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Science Interventions for Sustainable Marine Products Production: The Case of Sardines and Seaweeds

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ABSTRACT

This paper presents two cases of scientific interventions to address pressing sustainable production of marine products in the Philippines such as the sardine fishery and seaweed production. The Philippine sardine fishery accounts for about 25% of commercial and 11% of municipal fisheries. Due to dwindling catch, the biology, ecology, fish catch and environmental factors were investigated in Northern Zamboanga Peninsula where upwelling during the northeast monsoon supports a significant sardine population. The study resulted in a resource management program that remains adaptive and spatially explicit to ensure sustainability of the sardine fishery. On the other hand, the Philippine seaweed production contributes about 50% of the annual fishery production volume, of which 70% comes mainly from carrageenophytes or carrageenan-bearing seaweeds. Production of these seaweeds made the Philippines the world's top supplier of the raw dried seaweed for carrageenan production until 2007 after which seaweed production for the carrageenan industry placed second only to a neighboring country. Government agencies and academic institutions, thus, initiated studies to improve the productivity of this marine plant. For sustainability, tissue culture techniques were developed, and gene and seedlings banks were established in strategic parts of the country to ensure continued supply of quality seaweed seedlings to the farmers. Philippine standard specifications for raw material and carrageenan were formulated to comply with international standards. Continued science interventions to marine fishery industries are called for and should be intensified to promote further the country's progress.

Keywords:
Seaweeds,
sardines,
science interventions

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INTRODUCTION

This short review chronicles our efforts to establish marine reserves or No-Take Marine Reserves (NTMRs) in the Philippines which started more than 46 years ago.

The Philippines is rich in aquatic resources. The country exported about 500, 000 tons of fish and other marine products in 2019 (FAO 2020a). It is part of the coral triangle and is the world's second largest archipelagic country thus endowed with several coastlines. The Philippines has one of the highest rates of population growth in the world (Commission on Population and Development 2021). As of 2021, the country has a growth rate of about 1.2% (PSA 2021).

Many of the poorer segments of society live by the coast (Yoshioka et al. 2021; DENR-DILG-DA/ BFAR-CRMP 1997). Many of the poorer segments of society live by the coast. Inevitably, the rapidly increasing population exacts an increasing burden on the environment for basic sustenance.

The Philippines is exposed to climate variations which significantly affect economic activities such as agriculture and fisheries. Droughts and extreme flooding are common interannual events associated with El Nino – Southern Oscillation (ENSO) events (Cruz et al. 2017). In addition, the country lies directly along the typhoon belt, receiving on average about 20 typhoons a year (Cinco et al. 2016) making it vulnerable to severe weather events, given its geography. Analysis of typhoon track data reveal variations in tracks associated with ENSO and longer-term decadal timescales and are associated with large-scale temperature anomalies in the western Pacific (Tu et al. 2009; Ho et al. 2006). The data, however, do not show conclusively if this typhoon track variability is associated with climate change (Kubota and Chan, 2009). However, it has been observed that the frequency of typhoons in the country has increased from 0.4 per year (before mid-2000s) to 1.5 per year (He et al. 2017). These rapid changes in weather patterns have been attributed to climate change (Coracero 2021). With this, disaster risk reduction and management in response to climate change has been urgent.

In the face of these challenges, it is clear that our utilization of available resources is not optimal as discussed and shown in the pertinent sections of this paper. A book by the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) in 2004 extensively discusses the status of Philippine marine resources. With environmental factors and poverty considered, it has been seen that Philippine marine sources are depleting, degraded and inequitably distributed. The book concluded that critical solutions to improve the state of aquatic resources include improvement of post-harvest practices, maximization of research, drafting of appropriate policies and effective law enforcement.

Science interventions for sustainable marine products production are highlighted in two fishery industries important to food security and poverty reduction for inclusive growth. A clearer understanding of how oceanographic conditions, weather patterns, and the natural production of plankton has led to the ability to determine spawning of sardines in a locality. The simple intervention of limited ban on sardine fishing to allow the sardines to spawn resulted in increased yields. Without any phenomenon involved, it can be reasonably assumed that the increase in yield can be sustained. The Philippines is a world leader in the production of seaweed through cultivation and development (FAO 2020b) even if only four out of over 200 species that can be cultivated for food or development is being exploited. In fact, for the 10- year period that in ended 2015, Philippines ranked 3rd in the production of cultured seaweeds (FAO 2020b).

There is much room for improvement. In both cases, this paper will show that scientific interventions in both industries have yielded the expected and reasonably consistent results. Certainly such results can still be improved upon and the degree of such improvements largely depends on the soundness of the science of future interventions.

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UNDERSTANDING UPWELLING VARIABILITY FOR SUSTAINABLE SARDINE RESOURCES

Sardines belong to the Clupeidae family and are pelagic, schooling and migratory fish (Freon et al. 2005). In the Zamboanga Peninsula, the dominant sardine species being harvested is the *Sardinella lemuru* or Bali sardine (Willette and Santos 2012). Sardines, particularly the Bali and fimbriated sardines, comprise 15% of the total capture fisheries production in the Philippines (Bacordo et al. 2011). The Zamboanga Peninsula is the most productive region in the country, with fish landings five times that of any other region (Willette et al. 2011). Aside from being a cheap food source popular among the majority of the population, the sardine fishery supports an extensive post-processing industry in the Zamboanga Peninsula including 19 fishing companies (with 61 purse seine boats), 13 bottled sardine enterprises, 8 canning companies and 3 tin can manufacturers (Bacordo et al. 2011).

The abundance of sardines in the Zamboanga Peninsula is associated with the seasonal upwelling along the northern coast of the Zamboanga Peninsula during the Northeast Monsoon (NEM), when the wind blows parallel to the coast. This induces offshore Ekman transport of water near the coast, and coastal upwelling occurs. The shape of the coastline and its topography has orographic effects, which causes positive wind stress curl or horizontal variations of the wind stress and, consequently, upward Ekman pumping. These physical mechanisms were linked to increased phytoplankton concentrations and sardine production (Villanoy et al. 2011; Deauna 2015).

Upwelling in the Northern Zamboanga Peninsula

Analysis of wind fields show that upwelling driven by wind stress curl accounts for most of the upwelling off northern Zamboanga mainly due to the complicated coastline making up the Dipolog and Sindangan Bays (Figure 1). Obtaining good quality observations of wind stress curl is difficult because it requires high spatial resolution wind velocity measurements over the water. Atmosphere model data however show areas off the mouths of the embayments with the strongest positive wind stress curl (Figure 2). If the coast was a straight line, coastal upwelling would dominate.

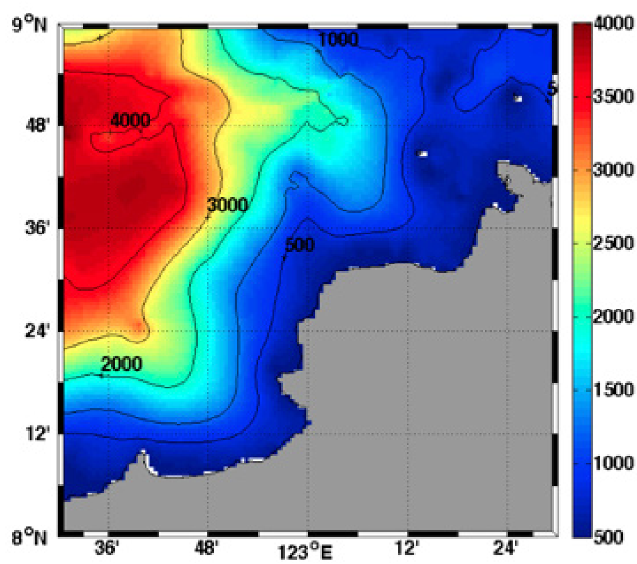

Figure 1. Bathymetric map of study area including Dipolog and Sindangan Bay. Data from Becker et al. (2009) bathymetric database.

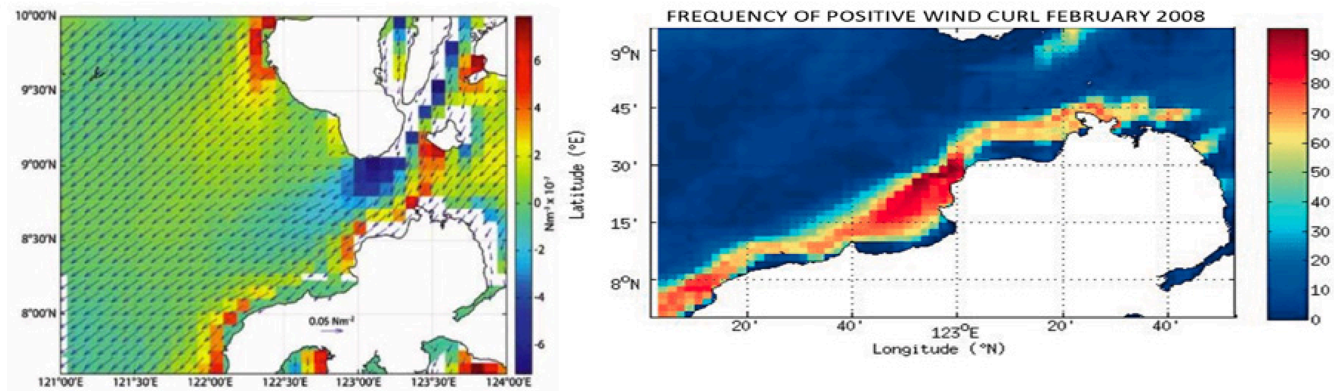

Figure 2. Wind stress vectors (Nm-2) and wind stress curl (Nm-3) in the Zamboanga Peninsula (from Villanoy et al. 2011) (left). Closer view of wind stress curl field from atmosphere model data.

Sardines are mainly planktivores, which makes them sensitive to changes in the environment that affects their food source. In addition, fishing activities also highly influence their production and abundance. Sustainability of this important fishery resource requires addressing issues related to enviromental variability as it affects the planktonic food source, sardine biology, and fishing effort spatial and temporal variability. These were the main objectives of the Department of Science and Technology (DOST)-funded Sardine Dynamics Program. In this paper, we will focus on the environmental variability, particularly on processes that influence upwelling variability. The sardine production in northern Zamboanga is driven by upwelling of nutrients that nourish the plankton communities in the upwelling zone; understanding upwelling variability is a necessary step in understanding sardine production variability.

Variability of the upwelling process

In the Zamboanga Peninsula, upwelling is highly seasonal and occurs only during the northeast monsoon (NEM) (Villanoy et al. 2011). However, the NEM upwelling process is also modulated by other large-scale atmospheric and climate-related processes. The El Niño Southern Oscillation (ENSO) has been found to have a major impact on marine upwelling ecosystems such as the Peru-Chile sardine fishery (Lehodey et al. 2006; Vargas et al. 2007), the California Current System (Macias et al. 2012), coastal upwelling in India (Krishna 2008) and along the Java and Sumatra coasts (Susanto et al. 2001). In the Humboldt ecosystem off the coasts of Peru and Chile, El Niño events do not affect or even encourage the growth of sardine stocks. One factor is the shift in zooplankton diversity towards smaller–sized copepods, which is more favorable for sardines (Lehodey et al. 2006).

For Zamboanga Peninsula, Villanoy et al. (2011) correlated sea surface temperature (SST) data from Pathfinder satellite data with the Multivariate ENSO Index. A positive index represents El Niño conditions and a negative index, La Niña conditions. SST anomalies show a strong seasonal signal with negative anomalies during the NEM due to general lower heat flux during winter and upwelling of cooler subsurface water. The negative SST anomalies were greater during El Niño conditions, implying higher upwelling rates (top panel of Figure 3).

A contributing factor in ENSO-modulated upwelling is the effect of precipitation on near surface stratification. Excessive rainfall on the surface of the ocean can produce a fresher surface layer and can result in salinity barrier layers. Barrier layers increases near surface stratification limiting vertical fluxes of heat and mass (Sprintall and Tomczak 1992; Cabrera et al. 2011) and

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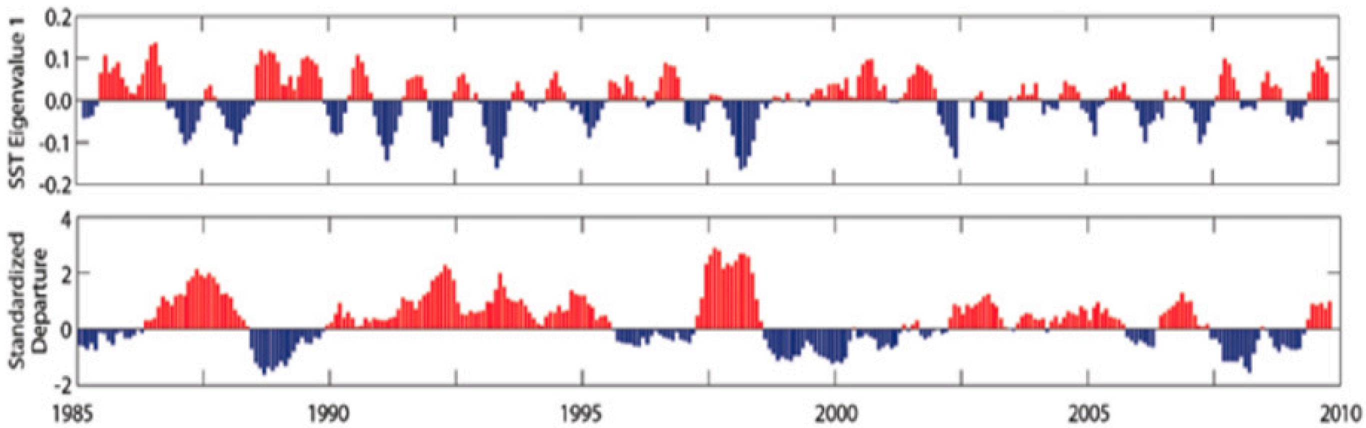

Figure 3. Temporal variation of the first empirical orthogonal function mode calculated from Pathfinder monthly SST data (top) and the Multivariate El Niño – Southern Oscillation Index or MEI (bottom). Negative (positive) values of SST temporal distribution correspond to cooler sea surface temperatures during El Nino (La Nina) events.

even upwelling. During La Niña, the Zamboanga Peninsula and the Bohol Sea receives more rain than usual (positive rainfall anomalies). The weaker stratification during El Niño conditions is more favorable to a stronger upwelling.

Consistently strong upwelling-favorable winds produces strong upwelling but not necessarily increasing upwelling productivity. In fact, at shorter time scales, highly variable winds in upwelling areas increase upwelling productivity (Garcia-Reyes et al. 2014). High wind variability at intra-seasonal time scales are usually characterized by alternating periods of wind bursts and relaxation periods and it is the combination of bursts and relaxation periods that enhances upwelling productivity. The strong wind bursts which last a few days enhance upwelling, pumping nutrient rich water from below the surface. If the wind bursts continue, the upwelled nutrients and the phytoplankton in the water are advected beyond the shelf area. However, if the burst is followed by a relaxation period, phytoplankton are retained in the euphotic zone and a more efficient uptake of nutrients can occur resulting in increasing phytoplankton population (Botsford et al. 2006; Wilkerson et al. 2006; Lucas et al. 2014).

Translating upwelling variability to sardine production remains a challenge because of the difficulty in estimating sardine production based on catch data alone. Some patterns do show some weak relationships between fish catch and upwelling intensity at interannual time scales. El Niño years generally show more sardines catch than La Niña years in the Zamboanga peninsula (Villanoy et al. 2011). The use of fishery-dependent and fishery-independent monitoring data will enable the separation of the fishing effects from population growth as influenced by environmental factors. Understanding the effects of environmental variability on sardine production is an important step in order to clearly understand the effects of fishing regulations such as fishing bans. The significant interannual variability of environmental oscillations and the strong influence requires that temporal scale of monitoring sardine production and catch and the marine environment A long-term monitoring program is needed, not only in the Zamboanga Peninsula but in other sardine fishing grounds as well such as in the Sulu Archipelago and the Visayan Sea.

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SCIENCE INTERVENTIONS IN SEAWEEDS

The Philippine seaweed industry became prominent with the introduction of the *Kappaphycos* farming in the 1960s. Seaweed production increased from 72,927 MT in 2011 to 101,900 MT in 2015 (Table 1). As a result, the Philippines supplied 70–90% of the world's demand for the carrageenan's raw material. It brought revenue to the country (Figure 4), but Indonesia has since overtaken the Philippines in seaweed production.

Table 1. The Philippines: Production of seaweed (by species), in tonnes, 2011–2015.

ASFIS Species	Weight in tonnes				
Tuna	2011	2012	2013	2014	2015
Ellchorn seamoss	1,697,682	1,608,401	1,428,707	1,434,714	1,457,865
Spiny *Eucheuma*	136,183	137,603	124,218	113,127	106,950
Caulerpa seaweeds	5, 145	3,928	3,029	1,199	1,219
Gracilaria seaweeds	1,823	1,139	2,424	536	327
Total (farmed)	**1,840,833**	**1,751,071**	**1,558,378**	**1,549,576**	**1,566,361**
Total (capture & culture)	**1,841,291**	**1,751,476**	**1,558,778**	**1,549,943**	**1,566,728**

Source: FAO 2018.

Table 2. The Philippines: Exports of dried seaweed, carrageenan, and agar agar, 2013–2016.

	Weight in tonnes; value in USD thousands							
	2013		2014		2015		2016	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value
Dried seaweed	37,063	34,356	18,493	49,300	14,910	21,739	11,052	8,539
Carrageenan	23,503	195,242	26,633	213,239	27,181	185,461	31,813	190,171
Agar agar	2	11	1	10	2	6	1	1
Total	**60,568**	**241,012**	**45,675**	**272,306**	**42,093**	**213,508**	**42,866**	**199,973**

Source: FAO 2018.

Note: Data in this presentation (i.e. yields, cultivated area, etc. are for *Kappaphycus spp*. and *Eucheuma denticulatum* only).

Although the Philippine seaweed production figures prominently as a world prominent source, the resulting production yields fall short of the supply requirements of domestic processors. The impact of climate change like Typhoon Yolanda in 2013 and the concomitant algae disease disrupted the production growth. Consequently, the raw material shortage was covered by importation from Indonesia (See Figure 4).

The BARMM region's income from the production of raw dried seaweed is highest among all regions in the country (Table 3), yet the regional poverty index is also high (Table 3). This could be attributed to inequitable distribution of benefits from the resources (DA-BFAR 2004), conflicts related to land and resource due to cultural differences (Caballero 2002), inaccessibility to electricity (Mendoza Jr et al. 2019) and other social-economic factors. The study of Caballero (2002) explains the social strata of the population, culture, economic, and religious practices of the area. With this, the trading and business practices of the seaweed industry of the local populace must be carefully documented.

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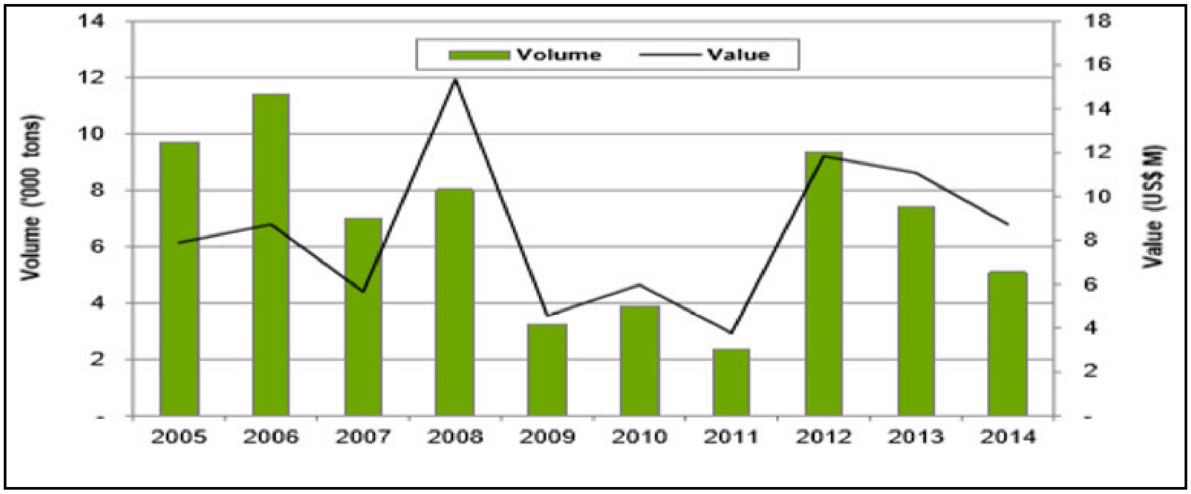

Figure 4. Philippine Raw Dried Seaweeds (RDS) importation from Indonesia.
Source: Philippine Statistical Authority (PSA) 2012.
Note: Data in this presentation (i.e., yields, cultivated area, etc. are for *Kappaphycus spp.* and *Eucheuma denticulatum* only).

Table 3. Seaweed Production Volume vs Poverty Indices - 2012.

Regions	Production volume (MT)	Average Poverty Index	PI	High PI
BARMM	627,435.50	43.2	21.9	67.3
8	18,513.40	41.56	31.4	55.4
12	358.65	39.25	25.8	46
9	240,180.45	36.97	25.9	48
10	39,409.13	35.36	19.1	41.5
CARAGA	14,798.71	31.78	27.7	37.3
5	55,382.09	31.05	21.7	40.6
11	8,384.02	28.17	20	37.8
4B	395,125.83	25.22	20.5	30.4
6	80,572.11	24.69	16.19	43.9
7	96,588.56	23.6	18.9	30.6
2	266.46	19	48020	27.1
1	26.47	13.08	8.4	15.3
4A	23,492.73	9.44	2.6	20.3
3	1,827.50	5.35	4.5	12.1

Source: Philippine Statistics Authority 2012.

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The Philippine share in the lucrative US market provides significant support to sustain the long-term viability of the seaweed industry (Table 4).

Science has played a critical role in the development of the *Kappaphycus* seaweed/ carrageenan industry and was introduced in all aspects of the value chain as depicted in Figure 6. In each stage of the chain, opportunities for improvement would always have place for science intervention. The Farming side would have to contend with the issue of Climate Change Adaptation, which welds direct impact as to the nature, timing and extent of farming culture applications and methods of propagation, as highlighted by Largo et al. (2017) on Impact of Climate Change on *Eucheuma* and *Kappaphycus* Farming (2017). Scientific innovations could serve well in addressing the challenges associated with post- harvest handling that bear direct impact on the seaweed quality and ultimately, with that of pricing (Ali et al. 2017).

Important and critical are science interventions in seaweed farming particularly in the production of seedstocks for planting and in the prevention of seaweed maladies and engineering applications in farming techniques. Science innovation is important and relevant in the post-harvest activities to maintain quality and the development of seaweed products. Trade and promotions of Philippine seaweed products needs science to support continued compliance with international regulatory standards such as the Joint European Committee on Food Additive and Codex Alimentarius.

NOTABLE RECENT SCIENCE INTERVENTIONS IN THE SEAWEED/CARRAGEENAN INDUSTRY

The Philippines has 197 species in 20 families for green algae, 158 species in 10 families for brown algae, and 153 species in 52 Families of red algae (Ang et al. 2013) totaling 893 identified species of algae. More species will certainly be discovered if a thorough survey of the marine flora in the Pacific Seaboard will be conducted.

Table 4. Philippine Seaweed Exports 2016.

Total Volume in Metric Tons (MT)	49200
Total Value in US$ (Millions)	197.4
US Share	
Volume	19,500 (40%)
Value	42.5 (22%)

Source: Pedrosa A A. 2017 Seaweed Industry Association of the Philippines (SIAP)

Note: Data in this presentation (i.e. yields, cultivated area, etc. are for *Kappaphycus spp*. and *Eucheuma denticulatum* only)

Currently, only four species are being farmed namely, *Kappaphycus spp*. and *Eucheuma spp*. for carrageenan production, *Caulerpa spp*. for the salad market and *Gracilaria spp*. for the agar production and as a marine vegetable. It is noted that *Kappaphycus spp*. and *Eucheuma spp*. are also farmed for the fresh salad market and seaweed pickle production (Villanuera 2010).

There are plans to culture more species that have economic importance:

1. *Sargassum spp.* – source of alginates, fucoidan, fucoxantin, feeds and fertilizer which has existing commercial demand both locally and abroad in the raw dried form. Supply comes from wild stock but this species has the potential to be farmed or cultured. Presently, gathering of this seaweed is banned. The Bureau of Fisheries and Aquatic Resources (BFAR), Seaweed Industry Association of the Philippines (SIAP) and other stakeholders are working together to find acceptable approach for the lifting of ban and development of protocol for farming. Recent studies on the culture of this brown seaweed were conducted by BFAR and University of San Carlos (USC).
2. *Ulva lactuca* Linnaeus – a green algae that grows wild and is considered a nuisance

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in Kapaphycus farming. There is demand for export as material for livestock feed production with a monthly minimum requirement of 200 dried metric tons. It is a seaweed that contains high polyunsaturated fatty acids (PUFA) and protein content. It is also a source of ulvans used in the cosmetics industry (Tabarsa et al. 2012).

3. *Porphyra spp. – gamet* or the local version of nori grows along the northern coastlines of Luzon. It is now the subject of BFAR and University of the Philippines-Molecular Biology and Biotechnology (UP- MBB) research to establish ways to propagate it by open sea farming. Current supply can not meet domestic demand.
4. *Halymenia durvillae* Bory de Saint-Vincent – is a red seaweed that contains lambda carrageenan and pigments such r-phycoerythrin & r-phycocyarin. Earlier reports mentioned their high iodine content. Recent developments also show its high quorum sensing inhibitor activity. It is one of the popular seaweed foods in the Ilocos region. Efforts to culture the seaweed from spores was led by National Scientist Gavino Trono and his group. Propagation of the seaweed by cuttings was initiated by BFAR in the Bicol region.

Current farming techniques and selection of best strains were the results of several studies (Trono et al. 2000; Hurtado et al. 2013; Villanueva et al. 2011). The best timeframe to harvest the farmed seaweed was obtained by Villanueva et al. (2011). Tissue culture techniques and nursery development had been implemented based on earlier techniques (Dawes et al. 1994; Trono et al. 2000).

To maintain the Philippine strains (Azanza-Corrales et al. 1996), gene banks have been established in leading universities and strategic locations in the country (Dawes et al. 1994). Seedling nurseries were established in focal areas in the country to ensure supply of propagules to farming areas.

To maintain the Philippine strains (Azanza-Corrales et al. 1996), gene banks have been established in leading universities and strategic locations in the country (Dawes et al. 1994). Seedling nurseries were established in focal areas in the country to ensure supply of propagules to farming areas.

Seedling nurseries

Studies on the prevention and treatment of ice-ice disease and other seaweed diseases are still being conducted (Largo et al. 1995a; Largo et al. 1995b; Hurtado et al. 2013).

Improved drying techniques such as "*sampayan*" method and "*sauna*" method were introduced (Ali et al. 2014). Portable green houses were developed not only for eucheumatoids but for all types of seaweeds (DA-BFAR).

Water quality in seaweed farms are in compliance with the Philippine Clean Water Act (Republic Act 9275) as industrial effluents from seaweed processing plants are regulated by DENR Administrative Order (DAO) 2016-18 otherwise known as the "Water Quality Guidelines and General Effluents Standards".

To assure the quality of the raw dried seaweed and the corresponding carrageenan produced, the Philippine National Standards (PNS) for this product was established. The Bureau of the Agriculture and Fisheries Product Standards (DA-BAFPS) and the Bureau of Product Standards together with concerned government industries formulated PNS 601:2011 for Carrageenan and Processed Eucheuma Seaweed (DTI 2011) and PNS BAFPS 85-2012 for the Raw Dried Seaweed (DA-BAFS 2012). The lowering glycemic indices of foods with carrageenan have also been reported (Dumelod et al. 1999).

INDUSTRY POTENTIAL FROM R&D

Energy. Seaweed as a source of bioethanol is currently under investigation by UP Los Baños researchers. Presently, the country imports 169

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million liters of biofuel as local sources cannot not meet the domestic demand. The demand for bioethanol as blending agent grows at an average of 4% per year (Lim 2020; Department of Energy 2006 as cited by International Society for Southeast Asian Agricultural Sciences, Inc. 2007). This accounts for 581 million liters in 2016 based on projected gasoline consumption (Gatdula and Demafelis 2016). Potential seaweed sources for biofuel are *Sargassum* and *Kapaphycus* species. Biogas production from sea wrack (seaweed and other organic materials that wash ashore) also has potential as a source of bioenergy (Marques et al. 2014a; Marques et al. 2014b).

Livestock feeds and agricultural supplements. Ulva and *Sargassum* are candidates for this purpose, and BFAR is leading the study. Currently, the source of seaweeds comes from wild stock, so the next move is to develop farming protocols (Montaño et al. 2006)

As fertilizer – the Philippine Council for Agriculture Aquatic, Resources Research and Development (PCAARRD) funds studies on the use of ordinary seaweed or carrageenan as a growth enhancer for rice. Carrageenan is irradiated and converted to oligosaccharides which are responsible for the growth hormonal effect (Abad et al. 2016). The country's importation of inorganic fertilizer is significant, and should this research be successful, and commercialized, this would be a tremendous push for seaweed production not to mention lessen the country's reliance on imports. At present, only liquid organic fertilizers extracted from seaweeds are available in the market (Montaño and Tupas 1990; Alino et al. 2006).

As medicinal products – biorefining of the range of bioactive compounds from seaweeds with anti-biotic anti-cancer, antioxidant, anti-inflammatory and other pharmaceutical properties like fucoidan, fucoxanthin, and pigments would boost the further development of the medical and pharmaceutical industries utilizing the marine plants as raw materials

Packaging –development of packaging materials to extend the shelf life of seaweeds for the fresh produce market, and make produce visually attractive to the consumers, biodegradable packaging materials from seaweed polysaccharides and food grade resins are currently being developed.

Oil drilling – traditionally, alginates are used as additives in oil fracking to inhibit bacterial growth which minimizes friction and increases viscosity during extraction of oil from shale but recently, carrageenans are also being explored for this purpose.

Biofilter – seaweeds absorb excess nutrients and bind with heavy metals in the marine environment, playing a significant role in abatement of marine pollution (Montaño 1987; Montaño 2012; Rodriguez 2007a; Veroy et al. 1980).

Personal care – the development of personal care and cosmetics lines from seaweeds was welcomed by environmental groups as well as non-consumers of animal products (Couteau and Coiffard 2016).

Pesticides – some seaweeds are used traditionally to repel insects in orchids and cacao plants. This practice is popular in the Visayas and Mindanao regions.

Industrial – the cellulose fiber in seaweeds are made into textile, paper pulp and high-density fibers. Seaweeds and their derivatives are also used in electronic products such as disposable batteries and capacitors (Raymundo-Piñero et al. 2006; Nystrsm et al. 2009; Qin 2007).

The seaweed industry is hardly a sunset industry in this archipelagic country. Farming of other species can boost the efforts to alleviate or reduce the poverty in the poorest sector of the Philippine society. The sense of nationalism and love of country is definitely needed by all the stakeholders to develop further the marine resource given by nature to the Philippines.

Proper utilization of the marine resources will provide a great opportunity for food security and sustainable industries. Marine science and technology interventions are poised to yield greater benefits overtime. It underscores the need for further studies to increase the available science interventions we can deploy.

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CONCLUSION

The Philippines' largest resource is its long coastal areas which comprise over 80% of our entire territory. The knowledge and understanding of the available resources and the interactions of the factors affecting this resource is still lacking. The simple timed intervention of fishing bans of sardines in a particular area has consistently led to greater harvests that, barring unforeseen catastrophic events, can reasonably expected to be sustainable.

The Philippines is already a major global player in the seaweed production industry with only four species being utilized and yet there are 900 other species with potential commercial values that have not been explored. Science interventions would augur well in enhancing the productivity, efficiency, viability, and sustainability of the seaweed industry. Current science intervention for the seaweed industry focuses on the production of raw dried seaweed for carrageenan and in maintaining the quality of carrageenan within the standards set by the US Organic list classification. Long overdue are solutions based on social science and policy regulation for the respective industries, particularly in coastal zones with high poverty index. It is necessary to optimally understand how the interplay of factors emanating from science, judicious utilization of available marine resources, adaptation to prevailing natural environment would bring forth the results that we seek to produce without adversely affecting other resources we wish to develop now or may want to develop in the future for posterity. The fruition of science interventions presents our best hope in reaping equitable and sustainable economic rewards, necessary for uplifting the fisherfolk/stakeholders living standards in poverty-stricken areas.

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