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SUMMARY - When considering the intensive culture of marine fish species and the relationships between aquafeeds and the environment, a major factor influencing the pattern of effluent discharge to the environment is the culture system employed. This paper presents the results of a one-year study on the retention and discharge of nitrogen (N) and phosphorus (P) from a pilot cage farm for on-growing gilthead seabream (*Sparus aurata*) located in the Canary Islands (Melenara bay, Gran Canaria). Throughout this period, data on fish weight, and body and feed N and P content were collected every three months. In addition, sediments from different areas beneath the cages were also analysed for N and P content at two monthly intervals. The results obtained concerning percentages of N and P retention during the study were similar to those reported by commercial feeds manufacturers for the same species when calculated for similar extruded diets and culture systems. Moreover, analyses of nutrients within the sediments below the cages over the course of the study revealed no noticeable accumulation of solid particulate wastes from the farm.

Key words: Aquaculture, environmental impact, seabream, cage, mass balance.

RESUME *- "Rétention et rejets de nutriments d'une ferme marine avec cages dans les Iles Canaries. Résultats préliminaires". Si l'on considère l'élevage piscicole d'espèces marines et les rapports entre l'aliment et le milieu, les structures utilisées peuvent changer le modèle d'élimination des effluents dans le milieu. Ce travail présente les résultats de rétention et rejet d'Azote (N) et de Phosphore (P) obtenus pendant une année, dans une ferme pilote d'élevage de daurade (Sparus aurata) utilisant des cages et située dans les Iles Canaries (Baie Melenara, Gran Canaria). Pendant cette période on a recueilli des données concernant le poids des poissons, et les teneurs en N et P du corps entier et des aliments tous les trois mois. Les sédiments prélevés dans différentes zones sous les cages ont également été analysés pour connaître leur teneur en N et P tous les deux mois. Les résultats concernant les pourcentages de rétention des nutriments obtenus dans ce travail sont similaires à ceux obtenus par des producteurs d'aliment pour poisson, en calculant ces pourcentages pour des aliments et des structures d'aquaculture semblables à ceux testés dans ce travail. Les teneurs en nutriments des sédiments pendant le temps d'expérimentation ont révélé qu'il n' y avait pas eu d'accumulation notable de particules solides provenant de la ferme.*

Mots-clés *: Aquaculture, impact environnemental, daurade, cage, bilan de masse.*

Introduction

Recognizing the links between the environment and the sustainability of aquaculture, one of our main goals is to try to predict the occurence of possible adverse environmental impacts of aquaculture development, so as to take measures to avoid, reduce or remedy them where ever possible. Nutrient loading (nitrogen and phosporus principally) from fish culture facilities can be separated broadly into a dissolved fraction and a particulate fraction. Solid wastes consist almost exclusively of uneaten feed pellets and faecal pellets. Some of this material is eaten by wild fish as it settles and some is lost in the water column by dissolution. Most, however, settles to the sea bed near the cages where it is either consumed by benthic fauna or decomposed by bacteria. Those nutrients absorbed in excess by the cultured fish are excreted together with the end products of protein catabolism in the form of dissolved ammonia and urea, through the gills. The reported negative effects of these nutrients and waste products under extreme conditions include the depletion of dissolved oxygen, the generation of carbon dioxide, hydrogen sulphide and methane from anoxic sediments, changes in the benthic macrofauna, hypernutrification and eutrophication, and the development of toxic algal blooms.

Thus, in general terms the environmental impact of aquaculture, and that of floating cage farming in particular, is mainly a function of feed composition and feed conversion. In addition, rearing techniques, chemical usage, site selection, size of farm and type of organisms cultivated should also be considered as important factors.

The **nutrient-budget balance or mass balance model** (Gowen *et al.*, 1988) is generally used to assess the relationships between feed nutrients input, nutrient retention in the cultured fish, and nutrient release to the environment in relation to a given production tonnage. In general terms, about 25 percent of the nutrients offered to cultured fish via feeds in the form of pellets is retained in the fish flesh, while about 75 percent will be discharged to the environment (Figure 1); 62% as dissolved nitrogen and 11% as dissolved phosphorus, and 13% nitrogen and 66% phosphorus in the form of solid wastes (Folke and Kautsky, 1989).

Several authors have reported mass balances for nitrogen and phosphorus in different fish species (Table 1). We can see that there exist differences not only among species, but also within a particular fish species, depending upon the different feeds employed, feeding regimes, culture systems and environmental parameters of a particular location.

The aim of the present investigation was to study the retention and discharge of nitrogen and phosphorus from a pilot cage farm, located at Melenara Bay, Gran Canaria, Canary Islands, over a one year on-growing cycle of gilthead seabream (Figure 2). Nutrient and organic matter levels within the sediments under the cages were also studied over this period.

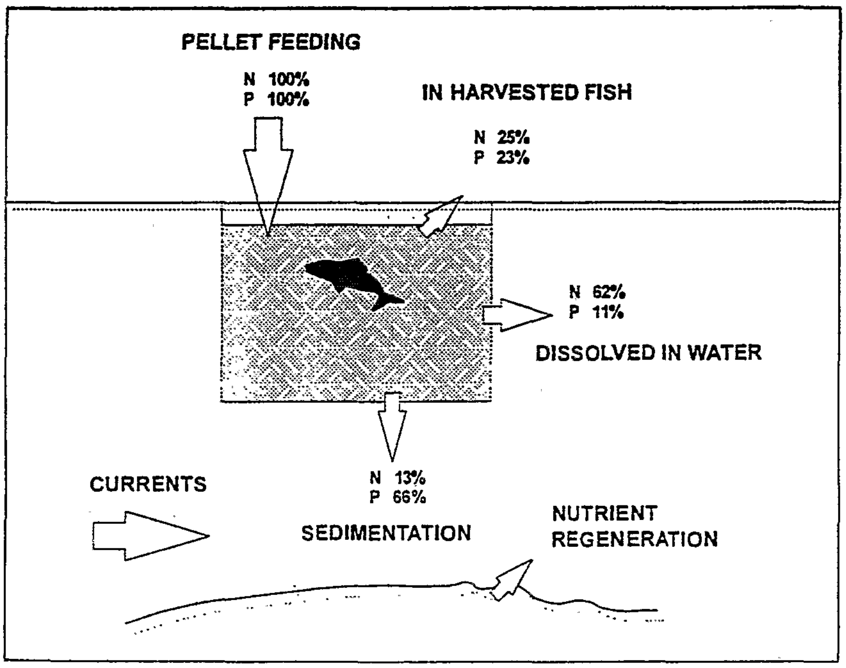

Fig. 1. Diagram showing main nutrients budget in a fish farm (modified from Folke and Kautsky, 1989).

Table 1. Repoted mass balance of nitrogen and phosphorus for different fish species

Fish species		Nutrient feed content	Nutrient fish retention	Nutrient loading	Reference
Catfish *Ictalurus punctatus*	(Ponds)	5% N 1% P	28 % N 29 % P	72% N 71% P	Schwartz and Boyd,1994a
Rainbow trout *Oncorhynchus mykiss*	(Cages)	6-9% N 1.1-1.6% P	27-28% N 17-19 % P	67-71% N 78-82% P	Hall et al. 1990 Holby and Hall, 1991
	(Cages)	-	26 % N 18 % P	74% N 87% P	Enell, 1987
	(Cages)	-	27.7% N 29.8% N	72.3% N 70.2% P	Ackefords and Enell, 1990
Salmon *Salmo salar*	(Cages)	-	25% N 23% P	75% N 77% P	Folke and Kautsky,1989
Gilthead seabream *Sparus aurata*	(Ponds)	6% N 1.2% P	26% N 21% P	74% N 79% P	Neori and Krom,1991
	(Cages)	7.5% N 1% P	22.2% N 27.8% P	77.8% N 72.2% P	Ewos, S.A., 1996

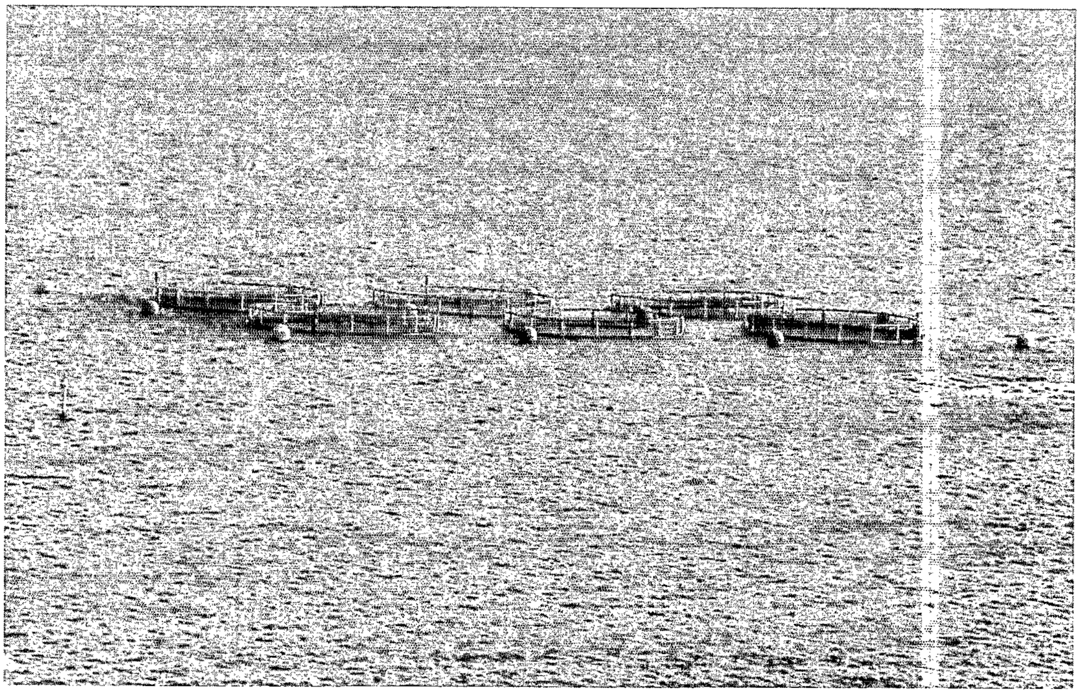

Fig. 2. Pilot off-shore cage farm at Melenara Bay, Gran Canaria, Canary Islands.

Material and methods

The pilot farm belongs to the Aquacuture Research Group (Universidad de las Palmas de Gran Canaria, and Instituto Canario de Ciencias Marinas), and has been operated by a private company (ADSA) since 1994 by means of an Agreement of Cooperation that allows the company to carry out the production of seabream and seabass on a commercial scale. In return, our research group is funded to carry out several research projets on the farm, including the assessment of biological, engineering and economic feasibility, and environmental impact studies.

Six flexible, poliestirene off-shore cages, 12 meters in diameter and 8 meters mesh depth each (900 m^3), were anchored at an average depth of 20 meters above a sandy bottom. Fish stocked in these cages were fed by hand, four times a day, using feeding tables provided by feed producers and later modified by the farmers according to fish performances.

Over a one year cycle (i.e. from June 1994 to August 1995) 350 fish from one cage (i.e. 1% of the cage population from cage nº 5) were weighed at three monthly intervals, and 24 fish sacrificed for analysis of body nitrogen and phosphorus content. In addition the various extruded commercial diets employed on the farm over this period were also analysed for nutrient content. Total nitrogen content was estimated using the Micro-Kjeldhal technique with a Tecator/Kjeltec System 1002 distilling unit (AOAC, 1985). Phosphorus content was estimated as reactive molibdate phosphorus using spectrophotometry (Strickland and Parson, 1972), after digestion with concentrated nitric and perchloric acids (Burton and Riley, 1956). Data were later recalculated for the total biomass of that particular cage, and extrapolated for every cage in operation during that time period, using growth, biomass and feeds usage data provided by the private company. Nitrogen and phosphorus retention percentages for every cage were calculated using the "protein productive value" formula:

$$PPV = \frac{\text{Mean final N - Mean initial N}}{\text{Ingested N}} \times 100$$

where values of nitrogen and phosporus where employed, respectively.

Sediment samples were collected by divers using PVC cores of 25 cm length and 8 cm internal diameter with screw covers at the ends. Three influence zones (1, 2 and 3) were sampled every two months: underneath the cages (two sampling points); 60 meters from the cages (four sampling points); and 200 meters from the cages (four sampling points) (Figure 3). Two samples were taken at every point, where exclusion chambers were previously located to avoid the action of predators on the sediments.

In order to determine organic matter, weighed sediment samples were dried in an oven at 105°C until constant weight, and then ashed in a muffle furnace at 650°C for 12 hours (AOAC, 1985). The nitrogen and phosphorus content of the sediments were estimated using the methods described previously.

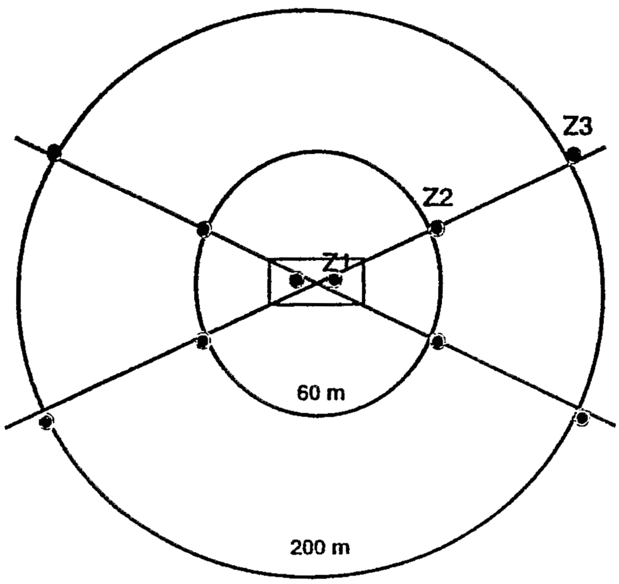

Fig. 3. Diagram showing the different sediment sampling zones. (Z1, Z2 and Z3: Zones 1,2 and 3, respectively).

Results and discussion

The growth of gilthead seabream stocked within cage number 5 over the one year production cycle is shown in Figure 4. It can be seen that during summer (July - October) there was a slight improvement in growth, due to elevated water temperatures over this period (23-24°C versus 17-19°C in winter). It is interesting to mention here the constant growth of this species obtained under these almost constant water temperature regime, as compared with the two different growth patterns usually observed when gilthead seabream are cultured in the Mediterranean. The growth data from the other cages provided by ADSA were also similar. The reported economic food conversion ratio for the cages was about 1.6 (i.e. not including fish mortality).

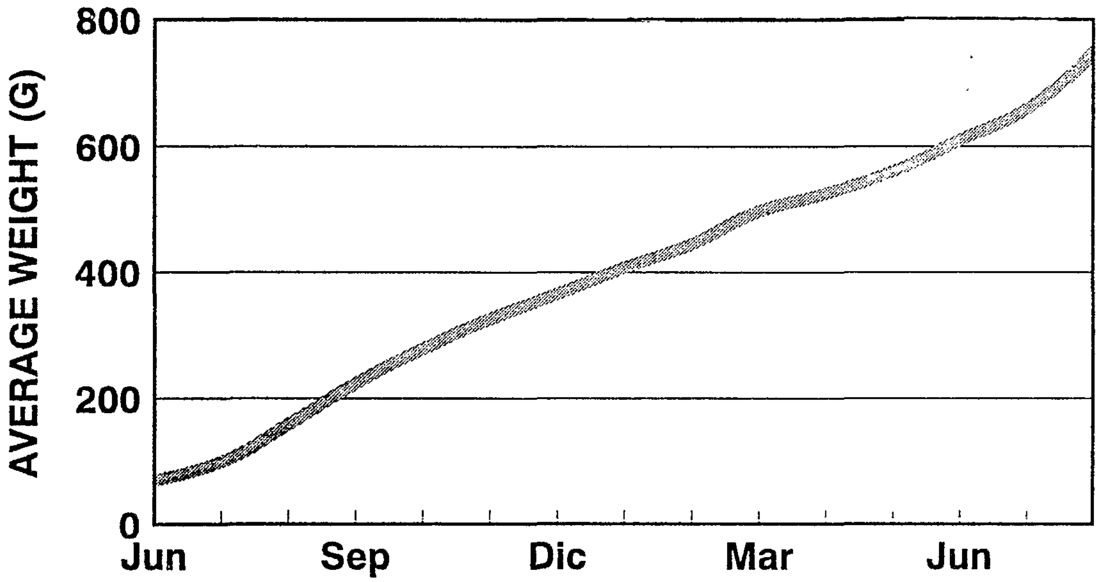

Fig. 4. Growth of gilthead seabream within cage number five over the experimental study.

Table 2 shows the data used to calculate the total nitrogen and phosphorus inputs for the farm, and percentage retention for these nutrients in the fish.

Table 2. Data employed to calculate total nitrogen and phosphorus inputs on the farm, and percentage of nutrient retention in fish

	Cage 1	Cage 2	Cage 4	Cage 5	Cage 6
Mean initial weigth (g)	34.5	29.3	25.2	70.5	12
Mean final weigth (g)	464	469	411	750	411
Initial biomass (kg)	1225	1084	908	3683	421
Final biomass (kg)	16226	17076	14570	15827	15219
Mean initial fish N (%)	7.9	7.9	7.9	7.4	7.9
Mean final fish N (%)	5.9	5.9	6.4	4.5	6.4
Mean initial fish P (%)	0.89	0.89	0.89	1.1	0.89
Mean final fish P (%)	1.03	1.04	1.02	1.27	1.02
Total feed N content (kg)	2559	2087	2307	3465	1881
Total feed P content (kg)	373	304	335	544	276
Average N retention (%)	15.7	20.8	16.1	19.6	22
Average P retention (%)	26.8	35.2	27.3	35.9	31.8
Mortality (%)	0.34	0.63	0.31	2.15	0.98

Table 3 shows the results concerning nutrient feed content, nutrient fish retention, and nutrient loading for the total five cages. When compared with data reported for other fish species, the mean percentage of nitrogen retention obtained during this study (**18.8%**) is lower than the values usually reported for others fish species (25-28%), although much closer to the value obtained by Ewos S.A. for the same species cultured in cages and fed a similar extruded diet (**22%**). On the other hand, the values for phosphorus retention (**31.4%**) were higher than those reported for other fish species (17-30%), but again similar to those reported for this species cycle in cages and fed similar extruded diets (**27.8%**). It must be mentioned that the results on mass balñance for this species reported by Ewos, S.A. were calculated using average feed, fish and faeces nutrient contents. On the contrary, those presented in the present study were determined from biochemical analyses carried out on a substantial fish population over a one-year growth cycle.

Table 3. Results on nutrient feed content, nutrient fish retention and nutrient loading from this study (Molina *et al*, 1996), compared with the reported results from other authors for the same and different fish species

Fish species		Nutrient feed content	Nutrient fish retention	Nutrient loading	Reference
Catfish *Ictalurus punctatus*	(Ponds)	5% N 1% P	28 % N 29 % P	72% N 71% P	Schwartz & Boyd,1994a
Rainbow trout *Oncorhynchus mykiss*	(Cages)	6-9% N 1.1-1.6% P	27-28% N 17-19 % P	67-71% N 78-82% P	Hall et al. 1990 Holby and Hall, 1991
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Gilthead seabream *Sparus aurata*	(Ponds)	6% N 1.2% P	26% N 21% P	74% N 79% P	Neori & Krom,1991
	(Cages)	7.5% N 1% P	22.2% N 27.8% P	77.8% N 72.2% P	Ewos, S.A., 1996
	(Cages)	7.9% N 1.08% P	18.8% N 31.4% P	81.2% N 68.6% P	Present study (Molina et al., 1996)

Fig. 5 shows the results concerning the nitrogen and phosphorus content of the sediment within the three sampling zones (i.e. underneath the cages, 60 m and 200 m from the cages), over the course of the study. The average nitrogen content of the sediments directly underneath the cages were significantly ($p<0.05$) higher than in the other zones sampled. However, no significant differences were found for the phosphorus content of the sediment between the three zones sampled. The observed seasonal variations for the two nutrients were very similar in all zones, with a repeated trend to recover initial values in all zones, except perhaps for nitrogen content in zone 1.

With respect to the organic matter content of the sediments, the values oscillated between 5 and 6%, with no significant differences observed between the different zones.

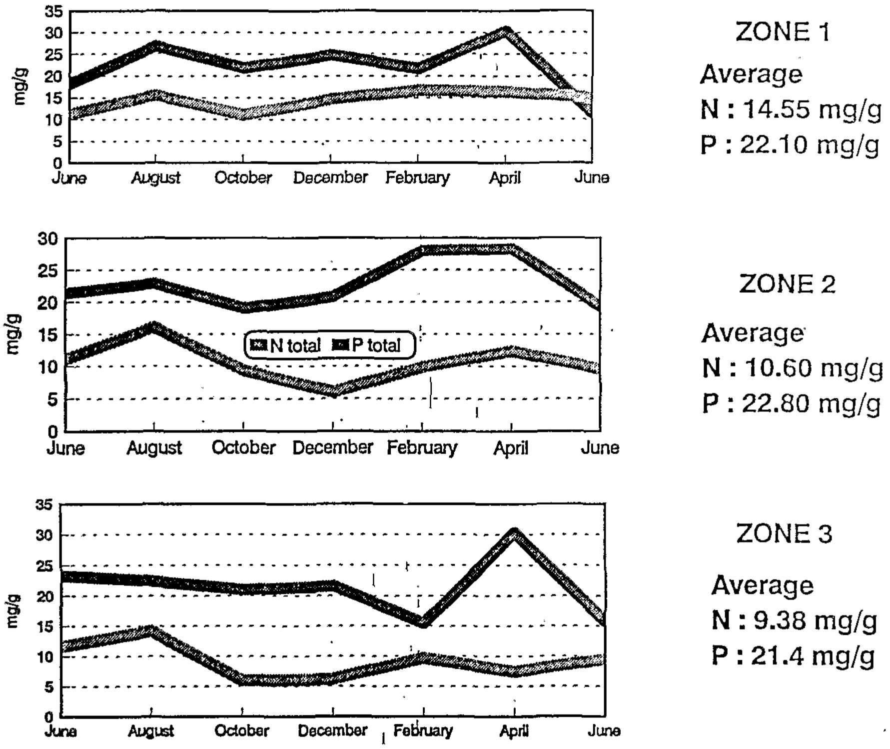

Fig. 5. Nitrogen and phosphorus contents of the sediments in the sampling zones (Zone 1: underneath the cages; Zone 2: 60 m from the cages; Zone 3: 200 m from the cages).

Conclusions

In order to minimize adverse environmental impacts, and to improve both feed efficiency and flesh quality within the final fish product (i.e. diminishing tissue lipid levels), it is very important that a continuous improvement of the quality of commercial diets available for gilthead seabream be made, from the view point of nutrient quality and availability to fish. This is a field of study which requires a continuous research effort, and it is an area where our group is fundamentally concentrated.

With respect to the sediment analyses, the fact that no significant differences were found for organic matter and phosphorus content between the different influence zones studied, may suggest that no noticeable accumulation of solid particulate wastes from the farm had taken place over the time period of this study; especially if we compare data from the sediment sampling carried out before the farm started its operation. The phosphorus content of this previous sample was 23.0 mg/g (higher than the average values obtained in this study for all zones of sediment) and the nitrogen content of the initial sample 1.3 mg/g was only slightly lower than the average values for zone 1 (14.55 mg/g), and higher than those for zones 2 and 3. It is possible that the average water current velocity (about 6 cm/sec) was sufficient to distribute solid wastes, thus avoiding the undesirable effects of organic sediment accumulation both under the farm and on the environment, not to mention the small size of the farm under study.

Despite these encouraging preliminary results, a more prolongued and detailed sampling program is currently being undertaken, including continuous measurement of current speed and direction, dissolved nutrients, the use of sediment traps, and ecologycal surveys on the nearby coasts. We hope these studies will allow us to have a more complete picture of the situation and sufficient data to construct a nutrient load model concerning the interactions between this particular fam and its surrounding environment.

Aknowledgements

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