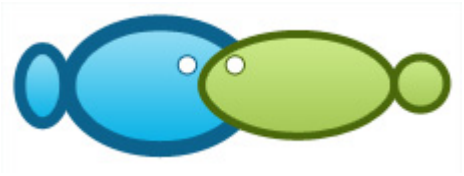

Sustainable nondestructive mangrove-friendly aquaculture in Nigeria II: models, best practices and policy frame work

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Abstract. The coastal waters of Nigeria are lined with mangroves which provide invaluable ecological services. Much of these mangroves are not adequately classified or protected by specific laws, policies or agencies. There are different perceptions on the sustainability of aquaculture in mangroves. This paper upholds the principle of precautionary approach where doubts arise and suggests global best practices including elaborate technical assessments in site selection for pond construction, policy frameworks that ensure mangroves maintain their functions while being exploited, requiring investors to maintain environmental management systems, product certification, allocation of aquaculture sites outside pristine mangrove areas, empowerment of relevant agencies for continual satellite-based environmental change monitoring and making reforestation obligatory to investors. It also outlines mangrove management strategies and policies in selected Asian countries compared to Nigeria, harmonizing priorities of externally-funded mangrove projects with local priorities and needs and other supportive policy instruments for strengthening independent regulatory agencies for biodiversity conservation of mangroves in Nigeria. The paper particularly advocates mangrove-friendly aquaculture models such as silvofishery vis-a-vis community concessions and adoption of integrated coastal zone management.
Key Words: eco-friendly conservation, legislation and government policies, silvofishery, site selection.

Introduction. There are different perceptions on the sustainability of mangrove aquaculture both globally and locally, with increasing interests in diversification of national productivities, and private sector- and market-driven economies often catalysed and supported by multinational companies and development partners. The rapid expansion of agriculture and aquaculture into marginal lands and new environments like mangroves is anticipated.

Much of these mangroves, like in Nigeria, are not adequately classified or protected by specific laws, policies or agencies to sustain its ecosystem dynamics vis-a-viz utilization. The phenomenal growth of aquaculture in Nigeria has gained global reckoning with possibilities for uncontrolled expansion. However, institutional and community capacities and indigenous knowledge-base need be strengthened. This paper therefore seeks to articulate and suggests global best practices, ecosystem approaches, supportive policy instruments, and strategies for mangrove and coastal zone development based on desk research utilizing available information. It recommends biodiversity conservation of mangroves for sustainable food supply in Nigeria particularly through silvofisheries and product certification.

Background. The African Regional Aquaculture Centre (ARAC) Brackish Water Research Station at Buguma in Rivers State, Nigeria has developed techniques for the propagation and culture of brackish water fish species such as tilapia, mullets, tarpon, catfish, cockles, oysters, periwinkles, shrimps (Deekae et al 1994; Ansa & Bashir 2007; Akinrotimi et al 2005; Ansa 2009a); and conducted intensive training on farm design, pond construction, feed manufacture and general fish farm management. However for

the purpose of mangrove aquaculture community-based environmentally-friendly silvofishery is recommended as opposed to replacement of mangroves with fish farms.

The dilemma and discuss on shrimp farming in Nigerian mangroves. The potentials of shrimp fisheries are highly significant. In 2007 inshore shrimping generated a revenue of ₦19,320,000.00 (about USD 113,647.06) while inshore fishing yielded ₦ 3,360,000.00, USD 19,764.71 or 17.4% of the former (FDF 2007). In 2004 Shell Petroleum Development Company (S.P.D.C.) and the United States Agency for International Development (USAID) proposed investing 266 billion (Nigerian naira) to convert mangrove in Nigeria to shrimp production ponds for export. This attempt was scuttled following protest by an NGO, the Centre for Environment, Human Rights and Development (CEHRD). The project proponents claimed they would adopt the FAO code of conduct for responsible aquaculture, and allow independently-conducted integrated Environmental, Social and Health Impact Assessment (ESHIA) in accordance with internationally recognized best practices (Business Day 2004). However, CEHRD contended that shrimp farming was environmentally unsustainable, monolithic, limited livelihood opportunities of local populations and targeted the "fragmentary" mangrove forests while destroying a multi-resource based ecosystem (like mangroves). They cited examples from countries like Indonesia, Bangladesh, Peru, Ecuador, Brazil, etc. Consequently, the Shell/USAID Shrimp project was suspended.

CEHRD noted that the 'responsible aquaculture and best practices' concepts are key guidelines, which, if duly followed, might yield less negative impact on the mangrove but hinges her resistance to the execution of the project on the poor environmental track records of the sponsor, S.P.D.C. CEHRD noted that despite the prohibition of gas flaring in Nigeria since 1984, S.P.D.C. had flared approximately 2.2 billion cubic feet of gas daily over the years with little or no end in sight (Zabbey 2006).

Similarly, Ansa (2009b) objected to the "zero-exchange" technology proposed for siting of complete shrimp production processes from hatchery to grow-out in inland/freshwater environment. The business proposal was put up by Sulalanka Nigeria Ltd. (an Italian-based Company), consulting for some State Governments in Nigeria. Zero exchange implies no discharge of wastes or water from shrimp farms into the environment in a facility that intends to use brine with 100 ppt salinity, diluted as required and used again and again. Being a new technology, its use is fraught with many challenges under Nigerian circumstances for which the users may not be capable of managing. She recommended the development and adoption of local or home-grown technologies and disapproved the attempt by foreign companies to commandeer the industry, targeting international markets rather than meeting local demands. Suryadiputra & Kurniasari (2007) also reported the challenge posed by 'big investors' who tried to persuade farmers around Cikeong (Indonesia) to cut down the mangrove forest to make way for ponds using the environmentally damaging non-silvofishery models.

The burden of proof of harmlessness of a new technology, process or activity lies with the proponents, not with the general public, under the Principle of Precautionary Approach, which expects all to take appropriate action, "based on the possibility of significant environmental damage, even before there is conclusive, scientific evidence, that the damage will occur" (FAO 1995a). Hence, before introducing a new technology, process, or starting a new activity, communities and investors have an obligation to examine 'a full range of alternatives' including the alternative of doing nothing. People, therefore, have a duty to take anticipatory action to prevent harm (WCED 1987). Though CEHRD and Ansa (2009b) subscribe to the 'concepts of responsible aquaculture and best practices' they were however weary of the character of the proponents and eco-friendliness of the technology.

The different interactive communications and perspectives reiterated above suggest *inter alia* that the main contention in utilization of mangroves for aquaculture rest in adopting environmentally nondestructive mangrove-fishery models. The technology for zero exchange works on the principle of Recirculatory Aquaculture System, which with improvement in public infrastructure, particularly, water supply and

power, has fully gained adoption suited to local realities and operational in Nigeria. The zero-exchange technology has revolutionized mariculture and presently drives (saline) aquaculture industry in Europe and Australia (Allan et al 2008), America and globally (Audelo-Naranjo et al 2012) with outstanding results. The zero-exchange technology is suitable for mangrove-aquaculture if applied within the limits of E.S.H.I.A. at low-scale and community-driven level. However community-based environmentally-friendly silvofishery remains the best option.

Current technical and socio-economic dimensions in mangrove-aquaculture in Nigeria. Brackish water fish farming is usually constructed on a low-lying tidal mud-flat, to ensure steady exchange of tidal waters between the farm and the adjoining creek, estuary and lagoons. The distinguishing features of brackish water fish ponds (that are non-silvofishery) are discussed by Dublin-Green (1987) and Udoh et al (2007), among others. Generally the methods require destruction of mangroves. Figure 1 shows the 6-hectare modern brackish water fish farm at Buguma in Rivers State, Nigeria while Figure 2 shows the layout of a large scale brackish water pond in Asia.

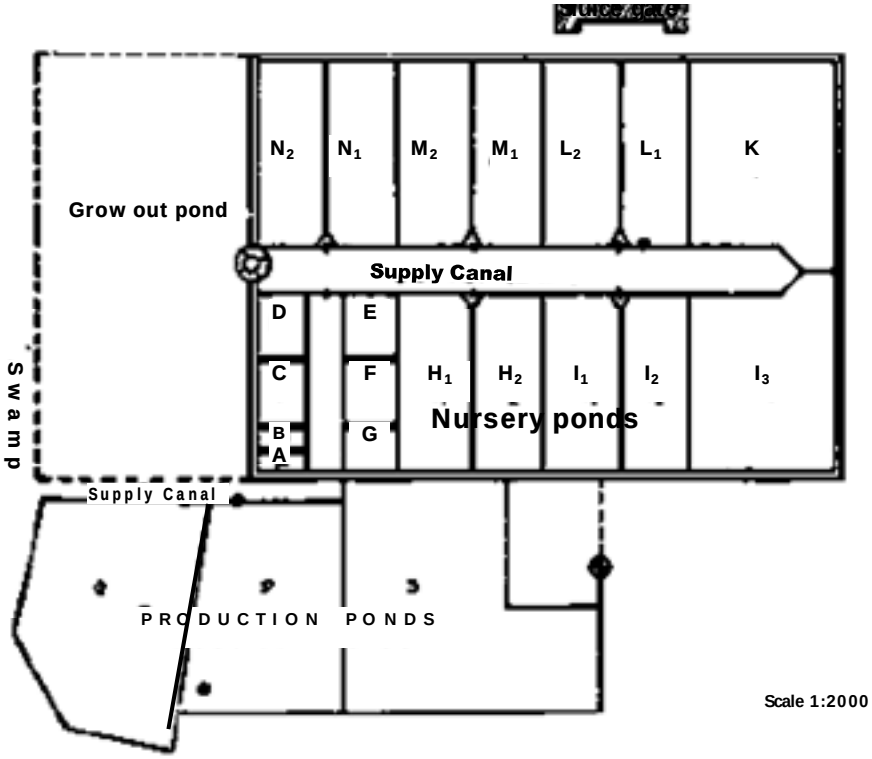


Figure 1. The brackish water experimental fish farm, Buguma, Rivers State (Dublin-Green 1987).

Tables 1 and 2 present preliminary and essential technical considerations in determining the suitability of a site for mangrove aquaculture pond in Nigeria (Table 1) and the more encompassing Malaysian model (Table 2).

Figure 2. Illustration of two large scale aquaculture systems in mangrove ecosystem - upper and lower plates (Baluyut 1989).

Table 1

Technical considerations and recommendations for relative suitability of mangrove areas for fish pond construction in Nigeria*

Parameter	*Recommendation*
Type and density of vegetation	
No vegetation	Ideal, area limited
Short sparse mangrove	Desirable, area unlimited
Short dense mangrove	Suitable
Large, high mangrove	Unsuitable, avoid
Raffia palms, thorn trees and other trees	Unsuitable, avoid
Types of soils	
Clay	Ideal
Sandy clay	Ideal
Clay with few mangrove roots	Desirable
Clay with many mangrove roots	Suitable
Loamy or sandy soil with little clay	Unsuitable, avoid
Soft soil of any type	Unsuitable, avoid
Tidal range	
1.0 or less	Unsuitable, too small
1.0 - 1.5 m	Suitable for fish
1.5 - 2.0 m	Suitable for salt water shrimp
2.0 - 2.5 m	Unsuitable, too large
Above normal highest tides	
No flooding	Ideal
50 cm or less	Suitable
More than 50cm	Unsuitable, avoid

*Modified from: Uyeh (1987).

Table 2

Dependent and independent variables for rating the relative suitability of the mangrove site for potential aquaculture in Malaysia

Checklist	*Rating**											
Site location	*Present state*			*Future development*					*Suitability*			
Category 1: Engineering	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*
Water supply											*x*	
a) Availability of stream for intake channel			*x*					*x*			*x*	
b) Stream morphology			*x*					*x*			*x*	
1.2 Hydrology			*x*					*x*			*x*	
a) River discharge			*x*					*x*			*x*	
b) Flood stages			*x*					*x*			*x*	
c) Turbidity (visual)			*x*					*x*			*x*	
1.3 Topography											*x*	
a) Land area for prototype of pond layout			*x*					*x*			*x*	
b) Ground elevation			*x*					*x*			*x*	
1.4 Soil											*x*	
a) Soil characteristics (visual)				*x*				*x*			*x*	
b) Soil sample — lab. analysis				*x*				*x*			*x*	
(ii) Acidity				*x*				*x*			*x*	
(iii) Potential acidity				*x*				*x*			*x*	
(iv) Pesticides residue (Not applicable?)				*x*				*x*			*x*	
b) Soil sample — lab. analysis				*x*				*x*			*x*	
(ii) Acidity				*x*				*x*			*x*	
(iii) Potential acidity				*x*				*x*			*x*	
(iv) Pesticides residue				*x*				*x*			*x*	
Category 2: Water Quality	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*
2.1 On-site water analyses												
a) Salinity				*x*				*x*			*x*	
b) Salinity profile				*x*				*x*			*x*	
c) Temperature				*x*				*x*			*x*	
d) Dissolved oxygen (DO)				*x*				*x*			*x*	
e) pH				*x*				*x*			*x*	
2.2 Water sample analyses								*x*			*x*	
a) Biological Oxygen Demand (BOD)				*x*				*x*			*x*	
b) Sediment — settling rate				*x*				*x*			*x*	
c) Sediment load				*x*				*x*			*x*	
d) Bacteriological test (*E. coli* count)				*x*				*x*			*x*	
Not applicable												
2.3 Water pollution risks								*x*			*x*	
a) From agriculture				*x*				*x*			*x*	
b) From industries				*x*				*x*			*x*	
c) From ship traffic				*x*				*x*			*x*	
d) From settlements				*x*				*x*			*x*	
Category 3: Forestry	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*
3.1 Forest economy												
a) Species composition (in regard to forest interest)			*x*					*x*			*x*	
b) Growth condition (standing biomass)			*X*					*x*			*x*	
c) Management scheme				*x*				*x*			*x*	
d) Value of site				*x*				*x*			*x*	
(i) timber				*x*				*x*			*x*	
(ii) other products				*x*				*x*			*x*	
3.2 Ecology								*x*			*x*	
a) Site in regard to marine habitat			*x*					*x*			*x*	
b) Width of protective belt (or possibility for sufficient belt)			*x*					*x*			*x*	
Category 4: Socio-Economics	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*	*O*	*M*	*A*	*G*
4.1 Infrastructure												
a) Services provided by government		*x*						*x*			*x*	
b) Private sector services		*x*						*x*			*x*	

4.2 Verification of input-output			*x*	*x*
a) Ex-farm prices	*x*		*x*	*x*
b) Pond operation costs	*x*		*x*	*x*
c) Seed, feed availability	*x*		*x*	*x*
4.3 Welfare and general development aspects			*x*	*x*
a) Increase in number of fish farmers—shift from catch fishery	*x*		*x*	*x*
Category/Summary rating (O, M, A or G)	*Not suitable*	*Marginal*	*Acceptable*	*Good*
1) Engineering			+	
2) Water quality				+
3) Forest				+
4) Socio-economics				+
(+) Better than average				
(-) Not as good as average				

* Rating Categories: O = not suitable, M = marginal, can be accepted if other parameters rate good, A = acceptable, i.e., average, G = good (suitable for pond development if mangrove habitat had been destroyed/impacted), N.A. = not applicable Source: South China Sea Fisheries Development and Coordinating Programme (1982).

Eco-friendly designs and appropriate silvofishery models in mangrove ecosystems. Nigeria is yet to witness an eco-friendly silvofishery model. Hence, there are several uncertainties that need to be resolved through research and design of appropriate technology, adequate knowledge of the resource potentials of mangrove areas suitable for this model, developing bio-technical skills and mobilizing and educating aquaculture entrepreneurs for adoption. One thing is certain, the adoption of this model is multi-disciplinary, requires high initial capital and operating costs and should be carried out in phases. It is incumbent on regulatory agencies and research organizations to work in concert to reduce or eliminate these challenges with insight into some policy issues associated with this model.

Since mangrove forest resources are the breeding ground for marine fishes, an integrated approach ensuring nondestructive harmonious interactions between themarine and the terrestrial resources and among socio-economic conditions, cultural values, agricultural production and environmental conditions should be applied. Such as:

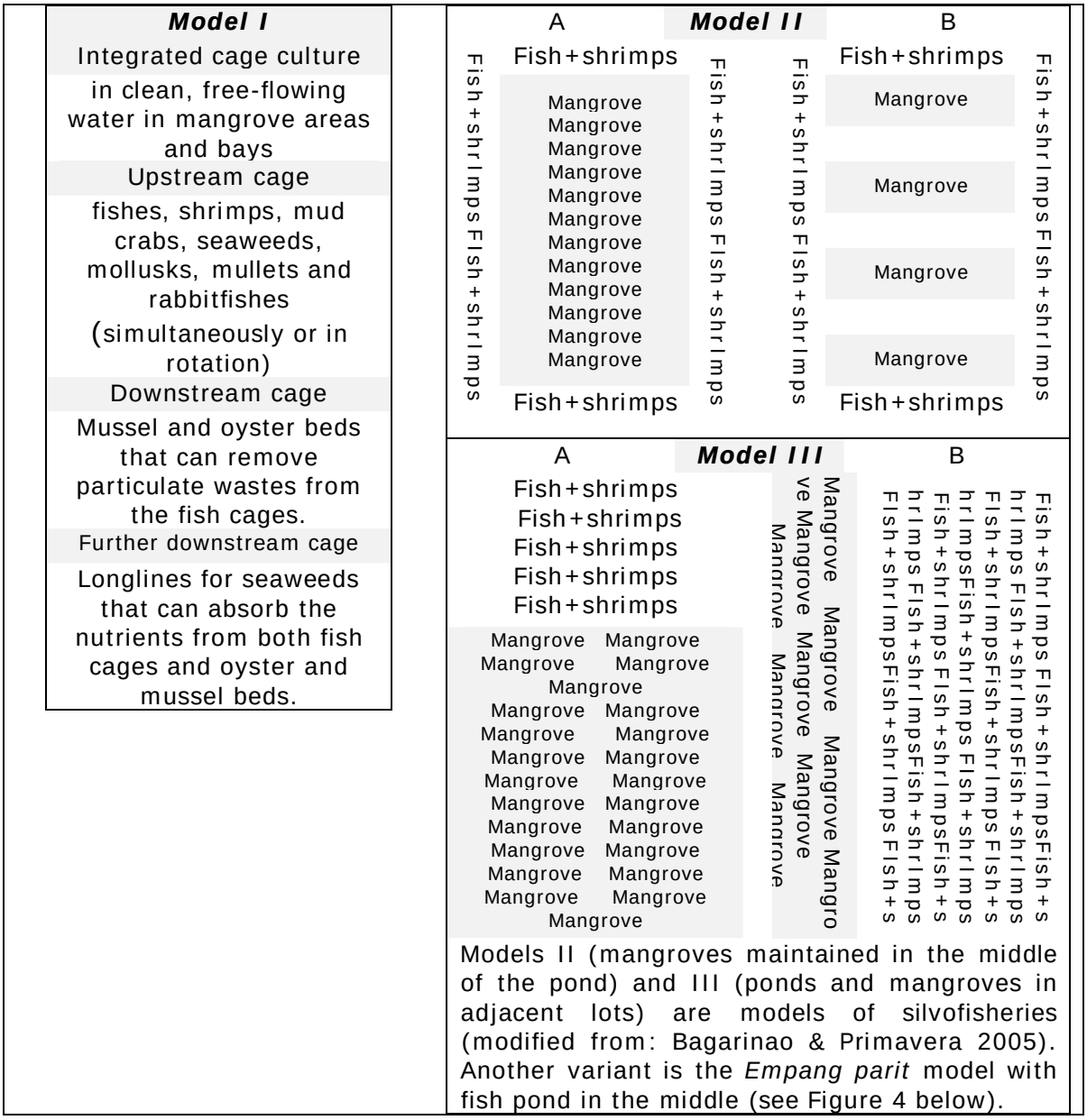
- integration of existing aquaculture culture systems such as polyculture, floating pens/cages, cage culture, raft culture and on-bottom culture systems like pens with the silvofishery models (widely used along channels in Southern Thailand - Huitric et al 2002);

- intensively run shrimp ponds (linked to sea water by channel) behind the mangroves;

- silvofishery models (Figures 3-5) are site-dependent and integrated into coastal zone management, requiring a 20:80 ratio between pond and forest area (Aksornkae 1996);

- shrimp hatcheries require high salinities and are best sited close to brackish water habitats while grow-out ponds should be sited in inland or fresh water areas to further reduce the pressure on mangroves.

Eco-friendly silvofishery managed within the context of integrated coastal zone management (ICZM) incorporates multiple uses such as urban settlement, industrial development, waste disposal, ports and marine transportation, fisheries, forestry, eco-tourism - sport fishing, water racing, and wind power generation, in addition to polyculture brackish water fish farming facility. To achieve this it is mandatory for priority zones for mangrove development areas to be designated (Bird & Kunstadter 1986). There has been widespread promotion and adoption of eco-friendly silvofishery models across Southeast Asia with assistance of scientists at the Aquaculture Department of the Southeast Asian Fisheries Development Centre (SEAFDEC).



Models II (mangroves maintained in the middle of the pond) and III (ponds and mangroves in adjacent lots) are models of silvofisheries (modified from: Bagarinao & Primavera 2005). Another variant is the *Empang parit* model with fish pond in the middle (see Figure 4 below).

Figure 3. Appropriate silvo-fishery models suitable for integration into coastal zone management.

Frameworks for mangrove conservation and aquaculture development. In order to ensure that mangroves maintain their functions while being exploited there is need for government, development agents and institutions to collaborate on formulating logical frameworks for mangrove conservation and development. The International Convention on Biological Diversity (CBD, www.cbd.int/doc/world/) recognizes the interplay between trade and commercial exploitation of natural resources, on the one hand, and conservation and protection, on the other and therefore upholds a balance between the two opposing objectives - conservation and utilization of natural resources (Article 1 of the CBD). The FAO Code of Conduct for Responsible Fisheries (FAO 1995b, 1997) is aimed at achieving this. The Code is a voluntary obligation made by States, entirely based on international law especially the United Nations Convention on the Law of the Seas, and adopted by the 28th session of the FAO Conference on 31 October 1995. The Code is a concept encompassing principles and international standards of capture (fishing) and culture (farming) that are not harmful to ecosystems and resources, transformation processes that add value to the products and meet the required sanitary standards, and commercial practices that provide consumers good quality products.

The basic features and highlights of the guidelines as it relates to mangrove-friendly aquaculture include:

- recognition of mangrove ecosystems as providers of vital ecological services and their protection and conservation to sustain these services and goods;
- improving governance and sustainable use of mangroves, such as for aquaculture;
- integrating aquaculture and mangrove conservation into coastal zone management and promoting only sustainable small-scale integrated mangrove aquaculture;
- proper classification and zoning of existing mangrove ecosystems;
- retention (and replanting, where necessary) of a mangrove greenbelt acting as buffer zone along coasts and rivers where mangroves naturally occur;
- locating aquaculture farms outside of (and prohibiting developments in) pristine mangroves, coral reefs, and sea grass beds;
- if large-scale aquaculture farms must be built in mangroves, then require a full environmental impact assessment;
- employing and promoting appropriate technologies through information dissemination on best management practices for mangrove aquaculture as well as applying appropriate incentives and disincentives, including eco-labeling and certification of mangrove-friendly aquaculture and fishery products, revoking permits or lease of underutilized aquaculture farms in mangrove areas, rehabilitating abandoned aquaculture ponds back to mangroves, establish/enforce land and water quality criteria for aquaculture, preventing pollution, disease contamination, and hydrological alterations in mangrove ecosystems and regulating introduction of exotic species for aquaculture;
- actively supporting research, training, and education about mangroves and mangrove-friendly aquaculture through technology transfer, training, information dissemination, communication, and widespread public education about mangrove conservation and mangrove-friendly aquaculture;
- establishing mechanisms for resolving conflicts on compensation schemes and other issues between aquaculture and other mangrove users.

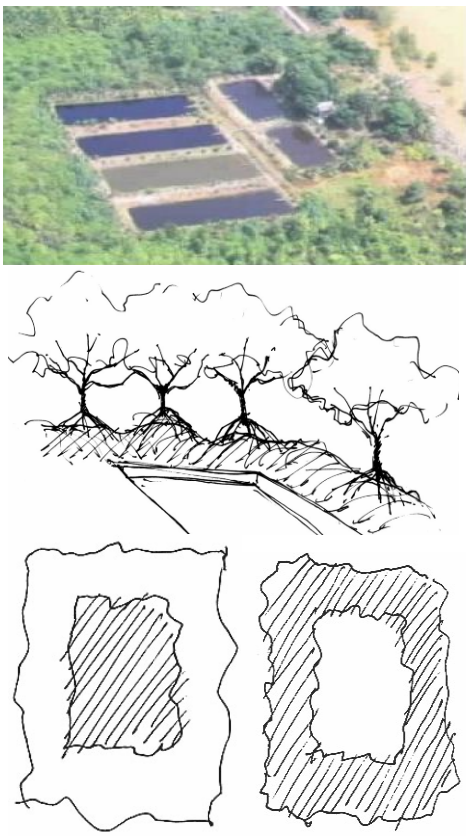
In 2001, the Southeast Asian Fisheries Development Center (SEAFDEC) internalized this code and produced her own version (SEAFDEC/AQD 2005). Tables 3 and 4 illustrate various applications and policy instruments designed and adopted. For instance, mangrove areas may be exploited, allocated or used only after their classification in terms of ecological quality (Table 4). Nigeria lacks such robust state laws for governance of mangroves.

The adoption of the Ecuadorian model (Beitl 2012) is also proposed to shift from the current passive open access coastal/mangrove policy with weakly regulated exploitation by local communities and oil companies to one of sustainable development through issuance of mangrove concessions (custodias). The holders of *custodias* sign agreements for the sustainable use and stewardship of mangroves, under the management and vigilance of the national park service. These mangrove concessions are by themselves protected areas under State laws or national park service. This method ensures the compatibility of the multiple use of the mangrove for aquaculture, urban development, infrastructure and artisanal fishing in an integrated coastal zone development. Policies requiring artisanal fishers and shellfish collectors to carry a government-issued ID card identifying them is used to minimize conflict among users (Beitl 2012).

Bravo (2006a, b, c, 2007) drafted several management plans for different *custodias* as well as a set of criteria by which communities qualify for a concession. In Nigeria's case it should be mandatory that groups (communities) desiring to exploit mangrove resources first register as corporate entities with the Bureaus and Departments responsible for Cooperative and Rural Development or Corporate Affairs Commission. Such groups may be "organized ancestral communities" or local civil society organizations, fishing cooperatives and associations (but not single individuals or entrepreneurs) and should be capable of providing maps, a list of members, a management plan detailing sustainable use of mangrove resources, a copy of the

association's agreement, names of the officers, and two-year agreement with an external institution for receiving technical assistance (Bravo 2007).

The Departments of Fisheries, Forestry and Environment should design the mangrove-friendly inter-disciplinary management plans to be administered to intending mangrove *custodias* and/or aquafarmers (Figure 5). Activities considered "sustainable" in the management plans should include controlled selective logging for charcoal production, conservation, education, research, reforestation, tourism, artisanal fishing, and culturing of a variety of fish, mollusks, and crustaceans, i.e., aquafarming (Bravo 2007). Beitl (2011) notes that *custodias* provide legal backing to "ancestral users" (*socios*) with promote sustainable fishing within the boundaries of the *custodia* at the expense of excluding other independent mangrove exploiters. However, in case of multiple uses or when independent aquafarmers or shellfish collectors are granted rights to sections within the *custodias* (shared resources) the *socios* could still defend their property rights, uphold the law, and continue deriving benefits from mangrove fisheries for their community. This compatibility in multiple eco-friendly uses of mangrove resources becomes an issue for stakeholders' conservation-oriented consultations and legislation addressing issues of equity and access (i.e., modifying Nigeria's policy on mangrove, as access can only be gained through *custodias* - a form of access acquired by rights-based law). It also follows that many coastal dwellers would be denied access and this might affect their livelihood, and also breed corruption among officers holding the *custodias.*



Empang parit or *tambak tumpang sari* is the traditional application of integrated aquaculture in the mangrove area. It usually consists of an unexcavated central platform (usually 3-5 m wide) that alternates between being flooded and exposed and a canal that runs along the pond dikes where fish, shrimp, and crabs are cultured. Tides are used to carry seed stock into the system and to exchange water. The central platform is flooded intermittently as the pond water level changes with the tidal cycle, giving the mangroves trees successive periods of inundation and exposure to air. When inundated, the mangrove platform also provides valuable additional habitat for the farmed stock; mangrove crabs in particular like to use the platform in this manner. The farm lay-out can be varied to meet local conditions and production needs. The ratio of mangrove forest to pond area could be varied, or the density of trees adjusted (0.17-2.5 trees m^{-2}). *Rhizophora* spp. are planted round the banks of each pond, both inside the pond and outside on the embankment. They function as filters to clarify the water; as spawning grounds, shelter and nurseries for the fish and prawns; to strengthen the embankments and prevent them from collapsing; and to provide shade for workers. The system is very common in Indonesia. They are locally run, operated and self-managed by the community. In some cases farmers plant *Avicennia* spp. in the centre of the ponds.

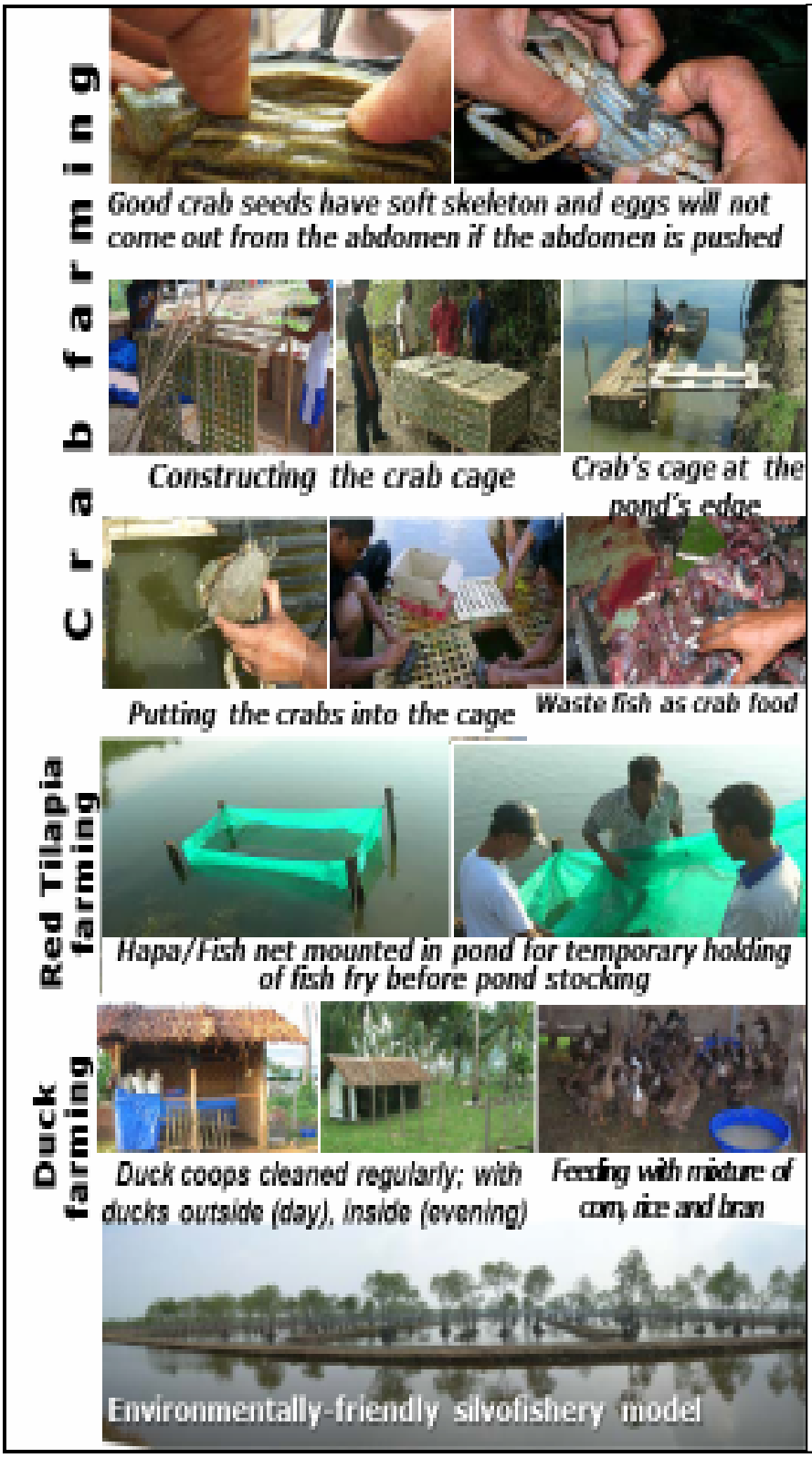
Production:

i. Semi-intensive polyculture advocated;
ii. The cultured species include mullets, *Chrysichthys*, shrimp, and mudcrab;
iii. Farmers operate between 4 to 25 acre of silvofisheries ponds and earn an average gross income of US \$589 ha^{-1} $year^{-1}$;
iv. Mangroves provide only limited nutrient inputs.

Disadvantages of Empang parit or *tambak tumpang sari:*

i. Greater construction cost per unit area;
ii. Greater difficulty to manage;
iii. Reduced water circulation and greater potential for stagnant areas with low oxygen levels;
iv. Limitation on species cultured;
v. Mangrove trees reduce the penetration of sunlight to ponds lowering the productivity of phytoplankton and benthic algae;
vi. Potential toxicity of tannin from mangroves;
vii. In areas of forestry service supervised land, pond operators resist efforts to replant mangrove, as the status of the trees would revert to the forestry service - an outcome that shrimp farmers find unacceptable.

Figure 4. The popular *Empang parit* or *tambak tumpang sari* silvofishery model (Bagarinao & Primavera 2005; Suryadiputra & Kurniasari 2007).



- Mudcrab fattening in pens and cages in the mangrove forest;
- Mudcrab grow-out in pens and cages in the mangrove forest;
- Mudcrab-fish polyculture in mangrove pens;
- Small-scale fish cages in mangrove estuaries and lagoons;
- Cockle beds in mangrove tidal flats;
- Production of soft-shell crabs in floating cages in mangrove estuaries;
- Oyster and mussel rafts in mangrove waterways;
- Seaweed longlines in the mangrove waterways;
- Silvofisheries or *tambak tumpang sari* and *empang parit* (Indonesia);
- Brush park, rock piles, miracle holes or *amatong* - Philippines (Bagarinao & Primavera 2005; Suryadiputra & Kurniasari 2007);
- *Integrated mangrove-shrimp farm system:* 6.4 ± 5 inds/m^2; Shrimp seed: PL_{12-15}, no feeding, liming and fertilizing.
- Production = 426 + 31.7 coded location - 1.94 water area - 2.42 sediment depth +142 harvesting techniques - 2.46 exchanged water level (R^2 = 59.9%)
- *Integrated mangrove-shrimp crab farm system:* 0.09 ± 0.1 crab/m^2, no feeding, liming and fertilizing.
- Production = - 122 - 1.25 water area + 595 water depth + 90.1 harvesting technique + 2.66 exchanged water level (R^2 = 58.6%)
- *Net profit:* USD 1,145.2 /household/yr (mangrove-shrimp-crab farms) > mangrove-shrimp farms.
- *Ratio of profit/cost:* 121% (mangrove-shrimp-crab farms) > mangrove-shrimp farms (41.3%) (Hai et al 2007)

Environmentally-friendly silvofishery model for mangrove ecosystem currently employed in Indonesia; mangroves within the pond with a ratio of 60-80% mangroves and 20-40% pond canal (Suryadiputra & Kurniasari 2007).

Figure 5. Small-scale aquaculture technologies appropriate in mangrove areas.

Table 3

Mangrove management strategies and policies in selected Asian countries compared to Nigeria

Country/Nature of mangrove	*Conservation and restoration measures*	*Legislation and government policies*
BANGLADESH World largest Mangrove forest area of 10,000 km^2, Sundarban	*Massive mangrove reforestation and plantation*: Commenced in 1906. In 2001, about 1,485 km^2 plantation was planted (Islam 2004); reforestation along a large portions of tropical coastline; 120 000 ha were planted in the eastern Sundarbans from the Ganges and Brahmaputra Rivers. *Funding*: Long-term funding of 10-15 years secured and mobilized. *Some difficulties encountered* include sediment stability.	Many regulatory measures are taken such as Forestry Policy, 1994, Sustainable Environment Management Program (SEMP), 1997; Environment Conservation Act, 1995, Forest Act, 1927 & 1989 and many conventions. Government established Environment Ministry to restore the Environment (Siddiqi 2001).
REPUBLIC OF FIJI Mangrove covers an area of 42,464 hectares (Senibulu 2000)	*Reserved Forest*: In 1975, the Government designated all mangroves Reserved Forest management for Department of Lands and Surveys. *Compensation*: paid compensation to owners of traditional fishing rights for loss of fishing areas reclaimed for development purposes. *Management Committee*: Government established a National Mangrove Management Committee in 1983, to review proposals on development in mangrove areas (Senibulu 2000).	The principal statutory legislations related to management of mangroves are the Crown Lands Act, the Fisheries Act, and the Forestry Act. However, there is no specific legislation governing the protection of mangroves (Senibulu 2000).
INDIA India is a pioneer country in the management of mangroves. The first management plan was introduced in 1892 for the Sundarban mangrove forests (Kathiresan 2006).	*Leadership*: Government provides 100% support to mangrove plans and research activities. The Mangrove management plan started in 1892. *Mangrove protected areas and restoration:* There are not less than 38 mangrove protected areas including the Sundarbans Tiger Reserve; 5 wildlife Sanctuaries, Pirotan National Park and 4 Biosphere Reserves; in addition to a National Mangrove. Genetic Resource Centre to protect 64 mangrove species in 2,000ha area. Government supports coastal village fisherforks in its mangrove restoration (Kathiresan 2006).	Provide Coastal Regulation Zone (CRZ) Notification in 1991, 2004 to prohibit developmental activities in mangrove. Environment Protection (1986). Wildlife Protection Act, 1972. National Environment Policy, 2005. Supreme and High court Order of 1996 and 2005. Indian Forest Act, I927 Indian Fisheries Act, I897. National Forest Policy and the National Wildlife Action Plan, I988. National Conservation Strategy and Policy Statement on Environment and Development. Citizens have constitutional right to protect, and have compassion for all creatures. The State Government prepares management action plans for specific mangrove areas. After getting approval of the State Level Steering Committee, the action plans are submitted to the National Committee for financial assistance (Kathiresan 2006).
JAPAN Japan is the Northern limit of global mangroves, around Islands of Ishigaki and Iriomote of Okinawa province (Kathiresan & Baba 1999).	The reserved areas are purchased by the Government of Nago, and the mangroves were preserved along the Okawa River. Students from junior colleges are being involved in mangrove plantation (Kathiresan & Baba 1999). Research efforts: The Global Mangrove Database and Information System (GLOMIS) is a project of the International Society of Mangrove	National Mangrove Committee was established in 1970. State Forest Corporation in control. Mangrove studies have been inscribed in the emblems of the elementary schools and colleges of the Yagasishima Island. Mangroves have also being included in the academic

	Ecosystems based in Okinawa, Japan. The project puts emphasis on the exchange of information and cooperation among scientists, governments, and coastal stakeholders for the conservation, rational use, and management of the mangroves of the world. ISME coordinates information provided by regional centers in Brazil, Fiji, Ghana, and India. Mangrove plantations mainly serve two purposes: sea defenses and landscaping along the coastal sea (IITO/ISME 2004)	curriculum of the country (Kathiresan & Baba 1999).
MALAYSIA Mangrove area is 653,400 ha, rich species diversity. About 72% designated as reserve. Matang mangrove reserve started in 1902 (Macintosh & Ashton 2002).	*Mangrove area is designed for ecotourism. *Construction of artificial lake system as additional habitat for birds and fish, nesting platforms for birds, breeding and research on endangered species (*e.g* milky stork and mangrove associated fireflies. *Inter-agency and licensing practices were followed to reserve the area. *Good relationship between government agencies and the local community (Macintosh & Ashton 2002).	Inter-agency consultations and licensing practices are followed Fisheries Department issues licenses for fish cage practices while Forestry did for bird sanctuary. National Museum manages archaeological sites, etc. Bird sanctuary is managed by wildlife department The administrative and operational issues are dealt with the state and district level committees. The Department of Fisheries implements a National Fisheries Policy in the mangrove areas, restricts inshore and coastal waters up to 5km from the shoreline exclusively for artisanal fishermen (Macintosh & Ashton 2002).
PAKISTAN Has mangrove area of 260000 ha. About 100,000 ha destroyed due to aquaculture, urbanization and overexploitation for fuel (Kathiresan 2006).	Afforestation and restoration programme started in l985. Over 16,000 ha planted and 3,000 ha under natural regeneration. Supported by UNDP/UNESCO Regional Mangrove Project, IUCN and the Forest Department. About 100,000 people mobilized in a mass scale planting of mangroves in the vicinity of their villages on government lands to meet their fuel wood and fodder requirements (Kathiresan 2006).	*National Environmental Policy (2005). Laws were established to: ensure sustainable management of the forest and tree population, involves the local communities in the restoration of the mangrove (Kathiresan 2006).
THE PHILIPPINES Mangroves are fast disappearing at a rate of about 100,000 ha yr^{-1}, as against 500,000 ha yr^{-1} (Primavera 2000).	*Local ordinances*: Communities enacted local ordinances prohibiting the sale of mangrove fuel wood to bakeries thereby halting illegal cutting. *Community leases:* Leases for 25 years are provided to the local communities as community based mangrove forest management agreements. *Funding:* The harvest value of the mangroves wood are shared 75% to the community, 25% to the government which set aside 10% in a Department of Environment and Natural Resources Trust Fund to support mangrove replanting costs. *Community involvement and reforestation projects*: A 70-hectare mangrove plantation project was successfully implemented in New Buswang, Kalibo, through a synergy between the local governments (Initiator), the people's Association - a 27 member families (Implementers), together with a non-government Organization (Facilitator). The 27 member families planted, maintained and protected 50 ha of river delta to *Rhizophora* species and *Nypa fruticans;* and kept record for 3 years.	Laws are promulgated on the construction of fish ponds, etc from mangrove. Philippine Fisheries Code of 1998 (BFAR 2001) recognizes tidal swamps, mangroves, marshes, foreshore lands, and ponds suitable for aquaculture as public lands (not to be privatized). The government determines areas or portions of available public lands suitable for fish pond purposes, or to be declared as fish reserve or sanctuary for conservation and ecological purposes. Lease of public lands (mostly mangroves) for fish ponds shall be according to Fishpond Lease Agreements (FLAs) subject to the following conditions: FLA holders: only Filipino citizens, Preferred FLA grantees: fisherfolk cooperatives/ associations or small and medium enterprises FLA area: up to 50 ha for individuals and 250 ha for fisherfolk organizations

	Research: The technology of growing mud crabs in pens in the mangroves is progressively being adopted; further research is ongoing into the hatchery production of mudcrab seed and the formulation of low-cost pellets to help farmers reduce the use of 'trash' fish to feed the mud crabs. *Green belts of mangroves or buffer zones* are also established though not throughout the country due to conflicting policies, poor law enforcement and lack of political will (Primavera 2000). *Aquaculture farms* in mangrove areas are required to maintain a greenbelt for protection of the dikes and for treatment of farm effluents (Primavera, 2000).	Lease period: 25 years, renewable for another 25 years, Lease rates: shall be set at levels that reflect resource rent accruing from the use of the pond resources and shall be determined by Fisheries Department (BFAR 2001). Pond development shall begin within 6 months or the FLA is cancelled. Ponds shall be commercially productive within 3 years. Ponds not fully producing within 5 years shall revert to the public domain for reforestation. Reforestation shall be done by FLA grantee of 50 m wide strip of seashore or river bank fronting the fish pond. Abandoned, underdeveloped, or unused fishponds covered by FLAs shall be identified by Federal and the local government, and shall be restored to the original mangrove state. Philippine law requires that 20 m strip along creeks and rivers be excluded from pond development; 20 m strip to be retained or replanted by pond or mangrove lease holders; 20 m along river banks, 50 m fronting seas, oceans, 50-100 m along shorelines and 20-50 m along riverbanks to be retained in storm surge areas (Primavera, 2000).
SRI LANKA Upon the dramatic Tsunami flood disaster of 2004 in Asia, with funding from European Commission, Germany and a grant Swiss company the country implemented restoration projects (Kathiresan 2006).	A three-year project on protection and rehabilitation of threatened mangrove forests in three wetland regions was executed. New nurseries were established with community participation. The trees were replanted in areas where intact mangrove forests had been destroyed in the past. Rural community, International organizations (IUCN) and NGOs Partnered in the conservation effort. Fishermen cultivate mangroves in the mudflats close to their homesteads as well as in government–owned lands (Amarasinghe et al 2002). Twigs and branches from mangroves were collected by the local community and installed in the coastal waters as fish aggregating device (brush parks) under local government licenses. Local government also issue licenses for selective and controlled bark extraction while debarked stems are sold as firewood (Kathiresan 2006).	Forest Department is responsible for development and implementation of forest policy and for management of mangrove forest. In 1990 it introduced centrally managed integrated coastal zone management plan. 1992 – The first tropical country to have National Mangrove Conservation Project started by Forest Department with financial assistance from donor agencies; Forest Department deals with protection of biodiversity in the mangrove habitats, environmentally sensitive areas, practices that have a detrimental effect on the mangrove ecosystem and protection of the interests of both the people and fauna of Sri Lanka using participatory approach 1997 - The revised edition of the Coastal Zone Management Plan 2004 - National Wetland Policy (Kathiresan 2006).
THAILAND Has 1,67,000 ha of mangroves (50% of the entire coastline of 2614 km is covered by mangrove forests).	Though heavily exploited in the past, harvesting area have restricted to a narrow 10-100m fringe along the coast. The Government formulated distinct policies and management practices particularly silviculture systems, mangrove afforestation	Most of the mangrove forests have been declared reserved forest. Illegal private possession for shrimp farming and salt production banned.

Extent of Mangrove areas dwindled from 312, 723 to 244,085 ha between 1993 and 2000 (Kathiresan et al 2006).	sustainable aquaculture development in mangrove areas, mangrove research programmes and community participation in mangrove conservation (Kathiresan et al 2006) and promotes establishment of large-scale private plantations of mangroves. Government conducts regular community training in mangrove resource management in partnership with non-government organizations that help to mobilize government and public support for the poor coastal community.	Policy dividing the mangrove forest area into 2 zones – (i) Conservation Zone (426 km^2 or 11.46% - includes historic areas, areas susceptible to damage and erosion, areas with local uniqueness, National parks, wildlife sanctuaries, etc. (ii) Development zone (3,296 km^2) further divided into two sub-zones (a) Economic Zone A (1,996 km^2 or 53.61%), and (b) Economic Zone B (1,300 km^2or 34.93%). Declaration of 21 or more Marine Protected Areas (MPAs) covering 5,810.23 km^2(11.13% of the country) *The government Decentralization Plan and Process Act*, 1999 under Article 284 of Constitution 1997 grants local organizations and municipalities the rights/power in organizing public services like social infrastructure development and (ii) quality of life development to promote integrated conservation management systems between mangroves and aquaculture, conservation and rehabilitation of mangroves forests, and to promote women's participation in mangrove conservation programmes (Kathiresan et al 2006).
VIETNAM Mangroves have dwindled significantly due to overexploitation (Macintosh & Ashton 2002).	Vietnam has *community level regulations* to prevent unlawful exploitation of mangroves based on punishment and reward systems. *Restrictions*: Cutting, catching of aquatic species and grazing by domestic animals are not allowed. *Fines*: Culprits charge some fines and 50% of the fine given to the informers. *Reserve*: The Can Gio Mangrove Forests have been recognized by UNESCO/ MAB as the Mangrove Biosphere Reserve. From 1978 to 1997, 20,638 ha of mangrove areas were under afforestation. *Community involvement*: Government conducts regular community training in mangrove resource management for farmers in Ca Mau, Lower Mekong Delta by the Division of Forestry, Department of Agriculture and Rural Development. The farmers are from both the State-managed Forest and Fishery Enterprises and from private farms. The planting and maintenance techniques that they learn are put in to practice on their farms with good success. *Research*: Culture of mangrove-associated species like mud crab and mudskipper in mangrove ponds (as opposed to collection from the wild) is developing rapidly, with aggressive research into the breeding and production of seedstock of mud crabs and mudskippers in hatcheries and nurseries (Hai et al 2007)	*After the war, government spent a huge sum on restoration of mangrove. *Mangrove divided into three protection zones: (i) Full Protection zone; (ii) buffer zone; and, (iii) Economic zone. *The information of mangrove management policies well disseminated to local people. *Management Board for Environmental Protection allocates land and forests to households for their protection on a30 years contracts; thereby reducing mangrove destruction (Macintosh & Ashton 2002).
NIGERIA Forest reserves occupy about 96,043 km^2 (or about 10 million ha or 10% of	The Nigeria Forest Policy (Federal Government of Nigeria 2006). Has inadequate provision for mangrove forest conservation; currently, mangroves are not classified as "forest"; only one mention of	Obsolete and inadequate policies, law and weak institutional provision for mangrove forests (Akinola 2006).

Nigeria's land area of 923,767 km^2. Over 60% of the mangrove stands are found in the Niger Delta coastal region. About 0.71% (75,874 ha) of the total forest reserves fall within the swamp and mangrove forest zones. Mangrove with trees are 0.0ha and 5,314ha in reserved and free forests, respectively. Mangrove depletion poses threat to fisheries development.	"mangrove" (alongside fresh water swamp),-identifies weak institutional capacity to effectively implement sustainable forest management strategies, subscribes to forestry valuation but no record of such cost/benefit valuations, emphasizes 19 priority areas among which are Biodiversity Conservation, National Parks and Games Reserves of Conservation Interest and Environmental Services of Forests, recognizes the socio-economic and ecological roles of agroforestry (it is advisable to also develop a silvofishery policy to cater for mangrove-aquaculture), accords forest rights and legal powers of usage to local communities (subject to necessary ecological controls), establishes forest reserves as areas designated by state governments, though most are poorly managed, The mangrove forest reserves include those of Stubbs Creek, Edumanom, Lower Orashi River and Nun River (Community Forest). Upper Orashi wetlands (Rivers) and Apoi Creek Forest (Bayelsa) are listed as sites of international significance (Ramsar Sites no. 1759 and 1751, respectively) (USAID 2008).	Mangroves tend to be marginally defined - not classified as "forest" rather as "mangrove with trees" (Federal Department of Forestry 1999). Cross River State Forest Law, Cap 47- in 2005 created a Mangrove Forest Reserve (about 250 km^2), along the Calabar-Cross River Estuaries. National Park Service Decree, 1999 **-** allows communities to participate in the governance and conservation of wildlife communities, biological diversity and Protected Areas (PAs). Forest Law, Cap 55. *Land Use Act, 1990 - State governments own the lands. National Policy on Environment, 1999. National Agenda 21, 1999 Nigerian Biodiversity Strategy and Action Plan (NBSAP). Indigenous and Community Conserved Areas (ICCAs). Convention on Biodiversity, African Convention on the Conservation of Nature and Natural Resources (1968) RAMSAR Convention on the Conservation of Wetlands of International Importance. Convention on International Trade in Endangered Species of Fauna and Flora (CITES 1973). Conservation of Migratory Species of Wild Animals (1973). Framework Convention on Climate Change (1992). Convention to Combat Desertification (1994). Community-based Natural Resources Management (CBNRM). Convention on Ozone Layer The National Council on Environment coordinates forest and biodiversity management at both the federal and state levels. No government agency solely devoted to mangrove management (Federal Government of Nigeria 2006; USAID 2008).

Table 4

Classification of mangrove ecosystems

Ecological quality	*Present use and status*	*Zoning*	
		Category/designation	*Remark*
Excellent	not yet used, pristine	Forest Reserve (Full permanent protection, non-use, 'no touch zone'; declared as national parks or wildlife refuges)	Large mangrove forests (areas greater than 100 hectares), habitat for rare species, richness and diversity of species; managed for protective and scientific functions; identify and encourage the use of best management practices for utilization of mangrove resources through research, education and awareness by resource users; identify and promote alternative sustainable uses of the resources
Good	slightly used	Forest Reserve 'no touch zone'	Mangrove forests which act as natural barriers/buffers against environmental hazards, shore erosion, strong winds and storm floods should be left untouched
		Transition/ greenbelt/buffer/ economic zone (minimum of 20 m required and declared to be buffer strip protection for forest conservation)	Mangrove areas containing a variety of agricultural activities, human settlements and other uses; government managed for the sustainable use, production of mangroves, approved goods and services; conserved for utilization by people either those who are dependent on the mangrove forest products for their livelihood/domestic needs (e.g. firewood, crabs, molluscs) or for tourism; suitable for silvofisheries. Government supervises and manages this area ensuring that the following areas are excluded from activities: • Conservation areas; • Areas declared as protected under national legislation; • Areas of cultural importance; • Areas required for community needs; • Sites susceptible to degradation. Engage, promote, increase and strengthen stakeholders on best management practices; and promote alternative sustainable livelihood options. In areas where mangrove harvesting is permitted, concessionaires shall be required to replant mangroves and adopt a sustained-yield management system (of allowing 20 years in between harvesting an area)
		(For rivers and creeks, 30 m and 20m buffer strip/greenbelt, respectively on each side)	Mangrove vegetation adjoining the mouth of major river systems should be preserved (no felling allowed) on both sides of the mouth of the river fronting the sea, to maintain the ecological balance of estuarine areas; suitable for silvofisheries
Poor	fully converted, damaged	Rehabilitation zone	Areas managed for the rehabilitation of mangroves; suitable for silvofisheries; local people should be encouraged to initiate the reforestation and re-established of mangrove ecosystems. They should be supported with tree nursery run by the local people
		Multiple-use zone for optimum use	Mangrove forest managed for the production of fire wood, bark, fish, honey, etc.; suitable for aquaculture in floating pens, cages and raft culture along river channels; intensively run shrimp ponds behind the mangroves -linked to sea water by channel; silvofishery systems with pond:forest area ratio = 20:80

Requirements of investors. Intending mangrove aquafarmers in Nigeria must subscribe to upholding and applying FAO Code on Responsible Fisheries and ecologically sustainable principles in their organizational structure, goals, production processes and products. It should be mandatory for them to make a written request for site visit by delegations from the Forestry and Fisheries Departments of Ministry of Agriculture prior to commencement/design of the Project to assess whether their investment plan complies with Responsible Fisheries and ecologically sustainable principles. They should also sign agreement to disclose information on sources of fingerlings, production statistics, and to allow access for periodic inspection before permits are issued. Such request should be

granted or denied in writing stating with specificity the reasons for denial, within 60 days after receipt or deemed approved if the Department fails to respond within the 60-day time period. Additionally, mangrove aquafarmers should be required to offer full time employment to the locals by means of a quota system. They should keep off designated conservation and protected areas unless degraded areas needing restoration vis-à-vis community concessions for participatory management.

Mangrove aquafarmers should be allocated clearly demarcated sites outside of coral reefs, seagrass beds and pristine mangrove areas, after full, independent, and public Environmental, Social and Health Impact Assessment (ESHIA), procedures are executed highlighting impact of the farm on the mangrove ecosystem and on the food supply and livelihoods of local communities. The ESHIA should also provide for a management plan - species to be cultured, farm layout, production strategies including minimum water quality standards to be maintained, production targets, costs and revenues per species or culture system to be adopted; the necessary mitigating measures, and periodic monitoring and evaluation of the farm operations (Bagarinao & Primavera 2005). The precautionary principle should be adopted if the doubts are not substantially cleared. Also only small-scale (employing limited capital and household labor) integrated mangrove-aquaculture systems that are non-destructive, sustainable, and beneficial to fishing communities should be promoted. Mangrove-aquafarm owners should be encouraged or provided incentives to voluntarily trim and maintain mangroves, encourage mangrove growth, and plant mangroves along their shorelines in a manner that will not result in the removal, defoliation, or destruction of the mangroves.

Companies and organizations desiring to exploit the mangrove must in addition obtain ISO 14001 certification to establish, maintain and continually improve their environmental management systems (EMS), before embarking on any project. The 1994 World Trade Organization (WTO) Technical Barriers to Trade Agreement (TBT), allows States to use the international standards of ISO as basis for technical regulations governing access to their markets. The legal implication is that Nigeria must also develop national standards on the basis of international standards like ISO 14001. Nigeria is a signatory to this standard. In the mean time investors should demonstrate good (best) management practices (GMPs) that are practical and effective in preventing or reducing environmental and social impacts. These GMPs should be structural, biological, technological or management-oriented approaches or solutions as dictated by species cultured, farm facility, phase, or method of production (World Bank/ISME/Center Aarhus 2005). It is expected that stakeholders will consult widely to draft a Code of Practice for Mangrove aquaculture alongside community-based projects to promote sustainable management of mangrove ecosystems such as done by Asian governments. A creative idea is the Fishpond Lease Agreements, FLAs in the Philippines (BFAR 2001), the Ecuadorian *custodias* (Beitl 2012) or using the concept of territorial use rights for fisheries, TURFs; aquafarmers should not be allowed to use the aquaculture permit to hold lease on the mangrove land for other purposes and to bring underutilized aquaculture farms to full use or have the permits or lease revoked.

Externally-funded mangrove projects and direct foreign investments should be encouraged and attracted as a matter of fact. At the same time, mismatches in policies and priorities in the implementation of coastal management and mangrove conservation initiatives to the detriment of the environment should be avoided. Agardy (2005) recommends building the capacities of stakeholders and harmonizing priorities of international funding agencies with local priorities and needs, to all intents and purposes. This would largely gain the good will of environmental pessimists, who expect the worst.

Requirements of products. The use of labels (such as eco-labels) for environmental purposes has become an issue in international trade, with many producers of fish and fishery products voluntarily adopting ISO 9000 certification and other eco-labels (e.g. “sustainably managed forest”, "dolphin-safe tuna" labels and the Marine Stewardship Council). Products from mangrove environment (including charcoal, timber, shrimps, crabs, periwinkles, tar, fish, etc.) should also be eco-labeled testifying to their specific qualities, product content, geographic origin, and the traditional processing method. Such

would make the products to command higher prices because of their traceability, food safety, species sustainability and increase their demand being derivatives from "sustainably managed forest" (World Bank/ISME/Center Aarhus 2005).

Monitoring. Ekpenyong (2008) identifies the lack of current and accurate spatial data for decision making as the real threat to food security, especially considering services mangrove provide. Twumasi & Merem (2006) demand regular time-series spatial database of mangrove, land use map and inventory on the coastal mangrove resources, such as drainage systems using best practices such as remote sensing and GIS technologies, high-tech geo-referenced and high resolution aerial photography. The National Space Research and Development Agency (NSRDA) through NigeriaSat-1 has a programme for satellite-based environmental change research in the Niger delta, forest monitoring, flood mapping, etc., in Nigeria. The agency should be properly funded to build capacity of academics and researchers and to fashion out criteria and guidelines for institutional procedures for access to shared database on mangrove research.

Land and water quality criteria for mangrove aquaculture ponds should be established. Thailand offers an example (Tookwinas et al 2000). Aquafarms must maintain water quality criteria of: pH 6.5-9.0, total nitrogen < 4.0 mg L^{-1}, total ammonia nitrogen < 1.1 mg L^{-1}, total phosphorus < 0.4 mg L^{-1}, total suspended solids < 70 mg L^{-1}, hydrogen sulfide < 0.01 mg L^{-1}, biochemical oxygen demand - 5 days < 20 mg L^{-1} and 20 days < 20 mg L^{-1}.

Mangrove harvesting. The Guyana model (Mangrove Action Project 2010) stipulates that irrespective of the zone to which mangrove is located, no harvesting of mangroves should be done (including for local uses, grazing by domestic animals, fuel wood, pole supplies) without authorization, nor within 1½ mile of mean high water mark or along the sea foreshore or areas managed for sea defenses. Mangroves near or adjacent to traditional productive fry and fishing grounds are protected. Harvesting is done in zones marked for control and multiple uses every 20 years; and when harvesting, strips of 20 m width must be left undisturbed between harvested areas to allow for natural regeneration. The Nigeria Forest Policy (Federal Government of Nigeria 2006) recognizes the role of forests to protect watersheds, buffer zones around rivers and hills, prevention of water and wind erosion; and allocates concessions to private investors on a case-by-case basis or to people in surrounding communities. No reforestation obligation is imposed on logging firms. Except for traditional uses mangrove species are not currently commercially utilized in Nigeria.

Adherence to national environmental and forestry standards. National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria Environmental Policy, NEP (FRN 1998) and Nigeria Forestry Policy (Federal Government of Nigeria 2006) have made provisions for management of mangroves, though weak. These among others include precautionary principle, pollution prevention pays principle (3p+), user pays principle (UPP) and inter- and intragenerational equity, to encourage cost-effective exploitations that prevent environmental degradation without compromising the ability of future generations to meet their own needs.

Given the right incentives and socio-technical infrastructure, farmers are able to adopt new practices for scaling up sustainable intensification of agriculture, including buying degraded land, rehabilitating and improving them into productive land and transformed yields (Pretty et al 2011). With the drive for profit and personal achievement, many successes have emerged without the ideal supportive policy environments. Such was the case in Southeast Asia, where private sector practitioners without government policy guidelines, but with a quick profit-making mind-set, massively destroyed and converted mangrove to intensive shrimp aquaculture ponds (Huitric et al 2002). To attract externally-funded mangrove projects and avoid mismatches in policies and priorities in the implementation of coastal management and mangrove conservation initiatives to the detriment of the environment, it is necessary to build capacities of

stakeholders and harmonize priorities of international funding agencies with local priorities and needs (Agardy 2005). With appropriate policy and managerial support, such as highlighted in this paper, destruction of mangroves could be averted in Nigeria vis-à-vis poverty reduction through aquaculture.

Conclusions. This paper envisaged expansion of Nigeria's aquaculture into poorly managed marginal lands like mangroves and suggests strengthening the presently weak institutional policy instruments while promoting mangrove-friendly aquaculture models such as silvofishery vis-a-vis the use of community concessions (*custodias*) and adoption of integrated coastal zone management (ICZM). Furthermore, high-priority research into eco-friendly brackish water farming utilizing new production technologies like zero-exchange recirculatory, ensiled or closed systems and silvofishery should be encouraged for the long-term goal of making Nigeria's aquaculture sector a higher contributor to our national GDP. However, there are several unutilized and underutilized beaches, burrow pits, lakes, springs, creeks and rivers along the coastline - rich in biodiversity, which could be utilized for coastal shrimp/fish culture without destroying the mangroves. Cage culture in large water bodies should also be encouraged, through territorial use rights, to reduce pressure on the land and mangrove ecosystems.

References

Agardy T., 2005 Global marine conservation policy versus site-level implementation: the mismatch of scale and its implications. Marine Ecology Progress Series 300:242–248.

Akinola S. R., 2006 Land use decree, forest administration and governance crises in Nigeria. 5th FIG Regional Conference, Accra, Ghana, March 8-11, 16 pp.

Akinrotimi O. A., Owhonda K. N., Ibemere I. F., 2005 Brackish water fish farming: a viable options in poverty alleviations in Niger delta. Paper presented at Fisheries Society of Nigeria (FISON), Conference November 22-27th, Port Harcourt, Nigeria, pp. 6.

Aksornkae S., Priebprom S., Saraya A., Kongsangchai J., 1986 Mangrove resources and the socio-economics of dwellers in mangrove forests in Thailand. In: Man in the mangroves: the socio-economic situation of human settlements in mangrove forests. Kunstadter P., Bird E. C. F., Sabhasri S. (eds), Tokyo, The United Nations University, pp. 11-43.

Allan G. L., Heasman H., Bennison S., 2008 Development of industrial-scale inland saline aquaculture: coordination and communication of R & D in Australia. Final report to FRDC Project No. 2004/241. NSW Department of Primary Industries – Fisheries Final Report Series No. 100, 245 pp.

Amarasinghe U. S., Amarasinghe M. D., Nissanka C., 2002 Investigation of the Negombo estuary (Sri Lanka) brush park fishery, with an emphasis on community-based management. Fisheries Management and Ecology 9:41-56.

Ansa E. J., 2009a Sustainable production of mangrove oyster *Crassostrea gasar* (Adanson, 1757) in Rivers State, Nigeria. In: Proceedings of the 24th annual conference of the Fisheries Society of Nigeria (FISON), Vol. I. Fagbenro O. A., Bello-Olusoji O. A., Adeparusi E. O., Adebayo O. T., Nwanna L. C., Dada A. A., Olufayo M. O. (eds), October 25–28, Akure, pp. 134–137.

Ansa E. J., 2009b Opportunities for shrimp farming in the Niger delta: dilemma of sustainable production in the absence of regulatory framework. In: Proceedings of the 24th annual conference of the Fisheries Society of Nigeria (FISON), Vol. I. Fagbenro O. A., Bello-Olusoji O. A., Adeparusi E. O., Adebayo O. T., Nwanna L. C., Dada A. A., Olufayo M. O. (eds), October 25–28, Akure, pp. 138–142.

Ansa E. J., Bashir R. M., 2007 Fisheries and culture potentials of the mangrove oyster (*Crassostrea gasser*) in Nigeria. Research Journal of Biological Sciences 2(4):392-394.

Audelo-Naranjo J. M., Voltolina D., Romero-Beltrán E., 2012 Culture of white shrimp (*Litopenaeus vannamei* Boone, 1931) with zero water exchange and no food addition: an eco-friendly approach. Latin American Journal of Aquatic Research 40(2):441-447.
Bagarinao T. U., Primavera J. H., 2005 Code of practice for sustainable use of mangrove ecosystems for aquaculture in southeast Asia. SEAFDEC Aquaculture Department, Iloilo, Philippines, 48 pp.
Baluyut E. A., 1989 Aquaculture systems and practices: a selected review. United Nations Development Programme, Rome.
Beitl C. M., 2011 Cockles in custody: the role of common property arrangements in the ecological sustainability of mangrove fisheries on the Ecuadorian coast. International Journal of the Commons 5(2):485-512.
Beitl C. M., 2012 Shifting policies, access, and the tragedy of enclosures in Ecuadorian mangrove fisheries: towards a political ecology of the commons. Journal of Political Ecology 19:94-113.
BFAR, 2001 Code of practice for sustainable shrimp farming. Department of Agriculture, Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines, 16 pp.
Bird E., Kunstadter P., 1986 Recommendations with respect to the special case of the mangrove forest of Thailand. In: Man in the mangroves: the socio-economic situation of human settlements in mangrove forests. Kunstadter P., Bird E. C. F., Sabhasri S. (eds), Tokyo, The United Nations University, pp. 113-115.
Bravo M., 2006a [Update of the management of the mangrove forest concession plan designed for Association of Crabbers July 6, Naranjal in Guayas, Ecuador]. In: [Management of coastal resources]. Guayaquil, Ecuador, 53 pp. [in Spanish]
Bravo M., 2006b [Update of the management of the mangrove forest concession plan designed for Association of Artisanal fishermen, in Mariscadores and around Costa Rica: Archipelago of Jambeli]. In: [Management of coastal resources, procedure No.PMRC-035-2005 ITC program]. Guayaquil, Ecuador, 61 pp. [in Spanish]
Bravo M., 2006c [Update of the management plan for the sustainable custody of mangrove in the Santa Rosa community, Eloy Alfaro Canton, in Esmeraldas province]. In: [Management of coastal resources, ITC procedure No. PMRC-035-2005]. Guayaquil, Ecuador, 38 pp. [in Spanish]
Bravo M., 2007 [Analysis of the legal basis for granting concessions of areas of the mangrove, legal responsibilities regarding utilization of concession areas, and competency to issue agreements for sustainable use and custody of the mangrove]. In: [Management of coastal resources, ITC procedure No.PMRC-035-2005: Update of the mangrove forest management plans]. Guayaquil, Ecuador, 46 pp. [in Spanish]
Business Day, 2004 Shell/USAID ₦266bn shrimp project on shaky start. Business Day Newspaper 3(374):1-2.
CBD, 1992 Convention on Biological Diversity. Available at: www.cbd.int/doc/world/. Accessed: December, 2013.
Deekae S. N., Ayinla O. A., Marioghae I. E., 1994 Possibilities of the culture of mangrove molluses with special reference to the Niger Delta. NIOMR Tech Paper 96:20.
Dublin-Green C. O., 1987 Investigations on the acid-sulphate soils of the brackish water experimental fish farm, Buguma, Rivers State. ARAC working paper, ARAC/87/WP/9, 12 pp.
Ekpenyong R. E., 2008 An assessment of the threats to food security in Akwa Ibom State, Nigeria. 10th International Conference on Global Spatial Data Infrastructure, GSDI, 25–29 February, 2008, St Augustine, Trinidad. Available at: http//:www.gsdi.org/ gsdiconf/gsdi10/papers/TS18.4paper.pdf. Accessed: May, 2015.
FAO (Food and Agriculture Organization of the United Nations), 1995a Precautionary approach to fisheries. Part I: guidelines on the precautionary approach to capture fisheries and species introductions. FAO Fisheries Technical Paper 350(1):52 pp.
FAO (Food and Agriculture Organization of the United Nations), 1995b Code of conduct for responsible fisheries. Food and Agriculture Organization, Rome, 41 pp.

FAO (Food and Agriculture Organization of the United Nations), 1997 FAO Technical Guidelines for Responsible Fisheries No. 5. Aquaculture Development, Food and Agriculture Organization, Rome, 40 pp.
Federal Department of Fisheries (FDF), 2007 Fishery statistics of Nigeria. 4th edition 1995–2007, 49 pp.
Federal Department of Forestry, 1999 Approved Forestry Development Programme, December – 1999, FDF, Abuja.
Federal Government of Nigeria, 2006 National Forest Policy. Federal Ministry of Environment, Abuja, 93 pp.
Federal Republic of Nigeria (FRN), 1998 National policy on the environment. Federal Ministry of Environment, Abuja, 58 pp.
Hai T. N., Phuong N. T., Yakupitiyage A., 2007 Improvement in management of mangrove and the integrated mangrove – aquacutlure in ca mau province. In: Proceedings of the 11th International Symposium on the Efficient Application and Preservation of Marine Biological Resources, Nha Trang University, 1-2 November, pp. 253-263.
Huitric M., Folke C., Kautsky N., 2002 Development and government policies of the shrimp farming industry in Thailand in relation to mangrove ecosystems. Ecological Economics 40:441-455.
IITO/ISME, 2004 Introduction and some contents of Global Mangrove Database And Information System (GLOMIS) PD 14/97 Rev. 1(F). International Society for Mangrove Ecosystems and International Tropical Timber Organization, International Society for Mangrove Ecosystems, Okinawa, Japan, 225 pp.
Islam M. R. (ed.), 2004 Where land meets the sea: a profile of the coastal zone of Bangladesh. Published for Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP) of water Resources Planning Organization (WARPO) by the University Press Limited, Dhaka, BD, 317 pp.
Kathiresan K., 2006 Conservation and management of mangroves in South Asia. Proceedings of the International Conference and Exhibition on mangroves of Indian and Western Pacific Oceans (ICEMAN 2006), 21-24 August, Kuala Lumpur, Malaysia, pp. 1-26.
Kathiresan K., Baba S., 1999 Facts about mangroves of Japan. Seshaiyana 7(2):3-6.
Kathiresan K., Bingham B. L., 2001 Biology of mangroves and mangrove ecosystems. Advances in Marine Biology 40:81-251.
Kathiresan K., Jumnongsong S., Plathong S., 2006 Mangroves of Thailand: policy and management practices. SDNP-ENVIS Newsletter 1:2-8.
Macintosh D. J., Ashton E. C., 2002 Principles for a code of conduct for the management and sustainable use of mangrove ecosystems. World Bank, ISME Center Aarhus, 107 pp.
Mangrove Action Project, 2010 National Mangrove Management Action Plan 2010-2012. Guyana Forestry Commission, 91 pp.
Pretty J., Toulmin C., Williams S., 2011 Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9(1):5-24.
Primavera J. H., 2000 Development and conservation of Philippine mangroves: institutional issues. Ecological Economics 35:91-106.
Saenger P., Hegerl E. J., Davie S., 1983 Global status of mangrove ecosystems. IUCN Commission on Ecology Papers No. 3, Gland, Switzerland, 88 pp.
SEAFDEC/AQD, 2005 Regional guidelines for responsible fisheries in Southeast Asia - responsible aquaculture. SEAFDEC Aquaculture Department, Iloilo, Philippines, 44 pp.
Senibulu M., 2000 Role of the national government in economic development of mangroves in Fjji. In: Proceedings of Asia-Pacific Cooperation on Research for conservation of mangroves. Okinawa, Japan, pp. 147-154.
Siddiqi N. A., 2001 Mangrove forestry in Bangladesh. Institute of Forestry and Environmental Sciences, University of Chittagong, BD.

South China Sea Fisheries Development and Coordinating Programme, 1982 Training on assessment of coastal aquaculture potential, Malaysia, SCS/GEN/82/35, FAO, Rome. Available at: http://www.fao.org/docrep/field/003/AB767E/AB767E00.htm#TOC. Accessed: December, 2013.

Suryadiputra I. N. N., Kurniasari T., 2007 Demonstration of community-based mangrove reforestation in aquaculture landscapes to promote ecological productivity, sustainability and environmental security in Aceh, Indonesia - Final Report. Indonesia, Wetlands International – Indonesia Programme, Bogor, 67 pp.

Tookwinas S., Dirakkait S., Prompoj W., Boyd C. E., Shaw R., 2000 Marine shrimp culture of Thailand: operating guidelines for shrimp farms. Aquaculture Asia 5(1):25-28.

Twumasi Y. A., Merem E. C., 2006 GIS and remote sensing applications in the assessment of change within a coastal environment in the Niger Delta region of Nigeria. International Journal of Environmental Research and Public Health 3(1):98-106.

Udoh J. P., Ekpo I. E., Nlewadim A. A., 2007 Quality of bottom soils of semi-intensive fresh and brackishwater aquaculture ponds in southeastern Nigeria. Nigerian Journal of Agriculture, Food and Environment 4(1-4):98-108.

USAID (United States Agency for International Development), 2008 Nigeria biodiversity and tropical forestry assessment: maximizing agricultural revenue in key enterprises for targeted sites (MARKETS). Prepared by Chemonics International Inc., USA, 98 pp.

Uyeh E. W., 1987 Some experiments on commercial pond fish culture in the tidal mangrove area of the Niger Delta of Nigeria. In: Proceedings of the 5th Annual Conference of the Fisheries Society of Nigeria (FISON). Ita E. O., Ajayi T. O., Ezenwa B., Olaniawo A. A., Udolisa R. E., Taggert P. A. (eds), September 22-25, Ilorin, pp. 414-428.

World Bank/ISME/Center Aarhus, 2005 Principles for a Code of Conduct for the Management and Sustainable Use of Mangrove Ecosystems. (Version 10 March 2005), 106 pp., work in progress. Available at: http://mit.biology.au.dk/cenTER/MCB_Files/2005 _MCB _Code_ March.pdf. Accessed: December, 2013.

World Commission on Environment and Development (WCED), 1987 Our common future. Oxford University Press, Oxford, 383 pp.

Zabbey N., 2006 The challenges of sustainable shrimp fisheries in Nigeria. Keynote address presented at a national workshop on Catch data transparency and bycatch reduction, organized by the Centre for Environment, Human Rights and Development (CEHRD), with support from the World Conservation Union (IUCN), Amsterdam, The Netherland; held in Port Harcourt, Rivers State, Nigeria. Available at: http://www.cehrd.org/files/SUSTAINABLE_SHRIMP_FISHERIES_IN_NIGERIA.doc. Accessed: December, 2013.

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