# Effluents from land based marine farms: nature, treatment, valorisation, modelisation. Applications to fish and shrimp rearing

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## Abstract

Fish culture (seabass, turbot...) on the French metropolitan coast, and shrimp culture in the overseas territories (essentially New Caledonia and Tahiti) are subject to a regular development through land based farms. Three thematic of research on aquaculture ponds are carried out in CREMA-L'Houmeau, in collaboration with producers. The aim of the first one is to determine the optimal rearing conditions (stocking density, water renewal rate, input of oxygen, rate of feeding...) which allow to minimise the quantity of wastes for a similar final biomass. The second part aims to reduce the nutrient loading in the effluent, through open-air treatments: sedimentation ponds, foam fractionation, mass production of phytoplankton, and rearing of molluscs on the produced phytoplankton. The third part concerns research aiming to model the " production - treatment - valorisation " relationships.

## Communication

### Introduction

Fish (seabass: *Dicentrarchus labrax*) on the French Atlantic coast, and shrimp (*Penaeus stylirostris*) in the overseas territories (New Caledonia and Tahiti) are produced in land-based marine ponds.

Three research thematic are being carried out in Crema-L'Houmeau, in collaboration with producers :

- The aim of the first one is to determine the optimal rearing conditions (stocking density, water renewal rate) which allow to minimise the quantity of wastes for a similar produced biomass.

- The second thematic aims to reduce the nutrient loading in the effluent, through open-air treatments: sedimentation ponds, foam fractionation, mass production of phytoplankton, and rearing of molluscs on the produced phytoplankton.

- The third thematic concerns research aiming to model the “ production - treatment - valorisation ” relationships.

All three research thematic were linked both to optimise the food conversion to the cultured species and to valorise the waste through a secondary production. The latter also contribute to decrease the aquaculture impact on the surrounding environment.

## I. Optimising the rearing conditions to minimise wastes

The rearing performances (survival and growth), the quantity, nature and fate of wastes have been studied in relation to pond management parameters such as stocking density and water renewal rate. Results on fish culture (Hussenot, 1998 ; Djemali et al., 1998) and on shrimp culture (Garen and Martin, 1998 ; Martin et al., 1998) showed that those two parameters had an influence on the survival and growth.

On shrimp culture, increasing the stocking density (from 4 to 30 shrimps.m$^{-2}$) increased the production of waste (expressed per unit of shrimp biomass produced) (*table 1*). Thus, the food conversion ratio (FCR) increased from 1.54 to 2.73. Furthermore, increasing the stocking density increased the proportion of waste accumulated in the sediment (from 22.8 to 43 % of total waste), while it decreased in outflow (from 33.7 to 16.2 % of total waste). When the water renewal rate increased, from 0.05 to 0.4.day$^{-1}$, there is no evidence of an increasing production of waste (FCR ranged from 2.0 to 2.3) (*table 2*). Nevertheless, the proportion of waste accumulated in the sediment decreased from 22.9 to 7.8 % with increasing renewal rate.

## II. Reducing wastes by open-air treatments

Physical treatments as simple retention lagoons are being used by fish farmers with an efficiency on particulate material (1 metric ton.ha$^{-1}$.day$^{-1}$), while dissolved materials are poorly treated. Aeration and foam-fractionation of treatment ponds (*figure 1)* are complementary solutions to remove dissolved organic compounds (Hussenot et al., 1998 ; Lecossois and Hussenot, 1998). In temperate climate, biological treatments using continuous mass production of diatom microalgae (Lefebvre et al., 1996 ; Lefebvre

*Table 1: Fate of feed-nitrogen in shrimp pond-culture of Penaeus stylirostris according to different stocking densities(number.m$^{-2}$) and a constant water renewal rate of 0.1.day$^{-1}$*

| Stocking density | FCR | % Feed-N in shrimp | % Feed-N in outflow | % Feed-N in sediment | % Feed-N to |
|---|---|---|---|---|---|
| 4 | 1.54 | 29.7 | 33.7 | 22.8 | 13.9 |
| 7 | 1.71 | 26.1 | 20.3 | 24.2 | 29.5 |
| 15 | 1.58 | 29.2 | 14.2 | 18.8 | 38.1 |
| 22 | 2.34 | 19.7 | 16.0 | 35.4 | 28.8 |
| 30 | 2.73 | 17.0 | 16.2 | 43.0 | 23.8 |

(from Garen and Martin, 1998) FCR: feed conversion rate

*Table 2: Fate of Feed-N in shrimp culture of <u>Penaeus stylirostris</u>: influence of water renewa rate (day$^{-1}$) for intensive conditions, experimented in concrete raceways.*

| Water renewal | FCR | % Feed-N in shrimp | % Feed-N in outflow | % Feed-N in sediment | % Feed-N to atmosphere. |
|---|---|---|---|---|---|
| 5 | 2.0 | 19.8 | 43.2 | 22.9 | 14.1 |
| 10 | 2.2 | 18.3 | 39.4 | 18.5 | 23.8 |
| 20 | 2.3 | 17.5 | 35.3 | 17.1 | 32.1 |
| 30 | 2.3 | 17.4 | 33.8 | 9.7 | 39.1 |
| 40 | 2.0 | 19.8 | 33.7 | 7.8 | 35.7 |

(from Martin et al., 1998)

and Hussenot, 1998) combined with oyster filtration (Shpigel et al., 1993) were experimented to treat the mineral part (*figure 2*). Optimal retention times in algal reactors were determined for different temperatures and light conditions, varying between 0.2 and 2.0.day$^{-1}$. Using a silicate complementation if necessary, induced blooms are essentially composed of the diatom *Skeletonema costatum* in all seasons. Feeding responses of oysters to gross and treated effluents were carried out (Lefebvre, unpublished). The different treatments proposed are complementary from each other as indicates it *table 3*.

## III. Modelling wastes and treatments

A model was performed with Seneca 2.0 software (Lefebvre et al., 1998) to calculate the water nitrogen flux in earthen ponds of an intensive private fish farm. The model produces a daily predictive value of nitrogen and phosphorus water concentrations and results can be used to develop simulations of the biological treatments and the resulting nitrogen mass balance (*figure 3*). Treatment and valorisation models have being developed to conceive management and economical study.

*Table 3: Removal efficiency of particulate (TSS: total suspended solids, CHLa: chlorophyll-a) and dissolved (TAN: total ammonia nitrogen, DOM: dissolved organic matter, $PO_4$: phosphates) materials by different open-air treatments in land-based fish-farms*

| Treatment / Parameter | TSS | CHL*a* | TAN | DOM | $PO_4$ |
|---|---|---|---|---|---|
| RETENTION LAGOON | +++ | o / - - | o / + | o | + |
| FOAM FRACTIONATION | + | + | + | +++ | + |
| µ-ALGAE REACTOR | - | - - - | +++ | o / - | +++ |
| BIVALVE FILTER | + + | +++ | o / - | - | o |

level of removal: o : no, +: low, ++: medium:, +++: high positive effect, - : low, --: medium, ---: high negative effect

*(from Hussenot et al. (1998)*

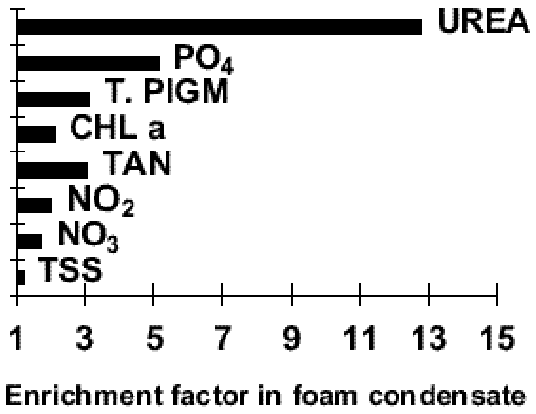


*Figure 1: Efficiency of giant foam fractionators as described by Hussenot et al. (1998)*

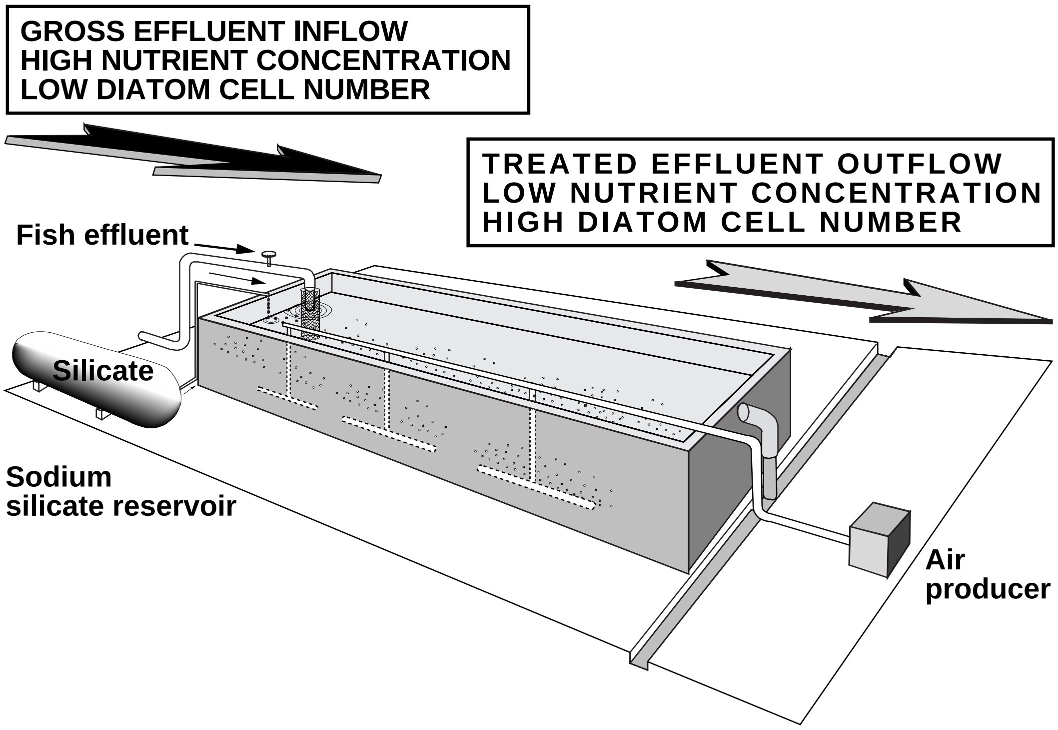


*Figure 2: View of the open-air microalgae reactor equipped with silicate injection to develop diatom blooms (from Hussenot et al;, 1998)*

## Conclusion

In conclusion, all the proposed strategies can contribute, individually or associated, to reduce the aquaculture impact of land-based marine farms. This is specially important in coastal wetlands (marshes, mangroves,…) where sustainable practices are essential. On an economical point of view, the presented open-air treatments are the best to reduce pond-culture effects on the environment because secondary aquatic productions (algae, bivalves, fishes) can cover the treatment costs.

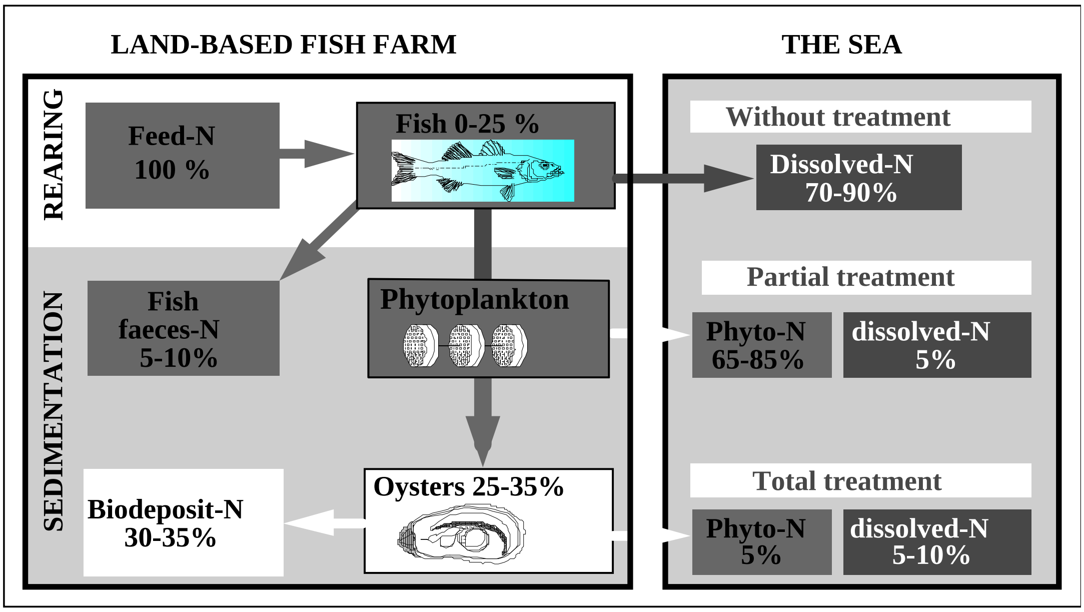


*Figure 3: Calculated nitrogen (N) mass balance (in % of feed nitrogen input) in a seabass fish-farm without treatment, with a partial treatment using a microalgae reactor, and with a complete treatment adding a bivalve filter.*

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