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The Propagation of Cod *Gadus morhua* L.

COD LARVAE SAMPLING WITH A LARGE PUMP OFF SW-ICELAND

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ABSTRACT

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In an attempt to collect adequate samples of cod and other larvae in the spawning areas off SW-Iceland, experiments using a large fish pump for this purpose were carried out from 1981 to 1983. The pump used was an 8" hydraulic centrifugal pump commonly used by fishing vessels in Iceland.

In 1981 samples were taken at a fixed station off Reykjanes at 6-8 depths from 0 to 34 m at 4 h intervals for 36 h. In 1982 and 1983 vertical profiles were taken at various stations.

From the samples valuable information on the larvae and their distribution and feeding was obtained.

It is concluded that the development of a convenient pumping system has been quite successful. The main limitations of the system is that sampling would be rather time consuming in areas of low larval density. For the present studies it does not matter but this could be limiting in studies in coming years of other areas at Iceland with less spawning.

INTRODUCTION

In the investigations of spawning off Iceland conducted since 1976 a Gulf-3 sampler has been used to collect material. The sampling volume of the Gulf-3 is about 20 m^3 per haul. Gulf-3 gives good samples of pelagic eggs of the most abundant larvae, e.g. capelin (*Mallotus villosus* (Müller)) and sandeel (*Ammodytes* spp.), but too small samples of other larvae, e.g.

cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus* (L)). In an effort to collect adequate samples of larval cod and haddock, experiments using a large fish pump were carried out in 1981, 1982 and 1983. This paper gives an account of the pump system developed for sampling vertical profiles and the material collected using the pump in those three years.

MATERIALS AND METHODS

The pump used was an 8" hydraulic centrifugal pump commonly used by fishing vessels in Iceland. In 1981 trials were carried out with the initial Norwegian system of rubber hoses from the pump on to the deck (Ellertsen et al., 1977, 1981; Solemdal, 1982). This system is convenient because control of the pumped volume and the sample volume is easy but the equipment is heavy and difficult to handle. The system is shown in Fig. 1.

To the outlet of the pump a 10 m long rubber hose, 12" in diameter, was connected. At the end of the hose an aluminium cylinder, 1 m long and 12" in diameter, was fastened. Inside the cylinder a flowmeter was attached to a bar and the filtering net fitted to the cylinder. This equipment was relatively easy to handle, but the control of the volume of the sample and the filtered volume was more difficult than when pumping directly on to the deck. A digital flowmeter model 2030 from General Oceanics was used to measure the volume of sea water filtered. These flowmeters have been used for several years to measure the filtered volume in Gulf-3 samplers, and they have turned out to be quite reliable. In 1983 some modifications were done on the pump. The rubber hose was cut down to 2 m in length and, after the experience with the pump that year, it is planned to substitute the rubber hose with an aluminium cylinder 1.5 to 2 m long with bars near to the pump to break down turbulence waves from the pump. In 1983 a new flowmeter model 2035 MK III from General Oceanics was used with a remote control of the flow speed on deck. In 1981 and 1982 a 1.5 m long filtering net with a 200 µm mesh size was used, but in 1983 a filtering net with 500 and 355 µm mesh sizes (Fig. 1)

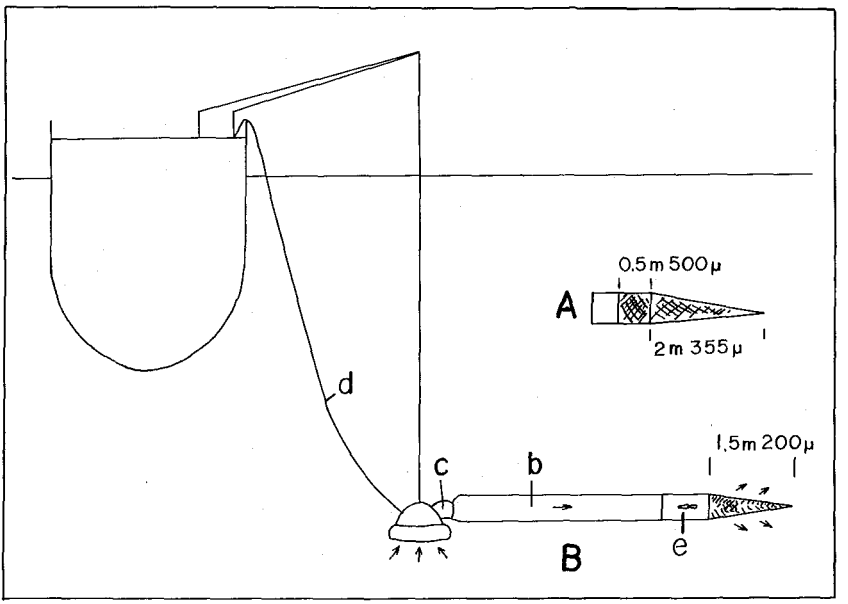

Fig. 1. A. Filtering net used in 1983. B. The pumping system. b) Rubber hose, c) outlet of pump, d) hydraulic hoses, e) flow meter.

was used to prevent clogging of the net by phytoplankton.

In 1981, when the pump was tried in the field, it was found that the pumping at full capacity the larvae caught were of poor quality. By lowering the capacity better quality larvae were caught. The samples were fixed in 4% formalin. In the laboratory all larvae were separated from the samples. The whole sample was weighed and a weighed sub-sample used to identify and count eggs. The cod larvae were separated into yolk sac stages according to Ellertsen et al. (1980). All the material from 1981 has been worked up and is presented here. In 1982 the samples were inadequate due to some difficulties in sampling, therefore, only the distribution of larval cod and material on cod feeding is presented. Good material was collected in 1983, but as it has not yet been processed, only an account on larval cod distribution is given.

Continuous sampling at a fixed station in 1981.

Continuous sampling at a fixed station in 1981.

During the 13th and 14th of May 1981, material was collected with the pump for 36 h at a fixed station nearshore, west of the southern part of Reykjanes. The station was situated in an area where a lot of eggs and larvae drift through from the spawning area at Selvogsbank and south of Reykjanes.

The vessel was at anchor during pump sampling. Samples were taken at 6 to 8 depths from 0 to 35 m at 4 h intervals. The duration of pumping at each depth was 10 min.

The volume filtered in 10 min. at each depth varied from about 50 m^3 to 300 m^3. The oil pressure was kept constant at 80 kg/cm^2. The volume pumped at depth down to 10-15 m turned out to be less than at greater depths. The reason for this was not clear until 1983. The explanation is that the outlet of the pump was directed upwards and when pumping near the surface down to 10-15 m the rubber hose was bent and partly closing the outlet from the pump. At greater depths the hose was directed upwards and open.

RESULTS AND DISCUSSION

The vertical distribution of eggs at a fixed station in 1981.

Eggs of 11 species were found in the samples. The mean number of eggs of each species is shown in Fig. 2.

Cod and haddock eggs were most abundant, contributing 39.5 eggs per m^3 or 83.5% of all eggs. There were 2.9 dab eggs per m^3, representing 6.1% of all eggs. The eggs of all other species were less common. The depth distribution of cod and haddock eggs (mean values) is shown in Table 1 and the vertical distribution of eggs of different developmental stages is shown in Table 2.

Spawning takes place at greater depths than 35 m. The time from spawning to the beginning of developmental stage II does not exceed 4-5 h. During that time the eggs distend and float towards the surface. Developmental stage I was rarely found in the samples.

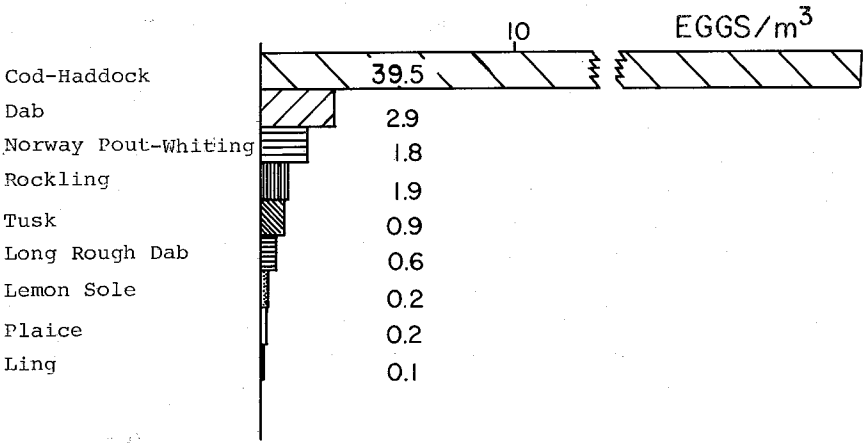

Fig. 2. Mean number of eggs per m^3 in all samples.

TABLE 1

Mean number of cod and haddock eggs per m^3 filtered sea water.

Depth (m)	0	5	10	15	20	25	30	35
Number of eggs	115	49	34	19	19	11	12	10
Percentage	43	18	13	7	7	4	4	4

TABLE 2

Percentage distribution of each developmental stage according to depth. Developmental stages are according to Fridgeirsson (1978).

Depth (m)	0	5	10	15	20	25	30	35
Stage II	41	21	20	7	2	3	4	2
Stage III	58	18	8	5	4	3	2	2
Stage IV	41	19	13	8	5	4	6	4
Stage V	39	17	10	7	12	5	5	5
Cod VI	34	16	13	11	8	5	7	6
Haddock VI	23	11	13	10	13	13	10	7

From the distribution of eggs at different stages (Table 2) it is obvious that at stage II the ascent of the eggs was almost finished, although a larger proportion of the eggs was still found at depths down to 10-15 m than eggs at stage III. From stage V towards hatching an increasing proportion of the eggs sink. The sinking of the eggs was obviously slow and the majority of the eggs were probably above 35 m depth. This seemed to be true for the cod eggs but was more doubtful for haddock eggs. The sampling took place in calm weather when little vertical mixing due to wind and wave action was to be expected, but the sampling area is a turbulent one due to strong currents.

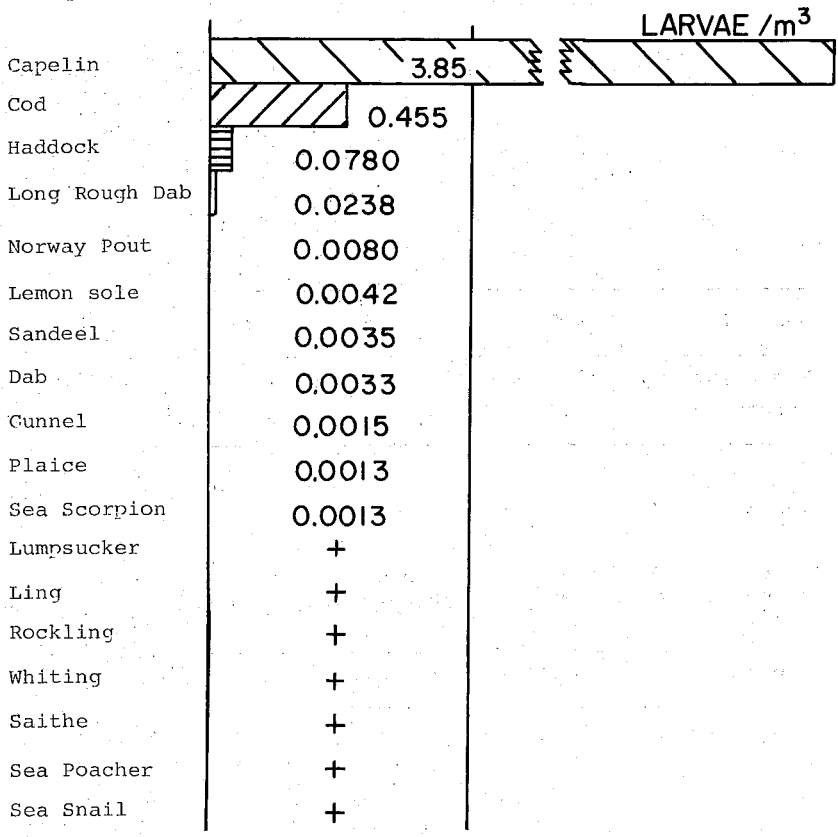

Fig. 3. Mean number of larvae per m^3 in all samples.

Larval distribution at a fixed station in 1981.

18 species of larvae were found in the samples. The total density of all fish larvae per m^3 was 4.5. As shown in Fig. 3, capelin larvae comprised the greatest part with a density of 3.85 larvae per m^3 representing 85.6% of all the larvae. There were 0.455 cod larvae per m^3 representing 10.1% of the total catch. There were only 0.078 haddock larvae per m^3 or 1.7% of all larvae. The diurnal vertical distribution of larval capelin, cod and haddock is shown in Fig. 4, 5 and 6.

The vertical distribution of capelin and cod are similar. The larvae swim upwards during the darkest hours of night and down during the daytime.

From the vertical distribution of haddock eggs at the last stages of development (Table 2), it is evident that the haddock hatch at a relatively greater depth than the cod. It can, therefore, be expected that haddock larvae would be found in deeper layers than cod larvae. From Fig. 6 it is clear that this was the case, the haddock larvae were distributed deeper in the water column than the cod larvae and, most probably, a larger part of the haddock larvae occurred beneath 35 m depth than the cod larvae. This is further confirmed by the fact that of cod and haddock, 33% of the eggs were haddock, but only 14.6% of the larvae were.

When studying possible competition for food of these three species the difference in vertical distribution could be a valuable point and therefore needs further attention.

Feeding of larval cod caught at a fixed station in 1981.

The feeding of cod larvae from four of seven vertical profiles taken in 1981 has been studied. The profiles were I - at 10.20 to 11.40 and III at 22.00 to 23.15 on the 13th of May and VI - at 16.05 to 18.00 and VII at 22.00 to 23.40 on the 14th of May.

Measurements of 714 larvae from those profiles are shown in Table 3, while Table 4 gives the cod larvae separated into yolk

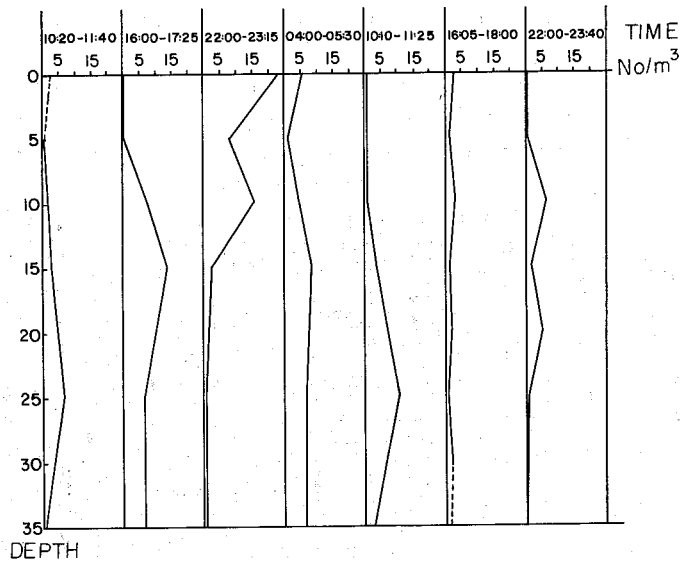

Fig. 4. Diurnal vertical distribution of capelin larvae. At a fixed station in 1981.

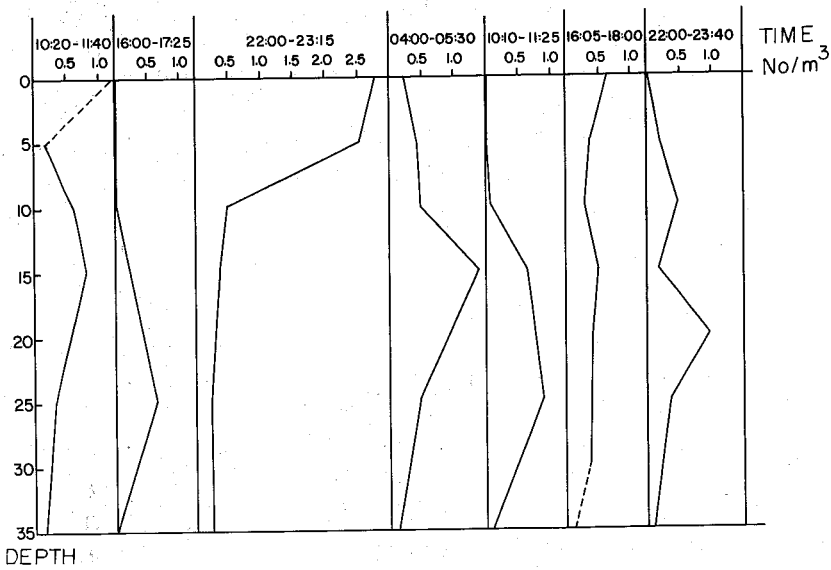

Fig. 5. Diurnal vertical distribution of cod larvae. At a fixed station in 1981.

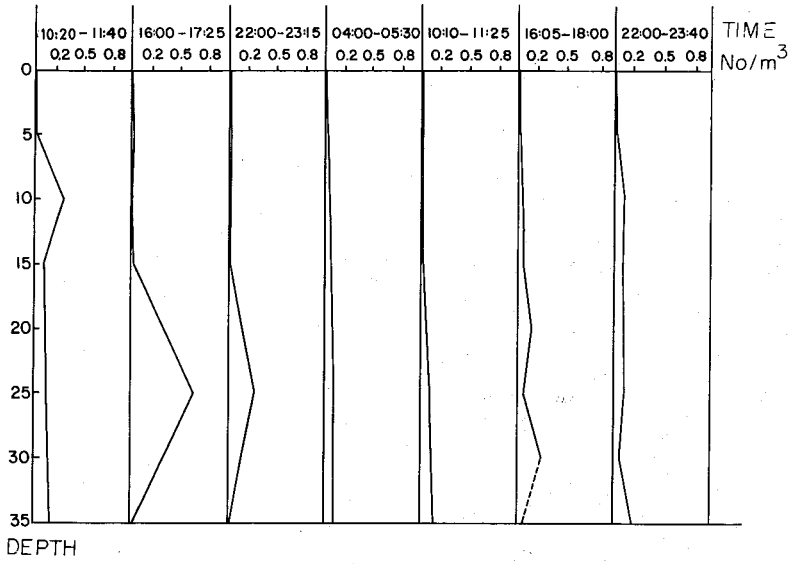

Fig. 6. Diurnal vertical distribution of haddock larvae. At a fixed station in 1981.

TABLE 3

Length distribution of larvae

	Length (mm)									
	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6
Number	14	30	44	40	106	86	116	86	78	39
%	2.0	4.2	6.2	5.6	14.8	12.0	16.2	12.0	10.9	5.5

cont.

	Length (mm)									
	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6
Number	37	17	12	2	2	2			1	2
%	5.2	2.4	1.7	0.3	0.3	0.3			0.1	0.3

sac stages. Judging by the length distribution and the yolk sac stages, it is obvious that the majority of the larvae were already able to take and utilize food.

TABLE 4

Separation of yolk sac stages

	Yolk sac stage						
	1	2	3	4	5	6	7+
Number	32	11	11	4	32	78	476
%	5.0	1.7	0.7	0.6	5.0	12.1	73.9

TABLE 5

a) Number of feeding larvae, b) eaten food particles

a)

Profiles	I		III		VI		VII		Total	
Time	10:20-11:40		22:00-23:15		16:05-18:00		22:00-23:40			
	No	%	No	%	No	%	No	%	No	%
Analysed larvae	170		141		91		278		680	
Feeding larvae	44	25.9	92	65.5	56	61.5	178	64.0	370	54.4

b)

Profiles	I		III		VI		VII		Total	
	No	P/l	No	P/l	No	P/l	No	P/l	No	P/l
Food particle										
Eggs of copep.	153	3.48	412	4.48	220	3.93	912	5.12	1697	4.59
Copep. nauplii	1	0.02			4	0.07	5	0.03	10	0.03
Larv. of mussel			4	0.04	7	0.12	10	0.06	21	0.06
Ciliate			3	0.03	6	0.11	2	0.01	11	0.03
Phytopl.			1	0.01	14	0.25	22	0.12	37	0.10
Rotatoria					1	0.02			1	+
Unrecogn.			2	0.02			12	0.07	13	0.04
Total	154	3.5	422	4.59	252	4.50	963	5.41	1791	4.84

P/l - Particles per larva (feeding ratio)

Of 680 larvae analysed, food particles were found in the stomach and gut of 370 larvae or 54.4%. In Table 5 the number of feeding larvae and the stomach and gut contents are shown. The feeding rate, number of larvae with stomach contents and the number of particles per larvae was lowest in the profiles taken in the morning and highest in the two profiles just before midnight. The larvae were mainly feeding on eggs of copepods, other food particles were only occasionally found. Information on the available food particles in the sea at this location is not available, but it seems obvious that spawning of copepods had started in the location and nauplii of copepods had not yet become available for the larvae.

Vertical profiles taken with pump in 1982.

From 9th to 12th of May 1982 vertical profiles were taken at eight stations on Selvogsbank and one in Faxaflói. Several difficulties made this sampling less successful than intended. Due to a rupture of the hydraulic hose, the depth at which pumping was possible was limited to 25 m. Besides that, a dense phytoplankton concentration in part of the Selvogsbank area made sampling difficult.

It turned out in 1982 that clogging of the filtering net with phytoplankton can be a severe problem while sampling in blooming areas. The pump did not slow down when the flow pressure built up in the hose and net. In several cases the net became so clogged that it ruptured. The flowmeter readings are probably unreliable in those situations, and the inconvenience of no direct control over pumped volume and filtering is great.

Results from 1982.

The distribution of cod larvae as found with Gulf-3 sampling is shown in Fig. 7. The highest number of larvae caught with the Gulf-3 samples was 28 per m^2 of surface. The density of larvae varied from 0.006 to 0.43 larvae per m^3 at the pumping stations, marked D in Fig. 7. It has to be kept in mind that

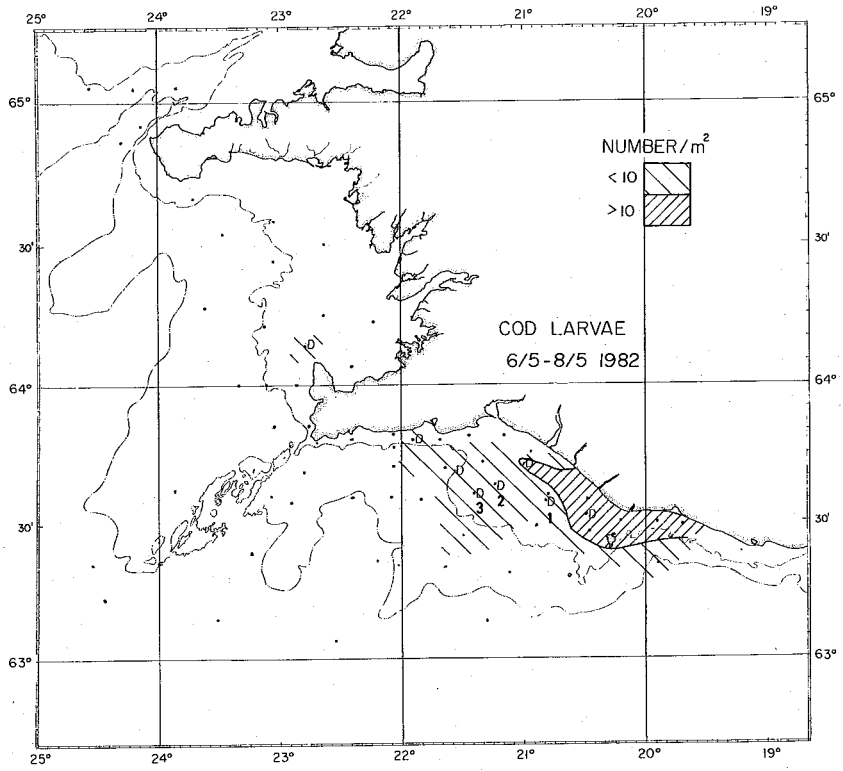

Fig. 7. distribution and quantity of cod larvae in 1982. D - pumping station. Gulf-3 stations are marked by points.

the maximum sampling depth was only 25 m with the pump, 50 m with the Gulf-3 and at the three stations nearest to the shore of Selvogsbank, sampling was difficult because of dense phytoplankton which probably affected the results.

As a rule, larvae spawned and hatched in the Selvogsbank area drift along the southern part of Reykjanes and into the outer part of Faxaflói, but at that time the majority of the larvae had been kept in the Selvogsbank area by westerly and northerly winds and were probably too scattered in Faxaflói to be detected by Gulf-3 sampling.

Feeding of larval cod in 1982.

The feeding of cod larvae from three vertical profiles taken in 1982 were studied. The location of the three profiles is shown as D1, D2 and D3 in Fig. 7. Profile 1 was taken from 22.00 on the 9th to 01.00 on the 10th of May, profile 2 at 03.00 to 05.00 and profile 3 at 08.00 to 10.00 on the 10th of May. Due to several difficulties, the material was sparse and some of the larvae of poor quality.

Only 138 larvae were studied. The length distribution of the larvae is shown in Table 6 and the separation of yolk sac stages is shown in Table 7. The majority of the larvae had still the remnants of the yolk sac although they were already feeding. In Table 8 the number of feeding larvae and the stomach and gut contents are shown.

Information on available food particles in the sea are not yet available, but the low feeding rate on copepod eggs and nauplii compared to that in 1981 probably shows a lower availability of copepod eggs and nauplii than in 1981. The larvae were occasionally feeding on ciliata and rotatoria and the larvae caught in the second vertical profile seemed to be actively feeding on phytoplankton. There was only one larva (4.4 mm long, yolk sac stage 6) with no stomach or gut content. Of the 34 feeding larvae, 21 contained copepod eggs and nauplii, and of those, only three larvae had not got phytoplankton in their stomachs or guts. Most (99.1%) of the phytoplankton particles were *Thalassiosira* spp. Other particles were *Coscinodiscus* spp. and different dinoflagellates.

Cod larvae investigations in 1983.

From the 11th to 15th of May 1983 a survey with a Gulf-3 sampler was done in the Selvogsbank and Faxaflói areas. From 16th to 20th of May, nine vertical profiles were taken at Selvogsbank and in Faxaflói. The big mesh size used in the filtering net in 1983 made pumping in locations of intense phytoplankton blooming much more successful than in 1982. A

TABLE 6

Length distribution of larvae

Length mm	Profile 1	Profile 2	Profile 3	Total	Percentage
3.0			1	1	0.8
3.2			1	1	0.8
3.4			7	7	5.5
3.6			18	18	14.2
3.8	2	2	19	23	18.1
4.0	6	6	14	26	20.5
4.2		7	11	18	14.1
4.4	2	7	4	13	10.3
4.6	1	8	3	12	9.4
4.8		4	3	7	5.5
5.0		1		1	0.8
Total	11	35	81	127	100.0

TABLE 7

Separation of yolk sac stages

Yolk Sac stage	Profile 1	Profile 2	Profile 3	Total	Percentage
1					
2					
3					
4	6		3	9	15.0
5	1	6	14	21	35.0
6		2	25	27	45.0
7+		2	1	3	5.0
Total	7	10	43	50	100.0

TABLE 8

a) Number of feeding larvae, b) eaten food particles

a)

	Profile 1		Profile 2		Profile 3		Total	
	No	%	No	%	No	%	No	%
Analysed larvae	12		35		91		138	
Feeding larvae	11	92	34	97	79	87	124	90

b)

	Profile 1		Profile 2		Profile 3		Total	
	No	P/l	No	P/l	No	P/l	No	P/l
Food Particles								
Eggs of copep.	1	0.09	17	0.50	73	0.92	91	0.73
Copep. nauplii	10	0.91	13	0.38	14	0.18	37	0.30
Larvae of mussel					2	0.03	2	0.02
Ciliata	6	0.55	9	0.26	102	1.29	117	0.94
Phytopl.	40	3.64	913	26.85	27	0.34	980	7.90
Rotatoria			9	0.26	70	0.89	79	0.64
Unrecogn.	1	0.09	2	0.06	2	0.03	5	0.04
Total	58	5.27	963	28.32	290	3.67	1311	10.57

P/l - particles per larvae (feeding ratio)

flow rate of 1.5 to 2.1 m per second could be maintained, with a pumping capacity of 100 m^3 in 12.5 to 17 min without spoiling the cod larvae. The remote control of the flow speed was most convenient.

Some results from 1983.

The distribution and quantity of cod larvae found in the

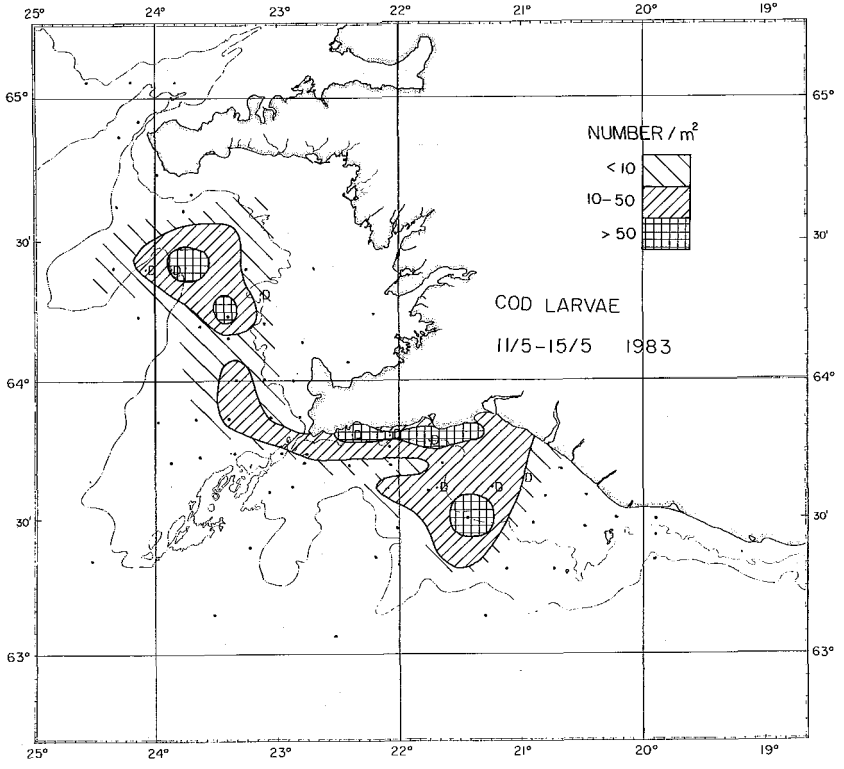

Fig. 8. Distribution and quantity of cod larvae in 1983. D - pumping stations. Gulf-3 stations are marked by points.

Gulf-3 sampler survey are shown in Fig. 8. By comparison with the quantity of larvae found in 1982 (Fig. 7) it looks as if material for a good yearclass of cod may have been produced from the spawning in spring. The pumping stations taken are shown in Fig. 8. Before the vertical profiles were taken with the pump, a grid of Gulf-3 stations at 2-5 mile intervals were taken to locate concentrations of larvae. Because the material from 1983 has not been fully processed no results can be presented here.

CONCLUSION

The development of convenient pumping system during the last three years has been quite successful. The main limitations of the system is that in areas of low larval density sampling would be rather time consuming. For the present studies it did not matter, but this could be limiting in studies in coming years of other areas off Iceland with less spawning.

It is too early to draw any firm conclusions from the material because the results from the 1983 survey have not yet been fully evaluated.

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