

Comparative Growth, Respiration and Delayed Feeding Abilities of Larval Cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus*) as Influenced by Temperature During Laboratory Studies

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Abstract

Comparative growth and respiration were measured during the period hatching to metamorphosis for larval cod (*Gadus morhua*) at 4°, 7° and 10°C and for haddock (*Melanogrammus aeglefinus*) at 4°, 7° and 9°C. Growth was positively correlated with temperature for both species. Specific growth rates on a daily basis indicated good growth for the two species at the upper two temperatures and suppressed growth at 4°C. Respiration rates measured by oxygen consumption were similar for both species. Variable and elevated oxygen consumption at 4°C indicated physiological stress at that temperature. Delayed feeding abilities, feeding initiation, yolk absorption and morphological development related to first feeding ability were similar for both species at 7° to 10°C. Larvae could survive without food and still initiate feeding until 10 days after hatching at 7°C and until 8 days at 9° to 10°C.

Introduction

Increasing attention is being directed to laboratory and field studies of growth and survival processes of larval fish (Hunter, 1976). This emphasis should contribute to a better understanding of factors controlling adult population size and recruitment dynamics (stock-recruitment relationship). In addition, larval fish are good indicators of environmental quality, and survival studies in this area are increasingly important (Blaxter, 1970; Rosenthal and Alderdice, 1976).

Failure to initiate and maintain successful feeding as well as predation are the primary causes of larval fish mortality. Studies on food capture and ensuing conversion for growth and metabolic processes as influenced by environmental factors help to elucidate some of these causes of mortality (Laurence, 1975, 1977). During the winter and early spring (January-April), both cod and haddock spawn off the Atlantic coast of North America (Colton and Marak, 1969), and the larvae co-exist in the area from Martha's Vineyard north to the Grand Banks (Bigelow and Schroeder, 1953). Here, I present the results of studies on the effects of temperature on the

comparative feeding, growth and respiration of larval cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). This is an attempt to determine any interspecific differences that might be responsible for differential natural mortality.

Materials and Methods

Adult *Gadus morhua* were captured by otter trawl net in Block Island Sound, Rhode Island, and by set line approximately 18 km south of Chatham, Massachusetts, USA. Adult *Melanogrammus aeglefinus* were captured by set line in the same vicinity off Chatham and approximately 20 km east of Cape Ann, Massachusetts. The adults were transported to the Narragansett Laboratory, where they were separately maintained in 28,000 and 57,000 l aquaria.

Natural spawnings were induced by standard techniques, controlling temperature and photoperiod, developed at the Narragansett Laboratory (Laurence, 1974; Laurence and Rogers, 1976). Newly fertilized embryos were collected from the experimental spawning aquaria with a 0.5 m (453 µm mesh) plankton net and placed in appropriate rearing containers.

All experiments and rearing were conducted at constant temperatures in the

range of 4° to 10°C and at 32 to 34‰ S. Approximately 1,000 newly fertilized embryos were placed in series of black 64 l glass aquaria for growth studies. The aquaria were placed in an environmental room or in water baths where the temperatures were maintained by program recorders controlling heating and cooling coils. They were semiclosed systems, aerated by airstones, with a portion of the seawater being drained and replenished every 1 or 2 days. Illumination controlled by timers provided a 12 h day : 12 h night photoperiod. Larvae were fed natural populations of zooplankters in concentrations of 2 to 3 organisms per ml, which were known to provide optimum growth rates (Laurence, 1974). Zooplankters fed during experiments consisted mainly of the nauplii, copepodites and adults of the copepod *Acartia clausi* and *Centropages hamatus*, with smaller amounts of *Eurytemora affinis* and nauplii of the barnacle *Balanus balanoides*. All zooplankton collections were made using 0.5 m nets with 60 or 120 µm mesh netting and were subsequently sieved through 200 or 500 µm mesh, depending on the size of the larvae to be fed.

Specific methods for determining growth and respiration rates are described in detail by Laurence (1975). Briefly, growth at a particular temperature was determined by measuring dry weights once a week from hatching to metamorphosis for individual larvae in samples of 10 to 25. Metamorphosis, as defined in this research, was when the larvae of both species developed anatomical and morphological characteristics similar to adults (i.e., fully developed fins, functional gills, "devil's thumbprint" pigmentation ventral to the anterior part of the lateral line in haddock, etc.). This occurred at a size of approximately 1,000 µg dry weight and 10 mm standard length for both species. Respiration, measured by oxygen consumption, was likewise determined once a week for 6 replications of groups of 10, 5 or individual larvae at each designated rearing temperature. These measurements were considered to be "routine" oxygen consumption, with larvae allowed 1 to 2 h for acclimation in the respiration flasks before results were recorded with a Gilson differential respirometer during 2 h experimental trials.

Daily specific growth rates were calculated from the antilogarithms ($\log_e 10$) of the slopes of the regression equations, describing the relationship of \log_{10} of dry weight as the dependent variable and time in days as the independent variable.

Delayed feeding experiments were conducted at 7° and 10°C for cod and 7° and 9°C for haddock. These experiments were designed to ascertain the latest point in time after hatching when food had to be available for larvae to initiate successful feeding before starvation rendered them too weak to feed. Groups of approximately 50 larvae were placed in a series of aerated 3.8 l black aquaria at the designated temperatures. The groups of larvae were fed zooplankters (>2 per ml), starting with the first group at hatching and adding an additional group at ensuing 2 day intervals so that individual groups were initially given food at 0, 2, 4, 6, 8, 10 and 12 days from hatching. Zooplankton prey levels were maintained by adding food every 24 h after the initial feeding. Samples of 10 larvae were taken every 24 h after first exposure to food and analyzed for stomach contents, eye pigmentation, functional mouth, and available yolk until it was obvious that they had been deprived of food long enough so as to be unable to initiate feeding. Successful feeding was defined as 50% or more of the sampled larvae containing food in the alimentary tract. If less than 50% of a sample contained food, the group from which the sample came was allowed to continue feeding and sampled at successive 24 h intervals until it was obvious whether they could or could not feed according to the definition of successful feeding.

All statistical and regression analyses were calculated according to the methods proposed by Steel and Torrie (1960) and Draper and Smith (1966).

Results

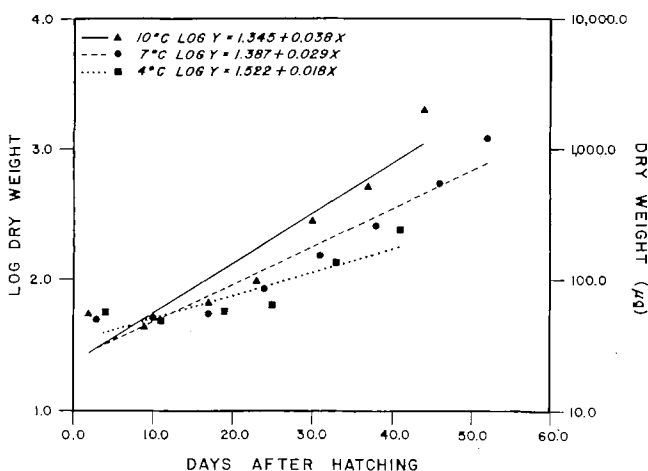
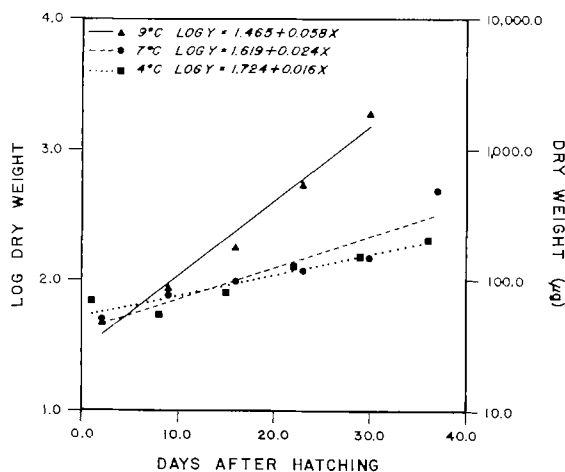
Growth

Growth of larval *Gadus morhua* was strongly influenced by temperature (Table 1). All larvae hatched at 4°C died within 41 days; those hatched at 7°C metamorphosed in 52 days, and those hatched at 10°C metamorphosed in 44 days. Specific growth rates were 4.15% per day at 4°C, 6.67% per day at 7°C, and 8.75% per day at 10°C. Regression analyses of the semi-logarithmic transformation of growth on time also demonstrated temperature's influence on growth rates. Slopes of the regression lines increased with increasing temperature (Fig. 1).

Larval *Melanogrammus aeglefinus* growth was also directly affected by temperature (Table 1). Repeated attempts to rear haddock at 10°C failed, with mortalities consistently occurring 10 to 13

Table 1. *Gadus morhua* and *Melanogrammus aeglefinus*. Mean weekly growth (μg mean dry weight) at 3 different temperatures

Weeks after hatching	Cod			Haddock		
	4°C	7°C	10°C	4°C	7°C	9°C
0	56.5	49.2	55.0	69.8	50.3	47.6
1	48.3	51.3	43.4	55.0	76.8	86.9
2	57.3	54.7	66.5	81.0	98.3	178.6
3	64.3	85.9	100.0	129.2	119.0	532.9
4	137.1	153.8	284.0	151.2	151.0	1,858.9
5	242.7 ^a	200.2	520.7	205.8 ^a	483.8 ^b	
6		544.5	2,008.5			
7		1,217.4				

^aComplete mortality.^bMalfunction in rearing system terminated measurements.Fig. 1. *Gadus morhua*. Dry weight growth of cod larvae for period of yolk absorption to metamorphosis at 3 temperaturesFig. 2. *Melanogrammus aeglefinus*. Dry weight growth of haddock larvae for period of yolk absorption to metamorphosis at 3 temperatures

days after hatching. Rearing at 9°C allowed survival and growth (Table 1, Fig. 2). Complete mortality of haddock occurred in the fifth week (36 days) after hatching at 4°C, similar to mortality in

cod. Haddock larvae metamorphosed in the fourth week (30 days) after hatching at 9°C. Unfortunately, a malfunction took place in the haddock rearing aquarium at 7°C and all larvae died during the sixth week (37 days) after hatching. However, the growth rate up to that time was comparable to previously reported results at 7°C (Laurence, 1974) and indicated that the larvae would have metamorphosed during the sixth to seventh week after hatching. Specific growth rates were 3.68% per day at 4°C, 5.53% per day at 7°C, and 13.36% per day at 9°C. Regression analyses showed the influence of temperature on growth, with slope values increasing with increasing temperature (Fig. 2).

Respiration

The relationship of mean hourly oxygen consumption in μl per individual and dry body weight for cod larvae was treated as a power function (Fig. 3). Correlation coefficients indicated high statistical significance between the logarithms of oxygen consumption and body weight at 7°C and 10°C [$r = 0.80 > r$ (tabulated) = 0.33, DF 1 and 35, $P = 0.05$ at 7°C; and $r = 0.75 > r$ (tabulated) = 0.29, DF 1 and 45, $P = 0.05$ at 10°C]. Slight non-statistical significance was calculated at 4°C [$r = 0.41 < r$ (tabulated) = 0.45, DF 1 and 17, $P = 0.5$], indicating variable respiration with increasing body weight. Respiration rates, indicated by similar regression line slopes, were quite uniform with temperature; however, absolute respiration increased with increasing temperature as shown by the increased elevation of the regression lines (Fig. 3).

The relationship of larval haddock oxygen consumption and dry weight showed statistically significant correlations at all 3 temperatures [$r = 0.84 > r$ (tabulated) = 0.44, DF 1 and 18, $P = 0.05$ at 9°C; $r = 0.74 > r$ (tabulated) = 0.39, DF 1 and 24, $P = 0.05$ at 7°C; $r = 0.75 > r$ (tabulated) = 0.45, DF 1 and 17, $P = 0.05$ at 4°C]. Rates of haddock respiration and absolute values were similar at 9°C and 7°C, as indicated by the similar slopes and elevations of the regression lines (Fig. 4). The regression relationship at 4°C showed an unusually high and somewhat anomalous slope indicating, perhaps, that some stress factor was operating at this temperature.

Although absolute oxygen consumption values for a given dry weight were somewhat higher for haddock larvae at 9°C and 7°C compared to cod at 10°C and 7°C, 95% confidence limits about the origins and

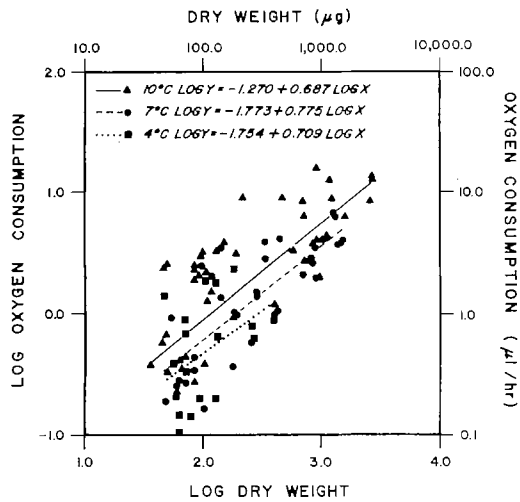


Fig. 3. *Gadus morhua*. Regressions of hourly oxygen consumption on dry weight of cod larvae at 3 temperatures

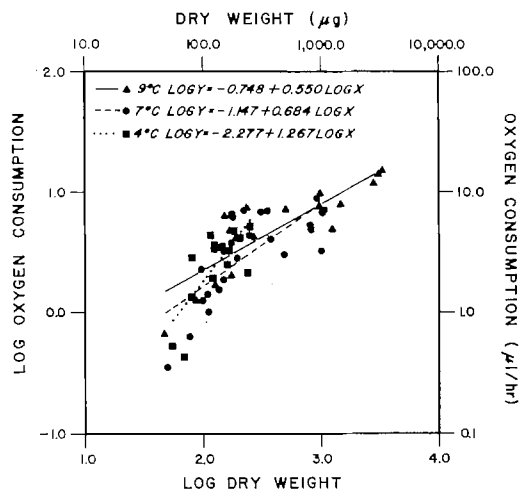


Fig. 4. *Melanogrammus aeglefinus*. Regressions of hourly oxygen consumption on dry weight of haddock larvae at 3 temperatures

slopes of the regression lines at these temperatures revealed no statistically significant differences between the two species. Comparisons were not made at 4°C because of the variability of the data.

Delayed Feeding Abilities

Both cod and haddock larvae were well developed at hatching with pigmented eyes, functional mouths, and completed alimentary tracts, and were able to initiate feeding within 1 day at temperatures of 7°C to 10°C. No real differences were noted in delayed feeding abilities of the two species (Table 2). Both spe-

Table 2. *Gadus morhua* and *Melanogrammus aeglefinus*. Delayed feeding abilities as indicated by criterion of 50% feeding success. Values are percentages with food in alimentary tract. -: no samples taken

Days after hatching	Cod		Haddock	
	7°C	10°C	7°C	9°C
1	90	20	60	50
2	-	40	-	-
3	80	70	80	50
4	-	-	-	-
5	60	90	50	70
6	-	- ^a	-	- ^a
7	50 ^a	70	40 ^a	60
8	-	-	60	-
9	60	10	90	0 ^b
10	40	0 ^b	-	-
11	30	-	40	-
12	0 ^b	-	0 ^b	-

^aYolk absorption completed.

^b50% mortality.

cies were able to initiate feeding (as determined by the 50% feeding criterion) until Days 9 to 10 after hatching at 7°C. Cod were able to commence feeding until Days 7 to 8 at 10°C, as were haddock at 9°C. There were no essential differences in yolk absorption times between the two species at comparable temperatures.

Discussion

The successful rearing and growth of *Gadus morhua* at 10°C and lack of success with *Melanogrammus aeglefinus*, despite several attempts, is interesting. A drop of 1°C to 9°C permitted haddock larvae to survive and grow in spite of the fact that haddock embryos incubate and hatch reasonably well at 10°C (Laurence and Rogers, 1976). This indicates that the scope for posthatching growth and subsequent survival may be slightly temperature-limited in the upper ranges for haddock larvae compared to cod. A specificity to temperature by young haddock was also noted by Tatyankin (1972), who tested the thermal preference of juvenile cod, haddock and pollock (*Pollachius virens*) in the laboratory. He found haddock to be the most stenothermal of the three species.

Both species displayed a tendency towards increased growth rates with increased temperature (Figs. 1 and 2). Growth rates of haddock larvae were similar to but higher than those of cod at all temperatures, but more significantly

so in the 9° and 10°C comparison. Specific growth rates of both species were depressed at 4°C, and neither survived to metamorphosis size under optimum feeding conditions at this temperature. This general increase in growth rate with increase in temperature exhibited by both species has often been observed in various young fishes (Shelbourn *et al.*, 1973).

Some similarities were noted in a comparison of the specific growth rates of these controlled laboratory studies with data extrapolated from the results of field studies of other researchers.

Jones (1973) reported a weight increase of 12% per day for Faroe haddock larvae, which is very close to the 13.36% per day at 9°C in this study. A recalculation of Sysoeva and Degtereva's (1965) length-weight-age data for larval cod during the first 2 months of life gave an 8.5% per day specific growth rate for weight. This value is in the range of the 6.67 to 8.75% per day at 7° and 10°C noted for cod in the present research. Other larval species which develop at approximately the same temperatures as cod and haddock display comparable specific growth rates. A calculated 6.6% per day rate was derived from Marshall *et al.*'s (1937) data for 0 to 60 day post-hatching, spring-spawning herring (*Clupea harengus*), and rates of 5.8 to 10.1% per day at 5° and 8°C were recorded for winter flounder larvae (Laurence, 1975).

Respiration measurements in the present studies were from larvae acclimated to temperature and allowed to swim freely in flasks devoid of food. These measurements are considered to be estimates of "routine" metabolism according to the definition of Fry (1971). Routine metabolism is intermediate between "active" measured under conditions of forced activity and "standard" measured in a resting state with no food in the alimentary tract. Power functions describing the regression relationship of oxygen consumption and dry body weight were used because they traditionally have allowed comparisons between different species (Winberg, 1956) and were statistically comparable in these studies of cod and haddock larvae.

The lack of statistically significant differences of respiration on a unit weight basis between the two species in the temperature range of 7° to 10°C indicates a physiological similarity. Also, respiration measurements of both species at 4°C indicate an apparent stress situation. Cod respiration was quite variable and did not correlate significantly with dry body weight, while haddock respiration was extremely elevated. Rosenthal and Alderdice (1976) indicated that

breakdown in biochemical systems of larval fishes attempting to compensate in the presence of environmental stress could result in variable or increased metabolism.

Respiration measurements of larval fishes have been scarce (Blaxter, 1970) and, as far as is known, the present study is the first to report results for cod and haddock larvae. Other studies have been conducted with juvenile and adult cod, and the slopes of the regression relationships of the logarithmic conversions of oxygen consumption per hour on body weight show values similar to larvae in this research. Saunders (1963) reported slope values of between 0.76 and 0.83 for cod routine metabolism in the temperature range 3° to 15°C. Sundnes (1957) presented slope values of 0.62 to 0.73 for cod and pollock at 8° to 11°C, and Edwards *et al.* (1972) calculated a slope for cod standard metabolism of 0.82.

Although no significant differences in delayed feeding abilities between cod and haddock larvae were noted, some interesting observations were made. Both species were physically advanced in regards to feeding ability potential (pigmented eyes, functional mouth, complete alimentary tract) at hatching in the temperature range 7° to 10°C and could feed well in advance of yolk absorption. This is not generally the case with most marine pelagic larvae which, although many commence feeding while there are still some remnants of yolk left, require a certain amount of temperature-dependent time after hatching to physically develop feeding capabilities (Blaxter, 1970). Early feeding ability while there is still a large supply of endogenous yolk would seem to confer a survival advantage to cod and haddock larvae if food were limited in abundance or distribution for a time around the period of yolk absorption. Early feeding of cod and haddock larvae has been noted by other investigators. Stomach analyses of field-sampled cod and haddock larvae of hatching length sizes and with large amounts of yolk remaining showed substantial numbers with food in the gut (Ogilvie, 1938; Wiborg, 1948; Marak, 1960). Ellertsen *et al.* (1976) reported that more than 80% of cod larvae sampled in laboratory experiments fed on small flagellates the day after hatching.

The yolk absorption times and delayed feeding abilities of both cod and haddock larvae in this research agree reasonably well with the results of Ellertsen *et al.* (1976) and Tilseth and Strømme (1976). They found, respectively, complete yolk absorption of larval cod at

5°C occurring on the eighth day after hatching and delayed feeding ability ("point of no return") as defined by changes in buoyancy and activity rather than feeding criteria occurring on the eleventh day. Other studies have shown that starvation times and delayed feeding ability times after complete yolk absorption are temperature- and species-dependent. Detwyler and Houde (1970) found yolk absorption was complete 36 h after hatching at 26°C for scaled sardines (*Harengula pensacolatae*) and bay anchovies (*Anchoa mitchilli*), and that food was necessary within the next 12 h to prevent starvation. Spectorova et al. (1974) determined that Black Sea turbot larvae (*Scophthalmus maeoticus*) absorbed their yolk within 134 h after hatching and were unable to initiate successful feeding by 182 h at 14.6°C. Survival rates at 22°C of northern anchovy larvae (*Engraulis mordax*) 5 days after first feeding were much greater for groups fed prior and up to 12 h after yolk absorption than for those fed later, with complete yolk absorption occurring 1½ days after hatching (Lasker et al., 1970). It is interesting to note from the present studies of cod and haddock (Table 2) and the above-cited studies that, regardless of temperature and species, the delayed feeding time after yolk absorption which still allows larvae to start successful feeding seems to be approximately equal to 25% of the time from hatching to complete yolk absorption. This is a subject for further interspecific studies.

In conclusion, there appear to be no major differences in comparative respiration metabolism, growth rates or delayed feeding abilities at different temperatures between larval cod and haddock in relation to survival potential. Feeding initiation times, gross anatomical development in relation to feeding ability, and ability to withstand starvation at different temperatures were virtually identical. Respiration rates and patterns were similar at the same and comparable temperatures. The only slight and somewhat subtle differences between the two larval species were in growth potential, and these differences seemed to offset each other in relation to potential comparative survival. Haddock displayed a slightly narrower scope for successful growth in terms of temperature but slightly higher growth rates within that scope than cod. It is not known nor can it be inferred at this time if subtle differences such as these during the larval stage can make a difference in the potential year-class strength of species like cod or haddock.

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Literature Cited

- Bigelow, H.B. and W.C. Schroeder: Fishes of the Gulf of Maine. Fishery Bull. Fish Wildl. Serv. U.S. 53, 1-577 (1953)
- Blaxter, J.H.S.: Development: eggs and larvae. In: Fish physiology, Vol. III. pp 178-241. Ed. by W.S. Hoar and D.J. Randall. New York: Academic Press, Inc. 1970
- Colton, J.B. and R.R. Marak: Guide for identifying the common planktonic fish eggs and larvae of continental shelf waters, Cape Sable to Block Island, 43 pp. Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Lab. ref. no. 69 (1969). (Copies available from: John B. Colton, NMFS, Northeast Fisheries Center, Narragansett Laboratory, Narragansett, Rhode Island 02882, USA)
- Detwyler, R. and E.D. Houde: Food selection by laboratory-reared larvae of the scaled sardine *Harengula pensacolatae* (Pisces, Clupeidae) and the bay anchovy *Anchoa mitchilli* (Pisces, Engraulidae). Mar. Biol. 7, 214-222 (1970)
- Draper, N.R. and H. Smith: Applied regression analysis. 407 pp. New York, N.Y. John Wiley & Sons 1966
- Edwards, R.R.C., D.M. Finlayson and J.H. Steele: An experimental study of the oxygen consumption, growth, and metabolism of the cod (*Gadus morhua* L.). J. exp. mar. Biol. Ecol. 8, 299-309 (1972)
- Ellertsen, B., E. Moksness, P. Solemdal, T. Strømme, S. Tilseth and V. Olestad: The influence of light and food density on the feeding success in larvae of cod (*Gadus morhua* L.); field and laboratory observations. Int. Counc. Explor. Sea Comm. Meet. F:34, 1-16 (1976)
- Fry, F.E.J.: The effect of environmental factors on the physiology of fish. In: Fish physiology, Vol. VI. pp 1-98. Ed. by W.S. Hoar and D. J. Randall. New York: Academic Press, Inc. 1971
- Hunter, J.R., Ed.: Report of a colloquium on larval fish mortality studies and their relation to fishery research, January 1975. NOAA tech. Rep. U.S. Dep. Comm. Spec. scient. Rep. (Fish.) natn. mar. Fish. Serv. 395, 1-5 (1976)
- Jones, R.: Density dependent regulation of the numbers of cod and haddock. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer 164, 156-173 (1973)
- Lasker, R., H.M. Feder, G.H. Theilacker and R.H. May: Feeding, growth, and survival of *Engraulis mordax* larvae reared in the laboratory. Mar. Biol. 5, 345-353 (1970)
- Laurence, G.C.: Growth and survival of haddock (*Melanogrammus aeglefinus*) larvae in relation

- to planktonic prey concentration. J. Fish. Res. Bd Can. 31, 1415-1419 (1974)
- Laboratory growth and metabolism of the winter flounder *Pseudopleuronectes americanus* from hatching through metamorphosis at three temperatures. Mar. Biol. 32, 223-239 (1975)
 - A bioenergetic model for the analysis of feeding and survival potential of winter flounder, *Pseudopleuronectes americanus*, larvae during the period from hatching to metamorphosis. Fish. Bull. U.S. 75, 529-546 (1977)
 - and C.A. Rogers: 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 (1976)
- Marak, R.R.: Food habits of larval cod, haddock, and coalfish in the Gulf of Maine and Georges Bank Area. J. Cons. perm. Int. Explor. Mer 25, 147-157 (1960)
- Marshall, S.M., A.G. Nicholls and A.P. Orr: On the growth and feeding of the larval and post larval stages of the Clyde herring. J. mar. biol. Ass. U.K. 22, 245-268 (1937)
- Ogilvie, H.S.: The food of post-larval haddock with reference to the annual fluctuations in the haddock broods. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer 107(3), 57-66 (1938)
- Rosenthal, H. and D.F. Alderdice: Sublethal effects of environmental stressors, natural and pollutional, on marine fish eggs and larvae. J. Fish. Res. Bd Can. 33, 2047-2065 (1976)
- Saunders, R.L.: Respiration of the Atlantic cod. J. Fish. Res. Bd Can. 20, 373-386 (1963)
- Shelbourn, J.E., J.R. Brett and S. Shirahata: Effect of temperature and feeding regime on the specific growth rate of sockeye salmon fry (*Onchorhynchus nerka*), with a consideration of size effect. J. Fish. Res. Bd Can. 30, 1191-1194 (1973)
- Spectorova, L.V., T.M. Aronovich, S.I. Doroshev and V.P. Popova: Artificial rearing of the Black Sea turbot larvae (*Scophthalmus maeoticus*). Aquaculture 4, 329-340 (1974)
- Steel, R.G.D. and J.H. Torrie: Principles and procedures of statistics, 487 pp. New York: McGraw-Hill 1960
- Sundnes, G.: Notes on the energy metabolism of the cod (*Gadus callarias* L.) and the coal fish (*Gadus virens* L.) in relation to body size. FiskDir. Skr. (Ser. Havunders.) 11(9), 1-10 (1957)
- Sysoeva, T.K. and A.A. Degtereva: The relation between the feeding of cod larvae and pelagic fry and the distribution and abundance of their principle food organisms. Spec. Publs int. Commn NW Atlant. Fish. 6, 411-416 (1965)
- Tatyankin, Y.V.: The distribution of juvenile cod (*Gadus morhua morhua* (L.)), pollack (*Pol-lachius vivens* (L.)) and haddock (*Melanogram-mus aeglefinus* (L.)) under temperature gradient conditions. J. Ichthyol. 12, 1002-1011 (1972)
- Tilseth, S. and T. Strømme: Changes in buoyancy and activity during starvation of cod larvae (*Gadus morhua* L.) Int. Counc. Explor. Sea Comm. Meet. F:33, 1-11 (1976)
- Wiborg, K.F.: Investigations on cod larvae in the coastal waters of Northern Norway. Fisk-Dir. Skr. (Ser. Havunders.) 9(3), 1-27 (1948)
- Winberg, G.E.: Rates of metabolism and food requirements of fishes. Nauch. Trudy belorussk. gos. Univ. V.I. Lenina (Minsk) 1-253 (1956). [Transl. Fish. Res. Bd Can. No. 194, 202 pp. 1960]
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