ICES Journal of Marine Science, 58: 21–28. 2001
doi:10.1006/jmsc.2000.0985, available online at http://www.idealibrary.com on IDEAL®

Short communication

Notes on the distribution and length composition of *Raja lintea*, *R. fyllae*, *R. hyperborea* and *Bathyraja spinicauda* (Pisces: Rajidae) in the deep northeastern North Sea and on the slope of the eastern Norwegian Sea

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Skjæraasen, J. E., and Bergstad, O. A. 2001. Notes on the distribution and length composition of *Raja lintea*, *R. fyllae*, *R. hyperborea* and *Bathyraja spinicauda* (Pisces: Rajidae) in the deep northeastern North Sea and on the slope of the eastern Norwegian Sea. – ICES Journal of Marine Science, 58: 21–28.

The distribution and length composition of four skate species inhabiting deep shelf and upper slope waters of the Northeastern Atlantic are compared. *Raja lintea* and *Raja fyllae* primarily inhabited the Norwegian Deep of the northeastern North Sea, but also occurred in the upper slope waters of the eastern Norwegian Sea, and they had species-specific but partially overlapping distributions. Their areas of distribution were associated with relatively warm Atlantic water masses. In the deeper slope areas with colder Norwegian Sea Deep Water, *Raja hyperborea* was the only abundant skate, whilst *Bathyraja spinicauda* seemed associated with the frontal zone between the warm and cold water masses on the upper slope.

The entire size range of *Raja fyllae* was found, but mainly large *Raja lintea*. The catches of *Raja hyperborea* consisted of mostly large individuals, whereas the *Bathyraja spinicauda* were small, immature specimens.

Key words: Rajidae, *Raja lintea*, *Raja fyllae*, *Raja hyperborea*, *Bathyraja spinicauda* distribution, abundance, size, Norwegian Sea, North Sea.

Received 20 October 1999; accepted 8 June 2000.

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Introduction

In an earlier paper (Skjæraasen and Bergstad, 2000) we analysed the distribution and feeding ecology of *Raja radiata* (Donovan, 1808), in the northeastern North Sea and the Skagerrak based on data from bottom trawl investigations in the years 1984–1987 and 1995–1996. In the present paper we consider distribution and length composition of other less abundant Rajidae collected in the same investigations. The four species are *Raja fyllae* (Lutken, 1888), and the comparatively large *Raja lintea* (Fries, 1839), both of which are common in deep northeastern areas of the North Sea (Bergstad, 1990), and two species occurring in slope waters and in the Arctic but rare in the North Sea, i.e. *Bathyraja spinicauda* (Jensen, 1914) and *Raja hyperborea* (Collett, 1879). All these species are characteristic members of the fish communities in these waters (Stehmann and Burkel, 1984; Bergstad, 1990; Bergstad *et al.*, 1999), but little information on their distribution and abundance has been reported.

Materials and methods

Our study areas comprised the Norwegian Deep and the continental slope waters off western Norway northwards to about 68°N (Figure 1). The Norwegian Deep forms

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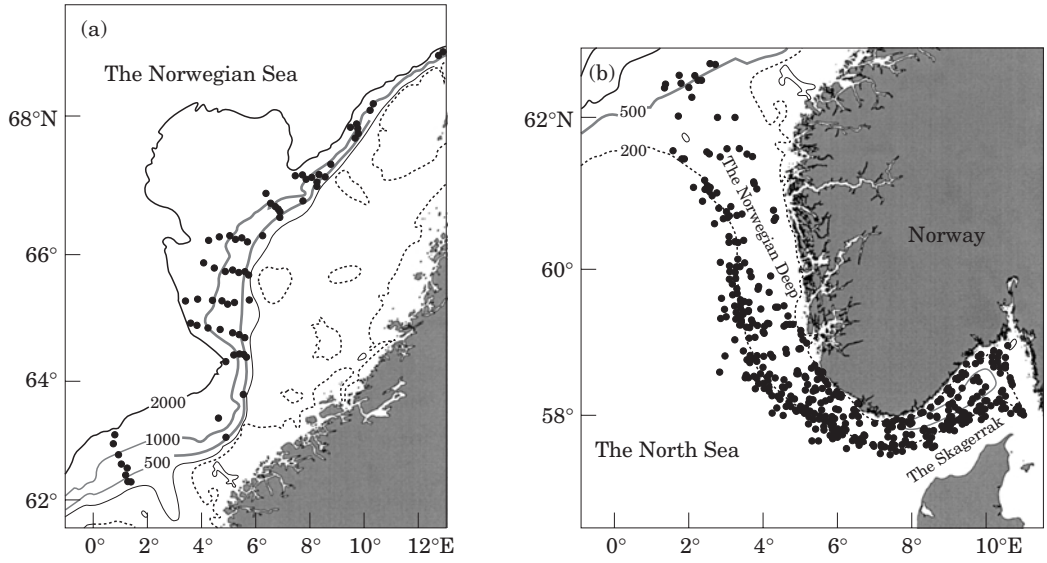

Figure 1. Study areas and distribution of bottom trawl stations in the 1984–87 and June 1995 research vessel surveys (b), and the December 1995 chartered trawler survey (a). Depths in m.

the most extensive deep channel in the North Sea and Skagerrak, with depths ranging 200–700 m. The most conspicuous hydrographical feature in this area is the strong inflow of warm and saline Atlantic Water along the western slope (Otto *et al*., 1990). The catch data from the Norwegian Deep were in some cases analysed by two subareas, i.e. "The North Sea" and "The Skagerrak", defined as areas to the west and east of 7°E, respectively, i.e. the border between ICES Divisions IVa and IIIa. There are no physical barriers limiting e.g. migration between these two subareas, but the former represents the shallower area with the stronger influence of the Atlantic Inflow (Furnes *et al*., 1986). The Skagerrak is considerably deeper (720 m), and there is a steady cyclonic circulation of the deepwater (Rohde, 1996). In each area, hauls were further stratified by the four depth strata: <180 m (1), 180–239 m (2), 240–300 m (3), and >300 m (4). These four strata were adopted on most of the 1984–1987 cruises. In seasonal distribution and abundance analyses, summer was defined as the months July–October, and winter as January–April.

The Norwegian Sea slope off western and mid-Norway extends to depths of 3000–3500 m, and the hydrography is characterized by three different water masses (Eggvin *et al*., 1963; Blindheim, 1986). There is an upper layer of warm saline Atlantic Water below which there is a layer of cold Intermediate Arctic Water overlaying the homohaline Norwegian Sea Deep Water with temperatures 0° to 1°C. The cross-slope stratification produced by these water masses greatly influences the identity and distribution of fish communities (Bakken *et al*., 1975; Bergstad *et al*., 1999).

Sampling

The catch data and samples of skates used in this paper originated from a number of research vessel cruises conducted in two periods, 1984–1987 and 1995 (Bergstad *et al*., 1999; Skjæraasen and Bergstad, 2000; Table 1). The distribution of trawl stations from the 1984–1987 cruises used for analyses of distribution and abundance is shown in Figure 1(b). For the work within the North Sea, full descriptions of trawl gear and sampling strategy were given by Bergstad (1990) and Skjæraasen and Bergstad (2000).

On the slope of the Norwegian Sea, data were available from a research vessel cruise and a chartered trawler investigation. The research vessel cruise was conducted in June 1995 by the RV "Håkon Mosby" and the trawl stations from that cruise were included in Figure 1 [(b), stations at approximately 62°N or higher]. A Campelen 1800 sampling trawl was used, and details on stations and sampling procedures were given by Bergstad *et al*. (1999). In December 1995, a chartered trawler fished the slope waters from about 62°N to 68°N using a bigger trawl (see Bergstad *et al*., 1999). The target species on that survey was Greenland halibut *Reinhardtius hippoglossoides* but the skates caught were identified to species. The distribution of trawl stations is shown in Figure 1(a). In the analyses of abundance, the catch data from the trawler were not pooled with those from the RV "Håkon Mosby" due to probable selection differences between the gears.

For all trawls, the catch in terms of weight and numbers was recorded and also a length distribution.

Table 1. Cruises that provided data for the present study of Rajidae in the deep northeastern North Sea and on the slope of the eastern Norwegian Sea.

Vessel	Time period
F/F Eldjarn (IBTS)	8 February–19 February 1984
F/F Håkon Mosby	31 March–9 April 1984
F/F Håkon Mosby	3 August–9 August 1984
F/F Michael Sors	5 October–19 October 1984
F/F Håkon Mosby	12 March–19 March 1985
F/F Håkon Mosby	9 April–13 April 1985
F/F Håkon Mosby	26 July–2 August 1985
F/F Michael Sors	12 October–27 October 1985
F/F Eldjarn (IBTS)	28 January–6 February 1986
F/F Håkon Mosby	8 March–26 March 1986
F/F Håkon Mosby	4 August–10 August 1986
F/F Michael Sars	22 October–8 November 1986
F/F Eldjarn (IBTS)	31 January–18 February 1987
F/F Håkon Mosby	24 February–13 March 1987
F/F Håkon Mosby	8 September–14 September 1987
F/F Michael Sars	20 October–9 November 1987
Commercial vessel	December 1995
F/F Håkon Mosby	19 June–27 June 1995

Data on gears used in 1984–1987 are given in Bergstad (1990). IBTS indicates supplementary tows made during the ICES coordinated International Bottom Trawl Survey, Quarter 1.

Total length (TL) from the snout to the endpoint of the caudal fin was measured. On selected cruises, more detailed information on individual specimens was collected, i.e. individual TL, weight, sex, stage of maturity, and stomach contents. These data were analysed by Skjæraasen (1998), and the diet data for *R. hyperborea* were included in Bjelland *et al.* (2000). Only data on distribution and length are presented in this paper.

When comparing catch levels between pairs of strata, only positive catches were used. In cases where one of the strata contained over twice as many catches as the other, a random sample of the catches in the stratum with the higher number of observations was used. Pairwise tests were only conducted if at least ten catches had been made in each of the strata.

Results

Distribution

Raja fyllae

R. fyllae occurred in the Norwegian Deep and on the Norwegian Sea slope north to about 63°N. Of the 639 trawls made in the Norwegian Deep in 1984–1987, 107 contained this species, and there was a concentration of large catches off southern and southwestern Norway (Figure 2). *R. fyllae* was much less common on the Norwegian Sea slope. In the June 1995 cruise, at about 62–63°N, it occurred at depths of 530 m and shallower. Only a single specimen was recorded during the chartered trawler cruise in December 1995.

Within both the North Sea and Skagerrak sub-areas, the highest numbers were caught at depths greater than 240 m both in summer and winter (Table 2). No significant difference was found between the seasons when the catches from depths >240 m in winter were compared with corresponding summer catches ($p>0.80$, pairwise Mann–Whitney test). The results were similar when comparing catches in terms of biomass (Table 3). In the Skagerrak, *R. fyllae* was not caught shallower than 240 m.

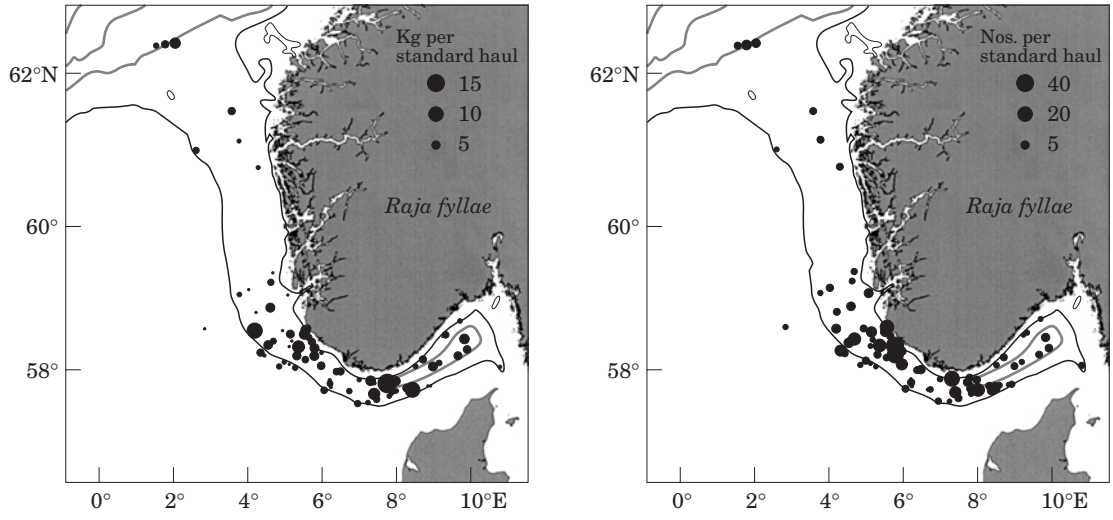

Figure 2. *Raja fyllae*. Catch in terms of biomass and numbers in individual trawls.

Table 2. *Raja fyllae* and *Raja lintea*. Frequency distribution of catches by subareas "North Sea" and "Skagerrak", season and depth zone.

Depth	Number caught	*Raja fyllae*				*Raja lintea*			
		North Sea		Skagerrak		North Sea		Skagerrak	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
<180 m	n	68	31	46	8	68	31	46	8
	0	0.97	0.97	1	1	1	1	1	0.88
	1–2	0.03	0.03	0	0	0	0	0	0.13
	3–4	0	0	0	0	0	0	0	0
	5–8	0	0	0	0	0	0	0	0
	9–16	0	0	0	0	0	0	0	0
	17–32	0	0	0	0	0	0	0	0
180–239 m	n	52	33	28	5	52	33	28	5
	0	0.94	0.88	1	1	0.94	0.91	0.93	0.6
	1–2	0.04	0	0	0	0.04	0.06	0.07	0.4
	3–4	0.02	0.06	0	0	0.02	0.03	0	0
	5–8	0	0	0	0	0	0	0	0
	9–16	0	0.03	0	0	0	0	0	0
	17–32	0	0.03	0	0	0	0	0	0
240–300 m	n	114	35	29	8	114	35	29	8
	0	0.79	0.71	0.83	1	0.85	0.86	0.69	0.88
	1–2	0.04	0.06	0.1	0	0.12	0.14	0.31	0.13
	3–4	0.07	0.11	0.03	0	0.01	0	0	0
	5–8	0.06	0.06	0.03	0	0.02	0	0	0
	9–16	0.03	0.03	0	0	0	0	0	0
	17–32	0	0.03	0	0	0	0	0	0
>300 m	n	34	28	90	30	34	28	90	30
	0	0.74	0.68	0.69	0.73	0.62	0.79	0.31	0.37
	1–2	0.12	0.04	0.1	0.07	0.21	0.18	0.3	0.27
	3–4	0	0.07	0.06	0.1	0.12	0	0.24	0.13
	5–8	0.06	0.11	0.07	0.07	0.06	0.04	0.1	0.17
	9–16	0.03	0.04	0.03	0.03	0	0	0.04	0.03
	17–32	0.06	0	0.05	0	0	0	0	0.03
	33–64	0	0.07	0	0	0	0	0	0

n=number of tows in stratum.

Table 3. *Raja fyllae* and *Raja lintea*.

Depth, m	*Raja fyllae*				*Raja lintea*			
	North Sea		Skagerrak		North Sea		Skagerrak	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
<180	0.03	0	0	0	0	0	0	1.35
180–239	0.03	0.19	0	0	0.68	1.34	1.40	2.34
240–300	0.19	0.65	0.18	0	0.99	1.18	2.05	0.01
>300	0.45	0.44	0.85	0.45	5.07	2.79	14.52	13.66

Arithmetic mean catch in terms of biomass by area, season and depth stratum.
Catches in kg h^{-1}.
Number of tows by stratum are given in Table 2.

Raja lintea

This rather large skate was only caught once on the eastern Norwegian Sea slope, at the southernmost and shallowest station on the June 1995 cruise. However, the species was comparatively common in the Norwegian Deep where it occurred in 156 of 639 trawls in 1984–1987. The highest frequency of large catches occurred in the Skagerrak sub-area (Figure 3). Very few *R. lintea*

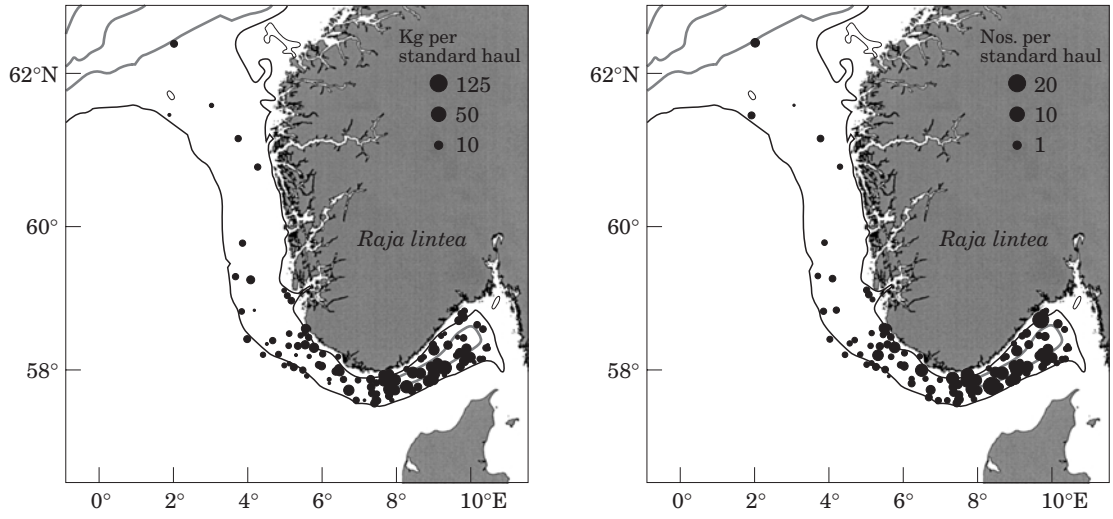

Figure 3. *Raja lintea*. Catch in terms of biomass and numbers in individual trawls.

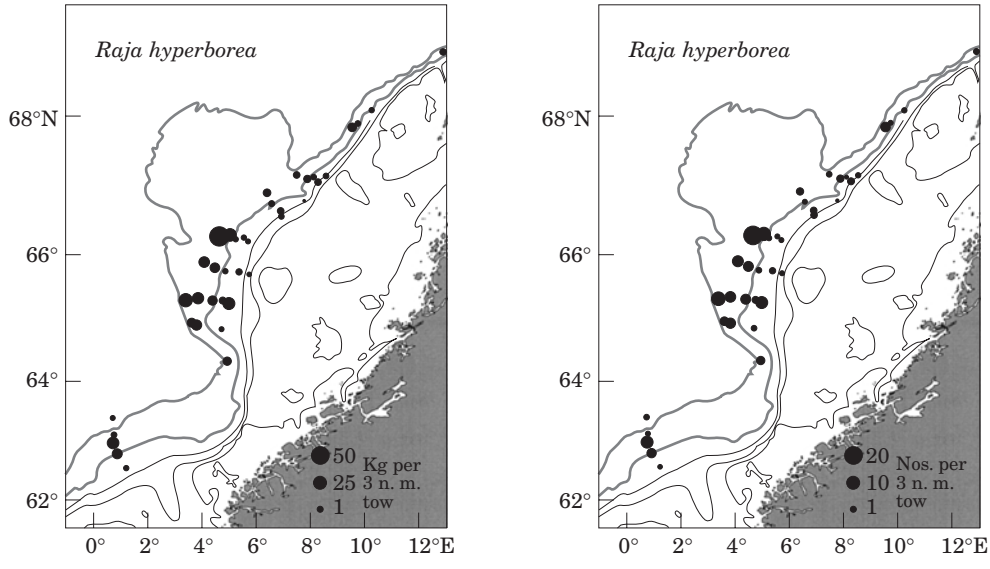

Figure 4. *Raja hyperborea*. Catch in terms of biomass and numbers in individual trawls.

were caught at depths <180 m (Table 2). The catches were highest at depths greater than 300 m in both the North Sea and Skagerrak sub-areas ($p<0.008$ and $p<0.016$ respectively, pairwise Mann–Whitney tests), and there was no indication of seasonality in depth distribution or abundance. Catches were higher in the Skagerrak than in the North Sea, both in terms of numbers and weight (Tables 2 and 3).

Raja hyperborea

R. hyperborea was common along the Norwegian Sea slope (Figure 4), but was never caught in the Norwegian Deep. On the slope the catches increased with depth (Table 4) and were highest at and beyond the depth corresponding to the hydrographical transition layer between Atlantic Water and Norwegian Sea Deep Water, i.e. at around 700 m. However, in the very deepest areas sampled, 2000–2050 m, no catches were made, suggesting a lower limit to its depth range.

Bathyraja spinicauda

In December 1995, *B. spinicauda* occurred north of 65°N (Figure 5), but several catches were also made further south at 62–63°N in June 1995 on the RV "Håkon Mosby" cruise. The species seemed most abundant at 600–850 m in intermediate water masses (Table 4). It appeared to be less abundant and have a shallower

Table 4. Average catches of *Raja hyperborea* and *Bathyraja spinicauda* at different depths on the slope of the eastern Norwegian Sea.

Depth, m	*Bathyraja spinicauda*	*Raja hyperborea*
450–650	0.02	0.4
650–850	0.2	2.0
850–1050	0	6.5
1050–1250	0	13.6
1250–1450	0	12.8

Depths are in metres and catches in kg per 3 nautical mile tow.

depth range than *R. hyperborea*. Within the Norwegian Deep, only a single catch was recorded, at 59°N.

Size

Raja fyllae

The length range of the specimens caught in the Norwegian Deep was 8–68 cm TL, and the length distributions of males and females were very similar (Figure 6).

Raja lintea

The length range of the *R. lintea* was 18–118 cm, but the length distribution was skewed towards large individuals with 56% being larger than 100 cm. There were only small differences between the sexes, but slightly elevated proportions of very small and very large females (Figure 6). There were no indications of seasonal differences in length composition, or of differences between the North Sea and Skagerrak subareas.

Raja hyperborea

In the June samples from about 62°N, the length range of *R. hyperborea* was 23–84 cm TL with a mean of 62.9 cm. The range was wider in the more extensive December survey, i.e. 14–97 cm with a mean of 57.9 cm (n=171). In both surveys there was a high percentage of large, adult individuals. The length distribution from December is shown in Figure 6.

Bathyraja spinicauda

In the June 1995 samples specimens of 37–95 cm TL occurred (mean=67.9 cm), and on the December 1995 survey seven specimens in the length range 30–86 cm were caught (mean=51.6 cm).

Discussion

Distribution patterns

An analysis of abundance based on trawl catches depends on assumptions regarding catching efficiency and selectivity of the gear. Since there may be significant catchability differences between species, our conclusions on relative abundance must be interpreted with some caution. It is also possible that skates are considerably more abundant than the impression gained from trawling.

It was shown earlier that the three species *R. radiata*, *R. fyllae*, and *R. lintea* were the three characteristic Rajidae of the northeastern North Sea fish communities

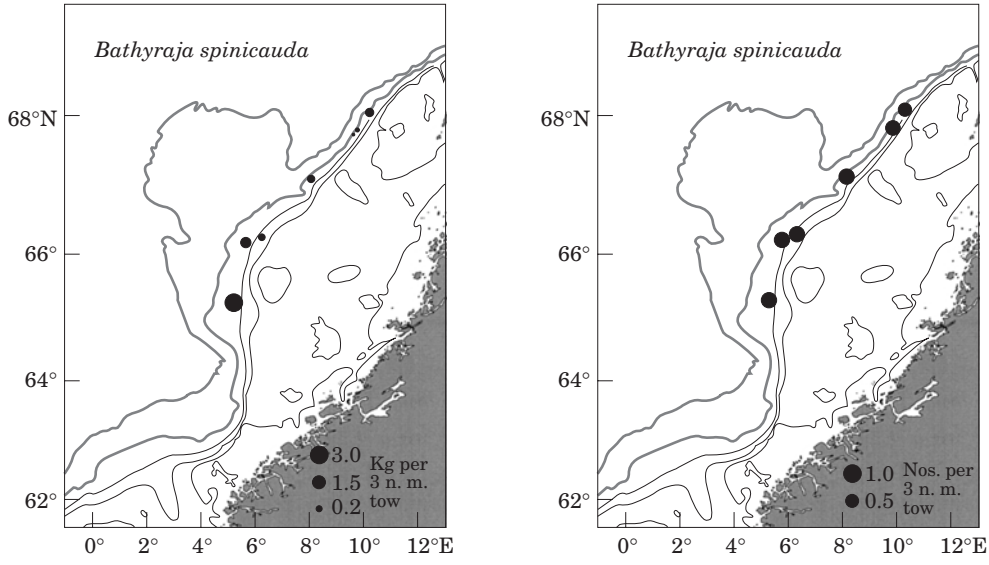

Figure 5. *Bathyraja spinicauda*. Catch in terms of biomass and numbers in individual trawls.

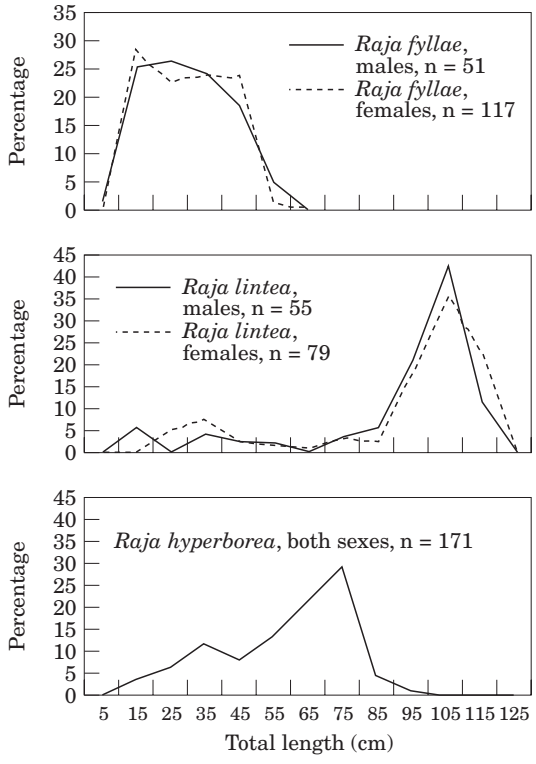

Figure 6. *Raja fyllae*, *Raja lintea* and *Raja hyperborea*. Length distributions based on data from the Norwegian Deep in 1984–87 (*R. fyllae* and *R. lintea*) and the eastern Norwegian Sea in December 1995 (*R. hyperborea*). n=numbers measured.

(Bergstad, 1990). From the data presented here and previously published data on *R. radiata* (Skjæraasen and Bergstad, 2000), it may be concluded that *R. radiata*, *R. lintea* and *R. fyllae* have overlapping geographical distributions in this area. Compared with *R. radiata*, which occurs in the entire northern and central North Sea (Sparholt and Vinther, 1991; Knijn *et al*., 1993; Walker and Heessen, 1996), *R. lintea* and *R. fyllae* appear to be more restricted to the deeper parts of the area, and were especially abundant in the Skagerrak and off southwestern Norway. They appeared to be considerably less abundant than *R. radiata* (see Skjæraasen and Bergstad, 2000 for comparison), and at least *R. lintea* seemed rather uncommon along the continental slope north of the North Sea. According to Stehmann and Burkel (1984), *R. lintea* has a relatively restricted range within the Northeastern Atlantic, including only waters from the Iceland–Faroe rise to southern Norway.

On the upper continental slope of the eastern Norwegian Sea, *R. hyperborea* is the most common skate after *R. radiata* (Bergstad *et al*., 1999). According to Stehmann and Burkel (1984), *R. hyperborea* is widespread in the Arctic at 300–1500 m. On the slope off Norway it had a deeper upper distribution limit corresponding with the transitional zone between the warm Atlantic Water and the cool Norwegian Sea Deep Water of Arctic origin. There was a decrease in catch rate with depth beyond 1450 m, and it is unlikely that *R. hyperborea* is common deeper than about 2000 m. It seemed improbable, as indicated previously (Stehmann and Burkel, 1984), that the species inhabits the 3000–3500 m deep-water basins of the Norwegian and Greenland Seas. In the upper part of its depth range, *R. hyperborea* overlapped with *B. spinicauda* and *R. radiata* (see also Bergstad *et al*., 1999). *B. spinicauda* had a more restricted distribution by depth and appeared to prefer somewhat warmer waters. Its overall area of distribution is wider and more southerly than that of *R. hyperborea* (Stehmann and Burkel, 1984).

In shallower shelf areas of the eastern Norwegian Sea, *R. radiata* is probably the most abundant skate (Bergstad *et al*., 1999), but *R. fyllae* also inhabited this area and the latter species has also been reported from the Barents Sea (Williams and Richards, 1978). Our data suggested that *R. fyllae* is much less abundant than *R. radiata*. According to Stehmann and Burkel (1984), *R. fyllae* has a wide distribution from northern Svalbard to southern Norway and further south at least to the Bay of Biscay.

Size

The maximum length of *R. fyllae* is 55 cm (Stehmann and Burkel, 1984), hence the entire size range was represented in our trawl catches. This suggests that all life stages occur in the areas studied. For the other species, either mostly relatively small (*B. spinicauda*) or large (*R. lintea*, *R. hyperborea*) specimens were caught. According to Stehmann and Burkel (1984) the maximum lengths of *B. spinicauda*, *R. lintea*, and *R. hyperborea* are 170, 110, and 85 cm, respectively. For *B. spinicauda* and perhaps *R. hyperborea*, the limited size ranges observed may be artifacts of low sample sizes. However, for *R. lintea* a high number of catches were made, and the low incidence of juvenile fish in the catches probably reflected a real absence caused by a significant ontogenetic change in distribution and/or behaviour in relation to the gear.

Acknowledgements

The collection of skates was initiated as part of a project run by the University of Bergen in the period 1984–1987 and grant-aided by the then Norwegian Fisheries Research Council. The sampling in 1995 was an element of fish studies under the Mare Cognitum programme and was partially funded by the Norwegian Research Council.

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