital calipers (0.01 mm). When available, otoliths were collected from the stomach contents and/or extracted directly from prey fish. Otolith length was measured using digital calipers. Otoliths found within stomach contents (*i.e.,* not extracted from prey) that showed signs of digestion or were from families whose validity of prior otolith identification is less certain (*e.g*., Liparidae) were identified with a high degree of caution. Often what remained following separation of the stomach contents into the different taxonomic categories was highly digested unidentifiable material that was weighed and entered as 'unidentifiable material' under the third stage of digestion. Stomachs that contained a high degree of liquid (likely due to melted ice) had their contents strained and weighed following discard of the filtrate.

2.3 DATA ANALYSIS

Prey items of different taxonomic categories were expressed as percent by weight (%W) and percent by number (%N). The %W indicates the proportionate weight of a specific prey taxa relative to the overall weight of all prey taxa, including unidentified material, found within the stomachs. %N indicates the proportional abundance of individual prey items of a specific prey taxa found within the stomachs relative to the total number of individual prey items found within the stomachs, excluding unidentified material. All three stages of digestion for the weights of each prey taxa and individual prey items were combined and included in the %W and %N calculations, respectively. Contents identified as 'parasitic' (*e.g.,* nematodes) were excluded from both %W and %N calculations.

3.0 RESULTS

3.1 PREDATOR DISTRIBUTION BY ASSESSMENT AREA, LENGTH, AND DEPTH

A total of 1,014 stomachs were dissected from the four target predators; the majority coming from Greenland Halibut (633), followed by redfishes (186), skates (168), and Atlantic Cod (27) (Figure 3). From a geographical perspective, there were 489 stomachs analyzed from the EAZ, 238 from the WAZ, and 287 from SFA 4 (Figure 4). Greenland Halibut accounted for the majority of stomachs from each assessment area, having 308 stomachs from the EAZ, 174 from the WAZ, and 151 from SFA 4 (Figure 4). Atlantic Cod accounted for the least amount of stomachs from each assessment area, having 4 stomachs from the EAZ, 23 from SFA 4, and no stomachs from the WAZ (Figure 4). For redfishes, 100 stomachs were examined from the EAZ, 17 from the WAZ, and 69 from SFA 4; for skates 77 stomachs were examined from the EAZ, 47 from the WAZ, and 44 from SFA 4 (Figure 4).

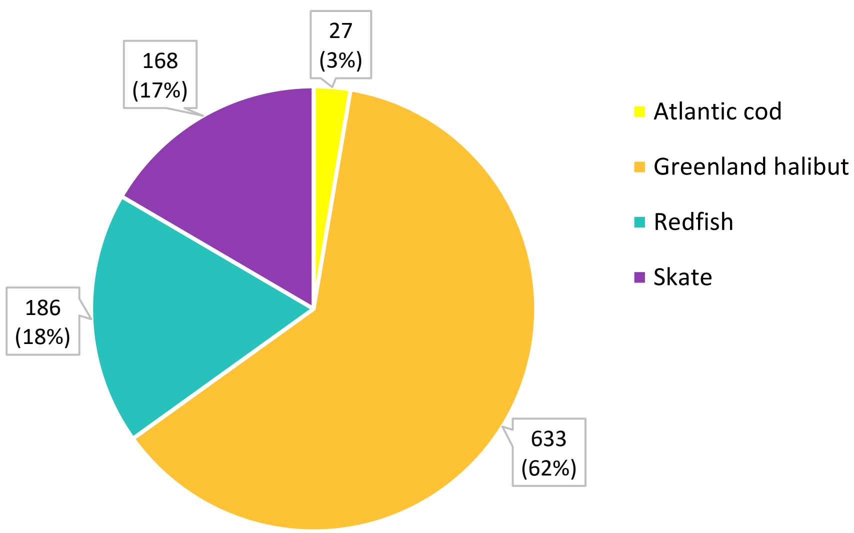

*Figure 3. Proportion of Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossides*), redfish (*Sebastes *sp.), and skate (Rajidae) stomachs analyzed, calculated as a percent total.*

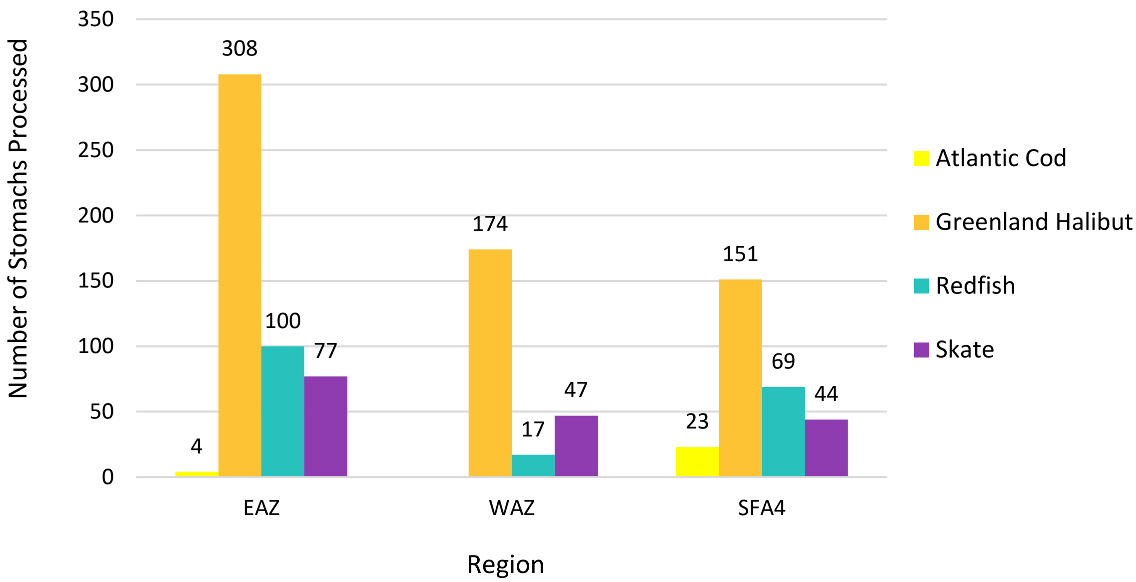

*Figure 4. Number of Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossides*), redfish (*Sebastes *sp.), and skate (Rajidae) stomachs analyzed from the Eastern Assessment Zone (EAZ), the Western Assessment Zone (WAZ), and Shrimp Fishing Area 4 (SFA 4).*

In general, stomach collection was the most comprehensive for Greenland Halibut, with stomachs collected from most depth strata and size classes, while stomach collection was the least comprehensive for Atlantic Cod, with stomachs collected from few depth strata and size classes. Inclusivity of stomach collection for redfishes and skates was between that of Atlantic Cod and Greenland Halibut, with collection skewed to the low-to-mid length ranges. Atlantic Cod stomachs were collected from fish between 31–35 cm to 51–55 cm and from depths between 100–400 m (Figure 5a). Greenland Halibut stomachs were collected from fish ranging from 6–10 cm to 76–80 cm in length and from depths of 100–750 m (Figure 5b). Redfish and skate stomachs were collected from fish between 6–10 cm to 41–45 cm and 6–10 cm to 46–150+ cm, respectively, with redfishes caught at depths of 200–750 m and skates caught at depths of 100–750 m (Figures 5 c,d).

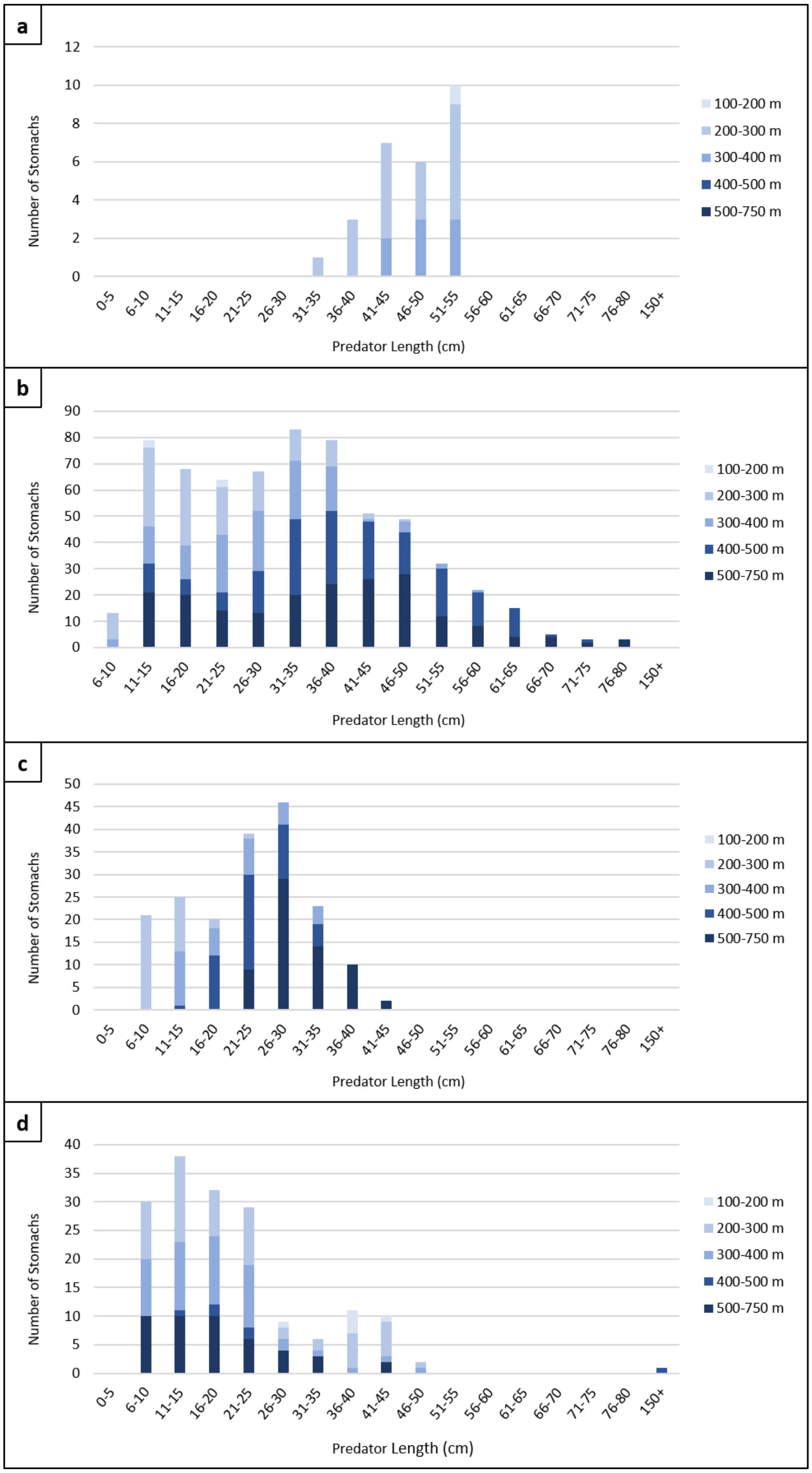

*Figure 5. Number of stomachs sampled from (a) Atlantic Cod (*Gadus morhua*), (b) Greenland Halibut (*Reinhardtius hippoglossides*), (c) redfishes (*Sebastes *sp.), and (d) skates (Rajidae) per size class within each depth stratum. Total length was used to measure all predators.*

3.2 PROPORTION OF FULL VS. EMPTY STOMACHS

The proportion of full versus empty stomachs was different for each predator species. All 27 (100%) Atlantic Cod stomachs contained prey items (Table 2). Of the 633 Greenland Halibut stomachs, 428 stomachs (67.6%) contained prey items and 205 stomachs (32.4%) were empty (Table 2). Of the 186 redfish stomachs analyzed, 103 stomachs (55.4%) contained no prey items and 83 stomachs (44.6%) contained prey items. The majority of the 168 skate stomachs contained prey items: 156 (92.9%) contained prey and 12 (7.1%) were empty (Table 2).

*Table 2. Number of full[1], empty, and total (full and empty) stomachs collected for Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossides*), redfishes (*Sebastes *sp.), and skates (Rajidae) within each size class[2].*

	Atlantic Cod			Greenland Halibut			Redfishes			Skates		
Size Class	Total	Full	Empty	Total	Full	Empty	Total	Full	Empty	Total	Full	Empty
0–5	-	-	-	-	-	-	-	-	-	-	-	-
6–10	-	-	-	13	13	-	21	16	5	30	26	4
11–15	-	-	-	79	62	17	25	13	12	38	35	3
16–20	-	-	-	68	50	18	20	11	9	32	31	1
21–25	-	-	-	64	47	17	39	14	25	29	27	2
26–30	-	-	-	67	45	22	46	17	29	9	8	1
31–35	1	1	-	83	52	31	23	8	15	6	6	-
36–40	3	3	-	79	49	30	10	4	6	11	10	1
41–45	7	7	-	51	29	22	2	-	2	10	10	-
46–50	6	6	-	49	26	23	-	-	-	2	2	-
51–55	10	10	-	32	20	12	-	-	-	-	-	-
56–60	-	-	-	22	17	5	-	-	-	-	-	-
61–65	-	-	-	15	11	4	-	-	-	-	-	-
66–70	-	-	-	5	4	1	-	-	-	-	-	-
71–75	-	-	-	3	2	1	-	-	-	-	-	-
76–80	-	-	-	3	1	2	-	-	-	-	-	-
150+	-	-	-	-	-	-	-	-	-	1	1	-
TOTAL	27	27	0	633	428	205	186	83	103	168	156	12

[1] A full stomach is any stomach that was not empty and contained prey items other than only parasites and/or only mucous.

[2] Total length (cm) was used to measure all predators.

3.3 COMPOSITION OF PREY ITEMS

Excluding unidentifiable material, 10 different taxa of prey were observed in the stomachs of Atlantic Cod (Table 3), 42 in Greenland Halibut (Table 4), 15 in redfishes (Table 5), and 34 in skates (Table 6). Unidentifiable material accounted for 1.2% of all biomass found in the stomachs of Atlantic Cod (Table 3), 5.3% in Greenland Halibut (Table 4), 8.4% in redfishes (Table 5), and 6.0% in skates (Table 6).

3.3.1 Composition of Prey Items by %W

There were 2 taxonomic categories of prey observed in Atlantic Cod stomachs that had %W values greater than 10.0%: *P. borealis* (68.9%) and *Pandalus* sp. (17.1%) (Table 3). The remaining 8 taxonomic categories of prey observed in Atlantic Cod stomachs had %W values less than 5.0% (Table 3).

There were 3 taxonomic categories of prey observed in Greenland Halibut stomachs that had %W values greater than 10.0%: *P. borealis* (15.9%), *R. hippoglossoides* (14.6%), and unidentifiable Pisces (14.4%) (Table 4). There were 5 taxonomic categories of prey that had %W values between 5.0% to 10.0%: unidentifiable Cottidae (sculpins, 6.7%), *Macrourus berglax* (Roughhead Grenadier, 6.4%), unidentifiable Gadidae (5.9%), *P. montagui* (5.4%), and unidentifiable Decapoda (5.3%) (Table 4). The remaining 34 taxonomic categories of prey observed in Greenland Halibut stomachs had %W values less than 5.0% (Table 4).

There were 3 taxonomic categories of prey observed in redfishes that had %W values greater than or equal to 10.0%: unidentifiable Crustacea (30.6%), unidentifiable Pisces (23.8%), and *Boreogadus saida* (Arctic Cod, 10.0%) (Table 5). There were 2 taxonomic categories of prey that had %W values between 5.0% to 10.0%: *Pasiphea multidentata* (8.8%) and unidentifiable Cephalopoda (5.5%) (Table 5). The remaining 10 taxonomic categories of prey observed in redfish stomachs had %W values less than 5.0% (Table 5).

There were 3 taxonomic categories of prey observed in skate stomachs that had %W values greater than 10.0%: unidentifiable Anarchichadidae (wolffishes, 49.3%), *P. borealis* (13.6%), and unidentifiable Pisces (11.4%) (Table 6). The remaining 31 taxonomic categories of prey observed in skate stomachs had %W values less than 5.0% (Table 6).

3.3.2 Composition of Prey Items by %N

There were 2 taxonomic categories of prey observed in Atlantic Cod stomachs that had %N values greater than 10.0%: *P. borealis* (76.4%) and *Pandalus* sp. (19.4%). The remaining 3 taxonomic categories of prey observed in Atlantic Cod stomachs for which %N values were able to be calculated had %N values less than 5.0% (Table 3).

There were 4 taxonomic categories of prey observed in Greenland Halibut stomachs that had %N values greater than or equal to 10.0%: *Themisto* sp. (36.7%), *Boreomysis arctica* (11.9%), *Themisto libellula* (10.9%), and *P. borealis* (10.0%) (Table 4). There were 2 taxonomic categories of prey that had %N values at or between 5.0% to 10.0%: unidentifiable Decapoda (5.8%) and *P. montagui* (5.0%) (Table 4). The remaining 36 taxonomic categories of prey observed in Greenland Halibut stomachs for which %N values were able to be calculated had %N values less than 5.0% (Table 4).

There were 4 taxonomic categories of prey observed in redfish stomachs that had %N values greater than 10.0%: *Calanus hyperboreus* (33.3%), *Pasiphea multidentata* (21.0%), *Themisto* sp. (19.3%), and *Boreomysis arctica* (10.5%) (Table 5). There was 1 taxonomic category of prey that had a %N value between 5.0% to 10.0%: *Themisto libellula* (5.3%) (Table 5). The remaining 5 taxonomic categories of prey observed in redfish stomachs for which %N values were able to be calculated had %N values less than 5.0% (Table 5).

There were 3 taxonomic categories of prey observed in skate stomachs that had %N values greater than 10.0%: *P. borealis* (29.4%), unidentifiable Copepoda (15.3%), and unidentifiable Amphipoda (14.1%) (Table 6). There were 2 taxonomic categories of prey that had a %N value between 5.0% to 10.0%: unidentifiable Crustacea (5.9%) and unidentifiable Mysida (5.9%) (Table 6). The remaining 18 taxonomic categories of prey observed in skate stomachs for which %N values were able to be calculated had %N values less than 5.0% (Table 6).

*Table 3. Relative contribution, expressed as percent by weight (%W) and percent by number (%N), of different prey taxa found in the stomachs of Atlantic Cod (*Gadus morhua*).*

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
ANNELIDA		
Unidentifiable Polychaeta	0.2	-
ARTHROPODA		
Crustacea		
Unidentifiable Crustacea	0.1	-
Amphipoda		
Themisto sp.	< 0.1	-
Decapoda		
Unidentifiable Decapoda	4.0	-
Pandalus borealis	68.9	76.4
Pandalus montagui	1.1	1.4
Pandalus sp.	17.1	19.4
PISCES		
Unidentifiable Pisces	4.2	-
Unidentifiable Gadidae	2.8	1.4
Benthosema glaciale	0.4	1.4
UNIDENTIFIABLE MATERIAL	1.2	-

*Table 4. Relative contribution, expressed as percent by weight (%W) and percent by number (%N), of different prey taxa found in the stomachs of Greenland Halibut (*Reinhardtius hippoglossides*).*

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
ANNELIDA		
Unidentifiable Polychaeta	< 0.1	-
ARTHROPODA		
Unidentifiable Pycnogonida	< 0.1	0.2
Crustacea		
Unidentifiable Crustacea	1.9	0.6
Amphipoda		
Unidentifiable Amphipoda	< 0.1	0.5
Eusirus cuspidatus	< 0.1	0.2
Eusirus holmi	< 0.1	0.3
Themisto libellula	0.2	10.9
Themisto sp.	0.8	36.7
Copepoda		
Calanus hyperboreus	< 0.1	0.2
Decapoda		
Unidentifiable Decapoda	5.3	5.8

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
Argis dentata	< 0.1	0.2
Atlantopandalus propinqvus	1.3	0.8
Pandalus borealis	15.9	10.0
Pandalus montagui	5.4	5.0
Pandalus sp.	2.1	0.5
Pasiphaea multidentata	0.5	2.4
Euphausiacea		
Unidentifiable Euphausiacea	< 0.1	0.3
Thysanoessa sp.	< 0.1	0.3
Mysida		
Unidentifiable Mysida	< 0.1	0.2
Boreomysis arctica	1.3	11.9
Boreomysis sp.	< 0.1	0.2
Boreomysis tridens	< 0.1	0.6
Mysis oculata	< 0.1	0.3
ECHINODERMATA		
Ophiopholis aculeata	< 0.1	0.2
MOLLUSCA		
Unidentifiable Cephalopoda	0.6	0.2
Unidentifiable Decapodiformes	0.8	0.3
Unidentifiable Incirrata	0.1	0.3
PISCES		
Unidentifiable Pisces	14.4	1.9
Cottidae		
Unidentifiable Cottidae	6.7	1.1
Myoxocephalus sp.	0.2	0.2
Gadidae		
Unidentifiable Gadidae	5.9	2.1
Arctogadus glacialis	0.5	0.2
Boreogadus saida	3.7	1.0
Liparidae		
Liparis fabricii	4.7	2.2
Macrouridae		
Macrourus berglax	6.4	0.2
Myctophidae		
Benthosema glaciale	0.1	0.2
Pleuronectidae		
Unidentifiable Pleuronectidae	0.4	0.2
Reinhardtius hippoglossoides	14.6	1.0

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
Stichaeidae		
Lumpenus lampretaeformis	0.2	0.3
Lumpenus sp.	0.4	-
Zoarcidae		
Lycodes sp.	0.1	0.2
PRIAPULIDA		
Unidentifiable Priapulidae	< 0.1	0.2
UNIDENTIFIABLE MATERIAL	5.3	0.3

*Table 5. Relative contribution, expressed as percent by weight (%W) and percent by number (%N), of different prey taxa found in the stomachs of redfish (*Sebastes *sp.).*

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
ARTHROPODA		
Crustacea		
Unidentifiable Crustacea	30.6	-
Amphipoda		
Unidentifiable Amphipoda	0.7	1.7
Anonyx nugax	0.2	-
Themisto libellula	0.1	5.3
Themisto sp.	0.7	19.3
Copepoda		
Calanus hyperboreus	2.6	33.3
Decapoda		
Unidentifiable Decapoda	1.0	-
Pasiphaea multidentata	8.8	21.0
Euphausiacea		
Unidentifiable Euphausiacea	2.9	1.8
Meganyctiphanes norvegica	0.3	1.8
Mysida		
Unidentifiable Mysida	0.3	1.7
Boreomysis arctica	4.0	10.5
ECHINODERMATA		
Ophiopholis aculeata	< 0.1	0.2
MOLLUSCA		
Unidentifiable Cephalopoda	5.5	-
PISCES		
Unidentifiable Pisces	23.8	-
Gadidae		
Boreogadus saida	10.0	3.5

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
UNIDENTIFIABLE MATERIAL	8.4	-

Table 6. Relative contribution, expressed as percent by weight (%W) and percent by number (%N), of different prey taxa found in the stomachs of skates (Rajidae).

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
ANNELIDA		
Unidentifiable Annelida	0.4	-
Polychaeta		
Unidentifiable Polychaeta	2.1	-
ARTHROPODA		
Crustacea		
Unidentifiable Crustacea	3.8	5.9
Amphipoda		
Unidentifiable Amphipoda	0.9	14.1
Ampelisca sp.	0.2	3.5
Anonyx nugax	< 0.1	1.2
Apherusa sp.	< 0.1	-
Cleippides quadricuspis	0.4	1.2
Brachyura		
Unidentifiable Brachyura	0.2	-
Copepoda		
Unidentifiable Copepoda	< 0.1	15.3
Decapoda		
Unidentifiable Decapoda	4.9	3.5
Argis dentate	0.1	-
Pandalus borealis	13.6	29.4
Pandalus montagui	0.1	-
Pandalus sp.	0.3	1.2
Pasiphaea multidentata	0.1	1.2
Euphausiacea		
Unidentifiable Euphausiacea	0.1	1.2
Meganyctiphanes norvegica	< 0.1	1.2
Isopoda		
Unidentifiable Isopoda	< 0.1	2.3
Mysida		
Unidentifiable Mysida	< 0.1	5.9
Boreomysis arctica	0.1	2.3
Mysis oculata	< 0.1	2.3
MOLLUSCA		

Prey/Taxon	Percent by Weight (%W)	Percent by Number (%N)
Unidentifiable Bivalvia	< 0.1	1.2
Unidentifiable Cephalopoda	0.8	1.2
Unidentifiable Mollusca	< 0.1	1.2
NEMERTEA		
Unidentifiable Nemertea	0.8	-
PISCES		
Unidentifiable Pisces	11.4	-
Anarhichadidae		
Unidentifiable Anarchichadidae	49.3	1.2
Cottidae		
Unidentifiable Cottidae	0.1	-
Artediellus sp.	2.3	1.2
Gadidae		
Unidentifiable Gadidae	0.5	1.2
Boreogadus saida	1.9	-
Zoarcidae		
Unidentifiable Zoarcidae	< 0.1	-
PRIAPULIDA		
Unidentifiable Priapulidae	0.2	1.2
UNIDENTIFIABLE MATERIAL	6.0	-

3.4 *Pandalus* as Prey

3.4.1 Relative Proportion of Pandalid Prey by Predator Species

Pandalid prey accounted for 87.1% of all taxonomic categories of prey observed in Atlantic Cod stomachs by %W, with the composition of this Pandalid prey being: *P. borealis* (68.9%), *Pandalus* sp. (17.1%), and *P. montagui* (1.1%) (Figure 6a). Pandalid prey accounted for 23.4% of all taxonomic categories of prey observed in Greenland Halibut stomachs by %W, with the composition of this Pandalid prey being: *P. borealis* (15.9%), *P. montagui* (5.4%), and *Pandalus* sp. (2.1%) (Figure 6a). Pandalid prey accounted for 14.0% of all taxonomic categories of prey observed in skate stomachs by %W, with the composition of this Pandalid prey being: *P. borealis* (13.6%), *Pandalus* sp. (0.3%), and *P. montagui* (0.1%) (Figure 6a).

Pandalid prey accounted for 97.2% of all taxonomic categories of prey observed in Atlantic Cod stomachs by %N, with the composition of this Pandalid prey being: *P. borealis* (76.4%), *Pandalus* sp. (19.4%), and *P. montagui* (1.4%) (Figure 6b). Pandalid prey accounted for 15.5% of all taxonomic categories of prey observed in Greenland Halibut stomachs by %N, with the composition of this Pandalid prey being: *P. borealis* (10.0%), *P. montagui*. (5.0%), and *Pandalus* sp. (0.5%) (Figure 6b). Pandalid prey accounted for 30.6% of all taxonomic categories of prey observed in skate stomachs by %N, with the composition of this Pandalid prey being: *P. borealis* (29.4%) and *Pandalus* sp. (1.2%) (Figure 6b).

There was no Pandalid prey observed in redfish stomachs either by %W or %N (Figure 6a and 6b).

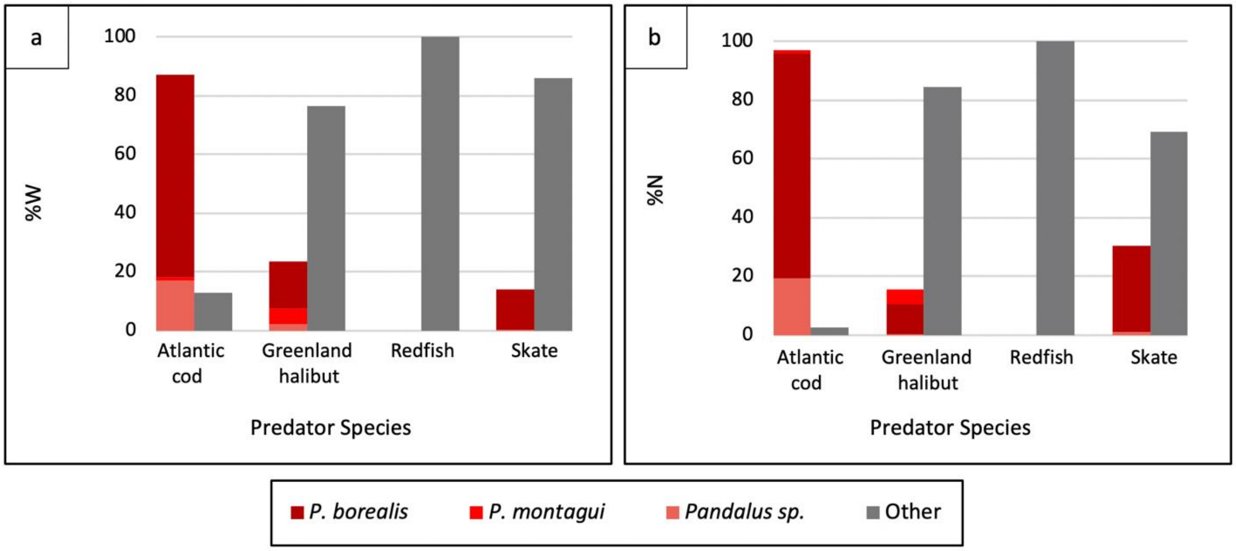

Figure 6. Relative contribution by (a) percent weight (%W) and (b) percent number (%N) of P. borealis*,* P. montagui*, and unidentifiable* Pandalus sp. *within Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossides*), redfish (*Sebastes *sp.), and skate (Rajidae) stomachs in comparison to other taxonomic categories of prey.*

3.4.2 Relative Proportion of Pandalid Prey by Survey Area and Depth

With regards to survey area, predator stomachs from SFA 4, followed by the EAZ and WAZ had the highest overall proportion of Pandalid prey relative to all other taxonomic categories of prey by %W across all depth strata (Figure 7a). With regards to depth, predator stomachs from the 300-400 m depth stratum, followed by the 200-300 m, 100-200 m, 400-500 m, and 500-750 m depth strata had the highest overall proportion of Pandalid prey relative to all other taxonomic categories of prey by %W across all survey areas (Figure 7a). Predators captured between 100-200 m depth had the highest %W values for Pandalid prey in the WAZ (42.2%), followed by SFA 4 (22.3%) (Figure 7a). There was no Pandalid prey observed in predator stomachs by %W from the 100-200 m depth stratum in the EAZ (Figure 7a). Predators captured between 200-300 m depth had the highest %W values for Pandalid prey in the EAZ (56.1%) and SFA 4 (40.9%) (Figure 7a). There was no Pandalid prey observed in predator stomachs by %W from the 200-300 m depth stratum in the WAZ (Figure 7a). Predators captured between 300-400 m depth had the highest %W values for Pandalid prey in SFA 4 (86.6%), followed by the EAZ (44.9%) (Figure 7a). There was no Pandalid prey observed in the predator stomachs by %W from the 300-400 m depth stratum in the WAZ (Figure 7a). Predators captured between 400-500 m depth had the highest %W values for Pandalid prey in the EAZ (24.9%), followed by the WAZ (21.2%) and SFA 4 (3.0%) (Figure 7a). Predators captured between 500-750 m depth had the highest %W values for Pandalid prey in SFA 4 (22.7%), followed by the WAZ (6.6%) and EAZ (5.6%) (Figure 7a).

With regards to survey area, predator stomachs from SFA 4, followed by the EAZ and WAZ had the highest overall proportion of Pandalid prey relative to all other taxonomic categories of prey by %N across all depth strata (Figure 7b). With regards to depth, predator stomachs from the 300–400 m depth stratum, followed by the 400–500 m, 100–200 m, 200–300 m, and 500–750 m depth strata had the highest overall proportion of Pandalid prey relative to all other taxonomic categories of prey by %N across all survey areas (Figure 7b). Predators captured between 100-200 m depth had the highest %N values for Pandalid prey in SFA 4 (66.7%), followed by the WAZ (12.5%) (Figure 7b). There was no Pandalid prey observed in predator stomachs by %N from the 100-200 m depth stratum in the EAZ (Figure 7b). Predators captured between 200-300 m depth had the highest %N values for Pandalid prey in SFA 4 (61.4%) and the EAZ (10.3%) (Figure 7b). There was no Pandalid prey observed in predator stomachs by %N from the 200-300 m depth stratum in the WAZ (Figure 7b). Predators captured between 300-400 m depth had the highest %N values for Pandalid prey in SFA 4 (94.0%), followed by the EAZ (28.9%) (Figure 7b). There were no Pandalid prey observed in the predator stomachs by %N from the 300-400 m depth stratum in the WAZ (Figure 7b). Predators captured between 400-500 m depth had the highest %N values for Pandalid prey in SFA 4 (44.4%), followed by the EAZ (44.2%) and the WAZ (22.0%) (Figure 7b). Predators captured between 500-750 m depth had the highest %N values for Pandalid prey in SFA 4 (25.0%), followed by the EAZ (14.3%) and EAZ (2.1%) (Figure 7b).

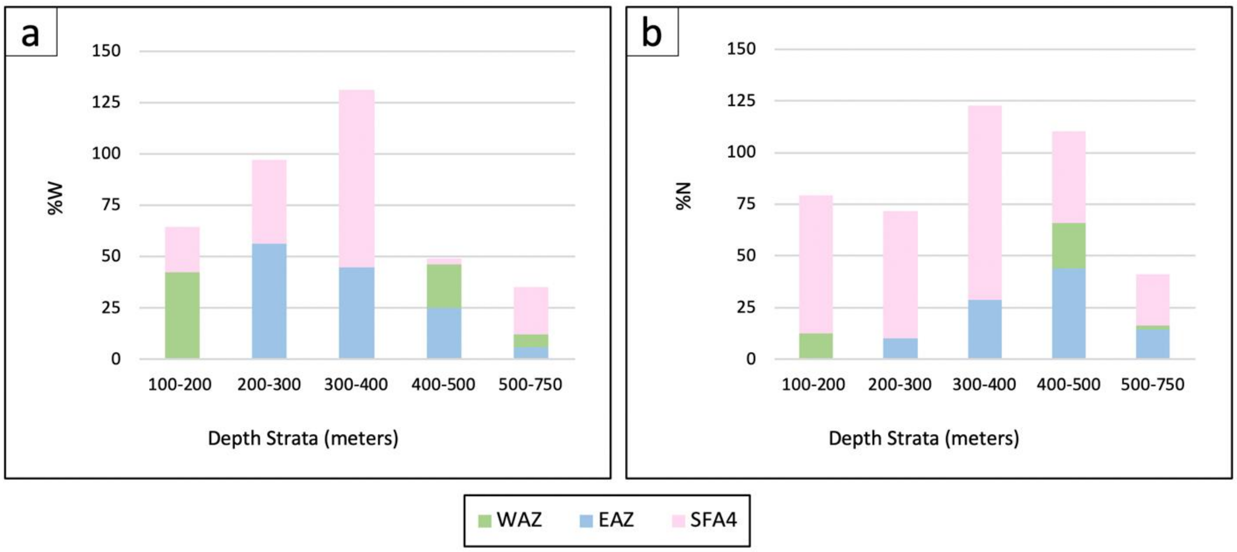

Figure 7. Relative contribution of Pandalus *(*P. borealis, P. montagui*, and unidentifiable* Pandalus *sp.) by (a) weight (%W) and (b) number (%N) found within predator stomachs at each depth stratum within the Eastern Assessment Zone (EAZ), Western Assessment Zone (WAZ), and Shrimp Fishing Area 4 (SFA 4). Data presented as cumulative values for all sampling areas.*

3.4.3 Relative Proportion of Pandalid Prey by Size Class for Atlantic Cod

Pandalid prey was found in all 5 size classes of Atlantic Cod stomachs analyzed by %W (Figure 8a). The %W values for Pandalid prey relative to all other taxonomic categories of prey in Atlantic Cod stomachs by size class were: 31–35 cm (100.0%), 36–40 m (95.3%), 41–45 cm (71.6%), 46–50 cm (89.1%), and 51–55 cm (87.9%) (Figure 8a).

Pandalid prey was found in Atlantic Cod stomachs by %N from predators that ranged from 36–40 cm to 46–55 cm in length (Figure 8b). The %N values for Pandalid prey relative to all other taxonomic categories of prey in Atlantic Cod stomachs by size class were: 36–40 cm (100.0%), 46–50 cm (96.8%), and 51–55 cm (96.7%) (Figure 8b).

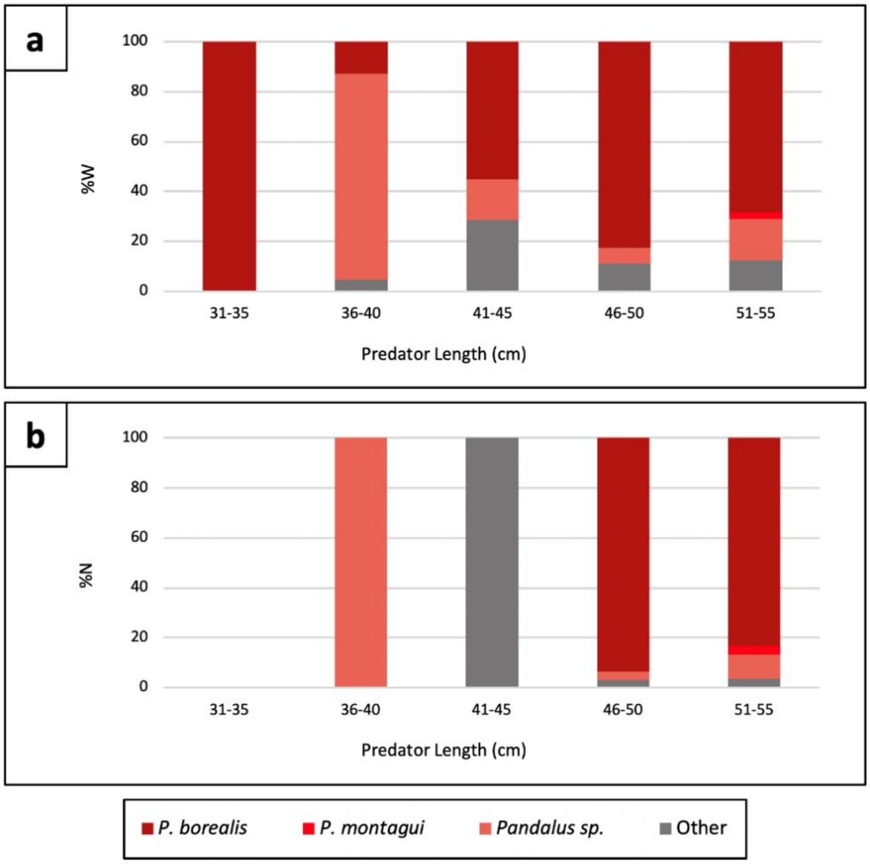

Figure 8. Relative contribution of P. borealis, P. montagui*, and unidentifiable* Pandalus *sp. by (a) weight (%W) and (b) number (%N) found within Atlantic Cod (*Gadus morhua*) stomachs in comparison to other taxonomic categories of prey.*

3.4.4 Relative Proportion of Pandalid Prey by Size Class for Greenland Halibut

Pandalid prey was found in Greenland Halibut stomachs by %W from predators that ranged from 21–25 cm to 66–70 cm in length (Figure 9a). The %W values for Pandalid prey relative to all other taxonomic categories of prey in Greenland Halibut stomachs by size class ranged from 8.3% in the 61–65 cm length class to 45.1% in the 66–70 cm length class (Figure 9a).

Pandalid prey was found in Greenland Halibut stomachs by %N from predators that ranged from 21–25 cm to 66–70 cm in length (Figure 9b). The %W values for Pandalid prey relative to all other taxonomic categories of prey in Greenland Halibut stomachs by size class ranged from 9.5% in the 21–25 cm length class to 60.7% in the 36–40 cm length class (Figure 9b).

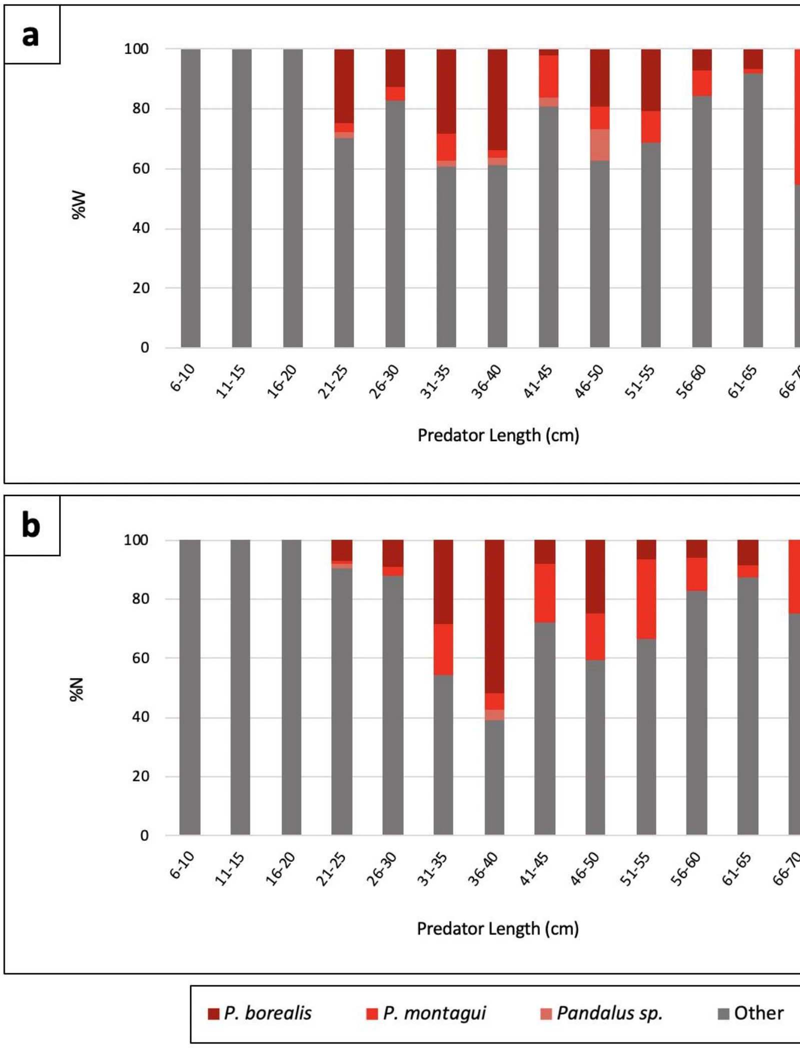

Figure 9. Relative contribution of P. borealis, P. montagui*, and unidentifiable* Pandalus *sp. by (a) weight (%W) and (b) number (%N) found within Greenland Halibut (*Reinhardtius hippoglossides*) stomachs in comparison to other taxonomic categories of prey.*

3.4.5 Relative Proportion of Pandalus Prey by Size Class for Redfishes

There was no Pandalid prey found in the stomachs of redfish by either %W or %N.

3.4.6 Relative Proportion of Pandalid Prey by Size Class for Skates

Pandalid prey was found in skate stomachs by %W from predators that ranged from 16–20 cm to 41–45 cm in length (Figure 10a). The %W values for Pandalid prey relative to all other taxonomic categories of prey in skate stomachs by size class ranged from 3.4% in the 16–20 cm length class to 51.4% in the 36–40 cm length class (Figure 10a).

Pandalid prey was found in skate stomachs by %N from predators that ranged from 21–25 cm to 41–45 cm in length (Figure 10b). The %N values for Pandalid prey relative to all other taxonomic categories of prey in skate stomachs by size class ranged from 13.3% in the 21–25 cm length class to 76.5% in the 36–40 cm length class (Figure 10b).

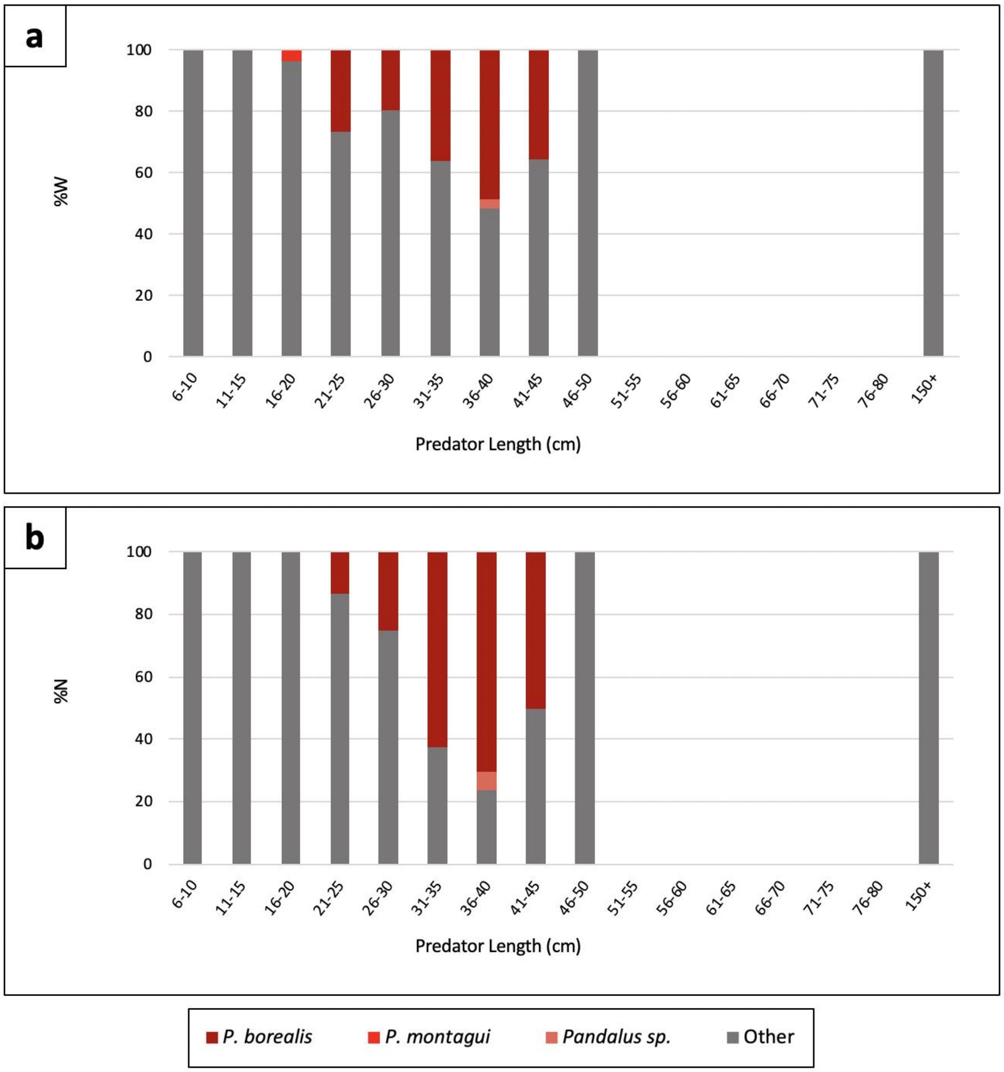

Figure 10. Relative contribution of P. borealis, P. montagui*, and unidentifiable* Pandalus *sp. by (a) weight (%W) and (b) number (%N) found within skate (Rajidae) stomachs in comparison to other taxonomic categories of prey.*

4.0 ACKNOWLEDGEMENTS

The authors would like to thank the NSRF ship crew for their help with sample collection and for accommodating the biologist, Olivia Lacasse, onboard. Funding for this project was secured from Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) grant (Project: Towards understanding predator-prey relationships in the populations of Northern and Striped Shrimp in the economically important fisheries of the Eastern Arctic) for W. Walkusz.

5.0 REFERENCES

Babcock, E., Pikitch, E., Mcallister, M., Apostolaki, P., and Santora, C. 2005. A perspective on the use of spatialized indicators for ecosystem-based fishery management through spatial zoning. ICES J. Mar. Sci. 62(3): 469–476.

Bergström, B. 2000. The biology of *Pandalus*. Adv. Mar. Biol. 38: 55–245.

Dawe, E., Koen-Alonso, M., Chabot, D., Stansbury, D., and Mullowney, D. 2012. Trophic interactions between key predatory fishes and crustaceans: comparison of two Northwest Atlantic systems during a period of ecosystem change. Mar. Ecol. Prog. Ser. 469: 233–248.

DFO. 2018. Integrated Fisheries Management Plan (IFMP): Northern shrimp and striped shrimp – Shrimp fishing areas 0, 1, 4-7, the Eastern and Western Assessment Zones and North Atlantic Fisheries Organization (NAFO) Division 3M. Fisheries and Oceans Canada, Ottawa, ON. 84 p.

DFO. 2019. Assessment of Northern Shrimp, *Pandalus borealis*, and Striped Shrimp, *Pandalus montagui*, in the Eastern and Western Assessment Zones, February 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/011.

Hudon, C. 1990. Distribution of shrimp and fish by-catch assemblages in the Canadian eastern Arctic in relation to water circulation. Can. J. Fish. Aquat. Sci. 47: 1710–1723.

Hyslop, E.J. 1980. Stomach contents analysis-a review of methods and their application. J. Fish Biol. 17(4): 411–429.

King, J., Boldt, J. and King, S. 2018. Proceedings of the Pacific Region workshop on stomach content analyses, February 27-March 1 2018, Nanaimo, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 3274: v + 55 p.

Parsons, D.G. 2005. Predators of northern shrimp, *Pandalus borealis* (Pandalidae), throughout the North Atlantic. Mar. Biol. Res. 1(1): 48–58.

Pérez-Rodríguez, A., Koen-Alonso, M., González-Iglesias, C., Saborido-Rey, F. 2011. Analysis of common trends in the feeding habits of main demersal fish species on the Flemish Cap. NAFO SCR Doc 11/77. 30 p.

Young, J.W., Hunt, B.P., Cook, T.R., Llopiz, J.K., Hazen, E.L., Pethybridge, H.R., Ceccarelli, D., Lorrain, A., Olson, R.J., Allain, V., Menkes, C., Patterson, T., Nicol, S., Lehodey, P., Kloser, R. J., Arrizabalaga, H., and Anela Choy, C. 2015. The trophodynamics of marine top predators: Current knowledge, recent advances and challenges. Deep-Sea Res. Pt II. 113:170–187.

Walkusz, W., and Atchison, S. 2020. Information in support of establishing new Limit Reference Points for Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*Pandalus montagui*) stocks in the Western Assessment Zone and updating the existing Limit Reference Points for the Eastern Assessment Zones. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/072. iv + 26 p.