Some Considerations of Fisheries Management in the Yellow Sea Large Marine Ecosystem

M.E.M. Walton and Yihang Jiang

UNDP/GEF project "Reducing environmental stress in the Yellow Sea Large Marine Ecosystem"
KORDI compound, 1270, Sa2-dong, Sangnok-gu, Ansan-si, Gyeonggi-do,
426-744 Republic of Korea

Background Information from TDA and SAP

In 2007 the UNDP/GEF Yellow Sea Large Marine Ecosystem (YSLME) Project published the Transboundary Diagnostic Analysis (TDA) (UNDP/GEF 2007a). This report identifies the environmental issues and problems, outlines the root causes and provides suggestions for management interventions. Under the fisheries section, the major problems were a decline in the catch of some commercial species and a change in the composition of the fisheries catches with an increase in the landings of low value species (UNDP/GEF 2007a) based on scientific findings (Jin 2003; Jin and Tang 1996; Zhang et al. 2007). The root cause was identified as overexploitation of fish stocks as a result of over capacity in the fishing fleets of China and Republic of Korea.

In response to the identified problems, the Strategic Action Programme (SAP) for the YSLME set 2 targets for capture fisheries to be realised by the year 2020: (i) a 25-30% reduction in fishing effort; and (ii) the rebuilding of fish stocks (UNDP/GEF 2009). To achieve these targets various management actions are recommended such as: a reduction by 25-30% of boat numbers with strict control in the building of new boats; the closure of areas and seasons for fishing to protect spawning fish and nursery grounds; improved monitoring, an increase in the mesh size to reduce the catch of juvenile and introduction of more selective gears; continued use of habitat improvement and stock enhancement using healthy, genetically diverse fry; and the introduction of individual transferable quotas (ITQs) and ecosystem based management of the existing fisheries.

Both China and the Republic of Korea are already implementing many of the proposed management actions and both are firmly committed to reducing fishing effort. Under the current 5 year plan ending in 2010 China plans to reduce the number of fishing boats by 10% and the marine catch by 15%; and by the year 2020 aims to reduce the fishing fleet and marine catch by 33%. To implement these plans the Chinese government has invested significant funds, more than 270 million Yuan each year for scrapping old fishing boats, with extra funding from local governments, and an additional 90 million Yuan specifically for enforcement of fisheries legislation. Further funds are also available for retraining, job creation and tax breaks for ex-fishermen and for stock enhancement and habitat improvement. The Republic of Korea has invested similar amounts with over a million US dollars invested in boat-buy back annually.

Logical Considerations on the Management Actions

In order to solve the identified problem of over-fishing, there is a need to reduce fishing effort. However, cutting fish catches by one third will leave China, in particular, with a substantial deficit in fish protein. Until stocks recover, there is a need to make up this shortfall with protein provided by marine aquaculture or mariculture. To ensure the negative impacts from mariculture are minimized, while productivity is enhanced, the issue of sustainability needs to be addressed. One of the solutions from the management actions of YSLME is to introduce integrated multi-trophic aquaculture (Figure 1).

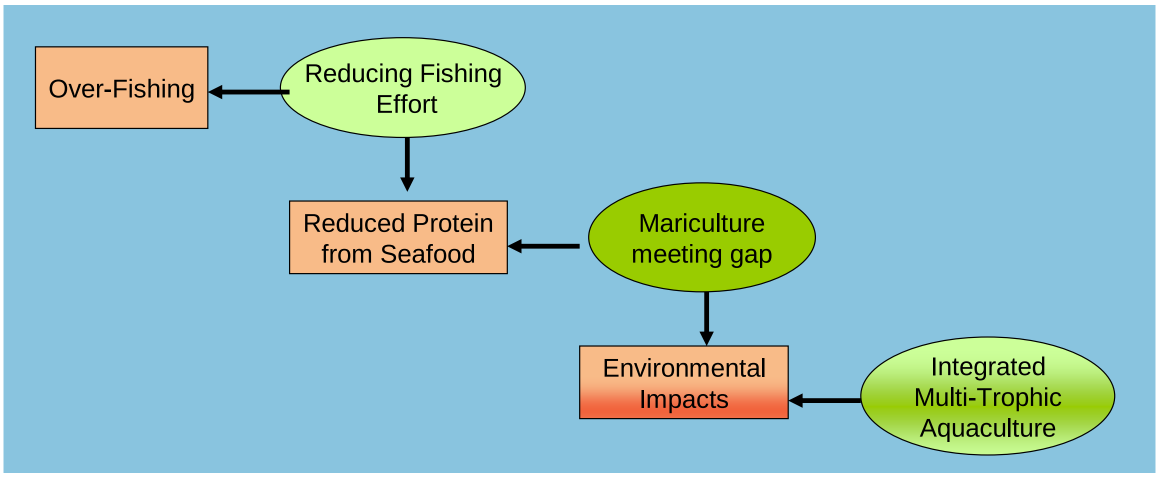

Figure 1. Logical considerations of management implementation

Currently, the total capture fishery production is almost 15 million tonnes annually (1998-2007) (FAO 2009). To compensate for the initial shortfall in fish catches, production from mariculture will have to increase, and indeed production in China has already dramatically increased from 5 to more than 30 million tonnes in the last 20 years (Figure 2) and there is high probability of this growth continuing. However, finfish/crustacean production has only reached 310,000 tonnes (UNDP/GEF 2007b). Just in order to compensate for the decreased wild catch from the Yellow Sea, production needs to rise by over a million tonnes by 2020. Moreover, to keep pace with the likely increase in demand for fish, shrimp and other crustaceans from an increasingly wealthy population could require a six or seven fold rise in production. This is going to be quite a challenge given the spatial and environmental constraints. Unregulated mariculture can have huge environmental impacts contributing to the already stressed coastal environment through inputs of nutrients and chemicals, the introduction of disease causing pathogens and alien species. As a result of the increase in stress, survival and growth of the cultured organism suffers and productivity decreases. This has already happened. Moreover, most fish and crustacean culture requires large amounts of fish protein and fish oil that comes from species which in many parts of the world and particularly in China and R. Korea, are consumed by humans.

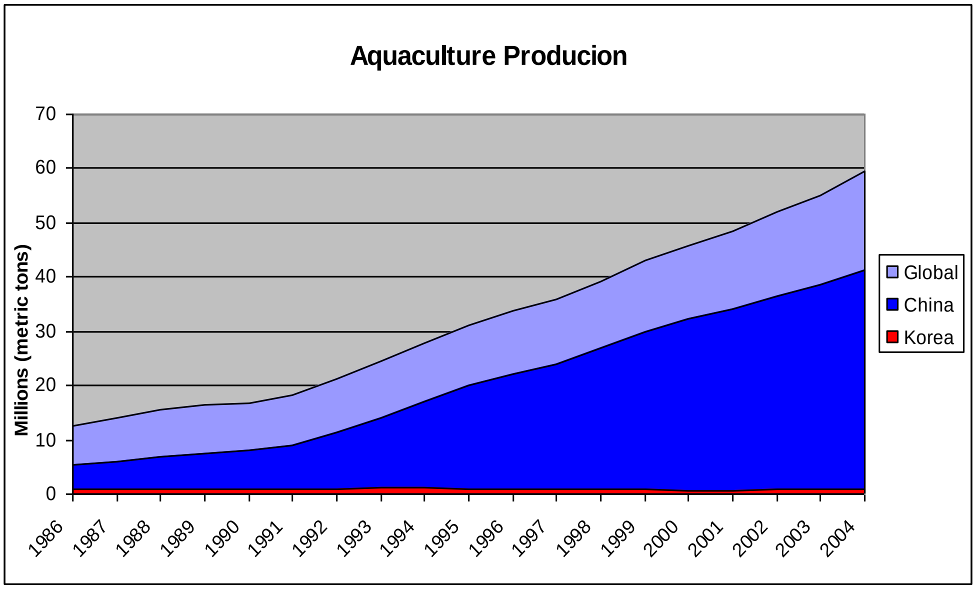

Figure 2. Aquaculture production (fresh, salt and brackish water culture) since 1986 (millions of tonnes).

The YSLME project is using a novel approach in environmental management. We realise that every management decision and all human activities have an impact on more than one sector of the marine environment. We, therefore, decided to use the idea of ecosystem carrying capacity (ECC) as defined as the sum of the ecosystem services (provisioning, regulating, supporting and cultural) that benefit mankind. This helps conceptualise the idea that all ecosystem services are linked and interdependent. Consequently, ecosystem based management is the only logical method for managing the environment, as traditional sector-based approaches cannot manage these inter-linkages inferred in ecosystem carrying capacity. For example, reducing fishing effort by 25-30% will not necessarily result in the recovery of fish stocks. We also need to manage the other impacts on the ECC. Hence, the YSLME SAP also sets targets for reducing pollution, improving sustainability of mariculture, and controlling habitat loss as these all affect fisheries production.

Current Capture Fisheries Activities.

The SAP proposed a target of a 25-30 % reduction of fishing effort to be achieved through: the control of boat numbers with 25-30% of the fishing fleets being decommissioned by 2020; the stopping of fishing in certain areas and seasons, to protect vulnerable stocks or life stages of certain species; and improved monitoring and assessment of fish stocks (UNDP/GEF 2009). The SAP also proposed that fish stocks should be rebuilt through: an increase in mesh sizes and the use of more selective fishing gear; stock enhancement by restocking of overexploited stocks and through habitat improvement; and improved fisheries management and the use of Total Allowable Catch (TAC) and Individual Transferable Quotas (ITQ) (UNDP/GEF 2009).

Currently there are three activities to demonstrate the effectiveness of these fisheries SAP management actions:

a) Demonstrate the effectiveness of closed areas and seasons in fisheries management.
   Outputs: Assessment of the reduction in fishing effort due to closed areas and seasons, and their impact on fish stocks and fish catches.
   Progress: Monitoring the catches of selected fishing boats before and after the area closures, carrying out a cost benefit analysis of the area closures, and collecting historical records to compare the species composition changes that are currently being recorded after the area closure.

b) Demonstrate the effectiveness of stock enhancement
   Outputs: Assessment of the effectiveness of the release of hatchery-raised juvenile olive flounder (*Paralichthys olivaceus*) in rebuilding fish stocks using mark-recapture techniques in Shandong province. Assessment of restocking of Chinese fleshy shrimp (*Fenneropenaeus chinensis*) in Liaoning province.
   Progress: Currently monitoring the recaptures and conducting independent trawl surveys.

c) Demonstrate the effectiveness of boat-buy back
   Outputs: Description of the success of the R. Korea government's fishing boat buy-back and its impact on reducing fishing effort.
   Progress: Currently interviewing fisherfolk to assess the perception of the impact on fish stocks and assessing the government's policy on reducing fishing effort.

The project is also involved in the organisation of the first ever joint regional fisheries stock assessment exercise between China and R. Korea. The results are currently being analysed. Early results of harmonisation exercises in ageing of fish and stomach contents analysis suggest that diets of fish species on each side of the Yellow Sea are very different and that earlier differences in growth rates in such fish as small yellow croaker and chub mackerel maybe real and not the result of differences in measuring techniques as previously suggested. These surveys have now sparked interest in further collaboration.

The assessment also showed that jellyfish occupied as much as 86% by weight of the total autumn catch in the west side of the Yellow Sea and that the species of the jellyfish in the east and west sides are different. These findings provided important scientific information to improve management of the Yellow Sea ecosystem.

Current Mariculture Activities

Although finfish and crustacean production have made substantial improvements in recent times, their culture has one of the worst environmental records in the industry. The increased demand for fish protein as a result of the decreased wild catches and increased wealth of the population presents some serious challenges for both China and R. Korea. To ensure that this increase in fish and shrimp production is sustainable, the SAP proposed a target of an improvement in mariculture techniques to reduce environmental impact by: developing and promoting environmentally friendly mariculture techniques; reducing nutrient discharges from mariculture facilities; and controlling disease.

Currently there are two demonstration activities on integrated multi-trophic aquaculture (IMTA) and heterotrophic shrimp culture that will show producers how increased productivity and profitability can be achieved without damaging the environment.

a) IMTA

Polyculture is where two or more species are cultured together, usually with some added benefit in terms of productivity. IMTA is a type of polyculture where species from different trophic levels (eg. algae, fish and oysters) are cultured together so that the waste products of one species are utilised by another (Figure 3).

In Sanggou Bay on the eastern tip of Shandong province, a number of different IMTA systems are being tested and evaluated. In China, more than 11 million tonnes of shellfish were cultured in 2006 (Fang et al. 2009). Shellfish (mollusc) culture is often associated with environmental impacts due to organic enrichment of the sediments associated with the increased sedimentation rates from the production of pseudofaeces and faeces produced by the molluscs (oysters, clams, scallops, etc). This enrichment can result in anoxic conditions causing changes in the benthic community toward domination by opportunistic polychaetes. However a recent study in Sanggou Bay, suggested that despite 20 years of mariculture, it had avoided the environmental impacts associated with shellfish culture in other parts of the world as a result of the low culture density, the current regime and the co-culture of oxygen-producing seaweed that prevent anoxia in the sediments (Fang et al. 2009).

As farmers switch to the more profitable shellfish and fish culture, demands on the environment will increase. To counteract this, the YSLME project is promoting the use of IMTA and the concept of carrying capacity. Carrying capacity models together with adaptive management can be used to optimize the culture density of various species so that nutrient flows are balanced and the environmental condition is maintained (Figure 4).

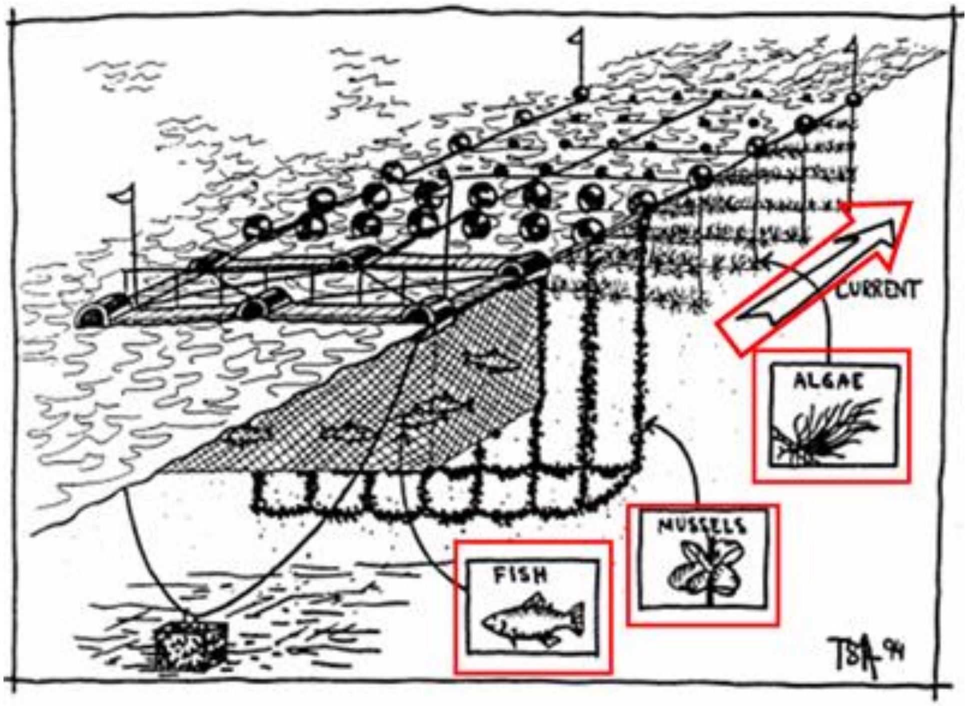

Figure 3. Diagrammatic representation of IMTA from Troell and Norberg (1998)

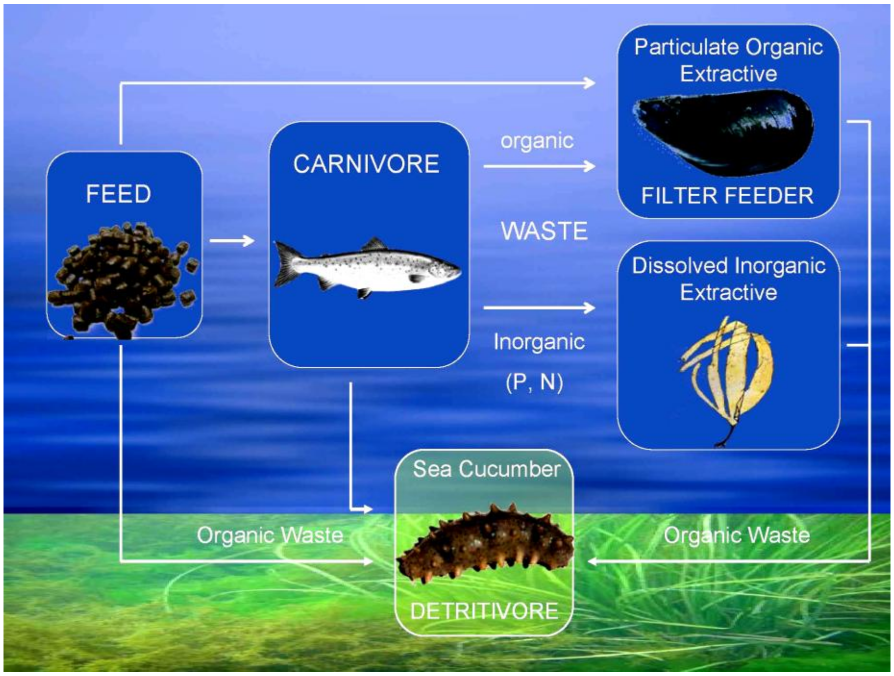

Figure 4. IMTA concept: The particulate waste in the water column is removed by filter feeding bivalves, while the portion that ends on the seafloor is utilised by sea cucumbers. The dissolved inorganic nutrients (N, P & CO_2) are absorbed by the seaweed that also produces oxygen, which in turn is used by the other cultured organisms. Modified from (Fang et al. 2009)

(i) IMTA of abalone and kelp

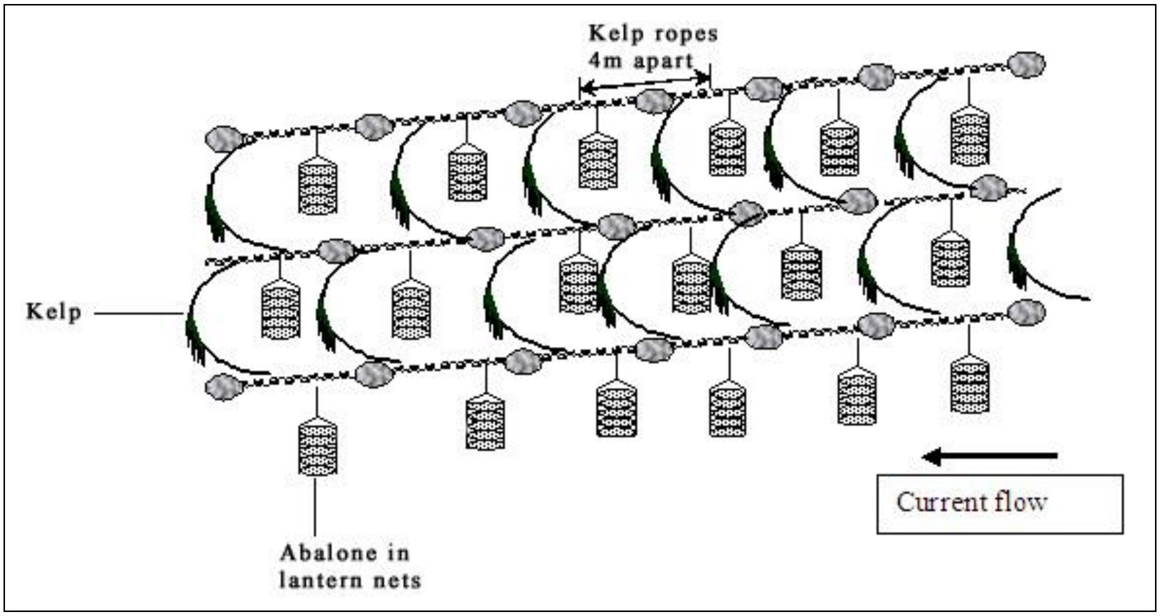

Figure 5. Diagrammatic representation of IMTA of long-line culture abalone and kelp

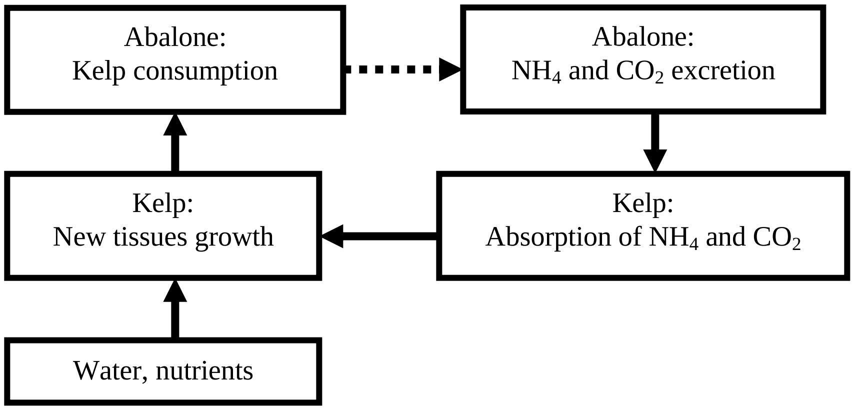

Figure 6. Diagrammatic representation of nutrient flows in IMTA of long-line culture abalone and kelp

The excretory products of the abalone are absorbed by the kelp, a small proportion of which is then used for feeding the abalone (Figures 5 and 6).

Method for IMTA of fish, bivalve and kelp

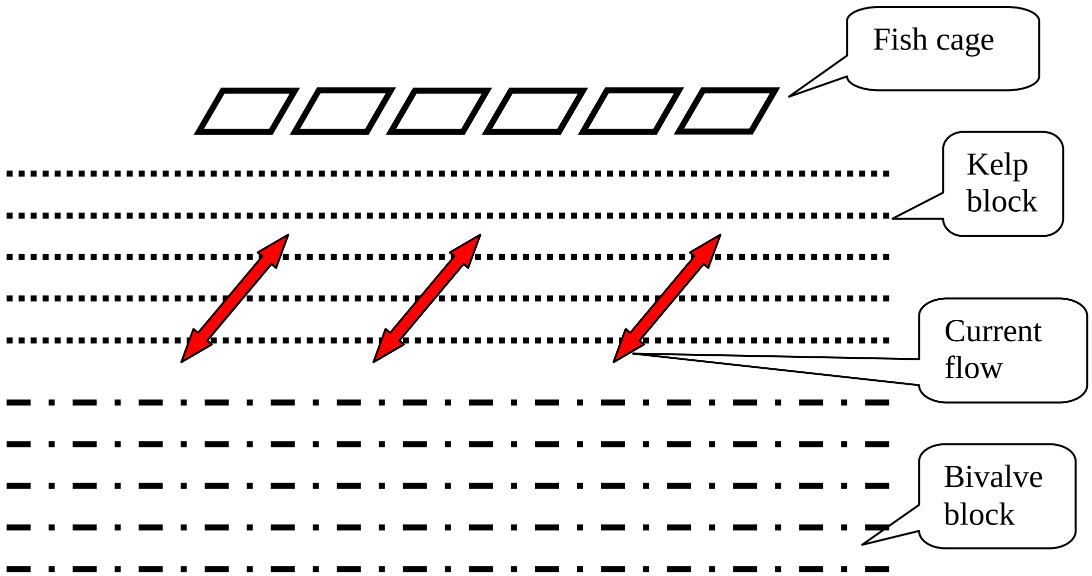

Figure 7. Diagrammatic representation of IMTA of long-line bivalve and kelp culture with cage culture of finfish

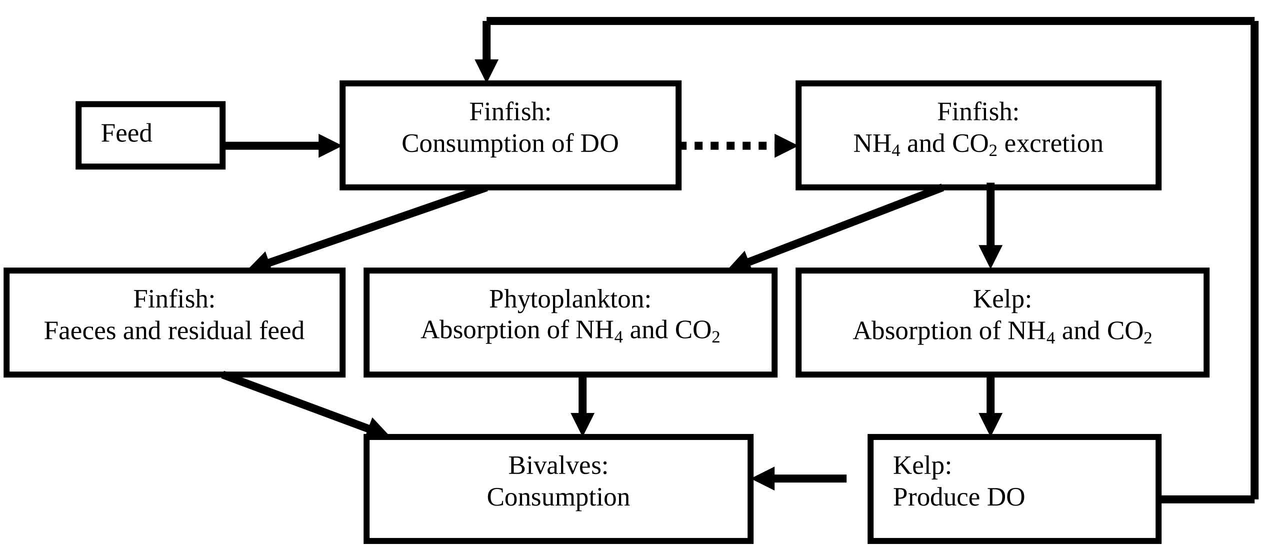

Figure 8. Diagrammatic representation of nutrient flows in IMTA of long-line culture finfish, bivalve and kelp

The purpose of this activity is to demonstrate:

- How nutrient flows can be balanced so there is no detrimental effect of eutrophication (Figures 7 and 8).
- How far productivity can be increased as a result of optimizing the densities of the various culture species, without over-stretching the carrying capacity of the bay and through utilizing the 3 dimensional culture space.
- How the profitability of these systems can be increased as a result of integration.

Heterotrophic shrimp culture

Shrimp culture is one of the most important mariculture industries in both China and R. Korea, but traditional methods using intensive or semi-intensive technology have a number of associated environmental impacts that have tainted the industry such as:

- The release of nutrients and particulates from the pond during water exchange can cause coastal eutrophication and smother benthic organisms.
- Outflows can also contain disease causing pathogens or parasites that may affect wild stocks.
- Large amounts of fish protein are used in production of cultured shrimp, competing with the local population for fish catches.
- Large areas are required for shrimp cultivation often competing with other users such as farmers or with natural coastal habitats. The conversion of these habitats can have unforeseen consequences due to the loss of ecosystem services.

Recently the industry in both China and R. Korea has suffered from decreased productivity due to disease and water quality problems.

Heterotrophic shrimp culture is a more stable method of shrimp culture that encourages the growth of bacterial flocs through the addition of a carbohydrate source and intensive aeration that keeps particulates in suspension. These bacterial flocs use the eaten food and shrimp wastes as a nitrogen source to increase biomass and hence recycle the food as they are consumed by the shrimp. This in turn reduces the percentage of fish protein required in diet hence reducing the amount of fish protein used in the production of shrimp as the food is used more effectively and food conversion ratios (FCRs) become closer to 1 (i.e. 1 kg shrimp produced using 1 kg feed).

This recycling of nutrients means that the water quality remains stable and no water exchange is needed, except some freshwater to allow for evaporation, which reduces the outflow of nutrients, pathogens and chemicals to the environment. It also means that there are no incoming diseases, therefore survival is much higher. The stability of the water quality means that much higher culture densities can be obtained, reducing the need for the huge pond areas, and the competition for space with other users.

Progress: Initial trials are very promising, stocking densities of 300 *Litopenaeus vannamei* juveniles per m^2 (traditional stocking densities are 15-30 shrimp/m^2) in outdoor lined ponds resulted in a production of almost 2.72 kg/m^2/crop and food conversion ratios (FCRs) of 1.39 over 3 month's culture achieving an average body weight of 12.5 g with survival rates in excess of 70%. Indoor raceways have achieved a production of >20 kg/m^2/year with 2.5 crops per year, this more than 70 times higher than traditional pond culture (Jang 2009). Nursery culture has also been very successful resulting in even lower FCRs at densities of up to 5000 post larvae /m^2.

Recently two new indoor commercial scale culture tanks were constructed offering even better bio-security and enhanced water quality control and, at the tanks' inauguration, a number of aquaculture farmers expressed interest in this new technology; one commercial farm is currently in operation.

Integrated Multi-trophic Aquaculture summary

Both these methods offer the opportunity of enhancing mariculture productivity to compensate for the shortfall in capture fisheries production following cuts in fisheries effort. These methods offer a way to increase production without also increasing negative impacts on both ecosystem health and fisheries production.

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