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# Assessment of the Scotian Shelf silver hake population in 1998

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## Abstract

The status of the Scotian Shelf silver hake population in 4VWX was evaluated using updated catch-at-age (1979-98), research surveys, commercial CPUE, and biological indices. An analytical assessment of yield was not possible, as the model results could not be accepted due to a large retrospective pattern in the estimates of population numbers. Other attributes of stock status were not consistent. Recruitment will likely be above average in 2000, and resource concentration and geographical range distribution exhibit positive trends. However, survey biomass is very low and total mortality estimates from the survey are high. The extreme values of these important indicators are cause for concern. Other attributes, such as length-at-age, condition, and size at maturity, while not at near lowest levels, are below long term averages. Under these circumstances, catches should be restricted to that seen from 1997-99.



## Résumé

L'état de la population de merlu argenté du plateau néo-écossais dans les divisions 4VWX a été évalué au moyen des données sur les prises selon l'âge (1979-1998) mises à jour, des relevés de recherche, des CPUE de la pêche commerciale et des indices biologiques. Il était impossible d'effectuer une évaluation analytique du rendement, car les résultats de modélisation n'ont pu être acceptés en raison du fort caractère rétrospectif de l'effectif estimé de la population. D'autres caractéristiques concernant l'état du stock n'étaient pas cohérentes. Le recrutement sera probablement supérieur à la moyenne en 2000, et la concentration et la répartition géographique de la ressource présentent des tendances positives. Cependant, les relevés indiquent une biomasse très faible et une mortalité totale estimée très élevée. Les valeurs extrêmes de ces indicateurs importants sont préoccupantes. Les autres caractéristiques, comme la longueur selon l'âge, la condition et la taille à maturité, même si elles n'approchent pas les niveaux les plus bas, demeurent inférieures aux moyennes à long terme. Dans ces conditions, il faudrait limiter les prises aux valeurs obtenues entre 1997 et 1999.

## The Fishery

The silver hake fishery has been conducted on the Scotian Shelf since the mid-1960's, primarily by the distant water fleets of Russia, Cuba and Japan in the early years. Prior to 1977, fishing on the Scotian Shelf was unrestricted in terms of area, mesh size and season. During this period fishing was conducted over the entire shelf, and the use of trawl mesh as small as 40 mm was common. Following the extension of jurisdiction to 200 miles by coastal states in 1977, Canada implemented the Coastal Fisheries Protection Act, which restricted fishing for this species to the seaward side of the Small Mesh Gear Line (SMGL, Fig 1), west of $60^{o}$ W longitude, with a minimum mesh size of 60 mm. On an experimental basis, a portion (4-6 vessels) of the fleet was allowed to fish landward of the SMGL during 1978 and 1979. From 1980 through 1983, fishing was permitted by condition of license in an eastern extension of the Silver Hake Box as far as $57^{o}$ W longitude; from 1984 to present this eastern extension has been restricted to $59^{o}$ W longitude. In 1994 further restrictions were introduced to minimize incidental catches of cod, haddock and pollock in the silver hake fishery. These included a repositioning of the SMGL to prevent fishing in depths less than 190 m (Branton, 1998) and the use of a separator grate in the lengthening piece of the trawl.

Canadian fishing interests have engaged in experimental harvesting of this species since 1975, although until 1995 these efforts were developmental in nature (Showell and Cooper, MS1997). From 1995 to present a commercial fishery has been conducted by the Canadian tonnage class 3 (< 65') mobile gear fleet in and around Emerald and LaHave basins (Fig. 1). Based on concern over the harvesting of small fish in these areas, 55 mm square mesh was used by some vessels in 1998, rather than the traditional 60 mm diamond, and it's use was made mandatory in 1999. While experimental evidence had suggested this change to 55 mm square mesh would be effective in releasing small silver hake (Cooper, 1995), it's implementation in the commercial fishery differed from the experimental protocol. The tensile strength of the twine used to manufacture the square mesh was lower than that of traditional diamond mesh, and potential solutions such as increasing the twine diameter or knitting double twine were not considered practical. As a result, 90 mm topside chafers were required to support the codend during haulback, potentially blocking the meshes and mitigating the benefits of the square mesh. In recognition of this problem, guidelines for the use of topside chafers were developed in 1999 in consultation with industry. If a topside chafer was necessary, a 110 mm square mesh was thought provide the highest level of escapement, and the use of this gear configuration was implemented as of May 1, 1999 while other potential solutions were examined.

Nominal catches from this stock range from 300,000 tons in 1973 to 8,000 tons in 1994 (Table 1). Catches by the foreign fleet were generally high during the mid to late 1980's, with catches in recent years much lower (Table 1, Fig. 2). As the inshore Canadian fishery has developed, the proportion of the catch harvested by each fleet component has changed, and in 1998 the catch by the inshore fleet exceeded that of the offshore. This trend has continued in 1999, with the preliminary catch from Emerald and LaHave Basins in excess of 5,000 mt, while the catch by Cuban vessels fishing offshore under Canadian allocations has dropped to less than 4,000 mt (Fig. 3).

Distribution of fishing effort through the year has also changed. While generally the offshore fishery has been conducted from April to August, in 1998 a single Cuban vessel remained in the Canadian zone until December, although the catch for this period was very small (100 t). The inshore fishery also persisted late in 1998, with almost 20% of the catch coming from the last quarter of the year (Fig. 4).

Recent scientific advice, TAC's and catches ('000 tons) are as follows:

| Year | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Advice | 167 | 235 | | 100 | 105 | 75 | 51 | 79 | 64 | 50 | 65 | ** |
| TAC | 120 | 135 | 135 | 100 | 105 | 86 | 30 | 50 | 60 | 50 | 55 | 30 |
| Catch | 74 | 91 | 69 | 68 | 32 | 29 | 8 | 18 | 26 | 16 | 16 | 9[1] |

[1] preliminary

** RAP Assessment

## Removals at Age & Size and Weights at Age

While no foreign allocations of silver hake were caught in 1998, the fishery was conducted by two distinct fleets - Canadian flag vessels < 65' fishing in or near to Emerald and LaHave Basins, and the Cuban flagged tonnage class 7 vessels fishing seaward of the SMGL line under charter arrangements with Canadian partners. While modifications were made to the SMGL in 1994, several changes were subsequently made, and numerous exemptions granted to the Cuban fleet fishing in this area. Details of these changes are can be found in Branton, 1998.

Sampling for length composition and aging material from the Cuban vessels in 1998 was conducted by Canadian observers, with 100% of the fishery covered. Sampling levels were relatively high, with more than 400 length samples and 500 otolith pairs collected. The commercial removals at age were calculated using the same procedures as the previous assessment, using the Canadian observer unculled length frequency data and monthly age/length keys, by sex, constructed from Canadian aging data. Regressions of lengths and weights from the Canadian July research vessel survey were used to calculate

yearly alphas and betas by sex (Table 2) used in the calculation of sample weights and commercial mean weight-at-age. Age/length sampling for the August-December period was poor, therefore the catch-at-age for this period was constructed using the July age/length key and included with the July totals. Results are presented in Table 3.

Landings by the Canadian fleet were sampled routinely by DFO shore samplers in 1998, with 27 samples collected in total. Commercial removals at age and mean weight at age for this fishery were calculated on a quarterly basis, using the same methodology as used for the foreign fishery (Table 4).

As was the case in 1997 the majority of the Canadian catch was composed of age 2 fish, as compared to age 3 in the Cuban fishery (Fig. 5). Further, the extension of the Canadian fishery into the last quarter of the year resulted in the catch of substantial numbers of age 1 fish by this fleet.

The removals at age for 1977-96 were taken from the previous assessment (Showell, 1997a) to provide estimates for the period 1977-97 inclusive (Table 5).

Commercial mean weight-at-age was calculated for the same periods as the catch-at-age for each fleet, weighted by monthly catches. An aggregate mean weight-at-age was than calculated, weighting by the catches of each fleet. As has been noted in the past for this stock, commercial mean weight-at-age declined from 1992 to 1994, and has stayed relatively stable at this level in subsequent years (Fig. 6).

## Size composition – Inshore fishery, 1998 & 1999

As has been noted in the past, the inshore Canadian fishery catches smaller silver hake than the fleet fishing offshore. These trends continued in 1998 and at least the first half of 1999 (Fig. 7 & 8), with the peak in the foreign catch consistently 2-4 cm larger than that of the Canadian catch. However, examining the Canadian size distribution on a quarterly basis (Fig. 9), some change in size distribution of the catch can be seen, with the proportion of fish < 21 cm reduced in 1998 and 1999. These changes coincide with the introduction of square mesh, and likely reflect changes in selectivity for this new gear. With the adoption in May 1999 of further changes in the attachment of topside chafers to prevent mesh blockage, selectivity would be expected to change again towards larger fish. A comparison of size distribution in the month immediately before and immediately after this change confirms this (Fig. 10).

## Commercial Catch Rates

Multiplicative analysis of catch rates in the offshore component of the silver hake fishery using observer data showed no significant effect by country, month or NAFO area on catch rate (Smith & Showell, MS1996), indicating that a model with year alone has as much explanatory power as one which includes all four factors. Based on this analysis, a non-standardized catch rate series was developed using Canadian observer data (Fig. 11). The catch rates for this fleet have dropped from high levels in the period 1984-89, to relatively low levels since 1992. In 1998 fishery the catch rate rose slightly, but fell in 1999 to less than 1 ton/hour, which is the lowest in the time series.

An analysis of the effect of separator grates on silver hake catch rates by Halliday and Cooper (MS1997) indicates that the use of this equipment reduces the catch rate by about 5%. CPUE and effort, adjusted for this factor, are presented in Table 6.

The inshore fleet has been conducting a true commercial (as opposed to exploratory) fishery for silver hake, in and around Emerald and LaHave Basins only since 1995, rather than exploratory. Catch and effort statistics from the commercial landings (C/L) database for TC 1-3 vessels directing for silver hake are available. Catch per day and catch per hour show similar trends, with levels increasing in 1996, stable for 1997, then declining subsequently (Fig. 12). Changes to the manner in which this fishery is conducted may be responsible for this decline, as the inshore fishing areas were expanded to allow exploratory fishing and the development of new markets resulted in a year round fishery. Further, there are anecdotal reports from Industry of nets being fouled by an invertebrate species (likely a tunicate) which was present in high concentrations in the fishing areas.

In recent years the fishing effort directed towards the offshore component of the fishery has dropped dramatically, from a peak of approximately 3000 fishing days in 1991 to less than 500 in 1998 and 1999 (Fig. 13). Industry has noted a decline in fishing capability on the part of the Cuban fleet, citing poor mechanical condition of the vessels as reasons for reduced catch rates. However, equipment failure and other associated breakdowns, while reducing catches, may not necessarily reduce catch rates. An examination of fishing effort expressed as hours on ‘bottom’ per day (Fig. 14) does not show a significant decline in recent years, indicating that fishing practices may not be unusual when a vessel is operational. However, silver hake is a mobile species, and the loss of search capability associated with reductions in the number of vessels participating may adversely affect catch rates. As well, areas where catch rates have historically been high are on occasion not accessible because of the potential for gear conflict with the swordfish and offshore crab fleets. For these reasons catch rates for this fleet in recent years may not reflect abundance.

## Industry Comments

Industry input on the status of the silver hake resource and fishery was solicited through the Silver Hake Advisory Committee. Membership in this group includes fishermen and plant operators involved in the silver hake fishery.

A number of issues were raised related to catch rates in 1999. Through most of the summer in the inshore silver hake fishery, large quantities of an unidentified algae or marine plant made fishing difficult, as the net quickly became fouled. Clearing the nets was almost impossible at sea – some vessels even used steam cleaners and high pressure washers with limited success. The defined fishing areas in the basins were also identified as a problem in harvesting this species, as it was felt in many cases the best fishing occurred near the boundaries of the polygons, and concentrations just outside the line could not be fished.

As was the case in 1998, the comparability of the foreign fishery in 1999 to historical efforts was questioned, with search capability and reliability of the vessels and fishing equipment identified as potential problems in the fishing success of the Cuban fleet.

Questions were raised over the effect of square mesh in reducing mortality on silver hake, with reports of large numbers of fish seen dead in the water during haulback.

The fishing areas currently defined for Emerald and LaHave Basins are relatively small compared to the number of vessels available. Fishing outside Emerald and LaHave Basins was therefore conducted under controlled conditions, with trips made to areas which appeared promising based on research vessel catch rates. The results of this exploratory fishing were not consistent. In some cases (Georges Basin) initial high catch rates did not persist, while fishing in test areas to the east of Emerald Basin resulted in generally poor catches.

## Canadian Bottom Trawl Surveys

The July stratified random design groundfish survey has been conducted on the Scotian Shelf from 1970 using three Canadian research vessels (A.T. Cameron, Lady Hammond, and the Alfred Needler). A conversion factor of 2.3 is applied to the series prior to 1982 to account for the effect of vessel and gear changes between the A.T. Cameron and the other two vessels (Fanning, MS1985). No conversion factor is required between the Lady Hammond and the Alfred Needler.

Silver hake found in the Bay of Fundy area likely represent a portion of the Gulf of Maine/N. Georges Bank silver hake stock, rather than the Scotian Shelf stock. As was the case in the previous assessment of this resource, survey trends in both total numbers and biomass were therefore calculated for the Scotian Shelf portion of 4VWX only, excluding strata 484 through 495.

Survey trends in both numbers and biomass show relatively high abundance in the early to mid-80's, followed by a decline to relatively low levels over the period 1988-94 (Fig. 15). Abundance and biomass increased in 1995 and 1996, but has subsequently declined to low levels – similar to that seen in 1991-92.

Numbers at age for the Scotian Shelf strata only are presented in Table 7. As estimated by the 1998 survey, the two year old age group is about average in abundance – all other year classes, particularly the age 1 group, are below average in abundance.

## Juvenile Survey

A standardized IYGPT O-group survey for this species was conducted since 1981 (1992 excluded) during the October-November period. Results of these surveys for the core strata (460-478) are presented in Table 8. This survey was discontinued in 1998.

## Biological Indices

Previous analysis (Showell, 1997b) has shown both condition (weight for given length, Fig. 16) and mean length at age (Fig. 17) to have declined from 1971 to 1995, with the two factors combining to produce mean weights at age for ages 3 and 4 which were the lowest in the time series in 1994. With the addition of 1996 and 1997 survey data, a modest increase was seen over the previous low levels (Fig. 18). This rising trend appears to have stopped in 1998, and the mean weight at age continues to be low for these age groups.

Maturity observations have been routinely collected for this species on the July RV survey. The survey immediately proceeds the spawning period for silver hake, and this timing allows accurate distinction between mature and immature fish. Length of 50% maturity has declined over the time series (Fig. 19), with females declining from about 27 cm in the 1971 to 1981 period, to approximately 23 cm from 1991 to present. Males show similar trends, with length of 50% maturity generally greater than 23 cm from 1971 to 1980, compared to 19 or 20 cm in recent years. Changes of this nature have been attributed to a population undergoing stress (Trippel, 1995). Given the early maturation of silver hake, significant declines in length of maturity for this species may approach a physiological limit for spawning.

## Environmental Considerations

Environmental conditions play an important role in recruitment success for many gadoid species. For example, Frank *et al*, 1994 found correlations between environmental signals and yearclass strength for 4VsW cod which could be used to predict recruitment. Silver hake is a species with a higher temperature preference than most gadoids on the Scotian Shelf, and might be expected to be adversely affected by cold water events. In 1997 and early 1998, a persistent mass of cold water moved onto the Scotian Shelf, lowering the bottom temperatures of Emerald and La Have basins by several degrees C (Drinkwater *et al*., 1998). This event coincided with the disappearance of the 1997 yearclass, which had been thought to be abundant as O-group (Table 8), but appeared below average at age 1 in the subsequent July RV survey (Table 7).

Near bottom temperature anomalies in Emerald Basin were compared with RV silver hake abundance at age 1 from 1971 to 1999. While low recruitment coincided with negative temperature anomalies in several cases, overall the relationship was poor (Fig. 20). Similar comparisons in adjacent areas produced similar results.

## Estimation of Parameters

### Sequential Population Analysis

The adaptive framework (ADAPT, Gavaris, 1998) was used to calibrate an age based sequential population analysis. An ACON compiled version of ADAPT was used to minimize the non-linear least squares gradient technique (the Malquardt algorithm). The Canadian July R/V survey for strata 440-483 (excludes Bay of Fundy) was used as a tuning index from 1983 onward only, as the survey vessel changed in that year, and calibration coefficients for silver hake were not considered reliable. Tracking of cohort strength in the is difficult for older ages, and as a result the ages 1-6 were used to calibrate the analysis. Commercial CPUE from the foreign fishery had been used as tuning index in the previous assessment, but was excluded this year due to concern over the comparability of the fishery in recent years to that of the past. The resulting formulation was as follows:

Ca,y=catch; a=1 to 9, y=1983-1998
RVa,y=Canadian July RV; a=1 to 6, y=1983-1998

Natural mortality was assumed constant and equal to 0.4, and errors in the catch at age were assumed to be without error relative to the abundance indices. F at age 9 was calculated as the average of ages 4 to 6 in the same year, and a dome was not forced.

Parameter estimates from the analysis are show in Table 9. Bias adjusted beginning of year population numbers, fishing mortality, and population biomass are shown in Tables 10, 11 & 12**.** Population biomass (2+) estimated from the model, the q-adjusted survey index, and a graphical representation of the scaled residuals from the ADAPT are shown in Fig. 21.

In past assessments of this resource (Showell, 1998), population numbers have shown changes with the addition of data in subsequent years, with a tendency for the current estimate of population size to be overly optimistic. As a result, an analysis for a retrospective pattern was conducted. The retrospective effect on age 2+ biomass (ie the proportion of the fishery important to the commercial fishery) is presented in Fig. 22. To quantify the effect of the retrospective pattern, an analysis of initial estimates of population numbers compared to the most recent estimates was conducted, and the proportion of the 1998 estimate to the initial estimate was averaged for the past 8 years. When the initial estimate was compared to the estimate with several more years data added, a difference of 30 to 57% was seen in ages 1 though 4 with higher levels for older ages (Table 13). Fishing mortality for the fully recruited age groups (ages 4-6), was severely underestimated as well (Fig. 22). In the previous assessment of this resource (Showell, 1998), the magnitude of the retrospective pattern was much smaller (17 to 23%) and an approach was adopted whereby SPA numbers were discounted prior to projection. Given the size of the reductions required in the current reconstruction of the population, this approach is not considered appropriate, and a reliable projection of yield is not possible.

## Estimates of Total Mortality (Z)

The mean numbers per tow index from the July survey was used to calculate total mortality. To reduce variability in the estimates, the results were grouped into age classes (2-3, 4-5, 6-7) and smoothed using a two year moving average (Fig. 23). Based on this method, total mortality on age 2 and 3 fish (ie the age classes on which the fishery is conducted) has remained relatively high, despite a sharp decline in catches, with Z for ages 4 and 5 higher still. In recent years total mortality for the oldest ages has declined relative to that of age 4-5, likely as a result of gear changes which required use of a grate from 1994 onwards.

## Recruiting Yearclass Sizes

Estimates of age 1 in the terminal year of the VPA are unreliable, as they result from a single estimate in the calibrations block, and as a consequence the best available estimate for the 1997 year class is derived from age 1 RV abundance in 1998. Using the age 1 catchability coefficient (q) for the RV age 1

from Table 9, the size of this yearclass is estimated to be below average at 220 million fish, confirming the length based estimate made last year (Showell, 1998).

The 1999 July survey has been conducted, but aging is not complete. However, a reasonable estimate of the 1998 yearclass at age 1 can be made based on abundance of fish <23 cm (Branton *et al*., 1997). Based on this method, this yearclass is relatively strong (Fig. 24), and the abundance adjusted using RV age 1 q from the VPA is about 840 million fish.

## Outlook

Given the large retrospective pattern in the estimates of population numbers, an analytical assessment of yield for this resource was not possible. However, SPA methodology is only one of several tools available to assess the population. Several other indices were available which are considered to be equally important attributes of stock status. Recruitment will likely be above average in 2000, and resource concentration and geographical range distribution exhibit positive trends. However, biomass estimates from the summer survey are very low, at levels similar to those seen during the 1970's when this stock was in decline. Further, total mortality estimates from the survey are above $F_{0.1}$ for ages important to the fishery, despite relatively low catches in recent years. The extreme values of these important indicators are cause for concern. Other attributes, such as length-at-age, condition, and size at maturity, while not at near lowest levels, are below long term averages. Under these circumstances, catches should be restricted to that seen from 1997-99.

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Table 1: Nominal catches (mt) for 4VWX silver hake 1970-1998 (1995-1999 preliminary).

| **Country** | **1970** | **1971** | **1972** | **1973** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 1722 | 3088 | 862 | 606 | 4639 | 817 | 0 | 0 |
| Canada | 0 | 0 | 0 | 0 | 11 | 101 | 26 | 10 | 26 | 13 | 104 | 6 | 38 |
| Cuba | 0 | 0 | 201 | 0 | 0 | 1724 | 12572 | 1847 | 3436 | 1798 | 2287 | 642 | 11969 |
| France | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 2[1] |
| FRG | 0 | 0 | 10 | 0 | 296 | 106 | 97 | 684 | 0 | 0 | 0 | 0 | 0 |
| GDR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| Ireland | 0 | 0 | 0 | 0 | 0 | 108 | 106 | 0 | 0 | 9 | 0 | 0 | 0 |
| Italy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 106 | 5 | 0 | 541 | 37[1] |
| Japan | 129 | 8 | 63 | 88 | 67 | 54 | 78 | 19 | 161 | 219 | 239 | 120 | 937 |
| Poland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 295 | 2 | 0 | 0 | 1[1] | 31[2] |
| Portugal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 2044 | 2[1] |
| Romania | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 1 | 0 | 0 | 0 |
| Spain | 0 | 15 | 0 | 0 | 0 | 6 | 0 | 0 | 2 | 0 | 40 | 0 | 0 |
| USA | 0 | 1 | 1 | 1 | 1 | 7 | 1 | 14 | 0 | 0 | 0 | 3 | 2 |
| USSR | 168916 | 128633 | 113774 | 298533 | 95371 | 112566 | 81216 | 33301 | 44062 | 45076 | 40982 | 41243 | 47261 |
| Total | 169045 | 128657 | 114048 | 298621 | 95745 | 116394 | 97184 | 37095 | 48404 | 51760 | 44525 | 44600 | 60251 |

| **Country** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 88 | 0 | 0 | 0 | 0 | 0 |
| Canada | 15 | 10 | 2 | 9 | 13 | 9 | 337 | 10 | 34 | 4 | 73 | 57 | 300[1] |
| Cuba | 7418 | 14496 | 17683 | 16041 | 20219 | 9016 | 14541 | 13888 | 23708 | 16528 | 22018 | 7788 | 16835[1] |
| France | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FRG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GDR | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ireland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Italy | 2[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | 649 | 530 | 120 | 66 | 144 | 0 | 194 | 315 | 781 | 547 | 0 | 0 | 0 |
| Poland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Portugal | 378 | 1714 | 1338 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USA | 0 | 0 | 0 | 1 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| USSR | 27377 | 57423 | 56337 | 66571 | 41329 | 65349 | 72917 | 55429 | 40786 | 14716 | 7139[1] | 0 | 0 |
| Total | 35839 | 74266 | 75480 | 82688 | 61705 | 74374 | 87989 | 69730 | 65309 | 31795 | 29230 | 7845 | 17835 |

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data

| Country | 1996 | 1997 | 1998 | 1999* |
|---|---|---|---|---|
| Bulgaria | 0 | 0 | 0 | 0 |
| Canada | 3473 | 4203 | 9979 | 4961 |
| Cuba | 2177 3[1] | 11961[1] | 6083[1] | 3897[1] |
| France | 0 | 0 | 0 | 0 |
| FRG | 0 | 0 | 0 | 0 |
| GDR | 0 | 0 | 0 | 0 |
| Ireland | 0 | 0 | 0 | 0 |
| Italy | 0 | 0 | 0 | 0 |
| Japan | 0 | 0 | 0 | 0 |
| Poland | 0 | 0 | 0 | 0 |
| Portugal | 0 | 0 | 0 | 0 |
| Romania | 0 | 0 | 0 | 0 |
| Spain | 0 | 0 | 0 | 0 |
| USA | 0 | 0 | 0 | 0 |
| USSR | 669 | 0 | 168 | 0 |
| Total | 25927 | 16,164 | 16062 | 8858 |

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data
*incomplete

Table 2: Length/weight regressions: Male and female alpha and beta's used in the construction of the silver hake catch at age used in this assessment. Lengths (cm) and weights (kg) used were from the Canadian July Research Vessel Survey of the Scotian Shelf (4VWX).

| Year | Male - Alpha | Female - Alpha | Male - Beta | Female - Beta |
|---|---|---|---|---|
| 1977 | 0.000006260 | 0.000006930 | 3.0626 | 3.0350 |
| 1978 | 0.000004630 | 0.000003070 | 3.1366 | 3.2531 |
| 1979 | 0.000010200 | 0.000005880 | 2.9001 | 3.0675 |
| 1980 | 0.000002330 | 0.000001800 | 3.3417 | 3.3989 |
| 1981 | 0.000006830 | 0.000005080 | 3.0206 | 3.1172 |
| 1982 | 0.000011600 | 0.000006740 | 2.8575 | 3.0232 |
| 1983 | 0.000006480 | 0.000003320 | 2.9935 | 3.2034 |
| 1984 | 0.000018300 | 0.000006490 | 2.7052 | 3.0284 |
| 1985 | 0.000013500 | 0.000004530 | 2.7848 | 3.1235 |
| 1986 | 0.000007970 | 0.000003820 | 2.9384 | 3.1685 |
| 1987 | 0.000009990 | 0.000004240 | 2.8798 | 3.1456 |
| 1988 | 0.000014300 | 0.000004800 | 2.7942 | 3.1241 |
| 1989 | 0.000006750 | 0.000004440 | 3.0114 | 3.1416 |
| 1990 | 0.000034320 | 0.000021000 | 2.5234 | 2.6958 |
| 1991 | 0.000007773 | 0.000003488 | 2.9582 | 3.2036 |
| 1992 | 0.000003938 | 0.000003157 | 3.1824 | 3.2533 |
| 1993 | 0.000003461 | 0.000003089 | 3.178 | 3.2202 |
| 1994 | 0.000003336 | 0.000003147 | 3.2009 | 3.2228 |
| 1995 | 0.000003340 | 0.000002367 | 3.2151 | 3.3233 |
| 1996 | 0.000002548 | 0.000002460 | 3.2909 | 3.3040 |
| 1997 | 0.000002939 | 0.000002479 | 3.2511 | 3.3050 |
| 1998 | 0.000003682 | 0.000003049 | 3.1783 | 3.2390 |
| 1999 | 0.000002822 | 0.000002998 | 3.2564 | 3.2392 |

Table 3: Catch at age ('000's) for Scotian Shelf silver hake in 1998 by Cuban vessels.

| 6083t | age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| March | 0.1 | 761.9 | 1655.2 | 821.0 | 32.7 | 7.1 | 0 | 0 | 0 |
| April | 0 | 1711.5 | 4973.0 | 2170.0 | 279.0 | 0 | 0 | 0 | 0 |
| May | 0 | 3147.6 | 8350.3 | 2493.9 | 250.0 | 13.7 | 0 | 0 | 0 |
| June | 11.3 | 5999.5 | 6788.3 | 2064.5 | 356.2 | 6.1 | 19.9 | 0 | 0 |
| July | 59.8 | 2299.2 | 2108.6 | 660.4 | 83.1 | 5.1 | 1.7 | 0.5 | 0 |
| Total | 71.3 | 13919.7 | 23875.4 | 8209.8 | 1001.0 | 32.0 | 21.6 | 0.5 | 0 |
| % | 0.2 | 29.5 | 50.7 | 17.4 | 2.1 | 0.1 | 0.0 | 0.0 | 0.0 |

Table 4: Catch at age ('000's) for Scotian Shelf silver hake in 1998 by Canadian vessels.

| 9979t | age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| q1 | 0 | 0 | 2157.0 | 1388.0 | 223.0 | 124.0 | 0 | 0 | 0 |
| q2 | 357.0 | 15754.0 | 10751.0 | 350.0 | 45.3 | 23.6 | 0 | 0 | 0 |
| q3 | 3946.0 | 8658.0 | 1727.0 | 641.6 | 182.3 | 63.6 | 0 | 0 | 0 |
| q4 | 9858.0 | 5686.0 | 1801.0 | 858.0 | 148.0 | 10.3 | 0 | 0 | 0 |
| total | 14161.0 | 30098.0 | 16436.0 | 3237.6 | 598.6 | 221.5 | 0 | 0 | 0 |
| % | 21.9 | 46.5 | 25.4 | 5.0 | 0.9 | 0.3 | 0 | 0 | 0 |

Table 5: Catch at age ('000's) for Scotian Shelf silver hake, 1979-98 – all fleets combined.

| age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1979 | 20569 | 57893 | 72891 | 36669 | 22380 | 9970 | 3168 | 495 | 374 |
| 1980 | 16588 | 70696 | 70391 | 32032 | 14465 | 5184 | 1431 | 451 | 98 |
| 1981 | 2358 | 25214 | 109035 | 37573 | 11928 | 3234 | 1201 | 290 | 141 |
| 1982 | 20189 | 52976 | 75876 | 68400 | 31752 | 5945 | 2042 | 465 | 64 |
| 1983 | 5849 | 96852 | 56158 | 29282 | 11388 | 3395 | 819 | 253 | 88 |
| 1984 | 59588 | 45828 | 206900 | 82911 | 19344 | 4268 | 1038 | 183 | 10 |
| 1985 | 14970 | 130814 | 98346 | 128365 | 34110 | 9327 | 2344 | 226 | 85 |
| 1986 | 45598 | 70269 | 229126 | 84097 | 28635 | 8760 | 1436 | 497 | 111 |
| 1987 | 6804 | 214235 | 114417 | 54211 | 13063 | 6045 | 347 | 156 | 117 |
| 1988 | 5110 | 62791 | 265307 | 39242 | 21303 | 3106 | 2133 | 208 | 143 |
| 1989 | 24264 | 85846 | 158745 | 145105 | 20025 | 9369 | 1569 | 1166 | 39 |
| 1990 | 6516 | 209620 | 142862 | 41215 | 11741 | 1648 | 640 | 107 | 40 |
| 1991 | 5738 | 117305 | 201243 | 46414 | 12154 | 3954 | 290 | 181 | 50 |
| 1992 | 7461 | 74491 | 73526 | 27777 | 3461 | 1247 | 159 | 33 | 5 |
| 1993 | 31572 | 83140 | 70735 | 35222 | 5511 | 595 | 71 | 30 | 3 |
| 1994 | 1651 | 13265 | 35250 | 8847 | 1283 | 150 | 18 | 8 | 0 |
| 1995 | 3500 | 35925 | 45615 | 31316 | 5183 | 457 | 58 | 41 | 3 |
| 1996 | 33501 | 92030 | 43686 | 23234 | 4928 | 888 | 148 | 75 | 0 |
| 1997 | 16132 | 34018 | 37497 | 25384 | 3579 | 339 | 29 | 27 | 2 |
| 1998 | 14232 | 44018 | 40311 | 11447 | 1690 | 235 | 22 | 4 | 0 |

Table 6: CPUE (t/hr) and effort (hrs), raw and (corrected) for the effect of separator grates, for the Cuban and Russian 4VWX silver hake fishery, 1979-99.

| year | CPUE | effort (hrs) |
|---|---|---|
| 1979 | 1.71 | 30,271 |
| 1980 | 2.04 | 21,811 |
| 1981 | 1.71 | 26,083 |
| 1982 | 3.20 | 18,841 |
| 1983 | 1.76 | 20,406 |
| 1984 | 2.94 | 25276 |
| 1985 | 2.82 | 26,791 |
| 1986 | 3.48 | 23,755 |
| 1987 | 2.75 | 22,433 |
| 1988 | 2.80 | 26,535 |
| 1989 | 3.89 | 22,624 |
| 1990 | 1.89 | 37,288 |
| 1991 | 1.70 | 39,911 |
| 1992 | 1.32 | 24,148 |
| 1993 | 1.43 | 20,369 |
| 1994 | 1.36 (1.43) | 5,767 (5,479) |
| 1995 | 1.34 (1.41) | 12,519 (11,893) |
| 1996 | 1.28 (1.34) | 17,010 (16,160) |
| 1997 | 1.02 (1.07) | 11,726 (11,140) |
| 1998 | 1.35 (1.42 ) | 4,505 (4,280) |
| 1999 | 0.88 (0.92) | 4,428 (4,207) |

Table 7: Scotian Shelf silver hake July RV survey numbers ('000) at age, (strata 484-495 excluded). 1977 to 1982 corrected for vessel effect.

| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1977 | 4678 | 23530 | 19417 | 4565 | 1361 | 1213 | 938 | 327 | 284 |
| 1978 | 23504 | 22781 | 16119 | 8923 | 6696 | 3050 | 1288 | 502 | 866 |
| 1979 | 69803 | 146692 | 69097 | 20341 | 11565 | 5083 | 2683 | 976 | 277 |
| 1980 | 11491 | 19280 | 28116 | 7884 | 4292 | 3358 | 1478 | 805 | 382 |
| 1981 | 31646 | 84254 | 129884 | 60439 | 16084 | 5237 | 2428 | 794 | 654 |
| 1982 | 177636 | 29113 | 7743 | 6201 | 3210 | 817 | 350 | 252 | 33 |
| 1983 | 41989 | 99363 | 38242 | 18996 | 10603 | 2779 | 882 | 401 | 333 |
| 1984 | 174499 | 65030 | 209275 | 39603 | 12120 | 8042 | 2873 | 1141 | 523 |
| 1985 | 37657 | 163470 | 33877 | 73811 | 22537 | 9947 | 2662 | 1224 | 215 |
| 1986 | 262382 | 73829 | 74006 | 22644 | 13552 | 4148 | 1656 | 714 | 334 |
| 1987 | 139673 | 253815 | 42291 | 18612 | 6068 | 4104 | 1256 | 669 | 477 |
| 1988 | 68466 | 87117 | 82662 | 16966 | 14226 | 2514 | 2373 | 481 | 148 |
| 1989 | 128836 | 60127 | 23090 | 13012 | 3549 | 1744 | 697 | 318 | 129 |
| 1990 | 89477 | 115013 | 46417 | 13857 | 4057 | 1155 | 407 | 208 | 81 |
| 1991 | 39736 | 80924 | 35098 | 13165 | 6624 | 2417 | 402 | 143 | 124 |
| 1992 | 25952 | 56010 | 45726 | 11077 | 4464 | 2230 | 423 | 139 | 192 |
| 1993 | 113930 | 89870 | 63214 | 27290 | 2531 | 807 | 584 | 98 | 38 |
| 1994 | 86323 | 56315 | 57237 | 25354 | 8180 | 1147 | 331 | 210 | 133 |
| 1995 | 90254 | 72148 | 82582 | 56655 | 15599 | 3415 | 1295 | 614 | 652 |
| 1996 | 94124 | 170255 | 57251 | 42983 | 10622 | 1584 | 295 | 567 | 156 |
| 1997 | 143034 | 122443 | 53562 | 6064 | 3663 | 594 | 88 | 77 | 77 |
| 1998 | 34000 | 92900 | 35200 | 13700 | 2100 | 1300 | 280 | 100 | 100 |

Table 8: Stratified mean catch per tow for the Canada-Russia juvenile silver hake survey, core strata (60-78).

| Year Class | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|
| mean catch/tow | 579.0 | 8.8 | 232.2 | 43.4 | 284.8 | 198.0 | 102.0 | 204.8 | 131.5 |
| std.error | 64.4 | 1.2 | 24.4 | 7.1 | 62.2 | 37.9 | 23.0 | 35.3 | 19.0 |
| CV | 0.11 | 0.14 | 0.11 | 0.16 | 0.22 | 0.19 | 0.23 | 0.17 | 0.14 |
| number of sets | 77 | 61 | 64 | 71 | 82 | 74 | 105 | 79 | 74 |
| July RV age 1 #'s ($10^6$) | 178 | 42 | 175 | 38 | 262 | 140 | 68 | 129 | 89 |

| Year Class | 1990 | 1991 | 1992[1] | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|
| mean catch/tow | 187.4 | 78.6 | - | 186.5 | 105.4 | 252.0 | 444.1 | 578.6 |
| std.error | 24.1 | 10.4 | - | 17.2 | 8.4 | 60.5 | 186.5 | 214.1 |
| CV | 0.13 | 0.13 | - | 0.09 | 0.08 | 0.24 | 0.42 | 0.37 |
| number of sets | 68 | 71 | - | 95 | 73 | 83 | 81 | 81 |
| July RV age 1 #'s ($10^6$) | 40 | 26 | 114 | 86 | 90 | 94 | 143 | -- |

[1] no survey in 1992.

Table 9: Parameter estimates from ADAPT analysis for Scotian Shelf silver hake; July RV abundance at age used as tuning index.

| Est. | Param. | SE | CV | Bias | |
|---|---|---|---|---|---|
| 1 | 12.0565 | 0.918075 | 0.0761475 | -0.00643 | f1 |
| 2 | 12.7188 | 0.870579 | 0.0684481 | 0.13739 | f2 |
| 3 | 11.6231 | 1.55832 | 0.134071 | 2.09656 | f3 |
| 4 | 10.6733 | 0.62688 | 0.0587337 | 0.20207 | f4 |
| 5 | 7.67372 | 1.18471 | 0.154386 | 1.48064 | f5 |
| 6 | 6.97489 | 1.6581 | 0.237724 | 3.25563 | f6 |
| 7 | 1.53137E-005 | 3.33477E-006 | 0.217764 | -0.251059 | q1 |
| 8 | 2.80064E-005 | 5.93872E-006 | 0.212049 | -0.651266 | q2 |
| 9 | 3.9855E-005 | 8.41036E-006 | 0.211024 | -1.60641 | q3 |
| 10 | 6.51858E-005 | 1.36005E-005 | 0.208642 | -0.148929 | q4 |
| 11 | 0.000108786 | 2.32477E-005 | 0.213701 | -1.3064 | q5 |
| 12 | 0.000177426 | 3.80767E-005 | 0.214606 | -3.17273 | q6 |

## Table 10: SPA results – bias corrected population numbers.

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 830906 | 1379660 | 757154 | 1865128 | 807386 | 766597 | 1108327 | 578833 | 410995 | 417547 | 318292 | 317012 | 545088 | 587118 | 863005 | 271136 |
| 1032970 | 552184 | 876027 | 495279 | 1212900 | 535636 | 509682 | 723068 | 382668 | 270801 | 273782 | 187509 | 211148 | 362518 | 366129 | 565282 |
| 352457 | 613125 | 332619 | 480117 | 274464 | 637630 | 307639 | 271365 | 313065 | 160469 | 120535 | 115452 | 114830 | 112124 | 167655 | 217572 |
| 105428 | 190281 | 241594 | 142442 | 134240 | 90302 | 210201 | 76247 | 64936 | 45090 | 47368 | 22884 | 48530 | 39627 | 39392 | 81683 |
| 31356 | 46697 | 59667 | 56849 | 26629 | 45599 | 28403 | 22100 | 17366 | 5527 | 7483 | 2914 | 8096 | 6891 | 7540 | 5622 |
| 7207 | 11695 | 15464 | 12069 | 14663 | 7155 | 13125 | 2644 | 5202 | 1690 | 871 | 504 | 903 | 1184 | 584 | 2124 |
| 1651 | 2051 | 4345 | 2730 | 918 | 4880 | 2253 | 1127 | 423 | 249 | 112 | 97 | 215 | 231 | 66 | 114 |
| 345 | 436 | 525 | 993 | 654 | 331 | 1524 | 226 | 232 | 46 | 37 | 17 | 50 | 97 | 34 | 21 |
| 227 | 24 | 142 | 167 | 259 | 311 | 52 | 67 | 64 | 7 | 4 | 0 | 5 | 0 | 3 | 1 |
| 1+ | | | | | | | | | | | | | | | |
| 2362546 | 2796153 | 2287539 | 3055775 | 2472113 | 2088442 | 2181206 | 1675677 | 1194950 | 901426 | 768483 | 646389 | 928865 | 1109789 | 1444409 | 1143555 |

## Table 11: SPA results – bias corrected fishing mortality.

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01 | 0.05 | 0.02 | 0.03 | 0.01 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.13 | 0.01 | 0.01 | 0.07 | 0.02 | 0.07 |
| 0.12 | 0.11 | 0.20 | 0.19 | 0.24 | 0.15 | 0.23 | 0.44 | 0.47 | 0.41 | 0.46 | 0.09 | 0.23 | 0.37 | 0.12 | 0.10 |
| 0.22 | 0.53 | 0.45 | 0.87 | 0.71 | 0.71 | 0.99 | 1.03 | 1.54 | 0.82 | 1.26 | 0.47 | 0.66 | 0.65 | 0.32 | 0.26 |
| 0.41 | 0.76 | 1.05 | 1.28 | 0.68 | 0.76 | 1.85 | 1.08 | 2.06 | 1.40 | 2.39 | 0.64 | 1.55 | 1.26 | 1.55 | 0.19 |
| 0.59 | 0.71 | 1.20 | 0.96 | 0.91 | 0.85 | 1.97 | 1.05 | 1.93 | 1.45 | 2.30 | 0.77 | 1.52 | 2.07 | 0.87 | 0.46 |
| 0.86 | 0.59 | 1.33 | 2.18 | 0.70 | 0.76 | 2.05 | 1.43 | 2.64 | 2.32 | 1.80 | 0.45 | 0.96 | 2.48 | 1.23 | 0.15 |
| 0.93 | 0.96 | 1.08 | 1.03 | 0.62 | 0.76 | 1.90 | 1.18 | 1.82 | 1.51 | 1.49 | 0.26 | 0.40 | 1.52 | 0.76 | 0.26 |
| 2.27 | 0.72 | 0.75 | 0.94 | 0.34 | 1.45 | 2.72 | 0.86 | 3.10 | 2.08 | 4.57 | 0.87 | 5.53 | 2.97 | 3.77 | 0.26 |
| 0.62 | 0.68 | 1.19 | 1.47 | 0.76 | 0.79 | 1.96 | 1.19 | 2.21 | 1.72 | 2.16 | 0.62 | 1.35 | 1.94 | 1.22 | 0.26 |
| avg4-6 | | | | | | | | | | | | | | | |
| 0.62 | 0.68 | 1.19 | 1.47 | 0.76 | 0.79 | 1.96 | 1.19 | 2.21 | 1.72 | 2.16 | 0.62 | 1.35 | 1.94 | 1.22 | 0.26 |

## Table 12: SPA results – bias corrected population biomass.

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37713 | 62619 | 38024 | 86854 | 28558 | 19628 | 28795 | 22818 | 17432 | 11371 | 21715 | 14733 | 19272 | 27287 | 21832 | 9355 |
| 111189 | 54613 | 85474 | 49180 | 96324 | 42363 | 39726 | 66033 | 35810 | 21967 | 25683 | 14524 | 14930 | 28081 | 23156 | 40959 |
| 64620 | 93324 | 53470 | 75950 | 42838 | 94608 | 50648 | 42769 | 50743 | 26078 | 17467 | 13806 | 13587 | 13219 | 19576 | 25743 |
| 23619 | 39870 | 47102 | 29964 | 26450 | 17635 | 42790 | 15684 | 12916 | 8983 | 9000 | 3654 | 7214 | 6095 | 6049 | 12617 |
| 8199 | 11906 | 13949 | 13026 | 6631 | 10680 | 7135 | 5124 | 4149 | 1307 | 1644 | 554 | 1530 | 1293 | 1394 | 1061 |
| 2497 | 3735 | 4380 | 3121 | 3921 | 1925 | 3954 | 782 | 1428 | 459 | 235 | 126 | 219 | 294 | 143 | 519 |
| 519 | 789 | 1653 | 928 | 323 | 1652 | 773 | 405 | 163 | 85 | 36 | 32 | 71 | 91 | 24 | 33 |
| 132 | 216 | 255 | 456 | 266 | 157 | 690 | 91 | 101 | 20 | 13 | 7 | 21 | 41 | 16 | 12 |
| 119 | 13 | 92 | 102 | 134 | 167 | 33 | 35 | 30 | 4 | 2 | 0 | 2 | 0 | 2 | 0 |

1+

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 248608 | 267086 | 244400 | 259580 | 205444 | 188816 | 174544 | 153742 | 122770 | 70273 | 75797 | 47436 | 56847 | 76400 | 72193 | 90299 |

SSB

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 155301 | 177160 | 163639 | 148136 | 128725 | 148007 | 125886 | 97908 | 87434 | 47919 | 41239 | 25440 | 30110 | 35073 | 38782 | 60464 |

Table 13: Ratio of 1998 estimates of population numbers from VPA to initial estimates from retrospective (8 year)analysis.

| age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| ratio | 0.69 | 0.56 | 0.53 | 0.43 | 0.34 | 0.33 | 0.48 | 0.33 | 0.35 |

Table 14: Results of projection for Scotian Shelf silver hake.

| Year | F | Yield(t) | Biomass(t) | SSB |
|---|---|---|---|---|
| 1999 | 0.908 | 13999 | 71124 | 35447 |
| 2000 | 0.700 | 14220 | 80129 | 43142 |
| 2001 | 0.700 | 17220 | 88184 | 60983 |
| 2002 | 0.700 | 22055 | 88807 | 61606 |
| 2003 | 0.000 | 0 | 84266 | 57065 |

numbers ('000)

| AGE | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|
| 1 | 837578 | 432000 | 432000 | 432000 |
| 2 | 90244 | 551347 | 285552 | 285552 |
| 3 | 180507 | 52793 | 332741 | 172332 |
| 4 | 48115 | 84163 | 26746 | 168572 |
| 5 | 15394 | 13015 | 28015 | 8903 |
| 6 | 788 | 4164 | 4332 | 9326 |
| 7 | 585 | 213 | 1386 | 1442 |
| 8 | 19 | 158 | 71 | 461 |
| 9 | 4 | 5 | 53 | 24 |

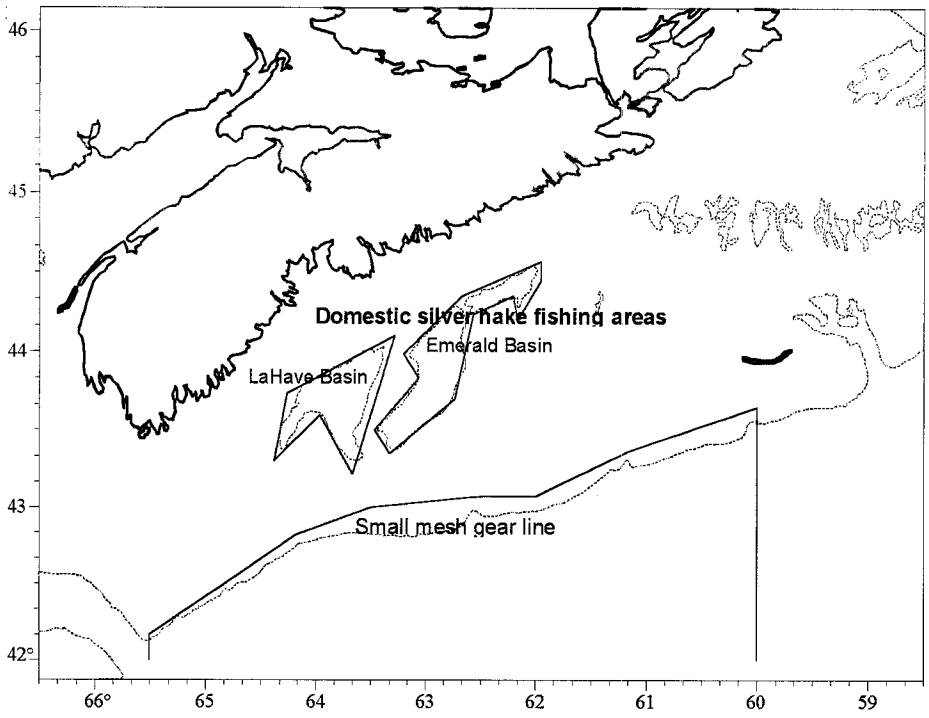



Fig. 1: Scotian Shelf silver hake fishing areas.

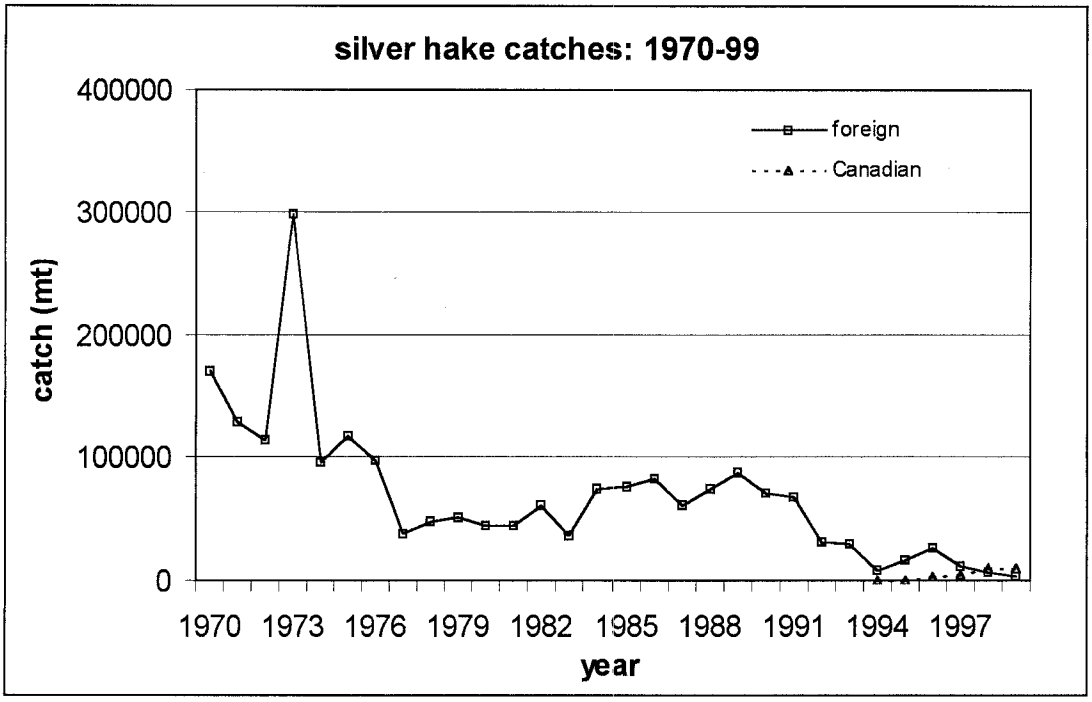



Fig. 2: Historical catches of Scotian Shelf silver hake, 1970-99 (1999 estimated).

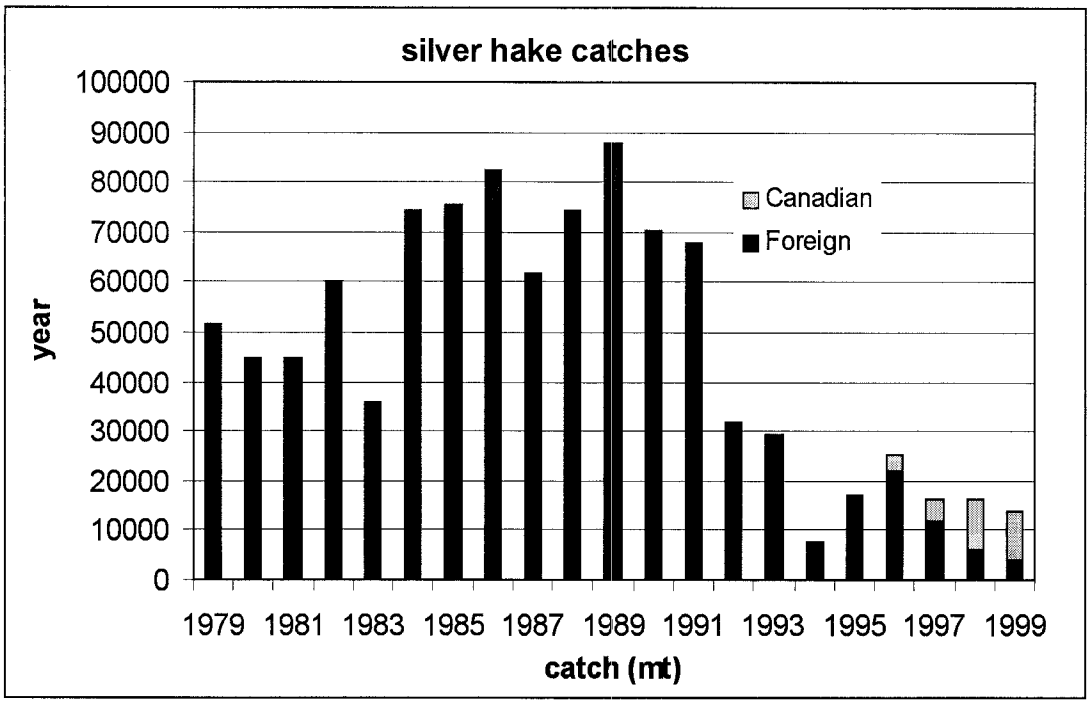



Fig. 3: Catches of Scotian Shelf silver hake by Canada and foreign fishing vessels, 1979-1999 (1999 estimated).

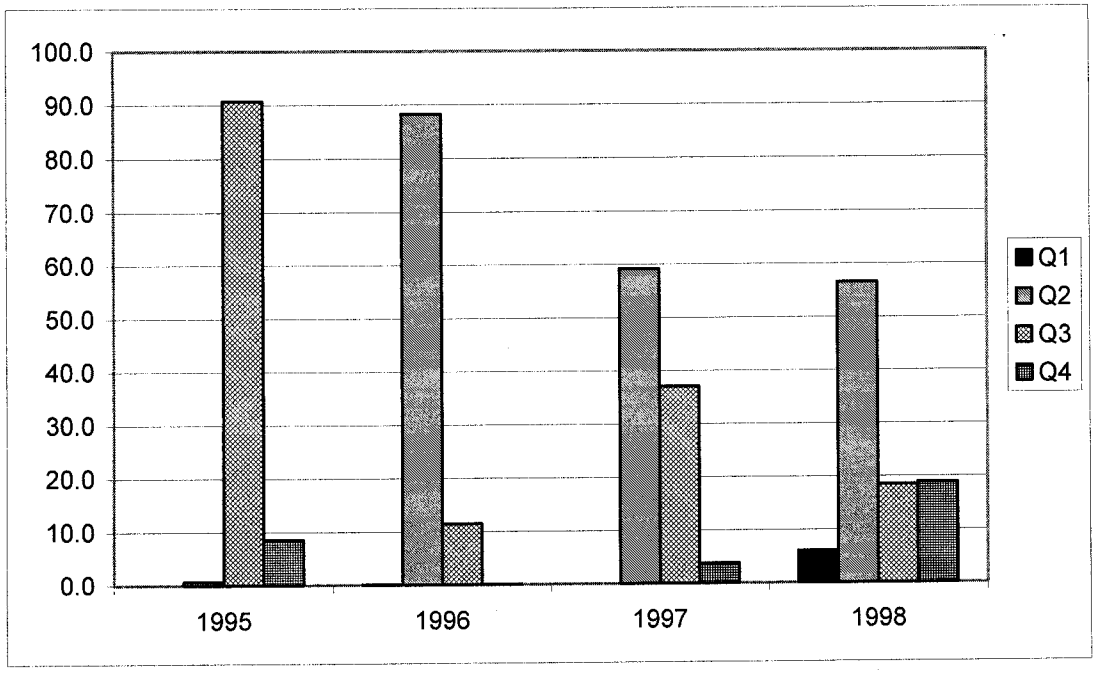



Figure 4: Silver hake catches from Emerald and LaHave Basins, 1995-98; percentage landed by quarter.

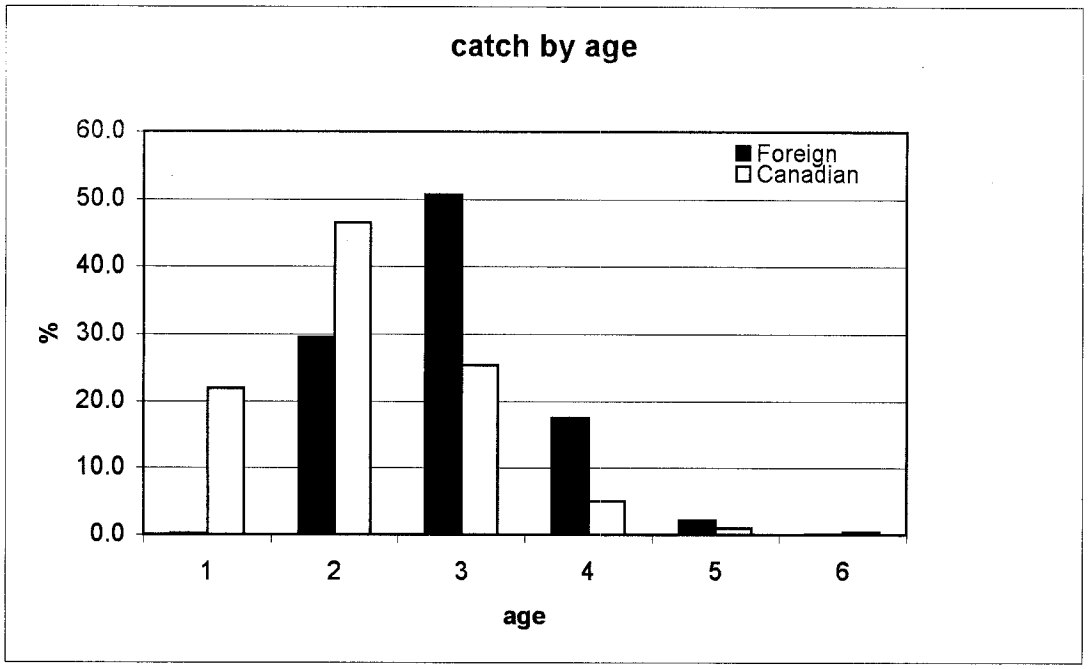



Fig. 5: Catch at age of Scotian Shelf silver hake in 1998 by Foreign and Canadian fleets.

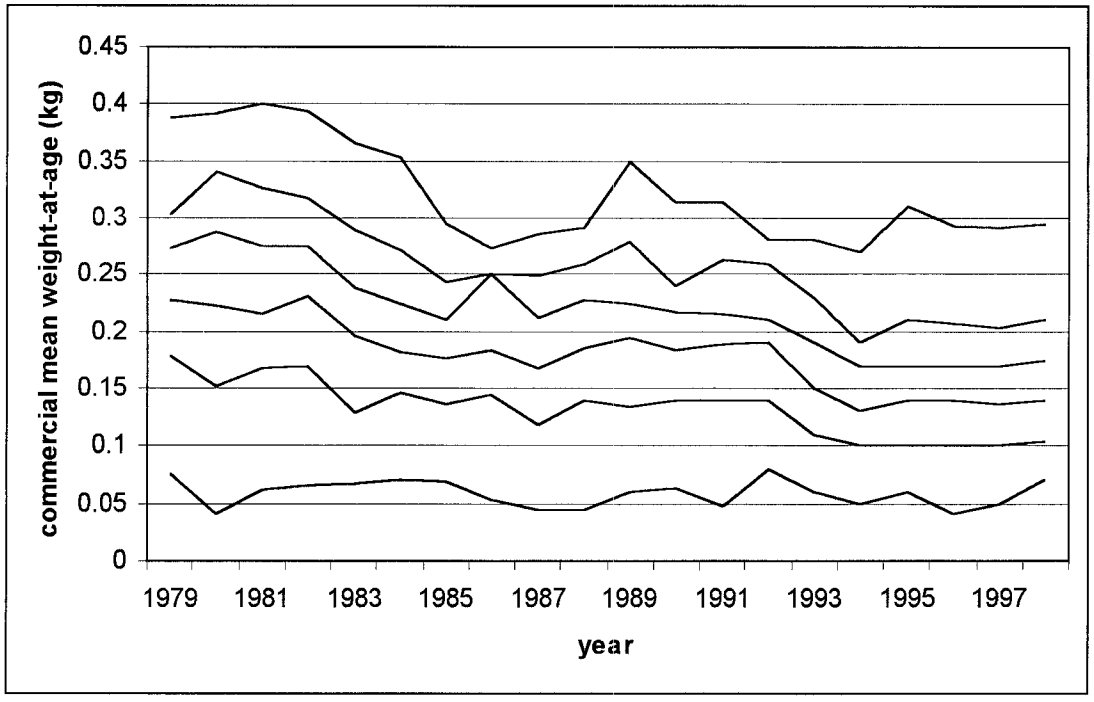



Fig. 6: Commercial mean weight-at-age for Scotian Shelf silver hake, age 1-6.

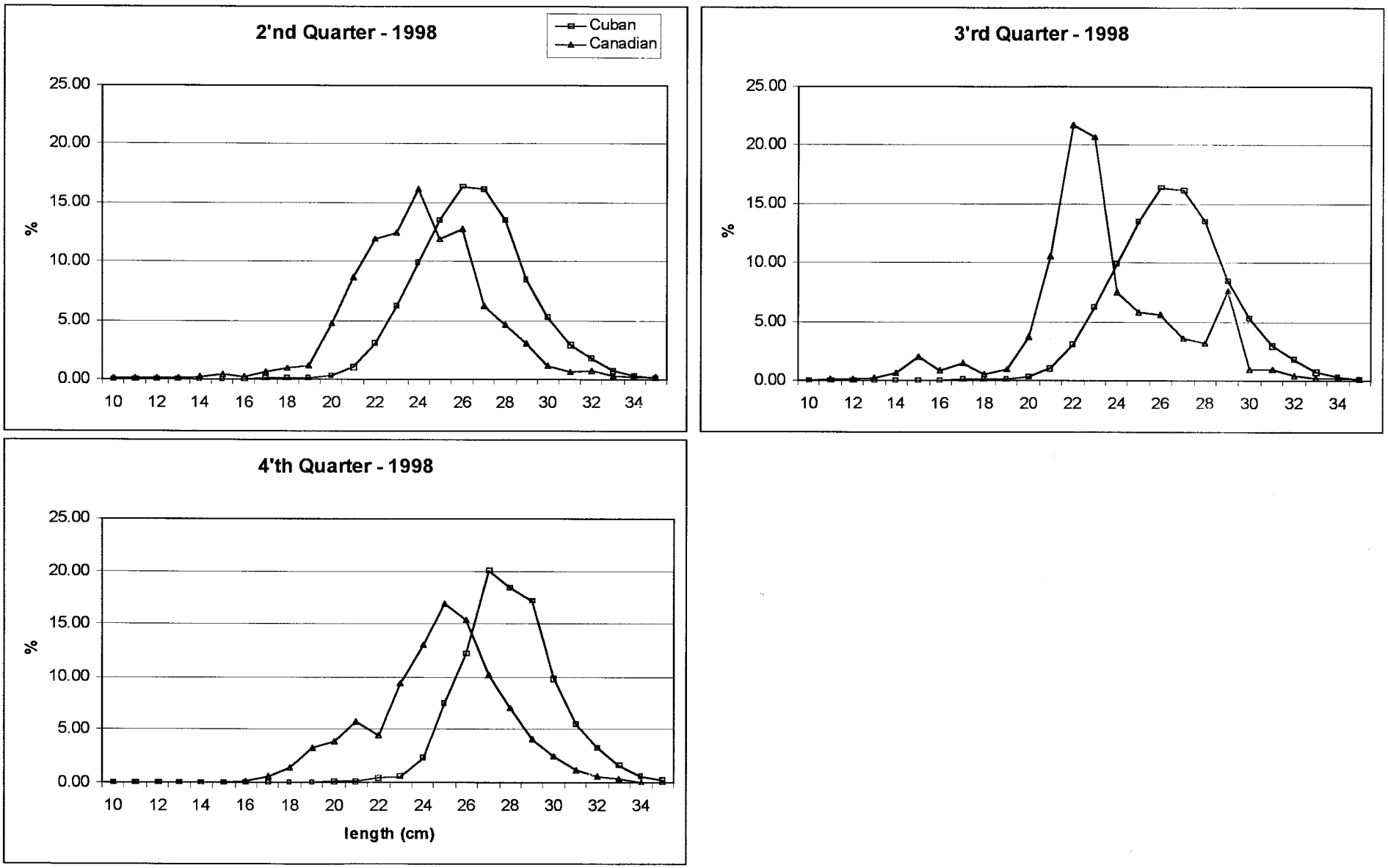
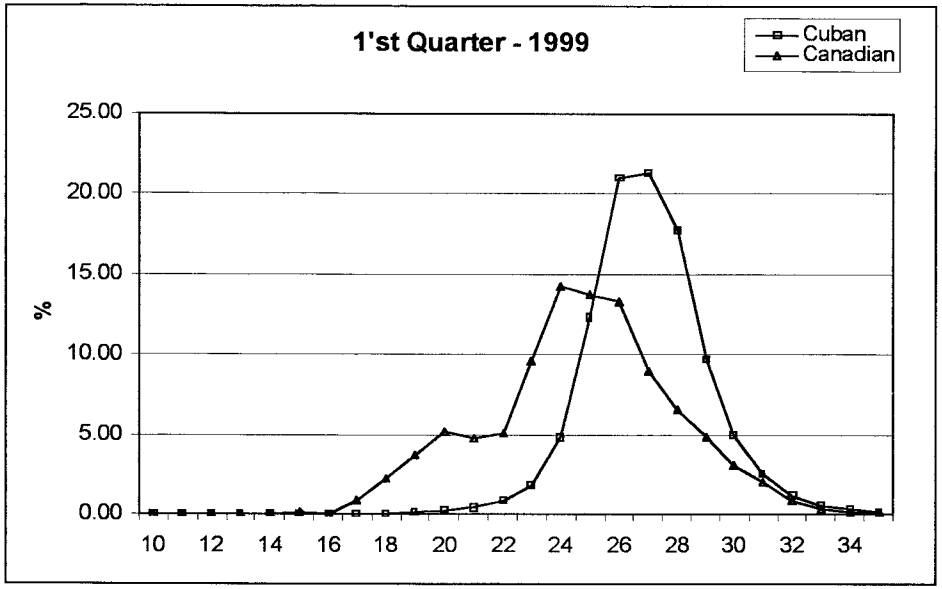
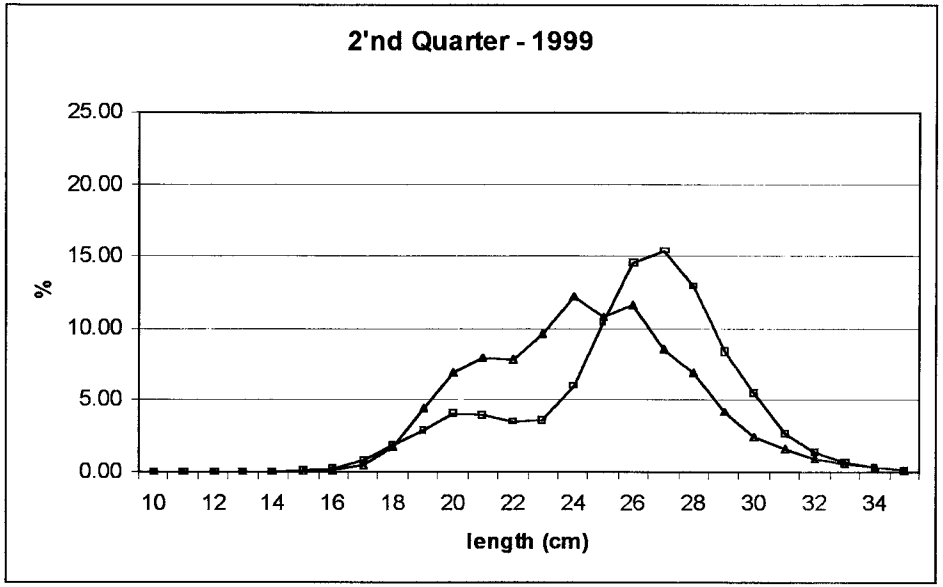



Figure 7: Comparison of size distribution of landings from the 1998 Cuban and Canadian silver hake fisheries. Cuban data from Canadian observers, Canadian data from Industry sampling.



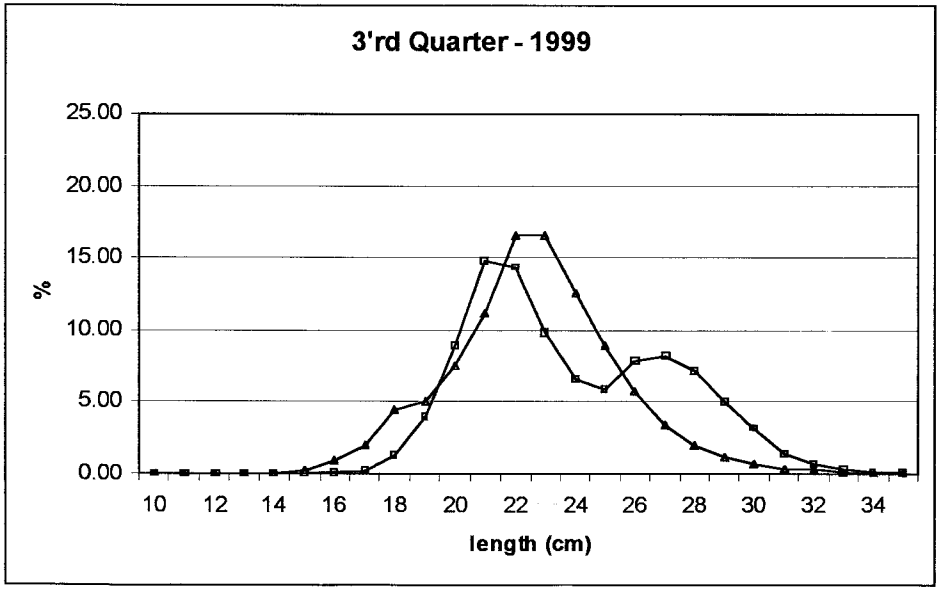




Figure 8: Comparison of size distribution of landings from the 1999 Cuban and Canadian silver hake fisheries. Cuban data from Canadian observers, Canadian data from Industry sampling and DFO port sampling.

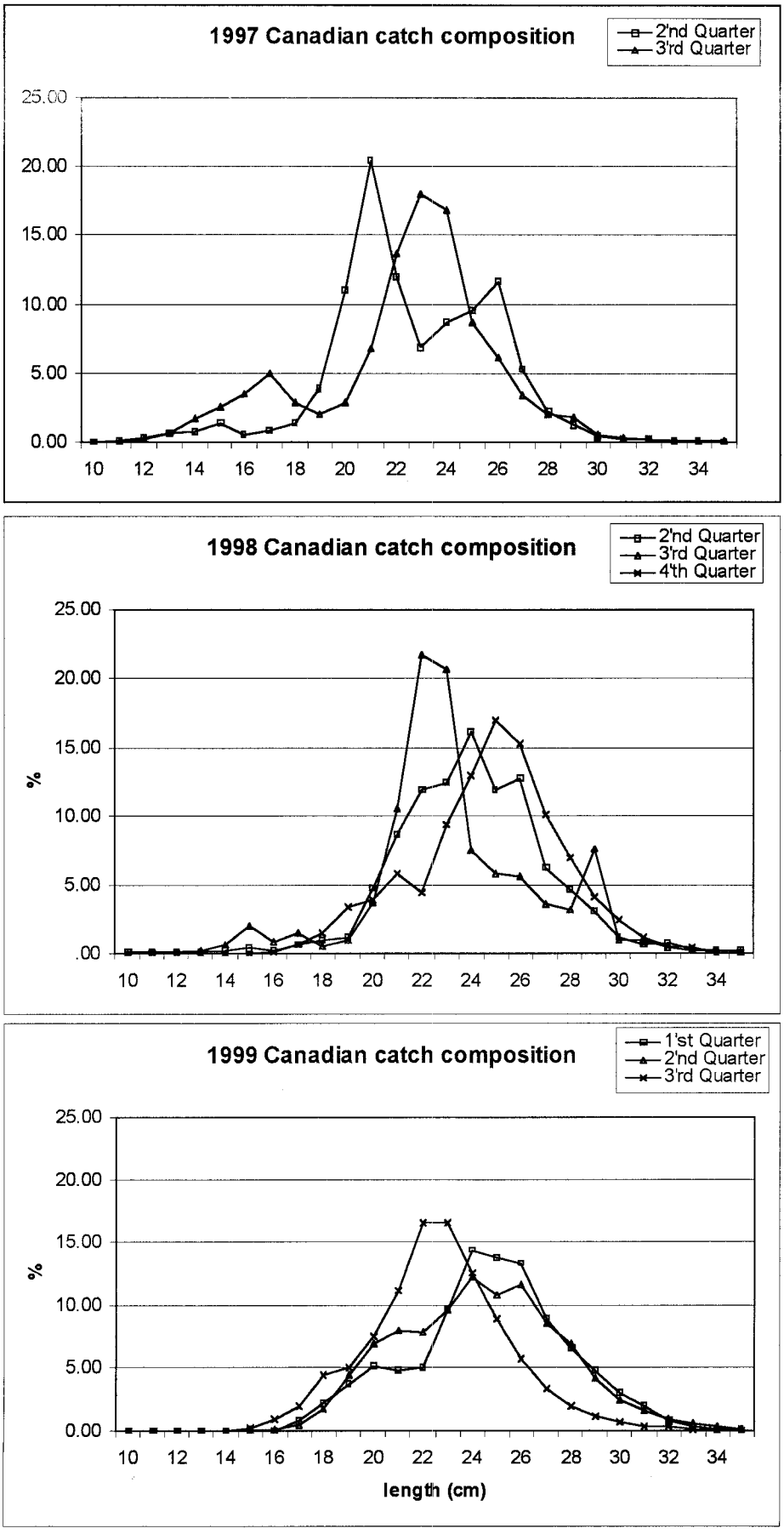



Figure 9: Comparison of size distribution of landings from the 1997-99 Canadian silver hake fishery, by quarter. 1997 & 1998 data from Industry sampling, 1999 data from Industry and DFO port sampling.

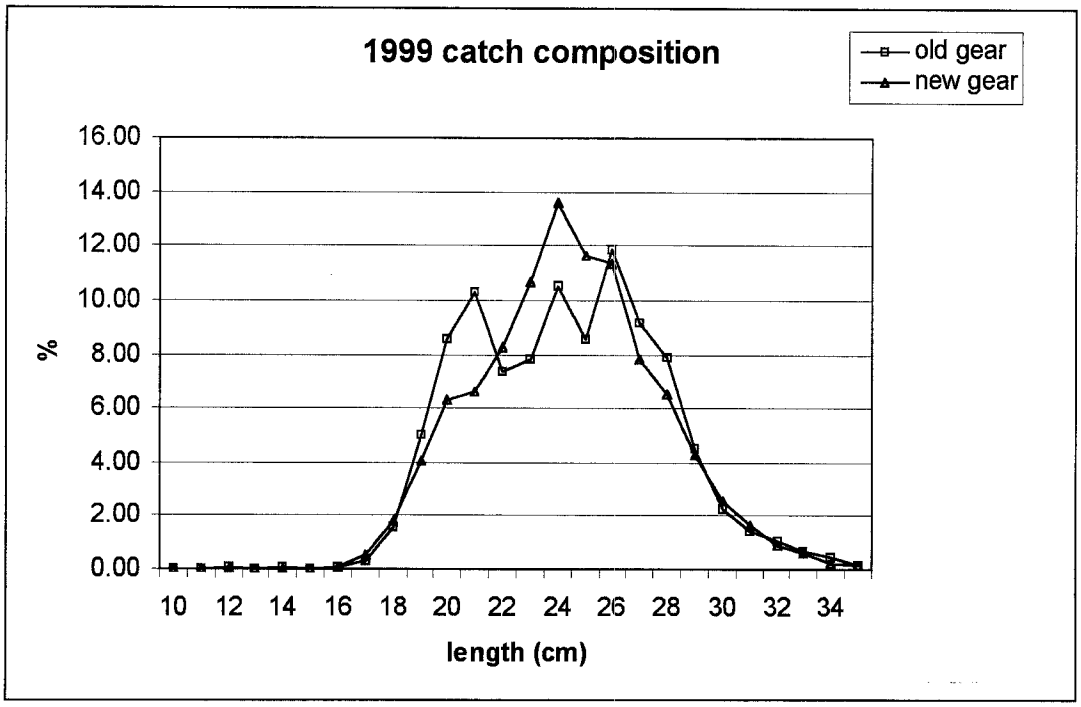



Figure 10: Comparison of size distribution of silver hake landings in April (old gear) and May (new gear) 1999. Data from Industry and DFO port sampling.

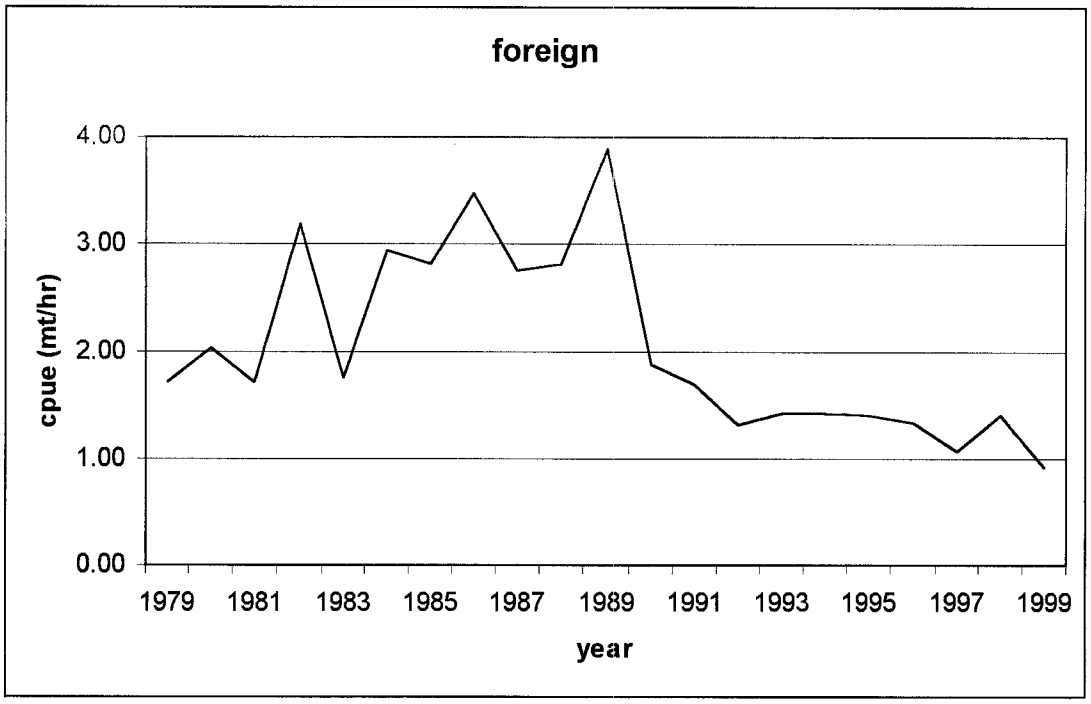



Fig 11: Commercial catch rates by foreign vessels, 1979-99 for Scotian Shelf silver hake, from Canadian observer data.

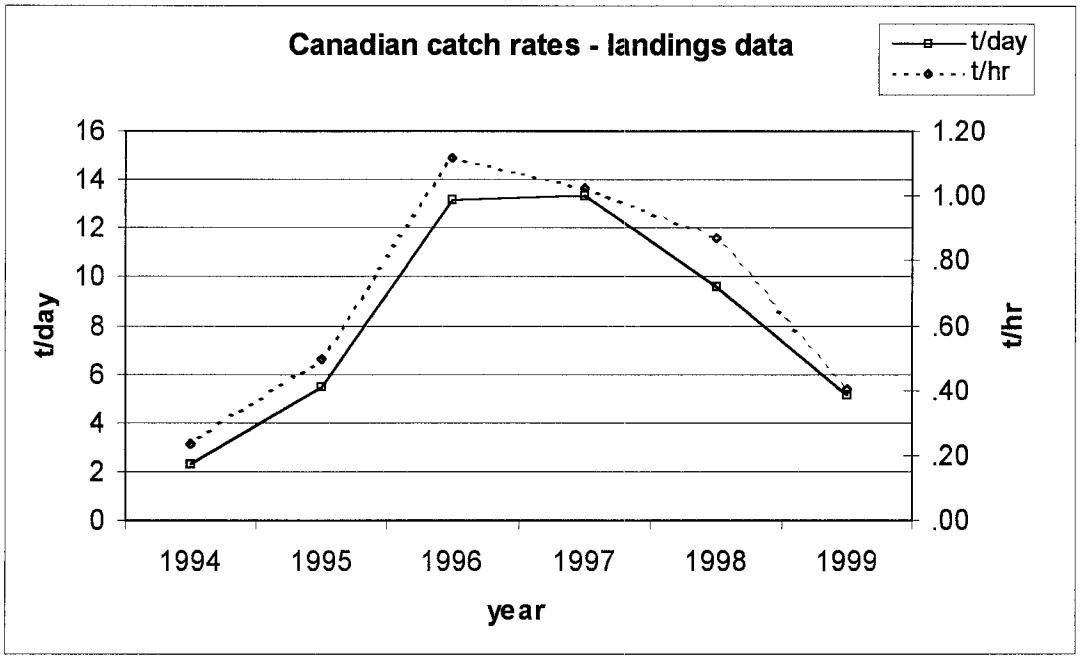



Fig 12: Commercial catch rates by Canadian vessels, 1994-99 for Scotian Shelf silver hake, from commercial landings data (1999 incomplete).

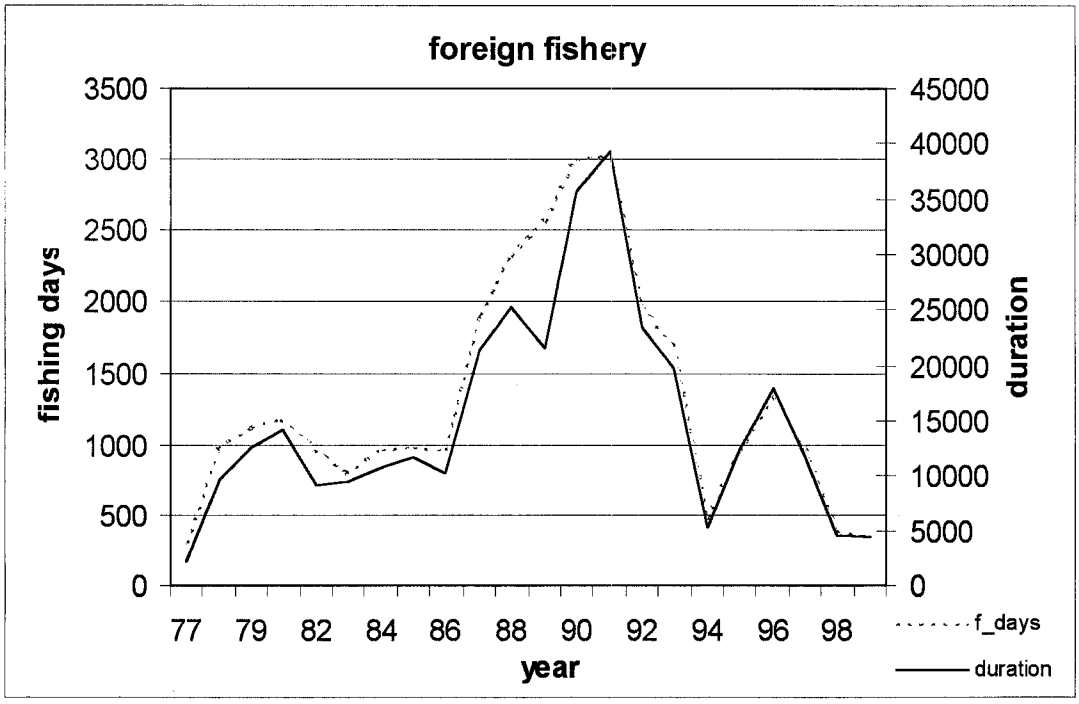



Fig 13: Fishing intensity (hours and days fished) by foreign fishing vessels on the Scotian Shelf, 1977-99.

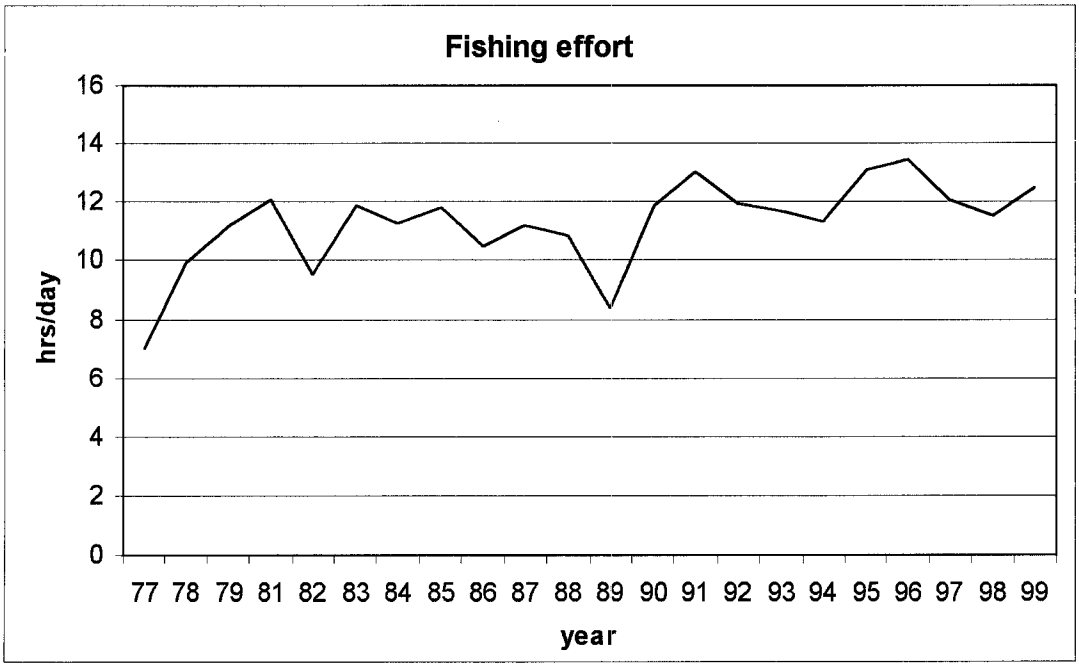



Fig. 14: Fishing effort (hours fished per day) by foreign fishing vessels on the Scotian Shelf, 1977-99.

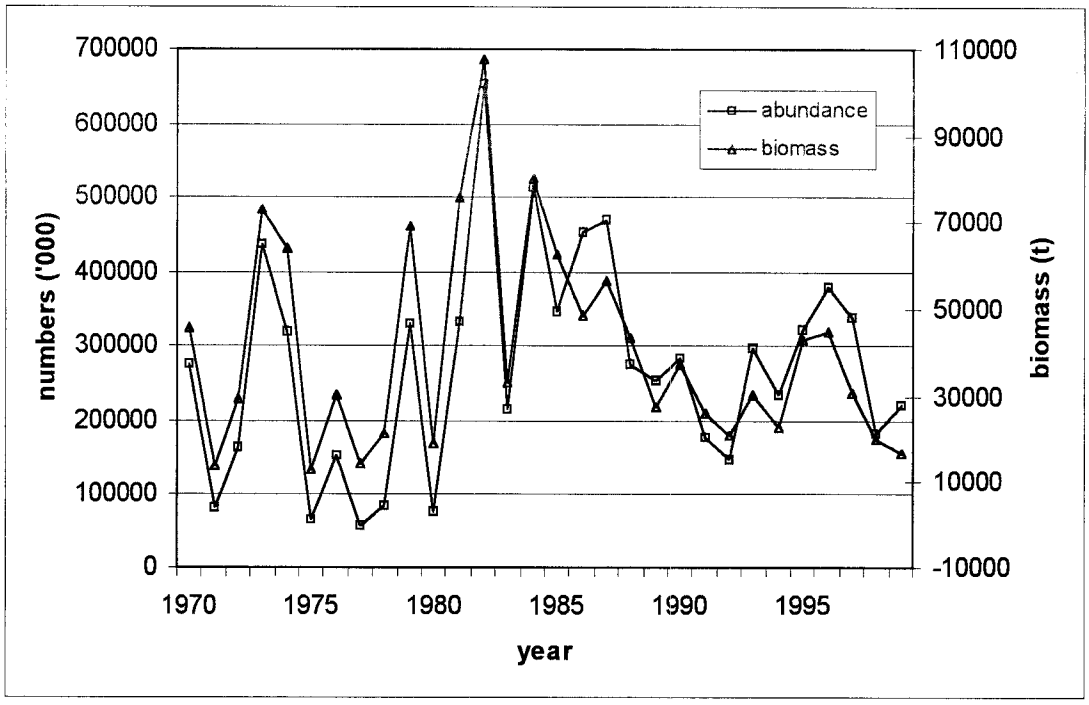
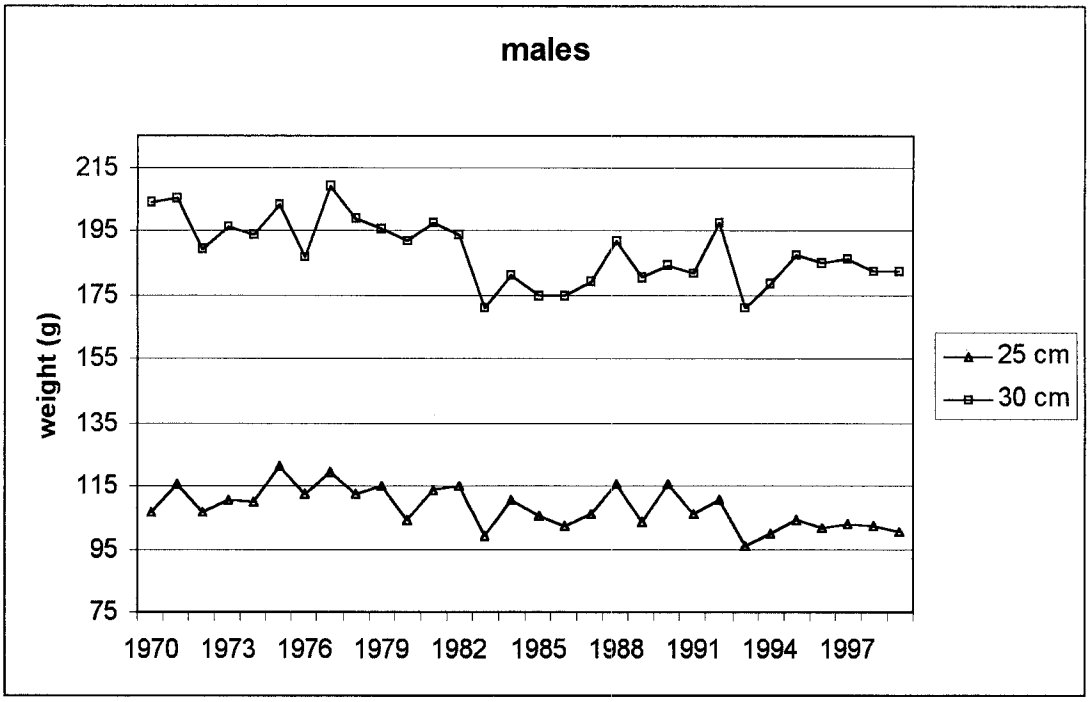



Fig. 15: Silver hake abundance and biomass estimates from Canadian RV survey, 1970-99 for Scotian Shelf strata 440-483 (excludes Bay of Fundy). Years1970-82 corrected for survey vessel effect.



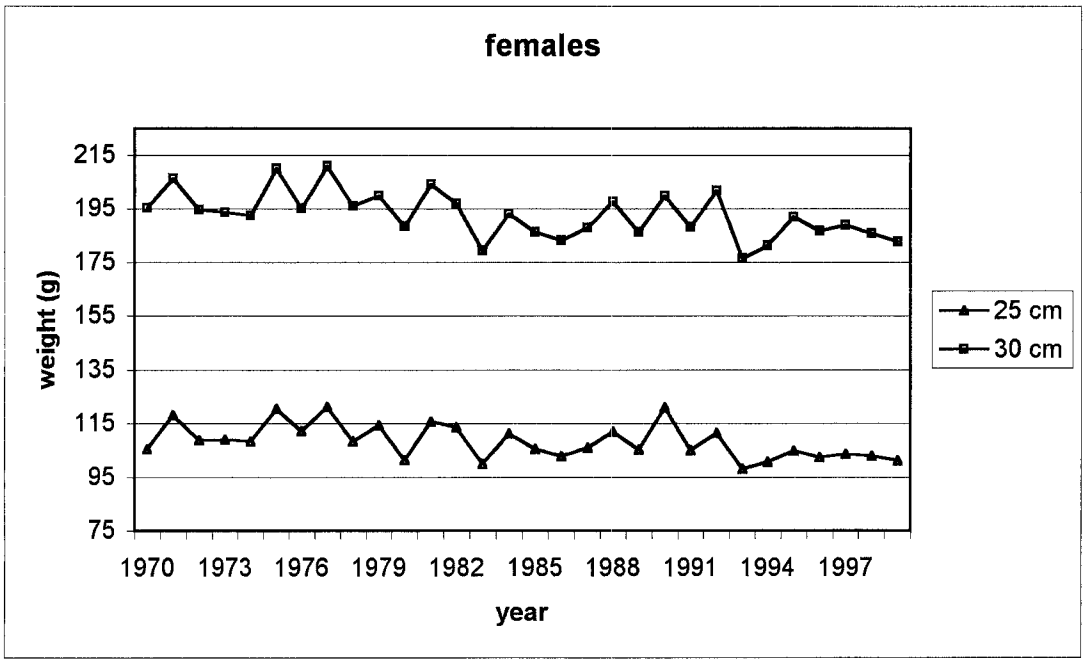
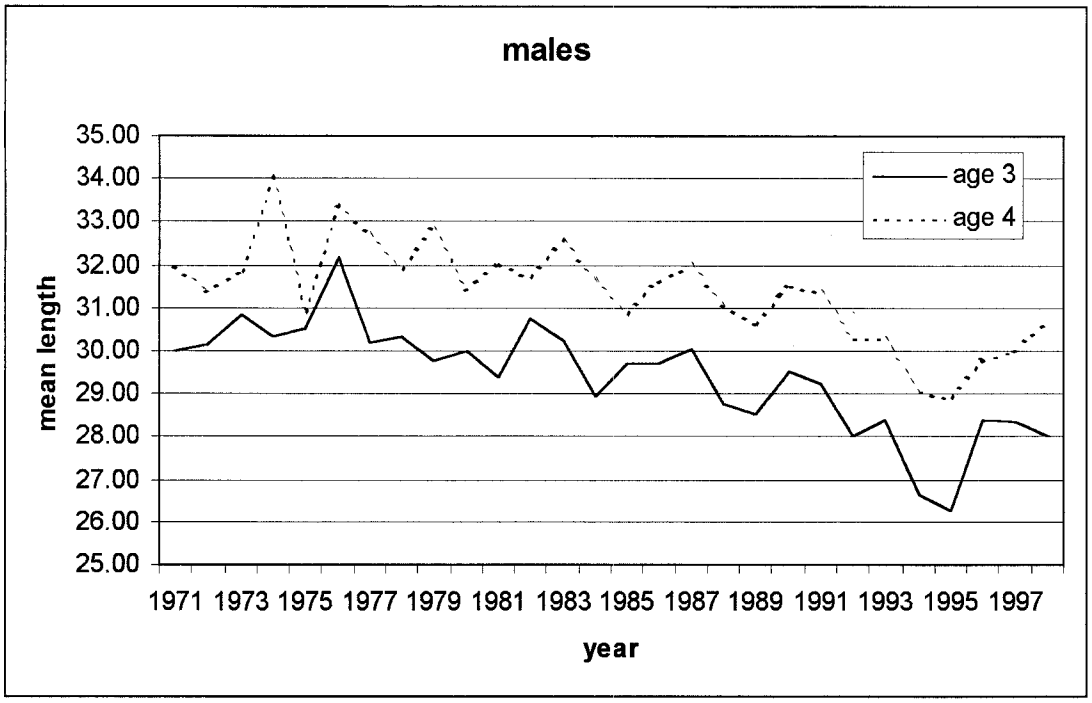




Fig. 16: Condition factor (weight at given length) for Scotian Shelf silver hake, from July RV survey data.



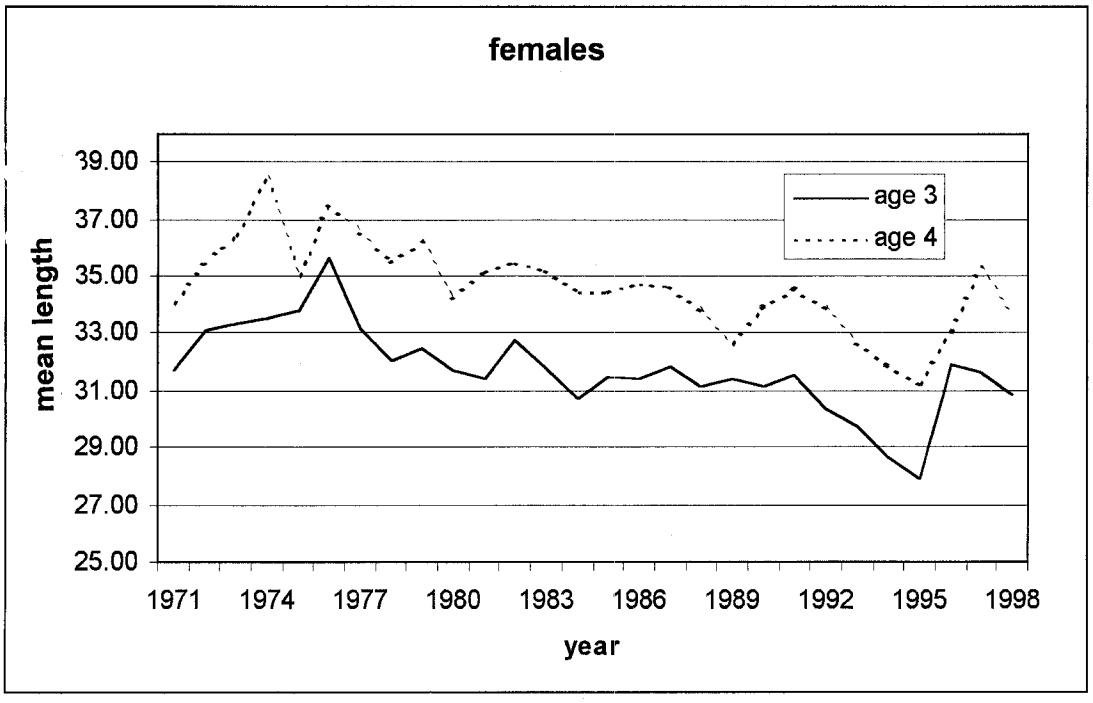
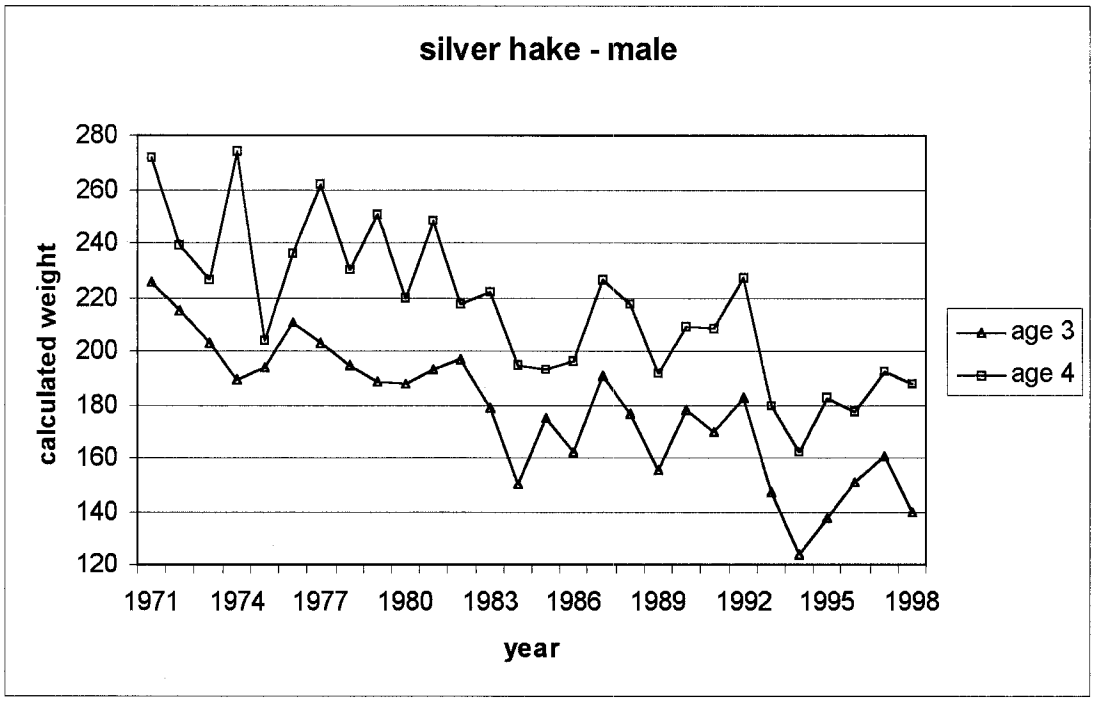




Fig. 17: Mean length at age 3 and 4, for Scotian Shelf silver hake, from July RV survey data.



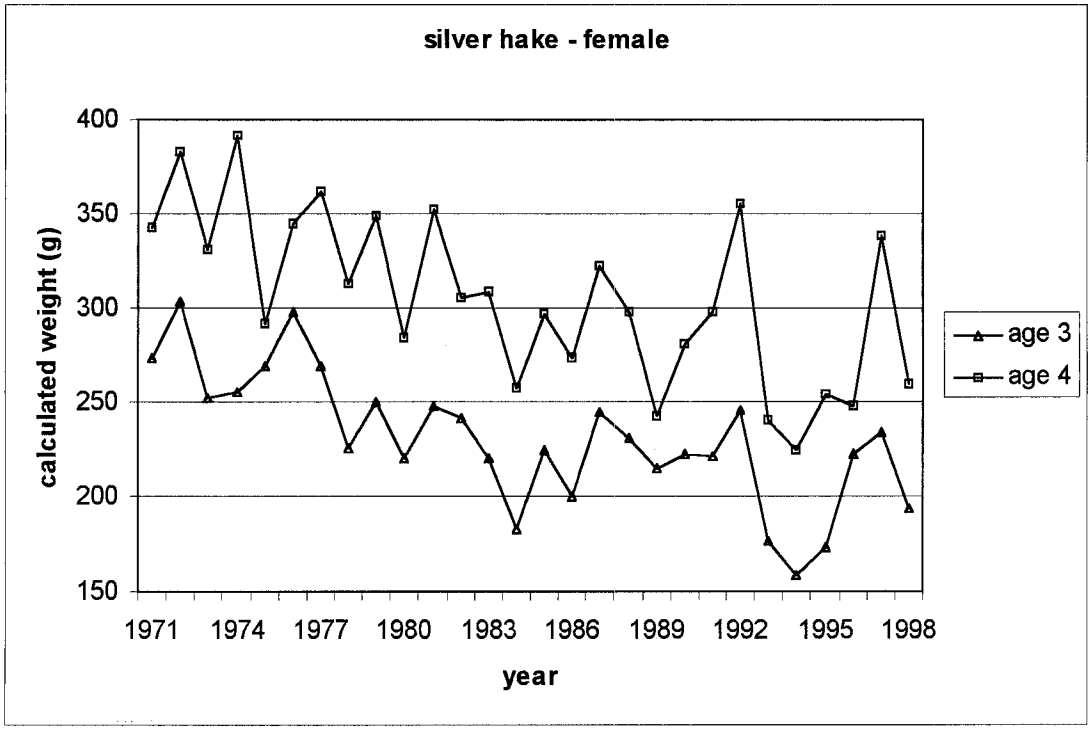




Fig 18: Calculated weight-at-age for Scotian Shelf silver hake, from July RV survey data, incorporating condition and mean length at age.

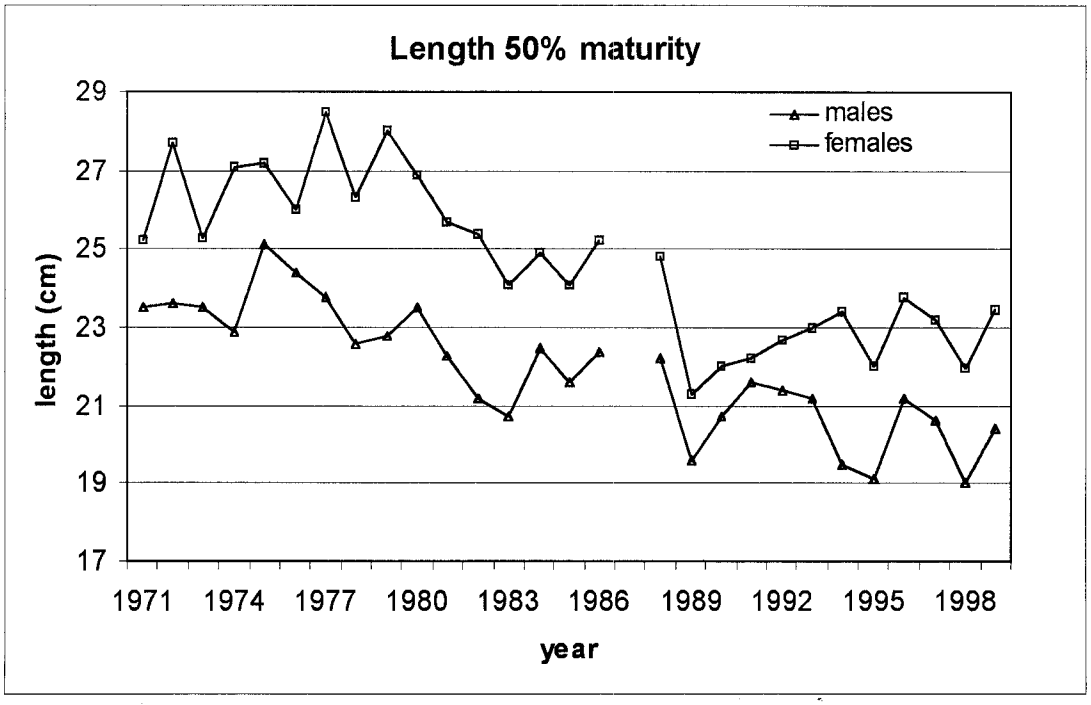
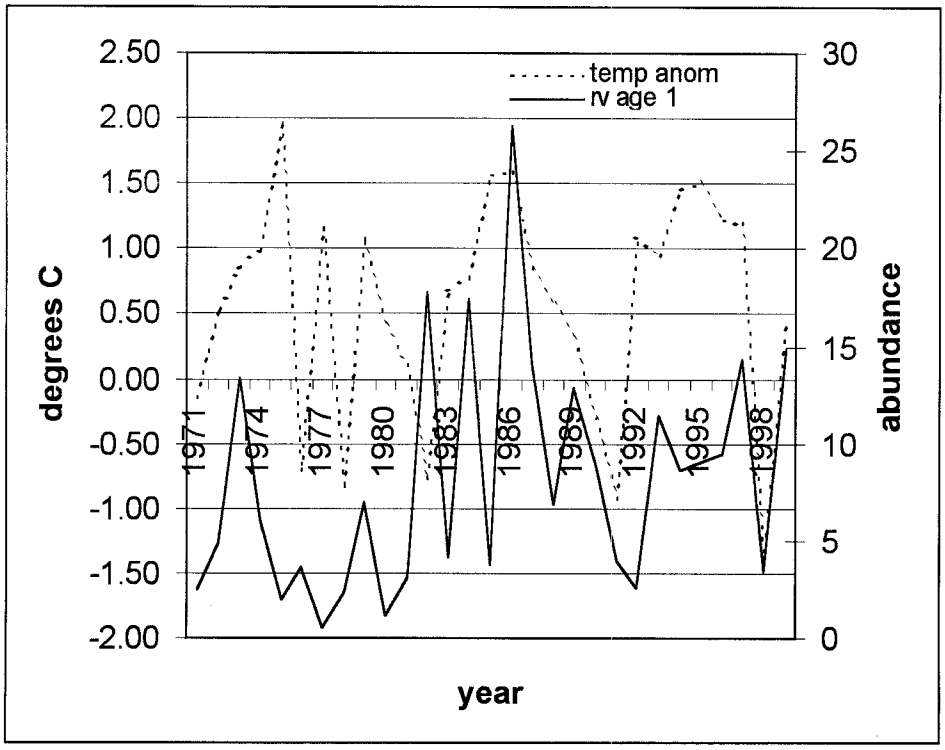



Fig. 19: Length of 50% maturity for Scotian Shelf silver hake, from probit analysis of July research survey maturity observations, 1971-98 (no data 1987).



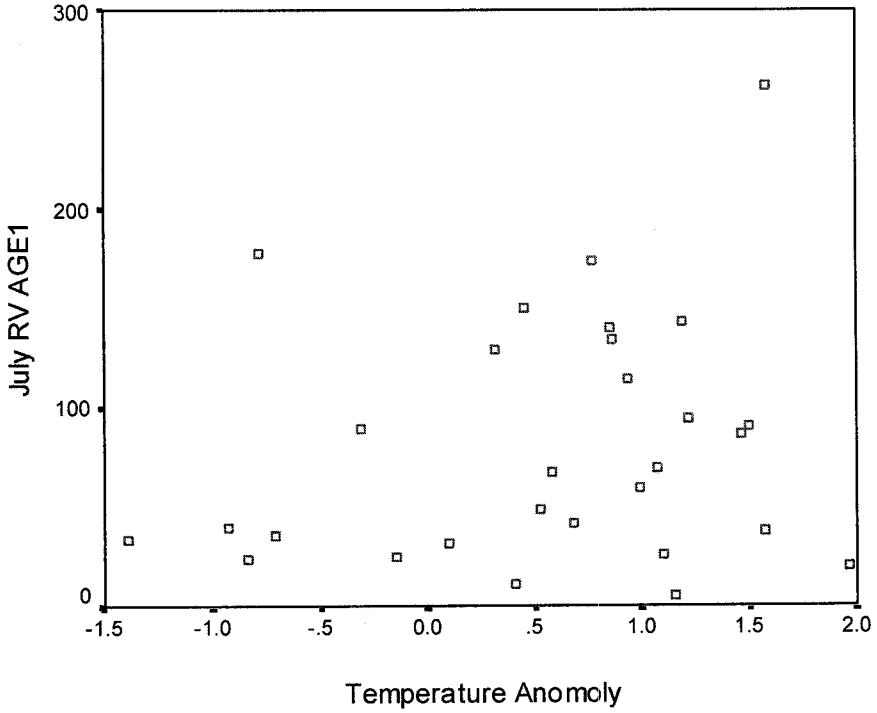




Fig. 20: Comparison of July RV estimates of silver hake abundance at age 1 to near bottom temperature anomalies in Emerald Basin, 1971-99 (1999 estimated from RV numbers at length, 1971-82 numbers adjusted for vessel effect).

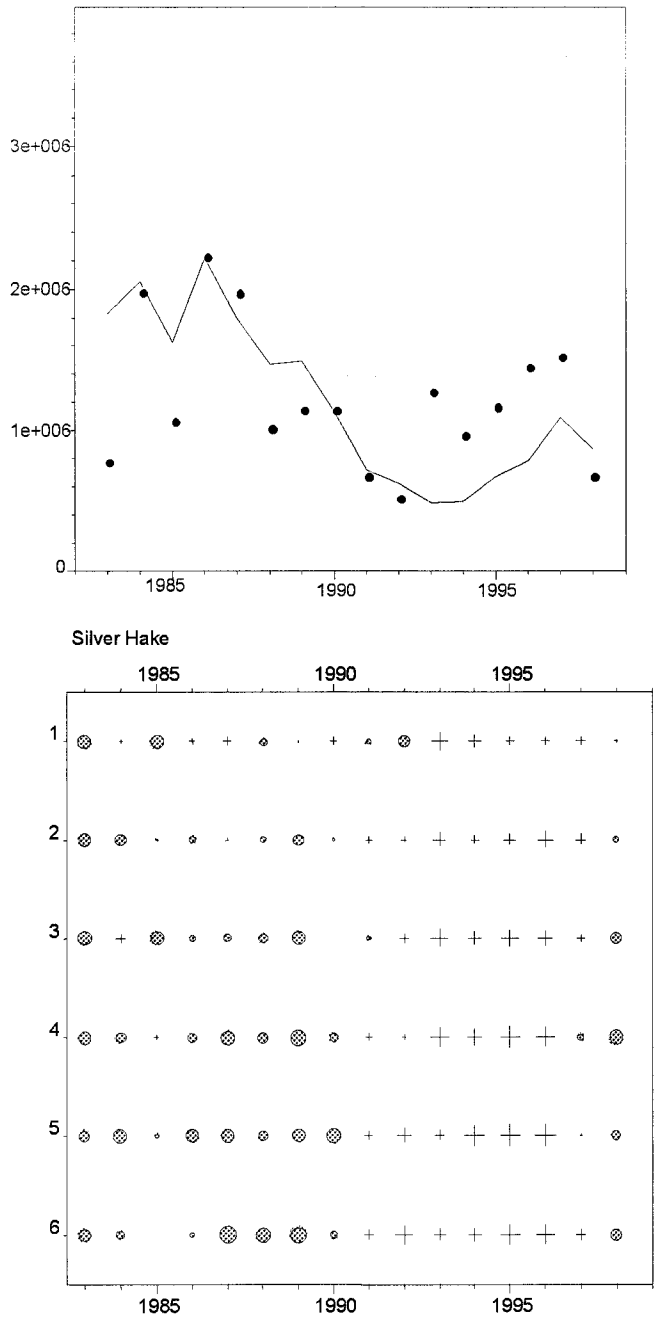



Fig 21: Population numbers (1+) estimated by SPA with q adjusted survey indices (top). Expanding symbol plot of residuals by age, bottom panel (+=positive, o=negative).

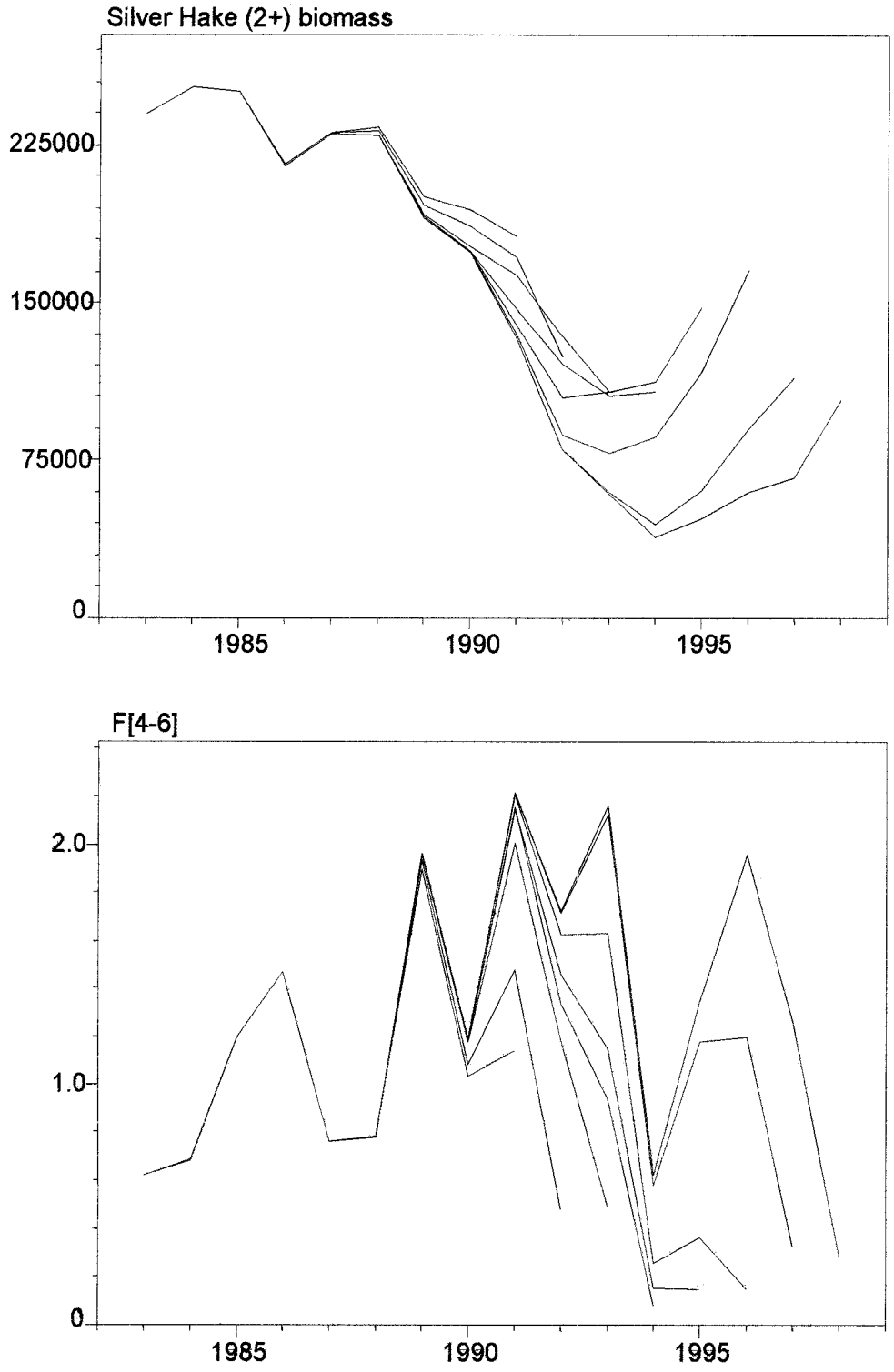



Figure 22: Retrospective analysis of SPA results for 4VWX silver hake


Fig. 23: Smoothed estimates of total mortality for Scotian Shelf silver hake from July RV abundance, grouped by ages 2-3, 4-5 and 6-7.

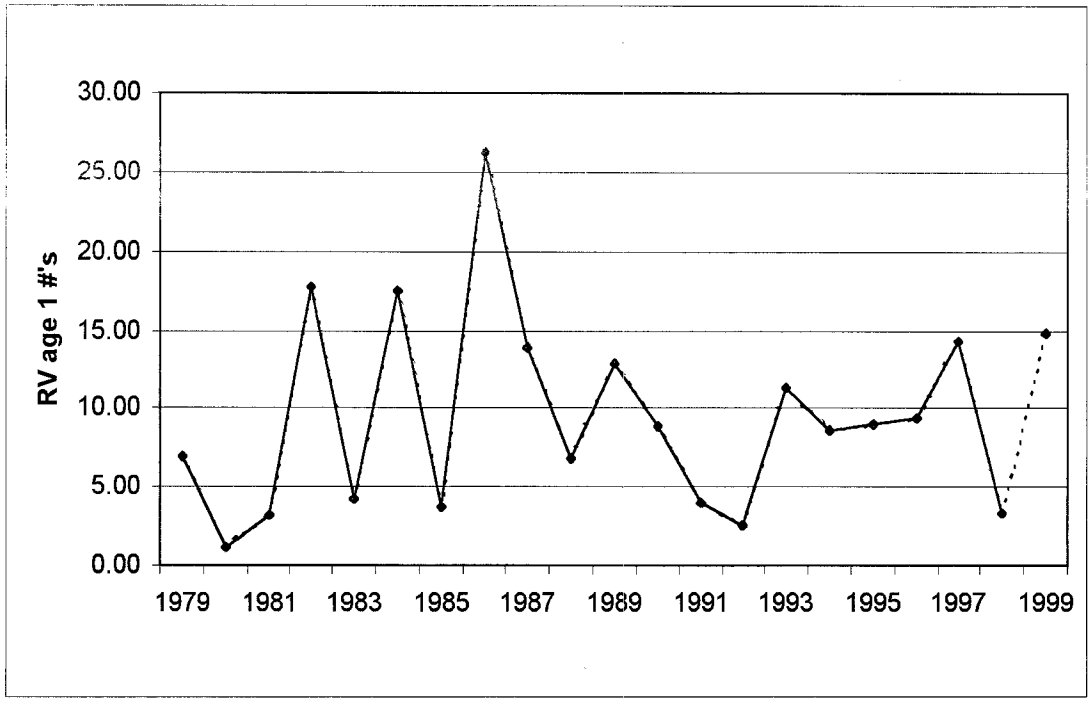



Figure 24: Recruitment estimates for Scotian Shelf silver hake, from age 1 RV abundance (1999 point estimated from length data).