Environmental interactions of marine aquaculture in Japan

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Environmental interactions of Aquaculture

- Fish culture
- Shell fish culture
- Marine algae culture
- Polyculture (IMTA)

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- Near field effects
  - Physical changes
  - Chemical changes
  - Biological changes
- Far field effects
  - Chemical changes
  - Biological changes

Outline

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2. Impact of Aquaculture
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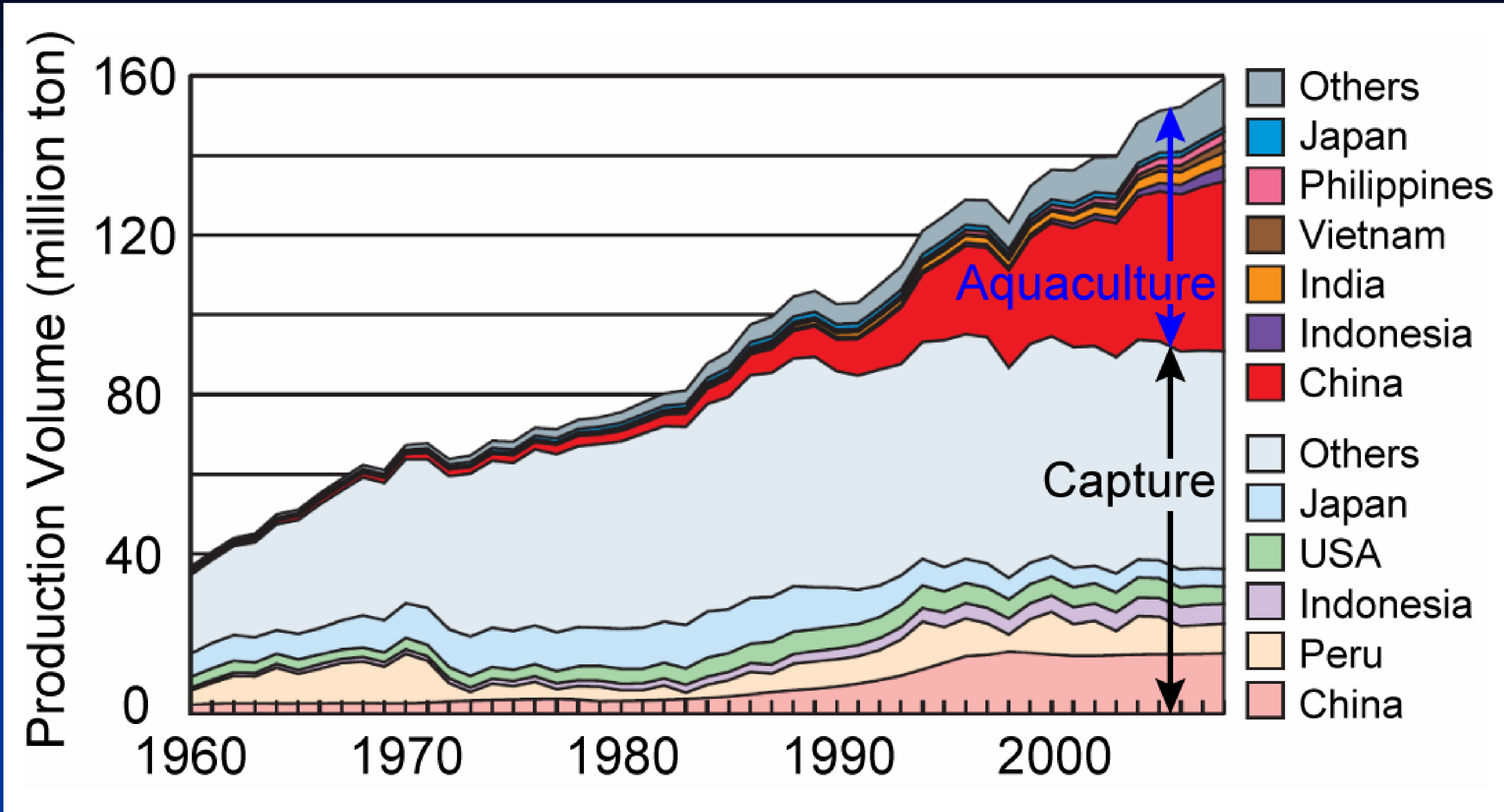
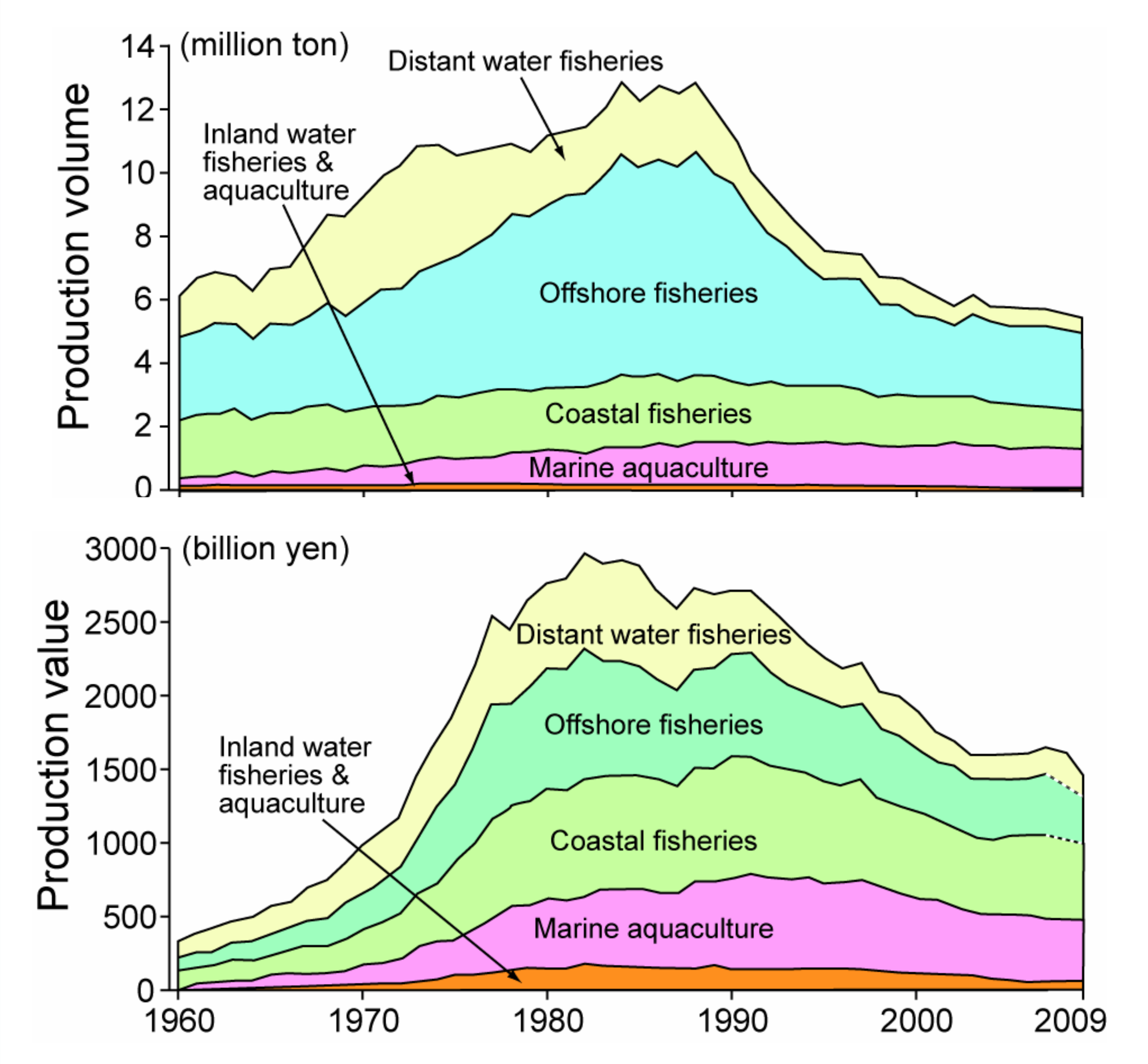
(2) Shellfish
(3) Marine algae, Integrated Aquaculture



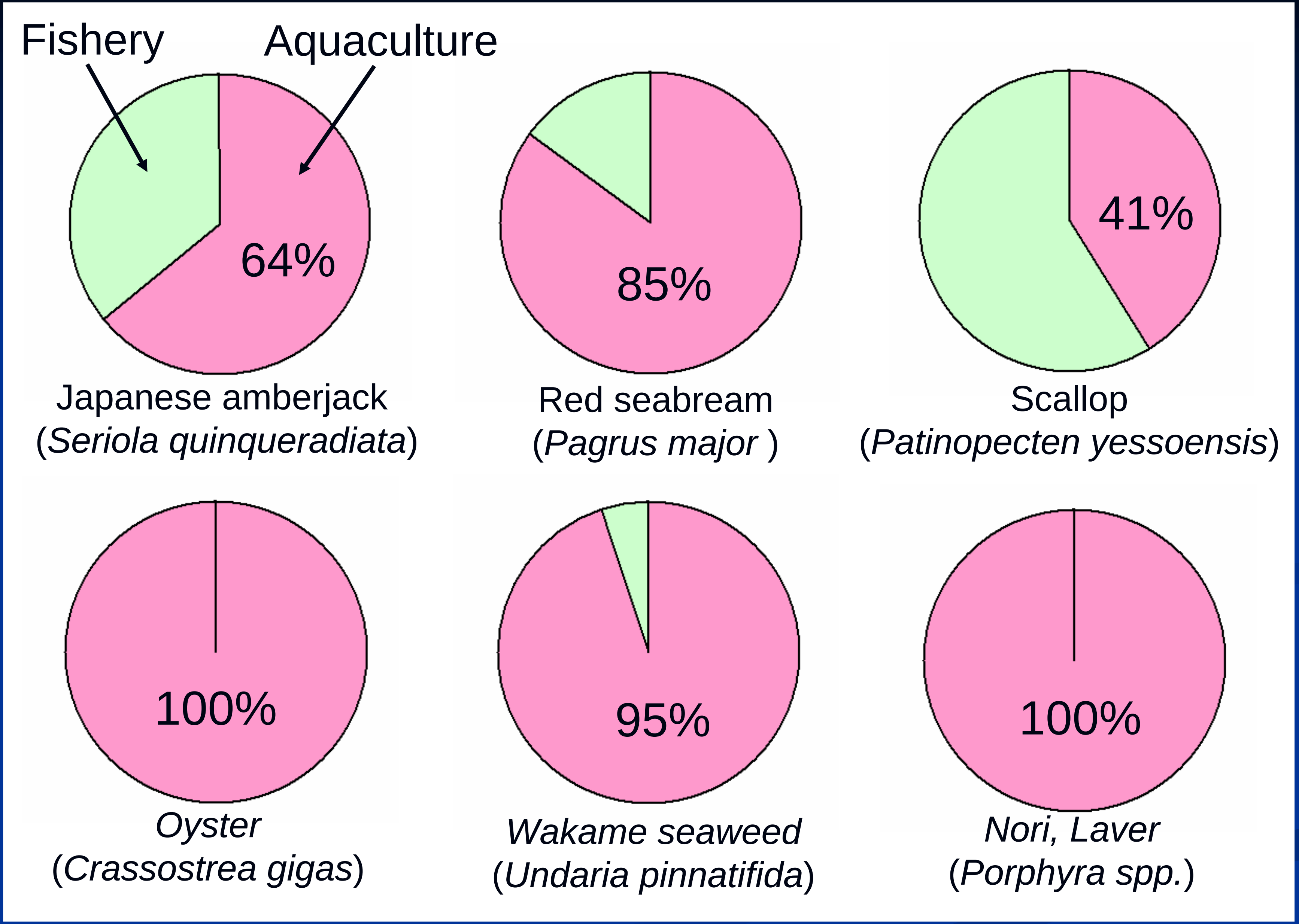
Capture and aquaculture production in the world 1960-2008 (FAO)



Fisheries production volume and value in Japan

Marine aquaculture production in Japan (2007)

Species	Value (billion yen)	Production (thousand tons)
Fin fish	(213.8)	(262)
Yellowtail (Amberjack; *Seriola quinqueradiata*)	113.5	160
Red seabream (*Pagrus major*)	55.5	67
Flounder (Bastard halibut; *Paralichthys olivaceu*	7.4	5
Ocellate puffer (*Takifugu rubripes*)	9.1	4
Coho salmon (*Oncorhynchus kisutch*)	5.6	14
Shellfish	(72.1)	(454)
Scallop (*Patinopecten yessoensis*)	40.9	248
Oyster (*Crassostrea gigas*)	30.0	205
Seaweed	(116.2)	(514)
Nori (Laver; *Porphyra spp*)	95.0	396
Kombu (*Laminaria spp*)	10.6	41
Wakame (Seamustard; *Undaria pinnatifida*)	7.3	54
Kuruma prawn (*Marsupenaeus japonicus*)	8.7	2
Pearl	18.0	3



Ratio of aquaculture products in the total production volume

Environmental interaction

(1) Finfish

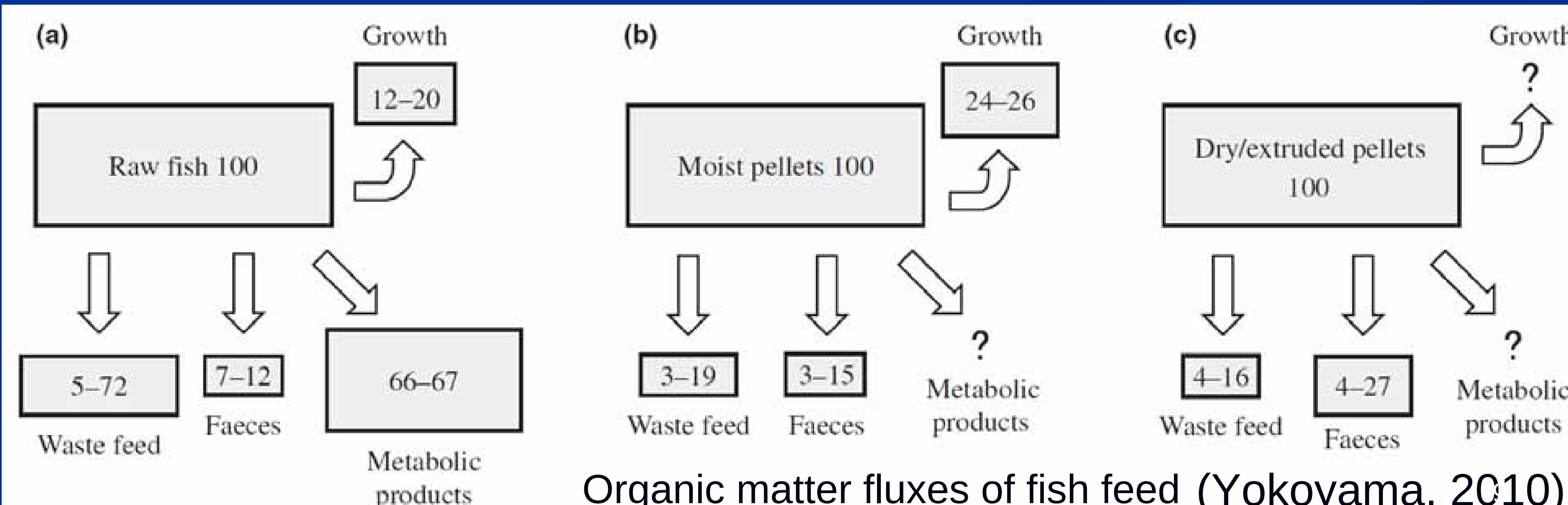
Fish farming generates large amounts of waste in the form of particulate organic matter, dissolved organic matter and nutrients. In Japan, the negative effects have become conspicuous since 1970s. A large amount of organic matter is discharged into surrounding area resulting in chemical and biological changes of benthic environments in and around the culture facilities.

Flux of fish feed (finfish aquaculture)

Table 1 Flux of fish feed. Feed used for fish culture = 100%

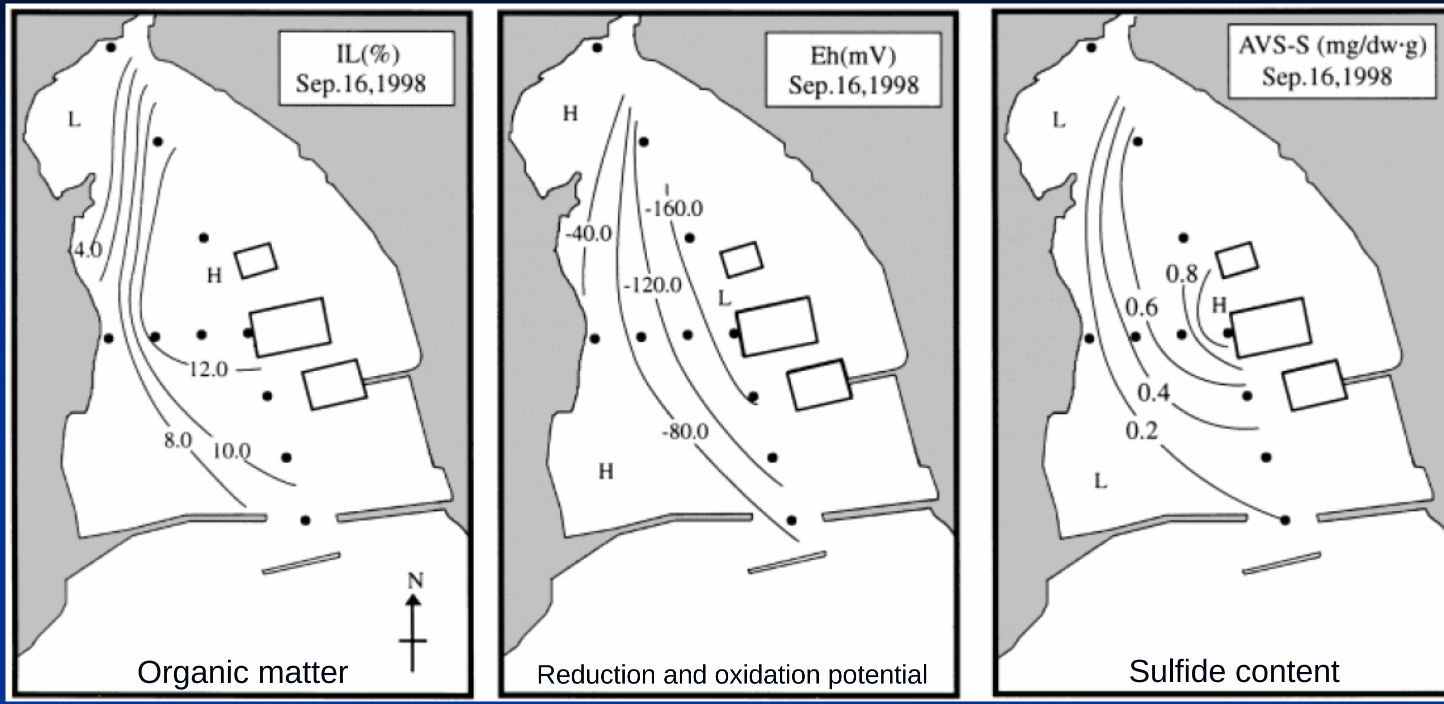
Feed	Cultured fish	Target material	Growth of fish (%)	Metabolic products (%)	Waste feed (%)	Faeces (%)	Reference
Raw fish	Yellowtail	Carbon	20	66	5	9	Tanaka (1977)
Raw fish	Yellowtail	Nitrogen	21	67	5	7	Tanaka (1977)
Chopped raw fish	Red sea bream	Dry matter	–	–	6	12	Uede (2006)
Minced raw fish	Yellowtail	Nitrogen	12	–	24	–	MPFES (1983)†
Minced raw fish	Yellowtail	Dry matter	15	–	72	–	Watanabe (1991)
Moist pellets	Yellowtail	Nitrogen	24	–	11	–	MPFES (1983)†
Moist pellets	Yellowtail	Dry matter	–	–	3–5	12–15	WRCAFF (2002)‡
Moist pellets	Yellowtail	Dry matter	26	–	19	–	Watanabe (1991)
Moist pellets	Red sea bream	Dry matter	–	–	10–19	3–11	Uede and Takeuchi (2007)
Dry pellets	Yellowtail	Dry matter	–	–	10	27	WRCAFF (2002)‡
Extruded pellets	Red sea bream	Dry matter	–	–	4–16	4–6	Uede and Takeuchi (2007)

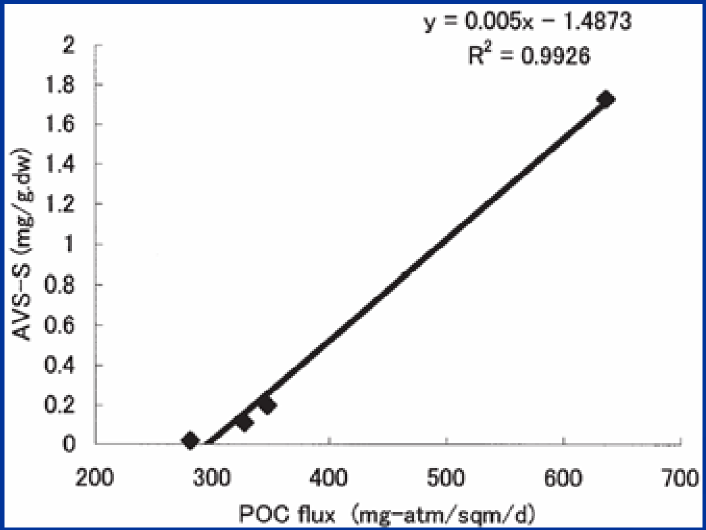
†Mie Prefectural Fisheries Experimental Station. ‡Wakayama Research Center of Agriculture, Forestry and Fisheries.



Organic matter fluxes of fish feed (Yokoyama, 2010)

Impact of finfish aquaculture on benthic quality

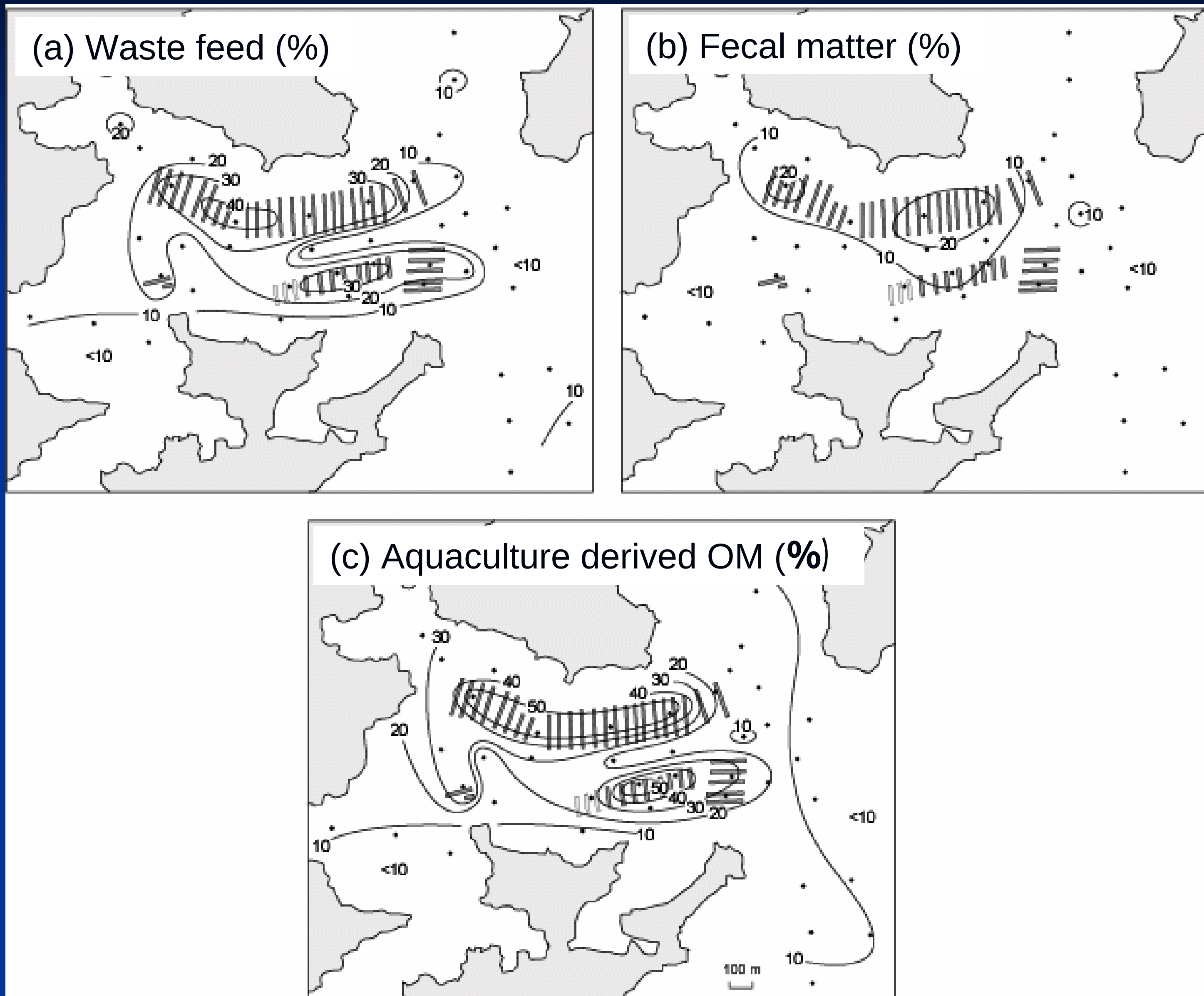




A case study of aquaculture in the Seto Inland Sea, Japan (Pawar et al., 2001)

Acid volatile sulfide (AVS) is an common indicator for assessing benthic environment

Impact of finfish aquaculture on benthic quality



(Yokoyama et al., 2006)

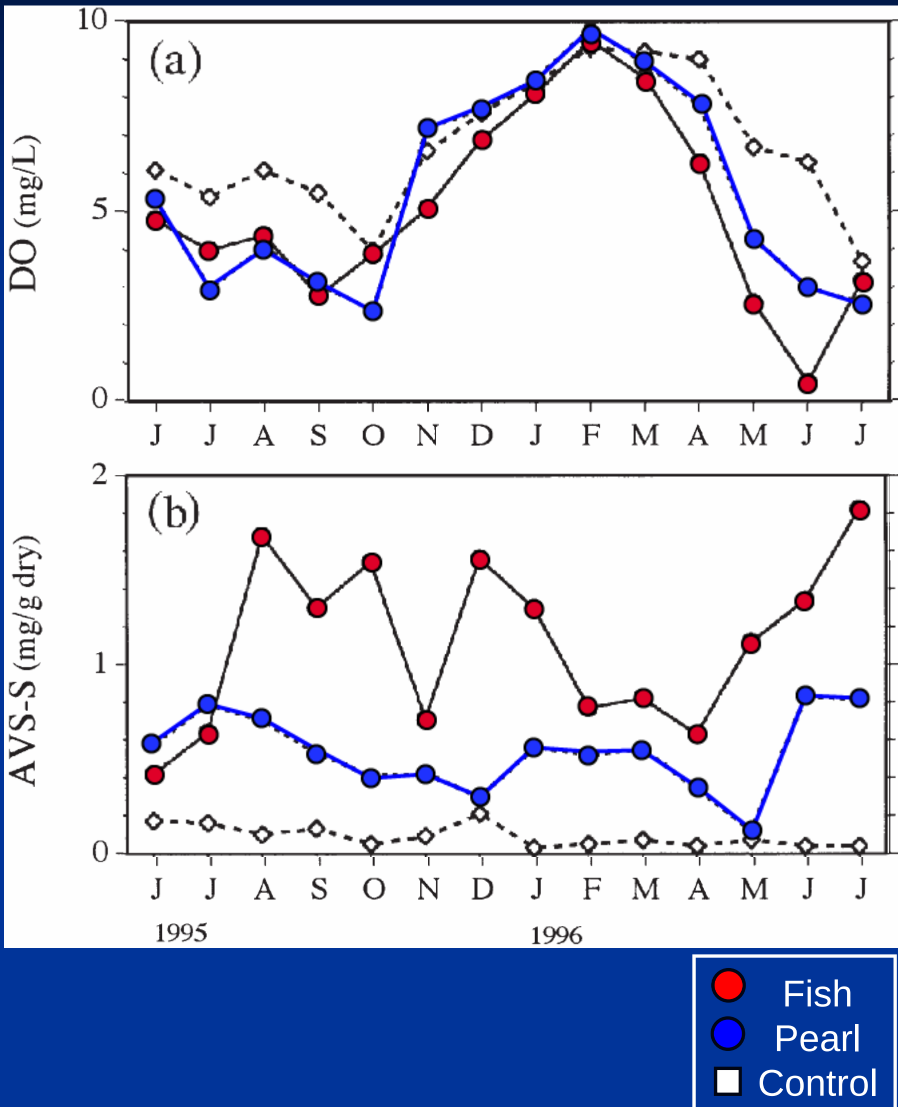
Environmental interaction

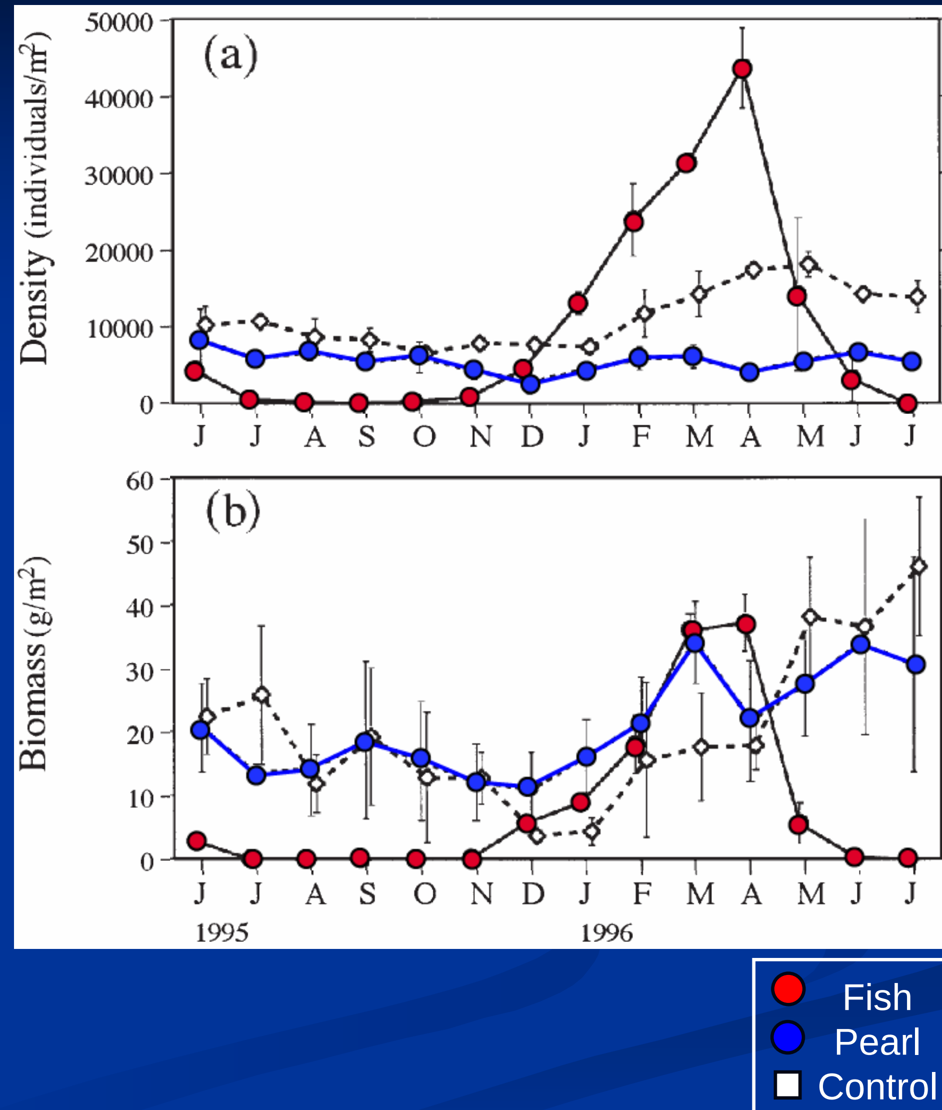
(2) Shellfish culture (Suspended culture)

Oyster (*Crassostrea gigas*) and Scallop (*Patinopecten yessoensis*) are the major species of shellfish culture which occupy 99% of annual production volume of shellfish culture in 2009. Pearl oyster (*Pinctada fucata martensii*) is also an important culture species which is 12 % worth of shellfish culture production values in 2009.

Shellfish culture (no-feeding culture) has much less impact than fish culture.

Environmental impacts of oyster culture and fish culture

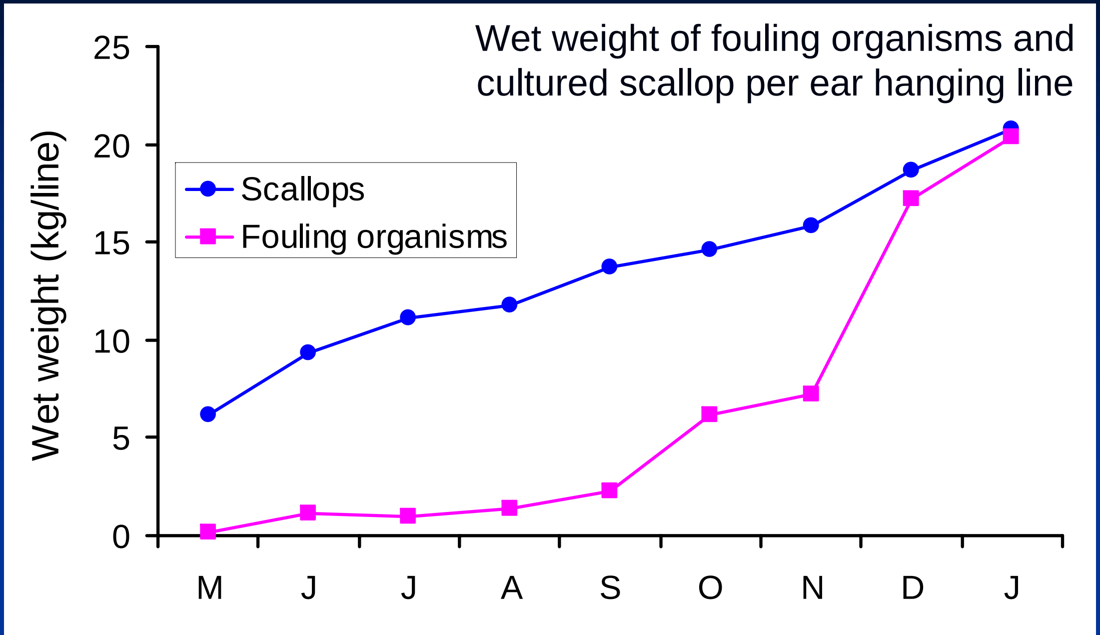


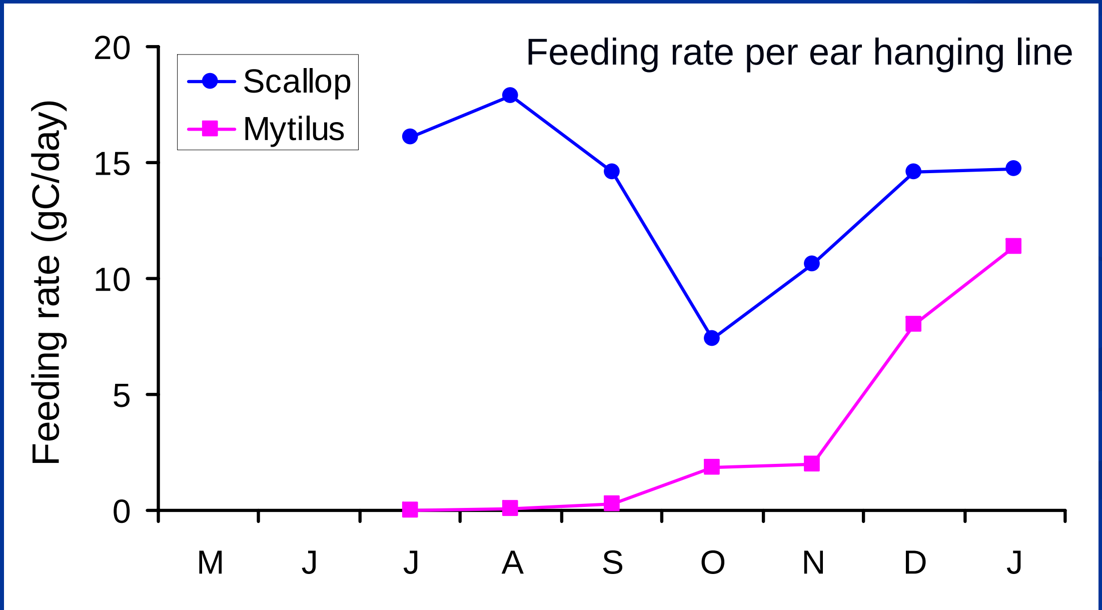


Benthic environments of oyster culture area compared with those of fish culture and control areas

Yokoyama (2002)

Impact of fouling organisms in scallop aquaculture in Funka Bay





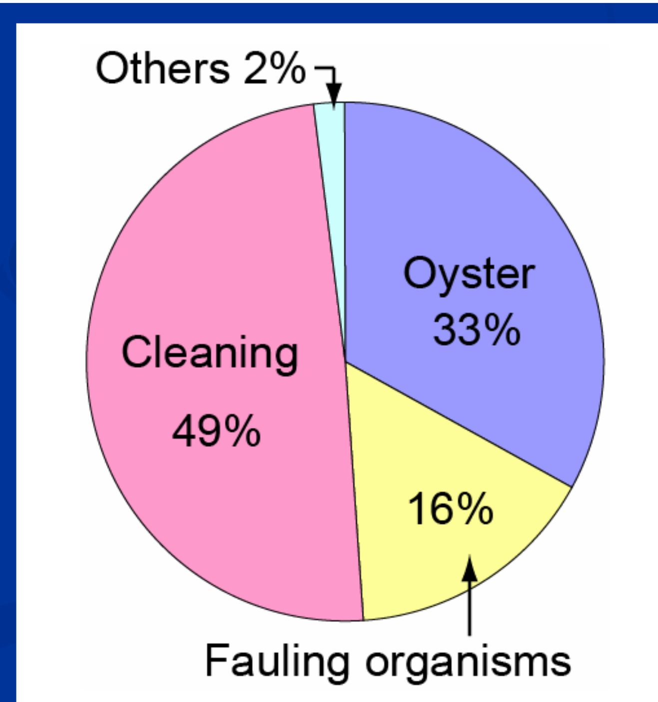
(Kurata et al., 1996)

Organic discharge from pearl oyster culture in Ago Bay

Cleaning

Organic discharge in pearl oystre culture area

Pearl oyster	(gC/100ind.)	0.23
Fouling organisms	(gC/m^2)	0.14
Cleaning A-type	(gC/10ind./time)	0.37
Cleaning B-type	(gC/10ind./time)	0.10
Others	(gC/m^2)	0.02



(Ueno et al., 2000)

Environmental interaction

(3) Marine Algae

As marine algae absorb nutrients from sea water and reduce eutrophication, marine algae culture has positive effects on surrounding environments.

- Integrated Multi Trophic Aquaculture

In Japan the effectiveness of integrated aquaculture has been confirmed from experimental fish farms using *Ulva*, *Laminaria* and *Undaria* as biofilter.

Requirements for available seaweed species in IMTA

(1) high efficiency of nutrient removal
(2) high activity during the warm season
(3) high economic value
(4) easy cultivation

Carmona *et al.* (2006) indicated that *Porphyra* appears to be an excellent choice for bioremediation of moderately eutrophic effluents, with the added benefit that tissue may be harvested for sale.

In Japan the effectiveness of integrated aquaculture has been confirmed from experimental fish farms using *Ulva*, *Laminaria* and *Undaria* as biofilter. However, this system has not been adopted on a commercial-basis, due to the lack of financial reward for the farmer's additional work to implement such measures.

WG-24 country report on environmental interactions (2011)

3 Japan

3.1 Overview

In Japan marine aquaculture produced 1,146,000 metric tons and 418 billion yen (ca. 5 billion US$) in 2009 which occupied 20% and 26% of Japanese fisheries production in terms of volume and values, respectively. Since mariculture generates large amounts of organic wastes and nutrients in and around aquaculture facilities, it may have large impacts on the benthic environments. Especially, feeding aquaculture (fish farming) discharges large amount of organic waste to benthic environment. Although non-feeding aquaculture (shellfish culture, algae culture) has less impact, intensive and long-term culture activity causes eutrophication and hypoxia due to feces and associated remnants, which may alter the benthic animal communities in the culture area.

3.2 Fish farms

Yellowtail (*Seriola quinqueradiata*) and red seabream (*Pagrus major*) are the main species reared in finfish cage culture in Japan. Recently, blue fin tuna (*Thunnus orientalis*) has begun to be cultured with net cage culture. Fish farming generates large amounts of waste in the form of particulate organic matter, dissolved organic matter and nutrients. In Japan, the negative effects have become conspicuous since the commencement of large-scale fish farming in the mid 1960s and its subsequent rapid development during the 1970s and 1980s. A large amount of organic matter is discharged into surrounding area resulting in chemical and biological changes of benthic environments in and around the culture facilities.

3.2.1 Near field effects

3.2.1.1 Physical changes

Organic wastes (feces and uneaten feed) derived from fish farming facilities settle on the seabed. In Japan, fish farming are often conducted intensively in enclosed basins and large amount of sludge are accumulated on the seafloor. In such case, dredging sludge under the farming facilities is conducted occasionally to treat benthic environments even if its sustainability is in doubt.

3.2.1.2 Chemical changes

A large amount of feed is used to culture fish and a large proportion of given organic matter is discharged into the environments in various forms. The flux of organic matter has been investigated mainly from laboratory rearing experiments (Yokoyama, 2010). The proportion of organic matter retrieved as harvested fish has been estimated to be 12% of the total nitrogen in minced raw fish fed (Mie Prefectural Fisheries Experimental Station 1983) and to be 26% of total dry matter in case of moist pellets feed (Watanabe 1991). The remainder (88 or 74% of the total input of organic matter) results in a load to the surrounding water body. Particulate organic matter that is comprised of faecal matter and waste feed settles on the seabed. Fecal matter accounts for 3% of total dry matter in moist pellets (Uede & Takeuchi 2007) to 27% of total dry matter in dry pellets (Wakayama Research Center of Agriculture, Forestry and Fisheries 2002). The proportion of waste feed is variable, accounting for 3% of total dry matter in moist pellets (Wakayama Research Center of Agriculture, Forestry and Fisheries 2002) to 72% of total dry matter in moist pellets (Watanabe 1991).

Organic enrichment of the seabed, deoxygenation of the bottom water and occurrence of sulfides are the most remarkable impacts of fish farming on the benthic environments. In the intensive fish farming site in the basins, indices of organic matter loadings (chemical oxygen demand (COD), ignition loss(IL), total organic carbon(TOC), total nitrogen(TN), carbohydrates and amino acid contents in the surface layer of the sediment) become extremely high. Increasing organic enrichment of the sediment was occurred in various fish farming area in the southwestern part of Japan. Acid volatile sulfide (AVS) in the sediment is commonly used in Japan as an indicator of environmental deterioration in fish farm (Pawar *et al.* 2001; Yokoyama *et al.* 2002a,b, 2004; Uede 2008). Fish farming change the stable carbon and nitrogen isotope ratios of the sediment due to differences of the ratios between natural sediment and aquaculture derived organic matter. The stable isotope ratios can be a useful indicator to quantify organic wastes from

3.3 Shellfish Culture

In Japan, Oyster (*Crassostrea gigas*) and Scallop (*Patinopecten yessoensis*) are the major species of shellfish culture which occupy 99% of annual production volume of shellfish culture in 2009. Pearl oyster (*Pinctada fucata martensii*) is also an important culture species which is 12 % worth of shellfish culture production values in 2009.

Shellfish cultures have farther less impact on environments than feeding aquaculture such as fish farms. Yokoyama (2002) indicated that pearl oyster farming caused less effect on the benthic fauna whereas fish farming had large impact on the macrofauna. On the contrary, shellfish culture system could act as an efficient biological tool to harvest material from the coastal ecosystem to the land (Songsangjinda *et al.* 1997). Nevertheless, accumulative impacts of shellfish culture on environments cause eutrophication, hypoxia and changes of benthic animal communities.

3.3.1 Near field effects

3.3.1.1 Suspension Culture

3.3.1.1.1 Physical Changes

Suspended shellfish culture enhances sedimentation due to depositions of the feces on the seafloor beneath the farming facility.

Fluid resistance of suspended culture facility reduces current velocity affecting transport of the materials in the water around the culture area.

3.3.1.1.2 Chemical Changes

The primary effect of shellfish culture on marine environments is enhanced sedimentation. Mori (1999) estimated ca. 20 metric tons dry weight of feces was produced per year per raft of oyster culture. The fecal production varies depending on culture density (Yamamoto *et al.* 2009). Considering attached organisms on the farming facility, more fecal materials are accumulated to the benthic environment. Kusuki (1981) reported increases of COD, organic carbon, total nitrogen, total sulfide and phaeo-pigments in the surface sediment in oyster culture cites in Hiroshima Bay. Such increase of organic matter contents in the sediments were reported in the oyster culture area of Matsushima Bay, Kesen-numa Bay, and Ago Bay.

3.3.1.1.3 Biological Changes

Shellfish culture affects the benthic animals beneath the farming facility. In the suspended scallop culture area in Saroma Lagoon, accumulative impact of the intensive scallop culture affected polychaete community structure, where the species number, density and species composition of the community were changed significantly (Sonoda *et al.* 2002).

Cultured shellfish excrete high level of ammonia, promoting increased productivity of attached organism to the farming facilities. Attached organisms not only compete food materials with cultured shellfish but increase biodeposition from the facility to the benthic environment. Production of the fouling organisms attached to hanging line of scallop culture was estimated to be equal to the scallop production (Kurata *et al.* 1996). In the pearl oyster culture area, on-site cleaning fouling organisms leads to increase of organic matter loads which amount 50 % of total organic load of the area (Ueno *et al.* 2000).

3.3.1.2 On-bottom Culture

(Physical Changes, Chemical Changes, Biological Changes)

On-bottom culture exploits sea area two dimensionally and has less production efficiency and less impact on environment than suspension culture which exploits sea area three dimensionally. Although the impacts are less than suspension culture, on-bottom culture may have significant role on surrounding ecosystems by removing organic materials from water column and enhancing biodeposition to benthic environment.

3.3.2 Far field effects

End