COSEWIC
Assessment and Status Report

on the

Roundnose Grenadier
Coryphaenoides rupestris

in Canada

ENDANGERED
2008

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Roundnose Grenadier — Courtesy of the Department of Fisheries and Oceans.

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COSEWIC
Assessment Summary

Assessment Summary – November 2008

Common name
Roundnose Grenadier

Scientific name
Coryphaenoides rupestris

Status
Endangered

Reason for designation
Survey data indices of adult numbers show declines of 98% from 1978 to 1994 with a further decline from 1995 to 2003. Although much of the population lives at depths greater than those surveyed, adding uncertainty to the assessment, this constitutes the best available information to assess species status. The species is long-lived (60 yr) and matures late (around 10 yr) which makes it susceptible to human-caused mortality. Commercial catches were high in the 1960s and 1970s but have since declined, although harvest still occurs.

Occurrence
Arctic Ocean, Atlantic Ocean

Status history
Designated Endangered in November 2008. Assessment based on a new status report.

COSEWIC
Executive Summary

Roundnose Grenadier
Coryphaenoides rupestris

Species information

Coryphaenoides rupestris, commonly known as the Roundnose Grenadier (occasionally, rock grenadier) in English or *Grenadier de roche* in French, belongs to the family Macrouridae or rattails. It is distinguished from other grenadiers in the North Atlantic by its soft, rounded snout and relatively short, compressed head.

Distribution

C. rupestris is found along the continental slope and mid-Atlantic ridge of the North Atlantic Ocean. In waters off Canada, it has been observed from the Davis Strait to Georges Bank, but is reported to be more abundant in the northern part of the range (Labrador and Northeast Newfoundland shelves, Davis Strait). Its range in the Northwest Atlantic extends beyond the 200-mile limit and outside Canada's jurisdiction.

Habitat

In the western North Atlantic, Roundnose Grenadier has been reported at depths between 200 and 2600 m; there is some inconsistency in published accounts of preferred depths but they are probably most abundant at depth greater than 800-1000m. Proportion of mature individuals tends to increase with depth. Reported preferred temperatures are 3.5-4.5ºC in Canada, somewhat warmer in European waters. The species is reported to occur frequently some distance off bottom (ca 100 m) although factors affecting vertical movements are not well known.

Biology

Partly because of its deep habitat, the biology of this species is relatively little known. Roundnose Grenadier is a relatively long-lived, slow-growing species, with a reported maximum age of 60 years and age at maturity about 10 years for females. Generation time is about 17 years. They feed on a variety of deep-sea invertebrates, ranging from amphipods to squid.

Population sizes and trends

Minimum trawlable abundance estimates based on trawl survey catches in part of the Canadian range in recent years average 74 million for all sizes and 4.4 million for adults. The estimate for adults in these areas declined from 44 million in 1996 to 2.5 million in 2003. These numbers are provided recognizing that they substantially underestimate population abundance since they do not cover all depths where the species occurs, or the entire Canadian range, and that not all individuals in the path of the trawl are captured.

Except for the fall survey of the Labrador and Northeast Newfoundland Shelves (NAFO Divisions 2J3KL), all annual research surveys in Atlantic Canada are restricted to waters too shallow to provide indications of abundance trends for this species. Catch rates of adult sizes in the most representative fall survey declined by 98% over the 1978-1994 period (1 generation). In this area, surveys after 1995 are not comparable to the earlier surveys due to a gear change, but catch rates in the recent surveys continued to decline (by 91% for adult sizes between 1996 and 2003). Catches of Roundnose Grenadier in these surveys are restricted to the offshore margin of the survey area, and the species' range goes considerably beyond survey depths, so these declines may not reflect the situation in the whole population. Analyses in this assessment suggest that changes in distribution are unlikely to have caused the survey index declines, unlike the situation for a related species, the roughhead grenadier.

Catch rates in the fishery declined by 74% over the 1967 – 1991 period. Changes in catch rates may not reflect population abundance changes well; for example, declines in catch rates of species where aggregations can be targeted may underestimate declines in fish population size. In the case of this fishery, it has been argued by some that the declines in catch rates do not reflect declines in grenadier biomass, instead reflecting biases in the data, effects of fishery regulations on fishing behaviour or changes in the availability of grenadier to the fishery. However, analyses to quantify these effects are not available.

Limiting factors and threats

Roundnose Grenadiers have been subject to commercial exploitation through a directed fishery in the past and as by-catch more recently. A directed fishery developed in the late 1950s-early 1960s targeting concentrations of Roundnose Grenadier along the slope of the Labrador and NE Newfoundland Shelves. Reported catches averaged 26,000 t/yr from 1967-78 and declined precipitously thereafter to 5,000 t/yr in the 1980s and 600 t/yr in the early 1990s. No targeted fishing is currently permitted but the species is taken as bycatch. There is considerable uncertainty about fishery removals but estimates since 2000 have varied between 60 and 5400 t/yr.

Special significance of the species

The Roundnose Grenadier is an important deep-sea fish that was commercially exploited. It is not thought to be closely related to any of the other species within the genus *Coryphaenoides*. One other species in this genus is found in Canadian Atlantic waters; *Coryphaenoides guentheri* (Vaillant, 1888); other Atlantic species once included in *Coryphaenoides* are now classified in *Nematonurus* and *Lionurus.*

Existing protection or other status designations

In 1974, a total allowable catch (TAC) was set on the Roundnose Grenadier fishery in Canadian waters. However, catches in this fishery never reached the TAC. Directed fishing for *C. rupestris* is currently under moratorium in NAFO Subareas 2 and 3 in Canadian waters. In waters adjacent to the Canadian exclusive economic zone the fishery is unregulated except for mesh size. Assessments of this species in European waters express concern about unregulated fishing and recommend bringing the species under more stringent management.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2008)

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

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

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

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

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COSEWIC Status Report

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SPECIES INFORMATION

Name and classification

Coryphaenoides rupestris, Gunnerus, 1765, the Roundnose Grenadier, is a deepwater marine fish species of the family Macrouridae, often referred to as rattails. Common synonyms are *Macrourus rupestris* Günther, 1887; *Coryphaena rupestris* Müller, 1776*; Macrourus stroemii* Reinhardt, 1832*; Lepidolepus norvegicus* Nilsson, 1832*; Macrurus norvegicus* Nilsson, 1885; *Coryphaenoides norvegicus* Günther, 1862 (Cohen *et al*. 1990). This species is also known as the rock grenadier, blunt-snouted grenadier, and the black grenadier. Grenadier de roche is its common name in French.

Description

The basic body and head shape of the Roundnose Grenadier are typical for the family Macrouridae (Figure 1). Their bodies are short, slightly compressed, and taper evenly to sharp pointed tails (Scott & Scott 1988). *C. rupestris* can grow to more than 100 cm in total length (TL) (Cohen *et al*. 1990) (note, because of frequent damage to the tail, preanal lengths are often given for this species). Its head is fairly short and compressed and comprises approximately 15% of its body length (Whitehead *et al*. 1986). It has a medium brown to grey body colouration, with black to brownish orbits, mouth, gill cavity, and fins (Cohen *et al*. 1990). *C. rupestris* is distinguished from other grenadiers in the North Atlantic by its fairly short, compressed head and soft, rounded nose (Whitehead *et al*. 1986). Scaling on the gular membrane, a high number of gill rakers on the second arch, and reduced mandibular dentition are other distinguishing features (Whitehead *et al*. 1986).

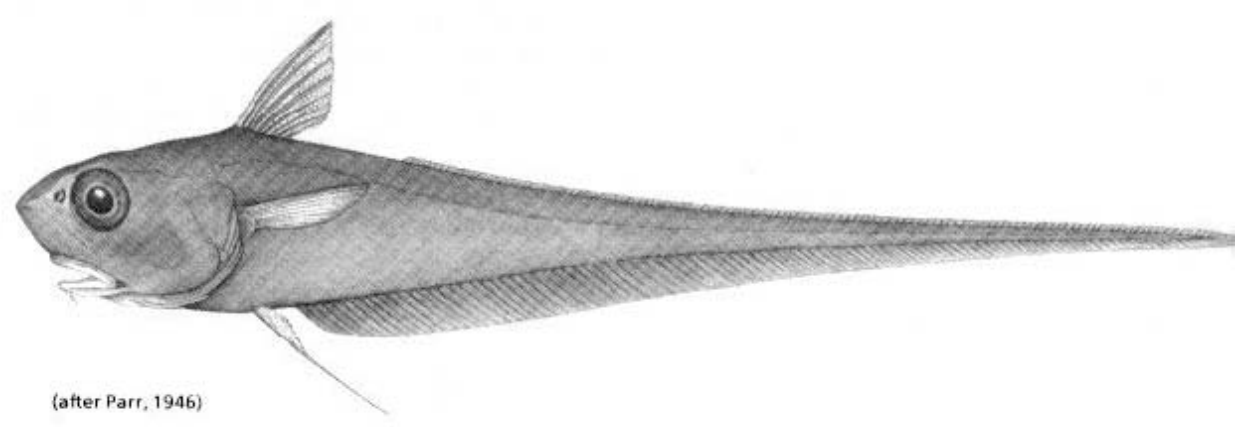

Figure 1. Illustration of *Coryphaenoides rupestris* (Roundnose Grenadier). Adapted from Parr 1946.

Designatable units

There has been much debate concerning the population structure of Roundnose Grenadier (summarized by Atkinson 1995). One hypothesis has been that a single stock exists in the North Atlantic. According to this hypothesis, spawning occurs off Iceland, eggs and larvae are passively distributed throughout the North Atlantic, and mature adults migrate back to Iceland to spawn. However, there is no evidence that Roundnose Grenadier undertake such large-scale migrations, and their poor swimming ability makes such migrations unlikely. A second hypothesis is that self-sustaining populations are limited to the Mid-Atlantic Ridge and northeastern Atlantic. According to this hypothesis, the cooler water in the northwestern Atlantic prevents maturation, and this area represents a population sink, sustained by the drift of eggs and larvae from other areas. A third hypothesis, supported by the occurrence of both early juveniles and mature adults in the northwest Atlantic as far south as the Scotian Shelf, is that local populations occur throughout the species range, including the northwest Atlantic. Based on allozyme variation, Logvinenko *et al*. (1983) concluded that reproductively isolated groups occur in the eastern, central and western North Atlantic. In the absence of any information to suggest local adaptation and genetic differentiation within the western North Atlantic, the working hypothesis for this report is that Roundnose Grenadier comprise a single designatable unit (DU) in the waters off Atlantic Canada, including the deeper waters beyond the 200-mile limit.

DISTRIBUTION

Global range

The Roundnose Grenadier is distributed on continental slopes and the mid-Atlantic ridge of the temperate North Atlantic (Figure 2). In the western North Atlantic, it ranges from off Cape Hatteras north to Baffin Island and Greenland (Atkinson 1995). An isolated capture of two specimens was reported in the Bahama Islands (Cohen *et al*. 1990). In the eastern Atlantic, it is found from off Norway south to North Africa (Kelly *et al*. 1997).

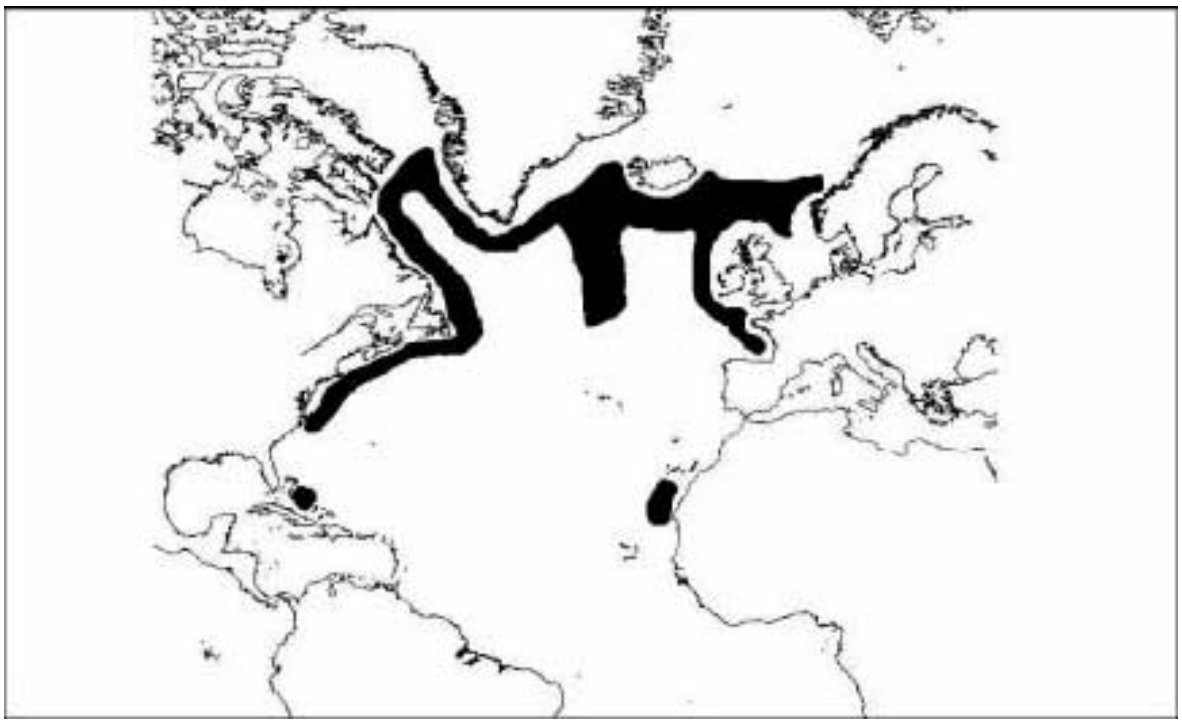

Figure 2. Global distribution of *Coryphaenoides rupestris* (Roundnose Grenadier). Adapted from Cohen *et al.* (1990).

Canadian range

The Roundnose Grenadier is a continental slope species and therefore the deeper part of its range has not been well surveyed. Figure 3 represents the known distribution of Roundnose Grenadiers within their Canadian range, using research survey data from the East Coast of North America Strategic Assessment Project (ECNASAP). Records in the Gulf of St. Lawrence and St. Lawrence estuary are almost certainly erroneous as these are in depths shallower than normally inhabited by this species. The surveys in the ECNASAP database do not extend into the deepest waters occupied by Roundnose Grenadier. Roundnose Grenadier have been caught in surveys in Davis Strait, along the continental slope off Newfoundland and Labrador, and along the edge of the Grand Bank. Occasional captures have been made along the slope of the Scotian Shelf off Nova Scotia. (Sampling effort on the Scotian Shelf has been much greater than in Davis Strait, but depths sampled are generally shallower than further north so the relative abundance of Roundnose Grenadier in this area is not known from these surveys.) Generally this species appears to be more abundant in the northern part of its Canadian range (Grand Banks to Davis Strait) than further south (Atkinson 1995).

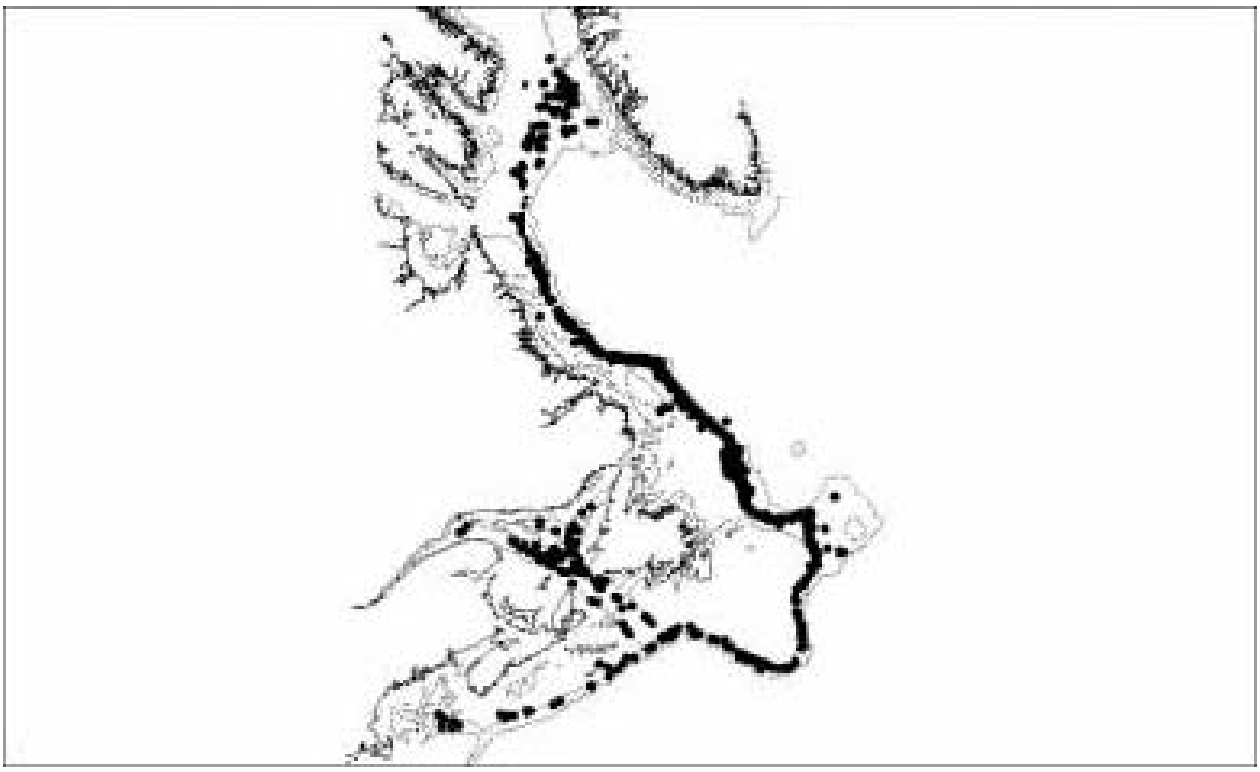

Figure 3. Canadian distribution of *Coryphaenoides rupestris* (Roundnose Grenadier), from ECNASAP data. Records from Gulf of St. Lawrence are probably erroneous, based on misidentification. See also Figures 9-10 for distribution of confirmed specimens.

Further information on the distribution and area occupied by Roundnose Grenadier is given below in sections on analyses of research survey data.

HABITAT

Habitat requirements

Published observations on depth distribution are somewhat inconsistent although it is clear that this is a species of relatively deep slope waters. In the western North Atlantic, Roundnose Grenadiers have been reported to occur at depths between 180 and 2200 m, with greatest abundance in depths between 400 to 1200 m (Haedrich & Merrett 1988; Cohen *et al*. 1990). Maximum recorded depth of capture in Canada is 1750-2600 m (Atkinson 1995). Surveys off Newfoundland in 1995-99 show density of Roundnose Grenadier increasing with depth out to the maximum surveyed, with highest densities at depths greater than 1000 m (Kulka 2001). Surveys to the west of Scotland show highest catch rates at 1400-1600 m, with some indication of a shift to deeper waters since the 1990s, possibly as a result of depletion in shallower waters (ICES 2006). Further details on depth distribution are given below in sections on analyses of research survey data.

Roundnose Grenadiers prefer areas of weak or absent current and form dense concentrations in troughs, gorges, terraces and lower parts of the slope (Zaferman 1992). Zaferman (1992) found *C. rupestris* in aggregations above peaks and slopes of seamounts of the North Atlantic Ridge. Typically, along New York and New England, *C. rupestris* prefers the canyon areas rather than the open slope (Snelgrove & Haedrich 1985).

Roundnose Grenadier are usually found in waters 3.5-4.5°C in Canada (Atkinson 1995). The species is usually found in warmer waters off Europe (up to 6-7°C) but reasons for this difference are not known (Atkinson 1995).

Larger fish are generally, but not always, found further north and in deeper water (Atkinson 1995).

Kelly *et al*. (1997) found fertilized eggs and juveniles in mesopelagic waters (below the surface pelagic zone) of the Rockall Trough. Mature individuals can be found throughout the entire depth range; however, immature specimens tend to prefer the shallower regions (Podrazhanskaya 1971).

Roundnose Grenadier have been reported to occur some distance off the bottom (100+ m), and there is some evidence for diel movements, but there is little detailed information on distribution with respect to bottom and further studies are required to clarify this. Seasonal movements up and down the continental slope have also been reported but are relatively little known (Atkinson 1995).

Protection/ownership

For waters within 200 mile EEZs, management responsibilities off eastern Canada were moved from NAFO to Canada and Denmark (on behalf of Greenland) for northern waters (NAFO 0+1), and to Canada alone for more southerly waters (NAFO 2+3) in 1979 following extension of jurisdiction (Atkinson 1995). Countries responsible for management request scientific advice on stock status from NAFO.

The range of Roundnose Grenadier extends beyond the 200-mile limit of Canada's EEZ boundaries and it is thus a straddling species. Canada lacks the authority to enforce fisheries restrictions beyond the 200-nautical mile limit, and only regulations developed by NAFO apply.

BIOLOGY

General

The family Macrouridae, of which Roundnose Grenadier is a member, is the most widely occurring fish family on the continental slope of the North Atlantic and along the mid-Atlantic ridge. Maximum length of female Roundnose Grenadiers is almost 4 cm greater than that of males (Kelly *et al*. 1997). Roundnose Grenadiers are long-lived, slow to mature, slow moving and therefore, considered to be vulnerable to over-fishing (Scott & Scott 1988; Cohen *et al*. 1990; Zaferman 1992; Kelly *et al*. 1997).

Age and growth

Roundnose Grenadier are relatively slow-growing. Atkinson (1995, based on various sources) indicates maximum recorded age based on otoliths to be 40 yr, with individuals of this age 90-100 cm in length, while ages at length from scales are 10-15 yr at 60-80 cm and 25 yr at 95 cm. Males are smaller at age than females (Atkinson 1995, citing various sources).

Other authors indicate a maximum age above 60 years (Kelly *et al*. 1997; Lorance *et al*. 2001b). According to Kelly *et al*. (1996) the majority of fish are between 10 to 35 years of age in Rockall Trough, and Bergstad (1990) found fish between 18 and 30 years of age to be most abundant in Skagerrak.

Reproduction

Published sources vary with respect to spawning time. Some researchers believe it occurs from May through September, peaking in late July and early August (Scott & Scott 1988; Cohen *et al*. 1990). Others believe it occurs throughout most of the year (Lorance *et al*. 2001a). It is now generally agreed that spawning takes place throughout the year, with periods of more intense spawning occurring at different times in different areas (Atkinson 1995). Studies have shown that males usually make up approximately 65% of the population but this can vary within and between years. Nevertheless, there is generally a high ratio of males to females, and the ratio may vary seasonally. Alekseyev (1995) believes this may be a result of differential spawning cycles, with males spawning annually while females spawn biennially with approximately half of the population spawning in a given year.

Eggs are fertilized at the time of spawning. The eggs are free-floating, spherical and 2.3 to 2.4 mm in diameter (Scott & Scott 1988). A single female will produce between 12 000 and 55 000 eggs (Scott & Scott 1988), a low fecundity compared to shelf gadoids. Although some work has also indicated a higher fecundity (Kelly *et al*. 1996), the annual fecundity was indeterminate making the fecundity estimates uncertain (Lorance *et al*. 2001a).

Maturation of the Roundnose Grenadier is thought to be a function of size rather than age (Kelly *et al*. 1997). Bergstad (1990) reported that maturity is reached at 46.5 cm total length (TL). Although the exact measurements at maturity are often debated, it is generally agreed that they will begin to mature between lengths of 40 to 50 cm TL or at about 10 yr (Atkinson 1995). Bergstad & Isaksen (1987) found that off Norway male and female Roundnose Grenadiers will take at least 8 to 10 years to mature, respectively, while Bergstad (1990) indicated that maturation occurred at 110 mm and 85 mm for females and males (preanal length) respectively.

Generation time is estimated to be approximately 17 years using the formula (age at maturity) + 1/(natural mortality) where age at maturity is 10 years (Bergstad & Isaksen 1987) and natural mortality is 0.15 (Lorance *et al*. 2001a).

C. rupestris is a sexually dimorphic species. Females grow slightly longer than males. The difference in length between the sexes increases with size (Savvatimsky 1985). As well, the females are heavier than males of the same length (Kelly *et al*. 1997). They are known to have a very slow growth rate between 0.06 and 0.13 kg/yr (Large *et al*. 2001).

Survival

Bridger (1978) found the natural mortality of Roundnose Grenadiers to be approximately 0.2, although others have considered this estimate to be high for such a long-lived fish (Atkinson 1995). Lorance *et al*. (2001a) found that a natural mortality of 0.1 to 0.2 in the Northeast Atlantic was acceptable and plausible.

Roundnose Grenadiers are particularly slow swimmers. Zaferman (1992) used direct observations to determine that in the absence of current Roundnose Grenadiers are almost immobile.

Roundnose Grenadiers are one of two grenadiers to be commercially exploited, the other being the roughhead grenadier. They are targeted by commercial fisheries in some areas (e.g. off eastern Canada in the 1970s, and in the northeastern Atlantic since the mid-1990s) and are a significant component of the by-catch in deepwater fisheries for other species such as Greenland halibut (Duran *et al*. 1997) (further details below).

Physiology

In the Northwest Atlantic, Roundnose Grenadiers tend to prefer waters near 4ºC and form dense concentrations where warm water lies directly above the bottom (Scott & Scott 1988; Atkinson 1995). In the Northeast Atlantic, they are usually found in warmer waters near 6 ºC (Atkinson 1995).

Rattails (family Macrouridae), like some other deep-sea fish, have specialized swim bladders that function at great depths, and thus pressures, in the ocean. Lipids present in the wall of the swim bladder resist the outward diffusion of oxygen and this is considered an adaptation to life in deep water conditions (Wittenberg *et al*. 1980).

Movements/dispersal

C. rupestris is thought to undergo seasonal migrations, as well as diurnal vertical migrations that may carry them more than 1000 metres off the bottom (Cohen *et al*. 1990). Explanations for diurnal vertical movements are conflicting in terms of timing and purpose (Atkinson 1995). Roundnose Grenadiers are thought to move up and down the slope seasonally (Cohen *et al*. 1990; Atkinson 1995). Off northeast Newfoundland and Labrador, *C. rupestris* was observed moving to deeper water in the winter and to shallower water near the end of summer (Atkinson 1995). Many believe this migration is in pursuit of prey, others believe it is temperature-related (Atkinson 1995).

Roundnose Grenadiers are thought by some researchers to spawn only in Icelandic waters during the summer and autumn months and to be recruited in the Northwest Atlantic (Atkinson 1995). However, its poor swimming ability, different parasite infestations, and the observation of immature and maturing individuals in the Northwest Atlantic suggest that spawning takes place in different areas throughout the North Atlantic (Savvatimsky 1982; Atkinson 1995; Lorance *et al*. 2001a). Grigorev (1972) found juveniles along the Canadian coast.

Nutrition and interspecific interactions

Roundnose Grenadiers occupy a middle trophic level in the deep-sea ecosystem. They feed primarily in the water column on a variety of copepods and amphipods, squid and small fishes such as myctophids (lantern fish) (Whitehead *et al*. 1986; Cohen *et al*. 1990; Atkinson 1995). Young feed primarily on copepods and amphipods, becoming more piscivorous with age. The feeding habits of males and females are very similar. Magnusson & Magnusson (1995) conducted a study in Icelandic waters which concluded that 90.9 % of the stomach content of mature Roundnose Grenadiers was euphausiids, 1.1% shrimps, 2.3% fish, and 5.7% was unrecognizable.

Their feeding is thought to be somewhat seasonal, occurring predominantly during the fall months (Scott & Scott 1988). Podrazhanskaya (1971) found that stomach fullness increased during September to December. It is hypothesized that during this time they migrate to the upper continental slope where prey items are more abundant.

Behaviour/adaptability

The combination of low fecundity, slow growth rates, late maturity and long population turnover times make these fish highly vulnerable to population disturbance. Therefore, they are thought to have low adaptability to change.

FAO (Food and Agricultural Organisation of the United Nations) has proposed guidelines for classifying commercially exploited marine species as of “high”, “medium” or “low” productivity for assessing proposals for listing such species under CITES (Convention on International Trade in Endangered Species) (FAO 2001). According to these guidelines Roundnose Grenadier would be classed as a “low” productivity species (species of low productivity have natural mortality less than 0.2; lifespan greater than 25 years; generation time greater than 10 years; age at maturity greater than 8 years).

POPULATION SIZES AND TRENDS

Research survey data

Data and methods

Data are from stratified-random bottom trawl surveys conducted annually by the Canadian Department of Fisheries and Oceans. Analyses are restricted to surveys of the Grand Bank and the Labrador and NE Newfoundland Shelves.

Two sets of surveys are considered here: 1) spring surveys conducted from April to June on the Grand Bank (NAFO Divisions 3LNO, Figure 4) and in February to April in NAFO subdivision 3Ps, and 2) a fall (mostly October-December) survey of the Labrador and NE Newfoundland Shelves (NAFO Divisions 2J3K). The fall survey was extended to include the northern Grand Bank (3L) in 1981 and the southern Grand Bank (3NO) in 1990. It also occasionally covered the Flemish Cap (3M) and northern areas off Labrador (2GH). Stratum coverage within each division has been variable from year to year. Additional deepwater strata were added to the surveys in the mid-1990s.

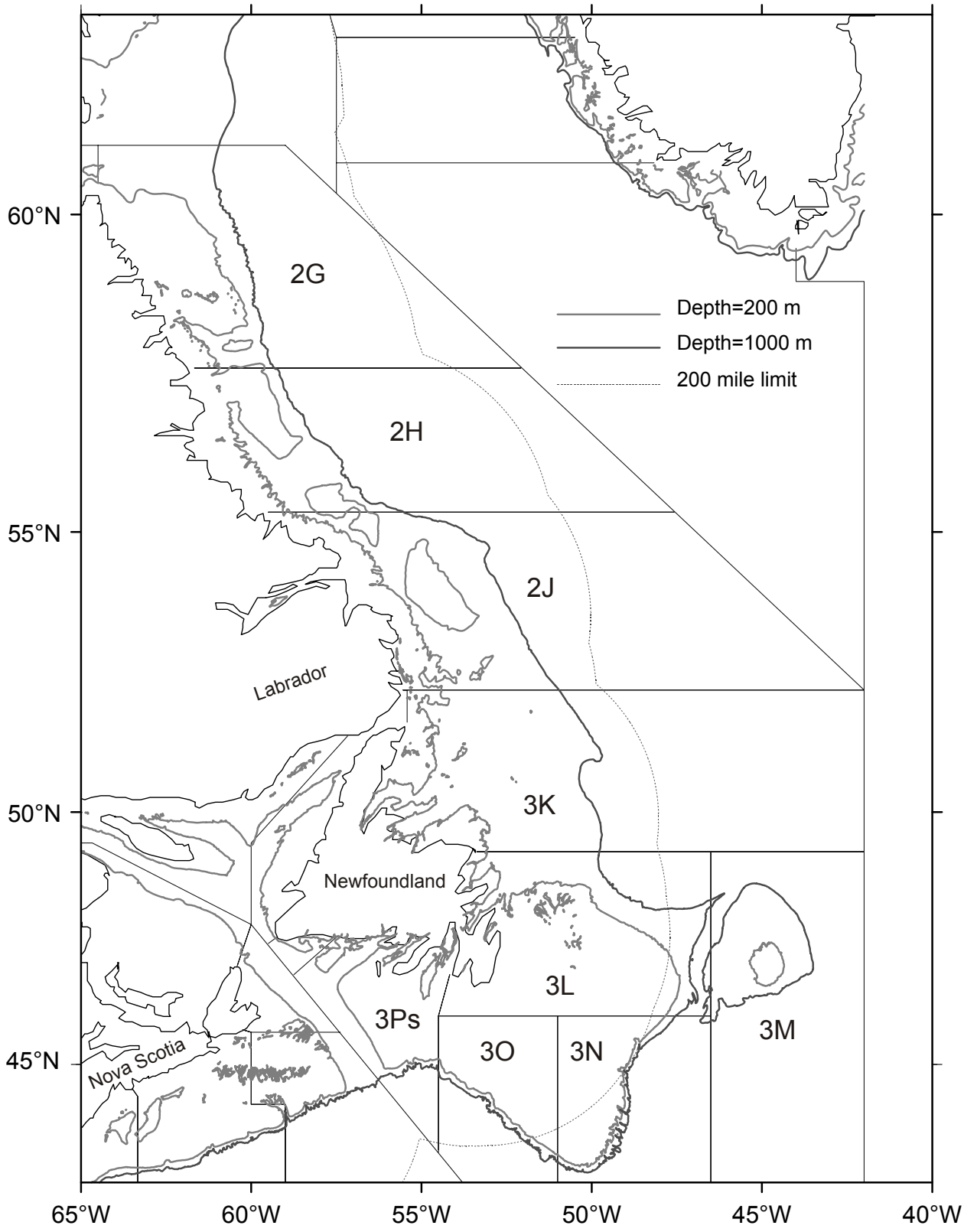

Figure 4. Northwest Atlantic Fisheries Organization (NAFO) divisions referred to in this report.

Survey catch rates provide an index of trends in abundance if catchability to the survey gear and the proportion of the population available to the survey do not change from year to year. The gear used in the fall Newfoundland surveys changed from an Engels trawl to a Campelen trawl in 1995. The spring Newfoundland surveys used a Yankee 41.5 trawl from 1971 to 1982, the Engels trawl from 1985 to 1995, and the Campelen trawl since 1996. A change in survey vessel also occurred in the fall survey in 1995 and in the spring survey in 1985. No estimates of relative fishing efficiency between these trawls and vessels are available for grenadiers. Thus, the Yankee, Engels and Campelen surveys are treated here as separate time series.

Indices for consistently sampled subsets of strata were constructed in order to reduce the likelihood that the proportion of the population covered by the survey varied from year to year (and to avoid other biases that result from changes in the area surveyed). Three indices were calculated using the fall data: 1) 2J3K, starting in 1978; 2) 2J3KL, starting in 1981; and 3) 2J3KLNO including the new deep strata, starting in 1996. Two indices were calculated using the spring data: 1) an index for the 3PsLNO area starting in 1972 but restricted to shallow strata with depths mostly less than 350 m ; 2) an index for the 3LNO starting in 1996 but including depths down to about 700 m. Indices were calculated up to 2002, 2003 or 2005, depending on data availability. Note that the fall index covers a much greater portion of the Roundnose Grenadier distribution, including strata in the 750-1000 m range even in the early years.

Roundnose Grenadier occur in relatively deep waters, including areas beyond the offshore margin of the area covered by these surveys. Thus, shifts in the distribution of these grenadiers with depth could result in changes in availability to the surveys, such that changes in catch rates in the surveys would not accurately reflect changes in population abundance. To investigate this possibility, interannual variation in geographic distribution and bathymetric pattern was examined for the fall surveys. Grenadier density as a function of depth was examined using Generalized Additive Models, following the methods of Swain & Benoît (2006).

Adult catch rate indices were also calculated for the fall survey. These consisted of catch rates of fish with a preanal fin length (AFL) over 110 mm. This corresponds approximately to the length at maturity (Bergstad 1990). Based on this length at maturity, 47% of Roundnose Grenadier caught by the Engels trawl and 11% of those caught by the Campelen trawl were considered mature (Figure 5).

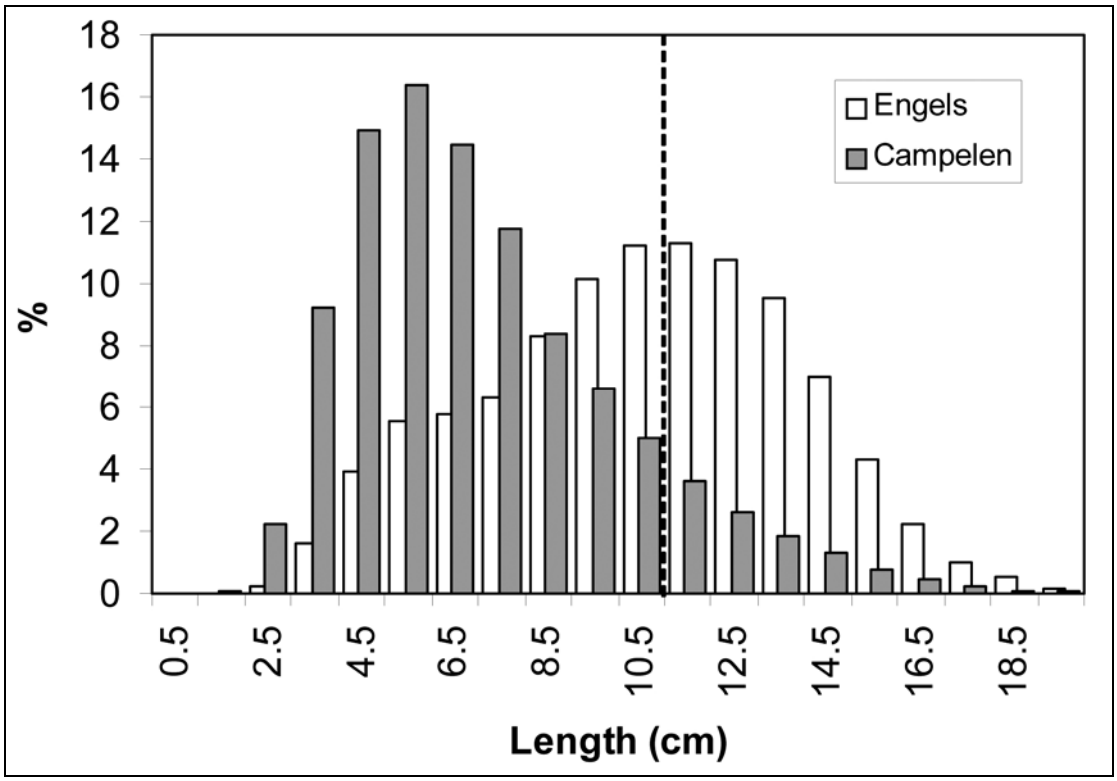

Figure 5. Length distribution of Roundnose Grenadier catches in the fall surveys of the Labrador and NE Newfoundland Shelves and the Grand Bank. Lengths are preanal fin length (AFL). Distributions are shown separately for the Engels trawl used prior to 1994 and for the Campelen trawl used since 1995. The dashed line denotes the approximate length at maturity.

To assess rates of change, $\log_e$ of the stratified mean catch rate was regressed against year. Percent change was calculated as $100 \cdot (1-e^{-b\Delta t})$, where b is the regression slope and Δt the change in time (years).

Trends in survey catch rates

Fall surveys-all individuals

Catch rates in the fall survey declined sharply over the 1978-1994 period in the 2J3K area (Figure 6a). The linear trend in $\log_e$ catch rates over this time period was highly significant (R^2=0.64, P<0.0001, Figure 6b), and corresponded to an 96% decline over 16 yr. Catch rates after 1994 are not directly comparable to the earlier catch rates because of the change in gear in 1995. Catch rates were roughly stable over the 1995-2005 period. The linear trend in $\log_e$ catch rates was negative but non-significant (R^2=0.10, P=0.34, Figure 6b).

Similar trends are evident in the 2J3KL indices (Figure 6c,d). Catch rates declined sharply over the 1981-1994 period, corresponding to a 93% decline in 13 yr. Catch rates were roughly stable after 1994, with no significant trend in $\log_e$ catch rates over the 1995-2003 period (R^2=0.01, P=0.78, Figure 6d).

Catch rates were substantially (about 1.7 times) higher in the index expanded to include the deep strata added in 1996 (Figure 6c), reflecting the relatively high densities of grenadiers in these deep strata. The index including these deep strata has been declining since 1996. The significant negative trend in $\log_e$ catch rates (R^2=0.70, P=0.0093, Figure 6d) corresponds to a 58% decline over 7 yr.

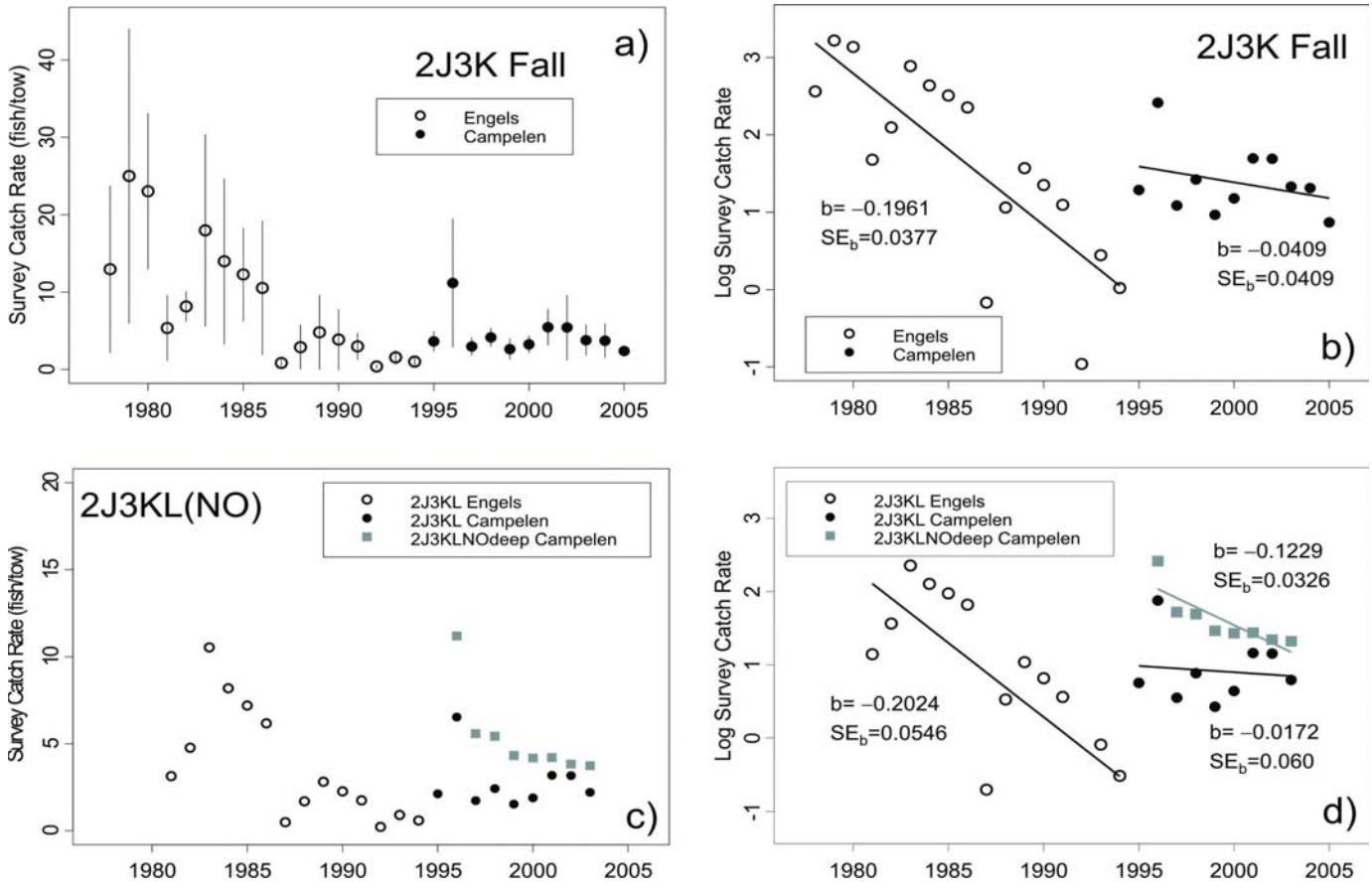

Figure 6. Stratified mean catch rates of Roundnose Grenadier (all sizes) in fall surveys of the Labrador and NE Newfoundland Shelves and the Grand Bank. Regression lines are shown for $\log_e$ catch rate versus year in panels b and d, along with their slope b and its standard error. Vertical lines in panel a are ±2SE. Different symbols denote different areas and/or gears.

Spring surveys-all individuals

Catch rates in the spring surveys were much lower than in the fall survey (Figure 7), reflecting the lack of coverage of deep waters by these surveys. Roundnose Grenadier were caught in only 231 of the 12371 spring sets (1971-2003). Of these, only 24 catches were in the subset of strata that were sampled in most years in the time series. Coverage by the spring surveys of grounds occupied by Roundnose Grenadier was judged to be inadequate to provide an indication of trends in abundance. Catch rates increased over 100-fold including the deep strata sampled since 1996 (Figure 7), though even including these deep strata catch rates remained about an order of magnitude lower than those in the fall survey. There was no trend in the index including these deep strata (R^2<0.01).

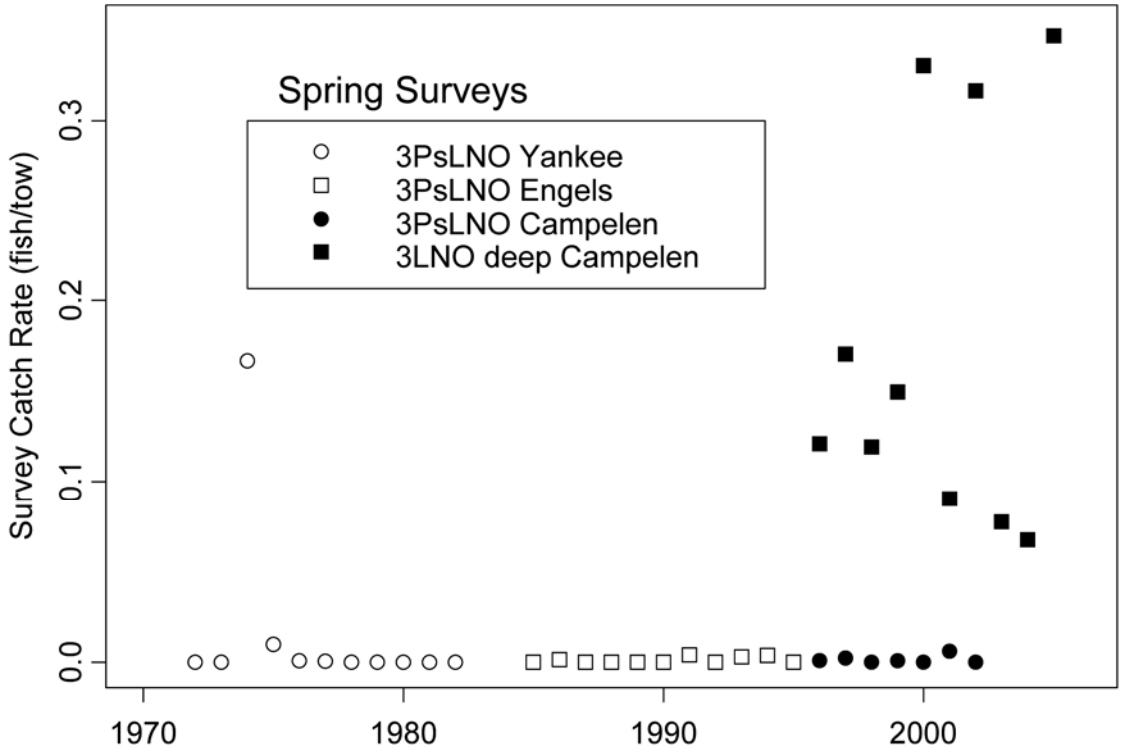

Figure 7. Stratified mean catch rates of Roundnose Grenadier (all sizes) in spring surveys of NAFO subdivision 3Ps (St. Pierre Bank) and/or divisions 3LNO (the Grand Bank). Different symbols denote different areas and/or gears. Solid squares indicate catch rates including deep strata added to the survey in 1996.

Fall surveys-mature individuals

Adult catch rates declined sharply over the 1978-1994 period in the fall survey of 2J3K (Figure 8a). The linear regression of $\log_e$ catch rates versus time was highly significant over this period (R^2=0.68, P<0.0001, Figure 8b), and corresponded to an 98% decline over 16 yr. Adult catch rates in 2J3K also tended to decline at about the same rate between 1995 and 2003, but the decline during this period was not statistically significant (R^2=0.30, P=0.13).

Similar patterns are evident extending the analysis to include 3L (Figure 8c,d). The decline in catch rate was highly significant over the 1981-1994 period (R^2=0.53, P=0.003), corresponding to a 95% decline over 13 yr. Although tending to decline at about the same rate in 1995-2003, this decline was not statistically significant (R^2=0.30, P=0.13). Adult catch rates were substantially higher extending the analysis to include the deepwater strata sampled since 1996. Including these deepwater strata in the analysis resulted in a sharp and highly significant decline in catch rates from 1996 to 2003 (R^2=0.87, P=0.0006), corresponding to a 91% decline in 7 yr. (Figure 8d).

Geographic distribution and bathymetric pattern

Roundnose Grenadier are distributed along the offshore margin of the surveyed area (Figures 9 and 10). Taking into account changes in the area surveyed, there are no indications of changes in geographic distribution over the 1978-2003 period, except for a more northerly distribution in the late 1980s.

The distribution of Roundnose Grenadier with respect to depth is described in Figure 11. The analyses presented in this figure are based on all available tows (Figure 9-10), not just the subsets used to construct the standardized catch-rate indices presented above. Tows from all survey gears are described here; this is considered appropriate for a description of distribution rather than abundance.

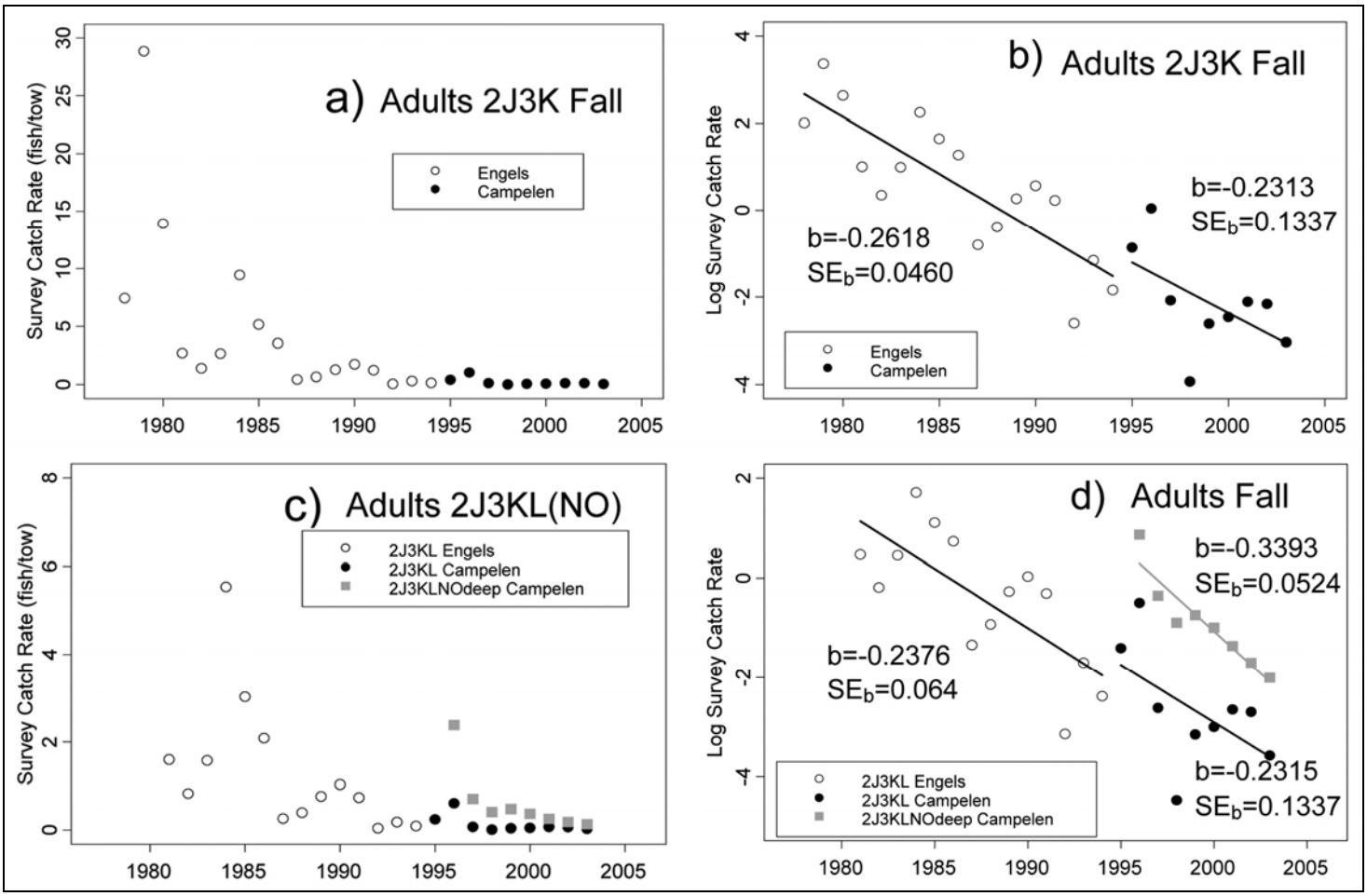

Figure 8. Stratified mean catch rates of adult Roundnose Grenadier in fall surveys of the Labrador and NE Newfoundland Shelves and the Grand Bank. Regression lines are shown for loge catch rate versus year in panels b and d, along with their slope b and its standard error. Different symbols denote different areas and/or gears

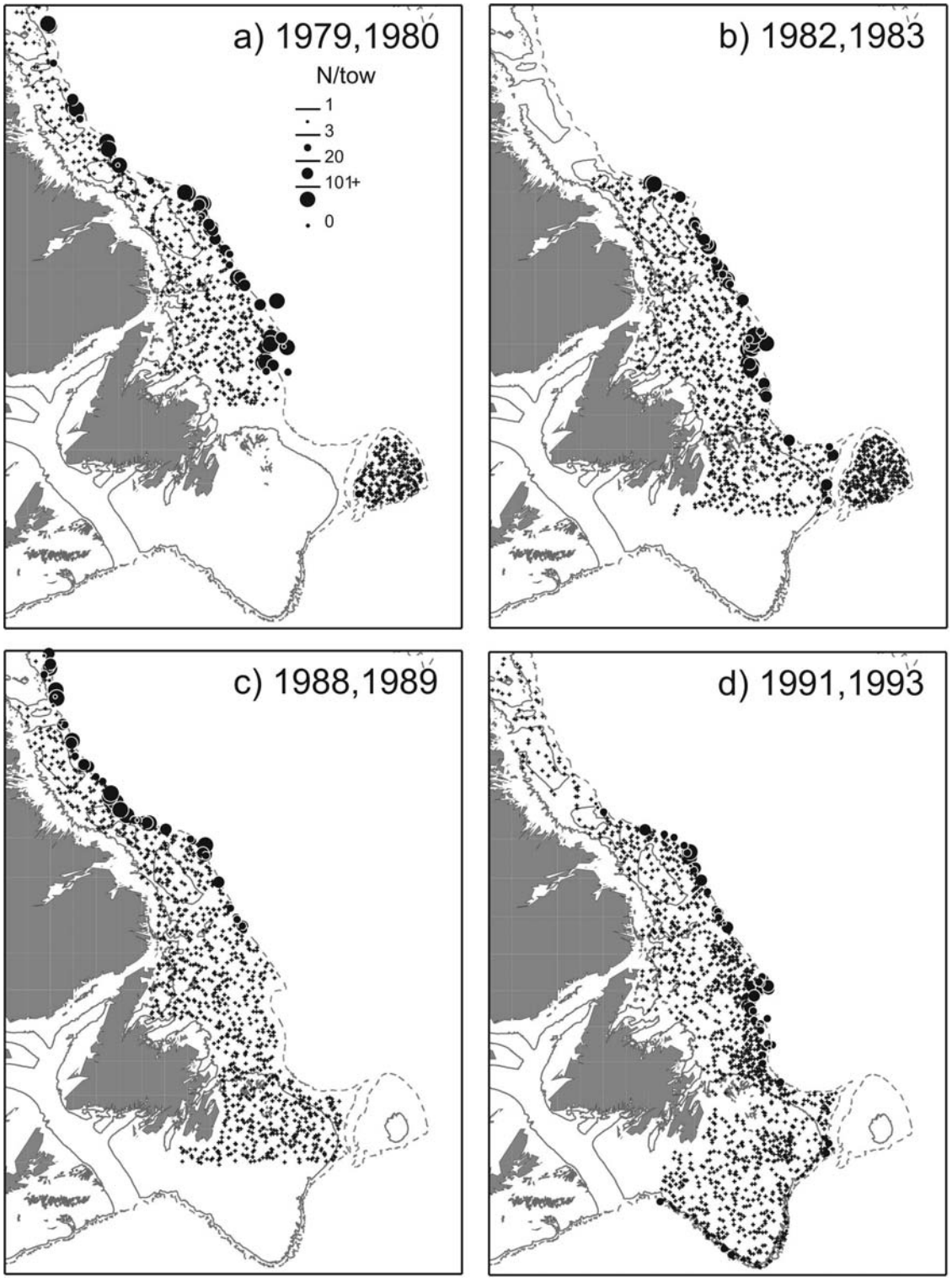

Figure 9. Geographic distribution of Roundnose Grenadier catches in the fall surveys of the Labrador and NE Newfoundland Shelves and the Grand Bank for selected years between 1978 and 1994 (Engels surveys). Circle size is proportional to catch. Cutpoints are the 10th, 25th, 50th, and 75th percentiles of the non-zero catches. Crosses indicate zero catches. The 200 and 1000 m depth contours are denoted by solid and dashed lines, respectively.

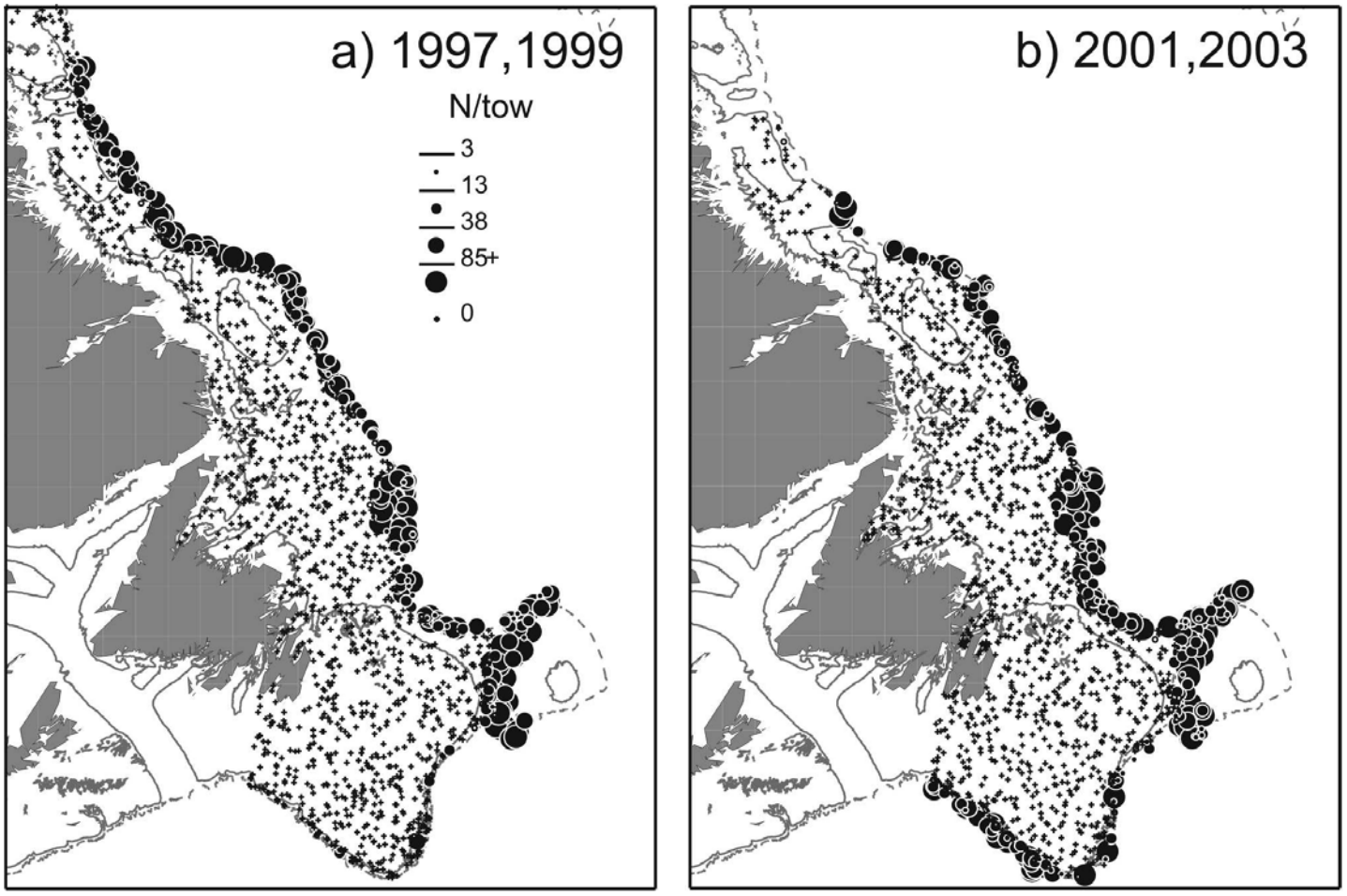

Figure 10. Geographic distribution of Roundnose Grenadier catches in the fall surveys of the Labrador and NE Newfoundland Shelves and the Grand Bank for selected years between 1995 and 2003 (Campelen surveys). See Figure 9 caption for further details.

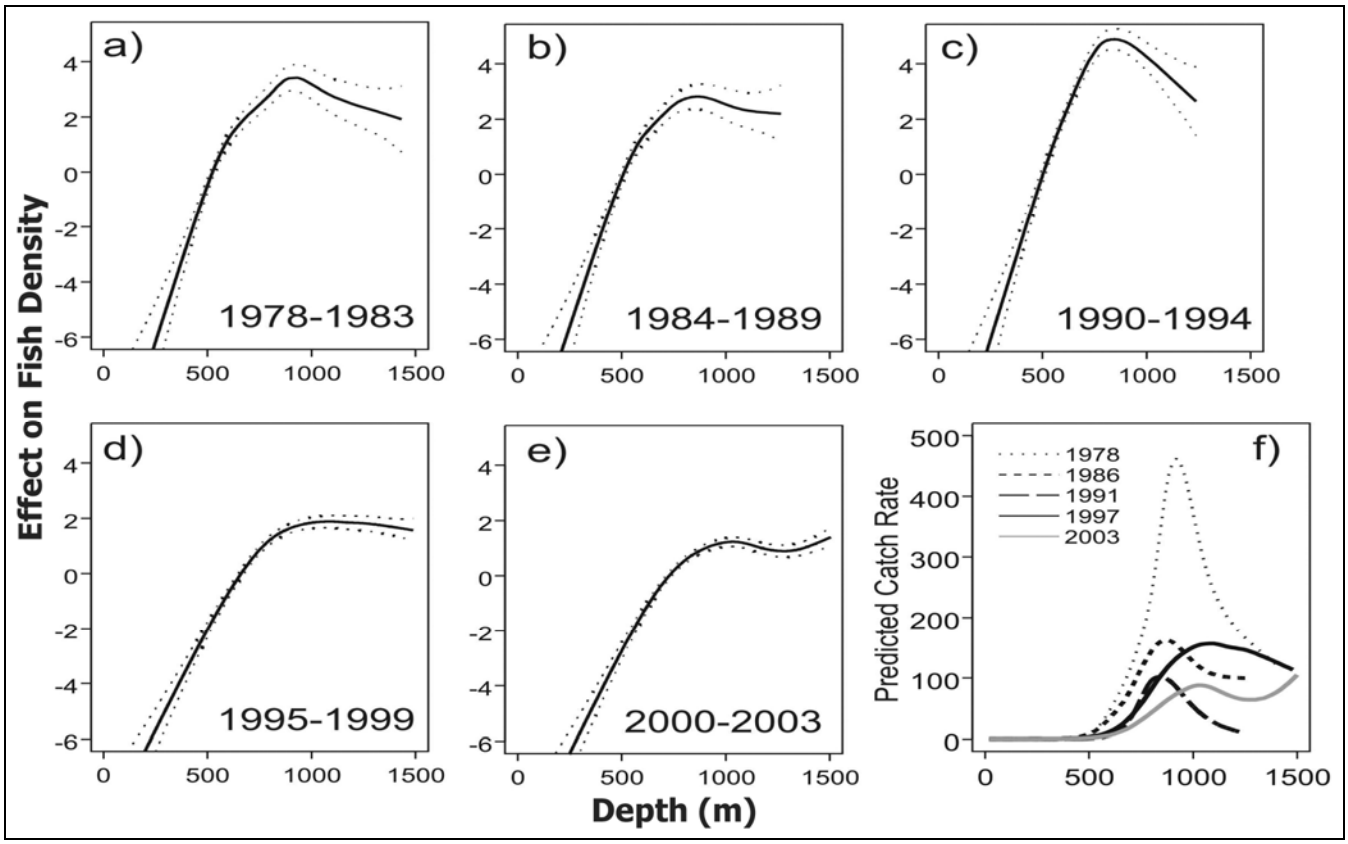

Figure 11. Effect of depth on the local density of Roundnose Grenadiers in fall surveys off Newfoundland and Labrador. Panels a-e: effect of depth (on a $\log_e$ scale) on grenadier density in 5 time periods. Solid line shows the predicted relationship, and the dotted lines are ±2SE. Note that models included an effect of year not shown in these panels. Panel f: predicted density for a selected year in each period.

In contrast to some other species (e.g., roughhead grenadier), there is no indication that the distribution of Roundnose Grenadier shifted into deeper waters as their catch rates in the fall survey declined from 1978 to 1994. In all years, catch rates of Roundnose Grenadier were negligible at depths less than 500 m. In the three periods shown between 1978 and 1994, predicted catch rates peaked at depths of 840 m (1990-1994) to 920 m (1978-1983), and then declined with further increases in depth. In the 1990-1994 period, catch rates declined to low levels at depths over 1000 m (though there were few tows at these depths). In the two periods between 1995 and 2003, catch rates peaked at somewhat greater depths (about 1050 m) and remained high up to the greatest depths sampled (about 1500 m). This apparent change in distribution may reflect the much greater sampling intensity at depths over 1000 m starting in 1996. If it instead reflects a real shift in distribution to deeper waters, these results suggest that the shift occurred in the mid-1990s after, not coincident with, the decline in survey catch rates in the 1980s and early 1990s.

Kulka (2001) presented distribution of Roundnose Grenadier with depth showing an increase in biomass in deeper strata (Figure 12). Because average size of individuals increases in deeper waters, the increase in biomass with depth could be consistent with a decrease in abundance with depth as shown by analyses in the present report (Figure 11). This species does occur at depths beyond those sampled by the trawl surveys but the proportion of the population at these greater depths is not known.

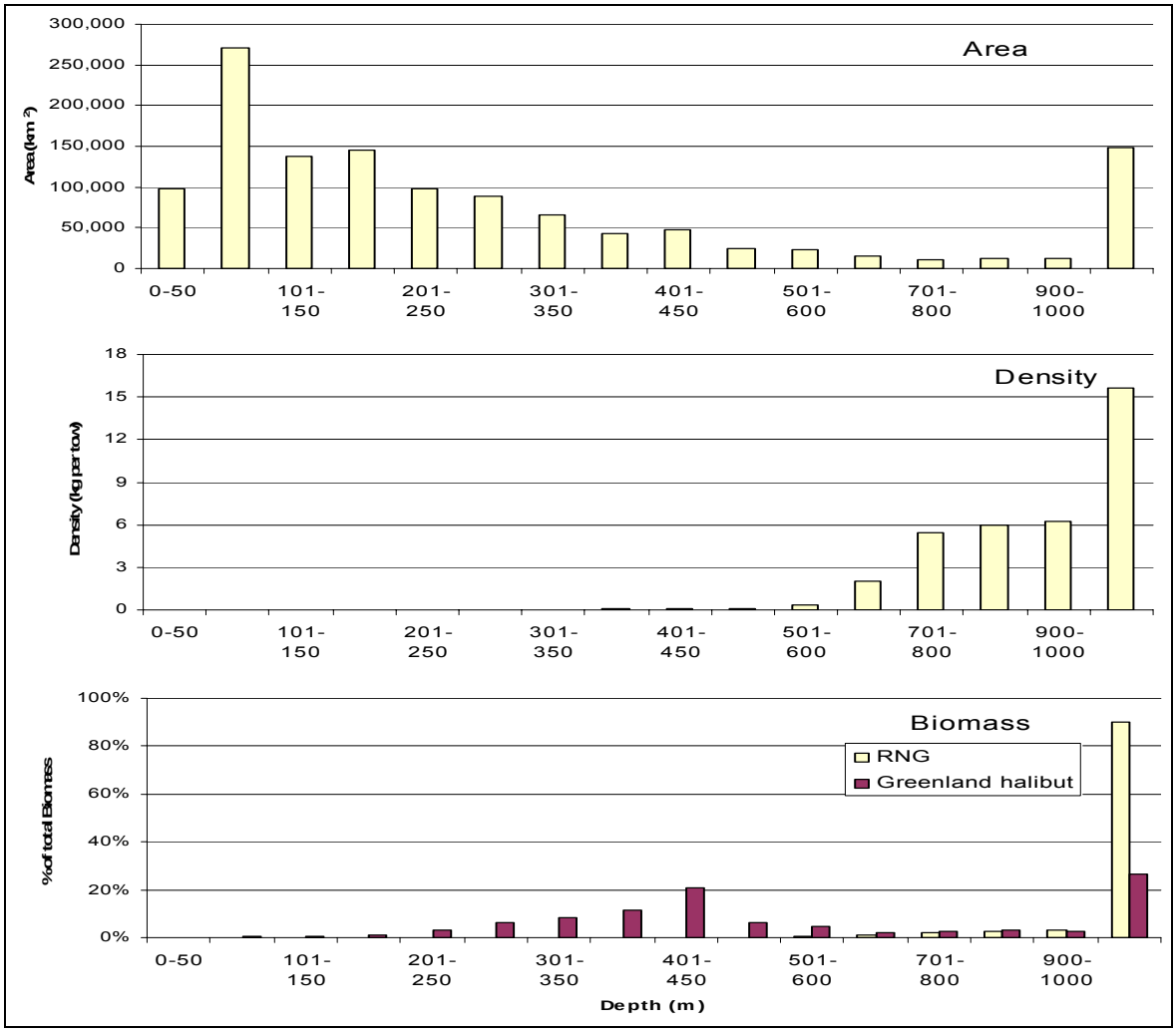

Figure 12. Distribution of Roundnose Grenadier biomass by depth: Upper panel-available area (km^2 by depth range); Middle panel-density (average kg per tow by depth range); Lower panel-biomass (t) (Source: Kulka 2001).

Summary of survey trends

Roundnose Grenadier are restricted to deep waters, occurring in the surveys analysed at negligible densities in depths less than 500 m. Except for the fall survey of the Labrador and NE Newfoundland Shelves (NAFO Divisions 2J3KL), all annual research surveys in Atlantic Canada are restricted to waters too shallow to provide indications of abundance trends for this species. Catch rates in the fall 2J3K survey declined sharply between the late 1970s and early 1990s, both for adults and for all sizes combined. The estimated decline rates corresponded to a 98% decline in catch rates of adults and a 96% decline in catch rates of all sizes classes combined from 1978 to 1994, a period roughly equal to the estimated generation time of Roundnose Grenadier.

Catch rates continued to decline in surveys conducted after 1994. (Catch rates in these surveys are not comparable to those conducted in 1994 and earlier due to a change in survey gear.) Indices including the deep strata added to the survey in 1996 declined significantly from 1996 to 2003 for both adults and all sizes combined. Declines amounted to 91% for adults and 58% for all size classes over a 7 year period (about 40% of the generation time of Roundnose Grenadier).

Roundnose Grenadier are distributed along the offshore margin of the fall 2J3KL survey and are known to occur in waters deeper than those surveyed, as well as in areas northwest and southeast of these NAFO divisions. Thus, it is possible that there have been changes in availability to the survey due to shifts in the distribution of Roundnose Grenadier. For example, it could be argued that the decline in survey catch rates reflects a shift in distribution into waters deeper than those surveyed. However, there is no information to indicate that such a shift has occurred. In particular, no change in depth distribution is evident over the 1978-1994 period, when catch rates in the survey declined sharply. Throughout this period, catch rates in the survey peaked at about 850-900 m and then declined with further increases in depth, particularly in the 1990-1994 period.

Fishery catch rates

A directed fishery for Roundnose Grenadier developed in the northwest Atlantic in the late 1960s (Atkinson 1995; see details below). This fishery may provide additional information on changes in abundance and distribution of Roundnose Grenadier. Time series of annual mean standardized catch-per-unit-effort (tonnes/hr) for Roundnose Grenadier in NAFO subareas 2 and 3 were taken from Atkinson (1995) and are shown in Figure 13 after $\log_e$ transformation. Two time series are shown, one based on NAFO data on catch and effort and a second based on data collected by Canadian fishery observers. Linear trends in catch rate over time were examined by analysis of covariance. There were no differences in intercept or slope between the two data sources ($P>0.3$), so an analysis using a common slope and intercept was conducted. This analysis indicated a highly significant negative trend in catch rates over time (Figure 13), corresponding to a 74% decline over 24 years.

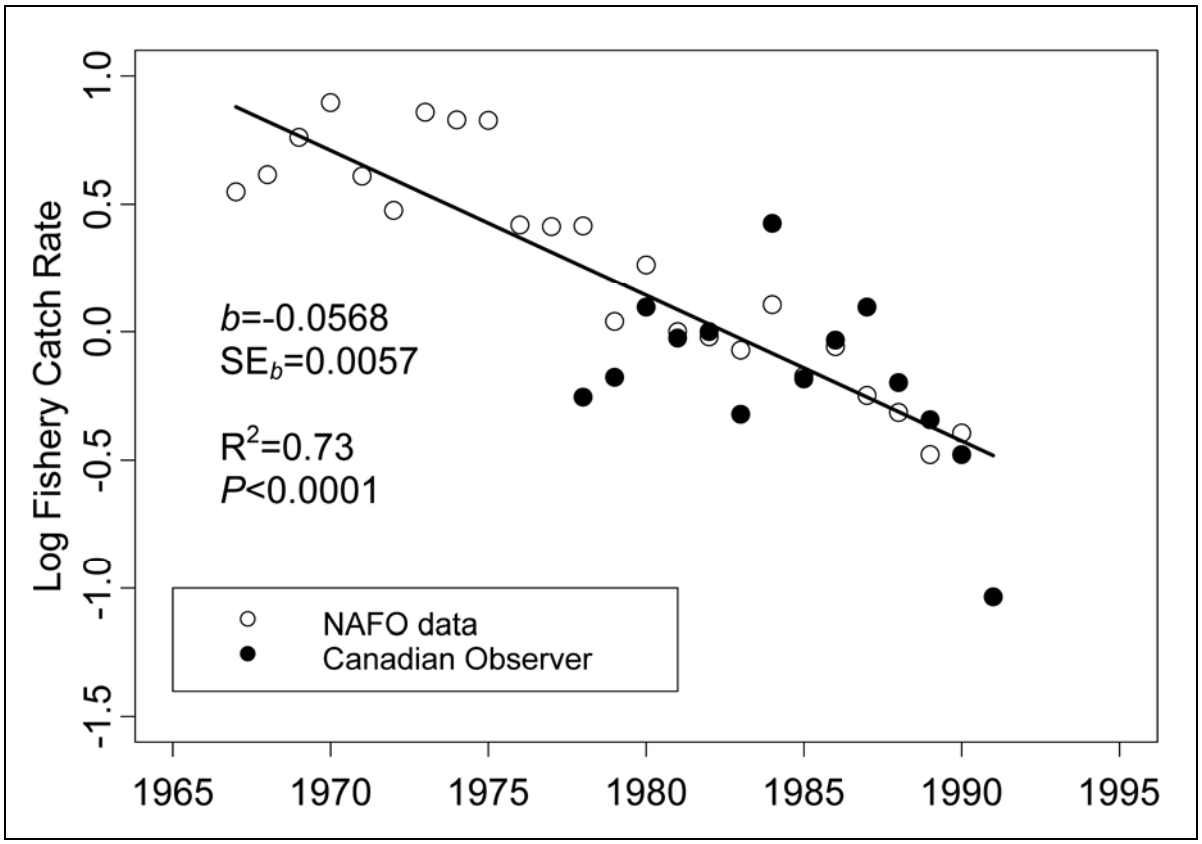

Figure 13. Log_e-transformed standardized catch rates (tonnes/hour) in the fishery for Roundnose Grenadier in NAFO subareas 2 and 3, calculated from catch and effort data available from NAFO and the Canadian Observer Program. Catch rates obtained from Figure 12 in Atkinson (1995). The line shows predicted catch rates from the regression of log_e catch rate versus year; b is the estimated regression slope, and SEb is its standard error.

Compared to survey data, fishery data have the advantage that they potentially cover a greater portion of the habitat occupied by Roundnose Grenadier. The fishery targets grenadier concentrations. Thus, in the case of this species which is distributed along the offshore margin of the survey area, variation in availability may be less likely for the fishery than for the survey. However, availability to the fishery may still vary if Roundnose Grenadier move into waters deeper than those normally fished. In NAFO subareas 2 and 3, fishing traditionally occurred between depths of 500 and 2000 m in Divisions 2G, 2H, 2J and 3K (Figure 14).

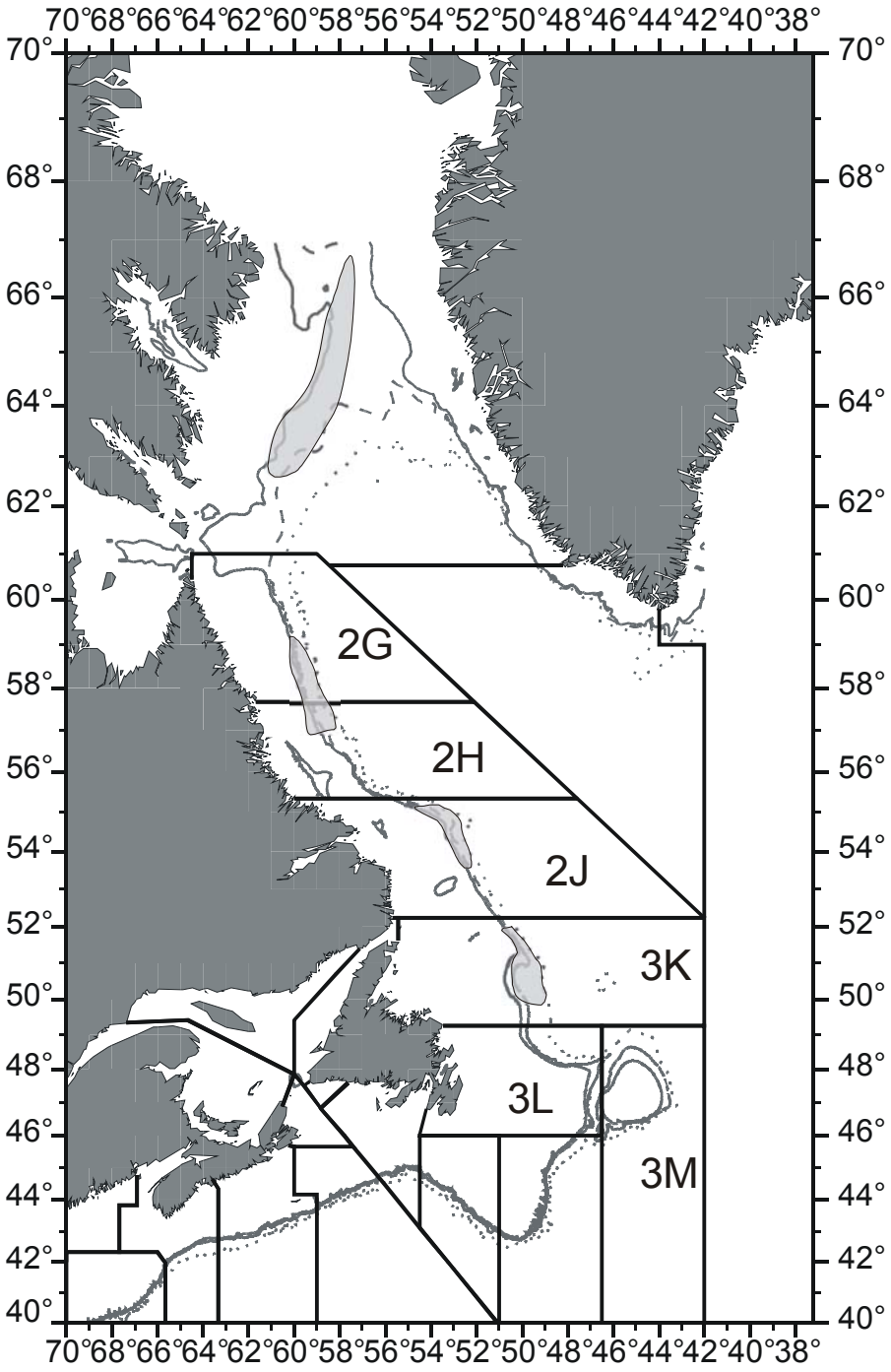

Figure 14. Traditional fishing areas for Roundnose Grenadier in the Northwest Atlantic. Adapted from Atkinson (1995, Figure 9). The 500, 1000 and 2000 m depth contours are denoted by solid, dashed and dotted lines, respectively

Compared to survey data, fishery data have the disadvantage that catchability to the fishery is likely to vary for a number of reasons. In general, catchability is expected to increase over time due to technological improvements. Effects of some of these improvements can be adjusted for in catch rate standardizations (e.g., increased

vessel tonnage or horsepower), but effects of others usually cannot (e.g., improved fish-finding technology). Catchability to fisheries is often also density-dependent, increasing as abundance decreases and area occupied declines (Paloheimo and Dickie 1964). This reflects the ability of fishers to target fish aggregations, maintaining high catch rates despite low fish population abundance. For example, catch rates in some fisheries for northern cod remained high or even increased as the stock collapsed to very low levels (Rose and Kulka 1999). Thus, due to improving technology and density-dependent catchability, declines in fish abundance may be underestimated by declines in fishery catch rates.

On the other hand, catch rates may overestimate population declines, since they are affected by fishery management changes as well as by biological conditions. It has been argued that the decline in fishery catch rates for Roundnose Grenadier throughout the 1980s may not reflect a decline in Roundnose Grenadier abundance, for the following reasons (summarized by Atkinson 1995):

1) Catch rates were meant to be based on directed effort, defined as catches where Roundnose Grenadier comprised over 50% of the total catch. However, because of the way in which the NAFO data were grouped before being available for analysis, it was possible that non-directed effort (i.e., individual trawl tows where the catch was < 50% Roundnose Grenadier) was included in the analysis, affecting the estimated catch rates. An analysis of observer data, available for individual tows, discounted this argument. Catch rate trends were similar between the NAFO data and the observer data.
2) Declines in catch rates may reflect changes in fishing behaviour to avoid exceeding by-catch limits. Prior to 1986 or 1988 (depending on the fleet), by-catch of Greenland halibut was limited to 10% in the Roundnose Grenadier fishery. It was argued that, as the Greenland halibut stock increased in abundance, the fishing shifted to marginal areas for Roundnose Grenadier in order to avoid by-catch of Greenland halibut. However, an analysis of the catch and effort data did not support the theory that by-catch limits were restricting catches of Roundnose Grenadier.
3) Declines in catch rates may reflect a shift in Roundnose Grenadier distribution into waters deeper than those fished. It is argued that this shift occurred in response to the cooling of the northwest Atlantic in the 1980s. However, Atkinson (1995) noted that temperatures fluctuated by only tenths of a degree in the deep waters occupied by Roundnose Grenadiers and suggested that it seems unlikely that such small changes would precipitate the large-scale distribution changes required to explain the fishery trends during this period. Furthermore, an analysis of the observer data indicated that, except in the 500-750 m depth range where catch rates did not decline, catch rates declined simultaneously over all other depth ranges in the late 1980s and early 1990s. This suggests that if the Roundnose Grenadier had moved deeper, they did so on a large scale in a short period of time, a possibility that Atkinson (1995) considered unlikely.

4) A number of species are believed to have moved further south and to the east when water temperatures cooled in the 1980s and early 1990s. An example is Greenland halibut, for which there has been an increase in fishing effort and catches in divisions 3LMN, south of the traditional fishing areas. Atkinson (1995) suggested that Roundnose Grenadier may also have to some extent moved south and east from their traditional grounds. Reported by-catch of Roundnose Grenadier in the developing Greenland halibut fishery in 3LMN in 1992 and 1993, though low on a percentage basis, were the highest catches ever reported south of Division 3K (Atkinson 1995). However, it has now been determined that these catches, reported as Roundnose Grenadier, were predominantly roughhead grenadier (Power 1999).

In summary, catch rates in the directed fishery for Roundnose Grenadier in subareas 2 and 3 declined by 74% over the 1967-1991 period, suggesting a substantial decline in the biomass of this stock. In general, declines in catch rates in commercial fisheries may underestimate declines in fish population size for a number of reasons. However, in the case of this fishery, it has been argued that the declines in catch rates do not reflect declines in grenadier biomass, instead reflecting biases in the data, effects of fishery regulations on fishing behaviour or changes in the availability of grenadier to the fishery. However, empirical support for these arguments is lacking.

Population size

A rough minimum estimate of population size can be obtained by expanding the mean survey catch per tow to the survey area (i.e., by multiplying by the survey area divided by the area swept by a standard tow). This estimate is an underestimate because 1) catchability to the survey gear is likely substantially less than 100%, and 2) a substantial portion of the Roundnose Grenadier population likely occurs outside of the area surveyed. Estimates based on the index from the fall survey of NAFO Divisions 2J3KLMNO (Figure 6c) varied from 206 million in 1996 to 69 million in 2003, averaging 73.6 million in the 2000-2003 period. Estimates based on the adult index (Figure 8c) varied from 43.8 million adults in 1996 to 2.5 million adults in 2003, averaging 4.4 million adults in the 2000-2003 period.

NAFO stock assessment

The most recent assessment of Roundnose Grenadier in subareas 2+3 was conducted in 1999 (Power 1999). The assessment reported the catch history and focused on trends in the fall Canadian surveys from 1996 to 1998. It concluded that current stock status could not be determined relative to the historical period when there was a directed fishery (due to a gear change in the survey and incomplete coverage of grenadier distribution by surveys), but noted that recent catches (about 50 tons annually, taken as bycatch in other groundfish fisheries) corresponded to exploitation rates much less than 1%. NAFO's Scientific Council has classified this stock as "E0", meaning that stock abundance status is "uncertain/not assessed" and that exploitation status is also "uncertain".

Other regions

Roundnose Grenadier in NAFO Subareas 0+1 (Davis Strait) was assessed by NAFO in 2005. It concluded that the stock remained at the very low level observed since 1993 and was composed of small individuals (NAFO 2005). NAFO's Scientific Council has classified this stock as "D0"-stock abundance status is "depleted" and exploitation status is "uncertain".

ICES (International Council for the Exploration of the Sea), the agency responsible for providing scientific advice on fisheries management in the northeast Atlantic, has recommended 50% reductions in effort and catches in areas where high catches are being taken (mid-Atlantic ridge and European slope waters) (ICES 2006). ICES has also recommended that catches not be increased unless removals can be shown to be sustainable (ICES 2006).

AREA OCCUPIED

The area occupied by Roundnose Grenadier was estimated based on catches in the Canadian fall survey of NAFO Divisions 2GHJ3KLMNO. Because this survey does not cover all grounds inhabited by this species in the waters off Atlantic and Arctic Canada, the values reported here will be underestimates.

Estimates are based on the surveys in 1996-1999, a period with wide survey coverage in NAFO Subareas 2 and 3. The area covered by these surveys varied by about 10% from year to year (Table 1) and no attempt was made to adjust for this variation. The area occupied by Roundnose Grenadier within the survey area varied between 58,000 and 74,200 km^2 (Table 1).

Table 1. Area occupied (1000s km^2) by Roundnose Grenadier (all sizes or adult sizes) in the fall survey of NAFO Divisions 2GHJ3KLMNO in selected years with broad survey coverage.

	All sizes		Adult females	
Year	Surveyed	Occupied	Surveyed	Occupied
1996	634.4	70.6	632.7	43.7
1997	562.8	67.7	562.3	42.3
1998	594.0	74.2	594.0	42.3
1999	572.1	58.0	571.7	37.2

The analysis was repeated for adult sizes. All fish longer than 110 mm AFL were assumed to be adults. The area covered by this analysis was reduced slightly due to the omission of occasional tows with no length frequencies. The estimated area occupied by adults was 37,200-43,700 km^2 (Table 1).

In order to examine trends in area occupied, an analysis was conducted using a subset of "index" strata that were sampled in most years in the fall survey of areas 2J and 3K. Strata selection and summary data for these strata were kindly provided by M. Koen-Alonso and F. Mowbray (DFO St. John's, pers. comm.). The area covered by this set of index strata varied little from year to year except for an increase in area in 1996 associated with the addition of deepwater (>1000 m) strata to the survey (Figure 15). Area occupied within this subset of strata has been roughly stable over the 1981-2005 time period, except for low values in the late 1980s (Figure 15). Area occupied appears higher in the 1996-2005 period than in earlier years, but this reflects the addition of deepwater strata to the survey in 1996.

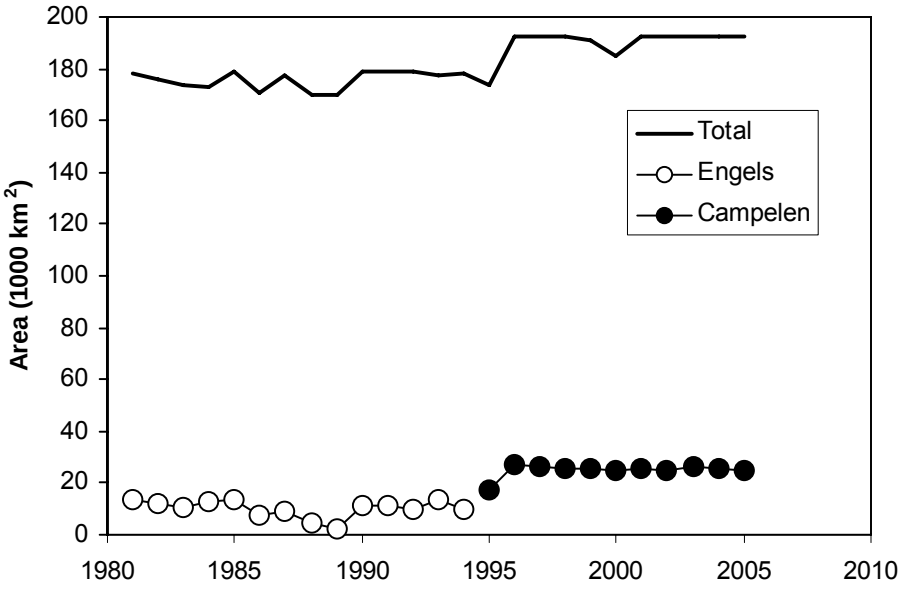

Figure 15. Area occupied by Roundnose Grenadier within a subset of index strata in the fall surveys of NAFO Divisions 2J and 3K. The line shows the total area surveyed each year, circles show the area occupied by grenadiers (open circles – years fished by the Engels trawl, closed circles – years fished by the Campelen trawl).

LIMITING FACTORS AND THREATS

Fishing is the principal known threat for this species. Limiting factors are related to its relatively low productivity, which means that vulnerability to mortality from human activities is high.

Exploratory fishing by the Soviet Union in the northwest Atlantic in the early 1960s revealed substantial concentrations of Roundnose Grenadier in slope waters at depths greater than 500 m, and this was considered a very promising deepwater fishery resource at the time (Atkinson 1995). A commercial fishery was initiated in 1967, though unknown amounts were caught before this time as bycatch in fisheries for other groundfish. The fishery was prosecuted primarily with bottom trawls, with occasional

catches by midwater trawls. Effort and catches were highest during the second half of the year in summer and fall when the fish were distributed in shallower slope waters (Atkinson 1995).

Although fishing occurred in both subareas 0+1 and 2+3, catches were predominantly from subareas 2+3 (70-90% of the annual catch during the 1967-1978 period). The annual catch in subareas 2+3 averaged 26,000 t in the 1967-1978 period, with an unusually high catch of 75,445 t reported for 1971 (Figure 16). Catches were predominantly from Division 3K, except in 1971 when over 54000 t were reported caught from 2G. Catches declined precipitously after 1978 (Figure 16). Reported annual catches averaged 5000 t in the 1980s and less than 600 t in the early 1990s (1990-1995). The first catch quota (Total Allowable Catch or TAC) was imposed for subareas 2+3 in 1974 at 32000 t (Figure 16). The TAC varied slightly over the 1974-1982 period, with a sharp reduction to 11000 t in 1983 and to 3000 t in Canadian waters in 1994. A moratorium on directed fishing for Roundnose Grenadier was imposed in 1997 for Canadian waters. Outside 200 n. miles the fishery is unregulated except for mesh size.

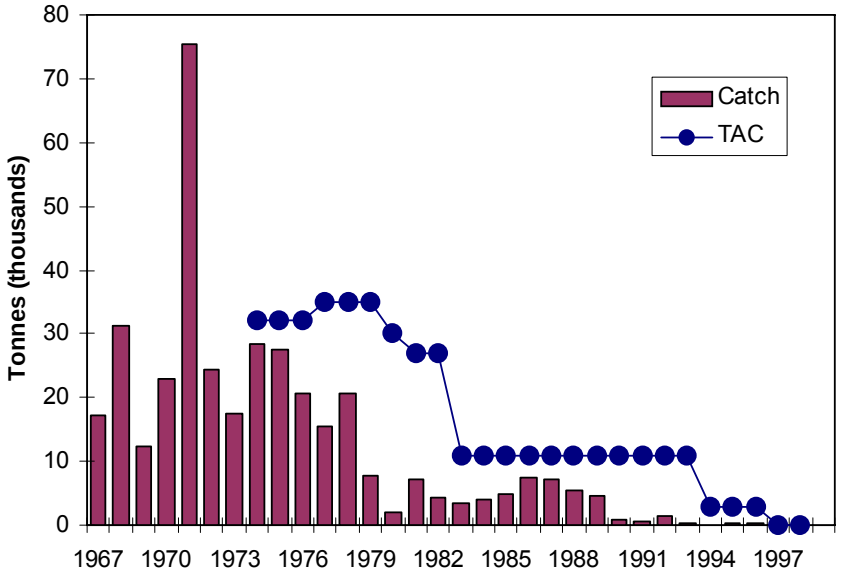

Figure 16. Reported catches and Total Allowable Catch (TAC) of Roundnose Grenadier in NAFO Subareas 2+3 (from Power 1999).

Recorded catches subsequent to the analyses of Power (1999) (Figure 16), which go up to 1999, show increases over the very low levels in the late 1990s (Table 2).

Table 2. Reported landings of Roundnose Grenadier (t), 2000-2006. Canada = waters inside Canada's extended economic zone (EEZ); NAFO = waters outside the EEZ). Source: NAFO 21A STATLANT Database, provided by Department of Fisheries and Oceans, August 2008.

Year	2000	2001	2002	2003	2004	2005	2006
Canada			4				
NAFO	63	5435	4880	3768	2802	2542	1179
Total	63	5435	4884	3768	2802	2542	1179

There is considerable uncertainty about actual removals, since Roundnose Grenadier and roughhead grenadier are not always accurately differentiated in landings. Further, in recent years Roundnose Grenadier have only been taken as bycatch in the Greenland halibut fishery, and removals are unregulated.

Catches in the directed fishery in subareas 2+3 were never restricted by (that is, never reached) the TAC, suggesting that the decline in catches may reflect a decline in Roundnose Grenadier abundance. It has been counter-argued that catch declines were instead due to management regulations (i.e., restrictions on the by-catch of Greenland halibut) or due to reduced availability of Roundnose Grenadier as a result of changes in their distribution (see references in Atkinson 1995). However, analyses to quantify these possible effects are lacking (see details in Atkinson 1995).

Roundnose Grenadier overlap in depth distribution with Greenland halibut (a species of relatively deep waters), and high bycatches have been taken in the Russian Greenland halibut fishery in deep waters (Kulka 2001; Kulka *et al*. 2001). As such, the fact that Roundnose Grenadier lives in deep waters does not necessarily provide this species with a refuge from exploitation.

Since 1990, Roundnose Grenadier in subareas 2+3 have been taken primarily as bycatch in the Greenland halibut fishery in Divisions 3LMN. Most by-catch is taken in the first half of the year corresponding to the period of most effort for Greenland halibut (Power 1999). Duran *et al*. (1997) reported that roundnose and roughhead grenadiers (*Macrourus berglax*) were the most significant species retained and discarded as by-catch in the Spanish Greenland halibut fishery between 1991 and 1994 in NAFO divisions 3LMNO. Rates of capture between 1991 and 1994 were estimated to range between 25 and 55 kg/hour with large trawls (Duran *et al*. 1997). The survival of discarded Roundnose Grenadier is unknown but is thought to be very low because of the large pressure change experienced as the fish are brought up from depths over 500 m.

Due to their life-history traits (i.e., late age at maturity, slow growth), Roundnose Grenadier populations are characterized by very low productivity and are thus susceptible to over-exploitation. Assuming that overfishing occurred in the 1970s, the limited potential of this species for recovery following a disturbance can be seen by the fact that after over 25 years of reduced catches there is no sign of recovery; instead the decline appears to be ongoing despite little fishing pressure over the past 10-15 years (cf. Atkinson 1995).

STATUS SUMMARY

Roundnose Grenadier abundance indices in trawl surveys have undergone a substantial decline between the 1970s and the 1990s, and the indices have continued to decline in recent years. Unlike the situation with a related species (roughhead grenadier) assessed by COSEWIC (COSEWIC 2007), there is no indication that a shift in distribution has contributed to the declines in survey indices. On the other hand, a substantial portion of the range of this species is at depths greater than those surveyed, so available survey information does not cover the entire distribution. Proportion of mature individuals tends to increase with depth, so coverage of the mature part of the population may be less complete than the immature part. Catch rates in commercial fisheries have also declined substantially over this period; these indices may be affected by factors other than abundance changes but analyses are not available to quantify such effects.

Removals of Roundnose Grenadier were large historically. Based on available information (which may be inaccurate because the two species of grenadiers are not always accurately separated in catches), recent catches could have been substantial relative to a depleted population. Catches are essentially unregulated; directed fisheries are not allowed but bycatch occurs in other fisheries in Canadian waters, and in international waters only mesh size is regulated. The species has market value, as suggested by the large increases in catches in European waters (where catches are also unregulated). The species overlaps in distribution with the species principally targeted in its area of distribution (Greenland halibut) and recorded bycatch in the Greenland halibut fishery has been substantial.

There are uncertainties about whether the available indices accurately reflect changes in the overall population: depth distribution (especially of mature individuals) is not covered, and survey trawl catchability in deepest waters may be lower than at shallower depths because of the difficulties of fishing at great depths. However, the declines in indices are substantial. In the absence of information on the unsurveyed part of the population, a cautious interpretation of the available information would be based on applying the observed declines to the population as a whole, despite the uncertainties.

Atkinson (1995) reviewed the history of assessment and management of this species to the mid-1990s. In concluding, he noted that problems with data and analytical methods had probably led to over-optimistic assessments in the early years of the fishery (1970s-1980s) and that indications of decline had not been taken at face value. Assuming that overfishing had occurred prior to 1977, the sensitivity of this species to exploitation was evident, since there was no sign of recovery and indeed, indices continued to decline. Atkinson (1995) considered that future prospects for recovery, given uncertainties about reproductive success and stock structure, were quite uncertain.

This species is being subjected to unregulated fisheries in the central and eastern North Atlantic, where there is evidence of depletion and a need for stronger restrictions on fisheries (ICES 2006).

SPECIAL SIGNIFICANCE OF THE SPECIES

C. rupestris is not thought to be closely related to any other species within this genus

(Cohen *et al*. 1973). Scott & Scott (1988) recognize one other species in the genus found in Atlantic Canadian waters: *Coryphaenoides guentheri* (Vaillant, 1888). This species occurs in fairly deep water and is shorter in length. The distantly related species *C. armatus* and *C. lionurus*, which occur in deeper waters of the area, have been referred to the genera *Nematonurus* and *Lionurus* respectively (Whitehead *et al*. 1986).

The Roundnose Grenadier is a commercially important deep-sea fish. In Canada, it is now only taken as by-catch.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

In 1974, a quota or total allowable catch limit (TAC) for bycatch of Roundnose Grenadier was established for the Northwest Atlantic Fisheries Organization (NAFO) areas in Canadian waters. Before this, no practice was in place to protect the Roundnose Grenadier. The TAC was never reached, in part due to poor knowledge of the species resulting in little scientific basis for the TAC (Atkinson 1995). Since 1997, in Canadian waters in NAFO Subareas 2 and 3, no directed fisheries for Roundnose Grenadier have been permitted and only a restrictive by-catch fishery is allowed (maximum 5% of targeted catch).

Currently there are no regulations affecting fisheries for Roundnose Grenadier, except for minimum mesh size regulations, in international waters adjacent to the Canadian exclusive economic zone (Power 1999).

The Roundnose Grenadier has not been assessed by the IUCN Species Survival Commission.

In response to substantial recent increases in landings of Roundnose Grenadier in European waters, ICES (International Council for the Exploration of the Sea), the agency responsible for providing scientific advice on fisheries management in the northeast Atlantic, has recommended 50% reductions in effort and catches in areas where high catches are being taken, such as to take catches back to the level prior to expansion of the fishery in the 1990s (ICES 2006). ICES has also recommended that catches not be increased unless removals can be shown to be sustainable (ICES 2006). A precautionary TAC is in place in one of a dozen EC fishery areas but it is not known if this represents a sustainable fishery level.

TECHNICAL SUMMARY

Coryphaenoides rupestris
Roundnose Grenadier Grenadier de roche
Range of Occurrence in Canada:
Continental slope of the Atlantic Ocean from Nova Scotia to Nunavut

Demographic Information

Generation time (average age of parents in the population)	17 yr
Population trend and dynamics	
Observed percentage of reduction in total number of mature individuals over the last 10 years or three generations:2J3K: 1978-94, 98% (Figure 8b) • 2J3KL: 1981-94, 95% (Figure 8d) • 2J3K, 2J3KL (same areas as above): 1995-2005, negative trend not statistically significant (Figs 8b, 8d) • 2J3KL (all areas surveyed, which includes deeper strata than 1981-94): 1996-2003, 91% (Figure 8d)	Greater than 95% in 1.5 generations in surveys covering part of the adult distribution
Projected percentage of reduction in total number of mature individuals over the next 10 years/3 generations.	N/A
Observed percentage reduction in total number of mature individuals over any 10-year/3 generation period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	Yes
Are the causes of the decline clearly understood?	Yes
Are the causes of the decline clearly ceased?	No
Observed trend in number of populations	Not applicable (a single population)
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	Not applicable

Number of mature individuals in each population

Population	N Mature Individuals
Total	Much greater than 2.5 million
Grand Total	

Extent and Area Information

Estimated extent of occurrence (km²)	Not calculated but much greater than 44,000 km^2
Observed trend in extent of occurrence	Probably stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²)	Much greater than 44,000 km^2
Observed trend in area of occupancy	Probably stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Observed trend in area of habitat	Probably stable

Quantitative Analysis

	Not done

Threats (actual or imminent, to populations or habitats)

Fishing is the principal known past and current threat. Directed fishing is not permitted but the species is taken as bycatch.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Davis Strait: depleted; others: unknown. The most likely source of immigrants is the Davis Strait area which is "upstream" from Atlantic Canada.	
Is immigration known or possible?	Possible (larval drift)
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Unknown but perhaps unlikely – potential source population is depleted

Current Status

COSEWIC: Endangered (November 2008)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	A2b
Reasons for Designation: Survey data indices of adult numbers show declines of 98% from 1978 to 1994 with a further decline from 1995 to 2003. Although much of the population lives at depths greater than those surveyed, adding uncertainty to the assessment, this constitutes the best available information to assess species status. The species is long-lived (60 yr) and matures late (around 10 yr) which makes it susceptible to human-caused mortality. Commercial catches were high in the 1960s and 1970s but have since declined, although harvest still occurs.	

Applicability of Criteria

Criterion A (Declining Total Population): Estimated population decline exceeds the criterion threshold for Endangered status.
Criterion B (Small Distribution, and Decline or Fluctuation): Does not apply because the range of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2.
Criterion C (Small Total Population Size and Decline): Does not apply because the estimated population size exceeds 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): Not undertaken.

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