Ecosystem-based approach to aquaculture management

Patrick White[1]* and Maria Lourdes San Diego-McGlone[2]
[1]Akvaplan-niva AS, BP 411 Crest Cedex 26402, France
Telefax : +33475431901
*Corresponding author Email: patrick.white@akvaplan.niva.no
[2]The Marine Science Institute University of the Philippines Diliman, Quezon City, 1101 Philippines
Date submitted: January 10, 2008; Date accepted: November 21, 2008

ABSTRACT

Ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring. Once thresholds and limits have been exceeded, changes can be irreversible. Diversity is important to ecosystem functioning. The ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. The application of the ecosystem approach will help to reach a balance of the three main objectives: conservation, sustainable use, and a fair and equitable sharing of the benefits and use of the natural resources. Aquaculture development needs to be within the carrying capacity of the water resource so that it is sustainable and does not greatly impact the environment. The determination of the carrying capacity needs to be science-based. The planning of development in ecosystems has been done for freshwater ecosystems within the PAMB (Protected Area Management Board) framework, but in many cases this does not give the correct significance to the impact of aquaculture on the water resources in the ecosystem. It also needs to be extended to river basins and estuaries, brackishwater areas, and inland bays, and seas. The planning and management of aquaculture needs to be undertaken at the local government unit (LGU) level in a coordinated manner by all the LGUs that have a part of the water resource. The co-management of aquaculture, in terms of monitoring of the environment, monitoring of production, and monitoring of licenses, needs to be funded out of license fees and non-compliance fines collected by the LGUs. A number of these management activities need to be undertaken jointly (monitoring the environment) and others separately but in a coordinated manner (e.g., checking licenses and checking compliance).

Keywords: Aquaculture, ecosystem, management

INTRODUCTION

Aquaculture has been developing rapidly over the last 25 years. It is now contributing a significant supply of quality food for humanity and is provider of employment and economic benefits to those engaged in this activity especially in Asia. In the Philippines, aquaculture production comprises approximately 50% of total fisheries production (BAS, 2007). However, with increased development of aquaculture, there is the realization that living aquatic resources, although renewable and adaptable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic and social well-being of the growing world's population is to be sustained.

The adoption in 1982 of the United Nations Convention on the Law of the Sea provided a new framework for the better management of marine resources. The new legal regime of the oceans gave coastal States rights and responsibilities for the management and use of fishery resources within the areas of their national jurisdiction, which embrace

some 90% of the world's marine fisheries.

In recent years, world aquaculture has become a dynamically developing sector of the food industry, and many countries have striven to take advantage of their new opportunities by encouraging the aquaculture development in response to growing international demand for fish and fishery products. It has become clear, however, that many aquatic resources used for aquaculture cannot sustain an often uncontrolled increase of exploitation.

The ecosystem approach is a management principle. As such, it builds on the recognition that the nature of the natural world is integrated and a holistic approach to environmental management must be taken. The science to support the ecosystem approach to management must also be integrated and holistic. A core element of this science is ecology, with focus on the properties and dynamics of ecosystems (Fenchel, 1987). Many scientists and managers have recognized the need for an ecosystem approach for fisheries (Likens, 1992), although it is only during the last 5-10 years that a broad awareness of the need for such an approach has grown in aquaculture.

The increased awareness and formalization of the ecosystem approach have emerged as a result of international environmental agreements within the framework of the United Nations. A fundamental description of the basis of an "ecosystem approach" was first formalized in the Stockholm Declaration in 1972 (Turrell, 2004). The most authoritative account of the ecosystem approach is probably that found in Decision V/6 from the meeting of the Conference of the Parties to the UN Convention on Biological Diversity in Nairobi, Kenya, in 2000. This decision has an annex with the description, principles and operational guidance for application of the ecosystem approach (www.biodiv.org/decisions/default.asp).

The Ecosystem-based approach to aquaculture management

Ecological integrity is a state of the ecosystem in which ecological diversity and resilience are present, allowing the ecosystem to sustain itself and the inhabitants dependent on it. Integrity of the ecosystem cannot be achieved, however, when irresponsible actions impair the beneficial uses of resources. Scientific inquiry, public policy development, and co-management programs are essential for achieving and maintaining ecological integrity.

An ecosystem approach entails an integrated, multiresource emphasis, and broad precautionary strategies that anticipate and prevent environmental damage. This approach respects and affirms the interconnectedness of ecological processes and requires people to understand and conduct themselves as an integrated part of the ecosystem rather than as an entity separate from it.

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three main objectives: conservation, sustainable use, and fair and equitable sharing of the benefits arising out of the utilization of the natural resources.

Design of ecosystem-based management systems

Aquaculture and fisheries ecosystem-based management plans should be designed and implemented based on the principles, goals and policies below, which have been adapted for aquaculture from the Ecosystems Principles Advisory Panel (1999).

Principles

- Define the goals and constraints that characterize the desired state of aquaculture and fisheries and undesirable ecosystem changes.
- The ability to predict ecosystem behaviour or impact is limited.
- Ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring.
- Once thresholds and limits have been exceeded, changes can be irreversible.

- Diversity is important to ecosystem functioning.
- Components of ecosystems are linked (watershed, water bodies).
- Ecosystem boundaries are relatively open.
- Ecosystems change with time.
- Impacts can be cumulative.

Goals

- Maintain a healthy and sustainable ecosystem
- Provide profitable and sustainable livelihoods
- Production within safe carrying capacity

Constraint

- There should be no irreversible changes in ecosystems (including the human dimension).

Policies

- Implement precautionary management measures that take account of aquatic species and industry interactions, and are adaptive to local environment and conditions.
- Allocate fishing rights and fishing quotas that are fair in a transparent process.
- Allocate aquaculture licenses in a fair and transparent process that favors the poor or landless.
- Plan sustainable production capacity on best available scientific knowledge.
- Develop management plans holistically.
- Learn from historical experiences.
- Monitor environment regularly and compare with previous years.
- Enforce quotas, remove unlicensed facilities.
- Promote participation, fairness, and equity in policy and management.
- Ensure participatory and transparent decision making.
- Protect the ecosystem for habitat and species of special concern or that are vulnerable.
- Provide management support, including scientific information, enforcement, and performance evaluation.
- Provide incentives for conservation and efficient use of living resources.

Ecosystem management plans should highlight:

- a hierarchy of management entities, from an ecosystem scale (national government) to the local scale (local government and communities);
- zoning of areas for fisheries and aquaculture, including marine and freshwater protected areas and other geographically defined management measures; and
- specification and sizing of authorized fishing and aquaculture activities, with protocols required for licenses, authorizations and production quotas.

Ecosystem management plans need to be based on scientific information that is relevant, responsive, respected, and sound. A multifaceted approach is needed, including monitoring of aquaculture, fisheries and ecosystems, monitoring of aquaculture production and fisheries catch, and monitoring fisheries resources. Scientific support should be to undertake the necessary research on which informed management decisions can be made. These include studies on carrying capacity and ecological modeling. Scientists should have collaborative research with the aquaculture and fishing industry, with transparent quality assurance of scientific advice.

PRINCIPLES UNDERLYING ECOSYSTEM-BASED AQUACULTURE MANAGEMENT

There are certain underlying principles that must be considered in the development of ecosystem based management of aquaculture (http://www.glc.org/ecochart/principles.html#rights#rights). These are as follows:

Responsible to look after the ecosystem

People have a right to live in an ecosystem that supports their health and well-being and provides a livelihood. The diverse communities of other organisms living in that ecosystem also have their own rights. People must accept responsibility to conduct themselves, individually and collectively, in ways that support a healthy ecosystem.

Responsible use of natural resources

People have the right to use natural resources for economic purpose and enjoyment, commensurate with the responsibility to rehabilitate and maintain the integrity of the ecosystem. People must take responsibility to enhance and maintain the health of the ecosystem for the use, benefit and enjoyment of the current and future generations.

People must adopt, pursue and promote principles and practices of sustainable use of the ecosystem resources. People must accept the responsibility to minimize or prevent activities that cause environmental harm.

Scientific research and support

There should be a coordinated, multidisciplinary research agenda, as it is necessary to improve understanding of the scientific, social, and economic dimensions of the ecosystem.

Scientific, social, and economic data and information should form the basis for public policies, agreements, and management plans for the ecosystem. Many aspects of the ecosystem and its dynamics are not well understood. A scientific program of basic and applied research is necessary to improve understanding of the ecosystem and the interactions between aquaculture, fisheries, and the environment. Partnerships should be formed among public agencies, academic institutions, businesses, and citizen organizations to conduct and coordinate basic and applied research on the ecosystem.

Action plans should be prepared for emergency response to pollution events. Applied research should be conducted on methods to mitigate impact on the environment. The research results should be made available and understandable to the public and useful to decision makers.

Sustainable communities

In a sustainable society, there are fundamental and inextricable links between economic activity and the natural ecosystem. Sustainable economic activity should meet the needs of the present generation without compromising the ability of future generations to meet their own needs, and respect the limits imposed by the capacity of the ecosystem to absorb the impact of human activities. Adopting principles of sustainability at the community and local government unit (LGU) levels will promote long-term economic viability and continued improvements in environmental quality.

Living in harmony with the ecosystem

Ecosystem integrity and the economic well-being of human communities are interdependent; achieving and protecting ecosystem integrity is, therefore, an essential part of economic activity within the area.

Natural resources within the ecosystem may supply people with drinking water, support a recreation/tourism industry, provide habitat for thousands of plant and animal species, offer livelihood opportunities, and support an agricultural industry. To ensure that natural resources in the ecosystem continue to provide such benefits, economic strategies and activities must ensure that essential ecological processes are maintained, natural resources are used sustainably, biological diversity is conserved, and infrastructure investment is appropriately pursued.

Principles of sustainability must be incorporated into public and private sector plans and programs that reflect an appropriate balance between ecosystem protection and economic development.

Policies and programs that provide for the efficient and sustainable use of natural resources should be supported to revise or eliminate those that do not. They should also encourage the development of the aquaculture industry but avoid pollution and mitigate impact.

There should be systematic data collection

monitoring and impact indicators to measure the environmental, social, and economic health of the ecosystem and well being to gauge progress in achieving a sustainable aquaculture and fisheries industry and society.

Management

The ecosystem governance and management should emphasize partnership arrangements among government entities, the private sector, community organizations, and other interests.

The interdependence of the economy and the environment amplifies the consequences of the individual and collective actions of all agencies, organizations, businesses, and individuals within the ecosystem. Their mutual interests must be explicitly acknowledged and partnerships developed to pursue public and private sector actions that benefit the ecosystem.

Existing partnerships that integrate interests and management approaches in the ecosystem, such as Protected Area Management Boards (PAMBs) and other water management plans, should be supported and expanded.

Following the development of the ecosystem-based management plan, there should be full implementation of relevant government, provincial and municipal laws and programs, and the dedication of adequate resources to accomplish the stated goals. Partnerships among basin interests should be formed to address commonly identified problems and to harmonize institutional relationships and authorities.

Ecosystem policies and programs should be based on the findings of sound scientific research.

Dissemination of plans and information

Timely, accurate, and accessible information should be provided to the public regarding all planned activities that may significantly affect the ecosystem.

Timely information enables the public to respond to current issues and opportunities in an appropriate time frame; accurate information enables the people to make informed decisions about their interests and concerns; and accessible information allows for all interested persons to obtain the desired information with relative ease. Programs that reflect these qualities help promote informed public policy, efficient and effective implementation and strong partnerships among the different users of the resource.

Timely, accurate, and meaningful information should be gathered about the state of the ecosystem. Monitoring programs and reports made on the progress in implementing programs consistent with the management plan and other relevant laws and agreements and be made available to the public and local communities.

Full and equal access should be made available to the public on public data, policies and related information concerning current and prospective conditions of the ecosystem, and the associated impact of proposed actions.

Formal and informal information links should be created to ensure ongoing and substantive dialogue on and dissemination of data and information relating to the ecosystem.

Decision-making

Responsible aquaculture and fisheries management planning requires many decisions about goals and objectives, a precautionary sustainable carrying capacity, sustainable fishing catches, a rights-based allocation of licenses method that is deemed to be fair, and avoidance of unacceptable changes in ecosystems.

As noted above, many of these decisions are subjective. Therefore, stakeholders need to have the opportunity to participate in the decision-making process and they need to be able to understand the basis for decisions. Stakeholders include the fish and mollusc farmers, fishermen, environmentalists with concerns about the effects of aquaculture on ecosystems, and anyone who is interested in the distribution of benefits.

There are also many different types of arrangements for stakeholders to participate in decision-making,

ranging from having input into the initial stages of decision-making where options are being formulated, to having the opportunity to comment before final decisions are made. Responsible fisheries and aquaculture management requires as much participation in decision-making as is practical, recognizing that ultimately, a management authority (e.g., government officials or an association of stakeholders) must be charged with weighing the options and making a decision.

Ecosystems and fisheries resource populations cover large geographic areas. Conservation measures and ecosystem protection need to be effective over the entire range of resource populations and the area of ecosystems. They are usually affected by the activities of many local communities. The management plan therefore needs to be holistic and implemented in a cooperative manner over the entire ecosystem by the LGUs and local communities. The local authority is likely to be limited to making decisions about the implementation of higher-level decisions.

One purpose of participatory and transparent decision-making is to gather the broadest possible support for decisions. However, there will usually be some participants in the process who could be unhappy with the outcome. Responsible aquaculture and fisheries management requires that even those who dislike decisions are nevertheless bound by them.

Management support

Fisheries and aquaculture management depends on scientific information. It is ineffective unless there is compliance with management legislation and regulations (sustainable carrying capacity, conservation measures, allocation rules, and restrictions for ecosystem protection). Fisheries and aquaculture management needs to evaluate its own performance in order to be responsible.

Sissenwine & Mace (2001) identified that management needs to be:

- relevant by providing the type of information that is needed in a form that fisheries managers can use, and that stakeholders can understand;
- responsive by being timely;
- respected (i.e., credible), which means that it must be perceived to be unbiased, and based on science conducted according to high scientific standards, including quality assurance; and
- right, which requires an investment in research and appropriate data, in addition to high scientific standards and quality assurance.

Compliance with fisheries and aquaculture management rules requires either rules that the aquaculture and fisheries industry believes in, such that most of the industry willingly comply and they do not tolerate noncompliance by others in the industry; or it requires enforcement capability and severe enough penalties to force compliance. The former is preferable.

Performance evaluation is a valuable element of a fisheries and aquaculture management system because it is a way of learning from experience, so that management can be improved. FAO (1999) discusses indicators of sustainability for fisheries. Indicators for aquaculture will include fish growth rate, survival, and food conversion rate (FCR). Such indicators can serve as the basis for performance evaluation.

Since ecosystems are defined geographically, an ecosystem approach to responsible governance of fisheries and aquaculture requires management institutions or arrangements that are defined geographically. Accordingly, there should be freshwater and marine ecosystems management, covering coastal waters that account for most aquaculture production, as logical units for research and governance. However, the geographic areas used for management should be sufficiently large to encompass reasonably self-contained ecosystems throughout their range.

ECOSYSTEM-BASED ENVIRONMENTAL MANAGEMENT AND RELEVANCE TO THE PHILIPPINES

Agriculture and fisheries in the Philippines directly account for about a fifth of the total economy and directly and indirectly (which considers the

backward and forward linkages, or the cluster universe) three fifths of the economy. More importantly, these directly employ about 10 million people, nearly 40% of the labor force. In 2007, the Philippines produced 2,214,826.16 metric tonnes from aquaculture (BAS, 2007).Aquaculture production is still rising rapidly.

Aquaculture tends to develop in "hot spots", initially with pen culture in Laguna de Bay, and, recently, with milkfish cage and pen culture in Dagupan and Bolinao in Pangasinan, and tilapia cage culture in Taal Lake. This rapid increase in production has put pressure on the aquatic ecosystems and incidences of fish kills have been observed.

In general, the management of fisheries and aquaculture should be undertaken with an ecosystem approach based on their scientifically calculated safe carrying capacity and implemented in a coordinated way by the concerned LGUs, through appropriate regulations for lake management.

Regulations covering aquaculture management

In the Philippines, the planning, management, monitoring, and control of fisheries and aquaculture have been devolved from the National Government to LGUs. In the case of lakes, there are three different regulations, namely:

(a) the Local Government Code or RA 7160 of 1991 which provides for the empowerment of the LGUs;
(b) the National Integrated Protected Areas System Act or RA 7586 of 1992 which provides for the establishment and management of national integrated areas system defining its scope and coverage. The Act includes the Protected Area Management Board (PAMB) which is responsible for the general administration of the area; and
(c) the Fisheries Code or RA 8550 of 1998 which aims for the rehabilitation of fisheries and other aquatic resources through enforcement of laws and regulations.

Agencies governing aquaculture development

At the national level, the two principal agencies with coastal management responsibilities that apply to aquaculture are the Department of Environment and Natural Resources (DENR) and the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR). These two agencies have retained authority over some land and water uses, management activities, and specific geographic areas.

While national government has devolved significant authority to the local level, national government agencies have maintained significant institutional presence especially at the regional, provincial, and in the case of one agency, municipal level (Lowry, et al., 2005). DA-BFAR and DENR have offices and staff at regional (multiple provinces) and provincial levels. The DENR has staff responsible for covering jurisdictional responsibilities in multiple municipalities. The Department of Interior and Local Government (DILG) is the primary national government agency responsible for overseeing, monitoring, and evaluating LGUs and the devolution process. Every municipality has one member of staff assigned from DILG. In spite of the broad representation of national government agency staff at provincial and municipal levels, coordination between national and local government is weak and major capacity gaps exist.

While LGUs are generally well versed in the provisions of the local government codes, they are less knowledgeable about special laws, such as the Fisheries Code, and environmental laws that are primarily under the jurisdiction of national government agencies. The primary implementing agency for the 1998 Fisheries Code is the DA-BFAR; however, many of the provisions in the law relate specifically to LGUs. Implementing Rules and Regulations and Administrative Orders are issued describing specific implementation requirements.

Unfortunately, the overlap in responsibilities, laws, and regulations has led to confusion as to the roles of DABFAR, DENR, DILG, and the LGUs in terms of planning, monitoring and control of aquaculture and fisheries, and has resulted in uncoordinated,

uneven, and, often, unsustainable development of aquaculture.

There is, therefore, a need to resolve inter-agency roles and improve linkages between DILG, DA-BFAR, and DENR and encourage cooperation between the main agencies involved with aquaculture development, management and control. The inter-agency Councils could be used for resolving conflict, overlap between agencies and to encourage cooperation between the agencies. There may be a need to draft joint BFAR/ DILG Administrative Orders or ordinances for monitoring and control of aquaculture development.

There are a number of initiatives to coordinate the planning and management of aquatic ecosystems among key national agencies. The Protected Area Management Boards of national protected areas are usually comprised of representatives of these different government bodies and private sector stakeholders. The joint memorandum order on the implementation of the Fisheries Code between DENR and DA-BFAR is a start at the national level. The Philippine Fisheries Code of 1998 provided for the creation of Fisheries and Aquatic Management Councils (FARMCs) to act as consultative bodies of the LGUs in determining priorities on fishing activities of municipal fishermen and aquaculture development. They also assist LGUs in the preparation of the Municipal Fishery Development Plans, recommend fishery and aquaculture ordinances and assist in the enforcement of laws. The DA-BFAR, LGU and Coastal Resource Management Plan (CRMP) have worked together in establishing and strengthening the capacity of FARMCs to fulfill their role in Coastal Resource Management.

Identification of ecosystems and aquaculture zones

Aquatic ecosystems have already been identified within the Clean Water Act prepared by DENR. Aquaculture zones have been identified by the Conservation International Priority Areas, and the Fisheries Resource Management Project (BFAR). These two resources should be used for identifying the aquatic ecosystems that are of significant importance for aquaculture.

The identified areas should then be checked to ascertain if these aquatic ecosystems have significant aquaculture production and ranked in terms of scale of resource use (low, intermediate, high).

Carrying capacity of ecosystems

There is, presently, little known about the sustainable aquaculture carrying capacities of water bodies in the Philippines. However, there is a need to base aquaculture development on the sustainable carrying capacity of the resource and to develop quality standards for aquaculture that can act as a measure of compliance. Carrying capacity can be calculated by using box models, such as the Environmental State Variable (or Vector) Model Concept (Dowd, 2005). These models can estimate the “state” or category, such as trophic state (eutrophic), or if the nutrient concentration in the water will be above a set quality standard. Models can represent some or all of these variables by dynamic equations.

State variables for assimilative capacity models include:

- concentrations of drivers such as nutrients;
- environmental factors such as temperature;
- environmental quality variables (EQVs) defined by the regulators, such as dissolved oxygen concentrations.

Some variables may belong to several categories.

The simplest models average values of each state variable over a substantial homogeneous boxed volume that, ideally, corresponds to a defined water body. More universal models, such as European Regional Seas Ecosystem Model (ERSEM), deal with a large number of linked volumes that may represent whole sea areas (Baretta, et al, 1995).

Models such as these, need to be tested and validated in different types of water body in the Philippines so that carrying capacities of the identified ecosystems suitable for aquaculture can be calculated. In addition, there is a need to review the water quality standards in waters where aquaculture is carried out and maximum limits set

so that these areas are not overly impacted by aquaculture.

Coordinated planning and zoning of aquaculture

There are two major aquaculture zoning plans developed, one by DA-BFAR (Coastal Resource Management Plan) and the other by DENR (Coastal Development Plans). In order for coordinated planning and zoning of aquaculture development, these two agencies need to work together to harmonize the plans. The criteria used for zoning aquaculture areas in these plans also need to be reviewed to ensure that they were based on relevant scientific criteria.

Coordinated co-management of ecosystems by surrounding LGUs

The Fisheries Ordinances issued by DA-BFAR are implemented by the coastal LGUs. In many cases, the LGUs surrounding an aquatic ecosystem act independently with varying levels of implementation of the ordinances and management of aquaculture. There is a need for a framework that encourages these LGUs to work together in a coordinated manner. However, there is need for an ecosystem-wide development plan for aquaculture and a need to motivate LGUs to plan and manage aquaculture in each ecosystem responsibly and sustainably.

In protected freshwater ecosystems, there are the PAMBs that bring LGUs in the catchment area together for unified planning and management of that aquatic ecosystem. In marine and brackishwater areas, there are Integrated Fisheries and Aquatic Management Councils (IFARMCs) that have been created in areas such as bays, gulfs, lakes and rivers, and dams, which are bounded by two or more municipalities/cities. IFARMCs could potentially undertake the same role as PAMBs but this needs to be prioritised and implemented within the IFARMCs.

CONCLUSIONS

An ecosystem-based co-management should be applied to aquaculture planning and development in the Philippines following a number of steps. Aquatic ecosystems and ecosystems with aquaculture or potential aquaculture should be identified using the Clean Water Act as basis. This data should be entered in a GIS database for easy data storage and analysis.

An estimate of the safe and sustainable aquaculture carrying capacity of the identified ecosystems should be made based on best available science. Within each ecosystem, an assessment should be made on the industries that have greatest impacts on the ecosystem. Within each ecosystem, an integrated development plan should be made (taking aquaculture into consideration) and prioritize commercial activities in the aquatic ecosystem.

A framework of planning and management should be developed at national, municipal, and local government levels using PAMBs and IFARMCs as the bases. Develop a management plan that is within the capabilities and funding of LGUs that will have to implement it. Find ways to encourage LGUs to implement the management plan and enforce aquaculture regulations.

The National Government must support the LGUs by formulating enlightened policy and sensible regulations, as well as undertaking or assisting with the collection of baseline environmental data on the ecosystem, estimation of the safe and sustainable aquaculture carrying capacities, and monitoring the environmental impacts of aquaculture.

REFERENCES

Baretta, J.W., Ebenhöh, W. & Ruardij, P., 1995. The European Regional Seas Ecosystem Model, a complex marine ecosystem model. *Netherlands Journal of Sea Research* 33:233-246.

Bureau of Agricultural Statistics, 2007. http://countrystat.bas.gov.ph

Dowd, M, 2005. A bio-physical coastal ecosystem model for assessing environmental effects of marine bivalve aquaculture. *Ecological Modelling* 183(2-3):323-34.

White, P. and San Diego-McGlone, M.L. 50 Ecosystem Principles Advisory Panel, 1999. Ecosystem-Based Fishery Management. U.S. Department of Commerce. Washington, DC, USA. pp54 .

FAO, 1999. Indicators for sustainable development of marine capture fisheries. FAO, Rome. pp 68

Fenchel, T., 1987. Ecology – potentials and limitations. In Kinne, O. (ed.). Excellence in ecology. Book 1. International Ecology Institute, Oldendorf/Luhe.

Likens, G., 1992. The ecosystem approach: its use and abuse. In Kinne, O. (ed.). Excellence in ecology. Book 3. International Ecology Institute, Oldendorf/Luhe.

Lowry K., White, A. & Courtney, C., 2005. National and local agency roles in integrated coastal management in the Philippines. *Ocean & Coastal Management* 48:314–335.

Republic Act No. 7586, NIPAS Law . http://eelink.net/~asilwildlife/REPUBLICACT7586.html

Republic Act 8550. http://www.da.gov.ph/FishCode/ra8550b.html

Sissenwine, M.P. & Mace, P.M., 2001. Governance for responsible fisheries: an ecosystem approach paper to the FAO Reykjavik Conference on Responsible Fisheries.

Turrell, W.R., 2004. The policy basis of the "Ecosystem Approach" to fisheries management. EuroGOOS Publication No. 21, EuroGOOS Office, SMHI, 601 76 Norrköping, Sweden.