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Formulation of an Incidental Harm Permit Strategy for wolffish species (*Anarhichadidae*)

Élaboration d'une stratégie d'octroi de permis pour dommages fortuits causés aux espèces de loups de mer (*Anarhichadidae*)

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ABSTRACT

In anticipation of the proclamation of Species at Risk Act, this paper examines conditions that would be included in an Incidental harm permit strategy for northern, spotted and striped wolffish. This work has implications for other marine fish that may be listed in the future given that wolffish are typically data deficient. As well, the marine environment in which it lives is poorly understood making the formulation of conditions for Incidental Harm Permits difficult. In this light, we review critical knowledge on wolffish biology, including distribution, abundance, and critical habitat, as well as patterns in fisheries mortality which must be known in order to determine the IHP conditions under which wolffish could be captured. Pre-conditions for the issuance of an IHP is demonstrating that incidental capture, or habitat destruction, will not prevent the recovery of the species. In the case of wolffish, and other poorly understood species, estimates of population growth and viability under various levels of by-catch will be difficult, if impossible to determine. For non-directed species, part of the IHP would constitute strategies such as spatial/temporal closures and gear restrictions that would minimize incidental capture in fisheries directed for other species. In this paper we discuss the efficacy of each of these potential measures. 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. At present, wolffish live-release, which is particularly feasible in fisheries where the gear does not harm wolffish has been considered presently to be the most viable strategy to reduce wolffish mortality. Alternatively, consideration could 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 observed in recent years.

RÉSUMÉ

En prévision de l'entrée en vigueur de la *Loi sur les espèces en péril,* nous examinons dans ce document les conditions qui figureraient dans une stratégie d'octroi de permis pour dommages fortuits (PDF) causés aux loups à tête large, aux loups tachetés et aux loups atlantiques. Compte tenu de l'habituel manque de données sur les loups de mer, le présent projet a des conséquences pour d'autres espèces de poissons marins qui risquent d'être désignées comme étant en péril. De plus, le milieu marin dans lequel vivent les loups de mer est très peu connu, ce qui rend difficile l'établissement des conditions de PDF. Dans ce contexte, nous examinons les données importantes sur la biologie des loups de mer, y compris sur leur répartition, leur abondance et leur habitat essentiel, ainsi que sur la mortalité due à la pêche, ces données devant être connues pour déterminer les conditions de PDF dans lesquelles des loups de mer pourraient être capturés. La condition préalable à l'obtention d'un PDF est la démonstration que toute prise accessoire, ou dommage à l'habitat, n'empêchera pas le rétablissement des espèces. Dans le cas des loups de mer et d'autres espèces peu connues, il sera difficile, voire impossible, d'estimer la croissance et la viabilité des populations en fonction de différentes quantités de prises accessoires. Pour ce qui est des espèces non ciblées, les PDF comprendraient des stratégies, comme des fermetures de certaines zones ou pendant certaines périodes et des restrictions sur les engins, qui réduiraient au minimum le nombre de prises accessoires de ces espèces. Dans ce document, nous discutons de l'efficacité de chacune de ces mesures possibles. En raison de la répartition étendue et des préférences diverses en matière d'habitat des loups de mer, ainsi que du fait que ceux-ci ne forment pas de bancs pour se reproduire ou s'alimenter, la fermeture de certaines zones n'est pas considérée comme étant une méthode efficace pour réduire le nombre de prises accessoires de loups de mer à ce moment-ci. De plus, puisque les périodes critiques du cycle de vie de ces espèces demeurent inconnues, l'efficacité des fermetures pendant certaines périodes est également limitée. À l'heure actuelle, la remise à l'eau des prises accessoires, qui est plus facile lorsque des engins qui ne blessent pas les poissons sont utilisés, est considérée comme étant la stratégie la plus viable pour réduire la mortalité des loups de mer. Par ailleurs, il serait possible d'étudier la possibilité d'imposer une limite de prise pour chacune des espèces. Cette limite serait établie d'après un indice d'exploitation déterminé à partir des indices du nombre de prises par rapport à la biomasse observée au cours des dernières années.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the status of populations that may be at risk and lists them according to their probable risk of extinction. Species listed as threatened, endangered or extirpated will be afforded legal protection under the Species at Risk Act (SARA). It is anticipated that the legislation, now passed in parliament will be proclaimed, likely in June 2003. Immediately, or up to one year after proclamation if an exemption is declared, the Act will impose automatic prohibitions on the killing and harming of species and harming of their residences.

However, the SARA legislation provides a competent Minister the option to issue an Incidental Harm Permit (IHP) to allow for unavoidable "incidental harm" to a listed species providing that certain conditions are met. In the case of marine fish, there are a number of activities that may constitute harm to either the species directly or to their residences that may require an IHP. For example, seismic testing has been shown to influence fish behaviour and distribution (Dalen and Raknes 1985), catch rates (Pearson et al. 1992; Skalski et al. 1992; EngÂs et al. 1996), and may cause egg and larval mortality in some species. Thus, seismic work may require an IHP. However, given the limited knowledge of the effects of this activity, determining what level of seismic activity will cause harm is very difficult.

Similarly, fishing effects on populations are not well understood, particularly with respect to uncommon species that are taken as bycatch. In terms of marine fisheries, incidental capture of a species that is designated at risk constitutes harm and thus any fisheries that capture designated species would require an IHP to continue operating. In addition, any fishery such as demersal trawling that involves direct interactions with the benthic habitat by scouring the substrate causing sediment suspension and alteration of the benthos (Jones, 1992; Collie *et al*., 1997; Goñi, 1998) would require an IHP if the critical habitat of a designated species is affected by the activity. Other indirect effects of trawling could include post-fishing mortality, long-term trawl-induced changes to the benthos and interruptions of natural competitive or predator-prey relationships. While direct mortality resulting from fishery removals is relatively easy to quantify, secondary effects such as habitat disturbance are not.

The issuance of an IHP is predicated on demonstrating that incidental capture will not prevent the recovery of the species. It must also be demonstrated that all possible actions are being taken to minimize the harm. In the case of marine fisheries, strategies that would minimize incidental capture in fisheries directed for other species would constitute part of the IHP. Such strategies might constitute area and seasonal closures associated with locations and time periods where and when the species are known to aggregate, areas deemed to be critical habitat such as spawning beds, or gear restrictions aimed at minimizing habitat disturbance. It might also include other measures that would enhance recovery of the species.

Four species of wolffish (family Anarhichadidae, genus *Anarhichas* commonly inhabit Canadian waters, *A. lupus,* (Atlantic or striped wolffish, *A. minor* (spotted wolffish), *A. denticulatus* (northern or broadhead wolffish), in the Atlantic and Arctic Oceans (Barsukov 1959, Templeman 1985, 1986b) and *A. orientalis*, the Bering wolffish occurring only in the Arctic Ocean (Houston and McAllister 1990). In May 2001, two species (spotted and northern) were designated by COSEWIC as "threatened" due to declines in their abundance and biomass. The COSEWIC listing report indicated that over three generations, the abundance of these two species had declined by over 90%, and specific threats included by-catch mortality in commercial fisheries and habitat degradation due to trawling. A third species, striped wolffish was listed by COSEWIC as a “species of concern”, suggesting that it is particularly sensitive to human activities or natural events but is not endangered or threatened at this time. Listed as special concern, striped wolffish will not legally require a management plan for 5 years nor will it require an IHP. Northern and spotted wolffish are the first two Atlantic marine fish to be listed by COSEWIC as threatened and thus will be afforded protection under SARA. They will require a strategy for recovery within 1 year of proclamation of the Act and their capture will constitute a violation in the absence of an IHP (although there is a provision to delay the need to issue IHP’s for up to one year after proclamation of the Act). For wolffish, the Recovery Strategy and Plan has been completed providing a series of actions recommended to promote recovery and some of those actions will constitute IHP conditions.

In anticipation of the proclamation of SARA, this paper examines conditions that would be included in an IHP for wolffish. Some knowledge of the following aspects of wolffish biology and the fisheries must be known in order to determine the (IHP) conditions under which wolffish could be captured:

a. **distribution of the species**
b. **population abundance**
c. **fishing mortality**
d. **critical habitat for the species**

In terms of a) **distribution of the species**, Simpson and Kulka (2002) described in detail the distribution of the spotted, northern and striped wolffish off Atlantic Canada as quite extensive, found rarely as far north as Lat. 72^0 N (Baffin Bay), increasingly common to the south, inhabiting most of the Labrador and northeast Newfoundland Shelves (less so in recent year) to the southern Grand Banks and Flemish Cap, mainly on the outer shelf. Spotted and northern wolffish also occur occasionally in the Gulf of St. Lawrence, the Scotian Shelf and the Bay of Fundy although their centre of distribution is the Grand Banks to Labrador Shelf. The southern limit is Georges Bank. Striped wolffish differed from the other two species in that they occupied the shallow part of the southern Grand Bank. McRuer et al. (2000) showed that striped wolffish is also more common in the deeper parts of the Gulf of St. Lawrence and on the Scotian Shelf, mainly to the southwest and in the Bay of Fundy. Considering what is known about their distribution, this paper will examine the potential benefits of fishery time and area closures for wolffish.

An absolute estimate of b) **population abundance** for the wolffish species is not available. However, Simpson and Kulka (2002) provide an index of abundance for the period 1973-2001 for all three species for the area where wolffish are most abundant (Labrador Shelf to the Grand Banks). This paper reviews the trends and provides an index of exploitation that relates fishing removals relative to the population.

To define c) **mortality related to fishing**, a detailed description of incidental capture of wolffish in fisheries directing for other species is presented. Understanding the harvesting practices that result in by-catch of wolffish is critical not only to recovery planning but to formulating conditions for permitting their capture. While wolffish are exploited in directed fisheries in other areas of the north Atlantic (i.e. off Greenland, Moller and Ratz 1999, Smidt 1981), within

Canadian waters, they are captured as bycatch in many fisheries directed at other species. During the 1980's, Kulka (1986) estimated that about 1,000 t (per year) of the 3 species of wolffish in Newfoundland waters were reported in a variety of demersal fisheries. This paper reviews available information on historical bycatches and assesses the potential impact of commercial fisheries on these populations by relating trends in fishing mortality to trends in relative abundance.

Finally, the distribution of wolffish in relation to d) **critical habitat** is examined. Critical habitat is that habitat and the environmental requirements that control or limit distribution, abundance, growth, reproduction, mortality and productivity. Habitats need to be accurately described by physical, chemical and biological components of the ecosystem where a species occurs. While unable to examine critical habitat directly, this paper will examine depth and temperature and bottom type preferences for wolffish on the Grand Banks (NAFO Divisions 3L, 3N, and 3O).

This paper not only considers the two species designated as threatened (spotted and northern) but also striped (special concern) because species assigned to that designation must have a management plan in place 5 years from the proclamation of the Act (Sect. 27. (s. 68(2))).

METHODS

Distribution and Abundance

Information from research trawl surveys, 1971-2001, were used to examine distribution, abundance and sizes of the three wolffish species. Methods used to describe the distribution of wolffish can be found in Simpson and Kulka (2002). Information from that paper on distributional and area of occupancy changes, and relative trends in abundance derived from fall research surveys from the Grand Banks, northeast Newfoundland and Labrador Shelves 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 two reasons: the species are not differentiated (reported as "catfish") and any wolffish discarded at sea are not recorded. A substantial portion of all three species are discarded but this is particularly a problem for northern wolffish that are usually not 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.

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. Fishery units were defined in relation to country, NAFO Division, Gear type, and Directed species. NAFO data for 1999 and 2000 are provisional, and that STATLANT 21A data for 1994 to 1998 have been finalized without USA submissions although this would not affect estimates of wolffish removals since the USA does not fish within Canadian waters. As well, ZIF data are not available for Newfoundland for 2002 (recently acquired), or for the Gulf and Quebec regions for 2001/2002. These results are compared to the non-differentiated (reported as "catfish") catch statistics (ZIF and NAFO). Estimates of removal mortality were estimated based on the ratio of estimated abundance from the STRAP program and the total removal estimates.

Critical habitat

We investigate the distribution of wolffish in relation to their association to three environmental variables, sediment type, temperature and depth on the Grand Bank. Similar information is not extensively available elsewhere within the centre of distribution of wolffish. Seabed classification data (ROXANN), which have been collected since 1992 were examined to derive a sediment type in the vicinity of survey trawl locations. From the acoustic returns of the survey ship, seabed *roughness* and *hardness* indices were derived to classify the sediment as either: mud, sand, sand & shell, shell & pebbles, small rock, hard bottom, or undefined (Naidu and Seward 2002 unpubl. data). An average sediment type was calculated for each tenth of a degree of latitude and longitude and was used to classify trawl locations within each area by sediment type. We first compared the mean number of wolffish captured by sediment type on an annual basis. In addition, we compared the empirical distribution of sediment types present for all survey sets and the cumulative distribution function for those sets in which wolffish were captured. Significant differences in available and occupied environments were tested using the Kolmogorov-Smirnov test of significance. A similar comparison of cumulative distribution functions for temperature and depth, derived from the research trawl surveys were also conducted.

RESULTS

Distribution and Abundance

Abundance and biomass indices for striped (Fig. 1), spotted (Fig. 2) and northern (Fig. 3) wolffish from the fall surveys demonstrate a significant decline in the estimated numbers and biomass starting in the early 1980's for all three species. Since 1995, all three species have shown some increase in biomass and abundance, particularly striped wolffish. However the magnitude of this increase is not comparable to the early time series due to the change in gear type and lack of a catchability conversion factor (between Engels and Campelen gear). For spring surveys, biomass and abundance indices for striped, spotted and northern wolffish increased during the 1970's, declined during the early 1980's, recovered during the late 1980's and declined during the early 1990's (Fig. 4). For all three species, the spring survey biomass and abundance indices decline from the late 1980's to mid-1990's, particularly on the northern Grand Banks (NAFO Division 3L), the northern most area surveyed in the spring. Unlike spotted and northern wolffish, a significant component of the spring biomass estimate of striped wolffish is concentrated in NAFO Divisions 3NO on the southern Grand Bank (Table 1g). Since 1996, the spring abundance and biomass indices have increased, however the magnitude of this increase is not comparable to early time periods as indicated above. While the decline in abundance and biomass estimates of all three species has occurred throughout Newfoundland waters, based on fall survey data, it appears that the magnitude of decline was greatest in more northern areas, namely the northeast Newfoundland Shelf and Labrador Shelf for striped and northern wolffish.

All three species of wolffish are widely distributed throughout waters off Newfoundland and Labrador. For northern wolffish, large catches occurred throughout the northeast Newfoundland Shelf and Labrador Shelf (NAFO Division 2J3K) during the early 1980's (Fig. 5). However, from 1986-2001, the distribution of larger catches of northern wolffish are increasingly limited to the shelf edge throughout the entire survey area. A similar pattern is also apparent in the distribution of striped wolffish. In addition to large catches on the shelf edge, striped wolffish are also captured in shallower waters, in particular on the southern Grand Bank (NAFO Division 3NO) (Fig. 6). This concentration of striped wolffish on the shallow part of the bank is not observed for other species. Similar to northern wolffish, spotted wolffish are increasingly limited to the periphery of the Labrador shelf and Grand Bank from 1990-2001 (Fig. 7). Overall, it appears that the distribution of all three species of wolffish has contracted in recent years relative to their distribution during the 1970's and early 1980's. This coincides with an observed decline in the relative biomass and abundance, described above

Fishing Mortality

NAFO landing statistics were summarized, for both Canadian and non-Canadian fishing vessels by NAFO Division, 1960-2000 (Table 1). Wolffish are usually not categorized by species, therefore catch statistics were summarized by combining the codes for wolffish (non-specified species) with the occasional records of striped and spotted. Newfoundland based vessels in NAFO division 3L consistently accounted for the majority of the Canadian wolffish landings records. Since 1986, the Canadian landings in any NAFO Division have not exceeded 1,000 t. However, prior to this period, landings of up to 2,327t in 3L were reported. Non-Canadian landings of wolffish during most years was limited to less than 1,000t by any one country, however during the early 1970's, the USSR consistently exceeded 2,500t's. Since the mid-1990's, non-Canadian landings of wolffish have accounted for 75% of the wolffish landings within Newfoundland waters (Table 2). Two countries, Portugal and Spain account for the majority of the non-Canadian landings.

ZIF landings show a consistent decline in wolffish landings since the 1980's (Table 3). Since 1990, total landings of wolffish have not exceeded 1,000 t. Landings occurred mainly on the Grand Banks from NAFO Divisions 3L, 3N and 3Ps (Table 4). Included in the ZIF data are small, occasional directed fishery records for wolffish but these likely represent miscodes. When considered by gear type, gillnets, lines and trawl fisheries accounted for the majority of wolffish landings reported in the ZIF data set (Table 5). These fisheries are prosecuted for a diversity of commercial fish species including Atlantic cod, Greenland halibut, yellowtail flounder, witch flounder, redfish, and American plaice amongst others. As well, wolffish are also captured in fisheries directed at commercial invertebrate species such as shrimp (trawl), crab (trap) and scallops (dredge).

Since 1995, nine gear-based fisheries were identified as the predominant fisheries in which wolffish are captured as by-catch. In NAFO division 3Ps, a line fishery prosecuted mainly for halibut and cod, but also other species including monkfish, white hake, plaice, pollock, haddock, redfish, lumpfish, Greenland halibut, wolffish and skates results in the capture of wolffish. This mixed fishery mainly occurs during June to October. As well, a gillnet fishery mainly directed at cod but also skates, yellowtail flounder, American plaice, pollock, halibut, lumpfish, winter flounder, white hake and redfish that occurs from May through July in NAFO Division 3Ps results in wolffish by-catch. In NAFO Division 3O, a diverse line fishery prosecuted from March to June, directed mainly towards haddock, halibut, white hake as well as cod, skate and Greenland halibut captures wolffish. In other areas of the southern Grand Banks, in NAFO Division 3N, trawl fisheries directed mainly towards a yellowtail flounder (but also skate, American plaice, white hake and cod) and line fishery directed mainly towards halibut (but also cod, white hake) capture wolffish. On the northern Grand Bank, in NAFO division 3L a trawl fishery directed mainly towards Greenland halibut (plus yellowtail flounder, American plaice, cod, and witch flounder), and a gillnet fishery directed mainly at Greenland halibut (but also skate, cod, winter flounder, American plaice and wolffish as well as unspecified groundfish) result in a wolffish by-catch. Two additional fisheries in NAFO Division 3K, a trawl fishery directed from April through October for Greenland halibut, shrimp and halibut and a gillnet fishery mainly prosecuted for Greenland halibut and cod result in wolffish by-catch. In some years, this fishery is directed towards American plaice, winter flounder, unspecified groundfish, and also wolffish. These landing records indicate that although not a target species, they constitute the most common bycatch species taken in just about every Atlantic fishery.

In the 1980's, northern wolffish were reported in the Observer catch records throughout Newfoundland waters, with the exception of NAFO division 2G in 1985. During this period, catches of northern wolffish were concentrated along the shelf edge of the northeast Newfoundland and Labrador Shelf (NAFO Divisions 2H, 2J and 3K) and on the northern Grand Bank in NAFO Division 3L (Fig. 8a). Since 1990, there has been a reduction in the catches reported throughout these areas, particularly in the northern Divisions. In general, the catches of northern wolffish are restricted to the edge of the Labrador shelf and the periphery of the Grand Banks (Fig. 8b). A similar decline in the catch and distribution of spotted and striped wolffish (as well as unspecified wolffish species) is also apparent (Fig. 9a.b, Fig. 10a and b). As indicated by the catch distribution maps, wolffish catches were mainly concentrated on the outer northeast Newfoundland and Labrador Shelf (NAFO Divisions 2H, 2J, 3K and 3L) between 1981-2001. While in the earlier years (1981-91) fisheries directed for flatfish such as yellowtail flounder, American plaice, witch flounder and for other species such as cod and roundnose grenadier captured the majority of wolffish. Since the early 1990's, many of these fisheries have been greatly reduced or have disappeared as the result of reduced TAC's and moratoria. In recent years, wolffish bycatches have come mainly from by yellowtail, Greenland halibut, shrimp and crab directed fisheries which dominate the directed effort for the Grand Banks and areas north.

In terms of species, the catch of wolffish is composed mainly of northern wolffish (Table 6) but nearly all of this is discarded. For the Labrador Shelf (NAFO Divisions, 2G, 2H and 2J), northern wolffish compose over 70% of the total catch of wolffish. In NAFO division 3K, northern wolffish are on average more than 50% of the total catch of wolffish species. However, on the northern Grand Bank, (NAFO Division 3L), spotted wolffish compose most of the wolffish catch. On the southern Grand Bank, (NAFO Divisions 3NO and in NAFO Subdivision 3Ps), the majority of the wolffish catch is composed of striped wolffish taken mainly from the concentration of this species located mainly on shallow part of the bank as bycatch in the yellowtail flounder fishery. By gear, all species of wolffish are mainly captured in trawl fisheries (Table 7). For spotted wolffish, trawl fisheries removed the majority of the catch, though more recently trap fisheries have contributed to spotted wolffish removals. For striped and northern wolffish, trawl fisheries consistently removed the majority of the catch with relatively low amounts removed by line/trap and gillnet fisheries respectively.

Overall fishing mortality, based on the estimated removals of wolffish and the estimated abundance are shown in Figure 16. With the exception of an extremely high estimated removal in 1994 for northern wolffish, the removal mortality was less than 20% for all three species. Spotted wolffish experienced the greatest removal mortality during the late 1980's and early 1990's, with an estimated mortality of 19% which declined throughout the late 1980's to less than 10%. Both northern and striped wolffish removal mortality was generally lower than 5%. Caution must be exercised when considering these removal estimates. The abundance values used to estimate the removal rate are minimum estimates. Furthermore, since the timing of some fisheries in which wolffish are captured does not coincide with timing of the research surveys there is a temporal mismatch.

Critical habitat

Six sediment types, mud, coarse sand, sand and shell hash, gravely sand, rocks, and boulders/rocks were identified on the Grand Banks (Fig. 11). Overall, the average number per tow was greatest for northern and spotted wolffish on sand/shell hash sediments (Table 8). For striped wolffish, the average number per tow was greatest on rock sediments. Analysis of the fall survey catches of northern wolffish in relation to sediment type, indicated that northern wolffish occupied sand/shell hash, gravely sand and rock sediments more frequently than their occurrence in the environment would suggest (Fig. 12, Table 9). However, striped and spotted wolffish did not show a clear preference for any particular sediment type during either spring or fall surveys.

In relation to temperature, Northern, spotted and striped wolffish showed a clear pattern of occurrence in the warmest available waters having the highest densities at about 3.5^{o}C. Cumulative frequency distribution plots of available and occupied temperatures indicated that all three species occupied cooler habitats less frequently than their availability in the environment (Fig. 13). Striped wolffish were captured, on average, in waters which were 2.6K1.6□C during spring RV surveys and 2.7K1.8□C during fall surveys. Both spotted (spring, 3.1K1.1□C: fall, 2.8K1.4□C) and northern wolffish (spring,3.8K.9□C: fall, 3.5K1.1□C) were captured in warmer waters. Similarly, all three species occupied shallower waters less frequently than expected based on their occurrence in the environment (Table 11, Fig. 14). For northern wolffish, the average depth at which they were captured during fall and spring research vessel surveys were 585K287.8m and 524 K 211m respectively. Spotted wolffish were captured in shallower waters (382K216m:spring, 341K138:fall) in both spring and fall RV surveys. Similarly, striped wolffish were consistently captured in shallower waters in fall (211K131m) and spring (211K169m).

DISCUSSION

Kulka and DeBlois (1996) first noted a significant decline in the numbers and weights of the three species of wolffish starting in the late 1970's and early 1980's. Subsequently, two species (northern and spotted wolffish) have been designated by COSEWIC as "threatened". This designation refers to species likely to become Endangered if limiting factors are not reversed and Endangered refers to species facing imminent extirpation or extinction. The COSEWIC listing reports (O'Day and Headrich 2002) indicated that abundance had declined by over 90% over three generations, extent of distribution had decreased, and that listed threats included mortality as by-catch in commercial fisheries and habitat alteration by bottom trawling. However, the Listing Document was unable to provide evidence that commercial fishing mortality or habitat destruction were the influential factors in the decline of wolffish. 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 (Atkinson 1994) and thus natural phenomena cannot be ruled out as decline influences. The third species, striped wolffish was listed as a "species of concern" (particularly sensitive to human activities or natural events but not endangered or threatened) because the overall population showed a lower decline rate. In fact, striped wolffish has been show to be stable or increasing in areas such as the southern Grand Banks, the Gulf of St. Lawrence and the Scotian Shelf whereas the Labrador Shelf component declined at a rate greater than the other two species. What this suggests is that at least for striped wolffish, the species may not constitute a single ESU Evolutionary Significant Unit or population). The population aspects are currently being investigated.

Spotted, northern and striped wolffish are widely distributed throughout the Labrador and northeast Newfoundland Shelves to the southern Grand Banks and Flemish Cap. During earlier periods of higher abundance, 1980-1984, the distribution of all three species was quite extensive and abundance was greater on the banks than at present. Since 1985, the distribution of all three species has been limited more to the shelf edges, and is less extensive (Kulka ad Simpson 2002). An exception to this pattern is the relatively dense distribution of striped wolffish on the southern Grand Bank in the vicinity west of the southeast shoal. Northern wolffish are also found in a similar location.

Information on the spatial dynamics of wolffish is relatively limited. Templeman (1984) demonstrated through tagging studies that wolffish undergo limited movement, with most recaptures occurring < 8 km from the tagging site. However, Kohler (1968) and Keats et al. (1985) reported seasonal movement inshore by striped wolffish. In addition, striped wolffish spawn in September and the entire larval stage was reported to be spent close to the location of hatching (Templeman 1985 and 1986a). Recent information showed that young of the year were widely spread in near surface waters of the northeast Newfoundland and Labrador Shelf. Information on spotted wolffish is more limited, but they appear to spawn in late autumn or early winter. The broad distribution observed for the three species coupled with limited movement as suggested by Templeman (1984) suggests the possibility of the existence of ESU's or sub-populations of wolffish. Nonetheless, based on the current information, there is no evidence of spawning or feeding aggregations in any of the three species of wolffish under consideration (see discussion of differential declines by area described above).

Wolffish have been exploited in a directed fishery off Greenland (Moller and Ratz 1999, Smidt 1981) but within Canadian waters, it has mainly been a by-catch species of fisheries directed for other commercial species. Kulka (1986) noted that annually, during the 1980's, about 1,000 t of the 3 species (combined) were caught in a variety of other fisheries. In more recent years, catches of wolffish declined during the early 1990's. With the exception of 1999, the total NAFO reported landings of wolffish have been less than 1,000t per year over the last ten years in Newfoundland waters. In most years, during this period of time, the majority of the catch has occurred in NAFO Division 3Ps, where a diverse fishery continues. However, significant catches of wolffish do occur on the northeast Newfoundland Shelf and the northern Grand Bank (NAFO Divisions 3K, 3Land 3N).

The decline in wolffish landings throughout the 1990's is 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 regulatory changes in fisheries directed at other species including cod, Greenland halibut, yellowtail flounder, witch flounder, redfish, and invertebrate species such as shrimp, crab and scallops. In addition, wolffish are captured by most common gear types, including gillnets, lines and trawls. Trawl fisheries are responsible for the majority of captures for all three species of wolffish. In the case of spotted wolffish, trawl fisheries removed the majority of the catch, though more recently, with declines in the some traditional fisheries and changes in the directed species, trap fisheries have increasingly contributed to spotted wolffish removals.

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 areas a variety of bottom types, thus their widespread distribution. As can be expected from the widespread distribution of wolffish, striped and spotted wolffish did not show a clear preference for any particular sediment type in either spring or fall surveys. However, northern wolffish did occupy sand/shell hash, gravely sand and rock sediments more frequently during the fall than their occurrence in the environment would suggest. However, in relation to depth and temperature, all three species show a distinct preference for warmer waters and an avoidance of shallower depths (with the exception of a concentration of striped wolffish on the southern Grand Banks). 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.

CONCLUSIONS

Pre-conditions for the issuance of an IHP to a fishing operation would be to demonstrate that incidental capture, or habitat destruction, would not prevent the recovery of the species. Defining the conditions under which this would occur is problematic for marine species given that population parameters and the environment in which they exist are poorly understood and naturally variable. Marine fish for example are highly fecund resulting in natural population fluctuations and environmental conditions that highly affect survival. As a result, 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. In particular, obtaining a measure of natural mortality (M) and longevity is problematic, as for most marine fish species. In addition, in the case of wolffish, 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. Consequently, absolute catch is not known, though estimates of total removals can be computed, and subsequently used in the development of an IHP limit.

Hence, our ability to differentiate human induced mortality from natural mortality is limited. Subsequently, determining biological limits, recovery strategies and what level of human induced harm will prevent recovery of a depressed population to previous levels is at best difficult because often, we cannot easily apportion the relative contributions of F and M that brought about a decline in the population. As well, defining a species critical habitat and human induced changes to these habitats is limited. In the case of wolffish, and other poorly understood marine fish species, habitat associations are poorly understood. Habitat changes brought about by gear affects are now only starting to be examined (Schwinghamer et al. 1998). The preliminary habitat association analyses presented in this paper (and the widespread distribution of the species) suggest that the wolffish species inhabit a wide range of available temperatures, depths and bottom types. Thus, critical habitat widespread and is not restricted limited areas.

Since wolffish are not targeted, part of the IHP 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 ESU's (currently being researched) uninformed spatial closures could result in the permanent loss of important genetic variants as well as loss of income from directed fisheries affected, potentially without a significant impact on wolffish survival.
- **Temporal closures**: For wolffish, the current lack of specific information on spawning times (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**: While the majority of wolffish are captured in trawl fisheries, there is no relative estimate of their impact on wolffish relative to other gear types. As well, recent shifts in fishing practices 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 captured in a variety of gears regulatory changes which would require live-releases, which 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.

Thus, the options for conditions associated with IHP's for wolffish are limited. Area and season closures based on aggregations for spawning or feeding do not appear feasible since wolffish are ubiquitous in space and time. They appear to have little or no preference for certain locations.

However, it has been observed that wolffish when captured are far more lively that most other species and therefore, mandatory release as soon after capture as possible should result in a relatively high level of survival. Tagging studies (Templeman 1984) conducted on wolffish have found return rates of 5, 7.4 and 3 percent on striped, spotted and northern wolffish respectively. Comparable tagging studies on other marine fish, such as Greenland halibut, have reported return rates on only 1.3% (Bowering 1984) and on Thorny skate 5% (Templeman 1984). A mandatory release rule would lead to a reduced level of mortality than under current license conditions that specify all wolffish must be landed. The assumption is that the IHP conditions for release would provide guidance for quick release methods in a manner that would not cause further damage to the fish. While live release may not ensure future reproductive success, it does increase the probability of survival and probably reproduction.

Alternatively, consideration could 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 observed in recent years. This option potentially would result in a higher rate of mortality and therefore might only be considered for striped wolffish that is a species "of concern". A consistent rule for all species is more 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 are presently landed for market. Clearly, further analyses of these impacts is warranted.

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Table 1. Canadian landings based on NAFO STATLANT 21A, by region and Division. Landings include wolffish (non-specified), spotted and Atlantic wolffish codes.

Region	Canada Maritimes							Canada Maritimes & Quebec							Canada Newfoundland						
Division	2H	2J	3K	3L	3N	3O	3Ps	2H	2J	3K	3L	3N	3O	3Ps	2H	2J	3K	3L	3N	3O	3Ps
1960	-	-	-	-	-	-	-	-	-	-	34	3	11	21	-	-	26	131	4	11	67
1961	-	-	-	-	-	-	-	-	-	-	11	1	27	28	-	-	54	162	16	22	77
1962	-	-	-	-	-	-	-	-	-	-	-	3	19	18	-	-	57	115	29	37	61
1963	-	-	-	-	-	-	-	-	-	-	8	4	32	3	-	-	102	172	39	31	98
1964	-	-	-	-	-	-	-	-	-	-	30	7	8	3	-	-	47	194	39	20	124
1965	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	522	81	9	132
1966	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	116	647	94	10	192
1967	-	-	-	-	-	-	-	-	-	-	20	1	5	41	-	10	131	873	59	19	133
1968	-	-	-	-	-	-	-	-	2	-	45	8	2	11	-	47	75	1,004	73	15	274
1969	-	-	-	-	-	-	-	-	-	-	75	-	10	12	-	7	133	1,574	111	34	215
1970	-	-	-	-	-	-	-	-	-	-	27	7	38	44	-	-	183	925	96	25	299
1971	-	-	-	-	-	-	-	-	-	-	70	61	13	30	-	-	180	1,782	116	34	339
1972	-	-	-	-	-	-	-	-	-	-	10	5	21	32	-	-	118	1,311	58	32	228
1973	-	-	-	-	-	-	-	-	-	-	-	6	12	27	-	2	84	1,244	168	170	246
1974	-	-	-	-	-	-	-	-	-	-	2	2	24	62	-	-	45	975	182	94	705
1975	-	-	-	-	-	-	-	-	7	2	-	1	2	25	-	-	47	873	211	42	110
1976	-	-	-	-	-	-	-	4	1	1	49	2	1	2	2	4	172	1,952	101	61	128
1977	-	-	-	-	-	-	-	-	3	3	12	-	11	35	-	2	218	1,203	80	54	308
1978	-	-	-	-	-	-	-	-	12	32	3	-	11	13	-	24	264	940	70	60	214
1979	-	18	55	8	2	16	15	-	-	-	-	-	-	-	-	33	270	1,001	70	40	237
1980	-	35	37	67	23	4	8	-	-	-	-	-	-	-	-	50	449	794	73	15	323
1981	3	23	12	62	3	1	13	-	-	-	-	-	-	-	5	20	412	1,379	58	15	352
1982	1	24	2	17	-	18	14	-	-	-	-	-	-	-	15	90	215	2,010	68	73	200
1983	6	24	33	80	3	3	17	-	-	-	-	-	-	-	2	68	267	2,327	46	43	153
1984	5	4	48	43	2	11	18	-	-	-	-	-	-	-	4	7	202	692	54	25	75
1985	-	1	12	8	9	19	26	-	-	-	-	-	-	-	-	2	103	1,009	79	51	97
1986	-	5	33	50	6	16	9	-	-	-	-	-	-	-	-	3	293	667	198	42	123
1987	-	2	10	33	57	46	14	-	-	-	-	-	-	-	-	5	41	713	277	111	109
1988	-	1	9	90	48	13	17	-	-	-	-	-	-	-	2	10	94	496	172	55	73
1989	-	6	25	21	39	19	31	-	-	-	-	-	-	-	-	78	118	593	101	53	68
1990	-	2	22	19	20	13	31	-	-	-	-	-	-	-	-	54	38	327	19	28	65
1991	-	-	8	1	10	10	11	-	-	-	-	-	-	-	-	1	52	359	50	40	87
1992	-	-	17	7	42	17	10	-	-	-	-	-	-	-	-	2	3	32	8	61	104
1993	-	-	-	-	8	18	8	-	-	-	-	-	-	-	-	-	15	2	34	113	58
1994	-	-	-	-	2	1	3	-	-	-	-	-	-	-	-	-	13	1	-	-	11
1995	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	1	-	-	13
1996	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	8	1	-	1	8
1997	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	9	3	-	4	47
1998	-	-	-	-	-	2	5	-	-	-	-	-	-	-	-	1	-	-	1	-	82
1999	-	-	-	-	4	1	3	-	-	-	-	-	-	-	-	2	1	-	4	7	227
2000	-	-	-	-	30	-	3	-	-	-	-	-	-	-	-	-	14	21	3	-	272

Table 2: Comparison of Canadian and non-Canadian catches of wolffish landings as reported by NAFO.

	Non-Can	Canadian	Total	% non-Can	% Canadian
1960	505	308	813	62.1	37.9
1961	430	398	828	51.9	48.1
1962	109	339	448	24.3	75.7
1963	599	489	1088	55.1	44.9
1964	883	472	1355	65.2	34.8
1965	1762	808	2570	68.6	31.4
1966	914	1059	1973	46.3	53.7
1967	918	1292	2210	41.5	58.5
1968	1132	1556	2688	42.1	57.9
1969	850	2171	3021	28.1	71.9
1970	980	1644	2624	37.3	62.7
1971	2843	2625	5468	52.0	48.0
1972	4017	1815	5832	68.9	31.1
1973	3224	1959	5183	62.2	37.8
1974	3488	2091	5579	62.5	37.5
1975	5268	1320	6588	80.0	20.0
1976	1382	2480	3862	35.8	64.2
1977	1209	1929	3138	38.5	61.5
1978	437	1643	2080	21.0	79.0
1979	428	1765	2193	19.5	80.5
1980	238	1878	2116	11.2	88.8
1981	374	2358	2732	13.7	86.3
1982	239	2747	2986	8.0	92.0
1983	272	3072	3344	8.1	91.9
1984	423	1190	1613	26.2	73.8
1985	269	1416	1685	16.0	84.0
1986	483	1445	1928	25.1	74.9
1987	976	1418	2394	40.8	59.2
1988	286	1080	1366	20.9	79.1
1989	190	1152	1342	14.2	85.8
1990	1167	638	1805	64.7	35.3
1991	2368	629	2997	79.0	21.0
1992	288	303	591	48.7	51.3
1993	167	256	423	39.5	60.5
1994	231	31	262	88.2	11.8
1995	321	20	341	94.1	5.9
1996	642	20	662	97.0	3.0
1997	590	66	656	89.9	10.1
1998	490	91	581	84.3	15.7
1999	798	249	1047	76.2	23.8
2000	412	343	755	54.6	45.4

Table 3: ZIF landings by NAFO Division, 1985-2002. (Newfoundland, Gulf and Quebec are not available for (2002, 2001/2002,2001/2002) respectively.)

	Div											
	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 4. ZIF landings by division as a percent of total landings.

	Div						
	2H	2J	3K	3L	3N	3O	3PS
1985	0.0	0.2	8.6	69.1	6.6	5.2	8.5
1986	0.0	2.5	25.2	38.1	16.8	4.8	8.9
1987	0.0	3.0	3.9	49.4	21.9	10.3	8.0
1988	0.0	1.0	9.3	53.1	20.1	6.2	8.1
1989	0.0	7.2	12.0	51.4	12.0	6.2	8.2
1990	0.0	10.0	10.6	43.7	7.8	7.3	17.0
1991	2.9	0.2	8.5	52.2	8.6	7.1	14.2
1992	0.8	0.4	5.8	8.8	14.5	22.6	32.5
1993	0.0	0.2	1.1	1.6	13.5	41.6	20.3
1994	0.6	1.0	37.4	4.0	5.5	3.8	40.4
1995	0.0	1.5	14.1	2.1	0.0	3.2	46.7
1996	0.0	8.4	55.1	5.1	7.6	10.5	12.5
1997	0.0	1.6	5.6	2.1	0.1	2.7	28.9
1998	0.0	0.5	0.2	0.3	1.5	1.5	59.0
1999	0.0	0.7	0.6	0.2	2.8	2.5	72.6
2000	0.0	0.3	18.9	27.6	49.2	0.7	3.3
2001	0.1	1.8	16.9	18.2	55.3	1.9	5.8
2002	0.0	0.0	0.0	0.0	0.0	2.9	97.1

Table 5. ZIF landings by gear type. Note: NAFO 3Pn and 3M have been included in this table.

	Gillnet	Lines	Other	Seine	Traps	Trawl	Total
1985	295.45	77.493		1.948	1.592	947.62	1324.103
1986	69.245	98.101	2.142	0.233	0.725	967.569	1138.015
1987	221.977	176.165		0.57	2.766	1124.91	1526.387
1988	138.14	139.744	0.111	0.594	4.035	822.222	1104.846
1989	113.844	132.096	0.51	1.441	1.769	913.721	1163.381
1990	80.993	113.449	0.723	1.773	1.214	366.624	564.776
1991	43.033	113.842	0.448	1.673	0.896	530.311	690.203
1992	29.083	169.796	0.449	2.167	0.286	141.865	343.646
1993	32.979	106.303	0.92	3.59	0.437	170.052	314.281
1994	11.094	2.468	0.758	0.36	0.073	18.891	33.644
1995	18.683	3.927	0.108	0.219	0.077	3.485	26.499
1996	4.952	1.184		0.299	0.037	5.128	11.6
1997	19.182	123.576		0.228	0.122	13.085	156.193
1998	23.702	126.607		0.164	0.076	8.166	158.715
1999	45.755	261.267		0.101	0.444	7.621	315.188
2000	13.056	35.52			1.616	26.413	76.605
2001	28.632	42.772			4.973	105.399	181.776
2002	0.866	0.278				0.203	1.347

Table 6. Composition of total catch (kept+ discard) in observer data by wolffish species, summarized across all Divisions.

	Species			
	Unspecified	Northern	Striped	Spotted
1981	20.90%	39.67%	6.34%	33.08%
1982	1.51%	56.64%	6.97%	34.87%
1983	1.46%	56.05%	6.35%	36.13%
1984	0.85%	66.30%	4.32%	28.54%
1985	0.95%	63.74%	11.49%	23.82%
1986	1.89%	59.96%	9.62%	28.53%
1987	0.67%	74.40%	7.00%	17.93%
1988	1.34%	48.18%	11.63%	38.85%
1989	1.66%	38.87%	18.42%	41.05%
1990	0.25%	48.31%	11.35%	40.09%
1991	1.24%	54.14%	5.90%	38.72%
1992	1.39%	68.41%	17.41%	12.80%
1993	1.23%	38.24%	36.27%	24.27%
1994	0.46%	59.56%	30.10%	9.88%
1995	0.00%	31.77%	56.11%	12.12%
1996	0.88%	32.89%	51.11%	15.13%
1997	5.34%	45.51%	42.14%	7.02%
1998	2.03%	60.43%	31.79%	5.75%
1999	9.12%	43.35%	39.76%	7.77%
2000	8.42%	45.57%	30.07%	15.94%
2001	0.65%	21.96%	66.74%	10.65%
All	3.02%	55.16%	11.33%	30.49%

Table 7a. Observer catch by gear type for spotted wolffish

	Gear					
	Gillnet	Lines	Trawl	Seine	Traps	Other
1980	4246		197630	0	0	0
1981	10	4650	213872	0	0	0
1982	1275	19038	301410	0	0	0
1983	3050	21538	227381	0	0	0
1984	1810	6925	156659	0	0	0
1985	191	16190	86771	0	0	0
1986	211	598	127391	0	0	0
1987	100	885	147698	0	0	0
1988	40	457	185611	0	0	0
1989	31	727	215208	5	0	0
1990	0	1625	173723	480	305	0
1991	412	154.8	224147	5	8	159
1992	60	132.2	38439	290	0	0
1993	371	747.9	32428	0	144	0
1994	30	54.9	5830	0	56	0
1995	20	72	7535	26	456	0
1996	4	230	9246	20	624	10
1997	24	640	1962	0	147	5
1998	75	104	1365	4	375	0
1999	189	243	1108	37	2752	0
2000	1677	821	4769	106	4683	0
2001	737	707	4483	65	8764	0

Table 7b: Weight of catch by gear type for Atlantic wolffish.

	Gear					
	Gillnet	Lines	Trawl	Seine	Traps	Other
1980	22	0	65316	0	0	0
1981	0	2260	50955	0	0	0
1982	525	7997	59586	0	0	0
1983	5	17771	28117	0	0	0
1984	5	7700	19173	0	0	0
1985	34	16045	36855	0	0	0
1986	0	117	45110.5	0	0	0
1987	0	35	58306	0	0	0
1988	0	1120	55576.5	0	0	0
1989	0	225	96343.9	34	0	0
1990	0	1628	47023	885	0	0
1991	0	200	35706.6	48	0	20
1992	33	1026.8	47099.1	526	0	0
1993	321	417.5	46828.9	406	0	0
1994	78	47.2	6647.8	0	2	0
1995	52	92	4774	64	214	0
1996	225	109	18300	24	76	10
1997	361	2217	11167	0	5	70
1998	988	310	8765	12	413	0
1999	791	4541	11684	27	3223	0
2000	382	7889	11690	78	802	0
2001	583	2873	87892	200	861	46

Table 7c: Weight of catch by gear type for northern wolffish.

	Gear					
	Gillnet	Lines	Trawl	Seine	Traps	Other
1980	673	0	223277	0	0	0
1981	19	16148	283968	0	0	0
1982	2030	137663	432002	0	0	0
1983	5835	95084	326611	0	0	0
1984	580	35420	344779.8	0	0	0
1985	950	126965	146619	0	0	0
1986	27	20275	246926.8	0	0	0
1987	0	15622	600712	0	0	0
1988	74	11166	224983	0	0	0
1989	60	22646	187352	15	0	0
1990	142	43586	246354	60	448	0
1991	1095	8361.7	359331.6	16	2	30
1992	1930	41150.7	227827.5	5	0	0
1993	2629	1093.1	78517.8	8	8	0
1994	661	193.2	33317.3	0	15	0
1995	281	10192	51744	0	9	0
1996	1528	960	29667	0	42	5
1997	399	74	15714	0	97	0
1998	561	80	8081	0	7899	0
1999	880	34	3611	2	18062	0
2000	3829	403	20719	0	8751	0
2001	2085	631	20354	21	6756	0

Table 8. Average catch per tow for Northern. Spotted and striped wolffish on sediments in NAFO division 3LNO as derived from spring and fall research surveys from 1996-2001.

Average/tow	Fall			Spring		
Sediment Type	Northern	Spotted	Striped	Northern	Spotted	Striped
Mud	0	0.6	0	0	0.2	0
Coarse sand	0.112951	0.185624	0.963193	0.234679	0.300952	0.576901
Sand and Shell Hash	0.242475	0.260584	0.707821	0.219048	0.298337	1.139231
Gravelly Sand	0.197957	0.092761	0.905966	0.158742	0.059315	0.609833
Rocks	0.052149	0.123603	1.422396	0.055852	0.091351	1.29685
Boulders and rocks	0.047454	0.066691	1.402654	0.016485	0.03834	0.583581
unidentified				0	0	0.5

Table 9. Comparison of sediment distribution functions for northern wolffish

	Spring K-S,p	Fall K-S,p
1996	ks = 0.3043, p-value = 0.1499	ks = 0.4161, p-value = 0.0007
1997	ks = 0.4082, p-value = 0.0513	ks- = 0.34, p-value = 0.0031
1998	ks = 0.3173, p-value = 0.0026	ks = 0.3217, p-value = 0.0004
1999	ks = 0.2566, p-value = 0.0849	ks = 0.3043, p-value = 0.0112
2000	ks = 0.3233, p-value = 0.0871	ks = 0.2983, p-value = 0.028
2001	ks = 0.4789, p-value = 0.0005	ks = 0.2983, p-value = 0.028

Table 10. Comparison of temperature distribution functions for northern wolffish .

	Spring K-S	Fall K-S
1996	ks = 0.6778,	ks = 0.502,
1997	ks = 0.6881,	ks = 0.5173,
1998	ks = 0.7205,	ks = 0.5524,
1999	ks = 0.6347,	ks = 0.5402,
2000	ks = 0.7597,	ks = 0.6313,
2001	ks = 0.7741,	ks = 0.4078,

Table 11. Comparison of depth distribution functions for northern wolffish

	Spring K-S	Fall K-S
1996	ks = 0.6815	ks = 0.6454,
1997	ks = 0.696,	ks = 0.5972,
1998	ks = 0.8126,	ks = 0.5625,
1999	ks = 0.7578,	ks = 0.6002
2000	ks = 0.8106	ks = 0.6747,
2001	ks = 0.8737,	ks = 0.6066,

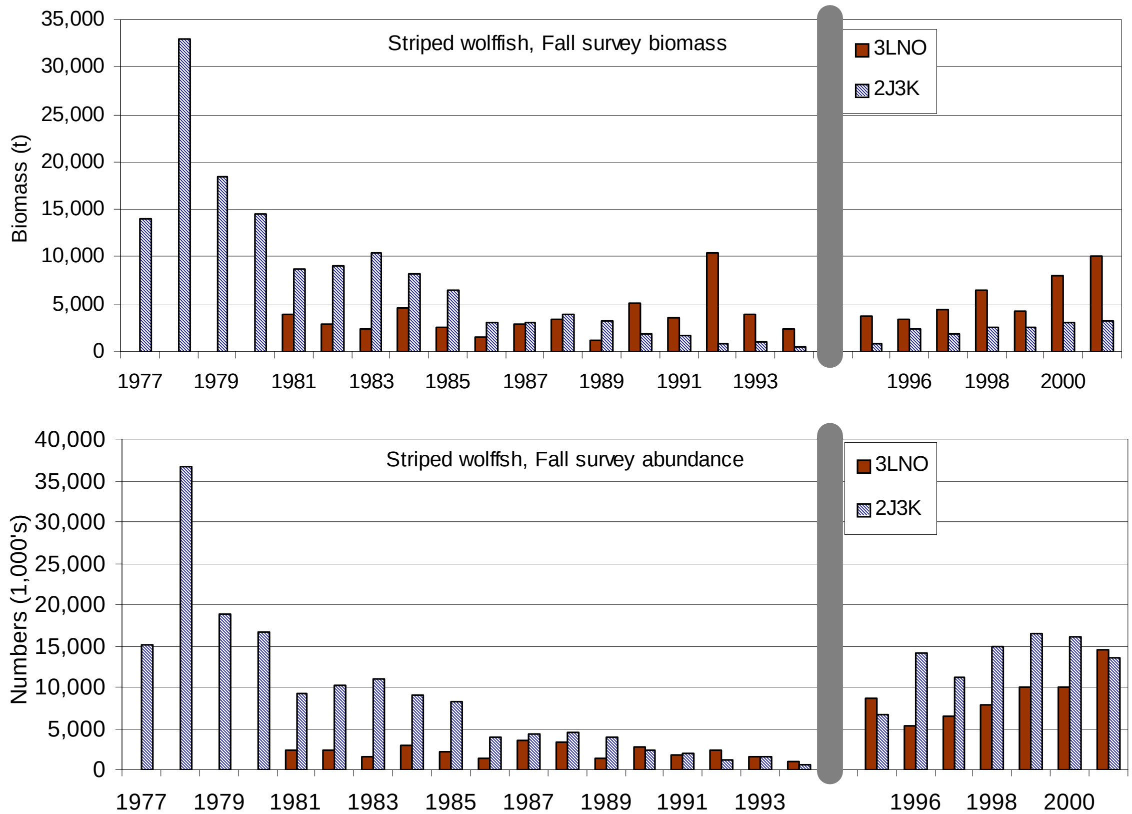

Figure 1. Fall research survey biomass (upper panel) and abundance (lower panel) indices for striped wolffish for the Grand Banks to Labrador Shelf (NAFO Divisions 2J and3KLNO), 1977-2001.

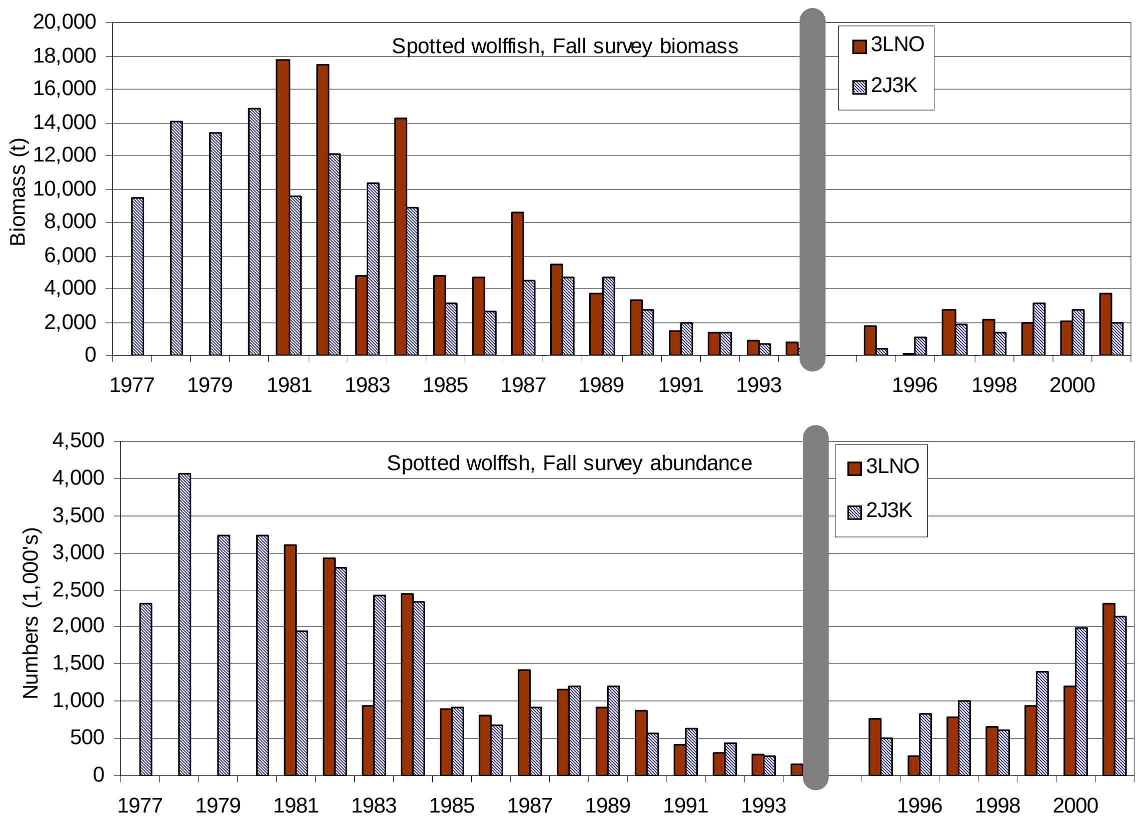

Figure 2. Fall research survey biomass (upper) and abundance (lower) indices for spotted wolffish for the Grand Banks to Labrador Shelf (NAFO Divisions 2J and3KLNO), 1977-2001.

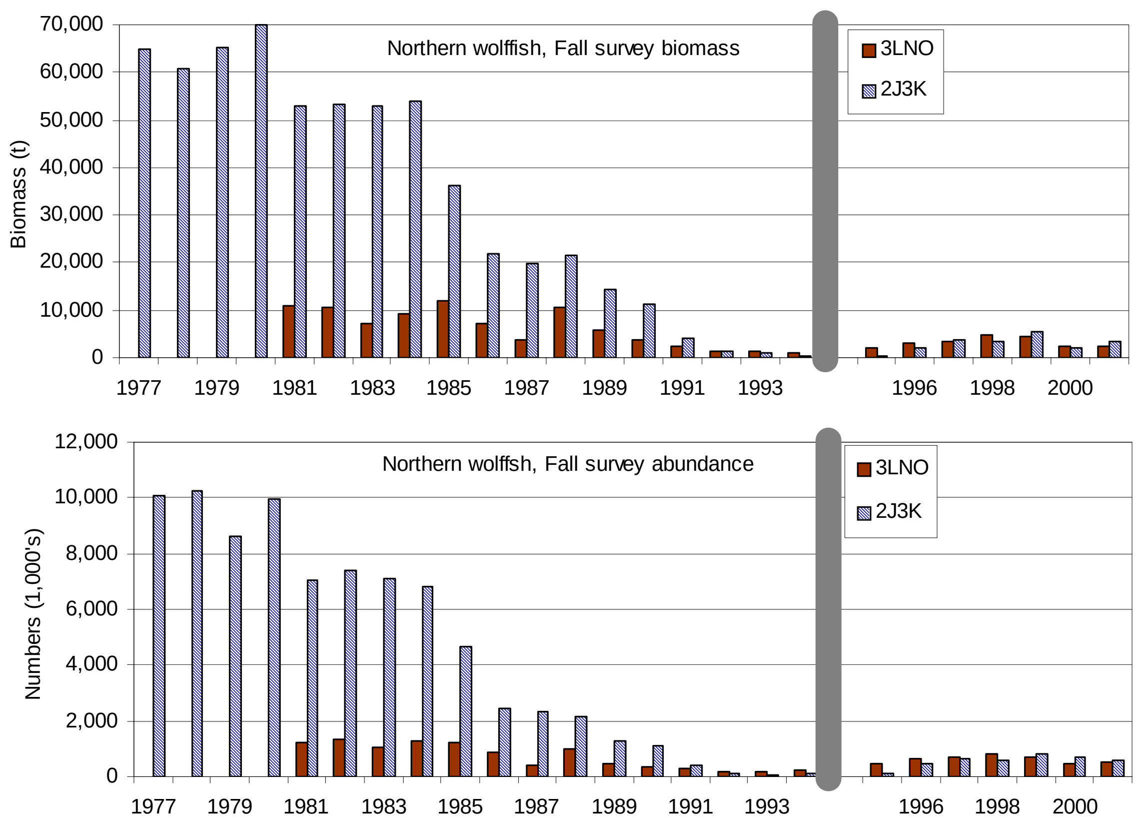

Figure 3. Fall research survey biomass (upper) and abundance (lower) indices for northern wolffish for the Grand Banks to Labrador Shelf (NAFO Divisions 2J and3KLNO), 1977-2001.

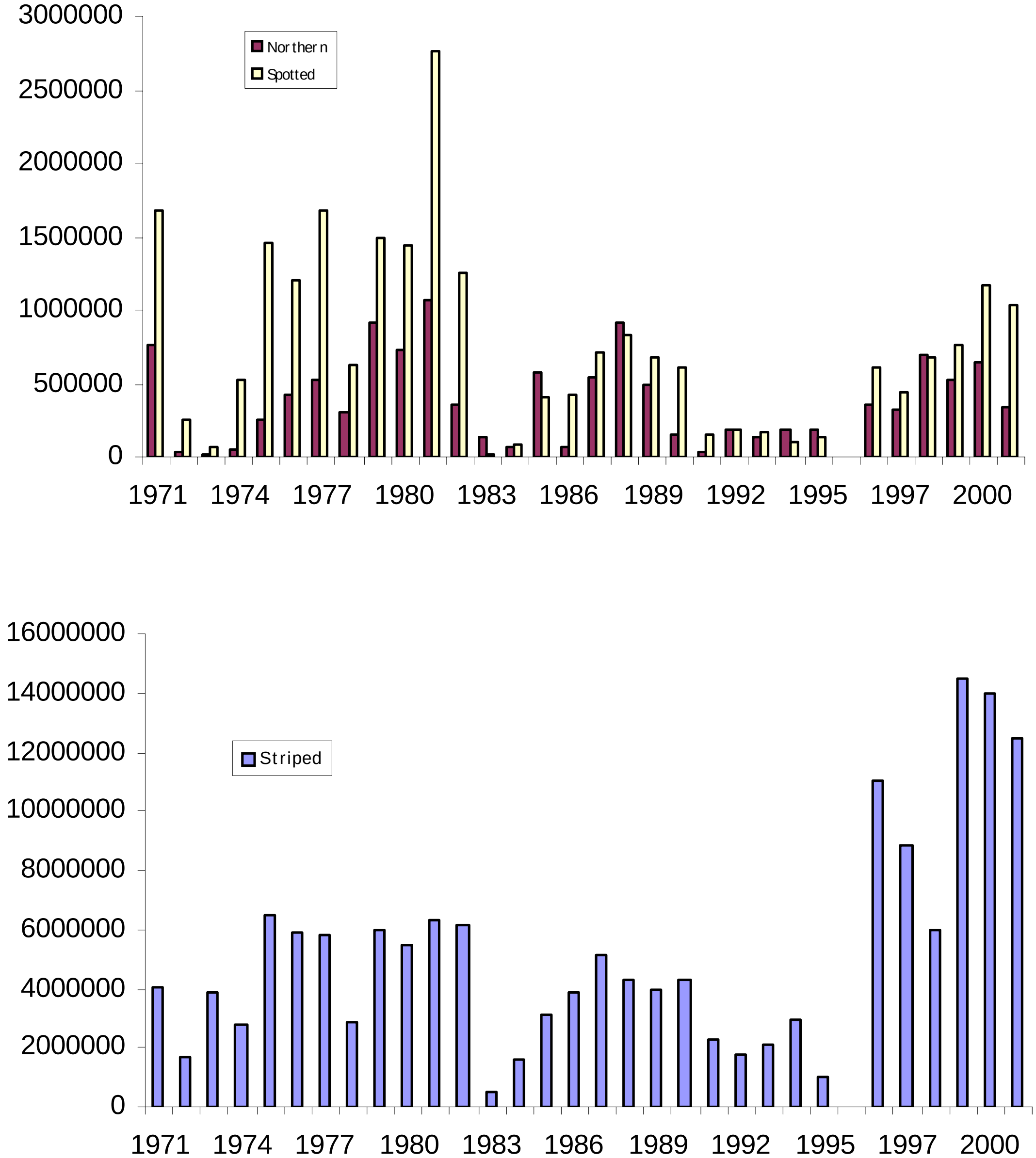

Figure 4. Spring research vessel abundance indices for Northern, spotted (Top panel) and striped (Bottom panel) wolffish FOR THE Grand Banks (NAFO Divisions 3LNOPs).

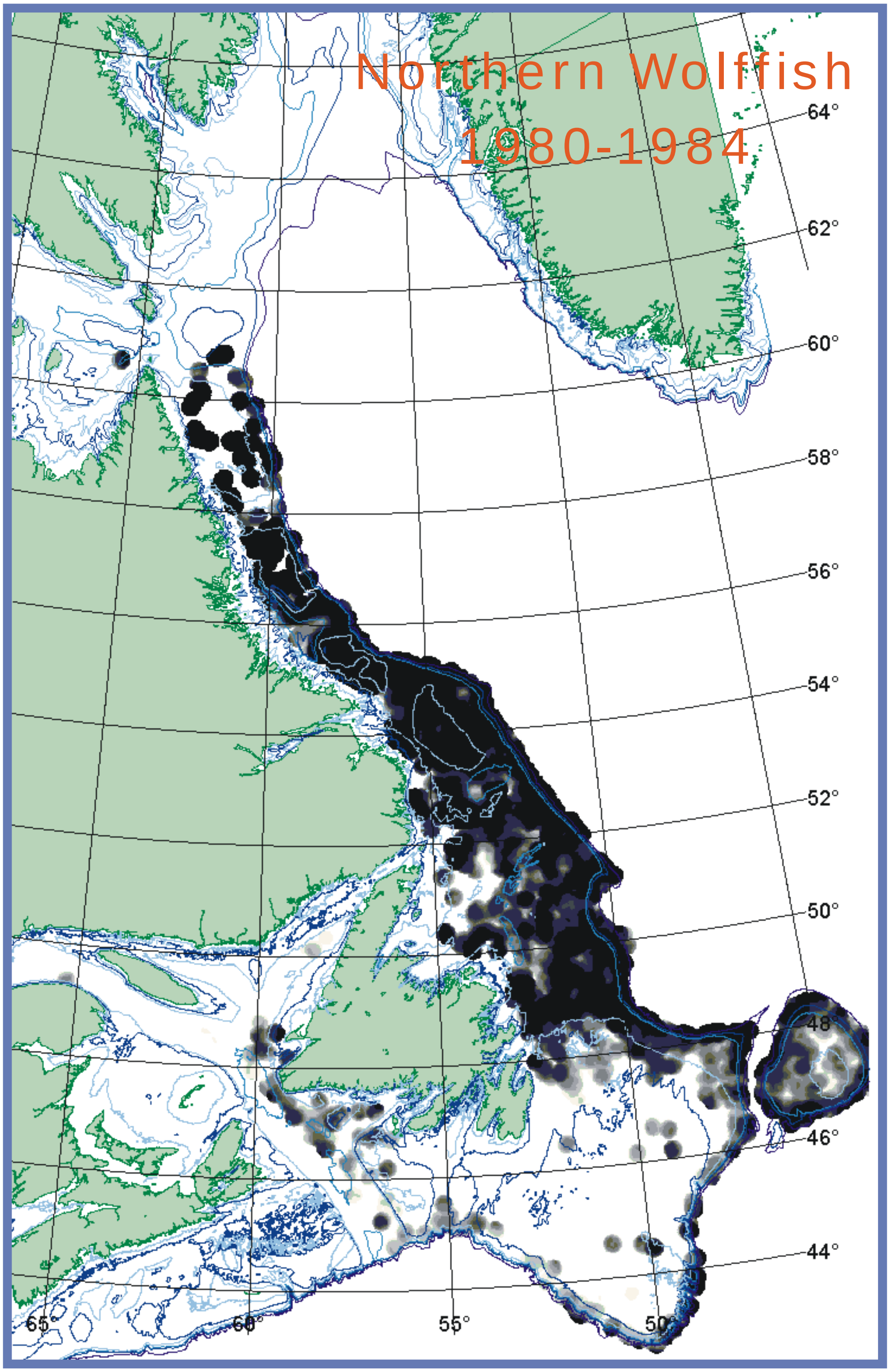

Figure 5a. Distribution of northern wolffish, 1980-1984. Darker shades denote denser concentrations.

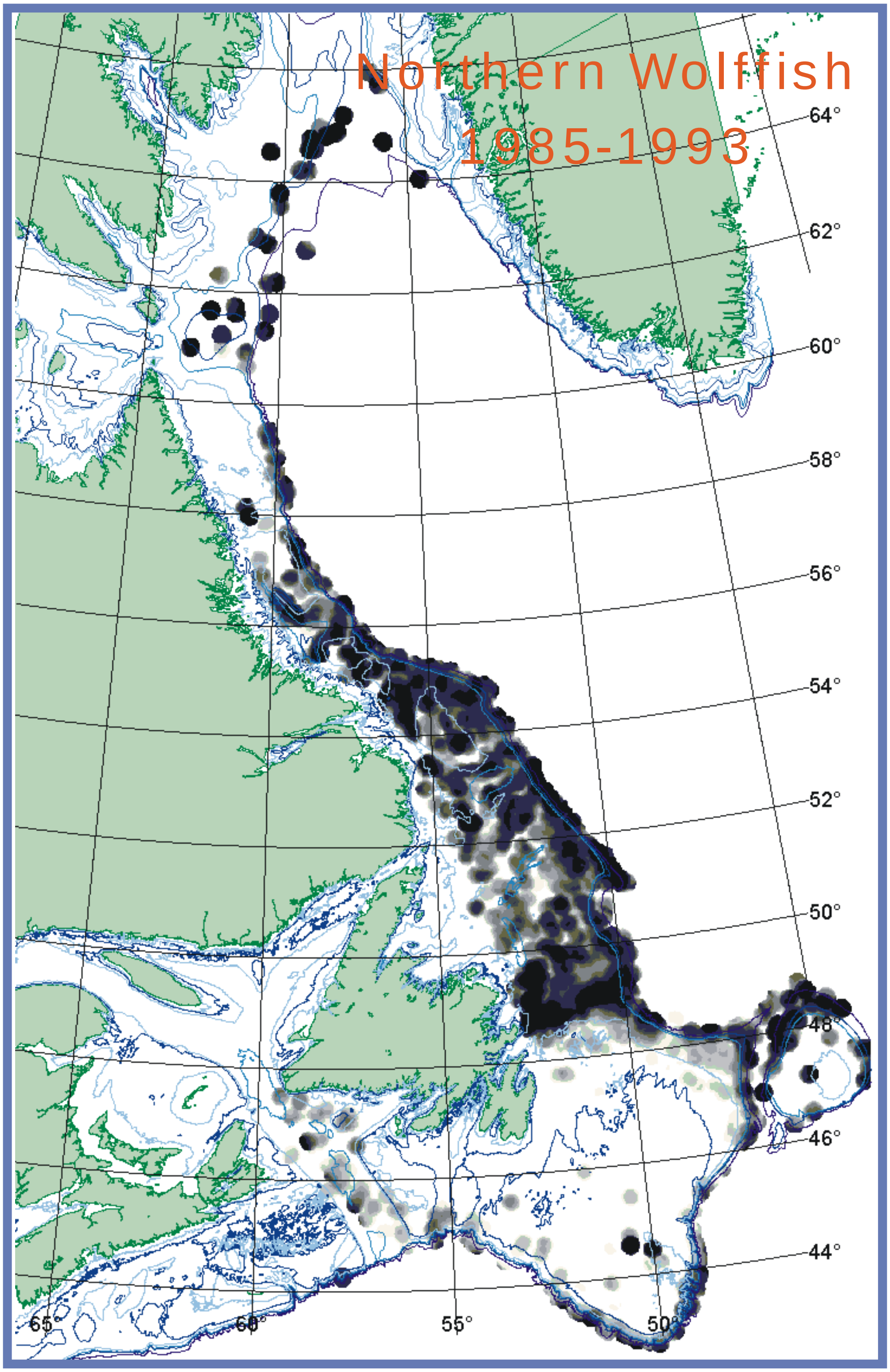

Figure 5b. Distribution of northern wolffish, 1985-1993. Darker shades denote denser concentrations.

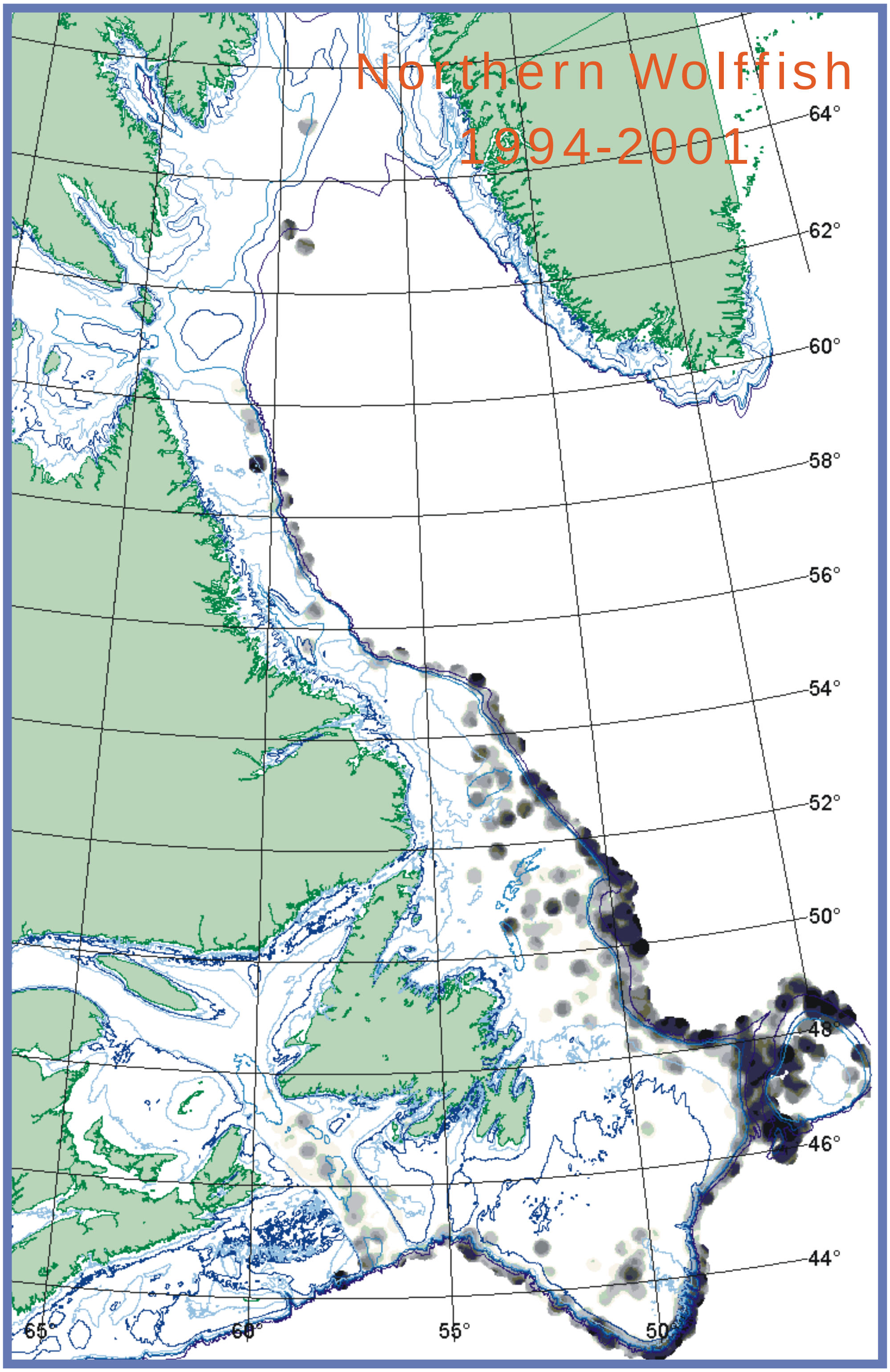

Figure 5c. Distribution of northern wolffish, 1994-2001. Darker shades denote denser concentrations.

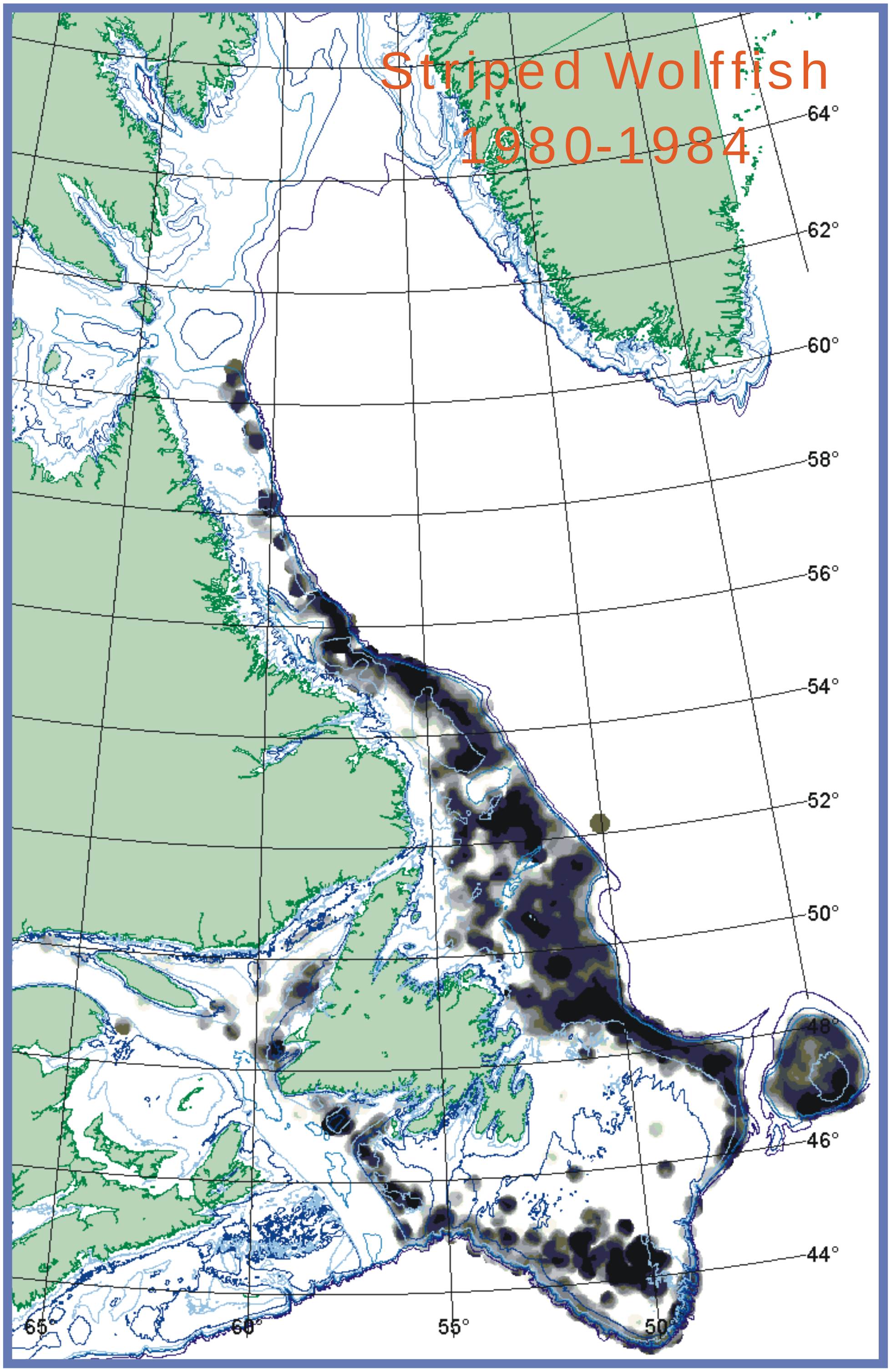

Figure 6a. Distribution of striped wolffish, 1980-1984. Darker shades denote denser concentrations.

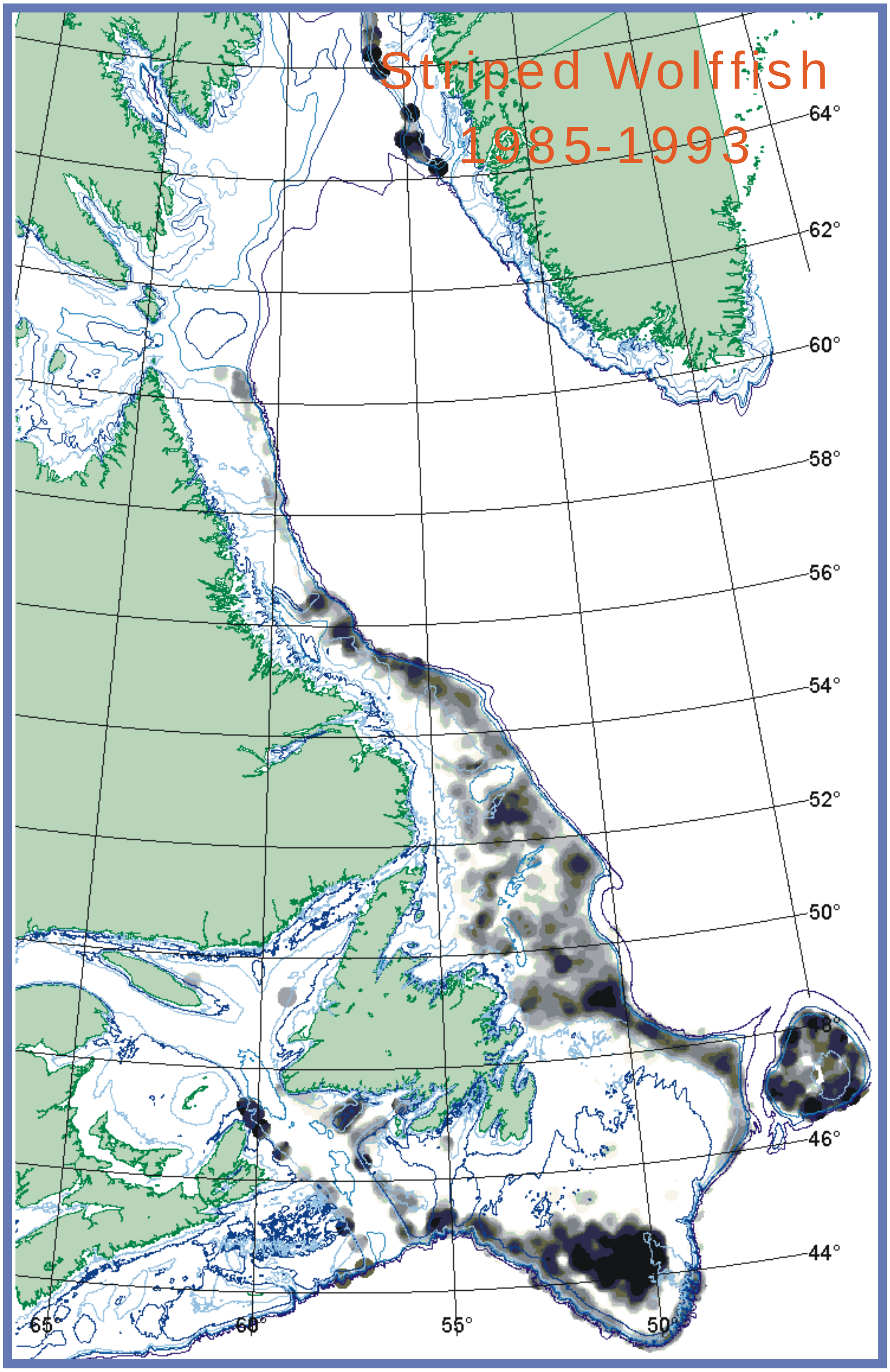

Figure 6b. Distribution of striped wolffish, 1985-1993. Darker shades denote denser concentrations.

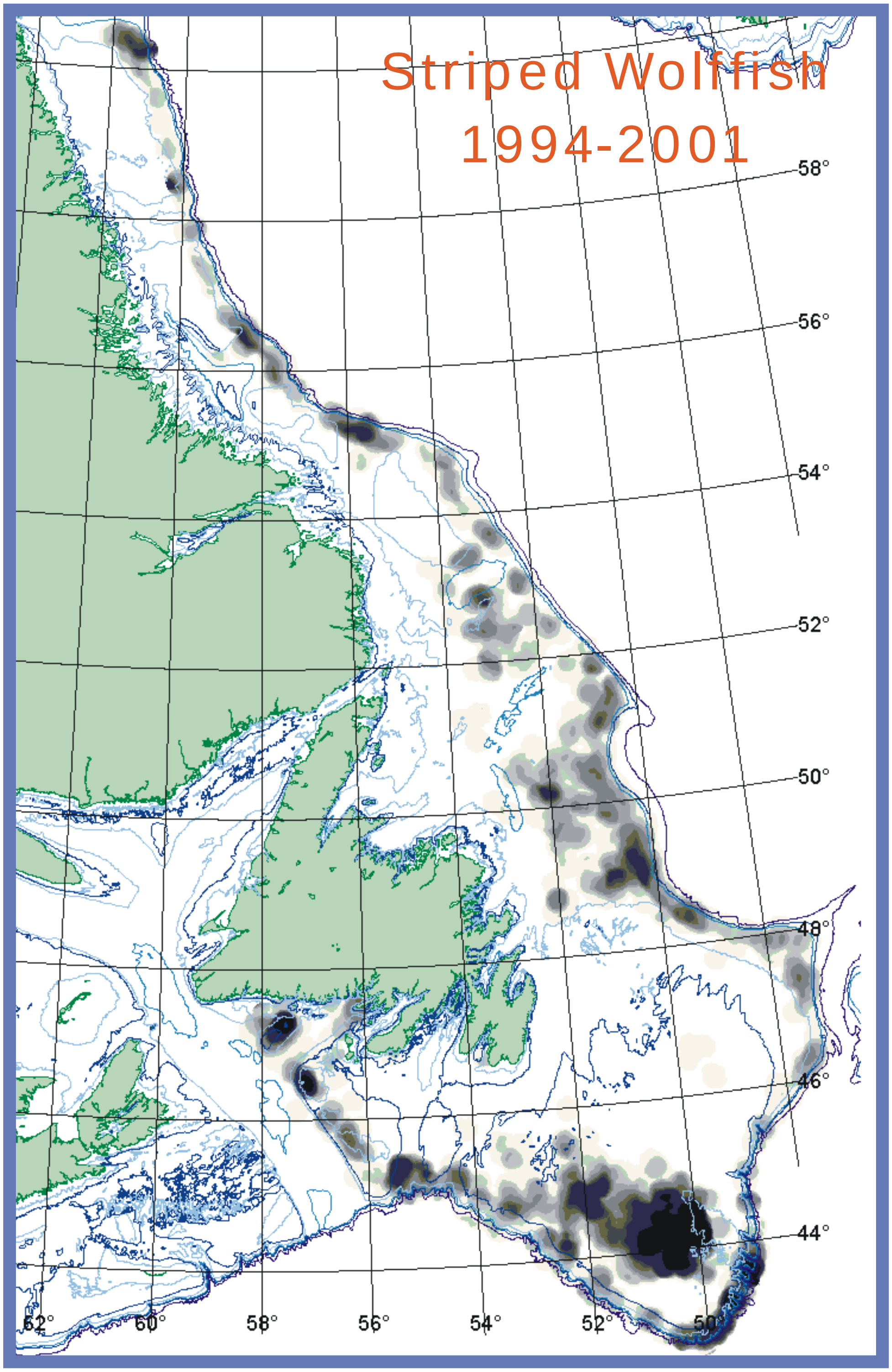

Figure 6c. Distribution of striped wolffish, 1994-2001. Darker shades denote denser concentrations.

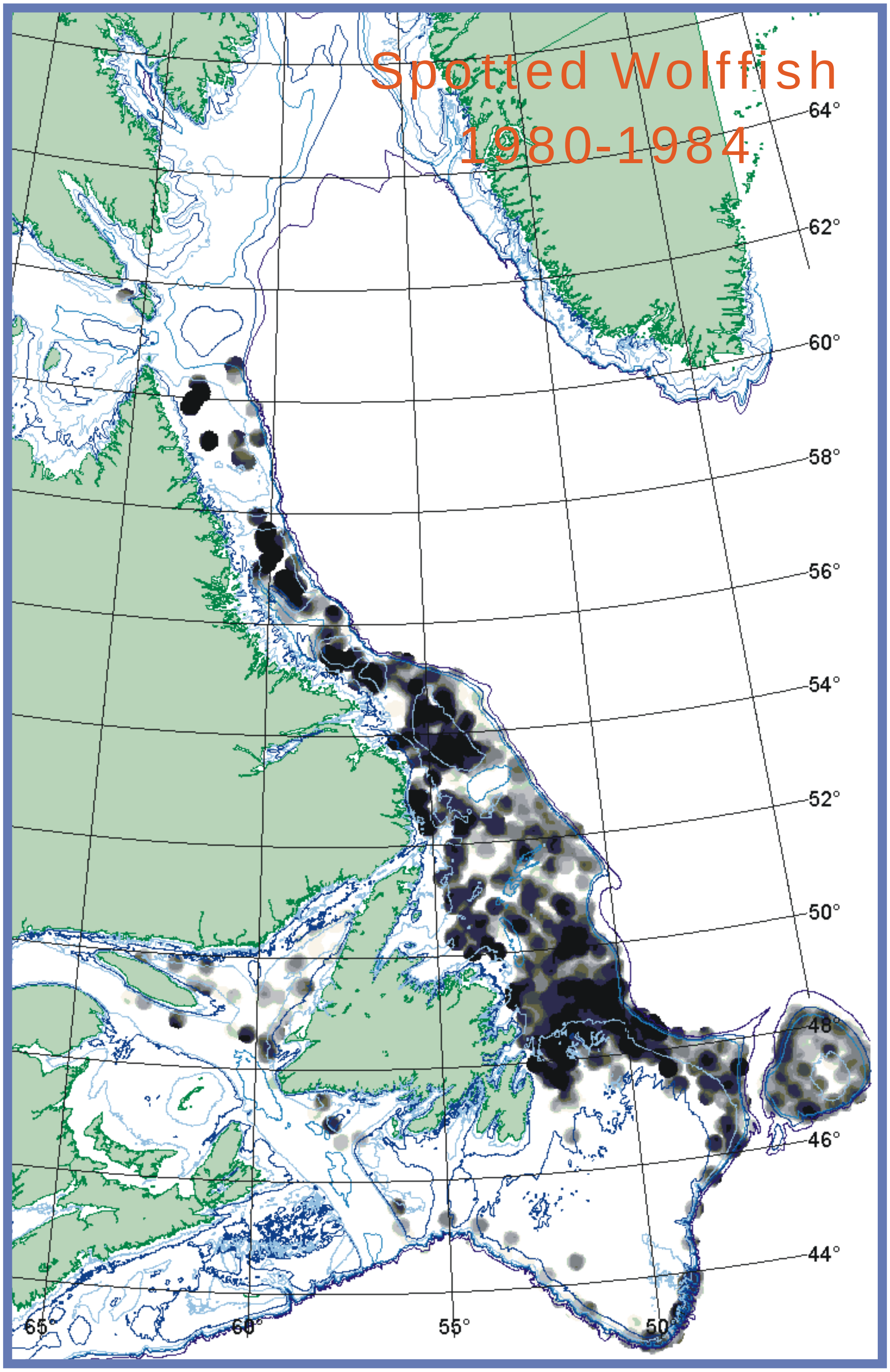

Figure 7a. Distribution of spotted wolffish, 1980-1984. Darker shades denote denser concentrations.

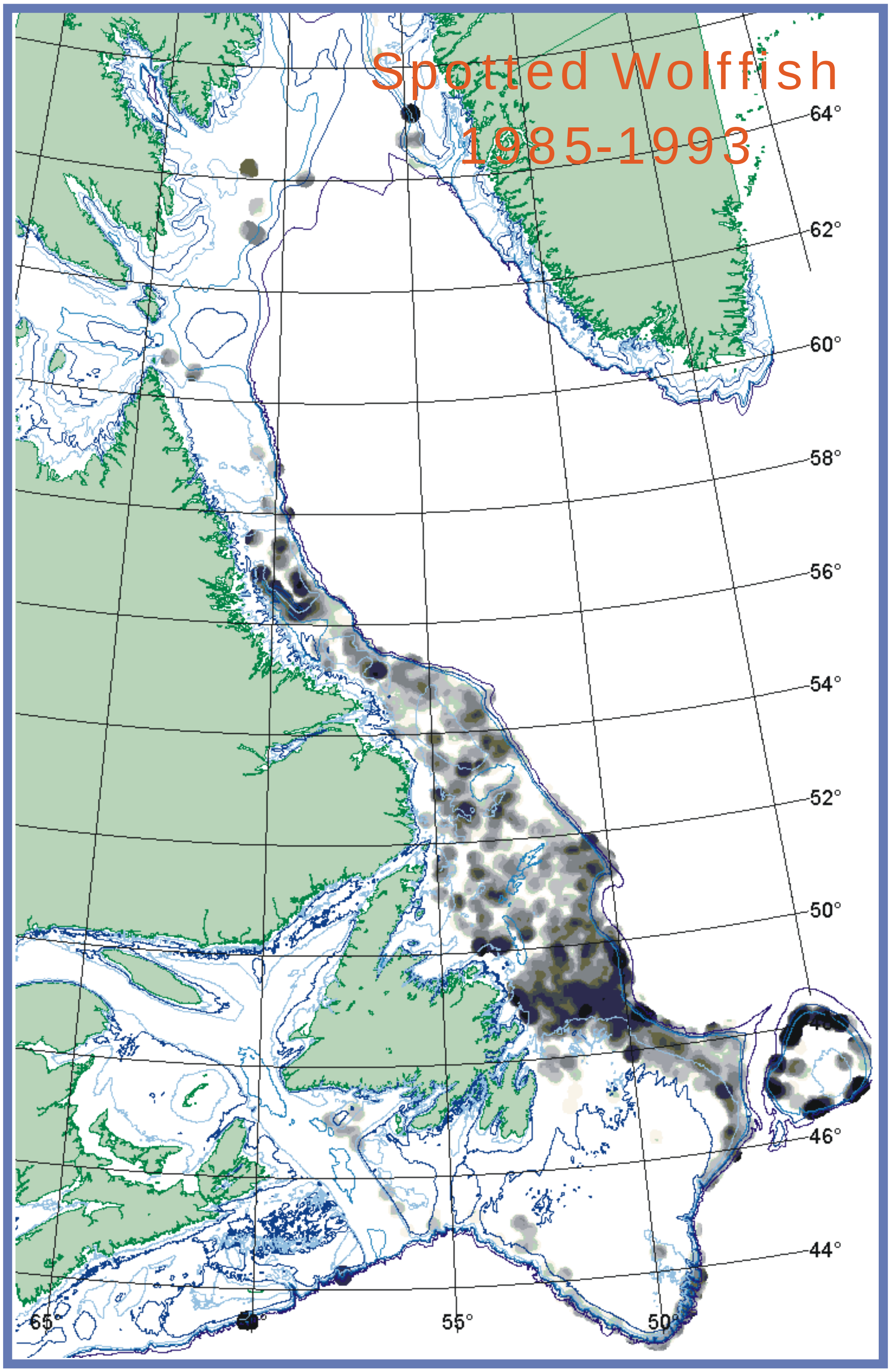

Figure 7b. Distribution of spotted wolffish, 1985-1993. Darker shades denote denser concentrations.

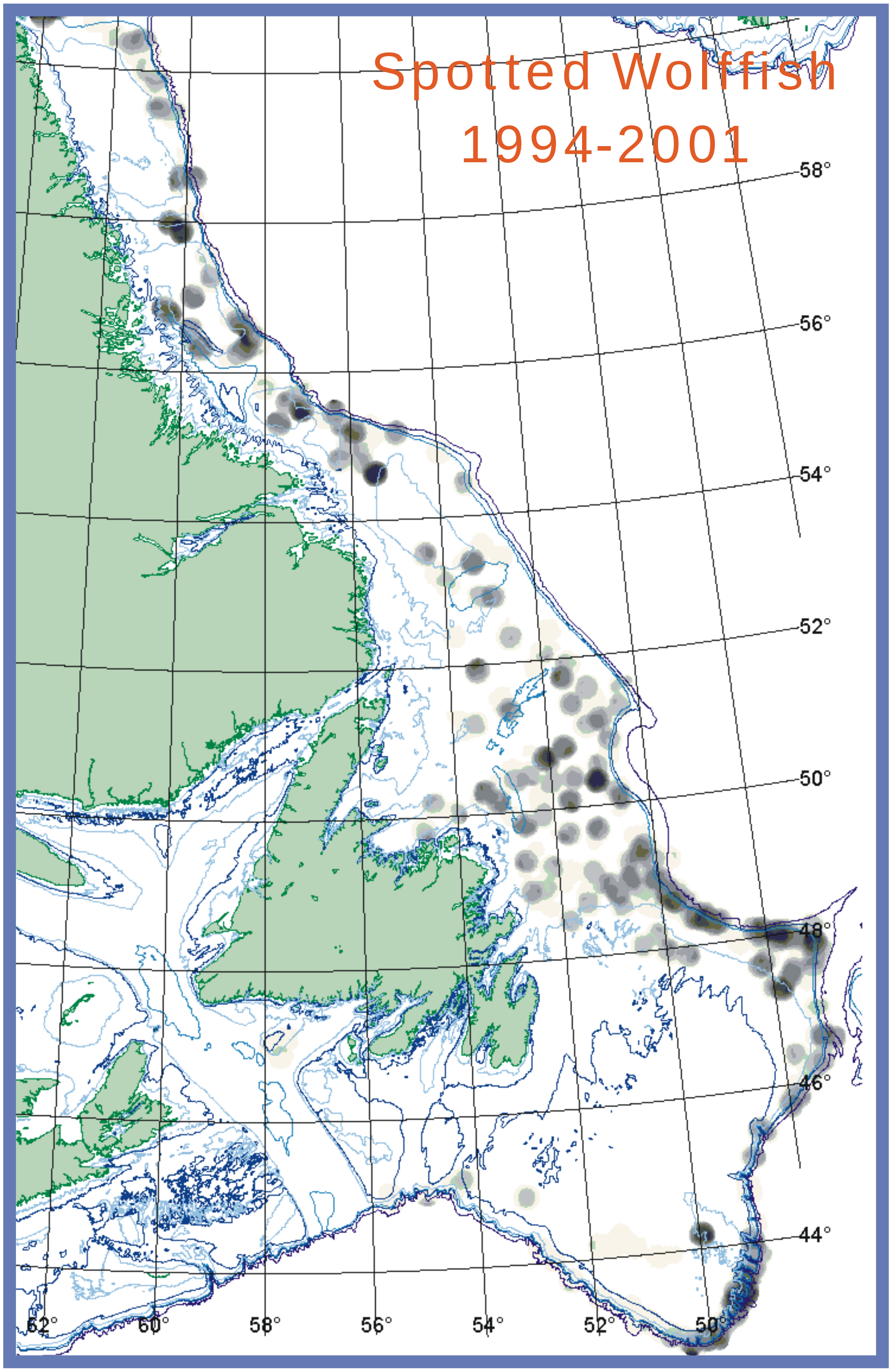

Figure 7c. Distribution of spotted wolffish, 1994-2001. Darker shades denote denser concentrations.

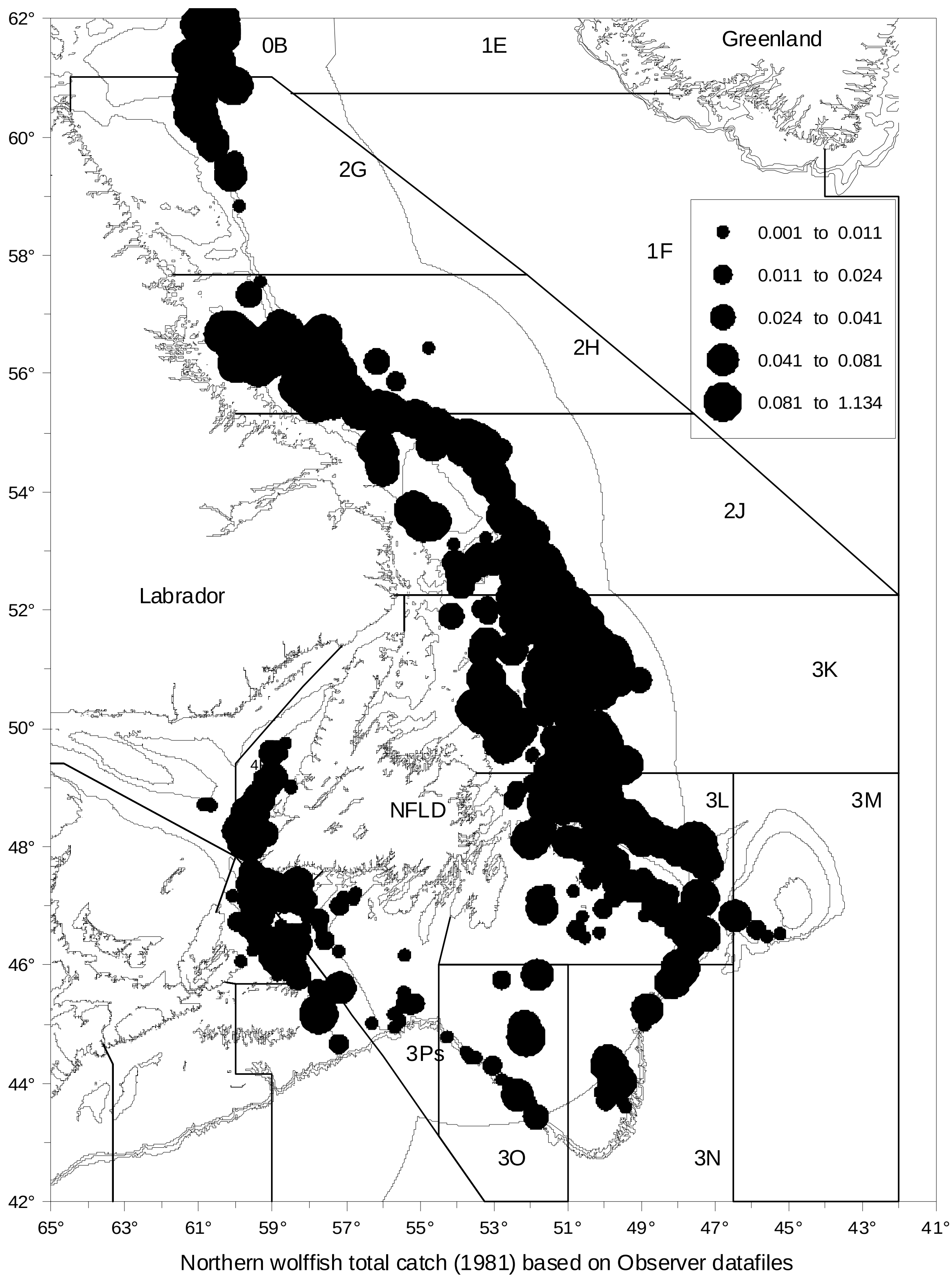

Figure 8a. Distribution of northern wolffish catches, 1981. Circle size indicates relative catch/tow.

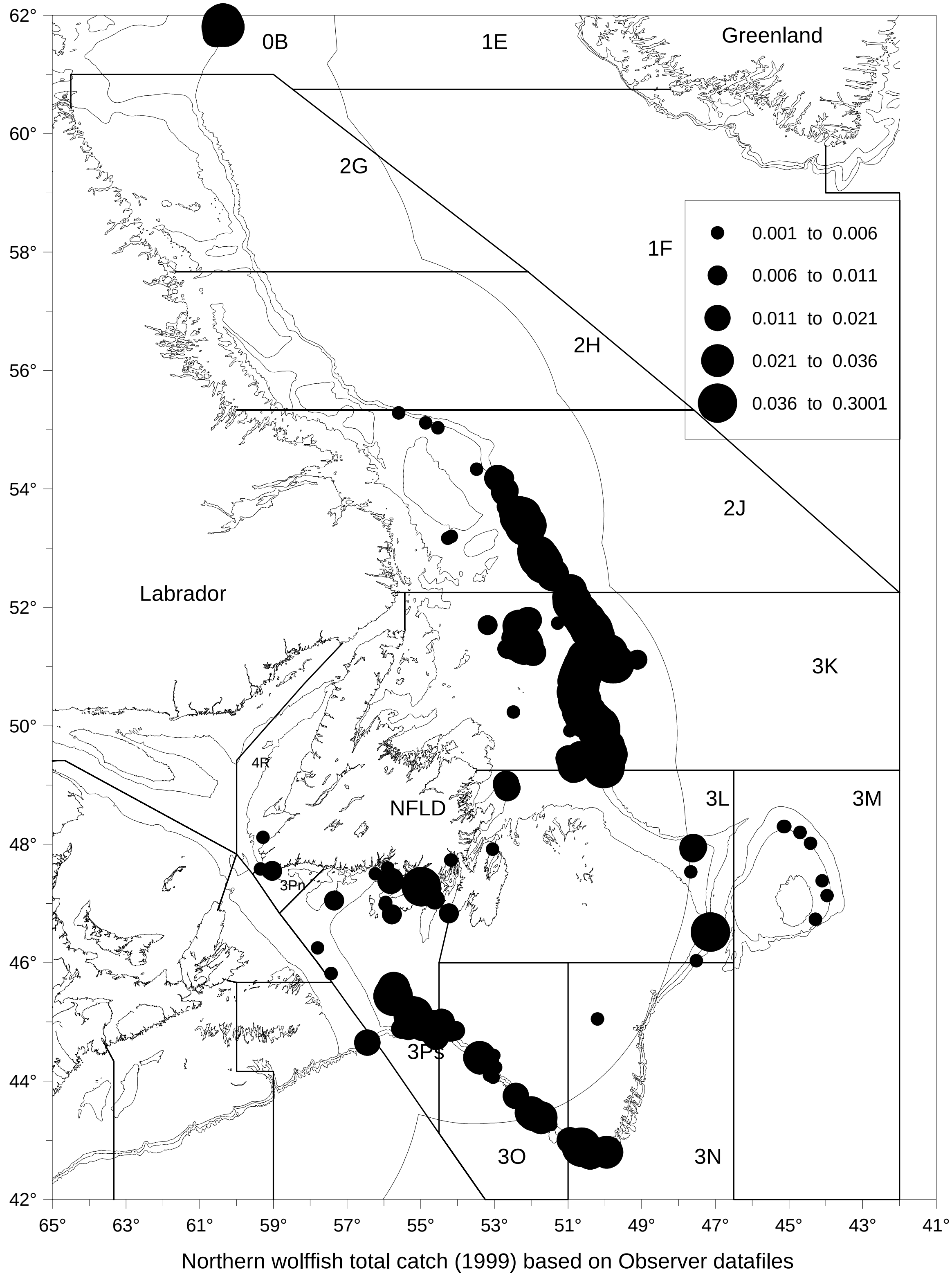

Figure 8b. Distribution of northern wolffish catches, 1999. Circle size indicates relative catch/tow.

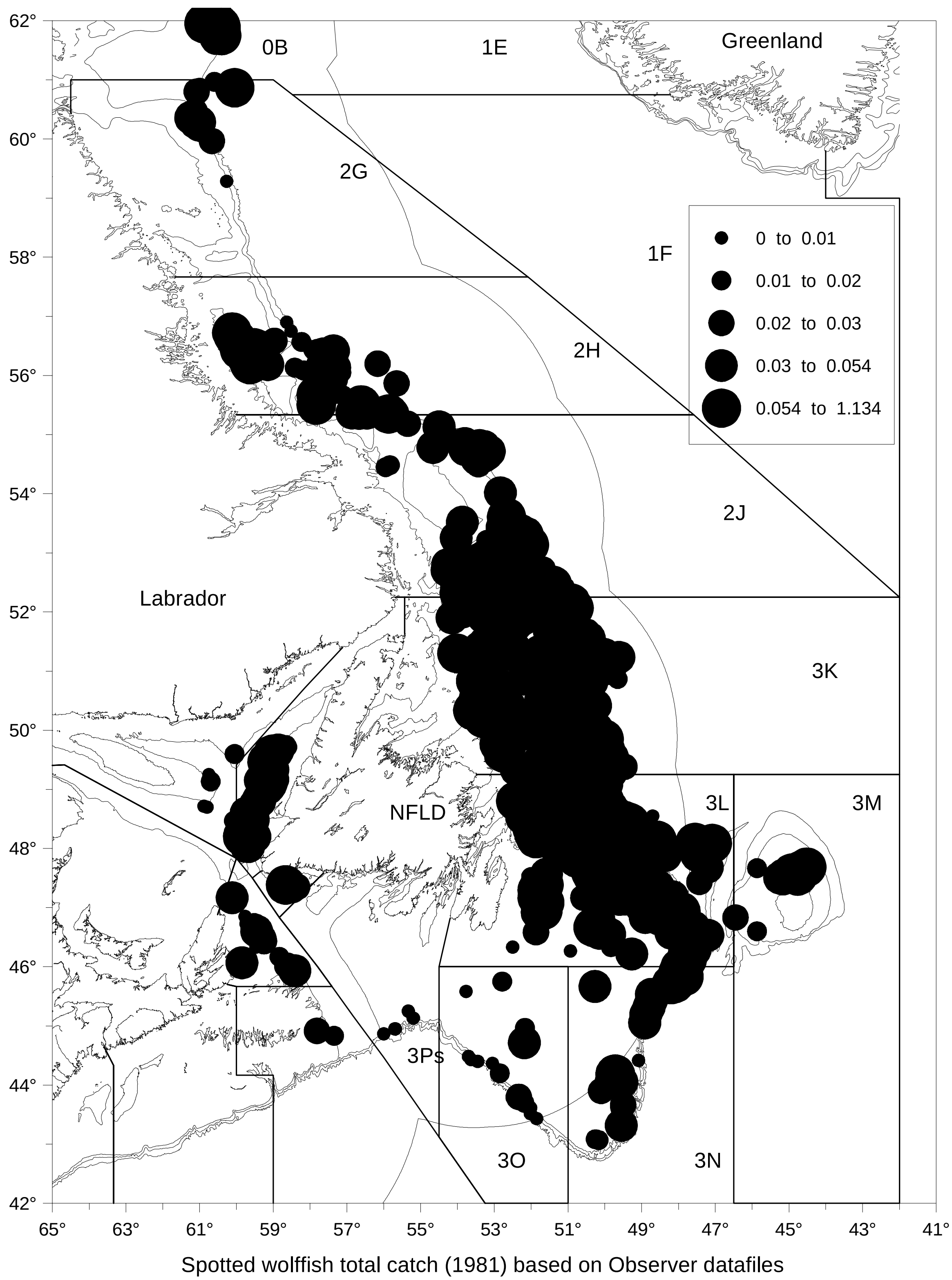

Figure 9a. Distribution of spotted wolffish catches, 1981. Circle size indicates relative catch/tow.

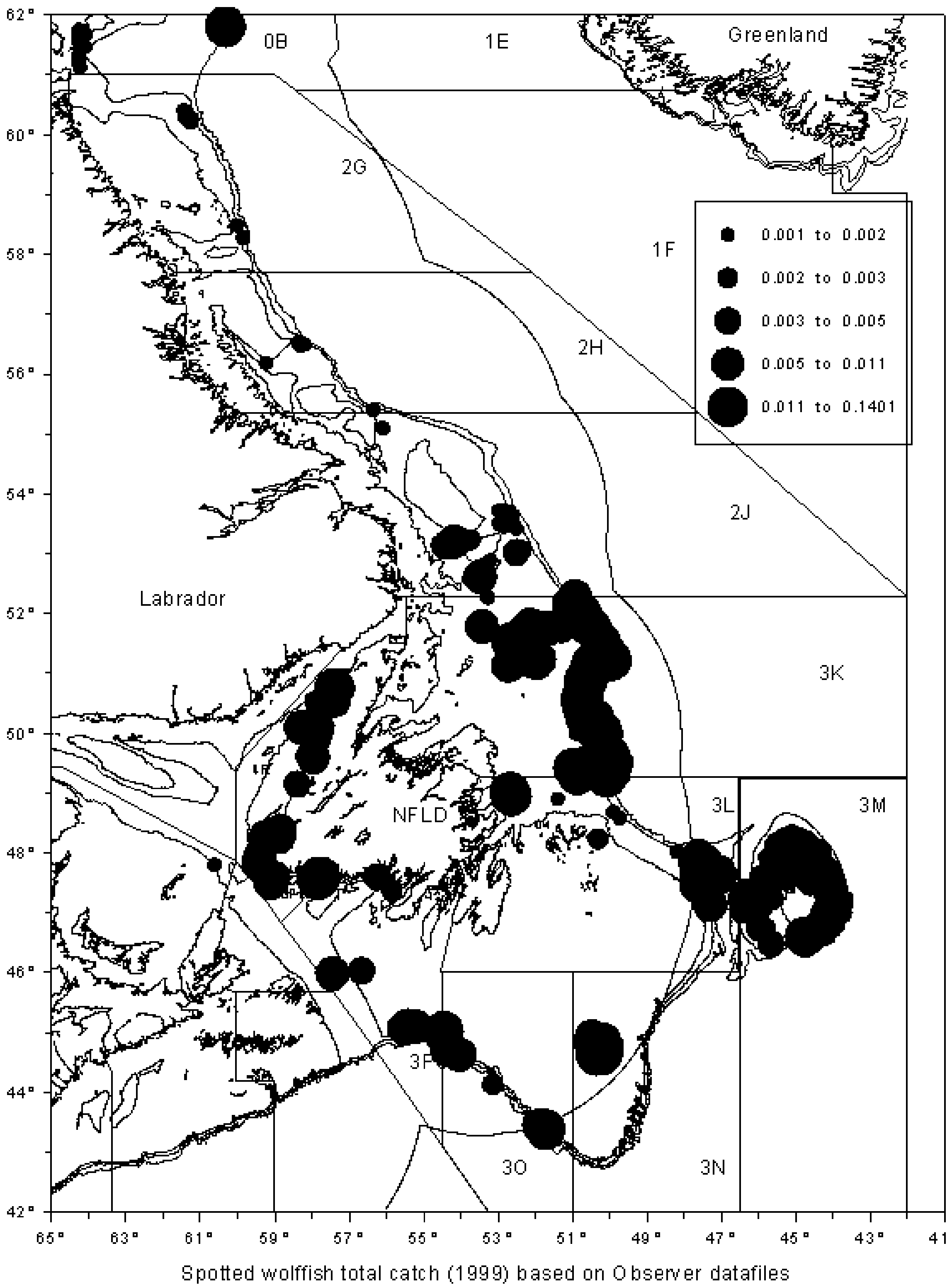

Figure 9b. Distribution of spotted wolffish catches, 1999. Circle size indicates relative catch/tow.

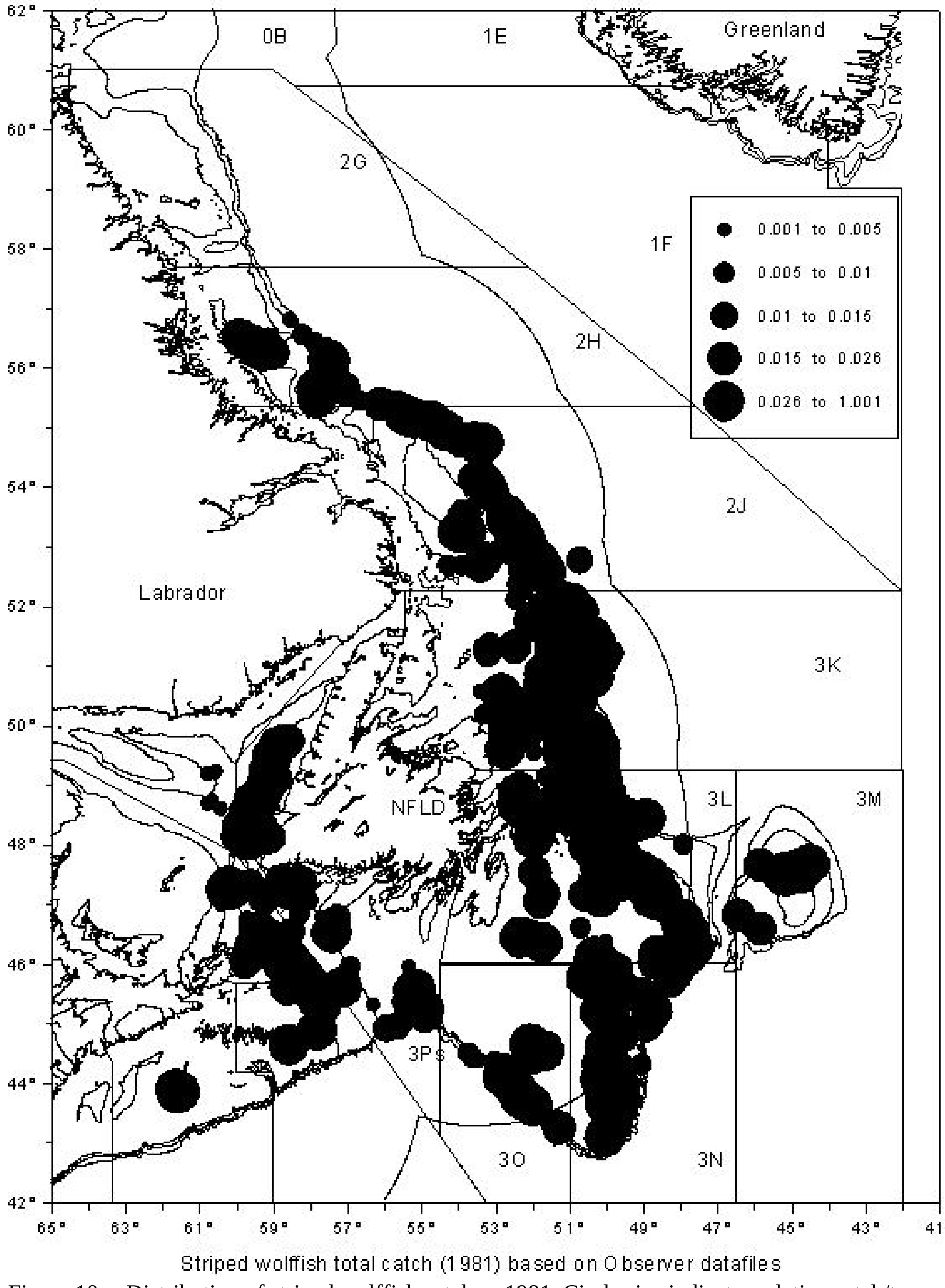

Figure 10a. Distribution of striped wolffish catches, 1981. Circle size indicates relative catch/tow.

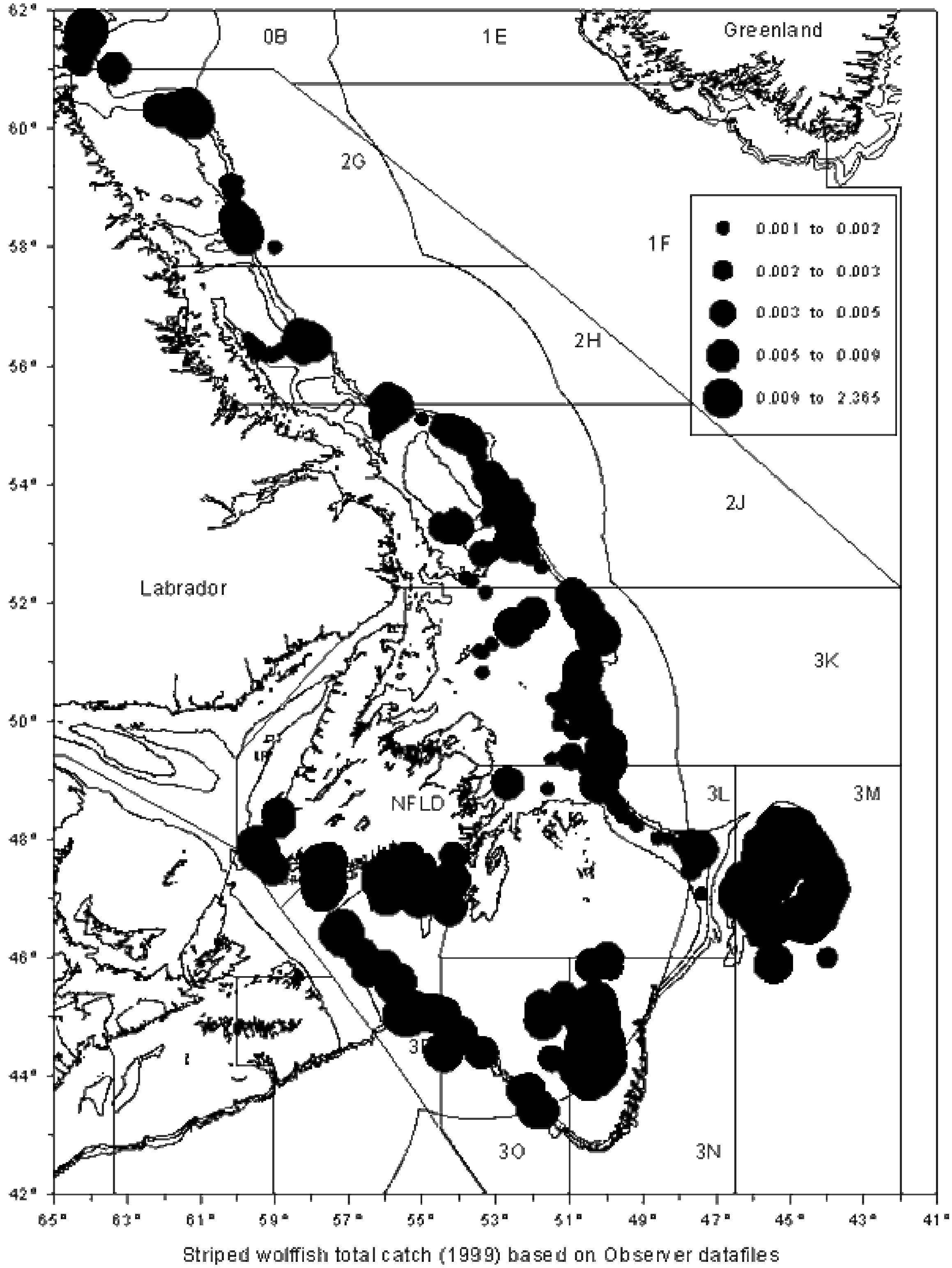

Figure 10b. Distribution of striped wolffish catches, 1999. Circle size indicates relative catch/tow.

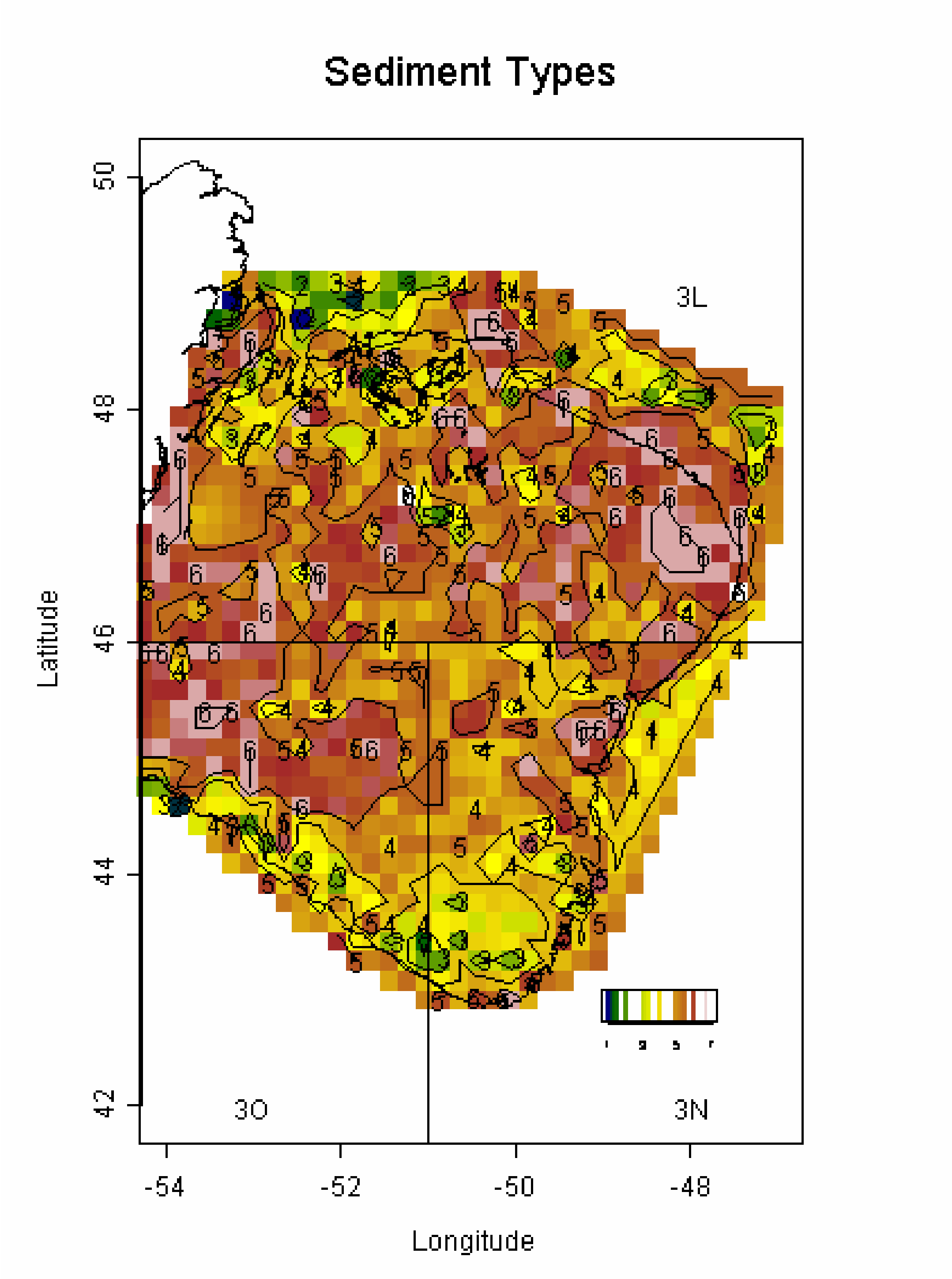

Figure 11. Distribution of sediment types on the Grand Banks, as determined from ROXAN data (see text for explanation). Sediments in NAFO divisions 3LNO were categorized as mud(Code 1), coarse sand (Cd. 2), sand/shell hash (Cd. 3), gravely sand (Cd. 4), rocks(Cd. 5) & boulder/rock(Cd. 6).

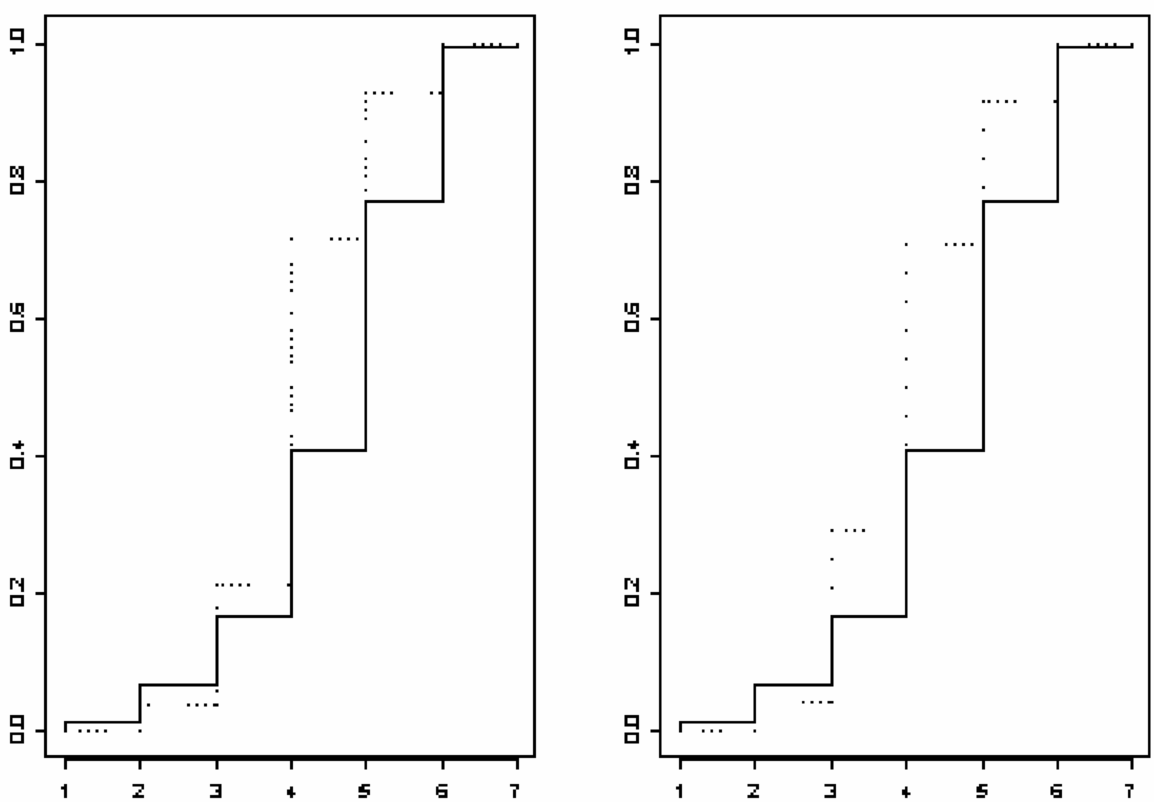

Fig 12. Cumulative distribution functions for northern wolffish(dotted line) in relation to available sediment types(solid lines) in two sample years. X-axis is sediment type: Sediments are categorized as 1=Mud, 2=muddy sand, 3=sand/shell hash, 4=gravely sand, 5=rocks & 6=boulder/rock, 7-unidentified.

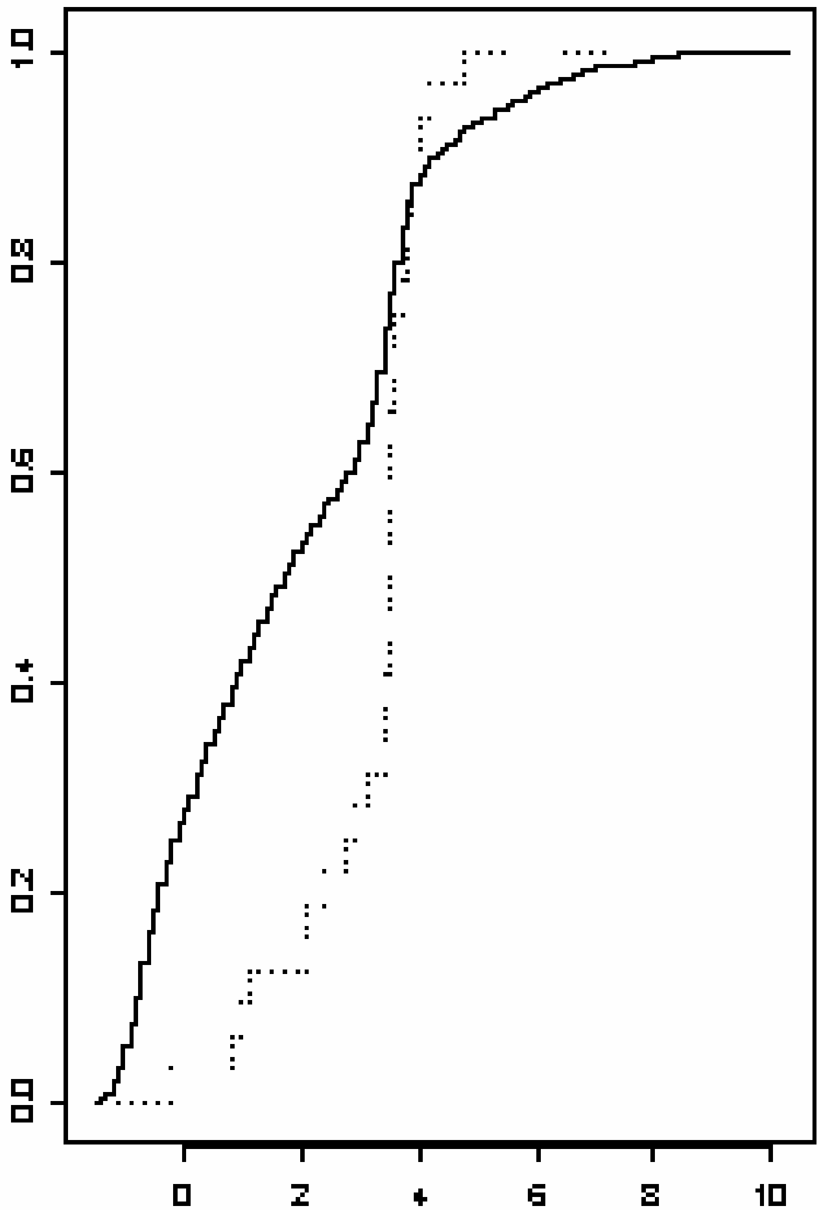

Fig. 13. Cumulative distribution functions for northern wolffish(dotted line) in relation to available temperatures(solid lines) in one sample year. X-axis is bottom temperature in deg. Celsius.

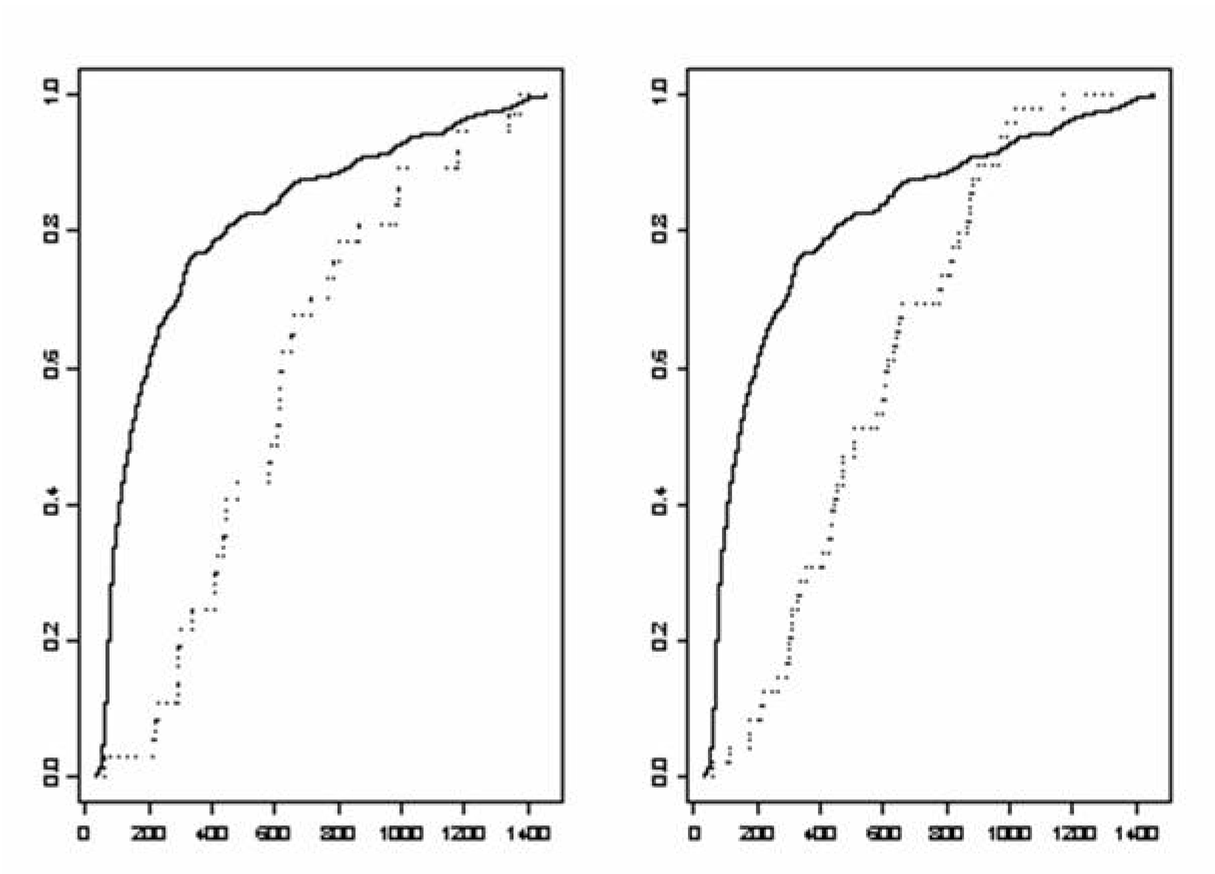

Fig. 14. Cumulative distribution functions for northern wolffish (dotted line) in relation to available depths(solid lines) in two sample years. X-axis is depth in m.

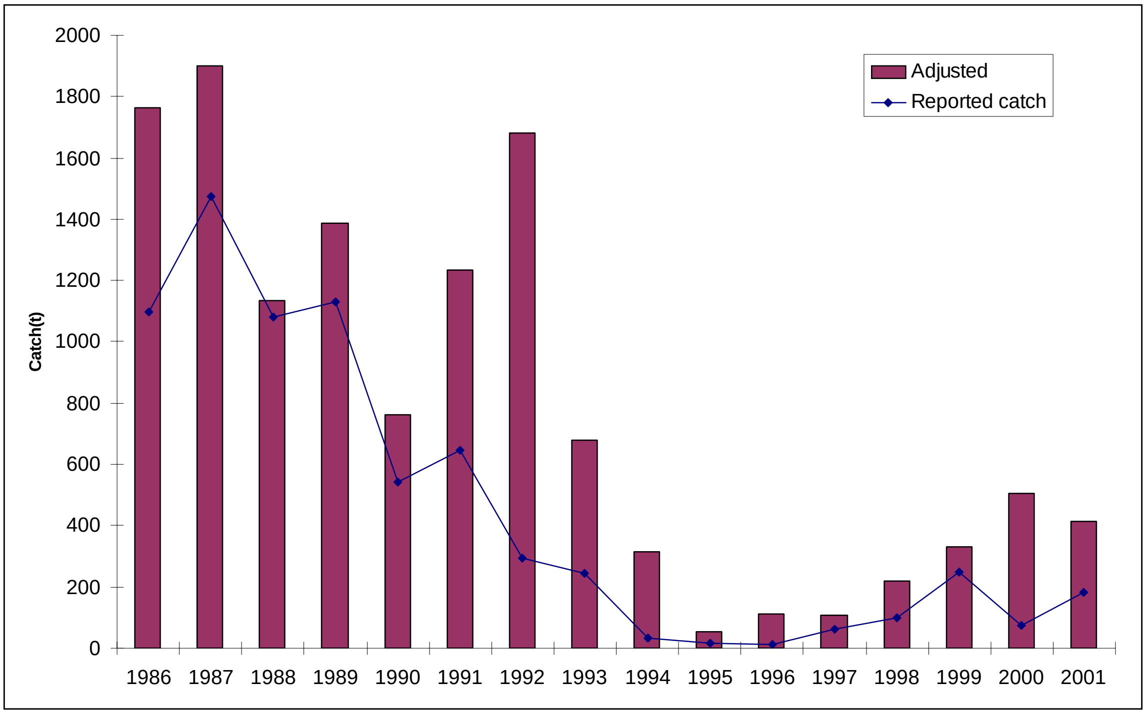

Figure 15: Comparison of reported and adjusted catches of wolffish (all species and areas combined).

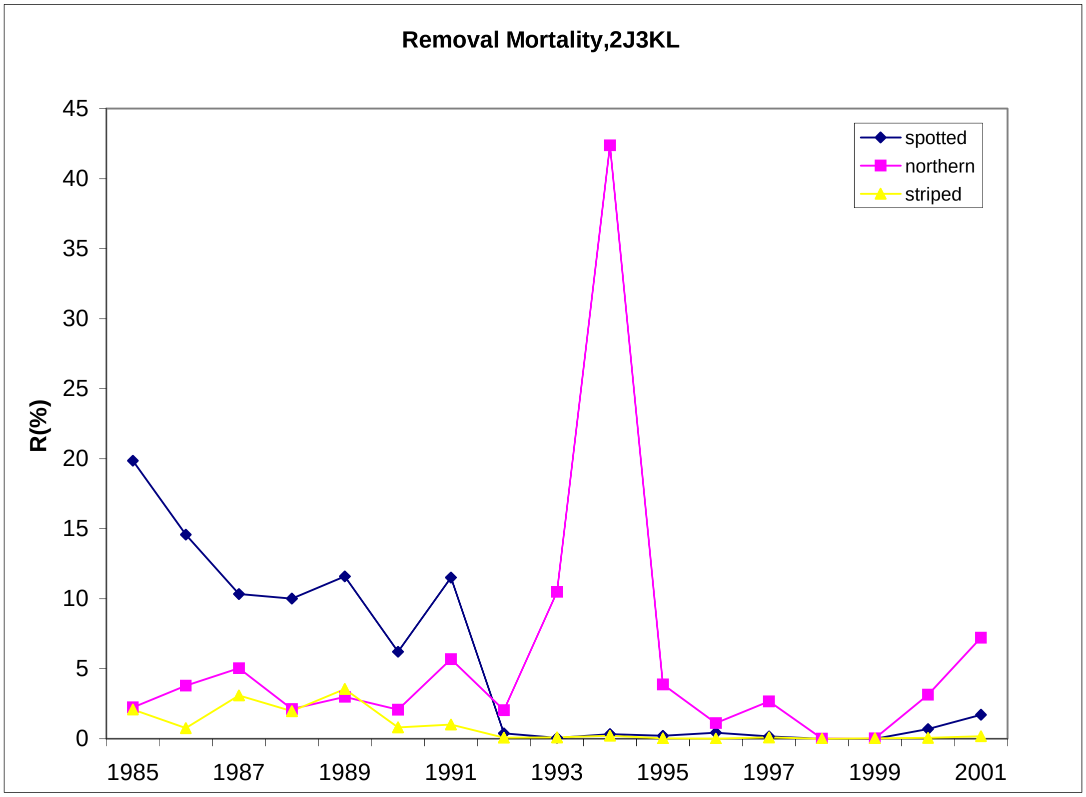

Figure 16: Estimated removal mortality in NAFO divisions 2J3KL for spotted, northern and Atlantic wolffish.