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INTENSIVE PRODUCTION OF COD FRY AT AUSTEVOLL. FINAL REPORT

by

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ABSTRACT

The experiences of this final season of the intensive cod fry production experiment are summed up. The brood stock yielded 369 liters of cod eggs. The production experiment in plastic pens had very high survival, but slow growth up to day 28. Between days 28 and 36 the majority of the larvae died due to prolonged insufficient ingestion. The lab experiments with cod larvae fed differently enriched rotifers supported that enrichment time should be several hours. Different enrichment mixtures did not seem to give different growth or survival. Dry feed based on cod roe did not give growth or significant survival.

INTRODUCTION

Research on the propagation of cod has long traditions in Norway (Sars, 1879; Dannevig, 1910; Hjort, 1914; Rollefsen, 1940; Dannevig, 1963; Ellertsen et al., 1980). The present worldwide interest in mariculture has given new growth in this field. Several research projects with strong emphasize on culture aspects (Kvenseth & Øiestad, 1984; Huse et al., 1982b; Molvik et al., 1984; Kjørsvik et al., 1984) have been launched.

The present project started in 1979, and the activities on the project have been reported annually to this Council (Jensen et al., 1979; Huse & Jensen, 1980; 1981; Huse, 1981; Huse et al., 1982a; 1982b; 1983). The 1984 season was the last of the project period. However, the different components and systems developed under this project will be utilized in other projects both with cod and other species. The material from the 1984 season will also be used for a Cand. scient. thesis in fishery biology.

MATERIALS AND METHODS

Spawning

The spawning pen and egg collecting system was described by Huse & Jensen (1983). 23 female and 38 male cod were transferred to the spawning pen on 13th of February. A further 33 females and 29 males were supplemented on 23th of February. Weights and lengths were measured before and after the spawning season, and each individual fish was tagged.

Temperature, salinity, oxygen, egg amount, and mean egg diameter was measured daily.

To prevent growth of the parasitic ciliate Tricodina which has caused significant mortality earlier years, the spawning pen was treated with formalin at a concentration of 1 to 4000 twice during the spawning season.

Incubation

The eggs were hatched in the same open circulation polyethylene cylinders as used earlier years (Jensen et al., 1979; Huse & Jensen, 1981).

Collection and production of food organisms

The plankton collection system was described by Jensen et al. (1979), and Huse et al. (1983). The general principle is to filtrate large amounts of sea water through double net cones to get hold of the intermediate plankton size fraction. This year 90 micron and 250 micron mesh sizes were used for the outer and inner net cones respectively. At day 20 of the experiment the mesh sizes of the outer cone was changed to 120 micron. At day 43 the inner cone was changed to 500 micron. The day number refers to the age of the larvae in days from mean hatching. As an extra precaution to avoid large zooplankters in the pens the plankton was filtered through a 200 micron net before being led into the concentration chamber up to day 36.

Rotifers of the species Brachionus plicatilis were produced in 5 tanks at a temperature of 24 C and salinity of 32 o/oo. Total production volume was 4000 litres. The rotifers were fed mainly dry feed according to the method described by Gatesoupe & Luquet (1981). An automatic feeder was developed to distribute feed to the rearing tanks. With this automat it was possible to control the amount and frequency of the feeding. The dry feed was mixed with water with an electric mixer in the distribution process. Cultured Nannochloris atomus was used as a feed supplement two or three times a week. The daily production with this system was 50 million rotifers with a daily

harvest of 1/4 of the culture volume and an average density of 50 B. plicatilis per ml.

Before the rotifers were fed to the cod larvae, they were nutritional enriched (Gatesoupe & Luquet, 1981) with a dry feed (table 1). In the pen experiment 400 litres rotifers were fed to the cod larvae twice a day. Once in the morning (8.00 a.m) and once at 4 p.m. The amount fed in the morning was harvested late in the evening the day before, and fed the enrichment mix no. 1 (table 1). The rotifers fed to the larvae at 4 p.m were harvested at 8.00 o´clock the same morning and enriched in the same way.

In the laboratory experiment the rotifers were enriched for at least 4 hours on different enrichment mixes (table 1) before they were given to the cod larvae.

Pen experiment

The pen experiment system consisted of eight 10m3 polyethylene pens as described by Huse et al.(1983). The pens were drained both through a bottom hose and a depth adjustable outlet. To reduce illumination the pens were covered with a net. The effect was a 70 % reduction. Filtered (15 micron) sea water was led into the pens at a rate of about 7 l/min. To prevent the larvae from escaping through the bottom hose 20 l of saturated NaCl solution was added through a hose to the bottom of each pen. Two times every week the bottom water of the pens was drained, and the salt plug renewed.

Plankton from the collection system was pumped automatically into the pens from the concentration chamber. The pump was operating for 15 minutes every second hour during daytime, and every third hour during the night. This feeding regime was maintained for the whole experimental period. Rotifers were supplied to the pens through the same distribution system as the plankton. Up to day 23 rotifers were supplied twice daily and then

once daily until day 34 when rotifer feeding was stopped.

The larvae were transferred from the hatchery to the pens 16th of March three days after 50% hatching. Sampling was carried out with a device described by Huse et al.(1983). The principle of this device was to filtrate one per mille of the pen volume by enclosing a vertical water column from the bottom to the surface of the pen with a plankton gauze hose. The first sampling took place the day after transfer (day 4). Further samples were taken three times each week during the whole experiment. Each sample consisted of 3 subsamples in each pen. The samples were investigated to establish numbers and growth criteria of the larvae, and numbers and cathegories of plankters.

From day 56 to day 70 the fry populations in the pens were fished out with a net , counted and preserved on formalin.

Laboratory experiments

In the laboratory experiments 200 litres conical tanks were used. The experimental tanks were supplied with filtered (5 micron) and UV-treated sea water from 55 meter depth. The water circulation was set to exchange the water in the tank twice in 24 hours. A centre tube covered with plankton gauze (200 micron) was used to prevent food organismes from escaping. The relative large mesh size was choosen to avoid clogging. The centre tube was cleaned once a day. Temperture and salinity was measured every day.

Three lab. experiments were set up. In all experiment four days old cod larvae were transfered from the hatchery to the experimental tanks . The initial larval density varied in the three experiments. Rotifers were fed to the larvae at noon, 2 p.m and 4 p.m in all three experiments. In the 3.lab. experiment, however, two tanks with cod larvae were fed rotifers enriched for only 1/ hour and then cooled with cold sea water. These rotifers were given to the cod larvae at 8.30 a.m, 10.00 a.m, noon,

2.00 p.m and 4.00 p.m. Dry feed was given directly to the cod larvae at 8.30 a.m, noon and 4.00 p.m. Table 1 shows the different enrichment mixes and the dry feed given directly to the cod larvae. Collected zooplankton were given to the larvae from day 18 in the 1. lab. experiment and from day 14 in the 2. and 3. lab. experiments.

Triplicate tube samples in each tank were taken three times each week. The samples were investigated to establish numbers and growth criteria of the larvae.

RESULTS

Spawning

The salinity was about 33 o/oo (+/- 1) and oxygen content never lower than 80 % of full saturation. Temperature in the spawning pen is shown in figure 1.

The amount of eggs collected and the mean diameter of the eggs during the season is shown in figure 2 and figure 3 respectively. Total amount of eggs collected was 369 litres.

The mean weight of the spawning female cod was 8983 gram before spawning and 6755 gram after spawning.

Pen experiment

The salinity at the pen surface varied around 32 %. and the oxygen content was never below 95 % of full saturation. Temperatures are shown in figure 4. The survival and growth of the larvae is shown in figures 5 and 6 respectively. Mean numbers of plankters are shown in figure 7.

Laboratory experiments

Figure 8 gives the temperature during the three experiments. Salinities were stable at 33 o/oo (+/- 1). The development in dry weights of larvae in the lab. experiments are shown in figures 9 -11. Each point represents the mean of 30 larvae weighed individually. All experiments included one starving group (no.8), one group fed dry meal made of cod roe (no.3), and one or several groups fed enriched rotifers (table 1).

The starvation group died 13 to 16 days after hatching. Larvae given cod roe lived longer than starvation group, but did not gain weight. All groups fed enriched rotifers gained weight after day 10. Larvae fed rotifers enriched with fishmeal (no.5) in the 3.lab. experiment gave the best growth (fig.11).

Tables 2 - 4 show the number of larvae per liter water during the three experiments. The number per liter in the starvation groups was stable until the day before the groups died out in all three experiments. After the starvation groups were dead the groups fed cod roe had a high mortality rate. The double groups in experiment two had the same mortality rate.

All groups fed rotifers survived throughout the experiment exept one group (no.1) in experiment three which was killed by an accidental input of adult copepods.

DISCUSSION

Spawning

According to the figures given by Oosthuitzen & Daan (1974) the brood stock females should be able to yield approximately 400 litres of eggs. The actual collected amount was 369 litres. This is an acceptable result considering that 3 females died during the spawning season.

The correlaton between temperature and spawning was not tested, but appear to be rather weak.

Egg diameters declined throughout the season. This is in good accordance with other authors (Dannevig, 1921; Sivertsen, 1935; Huse & Jensen, 1981).

Pen experiment

Technically the pen system functioned well. The salinity in the pens was kept at a level close to natural conditions for newly spawned cod larvae. This prevented the larvae from sinking, which has caused problems earlier years. Temperature (figure 4) and oxygen level was also acceptable. The reduction of the light level caused by the net over the pens, may have been harmful. A great part of the larvae were often observed in the surface layer, while significantly fewer occupied the deeper part of the pens. This might have caused too high densities of larvae at the surface with harmful interactions as a result.

The contribution of rotifers to the pens was of major importance in the beginning of the experiment, but became less important later on as the nauplii concentration in the sea and thus in the pens increased.

The growth development the first days seemed to be quite normal, with a slight decrease in dry weight until day 10 (figure 6). Afterwards the increase in dry weight was very low, compared with other experiments (Kvenseth & Øiestad, 1984). This was most likely a result of to low food concentration caused by unequal distribution of the larvae in the water column, while the plankters where more equally distributed. Thus the plankters surronding the larvae were rapidly grazed down, creating starvation conditions around the larvae.

The average concentration of prey (figure 7) was much higher than what is normal in the sea and in successful extensive production experiments (Kvenseth & Øiestad, 1984). However, the average density is of litle interest as long as the larvae were unevenly distributed. A further investigation of a series of point samples from the pens will hopefully reveal more information.

So far it seems that much of the problems in producing cod fry intensively are connected to the distribution of the larvae.

The larvae in this year's pen experiment showed a very high survival up to day 27 (figure 5), and even on day 31 the total number in the 8 pens was more than 250 000. But the further development was very unfavourable ending up with a total production of 4648 fry after 70 days. A full investigation of the stomach content of the larvae in the critical periode is not yet carried out. The preliminary investigations indicate, however, that the bulk of the larvae died due to prolonged insufficient food consumption.

Laboratory experiments

A typical development in dry weight for cod larvae in lab. experiments is a decrease during the first ten days and then increase, death or stabilization (Huse et al., 1982b). This is probably due to the fact that cod is an extremely difficult laboratory specie in the larval stage, with nutritional demands which are not easy to met. However, the above mentioned development was not pronounced in this year's lab. experiments with rotifers (tables 2,3 and 4; figures 9, 10 and 11). This fact was probably due to a better nutritive value of the rotifers as a result of prolonged enrichment time as proposed by Watanabe et al. (1983).

The different enrichment mixtures did not give significantly different growth results. The mean growth in experiment 1 (figure 9) showed a marked decrease from day 13 to day 15. This decrease could hardly be caused by a sampling error since three subsamples were taken at each sampling, and the water in the tank was thoroughly mixed before each sampling. The decrease might have connection with the coinciding fall in temperature (figure 8). Another explanation might be that the largest larvae died out at this point due to abnormal development which might frequently occur in cod larvae (Peter Munk, pers.comm.). This theory might find some support in the survival numbers of group 1 in table 2, which show a decrease from 48.7 to 24.0 larvae per liter from day 13 to 15 in experiment 1. Group 2 shows the same weight development as group 1, but the survival results obviously are erroneous at this point. A further investigation of the material will hopefully be enlightening.

Compared to growth in the pen experiment the lab. larvae grew faster. This was especially the case for experiment 3 (figure 11). It should be noted, however, that the temperature was substantially higher at this time than at the corresponding periode in the pens (figures 4 and 8).

Survival was generally very low (around 1% to metamorphosis, tables 2,3 and 4), which is to be expected in lab.experiments with cod larvae. The different enrichment mixes did not give significant differences in survival.

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Table 1. Group numbers of rotifer enrichment mixtures (no.1,2,4,5,6) and dry feed (no.3) used in experiments. (Values is given in %).

	Group numbers						
	1	2	3	4	5	6	7
Fishmeal	55	-	-	-	80	55	55
Peptonal	25	80	-	-	-	-	-
Cod roe	-		100	90	-	-	-
Cod roe/Spirulina	-	-	-	-	-	25	-
Dried zooplankton	-	-	-	-	-	-	25
Cod liver oil	10	10	-	-	10	10	10
*Premix	10	10	-	10	10	10	10

*Content of premix

**Vit.premix	4.0
Choline chloride	3.0
DL-methionine	1.5
CaHP04	0.8
FeS04 : 7H20	0.2
Carophyll red	0.5

**Vit.premix is discribed by Gatesoupe & Luquet (1981).

Table 2. Lab.experiment I. Age, temperature, mean dry weights and numbers/litre. Group numbers refer to table I. Group number 8.- Starving.

day nr	temp °C	1 weight µg	1 larvae/ litre	2 weight µg	2 larvae/ litre	3 weight µg	3 larvae/ litre	8 weight µg	8 larvae/ litre
1		61.8		61.8		61.8		61.8	
4	7.5		130.0		99.0		18.0		48.0
6	7.1		55.0	89.9	38.0		23.7		41.3
8	7.0		41.3		35.3		28.3		38.3
11	7.4		54.3		22.7		37.7		40.3
13	6.0	113.0	48.7	104.4	10.3	43.1	29.3	45.9	36.3
16	6.6	72.7	24.0	75.4	24.7	39.6	13.0		18.3
18	5.2	93.3	26.3	74.1	7.3		6.8		
20	6.3		21.6		8.0		3.3		
21	6.4		7.5		6.8		1.0		
23	6.4		12.6		6.3		1.1		
27	6.8	104.4	8.0	104.4	6.2	91.2	0.8		
29	6.5		11.0		3.4		0.1		
32	5.9		7.0		4.2				
39	6.4	170.9	2.0	182.6	1.2				
57	8.2		1.3		0.2				

Table 3. Lab.experiment 2. Age, temperature, mean dry weights and numbers/litre. Group numbers refer to table 1. Group number 8 - Starving. 3(A) and 3(B) - replicate.

day nr	temp °C	1 weight µg	1 larvae/ litre	3(A) weight µg	3(A) larvae/ litre	3(B) weight µg	3(B) larvae/ litre	4 weight µg	4 larvae/ litre	8 weight µg	8 larvae/ litre
1		46.3		46.3		46.3		46.3		46.3	
5	6.4	48.3	12.3	58.4	9.3	47.3	5.0	49.4	25.3	50.1	20.7
7	6.1		9.0		11.0		7.3		19.7		26.7
9	7.2		13.3		8.0		7.3		5.0		26.7
12	7.4		7.7		9.7		11.7		13.3		22.0
14	7.1		6.0		10.3		7.7		11.0		21.7
16	7.9	80.6	3.8	44.2	5.8	41.9	5.7	85.8	9.7	32.5	18.0
19	7.6		2.9		1.8		1.8		4.8		
21	8.4	123.4	3.8	50.5	1.2	51.8	3.6	101.3	6.3		
23	8.2		1.4		1.8		1.0		7.4		
26	7.0	132.9	0.3	49.8	0.1	48.9	0.1	134.4	1.3		

Table 4. Lab.experiment 3. Age, temperature, mean dry weights and numbers/litre. Group numbers refer to table 1. Group number 8 - Starving. 1(C) and 5(C) - cold enrich.

day nr	temp °C	1 weight µg	1 larvae/ litre	1(C) weight µg	1(C) larvae/ litre	3 weight µg	3 larvae/ litre
1		55.1		55.1		55.1	
5	7.4	46.2	21.7	39.5	19.7	40.8	31.00
7	7.2		20.7		29.0		18.00
10	7.6	50.6	25.0	48.4	20.7	34.7	29.70
12	9.3		14.3		13.3		21.30
14	8.3	72.5	19.3	57.0	14.0	34.8	4.70
17	9.6		9.7		14.0		
19	9.1	88.7	9.7	75.0	9.7	42.4	0.03
21	10.3	111.0	5.2	86.9	12.0		
24	10.0		7.6		6.7		
26	10.9	206.6	4.4	148.3	2.8		
28	10.0				1.9		
31	10.5		0.1		3.1		
33	10.2				2.4		
35	9.7			473.9	0.4		

day nr	temp °C	5 weight µg	5 larvae/ litre	5(C) weight µg	5(C) larvae/ litre	6 weight µg	6 larvae/ litre	7 weight µg	7 larvae/ litre	8 weight µg	8 larvae/ litre
1		55.1		55.1		55.1		55.1		55.1	
5	7.4	44.2	24.0	40.7	22.3	45.5	19.7	50.5	31.7	41.9	100.6
7	7.2		21.7		25.7		7.5		15.7		144.2
10	7.6	63.4	14.7	52.2	23.0	52.1	11.7	57.0	15.7	27.9	155.1
12	9.3		9.7		22.0		11.0		14.3		153.9
14	8.3	72.6	10.7	70.5	14.7	79.7	8.6	76.5	11.0	29.6	17.0
17	9.6		9.3		9.7		7.7		10.0		
19	9.1	89.7	12.0	74.9	6.0	96.1	6.3	89.0	9.3		
21	10.3	106.3	4.0	95.7	5.8	108.0	5.0	96.0	7.3		
24	10.0		1.9		3.3		2.6		4.7		
26	10.9	255.1	1.4	182.3	2.0	230.0	2.5	226.5	2.3		
28	10.0		1.2		1.3		0.7		1.7		
31	10.5		1.1		2.1		2.0		1.9		
33	10.2		0.6		1.1		1.1		1.3		
35	9.7	804.0	0.3	375.5	0.2	767.7	0.6	773.9	0.9		

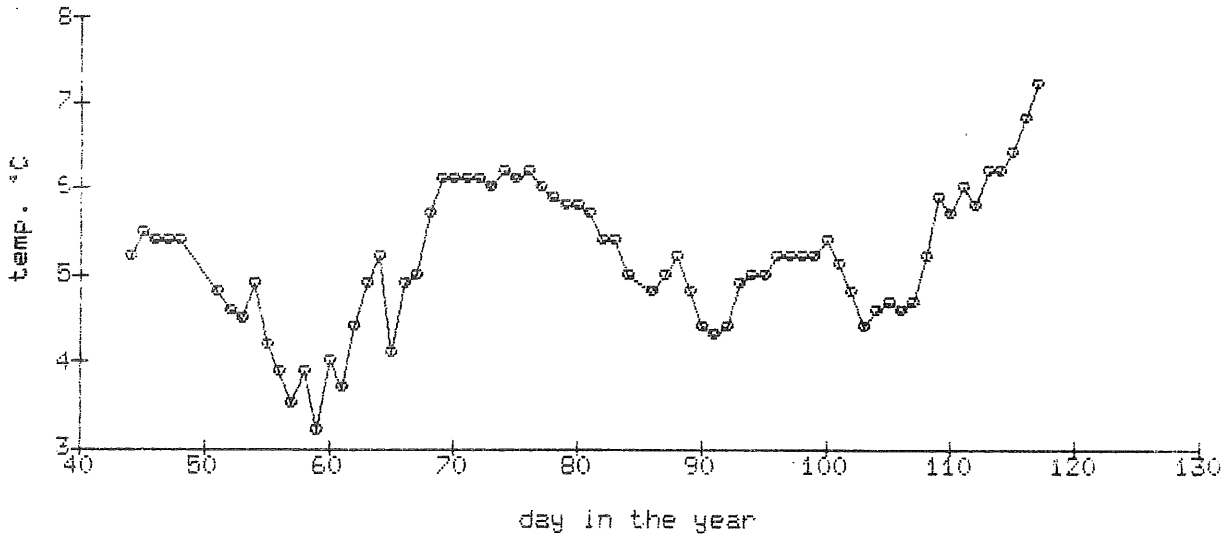


Figure 1. Temperatures during the spawning season. Days from first of January.

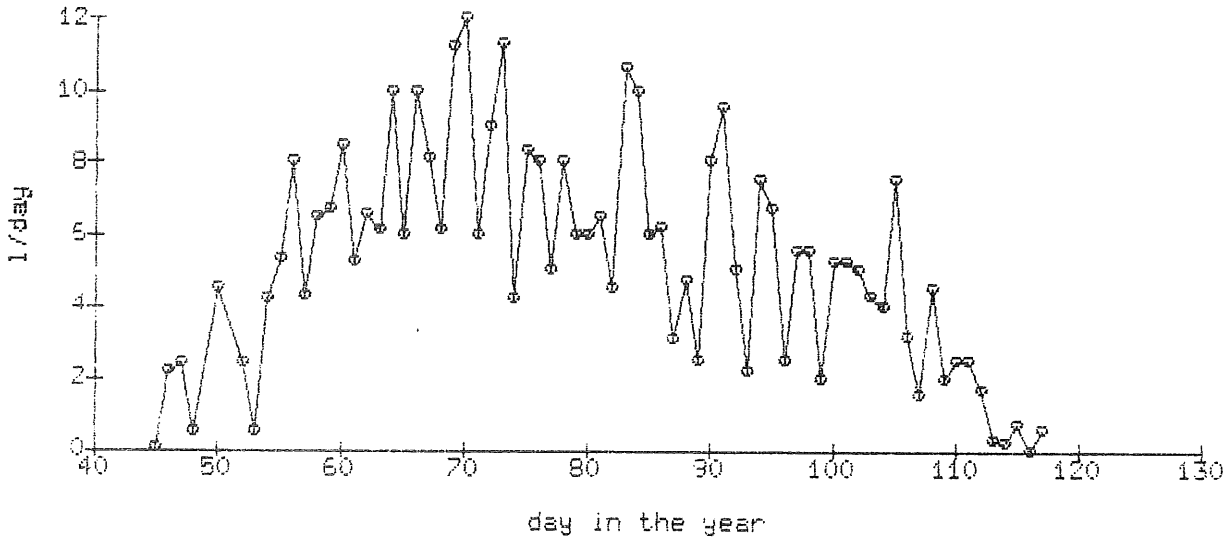


Figure 2. Egg amount collected from spawning pen.

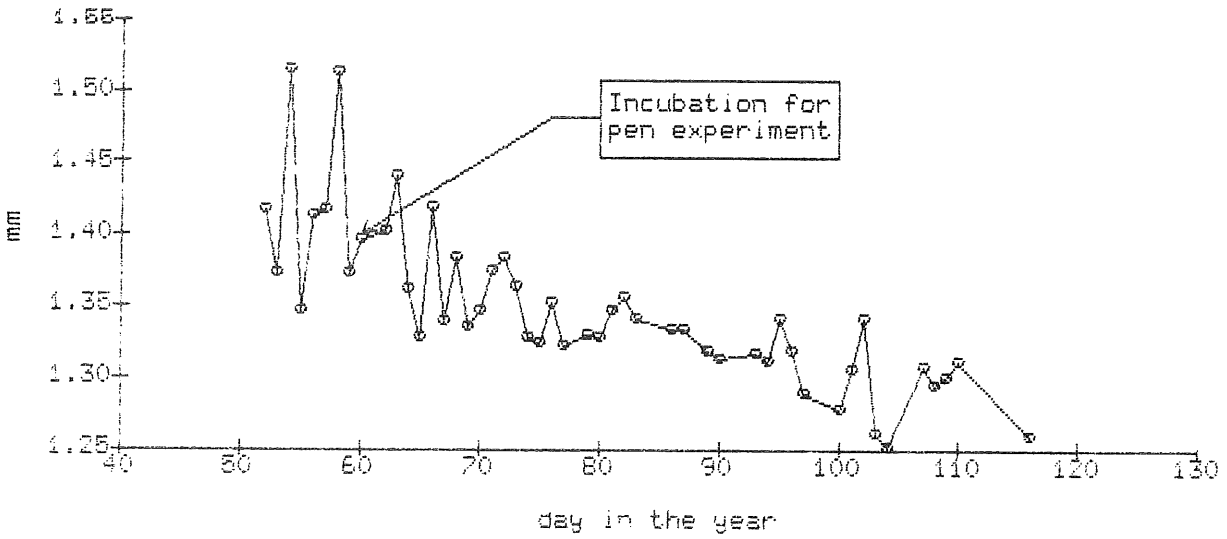


Figure 3. Egg diameters (mean of 20) during the spawning season.

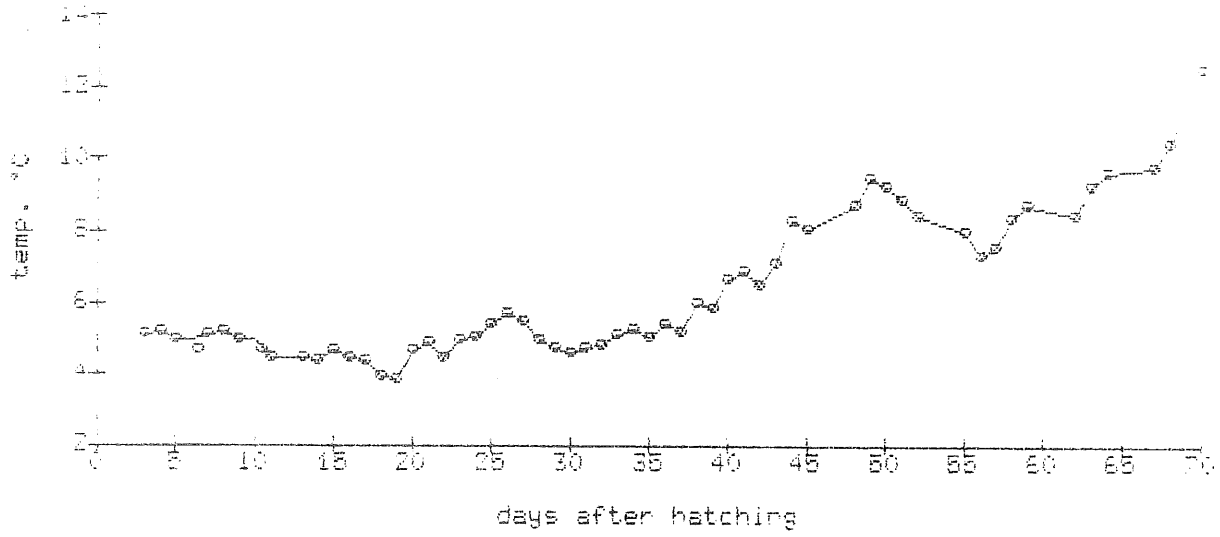


Figure 4. Temperatures (^{o}C) in the experimental pens.

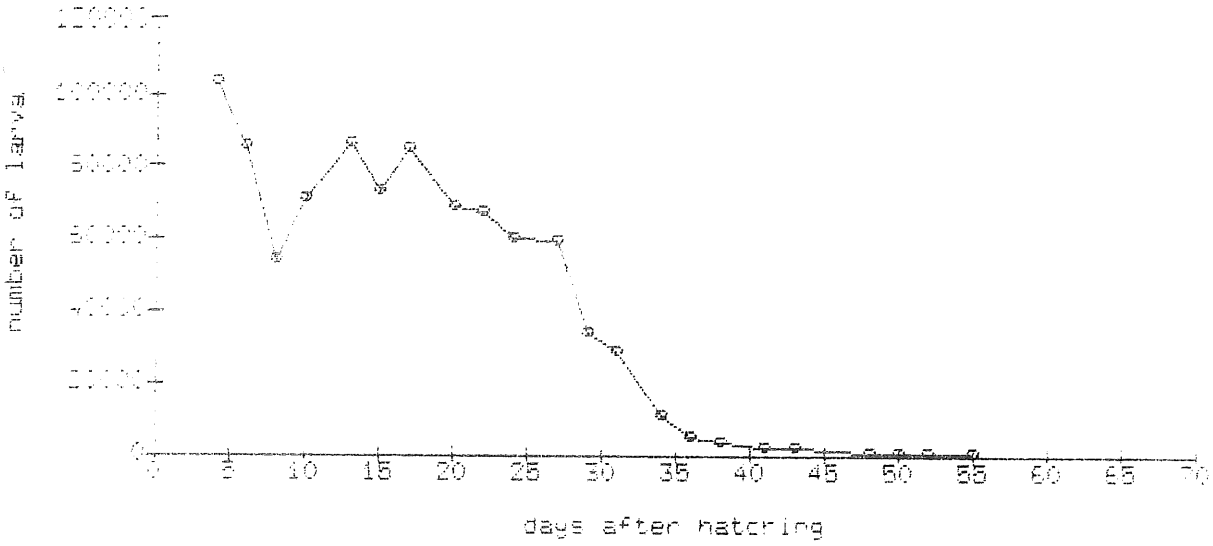


Figure 5. Mean survival per pen.

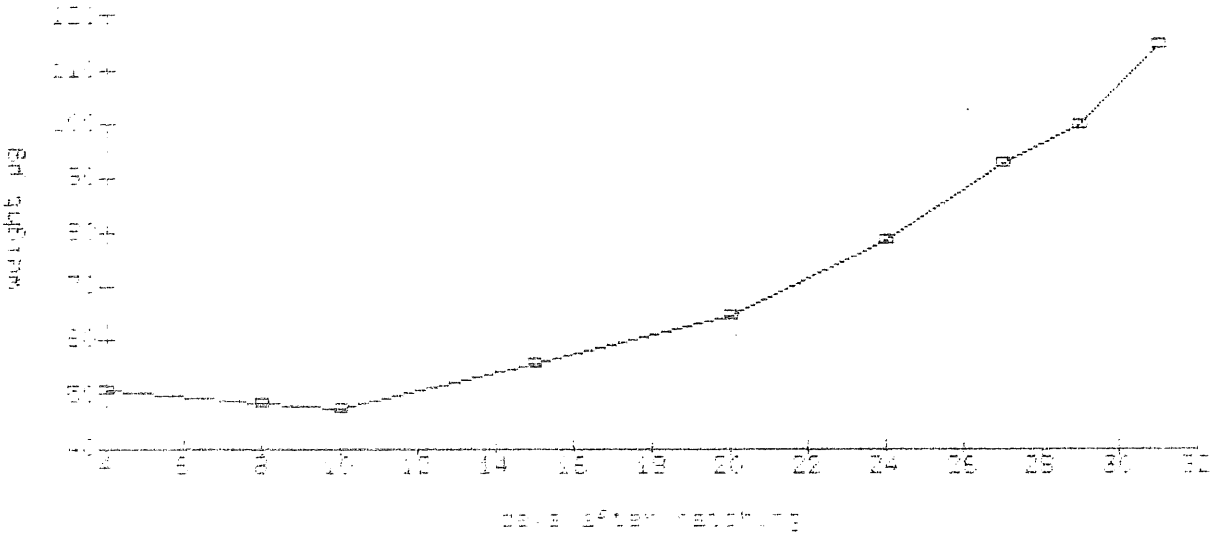


Figure 6. Mean dry weights of 10x8 larvae per curve point

Table 5. Number of fry in each pen at the end of the experiment

Pen number	2 Finished at date	3 Number of fry
1	15-May	434
2	15-May	206
3	16-May	1241
4	18-May	825
5	8-May	481
6	22-May	195
7	21-May	195
8	21-May	1059

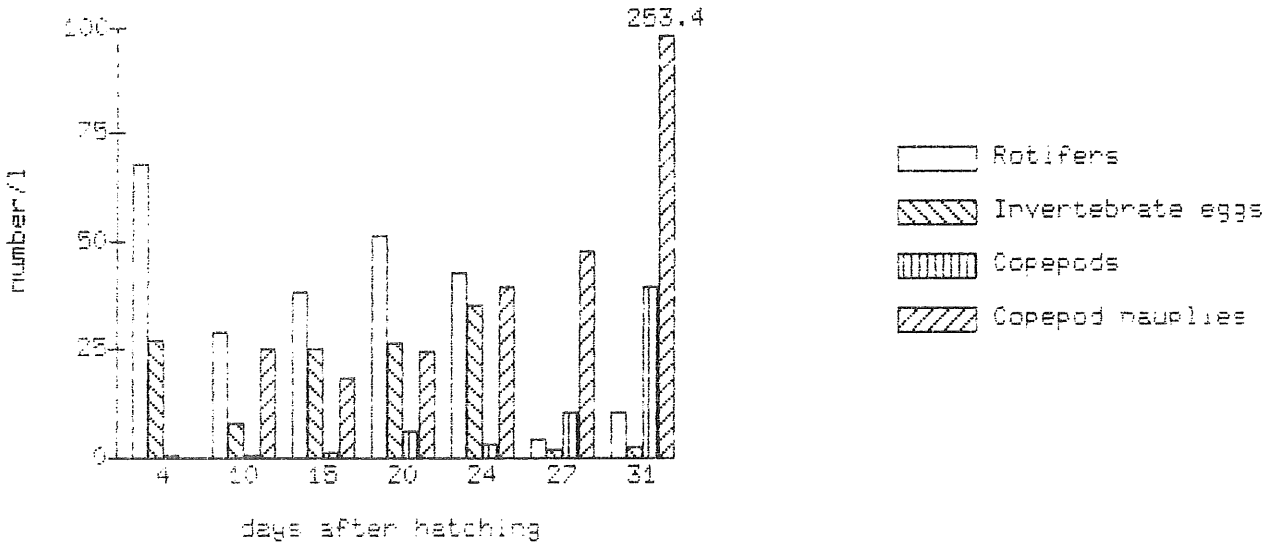
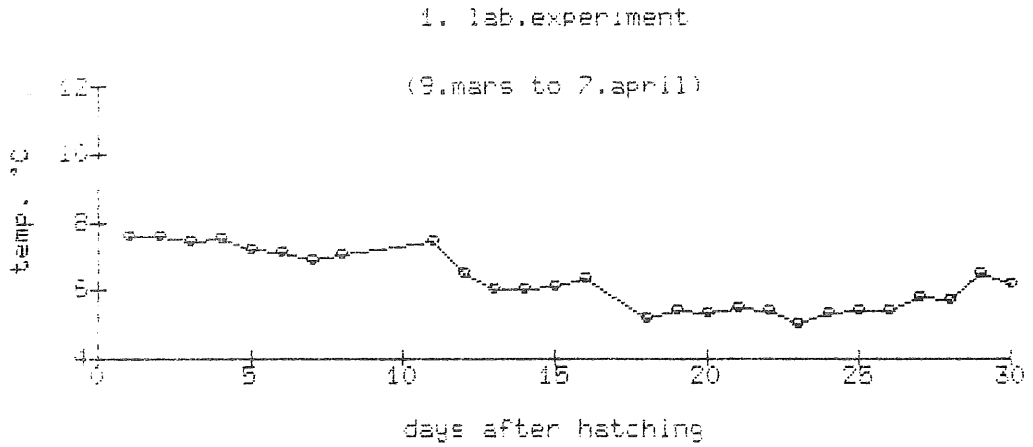
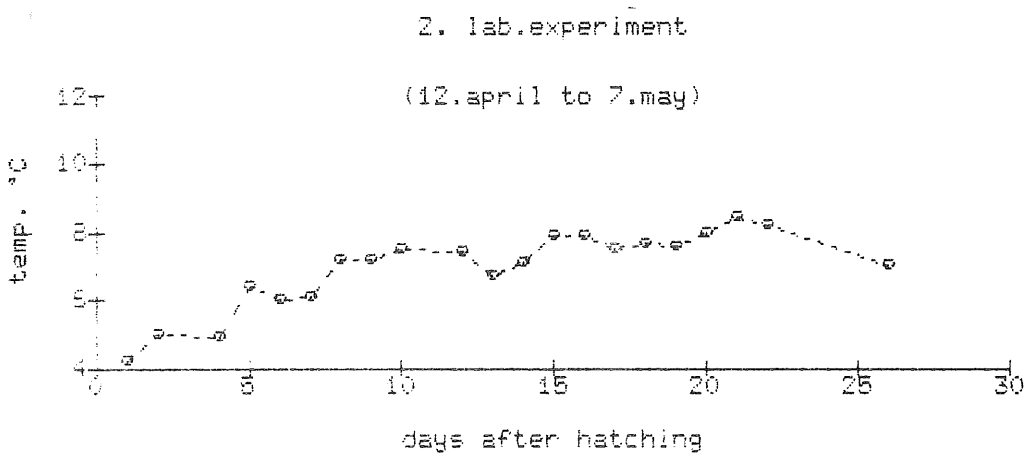


Figure 7. Densities of some important prey groups in the pens. Each bar represents the mean for three pens.





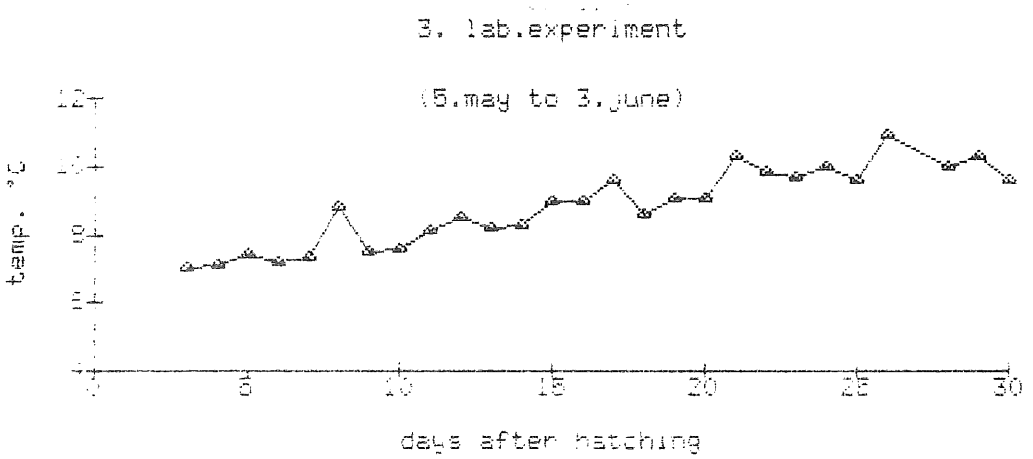


Fig. 8. Temperature(°C) during I., 2. and 3. lab.experiments.

(Fig. 7: See table 5)

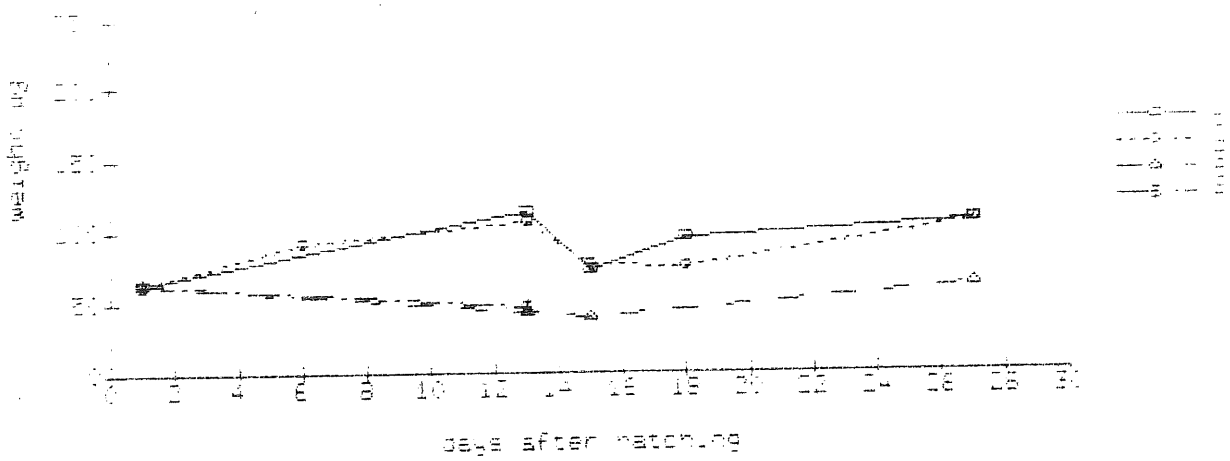


Fig. 9. Age and mean dry weights of 30 larvae in 1.lab.experiment. Group numbers refer to table 1. Group number 8. Starving

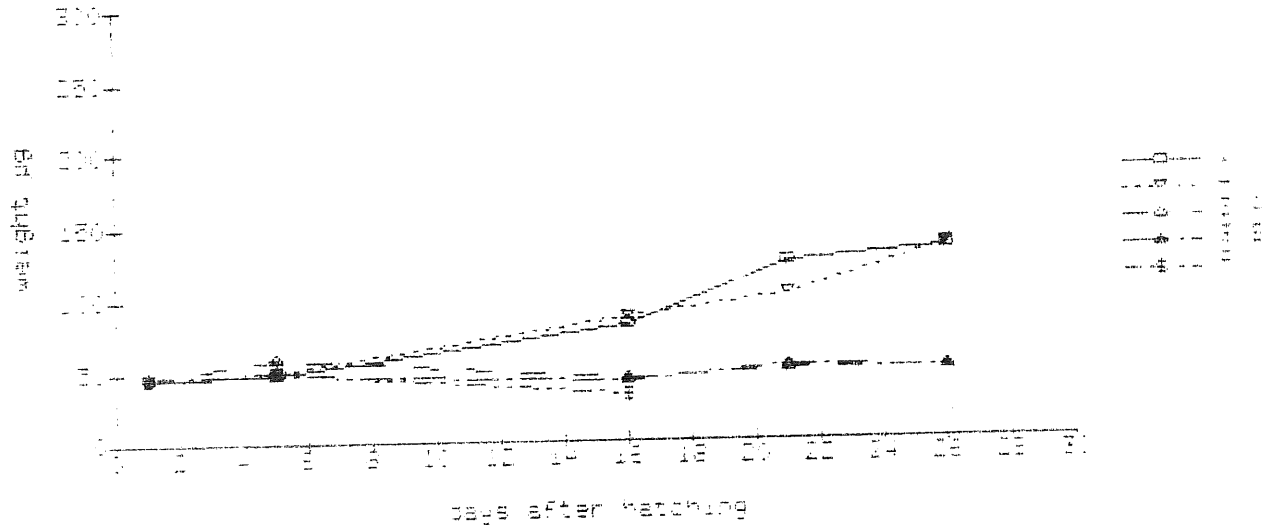


Fig. 10. Age and mean dry weights of 30 larvae in 2.lab.experiment. Group numbers refer to table 1. Group number 8. Starving.

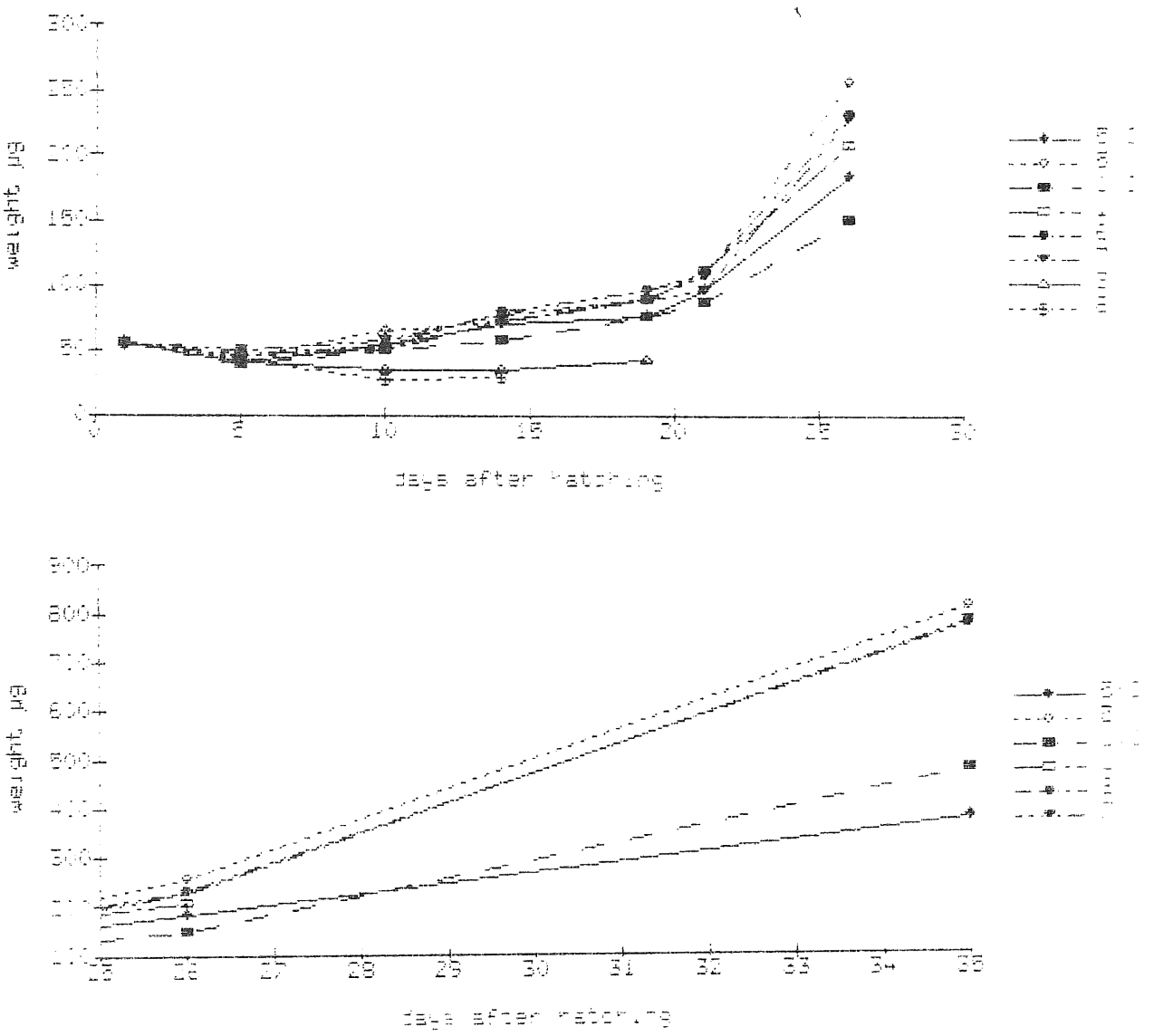


Fig. 11. Age and mean dry weights of 30 larvae in 3.lab.experiment. Group numbers refer to table 1. Group number 8. Starving.