Atlas of Sponges from the Estuary and Northern Gulf of St. Lawrence Multidisciplinary Trawl Survey in 2006-2017

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2020

Canadian Technical Report of
Fisheries and Aquatic Sciences 3364

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Cat. No. Fs97-6/3364E-PDF ISBN 978-0-660-34207-8 ISSN 1488-5379

Correct citation for this publication:

Nozères C., Faille, G., Coté, G., and Proudfoot, S. 2020. Atlas of Sponges from the Estuary and Northern Gulf of St. Lawrence Multidisciplinary Trawl Survey in 2006-2017. Can. Tech. Rep. Fish. Aquat. Sci. 3364: iv + 53 p.

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ABSTRACT

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This report is intended to provide an update on marine sponges (Phylum Porifera) found in the Lower Estuary and northern Gulf of St. Lawrence. A digital photo catalogue was reviewed for sponge captures collected from multidisciplinary trawl surveys conducted by the Department of Fisheries and Oceans between 2006 and 2017. Photos from 814 trawl sets revealed 16 sponge taxa, with records presented as maps by presence and catch biomass. This review with the photo catalogue also served to correct values for some of the large sponge catches. Recently established sponge marine refuges are characterized here for the first time for the presence and relative abundance of these distinctive sponge taxa sampled in scientific trawl sets.

RÉSUMÉ

Nozères C., Faille, G., Coté, G., and Proudfoot, S. 2020. Atlas of Sponges from the Estuary and Northern Gulf of St. Lawrence Multidisciplinary Trawl Survey in 2006-2017. Can. Tech. Rep. Fish. Aquat. Sci. 3364: iv + 53 p.

Ce rapport vise à fournir une mise à jour sur les éponges marines (Embranchement Porifera) trouvées dans l'estuaire maritime et le nord du golfe du Saint-Laurent. Un catalogue de photos numériques a été examiné pour les captures d'éponges recueillies à partir des relevés multidisciplinaires au chalut effectués par le ministère des Pêches et des Océans entre 2006 et 2017. Les photos de 814 traits de chaluts ont révélé 16 taxons d'éponges, avec des enregistrements présentés sous forme de cartes par présence et capture de biomasse. Cette revue avec le catalogue de photos a également permis de corriger les valeurs de certaines des grosses captures d'éponge. Les refuges marins d'éponges récemment établis sont caractérisés ici pour la première fois pour la présence et l'abondance relative de ces taxons d'éponges distinctifs échantillonnés dans des traits de chalut scientifique.

INTRODUCTION

Sponges (Phylum: Porifera) are a group of animals that has so far been relatively little studied. Currently, 9,189 species of sponges are known worldwide (van Soest et al. 2019), divided into four classes: Calcarea, Hexactinellida, Demospongiae (Bergquist, 1978) and, more recently, Homoscleromorpha (Gazave et al. 2010, 2012, van Soest et al. 2012). Sponges may be slow-growing and long-lived (Klitgaard and Tendal 2004, Leys and Lauzon 1998), which may make them vulnerable to disturbance (Freese 2001, Hogg et al. 2010). Anthropogenic threats may arise from multiple sources, including for example removal or direct damage by bottom-contact fishing gear (DFO 2010), or indirectly, by suspended sediment clogging the sponge canal filtration system (Leys 2013, Tjensvoll et al. 2013).

Sponges play essential ecological roles in the benthic environment. They accommodate a wide variety of organisms, including crustaceans and polychaete worms, both inside their canals and on their surface, in addition to supplying nutritive elements to some animals (Wulff 2006, Buhl-Mortensen et al. 2010, de Goeij et al. 2013, Miller et al. 2012). Sponges also provide shelter or refuge from predators and sponge aggregations may serve as a fish nursery (Scharf et al. 2006, Wulff 2006, Buhl-Mortensen et al. 2010, Marliave et al. 2009, Miller et al. 2012, Freese and Wing 2003, Rooper et al. 2019). In addition, sponges may contribute to bentho-pelagic coupling (Pile et al. 1996, Rützler 2004, Wulff 2006, Maldonado et al. 2016). By feeding on suspended particulate organic matter, sponges represent an important link between the water column and the benthos, relaying nutrients to higher trophic levels through predators (Wulff 2006).

Given the ecological roles of sponges, it is important to carefully manage human activities, such as fisheries, that may affect them. The United Nations Resolution (61/105) of 2006 requires regional fisheries management organizations to develop measures to protect vulnerable marine ecosystems from the negative impacts of fishing gears. This resolution led the Northwest Atlantic Fisheries Organization (NAFO) to undertake work to determine the impact of fisheries on sponges, define vulnerable marine ecosystems including sponge communities, and establish closure areas for bottom-contact gear (NAFO 2016; NAFO 2017).

Following international recommendations, Fisheries and Oceans Canada (DFO) published in 2009 the Management Policy for the Impact of Fishing on Vulnerable Benthic Areas which states that habitats characterized by a predominance of cold-water coral or sponges are important benthic areas (DFO 2009). DFO also developed a variety of management tools, including the Ecological Risk Assessment Framework (ERAF) for cold-water coral and sponge communities (DFO 2013) and the Coral & Sponge Conservation Strategy for Eastern Canada (DFO 2015).

To promote the implementation of the Policy, the ERAF, and the Strategy, in 2016 DFO refined the delineation of significant areas of corals and sponges in the Northwest Atlantic, including the Gulf of St. Lawrence, based on trawl survey data (Kenchington et al. 2016, DFO 2017). In 2016 and 2017, a DFO internal working group used those

significant areas, combined with fisheries data to determine the placement of 11 marine refuges for the conservation of coral and sponges (Coral and Sponge Conservation Measures in the Estuary and Gulf of St. Lawrence). Fisheries closures for all bottom contacting gears were officially put in place for these marine refuges in December 2017 (List of Marine Refuges).

At the time, data refinement only allowed for sponges to be treated at the aggregated level of the phylum (Porifera). In an ecological context, taxonomic resolution to the species level may be important, since lumping taxa into general groupings can lead to errors, for example, in estimating population size and in predicting the response of different body forms to disturbance (Wulff 2012). In addition, species may differ widely in morphology, size and ecological value. In a conservation context, it is useful to have knowledge of the distribution of individual species in order to determine the areas requiring more attention. This report partially fills that knowledge gap for the northern Gulf of St. Lawrence by partially responding to an action requested in the Strategy (DFO 2015) to support the objective of identifying and defining areas of importance for sponges:

> "Develop a list of sponge species of ecological and biological importance and collect and map existing data on the distribution and relative abundance of sponge species" (DFO 2015).

For this purpose, a review of sponge photos and catch records from the multidisciplinary trawl survey of the Estuary and northern Gulf of St. Lawrence was undertaken. The information presented in this Atlas summarizes the results of that review and helps to better characterize the six sponge marine refuges established in 2017.

MATERIALS AND METHODS

NORTHERN GULF SURVEY

A groundfish and shrimp multidisciplinary survey is conducted each summer in the Lower Estuary and northern Gulf of St. Lawrence (Bourdages et al. 2019). It covers NAFO Divisions 4R, 4S and part of 4T with 53 strata in five classes defined mainly by depth, from less than 40 to more than 500 m (blue areas, Figure 1). Since 2008, the coverage of Division 4T has increased in the upstream portion of the Lower Estuary to include shallow strata (851, 852, 854 and 855) ranging from a depth of 37-183 m. Nearshore (0-37 m) and rough bottom areas considered too difficult to trawl, particularly in the easternmost region of Quebec, are excluded (gray areas, Figure 1). The sampling strategy follows a stratified random design. The allocation of the number of stations is proportional to the area of the stratum, with a minimum of two stations for the smallest strata. Each station, or set, is trawled for 15 minutes along the sea bottom. Since 2004, the survey has been conducted with the CCGS *Teleost* using a *Campelen 1800* shrimp trawl net with a mesh size of 44 to 80 mm and a codend mesh of 12.7 mm. Upon completion of a trawl set, the catch is moved onto a conveyor, visually sorted, and recorded in a database. Commercial species are weighed and measured, while the remaining sorted catch is identified to the nearest taxon and weighed.

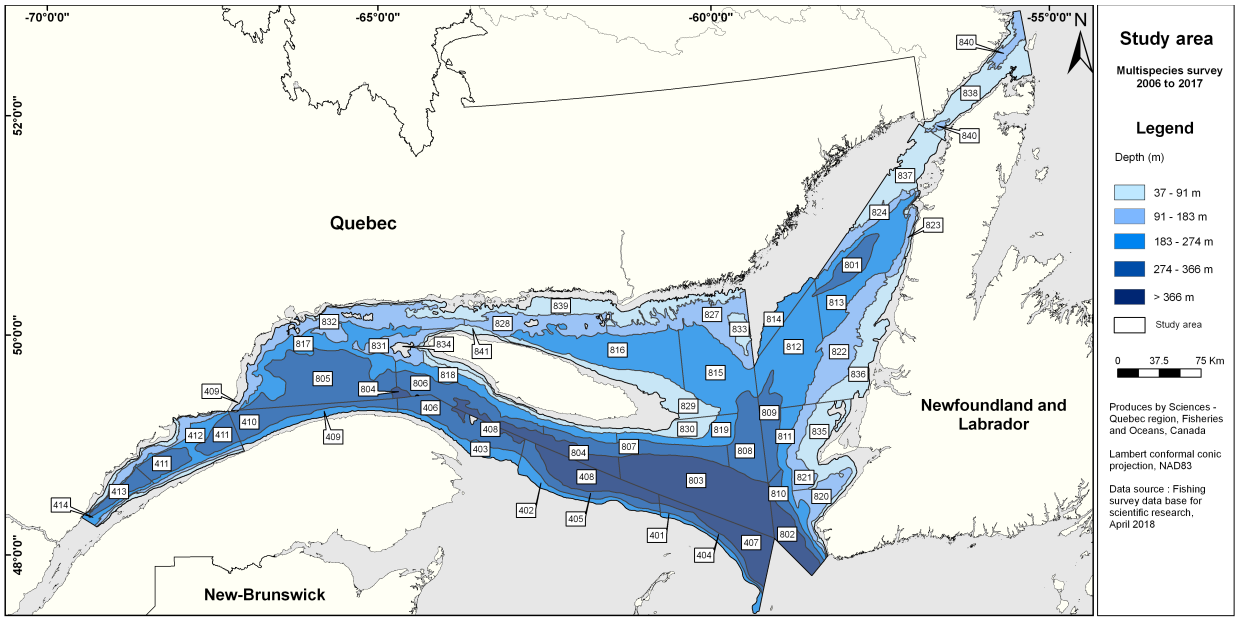


Figure 1. The sampling strata and the five depth classes (blue) of the annual multidisciplinary survey of the Estuary and northern Gulf of St. Lawrence.

BIODIVERSITY

While the sorting and identification of survey catches initially focussed on species of commercial interest, in the last two decades there has been growing interest towards documenting the species in the bycatch. Procedures for identifying invertebrate taxa were improved in the 2000s, beginning with a general species guide (Nozères and Bérubé 2003), an analysis of 2007-2009 invertebrate captures (Lévesque 2009), a shrimp atlas (Savard and Nozères 2012), and a bycatch invertebrate photo catalogue and poster photo folio (Nozères et al. 2014, Nozères and Archambault 2014).

Starting In 2011, additional efforts were undertaken to identify sea pen corals (Pennatulacea) and sponges (Archambault et al. 2012, Nozères et al. 2015, Kenchington et al. 2015, Murillo et al. 2018). Because of the difficulty in quickly identifying individual sponge taxa, catches were often only recorded to the level of Porifera. In some cases, when an identification was made but was in doubt, a specimen was frozen for later laboratory examination. Some samples were identified using spicules in 2016 by Gabrielle Tompkins-MacDonald, Emily Baker, and Javier Murillo (DFO-Maritimes Region), and using spicules and DNA in 2018 by Curtis Dinn (DFO-Gulf Region). All taxonomic names here follow the World Marine Species Registry (WoRMS, http://www.marinespecies.org), while a checklist of sponge taxa for all of the Gulf of St. Lawrence, based on five sources including a catalogue by Brunel et al. (1998), is provided in Appendix A.

PHOTO CATALOGUE

The photo catalogue is a collection of digital photos to document the taxa captured on the trawl sets. It serves to verify the species along with the size, shape, and relative quantity recorded as catches in the survey database. Photographing non-commercial invertebrates was done occasionally for several years and became a standard practice in 2008 (Nozères et al. 2014). The protocol used has varied over the years; it currently consists of taking photos at each station of the sorted capture, as well as of any specimen of particular interest or uncertain identification. A reference label with a printed scale, date, survey and station number, is included in the photo field of view. The image files are stored in a computer to be cataloged, corrected if necessary (exposure, white balance, cropping). In order to be searchable, the photos are tagged with metadata (keywords, survey identifiers, and GPS coordinates) using Adobe Lightroom software. It is the Lightroom database file that serves as the photo catalogue.

IDENTIFICATION OF SPONGES IN THE PHOTO CATALOGUE

The photo catalogue records from 2006 to 2017 were reviewed for the presence of sponges by C. Nozères and G. Côté (Figure 2). Prior to 2006, very few sponges were recorded in either photos or the catch database. With the use of photos from guides for the Atlantic (Kenchington et al. 2015) and Arctic (Dinn and Leys 2018), several of the sponges in the photo catalogue were tentatively identified. The confirmation of species from examined samples was also used to name photos of similar looking sponges. Because sponge identification from photos is generally difficult, only some very distinctive species could be named. In other cases, the species could be named based on existing classification, but the taxonomy is under review and may be subject to changes. For this report, 16 taxa were named in the trawl catches (Table 1).

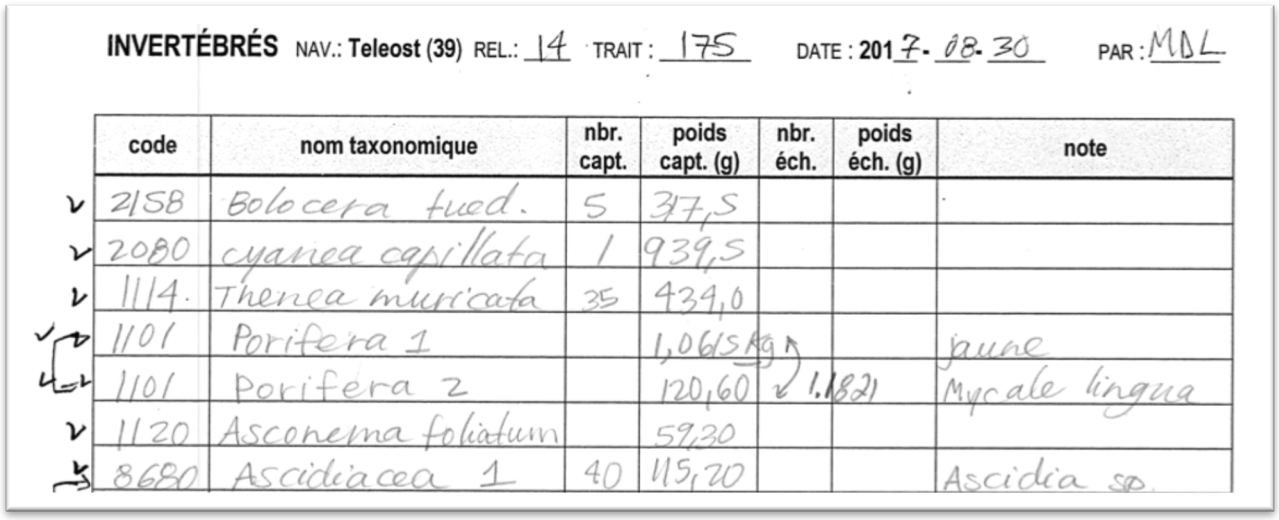
Table 1. List of sponge taxa used in the photo review.

Group	Sponge	Group	Sponge
2.1	Family Polymastiidae (unspecified)	2.5	*Hemigellius arcofer*
2.1.1	*Tentorium semisuberites*	2.6	*Asconema foliatum*
2.1.2	*Polymastia hemisphaerica*	2.7	*Artemisina arcigera*
2.1.3	*Weberella bursa*	2.8	*Craniella polyura*
2.1.4	*Polymastia grimaldii*	2.9	*Semisuberites cribrosa*
2.2	*Mycale* sp.	2.10	*Thenea muricata*
2.3	*Stylocordyla borealis*	2.11	*Cladocroce spatula*
2.4	Order Suberitida	2.12	*Sycon* sp.

Figure 2. Example of a sorted capture of sponges with several taxa present in the photo.

DATABASE RECORDS

Along with indicating the presence of certain sponge taxa, the photo catalogue was also used to update records with biomass. In general, the survey database recorded the sponge captures as Porifera (survey code 1101) at each station and the weight is recorded for the entire catch. Occasionally, sorted captures (by morphotype) were individually weighed and recorded on paper sheets (Figure 3). However, each taxon to be entered in the catch database requires both a survey taxonomic code (Miller and Chabot 2014) and a weight (presence-only cannot be recorded). In cases where sorted sponge types did not have an attributed code, the pooled weight was recorded under Porifera (survey code 1101) in the database. By reviewing the sponge catch from the photos and the paper records, the weight of individual taxa/morphotypes could be specified for certain stations and used along with the catch database to produce maps of biomass distribution by taxa.



INVERTÉBRÉS NAV.: Teleost (39) REL.: 14 TRAIT : 175 DATE : 2017-08-30 PAR : MDL

code	nom taxonomique	nbr. capt.	poids capt. (g)	nbr. éch.	poids éch. (g)	note
2158	Bolocera tued.	5	37,5			
2080	cyanea capillata	1	939,5			
1114	Thenea muricata	35	434,0			
1101	Porifera 1		1,065 kg			jaune
1101	Porifera 2		120,60	1,182		Mycale lingua
1120	Asconema foliatum		59,30			
8680	Ascidiacea 1	40	115,20			Ascidia sp.

Figure 3. Partial view of a bycatch record sheet as used on the survey, with two types of unidentified Porifera (1 and 2) that were weighed individually but summed to be entered under the generic heading Porifera (survey code 1101) in the catch database; these can then be attributed to an individual biomass when subsequently identified in photos.

MAPPING SPONGE TRAWL DATA

The distribution of sponges in the northern Gulf of St. Lawrence was mapped using ArcGIS 9.2 software. Only data collected in trawl tows indicated as successful (without major breakage of gear, acceptable tow duration) are presented. The maps display the presence of sponge taxa, and their biomass when available, as compiled from the database records and updated by analysis of the photo catalogue. However, because not all sponge records from the database could be attributed to a specific taxon, the maps for presence are partial and should be interpreted with caution. For the biomass maps, two different scales were used, as catches of some taxa were much smaller than others, with weights varying from <0.001 kg to 44 kg. For clarity, the trawl sets are presented as stations using the point coordinates at the beginning of each tow at the sea bottom, while the survey area of the Lower Estuary and northern Gulf is hereafter referred to as the northern Gulf.

RESULTS

1. SUMMARY OF SPONGE CATCHES IN 2006-2017 SURVEYS

Presence and Biomass

A total of 2,137 stations were sampled from 2006 to 2017, for an average of 178 stations per year. Sponges were present in 1,393 (65%) of the 2,137 stations, with a generally wide distribution in area and depth (Figure 4). Sponges were collected from 39 to 519 m depth, and most frequently between 50 and 299 m (Table 2). The mean catch biomass by set was 0.9 kg, with a maximum per set of 44 kg, for a total of 1,418 kg over the 12-yr period. Large (e.g., >2 kg) catches occurred mainly around Anticosti Island and off the west coast of Newfoundland to the East, and into the Strait of Belle Isle to the north. Catches were smaller in much of the Laurentian Channel, especially to the southeast near Cabot Strait, with the exception of the Estuary where important catches took place near the western head of the channel.

Table 2. Sponge occurrences in trawl sets by 50 m depth intervals.

Depth interval (m)	Present in set	Total sets	Proportion of sets
0-49*	21	35	0.60
50-99	221	301	0.73
100-149	201	253	0.79
150-199	184	229	0.80
200-249	212	311	0.68
250-299	247	369	0.67
300-349	168	311	0.54
350-399	79	183	0.43
400-449	43	89	0.48
450-499	12	37	0.32
500-549	4	12	0.33
All depths	1392	2130**	0.65

*Shallowest capture was at 39 m depth **Seven sets had no depth data

Database Corrections

The review of catch records with the photo catalogue led to corrections of high biomass values for Porifera at four stations (Figure 5). Two of the stations had the largest captures of sponges in the region (70.9 and 56.3 kg, Table A1.6, Kenchington et al. 2016), but had been recorded with incorrect units (kg instead of g. During a review process to identify significant sponge areas, these stations were initially presented as important, but one area was then trimmed on the basis of distribution modelling and expert judgement (Kenchington et al. 2016). Both areas were later excluded for the delineation of significant areas. However, caution should still be exercised when citing reports or using datasets extracted prior to the present review, conducted in 2018.

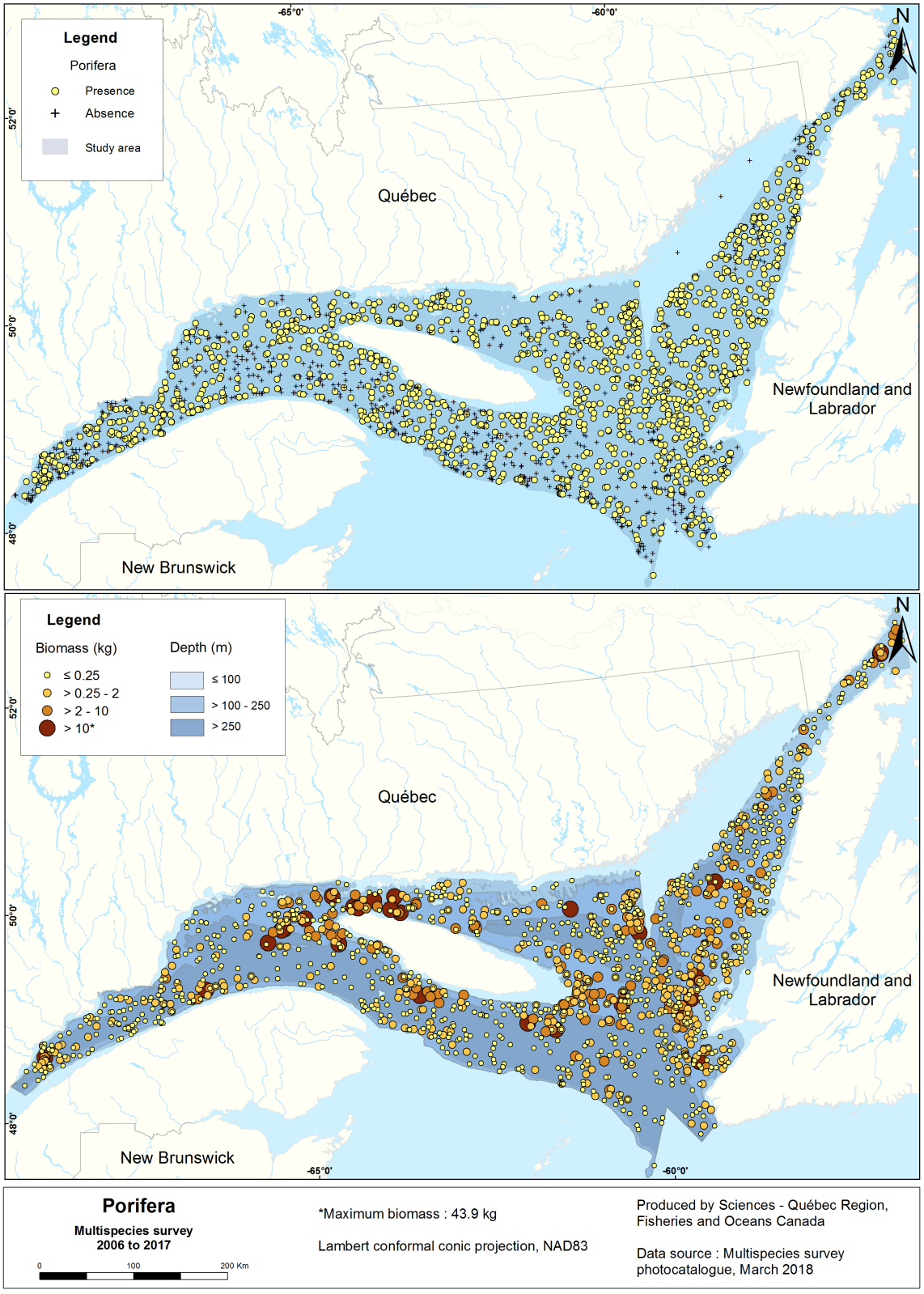


Figure 4. Distribution of sponge catches on the northern Gulf multidisciplinary survey from 2006 to 2017, displayed in stations by presence and absence (top) and by biomass class (bottom).

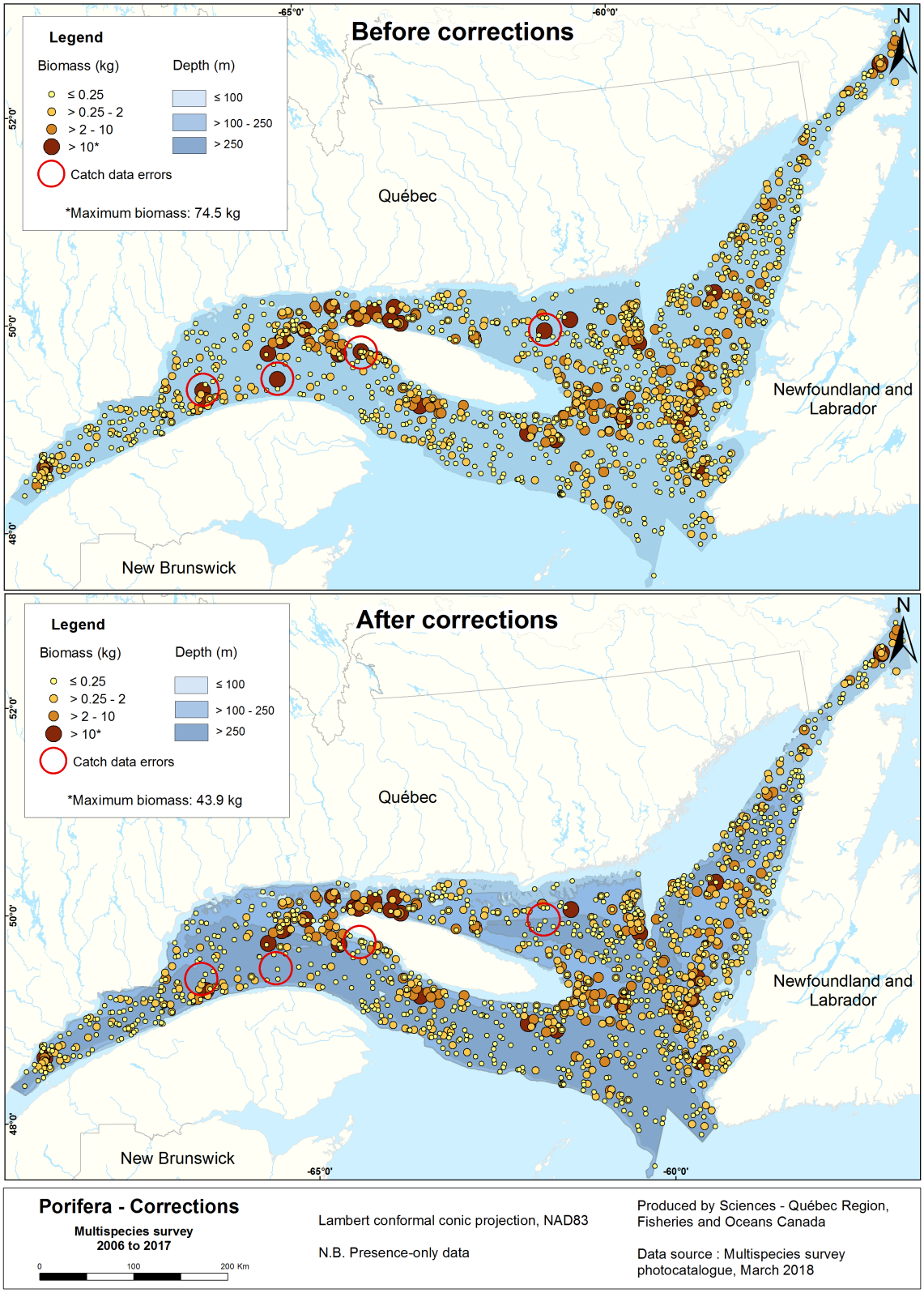


Figure 5. Distribution of sponge catches on the northern Gulf survey from 2006 to 2017, displayed in stations by biomass class in kg, before (top) and after (bottom) data corrections (located within the red circles).

2. PHOTO-IDENTIFIED SPONGE CAPTURES

For nearly 60% of the sponge-positive stations (n=814), photos were available for the review of catches and placement into 16 sponge taxa or morphotypes (Table 3). Frequently seen types were Family Polymastiidae (sum of Group 2.1) with 509 records, *Mycale* sp. with 211 records, and *Stylocordyla borealis* with 188 records (Table 3). When compared to the catch records, *S. borealis* was relatively frequently recorded (136 occurrences in catches, compared with 188 seen in photos), while all other sponges were underreported in the catch by 2 to 16 times when compared to photos.

Table 3. Sponge types sampled during the multidisciplinary survey from 2006 to 2017, listed as identified presence by station (number of occurrences) in the photo catalogue, and the sum of catch occurrences and weights, and mean weights from the database.

Group	Sponge taxa or morphotype	Photo occur. (stns)	Catch occur. (stns)	Sum catch (kg)	Mean catch (kg)
-	Porifera (unspecified)	659	1223	1194	0.98
2.1	Polymastiidae (unspecified)	250	52	2.44	0.05
2.1.1	*Polymastia hemisphaerica*	98	22	0.53	0.02
2.1.2	*Polymastia grimaldii*	28	9	0.70	0.08
2.1.3	*Tentorium semisuberites*	102	26	0.69	0.03
2.1.4	*Weberella bursa*	31	2	0.81	0.40
2.2	*Mycale* sp.	211	34	8.84	0.26
2.3	*Stylocordyla borealis*	188	136	0.25	0.002
2.4	Suberitida	101	29	52.47	1.81
2.5	*Hemigellius arcofer*	86	26	77.08	2.96
2.6	*Asconema foliatum*	74	33	81.80	2.48
2.7	*Artemisina arcigera*	66	15	0.74	0.05
2.8	*Craniella polyura*	55	6	0.11	0.02
2.9	*Semisuberites cribrosa*	39	7	1.68	0.24
2.1	*Thenea muricata*	31	5	1.55	0.31
2.11	*Cladocroce spatula*	16	2	0.24	0.12
2.12	*Sycon* sp.	17	8	0.04	0.005

The following sections present a general summary and distribution maps of photo-identified presence (occurrence) and biomass (catch weight) for each of the sponge taxa (Table 3), with the exception of polymastiids which are all treated together as Polymastiidae (Group 2.1).

2.1. Family Polymastiidae

This family includes 15 genera and approximately 122 species worldwide (van Soest et al. 2018). The genus *Polymastia* includes more than 70 species (Plotkin et al. 2018) which are encrusting, spherical, hemispherical or cushion-shaped, and with papillae (Figure 6). Nine species have been identified in the Gulf of St. Lawrence as of 2017 (Appendix A) from multiple sources. Following this review, the genus, *Sphaerotylus* has also been confirmed for the region (Dinn et al. 2020, in press). Four polymastiid taxa (*Tentorium semisuberites, Polymastia hemispherica*, *Weberella bursa, Polymastia grimaldii*) were identified from the photo catalogue and are shown in the next section.

Figure 6. Examples of sponges of the Family Polymastiidae not identified to species, possibly including specimens of S*phaerotylus* sp.

Distribution of the family Polymastiidae in the northern Gulf of St. Lawrence

Polymastiid specimens were collected at a wide range of depths and locations in the survey area, although captures in the Estuary were mostly at depths >250 m (Figure 7). Despite occurring frequently in photos, only five records had >0.15 kg biomass.

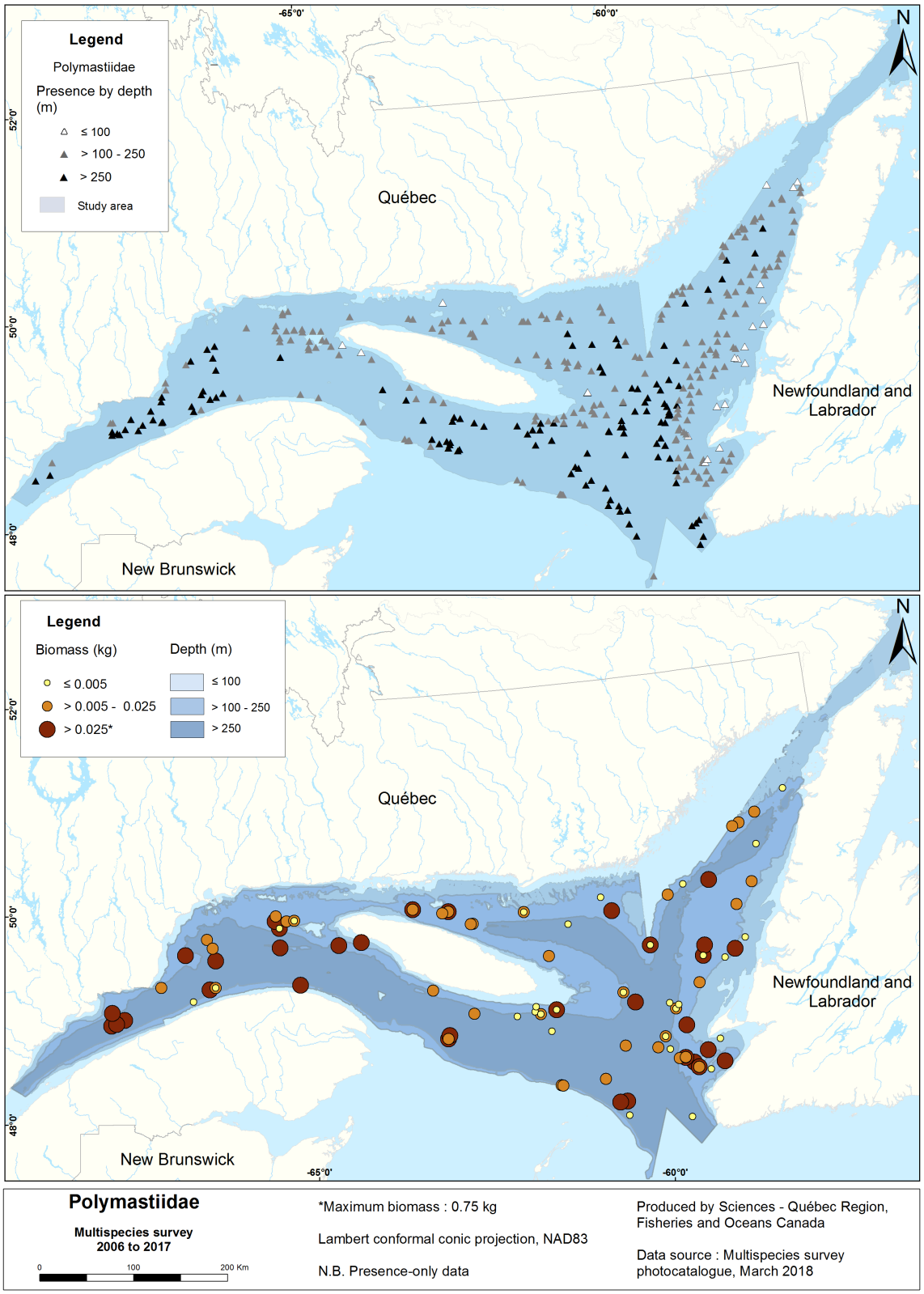


Figure 7. Distribution of sponges of the family Polymastiidae in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.1.1. Polymastia hemisphaerica (synonym: *Radiella hemisphaerica*)

This sponge has a flattened discoid or semi-hemisphaerical form, usually less than 8 cm in diameter, with a convex upper surface studded with a few papillae 1-5 mm high (Figure 8). Specimens are pale yellow brown with a darker fringe. This small sponge is generally found in deep waters (141-850 m) (Plotkin et al. 2018). It has been recorded in the Gulf of St. Lawrence (Whiteaves 1874, 1901; Lambe 1896), off of Newfoundland (Murillo et al. 2016), and elsewhere in the North Atlantic (Plotkin et al. 2018). In the northern Gulf of St. Lawrence survey, this sponge was caught from 200-443 m depth. It is similar to and may be confused with small specimens of another deepwater species with a flattened spherical shape, *P. grimaldii* (see below).

Figure 8. Examples of the sponge *Polymastia hemisphaerica.*

2.1.2. Polymastia grimaldii

This species has a flatttened discoid shape, and can be fairly large, up to 16 cm in diameter (Figure 9). The upper surface is hispid, greyish with long papillae (Boury-Esnault and Bezac, 2007, Plotkin et al. 2018). At the edge of the upper and lower surface, long filaments of spicules act as a fringe, that allows the specimen to remain atop the sediment (Boury-Esnault and Bezac, 2007, Plotkin et al. 2018). This species has been collected at depths of 23-1630 m, near Newfoundland and in the Arctic Ocean (Plotkin et al. 2018). On the northern Gulf survey, most captures were made near 300 m depth.

Figure 9. Examples of the sponge *Polymastia grimaldii.*

2.1.3. Tentorium semisuberites

This polymastiid species has a columnar shape with a semi-spherical or globular upper part (Figure 10). Specimens are usually 1 to 3 cm high and 0.5 to 1.5 cm in diameter, with 1 to 3 oscules present on the small papillae of the upper surface (Boury-Esnault, 2002). While specimens are now frequently seen in the survey, their small size and unusual form may have cause them to be recorded as unknown or ignored as debris, especially in the early years of the survey. This species was found most often at relatively shallow depths of 100-200 m.

Figure 10. Examples of the sponge *Tentorium semisuberites*.

2.1.4. Weberella bursa

This species is generally large-sized (>10 cm), yellow in colour, and has a smooth, globular form (Figure 11). The upper surface has many exhalant papillae, 2 to 8 mm high and generally 8 mm wide at the base and 2 mm at the top (Plotkin et al. 2018). The species has been recorded near the east coast of Canada, in the Barents Sea and off the coast of Norway (Plotkin et al. 2018). Similar to *Tentorium semisuberites*, this species was collected at relatively shallow depths, most often near 150 m. It is similar in appearance to *Sphaerotylus capitatus* (Dinn et al. 2020, in press.) and records may need to be re-examined to distinguish between these two species.

Figure 11. Examples of two large specimens of *Weberella bursa* (labelled) mixed with smaller fragments of unidentified sponge species.

2.2. *Mycale* sp.

This genus includes approximately 200 species (van Soest and Hajdu, 2002). While *Mycale lingua* is the only species thus far confirmed in the region, some specimens have been reported as differing and are recorded as *Mycale* sp. (Dinn et al. 2020, in press). While awaiting further confirmation, all *Mycale* sponges are presented here at the genus level (Figure 12).

Sponges of the genus are widely distributed in northern seas (Stone et al. 2011). They have been found at depths ranging from 30 to 2460 m (van Soest and Hajdu, 2002). While only seen here as fragments from trawl captures, when intact, the species *M. lingua* can form large colonies up to 30 cm in diameter (Dinn and Leys 2018).

Figure 12. Example fragments of the sponge *Mycale* sp.

Distribution of *Mycale* sp. in the northern Gulf of St. Lawrence

This sponge was among the most frequent observed in photos, either as traces or in larger amounts (Figure 13). Numerous captures took place in or near the Anticosti and Esquiman Channels, while only a few were in the Laurentian Channel. The average depth of the catches was 239 m, but specimens were also collected at depths less than 100 and greater than 250 m. The largest capture weighed 1.86 kg.

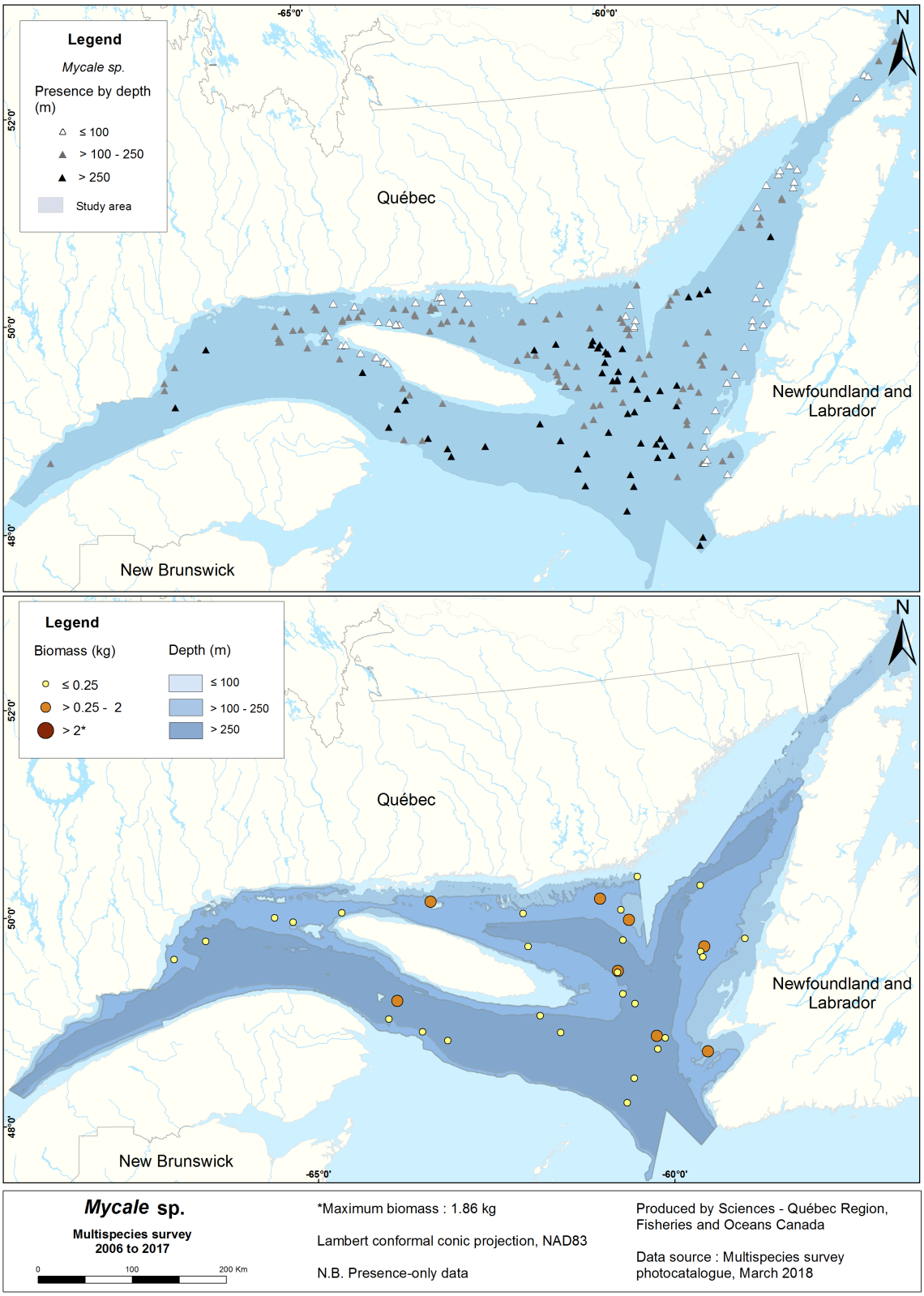


Figure 13. Distribution of sponges of *Mycale* sp. in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.3. *Stylocordyla borealis*

This small sponge is composed of a very thin rod, or stalk, rooted in the sediment and topped by an oval body (van Soest 2002a) (Figure 14). The body can sometimes be lost but may grow back again from the peduncle (Kaandorp 1999).

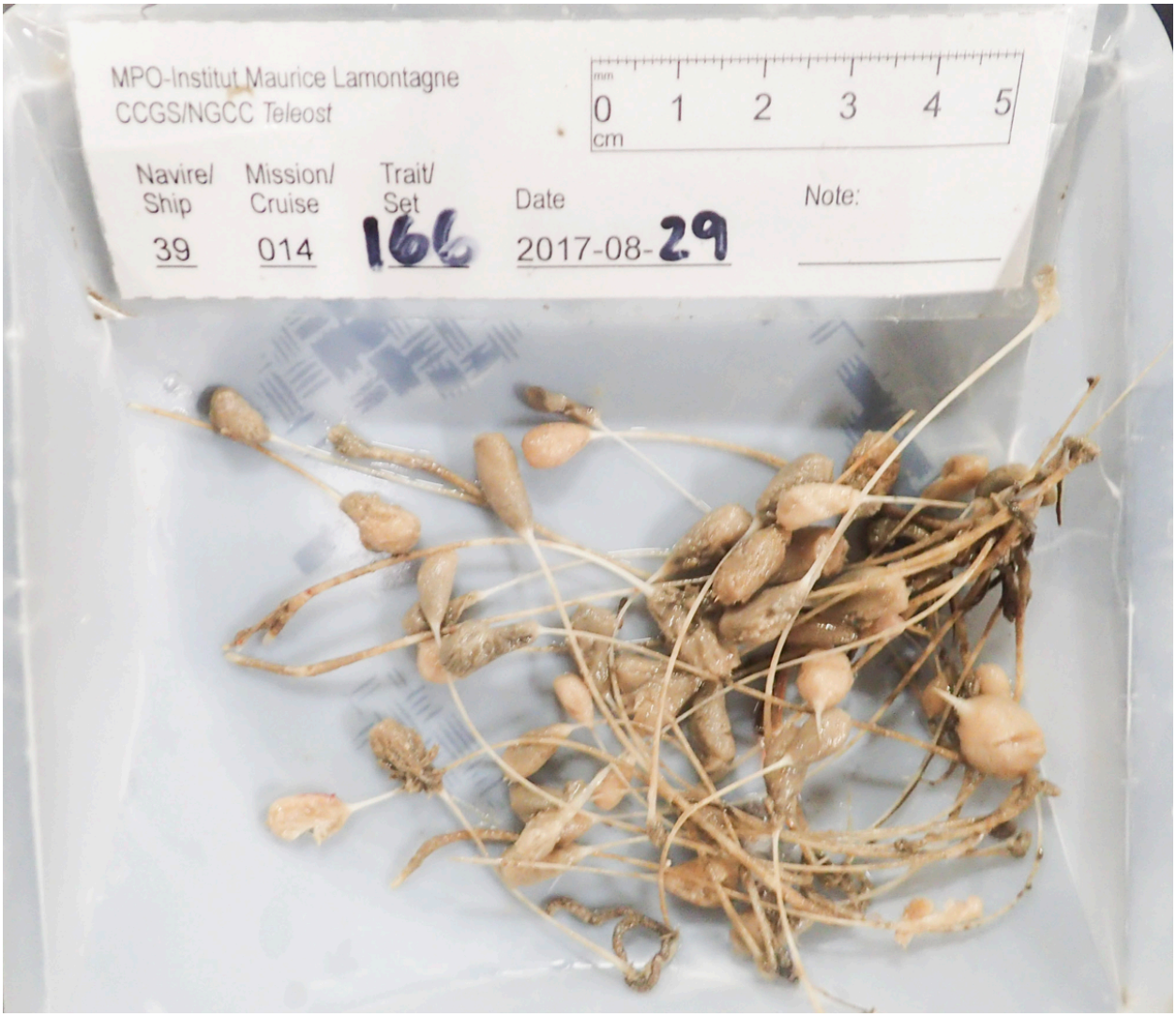


Figure 14. Examples of the sponge *Stylocordyla borealis*.

Distribution of *Stylocordyla borealis* in the northern Gulf of St. Lawrence

Most of the catches occurred in the channels, but not in the Estuary, and at depths greater than 250 m, although some catches were also recorded at less than 100 m (Figure 15). Captures may be comprised of large numbers of individual colonies, but with very low biomass, usually only a few grams.

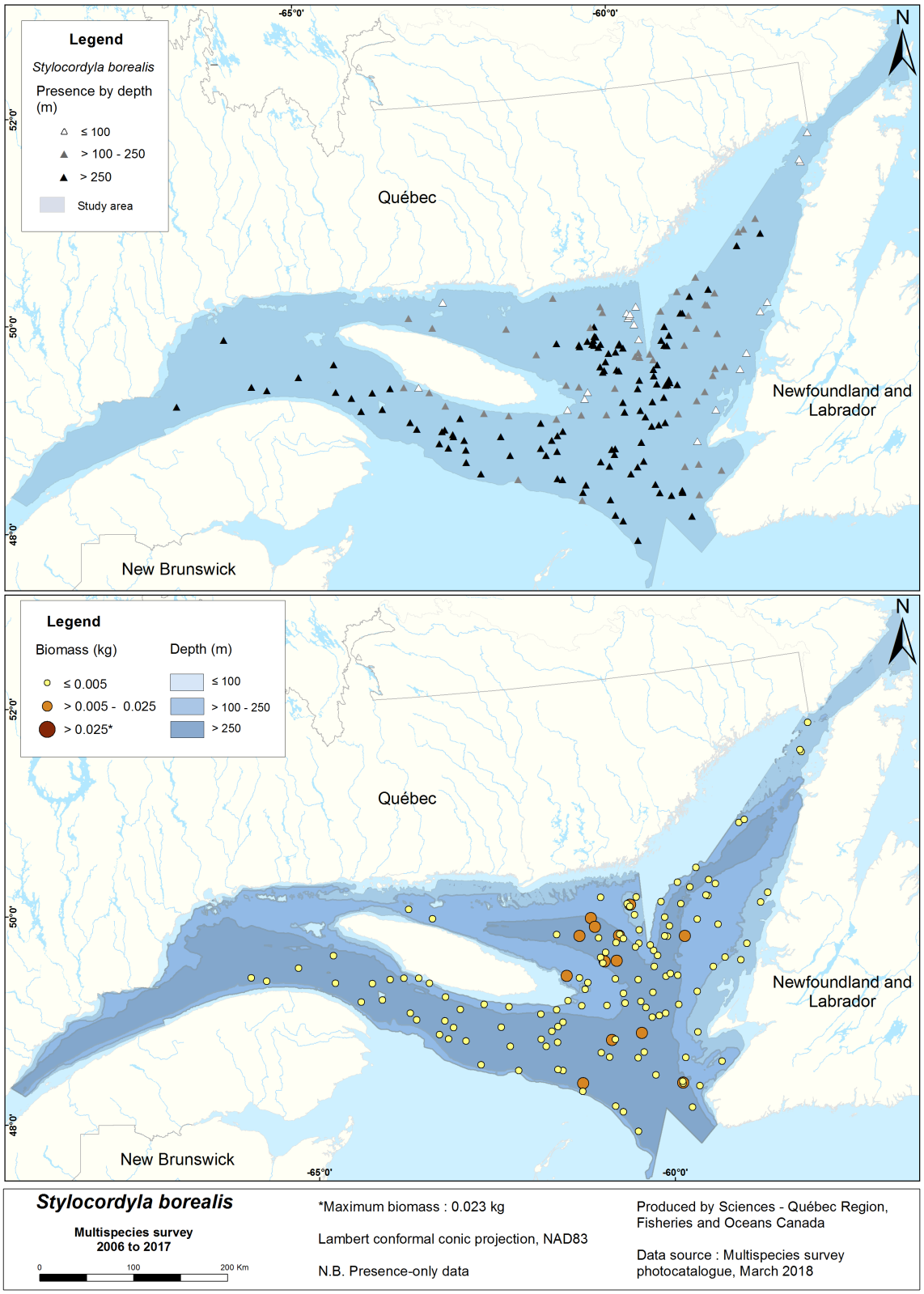


Figure 15. Distribution of sponges of *Stylocordyla borealis* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.4. Suberitida

The sponges of this order are compact and highly variable in form, being spherical, lobed or elongated (Figure 16). They also generally have a velvety texture due to the vertical position of their tylostyles (spicules with a swollen and rounded base) (van Soest 2002b). Several unknown species may be present, along with *Suberites ficus* (Dinn et al. 2020, in press). This large species has sizes between 10 and 40 cm in diameter (van Soest et al. 2000). This sponge is generally found in the circalittoral zone, attached to stones, pebbles or empty shells.

Figure 16. Example of a small Suberitida sponge fixed to a stone.

Distribution of Suberitida sponges in the northern Gulf of St. Lawrence

Important captures of this sponge took place in the western part of the study area, especially in the Estuary (Figure 17). Catches were often at depths greater than 250 m, but there were also captures at less than 100 m (Figure 17). Biomass catches of these sponges were among the largest, ranging from less than 1 to 28 kg by station.

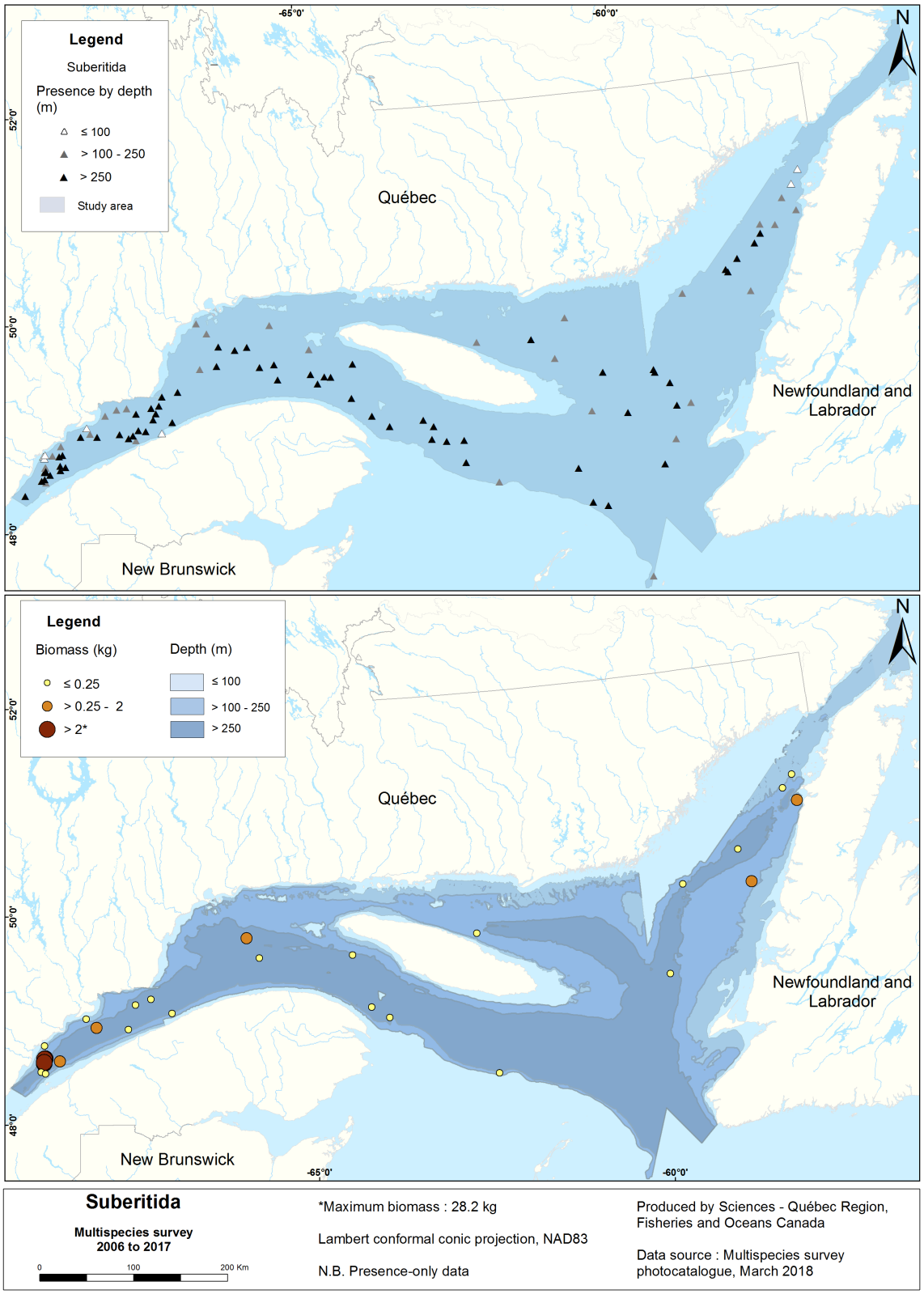


Figure 17. Distribution of Suberitida sponges in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.5. *Hemigellius arcofer*

This sponge has a fan shape and a highly fibrous texture (Weerdt and van Soest 1987). Many circular or oval holes of 1 to 4 mm may be present. The species may be greyish or yellowish and is found at depths greater than 70 m firmly attached to rocks. While the maximum size of colonies is not known, fragments >30 cm have been collected in the trawl (Figure 18). It has been found in the Gulf of St. Lawrence, near Baffin Island, near Greenland, between Iceland and the Faroe Islands, near Norway, Svalbard, and in the Barents and Kara seas (Weerdt and van Soest 1987).

Figure 18. Example of a piece of the sponge *Hemigellius arcofer.*

Distribution of *Hemigellius arcofer* in the northern Gulf of St. Lawrence

Fragments were collected between 50-350 m depth, with most found near 100 m depth (Figure 19). Most specimens were collected around Anticosti Island, Beaugé Bank (North Shore), and along the west coast of Newfoundland. Some of the heaviest identified catches were for this sponge, with several records over 2 kg, and a capture of 23.23 kg revealed in photos.

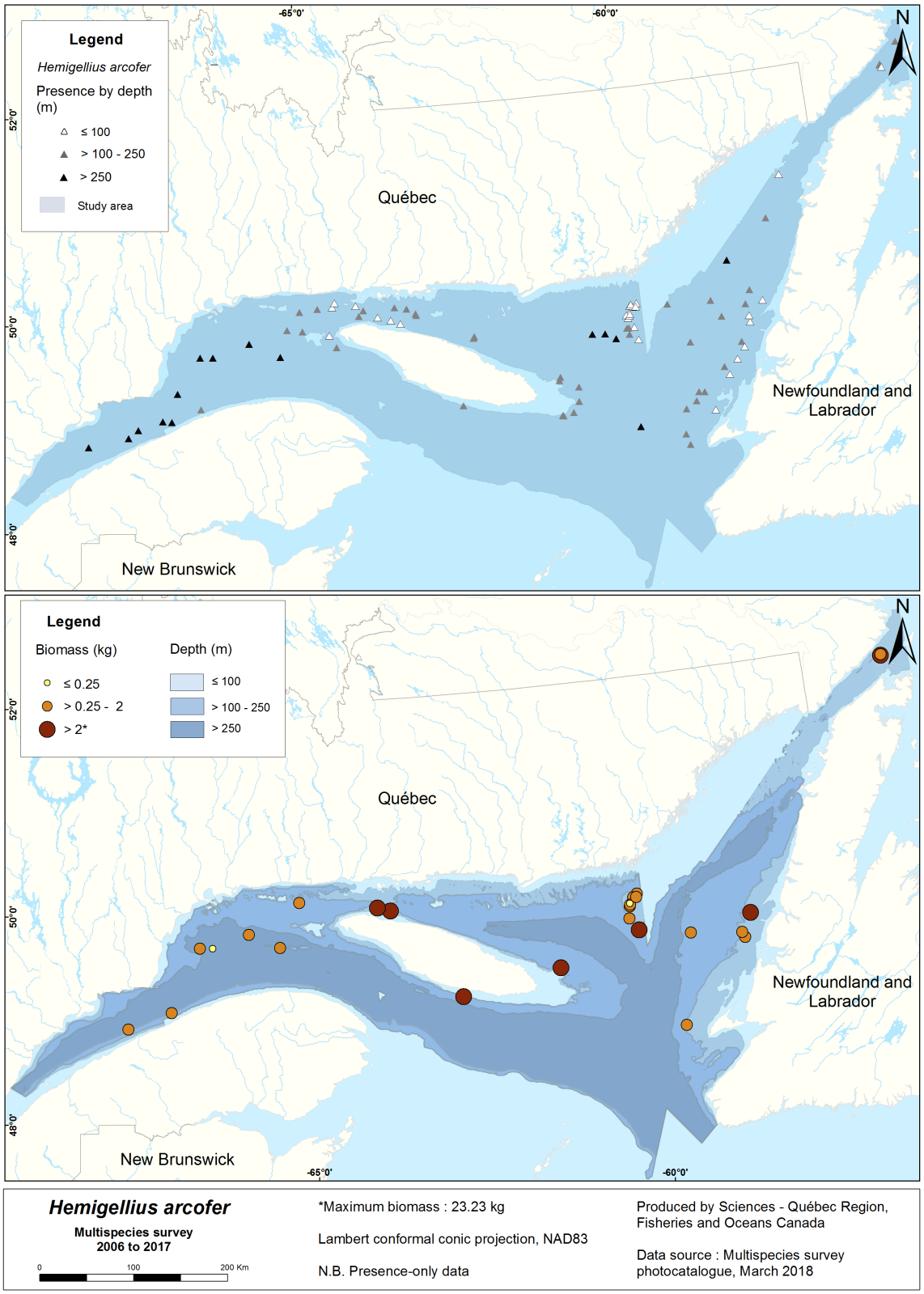


Figure 19. Distribution of the sponge *Hemigellius arcofer* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.6. *Asconema foliatum*

The only hexactinellid (glass) sponge found in the survey (Figure 20), this species is comprised of a skeleton of glass fibers in thin sheets (1 to 2 mm thick) that form fused tubes when intact (Casabonnet and Aish, 2013). This species is white or gray in color and may reach large sizes (>30 cm). It is usually found on gravel or rocky outcrops (Casabonnet and Aish 2013).

Figure 20. Example of the sponge *Asconema foliatum.*

Distribution of *Asconema foliatum* in the northern Gulf of St. Lawrence

The majority of the specimens were caught at more than 250 m depth, at or close to the junction of the Laurentian and Esquiman channels (Figure 21). Several large catches of 2 to 15.6 kg were recorded at depths of more than 250 m.

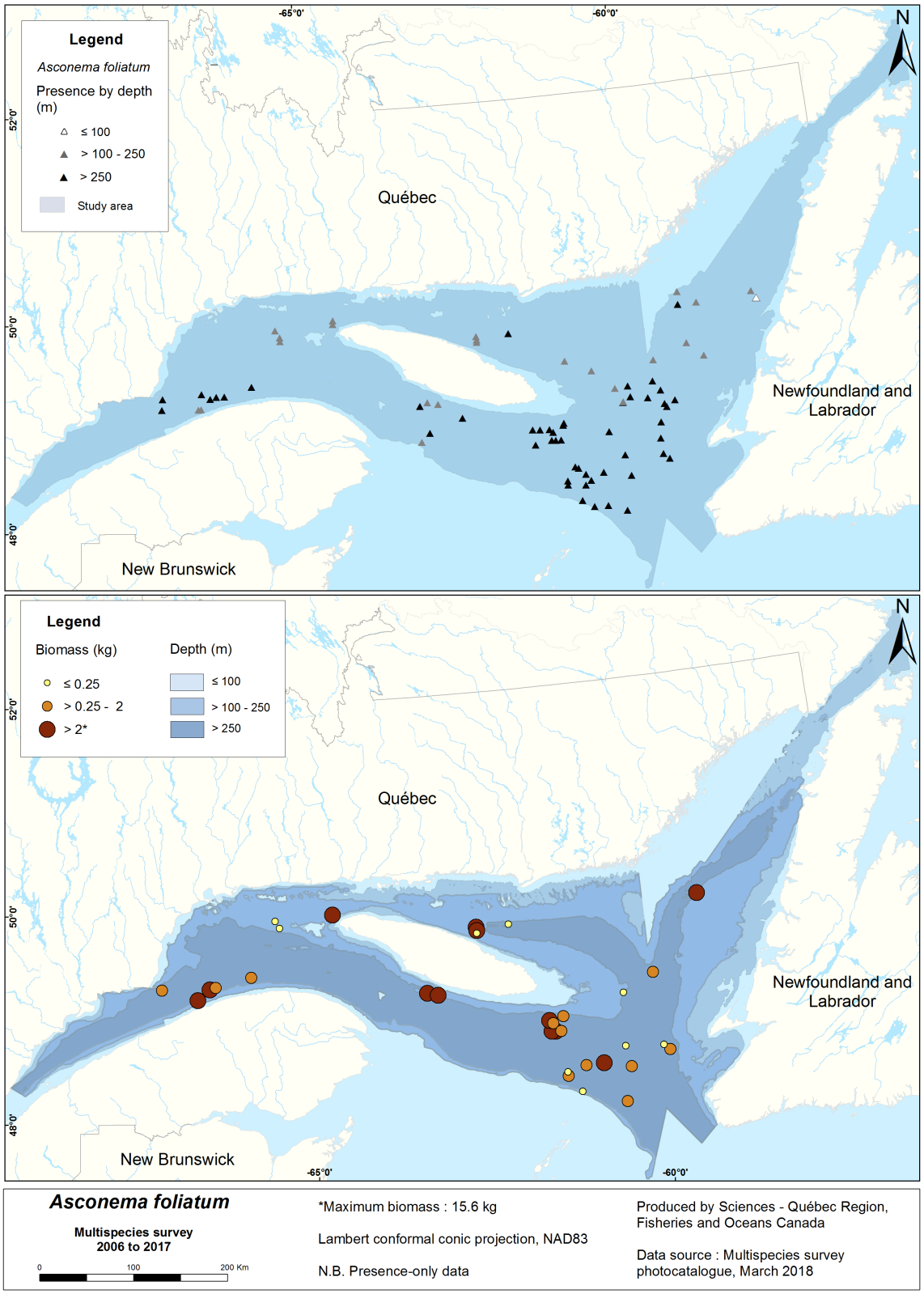


Figure 21. Distribution of the sponge *Asconema foliatum* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.7. *Artemisina arcigera*

This small sponge has an oblong, globular or cushion shape (Figure 22). It is an encrusting sponge that binds to hard substrates like pebbles or shells (Lundbeck, 1905). It has been found at depth of 80 to 800 m near Greenland, Iceland, Norway, Spitzbergen, and Nova Scotia (Lundbeck, 1905).

Figure 22. Examples of the sponge *Artemisina arcigera*

Distribution of *Artemisina arcigera* in the northern Gulf of St. Lawrence

Some specimens were collected all across the northern Gulf of St. Lawrence except in the Estuary (Figure 23). Several of these catches were located west of Anticosti Island, or in the Esquiman Channel, mainly between 100 and 250 m depth. Catches were often of low biomass and numbers, with the exception of a larger sample in 2017 which weighed 0.29 kg.

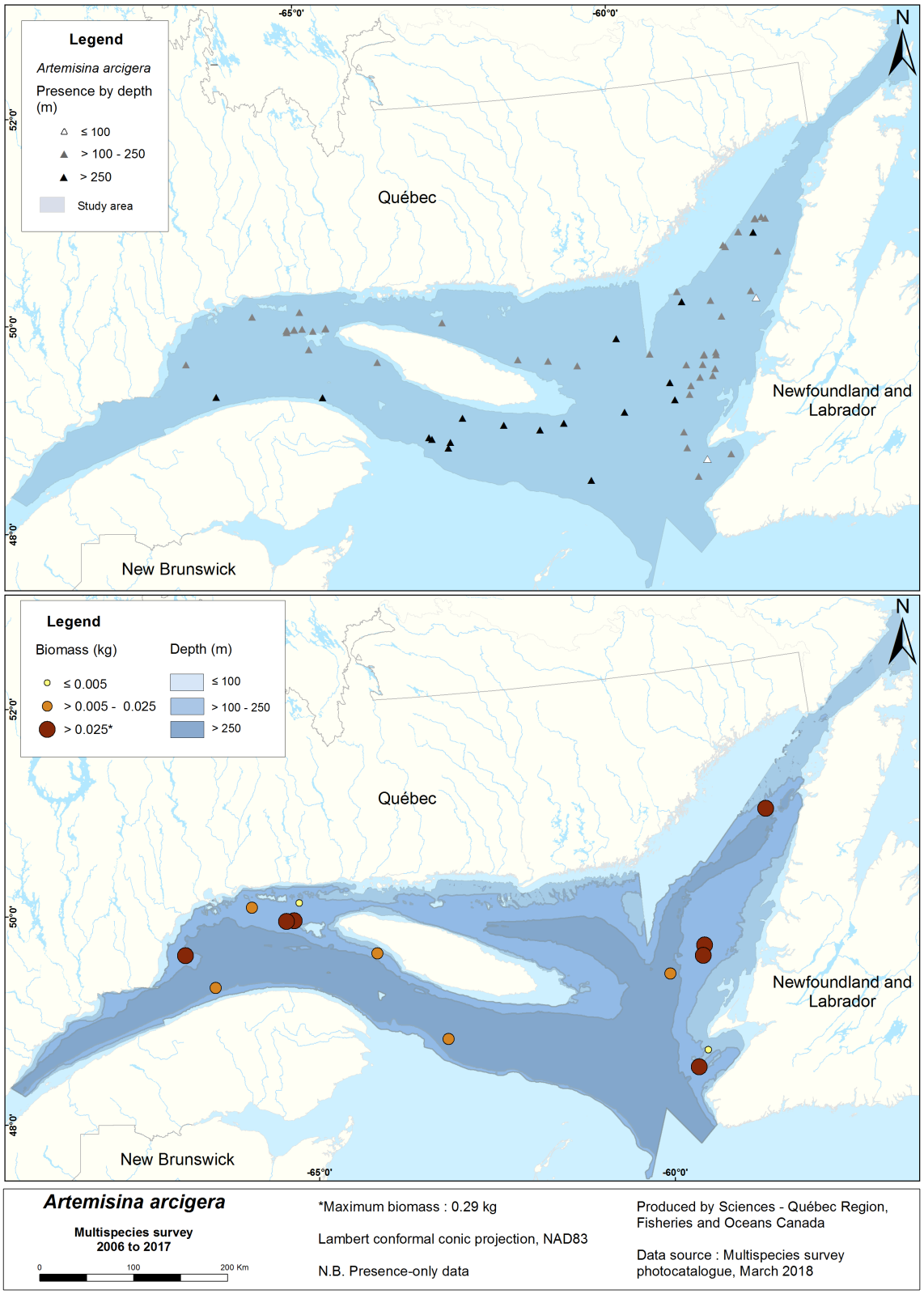


Figure 23. Distribution of the sponge *Artemisina arcigera* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.8. *Craniella polyura*

Sponges of this group (Family Tetillidae) are characterized by a globular shape with a smooth surface that is sparsely covered with short tubercles (van Soest and Rützler 2002) (Figure 24). Spicule bundles at the base of the sponge act as the anchor. These sponges usually have some oscula on the upper surface (van Soest and Rützler 2002). The species *Craniella polyura* has been found at depths ranging from 25 to 595 m. It has been recorded near Iceland, Norway and in the Arctic (Koltun 1966).

Figure 24. Examples of the sponge *Craniella polyura*.

Distribution of *Craniella polyura* in the northern Gulf of St. Lawrence

Most specimens were collected at more than 250 m depth in the Anticosti and Esquiman channels (Figure 25). This species was only found twice at less than 100 m depth. Catches of this sponge were very small, reaching a maximum of 37 g.

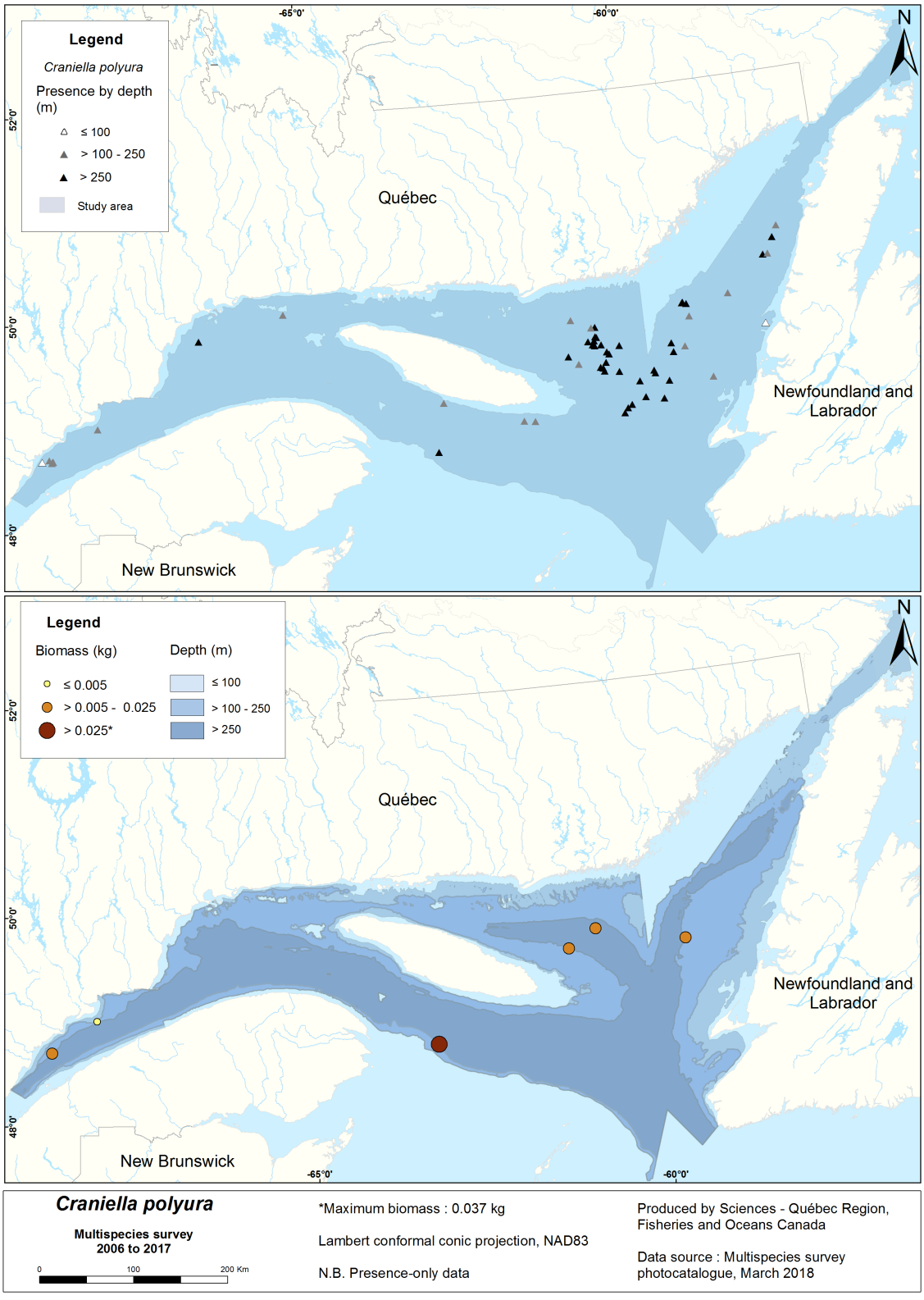


Figure 25. Distribution of the sponge *Craniella polyura* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.9. *Semisuberites cribrosa*

This large, stalked fan or funnel-shaped sponge has been historically misidentified as *Phakellia* sp. (*P. ventilabrum* or *P. bowerbanki*), but it is likely *Semisuberites cribrosa* (Stone et al. 2011) (Figure 26). Specimens are currently under review with spicule and DNA analysis for confirmation.

Figure 26. Example of the stalked fan-type sponge *Semisuberites cribrosa* previously misidentified as *Phakellia* sp.

Distribution of the sponge *Semisuberites cribrosa* in the northern Gulf of St. Lawrence

This sponge was collected at mostly intermediate depths of 100-250 m around Anticosti Island and in the Esquiman Channel off of Newfoundland (Figure 27). A few captures occurred at shallower stations, and several were at deeper locations, particularly to the southeast of Anticosti. No specimens were collected in the Estuary. Catch weights of this sponge were intermediate, reaching a maximum of 540 g.

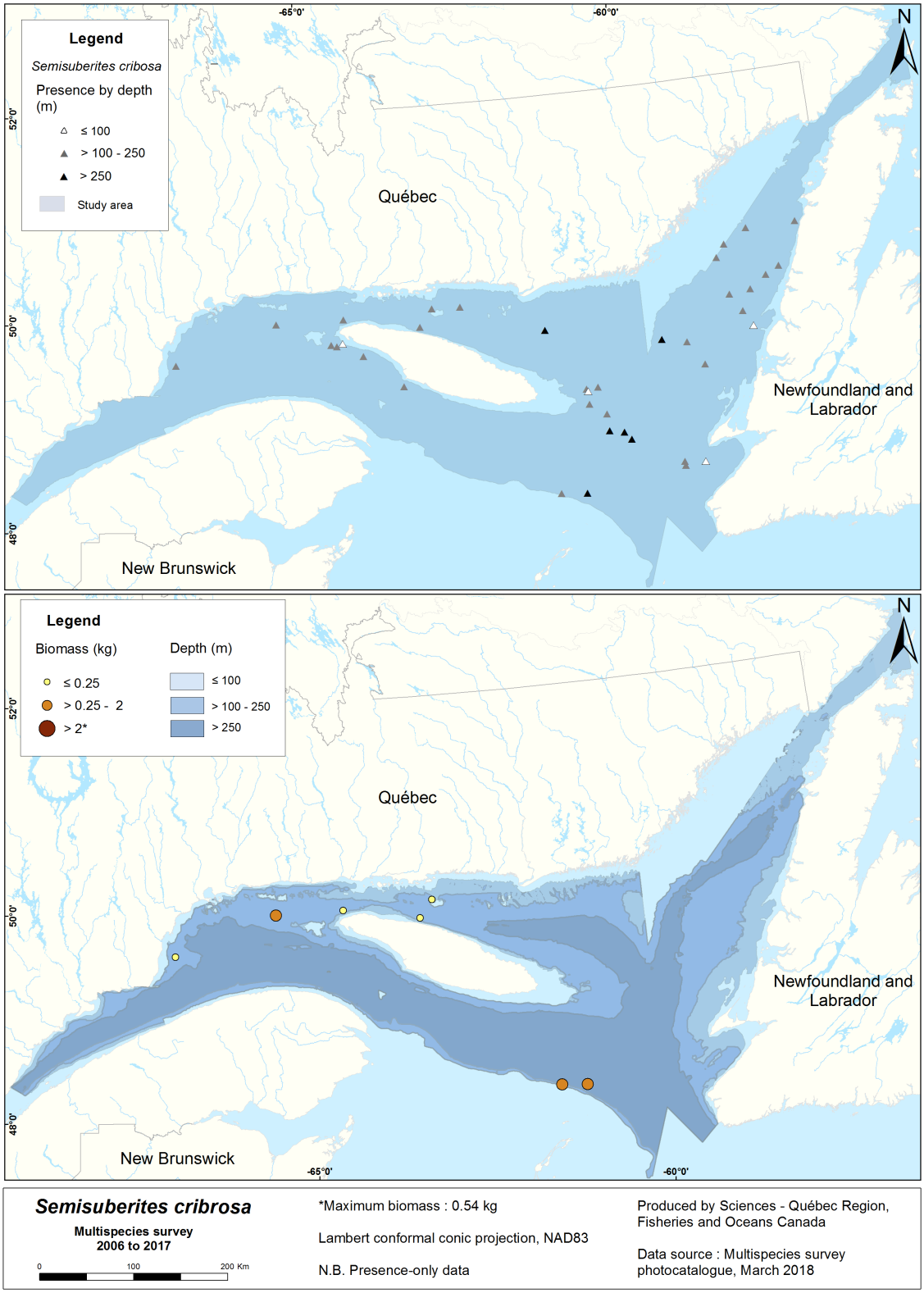


Figure 27. Distribution of the sponge *Semisuberites cribrosa* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.10. *Thenea muricata*

Species in this genus have a rudimentary root system to anchor to sediment on deep bottoms (Maldonado 2002) (Figure 28). Specimens identified to date are of *Thenea muricata*, although other species may be present, such as *Thenea levis* (Cardenas and Tore Rapp 2015). Specimens are oval shaped, resembling a potato, and grey-brown in color (Boury-Esnault et al. 1994). It is generally 0.5- 2 cm in size (Hooper 2002) but can exceptionally reach 50 cm in diameter (Maldonado et al. 2016). This sponge is found at depths of 60-4020 m, mainly on fine substrates (Boury-Esnault et al. 1994).

Figure 28. Examples of the sponge *Thenea muricata*.

Distribution of the sponge *Thenea muricata* in the northern Gulf of St. Lawrence

Most of the catches of this sponge occurred between Anticosti Island and the west coast of Newfoundland, frequently at depths of 100-250 m (Figure 29). Only five of the identified catches had an attributed weight, with the largest being 0.76 kg.

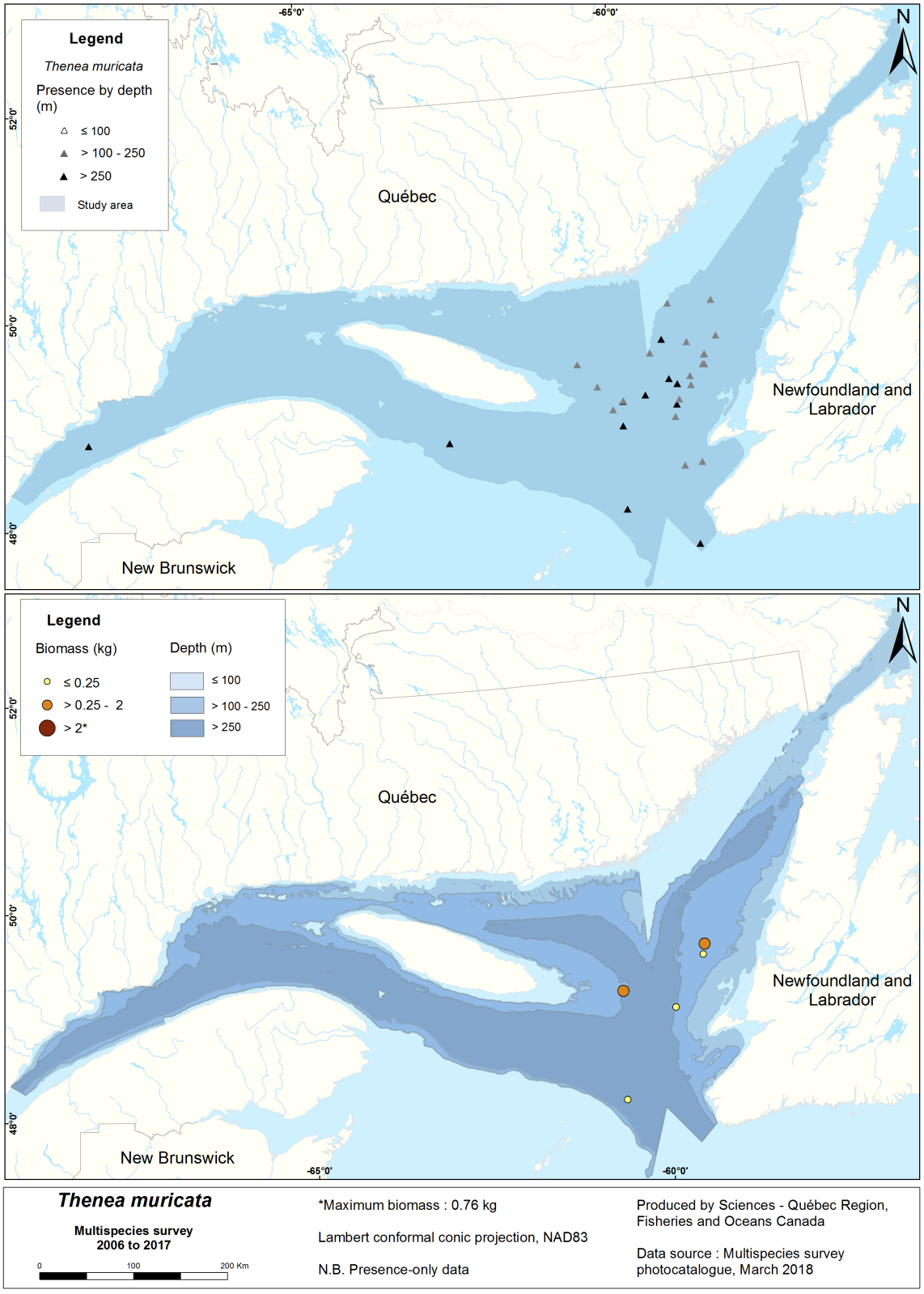


Figure 29. Distribution of the sponge *Thenea muricata* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.11. *Cladocroce spatula*

The palmate fan shape and large oscules of this sponge has led to it being misidentified in photos (Nozères et al. 2014) as the nearshore *Isodictya palmata* or *Haliclona oculata* (Fontaine 2006). However, examined specimens appear to be of *Cladocrace spatula* (Figure 30), with no confirmation so far that *Isodictya* sp. occur in the Gulf of St. Lawrence (Dinn et al. 2020, in press). The sponge *H. oculata* is frequently present in debris on the shores of the Estuary and Gulf of St. Lawrence but was not found in offshore captures.

Figure 30. Example of a palmate-fan type sponge *Cladocroce spatula* that was previously misidentified as *Isodictya palmata*.

Distribution of the sponge *Cladocroce spatula* in the northern Gulf of St. Lawrence

There were only 16 captures for this sponge in the survey, with all but four at less than 100 m depth (Figure 31). Most captures were in the Estuary, while others were on the North Shore near the Mingan archipelago and off of the west coast of Newfoundland. Only two identified catches were weighed, both were less than 150 g.

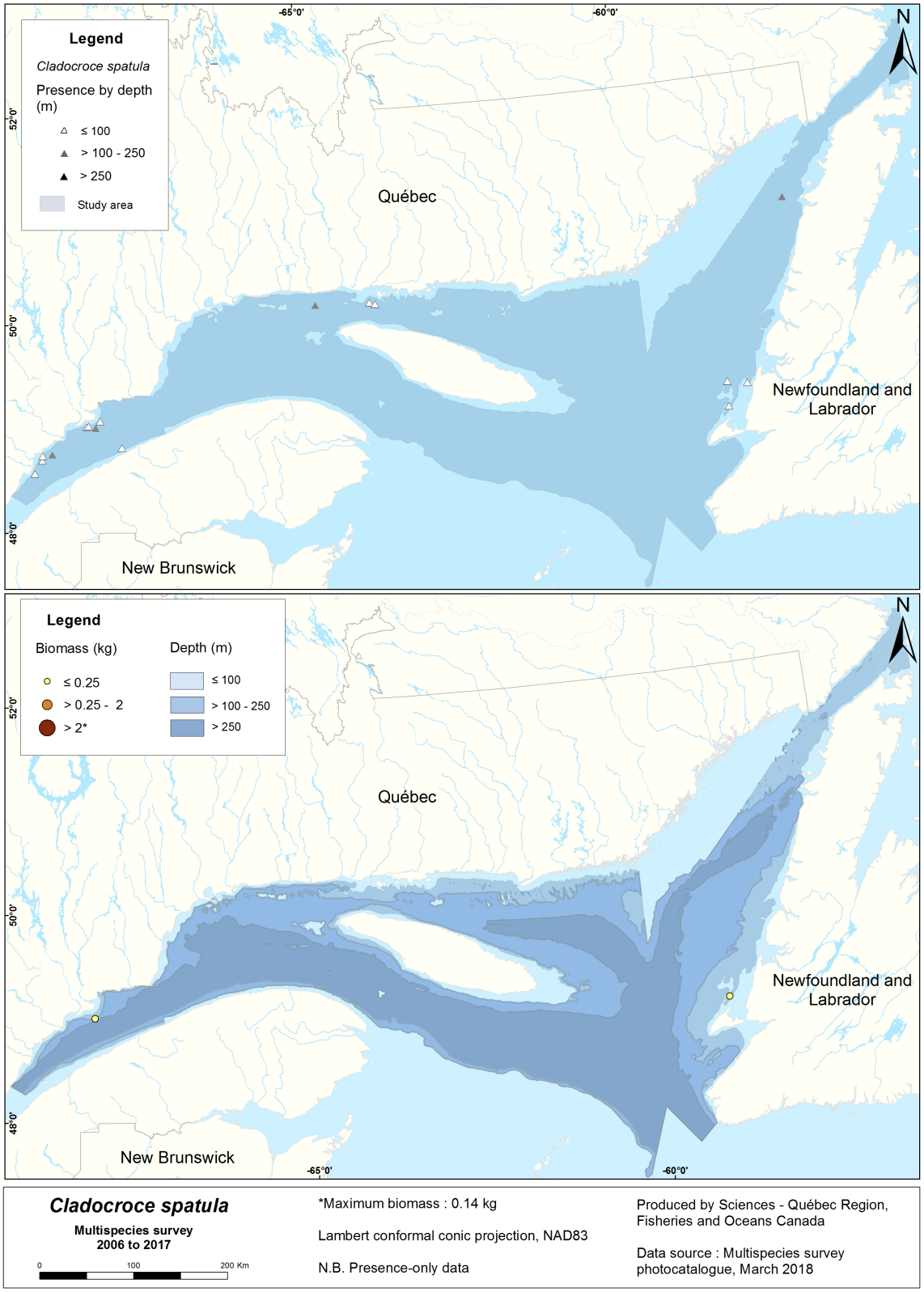


Figure 31. Distribution of the sponge *Cladocroce spatula* in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

2.12. *Sycon* sp.

The species in this sponge genus, as with all calcareous sponges, are taxonomically difficult (Dinn and Leys 2018). Specimens are usually composed of small, oval-shaped cylinders. The base is attached to various submerged solid objects (rocks, shells), with an exhalant pore at the end surrounded by a spike collar, appearing as an elongated tuft of 'hair' in collected specimens (Figure 32). These sponges are widely distributed in shallow waters in northern seas (Lambe 1900, Brunel et al. 1999).

Figure 32. Examples of the sponge *Sycon* sp.

Distribution of *Sycon* sp. in the northern Gulf of St. Lawrence

Most specimens were found at less than 100 m depth, near the west coast of Newfoundland up to the Strait of Belle Isle, and north of Anticosti Island, while two were also collected at depth in the Anticosti Channel (Figure 33).

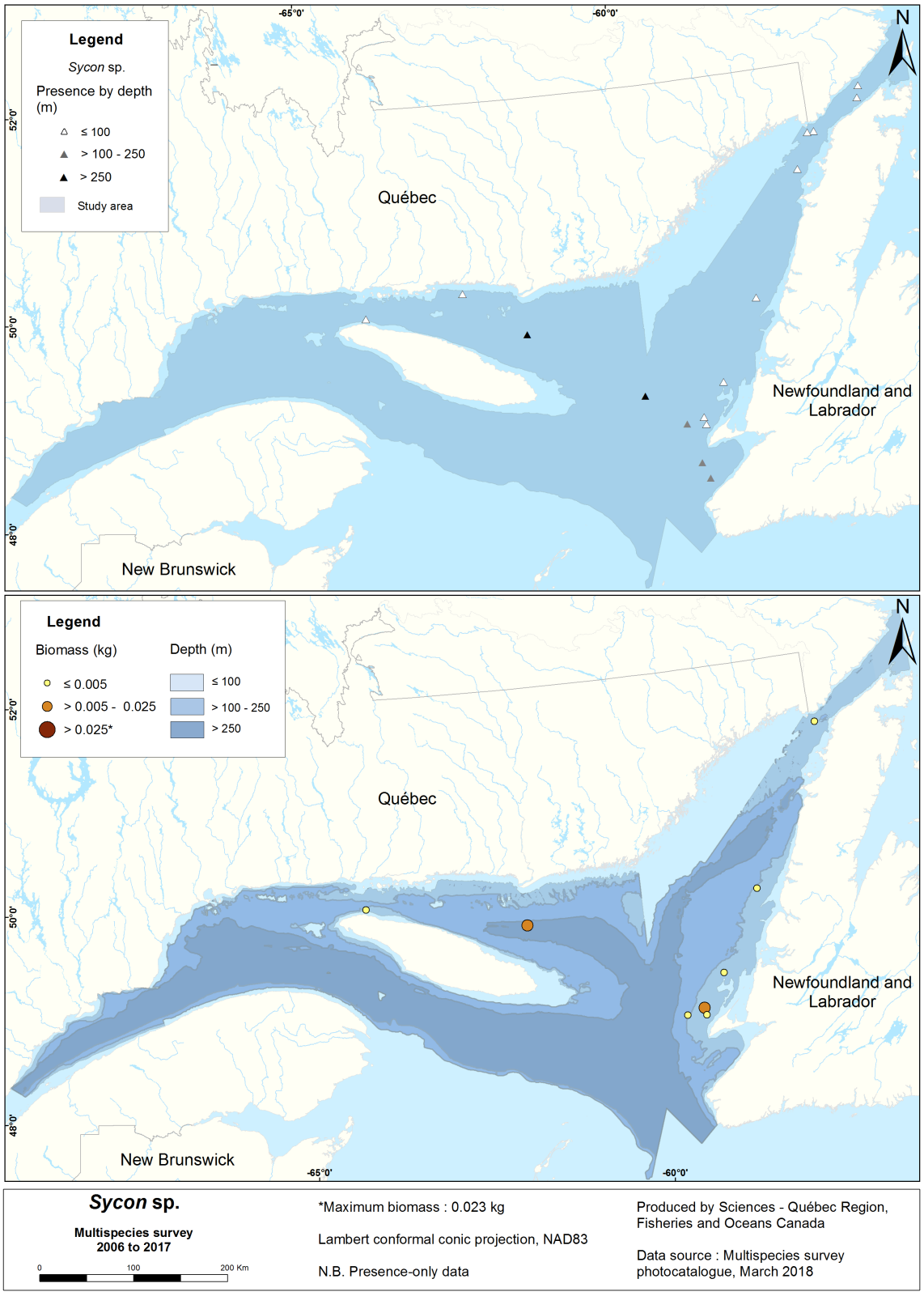


Figure 33. Distribution of the sponge *Sycon* sp. in the multidisciplinary survey from 2006 to 2017, by occurrence in photos (top) and by biomass in catch records (bottom).

3. PRESENCE OF TAXA IN SPONGE MARINE REFUGES

The catch data from the trawl survey and the identifications from the photo catalogue were used to compile a preliminary list of sponge taxa or morphotypes (Table 4) for each of the six sponge refuges (Figure 34).

Table 4. Presence of sponges identified in photos and maximum weight of catch (kg) by station for each of the refuges: 1) Parent Bank, 2) Jacques-Cartier, 3) Honguedo-East, 4) Anticosti-South-East, 5) Anticosti-East, 6) Beaugé Bank.

Group	Sponge species or type	Sponge Marine Refuge					
	(**bold**: large-sized (>10 cm) sponges)	**1**	**2**	**3**	**4**	**5**	**6**
2.1	Polymastiidae (unspecified)	1	-	1	1	1	-
2.1.1	*Polymastia hemisphaerica*	1	-	1	1	-	-
2.1.2	*Polymastia grimaldii*	-	-	-	-	-	-
2.1.3	*Tentorium semisuberites*	1	-	1	-	1	-
2.1.4	***Weberella bursa***	-	-	1	-	-	-
2.2	***Mycale* sp.**	1	1	1	-	1	1
2.3	*Stylocordya borealis*	-	-	1	1	1	1
2.4	**Suberitida**	-	-	1	-	1	-
2.5	***Hemigellius arcofer***	1	1	-	-	1	1
2.6	***Asconema foliatum***	-	-	1	1	-	-
2.7	*Artemisina arcigera*	1	-	1	1	-	-
2.8	*Craniella polyura*	-	-	-	-	-	-
2.9	***Semisuberites cribosa***	-	-	-	-	1	-
2.10	*Thenea muricata*	-	-	1	-	-	-
2.11	***Cladocrace spatula***	-	-	-	-	-	-
2.12	*Sycon* sp.	-	-	-	-	-	-
	Total taxa identified	5	2	10	5	7	3
	Maximum weight by station (kg)	8.2	17.3	13.6	15.6	7.2	10

Based on this preliminary list, two to ten taxa were found in each refuge. *Mycale* sp. was the most common taxon, found in five of the six refuges. Four taxa (*Cladocroce spatula, Craniella polyura, Polymastia grimaldii*, *Sycon* sp.) have not been identified in any of the refuges. The two northernmost refuges, Jacques-Cartier and Beaugé Bank, were similar for their presence of the large-bodied sponges *Hemigellius arcofer* and *Mycale* sp. There were also other sponge catches in each refuge that could not be identified; these records remained as Porifera in the dataset. For the purpose of benthic conservation, generally large-sized (>10 cm) sponges (Table 4, in bold) are of particular interest. From the photo catalogue, five of six large taxa thus far detected in the northern Gulf were seen in the refuges. All refuges had at least one of these taxa, with the Anticosti-East refuge seemingly having the most, with four such taxa identified.

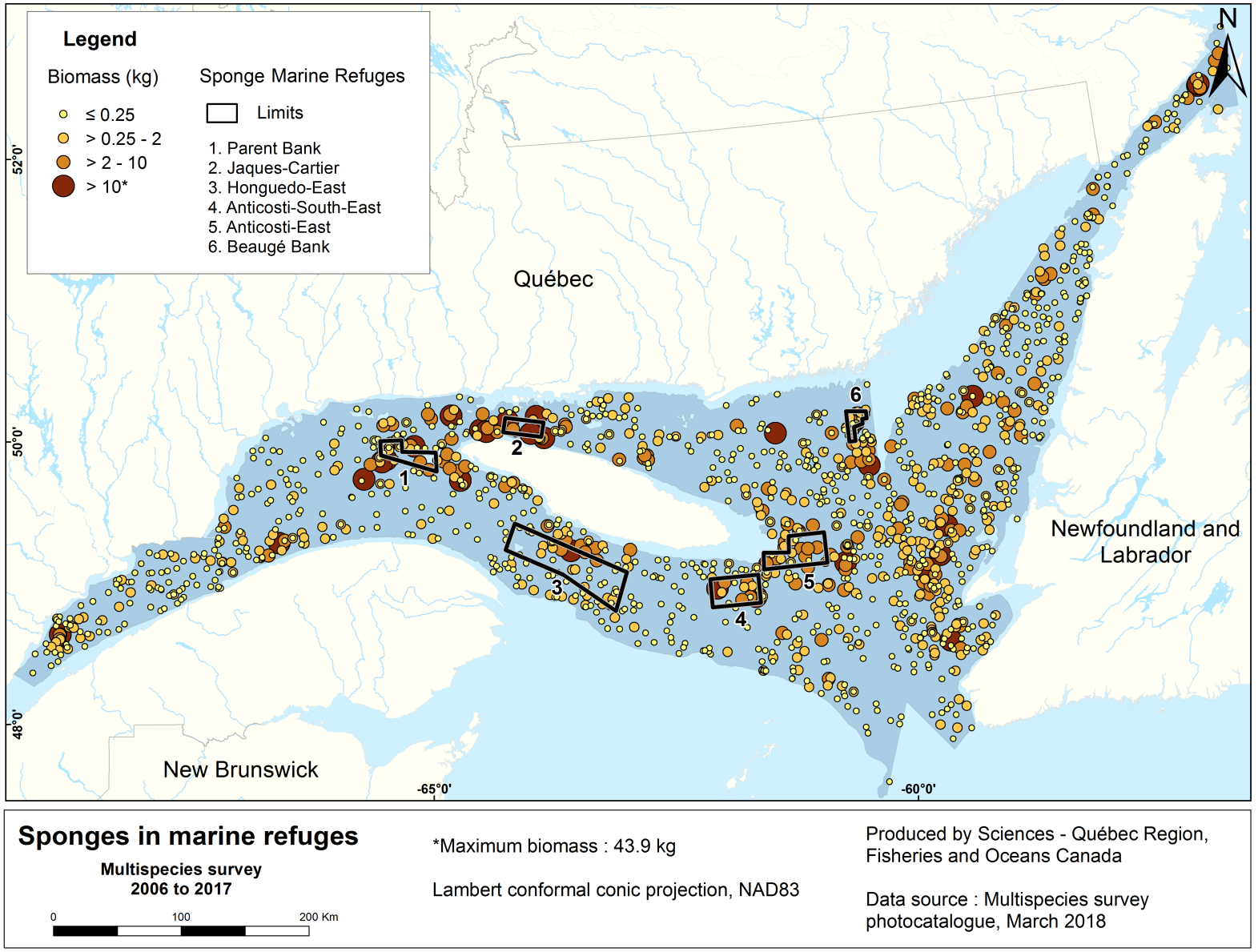


Figure 34. Map of refuges with the catches (kg) of sponges from the northern Gulf trawl survey (2006-2017).

DISCUSSION

Sponge distribution and catches

As was first shown in Kenchington et al. (2016), sponges are broadly distributed throughout the Estuary and Gulf of St. Lawrence, and are found at all depths sampled by the multidisciplinary survey (approx. 40 to 525 m), frequently between 50 and 299 m. However, those conclusions are limited to the trawl survey study area. Nearshore shallows and non-trawlable bottom areas were not examined and certainly warrant investigation.

With regards to quantities, there were a large number of small captures (<0.25 kg), while only 10% of the catches were relatively large (>2 kg). Overall, 27 sets had large catches, between 10 to 44 kg. These values are similar to catches elsewhere in the southern Gulf region, however they are much smaller compared to captures on surveys in the Atlantic Ocean, where several hundred, or even thousands, of kg of sponges may be collected in a single trawl set (Murillo et al. 2012, Kenchington et al. 2016). The deep Atlantic Ocean is host to several massive species such as *Geodia* sp. and *Vazella pourtalesi*, which are absent in the relatively shallow inland sea of the Gulf. Another factor may be the capturability of sponges by the trawl, in particular for areas of rough bottom. Underwater image surveys have revealed important quantities of sponges fixed to large boulders and vertical cliffs that will not be sampled by a bottom trawl.

Visual surveys have also revealed the patchy distribution of sponges on the sea bottom, making it a challenge to interpret distributions and biomasses from the randomly stratified trawl stations that may not sample specimens from a given area. Furthermore, difficult (rough bottom) areas may not be successfully sampled each year on the survey, and thus it requires a longer time series to build a portrait of distributions from trawls. This final point may also be an issue if examining for trends such as capture biomass across the survey years. While the total captures for sponges appear to decline over the surveys from 2006-2014 (Bourdages et al. 2019), this has to be evaluated for the success of sampling areas each year that are significant for sponge concentrations.

A potential issue with mapping sponge distribution records is the presence of sponge fragments remaining over from an earlier trawl set, especially when it had a large catch. This becomes important if consecutive trawl sets take place in ecologically different areas, for instance at very different depths than the initial capture, because they could suggest a presence when in fact sponges are absent. Occasionally, the review of photos is suggestive of sponge debris fragments in catches. The catch database then has the potential to be updated, either by ignoring records of debris fragments, or possibly by having those fragments added to the most likely preceding capture. Procedures to deal with debris fragments in the survey have yet to be established

Photo catalogue

Through the review of photos, more than half (60%) of the sponge catches from the trawl survey could be identified completely or in part. The partial identifications were when not all sponge pieces in the photo were assignable to a species. During the development of this report, new information became available and several taxa confirmed or added by microscope and DNA analyses, with perhaps 40 (rather than 16) taxa that could be encountered and possibly identifiable from photos on surveys in the Gulf region (C. Dinn, pers. comm. 2019). These improvements will help with 1) a second review of photos for the additional taxa, 2) improved sorting by taxa type for photos in future surveys, and 3) a better attribution of biomass values by taxon.

Table 5. Additional sponge taxa currently being identified from trawl surveys in the Gulf of St. Lawrence (C. Dinn et al. 2020, in press), that may be reviewed in the photo catalogue.

Taxon	Note	Taxon	Note
Biemna varianta	large	*Myxilla incrustans*	large
Crella sp.	small	*Phakelllia*-type *bowerbanki*	large
Halichondria panicea	coastal	*Polymastia andrica*	small
Halichondria sitiens	encrusting	*Polymastia bartletti*	encrusting
Haliclona (Flagellia) sp.	large	*Polymastia thielei*	small
Haliclona oculata	nearshore	*Polymastia uberrima*	small
Haliclona xenomorpha	large	*Pseudosuberites montiniger*	large
Iophon sp.	large	*Sphaerotylus* sp.	large
Lissodendoryx indistincta	large	*Tedania suctoria*	encrusting

While there are limitations on the identification of sponge species based only on photos, a photo catalogue is still useful to produce a general view of the diversity and types of sponges present in a survey region, as was done here. Furthermore, a photo catalogue will assist with the review of earlier identifications, and even of catch quantities. This can lead to data updates and corrections, in species and values, that would otherwise not be possible. Nonetheless, there is a need for baseline work, with reference samples for examining for spicules and for DNA analysis. Current work, producing reference specimen slides of spicules for the Gulf, has already led to updates of long-standing misidentifications for some of the most common and largest-sized sponge taxa, notably, *Cladocroce spatula*, *Hemigellius arcofer*, *Mycale*, and *Semisuberites cribrosa*. Overall, the catalogue of survey photos has served as a useful complement to document recent historical captures of sponges alongside detailed work for their identification.

Sponge marine refuges

The protection of sponges in marine refuges comes with the aim of monitoring the ecological features identified for conservation. Indeed, it is of great importance to describe and characterize more precisely those marine refuges, and especially to list all the sponge species encountered on the seafloor. This Atlas for several sponge taxa is

an improvement on the more general information that was previously available. However, trawl surveys in the refuges can be difficult (rough bottom) and destructive, yet more information is needed to better understand the communities in these important areas that may be revealed through benthic imagery surveys in the region, as for example was done in Jacques-Cartier Strait in 2019.

Future work

In the near term, the priority is to update the multidisciplinary survey catch database with the new information on biomass by sponge taxa that has resulted from this review conducted from 2015-2018. As new species information is now available from the ongoing work of C. Dinn (DFO-Gulf Region), a second photo catalogue review should be undertaken to create maps of the additional taxa (Table 5). An optional feature would be to produce a new database table to record presences by taxa or type even when a weight is unavailable, but the taxon is confirmed to be present by photo-identification.

Four additional lines of work might be conducted. The first is the compilation of data from different kinds of surveys that took place in the region, in particular if photos or specimens are available, and especially from coastal and nearshore areas. The second is further work on sponge spicules and DNA analyses to resolve complex species groups such as *Polymastia* and *Iophon*. The third is to use benthic imagery from underwater surveys as an alternative means to survey fauna in areas that are untrawlable (rocky, nearshore). Finally, the identification of taxa from past surveys will assist with analyses exploring both for trends in sponge captures in key areas across years, and for biodiversity in community assemblages associated with sponges.

CONCLUSION

This report presents for the first time the distribution of selected sponge taxa based on a photo catalogue from the northern Gulf multidisciplinary survey. The review of 16 taxa provided a basis for mapping their presence from 2006-2017 captures. This will be useful to update the catch database, to refine information on sponge refuges, and to prepare for sorting and weighing additional sponge taxa during future surveys.

ACKNOWLEDGEMENTS

We thank the many technicians, biologists and crews of the CCGS *Teleost* who over the years assisted in sorting, photographing, and identifying the catches, including Mylène Bourque, Pierre-Marc Scallon-Chouinard, Johanne Gauthier, Mélanie Lévesque, Laure de Montety, Éric Parent, Paul Robichaud, and Marilyn Thorne. Thanks to Ellen Kenchington, Gabrielle Tompkins-MacDonald, Emily Baker, and Javier Murillo of the Bedford Institute of Oceanography (DFO Maritimes Region) for work on sponges in 2016. Special thanks to Curtis Dinn (DFO Gulf Region) for the work on Gulf sponges in 2018-2019 and for initial comments during the report preparation. Thanks to reviewers Denise Méthé, Javier Murillo, and Bernard Sainte-Marie for their valuable corrections and suggestions that helped improved this report.

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APPENDIX

Appendix A. Sponge Checklist for the Estuary and Gulf of St. Lawrence.

A checklist compiled using five sources: trawl surveys (Nozères et al. 2015), the taxonomy list on CaRMS (http://www.marinespecies.org/CaRMS/checklist.php), the occurrences according to OBIS in 2018 (www.obis.org), the invertebrate catalogue by Brunel et al. (1998), the MLI permanent collection, and the Quebec species register (https://iqbio.qc.ca/biodiversite-du-quebec/les-especes-du-quebec/).

Note: the taxa in this list are currently under review; in particular, *Phakellia* and *Isodictya* may have been misidentified for *Semisuberites cribrosa* and *Cladoroce spatula*, respectively, while *Iophon* sp. and *Polymastia mammilaris* await confirmation.

Table A1. Current names and synonyms (WoRMS, http://www.marinespecies.org/, 2019-12-10) of sponges found in the Estuary and Gulf of St. Lawrence according to trawls (T) and other sources (C = CaRMS, O = OBIS, B = Brunel, M=MLI, Q = IQBIO).

Scientific Name	Synonym	T	C	O	B	M	Q
Amphilectus lobatus	*Mycale ovulum*			x	x		x
Artemisina arcigera	*Suberites arciger*	x				x	x
Asbestopluma (Asbestopluma) pennatula	*Cladorhiza pennatula*				x		x
Asconema foliatum		x				x	x
Biemna variantia	*Halichondria variantia*	x			x	x	x
Cladorhiza abyssicola					x		x
Clathria (Clathria) prolifera	*Clathria prolifera*				x		x
Clathrina cancellata		x			x	x	x
Clathrina coriacea					x		x
Cliona celata				x	x		x
Cliona lobata					x		x
Craniella polyura		x				x	x
Grantia canadensis	*Grantia canadensis*				x		x
Halichondria (Eumastia) sitiens	*Halichondria sitiens*		x	x	x	x	x
Halichondria (Halichondria) panicea	*Halichondria panicea*		x	x		x	x
Haliclona (Flagellia) flagellifera	*Hemigellius flagellifer*				x		x
Haliclona (Gellius) fibulata	*Gellius jugosus*		x				
Haliclona (Gellius) laurentina	*Gellius laurentinus*				x		x
Haliclona (Haliclona) oculata	*Haliclona oculata*	x				x	x
Haliclona (Haliclona) urceolus	*Haliclona urceolus*				x		x
Haliclona (Reniera) cinerea	*Haliclona permollis*				x		x
Haliclona (Rhizoniera) rufescens	*Renierea rufescens*						x
Halisarca dujardinii	*Halisarca dujardini*						x
Hemigellius arcofer		x				x	x
Heteropia rodgeri	*Heteropia rodgeri*		x		x		x

Scientific Name	Synonym	T	C	O	B	M	Q
Iophon piceum	*Iophon piceum*	x			x	x	x
Isodictya deichmannae	*Isodictya deichmanni*				x		
Isodictya palmata	*Isodictya palmata*	x			x	x	x
Leucosolenia botryoides	*Leucosolenia botryoides*						x
Leucosolenia fragilis	*Leucosolenia thamnoides*				x		x
Lissodendoryx (Lissodendoryx) indistincta	*Lissodendoryx indistincta*	x				x	
Melonanchora elliptica							x
Mycale (Carmia) babici	*Esperella modesta*						x
Mycale (Mycale) lingua	*Mycale lingua*	x			x	x	x
Myxilla (Myxilla) incrustans	*Myxilla incrustans*	x			x		x
Phakellia ventilabrum	*Phakellia bowerbanki*	x				x	
Pione vastifica	*Cliona vastifica*				x		x
Polymastia affinis		x				x	
Polymastia andrica		x		x	x	x	
Polymastia boletiformis		x			x	x	x
Polymastia grimaldii		x			x	x	x
Polymastia hemisphaerica	*Radiella hemisphaerica*	x				x	x
Polymastia mamillaris		x			x	x	x
Polymastia thielei		x				x	
Polymastia uberrima		x				x	
Sphaerotylus borealis		x				x	
Stylocordyla borealis		x	x	x	x	x	x
Suberites ficus		x			x	x	x
Suberites suberia							x
Sycettusa thompsoni	*Amphoriscus thompsoni*		x		x		x
Sycon lambei	*Sycon lambei*				x		x
Sycon lingua	*Sycon lingua*	x			x		x
Sycon protectum	*Sycon protectum*				x		
Tedania (Tedania) suctoria	*Tedania suctoria*					x	
Tentorium semisuberites		x			x	x	x
Thenea muricata		x			x	x	x
Trachyteleia hispida	*Polymastia hispida*				x		x
Weberella bursa	*Polymastia bursa*	x				x	