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Annual Trends in Abundance and Bycatch Removals of Blue Hake (*Antimora rostrata* Günther 1878) in the Northwest Atlantic

Tendances annuelles de l'abondance et des prises accessoires du hoki (*Antimora rostrata* Günther 1878) dans l'Atlantique Nord-Ouest

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Abstract

Blue hake form a continuous distribution in slope waters off North America and into the northeast Atlantic. In fact, it has been found to inhabit most of the world's slope waters that have been surveyed. Our study examines annual trends in a) mortality attributable to fishing and b) trends in abundance. Trends in deepwater fisheries that captured blue hake as a bycatch were examined and fisheries observer data are used to estimate amounts of blue hake captured in the fisheries. On average, 84 t (since 1980) and 16 t (since 1993) have been removed annually as bycatch in the slope fisheries off Canada since 1985, primarily from the grenadier and Greenland halibut directed fisheries. Given the greater deepwater effort in the 1960's and 1970's catches were greater during that period (estimated peak catch was 887 t in 1971). Catch rate increased steadily out to the maximum depths fished for commercial gear and peaked at about 1 400 m for survey trawls although depths greater than 1 200 m were poorly sampled. Deep (1 371-2 286 m) longline survey sets from the 1960s (and catches from depths in excess of 3 000 m in USA waters to the south) indicated that blue hake are distributed well beyond depths commercially fished. In terms of using standard surveys to estimate abundance, 95% of survey sets containing blue hake occurred at depths greater than 600 m while < 5 % of survey sets occurred at those depths. In addition, maximum depth surveyed changed from year to year (deeper in recent years). Thus, only a fringe of the blue hake population in Canadian waters falls within the survey area. Most of the population is well beyond depths surveyed (or fished). The limitations and the difficulties associated with using a shelf based survey to study changes in the abundance of a slope species are discussed.

Résumé

Le hoki occupe les eaux de talus continental au large de l'Amérique du Nord jusque dans l'Atlantique Nord-Est. En fait, on l'a trouvé dans la plupart des eaux de talus continental du monde qui ont fait l'objet d'un relevé. Notre étude porte sur les tendances annuelles de sa mortalité par pêche et de son abondance. Nous avons examiné les tendances des pêches en eau profonde qui capturent le hoki de façon accessoire et nous nous sommes servis des données recueillies par les observateurs des pêches pour estimer les quantités de hokis capturés. Les pêches dans les eaux du talus au large du Canada, surtout les pêches dirigées du grenadier et du flétan noir, ont prélevé en moyenne 84 t (depuis 1980) et 16 t (depuis 1993) de hokis par année. Comme l'effort de pêche en eau profonde était élevé dans les années 1960 et 1970, les prises de hokis étaient plus abondantes durant cette période (les prises estimées ont atteint un sommet de 887 t en 1971). Le taux de capture augmentait graduellement jusqu'aux profondeurs maximales de la pêche commerciale et atteignait un maximum à environ 1 400 m dans les relevés au chalut (mais les profondeurs supérieures à 1 200 m ont été peu échantillonnées). Des relevés à la palangre effectués en eau profonde (de 1 371 à 2 286 m) dans les années 1960 (ainsi que des prises faites à plus de 3 000 m dans les eaux américaines au sud) ont montré que le hoki est présent à des profondeurs bien plus grandes que celles de la pêche commerciale. Quant à l'utilisation de relevés standard pour estimer l'abondance, 95 % des mouillages d'engin ayant capturé du hoki ont été faits à des profondeurs de plus de 600 m, alors que moins de 5 % des mouillages d'engin ont été effectués à ces profondeurs. En outre, la profondeur maximale des relevés variait d'une année à l'autre (plus grande ces dernières années). Ainsi, les relevés ne couvrent qu'une faible partie de la population de hokis des eaux canadiennes, car la majorité de la population se trouve à des profondeurs bien plus grandes que celles couvertes par les relevés (ou par la pêche). Nous discutons des limitations et des difficultés de l'utilisation d'un relevé axé sur le plateau continental pour étudier l'évolution de +l'abondance d'une espèce associée au talus continental.

Introduction

Blue hake (*Antimora rostrata* Günther, 1878), a member of the family Moridae was originally described by A. Günther (British Museum) in 1878 from specimens taken in the Indian and South Atlantic oceans. The genus *Antimora*, formerly divided into five species, was amalgamated to a single species retaining the original name, *A. rostrata* by Schroeder (1940). Small (1981) then divided the genus into two species, *A. microlepis* inhabiting the North Pacific Ocean and *A. rostrata* elsewhere including the Atlantic.

Worldwide, blue hake is one of the most abundant fish species inhabiting bathyal depths. Grey (1956) provided the earliest summary of its global distribution and Small, (1981) updated the records. Based on these and numerous other published records, it has been reported in varying concentrations in the Atlantic and Pacific distributed mainly on the continental slopes between 400 and 3 000 m (Wenner and Musick, 1977).

In the Canadian Atlantic, where it is being examined in the context of risk of extinction (extirpation in this case given that it is distributed beyond Canadian waters), blue hake has been reported to form a continuous distribution along the slope from the southern extent of Canada's 200 mile limit off Georges Bank to the Labrador Shelf and Davis Strait at Lat 65^o N, but rarely north of Lat 63^o N (Kulka *et al.* 2003). Commercial fishery records also indicate that blue hake inhabit the deep (450-600 m) trenches on the shelf off Labrador and northeast Newfoundland and in the Laurentian Channel leading into the Gulf of St. Lawrence although sporadically and in very low numbers. Blue hake are under-represented in the survey and fishery records on the Scotian Shelf and in the Gulf of St. Lawrence since few sets were prosecuted at depths where they are distributed (Kulka *et al.* 2003). As a percent of total catch, blue hake abundance in Canadian waters increased from near zero at 600 m peaking at 1.6% of the total catch at 1600 m. However, Kulka *et al.* (2003) noted that sampling was extremely low beyond 1 400 m and it is not possible to determine exactly where abundance reached a maximum or what is the maximum depth of distribution.

Given its widespread distribution, blue hake has been the subject of a considerable number of papers. However, with few exceptions, past publications have not dealt with annual trends in abundance or fishery removals. Parsons (1976) first described the distribution of this species in Canadian slope waters, but mainly in the context of its commercial potential. Kulka *et al.* (2003) dealt with the details of its distribution and some aspects of its biology. Those studies provided nothing in regard to annual trends. Gordon and Duncan (1985) presented information on changes in abundance in the northeast Atlantic where deep water effort has been increasing in recent years, raising concerns about vulnerability of long lived deepwater species to increasing fishing pressure.

The purpose of this study is to present an annual accounting of (bycatch) removals of blue hake from the slope fisheries off Canada (Fig. 1) to examine annual trends in abundance using fall (primarily) and spring surveys from the Grand Banks and Labrador Shelf, in the context of risk of extinction. The challenges in using the shelf based surveys to examine abundance of a slope based species are discussed. Annual trends in size of fish are also presented.

Methods

Information for this study was gathered from two sources: Canadian research surveys carried out during two periods, Spring and Fall to examine trends in abundance, and fishery statistics from three sources to examine mortality related to fishing.

Abundance indices from research surveys

A summary of the stratified-random survey design adopted by the Newfoundland region after 1970 can be found in Doubleday (1981). While survey design has remained constant, additional strata, mainly on the slope have been included in recent years (1994 to date) along with modifications to some of the original strata. An accounting of these modifications can be found in Bishop (1994). This paper examines the changes in strata, particularly in relation to depth given that blue hake are distributed only at the outer range of depths surveyed.

As well, there was a change in survey gear after the spring 1995 survey, from Engels 145 to Campelen 1800 bottom trawl. Gear conversion factors for amounts and sizes of fish caught were derived for the major species but not for minor species, including blue hake. Thus, the catch rate data and resulting biomass and abundance indices are on a different scale between the spring of 1995 and subsequent surveys. The two periods must be considered as unrelated time series. The change in scale is delineated on the various tables and figures.

Canadian random stratified Fall research surveys were used as the primary source of information on trends since they covered a broader range of latitudes and depths than the Spring survey (although not the entire range of blue hake). The random stratified series spanning 1978-2001 and covering the Grand Bank (excluding St. Pierre Bank), northeast Newfoundland and Labrador Shelves (NAFO Divisions 2JK3LNOPs) were used to estimate biomass and abundance for blue hake using STRAP (Smith and Somerton 1981). This an areal expansion method employing pre-defined strata added over the survey area. Spring random stratified surveys, a longer time series (1973-2001) were also examined but they covered only the Grand Banks (including St. Pierre Bank) and none of the northeast Newfoundland and Labrador Shelf. There were no consistent time series of surveys north of NAFO Division 2J (Lat 55^{o} 30’ N) but trawl survey sets did occur sporadically in Davis Strait and off northern Labrador (NAFO Divisions 0, 2G, 2H). As well, surveys on the Scotian Shelf and in the Gulf of St. Lawrence rarely captured blue hake since more than 99% of the survey effort occurred at depths less than 400 m, outside the range of blue hake (refer to Kulka *et al.* 2003 for a description of depth distribution). Thus, nearly all of the depth range of blue hake is not surveyed in those areas.

In addition to the standard surveys sets used to estimate the (STRAP) abundance indices, a number of additional (various experiments) trawl sets were done over the years. A significant proportion of these sets were prosecuted in deep waters. As well, non-standard surveys were carried out in years prior to 1978 (Fall) and 1971 (Spring). Average catch (kg) per tow of blue hake from these data is examined in relation the depths surveyed.

SPANS GIS (Anon 1997) was used to estimate the area of occupancy of blue hake. Based on evidence of blue hake out as deep as 2 300 m and data from USA waters showing blue hake in the mid-Atlantic Bight to exceed 3 000 m, area of occupancy was estimated for depths between 700 and 3 000 m.

Commercial fishery

Blue hake are not recorded in the landings statistics but are recorded on a set by set basis by fishery observers for a portion of the fisheries by the methods described in Kulka and Firth (1987). Three data sources were used to derive an estimate of catch of blue hake, including discards: Zonal Interchange Format (ZIF), NAFO STATLAN 21A (Northwest Atlantic Fisheries Organization), and Fisheries & Oceans Observer data (OBS). A ratio of observed directed species weight of catch (Observer data) to reported weight of catch of corresponding directed species (Canadian catch from ZIF, Non-Canadian catch from NAFO) was used to adjust observed estimates of bycatch weight of blue hake (Observer data, kept plus discard weight) to derive an estimate of total removals of each blue hake. Fishery units were defined in relation to Country, NAFO Division, Gear type, and Directed species. NAFO data for 1999 and 2000 are provisional. As well, ZIF data are not available for Newfoundland for 2002, nor for the Gulf and Quebec regions for 2001/2002 (blue hake capture in fisheries there is rare).

Blue hake were measured for total length by sex, 74 569 fish from otter trawls and 867 from longlines. Data from surveys (1 770 fish measured) and commercial sources (72 791 measured) were combined to provide increased sample size and temporal coverage. The data spanned the entire study area from 1973-1992, although not all years were represented and sampling was low in some years (refer to Table 2). All blue hake lengths were recorded as total length. Annual frequencies for years where measurements were done are presented.

Results

Abundance indices from research surveys

Blue hake are relatively uncommon in trawl survey catches prosecuted on the Grand Banks, northeast Newfoundland Shelf and Labrador Shelf. From a total of 15 210 standard trawl sets prosecuted during the 1978-2001 Fall surveys (covering the much of the northeast Newfoundland and Labrador shelves and the Grand Banks and part of the adjacent slope) 1 466 sets contained 10.3 t of blue hake (Fig. 1). For the 1971-2001 Spring surveys, from a total of 11 967 standard trawl sets (covering the Grand Banks and part of the adjacent slope), only 155 sets contained 156 kg of blue hake. Nearly all of this was taken since 1991 following the addition of deep sets and strata.

Blue hake are increasingly more common with depth. Table 1 shows that year, NAFO Division and depth had a significant influence on the number of blue hake captured in trawl surveys. In addition, there was a significant influence of depth on blue hake captures within NAFO Division. This interaction was due to differences in depths fished among Divisions as well as differences in the manner in which blue hake was distributed along the slope.

Standard surveys on the Scotian Shelf rarely exceeded 400 m in all years, therefore, catches of blue hake were very rare in these surveys. However, a non standard survey targeting redfish (*Sebastes sp*) and a longline fishery prosecuted between 1982 and 1988 targeting survey Atlantic halibut (*Hippoglossus hippolossus*) yield blue hake in the deep sets along the edge of the Scotian Shelf edge. It should be noted that indices quoted in this paper refer to the Grand Banks, north to the Labradors Shelf only.

Prior to 1978, Fall survey data (Grand Bank to Labrador Shelf) were not based on a random stratified design. Gear configuration was variable over time and survey sets occurring at depths > 500 m (where most blue hake occur) were variable and sparse (Fig. 2). Average catch rate per tow fluctuated, usually higher in years when there was a greater proportion of deep sets. Prior to the mid 1960's, survey trawl sets prosecuted at depths > 500 m were rare. Thereafter, proportion of sets at depths > 500 m fluctuated around 10% until 1977. Due to the scarcity of deep sets in earlier years (particularly prior to 1965), the fluctuation in proportion of deep sets after 1965 and the non-stratified nature of the survey data prior to 1978, trends in abundance of blue hake could not be determined.

Figure 3 (after Kulka *et al.* 2003), illustrates the depth distribution of blue hake averaged over

1977-2000 and includes non-standard sets and areas falling outside of the standard survey area (north of NAFO Division 2J). Comparing Fig. 3 with Fig. 4a (Fall) and 4b (Spring), illustrating annual changes in surveyed depths indicates that the surveys cover only a small portion of depths that blue hake inhabit. Survey catch rates were low out to about 1 000 m then increased exponentially, possibly peaking at 1 400-1 600 m. A similar pattern can be seen in the Fall standard survey catch rates (Fig. 4a, middle panel) although the limited Spring data suggest slightly higher densities at shallower (< 1000 m) depths particularly with Campelen gear (Fig. 4b, middle panel).

The truncated distribution suggests that the survey sampling (or commercial effort) did not cover the entire or even a substantial portion of the distribution of blue hake in terms of depth (Fig. 3). Limited deep survey longline sets from the 1960's showed that blue hake are found at least as deep as 2 286 m off Canada. Catch rate increased at a substantially slower rate in the shallower part of the distribution north of Lat 55^{o} compared to the area south of this latitude. This latitude corresponds closely to the northern border of the survey area (NAFO Divisions 2J) used in this study to estimate indices of biomass and abundance. Thus, the survey data used in this paper to examine annual trends (Fig. 4-8) fall within the Southern area illustrated in Fig. 3. Fig. 4a, lower panel shows that Fall survey catch rates at depths < 500 m were near zero in all years. At depths > 500 m, the catch rates fluctuated around about 3 kg/tow from 1988 to 1986 then dropped off to about an average of 1 kg per tow. Concurrent with the change in survey gear to Campelen trawl in 1995, the catch rates at depths > 500 m underwent a sharp increase. Percent of standard Fall survey sets prosecuted at > 500 m (depths at which blue hake were distributed) fluctuated between 3 and 12% prior to 1996 and 20 to 25% thereafter (Fig. 4a lower panel). In particular, the addition of deep strata to the Fall survey in 1994 resulted in a significant increase in proportion of sets prosecuted beyond 1 000 m. This extended the survey into depths where blue hake abundance increases exponentially (Fig. 3 and middle panel in Fig. 4a). The Spring survey, prior to the 1990's, largely did not overlap with blue hake (Fig. 4b). After the 1990's overlap was minimal but increasing corresponding with an increase in deep sets.

Annual average values of Fall survey catch per tow (kg) increased with an increase in proportion of trawl survey sets > 1 000 m indicating that estimates of biomass of blue hake are increasing influenced by the deeper sets (Fig. 5).

Notwithstanding the deficiencies in survey coverage as it relates to blue hake, two random stratified design time series, Fall Engels after 1977 and Fall Campelen, after 1994 were used to examine trends in abundance because these are the best available data (Table 2, Fig. 6 and 7). Fig, 6 shows that the Fall survey indices in each of the NAFO Divisions show similar trends where sufficient data are available. Catch rates were usually lower in NAFO Divisions 3L, 3N and 3O due at least in part to the shallower proportion of deep sets in those areas. Fig. 7a, the index of biomass and abundance for the entire survey area showed a decreasing trend during the late 1970's and early 1980's, fluctuating thereafter until the mid-1990's and then increasing thereafter. After the change to Campelen survey gear in 1995, the biomass and abundance increased rapidly over the 7 year period. The panels to the right include data from the deep strata that were added after 1995. The panel to the left exclude those strata. With or without the deep strata, the index increased rapidly.

Table 2 shows that for some of the areas, particularly NAFO Divisions 3L, 3N and 3O, sampling was not consistently available. Thus, a time series of abundance and biomass indices based only on NAFO Divisions 2J and 3K (Fig. 7b). The time series for this specific area is quite similar for the overall series. This is expected because on average the majority, 84% of the biomass between 1978 and 1994 and 46% of the biomass between 1978 and 1994 is attributable to

NAFO Divisions 2J and 3K. This is at least in part a result of a greater proportion of deep sets that occur in those two areas.

For the Spring, data back to 1971 were available but this survey was restricted to the Grand Banks and to depths largely < 500 m until the mid-1990's. The resulting indices from that survey show near zero values until 1995 (Fig. 8). After the fall of 1995, corresponding with the change to Campelen gear and the addition of deep strata was a rapid rise in the survey indices. However, the degree to which this increase in the indices is related to the addition of deep survey sets is unclear.

Survey data indicate that blue hake are increasingly more common with depth out to the maximum depths surveyed. While the surveys does not cover the full extent of the population of blue hake in Canadian waters, other information (evidence of blue hake out as deep as 2 300 m and data from USA waters showing blue hake in the mid-Atlantic Bight exceeding 3 000 m) suggests that the area of occupancy is the entire slope between 700 and 3 000 m. This slope area (700-3 000 m). amounts to 700 000 km^2. There is no way to determine if the area of occupancy has varied over time since only a fringe of the depths occupied have ever been surveyed. However, blue hake were noted to occur in deep sets in all years surveyed suggesting, at least on a latitudinal scale within the surveyed area that area occupied did not change.

Commercial fishery

From a total of 479 682 observed commercial trawl fishing sets (Observer Program) covering most of the banks and the outer shelf from the Scotian Shelf to the Davis Strait, 22 828 sets yielded 686 t of blue hake (as bycatch in other fisheries) or 0.04% of the total observed catch of all species during that period. It is these sets that were used to estimate total annual removals of blue hake, adjusted to total landings of the directed species with which blue hake were taken as bycatch.

Ninety-four percent of the weight of blue hake was captured in two fisheries for: roundnose grenadier (*Coryphaenoides rupestris*) and Greenland halibut (*Reinhardtius hippoglossoides*). Blue hake were also infrequently encountered in witch (*Glyptocephalus cynoglossus*), redfish (*Sebastes sp.*), cod (*Gadus morhua*), American plaice (*Hippoglosoides platessoides*), shrimp (*Pandalus sp.*) and halibut (*Hippoglossus hippoglossus*) fisheries that occur along much of the outer shelf and slope of the Grand Banks, northeast Newfoundland and Labrador Shelf. Blue hake were caught primarily with grenadier and Greenland halibut because these fisheries are prosecuted at the greatest depths along the slope, between 500 and 1 400 m. Only the deepest sets from the other fisheries yielded blue hake given that range of depths fished (< 700 m), for the most part did not correspond with the blue hake distribution. Bycatch of blue hake was rare for the Gulf of St. Lawrence, Scotian Shelf, Georges Bank given that fishing activity in these areas rarely exceeded 400 m.

Estimated bycatch of blue hake in the commercial fisheries (Fig. 9, Table 3) ranged between 4 t in 1962 and 887 t in 1971. With the exception of 1971, estimated catches did not exceed 461 t in any year and the average annual catch since 1980 was 84 t and 16 t since 1993. The declining trend in catch of blue hake is a result of reduced deep water effort off Canada, in particular, the disappearance of the grenadier fishery in 1993. During the last few years (since 1993), bycatches of blue hake occur almost exclusively (98%) in the Greenland halibut fishery.

Blue hake length frequency distributions, summarized by gear across years indicate a distinct difference in size distribution between the sexes (Fig. 10). From otter trawl catches, males form a narrow mode with a mean of 38 cm whereas females have a wider range of sizes with a mean size of 47 cm. Annual means, medians, modes, minimum and maximum sizes and variation are reported in Table 4 where available. Trawl frequencies were available only for certain years. Between 1978 and 1987 when blue hake measurements were done, only 9 years yielded sufficient measurements. The range of sizes was similar across years, all showing a pattern similar to the cumulative graph (Fig. 11, upper panel). Male distributions were unimodal in all years observed, the mean ranging from 36-40 cm (for years where sample size was sufficiently large) whereas female distributions were bimodal, with modes at 30-40 cm and 50-55 cm. The strength of each of the modes varied among years presumably due to variations in year class strengths. In particular, 1978, 1979, 1980 and 1987 showed a strong 30-40 cm mode suggesting good recruitment in preceding years.

Fish taken with longlines (mean of 36 cm for males, 38 cm for females) were smaller than those from otter trawl catches indicating selectivity for smaller individuals (Fig. 11, lower panel). The small mode of fish, ranging from 5-17 cm, was taken in two sets, one comprising 68 (61 less than 15 cm) fish, the other with 3 fish off northern Labrador. Fish less than 15 cm were also encountered in 29 otter trawl sets but only as single captures per set mixed with larger individuals.

Figure 12 (values in Table 5) illustrate the relative rate of exploitation of blue hake (a ratio of estimated catch), 1978-2001. Rate of exploitation was highest in the 1970’s and 1980’s, averaging about 5% until the early 1990’s. However, the highest values of the exploitation index (proportion of estimated fishery removals to biomass estimated from the surveys) from 1978-1994 averaged 5% when Engels gear was used. Since 1995, after the switch to Campelen survey gear and the addition of deep strata, the exploitation index averaged about 0.1%. Although there was no survey index available prior to 1978, it is likely that the rate of exploitation was higher during those years because of the higher effort.

Discussion

Survey Estimates

The Canadian surveys, originally designed to inventory commercial species that are distributed across the shelf, such as cod and haddock, cover only a relatively small and varying proportion of the latitudinal and depth range of blue hake.

In terms of latitude, survey sets occur along only a portion of where blue hake distribute, along a slope that stretches for about 4 000 km within Canadian waters. The slope along the Georges Bank and Scotian Shelf north to the Laurentian Channel are not covered by standard surveys within the depth range of blue hake. On the Grand Banks north to the Labrador Shelf, the rate of effort was 1 survey set per 190 km of slope prior to fall 1995 and 1 set per 32 km of slope after the fall of 1995. Surveys were sporadic north of Lat. 55^{o} 20’N (northern Labrador Shelf and entrance to Davis Strait) precluding the formulation of a biomass index for that area. However, both survey sets prosecuted in some years and a substantial number of commercial fishing sets indicated that blue hake were at least as abundant north of Lat. 55^{o} 20’N to Lat 63^{o} N as in the area south of that latitude (Kulka *et al*. 2003). To the south of the survey area on the Scotian Shelf and Georges Bank, survey effort rarely exceeded 400 m and thus did not overlap with the distribution of blue hake. However, the deepest survey sets in those areas and also the few deep commercial sets yielded limited numbers of blue hake at rates similar to what was observed on the Grand Banks, northeast Newfoundland Shelf and Labrador shelf at corresponding depths (Kulka *et al.* 2003). Also, immediately south of the Scotian Shelf in USA waters, blue hake were found to be abundant (i.e. Haedrich *et al*. 1980) suggesting a similar abundance in the Scotian Shelf slope waters. Blue hake were also occasionally taken in the Laurentian Channel leading into the Gulf of St. Lawrence in both the surveys and in fisheries for redfish. Thus, in terms of latitude, blue hake are far more extensive in their distribution than the slope areas covered by the fall (Grand Bank to Labrador Shelf) survey, about half of the shelf length. The (only available) standard survey series covering a part of the depth range of blue hake, described in this paper cover only about ½ of the slope waters off Canada where blue hake are distributed.

In terms of depth, the abundance of blue hake was extremely low at < 700 m increasing out to the maximum depth sampled. Beyond about 1 400 m, survey sets are rare in any year, regardless of location. Blue hake abundance peaks beyond this maximum depth surveyed (Kulka *et al.* 2003). The Goode and Beane (1895) records (Carolinas to Scotian Shelf) ranged from 556-2 585m. Haedrich *et al*. (1980) from slope of Georges Bank (adjacent to our study area) found blue hake to be among the top 10 species by weight in 653-3 113 m and was dominant at 1 300-1 947 m. In comparison, the Fall survey occur out to a maximum of about 900-1 400 m (the deepest extent in recent years only) and are centered at shallow depths outside the range of blue hake. When Engels gear was in use (pre-1995), 4% or 21 sets per year and 17% or 124 sets per year when Campelen was used occurred within the depths that blue hake inhabit. The number of sets for the spring surveys is even lower, at 14 sets or 2.8% of the total survey sets. Figure 13, a schematic diagram of the distribution of survey effort in relation to the distribution of blue hake suggests that the overlap of surveys with the depth range of blue hake was low, probably < 30%. Given that only of a fringe of the survey corresponds with the distribution of blue hake, fluctuations in the population abundance of blue hake cannot be distinguished from changes in distribution with respect to depth or latitude. It is possible that blue hake may undergo inter-annual or seasonal changes in their distribution leading to variable proportions of the population occurring within the surveyed area.

In addition, since 1993, deeper strata have been added gradually to the survey area and survey gear was changed in the fall of 1995 from Engels to Campelen shrimp trawl (Campelen gear is more effective in capturing smaller fish given its smaller mesh but catchability of all sizes of fish are different between the two gears). The Engels (pre-1995) and the Campelen time series are not comparable because comparative fishing experiments done for the major commercial species to derive a size based conversion factor for the two gears were not carried out for blue hake. Three differences are usually noted in the size composition of the species captured by Engels vs. Campelen survey gear: in Campelen gear, more small fish are captured, fewer large fish are taken and survey indices are higher. While there appears to be a substantial difference in the magnitude of the index for the two gears, unlike most other species, the size of fish captured by the two gears was very similar. This is likely because blue hake below a certain size do not occur with the range of depths surveyed (young fish are rare world wide).

These considerable changes in survey design, in addition the incomplete coverage of the stock area confound the problem of trying to estimate the relative size of the population of blue hake in Canadian waters. Thus, due to the limited number of sets at the depths where blue hake inhabit, the estimates of biomass and abundance from these data would be expected to be highly variable even if they were representative of the entire population which they are very likely not due to incomplete coverage of the population, coupled with the catchability issues. Thus, the estimates of relative abundance and biomass resulting from the surveys do not reflect absolute abundance, relative abundance or changes in either of these parameters.

Within the shallow part of their range, the index for blue hake did show a decline between 1978 and 1994, then a rapid rise thereafter. However, as discussed above, interpretation of this trend is tenuous at best. Any shift in the distribution of blue hake at the shallow fringe of its ranges would affect the magnitude of the survey indices. If we were to assume that blue hake did not undergo a shift in their distribution with respect to depth or latitude over time, the Engel survey time series, fall 1978-1994, one could conclude that blue hake population in the Canadian Atlantic underwent a 88% decline during those years. This is based on the average of the first 5 years of the Engels survey series (1978-1992) compared to the last five years (1990-1994). Subsequently, the Campelen series would also suggest that blue hake underwent an 88% increase between 1995 and 2001 and a 32% increase between 1996 and 2001. Table 2 indicates a very large increase between 1995 and 1996. Biologically, such large fluctuations seem unlikely for a deepwater species that is thought to be long lived. What can be said is that blue hake in Canadian waters are widespread and it appears that their latitudinal range has not diminished over the survey period.

In adjacent waters, blue hake form a continuous distribution with those in Canadian waters. They are found southward from Georges Bank to the Bahamas (Sulak, MS 1984, Bigelow and Schroeder, 1955; Goode and Bean, 1895, Wenner and Musick, 1977). To the north, the abrupt truncation of commercial blue hake records at the 200-mile line off Greenland, the limit of observed fishing activity in Canadian waters suggests that they would be distributed eastward of that line, beyond the sampled area. No blue hake were recorded in the inventory of species from the south Greenland (1982-1996) surveys (Rätz, MS 1999) taking place east of our study area but the maximum depth that they fished was only 400 m. However, blue hake were commonly recorded in slope waters east and west of Greenland (pers. comm. Ole Jorgenson, Danish Institute for Fisheries Research, Charlottenlund Slot, DK 2920 Charlottenlund, Denmark). Directly east of Greenland, blue hake are found in the Denmark Strait and Irminger Sea off Iceland (Haedrich and Krefft, 1978; Magnusson, MS 1998: Muus et al., 1990)) to the slope waters of the Hebrides, west of Britain (Gordon and Duncan, 1985; Gordon et al. 1996), and on the mid-Atlantic Ridge (Magnusson, MS 1998, 2001). All these records together indicate that the distribution of northwest Atlantic blue hake is continuous with those in the eastern north Atlantic. Thus, even if the population in Canadian waters were to decline or disappear within the survey area, they would presumably continue to be present on surrounding area and other parts of the globe in general, as well as at depths beyond the locations surveyed or commercially exploited.

Commercial Fishery

Mortality due to bycatch of blue hake in deep water fisheries peaked in late 1960’s and early 1970’s when the deep effort was at its maximum. Since that time, deep effort aimed at the grenadiers (the primary source of blue hake bycatch) has disappeared. The Greenland halibut fishery continues to take blue hake. Given that the exploitation rate, based on an index of abundance that represents on a small portion of the total population is low, and that there are large areas (depths beyond 1 400 m anywhere, almost the entire extent of the distribution on the Scotian Shelf and Georges Bank) and parts of the Grand Banks, northeast Newfoundland and Labrador Shelf, it seems unlikely that mortality due to fishing has had a significant impact on the population. In recent years in particular, the bycatch of blue hake has been reduced to low levels due to waning deep water effort. Thus, particularly in recent years, it seems unlikely that mortality due to fishing would have a significant impact on the size of the population.

Conclusions

Using survey data to derive an index of abundance is problematic because:

- the surveys cover only a small proportion of the population both in terms of latitude and depth.
- the proportion of the population that occurs within the survey area varies among years
- part of the population, fish in the reproductive stage, eggs, larvae and juveniles (with the exception of a few 5-20 cm fish) has not been observed anywhere within their global distribution. Those components of population are missing from the survey indices.

Thus, the indices reflect only a fraction of the population located in Canadian waters. How closely the indices reflect actual changes in the population is uncertain.

Also, the contribution of fishing to total mortality is unknown. This species appears to be long lived and slow growing making the population particularly susceptible to exploitation or other sources of mortality. Although it cannot be definitively determined with the available data, it seems unlikely that mortality due to fishing is a large component of the total mortality since the fisheries co-occur only to a very limited degree with the blue hake population. The exploitation index based on a population estimate that represents a small fraction of the total population is low. If the declining survey index observed between 1978 and 1994 actually reflects a population decline then it seems likely that mortality due to reasons other than fishing are the main affect. All of this however is speculative.

Blue hake are globally distributed and similar to Canadian waters, most of their distribution exits at depths that exceed fishing grounds globally. However, in certain parts of the world, for example the northeast Atlantic, deep water fishing effort has been steadily on the rise in recent years (unlike the situation in Canadian waters), increasing the level of mortality due to fishing for blue hake. On a global scale, the chance of threatening the existence of blue hake due to over-fishing seems unlikely.

Summary

The Species at Risk National Assessment Process Terms of Reference require that information on distribution, abundance and life history characteristics of these species that could be used by COSEWIC to determine, following its assessment guidelines and criteria, the appropriate risk category. Information required by the Assessment Process on life history and ecological characteristics (to allow a general assessment of the resilience or general vulnerability of the species) for blue hake is as follows:

- Growth parameters: age and/or length at maturity, maximum age and/or length, growth parameters. – **For blue hake, these parameters are unknown in the Canadian Atlantic, or worldwide.**
- Fecundity, production of young per year. – **For blue hake, these parameters are unknown in the Canadian Atlantic, or worldwide.**
- Early life history pattern, duration of planktonic larval life, and major egg, larval, and juvenile transport mechanisms. – **For blue hake, these parameters are unknown in the Canadian Atlantic, and worldwide. These stages of life history have never been observed.**
- Specialised niche or habitat requirements. – **Blue hake inhabit slope waters globally, forming a continuous distribution in Canadian waters between depths of 500 and about 3 000 m.**

In terms of the status of the population:

1. The population structure in the context of "evolutionarily significant units" – **Blue hake form a continuous distribution along the Canadian slope waters. There is no evidence that blue hake in this area form any more than a single ESU and likely are part of a larger population that extends into surrounding waters.**
2. For ESU's identified in 1 and using information in the most recent assessments: (COSEWIC Criterion: Declining Total Population):
   a. Summarize overall trends in population size (both number of mature individuals and total numbers in the population) over as long a period as possible, and in particular for the past three generations (taken as mean age of spawners); **The only survey that provides a time series for a part of the population in Canadian waters, the Fall Grand Bank to Labrador Shelf survey, indicates that (within the surveyed area) the population of adults declined between 1978 (the first year of the survey) and 1994, the last year of the Engels series. The index has subsequently increased since 1995. However, this survey is deficient in terms of its coverage of the extent of the population. In terms of latitude, about half of the slope are where they are known to exist is not covered by the survey. In terms of depth, less than 1/4 of the depths occupied by blue hake are covered by the survey and the proportion varies among years. Further, the change in survey gear in 1995 resulted in two, non-comparable time series. Whether these indices reflect relative changes in the population abundance of blue hake is unclear.**
   b. Where declines have occurred over the past three generations, the degree to which the causes of the declines are understood, and the evidence that the declines are a result of natural variability, habitat loss, fishing, or other human activity; **Fishing mortality occurs as a result of bycatch in the deepwater fisheries, primarily with roundnose grenadier and Greenland halibut (where fishing effort exceeds 500 m). However, the highest values of the exploitation index (proportion of estimated fishery removals to biomass estimated from the surveys) from 1978-1994 averaged 5% when Engels gear was used. Since 1995, after the switch to Campelen survey gear and the addition of deep strata, the exploitation index averaged about 0.1%. Thus, particularly in recent years, it seems unlikely that mortality due to fishing would have a significant impact on the size of the population.**
   c. Where declines have occurred over the past three generations, the evidence that the declines have ceased, are reversible, and likely time scales for reversibility. **The index of abundance has increased rapidly since 1995. In part, this may have resulted from the addition of deeper sets to the survey.**
3. By stock, for species in Canada as a whole and for ESU's identified in 1 (COSEWIC Criterion: Small Distribution and Decline or Fluctuation):
   a. Summarize current area of occupancy (in km2). **While the survey does not cover the full extent of the population of blue hake, other information suggests that the area of occupancy is the slope between 700 and 3 000 m. This amounts to 700,000 km^2.**
   b. Summarize changes in area of occupancy over as long a time as possible, and in particular, over the past three generations. **There is no evidence that the area occupied by blue hake has changed since the 1980's and perhaps earlier. Both survey and commercial data confirm a widespread distribution.**
   c. Summarize any evidence that there have been changes in the degree of fragmentation of the overall population, or a reduction in the number of meta-

population units. **There is no evidence of fragmentation in Canadian waters.**

4. For ESUs identified in 1 and using information in the most recent assessments (COSEWIC criteria Small Total Population Size and Decline and Very Small and Restricted):
    a. Tabulate the best scientific estimates of the number of mature individuals; **The estimates produced from the surveys are for adult fish. Where the juveniles or other early life stages distribute is unknown. However, spawning grounds are also unknown (ripe females are rare in the surveys).**
    b. If there are likely to be fewer than 10 000 mature individuals, summarize trends in numbers of mature individuals over the past 10 years or three generations, and, to the extend possible, causes for the trends. **The abundance estimated for what amounts to only a small fraction of the total population in Canadian waters far exceed 10 000 mature individuals in all years. The abundance estimate for 2001 for NAFO Divisions 2J, 3K, 3L, 3N and 3O at depths out to 1 400 m is 33 million adult individuals. If one were to extrapolate (speculate), this index (minimum trawlable abundance) to the area thought to be occupied by blue hake, the numbers may be closer to 200 million.**

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Table 1. Results of a generalized linear model on numbers of blue hake captured in surveys in relation to year, NAFO Division and depth.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1094	1456304.413	1331.174	2.90	<.0001
Error	125	57295.340	458.363		
Corrected Total	1219	1513599.753			

R-Square	Coeff Var	Root MSE	NUMBER Mean
0.962146	61.99881	21.40941	34.53197

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	20	492761.5208	24638.0760	53.75	<.0001
div	7	89795.6887	12827.9555	27.99	<.0001
DEPTH	666	565394.9471	848.9414	1.85	<.0001
div*DEPTH	401	308352.2562	768.9582	1.68	0.0004

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	20	26957.6596	1347.8830	2.94	0.0001
div	7	46023.3514	6574.7645	14.34	<.0001
DEPTH	666	557595.3958	837.2303	1.83	<.0001
div*DEPTH	401	308352.2562	768.9582	1.68	0.0004

Table 2. Biomass and abundance indices for blue hake based on Fall Canadian surveys. Upper tables are show biomass (t), lower tables abundance (numbers/1000). Tables to the right exclude deep strata added since 1994, tables to the left include deep strata. A value of 0 indicates no fish, NA indicates no data for that NAFO Division and year.

Biomass (t), deep sets excluded									Biomass (t), deep sets included							
Fall	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**	**All**		**Fall**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**	**All**
1978	523	3,353	NA	NA	NA	NA	3,876		**1978**	523	3,353	NA	NA	NA	NA	3,876
1979	523	3,353	NA	403	NA	NA	4,279		**1979**	523	3,353	NA	403	NA	NA	4,279
1980	299	1,434	NA	403	NA	NA	2,135		**1980**	299	1,434	NA	403	NA	NA	2,135
1981	67	525	0	140	NA	NA	732		**1981**	67	525	0	140	NA	NA	732
1982	225	983	0	2	NA	NA	1,210		**1982**	225	983	0	2	NA	NA	1,210
1983	436	99	69	165	NA	NA	769		**1983**	436	99	69	165	NA	NA	769
1984	145	851	114	328	NA	NA	1,439		**1984**	145	851	114	328	NA	NA	1,439
1985	100	403	375	235	NA	NA	1,114		**1985**	100	403	375	235	NA	NA	1,114
1986	207	0	81	NA	NA	NA	288		**1986**	207	0	81	NA	NA	NA	288
1987	34	231	0	NA	NA	NA	265		**1987**	34	231	0	NA	NA	NA	265
1988	95	0	0	NA	NA	NA	95		**1988**	95	0	0	NA	NA	NA	95
1989	25	0	0	NA	NA	NA	25		**1989**	25	0	0	NA	NA	NA	25
1990	37	408	92	NA	0	0	537		**1990**	37	408	92	NA	0	0	537
1991	38	194	41	NA	5	21	299		**1991**	38	194	41	NA	5	21	299
1992	38	142	2	NA	0	0	182		**1992**	38	142	2	NA	0	0	182
1993	17	232	1	NA	49	7	306		**1993**	17	232	1	NA	49	7	306
1994	15	42	0	NA	14	10	81	0.9792	**1994**	19	45	0	NA	14	10	89
1995	159	3,911	0	NA	97	16	4,183		**1995**	190	3,157	130	NA	97	16	3,590
1996	2,301	3,892	16	459	62	50	6,780		**1996**	2,596	4,343	8,202	5,733	62	50	20,985
1997	2,736	4,867	72	0	28	5	7,709		**1997**	3,076	5,067	6,503	5,957	28	5	20,635
1998	2,494	4,683	8	0	98	72	7,355		**1998**	2,824	4,430	6,597	5,199	2,898	674	22,622
1999	2,672	6,828	56	0	155	73	9,784		**1999**	3,066	5,882	5,177	2,948	155	73	17,303
2000	2,618	6,653	327	0	329	79	10,006		**2000**	2,939	5,394	8,798	5,733	4,823	2,046	29,733
2001	4,716	8,152	302	0	275	54	13,500	0.6901	**2001**	5,221	8,002	6,354	5,000	4,560	1,732	30,870
						Avg 95-01	8,474								Avg 95-01	20,820

Numbers ('000's), deep sets excluded								Avg Size	Numbers ('000's), deep sets included							
Fall	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**	**All**	**(kg)**	**Fall**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**	**All**
1978	2,019	7,948	NA	NA	NA	NA	9,966	0.389	**1978**	2,019	7,948	NA	NA	NA	NA	9,966
1979	2,019	7,948	NA	1,196	NA	NA	11,162	0.383	**1979**	2,019	7,948	NA	1,196	NA	NA	11,162
1980	769	4,421	NA	1,196	NA	NA	6,386	0.334	**1980**	769	4,421	NA	1,196	NA	NA	6,386
1981	393	1,511	0	538	NA	NA	2,442	0.300	**1981**	393	1,511	0	538	NA	NA	2,442
1982	630	2,898	0	6	NA	NA	3,533	0.342	**1982**	630	2,898	0	6	NA	NA	3,533
1983	1,415	355	309	809	NA	NA	2,887	0.266	**1983**	1,415	355	309	809	NA	NA	2,887
1984	367	2,692	521	1,334	NA	NA	4,914	0.293	**1984**	367	2,692	521	1,334	NA	NA	4,914
1985	324	1,094	1,155	1,277	NA	NA	3,851	0.289	**1985**	324	1,094	1,155	1,277	NA	NA	3,851
1986	649	0	265	NA	NA	NA	914	0.315	**1986**	649	0	265	NA	NA	NA	914
1987	294	962	0	NA	NA	NA	1,256	0.211	**1987**	294	962	0	NA	NA	NA	1,256
1988	182	0	0	NA	NA	NA	182	0.521	**1988**	182	0	0	NA	NA	NA	182
1989	212	0	0	NA	NA	NA	212	0.119	**1989**	212	0	0	NA	NA	NA	212
1990	277	1,386	469	NA	0	0	2,132	0.252	**1990**	277	1,386	469	NA	0	0	2,132
1991	248	972	174	NA	52	13	1,459	0.205	**1991**	248	972	174	NA	52	13	1,459
1992	262	823	13	NA	0	0	1,098	0.166	**1992**	262	823	13	NA	0	0	1,098
1993	109	957	13	NA	253	50	1,382	0.222	**1993**	109	957	13	NA	253	50	1,382
1994	142	370	0	NA	56	49	617	0.131	**1994**	176	353	0	NA	56	51	635
1995	2,309	13,637	12	NA	1,442	329	17,729	0.236	**1995**	2,739	12,799	2,638	NA	1,442	337	19,955
1996	11,397	16,619	627	5,789	1,505	1,003	36,940	0.184	**1996**	12,745	18,231	30,303	22,563	1,505	8,202	93,548
1997	14,917	21,705	1,483	0	398	154	38,656	0.199	**1997**	16,522	23,870	31,806	21,191	398	154	93,941
1998	17,054	20,397	618	0	1,713	1,160	40,942	0.180	**1998**	19,024	22,092	27,282	22,636	16,294	6,253	113,582
1999	19,166	31,972	2,760	0	3,301	1,084	58,283	0.168	**1999**	20,953	31,029	33,911	11,439	3,301	1,086	101,719
2000	21,196	28,161	8,502	0	5,507	1,669	65,035	0.154	**2000**	23,357	27,583	47,030	28,353	28,497	10,462	165,282
2001	30,788	46,661	5,825	0	3,032	961	87,268	0.155	**2001**	33,561	47,283	41,393	29,493	24,738	11,160	187,628
						Avg 95-01	49,265								Avg 95-01	110,808

Table 3. Estimated catch (t) of blue hake taken in various fisheries occurring along the shelf edge, 1960-2001. Estimates of catch for years prior to 1980 were based on the average catch observed during 1980-1990 adjusted to total deepwater effort in each year. RNG refers to roundnose grenadier, GHL to Greenland halibut and Red to redfish.

Year	RNG	GHL	Red	Other	Total	% in RNG	% in GHL	% Other
1960	0	4	1	1	6	0.0%	70.4%	29.6%
1961	0	3	0	1	4	0.0%	76.8%	23.2%
1962	0	3	0	1	4	0.0%	66.3%	33.7%
1963	0	7	0	1	8	0.0%	83.3%	16.7%
1964	0	18	0	1	19	0.0%	92.4%	7.6%
1965	0	42	1	1	44	0.0%	96.5%	3.5%
1966	0	81	0	2	83	0.0%	97.2%	2.8%
1967	178	112	0	3	293	60.8%	38.0%	1.2%
1968	322	137	0	2	461	69.9%	29.6%	0.5%
1969	132	157	0	2	291	45.2%	54.0%	0.8%
1970	252	156	0	4	412	61.1%	37.8%	1.1%
1971	777	105	1	5	887	87.6%	11.8%	0.6%
1972	251	127	1	3	382	65.8%	33.3%	0.9%
1973	181	123	1	2	306	59.0%	40.1%	0.8%
1974	293	117	1	2	412	71.1%	28.3%	0.6%
1975	279	121	1	1	402	69.5%	30.2%	0.4%
1976	177	103	0	1	282	62.9%	36.6%	0.5%
1977	152	135	0	1	289	52.8%	46.7%	0.5%
1978	191	165	0	1	357	53.6%	46.1%	0.4%
1979	78	144	0	1	223	35.1%	64.3%	0.6%
1980	21	139	0	1	162	13.1%	86.1%	0.8%
1981	73	130	0	1	205	35.7%	63.7%	0.7%
1982	45	111	0	1	157	28.5%	70.7%	0.8%
1983	36	117	0	1	155	23.5%	75.7%	0.8%
1984	40	105	0	1	145	27.4%	72.0%	0.6%
1985	47	2	0	0	49	96.2%	3.8%	0.0%
1986	117	2	0	0	119	98.0%	2.0%	0.0%
1987	126	17	2	0	146	86.8%	11.7%	1.5%
1988	112	3	0	33	148	75.6%	1.9%	22.5%
1989	56	8	0	33	97	57.6%	8.5%	34.0%
1990	6	3	2	1	12	51.9%	26.0%	22.1%
1991	0	16	0	2	18	0.0%	89.7%	10.3%
1992	0	98	0	12	110	0.0%	89.4%	10.6%
1993	0	180	0	7	187	0.0%	96.0%	4.0%
1994	0	27	0	0	27	0.0%	99.9%	0.1%
1995	0	12	0	0	13	0.0%	99.0%	1.0%
1996	0	20	0	0	20	0.0%	99.9%	0.1%
1997	0	8	0	0	8	0.0%	99.8%	0.2%
1998	0	13	0	0	13	0.0%	99.8%	0.2%
1999	0	4	1	0	5	0.0%	85.8%	14.2%
2000	0	41	0	0	41	0.0%	100.0%	0.0%
2001	0	3	0	0	3	0.0%	99.9%	0.1%

Table 4. Inventory and summary statistics for blue hake length frequencies from otter trawl catches, 1973-1992. Data from research surveys and commercial fisheries are included. Size is recorded as total length (TL).

Otter Trawl

Year	Sex	Mean (cm)	Median (cm)	St. Dev.	Min. Size	Max. Size	Mode	# Meas.
1973	M	27	23.5	7.44	15	40	23	15
	F	34	31.5	9.84	22	51	37	17
1974	M	21	21.5	5.13	15	25	15	3
	F	22	21.5	9.00	13	31	13	3
1976	M	25	21.5	6.76	12	38	19	38
	F	28	26.5	5.11	19	36	27	27
1978	M	36	36.5	5.57	16	49	39	285
	F	46	47.5	9.11	6	64	50	455
1979	M	34	34.5	6.83	12	58	39	398
	F	37	33.5	9.53	16	61	31	420
1980	M	34	34.5	5.66	15	48	40	269
	F	42	41.5	9.29	15	61	36	525
1981	M	37	36.5	6.50	12	72	40	7,320
	F	44	44.5	9.75	7	69	50	13,143
1982	M	42	40.5	7.40	21	68	40	5,284
	F	50	50.5	7.80	12	71	55	14,236
1983	M	31	32.5	6.46	17	42	36	56
	F	31	29.5	7.62	21	61	29	46
1984	M	40	39.5	4.26	26	58	40	202
	F	50	50.5	6.74	25	69	53	1,357
1985	M	40	39.5	5.23	20	60	39	346
	F	50	50.5	7.00	27	66	51	1,224
1986	M	38	37.5	5.37	16	64	40	5,387
	F	48	49.5	8.23	22	73	52	17,497
1987	M	36	36.5	5.21	14	59	37	2,221
	F	43	40.5	9.65	16	70	38	3,767
1992	M	39	37.5	3.55	36	46	37	7
	F	47	48.5	7.69	32	57	48	21
Total	**M**	**38**	**38.5**	**6.52**	**12**	**72**	**40**	**21,831**
	F	**47**	**48.5**	**8.99**	**6**	**73**	**55**	**52,738**

Longline

Year	Sex	Mean (cm)	Median (cm)	St. Dev.	Min. Size	Max. Size	Mode	# Meas.
1983	M	35	34.5	5.65	8	56	35	231
	F	36	35.5	3.48	26	48	36	219
1987	M	36	36.5	5.10	5	49	40	119
	F	39	43.5	17.49	5	67	50	298
Total	**M**	**36**	**35.5**	**5.47**	**5**	**56**	**36**	**350**
	F	**38**	**37.5**	**13.55**	**5**	**67**	**36**	**517**

Table 5. Relative exploitation rate, a ratio of estimated catch of blue hake to survey biomass index.

	Biomass	Catch	Expoitation Index
1978	5,331	357	6.70%
1979	5,735	223	3.90%
1980	3,817	162	4.24%
1981	2,646	205	7.73%
1982	2,967	157	5.30%
1983	2,316	155	6.69%
1984	3,278	145	4.44%
1985	2,999	49	1.62%
1986	2,067	119	5.77%
1987	2,218	146	6.56%
1988	1,988	148	7.43%
1989	1,989	97	4.89%
1990	2,490	12	0.48%
1991	2,252	18	0.78%
1992	2,136	110	5.15%
1993	2,283	187	8.20%
1994	2,063	27	1.29%
1995	5,396	13	0.23%
1996	20,385	20	0.10%
1997	19,556	8	0.04%
1998	21,797	13	0.06%
1999	16,235	5	0.03%
2000	28,794	41	0.14%
2001	27,649	3	0.01%

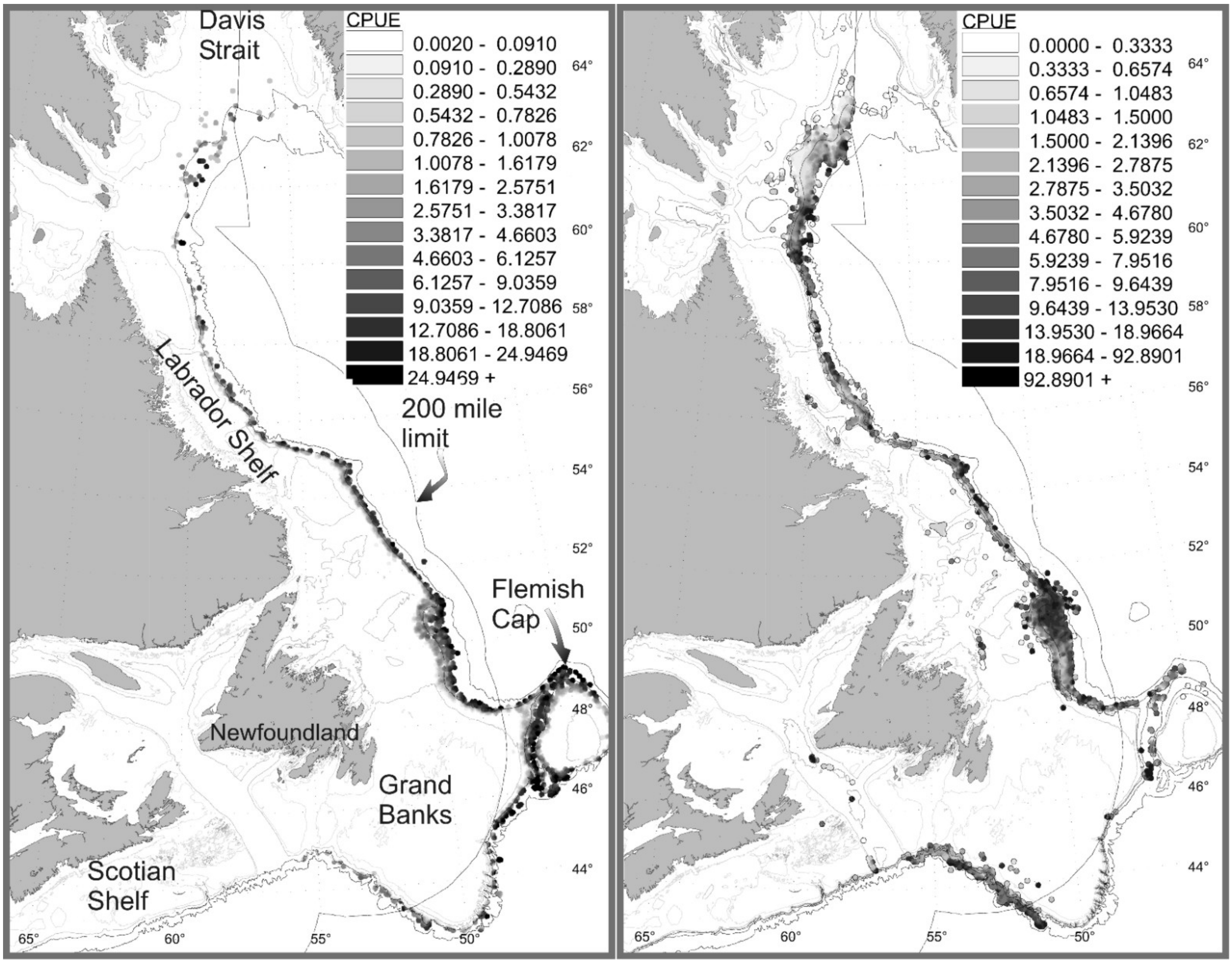


Fig. 1. Left Panel: Map of the study area showing blue hake distribution based on research surveys, 1977-2000 (CPUE = kg per hour, lighter shades of grey depicts areas with lower catch rates of blue hake, darker areas depict higher catch rates). Right Panel: Blue hake distribution based on commercial fishing sets (after Kulka et al. 2003).

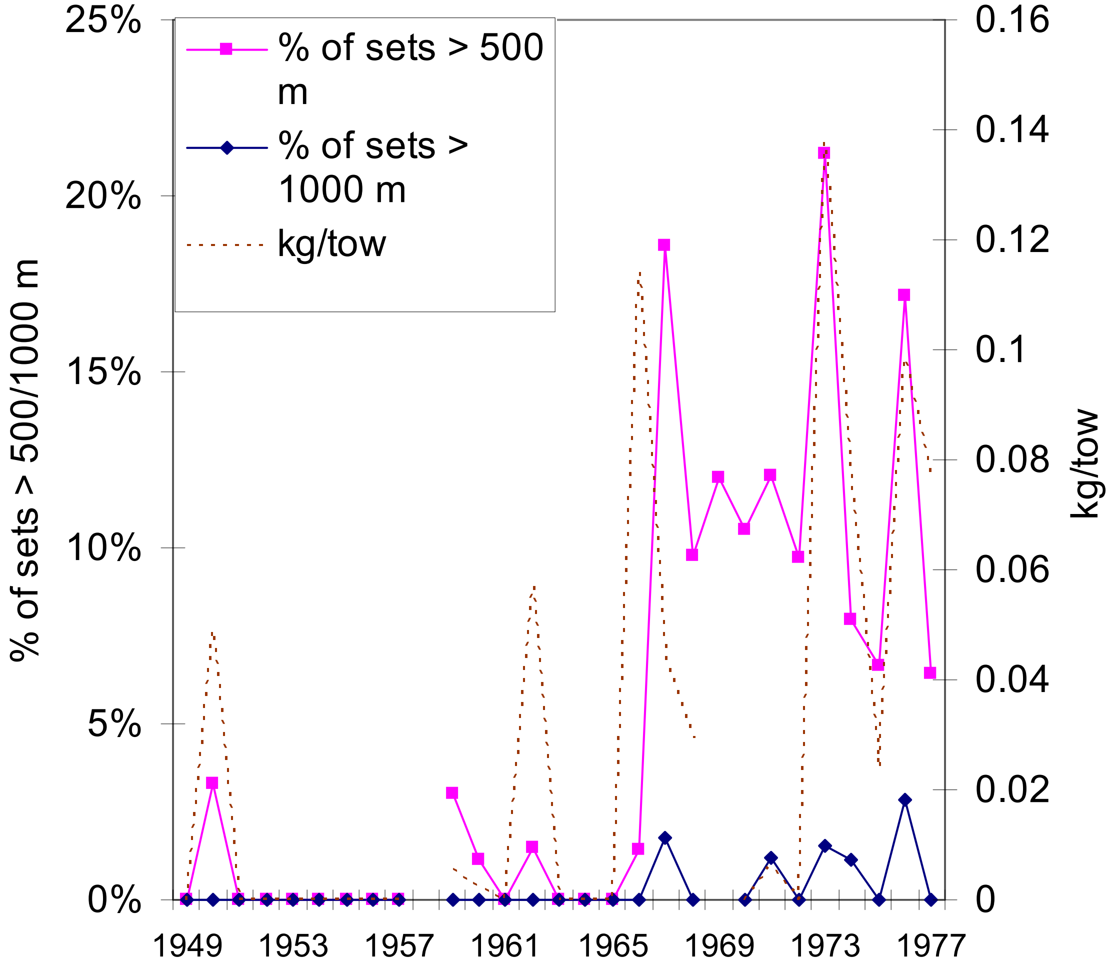


Fig. 2. Percent of fall trawl survey sets prosecuted at depths > 500 and 1000 m, and average weight per tow (kg) from trawl survey sets, 1949-1977. Non-standard trawl sets are included in all years.

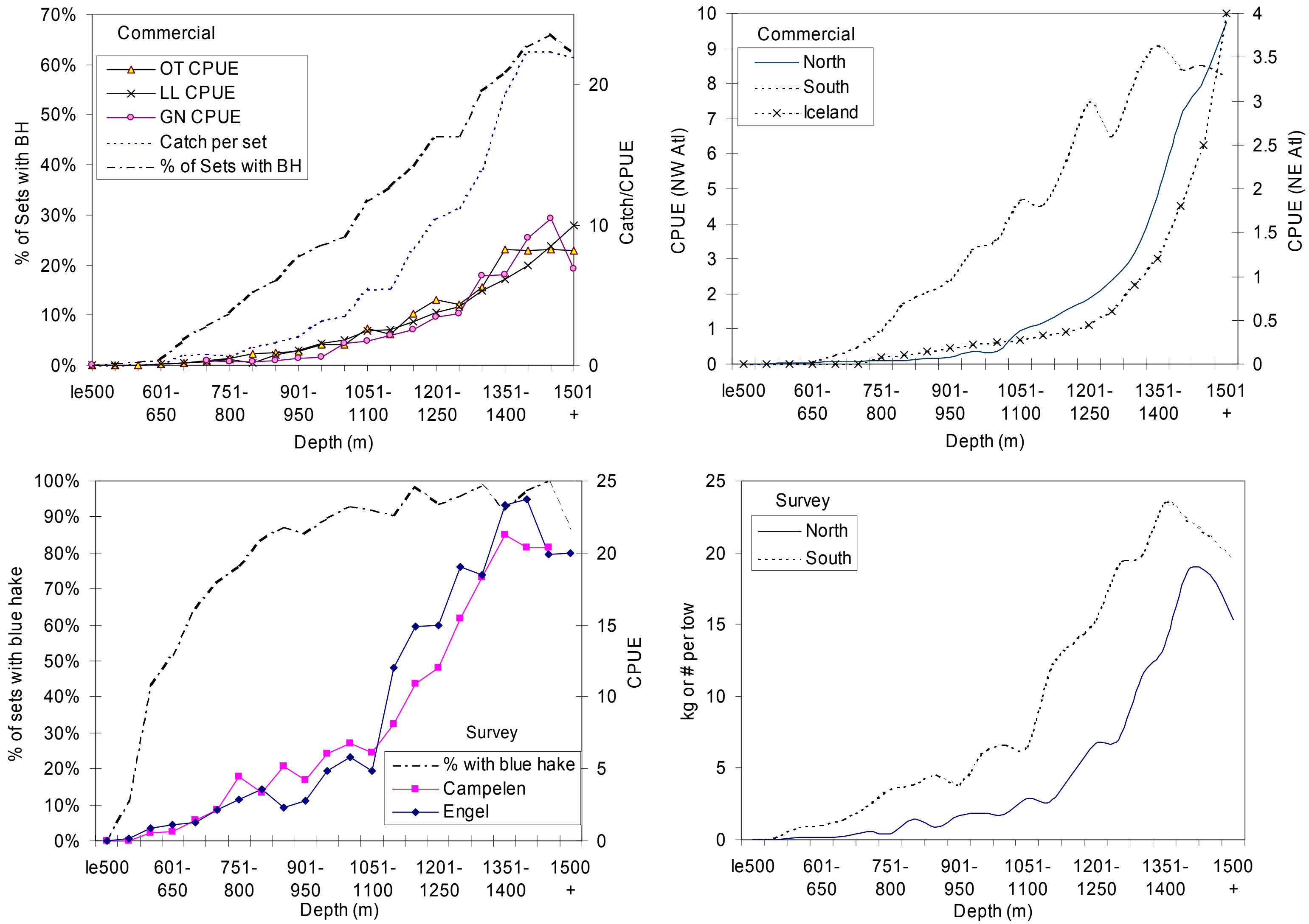


Fig. 3. Catch rates and number and percent of sets with blue hake by depth for commercial fishery and survey data. Upper left panel compares catch rates of the three commercial gears (kg per hour for otter trawl, per 1000 hooks for longline and per 100 nets for gillnet). The lower left panel compares Engel and Campelen standardized kg per tow. The upper right panel compares catch rate (standardized to kg per hour) north of Lat. 550 vs. south of Lat. 550 and catch rates reported by Magnusson (2001) off Iceland. The lower right panel shows standardized kg per tow for surveys north of Lat. 550 vs. south of Lat. 550 (after Kulka et al.2003).

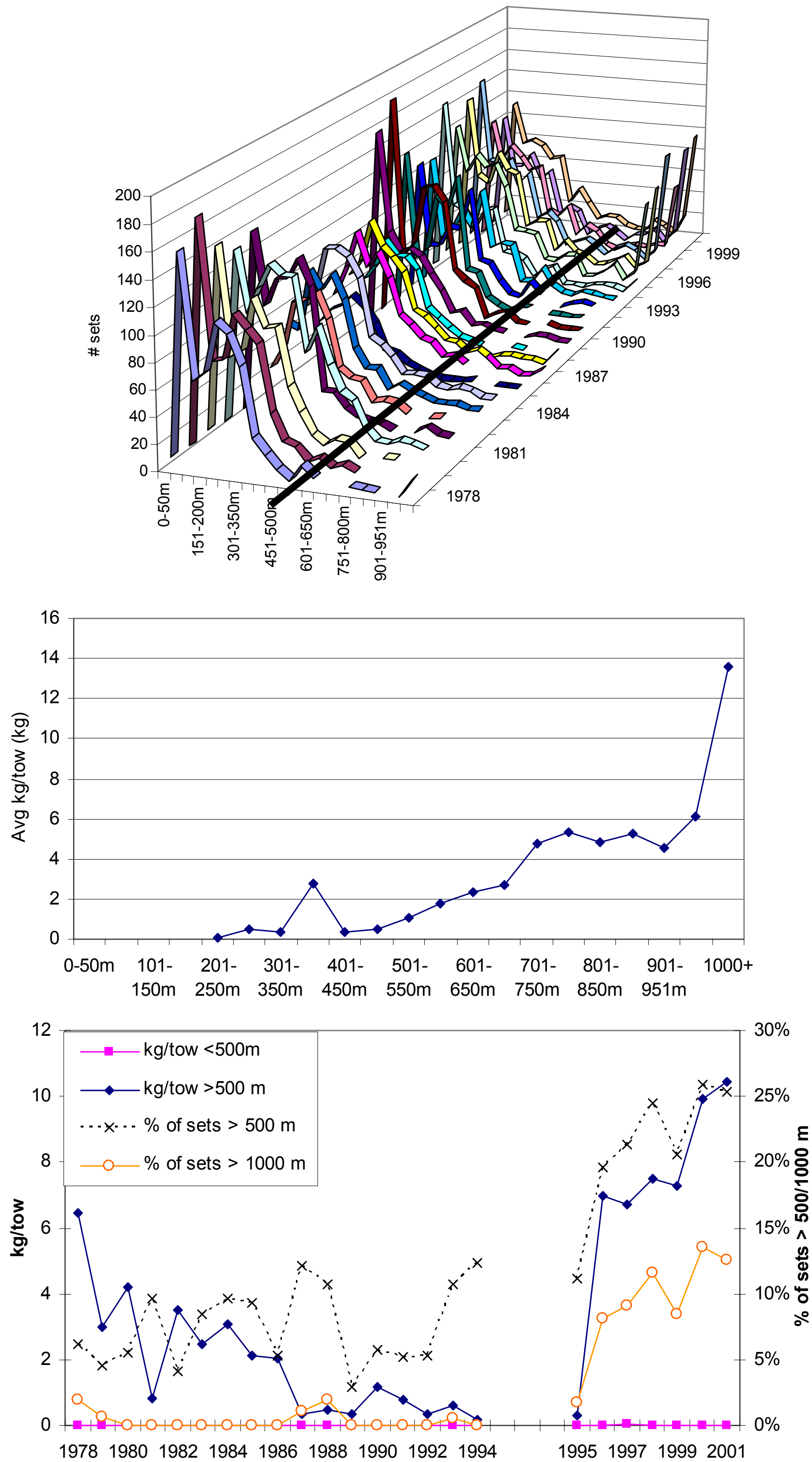


Fig. 4a. Upper Panel: Distribution of fall surveys sets in relation to depth. Black line delineates the 500 m contour. Middle Panel: Average kg per tow of blue hake at depth. Lower panel: Percent of sets in the fall survey that occur at depths > 500 m and 1000 m.

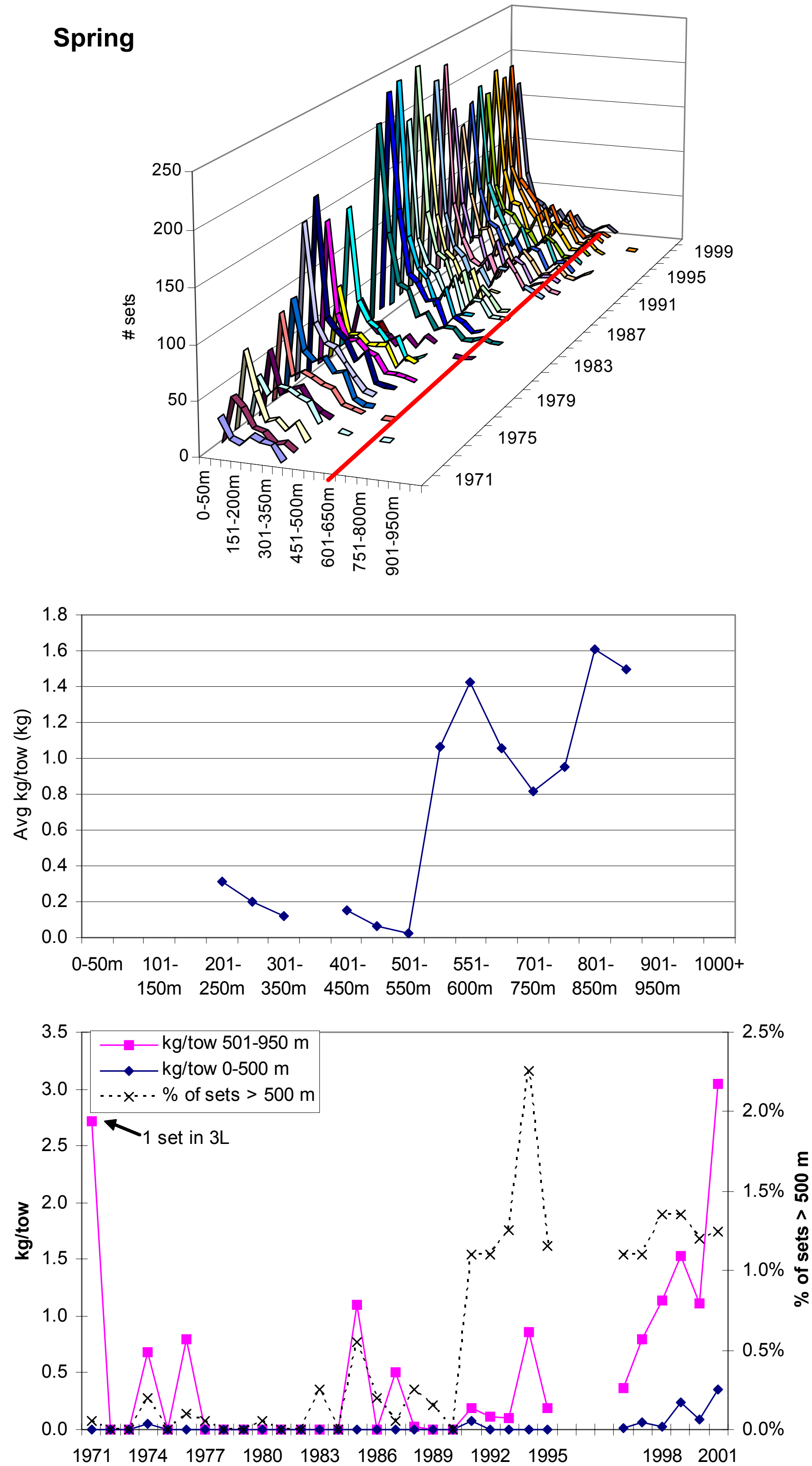


Fig. 4b. Upper Panel: Distribution of spring surveys sets in relation to depth. Red line delineates the 500 m contour. Lower panel: Percent of sets in the fall survey that occur at depths > 500 m.

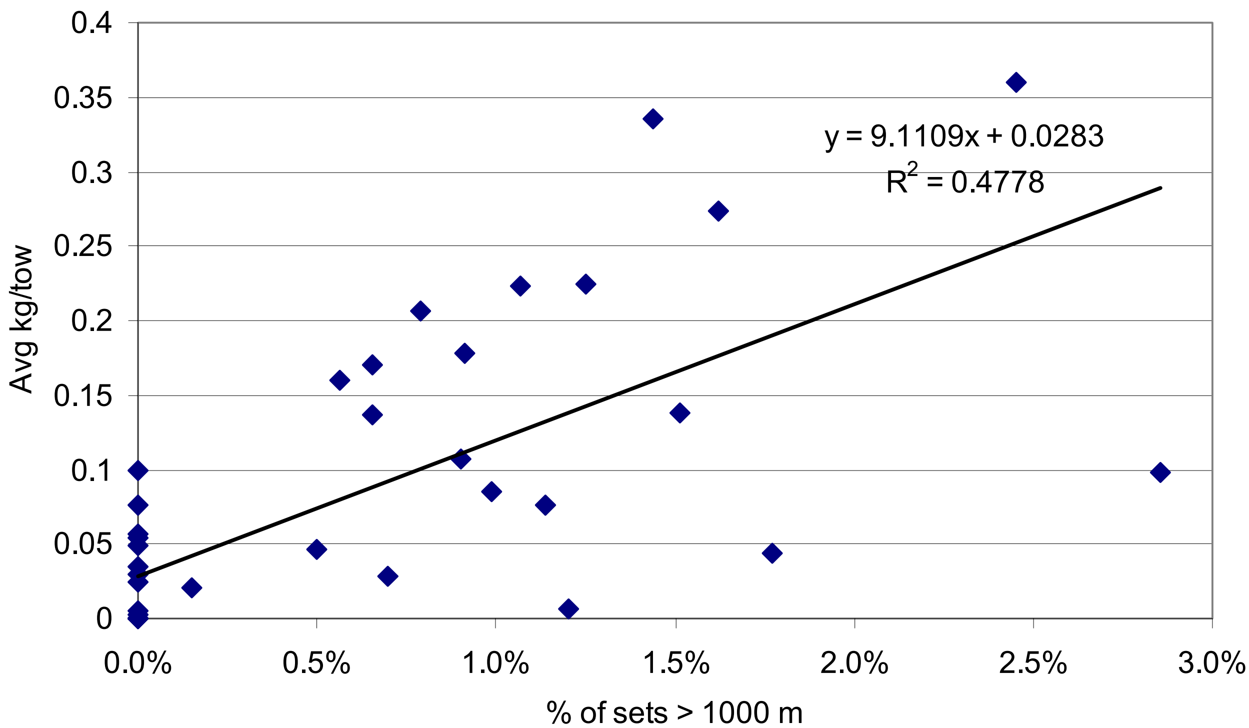


Fig. 5. Percent of fall trawl survey sets > 1000 m in relation to survey catch per tow (kg). Each point on the graph represents an annual estimate. Note that trawl gear used between 1949 and 1977 varied and survey design was not random stratified. Non-standard trawl sets are included in all years.

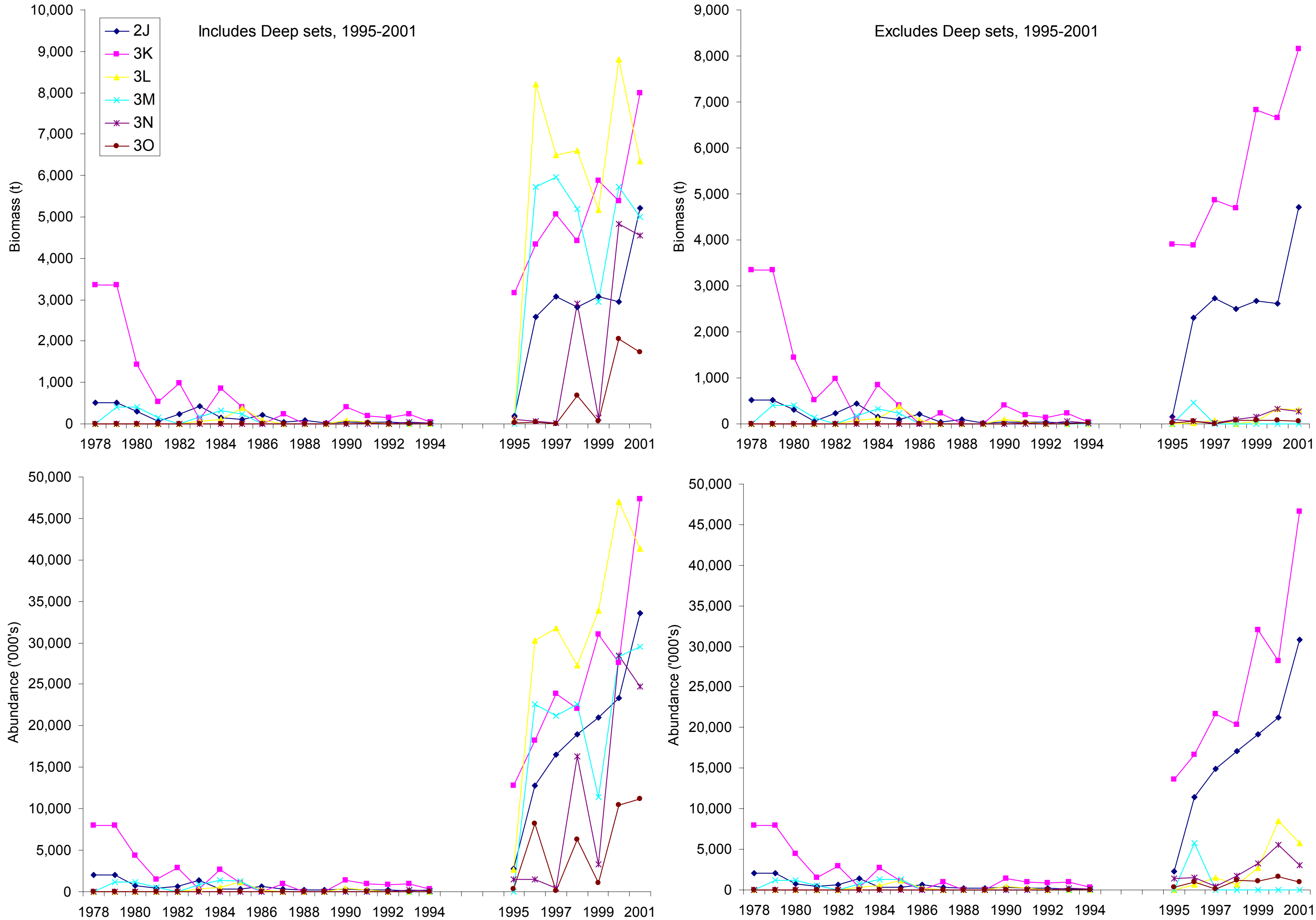


Fig. 6. Biomass and Abundance Indices: separate lines for NAFO Divisions 2J, 3K, 3L, 3N, 3M, 3O from the fall surveys. The space separates years where Engels gear was used from years where Campelen gear was used. Biomass is expressed as t, abundance as numbers/1000.

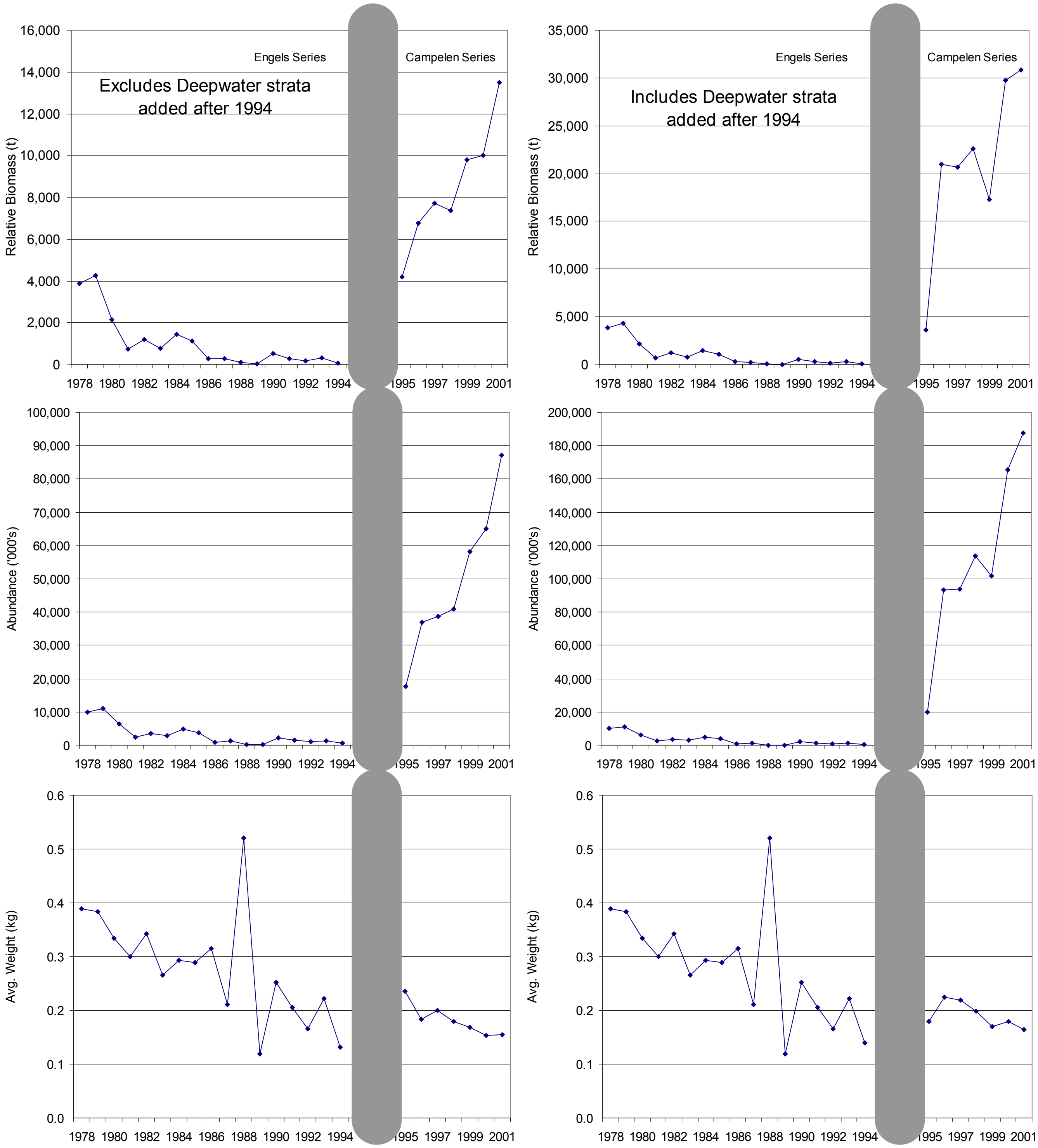


Fig. 7a. Fall Relative Biomass and Abundance Indices: includes NAFO Divisions 2J, 3K, 3L, 3N, 3M, 3O from the fall surveys. The grey bar separates years where Engels gear was used from years where Campelen gear was used. Biomass is expressed as t, abundance as numbers/1000.

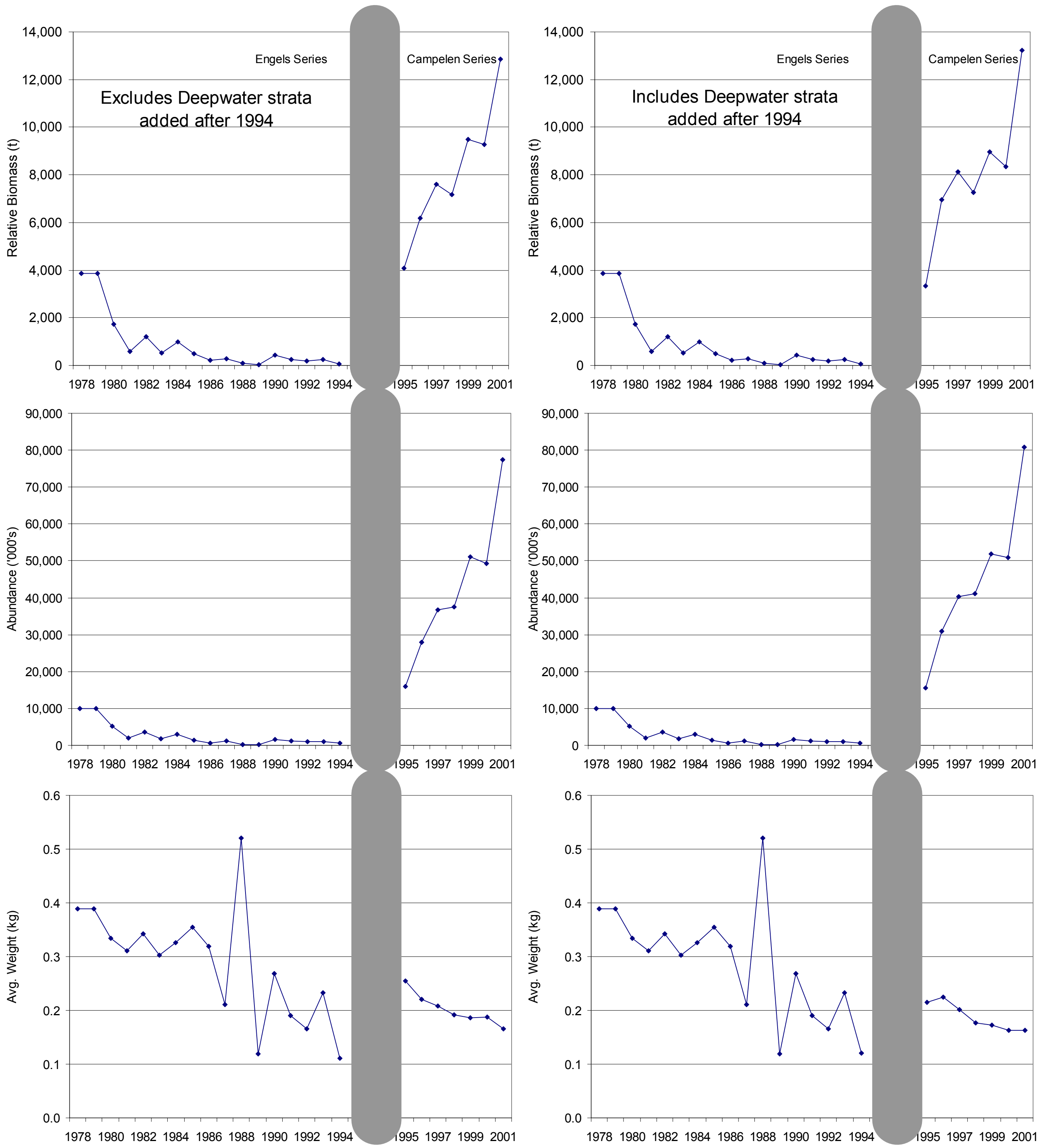


Fig. 7b. Fall Relative Biomass and Abundance Indices: includes NAFO Divisions 2J, 3K. The grey bar separates years where Engels gear was used from years where Campelen gear was used. Biomass is expressed as t, abundance as numbers/1000.

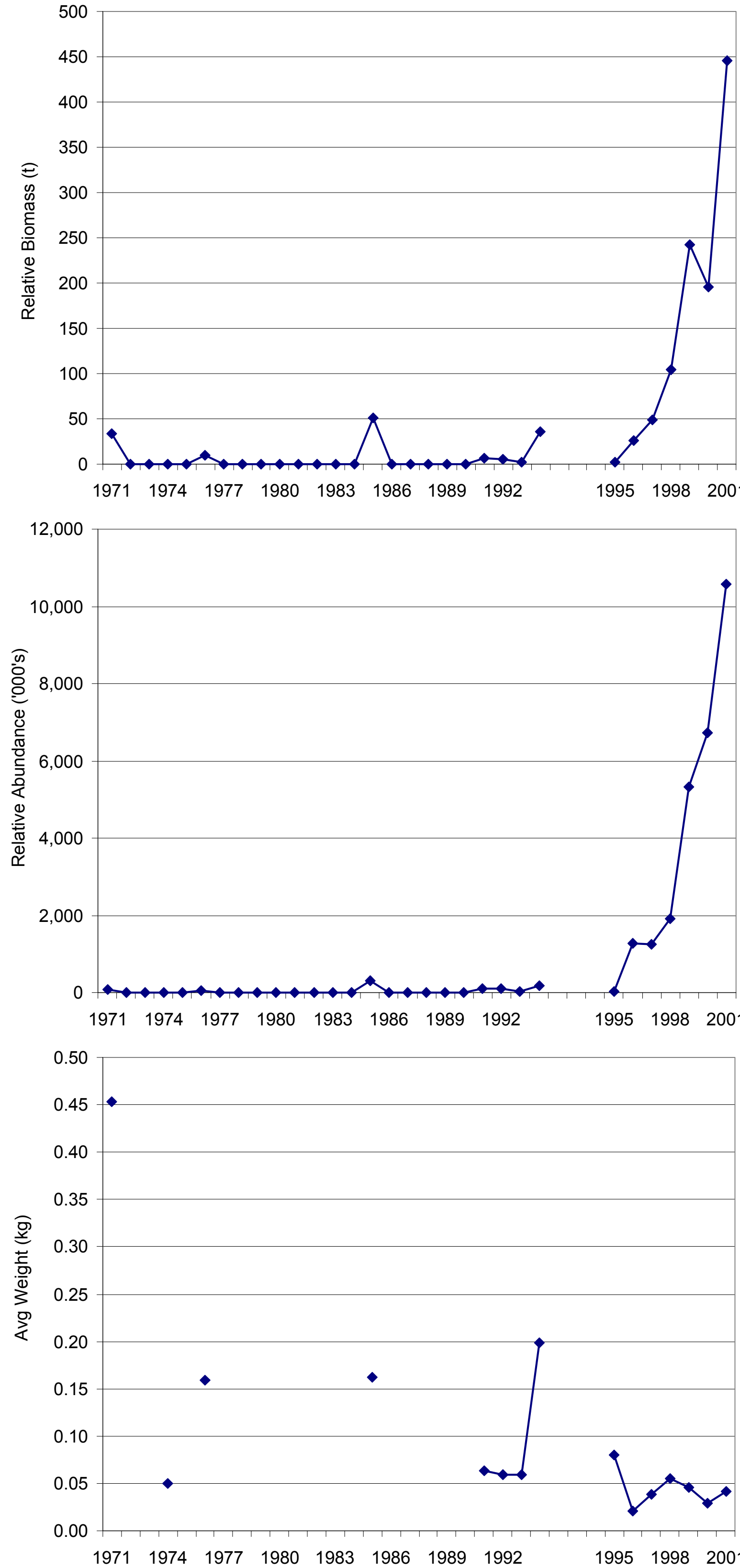


Fig. 8. Spring Relative Biomass and Abundance Indices: includes NAFO Divisions 3L, 3N, 3O, 3Ps. The space separates years where Engels gear was used from years where Campelen gear was used. Biomass is expressed as t, abundance as numbers/1000.

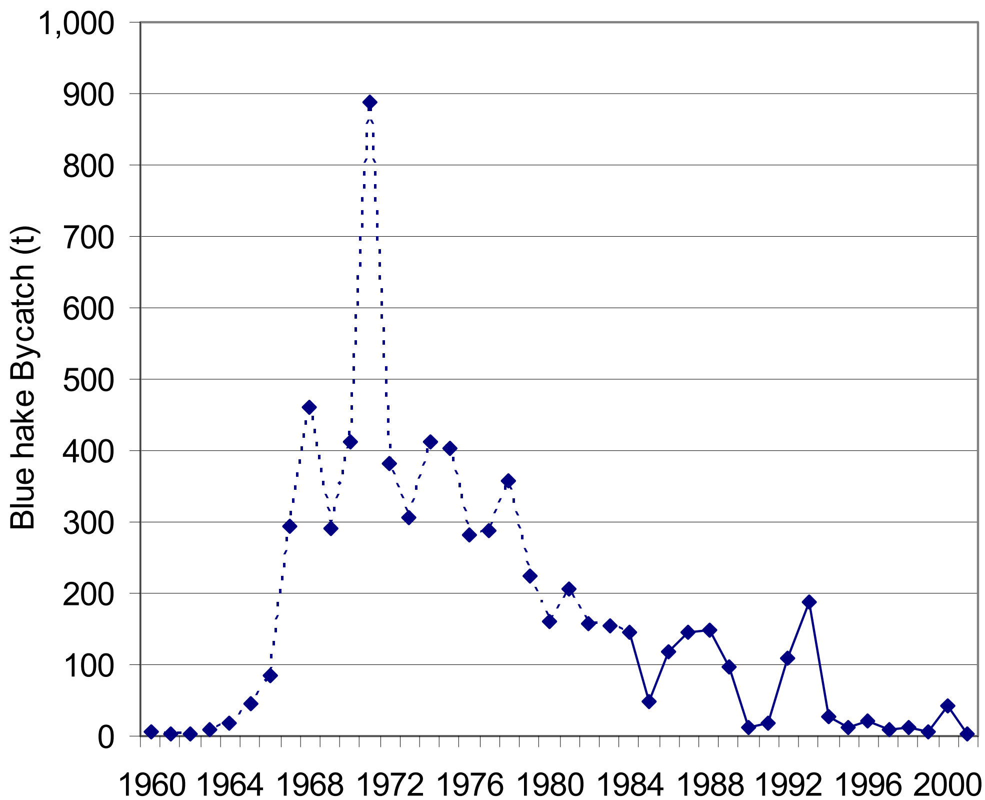


Fig. 9. Estimated catches of blue hake in Canadian Atlantic, 1960-2001. Estimates for the period 1960-1980 are based on average bycatch rates observed during 1980-1990 (when bycatch information was available) adjusted to level of effort in deepwater fisheries of that period. Catches of blue hake after 1979 are based on observed bycatch rates adjusted to total effort.

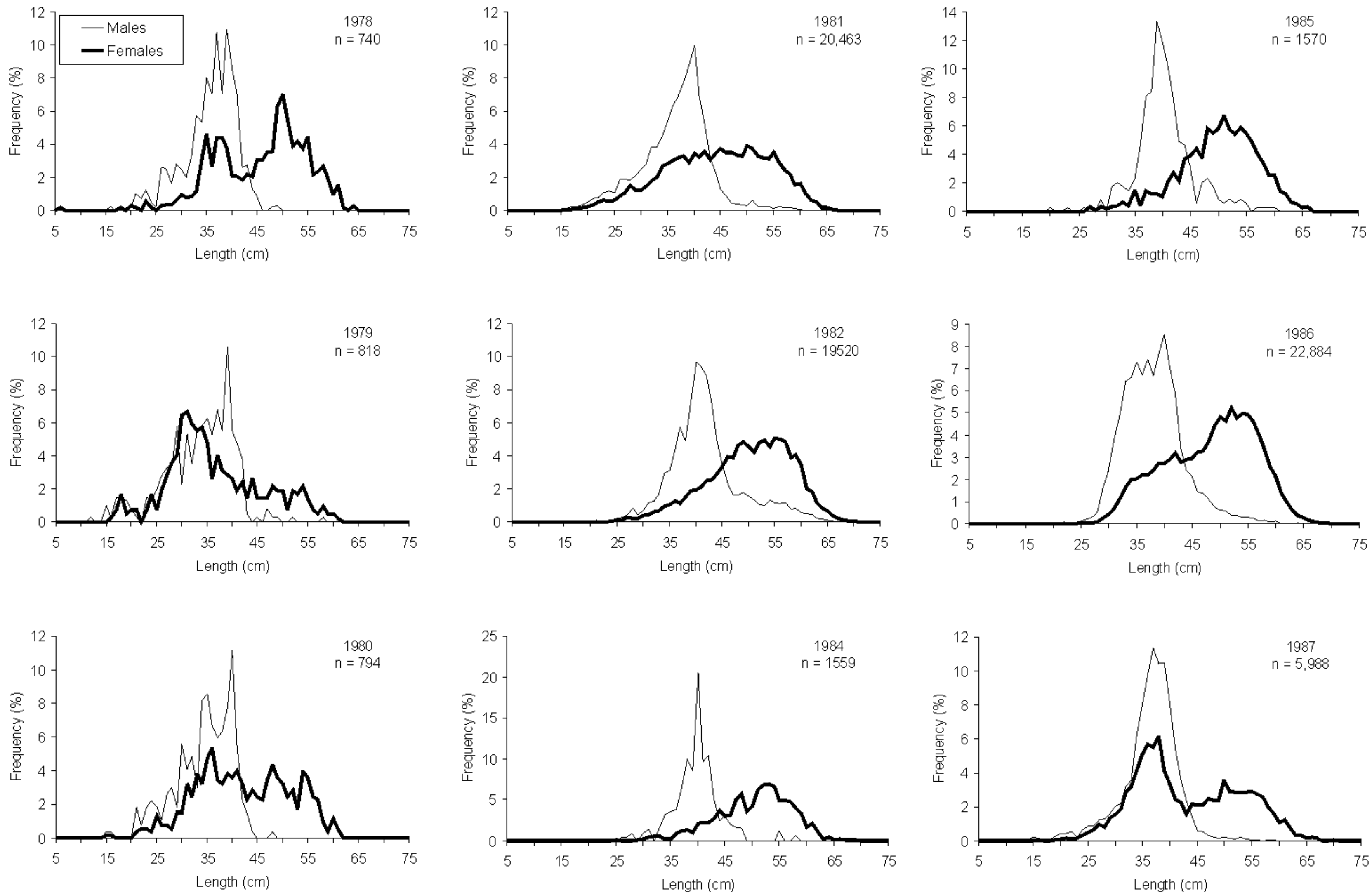
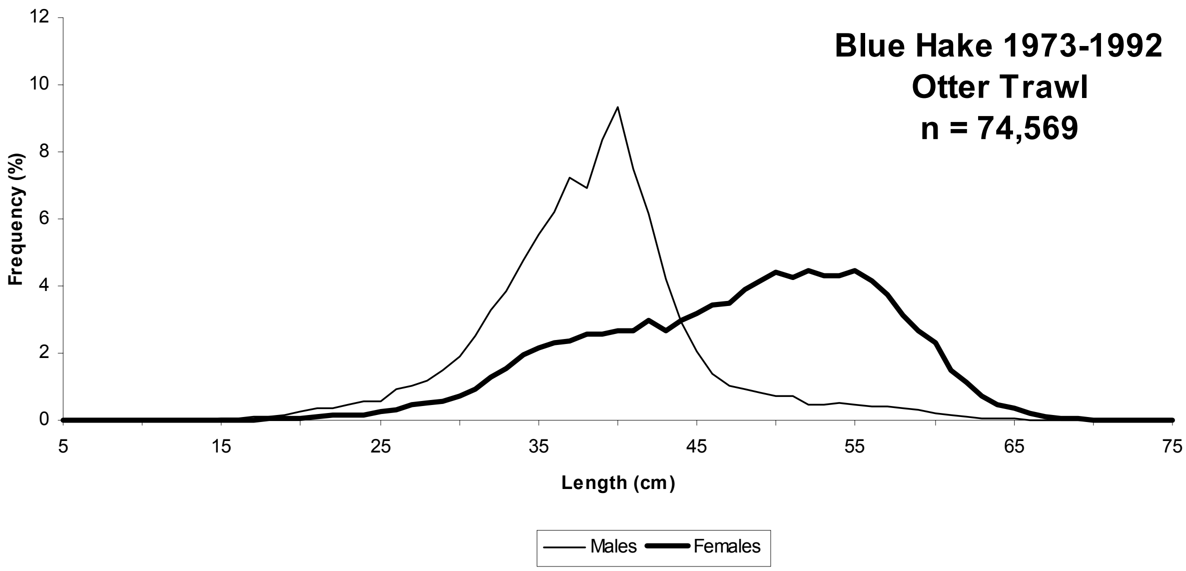


Fig. 10. Length frequencies of blue hake from otter trawls and longline gear by year. Lengths are recorded as total length.



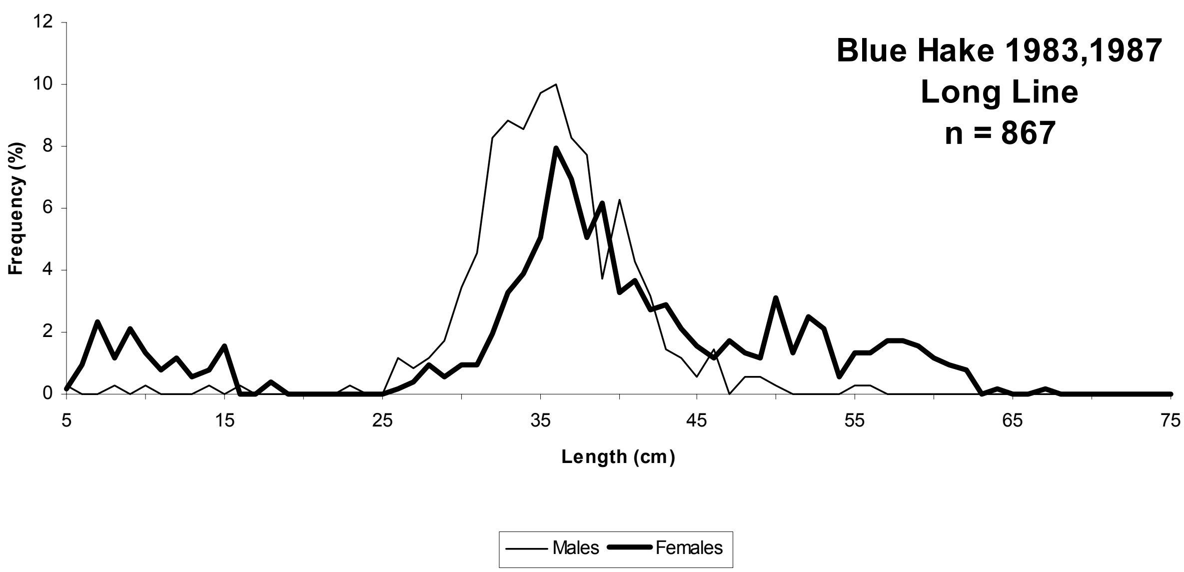


Fig. 11. Summary length frequencies of blue hake from otter trawls and longline gear. Lengths are recorded as total length.

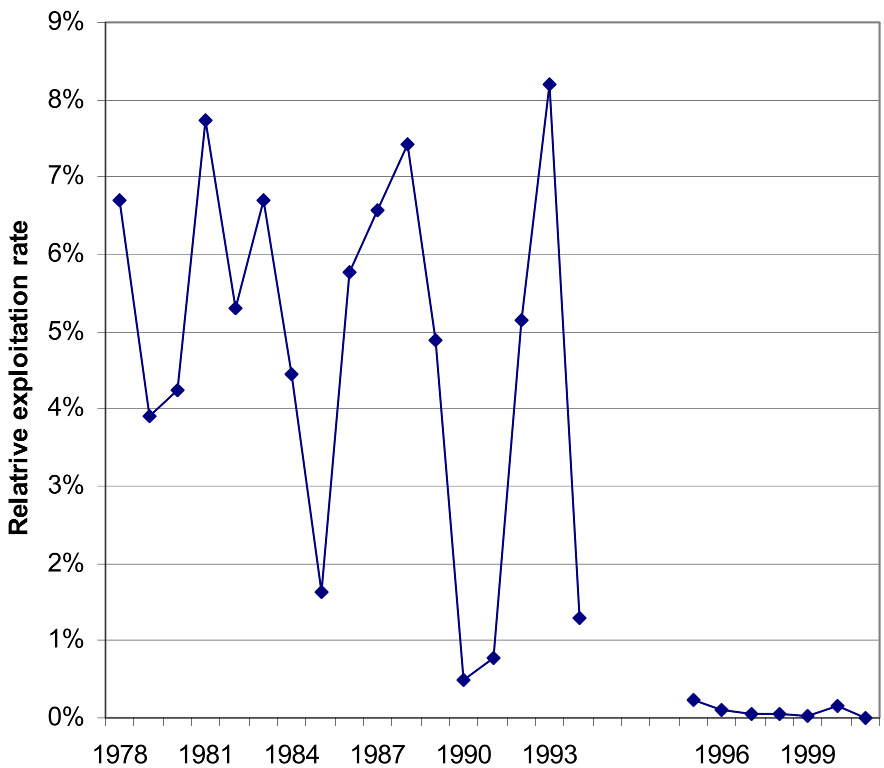


Fig. 12. Relative exploitation rate (estimated catch as a percentage of the Fall survey biomass index) 1978-2001.

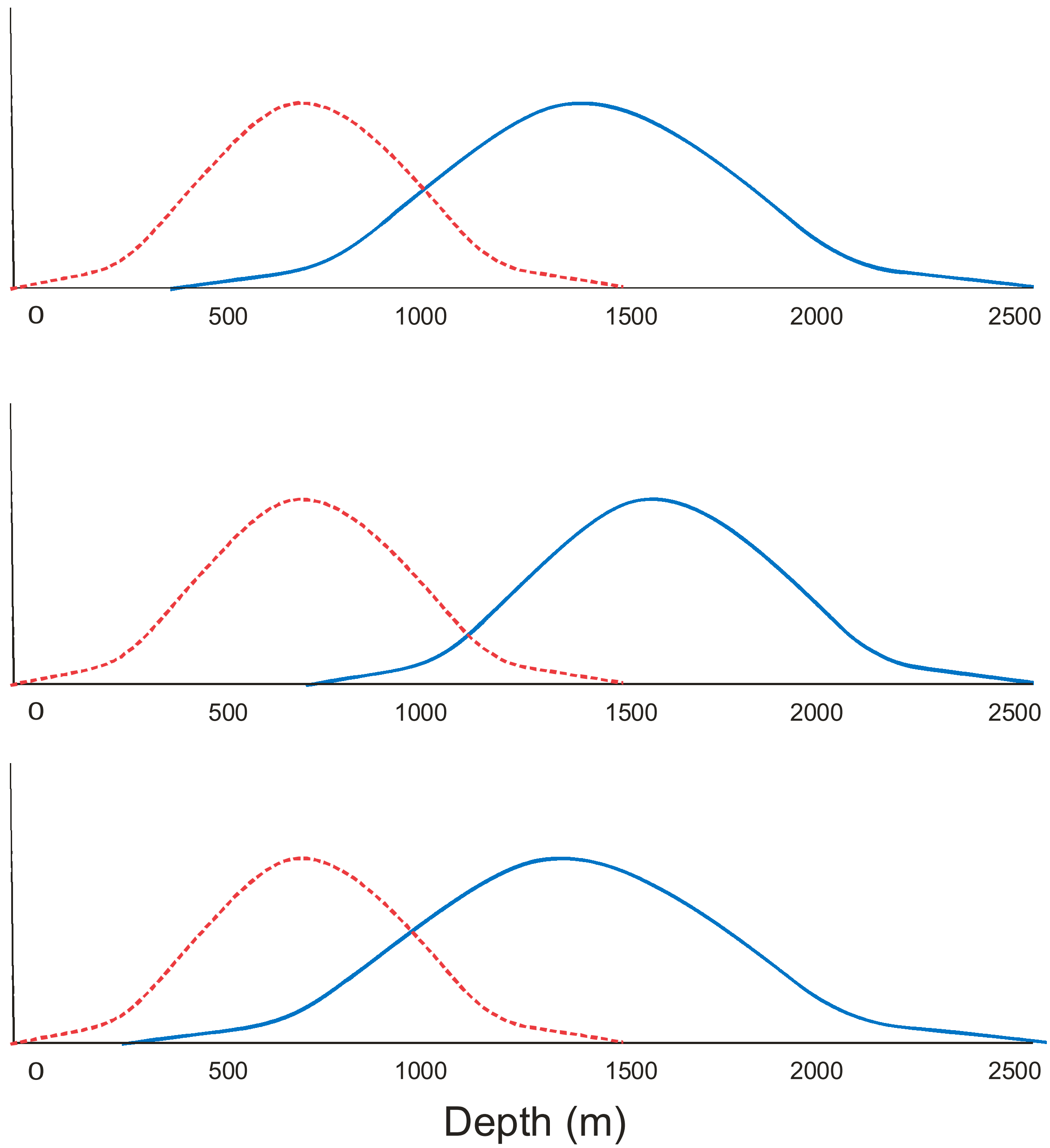


Fig. 13. Theoretical diagram of distribution of blue hake (blue line) in relation to depth in relation to survey sampling distribution (red line) with respect to depth. Three scenarios are illustrated, upper figure showing an average, middle figure showing a shift in the distribution of blue hake to greater depths and the bottom figure a shift to shallower depths.