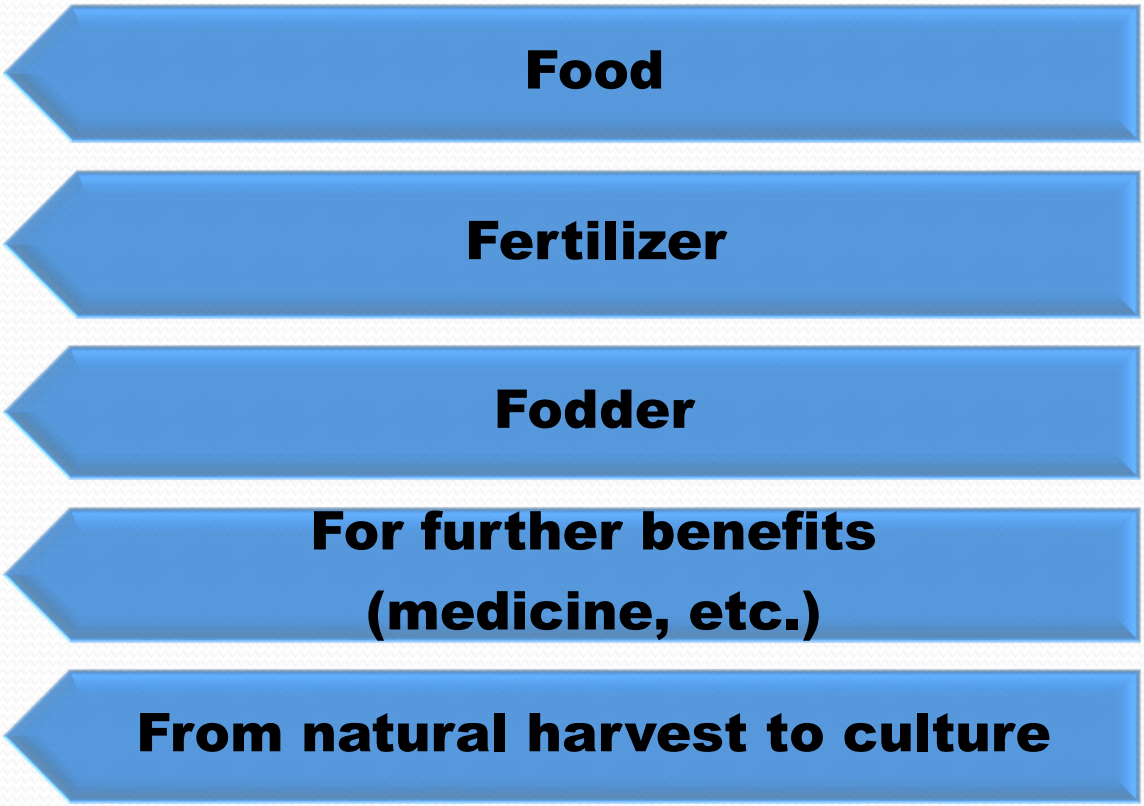
Seaweed Culture: Then, Now and What's Next?

Rhodora V. Azanza and Gavino C. Trono, Jr.

The Marine Science Institute, University of the Philippines
National Academy of Science and Technology

Seaweed uses



Trono, 1997; Montaño, 2015

Euchuema/Kappaphycus culture: Beginnings

- More than 6 years of R&D at University of Hawaii prior to 1972 test planting – Maxwell S. Doty and grad students
  - Countries- Fiji, Micronesia, Indonesia, Philippines

1975- only successful technology transfer in the Philippines

BFAR

UPMSI

University of Hawaii

US Sea Grant

USA Marine Colloids-now FMC Biopolymer

Doty 1971, 1973; Doty and Alvarez, 1975

List of edible seaweeds in the Philippines (Trono, 1997; Montaño, 2015)

Red

Porphyra crispata
Trichogloea requienii
Gelidiella acerosa
Halymenia dilatata
Halymenia durvillaei
Gracilaria arcuata
Gracilaria blodgetti
Kappaphycus cottoni
Eucheuma arnoldii
Acanthopora spicifera
Laurencia papillosa
Bostrychia tenella
Titanophora weberae
Hypnea charoides
Scinaia hormoides

Brown

Hydroclathrus clathratus
Sargassum
Rosenvingea intrica

Green

Ulva lactuca
Chaetomorpha crassa
Caulerpa lentillifera
Codium edule

Kappaphycus alvarezii

Caulerpa lentillifera

Rosenvingea intrica

Images from Trono, 1992 and Trono 1997

Seaweed harvested from wild and/or cultured

Species	Harvested from wild	Farmed/Cultured
Europe		
Alaria esculenta (brown)	UK	
Ascophyllum nodosum (brown)	UK, France, Ireland, Norway, Portugal	
Asparagopsis armata (red)		France, Ireland
Chondrus crispus (red)	UK, France, Ireland Spain, Portugal	France
Codium sp. (green)	Spain, Portugal	
Corallina officinalis (red)	UK, Ireland	
Dilsea carnosa (red)	Ireland	
Fucus sp. (brown)	UK, France, Ireland, Spain, Portugal	
Gelidium corneum (red)		
Gelidium sesquipedale (red)	France, Portugal, Spain	
Gigartina pistillata (red)	Spain, Portugal	
Gracilaria spp. (red)		Portugal, *Chile (South America)
Himanthalia elongata (brown)	UK, France, Ireland, Spain	
Laminaria digitata (brwon)	Uk, France, Ireland, Norway	UK, France, Ireland, Norway
Laminaria hyperborea (brown)	UK, Ireland, Norway, France	UK
Mastocarpus stellatus (red)	UK, France, Ireland, Spain, Portugal	
Palmaria palmata (red)	UK, France, Ireland, Portugal, Norway	France, Ireland
Porphyra umbilicalis (red)	UK, France, Spain	France, Ireland, Norway
Saccharina latissima (brown)	UK, France, Portugal, Norway	UK, France, Norway, Spain
Ulva sp. (green)	UK, France, Ireland, Norway, Spain, Portugal	France
Undaria pinnatifida (green)		France, Spain

Sources: SEAFDEC; NETALGAE; Australian Government: RIRDC

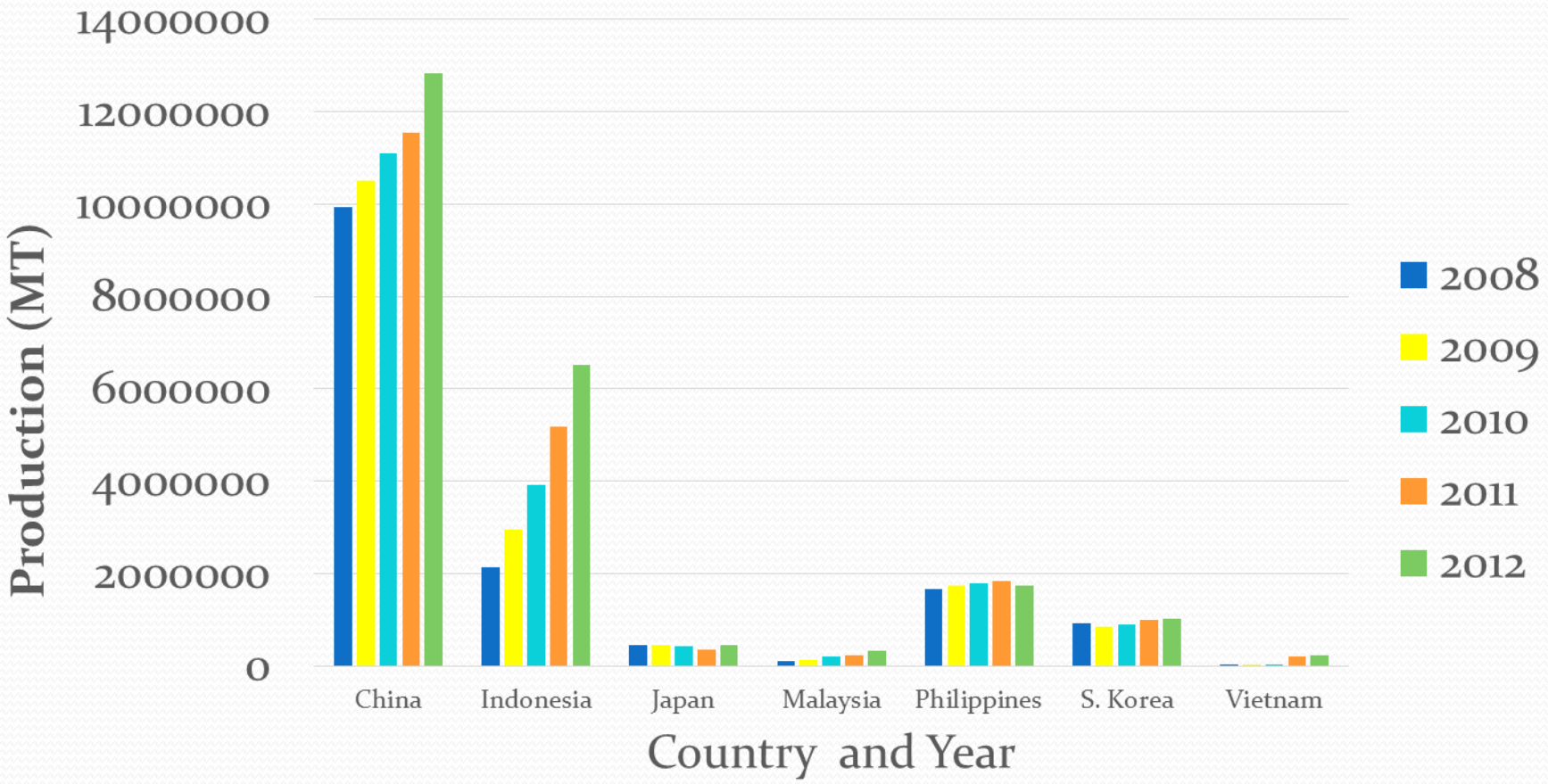
Seaweed harvested from wild and/or cultured

Species	Harvested from wild	Farmed/Cultured
Asia		
Porphyra (red)	Philippines, Hongkong, Thailand, Malaysia	Japan, Korea, China, Taiwan
Undaria (brown)		Japan, Korea, China
Laminaria (brown)		Japan, Korea, China
Eucheuma (red)	Malaysia	Philippines, Singapore,Indonesia
Gelidium(red)		China
Kappaphycus (red)		Philippines
Gelidium (red)		China, Philippines
Caulerpa (green)	Philipppines, Indonesia, Malaysia	Philippines
Codium(green)	Philippines	
Gracilaria (red)	Philippines, Singapore, Malaysia, Vietnam, Thailand, Taiwan, India	India
Sargassum (brown)	Philippines, Malaysia, Vietnam. India	
Acanthopora	Indonesia	
Australia*		
Phyllospora comosa (brown)		
Ecklonia radiata (brown)		
Dictyota sp. (brown)		
Petalonia sp. (green)		
Porphyra (red)		
Sargassum (Brown)		
Gracilaria (red)		
Ulva sp. (green)		

** pilot trials for culture; countries not specified*

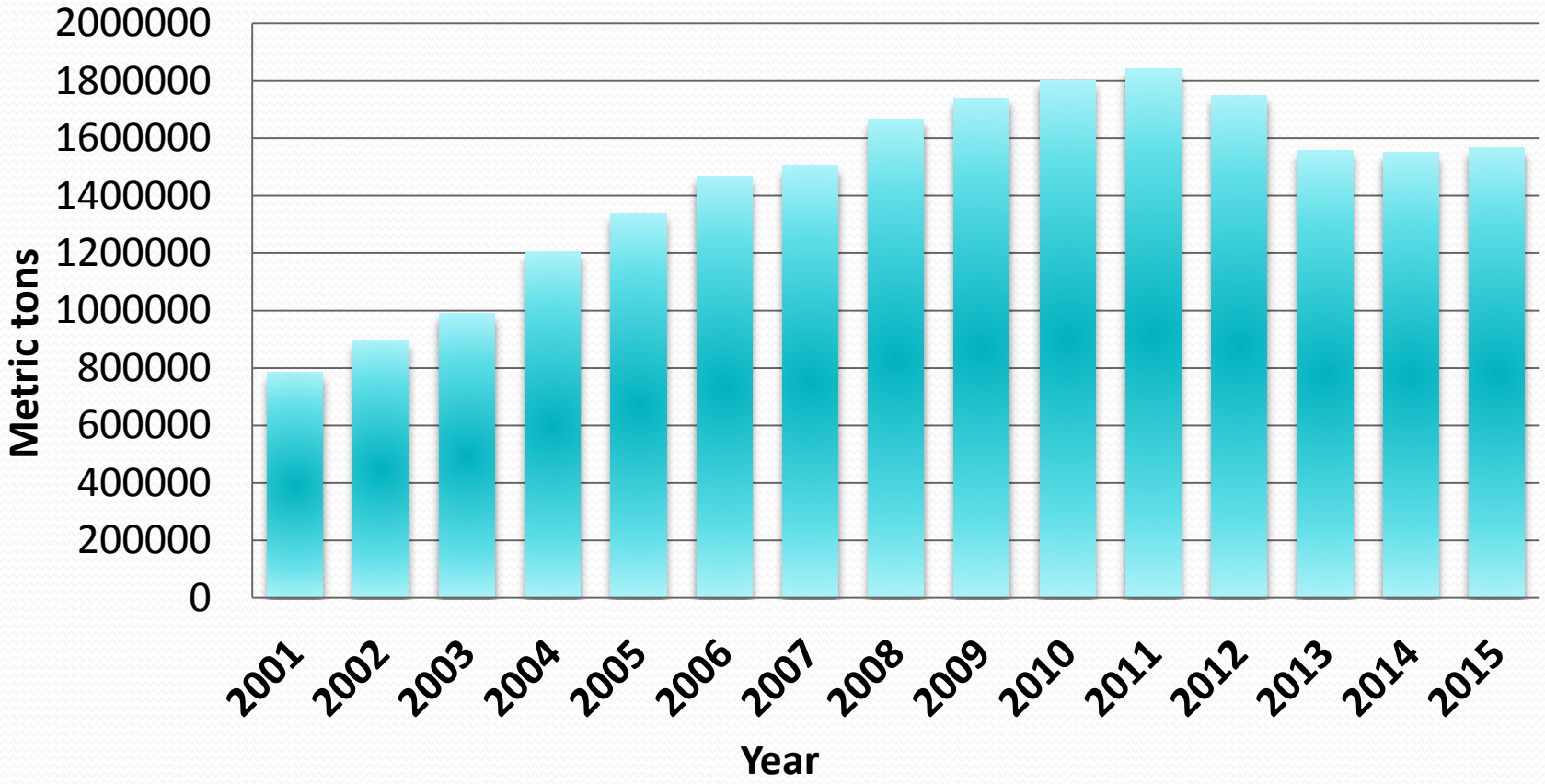
Sources: SEAFDEC; NETALGAE; Australian Government: RIRDC

World fresh seaweeds production (MT) from 2008-2012



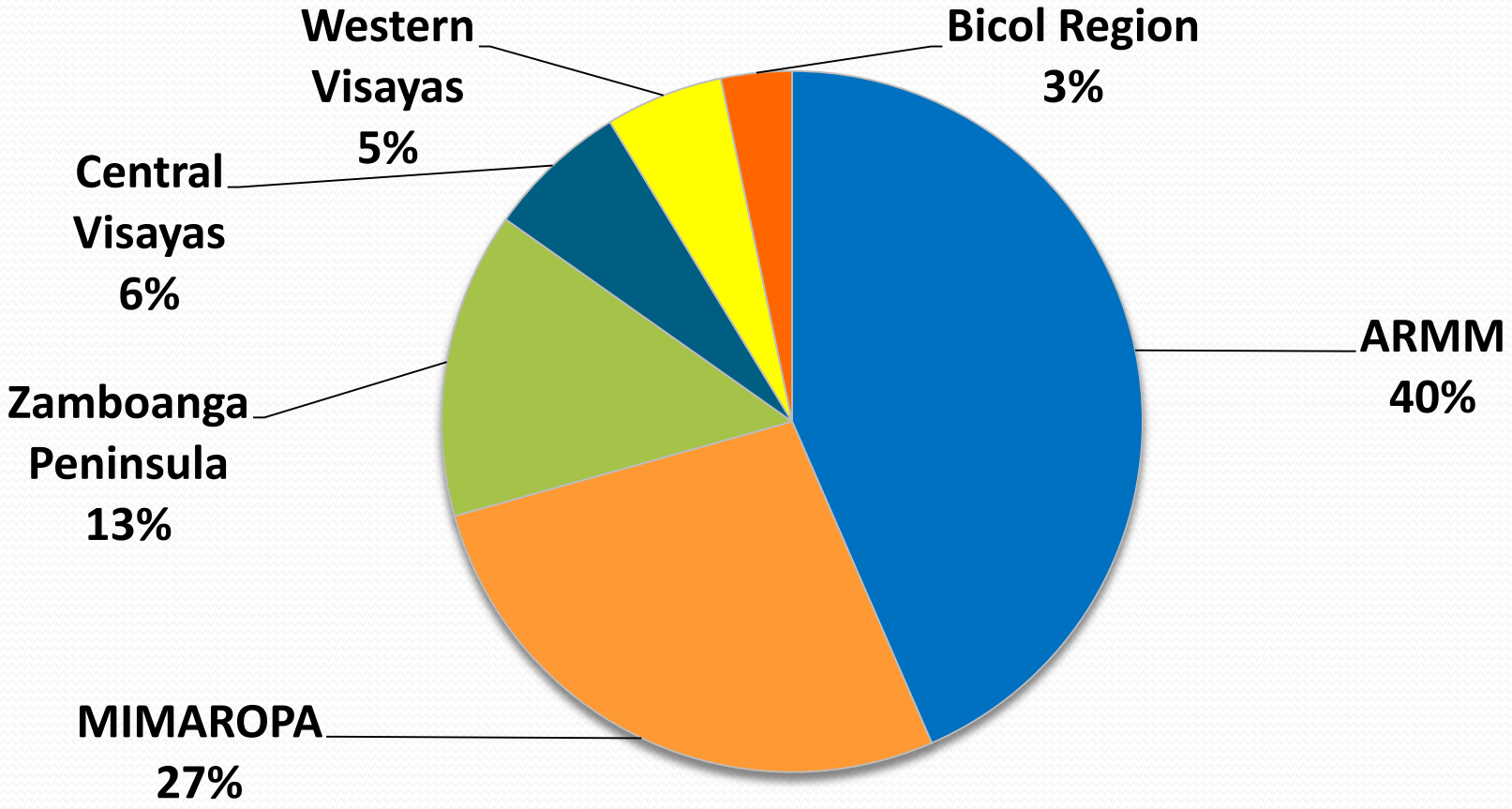
Source: FAO, 2012

Volume of seaweed production in the Philippines from 2001-2015

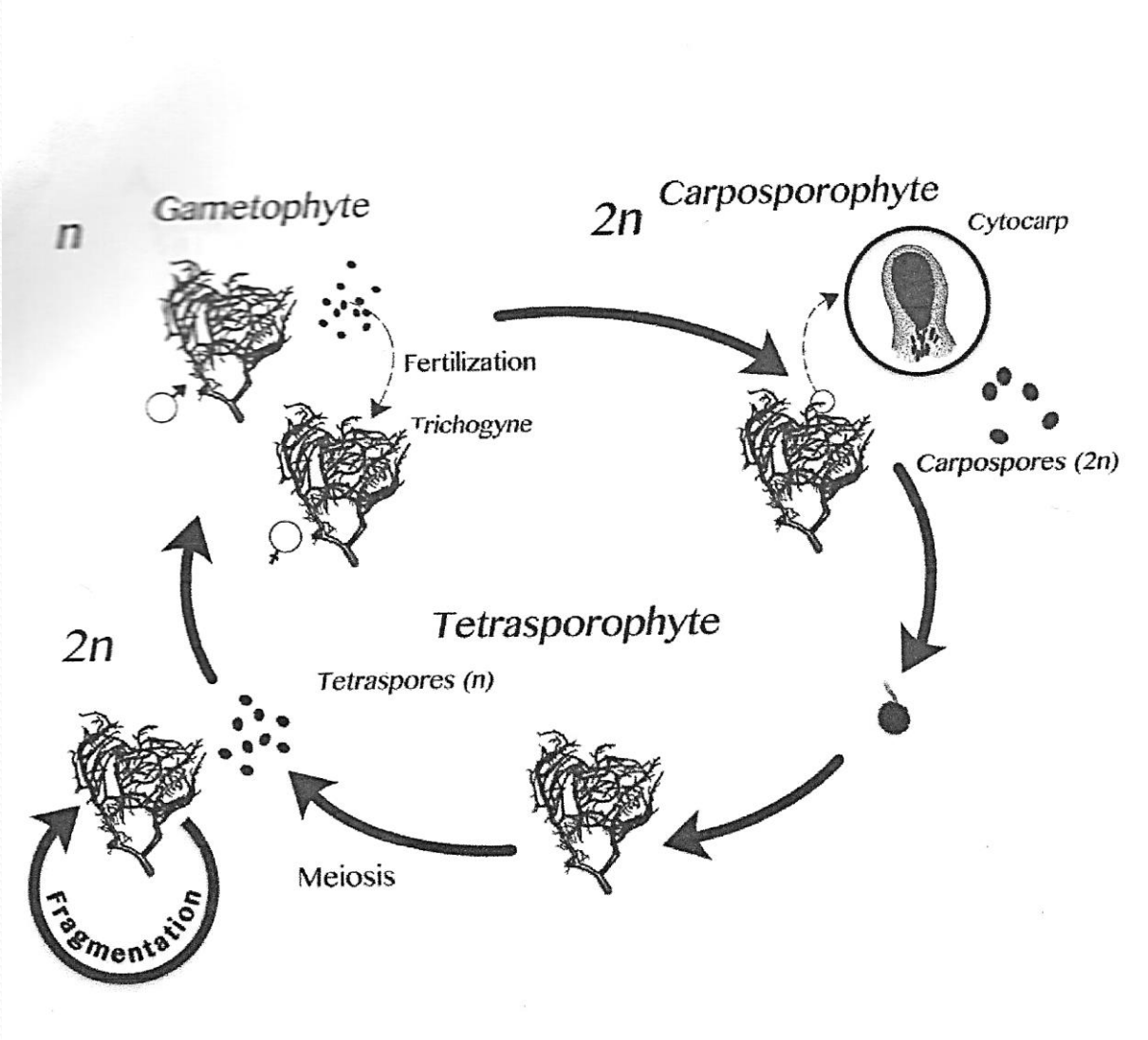


Source: Fisheries Statistics of the Philippines

Percent of major seaweed producing regions in the Philippines 2015



Source: Fisheries Statistics of the Philippines



Life cycle of *Kappaphycus* and *Euchema* (Azanza and Ask, in press)

Kappaphycus/ Eucheuma Spore studies

1. Morphology/shedding and germination/occurence in farms
   - Azanza-Corrales et al. 1992
   - Azanza and Aliaza 2001
2. Outplanting- Luhan and Sollesta 1997
3. Production in lab/ hatchery development- Fortes et al., 2010
4. Spore Coalescence/ hybridization- Azanza et al 2014 (unpubl.)

Seaweed farm in Zamboanga

EDGFortes photo

Spores in laboratory

ISN at the Marine Science Institute, U.P. Diliman

EDGFortes photo

ISN at the Mindanao State University – TCTO

Branch and micropropagule cultures

Open shelves with cultures

EDGFortes photo

TCTO = Tawi-Tawi College of Technology and Oceanography

Hatchery at UPMSI-BML in Pangasinan

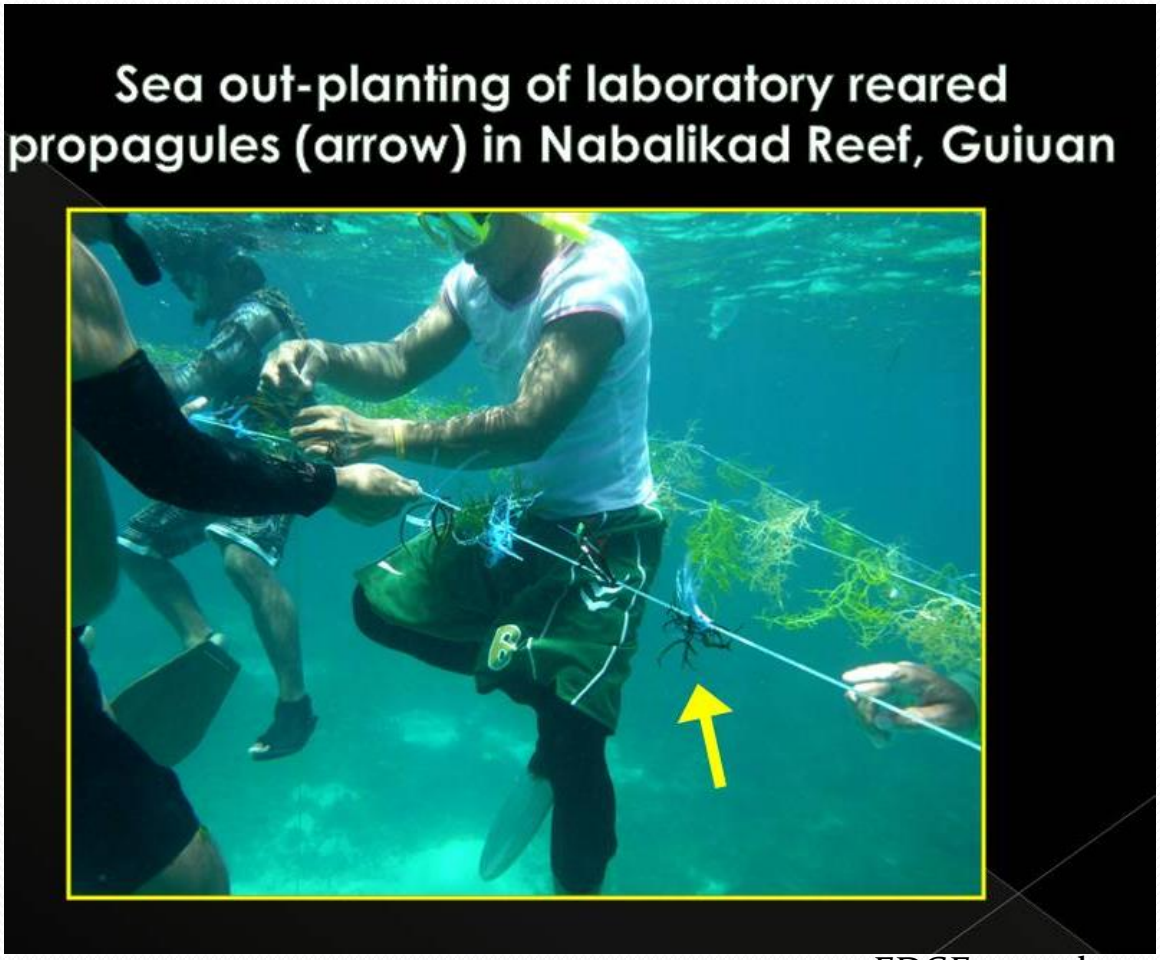
EDGFortes photo

Sea-based Nursery of UPMSI-BML in Pangasinan

EDGFortes photos

Floating bamboo rafts

Direct sea out-planting of spore and branch cultures from ISN



EDGFortes photos

With an indoor seaweed culture facility only, appropriately sized propagules (could be tied to the monoline) could be directly sea out-planted to generate biomass. Depth of monoline should be about half a meter below the water surface.

MSI Seaweed Researchers

Trono, G.C. Jr. – Taxonomy, Biology, Ecology, Culture

Fortes, E.G. – Taxonomy, Physiology, Culture

Montaño, M.N.E.- Seaweed Chemistry

Lluisma, A. - Genetics, Taxonomy, Ecology, Culture

Villanueva, R.†- Biology, Culture, Chemistry

Azanza, R.V.-Reproductive Biology, Physiology, Culture

Roleda, M.- Physiology, Ecology, Culture

Graduate students

Calala, L.

Hinaloc, Y.R

Researchers from other institutions

SEAFDEC-Luhan, M.R., Sollesta H., Hurtado, A.

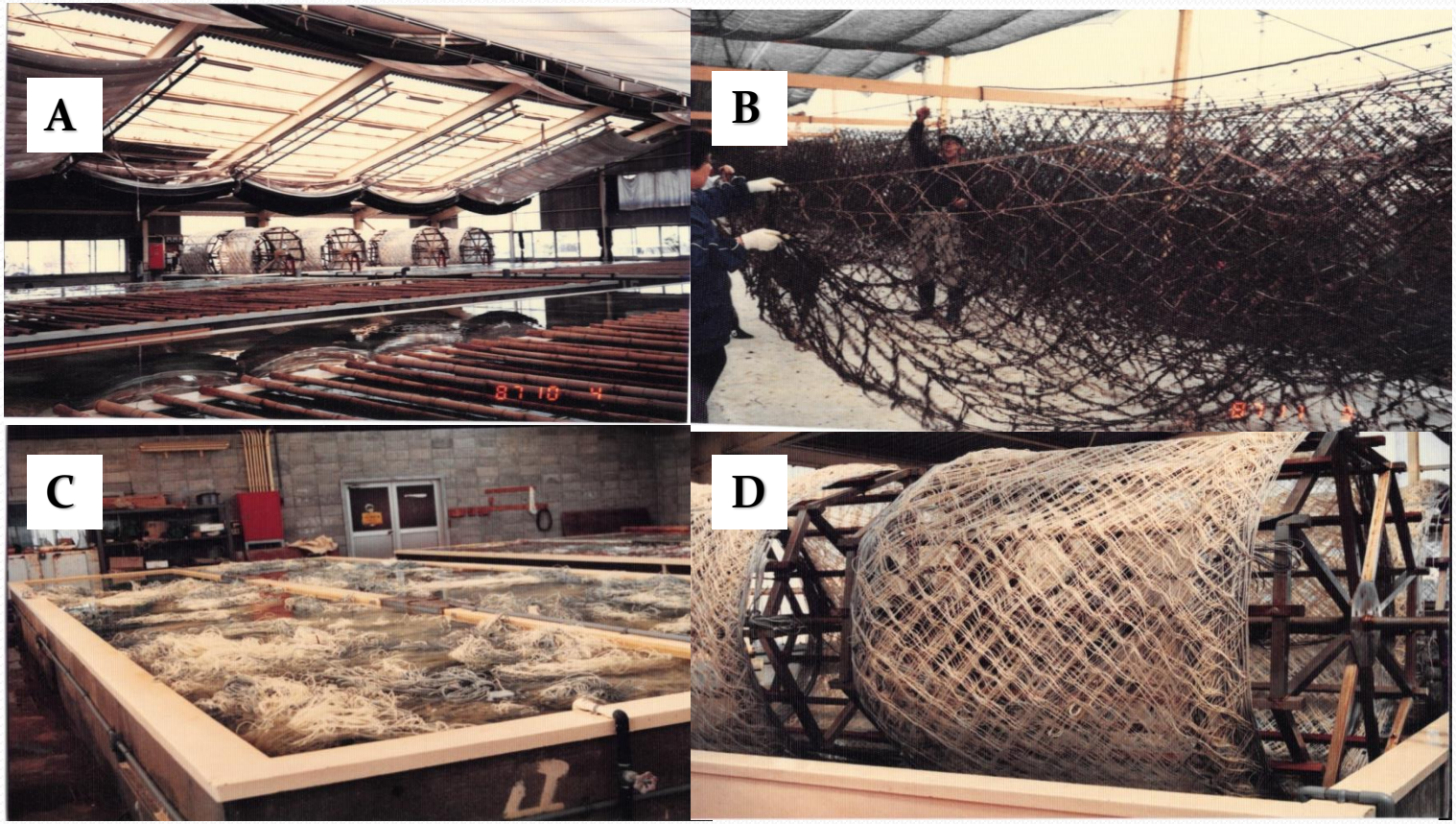
MSU- Romero, J., Alianza, T.

University of San Carlos- Largo, D

BFAR-Ferrer, S.

PNRI- Abadi et al

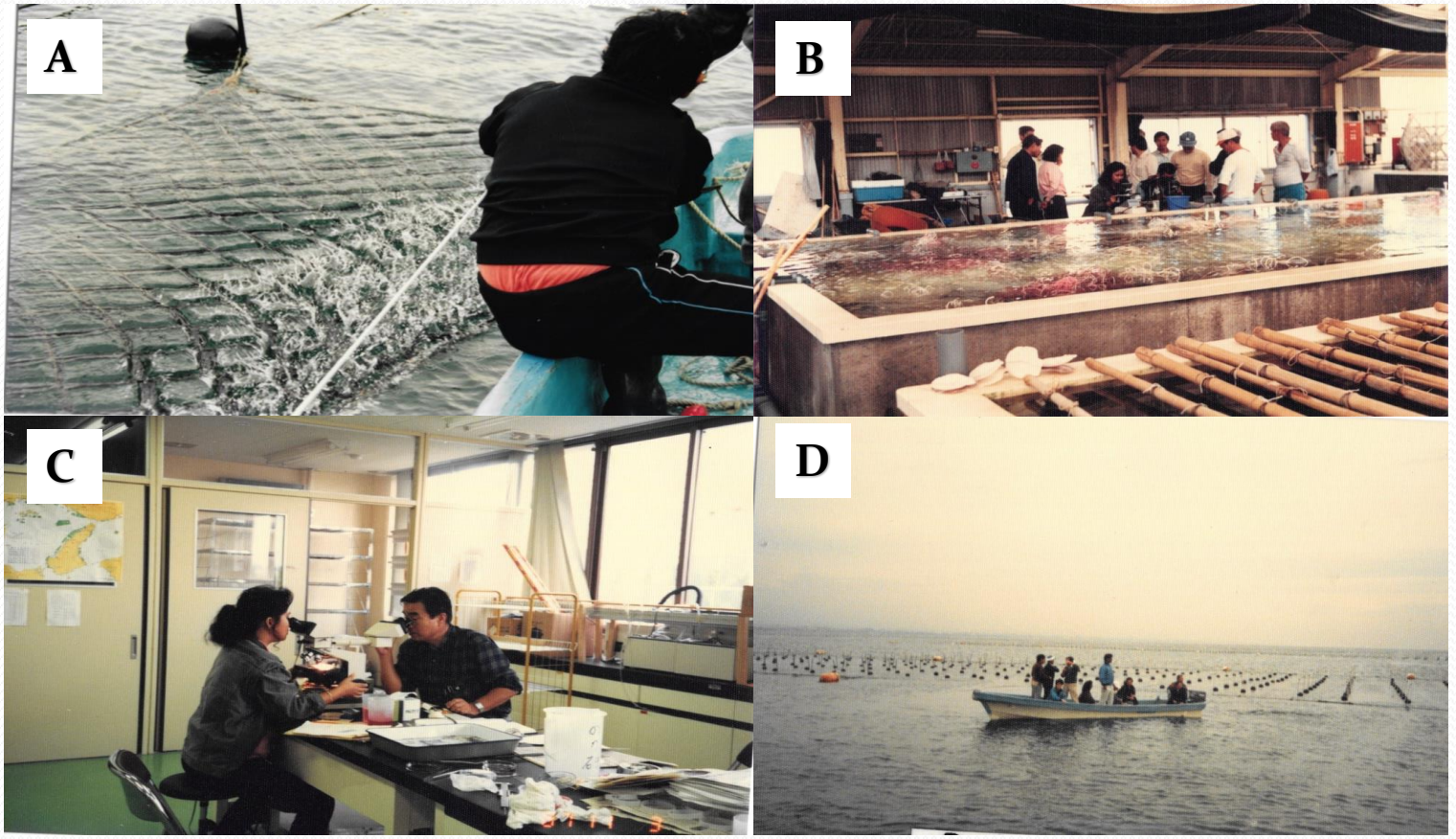
Porphyra culture in Japan



Rvazanza's photos

A) Seedling center; B) Nets with young seedling being air-dry; C) nets seeded with conchospores; D) Nets attached to moving systems for chonchocelis spore collection from shells.

Porphyra culture in Japan



RVAzanza's photos

A) *Porphyra* nets; B) *Porphyra* scientists and fisherman observing conchocelis stage;
C) Dr. Yamauchi Chief *Porphyra* Institute Gyogo Prefecture; and D) *Porphyra* cultivation site

Seaweed production/value chain

Major concerns	Possible causes	Intervention/Issue	Agencies
I. PRODUCTION a) Raw Material - lack of seedlings - poor quality seedlings - Diseases b) Farming techniques - improvement - enhanced per farmer productivity II. **ENVIRONMENT** - herbivores - pollution - lack of appropriate sites	- Storms/other natural calamities - Lack of access to sources - Seedlings becoming younger/lack of hybridization - Environmental - Socio-economic e.g. industrialization farming effort down new/ appropriate sites	- Gene bank/ Tissue culture banks - Nurseries land based/ Sea based - Crop management - Mechanization? - R & D - Water quality assessment, R & D - Zonation - Rehabilitation of sites - R & D	BFAR, UPMSI, other Academic Institution SEAFDEC private sector DENR LGUs LGUs/IDA/DTI National government LGU/DTI

Updated table from: Philippine Seaweed Indusctry Council Action Plan/ Minutes of Meeting of 7 March 2008 at BFAR Conference Room

Major concerns	Possible causes	Intervention/Issue	Agencies
III. POST HARVEST	- Lack of facilities/ Infrastructures product standard development	- Zonation - Trainings/Extension support	
IV**. SOCIO-ECONOMIC** - Marketing - Farmer Income/Credit	- Lack of credit program		
V. **POLICY/REGULATION**	- Marketing layers - Guarantee for harvest	- Seaweed Farmers Cooperatives - "Co-Management" - Income of big producers vs. Farmers - Crafting of appropriate support including farmer credit program	

Updated table from: Philippine Seaweed Indusctry Council Action Plan/ Minutes of Meeting of 7 March 2008 at BFAR Conference Room

Polyculture/ Integrated Multi-Trophic Aquaculture (IMTA)

- IMTA- eco-technological alternative for optimization and productivity and utilization of energy
  - Recycling of metabolites- use in recirculating systems
  - IMTA farm- coastal waters, ponds/tanks
    - Chopin et al. (2001, 2017), Neoni et al. 2007
  - Polyculture of seaweeds with other organisms- Azanza and Ask (2002)

Polyculture/IMTA

- *K. alvarezii* as biofilter in IMTA with oyster, shrimp, fish
  - Qian et al. (1996)- 1 hr w/ pearl oyster waste
  - Lombardi et al. (2006)- shrimps w/ *Kappaphycus* co-cultivated
  - Rodrigueza and Montaño (2007); Hayashi et al. (2008)- increased carrageenan from fish effluents

Some major R&D concerns

Culture/Farming Techniques

1. Polyculture/IMTA
2. Floating method/deep sea culture
3. Shift cultivation
4. Fertilization of culture areas
5. Mechanization

Seedlings

1. Banks/Nursery
2. Hybrids-carrageenan quality and growth rate

Products:

1. Medicine
2. Functional food
3. Plant growth regulators

Philippine Marine Agronomic Support Site (PhilMASS)

Future direction

Eucheuma/*Kappaphycus* have now become true marine agronomic crops farmed for several decades through cuttings or vegetative production.

1. Further studies in relation to changing environment for varied cultivation methods.
2. Research on potential acclimation of various seedstocks when exposed to various culture practices including IMTA
3. Descriptive and predictive modelling from available biological and physio-ecological experiments

To serve as inputs to collective goal of successful and sustained cultivation of carrageenophytes

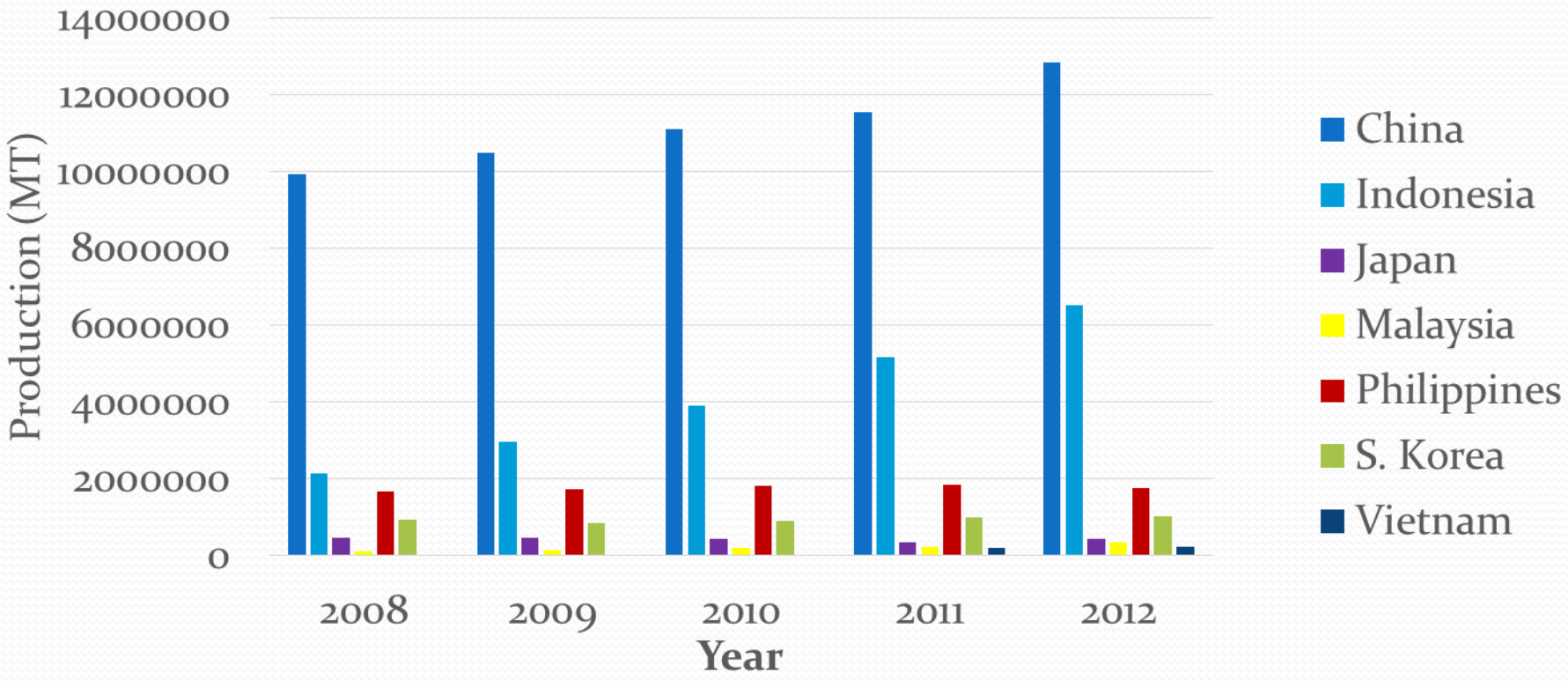
(Azanza & Ask, 2017, In Press)

Highlighting the far reaching societal impacts of the seaweed crops/Kappaphycus for livelihood support as mission mode project for coastal poor (“*Technology Empowers the Nation*”- Honorable Dr. APJ Abdul Kalam, President of India, May 2006)

Acknowledgements

- DOST- PCAARRD-PCAMRD
- BFAR
- UPMSI
- In collaboration with Montaño, Fortez and Lluisma
- Industry/ Farmers
- Philippine Statistics Authority

World fresh seaweeds production (MT) from 2008-2012



Source: FAO, 2012

Polyculture: *K. alvarezii*

1. Doty (1987)-reduction of nitrates and nitrites by 24%, phosphates by 6% in cultivated areas
2. Li et al. (1990)- NH_4 fertilization for 1 hr-

   5-25 mM=> high growth rates

   35-50 mM decreased growth-toxicity
3. Mairh (1999)= 1-3 $ugNL^{-1}$ or 3-5 $ugNL^{-1}$ of NH_4, NO_3 or $(NH_4)2SO_4$

   increased wetweight and bioaccumulation of N-NH_4- stored

4. Dy and Yap (2001)=surge of ammonium uptake w/n first 30 mins

   15-35 ugmol NH_4 g-1 dry weight

5. Msuya and Salin (2007)= high carageenan yield and strength in fertilized *K. alvarezii* TAN 81% efficiency

- Li et al. (1990)- intermittent fertilization- 1 hr every 3 day interval: 4% g.r.
  - C:N ratio 29 carrageenan 58%;
  - Gel strength 45-70 gcm^2

- *K. alvarezii*- integrated cultivation with fish in recirculating water
  - Hayashi et al. (2008)- Biofilter for culture effluents (reduce effluents)

    Removal efficiency:

    nitrate 18.2%

    Nitrite-50.8%

    Ammonium- 70.5%

    Phosphate- 26.8%

- Survival high, some with ice-ice
- *Chanos chanos* and *Trachinotus carolinus*

- Biofilter potential- Rodrigueza and Montano (2007)

THANK YOU!