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DESCRIPTION OF THE SPAWNING AND THE EARLY LIFE HISTORY OF HADDOCK (*Melanogrammus aeglefinus* L.) FROM THE NORWEGIAN SKAGERRAK COAST.

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ABSTRACT

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Matured haddock were caught in late January 1982 and 1983 and transferred to a spawning basin. Spawning took place within 90 days from late February to late May each year, with a maximum from the middle of March to the middle of April. In the two years the average number of eggs spawned by each female were 520.000 and 568.000 respectively. Egg diameter decreased during the spawning period, from a daily average of 1.50 to 1.29 mm, with an average of 1.38 and 1.39 mm in the two years. Fertilization rate was usually above 80% and the total mortality during the incubation period varied between 30 and 70%. Increasing temperature from 5.5 to 7.0°C decreased the incubation period from 17 to 12 days. There was a positive correlation between egg size and larval length at hatching. At temperatures between 5 and 9°C the peak starvation mortality occurred at larval ages of 22 - 17 days. The larvae lost about 25% of their dry weight during this period. The larvae started to feed at an age of 3 - 5 days and the dominant food organism was copepod nauplii in the size range 90 to 400 mm.

INTRODUCTION

Haddock is one of the important commercial species in Norwegian waters. Fluctuations in yearclass strength of the 0-group stages in Artic waters are well documented (Anon. 1986). Similar fluctuations can be expected for coastal populations of haddock, as have been observed for cod in the Skagerrak coast area (Tveite 1984). The causes of these fluctuations in local haddock stocks are to be found in the early life history as demonstrated for North Sea haddock (Saville 1956). In haddock, several experimental investigations have focused on the aspects of reproduction (Hislop et al. 1978, Hawkins et al. 1967), development and mortality during the egg stages (Laurence and Rogers 1976; Fridgeirsson 1978; Westernhagen 1968) and the development and growth of the early larvae stages (Laurence 1978; Fridgeirsson 1978). However, these investigations were conducted on haddock from waters other than the coast of Norway and, as pointed out by Anon. (1978), little is known of the biology of haddock from the Skagerrak area. In the present experiment, spawning of haddock from the Skagerrak area were observed during two seasons. The relationship between time of spawning, egg size and the size of the larvae were studied. During development of the larvae, observations were made on their food intake and growth beyond the first feeding stage.

MATERIALS AND METHODS

In 1982 and 1983 mature haddock were caught by long line near Arendal, Norway, at the end of January not more than three weeks before spawning started. The fish were transferred to a 45 m^3 indoor spawning basin at Flødevigen Biological Station. They were fed with shrimps and mackerel every day. The temperature increased from 4.0 to 7.0°C in 1982 and from 4.7 to 6.2°C in 1983, during the spawning period. The salinity was stable at 34.0 ± 0.2 ‰ in both years. Eggs were removed from an egg collecting device every morning and the egg diameter and volume spawned measured. The number of spawned eggs were calculated from the number of eggs in a small fraction of the total spawned volume. In addition, the expected number of eggs was estimated from the average total length of the spawning females in the two years from the relationships described by Raitt (1933) and Hislop et al. (1978). Length data for the females in the two years are given in Table 1.

Table 1

The number (N), average total length (TL) with standard deviation (SD) and range of the matured female haddocks in the experiment.

Year	N	TL (cm)	SD	Range (cm)
1982	28	45.6	5.9	37.0 - 65.5
1983	54	48.8	5.7	38.5 - 61.0

The eggs were incubated in 280 l cylindric tanks and the larvae remained in the same tanks after hatching. In feeding experiments in the laboratory the larvae were fed natural zooplankton collected in the bay with a net. Two food densities were established, one with mean monitored plankton consentration of 1.8 plankters/ml (high) and the other with mean plankton concentration of 0.6 pl/ml (low). In addition, two groups, each of 20.000, three day old haddock larvae were released into a 4400 m^3 outdoor basin. Samples of zooplankton were taken with a pump once a week. Samples of haddock larvae were taken daily with a net. A more detailed description of the basin and connected methods are given by Ellertsen et al. (1981).

While data were collected on live eggs, most of the larvae were preserved in 4% neutralized formaldehyde. Standard length was measured both on live and preserved larvae. The myotome hight was measured behind the anus. Dry weight of both eggs and larvae was measured after being dried at 60°C for 24 h before weighing. While data on dry weight was performed on single larvae, eggs were weighed together in groups of 10-20 and an average calculated. The daily specific growth rate was calculated from the formula:

$$SGR = 100\frac{Log\ GT - Log\ Gt}{T}$$

where GT and Gt are the size (mean dry weight) at the beginning and the end of the time interval in days (T). The experiments on the eggs and larvae were performed within a temperature range from 5.5 to 9.0°C, with a salinity of about 34 $^{o}/oo$.

In the spawning and the laboratory experiments a photoperiod of 15 h light and 8 h dark with 30 min dimmed light in the morning and in the evening was maintained.

RESULTS

Spawning

Spawning took place over a period of 90 days, from late February to the end of May (Fig. 1). Approximately 80% of

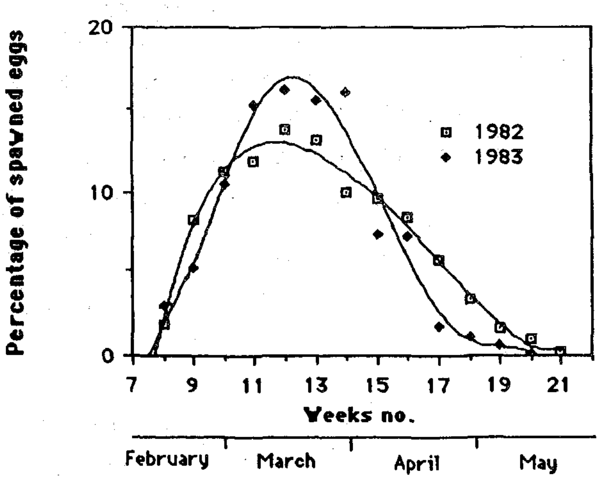

Fig. 1. The percentage of eggs spawned within each week of the spawning periods in 1982 and 1983.

the total amount of eggs was spawned within 45 days or 1/2 of the whole spawning period. The fertilization rate in the two years was mainly above 80%. The average number of eggs released by each female in the two years was 520.000 and 568.000 respectively (Table 2). The expected average number

Table 2

The average total length of the female (TL), the calculated numbers of eggs per female (N/♀) based upon spawned volume and the estimated number of eggs calculated from the average total length of the females, according to Raitt (1933) and Hislop et al. (1978).

Year	TL (cm)	N/♀	Raitt (1933)	Hislop et al. (1978)
1982	45.6	520.000	470.000	408.670
1983	48.8	568.000	618.700	518.600

of eggs spawned by each female, calculated from the relationships described by Raitt (1933) and Hislop (1978) are also given in Table 2.

The egg diameter in the two years ranged from 1.12 to 1.73 mm and decreased from a daily average of 1.50 to 1.29 mm during the spawning period. In the two years an average egg diameter of 1.39 and 1.38 mm was observed (Table 3).

Table 3

The average egg diameter with standard deviation (SD) and range in the two spawning seasons. N = number of eggs examined.

Year	N	Egg-diameter (mm)	SD	Range (mm)
1982	7661	1.39	0.08	1.12 - 1.73
1983	4951	1.38	0.08	1.13 - 1.62

Eggs

The number of days from fertilization to 50% hatching of the larvae decreased from 17 to 12 with increasing temperature from 5.5 to 7.0°C (Fig. 2). The results indicate a variation of 1 - 2 days at the same temperature. Dry weights of eggs at fertilization show a positive correlation with egg size (Fig. 3). The mortality during incubation of the different groups varied widely, from 30 to 70%. Fungus infection was observed in many of the egg groups.

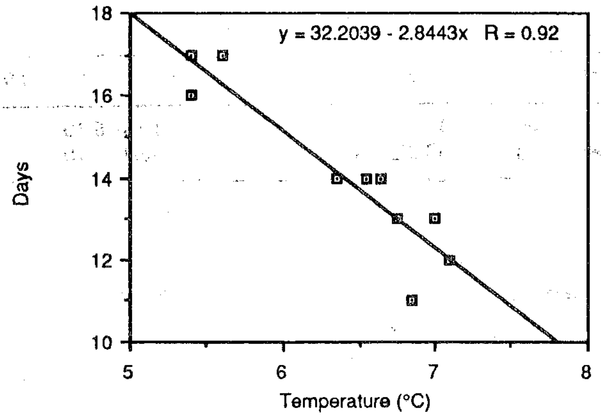

Figure 2. The incubation period in numbers of days (y) in the present data as a function of the temperature (x).

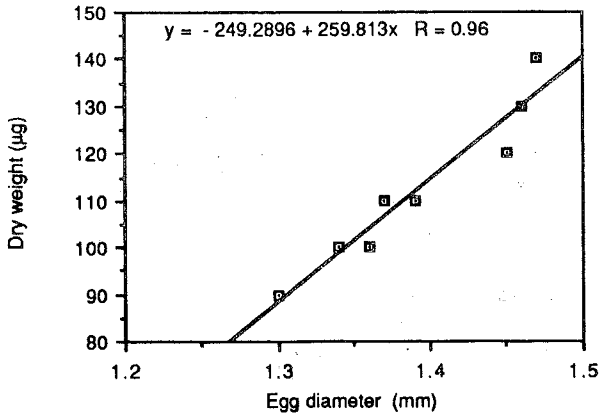

Figure 3. The dry weight of live haddock eggs (y) at fertilization as a function of the egg diameter (x).

Relation between eggs and larvae

Fig. 4 gives the relationship between egg diameter and the mean standard length in live haddock larvae at 50% hatching and the maximum standard length of live starving haddock larvae, usually at the end of the yolk sac stage (EYS). The maximum standard length gave a higher correlation (r^2=0.95) with egg diameter than the standard length at 50% hatching (r^2=0.79) indicating a greater variability of length at hatching than at the end of the yolk sac stage. The maximum live standard length at the end of the yolk sac stage ranged from 4.0 to 4.7 mm, while the length at hatching of larvae from the same batches ranged from 3.8 to 4.3 mm, indicating a length increase of 0.2 to 0.4 mm during the yolk sac stage.

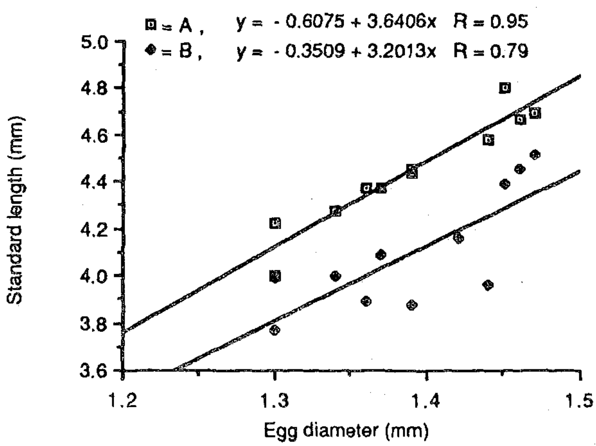

Figure 4. The relationship between average egg diameter and the average standard length of the larvae at 50% hatching and the maximum standard length of the starving larvae. A = Average standard length at hatching and B = average maximum standard length of starving larvae. Each point represent an average of 20 - 50 larvae.

Larvae

The effect of temperature on the number of days from 50% hatching to 50% mortality of starved haddock larvae is shown in Fig. 5. The number of days decreased from 16 at 5.5°C to 11 at 9.0°C. Within the period from hatching to mass mortality a daily mortality of 5% was observed in the different experimental groups. Within this period the starving larvae reached their maximum standard length and myotome height at

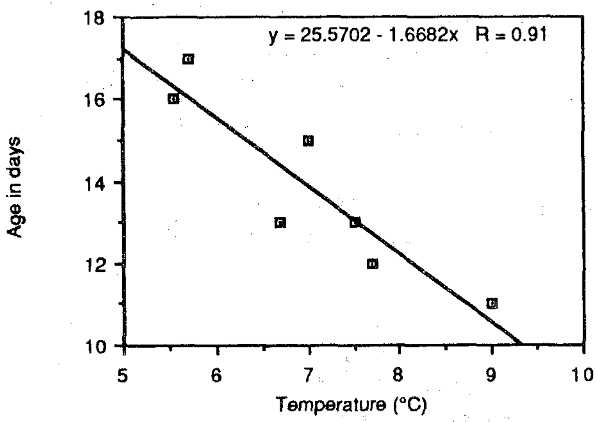

Figure 5. The relationship between the number of days (y) from 50% hatching to 50% mortality and the temperature (x).

an age of 4 days at 5.5°C (Table 4). The dry weight decreased from 56 µg to 35 µg (about 40%) in the period from hatching to mass mortality. All of the yolk was used after 10 days at 5.5°C.

In the feeding experiments, both in the laboratory and in the basin, the larvae started to feed at an age of 3 to 5 days at temperatures ranging from 9 to 5°C. However in "low" plankton concentrations (less than 0.6 pl/ml) in the laboratory, first feeding was delayed as indicated in Fig. 6. In the basin experiments the plankton concentration at the first feeding stage for the the released groups was between 0.03 and 0.1 pl/ml. In these experiments no delay in first feeding was observed. Haddock larvae in the first feeding stage predated on food particles of a size range of 90 to 400 mm, which were mainly copepod nauplii. Haddock larvae released in the basin selected the smaller food

Table 4

Average standard length (SL), average myotome height (MH) and average dry weight (DW) of starving haddock larvae at 5.5°C. N = number of larvae examined.

Age (days)	N	SL (mm)	MH (mm)	DW (mg)
0	136	3.83	0.23	0.056
1	127	3.84	0.21	0.056
2	88	4.12	0.25	0.072
3	54	4.35	0.26	0.063
4	47	4.26	0.25	0.057
5	86	4.19	0.25	0.063
6	63	4.23	0.24	0.062
7	65	4.22	0.24	0.063
8	70	4.27	0.24	0.059
9	68	4.23	0.23	0.055
10	80	4.37	0.25	0.047
11	73	4.24	0.23	0.049
12	75	4.10	0.22	0.047
13	93	4.21	0.22	0.040
14	49	4.10	0.21	0.036
15	54	4.25	0.22	0.038
16	0	-	-	-
17	47	4.06	0.22	0.035
18	58	4.13	-	0.035

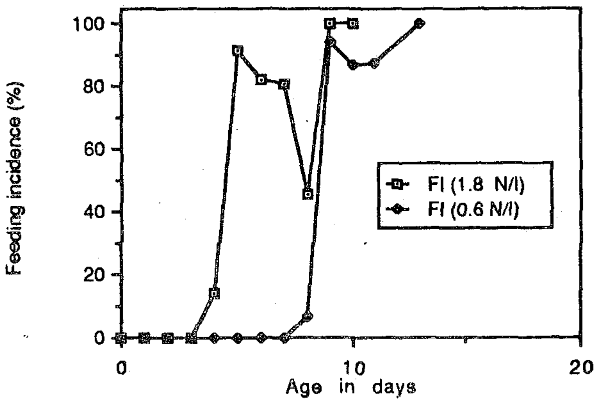

Figure 6. Feeding incidence of two groups of first feeding haddock larvae at 8.0°C in plankton concentration of 1.8 pl/ml (A) and 0.6 pl/ml (B).

organisms available (Fig. 7A). The preference for smaller food organisms was even more exposed in the second basin experiment (Fig. 7B) when the percentage of smaller organisms available was much reduced. The average size of the food particle in different feeding experiments, both in the laboratory and in the basin, varied from 130 to 215 mm (Table 5). This Table also indicates that the increase in the size distribution of the plankton was accompanied by an increase in the size distribution in the gut of the haddock larvae, though of a lower magnitude. In the two basin experiments the feeding Incidence of the larvae increased to

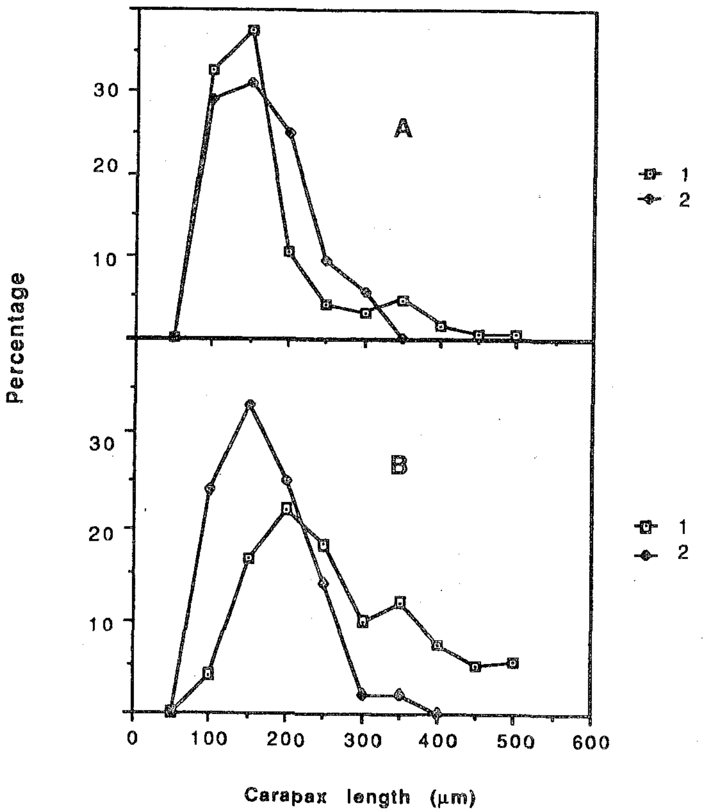

Fig. 7. The length-frequency of the zooplankton in the basin (1) and in the gut of the haddock larvae (2). A = Basin experiment no. 1, age 6 days, and B = Basin experiment no. 2, age 5 days of the haddock larvae.

Table 5

Average carapace length of plankton in feeding experiments (L-pl) and in the gut of the haddock larvae (L-gut). Standard deviation (SD) indicated.

L-pl (µm)	SD	L-gut (µm)	SD
152	52	131	47
152	52	132	35
220	200	167	52
290	140	177	60
340	160	214	61

about 80% in two days after feeding had started. At the same time the feeding ratio increased from 2 to 10. A higher specific growth rate (SGR) of 2.7%/day was observed in the basin experiment, than the SGR of 0.7%/day observed in the laboratory experiment with the highest plankton concentration (1.8 pl/ml).

DISCUSSION

The spawning

The observed spawning period of the Norwegian Skagerrak coastal haddock from late February to the end of May, with a maximum spawning intensity during the middle of March to the middle of April is in accordance with earlier results from field investigations (Saville 1959). The calculated number of eggs spawned by each female corresponds well with estimates from the formulae of Raitt (1932) and Hislop et al. (1978). These findings indicate that mature female haddock in the North Sea area release the same number of eggs as fish of the same length in the Skagerrak. The average daily egg diameter in both spawning years decreased throughout the season with 0.21 mm, from about 1.50 to 1.29 mm. Several reports have been concerned with factors influencing egg size. According to Hislop et al. (1978) the egg diameter decreased within each female, which was also indicated by Moksness and Riis-Vestergaard (1982). Hislop et al. (1978) also stated that the amount of food given to the matured and spawning fishes affected fecundity and the dry weight of the eggs positively. All of the fish in the experiment were fed at a "high" level throughout the experimental period so that egg size and dry weight of the eggs should have been maximal. Grauman (1965) found for Baltic cod, that the mean egg diameter decreased during the spawning season. She assumed that this was because the smaller females, known to produce smaller eggs, tend to spawn later than the larger females. However, the results of Hislop et al. (1978) indicate no differences in egg size from haddock with a total length range of 34.6 to 43.3 cm. In the present experiment each of the two "spawning populations" included females of different sizes but it has not been directly verified whether the later spawners were the smaller ones. The observed average egg diameter for a whole spawning season (1.38 and 1.39 mm) is less than that observed for cod eggs.

Eggs and larvae

The incubation period decreased by five days as temperature increased from 5.5 to 7.0°C. In four investigations on haddock (Dannevig 1895; Laurence and Rogers 1976; Walford 1938; Westernhagen 1968) a smaller decrease in incubation time was observed. However, the variation between the four papers is up to five days at the same temperature indicating either genetitical differences or differences in experimental conditions. The rather high mortality (30 - 70%) during incubation is believed to be caused by fungus on the eggs. However, the high mortality is within the range of earlier observations by Laurence and Rogers (1976).

The number of days to mass mortality of the starving haddock larvae in this experiment, 16 and 11 days at 5.5 and 9.0°C respectively, was somewhat higher than observed by Laurence

(1978), 12 and 9 days at 7.0 and 9.0°C respectively. In the same paper Laurence reports that yolk absorption was completed after 6 and 7 days in 10 and 7°C respectively. In the present paper complete yolk absorption was observed after 10 days at 5.5°C. These results indicate that the haddock larvae from the western Atlantic waters use their yolk faster than haddock larvae from the Norwegian Skagerrak coastal area. The reason for these differences might be differences in the haddock stocks at the eastern and western coast of the Atlantic Ocean.

The observed higher dry weights of eggs with increasing egg diameter are to be expected. So is the increasing standard length of the larvae with increasing egg diameter. The larvae might hatch at different developmental stages (Westernhagen 1968) explaining the higher variation in standard length at hatching compared to the end of yolk sac stage of starving larvae. The starving haddock larvae at 5.5°C reached their maximum standard length and myotome height at an age of four days. This is rather fast compared to cod at the same temperature (Solberg and Tilseth 1984) where maximum myotome height was reached after five days and maximum length after approx. seven days. Haddock larvae in the laboratory and basin experiments started to feed at an age of 3 to 5 days, about the same age as has been observed for cod (Ellertsen et al. 1980). It is reported that haddock larvae from western Atlantic starts to feed at an age of 2 days at 7.0°C (Laurence 1974). These observations might indicate differences between western and eastern Atlantic haddock. In all feeding experiments the haddock larvae seemed to prefer food organisms of size less than 250 μm. This observation corresponds well with field observations from Georges Bank area (Kane 1984), where first feeding haddock larvae also preyed upon smaller organisms than the first feeding cod larvae. The best SGR in the laboratory experiment, 0.7%/day (in 1.8 pl/ml), was below the SGR (0.85 - 1.12%/day) observed in plankton concentrations from 0.5 to 3.0 pl/ml. In the basin experiments, with plankton concentrations between 0.03 and 0.1 pl/ml, a SGR of 2.7%/day was observed in the first 13 days after hatching. These results reflect differences in experimental conditions more than differences between larvae from different haddock stocks.

CONCLUSION

The results in the present paper indicate that spawning and the early life history of haddock from the Norwegian Skagerrak coastal area do not differ much from haddock eslewhere in the North Sea area. However, the results indicate that there might be some differences in the early life history of haddock from the western and eastern Atlantic. The results confirmed earlier observations of a much better growth of fish larvae in basin experiments compared to laboratory experiments at the same prey densities.

REFERENCES

Anon. 1978. Report of the Danish-Swedish study group on fish stocks in the Kattegat and adjacent waters. Coun. Meet. int. Coun. Explor. Sea, 1978 (H:56): 1-51 [Mimeo.]

Anon. 1986. Preliminary report of the international 0-group fish survey in the Barents Sea and adjacent waters in August-September 1986. Coun. Meet. int. Coun. Explor. Sea, 1986 (G:78): 1-27 [Mimeo.]

Dannevig, H. 1895. The influence of temperature on the development of eggs of fishes. Rep. Fishery Bd Scotl., 13: 147-152.

Ellertsen, B., Moksness, E., Solemdal, P., Strømme T., Tilseth, S., Westgård, T. and Øiestad, V. 1980. Some biological aspects of cod larvae (*Gadus morhua* L.). FiskDir. Skr. Ser. HavUnders., 17: 29-47.

Ellertsen, B., Moksness, E., Solemdal, P., Tilseth, S., Westgård, T. and Øiestad, V. 1981. Growth and survival of cod in an enclosure. Experiment and a mathematical model. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178: 45-57.

Fridgeirsson, E. 1978. Embryonic development of five species of gadoid fishes in Icelandic waters. Rit. Fiskideildar, 5: 1-68.

Grauman, G.B. 1965. Changes in the egg size of cod (*Gadus morhua callaris* L.) within the spawning period. Coun. Meet. int. Coun. Explor. Sea, Baltic-Belt Seas Committee, No. 47: 1-10 [Mimeo.]

Hawkins, A.D., Chapman, K.J. and Symonds, D.J. 1967. Spawning of haddock in captivity. Nature, 215: 923-925.

Hislop, J.R.G., Robb, A.P. and Gauld, J.A. 1978. Observations on effects of feeding level on growth and reproductivity in haddock, *Melanogrammus aeglefinus* (L.) in captivity. J. Fish. Biol., 13: 85-98.

Kane, J. 1984. The feeding of co-occuring cod and haddock larvae from Georges Bank. Mar. Ecol. Prog. Ser., 16: 9-20.

Laurence, G.C. 1974. Growth and survival of haddock (*Melanogrammus aeglefinus*) larvae in relation to planktonic prey concentration. J. Fish. Res. Bd Can., 31: 1415-1419.
Laurence, G.C. 1978. Comparative growth, respiration and delayed feeding abilities of larval cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) as influenced by temperature during laboratory studies. Mar. Biol., 50: 1-7.
Laurence, G.C. and Rogers, C.A. 1976. Effects of temperature and salinity on comparative embryo development and mortality of Atlantic cod (*Gadus morhua* L.) and haddock (*Melanogrammus aeglefinus* L.). J. Cons. int. Explor. Mer, 36: 220-228.
Moksness, E. and Riis-Vestergaard, J. 1982. Spawning of haddock (*Melanogrammus aeglefinus* L.). Flødevigen rapportser., 2: 1-9.
Raitt, D.S. 1932. The fecundity of haddock. Scient. Invest. Fishery Bd Scotl., 1: 1-43.
Saville, A. 1956. Eggs and larvae of haddock (*Gadus aeglefinus* L.) at Faroe. Mar. Res., 3: 1-27.
Saville, A. 1959. The planktonic stages of the haddock in Scottish Waters. Mar. Res., 3: 1-23.
Solberg, T. and Tilseth, S. 1984. Growth, energy consumption and prey density requirements in first feeding larvae of cod (*Gadus morhua* L.). In: E. Dahl, D.S. Danielsse, E. Moksness and P. Solemdal (Editors), The Propagation of Cod *Gadus morhua* L. Flødevigen rapportser., 1, 1984: 145-166.
Tveite, S. 1984. 0-group cod investigations on the Norwegian Skagerrak coast. In: E. Dahl, D.S. Danielssen, E. Moksness and P. Solemdal (Editors), The Propagation of Cod *Gadus morhua* L. Flødevigen rapportser., 1, 1984: 581-590.
Walford, L.A. 1938. Effect of currents on distribution and survival of the eggs and larvae of the haddock (*Melanogrammus aeglefinus*) on the Georges Bank. Bull. Bur. Fish. Wash., 49: 1-73.
Westernhagen, H. von 1968. Versuche zur Erbrütung der Eier des Schellfisches (*Melanogrammus aeglefinus* L.) unter kombinierten Salzgehalts- und Temperaturbedingungen. Ber. Dt. Wiss. Komm. Meeresforsch. XIX (1968): 270-287.