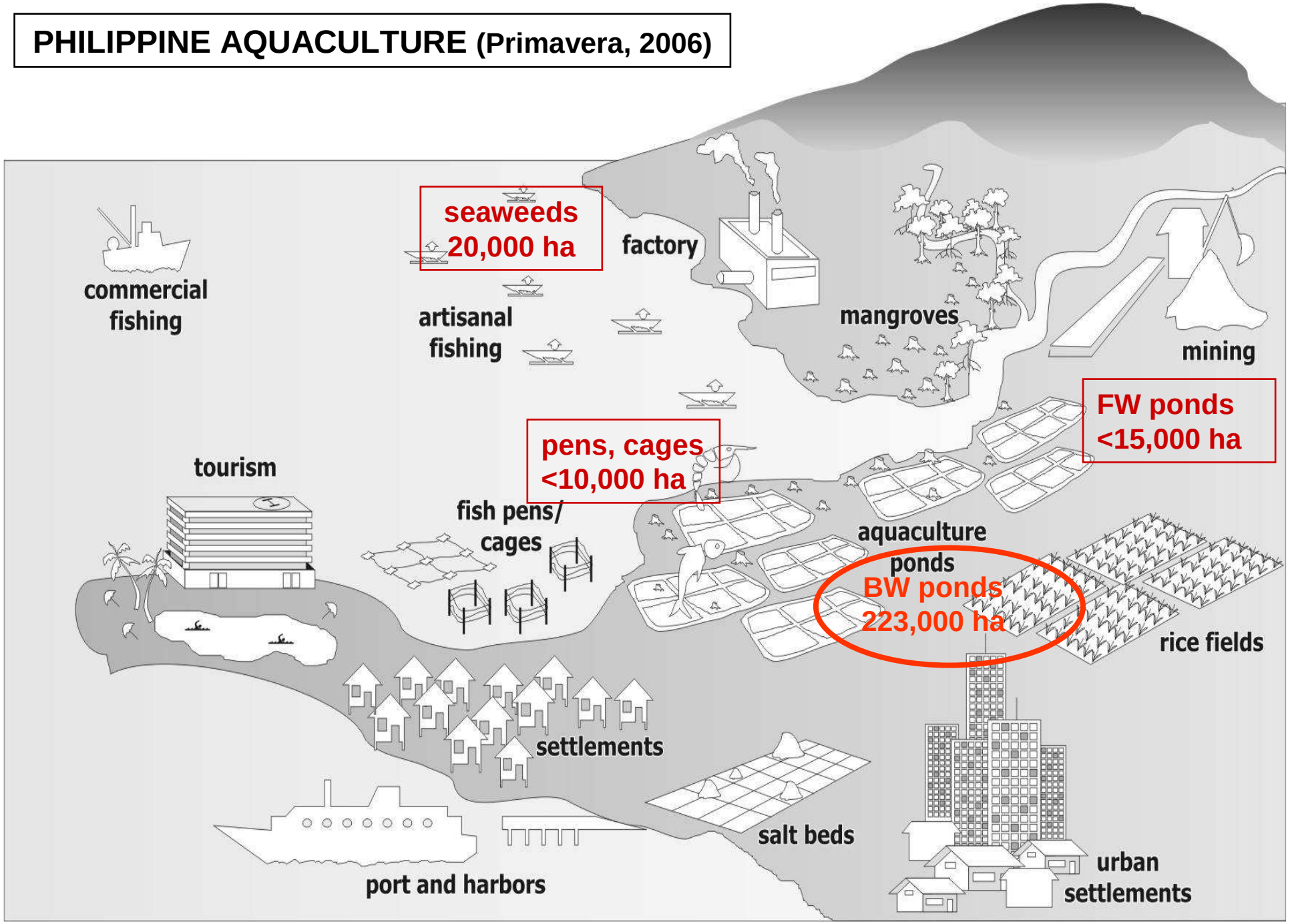
AQUACULTURE IN MANGROVES - WHY SHOULD WE/ HOW CAN WE??

J.H. Primavera
SEAFDEC Aquaculture Department
Tigbauan, Iloilo, Philippines

- **Aquaculture**
- **Mangroves**
- **Are they compatible?**
  - **Mangrove-Friendly Aquaculture in Asia**
  - **Mangroves as aquaculture filters**
  - **Mud crab culture in mangrove pens**
- **Mangrove rehabilitation (greenbelts, abandoned ponds)**

PHILIPPINE AQUACULTURE (Primavera, 2006)



SE ASIAN MANGROVES & SHRIMP CULTURE

SE Asia	Shrimp ponds (ha)[a]	Mangroves (ha)[b]	% Mangrove loss (30 yr)[c,d]
Brunei Darussalam	--	17,100	--
Cambodia	--	60,100	--
Indonesia	350,000	4,542,100	32 – 45
Malaysia	4,000	642,400	25 – 32
Myanmar	--	378,600	--
Philippines	60,000	160,700	40 – 80
Thailand	200,000	264,100	50 – 70
Vietnam	200,000	252,400	--
Total	814,000	6,317,500	
% world total	65	35	

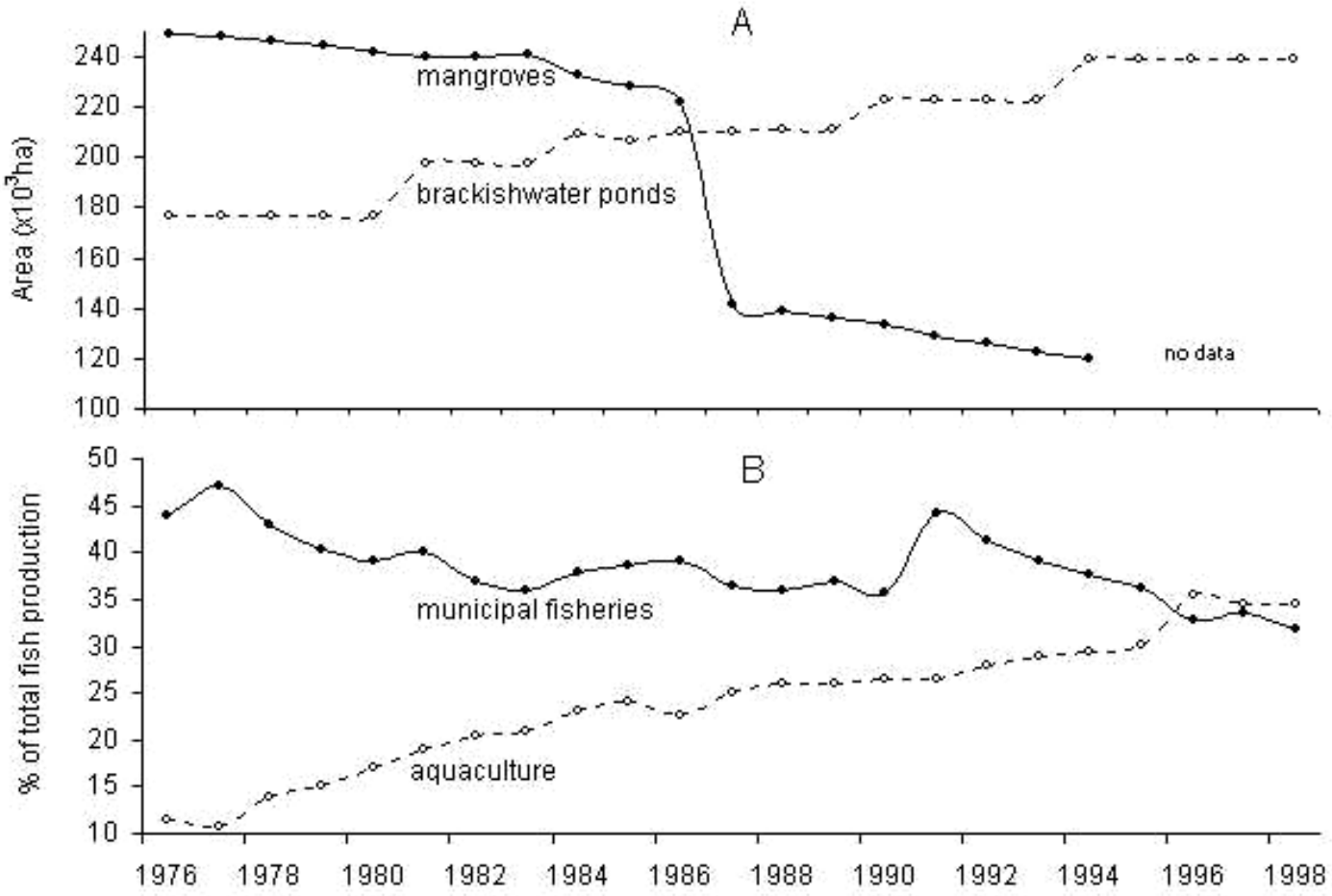
MANGROVES & SHRIMP CULTURE IN SOUTHEAST ASIA

World Total:
16-18 M ha mangroves
1.25 M ha fish/shrimp ponds

GLOBAL (Valiela et al., 2001)

54% - total present area represented in study
2.1% - yearly loss of existing area
35% - average loss since 1980s
52% - loss due to shrimp and fish culture

PHILIPPINES: Mangroves/Municipal Fisheries vs Ponds/Aquaculture Production (Primavera, 1997)



ASIAN AQUACULTURE SPECIES/SYSTEMS
(Primavera, 2006)

Group		System	Method
Plants:	*Eucheuma*, *Gracilaria* *Laminaria*	longlines, rafts, fixed bottom	extensive
Molluscs:	oyster, mussel, scallops	rafts, longlines, stakes	extensive
Crustaceans:	prawns/shrimps, crabs	ponds	extensive, semi-intensive, intensive
Marine/brackishwater fish:	milkfish, tilapia, grouper, snapper	pens, cages, ponds	extensive, semi-intensive, intensive
Freshwater fish:	tilapia carps, catfish	ponds, cages, pens	polyculture, intensive

INTEGRATED MANGROVE-AQUACULTURE SYSTEMS
(Primavera, 2000)

	Mangroves	Aquaculture	Problems
Hong Kong **gei wai**	natural *Avicennia*, etc.	tidal larvae, natural food	industrial pollution, declining shrimp
Indonesian **tambak**	natural/planted *Avicennia/Rhizophora*	tidal/stocked larvae, natural food	intensification of ponds
Indonesian **silvo-fisheries**	planted *Rhizophora*	wild/stocked larvae, nat./suppl. food	difficult management, conflict mangrove species
Vietnam **shrimp-mangrove**	planted *Rhizophora*	tidal shrimp, natural food	declining shrimp, illegal mangrove conversion
Philippines **aquasilvi-culture**	natural, planted *Rhizophora* etc.	tidal/stocked shrimp/crab, nat./supplied food	mangrove mortality, raw fish (feed) substitutes
Malaysia **mangrove pens**	logged over/planted *Rhizophora*	stocked mud crab, raw fish feed	seed supply, feeds

INTEGRATED MANGROVE-AQUACULTURE SYSTEMS

(Primavera, 2000)

	Technology, year started	Size, mangrove: water ratio	Objectives	Area covered status
Hong Kong	trad. **gei wai**, mid-1940s	~10 ha ponds, 30:70	shrimp/fish prod., mangrove/ wildlife conserv.	~250 ha, Ramsar site
Indonesia	trad. **tambak**, ca 1400s	1-4 ha ponds, mangrove on dikes, patches	food, fuel, fodder, fertilizer, soil stabilization	wide
Indonesia	state: **silvo-fisheries**, 1976	0.1-1 ha ponds, 60-85:40-45	solve forestry-fisheries conflict; mangrove conserv./rehab.	wide, eg. 6,600 ha in Cikiong, W. Java

INTEGRATED MANGROVE-AQUACULTURE SYSTEMS

(Primavera, 2000)

	Technology, year started	Size, mangrove: water ratio	Objectives	Area covered status
Vietnam	state: **mixed shrimp-mangrove systems**, mid-1980s	750-3,200 m^2 ponds, 70:20:10 (housing)	relieve land conflict; mangrove rehab.	widespread
Philippines	govt: **aqua-silviculture**, 1987	<1 ha pens, <2 ha ponds, 80:20	mangrove conserv., fish production	experimental, verification
Malaysia	govt: **mud crab pens**, 1992	18 x 9 m pens	increase income	130 pens in Sarawak

Integrated Mangrove – Aquaculture Systems in Asia

J.H. Primavera, *Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Philippines*

SUMMARY

1) Technology: traditional – *gei wai, tambak*
state-driven – silvofisheries, shrimp-mangrove (land conflict), aquasilviculture, crab pens (fish production, income, conservation)

2) Systems: pond – mixed or separate
pen (mudcrab: most lucrative)

3) Aquaculture: species – fish, shrimp, crab
seed – tidal vs stocked
feed – natural vs supplementary
production - <500 kg/ha/yr (extensive)

4) Mangroves: natural vs planted
Rhizophora vs *Avicennia*/others

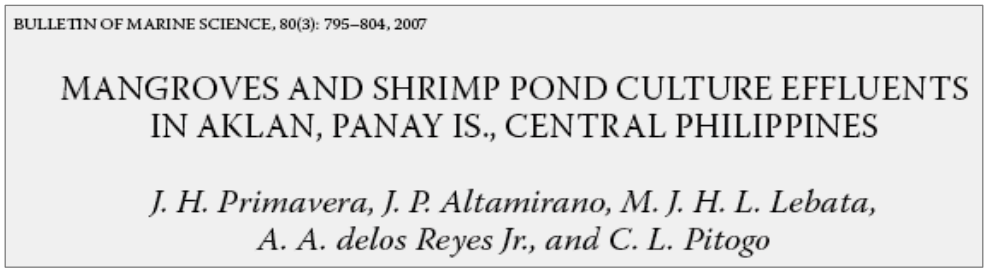
5) Flora/fauna diversity: lower in MFA ponds

6) Problems/R&D: mangrove/aquaculture species, pond design, mangrove:pond ratio, raw fish substitutes

MANGROVE-FRIENDLY AQUACULTURE

MODEL A: **low-density** culture of crabs integrated with mangroves

MODEL B: mangroves as filters to process effluents from **intensive** aquaculture ponds



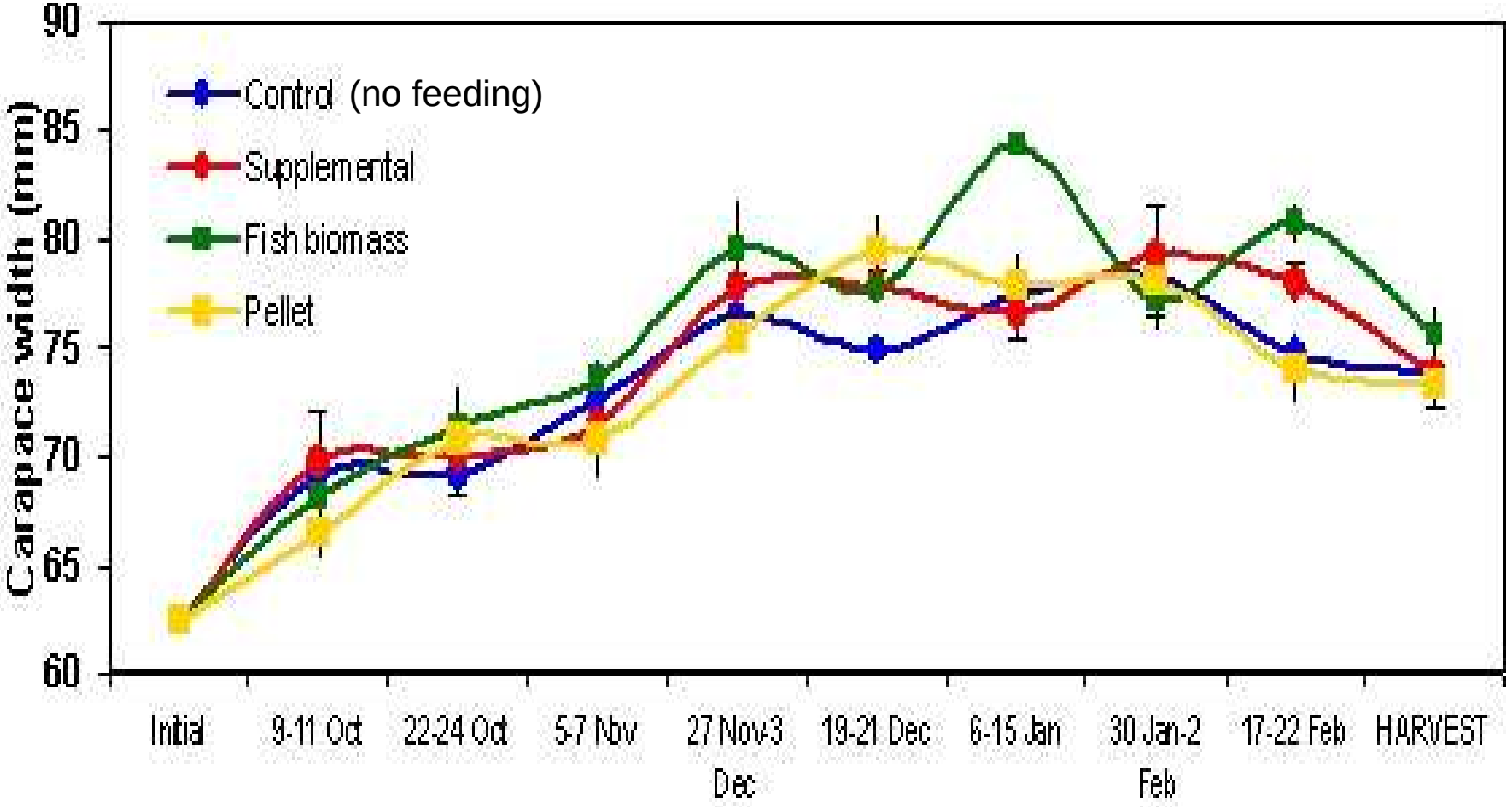
Mudcrab Culture in Mangrove Pens (Primavera et al 2009)

Growth and survival of wild *Scylla olivacea* in mangrove pens, Iloilo (Sept. 2002-March 2003).

Feeding Treaments	No Feed (Nat. Prod.)	Nat. Prod. + Suppl. Diet	Fish Biomass	Formulated Pellets
Mean CW (cm)	7.9 ± 0.1^{a}	8.1 ± 0.1^{ab}	8.2 ± 0.1^{b}	8.0 ± 0.1^{ab}
Mean CL (cm)	5.5 ± 0.1^{a}	5.7 ± 0.1^{ab}	5.7 ± 0.1^{b}	5.6 ± 0.1^{ab}
Mean BW (g)	114.5 ± 5.2^{a}	119.6 ± 5.2^{a}	129.3 ± 4.6^{a}	121.2 ± 4.6^{a}
Tot. prod (kg)	8.6	11.4	14.0	9.6
Survival rate (%)	15.2	19.2	21.8	15.9
No. berried	7	13	14	3

Scylla olivacea

- **wild juveniles – natural productivity of mangroves (no feeding) for 1-2 mo**
- **3 mo growth peak indicates time for selective harvest**



Cost-returns analysis for 1000 m² mud crab *Scylla serrata* pens using two feeding treatments, Batan (Primavera et al, 2009).

Production data	Pellets + Fish Biomass	Fish Biomass
Survival rate (based on literature, best replicate)	**37.2%**	**40.4%**
Corresponding body weight (based on lit., best replicate)	**252 g**	**211 g**
Production: 1/ 2 crops	82 kg/ 164 kg	74 kg/148 kg

Item	Total Value (PhP)[a]	Total Value (PhP)[a]
Revenue	24,467.18	22,205.45
Operating costs:		
Crab juveniles	13,050.00 (778 pcs)	13,050.00 (778 pcs)
Fish (kg)	2,825.33 (362.9 kg)	4,701.90 (603.5 kg)
Pellets (kg)	3,085.56 (118.9 kg)	0.00
Marketing expenses (2%)	489.34	444.11
Labor (20 man-days, 75 PhP/ man-day)	1,500.00	1,500.00
Sub-total	20,950.23	19,696.01
Depreciation	1,975.00	1,975.00
Caretaker's salary	1,5,00.00	1,500.00
Sub-total	3,475.00	3,475.00
Total operating cost run^{-1}	24,425.23	23,171.01
Net cash return crop^{-1}	3,516.95	2,509.44
Net cash return yr^{-1} (2 crops)	7,033.89	5,018.88
Net returns crop^{-1}	41.95	Negative
Net return yr^{-1} (2 crops)	83.90	Negative
Return on investment	**38.5 %**	**27.5%**
Payback period (years)	**2.6**	**3.6**

Impacts of crab pen culture on mangrove community structure in Zarraga, Aklan, central Philippines (Primavera et al, 2009).

			Pens		Control
		May 2002	Jan 2004	% change	Jan 2004
Stems/ha	Seedlings	4,984	9,850	97.6	90,833
	Saplings	3,216	5,003	39.9	12,533
	Trees	1,167	1,600	37.1	1,267
	Total	9,368	15,950	70.3	104,633
Basal area (m2 per ha)	Seedlings	0.10	0.2	90.0	1.8
	Saplings	1.01	1.4	39.6	3.9
	Trees	5.96	6.4	8.2	7.8
	Total	**7.07**	8.0	13.9	13.5
Shannon Index of Sp. Diversity		**0.52**	0.45		0.59

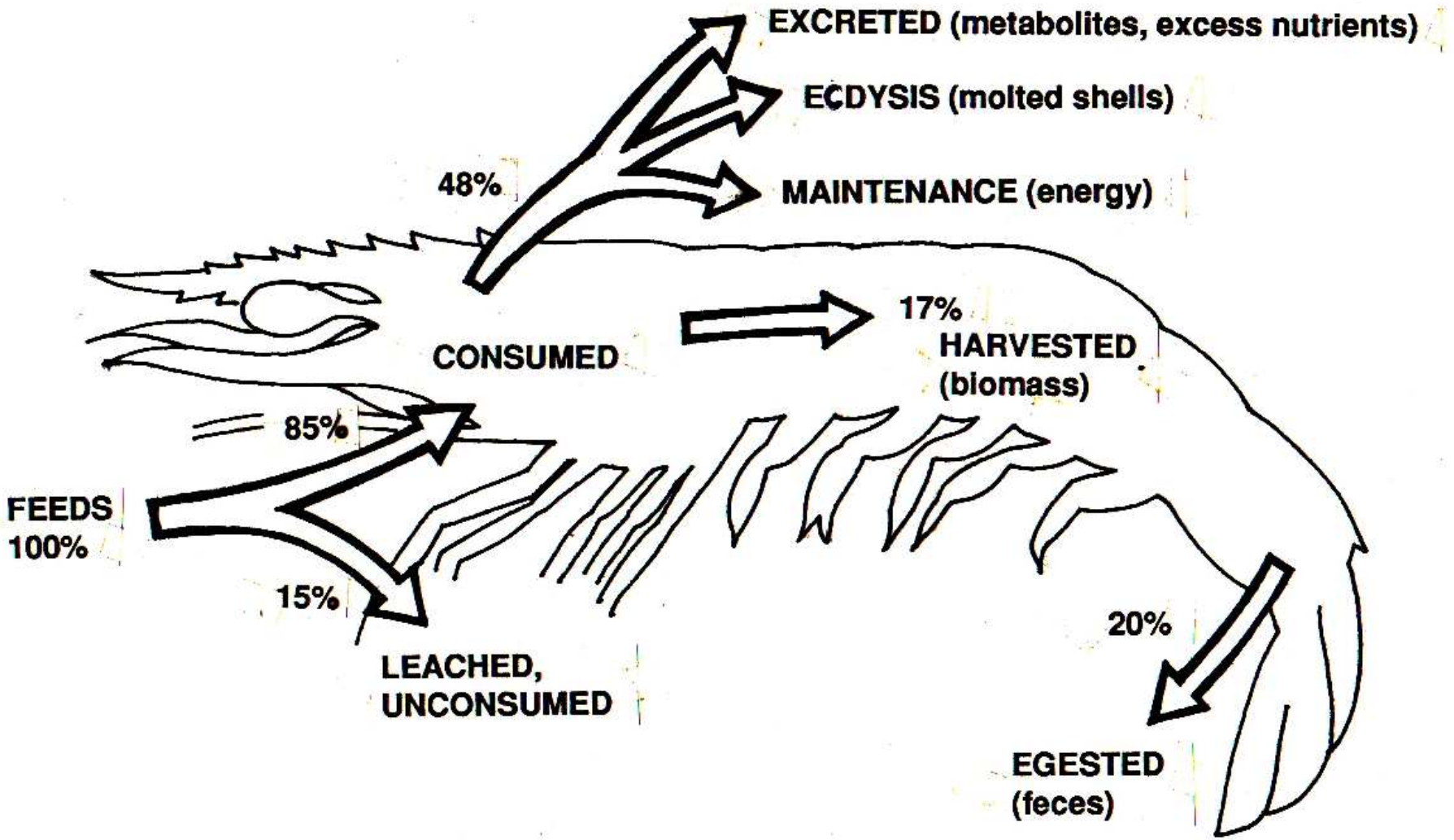
Conclusions (Primavera et al, 2009)

- Presence of crabs results in fewer mangrove seedlings and saplings, but **did not affect trees**
- Incomplete, low-cost pellets **can replace fish requirement** in mud crab diets
- Economic analysis showed **viability of crab culture in mangrove pens** using fish biomass + pellets to reduce requirement for (low-value) fish, a food item of poor coastal communities

PROTOCOLS FOR MUDCRAB PEN CULTURE (Primavera et al, 2009)

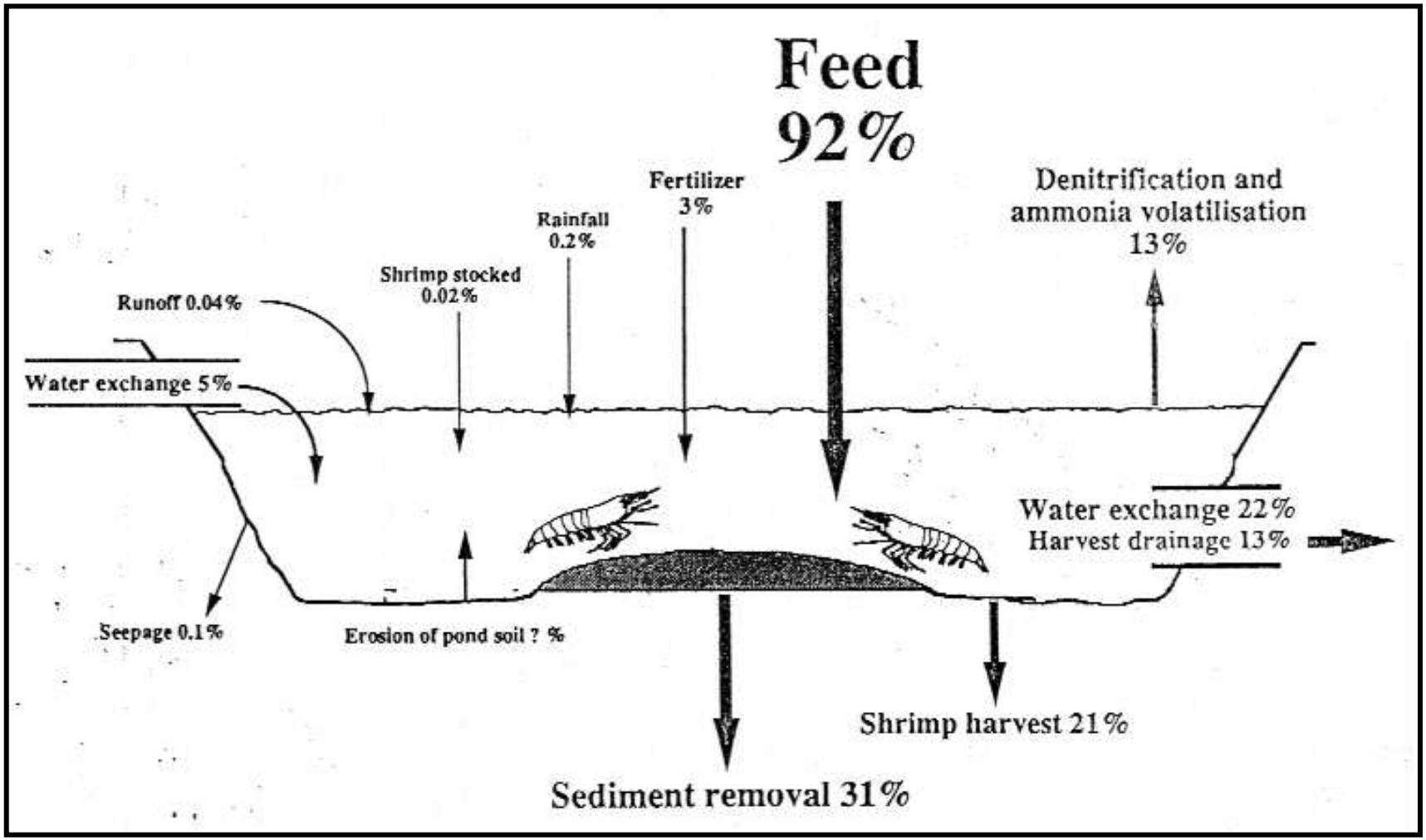
- sites with mature trees (not newly-colonized/planted areas)
- netpens of 2.3 cm mesh (smaller mesh = fouling + longer grow-out) = min. 3 cm CW crab size
- hatchery crabs need 1-2 nursery phases to reach 3 cm CW and behavioral conditioning (foraging, predator avoidance)
- wild juveniles = 1 mo natural food (no sup. feeds) vs cultured juveniles = immediate feeding
- wean nursery juveniles to pellets before transfer to mangrove pens
- stable pellets for handling by chelae; size suitable to size of mouthparts
- prevent rats by applying rat powder+boiled rice, installing bamboo matting bet. compartments, & feeding during high tide (depriving access to food)
- build canals in center of pen, away from partitions to avoid crab escapes

Alicia, Sibugay, Mindanao (J.H. Primavera)



**FATE OF SHRIMP FEEDS (BY DRY WT.)
GIVEN IN INTENSIVE SHRIMP PONDS**
(Primavera, 1991)

N budget: intensive shrimp pond (Briggs & Funge-Smith, 1994)



Creek

Mangrove Pond

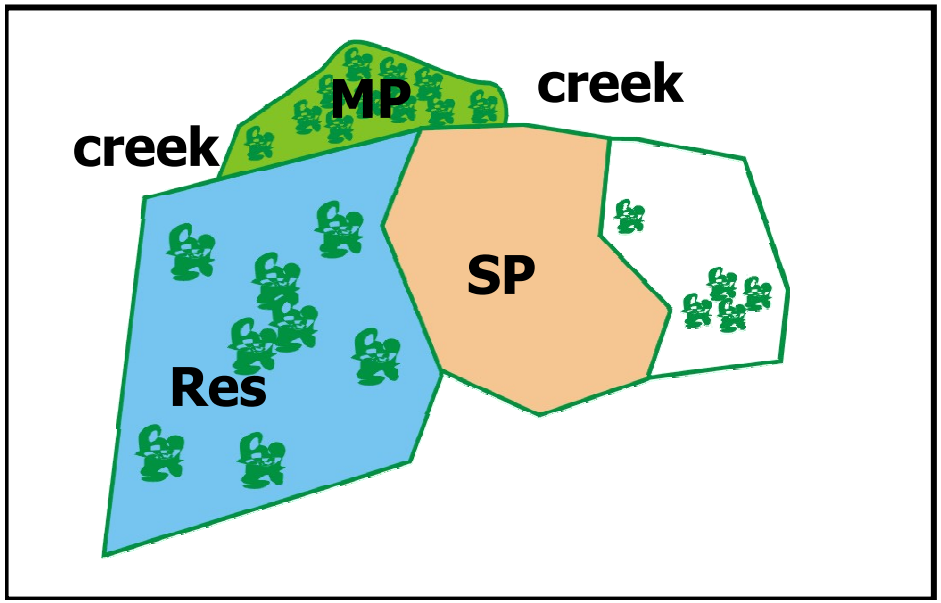
12-24 h

Reservoir

12 h

Shrimp Pond

1-5 days



WATER MANAGEMENT

(Primavera et al 2007)

Solids/nutrients (mg/L) in Impounded Mangrove at given intervals from draining of effluent from Shrimp Pond (Primavera et al 2007)

	0 h	6 h	12 h	24 h	6-h removal	12-h removal
Tot. suspended solids	102.83 ±52.22	36.83 ±5.19	34.50 ±4.66	47.00 ±6.73	66.00	68.33
Sulfide	0.05 ±0.01	0.03 ±0.01	0.03 ±0.01	0.04 ±0.01	0.02	0.02
PO_4	0.03 ±0.01	0.08 ±0.03	0.18 ±0.13	0.11 ±0.05	net add.	net add.
NH_3-N	0.64 ±0.18	0.48 ±0.06	0.49 ±0.07	0.63 ±0.08	**0.16**	0.15
NO_3-N	2.58 ±0.21	2.10* ±0.29	2.20 ±0.34	2.42 ±0.35	**0.48**	0.38

Nitrate removal from Shrimp Pond effluents by Mangrove

(Primavera et al 2007)

Rate×water vol (1 d = 6 h) **0.483 NO3-N mg/L/d** = 29,920 mg NO3-N/d
Impounded Mangrove (area) ÷ 320 m2
= **93.501 mg tot. N/m2 mng/d**

35% pond N loss thru water ex (Briggs & F.S./94)

$$\frac{93.501 \text{ mg N/m}^2 \text{ mng/d}}{0.35 \text{ N loss}} = \textbf{267.14 mg (0.267 g) tot. pond N/m}^2 \textbf{ mng/d}$$

60 g (6%) N kg^{-1} feed (I. Borlongan, pers. comm)

$$\frac{0.267 \text{ g tot. N/m}^2 \text{ mng/d}}{60 \text{ g N/kg feed}} = 0.00445 \text{ kg feed/m}^2 \text{ mng/d}$$

44 kg feed/ha mng/d

4% shrimp biomass feed rate

$$\frac{44 \text{ kg feed/ha mng/d}}{0.04 \text{ kg feed/kg shrimp/d}} = \textbf{1,100 kg shrimp/ha mng}$$

ABW (harvest) = 1,100 kg @ 20 g = 55,500 pcs/ha
@ 30 g = 36,700 pcs/ha

S.D. (m^2)	ha mng: per ha pond
10	1.82-2.72
20	3.64-5.45
30	5.45-8.18

Mangrove: Shrimp Pond area ratios for nutrient removal in pond effluents (Primavera et al 2007)

Reference	System	Mangrove: Pond Ratio	
		N	P
Boonsong & Eiumnoh,1995	Intensive	8.96	7.82
Robertson & Phillips, 1995	Intensive	7.21	21.7
	Semi-int.	2.4	2.8
Kautsky et al., 1997	Semi-int.	6.4	6.4
This study (nitrate only)	Intensive	3.6-5.4	
	Semi-int.	1.8-2.7	

4:1 MANGROVE: POND (Saenger et al. 1983)

Changes in plant numbers and biomass (m^2/ha) in Exptl. Mangroves (effluents) and controls in Ibajay, Aklan, Philippines (Primavera et al 2007)

		May 2001	April 2002		Nov. 2002	
			Exptal	Control	Exptal	Control
Stems/ha	Seedlings	343,333	82,667	45,600	93,467	74,933
	Saplings	5,733	11,600	10,533	19,933	9,067
	Trees	313	469	900	656	967
	Total	349,379	**94,736**	**57,033**	**113,456**	**84,967**
Stand basal area (m^2 per ha)	Seedlings	6.74	1.62	0.90	1.84	1.47
	Saplings	1.80	3.64	3.31	6.16	2.85
	Trees	10.45	13.58	17.50	26.74	23.77
	Total	18.99	**18.84**	**21.71**	**34.74**	**28.09**
Shannon Index of Sp. Diversity		0.6703	0.7108	0.7194	0.6661	0.7020

BULLETIN OF MARINE SCIENCE, 80(3): 795–804, 2007

MANGROVES AND SHRIMP POND CULTURE EFFLUENTS IN AKLAN, PANAY IS., CENTRAL PHILIPPINES

J. H. Primavera, J. P. Altamirano, M. J. H. L. Lebata, A. A. delos Reyes Jr., and C. L. Pitogo

Summary & Conclusions

- passing pond effluents **through mangroves reduced nutrient levels** in day, but not night; (nitrate reduction stat. significant)
- based on nitrate loss, vol. water drained, mangrove area, etc.: **1.8-5.4 ha mangroves to remove nitrate wastes from 1 ha shrimp pond**
- reduced daytime nutrients due to **biol. transformation** (plant uptake, denitrif.), rather than physical dilution (nighttime increases) or tidal flushing
- **N uptake by mangrove flora** shown by longer nipa palm leaflets, faster mangrove seedling growth in mangrove w/ effluents vs control mangrove
- nutrient removal/biofilter function of mangroves - **paradigm shift for aquaculture to clean up effluents before release**
- ecosystem health = **4:1 mangrove-pond ratio** (Saenger et al, 1983)

  Philippines at present **= 0.5:1 ha mangrove-pond** (need to reverse)

  effluent processing **= 2-9:1 for N, 2-22:1 for P**
- implement national laws: **greenbelt (20-, 50- and 100-m)** and **mangrove reversion of abandoned ponds**

Mangrove: Fish/Shrimp Pond Ratios (JH Primavera, unpub.)

Mangrove: Pond Ratio	Function	References
8.9:1 7.8:1	N filter: intensive shrimp culture P filter: intensive shrimp culture	Boonsong & Eiumnoh, 1995
7.2:1 21.7:1	N filter: intensive shrimp culture P filter: intensive shrimp culture	Robertson & Phillips, 1995
2.4:1 2.8:1	N filter: semi-intensive shrimp culture P filter: semi-intensive shrimp culture	Robertson & Phillips, 1995
6.4:1	N filter: semi-intensive shrimp culture	Kautsky et al., 1997
5.4-8.2:1	N filter: intensive shrimp culture	Primavera et al., in press
1.8-2.7:1	N filter: semi-intensive shrimp culture	Primavera et al., in press
4:1	Ecosystem health	Saenger et al., 1983
7.4:1	Philippines: 450,000 ha mangroves (1920) 60,998 ha ponds (1940)	Primavera, 2000
0.5:1	Philippines: 120,000 ha mangroves, 1994 232,000 ha ponds, 1994	Primavera, 2000

PHILIPPINE MANGROVE GREENBELT/OTHER LAWS
(Primavera et al, 2004)

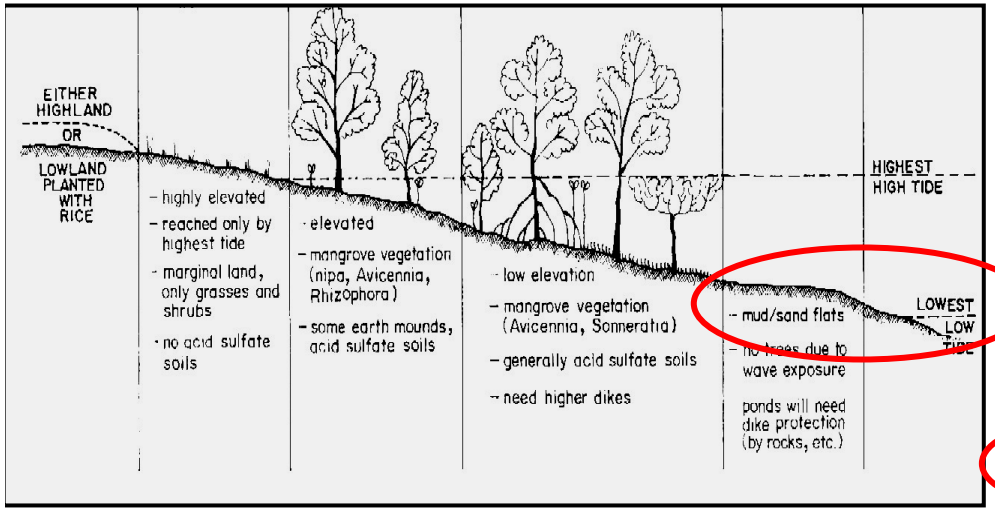
P.D. 705 (1975)	Revised Forestry Code: mangrove strips in islands providing protection from high winds, typhoons shall not be alienated
P.D. 953 (1976)	Fishpond/mangrove lease holders required to **retain or replant 20-m mangrove** strip along rivers, creeks
BFD A.O. 2 (1979)	Min. 25% of total mangrove forest in given area completely protected as Mangrove Wilderness Areas
P.P. 2151 & 2152 (1981)	Declaration of 4,326 ha mangroves as wilderness areas, 74,767 ha as forest reserves
MNR A.O. 42 (1986)	Expansion of **mangrove belt in storm surge, typhoon areas: 100 m along shorelines, 50 m along riverbanks**
DENR A.O. 76 (1987)	Establishment of buffer zone: 50 m fronting seas/oceans and 20 m along riverbanks; **lessees of FLA ponds required to plant 20-50 m-mangrove strip**
DENR A.O. 77 (1988)	Integrated Social Forestry Program (provision of legal tenure incentives for co-management of forest resources)
DENR A.O. 123 (1990)	Award of 25-yr Community Forestry Management Agreement for small scale mangrove use, *Rhizophora* and *Nypa* plantations, aquasilviculture
DENR A.O. 15 (1990)	Policies on communal forests, plantations, tenure through Mangrove Stewardship Contracts; revert abandoned ponds to forest; **ban cutting** of trees in FLA areas; **prohibit conversion** of thickly vegetated areas
DENR A.O. 3 (1991)	Policies and guidelines for Mangrove Stewardship Agreement
DENR A.O. 23 (1993)	Combined 3-yr Mangrove Reforestation Contract and 25-yr Forest Land Management Agreement into 25-yr FLMA for families (1-10 ha) and communities (10-1,000 ha)

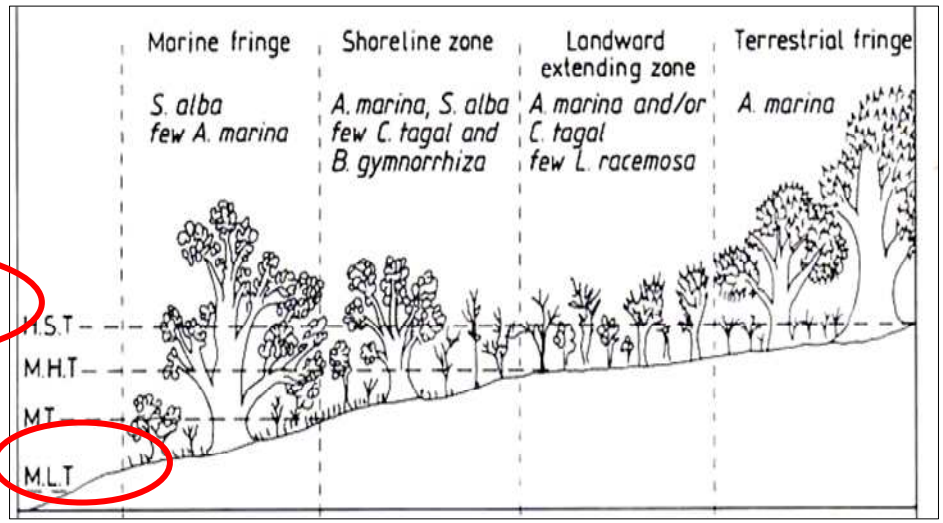
MANGROVE REHABILITATION – SEAFRONT PLANTING VS POND REVERSION

(JH Primavera, unpub.)

SEAFRONT PLANTING
Ecologically difficult
Sociopolitically easy

POND-MANGROVE REVERSION
Ecologically easy
Sociopolitically difficult





High mangrove mortality in plots (50 m from the beach) located in the subtidal or lower intertidal zone, both **non-optimal sites for mangroves** -- see **red circles** above.

Literature Cited

Primavera, J.H. 1991. Intensive prawn farming in the Philippines: Ecological, social and economic implications. Ambio 20: 28-33

Primavera, J.H. 1993. A critical review of shrimp pond culture in the Philippines. Rev. Fish. Sci. 1: 151-201

Primavera, J.H. 1995. Mangroves and brackishwater pond culture in the Philippines. Hydrobiologia 295: 303-309

Primavera, J.H. 1997. Socioeconomic impacts of shrimp culture. Aquacult. Res. 28:815-827.

Primavera, J.H. 2000. Integrated mangrove-aquaculture systems in Asia. Integrated Coastal Zone Management. Autumn edition: pp. 121-130

Primavera, J.H. 2006. Development and sustainability of Philippine aquaculture. International Conference Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives. Royal Academy of Overseas Sciences, Phnom Penh, 6-8 Feb. 2006, pp. 295-313

Primavera, J.H. 2006. Overcoming the impacts of aquaculture on the coastal zone. Ocean cstl. Area Mngt. 49: 531-545 (www.sciencedirect.com)

Primavera, J.H., J.P. Altamirano, M.J.H.L. Lebata, A.A. delos Reyes Jr. and C.L. Pitogo. 2007. Mangroves and shrimp pond culture effluents in Aklan, Panay Is., central Philippines. *Bull. Mar. Sci.* 80: 795-804

Primavera JH and Esteban JMA. 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecol. Mngmnt 16 (3): 173-253 (DOI 10.1007/s11273-008-9101-y)

Primavera, J.H. 2009. Field Guide to Mangroves of the Philippines. SEAFDEC Aquaculture Department (Tigbauan, Iloilo, Philippines), Pew Fellows Program in Marine Conservation and Zoological Society of London (Iloilo City, Philippines), 8 p.

Primavera, J.H., J.B. Binas, G.PB. Samonte-Tan, M.J. Lebata, V.R. Alava, M. Walton and L. LeVay. 2009. Mud crab pen culture – replacement of fish feed requirement and impacts on mangrove community structure. Aquaculture Research (doi: 10.1111/j.1365-2109.2009.02408)