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Distribution and Biology of Blue Hake (*Antimora rostrata* Gunther 1878) in the Northwest Atlantic with Comparison to Adjacent Areas

by

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Abstract

Blue hake (*Antimora rostrata*) is a globally distributed species found in most slope waters around the world Based on commercial fisheries data (it was found to be a common bycatch) and research survey records, this study examines the distribution and aspects of the biology of blue hake in Canadian waters. It forms a continuous distribution in slope waters from the US/Canada border in the south (contiguous with the distribution in US slope waters) to Arctic waters between Greenland and Baffin Island. In relation to depth, blue hake were found as shallow as 200 m but rare in less than 500 m. Only 9% of the survey sets containing blue hake occurred in less than 500 m but were most common in the deepest survey sets (1600 m). Longline sets from the 1960's at 2000-2400 m revealed that blue hake were relatively common at those depths. Studies from other parts of the world found blue hake distributed as deep as about 3000 m. Numbers per tow increased with depth, peaking at 1400 m (although depths greater than 1400 m were poorly sampled). This compares with peak abundance observed at depth of about 1700 m in US waters. Catch rate increased at a faster rate with depth in the southern part of our study area. With respect to temperature, sets with blue hake spanned a range of bottom temperatures between 0.9 and 8.7°C. However, only 1% of the survey sets with blue hake were associated with bottom temperatures less than 3°C and only 2% of the survey area was associated with bottom temperatures exceeding 3°C. This associated temperature range is similar to what has been observed in other parts of the world. Blue hake lengths were measured from sets of the deepwater commercial fisheries. The largest fish taken in Canadian waters were 65 cm. The smallest specimen was 5 cm although fish less than 22 cm were rare except in longline catches in 1987 when fish in the range of 5-15 cm were not uncommon. An attempt to use otoliths to age blue hake revealed that many more rings than years appears to be the case. Studies in US waters to the south found no evidence of spawning and scant evidence of mature individuals and it was hypothesized that spawning took place to the north in Canadian waters. The current studies indicate this not to be the case. No eggs or larvae of this species have been found in the area studied (as is the case elsewhere) and very few individuals less than 10 cm have been taken in either survey or commercial gear. Individuals with maturing gonads were also rare. Fishing mortality due to by-catch of this species was estimated. Determining absolute biomass of this species in Canadian waters and thus the impact of fishing on the population was not possible since a substantial portion of its range (depths greater than 1500 m) are not sampled.

Introduction

Blue hake (*Antimora rostrata* Günther, 1878, Fig 1) sometimes referred to as the flatnose codling in reference to its flattened rostrum is a member of the family Moridae. It is related to the commercially important Gadidae. It was originally described from specimens taken by A. Günther (British Museum) in 1878 from *Challenger* voyages in the Indian and south Atlantic Oceans but has subsequently been found to be a common inhabitant of slope waters in all oceans. Formerly taxonomically divided into five species within the Genus *Antimora*, (mainly because of the collection of widely separated specimens) it was subsequently amalgamated to a single species retaining the original name, *A rostrata* (Schroeder 1949). Iwamoto (1975) indicated that the amalgamation to one species was based on very limited data. Subsequently, Small (1981) has divided the genus into two species, *A. rostrata* inhabiting the Atlantic and *A. microlepis*, the Pacific, splitting the genus based on differences detected in 7 morphometric and 4 meristic characteristics.

Blue hake is one of the most abundant fish species inhabiting abyssal depths. Grey (1956) provided the earliest summary of its global distribution. The genus is globally distributed mainly on the slopes between 400 and 3000 m (Wenner and Musick, 1977). Based on numerous published records, it is found in varying concentrations in the Atlantic (elaborated below) and Pacific (Small, 1981) from the west coast of North and South America (Garman 1899; Bean, 1890, Pequeno, 1970; Quast and Hall, 1972) through the central and western ocean including the Hawiian Islands (Iwamoto, 1975; Paulin, C., 1995; Pearcy *et al*., 1982; Phleger, 1975), New Zealand (Paulin *et al*., 1989), Australia (Grey 1956) and Japan (Paulin, 1995). It is also known to distribute along parts of the slope of the Indian Ocean (Barnard, 1925; Fricke, 1999).

In the northeast Atlantic, blue hake is widespread from as far north as the waters northwest of Norway (minor bycatch in commercial catches, P. I. Savvatimsky, pers. comm.) from the slope waters of the Hebrides southward off Britain (Gordon and Duncan, 1985). Gordon *et al*. (1996) reports that it is among the ten most common species in depths between 500-2750 m in the Rockall Trough and the Porcupine Seabight west of Ireland. Blue hake has been found off Portugal (Sanches, 1989) and off Africa (Barnard, 1925; Merritt and Marshall). In the mid-Atlantic, it is common on the northern extent of the mid-Atlantic Ridge (Magnusson, 2001) and west of Iceland. In the southwest Atlantic, it was reported by Cousseau (1993) and Nakamura *et al*. (1986) off South America.

In the northwest Atlantic, the location of our study, blue hake has been reported as far south as the Bahamas (Sulak, 1984) off Cape Hatteras (Lat 33°, Bigelow and Schroeder, 1953; Wenner and Musick, 1977), on the southern slope of Georges Bank at Lat 40° and from the Scotian Shelf north to the Labrador shelf to Lat 56° (Cohen, 1977; Cross *et al*., 1973, Goode and Beane, 1879; Haedrich and Polloni, 1974; Haedrich *et al*., 1975; Markle and Musick, 1974; Musick *et al*., 1975; Parsons, 1976; Sedberry and Musick, 1978; Schroeder, 1955; Snelgrove, Haedrich, 1985 and Vasquez, 1991). It is sometimes reported as the dominant species in the deep waters catches of the mid-Atlantic Bight, specifically around the Norfolk Canyon (Wenner and Musick, 1977).

Blue hake has not been found within semi-enclosed basins such as the Gulf of St. Lawrence (Parsons, 1976), Gulf of Maine (Bigelow and Schroeder, 1939, 1953), Caribbean and Gulf of Mexico (Bright, 1970; Bullis and Struhsaker, 1970), Gulf of Aden (Marshall and Bourne, 1964), the Mediterranean Sea, Red Sea, Sulu Sea or Sea of Japan (Iwamoto, 1975). Most of these bodies of water with the exception of the Gulf of Mexico and Caribbean have incompatible depth and temperature regimes.

Blue hake has not been the target of a directed commercial fishery in any part of its range although it is commonly taken as a bycatch in slope fisheries directed at other species. Logbook and observer records from deep-water fisheries off Canada indicate that it is sometimes retained. However, it has not been reported to concentrate in sufficiently high densities to warrant directed commercial exploitation and its peak densities are generally located at great depths beyond 1500 m (Wenner and Musick, 1977). Thus, it is of limited commercial value but given the increase in deepwater fishing effort in the northeast Atlantic during the past ten years, it is increasingly common as a by-catch there. In the northwest Atlantic, blue hake continues to be taken in the Greenland halibut fisheries off the Grand Banks north to the Labrador Shelf although deep-water effort in this area is not as intense as in past years.

Given its widespread distribution, this species has been the subject of a considerable number of papers. However, much of the work of the past has dealt with records of occurrence and comparative systematics based mainly on morphometric and meristic descriptions (i.e. Musick *et al*., 1975; Small, 1981). Its biochemistry and physiology have commonly been studied since it is an easily accessible deepwater species (Josephson *et al*., 1975; Phleger, 1975; Somero and Seibenaller, 1979) including swimming performance and adaptation to low activity (Cohen, 1977; Graham *et al*., 1985). Relatively few studies have dealt with the life history or details of distribution such as relationship of relative abundance and fish size to the environment. Iwamoto (1975) touched on the biology of the species, Wenner and Musick (1977) examined the biology of blue hake from the mid-Atlantic Bight off the USA, Gordon and Duncan (1985) presented aspects of its biology in the Rockall Trough west of Great Britain, Priede *et* *al*., 1994 looked at biological aspects of blue hake off Britain and Magnusson (1998, 2001) looked at age, maturity and other biological parameters in Icelandic waters. Parsons (1976) first described the distribution of this species in Canadian slope waters, our study area, mainly in the context of its commercial potential, but that study provided little detail on the distribution and biology. More recently, Vasquez (1991) based on limited samples looked at morphometrics, diet and gonad condition of blue hake on the Flemish Cap.

The purpose of this study is to present a detailed description of distribution plus some aspects of the biology of blue hake from the Scotian Shelf north to the slope waters between Greenland and Baffin Island (refer to Fig. 1). In closest proximity to the northern extent of our study area, blue hake is found just east of Greenland in the Denmark Strait and Irminger Sea (Muus, 1990) and on the mid-Atlantic Ridge (Magnusson, 1998, 2001). To the south of our area, it has been reported off Cape Cod (Snelgrove and Haedrich, 1985) and the mid-Atlantic Bight. We look at distribution and fish size in relation to depth, bottom temperature and latitude and compare our findings to those adjacent areas. We also examine fish size over time and compare the morphometrics and meristics of the Canadian slope population to those elsewhere. Wenner and Musick (1977) found only larger fish in their catches from the mid-Atlantic Bight and consistent with all other work to date found no evidence of the reproductive phase for this species. They posed several hypotheses, one being of a northern spawning migration. A spatial analysis of size of blue hake is used to address this issue. The study also provides a comparison to the morphometric relationships described by Small (1981) for the northwest Atlantic.

Methods

Information for this study was gathered from two sources: research vessel surveys (1959-2000) and the commercial fishery (1978-2000). Both covered a range of depths from near shore to about 1500 m (with limited sets to 2200 m) over the nearly the entire extent of the slope off Canada from Lat. 41^0, the northern tip of Georges Bank to Lat 71°, between Greenland and Baffin Island.

Research Surveys

Catch standardized to the distance towed from Canadian trawl surveys was used to examine distribution of blue hake. Set locations from the surveys (differentiating sets with blue hake from those without) are depicted in Fig. 2, left panel. Two types of trawl gears, Engels (1977-spring 1995, 26,423 sets) and Campelen (fall 1995 to 2000, 8,972 sets) were used in the analyses. Average catch per tow was calculated by depth intervals of 50 m. Average tow by depth showed a similar trend and was of the same magnitude for Engels compared to Campelen gear (refer to Fig. 6, lower left panel). Thus, data for the two gears was combined for subsequent analyses.

Potential mapping in SPANS GIS (Anon 1997) was used to map the distribution of the blue hake (depicting variation in density) and to perform analyses in terms of distribution in relation to depth and bottom temperature. The potential mapping method converts highly variable point estimates (in this case geo-referenced catch per tow) into categorized catch rate strata. A full description of how this mapping technique works can be found in Kulka (1998). For the depth analysis, intervals were set at 50 m. Data less than 500 m were grouped into a single interval because of the rarity of records at lesser depths. Likewise for data deeper than 1500 m were grouped because of limited sampling at those depths. Average catch per tow was calculated for each depth interval. Similarly, contours of bottom temperature were created from set records associated with the research survey sets and from data supplied by MEDS (Marine Environments Data System). These long-term temperature means, 1972-1999 and associated geo-reference were converted to temperature surfaces using potential mapping. Fifteen strata of temperatures each with equal areas were created reflecting the range of temperatures observed. The geo-referenced sets were laid over this temperature surface and average catch rate was calculated within each temperature stratum.

Given the wide geographical range in the data, comparative analyses were done for two areas. The dividing line between the two areas, at Lat 55° was chosen as it equally divides the area studied and it falls between two focuses of fishing effort (northern effort centred at Lat 60°, southern effort at Lat 51°). Also, the two areas have very different temperature regimes and preliminary analyses indicated significant differences in distribution with to ambient temperature and depth between areas.

Commercial fishery

For the commercial fishery, observers collect detailed, geo-referenced (latitude and longitude) information on the catch, effort and other aspects of the fishing operations in a manner specified in Kulka and Firth (1987). The catch of all species taken in the gear is included in the records along with a geo-reference (latitude and longitude), depth, time as well as other effort information. From 1978-2000 for the Grand Banks north to Lat 71^0 in the Davis Strait, 479,682 commercial sets (with a catch of all species totalling of 1.5 M t) were observed for otter trawl, longline and gillnet fisheries. The fisheries over this period covered much of the area from the coastline out to the slope no deeper than 1700 m. Fishing was irregular both in terms of depth and latitude but at least in some years the observed effort covered most of the grounds beyond 200 m and a substantial part of the shallower areas. A gap in fishing activity exists on the nose and tail of the Grand Banks in most years because observers were not normally deployed to vessels fishing outside of Canada's 200-mile limit except on the Flemish Cap. Deep-water fishing does occur at these depths but the associated data were not available. Thus, the "nose and tail" of the Grand Banks, for the purpose of this study were under-sampled by the commercial gear. Locations of sets with blue hake are illustrated in Fig. 2, right panel.

Given the variability in locations covered by the fisheries from year to year, data from all years were combined to provide an overview of the distribution of blue hake. Catch rate data from the three commercial gears otter trawl (sets), longline (sets) and gillnet (sets) were used to study the distribution patterns of blue hake in relation to bottom depth and temperature. Catch rates were calculated as kg per hour for trawls, kg per 1000 hooks for longline and kg per 100 nets for gillnet. These values were then standardized (scaled) to otter trawl catch rate. Given the very similar standardized catch rate at depth, the catch rates for the three gears were combined to form a single CPUE standardized to (otter trawl) kg per hour (Fig. 6, upper left panel). As was done with the survey data, CPUE in relation to depth and ambient (bottom) temperature was compared south of Lat 55° vs. north of that latitude.

In a similar manner described above for survey data, potential mapping was used to map the distribution of the blue hake based on the commercial data and to perform analyses in terms of depth and bottom temperature. Depth intervals were set at 50 m except that data less than 500 m was grouped into a single interval, likewise for data deeper than 1500 m. Average standardized catch rates were calculated for each depth interval. The same temperature strata described for survey analyses were used. The geo-referenced fishing sets were laid over the temperature surface and average catch rate was calculated within each temperature stratum.

Morphometrics and Meristics

A total of 75,436 blue hake were measured for total length by sex in 1 cm length groups, 74,466 from otter trawls, the remainder from longlines. These data were obtained from the same research surveys and by fishery observers from the by-atch of commercial fishing as described above. Data from the surveys (18 sets, 1,778 measures) and commercial sources (1,325 sets, 72,791 measures) 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 other years (refer to Table 1). In the case of the commercial fisheries, the entire catch of each set was measured, whenever possible, up to a total of 200–250 fish. In cases where this was not possible, a random sample of the catch was obtained.

Length frequency data was initially plotted by gear type and year. Prior to summation by these factors, sets were first weighted by the ratio of sample weight to set catch weight. Summary statistics were generated for both the individual sets and the summary frequencies. Mean size, by sex, was plotted against depth, mesh size, and latitude. Sex ratios were examined by year, depth and latitude. Both size and sex ratio data was compared for sets north and south of 55° latitude, corresponding to the two general areas fished.

During 1979-1981, 2,044 specimens of blue hake were collected for detailed analysis. These specimens were measured for 17 morphometric characteristics with dial calipers and 18 meristic counts were done according to Hubbs and Lagler (1970). Not all fish were measured for all characteristics. Table 3 specifies the various measures taken and shows the abbreviations that are used in the text, tables and figures. These measurements and counts facilitated comparison of the northwest (Canadian) Atlantic fish with those from other parts of the world. Averages and variance statistics were calculated for each characteristic and mean values and ranges were compared to other studies.

Exploratory data analyses were conducted using S-Plus and SAS statistical packages. Univariate summaries for all continuous variables and count variables were conducted for each sex (Table 3, Fig. 13). In addition, a two-sample t-test was used to test for differences between male and female character distributions (Table 4). Equality of variance for the distributions was tested using an F-test (Table 5). Further analysis involved the calculation of a correlation matrix of all possible characters, and plotting the bivariate relationship of each variable with standard length (Table 6, Fig. 14). In addition, simple linear regressions of head characters with standard length were conducted and compared between the sexes. Variation in character distribution in relation to depth was also explored through the creation of box plots to display the variability of the median. Additional multivariate analyses to describe morphological and meristic variation in blue hake in relation to sex and depth were not successful because of missing cells. Finally, the results of the analyses from this study were compared with available literature values (Table 7, Fig. 17).

Results and Discussion

Distribution

Two independent sources, commercial fishery and trawl survey data show a very similar pattern of distribution for blue hake. From a total of 479,682 commercial trawl fishing sets observed, 22,828 sets yielded a total of 686 t of blue hake or 0.04% of the total observed catch during that period. Nearly all sets with blur hake were from the shelf edge (Fig. 2). All sets on the shelf including those from other commercial gears deployed in shallow, near shore locations were devoid of blue hake confirming that blue hake were restricted to slope waters and deep trenches. Similarly, 35,395 survey sets covering the shelf yielded 2,275 sets with blue hake, all from along the shelf edge (Fig. 2).

Figure 3 (commercial data) and Fig. 4 (surveys) show that blue hake is continuously distributed from Lat. 65° southwest of Greenland to the Scotian Shelf at Lat 41°, the southern limit of sampling. On the slope, blue hake were increasingly dense seaward and this pattern is consistent with what has been observed in other parts of the world (refer to Introduction). They were also found to a lesser degree in the deep trenches between the banks on the shelf. Previously not reported within semi-enclosed basins such as the Gulf of St. Lawrence (Parsons 1976, references in the Introduction), 11 midwater sets with blue hake in the Laurentian Channel leading in the Gulf of St. Lawrence constitute their greatest departure from slope waters.

We have defined the most northerly limit of this species in the northwest Atlantic. North of Lat 65° as far north as Lat 71°, of 38,095 sets observed, only one yielded blue hake, at Lat 66° Lon 58.5°. This corresponds with the northern extent of the continental slope in the northwest Atlantic. Coincidentally, this latitude corresponds with the northern limit of blue hake east of Greenland as reported by Magusson (2001). Although depths in the area north of Lat 66° are suitable for blue hake, bottom temperatures there are less than about 2°C out to 800 m and less than 1°C beyond 800 m, conditions where blue hake are not observed anywhere over their entire distribution (see Fig. 8, top panel).

To the north, limited fishing effort (commercial and survey) that occurred east of the 200-mile limit close to Greenland yielded blue hake (Fig. 3 and 4). As well, the abrupt truncation of the blue hake distribution at the 200-mile line (particularly apparent for commercial data since fishing activity was common along the border) suggests that blue hake are abundant eastward across that line along the slope off southwest Greenland. Given the close proximity of blue hake concentrations east of Greenland, off Iceland in the Irminger Sea and Denmark Strait (Haedrich and Krefft, 1978; Muus, 1990; Magnusson, 2001) to our study and the continuation of the continental slope around the southern tip of Greenland, it seems likely that the distribution of northwest Atlantic blue hake is continuous with those in the eastern north Atlantic. However, there are no published records to confirm this continuum around the southern tip of Greenland.

Immediately to the south of our study area, blue hake are reported as common and sometimes dominant in deep sets along the southern slope of Georges Banks at Lat 39° (Snelgrove and Haedrich, 1985). They are also common just south of Georges Bank in the mid-Atlantic Bight (Wenner and Musick, 1977) and farther south off the Bahamas and

Florida (Sulak, 1984). Whether they form a continuous distribution off USA is uncertain since published records of sampling from slope waters there are not complete. Commercial fishing activity, on the Corner Seamounts (directly south of the Grand Banks, west of the mid-Atlantic Bight adjacent to the mid-Atlantic Ridge) did not yield blue hake. Thus, available data suggest that blue hake inhabit the most or all of continental slope of North America and across to the eastern side of the Atlantic to the northern extent of the mid-Atlantic Ridge. In the northeast Atlantic, sampling of the slope waters off Europe and Africa is also not continuous but at many of the sampled deep-water locations (various studies referenced in the Introduction), blue hake were taken. Thus, the distribution of blue hake in the north Atlantic is extensive along the continental slope and mid-Atlantic Ridge, if not complete (continuous).

Figures 5 and 6 more precisely characterize the nature of the increase in abundance of blue hake with depth that was observed in Fig. 3 and 4. Catch rates increased with depth apparently peaking at 1400-1600 m. Depths greater than 1400 m were poorly sampled thus it is not possible to determine the exact depth where abundance reaches a maximum. A similar maximum was observed at about 1700 m in US waters (Wenner and Musick, 1977). Figure 5, shows that while catches (upper panel) and percent of sets with blue hake (lower panel) peaked at 1200 m, percent of total sets fished containing blue hake and catch rate (Fig. 6, upper panel) continued to increase beyond that depth out to the maximum depth observed. The reduction in absolute catch of blue hake beyond 1200 m occurred because fishing effort declined rapidly beyond that depth. Proportion of sets containing blue hake increased linearly from zero at 250 m to 70% at depths exceeding 1500 m. In the middle panel of Fig. 5, the catch of all species combined was predominantly located at depths less than 600 m. In contrast, blue hake as a percent of the total catch at 600 m was close to zero. Fromthere, blue hake increased to its maximum (1.6% of total catch) at 1600 m.

Three commercial gears, otter trawl, longline and gillnet were fished in deep water. Fig. 6 (upper right panel) shows that the catch per set and the standardized catch rate (reflecting local density of blue hake) increased exponentially. However, catch rate at depth increased at a substantially slower rate in the shallower part of the distribution north of Lat 55° compared to the area south of this latitude. The north and south catch rates for commercial gears merged at 1500 m. The survey catch rates at depth (Fig. 6 lower right panel) showed a similar pattern to what was observed from the commercial data except that the difference between the two areas (north vs. south) was not as great and the rates did not merge at the deepest depths. The catch rate trend with depth compared to that reported by Magnusson (2001) off Iceland (scaled to the northwest Atlantic catch per hour at depth) is very similar to the northern trend for our study area (Fig. 6). The two locations are relatively close, off southern Greenland. This suggests that the slope conditions east of Greenland are similar to those west of Greenland but is different to those farther to the south off the northeast Newfoundland Shelf.

The truncated distribution seen in Fig. 6 (maximum or near maximum values at the greatest depths sampled) suggests that neither the commercial effort or survey sampling cover the entire distribution of blue hake in terms of depth. Commercial fishing did not exceed 1700 m and only a very limited number of research survey sets (25) were prosecuted at depths exceeding 2000 m. However, 10 of those 25 deep longline sets, spread across the entire latitude range sampled yielded blue hake. Thus, although we do not have a detailed understanding of how blue hake distribute at the outer part of their depth range along the slope waters off Canada, these limited deep sets show that blue hake are found at least as deep as 2286 m. Intense sampling at the shallowest depths yielded the shallowest set with blue hake at 200 m but very rare at depths less than 500 m. For the commercial fisheries data, only 256 of 380,127 sets (0.07%) observed at depths less than 500 m contained blue hake. Similarly for the research survey data, 144 of 57,484 sets (0.25%) prosecuted at depths less than 500 m contained blue hake.

With respect to temperature, the upper panel of Fig. 7 shows that 49% (north) and 35% (south) of the study area is associated with bottom temperatures less than 2.0°C whereas 97% of commercial fishery sets with blue hake were associated with bottom temperatures exceeding 2.0°C. Commercial catch rate of blue hake peaked between 3.0 and 4.0°C in the south and 3.5 and 4.5°C in the north (Fig. 7, middle panel). All of the sets with blue hake where associated temperature exceed 5°C occurred on the southwest slope of the Grand Banks, the location of the warmest bottom waters within the study area. Research survey sets with blue hake spanned a similar range of bottom temperatures between 1.4 and 8.7°C (Fig. 7, lower panel) but sets but highest catch rates were found in higher temperatures north and south. Catch rates based on the survey data peaked at 4.1-4.5°C north and south. Almost no sets with blue hake were taken in the 1.4-3.0°C range as was observed from the commercial data. Only 1% of the survey sets with blue hake were associated with bottom temperatures less than °and only 2% of the survey area was associated with bottom temperatures exceeding 3°C. This associated temperature range is similar to what has been observed in other parts of the world. The average bottom temperature for sets with blue hake was 3.8°C, considerably warmer than the 2.2°C average across all sets with or without blue hake and close to the average temperature for depths exceeding 500 m.

Figure 8, upper panel shows that north of Lat. 65° where blue hake were absent, bottom temperatures at depth were much lower than the areas to the south. Since the depths were observed to be suitable for blue hake north of Lat. 65°, temperatures less than about 2°C may be the limiting factor. The upper panel also shows that temperature at depth differs slightly north vs. south of Lat. 55°, particularly in the mid range of depths where average temperature at depth was about 0.5°C cooler to the south. Sets containing blue hake were compared to sets without blue hake within temperature strata. That blue hake are selective of warmer areas in the shallow part of their range can be seen in the middle panel (north of Lat. 55°) and the lower panel (south of Lat. 55°) in Fig. 8. At the most shallow depths, (less than 650 m), within each depth range, sets with blue hake were associated with warmer temperatures than sets without. At greater than 650 m, the values matched. A difference in ambient temperature at depth is apparent when comparing the middle panels (north) to the lower panel (south). To the south, temperature at depth dropped off more rapidly and thus temperatures there were colder between about 700 m and 1200 malthough the difference is not great i.e.3.5 in the south vs. 3.8°C in the north at 901-950 m. Whether a 0.3°C or less difference would lead to the substantial difference in catch rate at depth as illustrated in Fig. 6, right panels or why the colder waters to the south yield higher catch rates over most of the depth range of blue hake is unclear. Temperature is clearly not the only factor influencing the distribution of blue hake.

Distribution with respect to depth and temperature is similar compared to other location in the Atlantic. As noted above, CPUE at depth described by Magnusson (2001) off Iceland was very similar to what was observed in the northern part of the study area. Haedrich and Kreftt (1978) in the Demark Strait and Irminger Sea, observed blue hake between 493 and 2058 m in 0.1-3.4°C, similar to our depth patterns but less so for our temperature profile. Headrich *et al*. (1980) sampled the south slope of Georges Bank (adjacent to our study area) down to 5000 m. Although the distribution by depth was not described in detail, blue hake was found to be among the top 10 species by weight in 653-3113 m depth, number 1 catch at 1300-1947 m and number 2 at 2116-3113 m. In the mid-Atlantic Bight off the USA, Wenner and Musick (1977) noted that the CPUE increased steeply from about 1000 m peaking at 1800 m. Haedrich and Kreftt (1978) also noted that blue hake reaches its greatest abundance at depths exceeding 1600 m in the mid-Atlantic Bight per the work of Wenner and Musick (1977) but reaches its greatest numbers in the Denmark Strait between 493-975 m. They cited this as an example of submergence whereby widespread species such as blue hake tend to live at shallower depths at higher latitudes. Our north/south comparison shows that within the area exa mined, quite the opposite was observed. Catch rate reflecting higher density of blue hake in the southern part of our area was substantially higher than to the north. Our analyses also indicate that the abundance of blue hake at depth was still increasing at 1500 m, at the same latitude as Headrich and Krefft (1978), more similar to the mid Atlantic Bight fish although they did not find fish as shallow as our study. We may not have sampled deep enough to precisely define where abundance of blue hake peaked. Gordon *et al*. (1996) for the northeast Atlantic reported that it is among the ten most common species in depths between 500-2750 m in the Rockall Trough and the Porcupine Seabight west of Ireland.

Morphometrics and Meristics

Blue hake length frequency distributions by gear are presented in Fig. 10. Fish from longlines (mean size = 36 cm for males, 38 cm for females) were smaller than those from otter trawl catches (mean size = 38 cm for males, 47 cm for females), particularly with regard to females. This size difference may be a function of small sample size for longline, combined with spatial and temporal effects in the data sets. Of particular interest is the catch of small fish in the 5-15 cm range. However, these small fish were observed from only one year of data. It represents amonst the smallest blue hake observed worldwide. For otter trawls, mean size was observed to be somewhat larger than that reported by Magnusson (2001), who observed sizes of 31.5 cm and 42.9 cm for males and females, respectively, at depths <1500 m.

Annual frequencies for 1978-1987 (Table 1, Fig. 9) indicate a distinct difference in size distribution between the sexes. Male distributions for all years were unimodal ranging from 36-40 cm, and exhibited positive kurtosis. Female distributions were either bimodal, with modes at 30-40 cm and 50-55 cm. Spatial and temporal inconsistencies in the data set preclude analysis of the female frequencies for periodicity in the modes. Overall frequencies appear similar in shape to those reported by Magnusson (2001).

Mean size was observed to increase with depth for both males and females (Fig. 11) particularly in the shallower depths less than 950 metres. Females exhibited a more pronounced change with depth from 700-950 m, with mean size increasing by +10 cm (37-47 cm) and median size by +15 cm (33.5-48.5 cm). Mean size for males increased by +4 cm (34-38 cm) over this same depth range, with the median increasing by +3 cm (34.5-37.5 cm). Below 950 m, both mean and median sizes remained relatively consistent for both sexes. This trend occurred both north and south of 55° latitude. Fish at comparable depth ranges tended to be larger in the south area where observed means at depth were +1 cm to +12 cm larger for males and +2 cm to +11 cm larger for females. Krefft and Haedrich, 1978, from 643-661 m, observed fish in the 23-60 cm range, similar to our overall otter trawl frequency. Polloni *et al*. (1979) observed that mean weight of fish tends increase with depth and this is certainly the case with blue hake – descibe our findings. Snelgrove and Haedrich, 1985 – showed fish less than 800 m were 150-200 g, about 600 g deeper than 1200 m.

Sex ratio, expressed as % females, was also seen to increase with depth (Fig. 12). Overall, values were observed to increase by approximately 40% (42.2% - 81.9%) from <500 m to 1300 m. This trend was seen in both the northern and southern fishing areas. At most comparable depth ranges, the percentage of females was higher in the south area.

While Wenner and Musick (1977) found that male *A. rostrata* were significantly smaller than female blue hake, little comparative morphometric work has been conducted between the sexes. Thus, our analyses were done separately by sex. We found significant differences existed between the sexes in 16 of the morphometric and meristic characters investigated (Table 4). Female blue hake are on average longer and heavier than male blue hake The length frequency distributions (Fig. 9 and 10) suggest that males and females grow at different rates (although ageing was not done to confirm this) which is consistent with previous studies on this species (Wenner and Musick, 1977; Small, 1981). Average total length of female blue hake was 339.14∀86.71 mm while the average total length of males was 320.1∀74.09 mm which was significantly smaller (t=4.48, p<0.001). Consequently, the head length, interorbital width, upper jaw length and rostrum length are proportionally greater in females than in males (Table 4). Similarly, female blue hake were significantly heavier (P<0.001) than male blue hake. Larger female body mass is also related to the associated larger girth, gut weight, gonad weight and liver weight of females (Table 4). Significant positive correlation between standard length and other linear measures (Table 6) further show that the significant morphometric differences between male and female blue hake are a consequence of scaling to body size. Furthermore, there were no significant differences between the slope and intercept of male and female blue hake regressions of head measurements with standard length (Fig. 14). Overall, the larger size of females, in total length, standard length and whole weight, relative to males explains the differences observed between the sexes in each of the morphological characters.

A distinguishing characteristic of the genus *Antimora* is the distinct rostrum. Small (1981) shows global differences in this morphological characteristic. While there was no significant difference between the sexes in the relationship of rostrum length to standard length (females y=5.7836 +0.0114 STDLEN, R^2=0.2864, males y= 5.1816+0.012STDLEN, R^2=0.2653), overall there was an apparent curvilinear relationship (Fig. 14). A log transformed model provided a better fit (LogROSLEN=-0.2226 + 0.4234log STDLEN, R^2=0.348) than a simple linear model (ROSLEN=5.3853 + 0.0120 STDLEN, R^2=0.2888) although the lower end of the curve is poorly fitted even with the curvilinear model. Further analysis of the relationship of rostrum length and standard length investigated differences in the slope of the relationship between three potential sub-sizes derived from visual analysis of the curve. As previously stated, standard length has a significant influence on rostrum length, moreover, the relationship varies such that in smaller fish (less than 275 mm), there is a proportionately larger change in rostrum length with standard length than in medium fish (276-400 mm), and larger fish (greater than 400 mm: Table 8).

There were no significant differences observed between the sexes in any of the measured meristic characters (Table 4). Morphological character variation in relation to depth demonstrated further variation in relation to overall size. Previous studies have observed that the average weight of fish, and blue hake in particular, increased with increasing depth (Polloni *et al*., 1979; Snelgrove and Haedrick, 1985; Wenner and Musick, 1977). In this study, larger blue hake, of both sexes, were found in deeper waters, consequently there is an overall trend for correlated morphological characters to increase with increasing depth. This pattern is based on the prevalence of female blue hake, which are larger than males, and larger males being captured in deeper waters. When standardized, by length and sex, there is no significant variation in character variation with depth for blue hake in our study area.

Previous morphological investigations of blue hake (Small, 1981: Table 2) provide 8 morphological characters, which can be compared to the current study (Fig. 16). Overall, there appears to be no significant difference between the average size of morphological characters, standardized to standard length, between blue hake reported by Small (1981) and the current study (Fig. 16). In addition, the relationship between head length or gill filament length and standard length as reported by Small (1981), is similar to that found in the current study (Fig. 17).

Conclusions

Given that blue hake does not form dense concentrations but rather distributes fairly homogeneously along the slope, it will never be a commercially important species. However, it does form a significant by-catch in deepwater fisheries over a wide area because of its extensive distribution. Estimated total removals of blue hake from Canadian waters of the northwest Atlantic for the 23 years observed are 686 t. About 20% of the deep-water (> 500 m) fisheries were observed. Thus it is estimated that close 3,500 t total or 150 t per year on average have been removed from the fisheries as by-catch. Given the reduction in deepwater effort since the 1980's, catches in recent years have diminished.

Blue hake was amalgamated to a single species by Schroeder (1949) but has subsequently been divided the genus into two species by Small (1981), *A. rostrata* inhabiting the Atlantic, *A. microlepis*, the Pacific. The continuity of the distribution of the species globally and the delineation between Atlantic and Pacific fish is less than clear. For example given that it is distributed around the southern tip of South America with no break it seems likely that there is considerable mixing of the Atlantic and Pacific components in that area. It would seem that extensive sampling of morphology in this area would show clinal variation. Thus, taxonomy of this species remains open for discussion. Morphometrically, the specimens from this study compare closely to the Atlantic species described by Small (1981).

Given its global distribution, blue hake ranks among the most common of marine fish. Along much of the east coast of North America and the Atlantic in general, along much of the slope it has been seen to form a continuous distribution. In spite of this, relatively little is known about certain aspects of its life history over much of its range. In part this is because it inhabits deep water where there is only limited commercial or research activity and it is not found in sufficiently dense concentrations to be targeted as a directed species. In particular, its reproductive habits and early life history are largely an unknown. In all of its known range, eggs, larvae or evidence of spawning have never been observed for blue hake. Wenner and Musick (1977) as for most other authors found only larger fish in their catches and no evidence of spawning eggs larvae from the mid-Atlantic Bight. They proposed 5 hypotheses:

a) Blue hake spawns in the Gulf Stream. They deemed this since eggs and larvae have never been found in the Gulf Stream.
b) Blue hake spawn at greater than 3000 m. This hypothesis is largely untested although sampling at greater than 3000 m has not captured blue hake.
c) Blue hake rise off the bottom to spawn. They deemed this unlikely since extensive midwater trawling by Krefft captured only one specimen. Make note that Wenner and Musick 1977 refer to Krefft as a single pelagic specimen at 2000 m in 5550 m However, our records from midwater commercial trawls (10 sets with 216 kg of fish along the southwest slope of the Grand Banks about x m off bottom (445 m below the surface) depths of xx m Use SPANS and 2 sets, 140 kg north of the Grand Banks) 860 m below the surface show that are occasionally found away from the bottom
d) For the Atlantic, blue hake spawns in the northern part of its range. This study provides no evidence in terms of eggs, larvae or spawning fish that this is the case (and we have defined its northern most limit). However, we have recorded the occurrence of fish between 5 and 15 cm on taken on longlines set for Greenland halibut between Lat 58 and 65°.

The presence of a greater proportion of 5-15 cm (1-2 years of age according to the ageing done in the Northeast Atlantic) fish taken on the longlines (albeit based on very limited samples) compared to the trawls fishing the same area suggests a catchability issue with the otter trawl gear that is what most records are based on. We have shown with limited effort that young fish do inhabit the northern part of their range in the western Atlantic. Our sampling only occurs as deep as 1700 m (with the exception of a few deeper longline sets). Where the density of blue hake is just reaching a peak. Thus, we are missing at least half of the distribution. The questions related to the early life history of this species remain. While our study provides for a much more detailed view of the distribution of the adult portion of the population off Canada, no eggs or larvae of this species have been found in the area studied (as is the case elsewhere) and very few individuals less than 10 cm have been taken in either survey or commercial gear. Individuals with maturing gonads were also rare. Our findings hint at the presence of very small blue hake to the north (two samples in 1983 and 1987) and also the presence of blue hake off the bottom but the findings do not support the hypothesis of Wenner and Musick (1977) that blue hake spend their reproductive period in the northern extent of their distribution in the Atlantic.

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Table 1. Inventory and summary statistics for blue hake length frequencies from otter trawl catches, 1973-1992. Data from research surveys and commercial fisheries are included. Upper table refers to otter trawl, lower table to longline gear.

Otter Trawl

Year	Number of Sets	Sex	Mean (cm)	Median (cm)	St. Dev.	Min. Size	Max. Size	Mode	Number Measured
1973	1	Male	27	23.5	7.44	15	40	23	15
		Female	34	31.5	9.84	22	51	37	17
		Total	31	30.5	9.47	15	51	37	32
1974	1	Male	21	21.5	5.13	15	25	15	3
		Female	22	21.5	9.00	13	31	13	3
		Total	21	21.5	6.59	13	31	22	6
1976	2	Male	25	21.5	6.76	12	38	19	38
		Female	28	26.5	5.11	19	36	27	27
		Total	26	25.5	6.38	12	38	19	65
1978	13	Male	36	36.5	5.57	16	49	39	285
		Female	46	47.5	9.11	6	64	50	455
		Total	42	39.5	9.22	6	64	37	740
1979	38	Male	34	34.5	6.83	12	58	39	398
		Female	37	33.5	9.53	16	61	31	420
		Total	35	34.5	8.47	12	61	39	818
1980	21	Male	34	34.5	5.66	15	48	40	269
		Female	42	41.5	9.29	15	61	36	525
		Total	40	38.5	9.04	15	61	40	794
1981	405	Male	37	36.5	6.50	12	72	40	7,320
		Female	44	44.5	9.75	7	69	50	13,143
		Total	41	39.5	9.48	7	72	40	20,463
1982	368	Male	42	40.5	7.40	21	68	40	5,284
		Female	50	50.5	7.80	12	71	55	14,236
		Total	48	47.5	8.50	12	71	42	19,520
1983	100	Male	31	32.5	6.46	17	42	36	56
		Female	31	29.5	7.62	21	61	29	46
		Total	31	31.5	6.97	17	61	29	102
1984	19	Male	40	39.5	4.26	26	58	40	202
		Female	50	50.5	6.74	25	69	53	1,357
		Total	49	49.5	7.41	25	69	53	1,559
1985	40	Male	40	39.5	5.23	20	60	39	346
		Female	50	50.5	7.00	27	66	51	1,224
		Total	48	48.5	7.74	20	66	51	1,570
1986	201	Male	38	37.5	5.37	16	64	40	5,387
		Female	48	49.5	8.23	22	73	52	17,497
		Total	46	45.5	8.78	16	73	52	22,884
1987	126	Male	36	36.5	5.21	14	59	37	2,221
		Female	43	40.5	9.65	16	70	38	3,767
		Total	41	37.5	8.92	14	70	38	5,988
1992	8	Male	39	37.5	3.55	36	46	37	7
		Female	47	48.5	7.69	32	57	48	21
		Total	45	47.5	7.69	32	57	48	28
Total	**1,343**	**Male**	**38**	**38.5**	**6.52**	**12**	**72**	**40**	**21,831**
		Female	**47**	**48.5**	**8.99**	**6**	**73**	**55**	**52,738**
		Total	**45**	**43.5**	**9.45**	**6**	**73**	**40**	**74,569**

Longline

Year	Number of Sets	Sex	Mean (cm)	Median (cm)	St. Dev.	Min. Size	Max. Size	Mode	Number Measured
1983	87	Male	35	34.5	5.65	8	56	35	231
		Female	36	35.5	3.48	26	48	36	219
		Total	36	35.5	4.73	8	56	36	450
1987	32	Male	36	36.5	5.10	5	49	40	119
		Female	39	43.5	17.49	5	67	50	298
		Total	38	39.5	15.10	5	67	40	417
Total	**119**	**Male**	**36**	**35.5**	**5.47**	**5**	**56**	**36**	**350**
		Female	**38**	**37.5**	**13.55**	**5**	**67**	**36**	**517**
		Total	**37**	**36.5**	**11.08**	**5**	**67**	**36**	**867**

Table 2. Explanation of abbreviations of morphological and meristic character names that appear in the text.

Morphological variables - 2044 incomplete records	
TOTLEN	- Total length
STDLEN	- Standardized length
HDLEN	- Head length
SNTLEN	- Snout length
UPJAWLEN	- Upper Jaw length
ORBLEN	- Orbit length
INTORBWI	-Interorbital width
CAUDPED	-length of caudal peduncle
BODEPTH	-body depth
GIRTH	-body girth
PRDORLEN	-predorsal length
PRPECLEN	-prepectoral length
PRVENLEN	-preventral length
PREANALN	-preanal length
ROSLEN	-rostrum length
DORAYLEN	-dorsal ray length
LGILFIL	-length of gill fillament

Meristic variables - 1930 incomplete records	
WHWT	-whole weight
CAECAE	-caecae weight
DORFIN1	-dorsal fin
DORFIN2	-dorsal fin
CAUDFIN	-caudal fin
ANALFIN	-anal fin
LPECFIN	-left pectoral fin
RPECFIN	-right pectoral fin
LPELFIN	-left pelvic fin
RPELFIN	-right pelvic fin
VERT	-number of vertebrae
GRU1	-GRU1
GRU2	-GRU2
LATPORES	-number of pores
GUTWT	-gut weight
GONWT	-gond weight
LIVWT	-liver weight
GILLFIL	-gill fillaments

Table 3. Univariate summary statistics for 36 morphological and meristic variables by sex.

Variable		Mean	Std Dev	N
ANALFIN	Unknown	41.79	4.57	39
	Female	42.85	4.12	68
	Male	42.32	3.32	69
BODEPTH	Unknown	35.47	20.80	15
	Female	52.71	19.98	133
	Male	52.43	18.46	128
CAECAE	Unknown	13.29	2.13	14
	Female	12.85	1.46	61
	Male	12.78	1.77	79
CAUDFIN	Unknown	35.49	2.47	35
	Female	35.19	2.75	72
	Male	35.59	2.26	79
CAUDPED	Unknown	8.43	2.35	97
	Female	9.36	2.36	260
	Male	9.68	2.21	277
DORAYLEN	Unknown	44.76	25.53	53
	Female	76.88	27.79	448
	Male	70.83	26.12	428
DORFIN1	Unknown	4.75	0.55	36
	Female	4.80	0.47	74
	Male	4.74	0.55	77
DORFIN2	Unknown	54.60	3.15	35
	Female	54.58	1.70	71
	Male	54.38	2.24	78
GILLFIL	Unknown	84.76	5.85	230
	Female	83.30	5.67	439
	Male	82.96	6.30	426
GIRTH	Unknown	92.57	45.24	60
	Female	169.39	62.73	562
	Male	150.81	50.21	546
GONWT	Unknown	3.49	4.66	376
	Female	1.82	3.59	647
	Male	0.25	0.40	595
GRU1	Unknown	4.76	0.44	21
	Female	4.83	0.45	71
	Male	4.89	0.46	72
GRU2	Unknown	12.76	0.94	21
	Female	13.09	0.98	69
	Male	12.83	0.77	72
GUTWT	Unknown	436.61	450.27	187
	Female	305.25	281.55	685
	Male	227.12	139.95	674
HDLEN	Unknown	55.14	16.41	153
	Female	73.17	19.00	727
	Male	67.12	14.64	742

Table 3 (cont.). Summary statistics for 36 morphological and meristic variables by sex.

Variable		Mean	Std Dev	N
INTORBWI	Unknown	12.71	4.29	144
	Female	17.06	5.65	695
	Male	15.42	4.26	685
LATPORES	Unknown	119.80	8.04	5
	Female	127.27	8.78	15
	Male	131.53	10.60	19
LGILFIL	Unknown	3.89	1.86	30
	Female	6.46	2.00	423
	Male	5.62	1.74	422
LIVWT	Unknown	37.71	51.34	324
	Female	19.63	28.79	503
	Male	13.57	13.54	464
LPECFIN	Unknown	19.83	0.94	36
	Female	19.44	0.94	80
	Male	19.73	1.03	86
LPELFIN	Unknown	7.29	4.38	38
	Female	6.01	0.19	80
	Male	5.99	0.11	84
ORBLEN	Unknown	15.03	3.70	151
	Female	19.55	4.43	723
	Male	18.34	3.68	726
PERGONWT	Unknown	0.39	0.29	369
	Female	0.35	0.26	579
	Male	0.08	0.09	547
PRDORLEN	Unknown	64.35	14.95	96
	Female	73.66	15.34	232
	Male	73.61	13.10	244
PREANALN	Unknown	111.78	46.67	58
	Female	173.67	50.48	552
	Male	156.45	40.29	533
PRPECLEN	Unknown	50.79	18.99	14
	Female	64.09	16.11	103
	Male	62.56	14.00	90
PRVENLEN	Unknown	40.67	14.06	15
	Female	52.58	12.97	97
	Male	51.99	12.03	87
ROSLEN	Unknown	8.20	2.09	153
	Female	9.28	1.71	732
	Male	8.69	1.58	738
RPECFIN	Unknown	20.03	0.91	38
	Female	19.35	1.07	79
	Male	19.49	1.05	85
RPELFIN	Unknown	6.05	0.32	38
	Female	5.95	0.22	77
	Male	6.01	0.11	84

Table 3 (cont.). Summary statistics for 36 morphological and meristic variables by sex.

Variable		Mean	Std Dev	N
SNTLEN	Unknown	18.76	4.89	151
	Female	23.91	5.12	714
	Male	21.62	4.03	734
STDLEN	Unknown	234.39	71.97	141
	Female	313.40	81.37	668
	Male	291.50	69.14	684
TOTLEN	Unknown	260.60	75.95	142
	Female	339.14	86.71	718
	Male	320.10	74.09	727
UPJAWLEN	Unknown	25.09	8.01	140
	Female	34.28	10.33	693
	Male	31.04	7.60	684
VERT	Unknown	57.30	1.25	10
	Female	57.14	1.85	21
	Male	57.37	1.52	30
WHWT	Unknown	532.03	498.02	480
	Female	367.31	349.61	640
	Male	261.26	168.49	648

Table 4. T-Tests comparison between sexes for various meristic characteristics.

Variable	Method	Variances	DF	t Value	Pr > |t|
DORFIN1	Pooled	Equal	145	0.38	0.7066
DORFIN1	Satterthwaite	Unequal	144	0.38	0.7059
DORFIN2	Pooled	Equal	143	0.67	0.5036
DORFIN2	Satterthwaite	Unequal	139	0.68	0.4981
CAUDFIN	Pooled	Equal	145	-1.02	0.3103
CAUDFIN	Satterthwaite	Unequal	134	-1.01	0.3149
ANALFIN	Pooled	Equal	132	0.93	0.3544
ANALFIN	Satterthwaite	Unequal	125	0.93	0.356
LPECFIN	Pooled	Equal	161	-1.74	0.0837
LPECFIN	Satterthwaite	Unequal	161	-1.75	0.0826
RPECFIN	Pooled	Equal	158	-0.84	0.4003
RPECFIN	Satterthwaite	Unequal	157	-0.84	0.4007
LPELFIN	Pooled	Equal	158	1	0.3202
LPELFIN	Satterthwaite	Unequal	120	0.98	0.327
RPELFIN	Pooled	Equal	155	-2.34	0.0207
RPELFIN	Satterthwaite	Unequal	105	-2.27	0.025
VERT	Pooled	Equal	47	-0.44	0.6634
VERT	Satterthwaite	Unequal	39	-0.43	0.6713
GRU1	Pooled	Equal	137	-0.97	0.3324
GRU1	Satterthwaite	Unequal	136	-0.97	0.3321
GRU2	Pooled	Equal	135	1.62	0.1075
GRU2	Satterthwaite	Unequal	125	1.61	0.1095
LATPORES	Pooled	Equal	30	-1.38	0.1768
LATPORES	Satterthwaite	Unequal	30	-1.42	0.1648
GUTWT	Pooled	Equal	1232	6.85	<.0001
GUTWT	Satterthwaite	Unequal	890	6.85	<.0001
GONWT	Pooled	Equal	1124	10.52	<.0001
GONWT	Satterthwaite	Unequal	593	10.81	<.0001
LIVWT	Pooled	Equal	868	4.35	<.0001
LIVWT	Satterthwaite	Unequal	638	4.45	<.0001
GILLFIL	Pooled	Equal	853	0.62	0.534
GILLFIL	Satterthwaite	Unequal	840	0.62	0.5346
PERGONWT	Pooled	Equal	1124	22.51	<.0001
PERGONWT	Satterthwaite	Unequal	712	23.03	<.0001

Table 4 (cont.). T-Tests comparison between sexes for various characters.

Variable	Method	Variances	DF	t Value	Pr > |t|
TOTLEN	Pooled	Equal	1443	4.49	<.0001
TOTLEN	Satterthwaite	Unequal	1403	4.48	<.0001
STDLEN	Pooled	Equal	1350	5.34	<.0001
STDLEN	Satterthwaite	Unequal	1305	5.33	<.0001
HDLEN	Pooled	Equal	1467	6.84	<.0001
HDLEN	Satterthwaite	Unequal	1364	6.82	<.0001
SNTLEN	Pooled	Equal	1446	9.46	<.0001
SNTLEN	Satterthwaite	Unequal	1352	9.43	<.0001
UPJAWLEN	Pooled	Equal	1375	6.62	<.0001
UPJAWLEN	Satterthwaite	Unequal	1272	6.64	<.0001
ORBLEN	Pooled	Equal	1447	5.68	<.0001
ORBLEN	Satterthwaite	Unequal	1398	5.68	<.0001
INTORBWI	Pooled	Equal	1378	6.07	<.0001
INTORBWI	Satterthwaite	Unequal	1289	6.09	<.0001
CAUDPED	Pooled	Equal	535	-1.62	0.1056
CAUDPED	Satterthwaite	Unequal	526	-1.62	0.1064
BODEPTH	Pooled	Equal	259	0.12	0.9076
BODEPTH	Satterthwaite	Unequal	259	0.12	0.9074
GIRTH	Pooled	Equal	1106	5.43	<.0001
GIRTH	Satterthwaite	Unequal	1067	5.45	<.0001
PRDORLEN	Pooled	Equal	474	0.04	0.9676
PRDORLEN	Satterthwaite	Unequal	455	0.04	0.9677
PRPECLEN	Pooled	Equal	191	0.7	0.4848
PRPECLEN	Satterthwaite	Unequal	191	0.71	0.4807
PRVENLEN	Pooled	Equal	182	0.32	0.7507
PRVENLEN	Satterthwaite	Unequal	182	0.32	0.7497
PREANALN	Pooled	Equal	1083	6.2	<.0001
PREANALN	Satterthwaite	Unequal	1046	6.22	<.0001
ROSLEN	Pooled	Equal	1468	6.86	<.0001
ROSLEN	Satterthwaite	Unequal	1457	6.86	<.0001
DORAYLEN	Pooled	Equal	874	3.32	0.0009
DORAYLEN	Satterthwaite	Unequal	874	3.32	0.0009
LGILFIL	Pooled	Equal	843	6.52	<.0001
LGILFIL	Satterthwaite	Unequal	828	6.52	<.0001
WHWT	Pooled	Equal	1286	6.95	<.0001
WHWT	Satterthwaite	Unequal	918	6.92	<.0001
CAECAE	Pooled	Equal	136	0.23	0.8213
CAECAE	Satterthwaite	Unequal	135	0.23	0.8168

Table 5. Test for equality of variances, between sexes for various charactersistics measured and counted.

Variable	Num DF	Den DF	F Value	Pr > F
TOTLEN	717	726	1.37	<.0001
STDLEN	667	683	1.39	<.0001
HDLEN	726	741	1.69	<.0001
SNTLEN	713	733	1.62	<.0001
UPJAWLEN	692	683	1.85	<.0001
ORBLEN	722	725	1.45	<.0001
INTORBWI	694	684	1.76	<.0001
CAUDPED	259	276	1.14	0.279
BODEPTH	132	127	1.17	0.3717
GIRTH	561	545	1.56	<.0001
PRDORLEN	231	243	1.37	0.0152
PRPECLEN	102	89	1.32	0.1759
PRVENLEN	96	86	1.16	0.4769
PREANALN	551	532	1.57	<.0001
ROSLEN	731	737	1.17	0.0317
DORAYLEN	447	427	1.13	0.1952
LGILFIL	422	421	1.32	0.005
WHWT	639	647	4.31	<.0001
CAECAE	77	59	1.48	0.1178
DORFIN1	74	71	1.31	0.2535
DORFIN2	75	68	1.72	0.0246
CAUDFIN	69	76	1.48	0.0941
ANALFIN	65	67	1.54	0.0825
LPECFIN	83	78	1.26	0.3021
RPECFIN	76	82	1.04	0.8547
LPELFIN	77	81	3.18	<.0001
RPELFIN	74	81	4.2	<.0001
VERT	20	27	1.39	0.4165
GRU1	69	68	1.18	0.4857
GRU2	66	69	1.61	0.0515
LATPORES	17	13	1.58	0.4062
GUTWT	615	617	4.23	<.0001
GONWT	578	546	83.66	<.0001
LIVWT	448	420	4.73	<.0001
GILLFIL	419	434	1.19	0.0683
PERGONWT	578	546	8.99	<.0001

Table 6. Correlation matrix for various charactersistics measured and counted.

	LPELFIN	RPELFIN	VERT	GRU1	GRU2	LATPORES	GUTWT	GONWT	LIVWT	GILLFIL
WHWT	0.3755	0.15389	0.15607	0.13252	0.02672	-0.206	0.99633	0.85451	0.88903	0.1979
	<.0001	0.0317	0.2378	0.0948	0.739	0.2213	<.0001	<.0001	<.0001	<.0001
	198	195	59	160	158	37	1397	1495	1183	1078
CAECAE	-0.04439	0.0153	-0.2286	-0.07924	0.19628	-0.14332	0.08383	0.09659	0.004	0.25266
	0.5986	0.8571	0.1505	0.3836	0.0303	0.4669	0.3013	0.2512	0.9762	0.2036
	143	141	41	123	122	28	154	143	58	27
DORFIN1	-0.09868	0.08712	-0.14517	0.08863	-0.08349	-0.00455	0.04162	0.01508	0.37403	0.04654
	0.1875	0.2475	0.2684	0.262	0.2939	0.978	0.5888	0.8547	0.0088	0.9211
	180	178	60	162	160	39	171	150	48	7
DORFIN2	0.23206	0.02456	0.05437	0.03179	0.05255	0.03895	0.09325	0.00457	0.1188	0.29386
	0.0025	0.7542	0.6934	0.6984	0.523	0.8189	0.2307	0.9562	0.4113	0.3298
	168	165	55	151	150	37	167	147	50	13
CAUDFIN	0.18401	0.01577	0.36776	-0.00069	0.09011	0.20238	0.21322	0.13753	0.02328	-0.08963
	0.0154	0.8382	0.0045	0.9931	0.2633	0.223	0.005	0.0933	0.8712	0.8055
	173	170	58	158	156	38	172	150	51	10
ANALFIN	-0.15151	0.13981	0.11818	0.02921	0.09227	-0.06081	0.12642	-0.03335	0.04462	.
	0.0486	0.0707	0.4088	0.72	0.2582	0.7169	0.1123	0.6999	0.779	.
	170	168	51	153	152	38	159	136	42	0
LPECFIN	0.03681	0.21405	-0.12057	-0.05286	-0.02028	0.11956	0.05799	0.1448	-0.04074	0.19221
	0.6066	0.0027	0.3717	0.5041	0.7991	0.4746	0.428	0.0611	0.7493	0.3573
	198	195	57	162	160	38	189	168	64	25
RPECFIN	0.0888	0.16903	-0.23917	-0.0469	0.05877	0.08308	0.08086	0.17851	-0.05815	0.22408
	0.21	0.017	0.0786	0.5522	0.459	0.6151	0.2726	0.0214	0.6535	0.3288
	201	199	55	163	161	39	186	166	62	21
LPELFIN	1	0.2441	-0.08271	0.0901	-0.19829	0.18385	0.14184	0.08041	0.04381	-0.13561
		0.0005	0.5521	0.2527	0.0117	0.2625	0.0535	0.3031	0.7353	0.5578
	202	199	54	163	161	39	186	166	62	21
RPELFIN	0.2441	1	-0.08271	0.05755	-0.27526	0.18385	0.07571	-0.01674	0.08756	.
	0.0005		0.5521	0.4683	0.0004	0.2625	0.3084	0.832	0.5022	.
	199	199	54	161	159	39	183	163	61	20
VERT	-0.08271	-0.08271	1	-0.09256	0.1081	-0.09044	0.1709	0.09295	0.17435	-0.40026
	0.5521	0.5521		0.5226	0.4549	0.6054	0.1917	0.5533	0.2695	0.3736
	54	54	61	50	50	35	60	43	42	7
	LPELFIN	RPELFIN	VERT	GRU1	GRU2	LATPORES	GUTWT	GONWT	LIVWT	GILLFIL
GRU1	0.0901	0.05755	-0.09256	1	0.14526	0.19787	0.11393	0.01141	0.1409	.
	0.2527	0.4683	0.5226		0.0651	0.2337	0.1501	0.8924	0.3796	.
	163	161	50	164	162	38	161	143	41	0
GRU2	-0.19829	-0.27526	0.1081	0.14526	1	-0.07654	-0.00322	-0.0439	-0.02551	.
	0.0117	0.0004	0.4549	0.0651		0.6479	0.9678	0.6052	0.8742	.
	161	159	50	162	162	38	159	141	41	0
LATPORES	0.18385	0.18385	-0.09044	0.19787	-0.07654	1	-0.20364	-0.44074	-0.21477	.
	0.2625	0.2625	0.6054	0.2337	0.6479		0.2137	0.0091	0.2378	.
	39	39	35	38	38	39	39	34	32	0
GUTWT	0.14184	0.07571	0.1709	0.11393	-0.00322	-0.20364	1	0.8005	0.85688	0.22338
	0.0535	0.3084	0.1917	0.1501	0.9678	0.2137		<.0001	<.0001	<.0001
	186	183	60	161	159	39	1546	1289	1014	903
GONWT	0.08041	-0.01674	0.09295	0.01141	-0.0439	-0.44074	0.8005	1	0.82582	0.09241
	0.3031	0.832	0.5533	0.8924	0.6052	0.0091	<.0001		<.0001	0.0027
	166	163	43	143	141	34	1289	1618	1216	1055
LIVWT	0.04381	0.08756	0.17435	0.1409	-0.02551	-0.21477	0.85688	0.82582	1	0.12271
	0.7353	0.5022	0.2695	0.3796	0.8742	0.2378	<.0001	<.0001		0.0002
	62	61	42	41	41	32	1014	1216	1291	923
GILLFIL	-0.13561	.	-0.40026	.	.	.	0.22338	0.09241	0.12271	1
	0.5578	.	0.3736	.	.	.	<.0001	0.0027	0.0002	
	21	20	7	0	0	0	903	1055	923	1095

Table 6 (cont.). Correlation matrix for various characteristics measured and counted.

	STDLEN	HDLEN	SNTLEN	UPJAWLEN	ORBLEN	INTORBWI	CAUDPED	BODEPTH
TOTLEN	0.99375	0.97324	0.94598	0.95394	0.91533	0.93947	0.88063	0.91022
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1853	1945	1930	1573	1658	1578	672	312
STDLEN	1	0.97752	0.94869	0.95849	0.93088	0.94471	0.90879	0.93496
		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1889	1860	1845	1483	1567	1486	562	304
HDLEN	0.97752	1	0.97137	0.96746	0.93709	0.95285	0.8995	0.9271
	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1860	2002	1973	1606	1691	1610	674	296
SNTLEN	0.94869	0.97137	1	0.94352	0.8942	0.92337	0.83963	0.85169
	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001
	1845	1973	1984	1594	1673	1599	665	288
UPJAWLEN	0.95849	0.96746	0.94352	1	0.89148	0.9435	0.82944	0.83813
	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
	1483	1606	1594	1623	1616	1616	677	299
ORBLEN	0.93088	0.93709	0.8942	0.89148	1	0.86101	0.829	0.89826
	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
	1567	1691	1673	1616	1708	1621	680	299
INTORBWI	0.94471	0.95285	0.92337	0.9435	0.86101	1	0.86235	0.89411
	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
	1486	1610	1599	1616	1621	1628	684	301
CAUDPED	0.90879	0.8995	0.83963	0.82944	0.829	0.86235	1	0.90754
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001
	562	674	665	677	680	684	687	291
BODEPTH	0.93496	0.9271	0.85169	0.83813	0.89826	0.89411	0.90754	1
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	
	304	296	288	299	299	301	291	314

	GIRTH	PRDORLEN	PRPECLEN	PRVENLEN	PREANALN	ROSLEN	DORAYLEN	LGILFIL
STDLEN	0.95135	0.95879	0.96532	0.92615	0.97187	0.5792	0.92859	0.8883
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1241	502	224	223	1213	1854	893	1060
HDLEN	0.94934	0.97191	0.96415	0.92835	0.96618	0.60689	0.91696	0.88982
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1240	609	234	226	1219	1985	952	1062
SNTLEN	0.9232	0.93996	0.91527	0.9104	0.94462	0.65988	0.87951	0.86642
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1231	599	227	219	1210	1970	942	1059
UPJAWLEN	0.93883	0.93195	0.92642	0.8855	0.95436	0.58583	0.90409	0.88201
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1240	610	231	222	1219	1608	888	895
ORBLEN	0.89692	0.84445	0.92595	0.88997	0.91211	0.58665	0.86784	0.83341
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1242	612	230	221	1221	1690	958	898
INTORBWI	0.94253	0.93345	0.92924	0.88488	0.94673	0.55956	0.88985	0.86181
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1241	614	232	223	1221	1611	891	894
CAUDPED	0.90941	0.87082	0.91119	0.87211	0.92691	0.46077	0.79757	0.70416
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	312	610	232	223	308	674	138	31
BODEPTH	0.97472	0.90144	0.91554	0.88456	0.93222	0.59351	0.82172	.
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	.
	305	233	227	226	292	294	68	0

Table 6 (cont.). Correlation matrix for various characteristics measured and counted.

	STDLEN	HDLEN	SNTLEN	UPJAWLEN	ORBLEN	INTORBWI	CAUDPED	BODEPTH
GIRTH	0.95135	0.94934	0.9232	0.93883	0.89692	0.94253	0.90941	0.97472
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1241	1240	1231	1240	1242	1241	312	305
PRDORLEN	0.95879	0.97191	0.93996	0.93195	0.84445	0.93345	0.87082	0.90144
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	502	609	599	610	612	614	610	233
PRPECLEN	0.96532	0.96415	0.91527	0.92642	0.92595	0.92924	0.91119	0.91554
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	224	234	227	231	230	232	232	227
PRVENLEN	0.92615	0.92835	0.9104	0.8855	0.88997	0.88488	0.87211	0.88456
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	223	226	219	222	221	223	223	226
PREANALN	0.97187	0.96618	0.94462	0.95436	0.91211	0.94673	0.92691	0.93222
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1213	1219	1210	1219	1221	1221	308	292
ROSLEN	0.5792	0.60689	0.65988	0.58583	0.58665	0.55956	0.46077	0.59351
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1854	1985	1970	1608	1690	1611	674	294
DORAYLEN	0.92859	0.91696	0.87951	0.90409	0.86784	0.88985	0.79757	0.82172
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	893	952	942	888	958	891	138	68
LGILFIL	0.8883	0.88982	0.86642	0.88201	0.83341	0.86181	0.70416	.
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	.
	1060	1062	1059	895	898	894	31	0

	GIRTH	PRDORLEN	PRPECLEN	PRVENLEN	PREANALN	ROSLEN	DORAYLEN	LGILFIL
GIRTH	1	0.95455	0.94159	0.90038	0.93774	0.58825	0.89989	0.886
		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1258	258	224	225	1217	1234	820	893
PRDORLEN	0.95455	1	0.95936	0.92617	0.96243	0.57172	0.91723	0.83401
	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	258	618	226	226	254	609	113	34
PRPECLEN	0.94159	0.95936	1	0.90243	0.95979	0.69255	0.93538	.
	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	.
	224	226	235	225	221	228	38	0
PRVENLEN	0.90038	0.92617	0.90243	1	0.91295	0.65811	0.9348	.
	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	.
	225	226	225	226	221	219	33	0
PREANALN	0.93774	0.96243	0.95979	0.91295	1	0.5988	0.9135	0.8742
	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
	1217	254	221	221	1227	1213	803	874
ROSLEN	0.58825	0.57172	0.69255	0.65811	0.5988	1	0.52965	0.51866
	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
	1234	609	228	219	1213	2004	953	1065
DORAYLEN	0.89989	0.91723	0.93538	0.9348	0.9135	0.52965	1	0.85293
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001
	820	113	38	33	803	953	958	709
LGILFIL	0.886	0.83401	.	.	0.8742	0.51866	0.85293	1
	<.0001	<.0001	.	.	<.0001	<.0001	<.0001	
	893	34	0	0	874	1065	709	1074

	GIRTH	PRDORLEN	PRPECLEN	PRVENLEN	PREANALN	ROSLEN	DORAYLEN	LGILFIL
TOTLEN	0.95201	0.95687	0.95598	0.92159	0.96942	0.56308	0.9223	0.88994
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	1224	603	234	225	1195	1947	925	1041

Table 6 (cont.). Correlation matrix for various charactersistics measured and counted.

	LPELFIN	RPELFIN	VERT	GRU1	GRU2	LATPORES	GUTWT	GONWT	LIVWT	GILLFIL
WHWT	0.3755	0.15389	0.15607	0.13252	0.02672	-0.206	0.99633	0.85451	0.88903	0.1979
	<.0001	0.0317	0.2378	0.0948	0.739	0.2213	<.0001	<.0001	<.0001	<.0001
	198	195	59	160	158	37	1397	1495	1183	1078
CAECAE	-0.04439	0.0153	-0.2286	-0.07924	0.19628	-0.14332	0.08383	0.09659	0.004	0.25266
	0.5986	0.8571	0.1505	0.3836	0.0303	0.4669	0.3013	0.2512	0.9762	0.2036
	143	141	41	123	122	28	154	143	58	27
DORFIN1	-0.09868	0.08712	-0.14517	0.08863	-0.08349	-0.00455	0.04162	0.01508	0.37403	0.04654
	0.1875	0.2475	0.2684	0.262	0.2939	0.978	0.5888	0.8547	0.0088	0.9211
	180	178	60	162	160	39	171	150	48	7
DORFIN2	0.23206	0.02456	0.05437	0.03179	0.05255	0.03895	0.09325	0.00457	0.1188	0.29386
	0.0025	0.7542	0.6934	0.6984	0.523	0.8189	0.2307	0.9562	0.4113	0.3298
	168	165	55	151	150	37	167	147	50	13
CAUDFIN	0.18401	0.01577	0.36776	-0.00069	0.09011	0.20238	0.21322	0.13753	0.02328	-0.08963
	0.0154	0.8382	0.0045	0.9931	0.2633	0.223	0.005	0.0933	0.8712	0.8055
	173	170	58	158	156	38	172	150	51	10
ANALFIN	-0.15151	0.13981	0.11818	0.02921	0.09227	-0.06081	0.12642	-0.03335	0.04462	.
	0.0486	0.0707	0.4088	0.72	0.2582	0.7169	0.1123	0.6999	0.779	.
	170	168	51	153	152	38	159	136	42	0
LPECFIN	0.03681	0.21405	-0.12057	-0.05286	-0.02028	0.11956	0.05799	0.1448	-0.04074	0.19221
	0.6066	0.0027	0.3717	0.5041	0.7991	0.4746	0.428	0.0611	0.7493	0.3573
	198	195	57	162	160	38	189	168	64	25
RPECFIN	0.0888	0.16903	-0.23917	-0.0469	0.05877	0.08308	0.08086	0.17851	-0.05815	0.22408
	0.21	0.017	0.0786	0.5522	0.459	0.6151	0.2726	0.0214	0.6535	0.3288
	201	199	55	163	161	39	186	166	62	21
LPELFIN	1	0.2441	-0.08271	0.0901	-0.19829	0.18385	0.14184	0.08041	0.04381	-0.13561
		0.0005	0.5521	0.2527	0.0117	0.2625	0.0535	0.3031	0.7353	0.5578
	202	199	54	163	161	39	186	166	62	21
RPELFIN	0.2441	1	-0.08271	0.05755	-0.27526	0.18385	0.07571	-0.01674	0.08756	.
	0.0005		0.5521	0.4683	0.0004	0.2625	0.3084	0.832	0.5022	.
	199	199	54	161	159	39	183	163	61	20
VERT	-0.08271	-0.08271	1	-0.09256	0.1081	-0.09044	0.1709	0.09295	0.17435	-0.40026
	0.5521	0.5521		0.5226	0.4549	0.6054	0.1917	0.5533	0.2695	0.3736
	54	54	61	50	50	35	60	43	42	7
	LPELFIN	RPELFIN	VERT	GRU1	GRU2	LATPORES	GUTWT	GONWT	LIVWT	GILLFIL
GRU1	0.0901	0.05755	-0.09256	1	0.14526	0.19787	0.11393	0.01141	0.1409	.
	0.2527	0.4683	0.5226		0.0651	0.2337	0.1501	0.8924	0.3796	.
	163	161	50	164	162	38	161	143	41	0
GRU2	-0.19829	-0.27526	0.1081	0.14526	1	-0.07654	-0.00322	-0.0439	-0.02551	.
	0.0117	0.0004	0.4549	0.0651		0.6479	0.9678	0.6052	0.8742	.
	161	159	50	162	162	38	159	141	41	0
LATPORES	0.18385	0.18385	-0.09044	0.19787	-0.07654	1	-0.20364	-0.44074	-0.21477	.
	0.2625	0.2625	0.6054	0.2337	0.6479		0.2137	0.0091	0.2378	.
	39	39	35	38	38	39	39	34	32	0
GUTWT	0.14184	0.07571	0.1709	0.11393	-0.00322	-0.20364	1	0.8005	0.85688	0.22338
	0.0535	0.3084	0.1917	0.1501	0.9678	0.2137		<.0001	<.0001	<.0001
	186	183	60	161	159	39	1546	1289	1014	903
GONWT	0.08041	-0.01674	0.09295	0.01141	-0.0439	-0.44074	0.8005	1	0.82582	0.09241
	0.3031	0.832	0.5533	0.8924	0.6052	0.0091	<.0001		<.0001	0.0027
	166	163	43	143	141	34	1289	1618	1216	1055
LIVWT	0.04381	0.08756	0.17435	0.1409	-0.02551	-0.21477	0.85688	0.82582	1	0.12271
	0.7353	0.5022	0.2695	0.3796	0.8742	0.2378	<.0001	<.0001		0.0002
	62	61	42	41	41	32	1014	1216	1291	923
GILLFIL	-0.13561	.	-0.40026	.	.	.	0.22338	0.09241	0.12271	1
	0.5578	.	0.3736	.	.	.	<.0001	0.0027	0.0002	
	21	20	7	0	0	0	903	1055	923	1095

Table 7. Summary of blue hake morphometrics from: Table 2. Small, G. J. 1981. A review of the bathyal fish genus Antimora (Moridae:Gadiformes). Proc. Cal. Acad. Sci., **42**: 341-348.

location	N Pacific	SD	SE Pacific	SD	N Atlantic	SD	S Ocean	SD
Snout length	11.9	0.86	11.8	1.33	12.7	1.16	12.6	1.53
Predorsal length	3.9	1.47	3.7	0.2	3.7	0.17	3.9	0.2
Maxillary length	7.1	0.36	6.9	0.5	7.2	0.38	7.4	0.49
First dorsal fin ray length	5.9	1.43	7.1	1.58	5.1	1.45	6.1	1.4
Eye diameter	15	1.2	15.3	1.34	16	1.42	16.2	1.36
Interorbital width	17.6	1.45	18.6	1.61	15.5	1.56	18.3	1.64
Longest gill raker length	73.4	14.07			76.9		103	16
total number of vertebra	59.1	0.86	58.8	0.96	59.8	1.26	59.6	1.02
total number of gill rakers	16.5	1.93	16.2	1.29	16.6	2.11	16	1.54
total number of anal fin rays	40.6	1.4	39.3	1.39	41.9	1.56	40	1.7
total number of dorsal fin rays	52.4	1.15	51.7	1.37	53.8	1.45	53.2	1.45

* lengths are represented as ratio of standard length to size of part

*regression of head length on standard length y=0.23x + 2.9432

*regression of gill filament length on standard length, y=0.02x - 0.7

Table 8. Summary of selected counts/measures (lengths presented as ratio of standard length/size of part) from the current study.

Character	mean	stdev	n
SNTLEN	13.22	1.34	1329
PRDORLEN	3.97	0.33	370
DORAYLEN	4.46	0.88	818
ORBLEN	15.90	1.76	1328
INTERORBWI	19.13	2.47	1258
VERT	57.27	1.68	49
ANALFINRAY	42.65	3.74	134
DORFINRAY2	54.48	2.02	145

Table 9. Results of a test of homogeneity of slopes of the rostrum/standard length relationship in small (>275), medium (276-400), and large (<400) blue hake.

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Stdlen	1	1115.806591	1115.806591	577.84	<.0001
Bin	2	31.187876	15.593938	8.08	0.0003
stdlen*bin	2	142.152828	71.076414	36.81	<.0001

Parameter	Estimate	Error	t Value	Pr > |t|
stdlen:bin1 (smallest)	0.02600008	0.00164262	15.83	<.0001
stdlen:bin2 (med fish)	0.00793892	0.00161142	4.93	<.0001
stdlen:bin3 (lg. fish)	0.00266231	0.00391314	0.68	0.4964

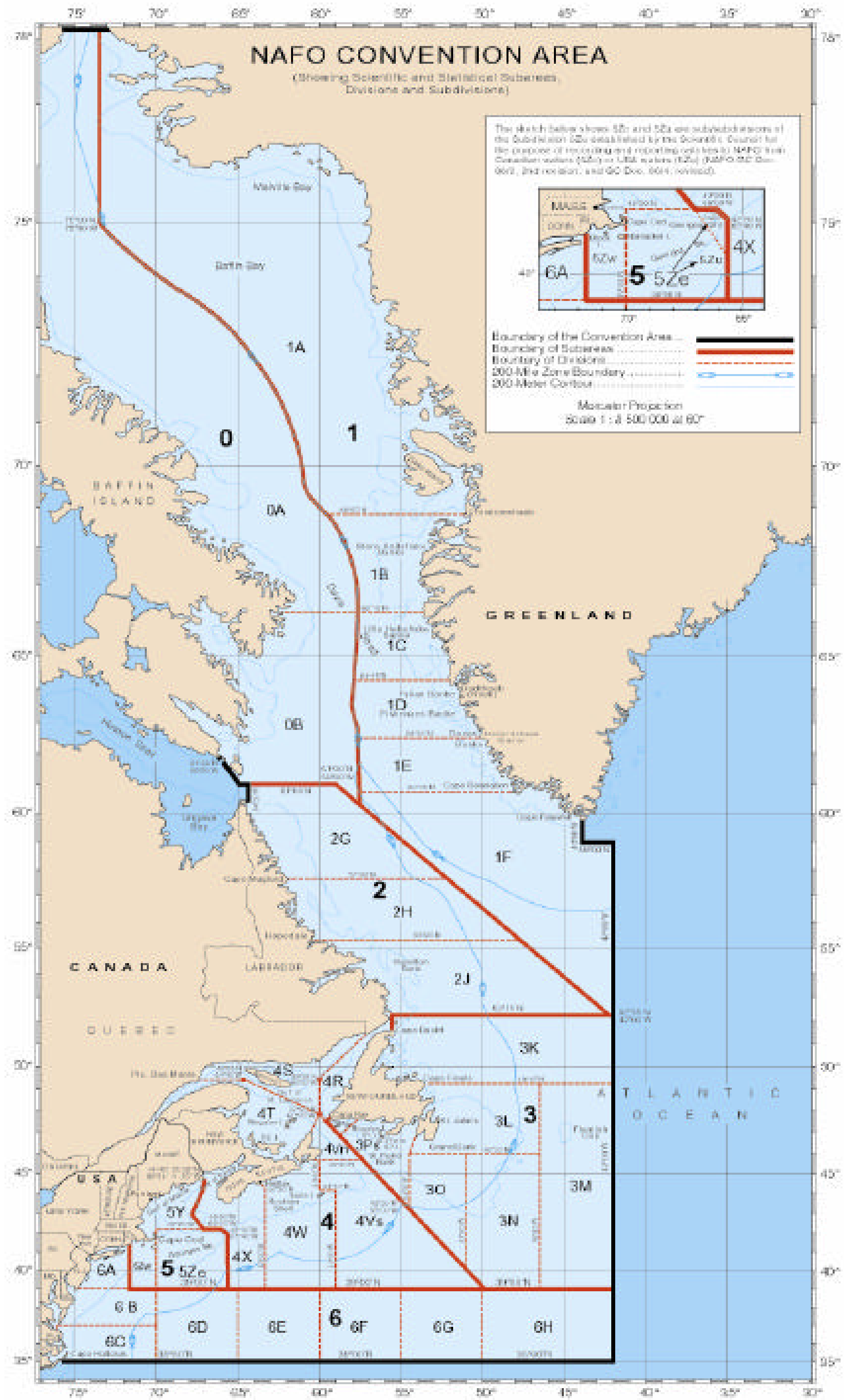


Fig. 1. Map of northwest Atlantic referencing latitude, longitude and NAFO Divisions.

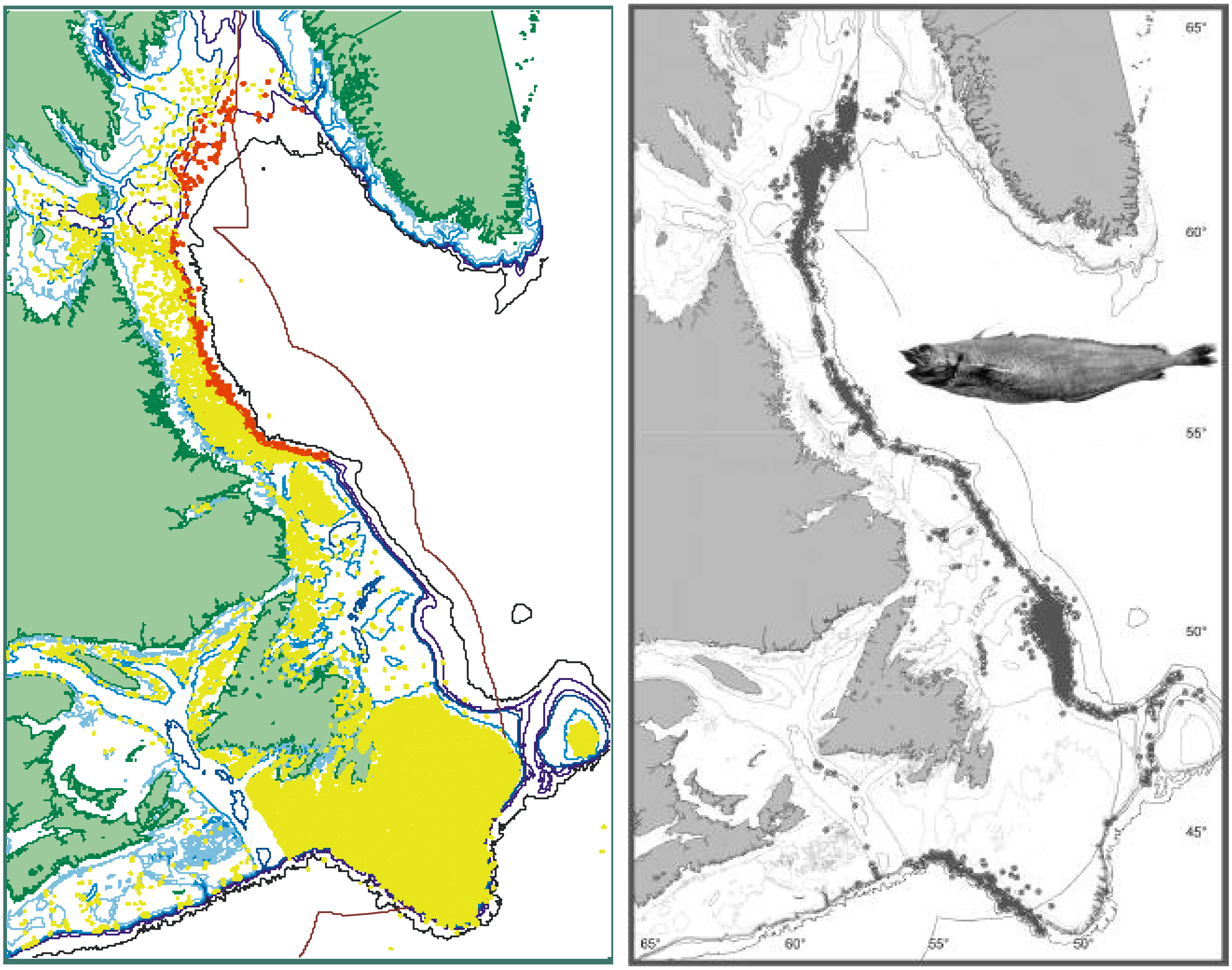


Fig. 2. Left Panel: Map of the study are showing research survey set locations, 1977-2000 (yellow or lighter depicts sets without blue hake, those containing blue hake in darker or red). Right Panel: Location of commercial fishing sets containing blue hake.

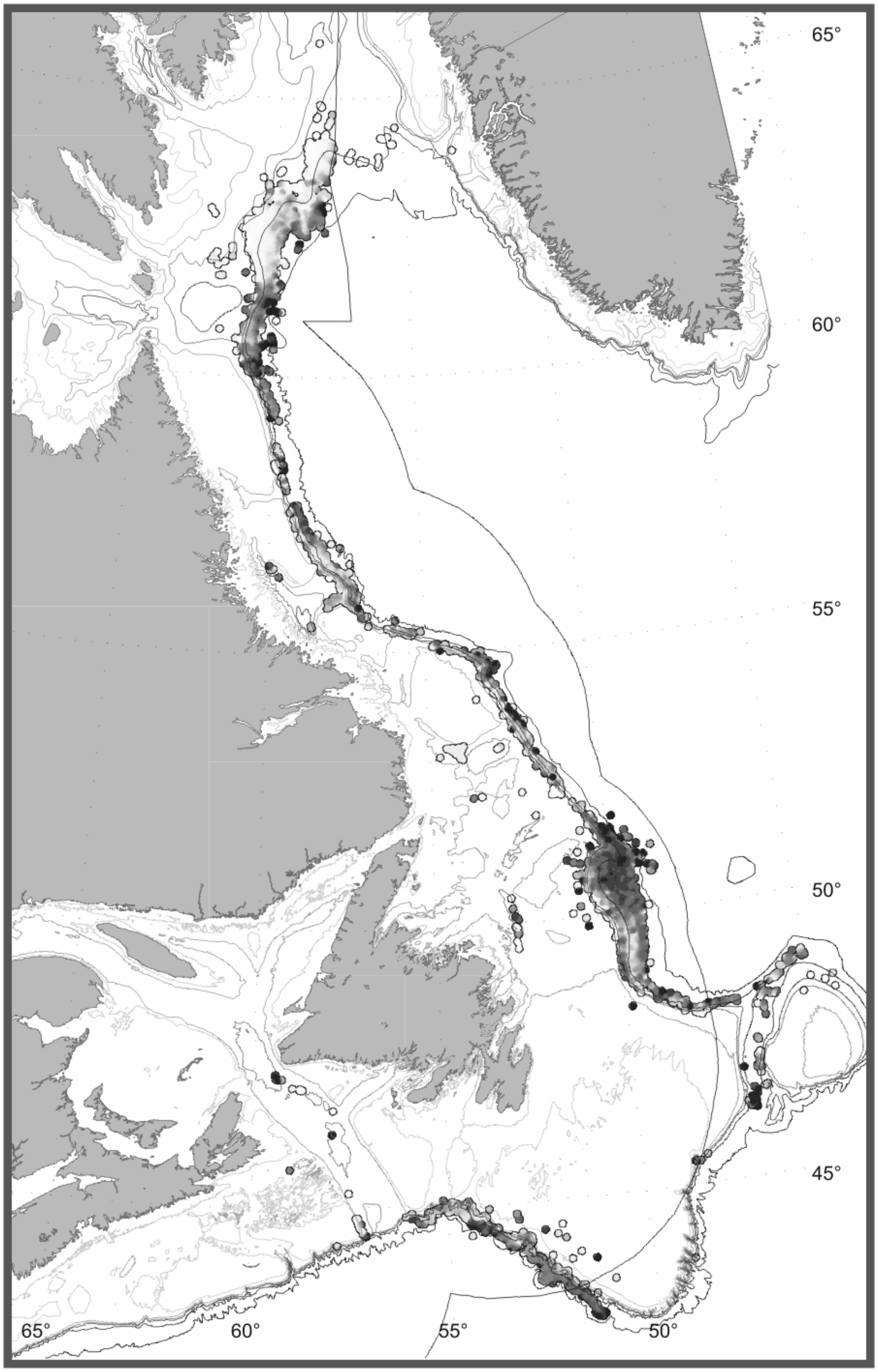


Fig. 3. Map of catch rates of blue hake from commercial fishing sets. Darker shades depict higher catch rates. Total area with blue hake is outlined.

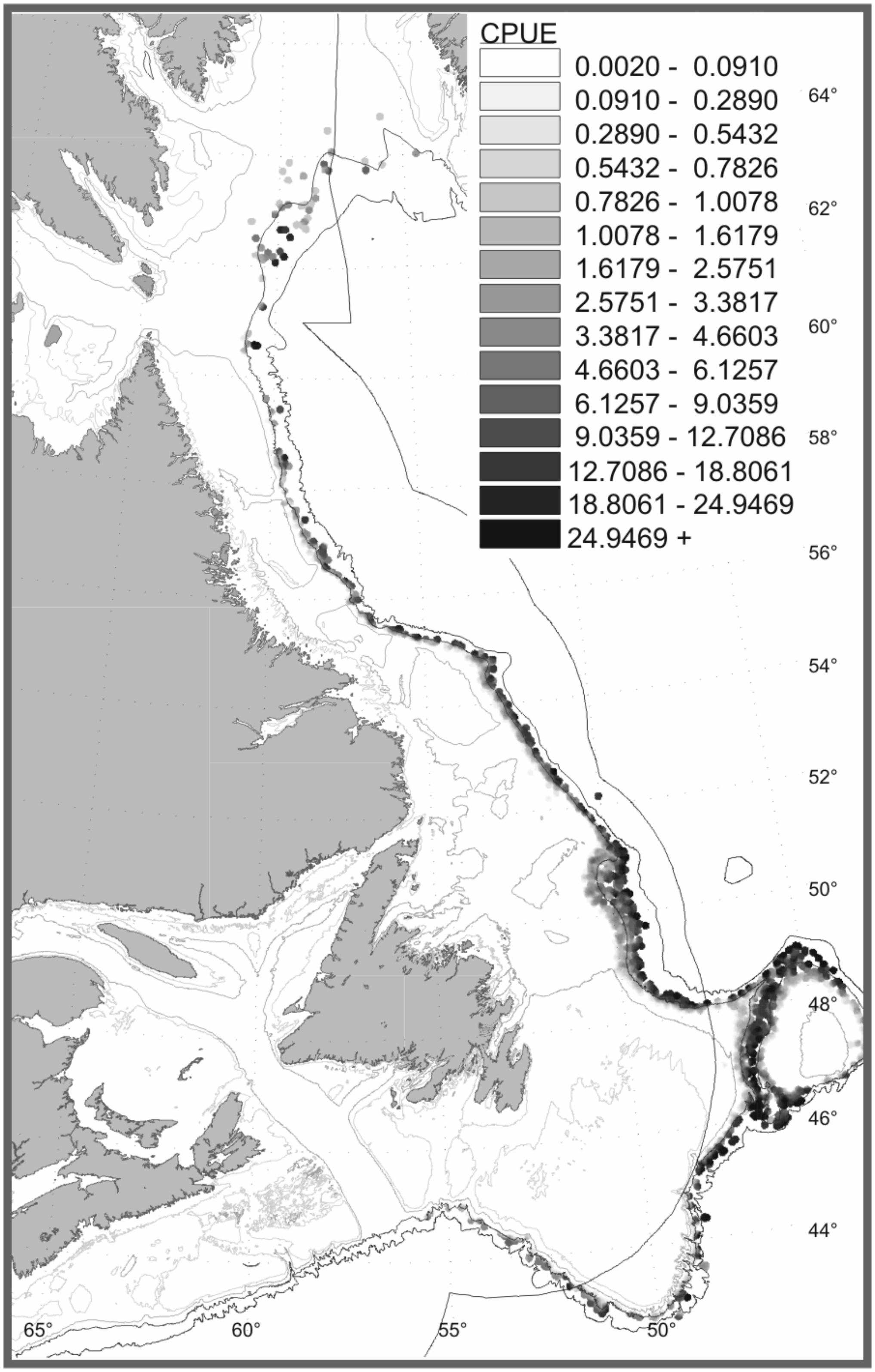


Fig. 4. Map of catch rates of blue hake from research survey sets. Darker shades depict areas of higher catch rates.

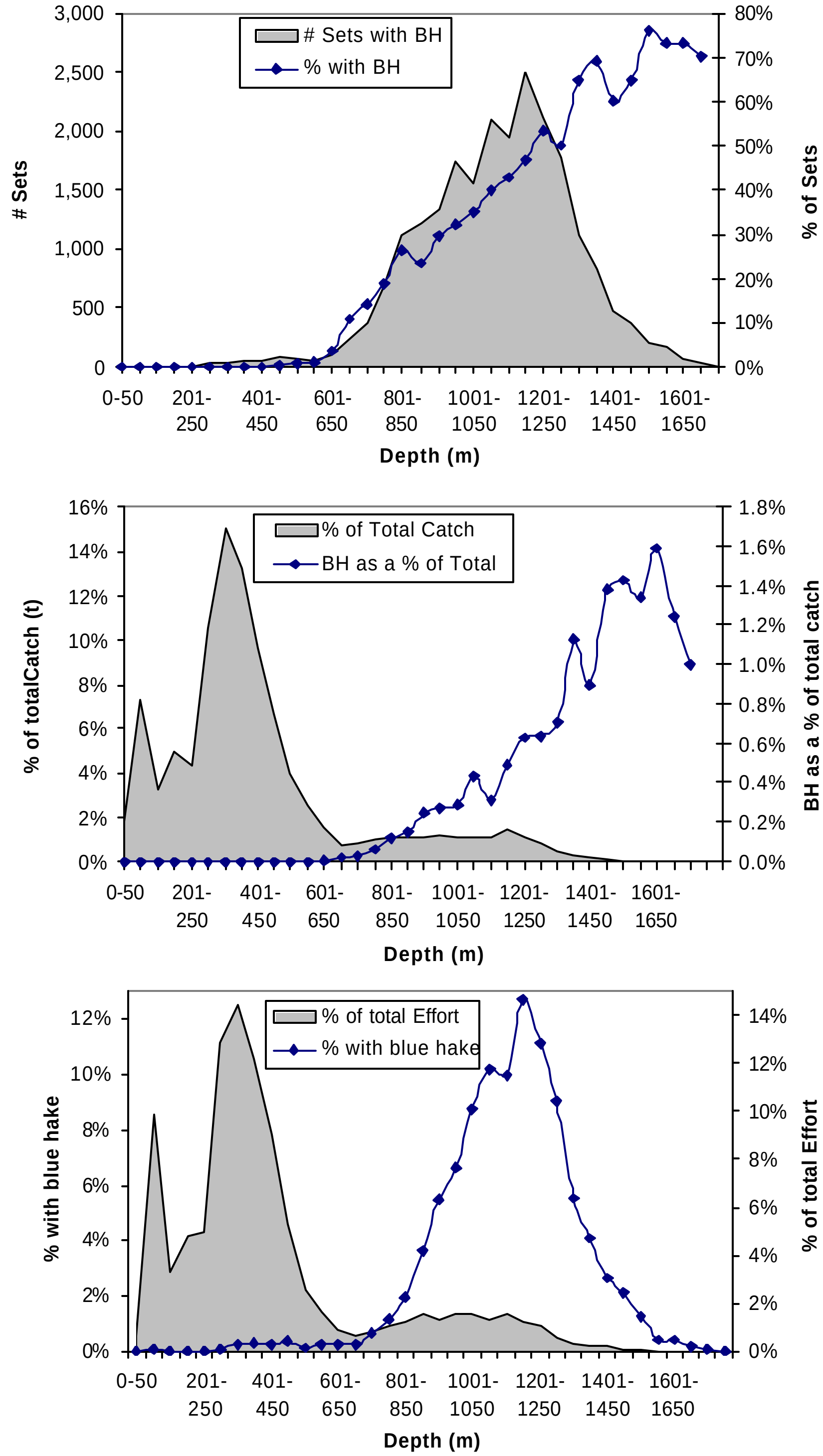


Fig. 5. Commercial fishing catch and effort (observed otter trawl, longline and gillnet, 1978-2000) by depth in relation to catch and effort of sets with blue hake. Upper panel shows number of sets with blue hake and percent of sets (of total commercial effort) with blue hake. Middle panel shows total catch of all species and blue hake as a percent of the total species catch weight. Lower panel shows percent of total effort and percent of total sets with blue hake by depth.

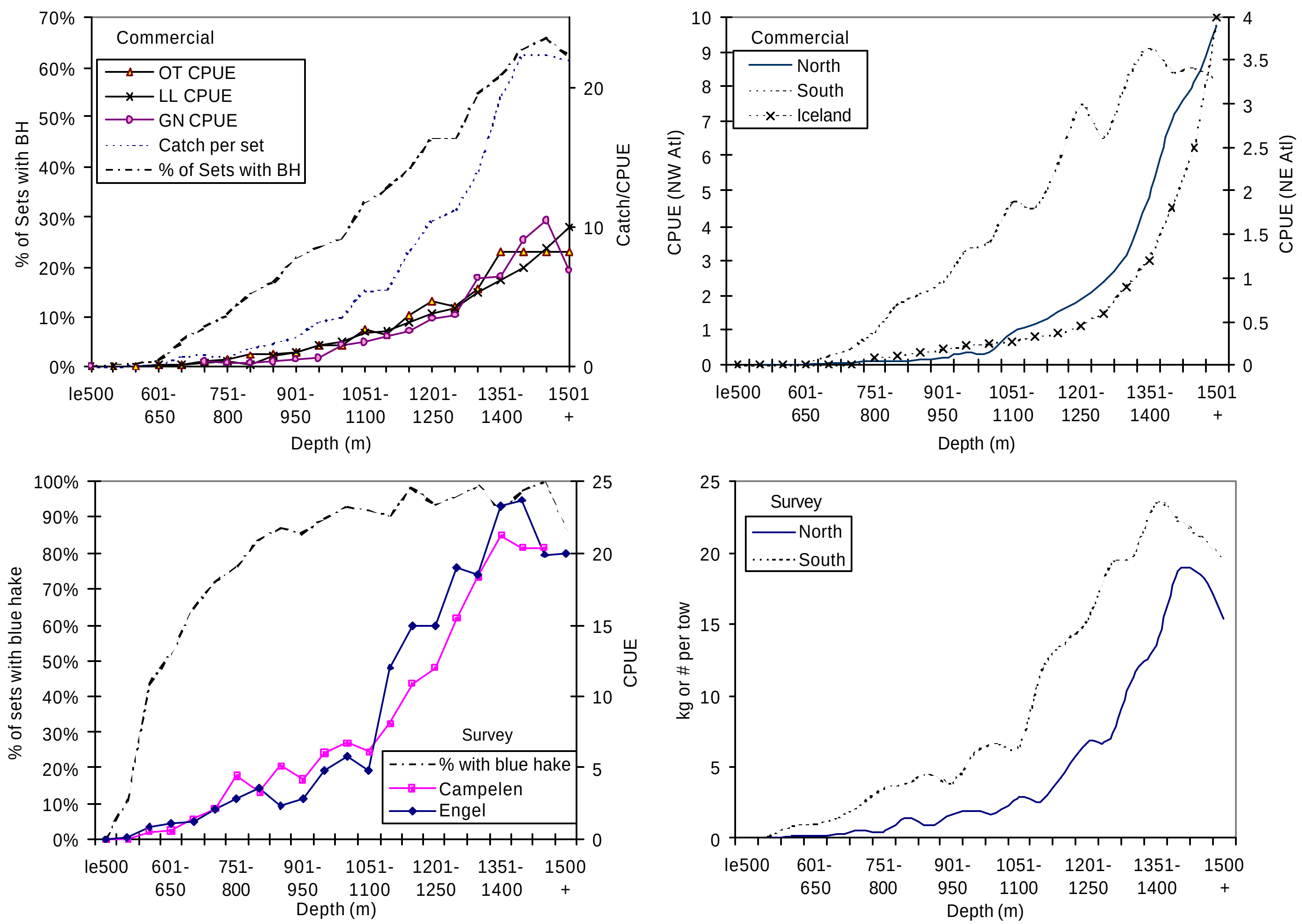


Fig. 6. Catch rates and number and percent of sets with blue hake by depth for commercial fishery and survey data. Upper left panel compares catch rates of the three commercial gears (kg per hour for otter trawl, per 1000 hooks for longline and per 100 nets for gillnet). The lower left panel compares Engel and Campelen standardized kg per tow. The upper right panel compares catch rate (standardized to kg per hour) north of Lat. 55° vs. south of Lat. 55° and catch rates reported by Magnusson (2001) off Iceland. The lower left panel shows standardized kg per tow for surveys north of Lat. 55° vs. south of Lat. 55°.

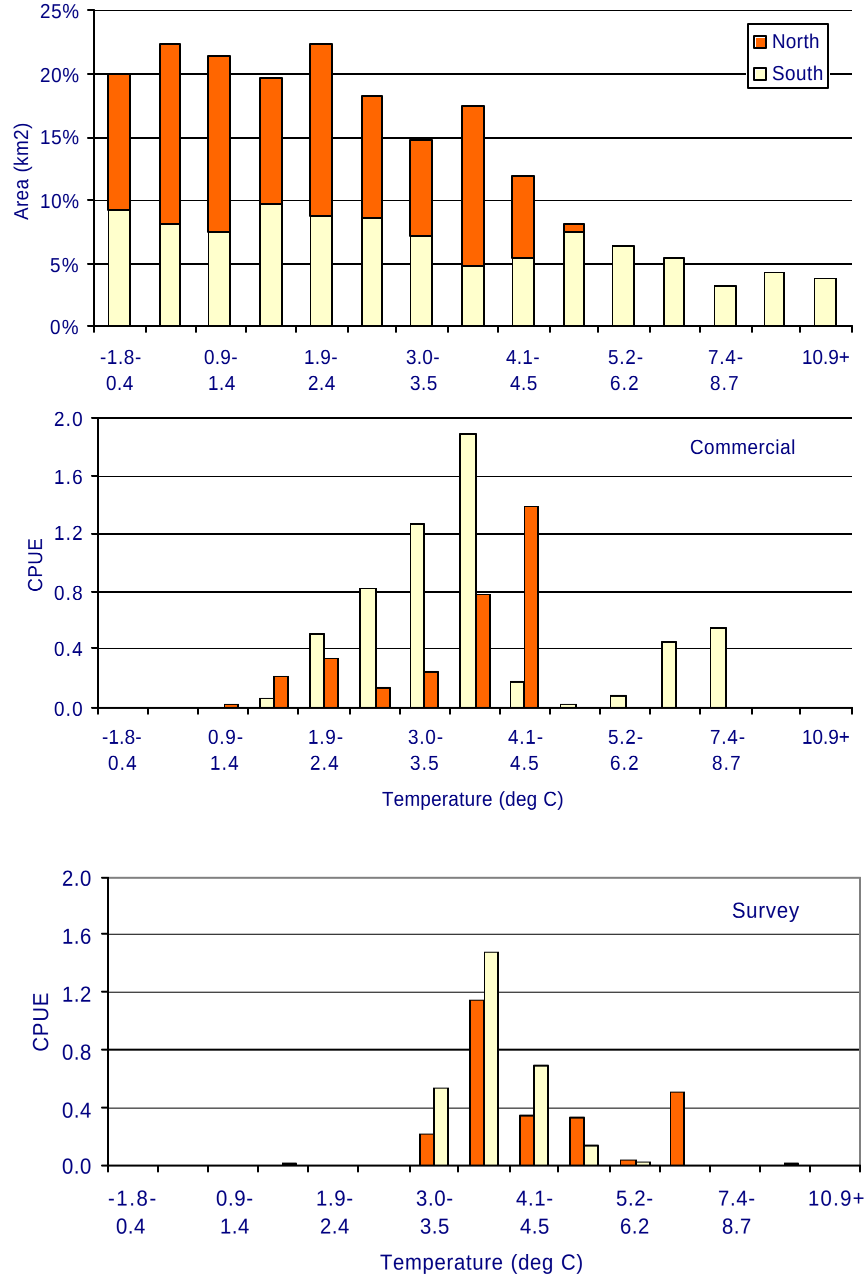


Fig. 7. Catch rate of blue hake with respect to bottom temperature based on commercial fisheries data. Upper Panel: Available habitat depicted as area of the ocean floor in km^2 within bottom temperature strata, north of Lat. 55° and south of the latitude. Lower Panel: Catch rate (kg per tow) of blue hake within these temperature strata.

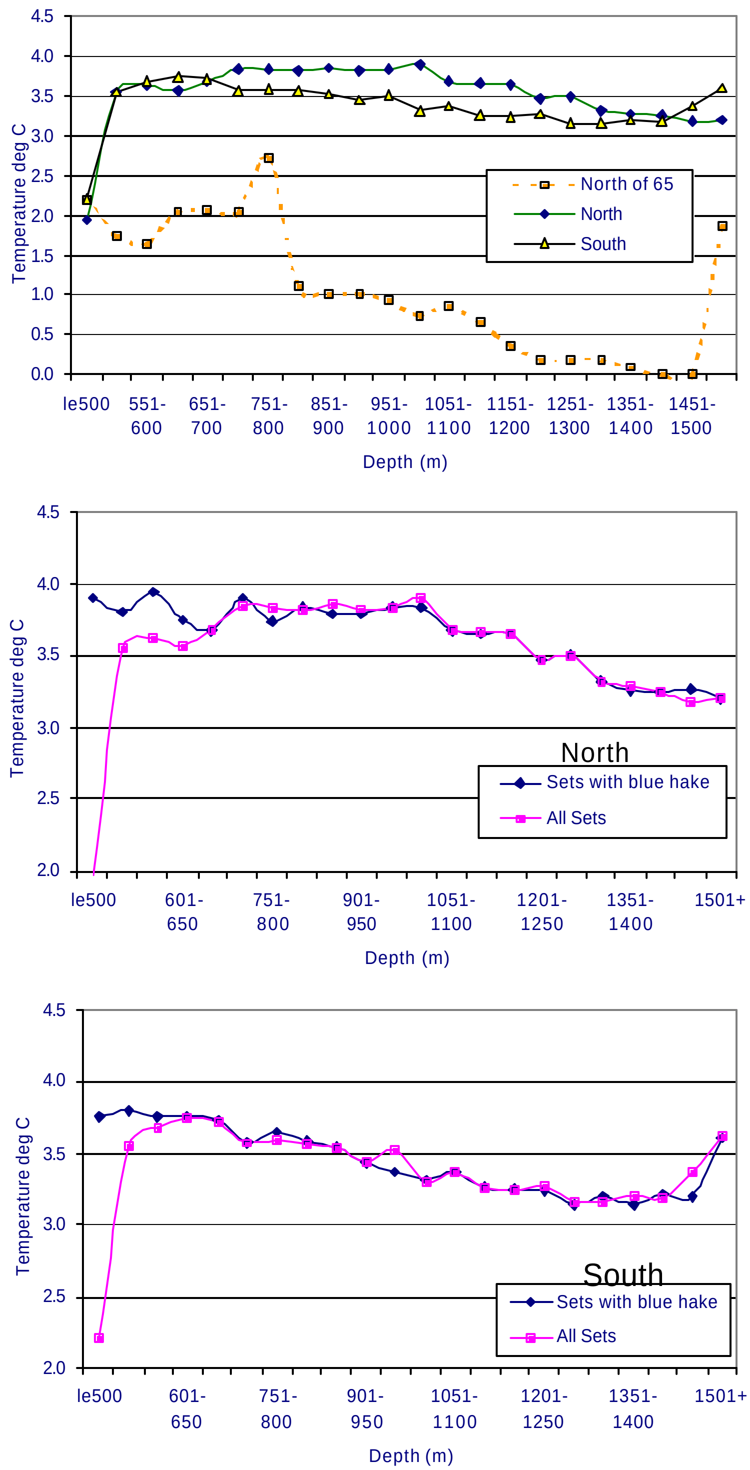


Fig. 8. Average temperature within depth strata for all research survey sets compared to only those sets with blue hake.

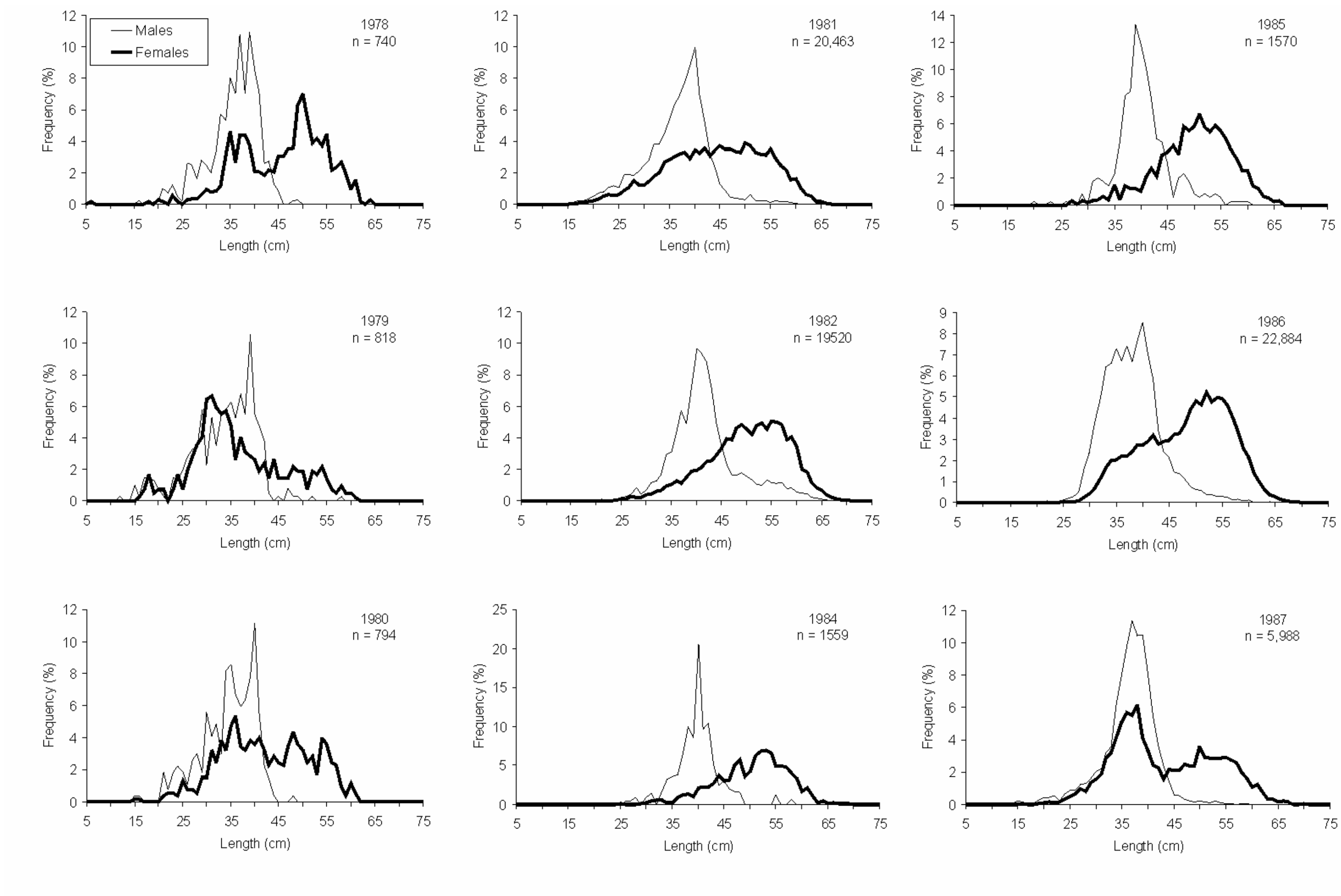


Fig. 9. Annual length frequencies of blue hake from otter trawls for years where sample size exceeded 500 individuals measured.

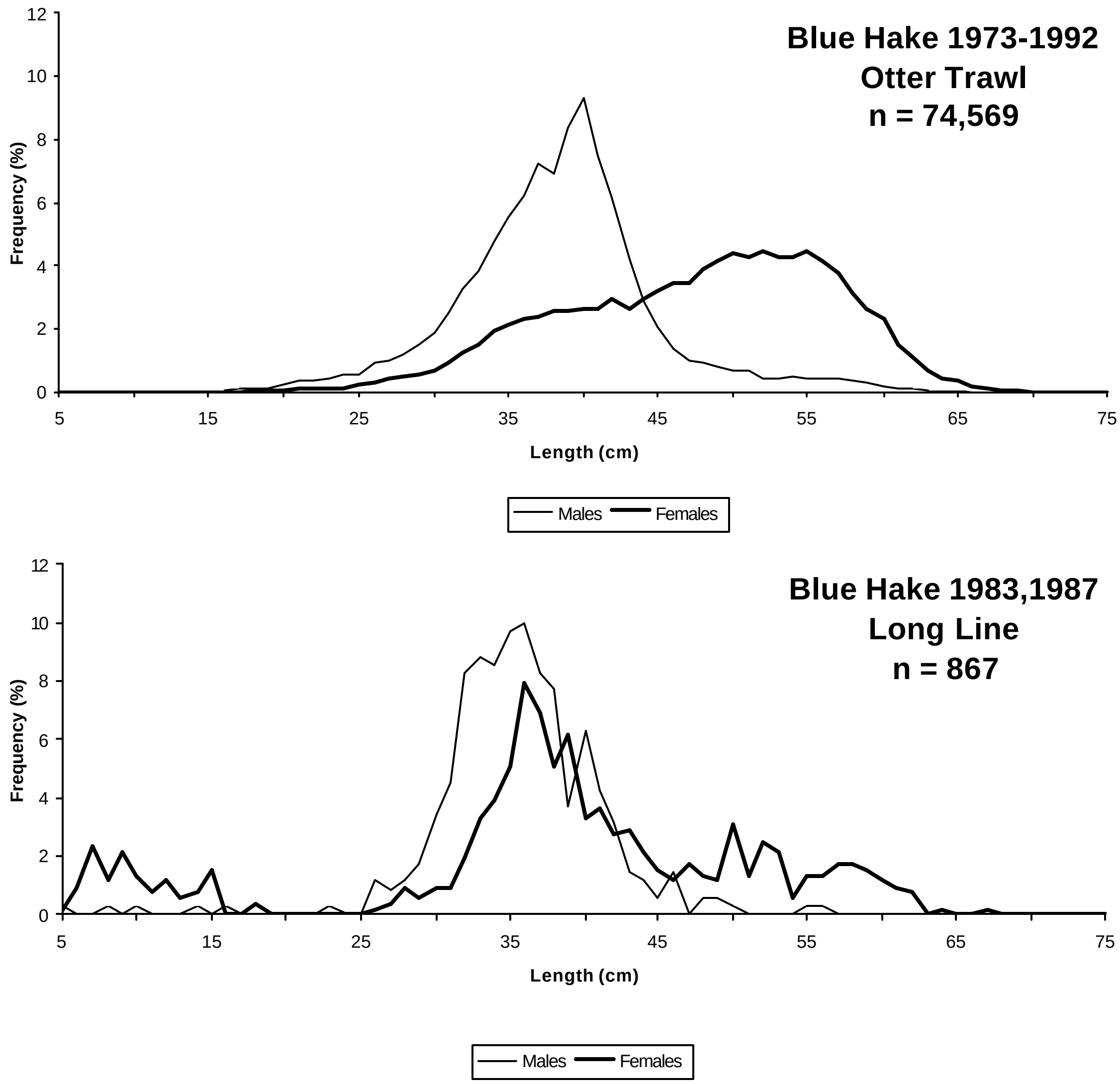


Fig. 10. Summary length frequencies of blue hake from otter trawls and longline gear.

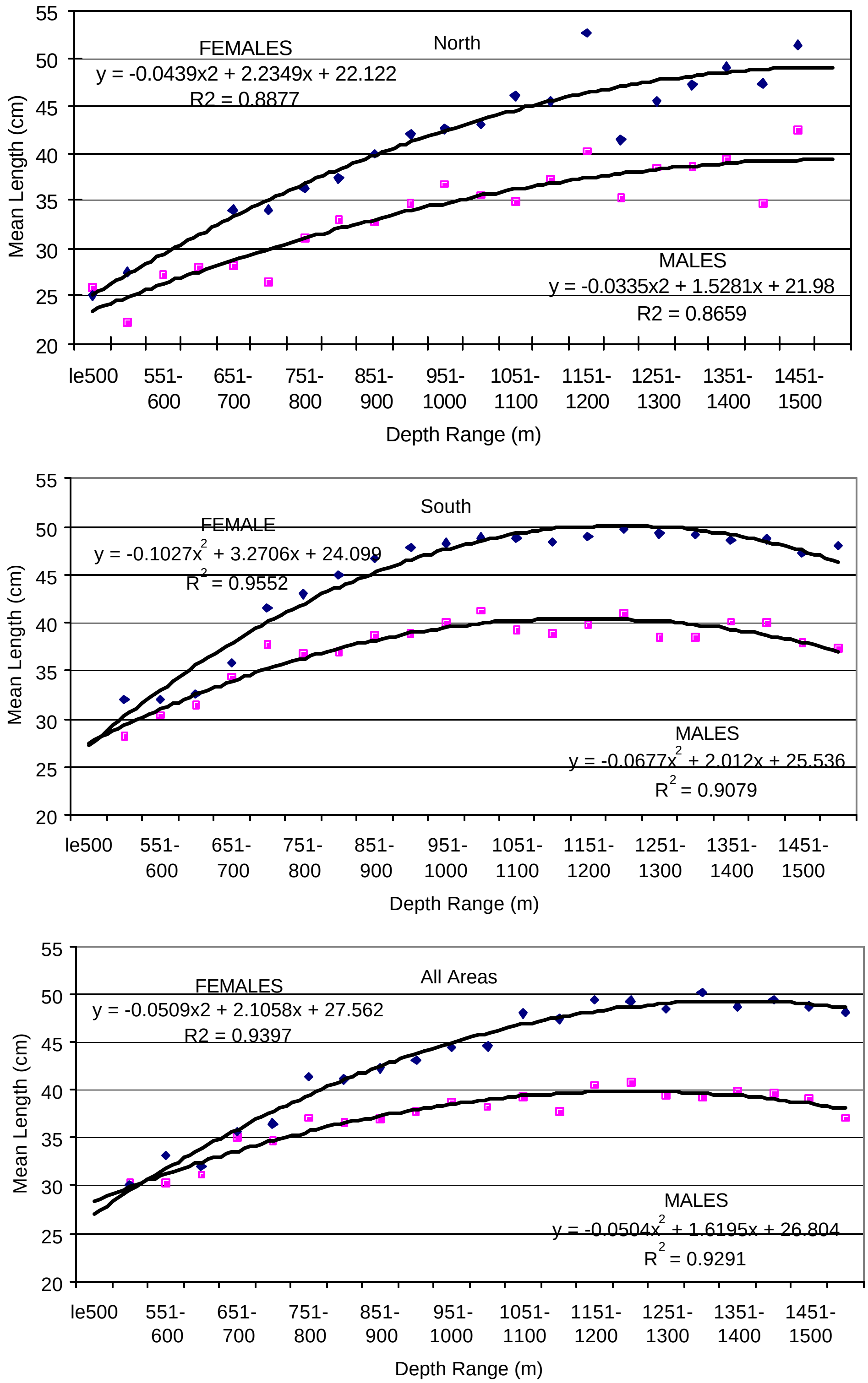


Fig.11. Mean length of blue hake with respect to depth north and south of latitude 55° and all areas combined.

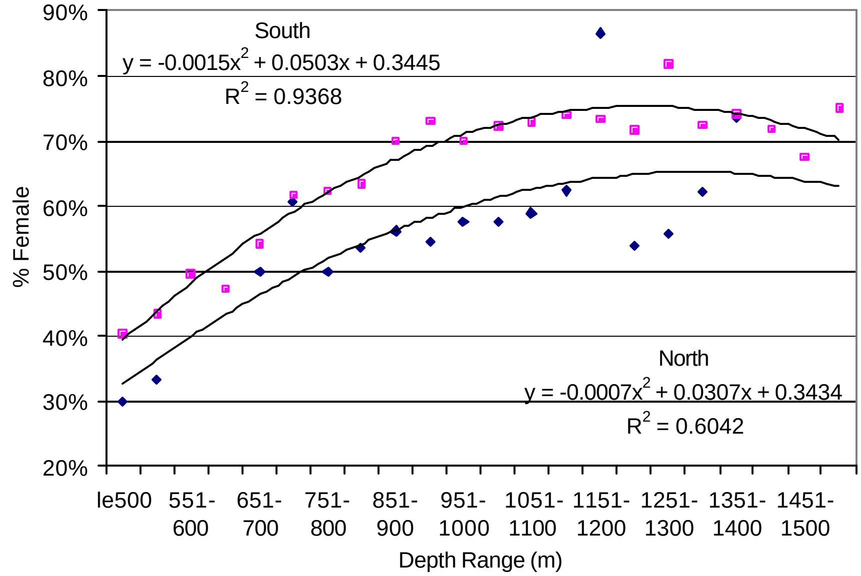


Fig. 12. Percent of female blue hake with respect to depth north and south of latitude 55° and all areas combined.

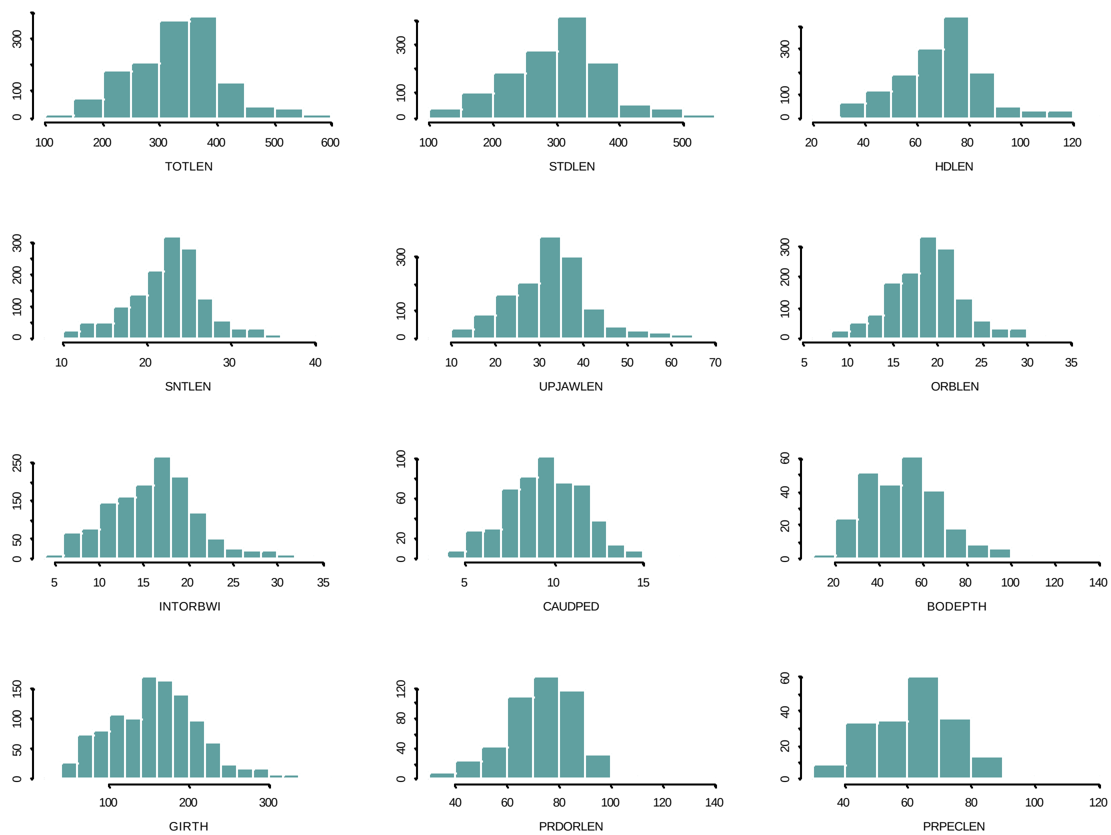


Fig. 13. Frequency distribution for all continuous variables and count variables by sex.

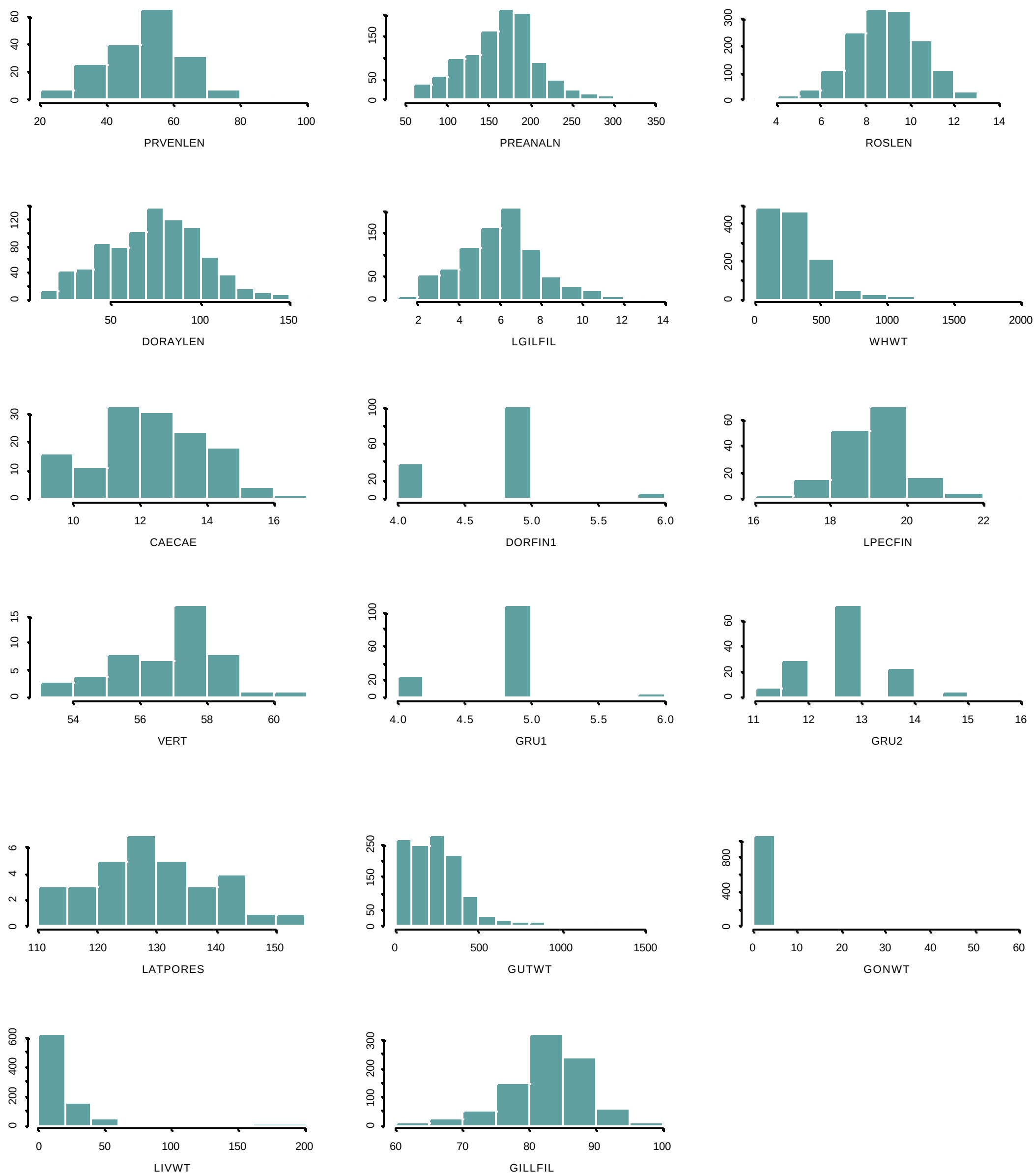


Fig. 13 (cont.). Frequency distribution for all continuous variables and count variables by sex.

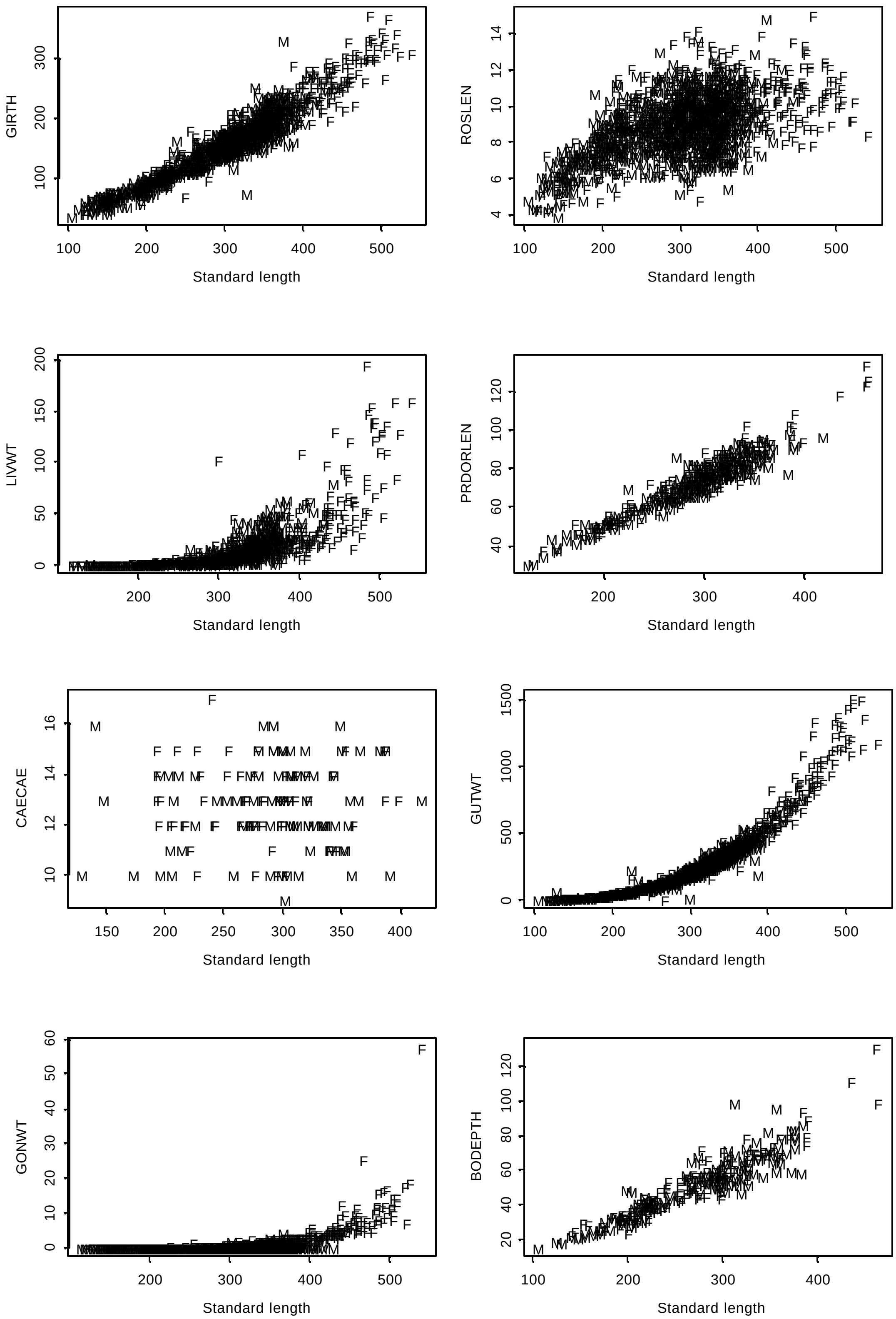


Fig. 14. Bivariate relationship of each morphometric variable with standard length.

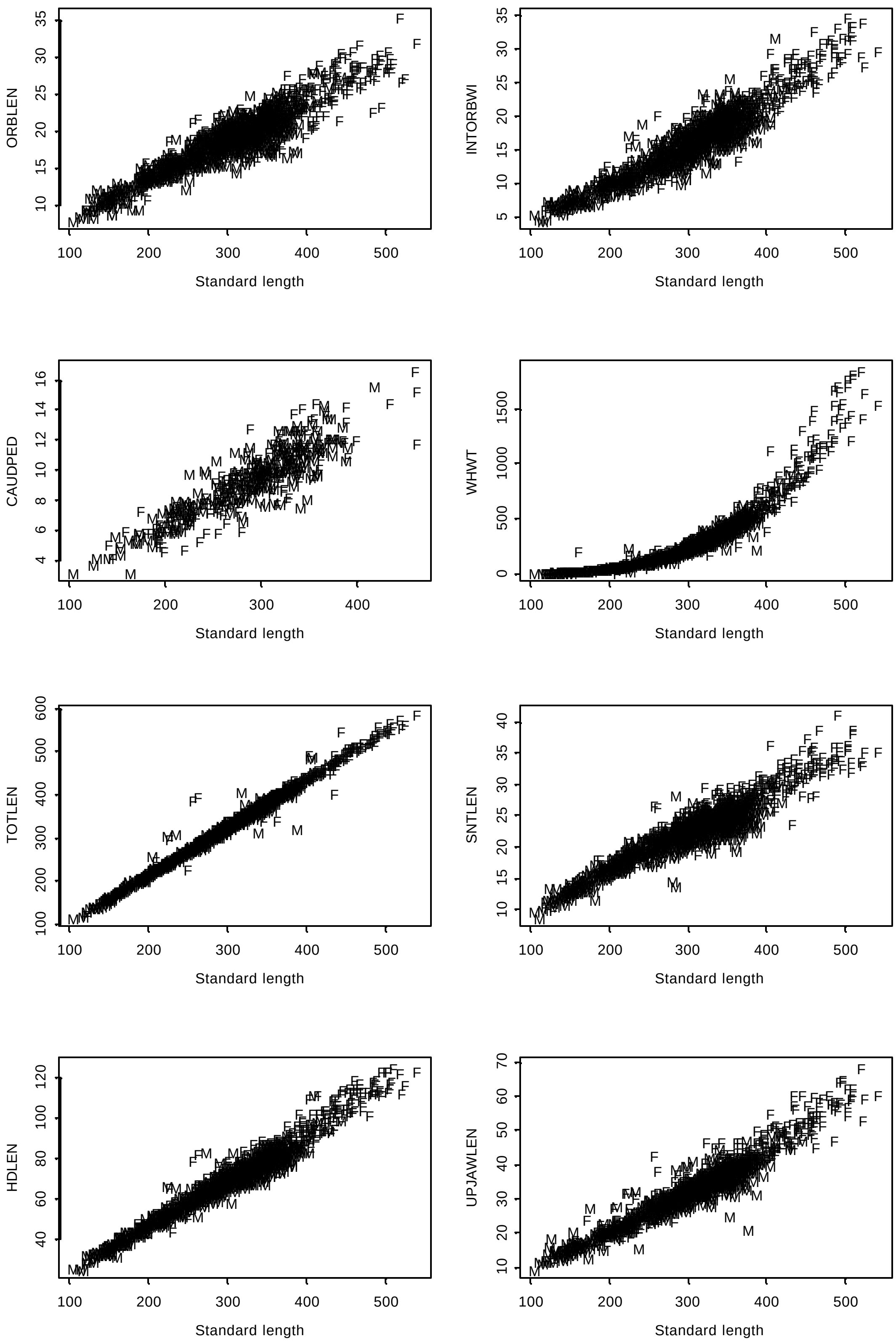


Figure 14 (cont.). Bivariate relationship of each morphometric variable with standard length.

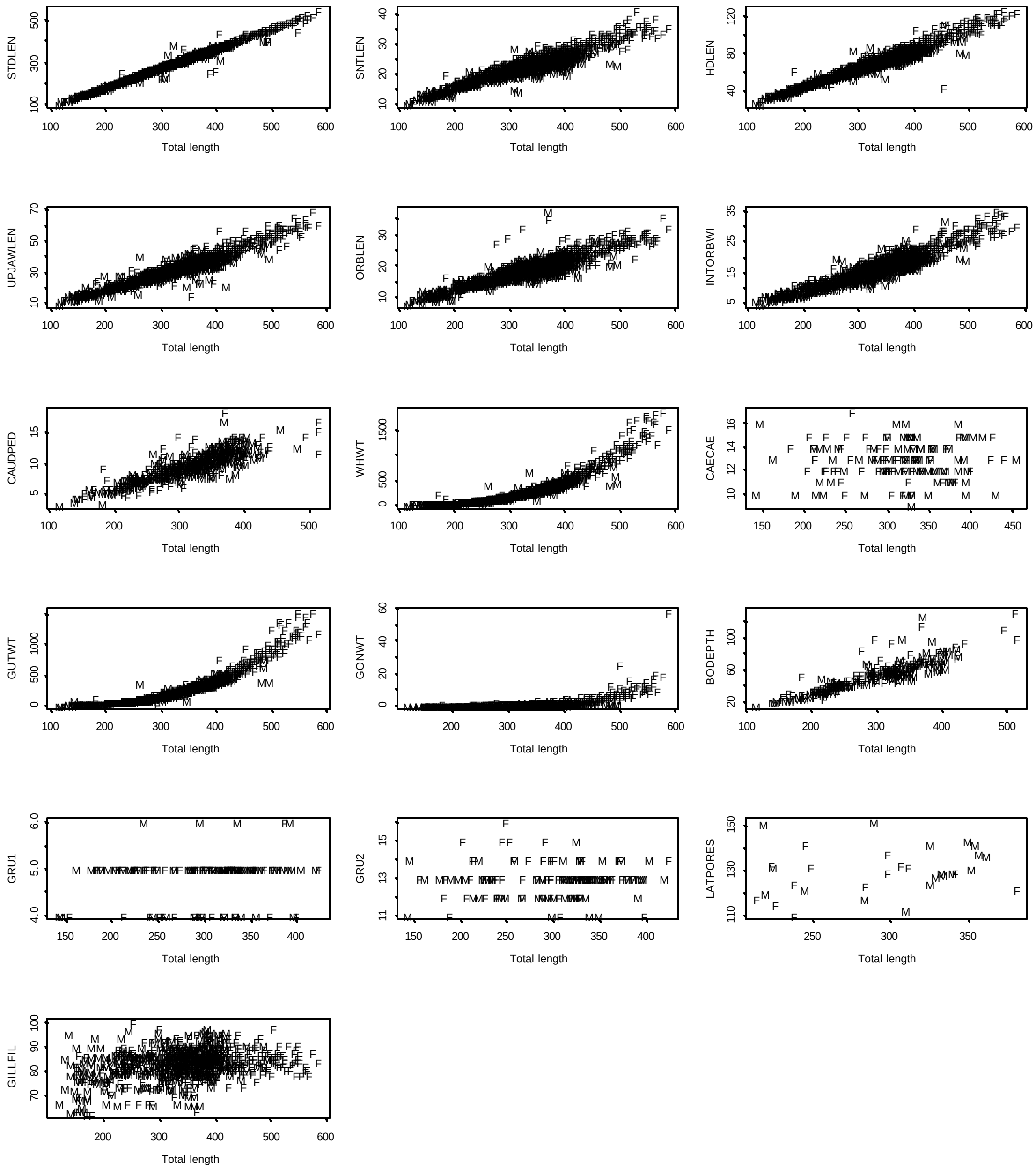


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.

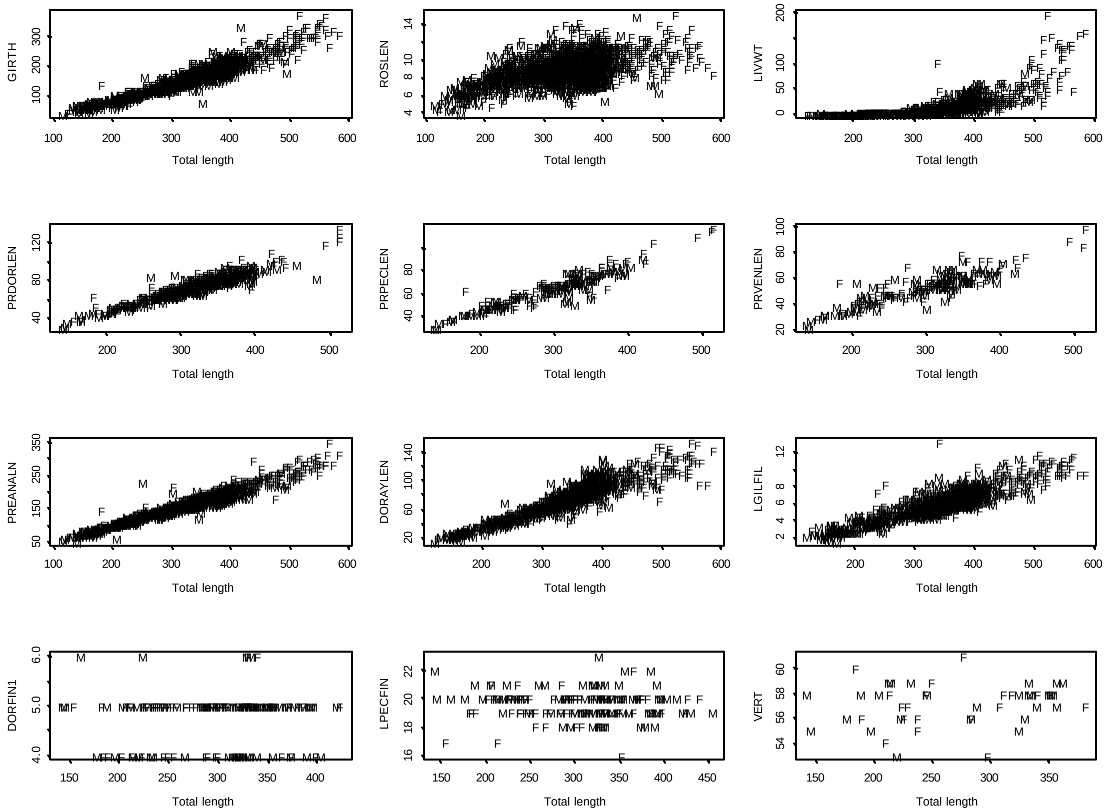


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length..

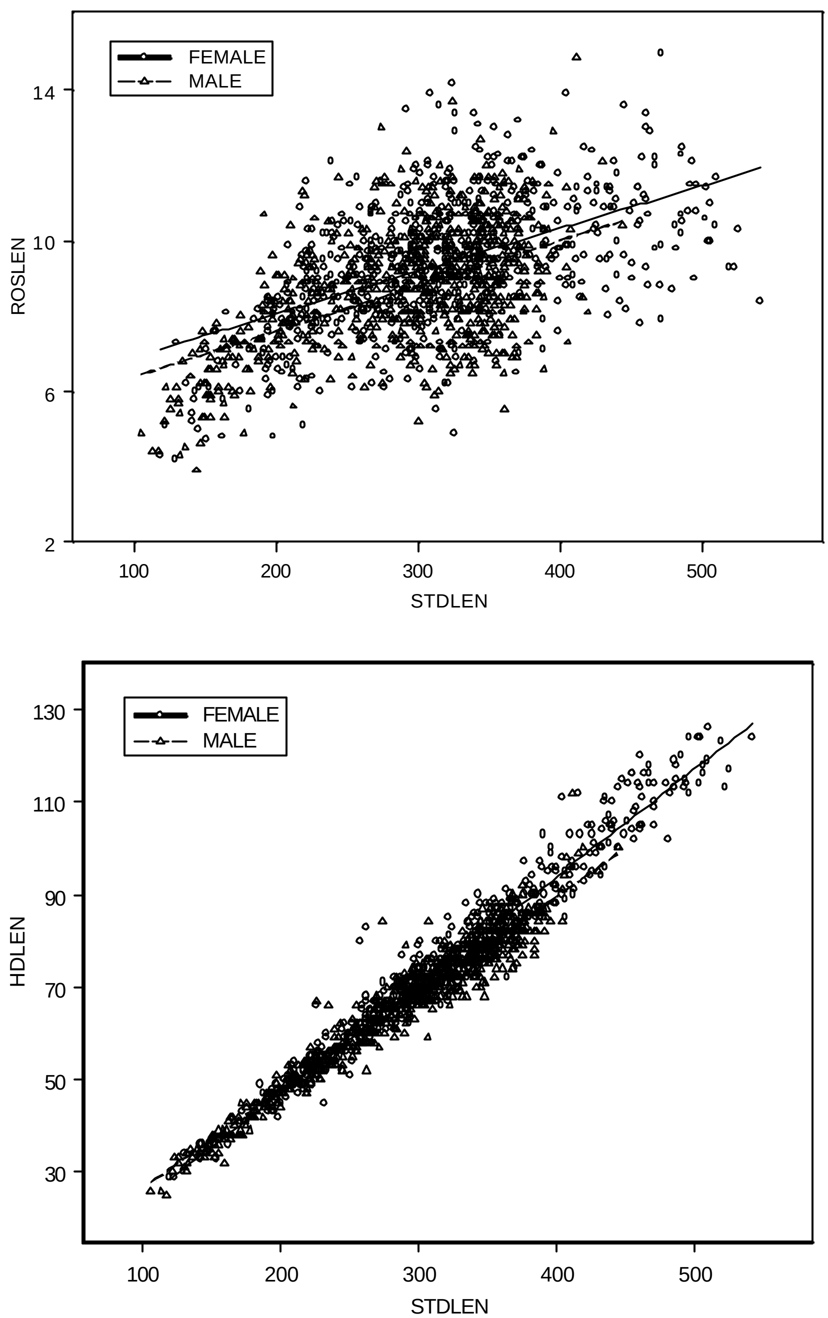
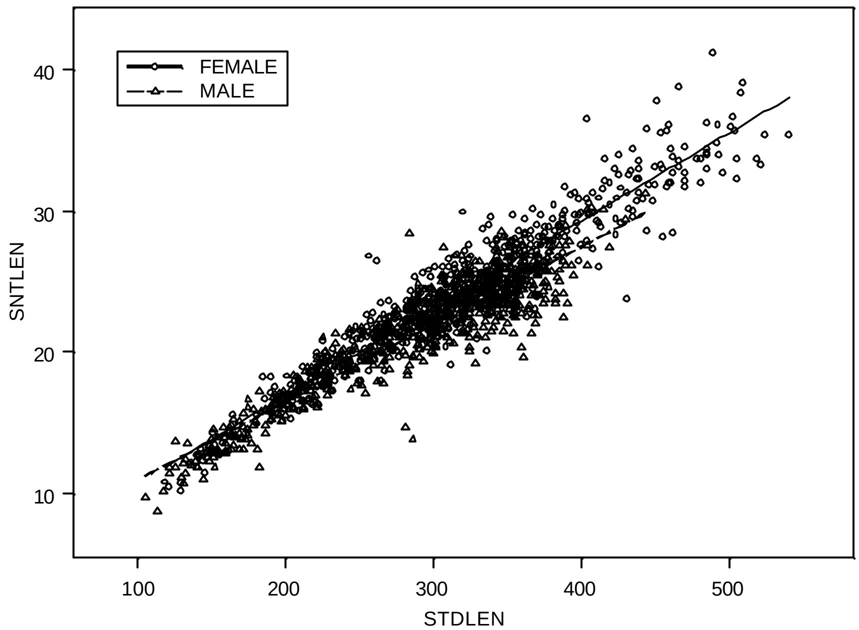


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.



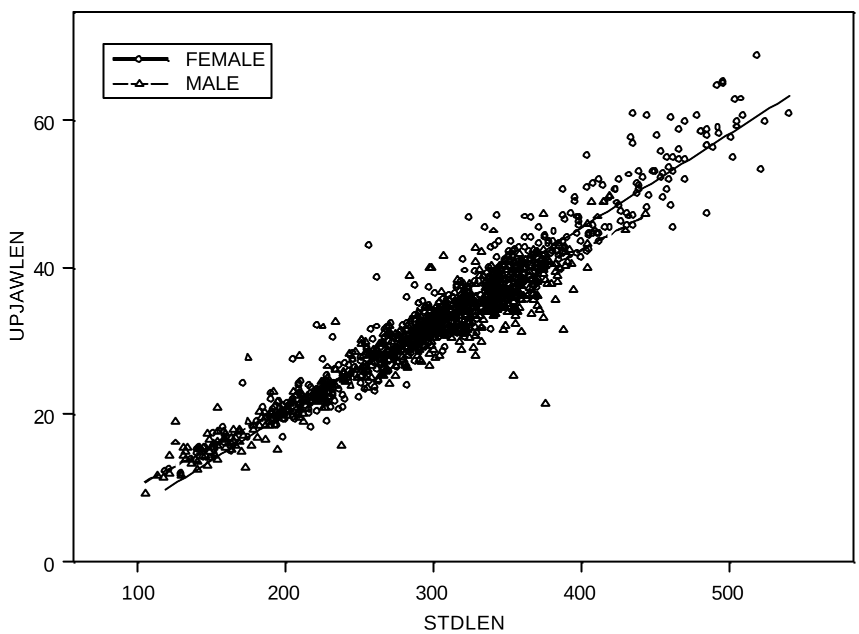
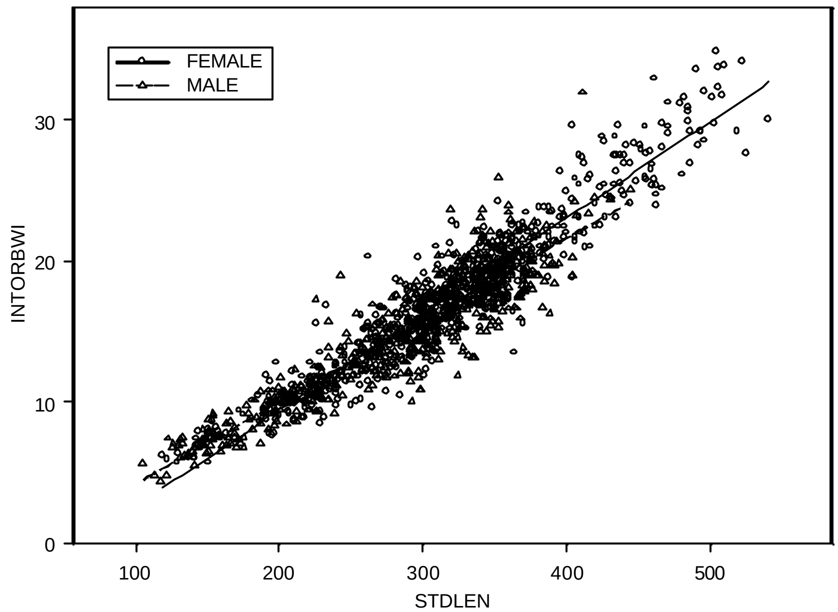


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.



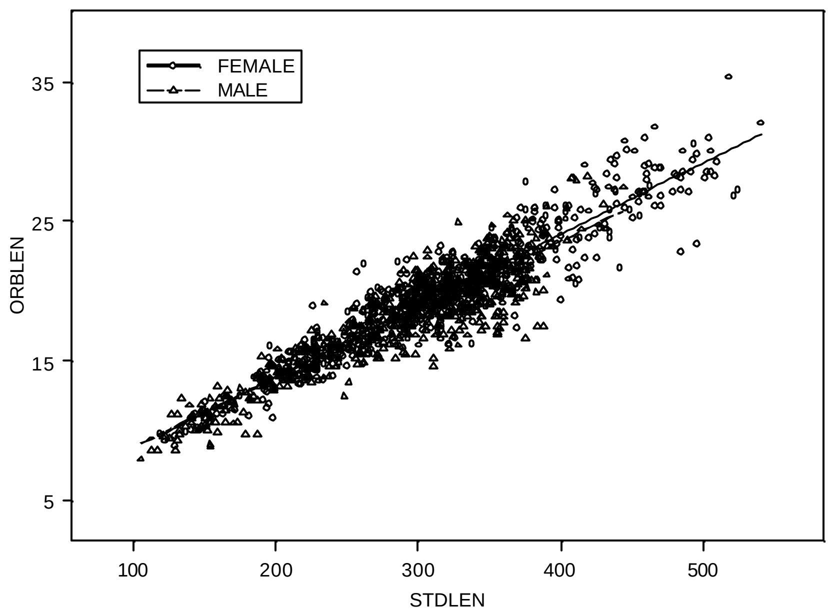
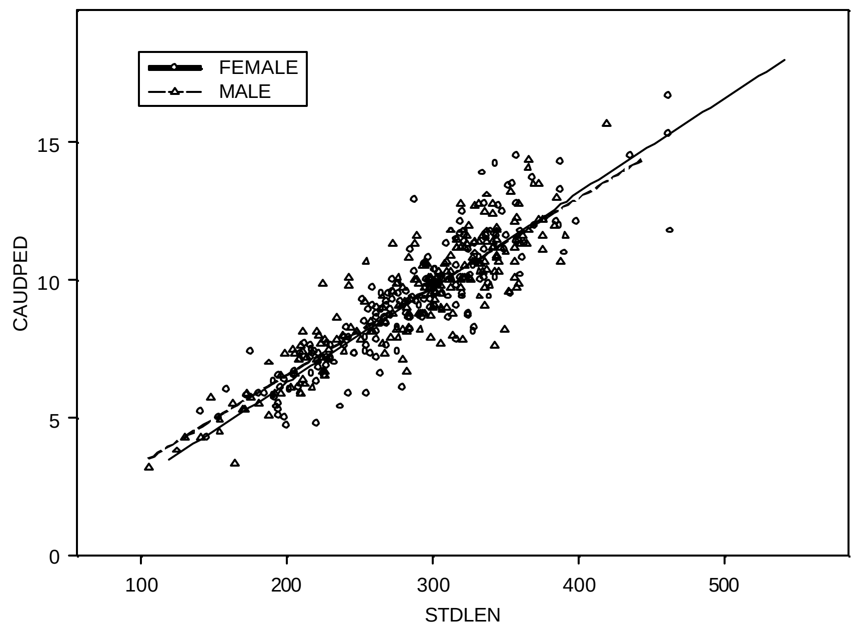


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.



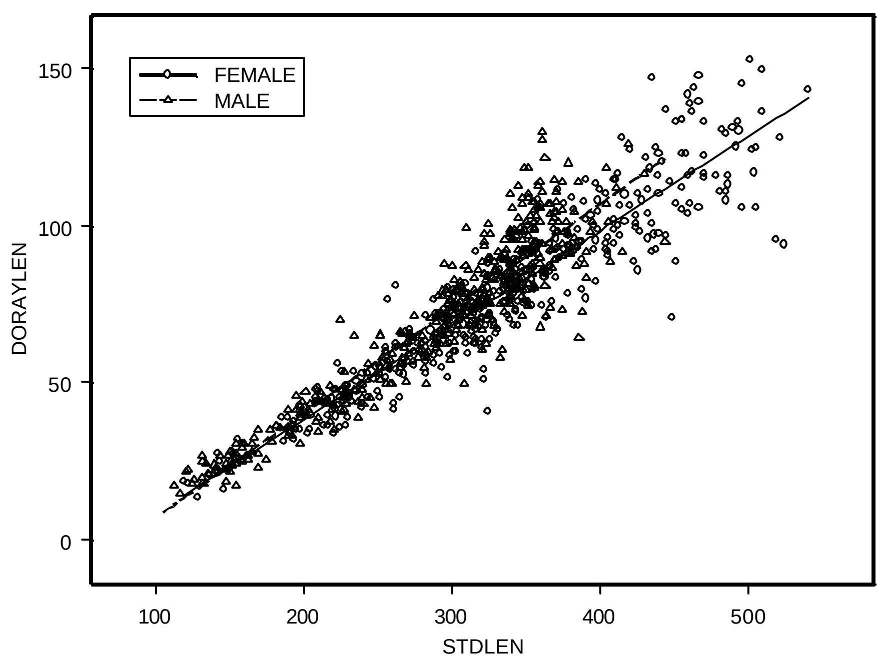


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.

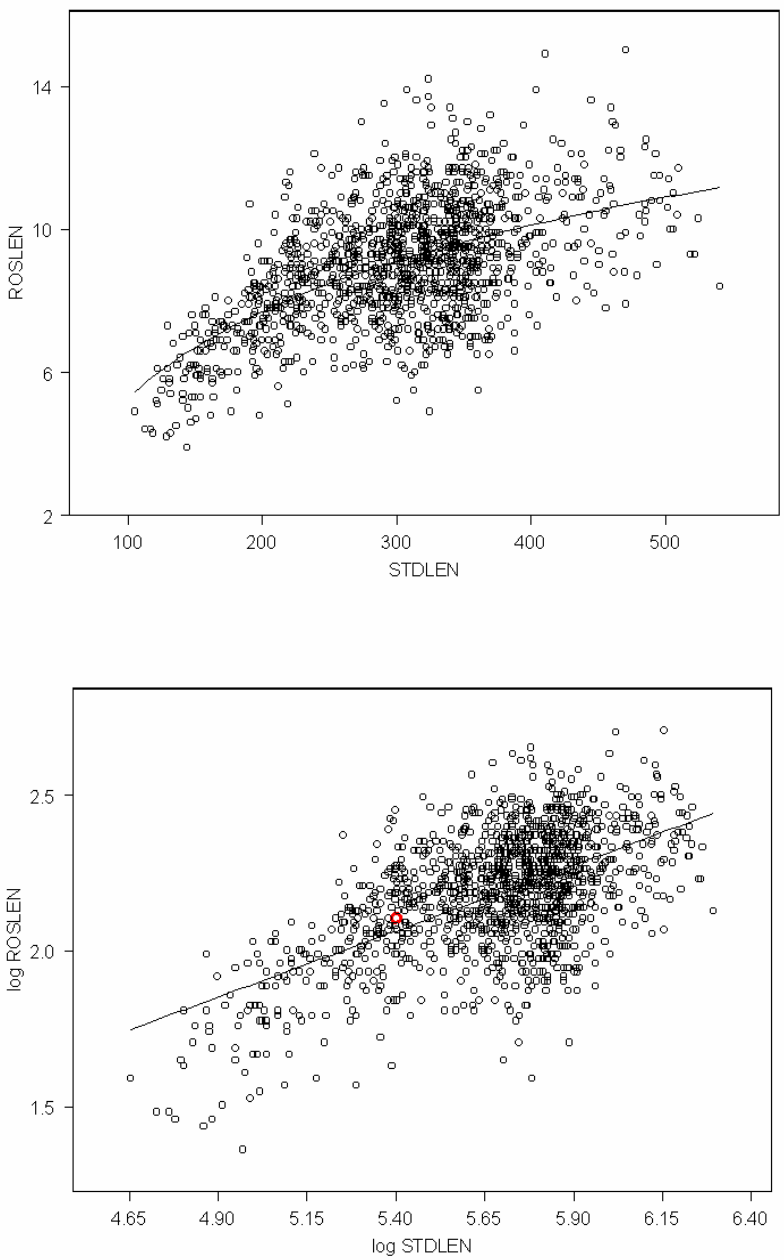


Fig. 14 (cont.). Bivariate relationship of each morphometric variable with standard length.

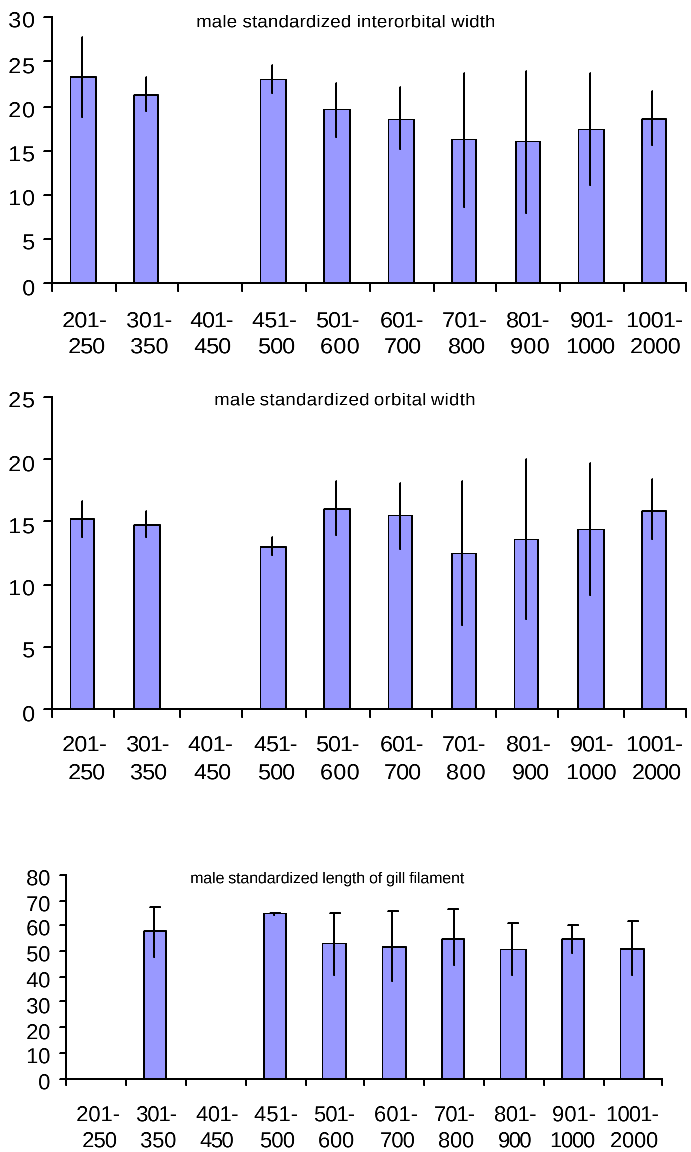
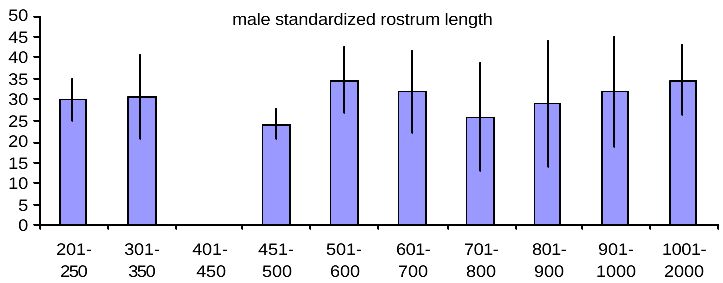
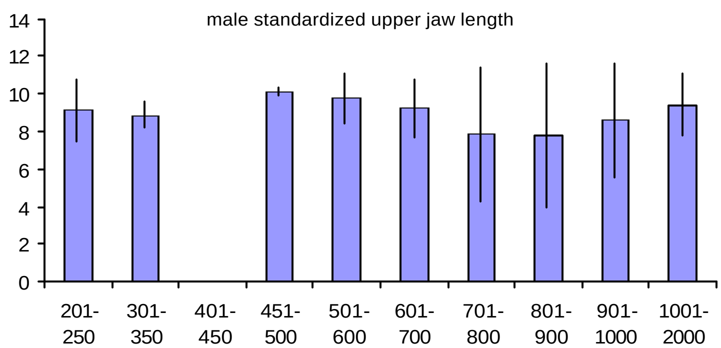


Fig. 15. Character variation with depth (by sex).





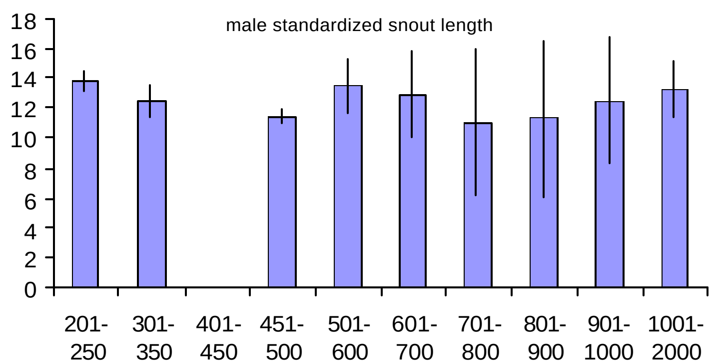
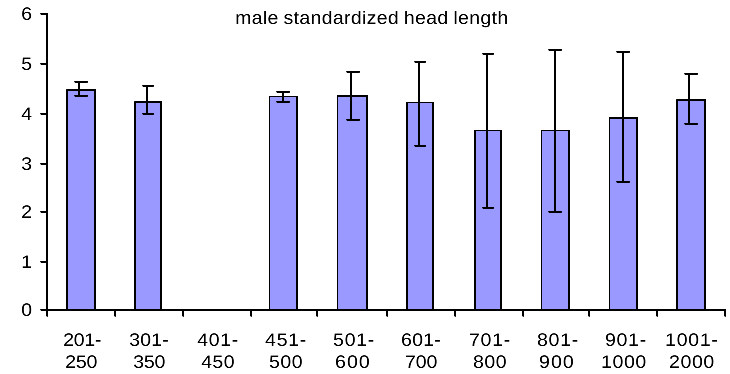
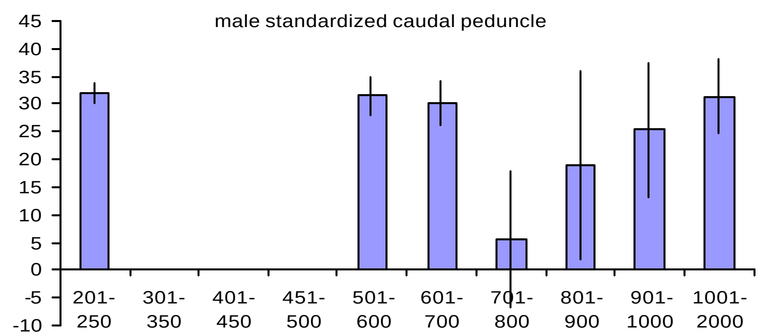


Fig. 15 (cont.). Character variation with depth (by sex).





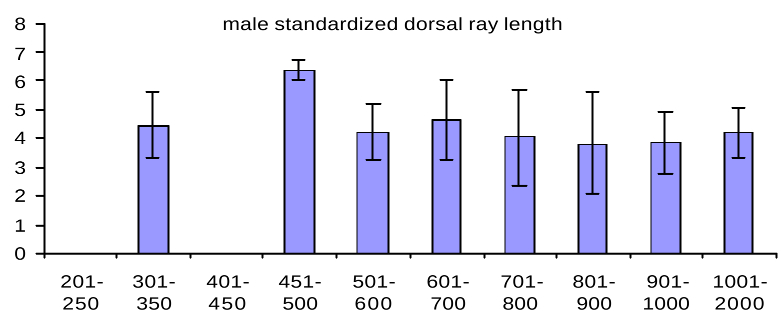


Fig. 15 (cont.). Character variation with depth (by sex).

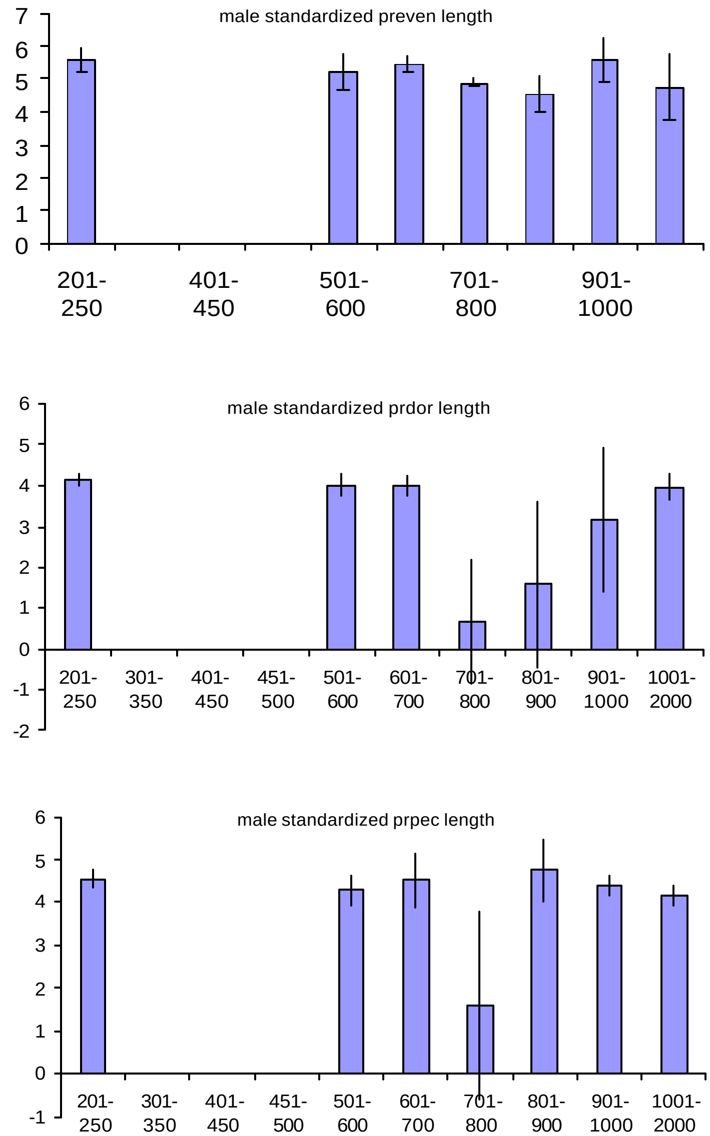


Fig. 15 (cont.). Character variation with depth (by sex).

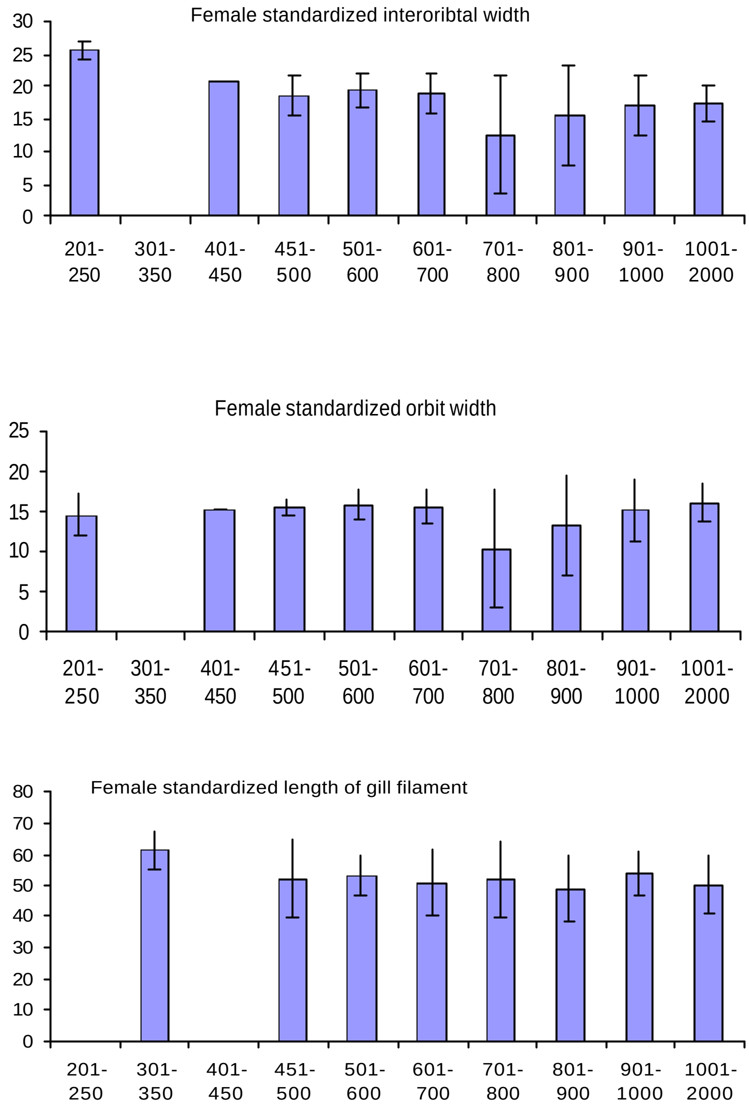


Fig. 15 (cont.). Character variation with depth (by sex).

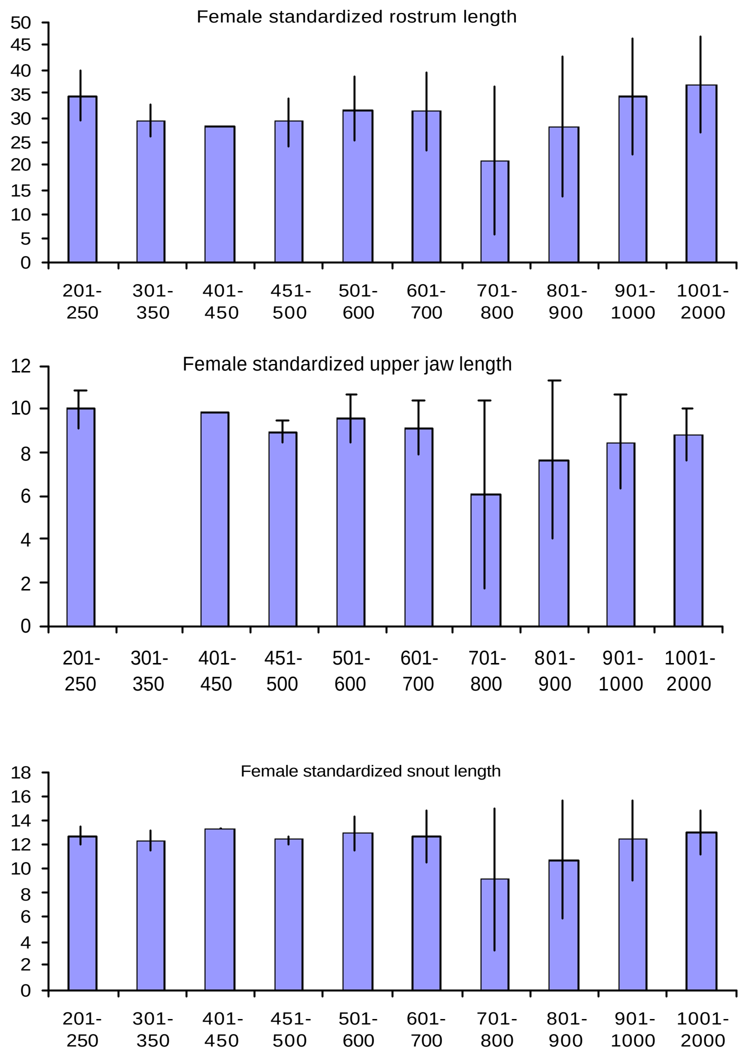


Fig. 15 (cont.). Character variation with depth (by sex).

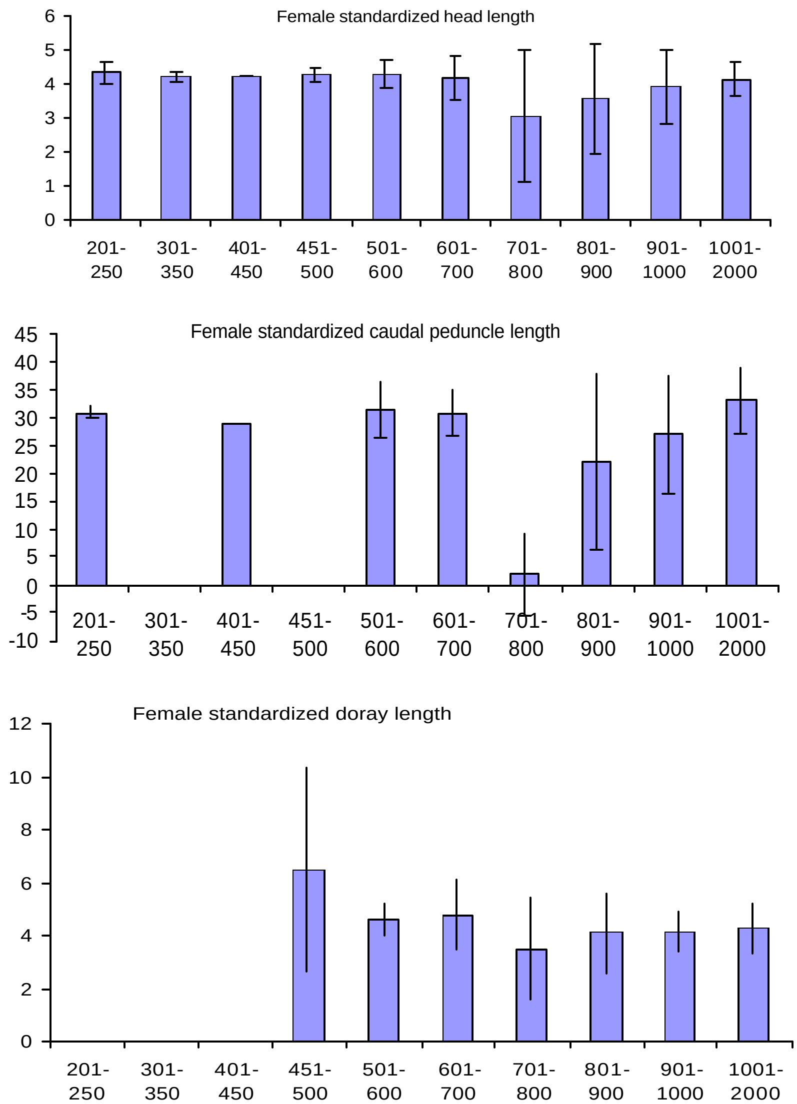


Fig. 15 (cont.). Character variation with depth (by sex).

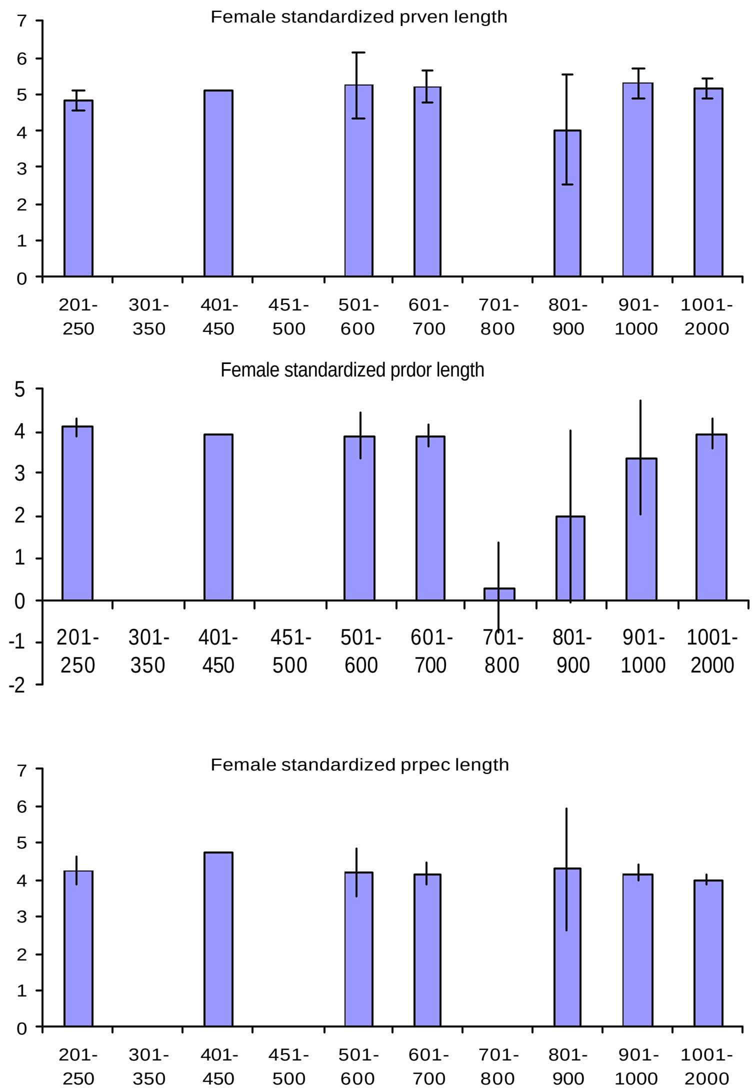
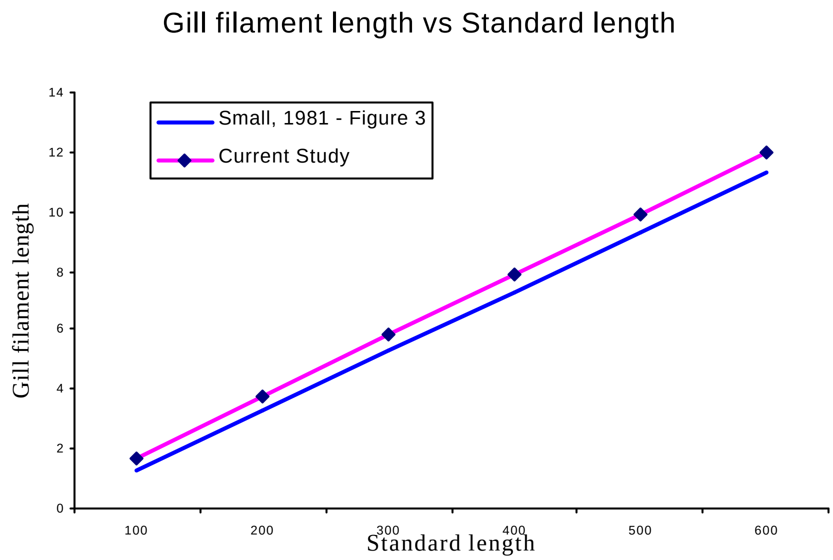


Fig. 15 (cont.). Character variation with depth (by sex).



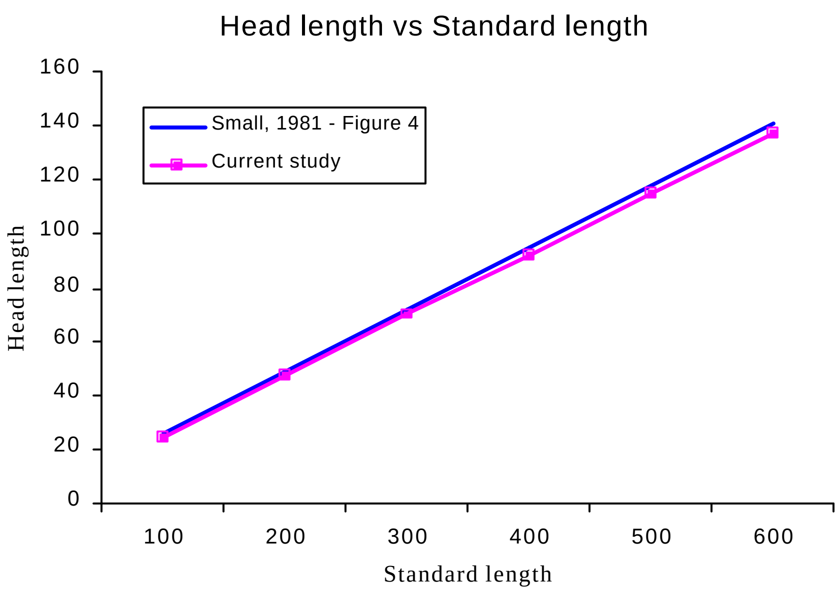


Fig. 16. Relationship between two key morphometrics gill filament length and head length with respect to standard length comparing the results of this study compared to Small (1981).

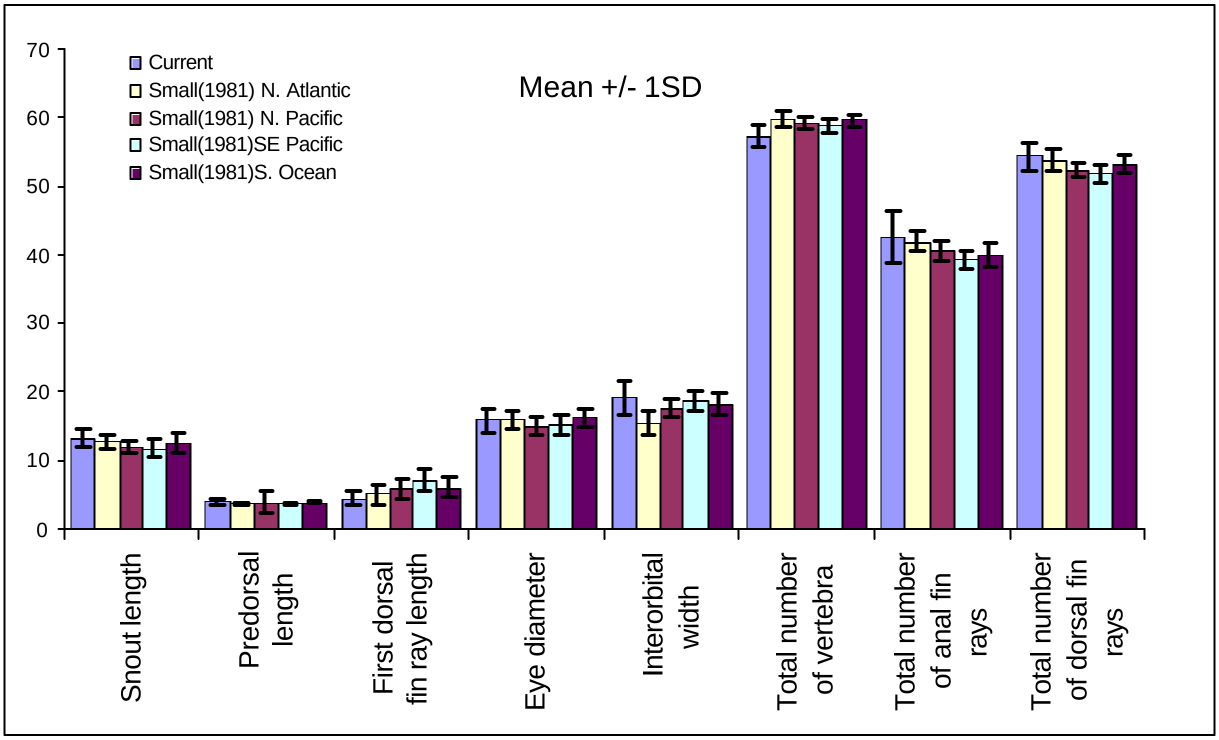


Fig. 17. Comparison of morphometric characteristics (expressed as a ratio of standard length) and meristic counts, current study to Small (1981).