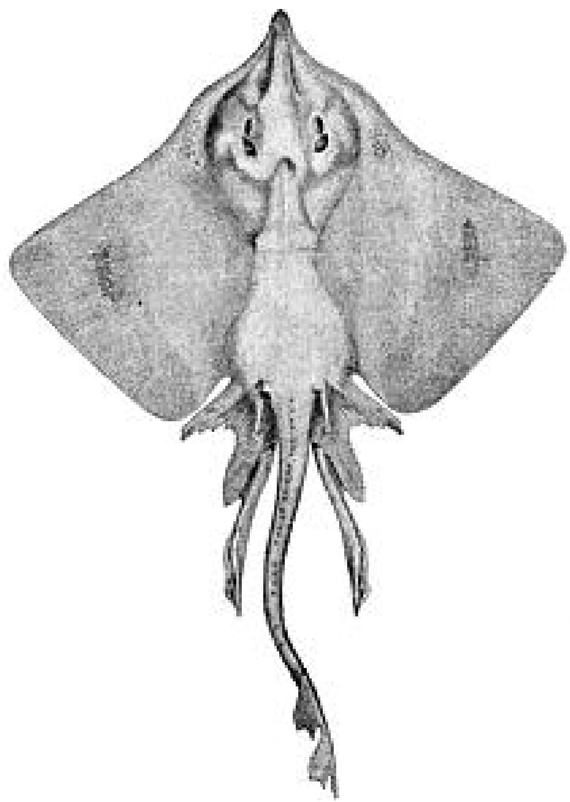
Status of the Barndoor Skate
(*Dipturus laevis*)



by

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December 2009

Acknowledgements

This status review of the barndoor skate was conducted by individuals from the National Ocean and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS). This review depended on information from scientific literature or data provided by various state agencies and individuals. The authors of this report would like to thank Peter Comeau, Toby Curtis, Todd Gedamke, and Katherine Sosebee for their helpful comments and suggestions during the peer review process. We would also like to thank Mary Colligan, Sarah Laporte, and Dwayne Meadows for their editorial reviews.

This document should be cited as:

Cavanagh, M.F., and K. Damon-Randall. 2009. Status of the barndoor skate (*Dipturus laevis*). National Marine Fisheries Service Report, Northeast Regional Office. 77 pp.

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List of Acronyms

B_{msy}	Biomass needed for maximum sustainable yield
B_{target}	Biomass target reference point necessary to produce B_{msy}
$B_{threshold}$	Minimum biomass threshold below which a species is in an overfished condition
BRP	Biological reference point
CMC	Center for Maine Conservation
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DAS	Days-at-sea
DFO	Department of Fisheries and Oceans of Canada
DPSWG	Data Poor Stocks Working Group
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
F	Fishing mortality
F_{msy}	Fishing mortality rate needed for maximum sustainable yield above which a species is overfished
FMP	Federal Management Plan
FR	Federal Register
k	Growth coefficient
K	Carrying capacity of a population
M	Natural mortality
MAFMC	Mid-Atlantic Fisheries Management Council
MRFSS	Marine Recreational Fishery Statistics Survey
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	Maximum sustainable yield
NAFO	Northwest Atlantic Fisheries Organization
Ne	Effective population size
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NERO	Northeast Regional Office
NMFS	National Marine Fisheries Service
NOAA	National Ocean and Atmospheric Administration
OY	Optimum yield
PDT	Plan Development Team
r	Intrinsic rate of population increase
RV	Research vessel
SAFE	Stock Assessment and Fishery Evaluation
SAP	Special access program
SAW	Stock Assessment Workshop
SBRM	Standard Bycatch Reporting Methodology
SMU	Skate Management Unit
SOC	Species of Concern
SSB	Spawning stock biomass

t_0	Theoretical age when length equals zero
TAC	Total allowable catch
TAL	Total allowable landings
Z	Total instantaneous mortality

Executive Summary

This report provides a summary of the best available information and published literature regarding barndoor skates (*Dipturus laevis*). The species was added to the Endangered Species Act candidate species list in 1999 and is currently considered a species of concern (SOC) as it was transferred to the SOC program in 2004 when NMFS redefined the use of the term "candidate species" (NMFS, 2004) and created the Species of Concern program. Because there is new information on barndoor skates since 2004, this report was initiated to present the best scientific and commercial data available to investigate the current status of the species relative to the criteria for remaining a SOC.

Barndoor skates are the largest member of the Rajidae family residing in the Northwest Atlantic. Like many other elasmobranchs, they are long-lived, slow growing, and have a late age at maturity. This life history strategy may make a species particularly vulnerable to overfishing, and such species will often exhibit a slow rate of recovery once fishing pressure or other threats are reduced or removed. Several studies have suggested that barndoor skates are vulnerable to exploitation (e.g., Casey and Myers, 1998; Frisk *et al.*, 2002). However, these studies suffered from a lack of detailed knowledge on the population dynamics and life history of the species and used indirect or coarse biological proxies for model input parameters that may have underestimated the rebuilding potential of the species. Recent research on the life history characteristics (Gedamke *et al.*, 2005; Parent *et al.*, 2008) and population dynamics (Gedamke *et al.*, 2009) of barndoor skates has yielded a more rapid rebuilding estimate and suggests the species may be more resilient to exploitation than previously believed.

The reported distribution of barndoor skates spans from the southwest slope of the Grand Bank and southern Gulf of St. Lawrence, along the northeastern coast and offshore banks of Nova Scotia, south to North Carolina (Bigelow and Schroeder, 1953a; McEachran and Musick, 1975; Scott and Scott, 1988). Within this broad geographic range, their reported depth range was from the shoreline to 430 m deep, but they were thought to be most abundant at depths less than 183 m (Bigelow and Schroeder, 1953a). However, recent Canadian survey data of the Newfoundland and Labrador Regions have encountered barndoor skates in survey sets at depths in excess of 1000 m.

Casey and Myers (1998) believed barndoor skates were on the brink of extinction after analyzing biomass indices determined by research vessel surveys from the early 1950s to mid 1990s. The survey data covered the southern Grand Bank down to Southern New England between 50 and 400 m depth contours. The life history information on barndoor skates needed for the analysis was unknown at that time so life history parameters were used from a similar species, the common skate (*Raja batis*). Recent research on the life history of barndoor skates suggests the barndoor skate is more fecund, has an earlier age of maturity, a shorter life span, and smaller maximum body size (Brander, 1981; Gedamke *et al.*, 2005; Parent *et al.*, 2008) than the common skate. Thus, Casey and Meyers (1998) modeling results may have overestimated the risks to barndoor skates.

When using demographic models, inaccurate assumptions of life history parameters can significantly change model outputs (Walker and Hislop, 1998). Furthermore, not taking into account the overall population dynamics of a species such as the density-dependent response barndoor skates may have to change in population sizes and fluctuating levels of available resources may exclude fundamental factors in understanding that species' response to declines in abundance (Gedamke *et al.*, 2009). Canadian catch records of the species' range extending to 1000 m also suggests that the data used by Casey and Myers (1998) did not cover the entire distribution of barndoor skates. Thus, Casey and Myers (1998) may have underestimated the total abundance of barndoor skates and their potential response to declines in abundance.

The National Marine Fisheries Service, Northeast Fisheries Science Center (NEFSC) spring and autumn bottom trawl survey biomass index documented barndoor skates in high abundance during the 1960s followed by a drastic decline throughout the 1970s and 1980s. There has been a consistent rise in the species' biomass index since the mid 1990s, with recent survey records higher than most peak indices from the 1960s. Length frequencies have followed a similar trend with a large length range in the 1960s that narrowed throughout the 1970s and 1980s. Since the mid 1990s, there has been a vast increase in size ranges as well as documentation of both juvenile and adult fish caught. Recent survey years have also been catching larger individuals that have been absent in surveys since the 1960s, when barndoor skate biomass was at its peak.

Due to concerns over declines in abundance of several species belonging to the Northwest Atlantic skate complex, as well as a petition to list barndoor skates as threatened or endangered under the Endangered Species Act (ESA), the New England Fisheries Management Council (NEFMC) developed a Skate Fishery Management Plan (FMP) for the Northeast Skate Complex. Biomass reference points (BRPs) for each of the seven species of skate were calculated and the FMP was implemented in 2003. However, the NEFSC trawl survey biomass index suggests that barndoor skates had already been in a rebuilding phase since the mid 1990s. This rebuilding coincided with the implementation of three large closure areas to groundfish and scallop vessels on Georges Bank in 1994 and is thought to have drastically reduced fishing mortality exerted on the species. Barndoor skates are primarily caught as incidental catch in trawls, gillnets, and scallop dredges. The skate wing and bait (primarily lobster) fisheries are directed at skates but do not target barndoor skates, though they do occur as incidental catch. However, due to overfishing concerns, possession and landings of barndoor skate have been prohibited since 2003. Thus, it seems management in other fisheries has already provided the necessary measures to promote population rebuilding, with the Skate FMP providing additional management benefits.

Several factors are considered when evaluating whether a species should be added to or removed from the SOC program. NMFS determined that demographic and genetic diversity concerns should be considered as well as, and the species' abundance and productivity, distribution, and life history characteristics. Information on natural or anthropogenic threats to a species, in isolation or in concert with information on demographic and diversity factors, can also indicate that a species should be added to the SOC list.

The most recent research on life history characteristics and population dynamics of barndoor skates has found a more rapid rebuilding estimate and suggests the species may be more resilient to exploitation than previously believed. In addition, the consistent rise in biomass as well as the large increase in size ranges, coupled with management in other fisheries and the Skate FMP, shows the continued rebuilding of barndoor skate stocks. Given the newly acquired information presented above, barndoor skates no longer meet the criteria for a species of concern and inclusion on the SOC list is no longer warranted.

1.0. Introduction

On January 15, 1999, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) published in the *Federal Register* a notification soliciting comments and reliable documentation on species it was considering adding to the Endangered Species Act (ESA) candidate species list (NMFS, 1999). In that publication, NMFS listed barndoor skates (*Dipturus laevis*) as one of the species under consideration.

On March 4, 1999, NMFS received a petition from GreenWorld to list barndoor skates as endangered or threatened under the Endangered Species Act (ESA) and to designate Georges Bank and other appropriate areas as critical habitat. GreenWorld requested that they be listed immediately, as an emergency matter, as well as similar looking species of skates to insure the protection of barndoor skates. On April 2, 1999, NMFS received a second petition from the Center for Marine Conservation (CMC), now the Ocean Conservancy, to list barndoor skates as an endangered species. This second petition was considered by NMFS as a comment on the first petition submitted by GreenWorld.

Both the petition and comment on the petition referenced a paper by Casey and Myers (1998) that presented data suggesting the potential extinction of barndoor skates. Casey and Myers (1998) calculated population estimates for barndoor skates on St. Pierre Bank (an area where the species was commonly found) of 600,000 barndoor skate individuals in the 1950s that decreased to less than 500 individuals in the 1970s. The paper also reported that barndoor skates, once a common bycatch species off southern Newfoundland, had become locally eradicated in parts of its northern range (i.e., St. Pierre Bank) (Casey and Myers, 1998). The petitioner cited bycatch in commercial fishing gear as the major threat to the species as well as the inadequacy of existing regulatory mechanisms. The petitioner also expressed concerns over inbreeding depression due to the small population size. On March 11, 1999, CMC also requested that the Secretary of Commerce categorize barndoor skates as "overfished" under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) so that rebuilding efforts could occur.

On June 23, 1999, after considering all available information, NMFS published its revised list of candidate species, which included barndoor skates (NMFS, 1999b). In that same month, NMFS published a finding that the petition to list barndoor skates under the ESA might be warranted (NMFS, 1999c). NMFS then initiated a review of the status of the species to determine if listing barndoor skates under the ESA was warranted. As part of that review, NMFS conducted a stock assessment of the species. NMFS used the information published in the Stock Assessment and Fishery Evaluation (SAFE) report instead of preparing a separate status review report.

On September 27, 2002, after reviewing the best scientific and commercial information available, NMFS published in the *Federal Register* its determination that listing barndoor skates as either threatened or endangered under the ESA was not warranted (NMFS, 2002). Survey data showed an increase in abundance and biomass, expansion of known areas where barndoor skates were encountered, an increase in size range, as well as an increase in small barndoor skates collected. This trend is not consistent with a species in danger of extinction. Furthermore, the major identifiable threat to the species, overfishing, had been reduced by regulatory measures affecting several northeast fisheries. In addition to the regulatory measures already in place, NMFS was working with the New England Fishery Management Council (NEFMC) to develop the Skate Fishery Management Plan (FMP). Due to remaining uncertainties regarding the status and population structure of barndoor skates, NMFS determined that leaving the species on the agency's list of candidate species was warranted until additional scientific and commercial data became available (NMFS, 2002).

The regulations implemented in Section 4 of the ESA define a candidate species as any species being considered by the Secretary of Commerce or Interior for listing as an endangered or a threatened species, but not yet the subject of a proposed rule. Species were added to the candidate species list based on consideration of their biological status. Biological status was determined by demography and genetic composition of the species. If there was evidence of demographic or genetic concerns that would indicate that listing may be warranted, the species would be added to the candidate species list. Demographic concerns would occur when there is a significant decline in abundance or range from historical levels that would indicate that listing may be warranted. This could result from overharvest, habitat degradation, disease outbreaks, predation, natural climatic conditions, and hatchery practices that lead to competition with natural stocks or depletion of natural fish for use as hatchery broodstock. Genetic concerns that would indicate that listing may be warranted include outbreeding and inbreeding depression resulting from poor hatchery practices or substantially reduced numbers of natural individuals.

As resources permitted, NMFS would conduct a review of the status of each candidate species to determine if it warranted listing as endangered or threatened under the ESA. Sometimes, even though NMFS may have determined, after conducting a status review, that a species did not warrant listing under the ESA, NMFS retained the species on the candidate species list due to remaining concerns or uncertainties. Thus, the purpose of the candidate species program expanded over time, and NMFS began using the list to draw attention to these particular species. The goal was that this increased attention might lead to implementing proactive conservation actions that would prevent the need to list the species under the ESA or voluntary efforts to research the remaining uncertainties associated with the species.

On April 15, 2004, NMFS published in the *Federal Register* (NMFS, 2004) recognition that using the candidate species list for these broader purposes may give the inaccurate impression that all these species were being considered for listing under the ESA. However, NMFS also recognized the importance in publicly identifying species that, although they are not being considered for listing, are nevertheless of concern for reasons identified above. In order to maintain a publicly available list of other species of concern, NMFS established a Species of Concern (SOC) program. The goals of the program are to: (1) identify species potentially at risk; (2) increase public awareness about those species; (3) identify data deficiencies and uncertainties in species' status and threats; (4) stimulate cooperative research efforts to obtain the information necessary to evaluate species status and threats; and (5) foster voluntary efforts to provide stewardship for the species before an ESA listing as threatened or endangered became warranted. At that time, barndoor skates were transferred to the SOC list to clarify that NMFS has concerns or insufficient information about the species, but is not actively considering listing them under the ESA.

Several factors are considered when evaluating whether a species should be added to or removed from the SOC program. NMFS determined that not only will the demographic and genetic diversity concerns be used, as they were previously used to identify candidate species as described above, but the species' abundance and productivity; distribution; and life history characteristics will also be considered when identifying whether a species is an SOC. Information on natural or anthropogenic threats to a species, in isolation or in concert with information on demographic and diversity factors, can also indicate that a species should be added to the SOC list. Factors related to a species abundance and productivity include the magnitude of decline (both recent and historical); natural rarity (species known only from a small number of specimens or that occurs infrequently and in small numbers due to ecological or evolutionary factors); and endemism (species or population that is native to a particular place and is only found there). Factors related to distribution include population connectivity, which is the level of reproductive exchange among related populations; endemism; and limited geographic range. Life-history characteristics include vulnerable life-history strategies (e.g., low fecundity, late age at maturity, slow growth rates); resilience to environmental variability and catastrophic events; and potential loss of unique life-history traits.

This report addresses the aforementioned SOC factors relative to the status of and threats to barndoor skates to determine whether the species should be retained on or removed from the SOC program. Factors that have changed since the species was last reviewed in 2004 are emphasized as most relevant to this decision.

2.0. Species Biology

2.1. Biological Overview

General Species Description

Barndoor skates are one of the seven species of skate that commonly occur in the Northwest Atlantic and are the largest member of this skate complex. The species is thought to be a close relative of the common skate (*D. batis*) in European waters and the Caribbean skate (*D. teevani)* off the southeastern United States (Bigelow and Schroeder, 1962). A detailed fact sheet on barndoor skates is located on the NMFS's SOC website at: http://www.nmfs.noaa.gov/pr/pdfs/species/barndoorskate_detailed.pdf.

Morphology

Barndoor skates are easily distinguishable by their large size, pointed nose, and smooth skin (Bigelow and Schroeder, 1953a). The species has a broad, diamond-shaped disk with its length approximately three fourths of its width (Bigelow and Schroeder, 1953b) and an acute anterior angle (sharpest of the skate complex) (Bigelow and Schroeder, 1953a). The front edges of the pectoral fins are concave with angled outer corners. They move through the water column by undulations of the pectoral fins and use their tail to steer. Male barndoor skates have a patch of spines above and below the corners of the pectoral fins (McPhie *et al.*, 2007). Two dorsal fins of approximately equal size are separated by a thin space near the end of the caudal fin. The caudal fin is almost as long as the disk, extending farther past the second dorsal than most other skates (Bigelow and Schroeder, 1953a). Comparatively small, thorn-like spines stretch from the middle part of the back of the disk to the first dorsal. One or two lateral rows of large, sharp spines (smaller on males than females) border the median row (Bigelow and Schroeder, 1953a). Spines are also located around the snout, above and below the eyes, along the anterior edges of the disk, and on the inter-space between the two dorsal fins (Bigelow and Schroeder, 1953a). The ventral side is relatively smooth except for a rough area around the margin of the snout that extends to the nostrils in females (McPhie *et al.*, 2007). The length of the claspers on an adult male are one third the width of its disk and extend three fourths the distance from the axils of its pelvic fins to the first dorsal (Bigelow and Schroeder, 1953a). The male and female upper and lower jaws are curved with 30 to 40 and 28 to 38 series of teeth, respectively (Bigelow and Schroeder, 1953a). Female and immature male barndoor skates have flat, plate like teeth while adult males have thin, sharp cusps (Bigelow and Schroeder, 1953a; Gedamke, 2006).

The upper surface of barndoor skates is brown to reddish brown with scattered dark spots of varying sizes except for some newly hatched individuals (Bigelow and Schroeder, 1962). Lighter reticulations sometimes surrounded by dark rings as well as a large, oval, dark spot on the base of the pectoral fins are also present (Bigelow and Schroeder, 1953a). The lower surface of barndoor skates is a distinctive irregular gray with white to gray blotches. Both surfaces contain conspicuous dark colored mucous pores near the eyes, snout, and parts of the anterior disk. It is the only skate in the Northwest Atlantic with dark pigmented pores that are visible in both small and large individuals (Bigelow and Schroeder, 1962).

Reproduction

Members of the skate family are oviparous and lay eggs that are encased in a hard leathery capsule commonly known as a mermaid's purse. Barndoor skate egg cases have been found on both stony and silty bottom (Vladykov, 1936 as cited in Kenchington, 1999), at 27 to 46 m depths, and empty cases have been picked up on beaches (Bigelow and Schroeder, 1953b). Barndoor skate egg cases are considerably larger than other skates. Bigelow and Schroeder (1953a) measured barndoor skate egg cases in the wild at approximately 13 cm long and 7 cm wide. However, Parent *et al.*'s (2008) breeding study of a captive barndoor skate recorded egg cases that were the same width observed by Bigelow and Schroeder (1953a) but at a longer length (16 cm). The eggs are yellowish or greenish brown with relatively small hollow tendrils (or horns) less than 3 cm at each corner that enable them to fasten to seaweed or other objects (Bigelow and Schroeder, 1953a). The egg capsules are also covered in loose sticky fibers, most likely to stick to benthic substrates. The dorsal side of the capsules is usually convex and the ventral side is relatively flat.

In skates, embryonic development may last for long periods of time and mainly occurs outside of the mother, a mode of egg-laying called extended oviparity. The tough egg case is the only form of protection. The eggs are deposited on the bottom in pairs of two. Before hatching the embryo develops temporary external gill filaments from the walls of the gill clefts which degenerate by the time of hatching (Bigelow and Schroeder, 1953a).

2.2. Life History

Fecundity

Until recently there was limited information on the reproductive life history of barndoor skates. Much of the knowledge was assumed from the life history parameters of its European relative, the common skate. Fecundity was assumed to be 47 eggs per year, based on the inverse relationship between fecundity and weight of hatchlings and common skate life history parameters (Casey and Myers, 1998; NEFSC, 2000; Dulvy, 2003). However, Parent *et al.* (2008) observed a barndoor skate in captivity (at a constant water temperature of 10º C) was able to produce an average of 75 eggs per year over four years. Parent *et al.* (2008) estimated the age of the female in 2006 was at least 9 and possibly 11 years. Length of the female in 2007 was 122 cm. There is no guarantee that captive fecundity mimics that in the wild and thus, it is not know if this is an accurate estimate of fecundity (T. Gedamke, *pers. comm.*, 2009). However, total lengths at birth (18 to 20 cm) were the same as wild hatchlings (18 to 19 cm; McEachran, 2002) and total length at age 2 (49 to 60 cm) were similar to 2 year olds from Georges Bank (45 to 60 cm; Gedamke *et al.*, 2005), suggesting a similar growth pattern in captivity (Parent *et al.*, 2008).

More fecund species are capable of sustaining more fishing pressure (Musick, 1999). The previously presumed low fecundity of barndoor skates was a source of concern given that low fecundity is known to be detrimental to exploited populations, especially for elasmobranch species. However, the information derived from Parent *et al.*'s (2008) captive breeding study suggests that barndoor skates are more fecund than previously assumed but are also one of the more fecund elasmobranchs. In their study, Parent *et al.* (2008) compared barndoor skate breeding habits to that of winter and thorny skate from the same captive environment. Between 2005 and 2006, seven female winter skates and two female thorny skates laid a mean number of 48 and 41 eggs per female per year, respectively (Parent *et al.*, 2008). McPhie *et al.* (2007) reported potential fecundity values for winter and thorny skate on the Eastern Scotian Shelf off Nova Scotia to be 52 and 56 eggs annually, suggesting that fecundity of skates in captivity may be similar to skates in the wild.

Barndoor skate eggs also had a much higher hatching rate than the two other skate species (73%, 59%, and 38% for barndoor, winter, and thorny; respectively) (Parent *et al.*, 2008). Hatchling survival was roughly the same for all the three species in captivity; however, barndoor skate hatchlings were the largest of the three with an average size of 32 g (± 3.9 g), which is 3.7 times more than winter skate hatchlings (8.6 g ± 1.0 g) and 2.5 times more than thorny skate hatchlings (12.6 g ± 1.8 g) (Parent *et al.*, 2008). Therefore, as would be suggested by the *r*-K (or life history) theory, due to their large size, barndoor skate hatchlings must have a much higher survival rate in the wild than winter and thorny skate Parent *et al.* (2008).

Bigelow and Schroeder (1953a) suggest barndoor skate egg capsules may be laid in the winter based on adult females with fully formed eggs caught in December and January in Nova Scotia around Sable Island. Parent *et al.* (2008), however, observed the female barndoor skate in captivity laid eggs throughout the year, which may or may not occur in the wild. The female was observed having the highest egg deposition in the fall (10 to 12 eggs per month) and the lowest in the spring (0 to 6 per month) (Parent *et al.*, 2008).

<u>Juvenile Phase</u>

In Parent *et al.*'s (2008) study, hatching of barndoor skate eggs in captivity occurred between 342 and 494 days (mean of 421 days) after eggs were found by the divers, suggesting an average incubation time of a little over 1 year. This is a longer incubation time than the previously believed 183 to 365 days reported by NMFS (2002). Hatchlings have been observed averaging about 19 cm long, 13 cm wide, and weighing an average of 32 g (Parent *et al.*, 2008). At the time of hatching, newborns are fully capable of catching prey and avoiding predators (McPhie *et al.*, 2007).

<u>Age and Size at Maturity</u>

Historically, there has been little information on the biology of barndoor skates. As stated previously, Bigelow and Schroeder (1953a) observed the species at lengths of up to 152 cm and weights of 20 kg. Casey and Myers (1998) assumed age at maturity for barndoor skates was comparable to that of the common skate, estimated at 11 years (Brander, 1981). However, the common skate is a much larger animal, reaching over 250 cm and 50 kg (Brander, 1981).

Frisk et al. (2001) estimated age at maturity to be between 8 and 11 years. Frisk *et al.* (2002) used empirical relationships described in their earlier paper (Frisk *et al.* (2001)) to estimate age at maturity. Using longevity of 50 years and total length of 150 cm, Frisk *et al.* (2002) estimated the age at maturity of barndoor skates to be reached at approximately 12 years. Packer *et al*. (2003) indicated that the NEFSC used observed survey maximum length of 136 cm (prior to the 140 cm barndoor skate caught in the fall of 2007) and Frisk *et al.*'s (2001) predictive equations to estimate age and length at maturity to be 102 cm and 8 years. Sosebee (2005) used body morphometry to determine the size of maturity from NEFSC survey data and suggests a length of maturity at 96 and 105 cm for females and males, respectively.

Dulvy (2003) analyzed Casey and Myers' (1998) 11 year assumption and the Frisk *et al*. (2001) 8 year estimate for barndoor skate age at maturity and concluded that the average age of mature individuals in the population (i.e., average generation length of the population) can be estimated to be 10 to 14 years. However, Dulvy (2003) suggested that the lower value for age at maturity is closer to reality. Dulvy (2003) presented longevity estimates between 13 and 18 years and, assuming that age of maturity is 60% of its total lifespan, concluded that age at maturity can be assumed to be 8 to 11 years (Frisk *et al.*, 2001 as cited in Dulvy, 2003).

In 2005, Gedamke *et al.* conducted the first directed study of barndoor skates' life history characteristics by collecting 2,310 barndoor skate individuals during commercial sea scallop dredging in the southern section of Georges Bank Closed Area II. Visual inspections of reproductive organs and preliminary analyses of vertebrae from 118 specimens determined that male barndoor skates mature at approximately 108 cm and 6 years and females at 116 cm and 6.5 to 7 years (Gedamke *et al.*, 2005). The application of the von Bertallanfy growth model to their age-at-size data revealed a growth coefficient (k) from 0.14 to 0.18 under the total length parameters of 166.3 cm and 150 cm, respectively (Gedamke *et al.*, 2005). Dulvy (2003) notes, however, that these types of life history characteristics may change due to variations in population density, food availability, and exploitation rates. Given the depleted condition of the stock when Gedamke *et al.* (2005) conducted their study, it would be expected that density-dependent compensation was at a minimum and that both size and age at maturity would be greater in follow up studies conducted at larger stock sizes (T. Gedamke, *pers. comm.*, 2009).

In the same study, Gedamke *et al.* (2005) observed male adolescence (the period where barndoor skates develop their reproductive organs) occurring between 85 and 90 cm. At this point, the ratio of clasper length to total body length changes because of dramatically increasing growth rate at around 100 cm. This accelerated growth ceases at about 120 cm indicating definitive upper and lower limits to male barndoor skate length of maturity. Due to the observed dynamics between total length and reproductive development, Gedamke *et al.* (2005) suggest male barndoor skates greater than 113 cm are mature and males less than 103 cm are immature. In the study by Gedamke *et al.* (2005), 48 males were found to be mature at 107.9 cm with 95% confidence intervals of 105.2 to 110.6 cm. Female barndoor skates reach adolescence around 90 to 95 cm. At this length, substantial maturation occurs until about 115 cm when egg development is initiated. The smallest female with developing or ripe eggs in Gedamke *et al.*'s (2005) study was 114 cm long. All females over 124 cm were sexually mature egg producers. At the time of maturity, the tooth morphology of male barndoor skates changes from molariform (plate-like) to cuspidate (pointed teeth) dentition. Female barndoor skates do not exhibit changes in dentition at maturity (Gedamke, 2006).

Researchers from the Department of Fisheries and Oceans of Canada (DFO) used Gedamke *et al.'s* (2005) aging data of barndoor skates on Georges Bank to estimate generation time of the species (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Using an age at 50% maturity for females of 7 years and assuming an M of less than 0.2 per year (due to the species' large body size) these researchers estimated the generation time of barndoor skates on Georges Bank to be approximately 13 years (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Given the uncertainty of M and the slower growth rate in Canada (due to colder water temperatures) these researchers suggest the true generation time for barndoor skates in Canada may be greater than 13 years (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

<u>Maximum Size</u>

The maximum size observed in the NEFSC bottom trawl survey was 140 cm in the fall of 2007, while Bigelow and Schroeder (1953a) cited 152 cm as the maximum ever recorded. Canada's halibut industry survey has recently recorded individuals up to 163 cm (J. Simon, A. Cook, and M. Simpson, *pers. comm*., 2009). Gedamke *et al.* (2005) used the von Bertallanfy growth model with empirically estimated age-at-size data which yielded a theoretical maximum size of approximately 166 cm.

Body size is a good predictor of demography and vulnerability to exploitation in skates and is an important parameter used to estimate processes such as consumption, mortality rate, and *r* (Hoenig and Gruber, 1990; Dulvy, 2003). Jennings *et al.* (1998) quantitatively demonstrated that the larger the maximum size of a species, the more susceptible it is to declines in abundance. Species of elasmobranchs greater than 100 cm are especially at risk, generally exhibiting lower growth rates, fecundity, and *r* (Frisk *et al.*, 2001). Thus, based on body size alone, barndoor skates might be one of the more vulnerable skate species (Musick *et al.*, 1999; Walker and Hislop, 1998; Frisk *et al.*, 2001; Frisk *et al.*, 2002; Dulvy, 2003) and the recent data suggest this vulnerability is higher than previously thought.

Large flatfish are, by their nature, vulnerable to depletion by trawl fisheries targeted on smaller flatfish or almost any size of roundfish (Kenchington, 1999). This is a consequence of the size-selective properties of trawl nets, which retain even small sized flatfish (Kenchington, 1999). Species with large adult sizes are more vulnerable to fishing before they are able to reproduce, which causes low rebound potentials (Frisk *et al.*, 2001). This results in a more pronounced depletion than most bycatch species experience (Kenchington, 1999). Larger fishes are also typically longer lived with lower natural mortality. This results in an increased susceptibility to depletion under any given level of fishing effort (Kenchington, 1999).

<u>Longevity</u>

As stated previously, Frisk *et al.* (2002) assumed a maximum age of barndoor skates at approximately 50 years by relating the species to its closest relative, the common skate, whose longevity is 51 years (Brander, 1981). Dulvy (2003) reported estimates of barndoor skate longevity between 13 and 18 years although the source of this estimate was not specified. Gedamke *et al.* (2009) conducted a study that analyzed NEFSC trawl survey data to assess the stock-recruitment dynamics and maximum population growth rate of barndoor skates. The maximum age observed in the study was 11 years; however, Gedamke *et al.* (2009) conducted vertebral analysis on the largest barndoor skates on record and found a 15 year old individual. They concluded that, since the age distribution is likely truncated due to extensive exploitation, prior to intense fishing pressure barndoor skates may have reached a maximum possible age of 25 years.

Long-lived marine species may be particularly vulnerable to fishing pressure and rapid stock collapse resulting in a recovery that may take decades (Musick, 1999). These species may not be able to react as strongly, or as quickly as more productive species to compensate for decreases in population densities (Sminkey and Musick, 1996). According to Musick (1999), the greatest threat to long-lived species like barndoor skates results from mixed species fisheries where they are taken as either directed catch or bycatch.

<u>Prey Selection</u>

Barndoor skates are generally benthivorous in nature as small individuals (< 80 cm) and piscivorous in nature for particularly larger individuals (> 80 cm) (NEFSC, 2006). Prey includes polychaetes, gastropods, bivalve mollusks, squids, crustaceans, hydroids, and fishes (Bigelow and Schroeder, 1953a; Scott and Scott, 1988; Bowman *et al.*, 2000; Avent *et al.*, 2001). Smaller individuals focus on the benthic invertebrates such as the polychaetes, copepods, amphipods, isopods, shrimp, and euphausids. Larger barndoor skates eat larger and more active prey such as razor clams (*Ensella spp.*), large gastropods (*Buccinum spp., Lunatia spp.*), squids, crabs, lobsters and fishes (Bigelow and Schroeder, 1953b; McEachran, 2002). Fish prey include spiny dogfish (*Squalus acanthias*), alewife (*Alosa pseudoharengus*), Atlantic herring (*Clupea harengus*), menhaden (*Brevoortia tyrannus*), hakes (*Urophycis spp.*), sculpins (*Myoxocephalus spp.*), whiting (*Merluccius spp.*), cunner (*Tautogolabrus adspersus*), tautog (*Tautoga onitis*), sand lance (*Ammodytes hexapterus*), butterfish (*Peprilus triacanthus*), and flatfishes (Bigelow and Schroeder, 1953a; Bigelow and Schroeder, 1953b).

On the offshore fishing banks, barndoor skates may also prey on fish such as juvenile cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) since the common skate is a known predator of these fish in European waters (Bigelow and Schroeder, 1953b; Kenchington, 1999). The predominant prey items for barndoor skates are herrings, pandalid shrimps and *Cancer* crabs (NEFMC, 2009).

Gedamke (2006) analyzed the stomach contents of 273 barndoor skates caught as bycatch from the scallop fishery on Georges Bank Closed Area II and Nantucket Lightship Closed Area between June and November of 1999, 2000, and 2003. He found 31 different prey items; the majority of which were sand shrimp (*Crangon septemspinosa*), rock crab (*Cancer irroratus*), acadian hermit crab (*Pagurus acadianus*), and bony fishes. The analysis showed distinct ontogenetic shifts in prey preference. Barndoor skates between 20 and 35 cm exclusively ate caridean shrimp. Around 35 to 45 cm, rock crab and acadian hermit crab became present, respectively. Stomach contents of barndoor skates larger than 70 cm did not contain caridean shrimp and there was a decrease in abundance of rock crabs for both sexes. As length continued to increase above 70 cm the amount of crustaceans consumed decreased and the presence of bony fishes increased. Above 80 cm, the diet of males started to consist of more bony fishes than the diet of females. At and above 105 cm, males fed primarily on bony fishes while females roughly ate an equal amount of fishes and crustaceans. The differences between mature male and female prey selections are presumed to be due to the sexually dimorphic dentition (Gedamke, 2006).

Habitat Preference

Currently, there are limited data available to assess key habitats for feeding, growth, or reproduction of barndoor skates. However, the preferred habitat (general range) conditions in areas where barndoor skates commonly reside are as follows:

> Depth- Barndoor skates have been caught from the shoreline to depths over 1000 m. Barndoor skates have been found on Georges Bank and off Cape Cod at depths between 37 and 110 m throughout the year but tend to move into shallow water in the Gulf of Maine during the summer. South of Cape Cod barndoor skates occur in relatively shallow water during the spring and autumn. Juvenile barndoor skates caught in the NEFSC spring and fall bottom trawl surveys from the Gulf of Maine to Cape Hatteras were found between 21 and 400 m, with the highest concentration from 61 to 140 m. Adults were found from 31 to 400 m and most often at 70 m in the spring and 40 m in the fall (Packer *et al.*, 2003). However, NEFSC bottom trawl surveys rarely sample below 400 m and thus may not adequately cover the entire depth range of barndoor skates. On the Scotian Shelf barndoor skates have been reported from 24 to 375 m but are most abundant between 50 and 150 m. Off Newfoundland they have been recorded as deep as 1174 m (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).
>
> Salinity- NEFSC spring and autumn trawl survey data from 1963 to 2002 recorded barndoor skates from the Gulf of Maine to Cape Hatteras in waters ranging from 32 to 36 ppt, but they have also been caught in salinities from 21 to 24 ppt at the mouth of Chesapeake Bay and in brackish water in the Delaware River near Philadelphia (Packer *et al.*, 2003).
>
> Temperature- The broad temperature range of barndoor skates is from about 1 to 20° C (Bigelow and Schroeder, 1953a; McEachran and Musick, 1975). Barndoor skates caught from southern Nova Scotia to Cape Hatteras have been recorded from 3 to 20° C, off northeastern Nova Scotia and on the Scotian Shelf from approximately 2 to 11° C with a preference

for 3 to 9° on the shelf and as low as 1.2° C in the Gulf of St. Lawrence (McEachran and Musick, 1975; J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). NEFSC 1963 to 2002 spring and fall bottom trawl surveys recorded juvenile barndoor skates from the Gulf of Maine to Cape Hatteras over a temperature range of 3 to 18° C. The majority were caught between 3 and 8° C in the spring and 6 to 11 ° C (usually 9° C) in the fall. Adult barndoor skates were found between 4 and 16° C (Packer *et al.*, 2003). Canadian commercial fisheries data suggests few barndoor skates occur in temperatures less than approximately 2° C (Kulka *et al.*, 2002). In northern and southern Canada, barndoor skates were most commonly present from 2 to 5° C and 4 to 9° C, respectively (Kulka *et al.*, 2002).

Substrate- Barndoor skates are bottom-dwelling fish. In shallow waters, the species tends to prefer sand or gravel substrates but are more often found on soft mud in deeper waters (Bigelow and Schroeder, 1953a).

Skates are not known to have large-scale migrations, but do migrate seasonally in response to changes in water temperature (Sosebee, 2000). Generally, they are found offshore in the summer and early autumn and inshore in the winter and spring (Sosebee, 2000).

Importance/Commercial Value

Before 2000, bycatches of barndoor skates from demersal fisheries had some commercial value in the United States (Parent *et al.*, 2008). Its commercial value was mainly driven by the export market (particularly France); however, due to the species low abundance in U.S. waters, commercial fisheries focus their efforts on winter and thorny skate. Barndoor skates are one of the three species of skate in the Northwest Atlantic (along with winter and thorny skate) that are large enough to be commercially valuable to the skate wing fishery. The meat from their large pectoral fins has been sold for human consumption along the North American coastline, Canada, Europe, and Asia. Skate wings have a texture and taste similar to scallops (McPhie *et al.*, 2007). The firm, white, and sweet flesh may also be used for lobster bait, fish meal, and pet food (Scott and Scott, 1988).

2.3. Vulnerable Life-History Traits

A life-history strategy (or pattern) is the set of reproductive, growth, and genetic traits that define a population of a given ecological setting (Stearns, 1976). These traits are thought to be coadapted through natural selection as a response to ecological problems to maximize the number of surviving offspring produced (Stearns, 1976; Adams, 1980). Hoenig and Gruber (1990) define a life-history strategy in terms of the connection between environmental conditions and biological responses that in turn describes the morphology, physiology, and ecology of a species as well as its response to exploitation.

Thus, any characteristic which affects the survival and reproduction of an individual is part of the life-history pattern of a species.

MacArthur and Wilson (1967 as cited in Adams, 1980) identified two modes of a life-history strategy determined by the relationship between habitat, ecological strategy, and population parameters of a given stock or individual. The two types are termed K-selective, referring to the carrying capacity of a population (K), and *r*-selective, referring to a species intrinsic rate of population increase (*r*).

Species in an unstable and unpredictable environment suffering from a high amount of nonselective or catastrophic mortality must be biologically capable to respond quickly when density constraints are released by uncrowded conditions (Hoenig and Gruber, 1990; Gedamke *et al.*, 2007). This environment results in a life-history pattern that favors increased fecundity with species that spend a large amount of their available resources on producing as many offspring as possible while exerting a minimal amount of its resources to each individual (Hoenig and Gruber, 1990; King and Anderson, 1971; Adams, 1980; Pianka, 1970). This strategy is density-independent in environments with a high amount of available resources and is geared towards the total productivity of distributing its resources to offspring (King and Anderson, 1971). Most teleost fishes exhibit this life-history pattern, which relies on the highly variable survival of many fragile offspring (Gedamke *et al.*, 2005). Species that exhibit this behavior have a high *r* value and are, thus, *r*-select species.

K-select species tend to live in high density, stable ecological areas. These ecosystems are close to K for the environment and exhibit high levels of competition for limited resources. K-select species must adapt a density-dependent reproductive strategy that produces offspring with the highest possible fitness and substantial competitive ability (Adams, 1980; Hoenig and Gruber, 1990; Pianka, 1970; King and Anderson, 1971). To do this a species must exert more energy into each individual prodigy (Pianka, 1970). Due to the relationship between fitness per offspring and the number of offspring produced the increase of fitness correlates to a decrease in total offspring (Adams, 1980). Therefore, K-select species are geared towards total efficiency at producing biomass that results in a direct and limiting relationship between the number of sexually mature individuals and the number of offspring per year (Hoenig and Gruber, 1990). Elasmobranchs (i.e.,barndoor skates) exhibit this type of less productive yet more efficient life-history strategy.

Adams (1980) noted that *r*-select species suffering from nonselective or catastrophic mortality increase reproductive productivity through adapting an early age of and size at maturity, rapid growth rate, and high fecundity. Energy is conserved for reproductive activities by having a small body size, high mortality rate, and relatively short life span. Less fecund K-select species must adapt a life-history strategy that increases reproductive abilities at later life stages to maximize overall survival. To do this, K strategists exhibit a late age at maturity, slow growth rate, relatively low mortality rates, large body size, and increased longevity (Adams, 1980).

The life history strategy of a species markedly affects its response to declines in abundance. Many studies have shown that the large, late maturing, slow growing, and long lived species (classic K-selected species) are more vulnerable to fishing pressure than the smaller, earlier maturing, shorter lived species (r-selected) (e.g., Frisk *et al.*, 2002; Jennings *et al.*, 1999; Hoenig and Gruber, 1990; Musick, 1999). For example, the European common skate and at least four other North Sea skates have all undergone severe regional population declines due in part to their relatively large size, late maturation, low fecundity and resulting sensitivity to fishing mortality (Brander, 1981; Walker and Heessen, 1996; Dulvy *et al.*, 2000 as cited in Gedamke *et al.*, 2005), an effect less apparent in smaller species (Gedamke *et al.*, 2005). Slow growing, less fecund species tend to produce low maximum sustainable yields (MSY) and recover more slowly from overfishing (Musick, 1999). Thus, although K-selected species have the advantage of being less susceptible to the many dangers of the marine environment (i.e., natural mortality; M), these fishes have a limited ability to compensate when additional mortality (i.e., fishing mortality; F) is introduced (Kenchington, 1999). Thus, their populations typically decline sharply under directed exploitation. Even the (usually lesser) pressures on a bycatch species caused by incidental capture in fisheries targeted on other resources could lead to depletion (Kenchington, 1999).

Understanding the life history traits and quantifying the age and growth parameters for individual species have been recognized as crucial in the risk assessment and management of marine fishes (Parent and Schrimi, 1995; Musick, 1999a; Musick, 1999b as cited in Gedamke *et al.*, 2005) because these traits can provide estimates of the maximum per capita growth rate, *r*, and predict a species' resilience to exploitation (Hoenig and Gruber, 1990). Although barndoor skates are generally a K-selected species, some of the recent data on the life history characteristics of the species reviewed above has shown that they are less K-selected than once thought.

Musick (1999) believed age at maturity may be the most important indicator of extinction risk for marine species. Elasmobranchs tend to have low natural mortality and high longevity with a population consisting of many old, slow growing individuals (Hoenig and Gruber, 1990). As such, barndoor skates spend more of their life span as mature adults than any other stage. If barndoor skate individuals are subjected to fishing mortality between the age they are first vulnerable to fishing gear, or age of first recruitment (2 years and 54 to 69 cm; Gedamke *et al.*, 2008), and age of maturation, the species will lose individuals who are capable of reproducing and thereby make it even more difficult to rebuild the population size. Thus, late age at maturity may limit population growth rate and lower the rebound potential of a species once fishing pressure is released (Frisk *et al.*, 2002).

The values used for age at maturity of barndoor skates in population models have varied among studies. As stated previously, studies conducted on the species' resilience to exploitation and maximum sustainable fishing pressure (Casey and Myers, 1998; Frisk *et al.*, 2002) assumed that age at maturity values of 11 to 12 years and fecundity at age of 47 eggs per year, which were considered the most accurate values of barndoor skate life history parameters at that time. Gedamke *et al.*'s (2005) life history study on barndoor skates estimate of age at maturity (6.5 to 7.2 years) is nearly half that of Casey and Myers' (1998) assumption. Furthermore, Parent *et al.*'s (2008) observation of a 10 to 12 year old captive barndoor skate laying 115 eggs in 2007 is more than double Casey and Myers' (1998) assumption of barndoor skates at the same age. If current estimates of age at maturity and fecundity at age were used, these older studies would show that barndoor skates are less susceptible to fishing mortality before they are able to reproduce, which indicates a greater resilience to declines in abundance and maximum sustainable fishing pressure than suggested by previous studies (e.g., Casey and Myers, 1998; Frisk *et al.*, 2002).

2.4. Resilience to Environmental Variability and Catastrophic Events

Casey and Myers' (1998) life table analysis estimated an instantaneous mortality rate (Z) capable of driving the species to extinction of 0.40 on Georges Bank (at a temperature of approximately 8.5º C) and closer to 0.20 in the colder northerly waters of the Grand Banks of Newfoundland (at a temperature of approximately 2.5º C). Frisk *et al.* (2002) used a stage-based matrix model to estimate the species' resilience to exploitation. The model estimated an F resulting in population equilibrium (r=0) of 0.20 and an M of 0.09 (Z=0.29) (Frisk *et al.*, 2002). The two methods used in these studies (life tables and matrix models) are classic demographic models that are commonly used to evaluate the ability an elasmobranch has to sustain designated levels of fishing pressure given the specific life history characteristics of that species (Gedamke *et al.*, 2007). These models are generally independent of stock size and provide an instantaneous rate of population growth for a specified set of life history traits corresponding to a specific population size (Gedamke *et al.*, 2007). The models are then used to compute rates of population growth presumed to be estimates of r that are then use to calculate implied estimates of the maximum sustainable F for that species (Gedamke *et al.*, 2007; Gedamke *et al.*, 2009). Due to the static nature of these demographic analyses, the model outputs in Casey and Myers (1998) and Frisk *et al.* (2002) studies are thought to be the lower bounds for both r and maximum sustainable F (T. Gedamke, *pers. comm.*, 2009).

As stated previously, when using fixed values for life-history parameters (e.g., fecundity, age at maturity, etc.) in demographic models (i.e., life tables and matrix models) the results are only as reliable as the model inputs (Frisk *et al.*, 2002; Walker and Hislop, 1998). Differences in the life history of even closely related species (i.e., barndoor skate vs. common skates) can lead to significant variability in model estimates. More importantly, the density dependent nature of the basic demographic analysis and use of stationary life history parameter input values do not take into account the pliable life history characteristics that may change due to density-dependent responses to decreased abundance and the consequential increase in available resources (food, space, etc.) (Gedamke *et al.*, 2007). This would result in changes in fecundity, length and age of maturity, and increased survival rates (especially of juveniles)(T. Gedamke, *pers. comm.*, 2009). This would result in higher reproductive potential and population growth rates (Walker and Hislop, 1998; Dulvy, 2003). An important aspect of predicting a species' response to exploitation commonly overlooked in elasmobranchs is this recognition that a population will only grow at a maximal rate at the lowest stock sizes (Gedamke *et al.*, 2007) when competition for resources is at a minimum and the subsequent increased survival results in maximum *r* (Gedamke *et al.*, 2009).

A lack of information and understanding of the overall population dynamics of barndoor skates has hampered further assessments and management options (Gedamke *et al.*, 2009). To compensate, Gedamke *et al.* (2009) used a stock-recruit analysis described by Myers *et al.* (1997, 1999 as cited by Gedamke *et al.*, 2009) that incorporates stock size explicitly to estimate maximum *r* at low population sizes. Two types of stock-recruit models were used in the analysis: the Ricker model and the Beverton-Holt model. Gedamke *et al.* (2009) used data from NEFSC autumn bottom trawl survey, an estimated M of 0.18 per year (estimated using the methods of Pauly, 1980; Hoenig, 1983; Peterson and Wroblewski, 1984; Chen and Watanabe, 1989; Jensen's, 1996 age at maturity method; and Jensen's, 1996 k method as cited in Gedamke *et al.*, 2009), and species-specific life history parameters determined by recent directed studies (i.e., Gedamke *et al.*, 2005; Parent *et al.*, 2008; and Gedamke unpublished observations as cited in Gedamke *et al.*, 2009) as input parameters for the analysis. The results suggest an *r* of 0.37 and 0.38 per year for the Beverton-Holt and the Ricker stock-recruit models, respectively.

A second analysis was also conducted using Gedamke *et al.*'s (2007) demographic analysis that incorporates stock size and density-dependent compensation into the density-independent framework of a Leslie matrix demographic model (Gedamke *et al.*, 2009). From this method, the maximum *r* for barndoor skates was estimated to be 0.36 to 0.48 per year (Gedamke *et al.*, 2009). Thus, Gedamke *et al.*'s (2009) analysis suggests that barndoor skates may be more resilient to fishing pressure than previously believed and capable of growing at an *r* in excess of 35% per year at low population sizes. Gedamke *et al.*'s (2009) demographic models also suggest that at the lowest population sizes barndoor skates may be capable of an *r* of up to 0.48 per year.

NEFMC (2009) estimates that, in the absence of fishing pressure, the barndoor skate population is currently growing at a rate of 0.41 per year. Not only is this rate higher than previous estimates but is also higher than for most other elasmobranch species. However, Gedamke *et al.*'s (2009) study suggests that although barndoor skate populations are capable of growing at relatively fast rates and are less susceptible to fishing pressure than previously believed, the population declines that were observed during the 1960s show that the species is still sensitive to exploitation.

2.5. Potential Loss of Unique Life-History Traits

When developing a fisheries management plan for slow growing, less fecund species, the potential loss of unique life-history traits must be considered due to these species' tendency towards more sophisticated life-history patterns (i.e., parental care, mating systems, and territoriality) (Adams, 1980). Information on the mating systems, social structure, critical habitats, or parental care after deposition for barndoor skates is limited

(Hoenig and Gruber, 1990). Therefore, potential loss of unique life history traits cannot be assessed at this time. However, given that the barndoor skate population appears to be increasing, loss of unique life history traits is not expected to occur or continue to occur.

3.0. Historic and Current Distribution

3.1. Historic Distribution

Barndoor skates are limited to the Northwest Atlantic. Bigelow and Schroeder (1953a) recorded their general range from the Banks of Newfoundland, Gulf of St. Lawrence and outer coast of Nova Scotia and Nova Scotia Banks down to North Carolina. McEachran and Musick (1975) presented catch records of barndoor skates from the Gulf of St. Lawrence, along the northeastern coast and offshore banks of Nova Scotia, to the northeastern Floridian coastline (Figure 1). However, McEachran and Musick (1975) suggest that barndoor skates may have been previously misidentified as *D. teevani* (then, *Raja floridana*) in its southern range and may not have occurred south of Cape Hatteras.

Figure 1. Distribution for *Dipturus laevis* (www.iobis.org).

The species was found from the shoreline to 430 m but most commonly at depths less than 183 m (Bigelow and Schroeder, 1953a). The greatest depths where barndoor skates were historically caught were 430 m along the continental edge off Nantucket, Massachusetts; 220 m on the southwest slope of the Grand Banks of Newfoundland; 192 m in the western side of the Gulf of Maine; 201 m in the central basin of the Gulf; and 291 m off Charleston, South Carolina (Bigelow and Schroeder, 1953b). McEachran and Musick (1975) noted the species presence at 315 m in the Gulf of St. Lawrence; off northeastern Nova Scotia between 24 and 375 m; from southern Nova Scotia to Cape Hatteras from 38 to 351 m and off northeastern Florida between 302 and 368 m depths. Very few barndoor skates were caught inshore less than 27 m deep or in the Mid-Atlantic regions (NMFS, 2006).

3.2. Current Distribution

3.2.1. Geographic Range

The center of barndoor skate distribution in the U.S. remains in the offshore strata of the Gulf of Maine, Georges Bank, and Southern New England (NEFSC, 2006). The highest concentrations of barndoor skates from NEFSC bottom trawl surveys are consistently located along the perimeter of Georges Bank. Records indicate that the surveys catch very few fish in areas less than 27 m in depth or in the Mid-Atlantic regions (Figures 2-5). NEFSC winter surveys off Southern New England and the Mid-Atlantic offshore regions show the species is most abundant in the offshore waters of Nantucket south to Delaware with the highest concentrations offshore of the eastern end of Long Island (Figure 4). The winter survey also catches small barndoor skates directly south of Cape Cod. The center of the distribution of this species in the survey data is Nantucket Lightship, and it is suggested that this is because of the seasonal migration from Georges Bank. However, the winter survey does not cover most of Georges Bank where barndoor skate occur in the spring. The survey shows barndoor skate concentrations on the southern flank of Georges Bank, which suggest the species' range may extend into deeper waters than covered by the survey data. Consequently, these surveys may not be sampling the species' entire distribution.

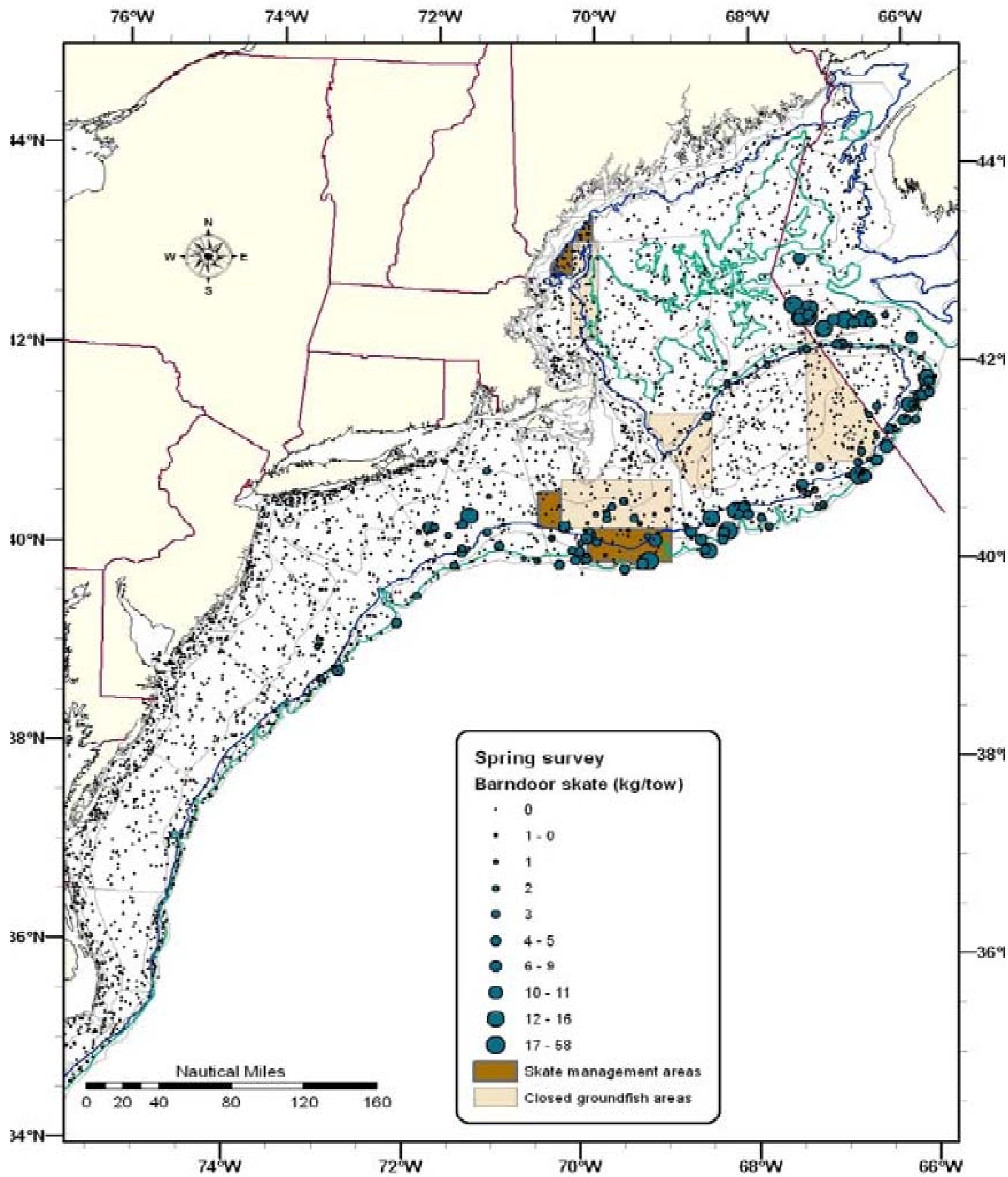

Figure 2. Barndoor skate biomass distribution in NEFSC spring (March – April) bottom trawl survey between 2000 and 2008 (NEFMC, 2009). The catch densities of barndoor skates from the survey data are shown by the blue circles, the areas managed under the Skate FMP are highlighted in dark brown, areas closed to groundfish are highlighted in tan, purple line is country/state borders.

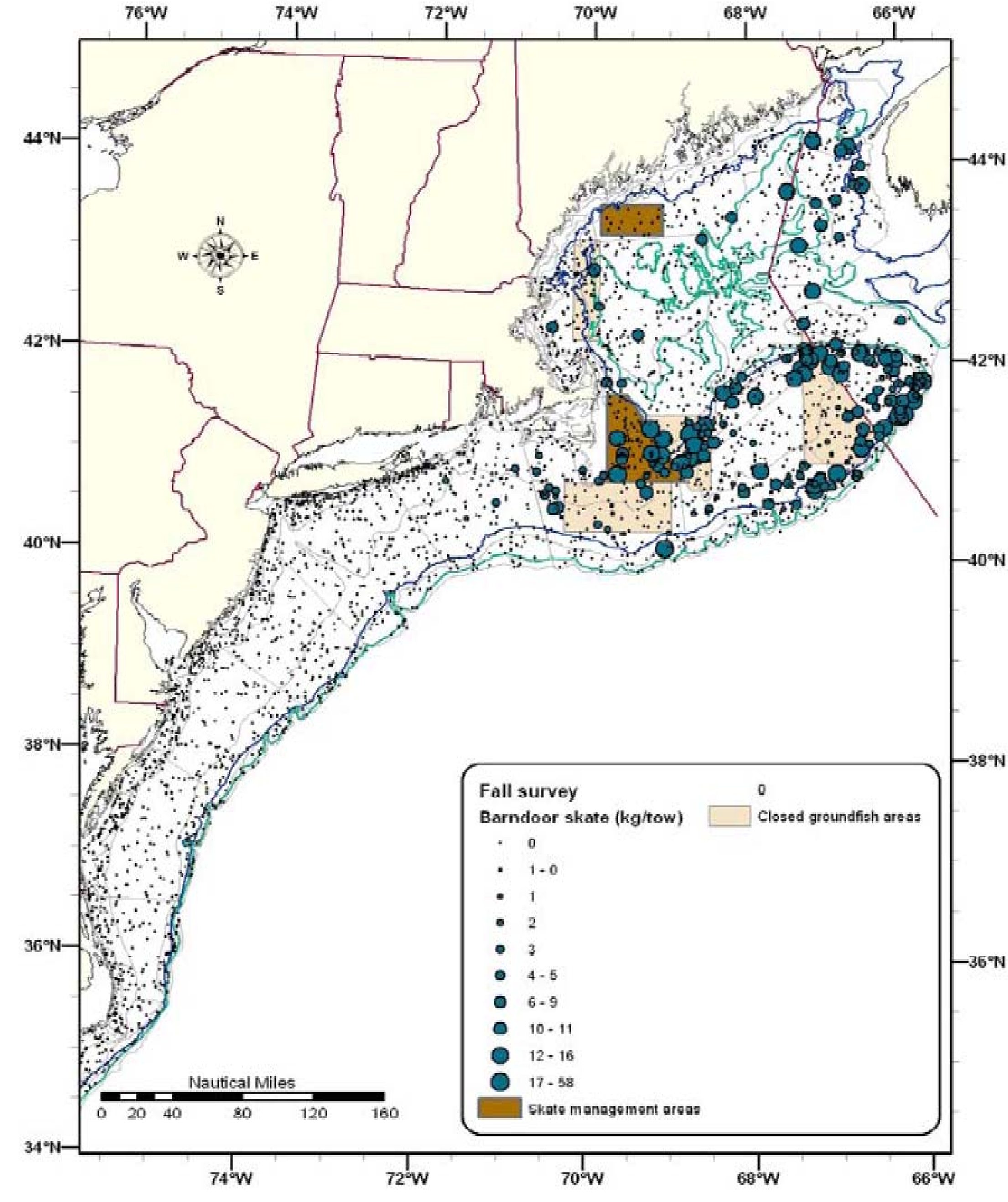

Figure 3. Barndoor skate biomass distribution in NEFSC autumn (September – November) bottom trawl survey between 2000 and 2007 (NEFMC, 2009). The catch densities of barndoor skates from the survey data are shown by the blue circles, the areas managed under the Skate FMP are highlighted in dark brown, areas closed to groundfish are highlighted in tan, purple line is country/state borders.

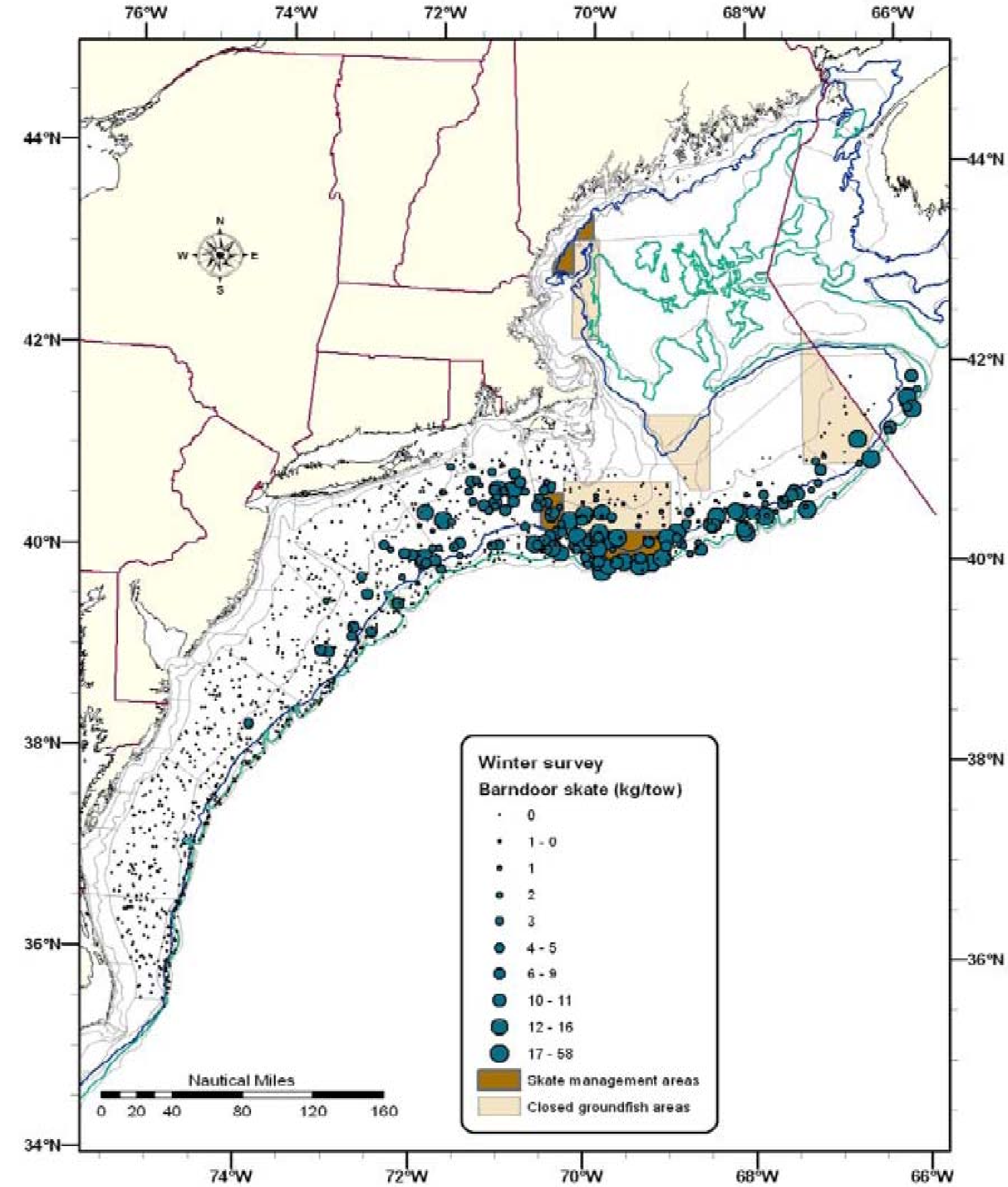

Figure 4. Barndoor skate biomass distribution in NEFSC winter (January – March) bottom trawl survey between 2000 and 2007 (NEFMC, 2009). The catch densities of barndoor skates from the survey data are shown by the blue circles, the areas managed under the Skate FMP are highlighted in dark brown, areas closed to groundfish are highlighted in tan, purple line is country/state borders.

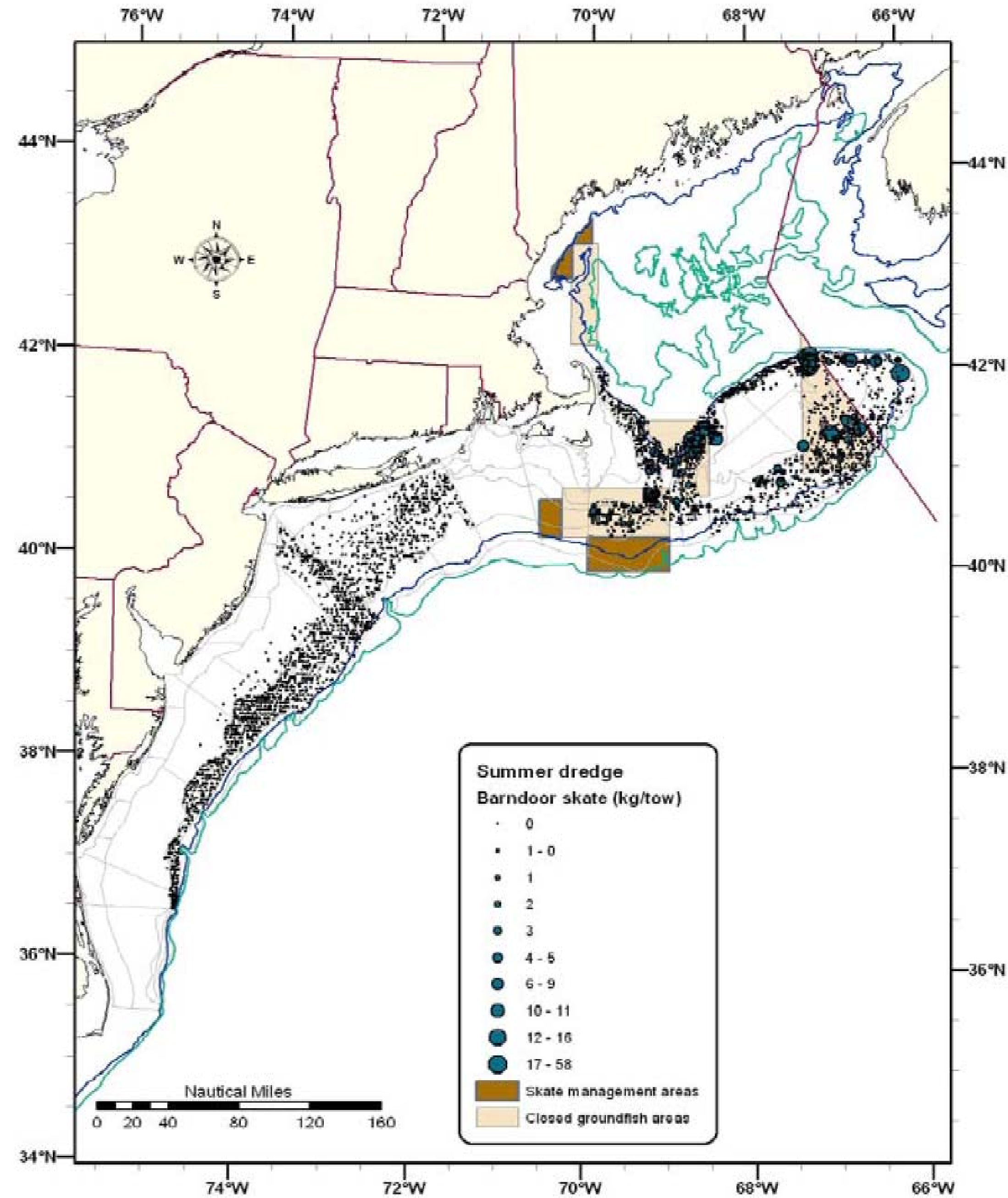

Figure 5. Barndoor skate biomass distribution in NEFSC summer (July – August) dredge survey between 2000 and 2007 (NEFMC, 2009). The catch densities of barndoor skates from the survey data are shown by the blue circles, the areas managed under the Skate FMP are highlighted in dark brown, areas closed to groundfish are highlighted in tan, purple line is country/state borders.

The Department of Fisheries and Oceans of Canada (DFO) have observed barndoor skates in Canadian commercial and research survey data since the late 1950s. The data come from both non-standard and standardized research vessel surveys and cover virtually all of the Canadian continental shelf waters. (Refer to Figure 28 on page 47 for all Northwest Atlantic Fisheries Organization's (NAFO) Divisions referenced in this analysis.)

The DFO summer research survey data of the Scotian Shelf observed barndoor skates concentrated mainly on the western Scotian Shelf and Gully (Figure 6). Between 1970 and 1992, the species was spread across the shelf, mostly in the Gully and Eastern Scotian Shelf (Division 4X) (Figure 6). From 1993 to 2008, barndoor skate concentrations shifted to the southern half of Division 4X and the western portion of Division 4W (Figure 6) (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). The longline sentinel survey of Scotian Shelf (Div. 4VsW) noted core concentration of barndoor skates between 1996 and 2007 along the central Scotian Shelf between Emerald Basin and Emerald Bank, southward to the edge of the shelf (Figure 7).

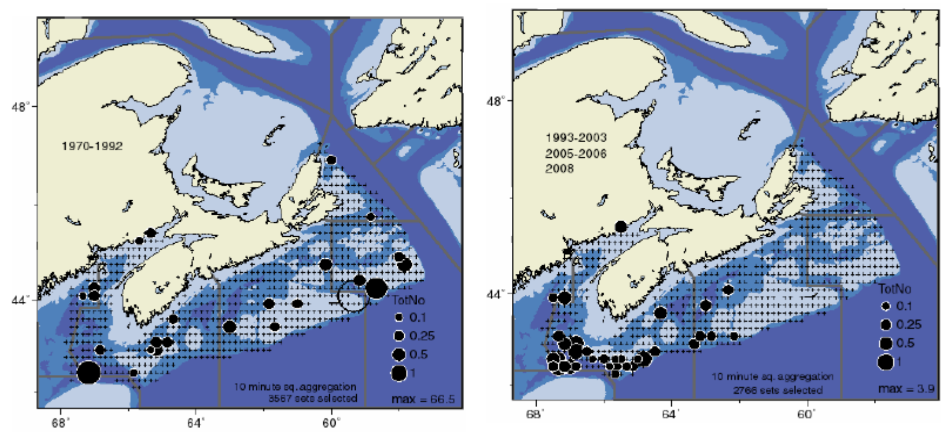

Figure 6. Distribution of barndoor skate from the summer RV survey between 1970 to 1992 (left) and 1993 to 2008 (right) (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

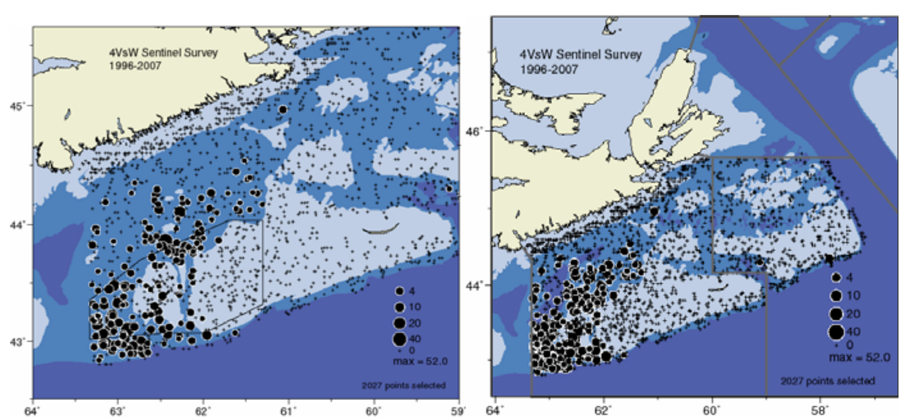

Figure 7. Distribution of barndoor skate (#/tow) from the longline sentinel surveys in Divisions 4VsW (right) and distribution of barndoor skate in Division 4W only (left) between 1996 and 2007. The 4W haddock nursery area (left), in place since 1987, is displayed (J. Simon, A. Cook, M. Simpson, <u>pers. comm.</u>, 2009).

The industry/DFO longline halibut survey, initiated in 1998, covers the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3N, 3O, 3Ps, 4V, 4W, 4X, and 5Zc). The fixed station portion of the survey has sampled 275 pre-selected fishing locations dispersed across the Scotian Shelf and along the shelf edge since 1998 (Armsworthy *et al.*, 2006). This phase of the survey found barndoor skates primarily located on Division 4X and the western part of Division 4W (Figure 8). Individuals were also found along the southern edge of the Scotian Shelf and on the Grand Banks (Figure 8) (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009). The fixed station data indicate that the species has a wide depth range with survey sets as deep as 730 m encountering barndoor skates. Length frequencies ranged from 58 to 129 cm with a peak between 100 and 125 cm (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009).

The commercial index portion of the halibut longline survey is sampled by survey participants with their own fishing protocols and locations of their choosing (see Armsworthy *et al.*, 2006 for a detailed description of sample locations and protocols) but generally at depths greater than 500 m along the slope of the continental shelf off Nova Scotia. In these deeper waters barndoor skates were found as far east as the tail of the Grand Banks (Figure 8). The commercial index also shows the wide depth range of the species with sets as deep as 700 m encountering barndoor skates. Length frequency data ranged from 52 to 163 cm peaking close to 100 cm (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009). Therefore, the fish in this survey capture the largest barndoor skates on record. Data from the commercial index stations in Divisions 3NOP suggest the largest fish are in this area (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009).

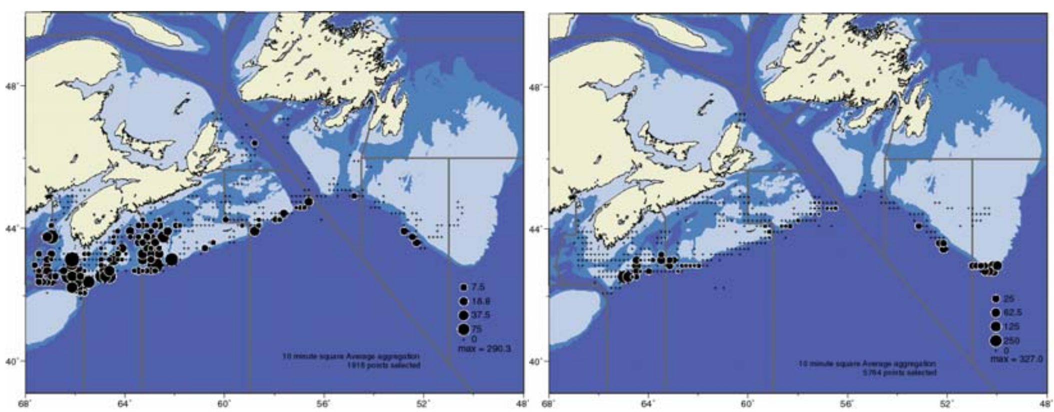

Figure 8. Distribution of barndoor skate during the fixed (left) and commercial index (right) portions of the halibut longline survey from Divisions 3NOPs4VWX5Zc between 1998 and 2007 (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009).

There has been recent controversy about the accuracy of Maritime observer records of barndoor skate catch in Canada (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Previous estimates summarized in Kulka *et al.* (2002) may have included incorrect identification of barndoor skates that may have actually been white skate (*Raja lintea*) or spinytail skate (*Raja spinicauda*) and vice versa. Confirmed records have shown barndoor skates being widespread in Divisions 3OP, especially near the edges of the Banks. Most of these records were taken from 1978 to 1982. Since 1998, there have been 21 confirmed records of the species, 19 of which were taken from the Flemish Cap (Figure 9) (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

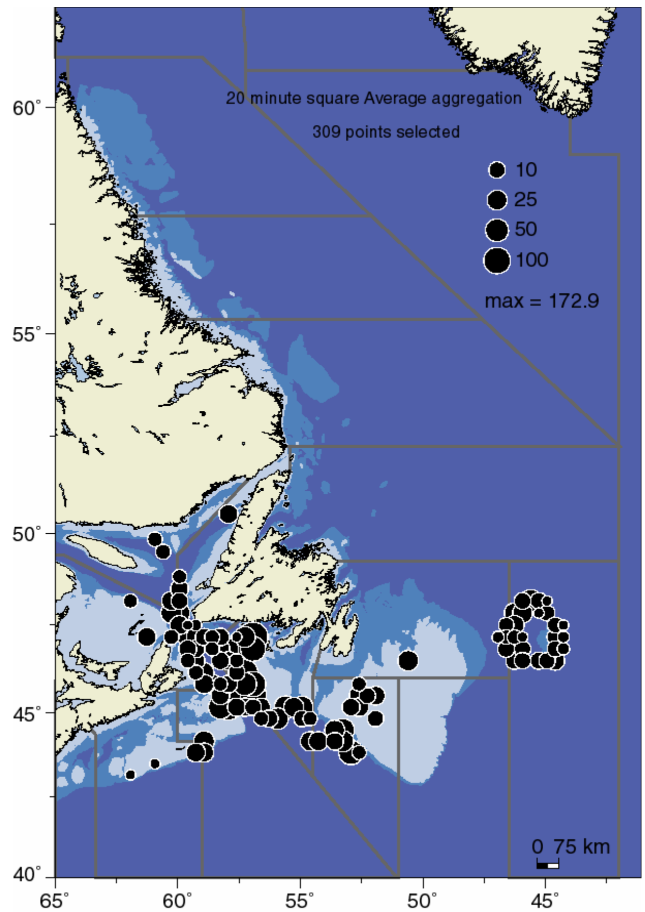

Figure 9. Distribution records of barndoor skate since 1992 as determined by the Newfoundland observer program (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

The DFO winter survey of Georges Bank has been sampling this area since 1986. Of the 2,038 survey sets conducted, barndoor skates appeared in 158 sets (7.8%). Individuals were mainly taken from the southern flank of Georges Bank from the Northeast Peak to the Great Southwest Channel (Figure 10). Small concentrations were noted along the northern edge of the Bank. Abundance in this area is predominately juveniles that are distributed throughout the area. Adults were generally encountered on the southern edge of the Bank (Figure 10) (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009).

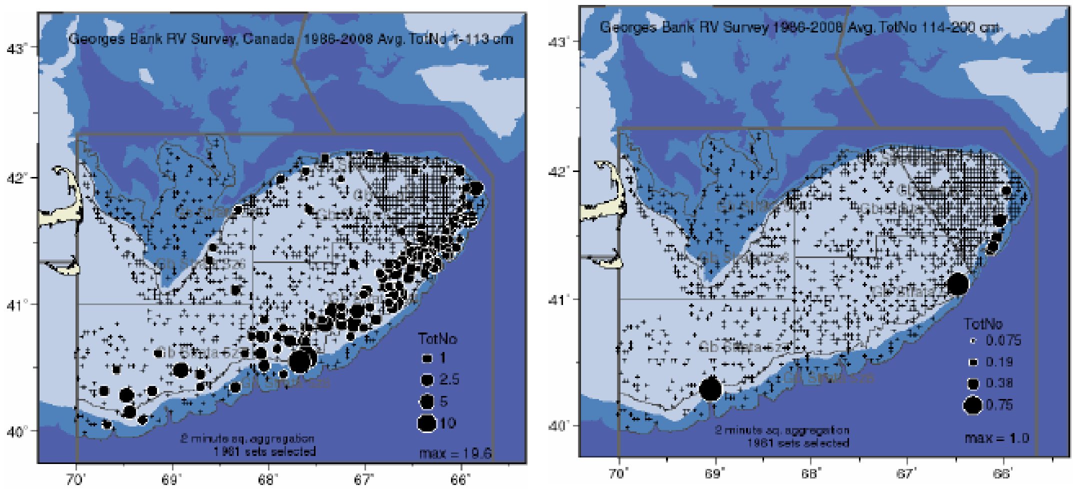

Figure 10. Distribution of barndoor skate from the DFO winter survey of Georges Bank from 1986 to 2008 disaggregated by juvenile (<113 cm) (left) and adult (114+ cm) (right) individuals (J. Simon, A. Cook, M. Simpson, pers. comm., 2009).

Catch data from surveys on Georges Bank did not indicate a break between U.S. and Canadian barndoor skate populations. Juvenile and adult barndoor skates appear to inhabit the same geographic area on both the Canadian and U.S. sides of Georges Bank; however, the U.S. surveys tend to catch more adult individuals. Canadian data show that juveniles are widespread across the Scotian Shelf while adults are more concentrated in the Fundian Channel (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Length frequency data from Canada's halibut longline survey suggest adult barndoor skates are more common at depths greater than the standard research vessel surveys but are also significant at shallower depths (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

3.2.2. Population Connectivity

The connectivity of barndoor skate populations seems to be continuous across its wide geographic range. The species is highly mobile, does not appear to exhibit site fidelity at any life stage, and does not posses any life history characteristic that would result in significant reproductive isolation across its range. Although there have been no surveys specifically looking for evidence of the population structure of barndoor skates, population connectivity does not appear to negatively affect the species.

3.2.3. Natural Rarity and Endemism

Barndoor skates are not naturally rare or endemic to a small geographic area, and as such, these criteria will not be evaluated further.

4.0. Historic and Current Abundance and Productivity

4.1. Historic Abundance

The areas of highest barndoor skate concentrations were Georges Bank, Gulf of Maine, and Southern New England. They were recorded in high abundance in the Bay of Fundy, Eastport, St. Mary, Casco and Passamaquoddy Bay, and along the coast of Maine. The species was found across the Scotian Shelf with highest concentrations on the central part of the Shelf (Simon *et al.*, 2002). They were also considered plentiful off the outer Nova Scotian coast (McEachran, 2002). During ground bottom trawl surveys conducted between 1967 and 1970, barndoor skates were most abundant in the eastern Gulf of Maine and on the eastern section of Georges Bank; none were captured in the western Gulf of Maine (McEachran and Musick, 1975; McEachran, 2002). Bigelow and Schroeder (1953a) reported that barndoor skates contributed to about 14% of the total skate catch on Georges Bank and Nantucket shoals at a general depth range of 46 to 64 m. Large numbers of barndoor skates were also caught from 37 to 110 m on Georges Bank and off Cape Cod throughout the year, the inshore waters off the southern coast of New England in the spring and autumn, and the near shore waters of the Gulf of Maine in the summer. They were also abundant in various localities across Massachusetts Bay (Bigelow and Schroeder, 1953a).

Bigelow and Schroeder (1953b) made a conservative estimate of 120 barndoor skate individuals per 1800 m^2 in the Eastern end of Long Island Sound after analyzing trawl catch rates between August 1943 and October 1944. In September 1929, 37 hauls made with an otter trawl on Georges Bank yielded 42 barndoor skates from a total of 495 skates of all kinds (Bigelow and Schroeder, 1953b). Off Southern New England, 44 mid-winter hauls in 86 to 123 m and 63 hauls in May at 40 to 430 m yielded 441 barndoor skates from a total of 748 skates of all kinds. As many as three dozen individuals were recorded in one lift of a fish trap in Narragansett Bay (Bigelow and Schroeder, 1953b). In June 1951, the ship *Eugene H* made 42 trawl hauls between Nantucket Lightship to the south-central part of Georges Bank. In this area, there was an average catch of 32 barndoor skates per haul between 48 and 64 m, 13 per haul between 66 and 90 m, and 6 per haul between 91 and 137 m (Bigelow and Schroeder, 1953a).

Barndoor skates were commonly encountered in the 1950s and early 1960s. According to a 1953 U.S. Fish and Wildlife Service Bulletin, fishing boats on Georges Bank off Massachusetts could bring in up to 600 individuals from the aggregated skate complex per day (Raloff, 1999). In 1951, one ship reported a cruise during which it landed 146 skates of all kind per haul, equating to approximately 9 to 10 skates per acre (Raloff, 1999). Places where trawlers routinely reported 6 to 30 barndoor skate individuals per tow in the 1950s noted the absence of barndoor skate in these areas throughout the 1990s (Raloff, 1999). Casey and Myers (1998) stated that research surveys on St. Pierre Bank off southern Newfoundland recorded barndoor skates in 10% of their tows in the 1950s that declined to no fish being caught from the 1970s to early 1990s. The NEFSC autumn bottom trawl survey data from the southern part of the species' range (below 43º N Lat. and less than 400 m depths from the Gulf of Maine to Southern New England) indicate that barndoor skate average mean catch rate declined from 1.922 kg per tow (1.82 individuals per tow) between 1963 and 1965 to an average of 0.0786 kg per tow (0.025 individuals per tow) between 1996 and 1998 (Dulvy, 2003). This represents a 96 and 99% decline in abundance (catch rate) for the Gulf of Maine and Southern New England, respectively (Dulvy, 2003).

4.2. Current Abundance and Productivity

United States Stock Status

NEFSC spring and autumn bottom trawl surveys started in 1968 and 1963, respectively, and are conducted from Cape Hatteras to the Gulf of Maine. Sample stations are generally located between 27 and 366 m depths with occasional deep tows in canyons of the continental shelf. NEFSC winter survey, implemented in 1992, overlaps the southern regions of the spring and autumn surveys, focusing on Southern New England and the Mid-Atlantic offshore regions. This survey has limited coverage on Georges Bank and no sampling is conducted in the Gulf of Maine. The spring and autumn surveys target groundfish by using large rollers while the winter survey targets flatfish by substituting a chain sweep with small cookies. The change in winter survey gear significantly increases the catchability of barndoor skates.

NEFSC spring survey biomass indices for the seven species of skate as a whole indicate the complex is presently at a medium biomass (Sosebee, 2006). NEFSC spring survey biomass indices for the aggregated skate complex were relatively stable from 1968 to 1980, increased to peak levels in the 1980s, and then declined steadily until 1994. The indices increased through 1999 and have since declined (Figure 11) (Sosebee, 2006; DPSWG, 2009). If the species in the complex are divided into large skates greater than 100 cm maximum length (barndoor skate, winter skate, and thorny skate) and small skates less than 100 cm maximum length (little skate, clearnose skate (*Raja eglanteria*), rosette skate (*Leucoraja garmani*), and smooth skate (*Malacoraja senta*)), it is evident that the large increase in skate biomass in the mid to late 1980s was dominated by winter skate and little skate (Sosebee, 2006; DPSWG, 2009). Biomass indices of the large sized skates declined from the mid 1980s to the mid 1990s, and have since been stable except for a spike due to an exceptionally large survey catch of barndoor skates in 2007 (Figure 12). Biomass indices of the smaller skates increased from 1980 through the mid 1990s but have declined from 1999 onwards (Figure 13). The trends in biomass of the aggregate skate complex since the mid 1990s are mainly due to trends in little skate biomass (Figure 12) (Sosebee, 2006; DPSWG, 2009).

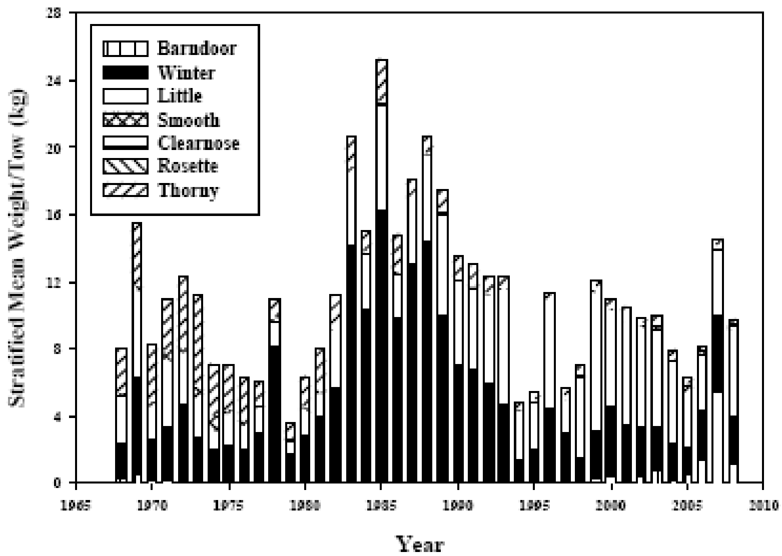

Figure 11. Species composition of the aggregated skate complex biomass from NEFSC spring survey (DPSWG, 2009).

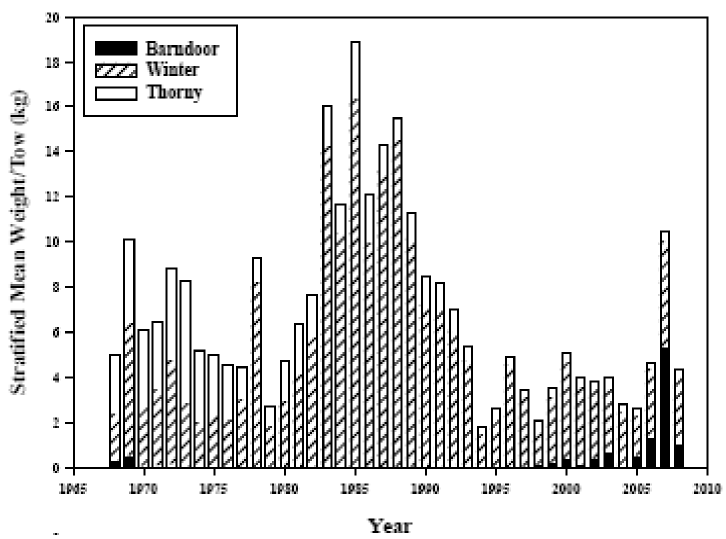

Figure 12. Species composition of the skate complex separated by large skates greater than 100 cm maximum length from NEFSC spring survey (DPSWG, 2009).

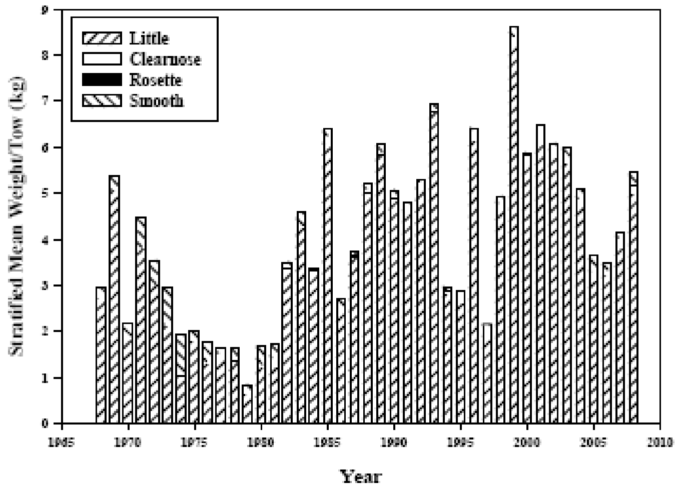

Figure 13. Species composition of the skate complex separated by small skates less than 100 cm maximum length from NEFSC spring survey (DPSWG, 2009).

NEFSC spring survey biomass index for barndoor skates fluctuated in the late 1960s and early 1970. There was a drastic decline to several zero indices throughout the late 1970s to 1990 but the index has been consistently increasing since the mid 1990s (Figure 14). A record breaking survey year occurred in 2007 when the biomass index peaked at 6.711 kg per tow. This value is drastically higher than for any other year of any of the three trawl surveys. It was driven mainly by one tow on southern Georges Bank totaling 1,500 kg. Although the spring survey index declined to 1.370 kg per tow in 2008 it is the third highest index for the spring survey and higher than all autumn surveys since 1965. The second highest spring biomass index is 1.706 kg per tow in 2006.

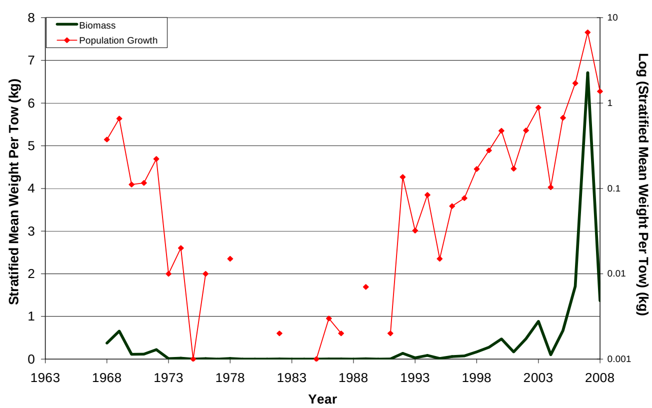

Figure 14. Barndoor skate biomass index (stratified mean weight per tow) in NEFSC spring bottom trawl research vessel surveys from the Gulf of Maine to Southern New England regions between 1968 and 2008. Data are also log transformed to show population growth trends over time (NEFSC, *pers. comm*. 2009).

NEFSC autumn survey index for barndoor skates was highest in the early 1960s starting at 2.633 kg per tow in 1963. Similar to NEFSC spring survey, the autumn biomass index declined to several zero kg per tow during the mid 1970s to mid 1980s (Figure 15). The index fluctuated at low density from the mid 1980s to mid 1990s but has been increasing at an average annual rate of 22% since 1984 (Figure 15). The increase observed in the 1990s occurred after three large areas on Georges Bank (off Massachusetts) were closed to all mobile fishing gear in 1994, however, the index had started to increase to an extent prior to the closing of these areas. Since then, survey indices for barndoor skates have been increasing at an average rate of approximately 43% per year (Gedamke *et al.*, 2007). Although this increase is dramatic, the NEFSC autumn survey biomass index from 1999 to 2006 was still less than 2 and 50%, respectively, of the peak observed in 1963 (Sosebee, 2000; Sosebee, 2006). Mean abundance over the past four autumn survey years is only 57% of the mean number from the first four years of the survey (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). The NEFSC 2007 autumn biomass index (0.798 kg per tow) is approximately 30% of its 1963 value.

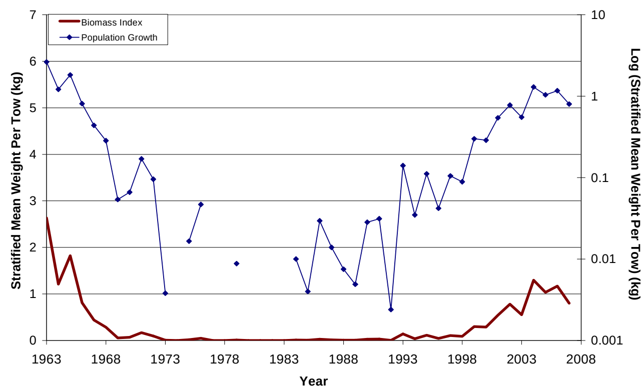

Figure 15. Barndoor skate biomass (stratified mean weight per tow) in NEFSC autumn bottom trawl research vessel surveys from the Gulf of Maine to Southern New England regions between 1963 and 2007. Data are also log transformed on secondary axis to show population growth trends over time (NEFSC, *pers. comm*. 2009).

NEFSC winter trawl survey has consistently higher biomass index values than the autumn and spring surveys with the exception of the first survey year (1992) when no fish were caught. The survey has a fluctuating increasing trend (Figure 16). With the exception of 2003, the winter survey biomass index has not fallen below 1.000 kg per tow since 2000. Furthermore, the 2000 and 2002 survey indices were over 2.000 kg per tow and the 2004 and 2006 survey indices were over 3.000 kg per tow. The 2007 survey index decreased slightly to 1.847 kg per tow.

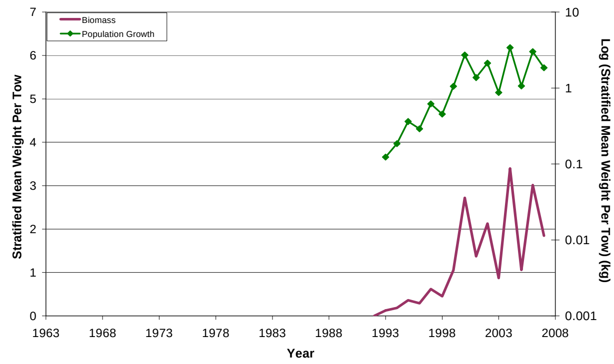

Figure 16. Barndoor skate biomass (stratified mean weight per tow) in NEFSC winter bottom trawl research vessel survey from Georges Bank to Mid-Atlantic regions between 1992 and 2007. Data are also log transformed on secondary axis to show population growth trends over time (NEFSC, *pers. comm*. 2009).

NEFSC spring survey total catch of barndoor skates started at 21 individuals in 1968 that then declined to 0 fish for several years during the 1970s and 1980s. No fish were caught in 1990 but catch increased to 15 fish in 1998. Total catch in NEFSC spring survey has increased dramatically since 2000 (Figure 17). The spring 2006 survey caught 196 individuals, averaging 0.6 fish or 1.7 kg per tow. In that year, a record high of 147 fish were caught at a single station weighing approximately 600 kg at lengths ranging from 48 to 135 cm. The haul had almost three times the total number of individuals caught in all the spring surveys between 1975 and 1990. NEFSC 2007 spring survey broke the 2006 record with a total catch of 325 individuals, driven by a southern Georges Bank tow of 277 individuals. Catch lengths at this sample station ranged from 20 to 132 cm with 137 of those individuals measuring over 100 cm. The catch in this one haul exceeded the total catch in all spring tows conducted between 1968 and 2005. Barndoor skates at this location were believed to be in a spawning aggregation at 296 m depth and 7º C. On a per tow basis, the 2007 spring catch equated to a maximum stratified mean number per tow of 1.5 fish, or 6.8 kg, per tow. The spring 2008 survey caught 140 individuals.

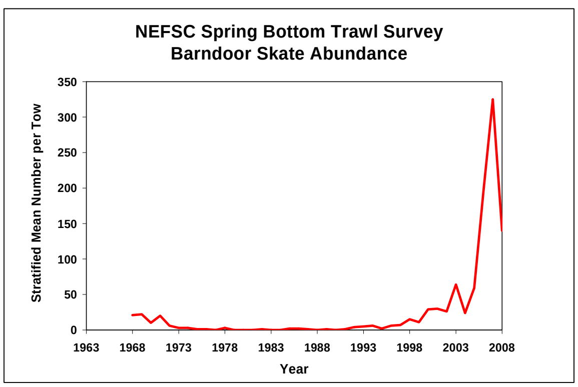

Figure 17. Barndoor skate abundance (stratified mean number per tow) in NEFSC spring bottom trawl research vessel surveys from the Gulf of Maine to Southern New England regions between 1968 and 2008 (NEFSC, *pers. comm*. 2009).

NEFSC autumn bottom trawl survey total catch exhibited a similar trend as the spring survey (Figure 18). Total catch was highest at the start of the time series with 120 fish caught in 1963, equating to a maximum stratified mean number per tow index of about 0.8 fish or 2.6 kg per tow. The autumn survey catch then decreased to several zero tows throughout the 1970s and 1980s. Survey catch increased in the 1990s, ranging from 2 fish in 1992 to 15 fish in 1999. Like the spring survey, there has been a drastic increase since 2000, ranging from 15 fish in 2000 to 102 fish in 2006. The 2007 autumn catch decreased to 71 individuals but encountered some of the largest barndoor skate specimens on record. This survey year caught one barndoor skate that was 140 cm long, which is greater than the 136 cm individual caught in NEFSC autumn survey of 1963, which was the previous record.

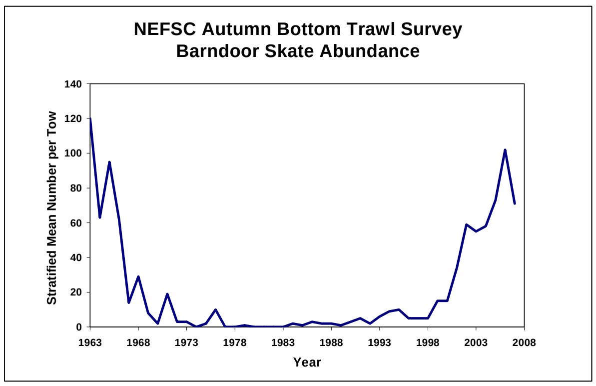

Figure 18. Barndoor skate abundance (stratified mean number per tow) in NEFSC autumn bottom trawl research vessel surveys from the Gulf of Maine to Southern New England regions 1963 to 2007 (NEFSC, *pers. comm*. 2009).

As stated previously, annual catch of barndoor skates in NEFSC winter trawl survey is consistently higher than the spring and autumn surveys with the exception of no fish caught in 1992 (Figure 19). This is due to the increased catchability of the winter survey sampling gear. Winter survey catch started at 0 fish in 1992, increased to 81 fish in 1999 (maximum stratified mean catch per tow of 0.7 or 1.0 kg per tow), and peaked at 335 individuals in 2006 equating to a maximum stratified mean catch per tow of 3.2 fish or 3.0 kg per tow for the 2006 survey year. In 2007, the winter survey caught 220 individuals. With the exception of 2003, this survey has not caught less than 100 fish since 2001.

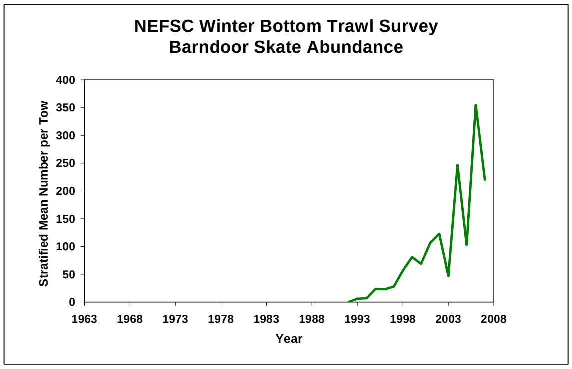

Figure 19. Barndoor skate abundance (stratified mean number per tow) in NEFSC winter bottom trawl research vessel surveys from the Gulf of Maine to Southern New England regions between 1992 and 2007 (NEFSC, *pers. comm*. 2009).

The minimum length of barndoor skates caught in NEFSC surveys is 20 cm, and the largest individual caught was 140 cm. The median length of the survey catch has ranged from 20 cm in the 1985 spring survey to 119 cm in the 1972 spring survey (NEFSC, 2006). The median length of the survey catch has been stable in recent years in both the spring and autumn surveys and is currently 70 to 75 cm (Figure 20)(NEFSC, 2006). Length frequency distributions from these surveys illustrate the decline in abundance of barndoor skates to survey catches of zero during the 1980s (Figure 21-25) (NEFSC, 2006). Recent catches have included individuals larger than those recorded during the peak abundance of the 1960s, and the large number of fish between 40 and 80 cm evident during the 1960s is now apparent in recent surveys (NEFSC, 2006). Furthermore, NEFSC winter survey length frequency distribution has shown a significant increase in the abundance of barndoor skates at lengths less than 80 cm (Figure 26) (NEFSC, 2006).

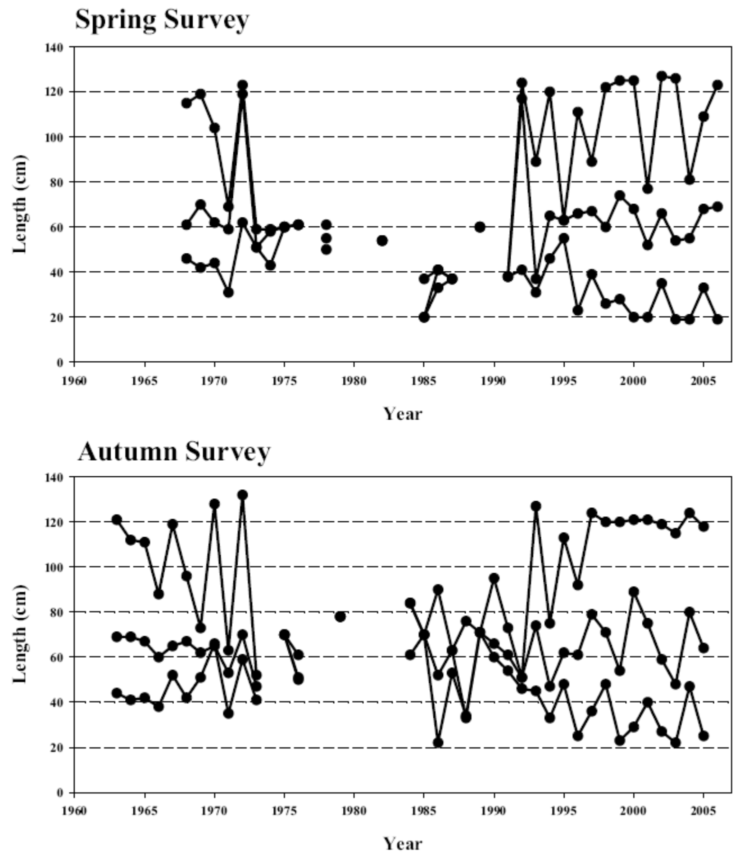

Figure 20. Percentiles of length composition (5, 50, and 95) of barndoor skate from NEFSC spring and autumn bottom trawl surveys from 1963 – 2006 (NEFSC, 2006).

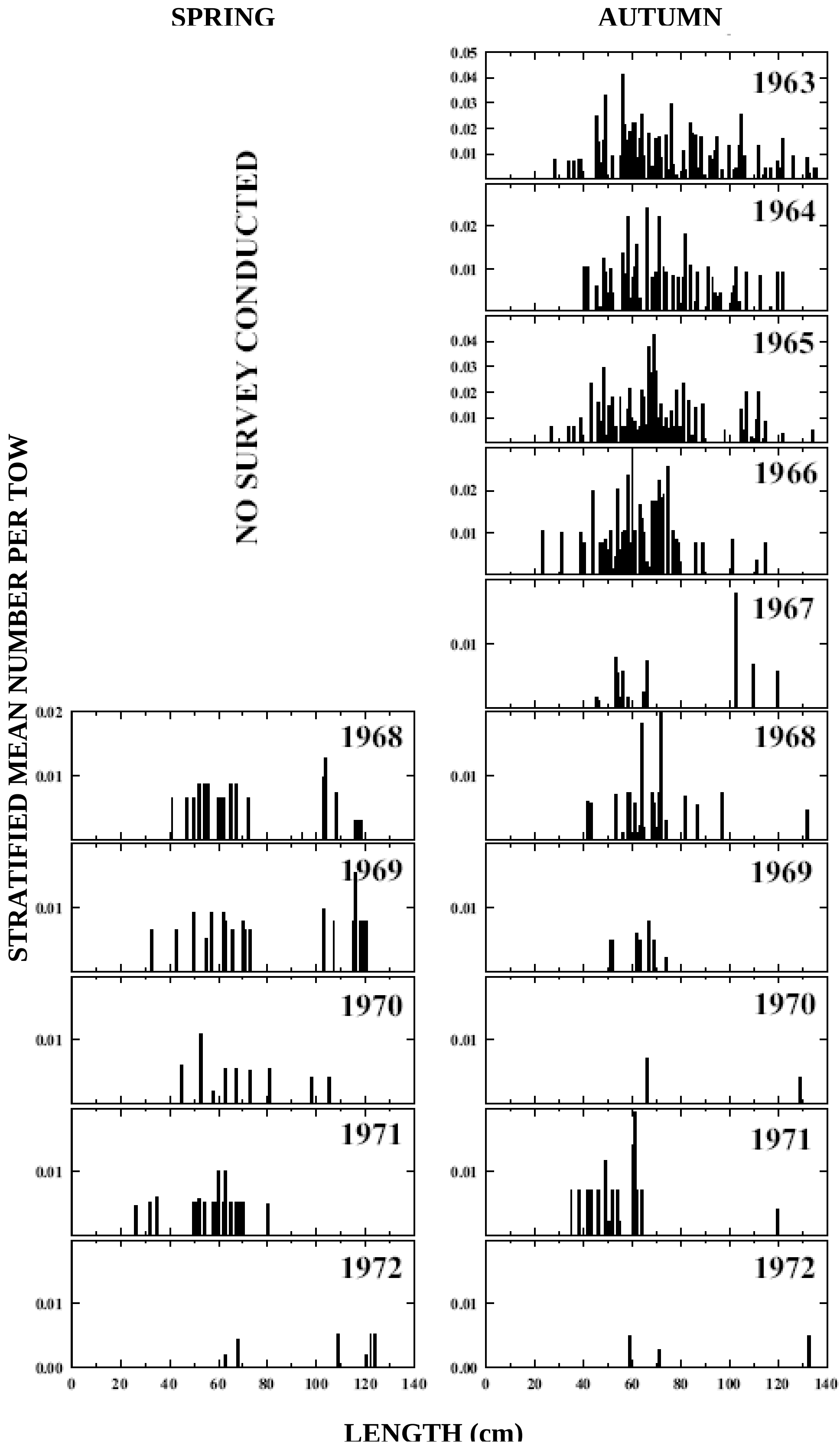

Figure 21. Barndoor skate length composition from the NEFSC spring (left) and autumn (right) bottom trawl surveys from 1963 - 1972 (NEFSC, 2006).

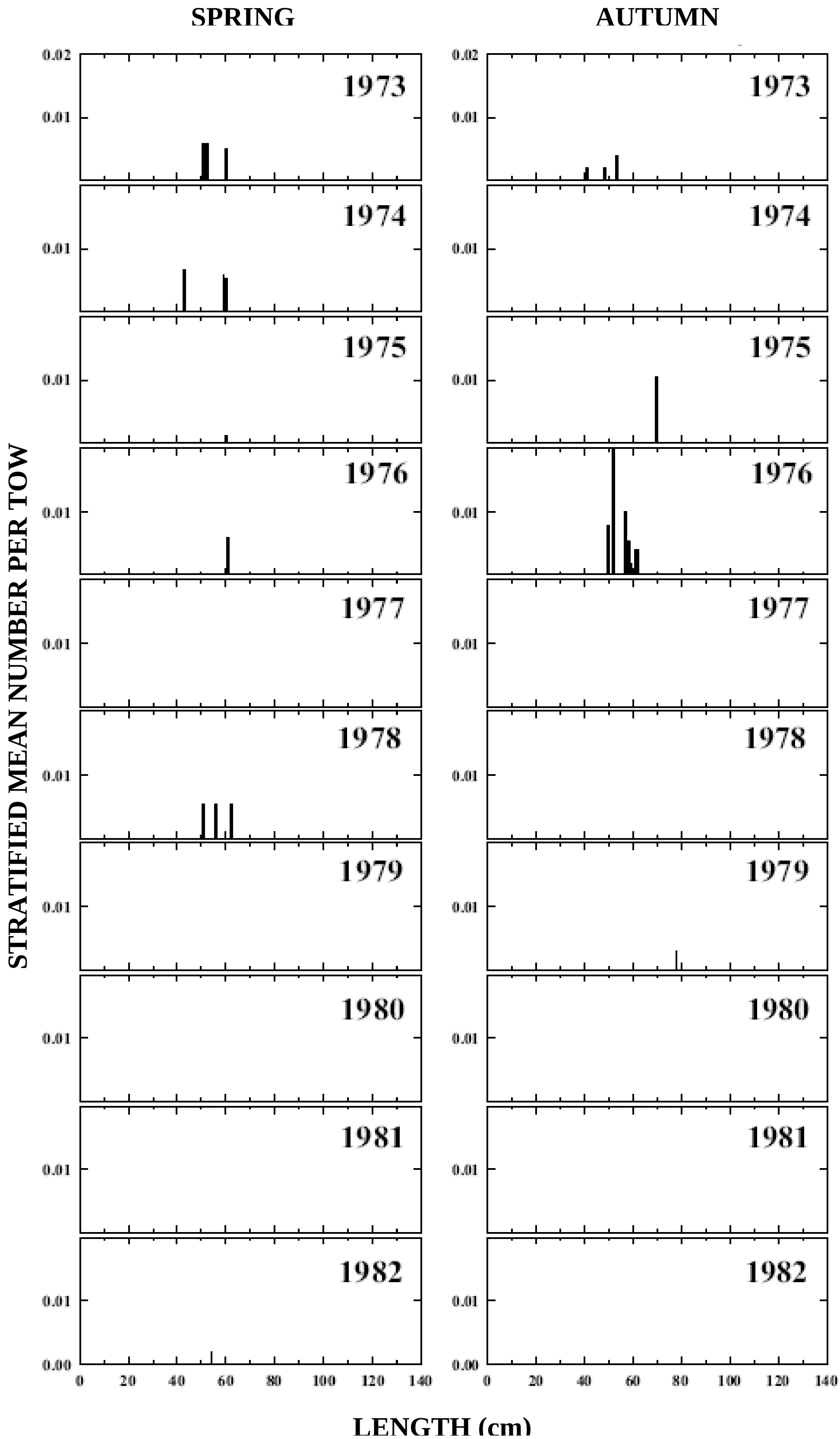

Figure 22. Barndoor skate length composition from the NEFSC spring (left) and autumn (right) bottom trawl surveys from 1973 - 1982 (NEFSC, 2006).

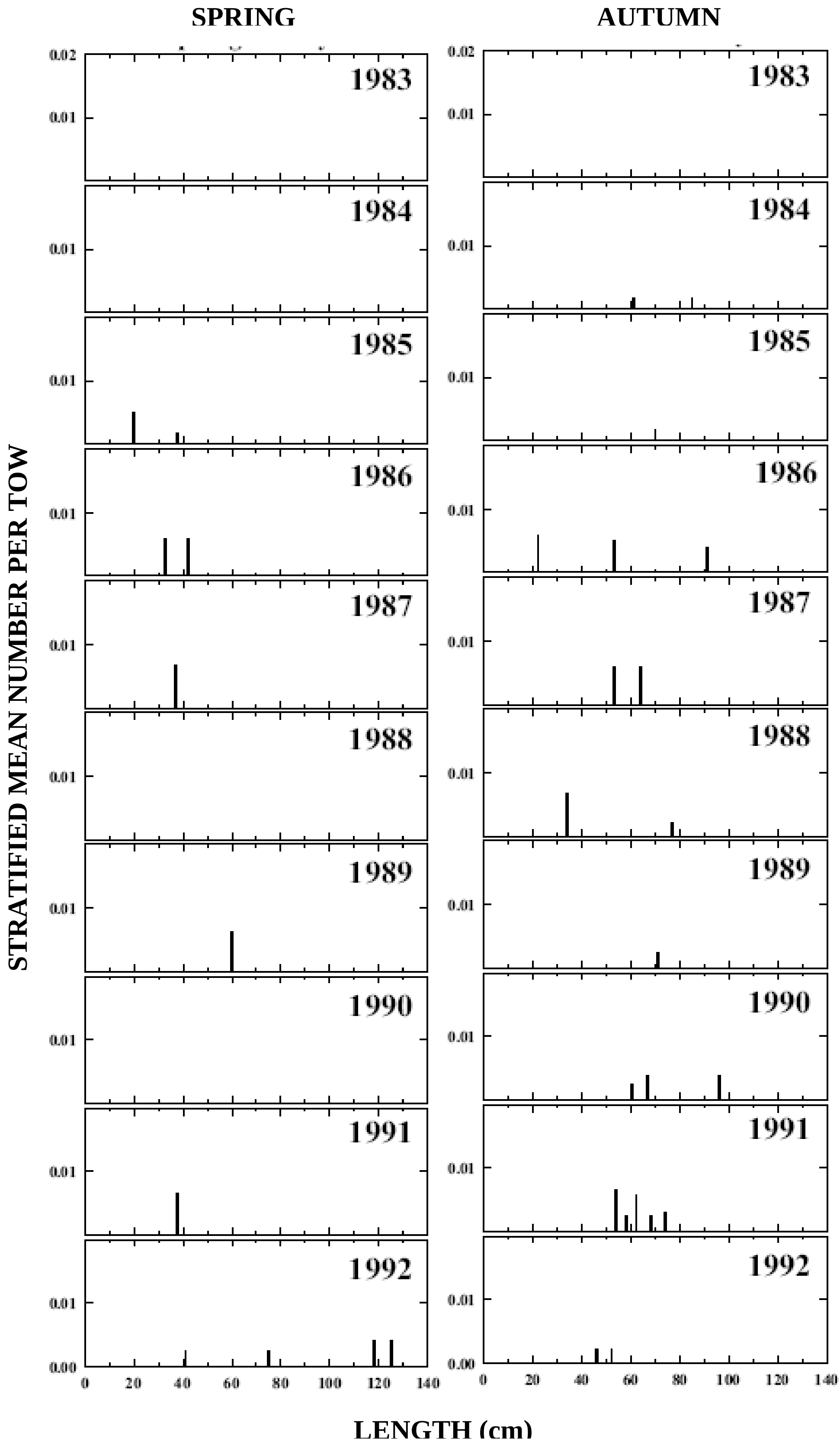

Figure 23. Barndoor skate length composition from the NEFSC spring (left) and autumn (right) bottom trawl surveys from 1983 - 1992 (NEFSC, 2006).

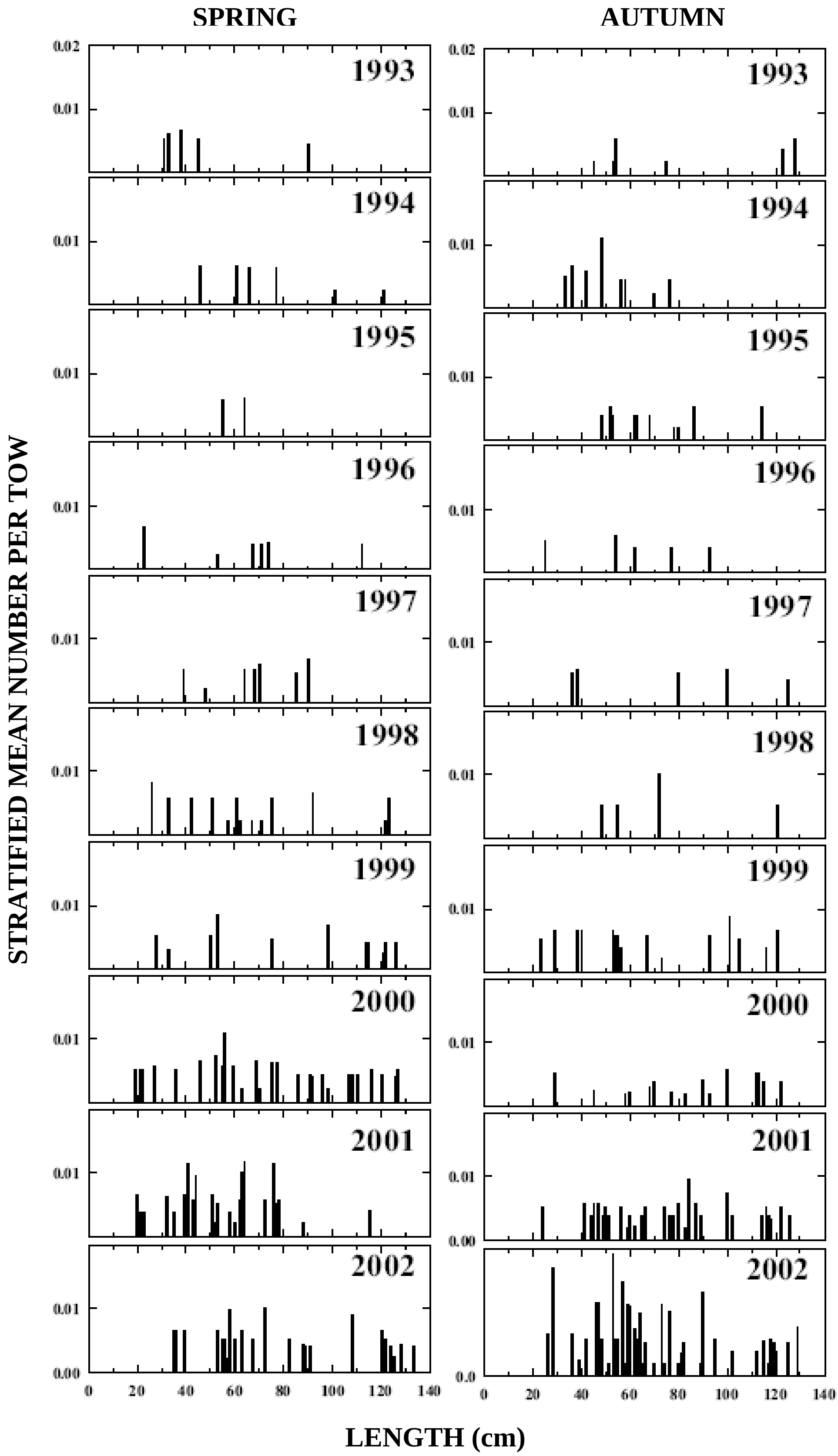

Figure 24. Barndoor skate length composition from the NEFSC spring (left) and autumn (right) bottom trawl surveys from 1993 - 2002 (NEFSC, 2006).

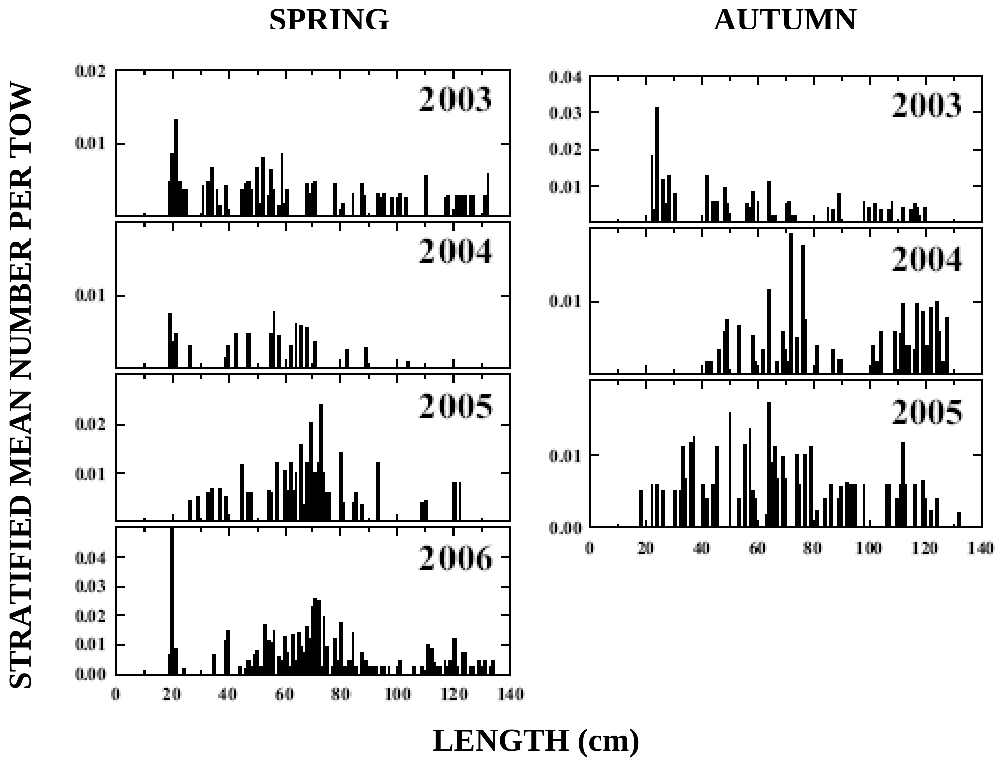

Figure 25. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys, 2003 - 2006 (NEFSC, 2006).

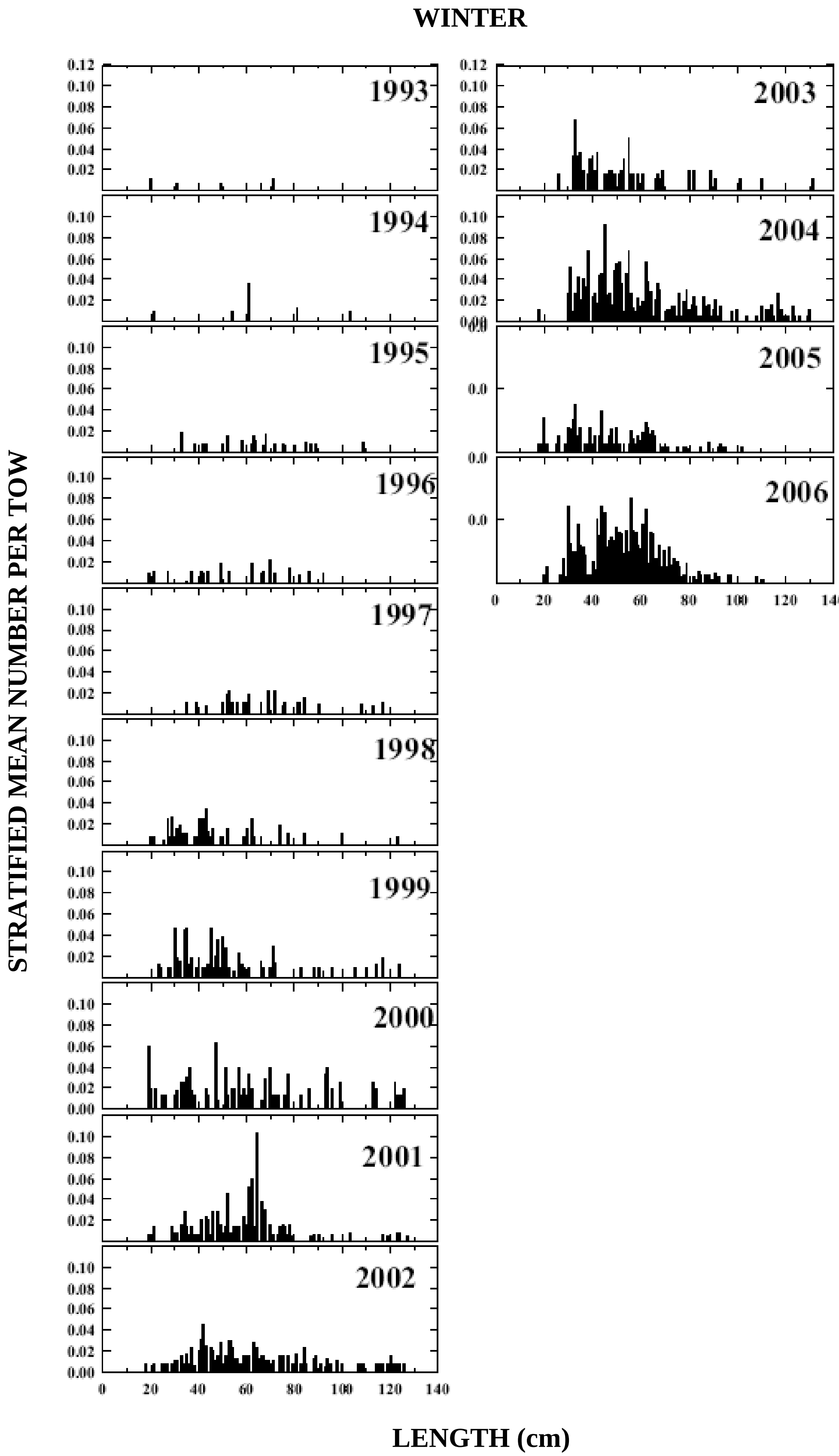

Figure 26. Barndoor skate composition from the NEFSC winter bottom trawl surveys, 1993 - 2006 (NEFSC, 2006).

Another way to assess the status of a population is by their spawning stock biomass (SSB). SSB differs from total biomass because it is a measurement of the total weight of sexually mature fish in the stock. Thus, the SSB index is a record of the reproductive potential of the population. The pattern in the barndoor skate SSB index is much the same as that of total biomass with high values in the early 1960s, followed by very low to nonexistent values in the 1970s and 1980s, and a consistent rise since the mid 1990s (Figure 27) (NEFSC, 2006). Barndoor skate recruitment (number per tow of individuals between 55 and 69 cm long and approximately 2 years of age) was high in the early 1960s, declined to low levels through the 1970s and the 1980s, but has since increased to about half the level observed in the 1960s (NEFSC, 2007). Young-of-the-year barndoor skate (less than 36 cm) have been at the highest level since 2000 (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

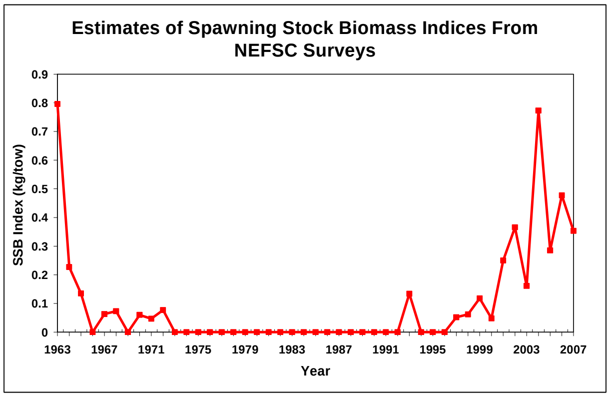

Figure 27. Estimates of spawning stock biomass indices from NEFSC surveys between 1963 and 2007 (NEFSC, *pers. comm.* 2009).

J. Simon, A. Cook, and M. Simpson calculated minimum abundance population estimates for barndoor skates in U.S. waters using NEFSC autumn trawl survey data (*pers. comm.*, 2009). The calculations suggest that between 1963 and 1975 the minimum total abundance was 1.1 million juveniles and 62,000 adults across the NEFSC autumn survey range (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). From 1976 to 1994, the mean abundance declined to 54,000 juveniles and 28,000 adults. Between 1995 and 2007, mean abundance increased to 79,700 juveniles and 112,000 adults (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Comparing the first four survey years (1963 to 1967) with the last four survey years (2004 to 2008) the average was 3.2 and 1.7 million fish per year, respectively (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). This number suggests that the recent population sampled in NEFSC autumn survey represents 53% of the peak abundance from the beginning of the autumn survey time series (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Upon analyzing J. Simon, A. Cook, and M. Simpson's minimum abundance estimates for barndoor skates on Georges Bank (both in U.S. and Canadian waters), it appears that between 1987 and 1995 the U.S. side of Georges Bank harbored 37,000 barndoor skate individuals (*pers. comm.*, 2009). The 1996 to 2009 estimate suggests abundance increased to 587,000 individuals of which 579,000 were juveniles and 8,700 were adults (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

Canadian Stock Status

Trends in survey abundance and biomass indices for barndoor skates in the shallow waters of Canada (less than 400 m) have been well documented (Kulka, 1999; Kulka *et al.*, 2002; Dulvy, 2003). A decline in the survey indices occurred in the mid 1960s to early 1970s, likely caused by the high fishing effort of distant water fleets on Georges Bank, followed by a period of low to zero catches (Simon *et al.*, 2002; Dulvy, 2003). Catch rates of barndoor skates on the southern Scotian Shelf (below 43º N) declined by 96 to 99% from the mid 1960s to the early 1990s (Dulvy, 2003). However, there has been a notable and sustained increase of barndoor skates observed in commercial and research survey data across Atlantic Canada since the mid 1990s. Below, we provide data grouped by NAFO divisions (see Figure 28 for locations of NAFO Divisions).

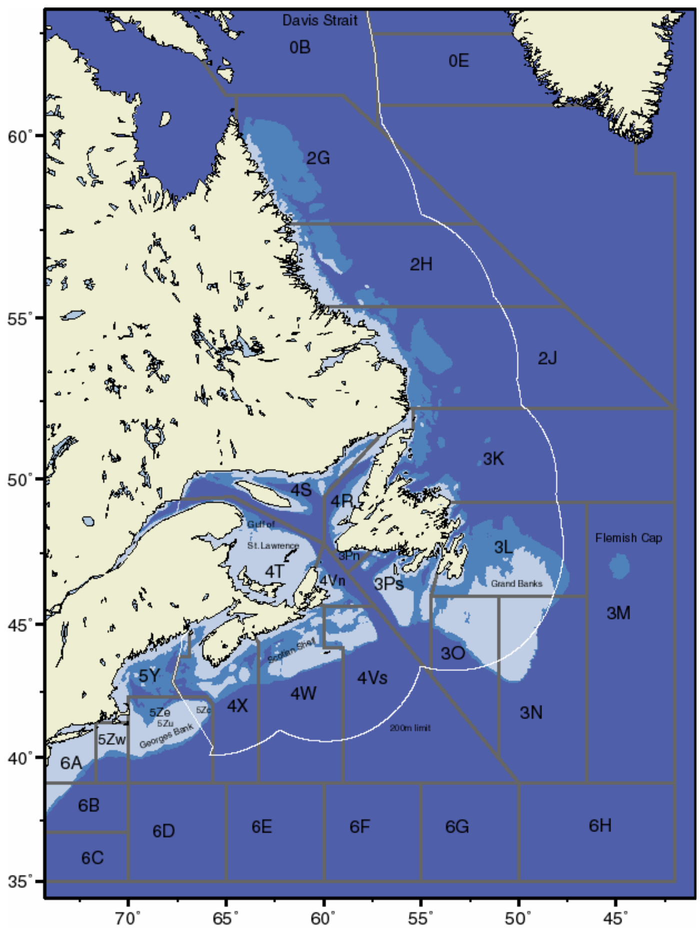

Figure 28. Geographic display of the areas and NAFO divisions mentioned for barndoor skate distribution.

In the northern Gulf of St. Lawrence (Divisions 4RS and Subdivisions 3Pn), barndoor skates were caught in 8 of the 7,830 survey sets or 0.04% between 1978 and 2007. In the southern Gulf (Division 4T), surveyed every September since 1971, barndoor skates were reported in 8 of the 5,163 sets or 0.15% (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). DFO spring survey of the Newfoundland and Labrador Shelf caught 3 barndoor skates out of a total 15,315 sets since the survey's inception in 1971. DFO fall survey extends from the Davis Strait to the Grand Banks. Out of the 18,992 survey sets completed since 1977 only 5 sets encountered barndoor skates in this area.

DFO summer survey data of the Scotian Shelf reveal the lowest time period of detectable barndoor skate abundance in Divisions 4VWX took place throughout the 1980s (Figure 29). Only two individuals were caught across the Shelf between 1981 and 1992. However, since 1993 barndoor skates have reappeared in Division 4X and have continued to increase. The 2007 and 2008 catches in that area are the highest and 3rd highest of the survey series, respectively, and the species has begun to reappear in Division 4W (Figure 29). Annual rate of increase since 1993 in this area has been 19% (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

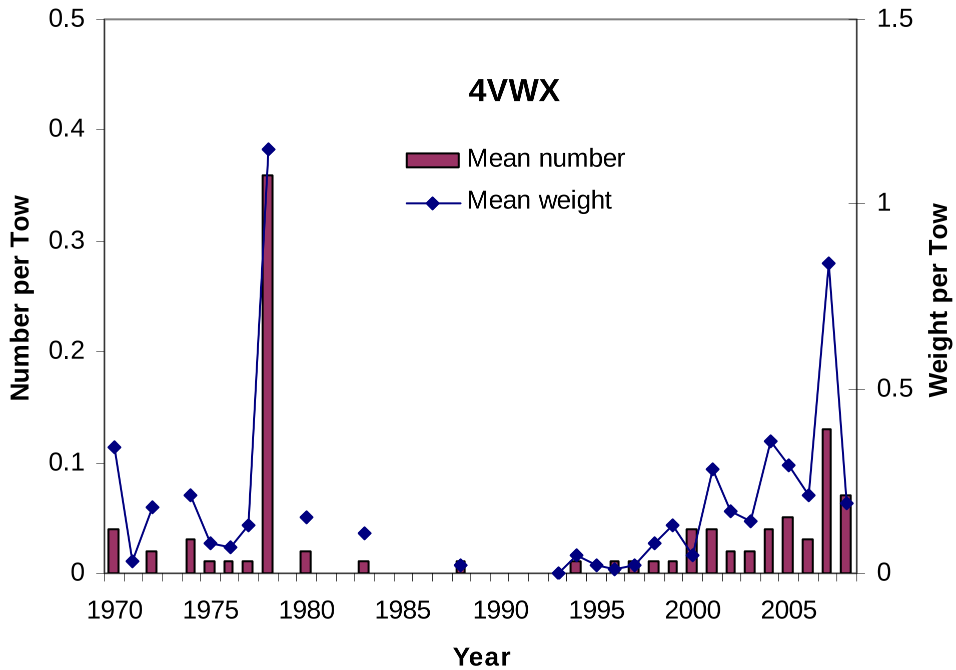

Figure 29. Stratified mean number and weight per tow from the DFO summer RV survey in NAFO Divisions 4VWX (J. Simon, A. Cook, M. Simpson, *pers. comm.*, 2009).

Catch in the summer survey of the Scotian Shelf consisted of mainly juveniles (less than 114 cm) (Figure 30). Adults (114 cm or more) were encountered in 13 sets in 39 years but have been increasing since 1998 (Figure 30). On the rare occasions adult individuals were caught, they were primarily taken from Division 4X in the Fundian Channel. Although the range of lengths caught by the survey has not changed significantly, in general the size of animals caught from 1970 to 1993 tend to be smaller than those caught in the 1993 to 2008 period (Figure 31). DFO scientists suggest the abundance time series may better reflect some measure of recruitment variation (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

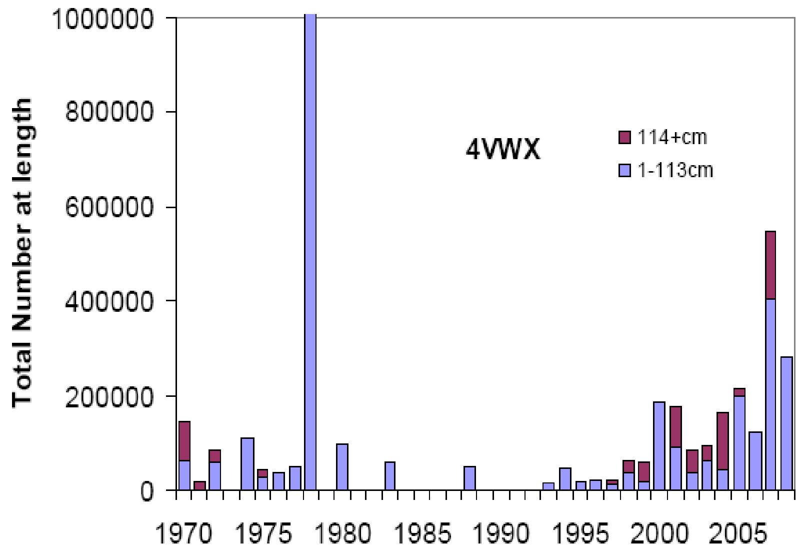

Figure 30. Abundance trend (#/tow) from the DFO summer RV survey from 1970 to 2008 disaggregated into juveniles (1-113 cm) and adults (114+ cm) (J. Simon, A. Cook, M. Simpson, *pers. comm.*, 2009).

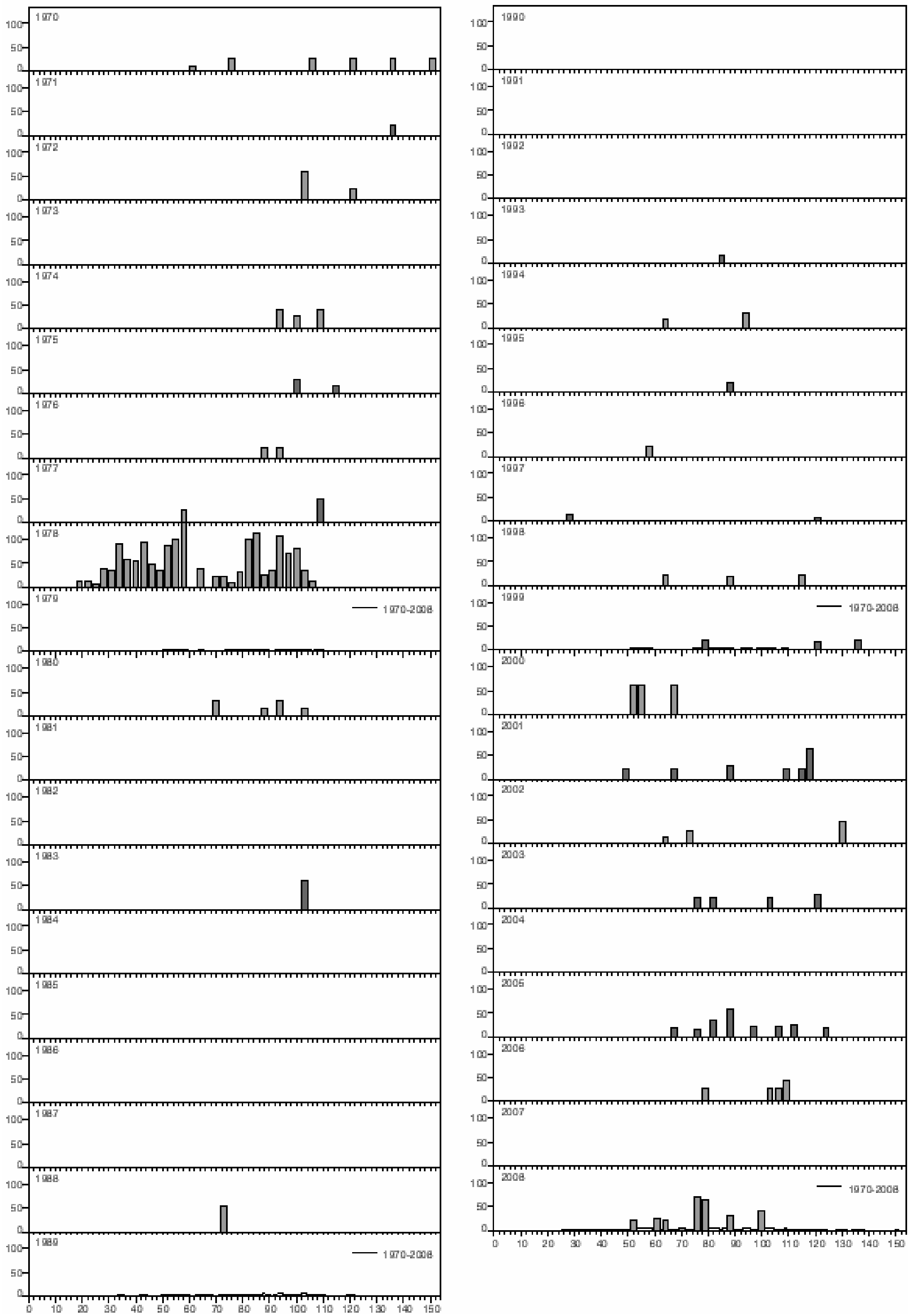

Figure 31. Annual length frequencies of barndoor skates from the DFO summer RV survey from 1970 to 2008, Divisions 4VWX (J. Simon, A. COok, M. Simpson, *pers. comm.*, 2009).

As stated previously, the longline sentinel survey of the Scotian Shelf (Divisions 4VsW) noted the core concentration of barndoor skates is along the central Scotian Shelf between Emerald Basin and Emerald Bank, southward to the edge of the shelf. The mean number and weight per tow of barndoor skates in this area has increased by 25% per year since 1996 (Figure 32). Percent occurrence of barndoor skates in survey sets from this area has ranged from about 10% in 1997 to nearly 60% in 2002 (Figure 33) (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

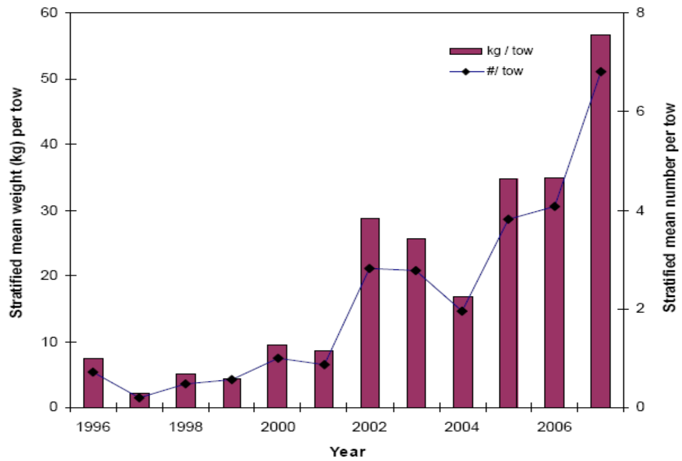

Figure 32. Stratified mean catch rate of barndoor skate from the 4VsW Sentinel Survey, 1996 – 2007 (J. Simon, A. Cook, M. Simpson, *pers. comm.*, 2009).

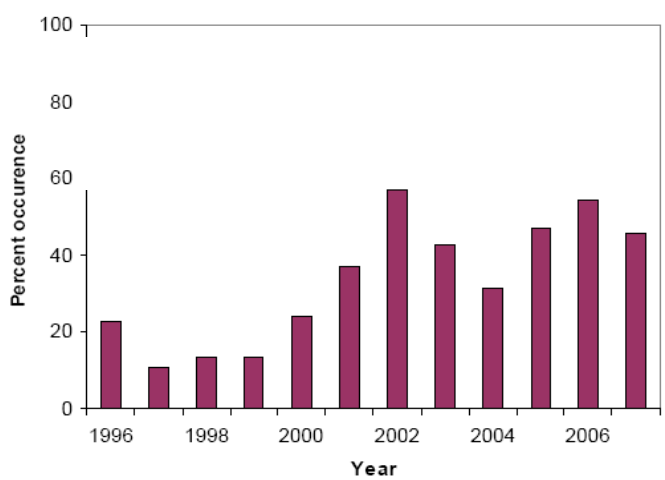

Figure 33. Percentage of barndoor skate caught between Emerald Basin and Emerald Bank, southward to the Scotian Shelf edge in the 4VsW Sentinel Survey (J. Simon, A. Cook, M. Simpson, pers. comm., 2009).

Catch rates of barndoor skates from the combined phases of the industry/DFO longline halibut survey of the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3N, 3O, 3Ps, 4V, 4W, 4X, and 5Zc) went from 2 kg per tow in 1998 to 17 kg per tow in 2007 with an annual rate of increase of 17% during this time period. Percent occurrence increased from approximately 10% in 1998 to over 20% in 2006 and 2007 (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Of the 1994 commercial index survey sets (mostly taken at depths greater than 500 m) conducted between 1998 and 2007, 269 (13.8%) of them captured barndoor skates (J. Simon, A. Cook, and M. Simpson, pers. comm., 2009).

The ITQ fixed station industry survey is a joint industry/DFO science resource otter trawl survey that covers Division 4X. A total of 2,523 survey sets have been conducted since 1996 with 90 of those sets or 3.6% containing barndoor skates. The majority of these sets occurred in the deep waters off German Bank and Browns Bank. The survey has shown an annual increase in barndoor skate abundance of 7.3% between 1996 and 2008 (Figure 34) (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

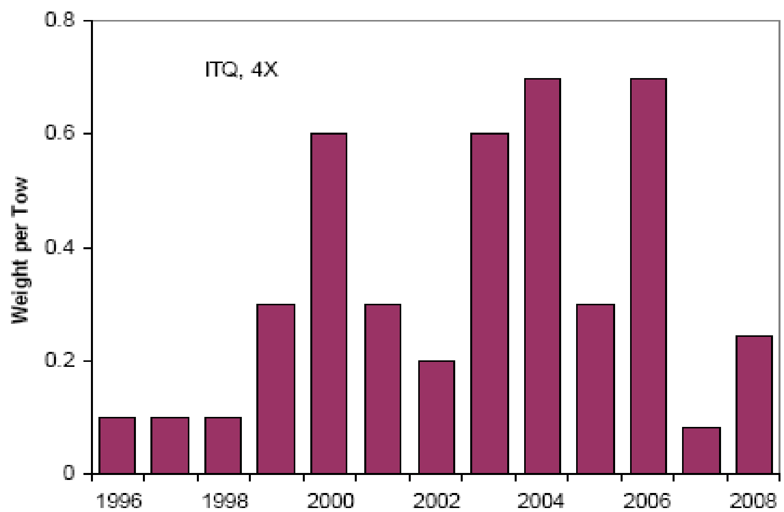

Figure 34. Abundance (kg/tow) of barndoor skate from the ITQ fixed station industry survey in Division 4X between 1996 and 2008 (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

Length frequency data from scallop dredge operations in Atlantic Canada suggest few adult barndoor skates remain in the population, with these generally less than 130 cm long (Dulvy, 2003). However, the scallop dredge gear may underestimate the abundance of larger size classes (Dulvy, 2003). Simon *et al.* (2002) reported the size of barndoor skates collected in Canada's winter research survey between 1986 and 2001 ranged from 15 to 125 cm, with the vast majority less than 100 cm. Simon *et al.* (2002) concludes that the survey data suggest the Canadian population is comprised of both juveniles and adults, but juveniles are the dominant catch. However, Canadian commercial fishery observer sampling of both mobile and fixed gears as well as the commercial index of the halibut survey referenced above indicates that commercial gear may regularly capture more and larger barndoor skates than are evident in research survey catches (NEFSC, 2000).

Upon analyzing research survey data from the southern Grand Bank and St. Pierre Bank, the Scotian Shelf, and Georges Bank to Southern New England, Casey and Myers (1998) believed barndoor skates were only present in three of the nine NAFO statistical areas in which they were formerly abundant and the distribution was then limited to Browns Bank and Georges Bank. Casey and Myers (1998) estimated barndoor skate population size from St. Pierre Bank decreased from some 600,000 individuals in the 1950s to less than 500 individuals in the 1970s. However, it is argued that the catchability of barndoor skates by the survey gear is low (D. Kulka, *pers. comm.* as cited in Dulvy, 2003; see Edwards, 1968) and that the historical trawl data from the early part of the time series are not comparable to recent surveys due to the drastic differences in sampling design and techniques (Kenchington, 1999; Dulvy, 2003). The species also continues to be found in all NAFO areas, but at reduced numbers (Kulka, 1999; Kulka *et al.*, 2002; Simon *et al.*, 2002; Dulvy, 2003). Furthermore, the various surveys used in Casey and Myer's (1998) analysis ended in 1993 to 1996, depending on the area concerned. Thus, their conclusions excluded any trends that occurred throughout much of the 1990s, during which time barndoor skate abundance increased substantially (Kenchington, 1999). Therefore, Casey and Myers' (1998) analysis did not include the evidence that suggest barndoor skate populations were beginning to rebuild.

In 2002, Simon *et al.* calculated population estimates from the DFO winter survey and concluded that the population has been increasing since the early 1990s with a peak of over 750,000 individuals in 1998. Prior to 1998, survey stratified mean number per tow for barndoor skates on the Canadian side of Georges Bank was 0.1 per tow; however, the 1998 stratified mean number per tow increased to 0.5 per tow. The overall increase of barndoor skates encountered in this survey is 3.4% per year since 1987. Taking into account the U.S. side of the Bank (using NMFS bottom trawl survey data), the increase observed is 14% since 1987 (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

J. Simon, A. Cook, and M. Simpson (*pers. comm.*, 2009) used both Canadian and U.S. research survey data from Division 5Z and Divisions 4VWX to calculate minimum abundance estimates. For Georges Bank (Division 5Z) in its entirety (U.S. and Canadian sides) between 1987 and 1995, there were an estimated 52,000 barndoor skate individuals. That number increased to 633,000 individuals between 1996 and 2009. Of that population, 622,000 are thought to be juveniles and 11,000 adults (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). On the Canadian side of Georges Bank minimum total abundance was lowered to 15,000 individuals between 1987 and 1995. The 1996 to 2009 time frame has a minimum total abundance estimate of 43,000 juveniles and 2,300 adults on for the Canadian side of the Bank (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). On the Scotian Shelf, J. Simon, A. Cook, and M. Simpson (*pers. comm.* 2009) estimated that there were 152,000 juveniles and 11,000 adults between 1970 and 1982 (although if excluding the anomalous 1978 survey year mean number of juveniles would drop to 38,000 individuals and the number of adults would increase slightly to 12,000 individuals). Between 1983 and 1995, the number of barndoor skates was estimated to have decreased to 15,000 juveniles and 0 adults (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). During the 1996 to 2008 time frame, the number is estimated to have increased to 118,000 juveniles and 39,000 adults (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

Although barndoor skate populations dropped to record low numbers throughout the 1980s, the increase in barndoor skate abundance since the mid 1990s exhibited through DFO commercial fishery and research survey data suggest that abundance is close to or has exceeded those seen in the early part of the survey time series throughout the central/western Scotian Shelf and Gulf of Maine area.

5.0. Threats Assessment

5.1. Extraction

5.1.1. Commercial Fisheries

United States Commercial Fisheries

One of the primary markets for skate products in the Northwest Atlantic is for lobster bait. The fishery is a historical and directed skate fishery, involving vessels primarily from southern New England waters (mainly Rhode Island). The bait fishery, although it is almost entirely a directed fishery for skates, is a relatively small fishery, contributing to less than 40% of total skate landings (NEFMC, 2003b). Catch is largely comprised of little skate (greater than 90%), with a smaller percentage of juvenile winter skate (less than 10%) occurring seasonally (NEFMC, 2009). Bait landings are primarily little skates (Sosebee, 2000). Almost all skates landed in this directed fishery are used for lobster bait and are caught by otter trawls (NEFMC, 2003b). A small percentage of skate landings is due to a seasonal gillnet incidental catch fishery as part of the directed monkfish gillnet fishery, in which skates (mostly winter skates) are sold both for lobster bait and as cut wings for processing (NEFMC, 2003b).

The other primary fishery targeting skates in the northeastern U.S. is the wing fishery, which represents approximately 60% of total skate landings (NEFMC, 2003b). The fishery for skate wings evolved in the 1990s as skates were promoted as "underutilized species," and fishermen shifted effort from groundfish and other troubled fisheries to skates and dogfish (NEFMC, 2009). The wing fishery is more of an incidental fishery where vessels tend to catch skates when targeting other species like groundfish, monkfish, and scallops, and land them if the price is high enough (NEFMC, 2009). The current market for skate wings remains primarily an export market with France, Korea, and Greece being the leading importers.

Wings are taken from large bodied skates (winter skate, thorny skate, and barndoor skate) with winter skate and thorny skate preferred for human consumption. However, due to their overfished status, possession and landing of thorny skate and barndoor skate has been prohibited since 2003. Winter skate is, therefore, the dominant component of the wing fishery, but illegal thorny skate and barndoor skate wings still occasionally occur in landings (Table 1) (NEFMC, 2009). Participation in the skate wing fishery has recently grown due to increasing restrictions on other, more profitable groundfish species. However, it is assumed that more vessels land skate wings as an incidental catch in mixed fisheries than as a target species (NEFMC, 2009).

Table 1. Preliminary skate wing fishery species composition (% total) in sampled landings by state (2006 to 2007). Source: Experimental skate wing dockside sampling process, NMFS Fisheries Statistics Office (NEFMC, 2009).

Species	ME	MA	RI	NJ
Winter	95.4	93.3	95.8	61.7
Thorny	3.0	6.7	0.2	0.0
Barndoor	1.6	0.0	0.1	0.0
Little*	0.0	0.0	4.0	14.9
Clearnose	0.0	0.0	0.0	23.4
Smooth	0.0	0.0	0.0	0.0
Rosette	0.0	0.0	0.0	0.0
N wings sampled	3,931	11,360	3,761	2,049

*likely misidentified winter skate

U. S. commercial fisheries have been landing skates since the late 1800s. However, commercial fishery landings, primarily from Rhode Island, never exceeded several hundred mt until the advent of industrial fisheries in southern New England in the 1950s followed by the distant water fleets during the 1960s (Sosebee, 2006). Aggregated skate landings are shown in Figure 35. Increased demand for lobster bait and, more significantly, the export market for skate wings in the mid 1980s resulted in a drastic increase in skate landings. Reported landings may have also increased due to improved statistical data collection (Sosebee, 2000; Sosebee, 2006). Landings have generally been on an increasing trend since 2000 and currently average around 15,000 mt (Figure 35) (Sosebee, 2006). The 2007 reported commercial landings of 19,000 mt are the highest on record, and are largely driven by increased landings of skate wings. However, a ban on possessing barndoor skate and thorny skate as well as a partial ban on smooth skate was implemented through the Skate FMP in 2003.

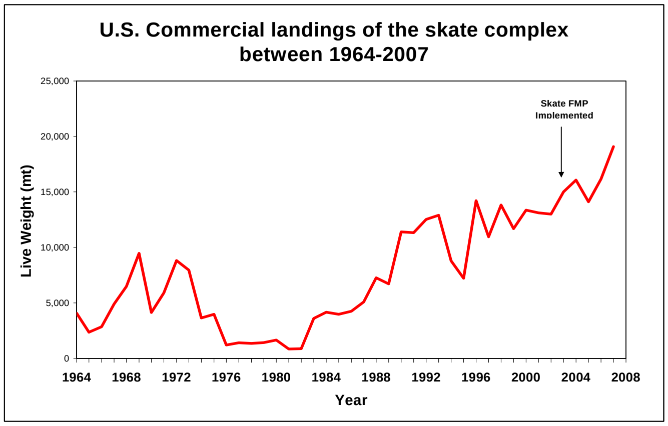

Figure 35. U.S. commercial landings of all species of skate between 1964 and 2007.

Commercial discards of skates have always been higher than skate landings and are estimated to be two to four times that of the landings average (Figure 36). However, the increased demand for skate products since the mid 1980s has caused fishermen to retain more skates resulting in a decline in skate discard rates. The decline may also be due, in part, to restrictions implemented in the multispecies, monkfish, and scallop dredge fisheries that significantly reduced overall bycatch in these fisheries. Furthermore, the days-at-sea (DAS) restrictions in the multispecies fishery resulted in more DAS being used to target skates. The possession of barndoor skate has been prohibited since 2003, thus, increased effort directed at skates should not affect barndoor skate landings. However, change in distribution of effort to areas known to have high skate concentrations as well as the use of gear tailored to catching skates may increase the amount of barndoor skate discards. Even though there is a significant decrease in aggregate skate discards, discards are still estimated to represent 60% of the total skate catch.

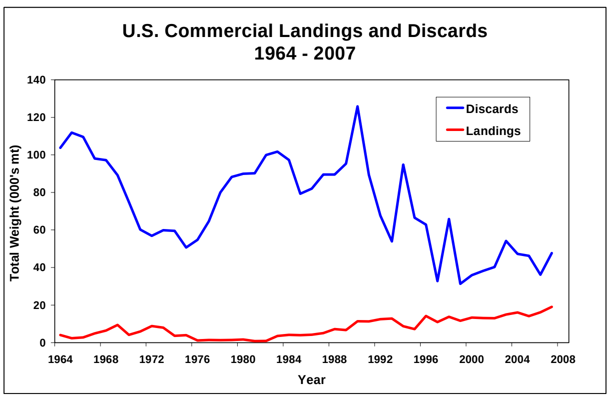

Figure 36. Commercial landings and discards of all species of skate between 1964 and 2007. Discard rates used were estimated by DPSWG (2009).

The discard mortality rates of skates captured by commercial fishing gear remains one of the biggest unknowns in skate population dynamics (NEFMC, 2009). A review of the primary literature reveals very little information on discard mortality of skate species in the Northwest Atlantic or elsewhere. Based on the limited discard mortality data from other ray and skate species (see Stobutzki *et al.*, 2002; Laptikhovsky, 2004; Benoit, 2006 as cited in NEFSC, 2009), managers calculate catch limits and associated targets using a 50% discard mortality assumption (NEFMC, 2009).

At-sea fisheries observers are typically trained to collect information onboard fishing vessels. Observer records are a potential data source that may aid in disaggregating the skate complex into individual species and deriving useful information such as discard rates by individual species. NEFSC (2006) mapped the catches of skates by species recorded through this program to determine if the data were potentially useful. Distribution data of barndoor skate from the observer database show fairly substantial amounts off Virginia and North Carolina. These records are considered to be misidentified barndoor skate catches that do not represent an expansion of the range of the species. This determination is due to the recorded catches being outside of the southern range of the known survey data from that period (NEFSC, 2006). Better species identification training for both observers and commercial fishermen was initiated in 2003, which has improved the accuracy of these records. While species identification errors may have frequently occurred, particularly before 2003, the large size and distinctive coloration of barndoor skates may mean some of the northern records have been identified correctly, indicating commercial fishery discards of a few hundred mt per year (NEFSC, 2000; Dulvy, 2003).

Commercial landings of skates have generally not been reported by species, with over 99% of landings prior to 2003 reported as "unclassified skates" (NEFSC, 2006). Although the Skate FMP has required skates to be reported by species (discards by general categories of large/small and landings by individual species) since 2003, as recently as 2006, 22% of kept skate haul weight were still unclassified and species reporting is still considered inconsistent and largely unreliable. Therefore, the amount barndoor skates contribute to total catch and trends over time is unknown. However, Edwards (1968) studied skate susceptibility to commercial gear by attaching underwater cameras to the head-ropes of standard trawl gear. He described barndoor skates as "extraordinarily adept at avoiding capture" because of the tendency to herd ahead of the nets. They do not generally get up off the bottom, which makes nets with rollers less efficient at catching the species (Edwards, 1968). Furthermore, barndoor skates are not known to aggregate often or to a significant degree and are thus, not thought to be caught in high numbers. In addition, possession of the species has been banned in U.S. commercial fisheries since 2003. Thus, their interaction with U.S. commercial fisheries does not currently seem to be a significant threat to the species.

Canadian Commercial Fisheries

Prior to 1994, skates were only caught incidentally in Canadian fisheries (predominantly groundfish fisheries). However, a Canadian directed skate fishery was initiated in 1994 as a response to closures in the traditional Canadian groundfish fishery and an increasing international market for skate wings (NEFMC, 2009). The directed skate fishery evolved in the northerly areas of barndoor skate distribution, on the eastern Scotian Shelf in NAFO Division 4Vs and Division 4W and primarily targets winter skate (greater than 90%) with a small bycatch of thorny skate (less than 10%) (NEFMC, 2001).

Barndoor skates have never been targeted in Canadian commercial fisheries; thus, the major threat to their continued existence is bycatch (Casey and Myers, 1998), particularly in the benthic trawl fisheries for cod and redfish and the dredge fishery for scallops. Kulka *et al.* (1996) first reported barndoor skates occasionally taken as bycatch in deepwater fisheries on the Grand Bank and Labrador Shelf but they were most commonly taken in otter trawl fisheries along the outer edge of the shelf. It should be noted that fishing effort on demersal fish in Canadian waters has declined substantially in the past decade as a result of several moratoria (cod, plaice), closed fisheries (grenadier), and reduced quotas (redfish, witch) (D. Kulka, *pers. comm.* as cited in Dulvy, 2003). Closures of many of the fisheries in these offshore areas in the early 1990's have meant that the incidence of bycatch species from slope fisheries, including barndoor skates, has likely diminished (Simon *et al.*, 2002).

There is little information that may be derived from commercial landings of skates in Canada because commercial fisheries do not separate landing records by species and report all skates caught as "skate unspecified." However, landings by the Canadian skate fishery (mainly winter skate) on the Scotian Shelf have been progressively lower since 1994, reflecting the total allowable catch (TAC) reductions. These reductions lowered Canadian skate catch from 4,200 mt in 1994 to 1,100 mt in 2006 (Kulka *et al.*, 2007 as cited by NEFSC, 2009). Furthermore, the directed fishery on the Scotian Shelf was then closed in 2005. Since Canadian skate landings are not reported by species, barndoor skates' contribution to total skate landings is uncertain at this time. However, barndoor skates are not targeted in Canadian fisheries. Thus, landings of the species are presumed to be negligible. Furthermore, a decrease in aggregated skate landings and directed effort most likely corresponds to a decrease in landings of barndoor skates.

<u>Barndoor Skate Response to Exploitation</u>

Gedamke *et al.* (2008) estimated total mortality (Z) of barndoor skates from Georges Bank and the Gulf of Maine between 1963 and 2005 from mean lengths and catch rates. The results suggest a very high Z in the late 1960s, from 0.89 to 1.04 per year. An observed reduction in Z occurred sometime between 1978 (approximately the same time as the cessation of the fishing activity of the distant water fleets on Georges Bank) and 1994 (Gedamke *et al.*, 2009). In 1994, three large closure areas for all groundfish vessels were implemented on Georges Bank that is believed to have greatly reduced fishing mortality on barndoor skates in that area (Gedamke *et al.*, 2008). From 1996 to 2005, Z was estimated to be between 0.04 and 0.23 per year. Gedamke *et al.* (2008) suggest current mortality rates are low at approximately 0.23 per year.

A Leslie matrix demographic analysis conducted by Gedamke *et al.* (2009) estimated that barndoor skate on Georges Bank declined at an instantaneous rate of -0.32 per year (1963 to 1979) and has since increased at an instantaneous rate of 0.36 per year (1996 to 2005) (Figure 37). Using an M value of 0.18, Gedamke *et al.* (2009) then estimated F to be 0.71 and 0.86 per year for the decline and 0.05 for the recovery. Gedamke *et al.* (2007) assume F applies to all ages because barndoor skates are born at a large size of nearly 20 cm total length. This suggests that fishing may have caused barndoor skate populations to decline throughout the 1960s and 1970s but has since decreased to low enough levels that should allow the species to rebuild.

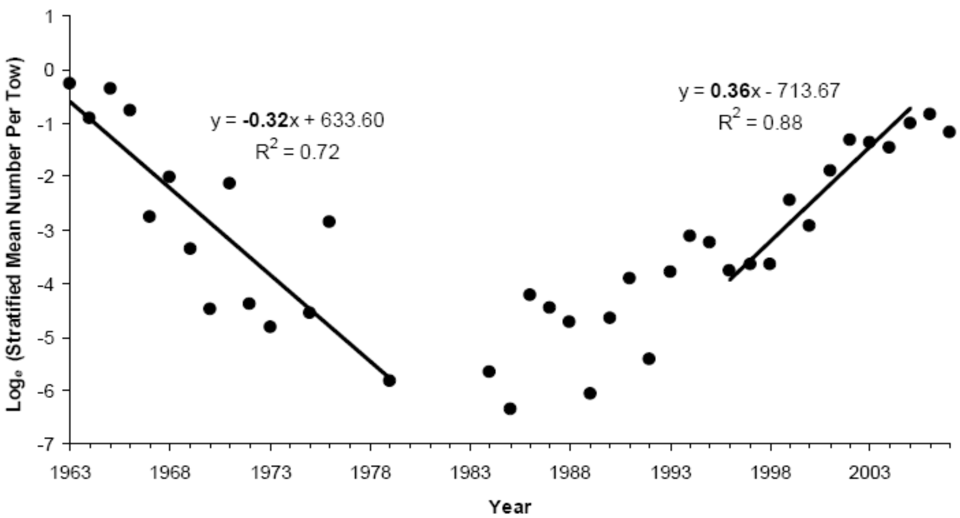

Figure 37. Barndoor skate survey indices from NEFSC autumn survey on Georges Bank and the Gulf of Maine. Data have been log transformed to estimate the rate of population change. Resulting estimates for the observed rate of population change from 1963 to 1979 (decline) and from 1996 to 2005 (recover) are indicated (Gedamke *et al.*, 2009).

Utilizing Gedamke *et al's.* (2005) growth parameters (total length of 166.3, growth coefficient (k) of 0.1414, and theoretical age when length equals zero (t_0) of -1.2912), J. Simon, A. Cook, and M. Simpson (*pers. comm.* 2009) calculated Z from the descending limb of Canada's halibut longline survey commercial index length frequency for barndoor skates in Division 3NOP. This resulted in a Z of 0.23 per year (J. Simon, A. Cook, and M. Simpson *pers. comm.*, 2009).

5.1.2. Recreational Fisheries

Skates have little recreational value and are not actively pursued by any recreational fishery. The Marine Recreational Fishery Statistics Survey (MRFSS) has collected recreational landings data in the U.S. Atlantic since its implementation in 1981. Like commercial landings, the survey does not distinguish between individual species within the skate complex; however, aggregate recreational landings of all skates between 1981 and 1998 never exceeded 300 mt. In recent years, recreational skate catch ranged from 1.4 million individuals in 2001 to 3.3 million individuals in 2003 (Figure 38) (NEFMC, 2009). Recreational landings of skates are considered negligible both in the context of all recreational fisheries (0.015% of all Atlantic coast recreational landings) and in the context of the overall skate fisheries (0.085% of all skate landings) (NMFS, 2007).

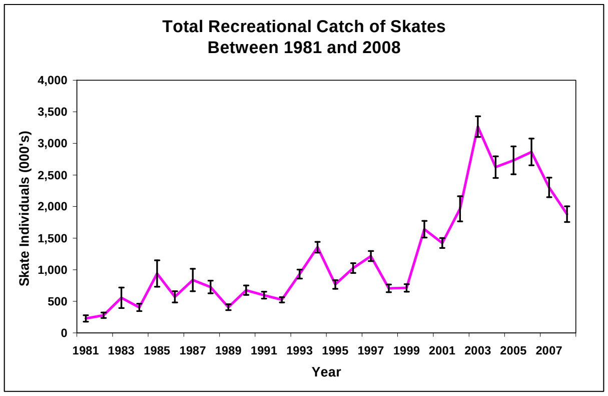

Figure 38. Recreation skate catch between 1981 and 2008.

The number of skates reported as released alive averages an order of magnitude higher than the reported landed number, thus bycatch mortality is a potential threat to the species. Recreational harvest where skates were retained or killed by anglers ranged from 0.4 and 3.0% of the total catch between 2000 and 2007 (Table 2) suggesting the vast majority of anglers release skates alive. Party/charter boats have historically been under-sampled compared to the private/rental boat sector, yet still account for most of the recreational catch and may have different discard rates (NEFSC, 2006). The recreational release mortality rate is unknown but estimated to range from 10 to 15% as it is thought to be analogous to that of flounders and other demersal species (NEFSC, 2006). Assuming a 10 to 15% release mortality rate would suggest that recreational fishery discard mortality is of about the same magnitude as recreational landings (NEFSC, 2006).

Table 2. Recreational harvest, discards, and total catch of skates in the U.S. Atlantic between 2000 and 2007.

Year	Harvest*	Live Discards	Total Catch
2000	47,106	1,593,523	1,640,629
2001	5,799	1,416,520	1,422,319
2002	10,540	1,954,776	1,965,316
2003	17,297	3,247,443	3,264,740
2004	13,306	2,610,375	2,623,681
2005	19,090	2,712,616	2,731,706

2006	138,880	2,724,872	2,863,752
2007	69,857	2,232,929	2,302,786

* Includes fish landed, used for bait, released dead, or filleted

5.1.3. Scientific or Educational Purposes

Scientific and educational utilization of barndoor skates is limited and not thought to cause a significant threat to the species.

5.2. Habitat Loss and Degradation

Auster and Langton (1998) explain that mobile fishing gear may have a negative impact on the structural components of habitat by direct removal or damage of epifauna, the reduction of bottom roughness, and the removal of structure forming organisms. The effects of bottom trawling on habitat depends on several factors including the type of sediment, type of gear used, and the habits of the species living on the bottom.

Our knowledge of the life history characteristics of barndoor skates is currently insufficient to explicitly analyze any potential impacts from bottom trawling. However, the species does not appear to require specific substrates for its survival at any life stage, and it seems barndoor skates have a wide range of adequate habitats at all life stages. Therefore, there is no evidence that habitat alterations as a result of trawling are having a negative impact on barndoor skates or their egg cases. Thus, the evidence does not suggest habitat loss and/or degradation threatens the continued existence of barndoor skates.

5.3. Predation and Disease

Elasmobranchs are cartilaginous fish. Due to the more rapid decay of their remains, it is very difficult to measure or estimate predation rates of skates. However, demersal scutes of both young and old skates have been observed in the stomachs of sharks, other skates or rays, and grey seals (McPhie *et al.*, 2007). Little except large sharks could capture an adult barndoor skate but the juveniles may be vulnerable to a wider range of large fishes and seals (Kenchington, 1999). Skate eggs are eaten primarily by carnivorous gastropods but may also be preyed upon by marine mammals and incidentally caught by sperm whales (McPhie *et al.*, 2007). However, little is known on mortality associated with predation on egg capsules (Frisk *et al.*, 2002).

Skates avoid predation by deterrence, defense, or flight. They may camouflage themselves around similarly colored substrate or burry themselves in the surrounding sediments to avoid detection. They are capable of moving in quick short burst to flee danger. Skates may also relocate to different habitats like areas of higher turbidity as well as change their level of activity to avoid predators. Parasites of barndoor skates include turbellarians, trematodes, cestodes, nematodes, and copepods. These organisms are found in the gills, skin and intestinal tract (Scott and Scott, 1988). Although barndoor skates are vulnerable to both disease and predation there is no evidence that indicates significant loss due to these two factors.

5.4. Other Natural or Manmade Factors

In the past, there was concern over inbreeding depression due to the small population size of barndoor skate. In response to the petition to list barndoor skates under the ESA, researchers undertook a survey that consisted of genetic sequencing of individual barndoor skates using mitochondrial markers (J. Quattro, *pers. comm.*, 2009). They analyzed barndoor skate samples from sites across the species' wide geographic range that were collected by Todd Gedamke and Jim Simon. They did crude analyses to estimate female effective population size and discovered that effective population size was approximately the same as perceived census sizes (J. Quattro, unpublished data). Comparing U.S. barndoor skate individuals to Canadian individuals, the DNA sequences also showed little to no variation between locations (J. Quattro, *pers. comm.*, 2009). Therefore, J. Quattro concluded that their data showed no evidence for a catastrophic loss of diversity in barndoor skates (*pers. comm.*, 2009).

Another common concern for marine populations is the effect of changes in ocean conditions in response to global climate change. There are no data that specifically address the response barndoor skates have to the effects of climate changes, however, their K-selected nature, although it may make them more vulnerable to the effects of exploitation than *r*-selected species, makes them more resilient to changes in the environment. The species has a wide temperature range, indicating that they will not be significantly affected by warming ocean conditions. Even if temperatures beyond the species' documented 20˚ C limit are reached, the temperature-dependent seasonal migration patterns observed by the species suggest that they are fully capable of relocating to more desirable conditions if necessary. Barndoor skates exhibit both benthivorous and piscivorous traits to which they have a plethora of prey selections to choose from. The species' large size deters concerns of increased predation and their low M characteristic of K-selected species prevents concerns about geographic shifts in parasite concentrations. Therefore, possible change in tropic patterns due to climate change does not appear to be an issue that would substantially affect the species. Furthermore, Parent *et al.*'s (2008) observation of growth patterns from newborns to juveniles being almost identical between captive and wild barndoor skates suggests that hatchlings and juveniles are not negatively affected by high levels of pollutants such as nitrate or phosphate, fluctuating water temperatures, or by the by-products of seawater ozonation. These life history characteristics suggest barndoor skates will not be substantially affected by climate change.

No other natural or manmade factor appears to threaten the species.

6.0. Conservation Efforts

6.1. U.S. Regulatory Measures

6.1.1. The Skate FMP

As mentioned previously, the 1999 petition to list barndoor skates as threatened or endangered prompted the development of a stock assessment for the entire skate complex. NMFS conducted the stock assessment at a workshop in January 2000. The stock assessment determined that barndoor skates were in overfished condition. NMFS identified the need to develop a Skate Fishery Management Plan (FMP) to end overfishing and rebuild this and other skate resources (NEFSC, 2009). In March of 2000, NMFS notified the New England Fishery Management Council (NEFMC) of its responsibility to develop and implement the Skate FMP. The primary objectives of the Skate FMP are to (1) protect species of skates from overfishing and increase biomass to the target levels specified in the FMP and (2) collect information that improves knowledge of the skate fishery by species and to monitor the status of skate fisheries, resources, and related markets, as well as the effectiveness of skate management approaches.

The NEFMC Skate Plan Development Team (PDT), using input from the workshop, designated overfishing definitions, or biological reference points (BRPs), for each member of the skate complex. Since landings and discard information do not accurately distinguish between skate species, BRPs were based solely off of NEFSC survey data. The sporadic encounter of barndoor skates throughout the survey time series required a unique method of determining BRPs. Their BRP (B_{target}) is the mean value of NEFSC autumn biomass index from 1963 to 1966 (1.62 kg per tow) and $B_{threshold}$ is one-half that value (0.81 kg per tow). The PDT concluded that if the barndoor skate three year moving average of the autumn survey mean weight per tow is less than 0.81 kg per tow, then barndoor skates are considered overfished. If the survey biomass declines for three consecutive years, or declines by more than 30% in one year, the PDT considers F to be greater than the maximum sustainable yield (F_{msy}) and barndoor skates, as well as the six other members of the Northeast skate complex, are experiencing overfishing.

During the development of the Skate FMP, after analyzing NEFSC 2001 autumn bottom trawl survey data, barndoor skate remained in overfished conditions. This required NEFMC to develop management measures to end overfishing and rebuild these resources in accordance with Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (NEFMC, 2009). The Northeast Skate Complex FMP was implemented on September 18, 2003. Management measures apply to vessels fishing within the designated Skate Management Unit (SMU), which covers federal waters from 35º 15.3' N. latitude, starting approximately at Cape Hatteras Light, North Carolina, northward to the U.S.-Canada border (Hague Line), extending eastward from shore to the outer boundary of the Exclusive Economic Zone (EEZ) (Figure 39).

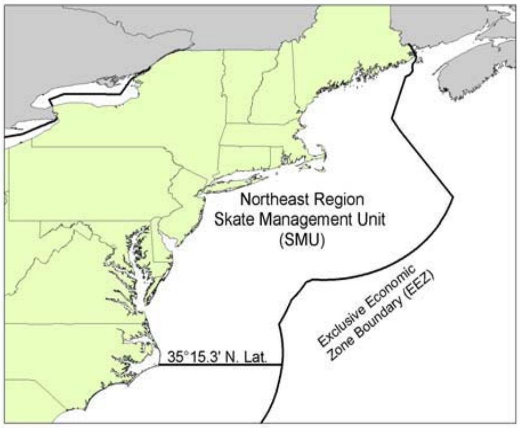

Figure 39. Northeast Region Skate Management Unit.

The key management measures within the SMU established by the FMP that benefit barndoor skate include: a requirement to report skate landings by individual species and skate discard by general categories (large/small); and a prohibition on possession, retention, or landing of barndoor skate. The FMP also established essential fish habitat (EFH) designations and overfishing definitions for all species; a rebuilding program for overfished skate species; a baseline of management measures in other fisheries (i.e., groundfish, scallop, and monkfish) that benefit skates; and a process for reviewing changes to the baseline management measures in fisheries that benefit skates.

6.1.2. Other FMPs

Skates are encountered by several other fisheries whose management measures may affect barndoor skate conservation. The indirect fisheries most likely to encounter barndoor skates are the scallop, monkfish, and multispecies fisheries because of their spatial overlap, relatively high level of incidental catch, and the fact that 90% of skate permit holders also have a permit for one of the other fisheries (usually the multispecies fishery). Any proposed changes to these FMPs that could result in an increase in fishing effort on skates are required to first undergo a “skate baseline review” under the provisions of the skate FMP to determine whether, and to what degree, the change may have an impact on skate conservation (NMFS, 2007). Mitigation is required for any proposed action that would likely increase fishing mortality on one of the skate species under a formal rebuilding program (including barndoor skates) (NMFS, 2007).

Since the Skate FMP was implemented in 2003, several amendments and framework adjustments in the Multispecies, Monkfish, and Scallop FMPs have been approved that have changed the effect that baseline measures had on skate catches. We will discuss relevant details under each FMP below. During this time skate wing landings have increased, skate bait landings have varied without trend, estimated discards have substantially declined, and total skate catch has declined, although the species composition of the catch has changed somewhat (NEFMC, 2009).

Multispecies FMP

The Northeast Multispecies FMP was implemented in 1986 to reduce fishing mortality of heavily fished groundfish stocks and to promote rebuilding. The Multispecies FMP is the most likely to impact skates and the skate fishery because of the significant spatial overlap between the two fisheries and the large amount of skates landed or discarded as incidental catch. Management measures relevant to barndoor skate under this FMP include seasonal and year-round area closures, gear restrictions, minimum fish size limits, and trip limits.

An important measure that may provide benefits to barndoor skates is Framework 33, implemented in 2000. This Framework Adjustment established a large area closure on Georges Bank during the month of May, as well as additional month, seasonal, and year-round closure areas that may overlap skate distribution (see Figure 40 for year round closure areas). These closures may provide a degree of protection for skate species by reducing overall fishing effort. However, it is important to note that seasonal and year round closed areas may result in effort relocation and perhaps not a complete effort reduction.

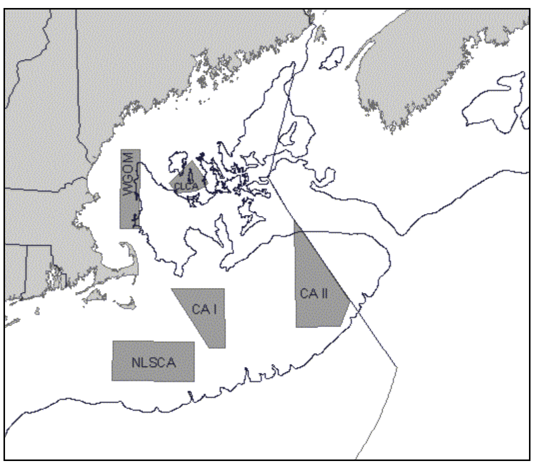

Figure 40. Multispecies year-round closed areas (NEFMC, 2003a).

The most notable management measure from the Multispecies FMP is Amendment 13, implemented in May 2004. This amendment was developed primarily to end overfishing on groundfish stocks and to rebuild groundfish stocks that are overfished. It includes a wide range of management measures to address impacts of the fishery on EFH, minimize bycatch, implement improved reporting and recordkeeping requirements, and address other conservation and management issues. The tools include effort reduction in all components of the fleet through days at sea (DAS) and TAC restrictions as well as closed areas, which has greatly reduced skate bycatch in this fishery.

Framework Adjustments 40A and 40B were also passed in 2004 and altered the multispecies DAS program and established several special access programs (SAPs). In particular, Framework 40A established a Category B DAS program which is aimed to target “healthy stocks of groundfish” and may be used to target skates in certain types of vessels (NEFMC, 2009).

In 2006, Framework 42 was implemented and significantly reduced the amount of Category A DAS vessels could use to target groundfish and other species as well as initiated differential DAS accounting in certain areas, which probably has an effect on the amount and distribution of fishing effort that affects the number of targeted and/or discarded skates (NEFMC, 2009). Two major effects of Framework 42 were the skate possession limits while fishing on a B regular DAS, as well as how A DAS can be used to target groundfish and other species. After implementation of Framework 42, trips targeting skates increased, mostly outside of the DAS program and through increased use of Multispecies A DAS to target skates. Skate landings on trips using B DAS declined to negligible amounts. Trawl vessels began using more A DAS and gillnet vessels began using more B DAS to fish for skate wings. There was an observed increase in total skate landings; however, the effect of Framework 42 on skate discards has not been estimated (NEFMC, 2009).

Other management measures include minimum mesh size requirements for gillnet and trawl gear and limits on the number of nets fished by day gillnet trip vessels, which affect the size and amount of skates caught. Furthermore, any multispecies fishing vessel fishing within the Gulf of Maine, Georges Bank, and Southern New England Regulated Mesh Areas in federal waters with gear capable of catching multispecies must fish under DAS restrictions which significantly reduces fishing effort. The majority of directed skate fishermen fishing in federal waters possess multispecies permits, and fish for skates with gear capable of catching multispecies. Therefore, these fishermen must use a DAS when fishing for skates unless fishing in an exempted fishery (NEFMC, 2009). Due to these management measures, the majority of full-time skate vessels are presently limited to less than 50 DAS per fishing year (NEFMC, 2009). Directed skate gillnet and trawl fisheries are exempt in the portion of the Southern New England Regulated Mesh Area that is south of 40° E 10° N. Lat. since they have been determined to meet the 5% multispecies bycatch criteria for exempted fisheries under the Multispecies FMP (NEFMC, 2009). However, this area may limit directed skate fishing to a small portion of the overall range of the skate complex.

Scallop FMP

Since its implementation in 1982, the Scallop FMP has passed Amendments 4 through 13 (with one pending) and 20 Framework Adjustments (with one pending). The Scallop FMP bycatch reduction regulations include DAS reductions, minimum twine top mesh requirement increase from six to eight inches (implemented through Scallop FMP Framework 11), as well as a reduction of chafing gear; all of which may reduce skate bycatch in this fishery (NEFMC, 2001). The Scallop FMP Amendment 10, implemented in June 2004, changed the DAS program by including a comprehensive program of area rotation and specific allocation of DAS by management area. It also included measures to reduce and minimize bycatch, as well as measures to minimize the adverse effects of fishing on EFH (NEFMC, 2009). The effects on skates were also a result of the spatial allocation of days or trips which were an outcome of scallop area rotation management. Allocations were further modified by Framework Adjustments 16 (2004) and 18 (2006) (NEFMC, 2009). These reductions and more comprehensive regulations may reduce total fishing effort, which in turn may reduce total bycatch (NEFMC, 2001).

Monkfish FMP

The Monkfish FMP was established in November 1999 and since its implementation has passed Amendment 1 through 3 and 5 Framework Adjustments (with one pending). These management measures include limited entry, DAS limits, trip limits, minimum mesh sizes to reduce bycatch, and caps on the number of gillnets permitted (NEFMC, 2003a). The most notable Monkfish FMP regulations that relate to skates are Amendment 2 and Framework Adjustment 3, both implemented in 2006. Amendment 2 made extensive changes in how monkfish DAS could be used, removed a seasonal 20-day block-out requirement, and made changes in allowable gear configurations (NEFMC, 2009). Framework Adjustment 3 prohibited targeting monkfish on a Multispecies Category B DAS. While this action may have made more B DAS available for vessels to target skates, it also reduced the DAS available to use to target monkfish and skates in a mixed fishery. However, it is unclear what effects either of these actions has on skate landings or discards (NEFMC, 2009).

Conclusion

As stated previously, the possession, retention, and landing of barndoor skates is prohibited under the Skate FMP. The management measures above could result in effort distribution to areas of known skate concentrations as well as increased use of gear efficient for catching skates which may increase incidental catch of barndoor skate and consequently the amount of individuals discarded. Since the mortality rate and species composition of skate discards is unknown, effort reduction in areas where barndoor skates are distributed as well as reductions in gear targeted to catch skates may markedly affect the impact fishing has on the species. Regulatory measures for other species such as area closures may be providing substantial benefits to the species by providing areas that promote population rebuilding (see Gedamke *et al.*, 2009).

6.1.3. Other Regulatory Actions

Lobster Fishery Regulations

Two existing and significant regulatory limitations on the directed bait skate fishery include lobster regulations which mandate a decrease in pot limits and multispecies DAS requirements. Relevant restrictions for the lobster fishery outlined in the Skate Stock Assessment and Fishery Evaluation (SAFE) Report consist of limited access permits, minimum lobster carapace size, prohibition of possession of certain lobsters or lobster parts, trap specifications, and landing limits for non-trap harvest (67 FR 61055).

In 1994, NOAA Fisheries implemented a 5-year moratorium on new entrants into the EEZ lobster fishery by a limited access permit system (67 FR 282). Federal lobster regulations extended the moratorium indefinitely in 1999 (64 FR 68228). This moratorium limits the number of people that can participate in the lobster fishery, thus, indirectly eliminating the possibility of any future increase in the amount of skates used as bait due to an increase in new entrants to the fishery (67 FR 61055).

Newly implemented measures in six lobster management areas and the associated restrictions are of particular relevance to the skate fishery. The various management areas have different trap limits associated with them. Vessel owners may decide to fish in several management areas; however, they must abide by the most restrictive trap limit of the areas they designate. These regulations are designed to limit effort in the lobster fishery. Therefore, any reduction in lobster fishery effort will indirectly reduce the amount of skates needed as bait (67 FR 61055).

Draft Amendment 3 to the Skate FMP

In April 2007, NEFSC began constructing a Draft Amendment 3 to the Skate FMP. The amendment is geared towards reducing and limiting skate catch to a sustainable level that will promote increases in biomass for stocks that are below B_{msy} (NEFMC, 2009). The amendment emphasizes changes to promote rebuilding of thorny skate, preventing overfishing, and avoiding other skate stocks (namely smooth skate and winter skate) from becoming overfished. The purpose of the amendment is, therefore, to initiate rebuilding of thorny skate biomass so that the biomass target is achieved within the mandated rebuilding schedule, or earlier if possible, and to end overfishing of thorny skate. To achieve this goal, the Amendment 3 objective is to reduce discards and landings sufficiently to rebuild thorny skate, prevent other skates from becoming overfished, avoid overfishing, and produce optimum yield (OY), which is the amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems (NEFMC, 2009).

NEFMC held a scoping hearing on May 22 - 24, 2007, where the Council developed a framework of measures and alternatives to reduce skate catch and landings, particularly for the wing fishery which catches and lands predominately winter skate (NEFMC, 2009). NEFMC (2009) also presented an updated SAFE Report which included the implementation of annual catch limits (ACLs) and accountability measures (AMs); a new mandate of the reauthorized MSFCMA; and revisions to a baseline review process that had become obsolete and less meaningful (NEFMC, 2009). As management measures proposed by Amendment 3 reduce exploitation of overfished skate species, the reduction in fishing effort for and around overfished members of the skate complex may assist in the rebuilding process of barndoor skates.

Data Poor Stocks Working Group

In December 2008, NEFSC convened the Northeast Data Poor Stocks Working Group (DPSWG) to evaluate novel approaches to assessing data poor and model resistant stocks. Skates were included to address and correct the uncertain species identification in landings and discards, and to develop new analytical assessments (NEFMC, 2009). Although the analytical assessments produced from this group were deemed to be exploratory, but unreliable for management at that time, significant progress was made to assign species to landings and discards. Trends in skate discards were re-estimated using sea sampling data, including observed discard/kept ratios and new approaches concurrent with the newly implemented Standard Bycatch Reporting Methodology (see below) (NEFMC, 2009).

The discard estimates determined by the DPSWG differed substantially from previous estimates. The new estimates had the same trend as the previous ones through 2002, but differed substantially from 2003 to 2006. Previous discard estimates suggested a decline of 62% in skate discards since the Skate FMP took effect. It was believed that discards had declined substantially due to the regulatory effects implemented by the Skate FMP. However, the new estimated discards do not show this decline. The DPSWG (2009) suggests most differences were due to inclusion of more trips from the last few years (e.g., SAPs). These more recent discard estimates are critically important because the Council uses the last three years of the discard time series to reduce the TAC limits and set landing targets. These new estimates had a meaningful effect on the Draft EIS specifications for the wing and bait fishery total allowable landings (TAL) (NEFMC, 2009). New BRPs were also created for some skate species. Although new estimates were not applied to barndoor skates, updated BRPs for other skate species were used to determine skates' TAC, which may also affect the number of barndoor skates caught.

Standard Bycatch Reporting Methodology

The Standard Bycatch Reporting Methodology (SBRM), implemented on February 27, 2008, is an omnibus amendment to all Northeast US FMPs (Amendment 1 to the Skate FMP) developed by NEFSC and Mid-Atlantic Fisheries Management Council (MAFMC) to assess the amount and type of bycatch occurring in the fisheries. The actions considered in the SBRM Amendment focused solely on the administrative processes through which data and information on bycatch occurring in Northeast Region fisheries are collected, analyzed, and reported to fishery scientists and managers. The new SBRM implemented an importance filter to establish and allocate target observer coverage levels, established a SBRM performance standard, the requirement to conduct periodic evaluations and prepare a periodic SBRM report, the prioritization process, and framework adjustment provisions (NEFMC, 2009). However, with increased knowledge on the bycatch rates of individual skate species, NEFMC can markedly increase the effectiveness of future management measures by using more accurate data that may benefit barndoor skate populations.

6.1.4. U.S. Management Status

In 2006, the Northeast skate complex was re-assessed at the 44th SAW (SAW 44). After analyzing the three-year biomass indice averages for each skate species SAW 44 concluded that overfishing was not occurring for barndoor skates (NEFSC, 2006). $B_{threshold}$ (0.81 kg per tow) was reached with the 2002 to 2004 three-year indices average of 0.88 kg per tow, which indicated that the stock was no longer overfished (Figure 41). Since then, the 2003 to 2005 index average rose to 0.96 kg per tow and then rose another 21% to 1.17 kg per tow for 2004 to 2006. The 2007 autumn biomass index declined to 0.80 kg per tow and lowered the three-year average to 1.00 kg per tow. However, this is above $B_{threshold}$ for barndoor skates and only declined from the previous average by 14% (less than the 30% critical percent needed for an overfishing designation). Thus, barndoor skates are not currently overfished and overfishing is not occurring.

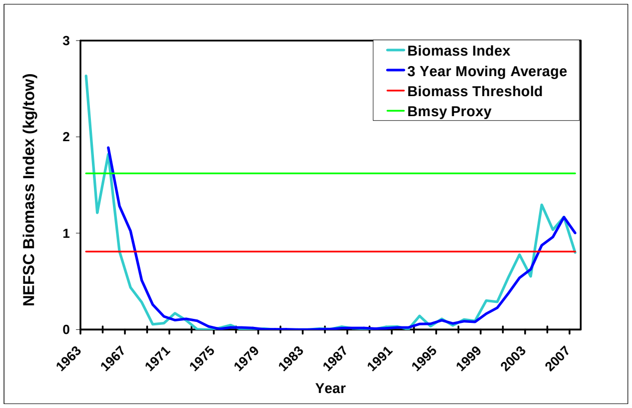

Figure 41. Barndoor skate three-year moving average and NEFSC autumn bottom trawl biomass index from 1963 to 2007. Horizontal lines represent upper and lower biological reference point limits that signify overfishing and target biomass thresholds, respectively (NEFSC, *pers. comm.* 2009).

By the time the Skate FMP took effect in 2003, barndoor skate biomass was already increasing and above $B_{threshold}$ (Figure 41 above). There is insufficient information to assess whether the Skate FMP has benefited barndoor skate populations since its implementation; however, recent increases in research survey catches as well as new information on the total mortality (Gedamke *et al.*, 2008) and maximum population growth rate of barndoor skates (Gedamke *et al.* 2009) indicate that annual survival rates are currently high and mortality rates low enough to allow recovery. The species has been discovered in waters deeper than previously covered by research surveys (Kulka *et al.*, 2002), where fishing effort is very low. This increase, along with the fact that there is no directed fishery and little market demand for barndoor skates, and that the best information available indicates that barndoor skates constitute a small amount of the total skate catch, suggests that there is no substantial factor limiting the rebuilding of barndoor skate populations. The trend in NEFSC three-year moving average index as well as the increasing trend in all three of NEFSC bottom trawl surveys suggest barndoor skates have been in a rebuilding phase since the mid 1990s and are approaching B_{target}.

6.2. Canadian Regulatory Measures

As summarized previously, skates (mostly thorny skate and winter skate) were traditionally landed by foreign fleets throughout the Northwest Atlantic until the implementation of the 200-mile EEZ limit in 1976 after which skates in Canada were caught mainly as bycatch and mostly discarded. Following the 1990s decline in traditionally targeted groundfish species in and around the Newfoundland area, there has been increased fishing effort on previously untargeted species such as those in the skate complex. In 1993, experimental fishing for skates on the southwestern Grand Bank, southern St. Pierre Bank, and the adjacent Scotian Shelf was initiated by the Provincial Department of Fisheries and was continued by DFO in 1994 (Kulka *et al.*, 1996). In 1995, a regulated Canadian skate fishery was established on the eastern Scotian Shelf in NAFO Divisions 4Vs and Division 4W. Winter skate was the primary focus of the fishery, constituting over 90% of the total catch. In addition to the directed winter skate fishery, there is a fishery for thorny skates in the Grand Bank Divisions 3L, 3N, 3O, and 3Ps. Neither fishery has ever targeted barndoor skates.

Catch quotas were put in place in 1994 for Divisions 3LNOPs and were separated between the Grand Bank (3LNO) and St. Pierre Bank (3Ps). Catch quotas for 1995, were set at 5,000 mt and 1,000 mt for the Grand Bank and St. Pierre Bank, respectively (Kulka *et al.*, 1996). Bycatch in other fisheries was set at 5% of the total catch. TAC has been lowered over the years and for skates is currently set at 2,250 mt for the Grand Bank and 1,050 mt for St. Pierre Bank.

6.2.1. Canadian Management Status

In 2001, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) called for a review of the status of barndoor skates to determine if the species is at risk in Canadian waters. Two research documents were produced and finalized in 2002 (Simon *et al.*, 2002; Kulka *et al.*, 2002). Simon *et al.* (2002) concluded that although the species showed a decline in abundance throughout the 1970s and 1980s, the species has been increasing since the mid 1990s and was sufficiently numerous to ease concerns about its conservation status. Kulka *et al.* (2002) presented fisheries observer data from the Newfoundland and Maritimes Regions that suggested a wide expansion of the species' known range, as far north as the Labrador Shelf to 62ºN and depths up to 1600 m. The document suggested this range extension meant research surveys only sampled a fringe of the species' distribution (given over 99% of DFO research surveys sampled above 450 m), and the newly known areas may provide refuge for barndoor skates due to the very low level of fishing pressure below 450 m.

In 2008, COSEWIC held a Northwest Atlantic Barndoor Skate Pre-COSEWIC Assessment meeting to address updated information on barndoor skates and to re-assess the status of the species in Atlantic Canada. Two working papers and a draft report are in preparation.

One of the Pre-COSEWIC assessment meeting working papers conducted a preliminary examination of the observer datasets used in Kulka *et al.*'s (2002) distribution analysis for barndoor skates. Samples identified as barndoor skate were collected from a number of fisheries and reanalyzed to assess the validity of the observer records presented by Kulka *et al.* (2002). These samples indicated that there was a potential problem in the identification of barndoor skates from both the Newfoundland and Maritimes Regions, especially from fisheries north of 50ºN and at depths greater than 1000 m (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Upon reexamining the 3,247 barndoor skate records from the Newfoundland observer database, only 309 of them were considered valid (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Of these confirmed records, 209 of them came from the Newfoundland Region with only 3 of these occurring north of the Grand Banks (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). Consequently, the extension in latitudinal range noted by Kulka *et al.* (2002) may not have actually occurred. However, DFO survey data has caught a small number barndoor skates deeper than 1000 m, which confirms discovery of an extension in the species' known depth range. An intensive species identification program has been developed for Canadian observers and new species identification cards have been created. These two factors have greatly improved confidence in observer reports for barndoor skates and will be beneficial to the distribution and abundance assessments currently in progress as well as in future assessments of the species.

Although barndoor skates may not be distributed farther north than previously documented, the draft report notes a continued increase in abundance on the Scotian Shelf similar to that seen on Georges Bank (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009). The review of these data suggests that barndoor skate abundance has increased to near historical levels in their central distribution; that they are expanding their range towards the east; and are now being captured near Sable Island (J. Simon, A. Cook, and M. Simpson, *pers. comm.*, 2009).

7.0. Conclusion

Although barndoor skate biomass from U.S. and Canadian survey data exhibited a drastic decline from its peak values in the 1950s and 1960s to several zero indices throughout the 1970s and 1980s, the species' biomass has been on a consistent rise since the mid 1990s. Commercial fisheries and research survey data show an increase in barndoor skate abundance and biomass in both U.S. and Canadian waters. Several record breaking tows have occurred in the NEFSC trawl survey over the past few years and Canadian data has shown the species' range expanded eastward. There has been an increase in the size range of fish caught as well as a rise in the number of small barndoor skates collected. Recent survey and commercial indices are also catching individuals larger than specimens collected during the species' peak abundance in the 1950s and 1960s. Updated life history information has yielded higher estimates of the species' resilience to exploitation and analyses of barndoor skates' mortality rates has indicated that, although the species was once under intense exploitation, fishing mortality has decreased since the mid 1990s to low enough levels to allow for population rebuilding. Furthermore, the species' major identifiable threat, overfishing, has been reduced by regulatory measures affecting several northeast fisheries and will continue to be directly reduced by management measures from the Skate FMP. COSEWIC is also in the process of developing an assessment of barndoor skates in Atlantic Canada that will provide a better understanding of barndoor skate populations in that area. The species is not naturally rare or endemic to a given region and there are no data that suggest the species is or will be markedly affected by habitat loss or degradation, predation or disease, or other natural or manmade factors such as inbreeding depression or change in ocean conditions due to climate change.

Based on the information presented in this report, barndoor skates no longer meet the criteria for a species of concern.

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