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Determination of Allowable Harm for Spotted (*Anarhichas minor*) and Northern (*Anarhichas denticulatus*) Wolffish

Détermination des dommages admissibles pour le loup tacheté (*Anarhichas minor*) et le loup à tête large (*Anarhichas denticulatus*)

D.W. Kulka and M.R. Simpson

Department of Fisheries and Oceans
P.O. Box 5667
St. John's NL Canada A1C 5X1

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ABSTRACT

General Prohibitions, Sect. 32 (1) of the Species at Risk Act, specifies that “no person shall kill, harm, harass, capture or take an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species”. However, Sect. 73 (1), also provides for exceptions where: “The competent minister may enter into an agreement with a person, or issue a permit to a person, authorizing the person to engage in an activity affecting a listed wildlife species, any part of its critical habitat or the residences of its individuals” subject to certain condition. Schedule 1 of the Act lists spotted (*Anarhichas minor*) and northern (*A. denticulatus*) wolffish as “threatened”. Thus, starting June 1 2004, prohibitions have been placed on the capture of those species. This paper examines conditions that would be required to allow the capture of spotted and northern wolffish without affecting their recovery.

We discuss the efficacy of measures aimed at reducing harm for wolffish species such as live release, spatial/temporal closures and gear restrictions. Due to their widespread distribution, diverse habitat preferences, and lack of particular spawning or feeding aggregations spatial closures are considered to be an ineffective method to reduce wolffish by-catch at this time. As well, since specific information on critical periods in the life history of these species is unknown, the efficacy of temporal closure is also limited. Preliminary studies indicate that a wide variety of gears capture wolffish species and as yet few gear modifications have been identified that effectively exclude wolffish. The exception is the Nordmore grate attached to shrimp trawls that exclude most wolffish (and other fish species) > 15-20 cm. At present, wolffish live-release, which is particularly feasible in fisheries where the gear does not harm wolffish is considered to be the most viable strategy to reduce wolffish mortality with minimal disruption to commercial fishing activities.

RÉSUMÉ

En vertu du paragraphe 32 (1) de la *Loi sur les espèces en péril* (Interdictions générales), « il est interdit de tuer un individu d'une espèce sauvage inscrite comme espèce disparue du pays, en voie de disparition ou menacée, de lui nuire, de le harceler, de le capturer ou de le prendre ». Cependant, le paragraphe 73 (1) prévoit des exceptions lorsque « le ministre compétent peut conclure avec une personne un accord l'autorisant à exercer une activité touchant une espèce sauvage inscrite, tout élément de son habitat essentiel ou la résidence de ses individus, ou lui délivrer un permis à cet effet », sous réserve de certaines conditions. Le loup à tête large (*Anarhichas denticulatus*) et le loup tacheté (*Anarhichas minor*) sont inscrits à l'annexe 1 de la Loi en tant qu'espèces « menacées ». C'est pourquoi, à partir du 1er juin 2004, on a imposé des interdictions concernant la capture de ces espèces. Le présent document traite des conditions qu'il faudrait imposer pour permettre la capture du loup à tête large et du loup tacheté sans que cela ne compromette leur rétablissement.

Nous traitons de l'efficacité des mesures d'atténuation des dommages causés aux espèces de loups de mer tels que la remise à l'eau, de la fermeture spatiale ou temporelle de certaines zones et de restrictions concernant les engins. En raison de la vaste aire de répartition des loups de mer et de leurs préférences diverses en matière d'habitat et de l'absence de regroupements particuliers pour la reproduction et l'alimentation, on s'interroge sur l'efficacité d'une fermeture spatiale pour réduire le nombre de prises accessoires. Par ailleurs, comme les périodes critiques du cycle biologique de ces espèces demeurent inconnues, l'efficacité d'une fermeture temporelle est également limitée. D'après des études préliminaires, une grande variété d'engins capturent les loups de mer et, jusqu'à ce jour, certaines modifications apportées aux engins ont permis de les exclure de façon efficace. L'une d'elles, la grille Nordmore, qui fixée aux chaluts à crevettes, exclut la plupart des loups de mer (et toute autre espèce de poissons) de plus de 15 à 20 centimètres. À l'heure actuelle, on considère que la remise à l'eau, que l'on peut notamment effectuer dans les pêches où les engins ne blessent pas les loups de mer, est la meilleure stratégie à appliquer si l'on veut réduire la mortalité de ces espèces, tout en perturbant le moins possible les pêches commerciales.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the status of populations and classifies risk of extinction: extinct, extirpated, endangered or threatened, special concern, data deficient or not at risk (Anon 2003). The Species at Risk Act (SARA), proclaimed on 5 June 2003, with prohibitions brought into effect one year later affords legal protection for species at risk listed on Schedule 1 of the Act which comprises a list of all species that have been listed at risk by the competent Minister. Those species assessed by COSEWIC as extirpated, endangered or threatened prior to the proclamation are automatically protected by rollover to Schedule 1, including *Anarhichas denticulatus* (northern wolffish, threatened) and *A. minor* (spotted wolffish, threatened).

The Act prohibits the killing and harming of Schedule 1 species, including northern and spotted wolffish. Sect. 32 (1), General Prohibitions, states that “no person shall kill, harm, harass, capture or take an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species”. However, Sect. 73 (1) of the Act also provides for certain situations where: “The competent minister may enter into an agreement or issue a permit to a person, authorizing that person to engage in an activity affecting a listed wildlife species, any part of its critical habitat or the residences of its individuals”, subject to certain conditions. Effectively, this means that the SARA legislation provides the competent Minister the option to allow for unavoidable “incidental harm” to a listed species providing that certain conditions are met.

Under Sect. 73(2) of the SAR Act, authorizations may **only** be issued for one or more of the following purposes:

- *(a)* the activity is scientific research relating to the conservation of the species and conducted by qualified persons;
- *(b)* the activity benefits the species or is required to enhance its chance of survival in the wild; or
- *(c)* affecting the species is incidental to the carrying out of the activity

Further, Sect. 73(3) establishes that authorizations may be issued **only** if the competent minister is of the opinion that **all three** of the following pre-conditions are met:

- *(a)* all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted;
- *(b)* all feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of its individuals; and
- *(c)* the activity will not jeopardize the survival or recovery of the species.

Where “allowable harm” is an option, competent Ministers will provide information to proponents about available alternatives and mitigation methods when applicable, and will take into account information provided by proponents in determining whether a proposed activity will jeopardize the survival or recovery of the species.

- Northern and spotted wolffish are the first two Atlantic marine fish to be assessed by COSEWIC as threatened and thus afforded protection under SARA. Their capture constitutes a violation in the absence of an Allowable Harm Permit (AHP) or a Recovery

Strategy that details the circumstances for allowable harm. The purpose of this paper is to determine conditions for allowing harm to spotted and northern wolffish.

METHODS

The guide used for determining allowable harm for wolffish species was the **Framework for Fisheries and Oceans to Address Permitting Requirements under Section 73 of SARA**. The key components comprise:

- A scoping of whether recovery of the species is feasible, if human activities which affect the species were to continue.
- A discussion on the important human activities and the boundary conditions within which they must operate, if recovery is deemed possible.

Development of specific options for those activities must be consistent with the provisions of Section 73 of the Act.

Framework

Following is a description of the Permitting Requirements Framework, designed to describe conditions that would allow human activity to occur without affecting recovery of the species. The Framework can be applied to a wide variety of conditions i.e. where level of data and knowledge may vary. The best information available may vary from qualitative or descriptive to age based models of the populations and its parameters.

Steps 1 to 4 of the Framework are designed to determine whether recovery of the species is feasible, if human activities were to continue.

1. **What is present/recent species trajectory**
2. **What is present/recent species status**
3. **What is expected order of magnitude/target for recovery**
4. **What is expected general time frame for recovery to the target**

If it is determined that the species is in such poor condition that no human-induced mortality can be permitted without jeopardizing survival or recovery, then permits cannot be issued.

Steps 5 to 8 scope out the important human activities and the boundary conditions within which they must operate, if recovery is deemed possible. Therefore, the following section is designed to define the conditions under which incidental harm can take place without affecting recovery.

5. **What is the maximum human-induced mortality which the species can sustain and not jeopardize survival or recovery of the species?**
6. **What are the major potential sources of mortality/harm?**
7. **For those factors not dismissed, quantify to the extent possible the amount of mortality or harm caused by each activity.**
8. **Aggregate total mortality/harm attributable to all human causes and contrast with that determined in Question #5.**

Steps 9 to 12 then develop the specific options for those activities, consistent with the provisions of Section 73 (3).

9. To support condition (a), science and management will have to:

- Develop an inventory of all reasonable alternatives to the activities in #7, but with potential for less impact.
- Document expected mortality/harm rates of alternate activities
- Document nature and extent of major ecosystem effects caused by the alternate activities.
- Document expected costs and benefits of options which could be adopted, at least when options may look promising

10. To support condition (b) science and management will have to:

- Develop an inventory of all feasible measures to minimize the impacts of activities in # 7
- Document the expected effectiveness of the mitigation measures for permitted activities
- Document the expected costs and benefit of options which could be applied, at least when options may look promising

11. To support condition (c), science and management will have to document:

- The expected mortality or harm for various scenarios carried over from #9 and/or #10 are below that determined in #5 and;
- The projected population trajectory under the various scenarios indicates that survival or recovery is not in jeopardy, considering cumulative sources of impact.

12. Prepare options and (where justified) recommendations regarding permits, including rationales, relevant conditions to ensure (a), (b), and (c) are covered, and performance measures.

In addressing the Permitting Framework for northern and spotted wolffish, information from Simpson and Kulka (2002, 2003) were used and summarized here. These include information on wolffish distribution and abundance and fishing mortality.

Distribution and Abundance

Information from Newfoundland & Labrador (NL) Region research trawl surveys, 1978-2003, were used to examine distribution and abundance of northern and spotted wolffish. Methods used to describe the distribution of wolffish can be found in Simpson and Kulka (2002). Information from that paper describing distribution and relative trends in abundance derived from fall research trawl surveys from the Grand Banks, northeast Newfoundland and Labrador Shelves (Fig. 1) are summarized here.

Fishing mortality

Three data sources were used to derive an estimate of catch of wolffish by species, including discards: Zonal Interchange Format (ZIF), NAFO STATLAN 21A (Northwest Atlantic Fisheries

Organization), and DFO Observer data (OBS). However, landing statistics for wolffish species do not accurately reflect fishing mortality. They are deficient for three reasons: the species are not differentiated (reported as “catfish”), any wolffish discarded at sea are not recorded and landings are not differentiated at dockside. A substantial portion of all three species are discarded but this is particularly a problem for northern wolffish that are almost never retained. Therefore, landings data cannot be used to determine mortality due to fishing on a species basis. Instead, information collected by fishery observers for a portion of the fisheries was used to estimate removals by species. Those data were recorded by species and included estimates of discards. On a fishery basis, a ratio of landed to observed weight of the directed species can be used to raise the estimate of observed catch of each species of wolffish.

Population trajectories

Data used to define population trends of wolffish at the centre of their distribution are derived from the fall NL surveys since this survey covers the main concentrations of spotted and northern wolffish (Simpson and Kulka 2002). For the purpose of this analysis, only the recent trajectory, defined as 1995 to date, is used for three reasons. First, 1995 marks the end of the decline for both spotted and northern wolffish. Secondly, a new survey gear, a Campelen shrimp trawl, was introduced for the NL survey. Prior to this recent time period, the Engel groundfish trawl was used for the NL survey. The two gears have been found to have very different size related catchabilities for a number of species. Areas on the fringe of the wolffish distribution, in particular the Scotian Shelf and Gulf of St. Lawrence, are considered separately since those time series employ different gears, are prosecuted at different times of the year and represent only a fringe of the population of northern and spotted wolffish (McRuer et al 2001).

RESULTS AND DISCUSSION

Following is a brief description of the population trajectories and distribution trends for the two listed threatened species.

Spotted wolffish

The spotted wolffish biomass and abundance trajectories for the fall (Engel) series decreased from the late 1970s to the early 1990s, the decline about equal in magnitude in the north, Div. 2J3K, northeast Newfoundland Shelf and the southern extent of the Labrador Shelf and south, Div. 3LNO, Grand Bank (Fig. 2). See Kulka et al. (2004) for a more detailed rationale for spatial partitioning.

The (Campelen) biomass and abundance trajectory then increased from 1995 to 2002 in NAFO Div. 3LNO in (Fig. 2). In Div. 2J3K, numbers increased to 2001 but biomass was relatively stable. The biomass and abundance of spotted wolffish was slightly lower in 2003. However, during the fall 2003 survey, with the exception of 8 sets, none of the deepwater strata in NAFO Div. 3NO, where spotted (and northern) wolffish are expected to be found in greatest abundance were surveyed due to mechanical problems. As well, in both 2002 and 2003, the surveys were extended into January of the following year due to mechanical problems with the research vessels. The influence of seasonality on wolffish catchability has not been investigated to date. In the Gulf of St. Lawrence, and Scotian Shelf spotted wolffish are caught only sporadically and in very low numbers over the life of the surveys (McRuer et al 2001). The abundance in these areas appears to be generally stable or increasing although at naturally low levels.

Survey maps at the center of distribution of the wolffish species, from the Labrador Shelf, northeast Newfoundland Shelf and Grand Bank, illustrate locations where *A. minor* were caught (Fig. 3a-c). By the mid-1990s, *A. minor* were encountered in fewer places and at lower density than where they had been a decade earlier. They are presently concentrated in the offshore and at deeper periphery of the former range. This change has been steady and unidirectional since the mid-1980s corresponding with the decline in the abundance. In the early part of the series, 40% or more of the sites at appropriate depths and temperatures for *A. minor* were inhabited, but by 1993 the percentage dropped to less than 6% (Kulka and Simpson 2002).

Northern wolffish

The northern wolffish biomass and abundance trajectories for the fall (Engel) series decreased from the late 1970s to the early 1990s, the largest decline occurring on the northeast Newfoundland Shelf and the southern extent of the Labrador Shelf (NAFO Div. 2J3K) (Fig. 4). Since 1995, the trajectory for the fall (Campelen) NL series has been relatively stable at low levels of abundance and biomass. As described above for spotted wolffish, survey estimates in 2002 and 2003 may underestimate biomass and abundance. Northern wolffish are relatively rare in the Gulf of St. Lawrence and on the Scotian Shelf and are only sporadically taken in surveys there (McRuer et al 2001). There is no evidence of negative changes in the population size from surveys in those areas.

Survey maps at the center of distribution of northern wolffish, from the Labrador Shelf, northeast Newfoundland Shelf and Grand Bank show that the proportion of the shelf where *A. denticulatus* were caught has steadily declined between the early 1980's and present (Fig. 5a-c). By the mid-1990s, *A. denticulatus* were encountered in fewer places than they had been a decade earlier, now mainly found in the offshore and deepest periphery of the former range. In the early part of the series, almost 80% of survey sites contained *A. denticulatus*, but by 1993 the percentage had dropped to 4% (Kulka and Simpson 2002).

RECOVERY

Following are summary advice or syntheses for the twelve-step **Allowable Harm Framework** described in the Method.

Target for recovery

Abundance estimates of pristine, non-exploited wolffish populations are not available since intense commercial effort has occurred over a part of the range of each of the wolffish species since the 1960s, before systematic surveys were instituted. Therefore, minimum recovery targets were established as the average population size (index) of the fluctuating population throughout the time series. Choice of the average population size eliminates the arbitrary selection anomalously high estimates of abundance or periods of high abundance as the recovery target and ensures population levels greater than historic minima from which the populations have previously recovered. There is no a priori reason to assume that, in particular for the fall abundance index, observed maximum levels of abundance should be the target given fluctuating population sizes.

Time frame for recovery

In the absence of information on growth and reproduction or predictive population models for the two threatened species of wolffish, a period of 15 years, which approximates two generations might be considered as an appropriate time frame for recovery until further research is completed on relevant life history aspects such as reproductive potential and affects of various sources of harm. The period of 15 years for recovery also matches the period over which the decline occurred. Whether recovery can be achieved during that time will not only depend on a reduction in the pressures on the spawning stock but also the production and survival of year classes of sufficient size to sustain growth. Given the deficient understanding of the population and its potential for growth, at the present time, monitoring of the stock status using research survey data is the only available approach to monitoring recovery against the target.

Maximum human-induced mortality without jeopardizing recovery

Quantifying maximum human induced mortality that would not jeopardize recovery is not possible at this time for the reasons stated above. However, given that wolffish are not a targeted commercial species and appear to survive the stress of capture better than most species, a key strategy that can be used to minimize human induced mortality is the immediate release of incidentally captured wolffish in a manner that maximizes chance of survival. This strategy is elaborated in the Wolffish Recovery Plan (presently in draft) and will requires extensive education of harvesters to ensure best methods of release. Other methods leading to reduction of catch of wolffish such as gear modifications (currently being investigated by Fisheries Management) are essential to further reduce human-induced mortality. Recent levels of wolffish bycatch (note this does not equate with total mortality given a level of survival of a proportion of wolffish released) appears to be sustainable as evidenced by stable or positive population trajectories up to 2003 (described above).

Sources of mortality/harm

The reasons for the decline of wolffish populations in eastern Canadian waters are not fully understood given that the relative or absolute impacts of various anthropogenic sources of harm are not well quantified. As well, magnitude of the role of natural versus human induced effects has not been determined, further confounding the interpretation of human affects.

However, we can exert control over some of the anthropogenic activities that have may have an impact on wolffish populations as part of the recovery strategy. To do this, we need to know which activities have an impact on populations and their habitat, and how to change or prevent these activities in order to lessen their impacts and at the same time, increase the chances of wolffish recovery. Potential and known sources of anthropogenic mortality are discussed in the sections below.

Directed fishing

There is no directed fishery for either northern or spotted wolffish either in Canadian Atlantic waters or in the adjacent NAFO Regulatory Area. Occasional records of directed catch do occur in the landing statistics but these are rare and likely constitute coding errors.

Bycatch

Bycatch in fisheries directing for other species is the primary source of quantified human induced mortality. However, landing statistics do not reflect the true mortality for two reasons: prior to prohibitions prescribed by the Act in June 2004, wolffish were kept for commerce but not differentiated (two species, spotted and striped are reported as “catfish” in the landings); and any wolffish discarded at sea were not recorded. A substantial portion of both species of wolffish are discarded but this is particularly an issue for northern wolffish that are virtually never retained and therefore does not appear in the landing records except on rare occasions.

A key strategy for lessening the mortality of wolffish is the release of those caught incidentally in a manner that minimizes post-release mortality. However, the degree to which discarded (released) fish survive has not yet been definitively established except in the yellowtail fishery (unpublished experiments quantifying survival of caught and caged wolffish). The manner in which they are caught (trawl, gillnet, longline, trap) and from what depth temperature that they are taken, how quickly they are released and how carefully they are handled upon release all affect survival. These various factors have not been analyzed across all fisheries but the preliminary results from experiments carried out on the Grand Banks yellowtail fishery suggest high level of survival when holding times are minimal. As well, preliminary observations by fishery observers indicate that in a variety of fisheries, a substantial proportion (63%) of wolffish that are returned to the sea are alive, and many are very active prior to release. Long term post-release survival however is unknown and this makes it impossible to accurately estimate mortality due to fishing. However, estimated catches of wolffish from the various Atlantic fisheries would constitute a maximum estimate of mortality.

NAFO landing statistics provide an estimate of total removals but do not differentiate species of wolffish. Reported landings are summarized for Canadian and non-Canadian fishing vessels by NAFO Division, 1960-2003 (Fig. 6). Greatest records of wolffish landings occur in the 1970s prior to their decline but as noted above, those records represent minimum estimates of wolffish unspeciated.

Newfoundland based vessels in NAFO Div. 3KL consistently accounted for the majority of the Canadian wolffish landings records (Table 1). Since 1986, the Canadian landings in any NAFO Div. have not exceeded 1,000 t. Prior to that period, landings of up to 2,327t in Div. 3L were reported. Non-Canadian landings of wolffish during most years was limited to less than 1,000 t by any one country, however during the early 1970's, the USSR reported landings consistently exceeded 2,500 t.

When examined by gear type, gillnets, lines and trawl fisheries accounted for the majority of wolffish landings (Table 2). These gears were used to catch a diversity of commercial fish species including Atlantic cod, Greenland halibut, yellowtail flounder, witch flounder, redfish, and American plaice, amongst others. As well, wolffish were also captured in fisheries directed at commercial invertebrate species such as shrimp, crab and scallops. Since 1985, wolffish have been captured in fisheries directing for 33 various species of commercial interest and annual landing statistics have averaged 507 t. In 2002-03, fisheries directed at 13 species of commercial species were identified as the fisheries in which spotted and northern wolffish and averaged 83 t (Table 3).

A combination of landings statistics and observer data was used to derive a preliminary estimate of bycatch of spotted and northern wolffish for 1985-2003 in the NL Region (Table 4). A ratio of observed directed species weight of catch (Observer data) to reported weight of catch of each directed species (Canadian catch from ZIF, Non-Canadian catch from NAFO) was used to adjust observed estimates of weight of each of the wolffish species to derive an estimate of total removals of each species for fisheries where observer coverage was adequate and where wolffish bycatch was significant. These data must be considered as preliminary. Greenland halibut (turbot) stands out as the predominant fishery in terms of bycatch of wolffish in recent years. This is because much of the effort for that fishery occurs where wolffish are most densely distributed. Other fisheries capture wolffish but are minor contributors to the overall harm. The average removals for these fisheries during 2000-2002 amounted to about 1,044 t for northern wolffish and about 394 t for spotted wolffish although 2002 was substantially higher than previous years.

Catches of wolffish taken on an annual basis during research trawl surveys represented only a small fraction of the removals due to commercial fishing representing an average of 127 kg of spotted wolffish and 183 kg of spotted wolffish (Table 5). A portion of those fish are retained for scientific research.

Habitat alteration - fishing activities
Detrimental impacts on habitats of wolffish by fishing activities are largely unknown for reasons elaborated below although most types of gears that take wolffish as bycatch come into contact with the bottom. Habitat characteristics of much of the area occupied by wolffish and benthic habitat requirements are poorly described and extent of the habitat that is critical for survival is also undefined (Kulka *et al.* 2004). However, a comparison of trawl activity to the distribution of wolffish suggests that habitat alteration may not have played a large role in the decline. A significant portion of the area that wolffish occupied prior to their decline corresponded to locations where trawl activity (or any other form of fishery) was low or non-existent. An examination of fish density (avg. kg/tow) in regard to trawl fishing activity indicates that the rate of decline of fish density between fished vs. unfished locations was similar or higher in unfished areas (Kulka *et al.* 2004). This observation does not support the hypothesis put for the in the draft COSEWIC Listing Report that habitat degradation due to trawling is one of the causes of the decline of the species. However, fishing gear in general and trawls in particular do alter the benthic structure and their affect is at best poorly understood. Thus, further work is required to assess the affect of these alterations on wolffish species habitats and ultimately, the species themselves.

Habitat alteration – other sources
Knowledge of exactly how habitat has and is being utilized by other than fisheries and to what extent available habitat is critical to the species survival or recovery is largely unknown (Kulka *et al.* 2004). Thus direct mortality by permitted habitat alterations is unknown. Therefore, how this habitat should be protected to allow wolffish recovery cannot be explicitly described at this time, particularly with respect to affects other than those related to fishing gears. However, the historic distribution (potential habitat) and present distribution have been described (Kulka *et al.* 2004). This information provides some insight into where potential affect could occur. It is those areas where wolffish have declined or are no longer present that should be scrutinized closely for affected habitat.

Seismic Activities
Nothing is known about the impact of seismic activity on wolffish at any stage of their life history and currently there is scientific considerable uncertainty regarding the potential impacts of seismic activity on marine organisms in general. Any knowledge gained by future scientific research must be provided as guidance to the industry. However, there is sufficient information from studies on other marine fish to postulate about potential impacts on wolffish species.

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 which underlies the sea. This involves the use of towed arrays of "airguns" and airgun blasts constitute a highly un-physiological sensory stimulus to fish (Sverdrup et al. 1994). The noise 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 < 5 m, air guns have the potential to cause direct physical injury to fish, eggs and larvae. Risk of physical injury would be greatest for those organisms that cannot swim away from the approaching sound source, especially eggs and larvae. However, the level of mortality for wolffish and marine fish in general is not regarded as having significant effects on recruitment to a stock (Dalen et al. 1996). In the case of wolffish, adults and eggs are 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. It is the near surface larval stages that potentially could be directly affected by seismic activity.

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. Further 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).

Oil and Gas Explorations

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.). However, large scale release of petrochemicals and other toxic material associated with oil exploration and production is infrequent.

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 potentially could be 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 but potential affects on wolffish have not been examined.

At Hibernia, the largest production well on the Grand Banks for example, the zone of biological effects seems to be very localized while in comparison, wolffish occupy a vast area. 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.

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 and would not be problematic for mobile species such as wolffish.

Ecotourism & recreation
The affect of ecotourism is likely nil. SCUBA diving occurs along the shores of the Canadian Atlantic but it is virtually all coastal at depths not exceeding about 20 m where spotted and northern wolffish rarely occur.

Shipping & transport
Shipping & transport and associated engine noise likely has little affect on wolffish species because most or all of the affects are near surface while wolffish spend most of their lives on or near the bottom more than 100 m from the surface. The only period in their life when they are in close proximity to the surface is during larval stages. There are no data to elucidate the effects of shipping on this stage but the area where larvae occur and young of the year are known to occur on the Grand Banks and Labrador Shelf is away from the bulk of shipping traffic and greatly exceeds in area the space traversed by shipping. Thus, shipping and transport affects are likely minute.

Fisheries on food supplies
Wolffish eat a wide spectrum of fish and invertebrates but the diet of spotted wolffish comprise mainly mollusks and echinoderms. They use their large canines and molars to crush the shells of their prey. There are very limited fisheries for sea urchins, an important component in the diet those fisheries are close to shore, well away from where spotted wolffish are distributed. Northern wolffish have a mainly pelagic diet. Thus, it is unlikely that fisheries on food supplies has had a significant affect on the populations.

Aquaculture; Introductions & Transfers
In the northwest Atlantic, the Quebec Region (northern Gulf of St. Lawrence) has undertaken some work on raising spotted wolffish for food but this activity is very limited, recent and remote from the center of concentration of the population. Affect of aquaculture is likely nil.

Ocean Dumping
Sewage sludge disposed of in the marine environment by coastal dumping or pipeline discharge, have a known impact on both planktonic and coastal benthic communities. Sewage sludge contains bacteria and viruses toxic to shellfish, but their effect on wolffish is unknown. Much of the dumping is coastal, well away from the center of concentration of spotted and northern wolffish. The effect of ocean dumping on wolffish is likely minimal or nil.

During the processing of fish and other marine organisms, a large volume of wastes are generated including fish heads, tails, guts, and internal organs. 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. 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.

However, these issues apply mainly to coastal habitat away from most location inhabited by the two wolffish species. While the effects on wolffish from the above mentioned are unknown, they are likely minimal since most of these effects are localized and coastal whereas wolffish tend to be widely distributed offshore.

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.

Marine and Land - Based Pollution

Associated land-based forms of pollution including runoff may contain excess nutrients, sediments, pathogens, persistent toxins and oil. These pollutants in theory may adversely affect the reproductive capabilities of wolffish, their prey and surrounding vegetation as well as interfere with their general health. However, most of the affects are coastal and spotted and northern wolffish are distributed mainly offshore.

Scientific research

A certain number of wolffish are captured (and retained) from DFO research surveys for research purposes. Table 4 summarizes the small amount of wolffish which are captured during the research vessel surveys in NL waters. In recent years, the number of wolffish retained has declined as research activities have shifted towards tagging studies of wolffish which ensures the prompt release of live wolffish.

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. Given the widespread distribution of wolffish and the spatial and temporal limits of military activity off Canada, it seems likely that the effects would be minimal.

Cables and Pipelines

The placement of physical structures on or in the bottom substrate/water column could affect wolffish habitat although in a very spatially limited manner given the widespread distribution of wolffish. Impacts associated with these activities have not been quantified but are thought to be minimal.

Global Climate Change

Investigation of climate change as a factor in the decline of wolffish populations needs to be investigated. 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. Affects of global climate on the sea is poorly understood and affects on wolffish are unknown

Aggregate of Harm

An aggregate of all quantifiable mortality/harm to northern and spotted wolffish populations attributable to human causes is dominated by bycatch mortality. Given limited resources, future research is best focused on this aspect.

Science and management Actions

The impact of incidental capture of wolffish in many fisheries is the leading (quantifiable) cause of human induced mortality. Possible bottom alteration due to fishing activities on or near wolffish habitat needs to be better quantified as there is currently little or no evidence that bottom trawling is the proximal cause of the decline. The effects of bilge and ballast water are unknown. Pollution from land-based sources that could effect 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.

It is likely that currently known threats will not be properly mitigated and suspected threats will not be studied to determine their relative effects if linking stewardship to recovery activities is not done. 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.

There is a need to determine the 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.

CONCLUSIONS

Kulka and DeBlois (1996) first drew attention to a significant decline in the numbers and weights of the three species of wolffish in Canadian waters starting in the late 1970’s and early 1980’s. Subsequently, two species (northern and spotted wolffish) were assessed by COSEWIC and designated as “threatened”. Potential or real threats identified included mortality due to by-catch in commercial fisheries and habitat alteration by bottom trawling. However, the draft COSEWIC assessment document was unable to provide evidence that commercial fishing mortality or habitat destruction were the proximal factors in the decline of wolffish. The declines in abundance of wolffish species was concurrent with a widespread reduction in abundance of many groundfish species from the Grand Banks to the northern Labrador Shelf (Atkinson 1994) and thus natural phenomena or larger anthropogenic affects such as secondary affects resulting from climate change cannot be ruled out as decline influences. Nonetheless, population declines exceeding 90% indicate that spotted and northern wolffish require protection against further decline as provided under SARA for listed species.

Mitigative affects were already in place prior to protection under SARA. The decline in wolffish landings throughout the 1970s to 1980s is in part a consequence of the groundfish moratorium. Since the large majority of wolffish are captured as by-catch in other fisheries, variation in catch and landings are highly influenced by magnitude of commercial effort in fisheries directed at most other species. Wolffish are captured by most common gear types. More recently, with changes in directed species and gears used, trap fisheries have increasingly contributed to wolffish (particularly spotted) capture.

Also related to the distribution of wolffish is the issue of critical habitat, that being the habitat and the environmental requirements that control or limit distribution, abundance, growth, reproduction, mortality and productivity. In the case of wolffish, there is no clearly identified critical habitat in relation to sediment type. They tend to inhabit a wide area including a variety of bottom types, thus their widespread distribution. In relation to depth and temperature, both species of wolffish show a distinct preference for waters where ambient temperature is above average. Nevertheless, due to the correlation between environmental variables, the analysis of the current variables may indicate a preference for a correlated unmeasured variable which confounds the definition of a critical habitat.

Defining the conditions under which recovery of wolffish and marine species in general would occur is problematic given that population parameters environmental associations are poorly understood and naturally variable. In the case of wolffish (and many other marine fish species), habitat associations are poorly understood and habitat changes brought about by gear affects are now only starting to be examined (Schwinghamer et al. 1998).

A confounding factor in assessing recovery of marine fish is their relatively high fecundity resulting in natural population fluctuations that highly affects survival potential. Marine fish populations undergo stochastic and variable natural fluctuations in population size and the fluctuations are often large, more so than many terrestrial species. Estimates of population size, growth and viability under various levels of by-catch will be difficult, if impossible to determine. Differentiating anthropogenic and natural affects is at best difficult. Obtaining an accurate estimate of fishing mortality (F), which is required to assure viability (F<M), is problematic when wolffish are captured in such a diversity of fisheries and where the three species are undifferentiated in the landing statistics. Absolute catch of each of the “threatened species” is not yet known, though estimates of total removals can be computed, and subsequently used in the development of an allowable harm limit.

Since wolffish are not targeted by a directed fishery, part of the allowable harm definition would constitute strategies that would minimize incidental capture in fisheries directed for other species. For any marine species, including wolffish, measures might include spatial/temporal closures and gear restrictions:

Spatial closures: Widespread distribution, diverse habitat preferences and lack of particular spawning or feeding aggregations, makes it difficult to define specific closed areas for wolffish that would effectively reduce F in greater proportion to the ratio of the closed to total grounds. Furthermore, without current knowledge of the stock structure and the configuration of DU’s (Designatable Units), uninformed spatial closures could result in the permanent loss of important genetic variants, as well as loss of income from affected directed fisheries, potentially without a significant impact on wolffish recovery. Taken as a whole, all of the Atlantic fisheries, trawl, longline, gillnet among others, that incidentally capture wolffish comprise a multi-billion dollar industry creating a livelihood for thousands of Atlantic Canadians. Spatial closures may have to be wide spread to be effective.

Temporal closures: For wolffish, the current paucity of specific information on spawning times in the northwest Atlantic (currently being researched) and other critical periods in the life history of the species limits this option. Furthermore, the removal of wolffish appears to be dependent upon the regulation and occurrence of other fisheries, and not on changes in wolffish catchability.

Gear restrictions: The majority of wolffish were historically captured in trawl fisheries but recent shifts to alternate fisheries have resulted in larger catches in other gears such as traps. The introduction of the Nordmore grate attachment on shrimp gears, made mandatory in the mid-1990's has resulted in the reduction of catches of adult wolffish (> 20 cm in length) to near-zero in the shrimp fisheries. This has proven to be an effective measure in reducing wolffish bycatch in the shrimp fishery (Kulka 1995). Gear modifications have not been introduced to other fisheries that would reduce wolffish bycatch. However, wolffish are captured in a variety of gears and regulatory changes which would require live-releases, that is particularly feasible in fisheries where the gear does not harm wolffish (currently under study) is a viable strategy to reduce wolffish mortality. As well, gear modifications may reduce the by-catch of wolffish.

Summary

Options for conditions associated with AHP's (Allowable Harm Permits) for wolffish are limited. Area and season closures based on aggregations for spawning or feeding do not appear feasible since wolffish occupy large areas of the shelf and highest densities appear to be associate with heavily fished areas offshore. However, it has been observed that wolffish when captured are far more lively that most other species and therefore, mandatory release in a manner that would result in maximum chance of survival is an option.

Tagging studies (Templeman 1984) conducted on wolffish have found return rates of 7.4 and 3% for spotted and northern wolffish respectively. A mandatory release rule would likely lead to a reduced level of mortality than under current license conditions that specify all wolffish must be landed. The assumption is that the AHP conditions for release would provide guidance for quick release methods in a manner that would not cause further damage to the fish. Live release may increase the probability of survival and reproduction.

Alternatively, consideration could be given to the imposition of a catch limit for each species of wolffish based on an exploitation index derived from a ratio of catch to biomass index observed in recent years. A consistent rule for all wolffish species is manageable and easier to enforce. However, release of all wolffish will have an economic impact, particularly at a few sites along the coast of Newfoundland where most wolffish, mainly striped (special concern) are presently landed for market. Clearly, further analyses of these impacts is warranted.

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Table 1. Landings of wolffish species combined, by NAFO Division, 1985-2002 deroved from ZIF database. Newfoundland, Gulf and Quebec are not available for 2002, 2001/2002,2001/2002 respectively.

	2H	2J	3K	3L	3N	3O	3PN	3PS	3M	3P	2G	Total
1985	0.1	2.4	114.3	914.8	87.3	69.5	22.8	112.9				1,324.1
1986	0.1	28.3	286.7	434.0	191.3	55.2	40.7	101.8				1,138.0
1987		46.2	60.3	753.6	334.8	156.5	52.5	122.5				1,526.4
1988		11.1	103.1	586.9	221.6	68.5	24.2	89.5				1,104.8
1989	0.2	83.3	140.1	598.1	139.5	72.3	34.0	95.1	0.8			1,163.4
1990	0.1	56.4	59.9	246.5	44.3	41.0	20.0	95.7	0.3	0.5	0.1	564.8
1991	20.1	1.4	58.8	360.0	59.6	49.3	42.7	97.9			0.3	690.2
1992	2.6	1.5	19.9	30.1	49.7	77.7	50.3	111.8				343.6
1993		0.5	3.6	5.1	42.4	130.8	68.3	63.7				314.3
1994	0.2	0.3	12.6	1.3	1.8	1.3	2.5	13.6				33.6
1995		0.4	3.7	0.6		0.9	8.6	12.4				26.5
1996		1.0	6.4	0.6	0.9	1.2	0.1	1.5				11.6
1997		2.5	8.7	3.3	0.1	4.3	92.3	45.1				156.2
1998		0.8	0.3	0.4	2.5	2.4	58.7	93.7				158.7
1999	0.0	2.2	1.9	0.5	8.8	7.8	65.2	228.8				315.2
2000		0.2	14.4	21.1	37.7	0.5	0.0	2.5	0.0			76.6
2001	0.2	3.3	30.8	33.1	100.5	3.4		10.6				181.8
2002						0.0		1.3				1.3

Table 2. Reported landings of wolffish, all species combined by gear type. Note: NAFO Div. 3Pn and 3M have been included in this table.

	Gillnet	Lines	Other	Seine	Traps	Trawl	Total
1985	295.45	77.49		1.95	1.59	947.62	1324.10
1986	69.25	98.10	2.14	0.23	0.73	967.57	1138.02
1987	221.98	176.17		0.57	2.77	1124.91	1526.39
1988	138.14	139.74	0.11	0.59	4.04	822.22	1104.85
1989	113.84	132.10	0.51	1.44	1.77	913.72	1163.38
1990	80.99	113.45	0.72	1.77	1.21	366.62	564.78
1991	43.03	113.84	0.45	1.67	0.90	530.31	690.20
1992	29.08	169.80	0.45	2.17	0.29	141.87	343.65
1993	32.98	106.30	0.92	3.59	0.44	170.05	314.28
1994	11.09	2.47	0.76	0.36	0.07	18.89	33.64
1995	18.68	3.93	0.11	0.22	0.08	3.49	26.50
1996	4.95	1.18		0.30	0.04	5.13	11.60
1997	19.18	123.58		0.23	0.12	13.09	156.19
1998	23.70	126.61		0.16	0.08	8.17	158.72
1999	45.76	261.27		0.10	0.44	7.62	315.19
2000	13.06	35.52			1.62	26.41	76.605
2001	28.63	42.77			4.97	105.40	181.78
2002	0.87	0.28				0.203	1.35

Table 3. Observed catches of northern and spotted wolffish by directed species for 2002-2003, recorded in kg. Data were derived from fishery observer records. Proportion of fisheries observed varies among fisheries observed and weights presented below have been adjusted to total landings.

Year	Directed species	Northern	Spotted	Total
2002	Shrimp - Montagui		15	15
	Skate	23	4	27
	American plaice	3	35	38
	Atlantic halibut	7	126	133
	Yellowtail flounder	159	9	168
	Witch flounder	171	29	200
	Redfish	382	52	434
	Cod	74	532	606
	Monkfish	760	3	763
	Shrimp - borealis	179	2391	2570
	Crab - Snow or Queen	1952	4799	6751
	Greenland halibut	72414	18631	91045
Total		76123	26626	102749
Year	Directed species	Northern	Spotted	Total
2003	Roughhead Grenadier	14		14
	Skate		29	29
	White hake	42		42
	Monkfish	44	3	47
	Cod	63	96	159
	Witch flounder	241	43	284
	American plaice	102	375	477
	Yellowtail flounder	447	142	589
	Redfish	429	284	713
	Crab - Snow or Queen	1122	1164	2286
	Shrimp - borealis	169	3773	3942
	Atlantic halibut	18034	1218	19252
	Greenland halibut	33803	1996	35799
Total		54510	9123	63633

Table 4. Estimates of catches of northern and spotted wolffish by directed species from 1985-2002. Numbers are derived from fishery observer data adjusted to total landings.

Northern wolffish catch(t)			Directed Species			
Year	Cod	Crab	Turbot	Yellowtail	Shrimp	Total
1985	793.16	0.00	102.04	15.38	80.262	990.84
1986	682.53	0.00	196.55	12.54	11.890	903.52
1987	385.33	0.00	1420.28	20.18	10.606	1836.40
1988	673.68	0.00	1309.97	50.98	12.183	2046.81
1989	589.70	0.00	886.37	2.67	8.454	1487.19
1990	713.44	33.20	306.19	5.35	3.067	1061.25
1991	814.67	2.10	269.18	8.73	1.819	1096.49
1992	18.72	0.00	2371.35	2.12	1.352	2393.55
1993	8.57	0.32	2014.86	3.72	0.139	2027.61
1994	0.00	0.00	1879.85	0.00	0.111	1879.96
1995	0.00	0.07	208.31	0.00	0.191	208.57
1996	0.00	0.51	756.70	0.00	0.098	757.31
1997	1.50	2.84	60.93	0.00	0.000	65.27
1998	3.15	130.99	62.93	0.02	0.173	197.27
1999	7.76	204.44	27.07	0.00	0.097	239.37
2000	1.82	77.46	723.14	0.06	0.445	802.92
2001	1.13	75.22	585.40	5.34	0.249	667.34
2002	1.21	24.81	1633.79	0.51	0.140	1660.46
Spotted wolffish catch(t)			Directed Species			
Year	Cod	Crab	Turbot	Yellowtail	Shrimp	Total
1985	501.71	0.00	19.11	0.00	15.11	535.92
1986	738.62	0.00	49.35	22.39	3.59	813.96
1987	497.58	0.00	34.67	7.27	6.32	545.84
1988	439.32	0.00	12.16	2.78	21.23	475.48
1989	845.92	0.00	26.31	6.21	23.81	902.25
1990	937.55	8.83	12.55	8.86	18.98	986.77
1991	544.12	10.83	34.36	0.86	14.79	604.97
1992	24.69	0.00	440.16	3.89	12.48	481.22
1993	8.53	5.67	3.39	4.00	7.17	28.77
1994	0.00	1.00	1.03	0.00	4.56	6.59
1995	0.00	3.09	33.52	0.00	6.53	43.14
1996	0.00	10.60	8.34	0.00	4.82	23.77
1997	3.16	4.49	5.86	0.00	0.46	13.98
1998	1.25	6.85	8.49	0.06	0.15	16.81
1999	35.95	27.72	4.93	0.28	0.61	69.48
2000	5.35	47.19	170.04	0.13	0.79	223.51
2001	11.12	99.61	108.55	0.86	0.18	220.32
2002	8.93	69.84	659.09	0.02	0.23	738.12

Table 5. Catches of wolffish taken during research trawl surveys of the NL Region, by NAFO Division (expressed in kg).

Spotted wolffish

YEAR		2G	2H	2J	3K	3L	3M	3N	3O	3P	3Q	4R	4U	4V	Grand
	1995			3	27	71		22	4	0	0		0	1	128
	1996	12	9	12	18	47	386	12	6	1	2		0	1	506
	1997	12	11	12	20	38	0	40	5	1	1	0	0	1	141
	1998	4	12	5	16	41	0	25	6	1	0				110
	1999	8	8	7	38	43	0	27	4	1	0				136
	2000			8	50	54	0	22	1	5	0		0	1	141
	2001		4	7	61	117	0	17	1	2	0				209
	2002			1	13	103	0	31	1	7	0		0	1	157
	2003			9	7	63		25	1	8	2				115
Grand		36	44	64	250	577	386	221	29	26	5	0	0	5	1643

Northern wolffish

YEAR		2G	2H	2J	3K	3L	3M	3N	3O	3P	3Q	4R	4U	4V	Grand Total
	1995			1	4	10		22	16	14	1		6	4	78
	1996	0	2	12	11	42	44	41	27	24	2		5	8	218
	1997	4	1	13	12	29	11	44	15	1	1	0	0	3	134
	1998	2	2	9	14	44	9	47	35	5	0				167
	1999	2	11	9	24	38	0	39	11	8	0				142
	2000			12	15	37	3	35	18	5	2		1	0	128
	2001		0	5	18	30	7	42	7	1	0				110
	2002			4	3	32	7	28	13	4	0		0	1	92
	2003			6	0	27		29	7	6	1				76
Grand Total		8	16	71	101	289	81	327	149	68	7	0	12	16	1145

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

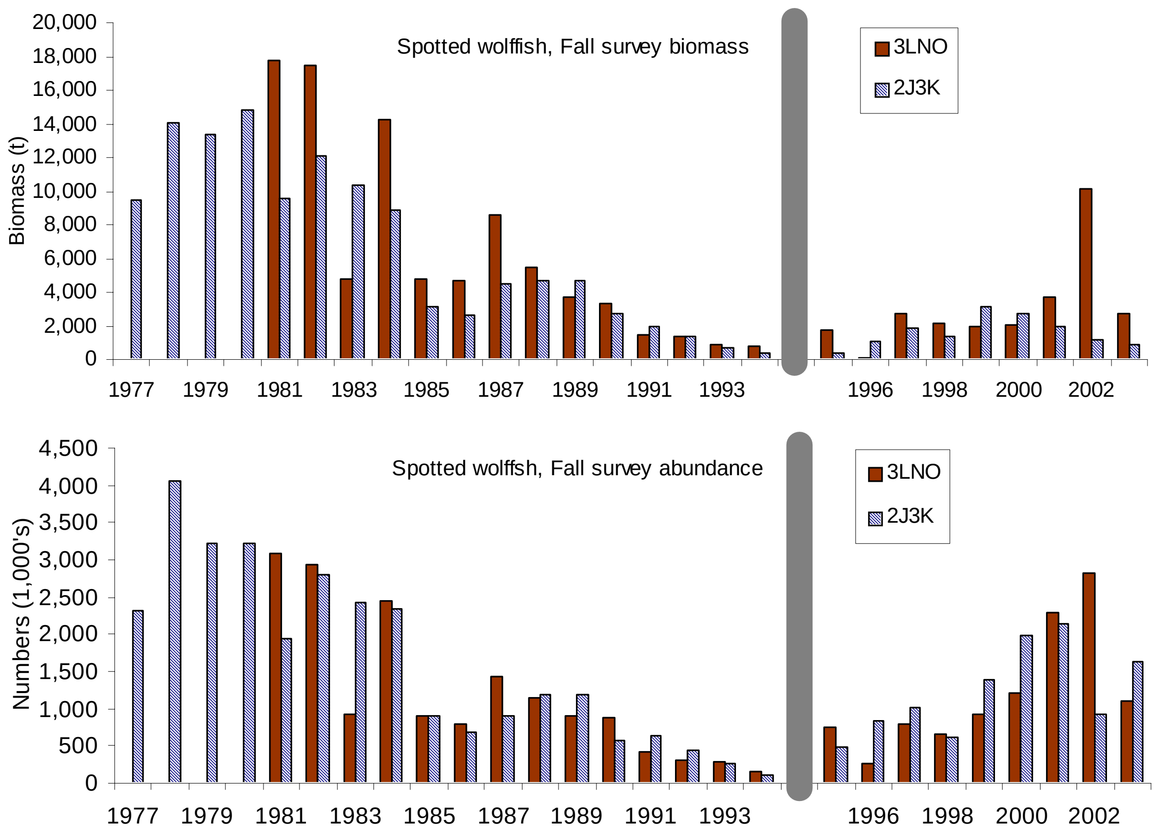

Figure 2. Fall research survey biomass (upper) and abundance (lower) indices for spotted wolffish for the Grand Banks to Labrador Shelf (NAFO Div. 2J3K (northeast Newfoundland Shelf and southern Labrador5 Shelf) and Div. 3LNO), 1977-2003.

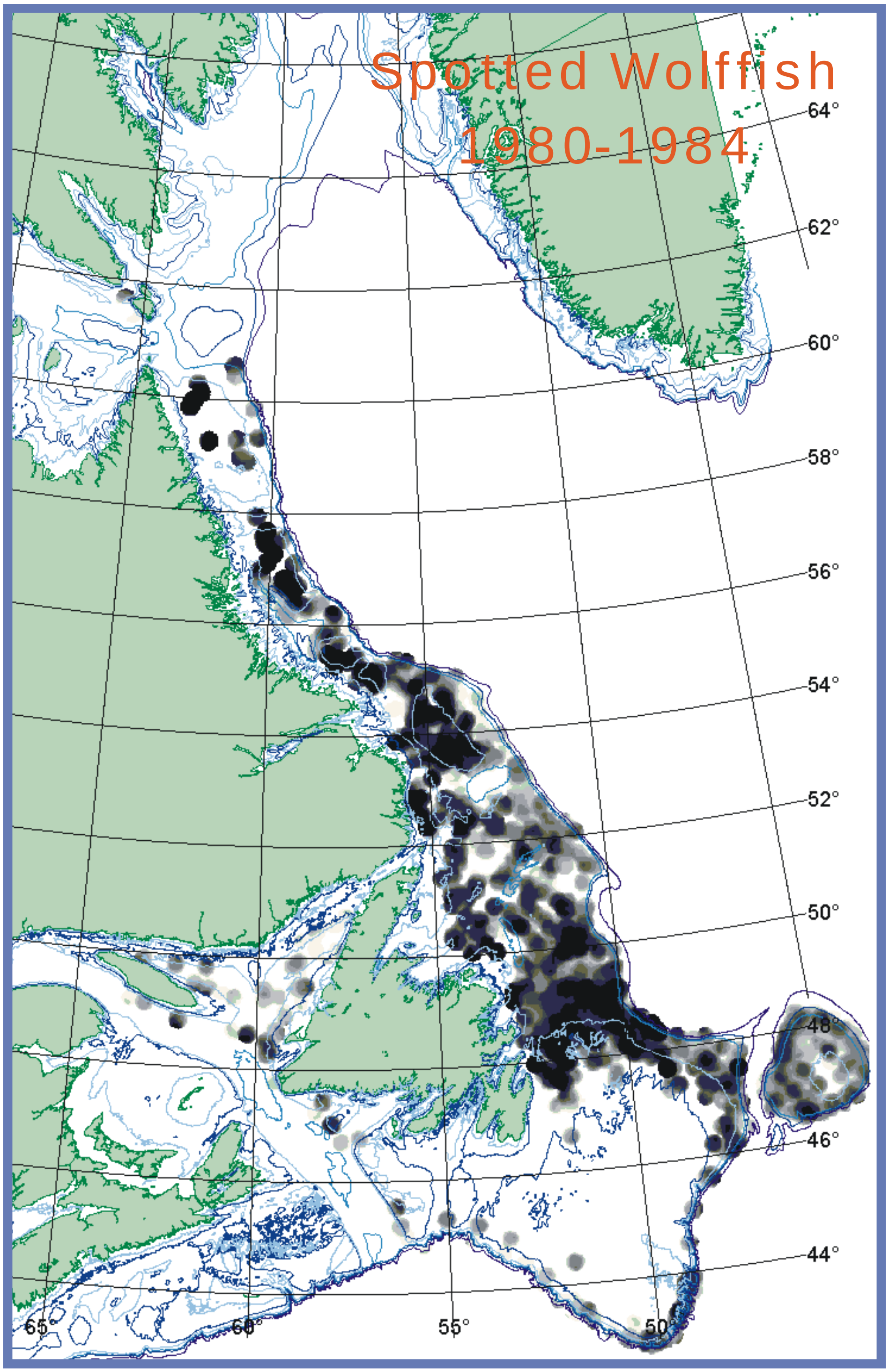

Figure 3a. Distribution of spotted wolffish, 1980-1984. Darker shades denote denser concentrations.

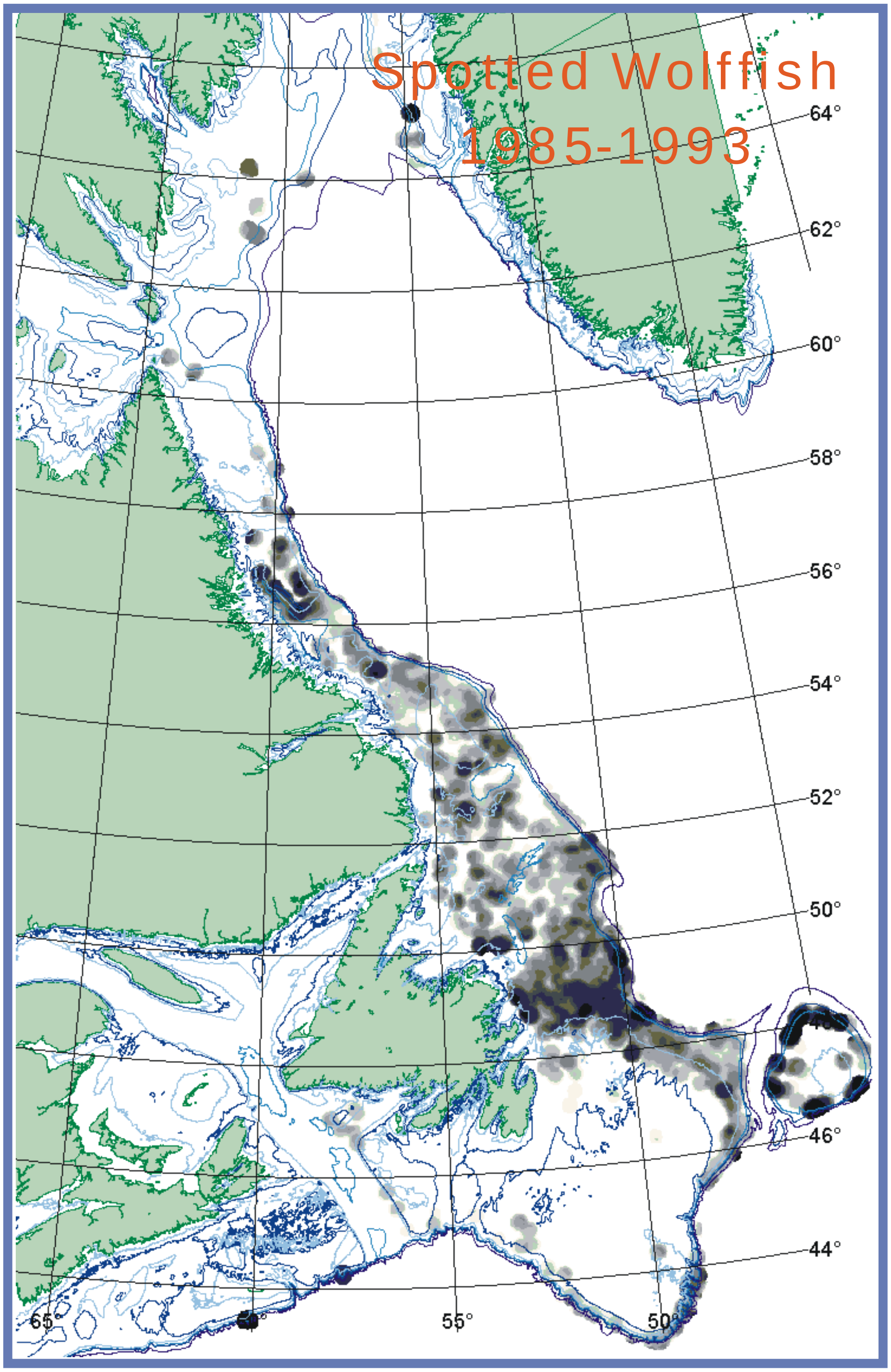

Figure 3b. Distribution of spotted wolffish, 1985-1993. Darker shades denote denser concentrations.

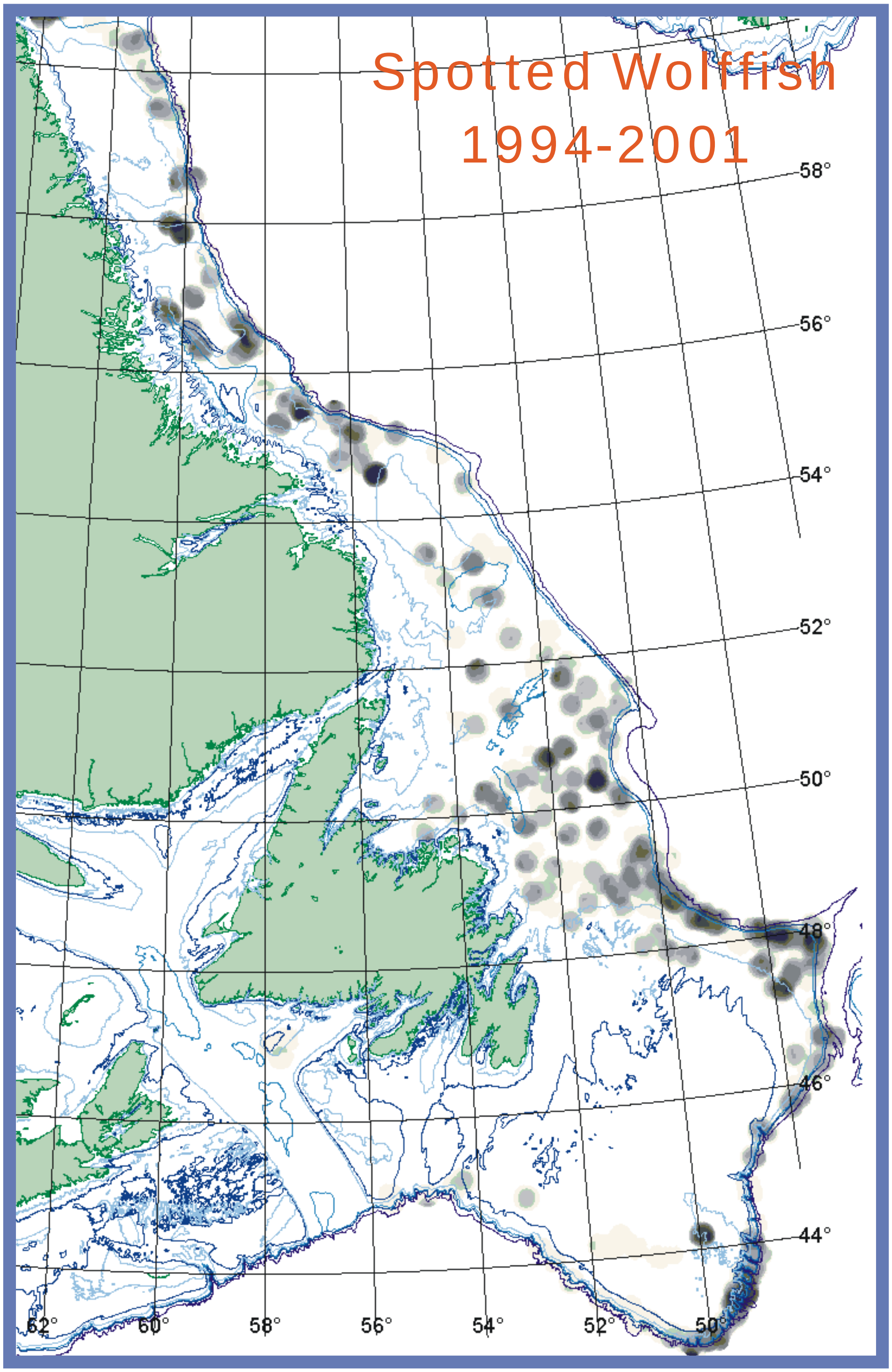

Figure 3c. Distribution of spotted wolffish, 1994-2001. Darker shades denote denser concentrations.

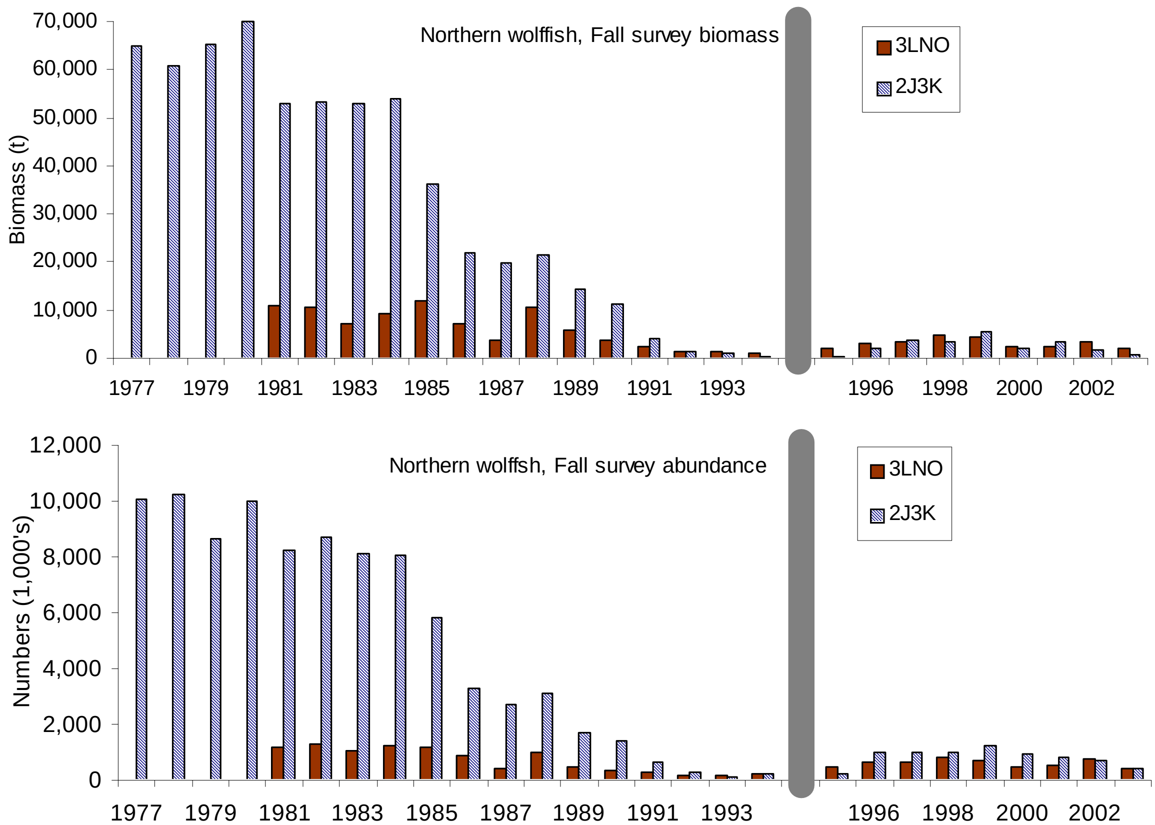

Figure 4. Fall research survey biomass (upper) and abundance (lower) indices for northern wolffish for the Grand Banks to Labrador Shelf (NAFO Div. 2J3K (northeast Newfoundland Shelf and southern Labrador5 Shelf) and Div. 3LNO), 1977-2003.

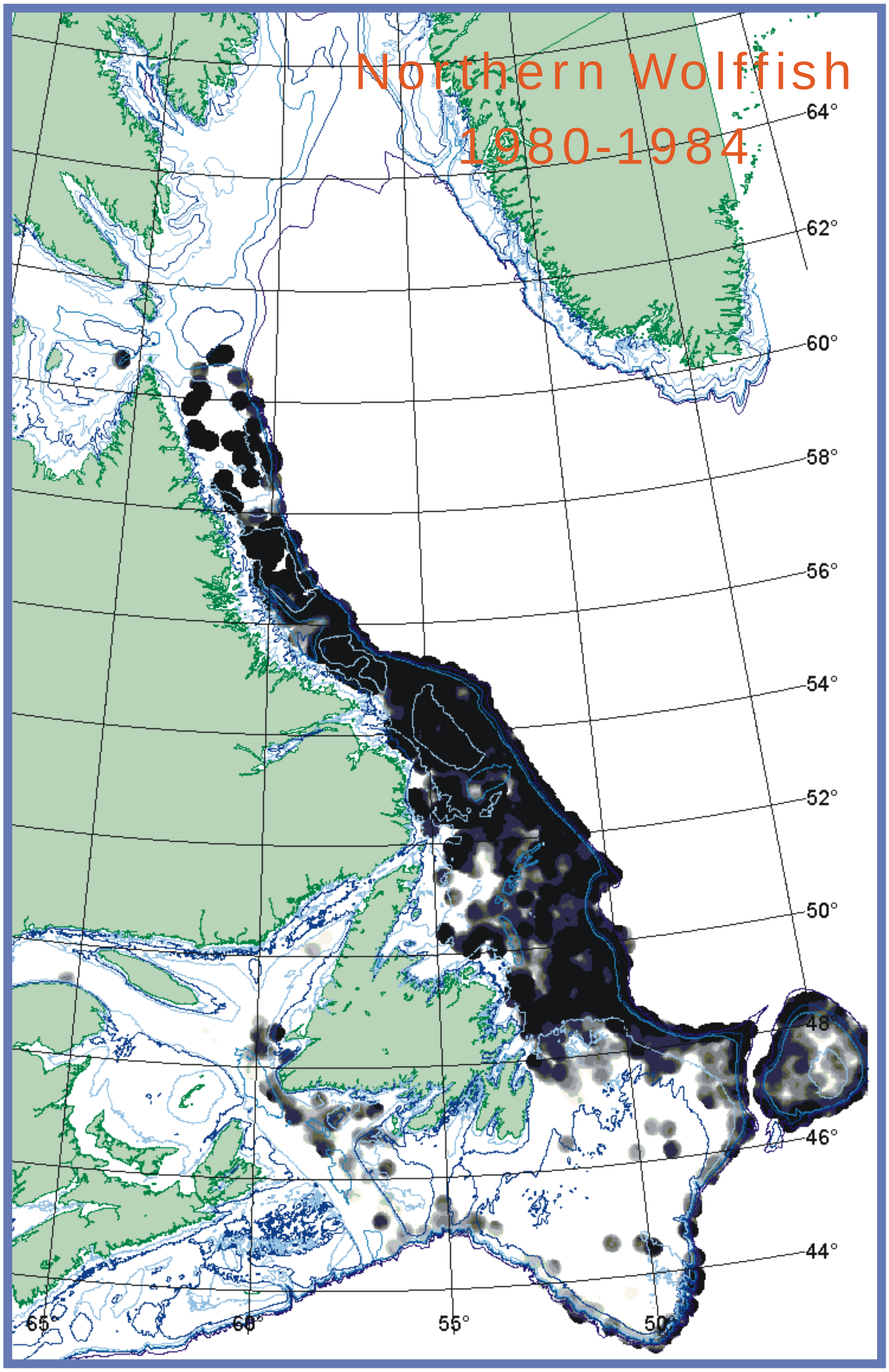

Figure 5a. Distribution of northern wolffish, 1980-1984. Darker shades denote denser concentrations.

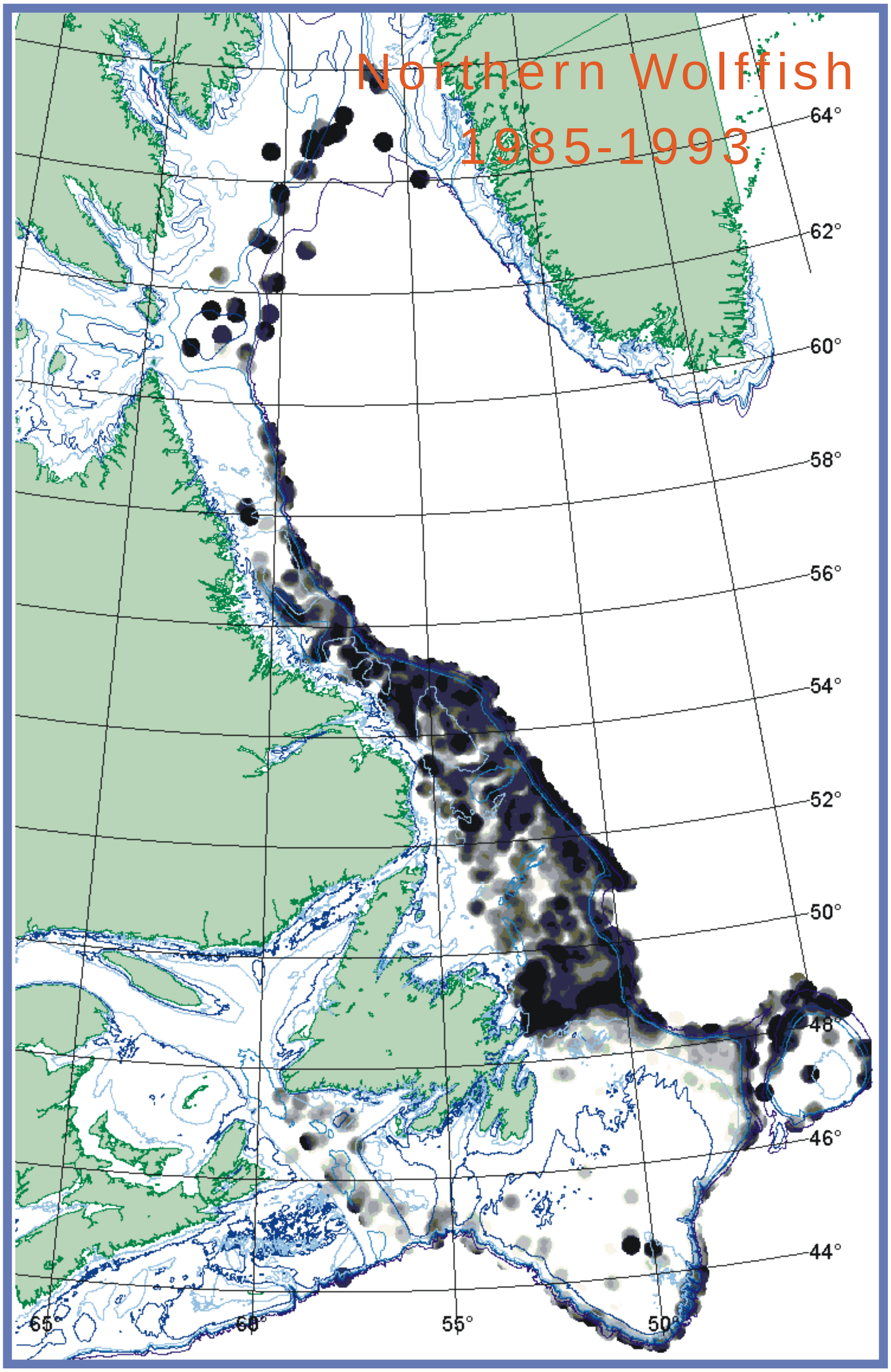

Figure 5b. Distribution of northern wolffish, 1985-1993. Darker shades denote denser concentrations.

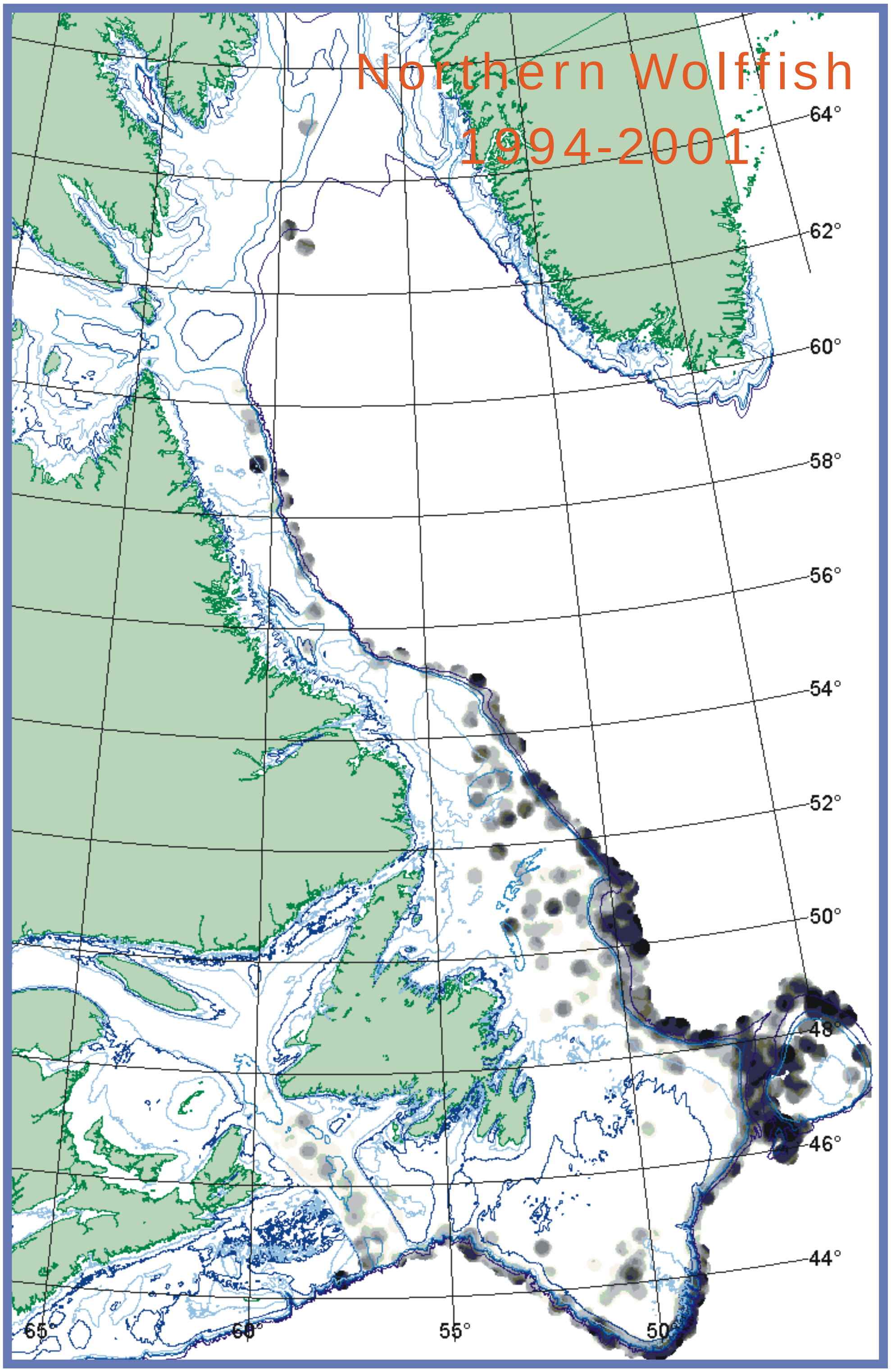

Figure 5c. Distribution of northern wolffish, 1994-2001. Darker shades denote denser concentrations.

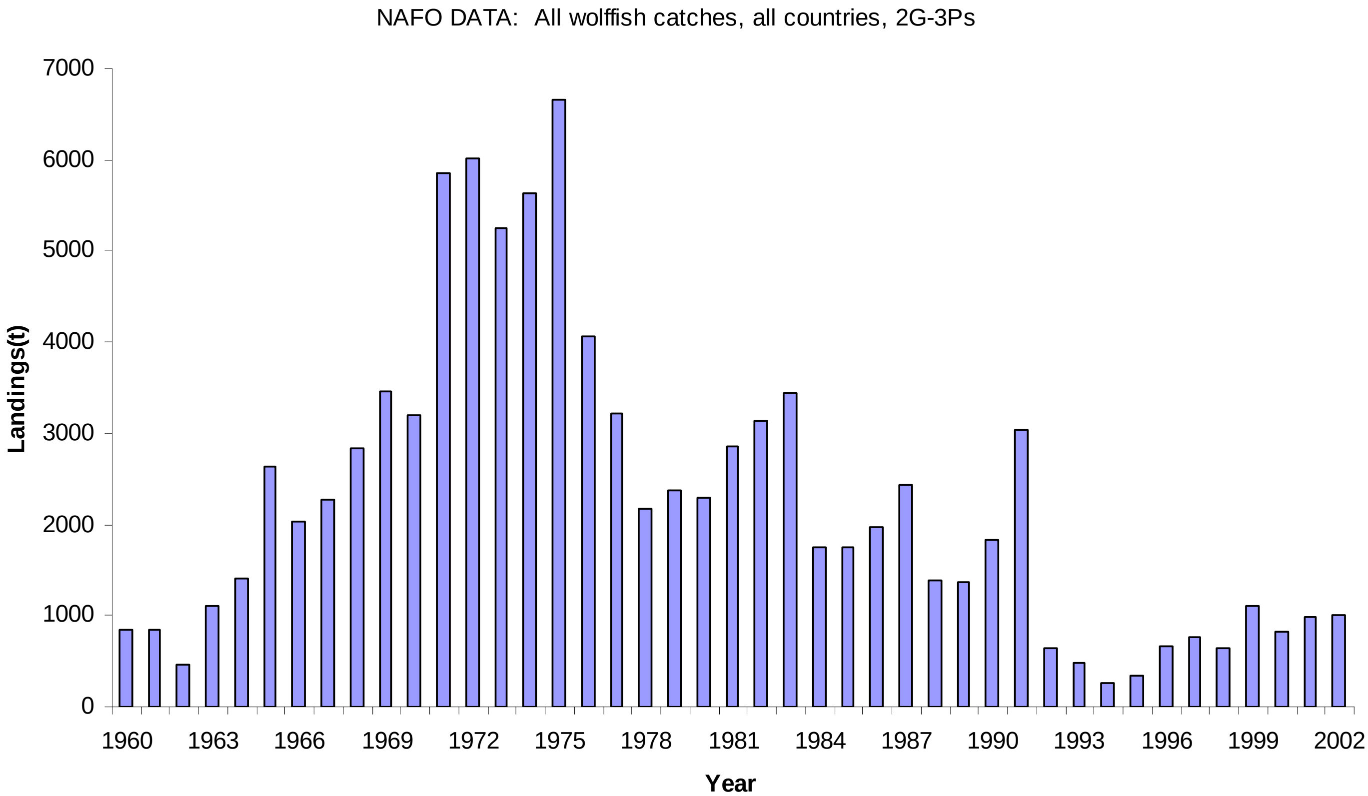

Figure 6. Total landings of wolffish, three species combined in NAFO Divisions 2G-3Ps. Landings statistics do not differentiate species nor do they reflect total removals due to fishing.