PN-ABC-885

C7-090

Environmental Engineering Center

Technion Research and Development Foundation

"Integration of Aquaculture in Irrigation Schemes"

(013-088)

Progress Report for the Period November 1987 - November 1988

Submitted to the CDR - U.S. Aid Programme

Project No. C7-090

Haifa, November 1988

I N D E X

I. ABSTRACT

This report describes experimental work performed in Israel during the period November 1987 to November 1988. It also describes the contact between the Costa-Rican and Israeli team and the reasons for the delay in starting the project in Costa-Rica.

In Israel three experiments were performed:

1) Tilapia was grown succesfully at four densities in cages, in an irrigation reservoir. Yields, fish growth rates and mortality were determined and showed that tilapia can be reared at a density of 200 fish/m3, where the highest yield was obtained, Another similar experiment is planned in order to test higher fish densities for a longer growth season, in order to reach an extreme situation and define the maximal density which can sustain growth.

2) Mullets were grown, apparently for the first time, in captivity in a closed system. It was shown that despite their nervous behaviour, they adapt to grow in relatively small channels.

3) Information was not found on the feed to be used for rearing mullets in monoculture, in captivity. A growth experiment was done to study the effect of three different commercial feeds on mullet growth

in channel shaped ponds. This set-up also tested the feasibility of using fish ponds drainage water, in a flow-through system.

In Costa Rica the exchange of investigators and the delay in receiving advancement funds, postponed the beginning of the project to Nov, 1988.

II. Background

Freshwater is becoming increasingly scarce, on a world-wide basis, due to an increase in the domestic and industrial demands. In Israel, as an example of a Semi-arid area, there is already a shift from the use of freshwater in agriculture to domestic and industrial uses (1)

Consequently, a lower percentage of the water budget will be available for food production. Water use efficiency in agriculture, will have to improve. One possible way to improve water use efficiency in agriculture is to apply the concept of water reuse, not in the sense of wastewater effluent reuse, but rather concerning the use of freshwater in super-intensive aquaculture, followed by its reuse in irrigated agriculture.

Extensive aquaculture practiced in large reservoirs which store irrigation water (2) and production of fish in irrigation reservoirs is becoming a common practice (3) (4). However, the use of irrigation channels, or suspended cages in irrigation channels or reservoirs for super-intensive aquaculture, is less documented. Intensive fish production units are based on the partial replacement of water for flushing out accumulated detritus. This together with high fish densities and supplemental feeding, results in high yields (5).

A super-intensive farm, in Japan, with a rapid and continuous exchange of water, is reported to have achieved yields of 1500 tm/ha/yr (7). A similar system would be irrigation channels modified for fish production. This is to be tried in Costa Rica. Since in Israel there are no open channels for irrigation, experiments were performed in an irrigation, resevoir, and in channels in a closed and Flow-through systems.

III. Objectives

The general objective of the project is to grow fish in irrigation water using the irrigation channels reservoirs, thus minimizing construction costs.

Specific objectives of the Israeli team were:

1. Study the effects of the stocking density on growth of tilapia in floating cages in an irrigation reservoir.

2. Study the possibility to grow Mullet (Mugil cephalus) in captivity, in channels of a closed system with water recirculation and determine growth and mortality rates.

3. Determine the best diet for M.Cephalus amongst existing commercial feeds.

IV. Activities in Israel

Three different set-ups were used for the experiments. Agreements were made with: 1) Moshav Elazar to use their irrigation reservoir.

2) Kibbutz Ein-Shemer to use a channel in a closed system inside a greenhouse; 3) the Dor Aquaculture Research Station, to perform a feeding experiment on mullet at their premises.

In exchange for being able to use these facilities, the project lent an air blower to Ein Yahav; two paddle-wheels, net cages and fish to Talme Elazar and six channel shaped ponds with accesories to the Dor Station.

IV.1 Material and Methods

IV.1.1 Tilapia growth experiment in cages at the Talme Elazar irrigation reservoir, 1987.

This experiment was performed to determine the effect of fish density on growth rate, when grown in cages, in an irrigation water reservoir.

The irrigation reservoir

The operational irrigation reservoir at Moshav Talme Elazar has 60.000 m3 capacity. Water is pumped from a source, and irrigation water is drawn during the dry season. During the last three years, since the irrigated area was reduced, the reservoir has never dried up at the end of summer. Since we didn't want to have the cages reach the bottom of the reservoir at the end of the summer, the cages were designed to be relatively shallow (1.5m). The reservoir has been leased to an aquaculturist, with whom we reached an agrement to perform the cage experiment.

The Cages

Four cages, 3m x 3m x 2.5m, were built with fishing nets (2.5cm eye). They were hanged from a floating frame (6mx6m), leaving 1.5m of the cage immersed (Fig. 1). Thus the volume of each cage was 13.5m3 . A pair of paddle-wheels were fixed to the cages frame, at about 3m distance from the nets and provided slow mixing (20 RPM) for water exchange and metabolites removal from the cages. Four demand feeders, one for each cage, were installed with a movable arm, to keep it in the middle of the cage when feeding and near the walking path for feed recharge.

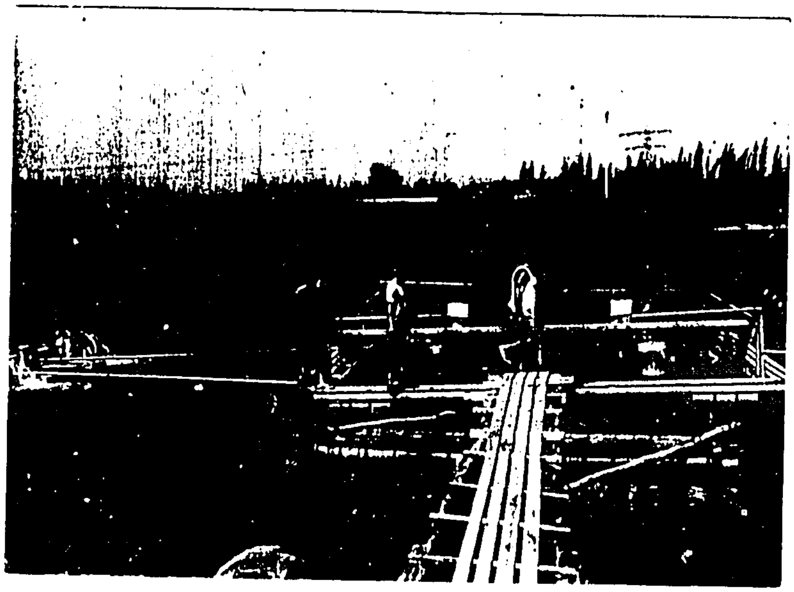


Fig. 1. Floating cages , at the Talme Elazar irrigation reservoir, used for tilapia growth at different stocking densities, September

Management

Fish were stocked on the 19/IX/87 and reared for 58 days until the 15/XI/87. The fish that died during the first three days were replaced with similar fish.

Feed was added once a day, 6 days per week to the demand feeders at a 4% rate of the fish body weight, of each cage. The feed used was a commercial feed, 25% protein, enriched with 1.5% PO_4NaH_2, vitamins and lignosulfonic as a binder. Feed rates were recalculated beeweekly according to the weighing of not less than 20% of each cage population and the fish were returned to their cages.

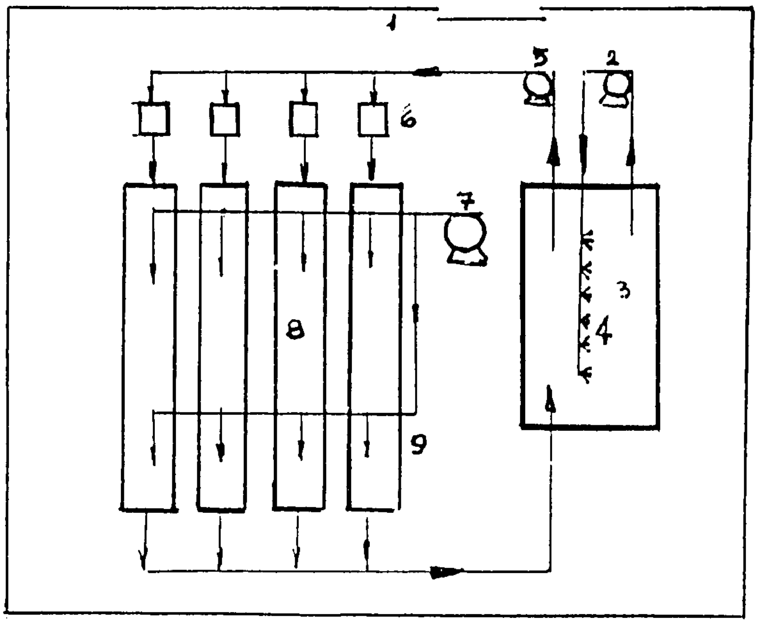
At the end of the growth season, all the fish were harvested and total yield per treatment and mortality rate were determined.

IV.1.2 Preliminary experiment on rearing mullets in a channel of the closed aquaculture unit at Kibbutz Ein Shemer.

Kibbutz Ein Shemer greenhouse is used for educational purposes by the Agriculture high school, where students operate and attend several aspects of solar energy utilization, cultures in controlled environments and more recently, aquaculture. An agreement was done between the project and the kibbutz, by which we are allowed to perform experiments in the greenhouse and in turn we lend an air blower. Students of the shcool attend our experiments and get familiar with fish rearing. The first experiment was to grow mullet in captivity in a closed system and determine its growth rate.

The aquaculture unit at Ein Shemer

This unit has been built by the Kibbutz as part of an energy saving project, where water is heated during the day in a solar heat collector, inside the greenhouse, and releases heat at night. The whole system consists of: 1) a 150m3 water pond, 2) a series of four P.V.C channels operated in parallel 3) a solar heat collector 4) circulation pumps 5) an air blower for aeration and air-lift purposes and 6) biological filters and bacterial support for ammonia removal from the recirculated water (Fig. 2).



1. Greenhouse
2. Heat Collecter pump
3. Pond $150m^3$
4. Solar Heat Collector
5. Recirculation Pump
6. Biological filters
7. Air Blower
8. Fish Culture Channels
9. Air Lifts

FIG. 2 CLOSED SYSTEM AT EIN SHEMER

The $150m^3$ water pond receives the effluent from four $15m^3$ channels. Water is pumped from this pond, during the day, to the solar heat collector, which also helps for water aeration by spraying the water back to the pond. Inside the pond, a net filled with plastic pipe sections, serves as support for nitrifying bacteria. The water from the pond is pumped to four gravel filters, one for each channel, flowing by gravity from the filter to the channel.

We used one of the four PVC channels to grow mullets (Fig. 3).

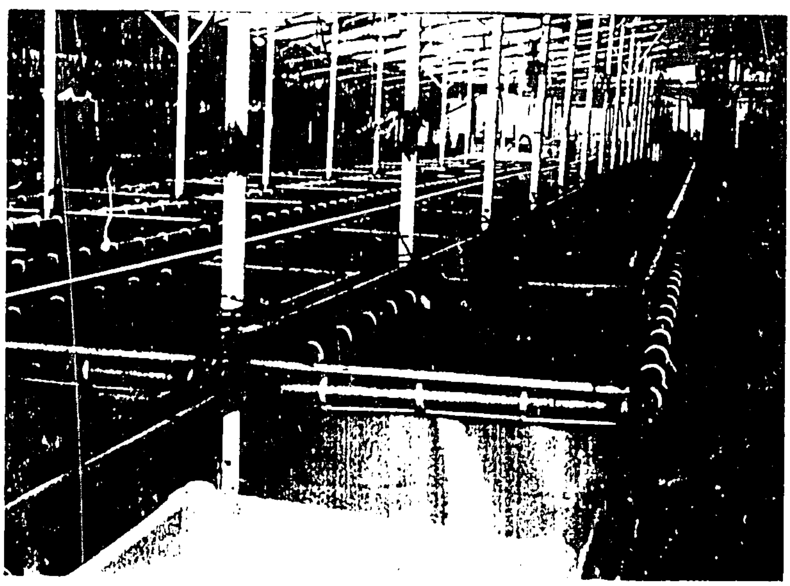


Fig. 3: Channel in closed system at kibbutz Ein Shemer where the mullet experiment was performed during February-June 1988.

The channels ($20m \times 1m \times 0.75m = 15m^3$) were provided by four air lifts for aeration and water movement purposes and an overflow for water level adjustment.

Trays covering the channels were planned to be used for growing interior plants. However, they were used only in part of the channel.

Culture Managment, mullet experiment at Ein-Shemer

Three hundred mullet average weight (130gr/fish) caught in a close reservoir were stocked into the channel , 20 fish/m^3, on February 1988. During the first days, 134 fish died. This high mortality was attributed to collection handling and transport injuries. The stocking density after mortality was 11 fish/m^3.

The fish were fed carp pellets (25% protein) through a demand feeder, at 4% of their initial body weight, six days per week.

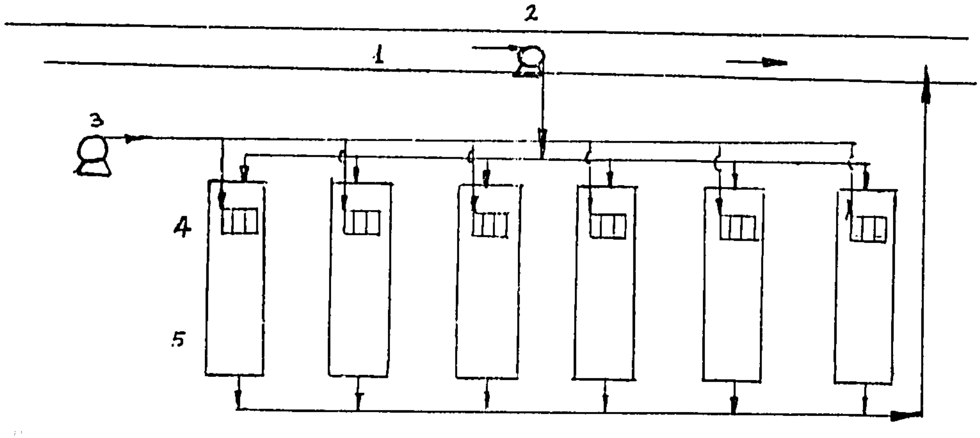
Since mullet didn't actionate the demand feeder, four carps were added into the channel to draw feed. A total of 114 Kg of feed was used during the growth period.

Feed rate was not adjusted during the experiment, since fish were not weighed in order to avoid more mortality to the already high mortality rate, due to fish jumping out of the channel. At the end of the experiment fish were counted, separated into two size groups, weighed and sent to the market.

IV.1.3 Mullet Feeding Experiment at the Dor Aquaculture Research Station

The Ponds

This experiment was performed using six rectangular cement asbestos-fiberglass ponds (3.5x1.5x0.85 4.5m^3). They were supplied with drainage water from adjacent fish ponds, by a submerged pump immersed in a drainage channel (Fig. 4). The total flow was divided into six equal flows of 5 l/m which provided 1.5 water changes per day. The quality of the water was determined following Standard methods (7). Drainage water analysis is given in Table 1.



1. Drainage channel
2. Water pump Q=301/m
3. Air blower
4. Porous tubes
5. Channeled ponds 4.5m^3

FIG.4 FLOW TROUGH CHANNEL PONDS AT DOR.

Table 1: Analysis of fish ponds drainage water used in the mullet feeding experiment. Dor, 1988

pH	7.45
D.O.	above saturation
Conductance	2.18 mmho/cm^2
NH_4	1.75mg/l
PO_4	0
T.S.S	106mg/l
F.S.S	59.1mg/l
V.S.S	46.9mg/l
COD	82.3mg/l

An air blower, continuously provided air, which was bubbled into the fish ponds through porous tubes. The ponds were covered with nets, to prevent the fish from jumping out.

The fish

M.cephalus imported from Spain were reared in cement ponds and were transfered to a cage kept in a water reservoir. The fish were grown to an average weight of 25g/fish and they were transfered the cement-asbest ponds at Dor at a stocking density of 20 fish/m^3.

Fish Culture Managment

The experiment lasted for 58 days between the 31/VIII/88 and the 27/X/88. Three treatments, with duplicates, tested three commerical feed pellets, which have three protein levels 1) carp feed (25% protein) 2) tilapia feed (30% protein) and 3) trout feed (40% protein).

Feed was added twice a day, at a rate of 8% of the fish body weight per day. The feeding rate was adjusted after weighings done at two weeks intervals by sampling twenty fish, or more, per pond. Mortality rate was calculated at the end of the experiment. The fish of the experiment were kept alive and transported to Ein-Shemer for an experiment that will start in December 1988. Four fish from each treatment were sampled, frozen, minced and analyzed for fat, protein, ash, and moisture.

IV.2 Results

IV.2.1 Tilapia growth experiment in cages, Talme Elazer 1987.

The Tilapia growth experiment in which fish were stocked at four stocking densities was concluded on the 15/XI/87 after a growth season of 58 days. Its results are summarized in Table 2 and Fig. 5.

Table 2: Results of experiment testing the effect of fish density on growth and mortality rate. Talme Elazar, tilapia in cages, 1987.

Pond 1. Fish density 37 fish/m^3.

Date	No. of fish	Mean weight (g/fish)	Weight Increment (g/fish/d)	Standing crop (Kg/m^3)	Mortality rate (%)
18/IX	507	177.3	-	6.6	
3/X		181.2	0.3	6.8	
14/X		245.0	2.6	9.2	
25/X		249.3	2.0	9.4	
15/XI	457	236.8	1.0	8.0	9.8

Pond 2. Fish density 50 fish/m^3.

Date	No. of fish	Mean weight (g/fish)	Weight Increment (g/fish/d)	Standing crop (Kg/m^3)	Mortality rate (%)
18/IX	670	213.0	-	10.7	
3/X		259.9	3.13	12.9	
14/X		298.9	3.3	14.8	
25/X		316.6	2.8	15.7	
15/X	553	311.3	1.7	12.7	17.4

Pond 3. Fish density 100 fish/m^3

18/IX	1350	199.6	-	19.9	
3/X		259.9	4.0	26.0	
14/X		274.1	2.8	27.4	
25/X		304.6	2.8	30.5	
15/XI	892*	316.2	2.0	20.9	not calculated*

Pond 4. Fish density 200 fish/m^3.

18/IX	2650	190.5	-	37.4	
3/X		232.4	2.8	45.6	
14/X		268.8	3.0	52.8	
25/X		271.3	2.2	53.3	
15/XI	2513	287.0	1.7	53.4	5.2

* Fish were stolen by children.

The daily weight increment per fish calculated for the period 18/IX/87-14/X/87 (water temp: 28°C) was: 2.6, 3.3, 2.8 and 3.0 g/fish/day for the 37, 50, 100 and 200 fish/m^3 densities, respectively. When considering the whole growth-period (18/IX/87-15/XI/87), in which water temperature droped to 24° max and 15°C min from the 20/X, the daily increment was 1.0, 1.7, 2.0 and 1.7g/fish/day, respectively for the four densities.

The highest standing crop reached was of 53.4 Kg fish/m^3 cage. It was not observed an increase in the mortality rate related to stocking density or standing crop increase.

Results of periodic weighings (Table 2) are seen in Fig. 5. Excluding the 37 fish/m^3 the cage, the rating for growth rate was as expected, inversely related to fish density, higher for the cage with 50 fish/m^3 and lower for the cage with 200 fish/m^3.

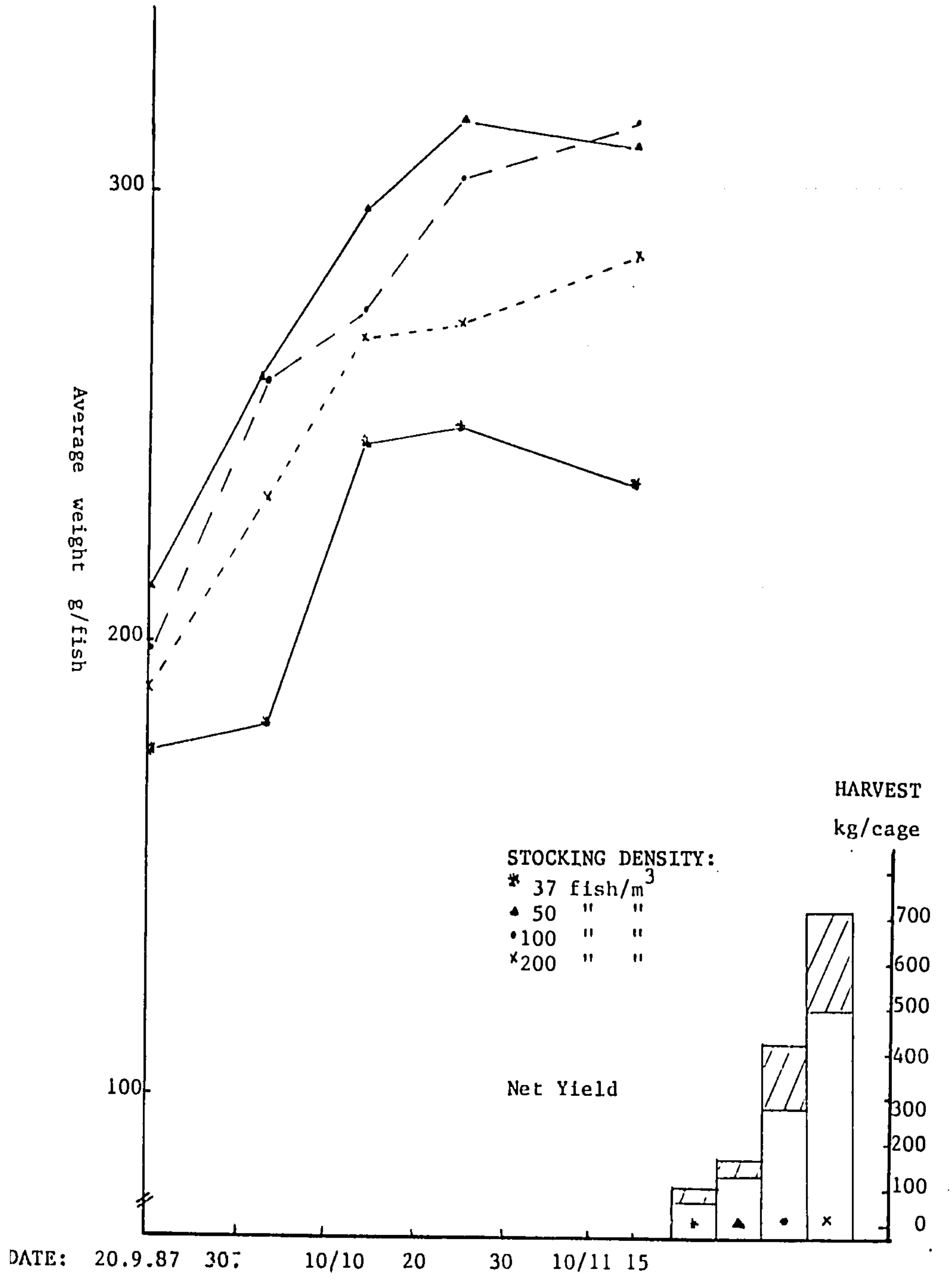


FIG. 5 GROWTH RATE AND NET YIELD OF TILAPIA GROWN IN CAGES AT DIFFERENT STOCKING DENSITIES. TALME ELAZAR, 1987.

Table 3: Results of High Density Culture of Tilapia in Floating Cages At the Talme Elazar Irrigation Reservoir.

CAGE	1	2	3	4
Fish density (fish/m^3)	37	50	100	200
Fish stocked per cage (13m^3)	500	670	1350	2650
Fish harvested per cage	457	553	892	2513
Mortality (%)	0.6	14.4		5.2
Stock Date	18/IX	18/IX	18/IX	18/IX
Harvest Date	15/XI	15/XI	15/IX	15/XI
Days of Culture	58	58	58	58
Mean stock weight (gr/fish)	177.3	213.0	199.56	190.46
Mean Harvest Weight (gr/fish)	236.8	311.3	316.2	287.10
Mean increment (gr/fish)	59.5	98.3	116.6	96.5
Specific Growth Coefficient (All period of experiment)	0.029	0.041	0.050	0.044
Specific Growth Coefficient (18/IX/87-25/X/87 when the Min water T= 18°C)	0.055	0.069	0.072	0.058
Stock (Kg/Cage)	88.6	142.7	269.4	504.7
Harvest (Kg/Cage)	108.2	172.1	404.7**	721.2
Net Yield (Kg/Cage)	19.6	29.4	135.3**	217.5
Kg/Cage/dy	0.34	0.51	2.3**	3.75

** Fish stolen. Calculted assuming 5.2% mortality and 316.2g/fish, actual harvest=104Kg/cage.

Since the mean stock weight (gr/fish) differed among ponds (Table 3), the specific growth coefficient for comparison of growth rates among fish of different weight was calculated, following the procedure by Schroeder and Hepher (8).

The differential growth rate of fish is described by equation (1)

$$(1) \qquad dw/dt = w^{0.67}$$

where w is the weight of the fish.

The specific growth coefficient "a" can derived.

$$(2) \qquad a = 3.03\ (W_2^{0.33} - W_1^{0.33})\ /\ t2-t1$$

"a" provides a mean to normalize growth rates of unequal fish weights. The specific growth coefficient multiplied by 100, gives the percentage instantaneous growth rate of a fish of unit weight.
Specific growth coefficients were calculated for the four treatments of the experiment for the period between the 18/IX and 25/X, when the minimum temperature of water was above 18^oC. Results seen in Table 3, show that the highest specific growth coefficient was observed in the cage with 100 fish/m^3. The rating in the period with temperature above 18^oC was: Cages 3-2-4-1, which is the same rating as the mean

increment and of the mean harvest weight. Obviously, the rating for yields was: cages 4-3-2-1 (Fig. 5), though the fish in the 200 fish/m3 treatment reached a mean harvest weight of 287g/fish as compared to more than 300g/fish for the 50 and 100 fish/m^3 treatments.

The highest net yield obtained was of 217.5 Kg per cage, equivalent to 3.75 Kg/cage/day in the cage with 200 fish/m^3. (Table 2, Fig. 5).

Water analysis showed no difference between samples taken inside the cage with 200 fish/m^3, as compared to samples taken outside the cage (Table 4), indicating that mixing by the paddle-wheels was effective for changing water inside the cages. A small reduction of D.O. was observed inside the cage, but D.O. values were always above 5mg/1/

Table 4: Water parameters inside and outside the tilapia cages.
Talme-Elazar, 1987.

Date			Outside cages	inside cage with 200 fish/m^3.
23/IX/87	NH_4(mg/l)		0	0
	PO_4 "		3.4	3.4
	S.S. "		21.0	21.7
	pH		7.8	7.6
	Temp.		28.5	28.0
	D.O. depth	0_m	8.0	7.3
	" " "	0.5m	7.8	6.9
	" " "	1.5m	4.8	6.2
4/X/	" " "	0m	6.0	5.8
		0.5	5.8	5.4
		1.5	4.8	5.0
	Temp (°C)		27.5	27.5
14/X/	DO depth	0m	7.0	7.6
	" " "	0.5	5.8	5.4
		1.5	5.0	5.0
	Temp (°C)		25, 24.5, 24	25
20/X	Temp. max (°C)		24	
	Temp. min (°C)		15	
15/XI	Temp. max (°C)		21	
	Temp. min (°C)		11	

2.2 Results of the Preliminary experiment on rearing mullets in a closed aquaculture unit, Kibbutz Ein-Shemer, 1988.

This preliminary experiment showed that it is possible to rear mullets in channels. Results of the experiment are summarized in Table 5.

Table 5: Results of rearing mullet in closed system channel, Ein Shemer, Feb. - June 1988.

Growth Period (days)	100
Fish Stocked	307
Fish Density (fish/m^3)	20
Fish that Died During First week	134
Fish in experiment	173
Fish density during Experiment (fish/m^3)	11
Mean stock weight (gr/fish)	130
Mean harvest " (gr/fish)	3 [illegible]
Mean increment (gr/fish)	240
Mortality Rate During Experiment	38%
Fish harvested	107
Medium size fish	62
" " " mean weight (gr/fish)	336
Large size fish No.	45
" " mean weight (gr/fish)	419 (see Fig. 6)
Harvest (Kg/channel)	62.9
Standing crop (Kg/m^3)	4.2
Feed coefficient	4.4

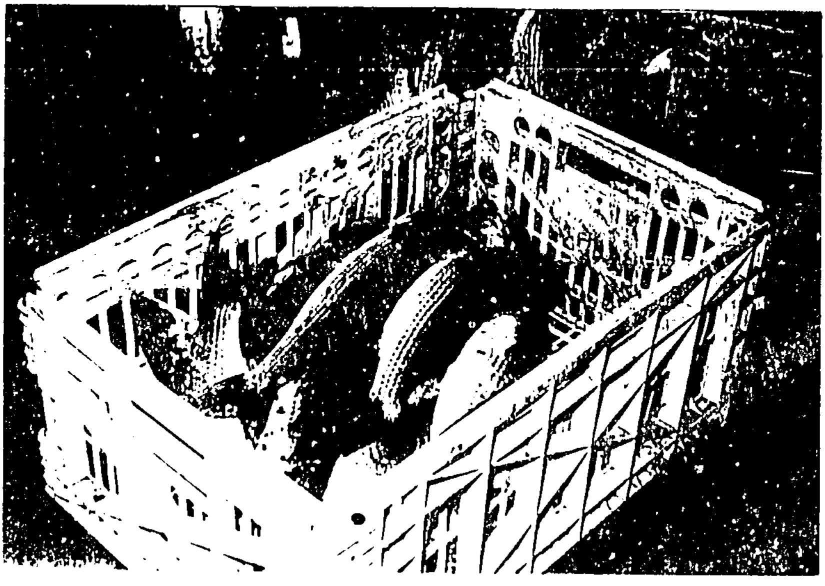


Fig. 6: Mullet reared in closed system at Ein Shemer, 1988 (Mean weight of 45 fish, 419g/fish)

The high mortality (38%) observed during the experiment,was mainly due to fish which jumped out of the channel. The mean increment per fish of 240g in 100 days, results in a daily mean increment of 2.4gr/fish day, which compares favourably to growth rates of 2.9-3.7g fish/day, in ponds stocked with 75 to 125 fish/ha, at a weight interval between 50-415g (9). The total fish biomass at the end of the growth period was 62.9Kg which is equivalent to 4.2kg/m^3 standing crop. The feed coefficient ratio was 4.4. Since common pellets for carp were used in this experiment, another experiment was performed to test the effect of other commercial feeds.

The water parameters determined in this experiment are seen in Table 6.

Table 6: Water parameters measured in the channel where Mullet was reared. Ein Shemer, 1988.

Date		NH_4(mg/l)	NO_2(mg/l)	NO_3(mg/l)	pH
17/2	Pond	0.076	0.76	-	
2/3	Channel inflow	0.114	0.03	0.71	8.06
	Channel outflow	0.116	0.04	0.66	7.79

Minimum water temperature in the channel was 16.5 C and max temp. 27°C.

Before the experiment started,the Nitrite concentration was 0.7mg/l but as soon as there was circulation through the channel and filters this concentration was reduced to 0.03-0.04 mg/l with a parallel increase in nitrate. The level of ammonia was always below water quality guidelines for aquaculture.

IV 2.3 Results of feeding experiment with mullets, Dor 1988

In this experiment, where mullets fed three different commercial feeds, with duplicates for each treatment, fish were weighed every 10 to 14 days to follow grow rate and recalculate the daily feed supply.

A very high morvality rate was observed. It was accounted only at the end of the experiment.

Results of mullet growth rate, and mortality are given in Table 1 and Fig. 7. Feed coefficient was not calculated since feed was supplied in excess (8% of body weight) to assure maximum possible growth.

Table 7: Results of mullet feeding experiment, Dor, 1988.

Stock Date	22/VIII/88					
Feeding Started	31/VIII/88					
Harvest Date	27/X/88					
Days of culture	57					
Feed Rreatment	25% Protein (carp)		30% Protein (Tilapia)		40% Protein (trout)	
Mean Stock Weight (g/fish)	23.3	23.7	24.7	24.5	27.0	25.0
Mean Harvest " (" ")	30.0	26.4	30.7	30.1	32.9	34.6
Mean Increment (g/fish)	6.7	2.7	6.0	5.6	5.9	9.6
" " Of Stock Weight	28.5	11.7	24.5	22.8	21.8	38.4
Fish Stocked	90	90	90	90	90	90
Fish Harvested	58	82	84	84	43	79
Mortality (%)	35	8.9	6.7	6.7	52	12.2

The highest weight increment was observed in the ponds receiving trout feed. It seems there is no difference between the carp and tilapia feed for the growth of mullet used in this experiment. It is interesting to note that there was a low mortality rate in the two ponds which received tilapia feed. The very high mortality in the other treatment was accounted only at the end of the experiment, when the ponds were emptied. Further work on mullet diets will be done for a whole growth season in small cages suspended in the Ein Shemer channel.

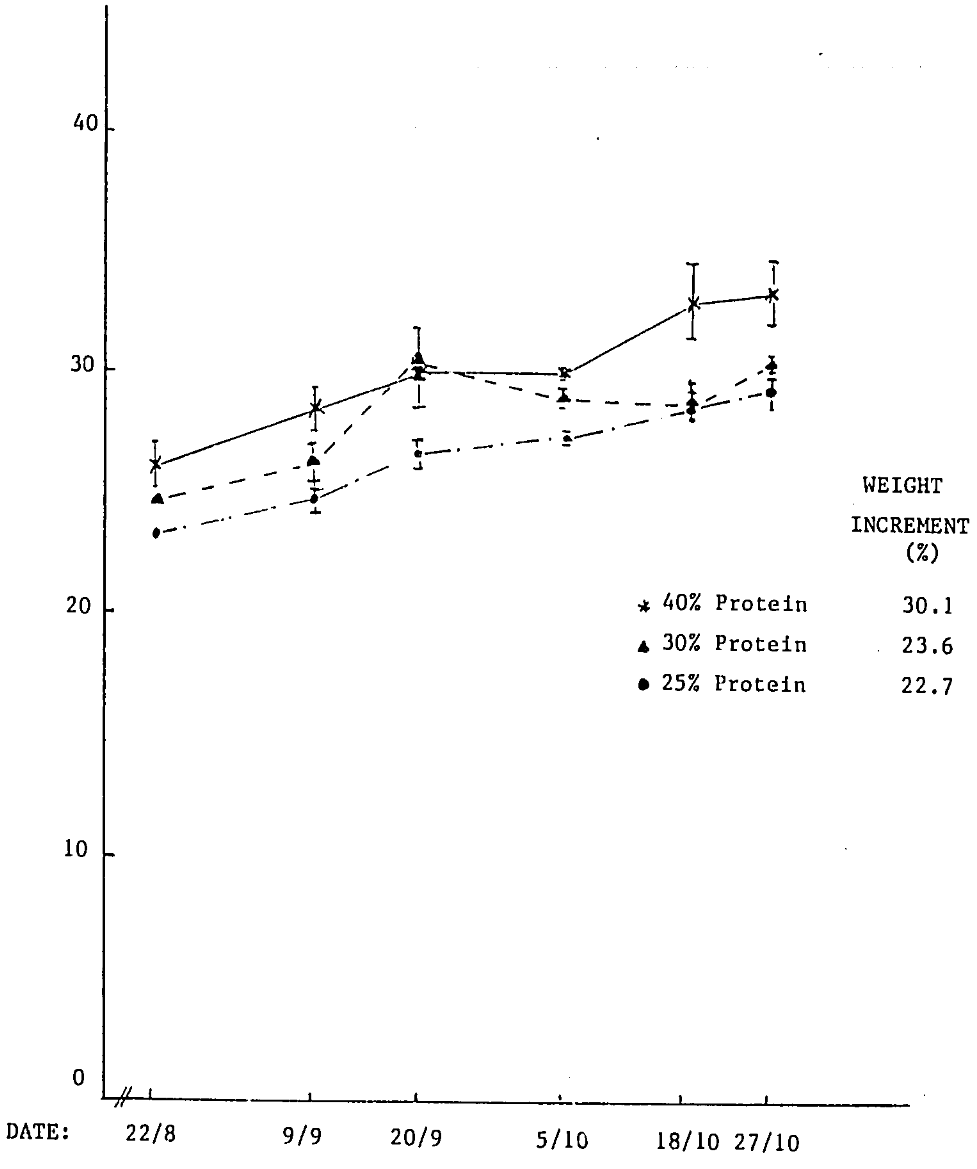


Fig. 7: Growth rates of mullet fed different commercial feeds.
Dor, Aug. 1988.

The composition of minced fish (whole) did not differ among treatments (Table 8).

Table 8: Composition of mullet fed different diets, 1988.

	Pelletized Diets		
	25% PROT. (CARP)	30% PROT. (TILAPIA)	40% PROT. (TROUT)
Protein	16.51	16.2	16.3
Fat	13.9	13.8	13.6
Moisture	65.2	65.[illegible]	65.3
Ash	4.4	4.7	4.3

IV.3. Reccomendations for future work.

1) Perform a tilapia experiment in channels, in the closed system, at different densities and study effect on water quality.

2) Perform a tilapia experiment in cages in the irrigation reservoir at fish densities ranging from 100 to 400 fish/m3 during a whole growth season, to reach 400-450g/fish and determine if there is growth retardation.

3) Perform a feeding experiment with mullet in cages, inside the P.V.C. channel at Ein-Shemer and test pellets, powdered feed and a pasted feed,

4) Check effect of water velocity in channel on tilapia.

V. Activities in Costa-Rica

Some difficulty was found in advancing the project in Costa Rica.

Dr. Sandbank visited Costa-Rica in April 1987 (See attached description).

Following this visit it was agreed that Costa-Rica's Co-Principal Mr. Nanne Echandi would organize working procedures and would visit Israel in order to confirm the experimental design and present an advanced payment application to start experimental work. Mr. Echandi postponed the date of his visit and this also delayed the presentation of their budget request.

In the meantime Mr. Echandi was promoted, took other responsabilities and asked to nominate Licenciado A Porras Porras as investigator in the project. Mr. Porras was accepted, contacts were restablished and he presented a request for funds, but it was not properly fundamented for an advanced payment. The change of investigator, the delay of his visit to Israel and the need of funds in Costa Rica to start work, but at the same time the difficulty fund in receiving an estimate of expenses, have delayed the beginning of work. Having presented recently an application for funds we are looking forward to seeing the Costa Rican team taking active participation as soon as they will receive the funds.

We have asked that the starting date for Costa Rica would be Nov. 1988 and we have suggested Lic. Porras Porras to collaborate with an existing fish farm at Guanacaste in order to speed-up work and in order to answer questions arising in the field.

V.1. Preliminary visit of Dr. E. Sandbank to Costa Rica in the framework of the U.S. Aid project.

"Integration of aquaculture in an irrigation Scheme"

In April 1987, Dr. E. Sandbank visited, in a short term mission, the Department of Fisheries and Aquaculture, Ministry of Agriculture, Costa Rica, to further define the research plan of the Costa Rican team, together with Mr. H. Nanne Echandi, Costa Rica's principal investigator.

The terms of reference were as follows:

I) To make a selection of the project site;

II) To plan an experimental design;

III) To make a cronogram of activities;

IV) To budget the Costa Rican expenses required to perform the program of work.

All the terms of reference were met as follows:

V.2. Selection of project site

The original selection of the Enrique Jimenez Numez Aquaculture Experimental Station as the base for the project was confirmed. The station is located 20 km. from the city of Canas, Province of Guanacaste.

Since its openning, the Station was meant to participate in the development of aquaculture not only in the Arenal reservoir (85 km) but also in the irrigation system to be built later on.

The Station has generated technology for the culture of fish specially of the genus Oreochromis (tilapias) in ponds under integrated polyculture.

The region has a large net of channels which are the first stage of the Arenal-Tempisque irrigation system. There are 8 km. of main channels already in operation with a potential flow of 30 m /s and 27 km. of secondary channels. These installations seem to be suitable for fish culture in cages or enclosures.

The main objective of the project is to develop technologies for fish culture in these installations.

Since Tilapia seems to have a market in the U.S.A. and the Caribean, it was decided to concentrate the work of the first year on three lines of Tilapia:

1) Hybrid of O. hornorum x O. mossambicus;

2) O. aureus;

3) Red tilapia.

V.3. Experimental design

Previous experience in cages in C. Rica has shown in preliminary experiments that a density of 200 fish per m is feasible. Since the flow rates in the channel will be increased from 0.1 - 0.15 m/s to 0.4 m/s - 1/2 m/s it was decided to perform an experiment with three densities: 200, 300 and 400 fish/m , with triplicates for the three lines. (3x3x3=27 cages).

This experiment will be started in January 1988 and will last 5 months, after which the fish are expected to reach their commercial size of more than 300 gr. per fish.

Every two weeks, representative samples of fish (more than 30%) for each repetiton, will be weighed and the daily ration will be readjusted according to the new weight.

Physico-chemical analysis (T , pH, D, O, NH - N, PO - P, Turbidity, TSS, V.SS) of the water in the channel, before and after the cages, will be related to the effect of fish production on the quality of the water which will be used for irrigation, on fish production and mortality.

A second experiment will be performed at the Enrique Jimenez Numez experimental Station, in a model of a cement lined secondary channel, which was built to make growth experiments of fish and other organisms. This experiment will be started in August 1987 and will be followed by the same analysis mentioned above. A density of 100 fish/m of each tilapia will be kept in three enclosures.

The time table of activities is described in the following Cronogram, assuming that the research will be starting in June 1987. Should there be any postponement, the activities will be postponed accordingly, if no climatic constraints will prevent doing so.

V.4 Cronogram

Time table of the first year of activities in Costa Rica on the "Integration of aquaculture in an irrigation scheme".

	1987							1988					
Task	J	J	A	S	O	N	D	E	F	M	A	M	J
Preparation of fish fry	x	x			x	x	x		x	x	x		
Preparation of cages	x	x											
Preparation of channel in E. JNE Station experimental Station	x												
Experiment in Experimental Station			x	x	x	x	x						
Analysis of water samples (once a week)			x	x	x	x	x						
Growth experiment in secondary irrigation channel									x	x	x	x	x
Analysis of water samples									x	x	x	x	x
Harvesting and analysis of results								x					x

V.5. Budget for the 1st year Costa Rica

		$
1) Salaries		
Salaries supplements and 1 worker salary		7,600
2) Equipment		
27 cages for secondary channel	2,500	
1 Hach analysis kit for water	1,500	
1 D.Q. meter YSI	1,000	
		5,000
3) Materials		
30 Tm Feed	9,000	
Reports, photocopies	200	
50000 fish	2,000	
		11,200
4) Travel		
National	4,600	
International	4,600	
		9,200
TOTAL FOR ONE YEAR		33,000

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Acknowledgments

Thanks are given to the US AID-CDR programme for funding in part this research.

Thanks are due to:

- Mr. Eli Roter from the Talme Eleazar Reservoir for his enthusiasm in building the floating cages and his help in performing the tilapia growth experiment.

- Kibbutz Ein Shemer Agriculture School students and instructors for attending the greenhouse and for rearing M. cephalus in one of the greenhouse channels.

- Mr. E. Sheieber and Mr. Yoram Beck for installing the ponds set up at the Dor Aquaculture Station and Mr. Israel Yizhak for attending the feeding experiment.

- Mrs. Ida Sekler for her help in water, feed and fish analysis.