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Maturity and other biological aspects of two deep water squaloid sharks, *Centroscyllium fabricii* (Reinhardt, 1825) and *Etmopterus princeps* Collett, 1904, in Icelandic waters.

by

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ABSTRACT

This paper presents some biological parameters of the black dogfish (*C. fabricii)* and the greater lantern shark (*E. princeps)* based on material collected during surveys of Marine Research Institute, Iceland.

C. fabricii was observed with the greatest abundance in depths between 800 and 1200 m (range 436 to 1653 m). The overall sex ratio was 1.00:1.19 in favour of females. Males were more numerous in shallower waters but in depths below 1000 m, the sex ratio was significantly in favour of females. *E. princeps* was observed in depths with the greatest density between 800 and 1000 m (range 436 to 1653 m). The overall sex ratio was 1.00:1.59 in favour of females, females being significantly more numerous in depths below 1000 m. For both species the tendency of decreasing length with increasing depths was observed. Further, there is an indication of sexual dimorphism in both species i.e. females become larger than males and are larger at maturity. Maturity stages were observed during two seasons and indicated that neither of these two species have a defined breeding season. A study of the diets showed that larger specimens of *C. fabricii* fed mainly on teleosts but smaller specimens seemed to feed more opportunistically on teleosts, cephalopods and crustaceans.

E . princeps seemed to feed mainly on three prey categories; teleosts, cephalopods and crustaceans.

A considerable amount of these two species, especially of *C. fabricii* could be discarded on fishing grounds of *Reinhardtius hippoglossoides* off West Iceland.

Keywords: *Centroscyllium fabricii*, depth distribution, *Etmopterus princeps*, feeding, length distribution, maturity, sex ratio.

INTRODUCTION

The black dogfish, *Centroscyllium fabricii* belongs to the family Squalidae. It is characterized by similar teeth in both jaws with narrow cusps and cusplets and is of a brownish colour mostly with whitish spots (due to small and rarely distributed dermal denticles) (Jónsson, 1992; Whitehead et al. 1984). It is known to be abundant on the upper and middle continental slopes in the North Atlantic and along the Mid Atlantic ridge (Compagno,1984; Haedrich and Merrett,1988; Whitehead et al.1984; Snelgrove and Haedrich,1985; Gordon and Duncan, 1985). In Icelandic waters, the black dogfish is most abundant off the west, southwest and southeast coasts (Kotthaus and Krefft, 1967; Haedrich and Krefft, 1978; Jónsson, 1992; Magnússon and Magnússon, 1995) in depths from 600 to about 1100 m. It is probably a common bycatch in the Greenland halibut (*Reinhardtius hippoglossoides*) fishery but is discarded because of little commercial value. Records of landings are rare and purely incidental.

The greater lantern shark, *Etmopterus princeps* is like the black dogfish a squaloid shark. It is characterized by upper teeth with 5 cusps and lower teeth with strongly oblique cusps and a uniform brown colour (Jónsson, 1992; Whitehead et al.,1984). It is kown to be distributed along the continental slopes from off Gibraltar, off the Hebrides, the Faroes and Iceland and from north-east United States to Nova Scotia (Whitehead et al., 1984, Compagno, 1984). The distribution in the waters around Iceland is known to be off the west, southwest and southeast coast but mainly along the slope of the Reykjanes Ridge (Magnússon and Magnússon, 1995). Its bathymetric distribution at Iceland is also similar to that of the black dogfish although it is recorded to be more abundant at greater depths than the black dogfish (Compagno, 1984; Magnússon and Magnússon, 1995).

Information on biology and bathymetric distribution of deep-sea sharks in Icelandic waters is limited. Very little has been published on the biology of these two species in the North Atlantic. Magnússon and Magnússon (1995) describe the distribution and some biological parameters of these two species in Icelandic waters. Mauchline and Gordon (1983) published some information on the diets of *C. fabricii* and *E. princeps* of the Rockall Trough. Yano (1995) described the reproduction biology of *C. fabricii* off western Greenland.

A financial support by the EC FAIR Programme CT95-655 made it possible to conduct a survey to the deep water slope of the Reykjanes /Mid Atlantic Ridge in 1997 and also to participate in the stock-estimation surveys for Greenland halibut, in 1996 and 1997.

This paper presents a study on some biological parameters of these two species in waters off Iceland.

MATERIAL AND METHODS

The material used for this study was collected in 10 surveys conducted during 1992-1997 by the Marine Research Institute, Iceland (MRI) (Table 1). The surveys were conducted for various purposes and covered most slope areas of the Icelandic continental shelf (Figs. 1 and 2). Surveys B3-93, S1-93 and KA1-97 were directed to the deep-water areas on the Reykjanes Ridge. TJ1-92 was conducted for stock estimation of deep-sea fishes in the slope area around Iceland, B12-93, B10-95 and B6-96 were redfish surveys. Surveys TBA1-93,TM3-96 and TBR2-97 were aimed at stock estimation of Greenland halibut.

During the surveys in 1996 and 1997, length, sex, maturity stages, total mass, gutted mass and liver mass were recorded (Table 1). On these cruises it was also possible to sample some data on stomach contents.

All samples used in this study were caught in bottom trawl. In most cases, the codend was lined with fine-meshed net with mesh size 36-40 mm (Table 1). Otherwise, the mesh size was 135 or 155 mm. The average trawl distance in all surveys was 3.3 n.m. and the average trawling speed was 3.3 n.m./hour.

Total length (TL, cm) was measured to the nearest cm (from snout to the tip of the upper caudal lobe). For the weighing, a Marel M2000 balance was used.

Maturity stages were defined as suggested by M. Stehmann for the FAIR-project (unpublished). Maturity stages for males range from 1- to 4: (1) Immature. Claspers undeveloped and small, shorter than extreme tips of posterior pelvic fin lobes. Sperm ducts straight and thread-like. (2) Maturing. Claspers more extended, longer then than posterior pelvic fin lobes. Sperm ducts beginning to meander posteriorly. (3) Mature, adult. Claspers fully formed and their skeleton stiff. Gonads enlarged, filled with flowing sperm and sperm ducts tightly coiled, also well filled with sperm. (4) Active. Glans clasper dilated and swollen. Sperm flowing from cloaca under pressure. Female maturity stages are divided in 3 ovarian stages and 4 uterine stages. The three ovarian stages are: (1) Immature marked by small ovaries with gelatinous or granulated internal structure. Oviducts (uteri) are narrow, thread-like. (2) Maturing specimens where ovaries are somewhat enlarged and oocytes becoming differentiated to various small sizes. (3) Ovaries large and oocytes obviously enlarged mostly of same size. The four uterine stages are: (4) Developing. Uteri is well filled and rounded with seemingly unsegmented yolk content. (5) Differentiating. Uteri well filled and rounded with segmented content of large yolk balls. Embryos variously small and without pigments. (6) Expecting. Embryos more or less fully formed, pigmented, external gills lost and yolk sacs obviously reduced. (7) Post-natal, spent. Ovaries at resting stage, similar to stage 1 or 2. Uteri empty but still widened considerably.

For calculation of maturity ogives all stages from 2 to 7 were summarized against stage 1 (immature, "mature" being defined as stages 2-7 for both sexes).

The hepatosomatic index (HSI) was calculated by the formula: $HSI = (LW/TW)*100$ where LW is liver mass (g) and TW is total body mass (g).

The determination of stomach contents was made macroscopically and simultaneously on board. The prey was identified to the lowest taxa possible. The data were quantified with frequency of occurrence (Percentage of stomachs containing food with a particular prey item).

The data from the surveys TM3-96 and TBR2-97 were used for comparison between areas. These surveys were conducted during the same month (October 1996 and 1997) with similar trawl stations in the same area each year. The western area was defined as an area west of 24°W and the eastern area as east of 20°W.

For a more detailed analysis of the catches an area was chosen which is known to be a common fishing ground for Greenland halibut. This area is shown in Figure 3.

RESULTS

Centroscyllium fabricii

C. fabricii appeared throughout the entire survey area with the greatest density in the slope west and south-east off Iceland (Fig.1).

The mean length was 60.36 cm (n=2222, SD=12.85, range 16-106 cm). The mean length of males was 59.85 cm (SD=9.57) and the mean length of females was 62.02 cm (SD=13.55) (Table 2). The mean length decreased significantly with increasing depths, by 12.49 cm for males and 14.87 cm for females. The length distribution differed between the sexes. Most males were of the size class 61-70 cm (52%) with 25% in size class 51-60 cm. The length distribution of females was more uniform; 19% were found in size class 41-50 cm, 25% in size class 51-60 cm, 21% in size class 61-70 cm and 24% in size class 71-80 cm. In the larger size classes, (71-80 cm and >80 cm), females were more numerous than males. Most males were found in the depth strata 801-1000 m (47%) and in depths between 1001-1200 m (28%) (Fig.4). The most frequent size classes for males (51-60 cm and 61-70 cm) were observed in all depth strata with a peak in depths between 801-1000 m. Smaller size classes were almost absent below 800 m. 32% of the females were found in depth strata 801-1000m, 36% between 1001-1200 m and 25% in depths below 1200 m. Thus, females showed a wider distribution than males both in length and in depth range (Fig.4).

Males seemed to be more numerous than females in shallower depths and females showed a higher abundance in deeper water than males. This is reflected in the sex ratio by depth (Table 3). Over 1000 m, the sex ratio differed significantly in favour of females.

The length-weight relationship was similar for both sexes to the length of about 60 cm (Fig.5). The average total body mass was 1551 g for females and 1145 g for males.

Maturity

Maturity stages have been recorded in three surveys (Table 1), two of them during October 1996 and 1997 and one in June/July 1997. In the June/July survey 43% of males were immature (stage 1) and 47% maturing (stage2) and only 4% active (Fig.6). In October (both years) more males were mature or active (21% in stage 3 and 13% in stage 4) (Fig.7). The majority of females were immature (stage 1) in both seasons (67% in June/July and 70% in October) and spent specimen (stage 7) were about 10% (10% in the summer and 11% in October). Uterine stages (stages 4-6) were very rarely recorded during both seasons and only 3 specimens have been found expecting (October 1997).

The length at which 50% of the population has reached maturity was calculated. Males gained 50% maturity at 27.87 cm but females at 39.36 cm, which is a difference of 11.5 cm. It must be noted, however that males showed first 100% maturity at 64 cm and females at 70 cm.

Liver

The average hepatosomatic index (HSI) of black dogfish was 20% and was the same for males and females (Fig.8). The average HSI differed somewhat between immature males (n=146, mean=18%) and mature ones (n=295, mean=20%). The average HSI of females showed a difference between various maturity stages. It increased during ovarian development (stages 2 and 3) and decreased again during the uterine stages (4-6). Spent specimens (stage 7) showed again increasing values.

Stomachs

Of 316 stomachs examined 80 contained food but 236 (75%) were found empty. The most important prey categories as evaluated by frequency of occurrence, were teleosts (47,4%), crustaceans (44,7%) and cephalopods (28,9%) as shown in Table 4. The importance (frequency) of teleosts and crustaceans as a prey category differed between the size classes. In the largest size class (>70 cm) teleost fish were much more frequent whereas crustaceans as a prey had lower frequency than in the other two size classes. The frequency of cephalopods was similar in all size classes.

Areas

In the surveys TM3-96 and TBR2-97, 920 specimens were collected off West Iceland. *C. fabricii* was observed at 59 out of 127 stations taken in the western area (46% of stations) (Table 5). The mean depth at all stations was 865 m whereas the mean depth of hauls with *C. fabricii* was 1022 m. Off East Iceland, 165 specimens were obtained at 16 of 135 trawling stations (12%). The mean depth at all trawling stations in the eastern area was 624 m while the mean depth at stations with *C. fabricii* was 803 m. The mean bottom temperature at the stations where *C. fabricii* was found in both areas was higher than the mean bottom temperature of all hauls taken in same area (Table 5). The mean length of *C. fabricii* in the western area was 59.95 cm (SD=11.55) whereas the mean length of the specimens in the eastern area was 67.52 cm (SD=12.52). There were also differences in the length distribution; in the western area, the length ranged from 18 to 88 cm compared to 34-91 cm in the eastern area.

The maturity stages differed between the two areas (Fig.9). The majority of *C. fabricii* was immature in the western area. In the eastern area the majority of the males were mature but none were active. In the eastern area a much greater proportion of the females was mature. The mature specimens were found in ovarian stages or already spent, but the uterine stages were almost lacking.

Etmopterus princeps

E. princeps was like *C. fabricii* observed throughout the entire survey area (Fig. 2). The mean length was 57.75 cm (n=773, SD=14.68, range 12-89 cm) (Table 6). The mean length of males was 56.86 cm (SD=10.80) which is 5.51 cm smaller than the mean length of females (62.37 cm, SD=13.03). The mean length decreased significantly with increasing depths, i.e. by 9.44 cm for males and 17.79 cm for females (Table 6). The length distribution was similar for both sexes. 80% of the males were observed at lengths between 51 and 70 cm with a peak (45%) in the 61-70 cm size class. 80% of the females were between 51-80 cm (19% in the 51-60 cm size class and 25% in the 71-80 cm size class) and the peak (36%) in size class 61-70cm was the same as for the males. Females were more numerous in the larger size classes (>71 cm) than males. Both males and females seemed to have the highest abundance in the depth range between 801-1000 m (52% of the males, 46% of the females) but females were more numerous than males in depths below1000 m (Fig. 10). In depths to 800m the sex ratio did not differ significantly from 1:1 but in depths greater than 800 m, females showed higher abundance than males (Tab.7).

The length-weight relationship for both sexes is given (Fig.11). Average total body mass was 950 g for males and 1375 g for females.

Maturity

Maturity was recorded in three surveys (Table 1) as described above for *C. fabricii* covering two seasons, June/July and October. In June/July the majority of both sexes were immature (stage 1). 45% of males were mature (stage 2-4) whereas 9% were observed active (stage 4). 62% of females were immature (stage 1) and 15% were spent. In October the majority of both sexes was mature. Males were numerous at most stages except at the active stage (8% at stage 4). Mature females were frequently observed in ovarian stages (stages 2 and 3) and as spent (stage 7), but uterine stages were rarely found during both seasons (Figs 12 and 13).
The length at which 50% of the population has reached maturity was calculated for both sexes. Males were 24.45 cm and females 37.30 cm at 50% maturity. Thus, the females were 12.85 cm larger than males at 50% maturity. Males showed first 100% maturity at 65 cm and females at 79 cm.

Liver

The mean value of HSI was 20.4 % for males and 19.4% for females (Fig.14). The mean value for males was similar between immature males (n=34, mean=20%) and mature ones (n=64, mean=21%). Mean value of HSI for females showed the same pattern as described for *C. fabricii*; there was an increase during the ovarian development (stages 2 and 3) and decrease during the development of the embryos (stages 4-6). Spent specimens (stage 7) showed again increasing values.

Stomachs

74 stomachs were examined of which 32 were empty (43%). Teleosts were the most frequent prey category (Table 8) but consisted mostly of unrecognisable fish remains. Myctophids were most abundant as prey group of identified teleosts. Cephalopods and crustaceans had a similar occurrence (25.8%) in the food of *E. princeps*. The proportion of prey categories was similar in all size classes.

Areas

In the surveys TM3-96 and TBR2-97, 199 specimens were collected. In the western area, 95 specimens were collected at 36 out of 127 stations in this area (28%) (Table 9). The mean depth of all trawl stations was 865 m and the mean depth of trawl stations with *E. princeps* was 1019 m. In the eastern area, 104 specimens were caught at 12 out of 135 stations. The mean depth of all trawling stations was 624 m, whereas the mean depth of trawling stations with *E. princeps* was 782 m.
The mean bottom temperature at stations containing *E. princeps* was in both areas higher than the mean temperature of all stations (Table 9). The lowest bottom temperature in which *E. princeps* was observed was 2.00°C (eastern area, <601 m in depth) and the highest was 6.40 (western area, <601 m). *E. princeps* was most abundant in both areas at temperatures around 4.00°C.
The mean length of specimens found in the western area was 63.60 cm (SD= 8,82, range 25-77 cm). The mean length in the eastern area was somewhat smaller (57.98 cm, SD=13,14) but the length range varied from 19 cm to 80 cm (Table 9).

The maturity differed between the two areas (Fig. 15). More males were found immature in the western area than in the eastern one. In the eastern area many specimens were in stage 3 but none were active in that area. Most females in the western area were immature (30%) or spent (32%). In the eastern area the majority of females were immature (61%) and none were found in the uterine stages (stages 4-6).

Catch proportions

The catch proportion of *R. hippoglossoides, C. fabricii* and *E. princeps* were calculated for the area shown in Figure 3 from surveys TM3-96 and TBR2-97. The catches were similar in both years (Table 10). The proportion of the black dogfish of the total catch of these three species was 22-23 % and the proportion of the greater lantern shark was about 2% for both years.

DISCUSSION

C. fabricii is the most common deep sea dogfish in Icelandic waters and the catches can be considerably high especially in certain areas west of Iceland. *E. princeps* was also found throughout the western area but in lower densities than the black dogfish. In the eastern area, the greater lantern shark seems to have a relatively high abundance compared to the black dogfish. It is also abundant along the Reykjanes Ridge and its geographical distribution extends further southward than the distribution of *C. fabricii* (it was observed as far south as to 56° N). The geographical distribution of these species in Icelandic waters have already been described (Magnússon and Magnússon 1995, Magnússon et al. 1998).

Both species show a similar bathymetric distribution in Icelandic waters (Figs.1 and 2) with the highest abundance in depths from 800-1200 m. *C. fabricii* is recorded in the Rockall Trough at the 1250 m and 1500 m bathymetric zones but *E. princeps* is distributed over a wide bathymetric zone, from 750 m to 1500 m (Gordon and Duncan, 1985). There are records of *E. princeps* from 689 to 1861 m in this area (Mauchline and Gordon, 1983). Yano (1995) reported the distribution of *C. fabricii* being between 500 and 1300 m in waters off West Greenland. Thus, the shallowest records of *C. fabricii* in Icelandic waters lie between those reported for the Rockall Trough and West Greenland waters. The bottom temperature showed that both species seem to be most abundant at about 3.5-4.5°C. This is the bottom temperature recorded for *C. fabricii* (Compagno,1984). In the eastern area, the bottom temperature seems to be an important limiting factor of the distribution of these species.

The length distribution differ between the sexes in both species, the females being larger than males and reaching maturity at a larger size. This indicates a sexual dimorphism for both species. A difference in the length range between the sexes is also recorded by Magnússon and Magnússon (1995) and Magnússon et al. (1998). A sexual dimorphism is also recorded for *C. fabricii* (females being larger than males) in West Greenland waters (Yano, 1995).

The tendency of smaller specimens being in greater depths than the larger ones was found for both species. This is different from what Yano (1995) observed for *C. fabricii* in West Greenland waters where he recorded an increase in mean length of both sexes with increasing depth.

Females of *C. fabricii* were more numerous than males, the overall sex ratio being 1.00:1.19. The proportion of the sexes was different depending on depth strata, with males were numerous in shallower depths but females more numerous in greater depths (over 1000 m). Yano (1995) recorded the sex ratio in shallower depths not

being significant from 1:1 down to 1000 m but below 1000 m, females were more numerous than males in western Greenland waters.
The overall sex ratio for *E. princeps* was also in favour of females (1.00:1.59). In depths below 800 m the sex ratio did not differ from equal but in depths below 800 m females were significantly more numerous.

Records of maturity stages were from two different seasons. More males of *C. fabricii* seemed to be active in October than during the summer time and in both seasons the majority of females were immature. For *E. princeps,* immature specimens of both sexes were more numerous during the summer survey than in the October surveys. A comparison of these two seasons indicates that neither *C. fabricii* nor *E. princeps* have a breeding season during June/July or October. *C. fabricii* is recorded to be without well defined breeding season in West Greenland waters (Yano, 1995). Presumably, *C. fabricii* and *E. princeps* have no defined breeding season in Icelandic waters but records of maturity stages need to be made more frequently throughout the year.

Uterine stages were rarely found both seasonally and geographically. Yano and Tanaka (1988) suggested that pregnant females of the deep sea squaloid sharks *Centroscymnus owstoni* and *Centroscymnus coelolepis* move into nursery areas, probably into deeper water. Perhaps the females in uterine stages of *C. fabricii* and *E. princeps* are bathypelagic and are not reachable by bottom trawls during gestation and littering period or they move to nursery areas in deeper water.

A depth segregation due to maturity has been observed for several deep sea squaloid sharks (Yano and Tanaka, 1988, Munoz-Chapuli, 1984). Further a segregation by sex and size has been observed for several other deep water sharks (Yano and Tanaka, 1983). There is an indication of a segregation by sex and size for *C. fabricii* and *E. princeps*. Yet, a segregation due to maturity was not found in our material.

Comparing different areas during the same season showed a difference in maturity in both species. More specimens of *C. fabricii* of both sexes were mature in the eastern area. Small specimens of *C. fabricii* were absent in the eastern area, (the smallest specimen observed was 34 cm) which might suggest that juvenile black dogfish have other distribution in this area than adults.
Also in *E. princeps,* there was a difference in the maturity between areas. Unlike *C. fabricii,* immature females were more numerous in the eastern area than in the western one. The length range was similar between those two areas.

The study on diets shows a high frequency of teleost prey for *C. fabricii* especially in the larger size classes where 82% of individuals larger than 70 cm fed on teleosts. Mauchline and Gordon (1983) studied diets of *C. fabricii* and *E. princeps* from the Rockall Trough and suggested *C. fabricii* to be principally a fish eater. Sedberry and Musick (1978) analysed a few specimens of *C. fabricii* feeding on fish, myctophid and crustacean fragments. Ebert et al. (1992) report *C. fabricii* to feed extensively on myctophids in South African waters. Older records of diets have reported cephalopods and medusae from Greenland waters (Bigelow and Schroeder, 1948) and Clarke and Merrett (1972) found decapod remains in a single specimen caught off northwest Africa. The present observation on feeding of *C. fabricii* in Icelandic waters supports the suggestion that the larger size classes prey mainly on fish but the smaller specimens seem to have a more varied diets consisting of teleosts, crustaceans and cephalopods.

E. princeps fed mainly on teleosts but the proportion of the three main prey categories were similar between size classes. Mauchline and Gordon (1983) suggested that *E. princeps* feed on micronekton probably at levels above the sea bed. High frequency of myctophids in stomachs may support this.

The proportion of liver weight to body weight (HSI) of both species is about 20% and is similar to records for other several squaloid sharks (Hareide, 1997 for several species, Yano 1995 for *C. fabricii*; Batista and Nunes,1992 for several species).

On a common fishing ground for Greenland halibut off West Iceland the catch of *C. fabricii* compared to *R. hippoglossoides* was considerable. This may suggests a substantial discard of the black dogfish. The catch of Greenland halibut in the same area and month (October) was in 1996, 427 tons and in 1997, 495 tons. Using the same proportion as calculated from the surveys it would mean that the discard of black dogfish in 1996 in this area and month might have been about 98 tons (9 tons of the greater lantern shark) and in 1997, about 109 tons (10 tons of the greater lantern shark). During the surveys the stations are taken systematically throughout the examined area whereas the fleet is more or less "following" the main density of Greenland halibut at each time. However *C. fabricii* and *E. princeps* were widely distributed throughout the area so these species may be a frequent bycatch in the Greenland halibut fishery off West Iceland. Records of the catch proportions of the fleet in this area are needed for an evaluation of the discard of these two species.

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REFERENCES

Batista, I. And M.L. Nunes, 1992. Characterisation of shark liver oils. Fish.Res.,**14**,329-334.

Bigelow, H.B. and W.C. Schroeder, 1948. Sharks. Mem. Sears.Fdn. mar. Res. 1, 59-546.

Clarke, M.R. and N. Merrett, 1972. The significance of squid, whale and other remains from the stomachs of bottom living deep-sea fish. J. mar. biol. Ass. U.K.,**52**, 599-603.

Compagno, L.J.V., 1984. FAO species catalogue, vol.4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date, part 1. Fisheries Synopsis. FAO, no.125, 249 pp.

Ebert, D.A., L.J.V. Compagno, P.D. Cowley, 1992. A preliminary investigation of the feeding ecology of squaloid sharks off the west coast of southern Africa. South African Journal of marine science/Suid-Afrikaanse tydskrif vir seewetenskap. Cape Town, **12**,601-609.

Gordon, J.D.M. and J.A.R. Duncan, 1985. The ecology of the deep-sea benthic and benthopelagic fish on the slopes of the Rockall Trough, Northeastern Atlantic. Prog. Oceanog., **15**, 37-69.

Haedrich, R.L. and G. Krefft, 1978. Distribution of bottom fishes in the Denmark Strait and Irminger Sea. Deep-Sea Research, **25**, 705-720.

Haedrich, R.L. and N.R. Merrett, 1988. Summary atlas of deep-living demersal fishes in the North Atlantic Basin. Journal of Natural History, **22**, 1325-1362.

Hareide, N.R., 1997. Rapport frå forsöksfiske på Midt-Atlanterhavsryggen med M/S Loran August - September 1996. Report no. Å9701, Möreforsking Ålesund, 53 pp.

Jónsson, G., 1992. Íslenskir fiskar. Fjölvaútgáfan, Reykjavík, 568pp.

Kotthaus, A. and G. Krefft, 1967. Observations on the distribution of demersal fish on the Iceland-Faroe ridge in relation to bottom temperatures and depths. Rapports et Procès-Verbaux des Réunions du Conseil International de la Mer, **157**,238-267.

Magnússon J.V. and J.Magnússon, 1995. The distribution, relative abundance, and biology of the deep-sea fishes of the Icelandic slope and Reykjanes ridge. In: A. G. Hopper (ed.), Deep-water fisheries of the North Atlantic Slope, NATO ASI Series E, Vol. **296**,161-199.

Magnússon, J., V. Vilhelmsdóttir, K.B. Jakobsdóttir, 1998. Djúpslóð á Reykjaneshrygg. Könnunarleiðangrar 1993 og 1997 (Deep water araea of the Reykjanes Ridge. Research surveys in 1993 and 1997). Hafrannsóknastofnun fjölrit, nr.65, 50pp.

Mauchline, J. and J. D. M. Gordon, 1983. Diets of the sharks and chimaeroids of the Rockall Trough, northeastern Atlantic Ocean. Marine Biology, **75**, 269-278.

Munoz-Chapuli,R.,1984. Reproduction behaviour of some sharks from the northeastern Atlantic (Ethologie de la reproduction chez quelque requins de l'Atlantique Nord-Est. CYBIUM, **8**, no.3, 1-14.

Sedberry, G.R. and J.A. Musick, 1978. Feeding strategies of some demersal fishes of the continental slope and rise off the Mid-Atlanic coast of the USA. Marine biology,**44**, 357-375.

Snelgrove, P.V.R. and R. L. Haedrich, 1985. Structure of the deep demersal fish fauna off Newfoundland. Mar.Ecol.Prog.Ser.,**27**, 99-107.

Whitehead, P.J.P., M.-L. Bauchot, J.-C. Hureau, J. Nielsen and E. Tortonese (editors) 1984. Fishes of the Nort-eastern Atlantic and the Mediterranean. Volume 1.UNESCO, 509 pp.

Yano, K. and S. Tanaka, 1983. Portuguese shark, *Centroscymnus coelolepis* from Japan, with notes on *C. owstoni*. Japanese Journal of Ichtyology(Japan), vol.**30**(3), 208-216.

Yano, K. and S. Tanaka, 1988. Size at Maturity, reproductive cycle, fecundity, and depth segregation of the deep sea squaloid sharks *Centroscymnus owstoni* and *C. coelolepis* in Suruga bay, Japan. Nippon Suisan Gakkaishi, **54**,167-174.

Yano, K., 1995. Reproductive biology of the black dogfish, *Centroscyllium fabricii*, collected from waters off western Greenland. Journ. Mar. Biol. Ass. U.K., **75**, No.2, 285-311.

Table 1. Overview over data used for both species. Surveys are listed in chronological order. All samples were taken with bottom trawl.

Centroscyllium fabricii

Cruise-year	Date	Area (FAIR)	Mesh size (mm)	total length male	total length female	total length unsex.	maturity male	maturity female	total weight male	total weight female	gutted weight male	gutted weight female	liver weight male	liver weight female	stomachs
TJ1-92	May-June	04/05	135-155	281	278	16	-	-	-	-	-	-	-	-	-
B3-93	March	04/05	40	49	11	160	-	-	-	-	-	-	-	-	-
S1-93	March	04	135	28	24	-	-	-	-	-	-	-	-	-	-
TBA1-93	Sep-Oct	05	40	19	33	7	-	-	-	-	-	-	-	-	-
B10-95	June	04/07	-	12	2	-	-	-	12	2	-	-	-	-	-
B6-96	June-July	04	40	8	2	9	-	-	-	-	-	-	-	-	-
TM3-96	June-July	04/05	40	166	248	83	129	200	190	249	-	-	-	-	-
KA1-97	Oct	04/07	36	74	127	1	73	125	83	144	80	133	55	115	17
TBR2-97	Oct	04-05	40	253	330	2	253	329	194	285	177	269	177	268	286
TOTAL				890	1055	278	455	654	479	680	257	402	232	383	303

Etmopterus princeps

Cruise	Date	Area (FAIR)	Mesh size (mm)	total length male	total length female	total length unsex.	maturity male	maturity female	total weight male	total weight female	gutted weight male	gutted weight female	liver weight male	liver weight female	stomachs
TJ1-92	May-June	04/05	135-155	20	32	-	-	-	-	-	-	-	-	-	-
B3-93	March	04/05	40	22	32	109	-	-	-	-	-	-	-	-	-
B12-93	Sept	04/07	135	-	-	5	-	-	-	-	-	-	-	-	-
S1-93	March	04	135	33	66	-	-	-	-	-	-	-	-	-	-
TBA1-93	Sep-Oct	05	40	4	9	3	-	-	-	-	-	-	-	-	-
B6-96	June	04	40	10	1	8	-	-	-	-	-	-	-	-	-
TM3-96	Oct	04/05	40	37	46	13	35	44	40	49	-	-	-	-	-
KA1-97	June-July	04/07	36	73	143	4	68	133	85	149	61	119	61	117	15
TBR2-97	Oct	04-05	40	45	58	-	45	58	41	51	39	49	37	49	57
Total				244	387	142	148	235	166	249	100	168	98	166	72

Table 2. *C. fabricii.* Mean length shown by depth strata. The decrease in length by depth was significant ($F_{1,2218}$= 139, p<0.001).

			Length (TL,cm)						
						Males		Females	
Depth-strata	n	%	Mean	Min	Max	n	Mean	n	Mean
<601m	51	2.3	66.18	33	83	28	63.82	15	72.80
601-800m	205	9.2	63.17	16	86	109	62.80	59	70.05
801-1000m	822	37.0	62.32	16	106	418	61.78	337	63.66
1001-1200m	734	33.0	60.09	22	88	244	57.81	379	61.75
>1200	410	18.5	54.55	20	89	87	51.33	265	57.93
	2222	100	60.36			886	59.85	1055	62.02

Table 3. *C. fabricii.* Number, Sex ratio and χ^2 in each depth strata. Asterisks indicate significance.

n=1941

depth-range	male	female	sex ratio	χ^2
<601m	28	15	**1.00:0.54**	3.9**
601-800m	109	59	**1.00:0.54**	14.9*
801-1000m	418	337	**1.00:0.81**	8.7*
1001-1200m	244	379	**1.00:1.55**	29.3*
1201-1400m	75	217	**1.00:2.89**	69.1*
>1400m	12	48	**1.00:4.36**	21.6*
Total	*886*	*1055*	**1.00:1.19**	*147.5*

* significant if p<0.01,** significant if p<0.05

Table 4. *C. fabricii.* Stomach contents by three size classes. Percentage of stomachs containing food with a particular prey.

	Length groups (TL,cm)			
	<61	61-70	>70	total
Stomachs with prey	25	27	28	80
Empty stomachs	106	73	44	223
Freq. of Occurrence (%)				
Teleostei	**24.0**	**40.7**	**82.1**	**48.7**
Argentinidae	0.0	3.7	0.0	1.3
Macrouridae	4.0	7.4	3.6	3.9
Micromesistius poutassou	0.0	0.0	21.4	7.9
Myctophidae	8.0	0.0	0.0	2.6
Paralepididae	0.0	0.0	7.1	2.6
Sebastes sp.	0.0	0.0	14.3	3.9
Teleosts guts	0.0	3.7	0.0	1.3
Teleosts unid.	12.0	25.9	35.7	25.0
Cephalopoda	**36.0**	**37.0**	**21.4**	**30.3**
Todarodes sagittatus	16.0	11.1	0.0	9.2
Octopoda	0.0	3.7	0.0	1.3
unidentified	20.0	22.2	21.4	19.7
Crustacea	**56.0**	**51.9**	**21.4**	**44.7**
Euphausiacea	20.0	22.2	10.7	18.4
Hymenodora glacialis	20.0	7.4	0.0	9.2
Pasiphacea	0.0	0.0	3.6	1.3
Natantia	4.0	3.7	3.6	3.9
unidentified	12.0	18.5	3.6	11.8
Other prey items	**12.0**	**0.0**	**10.7**	**7.9**
Polychaeta	4.0	0.0	3.6	2.6
Scyphozoa	8.0	0.0	7.1	5.3
Unidentified material	**12.0**	**11.1**	**17.9**	**14.5**

Table 5. *C. fabricii.* TM3-96 and TBR2-97. Number of all hauls and those containing *C. fabricii*, average temperatures, number of specimens and mean length. All given at each depth strata and each area.

W-Iceland (>24° W)

	All hauls in W-area		Hauls with *C.fabricii*			
depth strata (m)	All stations	Bottom temp °C	*C.fabricii* no.stat.	Bottom temp °C	*C.fabricii* no.indiv.	Mean length (TL,cm)
<601	29	3.74	3	6.27	9	63.11
601-800	26	3.43	11	5.41	114	63.26
801-1000	21	3.37	12	4.78	255	59.35
1001-1200	34	3.98	21	4.12	375	60.31
>1200	17	3.01	12	3.74	167	57.65
total/*average*	127	*3.58*	59	*4.42*	920	*59.95*

E-Iceland (<20° W)

	All hauls in E-area			Hauls with *C.fabricii*		
depth strata (m)	All stations	Bottom temp °C	*C.fabricii* no.stat.	Bottom temp °C	*C.fabricii* no.indiv.	Mean length (TL,cm)
<601	70	0.09	4	2.13	18	67.5
601-800	29	-0.01	7	3.00	28	66.93
801-1000	26	-0.18	5	3.62	119	67.66
1001-1200	10	-1.19	-	-	-	-
>1200	-	-	-	-	-	-
total/*average*	135	*-0.32*	16	*3.36*	165	*67.52*

Table 6. *E. princeps.* Mean length shown by depth strata. The decrease of length by depth was significant ($F_{1,771}$= 115, p<0.001).

			Length (TL,cm)			Males		Females	
Depth strata	n	%	Mean	Min	Max	n	Mean	n	Mean
<601m	20	2.6	55.85	22	75	12	55.58	5	69.06
601-800m	91	11.8	63.49	25	82	34	60.88	36	67.39
801-1000m	357	46.2	60.61	12	89	127	58.83	179	65.37
1001-1200m	167	21.6	56.8	18	77	34	57.56	84	64.43
>1200m	138	17.9	47.93	12	76	37	46.14	83	51.27
	773	100.0	57.75			244	56.86	387	62.37

Table 7. *E. princeps*. Number, Sex ratio and χ^2 in each depth strata. Asterisks show significant values.

n=631

Depth strata	male	female	sex ratio	χ^2
<601m	12	5	**1:0.42**	n.s
601-800m	34	36	**1:1.06**	n.s.
801-1000m	127	179	**1:1.41**	8.8*
1001-1200m	34	84	**1:2.47**	21.2*
1201-1400m	21	52	**1:2.48**	13.2*
>1400m	16	31	**1:1.94**	4.8**
Total	*244*	*387*	**1:1.59**	*50.9*

* significant if p<0.01, ** significant if p<0.05

Table 8. *E. princeps*. Stomach contents by three size classes. Percentage of stomachs containing food with a particular prey.

	Length groups (TL,cm)			
	<61	61-70	>70	total
Stomachs with prey	17	21	4	42
Empty stomachs	6	21	5	32
Freq. of Occurrence (%)				
Teleostei	**39.1**	**45.2**	**37.5**	**41.9**
Gadidae	0.0	3.2	0.0	1.6
Micromesistius poutassou	4.3	6.5	0.0	4.8
Myctophidae	13.0	6.5	12.5	9.7
Paralepididae	8.7	3.2	0.0	4.8
Scopelosaurus lepidus	4.3	0.0	0.0	1.6
Teleosts unid.	8.7	25.8	25.0	19.4
Cephalopoda	**21.7**	**25.8**	**37.5**	**25.8**
Todarodes sagittatus	0.0	3.2	12.5	3.2
unidentified	21.7	22.6	25.0	22.6
Crustacea	**26.1**	**25.8**	**25.0**	**25.8**
Euphausiacea	4.3	12.9	0.0	8.1
Hymenodora glacialis	4.3	6.5	0.0	4.8
Natantia	4.3	3.2	12.5	4.8
unidentified	13.0	3.2	12.5	6.5
Unidentified material	**13.0**	**3.2**	**0.0**	**6.5**

Table 9. *E. princeps*. TM3-96 and TBR2-97. Number of all hauls and those containing *E. princeps*, average temperatures, number of specimens and mean length. All given at each depth strata and each area.

W-Iceland (>24° W)

	All hauls in W-area		Hauls with *E.princeps*			
depth strata(m)	All stations	Bottom temp °C	*E.princeps* n.stat.	Bottom temp °C	*E.princeps* no.indiv.	Mean length (TL,cm)
<601	29	3.74	1	6.40	2	57.00
601-800	26	3.43	8	5.25	13	60.39
801-1000	21	3.37	14	3.98	33	64.58
1001-1200	34	3.98	8	4.07	27	63.96
>1200	17	3.01	5	3.85	20	64.25
total/*average*	127	*3.58*	36	*4.20*	95	*63.60*

E-Iceland(<20° W)

	All hauls in E-area			Hauls with *E.princeps*		
depth strata(m)	All stations	Bottom temp °C	*E.princeps* n.stat.	Bottom temp °C	*E.princeps* no.indiv.	Mean length (TL,cm)
<601	70	0.09	1	2.00	9	66.44
601-800	29	-0.01	6	2.60	39	64.46
801-1000	26	-0.18	5	3.78	56	52.17
1001-1200	10	-1.19	-	-	-	-
>1200	-	-	-	-	-	-
total/*average*	135	*-0.07*	12	*3.2*	104	*57.98*

Table 10. *R. hippoglossoides, C. fabricii* and *E. princeps*.
Catches of three species taken from defined area west off Iceland in surveys TM3-96 and TBR2-97.

	TM3-96		TBR2-97	
Species	Catch (kg)	%	Catch (kg)	%
R. hippoglossoides	1844	74.7	2328	76.7
C. fabricii	568	23.0	657	21.6
E. princeps	56	2.3	52	1.7
Total	2468	100.0	3037	100.0

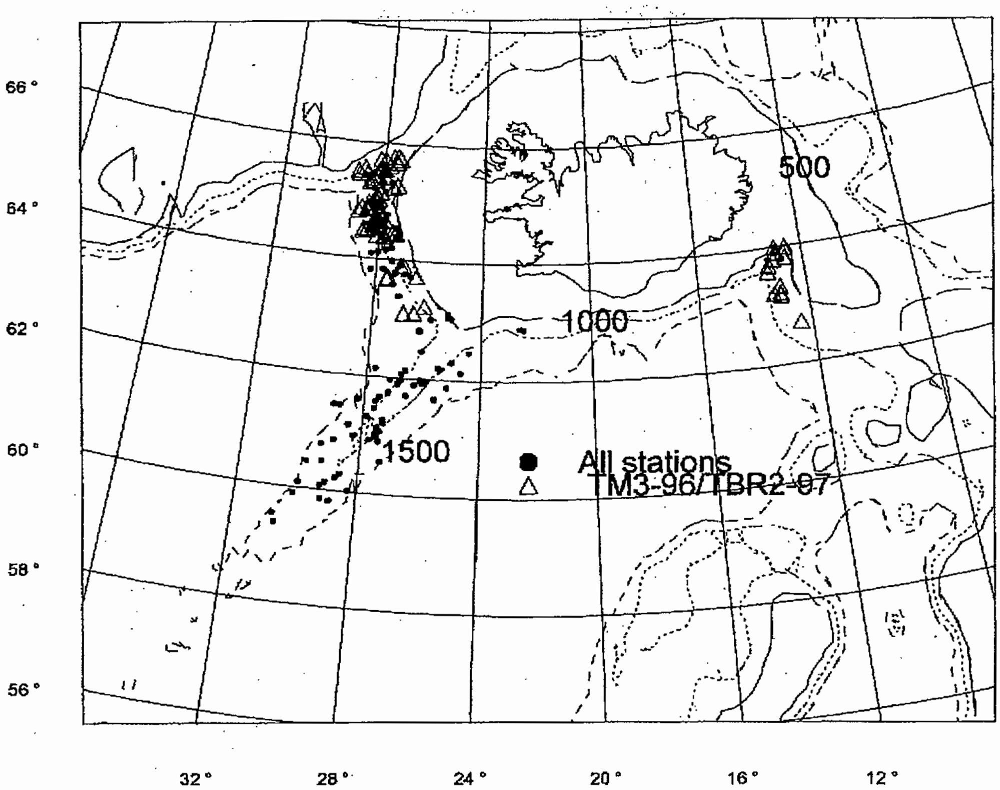

Figure 1. *Centroscyllium fabricii.* All sampling stations. TJ2/92, B3/93, S1/93, TBA1/93, B10/95, B6/96 and KA1/97 are shown with filled circles. TM3/96 and TBR2/97 are shown with triangles. 500,1000 and 1500 m depth lines are indicated.

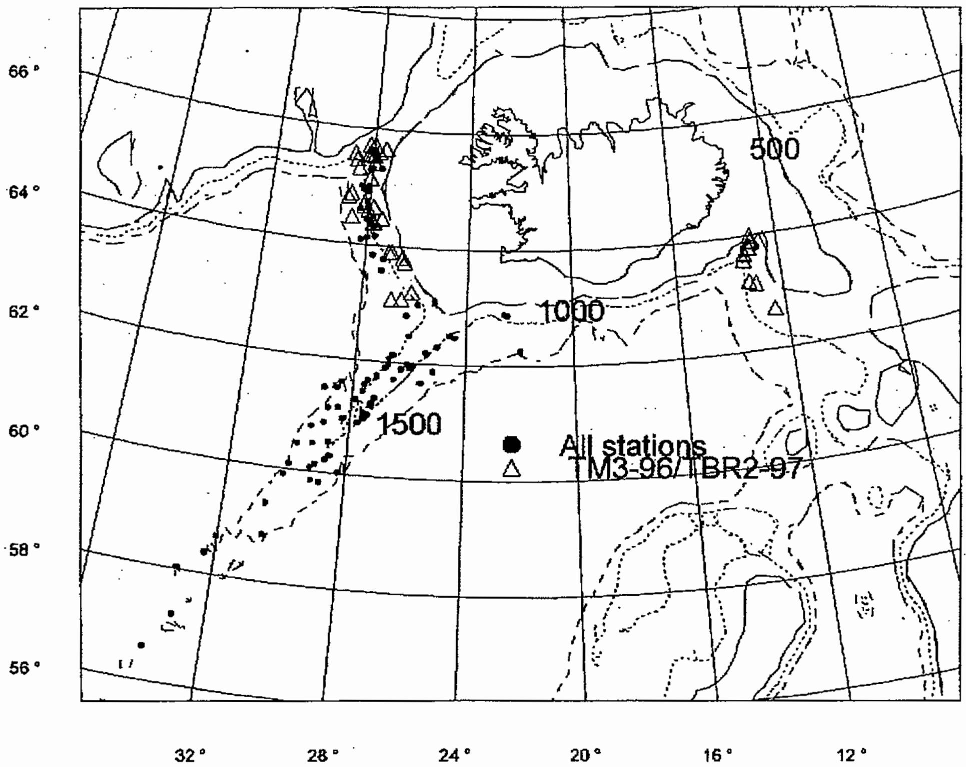

Figure 2. *Etmopterus princeps.* All sampling stations. TJ1/92, B3/93, B12/93, S1/93, TBA/93, B6/96 and KA1/97 are shown with filled circles. TM3/96 and TBR2/97 are shown with triangles. 500,1000 and 1500 depth lines are indicated.

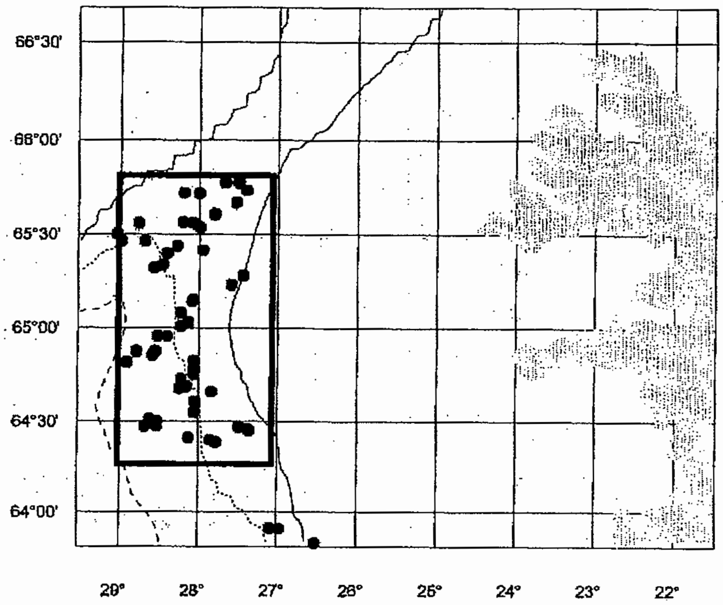

Figure 3. Surveys TM3-96 and TBR2-97. Defined area (64°30'-66°00'N and 27°00'-29°00' W). Filled circles: stations with *C. fabricii* and *E. princeps.*

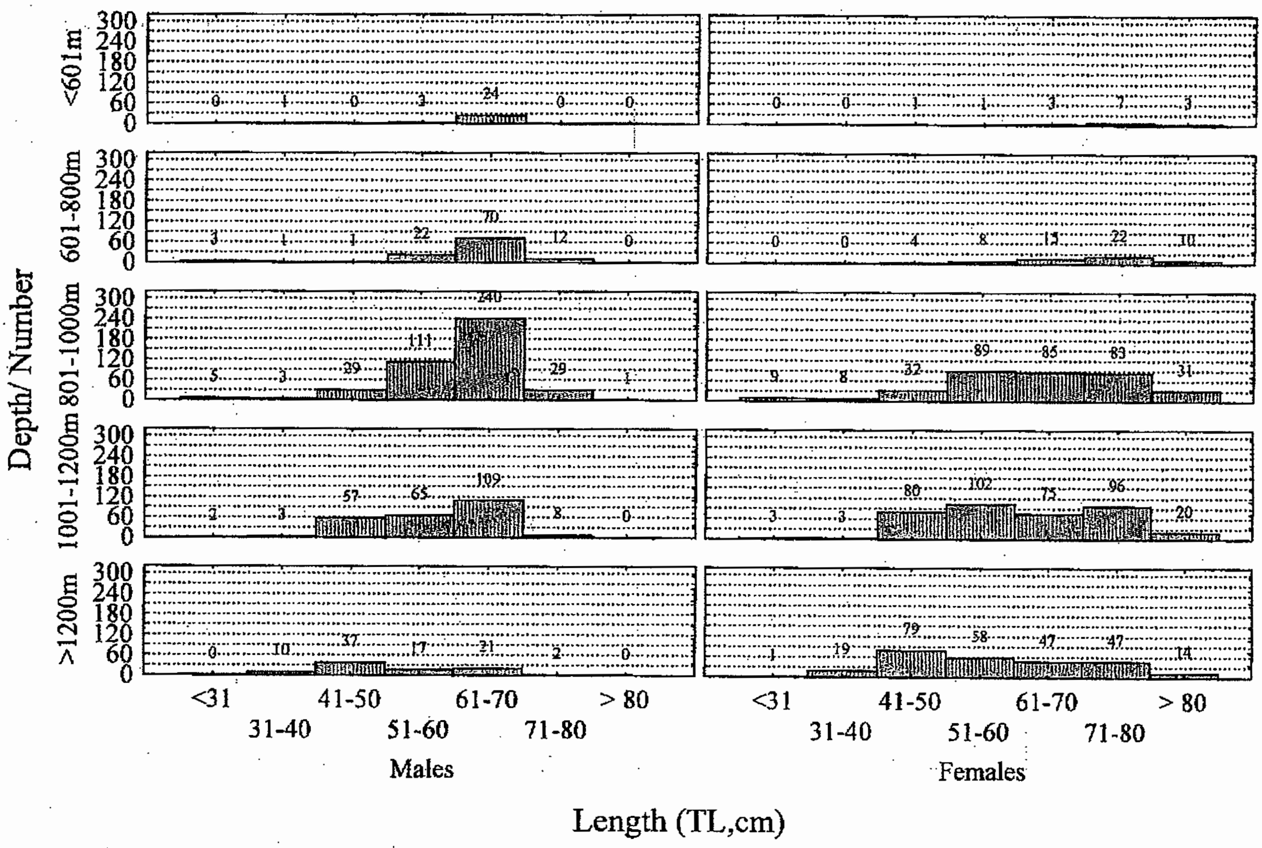

Figure 4. *C. fabricii.* Length distribution in each size class by 200 m depth intervals.

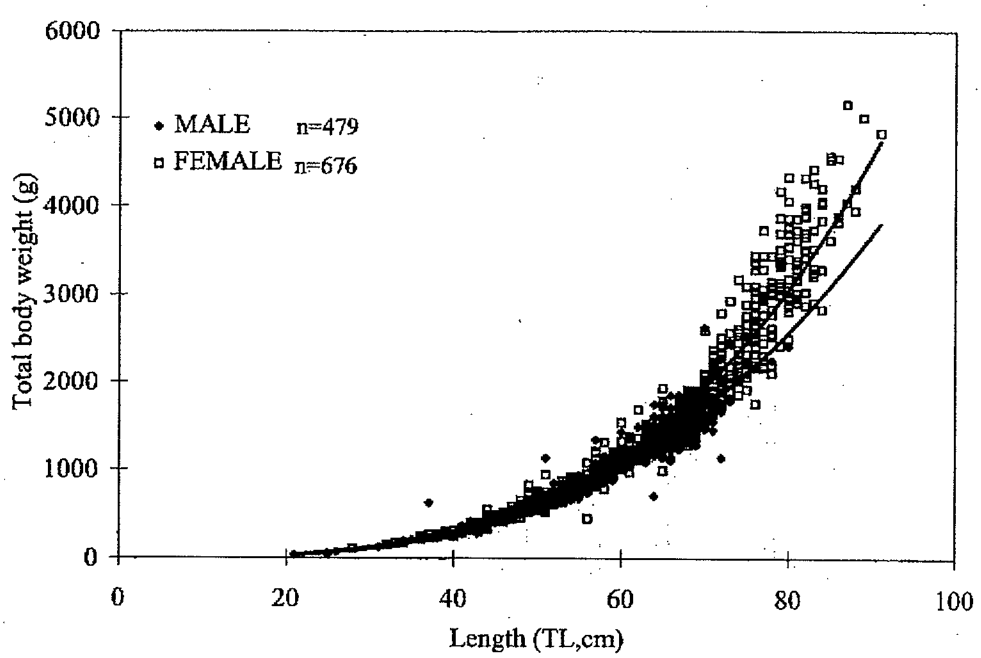

Figure 5. *C. fabricii.* Length-weight relationships.
Males: $W=0.004xTL^{3.050}$ $r^2= 0.9549$. Females: $W= 0.001x\ TL^{3.399}$ $r^2=0.9763$.

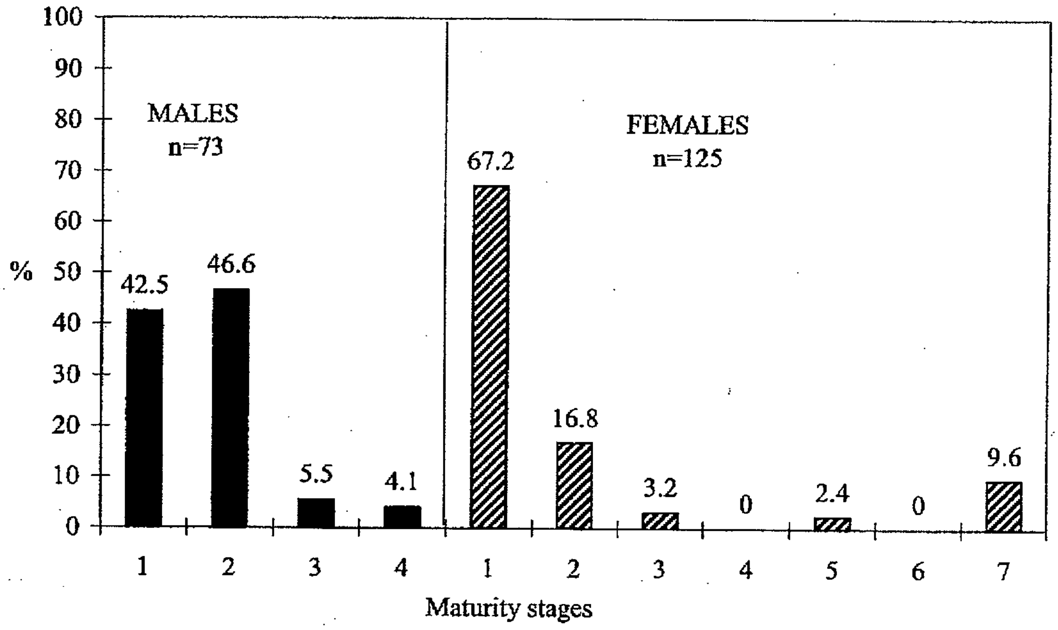

Figure 6. *C. fabricii.* Maturity stages in June-July. Survey KA1-97.

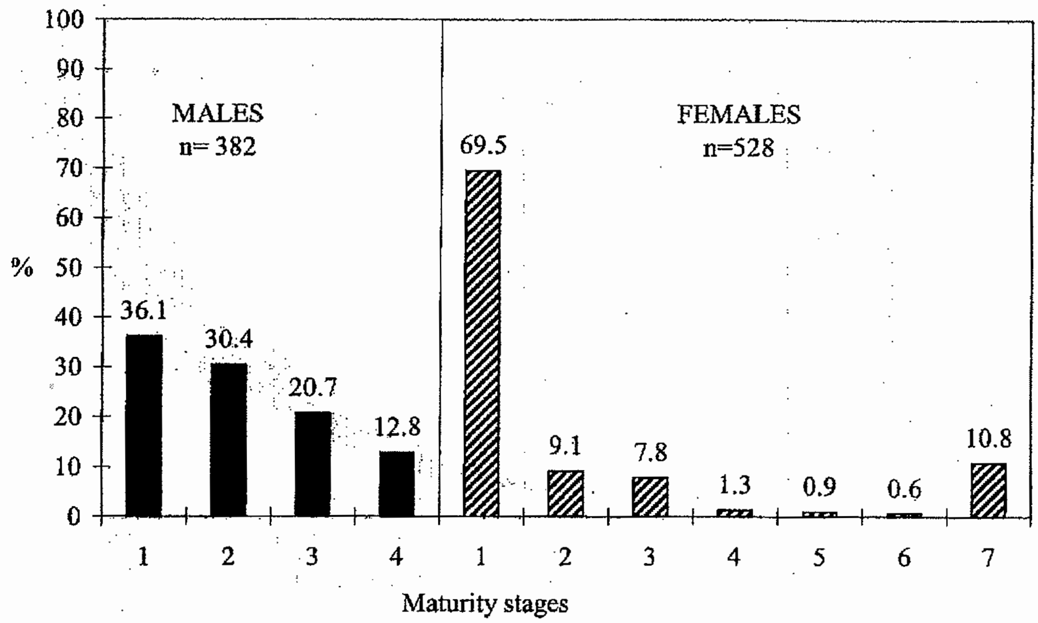

Figure 7. *C. fabricii.* Maturity stages October '96 and '97. Surveys TM3-96 and TBR2-97.

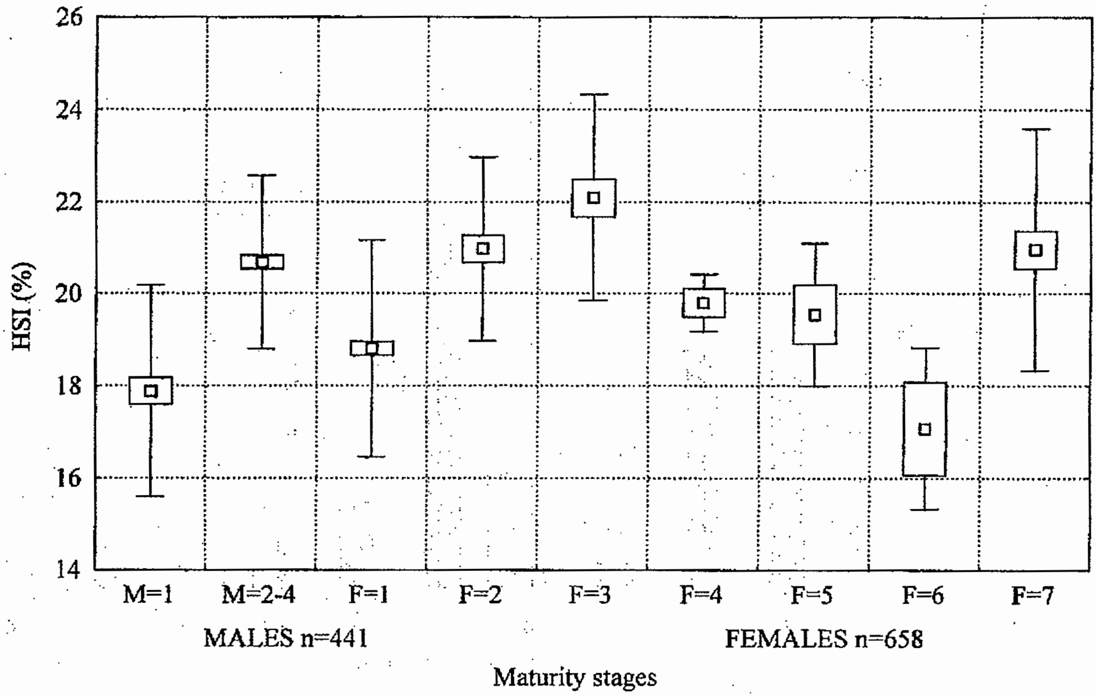

Figure 8. *C. fabricii.* Proportion liver weight of total body weight (HSI, %) given by maturity stages (M= males, F= females). Boxes show mean value and standard error, vertical bars show standard deviation from the mean.

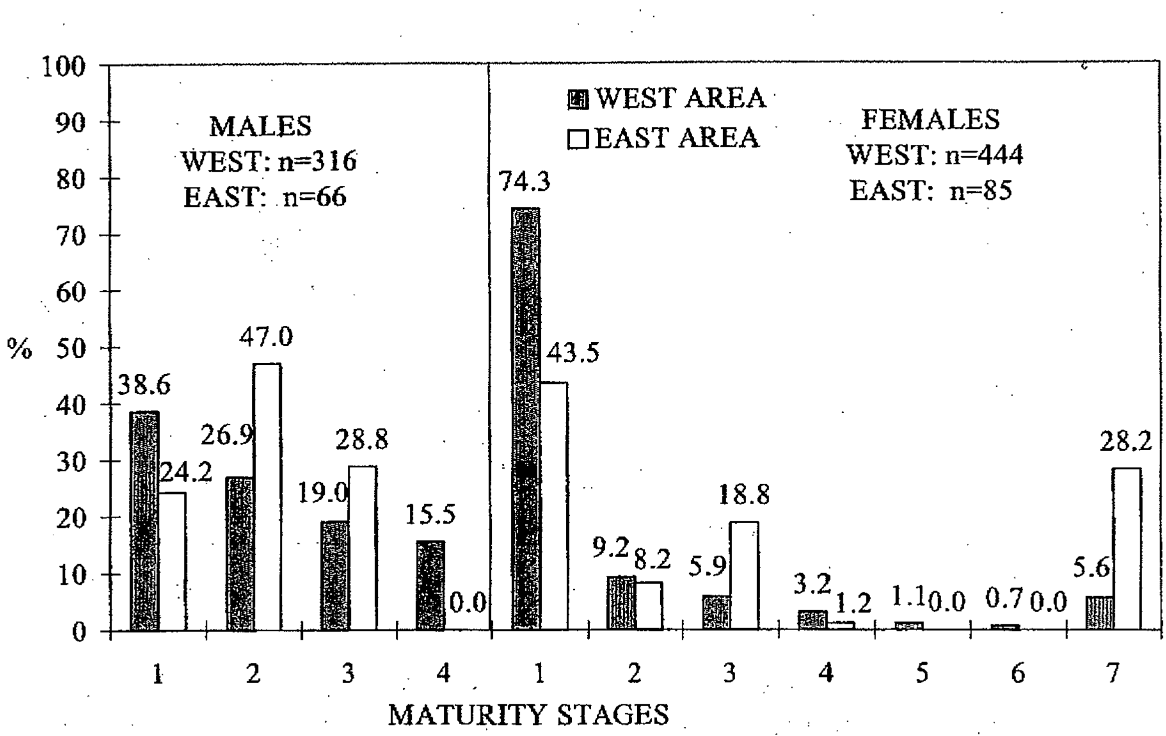

Figure 9. *C. fabricii.* Maturity stages in western area(>24°W) and eastern area (<20°W).

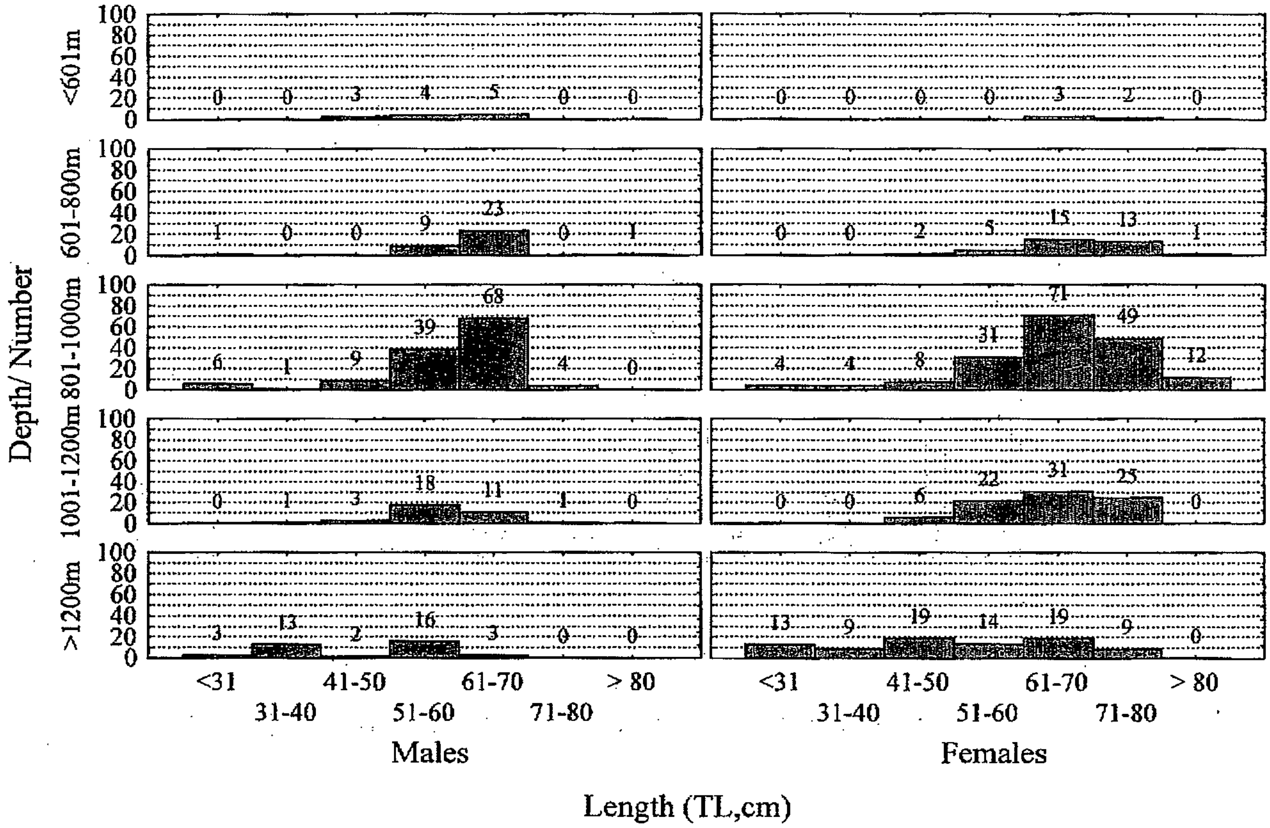

Figure 10. *E. princeps.* Length distribution in each size class by 200 m depth intervals.

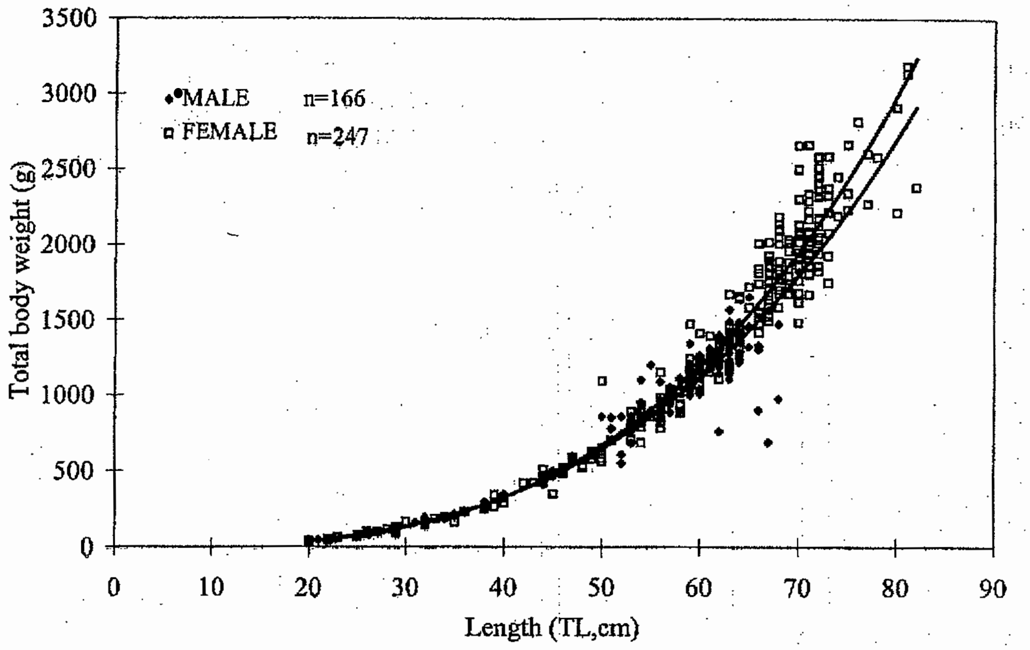

Figure 11. *E. princeps*. Length- weight relationships.
Males: $W=0.003xTL^{3,196}$, $r^2=0.9873$. Females: $W=0.004xTL^{3,058}$, $r^2=0.9793$.

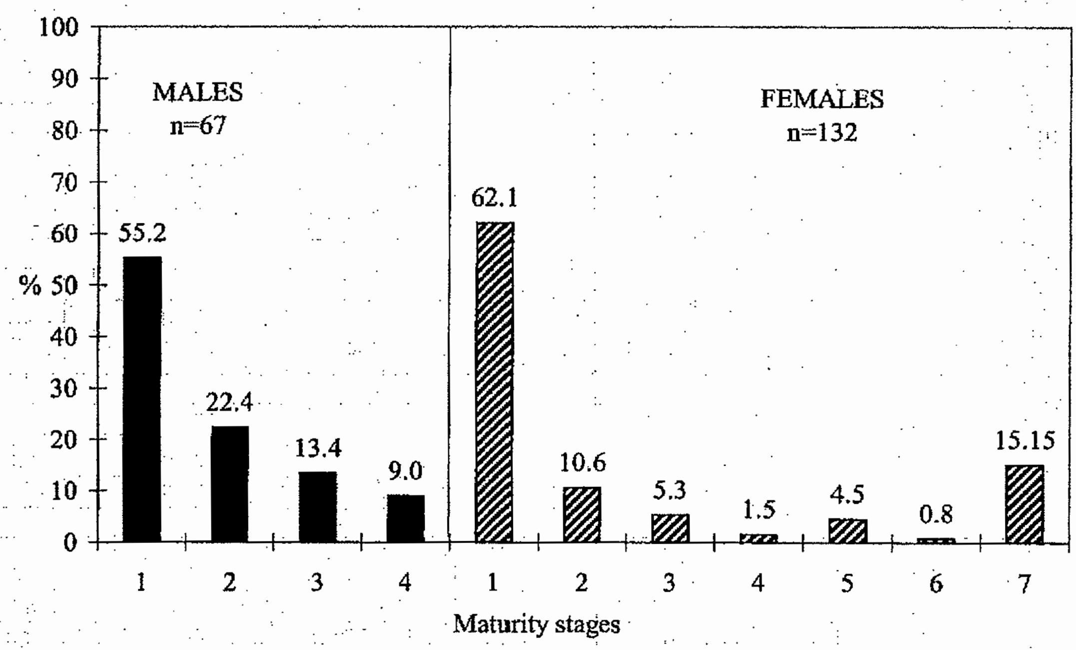

Figure 12. *E. princeps*. Maturity stages in June/July. Survey KA1-97.

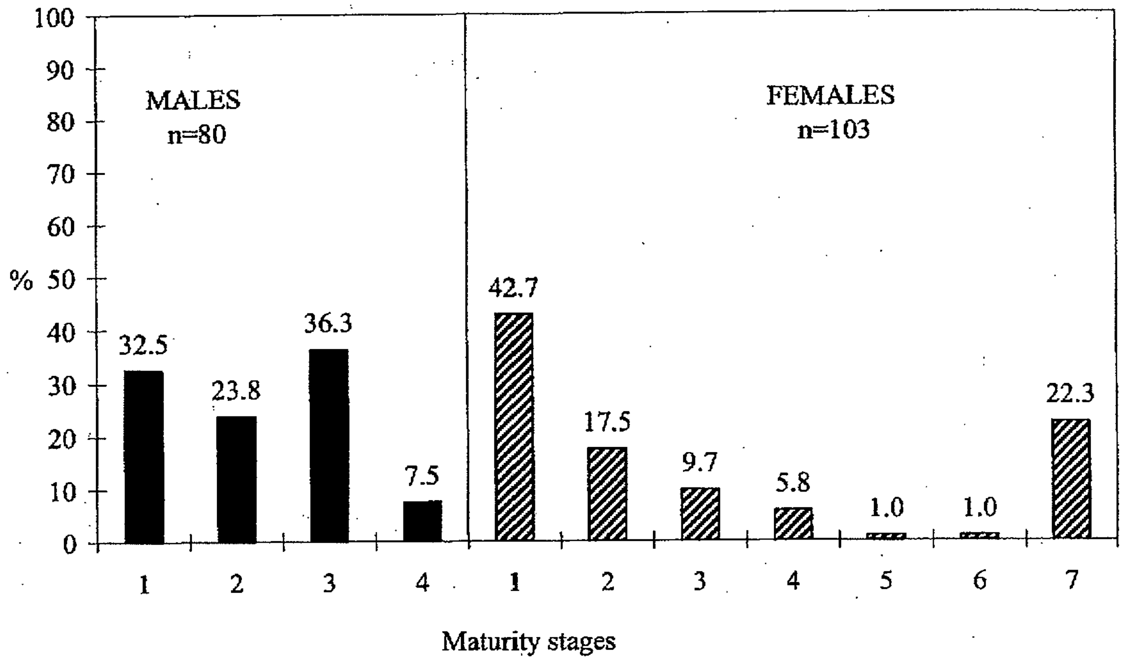

Figure 13. *E. princeps.* Maturity stages in October '96 and '97. Surveys TM3-96 and TBR2-97.

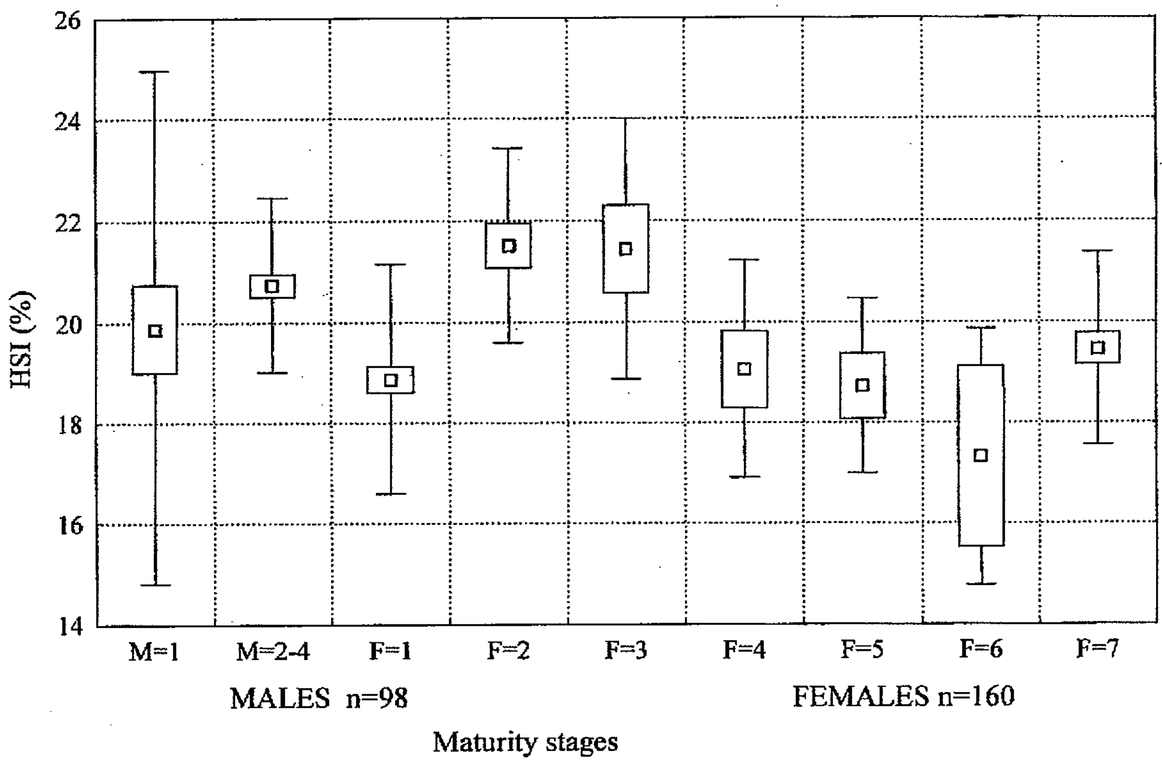

Figure 14. *E. princeps.* Proportion liver weight of total body weight (HSI,%) given by maturity stages (M= males, F= females). Boxes show mean value and standard error, vertical bars show standard deviation from the mean.

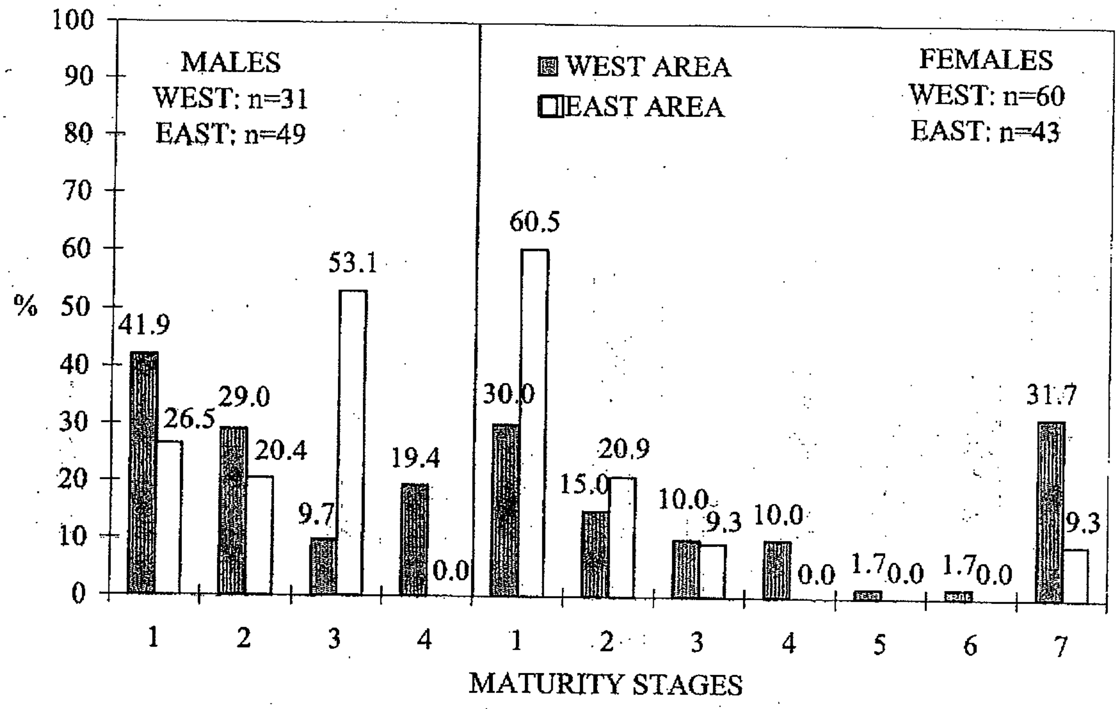

Figure 15. *E. princeps*. TM3-96 and TBR2-97. Maturity stages in western area (>24°W) and eastern area (<20°W)