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IMPACT OF ORGANIC POLLUTION FROM FISH FARM OPERATION TO THE CARRYING CAPACITY OF COASTAL ENVIRONMENT

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Ringkasan

Makalah ini mengulas tentang dampak pencemaran organik dari kegiatan pengoperasian keramba jaring apung (KJA) di daerah pesisir terhadap daya dukung perairan.

Sebagai salah satu alternatif peningkatan produksi perikanan dan ekonomi masyarakat pantai, KJA selama ini diusulkan sebagai suatu terobosan tapi sangat jarang menyebutkan dampak lingkungan yang dapat terjadi akibat pengoperasian secara berlebihan (intensif maupun ekstensif) dalam suatu ekosistem pesisir. Dampak lingkungan penting untuk dipertimbangkan karena usaha KJA umumnya berada di perairan pesisir, yang sangat peka terhadap pencemaran dan konflik antar pemangku kepentingan (stake-holders).

Meskipun bervariasi bergantung karakteristik perairan, jenis ikan yang dibudidaya dan ukuran pengoperasian keramba, dampak dari budidaya KJA umumnya tidak terlalu terlihat di badan air, akan tetapi menunjukkan perubahan berarti pada sedimen. Secara vertikal, akumulasi bahan organik di lapisan atas sedimen di bawah keramba terbukti dapat meracuni ikan peliharaan itu sendiri dengan terdeplesinya oksigen dan terbentuknya gas beracun H_2S di lapisan permukaan sedimen hingga kolom air tepat di bawah keramba. Akumulasi partikel padat dan tersuspensi juga turut memperlambat proses pembersihan alami (natural recovery), mesipun setelah aktivitas budidaya KJA tidak ada lagi di perairan tersebut.

I. Introduction

As the largest archipelagic state in the world with 17,508 islands, 81.000 km coastline, and 63% (3.1 million km^2) of its territorial area is covered by marine waters with diversed natural resources, Indonesia has a great potential both in capture and culture fisheries. Although the average annual production from both sectors has not yet optimised, the total fish production reached up to 4,797,060 mt in 1999. As many as 86% of the production (4,149,420 mt) comes from capture fisheries and only 14% (647,640 mt) from aquaculture (FAO, 2001).

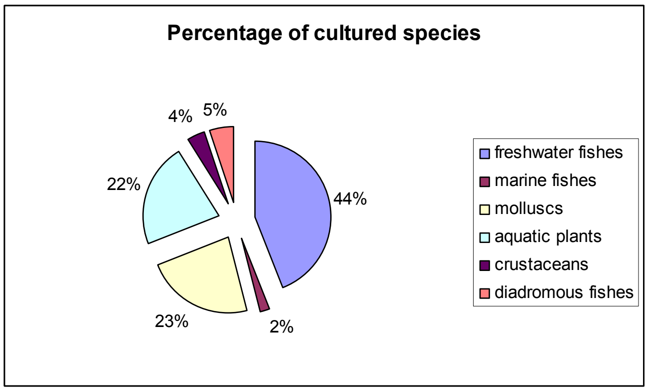

Figure 1. Aquaculture production in 2000 by species group (modified from Weber, 2003)

Since the last two decades, however, aquaculture industry has developed rapidly in Indonesia. As much as 25.67 million ha area has been allocated to boost the development of aquaculture. This consists of 0.76 million ha for freshwater culture, 0.91 million ha for brackish water and 24 million ha for marine aquaculture (Anonymous, 2002; FAO, 2001). This measures are expected to fill the gap of production since capture fisheries yield has consistently decreased due to overfishing and environmental degradation of many fishing grounds. At the same time large numbers of brackish fish pond practices have long been terminated due to high operation cost and decreasing survival rates (Jusuf and Nikijuluw, 1999).

Among the types of aquaculture activities practised in Indonesia, farming of marine fish has received littlest attention. This is similar to the global trend shown in figure 1 byWeber (2003) where the production from marine fish aquaculture contributes the smallest percentage. However, in the case of Indonesia, the government through its ministry of Fisheries and Marine Affairs has promoted marine fish farming to coastal villagers and private companies as one solution to enhance fisheries production as well as boost the economy of coastal community. In the next years it was then followed by rapid development of marine fish farm in the form of floating cages, pen nets and enclosures. Most of them are in bays and protected shores (Rachmansyah, 2004).

Nevertheless, there is a growing concern about the environmental impact of marine aquaculture (Wallin and Hakanson, 1991; Holmer et al., 2002; Lee at all, 2003) since the growth and intensity of fish farm operation in some coastal areas have gone beyond the carrying capacity of the coastal environment.

Unfortunately, such concern is not found at the same degree in Indonesia. Although there are a number of cases of reared fish massive mortality, there are not many comprehensive research dealing with impacts from marine fish farming activities. The government also seems hesitated to elaborate the ecological impacts of fish farming activities in their effort to promote this kind of alternative aquaculture. This can be seen in one article of the 2004 Ministerial decree on Authorization of Fish Aquaculture Operation (Ministry of Fisheries and Marine Affairs, 2004). An Environmental Impact Analysis (EIA or AMDAL in Indonesian version) is required only for a marine fish farm with rearing area reaches 5 ha or more, similar to at least 250 rearing units or 1000 cages. This means that impacts from fish farm operation are not expected to alter the adjacent coastal environment when the farm compund has less than 1000 cages. The article also ignores the fact that there are a lot more factors influencing the degree of environmental impact of fish farm activities. Maximum number of cages within one area, optimum rearing density, type of feeding, as well as a minimum distance between fish farm compound are not yet addressed in the decree, let alone regulated.

Therefore sufficient knowledge on such impact of fish farm is important for a safe and ecology-economical precaution for the future farmers. By learning the potential impact of their activities, future and present farmers can operate their farms in a safe and environmentally friendly way.

II. History of Fish Farm

Marine fish culture in cages was initially introduced in Japan as far back in 1950s when Fisheries Laboratory at Kinki University initiated the cage farming of yellowtail (Seriola quinqueradiata) for commercial purposes (Takashima and Arimoto, 2000). However, such practice started to boom and develop into successful industry not until 1980s to early 1990s. In Southeast Asian region particularly, large-scale marine cage culture activities developed not only in quantity but also the quality, such as rearing methods and techniques, type of feeding, and others. The most reared species in Indonesia were groupers (Epinephelus spp) and milkfish (Chanos chanos), possibly due to their high economic value (Baluyut, 1989).

The primary areas for grouper cultures are Aceh, North Sumatra (Nias and Sibilga), Riau Islands, Bangka Islands, Lampung, west Java, Karimunjawa Islands (central Java), Teluk Saleh (west Nusa Tenggara), South Sulawesi, North Sulawesi and Southeast Sulawesi. The supply of seed are mostly from wild-caught species, although more and more cage operators are using hatchery-reared seed. The most popular feeding they use is trash fish (Baluyut, 1989, Anonymous, 2001).

III. Possible Impacts

The impact of marine fish cages to the environment varies depending on the type of culture systems (including the type of fish being reared, feeding mode and type of feed), site selection, characteristics of the location and size of the farm. Some possible impacts expected from fish farm activities are:

Organic enrichment in water column

Under normal conditions the amount of organic material generated in the water column is in equilibrium with grazing and degradation processes Grazing pressure is usually a major factor influencing phytoplankton abundance. But in a condition where there is a consistent enrichment of organic matters, the degradation process by bacteria will be multiplied, resulting in the high rate of oxygen consumption. On the other hand, the grazing rate cannot take up as much organic material as it is available, causing high concentration of dissolved organic materials in the surrounding waters. The following processes such as eutrophication, buil up of hydrogen sulfide as well as organic accummulation on sediment are described in the next point of discussion.

The main nutrients characterizing the organic enrichment from fish farming are the total Nitrogen, Phosphorus and Carbon. When the release of these nutrients into waters is above the naturally adsorbed rate, high concentration of C,N and P will eventually cause environmental degradation of the area. For example, the N, P and C load released to the environment from a milkfish fish farm in Awarange Bay South Sulawesi as reported by Rachmansyah (2004) are 43.28kgN/ton fish production, 30.87kgP/ton production and 147.54kgC/ton production, respectively. These value according to him can result in organic enrichment and decrease the environmental quality in a long run since the flushing rate within the bay is not high and the current speed does not alter much. Therefore the impact tends be localized within the area. As the farm grows larger and the production becomes more intensive above the load rate natually tolerated by the bay environment, the organic enrichment can possibly cause overfertile condition, which is usually followed by eutrophication and hypoxia. This in some cases can intoxicate the reared species.

The main source of nutrient release from fish farm is uneaten food. It is about 25 to 30 percent of the total food given and contributes around 65 percent organic input to surrounding waters (Wallin, M. and Hakanson, L., 1991). Below is a table of uneaten feed mostly wasted in the waters arounfd the salmon fish farm. The table shows tha the method of feeding will also affect the percentage of uneaten food. It is found that hand feeding resulted in 3.6% wastage or 27 g/m2xday organic matter deposited to the bottom whereas automatic feeders resulted in wastage of 8.8%.

Table 1. Estimation of waste from iuneaten feed for Salmonid Culture.

Type of Feed (moisture content)	% Uneaten trout in tanks	% Uneaten salmon in net-cages	% Uneaten trout in net cages
Dry (9%)	1-5%	15-20%	27%
Moist (30-40%)	5-10%	>20%	31%
Wet (70%)	10-30%	Variable	

Eutrophication

Eutrophication arises when there are increased nutrient and dissolved organic matter (DOM) concentrations over natural levels, which in turn leads to a greater production of particulate organic matter (POM) in the water column or on the sea-bed, (Dugdale & Goering 1967 *in* Gray, 2002). The organic matter from fish farm comes from uneaten food which quantify around 25-30% of the given food, and from faeces or droppings of fish. About 30% of the food consumed by fish comes out as faeces and enrich the environment. If the amounts of organic matter produced are too large to be grazed, then they sink to the seabed along with faeces and other particulate organic matter (Gray, 2002).

There are three key elements of eutrophication process which come intermittently: (1)increased nutrient levels leading to (2) production of particulate and dissolved organic matter and (3) degradation of the organic matter leading to lowered oxygen concentrations or known as hypoxia. This can be lethal (deadly) to organisms, especially the reared fish in the farm vicinity.

Hydrogen sulphide

Although there are many research on the effect of organic enrichment in water which leads to the formation of the toxic substance, hydrogen sulphide (H_2S), most of them deal with freshwater fish species. There are relatively little on marine species. A research carried out by Holmer (2002) on the effect of milkfish pen net in the Philippines showed that hydrogen sulfide are often present when there is a depletion of oxygen both in water column and sediment following a high degradation process which uses up oxygen.

Organic enrichment on sediment

As mentioned in the abstract of this paper, impact on sediment is the main issue of organic enrichment from fish farm activities since it is easier and more significant to detect compared to impact in water column.

In most research on environmental impacts of fish farming, benthic enrichment beneath the sea farms is widely addressed as the most visible impact of fish farm operation. Several reports have showed the presence of a loose and flocculent black sediment under fish cages, commonly named "fish farm sediment" (Holmer, 1991 *in* Holmer et al, 2002). The commonly observed character of this type of sediment is low values of redox potential, high content of organic material and accumulation of nitrogenous and phosphorous compounds. Holmer et al (2002) also found in their research around milkfish pen net in Bolinao area of the Philippines, that the sedimentation rates were very high inside the fish pens at all sites and generally increased with the input of fish feed. Similar case applied to the POC and PON content of the sedimenting material following the increase of feed input.

Although showing a clearly-visible proof, the impact on sediment still depends on other factors, such as the current speed and water depth which in turns will determine the flushing rate. The higher the flushing rate is, the less significant impact found on the sediment underneath the cages.

In line with that, a research in Awarange bay of South Sulawesi conducted by Rachmansyah (2004) found that dispersion of particulate waste coming out of the milkfish floating cages could reach a radius of 8.8 to 65.7m, with sedimentation emphasis at 30m distance from the cages. Therefore he suggested that the feasible distance between bed of cages in a fish farm compund should be at least 100m in order to avoid accummulation of sediment.

A research conducted in Pramuka-Panggang islands strait of Seribu Islands in Jakarta also showed similar results. Although there is no publicised report available, the sediment investigation conducted in October 2004 showed a degrading impact of organic enrichment on sediment following distances away from the cages (personal observation and monthly investigation on site, 2004). The organic enrichment itself is not as severe as described in other reports but still can be expected to buil up through the course

Figure 2. Samples of sediment taken from Seribu Islands, Jakarta. Although not significant, there is a sign of oxygen depletion, shown by the darker part

of time (the fish farm compund has only operated there since early 2001). The adjacent picture of sediment sample taken by CRM divers using a sediment corer showed a sign of scattered black traces, explaining that there are some non-oxidized part of sediment. In a long run it may result in hypoxia in sediment layers, then the formation of hydrogen sulfide in the form of bubbles. This condition will goes up to the water column and eventually to the cages overhead where the reared fish could be intoxicated.

In order to assess the detailed impact on sediment up to the water surface, Karakassis et al. (2002) suggested to investigate patterns in vertical profiles as a means of assessing fish farming impacts. The measurement of surface values alone, although useful for the assessment of the size of the affected zone, may not provide adequate information on the dynamic processes related to the accumulation of waste material beneath the cages. Some of the environmental variables may be relatively constant in time while the depth of the farm sediment could vary considerably.

IV. Conclusion

1. Fish farms represents a significant point source load of organic matter and nutrients into coastal marine environments. Therefore it is important to ensure that the combined load into the rearing area (estuaries, straits, bays) does not exceed their assimilative capacity, leading to unacceptable environmental conditions.
2. Improved farm management practices (including stocking densities, feeding regimes, selective type of feed, cage rotation) will not only reduce environmental risk, but also increase farm profitability through improvements in carrying capacity, fish health and growth rates.

V. Suggested measures should be taken by farm operators are:

Biofiltration

To reduce the organic matter concentration in the water column, a biofiltration process is needed. Biofiltration by plants, such as macroalgae, is assimilative,c meaning that it can naturally adsorbed the excess nutrients in water and therefore adds to the assimilative capacity of the environment for nutrients. Algae, and in particular seaweeds, are the most suitable as biofilters since they can greatly reduce the overall environmental impact of fish culture and stabilize the culture environment.

Multiple species rearing

Rearing of herbivore species such as *Siganus javus*, is highly recommended since the species can eat up the excess nutrients as well as microalgae attaching to the net around the cages. Some farm operators in Seribu islands have already practised this technique because it has been proved to be very reliable, economically profitable and cost-effective in operation.

Ocean fish farm

Setting the fish farm away from any protected shores (bays, basins, fjord in estuaries) can be another alternative solution. The cages are moved into deeper water, with better circulation and flushing. There is a tremendous dilution factor from all of the water that moves through the fish farm area. The ammonia from the fish will be quickly broken down by natural bacteria in the water. The increase in the benthic biomass is to be expected when there is some greater organic input.

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Attachment/Appendix

Attachment 1. Potential of marine culture development in Indonesia

No	Provinces	Commodities/Products	Size of culture sites (ha)
1	NanggroeAceh	groupers, seagrass, oysters	203,35
2	North Sumatera	White snapper, oysters,sea cucumber, seagrass	734
3	West Sumatera	Mouse grouper, tiger grouper, seagrass, pearl oyster	128
4	Bengkulu	snapper, oysters, seagrass	203
5	South Sumatera	snapper, oysters	2.785.300
6	Riau	White snapper, seagrass	1.595
7	Jambi	White snapper	30
8	Lampung	Snapper, oyster	596,8
9	DKI Jakarta	Seagrass, oyster, groupers, snapper, siganus javus, pearl oyster	26,4
10	West Java	Snapper, grouper, sea cucumber, seagras	743,7
11	Central Java	Snapper, grouper, sea cucumber, seagras	677.700
12	DI. Yogyakarta	Snapper, grouper, sea cucumber,	18,8
13	East Java	Snapper, grouper, sea cucumber, seagras, pearl oyster	640,5
14	Bali	Snapper, grouper, oyster, sea cucumber, seagrass, pear oyster	39,2
15	West Nusa Tenggara	grouper, sea cucumber, seagras, pearl oyster	152,8
16	East Nusa Tenggara	Snapper, grouper, oyster, seagras, pearl	37,5
17	North Sulawesi	Snapper, grouper, oyster, sea cucumber, pearl	143,4
18	South Sulawesi	Snapper, grouper, oyster, sea cucumber, pearl, seagrass	600,5
19	Central Sulawesi	Seagrass, green clam, pearl oyster,sea cucumber	18,4
20	Southeast Sulawesi	Snapper, grouper, oyster, sea cucumber, seagrass, pearl	230
21	West Kalimantan	White snapper, grouper, lobster, sea cucumber	15,52
22	East Kalimantan	Snapper, grouper, lobster, seagrass	6,35
23	Central Kalimantan	Snapper, oyster	3.708.500
24	South Kalimantan	Groupers, oyster, clam, sea cucumber, abalone and white clam	1.962.505
25	Maluku	Snapper, grouper, oyster, sea cucumber, seagrass, pearl	1.044.100
26	Irian jaya	Snapper, grouper, oyster, sea cucumber, seagrass, pearl	9.938.100
TOTAL			24.528.178

Source : (Indonesian Directorate general of Aquaculture, 2002)

Attachment 2. Potential of inshore fish culture development in Indonesia

No	Province	Potential		Level of Exploitation	
		Size(ha)	%	Size (ha)	%
1	DI Aceh	34,8	4,02	42,847	123,12
2	Sumatera Utara	71,5	8,25	6,95	9,72
3	Riau	54	5,91	286	Dta
4	Jambi	3,3	0,36	100	Dta
5	Sumatera Selatan	13	1,88	100	0,61
6	Bangka Belitung	Dta	Dta	Dta	Dta
7	Sumatera Barat	7,7	0,89	3,613	46,92
8	Lampung	13,1	0,76	Dta	Dta
9	Banten	Dta	Dta	Dta	Dta
10	Bengkulu	6,8	0,79	143	2,09
11	Jawa Barat	47,2	7,23	54,308	86,68
12	Jawa Tengah	26	2,31	27,955	139,78
13	DI. Yogyakarta	1,9	0,22	Dta	Dta
14	Jawa Timur	35	3,90	Dta	Dta
15	Bali	4,6	0,54	678	14,58
16	Nusa Tenggara Barat	19,2	2,22	7,051	36,72
17	Nusa Tenggara Timur	2,5	0,29	346	13,84
18	Kalimantan Barat	91,6	10,59	557	0,61
19	Kalimantan Tengah	115	13,27	Dta	Dta
20	Kalimantan Selatan	28,6	3,30	2,363	8,26
21	Kalimantan Timur	82,9	9,26	15,428	18,50
22	Sulawesi Selatan	15,9	1,83	84,832	535,22
23	Sulawesi Tenggara	7	2,31	Dta	Dta
24	Sulawesi Tengah	5,5	9,63	5,85	107,34
25	Gorontalo	Dta	Dta	Dta	Dta
26	Sulawesi Utara	16,5	0,39	689	20,26
27	Maluku	188,4	22,06	45	0,02
28	Maluku	Dta	Dta	Dta	Dta
29	Irian jaya	21	2,42	213	1,01
TOTAL		913	100,00	344,759	40,00

Source : (Indonesian Directorate general of Aquaculture, 2002)