Distribution and abundance of eelpouts (Pisces, Zoarcidae) off West Greenland

Peter R. Møller & Ole A. Jørgensen

SARSIA

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New information on distribution and abundance of West Greenland (59°50'-73°21'N) eelpouts, was obtained during six bottom trawl surveys (616 hauls) and three longline surveys (78 sets) conducted in the period 1992-1998, at depths from 56 to 1495 m. A total of 17 eelpout taxa were recorded from 407 trawl hauls and 64 longline settings. Further, information on temperature and depth ranges, population structure, reproduction and length-weight relation is given.

Five species were recorded for the first time in West Greenland waters (*Melanostigma atlanticum*, *Lycenchelys muraena*, *Lycenchelys sarsii*, *Lycodes pallidus*, and *Lycodes* sp. 1) and six were new to Canadian waters (*L. muraena*, *L. sarsii*, *Lycodes luetkenii*, *Lycodes adolfi*, *Lycodes eudipleurostictus*, and *Lycodes* sp. 1). The distribution patterns were analysed by means of a correspondence analysis (CA). The middle slope (600-1500 m) north of the Greenland-Canada Ridge was characterised by *L. adolfi*, *L. eudipleurostictus*, *Lycodes vahlii*, *L. luetkenii*, *Lycodes* sp. 1, and *L. muraena* in low densities while the shelf-upper slope (0-600 m) was characterised by *L. eudipleurostictus*, *Lycodes seminudus*, *L. vahlii*, *Lycodes reticulatus*, and *Lycenchelys kolthoffi* in high densities and *L. sarsii*, *Lycodes esmarkii*, *Lycodes* sp. 1, *L. luetkenii*, *L. pallidus*, and *Gymnelus* spp. in low densities. South of the Greenland-Canada Ridge the shelf-upper slope was characterised by *L. vahlii*, *L. sarsii*, and *Gymnelus* spp. in high densities, while the middle slope was characterised by *Lycodonus mirabilis*, *Lycenchelys paxillus*, *Lycodes terraenovae*, and *M. atlanticum* in low densities. The Arctic species north of the ridge were caught at unusually high temperatures in 1998, probably due to an extraordinary strong inflow of warm West Greenland Current water.

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INTRODUCTION

The family Zoarcidae contains about 220 species. All but a few are benthic and adapted to relatively cold water (< 8 °C) (Anderson 1984, 1994). Many species inhabit deep or remote waters, and are therefore rarely caught. This does not imply that they are all rare, in fact some species have been reported to be characteristic species of certain areas e.g. *Lycodes frigidus* in the Norwegian Sea (Jensen 1902), and *Lycodes atlanticus* (= *L. terraenovae*) and *Lycenchelys verrillii* in the Norfolk Canyon middle slope (Hecker 1994). Species identification is often difficult due to great intraspecific variation of morphology, meristics and colour. Because of these difficulties our basic knowledge about distribution, abundance, and biology of most species are still very scarce. This also applies to the West Greenland eelpouts, despite the fact that their taxonomy has been studied for many years.

Our present knowledge is based primarily on works by Fabricius (1780), Reinhardt (1831, 1834, 1835, 1837) and Jensen (1902, 1904, 1952) of which the latter gives a detailed review on the Greenland records of Lycodinae. Since then several contributions have been published: Geistdoerfer & al. (1970) described *Lycenchelys labradorensis* (= *Lycenchelys alba*); Anderson (1982) reviewed the taxonomy of *Gymnelus* and recognised two species (*Gymnelus viridis* and *G. retrodorsalis*) off West Greenland; Karrer (1973) and Møller (1997) examined the taxonomy of *Lycodes terraenovae*; Nielsen & Fosså (1993) described a new species (*Lycodes adolfi*); Møller & Petersen (1997) added new information to the distribution and taxonomy of *Lycodes luetkenii*; Saito & Okamura (1995) and Koyanagi (1995) redescribed a number of species, but gave no detailed information on distribution and abundance; Chernova (1998) redescribed *G. viridis* and Møller (1999) redescribed *Lycenchelys paxillus* and *Lycenchelys alba* All these studies dealt with taxonomy and very little was mentioned about the biology of the species.

Only few studies of the distribution, abundance and biology of Atlantic-Arctic zoarcids have been published: Morosova (1982) described the distribution and abun-

dance of *Lycodes esmarkii*, *L. reticulatus*, and *L. vahlii* off Labrador and Newfoundland; Nash (1986) studied the general biology of *L. vahlii gracilis* in Oslofjorden; Dorrien (1993) studied the ecology of *L. reticulatus* and provided abundance data for 7 other species from Barents Sea and off Northeast Greenland; Albert (1993) studied the biology of *L. vahlii gracilis* in the Norwegian Sea; Hecker (1994) analysed the abundance of *L. verrillii*, *L. paxillus*, and *L. atlanticus* (= *L. terraenovae*) on the continental slope off Cape Hatteras, and Valtysson (1995) studied the distribution and feeding habits of six species of *Lycodes* (*L. esmarkii*, *L. eudipleurostictus*, *L. pallidus*, *L. reticulatus*, *L. seminudus*, and *L. vahlii*) in Icelandic waters.

West Greenland waters are divided by the relatively shallow "Greenland-Canada Ridge" in the Davis Strait between Greenland and Baffin Island (Fig. 1). With a maximum depth of c. 700 m it separates two deep basins: the cold Baffin Bay (north of Assiat-Durban Island c. 68°30'N) and the "warm" Labrador Sea (south of 64°N) (Riis-Carstensen 1948). Major differences in the deep-sea fauna north and south of the Wyville Thomson Ridge in the Northeast Atlantic were described by Jungersen (1897) and further documented for Lycodinae by Jensen (1902). Similar differences were later described for the deep-sea fauna north and south of the Greenland-Canada Ridge, mainly based on material from the Danish "Godthaab" expedition 1928 (Kramp 1963, invertebrates; Jensen 1950, liparids).

The hydrographic conditions at West Greenland are strongly influenced by several currents introducing water masses from other parts of the North Atlantic into West Greenland waters (Buch 1990). The area closest to the coast and over the banks are generally dominated by the East Greenland Current, which transports cold water of polar origin around Cape Farewell and northward along the West Coast. The current reaches down to about 200 m. On the outside of the banks and further off shore the Irminger Current dominates. This current is a branch of the North Atlantic Current that carries relatively warm water (4-6 °C) from the Irminger Sea round Cape Farewell and along the coast outside the East Greenland Current. The Irminger Current was unusually warm in 1998 (Buch 1998). The two currents mix gradually and become the West Greenland Current, which has a temperature up to 5 °C, warmest in late summer. At about 64°N a branch of the current starts to set westward and this movement becomes more marked further north. North of the ridge the West Greenland Current is weak and decreases northward (Buch 1990). However, the area north of the ridge regularly gets an inflow of this warm water. In 1998 the inflow was very strong and a core of warm water (3.5 °C) reached a far as 71°N in the central part of the Baffin Bay. Normally, water temperatures in the Baffin Bay are much more influenced by the Baffin Current, sending polar and melting ice water southwards (Buch 1998).

West Greenland waters from Cape Farewell to c. 73°N are extensively exploited by commercial fisheries, manly directed at shrimp (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglossoides*). Annual landings of these species in the last 10 years have been around 70 000 and 20 000 tons, respectively (Anon. 1997). Commercial species are monitored regularly, but few quantitative data on non-commercial species are published (Jørgensen 1996; Pedersen & Kanneworff 1995). Eelpouts are not caught commercially, but at least some of the species may be important elements in the ecosystem, as competitors, predators on shrimp and fish fry or as prey for larger fish.

The purpose of the present study is to use modern fisheries surveys to identify the various species of eelpouts and describe their distribution and abundance in West Greenland waters. The results are related to depth and temperature and the distribution patterns are analysed. Data on population structure, length-weight relation and reproduction are given for most of the species.

MATERIAL AND METHODS

Data and material were collected during six stratified random bottom trawl surveys and three longline surveys conducted in West Greenland waters from 1992 to 1998, by the Greenland Institute of Natural Resources. Three of the bottom trawl surveys were conducted by RV *Shinkai Maru* in co-operation with Japan Marine Fishery Resources Research Center. These surveys together with two surveys by RV *Paamiut* were aimed for groundfish, mainly Greenland halibut. A four month sur-

Table 1. Research vessels, gear data, date, and latitude range for the nine surveys from which West Greenland eelpout data were obtained.

Research vessel	Gear	Surveys	Stations	Year	Month	Latitude (°N)	Cod-end (mm)	Wing spread (m)	Net height (m)	Towing speed (knots)
Shinkai Maru	Groundfish trawl	3	267	1992, 93, 95	Aug.-Sept.	63°04'-69°46'	30	40	7.5	3.5
Paamiut	Groundfish trawl	2	119	1997, 98	Sept.-Oct.	63°06'-66°12'	30	21	6.5	3.0
Paamiut	Shrimp trawl	1	230	1998	July-Sept.	59°50'-72°13'	20	18	14.0	2.3
Adolf Jensen	Longline	3	78	1997,1998	July	69°02-73°38'	-	-	-	-

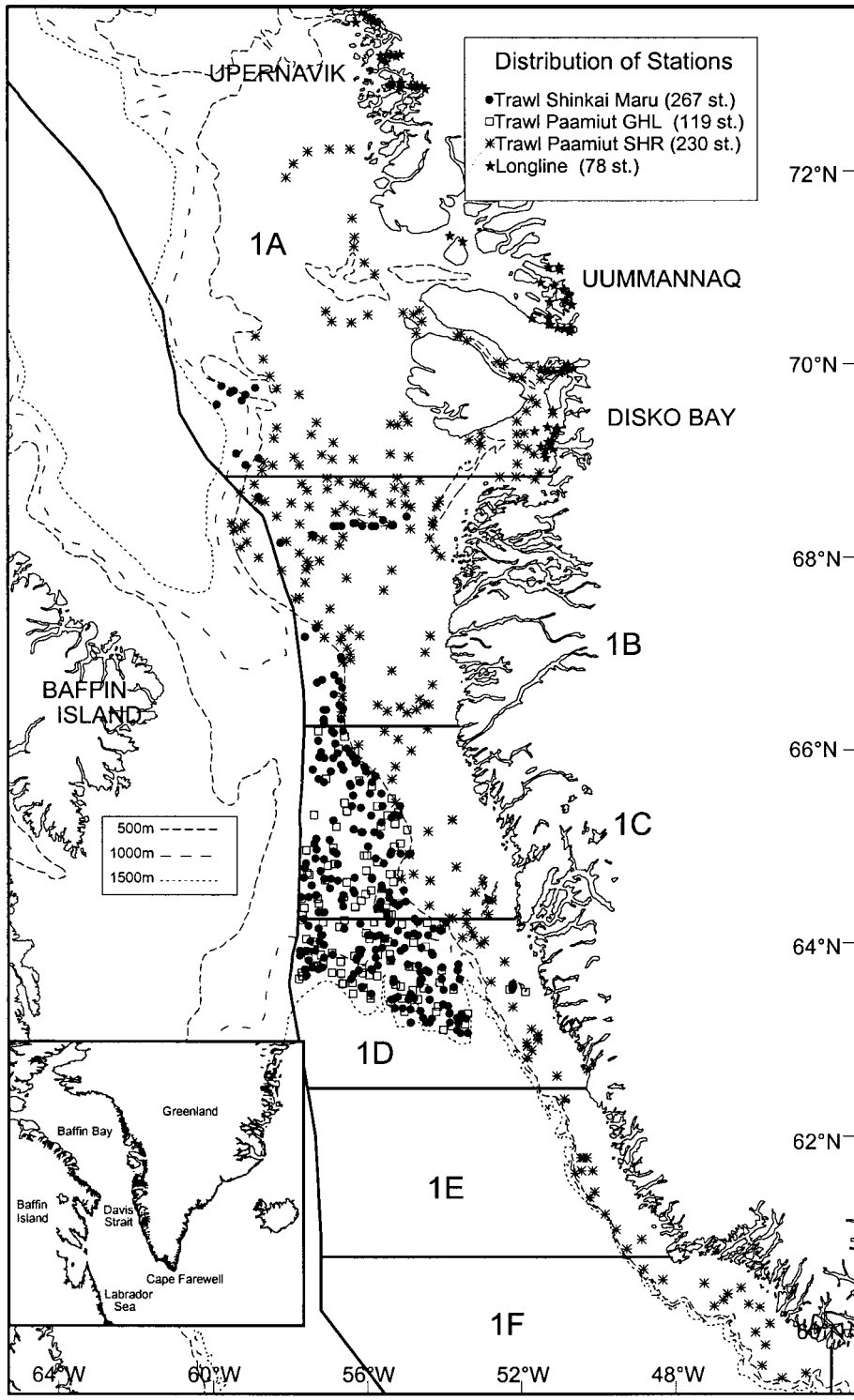

Fig. 1. Distribution of trawl and longline stations by survey. GHL = Greenland halibut survey, SHR = Shrimp survey. Further, NAFO divisions and names given in the text are shown.

vey by RV *Paamiut* was mainly aimed at shrimp (Fig. 1, Table 1). The surveys covered the area between 59°50'N and 73°38'N, at depths between 56 and 1495 m and temperatures from 0.0 to 5.8 °C (Table 2). Most stations were located within the Greenland exclusive economic zone, limited by the 200-mile line or the midline between Canada and Greenland. However, seven hauls were carried out in Canadian waters (Fig. 1).

The longline surveys were conducted by the 167 BRT RV *Adolf Jensen* within fjords and near shore areas in Northwest Greenland (Fig. 1). The number of hooks on each longline varied between 666 and 1723. The line was a 8 mm Mustad with 1.8 m between the ganglions (50 cm). The hooks were of the type Mustad (J) no. 8 and the bait was squid. Soaking time was approximately six hours. Further details about vessels and gears are given in Jørgensen (1998, 1999) and Carlsson & Kanneworff (1998).

During the groundfish surveys, the catch was sorted by species and weighed to the nearest 0.1 kg after each haul. The specimens were counted and/or length measured as total length (TL) to one cm below. All eelpouts from the shrimp and longline surveys were frozen onboard and sent to the Zoological Museum, University of Copenhagen (ZMUC) for identification and measuring.

In order to make trawl hauls taken with different gear comparable, all catches were standardised to number of specimens per km^2. Longline catches were standardised to catch per 1000 hooks. In a few cases survey results were supplemented with unpublished data from the ZMUC collection.

Near-bottom temperatures were measured at most stations (n = 572) in 0.1 °C increments, as close to the bottom as possible by either CTD, XBT or by a Seamon sensor mounted on a trawl door or longline (Table 2).

Data on abundance (log n+1 transformed) by trawl station were used in a correspondence analysis (CA) (ordination), employing the software NTSYSpc 2.0 (Rohlf 1998).

Definitions on depth intervals were modified after Haedrich & Merrett (1988) 0-600 m = shelf-upper slope, 600-1500 = middle slope.

Length frequency distributions were analysed for all species except *Gymnelus* spp. Data for *L. terraenovae*, *L. adolfi*, *Lycodes* sp. 1, *M. atlanticum*, and *L. mirabilis* were sampled partly or exclusively during the groundfish surveys, whereas all other length frequency data were sampled from the shrimp survey only.

For a number of species the length were measured to nearest 1.0 mm and weighed to nearest 1.0 g (0.1 g for *L. kolthoffi* and *L. sarsii*) to establish length-weight relationships. Regressions of weight on length using $\log_{10}$ transformed data were made for *L. esmarkii*, *L. eudipleurostictus*, *L. reticulatus*, *L. seminudus*, *L. vahlii*, *L. kolthoffi*, *L. paxillus*, and *L. sarsii*:

$$W = aL^b$$

where W = weight (g), L = length (cm), a = intercept and b = slope.

All species were tested for differences in length-weight relationship between sexes by means of an analysis of covariance (ANCOVA). No statistically significant differences between the sexes (at 5 %-level) were found in the slopes or the intercepts of the errors for any species, except in *L. vahlii*. The sexes were therefore combined in the length-weight relations. *Lycodes vahlii* was distributed in most of the investigated area, and an ANCOVA was made in order to test if there were differences in the length-weight relationship between areas (Disko Bay, Mid West Greenland (NAFO Division 1B), Southwest Greenland (NAFO Division 1D) and South Greenland

Table 2. Distribution of trawl hauls and longline settings by vessel. (a). Divided by 200 m intervals. (b). Divided by 1 °C intervals.

			Depth Range (m)						
			0-200	201-400	401-600	601-800	801-1000	1001-1200	1201-1500
Vessel		Total	Number of hauls						
RV *Shinkai Maru*	Groundfish trawl	267	-	-	43	73	52	58	41
RV *Paamiut*	Groundfish trawl	119	-	-	10	29	24	33	23
RV *Paamiut*	Shrimp trawl	230	55	126	49	-	-	-	-
RV *Adolf Jensen*	Longline	78	3	27	26	15	7	-	-
Sum		694	58	153	128	117	83	91	64

			Bottom Temperature Range (°C)					
			0.0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9
Vessel		Total	Number of hauls					
RV *Shinkai Maru*	Groundfish trawl	173	9	12	13	131	8	-
RV *Paamiut*	Groundfish trawl	107	-	-	3	85	16	3
RV *Paamiut*	Shrimp trawl	230	1	18	70	61	68	12
RV *Adolf Jensen*	Longline	62	7	29	26	-	-	-
Sum		572	17	59	112	277	92	15

(NAFO Div. 1F)). All variables not significant at the 5 %-level were successively removed.

Reproductive data were collected from all species. All data were sampled from the shrimp trawl survey, except for *L. mirabilis* and *L. terraenovae,* which were sampled during the *Shinkai Maru* groundfish surveys (Table 1). Eggs were counted and measured, and the state of maturity was determined. Females: egg diameter < 1 mm = immature, egg diameter > 1 mm = ripening (Markle & Wenner 1979). Males: paired testes small and string shaped = immature, paired testes broad and swollen = ripening.

A key to identification of eelpouts in West Greenland Waters was established (Appendix 1). The key was based mainly on characters that could be observed in the field with some (e.g. lateral lines, scales, teeth), however, often require a magnifying device.

RESULTS

Lycenchelys kolthoffi Jensen, 1904

Lycenchelys kolthoffi was recorded from 12 trawl hauls in relatively high densities (up to 1638 specimens per km^2). These were caught between 66°57' and 71°03'N at depths from 229 to 555 m and temperatures between 1.7 and 4.1 °C (Fig. 2, Tables 3-5). The length ranged from 11 to 21 cm with a mode at 18 cm. Females were more frequent than males in the length interval 16-19 cm, while males were more frequent from 20 to 21 cm (Fig. 12). No sexual dimorphism in maximum size or length-weight relationships was observed (Table 6). Ripening gonads were observed in both sexes in specimens above 14 cm. About 51 % of the females (n = 33) and 55 % of the males (n = 20) above this length had ripening gonads. Six females (18-19 cm) had 23 to 27 yellow-green eggs, with diameters from 4.5 to 6.0 mm.

The species has previously been reported from four West Greenland localities between 69°30' and 78°14'N, at depths from 202 to 672 m (Jensen 1952). Elsewhere, it is known from Hudson Strait, off East Greenland, north of Iceland, Faroe Islands, Svalbard Archipelago and Laptev Sea at depths from 202 to 930 m and temperatures between -0.9 and 3.0 °C (Andriashev 1954, 1986; Møller 1995; Coad & al. 1995).

Lycenchelys muraena (Collett, 1878)

Lycenchelys muraena was caught in only 4 trawl hauls in low densities (up to 70 specimens per km^2). It is recorded here for the first time in West Greenland waters between 68°22' and 69°04'N at depths from 534 to 1271 m and temperatures between 1.5 and 3.4 °C (Fig. 2, Tables 3-5). A record from 68°37'N, 58°49'W, 551 m is the first from Canadian waters. The length ranged from 15 to 18 cm. No ripening females were observed, but three 18 cm males caught in July were ripening. A 203 mm TL female caught 24 September 1994, in the Denmark Strait, had 21 light yellow eggs 8 mm in diameter (ZMUC P762547).

Elsewhere, it is known from the Norwegian and Kara Seas at depths from 622 to 1175 m and temperatures below 0 °C (Andriashev 1986).

Lycenchelys paxillus (Goode & Bean, 1879)

Lycenchelys paxillus was recorded from 95 trawl hauls in moderate densities (up to 658 specimens per km^2). These were caught between 62°22' and 69°45'N at depths between 424 and 1093 m and temperatures from 0.9 to 5.5 °C (Fig. 3, Table 3). The species was most common south of 67°N at depths from 600 to 800 m and temperatures between 3 and 5 °C. Highest densities were, however, found in a few deep holes on the shelf, with a relatively high temperature and shallow water compared to the continental slope area (Fig. 3, Table 4-5). The length ranged from 14 to 26 cm with modes at 20 and 23 cm. The sex-ratio was approximately 1:1. No sexual dimorphism in maximum size or length-weight relationship was observed (Fig. 13, Table 6). Ripening gonads were observed in specimens above 23 cm (females) and 18 cm (males). About 30 % of the specimens (both sexes, n = 69) above these lengths had ripening gonads. Møller (1999) mentioned females caught in September with up to 85 eggs 3.1 mm in diameters.

Jensen (1902) described a specimen caught at West Greenland (64°54'N, 55°10'W) as a new species, *L. ingolfianus*. Until recently this was the only record from West Greenland waters (Jensen 1952). *Lycenchelys ingolfianus* is now regarded as a junior synonym of *L. paxillus* (Møller 1999). Elsewhere, it is known from off Nova Scotia to Virginia at depths from 46 to 1097 m (Scott & Scott 1988).

Lycenchelys sarsii (Collett, 1871)

Lycenchelys sarsii was recorded from 37 trawl hauls in moderate densities (up to 533 specimens per km^2). These were caught between 60°15' and 68°53'N at depths from 107 to 572 m and temperatures between 2.2 and 5.6 °C (Fig. 2, Table 3). It was, however, rare in depths below 200 m and temperatures below 3 °C (Table 4-5). A record from 68°18'N, 59°18'W, 350 m was the first from Canadian waters. The length ranged from 10 to 23 cm with a mode at 15 cm. Males were slightly more frequent than females in the length interval 14-18 cm. No sexual dimorphism in maximum size or length-weight relation was observed (Fig. 14, Table 6). Ripening gonads were observed in both sexes at lengths above 11 cm. About 60 % of the females (n = 35) and 70 % of the males (n = 41) above this length had ripening gonads. Six females (14-16 cm) had from 12 to 18 eggs, with diameters from 3.5 to 4.5 mm.

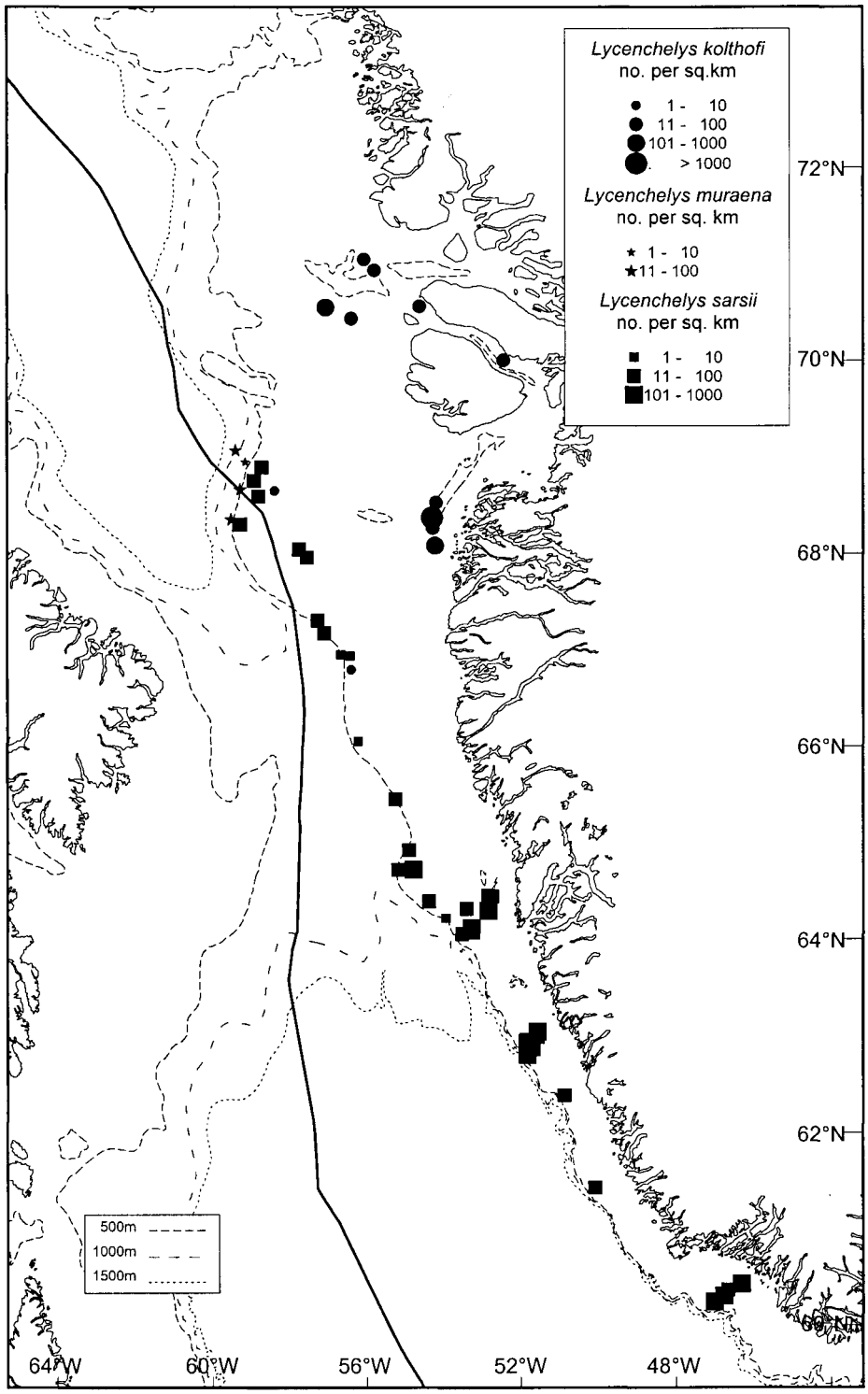

Fig. 2. Distribution and density of *Lycenchelys muraena*, *Lycenchelys kolthoffi* and *Lycenchelys sarsii* in West Greenland waters 1992-1998.

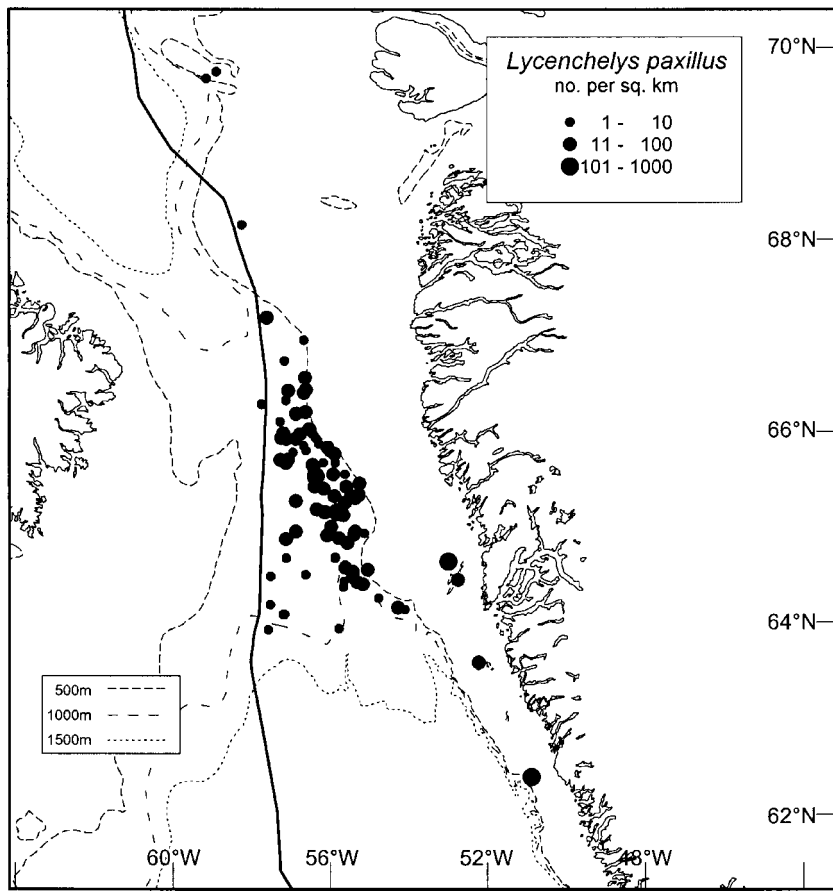

Fig. 3. Distribution and density of *Lycenchelys paxillus* in West Greenland waters 1992-1998.

Elsewhere, it is known from north of Iceland (Jónsson 1992), Norwegian fjords from Skagerrak to Kola Bay at depths from 150 to 600 m and temperatures between 0 and 6 °C (Andriashev 1986).

Lycodes adolfi Nielsen & Fosså, 1993

Lycodes adolfi was recorded from 3 trawl hauls only in low densities (up to 87 specimens per km^2). These were distributed between 69°01' and 69°35'N at depths from 420 to 1436 m and temperatures from 0.0 to 2.2 °C (Fig. 4, Table 3). Highest density was seen in the deepest and coldest location (Tables 4-5). The length ranged from 7 to 18 cm without any clear modes. All specimens were immature. Nielsen & Fosså (1993) suggested that spawning takes place during summer time.

The temperatures of the present records are markedly lower than the temperatures of previous West Greenland records (68°23'N-69°42'N, depths 527-1322 m, 3.5-3.7 °C) (Nielsen & Fosså 1993). Since the description of *L. adolfi* a few ZMUC specimens have been reassigned to this species, including a specimen from 71°35'N, 60°50'W, 1398 m, a specimen from the Canadian part of Baffin Bay (69°50'N, 61°37'W, 1880 m) and a specimen from off Iceland (67°04'N, 17°55'W, 386 m). The species is also known from East Greenland waters at depths from 1283 to 1380 m and temperatures between –0.3 and –0.2 °C (Nielsen & Fosså 1993).

Lycodes esmarkii Collett, 1875

Lycodes esmarkii was recorded from 31 trawl hauls in moderate densities (up to 388 specimens per km^2). The species was evenly distributed between 63°45' and 70°33'N at depths from 310 to 1090 m and temperatures between 1.0 and 5.3 °C (Fig. 5, Tables 3-5). The length ranged from 8 to 42 cm with modes around 17 and 29 cm (Fig. 15). Three slightly larger specimens (44, 44, 46 cm) were caught on longline. The sex-ratio was approximately 1:1 and no sexual dimorphism in maximum size or length-weight relationship was observed (Table 6). Ripening gonads were observed in specimens above 35 cm (females) and 38 cm (males). Only 3 of 87 sexed specimens were ripening. A 36 cm female had 216 eggs.

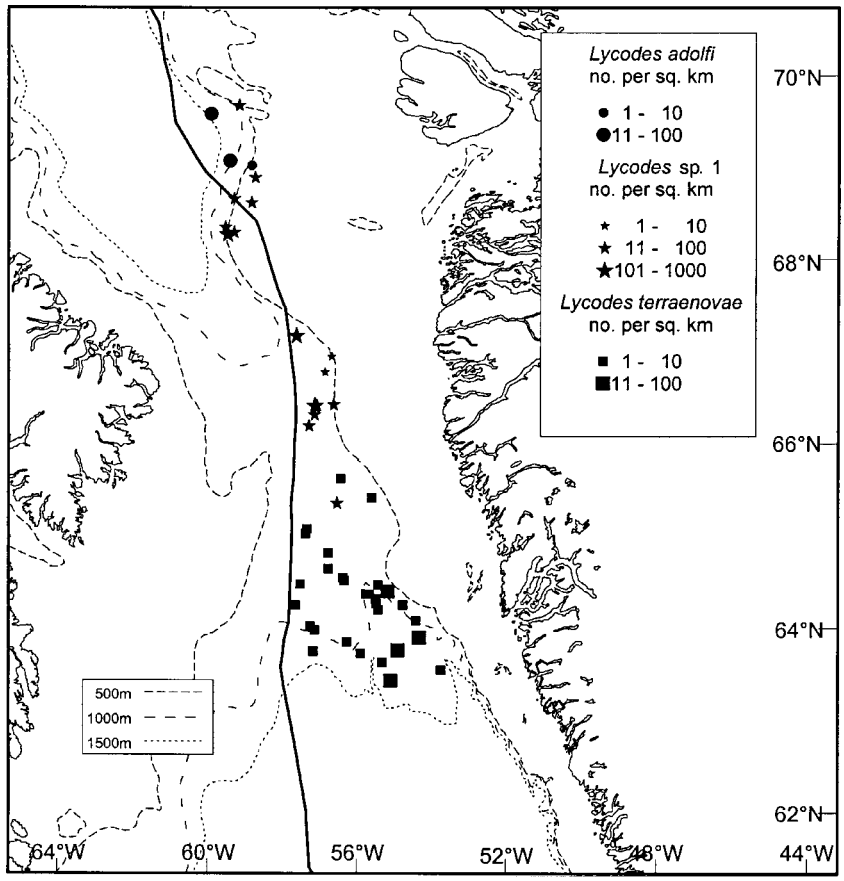

Fig. 4. Distribution and density of *Lycodes adolfi*, *Lycodes* sp. 1 and *Lycodes terraenovae* in West Greenland waters 1992-1998.

Andriashev (1986) reported up to about 1200 eggs, 6 mm in diameter. In Icelandic waters ripe specimens were reported at the end of June (Joensen & Tåning 1970).

Previously this species has been reported at two positions in West Greenland waters (66°41'N, 56°17'W, 270 m and 66°37'N, 56°37'W, 460 m) (Jensen 1952). Elsewhere, it has been reported from the Labrador-Newfoundland area at depths from 151 to 500 m and temperatures between –0.4 and 5.0 °C (Morosova 1982). In the Northwest Atlantic it is found southwards to off Virginia (Markle & Sedberry 1978) and in the Northeast Atlantic it is known from the western Barents Sea, the Faroe-Shetland Slope, north of Iceland and in the Denmark Strait (Andriashev 1986).

Lycodes eudipleurostictus Jensen, 1902

Lycodes eudipleurostictus was recorded from 80 hauls in high densities (up to 5216 specimens per km^2). It was found between 65°20' and 73°38'N at depths between 188 and 975 m and temperatures ranging from 0.5 to 4.9 °C (Fig. 6, Table 3-5). Three records (e.g. 68°22'N, 59°30'W, 552 m) are the first from Canadian waters. The length ranged from 8 to 41 cm with modes around 11, 15, 17 and 22 cm. The sex-ratio was approximately 1:1 at length below 30 cm (Fig. 16a). In the longline catches it was recorded from 52 lines with up to 26 specimens per 1000 hooks (Fig. 6). The length ranged from 22 to 45 cm, with modes around 33 and 36 cm. The longline catches were heavily dominated by males indicating that males grow larger than females (Fig. 16b). No sexual dimorphism in length-weight relationship was observed (Table 6). Ripening gonads were observed in specimens above 23 cm (females) and 29 cm (males). About 26 % of the females (n = 27) and 31 % of the males (n = 211) above these lengths had ripening gonads. Three females (28-33 cm) had 120 to 300 orange eggs, with diameters from 2.7 to 5.3 mm. Jensen (1952) reported 260 eggs, 8 mm in diameter for a 35 cm female caught in August in Smith Sound (78°14'N, 74°10'W, 672 m).

In West Greenland waters (Jensen 1952) reported this species from Bredefjord (60°45'N) and from Godthaabsfjord (64°N) to Smith Sound (78°N). Elsewhere,

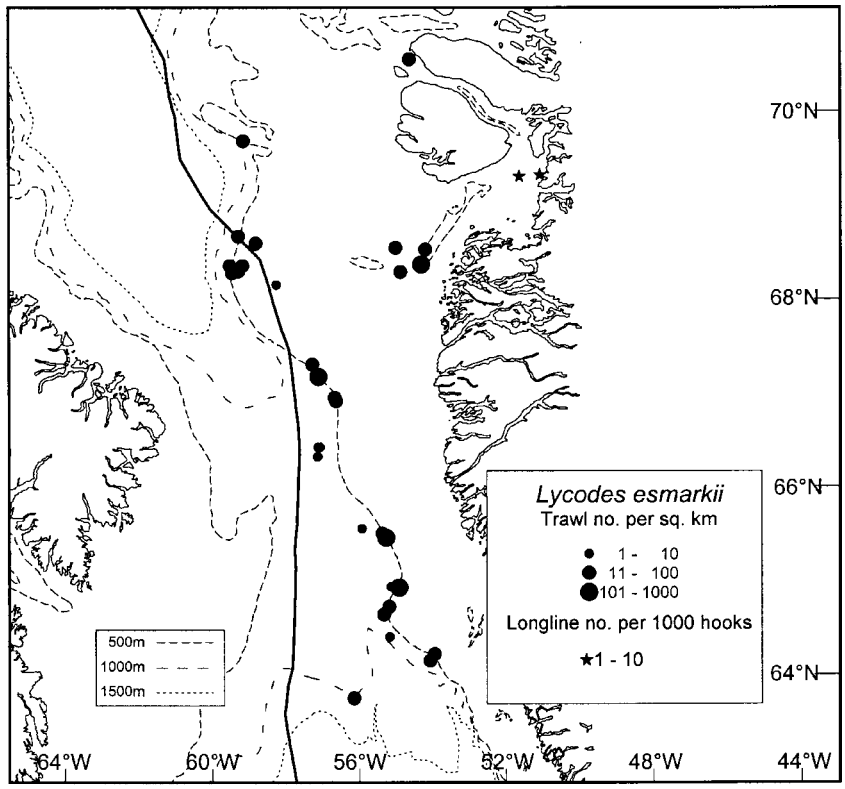

Fig. 5. Distribution and density of *Lycodes esmarkii* in West Greenland waters 1992-1998.

the species is known from East Greenland, off Iceland, Beaufort Sea, off Severnaya Zemlya and Barents Sea including the Svalbard Archipelago at depths from 249 to 914 m and temperatures around 0 °C (Jensen 1952; Andriashev 1954, 1986).

Lycodes luetkenii Collett, 1880

L. luetkenii was recorded from 5 hauls only in low densities (up to 78 specimens per km^2). It was found between 68°22' and 71°03'N at depths between 259 and 553 m and temperatures ranging from 1.5 to 3.4 °C (Fig. 7, Table 3-5). One specimen caught at 68°22'N, 59°30'W, 552 m is the first reported from Canadian waters. The length ranged from 13 to 53 cm without clear modes. The largest specimen was a female. Møller & Petersen (1997) reported a 462 mm female from West Greenland, having about 1000 orange eggs 5 mm in diameter.

The species was reported by Møller & Petersen (1997) from off Southwest Greenland (60°21'N, 47°39'W), off Disko Island (69°07'-69°15'N, 59°00'W) and in Uummannaq fjord (70°50'N, 53°00'W). Elsewhere, it is known from a few specimens only, from off Svalbard, Faroe Islands, East Greenland and northern Iceland at depths between 112 and 1098 m and temperatures around 0 °C (Andriashev 1986, Møller & Petersen 1997).

Lycodes pallidus Collett, 1880

Two immature females of *L. pallidus* (14 and 15 cm) were recorded from a single haul, corresponding to a density of 48 specimens per km^2, at 71°29'N, 56°23'W, 270 m, 1.6 °C (Fig. 7, Tables 3-5). A 162 mm female caught off Disko Island in August 1997 (ZMUC uncat.) had 58 eggs 4.7 mm in diameter. Andriashev (1986) mentioned a female with about 35 eggs, 6.1 mm in diameter in September and Altukhov (1979) reported the hatching size of the eggs to be 10-12 mm.

Saito & Okamura (1995) reported this species from Greenland waters, but their specimens from West Greenland belongs to *Lycodes* sp. 1 (see section on *Lycodes* sp. 1 below). Two specimens from ZMUC (P762257-58) were caught at 68°54'N, 52°30'W, 240 m. Elsewhere, it is known from Denmark Strait, north of Iceland and Faroe Islands, Svalbard Archipelago, White Sea, Barents Sea to Laptev Sea, Beaufort Sea, and from Arctic Canada to The Gulf of St. Lawrence at depths from 16 to 932 m and temperatures below 0 °C (Andriashev 1954, 1986). In the mouth of Raudfjord, Svalbard, however, it was caught at temperatures up to 3.7 °C (Møller pers. obs.).

Lycodes reticulatus Reinhardt, 1835

Lycodes reticulatus was recorded from 24 trawl hauls in

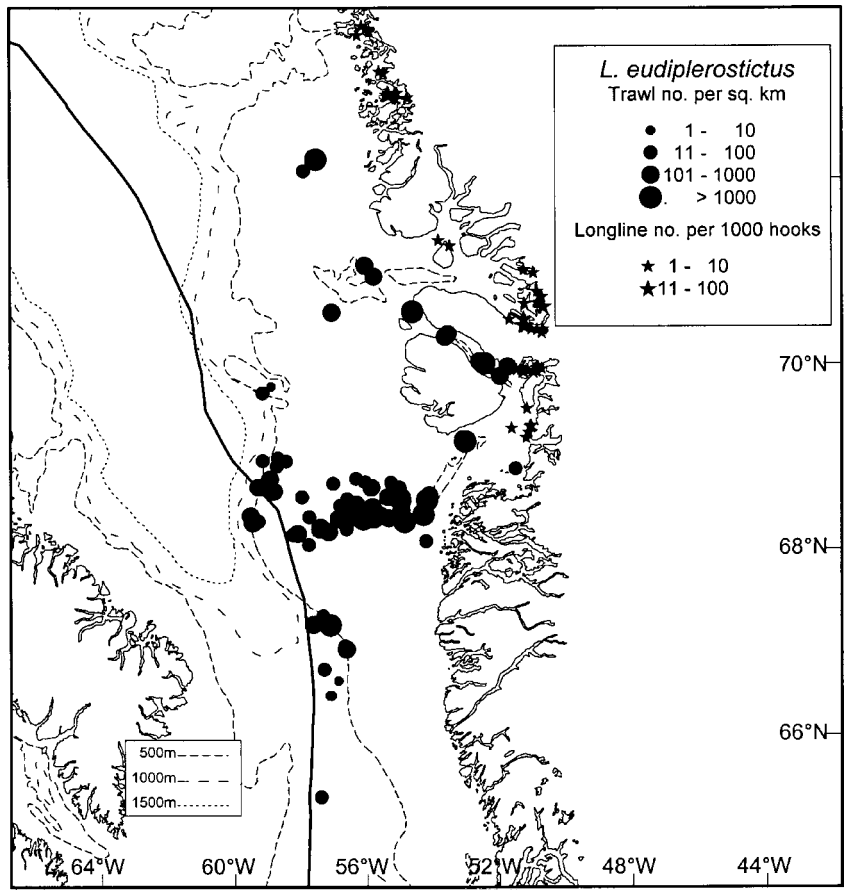

Fig. 6. Distribution and density of *Lycodes eudipleurostictus* in West Greenland waters 1992-1998.

relatively high densities (up to 763 specimens per km^2). It was caught between 66°24' and 72°13'N at depths between 164 and 412 m and temperatures ranging from 1.6 to 4.5 °C (Fig. 7, Tables 3-5). The length ranged from 7 to 36 cm with modes around 8, 11, 17 and 20 cm (Fig. 17). Four relatively large specimens (29, 32, 34 and 56 cm) were caught on longline (Fig. 7). The sex-ratio was approximately 1:1 and no sexual dimorphism in maximum size or length-weight relationship was observed (Fig. 17, Table 6). The largest specimen was a female. Ripening gonads were observed in specimens above 20 cm (females) and 23 cm (males). About 41 % of the females (n = 17) and 27 % of the males (n = 11) above these lengths were ripening. The most mature female (27 cm) had 325 yellow eggs, 4 mm in diameter. A specimen (28 cm) caught in the Denmark Strait in September 1994 had 208 eggs 10 mm in diameter (ZMUC P763416).

In West Greenland waters *L. reticulatus* has previously been recorded from Julianehaab (60°N) to Smith Sound (78°15'N) at depths from 55 to 930 m and temperatures from –1.4 to 1.0 °C (Jensen 1952). Elsewhere, the species is recorded from Hudson Bay, from off Labrador to Nova Scotia at depths from 51 to 750 m and temperatures from –1.4 to 3.5 °C (Morosova 1982), and from off East Greenland, northern Barents Sea, Kara Sea, and Laptev Sea (Andriashev 1986), off northern Iceland (Jónsson 1992; Valtysson 1995), and in the Denmark Strait and the Svalbard Archipelago (Dorrien 1993)).

The species *Lycodes lavalaei* Vladykov & Tremblay, 1936 is very similar to *L. reticulatus*, and Andriashev (1973) reidentified some of Jensen's (1904) West Greenland specimens to *L. lavalaei*. However, no arguments for this were given and in the present study all specimens were identified as *L. reticulatus* based on squamation, coloration and meristics. The differences between these and related species (e.g. *L. rossi* Malmgren, 1865 and *L. raridens* Taranetz & Andriashev, 1937) need to be studied further.

Lycodes seminudus Reinhardt, 1838

Lycodes seminudus was recorded from 62 hauls in very high densities (up to 7326 specimens per km^2). It was

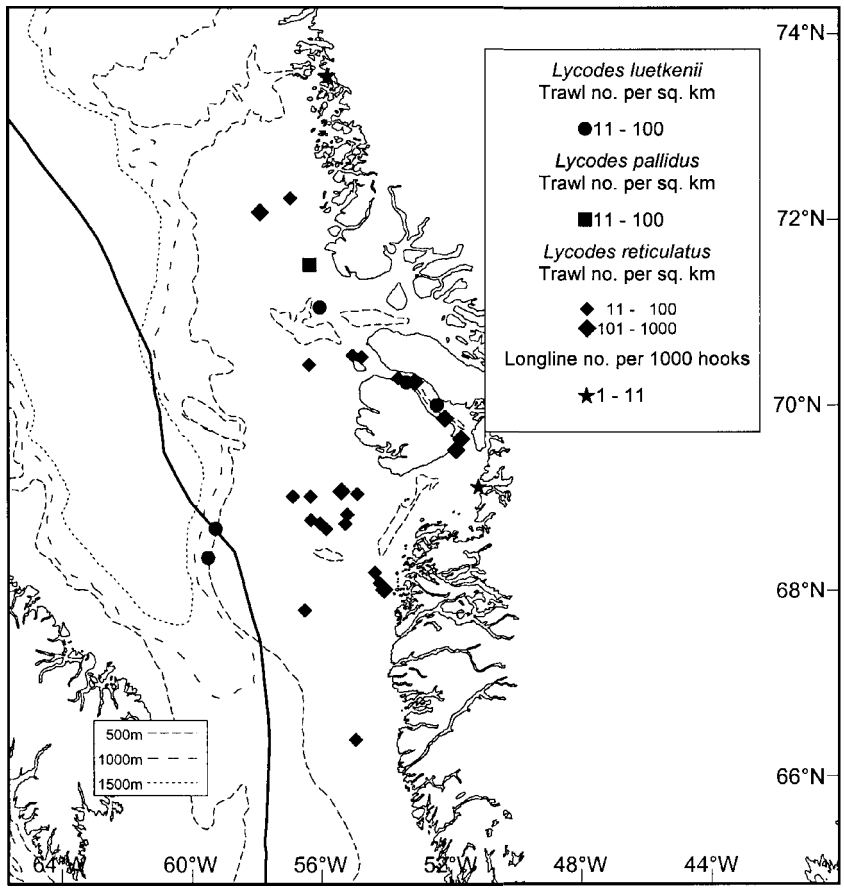

Fig. 7. Distribution and density of *Lycodes luetkenii*, *L. pallidus* and *L. reticulatus* in West Greenland waters 1992-1998.

found between 68°10' and 73°38'N at depths between 181 and 743 m and temperatures from 0.5 to 4.9 °C (Fig. 8, Table 3-5). The length ranged from 7 to 41 cm with modes around 10, 15, 20 and 28 cm. The sex-ratio was approximately 1:1 (Fig. 18a). The species was recorded from 39 longline sets with up to 47 specimens per 1000 hooks (Fig 8). The length ranged from 27 to 57 cm with modes around 31, 34, 40, 43, 46 and 49 cm. The longline catches were dominated by males, and the largest female was 39 cm (Fig. 18b). No sexual dimorphism in the length-weight relationship was observed (Table 6). Ripening gonads were observed in specimens above 26 cm (females) and 32 cm (males). About 61 % of the females (n = 36) and 40 % of the males (n = 99) above these lengths were ripening. Two females (34 and 39 cm) had 135 and 400 yellow eggs, with diameters 3.7 and 4.1 mm, respectively. Andriashev (1986) reported about 300 eggs 8.2 mm in diameter and ripe in June.

In West Greenland waters *L. seminudus* has previously been reported from Godthaabsfjord (64°N) and from Disko Bay (69°N) to Hvalsund (77°28'N) at depths down to 1200 m (Jensen 1952). Elsewhere, *L. seminudus* is known from off East Greenland to the Faroe Islands, the Svalbard Archipelago, northern Barents Sea, Kara Sea, and Beaufort Sea (Andriashev 1986; McAllister & al. 1981) at depths from 130 to 1400 m and at negative temperatures. A dark colour morph from Amerdlok and Ikertok fjords (c. 65°50'N, depth 250 to 457 m) was described as *L. nigricans* Jensen, 1952. It was given subspecific status (*L. seminudus nigricans*) by Andriashev (1954). The present study does indicate that southern fjord populations are isolated from the main northern distribution area, but since specimens of similar coloration have been caught in Icelandic waters as well (Møller pers. obs.), the subspecies status probably is not valid.

Lycodes sp. 1

An undescribed species of *Lycodes* was recorded from 17 trawl hauls in moderate densities (up to 179 specimens per km^2). The species was evenly distributed be-

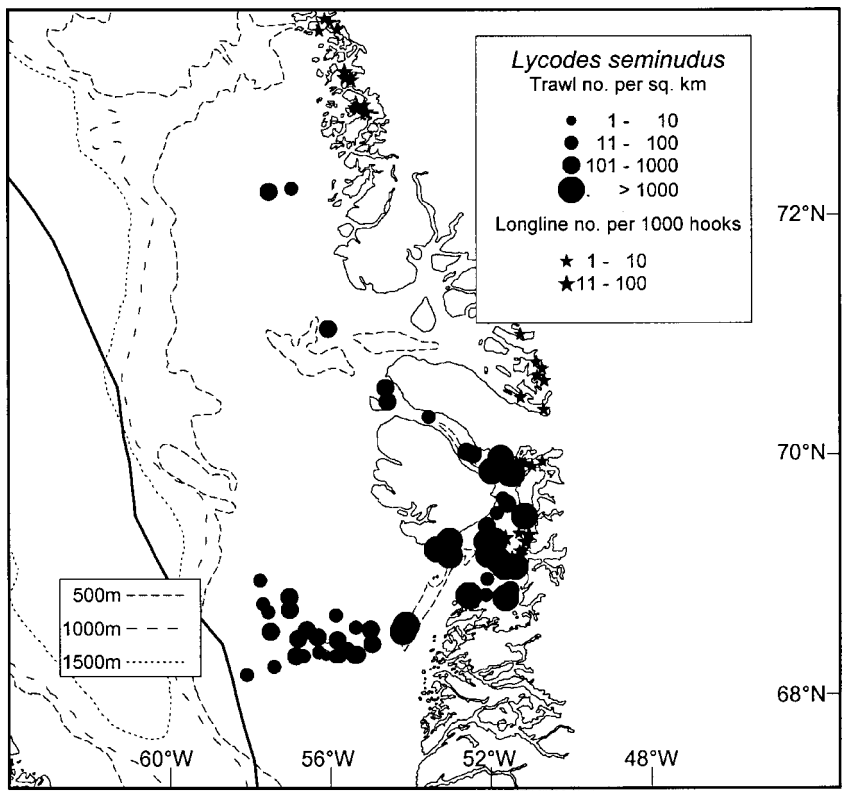

Fig. 8. Distribution and density of *Lycodes seminudus* in West Greenland waters 1992-1998.

tween 65°22' and 69°41'N at depths from 337 to 1271 m and at temperatures between 0.9 and 4.4 °C. Three records were located in Canadian waters (Fig. 4, Table 3-5). The length ranged from 9 to 24 cm with a mode around 17 cm. Females were more frequent than males in length intervals from 11 to 19 cm. Males seems to grow slightly larger than females (Fig. 19). Ripening gonads were observed in specimens above 14 cm. About 78 % of the females (n = 27) and 90 % of the males (n = 19) above this length were ripening. The ripest females (16 and 22 cm) had 21 and 34 yellow eggs, with diameters 6.0 and 4.0 mm, respectively.

Saito & Okamura (1995) identified specimens of this species as *L. pallidus* and *L. frigidus*. Elsewhere, it is recorded from Denmark Strait, Iceland, Faroe Islands and Norwegian Sea. This new species is being described (Møller in prep.).

Lycodes terraenovae Collett, 1896

Lycodes terraenovae was recorded from 30 trawl hauls in low densities (up to 21 specimens per km^2). It was evenly distributed between 63°26' and 65°38'N at depths between 697 m and 1365 m and temperatures from 3.0 to 3.9 °C (Fig. 4, Tables 3-5). The length ranged from 11 to 41 cm without clear modes and the sex-ratio was 1:1. Ripening gonads were observed in specimens above 35 cm (females) and 38 cm (males). About 75 % of the females (n = 4) and 66 % of the males (n = 3) above this length were ripening. A large 40 cm female had 320 orange eggs, about 4 mm in diameter.

Previously, the species has been reported southwards to 63°21'N in West Greenland waters (Møller 1997) and from the Canadian part of the Davis Strait (Karrer 1973). Elsewhere, the species has been recorded southward to off Florida in the western Atlantic and from off Ireland (Bill-Bailey Bank) to off South Africa in the eastern Atlantic. It inhabits deep waters (150-2600 m) at temperatures between 2.0 and 5.0 °C (Møller 1997). Recent examination of the type specimens of *L. terraenovae* at Musée Océanographique de Monaco confirmed that *L. terraenovae* is a senior synonym of *L. atlanticus* Jensen, 1902 as suggested by Møller (1997) (Møller in press).

Lycodes vahlii Reinhardt, 1832

Lycodes vahlii was recorded from 142 trawl hauls in high densities (up to 7618 specimens per km^2). It was distributed between 59°32' and 73°34'N at depths from 71 to 750 m and temperatures from 1.4 to 5.8 °C (Fig. 9, Ta-

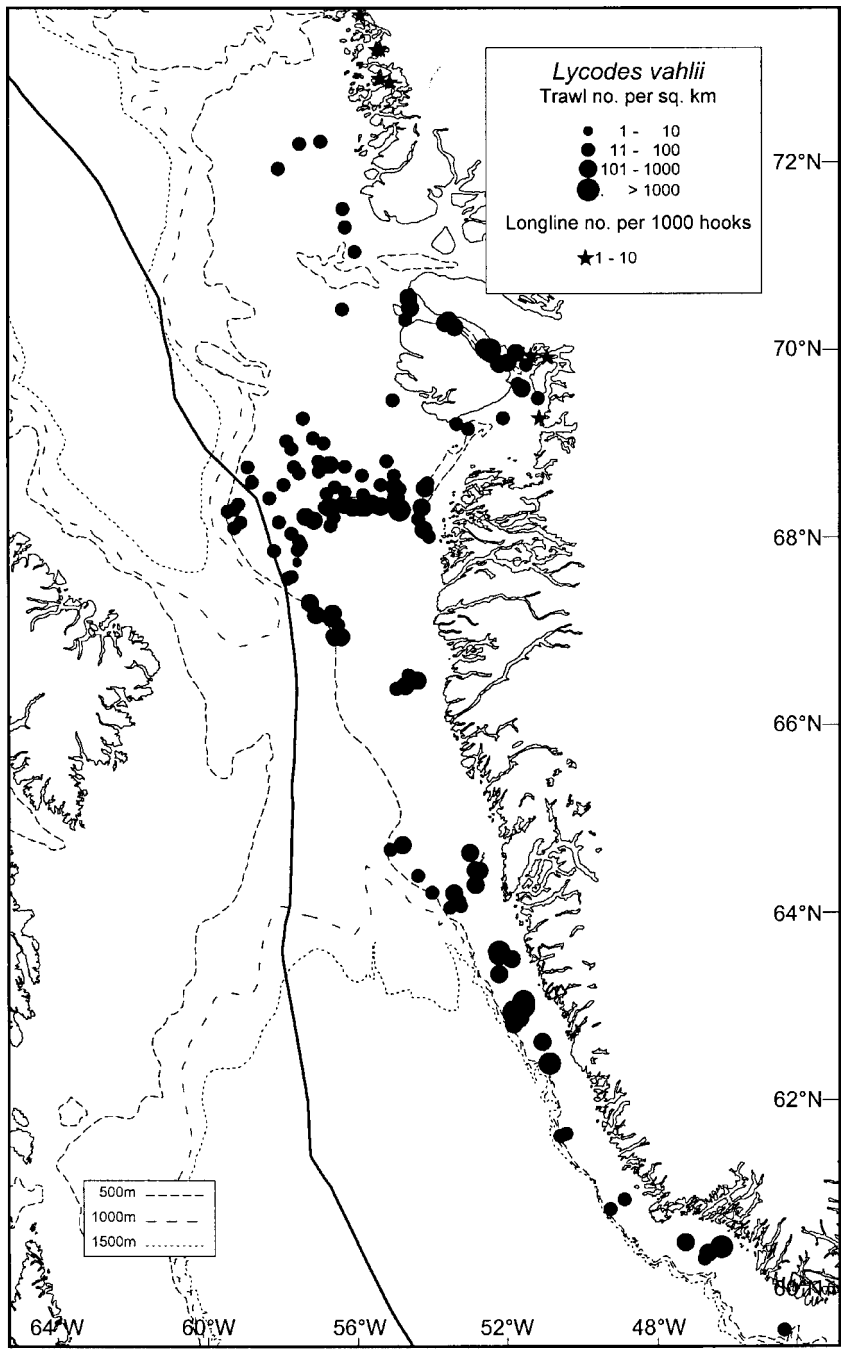

Fig. 9. Distribution and density of *Lycodes vahlii* in West Greenland waters 1992-1998.

bles 3-5). *L. vahlii* occurred in most of the investigated area. No obvious differences in the length distributions were observed between NAFO Divisions and all data are pooled. The length ranged from 8 to 40 cm with modes at 13, 17 and 24 cm. Females were slightly more frequent than males at lengths below 25 cm, while males were more dominant above 25 cm. The largest female was 40 cm (Fig. 20a). The species was recorded from 8 longline sets with up to 8 specimens per 1000 hooks. It was absent from the Uummannaq longline catches (Fig.

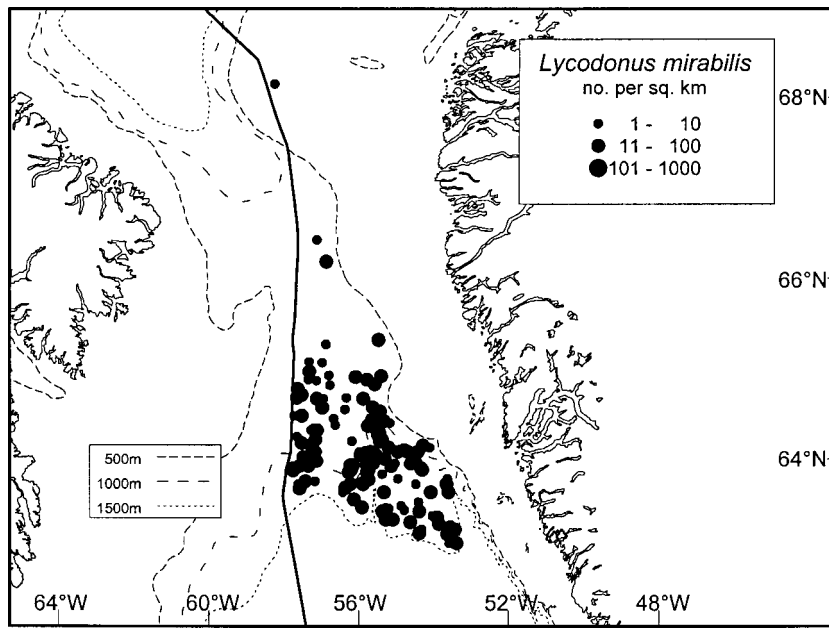

Fig. 10. Distribution and density of *Lycodonus mirabilis* in West Greenland waters 1992-1998.

9). The length ranged from 39 to 57 cm without clear modes. All sexed specimen in the longline catches were males, indicating that males grow larger than females (Fig. 20b). This has previously been reported for *L. vahlii gracilis* in the Norwegian Sea (Albert 1993). The ANCOVA analysis showed that the length-weight relationship differs between sexes (Table 6).

Ripening gonads were observed in specimens above 14 cm (females) and 17 cm (males). About 15 % of the females (n = 230) and 20 % of the males (n = 174) above these lengths had ripening gonads. In 12 females (15-22 cm) the number of eggs varied from 20 to 75, with diameters from 3 to 7 mm. Andriashev (1986) reported 27-93 eggs 4.5 mm in diameter and Nash (1986) found 18-40 yolked eggs 2.4-6.5 mm in diameter.

In West Greenland waters this species has been reported from 60 to 71°N at depths from 110 to 510 m (Jensen 1952). Elsewhere, the species is widely distributed from the Svalbard Archipelago (Dorrien 1993)), southern Barents Sea to Kattegat, off Iceland, Denmark Strait and from off Newfoundland to Nova Scotia at depths from 170 to 365 m and temperatures between – 0.7 and 6 °C (Andriashev 1986, Nash 1986).

Lycodonus mirabilis Goode & Bean, 1883

Lycodonus mirabilis was recorded from 134 hauls in low densities (up to 72 specimens per km^2). It was distributed between 63°04' and 68°09'N, at depths from 424 to 1433 m and temperatures between 1.0 and 4.5 °C (Fig. 10, Table 3). The greatest abundance was observed south of 66°N at depths between 600 and 1400 m and temperatures between 3.0 and 4.5 °C (Tables 4-5). The length ranged from 8 to 31 cm with modes at 8, 15, and 25 cm. Females were more frequent than males in the length interval 24-30 cm. No sexual dimorphism was seen in maximum size (Fig. 21). Ripening gonads were observed in specimens above 22 cm. About 48 % of the females (n = 42) and 88 % of the males (n = 16) above this length had ripening gonads. In nine females (24-30 cm) the number of orange-red eggs varied from 32 to 88, with diameters from 3.1 to 4.8 mm.

The present distribution range is markedly different from the single previously recorded specimen from West Greenland waters (73°12'N, 58°08'W, 850 m, 0.47 °C) (Jensen 1952). Elsewhere, the distribution reaches southwards from off Newfoundland along the slope (800-2100 m) to off Cape Hatteras (Anderson 1994).

L. mirabilis is very similar to *L. flagellicauda* (Jensen, 1902) (see Koyanagi 1995), but an examination of all *Lycodonus* from West Greenland in the ZMUC collection revealed no *L. flagellicauda*.

Melanostigma atlanticum Koefoed, 1952

Melanostigma atlanticum was recorded from 7 trawl hauls in low densities (up to 12 specimens per km^2). It was recorded for the first time in West Greenland waters between 63°14' and 65°04'N at depths from 705 to 1199 m and temperatures between 3.0 and 3.9 °C (Fig. 11, Tables 3-5). The length ranged from 12 to 16 cm without particular modes. A 12 cm female caught in Septem-

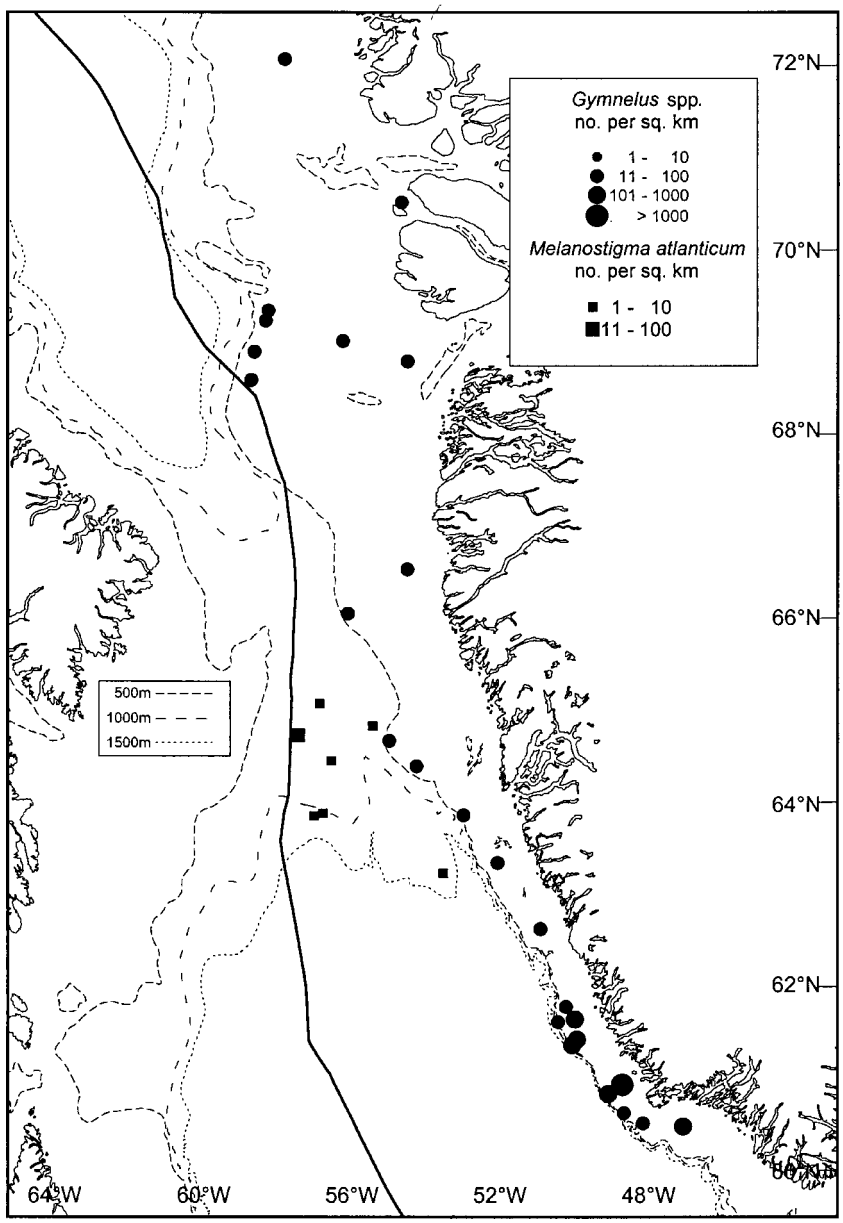

Fig. 11. Distribution and density of *Gymnelus* spp. and *Melanostigma atlanticum* in West Greenland waters 1992-1998.

ber had 75 orange eggs, 2.3 mm in diameter. The number of eggs was considerably higher than the "about 30 eggs" mentioned by Andriashev (1986), whereas time of spawning and egg diameter are in agreement with studies of benthic spawning made by Markle & Wenner (1979) and Silverberg & al. (1987) off eastern North America.

Elsewhere, it is recorded from off Newfoundland to Virginia in the western Atlantic and from the Faroe-Iceland Ridge to off Mauritania including the Mediterranean in the eastern Atlantic (Koefoed 1952; McAllister & Rees 1964; Anderson 1994).

GYMNELUS SPP.

Most *Gymnelus* were identified as *G. viridis* (Fabricius, 1780) or *G. retrodorsalis* Le Danois, 1913 based on the position of the dorsal fin origin. However, the genus *Gymnelus* is currently being reviewed and several new species will be described in the near future (N.V.

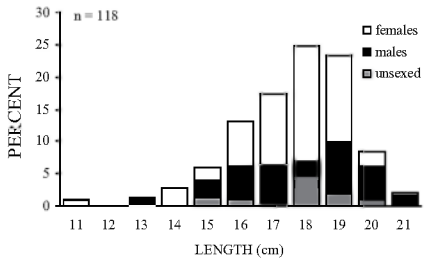

Fig. 12. Length distribution of *Lycenchelys kolthoffi* caught in shrimp trawl 1998.

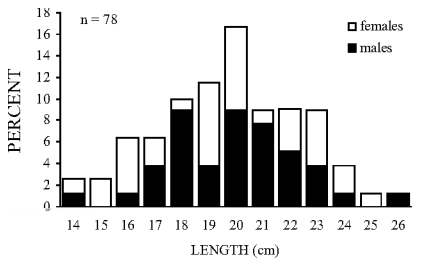

Fig. 13. Length distribution of *Lycenchelys paxillus* caught in shrimp trawl 1998.

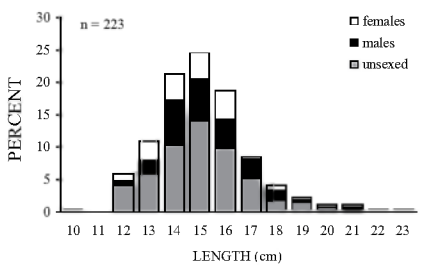

Fig. 14. Length distribution of *Lycenchelys sarsii* caught in shrimp trawl 1998.

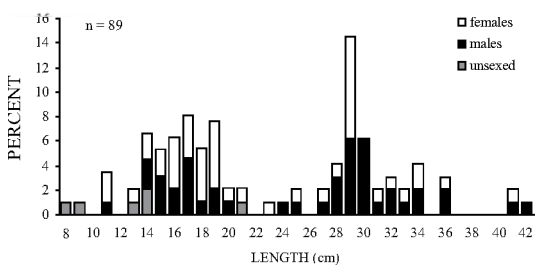

Fig. 15. Length distribution of *Lycodes esmarkii* caught in shrimp trawl 1998.

Chernova, Zoological Institute St. Petersburg, pers. commn 1998). Some of these species might have been present in our material and therefore all specimens are treated as *Gymnelus* spp.

Gymnelus spp. was recorded from 28 trawl hauls in relatively high densities (up to 1321 specimens per km^2). They were found between 60°27' and 72°04'N at depths from 72 to 360 m and temperatures between 1.6 and 5.8 °C (Fig. 11, Table 3). The highest density was found on the southern shelf and it was the most prevalent taxon in shallow water (0-200 m) (Tables 4-5).

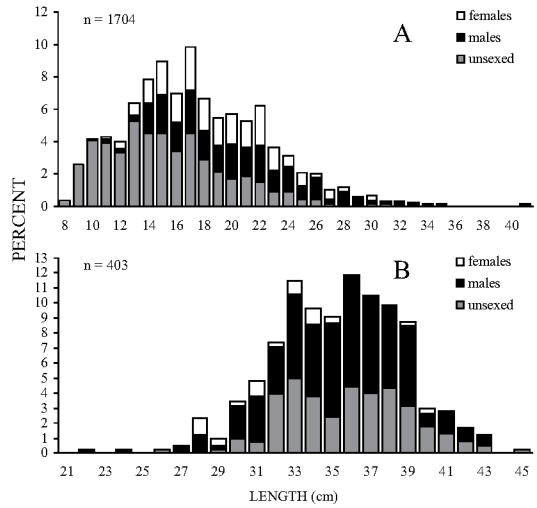

Fig. 16. Length distribution of *Lycodes eudipleurostictus*. A. Caught in shrimp-trawl 1998. B. Caught on longlines 1997-1998.

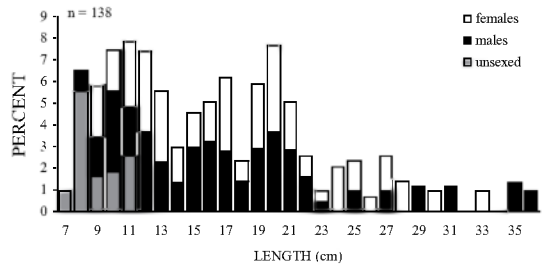

Fig. 17. Length distribution of *Lycodes reticulatus* caught in shrimp trawl 1998.

According to Anderson (1982, 1994) *G. viridis* has a circum-arctic distribution and occurs between 60°08'N and 76°40'N in West Greenland waters and up to 82°29'N on the Canadian side of the Ellesmere Island Sound. Chernova (1998) included eight specimens of *G. viridis* from West Greenland in her redescription of the species, but stated that the species is replaced by related species in other parts of the Arctic Ocean.

Gymnelus retrodorsalis has previously been recorded from 59°44'N to 76°32'N in West Greenland waters (Anderson 1982). Elsewhere, *G. retrodorsalis* is distributed from eastern Canada westward to the Kara Sea (Anderson 1982, 1994).

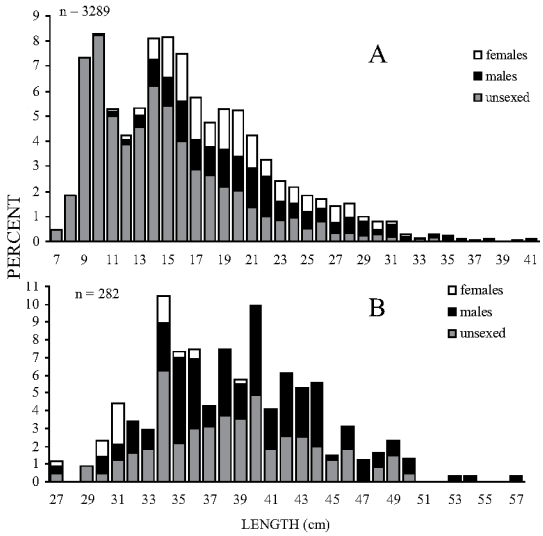

Fig. 18. Length distribution of *Lycodes seminudus* A. Caught by shrimp-trawl 1998. B. Caught on longlines 1997-1998.

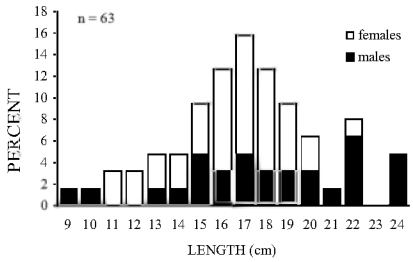

Fig. 19. Length distribution of *Lycodes* sp. 1 caught in shrimp trawl 1998.

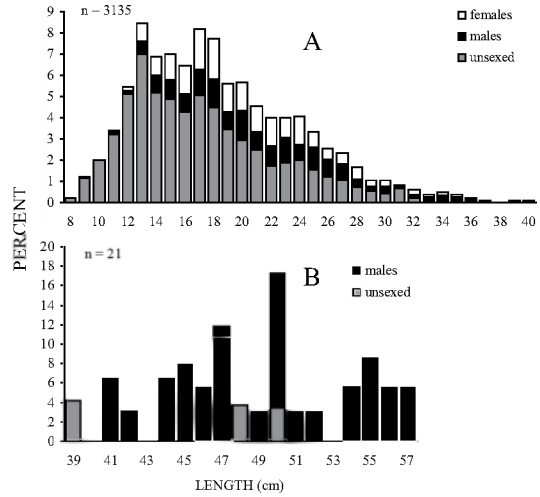

Fig. 20. Length distribution of *Lycodes vahlii* A. Caught in shrimp trawl 1998. B. Caught on longlines 1997-1998.

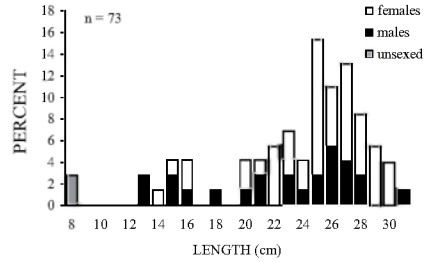

Fig. 21. Length distribution of *Lycodonus mirabilis* caught in ground fish trawl 1995.

General distribution patterns

The result of the Correspondence Analysis (CA) is shown in Fig. 22. Most of the species were placed relatively close together near the origin, due to their coexistence on the shelf-upper slope north of the Canada-Greenland ridge. In this area the zoarcid fauna was characterised by relatively high densities of *L. seminudus*, *L. reticulatus* and *L. kolthoffi*, which were found in this part of the survey area only. *Lycodes eudipleurostictus* and *L. vahlii* also were very abundant, whereas *Gymnelus* spp, *L. esmarkii*, *L. luetkenii*, *L. pallidus*, *L. sarsii* and *L. mirabilis* occurred in lower densities. Axis 3 appears to represent a depth gradient for these species and *L. seminudus* was placed low on this, due to its very high abundance in several relatively deep hauls near the shore in the Disko Bay.

Gymnelus spp. was placed with greatest distance to the others along axis 3, due to its relatively high abundance on the most shallow locations, especially south of the ridge. Closest to *Gymnelus* spp. were three other shallow water species *L. sarsii*, *L. reticulatus* and *L. pallidus*, held together by their independent coexistence with the widespread *L. vahlii*. They were not found together, but *L. vahlii* corresponded strongly with *L. sarsii* south of the ridge and with *L. reticulatus* and *L. pallidus* north of the ridge.

Axis 1 seems to represent a north-south gradient for slope species and *L. mirabilis*, *L. terraenovae* and *M. atlanticum* made up a very distant group at the extreme end of this axis. They were caught in low densities on the middle slope south of the ridge. The latter two were restricted to this area, characterised by relatively warm Atlantic water, whereas *L. mirabilis* occurred in few hauls further north. *Lycenchelys paxillus* showed some affinity to these species due to coexistence on the middle slope south of the ridge, but was drawn towards the other species, due to coexistence with *Lycodes* sp. 1 and *L. esmarkii* on both sides of the ridge; *L. sarsii* and *L. vahlii* south of the ridge and with *L. eudipleurostictus* and north of the ridge.

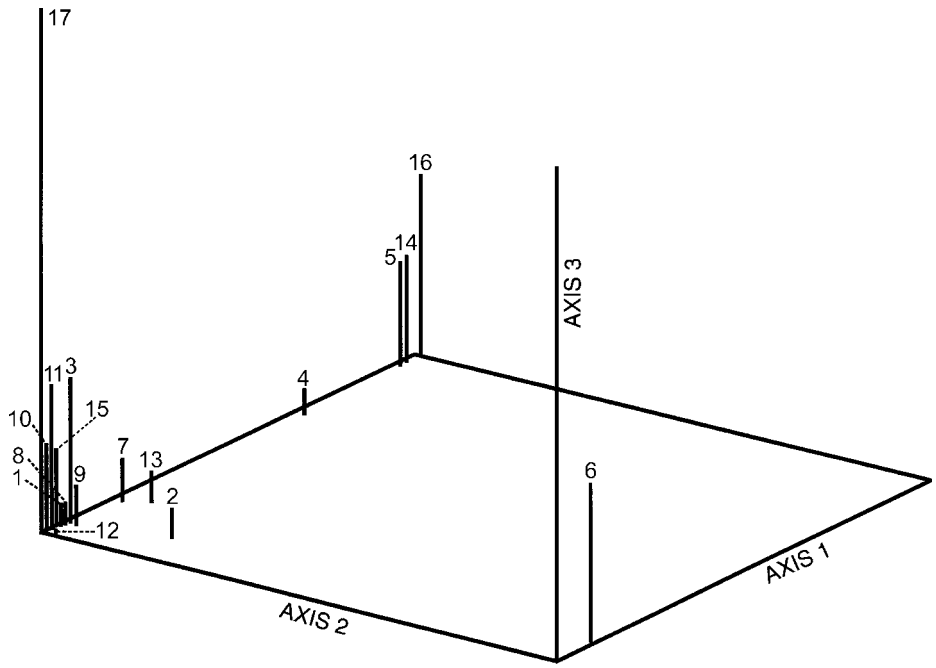

Fig. 22. Correspondence analysis of the distribution patterns of eelpouts off West Greenland based on abundance in trawl catches 1992-1998. 1 = *L. kolthoffi*, 2 = *L. muraena*, 3 = *L. sarsii*, 4 = *L. paxillus*, 5 = *L. mirabilis*, 6 = *L. adolfi*, 7 = *L. esmarkii*, 8 = *L. eudipleurostictus*, 9 = *L. luetkenii*, 10 = *L. pallidus*, 11 = *L. reticulatus*, 12 = *L. seminudus*, 13 = *Lycodes* sp. 1, 14 = *L. terraenovae*, 15 = *L. vahlii*, 16 = *M. atlanticum*, 17 = *Gymnelus* spp.

L. adolfi was placed far from the rest along the axis 2. It was caught as the only zoarcid in two hauls on the middle slope north of the ridge and coexisted with another zoarcid (*L. muraena*) in a single haul only. *Lycodes* sp. 1, *L. eudipleurostictus* and *L. luetkenii* also occurred on the middle slope north of the ridge, but were found on the shelf-upper slope as well. Furthermore, *L. paxillus* and *L. esmarkii* were caught a few times on the middle slope. All species occurred in relatively low densities, but it should be noted that the coverage of this area was less extensive compared to the other areas (Fig. 1, Table 1).

DISCUSSION

Gear selection

Differences in gear selection between longline (inshore) and trawl (offshore) were indicated by the number of species and length compositions in the two gears. Only five species were represented in the longline catches. The sizes were generally much larger than specimens of the same species taken in trawls. The size of the bait/hook physically prevents fish below a certain size taking the bait and hence being recorded from the longlines. Small sized fish are probably present also in the inshore areas. Most of the trawl length-frequency distributions presented are based on observations from a shrimp trawl, towed relatively slowly (2-2.5 knots), rigged with steel bobbins and 75-cm straps between the ground gear and the footrope. This allows fish either to swim away from the trawl or to escape beneath it. Low catchability for large specimens in trawls versus longline has been reported previously for a number of other species off West Greenland (Jørgensen 1995). A few species have been observed to hide in the sediment (e.g. *M. atlanticum*, (Silverberg & al. 1987)) and a cryptobenthic habit may not be uncommon (Nash 1986). Low catchability in the trawl is expected, due to the size and body shape of *Gymnelus* spp., *M. atlanticum* and *Lycenchelys* spp, *L. mirabilis* and small specimens of *Lycodes* spp. Thus, the observed densities are probably underestimated and should be regarded as indices only.

Comparisons of density estimates obtained from trawl and still photographs have shown that the trawl underestimates the density by up to an order of magnitude (e.g. Haedrich & al. 1975). Further, *M. atlanticum* is a midwater species outside spawning season and the abundance is therefore heavily underestimated in bottom trawl surveys (Markle & Wenner 1979; Merrett 1986).

Distribution patterns

A few eelpouts previously reported from West Greenland waters were not caught during the present surveys. Three specimens of *Lycodes mucosus* Richardson, 1855 were reported from the Thule area (76°35'N), all caught in shallow water (Jensen 1952). A fourth specimen from 75°20'N, 58°38'W is present in the ZMUC collection (unpublished data). A single specimen of *Lycodes polaris* (Sabine, 1824) has been reported from off West Greenland (69°29'N, 55°26'W, 212 m) (Jensen 1952), but further six specimens, caught in shallow water (47-180 m) between 69°N and 76°N, are present in the ZMUC collection (unpublished data). The reason why these species are missing in the present material is probably due to the low coverage of shallow areas north of 70°N. Furthermore, a single specimen of *Lycenchelys alba* (Vaillant, 1888) has been reported from off Southwest Greenland (58°51'N, 53°04'W, 3365 m). It was originally descried as a new species *L. labradorensis* Geistdoerfer & al., 1970, but is now regarded as a junior synonym of *L. alba* (Anderson 1994; Møller 1999). The Arctic deep-sea species *Lycodes frigidus* Collett, 1878 was reported from both coasts of Greenland by Saito & Okamura (1995), but the West Greenland specimens belong to *Lycodes* sp.1. Thus there are no valid records of *L. frigidus* from West Greenland waters.

If previously recorded species are included, 11 species (including *Lycodes* sp. 1) have their main distribution on the shelf-upper slope (0-600 m) north of the Greenland-Canada Ridge, while three shelf-upper slope species occur on both sides of the ridge. Some of the species with a northern distribution (*L. eudipleurostictus*, *L. seminudus* and *L. reticulatus*) have previously been recorded from cold threshold fjords in southern West Greenland (Jensen 1952). The results of the present study indicate that such populations are now more or less isolated from the northern populations. The isolation factors are probably both high temperatures and physical barriers (shallow water). This is also observed in Porsanger Fjord, northern Norway, where a relict population of *Lycodes rossi* Malmgren, 1965 is isolated from the main population in the northern Barents Sea (Andriashev 1986). Most of the 11 northern shelf-upper slope species are obviously not limited by the physical barrier of the ridge, since they all live at depths less than 700 m. The temperature might be a barrier for dispersal southwards, but this cannot be concluded directly from these investigations because the temperatures observed were at the same level as south of the ridge at least during summer/autumn.

Of the four species on the southern middle slope (600-1500 m), *L. terraenovae* and *M. atlanticum* inhabit so

Table 3. Depth and temperature ranges with +/- Standard Error (SE) of West Greenland eelpouts. Mean values are weighted by the number of fish per km².

Taxa	Depth (m)					Temp. (°C)				
	n (obs)	min	max	Mean weighted	SE	n (obs)	min	max	Mean weighted	SE
Lycenchelys kolthoffi	12	229	555	408	13.4	12	1.7	4.1	3.3	0.23
Lycenchelys muraena	4	534	1271	629	129	3	1.5	3.4	2.1	0.62
Lycenchelys paxillus	95	424	1093	659	17.3	77	0.9	5.5	4.1	0.11
Lycenchelys sarsii	37	107	572	359	13.7	37	2.2	5.6	4.5	0.11
Lycodes adolfi	3	420	1436	1326	177.2	2	0.0	2.2	0.2	0.63
Lycodes esmarkii	31	311	1090	529	22.1	29	1.0	5.3	3.8	0.18
Lycodes esmarkii (line)	2	310	430	358	58.7	-	-	-	-	-
Lycodes eudipleurostictus	80	237	871	475	7.3	71	0.9	4.9	3.3	0.10
Lycodes eudipleurostictus (line)	52	188	975	548	30.0	41	0.5	2.8	1.7	0.10
Lycodes luetkenii	5	259	553	480	50.7	5	1.5	3.4	2.4	0.29
Lycodes pallidus	1	271	271	271	-	1	1.6	1.6	1.6	-
Lycodes reticulatus	24	164	412	233	9.1	24	1.6	4.5	2.1	0.10
Lycodes reticulatus (line)	2	171	402	262	113.0	2	1.3	1.5	1.4	0.08
Lycodes seminudus	62	181	588	429	9.3	56	1.6	4.9	3.4	0.08
Lycodes seminudus (line)	39	187	743	348	15.1	27	0.5	2.8	1.5	0.10
Lycodes sp.1	17	337	1271	632	32.3	15	0.9	4.4	2.0	0.35
Lycodes terraenovae	30	697	1365	993	32.1	19	3.0	3.9	3.3	0.05
Lycodes vahlii	142	71	588	395	7.6	135	1.6	5.8	4.2	0.89
Lycodes vahlii (line)	8	370	750	464	29.1	6	1.4	2.2	1.5	0.09
Lycodonus mirabilis	134	298	1490	1031	15.9	99	1.0	4.5	3.3	0.03
Melanostigma atlanticum	7	705	1199	926	75.1	3	3.0	3.9	3.4	0.27
Gymnelus spp.	28	72	360	214	9.2	28	1.6	5.8	3.7	0.17

Table 4. Number of records, percentage of occurrence and mean density with +/– Standard Error (SE) of West Greenland eelpouts by species and 200 m depth intervals.

	0-200 m	201-400 m	401-600	601-800 m	801-1000 m	1001-1200 m	1201-1500 m	Total
Trawl hauls	55	126	102	102	76	91	64	616
Taxa	Occurrence							
Lycenchelys kolthoffi	-	3 (2%)	9 (9%)	-	-	-	-	12 (2%)
Lycenchelys muraena	-	-	2 (2%)	1 (1%)	-	-	1 (2%)	4 (1%)
Lycenchelys paxillus	-	-	18 (14%)	46 (45%)	27 (35%)	4 (4%)	-	95 (15%)
Lycenchelys sarsii	1 (2%)	22 (17%)	14 (14%)	-	-	-	-	37 (6%)
Lycodes adolfi	-	-	1 (1%)	-	-	-	2 (3%)	3 (0.5%)
Lycodes esmarkii	-	4 (3%)	17 (17%)	7 (7%)	2 (3%)	1 (1%)	-	31 (5%)
Lycodes eudipleurostictus	-	26 (21%)	46 (45%)	7 (7%)	1 (1%)	-	-	80 (13%)
Lycodes luetkenii	-	1 (1%)	4 (4%)	-	-	-	-	5 (1%)
Lycodes pallidus	-	1 (1%)	-	-	-	-	-	1 (0.2%)
Lycodes reticulatus	6 (11%)	17 (13%)	1 (1%)	-	-	-	-	24 (4%)
Lycodes seminudus	1 (2%)	24 (19%)	37 (36%)	-	-	-	-	62 (10%)
Lycodes sp.1	-	2 (2%)	6 (6%)	7 (7%)	1 (1%)	-	1 (2%)	17 (3%)
Lycodes terraenovae	-	-	-	8 (8%)	8 (11%)	12 (13%)	2 (3%)	30 (5%)
Lycodes vahlii	7 (13%)	80 (63%)	55 (54%)	-	-	-	-	142 (23%)
Lycodonus mirabilis	-	-	1 (1%)	23 (23%)	37 (49%)	47 (52%)	26 (41%)	134 (22%)
Melanostigma atlanticum	-	-	-	3 (3%)	1 (1%)	3 (3%)	-	7 (1%)
Gymnelus spp.	13 (23%)	15 (12%)	-	-	-	-	-	28 (5%)
	Mean density (specimens per km^2)							Total (+/-SE)
Lycenchelys kolthoffi	-	296	221	-	-	-	-	240 (+/-144.0)
Lycenchelys muraena	-	-	53	7	-	-	13	32 (+/-14.2)
Lycenchelys paxillus	-	-	76	23	29	7	-	34 (+/-7.5)
Lycenchelys sarsii	24	102	85	-	-	-	-	94 (+/-22.6)
Lycodes adolfi	-	-	8	-	-	-	61	44 (+/-23.3)
Lycodes esmarkii	-	12	71	11	40	14	-	46 (+/-15.0)
Lycodes eudipleurostictus	-	118	835	81	14	-	-	520 (115.8)
Lycodes luetkenii	-	24	36	-	-	-	-	34 (+/-11.4)
Lycodes pallidus	-	49	-	-	-	-	-	49
Lycodes reticulatus	107	116	27	-	-	-	-	110 (+/-33.4)
Lycodes seminudus	24	952	1548	-	-	-	-	1293 (+/-261)
Lycodes sp.1	-	12	72	70	21	-	7	57 (+/-14.2)
Lycodes terraenovae	-	-	-	7	9	9	8	8 (+/-0.6)
Lycodes vahlii	120	335	482	-	-	-	-	381 (+/-85.9)
Lycodonus mirabilis	-	-	7	15	20	24	18	20 (+/-1.3)
Melanostigma atlanticum	-	-	-	9	7	8	-	8 (+/-0.7)
Gymnelus spp.	77	147	-	-	-	-	-	109 (+/-47.5)
Longlines	3	27	26	15	7	-	-	78
	Occurrence							
Lycodes esmarkii	-	1 (4%)	1 (4%)	-	-	-	-	2 (3%)
Lycodes eudipleurostictus	1 (33%)	17 (63%)	20 (77%)	7 (47%)	7 (100%)	-	-	52 (67%)
Lycodes reticulatus	1 (33%)	-	1 (4%)	-	-	-	-	2 (3%)
Lycodes seminudus	2 (67%)	21 (78%)	14 (54%)	2 (13%)	-	-	-	39 (50%)
Lycodes vahlii	-	2 (7%)	4 (15%)	2 (13%)	-	-	-	8 (10%)
	Mean catch per 1000 hooks							
Lycodes esmarkii	-	1	1	-	-	-	-	1.2 (+/-0.2)
Lycodes eudipleurostictus	6	4	5	8	9	-	-	6 (+/-0.7)
Lycodes reticulatus	2	-	1	-	-	-	-	1.6 (+/-0.4)
Lycodes seminudus	4	9	3	3	-	-	-	6 (+/-1.4)
Lycodes vahlii	-	2	3	1	-	-	-	2 (+/-0.9)

Table 5. Number of records, percentage of occurrence and mean density of West Greenland eelpouts by species and 1 °C temperature intervals.

	0.0-0.9 °C	1.0-1.9 °C	2.0-2.9 °C	3.0-3.9 °C	4.0-4.9 °C	5.0-5.9 °C	Total
Trawl hauls	10	30	86	277	92	15	510
Taxa			Occurrence				
Lycenchelys kolthoffi	-	1 (3%)	3 (3%)	7 (3%)	1 (1%)	-	12 (2%)
Lycenchelys muraena	-	2 (7%)	-	1 (0.4%)	-	-	3 (1%)
Lycenchelys paxillus	2 (20%)	5 (17%)	4 (5%)	51 (18%)	13 (14%)	1 (7%)	76 (15%)
Lycenchelys sarsii	-	-	3 (3%)	9 (3%)	17 (18%)	8 (53%)	37 (7%)
Lycodes adolfi	1 (10%)	-	1 (1%)	-	-	-	2 (0.4%)
Lycodes esmarkii	-	4 (13%)	1 (1%)	8 (3%)	14 (15%)	2 (13%)	29 (6%)
Lycodes eudipleurostictus	4 (40%)	4 (13%)	14 (16%)	21 (8%)	28 (30%)	-	71 (14%)
Lycodes luetkenii	-	1 (3%)	2 (2%)	2 (1%)	-	-	5 (1%)
Lycodes pallidus	-	1 (3%)	-	-	-	-	1 (0.2%)
Lycodes reticulatus	-	5 (17%)	12 (14%)	6 (2%)	1 (1%)	-	24 (5%)
Lycodes seminudus	-	2 (7%)	19 (22%)	19 (7%)	16 (17%)	-	56 (11%)
Lycodes sp.1	1 (10%)	6 (20%)	1 (1%)	4 (1%)	3 (3%)	-	15 (3%)
Lycodes terraenovae	-	-	-	19 (7%)	-	-	19 (4%)
Lycodes vahlii	-	8 (27%)	31 (36%)	35 (13%)	54 (59%)	7 (47%)	135 (26%)
Lycodonus mirabilis	-	1 (3%)	6 (7%)	88 (32%)	4 (4%)	-	99 (19%)
Melanostigma atlanticum	-	-	-	3 (1%)	-	-	3 (1%)
Gymnelus spp.	-	5 (17%)	8 (9%)	4 (1%)	9 (10%)	-	28 (5%)
			Mean density (specimens per km^2)				
Lycenchelys kolthoffi	-	8	431	278	36	-	-
Lycenchelys muraena	-	39	-	36	-	-	-
Lycenchelys paxillus	18	7	16	24	54	657	-
Lycenchelys sarsii	-	-	18	78	78	165	-
Lycodes adolfi	88	-	9	-	-	-	-
Lycodes esmarkii	-	28	8	55	57	15	-
Lycodes eudipleurostictus	186	120	543	1060	301	-	-
Lycodes luetkenii	-	18	52	23	-	-	-
Lycodes pallidus	-	49	-	-	-	-	-
Lycodes reticulatus	-	121	136	47	194	-	-
Lycodes seminudus	-	29	797	2517	510	-	-
Lycodes sp.1	180	72	37	37	48	-	-
Lycodes terraenovae	-	-	-	8	-	-	-
Lycodes vahlii	-	112	232	207	481	1301	-
Lycodonus mirabilis	-	7	15	23	21	-	-
Melanostigma atlanticum	-	-	-	8	-	-	-
Gymnelus spp.	-	19	73	121	194	55	-
Longlines	7	29	26	-	-	-	62
			Occurrence				
Lycodes eudipleurostictus	6 (86%)	17 (59%)	18 (69%)	-	-	-	-
Lycodes reticulatus	-	2 (7%)	-	-	-	-	-
Lycodes seminudus	5 (71%)	13 (45%)	9 (35%)	-	-	-	-
Lycodes vahlii	-	4 (14%)	2 (8%)	-	-	-	-
			Mean density (specimens per km^2)				
Lycodes eudipleurostictus	9	4	7	-	-	-	-
Lycodes reticulatus	-	2	-	-	-	-	-
Lycodes seminudus	7	19	3	-	-	-	-
Lycodes vahlii	-	4	1	-	-	-	-

deep water that the ridge may form a barrier for a northward dispersal. *Lycodonus mirabilis* and *L. paxillus* are able to live at low temperatures, but are rarely found north of the ridge. Thus, the middle slope eelpout fauna south of the ridge resembles the West Greenland macrourid fauna of which only one of nine species is found north of the ridge (Jørgensen 1996). The definitions "*kingdom of the eelpouts*" and "*kingdom of the macrourids*" by Jungersen (1897) for the areas north and south of the Wyville Thomson Ridge in the Northeast Atlantic are thus equally relevant for the Northwest Atlantic.

Several Arctic species were, however, caught in surprisingly warm water. When compared to Andriashev's (1986) study it seems that many species occur at considerably higher temperatures in the Northwest Atlantic than in the Northeast Atlantic. This has previously been noticed for *Lycodes adolfi* (Nielsen & Fosså 1993) and *L. reticulatus* (Morosova 1982), but Arctic eelpouts (e.g. *L. kolthoffi* and *L. pallidus*), thought to be restricted to temperatures below 0 °C, have also been caught off West Spitsbergen, which is influenced by the warm West Spitsbergen current (Møller 1995). It is thus clear that the shelf species north of the Greenland-Canada Ridge are able to tolerate relatively warm water that overflows the ridge mainly during summer and autumn. This overflow was probably extensive in 1998, where most of the sampling in this area was done.

Densities

L. seminudus was found in the highest mean densities off West Greenland, more than twice as dense as *L. eudipleurostictus* and more than three times as dense as *L. vahlii*. Morosova (1982) found *L. reticulatus*, *L. esmarkii*, and *L. vahlii* to be the most abundant eelpout species off Labrador and Newfoundland (depths 0-750 m). A large proportion of the hauls in that study were carried out at temperatures below 1.5 °C and this might be the reason for the high density of *L. reticulatus*. In the present study, where few hauls were carried out at temperatures below 1.5 °C, *L. reticulatus* had the fifth highest mean density. The zoarcid density of the Greenland shelf and slope north of the Greenland-Canada ridge is also comparable with the results of Dorrien (1993) from the Svalbard Archipelago/Barents Sea (140-400 m) and off N.E. Greenland (100-490 m). In the first area the most abundant zoarcids were *L. pallidus* (up to 6296 km^{-2}), *L. reticulatus* (up to 3571 km^{-2}) and *L. eudipleurostictus* (up to 1010 km^{-2}). *L. eudipleurostictus* (up to 1144 km^{-2}), *L. reticulatus* (up to 818 km^{-2}) and *L. pallidus* (up to 641 km^{-2}) was the most abundant zoarcids off Northeast Greenland. The differences in species abundance compared to West Greenland waters are partly explained by differences in the depth range covered (shallower) and temperature range (colder) of these areas.

Table 6. Relationship of total length (cm) and weight (g) for nine species of West Greenland eelpouts. Since significant difference between sexes was observed in *L. vahlii* only, the other species are showed as sex combined.

Species	n	Regression		
		Slope	Intercept (log_{10})	r^2
Lycenchelys kolthoffi	59	2.901	–2.599	0.854
Lycenchelys paxillus	69	3.375	–3.304	0.904
Lycenchelys sarsii	80	2.666	–2.367	0.823
Lycodes esmarkii	87	3.384	–2.885	0.994
Lycodes eudipleurostictus	499	3.254	–2.657	0.992
Lycodes reticulatus	136	3.104	–2.346	0.984
Lycodes seminudus	506	3.148	–2.469	0.993
Lycodes terraenovae	9	3.368	–2.943	0.971
Lycodes vahlii				
Male	199	3.167	–2.627	0.983
Female	221	3.167	–2.609	0.958
Sexes combined	485	3.179	–2.636	0.979

Interspecific competition

From the present study, little can be said about the interspecific competition between species, since the feeding biology is completely unknown for several species and has not been studied in West Greenland populations. Valtysson (1995) found a relatively high degree of food segregation among six species of *Lycodes*, which might explain the coexistence of e.g. *L. vahlii*, *L. eudipleurostictus* and *L. seminudus* in high densities. "Shorttailed" *Lycodes* spp. (e.g. *L. luetkenii*, *L. reticulatus* and *L. seminudus*) are assumed to be more predatory than "longtailed" species (e.g. *L. esmarkii*, *L. vahlii* and *L. pallidus*). Hecker (1994) explained extremely high densities (up to 0.30 and 0.75 specimens/m^2) of *L. atlanticus* (= *L. terraenovae*) and *L. verrillii* (Goode & Bean, 1877) off Cape Hatteras with a high abundance of infaunal prey, but such correlations are not possible to make in the present study.

Reproduction

Most species in the investigation showed signs of sexual maturation (*Gymnelus* spp. not considered). The only exceptions were *L. adolfi* and *L. luetkenii*, but sexual maturation has been observed previously for these species (Nielsen & Fosså 1993; Møller & Petersen 1997). No spawning or spent specimens were observed, indicating that spawning for all species takes place later in the year, i.e. autumn/winter. This is supported by the fact that the size of the eggs generally was lower than observed by previous authors (e.g. Andriashev 1986). The fecundity of all species was low, ranging from 12 eggs in *L. sarsii* to about 400 in *L. seminudus*. In all species only a fraction of the specimens above the size of first

maturity showed sign of maturation (this also applies to the largest individuals), indicating that spawning might not take place every year. The present data confirms that the family displays a typical precocial pattern with few large eggs (Flegler-Balon 1989; Merrett 1994). Within genera and species the egg number was correlated to fish length (Fig. 23). This is in contrast to Merrett (1994), who found that the egg number in zoarcids is relatively uncorrelated with adult size. The fecundity could not be related to distribution patterns with any certainty.

Historical biogeography

The historical biogeography of West Greenland eelpouts is not clear since no phylogenetic studies on the species have been carried out. It has been suggested that the Atlantic and Arctic species have a north Pacific origin and evolved after trans-Arctic dispersal, with fluctuating glacial and interglacial conditions as the vicariant events (Berg 1934; Shmidt 1950; Briggs 1974). Only two (*L. paxillus* and *L. mirabilis*) of the 16 species (*Gymnelus* not considered) are endemic to the Northwest Atlantic. Four species (*L. muraena*, *L. sarsii*, *L. luetkenii* and *L. eudipleurostictus*) are widely distributed in the eastern North Atlantic and Arctic, but seems to have the western limit of their distribution off West Greenland.

Further investigations

The lack of knowledge on distribution and biology of Northwest Atlantic and Arctic eelpouts is demonstrated by the present study, which revealed five species new to West Greenland (*M. atlanticum*, *L. muraena*, *L. sarsii*, *L. pallidus* and *Lycodes* sp. 1) and six new to Canadian waters (*L. muraena*, *L. sarsii*, *L. luetkenii*, *L. adolfi*, *L. eudipleurostictus* and *Lycodes* sp. 1). Additional sampling in the northern and deep southern parts of West Greenland should be carried out to get a more complete picture of the distribution patterns of the high Arctic (> 73°N) and deep-sea (> 1500 m) species.

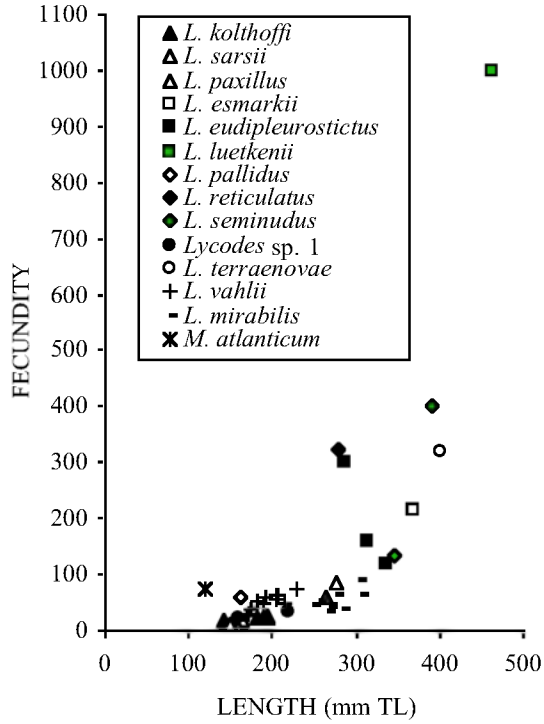

Fig. 23. Relationship between fecundity (egg number) and length (TL) among eelpouts from off West Greenland.

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Appendix 1. Key to the eelpouts off West Greenland.

1. a. Pelvic fins absent, pectoral fin rays < 15 ..... (Gymnelinae) 2
   b. Pelvic fins present, pectoral fin rays 15-24 ..... (Lycodinae) 4
2. a. Flesh gelatinous, gill opening pore-like ..... *Melanostigma atlanticum*
   b. Flesh firm, gill opening not pore-like ..... (*Gymnelus*) 3
3. a. Origin of dorsal fin at posterior part of pectoral fin ..... *Gymnelus viridis*
   b. Origin of dorsal fin well behind end of pectoral fin ..... *Gymnelus retrodorsalis*
4. a. Body very long and rounded, head pores very large, lover jaws without cartilage crests 5
   b. Body moderately long and laterally compressed, head pores minute or moderate, lower jaws with cartilage crests ..... (*Lycodes*) 10
5. a. Dorsal and anal fin rays with bony plates at basis (6-10 free plates in front of dorsal fin) ..... *Lycodonus mirabilis*
   b. Dorsal and anal fin rays without bony plates at basis ..... (*Lycenchelys*) 6
6. a. Predorsal length > 24 % SL ..... *Lycenchelys alba*
   b. Predorsal length < 24 % SL 7
7. a. Abdomen naked, dorsal fin with dark and white blotches. Body and head light with dark reticulations dorsally on head and body and with dark spots on the ventral site ..... *Lycenchelys kolthoffi*
   b. Abdomen scaled, dorsal fin uniformly dark brown 8
8. a. Predorsal length < 19 % SL, pectoral fins light with dark dorsal margin ..... *Lycenchelys muraena*
   b. Predorsal length > 19 % SL, coloration of pectoral fins different 9
9. a. Suborbital head pores 7, pectoral fins uniformly dark ..... *Lycenchelys paxillus*
   b. Suborbital head pores 6, pectoral fin light anteriorly, dark posteriorly ..... *Lycenchelys sarsii*
10. a. Ventral lateral line present (additional lines may be present). Preanal length usually < 45 % SL 11
    b. Ventral lateral line absent (medio-lateral lateral line always present), preanal length usually > 45 % SL 18
11. a. Lateral line system "double" (ventral and medio-lateral lines) 12
    b. No medio-lateral lateral line present 16
12. a. Area in front of dorsal fin scaled, medio-lateral neuromasts on trunk and tail, vertebrae > 105 13
    b. Area in front of dorsal fin without scales, medio-lateral neuromasts on tail only, vertebrae < 105 15
13. a. Medio-lateral lateral with many neuromasts (> 65), length of premaxillary teeth row equal to palatine teeth row, pectoral fins more or less emarginate, basis without scales ..... *Lycodes eudipleurostictus*
    b. Medio-lateral lateral line with few neuromasts (< 65 neuromasts), length of premaxillary teeth row usually longer than palatine teeth row, pectoral fin rounded, basis scaled 14
14. a. Dorsal part of body dark with 5-9 white marks ..... *Lycodes esmarkii*
    b. Body uniformly light or dark brown ..... *Lycodes terraenovae*
15. a. Nostril tubes long (> 1.0 % SL), eyes oval, scalerows above origin of anal fin 10-17, body with 5-12 light bars or uniformly brown ..... *Lycodes pallidus*
    b. Nostril tubes short (< 1.0 % SL), eyes circular, scalerows above origin of anal fin > 17, body always uniformly brown ..... *Lycodes* sp. 1
16 a. Dorsal part of body grey-brown with irregular dark stripes, lower part light. Dorsal fin with 0-3 black spots anteriorly. Postorbital head pores 4, occipital head pores 3 ..... *Lycodes vahlii*
    b. Body uniformly dark black or brown. Postorbital head pores 1-2, occipital head pores 0-2 17
17. a. Body covered with small scales, pectoral finrays 19-23 (not found in West Greenland waters yet) ..... *Lycodes frigidus*
    b. Anterior half of body (45-58 % SL) without scales, pectoral finrays 16-19 ..... *Lycodes adolfi*
18. a. Peritoneum weekly pigmented, anterior scales begins 31-56 % SL from tip of snout, snout concave .... *Lycodes seminudus*
    b. Peritoneum not pigmented, anterior scales begins less than 31 % SL from tip of snout, snout convex 19
19. a. Colour more or less pink with 7-8 white bars dorsally, juveniles grey brown with pink pectorals, pectoral finrays 23-24 ..... *Lycodes luetkenii*
    b. Colour not pink, pectoral fin with less than 23 rays 20
20. a. Body naked or with very few scattered scales 21
    b. Body scaled 22
21. a. Body with 9-13 narrow white bands dorsally, one straight white band on neck, predorsal length < 51 % SL ..... *Lycodes polaris*
    b. Body with 3-6 triangular white marks, one "horseshoe" shaped band on neck (sometimes reduced in large specimens), predorsal length > 51 % SL ..... *Lycodes mucosus*
22. a. Neck scaled, vertebrae 100-104, pectoral fin length 14-18 % SL, margin of dorsal and anal fin with black and light bands (not found in West Greenland waters yet) ..... *Lycodes lavalaei*
    b. Neck naked, vertebrae 92-99, pectoral fin length 12-16 % SL, no marginal bands on vertical fins ..... *Lycodes reticulatus*