Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S

Canadian Science Advisory Secretariat

S C C S

Secrétariat canadien de consultation scientifique

Research Document 2003/100

Document de recherche 2003/100

The status of Monkfish (*Lophius americanus* Valenciennes 1837; Lophiidae) on the Grand Banks, NAFO Divisions 3L, 3N, 3O, and Subdivision 3Ps.

État des stocks de baudroie (*Lophius americanus* Valenciennes 1837 Lophidae) sur les Grands Bancs – Divisions 3L, 3N et 3O et sous-divisions 3Ps de l'OPANO.

D.W. Kulka and C.M. Miri

Department of Fisheries & Oceans Canada
Northwest Atlantic Fisheries Centre
P.O. Box 5667
St. John's, NL, Canada A1C 5X1

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

ISSN 1499-3848 (Printed)

Canada

ABSTRACT

Monkfish (*Lophius americanus* Valenciennes 1837; Lophiidae) is described at the northern end of its distribution. It was found to be restricted primarily to the southwest slope of the Grand Banks, closely associated with the warmest available bottom waters. Research survey data also indicate occasional records to the north on the Labrador Shelf in deeper, warmer trenches and on the slope edge. The general location of monkfish have remained constant over time (records back to the 1950s but biomass at depth was observed to change over time. A shift to deeper waters after the mid1980s followed by a return to shallower depths in recent years may be related to a cooling trend during the mid1980s. The highest densities (kg per tow) of monkfish on the Grand Banks were located where bottom temperatures exceeded 4^0 C. Nearly all of the biomass from Spring surveys occurred in NAFO Div. 3O and Subdiv. 3Ps; with two-thirds in Div. 3O. Biomass and abundance (less pronounced than biomass) indices fluctuated over time, peaking in 1977, declining to a low in 1979, peaking again in 1988. Biomass then fluctuated downward reaching a low in 1992-93. Since then, the index has increased, fluctuated widely. 2003 represents a year of peak abundance, almost double that of the previous year. The abrupt changes from year to year likely do not reflect dramatic fluctuations in the population. Rather, these changes suggest that there may be a catchability issue. However, there is a distinct pattern of increases followed by declines over time, the biomass having peaked 3 times in the last 33 years. Mean weight of monkfish also peaked in the mid1970s and late 1980s, in conjunction with the peaks in biomass. However, unlike the biomass, it has declined since 1996. A Canadian experimental trawl fishery for monkfish contributed to an increase in monkfish landed in 1991. A directed gillnet fishery began in 1993. In 1995-1997, a 200 metric tonne quota was instituted, but was removed in 1998. Landings increased from 1995 to 1998 then declined. In 1998-2000, bycatch restrictions as per licence conditions was the primary limitation on effort in the fishery and catch of monkfish. However, an expansion into the South Korean market and associated high price for the product has led to sharply increased (record) effort. Participant in the fishery increased from 9 in 2001 to about 80 in 2003. Total catches increased from 168 t in 2000 to 2,994 t in 2003. Correspondingly, relative F (index of exploitation) has increased by 5 times in the past two years after declining since 1998 and may now exceed a sustainable level.

RÉSUMÉ

La présente étude décrit la baudroie (*Lophius americanus* Valenciennes, 1837; Lophiidés) dans la partie nord de son aire de répartition. L'espèce fréquente principalement le talus sud-ouest des Grands Bancs et privilégie les eaux de fond les plus chaudes. Les données de relevé révèlent qu'elle est aussi présente à l'occasion plus au nord, sur le plateau continental du Labrador, dans les fosses plus profondes et plus chaudes et sur le bord du talus. L'aire de répartition générale de la baudroie est demeurée constante au fil du temps (depuis les années 1950), mais pas la biomasse selon la profondeur. Le déplacement de la baudroie vers des eaux plus profondes après le milieu des années 1980 et son retour à des profondeurs moindres aux cours des dernières années pourraient être dus à un refroidissement progressif des eaux au milieu des années 1980. Les plus fortes densités (kg/trait) de baudroie sur les Grands Bancs ont été observées aux endroits où la température de l'eau au fond était supérieure à 4 ^{o}C. Presque toute la biomasse capturée lors des relevés de printemps a été récoltée dans la division 3O (les deux tiers de la biomasse) et la sous-division 3Ps de l'OPANO. Les indices de biomasse et d'abondance ont fluctué avec le temps, atteignant un sommet en 1977, un creux en 1979 et un nouveau sommet en 1988 (l'indice d'abondance a cependant moins fluctué que l'indice de biomasse). L'indice de biomasse a par la suite chuté pour atteindre un autre creux en 1992-1993, et il augmente depuis, tout en continuant de fluctuer beaucoup. L'abondance a atteint un sommet en 2003, se chiffrant à presque deux fois celle observée l'année précédente. Ces variations brusques d'une année à l'autre ne reflètent probablement pas des fluctuations marquées dans la population. Elles semblent plutôt indiquer qu'il existe peut-être des différences de capturabilité. Il existe un cycle évident de hausses et de baisses puisque la biomasse a atteint un sommet à trois reprises au cours des 33 dernières années. Le poids moyen de la baudroie a également atteint un sommet au milieu des années 1970 et à la fin des années 1980, soit en même temps que la biomasse. Contrairement à celle-ci, le poids moyen a baissé depuis 1996. Une pêche expérimentale canadienne de la baudroie au chalut a contribué à une augmentation des débarquements en 1991. Une pêche dirigée au filet maillant a commencé en 1993. Le quota de 200 tonnes métriques mis en vigueur en 1995-1997 a été éliminé en 1998. Les débarquements ont augmenté entre 1995 et 1998, puis ont chuté. En 1998-2000, des limites de prises accessoires établies comme une condition de permis étaient le principal moyen pour limiter l'effort de pêche de la baudroie. Une expansion du marché en Corée du Sud et la hausse subséquente du prix du produit ont cependant entraîné un accroissement important (record) de l'effort. Le nombre de participants à cette pêche est passé de 9 en 2001 à environ 80 en 2003, tandis que le nombre total de prises est passé de 168 t en 2000 à 2 994 t en 2003. De ce fait, le F relatif (indice d'exploitation), en baisse entre 1998 et 2001, a quintuplé au cours des deux dernières années. Étant donné nos connaissances limitées sur la plupart des aspects de la biologie de la baudroie et des pêches qui la concernent, il est difficile de déterminer quel est l'état du stock et si le taux d'exploitation est approprié. L'indice de biomasse a continué d'augmenter en dépit de l'accroissement de l'effort de pêche. Même du point de vue de l'approche de précaution, le rapport des prises commerciales et des estimations de la biomasse faites à partir de relevés semble être peu élevé ces dernières années, sauf en 2002 et en 2003. Aucune donnée présentée dans ce document ne suggère que les niveaux actuels de pêche ont des répercussions néfastes importantes sur la baudroie.

INTRODUCTION

Fishes of the Order Lophiiformes are distinguished by the presence of a mobile illicium: a modified dorsal spine with a fleshy esca at the tip which is used to attract prey. This appendage is waved above the mouth as a lure; hence the common name "anglerfishes". From the family Lophiidae (monkfishes), consisting of four genera and twenty-five species, the monkfish or goosefish (*Lophius americanus* Valenciennes 1837) is the only northwest Atlantic member that is found north of the Gulf of Maine in Canadian waters (Bigelow and Schroeder 2002).

Several species from this family (off Europe and South America) are highly regarded commercially and have been fished for many years. A closely related European species, *L. piscatorius,* has been the target of a directed fishery for many years. Consequently, aspects of life history and the fisheries are well documented (McKenzie 1936, Caruso 1986). Originally, there was some confusion over whether that closely related species also occurred in the northwest Atlantic, but it was determined to be a case of mis-identification and *L. piscatorius* is restricted to the northeast Atlantic.

In the northwest Atlantic, there has been a directed fishery for *L. americanus* since the 1970s in USA waters but in Canadian waters, until the mid1990s, it was taken only as incidental catch and usually discarded. Thus, most of the (limited) research on this species has been done in the USA where such aspects as reproduction, growth, distribution, migration and stock structure have been examined (Armstrong *et al.* 1992, others reviewed by Steimle *et al.* 1999, Richards 2000, Bigelow and Schroeder 2002). Until Armstrong *et al.* (1992) completed their work on growth and maturity, much of the literature pertaining to *L. americanus* was general and anecdotal in nature.

In Canadian waters, specifically on the Scotian Shelf, in the Gulf of St. Lawrence, and on the Grand Banks, studies on this species are very limited. Beanlands and Annand (1996) carried out a preliminary assessment on the Scotian Shelf and Beanlands *et al.* (2001) using data from cooperative a Fisheries and Oceans Science/Industry project started in the mid1990s reported on some preliminary aged based analyses. Preliminary assessments were also done for the Grand Banks (Fig. 1) by Kulka and Deblois (1996) and Kulka and Miri (2001) based largely trends in research survey biomass/abundance indices. Grégoire (1998) looked at commercial potential for the Gulf of St. Lawrence. With the exception of preliminary analyses on age, growth and reproduction by Beanlands *et al.* (2001), little basic work on biological matters is contained in those papers pertaining to Canadian waters.

Biology

L. americanus (hereafter referred to as monkfish) occurs as far south as Florida but mainly in shelf waters of the mid-Atlantic Bight, on Georges Banks, Scotian Shelf, in the Bay of Fundy and throughout the southern Gulf of St. Lawrence, on the southern Grand Banks. (Scott and Scott 1988). It is also occasionally captured on the Flemish Cap (Alpoim *et al.* 2002) and the Labrador Shelf at the northern limit of its range (Kulka and Miri 2001). On the Grand Banks, it is restricted to the southwest slope of the Grand Bank, the western slope of St. Pierre Bank and into the Laurentian Channel (Kulka and Miri 2001).

The stock structure of this widespread species is largely unknown. There was a single genetic study in the western Atlantic (Chikarmane *et al.* 2000), that detected no genetic variation among monkish from North Carolina to Maine, a south to north distance of about 1,000 km. Degree of mixing of monkfish in Canadian waters (Georges Bank to Labrador Shelf) is unknown, although discontinuities in its distribution between the Scotian Shelf, Gulf of St. Lawrence, and the Grand Banks suggest the possibility of distinct populations. Kulka and Miri (2001) noted that there appears to be no discontinuity with a concentration across the Laurentian Channel onto the northeast edge of the Scotian Shelf in NAFO Div. 4Vn but there is a distinct separation between those fish and the remainder of the Scotian Shelf to the southwest (Beanlands and Annand 1996 and Beanlands *et al.* 2001). For the purpose of management of the fisheries, monkfish on the Scotian Shelf are considered as a unit and on the Grand Banks, the stock area is defined as NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps (hereafter referred to as 3LNOPs: Fig. 1).

Monkfish have been reported in depths from the tide line down to 840 m in USA waters (Armstrong *et al.* 1992). In From mid-Atlantic Bight to Georges Bank, Bay of Fundy and Georges Bank, monkfish were distributed widely on the shelf, from the shoreline out to about 200 m (NEFSC 2000, Beanlands *et al.* 2001). Beanlands *et al.* (2001) indicated that highest catches were observed from depths of 70-100 m on the Scotian Shelf and Bay of Fundy. On the Grand Banks, near its northern distributional limits, monkfish occupies a similar range of depths to what has

been reported elsewhere (70-700 m) but the highest concentrations of fish are located in a narrow band between 250-500 m, considerably deeper than areas to the south (Kulka and Miri 2001). This significantly different pattern (less widespread and deeper) is likely related to limited suitable habitat (refer to the following section).

Although monkfish have been found in a wide range of temperatures, from 0-21^{0}C according to Scott and Scott (1988), the preferred temperature for the species in US waters is 6-10^{0}C (Steimle *et al.* 1999). On the Scotian Shelf and Bay of Fundy, monkfish typically occupy temperatures in the 3-10^0 C range, conditions that are widespread there (Beanlands and Annand 1996). The distribution on the Grand Banks is far more restricted because a large proportion of the banks (88%) are covered by bottom waters < 3^0 C. The large majority of monkfish biomass (81% in spring, 70% in the fall) was found in waters warmer than 3^0 C along the southwest slope and into the Laurentian Channel and the highest densities (kg per tow) of monkfish were associated with bottom waters exceeding 4^0 C (Kulka and Miri 2001). Monkfish, as noted above are also taken occasionally in the Labrador Shelf surveys and are taken as bycatch in some of the deepwater slope fisheries to the north where depths exceeded 800m and bottom temperatures exceeded 3^0 C (Kulka and Miri 2001).

The extent of the distribution of monkfish on the Grand Banks has changed little over the past 50 years (Kulka and Miri 2001), this stability contrasting with reductions reported for many other species distributed on the Grand Banks and Labrador Shelf. (Atkinson 1993). However, based on spring research surveys, the centre of distribution of monkfish at depth was observed to shift slightly over time. Kulka and Deblois (1996) reported that the average depth at which monkfish were caught during research surveys was: 200 m in 1976-85; 275 m during 1986-1990; 325 m during 1991-1994. and 270 m during 1995-1999,. This change to deeper waters after the mid-1980s, followed by a return to shallower depths, was thought to be related to a cooling trend during the mid1980s and early 1990s and a subsequent period of warming (Colbourne and Fitzpatrick 2003). A shift to deeper waters in cold years could reflect avoidance of more extensive cold waters on the shelf in those years.

Kulka and Miri (2001) reported that biomass in the spring was found to be bimodally distributed, peaking at 125 and 375 m (during the late 1990s). This bimodality suggests that the population may be segregated by size or sex. However, at that time, monkfish were not measured or sexed and it was not possible to determine if the bimodal distribution was related to size or sex.

Comparisons of survey data in the spring and fall of 1995-2000 showed a slight change in seasonal distribution of monkfish on the Grand Banks (Kulka and Miri 2001). In the fall, when warm bottom temperatures were more widespread, monkfish were spread more onto the bank and further along the edge to the east although this seasonal expansion this limited. Hartley (1995) indicated that monkfish in the Gulf of Maine was observed to undergo a limited seasonal migration to shallower water in summer and deeper water in winter, in order to avoid colder temperatures. Beanlands and Annand (1996) indicated that similar movements were not observed on the Scotian Shelf.

Armstrong *et al.* (1992) and Hartley (1995) reported that monkfish off the USA have a length at 50% maturity (L_{50}) of 43 cm for males and 46 cm for females in the northern management area (Gulf of Maine, in closest proximity to our study area). Assessment data gathered in 1992-2001 agreed fairly closely with these earlier estimates (NEFSC 2002). Those studies also noted that monkfish matured at a slightly larger size at the southern end of its distribution. Preliminary results from the Scotian Shelf studies indicate that females appear to mature at a smaller size, between 30 and 40 cm (Beanlands *et al.* 2001). No data are available from the Grand Banks but size at maturity is likely to be most similar to the adjacent Scotian Shelf.

Spawning has been reported over much of its range (Steimle *et al.* 1999) occurring in the spring at the southern most part of its range. Off Nova Scotia, spawning was reported to occur from June to September by McKenzie (1936). More recently, Beanlands *et al.* (2001) indicated that monkfish on the Scotian Shelf spawn in late summer and fall. No data are available for the Grand Banks.

Published reports of the presence of eggs in Canadian waters are scarce (until recently, see below). As for other Lophiids, eggs are deposited at the surface in large mucous sheets referred to as veil. For monkfish, veils produced by each female are the largest of any Lophiid species, sometimes contain more than 1 million eggs (Bigelow and Schroeder 2002). Recently, observations of numerous veils were reported in November on the Scotian Shelf (Beanlands *et al.* 2001). Thus, the reproductive cycle is considerably later on the Scotian Shelf than to area south. For the Grand Banks, only one early anecdotal record (Murray and Hjort 1912) exists, reporting the presence of eggs

south of the Grand Banks near the 2000 m contour. There, no studies have been carried out on the reproductive cycle.

Upon hatching, larvae with enlarged dorsal head spines and pelvic fins float to the surface, spending several months in a pelagic phase, then settle to the bottom as post-larvae. Young stages have been found from Cape Hatteras to as far north as the northeastern edge of the Grand Banks and are particularly abundant in the Gulf of Maine, Bay of Fundy (Bigelow and Schroeder 2001).

Growth appears to be rapid and fairly similar between sexes. Information, mainly from the USA suggests they reach a length of about 11 cm (3 inches) at age 1, 40 cm (16 in) at age 3, 76 cm (30 in) at age 7 and 102 cm (40 in) at age 10 (Almeida *et al.* 1995). Growth may be slower on the Grand Banks given the lower ambient temperatures. Monkfish is thought to be a relatively short lived species, with a maximum age of about 11 years. The largest specimens weigh about 27 kg (Armstrong *et al.* 1992, Hartley 1995).

The Fishery

Directed fisheries for monkfish exist along much of the shelf and slope waters from the Carolinas north to the Grand Banks. At the 31st Northeast Regional Stock Assessment Workshop, USA (NEFSC 2000), concern was expressed that monkfish has been overfished in American waters. Gulf of Maine/Middle Atlantic commercial catch and effort for that species steadily increased from near zero the early 1970s to > 25,000 metric tonnes (t) in recent years. At the same time, the survey indices decreased (from an average of >2 fish per standard survey tow in the 1970s to < 1 fish after the late 1980s) and the size distribution became truncated on the upper end. Beanlands and Annand (1996) and Beanlands *et al.* (2001) indicated that catches increased from about 500 t in 1985 to close to 3,000 t in 1986 but has declined since to about 1,000 t for the Scotian Shelf. As well, very large amounts of small monkfish were reported as discarded bycatch in the scallop dredge fishery on the Scotian Shelf. Grégoire (1998) for the Gulf of St. Lawrence indicated that up to 1997, monkfish have been taken and landed in small amounts (largest landings reported was 73 t in 1994) as bycatch from other fisheries.

The Grand Banks mixed mobile and fixed gear fisheries for monkfish (skate, *Amblyraja radiata* and white hake. *Urophysis tenuis*) has a smaller yield than the fisheries to the south because the extent of the distribution of monkfish there is much smaller (65,000 km^2) than off the USA and on the Scotian Shelf (hundreds of '000s of km^2). Prior to 1991, monkfish was not targeted in a directed commercial fishery on the Grand Banks but was a common bycatch in some groundfish fisheries, primarily in NAFO Div. 3O and 3P (Kulka, 1982, 1984, 1986a and b). Most of the catch records during those years relate to bycatch in otter trawls. Since the early 1990s, however, following the decline of many major species, monkfish has become a target for commercial effort (Kulka and Deblois 1996). Canadian landings increased sharply in 1991, as markets were developed for this species. Churchill (1994) reported on an experimental fishery on the Grand Banks in 1993 and 1994, which led to a limited directed fishery using large mesh gillnet for monkfish. A precautionary quota of 200 t was imposed in 1995, but discontinued after 1997. Since then, the fishery has been regulated only by gear, restrictions on bycatch of major commercial species and species under moratoria, and fishing season closures. The primary market for product was in South Korea where much of the monkfish taken off the USA was being exported. Also, monkfish is considered a delicacy in several European countries and there, a potential market for monkfish products exists.

As noted above, information on monkfish from the Grand Banks is very limited. There is little information on its basic biology; therefore, an analytical analysis of the status of this management stock is not possible. Given the available information, this paper provides an examination of the trends in biomass and abundance for monkfish from 1971-2003. The paper also updates Kulka and Miri (2001): describing the distribution of this species northeast of the Laurentian Channel on the Grand Banks (Fig. 1). It provides baseline biology for *L. americanus*, allowing comparisons with any subsequently observed patterns to determine population changes. Landings information are presented back to 1985, and commercial fishing grounds are mapped. New (limited) information on monkfish sizes from research vessel surveys and commercial catches is also presented.

METHODS

Catch data for monkfish have routinely been collected during research surveys in waters around Newfoundland, employing a stratified random survey design. A summary of the survey design, adopted after 1970 by the Newfoundland region, can be found in Doubleday (1981). While survey design has since remained constant, strata

have been added to survey areas in recent years, along with modifications to some of the original strata. These modifications are described in Bishop (1994). However, most of these added strata occur very close to shore or in waters generally exceeding 700 m during the fall survey. Therefore, this expanded survey area even for the fall data would have little impact on analyses of monkfish, because they occur mainly between 70 and 700 m (Kulka and Miri, 2001). The extent of the spring survey has remained relatively constant although average depth increased slightly in recent years (described below).

In addition, there was a change in standard survey gear after the spring 1995 survey: from the Engel 145 groundfish trawl to the Campelen 1800 shrimp trawl. Although both gears are bottom trawls, configuration and mesh size differ significantly. Conversion factors to standardize the numbers by size of fish caught by both gears were subsequently derived for major commercial species, but not for monkfish. Thus, catch rate data and biomass and abundance indices are on a different scale that begins in fall 1995. This change affected selectivity of fish by size for the major commercial species. For many fish species, the Campelen trawl tends to catch a larger proportion of smaller fish as compared to Engel gear (Walsh 1992). However, any effect on size selectivity of monkfish is unknown, since this species was not historically measured for length in surveys deploying Engel gear. In this paper, gear change is delineated on tables by a horizontal line and on figures by a vertical bar. The time series prior to fall 1995 is not directly comparable to fall 1995 or afterwards.

Trawl data from spring (April-June) stratified random surveys in NAFO Divisions 3LNO and Subdivision Ps were used to estimate biomass and abundance, and examine trends in average size (biomass/abundance) of monkfish from 1971 to 2003. Fall data were not used for this analysis because NAFO Division 3P, an important area for monkfish, is not surveyed then. STRAP2 (Smith and Somerton 1981) was used to estimate biomass and numbers of monkfish by areal expansion within a series of predefined strata, partially related to depth. These strata estimates are then added over the survey area. Extra sets, which are not part of standard surveys, have recently been added to some strata for diurnal research. These represent a deviation from the proportional allocation of survey sets, but do not differ in sampling protocol. Diurnal sets are included in all STRAP2 estimates.

STRAP1 (Smith and Somerton 1981) was used to estimate numbers at length for predefined depth strata. Total abundance at length was then the addition of these estimates over the research vessel survey area. Due to the absence of length-weight data from DFO stratified random surveys in NAFO Divisions 3LNOPs, sexed length-weight relationships of monkfish generated by Armstrong *et al.* (1992: from NMFS spring and fall groundfish surveys in the Mid-Atlantic Bight and southern New England during 1982-85) were utilized for males and females in STRAP1 calculations. An unsexed relationship derived by Almeida *et al.* (1995: from NEFSC research surveys in the Gulf of Maine and northern Georges Bank during 1992-93) were applied to all unsexed data in STRAP1 calculations. All calculations assumed that weight at length remained constant throughout the entire survey period.

For analysing monkfish distribution, the same data were used as for biomass and abundance estimations, plus additional Campelen sets from special August surveys in Div. 3Ps (which primarily covered the Laurentian Channel). These extra sets were grouped with fall data. This provided a more complete picture, because monkfish is distributed continuously across the Laurentian Channel onto the shelf in NAFO Div. 4Vn. Grouping data from the two time periods is logical, since monkfish tend to show little interannual movement (fall and spring distributions almost completely overlap).

SPANS GIS (Anon. 2003) was used to investigate changes in distribution, area occupied and distribution in relation to depth and temperature, from 1980-2003 in three-year periods. As well, annual maps were generated for 2001-2003. Distribution maps (density surfaces showing where fish were more abundant) were produced using potential mapping in SPANS. Catch rates (kg per standard tow) for individual survey sets (point data) were converted to surfaces (classified maps), depicting differing levels of fish density. The strata class bounds (catch per tow legend values) were held constant across years (a single legend for all years), so that different amounts of each colour (each representing a density level) would reflect relative changes in density over time. In the resulting maps, red areas represent the highest density of monkfish (highest catch per tow), while green illustrates the lowest density. Grey areas depict sampled areas with no monkfish catch, and white denotes unsampled areas.

A CTD, BT, or XBT hydrographic sampling device was used to record bottom temperatures at all research survey locations. An analysis of monkfish catch at depth and with respect to bottom temperature was done (see below), and results compared to earlier years.

Bottom temperature maps were created using potential mapping in SPANS for both spring and fall using 15 strata of equal size, varying from –1.3 to 5.2+ ^{0} C. These comprised the temperature strata. Details of the mapping method are elaborated in Kulka (1998). Distribution in relation to depth was determined by calculating average kg per standard tow within each of the depth strata (0-50, 51-100, 101-150, 151-200, 201-250, 251-300, 301-350, 351-400, 401-450, 451-500, 501-600, 601-700, 701-800, 801-900, 901-1000, 1001-2000 m). The survey catch rate (kg per tow) and point (survey set) data were overlaid on temperature strata, then averaged within each stratum to yield a measure of density of monkfish by stratum.

Data on monkfish removals in NAFO Div. 3LNO and Subdivision Ps for 1985-2002, and information to date for 2003 were obtained from four sources:

a) Canadian landings were compiled from statistical records in Zonal Interchange Format (ZIF) files; available for 1985-2003. Data were summarised by fishing gear, NAFO Division, and month;
b) Amounts discarded at sea were estimated from Fisheries Observer records (see description of Observer coverage below). Observer data were also used to quantify non-Canadian catches inside the 200-mile-limit;
c) Non-Canadian catches outside Canada's 200-mile-limit are based on information reported to NAFO (Northwest Atlantic Fisheries Organization); and
d) Canadian fishing logbook data recorded on a set-by-set basis with latitude, longitude, and catch; available for 1999-2003.

From 1993 (the beginning of a Canadian directed monkfish fishery) to 2001, fisheries Observers have been deployed to cover approximately 8% of commercial effort. In 2002, as effort greatly expanded, Observer coverage increased to nearly 100%; then decreased to 20% in 2003 (although effort surpassed that of 2002). Observers collected set-by-set information on catches as per methods described in Kulka and Firth (1987; updated in annual unpublished versions of the Newfoundland Fisheries Observer Program Training Manual).

Observer data were used to examine discarding, distribution of fishing effort, and catch rates. Discards from Canadian fisheries inside Canada's 200-mile-limit were calculated by applying the proportion of monkfish catch to groundfish landings (kept fish, all species) in the Observer database to the reported landings of groundfish in ZIF files. These were then summarised by Division and year. Also, monkfish catch (kept plus discards) of non-Canadian vessels inside 200 miles were extracted from fisheries Observer reports. Observers have been placed on nearly all non-Canadian vessels fishing in Canadian waters. Fishing logbook data were used to map the distribution of commercial effort. The potential mapping method described above was used to create distribution maps of observed fishing activity (catch rate over area by gear). Fishing grounds were then compared to monkfish distribution as determined from research vessel surveys.

RESULTS

Distribution

Monkfish on the Grand Banks are restricted to 15% of the total shelf area (inside 800 m): forming a narrow band 45-55 km across in spring; widening to 70 km in the fall and 875 km long (Laurentian Channel to the southwest edge of the Grand Banks, as far as Longitude 51^{0} N to the east: Fig. 2). The densest concentrations of monkfish are located between Longitude 55^{0} N and 53^{0} N near the slope. Smaller areas of high concentration are also located in the upper part of the Laurentian Channel. Annual spring maps (Fig. 2a-2d) show some gaps along this "band", but these discontinuities are likely a result of limited sampling effort and low catchability. Given its restricted southern distribution, only twenty-seven spring survey sets per year (7% of the total) on average encounter monkfish.

Area of occupancy has changed over the past twenty-three years (Fig. 3). While the general location occupied by monkfish has remained constant over time, they have increased and decreased the size of the area that they occupy by approximately 25%. From about 50,000 km^2 in the early to mid-1980s, area occupied has increased to 70,000 km^2 in 2003. However, unlike previous periods of expansion, the area corresponding to high concentrations of monkfish (where kg per tow >1.9) decreased from 40,000 km^2 in the mid-1990s to a low of 6,000 km^2 in 2003; while total area occupied had increased. This indicates that in recent years, while monkfish expanded their distribution, they became more dispersed.

Since 1996 (when spring research surveys began using a Campelen trawl), the percent of spring survey sets containing monkfish has increased, particularly after 2001, but average survey depth and extent of the survey have remained relatively constant (Table 1, Fig. 4). About 5% of sets from the spring survey contained monkfish in 1996, increasing to 12% in 2003. This provides further evidence that monkfish have increased their area of occupancy since the mid-1990s.

On the Grand Banks, monkfish are found in 100-700 m, but are concentrated mainly in 200-500 m (Fig. 5). Although more than 75% of the Grand Banks extends over depths < 200 m, almost no monkfish were taken at those depths. Monkfish are bimodally distributed: peaking at 125 and 375 m, both in terms of numbers and weight per tow (Fig. 5, lower panel). The upper panel in Figure 6 shows that they are slightly larger on average at greater depths: at < 350 m in 2001-2003, monkfish averaged 52 cm total length; at > 350 m, 60 cm. In addition, there appeared to be fewer males at greater depths. The ratio of males to females was 1.3 at < 350 m, and 1.0 at > 350 m. However, sample size was small: 294 fish measured in total; 70 of these from > 350 m. Therefore, information on size and sex ratio at depth are considered to be preliminary.

Monkfish from research surveys were not measured for length prior to 2001. However, mean size (weight of monkfish divided by numbers caught) was used as a proxy to examine size at depth prior to 2001. Figure 6 (lower panel) indicates that fish at < 350 m (representing the 125 m mode) were on average lighter in most years, compared to fish from the 375 m mode. Sample size was also small: only 3 fish were caught, counted, and weighed per year on average from depths exceeding 350 m in 1972-2003).

Average depth at which monkfish were caught during spring surveys has changed over time. In 1972-1985, average depth was 235 m; 1986-1990, 295 m; 1991-1995, 335 m; 1996-2003, 310 m (Fig. 7). The shallower average depth observed in earlier years may be due partly to fewer deep sets prosecuted during research surveys. Figure 7a shows slightly fewer deep sets in earlier survey years, prior to 1990. However, the proportion of sets at depth was not very different across years, and the same range of depths was covered in all survey years. Average depth of survey sets increased from 165 m in 1971-1992 to 190 m thereafter, due more deep sets. However, the large decrease in average depth of sets with monkfish (to 250 m) in 1999-2001 cannot be explained by a change in survey depth during that period. Figure 5 shows that monkfish on the Grand Banks are constrained to depths between 100 and 700 m, and this corresponds to depth ranges that have been surveyed over the long term.

A large portion of the Grand Banks has cold bottom temperatures throughout the year: < 3^0C covering more than 70% of the bank (Fig. 8, top panel). However, nearly all monkfish are found where bottom temperature exceeds 3^0C and highest densities occur where bottom temperature exceeds 4^0C. This pattern has been consistent since at least the mid-1990s and between seasons (Fig. 8, middle and bottom panel, 1995-2000; Fig.9, 2001-2003). Thus, monkfish are consistently restricted to a small area in the southwest where bottom temperatures are at their warmest on the Grand Banks.

Biomass and Abundance

Rate of capture of monkfish in the spring surveys is low, showing sampling effort, catch and numbers per tow by strata (Table 1). Only 7% of spring survey sets yielded monkfish and only 7 sets over the entire period yielded 12 or more fish (Fig. 10). Percent of sets with monkfish varied from year to year (Fig. 10a, lower panel). In some years, higher proportions with monkfish resulted from areas without monkfish (northern extent of the survey area) not being surveyed. The most obvious example is 1983, when a large part of the northern Grand bank was not surveyed resulting in an anomalously high proportion of sets with monkfish. Thus, biomass and abundance estimates for this species are based on a small sample size. However, with the exception of one set with 34 fish in 1987 and one set with 37 fish in 1994 (resulting in a much higher value in that year compared to adjacent years), there were no other large sets that could produce anomalously large values of abundance and biomass in the index series.

On average, from 1972-2003, > 99% of the biomass of monkfish (from spring surveys) occurred in NAFO Div. 3OPs, 66% in 3O. Between 1972 and 2003, in NAFO Div. 3OPs, there was a distinct pattern of fluctuation in biomass and abundance (Fig. 10a, Table 2). The biomass has reached maxima 3 times in the last 34 years, peaking in 1977, declining to a low in 1979, peaking again in 1988. Biomass then declined to a low in 1992-93. Since then, the index has increased such that 2003 represents a year of peak abundance in the Campelen times series. The long term fluctuations were more pronounced for biomass trends than for abundance.

Percent of sets with monkfish (Fig. 10a) and size of the area occupied by monkfish (see Fig. 3) tended to increase and decrease synchronous with fluctuations in the biomass and biomass (larger biomass, larger area occupied, more survey sets with monkfish). The highest peak in biomass observed is the current one. However, with the change of gear from Engel to Campelen trawl, relative biomass and abundance cannot be compared post-1995 to earlier years. The peak in biomass reached in 1986-89 was about 3 times higher than the 1975-78 peak. As noted above, fewer deep sets in the range of 400-700 m were prosecuted in the earlier years (1975-1978, Fig. 7a lower panel) compared to 1986-1989. The lower peak in biomass in 1975-78 may in part be a function of the deepest extent of the range not being sampled as intensely although sampling effort was low in the range during both periods and the differences were small. The biomass was likely larger in 1986-89 compared to 1975-78.

Similar fluctuations over time were observed in both NAFO Div. 3O and 3Ps although abrupt changes between years were more apparent in 3O (Fig. 10b). These abrupt changes that occur in adjacent years likely do not reflect actual inter-annual changes in the population. Rather, these spikes suggest that there may be a catchability or availability issue related to low sample size (on average, only 27 sets per year contain monkfish, in both Divisions combined).

Average weight of monkfish peaked in both NAFO Div. 3O and 3Ps in 1990 corresponding with a peak in biomass (Fig. 10a, Table 2). Largest animals were observed in the late 1980s when monkfish averaged 8 kg in NAFO Div. 3Ps and 10 kg in 3O. However, since the introduction of Campelen gear in 1996 (spring), average weight of monkfish has declined. Currently, average size is about 3 kg. Average size of monkfish taken in the years immediately prior to the change in survey gear compared to years immediately following the change post-1995s were similar. While estimates of biomass and abundance from the Campelen series cannot be compared to earlier years, the two gears catch fish that with a very similar average weight. With most other species, the Campelen gear captures more small fish and fewer large fish, perhaps not the case for monkfish.

The fall series, shown in Fig. 10d is much shorter in time for the areas where monkfish occur, in NAFO Div. 3O. However, for the corresponding period, the pattern in the spring (Fig. 10c) and fall trends is fairly similar. Both trends were highest in the most recent period. The percent difference in biomass between the periods is variable over time: fairly similar between 1990 and 1992, higher in the spring between 1993 and 1996 then closer to even thereafter (Fig. 10e). Once again, however, the sample size upon which this analysis is based.

A subsample of monkfish taken in the 2001-2003 spring surveys have been measured (Fig. 11). Although using a small (32 mm) mesh with the Campelen gear, captures of monkfish < 14 cm are non-existent and 90% of the fish in the samples exceeded 30 cm. The distribution was unimodal, peaking at about 58 cm which corresponds to a weight of about 3 kg (see Fig. 12). A greater proportion of females tended to be more predominant in sizes classes > 70 cm. There were fewer fish > 80 cm in 2002 and 2003 compared to 2001 (Fig. 13) and proportion of smaller fish increased in 2003. Percent below 40 cm increased from 20% in 2002 to 40% in 3003 (Fig. 13). It should be noted that sample size comprised only 297 fish for all three years.

Although individual monkfish were not weighed and measured for length during research surveys on the Grand Banks, 37 individuals were measured and weighed during the 1993-1994 experimental fishery (Fig. 12). Catch size at the low end of the spectrum, 43 cm, were equivalent to 1.4 kg (aged 3) and at the upper end, 118 cm, equivalent to about 26 kg or 10 years, close to the maximum age observed in other areas.

The Fishery

Although monkfish on the southwest Grand Banks (3LNOPs) likely comprise a single biological unit (or perhaps part of a larger population), two areas NAFO Div. 3NO and NAFO Subdiv. 3Ps are managed separately in terms of licensing. Each area is fished by different fleets (although a few of the same vessels fish both areas) and each has separate Conservation Harvesting Plans and license provisions. In total, about 80 vessels participated in the 2003 fishery up from 9 in 2000. In both areas, when directing for monkfish (and skate in a mixed fishery), the daily bycatch restriction for American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Limanda ferruginea*), Atlantic cod (*Gadus morhua*) and witch (greysole, *Glyptocephalus cynoglossus*) is 5%, and longer term closure rules apply if bycatch levels exceed a certain level depending on bycatch species (usually 10-15%). The incidental catch of white hake in the monkfish gillnet fishery cannot exceed the catch of monkfish on a trip basis. Monkfish are also taken as bycatch with directed trawl fisheries for skate and white hake.

When fishing (directing) for monkfish in NAFO Div. 3NO, the following additional provisions apply:

- Use of Gillnets and Longline are permitted but not both during the same fishing trip.
- When fishing gillnets monkfish (and skate), the minimum mesh size permitted is 12 inches and the maximum number of gillnets permitted is 200.
- A portion of the vessels are covered by fishery observers and 100% of the landings are recorded by dockside monitors.
- In 2003, the gillnet fishery took place between May 22 and July 10. The fishery using longlines opened May and remained open as of Oct. 17.
- Test fisheries must first be undertaken to ensure that bycatch will not be at issue on the chosen grounds.
- A preliminary harvest cap of 3.5 million lbs (1,591 t) was requested by industry and included in the CHP (although this was greatly exceeded).

When fishing (directing) for monkfish in NAFO Subdiv. 3Ps, the following additional provisions apply:

- There is no limit on the quantity taken.
- Only gillnets are permitted, with a maximum of 40 gillnets having a minimum mesh size of not less than 266.7mm (10 ½ in) when fishing less than 12 miles from land or 200 gillnets having a minimum mesh size of not less than 304.8 mm (12 in) when fishing greater than 12 miles from land.
- Operators are permitted to fish for monkfish (and skate) within 12 miles of land only with registered vessels < 35 feet in length.
- A portion of the vessels are covered by fishery observers and 100% of the landings are recorded by dockside monitors.
- The season for > 12 miles from land is June 2, 2003 to February 28, 2004 and < 12 miles from land is July 7, 2003 to February 28, 2004. The fixed gear fishery for vessels < 35 feet closed on Aug 23 when the harvest cap was reached. The season for mobile gear was April 11 to May 5, 2003
- Bycatch provisions are as follows:
  - Amercian Plaice – 10% or 1000 lbs
  - Yellowtail flounder– 10% or 200 lbs
  - Cod & Greysole – 10% or 200 lbs
  - Pollock (*Pollachius virens*) – the weight of the directed species or 4,000 lbs whichever is greater to a max of 16,000 lbs per week
  - White hake (when the directed white hake fishery is closed) – 20% or 200 lbs

Location of the area fished for the Canadian mixed multi-gear (gillnet, longline, trawl) fishery on the southwest Grand Banks was similar among years (1999-2003), effort location corresponding to much of the distribution of monkfish (Fig 14). Only parts of the lower Laurentian Channel were not consistently fished across years. However, extent of area fished increased from 35,000 km^2 (3,000 km^2 intensely fished) in 1999-2000 to 60,000 km^2 (8,500 km^2 intensely fished) in 2001-2002. The extent of area fished was lower in 2003 but those data are preliminary.

Gillnet effort has dominated the Canadian fishery in recent years and effort was distributed over much of the distribution of monkfish (Fig. 16). Catch (kg) per net was relatively low in 1999 over much of the area fished (Fig. 16a). Between 2000 and 2002, catch rates increased at two locations along the southwest slope and a small part of the upper Laurentian Channel. In 2003, the high catch rates, exceeding 9.7 kg per net occurred over much of the southwest slope in the mid range of depths fished. Proportion of area fished with gillnets where monkfish were caught increased from about 10,000 km^2 in 2000 to a maximum of just over 20,000 km2 in 2002 (Fig. 17). Although extent of the area fished by the gillnet fleet decreased in 2003 to 14,000 km^2, the extent where high catch rates occurred remained about the same as in 2002 (~5,000 km^2). In terms of depth fished, all three gears were deployed at relatively shallow depths, mainly between 50 and 250 m. However, relatively high catch rates of monkfish occurred over a wider range of depths, out to about 700 m (Fig. 18).

CPUE (kg per gillnet) and effort (number of sets prosecuted) are illustrated in Figure 19 for the major components of the fishery, vessels > 100 ft in NAFO Div. 3O, vessels < 65 ft in 3O and vessels < 65 ft in 3Ps, based on set by set log book data. CPUE for other gillnet sectors and other gear types are not presented because effort was low for those

components and information on effort was often missing. The catch per gillnet increased for all 3 components between 1999 and 2003, with the exception of a higher mid value in 2001 for vessels > 100 ft. The greatest increase occurred for vessels < 65 ft in 3O.

Catches of monkfish for all countries have been recorded in NAFO (and ICNAF) statistical records back to at least 1960 (Fig. 20). However, prior to the mid1990s, monkfish were taken only as a bycatch and reporting of catches was erratic. Figure 20 shows large spikes in certain years followed by periods of no reported catches. Thus, catch history is only analysed since 1985 and non-Canadian catches are considered unreliable.

Figure 21 and Table 3 show that, with the exception of 1987, reported catches of monkfish remained low between 1985 and 2000, averaging just over 400 t per year. The non-Canadian catch in 1987 is likely, in part reporting of other species as monkfish. In 2001 (926 t), the total catch (all countries including estimated discards) increased by more than 5 times compared to 2000 (168 t) then nearly tripled in 2002 (to 2,511 t) and increased again in 2003 (to 2,994 t). Since 1992, the large majority of the catch was taken by the Canadian fleet given that no non-Canadian vessels have fished inside Canada's 200 mile limit on the Grand Banks during that period and less than 5% of the biomass of monkfish occurs outside of the 200 mile limit. On average, during that period, 6% of the monkfish taken were discarded.

The majority of Canadian landings of monkfish have originated from NAFO Div. 3O in most years (Fig. 22). During 2001-2003 when landings were highest, 74% of the catch came from NAFO Div 3O and most of the remainder from NAFO Div. 3Ps whereas the proportion of the biomass that occurred in NAFO Dive 3O was 46%.

Figure 23 (upper panel) shows that prior to 2001, 77% of the landings were recorded as bycatch in fisheries for other species, primarily skate, witch and American plaice (Table 3b). During 2001-2003, 86% of monkfish landed accrued from the directed fishery and 9% occurred as bycatch in the skate fishery. Figure 23 (lower panel) shows that prior to 1994, most of the catch of monkfish came from trawls but most have been landed from gillnets since. As part of a mixed monkfish/skate fishery, often with a substantial bycatch of white hake, Atlantic cod, pollock and American plaice (Table 3b).

Figure 24 shows that trawls, predominantly used during the earlier years of the fishery (1991-1993) were employed mainly during winter months. Gillnets predominated as the gear of choice after 1993, and effort occurred primarily during April-July due to seasonal restrictions. In 2000, fishing outside 12 miles was restricted to May 15 or later. The fishery closed earlier than in previous years, in Aug. when the voluntary cap of 3.5 million lbs was exceeded. Thus, seasonality observed in the fishery was related to regulatory restrictions rather than stock availability.

Length frequencies from commercial catches show that monkfish captured in gillnets ranged in size mainly from 40 to 120 cm from 1993-2003 (Fig. 25). Only in the past 4 years has the fishery been sampled intensely. In all years, the largest mode occurred at about 65 cm. There are no data from earlier years in either directed or non-directed fisheries. In 1993 and 1994, the first two years of the directed experimental fishery, a significant proportion of the catch exceeded 110 cm with a large mode at about 95 cm. These larger fish were largely absent in subsequent years, although gear used in the fishery was similar among years. Notable is a large pulse of fish in 2000 averaging about 87 cm, a mode not seen since 1995. However, that mode was gone by 2002. The fishery was prosecuted mainly outside 12 miles, and thus minimum mesh observed was 300 mm (as regulated). A 356 mm mesh was also occasionally used. Figure 12b (left column) indicates that these two different sizes of mesh made little difference to the size of monkfish caught.

An index of exploitation (total catch/spring survey biomass) is fairly constant between 1985 and 1991, with the exception of 1987. However, that point (NAFO Div. 3O) is not included in the series because large amounts of monkfish in that year were probably misreported by Spain (Fig. 26). In 1992-1993, the index spiked as a result of very low estimates of biomass in NAFO Div. 3O in those two years, the lowest in the times series. A smaller spike also occurred in 1998 due also to a low biomass estimate in NAFO Div. 3O. The index increased substantially in 2002 and 2003 to 60% from about 10%, in this case, the result of very large catches compared to previous years.

DISCUSSION

Monkfish, a temperate species near the northern limits of its distribution on the Grand Banks, has a limited distribution constrained by local conditions (Kulka and Miri 2001). There, very cold bottom temperatures typify a large proportion of the Grand Banks (Colbourne and Fitzpatrick 2003). As a result, monkfish are restricted to the southwest slope and the Laurentian Channel, the only area where bottom (ambient) temperatures fall between 3 and 10^0C, their normal range of occurrence (Steimle *et al.* 1999). Monkfish are distributed much more widely to the south, from the shoreline to about 200 m on the Scotian Shelf and in USA waters (NEFSC 2000, Beanlands and Annand 1996, Beanlands et al. 2000). This more widespread distribution is a result of more extensive suitable habitat i.e. a much greater proportion of the shelf area with bottom temperatures >3^0C.

Monkfish are also caught north of the Grand Banks in isolated deeper areas of the northeast Newfoundland and Labrador Shelf, in small numbers. It was not an uncommon bycatch in the Greenland halibut and grenadier fisheries of the 1980s north of 49^0 Lat. and as far north as 55^0 Lat., where depths exceeded 800 m and only where bottom temperatures exceed 3^0C (Kulka and Miri 2001). However, they are rare on the Flemish Cap (Alpoim *et al.* 2002) even though much of the Cap is covered by warm bottom temperatures (> 4^0C). Thus, there is a component of the population that occupies deep waters of the shelf over a northern range of latitudes, but in small numbers. The deep water northern component is not included in the biomass and abundance estimates described in this paper.

A single genetic study on monkfish in the western Atlantic (Chikarmane *et al.* 2000) detected no genetic differences between monkish from North Carolina to Maine. No information is available on the population structure of monkfish in Canadian waters, but Beanlands and Annand (1996) and Beanlands *et al.* (2000) reported various separated concentrations of monkfish on Georges Bank, Bay of Fundy, and Scotian Shelf; including one along the western slope of the Laurentian Channel in NAFO Div. 4Vn. Our Grand Banks study shows that monkfish are concentrated along the eastern side of the Channel. It appears that the Grand Banks fish extending into the Laurentian Channel may be contiguous with the fish on the eastern Scotian Shelf. As well, Grégoire (1998) reported monkfish in the eastern Gulf of St Lawrence along the Laurentian slope apparently contiguous with those in our study area located at the northern end of the Laurentian Channel. Thus, various separations in the distribution suggest the possibility of separate biological components and continuities in the distribution between regions (Grand Banks, Scotian Shelf and Gulf of St Lawrence) also suggests the possibility of overlaps in stocks between management units. Studies on stock structure of monkfish are required to identify appropriate management units.

Survey catch rates for monkfish area low and annual distributions are patchy and variable. During spring 1971-2003, number per tow exceeded 12 in only 5 sets out of 11,81) and for sets containing monkfish, the average number per tow is 2 on the Grand Banks. Thus, they do not form dense aggregations. The concentrations of monkfish were also low in other areas: average number per tow in any year was no higher than about 1.5 and 5 fish on the Scotian Shelf (Beanlands *et al*. 2000), and off the USA (NEFSC 2000) respectively. Different survey gears used in the different areas preclude direct comparison of the catch rates among areas but consistently low numbers captured indicate low concentrations over the entire distribution, or low catchability in survey gear, or both.

On the Grand Banks, the distribution has been stable since the 1950s, monkfish consistently occupying the same area along the southwest slope and Laurentian Channel (Kulka and Miri 2000). The area occupied (km^2) has fluctuated (by 25%) over time, resulting from a narrowing and widening of the distribution, synchronous with fluctuations in biomass. There is no evidence of a shift in the distribution or near extirpation over parts of its range over the past 50 years, as opposed to what was observed for many other species on the Grand Banks and Labrador Shelf, particularly in the 1980s and 1990s (Atkinson 1993).

Hartley (1995) indicated that monkfish in the Gulf of Maine was observed to undergo a limited seasonal migration to shallower water in summer and deeper water in winter, in order to avoid colder temperatures. Beanlands and Annand (1996) noted no such movements on the Scotian Shelf. On the Grand banks, there is a subtle difference in seasonal distribution of monkfish in NAFO Div. 3O (this being the only area surveyed during both seasons). In fall, when warm bottom temperatures are more widespread, monkfish are dispersed, spread more onto the bank and occasionally further along the edge to the east indicating that monkfish on the Grand Banks undergo limited seasonal movement.

Average size of monkfish was found to increase with depth on the Grand Banks. As well, there tended to be fewer males at the greatest depths although the sexes were mixed over the entire range. Females grow to a larger size (Armstrong *et al.* 1992) and thus larger size at depth is likely a result of partial separation of the sexes by depth. However, sample size was small (294 fish measured in total, only 70 from > 350 m), thus information on size and sex ratio at depth are considered as preliminary.

The average depth at which monkfish was found in the spring surveys has changed over the years distributing deeper over time from the late 1970s (average depth ~250 m) to the early 1990s (~325 m). An increasing proportion of sets were prosecuted at the greatest depths surveyed causing the mean depth of the survey to increase by about 40 m after 1991. However, the same strata were surveyed and the effect of a shift to slightly deeper sets within the same strata should not have a large affect. A large decrease in average depth of monkfish 1999-2001, from 350 m to 250 m cannot be explained by change in survey depth (survey depth was consistent over that period). Thus, it appears that monkfish did change their depth over time to some extent, likely in response to cooling temperatures on the shelf during that period (Kulka and Miri 2001, Colbourne and Fitzpatrick 2003). Such interannual shifts have not been reported for other areas.

The change in survey gear in 1995 created a discontinuity in the time series.. After the spring 1995 survey the gear was changed from an Engels 145 groundfish trawl to a Campelen 1800 shrimp trawl. Although both are bottom trawls, configuration and mesh size differ significantly, as described by Bishop (1994). Size and age based conversion factors for amounts and sizes of fish caught were derived for major commercial species, but not for monkfish. Thus, catch rate data and biomass and abundance indices are on a different scale as of fall 1995. This gear change also affected selectivity by fish size as determined for major commercial species. For many fish species, the Campelen trawl tends to catch a larger proportion of smaller fish when compared to Engels gear (Walsh 1995). Monkfish were not measured prior to 2001 so it is not possible to compare sizes caught in the two gears. However, the similarity in average size of monkfish and average catch rate in the years just before and just after the change in gear suggest that the two gears capture similar sizes of fish at a similar rate (unlike many other groundfish). How similar is the catchability of the two gears for monkfish is unknown. Nonetheless, the Engel and Campelen series must be treated as separate indices of population size for monkfish.

Abrupt inter-annual changes in biomass and abundance indices of monkfish observed in some years likely do not reflect dramatic fluctuations in the population. Rather, these changes suggest that there may be sample size and catchability issues for this species. It does not seem reasonable that biomass could, for example, decrease by 4 times between two successive years, 1991-1992, at other times doubling or halving between years. The answer may rest with the behaviour of the species. Monkfish spend much of their time motionless on the bottom (camouflaged by the substrate), waiting for prey to come within striking range. This lifestyle may normally result in low catchability for monkfish, due to escapement under the trawl footrope. The number of monkfish caught per survey set is low, and thus only a few more fish in a set can make a substantial difference to resultant indices. These factors could not only explain the large inter-annual changes in the indices in certain years but also suggests a low value of Q (catchability). If this is the case, stock size may be substantially underestimated by the survey indices. Also, few fish < 30 cm (none < 14 cm) and larger components observed in commercial gears (> 85 cm) are rarely captured in the survey gear. It appears that fish of these sizes behave in a way that precludes their capture (or they are not present within the survey area) and thus the survey estimates does not include a significant portion of the population, < 30 and > 85 cm. Given that the survey gear does not capture young of the year (averaging about 11-2 cm based on studies by Armstrong *et al.* 1992) the survey does not provide an index of recruitment.

The first period of peak abundance in the series, 1975-78 was lower than the one that occurred in 1986-89, when there were slightly fewer sets in the 401-500 m range (where monkfish reach their greatest densities) in the earlier period. However, the range of depths surveyed did not change thus the same strata were surveyed. This small difference in distribution of sets should not affect the relative magnitude of the survey indices.

Not withstanding these deficiencies in the survey index as a relative measure of the population of monkfish on the Grand Banks, it can be seen that the biomass peaked 3 times during the 33 years studied, likely reflecting changes in the size of the population. Monkfish were more abundant in the late 1980s compared to earlier periods, at a time when many other groundfish on the Grand Banks were in decline. The long term fluctuations in the survey series were less apparent for abundance than for biomass. As well, mean weight peaked in conjunction with the peak in

biomass. This suggests that the biomass peaks corresponded with a period when fish from (a) good recruitment year(s) grew to a size that was captured by the survey gear, i.e. > 15-20 cm.

Monkfish from Grand Banks surveys have been measured only since 2001. Based on three years of data, frequency of sizes has been consistent, peaking at 58 cm and ranging from 14 to 98 cm. Beanlands *et al.* (2000) reported more small fish in the range < 35 cm on the Scotian Shelf, pariculray in recent years. Why fish of this size are not captured in significant numbers an the Grand Banks (at least since 2001 when monfish were measeaured in the surveys) is unclear. As well, on the Grand Banks average weight monkfish appears to be slightly lower at length than what was observed in US waters (Almeida et. al 1995) but once again, different sampling gear was used. They found a high degree of overlap in the relationship among different locations in US waters, and also indicated that their work agreed closely with earlier studies in the same areas.

The Fishery

Monkfish, until recently comprised a minor component of the Grand Banks fisheries. Until 1991, they were taken only as bycatch in gillnet and trawl fisheries comprising no more than few hundred tonnes. It was often retained by non-Canadian fleets, but discarded by Canadian vessels even though it was considered a premium fish other parts of the world, particularly in European markets.

Monkfish landings reported from the NRA (non-regulatory area outside 200 miles) by non-Canadian fleets was highly erratic since 1960, exceeding 1,500 t in three years, zero in others. After 1994, reports have been very small or null. In particular, Kulka and Miri (2001) showed a catch of 1,808 t in 1987 from the NRA, considerably more than what was reported in any other year after non-Canadian fleets were constrained to the NRA. It seems unlikely that such a catch is possible since the area where monkfish occur in the NRA amounts is only about 6% of the total area occupied by monkfish and <1 % of the NRA. A remarkably concentrated amount of effort would have to been prosecuted in that year in order for such catches to be achieved, and there is no evidence of that happening. All of this suggests mis-reporting: over-reporting in 1987 and non-reporting since 1994. Prior to 1985 (plus 1987), reported catches are considered unreliable.

Beginning in 1991, a Canadian experimental trawl fishery for monkfish contributed to an increase in reported landings. The majority of Canadian effort shifted to large meshed gillnets after a successful experimental fishery in 1993-1994 (Churchill 1994). In 1995, a 200 metric tonne quota was instituted for the emerging fishery. The quota was kept in place for 1996 and 1997, but was removed in 1998. Although monkfish on the southwest Grand Banks likely comprise a single biological unit, two areas are now managed separately; NAFO Div. 3NO and NAFO Subdiv. 3Ps each with different fleets with different Conservation Harvesting Plans and license provisions.

Effort has been unregulated by quota since 1997, although it is mandatory for all landings to be recorded by dockside monitors. Catches remained at a low level from 1995 to 2000. Relatively poor market conditions and bycatch restrictions as per licence conditions leading to closures were the primary limitation on effort in the monkfish fishery during that period. As part of a mixed monkfish/skate fishery, there is often with a substantial bycatch of white hake, Atlantic cod, pollock and American plaice. Due to new opportunities in the Korean market operators in the fishery increased from 9 to 80 resulting in an 18 times increase in landings between 2000 and 2003. The size of fishing grounds has also increased during that period. As well, since 1999, gillnet CPUE has increased. In part, this increase may be the result of a more concerted effort to set gear where monkfish are more abundant than skate or other bycatch species since it has become the most valuable of the species taken in the southwest slope mixed fishery. The added advantage is fewer closures due to bycatch limits being exceeded.

The range of sizes of monkfish captured in gillnets is 40 to 110 cm since 1994 although as large as 130 cm were recorded from the 1993 fishery but have not been recorded since. Whether this absence of large fish after 1993 was a result of an increase in exploitation in the previous years is uncertain. There are no comparative data from earlier years in either directed or non-directed fisheries. Based on length at maturity studies by Armstrong et al. (1992), only mature adults (> 40 cm) are captured in the Grand Banks fishery. Size ranges in commercial catches are somewhat different to what was observed in fisheries of the Scotian Shelf. In NAFO Div. 4X. There a large mode of small fish averaging 25 cm (7-40 cm) was recorded in the Summer survey (DFO 2002). Also, on the Scotian Shelf, a portion of the catch is comprised of small monkfish taken in dredges directing for scallops and clams (Beanlands

and Annand 1996). On the Grand Banks, distribution of dredge and gillnet fisheries (and fish) do not overlap. Thus, the problem of bycatch of juveniles in the dredges is not significant there. Very few monkfish juveniles are taken in the directed gillnet fishery, either on the Grand Banks or the Scotian Shelf.

Notable is a large pulse of fish averaging about 60 cm in 2000, a mode not seen in previous years. These small fish are likely 4-5 years old and just reaching maturity (if their growth characteristics are similar to what was observed in US waters; Steimle et al. 1999). Also, the sharp increase in abundance and decrease in mean size observed in the 2000 survey provides further evidence of recruitment. This information on fish size in the catches is very limited and must be used with caution.

Based on a small sample, monkfish on the Grand Banks weight appears to be slightly lower at length than what was observed in US waters (Almeida et. al 1995). They found a high degree of overlap in the relationship among different locations in US waters, and also indicated that their work agreed closely with earlier studies in the same areas.

Prior to 2001, fluctuations in the index of exploitation were due primarily to changes in the size of the population. In 2002-2003, the index increased substantially as a result of an increase in catch of monkfish. As with any population, there is a certain level of exploitation that is unsustainable. However, since catchability of monkfish is not known, there exists no absolute estimate of population size and thus fishing mortality cannot be estimated. In the case of the USA fishery, the level of sustainability was exceeded by a continually increasing catches since the 1970s resulting in a greatly reduced stock size.

The actual exploitation rate on the Grand Banks is probably considerably lower than the index because catchability is low, particularly for the juvenile portion of the population and the sedentary habits of monkfish probably result in low catchability for the portion of the population that it does capture.

CONCLUSION

In managing a commercially exploited species, it is important to have some knowledge of the growth, reproductive biology, spatial distribution (including how catches are taken relative to its distribution), stock structure, and composition of commercial catches (amounts, lengths, ages). For monkfish on the Grand Banks, information from both research surveys and commercial catches is limited. Monkfish is a relatively minor species in terms of amounts taken in research surveys, and fish lengths, ages, and maturities have not been measured during these surveys. With respect to commercial catches, processing of monkfish at sea (e.g., tails kept as product) prevents land-based sampling. Sampling at sea has been very limited until 2000, due to it not being a targeted species before the 1990s and low Observer coverage, with the exception of 2002 and 2003. Due to its relative non-importance historically and limited resources to study the emerging fishery, the status and historic perspective of monkfish is based largely on population indices that are not disaggregated by size or age, plus distribution studies. Further, a change in survey gear resulted in 2 non-comparable series, prior to and following 1995. Limited information on biology of the species must be extrapolated from other areas.

No information on stock structure has been presented in this paper or elsewhere in Canadian waters, NAFO are used to define stock managements areas but the current work indicates that NAFO division boundaries are not appropriate for defining monkfish management units. Stock definition, in the form of genetic research is required to rationalize stock management boundaries.

Analyses of biomass, abundance, and average size by NAFO Division suggest that survey trawl gear (Engel, and particularly Campelen) may not efficiently sample this species. In particular, small fish, < 15 cm and fish > 90 cm are largely absent in the survey. Based on survey data, the population appears to have fluctuated widely, peaking 3 times in the past 33 years with the most recent peak occurring at present. A change in survey gear in 1995 plus apparent changes in catchability from year to year, which caused large interannual fluctuations, in addition to the low priority accorded this species in terms of research resources for data collection and analysis (noted above), limit deductions that can be reached about the status of this stock.

Although monkfish has always been a regular bycatch in offshore fisheries, catch numbers were low until 2002 and, prior to 1991, there was no directed fishing effort. Consistent with the distribution pattern determined from research surveys, the majority of bycatch originated from the southern Grand Banks. An analysis of the ratio of total commercial catch and survey biomass (index of exploitation) indicates shows a very large increase in the rate of exploitation in 2003-2003 and a result of greatly increased catch/effort. Since the early 1970s, catches of monkfish off the USA have increased steadily resulting in a reduction of the size of the population (NEFSC 2002). Population size has remained low since the mid-1980s. No such decline has, as yet been observed for the Grand Banks population.

OUTLOOK

The status of monkfish in 3LNOPs is difficult to evaluate based on existing data. Survey biomass and abundance patterns show considerable fluctuation among years. In 2003, average size was at a low in the time series while abundance was relatively high suggesting the possibility of good recent recruitment. Survey biomass has increased from mid1990s to the present. Landings remained low until 2002-2003 when catches increased by about 6 times compared to the previous five years due mainly to an increase in effort driven by market conditions. This species is not currently under restriction of quota. As a result of the increase in landings in 2002-2003, index of exploitation has increased by 4 times in the past 5 years. Fishing mortality may now exceed a sustainable level. Further development of the stock will have to be closely monitored given the expansion of the effort on this resource. Fishing effort now occurs over much of the monkfish distribution.

DEFICIENCIES

There remain substantial limitations to our knowledge of monkfish in Newfoundland waters. In the absence of a time series of monkfish lengths from research surveys or adequate length sampling of commercial catches until recent years, a demonstration of size-dependent spatial distribution, coupled with commercial fishery catch locations to identify what part of the stock and what sizes were being targeted by the fishery, is not possible. Limited length measurements have been done for research surveys only since 2001 and no ageing of monkfish have been done, thus precluding any age disaggregated analyses. Biological sampling of commercial catches continues to be greatly inadequate, with only information on removals by weight available. There are uncertainties in reported landings particularly in earlier years, although this study tried to present a better accounting of monkfish catches. For these reasons, available data are not suitable for analysis by traditional stock assessment methods. In addition, all of the previous (limited) biological work such as feeding behaviour and diet, stock structure, morphology and reproduction is based on other populations located south of the Grand Banks. Studies of early life history could also lead to a better understanding of monkfish populations; however, the survey and commercial gears do not capture fish smaller than about 15 cm. Thus, there is no information on the young stages (YOY and age 1).

RESEARCH RECOMMENDATIONS

Little basic information on monkfish on the Grand Banks exists. The following areas of research would be required to facilitate an analytical assessment of the status of monkfish and providing management advice:

- Research is required to determine stock structure of the species to derive appropriate management units.
- Work on maturity has would permit the derivation of a SSB index. Derivation of exploitation indices series for various life stage components, particularly the SSB, can provide some of the input required to derive reference points and conservation limits. A recruitment index is not possible given that YOY and portion of the juvenile population are not captured by the survey gear.
- Age based analyses of the population would yield more options in terms of providing management advice for the stock. Monkfish have not previously been aged on the Grand Banks.
- Spatial dynamics of various population components should be examined in relation to environmental and fishery related influences to better understand the factors that affect the population status.
- Fishing mortality and its effects on the population are not well understood. Enhanced collection of information on size, sex and maturity of commercial catches is required to define the effects of fishing on the population.

- Information on annual yield potential and reproductive potential is required to provide quantitative fisheries management advice.
- The application of assessment models that may facilitate quantitative fisheries management advice for this stock should be examined.

SUMMARY

- There are deficiencies in the knowledge of monkfish in 3LNOPs, thereby limiting our ability to assess the species: lack of information on size and age structure, growth rates, age of maturity (most of the limited research on this species has been done in the USA), commercial catch size and ages, and uncertainties in reported landings.
- Monkfish on the Grand Banks are concentrated along the southwest slope and along the edge of the Laurentian Channel where bottom temperature are warmest (>3^0C). They occupy slightly shallower water in the Summer/fall. The general location has changed little in the past 50 years but there have been small shifts in the centre of concentration with respect to depth in response to changing ambient temperature.
- The population has shown significant fluctuations in survey biomass over the years. Biomass and abundance indices peaked in 1977 and 1988. After declining to a low in 1992-93, the index has increased and 2003 represents a year of peak abundance.
- Average size fluctuated with changes in population size likely a result of years of high recruitment entering the fishable population. Mean weight peaked at about 12 kg in the late 1980s but has declined since (Campelen gear may not select for the large sizes).
- A directed Canadian fishery started in the mid1990s, part of a mixed fishery for thorny skate and white hake, has expanded rapidly in 2002-2003. Total catches increased from 168 t in 2000 to 2,511 t in 2002 and 2,994 t (preliminary) in 2003 as a result of ~10 times increase in effort.
- Extent of fishing effort location increased in recent years and now extends over about 60,000 km^2. High density fishing effort now occurs over much of the distribution of monkfish.
- Correspondingly, relative F (index of exploitation) has increased by about 5 times in the past two years after remaining relatively stable at a low level since the mid1990s. While it is clear that exploitation at the levels observed prior to 2001 were sustainable, fishing mortality in 2002-2003 may exceed a sustainable level.
- Given the limited knowledge of most aspects of monkfish biology and relevant fisheries, it is difficult to determine stock health and whether the current level exploitation is sustainable. However, the index of biomass has continued to rise in spite of the increased effort in the fishery in the past two years.

ACKNOWLEDGEMENTS

We would like to thank Canadian Fishery Observers who collected information on catches and measurements of monkfish, and Department of Fisheries and Oceans Canada (DFO) staff who measured and counted monkfish during research surveys. We would also like to thank Fisheries Management and Policy & Economics (DFO) staff who provided us with licensing information and monkfish catch statistics.

REFERENCES

ALMEIDA, F.P, D-L. HARTLEY, AND J. BURNETT. 1995. Length-weight relationship and sexual maturity of goosefish off the northeast coast of the United States. N. Am. J. Fish. Man. 15: 14-25.

ALPOIM, R., A. ÁVILA DE MELO, R. BAÑON, M. CASAS, S. CERVIÑO, S. JUNQUERA, I. MARTÍN, H. MURUA, X. PAZ, G. PÉREZ-GÁNDARAS, J.L. DEL RÍO, E. RODRÍGUEZ-MARÍN, F. SABORIDO-REY, E.J. DOS SANTOS AND A. VÁZQUEZ. 2002. Distribution and Main Characteristic of Fish Species on Flemish Cap Based on the 1988-2002 EU-Surveys in July. NAFO SCR Doc. 02/72 Serial No. N4685 73 p.

ARMSTRONG, M.P., J.A. MUSICK, AND J.A. COLVOCORESSES. 1992. Age, growth, and reproduction of the goosefish *Lophius americanus* (Pisces: Lophiiformes). Fish. Bull. 90: 217-230.

ANONYMOUS. MS 2003. Geomatica V. 9 Users Guide. PCI Geomatics, 50 West Wilmot St. Richmond Hill. Ont.

ATKINSON, D.B. MS 1993. Some observations on the biomass and abundance of fish captured during stratified random bottom trawl surveys in NAFO Divisions 2J3KL, Fall 1981-1991. NAFO SCR Doc. 93/29, Serial No. N2209, 18 p.

BEANLANDS, D., AND C. ANNAND. 1996. Status of monkfish in 4VWX5Zc. DFO Atl. Fish. Res. Doc. 96/104: 25 p.

BEANLANDS, D., B. BRANTON, AND B. MOHN. 2000. Status of monkfish in 4VWX5Zc. DFO Atl. Fish. Res. Doc. 00/143: 67 p.

BIGELOW, H.B., AND SCHROEDER. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Edited by B.B. Collette and G. Klein-MacPhee. 3rd ed. Smithsonian Inst. Press. 748 p.

BISHOP, C.A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43. 10p.

CARUSO, J.H. 1986. Lophiidae. p. 1362-1363. *In* P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen, and E. Tortonese (eds.) Fishes of the North-eastern Atlantic and the Mediterranean, Volume 3. UNESCO, Paris.

CHIKARMANE, H.M., A.M. KUZIRIAN, R. KOZLOWSKI, M. KUZIRIAN, AND T. LEE. 2000. Population genetic structure of the goosefish, *Lophius americanus*. Biol. Bull. 199:227–228.

CHURCHILL, G.L. 1994. Experimental monkfish fishery, Newfoundland 1993-1994. Atl. Fish. Adjust. Prog., Industry Development Division Rep. 28 p.

COLBOURNE, E., AND C. FITZPATRICK. MS 2003. Physical Oceanographic Conditions in NAFO Subareas 2 and 3 on the Newfoundland and Labrador Shelf During 2002. NAFO SCR Doc. 03/14 Serial No. N4820 25 p.

DFO. 1996. Monkfish on the Scotian Shelf and northeast Georges Bank. DFO Stock Status Report 96/97E: 6 p. www.dfo-mpo.gc.ca/csas.

DFO. 2000. Monkfish on the Scotian Shelf and Northeast Georges Bank (Div. 4VWX and 5Zc). DFO.

DFO. 2001. Monkfish(*Lophius americanus*) in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps. DFP Stock Status Report A2-20 (2000) 4 p. www.dfo-mpo.gc.ca/csas

DFO. 2002. Monkfish on the Scotian Shelf and Northeast Georges Bank (Div. 4VWX and 5Zc). DFO Stock Status Report A3-30 (2002) 7 p. www.dfo-mpo.gc.ca/csas.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Stud. No. 2.

GRÉGOIRE, F. 1998. Débarquements commerciaux et prises accessoires de Baudroie (*Lophius americanus*) et de Grosse Poule de Mer *(Cyclopterus lumpus)* dans l'estuaire et le golfe du Saint-Laurent. Rapp. can. ind. sci. halieut. aquat. 243:x + 63 p.

HARTLEY, D-L. 1995. The population biology of goosefish, *Lophius americanus* in the Gulf of Maine. MSc. Thesis. Univ. of Mass. Amherst Mass. 142pp.

KULKA, D.W. 1982. Estimates of discarding by the Newfoundland offshore fleet in 1981. CAFSAC Res. Doc. 82/34: 22p.

KULKA, D.W. 1984. Estimates of discarding by the Newfoundland offshore fleet in 1982. NAFO SCR Doc. 84/28, Ser. No. N809: 16p

KULKA, D.W. 1985. Estimates of discarding by the Newfoundland offshore fleet in 1983. NAFO SCR Doc. 85/75, Ser. No. N1033: 19p

KULKA, D.W. 1986a. Estimates of discarding by the Newfoundland offshore fleet in 1984, with reference to trends over the past four years. NAFO SCR Doc. 86/12, Ser. No. N1120: 20p.

KULKA, D.W. 1986b. Estimates of discarding by the Newfoundland offshore fleet in 1985, with reference to trends over the past 5 years. NAFO SCR Doc. 86/95, Ser. No. N1221: 20p.

KULKA, D.W. 1989. Bycatch of commercial groundfish species in the northern shrimp fisheries, 1980-1994. DFO Atl. Fish. Res. Doc. 95/48: 16p.

KULKA, D.W. 1998. SPANdex - SPANS geographic information system process manual for creation of biomass indices and distributions using potential mapping. DFO Atl. Fish. Res. Doc. 98/60: 28p.

KULKA, D.W., AND E.M. DEBLOIS. 1996. Non traditional groundfish species on Labrador Shelf and Grand Banks – Wolffish, Monkfish, White Hake and Winter Flounder. DFO Atl. Fish. Res. Doc. 96/97: 49p.

KULKA, D.W., AND C.M. MIRI. 2001. The status of Monkfish (*Lophius americanus*) in NAFO Divisions 2J, 3K, 3L, 3N, 3O and Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 2001/004: 42p.

KULKA, D.W., AND J.R. FIRTH. 1987. Fisheries Observer Program Training Manual - Newfoundland Region. Can. Tech. Rep. Fish. Aquat. Sci. 1355 (revised): 197 p.

KULKA, D.W., AND S.C. STEVENSON. 1986. Trends in the discarding of Divisions 2J3KL cod by the Newfoundland offshore fleet for 1981-86, with particular reference to the size of fish. CAFSAC Res. Doc. 86/101: 19p.

KULKA, D.W., J.S. WROBLEWSKI, AND S. NARYANAN. 1995. Inter-annual patterns in the Winter distribution and recent changes and movements of northern Atlantic cod (*Gadus morhua* Linnaeus, 1758) on the Newfoundland-Labrador shelf. ICES J. Mar. Sci. 52: 889-902.

MCKENZIE, R.A. 1936. Some notes on the monkfish or angler (*Lophius piscatorius* Linn.). Can. Field Nat. 50: 55-56.

MURRAY, J., AND J. HJORT. 1912. The Depths of the Ocean: A general account of the modern science of Oceanography based largely on scientific results of the Norwegian steamer "Michael Sars" in the North Atlantic. MacMillan, London, 821 pp.

NEFSC. 2000. 31st Northeast Regional Stock Assessment Workshop (31st SAW). Northeast Fish. Sci. Center Ref. Doc. 00-14, 45 p.

NEFSC. 2002. Report of the 34th Northeast Regional Stock Assessment Workshop (34th SAW): Consensus Summary of Assessments. Northeast Fish. Sci. Center Ref. Doc. 02-06. 358 p.

SCOTT, W.B., AND M.G. SCOTT. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

SMITH, S.J., AND G.D. SOMERTON. 1981. STRAP: A user oriented computer analysis system for groundfish research vessel survey data. Can. Tech. Rep. Fish. Aquat. Sci. 1030: iv + 66p.

STEIMLE, F.W., W.W. MORSE, AND D.L. JOHNSON. 1999. Essential fish habitat source document: goosefish, *Lophius americanus*, life history and habitat characteristics. NOAA Tech. Memorandum NMFS-SE 127: 31 p.

STEVENSON, S.C. 1978. A descriptive report on the discarding of fish by the Canadian offshore fishery in ICNAF Subareas 2 and 3. ICNAF Res. Doc. 78/VI/67.

WALSH, S.J. 1992. Size-dependant selection at the footgear of a groundfish survey trawl. N. Am. J. of Fish. Mgmt. **12**: 652-633.

Table 1a. Number of sets prosecuted per stratum in Spring research surveys when Campelen trawl gear was deployed, 1996-2003.

			# of Sets							
Div.	**Depth (m)**	**Stratum**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
3O	57-92	330	8		8	7	7	7	7	7
3O		331	2	2	2	2	2	2	2	2
3O		338	7	6	7	7	6	6	6	6
3O		340	6	6	7	6	5	5	5	5
3O		351	8	8	10	9	8	8	8	8
3O		352	9	8	10	9	9	8	8	8
3O		353	5	4	5	5	5	4	4	4
3O	93-183	329	6	6	7	6	5	5	5	5
3O		332	4	3	4	4	4	3	3	3
3O		337	3	3	4	3	4	3	3	3
3O		339	2	2	2	2	2	2	2	2
3O		354	2	2	2	2	2	2	2	2
3O	184-274	333	2	2	2	2	2	2	2	2
3O		336	2	2	2	2	2	2	2	2
3O		355	2	2	2	2	2	2	2	2
3O	275-366	334	2	2	2	2	2	2	2	2
3O		335	2	2	2	2	2	2	2	2
3O		356	2	2	2	2	2	2	2	2
3O	367-549	717	2	2	2	2	2	2	2	2
3O		719	2	2	2	2	2	2	2	2
3O		721	2	2	2	2	2	2	2	2
3O	550-731	718	2	2	3	2	2	2	2	2
3O		720	2	2	2	2	2	2	2	2
3O		722	2	2	2	2	2	2	2	2
3Ps	<=56	314	8	7	7	8	7	7	8	7
3Ps		320	10	9	11	8	11	10	10	11
3Ps	57-91	315	6	6	7	7	7	7	7	7
3Ps		321	9	9	10	9	10	9	10	10
3Ps		325	9	6	8	8	8	8	8	8
3Ps		326	2	2	2	2	2	2	2	2
3Ps	57-92	293		2	2	2	2	2	2	2
3Ps		308	2	2	2	2	2	2	2	2
3Ps		312	3	2	2	2	2	2	2	2
3Ps		783		2	2	2	2	2	2	2
3Ps	93-183	294		2	2	2	2	2	2	2
3Ps		297		2	2	2	2	2	2	2
3Ps		307	4	3	3	3	3	3	3	3
3Ps		311	3	2	3	3	3	3	3	3
3Ps		317	2	2	2	2	2	2	2	2
3Ps		319	8	8	8	8	8	8	8	8
3Ps		322	11	11	13	12	11	12	13	13
3Ps		323	5	4	6	6	5	6	6	5
3Ps		324	3	3	4	4	4	4	4	4
3Ps		781	2	4	4	4	4	4	4	4
3Ps		782		2	2	2	2	2	2	2
3Ps	184-274	295		2	2	2	2	2	2	2
3Ps		298		2	2	2	2	2	2	2
3Ps		300		2	2	2	2	2	2	2
3Ps		306	3	3	3	3	3	3	3	3
3Ps		309	3	2	2	2	2	2	2	2
3Ps		310	2	2	2	2	2	2	2	2
3Ps		313	2	2	2	2	2	2	2	2
3Ps		779	3	3	3	4	4	4	4	4
3Ps		780		3	3	3	2	3	3	3
3Ps	185-274	316	2	2	2	2	2	2	2	2
3Ps		318	2	2	2	2	2	2	2	2
3Ps	275-366	296		2	2	2	2	2	2	2
3Ps		299		2	2	2	2	2	2	2
3Ps		705	2	2	2	2	2	2	2	2
3Ps		706	3	3	4	4	4	4	4	4
3Ps		707	2	2	2	2	2	2	2	2
3Ps		715	2	2	2	2	2	2	2	2
3Ps		716	5	4	4	4	4	4	4	4
3Ps	367-549	708	2	2	3	2	2	2	2	2
3Ps		711	4	5	5	5	5	5	5	5
3Ps		712	6	5	6	6	5	6	6	6
3Ps		713	7	6	7	7	6	6	7	7
3Ps		714	9	7	9	9	9	9	9	9
3Ps	550-731	709	2		2	2	2	2	2	2
3Ps	732-914	710				2				

Table 1b. Total number of monkfish caught per stratum in Spring research surveys when Campelen trawl gear was deployed, 1996-2003.

			Numbers per tow							
Div.	Depth (m)	Stratum	1996	1997	1998	1999	2000	2001	2002	2003
3O	57-92	330								
3O		331								
3O		338								
3O		340								
3O		351								
3O		352						1.0		
3O		353					1.0			
3O	93-183	329		0.9						
3O		332	1.0			5.0	17.0	5.0		19.0
3O		337				5.3	4.0	4.0	1.0	1.0
3O		339								
3O		354				1.0	1.0	1.1		
3O	184-274	333	3.1			0.8	1.0	2.0	2.0	2.0
3O		336		1.0	4.2	2.9	2.3	3.0	1.0	2.0
3O		355			0.9				2.0	
3O	275-366	334	1.9	2.7		1.7	3.7	1.8	5.0	2.0
3O		335		0.8		1.8	1.0	1.8	2.0	4.4
3O		356						0.9		
3O	367-549	717	1.0	21.9	0.9	0.8		2.8	10.0	8.0
3O		719		3.6		0.9	2.0	1.1	2.3	1.0
3O		721					0.9		0.9	1.8
3O	550-731	718		1.5					10.0	
3O		720		8.9						
3O		722		8.0					1.8	1.0
3Ps	<=56	314								
3Ps		320								
3Ps	57-91	315								
3Ps		321								
3Ps		325								
3Ps		326								
3Ps	57-92	293								
3Ps		308								
3Ps		312								
3Ps		783								
3Ps	93-183	294								
3Ps		297								
3Ps		307								
3Ps		311				3.0				
3Ps		317					5.0			
3Ps		319				1.0	3.0		2.0	
3Ps		322								
3Ps		323								
3Ps		324								
3Ps		781								
3Ps		782								
3Ps	184-274	295								
3Ps		298		1.0		1.8		3.0		1.0
3Ps		300					0.9			
3Ps		306		8.0		1.8	4.6	7.0	1.8	
3Ps		309					1.1			
3Ps		310	1.0	1.0	2.0	3.8	3.4	1.8		
3Ps		313	0.9	5.0	1.8	3.0	3.0	6.0	5.0	6.0
3Ps		779								
3Ps		780								
3Ps	185-274	316	6.0	8.0	13.0	6.9	8.0	7.0	5.0	9.0
3Ps		318		2.0			0.9	5.0	14.0	1.0
3Ps	275-366	296								
3Ps		299		2.0	0.8	1.0		1.0	3.0	4.4
3Ps		705	1.7	2.0	1.9	0.9		3.6	3.0	0.9
3Ps		706	1.0		3.0	1.8	2.9	2.0	4.0	3.0
3Ps		707	1.6	2.7	2.0			1.0		12.0
3Ps		715	1.9	4.1		1.0	1.8	0.9	1.0	1.0
3Ps		716	0.0	2.8	2.8		0.8	0.9	0.9	1.9
3Ps	367-549	708	1.0	6.6						1.0
3Ps		711	1.0	1.9	2.8	0.8	2.0	2.0	1.0	3.9
3Ps		712	2.0	7.0	1.0	0.8			2.0	6.7
3Ps		713	2.0	2.0	0.8		2.0	1.8	5.0	3.0
3Ps		714	1.9	0.9	1.0		1.9	4.4	8.3	7.9
3Ps	550-731	709	0.0							
3Ps	732-914	710								

Table 1c. Total catch (kg) of monkfish per stratum in Spring research surveys when Campelen trawl gear was deployed, 1996-2003.

			Numbers per tow							
Div.	**Depth (m)**	**Stratum**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
3O	57-92	330								
3O		331								
3O		338								
3O		340								
3O		351								
3O		352						0.3		
3O		353					4.2			
3O	93-183	329		0.1						
3O		332	10.6			9.0	10.6	30.5		29.2
3O		337				12.8	10.5	12.1	5.3	1.7
3O		339								
3O		354				3.8	3.4	0.7		
3O	184-274	333	13.6			0.9	1.0	5.8	6.0	6.1
3O		336		6.6	23.0	5.0	5.9	6.6	2.6	7.4
3O		355			3.2				6.9	
3O	275-366	334	5.8	2.0		6.9	12.7	8.0	13.2	8.2
3O		335		3.9		7.3	21.8	2.7	6.7	10.2
3O		356						2.8		
3O	367-549	717	2.8	49.0	5.2	1.5		5.1	30.2	30.0
3O		719		13.4		3.6	7.9	3.5	10.9	4.1
3O		721					3.0		3.2	6.1
3O	550-731	718		17.3					47.9	
3O		720		47.9						
3O		722		46.2					6.6	3.2
3Ps	<=56	314								
3Ps		320								
3Ps	57-91	315								
3Ps		321								
3Ps		325								
3Ps		326								
3Ps	57-92	293								
3Ps		308								
3Ps		312								
3Ps		783								
3Ps	93-183	294								
3Ps		297								
3Ps		307								
3Ps		311				8.5				
3Ps		317					14.0			
3Ps		319				1.6	5.3		1.2	
3Ps		322								
3Ps		323								
3Ps		324								
3Ps		781								
3Ps		782								
3Ps	184-274	295								
3Ps		298		0.1		1.7		3.3		5.2
3Ps		300					10.5			
3Ps		306		8.3		0.6	5.4	18.2	4.8	
3Ps		309					0.1			
3Ps		310	0.2	5.5	0.4	5.7	1.5	0.9		
3Ps		313	0.3	4.5	2.8	1.4	4.1	13.5	3.2	13.0
3Ps		779								
3Ps		780								
3Ps	185-274	316	22.1	10.7	11.6	10.6	8.6	7.8	8.1	24.7
3Ps		318		0.4			0.1	17.7	44.6	0.1
3Ps	275-366	296								
3Ps		299		13.8	6.0	7.7		3.3	1.9	22.2
3Ps		705	3.7	2.1	4.6	2.1		3.6	7.4	2.0
3Ps		706	0.7		8.8	3.1	17.4	7.1	14.2	7.0
3Ps		707	6.1	25.3	3.5			4.1		46.7
3Ps		715	1.0	36.8		3.5	1.8	0.7	10.9	1.2
3Ps		716		3.9	14.0		1.8	1.0	2.4	4.6
3Ps	367-549	708	9.1	62.6						10.2
3Ps		711	6.8	7.4	14.1	0.1	5.6	15.5	3.5	19.9
3Ps		712	7.2	26.9	3.1	1.0			4.9	32.9
3Ps		713	21.3	26.9	2.1		9.5	10.8	22.1	10.6
3Ps		714	2.7	0.0	7.0		1.0	8.7	31.1	32.9
3Ps	550-731	709								
3Ps	732-914	710								

Table 2. Biomass, abundance, and mean weight of monkfish in NAFO Div. 3LNOPs, 1972-2003, based on Spring research surveys.

	Biomass (t)				Abundance (thousands)				Mean Weight (kg)			
Year	Div. 3N	Div. 3O	Div. 3Ps	All Divs.	Div. 3N	Div. 3O	Div. 3Ps	All Divs.	Div. 3N	Div. 3O	Div. 3Ps	Average
1972	0	0	446	446	0	0	116	116			3.8	
1973	0	296	882	1,178	0	67	165	232		4.4	5.3	4.9
1974	0	0	746	746	0	0	190	190			3.9	2.0
1975	0	27	1221	1,248	0	8	166	174		3.4	7.4	5.4
1976	0	194	1029	1,223	0	25	224	249		7.8	4.6	6.2
1977	0	332	1,053	1,385	0	123	184	307		2.7	5.7	4.2
1978	0	506	597	1,103	0	70	157	227		7.2	3.8	5.5
1979	0	131	370	501	0	108	142	250		1.2	2.6	1.9
1980	0	535	223	758	0	161	208	369		3.3	1.1	2.2
1981	0	71	538	609	0	18	283	301		4.0	1.9	2.9
1982	0	1,231	218	1,449	0	313	94	407		3.9	2.3	3.1
1983	0	0	1,130	1,130	0	0	421	421			2.7	
1984	0	246	1,387	1,633	0	128	234	361		1.9	5.9	3.9
1985	0	682	1,098	1,780	0	129	357	486		5.3	3.1	4.2
1986	0	535	2,580	3,115	0	64	419	483		8.4	6.2	7.3
1987	0	916	2,843	3,759	0	157	412	569		5.8	6.9	6.4
1988	179	2,191	1,430	3,800	20	186	360	566	9.0	11.8	4.0	8.3
1989	0	359	1,445	1,804	0	44	235	279		8.2	6.2	7.2
1990	0	453	2,220	2,673	0	34	341	375		13.4	6.5	9.9
1991	0	909	2,187	3,096	0	196	425	621		4.6	5.1	4.9
1992	0	93	710	803	0	34	187	222		2.7	3.8	3.2
1993	0	185	474	659	0	29	107	137		6.3	4.4	5.4
1994	1	1,224	1,218	2,442	4	426	143	573		2.9	8.5	5.7
1995	0	232	1,098	1,331	0	38	167	204		6.1	6.6	6.4
1996	0	590	1,136	1,726	0	92	296	388		6.4	3.8	5.1
1997	0	1,515	2,881	4,396	0	461	778	1,239		3.3	3.7	3.5
1998	0	274	1,187	1,461	0	51	452	503		5.4	2.6	4.0
1999	0	1,165	640	1,805	0	509	370	879		2.3	1.7	2.0
2000	0	1,266	1,324	2,590	0	883	596	1,479		1.4	2.2	1.8
2001	0	2,287	1,626	3,913	0	601	629	1,230		3.8	2.6	3.2
2002	0	1,374	2,153	3,527	0	362	754	1,116		3.8	2.9	3.3
2003	0	2,107	3,008	5,115	0	1,136	800	1,936		1.9	3.8	2.8

Table 3a. Canadian and non-Canadian landings of monkfish in 3LNOPs, 1985-2003. Canadian landings are compiled from Zonal Interchange Format (ZIF) files. Canadian discards and non-Canadian catches inside 200 miles were estimated from Observer data. Catches in non-Canadian waters were collated from NAFO statistics. Note that 2002 and 2003 do not include NAFO estimates, and ZIF data for 2003 are preliminary.

	3L				3N				3O				3PS				3LNOPs
	Can. Land	Can. Disc.	non-Can.	All	Can. Land	Can. Disc.	non-Can.	All	Can. Land	Can. Disc.	non-Can.	All	Can. Land	Can. Disc.	non-Can.	All	All
1985	6.9	0.1	0.0	7.0	0.1	1.6	2.6	4.3	3.6	6.2	114.6	124.5	17.1	67.5	2.2	86.7	222.5
1986	8.4	0.1	68.0	76.5	0.1	0.0	34.0	34.1	21.9	60.8	53.1	135.8	33.2	8.5	1.0	42.7	289.1
1987	29.0	0.1	5.0	34.1	0.4	1.2	1,418.0	1,419.6	9.2	6.7	360.2	376.2	25.5	19.4	25.0	69.9	1,899.8
1988	1.4	0.1	79.0	80.4	0.3	0.4	352.0	352.7	9.2	42.4	5.7	57.3	8.5	30.3	45.0	83.8	574.3
1989	0.5	0.2	0.0	0.7	0.3	0.0	176.0	176.3	19.8	72.9	30.6	123.2	6.0	126.6	34.7	167.3	467.5
1990		2.3	46.0	48.3	0.1	0.9	138.0	139.0	13.1	56.3	2.7	72.1	8.4	77.9	6.8	93.1	352.5
1991	2.0	0.2	0.0	2.2	1.7	0.2	281.0	283.0	140.0	40.3	7.8	188.1	48.1	102.7	6.1	156.9	630.2
1992	2.6	0.3	0.0	3.0	0.7	0.0	7.1	7.9	246.7	13.8	45.5	306.0	91.3	21.2	4.8	117.3	434.1
1993		0.1	0.0	0.1	4.4	0.0	0.0	4.5	431.8	13.2	5.9	450.8	40.6	6.0	0.0	46.6	502.1
1994		0.0	0.0	0.0	0.1	0.0	0.0	0.1	441.7	3.0	0.0	444.7	388.0	2.4	0.0	390.5	835.2
1995	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	80.7	1.3	0.0	82.0	187.8	3.6	0.0	191.5	273.6
1996	3.1	0.0	0.0	3.1		0.0	0.0	0.0	122.6	1.3	0.0	123.9	110.2	3.9	0.0	114.1	241.0
1997	0.3	0.0	0.0	0.3	0.5	0.0	1.0	1.5	344.2	9.8	0.0	354.0	111.3	1.8	0.0	113.0	468.8
1998	0.0	0.0	0.0	0.0		0.0	1.0	1.0	266.8	28.9	1.0	296.8	165.0	0.5	1.1	166.6	464.4
1999		0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.3	7.7	0.0	109.0	67.1	0.3	0.0	67.4	176.4
2000		0.0	0.0	0.0	0.0	0.1	2.0	2.1	93.3	34.7	2.0	130.1	35.4	0.4	0.0	35.8	168.0
2001		0.0	0.0	0.0	1.6	0.0	0.0	1.6	521.7	81.5	0.0	603.2	275.6	45.9	0.1	321.6	926.3
2002	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	1,687.2	114.5	0.0	1,801.7	657.9	49.9	1.0	708.8	2,510.9
2003	0.6	0.0	0.0	0.6	0.3	0.0	0.0	0.3	2,174.4	165.7	0.0	2,340.1	619.7	33.4	0.0	653.1	2,994.1

Table 3b. Canadian monkfish landings in 3LNOPs, 1985-2003, by directed species. Data are compiled from Zonal Interchange Format (ZIF) files. Note that ZIF data for 2003 are preliminary.

Dir species	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Monkfish				0.0	0.4	0.4		0.2	12.6	270.3	72.1	143.0	103.4	185.7	49.2	30.5	581.9	1,945.7	2,593.2
Skates									0.1	22.6	129.6	44.2	283.0	206.1	84.2	85.3	112.8	326.2	121.7
Witch				0.7	0.5	1.8	108.1	198.3	317.8	16.0	1.4	5.4	3.7	14.8	1.4	0.4	8.1	3.6	8.0
Unspec	26.2	59.2	53.1	4.3	0.1		1.5	8.6	22.9	445.5	0.3	0.2	0.6		0.0	0.0	0.1	0.1	
Plaice	0.0		1.2	0.0	0.9	0.1	40.4	81.0	66.1	0.0	0.0			0.0			0.0	0.0	
Halibut				0.1	0.6	0.8	0.1	0.2	0.5	61.1	11.3	7.6		8.8	5.4	3.2	39.2	10.4	19.7
GF_unsp	1.0	3.9	5.6	1.7	0.3	2.9	7.9	14.7	3.6	9.7	43.0	23.2	0.1	0.0					
Cod	0.3		3.3	2.5	4.1	6.0	5.7	15.9	21.7	0.0	0.0	0.1	2.8	3.6	2.0	2.7	9.0	20.2	9.5
WhHake				0.6	1.4	0.8	0.0	7.9	1.6	0.2	8.4	9.5	5.7	3.0	1.1	0.9	25.2	13.2	21.9
Redfish	0.2	0.6	0.1	0.3	0.0	0.1	3.7	0.3	9.3	3.6	1.8	1.7	11.3	9.5	5.5	3.1	17.7	15.2	14.3
Turbot			0.9					0.4	0.8	0.6	0.1	0.7	44.1	0.4	19.4	2.3	3.3	7.5	3.4
Flat ns							15.1	10.8	15.9	0.1									
Haddock				7.3	14.5	4.8	5.6	4.6	2.2		0.0	0.3	0.3					0.0	0.0
Scallops				2.0	3.1	3.7	2.9	0.4	0.0	0.1									
Pollock				0.0	0.5	1.8	0.0	0.0	0.0	0.0	0.5	0.1	1.4	0.1	0.2	0.3	0.7	3.0	2.6
Y_Tail				0.0	0.0	0.1	0.8	0.7	2.0						0.0	0.0	0.8	0.4	0.4
Winter														0.0	0.1	0.1	0.0	0.0	0.0
Shrimp								0.2											
SnowCrab																0.0	0.0	0.0	0.1
Cusk				0.0			0.0												
S_Hake											0.0								
Lumpfish																	0.0		
Shark									0.0										

Table 3c. Canadian monkfish landings in 3LNOPs, 1985-2003, by directed and non-directed modes. Canadian landings are compiled from Zonal Interchange Format (ZIF) files, and discards are estimated from Observer data. Note that ZIF data for 2003 are preliminary.

	3L		3N		3O		3Ps		All	All		
Year	Bycatch	Directed	Bycatch	Directed	Bycatch	Directed	Bycatch	Directed		Bycatch	Directed	Discards
1985	7		0		4		17		28	28	0	75
1986	8		0		22		33		64	64	0	69
1987	29		0		9		26		64	64	0	27
1988	1		0	0	9		9	0	19	19	0	73
1989	1		0		19	0	6	0	27	26	0	200
1990			0		13	0	8	0	22	21	0	137
1991	2		2		140		48		192	192	0	143
1992	3		1		247	0	91	0	341	341	0	35
1993			4		419	13	41	0	477	464	13	19
1994			0	0	399	42	160	228	830	559	270	5
1995	0		0		64	17	132	56	269	197	72	5
1996	0	3			56	66	37	74	236	93	143	5
1997	0		1		286	58	66	45	456	353	103	12
1998	0				187	80	59	106	432	246	186	29
1999			0		83	18	36	31	168	119	49	8
2000			0	0	79	15	20	16	129	98	31	35
2001			0	1	123	399	94	182	799	217	582	127
2002	0		0		277	1,410	122	535	2,345	400	1,946	164
2003		1	0		88	2,086	113	506	2,795	202	2,593	199

Table 3d. Canadian monkfish landings in 3LNOPs, 1985-2003, by directed and non-directed modes and by gear type. Data are compiled from Zonal Interchange Format (ZIF) files. Note that ZIF data for 2003 are preliminary.

	Gillnet		Lines		Other	Trawl		Seine		Traps
Year	**Bycatch**	**Direct**	**Bycatch**	**Direct**	**Bycatch**	**Bycatch**	**Direct**	**Bycatch**	**Direct**	**Bycatch**
1985	6		0		13	8				
1986	8		0		23	31		2		
1987	27		1		15	19		2		
1988	4		2		2	9	0	3		
1989	0		1		3	21	0	1		
1990			0		4	17	0	0		
1991	1		0		3	187		1		
1992	35		0		0	298	0	7		
1993	22	12	0		0	437	0	5	1	
1994	492	270	0		0	67	0	0		
1995	139	72	0			56		1		
1996	65	143	0			27	0	0		
1997	307	103	0			45	0	0		
1998	209	186	0		0	37		0		
1999	95	49	0			24		0		
2000	94	31	0			4	0	0		0
2001	170	582	4			43		0		0
2002	377	1,942	1	4		21		0		0
2003	172	2,589	2	1		27	3	0		0

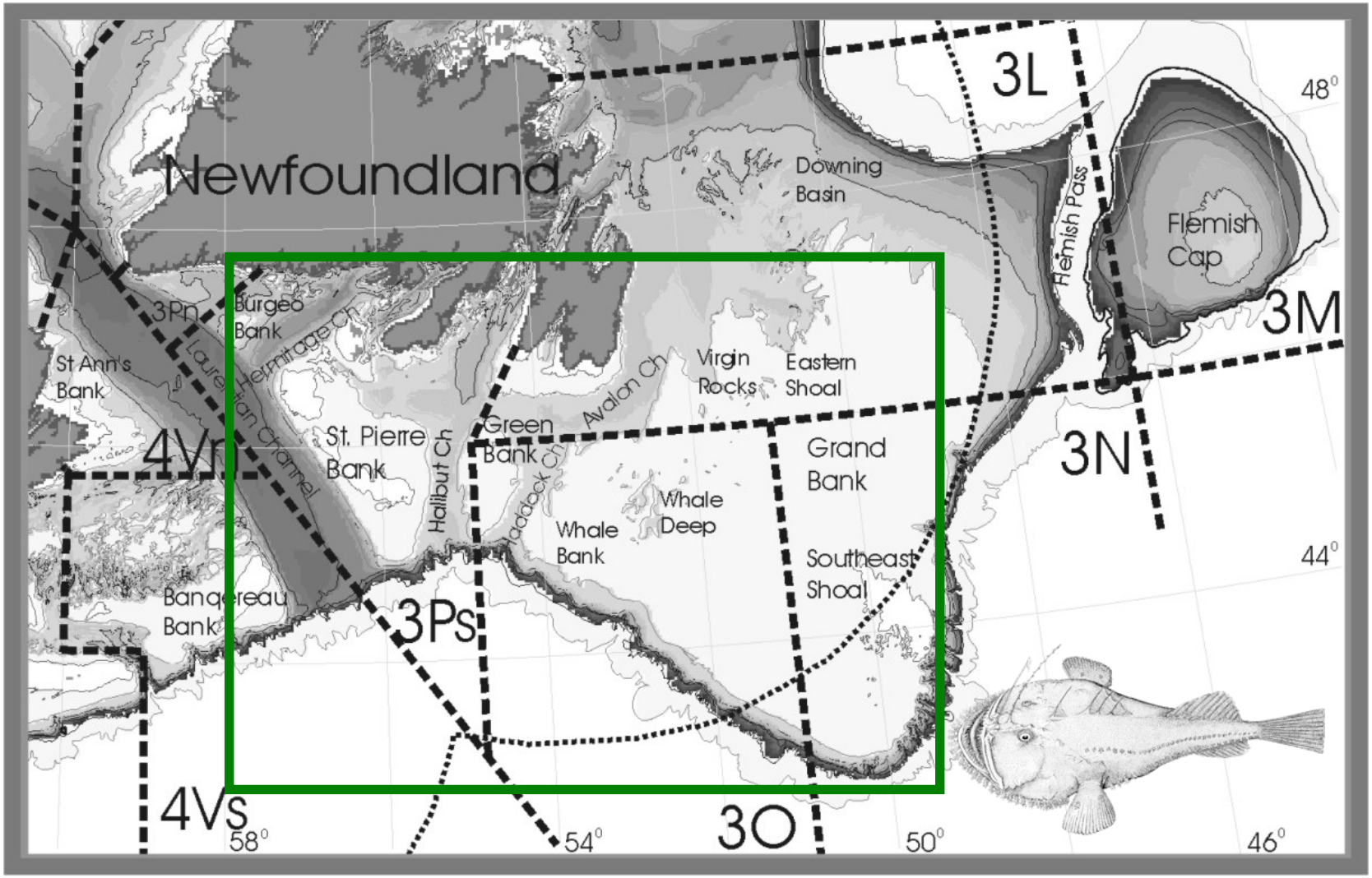


Figure 1. Study area for monkfish indicating NAFO Divisions, Canada's 200-mile-limit, particular locations, and bathymetry. Green box denotes location of the monkfish resource and commercial fishing grounds.

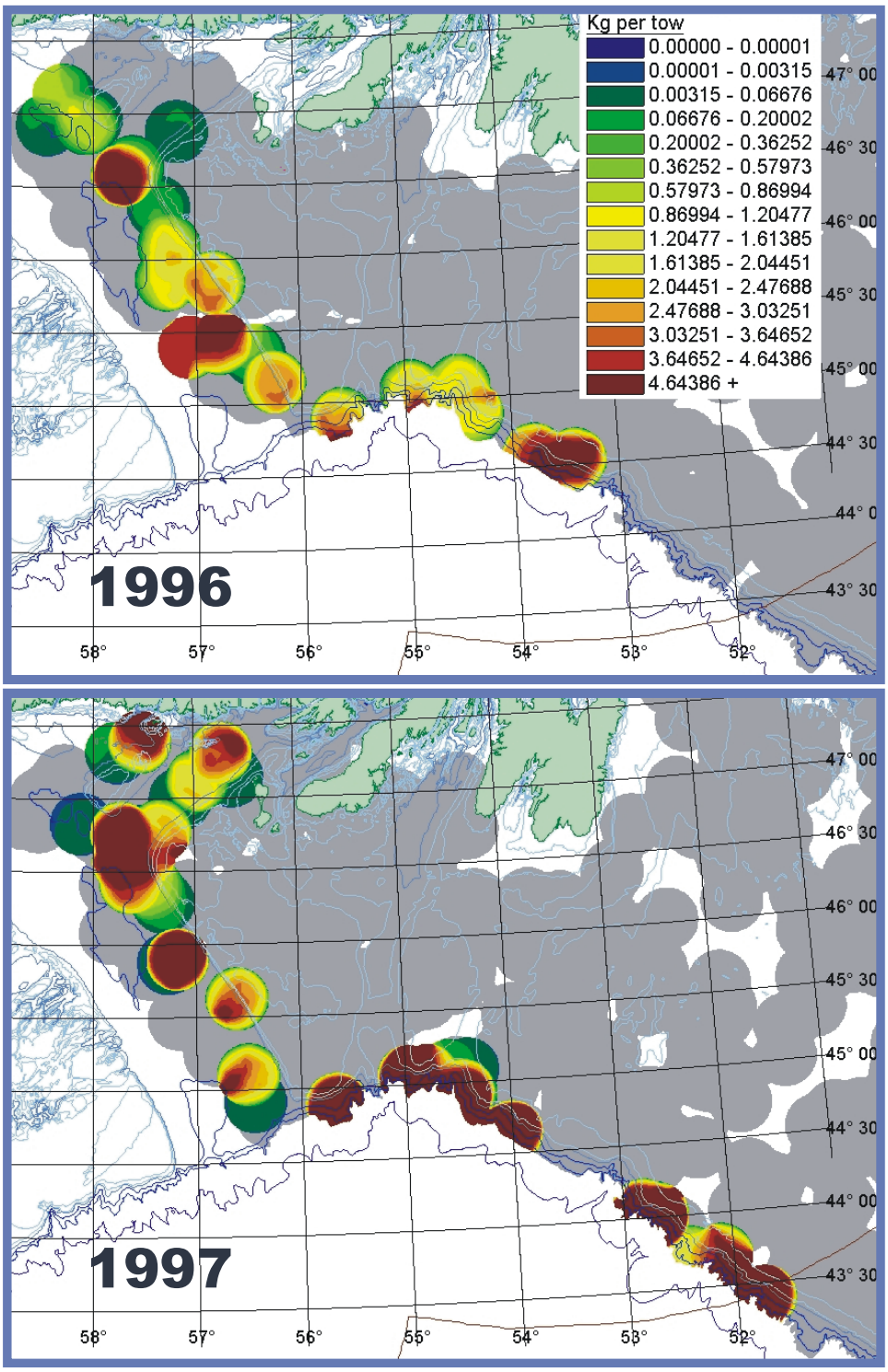


Figure 2a. Monkfish distribution from Spring research surveys, 1996-1997. Grey denotes surveyed areas. Other colours represent various densities (kg per tow) of monkfish: green illustrates low density; red indicates high density.

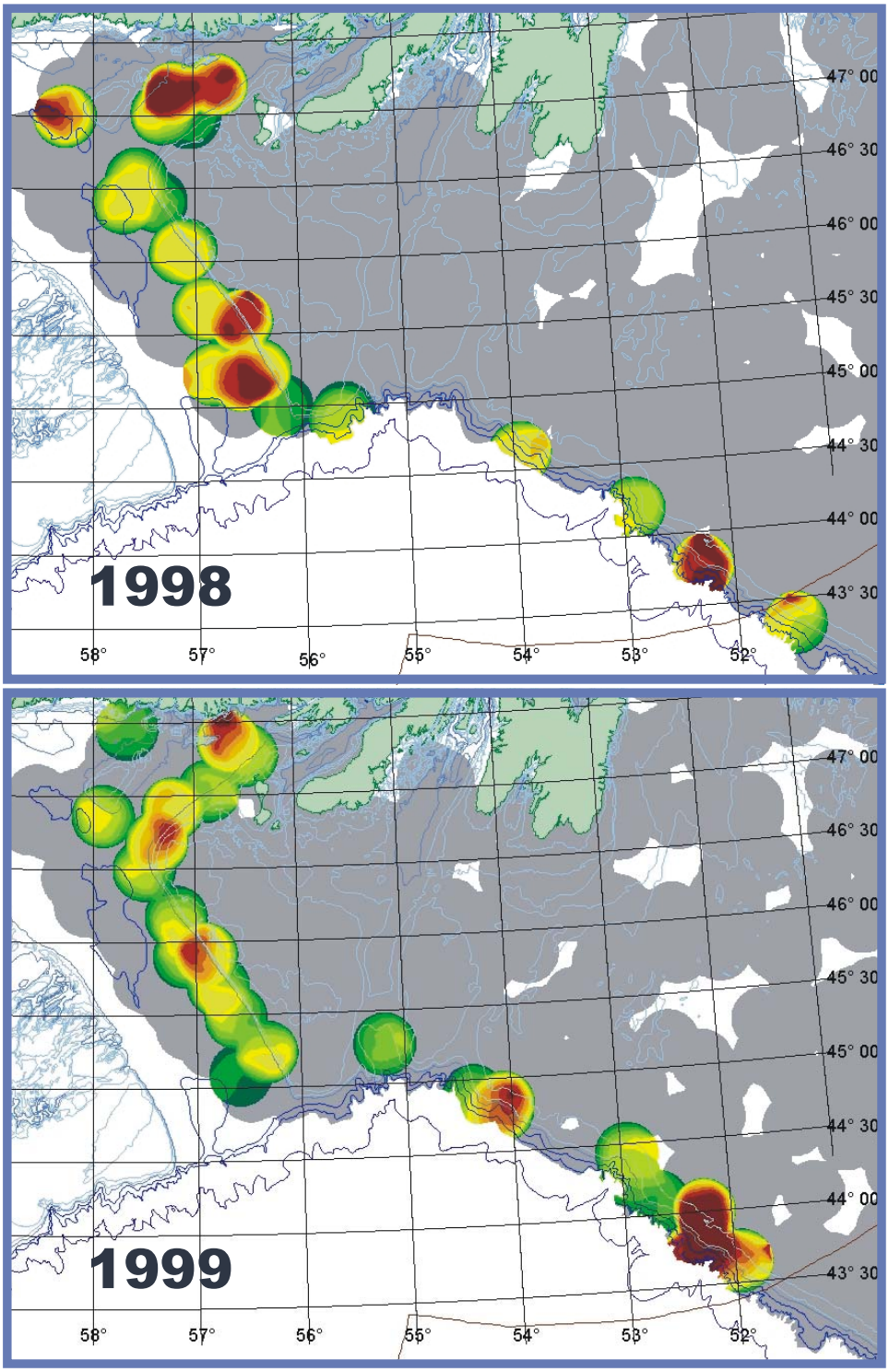


Figure 2b. Monkfish distribution from Spring research surveys, 1998-1999 (see Fig. 2a for legend). Grey denotes surveyed areas.

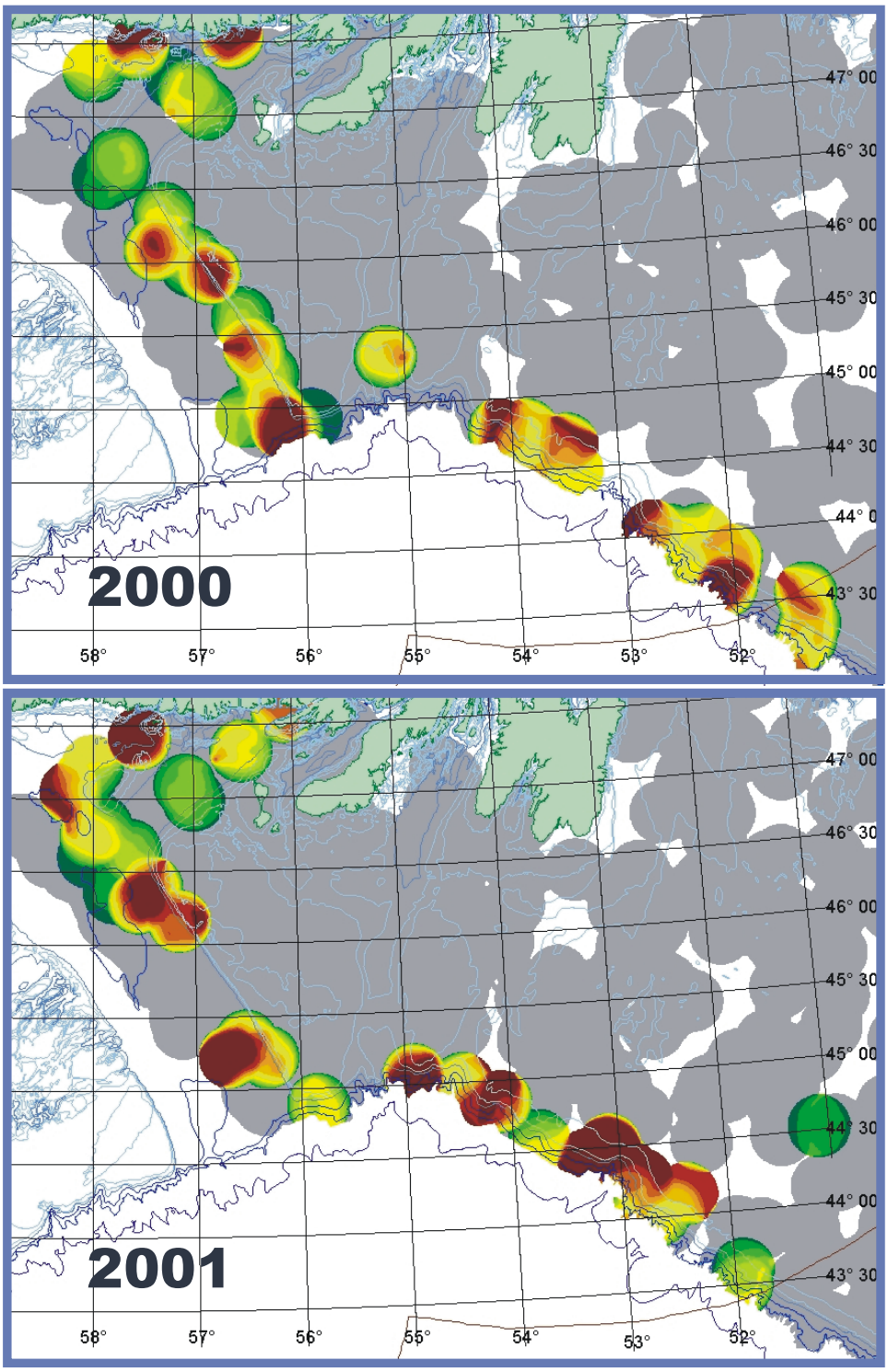


Figure 2c. Monkfish distribution from Spring research surveys, 2000-2001 (see Fig. 2a for legend). Grey denotes surveyed areas.

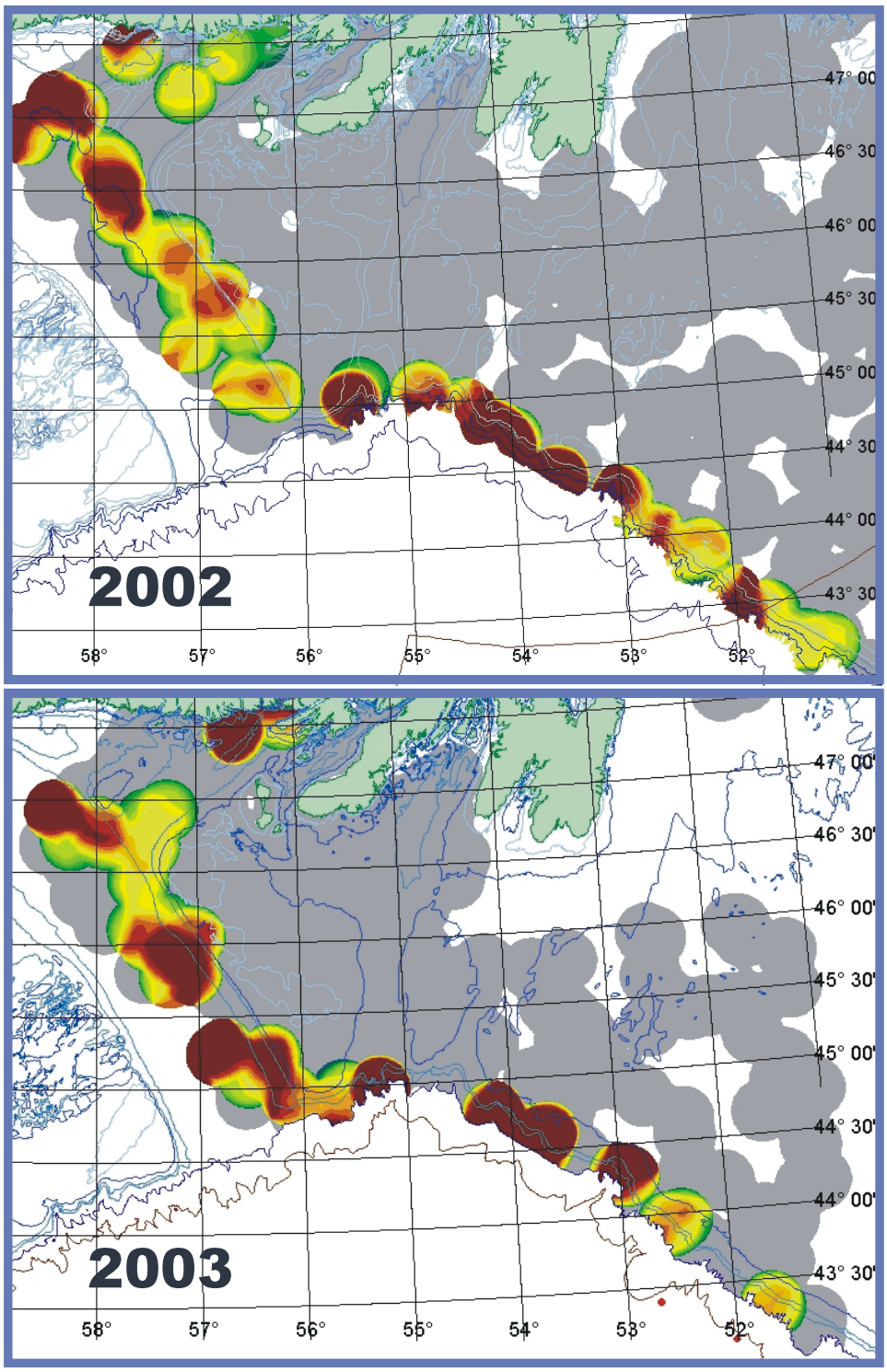


Figure 2d. Monkfish distribution from Spring research surveys, 2002-2003 (see Fig. 2a for legend). Grey denotes surveyed areas.

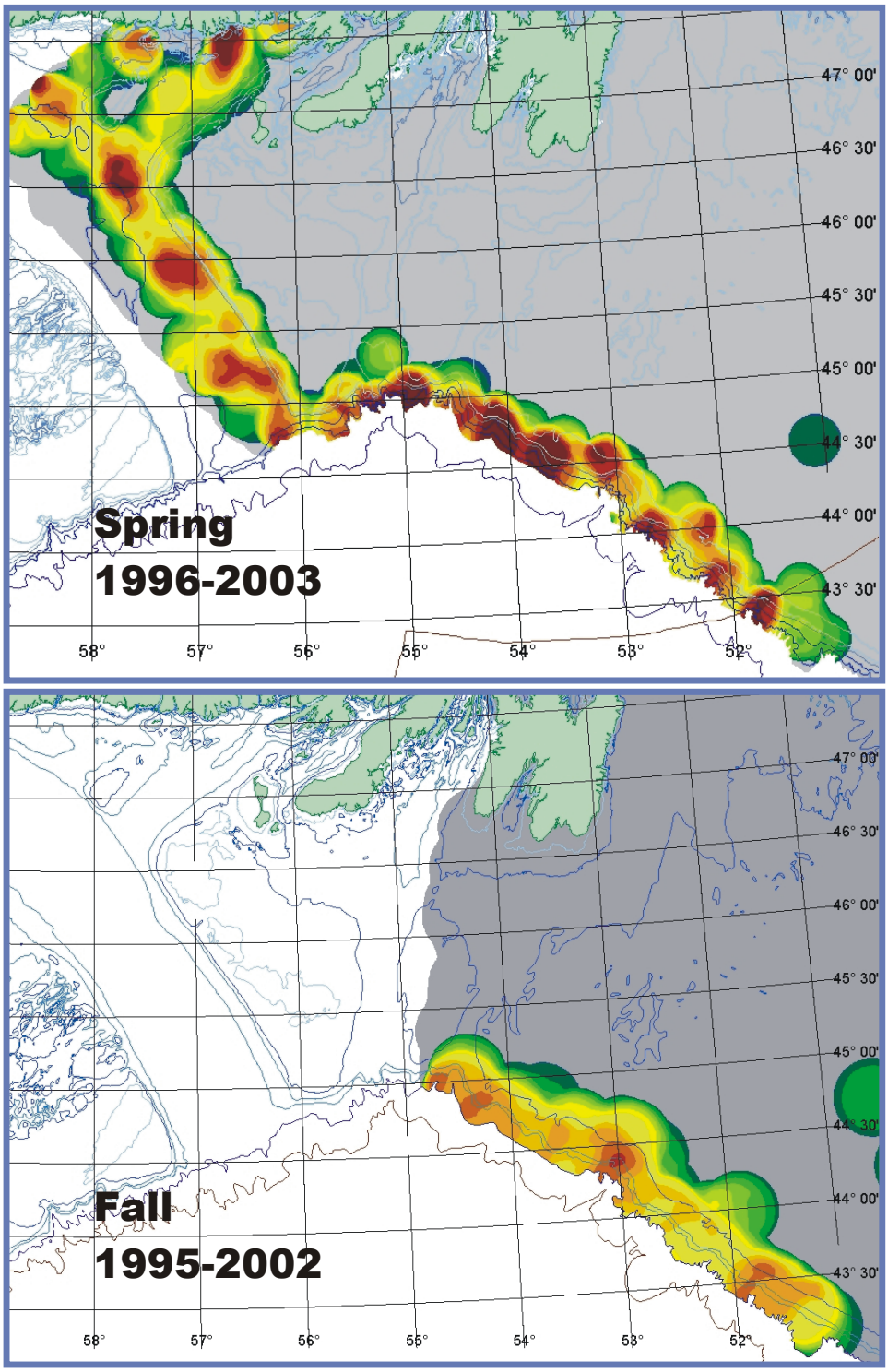


Figure 2e. Monkfish distribution from combined Spring 1996-2003 (upper panel) and Fall 1995-2002 (lower panel) research surveys (see Fig. 2a for legend.). Grey denotes surveyed areas.

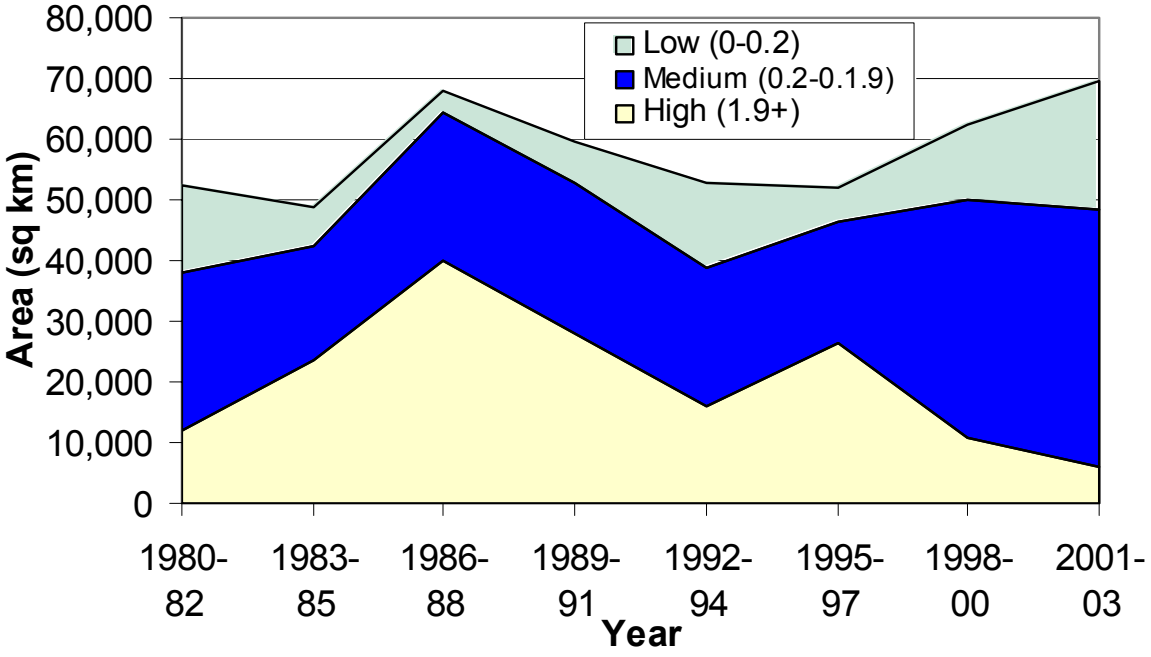


Figure 3. Area occupied by monkfish on the Grand Banks at low, medium, and high densities; based on Spring research surveys in 1980-2003.

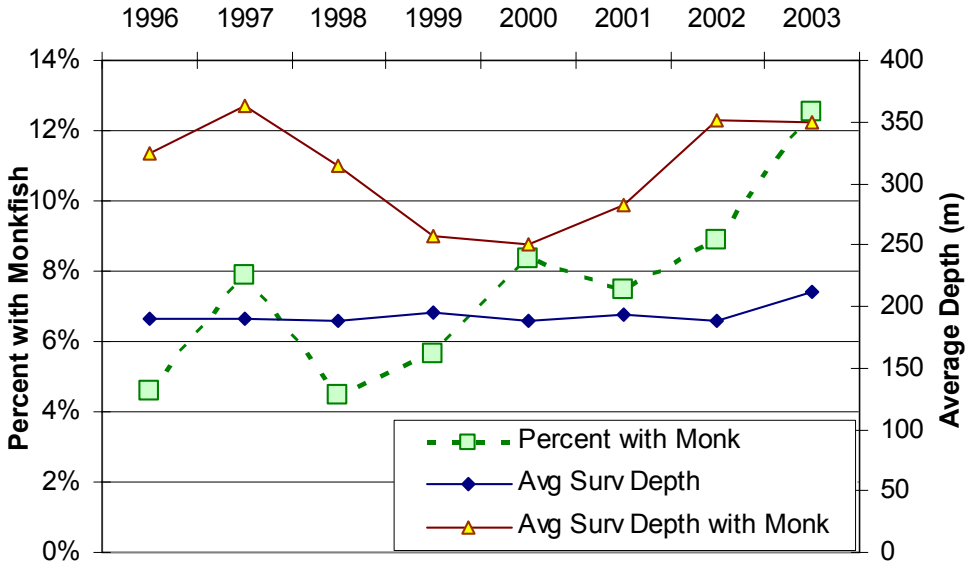


Figure 4. Percent of Spring research survey sets containing monkfish, and average depth surveyed (all sets, and sets with monkfish).

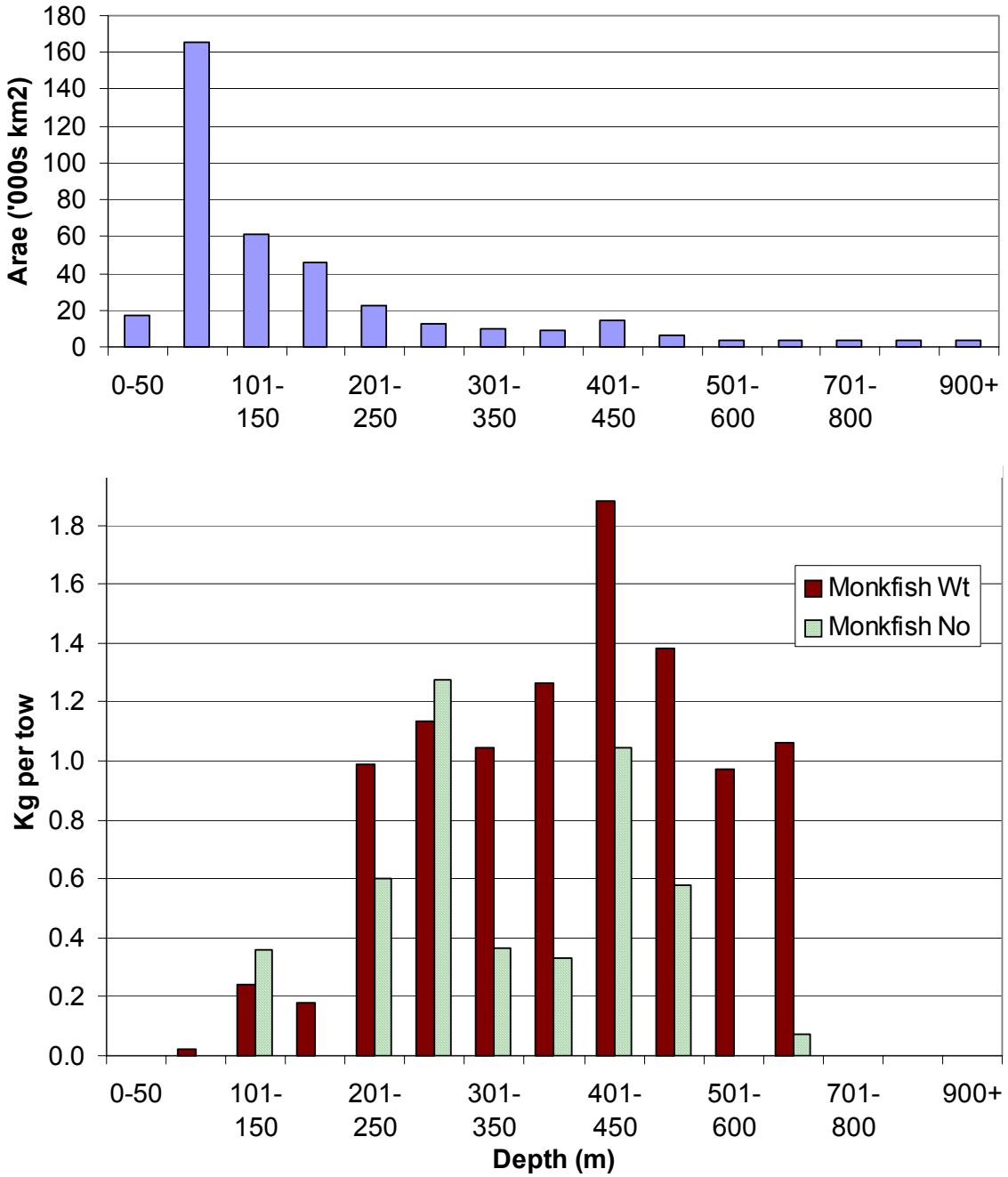
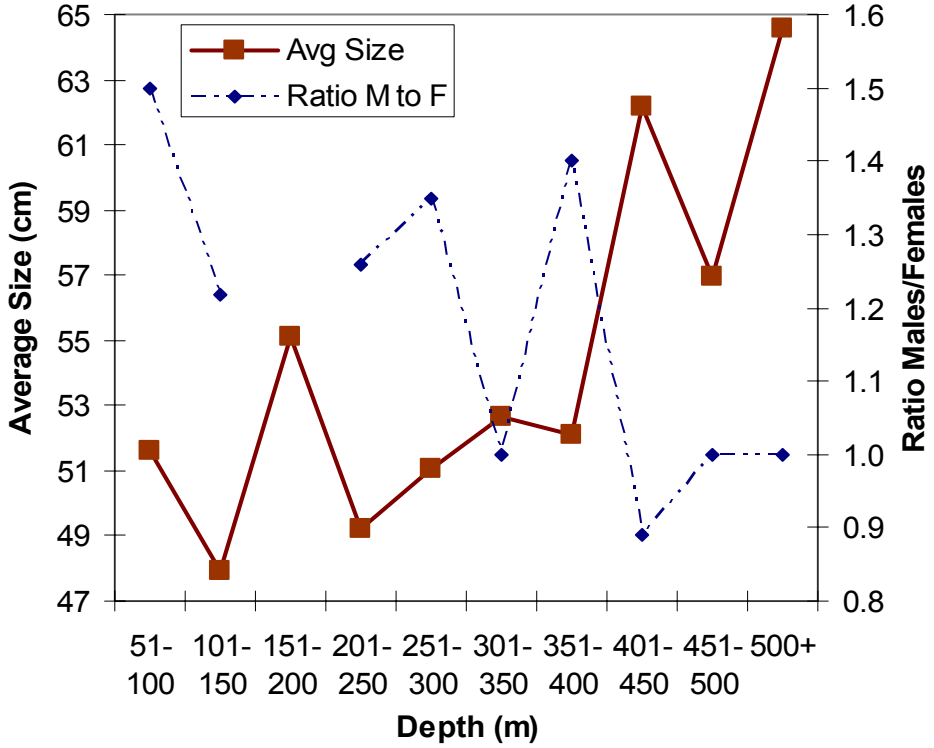


Figure 5. Upper panel: available area within depth strata on the Grand Banks. Lower Panel: distribution of monkfish with depth, based on Spring research surveys in 1996-2003, by weight and number per tow.



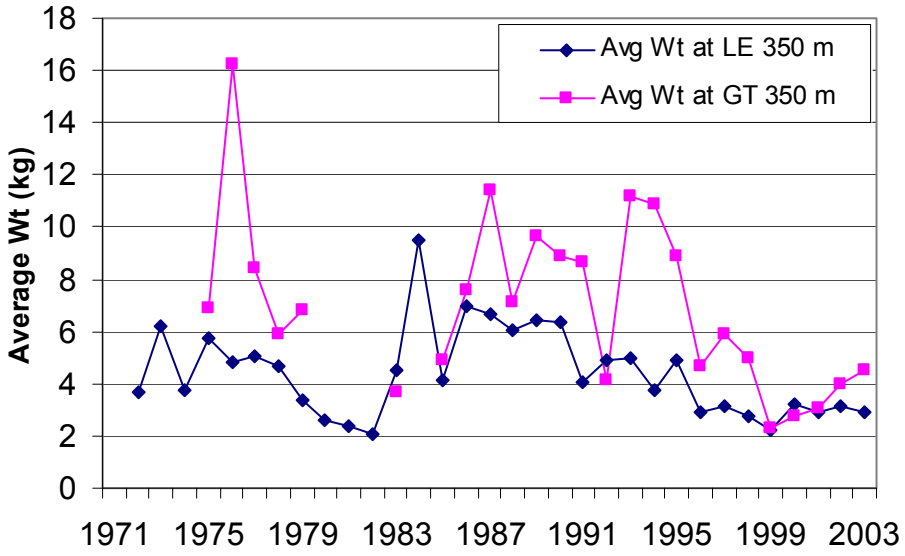


Figure 6. Upper panel: average size (Total Length in cm), and proportion of male to female monkfish by depth; based on Spring research surveys (n=297). Lower panel: average weight of monkfish in $\leq$ 350 m and > 350 m depths, 1972-2003.

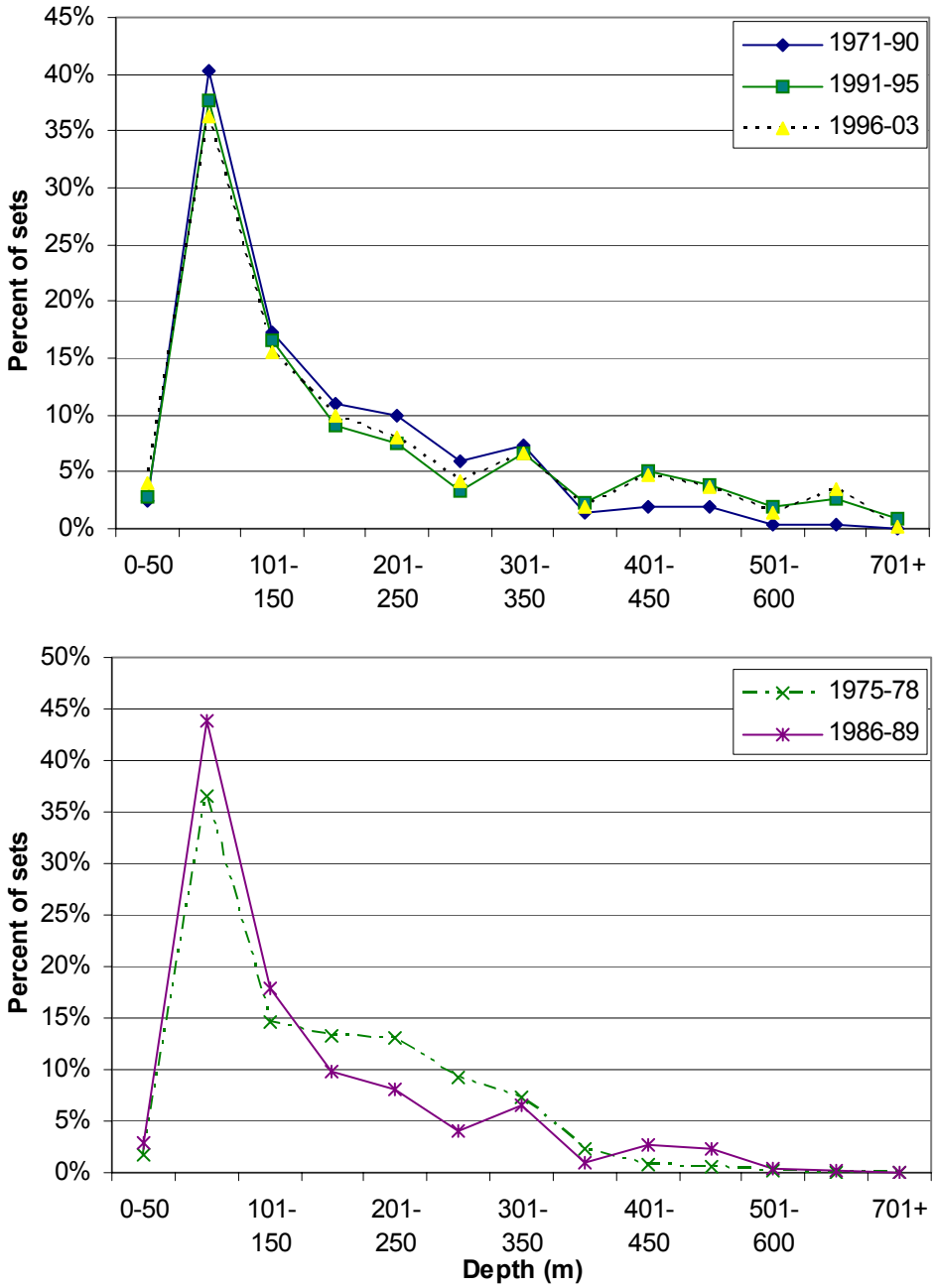


Figure 7a. Percent of sets prosecuted at depth during Spring research surveys on the Grand Banks. Upper panel: three periods when average depth differed (see Fig 7b). Lower panel: two periods when relative biomass and abundance peaked.

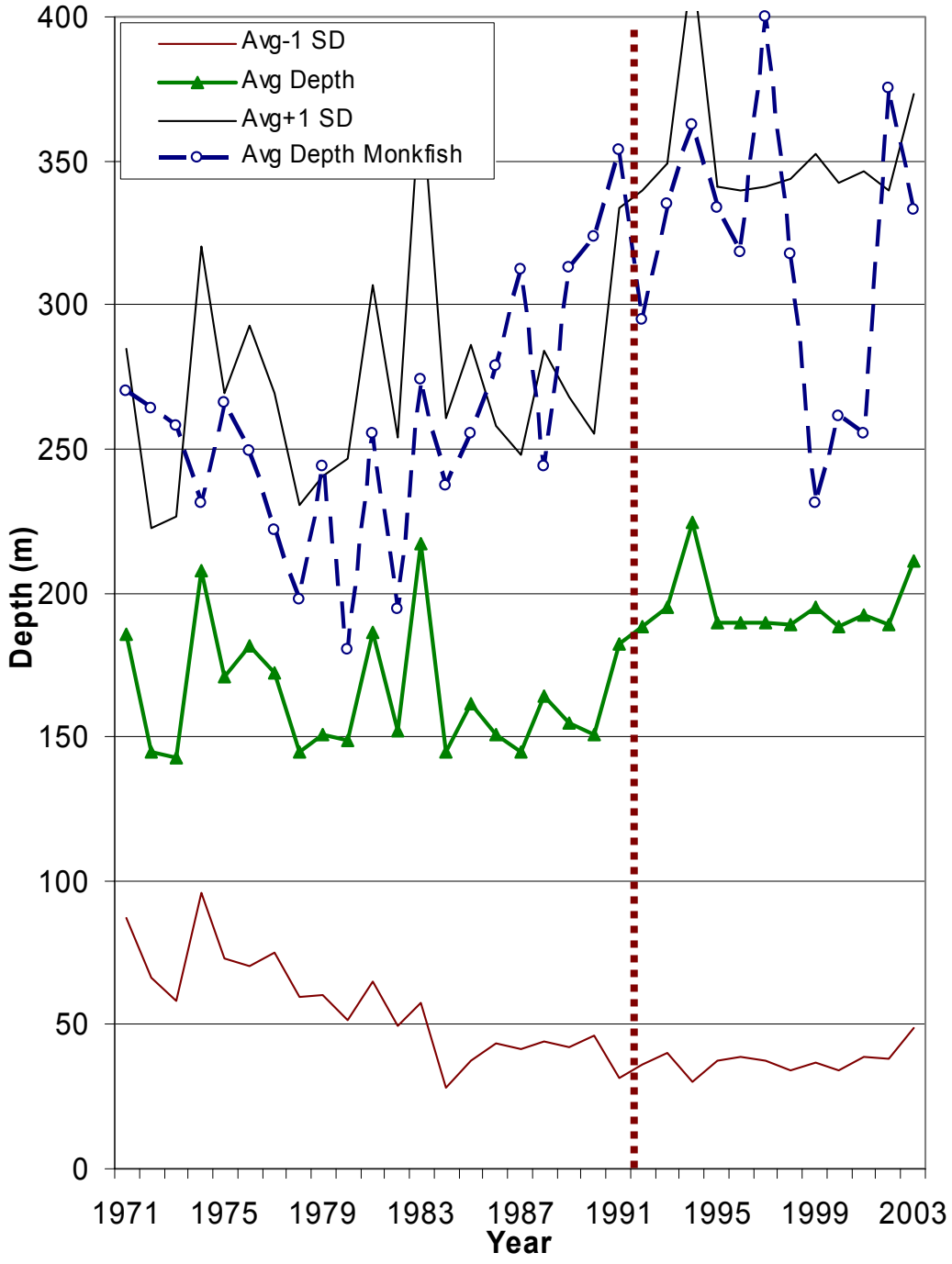


Figure 7b. Average depth at which monkfish were caught, 1972-2003; based on Spring research survey data. Dashed line delineates two periods when average depth of survey differed.

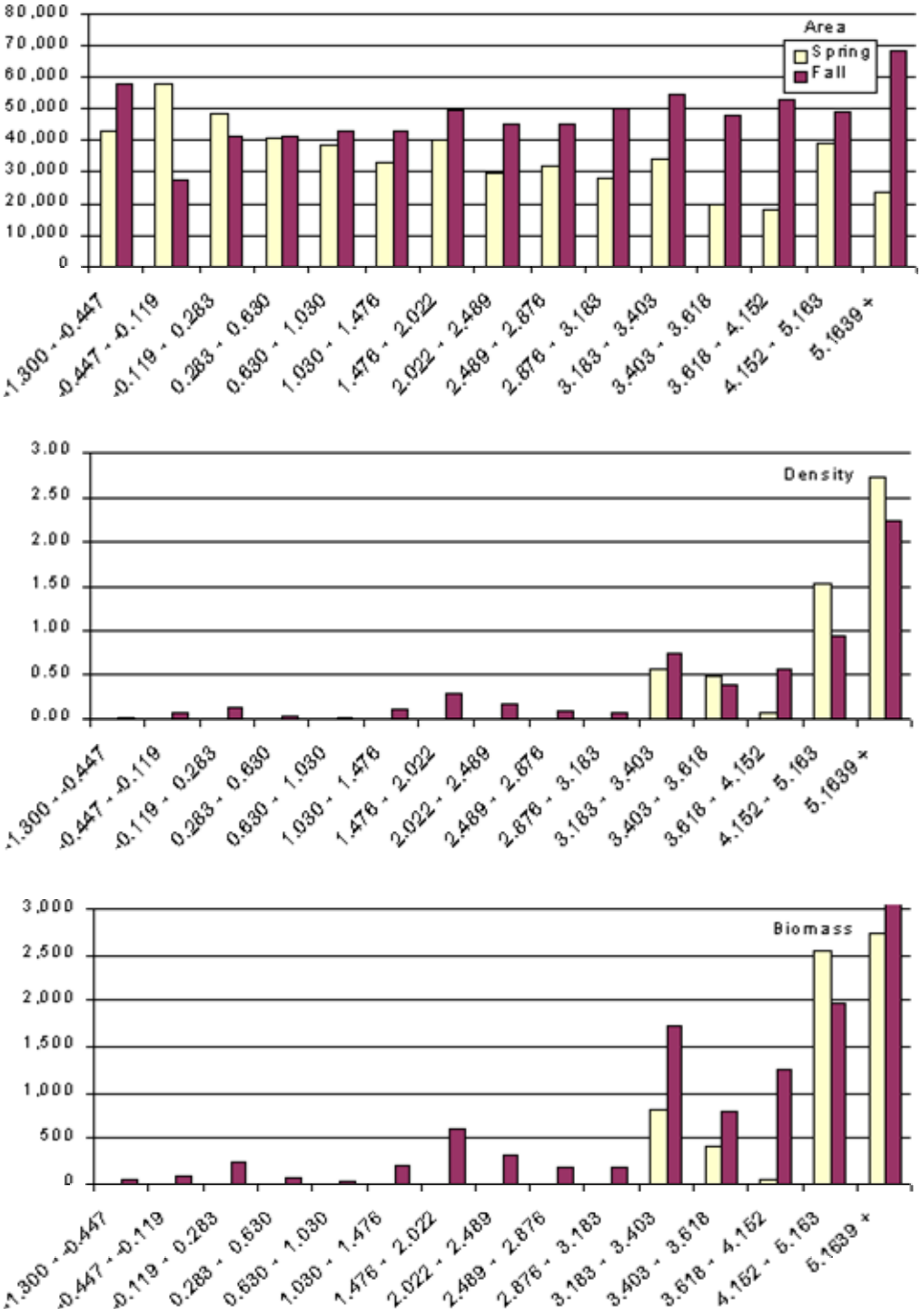


Figure 8. Bottom temperatures collected during research surveys; averaged over 1995-1999 for Fall and 1996-2000 for Spring.

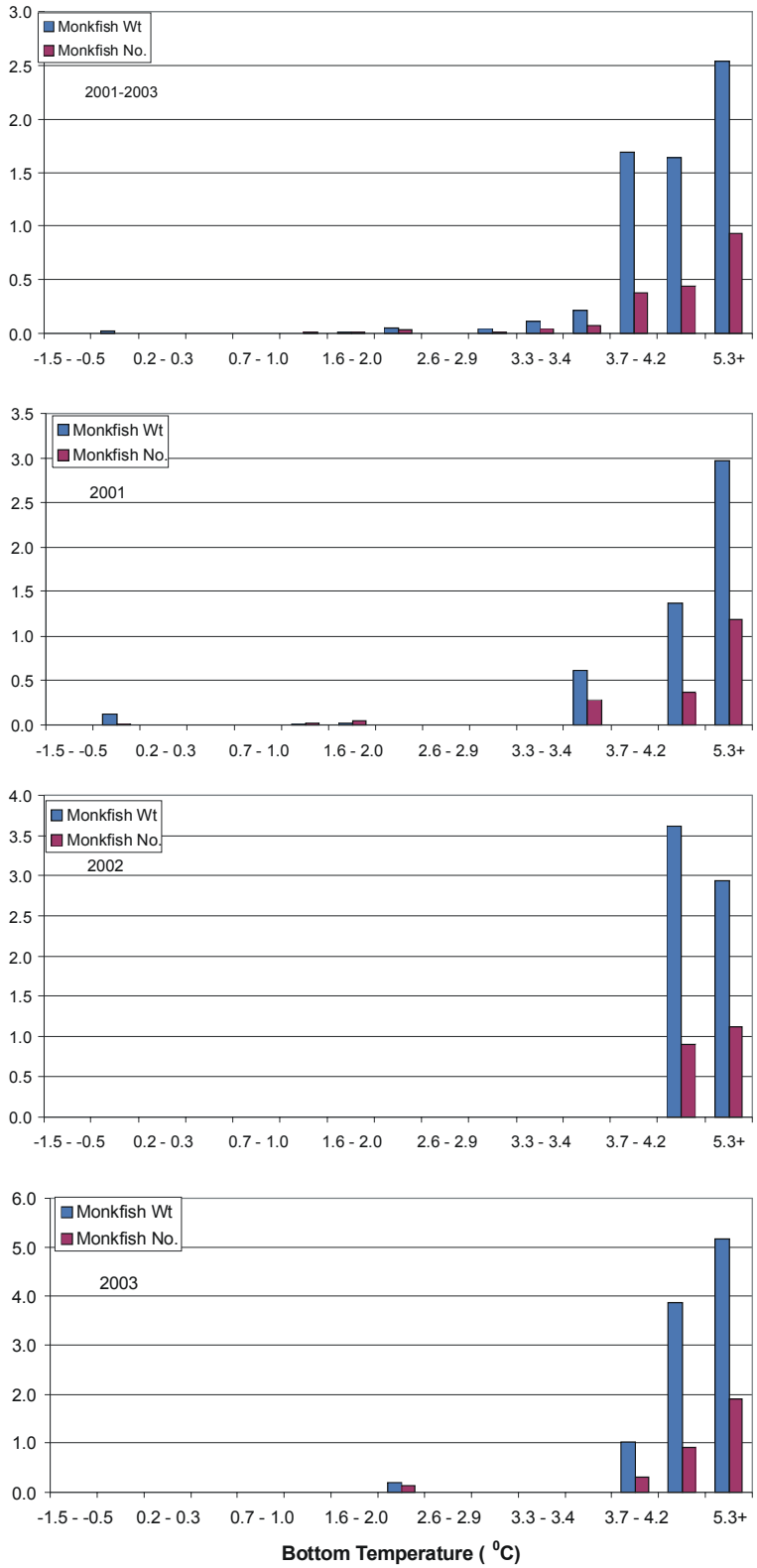


Figure 9. Distribution of monkfish in relation to temperature (° Celsius) for Spring, 2001-2003. Y-axis indicates density (mean kg per tow) for each depth interval.

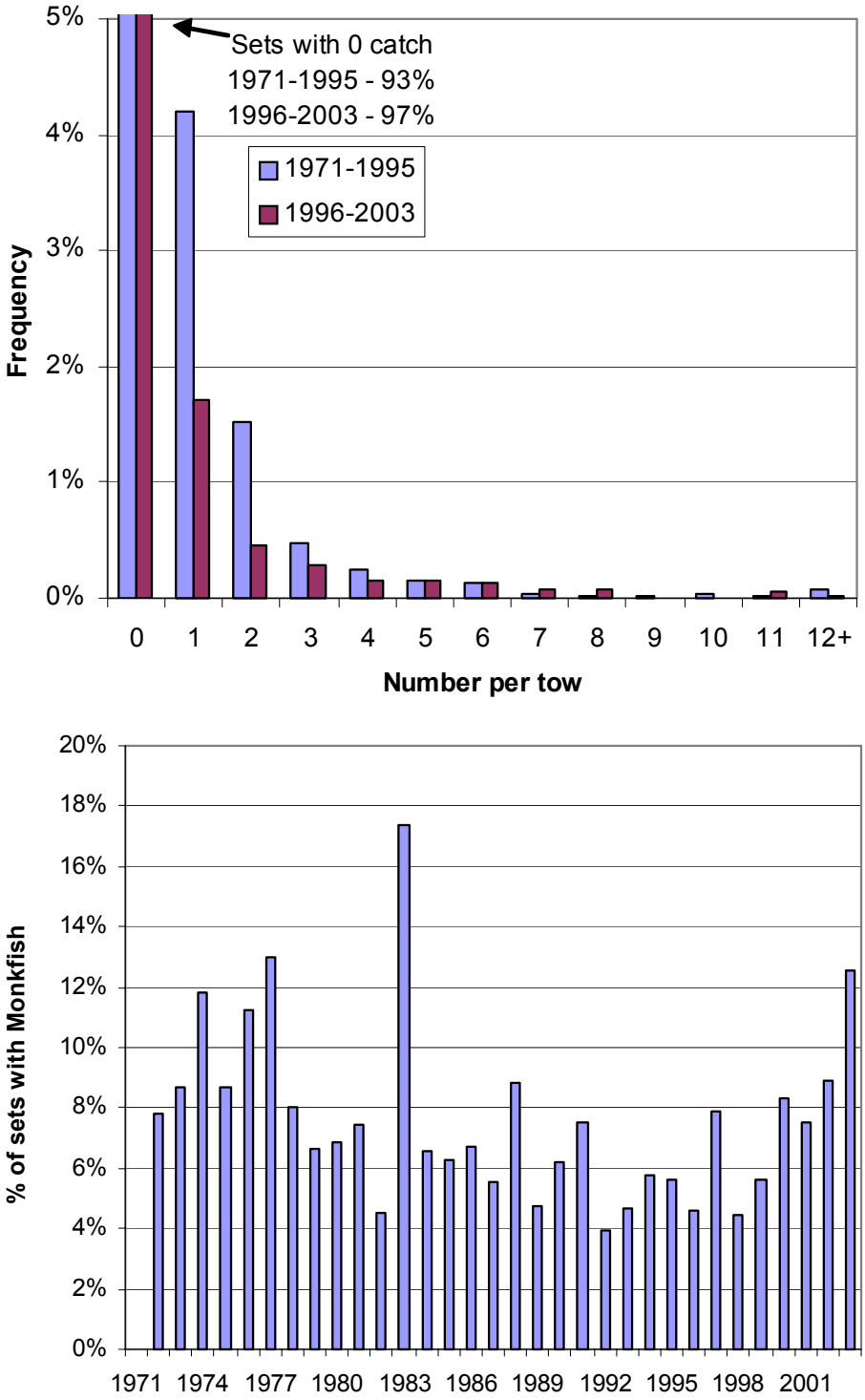


Figure 10a. Upper panel: Frequency of numbers of monkfish per tow in Spring surveys, 1971-2003. Lower panel: Percent of Spring survey sets containing monkfish.

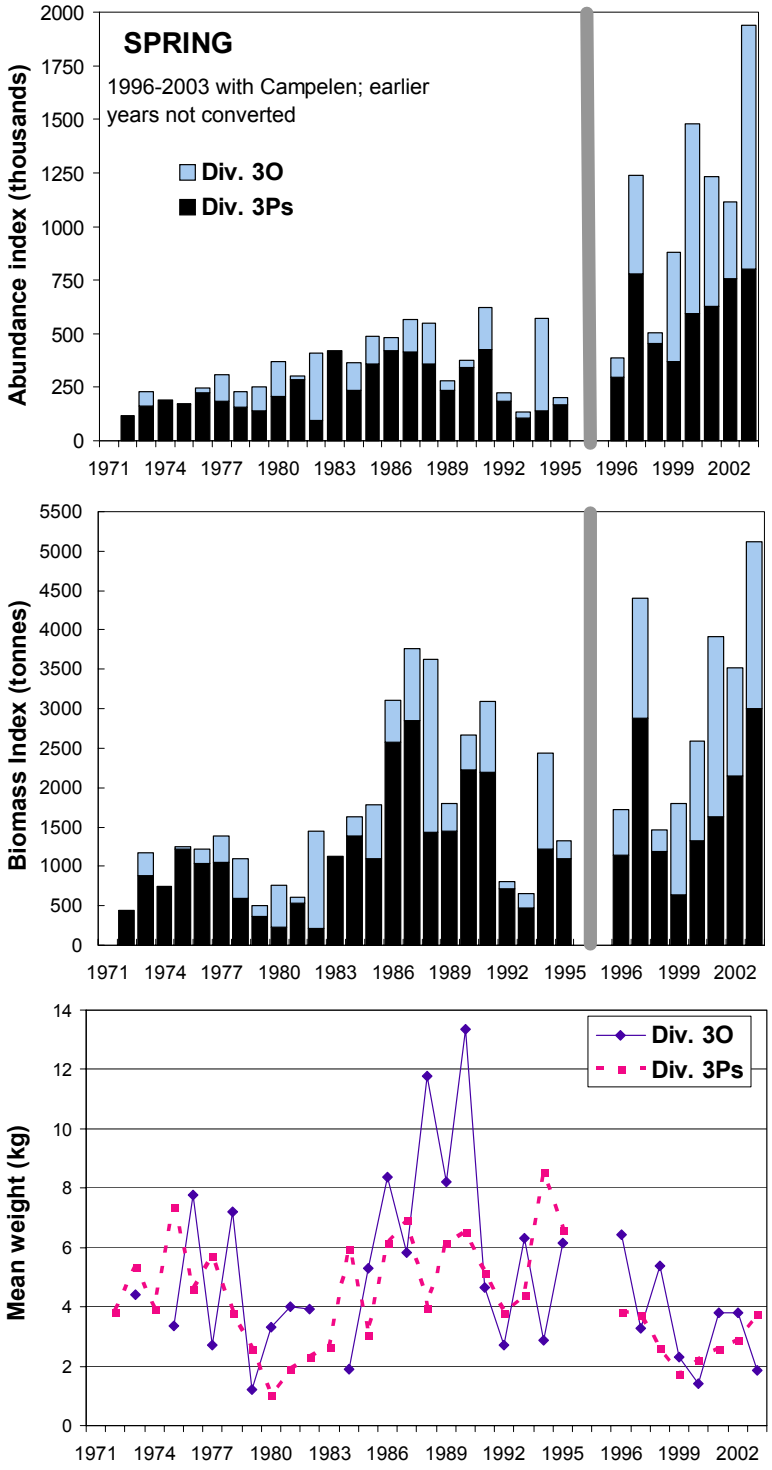


Figure 10b. Relative abundance (upper panel), biomass (middle panel), and average weight (lower panel) of monkfish in NAFO Div. 3OPs, 1971-2003. Indices are based on Spring research survey data.

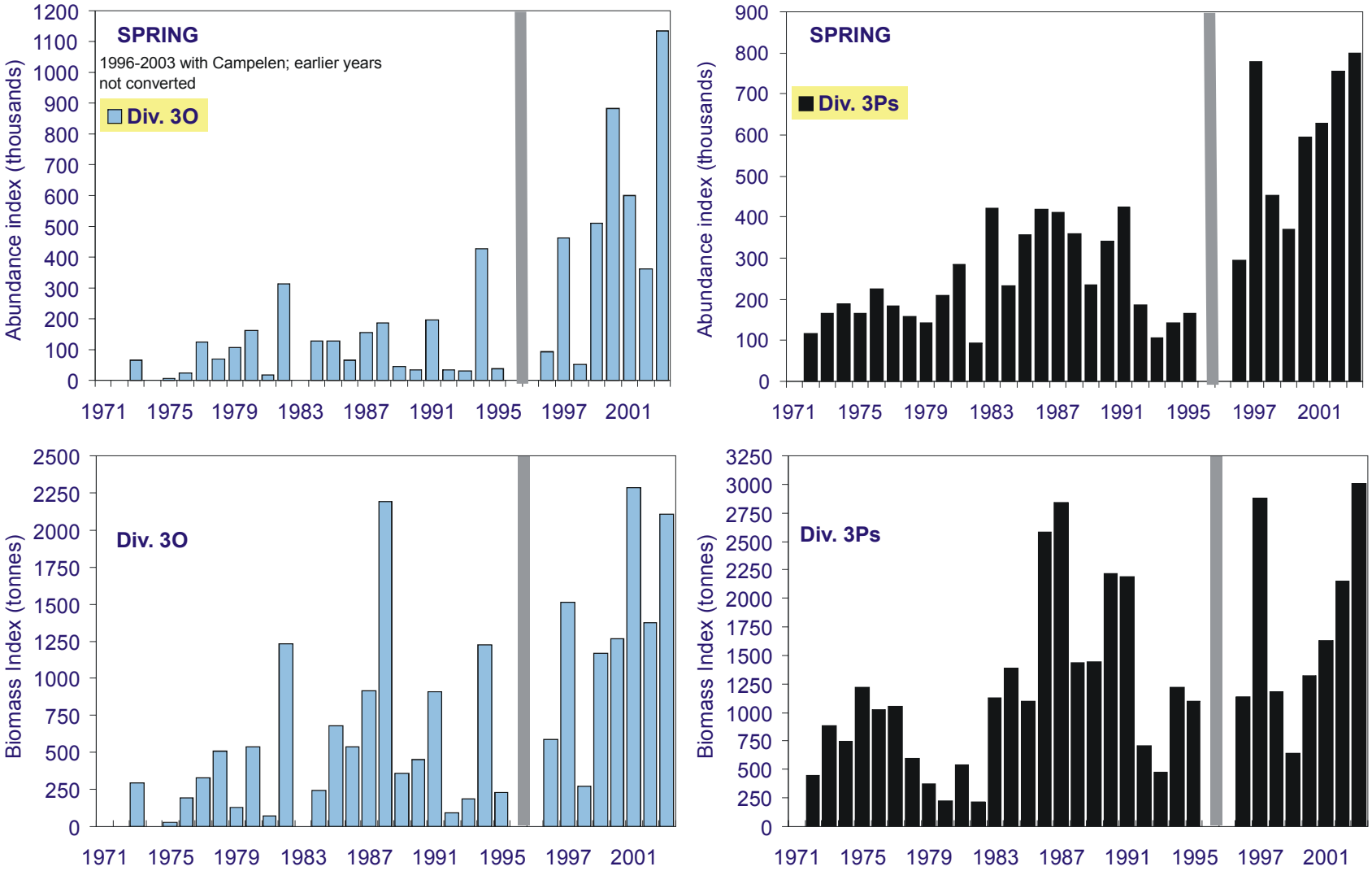


Figure 10c. Relative abundance and biomass of monkfish by NAFO Division, 1971-2003. Indices are based on Spring survey data.

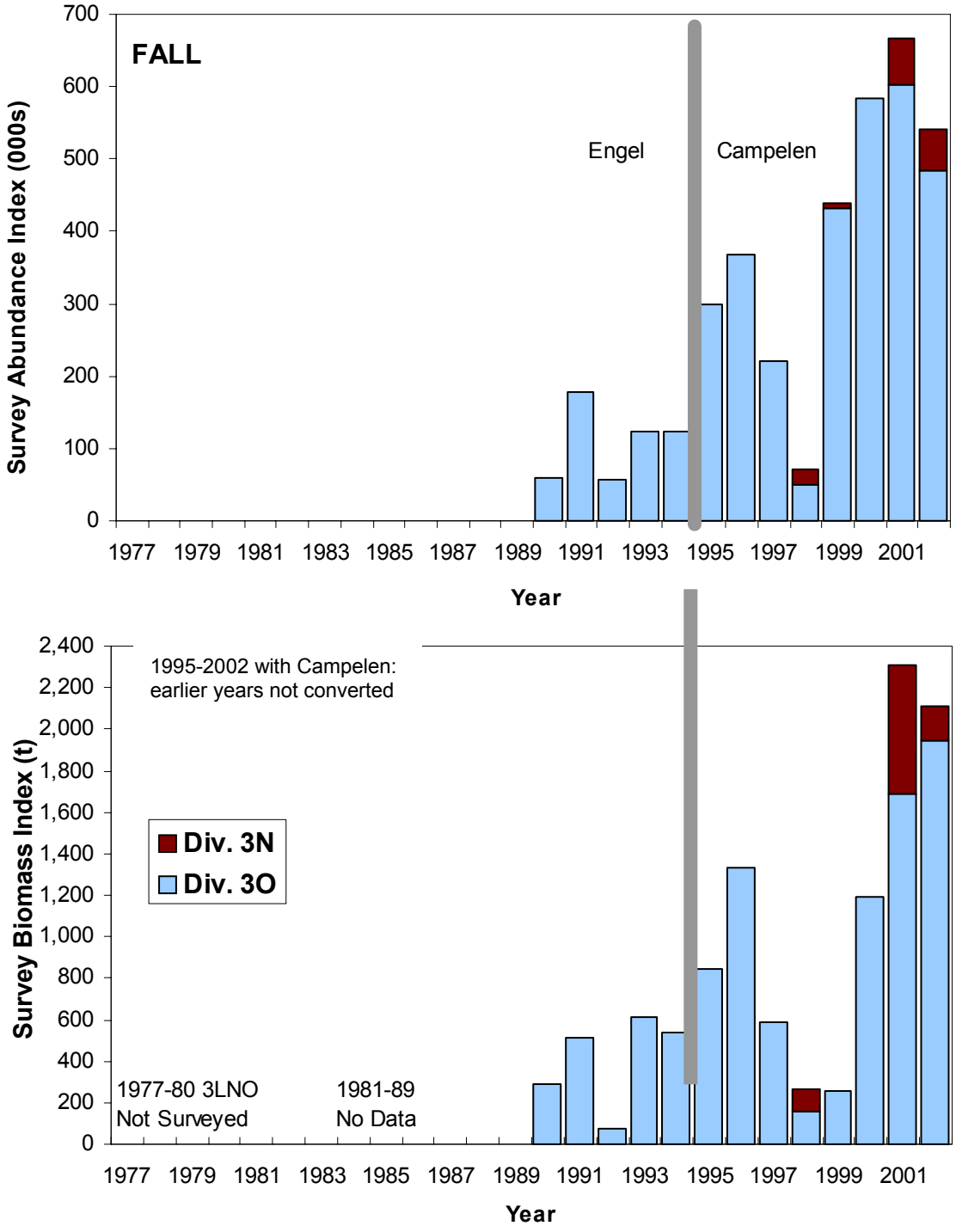


Figure 10d. Relative abundance (upper panel) and biomass (lower panel) of monkfish in NAFO Div. 3NO, 1981-2002. Indices are based on Fall research survey data.

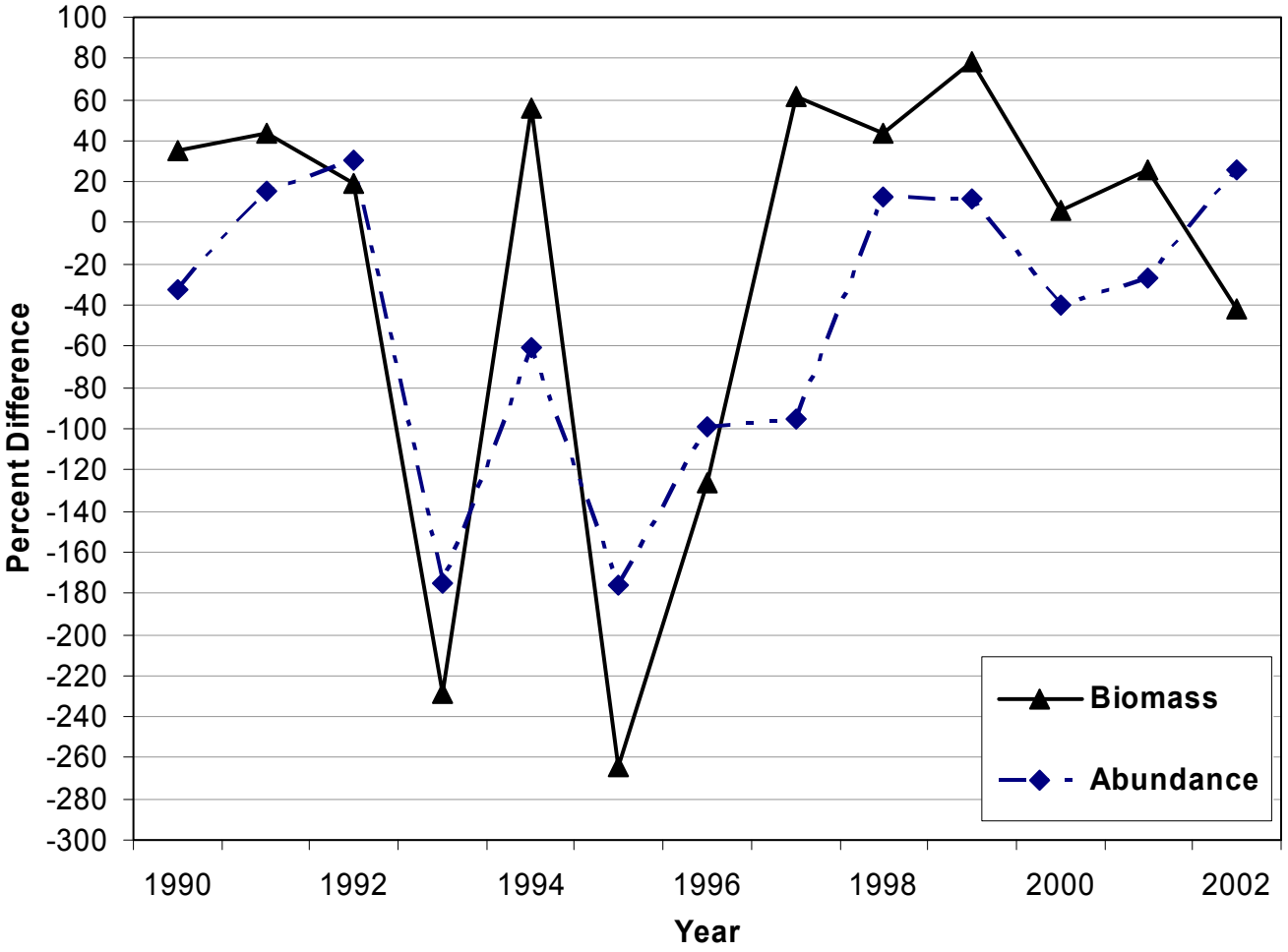


Figure 10e. Percent difference (Fall estimate divided by Spring estimate) between Spring and Fall survey estimates of monkfish biomass and abundance in NAFO Div. 3O, 1990-2002.

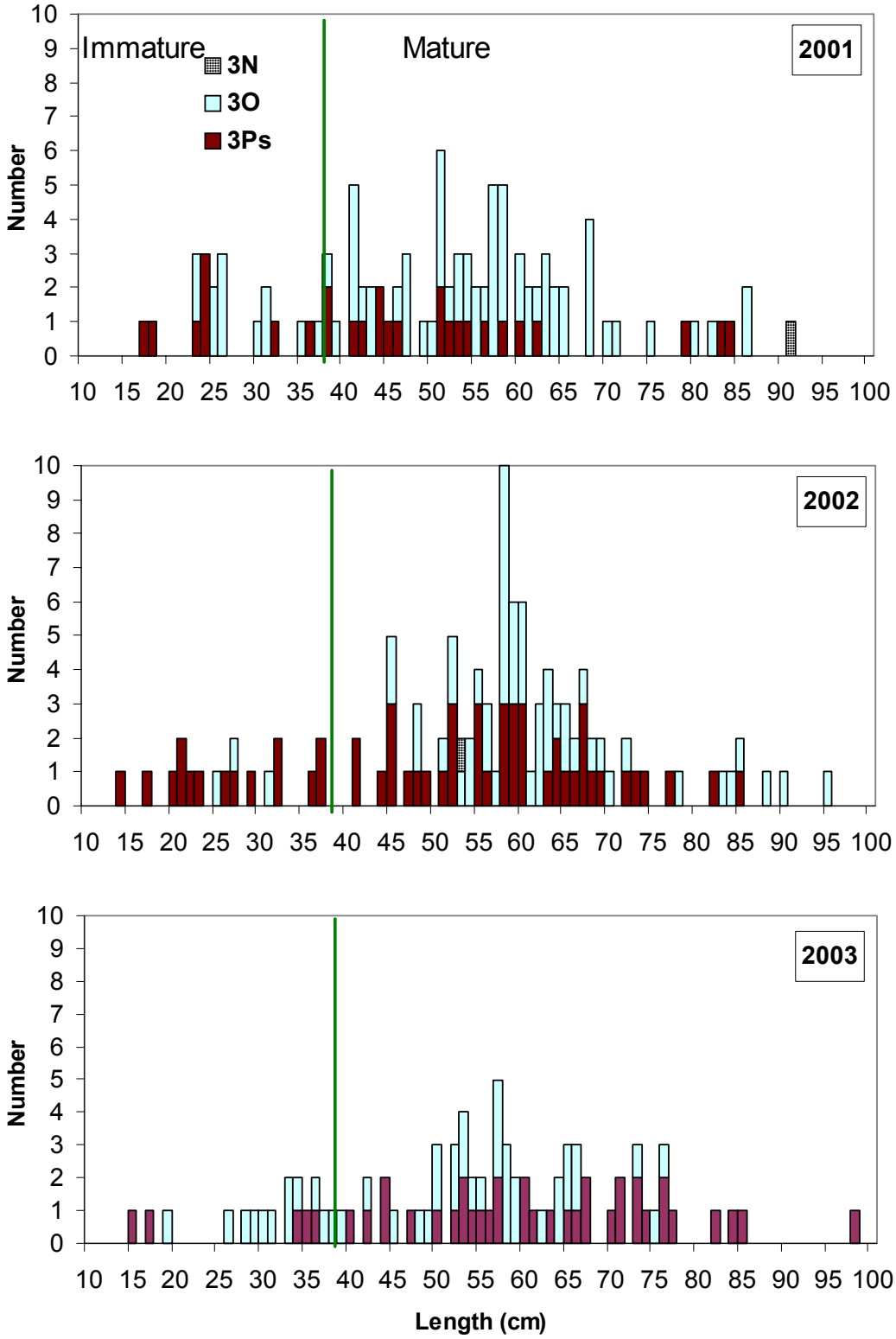


Figure 11a. Length distribution of monkfish from Spring research surveys on the Grand Banks, 2001-2003, by NAFO Division. Green line delineates mature and immature fish; based on information from Armstrong *et al.* (1992).

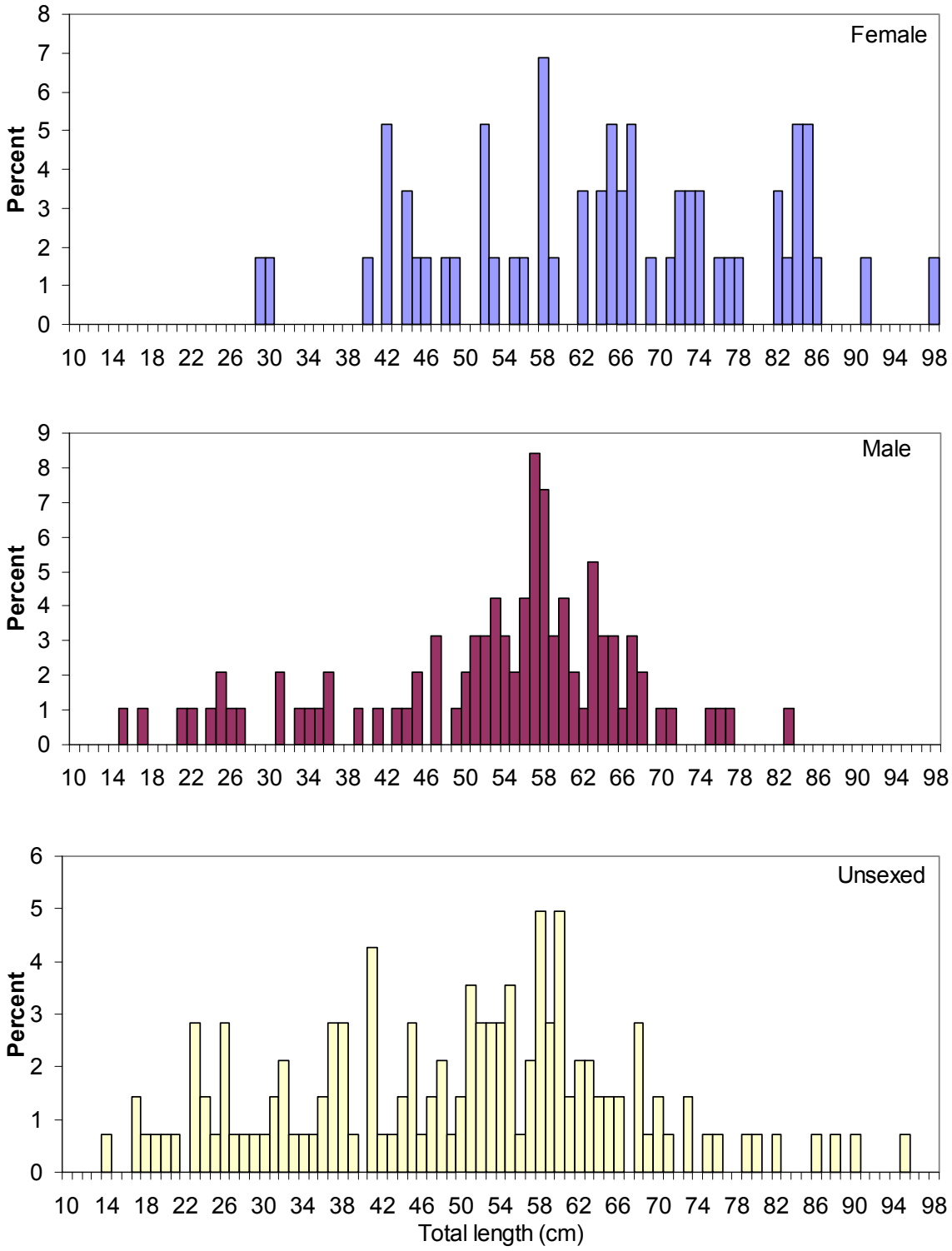


Figure 11b. Length distribution of monkfish by sex from Spring research surveys on the Grand Banks, 2001-2003.

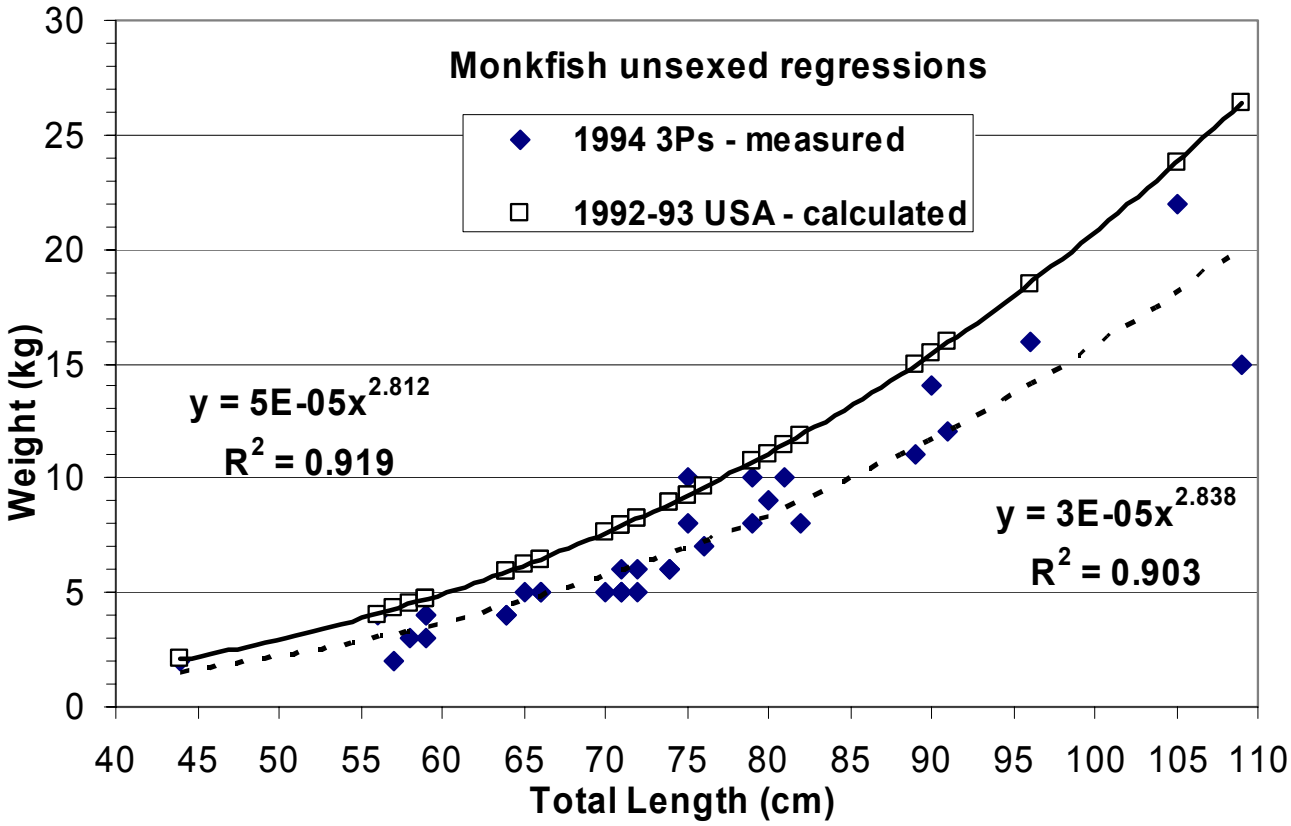


Figure 12. Length-weight relationships for unsexed monkfish. Solid line depicts a relationship derived by Almeida *et al*. (1995) for Gulf of Maine-northern Georges Bank fish. Dotted line illustrates a relationship based on Grand Banks fish.

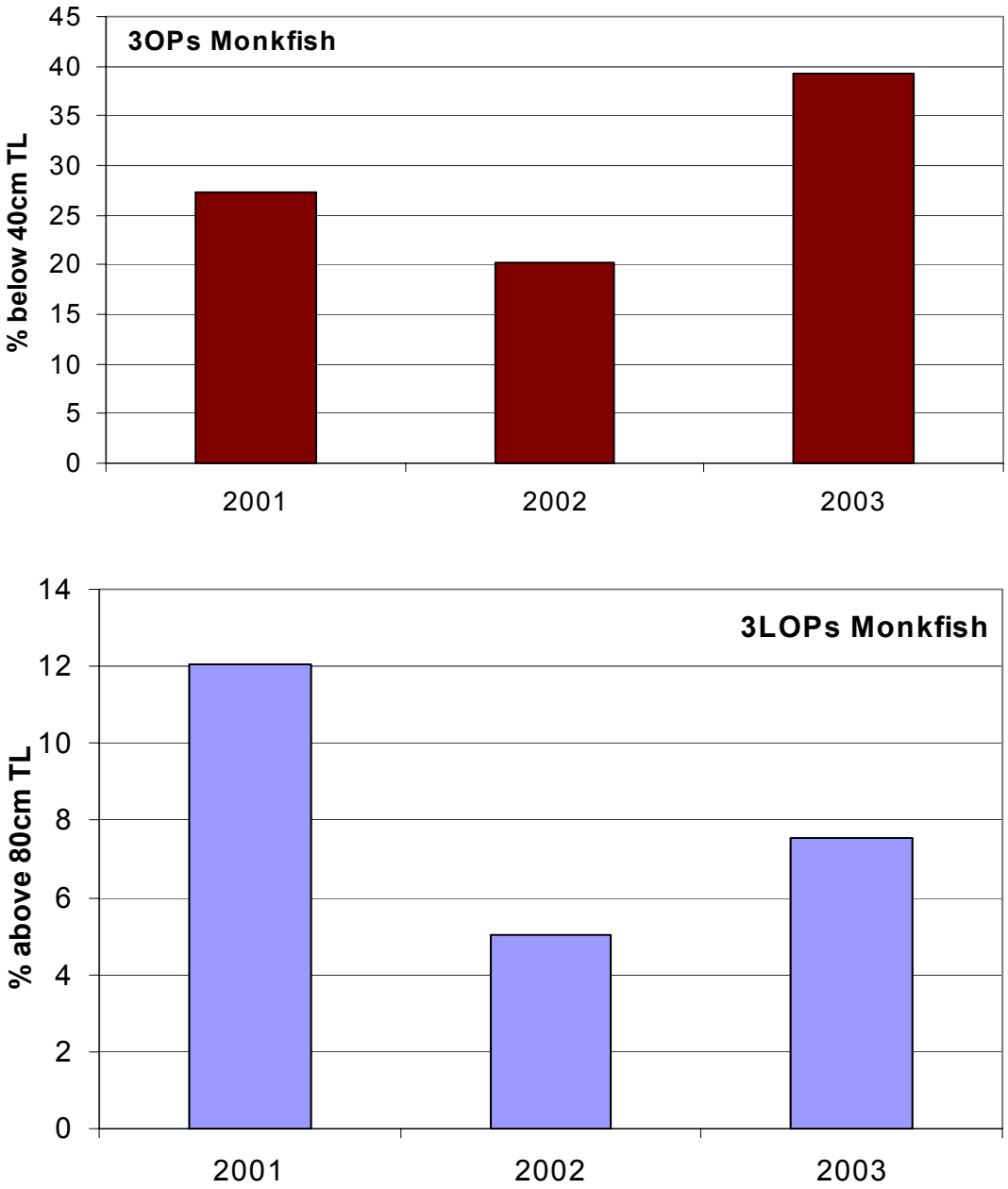


Figure 13. Percent of monkfish < 40 cm Total Length (upper panel) and > 80 cm TL (lower panel), based on Spring research surveys in NAFO Div. 3LOPs, 2001-2003.

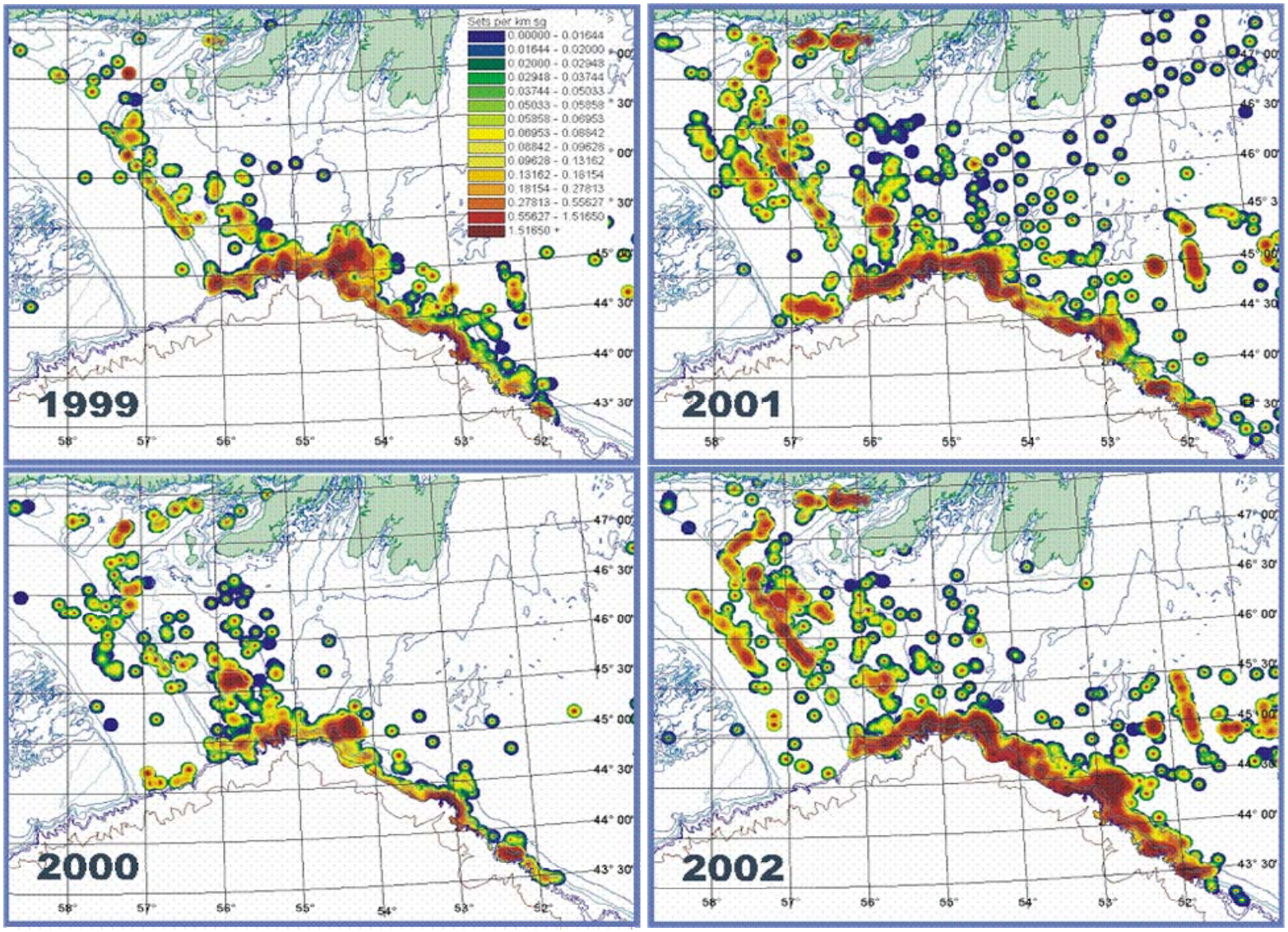


Figure 14a. Fishing grounds for the mixed fishery on the southwest slope of the Grand Banks, 1999-2002; based on fishing log data. Colours denote density (number of sets per km^2): red represents high density; green indicates low density.

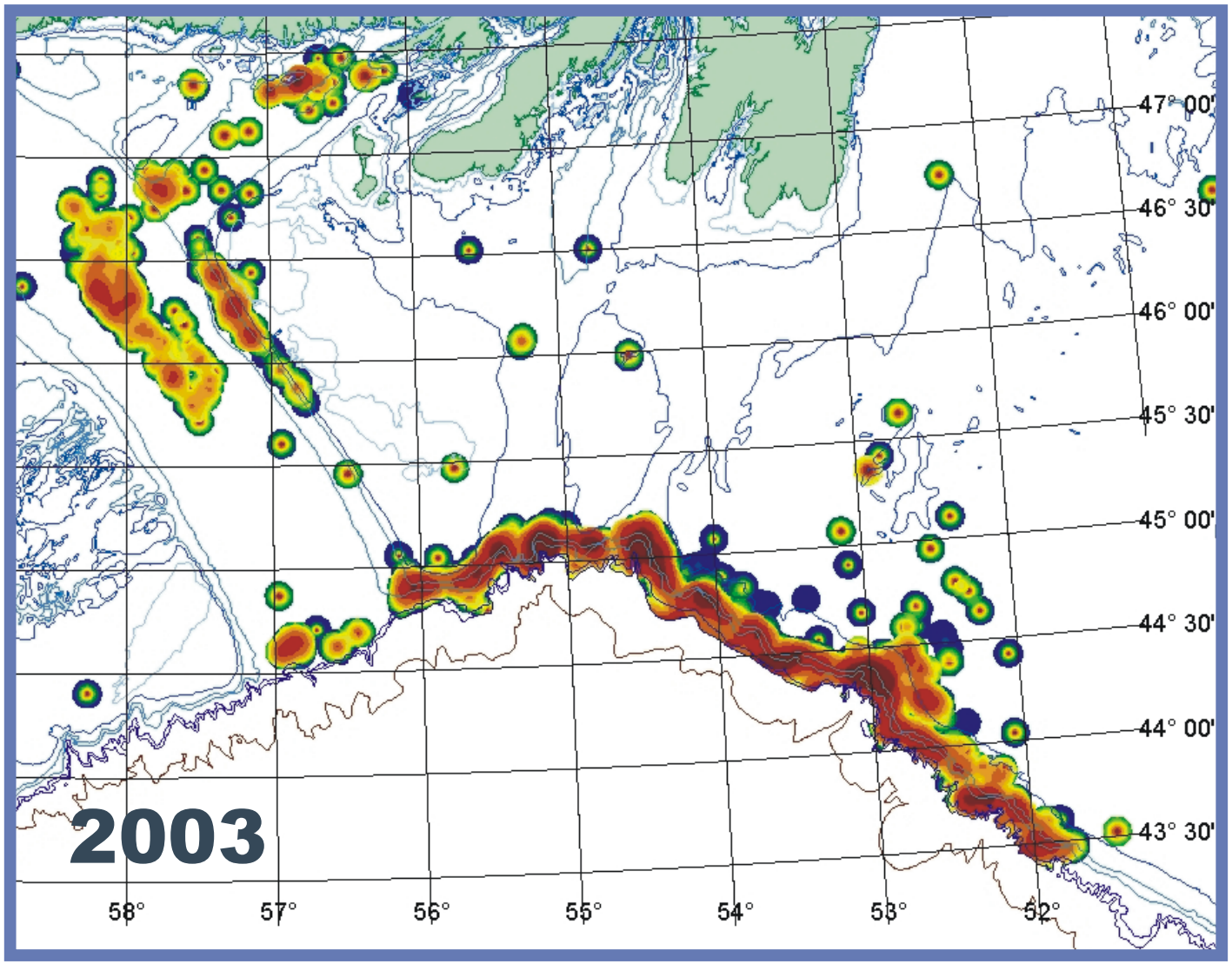


Figure 14b. Fishing grounds for the mixed fishery on the southwest slope of the Grand Banks, 2003; based on fishing log data. Colours denote density (number of sets per km^2): red represents high density; green indicates low density.

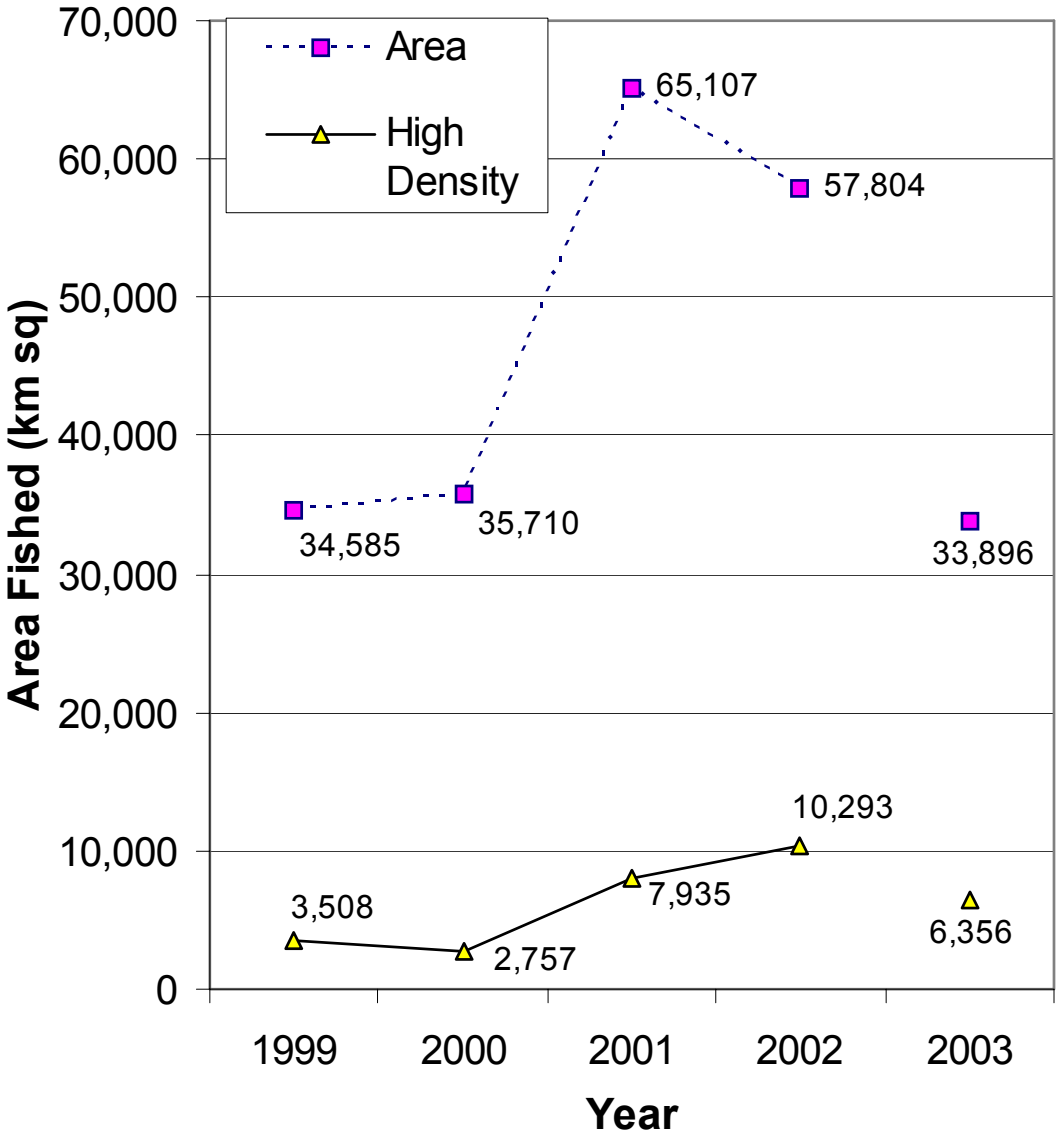


Figure 15. Extent of area fished for the mixed fishery on the southwestern Grand Banks, 1999-2001; based on fishing log data (see Fig. 14). Area of high density (solid line) refers to areas where density exceeded 0.6 sets per km^2.

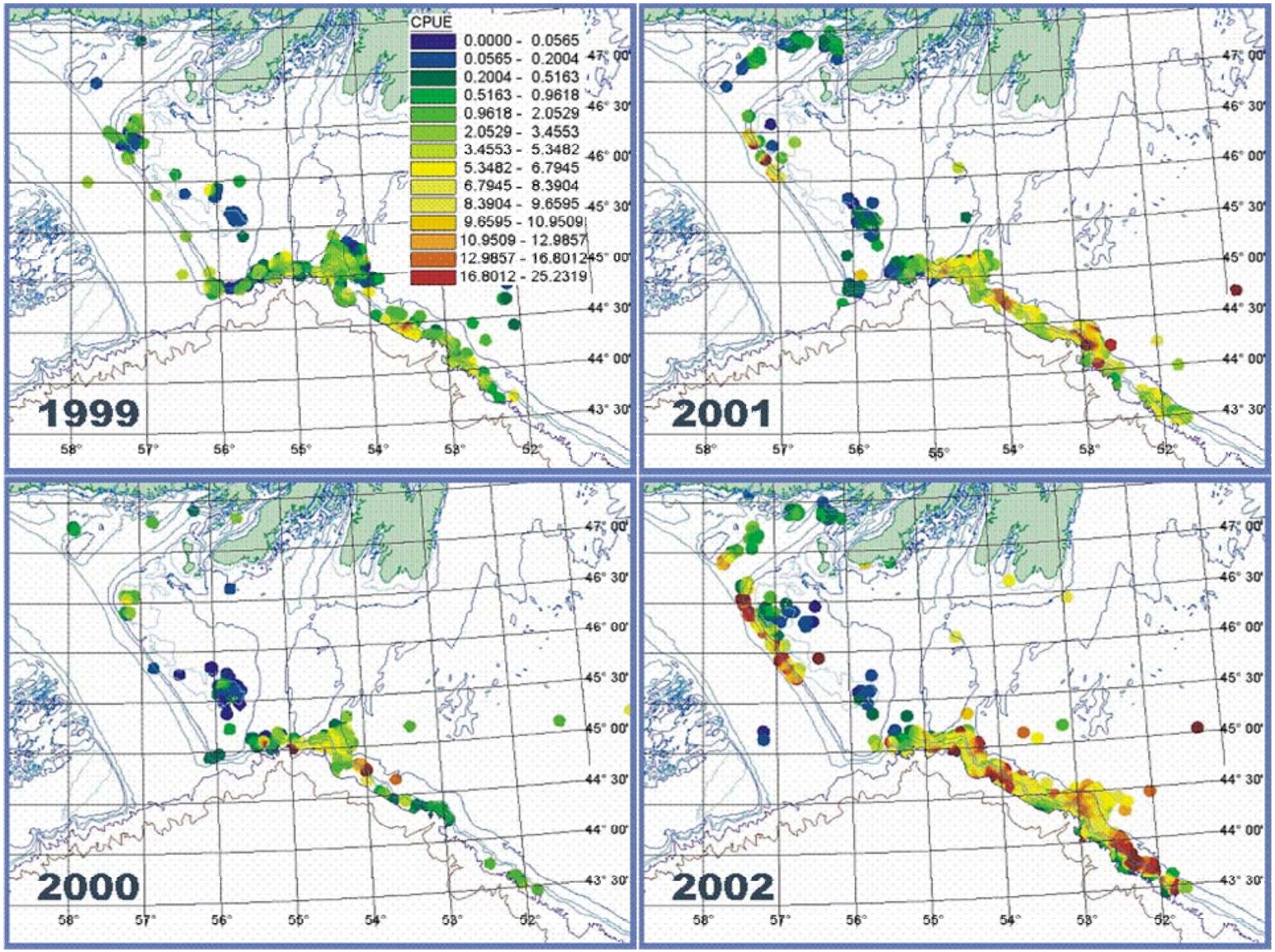


Figure 16a. Catch per unit effort (kg per gillnet) for the gillnet fleet in 1999-2002.

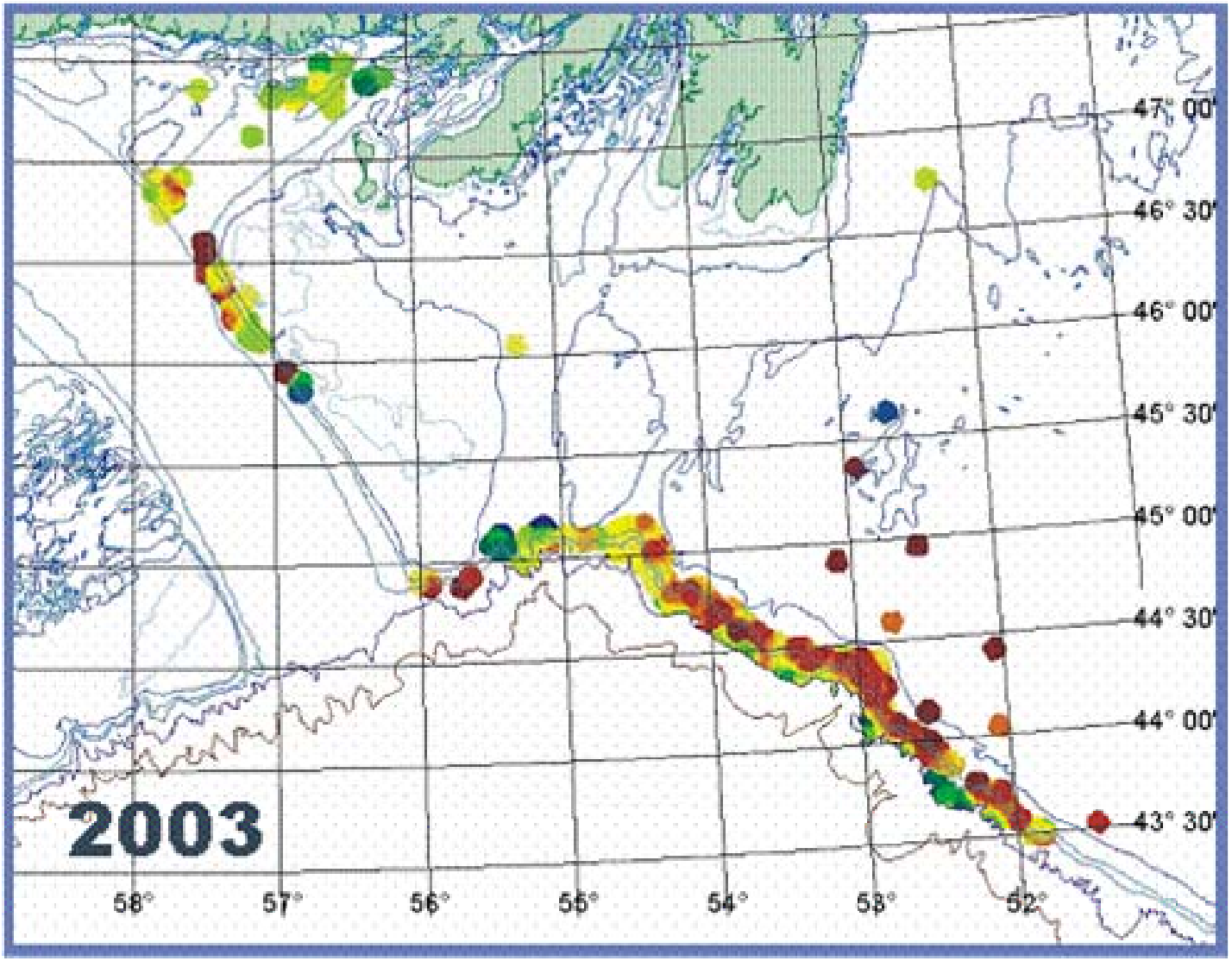


Figure 16b. Catch per unit effort (kg per gillnet) for the gillnet fleet in 2003.

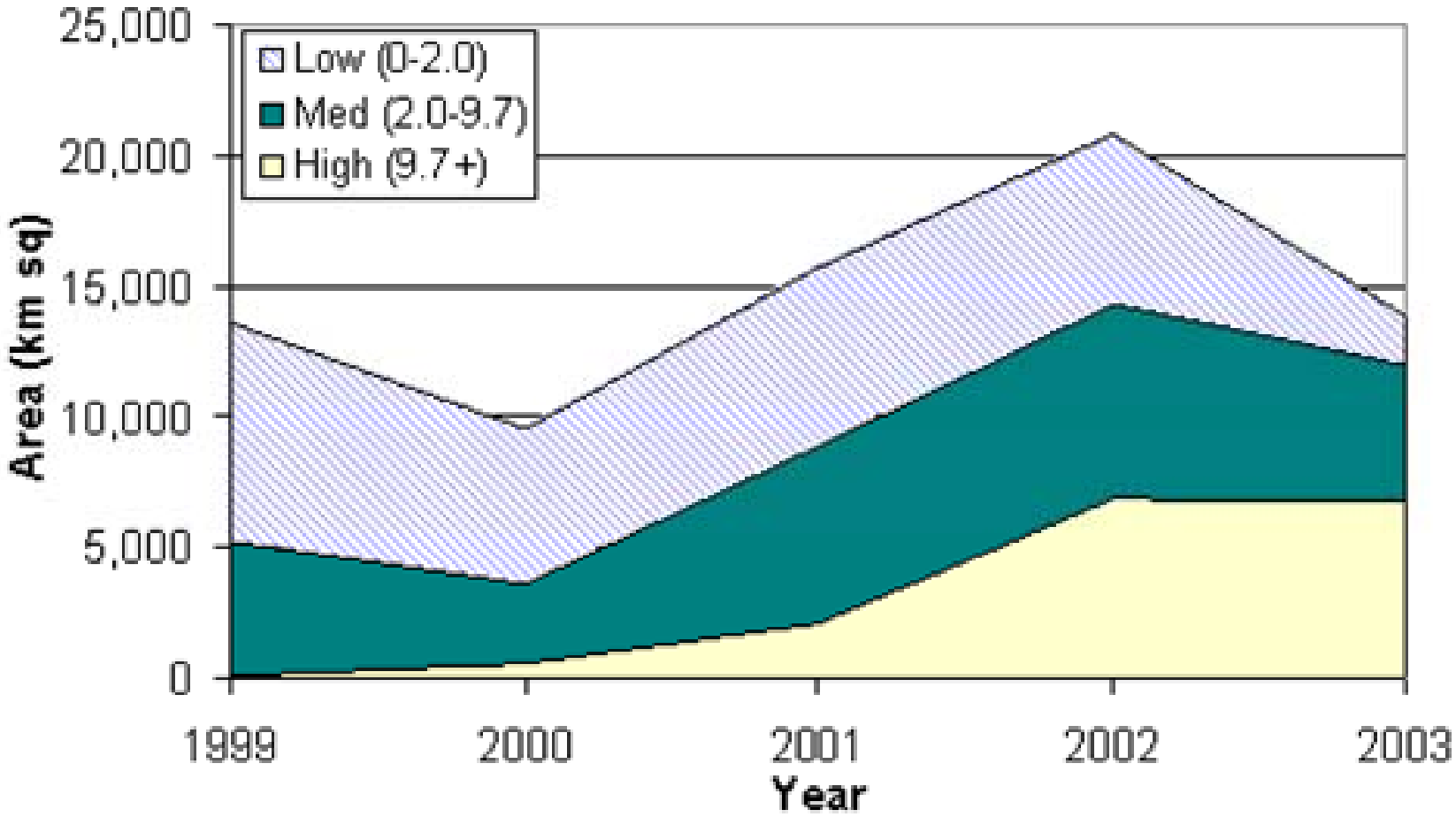


Figure 17. Extent of area fished by the gillnet fleet when directing for monkfish, 1999-2003, by catch rate category (kg per gillnet).

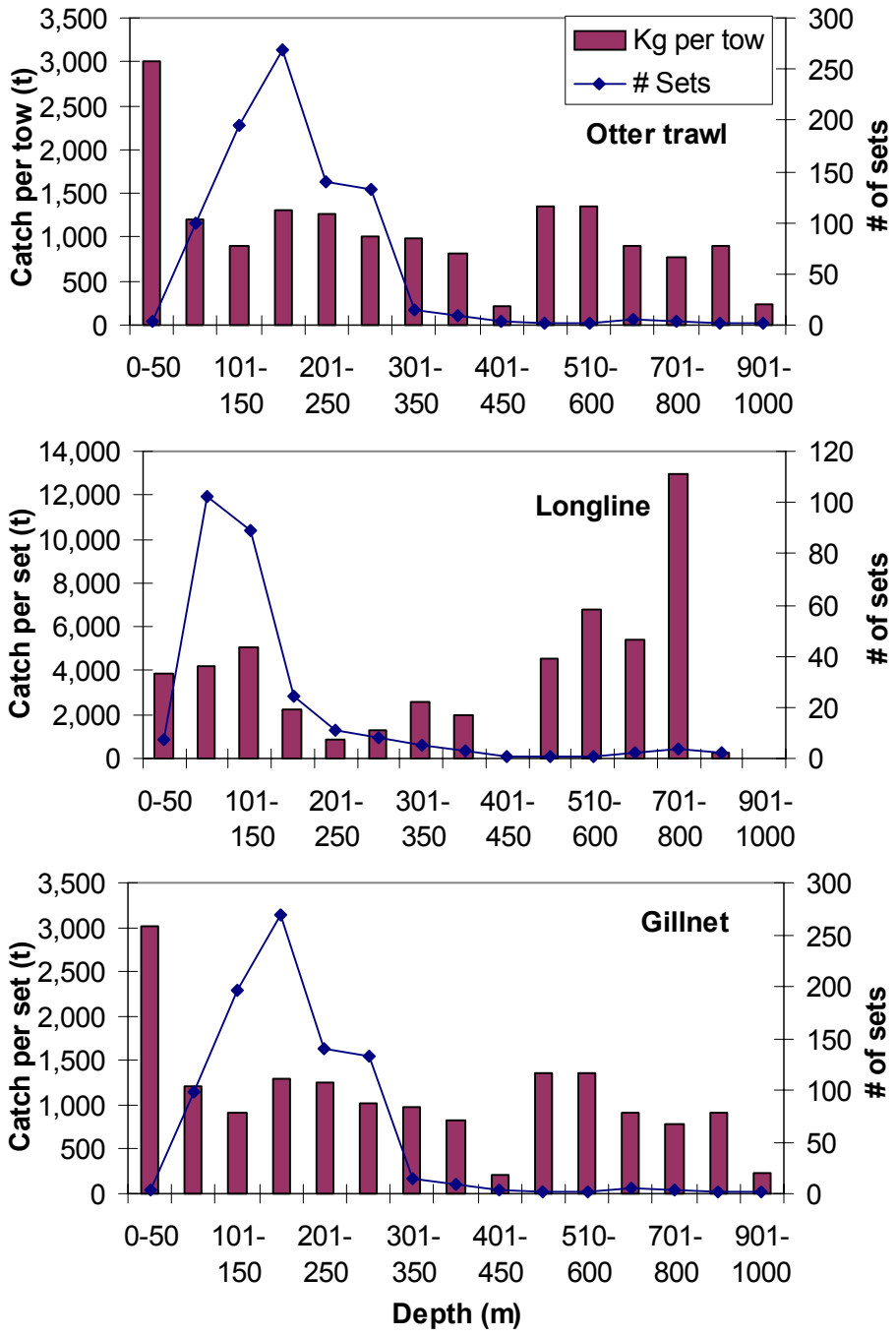


Figure 18. Catch rate and effort with respect to depth in the commercial fisheries for monkfish, 1999-2003.

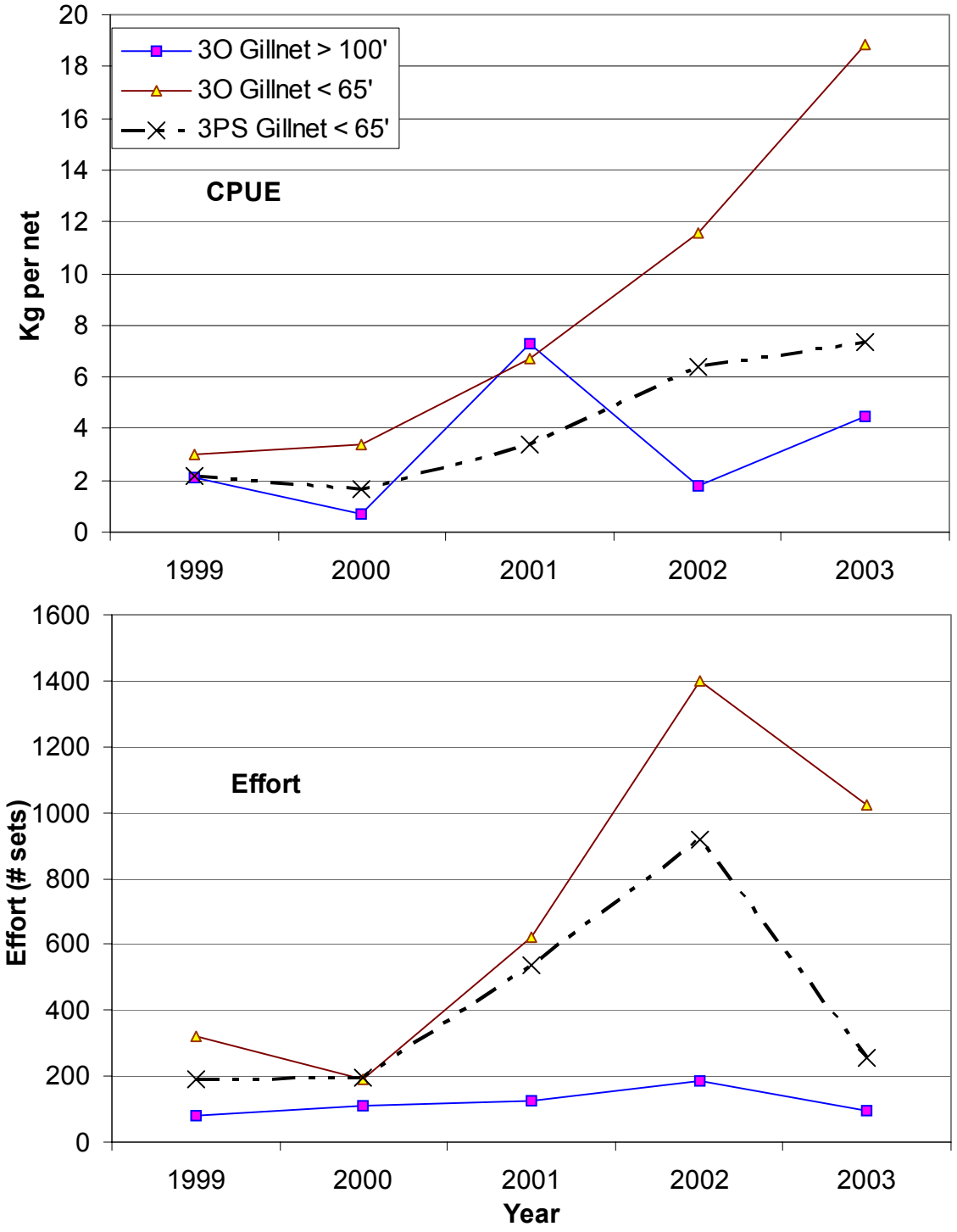


Figure 19. Effort for the major gillnet fleet components, 1999-2003; based on fishing log records. Upper panel: catch per unit effort (catch per gillnet). Lower panel: effort (numbers of sets).

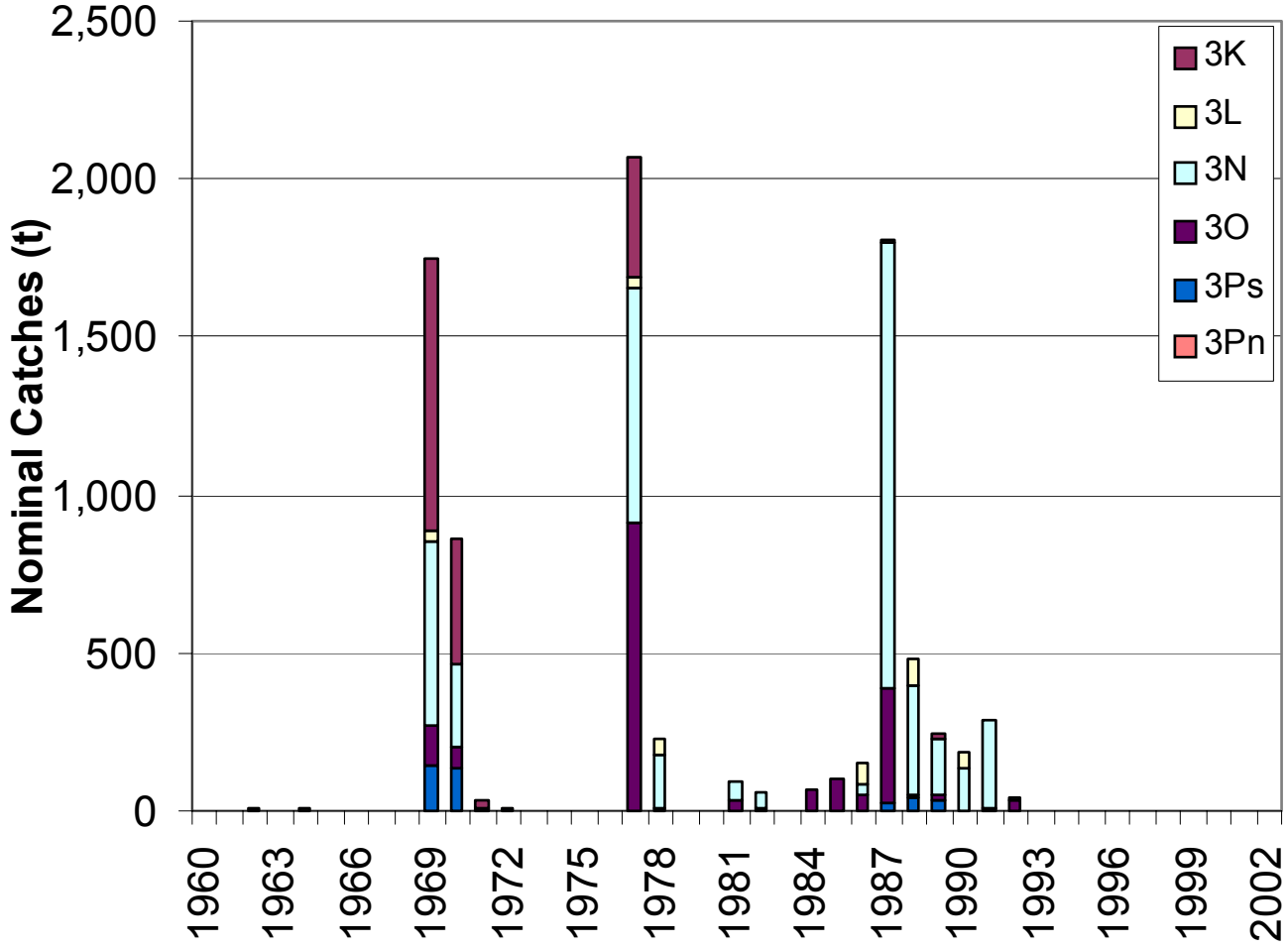


Figure 20. Nominal catches of monkfish by non-Canadian fleets; as reported to NAFO.

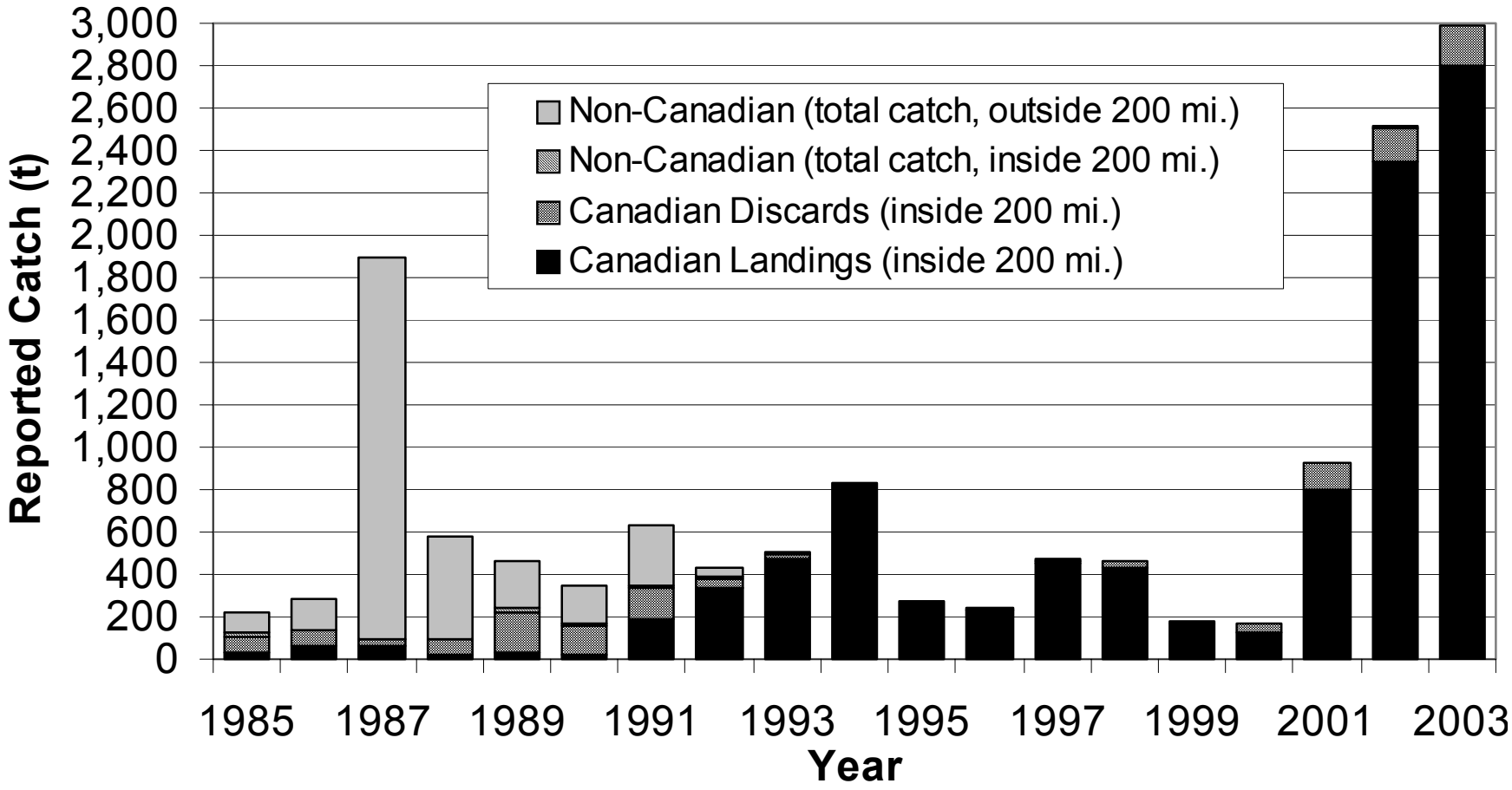


Figure 21. Canadian and non-Canadian landings of monkfish in 3LNOPs, 1985-2003. Canadian landings are compiled from Zonal Interchange Format (ZIF) files. Canadian discards and non-Canadian catches inside 200 miles are estimated from Observer data. Catches in non-Canadian waters were collated from NAFO statistics. Note that 2002 and 2003 do not include NAFO estimates, and ZIF data for 2003 are preliminary.

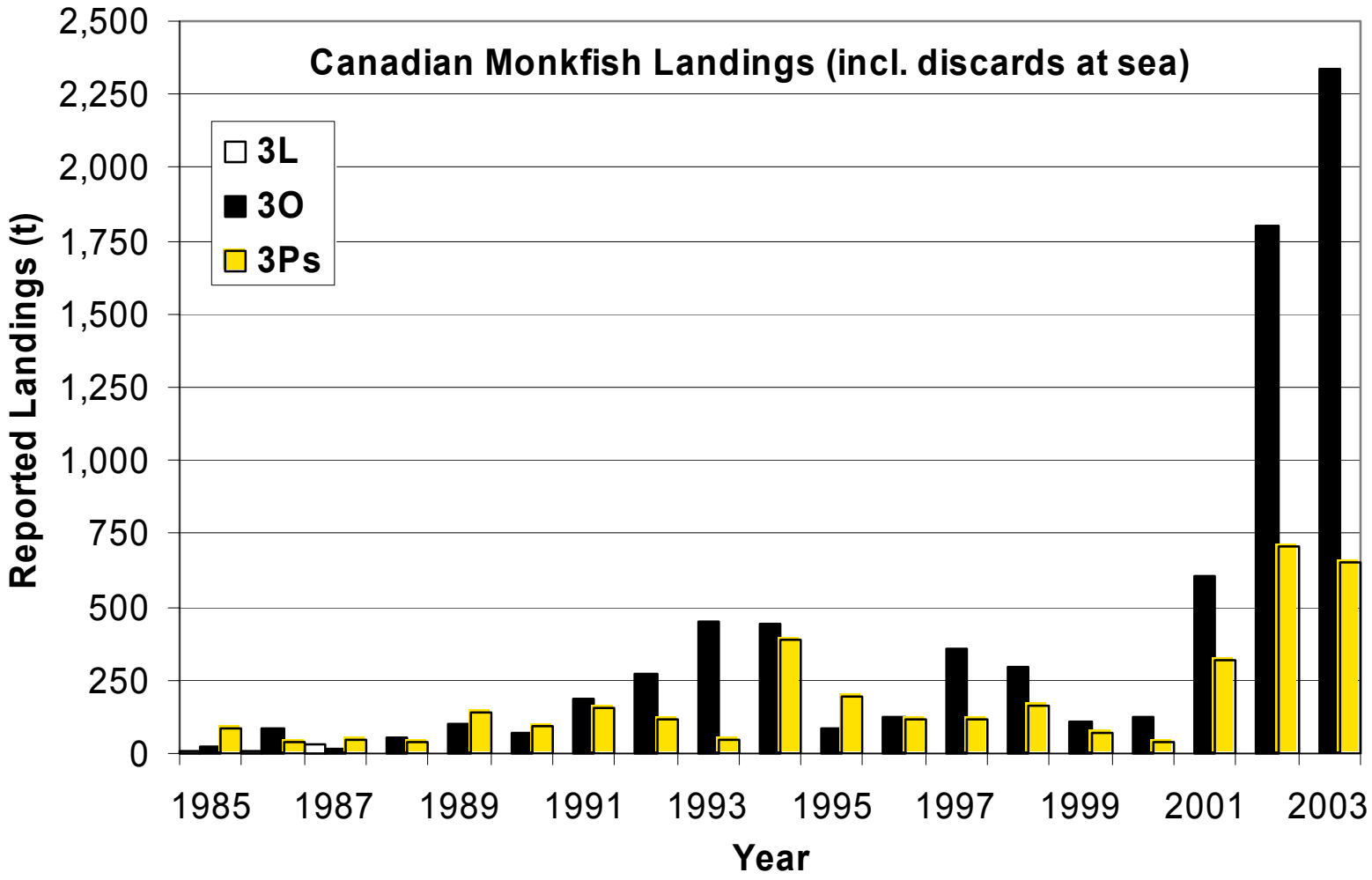


Figure 22. Reported catches of monkfish in 3LNOPs, 1985-2003, by NAFO Div. Landings are compiled from Zonal Interchange Format (ZIF) files, and discards are estimated from Observer data. Note that ZIF data for 2003 are preliminary.

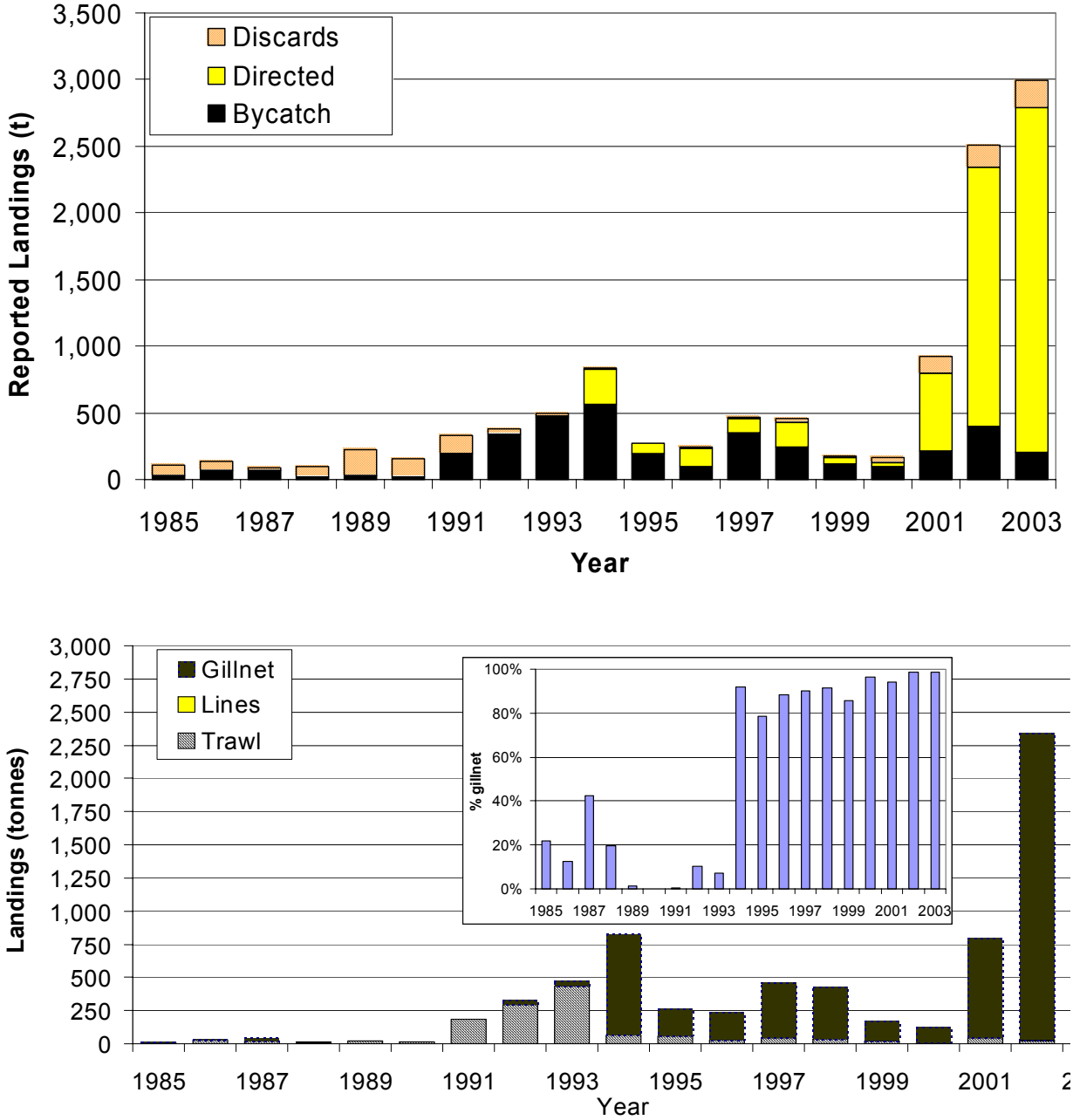


Figure 23. Canadian landings of monkfish in 3LNOPs, 1985-2003, by directed and non-directed modes (upper panel) and by gear type (lower panel). Canadian landings are compiled from Zonal Interchange Format (ZIF) files, and discards are estimated from Observer data. Note that ZIF data for 2003 are preliminary.

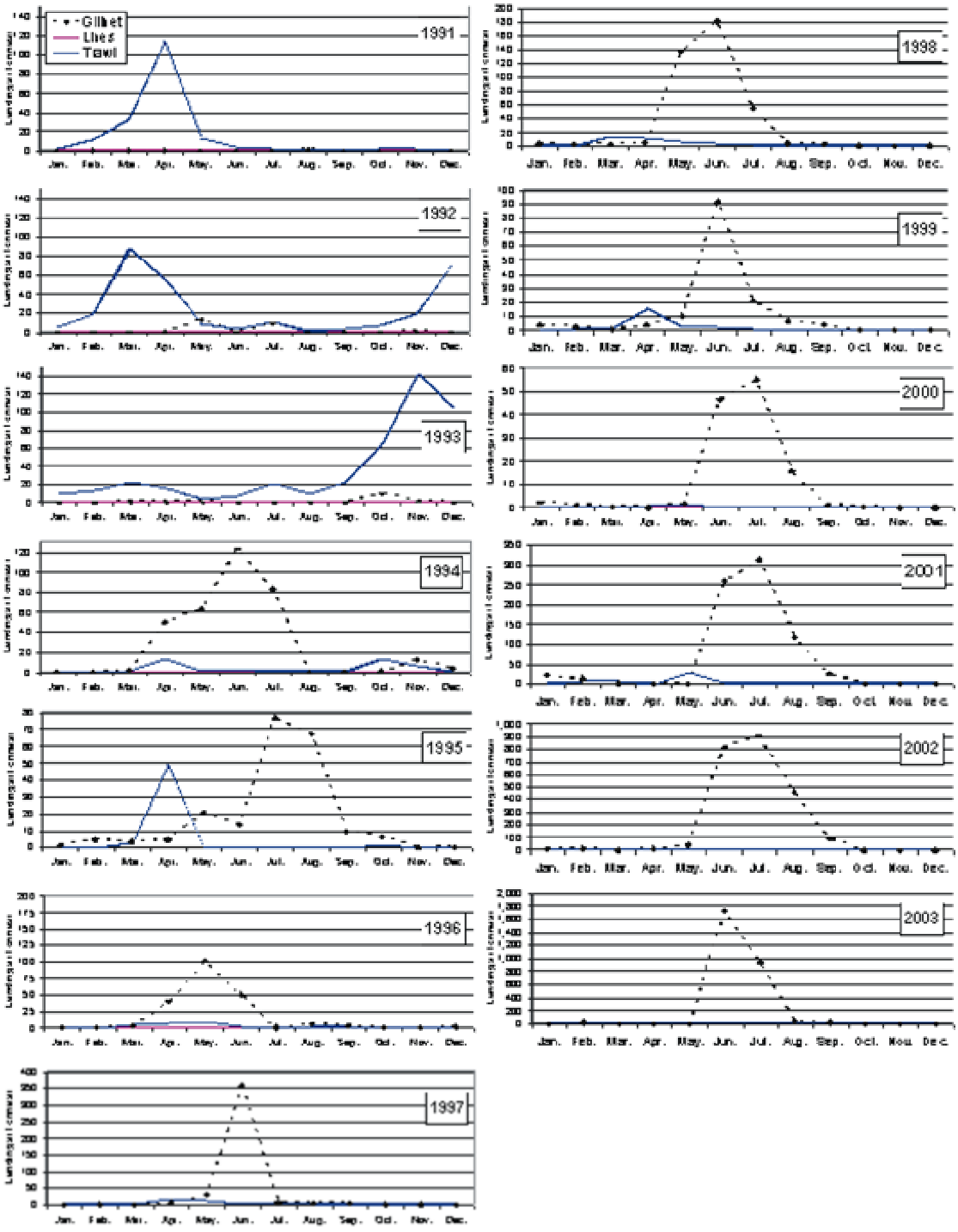


Figure 24. Canadian landings of monkfish by month and gear in NAFO Div. 3LNOPs, 1991-2003. Landings are compiled from Zonal Interchange Format (ZIF) files. Landing records for which no month was recorded are excluded.

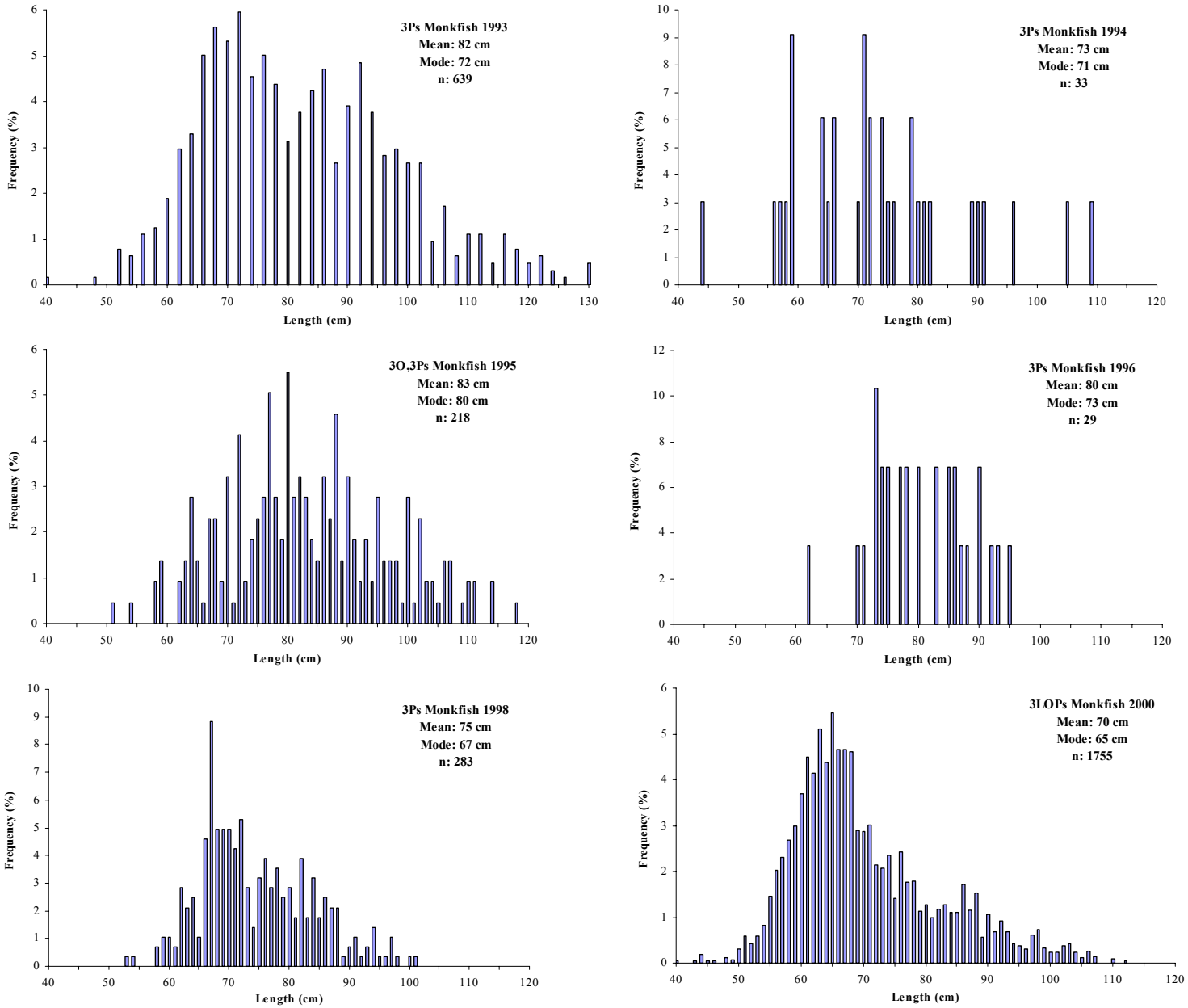


Figure 25a. Size of monkfish in commercial catches from gillnet gear in NAFO Div. 3LOPs, 1993-2000.

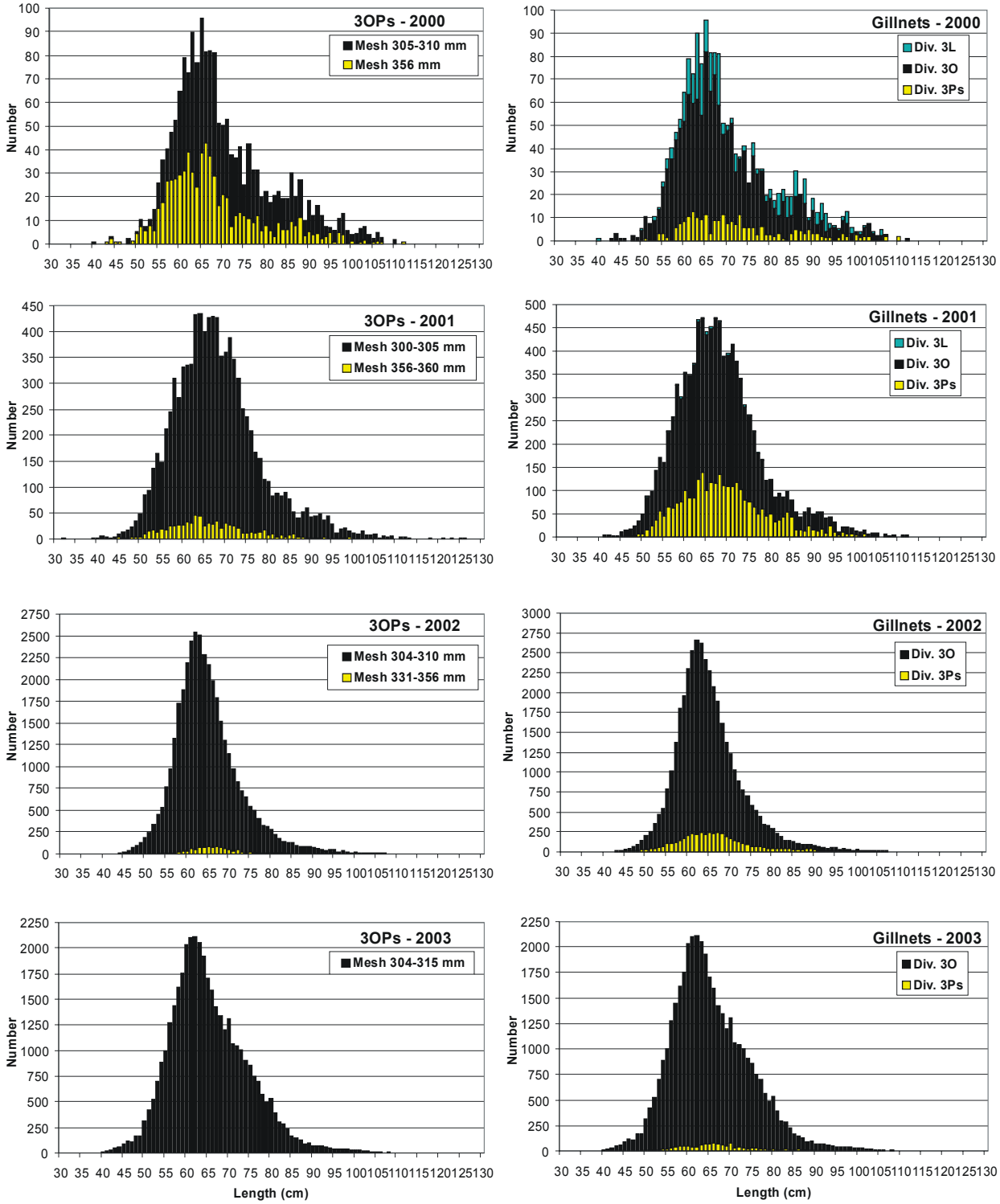


Fig. 25b. Size of monkfish taken in commercial gillnets in Div. 3LOPs, 2000-2003. Left panel: size according to two mesh sizes used in gillnets. Right panel: size in the catches by NAFO Division.

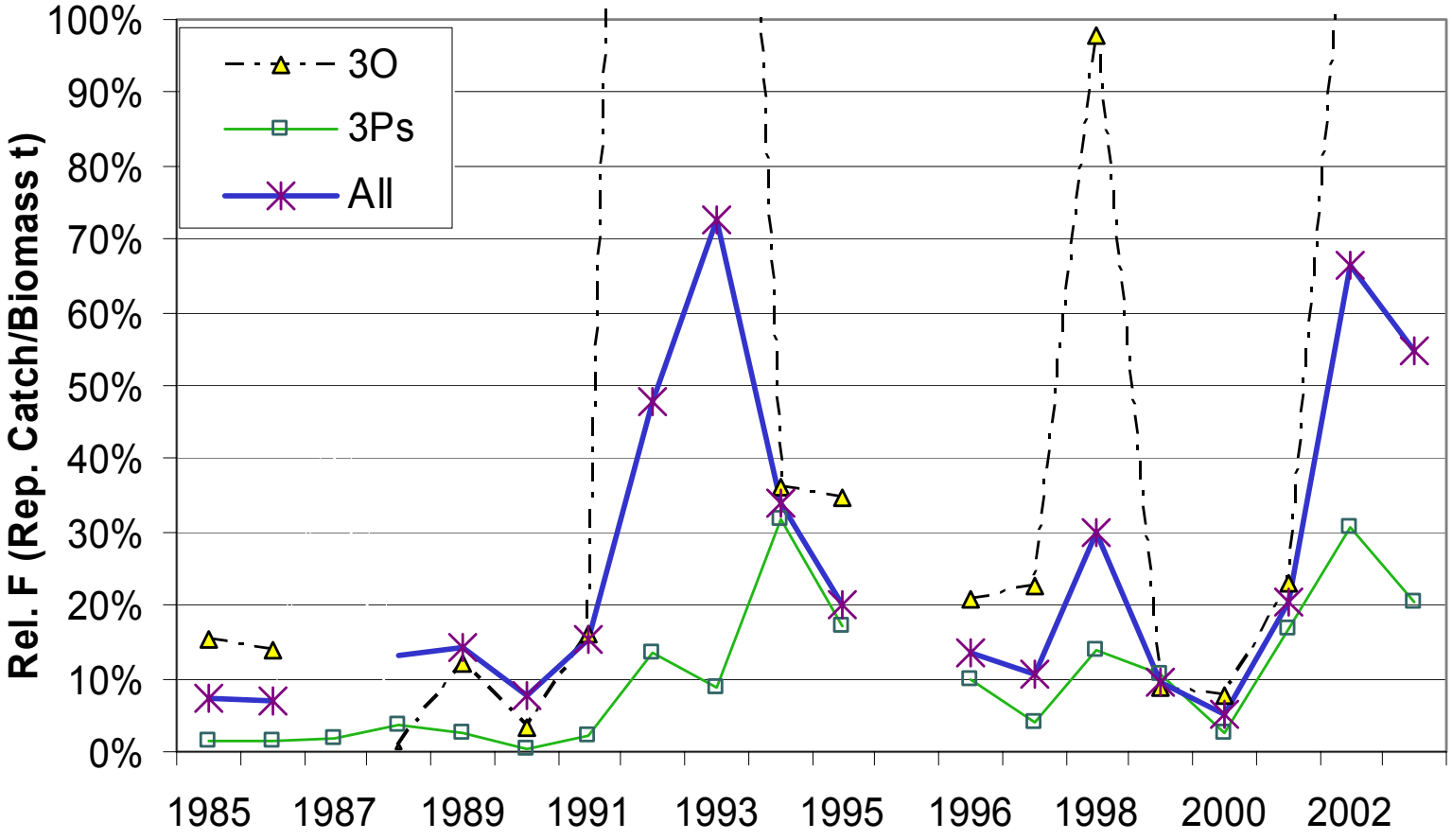


Figure 26. Exploitation Index or relative F for monkfish: Ratio of total commercial catch to research survey biomass index.