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Mangrove Revegetation Potentials of Brackish-Water Pond Areas in the Philippines

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1. Introduction

The Philippines is one of the countries with the most number of true – mangrove species (about 42 species, 18 families, **Table 1**) (Primavera, 2004; Spalding et al 2010; Polidoro et al 2010). However Philippine mangrove forests suffered greatly from anthropogenic activities, i.e. cutting for firewood and charcoal, siltation caused by upland deforestation, and conversion of mangrove areas to shrimp ponds, fishponds and salt ponds (Primavera 1991, 1995, 2000; Field, 1998; FAO, 2003, 2007). From 1918 (~450,000) to 1998 (112,400), mangrove cover declined by more than 75% (**Figure 1**). In 2007, the remaining mangrove areas in the Philippines was estimated at 289,350 hectares (DENR-NAMRIA 2007), a value which is 61% (176,950) higher than 1998 estimate. However, most of these are estimates based on satellite images that need to be validated on field.

The typical historical zonation of mangrove species in the Philippines follows that described by Duke et al in 1998 for mangroves found along Daintee River in Australia. Species with pneumatophores are commonly found at the low-intertidal; prop- and knee roots species are in the mid-intertidal; and buttress or plank root species are at the high intertidal area (**Figure 2a**). However due to the aforementioned large scale conversion to aquaculture ponds, the mangrove communities at the middle zone were diminished (**Figure 2b**).

Of the total mangrove areas that were deforested, sixty-eight percent were converted to brackish-water ponds (Primavera, 1995, 2000). One of the legal instrument of operation of brackish-water ponds in the Philippines is the Fishpond Lease Agreement (FLA) that is being granted by the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) under the Department of Agriculture (DA). In 2007, there were 59,923 hectares of potential brackish-water ponds with FLA belonging to 4,386 registered operators (BFAR, n.d.). However, the license agreement of almost 65% (39,152 ha) of these brackish-water ponds with FLA are already expired and as of the list posted in December 2010 had not been renewed. **Table 2** presents the details of the top 10 provinces in terms of the area with expired FLA licenses in the Philippines.

FAMILY[1]	SPECIES[1,2]
ACANTHACEAE	*Acanthus ebracteatus*
	Acanthus ilicifolius
ARECACEAE	*Nypa fruticans*
AVICENNIACEAE	*Avicennia alba*
	Avicennia marina
	Avicennia officinalis
	Avicennia rumphiana
BIGNONIACEAE	*Dolichandrone spathacea*
BOMBACACEAE	*Camptostemon philippinense*
	Camptostemon schultzii
CAESALPINIACEAE	*Cynometra iripa*
COMBRETACEAE	*Lumnitzera littorea*
	Lumnitzera racemosa
EBENACEAE	*Excoecaria agallocha*
LYTHRACEAE	*Pemphis acidula*
MELIACEAE	*Xylocarpus granatum*
	Xylocarpus moluccensis
MYRSINACEAE	*Aegiceras corniculatum*
	Aegiceras floridum
MYRTACEAE	*Osbornia octodonta*
PLUMBAGINACEAE	*Aegialitis annulata*
PTERIDACEAE	*Acrostichum aureum*
	Acrostichum speciosum
RHIZOPHORACEAE	*Bruguiera cylindrica*
	Bruguiera exaristata
	Bruguiera gymnorhiza
	Bruguiera hainesii
	Bruguiera parviflora
	Bruguiera sexangula
	Ceriops decandra
	Ceriops tagal
	Kandelia obovata
	Rhizophora apiculata
	Rhizophora mucronata
	Rhizophora stylosa
	Rhizophora x lamarckii
RUBIACEAE	*Scyphiphora hydrophylacea*
SONNERATIACEAE	*Sonneratia alba*
	Sonneratia caseolaris
	Sonneratia ovata
	Sonneratia x gulngai
STERCULIACEAE	*Heritiera littoralis*

Table 1. List of true mangrove species in the Philippines (Spalding et al, 2010[1]; Polidoro et al, 2010[2]).

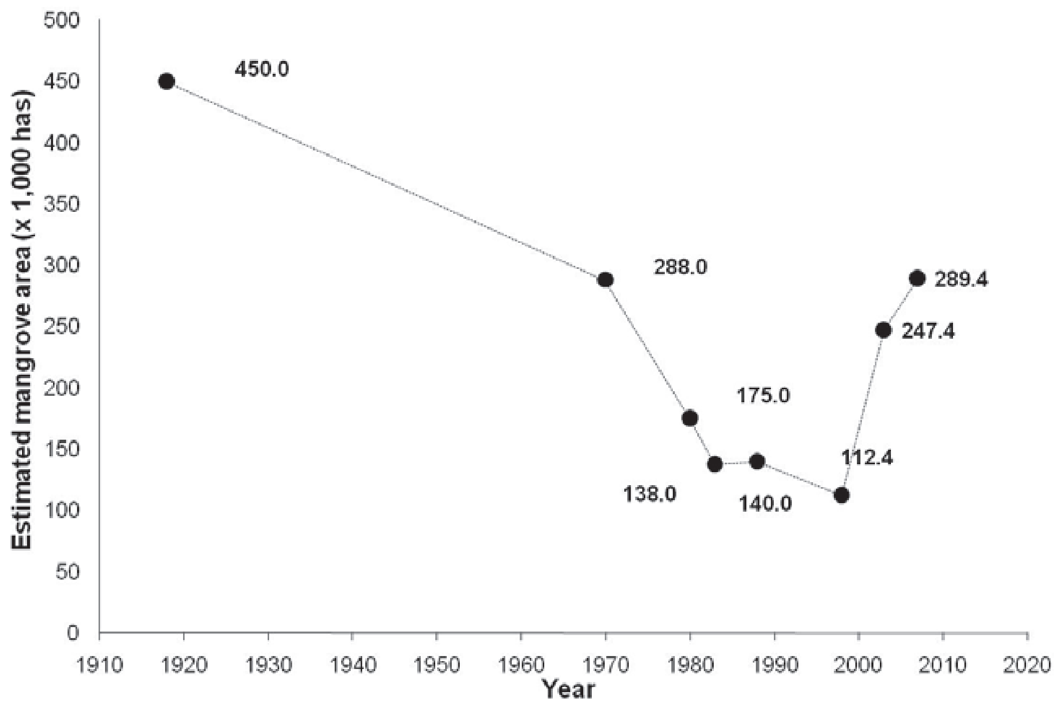

Fig. 1. Estimated extent of mangrove areas in the Philippines from 1918 (around 450,000 hectares) to 2007 (around 289,350 hectares).

PROVINCE	TOTAL FLA AREAS	NO. OF LESSEE	AVERAGE AREA GRANTED	TOTAL AREA WITH EXPIRED FLA	% EXPIRED
Antique	150.65	5	30.13	150.65	100%
Maguindanao	125.36	6	20.89	125.36	100%
Lanao del Norte	1141.11	26	43.89	1097.07	96%
Palawan	1422.96	25	56.92	1356.19	95%
Basilan	854.04	43	19.86	804.80	94%
Sulu	172.80	2	86.40	159.00	92%
Davao Oriental	369.58	17	21.74	334.42	90%
Sultan Kudarat	291.73	11	26.52	262.83	90%
Northern Samar	1010.24	34	29.71	893.87	88%
Camarines Sur	1181.93	75	15.76	1017.92	86%

Table 2. Top 10 provinces in terms of the area with expired FLA licenses in the Philippines.

It has long been noted by various authors that most of the brackish-water ponds in the Philippines are either idle, abandoned, underutilized and in an unproductive state (Primavera and Agbayani 1997; Primavera 2000; Yap 2007; Samson and Rollon 2008; Primavera et al, 2012). There had been efforts to promote the reversion of these ponds to mangrove areas however the implementing rules and regulations had been unclear, if not nonexistent. In most cases, holders of FLA certificates are unwilling to yield the pond area for mangrove restoration (Yap, 2007; Samson and Rollon 2008). These underutilized ponds

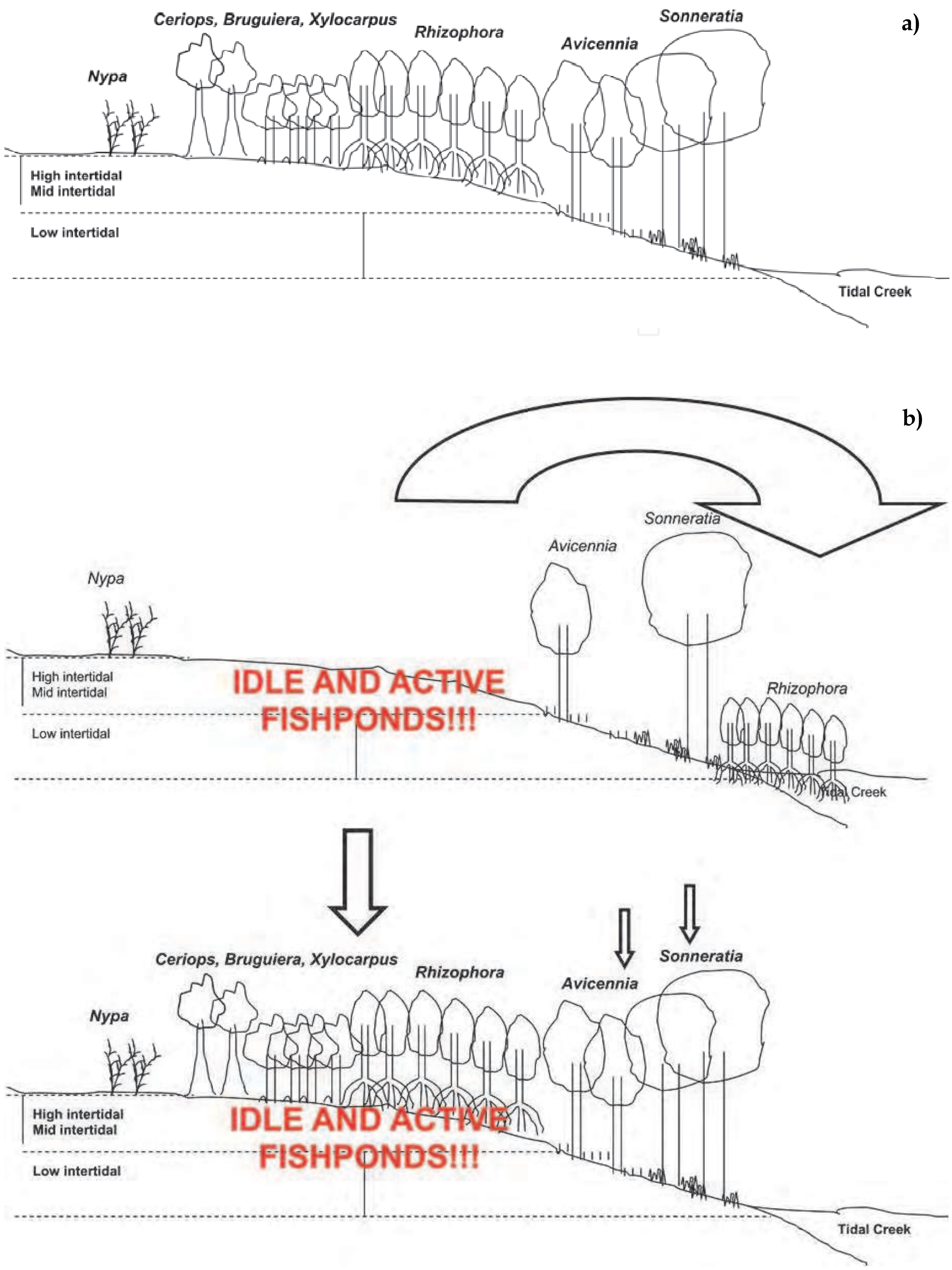

Fig. 2. Illustration of the a) historical and b) present condition and c) best management options for the mangroves and brackish-water pond areas in the Philippines.

perpetuates the loss of goods and services that mangrove areas could provide. The continued abandonment of these areas increases the vulnerability of coastal communities to the ancillary impacts of climate change such as increase in sea level (Alongi, 2002; Gilman et al, 2006; Gilman, 2008), tsunami (Alongi 2008; Dahdouh-Guebas, 2005; Vermaat & Thampanya, 2006), wave impact due to increased typhoon strength and frequency and coastal erosion (UNEP-WCMC, 2006; Primavera et al 2012).

If massive loss of mangrove areas in the Philippines could be attributed to aquaculture development, logically therefore, restoration of idle and underproductive brackish-water ponds at least to its ecologically productive state, should be the focus of management efforts (Primavera, 2006; Samson & Rollon, 2008; Primavera & Esteban, 2008; Primavera et al, 2012). This option will greatly enhance the ecological success of current efforts by 1) promoting healthy growth patterns of planted species, and 2) stop the afforestation of adjacent habitats (i.e. seagrass bed and mudflat area, **Plate 1**). These practices are widespread in the Philippines where the growth of species in afforested sites performed dismally as compared to those planted in natural mangrove forests (Samson and Rollon, 2008; **Figure 3**). Though the revegetation of idle and unproductive ponds may present a multitude of ecological, political and institutional challenges (Primavera, 2000; Samson and Rollon, 2008) to become feasible, conscious effort to move towards this objective must be prioritized. **Table 3** lists some factors that needs to be considered before deciding the reversion of idle or disused ponds to mangrove areas.

Plate 1. Some examples of the well-meaning planting initiatives but may be less successful in terms of ecological restoration in Talibon, Bohol, Philippines where mangroves were planted on seagrass and mudflat areas.

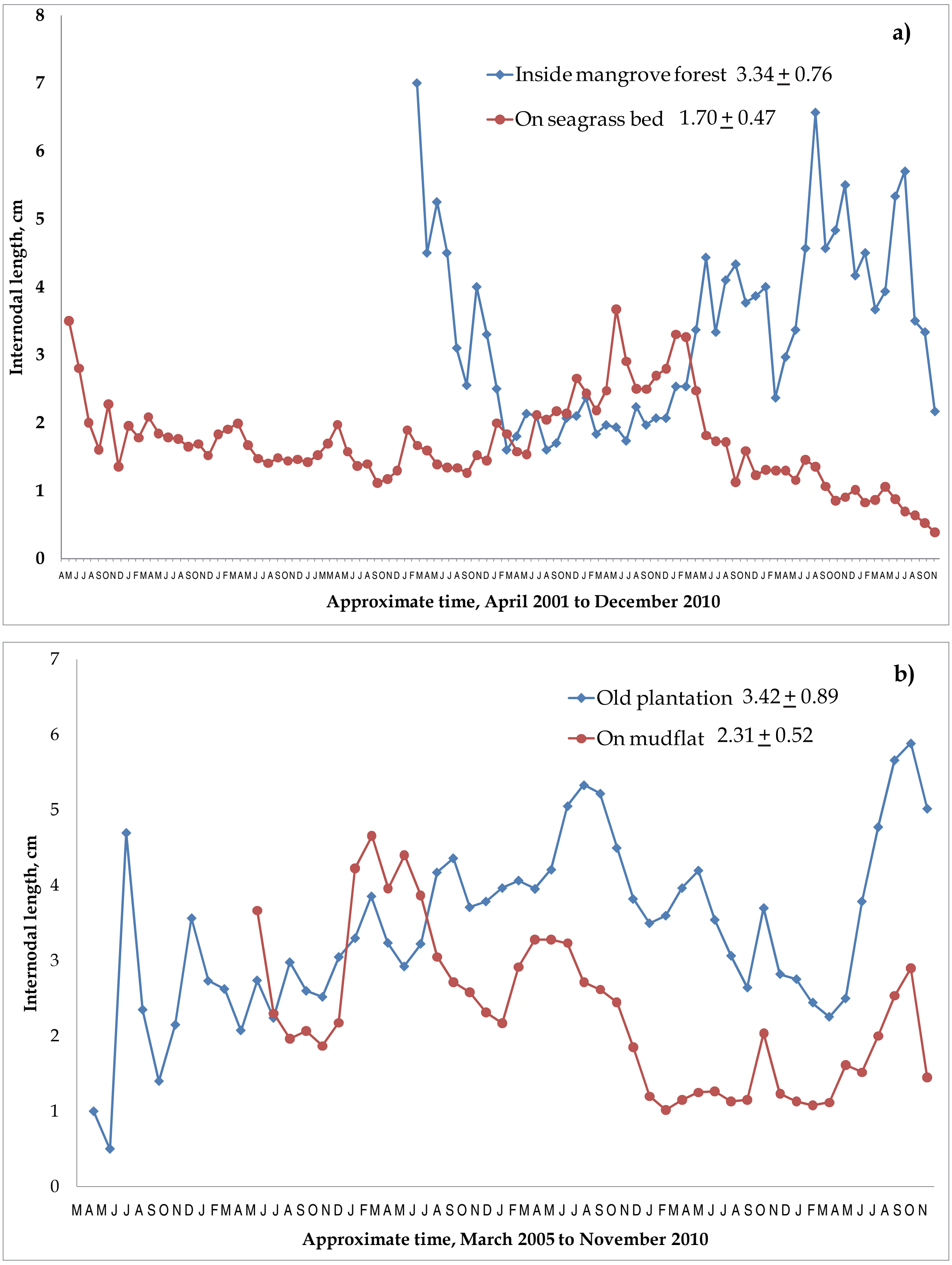

Fig. 3. A comparison of the internodal growth patterns of *Rhizophora stylosa* planted in different mangrove planting sites in Talibon, Bohol, Philippines: a) Cataban Island and b) Barangay San Francisco.

	CONSIDERATIONS
Ecological	If farm was constructed in an inappropriate site such that: Farm density is already too high Occurrence of diseases There is insufficient water supply Too much rainfall; Unsuitable soils Frequently hit by typhoons (Stevenson et al 1999)
	Poor productivity level due to high acidity and poor shrimp survival (Stevenson et al 1999)
	Further degradation of the ecosystem – i.e. acidification, soil erosion – if some rehabilitation activity is not undertaken (Stevenson et al 1999)
	Arrest surface erosion and subsidence and compaction of soil profile within and in the adjacent environment (Burbridge and Hellin, 2002)
	Tidal hydrology can still be restored (Lewis 2005)
	Availability of water borne seedlings and propagules from neighboring mangrove communities (Lewis 2005)
	Possibility of occurrence of natural process of secondary succession (Lewis 2005)
Economic	Non – sustainable and unproductive pond operation (Stevenson et al 1999)
	If degradation not arrested, repair may become progressively more expensive and difficult – rehabilitation costs would be balanced by costs avoided (Stevenson et al 1999)
Social	Willingness and cooperation of stakeholders (Stevenson et al 1999)
	Provide additional protection from strong waves; if infrastructures for protection against strong waves and typhoons are more costly than revegetation efforts (Stevenson et al 1999; Primavera 2000)
Institutional	Expired FLAs
	Existing comprehensive land – use plan
	Maintenance of mangrove greenbelt as required by law – Fishery Reform Code (Primavera, 1995)

Table 3. Factors to consider before deciding the reversion of idle or underproductive ponds to mangrove areas.

The issues surrounding the decline of mangrove areas in the Philippines and the proliferation of idle and underutilized brackish-water ponds in terms of area covered are inextricably linked and may be addressed in a more integrated and adaptive approach (**Figure 4**). **Figure 2c** illustrates what may be the best management options for mangroves and brackish-water ponds in the Philippines. As cited by Primavera and Esteban (2008), Saenger et al (1986) recommended the 4:1 mangrove to pond ratio to sustain the ecological function of the mangrove ecosystem. However this recommendation poses a great challenge to the Philippine government as the basic information on the present state of ownership and operation of these brackish-water ponds are lacking.

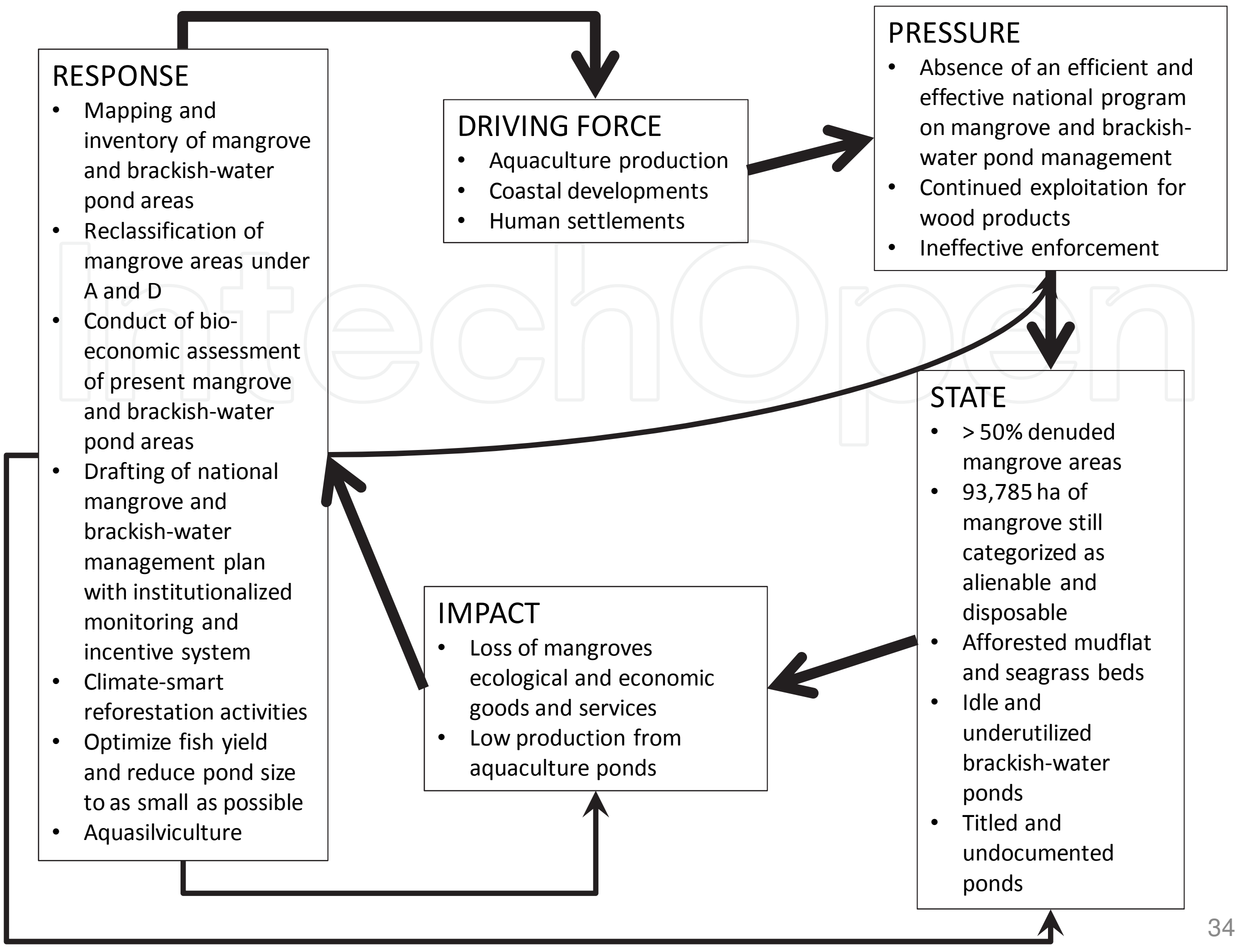

Fig. 4. DPSIR model on the state of mangrove forests and brackish-water ponds in the Philippines.

2. Mangrove-pond ratio of selected aquaculture production centers in the Philippines

As presented in the previous section, brackish-water ponds now occupy a large part of the natural mangrove areas in the Philippines. In the provinces with the largest area of brackish-water ponds in the Philippines, mangrove loss is more than 75% of the natural forest. The mangrove-pond ratio in these areas ranges from 1:2 to 1:1,586 (**Table 4**). However 44 to 99% percent of these brackish-water pond areas are not covered by FLA (**Table 5). Figure 5** presents the potential mangrove extent and hectarage of brackish-water pond area, with or without FLA in selected sites of the country. On the average, around 50% of the historical mangrove areas in these selected sites were converted to brackish-water ponds with Iloilo City having the highest percentage of converted area (90%). However, as in the situation in many provinces around the country, not all of the brackish-water ponds have FLAs, on the average only 40% are under the 25-years lease agreement with the government (**Table 6**). Worse, only 60% of these FLAs are still active. What could have happened to the other mangrove areas that were converted to brackish-water ponds? One possible answer to this is that the other areas have land titles or undocumented as in the case of the 72 has (92%) of ponds in Lian, Batangas.

Province	Estimated mangrove extent (ha, 2007)	Brackish water pond area (ha, 1994)	Mangrove to pond ratio
Former Zamboanga del Sur	19,830	32,992	1:2
Pampanga	220	22,231	1:101
Bulacan	10	15,861	1:1586
Negros Occidental	2,790	9,796	1:3
Capiz	2,810	8,404	1:3
Pangasinan	170	7,026	1:41
Iloilo	1,350	5,504	1:4
Masbate	2,440	4,974	1:2
Quezon	14,540	4,876	3:1
Aklan	360	4,653	1:12

Table 4. Estimated mangrove extent, brackish-water pond area and mangrove to pond ratio in the top 10 provinces with the largest hectarage of brackish-water ponds in the Philippines.

Province	Brackish water pond area (ha, 1994)	BW ponds with active FLAs (ha, 2010)	BW pond not covered by FLAs (ha, 2010)	% BW pond with no FLA
Former Zamboanga del Sur	32,992	1,700.81	31,291.19	94.8
Pampanga	22,231	79.27	22,151.73	99.6
Bulacan	15,861	70.00	15,791.00	99.6
Negros Occidental	9,796	1,514.52	8,281.48	84.5
Capiz	8,404	791.56	7,612.44	90.6
Pangasinan	7,026	1,132.02	5,893.98	83.9
Iloilo	5,504	3,067.12	2,436.88	44.3
Masbate	4,974	929.35	4,044.65	81.3
Quezon	4,876	1,576.41	3,299.59	67.7
Aklan	4,653	1,599.76	3,053.24	65.6

Table 5. The estimated brackish-water pond area, ponds with and not covered by FLA as of 2010 in the top 10 provinces with the largest hectarage of brackish-water ponds in the Philippines.

PROVINCE	MUNICIPALITY	POND AREA (ha)	FLA AREA (ha, 2010)
Batangas	Calatagan	299.43	111.21
	Lian	78.64	6.60
Quezon	Calauag	533.76	479.75
Sorsogon	Sorsogon City	318.81	137.06
	Prieto Diaz	463.48	299.40
Iloilo	Iloilo City	871.92	2.54
Former Zamboanga del Sur	Aurora	3,955.86	524.53
	Kabasalan	992.82	588.33

Table 6. Mangrove extent, brackish-water pond and FLA areas in selected sites of the Philippines.

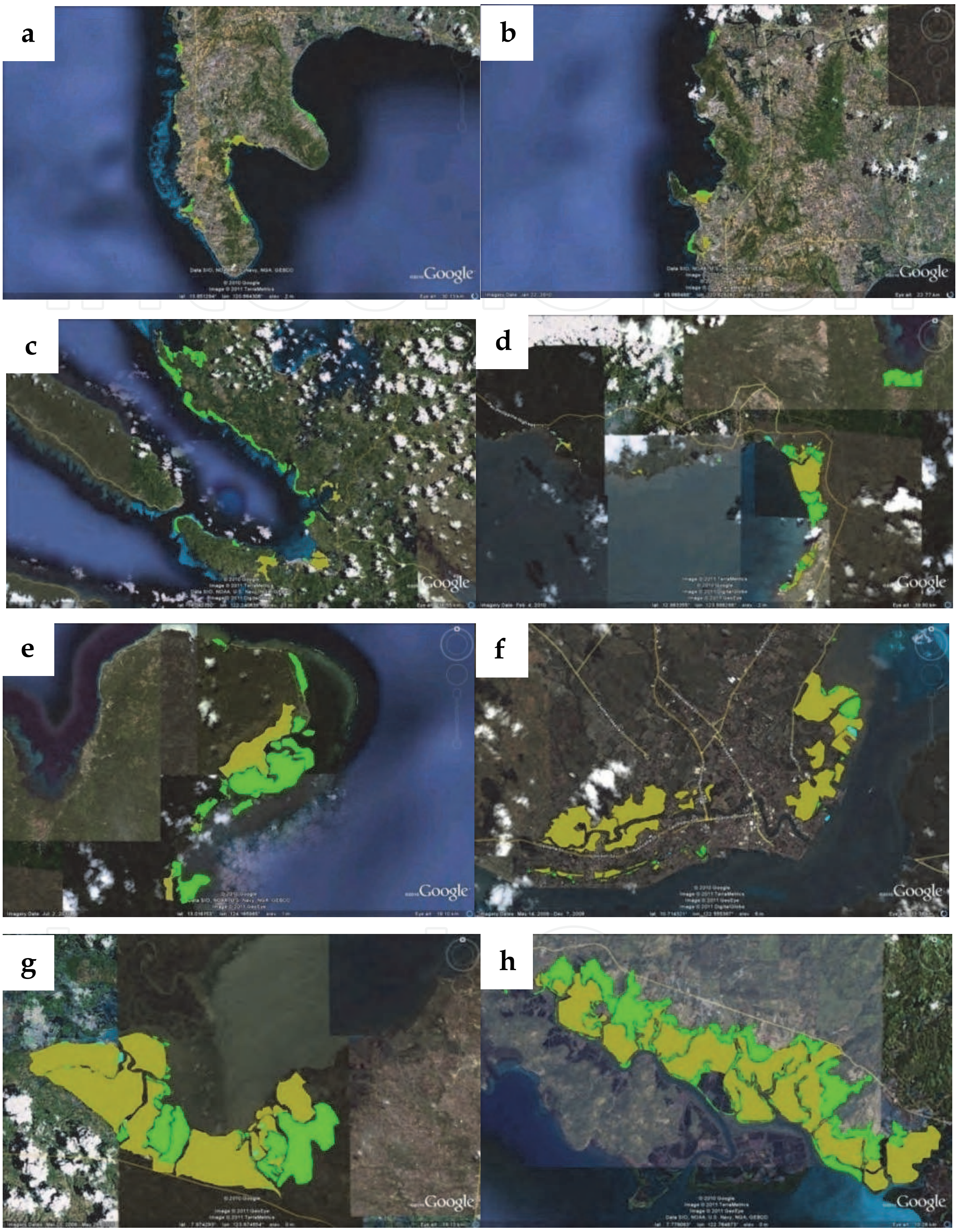

Fig. 5. Digitized Google Earth images of potential mangrove (green) and brackish-water ponds areas (dark yellow) in selected sites of the Philippines, a) Calatagan and b) Lian, Batangas, c) Calauag, Quezon, d) Sorsogon City, e) Prieto Diaz, Sorsogon, f) Iloilo City, g) Aurora, Zamboanga del Sur, and h) Kabasalan, Zamboanga Sibugay.

3. Pond area-fish yield in the past decade

The contribution of the aquaculture sector is still the highest (from 38 to 49%) in terms of the volume of production in the last decade (**Figure 6**). Almost fifty percent of the total fisheries production in 2010 comes from this sector. Brackish-water pond aquaculture is still the subsector with the highest percentage of production in terms of volume (**Figure 7**). However

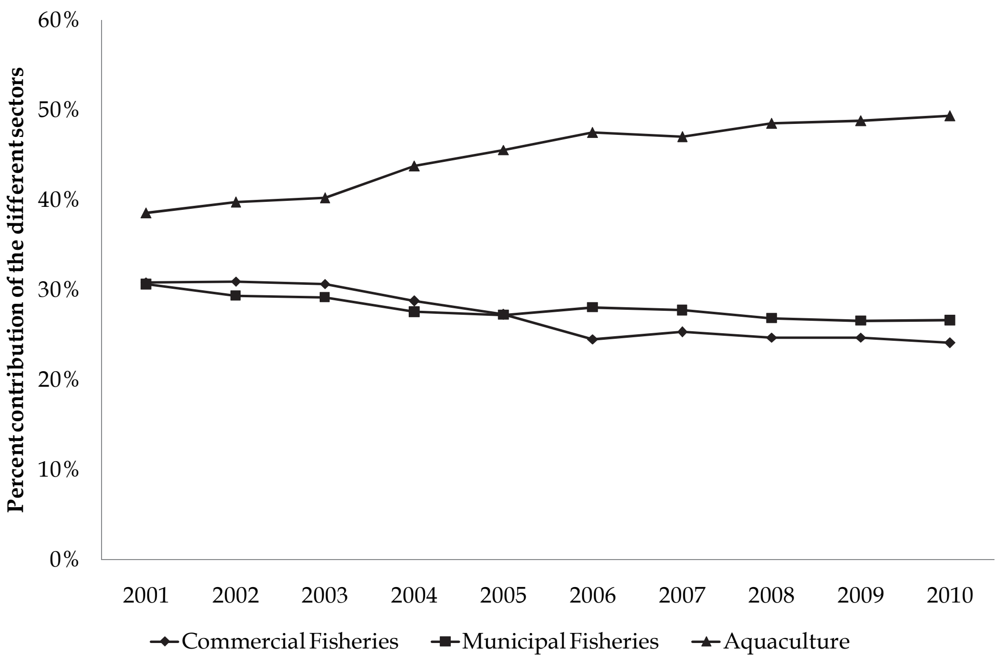

Fig. 6. Percent contribution of the different sectors of fisheries production in the Philippines from 2001 to 2010.

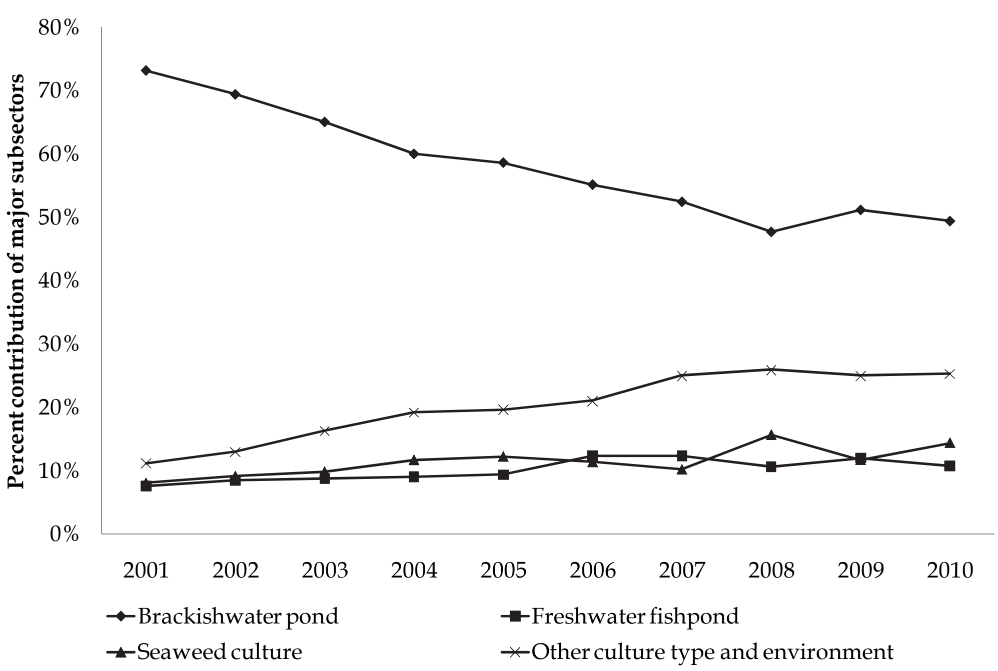

Fig. 7. Percent contribution of the different subsectors of aquaculture production in the Philippines from 2001 to 2010.

a steady decline of production from this sector is apparent from 2001 to 2010 and this may be due to the under productivity of almost 40% of brackish-water ponds in the country. Included in these areas are three of the provinces with the largest hectarage of brackish-water ponds, namely former Zamboanga del Sur, Bulacan and Aklan (**Table 7**).

Province	Volume of production (mt, 2010)		% contribution of BW ponds to total aquaculture production	Estimated annual production from BW ponds per hectare
	Aquaculture, total	Brackish-water pond		
Former Zamboanga del Sur	187,718	8,947.2	5%	0.27
Pampanga	148,603	47,400.1	32%	2.13
Bulacan	41,182	33,459.6	81%	2.11
Negros Occidental	23,200	20,411.0	88%	2.08
Capiz	40,216	26,340.3	65%	3.13
Pangasinan	85,523	15,645.2	18%	2.23
Iloilo	23,235	21,111.4	91%	3.84
Masbate	2,499	1,059.8	42%	0.21
Quezon	55,688	11,863.7	21%	2.43
Aklan	8,987	8,196.3	91%	1.76

Table 7. Volume of total aquaculture and brackish-water pond production in the top 10 provinces with the largest hectarage of brackish-water ponds in the Philippines.

In terms of the physical area utilized, brackish-water aquaculture is the biggest sub-sector in Philippine aquaculture (Cruz, 1997), however, its contribution to total fisheries production may not be proportionate with its physical magnitude in terms of area covered (~169,000 ha in 1995, Yap, 2007).

4. Management options for brackish-water pond areas in the Philippines

Brackish-water ponds in the Philippines may be classified into two: 1) those with valid legal instrument of ownership and operation, 2) those that do not have legal instrument of operation and undocumented. The first classification are of two types, those with FLAs and those with land titles. As presented in the previous section, 40 to 50% of these ponds, are now left idle or underproductive. A number of authors discussed several management strategies to address this problem (Primavera, 2000, 2006; Yap, 2007; Samson and Rollon, 2008; Primavera and Esteban, 2008; Primavera et al, 2012). Samson and Rollon in 2008 proposed a possible decision tree of options for idle and active brackish-water ponds in the Philippines. These options are specifically for those with FLAs.

The present paper is an attempt to extend the options presented by Samson and Rollon (2008) to include brackish-water ponds covered by land titles and those that are undocumented (**Table 8**).

PONDS WITH LEGAL INSTRUMENTS		PONDS WITHOUT EXISTING LEGAL INSTRUMENT OF OWNERSHIP
With active FLA	Titled ponds	
1. For ponds with active FLAs and the overall fish yield is optimal, apply semi-intensive aquaculture. (modified from Samson and Rollon, 2008). 2. Optimize fish yield and reduce pond size to as small as possible (Samson and Rollon, 2008). Follow the 4:1 mangrove-pond area ratio to maintain ecological health (as cited in Primavera, 2000).	1. Aquasilviculture (Primavera, 2000) 2. Optimize fish yield and reduce pond size to as small as possible (Samson and Rollon, 2008); revert unutilized areas to mangrove forest	1. If pond existence is necessary based on bioeconomic analysis, reapply FLA and optimize fish yield (Samson and Rollon, 2008). 2. Revert to mangrove areas: a. Natural revegetation b. Assisted planting

Table 8. List of management options for brackish-water ponds with and without legal instruments (with FLA, land titles) in the Philippines.

A total of six rational management strategies are being proposed for the utilization of brackish-water ponds in the Philippines. The options are specific for the current state of ownership of the ponds.

4.1 For ponds with active FLAs and the overall fish yield is optimal, apply semi-intensive aquaculture (modified from Samson and Rollon, 2008)

For ponds with existing FLA, the most rational objective of management will be semi-intensive aquaculture production to optimize the use of leased areas (Janssen and Padilla, 1999). In 2007, there were around 59, 923 hectares of potential brackish-water ponds listed in the website of the Bureau of Fisheries and Aquatic Resources. However, a closer look at the list revealed that only 44% of these have active FLAs, the rest of the lease are expired. This option may be of importance to the provinces of Quezon, Zamboanga del Sur, Iloilo, Occidental Mindoro, Negros Occidental, Samar, Masbate, Bohol, Zamboanga City and Capiz where brackish-water pond areas with FLAs are relatively extensive. Applying this intervention may yield a net income of US$680 million (at US$1 = Php 42.61) conservatively in 10 years.

4.2 For ponds with active FLAs and the fish yield is not anymore financially sustainable, production needs to be optimized and pond size may be reduced to as small as possible whereby a 4:1 mangrove-pond area ratio may be followed to restore and maintain the ecological health of the system (Primavera, 2000; Samson and Rollon, 2008; Primavera and Esteban, 2008)

This option particularly addresses brackish-water ponds with FLAs but are not operating sustainably. Technical assistance from concerned agencies (i.e. BFAR) must be sought to optimize the production of these ponds. However, it may also be that the reason for the under productivity of these ponds is that the area may not anymore be suitable for production hence the strategy on reducing the pond size and following the 4:1 mangrove-pond area ratio is being put forward (Primavera, 2006). This option on the reversion of some ponds with existing FLA to mangroves will require joint efforts from concerned agencies (i.e. Department of Environment and Natural Resources (DENR), BFAR, Department of Interior and Local Government (DILG)) and the institutionalization of strategies on how the pond operators will be convinced to reforest their underutilized ponds. Strategies may be in the form of incentives like granting of awards for operators with the most environment friendly operations. Another strategy may be is to highlight the importance of these reverted areas in bringing back mangrove goods and services which may become a sustainable source of income in the form of mangrove associated fisheries. The role of these former mangrove areas in mitigating the impacts of climate change such as sea level rise and increased storminess may also convince pond owners to reforest their idle and unproductive ponds. A more political-institutional approach will be to strengthen the monitoring of pond operations such that the 5 years limit for unproductive ponds will be imposed and those ponds will be reverted back to DENR. For the government, specifically BFAR, this is an opportunity to improve its system of monitoring and evaluation of existing FLAs in order to sustainably maximize the potential yield of these leased areas. Conservatively if strategically implemented, this option may yield a net income of US$657 million in 10 years.

4.3 For ponds with expired FLAs and the pond existence is necessary based on bioeconomic analysis, reapply FLA and optimize fish yield (Samson and Rollon, 2008)

For brackish-water ponds with expired FLAs, the management strategy will require a balance between the importance of the pond area for fish production and the importance of these areas in restoring its natural ecological health and function (Janssen and Padilla, 1999; Barbier, 2000). The importance of the pond for fish production should not only be assessed in terms of what the operators can gain from it but also if its needed in a broader context of fish production in an area. For example, if an area is a major source of fisheries products and the non-operation of some ponds will cause a disruption on the supply, then production must be sustainably optimized to meet the target volume. This kind of assessment must be included in the procedures being followed by BFAR before renewing the lease agreement of expired FLAs. A more rigorous evaluation of the production efficiency of the pond must be developed to ensure the optimal use of the leased area. Pond operators must be required to submit a regular report of their production, as well as their income during the period when the lease agreement is in effect. This report must first be reviewed by BFAR before granting renewal.

4.4 For ponds with expired FLAs and production is suboptimal and not necessary, revert to mangrove areas thru natural revegetation or assisted planting (Samson and Rollon, 2008)

As mentioned earlier, under productivity of the pond may be brought about by the inappropriateness of the site for fish production (Stevenson et al, 1999). Problems such as the lack of supply of water and sedimentation may cause fish production to go down to unsustainable level. If this is the case, the site can be properly assessed for reversion to its original habitat. Natural revegetation will require much less labor and financial output as compared to assisted planting, however, there are cases when the site's modification will not anymore allow the recruitment and settlement of mangrove propagules in the area. As of 2007, there are around 39t hectares of brackish-water ponds with expired FLAs. Revegetating these ponds will greatly increase the percentage of rehabilitation efforts in the Philippines. Provinces with 85 to 100% of expired FLAs are Antique, Maguindanao, Lanao del Norte, Palawan, Basilan, Sulu, Davao Oriental, Sultan Kudarat, Northern Samar and Camarines Sur.

4.5 For active titled ponds, apply aqua-silviculture

Primavera in 2000 estimated that there are around 230t hectares of mangroves which had been converted to brackish-water ponds, using this number and subtracting the areas listed with FLA (59, 293), it will give us an estimate of around 74% (170,707 hectares) brackish-water ponds which are titled or undocumented. For these titled ponds, the management strategies will not be straightforward as the utilization of titled ponds rely greatly on its owners. The most rational option for these active title ponds is to sustainably operate the ponds to maximize the production potential of the area. Incentive mechanisms may be institutionalized to encourage titled pond owners to apply the two options most especially if these ponds are idle. These may be in the form of tax incentives and awards for sustainable operation, technical assistance to optimize production, and provision of seedlings for revegetation and others. One of the strategies that may benefit both the pond operators and government will be aqua-silviculture (Melana et al 2000a & b). Aquasilviculture promotes the mix of sustainable pond operation and the revegetation of some parts of the brackish-water ponds (Melana et al 2000a & b). Although this culture practice has been and are being practiced in some parts of the country (i.e. Aklan; Quezon), its ecological and economic benefits are not yet fully realized.

4.6 For idle titled ponds, fish yield may be optimized but pond size as in option 2 may be reduced to as small as possible and revert unutilized areas to mangrove forest

The option of revegetating idle ponds will greatly benefit pond operators and coastal communities as this may bring back mangrove goods and services and may potentially be a supplemental source of livelihood. One of the important mangrove services that the pond operators may consider is coastal protection. In the light of the looming impacts of climate change, mangroves will play a pivotal role in mitigating tsunami, strong waves and coastal erosion (Alongi, 2002, 2008; Dahdouh-Geubas et al, 2005; Gilman, 2006, 2008; Mc Leod & Salm, 2006; UNEP-WCMC, 2006).

Proper accounting and management of all brackish-water ponds in the country should be a top priority. A comprehensive and proper accounting of these titled ponds may help the

Philippine government formulate policies that will encourage environmentally sustainable fish production and resolve the fisheries and forestry utilization conflict in our mangrove areas.

Using available literature on the direct and indirect uses of mangroves (White & Cruz-Trinidad, 1998; Samonte-Tan & Armedilla, 2004; Walton, 2006), the TEV of the different options were estimated. Of the six management options that were proposed, the option that involves the reforestation of idle and unproductive ponds and the practice of aquasilviculture may bring about the highest total economic value at US$ 4.28 billion (at US$1 = Php 42.61) in 10 years. These two options provide opportunities to sustainably maximize the aquaculture potential and the variety of mangroves goods and services that this ecosystem could offer. In the aquasilviculture option, the economic goods will not only come from fish production from the pond itself but also to the recruitment and settlement of mangrove associated fish and organisms. The ecotourism potential of the system and its coastal protection value may also be restored thereby increasing the total economic value of the system.

5. Topographic/ hydrological conditions of these 'excess' areas in selected areas of the Philippines

What may pose a problem in the natural revegetation of the target pond site is its mean sea level elevation relative to the mean sea level elevation of the adjacent mangrove area (**Figure 8**). A study site in Lian, Batangas revealed that the pond site is 1 meter lower than that of the adjacent mangrove area. However this may not pose a serious problem for natural revegetation. Perhaps a natural in-filling by erosion should be allowed for some time, and elevation monitored. The first necessary step in the revegetation of the pond will be the opening of the tidal gates to allow for natural in-filling of sediment. This would also allow the recruitment and settlement of propagules however during the first months of revegetation, seedlings may not grow as they may either drown or get buried by inflowing

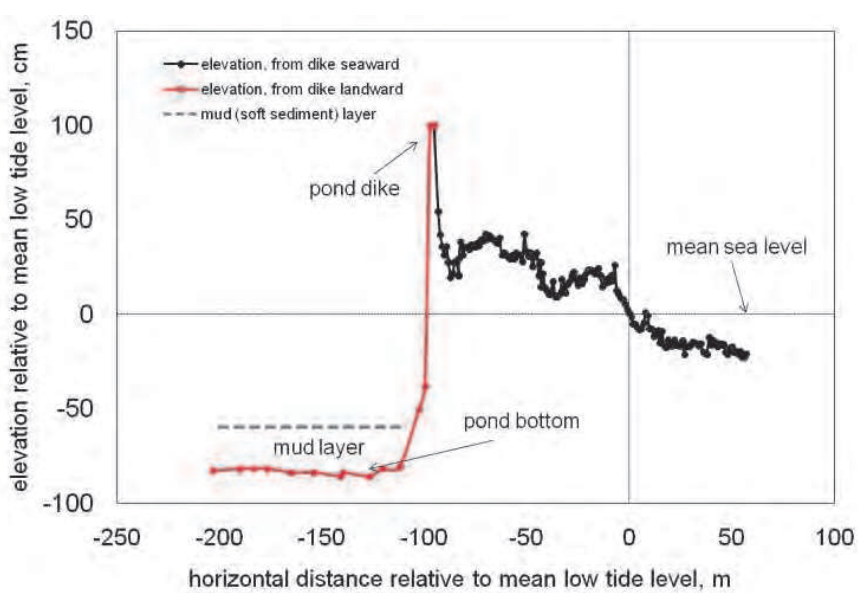

Fig. 8. Elevation map of the mangrove and pond site relative to mean low tide level at the study site in Lian, Batangas, Philippines.

of sediments (Krauss, 2008). As had been observed in other areas where tidal gates were destroyed, the pond elevation after some time levels with the adjacent mangrove forest, on the average this may take 1 to 2 years. This could then be followed by an observation period of where the seedlings will settle to determine if proper spacing of the seedlings to favor growth will be achieved. Natural recruitment of propagules in the pond site may not be a problem due to the abundance of seedlings near tidal gates as was observed in the study site in Lian, Batangas, (**Figure 9**). Assisted planting may be considered by replanting the propagules in the areas of the pond where elevation is relatively higher. Lewis (2005, 2009) in collaboration with various authors (1997, 2000) discussed in details the necessary steps for successful management and rehabilitation of abandoned or disused brackish-water ponds.

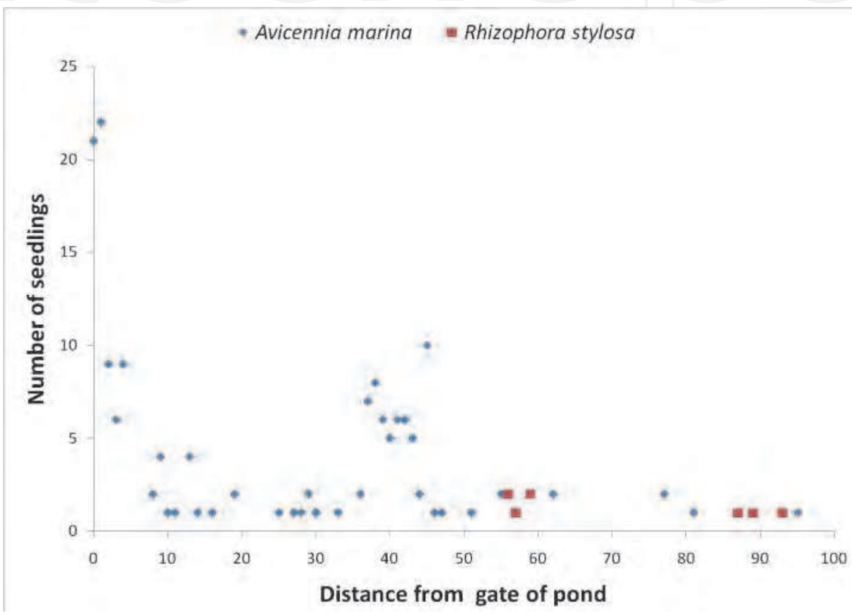

Fig. 9. Abundance of seedlings of *Avicennia marina* and *Rhizophora stylosa* from the seafront area of a mangrove forest to the gate of a brackish-water pond in Lian, Batangas, Philippines.

6. Conclusions

The inverse link between the remaining mangrove areas and existing brackish-water ponds in the Philippines had been well recognized for three decades now. The degraded state of mangrove areas is caused by its continued overexploitation for wood products, unregulated conversion for coastal development, inappropriate planting programs, and more importantly the absence or lack of more efficient and adaptive rehabilitation and conservation strategies. The proliferation of idle and underutilized brackish-water ponds is also an effect of the absence of efficient monitoring and evaluation system for the condition and status of these ponds. Laws and administrative orders for the rehabilitation and protection of mangroves areas as well as the responsible utilization of brackish-water ponds in the Philippines are in place, however, the implementing rules and regulations for these policies seemed to be lacking in coverage and effectivity. At present there are approximately 232,100 ha of brackish-water ponds, however only 59,923 ha have lease agreements from the Bureau of Fisheries and Aquatic Resources. At present, sixty-six percent of these FLAs are already expired. The remaining mangrove areas which were reportedly converted to brackish-water ponds are either titled or unaccounted. The appalling state of mangroves and brackish-water ponds in the Philippines results to continued loss of goods and services that these two systems could provide.

The strategies being proposed here aims to rationalize the environmental management of mangroves and brackish-water ponds in the Philippines. These strategies may be divided into three: 1) for brackish-water ponds with valid legal instruments and fish yield is still optimal, a more sustainable way of production must be adopted; 2) for ponds without legal instruments but fish yield is still bio-economically important, production must be sustainably optimized and legalized, and pond size may be reduced to as small as possible to maintain mangrove ecological health; and 3) for ponds with or without legal instrument and production is not anymore necessary, revegetation of the pond is being put forward. Of these options, the reforestation of idle and unproductive ponds and the practice of aquasilviculture may bring about the highest total economic values for these brackish-water ponds. The implementation of these options may not be straightforward and may need a conscious and concerted effort of different government agencies, academe and private institutions for an ecosystem based management approaches. These approaches should include mapping, inventory, status assessment and reprogramming and financing of existing management program.

With its current status, the vulnerability of mangroves to unsustainable anthropogenic activities (i.e. conversion to aquaculture areas, wood cutting, clearing for coastal developments) and the impacts of climate change may continue to degrade this ecosystem. Addressing these impacts may need the urgent rehabilitation of idle and unproductive ponds as these may decrease the level of vulnerability of these mangrove areas and the coastal communities behind them to the ancillary impacts of climate change. In all these, the government should take a proactive role in consolidating and monitoring these efforts to increase its efficiency and effectivity at the national scale as the present issues and problems on mangroves and brackish-water ponds in the Philippines cannot be appropriately addressed at the local scale.

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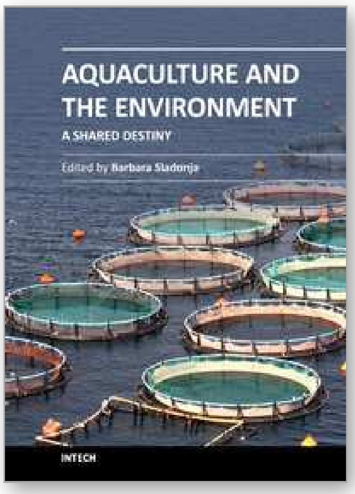

Aquaculture and the Environment - A Shared Destiny
Edited by Dr. Barbara Sladonja

ISBN 978-953-307-749-9
Hard cover, 246 pages
Publisher InTech
Published online 22, December, 2011
Published in print edition December, 2011

Aquaculture is the art, science and business of cultivating aquatic animals and plants in fresh or marine waters. It is the extension of fishing, resulted from the fact that harvests of wild sources of fish and other aquatic species cannot keep up with the increased demand of a growing human population. Expansion of aquaculture can result with less care for the environment. The first pre-requisite to sustainable aquaculture is clean wate, but bad management of aquatic species production can alter or even destroy existing wild habitat, increase local pollution levels or negatively impact local species. Aquatic managers are aware of this and together with scientists are looking for modern and more effective solutions to many issues regarding fish farming. This book presents recent research results on the interaction between aquaculture and environment, and includes several case studies all over the world with the aim of improving and performing sustainable aquaculture.