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SOME OBSERVATIONS ON THE FEEDING ECOLOGY OF NORWEGIAN SPRING SPAWNING HERRING *CLUPEA HARENGUS* ALONG THE COAST OF NORWAY

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ABSTRACT

The feeding ecology of Norwegian spring spawning herring *Clupea harengus* was studied with samples collected from cruises in February -March 1991, May 1992, and February and April 1993. A wide variety of zooplankton organisms were observed in the diet of herring, with crustaceans dominating except in samples from May 1992 when larvaceans (*Oikopleura* sp.) dominated. Fish were occasionally preyed. In addition to larvaceans, copepods (*Calanus finmarchicus* and *C. hyperboreus*) and amphipods (*Parathemisto* spp.) were important food items in the diet of herring captured in May 1992. Krill (*Thysanoessa inermis* and *Meganyctiphanes norvegica*) were the major prey of herring from the Møre coast in February-March 1991 and in February 1993. Plankton samples taken with MOCNESS from the same area also showed krill to be dominant. Sixty to seventy per cent of the stomachs examined from these two cruises were empty indicating low feeding activity during the spawning season.

Introduction

The Norwegian spring spawning herring (*Clupea harengus*) stock was the largest fish stock in the North Atlantic before its collapse in the 1960's (Dragesund *et al.*,1980). Overfishing is regarded as the main cause for the almost extinction of this species. Since 1975 the stock has gradually recovered and the size of the spawning stock in 1992 was estimated to be approximately 2 million tons (Røttingen, 1992, 1993).

The general distribution and migratory patterns of Norwegian spring spawning herring before and after the collapse have been described by several authors (Dragesund and Ulltang, 1978; Dragesund *et al.* ,1980; Jakobsson, 1985 and Røttingen, 1990, 1992). Following the collapse of the herring stock, changes in geographical distribution and timing of migration have being observed. These changes have resulted in variations in spawning and feeding seasons (Røttingen, 1990).

Before the collapse of the Norwegian spring spawning herring stock, the main feeding area was located between Iceland and Jan Mayen, whereas after the collapse the feeding area was restricted to the coastal waters of northern Norway (Nordland/Troms). As a consequence the feeding area of the adult herring and the drift area of larvae and 0-group have coincided. Due to the strong year classes in 1983 and in the most recent years, the stock size has increased and the feeding area has been observed to extend to the western part of the Norwegian Sea (Røttingen, 1989, 1990).

Crustaceans such as copepods, krill and amphipods have generally dominated the diet of adult herring in most studies carried out in the North Atlantic. In addition larvaceans, *Ammodytes* spp., fish larvae and fish eggs have also been found to be important in the diet of herring (Hardy, 1924; Ogilvie, 1934; Harding and Nichols, 1987; Last, 1989). Cannibalism could occur in the overlapping area between larval and older herring in the coastal waters of northern Norway, though the extent of this is poorly documented. Investigations carried out by Holst (1992) in the Lofoten area showed that in 5 out of 75 stations, young and adult herring had fed on 0-group herring.

In the current study food and feeding conditons of adult herring

have been investigated along the coast of Norway. The distribution of herring in relation to its prey organisms, has also been investigated. Another area of investigation which I am addressing is whether herring also feeds on herring larvae and whether this could contribute to recruitment variation.

Materials and Methods

Herring stomachs were collected from Møre to Vesterålen during cruises with R/V "G.O. Sars" in May 1992, February and April 1993 and with R/V "Michael Sars" in February - March 1991. Locations of the sampling stations are illustrated in Figure 1.

A Harstad trawl with 16 x 16 m mouth opening was used to catch herring. The trawl was 30 m long, with a mesh size of 8 mm (stretched) at the cod end. The towing speed of the ship at the time of trawling was 3 knots and the trawl depth varied usually from surface to 100 m. The trawl was fitted with a Scanmar depth sensor.

Twenty to thirty individuals of herring were randomly selected from the trawl catch. Their lengths were measured to the nearest cm below. The stomachs were removed, injected with 4% formalin and stored in small bottles with 4% formalin. The stomach contents were subsequently examined in the laboratory at the Institute of Marine Research (IMR). For all specimens the stomach fullness and the state of digestion of stomach contents were classified according to the scales given in "Instructions for sampling and coding of fish data" (Anon., 1990).

All food organisms present were recorded. All intact prey organisms were identified to species and their lengths were measured, to the nearest 0.2 mm, using an ocular micrometer. Stages of development of copeods and krill were also noted.

Data on age and maturity stages of herring used for this study were obtained from the Resource Center at the IMR.

For some of the cruises, the dry weight of the stomach contents was measured. The major prey categories were weighed separately while the rest were weighed together in another batch. Dry weight of the stomach content was obtained by keeping the samples in a

drying oven at 80 °C for two days (usually) or until a constant weight was obtained.

During most cruises, plankton samples were also taken using WP2 nets, Juday nets and MOCNESS. At present only a part of this material has been analysed.

Results

A wide variety of zooplankton organisms were observed in the diet of herring. Crustaceans were the dominant prey category except in the samples from May 1992 when larvaceans (*Oikopleura* sp.) dominated (Fig. 2, Table 1).

In addition to larvaceans, copepods *Calanus finmarchicus* and *C. hyperboreus* and amphipods *Parathemisto* spp. were important prey in the diet of herring caught from Lofoten/Vesterålen. Fish (*Maurolicus muelleri*) were also recorded occasionally (Fig. 2, Table 1).

Most of the analysed stomach samples are from the cruises in February-March 1991 and 1993, covering the herring spawning grounds in the Møre and Romsdal area. Three hundred and sixty eight and two hundred and six stomachs of herring, respectively, have been analysed from the two years. A high percentage of empty stomachs (59%) was observed in herring caught in February-March of 1991. The ones that fed had preyed mainly on krill (82% by numbers) (Fig. 2, Table 2). The dominant krill species were *Thysanoessa inermis* and *Meganyctiphanes norvegica.* Similar results were obtained from the February 1993 cruise in the same area when krill (mainly *T. inermis*) comprised 99% of herring stomachs by weight (Fig. 2, Table 3). Fish eggs, most probably of Norway pout (*Trisopterus esmarkii*) or saithe (*Pollachius virens*) (0.5% by weight), were also found.

Plankton samples from Møre in February-March 1991 using a MOCNESS (fraction above 2000 µm) showed krill to be important with a mean of 31.9% (range 10-93%, n=7) by numbers. Though copepods were higher in numbers in most stations, krill and star fish larvae dominated in biomass.

A high percentage of empty stomachs (60-72%) in February- March

indicates low feeding activity during the spawning season. About 57% of the fishes caught in February-March 1991 were mature (maturity stages 4 and 5), whereas 87% were mature in February 1993. In May 1992 only 7% of the fishes had empty stomachs. Most of the fishes from May had stomach fullness of 3 (little contents) and 4 (stomach full).

The samples from April 1993 are presently being analysed. Preliminary analysis of data from this cruise indicated that krill was the principal food of herring at Møre.

Most of the herring caught in February-March 1991 were of the 1983 year class and ranged between 25 and 35 cm in 1991 and 30 to 37 cm in 1993 (Røttingen, 1991 and unpublished data). The size of herring caught in May 1992 varied from 25 to 37 cm.

Discussion

Diurnal variation in diet could not be examined in the present study as only catches from night time were available. Previous efforts to catch herring during day time with Harstad trawl, have yielded very low catches, possibly due to visual avoidance of the trawl by herring. The trawl has a small mouth opening and is operated at relatively low towing speed (3 knots). A new trawl ("Åkratrålen") with a comparatively large mouth opening and mesh size will be tested in coming cruises.

The present analysis of stomach contents of adult herring (2-12 years) showed that copepods, krill, amphipods, larvaceans, fish eggs etc. were the most important prey in the diet. Ogilvie (1934), Harding and Nichols (1987), Last (1989) and other researchers made similar observations on herring from the North Atlantic.

Quantifying predation on herring eggs and larvae by adults, needs intensive sampling from the overlapping areas between prey and predator. Rapid analyses of stomach contents are also important as the presence of herring larvae in the stomachs of fish might be difficult to detect due to fast digestion (Balfoort, 1984). In the present study, herring occasionally preyed on fish and fish eggs. The fish that could be identifed was *Maurolicus muelleri* and the fish eggs were of gadoids. Herring feeding on herring larvae could cause variations in recruitment. I did not, however, find any herring

eggs or larvae in the diet of adult herring. Holst (1992) suggested that cannibalism might be a regulating factor for year class strength in the Norwegian spring spawning herring. Nicol and Harding (1987) have investigated the predation on planktonic fish eggs and larvae by fish predators. They found pelagic fish to be important predators of fish eggs and larvae. Their study showed that the diet of herring (3-24 cm) consisted of 0.3% fish eggs, 17.8% larvae and 6. 2% young fish.

Dietary differences were observed in herring caught from different regions and seasons. Krill (*T. inermis*, *M. norvegica*) was the principal food of herring at Møre in February- March. Herring caught in the Lofoten/Vesterålen region in May took larvaceans, copepods and amphipods as their major prey. Analyses of plankton samples from the Møre region from February-March 1991 showed that krill was a major component among the micronekton and macroplankton organisms (Melle *et al.* 1993 and unpublished data). High abundances (0.1-0.5 numbers per m^3) of krill were observed during day time at depths of 250-600 meters outside the continental shelf (Melle *et al.* 1993).

Last (1989) did not find any marked differences in the diet between the smaller and larger herring (10-34 cm). The size of herring used in the present study ranged from 21 to 38 cm. As in Last's study no clear ontogenetical variations in the diet of herring with size were observed.

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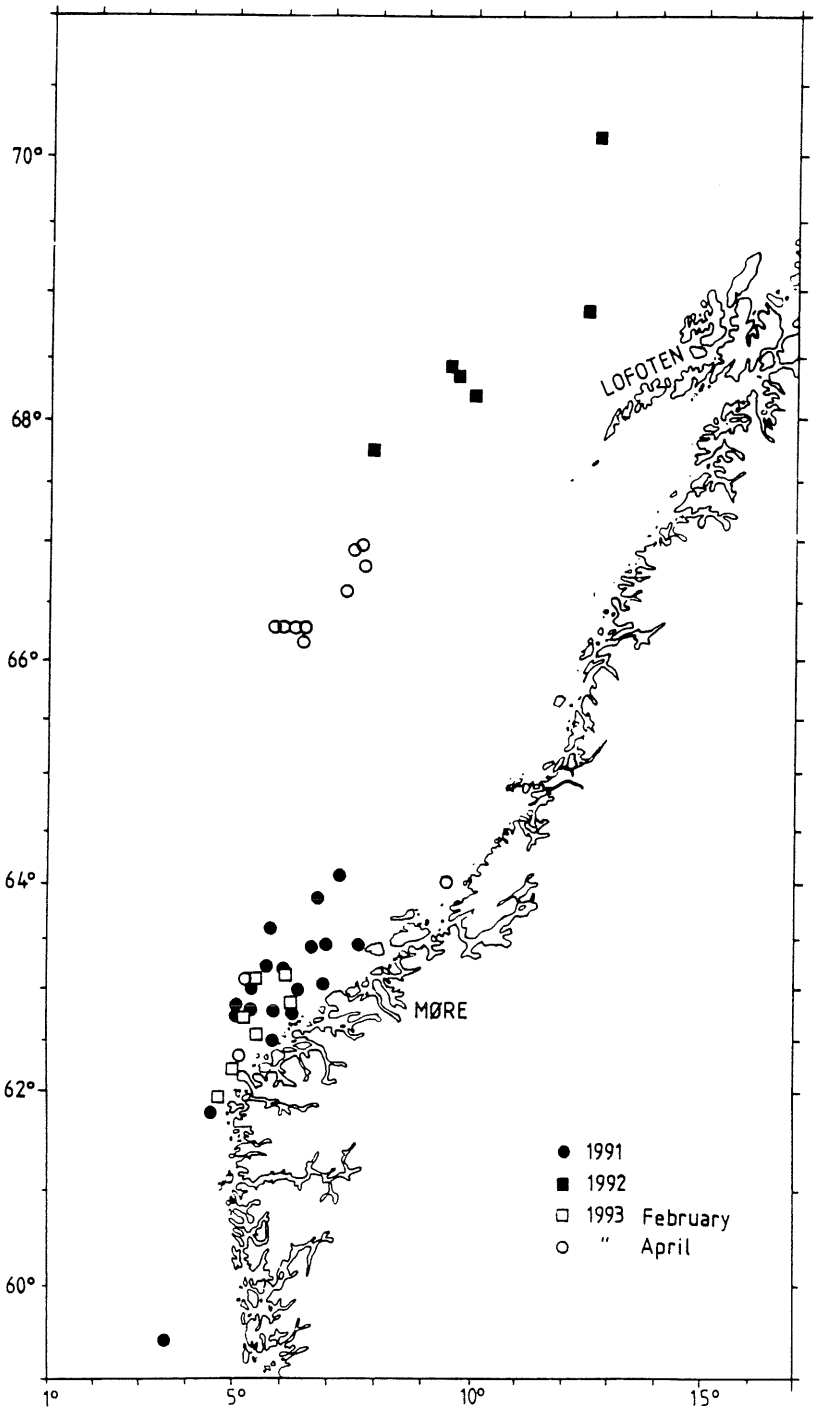
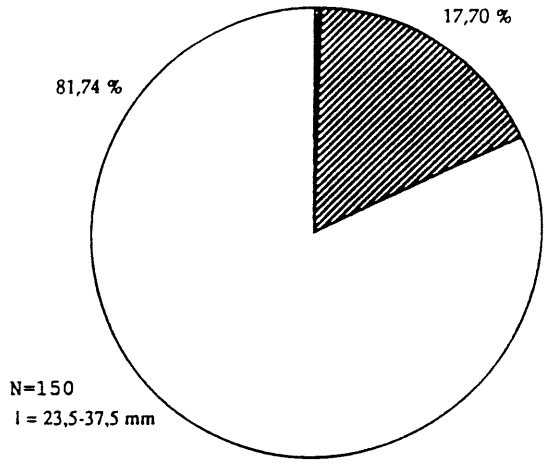
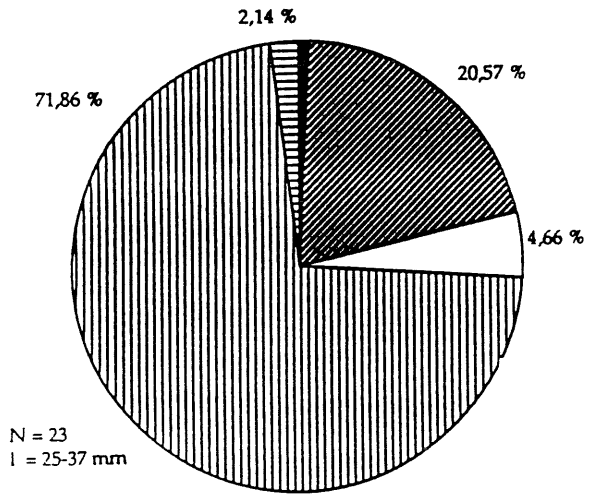


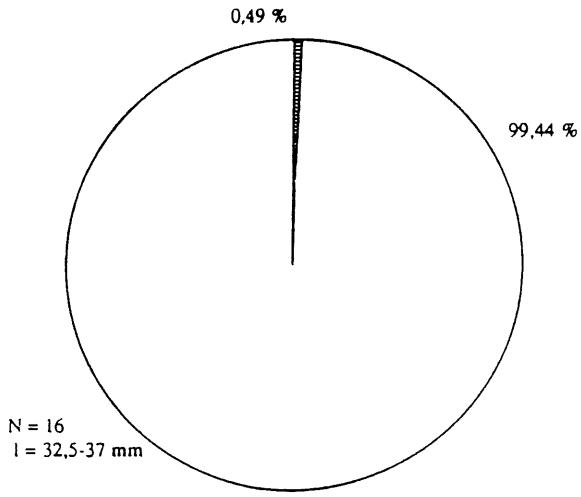
Fig. 1. Locations of pelagic trawl stations. Legend ■ = R/V "G.O. Sars" May 1992, □ = February 1993 , ○ = April 1993, ● = R/V "M. Sars", February -March 1991.



STOMACH CONTENT BY NUMBERS
"M. SARS" FEB. 1991



STOMACH CONTENT BY WEIGHT
"G.O.SARS" MAY 1992



STOMACH CONTENT BY WEIGHT
"G.O.SARS" FEB. 1993

AMPHIPODS
COPEPODS
FISH
FISH EGGS
KRILL
LARVACEANS
OTHERS

Fig. 2. Principal food organisms of herring as percentages of the total number or weight. Empty stomachs not included.

Table 1. Diet composition of herring from Lofoten/Vesterålen, May 1992; prey items in numbers. (s. c.=stomach contents)

St.no	No. of stomachs	No. empty	Fish length range (cm)	Wet wt. of s.c. range (mg)	KRILL T. inermis	M. norveg	T.longi	COPEPODS damaged	Calanus	others	damaged	AMPHIP.	FISH eggs	larvae	adults	LARVACEA	OTHERS	total prey
300	18	2	no data	102-1400	1	2	0	8	35		125	54	0	0	2	+	5	232
301	13	1	no data	313-1960	0	1	12	6	31	4	16	19	0	0	0	+	2	91
302	6	0	30-37	433-1230	0	0	0	9	255	8	475	15	0	0	0	+	2	764
303	2	0	25-35	1737-2002	1	0	0	18	48	0	322	24	0	0	0	+	2	415
312	1	0	34	2941	0	0	4	0	192	0	80	3	0	0	0	+	59	338
318	1	0	no data	_	0	0	0	0	0	0	0	0	0	0	0	+	0	0
320	58	4	29	29-1973	0	0	1	2	168	0	101	33	0	0	0	+	30	335

Table 2. Diet composition of herring from Møre, February-March 1991; prey items in numbers. (s. c.=stomach contents)

St.no	No. of stomachs	No. empty	Fish length range (cm)	Wet wt. of s.c. range (mg)	KRILL T. inermis	COPEPODS M. norveg	COPEPODS damaged	COPEPODS Calanus	COPEPODS others	COPEPODS damaged	AMPHIP.	FISH eggs	FISH larvae	FISH adults	OTHERS	TOTAL prey
26	20	19	23.5-29.5	95	0	1	0	0	0	0	0	0	0	0	0	1
29	20	19	28.0-36.5	159	0	0	1	0	0	0	0	0	0	0	0	1
31	20	5	31.5-35.0	30-9485	394	48	442	0	0	8	0	0	0	1	0	893
32	20	16	33.0-37.0	259-2162	40	3	19	0	0	0	0	0	0	0	0	62
33	20	13	33.5-36.5	20-3960	1	0	88	0	0	0	0	0	0	0	0	89
34	20	3	33.5-35.0	55-12303	395	0	30	1	0	1	1	0	0	0	8	436
35	20	18	32.5-35.0	179-213	0	0	2	0	0	0	0	0	0	0	0	2
37	20	6	32.5-36.0	37-5799	200	0	182	23	0	50	1	0	0	0	2	458
38	20	20	33.0-35.0	-	0	0	0	0	0	0	0	0	0	0	0	0
39	20	20	33.0-35.0	-	0	0	0	0	0	0	0	0	0	0	0	0
40	20	20	33.5-36.0	-	0	0	0	0	0	0	0	0	0	0	0	0
41	20	15	33.0-35.0	191-608	0	0	10	22	0	183	1	0	0	0	0	216
42	20	4	21.0-35.0	143-4991	45	42	106	0	0	21	0	0	0	0	0	214
43	20	16	29.5-35.5	170-2046	17	0	6	0	0	0	1	0	0	0	0	24
44	20	6	26.5-37.5	124-8482	7	60	36	0	0	0	0	0	0	0	0	103
45	20	6	30.0-35.0	98-11840	97	42	27	79	0	98	1	0	0	0	3	344
46	8	0	33.5-35.0	88-8647	169	1	6	60	0	54	0	0	0	0	0	290
47	20	5	33.0-35.0	165-4430	112	8	37	0	0	0	0	0	0	0	0	157
48	20	7	31.5-36.0	46-3016	16	11	69	0	0	0	0	0	0	0	0	96

Table 3. Diet composition of herring from Møre, February1993; prey items in numbers. (s. c.=stomach contents)

St.no	No. of stomachs	No. empty	Fish length range (cm)	Wet wt. of s.c. range (mg)	KRILL T. inermis	M. norveg	COPEPODS damaged	Calanus	others	damaged	AMPHIP.	FISH eggs	larvae	adults	OTHERS	TOTAL prey
99	30	30	33.0-37.5	–	0	0	0	0	0	0	0	0	0	0	0	–
100	30	29	34.0-37.0	49	0	0	0	0	0	0	0	0	0	0	+	+
101	30	14	34.0-38.0	45-5150	29	19	311	0	0	0	0	0	0	0	1	360
102	26	14	31.5-37.0	111-4352	27	15	193	0	0	0	0	0	0	0	0	235
103	30	23	30.5-37.5	53-5042	0	0	136	0	1	18	0	12	0	0	0	762
104	30	21	32.5-37.0	64-18400	253	0	208	0	0	0	0	204	0	0	1	666
105	30	17	28.5-36.5	39-3780	3	0	178	6	0	0	0	112	0	0	0	299