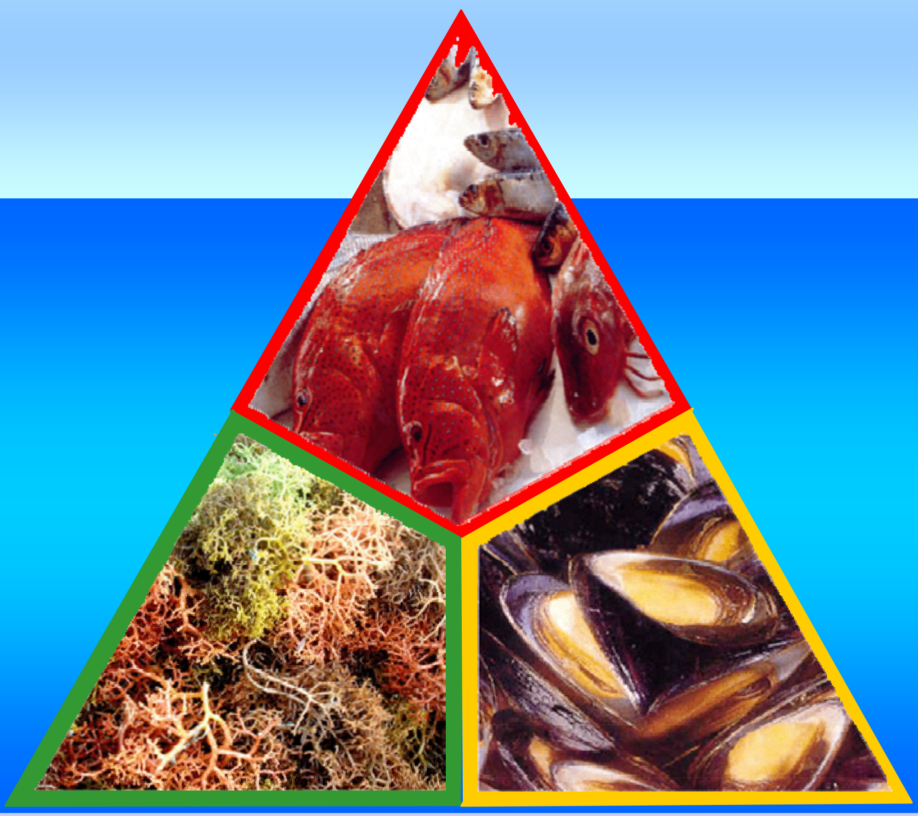
Tropical Red Seaweeds
as a Foundation for
Integrated Multi-trophic Aquaculture (IMTA)

Four propositions and an action plan for this major opportunity in the Coral Triangle



by Iain C. Neish, SEAPlant.net Monograph no. HB2E 1209 V3 IMTA. December, 2009

TABLE OF CONTENTS

A. CORAL TRIANGLE COMPARATIVE ADVANTAGE

B. SUSTAINABLE, INTEGRATED AQUACULTURE

C. INNOVATION THROUGH RELATIONAL VALUE-CHAINS

D. A MULTI-BILLION DOLLAR OPPORTUNITY

E. ACTIONS AND CONSEQUENCES

GLOSSARY

ADB - Asian Development Bank

ARMM – Autonomous Region of Muslim Mindanao.

ATC - Alkali-treated cottonii chips

AusAID - Australian Agency for International Development

BDS - Business Development Services

BIMP-EAGA – Brunei, Indonesia, Malaysia Philippines East ASEAN Growth Area

Coral Triangle – includes most of East Malaysia, Philippines, Indonesia, Timor Leste, Papua New Guinea and Solomon Islands

Cottonii – Kappaphycus spp.

Cultivar – A clone derived from vegetative propagation originating from a single seaplant thallus.

DKP - Dinas Kelautan dan Perikanan (Indonesian Department of Oceans and Fisheries)

EAI - East ASEAN Initiative of AusAID

End-user – an enterprise that utilises as-is or further-processed ingredient building-blocks or ingredient solutions in goods that are purchased by wholesale and retail enterprises.

Eucheuma - "spinosum" of the trade; source of iota carrageenan.

Eucheuma seaplants – Betaphycus, Kappaphycus and Eucheuma

FAO – United Nations Food and Agricultural Organization

Further processor – an enterprise that purchases -building blocks for further refinement.

GMP - Good Manufacturing Practises

Governance system - specifies the mutually agreed terms and conditions that apply to transactions; they specify how any disputes will be settled; and they settle things when disputes happen.

GTZ - Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)

Hierarchical governance - based on explicitly defined systems of authority, rank and layered reporting relationships that are typified by the presence of powerful leaders.

IBB - Ingredient building-blocks – products derived or extracted purely from one defined source of raw material and then sold to further-processors or solution providers.

IFC – AS - International Finance Corporation – Advisory Services

IFC-PENSA - IFC Small Business Development in Eastern Indonesia

IMTA - Integrated Multi-Trophic aquaculture

JaSuDa – Jaringan Sumber Daya (Source Net), a program of SEAPlant.net.

Kappaphycus - "cottonii" of the trade; a seaplant source of kappa carrageenan

KITS - Knowledge + Information + Tools + Solutions

Marinalg – World Association of Seaweed Processors (marinalg.org)

MSME - Micro, small or medium enterprise

RC - Refined Carrageenan

SME - Small to Medium Business Enterprise

Spinosum – Eucheuma spp.

SRC – semi-refined carrageenan (a.k.a. processed eucheuma seaweed, PES or E407a)

Strategic business alliances - result when two or more enterprises combine core values and unique resources in order to seek competitive advantage in specified value networks.

SPNF- Seaplant.net Foundation

SRC - Semi-refined Carrageenan

Tactical business alliances - result when two or more enterprises combine firm resources (including relational capital) in order to optimize process capacity.

Trust governance - based on established patterns of personal integrity, trust and commitment between individuals and among groups.

TNT – The Nature Conservancy

Unique resources - kept totally in-house as "core competencies". They are the basis for enterprise competitive advantage

USD – United States Dollar.

Tropical Red Seaweeds as a Foundation for Integrated Multi-trophic Aquaculture (IMTA):

Four propositions and an action plan for this major opportunity in the Coral Triangle

by Iain C. Neish, SEAPlant.net Monograph no. HB2E 1209 V3 IMTA. December, 2009.

OVERVIEW

Seaplants such as macroalgae, microalgae, sea-grasses and mangroves form the primary productivity base for seashore habitats and integrated multi-trophic aquaculture (IMTA) systems. The foundation for sustainable seashore development is therefore the effective utilization, cultivation and management of seaplant populations.

In the long run the aquaculture productivity of global seashores can be maximized if seaplants are effectively developed as cash crops, feeds, fodder and bio-mitigation agents within IMTA systems that make optimal use of lower trophic-level species.

In the Coral Triangle 400 million people live in archipelagos that have 100,000 kilometres of tropical seashore distributed among more than 25,000 islands. About 80 million of these people live below the poverty line and many aspire to gain a sustainable livelihood from well managed seashore habitats.

IMTA development along Coral Triangle seashores can generate tens of billions of USD in annual income for micro, small and medium enterprises owned and operated by the coastal people of the Coral Triangle. IMTA can be developed on the basis of already existing technology, it addresses existing market demands, it can alleviate poverty for millions of people and it can generate positive environmental impacts.

Stimulating adequate investment in this opportunity will generate substantial benefits that can be realised in the coming decades.

Contact us at: Seaplant.net Foundation, C/O BaKTI, Jalan Dr. Sutomo No. 26, Makassar 90113, Sulawesi Selatan, Indonesia, Fax : (62 411) 365 0323, Email: contact@seaplant.net, URL: http://www.seaplant.net

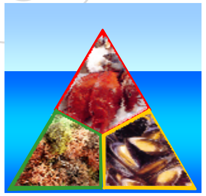
FOUR PROPOSITIONS AND AN ACTION PLAN

A. CORAL TRIANGLE COMPARATIVE ADVANTAGE

A substantial proportion of the world’s poor live along seashores of the Coral Triangle where there can be comparative advantage for micro, small and medium enterprises (MSME) that engage in integrated multi-trophic aquaculture (IMTA);

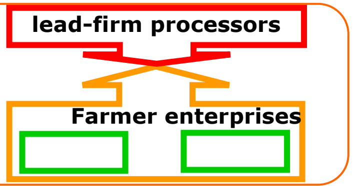
B. SUSTAINABLE, INTEGRATED AQUACULTURE

Seaweeds and other seaplants are aquaculture cash crops that provide the primary productivity base for building sustainable MSME based on IMTA



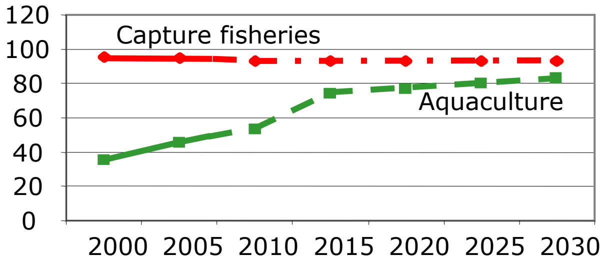
C. INNOVATION THROUGH RELATIONAL VALUE-CHAINS

Relational value-chain governance can foster innovative development of near-shore processing and IMTA and can thus provide sound business opportunities that contribute to poverty alleviation, prosperous seashore communities and sustainable seashore development



D. A MULTI-BILLION DOLLAR OPPORTUNITY

Over the next two decades adequate investment in IMTA development by MSME in the Coral Triangle can result in added global fisheries production worth tens of billions of US dollars per annum that must come from innovative aquaculture rather than from failing capture fisheries.



E. ACTIONS AND CONSEQUENCES

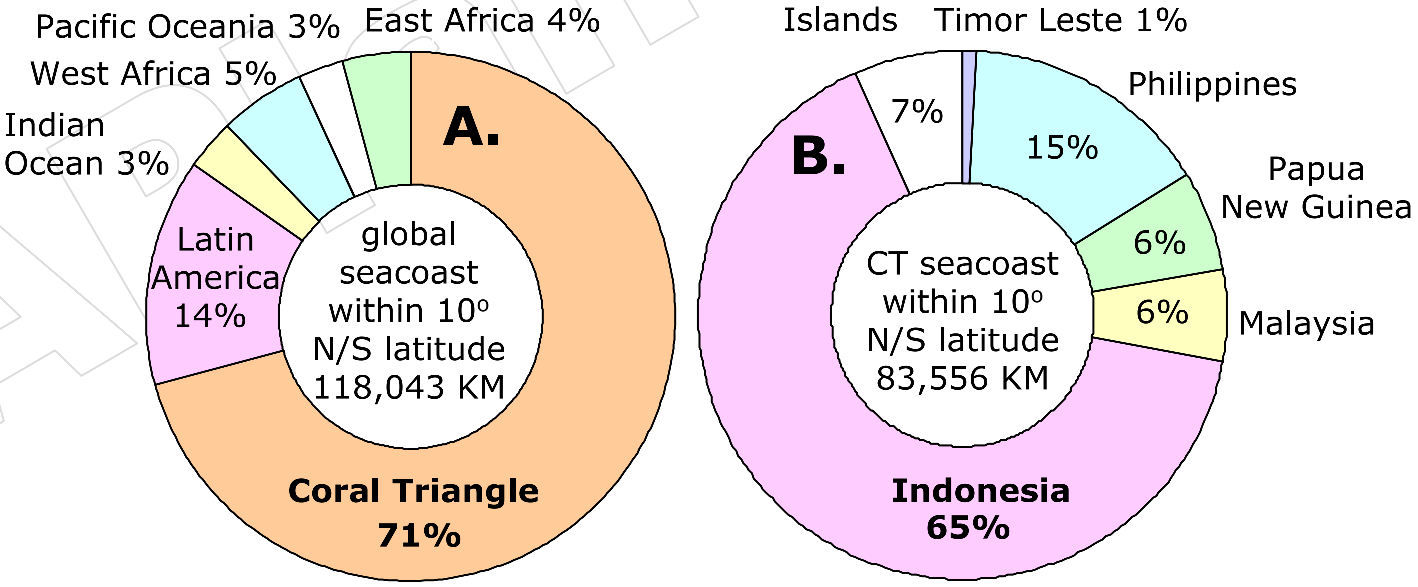
Evidence is provided in support of these propositions and suggestions are made as to how opportunities for seaplant-based IMTA can be developed in support of poverty alleviation and sustainable seashore development along tropical seashores.

SEAPlant.net Foundation

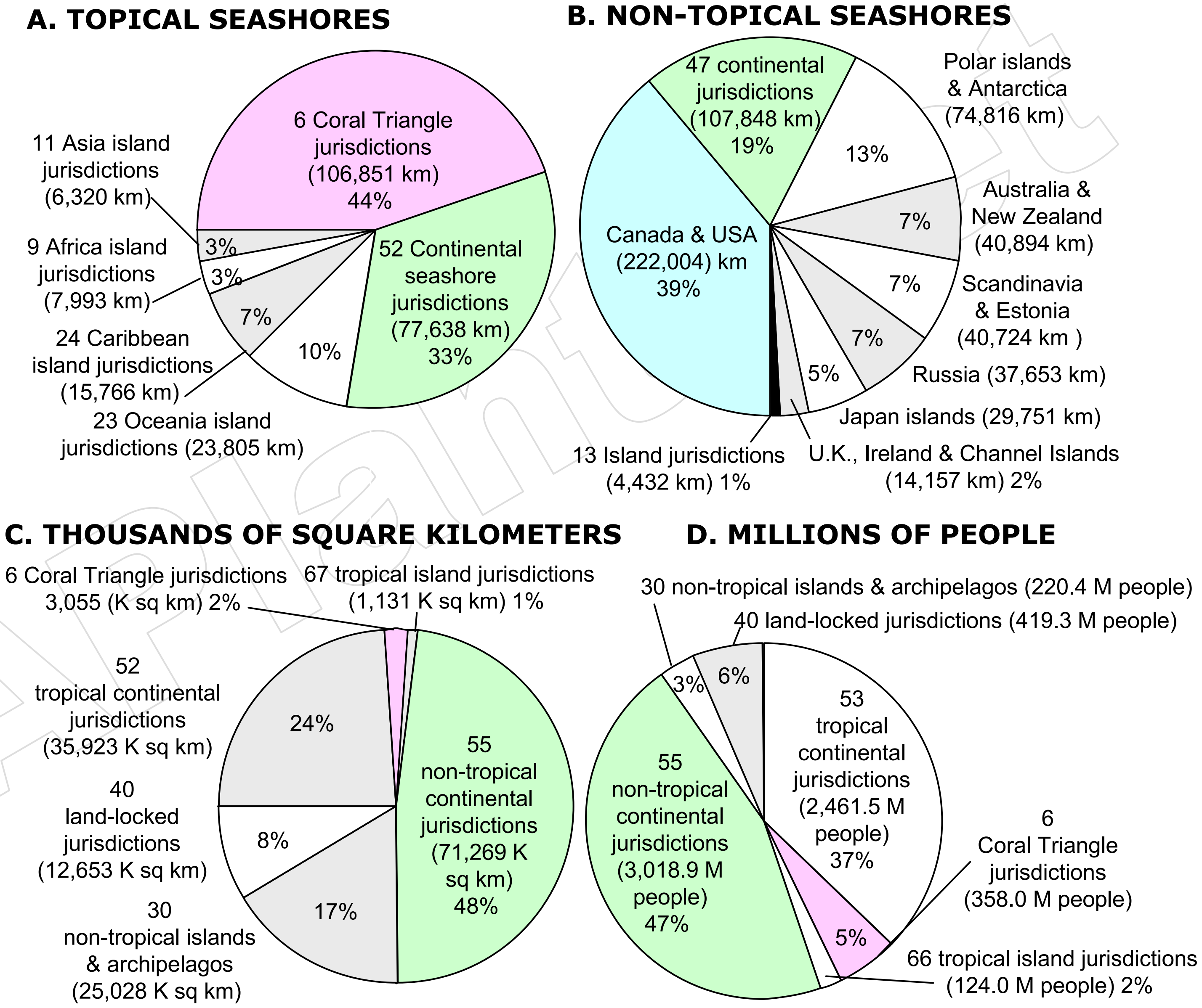
A-1 Global distribution of tropical shorelines

According to the World Factbook (CIA 2007) the total area of the planet earth is 510,072 million sq km. Of this 70.8% of the world's surface is water and 29.2% is land. About 8% of seas are above shallow continental shelves where most photosynthetic activity takes place. The coastlines of the world amount to about 356,000 km. Almost one third of that coastline (about 118,000 km) is within ten degrees north or south of the equator. It is within the ten-degree zone that opportunities are greatest for the sustainable development of livelihoods from sea products produced along tropical seashores. Almost 30% of the world's seashores occur in the tropics including 52 continental and 73 island countries. Island jurisdictions range from portions of single islands to archipelagos with thousands of islands. Among archipelagos, the "Coral Triangle Six" (CT6) states of Indonesia, Malaysia, Papua new Guinea, Philippines, Solomon Islands and Timor Leste include most of the world's tropical islands. Indonesia includes more than 17,000 islands and the Philippines includes more than 7,000 islands. Besides the Coral Triangle the largest aggregations of tropical islands are in the Caribbean (24 countries with about 16,000 km of seashores) and Pacific Oceania (23 countries with about 24,000 km of seashores).

Figure 1. Distribution of seashores that are within ten degrees north or south of the equator. **A.** Regions of the world. **B.** Coral Triangle. More than 70% of the ten-degree zone is in the Coral Triangle. Among the six Coral Triangle countries (the CT-6) Indonesia has about 65% of the total shoreline within the ten-degree zone, the Philippines has 15% of the shoreline and the remaining 20% is divided among Malaysia, Papua New Guinea, Timor Leste and the Solomon Islands.



A-2 Global distribution of shorelines, sea area and people



A. TOPICAL SEASHORES

B. NON-TOPICAL SEASHORES

C. THOUSANDS OF SQUARE KILOMETERS

D. MILLIONS OF PEOPLE

Figure 2. Global distribution of seashores, sea areas and populations. the total area of the planet earth is 510,072 million sq km. Of this 70.8% of the world's surface is water and 29.2% is land. About 8% of seas are above shallow continental shelves where most photosynthetic activity takes place. The coastlines of the world amount to about 356,000 km. Almost one third of that coastline (about 118,000 km) is within ten degrees north or south of the equator. Data are from the World Factbook. Geographic coordinates entry includes rounded latitude and longitude figures for the purpose of finding the approximate geographic center of an entity and is based on the Gazetteer of Conventional Names, Third Edition, August 1988, US Board on Geographic Names and on other sources.

Click to table of contents

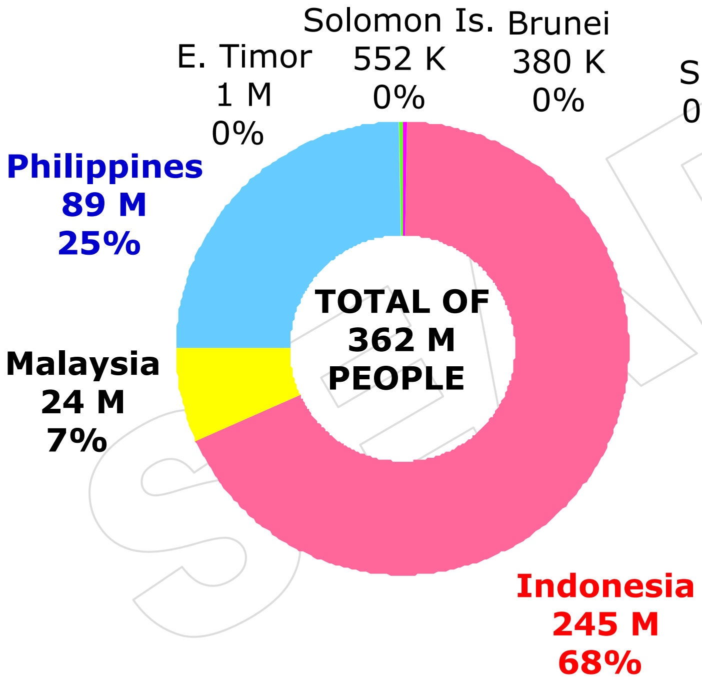
A-3 Coral Triangle demographics

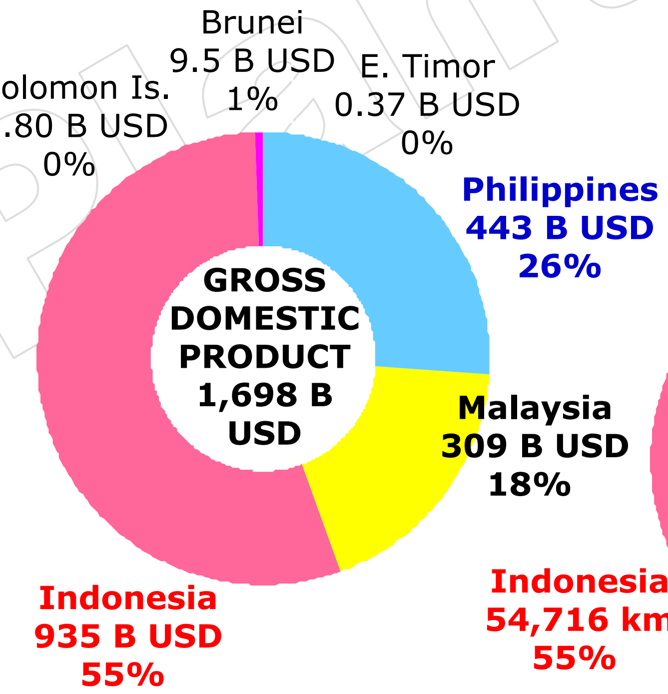
Table 1. Right.

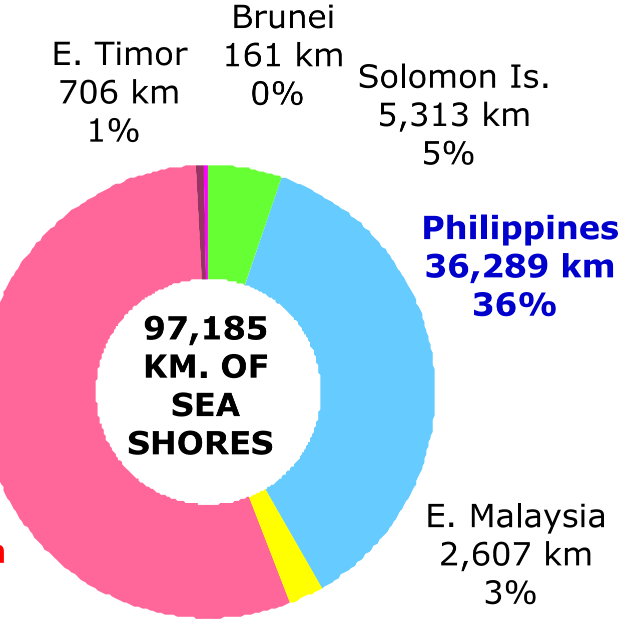
Figure 3. Below.

Coral triangle seashore and demographic statistics clearly show why Indonesia and the Philippines must be major drivers of development initiatives.

		Units	Brunei	East Timor	Indonesia	Malaysia	Philippines	Solomon Islands
GDP	**PPP**	B USD	9.53	0.37	935.00	308.80	443.10	0.80
	Real Growth	%	0.4	1.8	5.4	5.5	5.4	4.4
	Per capita	USD	25,000	800	3,800	12,700	5,000	600
Unemployment		%	4.0	N/A	12.5	3.5	7.9	N/A
Below poverty line		%	N/A	N/A	**17.8**	5.1	**40.0**	N/A
Labor force	**Total**	M	0.18	N/A	**108.20**	10.73	**35.79**	0.25
	Agriculture	%	2.9	N/A	**43.3**	13.0	**36.0**	75.0
	Industry	%	61.1	N/A	18.0	36.0	15.0	5.0
	Services	%	36.0	N/A	38.7	51.0	49.0	20.0







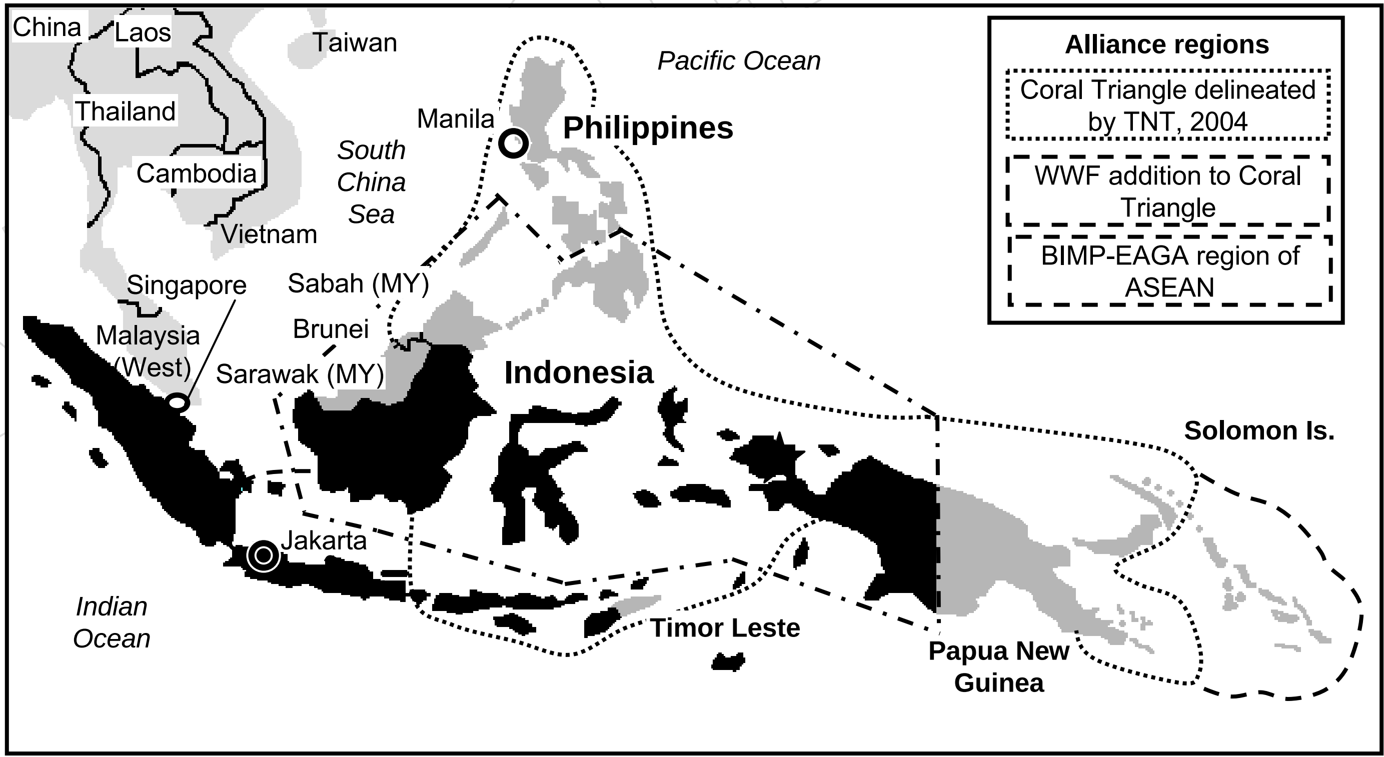
Click to table of contents

A-4 The Coral Triangle initiative (CTI)… Scope of the opportunity and of the responsibility

Boundaries of the Coral Triangle were defined in 2003 (Nature Conservancy, 2004) and several variations on that theme have been proposed since. The CTI gained political substance in 2007 when the six countries of the region banded together and succeeded in having the Coral Triangle Initiative included in the APEC Declaration on Climate Change at Sydney, Australia in September 2007. Coastal zone management will be a key component of CTI initiatives. (Maarif and Jompa, 2007). The Coral Triangle is a global centre of biodiversity and is a top priority for marine conservation. It includes 5.7 million square kilometers of sea and includes habitats where more than 600 reef-building coral species and more than 3,000 species of reef fish live.

Most seashores of the Coral triangle are sparsely utilized as sites for integrated aquaculture or other uses that are done in a sustainable manner. There is a huge development quandary there. The Coral Triangle is a region of immense importance in terms of global biodiversity and ecology yet there are tens of millions of coastal people in need of a decent livelihood that lifts them out of poverty and places them in the path of prosperity. With responsible development it will be possible to maintain high levels of biodiversity and biomass in the Coral Triangle and to also have prosperous communities sustainably producing goods and services from seashore habitats in the region.

Figure 4. Locator map showing Indonesia (black coloring) in relation to the Coral Triangle (Nature Conservancy, 2004) and BIMP-EAGA (Brunei, Indonesia, Malaysia, Philippines East ASEAN Growth Area).



Click to table of contents

A-5 Tropical poverty

At the time of writing an estimated 120 million people lived below the poverty line on tropical islands. Almost 83 million of these were among the CT6 which had an average of almost 3,400 people per km of seashore.

Table 2. Population data and percentage of populations living below the poverty line calculated from data in the World Factbook 2007. Poverty figures were available for 67 out of 125 countries. Overall these data applied to 85% of total populations.

Tropical jurisdictions	million total people	million in poverty	poverty %	Jurisdictions No data	With data	% population with data
Asia continental (8)	1,499.0	392.6	26.2	1	7	100.0
Africa & Mid-east continental (30)	513.3	257.5	50.1	9	21	83.0
Americas continental (14)	449.2	148.7	33.1	1	13	99.8
Coral triangle (6)	358.0	82.6	23.1	1	5	99.8
Caribbean islands (24)	43.1	20.1	46.6	15	9	61.6
Asia & Africa islands (20)	78.4	16.9	23.3	12	8	84.4
Oceania islands (23)	4.0	0.5	12.7	19	4	66.6
Totals	**2,944.9**	**918.9**		**58**	**67**	
Averages			**31.2**			**85.0**

Small island states, island protectorates and islands within large archipelagic states share certain features in common. With respect to seaweed development in SPC countries the forward to McHugh (2006) stated that "Experience so far suggests that the main impediments to a successful industry in the region are distances from markets and low outputs of individual countries. The total contribution of the region to world seaweed production is currently very small and variable and the transport costs to markets very high. There are also problems in the production process that need to be solved… the primary challenge at present is for Pacific island countries culturing seaweed to increase their production to a consistent level. This will require, among other things, provision of good technical support to farmers."

This passage probably applies to most island jurisdictions. It is true that SPC countries are small and geographically isolated and therefore have to overcome substantial logistic hurdles in order to participate in global value chains. The same is true of several Caribbean, Indian Ocean and African islands. It is also true of thousands of small islands within large archipelagic states such as the Philippines and Indonesia where decentralisation policies have granted substantial autonomy to provincial areas or where distances and political issues have left many small islands to fend for themselves.

A-6 Commercial goods based on seaplant utilisation

Seaplants are the primary productivity base for almost all life in the sea. The significance of seaplants such as algae, sea grasses, mangroves and salt-marsh plants to human life can be viewed as follows in terms of the goods, services and perturbations that they provide within ecosystems (e.g. Worm et al 2006 and 2007; Table 3).

World production of seaweed was reviewed by Zemke-White and Ohno (1999), McHugh (2003) and FAO (2004, 3006). Annual global seaweed (marine macro-algae) production was reported to be on the order of 1.4 million dry tons per annum. More than half of the seaplants utilised by humanity come from sustainable aquaculture. According to FAO (2006) seaweed-based value chains generated a range of products with annual production value estimated at 5.5 -7 billion USD/annum. Of this human food products accounted for about 90%, hydrocolloids for about 6-8% and other products such as agricultural nutrients accounted for the rest. Almost 90% of commercial seaweed production came from cultivation. Proportions of various seaweed genera that appeared in official trade data are shown in Figure 5.

Many seaplants and their products are exchanged in local markets. There were gaps in the available statistics and actual volumes were undoubtedly higher than the records show. For example production figures for mangroves and sea-grasses were unavailable since most were used within local commerce and public records were unavailable.

The world has more than 200 useful seaplant species distributed among more than 150 bodies of water. Currently there are 214 countries or territories in the world that have seacoast. Of these 42 have reports of commercial seaplant activity. The top ten countries/territories in terms of coastline length have 63% of the world's total of 531,864 km. The top ten producing countries contribute 96% of the world's commercial seaweed volume. About 50% of world seaplant production is cultivated. The seven top seaweed farming countries produce 99% of the volume. East Asia and Western Europe predominate.

At the time of writing most current seaweed production in tropical regions was used as raw material for making the red algal galactan (RAG) hydrocolloids known as carrageenan and agar. The most commonly cultivated red algal galactan seaweeds (RAGS) were of the genera Kappaphycus (cottonii of the trade); Eucheuma (spinosum of the trade) and Gracilaria. These were, respectively, sources of kappa-carrageenan, iota-carrageenan and agar.

Gracilaria is a genus with many species and these are distributed widely throughout both tropical and temperate seashores. Official data concerning Gracilaria production were sparse as of 2008. Commercial trading patterns suggested that most production of cultivated Gracilaria was from Indonesia and China where it was mostly used for production of domestically consumed agar. Chile was also a major Gracilaria producer.

A-7 Seaplants as the foundation for sustainable seashore development

Table 3. Exemplary lists of seaplant-related goods, services and perturbations that can be produced in seashore habitats.

COMMERCIAL GOODS		ECOSYSTEM SERVICES		PERTUBATIONS
TYPE	**CLASS**	**TYPE**	**CLASS**	**TYPE**
Nutrition	animal feed	**Nutrition**	Food for herbivores	alien invasions
	human food		symbiotic services	eutrophic blooms
	fertilizers	**Water quality**	assimilate macronutrients	fouling of beaches
Health	bioactive compounds		assimilate micronutrients	harmful algal blooms
	nutraceuticals		assimilate pollutants	
	soil conditioners		consume ammonia	
	well-being products		fix carbon dioxide	
Chemicals	biopolymers		provide oxygen	
	inorganics	**Habitats**	provide habitat niches	
Fuels	lipids		provide substrate	
	alcohols		stabilize seashores	
	biogases	**Other**	aesthetic services	
Other	construction materials		recreational services	

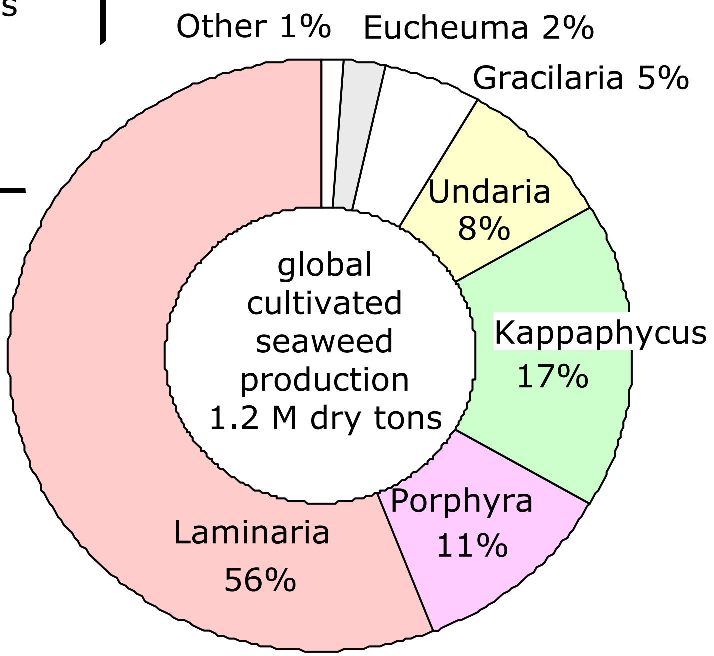


Figure 5. Percentage of global annual seaweed production accounted for by the major genera of commerce from 2002-2006. Of the genera shown in this figure almost all Kappaphycus and Eucheuma and about half of Gracilaria production came from the Coral Triangle. The others were cold water genera. Most Laminaria was cultivated in China. Since many seaplants and their products were exchanged in local markets there were gaps in the available statistics and actual volumes were undoubtedly higher than shown.

Click to table of contents

A-8 Sources of cultivated tropical seaweeds

Cultivation of Kappaphycus and/or Eucheuma is known to have been attempted or successfully undertaken in at least 29 countries (Neish, 2005, Table 1). An analysis of official import data from 2002-2006 for 34 countries active in the seaweed and hydrocolloid trades showed that 19 were sources of seaweed and seaweed products (Table 4). The Coral Triangle accounted for almost 86% of volume and 85% of value of tropical seaplant production. Official export data from Indonesia, Malaysia and the Philippines showed that import data from the basket of countries included in Table 4 accounted for 82% of reported export volume and 67% of reported export value from 2002-2006.

Table 4. Tropical countries known to have been sources of seaweed and seaweed hydrocolloids from 2002-2006. Note that Fiji is known to have exported some Kappaphycus during the reporting period but none appeared in these statistics. Also India is known to have exported several hundred tons of Kappaphycus since 2003 but these shipments are lumped with other products in the customs data so exact quantities were not known.

SOURCE	TOTAL TONS	% TONS	SOURCE	K USD CIF	% USD CIF
Indonesia	238,734	49.2	Philippines	251,605	51.2
Philippines	170,564	35.2	Indonesia	151,273	30.8
Tanzania	29,756	6.1	Taiwan	30,091	6.1
Peru	14,278	2.9	Malaysia	14,302	2.9
Vietnam	8,292	1.7	Peru	12,343	2.5
Malaysia	5,369	1.1	Tanzania	11,392	2.3
Thailand	5,191	1.1	Thailand	7,526	1.5
Cambodia	3,451	0.7	Tonga	3,144	0.6
Taiwan	2,553	0.5	Vietnam	3,128	0.6
Madagascar	2,365	0.5	Cambodia	2,165	0.4
Tonga	2,061	0.4	Madagascar	1,454	0.3
Kiribati	576	0.1	Brazil	1,139	0.2
Brazil	532	0.1	Senegal	554	0.1
Solomon Islands	471	0.1	Namibia	479	0.1
Namibia	374	0.1	Solomon Islands	358	0.1
Senegal	161	0.0	Kiribati	346	0.1
Dominican Republic	57	0.0	Cuba	339	0.1
Sri Lanka	44	0.0	Dominican Republic	73	0.0
Cuba	18	0.0	Sri Lanka	67	0.0
	484,850			**491,776**	

The period 2000-2006 was characterized by tight supplies of Kappaphycus but adequate supplies of Eucheuma and Gracilaria. Estimates of seaweed production in support of exports from the Coral Triangle indicated that by 2006 Indonesia production was about 100,000 dry tons and 2006 Philippine production was about 50-60,000 dry tons. Most of this was Kappaphycus. (From SEAPlant.net Monograph no. HB2B 0808 V2).

A-9 Major tropical seaweed production trends

Figure 6. A graphic history of the production of carrageenan-source seaplants from 1961 to 2007. **Top (green):** Estimated production of the commercially cultivated "warm water" seaweeds Kappaphycus spp. + Eucheuma spp. In Malaysia, Indonesia, and the Philippines 1975-2007 (SEAPlant.net data) **Bottom (yellow):** Estimated production of commercially harvested wild "cold water" red seaweeds (mostly Chondrus crispus; some Furcellaria fastigiata) from France, Canada, Chile and the U.S.A. 1961-2001. (after FAO and Prince Edward Island Fisheries Dept. statistics).

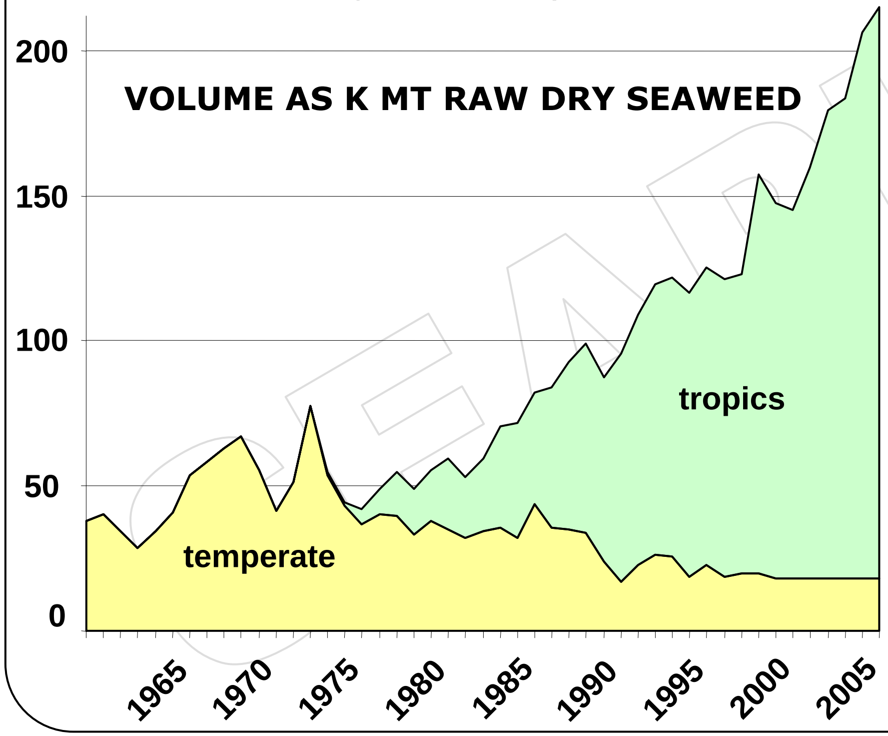
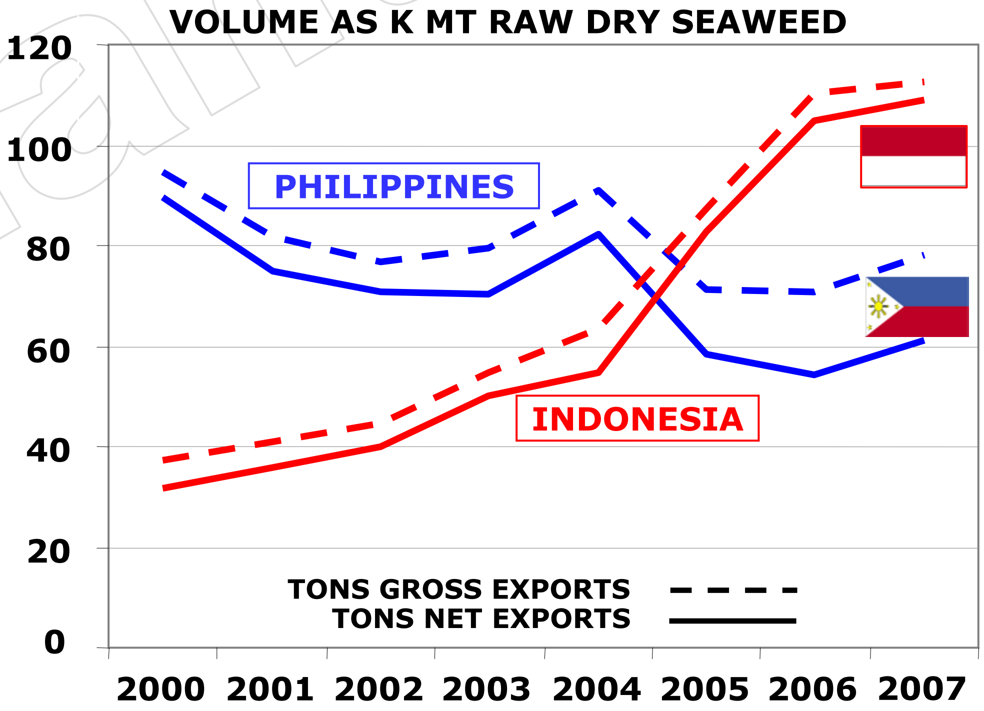


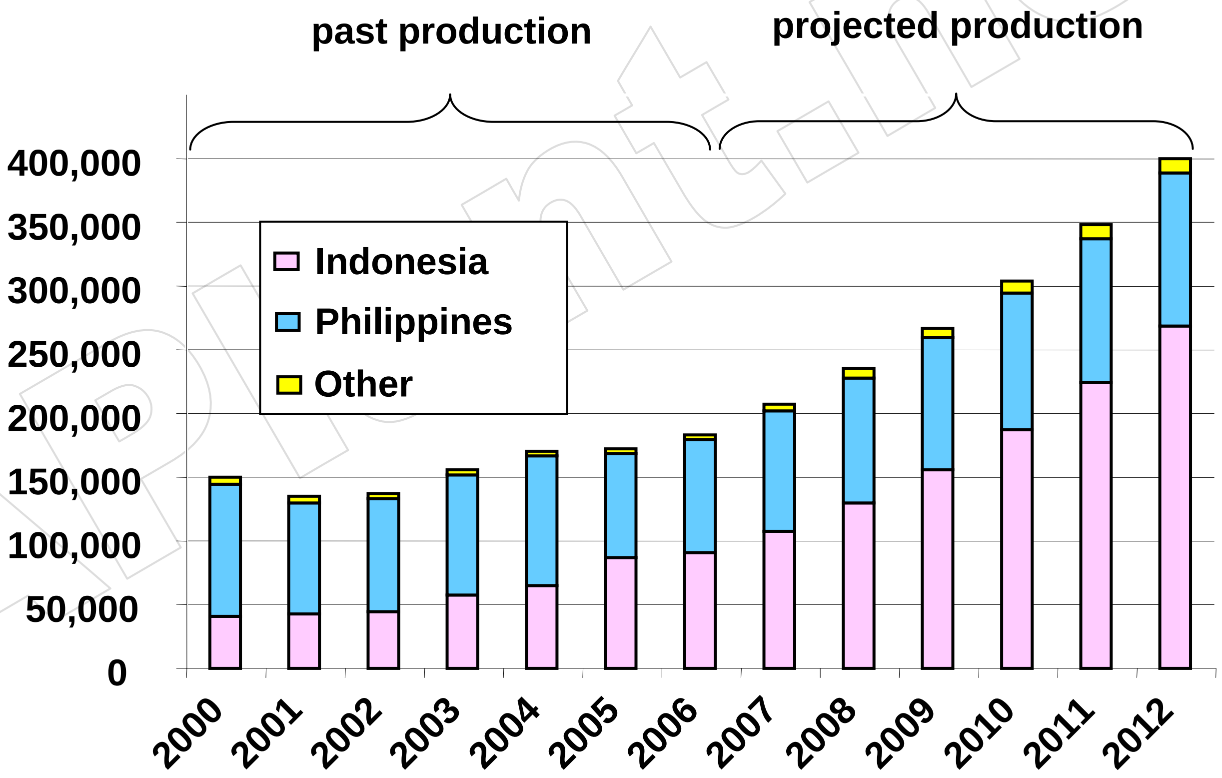
Figure 7. Most cultivated tropical seaweed was RAGS from Indonesia and the Philippines (Figure 5) and about 75% was Kappaphycus. Indonesian annual seaweed volume rose from less than 40 K MT/yr to over 100 K MT/yr from 2000-2007. Philippine seaweed production declined from about 90 K MT/yr to less than 80 K MT/yr from 2000-2007. Most Philippine exports were as value-added carrageenan building block products or as blended ingredient solutions rather than as raw, dried seaweed. Most Indonesian exports were as raw dried seaweed. (From SEAPlant.net Monograph no. HB2B 0808 V2).



A-10 Demand projection for value chains using present technology

The data examined for SEAPlant.net Monograph no. HB2B 0808 V2 indicated an overall market growth from 2002-2006 of 8% in volume and 15% in value for seaweed and gum imports. Based on trade data analyses and models SEAPlant.net has developed projections for the overall RAGS market (Figure 8). This projected doubling in the requirement for RAGS seaweed raw materials over the next five years. Most of this requirement was for sources of agar and kappa carrageenan that can be made in semi-refined or gel-press process facilities.

Figure 8. Past and forecast production (in dry metric tons) for Kappaphycus, Eucheuma and Gracilaria from the Coral Triangle. (SEAPlant.net data). Data are expressed in terms of commercially dry metric tons of seaweed. Numbers were derived from trade data for export products so domestic consumption was not included. The economic model based was on supply, demand, and trade data. Expected growth of 13% was projected from 2008 to 2012



B-1 Coral Triangle eco-regions – where tropical seaweed crops grow best

An ecoregion is defined by WWF as: *"a large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions"*. TNT defined ecoregions as geographically distinct areas with distinct natural communities and species environmental conditions (The Nature Conservancy [TNT] 2004) The 2004 CT workshop of TNT based a Coral Triangle ecoregion map on a map for coral reef fishes drafted by Dr Gerry Allen. Coral reef fish were considered to be the basis for showing overall trends of endemism and biodiversity because reef fish have limited dispersal capabilities and consequently have relatively restricted geographic distributions. The map of Dr. Allen was modified where there was convincing evidence based other taxa (eg. corals, foraminifera, stomatopods, etc) and/or physical data (e.g. currents and water masses). Based on Seaplant.net data and information concerning experience with RAGS farming each of these ecoregions has been rated according to its suitability for year-around production of Kappaphycus (Figure 9). Kappaphycus was selected as an exemplar because it is the major RAGS cash crop and it is also the most sensitive to seasonal shifts in environmental conditions. Seaplant.net has proposed that the following criteria are the major determinants of whether sustainable year-around RAGS farming can occur in an ecoregion:

1. **There are no typhoons.** In the Eastern Philippines typhoons have severely damaged farm areas several times during the past three decades. In recent years typhoons have begun to occur further south that they used to (eg. in the Zamboanga Peninsula which was formerly considered to be typhoon-free).

2. **Seasonality and incidence of diseases are minimal.** Some regions exhibit distinctly outbreaks of the malaise known as "ice-ice". Within such regions disease problems such as epiphytes have been observed (Hurtado and Critchley, 2006).

3. **Law and order prevails.** The ARMM region of the Philippines is an example of a major seaweed growing region where production is curtailed because seaweed farmers have fled productive areas where excessive rents are levied by armed groups.

4. **Farmers have rights over farm sites.** One of the strengths of Indonesia is that government de-centralisation polices have put considerable control of seashore utilisation into the hands of the people who live there.

5. **Infrastructure and shipping facilities are adequate.** Domestic shipping costs tend to be high in the CT especially in farm areas most remote from major ports. This puts remote regions at a competitive disadvantage.

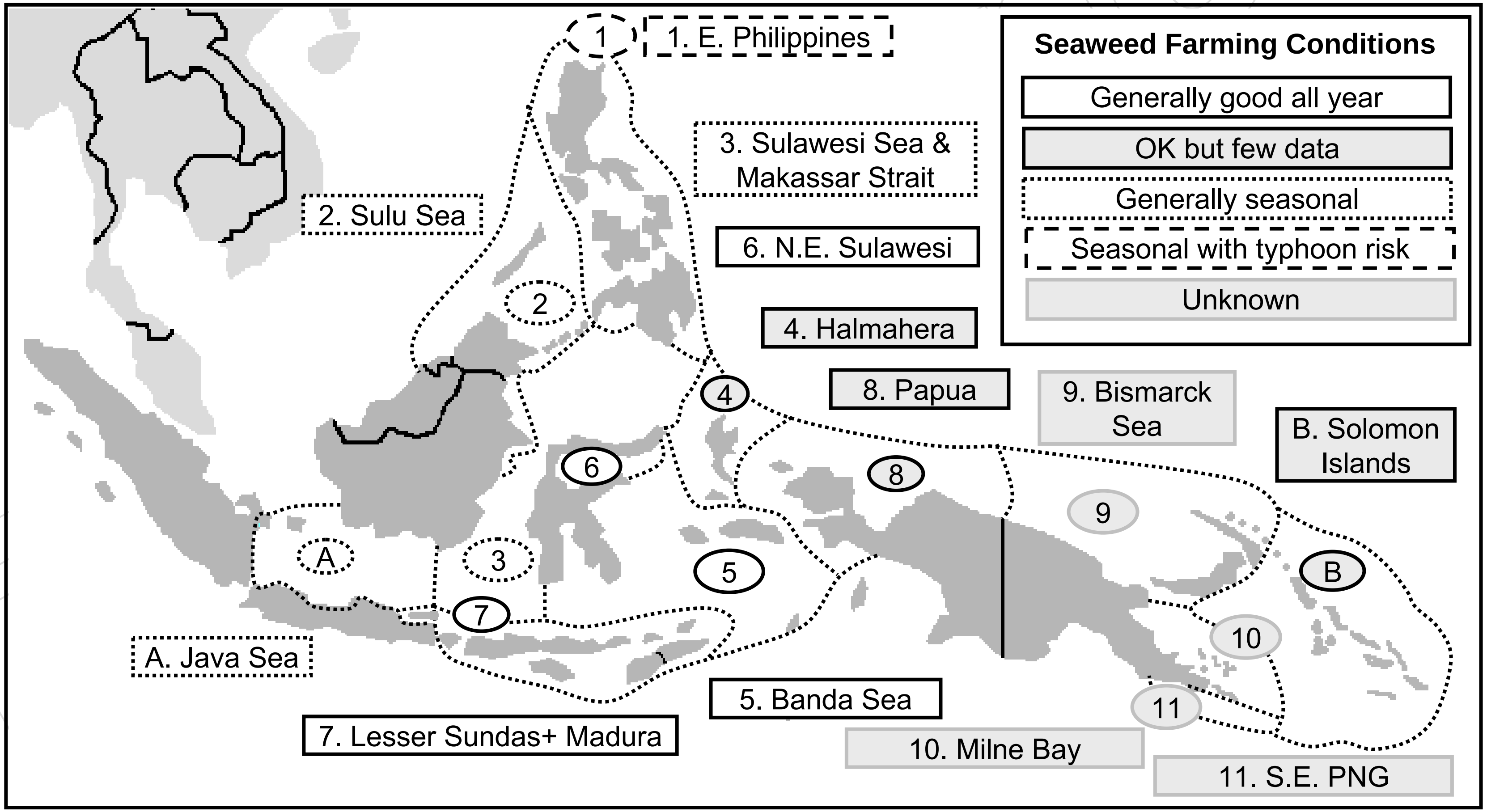
6. **Business essentials are available & applicable.** Throughout the CT business development services, access to finance, access to goods and services and other business essentials are lacking. Where business essentials have been provided seaweed farming has developed strongly.

B-2 Coral Triangle eco-regions map

Figure 9. Coral Triangle eco-regions defined after the Nature Conservancy, 2004. Boundaries of the ecoregions were originally delineated by the TNC Expert Workshop Bali, April 30 to May 2, 2003. The Java Sea and Solomon Islands portions were added by WWF. Ecoregion delineations are designated primarily by the distribution of coral reef fishes. General characteristics for seaweed farming are superimposed on the CT ecoregion map below. These are based on observations by the author and Seaplant.net Foundation staff.

Translating comparative advantage to competitive advantage is best achieved in regions where:

- There are no typhoons
- Seasonality and incidence of diseases are minimal
- Law and order prevail
- Farmers have rights over farm sites
- Infrastructure & shipping facilities are adequate
- Business essentials are available & applicable



Ecoregions defined after TNC and WWF

B-3 Ecosystem services from seaplants in seashore habitats

The goods described above are produced by seaplants growing in natural habitats or in aquaculture systems. Within those systems various elements associated with energy, materials, water, nutrients and gases exchange come together and seaplants perform functions that deliver “ecosystem services” (in the sense of Worm et al, 2006). A schematic view of a generalized system is shown in Figure 10.

Few people are aware of the fact that much of the oxygen in the atmosphere originates with algae. Estimates run as high as 70-80% (Hall, 2007). The production of oxygen occurs during photosynthesis as seaplants assimilate CO2 , fix carbon and release oxygen. Muraoka (2004) noted that about 2 gigatons of carbon enters seawater by gaseous interchange per annum and estimated that macrophyte production along the coasts of Japan fixes about 2.7 millions tons of carbon per annum.

Muraoka estimated that one ton of carbon is fixed for approximately 17 tons live weight for the tropical seaweeds grown in the CT. With current production at more m than 2 million tons fresh weight per annum this means that cultivated seaweeds in the CT fix about 120,000 tons of carbon and release about 240,000 tons of oxygen.

Besides metabolizing CO2 seaplants assimilate vast tonnages of macronutrients and micronutrients including much of what washes into the sea from freshwater runoff and erosion. Within integrated multi-trophic aquaculture (IMTA) systems many such nutrients can be recycled.

Neori *et al* (2007) have discussed the value of such bio-mitigation, especially as it relates to seaplants assimilating ammonia nitrogen. They point out that in 2004 combined seaweed + shellfish production of about 26.8 M tons contributed 88.9% of mariculture production and removed from the sea about 165,000-220,000 tons of nitrogen. This was enough to assimilate the total nitrogen discharges of global fish and shrimp although not all production was geographically coupled.

Seaplants provide means for recycling nutrients from the sea to terrestrial agriculture systems when they are used to produce plant foods, fertilizers and animal feeds. They also provide habitat services such as provision of habitat niches, provision of substrate and stabilization of seashores. In conjunction with that they provide venues for recreational activities such as diving, sport fishing, bird watching, and ecotourism.

Click to table of contents

B-4 Ecosystem perturbations associated with seaplant utilisation

Many people associate seaplants with perturbations that occur in the environments around them. In some cases these are the result of natural events such as heavy weather that causes seaweeds to be torn from the sea floor and stranded in huge rotting piles on beaches.

Algal blooms are another type of seaplant event that causes problems for people. Harmful algae such as toxic "red-tide" algae can bloom along seashores and render filter-feeding molluscs or other seafood species off limits for human consumption for certain periods of the year.

In other cases seaplants can clog waterways and form layers of "scum" on water surfaces as a result of eutrophication. This happens especially when nutrient-rich effluents and terrestrial runoff elevates macronutrients to the point where tolerant species bloom and less tolerant species die. An example is the persistent bloom of Ulva and other algae in the Venetian Lagoon.

"Alien invasions" such as Caulerpa in the Mediterranean Sea, Eucheuma in Hawaii and Undaria in European coastal waters have occurred when unchecked introductions were made into vulnerable seashore habitats. These situations highlight the need for using proper protocols when seaplants are moved around and introduced to coastal habitats (Sulu et al, 2003; Neish, 2005; Zemke-White and Smith, 2006).

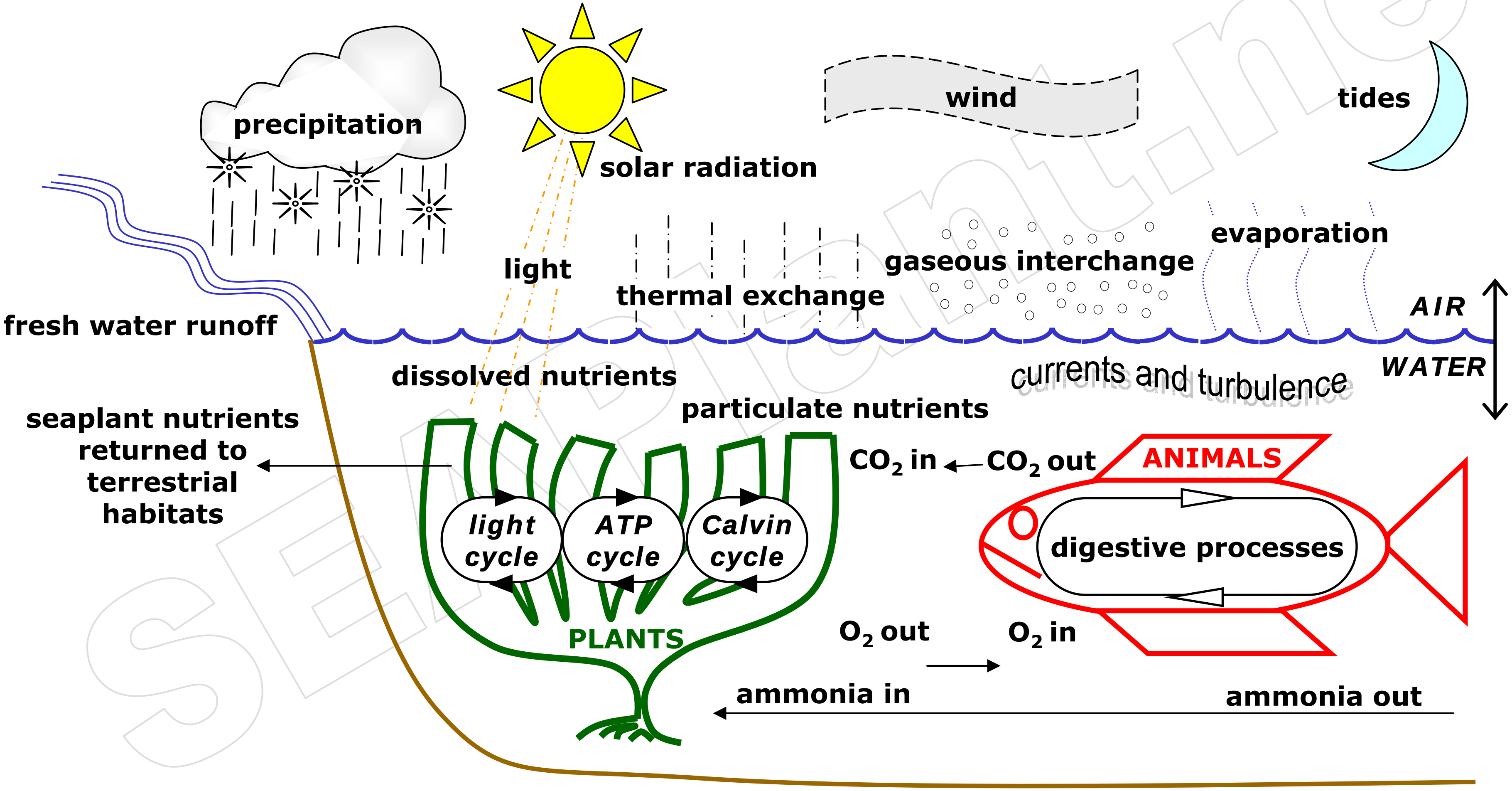
Another aspect of seaplant-related perturbations occurs when processing industries pollute local habitats. Unfortunately the marine hydrocolloid industry has been slow to adopt low-effluent, multi-stream process technology (Figure 18).

Many of the ecosystem perturbations caused by seaplant utilisation can be ameliorated as integrated, multi-trophic aquaculture (IMTA) is introduced in the context of comprehensive seashore management systems. IMTA systems are operated in a way that minimizes negative impacts on surrounding natural habitats and human socio-cultural entities.

As the technology for IMTA systems develops biodiversity within the systems will be increased and low-effluent, multi-stream processing will develop. This will enable aquaculturists to optimize production from scarce seashore real estate and should also maximize the capacity of the systems to generate sustainable year-around cash flow.

B-5 Important elements of energy, nutrient, water and gas exchange among seashore habitats

Figure 10. Seaplants perform functions that result in the delivery of ecosystem services. Their metabolic processes utilise energy, materials, water, nutrients and gases to produce biomass and metabolites that impact on other organisms. This occurs in natural systems; in aquaculture systems; and in combined systems.



B-6 Integrated multi-trophic aquaculture (IMTA)

CURRENT STATE OF THE ART

As of 2008 man's utilization of marine products was mostly still at the "hunter-gatherer" stage. It was primarily based on the capture of high trophic-level, wild-caught fish and invertebrates. Less than 20 % of the total was cultivated. Less than 10% of total fisheries production was as seaplants and the utilization of seaplants was in its infancy (Figure 12). In stark contrast, about 98% of terrestrial agriculture production was in the form of plant crops. Land agriculture was based on the cultivation of plants and herbivorous or omnivorous animals (Figure 11).

THE ESSENCE OF SUSTAINABLE IMTA SYSTEMS

The essence of IMTA systems is that energy and materials are cycled within them as much as possible so they function as "mini-biospheres" (Neori *et al* 2004, 2007). IMTA systems are a sub-set of the systems that have conventionally been referred to as "polyculture" but IMTA systems are distinguished by the fact that species are not simply grown together. They are linked together (Figure 13).

One of the most essential developments leading to increased sustainable aquaculture will be the development of seaplants as "fodder" in IMTA systems. For example the use of high levels of fishmeal in aquaculture diets is problematic and IMTA solutions must be found. The diversity of herbivorous fish and invertebrates endemic to tropical seashores gives cause for optimism that aquaculture development can progress based partly on lower trophic level species.

IMTA integrates aquaculture with agriculture and can produce crops useful for local, regional and export markets. The primary productivity base for IMTA systems is seaplants that grow within the nutrient and metabolite cycles of the system. Ideally IMTA systems can function in association with linked multi-trophic terrestrial systems.

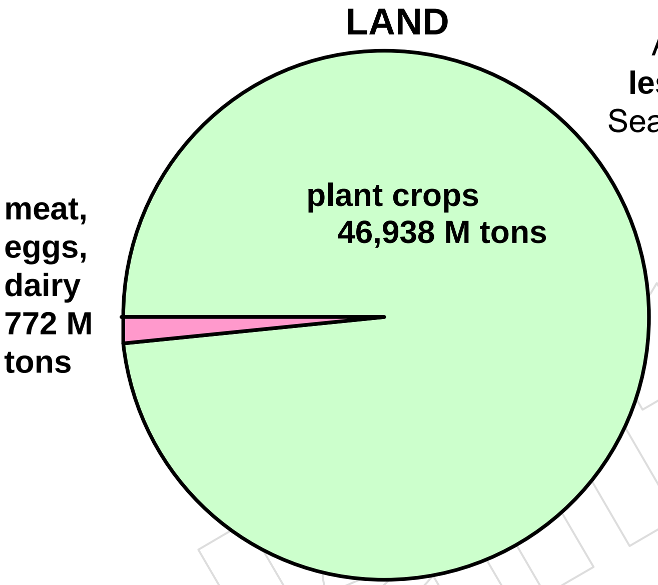
It is an essential feature of IMTA systems that they should minimize negative impacts on surrounding natural habitats and human socio-cultural entities. Figure 14 A indicates some of the major habitat types that occur along tropical seashores where IMTA systems operate. Figure 14 B indicates some of the subsystem types that operate within tropical IMTA systems. Managed and conserved seashore habitats (A) are mingled with integrated multi-trophic aquaculture (IMTA) along seashores (B). IMTA systems are managed in such a way that energy, nutrient, water and gas exchange are kept as much as possible within the IMTA system to minimize impacts on surrounding habitats.

B-7 Crop production from land and sea

Figure 11 (right).

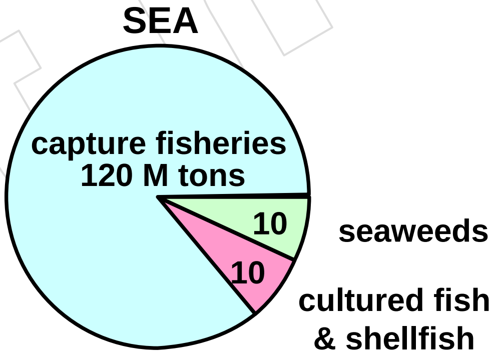
Land agriculture is based on the cultivation of plants and herbivorous or omnivorous animals (left). Human exploitation of the seas is mostly based on capture fisheries for carnivores (right). Figures as millions of tons.

Source: FAO 2000

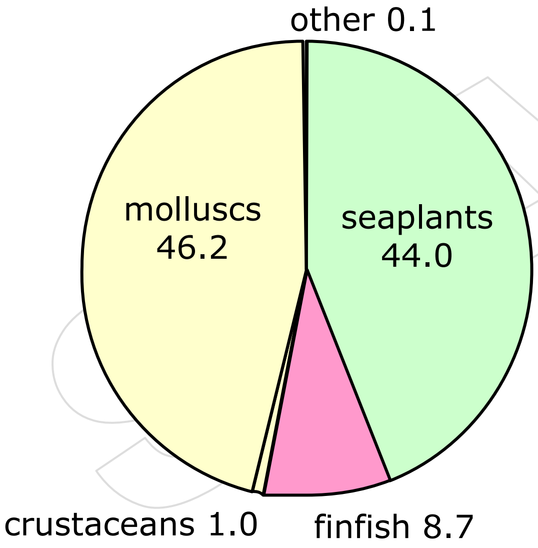


Animal-based food production from the sea is **less than 20 %** of production from farms on land
Seafoods are mostly carnivorous animals caught by "hunter gatherer" methods

The development of mankind's utilization of seaplants is still in its infancy



world aquaculture % production by weight (total 30.2 M tons)



Aquaculture average annual economic value (B USD)

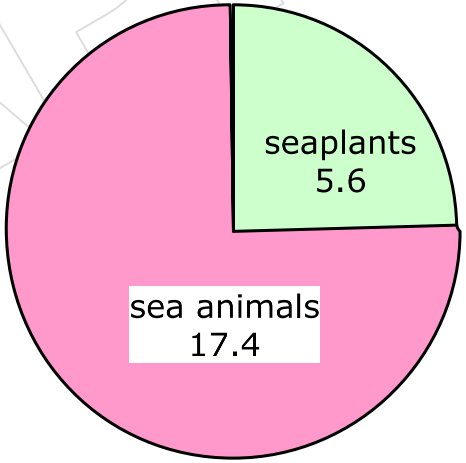


Figure 12 (left).

A summary of world aquaculture production as of 2004. As IMTA progresses more marine production will be based on seaplants, on extractive animals and on feeds that do not rely on capture fisheries for fish meal.

Source: FAO

B-8 Integrated multi-trophic aquaculture (IMTA) schematic

Figure 13. IMTA schematic

Seaplants use solar energy to photosynthesize

•

Restore water quality

•

Recycle nutrients

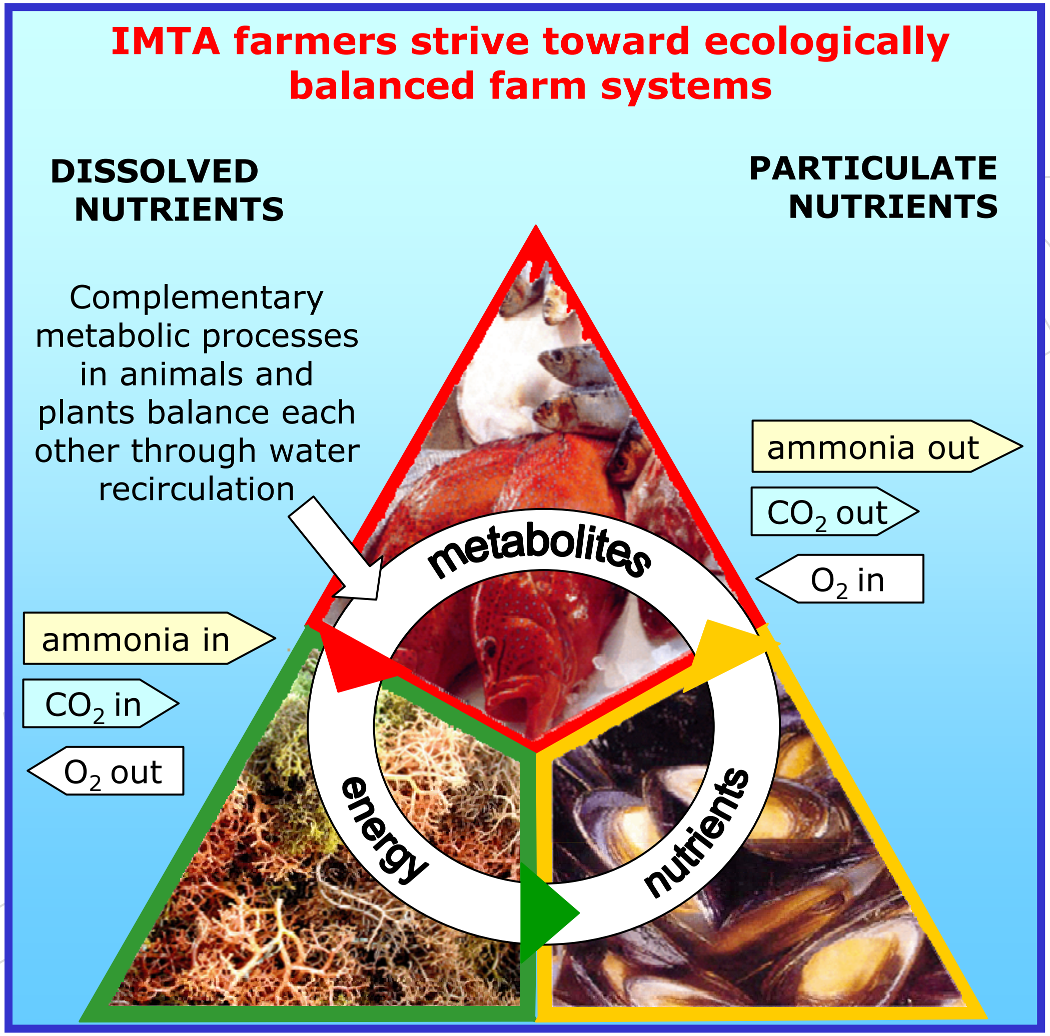
•

Produce marketable biomass

EXTRACTIVE PLANTS
(PHOTOAUTOTROPHS)

Plankton: microalgae, bacteria, protozoa

Macrophytes: macroalgae, vascular plants



IMTA farmers strive toward ecologically balanced farm systems

DISSOLVED NUTRIENTS

PARTICULATE NUTRIENTS

Complementary metabolic processes in animals and plants balance each other through water recirculation

FED ANIMALS
(HETEROTROPHS)

Omnivores: fish, crustaceans, holothurians

Carnivores: fish, shrimp, crabs

EXTRACTIVE ANIMALS
(HETEROTROPHS & PHOTOSYMBIONTS)

Symbiotics: corals, giant clams

Planktivores: fish, shellfish, zooplankton

Herbivores: fish, abalone, sea urchins

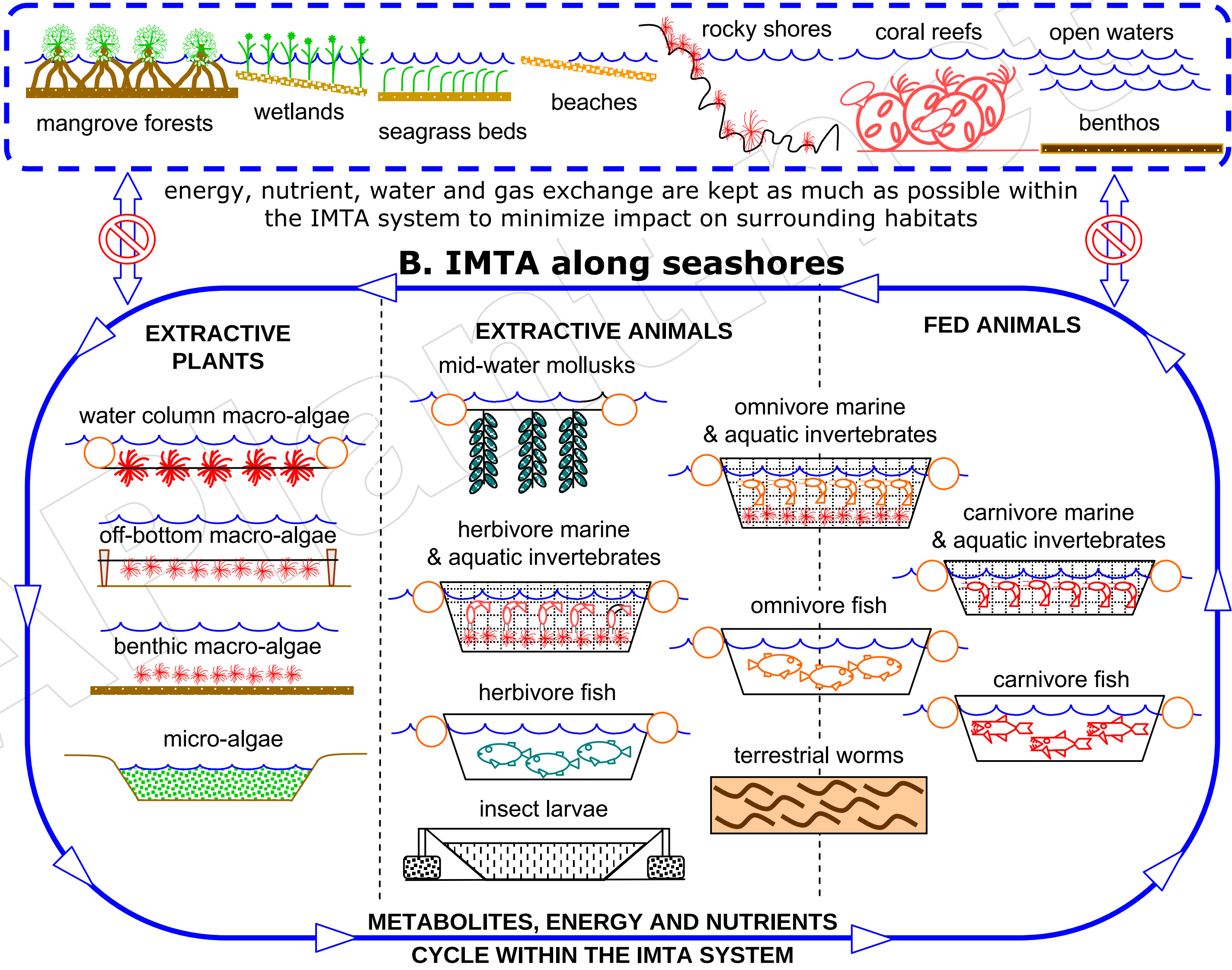
For IMTA to be sustainable it is essential to use seaplant biomass directly as feed and also as feed to produce extractive animals that can replace fish meal in carnivore diets

B-9 IMTA in managed and conserved seashore habitats

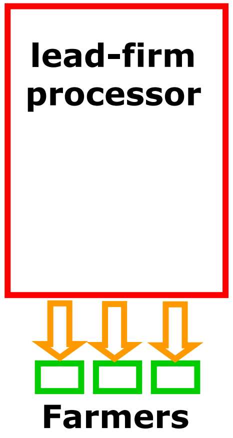
Figure 14. Managed and conserved seashore habitats (A) are mingled with integrated multi-trophic aquaculture (IMTA) along seashores (B). IMTA systems are managed in such a way that energy, nutrient, water and gas exchange are kept as much as possible within the IMTA system to minimize impacts on surrounding habitats.

One of the most essential developments leading to increased sustainable aquaculture will be the development of seaplants as "fodder" in IMTA systems. For example the use of high levels of fishmeal in aquaculture diets is problematic and IMTA solutions must be found. The diversity of herbivorous fish and invertebrates endemic to tropical seashores gives cause for optimism that aquaculture development can progress based partly on lower trophic level species.

A. Managed and conserved seashore habitats



C-1 Captive value chains drive innovation (1970s until mid-1980s)



CAPTIVE VALUE CHAIN HIGHLIGHTS

- ✓ Many small sellers and few major buyers (oligopsony)
- ✓ Carrageenan dominated by a few innovative SME
- ✓ Processor investment led to seaweed cultivation
- ✓ Mostly Marine Colloids (FMC now) & Genu (CP-Kelco now)
- ✓ R&D programs were linked to academia & government
- ✓ Philippines monopoly
- ✓ Buyers linked through Marinalg; Standards systems were driven by Marinalg members

The cultivation of tropical RAGS and the extraction of gums from them has gone from initial experimental trials to fully developed value chains since the early 1970s. Panlibuton *et al* (2006) have given an account of this development that was patterned after the analysis of global value chain governance undertaken by Gereffi *et al* (2005). An analysis of the structure and development of tropical red seaweed value chains with focus on the red algal galactan seaplants (RAGS) is presented in SEAPlant.net Monograph no. HB2A 0808 V1 (2008). A summary of the historical development of seaweed value chains in the Philippines and Indonesia is shown in Figure 15.

Initially innovation in process technology and the development of seaweed farming in the tropics was driven by a few major companies that were allied through Marinalg and other alliances. These companies dominated the carrageenan business and they collaborated with local entrepreneurs to develop farms through direct investment. Benefits were realized because they had a strong market position and built robust strategic alliances. Industry standards were mediated through Marinalg but enforced by each individual processor.

The availability of cultivated Kappaphycus made it possible by 1980 to introduce a disruptive technology known as semi-refined carrageenan (SRC). This lower-cost, lower-energy-consumption product was initially developed by collaboration by established carrageenan producers with end-users in the petfood industry. Single-stream processing (Figure 18) was used and this is still the industry norm. The original process technology was copied as new industry players entered the SRC business and recruited former employees, consultants and equipment suppliers of previously established manufacturers.

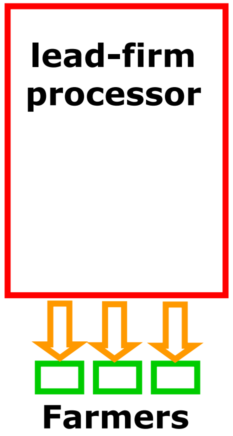
C-2 Evolution of RAGS value chain governance structures

Figure 15. Governance systems that have been applied to RAGS value chains (After: Gereffi, G., Humphrey, J. and T. Sturgeon, 2005 and Panlibuton, H., Porse, H. and E. Nadela, 2007). See SEAPlant.net monograph no. HB2A 0808 V1 for a more complete treatment of value chain structure and development.

1970s – mid 1980s

Captive governance

vertically integrated enterprises that control value chain functions



✓ Many small sellers and few major buyers (oligopsony)
✓ Carrageenan dominated by a few innovative SME
✓ Processor investment led to seaweed cultivation
✓R&D linked to academia & government
✓ Philippines monopoly
✓Standards systems driven by Marinalg members

mid 1980s - present

Modular governance

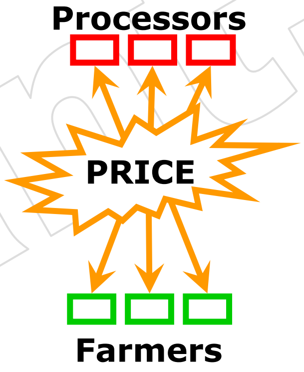
controlled by firms that determine product specifications, trade rules, etc.

✓Rapid growth driven by SRC
✓ Major traders become processors
✓ Innovation stagnated
✓ Development self-funded by farmers or trader-funded
✓ Indonesia and Tanzania develop as significant sources
✓ Standards still driven by Marinalg but weakening

mid 1990s - present

Market governance

"arm's length" transactions between buyers & sellers; little or no formal cooperation among participants

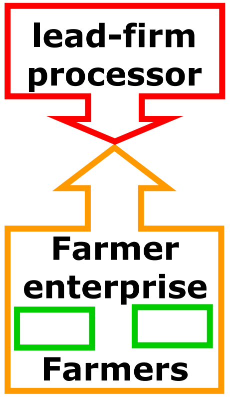


✓ Processors proliferate
✓ Many small sellers, tight cottonii supplies
✓ much "spot" selling… often in seller's markets
✓ Minimal innovation
✓ Demand-driven cottonii market leads to chaos in 2008
✓ Standards virtually ignored
✓ Market driven value chains function poorly carrageenan

developing now

Relational governance

fairly autonomous decision making among participants; cooperation & alliances prevail



✓ Fewer & larger sellers as farmer enterprises aggregate
✓ Processing sector consolidating
✓ need for transparent links from source to solution
✓ Farm development and processing moving toward integrated systems
✓Essential that standards be applied rigorously, transparently and globally

C-3 Modular value chains emphasize trading (mid-1980s to present)

MODULAR VALUE CHAIN HIGHLIGHTS

- ✓ Original few became "cash cow" divisions of large companies
- ✓ Rapid growth driven by SRC
- ✓ Major traders become processors
- ✓ Innovation stagnated as "R&D" became "copy & follow"
- ✓ Farm development done through supplier alliances
- ✓ Farm development driven by price manipulation
- ✓ Development self-funded by farmers or trader-funded
- ✓ Indonesia and Tanzania develop as significant sources
- ✓ Standards still driven by Marinalg but weakening as processors proliferated, consolidated and failed

Since the mid-1980s the number of SRC and kappa-carrageenan producers has increased tremendously, especially in Asia. At the time of writing about 60 processors were operating in China; at least six significant manufacturers (including the largest carrageenan producing factory in the world) were in the Philippines; about 20 manufacturers were in business in Indonesia; and three were in business in Malaysia.

The proliferation of Asian kappa-carrageenan capacity was partly driven by the fact that kappa-carrageenan and agar are gelling gums that can be produced in the same factories. Production of tropical Gracilaria species as a source of agar has increased to a level of about 40,000 dry tons per annum in Indonesia through the proliferation of simple local technologies that utilize fish ponds and shrimp ponds in a simple form of IMTA.

The proliferation of new entrants into RAGS value chains resulted in successive shifts in value chain dynamics from captive governance the mid-1980s to modular governance by the mid-1990s.

Captive governance had virtually ceased by the mid-1990s. Modular value chains still comprise a small proportion of the trade in RAGS especially for the longest established processors but market governance has dominated the marketplace since the turn of the century.

C-4 Market value chains result in a free-for-all (mid-1990s to present)

MARKET VALUE CHAIN HIGHLIGHTS

- ✓ Processors proliferate – especially in RP, RI & China
- ✓ Many small sellers, tight cottonii supplies
- ✓ much "spot" selling… often in seller's markets
- ✓ Minimal innovation
- ✓Supply growth mainly from farmer self-financing
- ✓ Demand-driven cottonii market leads to chaos in 2008; standards systems virtually ignored
- ✓ Market driven value chains function poorly for performance ingredients such as carrageenan

By the mid-1980s secondary and tertiary producers had built modular value chains through third party intermediaries such as local traders and collectors but by the mid-1990s much seaweed was being sold on the spot-market through market-governance value-chains. Systems of standards that once enabled buyers to trace and control quality broke down. As supply sources developed in less accessible island locations multiple levels of trading proliferated. Although they added little, value agents and officials were in a position to collect rents and gain trading advantage through their possession of capital, superior information and access to politically troubled regions.

Competition for reliable Kappaphycus sources intensified greatly as market demand could not be met by seaweed supplies. By mid-2008 raw, dried cottonii and sacol prices had reached record high levels of as much as 3,000 USD/ton FOB and temporary plant closures were occurring due to lack of raw material for making kappa-carrageenan. Seaweed quality decreased and moisture content increased as prices became higher. Market links ruptured as some major buyers resorted to seeking seaweed "at the beach" at almost any price and quality.

At the time of writing these prices had started to fall (Figure 16) and efforts of processors to find better ways to buy seaweed were underway. In September, 2008 Mr. Fabrice Bohin, global business director for hydrocolloids at Cargill Texturizing Solutions told FoodNavigator.com. that: *"Some customers… are looking more towards strategic suppliers rather than playing around to find the best price – especially if they have a branded product and need to guarantee supply. They are no longer looking for the cheapest alternative… Rather, they are asking how sustainable the supply is and how reliable, whether the company has critical mass, and whether it can assure food safety."*

C-5 The cottonii crisis of 2008 - 2009

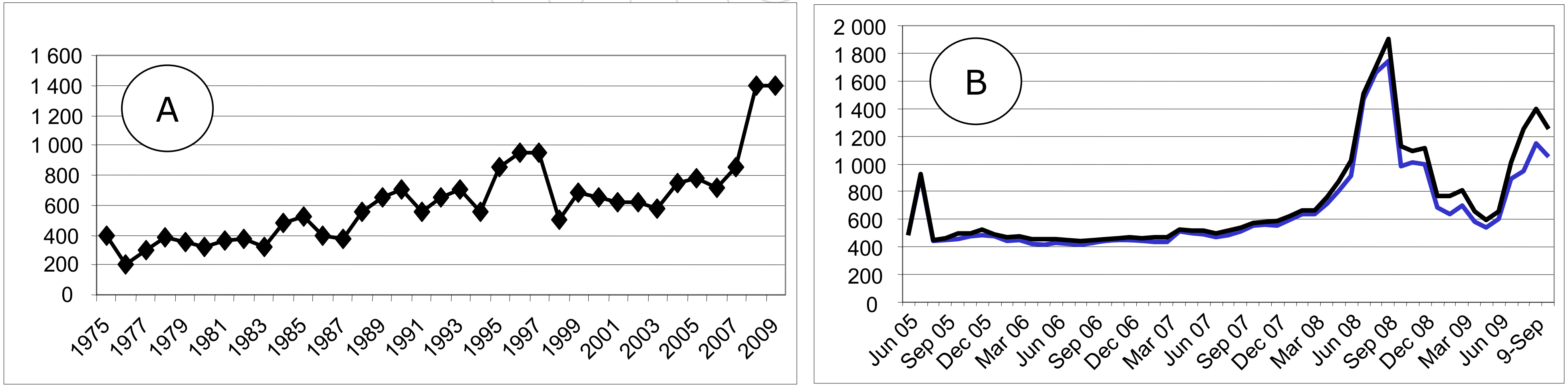
During 2008 spinosum and gracilaria prices remained stable but global prices for cottonii reached unprecedented levels (Figure 16 A).

The 2008 cottonii crisis occurred following 2007 farm production that was below the rate of demand growth by about 6-10,000 tons. By 2008 inventories were low at all value chain levels; many processors had poor knowledge of actual crop production levels and patterns; and unusually aggressive buying by some processors set off a period of panic-buying; As prices rose standards were poorly applied so cottonii quality reached generally low levels. Prices peaked around August and by October farm gate prices in Indonesia appeared to be leveling off at about 1,000 USD/ton (Figure 16 B).

During early 2009 cottonii prices climbed again during the first half of the year and by the end of 2009 farm gate prices were about 1,000 USD/ton again. Throughout 2008-2009 supplies of cottonii were tight and by the end of the year tight gracilaria volumes had stimulated high farm gate prices on the order of 600 USD/ton, which was almost double previous price levels.

Figure 16. A. Typical cottonii prices in USD/metric ton FOB Cebu City, Philippines from 1975 to mid-2008. (SIAP and Seaplant.net data). Prices from Indonesia were generally similar or slightly lower.

B Indonesian minimum and maximum farm gate prices in US$ per metric ton for June, 2005 through July, 2009 (Seaplant.net data)..



C-6 Stifled innovation and fractured links to sources

INNOVATIVE DEVELOPMENT YIELDS TO THE "TRADER MENTALITY" AND "COPY-CAT" TECHNOLOGY

Research and development has stagnated since the innovative SME that once dominated the carrageenan business were purchased by large multi-national owners during the late 1970s and into the 1980s. Those events coincided with a proliferation of SRC producers first in the Philippines and later in Indonesia, China, Chile and Malaysia.

Since the advent of semi-refined carrageenan technology much process capacity developed on the basis of technology obtained from former employees, consultants and equipment suppliers of previously established manufacturers. This process was facilitated by multi-national owners of formerly innovative carrageenan enterprises that cut back on R&D and farm development activities and also discharged many senior, long-term technical and management staff.

Figure 17. As captive value chains declined "research and development" was largely replaced by "copy and follow".

Moving beyond "copycat" technology

RAGS technology and product development have been stagnant for almost 30 years

multi-stream processing and IMTA innovations can have positive value-chain impacts

RAGS PROCESSORS CEASE MAJOR INVESTMENT IN THEIR RAW MATERIAL BASE

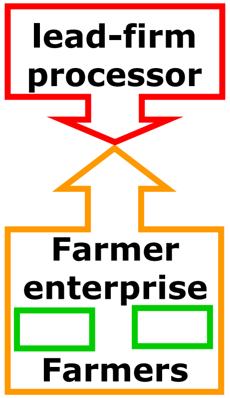
The proliferation of new entrants into RAGS value chains resulted in successive shifts in value chain dynamics from captive governance in the mid-1980s to modular governance by the mid-1990s then market governance by about 2001. The disintegration of exclusive value chain relationships caused side-selling to become a major problem both for the original Marinalg companies and for subsequent entrants as well. Investments in process development and farm development ended abruptly by the mid-1990s because investments could no longer be protected and internalized by private investors. Investment in farm development also diminished because the larger hydrocolloid producers decided that seaweed farming comprised aquaculture and they did not want to be in the aquaculture business.

MARKET GOVERNANCE = FAILED RAGS VALUE CHAINS

Carrageenan and agar are performance chemicals that are generally marketed as components of ingredient solutions. Product performance and production costs cannot be optimised unless seaweed raw material sources are transparently linked from farms through processors to solution providers and end-users. Market-governance value chains do not result in such links. Captive value chains are difficult to establish in today's world and modular value chains function little better than market-governance chains. Relational governance appears to be the best option for RAGS value chain development.

Click to table of contents

C-7 Relational value chains can restore innovation (developing now)



RELATIONAL VALUE CHAIN HIGHLIGHTS

✓ Fewer & larger sellers as farmer enterprises aggregate

✓ Processing sector consolidating (e.g. in China)

✓ Recognized need for transparent links from seaweed source to value solution

✓ Farm development and processing moving toward integrated systems (multi-stream, multi-product)

✓Essential that standards be applied rigorously, transparently and globally

As the twenty-first century commenced it became clear to many in business, government and aid organizations that something was broken in seaweed-to-hydrocolloid value chains. It was equally clear that developing diverse, transparent relational value chains could drive further industry growth and could also provide livelihoods to millions of people who were under the poverty line. Starting in 2003 the IFC-PENSA program (now IFC Advisory Services; a unit of the World Bank) set up its Seaplant Network Initiative in Indonesia to address this issue. Since then several private enterprises, government agencies, non-governmental organizations and aid agencies have commenced the support of relational value chain development. SEAPlant.net Foundation became independent in 2008 and is focusing on IMTA development through relational value chains that are based on the following rationale:

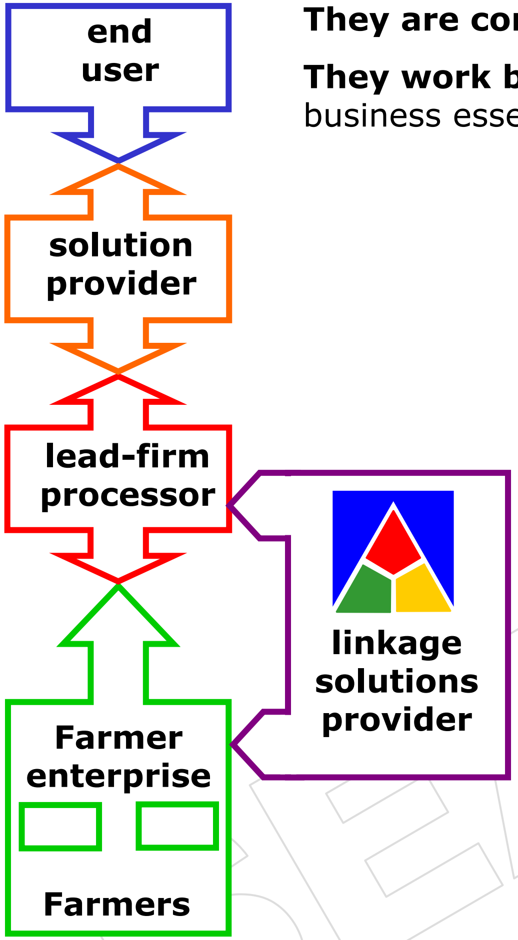
- ❖ Most of the world's seashores that are suitable for tropical aquaculture lay within the Coral Triangle and especially in Indonesia;
- ❖ aquaculture development in the Coral Triangle will be based almost entirely on small-holder farms;
- ❖ in order for small-holder farms to compete in regional and global value chains they must be aggregated into sustainable enterprise units;
- ❖ the long-term business of these enterprises will be sustainable, integrated multi-trophic aquaculture (IMTA);
- ❖ seaweed farming is a solid foundation for IMTA enterprises.

C-8 Relational links work well in seaweed-to-gums value chains

They predominate between solution-providers and end-users

They are common between processors and solution-providers

They work best for farmers if they are aggregated into robust enterprise units with access to business essentials such as those shown below:



Communication & logistics

- ✓ voice-over-Internet communication
- ✓ workshops and meetings
- ✓ training farmers in IT skills
- ✓ connecting farmers to logistic networks
- ✓transport systems

Fair finance

- ✓ warehouse receipting systems
- ✓ crop insurance
- ✓ financial products geared to MSME
- ✓ linkages to sources of assistance
- ✓ electronic banking

Essential goods & social services

- ✓ electronic buy – sell systems
- ✓ education & training systems
- ✓ health care other social services
- ✓ regional collection & distribution hubs

Strategic alliances

- ✓ alliance management systems
- ✓ websites & linkage tools
- ✓ E-business software solutions
- ✓ alliance network tools & solutions

Fair trade in global markets

- ✓ brand management
- ✓ adding value near crop sources
- ✓ secure electronic transaction systems
- ✓ traceable transactions & product flows
- ✓ testing, verification & certification
- ✓ market knowledge & information
- ✓ product innovation & development
- ✓ marketing & sales tools & services

Science & technology

- ✓ "good practices" systems
- ✓ education & training products
- ✓ innovative process & product technology
- ✓ crop science & technology

Click to table of contents

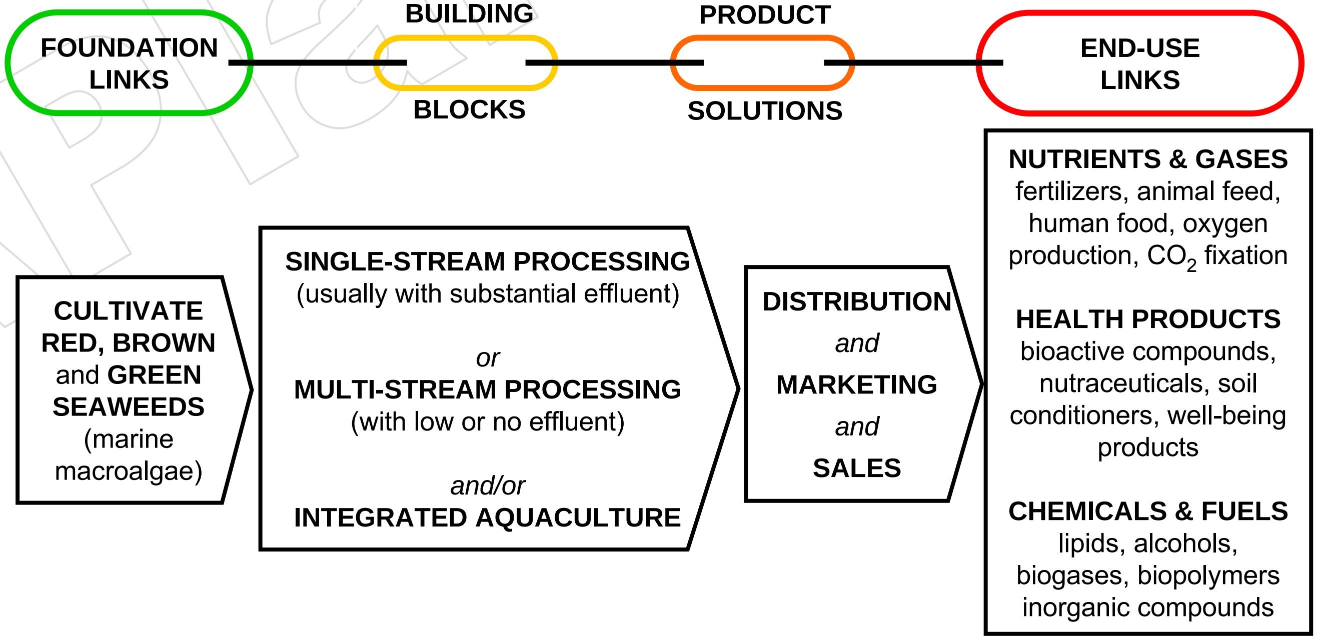
C- 9 Innovations in seaweed processing technology

Commercial goods from seaweeds are produced through the sorts of value chains depicted in Figure 18. Besides directly providing goods to humans seaweeds provide several "ecosystem services" (in the sense of Worm et al 2006) that add value to human life. These include seaweed as food for herbivores and omnivores; assimilating nutrients and pollutants; consuming ammonia; fixing carbon dioxide; producing oxygen; providing habitat niches; acting as substrates for other organisms; and supporting aesthetic experiences such as diving and wildlife watching.

Single-stream processing is the norm for Kappaphycus spp. (cottonii of the trade), Eucheuma spp. (spinosum of the trade) and Gracilaria spp. These genera comprise most tropical seaweed production and they are used primarily as raw material for manufacturing the hydrocolloids (gums) known as kappa-carrageenan, iota-carrageenan and agar. Generally tropical seaweeds are dried and shipped as raw seaweed and typical gum yields range from as low as 8% to 30% or more. About 70-92% of seaweed weight shipped enters waste streams at the site of processing.

Multi-stream processing is an innovation that could have positive impacts on the competitiveness of tropical seaweed products. Processing begins using small-scale facilities and appropriate technology starting with live crops near the farm. Nothing goes to waste. The nutrient component of seaweeds is extracted for local use or is processed for export. The gum component can be shipped as a high-yielding, low-waste concentrate or can be processed into finished form in "mini-factories".

Figure 18. Presently single-stream processing yields most products from seaweeds. In the future multi-stream processing and IMTA innovations can have positive value-chain impacts



FOUNDATION LINKS

BUILDING BLOCKS

PRODUCT SOLUTIONS

END-USE LINKS

CULTIVATE RED, BROWN and GREEN SEAWEEDS (marine macroalgae)

SINGLE-STREAM PROCESSING (usually with substantial effluent)

or

MULTI-STREAM PROCESSING (with low or no effluent)

and/or

INTEGRATED AQUACULTURE

DISTRIBUTION *and* **MARKETING** *and* **SALES**

NUTRIENTS & GASES
fertilizers, animal feed, human food, oxygen production, CO_2 fixation

HEALTH PRODUCTS
bioactive compounds, nutraceuticals, soil conditioners, well-being products

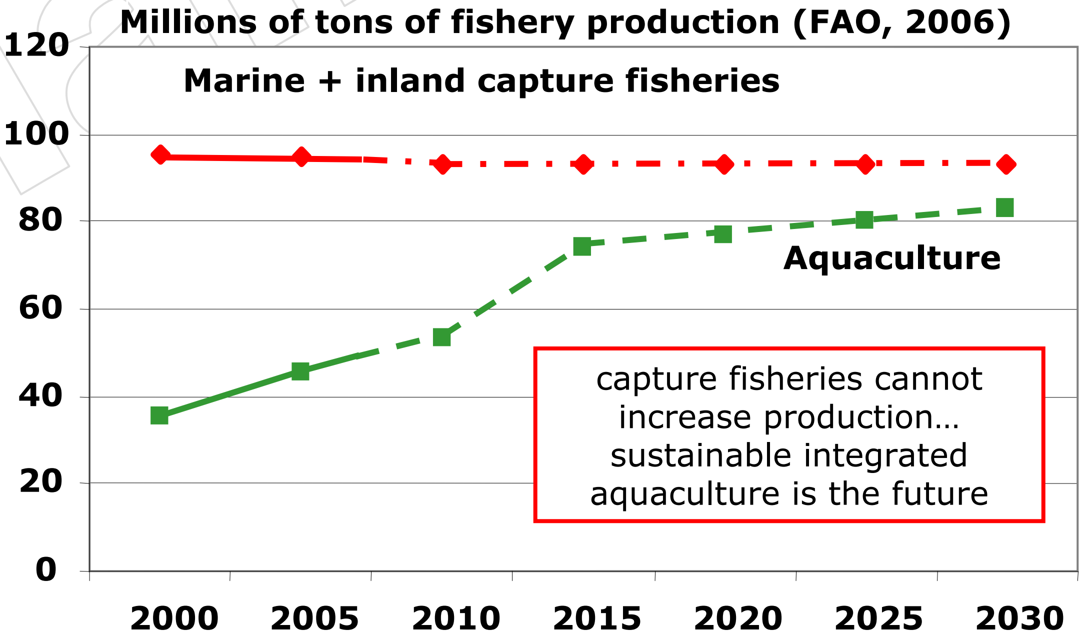
CHEMICALS & FUELS
lipids, alcohols, biogases, biopolymers inorganic compounds

D-1 The global need for aquaculture

FAO (2000, 2006) data and analyses indicated that aquaculture is essential if demands for fishery products are to be met over the coming decades. Average global annual growth rates from 1970-2004 were 8.8 % for aquaculture, 1.2 % for capture fisheries and 2.8 % for terrestrial meat production. FAO reported that:

- 2004 global capture fisheries production reached 95 M tons with first-sale value of 84.9 B USD.
- Animal aquaculture production in 2004 was 45.5 M tons with a value of 63.3 B USD
- Seaplant production was 13.9 M wet tons with a value of 7 B USD.
- From 2008-2030 the annual yield of capture fisheries will remain flat at about 93 M tons/yr.
- Animal aquaculture was projected to rise from about 50 M tons/annum to 83 M tons.
- This increase amounts to annual added production by 2030 of 33 M tons worth about 46 B USD (2004 values).
- Growth of animal aquaculture was projected to be 2.6 M tons/yr from 2000-2015 then 0.6 M tons/yr after 2015.
- The rate of growth for global aquaculture growth may have peaked except for some regions and species.
- From 2000-2004 China accounted for nearly 70 % of global aquaculture production
- Average annual growth rates were:
  - developed countries 2%;
  - China 5%;
  - Latin America/Caribbean 10%;
  - Near East/North Africa 14 %;
  - developing countries 11 %.
- Southeast Asia was not yet a leading aquaculture development region.

Figure 19. Outlook for global capture fisheries and aquaculture from 2000-2030 (excluding seaplants).



capture fisheries cannot increase production… sustainable integrated aquaculture is the future

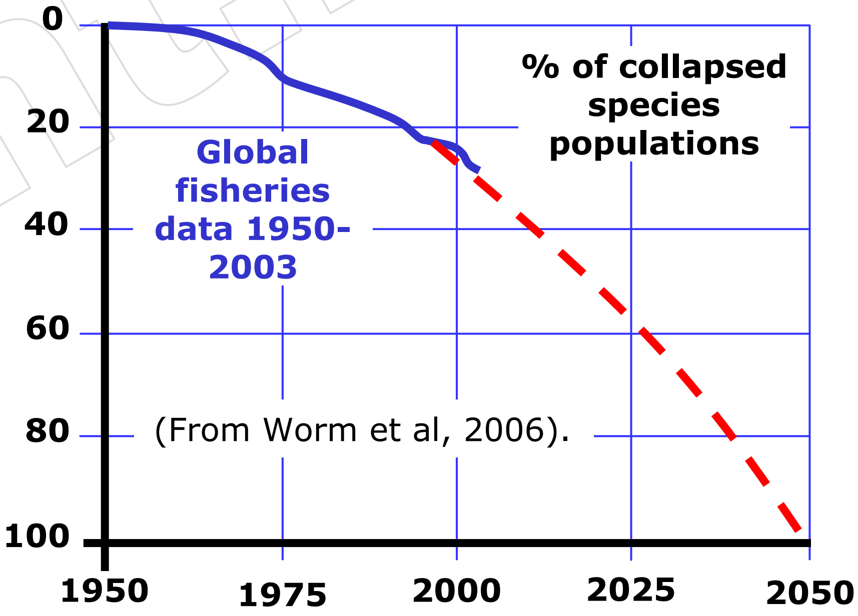
Click to table of contents

D-2 Biodiversity and biomass in managed ecosystems

The subject of biodiversity impacts on global fisheries has been active and contentious in recent scientific literature and much is being learned about this complex subject (Berkes *et al*; 2006; Worm *et al* 2006 and 2007). The 2006 paper of Worm *et al* attracted considerable international attention when they projected that current rates of biodiversity loss in ocean systems could conceivably lead to a collapse of all commercial fisheries by 2048 (Figure 20). Fisheries managers are still in the process of formulating and testing hypotheses relevant to the state of the world's fisheries but there seems to be common consensus among fisheries managers on some issues, namely:

1. Biodiversity has declined in many large coastal and open-ocean ecosystems.
2. Several fisheries have collapsed since man began intensive fishing of global ocean systems.
3. As biodiversity diminishes ecosystems become destabilized and the living populations within them are increasingly vulnerable to natural or man-made perturbations.
4. Many fisheries have been effectively unregulated or have not been controlled by defined jurisdictions. Therefore a "tragedy of the commons" has occurred and "roving bandits" have been able to exploit fisheries without concern for future impacts of their actions (Berkes *et al*; 2006).
5. Humanity is best served by management that sustainably maintains high biodiversity and biomass in ocean habitats.
6. Although considerable damage has been done to ocean habitats and populations there is still scope for humanity to implement management strategies that enable damaged habitats or populations to recover.

Figure 20. Extrapolated long-term trend at projected levels of fishing



(From Worm et al, 2006).

IMTA systems are a component of integrated seashore development strategies that can play a role in preserving ocean biodiversity and biomass. One of the main roles of IMTA is to take pressure off natural ecosystems so they can be managed and conserved to preserve biodiversity and biomass at high and sustainable levels. IMTA systems can also play a role in enhancing and sustaining recruitment in natural ecosystems.

D-3 Roving bandits and the tragedy of the commons

Berkes et al; (2006) have pointed out how "roving bandits" have devastated fisheries in habitats where they have had neither proprietary rights nor economic incentives to invest in sustainable resource utilization. The "tragedy of the commons" is that such common-property habitats can be destroyed before problems are even perceived. Even if problems are perceived there may be no jurisdiction that has the authority or capacity to do anything about fostering sustainable habitat survival.

The "tragedy of the commons" is most apparent in open-ocean fisheries but it has also occurred widely along seashores of the Coral Triangle where human populations have grown and low barriers to entry have prompted an increasing number of people to undertake artisanal fisheries, often using destructive devices such as explosives, toxins and monofilament gill nets (e.g. Maarif, and Jompa, 2007). Another instance of roving bandits along seashores in manifested by the uncontrolled cutting of mangrove forests that has occurred in the Coral Triangle where mangrove wood is a favoured cooking fuel and building material.

Fortunately there has been substantial progress toward building stewardship of seashores among coastal populations in some regions. In Indonesia, for example, decentralization programs have increasingly placed foreshore management in the hands of the people who live by the foreshore and there has been substantial effort undertaken by government and private organizations to build attitudes of stewardship.

If sustainable seashore development is to continue in the Coral Triangle, means must be found to promulgate the attitudes, methods and means for good stewardship throughout the region. At the same time legal governance systems must be put in place to manage proprietary rights and privileges for seashore property.

Most Coral Triangle seashores have not yet been extensively developed for aquaculture except in highly populated regions such as Luzon, East Java and South Sulawesi. Most of the region remains as an opportunity for future sustainable seashore development.

FAO noted that aside from marine shrimp most aquaculture production in developing countries comprised omnivorous and herbivorous fish or filter-feeders whereas carnivorous species accounted for most production in developed countries. This is an important difference since the diversity of herbivorous fish and invertebrates endemic to the Coral Triangle gives cause for optimism that aquaculture development can progress based on lower trophic level species.

Click to table of contents

D-4 IMTA is a multi-billion dollar per annum Coral Triangle opportunity

According to FAO (2006) animal aquaculture is projected to rise from about 50 M tons/annum to 83 M tons (Figure 19). This increment of increase amounts to added annual production by 2030 of 33 M tons worth at least 46 B USD.

The Coral Triangle region has about 25% of the world's coastline.

If it can capture at least 25% of the required projected growth in aquaculture production there would be between 10-20 M tons/annum more aquaculture production in the Coral Triangle by 2030 and this would be worth at least 14-28 B USD/annum to Coral Triangle economies.

If IMTA and other technologies raise limits to production and market forces take over the amount of increase could be significantly higher than FAO projections. For example if the rate of increase from 2008-2030 continued at the 2000-2004 rate of 2.6 M tons/yr then annual production by 2030 could be about 110 M tons/yr and added value would be on the order of 85 M USD/annum.

Seashores in the Coral Triangle are potentially among the most productive in the world so the comparative advantage of the Coral Triangle region could give it an opportunity to capture as much as 30-40% of any increase in global aquaculture production. In that case aquaculture could add as much as 40 B USD/annum to Coral Triangle economies by 2030. Much of this possible increase in aquaculture production would be in areas where "under-development" is the norm today and where economic opportunities seem few and far between.

At regional aquaculture planning meetings it has been evident that there is considerable willingness from a wide range of stakeholders to collaborate and move toward integrated, sustainable seashore development. The problem is that funds for moving forward are scanty at best. The resources of aquaculture planning agencies are so stretched that all those great ideas and sweeping plans tend to languish before they can even be set down in a proper report – never mind getting implemented.

With adequate investment integrated sustainable seashore development in the Coral Triangle can be a huge business opportunity based largely on existing technology; that addresses existing market demands; that can alleviate poverty for millions of people; and can be undertaken with beneficial environmental impacts.

In due course the need for outside support for agriculture and aquaculture development will diminish and IMTA MSME will be self sufficient. Before this can happen, however, it is necessary to put structures in place and to transfer knowledge, information, tools and solutions to people along tropical seashores who are currently near, at or below the poverty line. The actions described in Section E, below, are proposed as means of making this happen.

Click to table of contents

E-1 Develop "market pull" to drive sustainable development

The cultivation of seaweeds such as Kappaphycus, Eucheuma and Gracilaria developed in the Coral Triangle region during the 1970s and 1980s because producers of carrageenan and agar required those seaweeds as raw material and their businesses could not grow unless they pro-actively supported seaplant aquaculture. Consequently these producers played a very active role in developing seaweed farming. This market is still under-supplied with raw material and appears to be growing strongly (Figure 8). Doubling production over the next decade would add about 2 M tons per annum of fresh production worth about 100 M USD/annum at the farm gate. Developing multi-stream processing that recovers both gums and nutrients from the crop could at least double this value at the same time that it eliminates waste. Carrageenan and agar seaplants provide a nucleus and a cash flow base for thousands of seashore MSME. This base serves as a foundation for developing IMTA. The "market pull" model that has driven seaweed cultivation in the Coral Triangle can also drive the development of other IMTA crops. This can probably be done best through the producer organizations, networks and alliances cited in section E-5 below.

E-2 Build the capacity of micro, small and medium enterprises (MSME)

Throughout the Coral Triangle proprietary rights to utilize seashore property will almost certainly remain in the hands of the coastal people who live and work by the seashore. Aquaculture activities will be undertaken by MSME owned and operated by those people.

These enterprises require ongoing support from business development service providers (BDSP) and by financial institutions (FI). Between them the BDSP and the FI can support value chain participants with business essentials (see section E-5 below). The development of BDSP and FI supporting seashore-based MSME has grown substantially in the Coral Triangle during the past decade. but much more BDSP and FI capacity is required before the multi-billion USD/annum production potential of IMTA systems in the Coral Triangle can be realized.

The management of IMTA systems, MSME and integrated seashore management programs will require a steady supply of well educated technicians, scientists and business managers. BDSP services will have an important role to play in education during early stages of development but in the long run it is universities and other educational institutions that must provide the aquaculturists of the future.

For MSME to link into global value chains they must aggregate into strong business units. Options include the strengthening of cooperative systems and the development of franchise systems.

Click to table of contents

E-3 Develop and implement sustainable aquaculture protocols

FAO has taken the lead in developing global sustainable aquaculture protocols and FAO/NACA are in the lead in developing protocols specific to Asia and Pacific Oceania. It is an important feature of these protocols that they emphasize the minimization of impacts by aquaculture systems on adjacent seashore habitats and on capture fisheries. For example the need to conserve, manage and restore mangrove forests and wetlands is a high priority. So is the need to minimize the dependence of aquaculture systems on fish meal and food crops.

Seashores are among the most valued pieces of real estate on the planet. They are valued for a multitude of uses so clear and consistent systems of legal governance must be in place to prevent conflict risk among aspiring users. This is apparent to the governments of Coral Triangle countries and the development of effective seashore governance is an active activity for all of them.

It is essential for aquaculturists to ensure that IMTA finds its place in seashore planning. Long-term development of IMTA systems requires that economically and environmentally sustainable energy sources should be used. Along seashores of the Coral Triangle sunlight, wind and water movement all provide ample opportunity for the use of “green” sources of power for drying crops, driving pumps, regulating water temperature, aerating water and other necessary uses of energy.

There is still a lot to be learned about the role that seaplants can play in carbon cycles, nitrogen cycles and other nutrient cycles along coastal zones. Also the potential use of seaplants in production of bio-diesel, biogas, alcohol and other fuels is a subject that has been revisited several times. These are topics that require further research and analysis.

E-4 Bridge effectively from research and development to commercial scale-up

There are already useful networking systems among regional tropical aquaculture R & D organisations and there is a vast amount of technology that is on the brink of being applicable in commercial enterprises. It is evident, however, that the means for migrating R & D findings to commercial practice are weak. There is an urgent need for “incubator” enterprises that can nurture developed technologies from the laboratory, through pilot scale to full-scale IMTA systems.

This is not to say that further R & D is not required. On the contrary, the development and refinement of IMTA systems and seashore management systems will require sustained scientific research and technical development activities. This must go on for as long as there are people who want to consume and utilize sea products.

Click to table of contents

E-5 Build producer organizations, networks and alliances

Support from business development service providers (BDSP) and by financial institutions (FI) is best mediated through producer organizations, networks and alliances. The Coral Triangle countries are linked into NACA (Network of Aquaculture Centres in Asia-Pacific). At an FAO/NACA Mariculture Workshop held in Guangzhou, China during March, 2006 it was concluded (report in prep) producer organizations and alliance networks are essential to the efficient development of business functions and industry-representation functions for the mariculture sector of Asian economies. It was also concluded that such organizations can prosper if – and only if – the following elements are available, accessible and effectively utilized:

1. Appropriate local, national & regional plans including legal parameters that effect the industry.
2. Fair markets that include awareness of culture practices that relate to product quality and food safety and link effectively with market requirements.
3. Finance and insurance on equitable terms.
4. Knowledge, information, tools and skills relevant to appropriate technology, markets, business management practices, environmental considerations and social impacts.
5. Essential infrastructure, goods and services including communication and logistical links.

Specific actions recommended for achieving these objectives included:

1. Facilitate a few value chains that are of general regional significance (e.g.. cage culture of finfish for live markets; seaplants for specialty ingredient and agricultural uses; mollusks for general nutritional purposes.
2. Support development of effective “solution providers” (e.g. business development services; diagnostic, testing and treatment services; linkages to the essentials of enterprise management and operation).
3. Mobilize regional institutions in development of a comprehensive mariculture-oriented Geographic Information System (GIS) for coastal regions.
4. Place special emphasis on institutional collaboration in human resource development.

As of July, 2008 SEAPlant.net Foundation (SPNF) was spun-off from IFC and the purpose of SPNF is to use all available means to move forward on these and other actions proposed in this monograph.

REFERENCES

REFERENCES (1 of 3)

Berkes, F., Hughes, T.P., Steneck, R.S., Wilson, J. A., Bellwood, D. R., Crona, B., Folke, C., Gunderson, L. H., Leslie, H. M., Norberg, J., Nyström, M., Olsson, P., Österblom, H., Scheffer, M., and B.Worm (2006). Globalization, Roving Bandits, and Marine Resources. *Science*, Vol. 311, pp. 1557-.1558.

CIA, 2007. *The World Factbook*. United States of America Central Intelligence Agency. [E-book available as download January, 2008 https://www.cia.gov/library/publications/the-world-factbook]

Food and Agricultural Organization of the United Nations (FAO) 2000. *The state of world fisheries and aquaculture 2000*. [Electronic edition available January, 2008 http://www.fao.org/DOCREP/003/X8002E/x8002e00.htm ISBN 92-5-104492-9.

Food and Agricultural Organization of the United Nations (FAO) 2006. State of World Aquaculture 2006, *FAO Fisheries Technical Paper No. 500* (FAO Rome), 162 pp.

Gereffi, G., Humphrey, J. and T. Sturgeon, 2005. The governance of global value chains. *Review of International Political Economy* 12:1 February 2005: 78–104

Hall, Jack, 2007. *The Most Important Organism?* [Electronic article available Jan, 2008 http://www.ecology.com/dr-jacks-natural-world/most-important-organism/index.html]

Hurtado, A.Q. and Critchley, A.T. 2006. *Seaweed industry of the Philippines and the problem of epiphytism in* Kappaphycus *farming*. In Advances in seaweed cultivation and utilisation in Asia. Phang, S.M, Critchley, A.T and Ang, P.O. Editors. University of Malaya Maritime Research Centre.

JLJ Group, 2006. *Preliminary Study – Chinese Market for Seaweed and Carrageenan Industry.* Final Report July 6, 2007. A study undertaken for the SEAPlant.net Initiative of IFC-PENSA.

Maarif, Syamsul and Jompa, J. (2007). *The Coral Triangle and Coastal Community Development through Sustainable Integrated Aquaculture.* Paper presented at the Sustainable Integrated Mariculture Meeting & Workshop of Konsorsium Mitra Bahari. Makassar, Indonesia 27- 30 November, 2007.

Click to table of contents

REFERENCES (2 of 3)

McHugh, Dennis J., 2003. A guide to the seaweed industry, *FAO Fisheries Technical Paper No. 441*, Rome, FAO 105 pp.

Muraoka, Daisuke (2004). Seaweed resources as a source of carbon fixation. *Bulletin of Fisheries Research Agency (of Japan)* Supplement No. 1, 59-63.

Nature Conservancy, The, 2004. *Delineating the Coral Triangle, its ecoregions and functional seascapes Version 1.1*. Report on an expert workshop, held at Bali, Indonesia (April 30 - May 2, 2003)

Neish, Iain C. 2005. *The Eucheuma Seaplant Handbook Volume I : Agronomics, Biology and Crop Systems.* SEAPlantNet Technical Monograph No. 0505- 10A. ISBN 979 99558 0 7.

Neish, I. C. 2007. *Trade balances for BIMP-EAGA countries in seaweed-to-hydrocolloid value chains.* Report prepared for the Asian Development Bank. [Available on request to www.seaplant.net]

Neori, Amir, Chopin, T., Troell, M., Buschmanne, A. H., Kraemer, G. P. Halling, C., Shpigel, M. and Yarish, C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture* Vol. 231 pp. 361–391

Neori, Amir, Max Troell, M., Thierry Chopin, T., Yarish, C. Critchley, A. and. Buschmann, A. H. 2007. Blue Revolution: the Need for a Balanced Ecosystem Approach to Aquaculture. *Environment* Volume 49 Number 3 pp. 36-43.

Panlibuton, H., Porse, H. and E. Nadela, 2007. *Seaweed/Carrageenan Value Chain Assessment: Final Report*. Study conducted for Seaplant.net initiative of IFC Advisory Services and for GTZ Philippines. 47 pp.

SEAPlant.net 2008a. *An Analysis of the Trade in Tropical Red Seaweeds and their Products 2000-2007; focus on the BIMP-EAGA region of ASEAN in the Coral Triangle*. SEAPlant.net Monograph no. HB2B 0808 V2

SEAPlant.net, 2008b. *A Ten-step Functional Framework for building Ventures and Alliances among Seaplant Enterprises*. SEAPlant.net Monograph No. HB2C 0808 V1

REFERENCES

REFERENCES (3 of 3)

Sulu, R., Kumar, L., Hay, C. and Pickering, T. 2004. *Kappaphycus seaweed in the Pacific : review of introductions and field testing proposed quarantine protocols*. Noumea: Secretariat of the Pacific Community. (Aquaculture Technical Papers / Pickering) ISSN 1683-7568. Agdex Pacific Islands 395/609. ISBN 982-00-0041-6

Worm, Boris., Barbier, E.B, Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S. R., Sala,E., Selkoe, K. A., Stachowicz, J. J. and R. Watson. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science*, Vol. 314, pp. 787-790.

Worm, Boris., Barbier, E.B, Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S. R., Sala,E., Selkoe, K. A., Stachowicz, J. J. and R. Watson. 2007. Response to Comments on “Impacts of Biodiversity Loss on Ocean Ecosystem Services”. *Science*, Vol. 316, pp. 1285d.

Zemke-White, W. Lindsey and Ohno, M. 1999. World seaweed utilisation: an end of century summary. *Journal of Applied Phycology 11*: pp. 369-376

Zemke-White, W. L. and Smith, J. E. 2006. Environmental impacts of *Eucheuma spp.* farming. In The World’s Seaweed Resources 2nd Ed. (eds. Ohno M. & Critchely A. T.).

METHODS

Geographic and demographic came from the World Factbook 2007 (CIA 2007). Tropical jurisdictions were deemed to be those that have their geographic centres within the 24th parallels. Export and import data from 2000-2006 were obtained from Trade Data International Pty. Ltd. Data were processed and analyzed from 34 countries known to be among the most active in the seaweed and hydrocolloid trades. The data included harmonized customs codes commencing with 121220 (seaweeds and other algae) and 13023 (vegetable mucilages, thickeners and gums). A detailed description of how the data were analysed can be found in SEAPlant.net Monograph no. HB2B 0808 V2.

ACKNOWLEDGEMENTS

The present monograph was written with partial support from IFC Advisory Services and GTZ. The author would also like to acknowledge the contribution made by Dina Saragih, Boedi Julianto and Irsyadi Siradjuddin. He also acknowledges the contribution of scientific colleagues in the forefront of IMTA development including Anicia Hurtado, Amir Neori, Alan Critchley and Thierry Chopin.