COSEWIC
Assessment and Status Report

on the

Thorny Skate
Amblyraja radiata

in Canada

SPECIAL CONCERN
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2012. COSEWIC assessment and status report on the Thorny Skate *Amblyraja radiata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 75 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Production note:
COSEWIC would like to acknowledge David W. Kulka for writing the status report on Thorny Skate *Amblyraja radiata* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by John Reynolds, Co-chair of the COSEWIC Marine Fishes Specialist Subcommittee, with the support of Alan Sinclair, Margaret Treble, Howard Powles, Bruce Atkinson and Paul Bentzen from the Marine Fishes Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Raie épineuse (*Amblyraja radiata*) au Canada.

Cover illustration/photo:
Thorny Skate — Photo provided with permission by DFO, Newfoundland, Marine Species at Risk.

©Her Majesty the Queen in Right of Canada, 2012.
Catalogue No. CW69-14/656-2012E-PDF
ISBN 978-1-100-20720-9

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2012

Common name
Thorny Skate

Scientific name
Amblyraja radiata

Status
Special Concern

Reason for designation
These slow-growing, late-maturing fish have undergone severe population declines over the southern part of their distribution, including range contractions. The southern declines have continued in spite of a reduction in fishing mortality. In contrast, the abundance of mature individuals in the northern part of their range has been increasing, approaching abundance levels observed at the beginning of surveys (mid-1970s). Thus, while the species as a whole does not meet the criteria for a Threatened status, declines and range contractions in the south are causes for concern.

Occurrence
Nunavut, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador, Arctic Ocean, Atlantic Ocean

Status history
Designated Special Concern in May 2012.

COSEWIC
Executive Summary

Thorny Skate
Amblyraja radiata

Wildlife Species Description

Amblyraja radiata, commonly known as Thorny Skate in English and Raie épineuse in French, is a relatively large skate, reaching up to 110 cm long on the Grand Banks. It varies among regions in size, body proportions, growth, and age at maturity. It is distinguished from other skates in the northwest Atlantic by a row of 11-19 large thorns running down the middle of its back and along the tail. It is usually brown although younger individuals may have darker spots.

Distribution

Thorny Skate are found on both sides of the Atlantic, from Iceland south to the English Channel in the eastern Atlantic, and from Greenland to South Carolina in the western Atlantic. In Canada, it is distributed continuously from Baffin Bay, Davis Strait, Labrador Shelf, Grand Banks, Gulf of St. Lawrence, Scotian Shelf and Bay of Fundy to Georges Bank, over a wide range of depths. For this assessment, this distribution is considered as a single designatable unit extending from Baffin Bay south to Georges Bank and including the Gulf of St. Lawrence.

Habitat

Thorny Skate live on the bottom over a wide range of depths (primarily 18-1200 m) and typically in water temperatures of 0° to 10°C. They can be found on a variety of bottom types including sand, gravel, mud and broken shells.

Biology

The average age at maturity is 11 years and the fish live for 16-20 years. They lay 6-40 eggs per year. Little is known about their predators but it is likely that their egg capsules are eaten by gastropods, whereas juveniles and adults may be eaten by marine mammals and fishes.

Population Sizes and Trends

The most recent minimum estimate of population size in all Canadian waters is approximately 188.5 million individuals, approximately 63 million of which are mature. In southerly regions, mature individuals have declined by 63% to 97% since the 1970s, whereas numbers have increased recently in the middle and northern parts of their range. Declines have also occurred in the abundance of immature individuals over parts of their range.

Threats and Limiting Factors

Catches of Thorny Skate in some commercial fisheries are likely an important limiting factor but this has not been directly linked to the declines, the most severe of which have occurred in spite of reduced fisheries. Recovery in the southern part of their range may be due to increased mortality by predators. Catches in Canadian waters have declined since the mid-1990s with the closure of the skate fishery on the Scotian Shelf, reduction of catches in the Grand Banks fisheries and general reduction in fisheries where the fish are taken as bycatch.

Protection, Status and Ranks

Thorny Skate has been designated as a “Species of Concern” by the National Marine Fisheries Service in the United States. They are designated as “vulnerable” globally on the IUCN Red List. There is a directed fishery for this species on the Grand Banks that straddles Canada’s 200-mile limit, managed under quota by the Northwest Atlantic Fisheries Organization (NAFO). The portion of the total allowable catch allocated to Canada is managed as a licensed fishery under the *Fisheries Act*. A mixed fishery for Thorny Skate and Winter Skate (*Leucoraja ocellata*) on the eastern Scotian Shelf is presently under moratorium.

TECHNICAL SUMMARY

Amblyraja radiata
Thorny Skate — Raie épineuse
Range of occurrence in Canada (province/territory/ocean): Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, Nunavut. Arctic Ocean, Atlantic Ocean (Northern Labrador to Georges Bank)

Demographic Information

Generation time (average age of parents in the population) *Based on approximation for rate of natural mortality, which is probably an underestimate compared to pre-exploitation times.*	~ 16 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. Div. 0 (Davis Strait, Baffin Bay) • *% decline over time period observed (since 1999)*	 *Unknown*
Div. 2GH (northern Labrador Shelf) • *% change over time period observed (since 1974)*	*Unknown*
Div. 2J3K (southern Labrador Shelf) (1977-1994) • *% change over time period observed (17 years, 1.1 generations)*	*- 91%*
Div. 2J3K (southern Labrador Shelf) (1995-2008) • *% change over time period observed (13 years, 0.8 generations)*	*+ 821%*
Div. 3LNOPs (Grand Banks) (1974-1995) • *% change over time period observed (21 years, 1.3 generations)*	*- 79%*
Div. 3LNOPs (Grand Banks) (1996-2010) • *% change over time period observed (14 years, 0.9 generations)*	*+ 303%*
Div. 4RS (Northern Gulf of St. Lawrence) (1991-2010) • *% change over time period observed (19 years, 1.2 generations)*	*+ 253%*
Div. 4T (Southern Gulf of St. Lawrence) (1971-2010) • *% change over time period observed (39 years, 2.4 generations)*	*- 95%*
Div. 4VWX (Scotian Shelf) (1970-2010) • *% change over time period observed (40 years, 2.5 generations)*	*- 95%*
Div. 5Z (Georges Bank) (1987-2010) • *% change over time period observed (23 years, 1.4 generations)*	*- 85%*
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Not calculated
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Not calculated
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence *Within Canada's extent of jurisdiction, but excluding unsuitable habitat, EO = 2 197 307 km²*	3 750 847 km² within Canada's extent of jurisdiction
Index of area of occupancy (IAO) (Always report 2x2 grid value).	290,000 km²
Is the total population severely fragmented?	No
Number of locations* *The main threats include bycatch mortality in diverse fisheries over a large region, as well as potential predation in some regions*.	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	Unknown
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	> 63 million

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not calculated

Threats (actual or imminent, to populations or habitats)

Primary threats are both directed and undirected fishing mortality, as well as predation in the south (e.g. southern Gulf of St. Lawrence). Although fishing effort and catches have generally decreased, Thorny Skate continue to be taken as bycatch and in the directed fishery.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? **USA:** Thorny Skate have undergone significant, long-term declines in American waters and are currently listed as a species of concern by the National Marine Fisheries Service. **Greenland**: there is evidence of decline.	
Is immigration known or possible?	Likely
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Is rescue from outside populations likely?	Possibly not, given declines in USA and Greenland

Current Status

COSEWIC: Special Concern (May 2012)

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: These slow-growing, late-maturing fish have undergone severe population declines over the southern part of their distribution, including range contractions. The southern declines have continued in spite of a reduction in fishing mortality. In contrast, the abundance of mature individuals in the northern part of their range has been increasing, approaching abundance levels observed at the beginning of surveys (mid-1970s). Thus, while the species as a whole does not meet the criteria for a Threatened status, declines and range contractions in the south are causes for concern.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not apply. Time series are too short to calculate population changes over three generations, and inferences are hampered by changes in gear used by survey vessels. However, recent increases in number of mature individuals in the middle and northern part of their range partially offset reductions in the south, resulting in the total population trend probably not meeting this criterion.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence greatly exceeds 20,000 km^2 and the area of occupancy greatly exceeds 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the number of mature individuals greatly exceeds 10,000.
Criterion D (Very Small or Restricted Total Population): Does not apply because the number of mature individuals greatly exceeds 1,000 and the area of occupancy is very large.
Criterion E (Quantitative Analysis): Not undertaken

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Thorny Skate
Amblyraja radiata

in Canada

2012

TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Thorny Skate (*Amblyraja radiata* Donovan, 1808, Family Rajidae) are endemic to the North Atlantic. Other names include Starry Ray (commonly used in the northeast Atlantic), Starry Skate, Maiden Ray, Miller Ray, Raie épineuse or Raie radiée (FR) and Raya radiante (ES). Synonyms are *Raia americana* (DeKay, 1842), *Raia scabrata* (Garman, 1913), *Raja radiata* (Müller and Henle, 1841) and *Deltaraia radiata* (Leigh-Sharpe, 1924). Garman (1913) differentiated northwest from northeast Atlantic Thorny Skate by naming it as a new species but Bigelow and Schroeder (1953) restored the original name to the entire range, not finding significant differences between areas. This complex taxonomic history relates to its variable morphology, growth and reproductive parameters.

Morphological Description

Maximum size varies among areas: 90 cm (7.5 kg) on the Labrador Shelf, 110 cm (12.5 kg) on the Grand Banks (Kulka *et al*. 2004; Templeman 1987) and about 100 cm (10 kg) in the Gulf of St. Lawrence (Swain *et al.* 2011), Scotian Shelf (McPhie and Campana 2009a) and Gulf of Maine (Sulikowski *et al.* 2005b; Tsang 2005a and b). Maximum size in the northeast Atlantic is ~90 cm (Stehmann and Bürkel 1984).

Sulak *et al.* (2009) describe Thorny Skate as: disk spade to heart-shaped, corners rounded; snout rounded, no intervening thorn; tail 1.0-1.1 times body length. That have a single dominant mid-dorsal row of 11-19 large thorns (exaggerated in juveniles), which have stellate bases. There are 10 or fewer thorns behind the pectoral axil, usually three large orbital one, 1-3 on the shoulder, and a variable patch of large thorns medially on each wing. The centre of disk is smooth between large thorns. The upper (dorsal) surface is grey to brown, uniform or mottled. Juveniles have tiny, sparsely distributed dark spots and a distinctive tail banding pattern (Figure 1). Although Sulak *et al.* (2009) also describe the dorsal fins as separated by a distinct gap, this feature is highly variable in Northwest Atlantic specimens (C. Miri, unpublished). The feature that most distinguishes it from other skates in Canadian waters is the row of 11-19 large thorns running down the middle of the back and along the tail (Bigelow and Schroeder 1953). Dorsal colouration is variable so is not a reliable indicator. The ventral surface is usually white, without markings, though rarely with a few small darkly pigmented markings (C. Miri, unpublished).

Figure 1a. Specimen of a female Thorny Skate taken from the Grand Banks. Inset is a newly hatched 11 cm juvenile female.

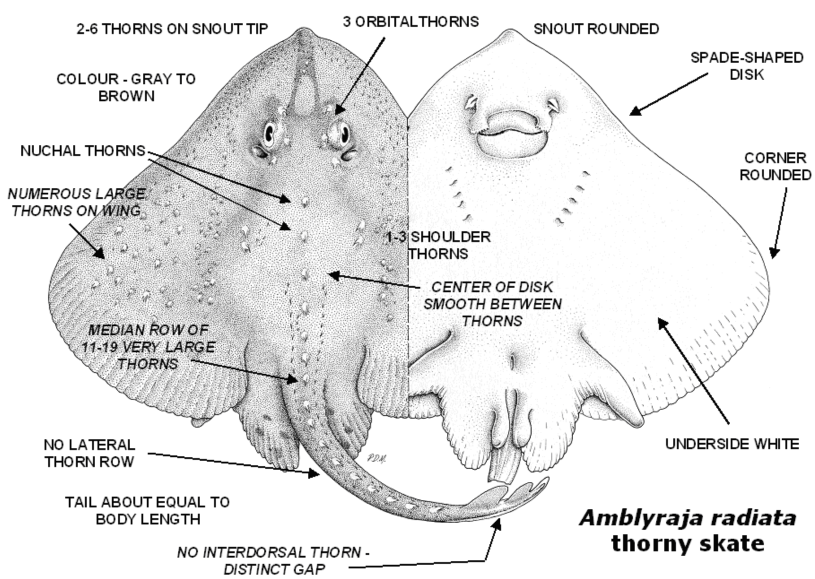

Figure 1b. Drawing of Thorny Skate highlighting morphometric attributes used to differentiate it from other species (after Sulak *et al.* 2009).

Templeman (1984 and 1987) examined 19 morphometric characteristics and in particular, he noted that the species becomes less thorny with age. This may have been the reason why Garman (1913) declared different species in the northwest and northeast Atlantic, based on different degrees of thorniness in the specimens examined. Templeman (1987) also noted north to south clines in some other characteristics including mean number of median dorsal thorns from Baffin Island southward to the Grand Banks, the Gulf of St. Lawrence, Scotian Shelf and Georges Bank, with higher numbers occurring at lower temperatures. There is a wide range of tooth counts (27-48, mean=36.9). Mean tooth row counts also show a cline, with an average of four fewer teeth at Lat 57^{o}N compared to Lat 43^{o}N off Canada.

Population Spatial Structure and Variability

Two studies have examined genetic variation in Thorny Skate. Coulson *et al.* (2011) reported on variation in mitochondrial DNA sequences of 38 individuals from the western Atlantic portion of the range. That study found that mitochondrial CO1 gene sequences were relatively variable, compared to other skate species in the region, but there was no assessment of spatial variation. Chevolot *et al.* (2007) also examined mitochondrial DNA, with samples from across the species' North Atlantic range. However, samples from Atlantic Canada were restricted to one locality in Newfoundland, from 30 individuals. They found little evidence of genetic differentiation and stated that: "The near absence of genetic differentiation in Thorny Skate does not conform to predictions based on life history characteristics of Rajidae." Although a lack of power and the use of only one molecular marker might explain this (Waples 1998), the authors also reported highly significant structure at the ocean basin scale in a parallel study using the same marker for another Rajid (*Raja clavata*) (Chevolot *et al*. 2007). They suggested that given their apparent genetic homogeneity, the range of movement of Thorny Skate may be greater over many generations i.e. that Thorny Skate may move incrementally over long periods, leading to genetic mixture. In the northwest Atlantic and the north Atlantic as a whole, there are no significant gaps in distribution (Figure 2).

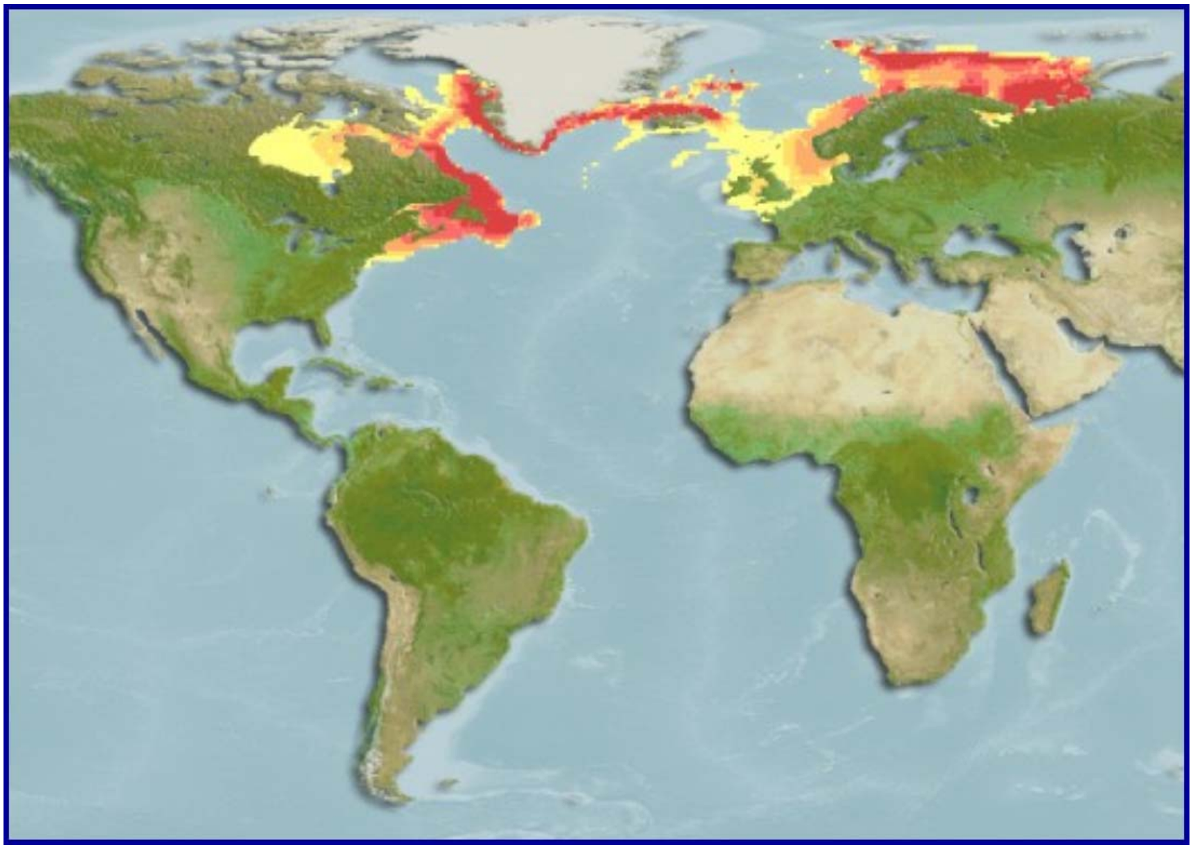

Figure 2. Thorny Skate global distribution (from Fishbase).

Designatable Units

Although Thorny Skates have relatively high variation in mitochondrial DNA sequences compared with other eastern Canadian skate species (Coulson *et al*. 2011), genetic studies to date do not match the considerable life history, morphometric and meristic variation noted throughout the range of this species. Templeman (1987) and Kulka (*in prep.*) determined that the fish are smaller, mature at a smaller size and differ morphologically on the Labrador Shelf compared to the Grand Banks. There is a conspicuous change in average weight of fish, maximum size and size at maturity at the northern edge of the Grand Banks (Lat. 49^{o}N), with the fish to the north of this line about 1.1 kg lighter on average (equivalent to 13 cm in length) and onset at maturity at about 40 cm, about 20 cm less than to the south. In referring to the Grand Banks vs. areas to the north, Templeman (1987) concluded that given great differences between areas in maximum length and sexual maturity, no large-scale migrations occurred between these areas. Local differences in conditions and limited mixing have likely contributed to this situation.

Tagging studies (mark/recapture) conducted for Thorny Skate (as well as for other Rajids) have indicated maximum travelling distances of individuals on the order of hundreds of kilometres, usually much less (Templeman 1984) as compared to thousands of kilometres for many bony and cartilaginous fishes (Metcalfe and Arnold 1997; Lawson and Rose 2000). That Thorny Skate have mixed across its entire Atlantic range from the USA to the Barents Sea seems highly unlikely, even over many generations, given that all life stages are sedentary although, as noted above, this is not supported by the genetic findings of Chevolot *et al.* (2007).

Large morphological and reproductive differences among areas in conjunction with indications of minimal migration suggest that there could be spatial variation in population structure. However, based on the lack of obvious disjunctions in the distribution of this species in Canadian waters, and in the absence of studies testing for genetic differentiation across Atlantic Canada, a single designatable unit (DU) for Thorny Skate is considered for this assessment. This one DU extends from Baffin Bay to Georges Bank, including nearly all of the shelf waters of Canada. Additional research is needed to determine whether northern and southern populations, which have shown different population trends, should be considered separate DUs in the future.

Special Significance

In Canada, Thorny Skate are targeted for their wings, for which a small market exists. Most are exported. The value of the domestic markets and exports are unknown.

DISTRIBUTION

Global Range

Thorny skate is the most widely distributed and abundant skate species in the North Atlantic (Fig. 2), found on the continental shelf from north temperate (Lat 40oN) to Arctic (south of Lat. 75oN) regions (Froese and Pauly 2000). In the northeast Atlantic, it ranges widely in the White and Barents Seas, as far south as the North and Irish Seas, and westward around Iceland and southern to central Greenland waters (ICES 2005). In the western Atlantic, it is distributed continuously along the shelf and on the shelf edge from west Greenland to South Carolina, USA.

Canadian Range

Thorny Skate is among the most widespread and abundant demersal fish species in Canadian waters. It occurs on most of the continental shelf, from Baffin Bay as far north as Lat. 68°N, Davis Strait, Hudson Strait and Ungava Bay, south along the Labrador Shelf, northeast Newfoundland Shelf, the Grand Banks, Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy and Gulf of Maine to the USA border (Templeman 1982a, Sinclair *et al*. 1984, Kulka *et al*. 2004, 2006a, Sulak *et al*. 2009, Figure 3), as well as in the Gulf of Maine in the USA (McEachran and Musick 1975). There is no evidence of spatial disjunctions across this range.

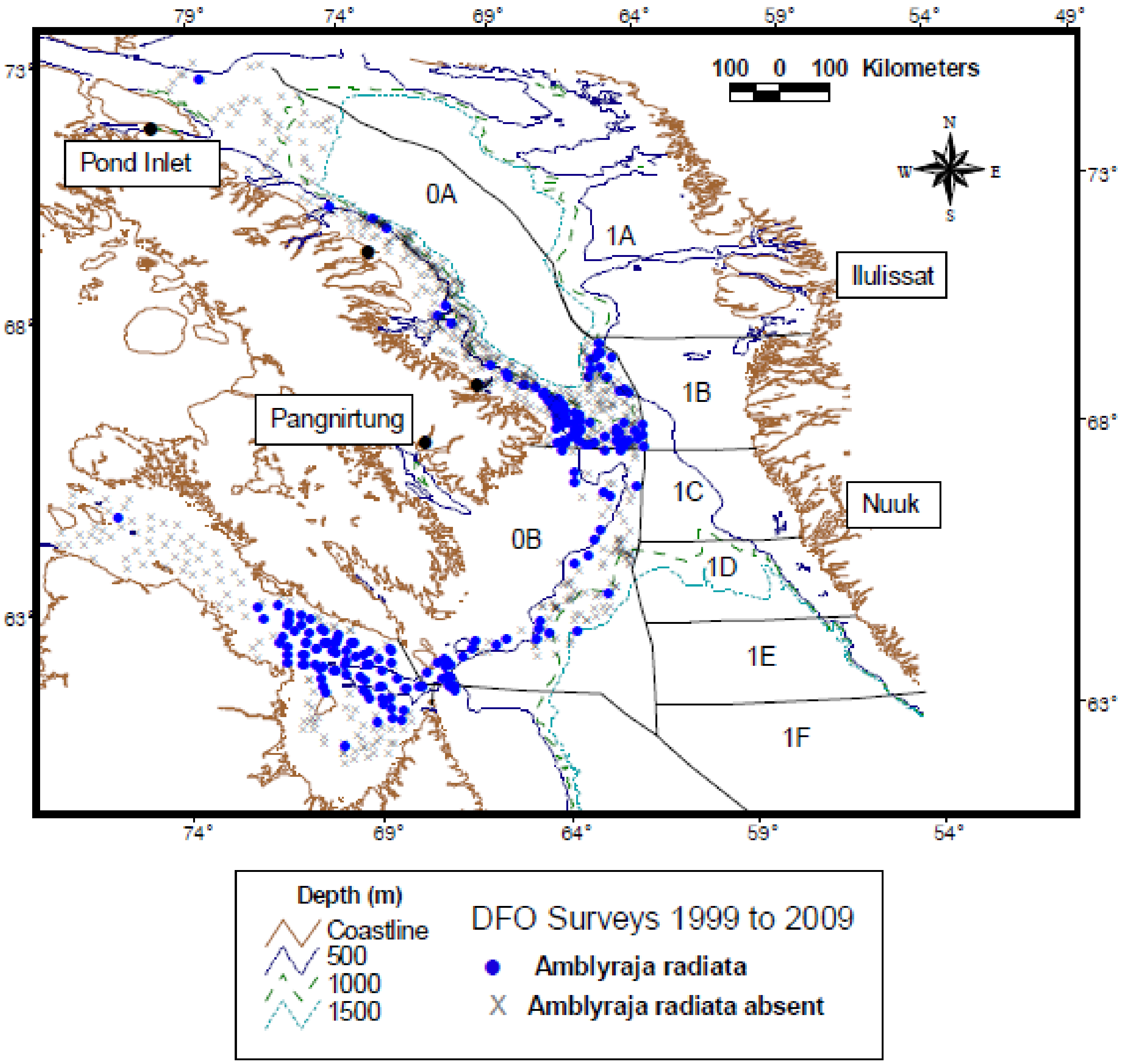

Figure 3a. Distribution of Thorny Skate in the Canadian waters north of Lat. 60° 30'N based on DFO surveys, 1999-2009. Blue dots represent where Thorny Skate were caught, x are symbols where fishing occurred but skate were not caught.

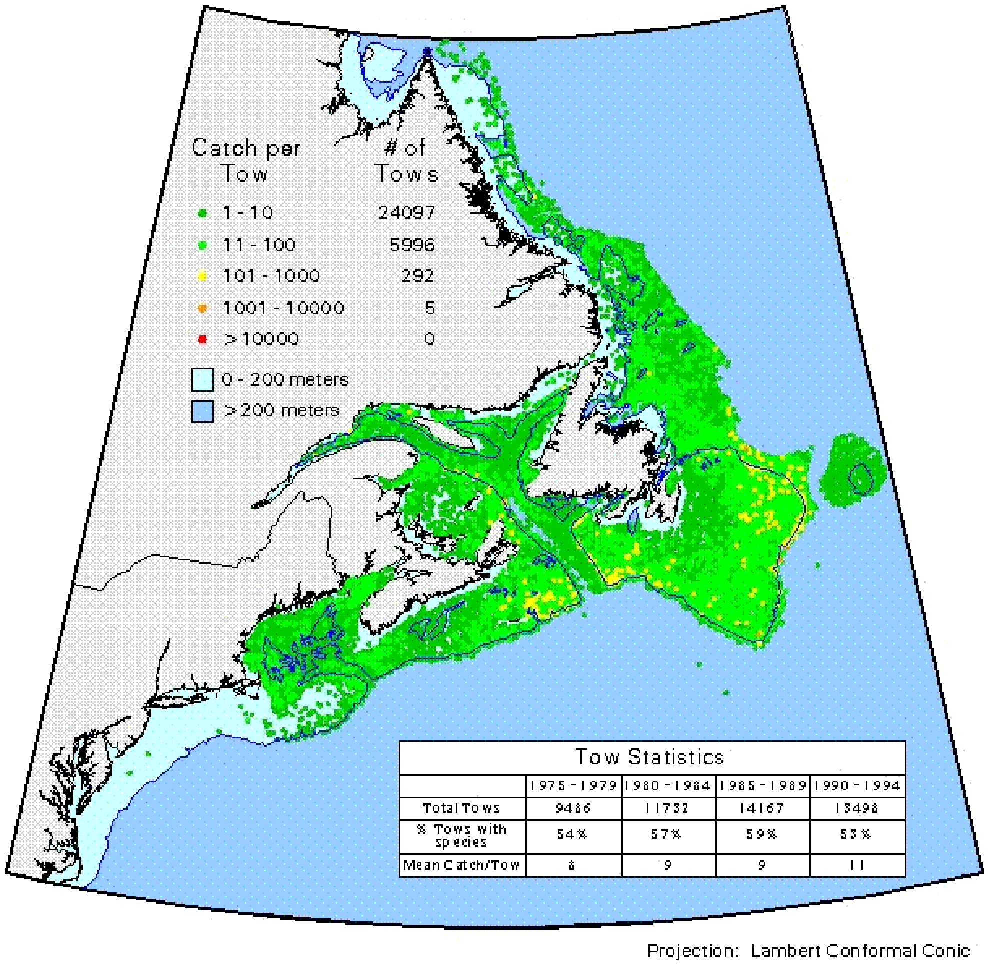

Figure 3b. Map showing extent of survey catches (different seasons and gears combined) of Thorny Skate on the Northwest Atlantic continental shelf. Data are from East Coast of North America Strategic Assessment Project surveys from 1975-1994 (Brown *et al.* 1994).

Thorny Skate are most abundant (densely concentrated) along the southern Grand Banks off Newfoundland and on the eastern portion of the Scotian Shelf. On the Grand Banks, they comprise about 90% of the skates caught during multispecies survey bottom trawling (Kulka and Miri 2003). Approximately 30-40% of Thorny Skate global range is in Canada.

Search Effort: Area of Occupancy and Extent of Occurrence

Distribution mapping was done differently by various DFO regions but all used research bottom trawl survey data. Trends in area of occupancy (AO) are presented by survey (DFO Region). Figure 4 shows the codes used by NAFO for areas in the northwest Atlantic.

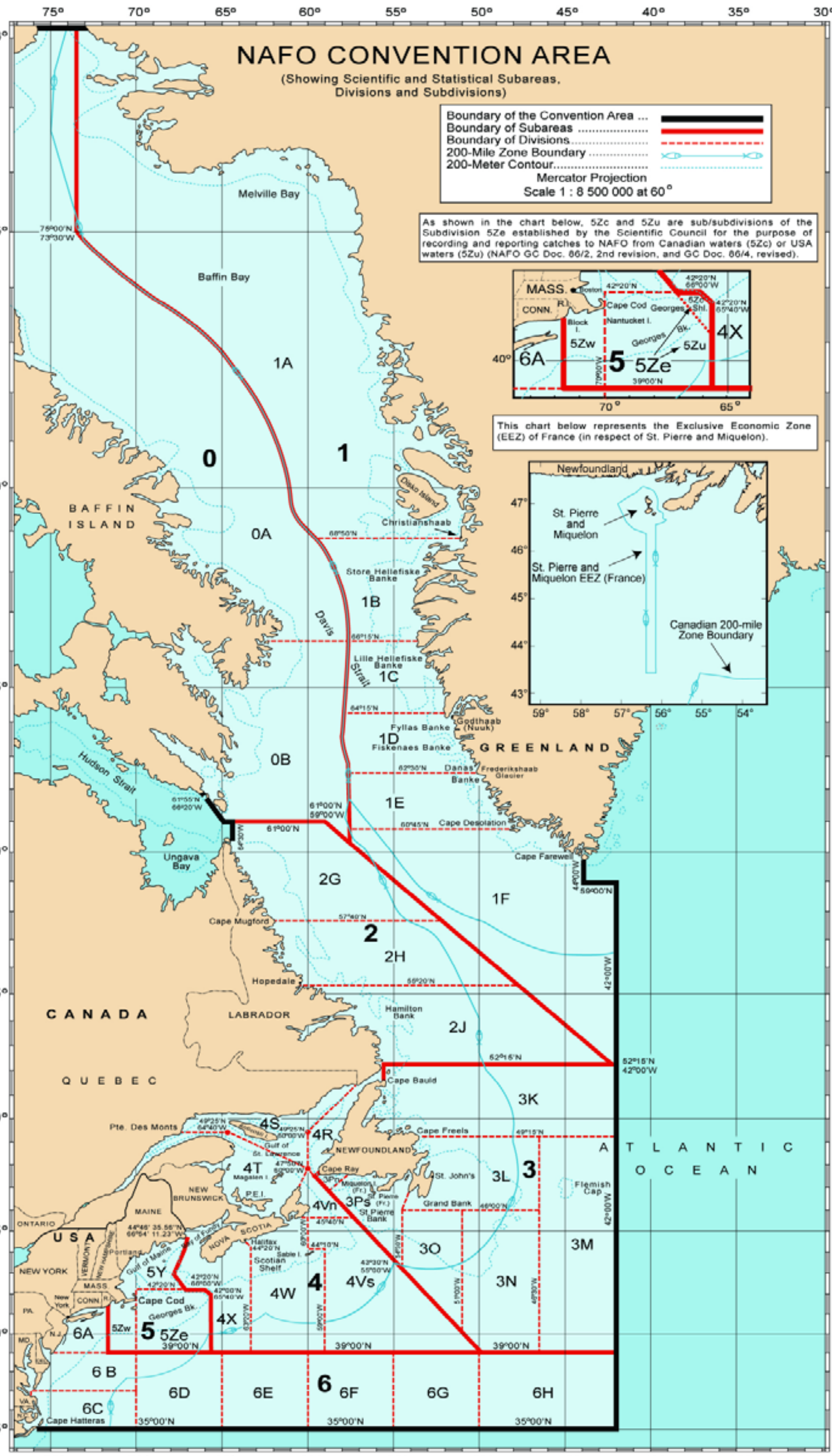

Figure 4. NAFO Convention Area showing NAFO divisions and subdivisions referred to throughout the text.

For Newfoundland and Labrador (NL) (as well as the overall range maps), SPANS GIS (Anon. 2003) was used. Details of potential mapping used for transformation of geo-referenced survey numbers per tow to areas depicting differential density of the species are described in Kulka (1998) and Kulka *et al*. (2006a). Survey data were separated into spring and fall for estimates of abundance and biomass, and grouped into four periods of differing population status: 1971-74 and 1975-79, when Thorny Skate were more abundant but sampling coverage was poor; 1980-84, when they were relatively abundant and Yankee gear was used; 1985-89, period of decline when Engel gear was used; 1990-spring to1995, low abundance when Engel gear was used; and fall 1995-1999, 2000-2004 and 2005-2009—three periods when abundance was lower than earlier years and Campelen gear was used. For the Quebec Region (northern Gulf of St. Lawrence), colour-coded expanding symbol maps were used to describe changes in distribution during decadal periods. For the Gulf Region (southern Gulf of St. Lawrence), geographic distribution was mapped using the data visualization software ACON (http://www.mar.dfo-mpo.gc.ca/science/acon, Swain *et al*. 2011). Shaded contours were drawn using Delaunay triangles. For the Maritimes Region, geographic distribution was mapped using the data visualization software ACON with expanding symbols based on data summarized to 10 minute squares or as otherwise specified on the maps (Simon *et al*. 2012).

Unless otherwise stated, AO values are design-weighted area of occupancy (DWAO) that incorporates the stratified-random survey design (Swain and Sinclair 1994; Smedbol *et al*. 2002). AO (A_t) was calculated for each size class of skates in year *t* as follows:

$$A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \sum_{i=1}^{n_j} \frac{a_k}{N_k n_j} I \text{ where } I = \begin{cases} 1 \text{ if } Y_{ijkl} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where a_k is the area of the stratum k, Y_{ijkl} is the number of fish in size class l caught in tow i at site j in stratum k, N_k is the number of sites sampled in stratum k, n_j is the number of tows conducted at site j, and S is the number of strata. Juveniles were defined as fish < 53 cm and adults as >= 53 cm (see section on Biology).

Swain and Sinclair (1994) noted that AO will decrease as population size decreases even if there is no increase in geographic concentration. In order to describe changes in geographic concentration, the minimum area containing 95% of skates, following Swain and Sinclair (1994), was calculated for the Gulf Region as well as the DWAO. Change in AO was calculated as the ratio of the mean AO of the first 3 years of data available to the mean AO of the last 3 years, unless otherwise specified.

Central and Arctic

Based on survey data north of 60° 30'N from 1999-2009, Thorny Skate were found in Baffin Bay, Davis Strait and Hudson Strait/Ungava Bay (NAFO Subarea 0) in lower densities than to the south (Figure 3a). Records are rare north of 68°N and west of 74°W, likely delineating the northernmost extent of the distribution of this species in Canada. In southern Davis Strait, the Canadian distribution is contiguous with fish from Greenland waters (Subarea 1) and areas east. In this area, data are insufficient to determine AO.

Newfoundland and Labrador

Thorny Skate is the 11th most abundant demersal fish species and the most abundant skate species in DFO NL surveys. It is distributed on nearly all shelf and upper slope waters as far north as the surveys go (Figure 5, Kulka *et al*. 2006a; Simpson *et al*. 2012). It is most densely concentrated and abundant on the Grand Banks. Highly concentrated but less widespread concentrations also occur off the northeast coast of Newfoundland and in the Hopedale Channel of the Labrador Shelf. All localities where Thorny Skate were recorded during 1977-2009 amounted to 590,000 km^2 or 94% of the survey footprint. Some inshore areas are not surveyed but densities are likely low given the shallow depths and cold temperatures (see section on Habitat). As well, the northern Labrador Shelf (Div. 2G) is rarely surveyed but historic survey sets indicate the presence of the species there.

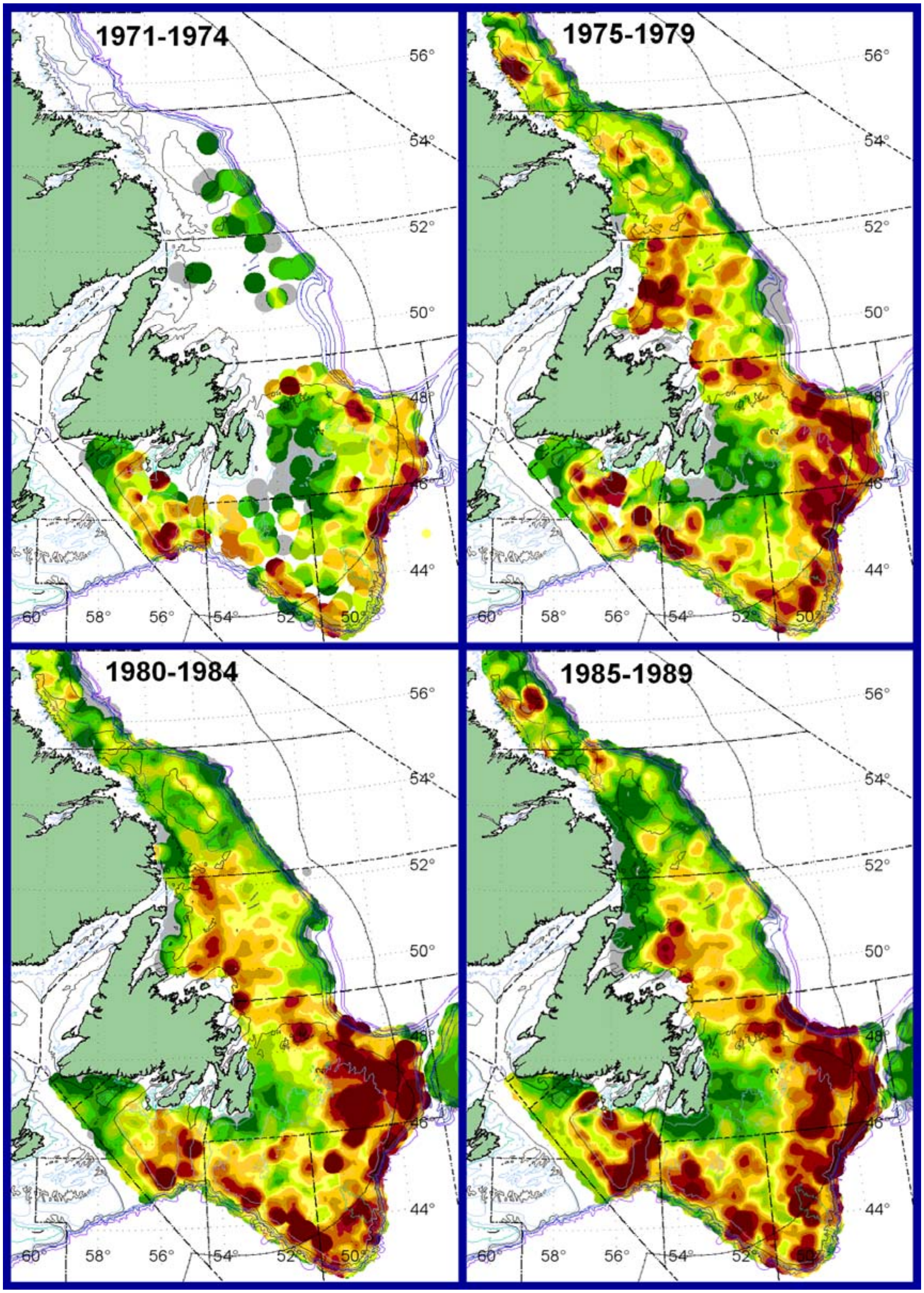

Figure 5a. Distribution of Thorny Skate during four periods between 1971 and 1989, with spring and fall surveys combined. Red depicts areas of highest concentration, green, lowest. Grey denotes areas surveyed with no catch of skate.

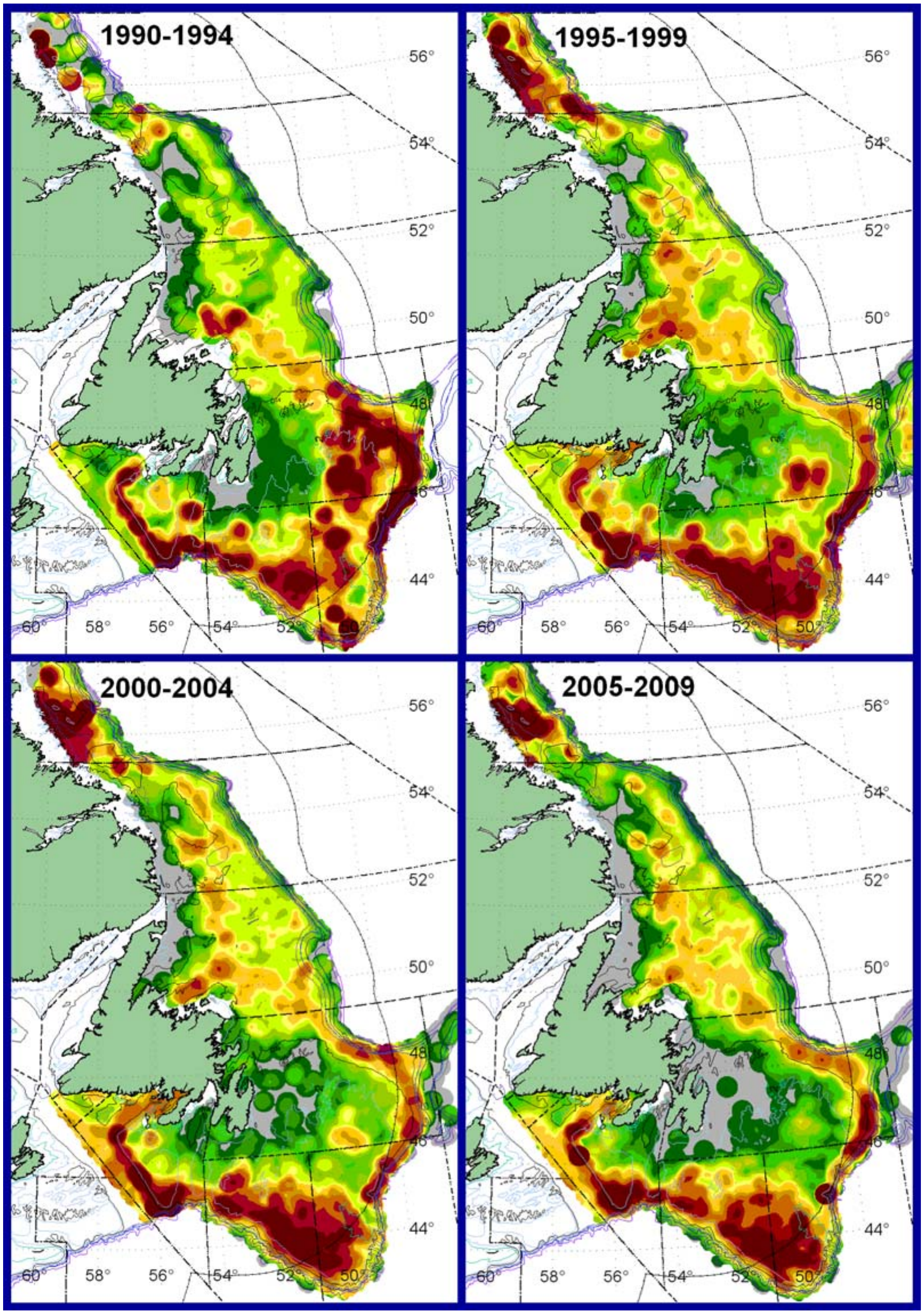

Figure 5b. Distribution of Thorny Skate during four periods between 1990 and 2009, with spring and fall combined. Red depicts areas of highest concentration, green, lowest. Grey denotes areas surveyed with no catch of skate.

During the 1980s, density of Thorny Skate north of 48°N was lower than in the 1970s (Figure 5a). More extensive concentrations appeared in the Hopedale Channel area after 1995, persisting to the present (Figure 5b). However, the largest changes in distribution occurred on the Grand Banks. A dense concentration on the northern half of the Grand Banks was reduced to a remnant along the shelf break by the mid-1990s (Figure 5b). During the same period, dense aggregations formed on the southwest Grand Banks. There, the fish became hyper-aggregated (Figure 6, after Kulka *et al*. 2006a), similar to what was observed for Northern Cod (*Gadus atlantica*) on the Labrador Shelf just prior to its collapse (Rose and Kulka 1999).

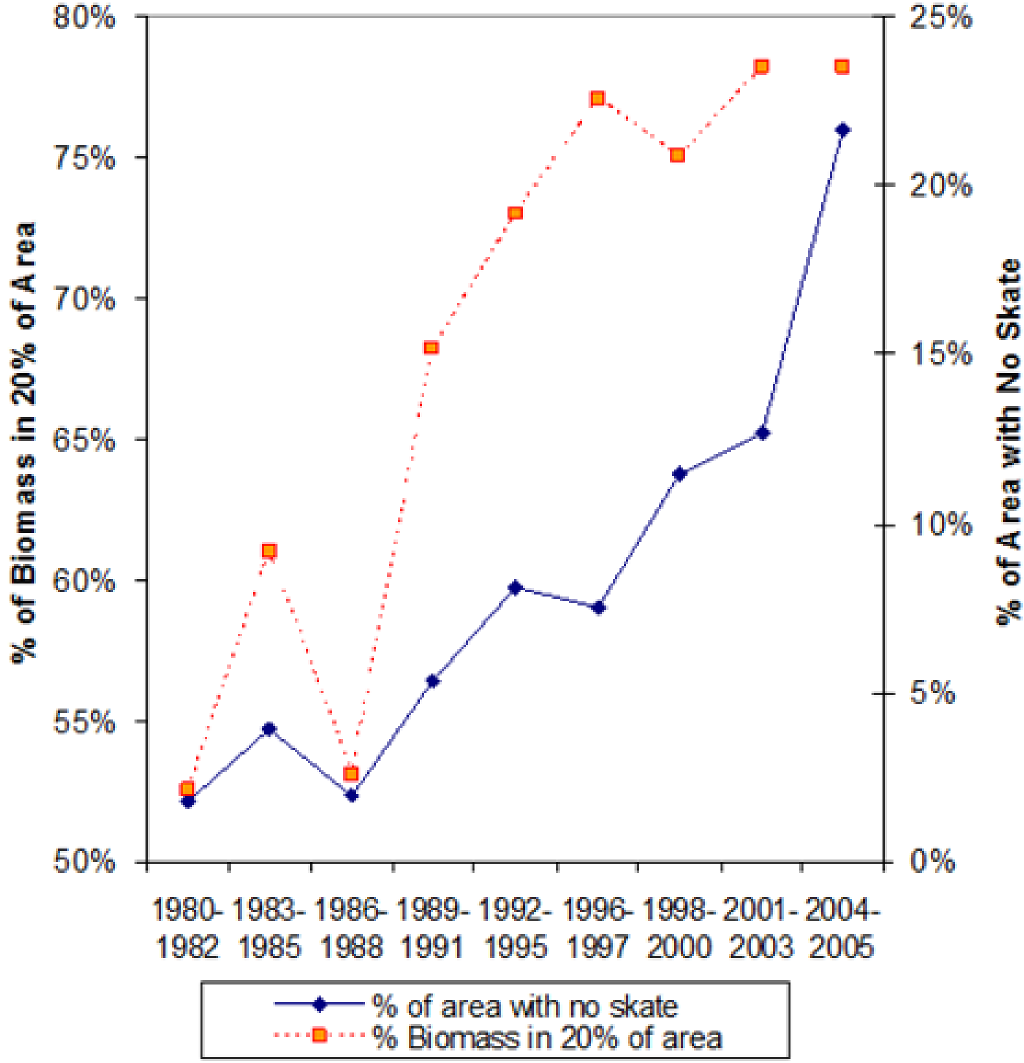

Figure 6. Changes in distribution, based on spring NL survey data, 1980-2005: Left: percent of the area on the Grand Banks without Thorny Skate (solid blue line), and percent of biomass contained within the area on the southern Grand Banks constituting 20% of the total distribution on the Grand Banks (dotted orange line). (After Kulka *et al*. 2006a).

Area of occupancy (AO) was examined from 1978-2010, when the areas were surveyed relatively consistently, based on index strata. Survey details can be found in Kulka *et al*. (2006b). AO in Div. 2J3K, Labrador Shelf and northeast Newfoundland Shelf and 3Ps, St. Pierre Bank, was relatively stable (Figure 7, upper panel) but declined on the Grand Banks (Div. 3LNO) from 1978 to 1996, and has been stable since (Figure 7, upper panel). Within the entire area (Div. 2J3KLNOPs), AO declined from 100,000 km^2 in the late 1970s to 76,000 km^2 in the mid-1990s and has been stable since (Figure 7, lower panel).

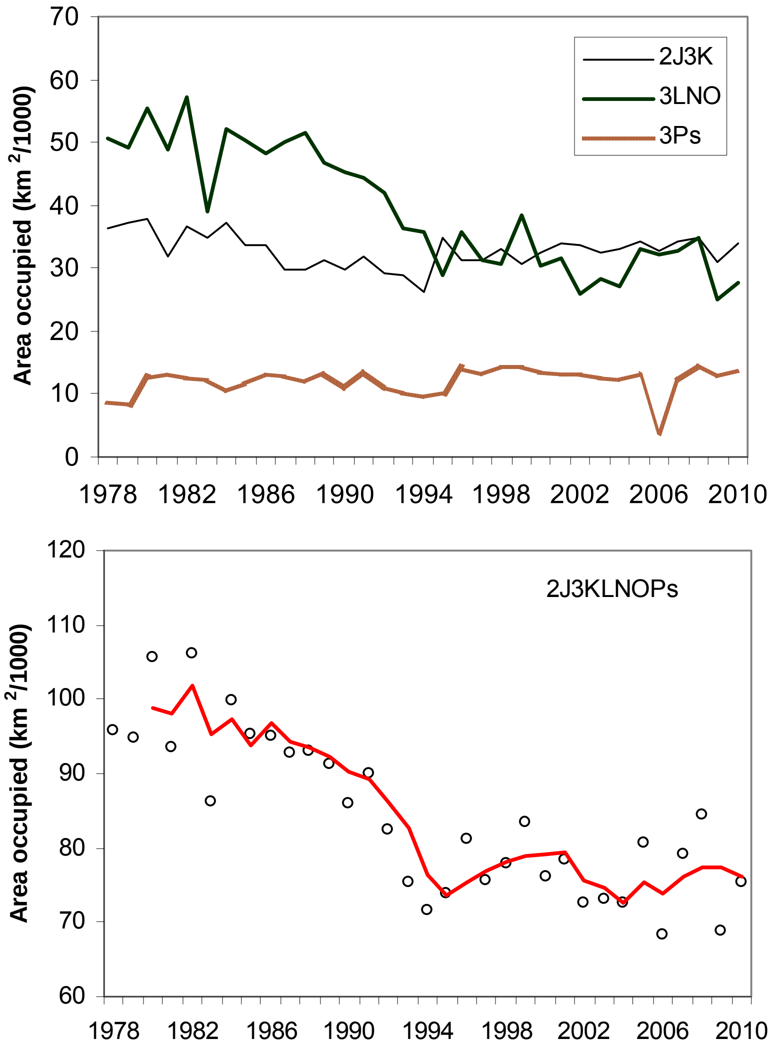

Figure 7. Area occupied (in thousands of km^2) in the NL Region surveys, in NAFO Div. 2J, 3K, (fall surveys) and 3L, 3N, 3O and 3Ps (spring surveys). Upper graph shows the difference in trends among areas, 2J3K – Southern Labrador Shelf and northeast Newfoundland Shelf, 3LNO – Grand Banks and 3Ps – St. Pierre Bank. Lower graph is for all areas combined. The red line is a 3-year running average.

Northern Gulf of St. Lawrence

Since 1990, distribution has increased and now covers most of the surveyed area (Figure 8a). AO doubled in the northern Gulf of St. Lawrence, from an average of 42,300 km^2 from 1991-1993 to 90,400 km^2 from 2008-2010 (Figure 8b).

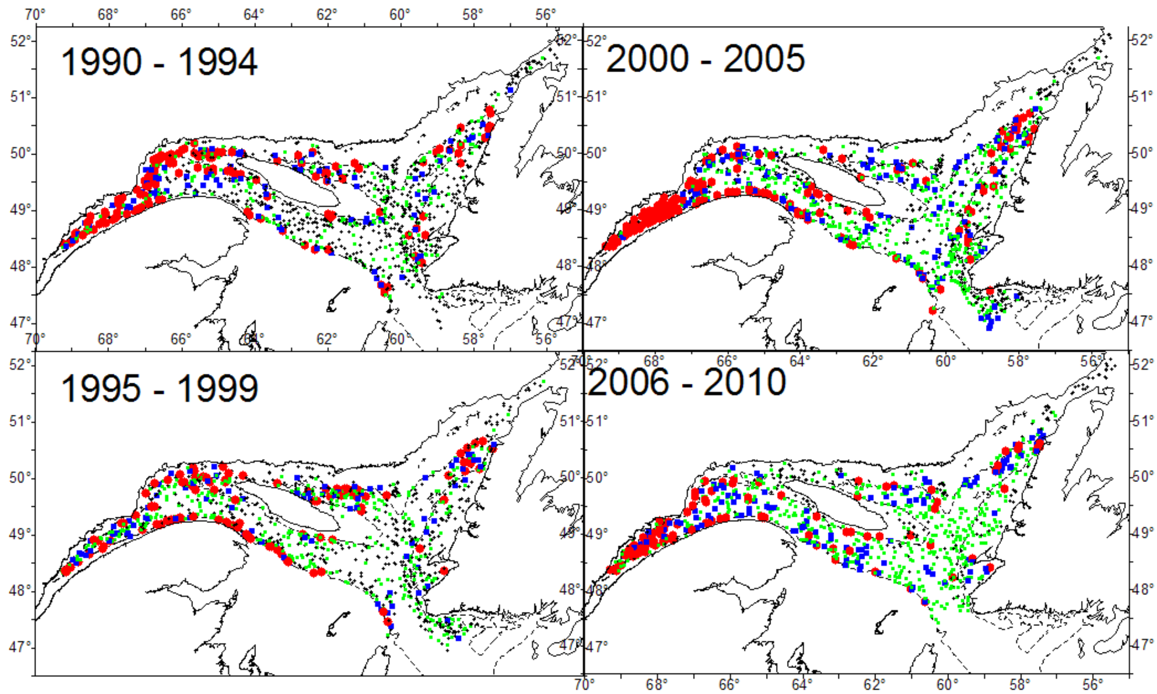

Figure 8a. Distribution of Thorny Skate catches (number per tow) in the northern Gulf of St. Lawrence (Div. 4RS) August survey series. Catch symbols: + = 0; green < 10; blue 10-20; red > 20.

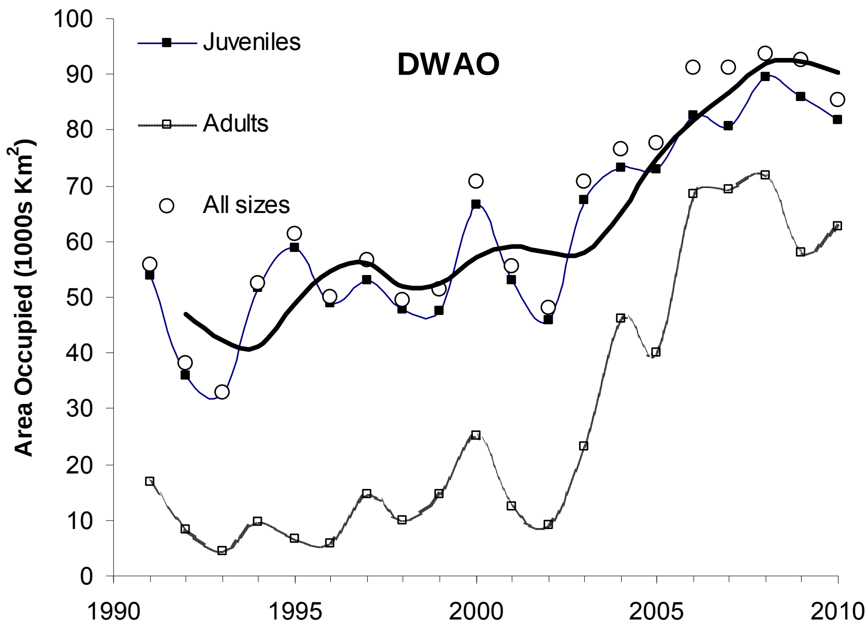

Figure 8b. Area occupied in the northern Gulf of St. Lawrence (Div. 4RS) from the Quebec Region surveys. The thick solid line for all sizes is a 3-year running average. Adults are defined as >= 53 cm (figure provided by DFO Quebec Region).

Southern Gulf of St. Lawrence

In the southern Gulf of St. Lawrence, the fish were distributed more evenly throughout the surveyed area in the 1970s except in the central Magdalen Shallows (Figure 9). By 2000, they were almost exclusively found in high concentrations along the Laurentian Channel edge (Figure 9) (Swain *et al.* 2011). This reduction was most evident in mature individuals (Figure 10), which underwent a steady decline in AO, now occupying 10% of the area at the start of the series (Figure 11). AO of juveniles was variable, reaching a maximum in the early 1990s.

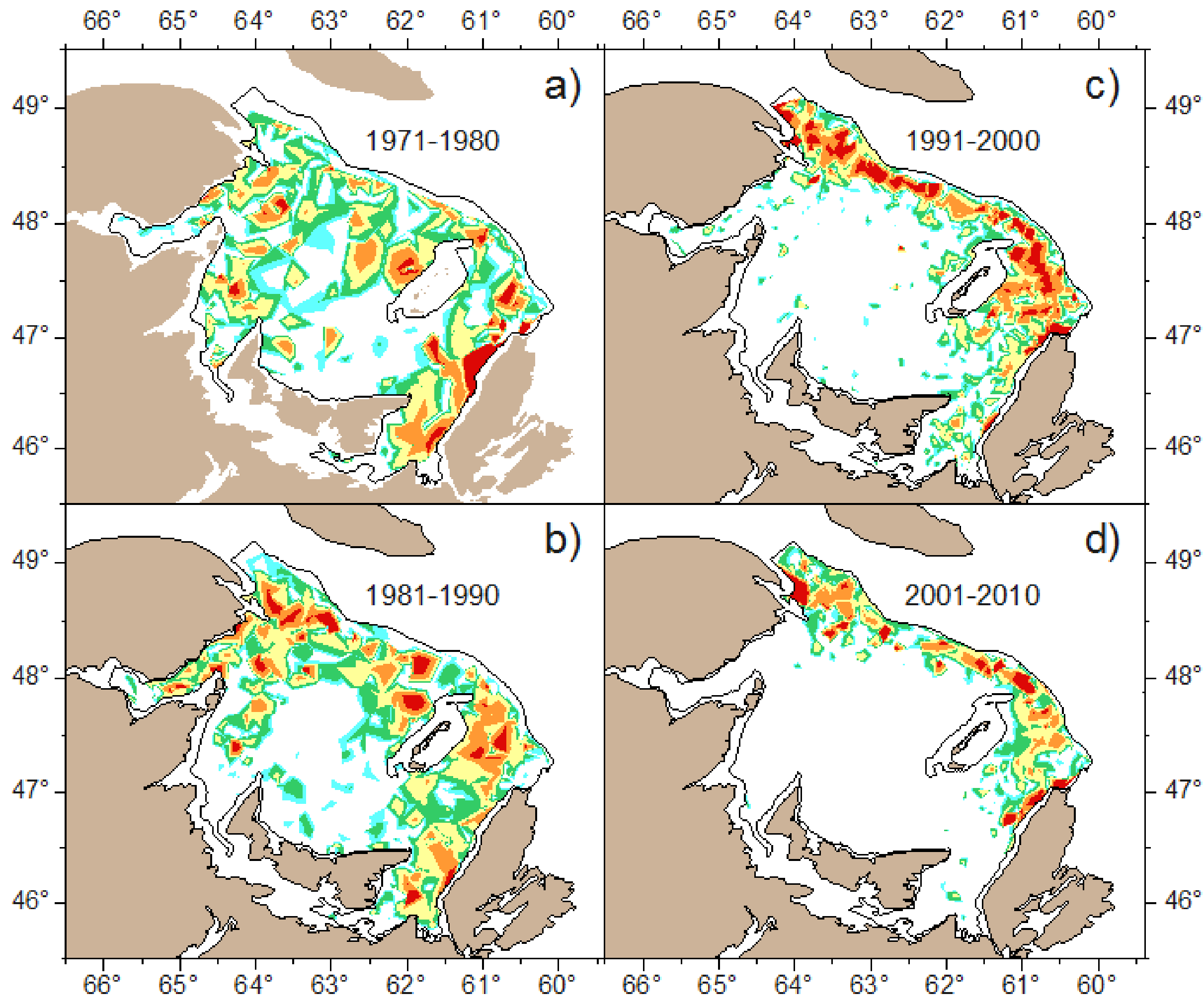

Figure 9. Distribution of Thorny Skate in the southern Gulf of St. Lawrence (Div. 4T), all sizes combined. Red areas depict the highest density, green lowest (after Swain 2011).

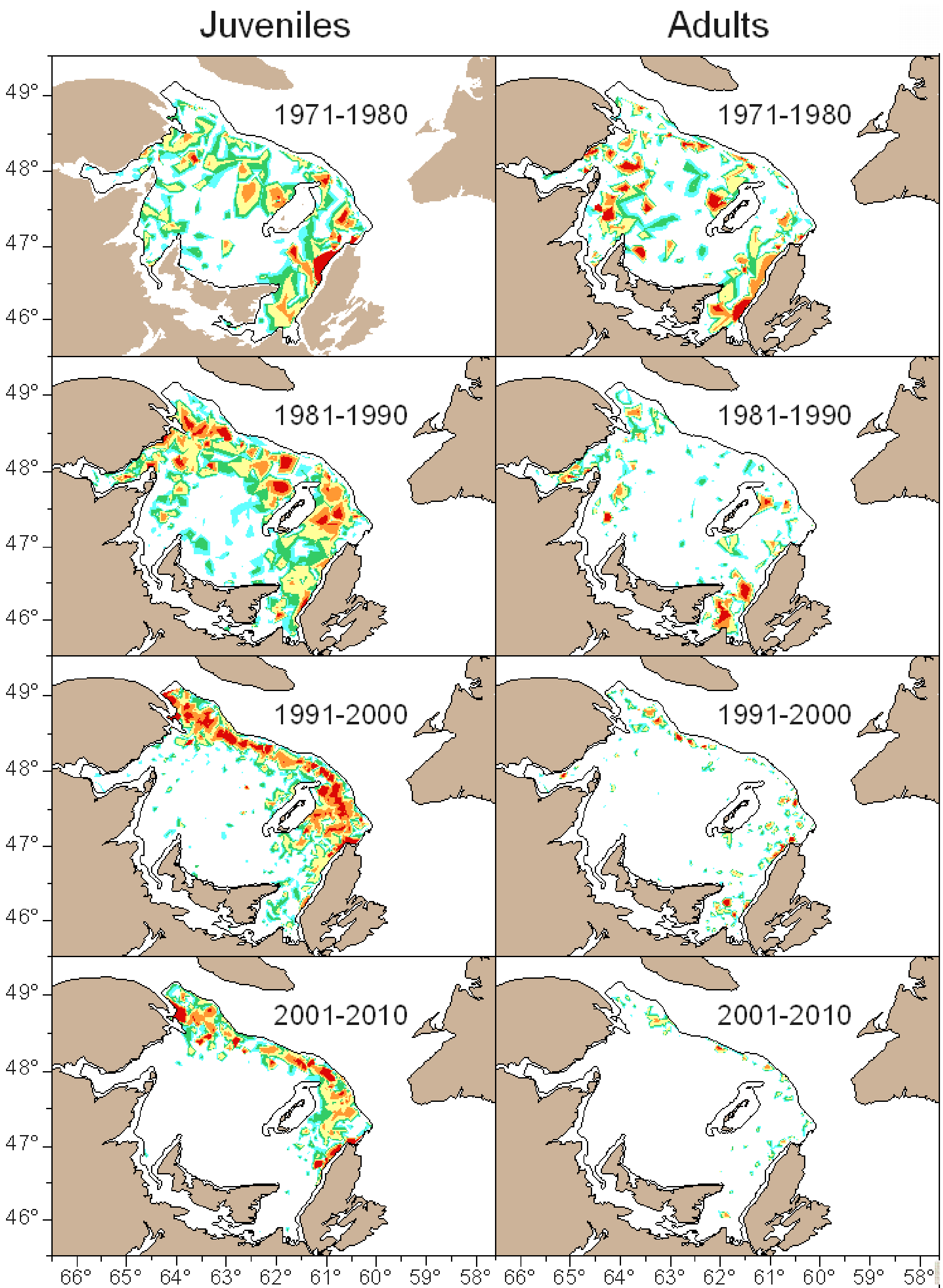

Figure 10. Distribution of Thorny Skate in the southern Gulf of St. Lawrence (Div. 4T), including juveniles and adults (after Swain 2011).

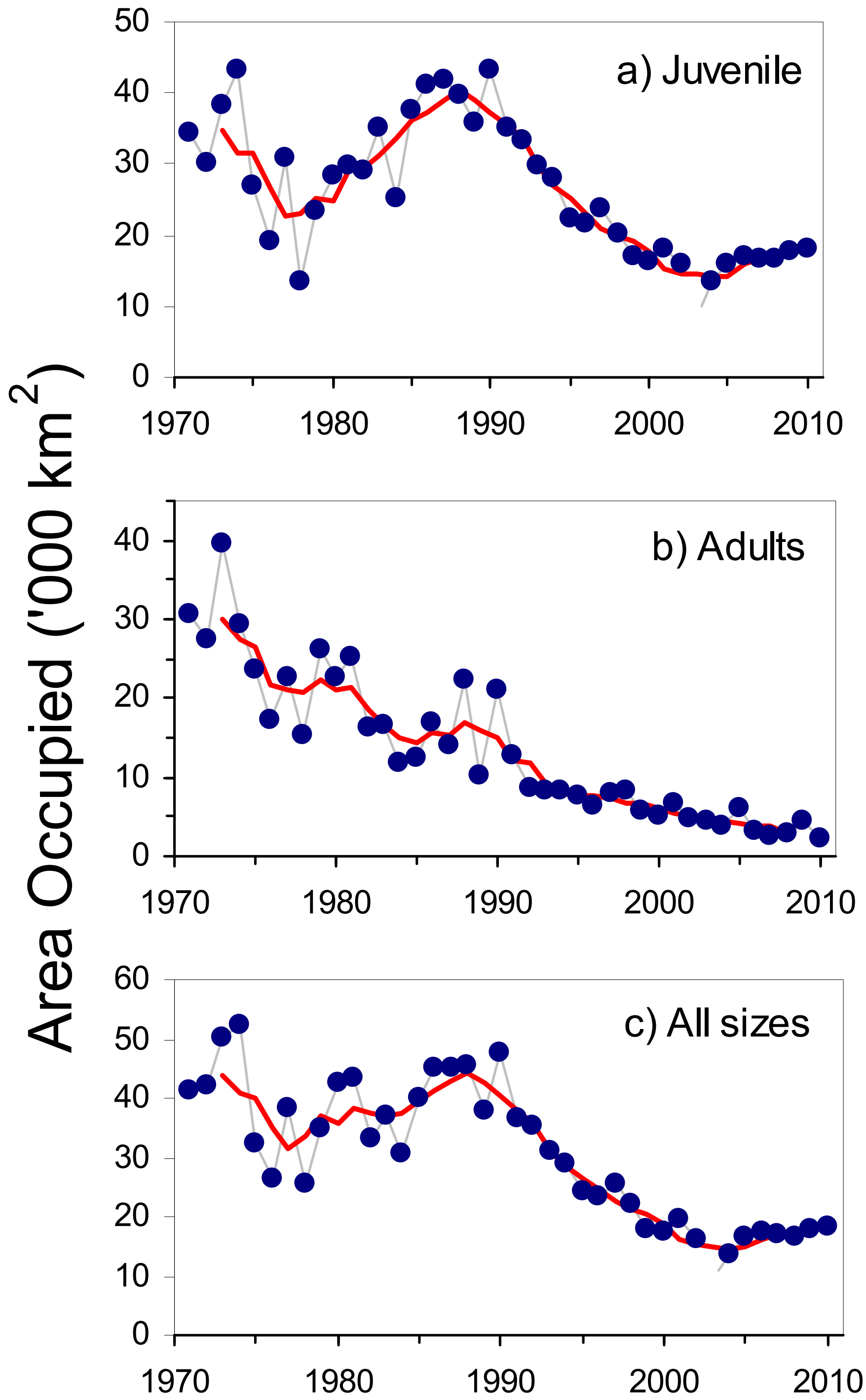

Figure 11. Area of occupancy of Thorny Skate in the southern Gulf of St. Lawrence, including juveniles, adults and all sizes. The red line represents the 3-year running average.

Swain *et al.* (2011) examined the following hypotheses for the causes of this change in distribution: 1) an earlier offshore migration to overwintering grounds in the deep waters of the Laurentian Channel in recent years; 2) mortality in the habitat that has been vacated; 3) density-dependent habitat selection; and 4) a shift in distribution in response to the prolonged cooling of the Magdalen Shallows in the 1990s. They concluded that the first two hypotheses were more feasible.

Scotian Shelf

Thorny Skate occur throughout the Scotian Shelf with higher concentrations on the eastern shelf and within the lower Bay of Fundy. Over time, these areas continued to support the highest density of fish, but their distribution decreased (Figure 12). By 2000-2010, concentrations were fragmented and some areas were nearly devoid of fish. One survey, which covered both the Scotian Shelf and the Grand Banks with the same gear, showed that concentrations on the Grand Banks were more dense than those on the Scotian Shelf (Figure 13). This supports the conclusion that the fish are at their highest density on the Grand Banks.

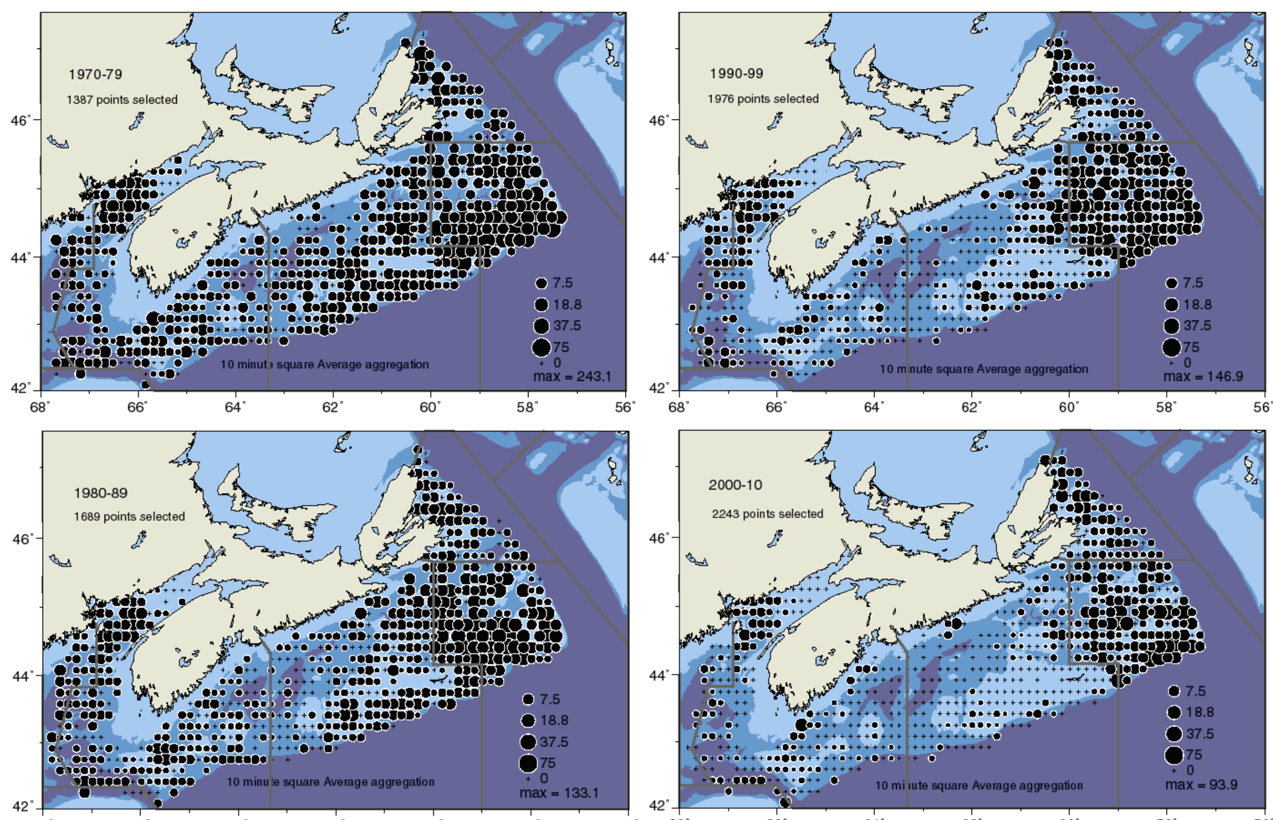

Figure 12. Distribution of Thorny Skate on the Scotian Shelf and in the Bay of Fundy by decade based on the summer research vessel surveys (after Simon *et al.* 2012).

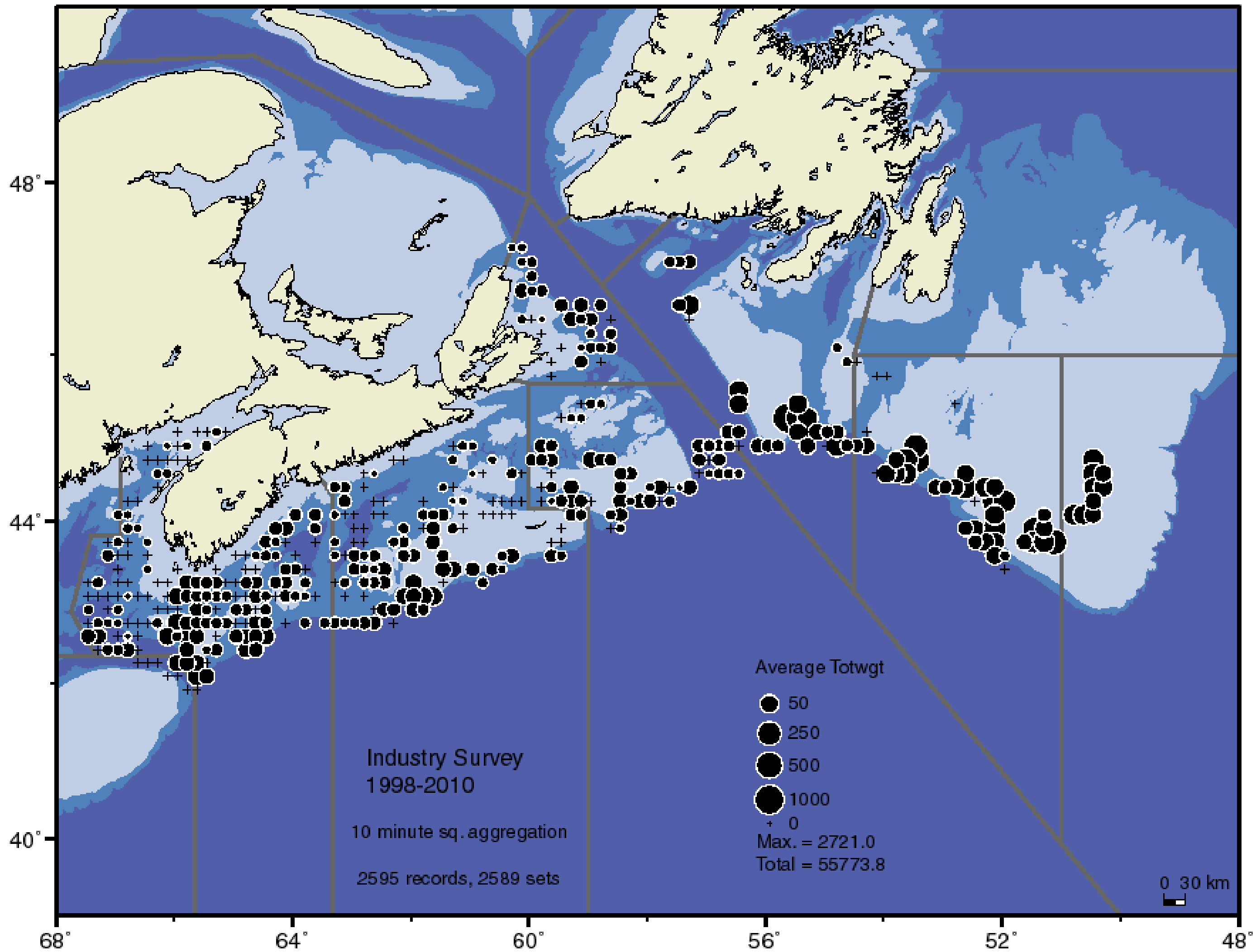

Figure 13. Distribution of Thorny Skate as indicated by the fixed survey sets of the Halibut Industry Survey, 1998-2010 (after Simon *et al.* 2012)).

AO of Thorny Skate on the Scotian Shelf has declined steadily over the time series, by 58% since 1970-1972, and 66% since 1974-1976 (Figure 14). The decline ceased in 2000.

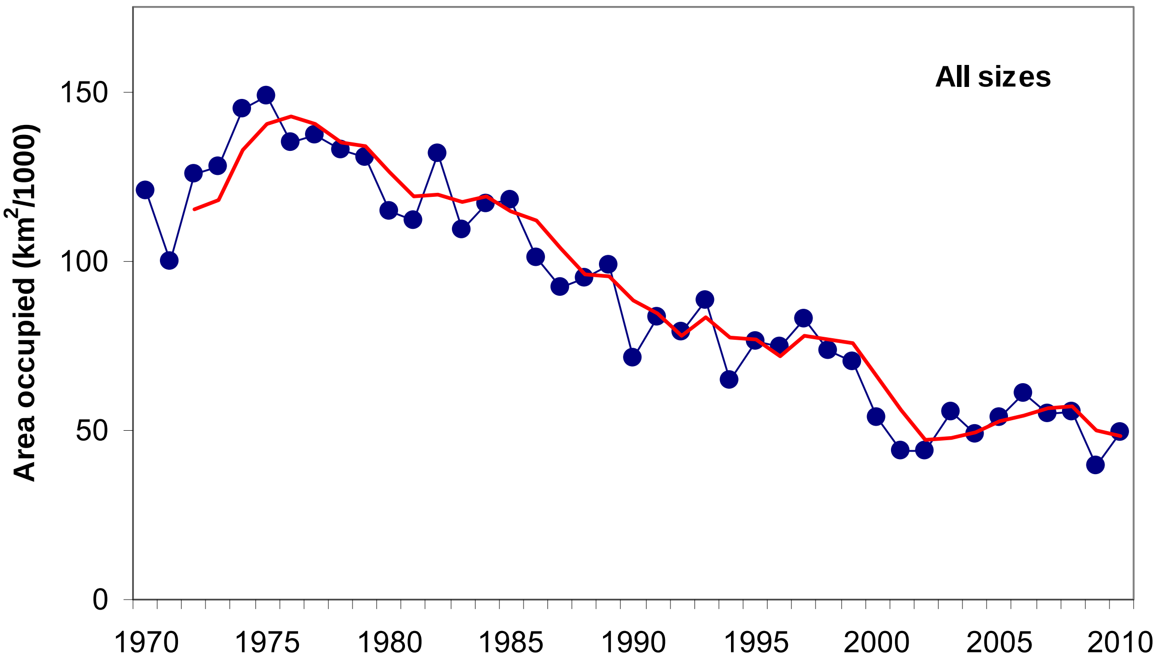

Figure 14. Area of occupancy of Thorny Skate on the Scotian Shelf based on the summer surveys. The red line represents the 3-year running average.

Georges Bank

Within the Canadian portion of Georges Bank, Thorny Skate are concentrated in deeper waters along the outer edge of the bank and are contiguous with fish in USA waters (Figure 15). On Georges Bank (Canada), AO has fluctuated and is about 40% lower in 2008-2010 compared to 1987-1989.

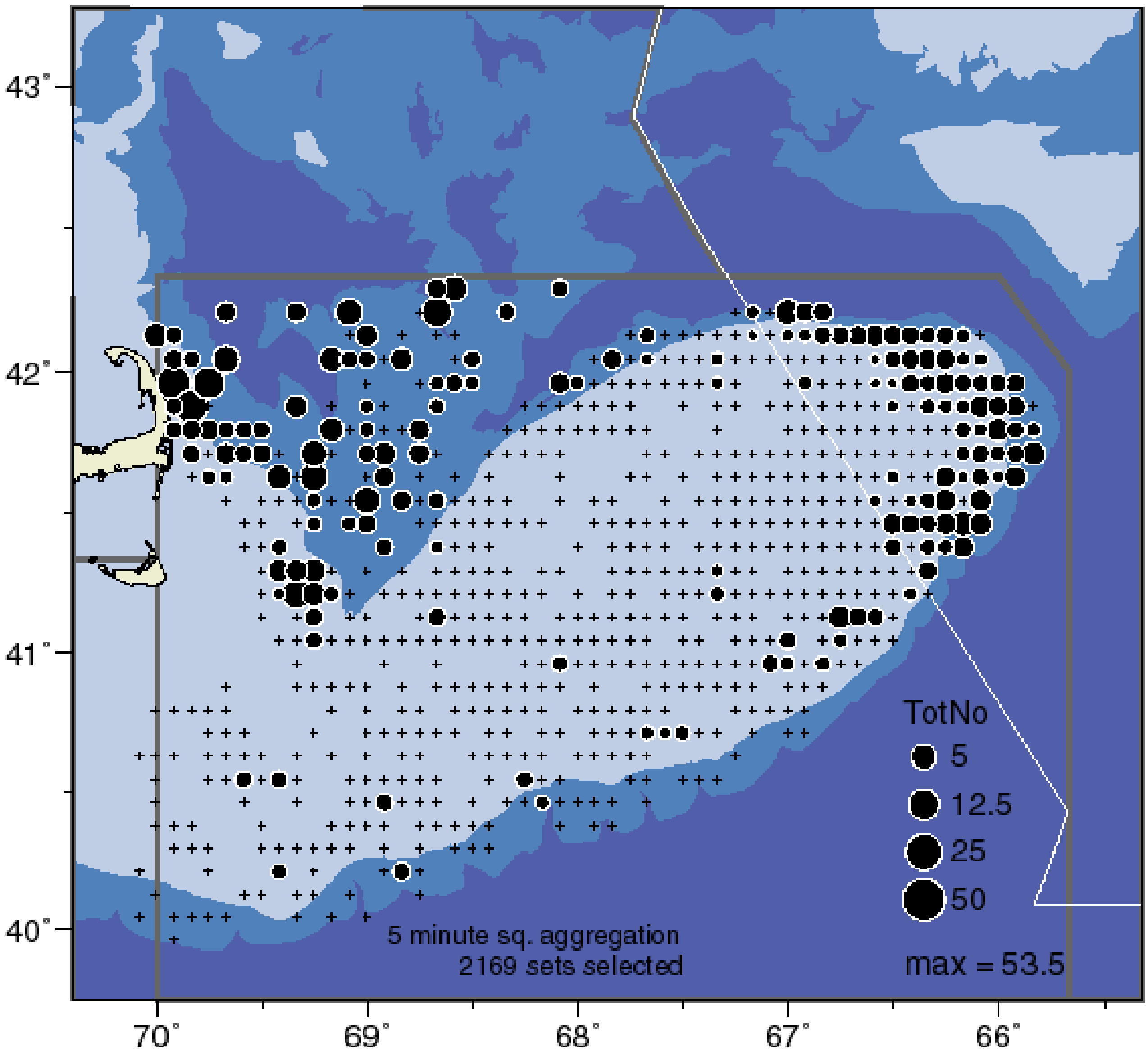

Figure 15a. Distribution of Thorny Skate, as survey number per tow, from the Georges Bank research vessel surveys from 1986-2010. The white line denotes the Canada-US boundary, with the Canadian portion to the right of this line. After Simon *et al.* (2012).

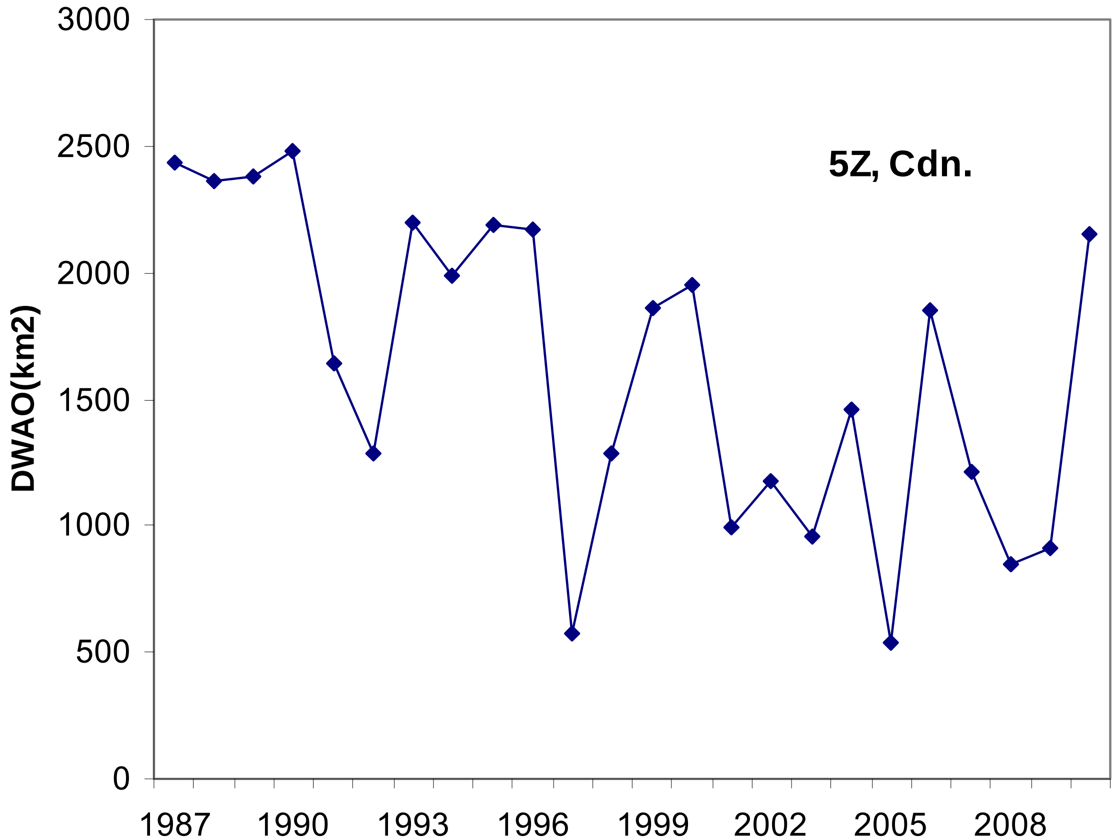

Figure 15b. Area of occupancy of Thorny Skate on the Georges Bank based on the summer surveys (after Simon *et al.* 2012).

<u>All Canadian waters combined</u>

A current estimate of AO for all areas surveyed off Canada (average for 2007-2009) is approximately 290,000 km^2, about 90,000 km^2 less than in the 1970s. Most of the decline occurred prior to 1991 and mainly on the Scotian Shelf.

<u>Extent of occurrence</u>

Reliable estimates of extent of occurrence are not available but would certainly be well above thresholds used by COSEWIC to determine species status. By definition extent of occurrence will be larger than the area of occupancy and smaller than the total area where Thorny Skate has been observed in Canadian waters since the 1970s, approximately 2 197 307 km^2, excluding land (Figure 38).

HABITAT

Habitat Requirements

Thorny Skate are found over most shelf waters off Canada in 18-1400 m, occupying a broad array of substrate types including sand, broken shell, gravel, pebbles and soft mud (Collette and Klein-MacPhee 2002). Since they inhabit nearly all shelf waters within their range, the concept of critical habitat has limited applicability. Packer *et al*. (2003) summarized information on geographic range and habitat in USA waters at the southern end of the range. The following describes habitat associations within various parts of the Canadian range.

NL Region

On the Labrador Shelf to the Grand Banks, 88% of Thorny Skates are between 50 m and 350 m (Figure 16), but they can occur as deep as 1400 m. Distribution by depth is similar among seasons but varies by area, peaking at a shallower and wider depth range on the Grand Banks compared to the northeast Newfoundland and Labrador Shelf (Figure 16). They are found at temperatures from -1.7°C to 11.4°C (nearly all the available temperature range) but 81% of the abundance occurs in 0° to 4°C (Colbourne and Kulka 2004). Distribution by temperature is similar among seasons (Figure 17). South of 49°N there are two peaks in abundance, one at 1-3° C and another at 6-9° C. North of Lat. 49°N distribution peaks at 1-3° C (Figure 17).

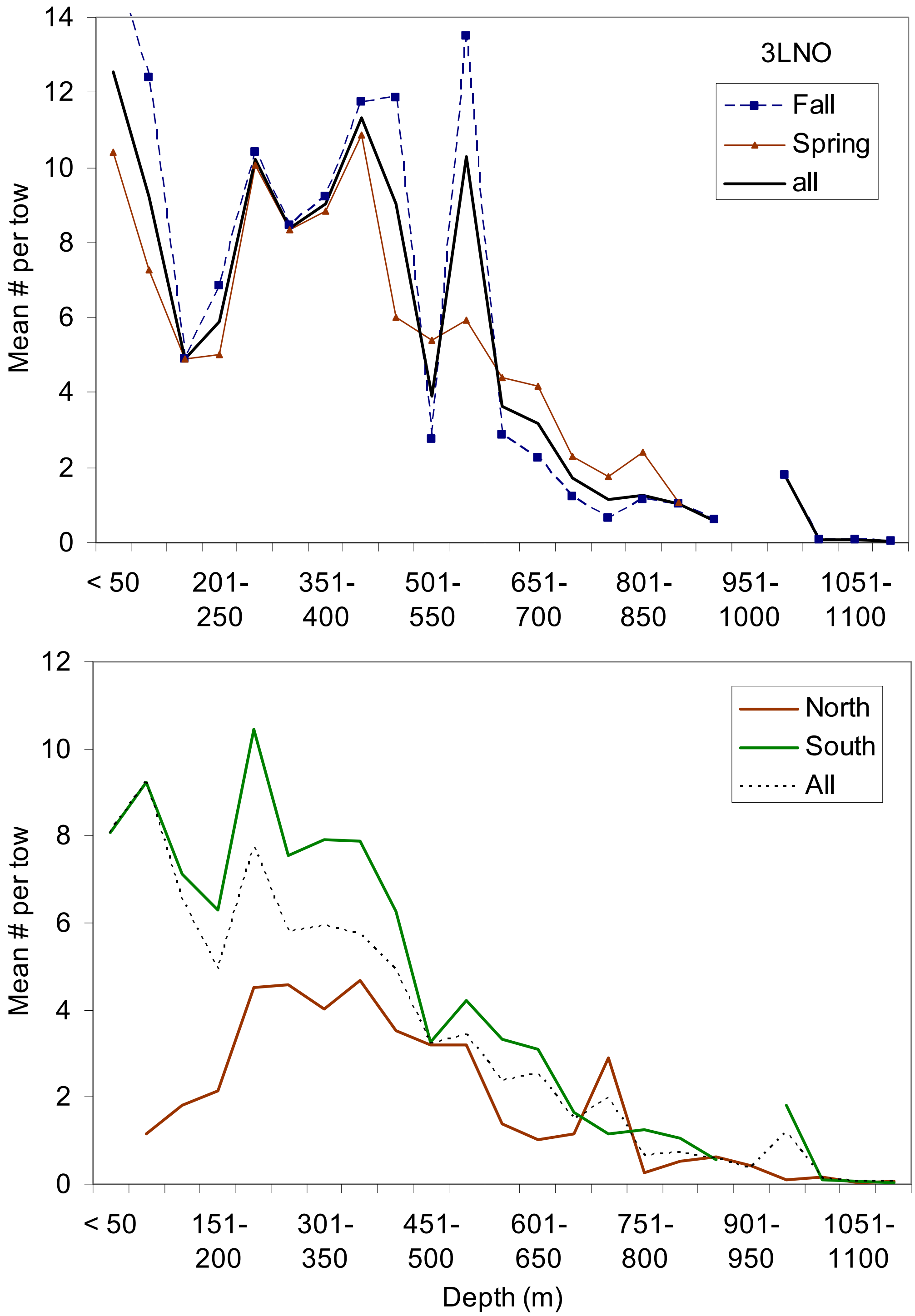

Figure 16. Depth distribution of Thorny Skate during 1971-2009. The upper panel compares data from spring and fall surveys in Div. 3LNO, the area where the two surveys overlap. The lower panel shows density of Thorny Skate by depth north of 49°N (the northeast Newfoundland and Labrador Shelf) and south of 49°N (the Grand Banks).

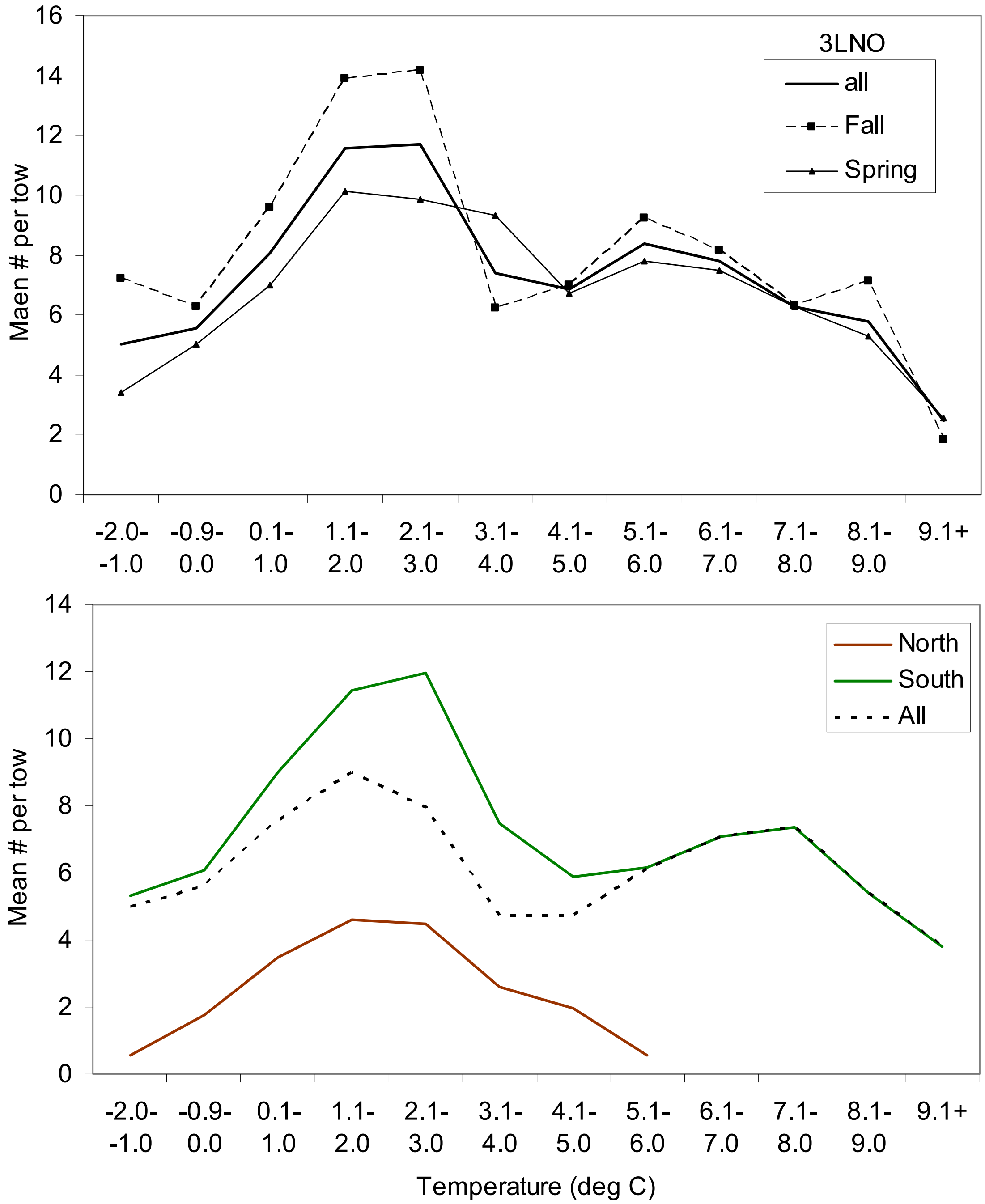

Figure 17. Distribution of Thorny Skate with respect to temperature during 1971-2009. The upper panel compares data from spring vs. fall surveys in Div. 3LNO, the area where the two surveys overlap. The lower panel shows density of Thorny Skate by depth north of 49°N (the northeast Newfoundland and Labrador Shelf) and south of 49 °N (the Grand Banks).

Quebec Region

For the northern Gulf of St. Lawrence, densities were greatest at approximately 200 m (Figure 18). Temperatures at these depths have generally been steady near 5.5^o C since the mid-1970s, nearly a degree warmer than in the 1950s to mid-1960s (Dufour *et al*. 2010).

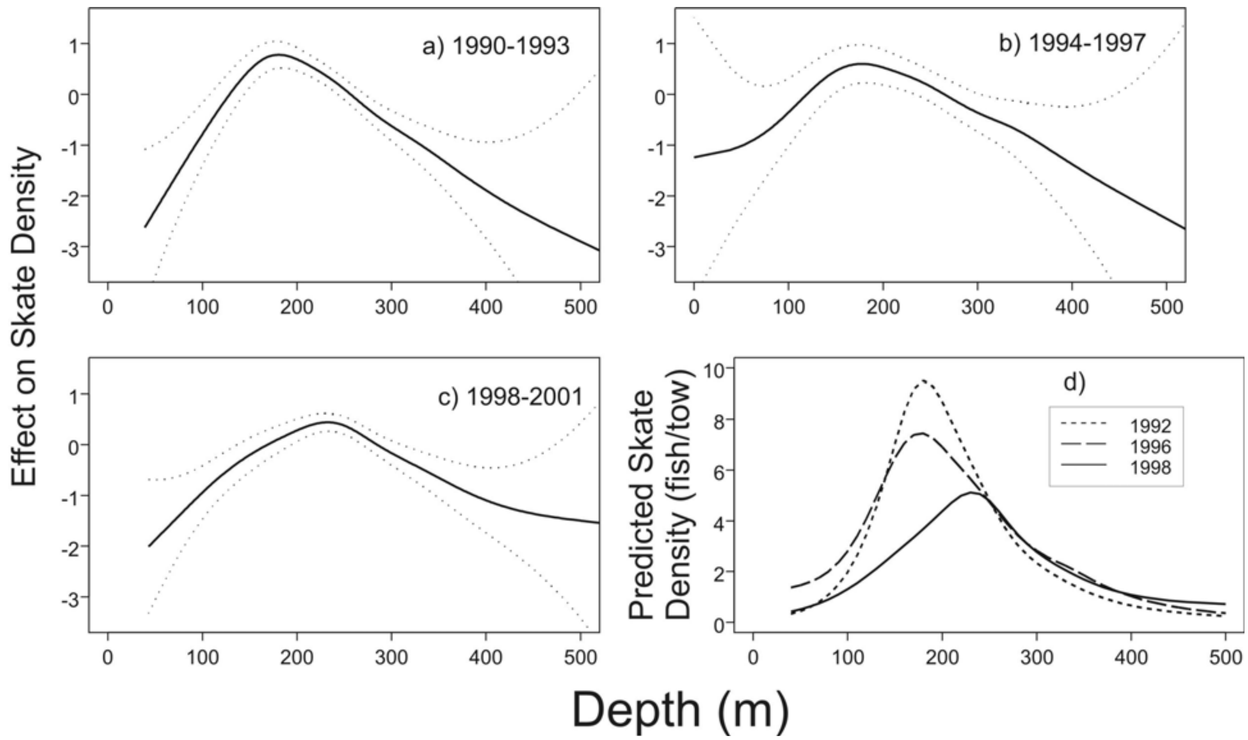

Figure 18. Relationship between depth and local density of Thorny Skate in the August surveys of the northern Gulf of St. Lawrence (after Swain *et al*. 2011). Panels a-c: relationship with depth (on a loge scale) for three time periods. The solid line shows the predicted relationship, and the dotted lines are ±2 SE. Note that models included an effect of year not shown in these panels. Panel d is the predicted density of Thorny Skate for a selected year in each time period. The density in the selected year was near the average for the period.

Gulf Region

In the southern Gulf of St. Lawrence, Thorny Skate prefer water from 0°C to 5°C and show a density-dependent temperature distribution, found in warmer waters when biomass is low. A change in habitat association has accompanied the recent contraction in distribution in the southern Gulf (Swain and Benoît 2006, Swain *et al.* 2011). Thorny Skate were most often found in < 100 m depth until the mid-1990s but have more recently occupied warmer, deeper waters (Figure 19).

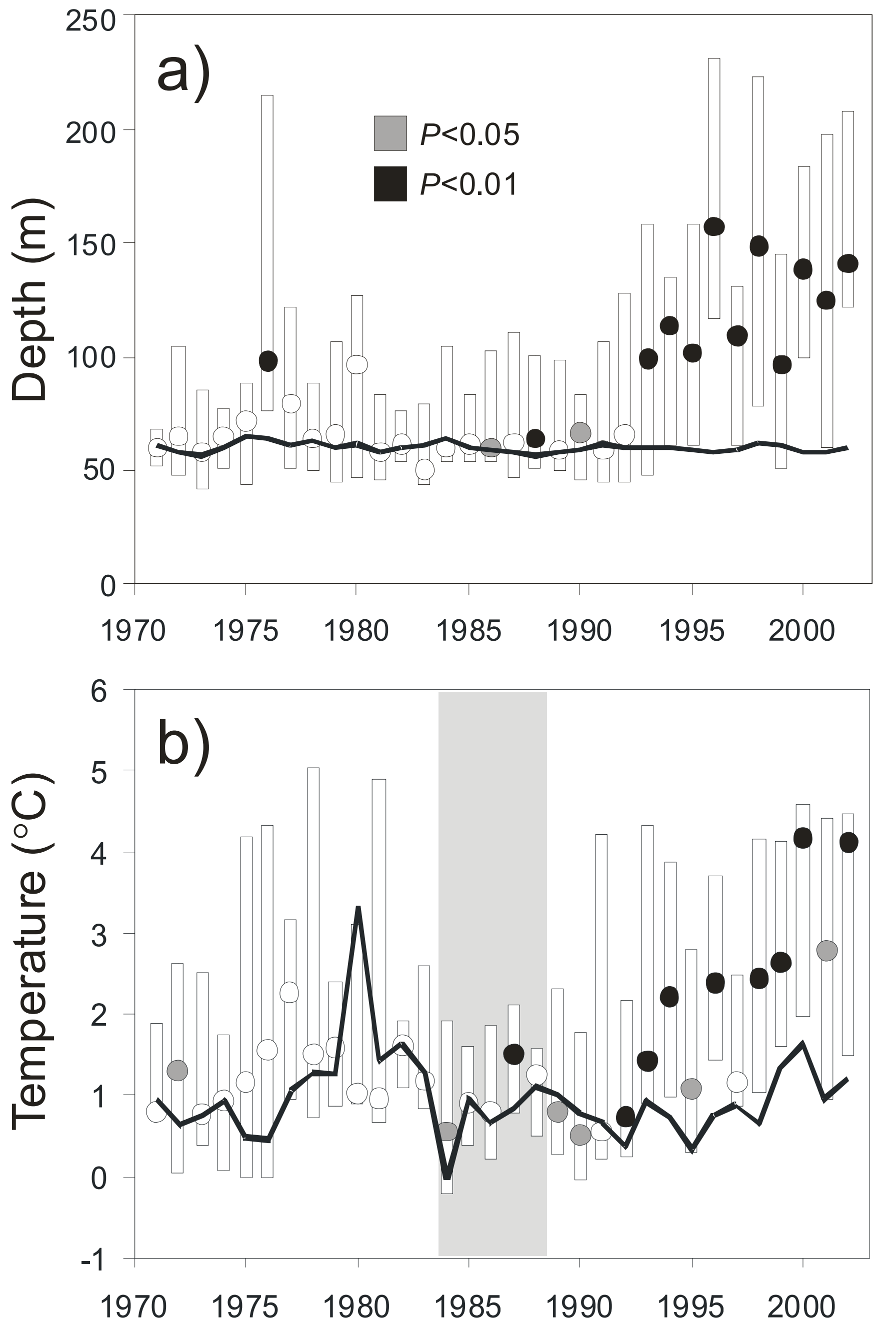

Figure 19. Associations of Thorny Skate with *a*) depth and *b*) temperature in September in the southern Gulf of St. Lawrence (after Swain *et al.* 2011). The line shows the median depth or temperature of potential habitats in the sampled area. Circles show the median depth or temperature occupied by Thorny Skate. Bars show the 25th to 75th percentiles of occupied depths or temperatures. Shaded circles indicate a significant association between skates and depth or temperature. Near-bottom temperatures were not available for depths greater than 155 m in the shaded years in panel *b* (1984-1988).

Swain *et al.* (2011) suggested that the shift in distribution toward the margin of the Laurentian Channel reduced availability to the survey, which would bias recent estimates of relative abundance downward. However, analyses on the depth distribution (Figure 20) suggest that availability to the southern Gulf survey does not appear to have declined in recent years. In the 1990s and 2000s, peak densities of skate occurred at depths between 150 and 250 m (Figures 20 and 21), well inside the survey area.

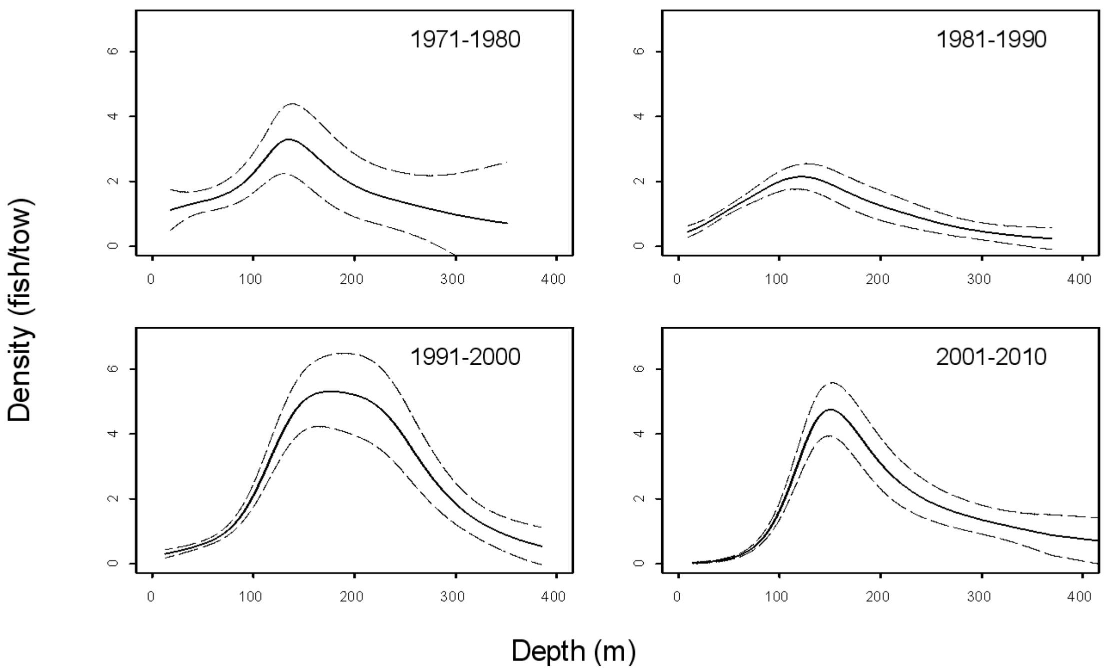

Figure 20. Effect of depth on the local density of Thorny Skate of all sizes in the southern Gulf of St. Lawrence in September (after Swain *et al.* 2011). Solid line is the predicted density and dashed lines are ± 2 SE.

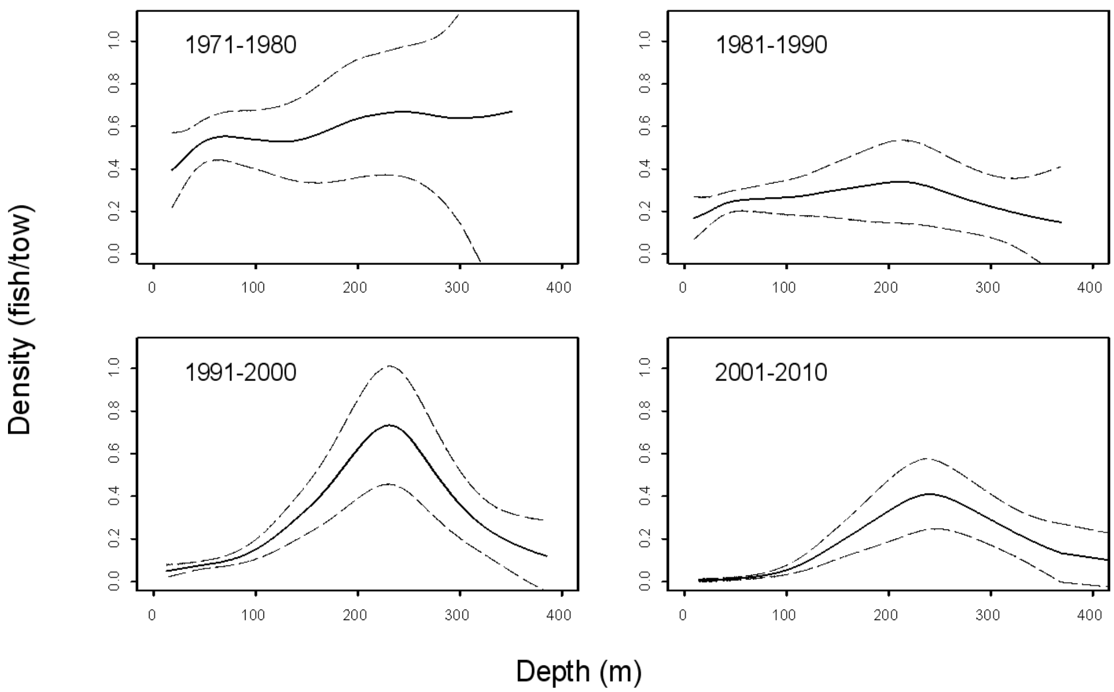

Figure 21. Effect of depth on the local density of adult Thorny Skate in the southern Gulf of St. Lawrence in September (after Swain *et al.* 2011). Solid line is the predicted density and dashed lines are ± 2 SE.

Maritimes Region

Cumulative estimates of abundance of Thorny Skate on the Scotian Shelf were compared to the cumulative stratified estimates of depth, temperature, and salinity from the summer research vessel surveys. Thorny Skate were found in slightly shallower depths than the average sampled during the surveys (Figure 22, Simon *et al*. 2012). They were also found in cooler and less saline waters than the survey averages. This indicates that conditions in parts of the Scotian Shelf, particularly the western areas, are warmer than the preferred temperature range of Thorny Skate. Densities are lower in this area and those areas to the south in USA waters where warmer conditions may be restrictive.

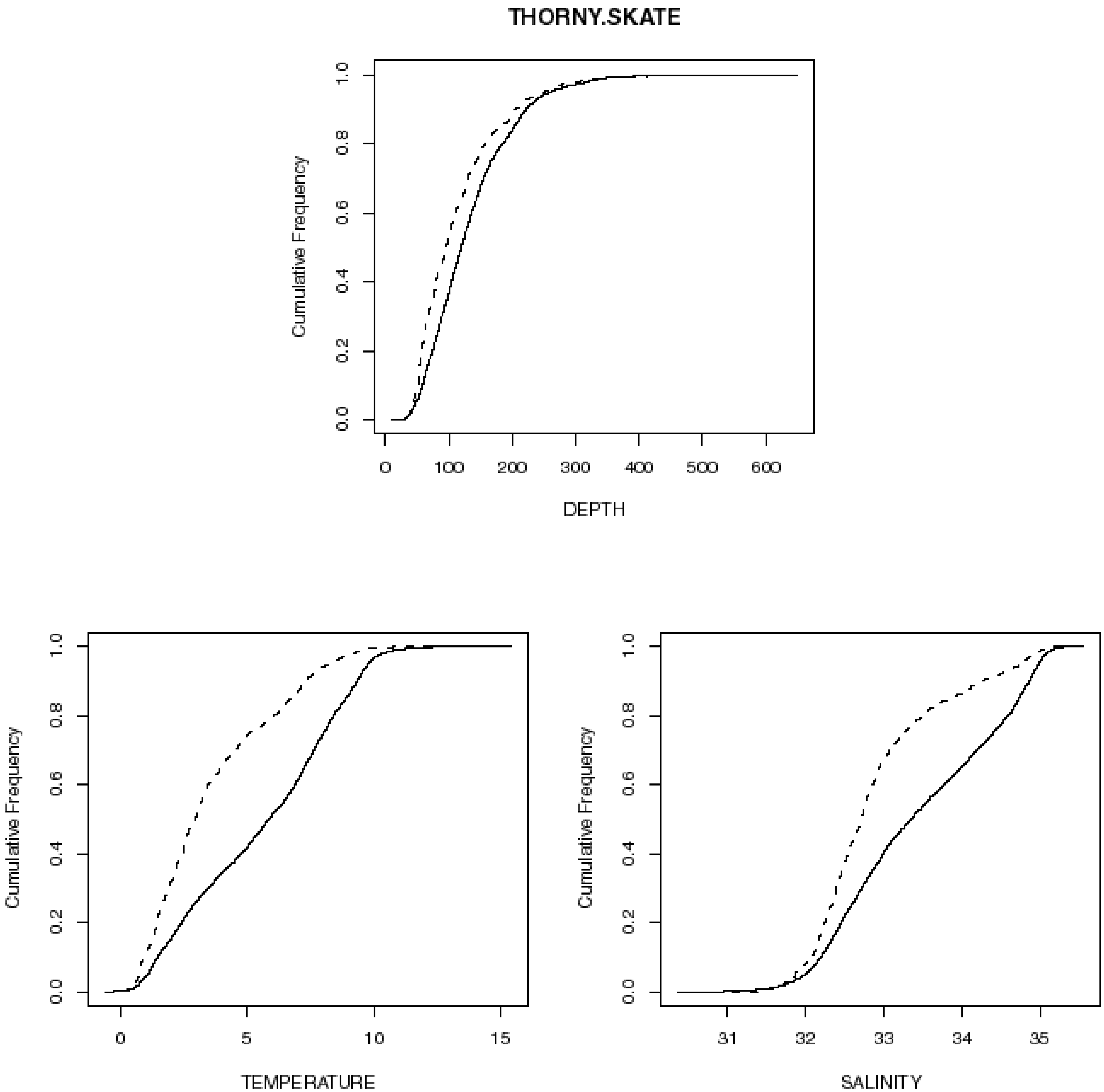

Figure 22. Cumulative stratified abundance of Thorny Skate compared to the cumulative stratified depth, temperature and salinity from the summer research vessel surveys on the Scotian Shelf. The solid line is the survey estimate and the dashed line is the estimate for Thorny Skate (after Simon *et al.* 2012).

Habitat Trends

Long-term temperature conditions at “Station 27” (0-175 m), just off St. John’s within the inshore branch of the Labrador Current, were generally warmer than average from 1950 until the early 1970s (Figure 23, after Colbourne *et al*. 2010). Temperatures were below average from the early 1970s to the mid-1990s, and coldest during the early 1990s. In the 2000s, water temperatures progressively increased to a high in 2008 and remained above average in 2009-2010. The warmest bank areas encountered during the fall surveys during 1995-2005 (Figure 24) match the occurrence of Thorny Skate fairly well.

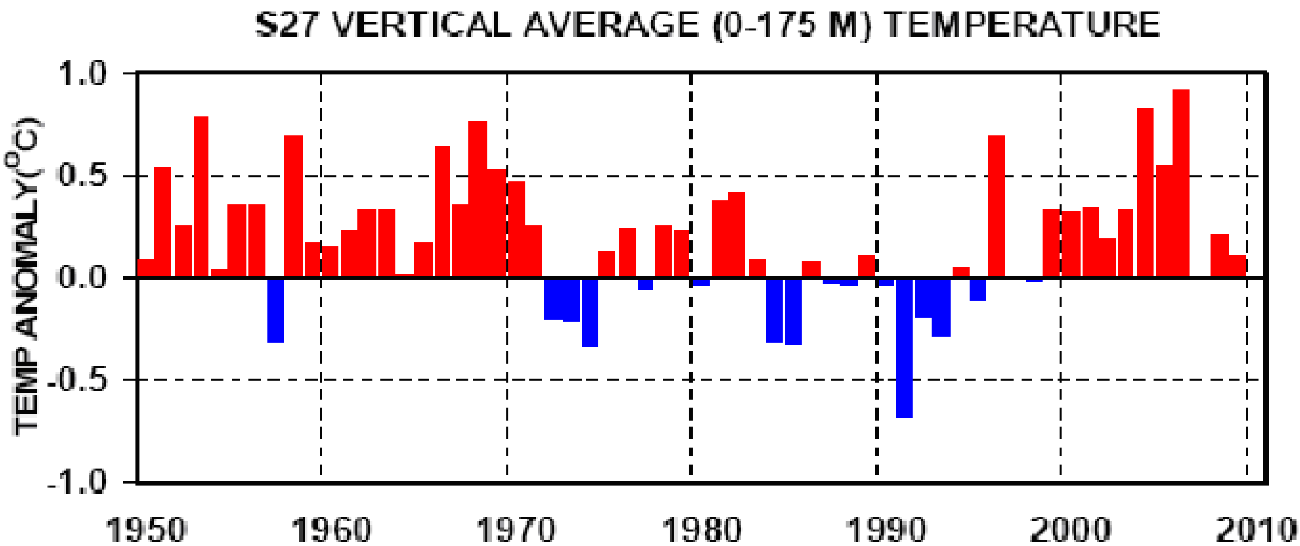

Figure 23. Long-term water temperature observations for the Grand Banks, Station “27” near the Avalon Peninsula, Newfoundland (after Colbourne *et al*. 2010).

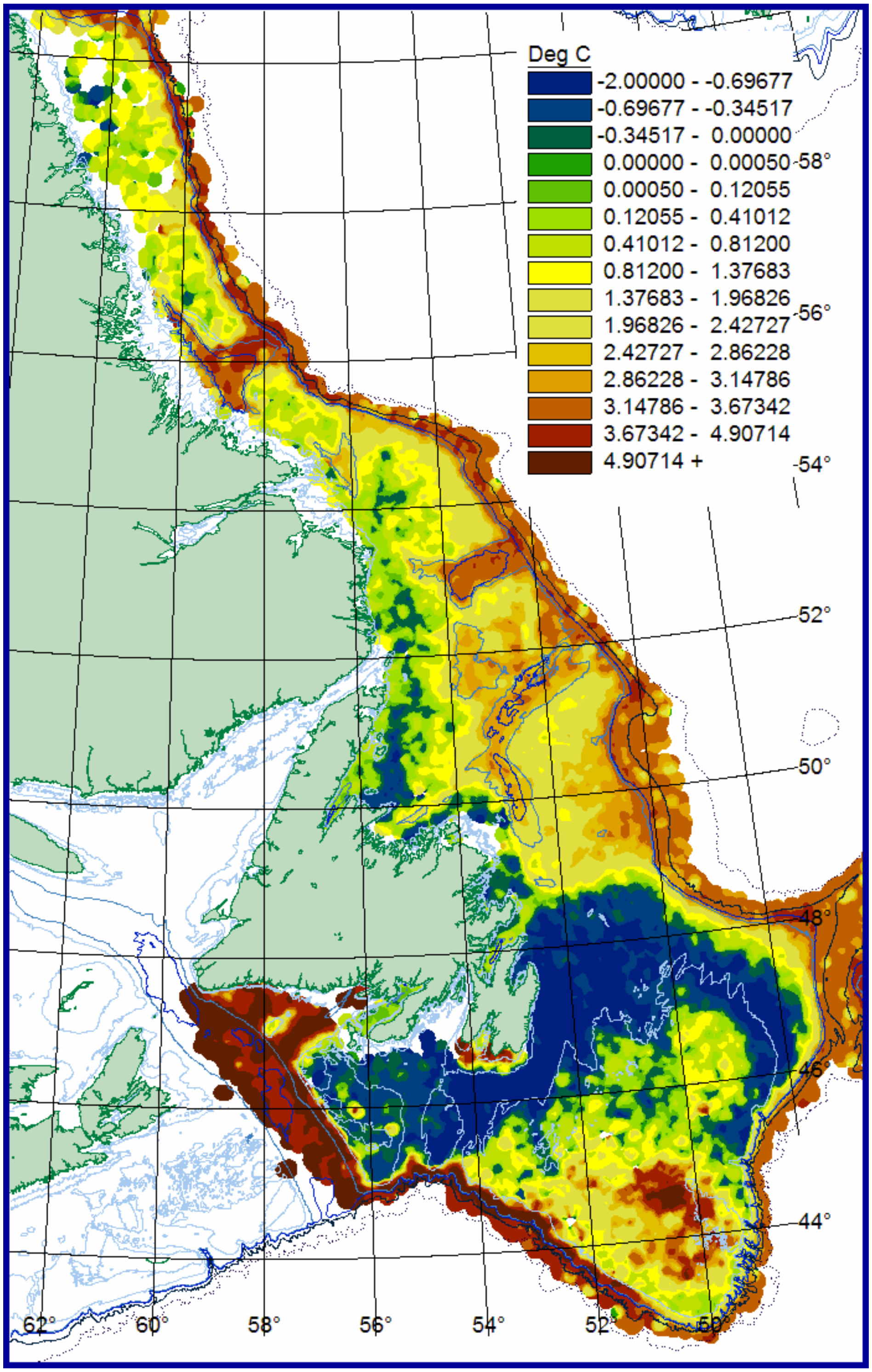

Figure 24. Bottom temperature averaged over 1995-2005 during Oct–Mar, brown areas are >2.4 ^{O} C (based on NL Region survey data).

Temperatures at 300 m, close to the depths at which Thorny Skate were distributed in the Gulf of St. Lawrence, have generally been steady near 5.5^o C since the mid-1970s, nearly a degree warmer than 1950s to mid-1960s (Dufour *et al*. 2010; Figure 25). Therefore, there is little evidence of temperature variability at depth during the period when the species was surveyed.

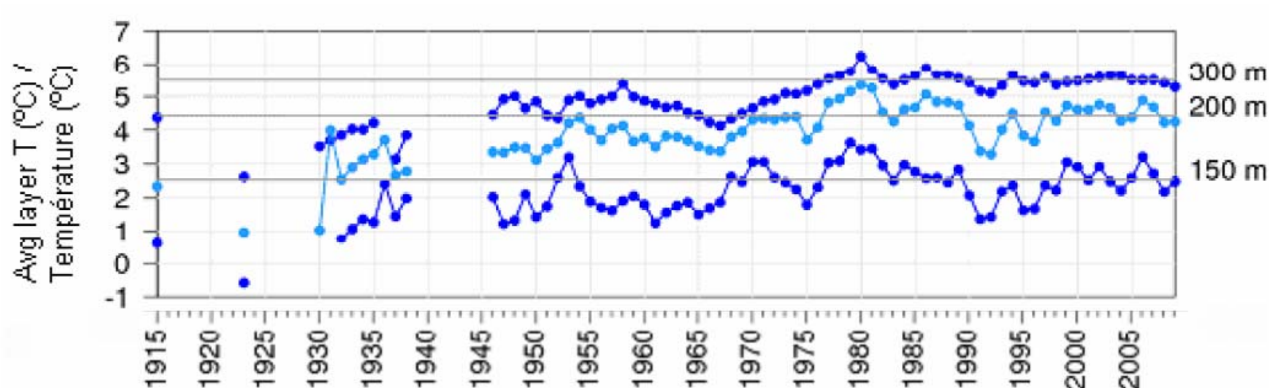

Figure 25. Long-term average water temperature for selected depths in the Gulf of St. Lawrence (after Dufour *et al*. 2010). The horizontal line is the 1971-2000 average.

Petrie and Pettipas (2010) examined long-term trends in temperature of various parts of the Scotian Shelf, Bay of Fundy and Georges Bank. Variation among areas is observed but a cooling period that occurred from the late 1970s to the early 1990s may have affected abundance, particularly if fisheries were also impacting abundance.

Habitat Protection/Ownership

The distribution of the Thorny Skate overlaps a number of closed areas and marine protected areas such as the "Gully" where regulations prohibit or restrict the disturbance, damage, destruction or removal of marine organisms. However, these areas represent only a tiny fraction of the distribution of the species in Canadian waters. Canada is presently considering portions of the Laurentian Channel as a Marine Protected Area. The Channel is an area concentration of Thorny Skate.

BIOLOGY

Maximum size, growth, size at maturity, and morphology are highly variable, affected by local conditions. There has been research on growth and reproduction in the Gulf of Maine (Sosobee 2005, Sulikowski *et al*. 2005a, 2005b), Scotian Shelf (McPhie and Campana 2009a and b) and the Grand Banks (Templeman 1987, Kulka *et al*. 2004), but significant knowledge gaps remain.

Life Cycle and Reproduction

Fish mature at a smaller size in colder areas such as northeast Newfoundland and Labrador shelves and the southern Gulf of St. Lawrence (where winter temperatures are near zero). The largest fish are on the southern Grand Banks (Kulka *et al.* 2004). However, some of the reported differences in size at maturity observed over its range may also relate to the manner in which maturity is determined.

Age and Growth

Skates have been aged using vertebrae (Gallagher *et al*. 2005, Gedamke *et al*. 2005, McEachran 1973, McPhie and Campana 2009a, Sulikowski *et al.* 2004, Sulikowski *et al*. 2005b, Tsang 2005a and 2005b) and with caudal thorns (Gallagher *et al*. 2002, Henderson *et al.* 2005) (Table 3). As there are no long-term age data, age-based analytical assessments have not been done for this species.

Estimates of maximum age on the Scotian Shelf range from 23 years (McPhie and Campana 2009a) to 20 years (Templeman 1984); a theoretical maximum age of 39 years was calculated by McPhie and Campana (2009b) but the oldest individual in this study was 19 years. In the Gulf of St. Lawrence, the maximum ages observed were 18 years for males and 22 years for females (Swain *et al*. 2011). Comparison of mean length-at-age of Thorny Skate in the southern Gulf to predicted lengths-at-age on the eastern Scotian Shelf, (McPhie and Campana 2009a), indicated that length-at-age is greater on the eastern Scotian Shelf than in the southern Gulf.

McPhie and Campana (2009a) suggested that Thorny Skate are a relatively slow-growing elasmobranch, with a growth coefficient on the Scotian Shelf of k = 0.07 (males and females combined). In the Gulf of Maine, Sulikowski *et al.* (2005b) indicated that female asymptotic length, L_{inf}, was 120 cm and the growth coefficient, k, was 0.13. However, the oldest skate in that study was 16 years and was considerably smaller (105 cm) than the calculated L_{inf}. Length of Thorny Skate was from 9 to 108 cm, but rarely >100 cm. Maximum size varied by area (Table 3) and was largest on the Grand Banks.

On the Grand Banks and Labrador Shelf, growth studies have not yet been published. However, maximum observed size of Thorny Skate on the Grand Banks (108 cm) and Gulf of Maine (105 cm) are larger than elsewhere and thus conditions in these areas appear to be optimal for growth (Table 3).

Reproduction

Templeman (1987) indicated that sexual maturity occurred at a smaller size on the northeast Newfoundland Shelf to West Greenland than on the Grand Banks (Table 3). Size at maturity also varies temporally. On the southeastern Grand Banks, the length at which 50% of individuals are mature, L_{50}, was 70 cm from the 1940s to the 1970s (Templeman 1987), whereas Del Rio and Junquera (2002) determined L_{50} to be 54-60 cm during 1997-2000. In the Gulf of St. Lawrence, age and length at 50% maturity were 12 yr and 50 cm for males and females. These results are similar to those of Templeman (1987), who reported L_{50} of 50-56 cm in the Gulf. On the Scotian Shelf, McPhie and Campana (2009b) reported an L_{50} more closely associated with the Gulf of St. Lawrence. They indicated that a 51 cm female corresponded to an age of 11 years.

Templeman (1987) determined that reproduction occurs year-round in waters off Atlantic Canada. Del Rio and Junquera (2001) indicated that peak spawning appears to occur in the fall and winter. McPhie and Campana (2009b) indicated that Thorny Skate egg case production averaged 41-56 per female per year on the Scotian Shelf. The New England Fishery Management Council (NEFMC) extrapolated data from a study by Parent *et al.* (2008) using captive skates and estimated the Thorny Skate's mean fecundity at 40.5 eggs per year, with a hatching success of 38% (i.e., roughly 15 surviving hatchlings per year).

Generation Time

Generation time, average age of parents of the current cohort calculated as:

$$G = A_m + 1/M$$

If a natural rate of mortality (M) of 0.2 is assumed (as is generally assumed for marine fish) and age at maturity (A_m) is 11 (McPhie and Campana 2009a, Simon *et al*. 2011) then the generation time is 16 years.

Predation

There is little information regarding predation on Thorny Skate. Examination of a database of over 156,000 stomachs of 68 predators found only 8 individuals of this species, in the following predators: Atlantic Halibut (*Hippoglossus hippoglossus*), Sea Raven (*Hemitripterus americanus*), American Plaice (*Hippoglossoides platessoides*), Atlantic Cod, and Porbeagle Shark (*Lamna nasus*) (Simon *et al.* 2012). Other skates in the northwest Atlantic are preyed upon by marine mammals such as Grey Seals (*Halichoerus grypus*), which may be responsible for increasing mortality on adult Thorny Skates in the southern Gulf of St. Lawrence (Benoît and Swain (2011)). Egg capsules are eaten by Atlantic Halibut, Goosefish (*Lophius americanus*), Greenland Sharks (*Somniosus microcephalus*) and gastropods (Cox *et al*. 1999).

Physiology and Adaptability

With the exception of work on stress due to capture and post-release mortality (Sulikowski 2011), physiological studies have not been carried out on Thorny Skate. However, the species is consistently found in a relatively narrow temperature range among areas and over time, suggesting that Thorny Skate are adapted to a narrow range of temperatures.

Dispersal and Migration

Templeman (1984) observed average movements of about 100 km, with a small proportion moving up to 440 km, suggesting limited dispersal. This was based on tagging studies in which fish were returned by commercial fisheries up to 20 years later. As well, the fact that egg cases are laid on the bottom precludes dispersal of that life stage. Seasonal, limited cross-shelf movements have been found on both the Grand Banks (Kulka *et al*. 2004) and in the southern Gulf of St. Lawrence (Hurlbut and Benoît 2001). The distribution in Canadian waters is continuous with that in American waters to the south and with West Greenland waters to the north but the extent of migration is unknown.

Interspecific Interactions

McEachran *et al.* (1976) reported a diversified diet of both epifauna and infauna and that the fish feed largely on decapod crustaceans and euphausiids but also polychaetes. For Georges Bank to Greenland (areas mainly north of that study), Templeman (1982b) noted that stomach contents consisted mainly of fish (Sand Lance *Ammodytes dubius* and Capelin *Mallotus villosus*), decapods (spider and hermit crabs, shrimp *Panadalus sp.*), cephalopods, polycheates and amphipods. Smaller skates had higher proportions of cephalopods, polychaetes and amphipods. Those two studies together covered much of the northwest Atlantic range and it is clear that diet varied by region and size of individual. Antipova and Nikiforova (1983) found a similarly diverse diet in the northeast Atlantic.

In a recent study on the Grand Banks, González *et al*. (2006) found a wide prey spectrum (90 species identified, mainly fish and crustaceans) compared to other skates. The proportion of fish and molluscs in the diet increased with size. Sand Lance and Snow Crab (*Chionocetes opilio*) were the two most important prey items.

POPULATION SIZES AND TRENDS

DFO demersal research trawl surveys provide the basis for the assessment of population sizes and trends. Details can be found in Tables 1-3 and in Kulka *et al.* (2006b). The research surveys are administered separately by five DFO regions: 1) Central and Arctic; 2) Newfoundland and Labrador (NL); 3) Quebec; 4) Gulf; and 5) Maritimes. There were differences in seasons and years surveyed and in survey trawl gears used, each with different, uncalibrated catchability. Thus, direct comparison among regional surveys of relative density and abundance is not possible. A further complication relates to changes in survey protocols, including gear changes that occurred over time within some regional surveys, precluding examination of long-term trends in some areas.

Table 1. DFO-NL research trawl surveys were conducted in spring on the Grand Banks (Div. 3LNOPs; refer to Figures 1 and 2) and fall/winter on the Labrador Shelf to Grand Banks (Div. 2GHJ3KLMNO). Various gears were employed (Yankee-41.5 otter trawl, depicted in brown; Engel-145 otter trawl, blue area; Campelen-1800 shrimp trawl, yellow area) on various vessels (*A.T. Cameron; Gadus Atlantica; Wilfred Templeman; Alfred Needler; Teleost*).

NAFO Div. north to south, for each seasonl survey											
	2H	**2J**	**3K**	**3L**	**3N**	**3O**	**3M**	**3L**	**3N**	**3O**	**3Ps**
Year	Fall	Fall	Fall	Fall	Fall	Fall	Fall/Winter	Spring	Spring	Spring	Spring
1971								brown	brown	brown	
1972								brown	brown		brown
1973								brown	brown	brown	brown
1974								brown	brown		brown
1975								brown	brown	brown	brown
1976								brown	brown	brown	brown
1977		blue	blue				blue	brown	brown	brown	brown
1978	blue	blue	blue				blue	brown	brown	brown	brown
1979	blue	blue	blue				blue	brown	brown	brown	brown
1980		blue	blue				blue	brown	brown	brown	brown
1981	blue	blue	blue	blue			blue	brown	brown	brown	brown
1982		blue	blue	blue			blue	brown	brown	brown	brown
1983		blue	blue	blue			blue				blue
1984		blue	blue	blue			blue	blue	blue	blue	blue
1985		blue	blue	blue			blue	blue	blue	blue	blue
1986		blue	blue	blue				blue	blue	blue	blue
1987	blue	blue	blue	blue				blue	blue	blue	blue
1988	blue	blue	blue	blue				blue	blue	blue	blue
1989		blue	blue	blue	blue	blue		blue	blue	blue	blue
1990		blue	blue	blue	blue	blue		blue	blue	blue	blue
1991	blue	blue	blue	blue	blue	blue		blue	blue	blue	blue
1992		blue	blue	blue	blue	blue		blue	blue	blue	blue
1993		blue	blue	blue	blue	blue		blue	blue	blue	blue
1994		blue	blue	blue	blue	blue		blue	blue	blue	blue
1995		yellow	yellow	yellow	yellow	yellow		blue	blue	blue	blue
1996	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow

NAFO Div. north to south, for each seasonl survey											
	2H	**2J**	**3K**	**3L**	**3N**	**3O**	**3M**	**3L**	**3N**	**3O**	**3Ps**
Year	Fall	Fall	Fall	Fall	Fall	Fall	Fall/Winter	Spring	Spring	Spring	Spring
1997											
1998											
1999											
2000											
2001											
2002											
2003											
2004											
2005											
2006											
2007											
2008											
2009											
2010											

Table 2. Quebec region survey series description summary.

Vessel	Length (m)	Year	Month	Gear	NAFO	Coverage	Tow duration (min.)	Tow speed (knots)	Standard tow (nm)	Wing spread (ft)
Gadus Atlantica	73.8	1978-1994 No survey in 1982	Jan.	Engels 145	3Pn, 4RS	Strata > 50 fathoms Estuary not covered Average surveyed area 62,550 km² Range 31,700 to 100,400 km² 3Pn and 4R strata were well covered	30	3.5	1.8	45
Lady Hammond	58	1984-1990	Aug.	Western IIA	4RST	Strata > 50 fathoms 3Pn was not covered, Estuary sparsely covered Average surveyed area 85,300 km²	30	3.5	1.8	41
Alfred Needler	50.3	1990-2005 No survey in 2004	Aug.	Uri Shrimp Trawl	3Pn, 4RS	Addition of shallow strata 20-50 fathoms 3Pn covered from 1993-2003 Average surveyed area 111,300 km² Range 95,070-119,000 km²	24	3	0.8	44
Teleost	63	2004-2010	Aug.	Campelen 1800 Rock Hopper foot gear	4RST	3Pn was not covered Average surveyed area 108,000 km² Range 91,600-116,100 km²	15	3	0.75	55.6

Table 3. Age and growth and reproductive parameters for Thorny Skate for the NL Region (Grand Banks to Labrador Shelf) (Kulka pers. com. for areas on the Grand Banks and north of Lat. 49°).

		Maturity							Size Range		Growth		
	Sex	**L_0[1]**	**L_{100}[1]**	**L_{50}[2]**	**L_{gon}[3]**	**L_{clas}[4]**	**L_{seg}[5]**	**%Mat[6]**	**L_{hat}[7]**	**L_{max}[8]**	**[9]L_{Inf}**	**K**	**Source**
Labrador Shelf	Male	39	63	50	42	48	26	53	10	79			Kulka *et al.*
	Female	35	81	47	39			46	10	81			Kulka *et al.*
Grand Banks	Male	45	90	75	53	54	48	53	10	108			Kulka *et al.*
	Female	45	85	64	45			46	10	108			Kulka *et al.*
Gulf of St. Lawrence	Male			51						80			Swain *et al*.(2011)
	Female			50						80			Swain *et al*.(2011)
Scotian Shelf	Male									92	81	0.09	McPhie and Campana (2009a,b)
	Female			51						87	102	0.06	McPhie and Campana (2009a,b)
Georges Bank/GOM	Male												
	Female			88						105	120	0.13	Sulikowski *et al.* (2005)
	Male												
	Female			50									Sosobee (2005)

[1]L_0 TL (total length) at first maturity

[2]L_{50} TL at 50% maturity (from ogives)

[3]L_{gon} Maturity estimated from gonad wt relative to TL

[4]L_{clas} Maturity estimated from clasper length curve inflection

[5]L_{seg} Maturity based on the break point from segmented regression, CL (clasper length?) vs. TL

[6]%Mat Ratio of the range of mature fish sizes (L_{50}) to range of all observed sizes, expressed as a percentage

[7]L_{hat} Estimated length at hatch (smallest size of fish with larval tails). In the case of Kulka *et al.*, it is based on actual observation

[8]L_{max} Estimated maximum length

[9]$L_{infinity}$ based on Von Bertalanffy growth model

Abundance

The surveys employ a stratified random design based on depth and latitude (Doubleday 1981; Brodie 2005). Estimates of survey abundance were calculated using the method of areal expansion by multiplying the average number of fish caught per tow within each stratum by the number of trawlable units for the respective stratum. The strata estimates are then summed over the entire survey area (Bishop 1994; Kulka *et al*. 2006b).

The type of survey gear greatly influences the proportions of the size of fish captured as well as overall catchability at any size and this confounds any comparative analyses among regional surveys (Benoît and Swain 2003). Thus, formulation of a trend for all Canadian waters or long-term trends in some areas is not possible.

Catchability (q) of most demersal fish in the surveys is thought to be <1 because fish escape from the passing nets. This is particularly true for skates, which can pass underneath the gear and, for some sizes, through the trawl mesh. Catchability has not been estimated for Thorny Skate but survey abundance estimates presented here are considered minimum estimates of population size, well below the true value.

Division of juveniles and adults was done at 53 cm for all areas (see section on maturity). This would tend to overestimate the abundance of adults on the Grand Banks where maturity occurs at a larger size. A summary of minimum abundance estimates (not adjusted for different catchability among gears) can be found in Table 4.

Table 4. Most recent estimates of minimum trawlable abundance derived from Fisheries and Oceans demersal trawl surveys. Different gears with different catchabilities are used in the various areas. The same gear (Campelen) is used for 2GHJ3KLNOPs4RS3Pn.

Region	NAFO Division	Years (averaged)	Total number	Mature numbers
Davis Strait	0	1999	1,541,751	616,700
N. Labrador Shelf	2GH fall survey	1977-1999	24,200,000	9,680,000
S. Labrador Shelf and NE Newfoundland Shelf	2J3K fall survey	2007-2009	19,400,000	7,760,000
Grand Banks	3LNOPs spring survey (areas north of 3L not available)	2007-2009	79,137,000	36,940,000
Northern Gulf of St. Lawrence	4RS (3Pn not sampled)	2008- 2010	40,536,487	6,668,374
Southern Gulf of St. Lawrence	4T	2008-2010	1,590,000	66,000
Scotian Shelf	4VWX	2008-2010	21,706,610	1,145,152
Georges Bank	5Z (Canadian portion only)	2008-2010	408,289	228,617
Total			**188,520,137**	**63,104,844**

Baffin Bay/Davis Strait/Ungava Bay

Minimum abundance estimates are available for southern Div. 0A from 1999 (241 t and 617,002 fish) (Treble *et al.* 2000) and Div. 0B from 2000 (628 t and 924,749 fish) (Treble *et al.* 2001). This indicates that only a small portion of Thorny Skate in Canadian waters (roughly 1%) occur in this area. The fish may be more abundant on the Greenland side where there used to be a fishery for this species.

Labrador Shelf to Grand Banks

The minimum population size (average minimum abundance 1977-1999) of all sizes of Thorny Skate on the northern Labrador Shelf (Div. 2GH) was 24.2 million fish (Table 4). Div. 2G was not sampled after 1999 but numbers in Div. 2H from 2004-2008 (17.5 million) were about the same as in 1997-1999 (18 million). The minimum population size (average minimum abundance 2008-2010) of fish on the northeast Newfoundland and southern Labrador Shelf (Div. 2J3K) is 19.4 million (Table 4). The proportion of mature individuals in recent surveys is approximately 40%, thus the estimated minimum abundance of mature individuals in Div. 2GHJ3K is approximately 17.4 million fish.

Recent estimates of minimum population size from the Grand Banks (NAFO Div. 3LNOPs) is 79.1 million fish estimated from the spring surveys in 2008-2010 averaged (Table 4), of which 47%, (36.9 million fish) were mature.

Northern Gulf of St. Lawrence

Current minimum abundance (2008-2010 average) in the northern Gulf (Div. 4RS) is 40.5 million fish of which 16.5% (6.7 million) were mature.

Southern Gulf of St. Lawrence

Average minimum abundance in 2008-2010 in the southern Gulf (Div. 4T) is 1.6 million fish, including 66,000 adults.

Scotian Shelf/ Bay of Fundy

The average abundance of Thorny Skate in 2008-2010 on the Scotian Shelf (Div. 4VWX) was 21.7 million fish. Mature individuals numbered approximately 1.1 million.

Georges Bank

This portion of the population is contiguous with fish in USA waters and represents a small fringe of that population. The minimum population size (2008-2010) of Thorny Skate on the Canadian side (Div. 5Z) is 408,000. The proportion of mature individuals was approximately 6% in 2008-2010, or 229,000.

All Areas

In summary, percentage of abundance in each area is as follows: 0AB - 1%, 2GH – 14%, 2JK – 11%, 3LNOPs – 46%, 4RST – 24%, 4VWX5Z – 4%, amounting to 188.5 million fish, of which 63.1 million are adults (Table 4). However, it should be noted that catchability differs among areas. About 2/3 of the abundance is found on the Grand Banks and Gulf of St Lawrence, centred around the Laurentian Channel.

A portion of the abundance of Thorny Skate on the Grand Banks falls outside of Canada's 200 mile limit; on the Nose and Tail of the Grand Banks and on Flemish Cap. Kulka *et al*. (2002) estimated that 15% of the Thorny Skate in Div. 3LNO (the Grand Bank) falls outside of Canadian waters. Fish that fall outside Canadian waters are included in the above minimum estimate for Div. 3LNOPs.

Fluctuations and Trends

Trends in abundance were estimated using individual surveys from each region. Rates of change for each survey were estimated by transforming mean number per tow to natural log values and using the slope of the resulting linear model to calculate rate of decline or increase. Although it would be ideal to estimate a common trend for the entire DU, this is not feasible given the multiple surveys using different gears and occurring at different times, with uncertainty over adjustments for gear efficiency. While it is difficult to get an overall picture of change for the species as a whole across its range, examination of the most recent numbers of fish (Table 4) in conjunction with the rates of change that have led to these values (Table 5) gives an approximation of the rough weighting that should be given to each region's trend, with the caveats noted above concerning differences in catchability.

Table 5. Estimated changes in Thorny Skate relative abundance in Canadian waters. Annual rates of change and absolute change over the time periods surveyed are reported. Yellow areas highlight declines.

Area	Period of Change	All individuals	Mature individuals	Immature individuals	Gen.
Davis Strait		Unknown - likely fluctuation without trend			
Northern Labrador Shelf (DIV. 2GH)		Unknown - likely fluctuation without trend			
Southern Labrador Shelf (Div. 2J3K)	Survey Engel (1977-1994)	-30.3%	-91.0%	-42.4%	1.06
	Annual change	-2.1%	-13.2%	-3.2%	
	Survey Campelen (1995-2008)	1.4%	821.0%	-15.5%	0.81
	Annual change	0.1%	18.6%	-1.3%	
Grand Banks (Div. 3LNOPs)	Survey Engel (1974-1995)	-58.9%	-79.4%	-40.5%	1.31
	Annual change	-4.1%	-7.3%	-2.4%	
	Survey Campelen (1996-2010)	61.4%	303.3%	-2.1%	0.88
	Annual change	3.5%	10.5%	-0.2%	
Northern Gulf of St. Lawrence (Div. 4RS)	Survey change (1991-2010)	-1.1%	253.0%	-15.9%	1.19
	Annual change	-0.1%	6.9%	-0.8%	
Southern Gulf of St. Lawrence (Div. 4T)	Survey change (1971-2010)	-57.3%	-95.1%	-35.1%	2.44
	Annual change	-2.1%	-2.4%	-1.0%	
Scotian Shelf (Div. 4VWX)	Survey change (1970-2010)	-81.3%	-95.3%	-75.5%	2.50
	Annual change	-4.1%	-2.3%	-3.5%	
Georges Bank (Div 5Z)	Survey change (1987-2010)	-62.0%	-84.8%	-40.4%	1.44
	Annual change	-4.1%	-7.9%	-2.2%	

Baffin Bay/Davis Strait/Ungava Bay

Abundance trends could not be calculated for this area as surveys have been conducted on a sporadic basis since 1999.

Grand Banks to Labrador Shelf

The northern Labrador Shelf (Div. 2GH) has been sampled only sporadically since 1978 and the Engel data prior to 1995 have not been adjusted to Campelen units. Thus, values tend to be higher after 1995. Based on the limited data, it appears that Thorny Skate abundance in this area has fluctuated without trend (Figure 26).

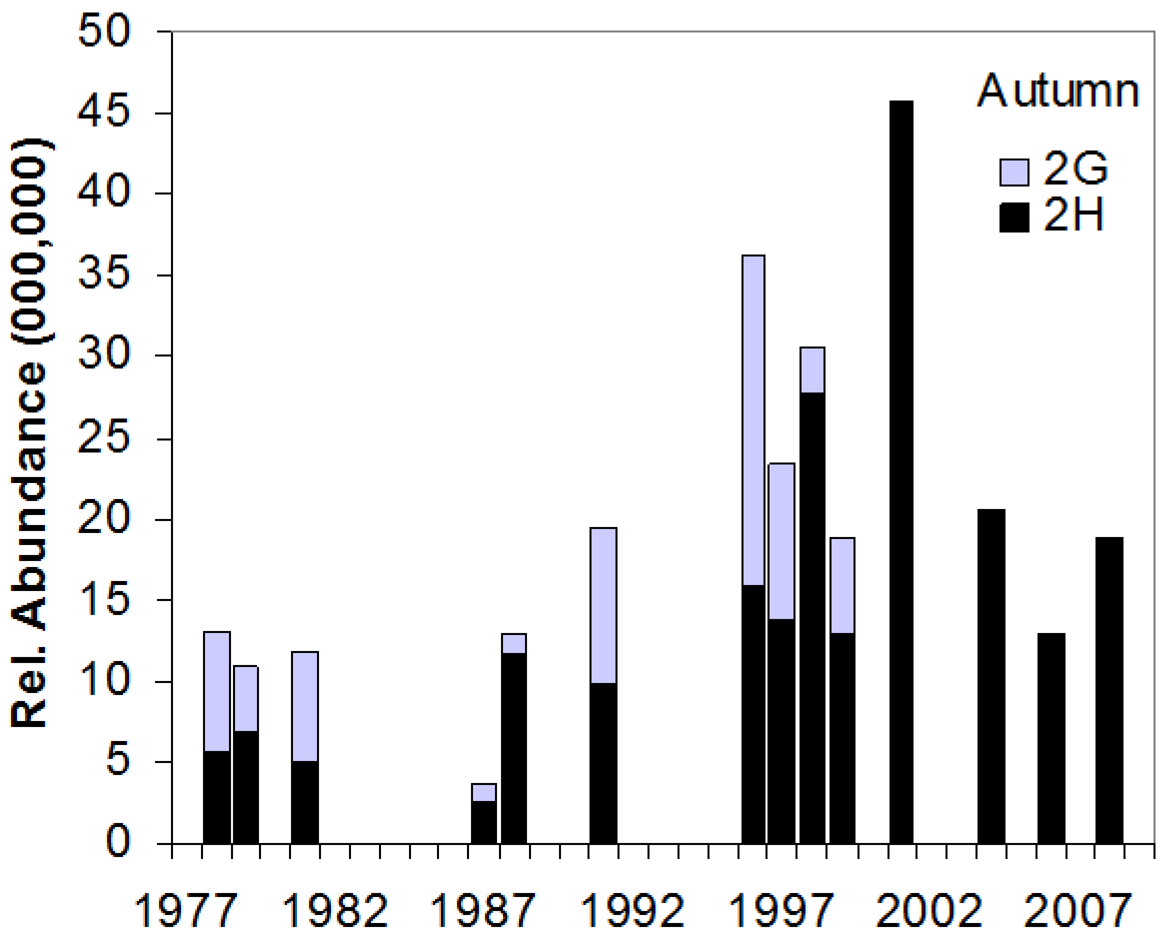

Figure 26. Fall research survey minimum abundance indices for Thorny Skate in NAFO Divisions 2GH, between 1978 and 2010. Surveys were not conducted in years without values. Div. 2H was not surveyed after 1999.

The conversion factor used to produce Campelen equivalents from Engel catch rates for the total population in the southern Labrador Shelf and the Grand Banks (Simpson and Kulka 2005) cannot be applied separately to juvenile and adult components since Campelen gear captures a higher proportion of juveniles. Applying the overall conversion factor to the two size groups would bias juvenile estimates on the low side, adults high. Also, the trajectory of the trend changed at about the same time that the gear changed and thus pre-1995 data must be analyzed separately from the later period.

On the southern Labrador Shelf (Div. 2J3K) Thorny Skate declined until 1995 and then stabilized or increased thereafter (Figure 27 and Table 5). Juveniles declined by 42% (1977-1994) then by 16% (1995-2008). Adults declined by 91% from 1977 to 1994 but subsequently increased by 821% from 1995 to 2008 (Table 5).

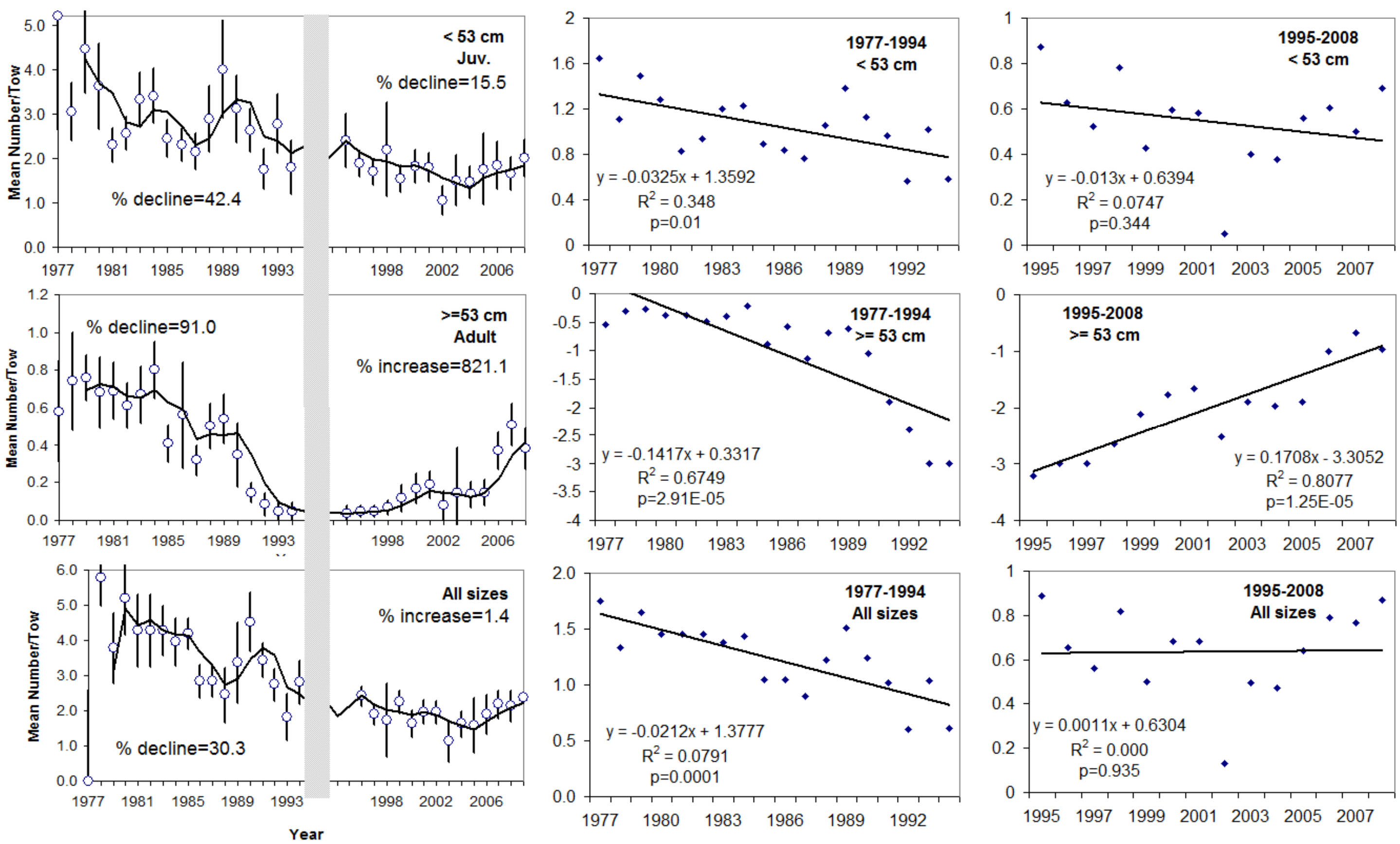

Figure 27. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from the southern Labrador Shelf (Div. 2J3K). Error bars represent ± 2 SD. Grey bar divides Engel from Campelen estimates. Ln transformed data are plotted for two periods when different survey gears were used. Vertical bars are ± 2 SD.

Similar patterns were seen on the Grand Banks (Div. 3LNOPs; Figure 28). Juveniles declined by 40% from 1974-1995 and by 2% from 1996-2010 (Table 5). Adults declined by 79% from 1974-1995 then increased by 303% from 1996-2010. A larger proportion of the fish shown as adults in Figure 28 may actually have been juveniles than in comparable figures for other regions, because fish in the Grand Banks mature at a larger size (Table 3). However, this should not bias the trend of increasing numbers of adults as there is no indication of an increase in juveniles in Figure 28. Examination of the rates of change in adults (Table 5) combined with the most recent numbers (Table 4) shows that the Grand Banks have always been and continue to be the most densely populated area within the species' range despite the decline in the early 1990s.

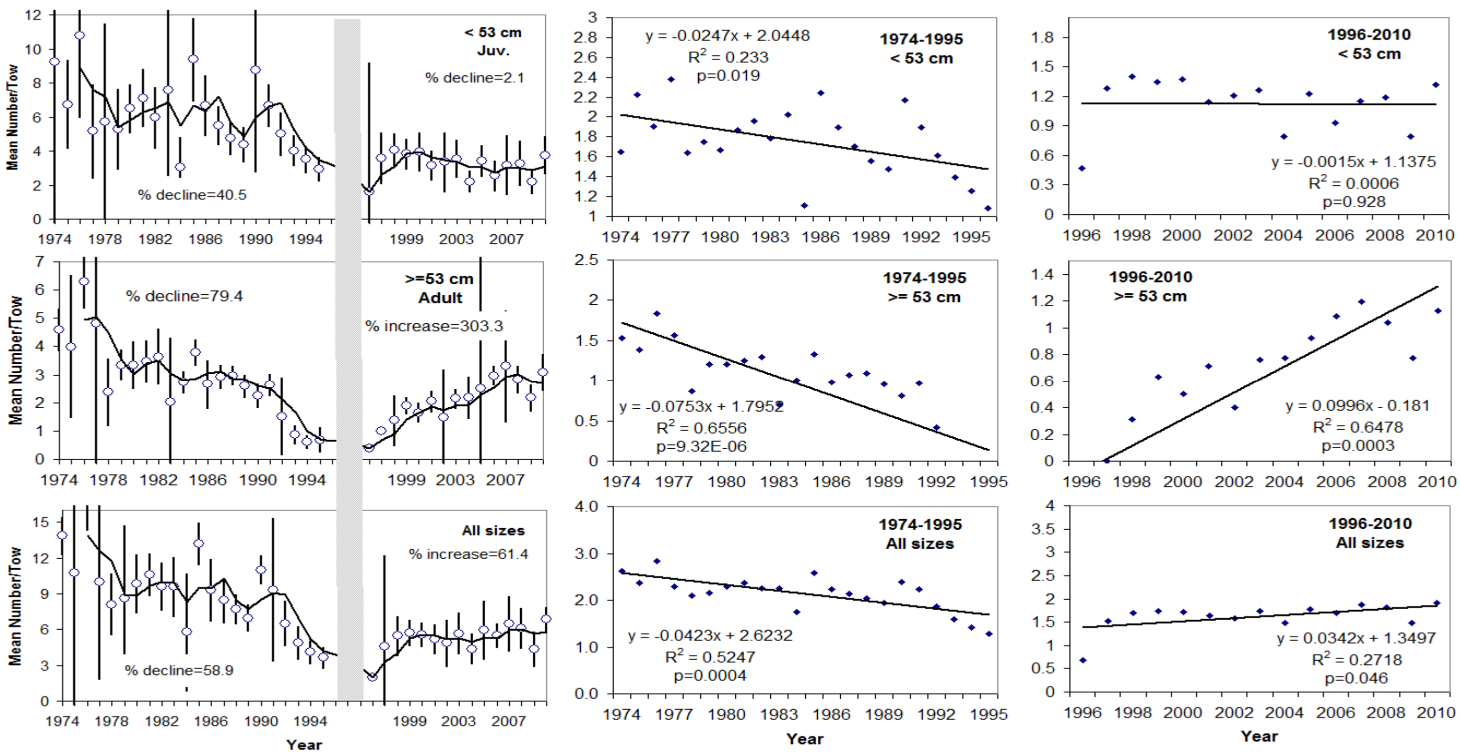

Figure 28. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from the southwest Grand Banks (Div. 3LNOPs). Error bars represent ± 2 SD. The grey bar divides Engel from Campelen estimates. Ln transformed data are plotted for two periods when different survey gears were used.

Northern Gulf of St. Lawrence

There was considerable variation in abundance from 1991-2010, without trend (Figure 29). Juveniles declined by 16%, whereas adults increased by 253% over 20 years.

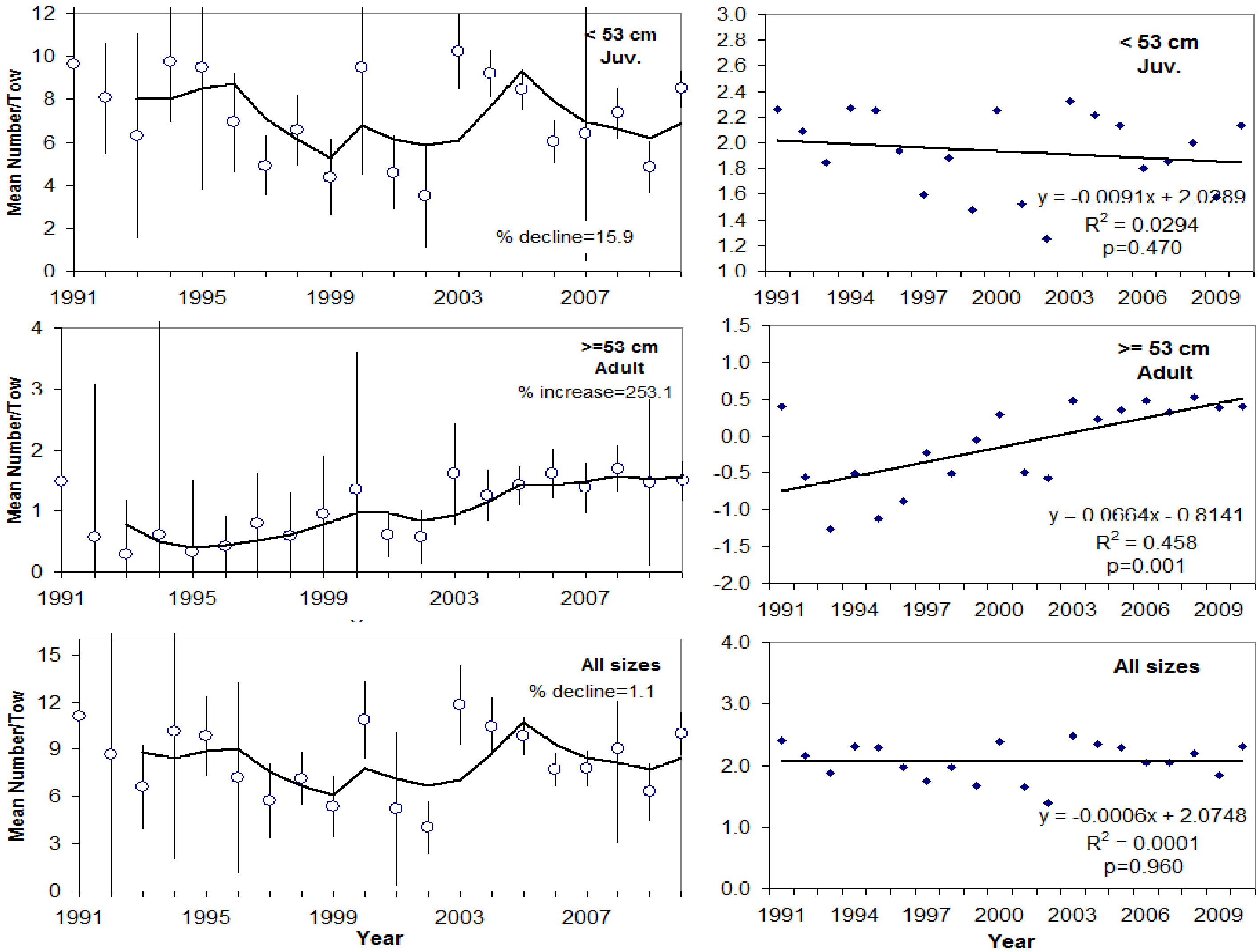

Figure 29. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from the northern Gulf of St. Lawrence (Div. 4RS). Error bars represent ± 2 SD.

Southern Gulf of St. Lawrence

Abundance of Thorny Skate of all sizes in the southern Gulf has fluctuated and is lower at the end of the series (Figure 30). Adults declined from 1971-2010 by 95% (Table 5). The rate of decline for juveniles was 32%, although there has been an increase during the last eight years. The declines in adults match increases in natural mortality over this period (Benoît and Swain 2011). How such small numbers of adults are producing increasingly large numbers of juveniles is uncertain.

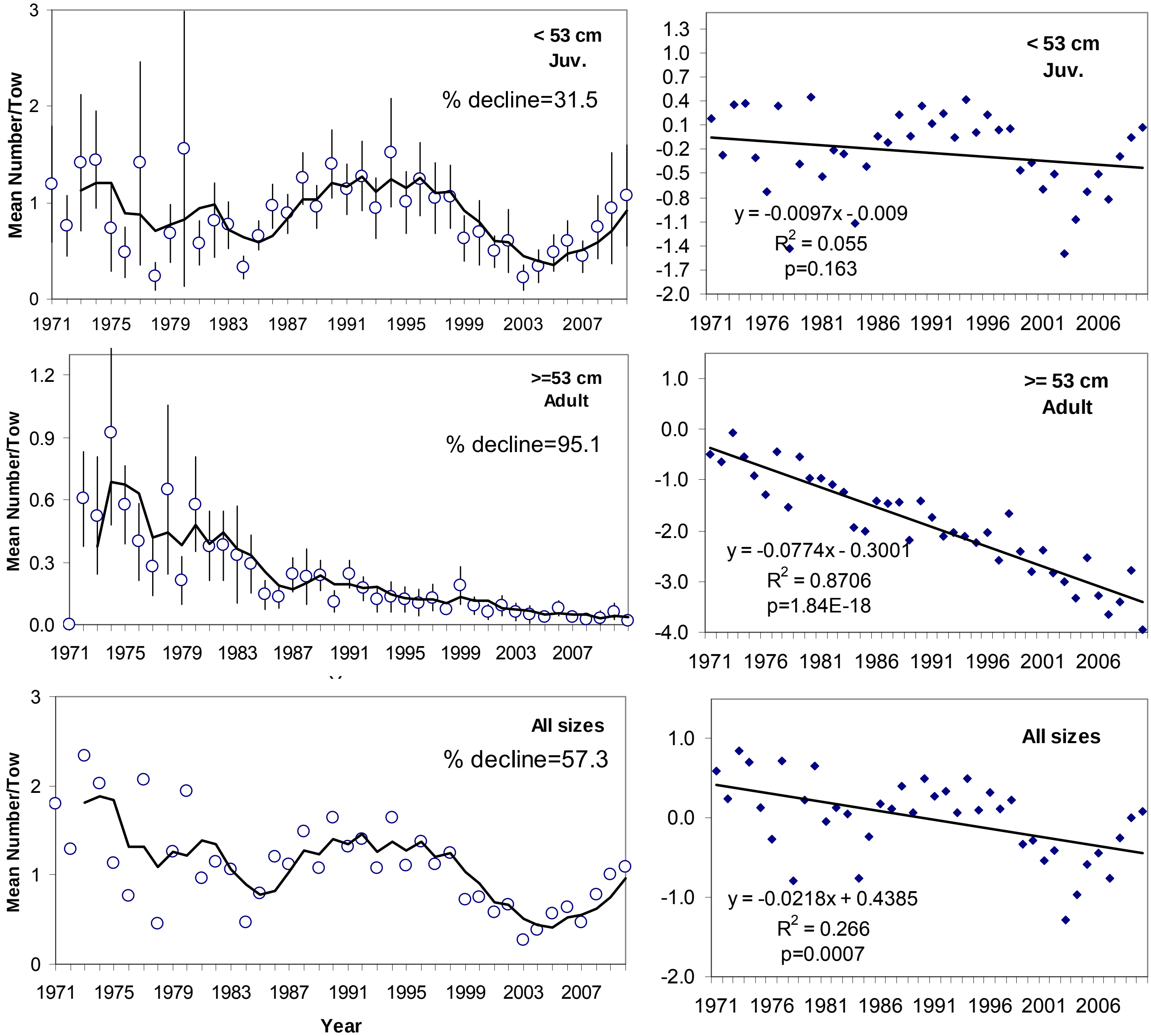

Figure 30. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from the southern Gulf of St. Lawrence (Div. 4T). Error bars represent ± 2 SD.

Scotian Shelf and Bay of Fundy

Skates of all sizes declined until the early 2000s and have remained low with some fluctuations since (Figure 31). For immature skates, the rate of decline was 76% over the entire survey (Table 5). The rate of decline for mature skates was greater, 95% over the entire survey. Consideration of these declines in conjunction with the most recent abundances (Table 4) suggests that this region was probably second only to the Grand Banks in historical abundance in the mid-1970s. There is no evidence that these declines are due to individuals moving north.

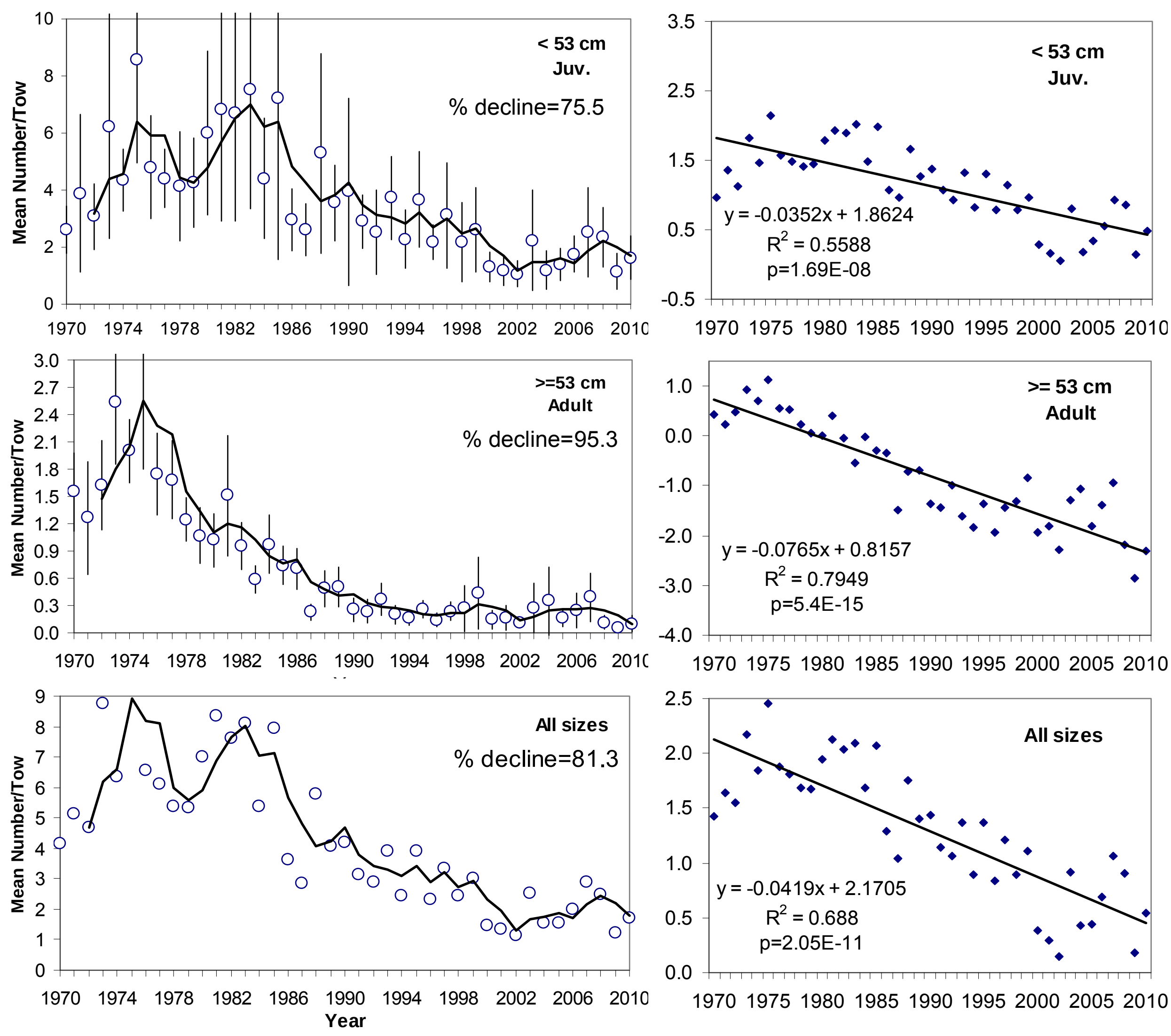

Figure 31. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from the Scotian Shelf (Div. 4VWX). Error bars represent ± 2 SD.

Georges Bank

Abundance declined on the Georges Banks (Canadian portion), with no pattern since the early 2000s (Figure 32). Juvenile skates declined by 40% (abnormally low 2009 value removed) and adults declined by 85%. This very minor component of the Canadian population is contiguous with fish in the USA.

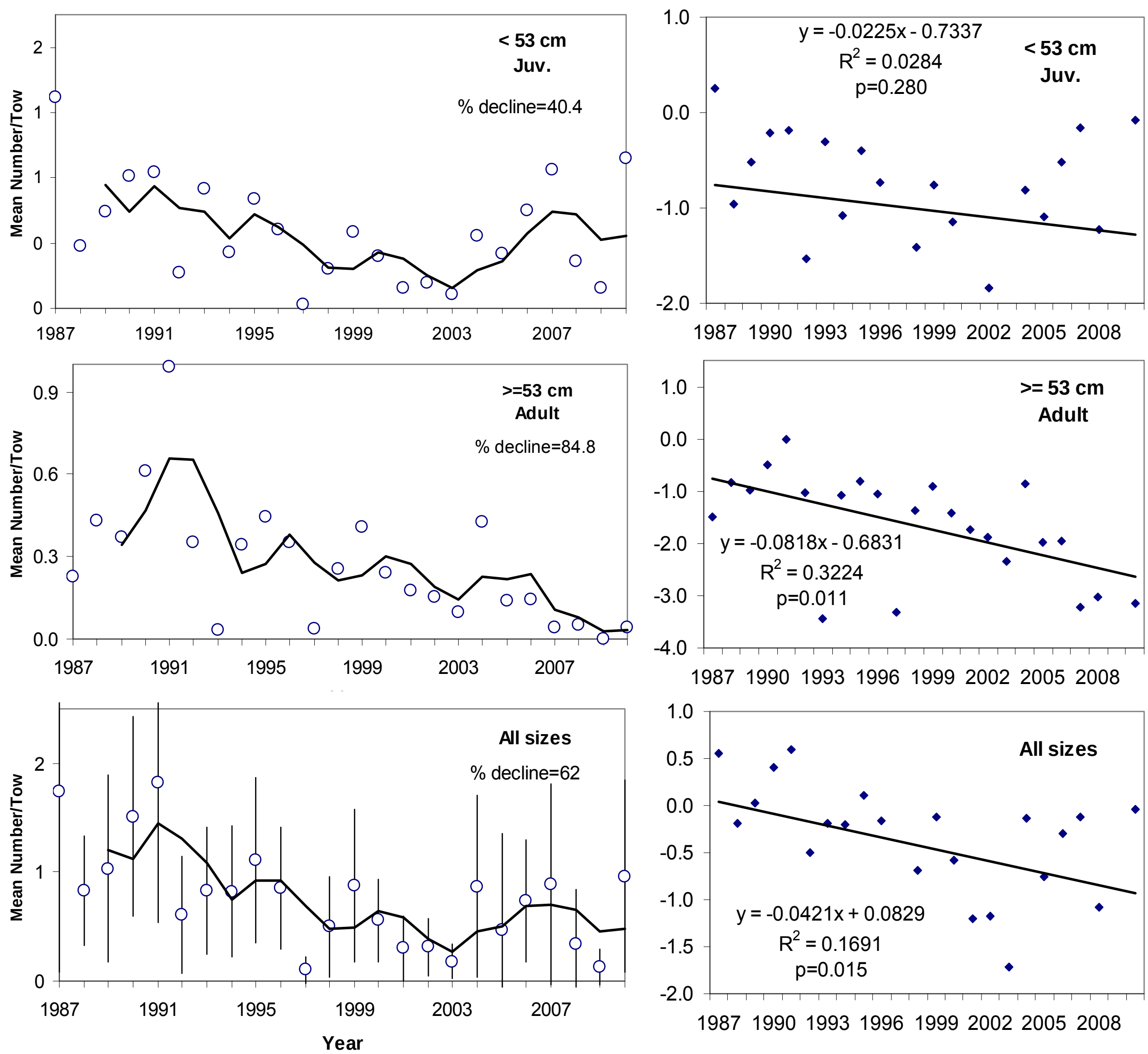

Figure 32. Mean number per tow of Thorny Skate juveniles, adults and all sizes combined from Georges Bank, Canada (Div. 5Z). Vertical bars are ± 2 SD.

Rescue Effect

The distribution of Thorny Skate in Canadian waters is continuous with that in American and West Greenland waters and there is a small area where the distribution extends into international waters of the Grand Banks. However, the degree of migration and dispersal between these areas, if any, is unknown.

Surveys off West Greenland since 1991 showed an increase in abundance in the initial period but since the early 2000s abundance has declined from a high of 12 million to about 5 million fish (minimum abundance estimate) (Nygaard and Jørgensen 2010).

Thorny Skate straddle Canada's 200 mile limit on the eastern extent of the Grand Banks. The Canadian survey covers the international waters and Kulka *et al*. (2002) determined that about 16% of Thorny Skate in Div. 3LNOPs (the Grand Banks) are outside the 200 mile limit. That portion is accounted for in the section on the Grand Banks, above.

Thorny Skate are listed by the USA National Marine Fisheries Service as a species of concern due to long-term declines in survey abundance, and the species was listed as "overfished" in 2003 (NMFS 2007). As well, a petition to list Thorny Skate under the USA *Endangered Species Act* (ESA) was filed Aug. 2011 (Smith 2011).

Given the declines in this species in both the United States and in Greenland, rescue effects may be unlikely.

THREATS AND LIMITING FACTORS

Predation

A recent analysis by Benoît and Swain (2011) has shown that in the southern Gulf of St. Lawrence, total mortality (natural + fishing) on juveniles has decreased since the 1970s, whereas mortality on adults has increased sharply over the same time period, reaching an instantaneous rate of mortality, *F*, of approximately 1.8 during the past decade. That is extremely high for a long-lived species such as a skate. As fisheries have been low since the early 1990s, this increased mortality may have been due to predation by Grey Seals (Benoît and Swain 2011). Seals have been undergoing strong increases in the region and have been shown to cause high mortality on many groundfish (Savenkoff *et al*. 2008).

Fisheries

The only directed fishery for Thorny Skate in Canada is on the Grand Banks. Previously, there was also a mixed fishery for Thorny Skate and Winter Skate (*Leucoraja ocellata*) on the eastern Scotian Shelf but that fishery was closed under Canada's *Fisheries Act* due to a decline in both species (Winter Skate was subsequently designated as "threatened" by COSEWIC in that area). Elsewhere in Canada, because Thorny Skate is so widespread, it is taken as bycatch in many fisheries under a variety of management regimes.

Skate are taken as bycatch in the Greenland halibut (*Reinhardtius hippoglossoides*) and shrimp fishery (*Pandalus sp.*) in the Labrador Shelf to the Davis Strait. Bycatches from the shrimp trawls have typically been much lower than further south (see below), typically 1-4 tonnes (range 0 – 45 tonnes), depending on the area (Siferd 2010). In the 1990s Nordmore grates were implemented in these shrimp fisheries in an effort to reduce bycatches.

On the Grand Banks, in addition to the directed fishery, there are bycatches of Thorny Skate in nearly all trawl, longline and gillnet fisheries in the area (Table 6).

Table 6. Estimated catches (landings plus discards, in metric tonnes) of various skate species in Canadian and non-Canadian waters of NAFO Div, 2GHJ3KLNOPs, 1985-2009. Thorny Skates comprise the majority of skates in commercial fisheries. Catches inside 200 miles were calculated from DFO landings statistics and observer data (Canadian discards and non-Canadian catches). Catches in non-Canadian waters were estimated from Conservation & Protection (DFO) boardings prior to 2003. Non-Canadian are from numbers "agreed" to by Scientific Council of NAFO.

Div.	2G	2H	2J	3K	3L	3N	3O	3Ps	2G-3K Lab Shelf	3LNOPs Grand Banks	All areas
1985	0	48	14	235	3,526	13,870	2,026	2,243	297	21,666	21,963
1986	0	62	66	1,509	3,330	11,815	2,296	2,682	1,637	20,123	21,760
1987	2	65	352	936	3,507	10,208	1,535	5,786	1,355	21,036	22,390
1988	1	51	36	593	4,206	7,931	1,967	2,787	681	16,891	17,571
1989	13	47	26	987	2,367	9,310	1,824	4,109	1,073	17,610	18,682
1990	10	77	123	705	3,833	12,885	1,853	3,945	915	22,515	23,430
1991	18	154	46	179	3,260	11,049	1,471	4,662	397	20,442	20,839
1992	45	102	224	39	1,036	6,143	2,153	2,431	410	11,763	12,173
1993	80	115	30	57	1,403	5,453	3,567	722	282	11,146	11,428
1994	12	60	58	138	919	6,763	1,369	1,241	268	10,293	10,561
1995	1	1	7	57	432	2,603	2,653	1,963	66	7,651	7,717
1996	1	3	57	51	1,271	3,008	2,351	997	112	7,626	7,739

									2G-3K	3LNOPs	
Div.	**2G**	**2H**	**2J**	**3K**	**3L**	**3N**	**3O**	**3Ps**	**Lab Shelf**	**Grand Banks**	**All areas**
1997	1	12	13	35	695	8,098	3,832	1,494	62	14,119	14,181
1998	2	6	12	21	329	7,261	1,340	1,523	40	10,453	10,493
1999	1	5	8	34	708	4,251	1,648	1,288	49	7,895	7,944
2000	1	11	4	247	485	6,015	1,104	1,075	264	8,680	8,943
2001	1	1	8	208	1,178	7,225	1,025	2,047	218	11,475	11,693
2002	2	2	11	126	821	3,475	1,733	1,741	141	7,770	7,911
2003	2	13	4	114	1,755	11,141	2,202	2,097	133	17,195	17,328
2004	2	5	8	82	1,219	10,077	973	1,287	97	13,555	13,652
2005	3	6	15	34	443	2,468	1,071	949	58	4,931	4,988
2006	3	12	7	146	316	4,762	757	1,368	168	7,202	7,371
2007	12	8	70	14	168	5,628	880	1,820	105	8,495	8,600
2008	3	1	70	28	364	5,079	1,078	1,264	103	7,786	7,889
2009	3	1	69	31	382	5,101	1,217	1,168	105	7,868	7,868

Figure 33 shows the areas where skate were taken as bycatch in various Newfoundland and Labrador trawl fisheries (the main source of skate bycatch). The highest proportions were on the southern Grand Banks where the directed fishery occurred (Kulka *et al.* 2006a). Most of the skate bycatch was attributed to the Atlantic cod (*Gadus morhua*), Monkfish (*Lophius americanus*), White Hake (*Urophycis tenuis*), Lumpfish (*Cyclopterus lumpus*), Atlantic halibut (*Hippoglossus hippoglossus*) and Greenland halibut (*Reinhardtius hippoglossoides*) fisheries in this area. About 17,000 t of Thorny Skate were taken annually in the commercial fisheries in this area in the mid-1980s, now reduced to about 6,000 t annually (Figure 34). Because of the reduced removals, relative fishing mortality (catch/relative biomass) has remained constant over time at about 10% for Thorny Skate (Figure 35).

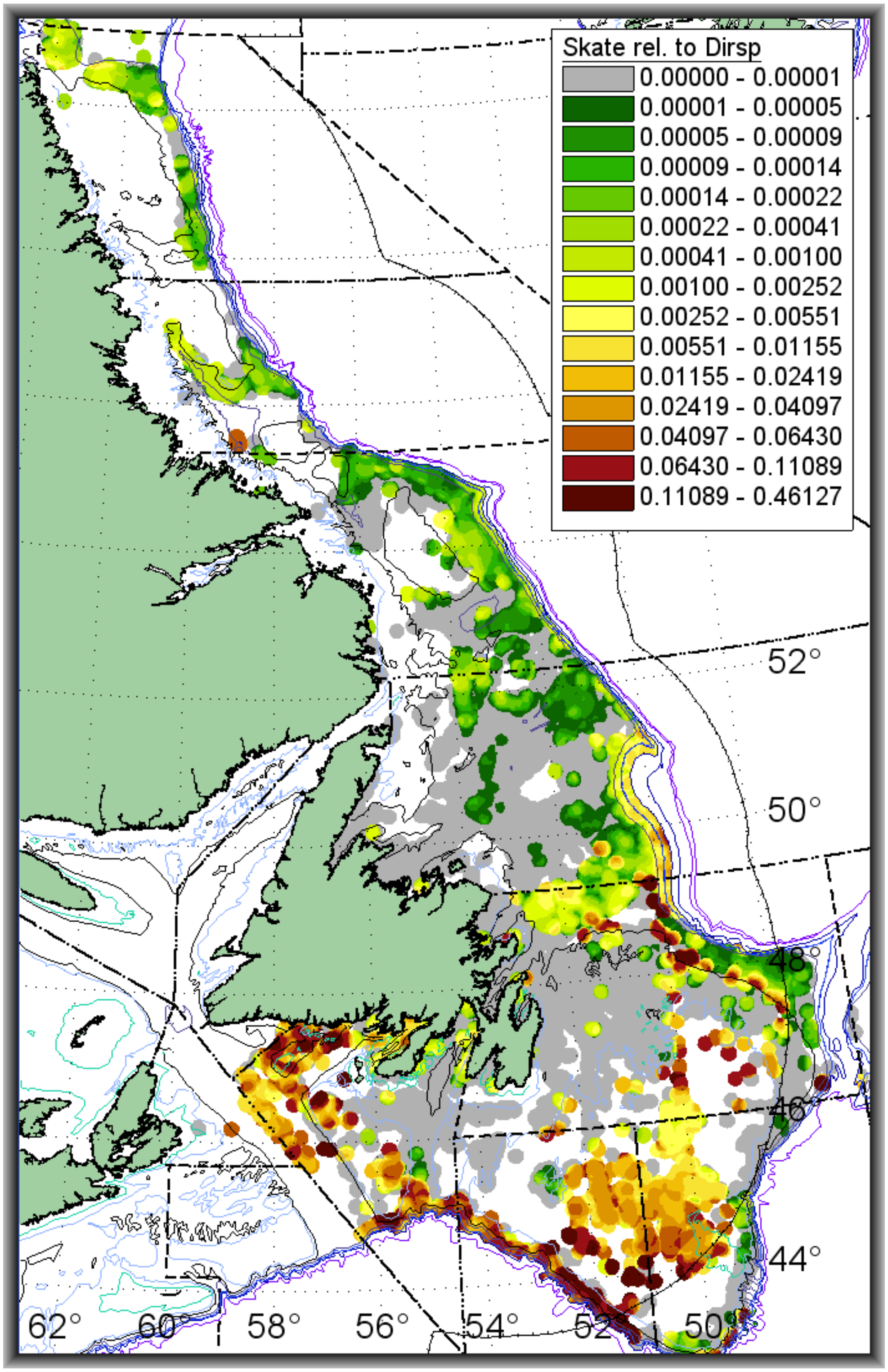

Figure 33. Thorny Skate captures in Canadian fisheries (2006-2009), from the Labrador Shelf to the Grand Banks. Brown areas indicate where skate was a high proportion of the catch, green areas, low. Grey areas are where fisheries occurred but no Thorny Skate were caught.

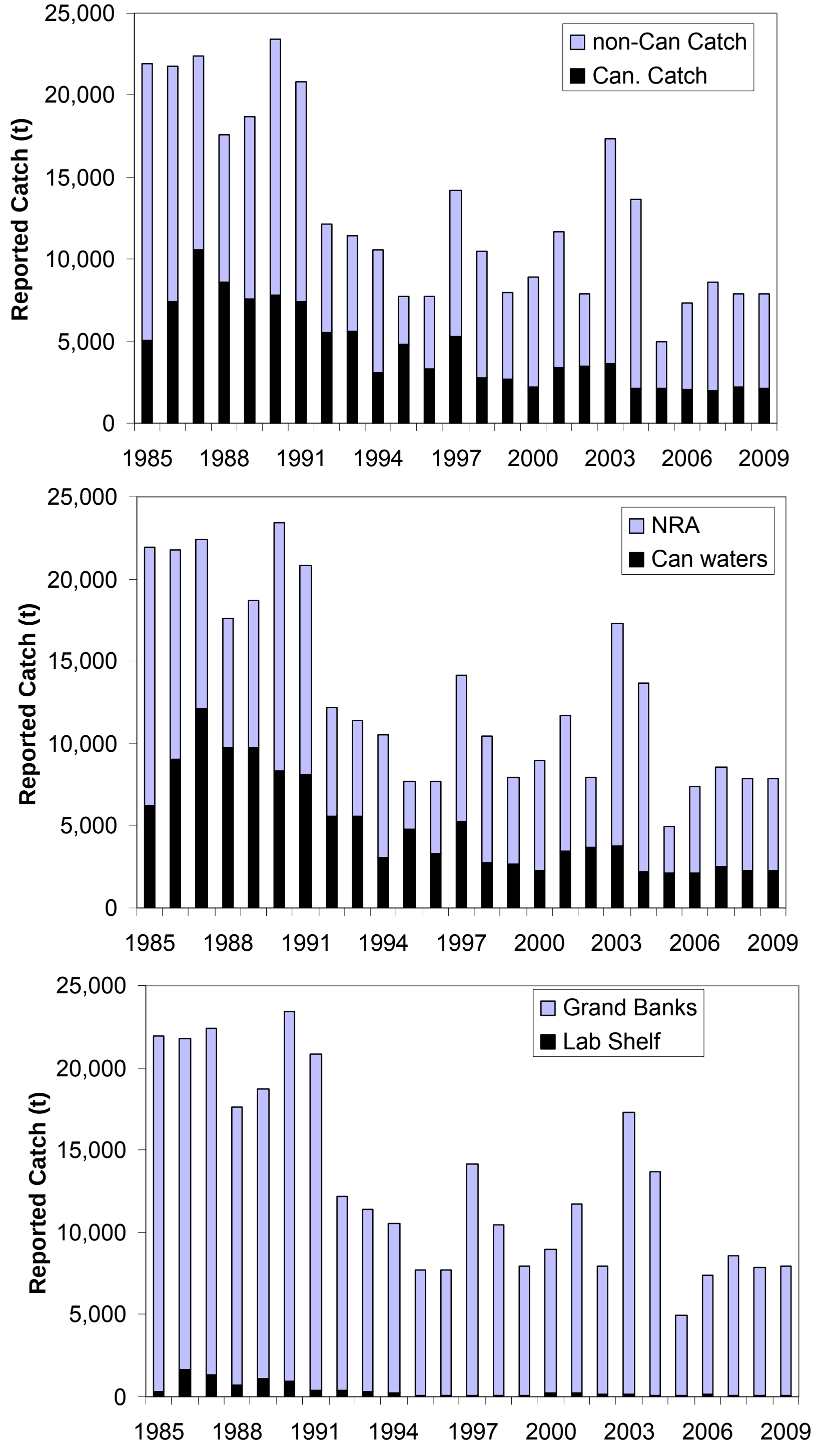

Figure 34. Reported catches of skate (Thorny Skate comprises 90% of these catch records) from the Labrador Shelf to the Grand Banks based on Canadian catch statistics and NAFO records (for non-Canadian countries). NRA is NAFO Regulatory Area (tail and nose).

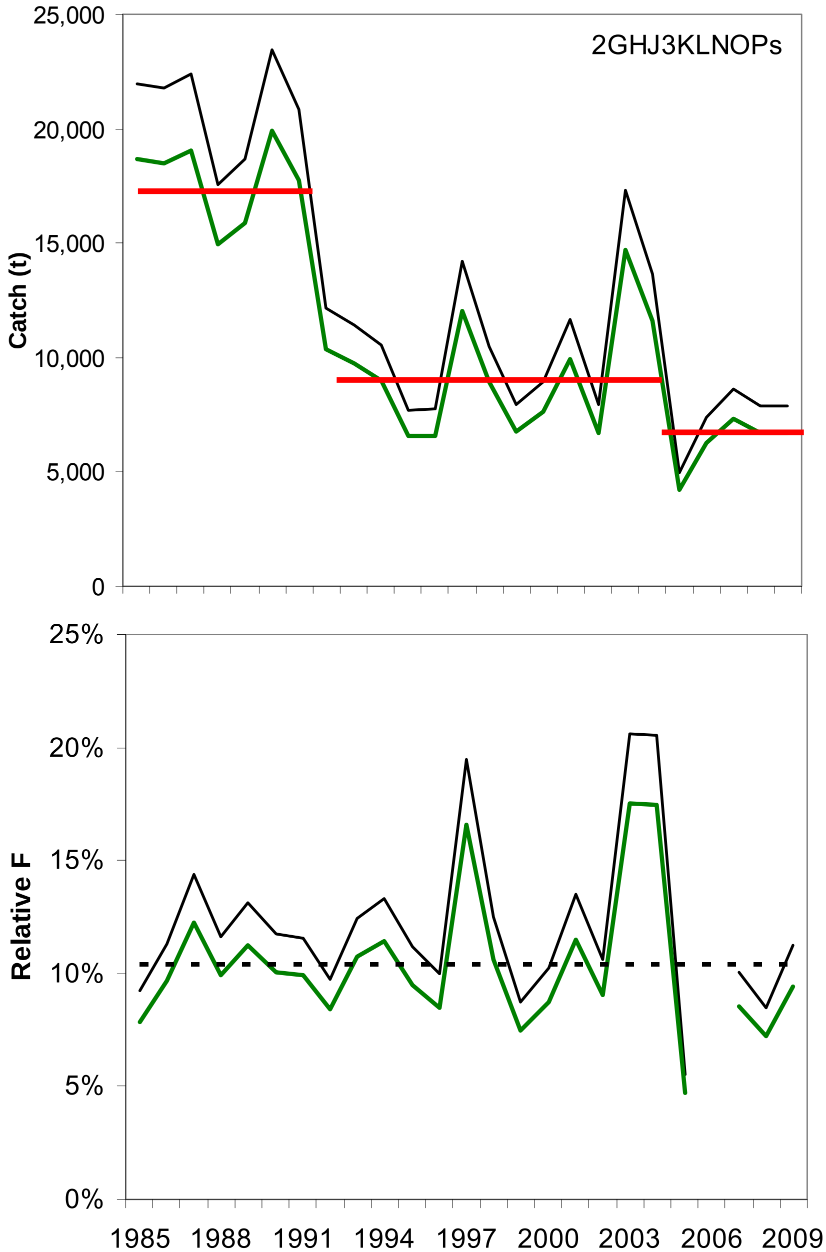

Figure 35. Upper: Reported removals of skate unspecified by all countries from the Labrador Shelf to the Grand Banks based on Canadian reported catch records and NAFO records (non-Canadian countries). The estimates include discards. About 10% constitute species other than Thorny Skate. The horizontal red lines represent average catches during the periods indicated. Lower: Relative fishing mortality (reported removals/relative biomass from DFO demersal surveys). The green line is Thorny Skate, the black line is all skates combined, and the dashed line is the average for all skates combined.

Fisheries in the northern Gulf of St. Lawrence (Div. 4RS) have reported landings of unspecified skates (comprising mainly Thorny Skate), which have averaged less than 107 t per year. Skate bycatch also occurs in the shrimp trawl fishery. In 2006, skates were found in 59% of the commercial shrimp fishery sets with an observer aboard although the numbers were very low; in 75% of those sets, skate catches were 1 kg or less (Swain *et al.* 2011).

In the southern Gulf of St. Lawrence, catches of skates (primarily Thorny and Smooth) have been variable since the early 1970s, with peaks in reported catches in the mid-1970s, the late-1970s and the mid-1990s. Since the early 1990s, reported skate landings have decreased from approximately 150 t to <20 t in the late 2000s (Figure 36). This represents a small fraction of the adult biomass in the area.

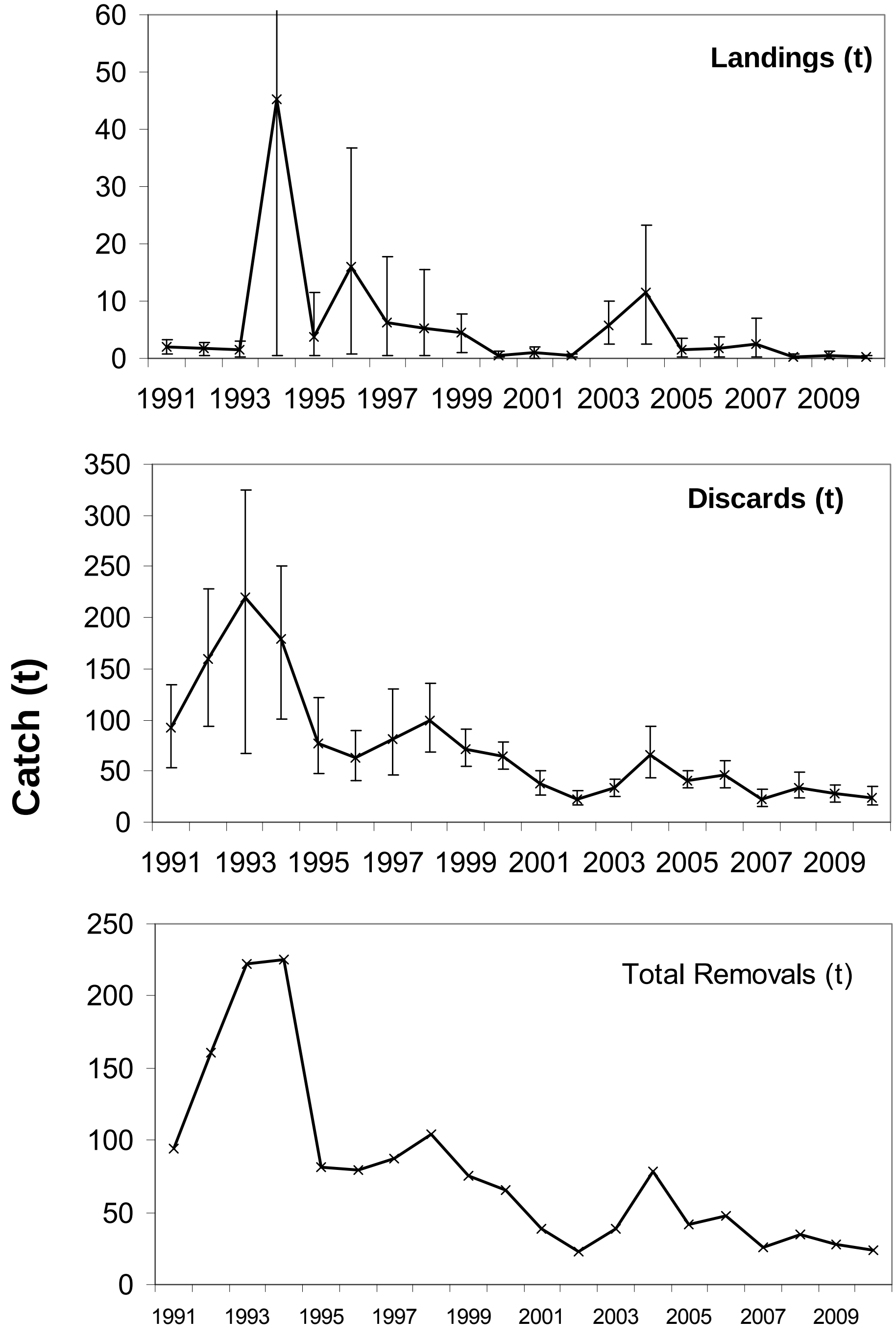

Figure 36. Estimated removals of Thorny Skate in the southern Gulf of St. Lawrence (data provided by H. Benoît). Vertical lines are ± 2 SD.

Catches of Thorny Skate the eastern Scotian Shelf (Div. 4VsW) have declined from about 7,000 t in the 1970s to under 50 t in recent years, following closure of the directed fishery in 2004 (Figure 37). On the western Scotian Shelf, bycatch of skate declined from about 1600 t in the 1980s-early 1990s to about 600 t in recent years. Removals on the Scotian Shelf were of sufficient magnitude to have affected abundance of Thorny Skate, although the effect has not been precisely quantified.

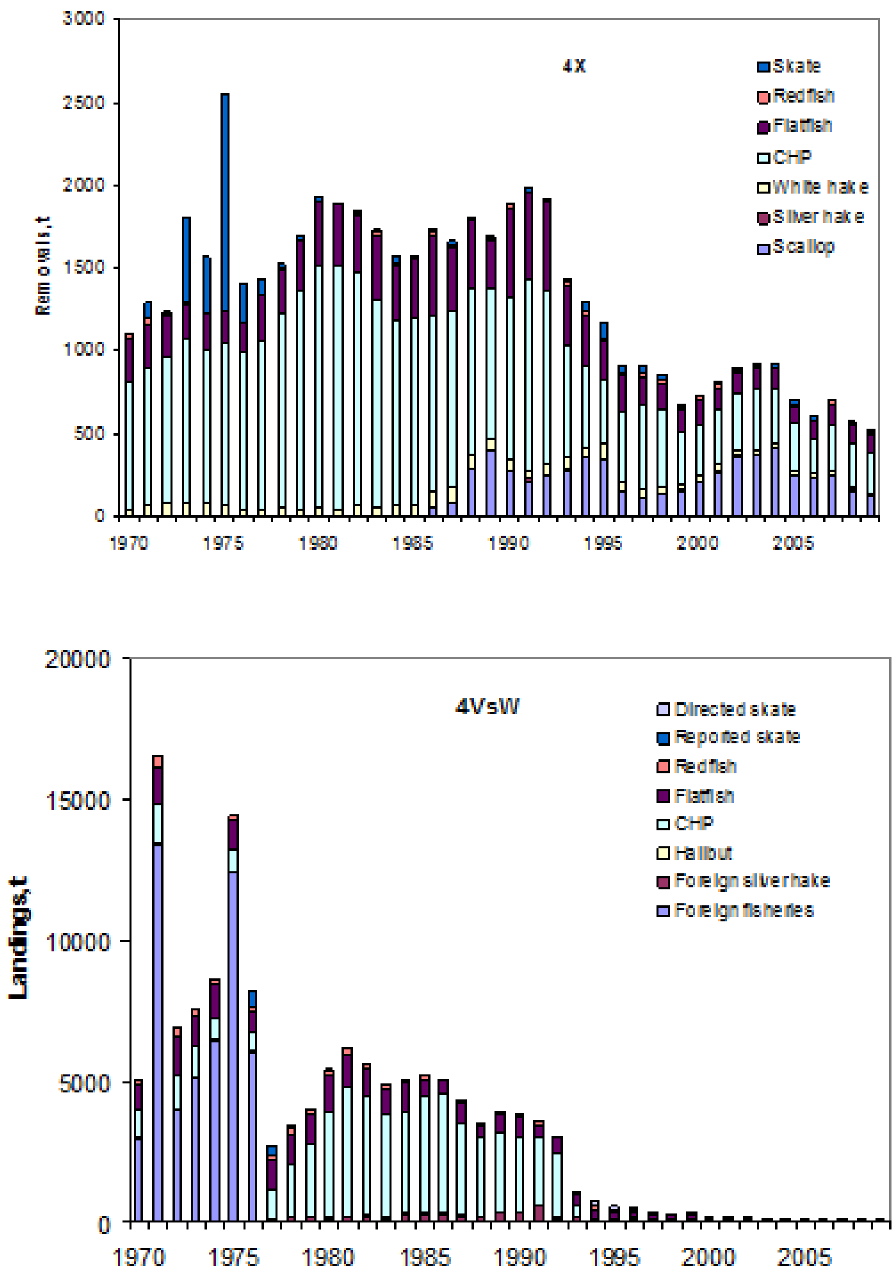

Figure 37. Estimated removals (t) of Thorny Skate from selected directed fisheries in Div. 4X and Div. 4VsW as derived from observer reports. Observer coverage in other fisheries was insufficient to estimate removals or Thorny Skate was not reported as bycatch (after Simon *et al.* 2012).

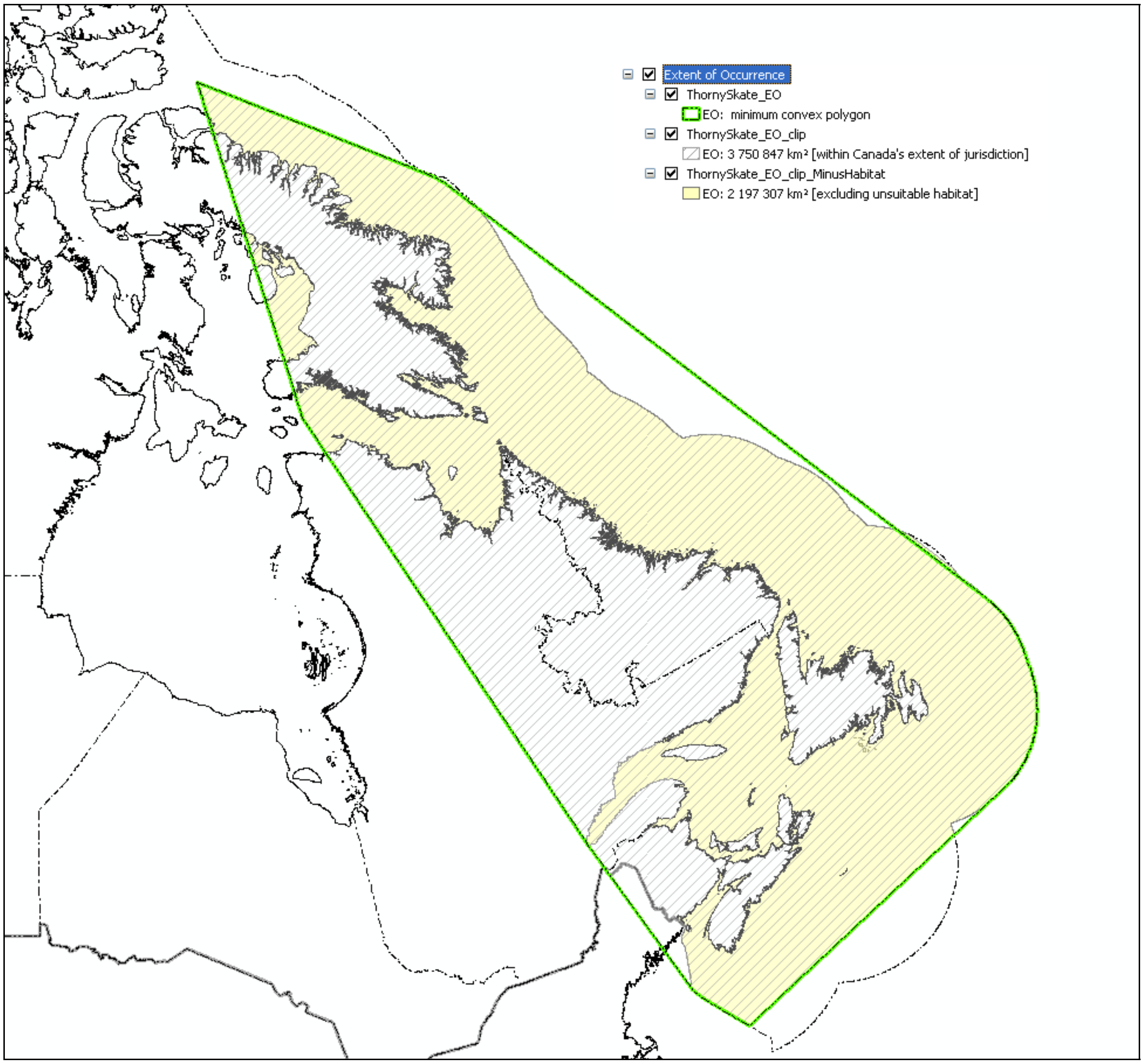

Figure 38. Extent of occurrence of Thorny Skate in Canadian waters.

PROTECTION, STATUS, AND RANKS

The IUCN has listed Thorny Skate as "vulnerable" on their Redlist, a global assessment of risk of extinction (Kulka *et al*. 2004). This species has been listed as a "Species of Concern" in USA waters by the National Marine Fisheries Service (NMFS) of the USA since 2004 (NMFS 2007). That listing was based on long-term declines in survey catches and a reduction in their median size. NMFS singles out mortality due to bycatch discards as the key factor of decline. The possession of Thorny Skate is currently prohibited in the Gulf of Maine fishery. A petition to list Thorny Skate as "endangered" or "threatened" under the *Endangered Species Act* (ESA) has recently been filed (Smith 2011).

Habitat Protection and Ownership

The distribution of the Thorny Skate overlaps a number of closed areas and marine protected areas such as the “Gully”, the 2J crab box, and the Funk Island Deep box. However, these areas represent only a tiny fraction of the distribution of fish in Canadian waters. Canada is presently considering a portion of the Laurentian Channel as a Marine Protected Area. This is an area of concentration of Thorny Skate.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The report writer wishes to thank Margaret Treble, Mark Simpson, Carolyn Miri, Jim Simon, Doug Swain and Brigitte Bernier for their cooperation with providing data and related background documents. Also, Jim Simon provided invaluable insight into the groundfish survey operation and James Sulikowski was a great source of information on Thorny Skate growth and reproduction biology. This report would not have been possible without the many years of service provided by ocean-going staff of Fisheries and Oceans Canada during their groundfish surveys. Funding for the preparation of this status report was provided by Environment Canada.

Authorities Consulted

Mark Simpson, Section Head, Fisheries and Oceans Canada, NL Region, St. Johns NL.

Carolyn Miri, Biologist, Fisheries and Oceans Canada, NL Region, St. Johns NL.

Brigitte Bernier, Biologist, Fisheries and Oceans Canada, Québec Region, Mont-Joli, Québec.

Doug Swain. Research Scientist, Fisheries and Oceans Canada, Gulf Region, Moncton, New Brunswick.

Hugues Benoît. Research Scientist, Fisheries and Oceans Canada, Gulf Region, Moncton, New Brunswick.

Jim Simon, Biologist, Fisheries and Oceans Canada, Maritimes Region, Dartmouth, Nova Scotia.

James Sulikowski, Assistant Professor, University of New England, Biddeford, Maine, USA.

Margaret Treble, Biologist, Fisheries and Oceans Canada, Central and Arctic Region, Winnipeg, Manitoba.

INFORMATION SOURCES

Anon. MS 2003. Geomatica V. 9 Users Guide. PCI Geomatics, 50 West Wilmot St. Richmond Hill. Ont.

Antipova, T.V., and T.B. Nikiforova. MS 1983. Some data on nutrition of thorny skate *Raja radiata* (Donovan) in the Barents Sea. ICES CM 1983/G:22.

Benoît, H.P., and D.P. Swain. 2003. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: adjusting for changes in research vessel, gear and survey protocol. Can. Tech. Rep. Fish. Aquat. Sci. No. 2505.

Benoît, H.P., and D.P. Swain. 2011. Changes in size-dependent mortality in the southern Gulf of St. Lawrence marine fish community. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/039. iv + 22 p.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull., U.S. Fish. Wildl. Serv. 74(53).

Bishop, C.A. MS 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43. 10 p.

Brodie, W.B. 2005. A Description of the Fall Multispecies Surveys in SA2 + Divisions 3KLMNO from 1995-2004. NAFO SCR Doc. 05/8 Serial No. N5083

Brown, S.K., R. Mahon, K.C.T. Zwanenburg, K.R. Buja, L.W. Claflin, R.N. O´Boyle, B. Atkinson, M. Sinclair, G. Howell, and M.E. Monaco. 1996. East Coast of North America Groundfish: Initial Explorations of Biogeography and Species Assemblages. NOAA, Silver Springs, MD, DFO, Dartmouth, Nova Scotia. 100+ pages.

Chevolot, M., Wolfs, P.H.J., Pálsson, J., Rijnsdorp, A.D., Stam, W.T., and J.L. Olsen. 2007. Population structure and historical demography of the Thorny Skate (Amblyraja radiata, Rajidae) in the North Atlantic. Mar. Biol. 151: 1275–1286.

Colbourne, E.B and D.W. Kulka 2004. A preliminary investigation of the effects of ocean climate variations on the spring distribution and abundance of Thorny Skate (*Amblyraja radiata*) in NAFO Divisions 3LNO and Subdivision 3P. NAFO SCR Doc. 04/29.

Colbourne, E. B., J. Craig, C. Fitzpatrick, D. Senciall, P. Stead and W. Bailey 2010 An Assessment of the Physical Oceanographic Environment on the Newfoundland and Labrador Shelf in NAFO Subareas 2 and 3 during 2009. SCR 10/16.

Collette, B.B. and G. Klein-MacPhee. 2002. Fishes of the Gulf of Maine. Smithsonian Institution Press. Washington and London. 748 pages.

Coulson, M.W., D. Denti, L. Van Guelphen, C. Miri, E.K. Kenchington and P. Bentzen. 2011. DNA barcoding of Canada’s skates. Mol. Ecol. Resources 11: 968-978.

Cox, D.L., P. Walker and T.J. Koob 1999. Predation on eggs of Thorny Skate. Trans. Am. Fish. Soc. 128: 380-384.

del Río, J.L., and S. Junquera. MS 2001. Spanish skate (*Raja radiata* Donovan, 1808) fishery in the Grand Bank (NAFO Division 3N): 1997-2000. NAFO SCR Doc. 01/031, Ser. No. N4408. 10p.

del Río, J.L., and S. Junquera. MS 2002. Some aspects of the thorny skate (*Raja radiata* Donovan, 1808) reproductive biology in NAFO Division 3N Regulatory Area. NAFO SCR Doc. 01/055, Ser. No. N4433. 13p. del Río, J.L., E. Roman, and S. Cervino. MS 2002. Abundance and distribution of Elasmobranchs in NAFO Regulatory Area (Divisions 3MNO). NAFO SCR Doc. 02/106.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Counc. Stud. No. 2.

Dufour, R., H. Benoît, M. Castonguay, J. Chassé, L. Devine, P. Galbraith, M. Harvey, P. Larouche, S. Lessard, B. Petrie, L. Savard, C. Savenkoff, L. St-Amand and M. Starr 2010. Ecosystem status and trends report: Estuary and Gulf of St. Lawrence ecozone. CSAS Res Doc. - 2010/030

Froese, R. and D. Pauly, Editors. 2000. FishBase 2000: concepts, design and data sources. ICLARM, Los Baños, Laguna, Philippines. 344 p.

Gallagher, M.J., C.P. Nolan, and F. Jeal. 2002. The structure and growth processes of caudal thorns. NAFO SCR Doc. 02/130, Ser. No. N4752. 7p.

Gallagher, M.J., C.P. Nolan, and F. Jeal. 2005. Age, growth and maturity of the commercial ray species from the Irish Sea. J. Northw. Atl. Fish. Sci. 35: 47-66.

Garman, S. 1913. The Plagiostomia (Sharks and Rays). Memoirs of the Museum of Comparative Zoology, Harvard College, Cambridge Massachusetts, v. 36, 528 pgs.

Gedamke, T., W.D. DuPaul, and J.A. Musick. 2005. Observations on the life history of the Barndoor skate, Dipturus laevis, on Georges Bank (Western North Atlantic). J. Northw. Atl. Fish. Sci. 35: 67-78.

González C., E. Román, X. Paz, and E. Ceballos 2006. Feeding Habits and Diet Overlap of Skates (*Amblyraja radiata*, *A. hyperborea*, *Bathyraja spinicauda*, *Malacoraja senta* and *Rajella fyllae*) in the North Atlantic. NAFO SCR Doc. 06/53 Ser. No. N5285, 17 p.

Henderson, A.C., A.I. Arkhipkin, and J.N. Chtcherbich. 2005. Distribution, growth and reproduction of the white-spotted skate *Bathyraja albomaculata* (Norman, 1937) around the Falkland Islands. J. Northw. Atl. Fish. Sci. 35.

Hurlbut, T. and H.P. Benoît 2001. The seasonal distribution of selected marine fish in the southern Gulf of St. Lawrence based on bottom trawl surveys. DFO Res. Doc. 2001/116

ICES. 2005. Report of the Working Group on Elasmobranch Fishes (WGEF). ICES CM 2005/ACFM:03. Ref. G210pp.

Kulka, D. W. 1998. SPANdex - SPANS geographic information system process manual for creation of biomass indices and distributions using potential mapping. DFO Atl. Fish. Res. Doc. 98/60 28p.

Kulka D. W., Power, D. and M. R. Simpson 2002. Allocation criteria: Analysis of biomass distribution and catch history for selected species of commercial interest in waters adjacent to Atlantic Canada, inside (Canadian waters) versus outside 200 miles. NAFO SCR Doc. 02/0122, Ser. No. N4743 60 p.

Kulka, D. W. and C. M. Miri 2003. The status of Thorny skate (Amblyraja radiata Donovan, 1808) in NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps. NAFO SCR Doc. 03/57, Ser. No. N4875. 100p.

Kulka, D.W., Miri, C.M., Simpson, M.R., and Sosebee, K.A. 2004. Thorny Skate (*Amblyraja radiata* Donovan, 1808) on the Grand Banks of Newfoundland. NAFO SCR Doc. 04/35.

Kulka, D.W., M.R. Simpson, and C.M. Miri 2006a. An Assessment of Thorny Skate (*Amblyraja radiata* Donovan, 1808) on the Grand Banks of Newfoundland. NAFO SCR Doc. 06/44.

Kulka, D.W., Swain, D., Simpson, M.R., Miri, C.M., Simon, J., Gauthier, J., McPhie, R., Sulikowski, J., and Hamilton, L. 2006b. Distribution, Abundance, and Life History of Malacoraja senta (M. senta) in Canadian Atlantic Waters. CSAS Res Doc. 2006/93.

Lawson G.L. and G. A. Rose 2000. Seasonal distribution and movements of coastal cod (*Gadus morhua* L.) in Placentia Bay, Newfoundland. Fisheries Research Vol. 49/1, 61-75. doi:10.1016/S0165-7836(00)00187-9

McEachran, J.D. 1973. Biology of seven species of skates (Pisces: Rajidae). Ph.D. dissertation, Coll. William and Mary, Williamsburg, VA. 127 p.

McEachran, J.D. and. J.A. Musick 1975. Distribution and relative abundance of seven species of skates (Pisces: Rajidae) which occur between Nova Scotia and Cape Hatteras. Fish. Bull. (U.S.) 73: 110-136.

McEachran, J.D., D.F. Boesch and J.A. Musick 1976. Food division within two sympatric species-pairs of skates (Pisces: Rajidae). Mar. Biol. 35: 301-317.

McPhie, R. P., and S. E. Campana 2009a. Bomb dating and age determination of skates (family Rajidae) off the eastern coast of Canada. ICES Journal of Marine Science, 66: 546–560.

McPhie, R. P., and S. E. Campana 2009b. Reproductive characteristics and population decline of four species of skate (Rajidae) off the eastern coast of Canada. Journal of Fish Biology 75, 223–246. doi:10.1111/j.1095-8649.2009.02282.

Metcalfe. J.D. and G. P. Arnold 1997. Tracking fish with electronic tags Nature 387: 665-666.

NMFS. 2007. Species of concern: Thorny Skate. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD.

Nygaard, R., and O.A. Jorgensen 2010. Biomass and Abundance of Demersal Fish Stocks off West Greenland Estimated from the Greenland Shrimp Survey, 1988-2009. NAFO SCR Doc. No. 10/30, 28 p.

McEachran, J.D. 1973. Biology of seven species of skates (Pisces: Rajidae). Ph.D. dissertation, Coll. William and Mary, Williamsburg, VA. 127 p.

McEachran, J.D., D.F. Boesch and J.A. Musick 1976. Food division within two sympatric species-pairs of skates (Pisces: Rajidae). Mar. Biol. 35: 301-317.

McPhie, R. P., and S. E. Campana 2009a. Reproductive characteristics and population decline of four species of skate (Rajidae) off the eastern coast of Canada. Journal of Fish Biology 75, 223–246. doi:10.1111/j.1095-8649.2009.02282.

McPhie, R. P., and S.E. Campana 2009b. Bomb dating and age determination of skates (family Rajidae) off the eastern coast of Canada. – ICES Journal of Marine Science 66: 546–560.

Packer, D. B. C. A. Zetlin, and J. J. Vitaliano 2003. Essential Fish Habitat Source Document: Thorny Skate, *Amblyraja radiata*, Life History and Habitat Characteristics NOAA Technical Memorandum NMFS-NE-178.

Parent S., S. Pepin J.-P. Genet, L.. Misserey and S. Rojas 2008. Captive breeding of the barndoor skate (*Dipturus laevis*) at the Montreal Biodome, with comparison notes on two other captive-bred skate species. Zoo Biology 0: 1-9.

Petrie B. and R. G. Pettipas 2010. Physical Oceanographic Conditions on the Scotian Shelf and in the eastern Gulf of Maine (NAFO areas 4V,W,X) during 2009. NAFO SCR Doc. 10/12, 22p.

Rose, G. A. and D. W. Kulka 1999. Hyper-aggregation of fish and fisheries: how CPUE increased as the northern cod declined. Can. J. Fish. Aquat. Sci. 56: 1-10.

Savenkoff, C., Morissette, L., Castonguay, M., Swain, D.P., Hammill, M.O., Chabot, D., and Hanson, J.M. 2008. Interactions between marine mammals and fisheries: Implications for cod recovery. In Ecosystem Ecology Research Trends, pp. 107-151. Ed. by J. Chen and C. Guo. Nova Science Publishers Inc.

Siferd, T. 2010. Bycatch in the shrimp fishery from Shrimp Fishing Areas 0-3, 1979 to 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/037. vi + 77 p.

Sinclair, M., J. J. Maguire, P. Koeller and J. S. Scott 1984. Trophic dynamic models in light of current resource inventory data and stock assessment results. ICES Rapp. Proc.-Verb., 183: 269-284.

Simon, J.E., S. Rowe, and A. Cook. 2012. Status of smooth skate (*Malacoraja senta*) and thorny skate (*Amblyraja radiata*) in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/080: viii + 102 p.

Simpson, M.R., Mello, L.G.S., Miri, C., Treble, M.M., and Siferd, T. 2011. A pre-COSEWIC assessment of thorny skate (*Amblyraja radiata* Donovan, 1808) on the Grand Bank, Newfoundland Shelf, Labrador and northern waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/084. iv + 56 p.

Simpson, M. R. and D. W. Kulka 2005. Development of Canadian Research Trawl Gear Conversion Factors for Thorny Skate on the Grand Banks Based on Comparative Tows. NAFO SCR Doc. 05/049 N5135 13p.

Smedbol, R.K., P.A. Shelton, D.P. Swain, A. Fréchet and G.A. Chouinard 2002. Review of population structure, distribution and abundance of cod (*Gadus morhua*) in Atlantic Canada in a species-at-risk context. CSAS Res Doc. 2002/82.

Smith, T. 2011. PETITION TO LIST The Northwest Atlantic Distinct Population Segment (DPS) of the Thorny Skate (Amblyraja radiata) as an Endangered or Threatened Species or, Alternatively, to List the United States DPS of the Thorny Skate as an Endangered Species UNDER THE U.S. ENDANGERED SPECIES ACT. Petitioner: Animal Welfare Institute 900 Pennsylvania Ave. SE Washington, D.C. 20003 http://www.nero.noaa.gov/prot_res/CandidateSpeciesProgram/AWI_Thorny_Skate_ESA_Listing_Petition_8-11-2.pdf

Sosebee K.A. 2005. Maturity of skates in Northeast United States waters. Journal of Northwest Atlantic Fishery Science 35: 141–153.

Stehmann M. and D. L. Bürkel (1984) Rajidae. In Fishes of the North-eastern Atlantic and the Mediterranean (Whitehead P.J.P., Bouchot M.-L., Hureau J.-C., Nielsen J. and Tortonese E., eds). UNESCO, Paris. Volume I, 163–196.

Sulak, K.J. P.D. MacWhirter, K.E. Luke, A.D. Norem, J.M. Miller, J.A. Cooper and L.E. Harris 2009. Identification guide to skates (Family Rajidae) of the Canadian Atlantic and adjacent regions. Canadian Technical Report of Fisheries and Aquatic Sciences 2850, 46 p.

Sulikowski, J. 2011. Elasmobranch Mortality and Stress Physiology

http://www.neaq.org/conservation_and_research/projects/project_pages/elasmobranch_mortality_and_stress_physiology.php

Sulikowski, J.A., J. Kneebone and S. Elzey 2005a. The reproductive cycle of the Thorny Skate (*Amblyraja radiate*) in the western Gulf of Maine. Fish. Bull. 103: 536-543.

Sulikowski, J.A., J. Kneebone and S. Elzey 2005b. Age and growth estimates of the Thorny Skate (*Amblyraja radiata*) in the western Gulf of Maine. Fish. Bull. 103: 161-168.

Sulikowski J.A., Tsang, P.C.W, and Howell, W.H. 2004. An annual cycle of steroid hormone concentrations and gonad development in the winter skate, *Leucoraja ocellata*, from the western Gulf of Maine. Mar. Biol. 144: 845-853

Swain, D.P. and H.P. Benoît 2006. Change in habitat associations and geographic distribution of Thorny Skate (*Amblyraja radiata*) in the southern Gulf of St. Lawrence: density-dependent habitat selection or response to environmental change? Fish. Oceanogr. 15: 166-182.

Swain, D.P. and A.F Sinclair 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51: 1046-1054.

Swain, D. P., D. Daigle and É. Aubry 2011. Life history and variation in the abundance and distribution of thorny skate *Amblyraja radiata* in the southern Gulf of St. Lawrence, 1971-2010. CSAS Res Doc.xxxxx

Templeman, W. 1982a. Development, occurrence, and characteristics of egg capsules of Thorny Skate, Raja radiata, in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 3: 47-56.

Templeman, W. 1982b. Stomach Contents of the Thorny Skate, *Raja radiata*, from the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 3: 123-126.

Templeman, W.1984. Migrations of thorny skate, *Raja radiata*, tagged in the Newfoundland area. J. Northw. Atl. Fish. Sci. 5: 55 64.

Templeman, W. 1987. Differences in sexual maturity and related characteristics between populations of Thorny Skate (*Raja radiata*) in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 7: 155–168.

Treble, M.A., W.B. Brodie, W.R. Bowering, and O.A. Jørgensen. 2000. Analysis of data from a trawl survey in NAFO Division 0A, 1999. NAFO SCR Doc. 00/31, 19 pp.

Tsang, P.C.W. 2005a. Age and growth estimates of the Thorny Skate (Amblyraja radiata) in the western Gulf of Maine. Fishery Bulletin; 1/1/2005.

Tsang, P.C.W. 2005b. Identification of Life History Parameters for Two Exploited Skate Species (Amblyraja radiata and Malacoraja senta) in the Gulf of Maine: Strategies for Fisheries Management. Award number: 111403 (UNH Account Number); NA16FL1324 (Grantor Number).

Waples, R.S. 1998. Separating the wheat from the chaff: patterns of genetic differentiation in high gene flow species. Journal of Heredity 89: 438-450.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

David Kulka, who prepared the current document, is retired from Fisheries and Oceans Canada, and holds an Emeritus position and is researching elasmobranch and fishery issues. Within DFO Mr. Kulka worked on assessment of skates as NAFO designated expert and also had several roles in the area of species at risk, at various times as head of Marine Fish, Species at Risk and regional coordinator for the species at risk program. Currently, Mr. Kulka is Chair of the ICES Fish Ecology Working Group, and co-Vice Chair, northwest Atlantic, of the Elasmobranch Species Specialist Group of IUCN. He is also a member of the COSEWIC Marine Fish Species Specialist Committee. Mr. Kulka is also involved in Marine Fishery Certification. One area of expertise and research is spatial analysis, which was applied in this document.