

Environmental Constraints and Aquaculture Development

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ABSTRACT

Aquaculture is an economic activity which is characterised by a great dependence on environmental conditions. Therefore, aquaculture development is subdued to institutional context which defines the rules for use and conservation of natural resources. This paper analyses the impact of marine environment regulations on economic operating of aquaculture enterprises and on industrial dynamics. Because aquaculture enterprises use common goods, an economic approach of aquaculture has to take into account not only the relations between enterprises and environment, but also the relations between the enterprises themselves, through production externalities. In this study, several economic tools are considered in order to incite enterprises to integrate part of the cost of their effects on the environment. Public policies have also to take into account the youth of the activity, the specific economic situation of the enterprises and the place of aquaculture in global coastal management. Cases studies of finfish farming in Europe and of tropical shrimp farming show that different public policies may be implemented according to social and economic context. These cases illustrate the connection between social and environmental viewpoints, and analyse the constraints and advantages of different tools used to coordinate individual choices at the collective level.

INTRODUCTION

Due to strong anthropic pressure, coastal areas are subject to congestion effects and competition among various uses such as urbanisation, industrial development, tourism, harbour activities, agriculture, aquaculture and fisheries. This is also true for other aquatic ecosystems and their surroundings. "Space", "water", "biomass" and "landscapes" are limited and valuable resources for these uses. They may play various role to sustain them :

- space needed for circulation or to set up production plants and housing
- water as a physical asset (irrigation, human consumption)
- water for its quality (human consumption, tourism, aquaculture)
- water for its capacity of assimilation or dispersion (industrial or urban waste, agriculture, aquaculture)
- biological resources in the sea (fisheries, extensive aquaculture)
- landscapes for their aesthetic and entertaining value (tourism, urbanisation).

The relation between aquaculture and environment is all the more complicated as there is both dependence on medium quality, impact on medium quality and interdependence among enterprises through that impact on environment. A minimum quantity of water of appropriate physical and chemical characteristics (temperature, salinity, oxygen concentration,...) is needed. Most of aquaculture production depends upon the availability of natural biological production (juveniles, phytoplankton, zooplankton or adult

fishes used for feed). Water is the media used to eliminate waste (faeces, nitrogen). As for aquaculture, off-shore or on-shore space is also required to set up cages, ponds or other facilities. If we consider the aquaculture production unit, space, water quantity, water quality and marine biomass are major inputs to the system. Water quality is also an output of the system. Competition for access to these resources and interdependency occurs among aquaculture units, with other activities along the coastline and with up-stream activities, like agriculture and industry, which may contribute to change the characteristics of the environment. Since aquaculture is so dependent on the environment, as far as we do not consider either closed systems nor recirculation, the risks of autopolution are also to be taken into account. It is the core interest of the case studies presented here.

It may seem uncommon for the economist to treat in the same way : space, biological production, water as an input or as a medium for waste dispersion, aquatic ecosystems as waste assimilators and landscapes. In fact, trade-off in the access to all these resources do not easily occur under market rule. This is their common feature. We stand here from the economist standard point of view, searching for interdependencies in access to limited resources that involve aquaculture and are not market regulated. That includes what is usually referred as externalities (pollution, over exploitation) when production or utility functions are affected by external decision. Space is another case. On land, it is generally allocated according to market mechanism under private property, while at sea competition for access to limited space is in most cases under administrative or common rule. For various reasons, land near the coastline is considered as public in many countries and also allocated under local community or administrative rule. The question of access regulation the these resources is then of specific interest to the economist. The purpose here is to suggest a general framework to analyse it in the case of aquaculture, referring to economic theory and illustrating with two case studies. : finfish farming in Europe and shrimp culture in Indonesia.

I. APPROPRIATION AT THE INTERFACE OF NATURAL AND SOCIAL DYNAMICS

From social sciences view, natural resources are elements of nature which are requested for uses. These uses may be in terms of resource subtraction like fish stock in fisheries and water consumption (inputs) or in terms of emission like pollution (outputs). Utility may result from the aesthetic value of natural amenities. Origin and effect link of these uses may be direct or indirect (cumulative effect), close or distant in space and time. This transformation of nature in a set of resources to the society is considered here as a *social process of nature appropriation*. It is dependent on :

- the technical and economic aspects of each **use** (logic of individual decisions)
- the characteristics of the **resource** (divisibility, subtractability, variability; ...)
- the social and economic context of the uses (political, legal aspects as well as symbolic representations).

To avoid the negative consequences of an excessive pressure on limited natural resources and to ensure sustainable development, **ways to coordinate individual choices** at the collective level must be found. This is the case for coastal resources. Limited space and renewable resources, ecological fragility make it necessary to develop coordination rules between the actors. These rules first aim at defining the conditions of access to the resource (eligibility, bundle of rights, transferability of rights...). Their definition and implementation require organizations, which may play different roles :

- discussion and definition of rules
- legitimating of rules and decision-making process (social recognition)
- implementation of rules (control structures)
- conflict settlement

As soon as they are due to a socially guaranteed contract between different persons, these rules and organizations may be called

institutions. The nature of these institutions as well as the constitution of the users' groups are very important to understand their functioning and how it is possible for public policy to play a role. The institutions are characterised by the relative importance of administrative links, market oriented links or personal links (cooperatives, village communities), by their ability to play the different roles quoted above and by the nature of the control of their activity (social, official). They may be informal, registered in the law or erected in permanent organisational structures.

Resources, uses and coordination means (institutions, and other organisational device as value systems) compose what we shall call an *appropriation regime of natural resources*. It lies at the interface of both natural dynamics and social dynamics. Biological, physico-chemical and geophysical cycles are the basic in natural dynamics while individual and collective choices are the key to social dynamics. Their determinants and referentials for space and time do not necessarily match. That is the reason why appropriation regimes are to be considered as complex systems with similarity of issues in principle and diversity in practice. The understanding of appropriation regimes centred on social and natural dynamics

interaction calls for multidisciplinary comparative research. This is the case when studying insertion of aquaculture in coastal economies and ecosystems and particularly when considering the issue of water quality. Different criteria can be used to measure the efficiency of various appropriation regimes : long-term viability, adaptability, conflict avoidance, maximisation of resource rent, resource preservation,... Multicriteria analysis is generally needed (figure 1).

2. THE COORDINATION FORMS OF INDIVIDUAL ACTS AT THE COLLECTIVE LEVEL

In aquaculture, as in many other industries, socially or economically based environmental issues arise. In order to meet objectives such as pollution reduction, increase of productivity, natural assets preservation, sustainability of uses..., various solutions can be envisaged to coordinate individual acts. The main possibilities are considered here from a theoretical standpoint. The opinion expressed about condition of feasibility considers observations quoted in various case studies in the literature. Several options are considered : direct negotiation, state intervention, market mechanism, insurance...

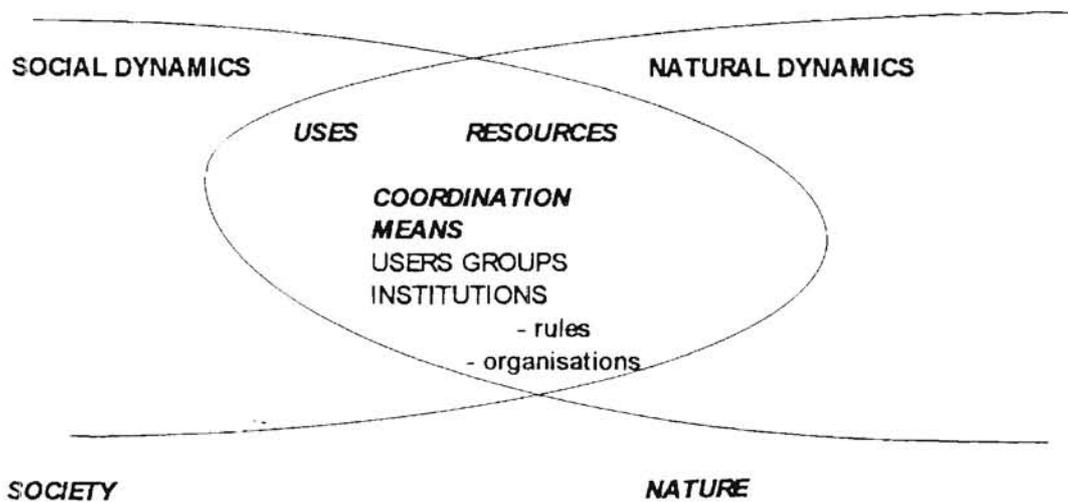


Figure 1. representation of an appropriation regime of natural resources

2.1. Individual agreements for self-limitation or compensation

This kind of agreement may occur easily in case of reciprocal externality, when two agents impose comparable externalities to each other. In other cases, the conditions to create a common decision-making unit and to reach such an agreement are very restrictive :

- few people have to be involved, on a small space and with a high level of social reciprocal control, in order to avoid the risk of free riders,
- the agents should share similarity in representations and logic of behaviour
- there must be property rules which specify that some rights or entitlements go with property

The different agents involved in this situation will bargain with each other, according to the Coase Theorem, which states that the level of output and the corresponding external costs remain the same whether polluters are bribed to reduce pollution or whether they are charged for marginal damages. This supposes albeit that all the participants have similar information in order to complete fair exchanges. In situation of scientific controversy, the lack of objective information is a major constraint to the resolution of pollution problems according to the Coase model.

2.2. State intervention

2.2.1. Regulatory tools

If such arrangements (voluntary or under court decision) fail to remedy a pollution problem, government intervention is required. Regulations enable public authorities, with the threat of penalties, to definite technical norms and to prescribe quotas in the use of the resources or limitations in the activities. The good point is that expected effects on medium quality are appraisable, but there is no incentive to go beyond the norms. Moreover, in the case of poor knowledge of the firms' costs, it may hamper their business and create price distortion. Another limitation to the

implementation of regulations is the presence of scientific controversy : the "states of the world" are incompletely known and unsteady, the injuries and causality links are not obvious and remain contingent, the interests of the actors are not clear (GODARD, 1993). Conservation principle such as "precaution rule" may justify state action.

2.2.2. Social transfers (taxes and subsidies)

In 1972 the member countries of the Organisation for Economic Cooperation and Development (OECD) adopted, as advised by the organisation, the "Polluter-Pays Principle" (PPP). According to this principle, the polluter should bear the expenses of carrying out measures decided by public authorities to ensure that the environment is in an acceptable state. In other words, the cost of these measures should be reflected in the cost of goods and services which cause pollution in production and/or consumption (HENRY, 1991). This principle is the recognition of a property right on a good quality environment but does not mean shared-liability on the long term. Different tools have been developed to put this principle into operation. They are all based on taxes or incentives.

According to Pigou theoretical works, taxes may oblige firms to bear not only their own operating costs but also the social costs of their activity. Taxes may be used in order to deter from polluting activities and to provide a financial help for depollution (financing role). *Discharge taxes* may be applied only to clearly identified point sources discharges. *Input taxes* are aiming at modifying the relative prices of inputs by taxing these which are particularly polluting at the level of fabrication, assimilation or discharge. *Tax differentiations* make it possible to reduce the state levy on some environment friendly products. This last method has no impact on production costs but does not provide money to the authorities. The economic theory sees many disadvantages in taxes. If the tax level is too low, there may be no motivation to technological progress. If too high, it may reduce investment in productivity gains. Social acceptability of taxes and ability of the public

authorities to collect taxes are major constraints to their use.

On the other hand, *public incentives* may be given to enterprises which implement new techniques to pollute less or to treat their waste. They require a counterpart in the public budget, and may be restricted by some supranational authorities (European Union for instance) as contradictory to free competition principle.

2.3. Market mechanism

This solution has been developed from the established fact that it could be very costly and inefficient to impose the same measures to all the enterprises, whatever their size or technological level, because of the lack of information of the authorities concerning the enterprises. The aim is to create a trade between agents and the role of the authorities is just to define a global level of emission or biological stocks predation and to give a regulatory framework to the exchanges. Such a market has proved to move toward an efficient way to achieve reductions of emissions in the case of air pollution in the USA. This tool gives a permanent incentive to adopt new technologies and does not require information on the economic operating of the enterprises. But there is no way to redistribute money and the control costs may be high. As far as management of water resources is concerned, no field of application yet has been considered as relevant for trading emission rights by the Environmental Protection Agency of USA (GASTALDO, 1992). In the case of biological resources, Individual Transferable Quota (ITQ) systems have been implemented in many fisheries. Most of them are now under severe trouble.

2.4. Common management

Common management is a vast area of social arrangements providing access rules to natural resources and environment neither under state control nor under market coordination. That encompasses all types of customary law, local community control, cooperative management. There is a huge variety of institutional arrangements that could be classified here. Their viability is more or less threaten or supported by

the global change in societies. But it is more and more quoted in the literature for its capacity to deal with complexity (diversity of uses, users groups, natural and economic viability) and to reduce the transaction cost of negotiation and implementation (social control) (OSTROME, 1990).

2.5. Liability insurances

In most countries, the notion of "ecological injury" is poorly taken into account. Most often, a public good like water can not claim compensation by insurances, but American and German law have just approached the issue of liability relative to environment preservation. In order to transfer part of water quality preservation expenses from public authorities to users, it may be considered that depollution costs should be covered by insurance policies, the premiums of which would be calculated for each enterprise depending on its own risks and on its investments for safety measures.

3. AQUACULTURE AND ENVIRONMENT : A TYPOLOGY OF ISSUES

3.1. External effects of aquaculture on other activities

Aquaculture is a production activity which may have an impact on other production or consumption activities on the coastline. First, aquaculture requires land, which induces conflicts both with agriculture (for on-shore installations and for wetlands) and fisheries (off-shore installations). On-shore aquaculture sea-water requirements may be the cause of damage to agricultural soils due to salinity increase. Last, seed requirements in most extensive forms of aquaculture may affect the natural stocks of juveniles and cause damage to traditional fisheries (PHILLIPS and al, 1993).

Fish farm waste can bring about enrichment of the coastal marine ecosystem through the release of soluble dissolved nutrients and particulate organic waste. In the case of off-shore installations, waste dispersion in the flows makes it very difficult to appraise the impact on the environment. Other potential effects such as genetic interaction and disturbance of wildlife communities may conflict with nature conservation (GOWEN, 1993).

From the consumer viewpoint, aquaculture modifies the aesthetic aspect of the coastline and its value for leisure. This judgement is very variable according to the tradition and the nature of the use of the seashore. What is considered as part of the landscape in Matsushima Bay in Japan may be rejected on the French Riviera. Free access to the seashore for tourism (swimming, sailing) is also restrained by aquaculture when priority is given to aquaculture, like in Japan.

3.2. External effects from other activities on aquaculture

Given the increase of the urban pressure on the coastline, aquaculture is particularly subdued to water quality and real estate speculation issues. Agriculture (fertilisers, pesticides) and industry are the cause of chemical pollution while urbanisation is the cause of bacterial pollutions which limit the zones of production and oblige aquaculturists to costly controls of water quality and to high investments in sea-products depuration. Most often, these pollutions are due to non point source discharges, which make very difficult to implement either regulatory policy, voluntary agreement or economic tools.

3.3. Effects on natural assets

Mangrove and wetlands are typical cases. Mangroves are important in coastal protection and their removal may cause coastal erosion, changes in patterns of sedimentation and shoreline configuration. Mangrove forests are also used for other products, including lumber, thatching material and a variety of foodstuffs. Thus, their removal can have far reaching economic and social aspects. The value of the mangroves is such that a "cautionary" approach seems warranted to ensure that the risk of developing such problems is reduced.

3.4. Externalities within the aquacultural sector

The modifications caused by aquaculture to the environment, as well on water quality as on substratum, may have impact on the aquacultural activity itself. These interactions may occur between different productions : for instance, organic matter settings due to fish farming are a

nuisance for seaweed cultures in Japan and in the Philippines. They may be applied also to the enterprises themselves, either by competition for the access to the resource or by spoiling the water. In the first case, the issue is that the water flow which carries the food (phytoplankton or zooplankton), which is an external resource, can not be appropriated and that every producer tries to get the most of it, leading to overstocking and resource over exploitation. This situation has been analysed in the case of French oyster farming (BAILLY and PAQUOTTE, 1990). Intensification of aquaculture means more water requirements, more fertilisers and industrial feed, more veterinarian products which are eventually discharged in the environment. In some sites characterised by little water renewal and weak currents, the waste dispersion capacity is not efficient enough to protect the farms from suffering from their own waste.

4. CASE STUDIES AND DISCUSSION

The analysis of aquaculture and environment issues should be done according to different analytical grids :

- the nature of the co-ordination forms implemented to manage the relations between resource and users, including the nature of the regulatory or economic tools which may be relevant to alleviate external effects and to have them internalised
- the nature of the externalities (outside the sector or inside).

Figures 2 and 3 summarise the main situations where aquaculture is involved for two cases : fish farming in Europe and shrimp aquaculture in Indonesia.

4.1. Fish farming in Europe

Inland fresh water trout farming in raceways (200 000 tons, mainly in France, Italy and Denmark), salmon farming in marine floating cages (250 000 tons, mainly in Norway, Ireland and United Kingdom) and sea-bass farming in marine floating cages or coastal ponds (25 000 tons mainly

	common management	direct negotiation	state intervention		market
			norms	taxes, subsidies	
aquaculture ▶ other activities		Constraints : * differential in economic power * very new activity	* inland aquaculture 1 - emission standards - requirements for treatment installations 2 - food composition - maximum allowable feed consumption	Denmark : - tax system on feed consumption France (forthcoming) : - pollution fee based on emissions - subsidies for water treatment investment	- label environment friendly
other act. ▶ aquaculture		* differential in economic power * very new activity	* floating cages and off-shore context of high scientific controversy France : - impact study		
autopollution farm to farm	- rotation - off-shore				
public space allocation		priority given to tourism along the coastline			- social benefits of aquaculture - attractivity

Figure 2 : analytical grid for analysis of aquaculture and environment issues in the case of European finfish farming

	common management	direct negotiation	state intervention		market
			norms	taxes, subsidies	
aquaculture ▶ other activities	- participation to negotiations if local community control - difficulty to participate if presence of outside investors	- negotiations with rice farmers salt producers shrimp producers local authorities prefectural aut. - definition of rights	- state power - court decision		
other act. ▶ aquaculture	idem	differential in economic power			
autopollution farm to farm (individual or group)	- density limitation - improvement of water circulation - scientific controversy - internalisation of control costs		- precautionary approach due to difficulty in limitations assessment		
public space allocation	- diversity of users groups		- precautionary and conservation principles - research needed to give value to natural assets and assessment of social and economic effects		

Figure 3 : analytical grid for analysis of aquaculture and environment issues in the case of Indonesian shrimp farming

in Greece) are the three first activities of finfish aquaculture in Europe.

In this case, figure 2 shows that most of the coordination means involved in European fish farming require state intervention. Indeed, it is a new activity, implemented on a coastal line already used by many other activities, and its economic weight is generally very small. A major constraint to the implementation of common management is also that most of the investments in aquaculture come from outside, and that the entrepreneurs seldom are local inhabitants. Moreover, priority is most often given by the state to tourism along the sea-shore, which weakens the possibilities of direct negotiation in an unfavourable legal context.

4.1.1. externalities toward other sectors

Because aquaculture is a relatively new and not yet fully developed sector, it comes under increasingly close scrutiny with respect to its environmental impact, perhaps even unfairly so in comparison with the safeguards demand for better known sectors, especially agriculture. The low economic weight of aquaculture compared to agriculture, fisheries or tourism has not made it possible to reach voluntary agreement and has obliged the public authorities to implement regulations.

In European aquaculture, the most common way to control impact on the environment is to definite emission standards and requirements for treatment installations (JENSEN, 1990). In the case of fresh water trout farming on inland rivers, this sort of measures is easy to set up but has not proved to be efficient enough. That is why, in a first step, the requirements have been extended to the composition of fish feed and to an annual maximum allowable feed consumption. This last item is aiming at inciting the producers to better husbandry and to lower Feed Conversion Ratio, rather than reduce their production.

Economic tools have been adopted first in Denmark, thanks to the good organisation of the producers, to the role of Water Authorities (Dutch

Waterschappen) and to the great attention brought by the government on environmental problems. A tax system on feed consumption has been implemented with satisfactory results for all the agents. A pollution fee is in the process of being implemented in France, taking into account three parameters for its calculation (particulate matter, nitrogen and phosphorus), with the counterpart of subsidies for water treatment equipment.

The issue of floating cages is more difficult to solve because of the difficulty to assess the impact on the surroundings, except when the cages are put in very sheltered embayments. In a context of high scientific controversy, the French public authorities (Ministry of Environment) have imposed to marine fish farms (over 20 tons/year) to achieve a complete impact study before starting the activity. This impact study is aimed at making possible for authorities to identify, to assess and to explain the effects of the project, as well as to know the measures adopted to suppress, reduce or compensate them. In a context of very poor knowledge of the real effects of an off-shore aquaculture plant, this kind of study needs the help of research institutions, because the issues are very specific to each location. So, it is a long, and costly, procedure which constitutes a brake to the setting up of small scale enterprises. Given the low ratio of profitability of French fish farming projects (below 15%, without taking into account of financial expenses) and the late return on investment (average 5 to 8 years), this increase in pre-operating time and costs can be assumed only by big corporates. In return, a capitalistic concentration of the activity (particularly with people coming from the agricultural and foodstuff industry sectors) will change the social balance between all the implicated agents.

Beyond extra-costs, the environment issue may be used as a marketing tool in order to gain new markets and to legitimate high added-value products thanks to a "environment friendly" label. This approach is not common yet in aquaculture, contrary to agriculture, but is at stake in the

development plans of most European aquaculture companies.

4.1.2 impact on aquaculture by other activities

As one of the most recent activities on the coast, aquaculture may hardly pretend to impose water quality requirements to other activities. Direct negotiation is not suitable in this case and no specific regulation exists to guarantee a good environment for aquaculture.

4.1.3. autopollution

The initial development of salmonid farming in Norway took place in sheltered embayments with little regard for environmental consequences. Enrichment of the seabed ecosystem, enrichment of the water column and resistance in sea-lice populations to pesticides were noted, but did not lead to give up the activity (GOWEN, 1993). Given the ability to the soils to be regenerated thanks to water flows, rotation of cages is advised and used in some places (Norway), but the technological gains have made it possible to set up plants offshore, where currents, and therefore dispersion capacity, are stronger.

4.1.4 public space allocation

The constraints related to space occupation are still a major issue, especially because of tourism and residential urbanisation. On the French Riviera, the planning procedures developed till now have always considered tourism as first priority, and aquaculture is considered as an odd, filthy and indecorous activity. Contestations have been brought to court, but it does not seem that the social benefits of aquaculture are taking into account. Despite a low economic weight, aquaculture may help to settle all year long inhabitants and therefore contribute to the perpetuation of public services (school, post office), as well as enhancing the touristic attractiveness for urban people in search of traditional activities and local products.

4.2. Shrimp culture in Indonesia

Shrimp culture is an old activity in Indonesia where it has long been practised on a very extensive basis (wild juveniles and feeding on natural

productivity at low density) mixed with fish species such as milkfish. This aquaculture in earth ponds (tambaks) is rapidly expanding and intensifying with the introduction of hatchery and intensive culture technology. Between 1989 and 1991, as a result of a national support program, international aid for technological transfer and high mobility of capital in Asian shrimp industry, the production has doubled from 60 000 to 120 000 tons (Globefish n° 3/92). Today in a leading position in Asia with China and Thailand, it has to face many environmental and other "common" issues. Some of them are responsible for the collapse of the Taiwanese shrimp industry. Very short periods of return on investment for extensive systems support speculative attitudes leading to conflicts and disruptive crisis.

4.2.1 water management

Farms near the shore easily pump water directly from the sea or in-going canal and discharge in a separate out-going canal. But ponds located in the back have often no other solution than to pump the water in the out-going canal of the former ones. When this development occurs in areas previously devoted to rice production, the clear delimitation between fresh and salt water is also a problem. Entry of salt water and flooding of rice fields are major causes of conflicts.

These two cases are typically water management problems, calling for hydraulic engineering work (canals, dams, gates, sluices...), but a large part of it is of common interest under private initiative. Negotiation and decision, including fund raising, involve the local farmers (rice and shrimps), salt producers sometimes, local administration and perfectural authorities. Technical solutions are generally easy to design but decision and realisation may be very conflictual. From observed cases¹, in locations where shrimp culture has developed under local community control with a strong prevention (sometimes exclusion) against external investors, few conflicts

¹ preliminary field observations for socio-economic survey presently conducted by BADC (Jepara, Indonesia) under the AADCP program in North Central Java.

have been recorded. Problems seem to be rapidly solved. The fact that rice and shrimp farmers are the same local people is probably one of the reasons. In other locations, groups of interest appeared among farmers (semi-intensive / intensive farms, local people / outside investors, village A / village B), that prevented any easy solution. In one case, urgency and economic stakes were such that it turned into a political affair and prefectural authorities were forced to act.

4.2.2. pollution affecting aquaculture

Shrimp culture development also revealed high levels of sea pollution in some areas. In various locations - of the studied area, high mortalities have been regularly observed. They all had in common to be close to river-mouths crossing up streaming industrial areas. Processing agro-industry such as tapioca was in particular accused by the coastal villages to pollute the sea water. Despite claims at the highest level of the state, negotiation with such big industries seemed to be always difficult to obtain, as well as research work to prove the validity of the assumptions. The argument of employment losses were these industries obliged to invest in waste treatment has been generally opposed to farmers claims. As shrimp culture and other activities (tourism) sensible to sea pollution are developing in Indonesia, conflicts regarding this issue will probably increase. At present, the administration seems to be the major institutional link for negotiation between polluters and sufferers (Figure 3). Recognition of the need for clean water by aquaculture has yet to be improved.

4.2.3. ecological carrying capacity of coastal ecosystems

In Indonesia, as it already happened in other countries, extension and intensification process met the limits of ecological carrying capacity of coastal ecosystems in various places. Assimilation and dispersion of organic and chemical matters discharged from ponds is no more satisfactory. Water entering the system does not meet any more quality requirements. Diseases develop and disseminate quickly. Mortality increases and growth

performances drop. The need is for a collective action to reduce the total amount of discharge through density limitation and technical improvement of water circulation. Precautionous development control by local communities can be seen in many villages, in the same conditions as above. In areas that have been open to large external investment, the answer is more individualistic. The inlet of the pumping system may be set regularly further out in the sea. When the distance reaches few hundred meters, and sometimes one kilometre, the extra cost makes it economically not feasible. Several areas have already be closed. The cost to reclaim salted land covered with one meter deep pond is very high, far beyond the value of any possible alternative use. More than the evaluation of the biological carrying capacity in the case of extensive aquaculture (BAILLY and PAQUOTTE, 1990), this is a very controversial issue for which scientific methodology still has to be developed. Precautionary limitations are very difficult to estimate and more and more to implement. Attempts to limit the solid content of outgoing water are under negotiation in some places.

4.2.4. other issues

Shrimp culture development has been very aggressive toward mangrove forests. Very high rates of return in very productive places led to speculative attitudes regardless of the ecological costs and of other benefits derived from the mangrove. International pressure has raised the concern of governments about mangrove and legislation are more or less efficiently promoted. Decision in their regard refers more to conservation and precautionary principles than to scientific proofs, ecological or economic assesments.

CONCLUSION

Aquatic ecosystems as life support, supplier of biomass and waste assimilator are a key factor to the sustainability of aquaculture. Aquaculture development raises many environmental issues involving the need for coordination of individual actions at a collective level. A framework has been proposed to build a grid of the main issues. Economic theory and recent development in

common management theory provide a basis for the understanding of the problem and suggest many answers. Case studies show the diversity of possible answers to practical problems. At this stage, more case-studies based comparative research is needed to be able to attach specific solutions to given situations.

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