Fol. 41 F

International Council for the Exploration of the Sea

C.M. 1990/F:47
Mariculture Committee

WEANING TRIALS WITH COD FRY ON ARTIFICIAL DIETS

by

Håkon Otterå[1] and Øyvind Lie[2]

[1]Institute of Marine Research, Division of Aquaculture, P.O. Box 1870, N-5024 Nordnes, Bergen, Norway

[2]Institute of Nutrition, Directorate of Fisheries, P.O. Box 1900, N-5024 Nordnes, Bergen, Norway

ABSTRACT

Three experiments with different size groups of cod fry, 13, 49 and 465 mg wet-weight were offered 6 different artificial diets. The experiments lasted for 28 days. Growth, and for the medium size-group chemical composition and gross energy-content of the fish were measured. Mortality was recorded daily, and the fish were counted after 14 days and at end of the experiments to correct for cannibalism.

Growth were similar on all diets, probably because of prominent cannibalism. Significant differences in biomass and survival were found. Survival ranged from 0 to 39 % for the smallest group and from 72 to 90 % for the largest group. Moist feed gave the best survival. About 50 % of the mortality was due to cannibalism.

INTRODUCTION

During the last years there has been a growing interest for intensive farming, as well as sea-ranching of Atlantic cod (Gadus morhua L.) in Norway. The production of cod fry has been one of the major problems in developing cod farming. Production so far has mainly been carried out in extensive systems (Øiestad et al., 1985), relaying on natural zooplankton as the only food source in the larval phase. These systems have shown to have a high potential for startfeeding of cod larvae, with relatively high survival beyond metamorphosis (Øiestad, 1985). The food demand of the rapidly growing cod fry is difficult to cover by zooplankton supplies alone, resulting in high mortality after metamorphosis due to starvation and subsequent cannibalism (Blom et al., 1990).

It thus seems to be essential for increasing the production capacity to start weaning of cod fry to formulated diets as early as possible. At present, this is done at an age of 2 - 3 months (Blom et. al, 1990; Bromley and Sykes, 1985; Folkvord, 1989; Øiestad et. al, 1985), but relatively scarce information is available on this topic.

The main purpose of this experiment was to investigate at what fish size weaning could bee done. Secondly too compare different diets available too get more basic knowledge for future works on weaning of cod fry.

MATERIALS AND METHODS

Three experiments (Exp.I, Exp.II and Exp.III) was carried out with different size-groups of cod fry during the summer 1989.

Six diets, with three replicates on each were tested in each experiment. The experiments were carried out in the hatchery connected to the production pond Parisvatnet (Blom et al., 1990), located 60 km outside Bergen, Norway. Eighteen circular tanks, made of black fiberinforced polyester and with a volume of 180 liters were used in each experiment (Figure 1). The seawater supply, from a depth of 30 m was filtrated (20 μm) and UV-lighted. Temperature and salinity was recorded daily.

The cod fry used in the experiments were gently collected from the production pond, where they preyed upon natural zooplankton. They were kept in a tank one day before start of each experiment to eliminate wounded individuals. The largest individuals were also removed. A sample of the remaining fish were measured for standard length, wet-weight and preserved on formalin, 50 individuals was measured in Exp.I and 101 in Exp.II and III (Table 1). From the rest of the fish small groups were distributed into the 18 experimental tanks in an arbitrary way to ensure a random grouping. Dead fish the following day were attributed to handling mortality and replaced with new fish.

TABLE 1: Stocking density, wet-weight in mg (±SD) and standard-length in mm (±SD) at start of the three experiments.

Exp.#	Date	Number	Wet-weight	Standard-lenght
I	10. May	100	12.8 (4.35)	12.2 (1.31)
II	19. May	100	49.2 (16.26)	18.6 (1.95)
III	9. June	50	464.5 (141.16)	37.1 (3.32)

Each experiment lasted for 28 days. Daily mortality was recorded and the fish were counted after about 14 days of the experiment. At the end all the fish were counted and individually weighted (wet-weight). From experiment II some fish were also freezed for chemical analysis and bomb-calorimetry. The difference in actual numbers of fish at day 14/day 28 and expected numbers due to the mortality record was attributed to cannibalism.

Diets and whole fish from all tanks were analyzed in pooled samples for water, protein, fat and ash. Protein (N * 6.25) was determined by the micro-Kjeldahl technique (Crooke and Simpson, 1971) and fat was extracted with ethyl acetate. Gross energy content in feed and pooled samples of whole fish were measured with a Gallenkamp Autobomb according to Ulgenes (1982). Measurements were not corrected for acid production.

The following six diets were used in the experiments:

wet feed (WF)
moist feed (MF)
dry feed 1 (D1)
dry feed 2 (D2)
dry feed 3 (D3)
dry feed 1 supplied with live plankton (D1P)

The wet feed was made of squid mantle, homogenized and supplied with sardine oil, vitamins and minerals as described by Hemre et al. (1989). It had a greasy consistence. The moist feed was made of commercially available salmon feed mixed with 16 % krill-meal and 1 % of vitamin c. It was graded through a 1 mm Endecott sieve for Exp. I and II, and a 2 mm sieve for Exp. III. Dry feeds 1 and 3 was commercially available diets for marine fish fry. At experiments I and II 0.6 mm granulates were used, and for experiment III 1.0 mm granulates were used. D2 was based on dried cod eggs. Table 2 gives the chemical composition of the diets.

All feeds except WF were fed in excess with automatic disc feeders, every 1 minute. WF was fed ad lib. 2 - 4 times a day. Live plankton for D1P was collected from a filtrating system for plankton and supplied 1 - 2 times per day. The amount of plankton supplied was not recorded, but was of minor quantities compared to the dry-feed. Surplus feed was removed from the bottom of the tanks once a day.

TABLE 2: Chemical composition (% of wet-weight) and gross energy (kJ/g dry-weight) of the diets used in the experiments.

	WF	MF	D1	D2	D3
Dry matter	25	67	92	94	91
Protein	18	33	39	73	51
Fat	2	10	12	4	12
Gross energy	-	21.9	20.8	24.7	21.5

Differences in survival and biomass between groups feed different diets at the end of each experiment were tested with model 1 ANOVA, and subsequent analyzed with

Scheffe's procedure (Sokal and Rohlf, 1981). Differences in chemical composition and energy content among the fish feed different diets were tested in the same way. Homogeneous variance and normal distribution were tested with Cochran's test and Wilk-Shapiro or Kolmogorov-Smirnov tests respectively (Sokal and Rohlf, 1981; Zar, 1974).

RESULTS

Temperature during the experiments varied from about 7 to 13 °C (Fig. 2) and salinity from 30.9 to 33.6 p.p.t.

Experiment I

The results from Exp.I are presented in Table 3. All the fish fed wet feed died during the experiment. 82 % of the mortality could be accounted for by dead fish collected, the remaining 18 % was due to cannibalism. The survival of the remaining 5 groups were significantly different ($p = 0.0022$). MF showed highest mean survival with 39 % which was significantly higher than D1, D3 ($p < 0.05$) and D2 ($p < 0.01$). Survival (Figure 3a) was lowest in D2 with a mean of 8 %. Highest mortality occurred during the first half of the experiment. Cannibalism contributed to about 50 % of the total mortality in MF, D1 and D1P and about 25 % in D2 and D3 which had the highest mortality.

Biomass per tank at end of the experiment (Figure 3b) was also significant different among the diets ($p = 0.0012$), and MF was significantly better than D1, D3 ($p < 0.05$) and D2 ($p < 0.01$).

TABLE 3: Survival (%), total mortality rates, Z[1], mortality rates due to cannibalism, C[2], percent cannibalism of total mortality, mean weight (mg wet-weight) and total biomass (mg wet-weight) at the end of Experiment I (replicate a, b and c).

	DIET	**WF**	**MF**	**D1**	**D2**	**D3**	**D1P**
	Survival a	0	42	10	10	12	32
	Survival b	0	36	26	8	15	33
%	Survival c	0	38	15	5	9	11
	Mean	**0**	**39**	**17**	**8**	**12**	**25**
	SD		3.1	8.2	2.5	3.0	12.4
R	Z First		4.1	8.9	14.7	10.4	6.2
A	C half		1.5	4.1	3.2	2.6	2.7
T							
E	Z Second		2.5	2.3	0.0	3.2	3.1
S	C half		2.1	1.9	0.0	2.5	3.1
%	**Cannibalism of total mortality**	**18**	**48**	**48**	**22**	**28**	**49**
	Mean a		66.8	38.8	72.3	75.4	65.7
W	SD		42.4	17.9	27.2	48.7	37.6
E	Mean b		83.5	64.7	107.8	120.3	63.7
I	SD		57.3	35.3	94.1	76.5	33.3
G	Mean c		59.1	68.1	54.8	106.1	166.0
H	SD		34.9	69.5	25.9	100.2	143.7
T							
	Mean		**69.8**	**57.2**	**78.3**	**100.6**	**98.5**
	SD		12.5	16.0	27.0	22.9	58.5
B	Biomass a		2805	388	723	905	2102
I	Biomass b		3005	1682	862	1804	2103
O	Biomass c		2247	1022	274	955	1826
M							
A	**Mean**		**2686**	**1031**	**620**	**1221**	**2010**
S	SD		393	647	307	505	160
S							

[1]Z is calculated as [100 * ($\ln N_2 - \ln N_1$)/dt] for each half of the experiment.

[2]C is calculated as Z multiplied with the proportion of mortality due to cannibalism in that period.

Experiment II
Table 4 details the results of Exp.II.

D3, MF and D1P gave highest survival, 65, 64 and 61 % respectively (Fig. 4a). Fish fed D1 and D2 had a markedly lower survival with 36 and 48 %, and only 9 % at WF. Although differences in survival among fish fed different diets were significant ($p = 0.0097$) the relatively large differences between triplicates resulted in that only WF and D3 were significant different according to Scheffe's procedure ($p < 0.05$).

Cannibalism contributed to a higher proportion of the total mortality than in Exp.I, especially in WF and D1 with more than 80 %, while more than 50 % of the mortality was due to cannibalism in the other diets. Mortality rates was of the same magnitude during the first and second experimental period.

Mean biomass per tank at the end of the experiment (Fig. 4b) also showed significant differences among the feeds ($p = 0.0025$). WF was significantly different from all other diets, except D1 ($p < 0.05$; $p < 0.01$ for D3).

TABLE 4: Survival (%), total mortality rates, Z[1)], mortality rates due to cannibalism, C[2)], percent cannibalism of total mortality, mean weight (mg wet-weight) and total biomass (mg wet-weight) at the end of Experiment II (replicate a, b and c).

	DIET	WF	MF	D1	D2	D3	D1P
	Survival a	4	74	22	62	75	71
	Survival b	15	54	63	52	63	73
%	Survival c	8	3[3]	22	31	56	39
	Mean	**9**	**64**	**36**	**48**	**65**	**61**
	SD	5.9	14.1	23.6	15.8	9.6	19.0
R	Z First	8.3	1.4	3.6	3.2	1.4	1.3
A	C half	7.0	0.8	3.4	1.8	0.9	0.8
T							
E	Z Second	9.0	1.8	3.7	2.0	1.7	2.3
S	C half	6.9	1.5	3.3	1.4	1.3	2.0
%	**Cannibalism of total mortality**	**84**	**72**	**92**	**58**	**69**	**74**
	Mean a	1041.0	453.0	922.7	505.2	516.9	499.0
W	SD	243.7	190.0	574.6	245.8	202.0	234.1
E	Mean b	467.4	620.3	537.9	620.2	538.7	564.2
I	SD	315.1	293.6	291.5	215.4	211.9	256.4
G	Mean c	447.0	526.0[3]	696.7	694.1	599.1	495.2
H	SD	159.9	152.7[3]	549.7	332.5	246.3	260.6
T							
	Mean	**651.8**	**536.7**	**719.1**	**606.5**	**551.6**	**519.5**
	SD	337.2	118.3	193.4	95.2	42.6	38.8
B	Biomass a	4164	33522	20300	31321	38769	35428
I	Biomass b	7011	33496	33889	32251	33938	41190
O	Biomass c	3129	1578[3)]	15327	21517	33547	19311
M							
A	**Mean**	**4768**	**33509**	**23172**	**28363**	**35418**	**31976**
S	SD	2010	18	9608	5947	2909	11341
S							

[1]Z is calculated as [100 * (ln N_2 - ln N_1)/dt] for each half of the experiment.

[2]C is calculated as Z multiplied with the proportion of mortality due to cannibalism in that period.

[3]Excluded from the calculations due to accidental mortality.

Experiment III

The results of Exp.III are given in Table 5. Survival (Fig. 5a) ranged from 72 to 90 %. As with Exp.II, MF and D3 gave highest survival. Although the differences between the diets were significantly ($p = 0.0276$), Scheffe's procedure did not reveal any pair of groups significantly different. Less than 60 % of the mortality was due to cannibalism. Like Exp. II mortality rates seemed to be about the same during the first and second part of the experiment.

Mean biomass per tank (Figure 5b) were quite similar on all diets, although significantly different ($p = 0.0174$) due to the low biomass of fish fed WF, which was significantly lower than on D3 ($p < 0.05$).

TABLE 5: Survival (%), total mortality rates, Z[1)], mortality rates due to cannibalism, C[2)], percent cannibalism of total mortality, mean weight (mg wet-weight) and total biomass (mg wet-weight) at the end of Experiment III (replicate a, b and c).

	DIET		**WF**	**MF**	**D1**	**D2**	**D3**	**D1P**
	Survival a		64	92	8[3]	72	82	90
	Survival b		74	90	78	80	56[3]	74
%	Survival c		78	90	82	76	92	86
	Mean		**72**	**90**	**80**	**76**	**88**	**84**
	SD		7.2	1.2	2.8	4.0	7.0	8.2
RATES	Z	First half	1.3	0.6	0.7	0.6	0.4	0.4
	C		0.4	0.2	0.1	0.2	0.0	0.3
	Z	Second half	1.0	0.2	0.9	1.5	0.5	0.9
	C		0.4	0.0	0.6	0.6	0.4	0.2
%	**Cannibalism of total mortality**		**36**	**20**	**60**	**42**	**50**	**38**
WEIGHT	Mean a		1754.3	1786.1	1373.3[3]	2381.9	2519.0	2067.6
	SD		810.5	652.1	471.1[3]	828.5	1077.2	687.0
	Mean b		2048.2	1881.2	2135.1	2339.0	2428.0[3]	2453.6
	SD		835.8	631.5	746.1	978.7	1096.0[3]	938.6
	Mean c		2028.2	1784.5	2208.8	2334.4	1956.1	2095.6
	SD		770.8	690.1	671.9	976.8	833.5	646.5
	Mean		**1943.6**	**1817.3**	**2172.0**	**2351.8**	**2237.6**	**2205.6**
	SD		164.2	55.4	52.1	26.2	398.0	215.2
BIOMASS	Biomass a		56136	82162	5493[3]	85747	103278	93041
	Biomass b		75782	84655	83270	93561	67985[3]	90785
	Biomass c		79101	80302	90562	88708	89982	90112
	Mean		**70304**	**82373**	**86916**	**89339**	**96630**	**91313**
	SD		12412	2184	5156	3945	9402	1534

[1]Z is calculated as $[100 * (\ln N_2 - \ln N_1)/dt]$ for each half of the experiment.

[2]C is calculated as Z multiplied with the proportion of mortality due to cannibalism in that period.

[3]Excluded from the calculations due to accidental mortality.

Chemical analysis and calorimetry

No significant differences in water-, protein- or fat content among fish fed different diets were found (Table 6). Gross energy content (Table 6) of fish fed different diets was significantly different ($p = 0.0040$), and Scheffe's procedure showed that fish fed D2 had significantly ($p < 0.05$) higher energy-content than fish fed the other diets. Fish fed WF were not analyzed due to insufficient amount of material.

TABLE 6: Chemical composition in % of wet-weight (±SD) and gross energy in kJ/g dry-weight (±SD) of fish from termination of Exp.II. PO denotes pooled values.

GROUP	MF	D1	D2	D3	D1P	PO
Dry matter	17.3 (.14)	18.1 (.36)	18.5 (.38)	18.4 (.68)	17.4 (.56)	18.0 (.64)
Protein	9.9 (.28)	9.6 (.26)	10.1 (.55)	9.6 (.56)	9.6 (.12)	9.8 (.39)
Fat	2.3 (.14)	2.7 (.35)	2.9 (.26)	2.6 (.10)	2.5 (.06)	2.6 (.27)
Gross energy	21.1 (.15)	21.1 (.27)	22.1 (.06)	21.2 (.33)	21.3 (.31)	21.4 (.46)

DISCUSSION

The setup procedure of each experiment with a pooled weighing of fish before distribution into the tanks may bias the results to some extent. Nevertheless we evaluated the risk of weighing such small cod to be of greater magnitude than the additional information we would have obtained. The use of three tanks for each diet should also value out any differences.

Our emphasis in evaluating the experiments is laid on survival and biomass per tank at the end of the experiments. In most cases these gave coinciding results. Growth is an unsuitable parameter in such experiments where cannibalism are so prominent, and thus masks the growth properties of the different diets.

The poor, or lacking survival in groups fed WF was probably a result of its unsuitable texture, as well as the infrequent feeding. Survival on MF was significant better than on the dry feeds. The reason for that may be attributed due to a better texture because of its higher water content, although water content was reduced due to drying on the disc feeder prior to feeding. Stradmeyer et al. (1988) reported salmon parr to prefer soft feed-particles before hard. Bromley and Howell (1983) on the other hand did not find any significant correlation between dietary water content and survival on turbot at about 1 gram size. Dry feed gave in fact better growth than moist feeds, which they assumed was caused by its better stability. The addition of krillmeal may give a better acceptance for MF, as extracts from various crustacea are known as attractants for fish (Lie et al., 1989; Mackie and Mitchell, 1985). The red colour of krillmeal could also have improved the visual characteristics of the feed (Jakobsen et al., 1987; Knights, 1985).

Looked on all experiments together D3 gave better results than D1, but the differences were minor. The much higher protein content in D3 does not seem to be of major importance for growth or survival, nor for the chemical composition of the fish. The latter is not surprising for cod feeding partly on their own conspecies. Survival on D2 was markedly poorer in Exp.I, but the difference became smaller in Exp.II and all diets gave comparable survival and biomass in Exp.III. The poor result for D2 on the smallest fish may be due to its low watercontent, only 6 %. The particles were also very rigid and were partly floating on the water surface and clinging to the walls of the tanks, thus unavailable to the cod. The difference in gross energy in cod fed D2 compared to the other diets was probably because of the higher fat content of that fish (on a dry weight basis). Some of it could also be explained by a rest of energy rich D2 feed in the stomach at the time of analysis. Anyway these results indicate that the high energy-content of the D2 feed are reflected in the chemical composition of the fish.

The addition of small quantities of live zooplankton had a positive effect. Particularly for the two smallest size groups D1P gave better survival and biomass than D1, although not significant. Bromley (1978) and Bromley and Sykes (1985) reported addition of live food to be important for weaning of small turbot larvae (< 15 mm) but not necessary for larger larvae.

Total mortality rates during the first and second experimental period were quite similar in Exp. II and III. In Exp.I mortality, particulary natural mortality, was usually much higher during the first experimental period. This may reveal the poor capacity of cod fry at that size to wean into an artificial diet, resulting in a rapid mortality of the smallest and weakest individuals. The size of the fish used in Exp.I corresponds to about 1 week after metamorphosis, when copepods are the main feed in nature (Wiborg, 1948). At this stage the morphological structures of the gut are not fully developed (Pedersen and Falk-Pettersen, 1990).

Cannibalism was a major part of the mortality in all experiments. The rates were of comparable magnitudes for Exp.I and II, although its relative magnitude compared to total mortality were highest in Exp.II. Folkvord (1989) reported cannibalism to account for 70 % of the mortality of 0.15 g cod but of minor importance for cod at 0.21 g.

The specific growth rate ($100*\{\ln W_2 - \ln W_1\}/dt$) ranged from 5.2 - 7.1 % and 8.4 - 9.6 % per day among the diets in Exp.I. and II respectively. This is well below what Blom et al. (1990) reported for cod fry at the same size reared in a pond (13 - 16 %). Folkvord (1989) also reported that cod fry of 0.15 grew better on zooplankton than on dry feed. For the largest size group (Exp.III) the growth in the tanks (4.9 - 5.8 %) was comparable to the growth in pond-experiments (Øiestad et al., 1985).

In conclusion, weaning of cod at about 0.5 gram should give satisfactory results on commercially available diets. Weaning at a smaller size can also bee achieved but growth and survival has to be improved, which requires a better weaning diet. Effort should be made not only in improving the nutritional status of the diet, but also on improving the physical properties of the feed particles, like texture and sinking rate. Cannibalism and feed quality are obvious nearly connected, but factors like size distribution of the fish and feeding regime should also be considered to reduce the amount of cannibalism.

ACKNOWLEDGEMENT

The authors would like to thank the staff at Institute of Marine Research, Parisvatnet, Geir Blom, Jan P. Pedersen and particulary John Kåre Stordal for help with running the experiments. Thanks to Margrethe Rygg at Institute of Nutrition who did the chemical analysis, and Gerd Eikeland Berge for help with the bomb-calorimetry. Also thanks to Bernt Strand, Austevoll Fiskeindustri who gifted raw materials for the MF diet. The experiments were financially supported by Trouw Research Center, Norway and Norske Felleskjøp.

REFERENCES

Blom, G., Otterå, H., Svåsand, T., Kristiansen, T.S. and Serigstad, B. 1990.
The relationship between feeding conditions and production of cod fry (Gadus morhua L.) in a marine semi-enclosed ecosystem in western Norway: illustrated by use of a consumption model. Rapp. P.-v. Réun. Cons. int. Explor. Mer, in press

Bromley, P.J. and Howell, B.R., 1983.
Factors influencing the survival and growth of turbot larvae, Scophthalmus maximus L., during the change from live to compound feeds. Aquaculture, 31: 31 - 40

Bromley, P.J. and Sykes, P.A., 1985.
Weaning diets for turbot (Scophthalmus maximus L.), sole (Solea solea L.) and cod (Gadus morhua L.). In: Nutrition and feeding in fish; Cowey, C.B., Mackie, A.M. and Bell, J.G. (Eds.), Academic Press, London. pp. 191 - 211

Crooke, W.M. and Simpson, W.E., 1971.
Determination of ammonium in Kjeldahl digest of crops by automated procedure. J. Sci. Agric., 22: 9 - 10

Folkvord, A. 1989.
Growth and cannibalism of cod fry (Gadus morhua L.) in intensive systems. In: Aquaculture - A biotechnology in progress; N. De Pauw, E. Jaspers, H. Ackefors, N. Wilkins (Eds.). European Aquaculture Society, Bredene, Belgium. pp. 133 - 138

Hemre, G.I., Lie, Ø., Lied, E. and Lambertsen, G., 1989.
Starch as an energy source in feed for cod (Gadus morhua): Digesability and retention. Aquaculture, 80: 261 - 270

Jakobsen, P.J., Johnsen, G.H. and Holm, J.C., 1987.
Increased growth rate in Atlantic salmon parr (Salmo salar) by using a two-coloured diet. Can. J. Fish. Aquat. Sci., Vol. 44: 1079 - 1082

Knights, B., 1985.
Feeding behaviour and fish culture. In: Nutrition and feeding in fish; Cowey, C.B., Mackie, A.M. and Bell, J.G. (Eds.), Academic Press, London. pp. 223 - 241

Lie, Ø., Lied, E. and Lambertsen, G., 1989.
Feed attractants for cod (Gadus morhua). Fisk.Dir. Skr., Ser. Ernæring, Vol II. No 7: 227 - 233

Mackie, A.M. and Mitchell, A.I., 1985.
Identification of gustatory feeding stimulants for fish-applications in aquaculture. In: Nutrition and feeding in fish; Cowey, C.B., Mackie, A.M. and Bell, J.G. (Eds.), Academic Press, London. pp. 177 - 189

Pedersen, T. and Falk-Pettersen, I.B., 1990.
Morphological changes during transformation from larvae to juvenile in cod (Gadus morhua L.) with particular reference to the development of stomach and pyloric caeca. Development and Aquaculture of Marine Larvae. Symposium 12 - 15 August, 1990, Bergen, Norway; poster no. 9

Sokal, R.R. and Rohlf, F.J., 1981.
Biometry. W.H. Freeman and Company, San Francisco. 776 pp

Stradmeyer, L., Metcalfe, N.B and Thorpe, J.E., 1988.
Effect of food pellet shape and texture on the feeding response of juvenile Atlantic salmon. Aquaculture, 73: 217 - 228

Ulgenes, Y., 1982.
Energi og ernæring hos fisk. Thesis, University of Bergen - In Norwegian

Wiborg, K.F., 1948.
Investigations on cod larvae in the coastal waters of northern Norway. Fisk.Dir. Skr., Ser. HavUnders., Vol IX. No 3: 227 - 233

Øiestad, V., 1985.
Predation on fish larvae as a regulatory force, illustrated in mesocosm studies with large groups of larvae. NAFO Sci. Counc. Stud. 8: 25 - 32

Øiestad, V., Kvenseth, P.G. and Folkvord, A., 1985.
Mass production of Atlantic cod juveniles Gadus morhua in a Norwegian saltwater pond. Transactions of the American Fisheries Society, 114: 590 - 595

Zar, J.H., 1974.
Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.Y. 620 pp

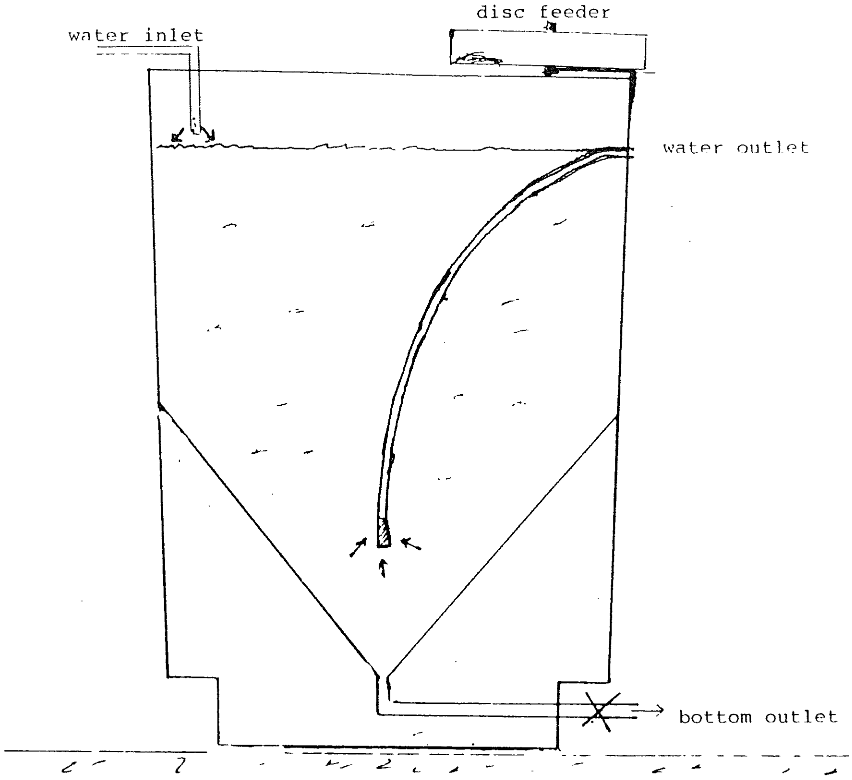


FIGURE 1: The experimental tanks

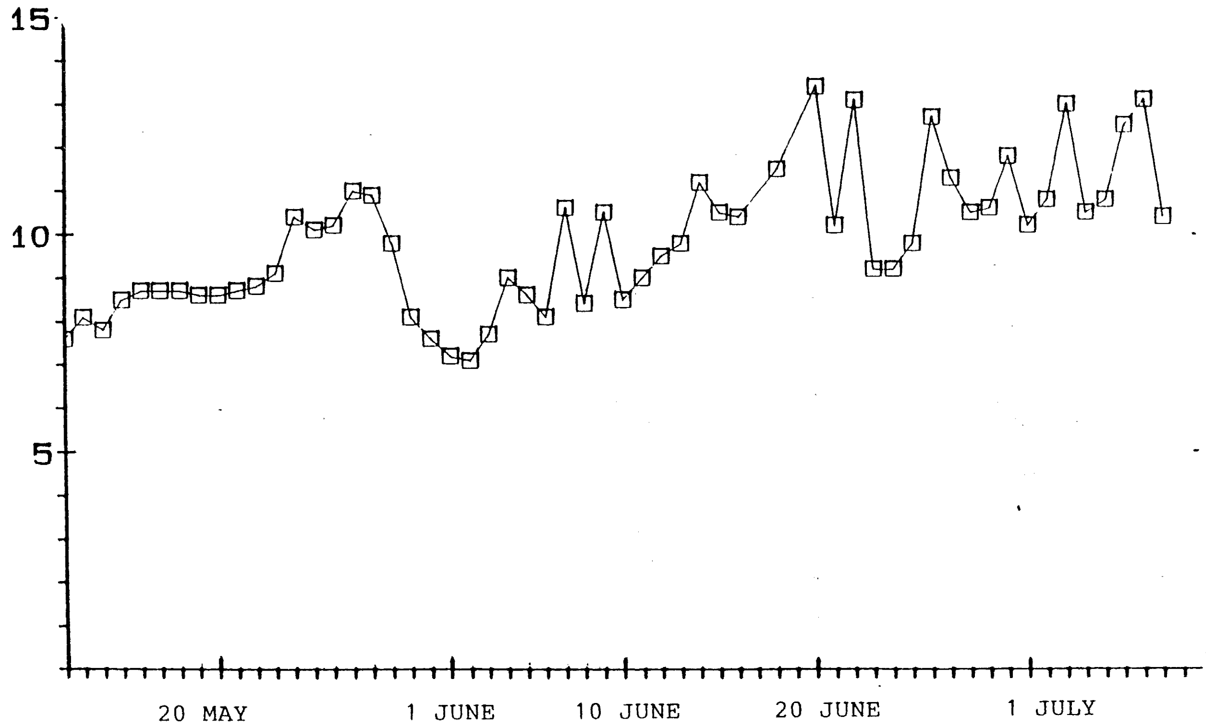


FIGURE 2: Temperature (°C) in one of the experimental tanks

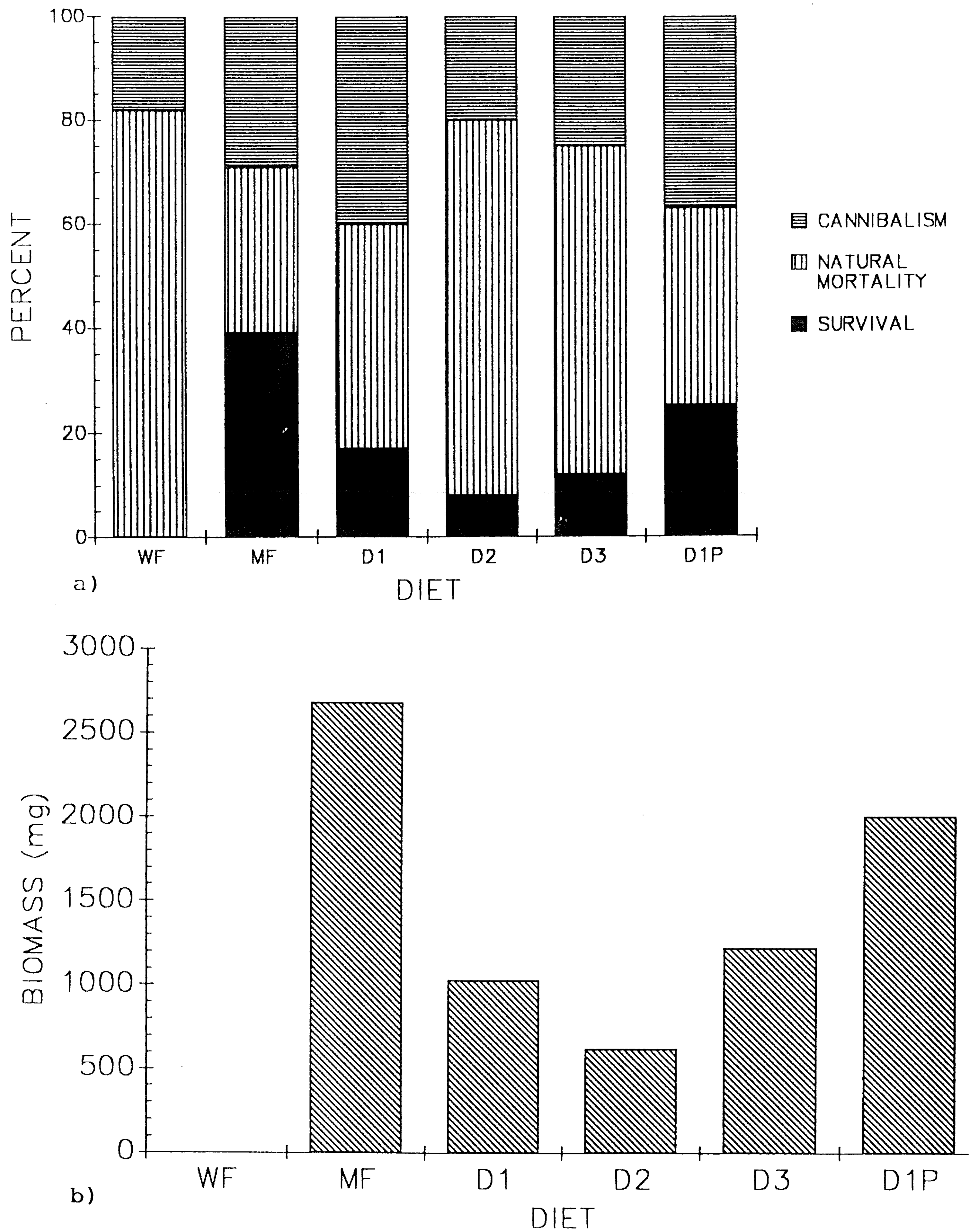


FIGURE 3: **a)** Survival, natural mortality and cannibalism at the end of Exp.I (mean of three tanks). **b)** Biomass at the end of Exp.I (mean of three tanks).

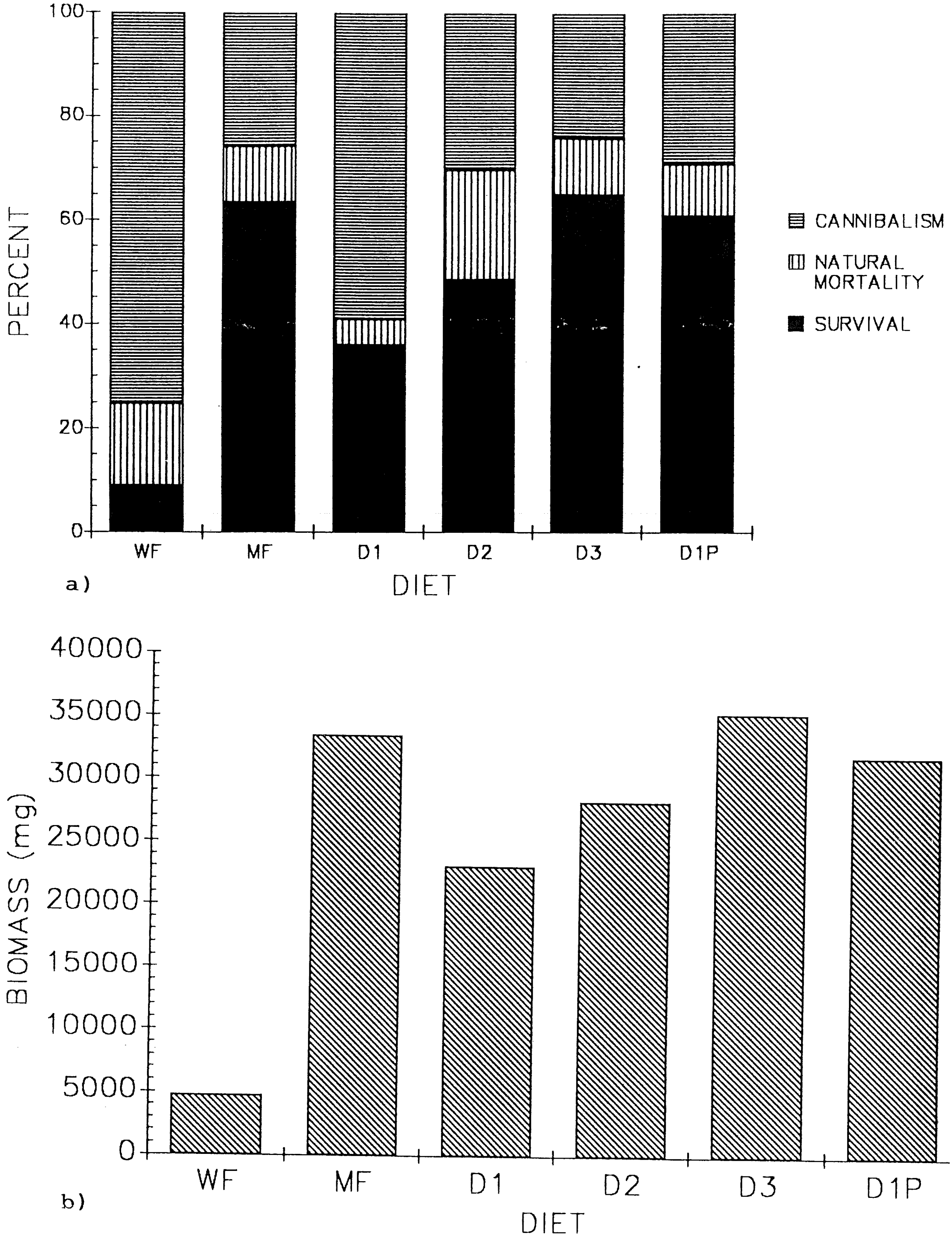
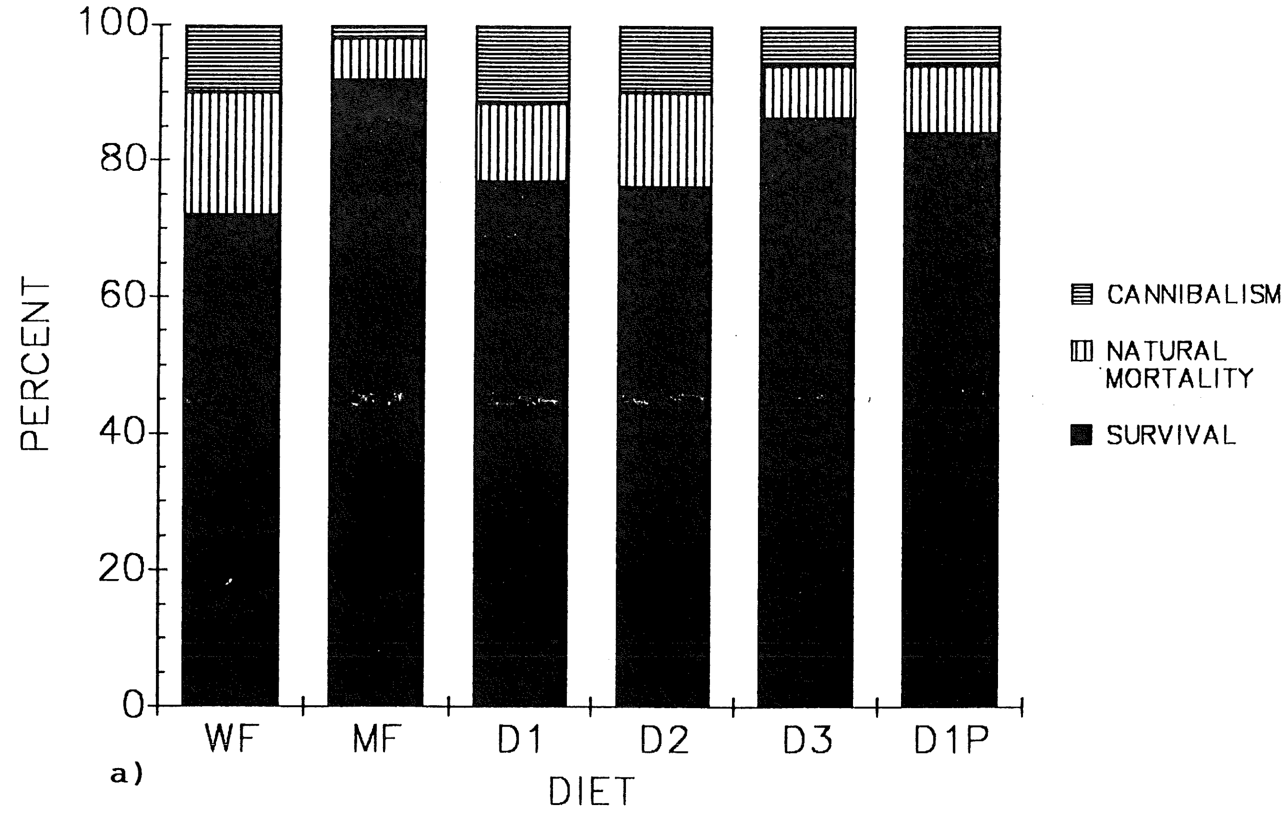


FIGURE 4: **a)** Survival, natural mortality and cannibalism at the end of Exp.II (mean of three tanks). **b)** Biomass at the end of Exp.II (mean of three tanks).



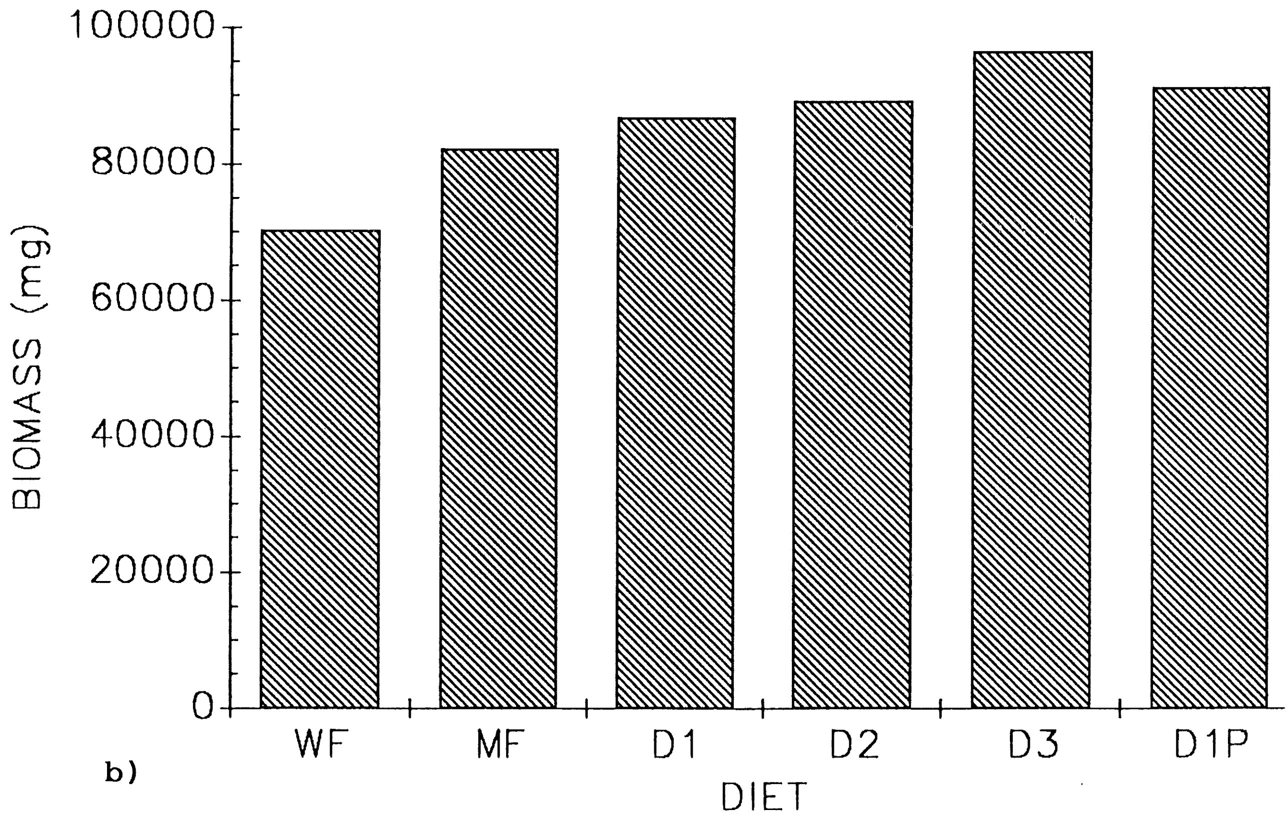


FIGURE 5: **a)** Survival, natural mortality and cannibalism at the end of Exp.III (mean of three tanks). **b)** Biomass at the end of Exp.III (mean of three tanks).