Fisheries and Oceans Canada | Pêches et Océans Canada

Science | Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2010/132

Document de recherche 2010/132

Variations on spatial distribution on fish abundance in eastern Scotian shelf over the past four decades

Variations de la distribution spatiale de l’abondance des poissons sur le plateau néo-écossais au cours des quatre dernières décennies

Valérie Harvey and Mike O. Hammill

Maurice Lamontagne Institute
Box 1000, Mont-Joli, QC. G5H 3Z4

ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

Correct citation for this publication:

Harvey, V. and Hammill, M. O. 2011. Variations on spatial distribution on fish abundance in eastern Scotian shelf over the past four decades. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/132. iv + 12 p.

ABSTRACT

Over the last four decades there have been major changes in demersal fish abundance. During the same period grey seal abundance has increased dramatically to the highest levels seen in the last 5 decades. Synoptic bottom trawl surveys conducted on the Scotian shelf (NAFO fishing zone 4VsW), were examined to determine if there have been changes in the abundance of fish with respect to distance from Sable Island. Survey data were combined into 10 years blocks (1970-1979, 1980-1980, 1990-1999, 2000-2009) which corresponded to periods of low, high, declining and low cod abundance for each decadal period respectively. Fish abundance was examined in relation to distance classes of 0-50 km, 50-100 km, 100-150 km and 150-200km from Sable Island. A significant shift in distances of high abundance away from the Island was observed for cod, hake, herring and haddock when the 2000s were compared with the 1970s as would be expected as a response to minimize predation mortality from grey seals.

RÉSUMÉ

Des changements majeurs dans l'abondance des poissons démersaux ont eu lieu au cours des quatre dernières décennies. Au cours de cette même période, l'abondance de phoque gris a augmentée de façon spectaculaire au niveau le plus élevé observé durant les 5 dernières décennies. Des relevés synoptiques au chalut de fond menés sur le plateau néo-écossais (4VsW zone de pêche de l'OPANO), ont été examinés afin de déterminer s'il ya eu des changements dans l'abondance de poissons par rapport à la distance de l'île de Sable. Les données ont été combinées en blocs de 10 années (1970-1979, 1980-1980, 1990-1999, 2000-2009) qui correspondent respectivement à des périodes où l'abondance de morue est faible, élevée, faible et en baisse. L'abondance de poisson a été examinée en fonction des classes de distance fixées à 0-50 km, 50-100 km, 100-150 km et 150-200 km de l'Île de Sable. Un changement important a été observé dans les années 2000 alors que, tel qu'il était plausible de s'y attendre afin de minimiser la mortalité causée par la prédation des phoques gris, les grandes abondances de morue, de merlu, de hareng et d'aiglefin étaient observées à une plus grande distance de l'Île qu'elles ne l'étaient dans les années 1970.

INTRODUCTION

Over the last four decades, Northwest Atlantic fish stocks have undergone significant changes in abundance, distribution and size structure. The biomass of large demersal piscivore fish, notably Atlantic cod (*Gadus morhua*), collapsed in the late 1980s and early 1990s, mostly due to overfishing and has not recovered despite limited fishing activity (Fanning et al. 2003, Bundy et al. 2009). At the same time, the abundance of small pelagic fish has increased considerably, leading to a shift towards an ecosystem dominated by the small pelagic grazers (Bundy and Fanning 2005, but see McQuinn 2009).

Marked increases in the abundance of Northwest Atlantic grey seal population have also been observed over the last four decades. Abundant throughout the North Atlantic up to the 17th and possibly early18th centuries, grey seal numbers declined and remained low throughout much of the first half of the 20th century (Lavigueur and Hammill 1993; Hammill and Stenson 2011). However, beginning in the 1960s the population has increased from roughly 13,000 animals in 1960, to roughly 400,000 in 2010 (Hammill and Stenson 2011). Much of this population is concentrated year-around on the Scotian Shelf around Sable Island.

Predation may have direct or indirect impacts on prey populations. Often only direct impacts of predation are considered but, predators can influence prey populations and the broader community by forcing prey to engage in costly anti-predator strategies which could lead to reduced survival, growth and reproduction (Christianson and Creel 2008, Searle et al. 2008, Wirsing et al. 2008). The importance of these indirect effects in structuring terrestrial and fresh-water communities has been examined extensively (Werner and Peacor 2003, Preisser et al. 2005, Verdolin 2006), but these effects remain poorly documented in marine systems (Dill et al. 2003, Wirsing et al. 2008). Grey seals may have an indirect impact on cod by excluding them from preferred areas. This impact could be manifested by the exclusion of cod from available habitat, leading to an overall reduction in environmental carrying capacity for cod or by the exclusion of cod from important habitat to marginal areas resulting in a decline in cod condition, survival or reproduction (Ainley et al. 2003, Preisser et al. 2005). Under both conditions, the reduction of habitat or exclusion of cod from critical habitat may not be important at low cod densities, but could become an important factor as stocks begin to recover.

Here, we used data fish survey conducted on 4VsW NAFO area to quantify the spatial distribution and abundance of fish on Scotian Shelf, an area heavily used by grey seals to test the hypotheses that grey seals are affecting the distribution of cod and other fish species near Sable Island. We expected that in years when seals were abundant, the abundance of fish that are consumed by grey seals would increase with increasing distance from the island. In contrast, we would not expect to see similar changes in spatial distribution of fish that are not important prey to seals.

MATERIAL AND METHODS

The Scotian Shelf, which encompasses NAFO fishing zones 4VsW NAFO, forms the continental shelf off the Atlantic coast of Nova Scotia. It is approximately 200 km wide, bounded by the Laurentian Channel on the northeast and the Northeast channel and the Gulf of Maine on the southwest. With an average depth of 90 m, the shelf has an irregular bathymetry, consisting of a number of basins and channels that separate shallow offshore banks. Sable Island, located approximately 300 km southeast of the Nova Scotia coast on the eastern part of the shelf (Zwanenburg et al. 2006) (Fig. 1).

Standard groundfish bottom trawl surveys have been conducted in this area by the Department of Fisheries and Oceans during July, from 1970 to present. The fish data presented here and used for our analysis were obtained from these surveys. The surveys used a stratified random survey design (Smith and Page 1996). The sample unit for the survey was defined as the area over the bottom covered by a trawl 12.5 m wide towed at 3.5 knots for a distance of 1.75 nautical miles. These sample units or sets were selected before the cruise and randomly located in each stratum.

At each survey station, fish abundance was sampled. In this study, seven species were retained and separated into 2 or 3 length classes (Table 1). These fish species are known to be important (eg. herring) or minor prey (eg. haddock) of grey seals. We used the *Geostatistical Analyst* extension of ArcGIS v9.2 (ESRI, 2006) to produce prediction maps of fish density for each group of fish, combining the data from each decade (1970, 1980, 1990 and 2000), so that 1970 is an average for 1970-79, 1980 is an average for 1980-1989 etc. These periods represented times of high (1980), decreasing (1990) and low (1970, 2000) fish biomass (Zwanenburg et al. 2006). We repeated these analyses for each survey dataset. We used the "ordinary kriging" method to model spatial structure based on an omni-directional, spherical semivariogram model. When more than one value was available at the same location, catch rates were averaged. The area of less than 100 m deep along the Nova Scotia as well as around Sable Island was excluded from the analysis since surveys did not sample these areas.

To determine if density of fish varied with distance from Sable Island, we created a grid of 10 km by 10 km over the survey area. We chose this cell resolution since at least one sampling station was located in each cell of the grid. We assigned each cell of the grid to a distance class (0-50, 50-100, 100-150, 150-200, >200 km), according to their distance from Sable Island. The cell of the grid was assigned to a distance class if more than 50% of its area overlapped with this distance class. We only kept cells located at less than 200 km from Sable Island since fish were sampled within this distance all around the Island. To minimise bias in fish abundance, we standardized the density of each cell using the formula: $1=(y_i-y)/s$

where yi= density of a given cell, y=average density of a group fish considering all cells and s,the standard deviation of the average density (Quinn and Keough 2002).

To evaluate if fish density within cells of 10 km² varied according to distance from Sable Island, we performed a general linear model considering distance and period of year as categorical variables. Variables were log-transformed to improve the normality of their distribution prior to analysis. We repeated these analyses for each group fish separately. All statistical analyses were done using SAS 9.2.

RESULTS

GENERAL TRENDS IN FISH ABUNDANCE

Indices of abundance from the July RV survey catches showed that cod in all size classes were much more abundant during the 1980s than during the other 3 decades (1970s, 1990s and 2000s) (Fig. 2a, b, c). A similar pattern was also observed for small and large haddock, with these classes being most abundant during the 1970s, while medium sized haddock was most abundant during the 2000's (Fig. 2d,e,f). Herring were only divided into two size classes, with both classes tending to be more abundant in the 1990s and 2000s, than during the 1970s and

1980s (Fig. 2g,h). Similar to cod, redfish were most abundant during the 1980s, but medium and large redfish were also abundant during the 1970s (Fig. 2i,j,k). Small and large silver hake and white hake were also more abundant during the 1980s, and slightly more abundant than the average during the 1990s than during other decades (Fig. 2l, m, o, p). Sand lance was most abundant during the 2000s (Fig. 2n).

FISH ABUNDANCE ACCORDING TO DISTANCE FROM SABLE ISLAND

Significant changes in abundance with distance from Sable Island have been observed over the last four decades. During the 1970's, small cod abundance increased at 50 km from the island out to 100 km from the island, then declined steadily out to 200 km from the island. During the 1980s, small cod abundance was greatest at 50 km from the island, then declined markedly at 100 km, then continued to decline out to 200 km. During the 1990s and 2000s, small cod density increased from 50 km out to 100 km, then declined with increasing distance (Fig. 2a). Among medium cod, abundance declined steadily from 50 km out to 200 km in the 1970s, and increased from 50 km to 100 km, then declined in the 1980s, 1990s, and 2000s (Fig. 2b). Large cod, were most abundant between 50-100 km in the 1970s, 1980s and 1990s, then a shift was observed to increased abundance between 100-150 km in the 2000s (Fig. 2c).

The abundance of small, medium and large haddock did not vary with distance from Sable in 1970, but shifted to decreasing abundance with distance among small haddock, during the 1980s, no change in abundance out to 100 km in the 1990s, an increase to a peak in abundance at 100 km, then declining abundance during the 2000s. Among medium and large haddock, abundance peaked at 100 km then declined during the 1980s-2000s (Fig. 2d, e, f).

For small and large herring little change in abundance was observed with distance from Sable Island during the 1970s, and 1980s, but beginning in the 1990s, abundance increased with increasing distance. (Fig. 2g, h).

For small redfish, no change in abundance with distance from Sable was observed during the 1970s, but beginning in the 1980s small redfish abundance was observed to decline with increasing distance from Sable Island out to a distance of 150km before levelling off. A similar pattern was observed in the 1990s and 2000s. Among medium redfish, abundance increased with increasing distance from Sable Island during the 1980s, but for the remaining three decades (70s,90s and 00s) little change in abundance with distance from Sable was observed. Large redfish abundance was variable with distance during the 1970s, increased with distance during the 1980s, and showed little change during the 1990s and 2000s (Fig. 2i, j, k).

Overall, silver hake and white hake abundance was constant or increased with distance moving offshore during the 1970s (Fig. 2l, m, o, p). With the exception of small silver hake that was more abundant between 150 and 200 km than in all others areas in 2000s, the highest density of these fish groups was observed at less than 100 km from the Island in 1980s, 1990s and 2000s.

During the 1970s, sandlance were most abundant within 50 km of the Island and decreased with increasing distance from the island, but no change in abundance with distance was observed during the 80s and the 90s. During the 2000 decade, sandlance abundance was very low within 50 km of the island, jncreased with distance out to 150 km, then decreased again out to 200 m (Fig 2n).

DISCUSSION

Fish biomass over the Scotian shelf as well as in other ecosystems of the eastern coast of Canada have encountered significant changes in biomass over the four last past decades (Bundy et al. 2009). These changes in fish abundance however have varied differently according to fish group. From a low density in 1970, the biomass of demersal fish was quite high during the 1980s, then declined by about 80% during the 1990s and has remained low throughout the 2000s. The major reason for this decline is overfishing (Zwanenburg et al. 2006). In contrast to this decline in groundfish biomass, small pelagic and forage fish have increased since the late 1980s. The result has been that ecosystems of the east coast of Canada appear to have shifted from one dominated by long-lived demersal ecosystems, to a shorter lived pelagic fish and invertebrate dominated ecosystems (Frank et al. 2005, Bundy et al. 2009).

In contrast to demersal fishes, the grey seal population on the Scotian Shelf has increased significantly over the four last decades, becoming a keystone species in the eastern shelf ecosystem (Bundy et al. 2009). From perhaps only 13,000 individuals in 1960, the grey seal population has increased to roughly 400,000 in 2010 (Hammill and Stenson 2011).

With such significant changes in the abundance of grey seals and their prey on the Scotian Shelf (4VsW), we examined if there had been changes in the distribution of several fish species around Sable Island, where much of the grey seal population is concentrated. In this analyses, we assumed that grey seals were the sole factor influencing abundance, and that impacts of grey seal predation would be reflected as shifts in distribution, particularly when compared to fish abundance during the 1970s, when cod abundance as well as grey seal abundance were low.

Information obtained from satellite telemetry indicates that grey seals spend much of their time foraging within 70 km of Sable Island (Breed et al. 2006, 2009). During the four decades we examined, we observed that there was a shift in the abundance of large cod, herring, sandlance and white hake to further offshore from Sable Island, with a peak at 100 km, particularly during the decade of the 2000s. This is what would be expected among prey, when exposed to predation pressure from a central-placed forager such as the grey seal (Ainley et al. 2003, Harvey et al. 2011). Little change was observed in the abundance of large redfish with distance, but given the body shape of these fish, large redfish may not be a preferred prey of grey seals. Although consumed by grey seals, and in some cases frequently such as in the United Kingdom, haddock is not a preferred prey of grey seals on the Scotian shelf (Bowen and Harrison 1994). However, this fish showed a similar change in distribution as observed among cod. Given the numbers of seals present in the Sable Island area, it is possible that even at low predation levels this pressure may have been sufficient to have caused a change in haddock distribution near the Island.

Although grey seals have likely affected the distribution of some species around Sable Island, other factors are also likely involved and we did not include these in our analyses. The data used to estimate fish abundance were collected by the groundfish RV surveys which are highly selective in terms of the kinds of fish caught. Recent analysis of acoustic data has suggested that the change in abundance of pelagic species such as herring, observed in the bottom trawl surveys, more likely reflected a shift in the vertical distribution of herring, rather than a major change in biomass (McQuinn 2009). Such a change may reflect a response to the removal of cod, which would prey on herring from below, and an increase in the abundance of grey seals, which would prey on herring from above. Nonetheless, in spite of the apparent increase in abundance of herring, we observed a change in distribution (compared to the 1970s), with abundance increasing as distance from Sable Island increased.

Other factors also possibly affecting fish distribution include prey resources for fish, environmental changes and changes in fishing patterns. For example, the shallow banks of Sable Island would limit fishing pressure close to the island, with increasing fishing pressure as distance from the island increased, with larger vessels fishing to the east of Sable Island, towards the continental shelf, and smaller fishing vessels providing increased pressure on the spatial distribution of fish moving west towards the Nova Scotia coast. This is more likely to have been a factor during the 1970s, 80s and early 90s when groundfish fisheries were still active, but likely less so during the most recent decade. Density-dependant effects are also likely to be quite important. Thorny skate in the southern Gulf as well as plaice around Newfoundland have been shown to contract their geographic range and to shift into warmer waters at low abundance (Swain and Morgan 2001, Swain and Benoît 2006). Water temperatures may also affect distribution, but does not appear to be likely to have had an impact on distribution of fish around Sable Island. Although, bottom temperatures of the eastern-shelf declined from the mid-1980s to the mid-1990s to the lowest values observed in 50 years, they were warmer than normal between 1998-2008 (Zwanenburg et al. 2006, Petrie et al. 2009). In the case of cod, even though their abundance was lower in 2000s than in previous decades, the highest abundance of large cod was observed at farther distance from the Island than in previous decades. Cod may have moved in more offshore areas in order to reduce metabolic costs as food rations decline around Sable Island while bottom temperature increased or to avoid increased predation by grey seals.

We did not investigate vertical distribution of fish over Scotian shelf. However, depth generally increased with distance from Sable Island and we observed that there was length class segregation in the study area among cod as has been observed elsewhere (Harvey et al. 2011, Swain 1993, 1999). When the abundance of cod increased in 1980, small cod were more concentrated within 50 km of the Island whereas larger cod were more abundant between 50-100 km from Sable Island. Among cod, the vertical distribution of fish also varies with length-at-age. Swain (1993) found that, at low abundance, the density of young cod tended to be highest in shallow water whereas the distribution of older cod was unrelated to depth. At high abundance, cod densities tended to be highest at intermediate depths (Swain 1993, 1999, Chouinard and Swain 2002). It has been suggested that these changes in the depth preference of cod reflect a trade-off between the density-dependent benefits of greater food supplies in warm, shallow waters and the density dependent benefits of lower metabolic costs in the colder waters at intermediate depths. However, recent analyses of the distribution of cod in the Gulf, showed an inshore-offshore gradient, which closely approximates a shallow to deeper distribution. Small cod occurred in inshore waters, with medium cod distributed farther offshore, and large cod distributed even further offshore. The inshore distribution of small cod may provide access to abundant food resources and also minimize predation from large cod, whereas the offshore distribution of large cod may be to minimize predation pressure from grey seals (Harvey et al. 2011). Such effects may be occurring around Sable Island, because the pattern of distribution of large fish according to distance has not shifted back to the low abundance pattern observed in 1970s, when fewer grey seals were observed around Sable Island.

ACKNOWLEDGEMENTS

We thank Jerry Black (DFO, Dartmouth) for his help in extracting the fish data.

REFERENCES

Ainley, D. G., Ford, R. G., Brown, E. D., Suryan, R. M. and Irons, D. B. 2003. Prey resources, competition, and geographic structure of kittiwake colonies in Prince William Sound. Ecology 84:709–723.

Bowen, W.D. and Harrison, G.D. 1994. Offshore diet of grey seals *Halichoerus grypus* near Sable Island, Canada . Mar. Ecol. Prog. Ser. 112:1-11.

Breed, G. A., Bowen, D., McMillan, J. I. and Leonard, M. L. 2006. Sexual segregation of seasonal foraging habitats in a non-migratory marine mammal. Proceedings of the Royal Society of London B 273:2319-2326

Breed, G. A., Jonsen, I. D., Myers, R. A., Bowen, W. D. and Leonard, M. L. 2009. Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state-space analysis. Ecology 90:3209-3221

Bundy, A. and Fanning, P. 2005. Can Atlantic cod recover? Exploring trophic explanations for the non-recovery of cod on the eastern Scotian Shelf Canada. Canadian Journal of Fisheries and Aquatic Sciences 62:1474–1489

Bundy, A., Heymans, J. J., Morissette, L. and Savenkoff, C. 2009. Seals, cod and forage fish: A comparative exploration of variations in the theme of stock collapse and ecosystem change in four Northwest Atlantic ecosystems. Progress in Oceanography 81:188–206

Chouinard, G. A. and Swain, D. P. 2002. Depth-dependent variation in condition and lenght-at-age of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences 59:1451-1459

Christianson, D. and Creel, S. 2008. Risk effects in elk: sex-specific responses in grazing and browsing due to predation risk from wolves. Behavioral Ecology 19:1258-1266

Dill, L. M., Heithaus, M. R. and Walters, C. J. 2003. Behaviourally mediated indirect interactions in marine communities and their conservation implications: Trait plasticity and community dynamics. Ecology 84:1151–1157

Fanning, L. P., Mohn, R. K. and MacEachern, W. J. 2003. Assessment of 4VsW cod to 2002. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/027

Frank, K. T., Petrie, B., Choi, J. S. and Leggett, W. C. 2005. Trophic cascades in a formely cod-dominated ecosystem. Science 308:1621-1623

Hammill, M. O. and Stenson, G. B. 2011. Modelling grey seals abundance in Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/014

Harvey, V., Hammill, M. O. and Swain, D. P. 2011. Summer overlap between a central-place forager and its prey in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/131.

Lavigueur, L. and Hammill, M. O. 1993. Distribution and seasonal movements of grey seals, *Halichoerus grypus*, born in the Gulf of St. Lawrence and eastern Nova Scotia shore. Canadian Field-Naturalist 107:329-340

McQuinn, I. H. 2009. Pelagic fish outburst or suprabenthic habitat occupation: legacy of the Atlantic cod (*Gadus morhua*) collapse in eastern Canada. Canadian Journal of Fisheries and Aquatic Sciences 66:2256-2262

Petrie, B., Pettipas, R.G. and Petrie, W.M. 2009. An overview of meteorological, sea ice and sea-surface temperature conditions off Nova Scotia and the Gulf of Maine during 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/041. vi + 32 p.

Preisser, E. L., Bolnick, D. I. and Benard, M. F. 2005. Scared to death? The effects of intimidation and consumption in predator-prey interactions. Ecology 86:501-509

Quinn, G. P. and Keough, M. J. 2002. Experimental design and data analysis for biologists, New York

Searle, K. R., Stokes, C. J. and Gordon, I. J. 2008. When foraging and fear meet: using foraging hierarchies to inform assessments of landscapes of fear. Behavioral Ecology 19:475-482

Smith, S. J. and Page, F. H. 1996. Associations between Atlantic cod (*Gadus morhua*) and hydrographic variables: implications for the management of the 4VsW cod stock. ICES Journal of Marine Science 53:597-614

Swain, D. P. 1993. Age- and density-dependent bathymetric pattern of Atlantic cod (*Gadus morhua)* in the southern Gulf of St. Lawrence. Canadian Journal of Aquatic Sciences 50:1255-1264

Swain, D. P. 1999. Changes in the distribution of Atlantic cod (Gadus morhua) in the southern Gulf of St. Lawrence – effects of environmental change or change in environmental preferences? Fisheries Oceanography 8:1-17

Swain, D. P. and Benoît, D. 2006. Change in habitat associations and geographic distribution of thorny skate (*Amblyraja radiata*) in the southern Gulf of St. Lawrence: density-dependent habitat selection or response to environmental change? Fisheries and Oceanogrphy 15:166-182

Swain, D. P. and Morgan, M. J. 2001. Sex-specific temperature distribution in four populations of American plaice Hippoglossoides platessoides. Marine Ecology Progress Series 212:233-246

Verdolin, J. L. 2006. Meta-analysis of foraging and predation risk trade-offs in terrestrial systems. Behavior Ecology and Sociobiology 60:457-464

Werner, E. E. and Peacor, S. D. 2003. A review of trait-mediated indirect interactions in ecological communities. Ecology 84:1083-1100

Wirsing, A. J., Heithaus, M. R., Frid, A. and Dill, L. M. 2008. Seascapes of fear: evaluating sublethal predators effects experienced and generated by marine mammals. Marine Mammal Science 24:1-15

Zwanenburg, K. C. T., Bundy, A., Strain, P., Bowen, D. W., Breeze, H., Campana, S. E., Hannah, C., Head, E. and Gordon, D. M. 2006. Implications of ecosystem dynamics for the integrated management of the eastern Scotian Shelf. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2652

Table 1. Fish species and size classes used in this study. The letter in the last coumn indicated at which group fish the graphs in Figure 2 and 3 referred.

Group fish	Size class (cm)	Reference in Figure 2
Cod (*Gadus morhua*)	<25	a
	25-35	b
	>35	c
Haddock (*Melanogrammus aeglefinus*)	<20	d
	20-30	e
	>30	f
Herring (*Clupea harengus*)	<30	g
	>30	h
Redfish (*Sebastes sp.*)	<20	i
	20-30	j
	>30	k
Sandlance (*Ammodytes dubius*)	all	n
Silver hake (*Merluccius bilinearis*)	<30	l
	>30	m
White hake (*Urophycis tenuis*)	≤35	O
	>35	p

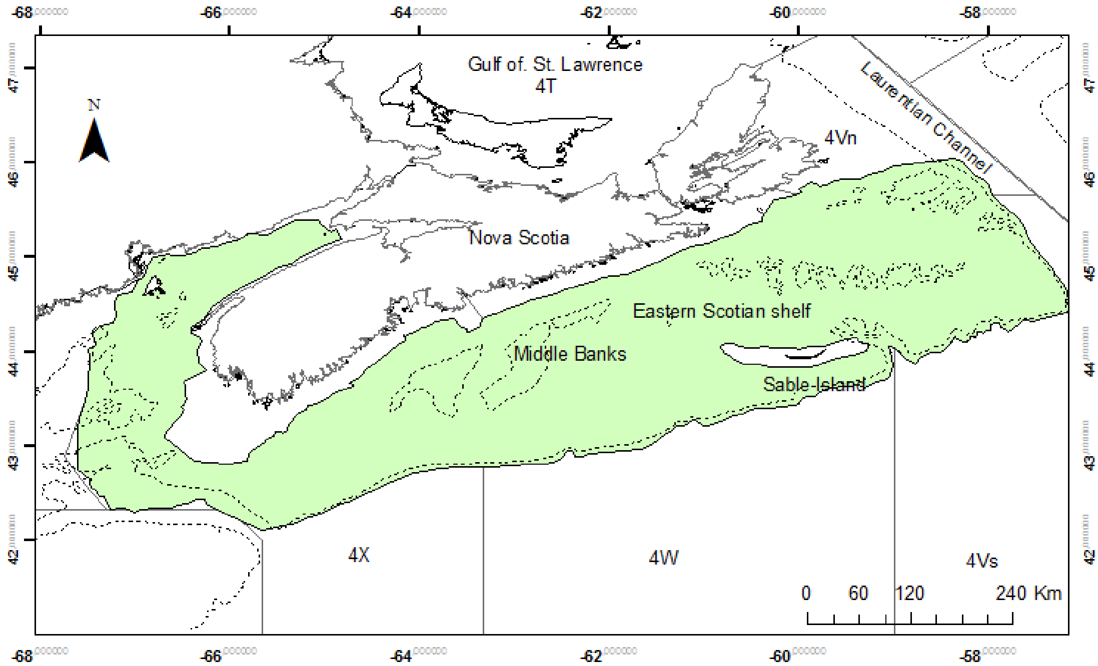

Figure 1. Part of the Scotian shelf covered by the bottom trawl research vessel survey conducted in July and March between 1970 and 2009 and the surrounding regions as well as the Northwest Atlantic Fishery Organization (NAFO) divisions (e.g. 4W). Dashed lines denoted 200 m isobath.

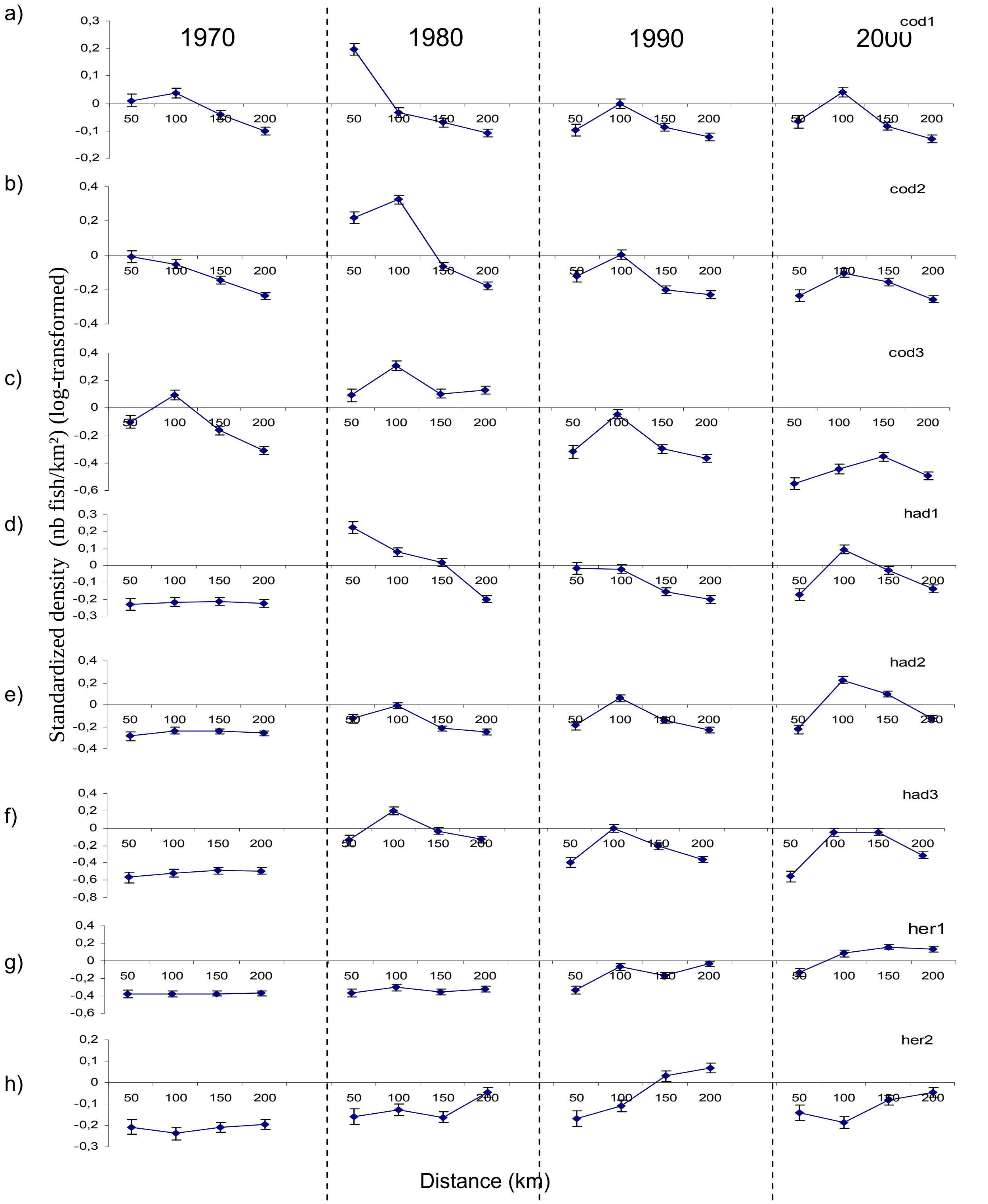

Figure 2. Log-transformed standardized mean (±sd) number of fish towed in an area of 10 km² by the RV bottom trawl fish survey conducted in July in over 4Vs and 4W NAFO areas according to distance class (50: 0-50 km; 100: 51-100 km; 150: 101-150 km; 200: 151-200 km) from Sable Island for the past four decades. Mean and standard error are provided by the linear models. These periods represented times of high (1980), decreasing (1990) and low (1970, 2000) fish biomass over the Scotian Shelf. Fish classes are shown in Table 1.

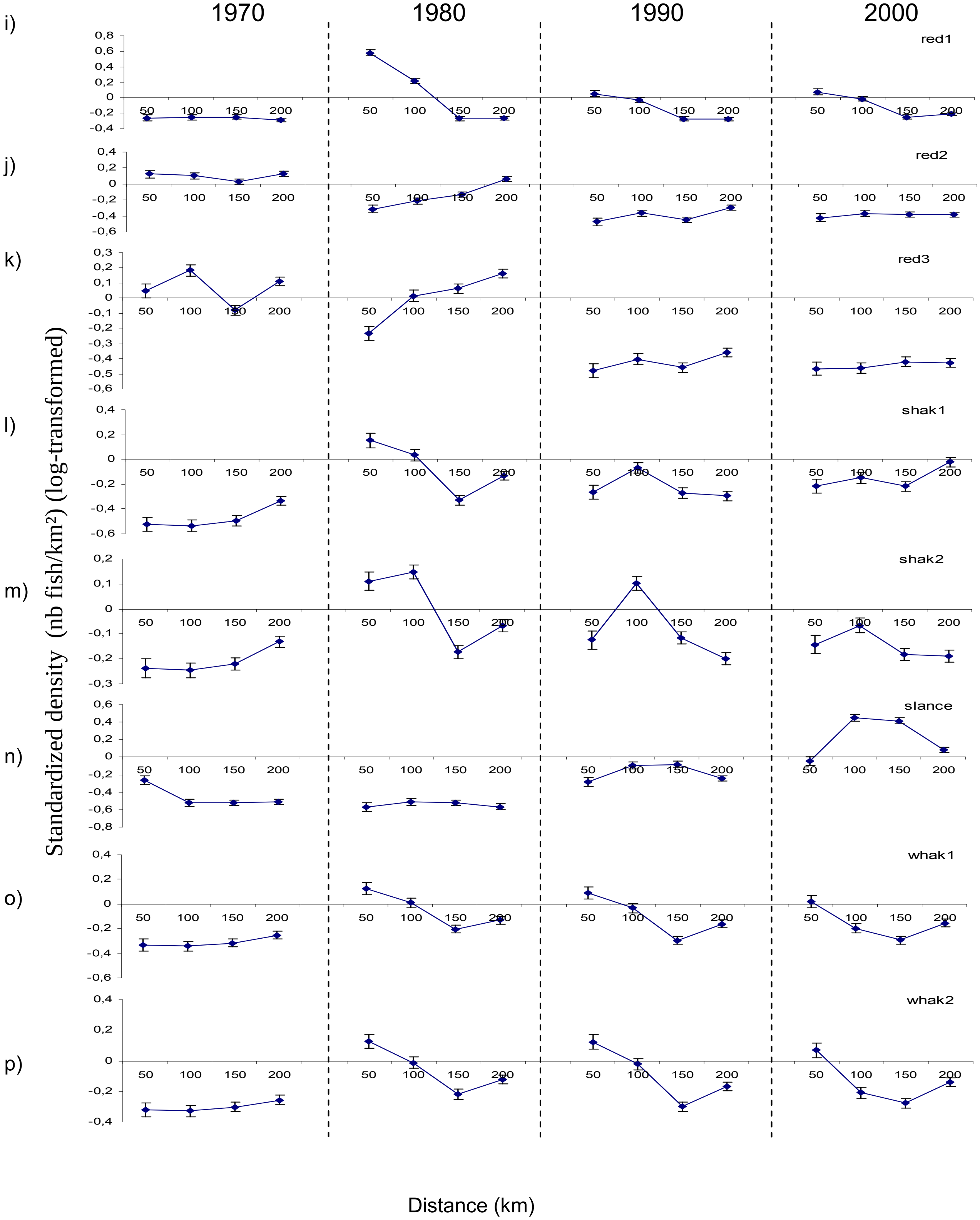
i)
j)
k)
l)
m)
n)
o)
p)
1970
1980
1990
2000
red1
red2
red3
shak1
shak2
slance
whak1
whak2
Standardized density (nb fish/km²) (log-transformed)
Distance (km)

Figure 2 (end).