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Selection of finfish species as candidates for aquaculture in French Polynesia

AQUACOP, J. FUCHS, G. NEDELEC and E. GASSET
IFREMER. B.P. 7004 TARAVAO. Tahiti. French Polynesia

Abstract — *A programme of selection of finfish was conducted by IFREMER from 1983 to 1987 to identify the most suitable species for aquaculture in French Polynesia. A first bibliographical selection, based on the economical interest of species and the existence of previous researches in Tahiti or abroad allowed to retain 4 local families (Carangidae, Coryphaenidae, Serranidae, Siganidae) and 2 imported ones from South-East Asia (Centropomidae, Cichildae).*

In a second step, species were selected according to the following criteria : growth potentiality, adaptation of fry to dry pelleted food, reproduction and spawning capacity, larval rearing and fry production, pathology and resistance to stress, economic interest on local market.

A classification in 3 groups is consequently proposed.

*— Species with a very high potential for aquaculture, allowing development projects on a short term basis : the Seabass (**Lates Calcarifer, Centropomidae**), originating from S.E. Asia.*

*— Species, potentially interesting but presenting some drawbacks, as difficulties to perform larval rearing (grouper **Epinephelus microdon, Serranidae** and dolfin fish : **Coryphaenae sp., Coryphaenidae**) or presenting pathological problem (red Tilapia strain **Oreochromis sp.** during grow-out in sea water cage).*

*— Species considered as difficult to rear and not retained like **Siganus argenteus, siganidae** (unsuccessfull larval rearing and poor economical value) or **Caranx ignobilis, Carangidae** (no acceptability of compounded diets).*

The result of the tests are synthetized with more details for Seabass considered as the most promising species for the area.

The future development of finfish in Polynesia is emphasized and a project of Sea bass netcage culture in Polynesian lagoon is presented.

INTRODUCTION

Situated in the center of the Pacific Ocean, between 8 and 27° of latitude south, French Polynesia became an Oceanic area of economical interest after the extension to 200 miles of his economic exclusive zone.

The exploitation of his natural fish resources, in a territory of 3.3 million of km 2 reached a total of 8000 tonnes in 1987 including 4000 tonnes exploited by industrial Japanese and Corean vessals, 2000 tonnes of pelagic fish (Tuna, Bonitos) caught nearly Polynesian Islands and 1700 tonnes of lagoonal fish traditionnaly captured by traps and nets in the Tuamotu Archipelagos (Service de la Mer et de l'Aquaculture, 1987).The recent tourism development in the last ten years increased the demand of fresh good quality products that traditionnal fishing methods are not totally able to supply due to the seasonnal fluctuations of the catching and the risk of ciguatera contamination encountered in many atolls.

The project of developping finfish aquaculture, using floating netcages, largely extensed in many tropical Asean countries, as Singapore, Hong-Kongand Thaïland (Chua, 1986), was recently investigated by the Centre Oceanologique du Pacifique (IFREMER) in Tahiti, considering the favorable characteristics of many lagoons and Islands of French Polynesia as :

- continuous reneval of water by the action of waves over the reef,
- good protection from ocean swells,
- easy accessibility of water and constant temperature around 27 to 28°C,
- abundance of sites.

This new aquaculture project could offer good quality products, strictly calibrated and available all over the year. It could also help to create new economical activity, fitting the capacity and the need of the Islands populations, in participating to their retention and even their return in the Islands.

The programme, initiated by IFREMER in 1982, to select the most suitable finfish species for Aquaculture thank to the financial support of EEC had three mean objectives :

1. introduction of new fields of activity in the oversea French Polynesia
2. development of scientific cooperation with other tropical countries allowing the improvement in establishing rearing techniques as maturation, nutrition in the future
3. the transfer of knowledge to foreign countries.

It was divided in 4 steps, each corresponding to a 3 or 4 years research programmes.

From 1983 to 1987, the programme of selection allowed to retain a limited number of species considering several economical and biological factors. Both local and imported species were studied and 4 local families (Carangidae, Coryphaenidae, Serranidae and Siganidae) and 2 imported ones from South East Asia (Centropomidae and Ciclinae) were chosen in a first estimation among the hundred identified by Nash (1988) as potentially interesting and largely present in South East Asia (Rabanal, 1988). The results of the test are emphazised for each of the six families and a final classification in 3 groups is proposed, considering their availability to be reared and the difficulties encountered to control the whole cycle of their production in French Polynesia.

In a second step, more specific researches were conducted to develop rearing techniques on the most potential species : *Lates calcarifer.* Details of the experiments realized during the nursing (3 to 6th month) and the grow out phases (6th to 12 th month) of this species, are emphazised and detailed. Research effort was focused on the adaptation of fry and juveniles to dry pelleted diet, transferring the existing rearing techniques developed with success by IFREMER on other species as European sea bass : *Dicentrarchus labra* and Sea bream : *Sparus auratus* to the local conditions of Tahiti, caracterized by the lack of fresh fish meat supply and the cost of labour.

The demonstration of the technical and economical feasibility of sea bass net cage culture at a pilot scale level is also presented as a possible future development of finfish aquaculture in Polynesian lagoons.

MATERIAL AND METHODS

Facilities

The facilities built to conduct the finfish programme include an experimental hatchery equiped with larval rearing and weaning tanks 0,5 to 1.5 m^3 capacity and a production unit of live preys : rotifers, *Brachionus plicatilis* and artemia, *Artemia salina.* A nursery unit situated out-door with 12 circular tanks protected by a shadow net allowe to wean and grow the fry up to 50 g mean weight, feeding then with dry pellet on automatic feeders. The grow-out facilities included a series of experimental floating netcages 8 to 24 m^3 each, equiped with automatic feeders and timer and connected to the shore by a floating pontoon. A 40 mm protecting net provided an efficient protection against predators. The broodstocks were maintained in 5 circular fiberglass tanks, 15 m^3 capacity, to conduct breeding and reproduction experiments. Three laboratories of pathology, nutrition and water quality control of IFREMER were associated in these researches.

Rearing conditions

- *Origin of animals.* Fry and adults of local species were captured in the wild around Tahiti (Rabbitfish, Jack Fish, Dolphin fish) or in the Tuamotu archipelogos (Grouper). The imported ones (Seabass, red Tilapia) were air-shipped from Singapore at different stages (eggs, larvae, fry or juveniles). Flight duration, superior to 20 hours did not induce any particular mortaiity when strict packing and density were respected : 1 to 1500 eggs or larvae per litre, 300 fry per litre.
- *Stocking density.* In order to standardize the rearing conditions low density was recommended : 30 larvae per litre during larval rearing. 1 to 8 fry per litre during weaning and nursing phase, 5 to 10 kg per m^3 at the end of the grow-out phase. Higher density was occasionally tested for Seabass grow-out in cage where final density reached 30 to 35 kg per m^3.

- *Water quality.* Ocean sea water was pumped in the lagoon at a mean deep of 20 metres. Frequent monitoring revealed a constant water quality and stability of temperature (26 to 28°C) and salinity (35 ppt).
- *Food and feeding regime.* 3 kinds of diets were tested during nursing and grow-out phases :
  1. fresh bonitos-meal
  2. semi-moist pelleted diet including a mixture of 50 % of bonitos meal and 50 % of Norway fish meal
  3. dry diet pelleted in Tahiti and including 56 % of protein and 16 % of lipid in the starter diet or 52 % P and 12 % L in the grower one (Table 1).

Tab. 1. — Proximate analysis (as fed) of compounded diets pelletized in Tahiti for experimental nursing (Starter diet) and grow-out tests (grower diet)

	STARTER DIET %	GROWER DIET %
Protein	58,1	51,8
Lipid	14,4	12,1
Ash	9,5	9,0
Moisture	6,5	7,8

The amount of diet was ajusted to the feeding behaviour of each species and to the size of the fry. This amount was generally decreasing from 10 to 2.5 % of the body weight per day at the end of the grow-out period.

Design of experiments

1. Selection of species

Each species was selected according to following biological and economical criteria :

(1) growth speed and time to reach the marketable size;

(2) adaptation to dry pelleted food;

(3) capacity of reproduction and spawning in captivity;

(4) larval rearing and control of fry production;

(5) resistance to disease and stress;

(6) economical criteria as price of the product and impact on the local market were also studied.

After selection, a classification in 3 groups was proposed considering the ability of each species to be reared in captivity and their potential in aquaculture :

group 1. very high potential

group 2. interesting potential but difficulties encountered at different stages of the rearing cycle

group 3. low potential.

2. Status of Seabass research in Tahiti

During the second phase of the programme, research effort was concentrated on Seabass nursing and grow-out.

During the nursing phase (3rd to 6th month), 2 topics were studied.

a — Effect of grading frequency on survival and growth of seabass fry :

In 3 preliminary experiments, the whole population was graded, every 15 days during 3 months and dispatched in different circular tanks. Grading system was similar to the grader described by Vasselin (1984). In the last experiment, ungraded and graded batches of fry of the same population were maintained at a constant density of 500 fry/m^3. Fry were fed with dry pellets (starter diet) automatically distributed 8 hours per day and the quantity were adjusted after each grading in order to maintain the conversion ratio inferior to 1.5 : 1.

b — Effect of feed distribution and feed formulation :

In one experiment, young fry (0.7 g mean weight) and 70 days old were fed on starter diet using 2 feeding distributions : automatic feeding during 8 hours at a constant level of 10 % of the body weight per day or self-feeding, allowing a distribution by the fry themselves. Survival, growth and feed efficiency were monitored after 20 days on 4 replicates.

In 2 other experiments, 2 feed formulations, starter or grower diets were compared on 2 sizes of seabass fry (1 and 6 grams respectively) during 2 months. The effect of protein level between 52 and 56 % tested on survival and growth was analyzed on 4 replicates.

During the grow-out phase (6th to 12 th month), one experiment was carried-out in cage (8 m^3), testing 3 initial densities, 15, 30 and 60 fry per m^3. It lasted 6 months with a month lag between the two replicates, due to the limited number of fry of the same weight (30 g around). Dry grower diet was distributed every 30 minutes during a 12 hours period and the quantity varied from 3 to 1.5 % of the body weight per day.

Two other trials were conducted in larger cages (24 m^3), at a higher density of 70 fry per m^3 in order to confirm the results of the first experiment slave; feed formulation and distribution were similar to the previous test.

Data analysis

All the data collected were analysed for the following : survival rate (%) with a daily control of the mortality; mean fish weight by frequent sampling of significant number of fry; weight gain and daily weight increase; food conversion ratio in as fed and daily feeding rate.

One way analysis of variance was used to test the differences between treatments in the seabass nursing and grow-out experiments.

RESULTS

Selection of candidate species for aquaculture

The results of the test of selections are synthetized in table 2 and a classification of the species in 3 groups is consequently proposed.

Tab. 2. — Synthesis of selection of the most suitable species for aquaculture in French Polynesia

	SPECIES	SEABASS	RED TILAPIA	GROUPER	DOLPHIN FISH	RABBIT FISH	JACKFISH
Growth	A > 500 g B > 300 < 500	A	B	B	No Trial	B	B
Adaptation Dry Pellet	A = easy B = progressive C = impossible	A	A	B	No Trial	A	C
Maturation Spawning	A = natural B = induced C = no obtained	B	No Trial	A	A	A	C
Larval rearing Fry Production	A = easy B = feasible C = unsuccessfull	B	No Trial	C	C	C	No Trial
Pathology	A = resistant B = sensitive	A	B (salinity)	A	B	A	B
Price/Kg	A = high B = medium C = low	A	B?	B	B	C	C
Group 1. : High Potential Group 2. : Drawback Group 3. : No retain.		group 1	group 2	group 2	group 2	group 3	group 3

Seabass : *Lates calcarifer*, imported from Singapore and classified in group 1, has the highest potential with a fast growth speed (mean weight of 500 grams obtained in one year from the eggs), feeding fry with artificial compounded diet. Maturation and spawning have been obtained in captivity and larval rearing has been demonstrated to be feasible. His resistance to stress and disease was satisfying and it has been sold at a high price (up to 7 US $/kg on the local market.).

Group 2 included 3 species : grouper (*Epinephelus microdon)* and dolphin fish (*Coryphaena sp)* are two very potential local species for aquaculture but difficulties have been encountered to control larval rearing and fry production (Table 2). Red tilapia hybrid : *Oreochromis sp.* also imported from Singapore, has an interesting grow-out potential in sea water, but has a poor resistance to sea water when grown in net cage at

a density superior to 10 kg per m^3. Regular mortalities with necrosis were observed during the whole cycle of rearing, reducing the survival at 30 % after 6 months of growing.

Rabbitfish : *Siganus argenteus* and Jackfish : *Caranx ignobilis* were considered as difficult to rear and were classified in group 3. The first one had an unsuccessful larval rearing and a poor economical value, the second refused any kind of compounded diet although his good behaviour in net cages (Table 2).

Details of the results of selection are indicated for each criterion in following tables :

Criterion 1 : Growth speed (Table 3)

Growth speed of seabass fry, fed on local compounded diet was fast (weight gain : 100 grammes per month) compared to red Tilapia (51g) and rabbit fish (37g). Jack fish was potentially interesting (weight gain : 61 g per month) when fry were fed on a semi-moist pelleted diet confirming previous work obtained by Aquacop (1979). Grow-out potential of grouper and dolphin fish were not investigated due to the lack of wild fry available but preliminary results obtained with larger groupers gave a very first indication of his growth potential (weight gain 34 g per month).

Tab. 3. — Comparative growth speed of selected species fed on dry grower diet or semi-moist pelleted diet

CRITERION 1. GROWTH SPEED

SPECIES	SEABASS	RED TILAPIA	JACK FISH	GROUPER	RABBIT FISH
ORIGIN	SINGAPORE	SINGAPORE	TAHITI	TAHITI	TAHITI
Initial mean weight (g)	30	3	20-30	300	6
Rearing Conditions	Cage	Cage	Tank	Tank	Tank
Food	Dry Pellet	Dry Pellet	Semi-Moist	Semi-Moist	Dry Pellet
Duration (Months)	6	6	12	7	6
Survival	97	36	80	100	72
Final mean weight (g)	640	310	760	530	230
Weight gain (g. month)	102	51	61	34	37
Conversion Ratio	1,6 : 1	3,2 : 1	11,1 : 1	5,5 : 1	2,7 : 1

Criterion 2 : Adaptation to dry pellet

All the species, except in the case of Jack fish, easily accepted dry pelleted diet after a short adaptation. The trials conducted to wean wild fingerlings of Caranx on dry or re-hydratable pellet using chemical or natural attractive substances were unsuccessful. After 4 months, survival rate was inferior to 40-50 % and the daily weight gain was around 0.1 to 0.2 grammes compared to 1 g per day when fed with semi-moist pellet.

Criterion 3 : Maturation and Spawning

Except in the case of Jack fish, all the species naturally matured and spawned in captivity using or not hormone injections. Characteristics of spawning and fecondity rate are presented in table 4. The size and morphological aspect of dolphin fish brooders, with 300 grammes mean weight spawning females suggested that this species was the pompano Dolphin Fish or *Coryphaena equiselis* (Palko, 1982). The Tilapia hybrid breeding was not investigated, because bibliographical studies (Fitzgerald, 1979; Lester, 1983), suggested that no special difficulty was encountered when maturation was conducted in freshwater.

Tab. 4. — Maturation spawning and larval rearing results during selection of candidate species for aquaculture

CRITERIA 3 - 4
MATURATION / LARVAL REARING

SPECIES	SEABASS	GROUPER	DOLPHIN FISH	RABBITFISH
Origin of Brooders	Singapore	Tuamotu Archipelagos	Tahiti	Tahiti
Period of reproduction	October to May (To confirm)	December to May	December to February (Trial COP)	December to February
Spawning behaviour	Induced spawning LHRH (a) Hormone	Natural	Natural	Natural
Characteristic (Kg)				
Male	2,5 to 5	1,65 ± 0,26	0,30 ± 0,1	0,25 ± 0,03
Female	2 to 6	1,51 ± 0,24	0,32 ± 0,1	0,30 ± 0,05
Fecondity EGGS per Kg Female	780000	645000	225000	1500000
Fecondation rate	Up to 98 %	94	91	91
EGG Diameter (mm)	0,79 ± 0,02	0,857 ± 0,014	1,31 ± 0,02	0,650 ± 0,02
Origin of Larvae	Singapore or Tahiti	Tahiti	Tahiti	Tahiti
Initial Density Number/Litre	20 to 30	20 to 40	10 to 20	20 to 40
Survival	Up to 80 % (D.20)	0 % Day 24	0 % days 15	0 % Day 19
Peak of Mortality	10 to 15	3 to 5 10 to 25	5 to 15	3 to 5
Size Larvae (mm) Day 0	2,82	2,2	4,54	2,6
	Rotifer D3 to 15 Nauplii D8 to 25	D3 to 25 D12 to 25	D3 to 8 D5 to 15	D3 to 19
FOOD SEQUENCY	Artemia 2 Days old Artemia D15 to 25			

Criterion 4 : Larval rearing and fry production

The results of larval rearing experiments, conducted on 4 of the 6 species, suggested that only seabass larvae were successfully reared up to methamorphosis (Table 4). Survival rate reached 50 to 80 % on day 20 with eggs and larvae imported from Singapore.

Rabbitfish, Grouper and Dolphin fish larvae were particularly difficult to rear and no successful survival rate was obtained after 20 to 25 days although, some methamorphozed grouper larvae were observed.

Weaning larvae after the first month of rearing on a dry pelleted diet, including a high percentage of protein was feasible with seabass and several batches were produced. The over-lapping from live prey to artificial pelleted diet allowed to obtain weaned fry with a survival rate superior to 50 % and a final mean weight of 1 to 2 grammes after the third month. Frequent grading were provided, every 8 to 10 days period to prevent strong cannibalism appearing as soon as lived preys were replaced by artificial dry pellet.

Fresh water red Tilapia hybrid larvae (mean weight, 0,7 grammes), imported from Singapore were gradually adapted to seawater in 10 days. Results of survival (94 %), growth speed (final mean weight = 2,6 grammes) and feed efficiency (conversion ratio inferior to 2 : 1), after one month, revealed a satisfying acclimatation of these larvae to seawater conditions of Polynesia, when reared in tanks.

Wild fry of Rabbitfish were easily observed in dense school, 2 or 3 months after the spawning season but mass collection was limited by the difficulties encountered to predict time of schooling and strong fluctuations from year to year.

Criterion 5 : Pathology, resistance to stress

The parasite : *Cryptocaryon irritans*, commonly observed in tropical waters was a major pathogen agent in Tahiti. All the species, excepted red Tilapia, were very sensitive when maintained in tanks, specially Dolphin and JackFish (Table 5). Nematode and cestode parasites were also encountered in large number in wild grouper brooders originated from Tuamotu archipelagos and all the tentatives to eradicate revealed unsuccessful. Handling Jackfish and Dolphin fish was difficult and necroses often followed by death were observed when manipulated. Other handling problem was noticed with Rabbitfish which presents a venomous barb on his dorsal fin.

All the species were adapted to the salinity of Polynesian water except the red Tilapia strain imported from Singapore which presents necrosis when reared at high density in netcages.

Criterion 6 : Price on local market

Seabass had the highest price (up to 7 US $/Kg) on local market (wholesale) and is a successful seafood product due to its delicious taste and presentation. Dolphin Fish and Grouper, commonly caught around Tahiti and Tuamotu Archipelagos are sold at a mean price of 5 to 6 US $/Kg. The price of Tilapia (6 US $/Kg) has to be confirmed on a larger

quantity as common Tilapia *(O. Mossambica)* is not consummed in Tahiti. Jackfish and Rabbitfish have the lowest price of 3 to 4 US $/Kg.

Tab. 5. — Parasitism and resistance to handling of the selected finfish species

CRITERION 5
PATHOLOGY — RESISTANCE TO STRESS

	SEABASS	RED TILAPIA	JACK FISH	GROUPER	RABBITFISH	DOLPHIN FISH
PARASITISM						
EXT : *CRYPTOCARYON IRRITANS*	+ +	0	+ + +	+ +	+	+ + +
INT : NEMATODE	0	0	0	+ + +	0	0
CESTONE	0	0	0	+ + +	0	0
HANDLING	0	0	+ + +	0	+ + (Venomous Barb)	+ + +
SALINITY 35 %	0	+ +	0	0	0	0

+ + + Very high sensibility
+ + Average sensibility
+ Low sensibility
0 No sensibility

Status of seabass research in Tahiti. Nursing phase (3rd to 6th Month)

Effect of grading frequency

The results of the three preliminary experiments conducted in tanks, with a grading frequency of the whole population, every 15 days, are indicated in Table 6. Survival rate exceeded 85 % and the mean weight of fry was superior to 25 grammes after 3 months at a final density of 5 to 8 Kg per m3. The weight dispersion indicated by the final coefficient of variation fluctuated from 32 to 64 % depending on the trials. Food efficiency was satisfying and the conversion ratio was inferior to 1,5 : 1 for a daily feeding rate decreasing from 10 to 4 % of the body weight per day.

In the last experiment (Table 6), if we consider the lost of 10 % of the animals by accident in the second ungraded tank on day 60, survival results were not strongly affected when fry were not graded in tanks as soon as the feeding regime was satisfying. Mortality related to cannibalism appeared after the 2nd month in both tanks affecting 20 to 30 % of the population, against 7 % in the control. Growth and weight dispersion were depending on the treatments with a better final mean weight (45 against 27 g) but a higher dispersion when fry were not graded. Frequent grading of fry allowed to maintain a better homogeneity of the population as indicated by the weigh frequency polygon of each batch (Figure 1). Food intake was not affected by the treatment and the final conversion ratio did not exceed 1 to 1,1 : 1.

In comparison, the nursing of seabass in net cages, as early as the 3rd month (Table 6) induces strong mortality with necrosis and cannibalistic behaviour in our rearing conditions. Survival did not exceed 30 to 50 % when fry were ungraded and in the two trials, final mean weight reached 60 to 70 g correlated to low survival. Nevertheless, food efficiency was satisfying and the conversion ratio was not surperior to 1,5 : 1.

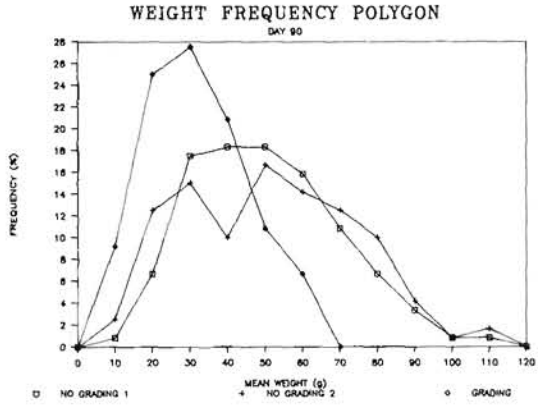

Figure 1. — Weight frequency polygon of Sea bass fry after 3 months of experiments. Two batches were not graded (1 - 2)and one (3) was graded every 15 days.

Effect of feeding regime and feed formulation

Survival was not affected when young fry were fed with automatic feeders or with self-feeders and no cannibalism was noticed (Table 7 - Trial 1). After 20 days, the final mean weights were not significantly different (3,4 and 3,7 g respectively). The advantage of using a self-feeder appeared on the feeding efficiency with significant better conversion ratio : 0,97 : 1 against 1,4 : 1 when fry were fed with automatic feeder. This preliminary experiment suggests that seabass fry are able to adapt their consumption as early as the 2nd month of rearing (Figure 2), when self-feeder is used. At the end of the experiment daily feeding rate was exactly adjusted to 7 % of the body weight for the fry fed with self-feeders.

The comparison of two formulations, starter or grower diet (Table 1), on survival and growth of seabass fry during nursing are indicated in Table 7 (Trial 2 and 3). For 2 weight ranges (1 and 6 grammes, initial weight), in the 2 trials, survival was very high and mortality was limited to 2 or 3 animals, during the 2 months of experiment. Significant growth differences appeared on youngest fry when fed with the higher protein level (56 % compared to the grower ($F=7,74$ $DF=6$ and $P<0,05$) and conversion ratio reached 1.1 : 1 and 1.3 : 1 respectively. In the case of larger fry (initial mean weight 6 g), results of growth speed and food efficiency were similar (Table 7), suggesting that seabass fry could be fed with grower diet as soon as their mean weight reaches 5 to 6 grammes.

Tab. 6. — Result of the effect of grading frequency on survival, growth and feed efficiency of seabass fry. Experiments are conducted in circular tank, 1,5 m³ of capacity or in cage, 8 m capacity

TREATMENT	REARING STRUCTURE	DURATION (Days)	INITIAL Number	SURVIVAL (%)	INITIAL WEIGHT (g)	DAILY WEIGHT INCREASE (% Day)	FINAL WEIGHT (g)	FINAL COEF. of variat.	CONVERSION Ratio (asfed)	REARING VOLUME (m^3)	DENSITY Kg/m^3
Grading	Tank	95	5.855	Variat. 86	1,1	3,3	25,6	39	0,9 : 1	21	6,1
Every	Tank	80	4.627	95	181	3,2	23,8	64	1,4 : 1	13,5	8,1
15 Days	Tank	70	1.496	86	0,3	6,5	27,6	32	1,2 : 1	7,5	4,7
No Grading	Tank	90	450	83	0,8	4,4	44,9	44	1,01 : 1	1,5	11,2
No Grading	Tank	90	450	63 *	0,8	4,5	46,0	50	1,01 : 1	1,5	9,4
Grading	Tank	90	1.113	93	0,8	3,9	27,4	47	1,05 : 1	4,5	6,3
No Grading	Cage	90	3.600	30	1,2	4,5	70,1	27	1,2 : 1	8	9,5
No Grading	Cage	90	3.600	56	2,3	3,7	64,0	28	1,1 : 1	8	16,1

* lost of 10 % of the population on day 60 by occident.

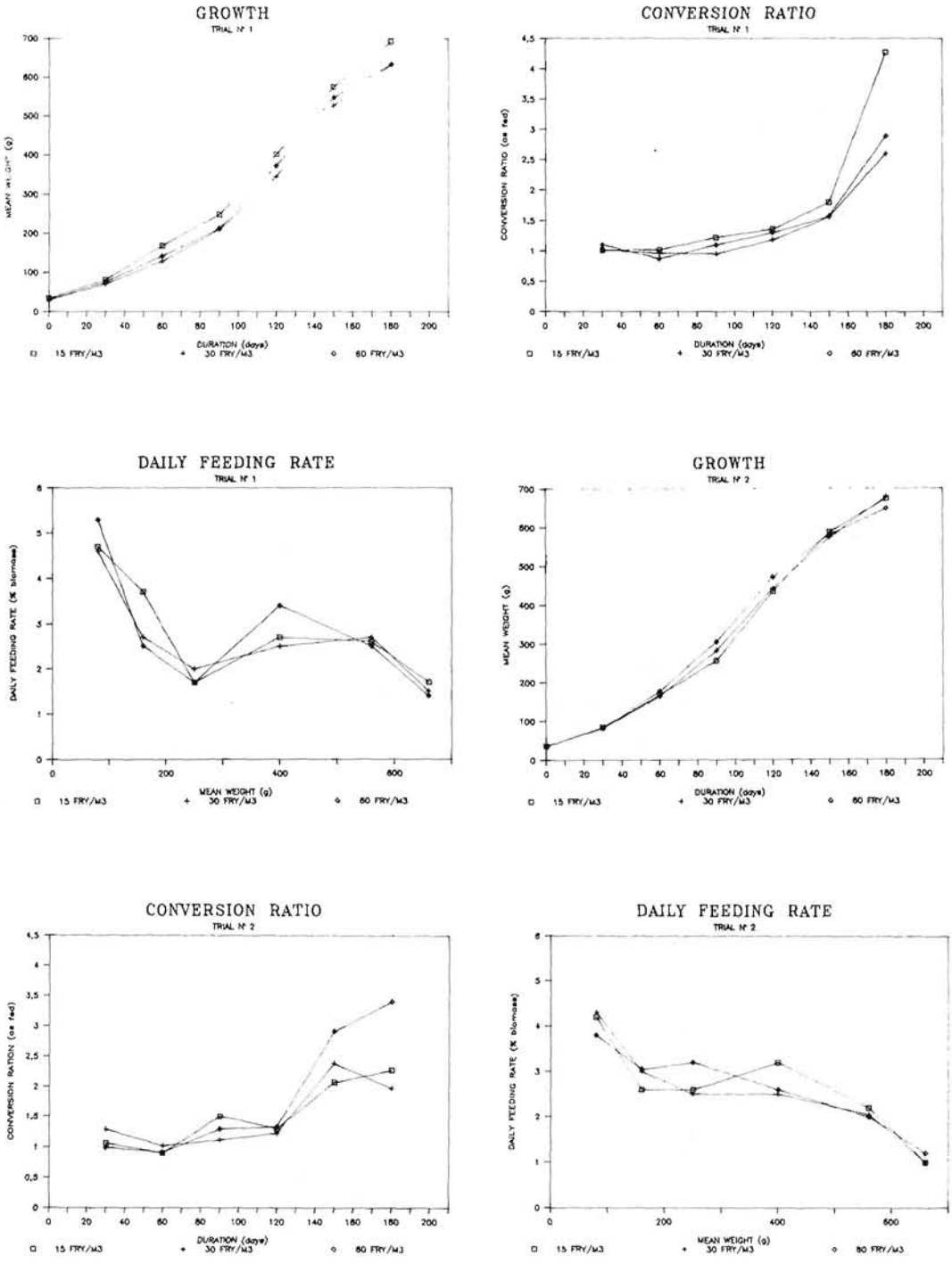

Figure 2. — Growth, conversion ratio and daily feeding rate of sea bass fry, reared in 8 m^3 netcages at initial densities of 15, 30 and 60 fry per m^3, during 6 months and fed on a 52 % protein and 12 % lipid compounded diet (Trial 1 and 2).

Tab. 7. — Results of the effects of the feeding regime and feed formulation on survival, growth and feed efficiency of seabass fry. Experiments are conducted in cylindro-conical tanks (150 liters capacity) in trial 1 and in rectangular tanks (800 liters capacity) in trials 2 and 3

TRIAL	TREATMENT	DURATION (Days)	INITIAL Number	SURVIVAL (%)	INITIAL Weight (g)	FINAL Weight (g)	DAILY WEIGHT Increase (Day)	CONVERSION Ratio	DENSITY Kg/m^3
1	Automatic	20	4 × 60	99,9	0,8	3,4	7.2	1.4 : 1	1,4
	Self-feeder	20	4 × 60	99,1	0,8	3,7	7.6	1.0 : 1	1,5
2	Starter	50	4 × 60	99.6	1.0	12,5 ***	5,05	1,01 : 1	3,7
	Grower	50	4 × 60	99,2	1,0	11,1	4,8	1,3 : 1	3,3
3	Starter	44	4 × 60	100	6,7	33	3,6	1.0 : 1	9,8
	Grower	44	4 × 60	100	6,7	31	3,5	1.0 : 1	9,3

(*** F = 7,74 DF = 6 P = 0,05).

Tab. 8. — Effect of the density on survival, growth and feed efficiency of seabass fry in 8 m^3 net cage fed on a 50 % protein and 12 % lipid compounded diet.
TRIAL 1 : Starting Oct. 24. 1985
TRIAL 2 : Starting Nov. 24. 1985

INITIAL STOCKING DENSITY (Fry/m^3)	DURATION (Months)	INITIAL Number	% Survival	INITIAL MEAN WEIGHT	FINAL MEAN WEIGHT	DAILY WEIGHT (% days)	DAILY FEEDING (% biomass)	CONVERSION RATIO (asfed)	FINAL DENSITY (Kg/m^3)
				TRIAL 1					
15	6	120	89	30,6 ± 1,2	692 ± 22	1,7	2,6	1,7 : 1	9,3
30	6	240	97	30,6 ± 1,2	634 ± 14	1,7	2,6	1,5 : 1	18,4
60	6	480	96	30,6 ± 1,2	633 ± 10	1,7	2,6	1,7 : 1	36,4
				TRIAL 2					
15	6	120	97	32,4 ± 1,2	674 ± 17	1,6	2,8	1,6 : 1	9,9
30	6	240	97	32,4 ± 1,2	677 ± 16	1,6	2,7	1,5 : 1	17,6
60	6	480	98	32,4 ± 1,2	648 ± 10	1,6	2,7	1,7 : 1	38,0

Tab. 9. — Grow out of seabass fry in 24 m^3 net cages, fed on a 50 % protein and 12 % lipid compounded diet.
Trial 1 : Fry originated from Singapore, arrival July 1987
Trial 2 : Fry originated from Singapore, arrival August 1987.

INITIAL STOCKING DENSITY DENSITY (FRY/m^3)	DURATION (months)	INITIAL Number	SURVIVAL	INITIAL MEAN WEIGHT (g)	FINAL MEAN WEIGHT (g)	DAILY WEIGHT INCREAS (% days)	DAILY FEEDING RATE (% biomass)	CONVERSION RATIO (Asfed)	FINAL STOCKING DENSITY (Kg/m^3)
				TRIAL 1					
70	6	1700	94	28,9 ± 2,0	321,3 ± 22	1,3	2,1	1,9 : 1	21,5
70	6	1700	62	33,2 ± 3,6	315,8 ± 15,3	1,3	2,4	2,9 : 1	13,9
					TRIAL 2				
68	5	1642	96,8	75,1 ± 6,1	403,2 ± 20,7	1,1	2,1	1,9 : 1	26,7
68	5	1642	96,8	77,5 ± 6,0	406,5 ± 22,1	1,1	2,0	1,9 : 1	27,0

Grow-out phase (6th to 12th months)

General results of effect of the density in net cage on survival and growth of seabass fry are indicated in Table 8. Survival rates, in all cages, exceeded 85 % after 6 months and were not correlated with the initial stocking density in a range of 15 to 60 fry per m^3. Mortality was related to accidental loss during net shifting. The final mean weight were very similar and varied in a range between 630 and 690 g corresponding to a daily weight increase of 1,6 to 1,7 % per day (Figure 3). No significant growth difference appeared as shown by results of analysis of variance ($F = 2,217$ $DF = 2,3$ NS $P < 0,266$), although the final density ranged 9,3 to 38 kg per m3. Food efficiency was satisfying and conversion ratio were not exceeding 1,7 : 1, feeding fry from 5 to 1,5 % of the body weight per day during the experiment (Figure 3).

The results of the 2 grow-out trials of seabass conducted in larger cages (24 m^3 capacity) and at high density (70 fry per m^3) are indicated in Table 9.

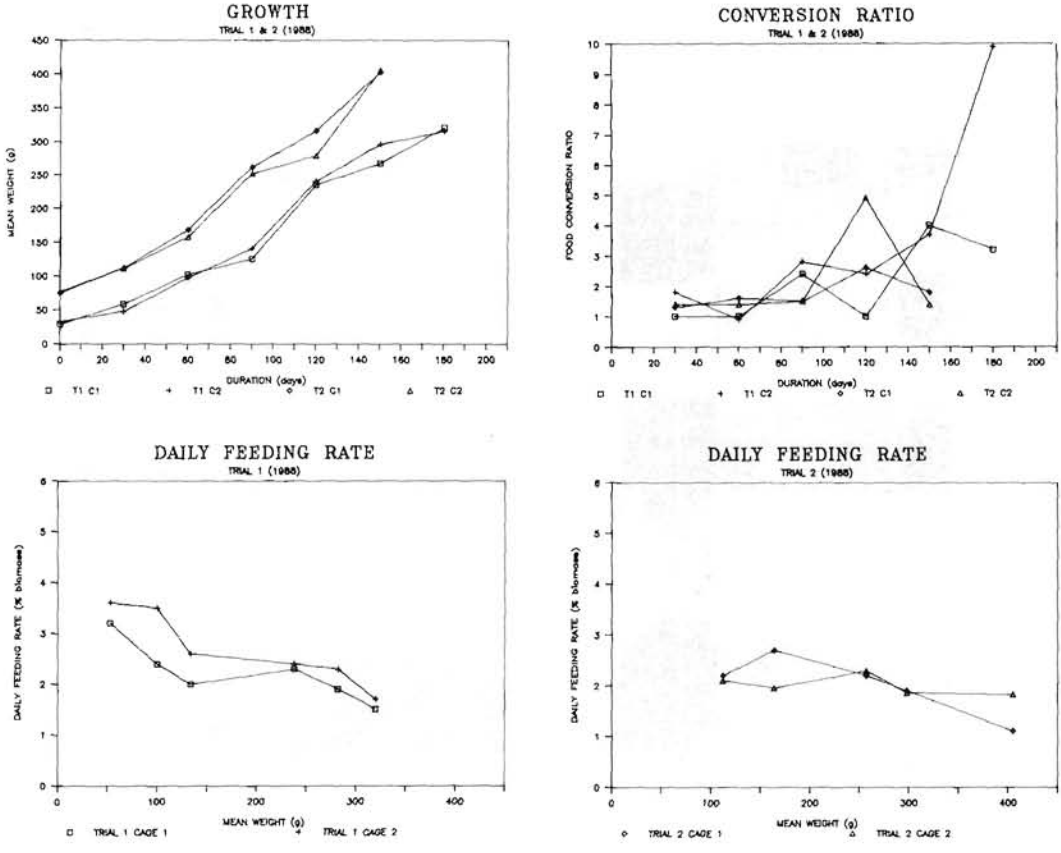

Figure 3. — Growth, conversion ratio and daily feeding rate of sea bass fry, reared in 24 m^3 netcage at an initial density of 70 fry per m^3, during 6 months and fed on a 52 % protein and 12 % lipid compounded diet (Trial 1 and 2).

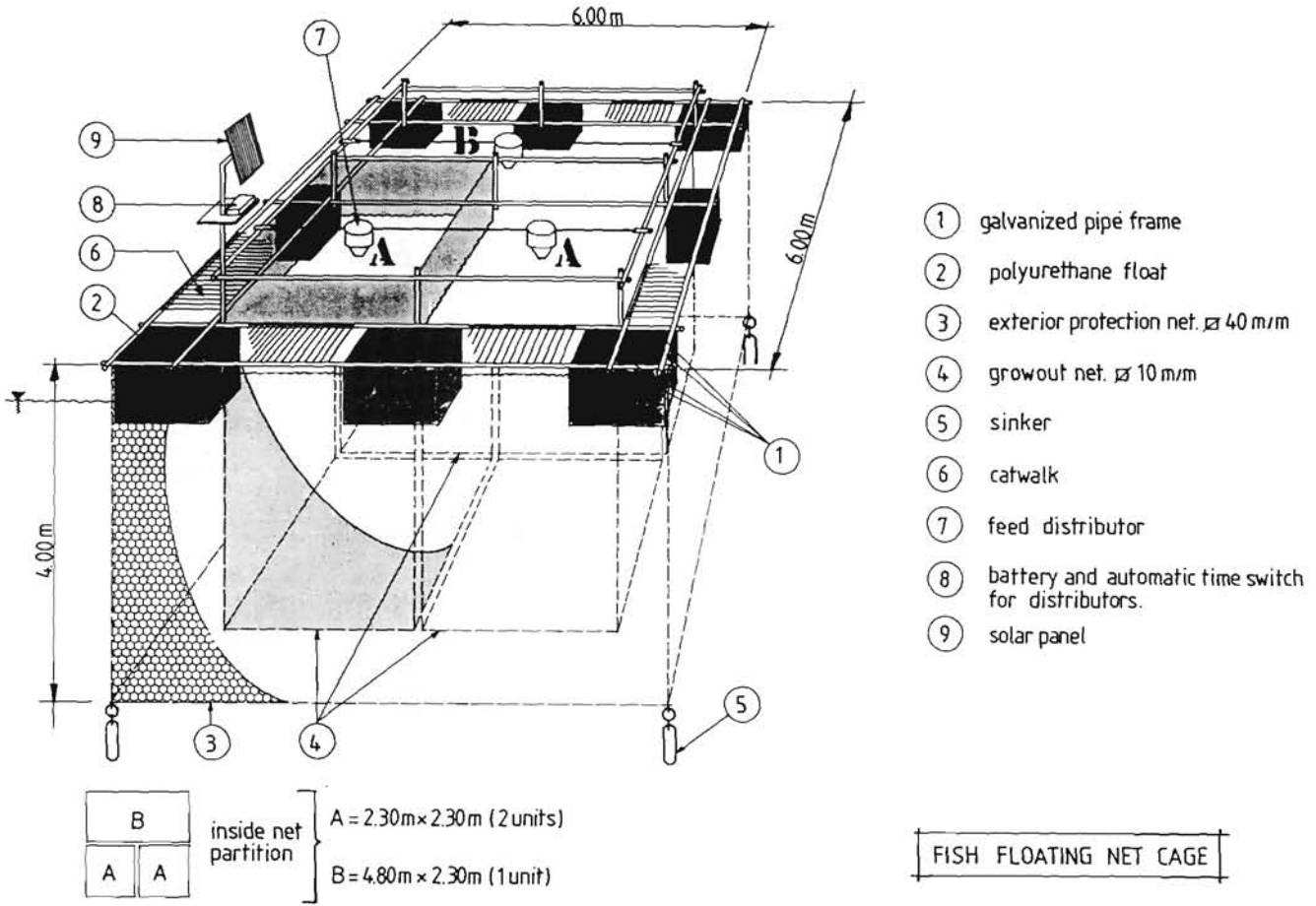

Figure 4. — Detail of the pilot-scale structure and equipment (capacity 75 m^3) for sea bass grow-out.

In both cases, survival was excellent, except in the second cage of trial 1 were 25 % of fry were eliminated after 3 months due to their low growth related to malformations. Final mean weight varied in a range of 316 ot 403 g and the daily weight increase was not exceeding 1,1 to 1,3 % (Figure 4).

The final density was 27 kg per m3 for the best trial and the conversion ratio varied from 1,9 : 1 to 2,9 : 1. Growth speed differences compared to previous experiment conducted in 8 m^3 cages suggest that fry quality and size of the cages are two parameters which need to be investigated in the futur.

DISCUSSION

Among the criteria retained to select suitable finfish species for aquaculture, a number of biological factors have to be considered as growth efficiency, mortality, grow-out, disease and crowding (Wu, 1989). Economical factors as the supply and the price of the fry, the price of adult, the cost of production have a major importance in the insular situation of French Polynesia which is confronted to the problem of high freight cost, low availability of lands and high price for food and energy.

The results of the tests of selection, conducted by IFREMER from 1983 to 1987 in Tahiti have clearly revealed that only a limited number of local finfish species had a high potential for aquaculture in French Polynesia. One of the major difficulties were related to the lack of fry supply from the wild and the problems encountered to control the seed production in captivity.

Rabbitfish, *Siganus argenteus*, is the only local species which presents the characteristic to form dense schools of fry in the vicinity of reef flats after the spawning season. Thece formations seem to be related to lunar cycle (Duray, 1988) but this supply strongly fluctuate from year to year with frequent break down of the recrutment, restricting the possibility of developing a large aquaculture project based on a supply of wild fry. For the other local species, research efforts have been carried-out for a better understanding of the cycle of reproduction as for grouper *E. microdon* (Debas et *al.*, 1989) but larval rearing is not yet controlled and only a limited number of metamorphosis larvae have been obtained in captivity.

The importation of two species, originated from South-East Asia, Seabass, *Lates calcarifer*, and red Tilapia hybrid, *Oreochromis sp*, allowed to extend the programme of selection to species of economical interest where feasible seed production techniques have already been developed : Seabass in Thailand (Srikul, 1987); red Tilapia in Taiwan and Singapore (Pullin, 1984; Cheong, 1987).

After screening several biological and economical criteria on the six local and imported species, four have been retained as potentially interesting for aquaculture in French Polynesia.

The tests of selection revealed that seabass, *Lates calcarifer*, performed well and was easily adaptable to the environmental conditions of French Polynesia. The advantage of this species was related to his ability

to actively eat on a dry pelleted diet as early as the 2nd month of rearing. Marketable size (4 to 500 g mean weight) was obtained in about 12 months from the eggs, raising fry in net cages at high density which confirm preliminary tests conducted in Tahiti (Fuchs, 1986) and in Australia (Mackinnon, 1986). First breeding and larval rearing experiments have already been achieved and encouraging results have been obtained testing traditional Seabass larval rearing (Maneewong, 1986) or adapting techniques developed by IFREMER on other species as European seabass (Chatain, 1986; Ronzani Cerqueira, 1986). Interest of this species for the local market has been demonstrated and a regular supply is actually requested at a high price.

In comparison, the three other selected species, red Tilapia, Grouper and Dolphin Fish, although their high potential for aquaculture, present several drawbacks indicating that more researches have to be resumed up to solve a number of critical points.

Grouper, *Epinephelus sp* is a species of economical interest in Asia and many laboratories are developing important research on breeding and larval rearing to overcome the problem of seed production like in Singapore (Chen, 1979), Hong Kong (Tseng, 1983), Malaysia (Chua et *al.*, 1980) and Koweit (Akatsu et *al.*, 1983). Local grouper, *Epinephelus microdon* appears to be a good candidate for aquaculture in French Polynesia due to its economical interest and its ability to be raised in captivity. Research efforts have been focused on the identification of the cycle of reproduction and the description of the sex reversal phenomeneous of this hermaphrodite species (Debas et *al.*, 1989). Maturation and spawning have been achieved in captivity without encountering difficulties in opposition to other grouper as *E. tauvina* where the obtention of ripe male is a major problem. Larval rearing results suggest that *E. microdon* larval are difficult to raise. This fact actually limits his propagation in aquaculture. More investigations with possible cooperations with foreign laboratories are needed to increase the knowledges on this interesting species before reaching the larval rearing results obtained with *E. tauvina* in Koweit (Saif et *al.*, 1986). Grow-out potential has also to be investigated to confirm or not the preliminary results revealing the lower growth speed of *E. microdon* compared to other grouper species like *E. tauvina.*

Dolphin Fish, *Coryphaena sp*, is certainly a very exciting species, regarding its growth potential (2 to 6 kg in one year) compared to the other finfish species. Recent advances in Hawaii demonstrated that breeding and fry production were under control at an experimental scale when precises and detailed rearing conditions were provided (Kraul, 1989). Survival rate reached 10 % on day 40 when fry were fed on fresh natural food. Preliminary investigations have been conducted in Tahiti after the successful catch of some Dolphin fish juveniles, identified as Pompano *C. equiselis.* Their behaviour has been observed during 3 months and some maturations and spawning obtained but larval rearing results revealed unsuccesssful despite numerous feeding regime trials. This species has been retained as potentially interesting but an important research effort is necessary in order to develop adapted rearing technics. Its growth potential in floating net cage at high density has also to be verified, considering the agressive behaviour of males, observed as soon as sexual maturity appears.

Red Tilapia hybrid, *Oreochromis sp*, largely reared in Taiwan and recently adapted to sea water in intensive conditions in Singapore (Cheong, 1987) has a good potential regarding its growth speed and the easiness to produce large number of fry. The difficulties encountered in Tahiti were related to regular mortalities observed during grow-out in sea water net cages at high densities. The hypothesis of a low resistance of this strain to the rearing conditions and particularly to the high salinity was emphasized, although L. Cheong (1986) obtained good survival and growth in sea water ponds at a final density superior to 30 Kg per m3. More investigations have to be done to select a suitable strain adapted to our conditions, for example the Florida red Tilapia strain considered by Watanabe (1989) as a good candidate due to its resistance to intensive rearing conditions in sea water both in tanks or cages. Its economical interest has also to be demonstrated because the strong variation of the red color of the selected strain could break the value although its interest has been demonstrated.

The tests of selection revealed that local Rabbit fish and Caranx species, apparently interesting, were difficult to rear in captivity. The preliminary results obtained by Pillai (1962) on Rabbit fish suggested that this family had a great potential in aquaculture with an abondance of wild fry and the possibilities to feed fry with low protein diets or algae. The tests of selection, conducted in Tahiti on *Siganus argenteus*, previously studied by Tobias (1976) and Burgan et *al.*, (1979) revealed three major problems : larval rearing is not successful, compared to the encouraging results obtained by Duray (1988) on *Siganus guttatus*, the handling is delicate and his economical value is low. Among carangidae, many species have a high potential in aquaculture as Yellow tail, *Seriola quiqueradiata* in Japon, *Trachinotus carolinus and T. falcatus* in French West Indies (Soletchnik, 1988). The case of local *Caranx ignobilis* is different and this species has not been retained in the selection tests althought preliminary encouraging results have been obtained by Aquacop (1975), feeding fry with semi-moist pelleted diet. Maturation and larval rearing have never been observed in captivity and fry are not available in the wild in large number. Feeding fry with dry pellet is difficult and nutritional studies would be necessary to develop an artificial pelleted diet adapted to the requirement of the species.

CONCLUSION

Seabass : *Lates Calcarifer*, imported from Singapore appears to be the most potential finfish species in aquaculture for the next few years in French Polynesia and a project of net cage culture at a pilot-scale level has been recently drafted. The mean objective of this 3 years programme is to demonstrate the technical feasibility of its grow-out and to verify the economical interest of its aquaculture in French Polynesia. Annual productions of 20 tonnes in 5 units is expected with the participation of territorial organisms in charge of the development and the training of futur farmers.

Each pilot built in galvanized pipe frame and equiped with protected net and automatic feeders (Figure 4) is calculated to produce 2200 Kg of marketable size of Seabass (450 to 500 grams, mean weight) per cycle of 6 months, in 75 m^3 net cage, at a final density of 30 Kg per m^3. A quantity of 6000 fry are requested for each cycle of production in a pilot. Financial estimation gives a cost of investment of around 10,000 US $/unit and a cost of production of 6 US Dollars per Kg corresponding ot a net gain of 1 to 1,5 US$/Kg. In this calculation, the cost of pellet and fry corresponds to 50 and 58 % of the operating cost. Priorities of research have consequently been identified as follows :

- larval rearing and fry production cost could be easily reduced, transferring and adapting the technologies of microparticulate diet developed with success on other species as European seabass, *Dicentrarchus labrax* in France (Person Le Ruyet, 1989). Partial substitution of live preys by artificial diet would be of major interest and preliminary experiments are encouraging.
- the transfert of seabass fry in net cage as early as the 2nd month of rearing would drastically reduce the cost of production but cage design and rearing conditions have to be improved as it has been recently done in Singapore (Lim et *al*, 1986).
- nutritional requirements of seabass, initiated by Chou (1985) and AQUACOP et *al.*, (1989) have also to be completed to propose a performing formulation adapted to the needs with lower cost ingredients instead of expensive fish meals.

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