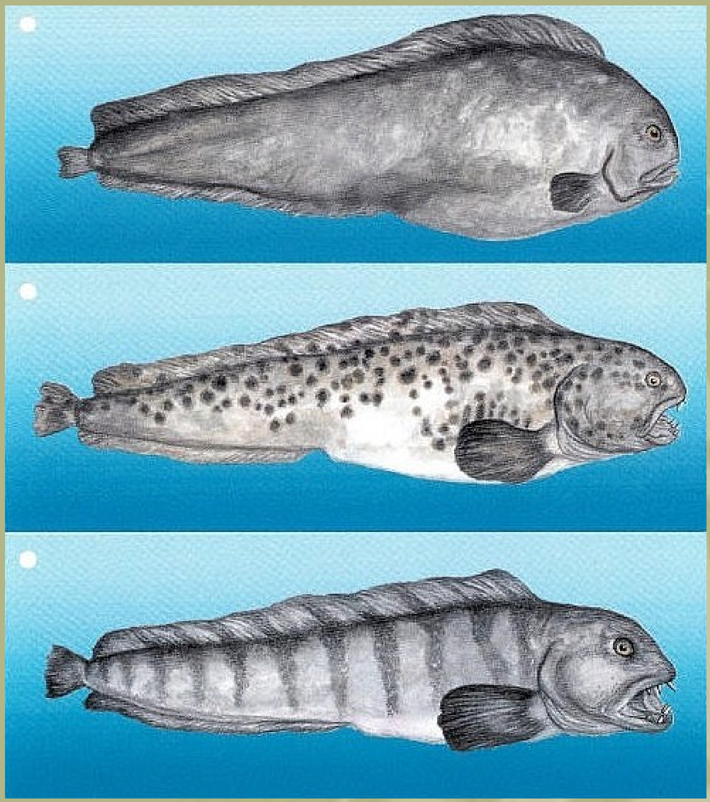
PROPOSED

Species at Risk Act
Recovery Strategy Series

Recovery Strategy for the Northern Wolffish (*Anarhichas denticulatus*) and Spotted Wolffish (*Anarhichas minor*), and Management Plan for Atlantic Wolffish (*Anarhichas lupus*) in Canada

Northern Wolffish, Spotted Wolffish, Atlantic Wolffish



June 2007

Fisheries and Oceans Canada
Pêches et Océans Canada

Canada

About the *Species at Risk Act* Recovery Strategy Series

What is the *Species at Risk Act* (SARA)?

SARA is the Act developed by the federal government as a key contribution to the common national effort to protect and conserve species at risk in Canada. SARA came into force in 2003 and one of its purposes is *"to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity."*

What is recovery?

In the context of species at risk conservation, **recovery** is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed and threats are removed or reduced to improve the likelihood of the species' persistence in the wild. A species will be considered **recovered** when its long-term persistence in the wild has been secured.

What is a recovery strategy?

A recovery strategy is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. It sets goals and objectives and identifies the main areas of activities to be undertaken. Detailed planning is done at the action plan stage.

Recovery strategy development is a commitment of all provinces and territories and of three federal agencies — Environment Canada, Parks Canada Agency, and Fisheries and Oceans Canada — under the Accord for the Protection of Species at Risk. Sections 37–46 of SARA (http://www.sararegistry.gc.ca/the_act/) outline both the required content and the process for developing recovery strategies published in this series.

Depending on the status of the species and when it was assessed, a recovery strategy has to be developed within one to two years after the species is added to the List of Wildlife Species at Risk. Three to four years is allowed for those species that were automatically listed when SARA came into force.

What's next?

In most cases, one or more action plans will be developed to define and guide implementation of the recovery strategy. Nevertheless, directions set in the recovery strategy are sufficient to begin involving communities, land users, and conservationists in recovery implementation. Cost-effective measures to prevent the reduction or loss of the species should not be postponed for lack of full scientific certainty.

The series

This series presents the recovery strategies prepared or adopted by the federal government under SARA. New documents will be added regularly as species get listed and as strategies are updated.

To learn more

To learn more about the *Species at Risk Act* and recovery initiatives, please consult the SARA Public Registry (http://www.sararegistry.gc.ca/) and the Web site of the Recovery Secretariat (http://www.speciesatrisk.gc.ca/recovery/).

Recovery Strategy for Northern Wolffish (*Anarhichas denticulatus*) and Spotted Wolffish (*Anarhichas minor*), and Management Plan for Atlantic Wolffish (*Anarhichas lupus*) in Canada [Proposed]

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Additional copies:

You can download additional copies from the SARA Public Registry (http://www.sararegistry.gc.ca/)

Cover illustration: Fisheries and Oceans Canada

Également disponible en français sous le titre
Programme de rétablissement du loup à tête large (*Anarhichas denticulatus*) et du loup tacheté (*Anarhichas minor*) et plan de gestion du loup atlantique (*Anarhichas lupus*) au Canada [Projet]

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DECLARATION

This proposed Recovery Strategy and Management Plan for the Northern Wolffish, Spotted Wolffish and Atlantic Wolffish has been prepared in cooperation with jurisdictions responsible for the species, as described in the Appendix 1. Fisheries and Oceans Canada has reviewed and accepts this document as its Recovery Strategy and Management Plan for these species as required by the *Species at Risk Act*.

Success in the recovery and management of these species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Fisheries and Oceans Canada or any other jurisdiction alone. In the spirit of the Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans invites all Canadians to join Fisheries and Oceans Canada in supporting and implementing this strategy for the benefit of the Northern Wolffish, Spotted Wolffish and Atlantic Wolffish, and Canadian society as a whole. Fisheries and Oceans Canada will endeavor to support implementation of this strategy, given available resources and varying species at risk conservation priorities. The Minister will report on progress within five years.

This strategy will be complemented by one or more action plans that will provide details on specific recovery measures to be taken to support conservation of the species. The Minister will take steps to ensure that, to the extent possible, Canadians directly affected by these measures will be consulted.

RESPONSIBLE JURISDICTIONS

The responsible jurisdiction for Northern Wolffish, Spotted Wolffish and Atlantic Wolffish in Atlantic Canadian waters is Fisheries and Oceans Canada.

AUTHORS

This document was prepared by D. Kulka, C. Hood and J. Huntington, through the advice of the Wolffish Recovery Team, on behalf of Fisheries and Oceans Canada. The Wolffish Recovery Team members include:

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ACKNOWLEDGMENTS

This Recovery Strategy and Management Plan was written by David Kulka, Catherine Hood and Julie Huntington with extensive input and cooperation from the Recovery Team and other stakeholders as appropriate. Editing was done by the co-chairs David Kulka and Catherine Hood, as well as Derek Osborne (DFO). Funding for the project was provided by the Species at Risk Office: Newfoundland & Labrador Region, Department of Fisheries and Oceans (DFO), St. John’s, Newfoundland & Labrador.

The Wolffish Recovery Team includes representatives from industry, academia, and the provincial and federal governments. The populations of wolffish, in particular the two threatened species, are concentrated largely from the Grand Banks to the Labrador Shelf, which is the jurisdiction of DFO Newfoundland and Labrador Region, and waters adjacent to the province of Newfoundland and Labrador. Thus, the majority of representation on the team was from this area. Industry was represented from leaders of both the inshore and offshore sectors. All sectors of DFO Newfoundland and Labrador Region were represented on the Team. Each Team member consulted extensively within their jurisdiction ensuring broad consultation such that key stakeholders were aware of and had the opportunity to input to this document.

An acknowledgement of gratitude is extended to all the team members for their effort toward the preparation of this Recovery Strategy and Management Plan, including all their efforts in informing and receiving feedback from their respective jurisdictions. The team also wishes to thank the numerous reviewers of this document, from various sectors of the Newfoundland and Labrador Region, from other Atlantic Regions and NHQ. Special thanks goes to MEHM staff who worked on several sections related to habitat, and CEAA and P&E staff from Newfoundland and Labrador, Quebec and Maritimes Regions who provided detailed economic analyses, to ensure best knowledge was included. The collective input of reviewers and contributors has ensured compliancy with the *Species at Risk Act* and has greatly enhanced the quality of a document that deals with a wide range of subject matter.

STRATEGIC ENVIRONMENTAL ASSESSMENT STATEMENT

A strategic environmental assessment (SEA) is conducted on all SARA Recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans and program proposals to support environmentally-sound decision making.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies many also inadvertently lead to environmental effects beyond the intended benefits. The recovery planning process based on national guidelines directly incorporates consideration of all environmental effects, with particular focus on possible impacts on non-target species or habitats. The results of the SEA are incorporated directly in the strategy itself, but are also summarized below.

This recovery strategy and management plan will clearly benefit the environment by promoting the conservation and recovery of northern wolffish, spotted wolffish and Atlantic Wolffish in Canadian waters. The potential for the strategy to inadvertently lead to adverse effects on other species was considered; however, because the recovery objectives recommend additional research on the species and education and outreach initiatives, the SEA concluded that this strategy will clearly benefit the environment and will not entail any significant adverse effects.

EXECUTIVE SUMMARY

Four species of wolffish (family Anarhichadidae) inhabit Canadian waters: *Anarhichas denticulatus* (northern), *A. minor* (spotted) and *A. lupus* (atlantic) in the Atlantic and Arctic Oceans, and *A. orientalis* in the Arctic Ocean only. In May 2001, *A. denticulatus* and *A. minor* were assessed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as "threatened" due to declines in their abundance and biomass. This assessment applies to species likely to become "endangered" if limiting factors are not reversed, while "endangered" refers to species facing imminent extirpation or extinction. COSEWIC indicated that over three generations the abundance of these two species had declined by over 90% and extent of distribution had decreased. Specific threats identified by COSEWIC included bycatch mortality in commercial fisheries and habitat alteration by trawling gear. A third species, *A. lupus*, was assessed by COSEWIC as "special concern", suggesting that it is particularly sensitive to human activities or natural events but is not endangered or threatened at this time. All three wolffish species where included in Schedule 1 of the *Species at Risk Act* (SARA) at the time of the Act's proclamation in June 2003.

A. denticulatus and *A. minor* are the focus of this document, but it also includes discussion of *A. lupus*. This is because the distributions of the three species overlap over much of their range. Although *A. lupus* is at a lower designation, it also underwent a decline as great as that observed for the two threatened species over the northern part of its range (Northeast Newfoundland and Labrador Shelf). The two threatened species are primarily distributed on the Grand Banks and areas to the north. *A. lupus* has a wider distribution in the Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy and Georges Bank, where the other two species are rare. While all three species have undergone substantial declines during the 1980s and 1990s, the proximal cause(s) remain uncertain.

This document has been developed by a multi-sector, multi-regional Recovery Team with representation from the fishing industry, academia and government, both federal and provincial. Government representation included expert scientists, fisheries managers and economists to assist in formulating a framework for the conservation and recovery of these wolffish species.

This Recovery Strategy and Management Plan represents a collaborative and consultative effort by the Recovery Team to present the available knowledge and recommend recovery solutions. The Recovery Team determined that it was best to incorporate both threatened wolffish species into a single "multi-species" document and to include *A. lupus*, a species of special concern, in the discussions due to similar life histories, ecology and taxonomically close relationship.

The Recovery Strategy and Management Plan identifies the paucity of information that exists in regard to population dynamics of wolffish, their ecology, abundance, distribution, habitat utilization, behaviour and interaction with fishing gear and their environment. It points out the immediate need for additional research to enhance formulation of recovery approaches. The document discusses the threats and issues

believed to be affecting wolffish conservation and recovery, and presents recommendations to mitigate them. It also promotes stewardship among stakeholders as a means to facilitate and promote recovery.

The goal of this document is to increase the population levels and distribution of *A. denticulatus*, *A. minor* and *A. lupus* in eastern Canadian waters such that the long-term viability of these species is achieved. This will be accomplished by communicating those objectives and strategies outlined below.

Five primary objectives have been identified to achieve this goal:

- **Enhance understanding of the biology and life history of wolffish species**
- **Identify, conserve and/or protect wolffish habitat required for viable population sizes and densities**
- **Reduce the potential for wolffish population declines by minimizing human impacts**
- **Promote wolffish population growth and recovery**
- **Develop communications and education programs to promote the conservation and recovery of wolffish populations**

All the objectives relate to activities that may be mitigated through human intervention and each is designed to achieve the goals of the Recovery Strategy and Management Plan.

Recommended actions to achieve these objectives are:

- **Study life history of threatened wolffish species**
- **Study population structure within eastern Canadian waters**
- **Identify recovery limit reference points**
- **Study wolffish and ecosystem interactions**
- **Identify wolffish habitat**
- **Define measures to conserve and/or protect wolffish habitat**
- **Identify and mitigate impacts of human activity**
- **Increase resource user knowledge and raise public awareness of wolffish species**
- **Promote stewardship initiatives**
- **Consult and cooperate with harvesters, processors, scientists, regulators, enforcement, observers, dockside monitors and other ocean users**
- **Monitor human activities and wolffish species**
- **Monitor wolffish spatial and temporal abundance patterns**
- **Monitor spatial and temporal patterns of natural and human induced mortality**

The Recovery Team acknowledges the need for adaptive management and the necessity to modify or revise this Recovery Strategy and Management Plan as new information becomes available. It is the view of the Recovery Team that adherence to the recommendations put forth in this document, including the mitigation of known threats, provides the best chance to conserve and restore the three wolffish species to a level where they are no longer considered at risk. It is also recognized by the Recovery Team that the implementation of recovery activities are constrained by available resources and that non-human elements (environmental influences) have played a role in the decline of the species and these effects cannot be controlled/mitigated.

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PART A: SPECIES INFORMATION AND EVALUATION OF CURRENT STATUS

1. INTRODUCTION

Wolffish (Family Anarhichadidae), also referred to as catfish by the fishing industry, inhabit a wide range of northern latitudes in the Atlantic and Pacific Oceans (Scott and Scott 1988). Four species of the genus *Anarhichas* commonly inhabit Canadian waters: *A. denticulatus* (northern or broadhead wolffish), *A. minor* (spotted wolffish) and *A. lupus* (Atlantic or Atlantic Wolffish) in the Atlantic and Arctic Oceans (Barsukov 1959, Templeman 1985, 1986b), and *A. orientalis* (Bering wolffish) in the Arctic Ocean (Houston and McAllister 1990). The first three species are also distributed in the northeastern Atlantic (Barsukov 1959, Baranenkova et al. 1960) including southeast and southwest of Greenland, (Möller and Rätz 1999, Stransky 2001), the latter contiguous with Canadian waters. The west Greenland components (*A. lupus* and *A. minor*) underwent a decline similar in magnitude and timing to the decline in Canadian waters while the east Greenland component did not (Möller and Rätz 1999). Reported catches off west Greenland have not exceeded 100 t in recent years. All three species extend into USA waters, but there they are uncommon (*A. lupus*) or rare (*A. minor* and *A. denticulatus*).

Kulka and DeBlois (1996) described the distribution of the three species off eastern Newfoundland as quite extensive, inhabiting most of the Labrador and northeast Newfoundland Shelves (less so in recent years) to the southern Grand Banks and Flemish Cap (Figure 1). The northern limit of all three species occurs in the Davis Strait. Research surveys on the Scotian Shelf and in the Gulf of St. Lawrence regularly take both *A. denticulatus* and *A. minor*, but at much lower rates than in the Grand Banks to Labrador Shelf region. This would indicate that the former regions represent the southern fringe of distribution for these two wolffish species. *A. lupus* differed from the other two species in that they are densely concentrated on the shallow part of the southern Grand Bank (Kulka and DeBlois 1996). *A. lupus* is also common in the deeper parts of the Gulf of St. Lawrence, on the Scotian Shelf, in the Bay of Fundy (McRuer et al. 2001) and Gulf of Maine/Georges Bank (Nelson and Ross 1992).

Through tagging studies, Templeman (1984) suggested that wolffish are largely sedentary, undergoing limited migration with most recaptures occurring within 8 km of the tagging site. Kohler (1968) and Keats et al. (1985) reported seasonal movement inshore by *A. lupus*. The broad distribution observed for the three species coupled with limited movement as reported by Templeman (1984) suggests the possibility of the existence of Evolutionary Significant Units (ESU's), also referred to as Designatable Units (DU's) or sub-populations. Work is under way to establish whether this is the case.

Wolffish fall into relatively "low" productivity category based on growth, fecundity and age characteristics of *A. lupus* in USA waters as described by Musick (1999). The testes of these species are relatively small, sperm and egg production is low, fertilization is internal, and eggs and larvae are large. Wiseman (1997) reports that newly hatched larvae of *A. lupus* are about 2 cm in length. Although fecundity is low, internal fertilization (Pavlov 1994), nesting habits and egg guarding behaviour in *A. lupus* (Keats et al. 1985) effectively increases potential for survival of individuals during the early life stages. *A. lupus* in Newfoundland waters spawn in September and the entire larval stage is spent close to the hatching location (Templeman 1985 and 1986a). Information on *A. minor* and *A. denticulatus* is more limited, but *A. denticulatus* appears to spawn in late fall or early winter (Templeman 1985 and 1986a). Nesting and egg guarding has not been observed for the either *A. denticulatus* or *A. minor*.

Details of wolffish life history in Canadian Atlantic waters are sparse, perhaps because it is not the target of a commercial fishery. Templeman (1984, 1985, 1986a, 1986b) and Albikovskaya (1982) examined certain aspects of its biology. Kulka and DeBlois (1996) and Simpson and Kulka (2002) described abundance and distribution. McRuer et al. (2001) examined fish sizes and maturity in addition to abundance and distribution of *A. lupus* on the Scotian Shelf and in the Gulf of St. Lawrence. However, many knowledge gaps remain. In particular, no age dis-aggregated studies have been carried out for the northwest Atlantic but age-length relationships are established for the northeast Atlantic (Shevelev 1995). Natural and fishing mortality in the Barents Sea (Shevelev 1992), migration (Riget 1986) and distribution and abundance off west Greenland (Riget and Messtorff 1987, Messtorff 1986) have been examined. The aquaculture potential of the two species (*A. minor* and *A. lupus*) has been examined through egg rearing (Falk-Petersen and Hansen 1994), growth rate (Moksness 1994, Moksness and Stefanussen 1990) and feeding (Orlava et al. 1989a, b) experiments.

Wolffish have been exploited in a directed fishery off Greenland (Mõller and Ratz 1999, Smidt 1981), but within Canadian waters they have only ever comprised bycatch. Kulka (1986) reported on bycatch levels of the three species in Canadian waters. It was noted that annually during the 1980s, about 1,000 t of the three species (combined) were caught in many fisheries directed for other species. About half of the *A. minor* and *A. lupus* caught was landed and all of *A. denticulatus* were reported as discarded. Information on distribution presented by Simpson and Kulka (2002) and Kulka and DeBlois (1996) indicate a potential for overlap of fisheries with the distribution of wolffish species outside 200 miles on the Grand Banks and the Flemish Cap. However, most data on catches of these species outside 200 miles are not accessible.

With the decline in the traditional groundfish (demersal species) resources in the waters around Newfoundland and Labrador, in the early 1990s, interest in the exploitation of alternate species increased. *A. minor* and *A. lupus* had been considered in the mid-1990s as potential candidates for new directed fisheries. However, experimental fishing did not identify areas where catch rates were sufficiently high to warrant directed commercial exploitation. This finding was consistent with studies that indicate wolffish do not form dense concentrations (Templeman 1986a, Kulka and DeBlois 1996, Simpson and Kulka 2002).

Kulka and DeBlois (1996) and Simpson and Kulka (2002) noted a significant decline in research trawl survey indices (numbers and weights) of the three species starting in the late 1970s and early 1980s. While all three species have undergone a substantial decline during the 1980s-1990s, the proximal cause remains uncertain. These declines in abundance were concurrent with a widespread reduction in abundance of many groundfish species from the Grand Banks to the northern Labrador Shelf.

In 2001, two species, *A. denticulatus* and *A. minor* were assessed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as “threatened”. This assessment refers to species likely to become “endangered” if limiting factors are not reversed, while “endangered” refers to species facing imminent extirpation or extinction. The unpublished COSEWIC status reports indicated that abundance of the two species had declined by greater than 90% over three generations, the extent of their distribution had decreased, and threats included mortality as bycatch in commercial fisheries and habitat alteration by bottom trawling. The third species, *A. lupus* was assessed as “special concern” (a species which may become a threatened or an endangered species because of a combination of biological characteristics and identified threats). All three wolffish species where included in Schedule 1 of the *Species at Risk Act* (SARA) at the time of the Act’s proclamation in June 2003.

This document outlines a strategy for the recovery of *A. denticulatus* and *A. minor*, and a management plan for *A. lupus*. The purpose of this document is to lay out a roadmap for scientists, managers and other stakeholders to promote the recovery of wolffish.

1.1 Species Information and Evaluation of Current Status

1.1.1 Species Information: Northern Wolffish

Common **N**ame:	Northern wolffish, Broadhead wolffish, Bullheaded wolffish, Catfish
Scientific Name:	*Anarhichas denticulatus*
Assessment **S**ummary:	2001 (New)
Status:	Threatened (SARA Schedule 1)
Reason for Designation:	Numbers of this large, slow-growing, long-lived, solitary, nest-building fish have declined over 95% in three generations, and the number of locations where the fish is found has decreased. Apparent threats may include mortality as a result of bycatch and habitat alteration by bottom trawling, ocean dumping and pollution, perhaps compounded by environmental change. Dispersal is limited (COSEWIC unpublished).
Canadian Occurrence:	Arctic Ocean, North Atlantic Ocean
Status History:	Assessed as threatened by COSEWIC in May 2001.

1.1.2 Species Information: Spotted Wolffish

Common Name:	Spotted wolffish, Leopardfish, Catfish
Scientific Name:	*Anarhichas minor*
Assessment Summary:	2001 (New)
Status:	Threatened (SARA Schedule 1)

<u>Reason for Designation</u>:	Numbers of this large, slow-growing, long-lived, solitary, nest-building fish have declined over 90% in three generations, and the number of locations where the fish is found has decreased. Apparent threats may include mortality as a result of bycatch and habitat alteration by bottom trawling, ocean dumping and pollution, perhaps compounded by environmental change. Dispersal is limited (COSEWIC unpublished).
<u>Canadian Occurrence</u>:	Arctic Ocean, North Atlantic Ocean
<u>Status History</u>:	Assessed as threatened by COSEWIC in May 2001.

1.1.3 Species Information: Atlantic Wolffish

<u>Common Name</u>:	Atlantic Wolffish, and Catfish
<u>Scientific Name</u>:	*Anarhichas lupus*
<u>Assessment Summary</u>:	November 2000 (New)
<u>Status</u>:	Special Concern (SARA Schedule 1)
<u>Reason for Designation</u>:	Numbers of this large, solitary, slow-growing, late-maturing, egg-guarding benthic fish have declined significantly since the 1970s, over a part of its range. Apparent threats are perhaps related to fishing and habitat alteration, ocean dumping, pollution, perhaps compounded by environmental change (COSEWIC unpublished).
<u>Canadian Occurrence</u>:	North Atlantic Ocean
<u>Status History</u>:	Assessed as Special Concern by COSEWIC in November 2000. Assessment based on a new status report.

1.1.4 General Description of Family Anarhichadidae

Wolffish (Family Anarhichadidae) are elongated fish inhabiting a wide range of northern latitudes and depths in the Atlantic, Pacific and Arctic Oceans (Scott and Scott 1988). They are named for their large powerful jaws with noticeable conical (canine-like) anterior teeth and large lateral molariform teeth used to crush various invertebrate prey (Rodriguez-Marine et al. 1994; Albikovskaya 1983). They have a soft rayed dorsal fin, a small caudal fin, large fan-like pectoral fins and no pelvic fins (Scott and Scott 1988).

Distinguishing features of the three Atlantic species are as follows. *A. denticulatus* is more evenly coloured (dark) with a large head in proportion to the body, hence the alternate name, broadhead wolffish. Templeman (1986b) also described a rarely occurring spotted form of *A. denticulatus*, some of which were previously suggested to be inter-specific forms between *A. lupus*, and *A. minor* (Luhmann 1954). *A. minor* is spotted and darker coloured from pale olive to chocolate brown and *A. lupus* is grey with vertical bars along most of its body length. The most recent information on the biology, distribution and status of wolffish in Canadian Atlantic waters can be found in McRuer et al. (2001) for the Gulf of St. Lawrence and Scotian Shelf, and Simpson and Kulka (2002) for the Grand Banks, northeast Newfoundland Shelf and Labrador Shelf. Life history characteristics of the three species are summarized in Table 1. Wolffish are widespread, but do not form dense concentrations sufficient to support a significant commercial fishery. Thus there is no directed fishery for these species in Atlantic Canada. However, all three are common bycatch in various fisheries. *A. minor* and *A. lupus* were sometimes retained for market.

Table 1. Comparison of essential life history characteristics of three Anarhichas species found in eastern Canadian waters. F = female, M = male. References cited below as superscript are found, similarly superscripted in Literature Cited.

Essential Life History Attributes	***A. denticulatus* (Northern Wolffish)**	***A. minor* (Spotted Wolffish)**	***A. lupus* (Atlantic Wolffish)**
FEEDING			
Prey Type (adults)	Primarily bathypelagic -ctenophores -medusae -some mesopelagic -also benthic invertebrates[1]	Primarily benthic invertebrates -echinodermata -molluscs -crustaceans Also some fish[1]	Primarily benthic invertebrates, -echinodermata, -molluscs, -crustaceans, Also some fish[1]
% stomach contents (by volume)	- majority is pelagic fish	77% inverts, 23% fish, individuals consuming fish were larger (90-107 cm) [3]	85% invertebrates, 15% fish[2]
Teeth replacement	- annually[1], probably during spawning period - reduce or stop feeding[8] - teeth are smaller and sharper and do not wear down as quickly[1]	- annually[1], probably during spawning period - reduce or stop feeding[8]	- annually[1],during spawning period[4] - reduce or stop feeding[8]
Prey Type (larvae)	Similar to *A. lupus*[8]	Similar to *A. lupus*[8]	Crustaceans, fish larvae, [5,6] and fish eggs[6]
REPRODUCTION			
Maturity	> 80 cm[8] (Barents Sea)	Female 75-80 cm NW Atlantic. [3]	Female – 43 cm Labrador (i.e. north) 58 cm St. Pierre Bank & Southern Grand Bank (i.e. South) [4] Female and Male- 5-7 yrs, 35 cm[6]
Fecundity	Low 23,485 eggs @ 112 cm[8] 23,380 eggs @ 134 cm[8] (Barents Sea)	Low 5,080 eggs @ 65 cm 19,760 eggs @ 91 cm[3] (NL)	Low 2,440 eggs@ 40 cm 35,320 eggs @ 120 cm[4] (NL) 2,100 eggs/kg (relative fecundity) [7]
Egg Characteristics	- 7.25 – 8.0 mm[8] - similar to *A. lupus*[8]	- 5.5 – 6.5 mm[11] - similar to *A. lupus*[8]	- 6.0 mm[9] - one cohesive mass[11,12] - not attached to substratum[12] - laid in crevices[12] - rocky bottom[8]
Fertilization Method	?	Internal[10]	Internal[7,11]
Courtship Behaviour	?	?	Extended, beginning 4-5 months prior to spawning[11,12]
Parental Care	?	?	- male guards egg mass[12] - also aerates & turns mass & coats it in skin mucus to prevent infection[13]

Spawning Time	Late in year	NL – Probably during or after July – August[3]	NL - Sept-Oct[12] White Sea – July-Sept[6]
Incubation Time	?	?	7-9 months over the winter[9]
LARVAE			
Size at hatch	25-26 mm[18]	20 – 24 mm[10]	20+ mm[9]
Characteristics at hatch	Similar to other wolffish[8]	- Small yolk sac[10] - Large functioning eyes - Darkly pigmented skin - Well developed fins	- Small yolk sac[9] - Large functioning eyes[9] -darkly pigmented[9] (as with spotted) - Well developed fins[9]
First Feeding	?	Within first few days posthatch[10]	Within first few days posthatch[9]
Behaviour	Pelagic[14]	Feed & live pelagically for several weeks until 40-60 mm[10]	- primarily pelagic until 30-35 mm[9]
DISTRIBUTION	1980-84 – largest concentrations on NE NF & Lab Shelf & Banks, also commonly found on SE & SW slopes of Grand Banks & along Laurentian Channel. Uncommon in the Gulf of St. Lawrence and rare on the Scotian Shelf. 1995-2003 - area occupied & density at low levels in NF and Lab Shelves[17, 19]	1980-84 – concentrated on the NE NF & Lab. Shelf & Banks, south on SE & SW slopes of Grand Banks. Also found in the Gulf of St. Lawrence and Scotian Shelf 1995-2003 - area occupied & density at low levels on NF & Lab shelves[17, 19]	1980-84 - Similar to *A. denticulatus* with an additional concentration on the S Grand Banks, in the Gulf of St Lawrence and on the Scotian Shelf and Georges Bank. Area occupied & density at low levels in northern part of survey range, distribution on S. Grand Banks, Scotian Shelf and Gulf of St Lawrence relatively constant[17, 19]
MIGRATION	Limited migrations noted from tagging [14]	Limited migrations noted from tagging [14]	- Short migrations, with some longer migrations noted from tagging[14] - observed moving inshore to spawn[12] - pelagic young may be dispersed by tides[6]
TEMPERATURE	NL-more common at 2-5°C[15] NE Atlantic- range of –1.0°-6.3°C, more common at 1°-2°C[16]	NL-more common at 1.5-5°C[15] NE Atlantic- range of –1°-7°C, more common at 1° -2°C[16]	NL-more common at –1.5°`–4.0°C[15] NE Atlantic- range of -1.3°-10.2°C, more common in 1°-4°C[16]
DEPTH	NL-Greater range of depth than other sp., 38-1504 m mainly at >500m-1000 m[19] NE Atlantic-down to 840m, best catch rates at 70-300m[16]	NL-Rarely in shallow areas, 56-1046 m, mainly at 200-750m[15] NE Atlantic-down to 600m, best catch rates at 200-530m[16]	NL-Nearshore to 918 m, mainly in 150-350m[15] NE Atlantic-down to 500m, best catch rates at <100m[16]

BOTTOM TYPE	Rocky bottom (at least) during spawning[8] Found over all bottom types observed but highest concentrations over sand and shell hash during the fall survey, coarse sand in spring.	Stony bottom (at least) during spawning[8] Found over all bottom types observed but highest concentrations over sand and shell hash during the fall survey, coarse sand in spring.	Stony bottom during spawning[8] - feeding period prefer complex relief of rocks, rarely in algal growths or even-silted sand, usually observed in shelters[6] - shelters located on 15-30° slopes, with good water circulation, slightly silted bottom, 1-5 openings[6] - occupy most convenient shelter, do not retain same shelter & do not protect them[6] - may have colonial settlements[6]

2. DISTRIBUTION

2.1 Global Range

Wolffish (Family Anarhichadidae) inhabit a wide range of northern latitudes and moderately deep waters in the Atlantic, Pacific and Arctic Oceans. The genus Anarhichas is widely distributed in both the eastern and western North Atlantic, the three species having somewhat overlapping distributions. In addition to its distribution in the northwest Atlantic, *A. denticulatus* occurs in the eastern Atlantic from Greenland, Iceland, the Faroe Isl., Finnmarken, Murman Coast, and Novaya Zemlya. *A. minor* occurs in the eastern Atlantic from Greenland, Iceland, the Faroes, Spitsbergen, White Sea, off the Murman coast, around Scotland, and on the Norwegian Coast south to Bergen. *A. lupus* occurs in the eastern Atlantic from Greenland, Iceland, the Faroes, Spitsbergen, White Sea, Murman Coast, south to the British Isles, and the western coast of France (Scott and Scott 1988).

2.2 Eastern Canadian Range

A. denticulatus, *A. minor* and *A. lupus* occur in the western North Atlantic from the Davis Strait to the Gulf of Maine. The distribution of *A. lupus* extends south of eastern Canadian waters, as far south as Cape Hatteras.

More specifically, *A. denticulatus* occurs from as far north in the Davis Strait at Lat.72°N off Nunavut (northern limit), off southwest Greenland, on the northeast Newfoundland and Labrador Shelves (center of concentration), on the Flemish Cap, in the Gulf of St. Lawrence (uncommon), on the Grand Bank and rarely on the Scotian Shelf (Banquereau and Sable Island Bank), Lat. 42°N. Similarly, *A. minor* occurs off west Greenland (northern limit at about Lat.72°N), on the northeast Newfoundland and Labrador Shelves (center of concentration), the Grand Banks, on the Flemish Cap, in the Gulf of St. Lawrence and on the Scotian Shelf. *A. lupus* has a slightly more southern distribution occurring from west Greenland, on the northeast Newfoundland and Labrador Shelves, in the Gulf of St. Lawrence, on the Grand Bank, on the Scotian Shelf, in the Bay of Fundy, and in the Gulf of Maine (Simpson and Kulka 2002, Scott and Scott 1988). *A. lupus* is common in the Gulf of St. Lawrence, on the Scotian Shelf and in the Gulf of Maine, where the other two species are uncommon or rare. Refer to Figure 2 (a, b and c) for a map of the distribution of the species from the Grand Banks to the Labrador Shelf, the center of their concentration.

2.3 Percentage of Global Distribution in Eastern Canadian Waters

Percentage of global distribution occurring in eastern Canadian waters is not known for any of the species. In Canadian Atlantic waters, each of the species occupies an area of about 500,000 km^2, a significant portion of the global distribution. Although the three species of wolffish are widely distributed in the western Atlantic and thus constitute a significant portion of the global population, *A. lupus* is more densely concentrated to the south and east of Greenland (east of Canada’s territorial limit) where they are dense enough to be the target of a directed commercial fishery.

2.4 Distribution Trends in Eastern Canadian Waters

Fisheries and Oceans Canada (DFO) carried out standard stratified random surveys in the Canadian Atlantic. However, the resulting survey series constitute relative indices because the catchability of wolffish (and other species) is unknown and the series are not comparable among DFO Regions because of different gears and protocols used. The extent of the two threatened wolffish species is far greater in areas of the Newfoundland and Labrador Region, and therefore this is thought to constitute the centre of its distribution. As well, the greatest decline occurred in this area. As such, this document is focused mainly on the Newfoundland and Labrador Region.

On the Grand Banks to the Labrador Shelf between 1977 and 2002, Newfoundland and Labrador regional fall research surveys recorded catches of all three species of wolffish widely distributed throughout the Labrador and northeast Newfoundland Shelves to the southern Grand Banks, the center of their distribution in Canadian waters (Simpson and Kulka, 2002, Kulka et al., 2004).

The area surveyed in the fall covers two distinct areas of distribution based on habitat characteristics. The northern area covers the Southern Labrador Shelf and the Northeast Newfoundland Shelf. There, all three wolffish species were present along the entire shelf to the coast, particularly prior to the decline. This area comprises mainly rocky substrate. To the south on the Grand Bank, the three species inhabit only the periphery of the bank along the shelf edge, with the exception of *A. lupus* that forms a concentration on the southern Grand Bank where the bottom is mainly pebble, sand and mud. Figure 2 (a, b and c), shows the change in distribution between the early 1980s and the 1990s. These aggregate plots of wolffish distributions for the time periods 1980-1984, 1985-1993 and 1994-2001 show a declining distribution in both intensity (lower catch rates) and extent of the distribution of the three wolffish species. This reduction in the area occupied coincides with an observed decline in the biomass and abundance estimates of these species (Simpson and Kulka 2002, Kulka et al. 2004).

In years when the Flemish Cap was sampled, the three wolffish species were also found in abundance there. Surveys were sporadic in the Arctic, but fisheries in Davis Strait as far north as Lat.72°N occasionally capture *A. denticulatus* and *A. minor*, describing the northern limit of the distribution. For *A. denticulatus*, large catches occurred throughout the northeast Newfoundland Shelf and the Labrador Shelf during the early 1980s. However, from 1986-2001, the distribution of larger catches of *A. denticulatus* was increasingly limited to the shelf edge throughout the entire survey area. Similar to the distribution of *A. denticulatus*, the catches of *A. minor* and *A. lupus* were increasingly limited to the periphery of the northeast Newfoundland and Labrador Shelves and the Grand Banks from the mid-1980s to 2001 (Kulka et al. 2004). Overall, the distribution of all three species of wolffish has contracted in recent years relative to their distributions during the 1970s and early 1980s.

A. lupus has a distinguishing feature in terms of its distribution on the Grand Banks. In addition to large catches on the bank edges as is the case for all three species, *A. lupus* is also captured in shallower waters on the southern Grand Bank, a circular on-shelf concentration, where the other two species are not found (Figure 2 a, b and c).

Between 1980 and 1984, *A. denticulatus* were widely distributed throughout the area north of the Grand Bank covering much of the shelf, the eastern Grand Bank shelf edge and the Flemish Cap. From 1985 to 1993, there was a decline in the extent and intensity of the distribution of *A. denticulatus*. Most recently, *A. denticulatus* have been concentrated only on the shelf edge, the edge of the southern Grand Bank and the Flemish Cap.

Prior to 1986, *A. minor* were extensively distributed north of the Grand Banks covering much of the shelf, with a few occurrences along the eastern Grand Bank shelf edge and the Flemish Cap. Between 1985 and 1993, previously observed areas of high density had disappeared, the distribution reduced to low density concentrations along the shelf edge and in deep channels. Most recently (1994-2001), there were no significant concentrations of *A. minor* compared to previous time periods.

Similar to the pattern observed for *A. denticulatus* during 1980-1984 north of the Grand Banks, *A. lupus* were widely distributed covering much of the northeast Newfoundland and Labrador shelves. In addition, a separate aggregation of *A. lupus* centered at Latitude 44°N, west of the Southeast Shoal on the tail of the Grand Bank was also apparent, well separated from the concentrations on the Labrador Shelf. During 1985-1993 and 1994-2001, there was a reduction in the extent and intensity of the northern component of *A. lupus*; however, the southern Grand Bank concentration remained relatively unchanged or increased slightly.

On the Scotian Shelf, the general pattern of distribution of *A. lupus* has remained relatively consistent over the 30-year history of the summer survey (McRuer et al. 2001). *A. lupus* are found over the entire Scotian Shelf, but in recent years, there have been reduced numbers in the mid-shelf regions and greater numbers along the Laurentian Channel and northeast Scotian Shelf. There are also concentrations in the approaches to the Bay of Fundy and around Browns, Roseway and LaHave Banks (McRuer et al. 2001).

Although few *A. lupus* are caught during the fall surveys of the southern Gulf of St. Lawrence, their distribution has gradually expanded in recent years (McRuer et al. 2001). During 1971 - 1980, *A. lupus* catches were restricted to a few areas along the slope of the Laurentian Channel. Since the 1980s, they have been caught along most of the slope of the Laurentian Channel and into the Cape Breton Trough, with small catches in shallower water (i.e., < 100 m) off the coasts of eastern Prince Edward Island (PEI) and the Acadian Peninsula. *A. lupus* have never been observed on the Magdalen Shallows in the central Gulf (McRuer et al. 2001).

Data from surveys in the northern Gulf of St. Lawrence show very little change in distribution (McRuer et al. 2001). *A. lupus* tended to be concentrated mainly along the coast of western Newfoundland and in the northeastern Gulf. Similar distributions were seen in the July and October sentinel surveys, conducted since 1995. The October series, however, shows the fish further offshore than either the research or the (July) sentinel survey, suggesting that the fish may move to deeper water in the fall.

At their center of concentration, both the relative and absolute area occupied by high, medium and low density concentrations of all three species declined from the high density periods of 1980-1984 relative to the current low density periods, 1995-2001 (Figure 3 upper panel; refer to Simpson and Kulka 2002 for a definition of density levels). The decline in the area occupied by high densities of wolffish was most pronounced for *A. denticulatus*, (55%), and least pronounced for *A. lupus* (38%), (Simpson and Kulka, 2002, Kulka et al. 2004). The area occupied by high density *A. minor* concentrations declined by 47%. The middle panel of Figure 3 shows that the overall area of occupancy also declined since the 1980s for the three species, but was most pronounced for *A. denticulatus*, and least pronounced for *A. lupus*. The concentration of *A. lupus* on the southern Grand Bank actually increased slightly (Figure 3 lower panel).

On the Scotian Shelf, the area occupied index (defined as the proportion of the annual survey sets in which a species occurs) for *A. lupus* has been lower in the 1990s following a decline in the 1980s. In the southern Gulf of St. Lawrence, this index increased during the early 1980s and has remained at slightly higher values since then. This index was not available for the northern Gulf of St. Lawrence (McRuer et al. 2001).

Wolffish young of the year (YOY), identified as *A. lupus*, were captured in IYGPT (International Young Gadoids Pelagic Trawl) sets conducted from 1996-1999 (August and September). They were widely distributed offshore on the northeast Newfoundland and Labrador Shelf (Simpson and Kulka, 2002). It is possible that some of those YOY taken in the survey comprised other species of wolffish since fish of that size are difficult to distinguish to the species level. Small (<55cm in length) wolffish, captured in the fall trawl surveys were also found to be distributed extensively in similar offshore areas. Overall, there is considerable overlap in the distribution of small and large (> 55 cm) *A. minor* and *A. lupus* including YOY. In the case of *A. lupus*, there was an increase in the size of catches of small fish from 1995 to 2000 along the edge of the northern shelf and on the southern Grand Bank. For *A. minor*, there has been no apparent increase in the proportion of small fish in recent years.

3. POPULATION ABUNDANCE

3.1 Global Range

Because wolffish are the target of a significant directed fishery in parts of the north Atlantic, primarily in the northeast Atlantic off Greenland (Möller and Rätz 1999) but not in Canadian waters, it is assumed that there is some sort of aggregating phase to their life history and that they form sufficiently dense concentrations there to make a directed commercial fishery viable. If these denser concentrations in the northeast Atlantic extend over an area at least as great as their area of occupancy in Canadian waters, this would suggest that the population of wolffish could be more abundant in other parts of the Atlantic. However, because of different survey gears and protocols used in different parts of the range of wolffish, relative population abundance among various parts of its range cannot be determined at this time.

3.2 Population Sizes and Trends in Eastern Canadian Waters

Biomass and abundance estimates for wolffish at the centre of their abundance, the Grand Banks to Labrador Shelf, were derived from Newfoundland and Labrador regional fall research surveys (Simpson and Kulka 2002) conducted between 1977 and 2001 (Grand Bank, Northeast Newfoundland Shelf and South Labrador Shelf) and spring research surveys between 1971 and 2001 (Grand Bank and St. Pierre Banks only). Neither these fall or spring surveys cover the Gulf of St. Lawrence, the Scotian Shelf or the Northern Labrador Shelf into Davis Strait, although all but the Davis Strait is surveyed at other times with different gears. Thus, the spring and fall series are not comparable and neither covers the entire range of wolffish species in Canadian Atlantic waters. The fall survey series is the best measure of wolffish relative abundance as it extends over the area where all three species are at the center of their distribution (Simpson and Kulka 2002). Thus, the fall survey is used to describe trends in abundance. Although surveys on the Northern Labrador Shelf have been infrequent, the wolffish species there appear to have undergone a similar if not greater pattern of decline from the early 1980s to the mid-1990s, as described below for areas directly to the south.

The magnitude of the Newfoundland and Labrador fall indices after 1995 is not comparable to that of the pre-1995 period due to a change in gear type used during the surveys. Catchability conversion factors between the Engel (pre-1995) and Campelen (current) trawl gear are not available for wolffish species. That gear change is delineated in Figure 4 by a gray vertical bar to distinguish the two series. The area surveyed in the fall is divided into two areas based on distinct distribution characteristics (described above) and habitats. The northern area (2J+3K in Figure 4) covers the Southern Labrador Shelf and the Northeast Newfoundland Shelf and the southern area covers the Grand Bank (3LNO in Figure 4). In both the northern and southern parts of the survey, the indices declined by more than 90% for all three species, since the 1980s, (Figure 4).

For the Grand Banks to Labrador Shelf, *A. denticulatus* underwent the most significant decline of the three species (Figure 4a), greatest in the north (2J3K) and steepest between 1984 and 1994. *A. denticulatus* underwent a less precipitous decline in the south (3LNO). Note that the southern area was not surveyed in the fall prior to 1981. As a result of different decline rates between north and south, after 1991, *A. denticulatus* actually had a higher abundance in 3LNO than in 2J3K whereas, prior to that time, abundance to the north was about 5-6 times greater. Since 1995, the indices for *A. denticulatus*, both north and south, have been stable.

A. minor underwent as nearly a dramatic decline as *A. denticulatus* (Figure 4b). However, in contrast, biomass was approximately equal in the northern and southern areas prior to the decline (Figure 4b). The decline rate was about the same in both areas, unlike *A. denticulatus*, and thus it retained about equal proportions of biomass between areas over the period of decline. Since 1995, the indices and particularly abundance has undergone a substantial increase, more than doubling numbers of wolffish between 1995 and 2001. This suggests recent recruitment and improved survival. However, it should be noted that since 1993, deep strata (and inshore strata) have been successively added to the surveys. What portion of the increase in the indices is attributable to an increased survey area is uncertain (a subject for future research).

Overall, the observed decline in *A. lupus* biomass was not as great as for the other species, but was on a similar scale in the north (2J3K) where most of the decline occurred for this species (Figure 4c). To the south (3LNO), the indices tended to be stable between 1981 and 1994. However, the fish that were located on the shelf edge of the Grand Bank did decline slightly, whereas the concentration on the southern bank actually increased slightly. After 1994 (and the change in survey gear to Campelen), the indices for *A. lupus* increased steadily, particularly to the south, in terms of biomass.

Spring surveys (starting in 1971) covered only the Grand Banks but the spatially restricted series is longer than that of the fall series. This index shows a fluctuating pattern over the longer term and if the spring survey indices reflect the entire population, this would suggest that the levels observed at the start of the fall survey series in 1977 represent a peak in the population (spring numbers were lower prior to 1977). The biomass and abundance spring indices for all three species of wolffish fluctuated over the survey period, increasing during the 1970s, declining in the early 1980s, increasing in the late 1980s and declining again in the early 1990s (Simpson and Kulka 2002). Since 1996, the spring abundance and biomass indices have increased. For both spring and fall surveys, the magnitude of the indices after 1995 are not comparable to earlier years due to the change in survey gear.

The relative size (total biomass/total number) of *A. denticulatus* increased during 1981-1991 in the north (2J3K), but declined thereafter (Simpson and Kulka 2002). For *A. minor*, the relative size of fish in the north was greater than in the south. Associated with the decline in abundance and biomass, the relative size of *A. lupus* also declined in the northern area (2J3K). Throughout the entire survey periods, relatively larger *A. lupus* were captured in the southern areas (particularly on the bank) than to the north. The relative size of all three wolffish species taken in the surveys is smaller in recent years (since 1995) across all areas. This is likely a result of changing to the Campelen survey gear that has a higher catchability for smaller fish. However, a proportionately greater increase in abundance than in biomass after 1995 observed in all three species, to differing extents, suggests that there may be recruitment in recent years as well.

The index of abundance for *A. lupus* from the summer survey of the Scotian Shelf and Bay of Fundy has been highly variable from year to year, and had no apparent trends until the latter half of the 1980s (McRuer et al. 2001). The index for this area increased to its highest values in the time series in the early 1990s, and has since remained above average. The biomass index (mean weight per tow) declined over the same period and is presently close to its lowest level in the series (McRuer et al. 2001). Examination of length frequencies from the Scotian Shelf summer survey indicates that the increase in abundance of *A. lupus* since 1986 was due to a greater proportion of smaller fish. The number of immature fish (<=55cm) since 1985 has been above average, while the number of mature fish declined throughout the period and is presently near the lowest observed in the series (McRuer et al. 2001).

The indices of abundance and biomass for *A. lupus* from the fall surveys of the southern Gulf of St. Lawrence also increased to above average values after 1987, but have declined to average values in recent years (McRuer et al. 2001). As was seen on the Scotian Shelf, the number of immature *A. lupus* increased in the southern Gulf fall survey. Mature fish from this survey were also more prevalent, contributing to the increased abundance after 1987, but have declined to low levels in the most recent surveys (McRuer et al. 2001).

The indices of abundance and biomass for *A. lupus* from the summer research survey of the northern Gulf of St. Lawrence (Div. 4RS), available since 1990, show an increasing trend (McRuer et al. 2001).

Population trends and changes in distribution are not available for *A. denticulatus* or *A. minor* in the Gulf of St. Lawrence or the Scotian Shelf as they are rare in these areas. There are no surveys in the Davis Strait (all three species are rare) and thus indices are not available for those areas either.

3.3 Percentage of Global Population in Eastern Canadian Waters

Different survey gears are used in different parts of the world (and in different parts of eastern Canada) to quantify population size and examine changes over time. Therefore, relative proportions of populations occurring in various parts of the range of the wolffish species in the Atlantic cannot be determined, although the Canadian Atlantic component certainly represents a significant proportion of the global population. Percentages of the global populations in eastern Canadian waters are not known at the present time.

4. BIOLOGICAL LIMITING FACTORS

Based on observed growth and fecundity of *A. lupus* in USA waters, Musick (1999) described the reproductive productivity of wolffish as “low”. The testes of these species are relatively small, sperm and egg production is low, fertilization is internal and eggs and larvae are large. Although fecundity is low, internal fertilization (Pavlov 1994), nesting habits and egg guarding behaviour in *A. lupus* (Keats et al. 1985) effectively increases potential for survival of individuals during the early life stages.

Many demersal fish species in the eastern Canadian waters have undergone similar changes in distribution and population decline over the same time period, but there is little consensus in the literature as to the proximal cause for these multi-species declines. The patterned declines and the contraction of distributions to deeper waters observed with wolffish have also been observed in other species during the same time period (Atkinson 1994, Kulka et al. 1995).

Attempts to relate changes in population size and distribution to environmental signals have met with little success. As well, over-fishing hypotheses have not been fully satisfactory in many instances in explaining the declines. Although bycatch mortality clearly has contributed to the declines, evidence of over-fishing as the proximal cause is lacking for non-commercial species (Simpson and Kulka 2002). For wolffish, the greatest declines occurred where fishing effort was low and the remaining concentrations largely coincide with the most heavily fished areas (Kulka and Simpson 2004). Future research may reveal the importance of environmental factors in the decline.

In addition to the problem of estimating the status of populations arising from incomplete coverage of the population range, the relatively short period that standard stratified random fall surveys have been done (1977 to present) is not sufficiently long to provide information on long term trends for these long lived species. Marine fish undergo natural fluctuations often resulting from variable recruitment and thus peaks and valleys over the long term are the norm. Fluctuating trends are apparent for virtually all monitored species. To pick a point in time when a population is at its peak and compare it to the low point in the trend may not be a valid measure of endangerment with extinction. Not enough is known about the long term population trends of these species, or the environmental influences to fully understand how critical the abundance levels reached in the mid-1990s are to the survival of the species in Canadian waters. However, for species, even at their lowest abundance still numbering in the multi-millions, during a time when the environment was apparently unfavourable (Atkinson 1994), it seems unlikely that biological extinction is an immediate issue.

Fishing pressure accentuates the downward component of fluctuations caused by natural influences even when the exploitation rate is relatively low. How much of the precipitous declines observed between the early 1980s and the mid-1990s is attributable to natural fluctuation and how much is an anomalous event caused by extraordinary circumstances (natural or anthropogenic, or both) is unknown. Nonetheless, attention must be paid to the declining biomass trends and the reduction in extent of the distribution in the 1980s and 1990s, particularly in the north.

If the survey time series for *A. minor* were only available from 1994, the conclusion in 2001 would be that this species nearly tripled in abundance and is at the highest value in the time series in 2001. Similarly, the 1997-1998 values could have been above average. The spring survey data on the Grand Banks going back to 1971 suggest this to be case.

The apparent increase in biomass and abundance since the mid-1990s, for *A. minor* and *A. lupus* is an encouraging sign. Whether this increase resulted from more favourable environmental conditions or reduced fishing pressure in the 1990s, or a combination of effects is unclear. However, several additional years of research survey data are required to confirm whether recovery is taking place. Furthermore, with any apparent increase in biomass, it seems likely that the extent of the wolffish distributions would also increase within the range previously observed in the absence of an environmental shift that might prevent a re-colonization (Simpson and Kulka 2002).

5. THREATS

A discussion of anthropogenic effects leading to the observed decline cannot be decoupled from natural causes since the two are surely linked. The magnitude of the role of natural vs. anthropogenic effects is poorly understood. It seems likely that a combination of natural and human induced mortality, perhaps in combination with poor recruitment, caused the wolffish populations to decline.

We can however exert control over some of the anthropogenic activities that have an impact on wolffish populations. To do this, we need to know which activities constitute a threat to the populations and their habitat, and how to change or curtail these activities in order to lessen their impacts and, at the same time, increase the chances of recovery of the wolffish populations.

However, the current level of knowledge limits the effectiveness and scope of Canadian recovery initiatives. Population structure, absolute estimates of population size and relative contribution of threats to the decline are unknown. Knowledge of exactly how habitat has and is being utilized and to what extent available habitat is critical to the species survival or recovery is unknown (Kulka et al. 2004). With development of that knowledge, a better understanding of the threats can be achieved and measures required to mitigate factors limiting recovery can be refined.

Preliminary information on total removals of wolffish species combined is provided in Simpson and Kulka (2002), but a species by fishery breakdown is required to evaluate the potential impact on each species. Possible bottom alteration due to fishing activities on or near wolffish habitat needs to be better quantified; there is currently little or no information on the effects of bottom trawling, although trawled locations have been delineated by Kulka and Pitcher (2001). The effects of bilge and ballast water are unknown. Pollution from land-based sources that could affect the well being of the species needs to be identified and, to the extent possible, mitigated. Offshore exploration for minerals, oil and other resources needs to be carried out with environmental protection in mind.

Linking stewardship to recovery activities, communication and education programs need to be specific and understandable for each stakeholder. If these initiatives are ineffective, cooperation from legislators, scientists, industry and all other stakeholders in the protection of an incidentally caught fish with low perceived economic value will be difficult to foster and promote. As a result, it is likely that currently known threats will not be properly mitigated and suspected threats will not be studied to determine their relative effects.

There is a need to delineate temporal and spatial effects of threats and the intensity of these threats on the various life stages of wolffish and their habitats. Regional cooperation to protect these threatened wolffish species and their habitat must be implemented.

5.1 Fishing

The impact of incidental capture of wolffish in many fisheries is thought to be the leading cause of human induced mortality. However, what proportion mortality due to fishing activities contributes to total mortality and to the decline of these species is unclear.

Prior to the requirement to release threatened wolffish species taken incidentally in Canadian fisheries, instituted in 2003-2004, wolffish catches and landings were unregulated. There is no directed fishery for wolffish in Canadian waters, but their extensive distributions which overlap fishing grounds have made them a common bycatch in many of the Atlantic fisheries.

Kulka (1986) and Simpson and Kulka (2002) noted that nearly all bycatch of *A. denticulatus* were discarded and about half of the other two species were retained, thus landing statistics underestimate actual catches. Reported catches of wolffish were considerably higher in the 1960s and early to mid 1970s prior to the period of decline (Simpson and Kulka 2002). Trawl effort in the years just preceding and during the decline was considerably lower and has remained low since. During the 1980s, Canadian catches, including amounts discarded at sea, exceeded 1,000 t in most years. Catches then declined after 1991, when many demersal fisheries were closed. Kulka and Pitcher (2001) showed that about 20% of the shelf area on the Grand Banks to Labrador Shelf was trawled annually during the early 1980s, dropping to about 5% in the 1990s. Since the early 1990s, the reduced effort has resulted in less bycatch of wolffish, affording them a level of protection.

A greater proportion of *A. lupus* and *A. minor* was retained in the 1990s. On the Grand Banks to Labrador Shelf, reported Canadian landings were only 23 t in 1996, but increased to 157 t in 1997, 155 t in 1998, 315 t in 1999 and 369 t in 2000. Recent increases are due mainly to bycatch from the cod longline fishery south of the island of Newfoundland. About 250 t are also taken in the yellowtail fishery on the Grand Banks, but all are discarded. In the areas south of the Grand Banks, from the Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy and Gulf of Maine, wolffish landings (almost exclusively *A. lupus*) were 1,000 to 1,500 t in the 1960s, increasing to about 2,000 t between 1968 and 1979 and peaking at about 4,000 t in 1983 (all countries included). Landings dropped steadily to 1,000 t in the early 1990s and were estimated to average about 625 t in the early 2000s, prior to mandatory release of the threatened species. Canadian landings represent approximately 55% of this total, with the remainder consisting mostly of U.S.A. landings from the Gulf of Maine area. Canadian landings of wolffish since 1986 were primarily from the southwest Scotian Shelf and constituted 81% of the total, with the western Gulf of St. Lawrence contributing 10% and the remainder spread out among other areas (McRuer et al. 2001). Since 2004, all *A. minor* and *A. denticulatus* taken incidentally in Canadian waters must be released in a manner that maximizes chance of survival.

Commercial landing statistics lump all wolffish together under the general category "catfish" that includes *A. minor* and *A. lupus*. However, fishery observer records do differentiate by species indicating that since the late 1990s, about 80% of the catch of the two threatened species, *A. minor* and *A. denticulatus* occurs in the Greenland halibut directed fisheries on the Labrador Shelf and Grand Banks (Kulka and Simpson 2004). Commercial log data are thought to underreport catch rates for all three species, as indicated by fishery observer data from various fisheries.

Areas of greatest decline for all three species, on the inner northeast Newfoundland and Labrador Shelf (where wolffish formed high density concentrations in the 1970s) are areas where trawling seldom or never occurs (Kulka and Pitcher 2001) or any other form of fishing seldom takes place. Some of the most intense fishing effort during the 1970s through the early 1990s was located on the shelf edge, north of the Grand Bank where significant concentrations of the wolffish species still occur and where the vestiges of some commercial species such as cod were concentrated just prior to their collapse (Rose and Kulka 1999). Thus, it is the most intensely trawled areas along the shelf edge from the northern Labrador Shelf to the Grand Banks where the three wolffish species continue to be most abundant. That these species undertake limited movements, (Templeman 1984) and given the mismatch in area of greatest decline for wolffish and trawling activity, while certainly contributing to the total mortality, the evidence is contrary to the hypothesis that trawling is the only or perhaps the proximal cause for the decline in wolffish (Kulka et al. 2004). This suggests significant non-fishery influences coupled with fishery related mortality contributing to the distribution and abundance changes observed.

A significant proportion of fishing mortality for wolffish occur outside Canada's territorial limit. Non-Canadian bycatch of wolffish in the NAFO (Northwest Atlantic Fisheries Organization) Regulatory Area (NRA) are thought to be underreported (Simpson and Kulka 2002). Depths fished and amount of effort fished in the NRA suggest that those bycatches could constitute a substantial proportion of the mortality since those captures are unregulated and most of the fish are retained for commercial purposes. Fish taken there are probably part of the same population that inhabits Canadian waters.

Presently, release of all threatened wolffish species captured in Canadian waters is mandatory. However, consideration must also be given to the effects that displaced effort would have if area closures are to be considered as part of a recovery strategy. To mitigate the impacts of human fishing activity, mechanisms for identifying potential bycatch caps and associated implementation measures need to be developed. The issue of over-exploitation due to bycatch (limits established for bycatch of wolffish exceeded in fisheries where quota of the directed species have not been reached) should be a focal point for examining the problems involved in managing a multi-species fishery.

The collection and processing of logbook data related to wolffish catches needs to be examined. To do this efficiently, essential input for logbooks must be identified through cooperation between harvesters, observers and scientists. Design of logbooks in the future must take into consideration that other marine species designated as at risk will have to be recorded. Logbooks should be organized to be able to accommodate the integrated collection of harvesting statistics for a wide range of species not currently reported, including wolffish.

Since harvesting was identified in the COSEWIC Status Report (unpublished) as a cause of the decline of wolffish populations, sustainable harvest bycatch levels need to be determined for each species or population for each fishery (although, as previously indicated, the proximal cause of the decline has yet to be determined). To prevent further population decline and promote population growth for Atlantic Canadian wolffish species, research on life history, population structure and their ecosystem interactions is essential to determine population size and structure, and ultimately how much of the population can be harmed by fishing without affecting recovery.

Harvesting technology, specifically bottom trawling and dredging, have been identified by COSEWIC as possible causes of wolffish habitat alteration. Incremental losses of nesting and shelter habitat (habitat alterations, degradation and associated fragmentation) due to fishing are potential threats to the recovery of wolffish species, a family of fish that apparently have limited dispersal and possible nesting requirements. However, for practical reasons, trawling operations avoid rocky areas since trawling in such areas leads to the destruction of expensive gear. This affords a level of protection for rocky habitats. Also, as noted previously, areas of greatest decline do not correspond with locations of most intense trawling.

5.2 Offshore Oil, Gas and Mining Activities

5.2.1 Seismic Activities

Eastern Canadian waters are a region of intense exploration for petroleum related resources. To identify probable oil and gas reserves, the offshore oil and gas industry uses seismic exploration techniques to evaluate the geology that underlies the sea. This involves the use of towed arrays of airguns – cylinders of compressed air containing a small volume (typically between 10-100 cubic inches) at a pressure of about 2000 psi. The array, containing some tens of cylinders, is repetitively discharged to generate a pressure pulse.

No research has been carried out on the affects of seismic activity on wolffish species but (Sverdrup et al. 1994) suggest that airgun blasts constitute a highly un-physiological sensory stimulus to fish. The noise from airguns generates a compression and decompression wave in the water that, at close range, is sufficient to kill fish at certain life stages (Boudreau et al. 1999). At less than about 5 m, air guns have the potential to cause direct physical injury to fish, eggs and larvae. However, Payne (2004) provides a literature review that suggests that injury to fish eggs and larvae even at close range is limited. It is likely that fish would be driven away from the noise prior to coming close to the air guns, so the risk of physical injury would be greatest for those organisms that cannot swim away from the approaching sound source, especially eggs and larvae. If seismic operations are conducted in areas where larvae are aggregated then higher levels of mortality may occur. However, the level of mortality for marine fish is not regarded as having significant effects on recruitment to a stock (Payne 2004, Dalen et al. 1996). In the case of wolffish, adults and eggs are generally found on or near bottom at distances of 100-900 m away from the surface. Hence, direct physical impact on these life stages will likely be minimal or non-existent. It is the near surface larval stages that could potentially be directly affected by seismic activity. Seismic activity synchronized with periods of larval hatching has the greatest potential for harm.

Little is known about the behavioral effects that may occur at greater distances from the air gun noise source. It is possible that wolffish adults guarding nests could leave the area of disturbance to the detriment of the egg cluster. However, no information exists for wolffish to confirm the potential effects. Effects noted by Dalen et al. (1996) for other fish species included changes in the organism’s buoyancy and changes in their ability to avoid predators. Research indicates a loss of structural integrity and the reduced functional responses indicated a temporary impairment of the vascular endothelium in response to seismic shock in other fish species (Sverdrup et al. 1994).

Research on the sand eel (Ammodytes sp.) indicates that, species lacking swim bladders have a higher hearing threshold than species with swim bladders (Hawkins 1981). The distance at which behavioral effects are induced in species without swim bladders, such as wolffish may likely be shorter than for species that possess swim bladders. Further research is required to determine the hearing capacity of wolffish.

At close distances, airguns produce shock wave forces that have the potential to cause internal damage to air and gas containing organs of fish. One would expect that fish with swim bladders are more susceptible to direct physical injury than those without (i.e. sand eel and wolffish). Therefore, it is incorrect to state that the distance at which biological damage occurs may likely be shorter than for those species with swim bladders. However, if species that lack swim bladders have a higher hearing threshold than species with swim bladders, it would be logical to surmise that the distance at which behavioral effects (i.e. scaring of fish) are induced should be shorter.

The impact of seismic activity and other exploration methods used to research offshore resources needs to be quantified with respect to wolffish and their habitat. There are no documented cases of mortality of any fish species upon exposure to seismic sound under field operating conditions (DFO 2004a). Nothing is known about the possible effect on wolffish species at any stage of their life history, and currently there is scientific uncertainty regarding the potential impacts of seismic activity on marine organisms in general. Any knowledge gained by scientists must be provided as guidance to the industry.

5.2.2 Oil and Gas Exploration and Production

Increased exploration and production of petroleum resources in eastern Canadian waters increases the possibility of oil spills, offshore well blowouts, tanker spills and other potential disasters. These accidents release petrochemicals, dissolved metals (toxic metal ingestion) and other solids to the ecosystem. In addition, exposure to these pollutants and other potential pollutants may result in direct mortality or a host of sub-lethal impairments to wolffish, their prey and their ecosystem (e.g., slower growth, decreased resistance to disease, etc.).

With any petroleum development there is always the chance of a major release of either oil or gas into the environment from a spill associated with the storage and movement of the product after extraction or a blowout during drilling. Well blowouts and major spills, however, have the potential of releasing hydrocarbons at a rate faster than natural ecosystems can accommodate them and of affecting organisms not previously exposed to oil derived hydrocarbons in concentrations greater than trace amounts.

The amount of spilled oil that enters the water by dispersion and dissolution varies considerably with composition and environmental conditions, but generally is on the order of 5-15%. Oil in the water column may have a higher potential toxicity than surface slicks due to the reduced potential for evaporation of the lighter toxic components (Boudreau et al. 1999).

The amount of oil reaching bottom sediments depends on numerous factors including the volume of the blowout, type of blowout (platform or sea floor), hydrocarbon composition, wind, currents and water column structure, depth of water and degree of water column mixing. Transport mechanisms include adherence to particles, incorporation into zooplankton faecal pellets, direct sedimentation of weathered oil particles and vertical mixing.

It remains very difficult to show the impacts of oil-induced mortality on early life stages of finfish and invertebrate resources because of their large and variable natural mortality. The effects of oil on adult fish in the field are difficult to study and therefore knowledge is incomplete. Any mortality of benthic species induced by a single event would probably be limited in both extent and time (Boudreau et al. 1999). If regulations and guidelines are followed, the impacts of accidental events are likely to be negligible for wolffish or other species. As well, the only near surface stage of wolffish is the larval stage and thus, this is the only part of the life cycle that could be potentially effected by the release of hydrocarbons.

Release of hydrocarbons is not the only potential issue. The debris generated from drilling operations has two major components; muds and cuttings. Muds tend to be finer, less dense material, while cuttings are generally coarser and heavier pieces of rock about the size of sand grains (Boudreau et al. 1999). The most obvious impacts of exploratory drilling on the environment have been associated with drilling muds. There are three classes of muds: water- based muds (WBM), diesel oil-based muds (OBM), and alternative-based muds (ABM) that include both mineral oil and synthetics. Once discharged, there are a number of different processes that act on them and that determine their fate and potential impacts on the environment.

The circulation and Benthic Boundary Layer Transport (BBLT) determines the fate of fine particles of drilling mud, the key determinants of dispersion, and how impacts might change with seasons (ESRF 2000). Roughly 10% of the discharged wastes is neutrally buoyant and forms a surface plume (NCR 1983). The factors that significantly affect the depth of descent were found to be mud density, depth of release, initial downward volume flux of the discharge, current strength and water column stratification (Andrade and Loder 1997). Discharged drilling muds can accumulate in low energy systems to smother benthic organisms near the rig and result in their suffocation. Similarly, in high settling velocity of the cuttings, there is reason to believe that smothering might kill significant numbers of slow moving or sessile organisms in the area directly under a drill rig (Boudreau et al. 1999).

A synthetic based drilling fluid (IA-35) is presently being used in the Newfoundland & Labrador offshore. Toxicity studies carried out on scallops as well as selected studies with plankton and fish larvae, indicate a very low potential for acute toxicity (Cranford et. al 2000; Armsworthy et al. 2000; Payne et al. 2001). The acute toxicity data available for both synthetic and water-based fluids indicates that discharges from platforms into well mixed waters should result in little or no chemically mediated acute effect (Neff 1987; GESAMP 1993; Payne et al. 1995). It has been demonstrated that cuttings have a very low acute toxicity as well (Payne et al. 2001).

At the Hibernia oil production site on the Grand Banks, the zone of biological effects seems to be localized. However, further studies should be undertaken on resource species such as American plaice. Hydrocarbons and metals decline within 1000m, polyaromatic hydrocarbons (PAHs) are below detection limits, the sediments are non-toxic, and there is no evidence of taint in American plaice caught within 3000 m of the platform. Overall, no significant impacts have been found (ESRF 2000). Extrapolations indicate little or no risk even as close as 1000m or less from the rig site over the life of the project. Risks could also be further reduced at development sites in deeper waters or sites with stronger currents and thus greater potential for particle dilution and dispersion (Payne et al. 2001).

Other literature indicates physical and toxic effects of discharges. Effects of high toxicity oil-based mud were found to be restricted to within 500m of rigs, however, subtle effects in benthic organism diversity and community structure can be observed as far away as several kilometers (Olsgard and Gray 1995; Daan et al. 1990; Kingston 1992). Water-based mud, although not toxic, can bury organisms, and its effects were found at 50-100m. The effects of synthetic-based mud were found at 250-500m. The toxic effects of ester-based muds are greater due to their high oxygen consumption (ESRF 2000).

Produced water contains heavy metals, hydrocarbons, nutrients, radionuclides and added chemicals. At present the environmental impacts of produced water are unclear. The potential for toxic effects may be reduced quickly through dilution but chronic effects may emerge due to long term exposure, and inhibitory effects may be seen. Also, contaminants may be sequestered in the benthic environment through physical and chemical processes (e.g. flocculation). Dilution does not completely abate the effects of dumping, nor does the waste sit still once it gets to the bottom (ESRF 2000).

Petroleum operations in Norway have been in operation for the past 20 years. Environmental assessments indicated distribution of effects of discharges to be up to a 10 km, much wider than predicted in the 1960s (ESRF 2000) but still a relatively small area in relation to the area occupied by wolffish.

Routine operational exploratory drilling activity is likely to have only localized impacts on the ecosystem components reviewed. The actual impacts will be dependent on the location, timing of the activities, and the properties of discharges. There exists a small probability that these impacts will have population and ecosystem level impacts (Boudreau et al. 1999).

In summary, operational discharges would cause some biological effects over relatively short time periods, and small distances from the discharge point. Smothering of benthic organisms by deposited mud and cuttings would not be anticipated outside an estimated 0.5 km radius from the rig. The use of lower toxicity water-based drilling muds should minimize the direct mortality on organisms, as would the use of low toxicity oil for lubrication and a spotting fluid. The zone of impact around a rig would vary with location time and quantity of discharge. Impacts would disappear rapidly once drilling ceases. It is anticipated that the dispersed muds, cuttings and associated hydrocarbons would cause localized sublethal effects for some bottom dwelling organisms. Because of the large degree of spatial and temporal variability in natural populations, and the limitations of current sampling methods, it is expected that it would be very difficult to detect the net result of any impact at the population level (Boudreau et al. 1999). Thus, any potential effects on wolffish would be highly localized insignificant to the population as a whole.

5.3 Ocean Dumping

5.3.1 Sewage Sludge

Sewage sludge may be disposed of in the marine environment by coastal dumping or pipeline discharge and have a known impact on both planktonic and coastal benthic communities. Sewage sludge contains bacteria and viruses, that are known to be toxic to shellfish, but their effect on wolffish is unknown. As much of this dumping is coastal, it is thought that the effect on widely distributed wolffish would be minimal. However, the potential of these effects need to be evaluated, and if identified as harmful, impacts must be mitigated.

5.3.2 Fish Waste

During the processing of fish and other marine organisms, a large volume of wastes are generated, including fish heads, tails, guts and internal organs. Fish waste can amount up to 75% of the weight of a fish before processing, depending on the species and process. Waste resulting from the industrial processing of fish and other marine organisms is rich in animal proteins and fats. Substances in the fish waste may undergo physical, chemical and biochemical changes when deposited in the marine environment. As well, various chemicals, primarily heavy metals and chlorinated hydrocarbons contained in the fish waste, may be accumulated in marine sediments, and subsequently released into the water column under specific circumstances, thereby becoming available to marine organisms.

The waste is subject to a rapid degradation process under the effects of heterotrophic bacteria. Waste that is not consumed by other marine organisms becomes an object for the activity of heterotrophic bacteria. Continuous dumping of the waste would lead to an increase in the density of heterotrophic bacteria in the dumping area. Eutrophication induced by the dumping of waste may change the structure of plankton and benthic communities. In critical conditions, oxygen depletion may have detrimental impacts, causing mortality.

Fish and other marine organisms may contain various chemicals, such as heavy metals, antibiotics and hormones. Concerns appear warranted regarding the overuse and misuse of certain chemicals, for which a proper risk assessment has not been made in relation to the marine environment. However, these issues apply mainly to coastal habitat and particularly to aquaculture species.

The susceptibility of fish waste to such changes should be considered in light of its eventual fate and potential effects. In addition, various chemicals contained in fish waste, as well as disease vectors and non-indigenous species, may have adverse impacts on wild fish populations consuming the fish waste. The chemicals may accumulate in the marine sediment, affecting benthic flora and fauna. In the past, it was common practice to dispose of such waste at sea, with the risk of overloading the ecosystem.

The effects on wolffish from the above mentioned are unknown, but are likely minimal since most of these effects are localized and coastal whereas wolffish tend to be widely distributed.

5.3.3 Dredging Spoils

It has been shown that sludge material dumped by barges reaches the ocean bottom, but not necessarily at the exact location where it was discharged, and that it has significant effects on the metabolism, diet, and composition of organisms that live there. The movement of dredge spoils from dumping can have multiple impacts on a series of adjacent habitats over time. The distance traveled by various particle types depends primarily on the size and density of the material, current velocities and weather patterns. The impact of the original spoil material may be magnified with subsequent re-suspension and deposition by tidal currents. Contaminants introduced to the sediments from dumping penetrated to a depth of 5cm below the sea floor as organisms living in the sediments burrowed through them. The contaminated materials that have entered the benthic food web have created a new benthic environment favoring species that can exploit the organic material available in sewage sludge.

Hard-bottom assemblages that become smothered by spoils from dumping can suffer drastic macrofauna and macroflora changes. Most invasive macrofauna are either sedentary and limited to settlement on exposed boulders above the spoil, or errant species (Elner and Hamet 1984). A positive effect of dredging was that species richness and individual weights increased in the dredged areas because the holes in the seabed created habitat refugia (Morton 2001). For wolffish, it seems likely that the impact of dumping of ocean spoils would be minimal since the area impacted would be very confined.

Wolffish and their habitat should be considered valued environmental components (VECs) and reported on when decisions are being made with regard to offshore activities requiring Environmental Assessments.

5.4 Military Activity

Military activity has and continues to take place in many areas of eastern Canadian waters. Little is known of the impacts of these activities and their effects on wolffish and their habitat. These effects need to be evaluated and potential impacts mitigated.

5.5 Cables and Pipelines

The placement of physical structures on or in the bottom substrate/water column could affect wolffish habitat although in a spatially limited manner. Given the widespread distribution of wolffish, impacts associated with these activities are likely minimal but need to be quantified.

5.6 Marine and Land-Based Pollution

Any human activity which has the potential to cause degradation to wolffish habitat, though marginal, needs to be identified, cleanup undertaken where appropriate, and prevention measures put in place. Associated land-based forms of pollution including runoff that contain excess nutrients, sediments, pathogens, persistent toxins or oil may significantly affect the marine ecosystem. The magnitude of change and its form depends on many factors including, the types of dissolved or suspended particles, such as non-biodegradable organic chemicals. These pollutants may adversely affect the reproductive capabilities of wolffish, their prey and surrounding vegetation as well as interfere with their general health.

5.7 Global Climate Change

The role of climate change as a factor in the decline of wolffish populations is currently unknown. Atmospheric changes may lead to changes in ocean productivity, species composition and habitat. Alterations in the chemical, biological and physical composition of habitats may influence population reproduction, mortality rates and individual behaviour. Historical data sources could be used to examine relationships between climate and trends in the distribution and abundance of wolffish. The investigation of climate change as a factor in the decline of wolffish is not a trivial task. It may be that no definitive answers will be found.

5.8 Natural Mortality (parasites, disease, predation and environment)

As with the vast majority of marine species, little is known of the effects of parasites, diseases, predation or environmental conditions on the survival of wolffish species. Pathological conditions and causal factors need to be identified as well as potential predators. Natural mortality may have played a significant role in the decline of these species, but as yet these processes are poorly understood.

5.9 Summary of Threats

Impact of incidental capture of wolffish in many fisheries is thought to be the leading cause of human induced mortality. However, the live release of spotted and northern wolffish mitigates the affect of incidental capture to some degree (see Part B, Section 5.3). Other potential sources of harm (habitat alteration, oil exploration and production, pollution, shipping, cables and lines, military activities, ecotourism and scientific research) are considered to have negligible impacts on the ability of both spotted and northern wolffish to survive and recover (DFO 2004b).

It is also recognized that non-human elements (environmental influences) may have played a role in the decline of the species and these effects cannot be controlled/mitigated. These environmental effects may continue to play an unpredictable role in the future. Thus, this document addresses anthropogenic influences only.

6. HABITAT IDENTIFICATION

Habitat characteristics within much of the area occupied by wolffish are poorly described given the vast area and great depths below the surface that constitutes the range of the species. Knowledge of the habitat associations of wolffish is limited (Simpson and Kulka 2003) and extent of the habitat that is critical for survival remains undefined (Kulka et al. 2004). Known associations are based on the occurrence of wolffish in research trawls and the associated depth and water temperature collected during the survey sets. Seabed classification data (ROXANN) that have been collected since 1992 were used to relate sediment type in the vicinity of survey trawl locations. From these acoustic data, seabed roughness and hardness indices were derived to classify the sediment to categories of mud, sand, sand & shell, shell & pebbles, small rock, hard bottom or undefined (Naidu and Seward 2002, unpubl. data). These studies, reported in Kulka et al. (2004) were undertaken at the center of distribution of the three species on the Grand Banks to Labrador Shelf.

6.1 Habitat Associations

The three wolffish species inhabit a large proportion of Canadian Atlantic waters over a variety of benthic habitats but are at the center of their distribution, reaching highest density and covering the largest area, on the northeast Newfoundland and Labrador Shelf. There they distribute over a wide range of depths, from about 20 m to >1500 m, with *A. denticulatus* occupying the widest range and *A. lupus* the narrowest. Temperature is an important feature of wolffish habitat. All three species are associated with a narrow thermal range of above average bottom temperatures (mainly 1.5-5.0°C) and are largely absent where temperatures are $<0^0$C. As such, wolffish may be classified as "temperature keepers"; they maintain a similar temperature range by changing their distribution. Given their narrow thermal association, cooling that occurred in the late 1980s-early 1990s may have contributed to the distributional changes observed for wolffish during that period (Kulka et al. 2004).

A common misconception is that the three species of wolffish share a common habitat association residing in rocky crevasses. Kulka et al (2004) indicated that each of the species occupies a somewhat different niche. Key differences between species, described below in more detail, are as follows: *A. lupus* distributes in more shallow, southern waters more often associated with hard bottoms than the other two species; *A. denticulatus* spends more time off bottom, and when on bottom at deeper locations are over more diverse bottom types; *A. minor* inhabits an intermediate niche in terms of depth and temperature.

6.1.1 *A. denticulatus*

A. denticulatus is a deepwater fish of cold northern seas. At the center of its distribution on the Grand Banks to Labrador Shelf, it is found at depths from 38 to 1504 m (maximum depth surveyed), densest concentrations occurring offshore between 500 and 1000 m (slightly shallower in the warmest months) at temperatures of 2 to 5° C, (Kulka et al. 2004). It inhabits a wide range of bottom types, including mud, sand, pebbles, small rock and hard bottom (Kulka et al. 2004). Unlike other wolffish, *A. denticulatus* has been found off bottom during both juvenile and adult stages in the northeast Atlantic (Shevelev and Kuzmichev 1990). In the Canadian Atlantic, it spends a significant amount of time in the mid-water as evidenced by a diet comprising a significant proportion of bathy-pelagic (water column below 200 m) and meso-pelagic (upper 200 m) organisms (Roman et al. 2004 and research presently under way). Like other wolffish, it does not form aggregations as dense as some commercial species. Tagging studies by Templeman (1984) suggests that it undertakes only limited migrations. In the northeast Atlantic, the species has been observed defending an area around bait and acoustic tracking showed that the size of that area was quite restricted (Godø et al. 1997). Refer to Table 1 and 2 for further details.

6.1.2 *A. minor*

The distribution of *A. minor* is quite similar to that of *A. denticulatus* except that they seldom inhabit the deepest trenches or as deep along the shelf slope. Observed in waters at depths between 56 and 1046 m, the densest concentrations of *A. minor* occur between 200 and 750 m and at temperatures of 1.5-5.0°C (Kulka et al. 2004). Similar to *A. denticulatus*, it inhabits a wide range of bottom types including mud, sand, pebbles, small rock and hard bottom (Kulka et al. 2004). Tagging and other studies indicate that migrations are local and limited (Templeman 1984). *A. minor* is a benthic feeder consuming a wide variety of echinoderms, crustaceans and molluscs associated with both hard and sandy bottoms. Refer to Table 1 and 2 for further details.

6.1.3 *A. lupus*

A. lupus is primarily demersal and inhabits shallower depths than the other two species. It is commonly observed near shore out to 918 m (the deepest record of occurrence off the Labrador Shelf) and tolerates temperatures from –1.0°C to 10.0°C. The densest concentrations are found between 150 and 350 m and at temperatures of 1.5°C to 4.0°C. Although this species is found as far north as the Labrador Shelf, highest densities are found on the southern Grand Banks and Scotian Shelf, and is the most common of the three species there and in the Gulf of St. Lawrence. Unlike the other two species, *A. lupus* is often observed as individuals close to shore by divers. They also form dense concentrations offshore. Movements are limited but seasonal inshore migrations may occur in the spring when mature fish are found in shallow waters at depths of 0 to 15 m. They feed around rocky bottoms on whelks, sea urchins, brittle stars, crabs, scallops and occasionally redfish. Large eggs are laid in clusters on the bottom, often in rocky crevasses, and are guarded by the male. Larvae remain mostly close to the bottom, rarely swimming to the surface and tend to remain close to the site of hatching (COSEWIC unpublished). Refer to Table 1 and 2 for further details.

Table 2. Average bottom depth and temperature by NAFO Division (from a spring and b) fall research surveys at locations where wolffish were captured.

a) Spring Surveys — **NAFO Division**

A. denticulatus	**3L**	**3N**	**3O**	**3P**
Avg. Depth (m)	406	483	452	385
Avg. Bottom Temperature (°C)	2.6	3.7	4.4	4.0
A. minor	**3L**	**3N**	**3O**	**3P**
Avg. Depth (m)	301	376	285	213
Avg. Bottom Temperature (°C)	1.9	3.0	4.6	3.9
A. lupus	**3L**	**3N**	**3O**	**3P**
Avg. Depth (m)	274	167	109	141
Avg. Bottom Temperature (°C)	2.0	2.0	2.1	2.5

b) Fall Surveys — **NAFO Division**

A. denticulatus	**2G**	**2H**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**
Avg. Depth (m)	416	398	350	386	398	465	477	544
Avg. Bottom Temperature (°C)	2.6	2.7	2.2	2.8	2.1	3.8	3.1	4.3
A. minor	**2G**	**2H**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**
Avg. Depth (m)	305	264	251	309	279	340	324	301
Avg. Bottom Temperature (°C)	2.6	1.8	1.7	2.4	1.4	3.9	2.4	4.5
A. lupus	**2G**	**2H**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**
Avg. Depth (m)	296	286	261	292	278	268	208	129
Avg. Bottom Temperature (°C)	2.6	2.4	2.0	2.4	1.8	3.9	2.6	2.9

Wolffish were observed to associate with six sediment types (Table 3). The bolded numbers show the largest values for each species for each survey period. In DFO fall research surveys, the average number per trawl was greatest on sand and shell hash sediments for *A. denticulatus* and *A. minor*, while the average number per trawl for *A. lupus* was greatest on rock habitats. All three species were associated with all sediment types except mud, in which only *A. minor* were captured. During the spring research surveys, the average number per tow for *A. lupus* was greatest on rock sediments, similar to the fall survey results. However, for both *A. denticulatus* and *A. minor*, the greatest number per tow occurred in association with coarse sand sediments. Kulka et al. (2004) also investigated inter-annual differences in the association of wolffish with sediment association.

Table 3. Average catch rates for wolffish from DFO spring and fall research surveys in relation to average bottom type derived from ROXANN data. Highest values are bolded.

	Fall			Spring		
Sediment Type	***A. denticulat.***	***A. minor***	***A. lupus***	***A. denticulat.***	***A. minor***	***A. lupus***
Mud	0	0.6	0	0	0.2	0
Coarse sand	0.112951	0.185624	0.96319	**0.234679**	**0.300952**	0.57690
Sand and Shell Hash	**0.242475**	**0.260584**	0.707821	0.219048	0.298338	1.139231
Gravelly Sand	0.197957	0.092760	0.905966	0.158742	0.059315	0.609833
Rocks	0.052149	0.123602	**1.422396**	0.055852	0.091352	**1.296845**
Boulders and rocks	0.047453	0.066691	1.402653	0.016485	0.038340	0.583581
Unidentified				0	0	0.5

These data provide preliminary information on wolffish habitat utilization with respect to three habitat features, temperature, depth and bottom sediment. However, they are insufficient to provide definitive evidence on habitat characteristics that are required to achieve and sustain viable wolffish populations.

6.2 Critical Habitat

Kulka et al. (2004) stated that “direct observations of physical habitat associations for widely distributed, oceanic species, such as wolffish, is problematic. Determining what is critical to survival of a species in an enclosed and directly observable environment such as a marsh or pond is far less complicated than for species that inhabit vast expanses of the unobservable ocean sub-surface.”

Three factors impede the definition of critical habitat in the open ocean in general and for wolffish in particular. First, deficient knowledge of wolffish life history, second, limited information on the influence of multi-scale processes upon wolffish population dynamics, and third the lack of information on acceptable targets for wolffish population abundance and range. Consequently, it is difficult to define critical habitats for wolffish, particularly since each developmental stage may have different requirements that are at present unknown.

Kulka et al. (2004) spatially defined changes in extent of the habitat for the three species on the Grand Banks, northeast Newfoundland and Labrador Shelves by mapping and overlaying the historic and present range of the three species (refer to Figure 5 in that paper). For all three, the area formerly but not presently occupied (potential habitat) occurs primarily on the inner portions of the northeast Newfoundland and Labrador Shelves off the coast of Newfoundland and Labrador. The presently unoccupied area is greatest for *A. denticulatus,* least for *A. lupus*.

Given that two of the species, *A. lupus* and *A. minor*, are increasing in part of the range and stable elsewhere, and that *A. denticulatus* is stable over much of its range, it may be that area presently occupied is sufficient to maintain viability. However, reoccupation of all or part of the formerly occupied range would constitute a desirable target and an indicator of recovery, in conjunction with an increase in abundance.

Minimum habitat needed to maintain or increase current population size for the three wolffish species are not known at this time. Initial wolffish habitat data have been collected (Simpson and Kulka 2003, Kulka et al. 2004 - see description of critical habitat above). These data, though inconclusive, give preliminary evidence of wolffish habitat preferences but are insufficient to provide definitive evidence on the habitat characteristics needed to achieve and sustain viable wolffish populations. However, for the reasons stated above, present occupation appears to be sufficient to at least maintain current population size.

6.3 Habitat Trends

Kulka et al (2004) described reductions in distribution of wolffish for the Grand Banks to Labrador Shelf. *A. denticulatus* occupied 57% of the surveyed area from the Grand Banks to Labrador Shelf, contracting to a low of 19% during 1990-1995, increasing to 23% since 1995. Unoccupied areas or areas previously occupied corresponded to the coldest locations. The area occupied by *A. minor* also decreased during the period of decline. Area occupied changes were less variable than for *A. denticulatus*, ranging from 48% to 23%, and currently at approximately 31%. *A. lupus* underwent the most significant changes in the northern part of the surveyed range, similar to the other two species. Area occupied, previously 55%, declined to a low of 38% and is currently at approximately 56%. The concentration of this species occurring on the shallower part of the Grand Banks underwent relatively little change.

The area occupied index for *A. lupus* on the Scotian Shelf was lower in the 1990s following a decline in the 1980s, steady at a low level since 2000 (McRuer et al. 2001). In the southern Gulf of St. Lawrence, this index increased during the early 1980s and has remained at slightly higher values since. *A. lupus* became slightly more concentrated on the Scotian Shelf during the 1980s and has remained so throughout the 1990s. In contrast, in the southern Gulf of St. Lawrence, the distribution increased in the 1980s and has remained marginally more wide-spread throughout the 1990s (McRuer et al. 2001).

Kulka et al. (2004) indicated that temperature is an important feature of wolffish habitat. Changes in temperature have affected distribution, if not abundance. All three species are associated with a narrow thermal range of above average bottom temperatures and absent where temperatures are <0°C. This explains why they do not occur on the northern Grand Bank or the banks northeast of the island of Newfoundland, where sub-zero temperatures occur year round. More specifically in terms of location, the inner portion of the shelf, where all three species underwent their greatest reduction, corresponded to the coldest areas of the range of each of the three species. At their lowest abundance (1990-1995), each of the species was restricted mainly to the warmest locations available along the outer shelf and it was during this period that some of the lowest bottom temperatures were recorded (Colbourne et al. 2004). Kulka et al. (2004) speculated that unfavourable temperatures over a part of the range could have restricted the extent and population size of wolffish.

In terms of sediment type, it is expected that sediments would have remained relatively constant with some alteration brought about by trawling activity over a relatively small part of the area (Kulka and Pitcher 2001).

6.4 Habitat Protection

At the present time, critical wolffish habitat has not been specifically defined and effect of fishing gears on the benthic habitat of wolffish is poorly understood. Thus, no specific protection plans can be put in place for the conservation and protection of wolffish habitat in eastern Canadian waters. Kulka and Pitcher (2001) showed that about 20% of the shelf area of the Grand Banks to Labrador Shelf, mainly on the outer shelf, was trawled annually during the early 1980s. Area trawled dropped to about 5% in the 1990s. It is these areas where alteration of the benthic habitat would have taken place. However, nature and extent of alterations and potential effect on wolffish species is unknown.

7. ECOLOGICAL ROLE

Eggs, larvae and juveniles of wolffish are susceptible to predation by a number of species, although for at least one of the species (*A. lupus*) the eggs are guarded by the adult males until hatching. Adults have fewer predators given their size and substantial teeth. They may also spend a part or their time in rock crevices. The role of each wolffish species as a forage fish is undetermined, though they do appear to be a food source for several species as larvae and young. *A. denticulatus* in the northeast Atlantic has been observed defending a territory around bait on the bottom from cod and haddock, and acoustic tracking over time showed that the size of that territory was quite restricted (Godø et al. 1997).

8. IMPORTANCE TO PEOPLE

Historically there were no significant directed fisheries for wolffish in Canadian waters and, prior to March 2003, the only applicable regulation regarding wolffish is contained in the 1985 Atlantic Fishery Regulations that mandated fishers to retain and land all wolffish bycatch.

Following the decline of many “traditional” species in the early to mid-1990s, *A. minor* and *A. lupus*, as well as other “non-traditional” species, were considered as potential candidates for new directed fisheries. Of the three wolffish species, only *A. minor* and *A. lupus* have commercial value and as a result of concerted marketing efforts in the 1990s, commercial interest in wolffish had increased. Product demand had improved its market value in the late 1990s. Increasingly, *A. minor* and *A. lupus* were processed into frozen or fresh fillets. In addition, it was known that the skin of *A. minor* can be tanned and used for leather. Since *A. denticulatus* has no commercial value, it had been discarded and not reported to DFO. *A. denticulatus* are occasionally consumed by Greenlanders, though their gelatinous flesh is not generally favored and its skin is not suitable for secondary processing (COSEWIC unpublished).

Experimental fishing, however, did not identify areas where catch rates were sufficiently high to warrant directed commercial exploitation. Therefore, all three species were caught in mixed fisheries or incidentally through targeted fisheries, primarily for Greenland halibut (*Reinhardtius hippoglossoides*) but also with other demersal fisheries such as cod (*Gadus morhua*), and yellowtail founder (*Limanda ferruginea*). Invertebrate fisheries such as for shrimp and crab species incidentally capture wolffish as well.

Mandatory release of *A. minor* and *A. denticulatus* in a manner that maximizes chance of survival, has been instituted through license amendments in the all Atlantic Regions of DFO as of 2004. Consequently, fishers, if previously retaining *A. minor* for market purposes, may notice a decrease in the total landed value of their catch as they are now required to return that species to the ocean at the point of capture. The greatest captures of wolffish for commercial trade were reported from the south coast of Newfoundland and from Nova Scotia. However, nearly all of the captures from those areas are *A. lupus*.

8.1 Newfoundland and Labrador Region Landings and Value

All three wolffish species in the Newfoundland and Labrador Region were reported in DFO landing statistics as "catfish". Therefore, species-specific analysis cannot be conducted and only broad socioeconomic conclusions can be reached.[1] However, fishery observers deployed to a portion of the fleets in most Newfoundland and Labrador fisheries estimate the catch of wolffish by species. Their records indicate that prior to the mandatory release requirement in mid-2003, *A. denticulatus* were discarded and thus landings comprised the other two species. Since June 2002, some processors/buyers have been documenting wolffish landings according to species, verifying that *A. denticulatus* are not landed, as recommended by the Recovery Team.

8.1.1 Landings and Value

There is no directed fishery for any species of wolffish in the Newfoundland and Labrador Region, but a bycatch of *A. lupus* was permitted from 2004-2005 to present. Prior to the implementation of the mandatory release policy, only *A. minor* and *A. lupus* had commercial value in Newfoundland and Labrador. *A. denticulatus* was discarded and not reported to DFO. As well, about 50% of *A. lupus* and *A. minor* bycatch were discarded (observer records) and not reported, thus the landing statistics underestimate the actual catch rate. The average yearly wolffish reported landing during 1995-2002 was 289,125 kg, peaking in 2002 at 522,752 kg. The average landed value over the same period was $136,182 with unit price per kg ranging from $2.05 in 1995 to $0.42 in 2002 (Table 4 and Figure 5).

[1] In DFO-NL Region the "catfish" is synonymous with and includes the three species of wolffish that inhabit waters surrounding Newfoundland and Labrador. In this report, "wolffish" will be used instead of "catfish".

Table 4. Landed Volume and Landed Value of Wolffish Bycatch (1995-2002) Newfoundland and Labrador Region.

Year	Landings (kg)	Value ($)	Average Price ($)
1995	42,929	87,981	2.05
1996	30,220	66,661	2.21
1997	235,236	173,646	.74
1998	207,323	57,184	.28
1999	384,485	104,689	.28
2000	495,437	209,189	.42
2001	395,615	172,717	.44
2002	522,752	217,391	.42
Average	289,125	136,182	0.86

8.1.2 Bycatch by Directed Fishery

Wolffish is a common bycatch in about 20 directed fisheries being conducted in nine NAFO (statistical) Divisions adjacent to the Newfoundland and Labrador Region (see Figure 1). With the exception of the crab fishery, all wolffish landings reported are bycatch in demersal fisheries.

The cod fishery accounted for the highest landings of wolffish bycatch during 1995-2002. During that period, nearly 59% of the total wolffish landings and 46% of wolffish landed value resulted as a bycatch in the cod fishery in NAFO Division 3P (Table 5).

Wolffish (primarily *A. lupus*) bycatch landings increased for many directed fisheries after 1994 given the increased interest as commercial species. During 2001 and 2002, both the Greenland halibut and yellowtail flounder fisheries reported significantly higher wolffish bycatch. This trend may be the result of increased directed fishing effort for those species during the late 1990s, increased retention and reporting of wolffish bycatch, and/or increase in the wolffish population itself (Table 6).

Table 5. Average Landings and Value of Wolffish Bycatch by Directed Fishery (1995-2002) Newfoundland and Labrador Region.

Directed Fishery	Wolffish Landings (kg)		Wolffish Value ($)	
	Yearly Average	%	Yearly Average	%
Cod	171,627	59	62,362	46
Unspecified	40,138	14	39,561	29
Yellowtail Flounder	31,921	11	14,568	11
Greenland halibut	29,158	10	11,455	8
Halibut	4,016	1	2,019	1
American Plaice	3,824	1	1,499	1
Witch	2,641	1	1,254	1
Redfish	2,292	1	1,275	1
Crab	1,337	.5	587	.4
Winter Flounder	626	.2	258	.2
Skate	587	.2	474	.3
Hake, White	574	.2	358	.3
Lumpfish	176	.1	317	.4
Monkfish	44	.02	15	.01
Haddock	23	.01	10	.01
Pollock	18	.01	7	.01
Other	122	.04	166	.1
Total	289,125		162,182	

Table 6. Yearly Wolffish Landings by Directed Fishery (1995-2002).

Directed	1995	1996	1997	1998	1999	2000	2001	2002
Cod, Atlantic	0	63	12,937	179,113	345,566	404,886	212,397	218,055
Yellowtail	0	0	0	2,614	5,434	4,290	54,873	177,157
G. halibut	3,730	8,049	13,560	2,051	11,628	34,520	61,996	97,729
Halibut	0	302	914	1,402	1,641	7,578	16,468	3,822
Am. Plaice	24	156	51	7,201	4,784	7,159	5,248	5,972
Greysole	714	878	989	1,628	2,474	4,648	4,159	5,639
Redfish	2,033	1,328	4,139	1,108	2,102	1,468	4,789	1,370
Crab	70	37	157	302	309	2,079	5,39	2,305
Winter	100	54	0	661	668	1,231	965	1,329
Skate	7	151	177	521	230	289	1,665	1,656
White Hake	440	86	47	62	67	511	2,871	510
Lumpfish	319	258	161	462	462	48	107	11

8.1.3 Bycatch by NAFO Division, Statistical Area and Statistical Sections

The highest wolffish bycatches were landed in NAFO Subdivision 3Ps (40%), Division 4R (19%), Subdivision 3Pn (18%) and Division 3N (12%) during 1995-2002 (Table 7, Figure 6). Observer records suggest that the majority of landings in these areas comprise *A. lupus*. The landed value for areas approximate the landed volumes. Combined, these divisions and subdivisions account for 256,843 kg (or 89%) of the total landings, and $122,611 (or 91%) of total landed value.

Table 7. Average Wolffish Landings and Value by NAFO Division (1995-2002) Newfoundland and Labrador Region.

NAFO (Sub) Division	Landings kg		Value $	
	Yearly Average	%	Yearly Average	%
3Ps	114,223	40	56,764	42
3Pn	52,312	18	23,429	17
4R	55,459	19	26,491	20
3N	34,849	12	15,927	12
3L	16,522	6	5,937	5
3K	11,835	4	5,499	4
3O	2,160	.7	1,280	1
2J	1,471	.5	644	.5
4S	182	.1	175	.1
4VN	77	.03	23	.02
2H	27	.01	13	.01
4VS	7	.002	3	.001
TOTAL	289,125		136,182	

When assessed, NAFO Subdivision 3Ps and 3Pn account for 49% of the average landings during the 1995-2002 and 45% of the landed value. Area I (Point Crewe – Pass Island Point) and H (Cape St. Mary's and Point Crewe) account for 14% and 12% of landed volume, respectively (see Table 8).

Table 8. Average Wolffish Landings and Value by Statistical Area (1995-2002).

Statistical Area	Landings kg		Value $	
	Yearly Average	%	Yearly Average	%
J (3Ps & 3Pn) Pass Island Point – Cape Ray	140,755	49	61,827	45
I (3Ps) Point Crewe – Pass Island Point	41,579	14	22,197	16
H (3ps) Cape St. Mary's –Point Crewe	35,491	12	18,548	14
K (4R) Cape Ray – Cape St. George	21,913	8	9,607	7
L (4R) Cape St. George – Cape St. Gregory	10,519	4	5,633	4
M (4R) Cape St. Gregory –Point Riche	9,890	3	5,741	4
D (3L) Cape Bonavista – Grates Cove	9,125	3	3,113	2
N (4R) Point Riche – Cape Norman	6,896	2	2,766	2
F (3L) Cape St. Francis – Cape Race	4,105	1	1,928	2
B (3K) Cape St. John – Cape Freels	3,465	1	2,037	1
C (3L) Cape Freels – Cape Bonavista	3,185	1	1,597	1
A (3K) Cape Norman – Cape St. John	1,712	1	894	1
E (3L) Grates Point – Cape St. Francis	438	<1	270	<1
G (3L) Cape Race – Cape St. Mary's	48	<1	20	<1
O (2J) Point St. Charles – Cape Rouge	16	<1	7	<1
TOTAL	289,125		136,182	

When assessed by "statistical section", Section 39 (Area J, 3Pn), encompassing the area between Rose Blanche Point and Cape Ray, accounted for 19% of the average landings during the 1995-2002 and 16% of the landed value. Section 37 (Area J, 3Pn), area including ports between Cape la Hune and Fox Point, accounted for 19% of total landings and 18% of total value, while Section 32 (Area I, 3Ps), area encompassing Jean de Baie Head to Point Crewe, reported 10% and 9% landed value (Figure 7 and Table 9).

Table 9. Average Wolffish Landings and Value by Statistical Area (1995-2002) Newfoundland and Labrador Region (Figure 6).

Statistical Section	Stat. Area	NAFO Div.	Landings (t)	% of Total	Value ($)	% of Total
39 Rose Blanche Pt. – Cape Ray	J	3Pn	55,370	19	18,239	16
37 Cape la Hune – Fox Pt.	J	3Ps	54,546	19	24,380	18
32 Jean de Baie Head – Pt. Crewe	H	3Ps	27,915	10	12,324	9
35 Boxey Pt. – Pass Island Pt.	I	3Ps	21,152	7	11,231	8
38 Fox Pt. – Rose Blanche Pt.	J	3Pn	19,740	7	10,491	8
40 Cape Ray – Harbour Pt.	K	4R	18,239	6	7,376	5
33 Pt. Crewe – Pt. Rosie	I	3Ps	15,441	5	7,462	5
36 Pass Island Pt. – Cape la Hune	J	3Ps	11,100	4	5,739	4
14 Cape Bonavista – South Head	D	3L	8,969	3	3,038	2
42 Cape St. George – Long Pt.	L	4R	7,770	3	4,087	3
48 Pt. Riche – Ferolle Pt.	N	4R	6,712	2	2,720	2
34 Pt. Rosie – Boxey Pt.	I	3Ps	4,986	2	3,504	3
45 Cape St. Gregory – Martin's Pt.	M	4R	4,944	2	2,525	2
31 Grandy Pt. – Jean de Baie Head	H	3Ps	4,580	2	4,708	3
41 Harbour Pt. – Cape St. George	K	4R	3,674	1	2,231	2
46 Martin's Pt. – Daniel's Harbour	M	4R	2,887	1	1,996	1
30 Bauld Head – Grandy Pt.	H	3Ps	2,249	1	1,227	1
26 Cape Broyle – Cape Race	F	3L	2,242	1	1,079	1
47 Daniel's Harbour – Pt. Riche	M	4R	2,059	1	1,220	1
8 Change Island – Fogo Island	B	3K	2,015	1	1,191	1
43 Long Pt. – Broad Cove Pt.	L	4R	1,381	1	1,033	1
24 Cape St. Francis – Cape Spear	F	3L	1,843	1	844	1
Remainder of Sections <1%			9,870	3	4564	3
Total			289,125		136,182	

8.1.4 Landings and Value by Community and Fishers for 2002

During 2002, 1005 fishers in the Newfoundland and Labrador Region reported wolffish landings. Only 18 fishers reported landed values greater than $1000, while 50 fishers reported values greater than $500 (Table 10). The remaining 955 fishers averaged $168. All fishers reporting wolffish bycatch were core fishers.

During 2002, Burgeo fishers reported the largest volume of wolffish totaling 25,885 kg at a value of $12,297; followed by Lapoile landed 22,873 kg valued at $12,023, and Channel – Port aux Basques landed 18,873 kg worth $9,847 (see Table 10).

During 2002, wolffish bycatch accounted for 5-7% of annual fishing income ($1,323-$5,063) for 7 fishers (1 Ramea, 1 Port aux Basques, 2 Lapoile, 3 Burgeo) in 3Ps and 3Pn.

Table 10. Wolffish Bycatch Landings and Values >$500 (2002), Newfoundland and Labrador Region.

Community	# of Fishers	NAFO Division	2002 Landings kg	2002 Values $
Burgeo	4	3Pn	25,885	12,297
Lapoile	6	3Pn	22,873	12,023
Channel–Port aux Basques	2	3Pn	18,569	9,847
Ramea	3	3Ps	9,480	4,180
Port aux Choix	4	4R	5,777	2,557
Margaree	3	3Pn	4,756	2,100
Three Rock Cove	1	4R	4,593	2,038
Codroy	2	4R	3,773	1,689
Isle aux Morts	2	3Pn	3,090	1,363
La Scie	1	3K	3,065	1,351
Burnt Island	2	3Pn	2,935	1,333
Fox Roost	2	3Pn	2,724	1,203
Harbour Breton	1	3Ps	2,488	1,097
Cape Ray	1	3Pn	1,764	959
Rose Blanche	1	3Pn	1,725	951
Daniel’s Harbour	1	4R	1,592	702
Petities	1	3Pn	1,288	624
Francois	1	3Ps	1,252	552
Heatherton	1	4R	1,219	538
Total 2002			522,752	217,391

8.1.5 Bycatch by Gear Type, Sector and Directed Species

During the 1995-2002 period, 64% of wolffish bycatch was caught by longline, 19% by bottom otter trawl and 14% by gillnet (Table 11).

Approximately 52% (149,558 kg) of the wolffish bycatch was caught during the longline cod fishery, while the bottom otter trawl yellowtail fishery accounted for 11% (31,339 kg) and the bottom otter trawl Greenland halibut fishery landed 7% (20,021 kg). The gillnet cod fishery accounted for 7% (17,211 kg) of the total landings (Table 12).

Approximately 66% (192,715 kg) of the wolffish bycatch was caught by vessels less than 35 feet. Longline gear accounted for 83% (159,678 kg) of the catch in this sector. The 100+ sector caught approximately 22% of the wolffish bycatch primarily using the bottom otter trawl, while the 35-64 feet fleet accounted for 12% using longline and gillnets (Table 13).

Table 11. Wolffish Landings and Landed Value by Gear for the Period 1995-2002.

Gear Type	Wolffish Landings (kg) Yearly Average	%	Wolffish Value ($) Yearly Average	%
Longline	183,972	64	70,567	52
Bottom Otter Trawl	54,803	19	23,550	17
Gillnet	41,480	14	37,701	28
Hand Line	4,074	1	2,177	2
Danish Seine	2,647	1	1,341	1
Pot	1,537	1	657	<1
Midwater Trawl	568	<1	166	<1
Trap	33	<1	16	<1
Scottish Seine	6	<1	3	<1
Shrimp Trawl	5	<1	2	<1
Total	289,125		162,182	

Table 12. Wolffish Landings and Landed Value by Gear and Directed Species (1995-2002).

Gear Type	Directed Fishery	Wolffish Landings (kg)	% of Total Landings
Longline (183,972 kg)	Cod	149,558	52
	Unspecified	28,845	10
	Halibut	3,978	1
	Greenland halibut	1,145	<1
	Hake	262	<1
Bottom Otter Trawl (54,803 kg)	Yellowtail	31,439	11
	Greenland halibut	20,021	7
	Redfish	1,611	1
	American Plaice	519	<1
	Skate	362	<1
	Unspecified	332	<1
Gillnet (41,480 kg)	Cod	19,211	7
	Unspecified	9,236	3
	Greenland halibut	7,919	3
	American Plaice	3,253	1
	Winter Flounder	624	<1
	Redfish	604	<1
Hand Line (4,074 kg)	Cod	2,557	1
	Unspecified	1,500	1

Table 13. Wolffish Landings and Landed Value by Sector and Gear (1995-2002).

Vessel Sector	Gear	Wolffish Landings kg	% of Total Landings
< 35 (192,715 kg)	Longline	159,678	55
	Gillnet	28,924	10
	Hand Line	3,837	1
	Pot	227	<1
100+ (55,664 kg)	Bottom Otter Trawl	52,923	21
	Midwater Trawl	568	<1
	Gillnet	42	<1
35-64 (38,629 kg)	Longline	21,019	7
	Gillnet	12,302	4
	Danish Seine	2,628	1
	Bottom Otter Trawl	1,312	<1
	Pot	1,135	<1
65-99 3,996 kg	Longline	3,270	1
	Bottom Otter trawl	567	<1
	Gillnet	148	<1
Total		289,125	

8.1.6 Bycatch by Month

During 1995-2002, the majority (85%) of wolffish bycatch was caught during the period spanning May to September (Table 14). During this timeframe, 40% of the bycatch was caught in Subdivision 3Ps, 18% in Subdivision 3Pn and 19% in Division 4R. The highest landings for Division 3O were reported during March, April, May and October.

Table 14. Wolffish Landings by Month (1995-2002).

Month	Wolffish Landings (kg)	
	Average Landings	% of Total
July	75,345	26
June	60,961	21
August	42,785	15
September	34,303	12
May	28,547	10
April	18,784	6
October	14,667	5
November	6,722	2
March	4,158	1
December	1,300	<1
February	1,123	<1
January	429	<1

8.1.7 Profiles for Wolffish Bycatch > 5% by NAFO Division and Subdivisions (1995-2002)

Landing an economic statistics are listed by NAFO (Sub) Division (see Figure 1 and 6).

3Ps:

- Total Landings: 114,223 kg (40%), Total Value: $56,764 (42%)
- Statistical Areas: H (Placentia Bay), I (Fortune Bay) and J (South Coast)
- Communities with Wolffish Landed Values > $500: Ramea ($9,480), Harbour Breton ($2,488), Francois ($1,219)
- Directed Fisheries Catching Wolffish: cod, redfish, winter flounder, skate, greysole, white hake, halibut, lumpfish, American plaice, Greenland halibut, monkfish, pollock, crab, haddock, and whelk
- Major Directed Fisheries:
    - Cod: landings 86%, value 63% (84% longline, 15% gillnet, 1% handline)
    - Unspecified: landings 11%, value 34% (57% longline, 34% gillnet, 9% handline)
    - Redfish: landings 1%, value 1% (58% gillnet, 39% bottom trawl, 2% midwater trawl)
- Vessel Sector: < 35 ft (83%), 35-64 (16%), 65-99 (< 1%), 100+ (< 1%)
- Major Gear Types: longline (78%), gillnet (19%), handline (2%)
- Primary Months: June (29%), July (28%), September (14%), May (10%), August (9%), October (5%), November (4%).

4R:

- Total Landings: 55,459 kg (19%), Total Value: $26,491 (20%)

- Statistical Areas: K (St. George's Bay), L (Port au Port ,Bay of Islands), M & N (Northern Peninsula) and O (Labrador)
- Communities with Wolffish Landed Values > $500: Port aux Choix ($2,557), Three Rock Cove ($2,038), Codroy ($1,689), Daniel's Harbour ($702), Heatherton ($538)
- Directed Fisheries Catching Wolffish: cod, redfish, winter flounder, skate, greysole, halibut, lumpfish, American plaice, Greenland halibut, crab, haddock, and mackerel
- Major Directed Fisheries:
  - Cod: landings 67%, value 52% (87% longline, 10% gillnet, 3% handline)
  - Unspecified: landings 20%, value 35% (75% longline, 21% gillnet, 2% handline)
  - American Plaice: landings 6%, value 5% (99% gillnet, 1% longline)
- Vessel Sector: < 35 ft (83%), 35-64 (17%)
- Major Gear Types: longline (75%), gillnet (18%), Danish seine (4%), handline (2%)
- Primary Months: July (36%), August (27%), September (16%), June (12%), May (5%), October (3%).

3Pn:

- Total Landings: 52,312 kg (18%), Total Value: $23,429 (17%)
- Statistical Areas: J (South & Southwest Coast)
- Communities with Wolffish Landed Values > $500: Burgeo ($12,297), Lapoile ($12,023), Channel – Port aux Basques ($9,847), Margaree ($2,100), Isle aux Morts ($1,363), Burnt Island ($1,333), Fox Roost ($1,203), Cape Ray ($959), Rose Blanche ($951), Petities ($624)
- Directed Fisheries Catching Wolffish: cod, redfish, winter flounder, skate, greysole, white hake, halibut, American plaice, Greenland halibut, haddock
- Major Directed Fisheries:
  - Cod: landings 70%, value 55% (97% longline, 2% handline, 1% gillnet)
  - Unspecified: landings 29%, value 44% (87% longline, 12% gillnet, 1% handline)
- Vessel Sector: < 35 (95%), 35-64 (5%)
- Major Gear Types: longline (94%), gillnet (4%), handline (2%)
- Primary Months: July (26%), August (24%), June (16%), September (12%), May (11%), October (10%), November (1%).

3N:

- Total Landings: 34,849 kg (12%), Total Value: $14,927 (12%)
- Statistical Areas: F (eastern Avalon), H (Placentia Bay) and I (Fortune Bay)
- Directed Fisheries Catching Wolffish: cod, redfish, skate, white hake, halibut, American plaice, Greenland halibut, and yellowtails
- Major Directed Fisheries:
  - Yellowtail: landings 91%, value 91% (99% bottom trawl, 1% midwater trawl, < 1% gillnet)
  - Halibut: landings 7%, value 6% (100% longline)

- Vessel Sector: 35-64 ft (< 1%), 65-99 (6%), 100+ (94%)
- Major Gear Types: bottom trawl (93%), longline (6%), midwater trawl (1%)
- Primary Months: April (49%), May (17%), March (11%), October (7%), July (6%), February (3%).

3L:

- Total Landings: 16,522 kg (6%), Total Value: $5,937 (4%)
- Statistical Areas: C (Bonavista Bay), D (Trinity Bay), E (Conception Bay), F (eastern Avalon) and G (St. Mary's Bay)
- Directed Fisheries Catching Wolffish: cod, winter flounder, American plaice, Greenland halibut,
- Major Directed Fisheries:
    - Greenland halibut: landings 98%, value 96% (78% bottom trawl, 13% gillnet, < 1% longline)
- Vessel Sector: < 35 ft (4%), 35-64 (10%), 100+ (86%)
- Major Gear Types: bottom trawl (86%), gillnet (13%), pot (1%)
- Primary Months: June (38%), July (35%), May (12%), August (5%), April (4%).

8.2 Quebec Region Landings and Value

Altough all three species of wolffish are found in the northern Gulf of St. Lawrence (Quebec Region), *A. lupus* is dominant. Scientific data from surveys, sentinel fisheries and the Fishery ObserverProgram were used to assess catches and species composition of wolffish.

Data on landings are collected by dockside monitors. However, those data do not differentiate the wolffish species. Statistical data currently use a single code and a single general description "wolffish". Consequently, the economic overview only provides a general picture of wolffish captures, although observer and research survey data suggest that the majority of wolffish landed are *A. lupus*. It is possible to identify some significant variables to assess the profile of the fleets that catch wolffish and the relative significance of these species for the fisheries activities in the Quebec Region.

8.2.1 Socio-Economic Profile

Catches of wolffish are incidental in fisheries directing for other species and represented only 0.4% of the total groundfish landings in Quebec in 2002. In terms of value, this proportion is only 0.1%. However, wolffish landings had been increasing since 1995. In 2002, the preliminary data indicated landings of 22.3 t, for a total value of $8500. This trend can be explained by the increase in the fishing effort directed at Atlantic cod. Indeed, the fixed gear fleet (>50 feet) is responsible for most wolffish landings in Quebec. Between 1998 and 1999, Atlantic cod landings by this fleet increased in a significant way, thus causing an increase in wolffish landings.

The average price at landing (live weight) was $0.38/kg in 2002. Therefore, wolffish is not a species of great commercial value. However, prices at landing increased between

1995 and 2002. When comparing 2002 with 1995, a price increase of $0.15/kg is noted. The demand for wolffish on the Quebec market (food services, fish shops) explains this trend. The data on production indicate a rise in wolffish fillet production, and a rise in the value of this product between 1996 and 2002.

The groundfish fixed gear fleet (greater than 50 feet) captures the majority of wolffish in Quebec Region waters. In 2002, that fleet landed 72% of the total volume of wolffish landings in Quebec. In 2000 and 2001, this proportion reached nearly 90%.

For this fleet in 2002, wolffish comprised 1.6% of the total landed weight of groundfish, all species considered. The main species harvested by this fleet are Atlantic cod, Atlantic halibut and Greenland halibut.

Table 15. Total wolffish landings per fishing fleet, 1999 to 2002. Volume (kg) – value ($)

	1999		2000		2001		2002	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value
Trawlers – 50 to 64 feet	44	14	0	0	54	23	64	52
Fixed gear < 35 feet (groundfish)	224	72	44	20	25	9	44	24
Fixed gear – 35 to 44 feet 11 inches (groundfish)	879	259	451	180	468	146	293	103
Fixed gear – 35 to 44 feet 11 inches (pelagic)					3	1		
Fixed gear – 45 to 49 feet 11 inches (groundfish)	252	74	87	32	153	37	67	12
Fixed gear – 50 feet and more (groundfish)	3,027	717	10,606	3,871	20,781	7,036	15,960	5,161
Crabbers of Lower North Shore, area 13	27	0	0	0			13	7
Crabbers of Lower North Shore, area 14							5,342	2,949
Crabbers of Lower North Shore, area 14 - allocations							15	8
Crabbers of Lower North Shore, area 15	5	0	0	0				
Crabbers of the Estuary, area 17	0	0	4	1				
Crabbers, area 12A	463	133	186	68	234	54	6	8
Crabbers, area 12B	79	51	155	54	323	102	36	23
Crabbers, area 12B - allocations							73	27
Crabbers, area 12C - allocations							6	3
Crabbers, area 12E	302	111	0	0	164	60	26	10
Shrimpers – temporary allocations	37	17	93	32	217	148	45	10
Gaspesian lobster boats, area 20	3	1	9	3	9	3	19	10
Gaspesian scallop vessels	0	0	144	55				
Magdalen islands lobster vessels	47	1	0	0				
North Shore scallop vessels					659	121		
Crabbers, area 17 – allocations					8	3	44	10
Crabbers, area 16 – allocations							11	5
Crabbers, area 12 – allocations					143	40	180	50
Out-of-Quebec vessels					80	44		
Unclassified vessels							16	9
Total:	5,390	1,451	11,777	4,316	23,321	7,829	22,260	8,482

Source: Statistics Services, DFO, Quebec Region
Compilation: PEB, DFO, Quebec Region

8.2.2 Processing Sector

Processing sector data indicated an increase in the production of wolffish fillets between 1995 and 2001. The average value of fillet production increased between 1996 and 2001 from $3.28/kg to $5.01/kg. The demand for this type of product increased on the Quebec food service market (Quebec area, for example) and in fish shops. However, production decreased in 2002, in favour of the fresh and whole wolffish.

Table 16. Wolffish production in Quebec (kg).

	1995	1996	1997	1998	1999	2000	2001	2002
Frozen								
Skinless fillets	91	23	175	59	209	426	2,363	57
Skinless and boneless fillets	0	86	400	371	45	0		
Fresh								
Dressed, not headed	120	134	0	62	275	0		648
Dressed, headed	0	0	0	0	200	0		
Whole	0	341	1,905	150	668	4	2,519	6,090
Skinless fillets	0	39	269	59	569	1,824	5,044	1,751
Skinless and boneless fillets	0	0	148	0	149	453	473	474
Undefined form	0	0	408	188	0	0		
Slightly salted								1,238
Total	211	623	3,305	889	2,115	2,707	10,398	10,259

Source: Statistics Services, DFO, Quebec Region
Note: the data of 2001 are preliminary

Table 17. Value of the wolffish production in Quebec ($/kg).

	1995	1996	1997	1998	1999	2000	2001	2002
Frozen								
Skinless fillets	2.71	6.09	5.50	4.41	5.22	4.96	3,83	6.06
Skinless and boneless fillets		4.98	4.96	4.59	5.00			
Fresh								
Dressed, not headed	1.10			0.56	0.55			0.67
Dressed, headed					1.32			
Whole		0.39	0.55	0.20	0.44	0.25	0.44	0.44
Skinless fillets		3.28	3.17	4.10	4.81	5.46	5.01	5,49
Skinless and boneless fillets			4.96		5.02	5.04	4.51	3.93
Undefined form			0.44	0.74				
Skinless fillets slightly salted								3.31

Source: Statistics Services, DFO, Quebec Region
Note: the data of 2001 are preliminary

8.3 Central and Arctic Region Landings and Value

The majority of bycatch in the Central and Arctic (C&A) Region occurs in the Greenland halibut fishery. Wolffish bycatch is not landed in plants in the region, but may be landed in the Newfoundland and Labrador Region. In the past, the Newfoundland and Labrador Region had collected bycatch data for NAFO Divisions 0A and 0B delineating the Davis Strait. The majority of directed fisheries licensed in the C&A Region are landed in other regions, especially Newfoundland and Labrador.

The bycatch wolffish in NAFO Division 0A is small (00s of kg annually) and consists primarily of *A. denticulatus* that has no commercial value and is discarded and/or not reported to DFO.

It appears at this time that wolffish species are far less abundant in this area and bycatch commercial fisheries are very low.

8.4 Maritimes Region Landings and Value

All three wolffish species in Atlantic Canada are reported in DFO landing statistics as "catfish". The intention is to distinguish landings by species, but Maritimes Region data up to 2002 was pooled, with the exception of a small volume of spotted wolffish data from 2000 and 2001.

8.4.1 Landings & Values

Discarding of wolffish is likely, but information on the amount of discards in unavailable in the Maritimes ZIF (zonal interface format) data. The average yearly wolffish landings between 1988-2000 were 515.1 t, with a peak of 1,012 t in 1988. Landings fell to 132.5 t in 2001 and 168.1 t in 2002 (to 21 Nov 02) (Table 18). The average landed value over the 1988-2000 period was $195,979 (with unit price per kg ranging from $0.33 in 1988 to $0.54 in 2000). Assuming an average price of $0.54 per kg for wolffish in 2001 and 2002 (processor prices were not reported for all landings), wolffish landings value were in the $100,000 per year range.

Table 18. Landed volume and landed value of wolffish by-catch in the Maritimes Region 1988-2002.

Year	Landings (RW tonnes)	Values (thousand $)	Price ($ per kg)
1988	1,012.0	$ 337.1	$ 0.33
1989	665.9	$ 228.4	$ 0.34
1990	690.8	$ 210.6	$ 0.30
1991	508.1	$ 173.6	$ 0.34
1992	753.0	$ 275.2	$ 0.37
1993	618.2	$ 212.3	$ 0.34
1994	428.9	$ 173.4	$ 0.40
1995	256.8	$ 108.4	$ 0.42
1996	381.7	$ 165.6	$ 0.43
1997	614.5	$ 280.0	$ 0.46
1998	311.1	$ 142.7	$ 0.46
1999	296.3	$ 154.6	$ 0.52
2000	158.8	$ 85.8	$ 0.54
2001	132.5	$ 71.5	$ 0.54
2002	168.1	$ 90.8	$ 0.54
Average	466.4	$ 196.0[1]	$ 0.42[1]

[1] Average value and price do not include 2001/2002 price and value estimates.

Landings are highly seasonal in the Maritimes Region, with a peak from May to August (Figure 8).

8.4.2 By-Catch by Main Landed Species

Wolffish is a common by-catch in the Maritimes Region groundfish fishery. With the exception of scallop – until 1995 – virtually all wolffish landings reported are the by-catch of groundfish fisheries. Figure 9 shows wolffish landings broken down by the main landings species (i.e., if 50-kg wolffish was landed as bycatch on a trip when haddock was the main species caught, the chart records the 50-kg in the 'haddock' category). Wolffish was the main species landed for 25.0% of trips, on average, over the period 1986 to 2002. Cod was the main species landed on 31.0% and haddock on 17.9% of trips. All other species were the main species landed <5% on average.

8.4.3 By-Catch by NAFO Division

The highest wolffish landings were reported in NAFO Division 4X between 1986 and 2002 (Figure 10). Figure 11 shows the distribution of landings by NAFO division for 2001. Landings within 4X were widely distributed (Figure 12). Figure 13 shows landings by NAFO unit within 4X. The vast majority of landings, especially in recent years, have been caught using bottom trawls (67.9% on average between 1986 and 2002) and longlines (25.2% on average between 1986 and 2002) (Figure 14).

8.4.4 Comparing Landed Values

The landed value of wolffish by-catches are insignificant in comparison to the values of the directed fisheries from which they are derived (Table 19).

Table 19. Summary of landed value by major species in the Maritimes Region 1988-2000.

Species	All Groundfish	All Pelagics	All Invertebrates	Wolffish (% Total)	
1988	$ 117,163,000	$ 39,291,800	$ 202,588,647	$ 337,115	0.09%
1989	$ 117,076,000	$ 36,410,400	$ 216,668,000	$ 228,410	0.06%
1990	$ 134,157,000	$ 36,174,800	$ 214,877,000	$ 210,631	0.05%
1991	$ 175,389,000	$ 32,996,100	$ 219,870,000	$ 173,554	0.04%
1992	$ 163,551,000	$ 39,911,800	$ 240,412,000	$ 275,156	0.06%
1993	$ 111,393,000	$ 42,939,600	$ 256,781,000	$ 212,304	0.05%
1994	$ 87,087,600	$ 38,622,100	$ 309,507,000	$ 173,433	0.04%
1995	$ 73,596,300	$ 45,550,500	$ 298,891,000	$ 108,397	0.03%
1996	$ 70,293,600	$ 39,897,900	$ 277,788,000	$ 165,587	0.04%
1997	$ 84,081,600	$ 41,183,200	$ 295,744,000	$ 280,013	0.07%
1998	$ 86,957,800	$ 36,143,700	$ 325,139,000	$ 142,656	0.03%
1999	$ 78,523,900	$ 34,103,400	$ 413,079,000	$ 154,619	0.03%
2000	$ 75,498,200	$ 35,540,400	$ 478,123,000	$ 85,846	0.01%

8.5 Gulf Region Landings and Value

Mandatory reporting requirements are in place for all landings. There are presently no reported discards of wolffish in the Gulf Region.

The average yearly wolffish landings between 1995-2001 were very small (i.e. 12.6 t). The total landed value over the same period was $3,803 with unit price per kg ranging from $0.20 in 1996 to $0.52 in 1999.

9. ANTICIPATED CHALLENGES

The following have been identified as possible challenges to successful realization of the goals and objectives put forward in this document:

- Gaining a more comprehensive understanding of wolffish life history;
- Identifying environmental effects;
- Identifying, conserving and protecting wolffish habitats;
- Quantifying spatial and temporal capture of wolffish, by species, by fishery gear;
- Evaluating the potential effects of fishing gears, particularly trawls and dredges on wolffish habitat;
- Developing mechanisms for engaging stakeholder support;
- Implementing fishery regulatory changes and their potential impact on traditional fisheries and subsequent costs to harvesters and other stakeholders;
- Obtaining the financial resources required for timely implementation of all aspects of the recovery initiative;
- Evaluating potential effects of other ocean resource activities; and
- Establishing inter-jurisdictional cooperation and collaboration.

10. BIOLOGICAL AND TECHNICAL FEASIBILITY OF RECOVERY

Natural history strategies such as relatively slow growth, nesting habits (*A. lupus*), limited dispersal in conjunction with potential human induced factors and changing environmental limitations have the potential to curtail the recovery ability for wolffish species. As such, research needs to be undertaken to define the relationship between wolffish and their environment. However, assuming that anthropogenic threats can be identified and mitigated through implementation of this Recovery Strategy and Management Plan, recovery is consider feasible based on the following criteria:

- Individuals capable of reproduction are currently available to improve the population abundance;

- Based on current knowledge of habitat requirements, sufficient suitable habitat is currently available to support these species;

- Significant anthropogenic threats to these species, as described in this document, may be mitigated through recovery actions; and

- Necessary recovery techniques to address these significant anthropogenic threats do exist and have been demonstrated to be effective.

Biological and technical feasibility of these species may also be influenced by unanticipated environmental affects that could unpredictably alter the course of recovery.

11. RECOMMENDED SCALE FOR RECOVERY

The Recovery Team chose to incorporate the three wolffish species into a single "multi-species" Recovery Strategy and Management Plan because of their similar distribution, life history, ecology and taxonomically close relationship. One document inclusive of both threatened species, as well as the special concern species, was believed to be the most efficient and least repetitive approach for implementation.

Currently, release of the two threatened wolffish species in a manner that will maximize likelihood of survival is a fisheries licence requirement. As well, various moratoria on groundfish put in place during the 1990s and current fisheries closures leading to decreased effort contributes to recovery. Reducing directed groundfish fisheries has indirectly protected wolffish, a primary source of incidental bycatch of all three species.

In all DFO Regions where wolffish are present, the Recovery Team recommends that the scale of recovery effort incorporate an ecosystem approach and that it be implemented in parallel with future conservation objectives of fisheries management and other industrial activities.

Due to the distribution of wolffish, recovery must be considered at both national and international scales. Not only do non-Canadian vessels capture wolffish outside and inside (in the past) Canadian waters, but large concentrations of wolffish in international waters adjacent to Canadian waters are potentially influential in the state of wolffish populations in Canadian waters.

12. PERSPECTIVE ON THE ASSESSMENT AND DESIGNATION OF WOLFFISH SPECIES

The mandate of the Wolffish Recovery Team is to develop and recommend a strategy and specific associated actions to conserve and promote the recovery of *A. denticulatus* and *A. minor*, designated as "threatened", as well as *A. lupus*, designated as "special concern. Designations are based on draft COSEWIC Status Reports and thus the contents of those Reports underlie the actions put forth in this document. The following section contains a Recovery Team perspective on aspects of the draft Status Reports that have influenced the nature and content of some of the recommendation of this Recovery Strategy and Management Plan.

- The basis for the COSEWIC "threatened" designation was negative biomass and abundance trends derived from fall survey time series covering the Grand Bank, northeast Newfoundland and Labrador Shelves. The time frame of the decline was 1978 to 1994, from the start of the fall survey series (the available abundance trend data) to the last year that the Engel trawl survey gear was used. The draft Status Reports assumed that 1978 represented the baseline population size, the starting point with which to measure the magnitude of the decline for the three species, and that the ensuing 17 years to 1994 represents 3 generations, the period that COSEWIC criteria specifies for the determination of decline rate. Insufficient information was provided to support the use of 1978 as a reference population size or 17 years as 3 generations. The life history of all of the wolffish species for the northwest Atlantic is unknown and thus represents a data gap.

- The use of any single point from fisheries surveys as a population size reference point as was done for the draft status reports is potentially misleading because of uncertainties in almost all fishery survey results. Pooling multi-year averages, basing “normal” population size on cyclic patterns in population size and using generation times based on life history attributes is a more robust approach.

- The unpublished COSEWIC Status Reports for all three wolffish species indicate that “the general decline continues to the present”. However, the fall survey data illustrated in the Status Reports indicate stable or increasing trends, not declines, since the mid-1990s (refer also to Figure 4).

- Based on fall survey data, the difference in the index between 1978 and 1994 was used to define the population decline. Natural fluctuations in population size were not considered in the draft status reports. However, spring survey data for a portion of the distribution shows that the population of the wolffish species was lower prior to 1978. Those data suggest that wolffish species, like most other fish species undergo fluctuations in population size and that 1978 may represent a peak in population size.

- The issue of heterogeneity in the population structure of wolffish species is not addressed in the draft Status Reports. The Reports assume a single Atlantic population (DU) for each species, with fall survey trends off Newfoundland and Labrador representing the population trends for the Atlantic. However, the existence of considerable spatial variation in abundance trends in different areas (see Part 3 and 6) of the Atlantic suggests the possibility of multiple DU’s for each of the species. The draft status report did not examine available survey trends in the Gulf of St. Lawrence or the Scotian Shelf where trends were stable or increasing.

- The draft Status Reports use unweighted mean number/tow as the index of abundance but do not account for the stratified design upon which Canadian surveys, including the fall NL survey, are based. It should be demonstrated that the within-year variance of treating each tow as a random event is not significantly different from the stratified random variance if weighted mean number/tow is used.

- The draft Status Reports suggest that habitat degradation resulting from bottom trawling may have been a proximal cause in the decline of the wolffish, but little evidence was presented to support that supposition. Data explorations by the Recovery Team and Kulka et al. (2004) suggest that areas most heavily fished by bottom trawlers continue to have the highest abundance of wolffish; areas not fished by bottom trawlers on the inner shelf have experienced the greatest declines. On the Labrador Shelf, where the decline of wolffish abundance was the greatest, only 20% of the region was heavily fished in the 1980s, and only 5% in the 1990s. Yet the decline appears to be universal in the Labrador region. Hence, there is insufficient evidence to conclude that habitat damage from bottom trawling was the sole or main factor leading to the decline of the wolfish species.

Table 20. Catch, relative biomass and index of exploitation for wolffish species in Div. 2J3KL for two time periods.

Period	Northern	Spotted	Striped
	Catch (t) 2J3KL		
1985-1989	1,499	950	131
1997-2001	353	96	42
	Biomass Index (t) 2J3KL		
1985-1989	30,568	9,351	6,268
1997-2001	5,652	4,300	4,302
	Exploitation index 2J3KL		
1980-1985	4.9%	10.2%	2.1%
1995-2002	6.3%	2.2%	1.0%

- The draft Status Report suggests that mortality due to fishing may have been a proximal cause of the declines. While there is no direct measure of fishing mortality for the wolffishes, the index of exploitation (catch/relative biomass), that represents a maximum estimate of the proportion of the stock that was removed from the population (given that the biomass index is a minimum value) is very low (Table 20). In addition, virtually all *A. denticulatus* and about 50% of the other two species have been discarded over the years. Survival of these discarded fish may be higher than for other species, given anecdotal information (from observers and survey technicians) that wolffish are much livelier than other species when captured and may stand a better chance of surviving. If so, the actual mortality for all species could be lower than the catch statistics reflected in Table 20. However, discard survival represents a data gap requiring quantification. Also, there is no indication that exploitation indices increased during the decline, as might be expected if fishing mortality was a proximal cause of the decline. In total, there is insufficient evidence to conclude that fishing was the sole or main factor leading to the decline of the wolffish species.

- Although the wolffish species have experienced significant declines in abundance since the late 1970s, there remain millions of each species, capable of survival and reproduction. These wolffish continue to be spread across a reduced but wide area.

- The Status Reports do not deal with the issues associated with population overlap or extension into adjacent jurisdictions (e.g., trans-boundary distributions). Specifically, distributions of the wolffish species appear to be contiguous in the north with fish in Greenland waters, with fish occurring in the NAFO Regulatory area and to the south with fish in USA waters.

The Recovery Team is deeply concerned about the declines that have taken place in the wolffish populations since the late 1970s. However, considering all available information, the Team feels that the proximal cause(s) of the declines remain uncertain.

The “threatened” designation is defined as applying to species likely to become “endangered” with imminent extinction if limiting factors are not reversed. For the purposes of proposing mitigating actions for species recovery, the Team has assumed that fishing is an important factor (despite the uncertain evidence), but also that other unidentified factors may be limiting wolffish recovery.

PART B: RECOVERY

1. OVERVIEW

This document is the first component of a framework to promote the conservation and recovery of three wolffish species in eastern Canadian waters. The second component, the Action Plan (as outlined in Part B, Section 7) will be completed at a later date. Where an activity has already been initiated to address the objectives laid out in this document, these actions are duly noted in Part B, Section 5 - Actions Completed or Underway.

The Recovery Team determined that it was best to incorporate both threatened wolffish species into a single "multi-species" document and to include *A. lupus*, a species of special concern, in the discussions due to their similar life histories, ecology and taxonomically close relationship. As such, this document represents both a recovery strategy for *A. denticulatus* and *A. minor*, as well as a management plan for *A. lupus*. As SARA prohibitions are not applicable to special concern species, conservation and recovery activities described in this document should be viewed as recommendations only for *A. lupus*.

2. GOALS, OBJECTIVES AND STRATEGIES

2.1 The Recovery and Management Goal

The goal of this Recovery Strategy and Management Plan is to increase the population levels and distribution of *A. denticulatus*, *A. minor* and *A. lupus* in eastern Canadian waters such that the long-term viability of these species is achieved. This will be accomplished by communicating those objectives and strategies outlined below.

2.2 Recovery and Management Objectives

The Recovery Strategy and Management Plan for wolffish species in eastern Canadian waters puts forth five broad inter-related objectives. All relate to activities that may be mitigated through human intervention.

Objective 1: Enhance knowledge of the biology and life history of wolffish species;

Objective 2: Identify, conserve and/or protect wolffish habitat required for viable population sizes and densities;

Objective 3: Reduce the potential of wolffish population declines by mitigating human impacts;

Objective 4: Promote wolffish population growth and recovery; and

Objective 5: Develop communication and education programs to promote the conservation and recovery of wolffish populations.

Each of these broad objectives is designed to achieve the goals of this document. As this Recovery Strategy and Management Plan is considered to be adaptive (i.e. a living document), objectives and strategies can be added or revised as new knowledge becomes available.

The following sections elaborate on the above objectives and link them with recovery strategies that include specific actions required for implementing this document. The order in which the strategies are presented does not reflect a ranking of importance. Rather, all strategies are considered critical to the recovery process and are recommended to be carried out in an integrated manner. The consequent activities (actions) of the recovery action plan will result in the implementation of the recovery strategies and objectives.

In general, the recovery of a species at risk involves a multi-faceted approach that takes into consideration individual populations, the number and nexus of these populations and the creation of adequate population levels to withstand events such as environmental shifts and climate change. According to the National Recovery Working Group, establishing a sustainable population requires:

- enough breeding adults to be considered sustainable in the long term;
- sufficient quality habitat available or potentially available to maintain sustainable population numbers;
- adequate or improving demographic parameters (e.g., sex ratio, birth and death rates); and
- mitigation against and control of human threats to the population, particularly those that initially contributed to the species' decline.

2.3 Recovery Strategies and Specific Actions to Meet Recovery Objectives for Wolffish Species

Five strategies constitute the basis of a framework for recovery: research, habitat conservation and protection, mitigation of human activities, promotion public knowledge and stakeholder participation in the recovery of wolffish populations and the conservation and protection of their habitat and monitoring of human activities. Associated specific actions required to achieve species recovery and anticipated effects of those actions are listed in Table 21.

Table 21, Linking recovery objectives to strategies and specific actions required to promote recovery of wolffish species.

Priority	Recovery Objective	Recovery Strategy	Recovery Actions	Anticipated Effect
Necessary, on going	1, 2, 4	A. Research	Conduct directed research on: 1. life history 2. population structure 3. identify limit reference points 4. ecosystem interactions	Better adaptive management decisions
Necessary, On going	2, 4, 5	B. Habitat conservation and protection	1. identify habitat 2. define measures to conserve and/or protect wolffish habitat	Increase potential of spawning, rearing, feeding, and other life processes
Urgent	3, 4, 5	C. Mitigate human activities	1. identify and mitigate impacts	Direct benefit to species numbers, reducing mortality at all life stages
Necessary, On going	3, 4, 5	D. Promote public knowledge and stakeholder participation in the recovery of wolffish populations and the conservation and protection of their habitat	Through: 1. education 2. stewardship 3. consultation 4. cooperation	Support for management measures and other recovery strategies
On going	3, 4	E. Monitor human activities	1. monitor wolffish spatial and temporal abundance patterns 2. monitor spatial and temporal patterns in natural and human induced mortality	Better adaptive management decisions

2.4 Recovery Strategy A - Conduct Research (Objectives 1, 2, 4)

Objective 1: Enhance knowledge of the biology and life history of wolffish;
Objective 2: Identify, conserve and/or protect wolffish habitat required for viable population sizes and densities; and
Objective 4: Promote wolffish population growth and recovery.

2.4.1 Recovery Action A1 - Study Life History

Although the subject of considerable research in the Northeast Atlantic, work on the life history of wolffish species residing in Canadian Atlantic waters has been limited, perhaps because they are not the target of a commercial fishery. There is much to learn about how wolffish in the eastern Canadian marine ecosystem reproduce, live, grow and die.

This basic knowledge is the foundation for understanding the population status of wolffish species and subsequently being able to formulate actions required to conserve the species and their habitat so that they are no longer at risk. The recovery objectives set forth by the Recovery Team are broad and we recognize our limitations at present for setting specific measurable objectives without having more complete information about the species; thus the objective for research.

Conduct directed research to study wolffish life history by expanding on available Canadian and international research in the following areas:

- Reproductive biology;
- Age, growth, and longevity;
- Diet and niche;
- Natural mortality (health condition i.e. diseases, parasites, environmental effects and anthropogenic interactions); and
- Traditional User Knowledge.

2.4.2 Recovery Action A2 - Study Population Structure within Eastern Canadian Waters

Identification of wolffish population structure, including Designatable Units (DUs), is fundamental to wolffish management. The observed population trends show very different patterns among areas, the decline being greatest on the Labrador Shelf. In contrast, the index for the Scotian Shelf increased to its highest values in the time series in the early 1990s, and has since remained above average. Understanding the reasons for these spatial differences and defining the population unit(s) are key to formulating appropriate recovery and management strategies and actions. To determine spatial variation in the population structure of the wolffish species in eastern Canadian waters, research needs to be conducted on:

- Age/sex population structure;
- Migration/seasonal movements and distribution;
- Wolffish habitat utilization during various life history stages including spawning, nursery, rearing areas and adult feeding;
- Wolffish abundance with respect to modeling and forecasting abundance; and
- Genetic, morphometric and meristic characteristics to determine if wolffish form a single DU or multiple Units as a basis for management.

2.4.3 Recovery Action A3 - Identify Biological Reference Points

Fisheries management regimes require the use of a combination of quantitative and qualitative biological reference points (BRP’s) such as biomass estimates or indices that might be considered indicators of a recovered population.

Insufficient data exist for the determination of wolffish BRP’s and these deficiencies require research on their own and with respect to those fisheries in which they are incidentally caught.

In the case of wolffish and other poorly understood species, estimates of population growth and viability under various levels of bycatch will be difficult, if not impossible to determine. In particular, obtaining a measure of natural mortality (M) and longevity is problematic for most marine fish species, including wolffish. In addition, in the case of wolffish, obtaining an accurate estimate of fishing mortality (F) that is required to assure viability is problematic when wolffish are captured in such a diversity of fisheries. Absolute catch is not known, though estimates of total removals can be computed, and subsequently used in the development of Allowable Harm Strategies.

Currently, the best available information for the development of biological reference points is the annual spring and fall research surveys from which biomass indices can be developed. While problematic, due to the lack of understanding of wolffish population dynamics, development of potential BRPs based on historic patterns of wolffish abundance and spatial distribution should be modeled. Given the population fluctuations that occur in wolffish populations, as indicated by research surveys, any abundance and distribution targets that are developed should attempt to incorporate this variability. For example, to develop crude initial reference levels, calculation of the average biomass, corrected for the change in gear, the years when the population was greatest may provide a target biomass index. Similar approaches to modeling of the spatial distribution of wolffish should also be conducted. Spatially, the extent/range of the populations can be used through a presence/absence area estimate, GIS spatial analysis, or other methods. Note again that determining the baseline is problematic and the temporal variation in these parameters should be considered. Since data are not available to define a virgin population, a 50% rule (or some variation upon this) could be employed until more explicit methods are identified. In the future, more refined models should incorporate age-structured population dynamics as additional information on population age-structure and maturity is acquired. With additional data and modeling, the spawning stock biomass and recruitment indices can be employed in the development of BRPs.

Alternatively, consideration should be given to the imposition of a catch limit for each species based on an exploitation index derived from a ratio of catch to biomass index. Further research would be required to determine what level of exploitation would not deter recovery.

2.4.4 Recovery Action A4 - Study Ecosystem Interactions

Altering the species composition, by extinction or decrease in biomass and/or distribution of a wolffish species, within the eastern Canadian marine ecosystem would have unknown effects that could escalate through the ecosystem. For example, they may be the direct prey or predator of commercially important species or wolffish may prey on species that are predators of commercial species. These relationships are poorly understood for wolffish (as for most other marine species). Regardless of their relationship with other species, the disappearance of a wolffish species is a loss to the genetic diversity of the eastern Canadian marine ecosystem. The following research should be conducted to more fully understand wolffish status and its relationships with other species within the eastern Canadian marine ecosystem:

- Predator/prey interactions;
- Ocean habitat associations;
- Abundance in relation to other species;
- Ecological linkages;
- The effects of temporal ecosystem disruptions/alterations to critical life history periods of wolffish and their predators and prey; and
- Possible effects of marine environmental shifts on life history.

2.5 Recovery Strategy B – Habitat Conservation and Protection (Objectives 2, 4, 5)

Objective 2: Identify, conserve and/or protect wolffish habitat required for viable population sizes and densities;
Objective 4: Promote wolffish population growth and recovery; and
Objective 5: Develop communication and education programs to promote the conservation and recovery of wolffish populations and their habitat.

2.5.1 Recovery Action B1 - Identify Habitat, including Critical Habitat

Knowledge of wolffish habitat and how it is utilized is extremely limited. This is not peculiar to wolffish and is generally the case for most marine fish species.

Wolffish historic geographic range defines its potential habitat in eastern Canadian waters (Refer to Part A). Preliminary research has been conducted to identify habitat associations with regard to depth, temperature, substrate and different life history periods have been identified (Refer to Table 1). However, the amount of ocean habitat required on spatial and temporal scales at different periods of the life history for the recovery and survival of wolffish species is not currently known. In addition, changes in wolffish abundance and distribution and seasonal fluctuations may be related to water temperature. Ocean ecosystem habitat complexities for wolffish are not fully understood, therefore species-specific research should be conducted in the following areas:

- Habitat characteristics and the environmental factors that control or limit distribution, abundance, growth, reproduction, mortality and productivity of wolffish;
- The physical, chemical and biological characteristics of the ocean ecosystem where wolffish occur;
- Spatial and temporal foraging and shelter/resting areas to determine habitat associations;
- Current and historic geographic range and stock size to determine spawning grounds, rearing areas, feeding grounds and the locations of important life history processes;

- The definition of critical habitat as it pertains to marine finfish, in particular wolffish in eastern Canadian waters in order to determine priority habitat sites. A schedule of studies to identify critical habitat is outlined in Table 22.

Table 22, Recommended studies and associated timelines for the identification of critical habitat, to the extent possible, for *A. denticulatus* and *A. minor*.

Recommended Studies	Start/End Date
Habitat characteristics and the environmental factors that control or limit distribution, abundance, growth, reproduction, mortality and productivity of wolffish.	2006-2007
The physical, chemical and biological components of the ecosystem where wolffish occur.	2006-2007
Spatial and temporal foraging and shelter/resting areas to determine habitat associations.	2006-2007
Current and historical geographic range and stock size to determine spawning grounds, rearing areas, feeding grounds and the locations of important life history processes.	2006-2007
The definition of critical habitat, if possible, for wolffish in eastern Canadian waters in order to determine priority habitat sites.	2007-2008

2.5.2 Recovery Action B2 - Define Measures to Conserve and/or Protect Wolffish Habitat

Effective conservation requires conservation and/or protection of habitat from the unintended effects of human activities on the eastern Canadian marine ecosystem. Legislation, policy, regulations, partnership agreements and stewardship are examples of mechanisms currently in place that can be utilized to protect wolffish and their habitat. Wolffish interact with many different species and these interactions may be critical to their survival, therefore an ecosystem-based approach is recommended. Research should be conducted in the following areas:

- Threats to wolffish habitat (natural and human induced);
- Existing or potential activities that may threaten wolffish habitat and the extent to which they can be mitigated;
- Prioritization of the spatial and temporal habitat needed to be protected to achieve the goal of population recovery; and
- Potential use of various management options as methods for the conservation and/or protection of wolffish habitat.

2.6 Recovery Strategy C - Mitigate Human Activities (Objectives 3, 4, 5)

Objective 3: Reduce the potential of wolffish population declines;
Objective 4: Promote wolffish population growth and recovery; and
Objective 5: Develop communication and education programs to promote the conservation and recovery of wolffish populations.

2.6.1 Recovery Action C1 - Identify and Mitigate Impacts of Human Activity

It is important for the recovery of wolffish species that the unintended human impacts on their populations and their habitats caused by fishing, offshore oil and gas activities and other potentially detrimental activities be identified and mitigation measures put in place. In addition, offshore mining, military activities, ocean dumping, land-based and atmospheric pollution, and global climate change are emerging issues, all of which may potentially affect the eastern Canadian marine ecosystem and subsequently wolffish populations. Current legislative and regulatory policies, that conserve and protect wolffish and their habitat must function in concert with non-legislative mitigation measures. Research should be conducted where possible to:

- Identify human impacts on all life stages of wolffish populations and their habitat on spatial, temporal and seasonal scales;
- Identify impacts and estimate their degree of severity or level of risk associated with their likelihood of occurrence;
- Identify how impacts can be mitigated both inside and outside the Canadian Exclusive Economic Zone (EEZ);
- Harmonize international, national, and provincial regulatory changes as they relate to wolffish conservation and incorporate education and stewardship as ways to mitigate human activities;
- Institute mandatory release of the two threatened wolffish species taken incidentally in all commercial fisheries in a manner that maximizes chance of survival;
- Promote modifications to gear and methods to avoid the catch of wolffish where practical; and
- Explore modification of gear/methods to reduce the potential impact on wolffish habitat.

2.7 Recovery Strategy D - Promote Knowledge and Stakeholder Participation in the Recovery of Wolffish Populations and Habitat Conservation and/or Protection (Objectives 3, 4, 5)

Objective 3: Reduce the potential of wolffish population declines;
Objective 4: Promote wolffish population growth and recovery; and

Objective 5: Develop communication and education programs to promote the conservation and recovery of wolffish populations.

2.7.1 Recovery Action D1 – Education and Communication

A key part of the strategy is to increase resource user knowledge and awareness of the plight of wolffish species, their population status, current threats and the actions required to ensure their recovery and long - term conservation. Publication of articles in local and regional newspapers and fishing related magazines, the distribution of wolffish identification material and information on species at risk to the fishing industry and posters along with the production of other educational and advisory materials could all be used to reach a wide audience, specifically harvesters. These materials should be available to the general public as well.

An educational program with both a regional and local component should include the following:

- The development of a comprehensive community education strategy aimed at resource users including:
- Identification of wolffish to species level (identification cards); general biology of wolffish and its historic population levels;
- Safe handling of incidentally captured wolffish in order to successfully release them live into their environment;
- Awareness of SARA and its importance to the conservation of wolffish;
- Enhancement of consultative activities including the production of related education and advisory activities; and
- Encourage resource user community involvement in the implementation of this Recovery Strategy and Management Plan.

2.7.2 Recovery Action D2 - Stewardship

Stewardship, simply stated, means Canadians - including landowners, private companies, volunteer community organizations, and individual citizens - are caring for our land, air and water, sustaining the natural processes on which life depends. Environmental stewardship can be described as the active expression of responsibility to ensure a healthy, diverse and sustainable environment for present and future generations. Implementing stewardship activities is therefore a high priority of this strategy and plays an important part in the conservation and protection of wolffish species and their ocean habitat. Consultation with applicable regional fishery groups will foster and maintain their involvement in recovery actions. Such resource user community involvement and support is critical to the success of the recovery of the wolffish species. This participation will serve as a basis for wolffish stewardship programs. Stewardship initiatives should:

- Promote the quick and safe release of incidentally caught wolffish to site of capture;
- Promote the accurate reporting of wolffish catches and subsequent release;

- Promote the identification of human impacts that may affect wolffish and their habitat;
- Initiate programs that implement stewardship activities with stakeholders;
- Provide technical and scientific information to conservation stewards;
- Enhance consultation activities including the production of related education and advisory materials; and
- Encourage resource user cooperation and community involvement in the implementation of this Recovery Strategy and Management Plan.

2.7.3 Recovery Action D3 - Consultation and Cooperation with Harvesters, Processors, Scientists, Regulators, Enforcement, Observers, Dockside Monitors, Governments, Aboriginal groups and Other Ocean Users

Consultation with resource users is a key component of the recovery process, required to ensure user involvement in recovery actions. Resource users interact daily with the incidental catch of wolffish species thus, they are provided with a knowledge base from which to design fishing gear to catch fewer wolffish as well as identify methods to safely release them. Such gear modification can be designed to avoid capture through harvesting strategies aimed at reducing encounter rates between wolffish and fishing gear. Therefore, it is important to foster ongoing consultation with resource users and all relevant Canadian jurisdictions. A comprehensive plan for realization of wolffish recovery includes consultation and cooperation amongst a diverse user group (located in each Atlantic Province) including but not limited to:

- any individuals or groups who may be affected by or may be useful assets in the process of wolffish species recovery and their long-term conservation and protection;
  - Fishing industry,
  - Fishery observers,
  - Aboriginal groups,
  - Provincial and Territorial Jurisdictions,
  - Federal Departments,
  - International Regimes and
  - Academic Institutions

2.8 Recovery Strategy E - Monitoring Human Activities and Wolffish Species (Objectives 3,4)

Objective 3: Reduce the potential of wolffish population declines; and
Objective 4: Promote wolffish population growth and recovery.

2.8.1 Recovery Action E1 - Monitor Wolffish Spatial and Temporal Abundance Patterns

Monitoring the abundance of wolffish species in eastern Canadian waters is essential to ensure that any improvement or deterioration of their status is detected as expediently as possible. This is essential if adaptive management is to be undertaken and be effective. Population size and structure needs to be monitored to discern trends, understand mortality patterns and identify recruitment problems.

Currently, research surveys, particularly stratified-random bottom trawl surveys are used to obtain fishery independent estimates of stock size and to provide quantitative estimates of recruitment. These data provide a basis for interpretation of abundance and distribution patterns that may provide some basis for defining adaptive management measures and recovery actions.

One of the primary objectives for monitoring wolffish spatial and temporal abundance patterns is to determine the effectiveness of any mitigation measures that have been implemented. Basic monitoring allows or enables early identification of unforeseen problems so that corrective measures can be undertaken in order to avoid further impacts. This ensures proper management (i.e. conservation and protection) of fish and their habitat.

Therefore, the recommended actions are to:

- Utilize research survey data to examine historical, current and future spatial and temporal abundance patterns of each wolffish species; and
- Utilize harvester's knowledge to gather spatial and temporal abundance patterns of each wolffish species.

2.8.2 Recovery Action E2 - Monitor Spatial and Temporal Patterns in Natural and Human Induced Mortality

By integrating research survey data with fisheries observer, statistical, dockside monitor and fishing logbook data, changes in wolffish distribution and abundance patterns can be examined to provide a basis for defining appropriate adaptive management measures and recovery actions. This integration of data will aid in the establishment of performance measures to evaluate:

- Effectiveness of recovery actions on wolffish and their habitat, in particular, effectiveness of the releasing wolffish back to their environment;
- Management methods on the conservation and protection of wolffish;
- Habitat protection on the conservation of wolffish; and
- Education, stewardship, consultation and cooperation on the conservation of wolffish.

3. PERMITTED ACTIVITIES

Subsection 83(4) of SARA allows for certain activities to be exempt from the general prohibitions of SARA, provided the activities are permitted in recovery strategies, action plans or management plans. In order for this section to be applicable, individuals must be authorized under an Act of Parliament, such as the *Fisheries Act*, to carry out such activities. Section 83(4) can be used as an exemption to allow activities, which have been determined to not jeopardize the survival or recovery of the species.

A Zonal Advisory Process (ZAP) held in St. John's, Newfoundland and Labrador in May 2004 provided an opportunity to review scientific advice regarding the determination of allowable harm for both wolffish species that are currently listed as threatened, *A. denticulatus* and *A. minor*. Participants of the review included individuals from government, industry and other non-governmental organizations. The advice resulting from this meeting was summarized in an Allowable Harm Assessment report (DFO 2004b).

The Allowable Harm Assessment concluded that recent (2000-2002) levels of mortality do not impair the ability of the species to recover. However, all efforts should be taken to enhance the survival in the fisheries, primarily through mandatory release of wolffish in a manner that will increase the chance of survival. This document adopts that conclusion and, in accordance with subsection 83(4) of SARA, permits fishers authorized under the *Fisheries Act* who are engaged in commercial or recreational fishing or in a First Nation's food, social and ceremonial (FSC) fishery for groundfish, shellfish and pelagic species (including emerging fisheries) that may incidentally kill, harm, harass, capture or take *A. denticulatus* or *A. minor* to carry out these activities under the following conditions:

- Every person on board the fishing vessel who incidentally catches northern *A. denticulatus* or *A. minor* while conducting fishing activities must return them to the place from which they were taken, and where they are alive, in a manner that causes them the least harm;

- Fishers are required to collect and subsequently report information to DFO for each fishing trip where *A. denticulatus* or *A. minor*is is caught, utilizing the standard logbook/logsheet protocol specified for the target species, vessel class or licence in question.

In accordance with subsection 83(4) of SARA, this document also permits scientific research activities that are authorized under the *Fisheries (General) Regulations*, SOR/93-53, that are conducted by Fisheries and Oceans Canada scientists for the purpose of monitoring and sampling various aquatic species, including wolffish. Scientific research was identified in the Allowable Harm Assessment as having negligible impacts of the ability of both *A. denticulatus* and *A. minor* to survive and recover (DFO 2004b).

In assessing allowable harm, the longer the timeframe being examined, the more uncertainty there is in projecting impacts of exploitation on the survival or recovery of a population. Given this uncertainty, the Allowable Harm Assessment for *A. denticulatus* and *A. minor* will be re-evaluated prior to 2010, incorporating any relevant new data. The Allowable Harm Assessment may be re-evaluated earlier if there is a significant increase in fishing pressure. **Current monitoring of incidental capture through both logbook data and at-sea observers will continue and will be used to assess the effectiveness of those conservation measures outlined above**.

While *A. lupus* has been listed in SARA Schedule 1 as a species of special concern (i.e. SARA prohibitions do not apply), it is recommended that live release protocols and reporting, as outline above for *A. denticulatus* or *A. minor*, also apply to this species. However, the implementation of this recommendation is at the discretion of the DFO regions, and should be approached as a voluntary measure to be used in cooperation with other *Fisheries Act* requirements.

4. POTENTIAL IMPACTS OF THE RECOVERY STRATEGY ON OTHER SPECIES/ECOLOGICAL PROCESSES

This Recovery Strategy and Management Plan recognizes the importance of the entire marine ecosystem. Multi-species approaches to conservation are known to be difficult due to the diverse interactions between species and their habitats that occur within a marine ecosystem. Recovery activities such as increased habitat protection and/or conservation and implementing mitigative measures to reduce human induced impacts may also benefit other species that co-occur with wolffish in eastern Canadian waters. The extent of such benefits is not yet completely understood. Collection of data to evaluate and model ecosystem interactions may help to address this unknown. In addition, stakeholder awareness and understanding of marine biodiversity and threatened species would be heightened through stated protection and/or conservation efforts for the wolffish.

5. ACTIONS COMPLETED OR UNDERWAY

A Multi-Stakeholder Recovery Team has been formed and the following initiatives have been initiated or have been completed:

- Prepare a Wolffish Recovery Strategy and Management Plan - This document;
- Update current knowledge - Summarized in this document;
- Define goals, objectives, strategies and actions for the wolffish recovery process - This document;
- A wolffish release program as a condition of license to examine the survival of released fish - Instituted in eastern Canada in 2003-2004 and is complete for certain fisheries;

- Commence a program of research on population structure, life history, habitat association and population status that will provide the information required to and facilitate effective recovery work - Instituted in 2002. Research is under way to examine population structure, life history, food and feeding and habitat associations;
- Increase understanding of the Allowable Harm Permitting process – An Allowable Harm Assessment has been undertaken and information has been provided to license holders for fisheries where wolffish may be taken as bycatch;
- Commence an education and communication program and promote stewardship geared mainly toward resource users but also the public in general - Education programs on species at risk issues in general and wolffish specifically have taken the form of meetings with fishers and information materials have been disseminated widely.

Intra-Departmental Collaboration has been promoted through:

- Cooperation between various Atlantic Canadian Regional DFO jurisdictions in terms of recovery and regulatory initiatives;
- Sharing data between Atlantic Canadian Regional DFO jurisdictions; and
- Preparation of preliminary economic profiling by regional DFO Policy and Economic Branches.

Federal, Provincial, and Aboriginal Collaboration has been promoted through:

- Continuing consultation and cooperative exchange with other federal departments (i.e. Environment Canada, Parks Canada);
- Continuing consultation and cooperative exchange with provincial representatives in NL Region; and
- Presentation of the strategy to Nunavut Wildlife Management Board and continuing dialogue with Aboriginal groups.

Industry and public involvement has been promoted through:

- Cooperative research initiatives;
- Education and communication with stakeholders: and
- Stewardship initiatives.

The above description of recovery related activities already under way, as promoted in draft versions of this document indicates that the Team and a host of other participants have already made significant progress in terms of recovery efforts. Progress is particularly reflected in the institution of an Atlantic release program and in research, education and stewardship initiatives presently being undertaken. Activities are elaborated in the following sections.

5.1 Recovery Strategy A - Conduct Research

Research under way includes:

- Population analyses to determine changes in historic distribution and abundance;
- Analysis of fishing impact;
- Definition of habitat associations and critical habitat (wolffish utilization of various habitat features including, temperature preferences, bottom type, depth etc.;
- Identification of gaps in current knowledge;
- Wolffish samples collected for the following analyses;
- Weights and numbers caught;
- Lengths by sex;
- Genetic, morphometric and meristic analyses to determine stock structure
- Otoliths for aging;
- Trends in abundance, distribution, stock (subpopulation) structure and life history; and
- Commercial catch (observer) data to estimate fishing mortality by species, sex, size, and age to permit the estimation of the impact of fisheries bycatch on the populations.

5.2 Recovery Strategy B - Habitat Conservation and Protection

Habitat required for the recovery and survival of the threatened wolffish species are being investigated by the Recovery Team (refer to Kulka et al. 2004).

5.3 Recovery Strategy C - Mitigate Human Activities

The Recovery Team recommended the quick release of all wolffish, alive wherever possible, caught incidentally by harvesters. Although *A. denticulatus* and *A. minor* have been declared threatened species by COSEWIC, these fish were still caught incidentally in many fisheries. Federal policy previously specified that they must be brought into port where fish processors either process them or discard them. In November 2002, the Recovery Team recommended that wolffish no longer be brought into port but rather be released in a manner that maximizes chance of survival.

Wolffish have been described as a “hardy species” that tend to be lively even after capture and have a good chance of survival if released quickly. Therefore, as of 2003-2004, Allowable Harm Permits have been issued to allow harvesters the incidental capture of wolffish. Permit requirements specify that harvesters estimate the weight of their wolffish catch by species and release them quickly and safely at the capture site. Further, research has been completed to examine survival of released species.

In 2004, DFO undertook an Allowable Harm Assessment for wolffish. In summary, the conclusions from that process are as follows:

"Given that mortality due to fishing is considered the dominant source of human induced mortality for northern and spotted wolffish and that the populations of both species have been steady or increasing prior to any prohibitions, it appears that the recent (2000-2002) level of mortality does not impair the ability of the species to recover. However, all efforts should be taken to enhance survival in the fisheries, primarily through mandatory release of wolffish in a manner that will increase the chance of survival. This can only be accomplished through education and permit conditions requiring the release of wolffish in a manner that will enhance their survival. As well, any gear modifications that lead to a reduction in the bycatch of wolffish (for example the Nordmore grate employed in shrimp fishery) should be employed wherever possible. Should there be a large increase in the size of any fisheries that take significant amounts of wolffish, other options may have to be considered. Finally, it is critical that the populations and sources of harm be monitored to ensure that recovery continues to take place".

Refer to DFO (2004) and Kulka (2004) and Kulka and Simpson (2004) for further details.

Survival of released fish is being evaluated. Publication of the results of a Habitat Stewardship Program (HSP) funded study examining survival of released wolffish is under way. As well preliminary observations suggest that fish released in an appropriate manner (placed back in the water quickly and with minimal handling, gills undisturbed) appear to have a high chance of survival. Programs educating fishers in best practices for release are under way.

5.4 Recovery Strategy D - Promote Knowledge and Stakeholder Participation in the Recovery of Wolffish Populations and Habitat Conservation and Protection

Wolffish identification cards (laminated), information sheets and posters have been widely distributed to stakeholders including fishers and fish processing plant workers. Videos are played at stakeholder meetings dealing with wolffish release and other species at risk issues.

The various forms of information have been disseminated at general meetings held by various resource user groups and by DFO. Knowledge and stewardship have also been the focus of several HSP initiatives. Direct interaction with stakeholders is a cornerstone of these initiatives. Harvesters are encouraged to get involved with the recovery of wolffish including the employment of best practices for release of wolffish and adherence to the requirement to record incidental catches.

5.5 Recovery Strategy E - Monitoring Human Activities and Wolffish Species

As part of a larger research initiative to estimate the effect of fishing activity on wolffish populations, observer coverage has been enhanced for fisheries where the majority of incidental catch of wolffish species has been identified, such as the Greenland halibut directed fisheries. Observer education and training has been undertaken to improve species identification and to provide for more detailed information collection and to pass this information on to harvesters. These data will be used to estimate removals by species which is the basis for estimating mortality related to fishing. A requirement for recording wolffish by species in log books has been instituted. Voluntary collection of wolffish landing data (by species for weight and size) at fish processing plants was instituted.

6. EVALUATION OF RECOVERY INITIATIVE

Evaluation of recovery criteria will most likely be based on the results of demographic analyses as outlined in this document. Demographic data on reproduction, age, growth and mortality will be based on best available scientific knowledge to estimate the level of increase or decrease in the wolffish population when compared to their status as designated by COSEWIC in 2001. Such data provide a means of documenting the recovery or lack thereof, for the wolffish population in eastern Canadian waters, thereby determining the efficacy of the recovery efforts.

Throughout implementation of the Recovery Strategy and Management Plan, the following questions can be utilized to evaluate progress on meeting the stated recovery goal and objectives and adjust performance measures as appropriate:

- Have estimates of biomass and Recovery Reference Points been researched?
- Have the distribution and population size increased? If so, have Recovery Reference Points been reached or exceeded?
- Have historic and present threats to wolffish populations and their habitat been fully identified, defined and mitigated?
- Have the recommended fishery management strategies been implemented? Are they effective in reducing mortality?
- Has habitat (i.e. critical habitat) necessary for the survival and recovery of the species been defined and accounted for in any recovery initiatives or management strategies?
- Are stakeholders involved in the recovery activities? Are the stewardship and education initiatives achieving the desired results?

7. STATEMENT OF WHEN ACTION PLAN WILL BE COMPLETED

An Action Plan has been drafted and will be finalized within two years of posting the final Recovery Strategy and Management Plan. A single, multi-species Action Plan for wolffish species is recommended to be consistent with this document.

The Action Plan will provide specific details for recovery implementation including measures to monitor and implement recovery, address threats, and achieve recovery objectives and specify when these measures are to take place. The Action Plan also includes an identification of critical habitat, to the extent possible, and examples of activities that are likely to result in its destruction.

LITERATURE CITED

References annotated with superscript numbers refer to numbered citations from Table 1:

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GLOSSARY OF TERMS

Aquatic Species (SARA section 2):
A wildlife species that is a fish, as defined in section 2 of the *Fisheries Act*, or a marine plant, as defined in section 47 of that Act.
- *where*

> **Fish** is defined as:
> (a) fish or its parts,
> (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and
> (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals;

- *and*

> **Marine Plant** is defined to include all benthic and detached algae, marine flowering plants, brown algae, red algae, green algae and phytoplankton.

Competent Minister (SARA section 2):
(a) the Minister of Canadian Heritage with respect to individuals in or on federal lands that are administered by that Minister and that are national parks, national historic sites or other protected heritage areas as those expressions are defined in subsection 2(1) of the Parks Canada Agency Act;
(b) the Minister of Fisheries and Oceans with respect to aquatic species, other than individuals mentioned in paragraph (a); and
(c) the Minister of the Environment with respect to all other individuals.

Critical Habitat (SARA section 2):
The habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the Recovery Strategy or in an Action Plan for the species.

Data Deficient:
A species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.

Endangered:
A wildlife species that is facing imminent extirpation or extinction.

Extinct:
A species that no longer exists.

Extirpated:
A species that no longer exists in the wild in Canada, but occurring elsewhere in the wild.

Federal Land (SARA section 2):

(a) land that belongs to Her Majesty in right of Canada, or that Her Majesty in right of Canada has the power to dispose of, and all waters on and airspace above that land;
(b) the internal waters of Canada and the territorial sea of Canada; and
(c) reserves and any other lands that are set apart for the use and benefit of a band under the Indian Act, and all waters on and airspace above those reserves and lands.

Fish Habitat *(Fisheries Act* section 34(1)):
Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

Habitat (SARA section 2):
(a) in respect of aquatic species, spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced; and
(b) in respect of other wildlife species, the area or type of site where an individual or wildlife species naturally occurs or depends on directly or indirectly in order to carry out its life processes or formerly occurred and has the potential to be reintroduced.

Not At Risk:
A species that has been evaluated and found to be not at risk.

Residence (SARA section 2):
A dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating

Special Concern:
A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.

Species:
Any indigenous species, subspecies, variety, or geographically or genetically distinct population of wild fauna and flora.

Threatened:
A wildlife species that is likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction.

Wildlife Species (SARA section 2):
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

(a) is native to Canada; or
(b) has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.

APPENDIX 1: RECORD OF COOPERATION AND CONSULTATION

The Recovery Team includes representatives from industry, academia, and the provincial and federal governments. The populations of wolffish, in particular, the two threatened species are concentrated largely from the Grand Banks to the Labrador Shelf, which is the jurisdiction of DFO Newfoundland and Labrador Region, and waters adjacent to the province of Newfoundland and Labrador. Thus, the majority of representation on the team was from this area. Industry was represented from leaders of both the inshore and offshore sectors. All sectors of DFO Newfoundland and Labrador were represented on the Team. Each Team member consulted extensively within their jurisdiction ensuring broad consultation such that key stakeholders were aware of and had the opportunity to input to the Plan.

The three species of wolffish are occasionally encountered in the Davis Strait. Thus, during development, elements of the Recovery Strategy and Management Plan were presented to the Nunavut Wildlife Management Board, and the Board was regularly informed of progress by the Team's DFO Central and Arctic member. Upon review of the proposed Recovery Strategy and Management Plan, the Nunavut Wildlife Management Board approved the document in January 2007. A presentation was also made to the Conne River Band (Newfoundland and Labrador) on the Recovery Strategy and Management Plan for wolffish species, and on species at risk issues in general. As well, the National Aboriginal Council on Species at Risk (NACOSAR) was informed through David Cole about the activities of the Team. Further, various Aboriginal owned fishing enterprises and Fisheries Product International (FPI) have been involved in recovery initiatives related to quantifying harm.

The team members, in the preparation of this National Wolffish Recovery Strategy and Management Plan, informed and received feedback from their respective jurisdictions. In early 2007, the proposed document was also forwarded to the Governments of Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Nunavut and Northwest Territories for review. Resulting comments were incorporated where applicable.

The Team wishes to thank the numerous reviewers of this document, from various sectors of the Newfoundland and Labrador Region, from other Atlantic Regions and NHQ. Special thanks goes to MEHM staff who worked on several sections related to habitat and CEAA and P&E staff from Newfoundland and Labrador, Quebec and Maritimes Regions who provided detailed economic analyses, to ensure best knowledge was included. The collective input of reviewers and contributors has ensured compliancy with SARA and has greatly enhanced the quality of a document that deals with a wide range of subject matter.

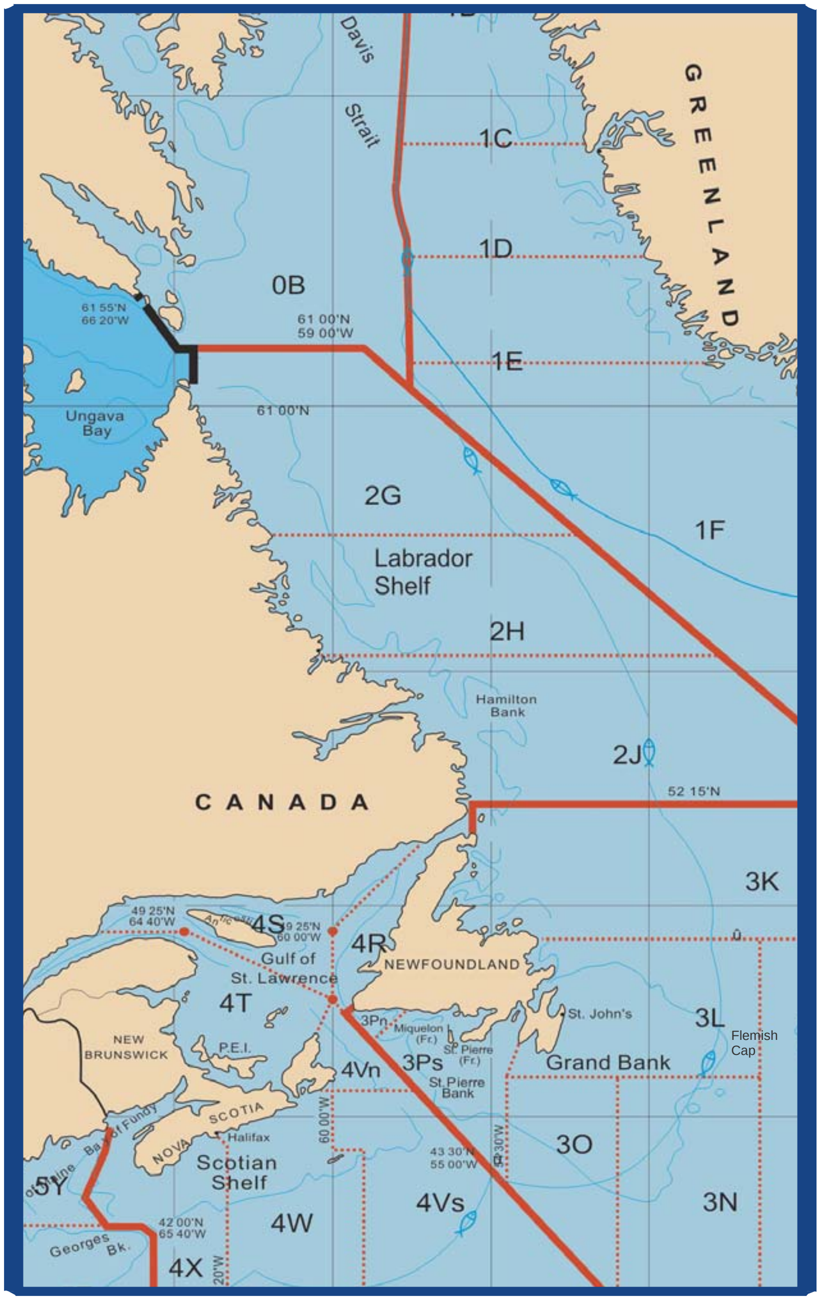


Figure 1, Map of Georges Bank to the Davis Strait, covering the distribution of wolffish species and showing various banks, basins and NAFO Divisions.

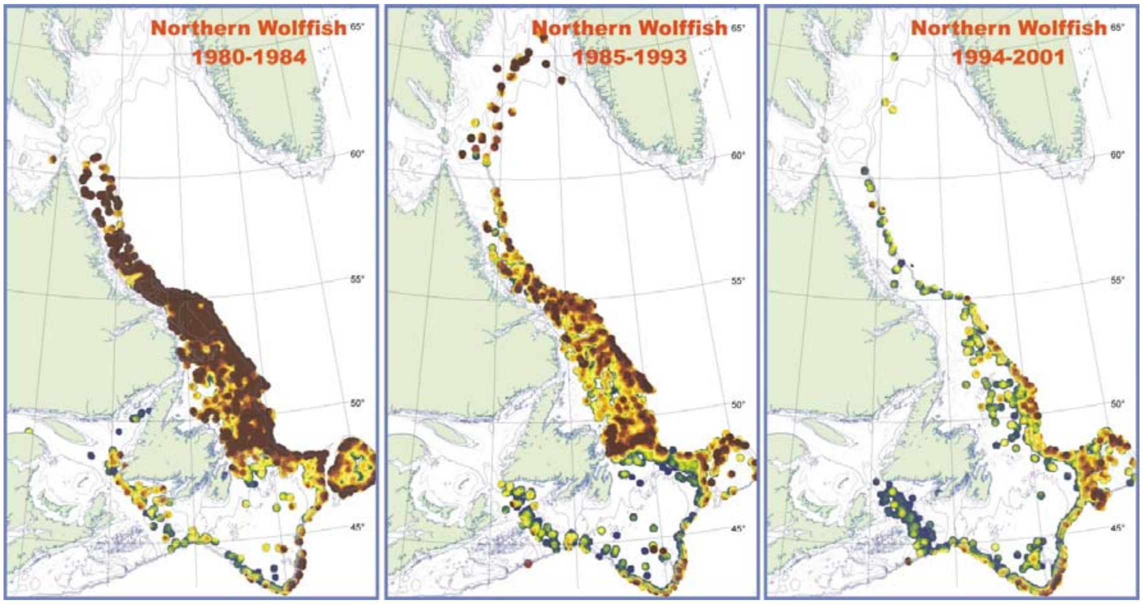


Figure 2a, Change in the distribution of *A. denticulatus* between 1980 and 2001 based on fall research surveys, Newfoundland and Labrador Region. Red shades depict areas of highest density, shading through yellow to green to blue as areas of lowest density. Sampling north of Lat.60°, in the Gulf of St. Lawrence and on the Scotian Shelf is incomplete.

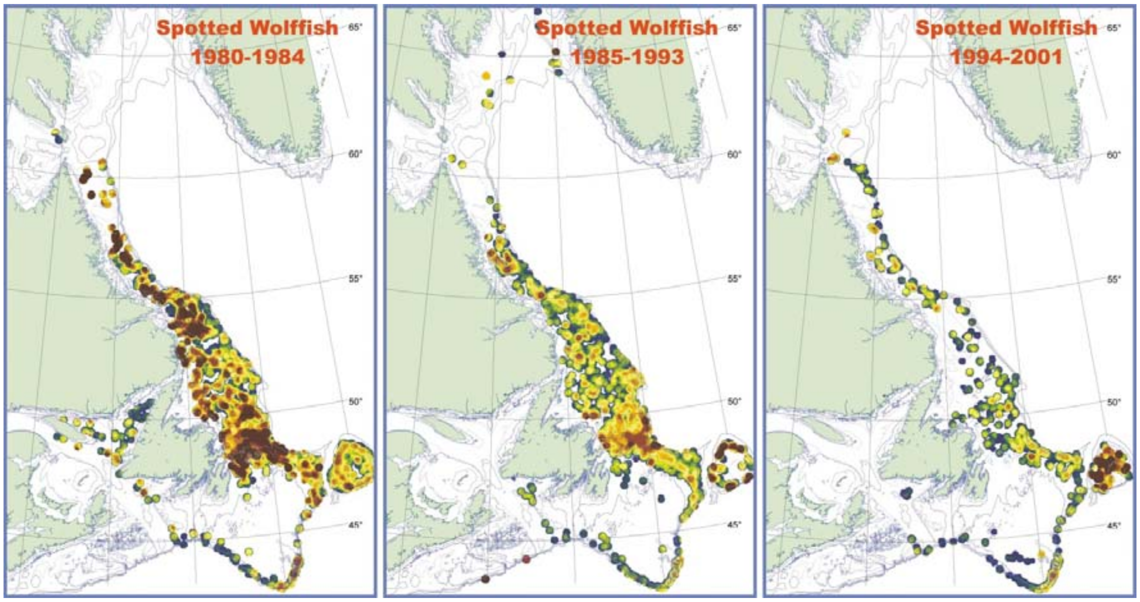


Figure 2b, Change in the distribution of *A. minor* between 1980 and 2001 based on fall research surveys, Newfoundland and Labrador Region. Red shades depict areas of highest density, shading through yellow to green to blue as areas of lowest density. Sampling north of Lat. 60^{o}, in the Gulf of St. Lawrence and on the Scotian Shelf is incomplete.

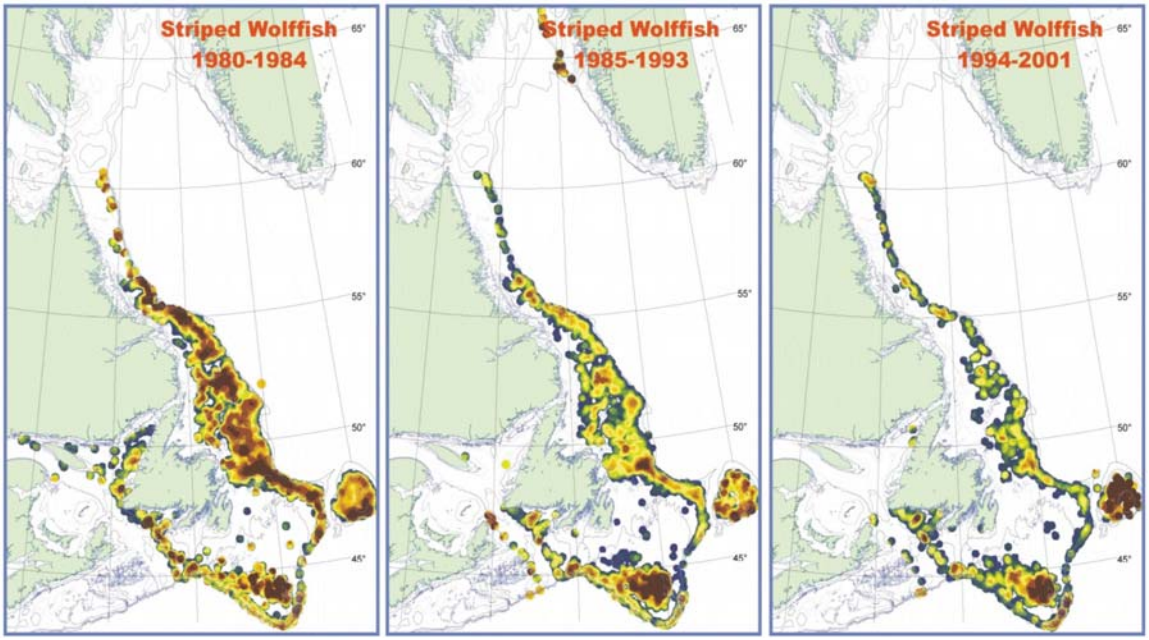


Figure 2c, Change in the distribution of *A. lupus* between 1980 and 2001 based on fall research surveys, Newfoundland and Labrador Region. Red shades depict areas of highest density, shading through yellow to green to blue as areas of lowest density. Sampling north of Lat. 60°, in the Gulf of St. Lawrence and on the Scotian Shelf is incomplete.

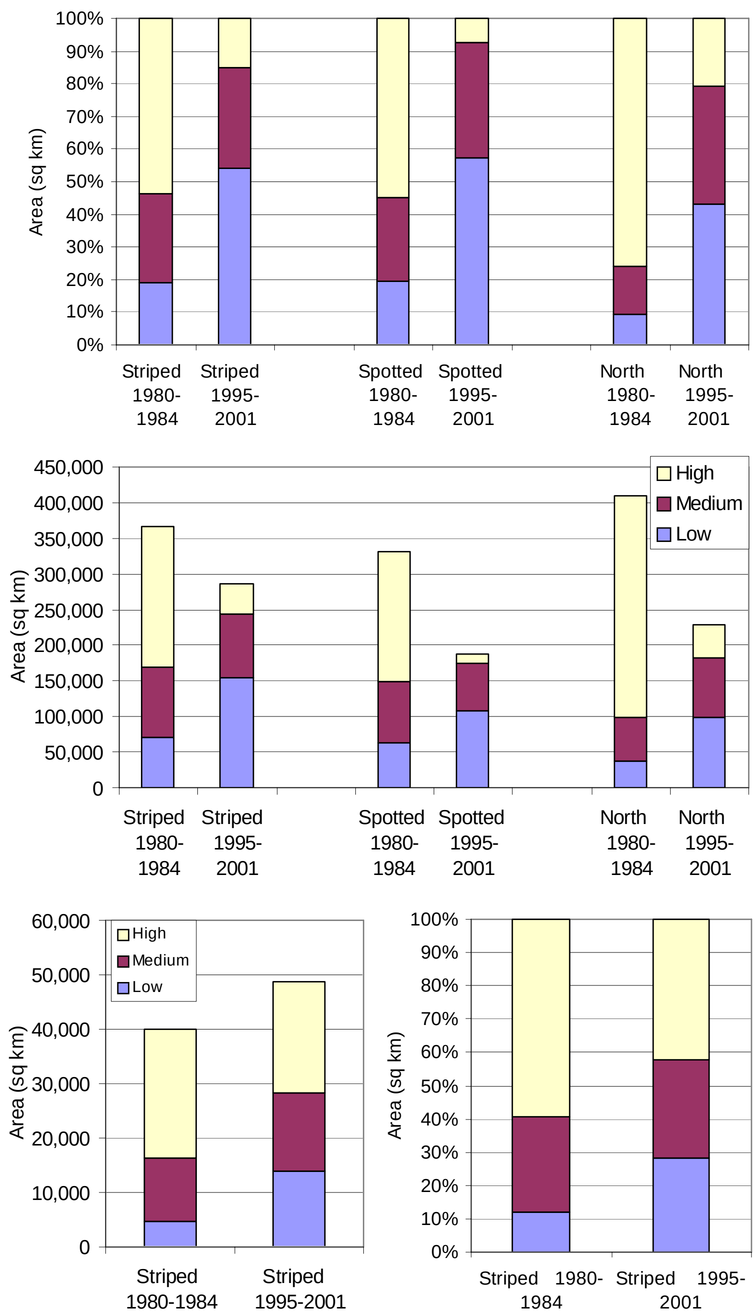


Figure 3, Change in the area of occupancy of *A. denticulatus*, *A. minor* and *A. lupus* between 1980 and 2001 based on fall research surveys, Newfoundland and Labrador Region (includes the Grand Bank, northeast Newfoundland Shelf and southern Labrador Shelf).

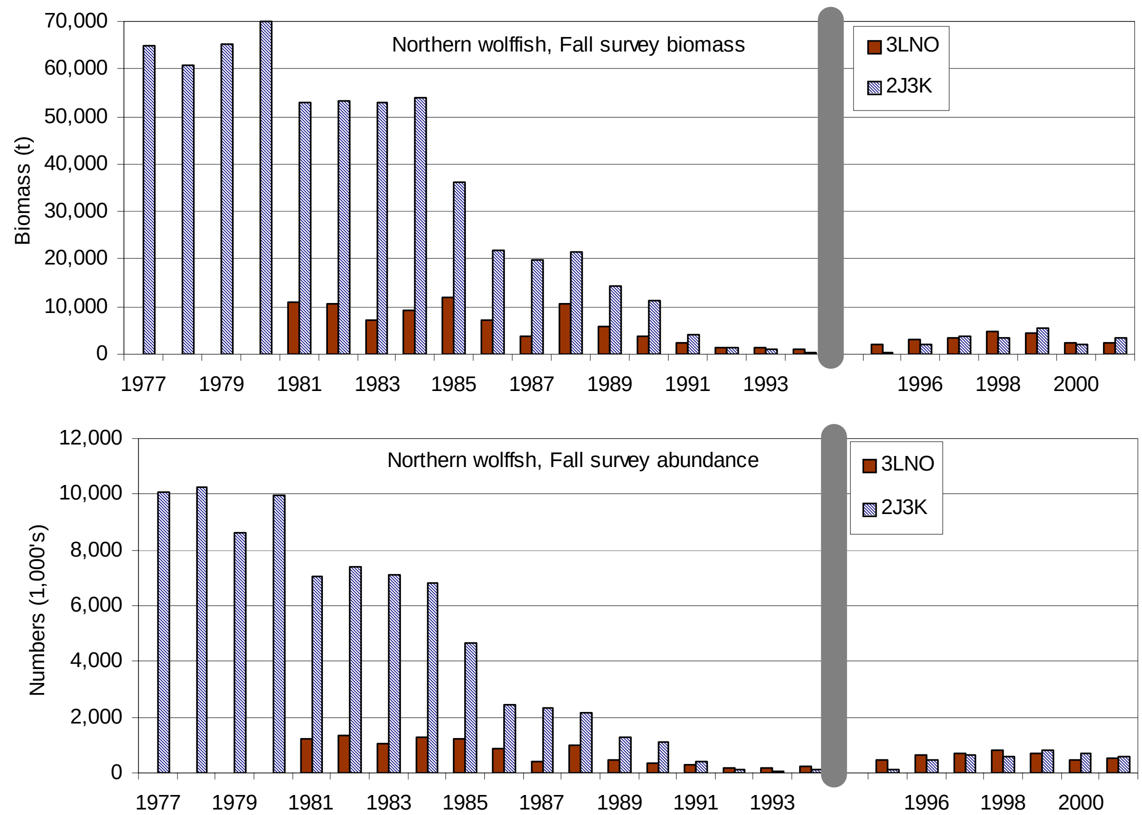


Figure 4a, Trends in abundance (lower panel) and biomass (upper panel) indices for *A. denticulatus* from 1977-2001. Indices were derived from fall Newfoundland and Labrador research surveys. The northern area (2J3K) trend is shown separately from the southern area (3LNO). The dark vertical bar separates the two time series. Engel trawl was used prior to the fall of 1995, Campelen in subsequent years (after Simpson and Kulka 2002).

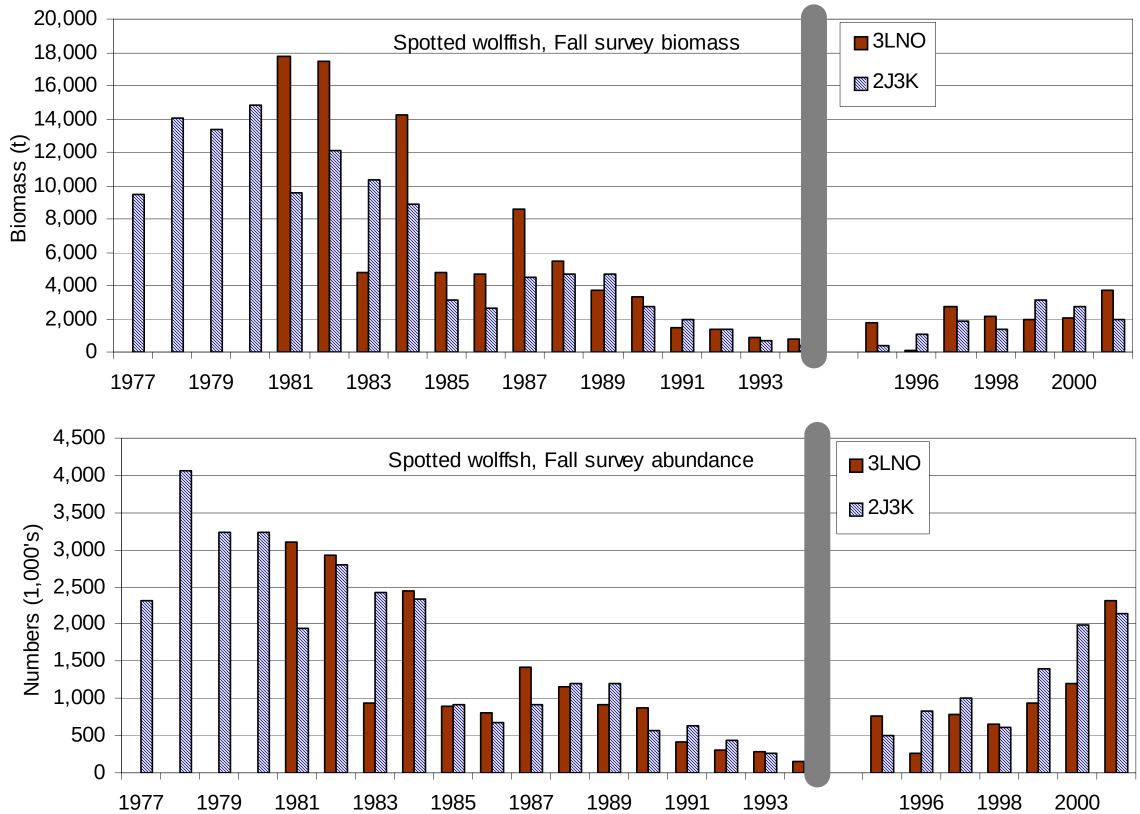
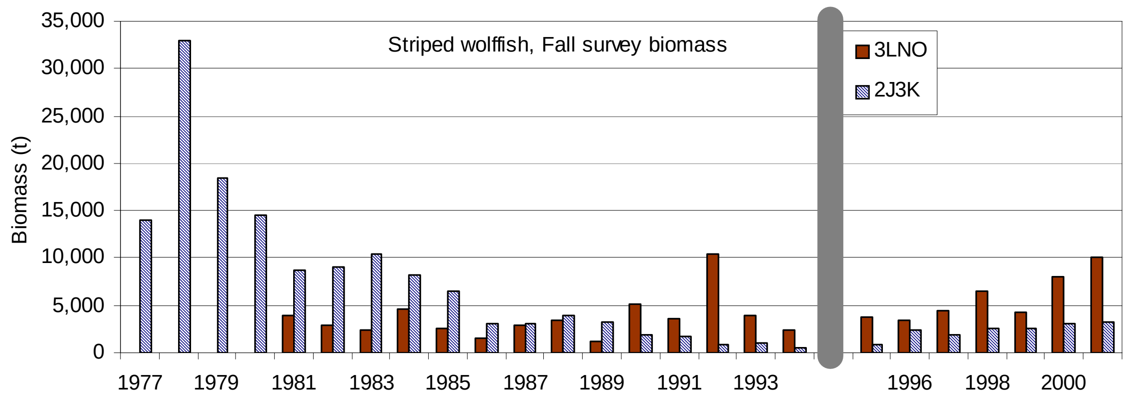


Figure 4 b, Trends in abundance (lower panel) and biomass (upper panel) indices for *A. minor* from 1977-2001. Indices were derived from fall Newfoundland and Labrador research surveys. The northern area (2J3K) trend is shown separately from the southern area (3LNO). The dark vertical bar separates the two time series. Engel trawl was used prior to the fall of 1995, Campelen in subsequent years (after Simpson and Kulka 2002).



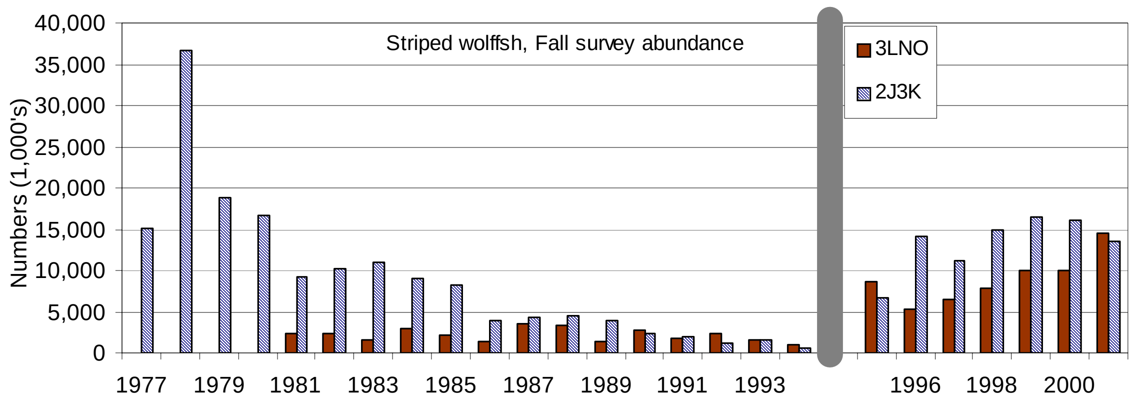


Figure 4 c, Trends in abundance (lower panel) and biomass (upper panel) indices for *A. lupus* from 1977-2001. Indices were derived from fall Newfoundland and Labrador research surveys. The northern area (2J3K) trend is shown separately from the southern area (3LNO). The dark vertical bar separates the two time series. Engel trawl was used prior to the fall of 1995, Campelen in subsequent years (after Simpson and Kulka 2002).

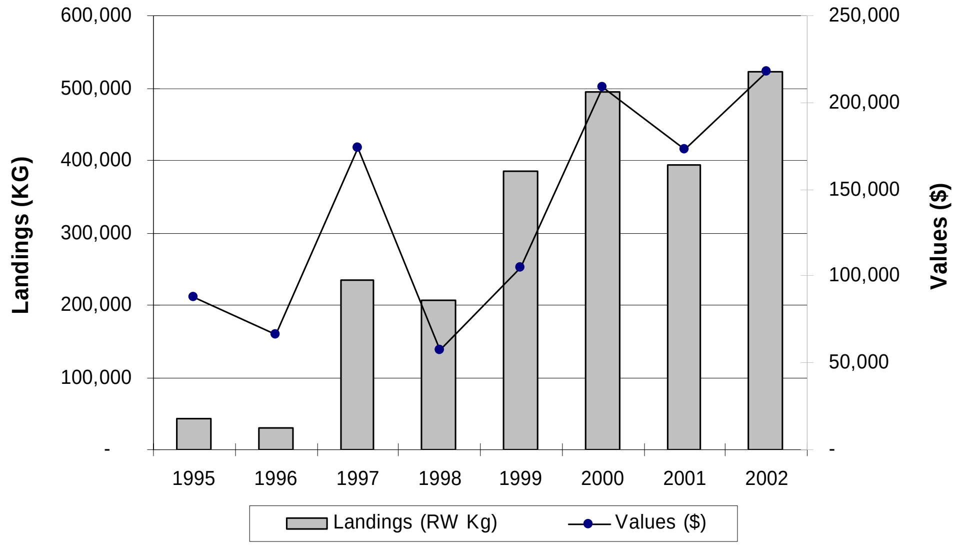


Figure 5, Wolffish Landings and Value (1995-2002), Newfoundland and Labrador Region

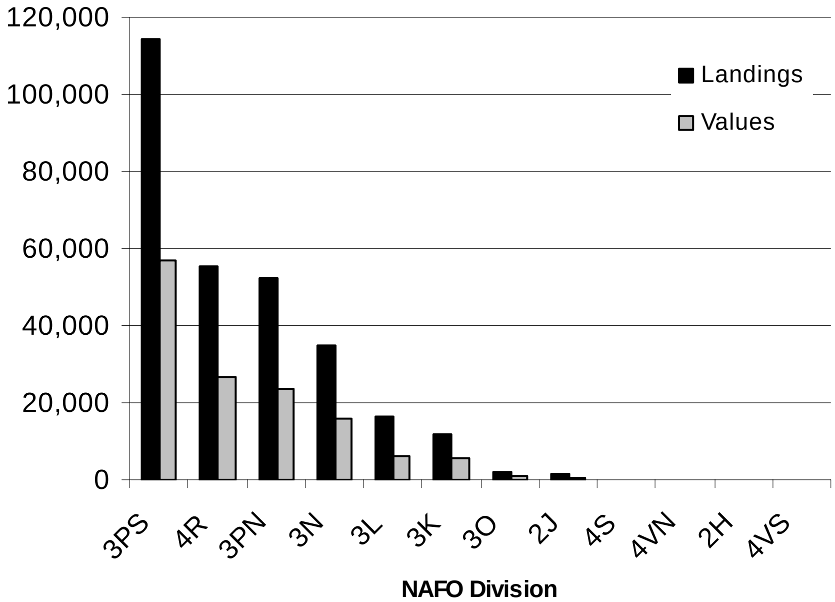


Figure 6, Average Wolffish Landings (Kg) and Value ($) by NAFO (Sub) Division, Newfoundland and Labrador Region (1995-2002).

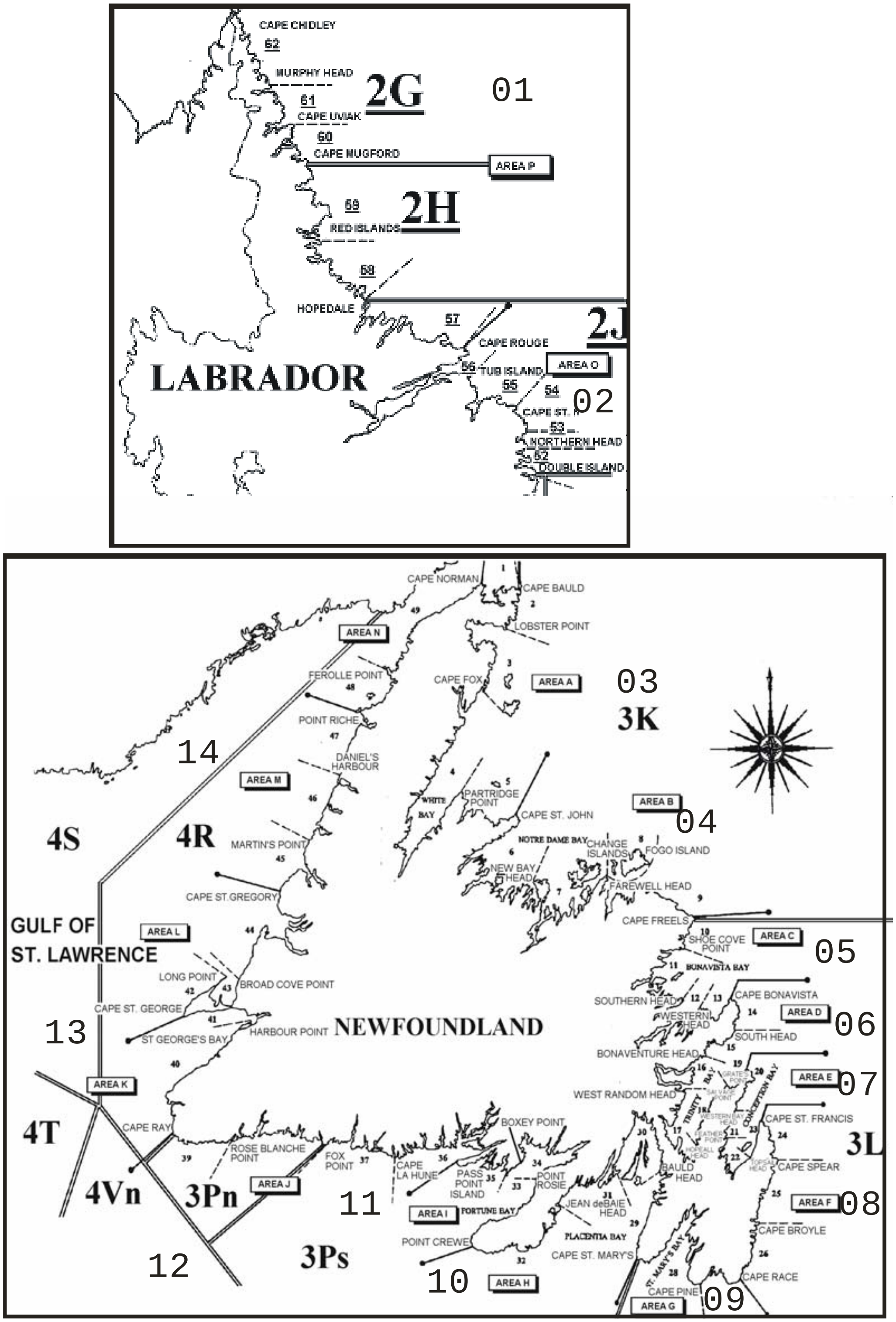


Figure 7, Economic statistical areas by number and name, Newfoundland and Labrador Region (see Figure 1).

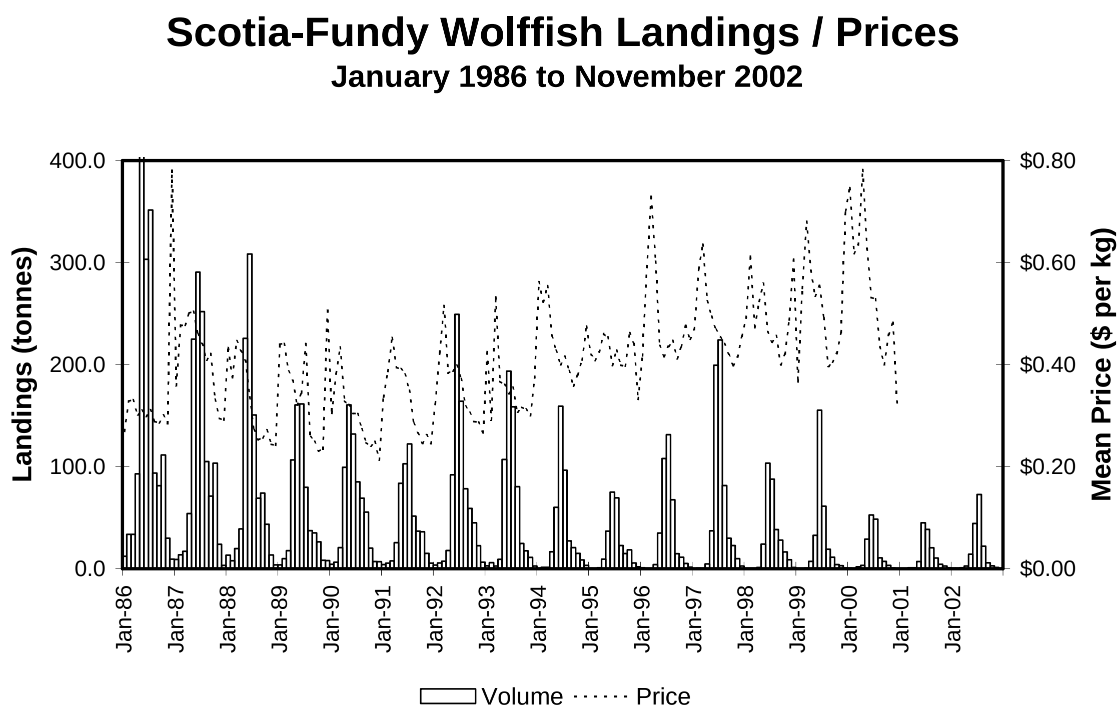


Figure 8, Maritimes (Scotia-Fundy) Region wolffish landings/prices – January 1986 to November 2002.

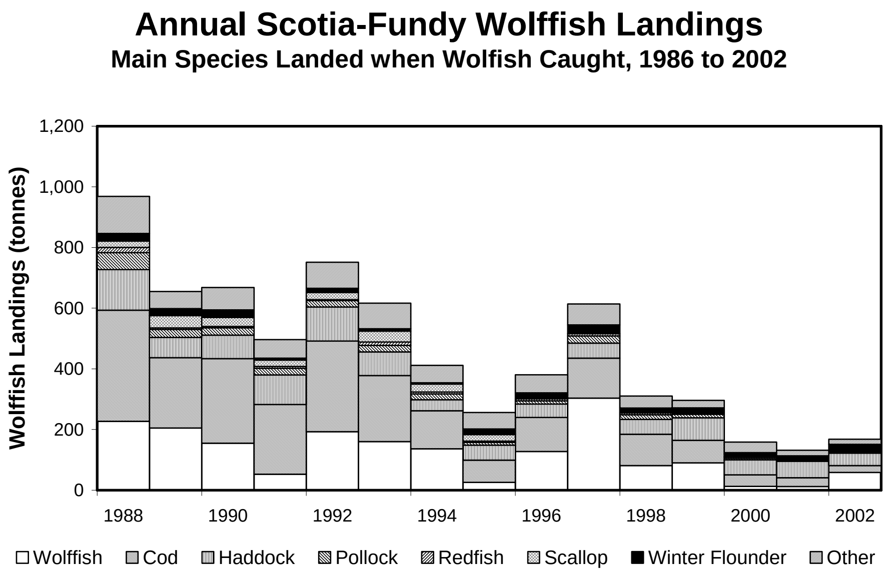


Figure 9, Annual Maritimes (Scotia-Fundy) Region wolffish landings (indicating main species landed when wolffish was caught) – 1986 to 2002.

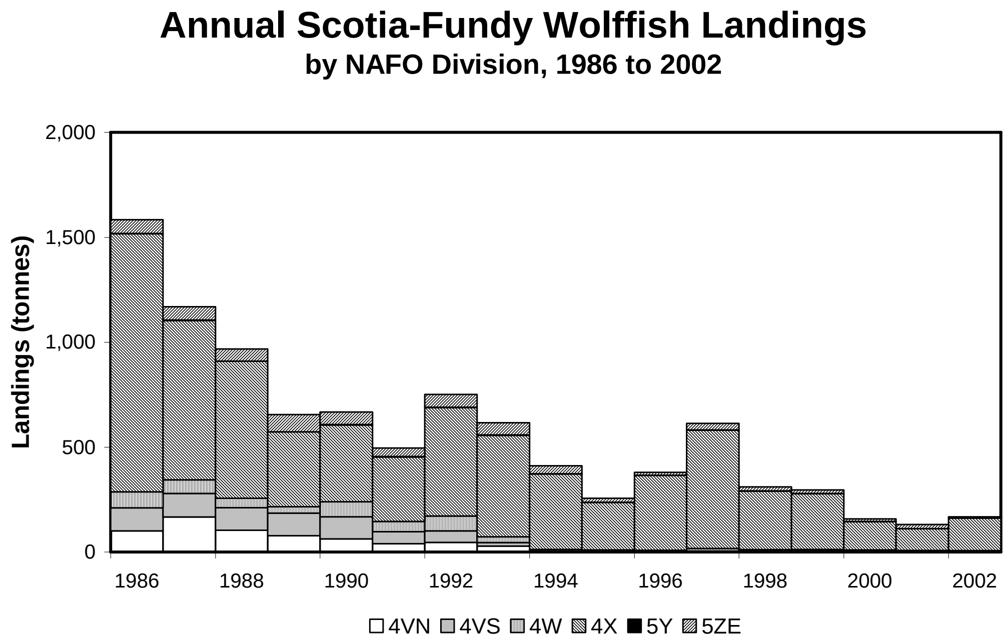


Figure 10, Annual Maritimes (Scotia-Fundy) Region wolffish landings by NAFO Division – 1986 to 2002.

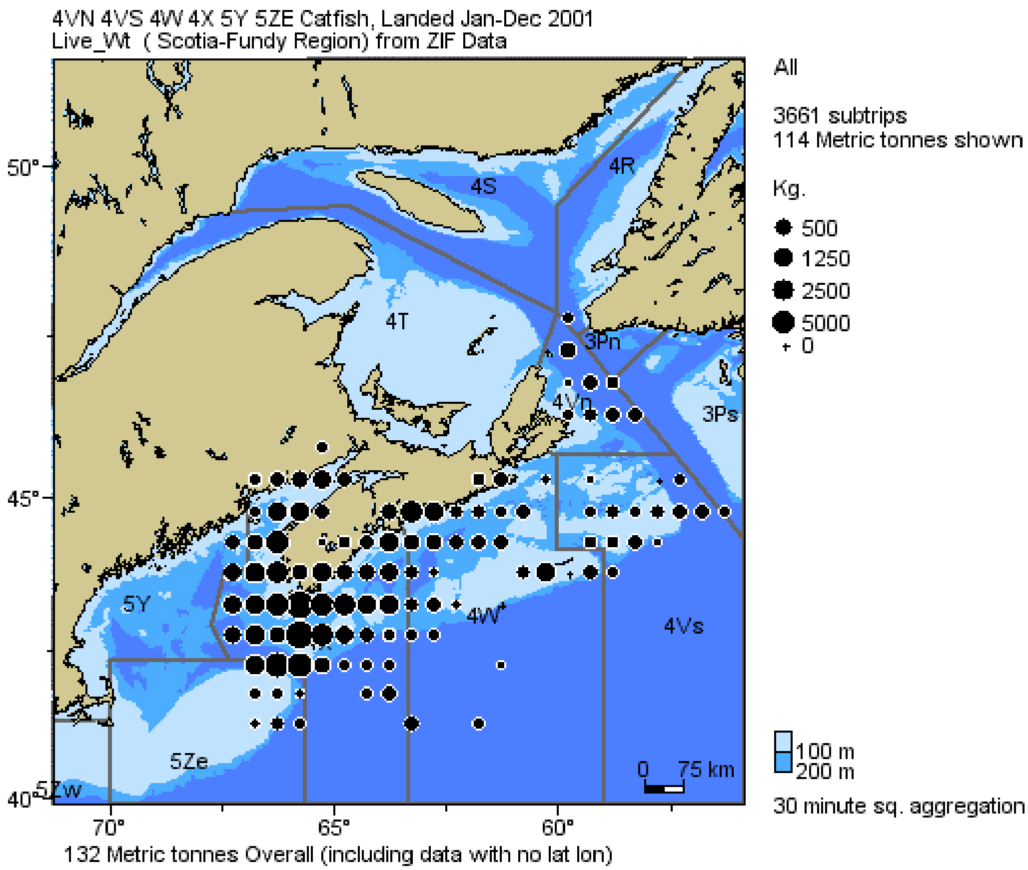


Figure 11, 4Vn, 4Vs, 4W, 4X, 5Y and 5Ze wolffish (catfish) landings, expressed as live weight – January to December 2001. Derived from Maritimes Region ZIF data.

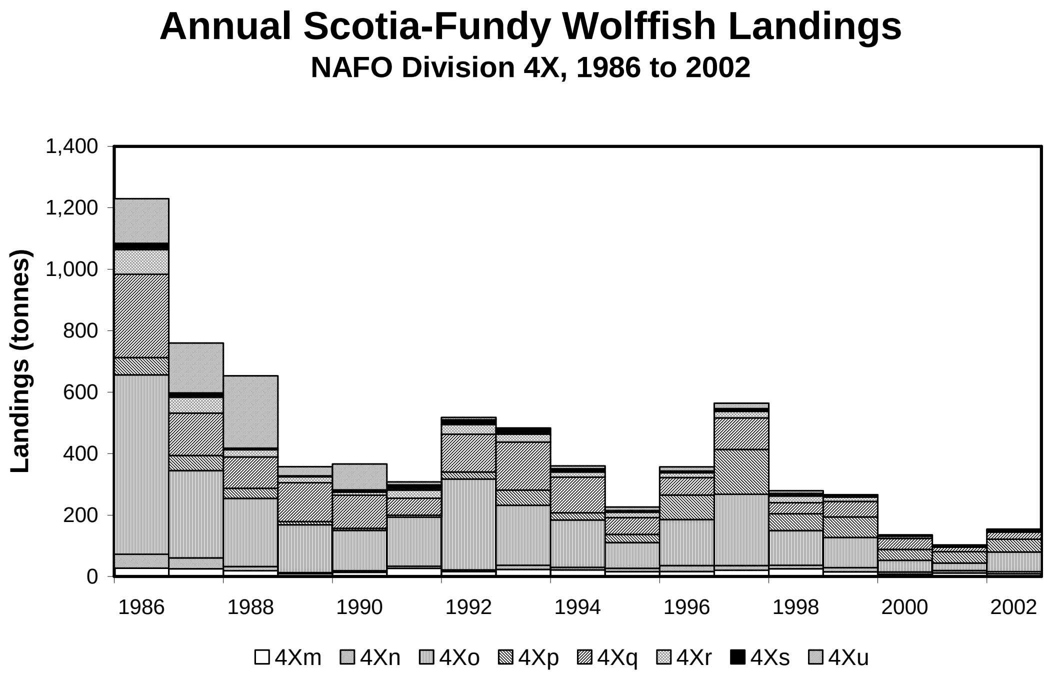


Figure 12, Annual Maritimes (Scotia-Fundy) wolffish landings in NAFO Division 4X – 1986 to 2002.

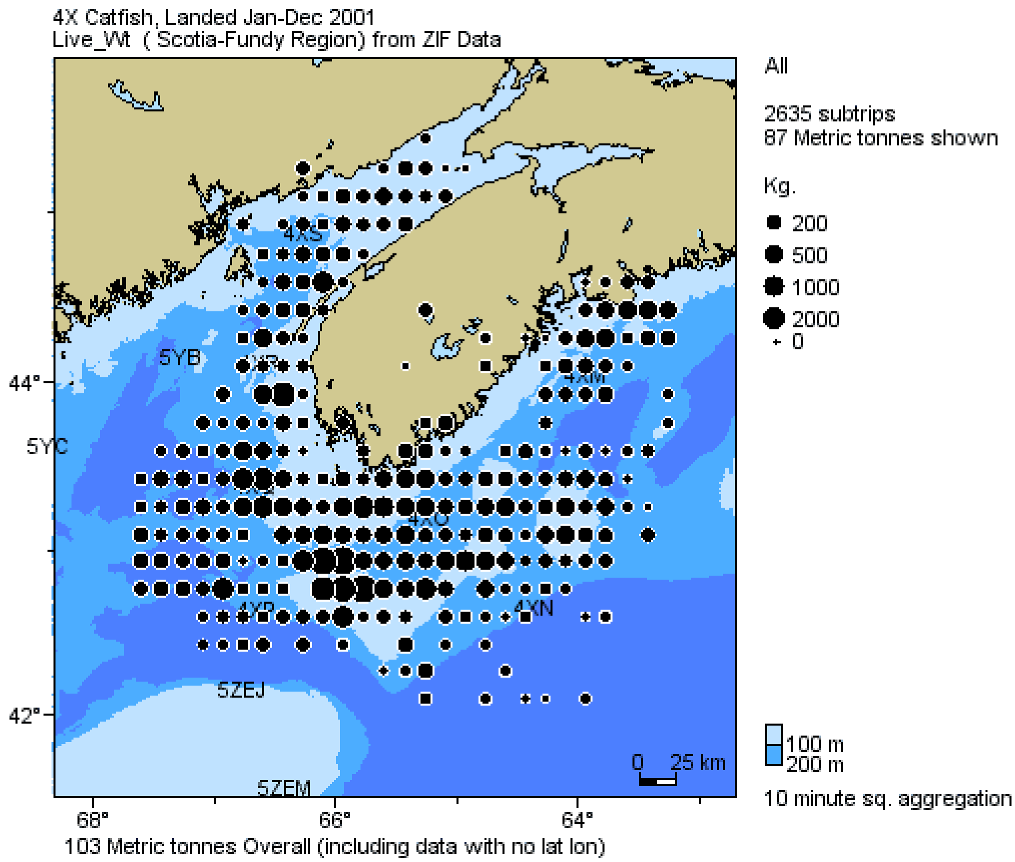


Figure 13, 4X wolffish (catfish) landings, expressed as live weight – January to December 2001. Derived from Maritimes Region ZIF data.

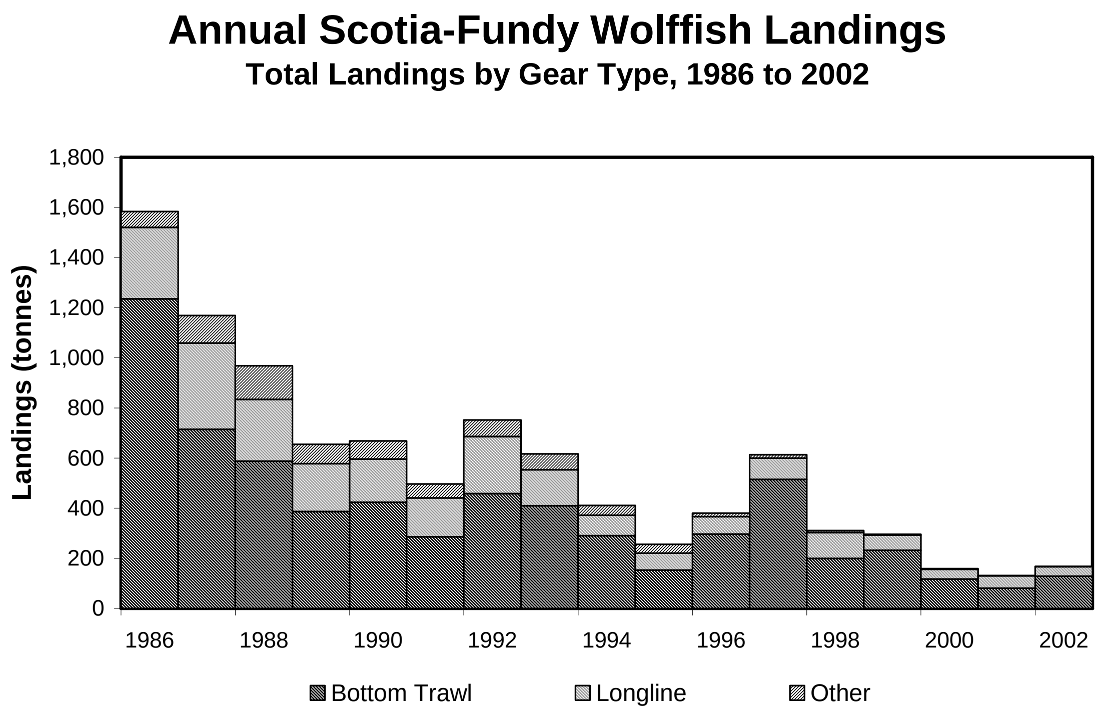


Figure 14, Annual Maritimes (Scotia-Fundy) Region wolffish total landings by gear type – 1986 to 2002.