COASTAL CONSERVATION AND SUSTAINABLE LIVELIHOODS THROUGH SEAWEED AQUACULTURE IN INDONESIA:

A Guide for Buyers, Conservation Practitioners, and Farmers

KEMENTERIAN KELAUTAN DAN PERIKANAN

NUSA TENGGARA TIMUR 1958

Yayasan TAHIJA

The Nature Conservancy

Mulutseribu Seaweed Farms, Indonesia; © Kevin Arnold

Cover photo: Wa Nuri harvesting seaweed in Wakatobi, Indonesia © Bridget Besaw

About The Guide

Authors

Global Aquaculture
Tiffany Waters
Robert Jones
Seth Theuerkauf

Indonesia Oceans
Hilda Lionata
Tomi Prasetyo Wibowo
Subhan Usman
Muhammad Imran Amin
Ilman Muhammad

Design and Artistic Direction
Arnaud Ghelfi, l'atelier starno

Illustrations
Colin Hayes

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Preface

Over one million coastal Indonesians engage in seaweed aquaculture, a unique and growing global industry for production of carrageenan and agar, direct consumption, and animal feeds, among other uses. Carrageenan and agar, refined from red seaweeds, are used as 'texturizers' or thickeners primarily within foods and cosmetics, but have growing utility within areas such as animal feeds and pharmaceuticals. Indonesian seaweed farming presents a significant economic opportunity with the potential to be managed in a more sustainable manner. The Nature Conservancy's (The Conservancy's) vision is for seaweed aquaculture to grow in harmony with marine conservation objectives, support livelihoods in coastal communities throughout Indonesia, and provide ecosystem services for habitat and nutrient bioremediation – **to encourage increased sustainability through the three dimensions of economic, social, and environmental.**

In response to the rapidly growing global market for carrageenan seaweeds, the environmental challenges and opportunities of seaweed farming, and the essential livelihoods that seaweed farming currently provides in Indonesia, The Conservancy presents this seaweed aquaculture guide for seaweed purchasers, conservation organizations working in seaweed, and seaweed farmers in Indonesia that are seeking to reduce environmental impacts, and to encourage sustainable livelihoods[1] by improving the value of farmed seaweed through better farming and post-harvesting practices.

This guide is divided into four main parts: (1) an introduction providing pertinent background regarding Indonesia in the context of carrageenan seaweeds; (2) a guide for seaweed buyers seeking to increase the sustainability of their supply chains; (3) a guide for conservation practitioners working in seaweed aquaculture for environmental, economic, and social gain; and (4) an illustrated guide for farmers to improve seaweed farming practices.

As a relatively data-limited industry, sources below range from 2007 to present, with attempts to utilize the most current data and information possible. As a living document, we ask reviewers and users to contact The Conservancy (aquaculture@tnc.org) with more recent or accurate resources or data, if available, for inclusion into the guide.

1. Sustainable livehoods is a term used by many development and aid organizations and is defined by FAO (2002) as "A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Adapted from Chambers and Conway 1992, cited in DFID 2000: 1)."

Introduction

Key Takeaways

- Seaweed farming is an important livelihood for many women, rural, and indigenous Indonesians. In Indonesia, aquaculture employs more Indonesians than even wild fisheries.
- Indonesia has a wet tropical climate that is key for growing the tropical *Eucheuma* and *Kappaphycus* sea weeds, but the extreme variability between seasons require localized seasonal calendars for proper growth and prevention of disease.
- Globally, there is a growing demand for processed foods, which has translated into a rapidly growing seaweed market to meet the demand for carrageenan and agar, which are derived from red seaweeds and are used as thickening agents within processed food and other products.
- Indonesia ranks second in the world for seaweed production, and first in the world for red seaweed farming – with the latter experiencing significant growth over the last decade. While Sulawesi is the current seaweed production center in Indonesia, there are significant production increases in other regions. Data shows large variability of production year-to-year in most provinces, which is concerning for sustainable livelihoods.
- The Indonesian and global red seaweed market for the thickeners of carrageenan and agar has a history of price volatility, with Chinese buyers currently dominating the market and able to secure more consistent pricing due to their large buying power.
- While two-thirds of Indonesian *Kappaphycus* seaweed is exported dried in raw form for processing elsewhere, one-third is processed in-country, mainly for an industrial grade product for pet food and/or alkali-treated *cottonii* (ATC), dried seaweed that has been cut into pieces to form chips for easier processing.

Society, Economy, Geography and Climate of Indonesia

Society and Culture

Culturally, ethnically, and linguistically, Indonesia is incredibly diverse. While Indonesia is the largest Islamic country in the world with ~87% of its population identifying as Muslim in 2010, the country is constitutionally secular and the government recognizes five other religions including two forms of Christianity (Protestantism, Catholicism), Hinduism, Buddhism, and Confuciansim. While the largest ethnic population is Javanese at ~41%, followed by the Sundanese, Malay, and Madurese, there are more 300 ethnic groups, including many groups that the Western world would consider as 'indigenous'.

The concept of indigenous is contested within Indonesia, with many believing that the term is not applicable within an Indonesian context as all Indonesian people, prior to the country's colonization, lived in kingdoms according to their own customs and rules and thus could be considered indigenous (Abbas, 2013). That stated, "masyarakat adat" has been adopted to describe communities that live by customary law and have a cultural attachment to a local place. AMAN, Aliansi Masyarakat Adat Nusantara or the Indigenous Peoples' Alliance of the Archipelago, was established by the Congress of Indigenous Peoples in 1999 and is estimated to serve 2,272 masyarakat adat that include more than 15 million people. These masyarakat adat face many of the same issues globally that other indigenous groups face, including contestation of rights regarding land tenure, human rights, customs and culture, and self-determination. While there are no known comprehensive statistics on ethnicities engaging in seaweed aquaculture, the coastal and rural nature of Indonesian seaweed farming means that many masyarakat adat engage in seaweed farming as a primary source of income. Many of these farmers state that seaweed has served as an important ancestral food source.

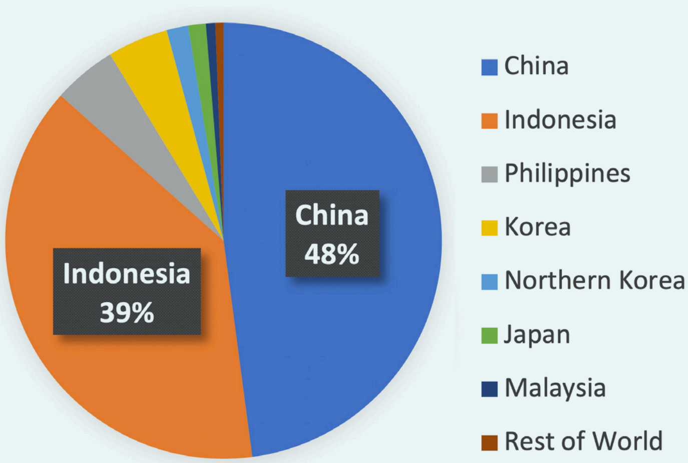
Women in Indonesian society, while diverse amongst religious and cultural groups, have generally been placed in a secondary role to that of men in both the house and workforce. While there have been recent improvements and efforts by the Indonesian Government for gender inclusivity, the Gender Inequality Index shows that Indonesian women are still behind men in reproductive health rights, empowerment, and employment (UNFPA, 2015). Globally, from Tanzania to the Philippines to the Solomon Islands, women play a significant role in seaweed farming. In Indonesia, it is also considered an important economy for women. A Sulawesi survey found that women relatives of seaweed farmers were instrumental in tying seed (Cai, Hishamunda & Rilder, 2013). Neish (2013) states, and The Conservancy's observational data confirms, that women play an important role in seaweed farming, with some women even becoming the main household earner despite previously earning little income. As seaweed farming is an important income for women and in traditional communities, increasing its environmental performance and profitability can support gender equity and indigenous rights.

Economy

The Indonesian economy has grown significantly in the last 20 years, with the GDP per capita rising from US$857 in 2000 to US$3,603 in 2016 and the World Bank describing Indonesia as an "emerging middle-income country." Despite this, 11% of Indonesians live below the poverty line and an additional 40% live marginally above the poverty line, considered to be vulnerable to poverty (World Bank, 2018). While Indonesia's largest exports are currently palm oil and coal briquettes (Indonesia, n.d.), Indonesia is the world's second largest producer of aquaculture after China (FAO, 2016). Indonesia also ranks second behind China in the production of seaweeds, contributing 38.7% of the world's seaweed. There are at least 555 species of seaweed in Indonesia, with at least 21 known to be used as a raw material for processing, including the three species of focus for this manual (Syamdidi, Irianto & Irianto, 2016)

In 2012, Indonesia's aquaculture comprised 35% of total seafood production in tons, with wild capture comprising the remaining 65%. However, the employment numbers in 2011 demonstrate that aquaculture employed more people in Indonesia than wild capture fisheries, with aquaculture employing 3.34M and wild capture employing 2.75M. While the GDP per capita for Indonesia as a whole is $3,603, many seaweed farmers were shown between 2007-2009 to make up to $5,000 per year (Neish, 2013), a 33% higher income than the current national average, showing that seaweed farming is an important and valuable industry. That stated, this higher income is highly variable, depending on the location, farming practices, and market prices, showing that improvements to the industry are needed for income stability.

FIGURE 1. Global Seaweed Production, 2016



FAO, 2018

Geography and Climate

Indonesia is made up of over 17,000 islands, has coastlines 104,000 km in length, and a population of 258.5M. It is a country defined by its natural, and in particular, marine resources, with 70% of its land coastal. The Ministry of Marine Affairs and Fisheries has estimated that there are approximately 12.2 million hectares of coastal areas suitable for seaweed farming in Indonesia. Only ~ 1.1 million hectares are currently used for this purpose, utilizing about 9% of suitable space for seaweed farming. That stated, while 91% of the Indonesian coastal areas may be considered by the government as suitable for expansion, there are a significant number of other marine uses and habitats that can conflict with seaweed farming; with any future growth, marine spatial planning should be employed in order to avoid habitat degradation and conflicting uses.

Indonesia has a wet tropical climate with two seasons - dry and rainy - with temperatures ranging from 21-33 degrees C. This climate is key for growing the tropical *Eucheuma* and *Kappaphycus* seaweeds, which can tolerate surface temperatures of 22-33 degrees C (Largo et al, 2017), but the extreme variability between seasons require localized seasonal calendars for proper growth and prevention of disease (see "Example Seasonal Calendar" on p.36). Due to tropical seaweed's temperature-driven range and coastal distribution, it is necessary to consider current and projected climate change-driven impacts on suitable production areas. Indonesia is expected to broadly see by 2030 an increase in: temperature of at least 1 degree C, net precipitation rates, and net sea level rise by 30-40cm yielding nearshore changes in salinity, infrastructure flooding, and increased storm surges (NIC, 2009). As a result of increased nutrient inputs and changing rainfall patterns, Indonesian seas are also expected to see an increase in eutrophication (Sinha et al, 2017).

Distribution and Genetic Diversity of *Eucheuma* and *Kappaphycus*

Distribution and Genetic Diversity

For all sectors of the supply chain, particularly those working on the Indonesia seaweed supply chain for better environmental practices, a basic understanding of the distribution, growing conditions, genetic diversity, and main risks to the *Eucheuma denticulatum*, *Kappaphycus striatus* and *K. alvarezii* seaweeds is necessary for a base understanding of the industry.

TABLE 1. Commercially Cultivated Indonesian Seaweed Names And Carrageenan Type Extracted.

Seaweed Name	Market Name	Carrageenan Type	Carrageenan Strength
Kappaphycus striatus	Sacol	Kappa	Strong gel when combined with potassium ions
Kappaphycus alvarezii	Cottoni	Kappa	
Eucheuma denticulatum	Spinosum	Iota	Soft elastic gel when combined with calcium ions

The three seaweeds of focus are all considered 'endemic' to the Coral Triangle, with all three native to the Philippines and Malaysia, and *Kappaphycus alvarezii* and *Eucheuma denticulatum* native to Indonesia. *K. striatus* was introduced to Indonesia for commercial cultivation and research, as were all three species to other areas of southeast Asia, the Pacific Islands, western Indian Ocean, and Latin and South America. Until the mid-1980s, *Kappaphycus* and *Eucheuma* were considered one species. Doty and colleagues removed *K. striatum* and *K. alvarezii* from the *Eucheuma* family and placed them within *Kappaphycus* due to differences in morphology and the type of the carrageenan extracted from these two seaweeds (Neish et al., 2017). Kappa, the highest valued form of carrageenan, is derived from *K. striatum and K. alvarezzi* (see Table 1).

All three species are generally grown within coastal areas in Indonesia, submerged in water near the surface for photosynthesis (although the seaweed can be placed in deeper waters, as long as water is clear), thriving in fast moving waters, but without too much wave action. Average growth and harvest cycles range between 45-60 days for smaller seaweeds and 30-45 days for larger seaweeds (Neish, 2004). To grow, farmers take cuttings from existing lines, a seed nursery, and/or purchase seed.

A 2014 genetic study in Malaysia, Philippines, Indonesia, and Vietnam showed that there are seven known haplotypes for *Kappaphycus alvarezzi*, seven for *K. striatus*, and two for *Eucheuma denticulatum*. Genetic applications within seaweed farming is a very nascent field, but could be important for identifying new strains, use of identification of seaweeds by genetic markers, tracking biodiversity, trait research (Tan, et al, 2017), and climate resiliency. Even without climate change impacts, both species will be vulnerable to disease without incorporating genetic diversity (Largo et al, 2017). That stated, selective breeding of seaweeds, as with any aquaculture species, would need to be managed due to the potential of "escapes" wherein bred seaweeds could potentially impact wild stocks.

Carrageenan Seaweed Export Trends and Prices

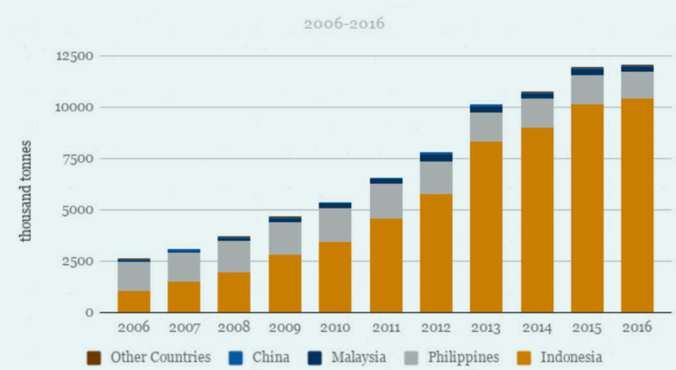
Hydrocolloid Markets

Globally, there is a growing demand for processed foods that is being driven by an ever-increasing population, as well as leveling trends that are leading to higher living standards in poorer populations and economic recessions in more wealthy populations – with the former able to purchase more processed food as a luxury and the latter purchasing more as a bargain buy (Campbell and Hotchkiss, 2017). This increased demand for processed foods has translated into a rapidly growing seaweed market to meet the demand for carrageenan and agar, which are derived from red seaweeds and are used as thickening agents within processed food and other products. The global value for the carrageenan market is estimated to be between $600-700M US and, at current growth rates, it is expected to reach $1B US by 2024 (Campbell & Hotchkiss, 2017). The carrageenan market is the fourth largest in monetary value of hydrocolloids, products that produce a gel when combined with water. The top three hydrocolloids above carrageenan that are perhaps more commonly known in the US are gelatin, starch, and pectin (Campbell & Hotchkiss, 2017), created from animal collagen, vegetables, and fruit, respectively.

Indonesian Carrageenan Seaweed Production

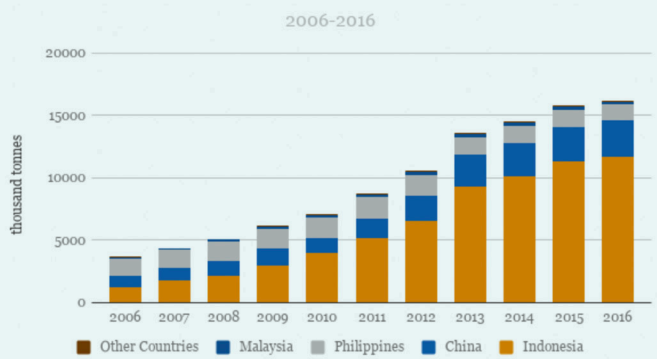
Over the ten-year period of 2006 to 2016, there was a 342% increase in the global seaweed production of red seaweeds, which are used for both agar and carrageenan. The clear majority of this increase was due to red seaweed production in Indonesia, which grew from 1.17M tons to 11.63M tons annually – representing an almost 900% increase over a 10-year period (FAO, 2018). This rise in Indonesia as a primary producer is

FIGURE 2. Global Production of Carrageenan Seaweeds



Data inclusive of Eucheuma and Elkhorn Sea Moss (Kappaphycus) (FAO FishStat, 2018).

FIGURE 3. Global Production of Red Seaweeds



Data inclusive of Gracilaria, Red Seaweeds, Eucheuma, and Elkhorn Sea Moss (Kappaphycus) (FAO Fish Stat, 2018).

more striking given that for over thirty years, from 1965 to 2006 (with the brief exception of 1976-77), the Philippines firmly held the role of the world's primary producer. An overall decline in production in the Philippines is generally connected to political violence and unrest in the country, as well as weather conditions that have not been favorable to seaweed farming (Valderrama, 2012). Additionally, the emergence of Indonesia as a major carrageenan player occurred after the advent of semi-refined carrageenan technology, which led to a large increase in demand for seaweeds. Processing company managers led a targeted effort in Indonesia to cultivate a second source of both *Eucheuma* and *Kappaphycus* and Indonesia has risen in prominence to what Neish et al (2017) refer to as a present status of 'alpha source' currently able to supply the entire global need for eucheumatoid seaweeds with the Philippines now serving as the 'beta source.'

In 2016, Indonesia produced almost 72% of the world's red seaweeds, followed by China which represented 18.4% of total production at almost 3M tons, the Philippines at 8%, and Malaysia at 1.3%. Other smaller producers ranging from 17K and 4K tons of production annually included Madagascar, Chile, the Solomon Islands, and Vietnam. Indonesia produces both *Eucheuma* and *Gracilaria* (FAO, 2016), the two species that produce about 90% of the world's carrageenan and agar (Campbell & Hotchkiss, 2017). While *Kappaphycus* is also grown and sold within Indonesia, it is not reported from Indonesia to FAO separately and – perhaps due to name switch of *alvarezii* and *striatia* from *Eucheuma* to *Kappaphycus* in the 1980s – is presumed to be grouped within the FAO *Eucheuma* production numbers.

In looking specifically at *Eucheuma* and *Kappaphycus*, the two species of focus for this guide and that are used for carrageenan, Indonesia represents even more prominently, producing ~87% of the world's supply of carrageenan seaweeds in 2016. The Philippines produced 10.8% at 1.3M tonnes followed by Malaysia at 1.7% or 205K tonnes, and China at only .42% of the world's production at 51K tonnes annually. Madagascar, the Solomon Islands, and Tanzania rank next producing 17K, 10K, and 7K tonnes in 2016, respectively. What is most interesting about this data in relation to the global production of red seaweeds is the that while China is a significant purchaser of carrageenan seaweeds, they are not a large producer, due mainly to their climate being currently too cold to farm these species.

TABLE 2. Trend of Wet Seaweed Production in Top Ten Provinces in Indonesia in 2011—2013.

Province	Production (Wet Ton) 2011	2012	2013	% change (2011-2013)
South Sulawesi	1,506,264	2,104,446	2,422,154	60%
East Nusa Tenggara	377,200	398,736	1,846,334	389%
Central Sulawesi	758,910	991,590	1,233,058	64%
Southeast Sulawesi	586,965	639,192	917,363	56%
West Nusa Tenggara	290,700	477,037	599,100	106%
Maluku	610,365	474,167	583,351	-4%
East Kalimantan	83,093	585,941	249,412	200%
North Sulawesi	98,838	159,909	164,021	66%
Bali	106,398	144,168	145,597	37%
Gorontalo	89,149	95,442	103,924	17%
Other provinces	662,949	915,683	960,392	44%
Total	5,170,831	6,986,311	9,224,706	78%

MMAF, 2014a; Salim 2015: 12

Sulawesi is the center of seaweed production in Indonesia, with South Sulawesi the highest seaweed producing province in Indonesia (See Table 2). In 2013, Sulawesi's three provinces produced 4.7M tons of seaweed, approximately the same amount as the rest of Indonesia's provinces combined.

However, in analyzing trends by percentage change from 2011 to 2013, the largest increase in seaweed production was East Nusa Tenggara, with an increase of almost 400%. This was followed by a 200% increase from East Kalimantan and 106% increase from West Nusa Tenggara. These numbers and analyses do represent a very small date range and are over five years old. As such, beyond percentage increases, what is perhaps most pertinent is that this data shows both a significantly growing industry and dramatic variability of production year-to-year in most provinces, which is concerning for sustainable livelihoods and better environmental farming practices.

Indonesian Carrageenan Seaweed Pricing and Purchasers

The global price of red seaweeds has a history of volatility, with particularly extreme events in the market taking place in 2008-2009 where prices soared in Indonesia in 2008 and tanked in the Philippines in 2008-2009 (UN Comtrade Database data in Cai et al, 2013). For seaweed exports and prices during this time, Indonesian prices during 2008-2009 appeared to roughly inversely correlate with the Philippines, demonstrating the interconnectivity of carrageenan as a global market and how price volatility in one of top two producers of seaweed may positively or negatively impact the other.

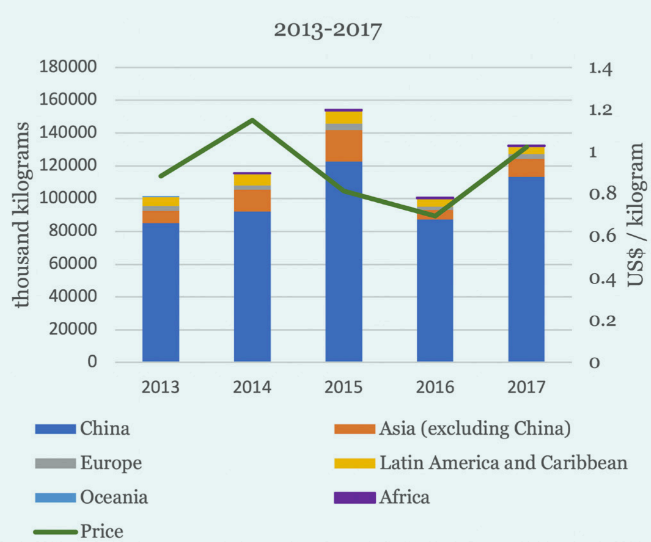
China first began dominating the Indonesian seaweed market in 2009, at which point it was purchasing approximately half of Indonesian seaweeds. According to the UN Comtrade Database (2018), Indonesia exported over 132M kgs or 132K metric tons in 2017, with almost 86% of this production sold to China. Other major regions that Indonesia exported seaweed to were Asia (excluding China) at 8.3%, Latin America and the Caribbean at 3.5%, and Europe at 2.2% (see Figure 4). Aggregated export prices show prices that ranged from US$ .85 to 1.02 / kg between 2013 and 2017, with the highest prices for Indonesian seaweed in 2014 and lowest prices in 2016.

It is rumored within Indonesia that the Chinese government provides a 15-35% fiscal stimulus / tax rebate to purchase seaweed, which allows their companies to purchase seaweed at higher prices. Higher prices from China aren't necessarily supported by the UN Comtrade Database data though, as reported by Indonesia. That stated, a stimulus could allow for greater bulk purchasing; China, with their large buying power, has been able to purchase Indonesian seaweed at the most uniform price, showing similar general trends with the other purchasers, but staying within .69 – 1.09 US$/kg between 2013 to 2017 (see Figure 5) with a standard deviation of only .18 US$/kg. By comparison, Europe showed about three times the volatility during this same time period with a standard deviation of US$ .54, purchasing seaweed between US$ .42 and 1.43/kg. Oceania data, not pictured here, showed the most extreme price volatility with a standard deviation of 1.7, purchasing seaweed at US$ 1.01/kg in 2013, US$ 2.35/kg in 2014, and even reaching US$ 4.35/kg in 2015 before leaving the Indonesian market – no export data to Oceania was reported for 2016 or 2017 (UN Comtrade Database, 2018).

Farmer carrying seaweed in Rote, Indonesia; © Robert Jones

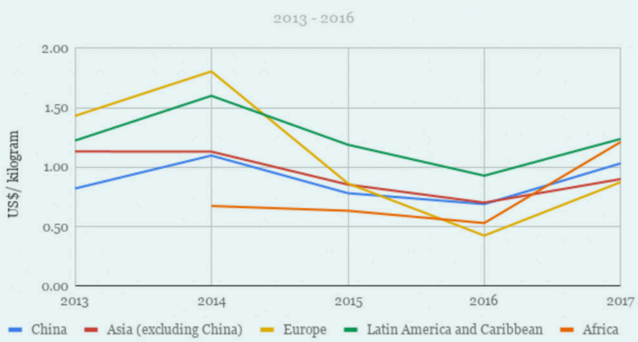
While the charts and data from UN Comtrade Database are inclusive of all seaweeds exported from Indonesia, the majority of seaweeds exported from Indonesia are for carrageenan and thus this data should track carrageenan seaweed exports closely. An additional data point comes from the purchaser CyberColloids

FIGURE 4. Indonesia Seaweed Export Volume and Price to Major Regions



Price calculated from value and quantity. No data for North American countries.; Commodities 121220, 121221. UN Comtrade Database, 2018.

FIGURE 5. Indonesia Seaweed Export Price by Major Region



UN Comtrade Database, 2018; commodities 121220, 121221. To provide more nuance for price by major purchasing region, Oceania 2013-2015 data was excluded as an outlier.

that provided their own *Kappaphycus* purchasing data for 2007 to 2016 from Indonesia that shows the 2008/9 significant price jump (~ US$2,500/metric tons) and dip (~ US$500/mt), and relatively steady price and trends around ~ US$1,000/mt in both 2010 after the market shakeup and September 2016, with peaks in between of ~ US $1,750/mt and lows of ~ US$800/mt. In March 2017, CyberColloids reported that they were paying US$ 900/mt (Campell & Hotchkiss, 2017), which is a bit under the UN Comtrade Database average data price for 2017 of US$ 1,230/mt.

Indonesian Carrageenan Processors and Policy

In 2017, there were 16 carrageenan processors in Indonesia, with no current foreign operators. While two-thirds of Indonesian Kappaphycus seaweed is exported dried in raw form for processing elsewhere, one-third is processed in-country, mainly for an industrial grade product for pet food and/or alkali-treated cottonii (ATC) (Campbell & Hotchkiss, 2017), dried seaweed that has been cut into pieces to form chips for easier processing. However, as of 2018, Chinese Shanghai Brilliant has now built an ATC and semi-refined carrageenan (SRC) plant in Indonesia, presumably the first foreign operator to do so.

In 2015, the Indonesian President discussed implementing a policy that bans or taxes the export of raw seaweeds, with the intention of exporting less raw product and creating more lucrative processing jobs. The Ministry of Marine Affairs and Fisheries stated in 2015 that domestic capacity for processing needed to increase gradually before enacting a tax or policy. According to the Indonesian Seaweed Association (M. Puspita, personal communication, December 2018), a current export ban could lead to a lack of economic viability for the seaweed farmers, as the local industry does not currently have the advanced technology, knowledge, or working capital that China possesses for processing the seaweed.

There has been discussion of a raw export seaweed ban in Indonesia for quite some time, with shifting dates for implementation, leading many in the industry to wonder if this ban will ever be implemented. However, there is precedent in other industries, as the Indonesian government imposed a cocoa bean export tax in 2010. This ban did lead to an increase in international investment in processing (Harrison-Dunn, 2015) and an overall shift from exporting raw cocoa bean to exporting processed cocoa products. There is some analysis showing lower cocoa export growth in Indonesia in comparison to other countries due to a decrease in competitiveness (Rifin & Nauly, 2013).

> **Chinese companies Shanghai Brilliant and Greenfresh are the top two carrageenan producers in the world.**
>
> *It is estimated that they are able to produce carrageenan at US $1-2/kg cheaper than those that can be produced by Indonesian or Philippines grades* (Campbell & Hotchkiss, 2017).

Aboulah Hatir transporting farmed seaweed; © Kevin Arnold

PART I:
Guide for Buyers of Seeking More Sustainable Seaweed Supply Chains

Part I: Guide for Buyers of Seeking More Sustainable Seaweed Supply Chains

Key Takeaways

- Reliable sources of seaweed that are farmed in environmentally better ways are not only of interest and benefit to coastal communities and environments, but to seaweed purchasers who are interested in securing stable and traceable sources of seaweed for their industries, in mitigating business reputational risks, and/or seeking to obtain market advantage.
- For seaweed purchasers interested in improving the sustainability of their supply chains, several third-party certifications exist and should be considered, although many of which have not been tailored to the unique circumstances of Indonesia's seaweed industry. In some cases, internal buying and traceability standards, vetted and audited by an independent third party, may be appropriate.
- There are significant challenges in Indonesia for supply chain traceability, including: a large number of small farmers that are located in geographically remote areas; a significant number of collectors and distributors that bloat the chain through side-selling; re-drying, co-mingling, and re-packing of product at multiple stages of the supply chain; and lack of general record keeping.
- Due to complexities, a large number of farmers, and higher costs associated with product segregation, a mass balance approach may be the most suitable traceability scheme for many parts of Indonesia at this time, but book and claim methods also show promise.
- In preparation for or in the process toward increased traceability and better environmental practices, buyers should work with their suppliers to increase record keeping and conduct, partner with local organizations working at the village level to encourage improvements, and be aware of and research emerging technologies for traceability.

Providing a guide for seaweed buyers as a key component for creating and fostering sustainable livelihoods and better environmental practices is part of The Conservancy's strategy to connect communities to socially and environmentally conscious buyers. Our strategy is rooted in the belief that, particularly for countries with lower regulatory controls for environmental protection, market forces can be a successful path to conservation gains while supporting coastal livelihoods. Reliable sources of seaweed that are farmed in environmentally better ways are not only of interest and benefit to coastal communities and environments, but to seaweed purchasers who are interested in securing stable and traceable sources of seaweed for their industries, in mitigating business reputational risks, and/or seeking to obtain market advantage.

Food retailers and customers are increasingly interested in their food origins and overall sustainability, with many looking more closely at ingredient lists for sustainably-sourced, fair trade, and organic products. In addition to this retailer/customer demand driving the sustainability market, seaweed purchasers may be interested in products that are sourced with sustainable eco-labels to ensure product differentiation in the market place, to mitigate reputational risk, and/or as part of a larger company commitment to a triple-bottom-line approach. From even a purely economic perspective, seaweed purchasers should be concerned about better farming practices in the seaweed sector as poor practices, whether environmental, social, or economic, can undermine long-term business viability.

Below is a discussion of options for seaweed buyers seeking to increase the sustainability and reliability of their supply chains, including current sustainable and organic seaweed standards, recommended minimum substantive guidelines for better seaweed practices, and traceability models and considerations.

Options for Seaweed Buyers Seeking More Sustainable Supply Chains

There are various strategies that purchasers can employ to advance sustainable livelihoods and better environmental practices in their seaweed supplies, including but not limited to: directly investing in improvement programs and technology within seaweed producing countries, providing direct trainings to farmers, and contributing to policy development in seaweed producing countries to help improve practices (UN, 2014). However, these options do not include traceability. To incorporate both better environmental practices and some form of traceability, seaweed purchasers have two principle options in seeking to increase the sustainability of their seaweed supply chains for their businesses and customers. While these are not mutually exclusive, these two options include:

- **implementing a third-party sustainable seaweed certification** that includes a requirement for traceability standards; or
- **developing and implementing internal purchasing and traceability standards**, vetted and audited by a credible third party

In addition to the above, buyers may choose to buy directly from farmers known to practice better environmental farming practices or work directly with an NGO to buy from farms practices better environmental practices (including those farms that are actively improving their practices). While this is a direct route to supporting better environmental practices and contributing to sustainable livelihoods as it cuts out suppliers and distributors and ensures complete traceability, this route can be challenging and potentially not currently attainable for many purchasers as enacting this at a scale for an entire product supply could be very costly. That stated, there are companies who may employ this model for small-scale purchasing, pilots, or in areas where the purchaser is physically located next to the farmers. As this option is based upon direct relationships and is generally smaller in scale, our more detailed discussions will focus on previously stated two options of obtaining a sustainable or organic seaweed certification and/or developing internal purchasing and traceability standards.

Off-bottom seaweed line in Rote, Indonesia; © Tiffany Waters

Sustainable and Organic Seaweed Certification Programs

An option for purchasers of seaweed that are both seeking to increase the sustainability of their seaweed supply chains and are interested in market verification/eco-branding of their products is to apply for and obtain a sustainability or organic certification. However, there is often uncertainty from consumers and companies regarding which certification is legitimate or the "right one" and how it might apply to specific regions. With this issue in the forefront, a new body - the Global Seafood Sustainability Initiative (GSSI) – is using FAO guidance to benchmark and recognize sustainability certification schemes. GSSI may be a valuable tool for seaweed buyers in the future, but as of the date of this report, they have not yet evaluated or endorsed any seaweed standards.

Below, we briefly detail the criteria of known seaweed sustainability and/or organic standards, and whether it is known if any farms in Indonesia have been certified. We outline these standards below with the caveat that The Conservancy does not actively endorse any specific certification program and welcomes other certification programs into future versions of this Guide. In discussing seaweed standards, The Conservancy aims to help seaweed buyers and all members of the supply chain understand the certification options, including both sustainable and organic standards.

Sustainable Seaweed Standards

There are many sustainable seaweed certification programs that a buyer can pursue, each with different strengths and weaknesses, depending upon the inclusiveness of social, economic, and environmental standards, and seaweed buyer needs. A brief discussion of Friend of the Sea, AsureQuality, the National Indonesian standard, and the new ASC/MSC standard is below.

Friend of the Sea

The Friend of the Sea seaweed standard is for both wild and farmed seaweed and currently includes requirements for: a management system, legal compliance, biomass and environmental impact assessment, water monitoring, air emissions monitoring, waste management, chemicals and hazardous substances, energy management, social accountability, and traceability. Of particular relevance to the environmental and social concerns in Indonesia, this standard explicitly includes the requirement of no destruction or removal of corals, sea grasses, predators, or mangroves; and states that the social concern of multi-use conflicts needs to be addressed. Friend of the Sea does not currently have any certified farms within Indonesia (P. Bray, personal communication, December 2018).

AsureQuality

The AsureQuality standard currently includes requirements for: a sustainable management plan, biomass estimate, seaweed production records including amount of fertilizer used, conversion period requirement, a carrying capacity assessment, recycling of gear, collection of juvenile seaweed from wild, and need to keep organic separate from non-organic. AsureQuality does not currently have any certified farms within Indonesia (E. Leader, personal communication, January 2019).

Indonesian Standard

The Indonesian national standard (Standar Nasional Indonesia / SNI) was created by the Indonesian government to increase the competitive value of the Indonesian seaweed. While this is a regulation rather than a voluntary "sustainability standard," we included it here as it is the only seaweed standard developed specifically for Indonesia. It is based on the WTO code of practice of openness, transparency, consensus and impartiality, effectiveness and relevance, and coherence and has economic development dimensions. It currently includes standards for the handling, processing, packaging, storing, distribution, and marketing of dry seaweed; as well as a guide from MMAF on how to harvest seaweed, including a minimum age of seaweed (45days), need to sort seaweed by carrageenan content, and need for seaweed to be free from algae and cut with a sharp knife.

Seaweed drying in Takalar, Indonesia; © Tiffany Waters

ASC-MSC

By far the most comprehensive of all the sustainability standards, the new Aquaculture Stewardship Council (ASC) - Marine Stewardship Council (MSC) sustainable seaweed standard for both wild and farmed seaweeds currently includes five principles of sustainable wild populations, environmental impacts, effective management, social responsibility, community relations and interactions, with 31 performance indicators against which performance is assessed and 69 scoring issues that are part of the assessment tree.

Of particular relevance to the environmental and social concerns in Indonesia, this standard explicitly includes guidance to: protect seagrasses, mangroves, corals, and sensitive habitats; minimize refuse of plastic bottles, Styrofoam, and ties through proper waste management and pollution controls; manage use conflicts and community impacts; include women in the management process; respect the right of indigenous peoples; and minimize the use of chemicals that persist as toxins in the marine environment. The ASC-MSC standard does not currently have any certified farms in Indonesia, but states that they "have received interest from Indonesian producers, but until an operation formally announces the audit, this information is kept confidential" (P. Bianchi, personal communication, December 2018).

Organic Seaweed Standards

The organic seaweed standards are typically designed for whole marketed seaweed, but may be relevant to carrageenan purchasers, depending on objectives of farmer and/or purchaser. Further discussion of EU Organic, US Organic, Natureland Organic, and ECOCERT organic are below.

EU Organic

The EU Organic standard currently allows for carrageenan to be included as an ingredient in organic products and still retain an organic label. EU Organic also has organic guidance for seaweed, with a requirement that an auditor recognized by the EU audits the organization or farms and currently includes requirements for: a sustainable management plan, environmental assessment, separating organic from non-organic production, recycling materials such as rope and other equipment, using no fertilizers with a preference for incorporation into a polyculture system, assessing carrying capacity, production records, and a conversion period of at least six months (need to be practicing all principles for six months prior to be certified). Of particular interest to Indonesian environmental concerns, there is the explicit requirement of not using fertilizers and requiring the reuse or recycling of materials.

USDA Organic

The USDA Organic standard recently and controversially approved carrageenan as an allowed ingredient in organic products. In 2018, the USDA reversed a prior National Organics Standards Board decision that had banned carrageenan from the approved organics list. Within the federal register, the USDA stated that even though the National Organic Standards Board (NOSB) recommended removing carrageenan, they "found sufficient evidence in public comments to the NOSB that carrageenan continue to be necessary for handling agricultural products because of the unavailability of wholly natural substitutes" (National Organic Program: USDA Organic Regulations, 2018).

Naturland Organic

The Naturland Organic standard currently includes requirements for: protecting fish and invertebrate habitat, no contamination, high water quality, sustainable management plan based on environmental assessment, fertilizing only allowed in tank-based facilities, no chemical anti-fouling agents, and culture density recorded. Of particular interest to Indonesian environmental concerns is the explicit requirement to be protective of mangroves, and the requirement to reuse or recycle materials.

ECOCERT Organic

The ECOCERT standard currently includes requirements for: minimum environmental and health characteristics for coastal water growing areas, separating out organic from non-organic production, a sustainable management plan that includes monitoring and minimizing negative impacts and nutrient discharge, use of renewable energy sources, collection of seed from wild occurs on regular basis for indoor stock for benefit of wide genetic gene pool, using no fertilizers at sea with a preference for incorporation into a polyculture system, recording and ensuring culture density does not have negatives effects on the environment, and recycling of ropes, equipment, and materials. Of particular interest to Indonesian environmental concerns is the explicit requirement of recycling of ropes and equipment, and using no fertilizers in marine waters.

Internal Purchasing and Traceability Standards

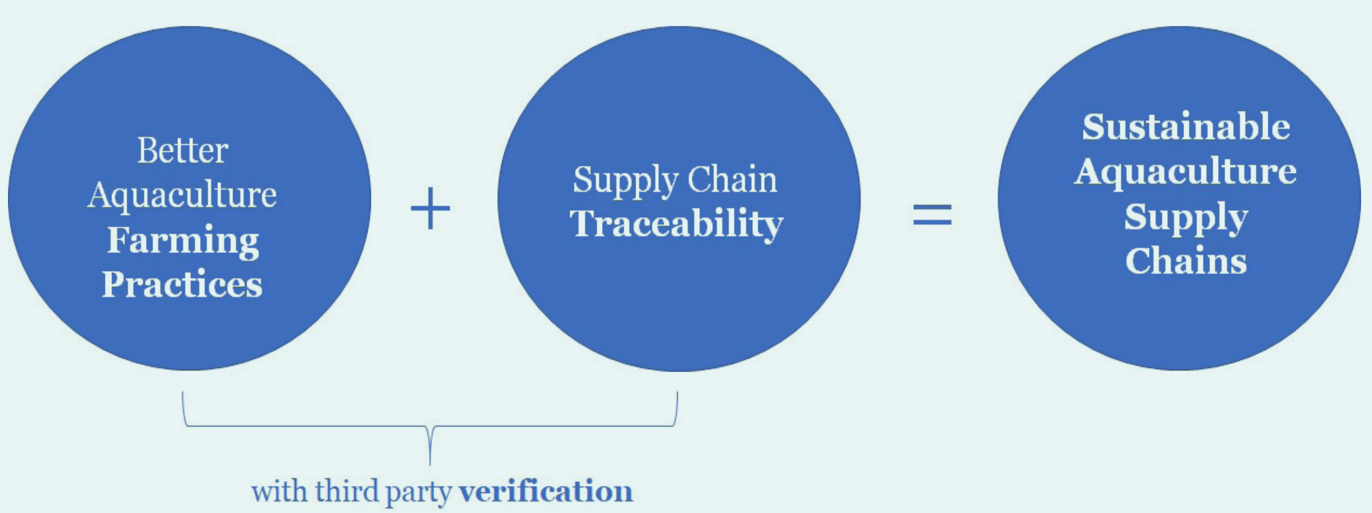
If a certification scheme is not currently feasible or preferred, purchasers may also advance sustainable livelihoods and better environmental practices in their seaweed supply chains by developing internal purchasing and traceability standards. In developing internal standards for increased environmental performance and reliability of seaweed supply chains, there are two key parallel components: 1) farming practices and supply chain that practice better environmental farming methods and incorporate safe human health and appropriate social guidelines; and 2) a traceability model that accompanies these standards to ensure that the farmed product with better management practices is traceable through its supply chain, with the farms and suppliers subject to monitoring and evaluation.

In addition to these two components, the company should work with a credible outside third party for review and verification of standards. There are discrete components to and challenges associated with both better aquaculture farming practices and supply chain traceability, which we outline below:

Minimum Substantive Guidelines for Better Environmental Practices and Encouraging Sustainable Livelihoods

Minimum standards that should be met by a seaweed purchaser are those that address the environmental, human health, and social challenges in the seaweed industry in Indonesia and include requisite standards for traceability, monitoring, and evaluation. As evidenced by the subject of this guide, we view better management practices in seaweed farming as key to conservation gains, social empowerment, and sustainable livelihoods for Indonesians. Below, we provide the Minimum Substantive Criteria for developing aquaculture certification standards

FIGURE 6. Sustainable Aquaculture Supply Chains



(Roberts & Walsh, in preparation), derived from the Technical Guidelines on Aquaculture Certification written by Food and Agriculture Organization United Nations Subcommittee on Aquaculture and Seaweed industry (FAO, 2011), and have also included more specific criteria that have particular relevancy for seaweed farming in Indonesia.

The above minimum criteria may be used in developing internal purchasing standards from seaweed farms and suppliers to encourage greater environmental management and seaweed farming practices. Companies may choose or need to develop their own purchasing standards for tropical seaweeds based on their customer needs, internal directives, or applicability of current standards to Indonesian seaweeds (see Sustainable and Organic Seaweed Certification Programs section above). If creating one's own standards, a credible and impartial third party with tropical seaweed knowledge should review and vet these standards.

TABLE 3: Minimum Substantive Guidelines for Better Seaweed Farming Environmental Practices, Sustainable Livelihoods in Indonesia

	Minimum Substantive Guidelines for Better Seaweed Farming Environmental Practices, Sustainable Livelihoods in Indonesia			
	Environmental	**Human Health**	**Social**	**Traceability, Monitoring, and Evaluation**
FAO Guidance	Habitat impacts avoided or mitigated	Actions taken to reduce human disease risk	Respect and compliance with relevant, local, national, or international legislation, regulations/ standards	Traceability and recordkeeping of farming activities and inputs
The Conservancy's recommendations for Indonesia	Includes protection for seagrasses, mangroves, corals, and sensitive habitats	" "	Includes managing for use conflicts, including fishing, tourism, and village planning	" "
FAO Guidance	Responsible use and disposal for aquaculture gear	Maintain healthy culture environment	Not jeopardize livelihood of aquaculture workers or local communities, including indigenous communities	Routine monitoring of farm sites
The Conservancy's recommendations for Indonesia	Includes references to minimizing debris from plastic bottles and ropes	" "	Includes recommendation to empower indigenous and local communities in planning processes	" "
FAO guidance	Impacts of movement and local sourcing of seaweed are considered	Responsible use of chemicals	Ensure fair labor treatment and pay	Tracking of key performance indicators or benchmarks
The Conservancy's recommendations for Indonesia	Includes reference to "local" sourcing of seaweed as qualitative and determined by region, but beneficial for resiliency	Includes reference to prohibiting use of green tonic or fertilizers	Includes encouragement and empowerment of women in planning and decision-making	" "
FAO guidance	Species-specific considerations (i.e., endemic or introduced species) are made	Water quality maintained at suitable level to produce products safe for human consumption		Actions taken if limits are approached and succeeded
The Conservancy's recommendations for Indonesia	Includes acknowledgement of naturalized species in Indonesia as appropriate to farm	" "		" "

Derived from Walsh and Jones, in preparation.

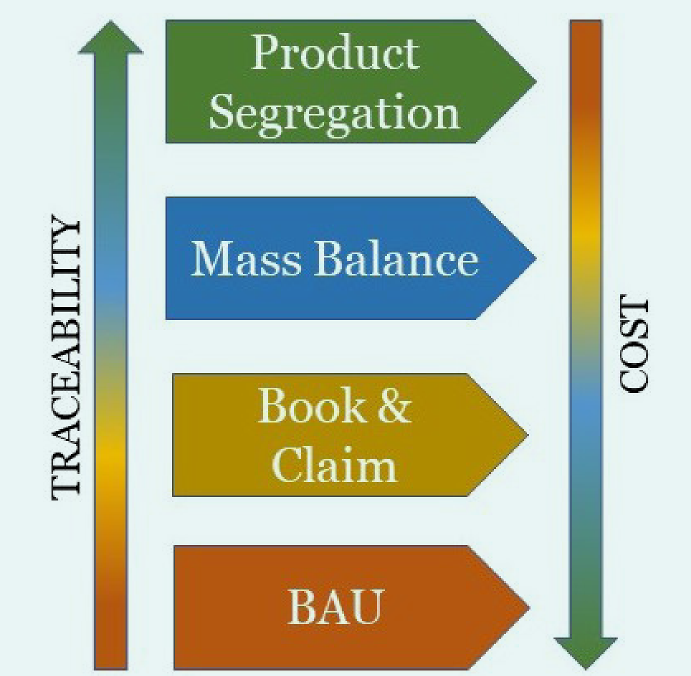
Traceability Models

While better environmental and social practices are a separate issue from traceability, traceability is an essential component to any certified sustainability supply chain endeavor as it is only through knowledge and tracking of a product from purchase to production that the sustainable practices can be connected with downstream buyers and consumers and product assurance can occur. Traceability is perhaps one of the greatest challenges of sustainable supply chains, but also represents great opportunities to re-unite consumers, retailers, corporations, stakeholders, and farmers for a common goal of improving the impacts of one product that is transported and co-valued within global networks. In this way, it can be a tool to increase not only awareness, but a sense of connection between the consumer and the farmer.

The UN Global Compact (2014) outlines three main traceability models: produce segregation, mass balance, and book and claim.

- **Product Segregation:** is aptly named in that it is a traceability model in which the certified materials are physically separated at every level of the supply chain. This model is the most stringent, requires data to be collected at every level of the supply chain, and is the most expensive to implement. Within this model, there are two types of product segregation:
    - *Bulk commodity:* allows for different products to be mixed along the supply chain, as long as each product comes from a certified farm. While this is considered product segregation, it does group products from different farms and thus is not complete traceability.
    - *Identity preservation:* requires that the identity of the specific certified product from a specific farm be retained through the full supply chain. This is the most stringent model, with full traceability in the supply chain.
- **Mass Balance:** is a model where it has been determined that a certain percentage of non-certified products are allowed to be intermingled with fully certified products. As such, the end consumer is not be able to determine complete traceability and whether their product is certified. However, within this model, only the total volume of certified products from the farm can be sold as certified.
- **Book and Claim:** allows producers to contribute certified materials to the market, receive a sustainability certificate for that specific volume of product, and then sell that certificate on a Book and Claim trading platform to a manufacturer or retailer. Most traceability within this model is removed wherein the end consumer is not able to determine if their product is certified, but the manufacturer or retailer is paying a premium to producers who practice sustainable farming, financially rewarding sustainable practices.

FIGURE 7. Correlated Function between Traceability and Cost for Traceability Models



In a globalized world and market, traceability has led to various initiatives and certifications to improve the social and environmental impacts of food, building materials, and supplies; examples include a goal for increased sustainable wild capture fishing through MSC, a commitment to improved farming practices through the Better Cotton Initiative, and a goal for more sustainable sugarcane and ethanol through Bonsucro's Certified (UN, 2014). For the latter, despite only starting in 2011, Bonsucro recently stated that their certified farms reduced their water usage by 40% and that in a four-year period from the certification's inception in 2011 to 2015, their certified mills saved the equivalent of 611,732 vehicles' annual emissions of greenhouse gases (Viart, Seixas & Tunon, 2017).

These traceability models can generally be thought of having a correlated function between traceability and cost, with higher traceability levels associated with the highest direct costs for implementation, lower traceability levels associated with lower costs, and business as usual (BAU) equaling no increased traceability and no increase in direct costs. The traceability models could also be viewed as steps in a ladder to incrementally achieve full traceability, with a Book and Claim model potentially being employed while supply chain mapping is underway for future implementation of a mass balance model, which could subsequently be employed until additional supply chain mapping occurs to later support product segregation. Ultimately, while full traceability may not be possible currently, some traceability beyond BAU and taking steps toward fuller traceability is highly recommended from even just a business case as poor sustainability and lack of connection between supply and demand can cause an increase in indirect costs by undermining long-term business opportunities; and there can be a market value-add in giving the customer a degree of product assurance and telling the story of product origin, including the community and livelihoods supported.

Traceability in Indonesia

Traceability helps to ensure that purchased seaweed comes from a known production area and can be a tool for ensuring seaweed purchased comes from a certified production unit that farms in a sustainable manner. While traceability can be an essential component to helping promote sustainable farming practices, it is particularly challenging in Indonesia due to its complex supply chain. Below, we discuss the history and known value-chain of seaweed in Indonesia, and recommendations for increased transparency and traceability of farmed seaweed in Indonesia.

Traceability and Current Supply Chain of Seaweed in Indonesia

The history of the supply and value chain of seaweed in Indonesia has changed significantly over time since seaweed farming's inception. Neish (2013) provides a succinct summary of what he refers to as the different governance models of the carrageenan seaweed supply chain, including direct, modular, market, and relational.

1) The **'direct governance'** phase of seaweed farming supply chains was the first stage from roughly 1974 to the mid-1980s where the purchasing of seaweed was dominated by the "big three" transnational companies of Marine Colloids, Auby, and CP. These three companies focused on innovations in processing technology and seaweed farming for increased carrageenan. Standards for seaweed farming were set by Marinalg, a trade association of which these three were associated. The transnational purchasers worked with and invested directly with farmers, with very few buyers and a growing number of small farmers.

2) The following phase of **'modular governance'** occurred from roughly the 1980s to the mid-1990s where suppliers become a significant part of the supply chain. Increased farming of *Kappaphycus* led to the development of the semi-refined carrageenan – a low-cost thickener developed originally for pet food – and new industries began manufacturing this new technology. The Philippines lost its monopoly on the carrageenan seaweed market as Indonesia and Tanzania starting increasing production. With more farmers, more industries, and the insertion of suppliers, purchasers no longer had many direct links to farmers. Marinalg still helped to set standards, but their influence to do so was not as strong.

3) The third phase of '**market governance**' started in the mid-1990s where farming grew within Indonesia to more remote islands and the supply chain grew to include collectors and traders, where there were two or more links in the supply chain between farmer and purchasers. While this 'side-selling' did not provide much value to the famers or purchasers, the collectors were able to capitalize on the increasing demand for carrageenan seaweeds and the large volumes that purchasers were buying. Purchasers reduced their investments in farms and trainings because their "investments could no longer be protected and internalized" (Neish 2013, p.67). There was significant divide between supply and demand and a huge amount of instability in the market between 2008-2009 where prices fluctuated significantly, leading to a growing recognition that a different model for market stability was needed.

> Disconnection
> *of supply (farmers) & demand (purchasers)*
> =
> market instability

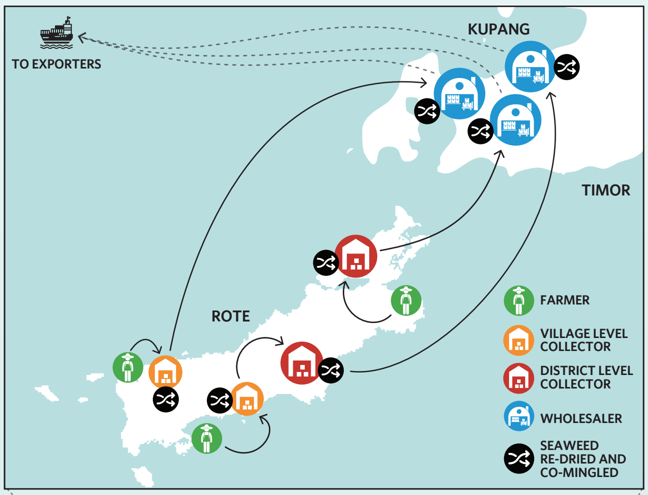
4) The fourth phase shift to **'relational governance'** first started in the early 2000s, with aid organizations and business development services helping to provide increased environmental performance and social assistance in the supply chain. A key part of this is structure is farmers creating co-operatives to better position themselves within the market, an overall creation of strategic and relational partnerships, and an increased market demand for transparency, sustainability, and fair trade.

The Conservancy's focus on partnerships and increased environmental, social, and economic performance positions us and our approach within this fourth phase of governance. However, much of the Indonesian seaweed chain is still firmly situated within the third market governance phase with the following challenges:

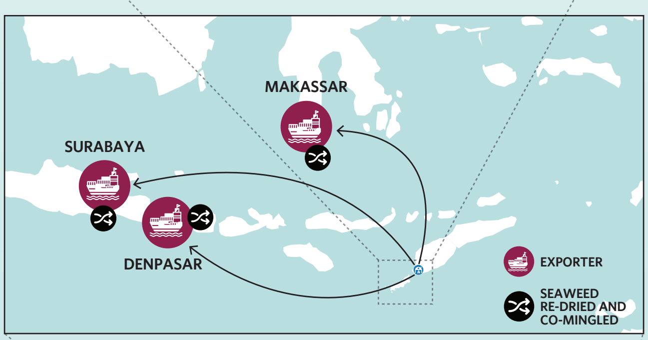
- many small farmers that are located in geographically remote areas, making direct connection to purchasers difficult and cost-prohibitive;
- a large number of collectors and distributors that bloat the chain through side-selling;
- a significant amount of re-drying, co-mingling, and re-packing

FIGURE 8. Example Indonesia Seaweed Aquaculture Supply Chain of Seaweed from Farmer to International Markets

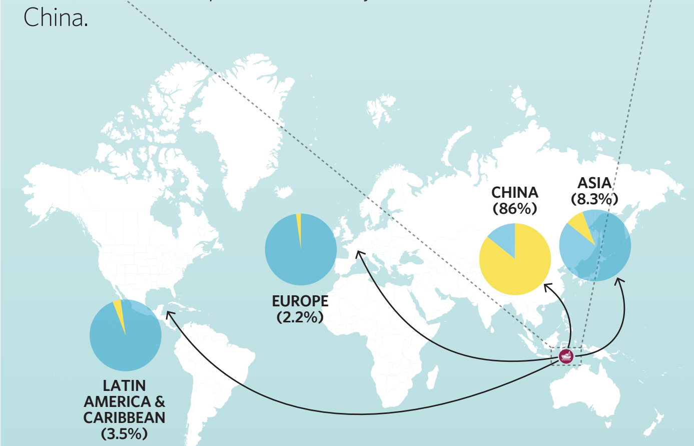
Using Rote Island as a case study, there are three main routes that the seaweed travels after being sold by the farmer, with all seaweed collected and sent to nearby Kupang on Timor Island before being sent to the export cities.



Seaweed is shipped from Timor Island to the main export cities of Makassar, Surabaya, and Denpasar. Seaweed is often re-dried and co-mingled along the supply chain.



The exporters ship the seaweeds to international markets. In 2017, Indonesia reported that they sold 86% of its seaweed to China.



Seaweed route information was gathered from an independent supply chain study. Farmer, collector, and wholesale locations are generalized and not representative of specific farmers or districts. Export locations and statistics are from Indonesia country-wide data (UN Comtrade Database, 2018), represent major country purchasers, and are representative of exported seaweed only (not inclusive of seaweed that remains in country for processing).

of product at multiple stages of the supply chain; and

- an overall lack of record-keeping and traceability, particularly at the early stages of the supply chain.

While these are significant challenges, other industries have faced and continue to face similar challenges and have had success in traceability and supply chain certification. In order to assist the carrageenan seaweed supply chain to continue moving toward a relational governance phase for greater social, environmental, and economic benefit for seaweed farmers and purchasers, we provide a set of recommendations for increased seaweed traceability in Indonesia.

Recommendations for Increased Traceability in Indonesia

This section will provide steps and recommendations for buyers to address traceability challenges in Indonesia, with a focus on doing so in accordance with better environmental and social practices. In order to understand the full supply chain and the challenges to be addressed in attaining full traceability, a purchaser should ideally conduct qualitative mapping of each stage of their specific supply chain (either internally or through a contract) to determine where and how to implement record-keeping and product segregation. However, in Indonesia – due to the challenges outlined above, this may be cost prohibitive and/or full traceability may not be the goal of all supply chain actors. With this challenge in mind, we have adapted the UN Global Compact's (2014) traceability for advancing sustainability recommendations, focusing on and adding Indonesian seaweed-specific recommendations and steps, as well as other emerging technologies:

- **Determine the supply chain inputs:** tracing the product back to its "raw" form helps to determine where risks can occur in the supply chain. For carrageenan seaweed, many large purchasers buy seaweed in a near-raw form, after being dried by the farmer, which makes it relatively less risky than other commodities that are processed at various stages of a supply chain. However, as discussed above, there is a lengthy supply chain and significant side-selling in most areas of Indonesia, which means that re-drying, intermingling, and re-packing occurs at multiple stages, representing a significant traceability risk/challenge.
- **Determine sustainability objectives and make the internal business case:** internally discuss the overall sustainability objectives and whether traceability will achieve these objectives, including strategizing internally about overall goals and conducting customer polling or analysis. Traceability may be determined to be one of multiple policies enacted to advance sustainability. If traceability is determined to be a priority for sustainability goals, then next steps include: surveying competitors for their traceability activities, conducting research on traceability models, and writing a business plan for action.

- **Commit to traceability:** by either engaging with a sustainable seaweed certification that includes a traceability requirement (see Sustainable and Organic Seaweed Certification Programs section) or creating internal purchasing standards that include both a better environmental and social practices and traceability component (See Internal Purchasing and Traceability section), with standards reviewed and validated by an independent third party. Key staff internally will need to be engaged and internal policies and processes should be enacted that support traceability. If creating internal purchasing standards, then the traceability model that best supports sustainability goals and is most applicable to Indonesia should be selected.

The third "commit to traceability" step is by far the most daunting and expensive. In reviewing the three traceability models and their applicability to the Indonesian carrageenan seaweed supply chain, we see product segregation to be most likely cost-prohibitive and potentially non-implementable at this market governance phase within Indonesia. The mass balance and book and claim models show more promise, given the complexity of the Indonesian supply chain. If a segment of a purchaser's supply chain can be traced, then the Mass Balance model may be the most suitable traceability model for Indonesian carrageenan seaweed supply chain at this time. As shown within Table 4, we view the Mass Balance model as most aptly suited and similar to commodities that have supply chains that range from complex to less complex, small to large-scale producers, and associated medium costs and traceability.

That stated, the book and claim is a model that, while not providing full traceability, presents a very promising opportunity for Indonesian purchasers to connect with and invest in the farmer implementing best practices directly, and could represent an important and intermediate step to invest in better environmental farming practices while working on further supply chain mapping in the long term. As demonstrated by the table below, many commodities are associated with more than once traceability scheme, as different countries and production centers will have differing levels of producers and supply chain complexity. Unfortunately, there is currently no existing book and claim platform for seaweed farming. If interested in this route, a purchaser should review the Roundtable on Sustainable Palm Oil or Bonsucro book and claim systems and reach out to local partners to create and implement this system.

Overall, purchasers should focus on commodities that are most material to their business; understand that significant time and resources will need to be devoted over the long-term; that internal capacity needs to be allocated to these tasks; and that relationships and communication are key (UN, 2014). Other steps that can be taken before full supply chain mapping occurs and/or in the process toward increased traceability and better environmental practices include:

- **Work top-down with direct suppliers**: to encourage traceability and record-keeping at a top-level. A purchaser can start with the part of the supply chain that they have direct connection to and by developing and implementing a supplier

TABLE 4. Traceability Models with their Sustainability Claims, Relative Complexity of Supply Chains, Cost, Traceability, and Examples.

	Sustainability Claims*	Complexity of Supply Chain	Size of Producers / farms	Cost	Traceability	Example Traceability Schemes	Example Commodities
Book and Claim	"product supports" the sustainable sourcing and production of seaweed	Highly complex	Many small-scale producers	Low to Medium	Low	Bonsucro Book and Claim, RSPO Book and Claim, Renewable energy certificates.	Palm oil, sugar cane, energy
Mass Balance	"product contains x%" of sustainably sourced and produced seaweed	Highly complex to moderately complex	Small to large-scale producers	Medium	Medium	Fairtrade, Forest Stewardship Council,	Cocoa, sugar, tea, timber, palm oil, juice, cotton (after bale split into yarn)
Product Segregation	"100% of product" comes from sustainable seaweed	Less complex	Small to large-scale producers	High	High	Fairtrade, Organic Food, Forest Stewardship Council, Marine Stewardship Council	Bananas, timber, some fish species, cotton (until bale is formed)

**Note that the basis for credible claims is also a function of credible impartial third party validation of standards and performance.*

code of conduct to guide ethical and environmentally sound business decisions for sourcing seaweed. This code of conduct should include implementable recordkeeping and chain of custody requirements, including working with distributors to implement record-keeping and minimize co-mingling. If able, the purchaser should prioritize and reward suppliers that meet these requirements.

- **Work bottom-up with local partners**: that are working in the buyer's area of purchasing to shorten and reduce the side-selling of the supply chain. In working with local partners, NGOs, aid organizations, etc., a purchaser can contribute to shortening the supply chain from the bottom up by helping to reduce side-selling. The current Conservancy approach (see Part II) is to encourage cooperative farming, gain acceptance and integrate better seaweed practices into the village development plan and budget, and with support of the village financial institution (BUMDes), recirculate the money within the village rather than out to a collector, thus shortening the supply chain by more directly linking the farmers to the suppliers.

Additionally, purchasers should be aware of and researching emerging technologies. There is a burgeoning field of identification technologies include DNA matching, stable isotopes, and near-infrared spectroscopy, all of which are applied in other food and natural commodity spaces, such as timber and fish. The applicability of these technologies to seaweeds is still nascent; one study investigating DNA barcoding testing of *Kappaphycus* and *Eucheuma* showed that while certain mitochondrial spacers could be promising markers for these species, the research revealed the poor overall comprehension of the taxonomy of the two species with only ~60% of seaweed identified correctly via DNA barcoding (Tan, Lim, Phang, Hong, Sunarpi & Hurtado, 2012).

Farmers harvesting seaweed in Takalar, Indonesia; © Robert Jones

Seaweed training in Rote, Indonesia; © Tomi Prasetyo Wibowo

PART II:
Guide for Conservation Practitioners: Engaging with Seaweed Farming as a Gateway to Conservation

Part II: Guide for Conservation Practitioners: Engaging with Seaweed Farming as a Gateway to Conservation

Key Takeaways

- Seaweed farming has great potential for use as a tool for conservation due to the economic, social, and environmental benefits it can provide when farmed in an environmentally and socially sound way. Benefits can include: gender and indigenous empowerment, livelihood improvements, coral reef and coastal habitat protection, coastal erosion mitigation, ecosystem services for water quality and habitat, climate change adaptation, in-roads to other conservation gains, and more effective marine protected area management.
- There are many challenges for seaweed farming to reach its potential as a conservation and community empowerment tool. These challenges include: habitat degradation from destructive farming practices, marine debris associated with farming activities, lack of technical knowledge on farming activities, a lack of regulatory controls and spatial planning for seaweed farming, a bloated supply chain and lack of farmer financing, climate change, and crop disease.
- Many seaweed farming challenges can be overcome by improving farmer knowledge through trainings on farming practices and making farmer information resources more readily available. Incorporating sustainable practices into village development plans, the development of cooperatively managed-nurseries, and working with financial institutions to provide access to capital and incentivize environmental practices are also critical steps to ensure the sustainability of farming activities.
- Asset-based community development, wherein local communities are committed to investing in themselves and their resources, is a model that NGOs and government can employ to work hand-in-hand with villages to improve seaweed farming practices, empower communities, and increase livelihoods. The Conservancy's "SIGAP" approach to asset-based community management can be applied to seaweed farming communities throughout Indonesia.

Due to the economic importance of seaweed aquaculture to coastal communities in Indonesia, seaweed farming represents both a challenge to conservation, as well as a significant opportunity. In viewing seaweed aquaculture as a gateway to conservation and social empowerment, conservation organizations, social justice organizations, and/or local or national governments can help advance important gains for the community as a whole and for the environment through minimizing impacts and maximizing the benefits of seaweed aquaculture.

Why Seaweed Aquaculture as a Conservation and Empowerment Tool?

Seaweed farming has great potential for use as an essential tool for conservation due to the economic, social, and environmental benefits it can provide when farmed in an environmentally and socially sound way. Within Indonesia, seaweed farming is an important industry for the overall burgeoning economy, as well as an incredibly important livelihood for rural populations, women, and masyarakat tradisional or cultural communities - an Indonesian equivalent of indigenous cultures wherein villagers live by customary law. A view that is increasingly recognized within the conservation community is when the basic needs of humans are not met, local environmental conservation is not possible. When livelihoods are dependent on natural resource extraction - through policy, encroachment, or theft – the food and shelter needs of the local people will first be met. Rather than viewing humans and nature as a zero-sum game, it is possible and even essential to see humans as a vital part of the natural environment and required allies for environmental stewardship.

Conservation Opportunities and Challenges

Conservation Opportunities

There are many reasons for conservation practitioners to engage in seaweed farming for social, economic, and environmental benefit, including:

Social

- **Gender and indigenous equity and empowerment:** it is an important livelihood for women, with some serving as the bread winners of their families. It is also an important income for rural masyarakat adat, such as villagers on Rote Island.
- **Alternative livelihood to fishing and piracy:** it can provide

an alternative livelihood to fishing and potentially reduce the burden on Indonesia's fisheries, many of which are fully or overfished, and has even been used as a tool against piracy recidivism by the Indonesian government (Marex, 2016) – all while potentially providing a larger per capita net income for the former and greater job (and life) security than the latter.

Economic

- **Important livelihood that has low entry costs:** it has few barriers to entry as it has low start-up / technology costs, is relatively easy to farm, there are low permitting costs, and it is relatively easy to enter local markets.
- **Great potential for growth and future benefit:** a recent World Bank analysis (Bjerregaard et al., 2016) shows that expanding seaweed farming in tropical areas like Indonesia, when done in a sustainable way, may further boost local incomes, food security through economic security, and environmental health.

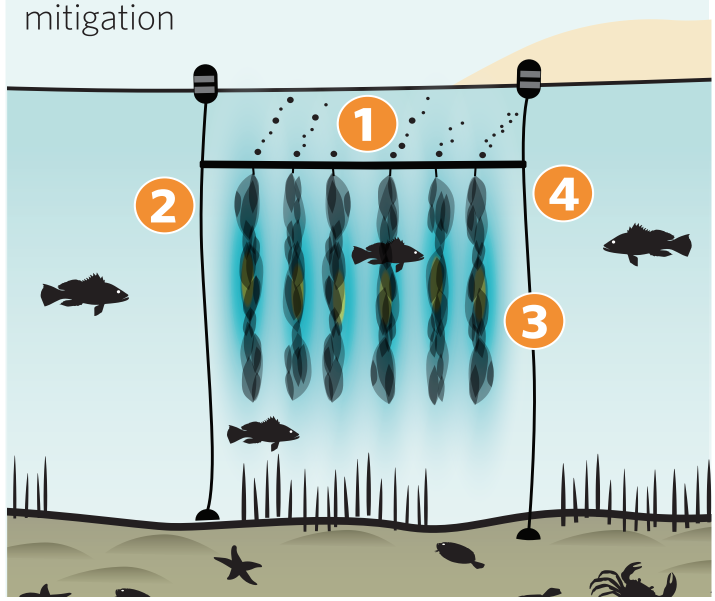
Environmental

- o **Coral reef and coastal habitat maintained:** when farmed unsustainably, aquaculture can lead to the removal and destruction of corals, mangroves, and sea grasses, which are important habitats for fishes, endangered and threatened species (sea turtles, dugongs), and marine invertebrates. By encouraging better farming practices of proper farm siting and seaweed farming intensification over expansion, these essential habitats can be protected.
- **Coastal erosion mitigation and storm resilience:** many seaweed farms currently cut down mangroves for stakes and remove seagrasses to establish farms. Mangroves and seagrasses are key for coastline protection, particularly in the face of increased sea level rise, flooding, and storms. In addition to helping retain sediments and preventing erosion, a 500-m wide forest of mangroves is estimated to reduce wave height by 50-100% (Beck et al, 2018). Farming seaweed in an environmentally better way—including use of alternative sources for stakes and protection of seagrasses—increases coastal resiliency.
- **Ecosystem services for water quality and habitat:** as 'restorative aquaculture,' seaweed farming can provide increased habitat and refugia for commercially important fish and invertebrates, and play an important role in increasing water quality through nutrient extraction.
- **Climate change adaptation strategy:** seaweed represents a farming activity that requires no freshwater to grow, which is particularly relevant given a warming climate. Seaweed, in removing nutrients from marine waters, can be an important climate adaptation strategy in improving water quality and accounting for projected impacts from increased precipitation and nutrient run-off. While additional research is needed, seaweed farming has been argued to reduce eutrophication at a greater rate than wild seaweed as it is harvested and removed from the marine system without being re-mineralized and consuming oxygen (Duarte et al, 2017).
- **In-roads and gateway to other conservation gains:** by working with villagers and building trust and relationships on a resource and economy that is important to them, spatial planning at the village level can be successful and more holistic conservation gains can be achieved, such as proper siting for both agricultural and seaweed farms, protection of freshwater resources, and reduction of trash and debris.
- **More effective marine protected area management:** efforts to develop, map, and enforce MPAs can be an important tool in effectively managing conflicting uses to ensure that every interest is accommodated and environmental impacts are minimized, particularly in regard to fishing, tourism, turtle nesting, and aquaculture. The Conservancy, by working on zoning and management plans of MPAs in conjunction with seaweed farming, is advancing a national government MPA priority of bringing economic benefit to the people, while also seeking to increase villagers' sense of "ownership" over their areas within the MPA, encouraging greater stewardship.

Conservation Challenges

As discussed above, there are multiple reasons why a conservation organization should work in increasing the environmental, social, and economic performance of seaweed aquaculture. While many of these have been alluded to above, there are many challenges to overcome socially, economically, and environmentally.

FIGURE 9. Seaweed farming can provide: 1. pollution mitigation; 2. habitat provisioning; 3. gear that provides macro-fauna refuge; 4. localized ocean acidification mitigation



Social

- **Lack of technical knowledge and support:** there is a general lack of technical support for and capacity of farmers to practice seaweed farming in a profitable way. Due to the low barrier to entry and easy start-up costs, it is relatively easy to begin seaweed farming. Regional governments have been known to supply seaweed farming supplies to villagers, but without the technical support on how to farm. While farming is considered relatively "simple" to learn, it does require localized knowledge of a seasonal calendar, support from a community group to cultivate and maintain healthy seed, general training on profitable farming techniques, knowledge of how to financially manage funds and sell seaweed, proper drying and post-harvest techniques, and knowledge of how to diversify one's markets beyond raw sale for carrageenan. Additionally, there is a lack of support for better environmental practices that include effective methods for disease prevention, maintenance, and pest management.
- **Lack of regulation derivatives and spatial planning in local level for seaweed farming:** As seaweed farming is a large and important industry within Indonesia, there are few regulations that limit the expansion of seaweed farming or address environmental conversion in a meaningful way. There is a law regarding coastal and small island areas (UU 27/2007) that states there is a prohibition of destruction or conversion of coral reef, mangrove, and sea grass ecosystems. However, at the local level, people many know nothing about this law, or when it is is known, there is no incentive to implement the law. Overall, there is no baseline monitoring required before installing a seaweed farm and very little to no monitoring of environmental conversion. Local governments have yet to establish marine spatial plans at scale, which would ideally require the consideration of the space requirements of multiple users (e.g., fishers, tourism) and critical habitats (e.g., coral reefs, seagrasses) to identify compatible locations for siting seaweed farms. In the absence of this type of marine spatial planning, significant spatial use conflicts are common.

Economic

- **Bloated supply chain and a lack of financing:** due to a complicated and long farmer → collector → wholesaler → exporter → purchaser supply chain, there is ultimately reduced profits for the farmer and a lack of financial investment in farming. Most local banks in Indonesia are not yet oriented toward financing aquaculture businesses, making fair financing often non-existent. The collector will often provide a loan to the farmer in exchange for purchasing their seaweed once grown – however, these loans are often high-interest and place farmers within an unsustainable cycle of owing more than or just as much as they produce. There is often a monopoly where only one local buyer is operating in a certain region, making an overall uneven power dynamic between the collector and farmers. Complex supply chains that lead to lower prices, poor farming techniques, environmental changes, and global shifts in supply and price have all led to a boom and bust cycle for seaweed farming, which has negative repercussions for the farmer and the environment.
- **Seed vulnerability and disease:** ice-ice is a significant disease of tropical seaweeds, owing its name to the bleaching of the tips (or "thalli") of the seaweed. Ice-ice can be triggered by a variety of drivers, such as changes in temperature or salinity, rather than caused by a pathogen – however, bacteria and fungi will attach themselves after the bleaching occurs and dissolve/consume the seaweed (Loureiro et al, 2017). The best defense against ice-ice is proper farming techniques that keep the seaweed submerged, but this cannot completely protect against storms or runoff that can cause a change in water temperature or salinity. Pollution and run-off from agricultural production and human settlement is also a significant issue for seaweed farming and can lead to disease, particularly during the rainy season when increased levels of precipitation cause significantly more nutrients to enter marine waters. Better and integrated spatial planning that includes wastewater treatment and accounts for placement of agriculture, freshwater resources, and seaweed farming at the village-level is the ultimate remediation for this issue. However, other ways to combat pollution and run-off are to have a protected seaweed nursery from which seedlings can be obtained to replenish damaged stocks and to create a seasonal calendar for seaweed farming that tracks the significant rainy times each year to avoid planting or harvesting during this time.

Environmental

- **Environmentally-destructive farming practices:** farmers can engage in the removal of seagrasses and corals, the cutting of mangroves, the use of green tonic fertilizer, and creation of plastic marine debris. In establishing off-bottom seaweed farms, many farmers will choose to remove the important habitats of coral reefs and seagrasses in order to create a smooth bottom for their seaweed lines. Farmers can use mangroves as a locally-available supply of wood that they cut down for use as seaweed farm stakes, removing a key habitat, shoreline stabilizer, and blue carbon reservoir. Some farmers, in seeking to stave off disease or increase production, will use a chemical green tonic fertilizer, which introduces excess nutrients into the water and decreases water quality.
- **Use of soft plastics and increase in marine plastic debris:** as part of long-line seaweed farming, single-use water bottles and styrofoam are generally used as flotation devices, which can degrade after 1-2 seaweed cycles and be a source of plastic marine debris and eventual contributor to microplastics. Farmers in both off-bottom and long-line seaweed farming use polyethylene (plastic) ropes of differing widths for lines and tying seaweed, creating large amounts of plastic fiber debris with each seaweed cycle and a source of debris, if left abandoned.

- **Potential climate change impacts, including warming waters and increased pathogens:** while we argue that seaweed can be used as a climate adaptation tool as it is a species that can be farmed in marine waters (limiting freshwater and land use) and may buffer acidifying water for bivalve benefit, it is important also to discuss how climate change may impact this industry. There is limited data on how *Eucheuma* and *Kappaphycus* seaweeds will be negatively impacted by climate change as most data and analysis is based on research on other species. However, negative impacts include the potential for: reduced spore production, germination, and recruitment; increase of bacterial disease and ice ice; decrease in gel strength and viscosity; increases in loss due to storms; and decrease in production or need to shift farming locations due to increases in freshwater. Perhaps the most clear-cut potential impact from climate change is warming sea surface temperatures, as both *Eucheuma* and *Kappaphycus* species have specific temperature constraints. Warming waters and environmental stress could lead to decreased germination and an increase of opportunistic pathogens, which could equal a decrease in product value and carrageenan strength. Decreased salinity from increasing rainfall could lead to reduced farming opportunities or the need to shift farming locations as salinity changes above or below the 30-35 ppt range for *Eucheuma* and *Kappaphycus* could negatively impact production (Largo et al., 2017).

While the above challenges are significant, we believe that relationship building, working with the local community at the village and district level on planning and financing, and win-win solutions that include both technical and environmental recommendations and successes can be important first steps in ameliorating these problems.

SIGAP Approach to utilize Seaweed as a Gateway for Conservation and Empowerment

The Conservancy's Indonesia chapter has been in country for over 20 years and has deeply-rooted relationships with communities due to previous work in marine protected areas, fisheries management, ecotourism, and forestry management, amongst other issues. An essential piece to working in Indonesia on these issues has been SIGAP, 'Aksi Inspiratif Warga untuk Perubahan' or Communities Inspiring Action for Change. This is a community-based planning and empowerment approach developed by The Conservancy's Indonesia chapter to improve the capacity and self-sufficiency of villages/kampung to create and implement development plans to manage their natural resources in integrated manner.

The essence of this approach, which can - and we argue should - be replicated by governments or conservation organizations, is "asset-based community development," which views community "assets" (human, financial, natural, social and physical resources) as the primary building blocks of sustainable community development. It emphasizes that empowered communities should be built from the inside out, bottom up and that significant and meaningful development can only take place when local communities are committed to investing themselves and their resources in the effort. By focusing on their available resources and aligning them with their vision of development, any investment and external resources can be appropriately allocated and can therefore be more effective.

Seaweed drying and plastic debris Takalar, Indonesia

SIGAP processes are grouped into seven phases: Disclosure-Define-Discover-Dream-Design-Delivery-Drive (7D). These are briefly discussed below:

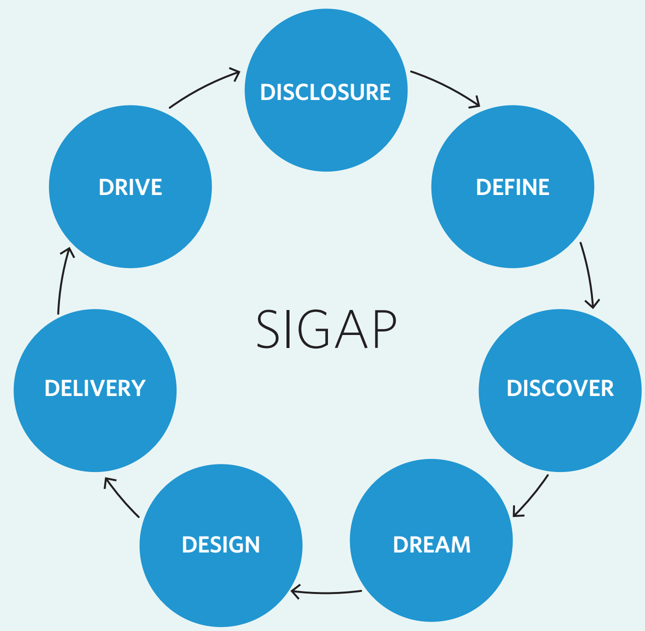
- Disclosure: initial phase where the government or conservation organization builds relationships and trust with the community in the working area. The interaction can be formal or informal and include engaging stakeholders from community, religious or prominent leaders, and officials from village government and related agencies.
- Define: a core team is established to define the scope of the community's current status, including issues such as economic activity, fishing practices, marine resource conditions, and general uses and trends.
- Discover: identification of strengths of the community, inventory of assets, and a discussion of ways to utilize these strengths in order to make changes for betterment of the people.
- Dream: all stakeholders are engaged in formulating a dream or a shared vision with a 10-15 year timeline for completion, based on the current and potential assets of the community.
- Design: using the dream as foundation and reference, a village workplan is formulated. Components of the workplan include a benefit and cost sharing scheme, planning for spatial use, and a participatory approach wherein the community is directly engaged in deciding or advising to protect or revitalize key natural resources.
- Delivery: a village stakeholder agreement is developed and the design phase is implemented, with actions for the economic, environmental, and social betterment of the community. Delivery includes monitoring of actions and results.
- Drive: evaluating the results of the prior six steps, including challenges and successes, in order to begin the planning process again.

While other conservation organizations may choose to use different language or engage in other processes, we see these as key replicable steps that can be used to empower villages to govern themselves towards sustainable change. Below, we discuss the applicability of SIGAP to improving the social, economic, and environmental dimensions of seaweed farming in Indonesia for the benefit of coastal communities.

Social: Improving Self-sufficiency of Villages

In 2014, the Indonesian national government created Law No.6, a new paradigm for village governance wherein the village is the base of the national economy, with an overall bottom-up approach to improve community welfare through the providence of basic needs, development of infrastructures, local economic potential and natural resource utilization in a sustainable way. The SIGAP approach aligns well with this new approach and through a participatory framework, encourages and respects the community as the main actor in driving change for improved

FIGURE 10. SIGAP 7D Phases



overall economic, social, and environmental conditions. Key actions for social change, as a basis for economic and environmentally sound practices, that a conservation organization can assist in facilitating or collecting data for are:

- **Determination if seaweed farming is a priority:** seaweed farming may not be a priority for all villages in Indonesia. In following the SIGAP approach, governments or conservation organizations can relatively quickly assess whether seaweed farming and related conservation objectives will be successful. One of The Conservancy's original pilot seaweed farms in Tablolong is no longer engaged in seaweed farming as the village did not deem it a priority economy for their village. While The Conservancy will continue to work with the village on other economic and conservation priorities, we will not advocate for seaweed farming in a village that does not currently consider it a priority industry.
- **Baseline monitoring and spatial planning:** in engaging the community in the first three stages of disclosure, define, and discover, the assets and current uses of the community are revealed and the government / conservation organization can work with the village to spatially map these uses, including seaweed farming and existing environmental habitats, including mangroves, corals, and seagrasses. Developing community maps of current uses and collecting social, economic, and environmental data provides a baseline from which progress is assessed and conflicting uses are identified – conflicting space use and lack of spatial planning is a major issue for seaweed farming in Indonesia, where it can compete with tourism, navigation, fishing, and protected areas.

- **Identifying village infrastructure and technical needs:** in helping facilitate the discover and dream phases, the gaps in skills and capacities for village administration, financial management, communication, and seaweed farming (and other concerns) can be identified, as well as the infrastructure that would be needed to manage the village and seaweed farming with increased benefits for the environment, economy, and society.
- **Development of an integrated mid-term village development plan inclusive of social, economic, and environmental needs:** the federal government requires all villages to create this plan in order to receive and utilize the village budget. In facilitating and helping base this plan on a collaborative 'dream,' the community is enabled to produce a long-term coastal use vision for the future to support the village development, protect the community land through better farming practices and conservation, and communicate this vision to external stakeholders. This plan also holds village stakeholders accountable to their commitment, vision and timeline; and ensures a commitment to monitor their own progress towards their vision. Conservation organizations can provide particular assistance and expertise to develop conservation-minded objectives in helping frame this plan.
- **Encouraging gender equity and inclusion of women:** included within the planning processes and decision-making stages above and within trainings listed below is a targeted inclusion of women. Seaweed aquaculture is an important livelihood for women in many areas already, but the involvement of women in the business management and decision-making should be encouraged for greater gender equity.

Economic: Increasing and Stabilizing Production of Seaweed Farmers

The SIGAP approach encourages stakeholders in the village to place economic development in perspective of social and environmental gains. In the villages that choose to focus on seaweed aquaculture as a main source of economic activity, village-specific needs and technical gaps will be identified. However, that stated, The Conservancy has found through its pilot seaweed farms, literature reviews, and in working with seaweed, that the following have been key steps in increasing and stabilizing production of seaweed, and working to increase financing to villagers while decreasing one level of "side-selling" in the supply chain.

- **Farmer trainings to improve economic stability:** as a lack of technical capacity has been identified as a constraining factor for many seaweed farmers, the conservation organization or government could hold trainings on: general financial management to help farmers budget according to the seaweed market and calendar, production of value-added products to help the farmer expand their market, proper drying techniques to increase the value of the product, and intensification practices to increase the volume of seaweed within one plot. These trainings will ideally be held in concert with the environmental trainings, so as to provide an overall economic value-add to the farmer while demonstrating better farming practices.
- **Development of a seaweed nursery for increased resiliency:** by helping to develop a seaweed seed nursery or bank for the village, the conservation organization or government helps to create a more stable quality of seaweed, with less outside seed needing to be procured. Having access to additional seedstock can also help buffer losses and help farmers rebound from mass mortalities caused from ice-ice, other diseases, and nitrogen run-off.
- **Working with the financial institution to recirculate investment in the village, encourage environmental practices, and shorten the supply chain:** there is a lack of investment in seaweed farming and a significant amount of 'side-selling' that reduces the economic return to the farmer. One strategy to The Conservancy has engaged in to ameliorate this is working with the local financial institution (currently the BUMDes – a village-owned business entity) to incorporate seaweed farming into the village economic plan in order to provide financial and social support. By engaging the BUMDes as a micro lender for seaweed farmers and even for seaweed infrastructure (e.g. village-specific warehouse), some collectors are eliminated from the supply chain, the supply chain is shortened, and this money instead circulates within the village.

Environmental: Better Seaweed Farming through the Protection of Corals, Seagrasses, and Mangroves, and Reducing Marine Debris

As part of the SIGAP process, the zoning for seaweed farming in conjunction with other land uses, is mapped and agreed upon by all stakeholders. In doing so, the community understands there are certain productive areas for farming, set areas for other commerce, and have agreed not to encroach on ecologically important ecosystems and species, such as seagrass, corals, mangroves, and nesting areas for turtles. Ecologically friendly farming methods of not dredging seagrass, not destroying mangrove and corals, and not using mesh net to allow turtle nesting are also endorsed and should be part of the program.

- **Corals, mangroves, and seagrass protection trainings:** should be conducted to instruct farmers to avoid corals and seagrasses, and recommend long-line farming, rather than off-bottom farming, in areas of corals and seagrass in order to protect and not disturb these key species; and intensification of practices, rather than continued expansion. Also, in addition to stating that mangroves should not be cut down for stakes, alternative trees should be suggested and information provided that discusses how important mangroves are for habitat and the village to combat coastal erosion.

- **Predator and grazer trainings:** should be conducted to encourage the removal, but not the killing, of sea turtles, dugongs, and other protected sea animals. Sea turtle spawning nesting beaches should be avoided and mesh nets should not be used for predator exclusion or marking of seaweed farm boundaries as sea turtles/dugongs can be become entangled.

TABLE 5. Example of Monitoring and Evaluation Framework for Organizations Working on Seaweed Aquaculture

	Criteria	Methodology	Sample Objectives*	Frequency
	ENVIRONMENTAL			
Coral reefs	# of incidence with long line seaweed lines/moorings found tied to coral % of off bottom farms in coral reefs	Field survey**:	No seaweed farms anchored on corals No off-bottom seaweed farms in coral reefs	Annual
Seagrasses	Percent cover # of incidence of off-bottom seaweed farms in seagrasses	Field survey**: Kirkman, 1996; Foley, 2018	No net loss No off-bottom seaweed farms in seagrass habitats	Annual
Mangroves	% of farms using mangrove stakes	Field survey	No mangroves used as stakes	Annual
Plastic debris	Debris density Debris material and type	Field survey: NOAA, 2012	25% decrease in first year; 5-10% decrease in following two years; no change in following years	Annual
	ECONOMIC			
Farmer income	Total income from seaweed	Village survey, interviews	25% increase after 3 years	Annual
	Price of seaweed	Village survey, interviews	Stable, or increasing	Annual
Income diversification	% of income value-added products vs carrageenan	Village survey, interviews	Increased diversification	Annual
Seaweed quality	Moisture content	Lab testing	30-35%	Semi-annual
	Carrageenan content	Lab testing	Depends on species	Semi-annual
	SOCIAL			
Gender equity	# of women participating in financial management workshops and/or management bodies for seaweed farming	Village survey, interviews	At least half of farmers participating in workshops are women by Year 2, with continued gender equity over time	Annual
Development plan	Incorporation of better seaweed farming practices in development plan	Village survey, interviews	Better seaweed farming practices included in plan by Year 2, with continued incorporation in plan over time	Annual
Infrastructure	Status/growth of seaweed nursery, warehouses, etc.	Village survey, interviews	Increased infrastructure to support better seaweed farming practices	Annual
BUMDes or other village economic institution	Incorporation of better seaweed farming practices into local economic institution	Village survey, interviews	Increasing steps taken toward village microfinancing in Year 1-4 with better seaweed farming practices incorporated into BUMDes by Year 5	Annual

**Targets will vary depending on site specific factors **These criteria can be assessed remotely, if technology allows.*

The trainings should include spatial mapping as an alternative for marking seaweed farm boundaries through rope, and strategies of removal and relocation of protected animals and the catching of animals that are appropriate to eat, for the purpose of reducing seaweed grazers and, in the appropriate cases, providing food.

- **Plastic marine debris and chemical trainings:** should be conducted to reduce plastic marine debris by gathering the single-use plastic bottles and collecting the polyethylene ropes to remove them from the marine environment. Trainings should also include information about the negative water quality impacts caused by chemical fertilizers, and promotion of farming methods that minimize or eliminate the need to use these chemicals.
- **Providing a guide for better seaweed farming practices:** in concert with the above trainings and/or to build from and scale out from the above trainings, an illustrated seaweed farming guide should be provided (see Part III).

Monitoring and Follow-up

In incorporating better seaweed farming practices into the village management plans and budget, these practices are committed to by the community. This commitment is particularly important for masyarakat adat, who are governed by and respectful of customary/traditional law. If done correctly, the disclosure step of SIGAP will involve meeting with local leaders who share their knowledge and customary laws and incorporate these into group visioning and management plans.[1] The last 'drive' step of the SIGAP process is reviewing the prior steps and work completed, including the baseline monitoring for social, economic, and environmental status, and building on that data to assess progress. This is perhaps the most key step that governments or conservation organizations can assist villages in structuring and following:

- **Environmental, social, and economic monitoring:** follow-up monitoring at regular intervals ranging from semi-annual to annual, is essential for tracking progress toward better farming practices.

The following chart describes the baseline monitoring to be done for key criteria, including recommended methodologies and frequency. While each area will need adapt methodologies to local conditions and monitoring may occur at a higher level, the above (p.29) represent our recommendations for assessing and tracking progress toward better environmental, economic, and social practices for seaweed farming. In assessing common measures throughout Indonesia and, as applicable, globally, data can be compared, trends assessed, and lessons learned communicated and shared.

1 On Rote Island, local wisdom and customs are referred to as "Papadak/Hoholok," which governs sustainable use of lands and sea and has its own enforcement strategies for those who break the Papadak/Hoholok. In 2016, The Conservancy helped assist in the endorsement of Papadak/Hoholok customary laws in three kingdoms in Rote Ndao District.

Additional criteria, including factors for operational needs (e.g. water quality samples), may also be included. SIGAP and the above listed social, economic, and environmental steps can not only increase environmental performance of seaweed farming at the village level, but strengthen community access to and rights over coastal areas by establishing collaborative management to ensure protection of and access to important natural and cultural resources. This type of collaborative planning can also enable villagers to be proactive and prepared to anticipate externally driven change (e.g. port development, large-scale offshore mining, etc.) that may affect their coastal areas.

Tk

Seaweed farms just off of Lembongan Island; ©Kevin Arnold

PART III:
Illustrated Guide for Seaweed Farmers of *Eucheuma* and *Kappaphycus*

Collaboration and seaweed nursery is essential

Farming seaweed in a community, rather than alone, will produce the highest quality seaweed. With the assistance of experts and planners, farmers can collaboratively plan seaweed farm sites and drying areas, maintain lines together in a shorter amount of time, and create a seaweed nursery that is tolerant to local conditions and has proven success.

Coaching:

Seaweed experts and planners can assist with farm mapping and work with farmers to pick the best spot for a nursery.

Seed selection:

Farmers should select the highest quality, best growing seed for local conditions, and create a seaweed nursery to provide a consistent source of seed.

Maintenance:

Like farmer-owned seaweed lines, the seaweed nursery needs to be regularly maintained. By working in a group to conduct maintenance, responsibility and work is shared.

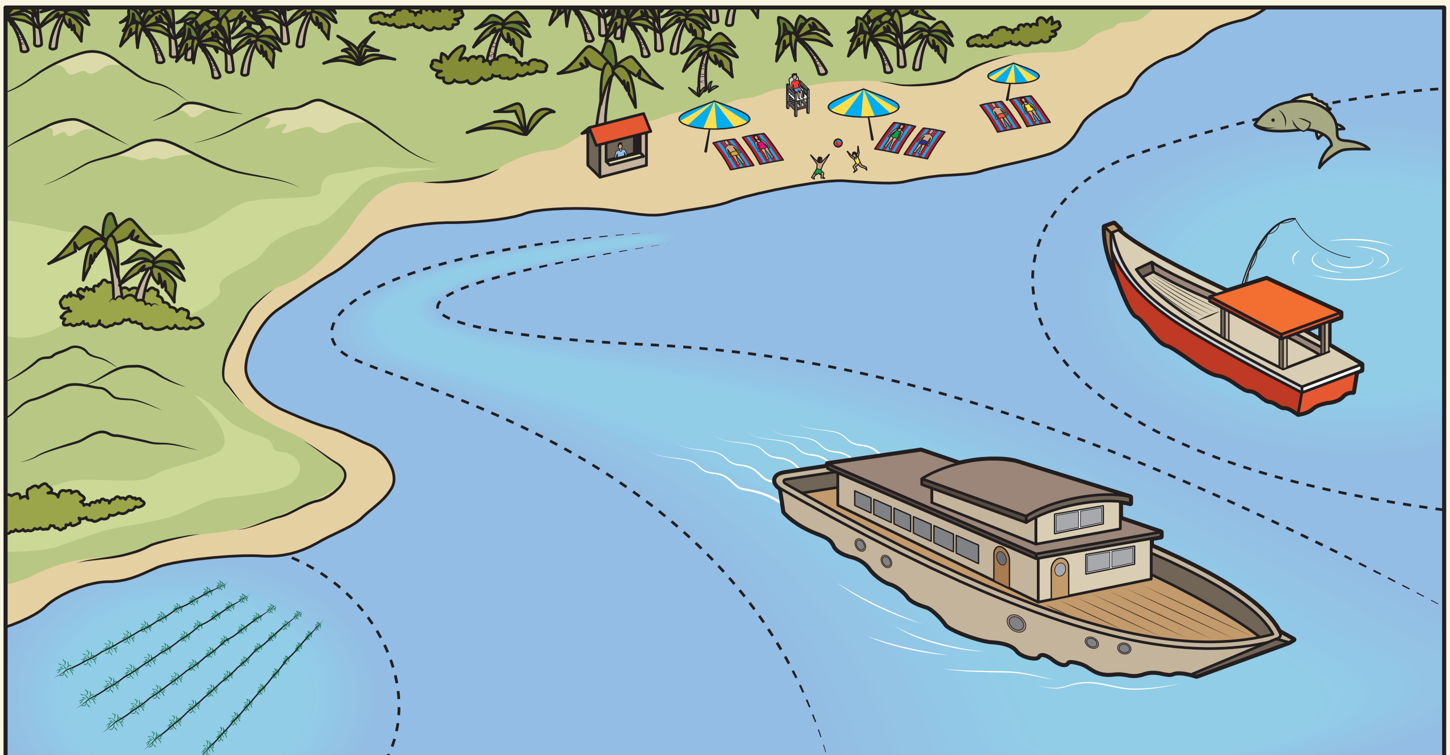
Healthy harvests:

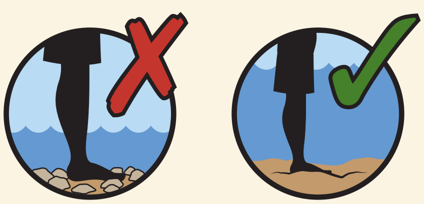
By maintaining a healthy seaweed nursery, seaweed can be farmed throughout the year and more seaweed can be produced.

Picking the right farming location is key to success

Seaweed farms should be sited in areas with good current, but away from conflicting uses like fishing areas, tourist area, and navigation channels; and sensitive habitats like coral reefs and seagrasses. Do not site drying racks near turtle nesting grounds - this is a protected species. Smart siting will protect the seaweed farms and reduce conflicts.

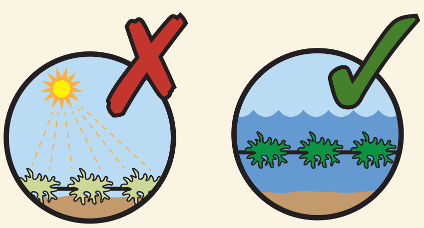
Small farmers must obtain TPUPI from Ministry of Marine Affairs and Fisheries. Farmers should also abide by all other laws and permits.





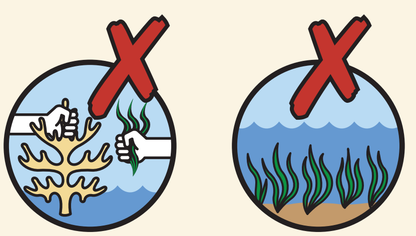
Water depth:

For off-bottom farming, depth should be around 1 meter deep at low tide so that the seaweed stays submerged under water.



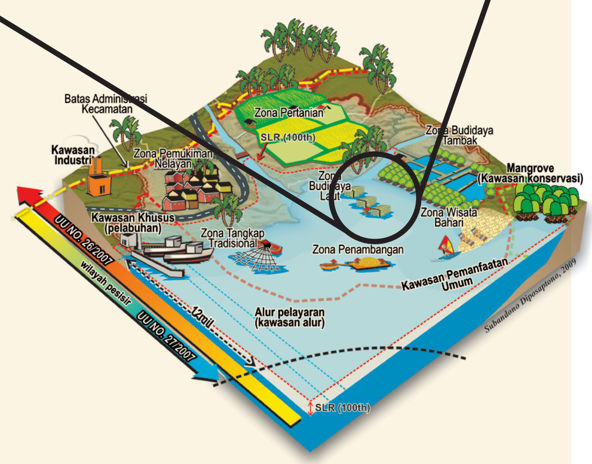
Sun exposure:

When seaweed is exposed to the sun, tips will turn white and disease will occur. Keep seaweed submerged under water.



Seagrasses and corals:

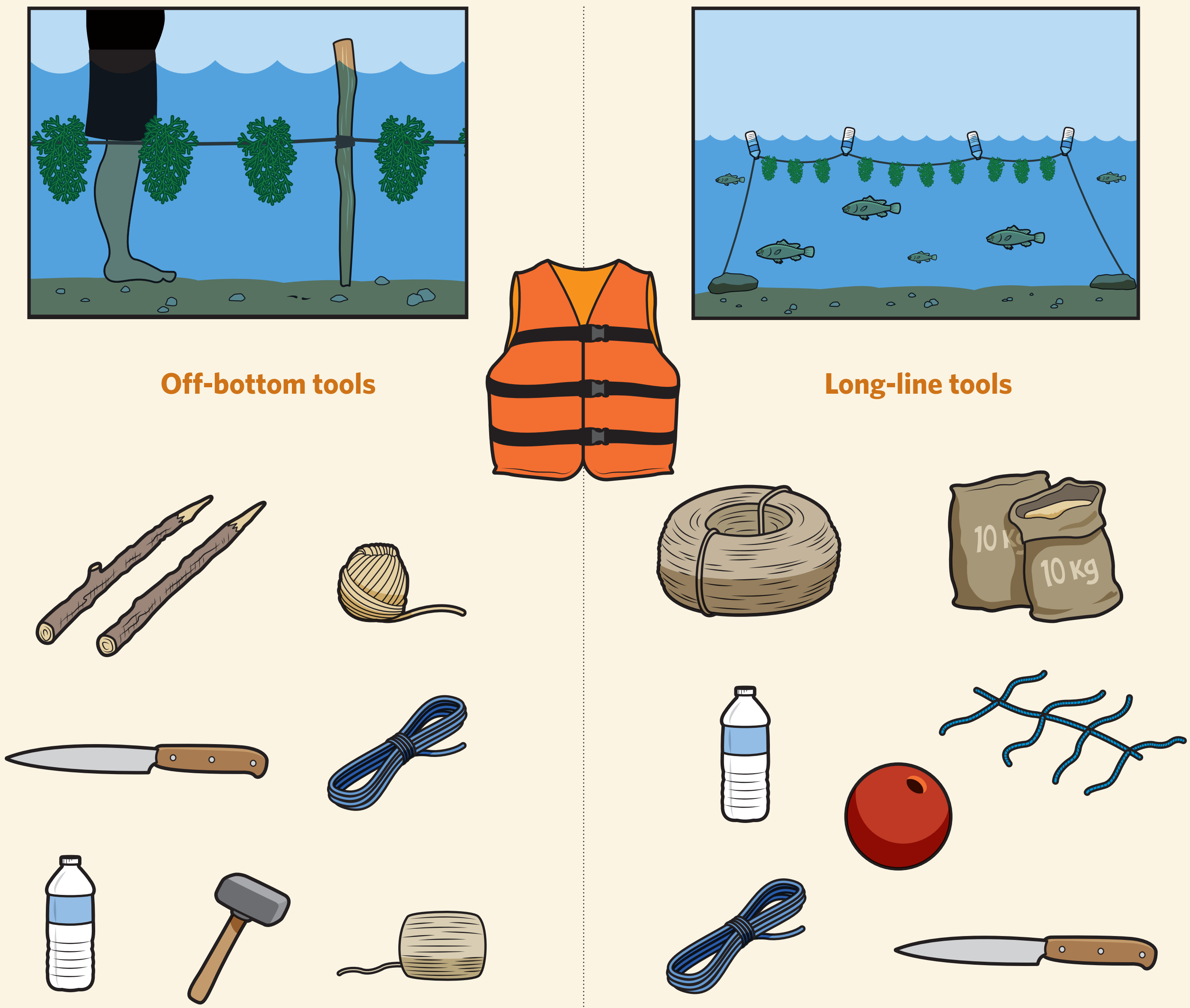
Try to avoid coral and seagrasses when siting farms. If they cannot be avoided, do NOT remove them as they are important habitat for fish and other species. In these areas, long-line farming method should be used.



Seaweed Farming Tools

Before constructing an off-bottom or long-line farm, the following tools are needed: rope (long and short), mallet, buoys or water bottles (buoys preferred), knife, stakes, life jacket, and cement or other object to anchor long lines to the bottom.

Track these tools and dispose of them properly, away from marine areas.



Plastics:

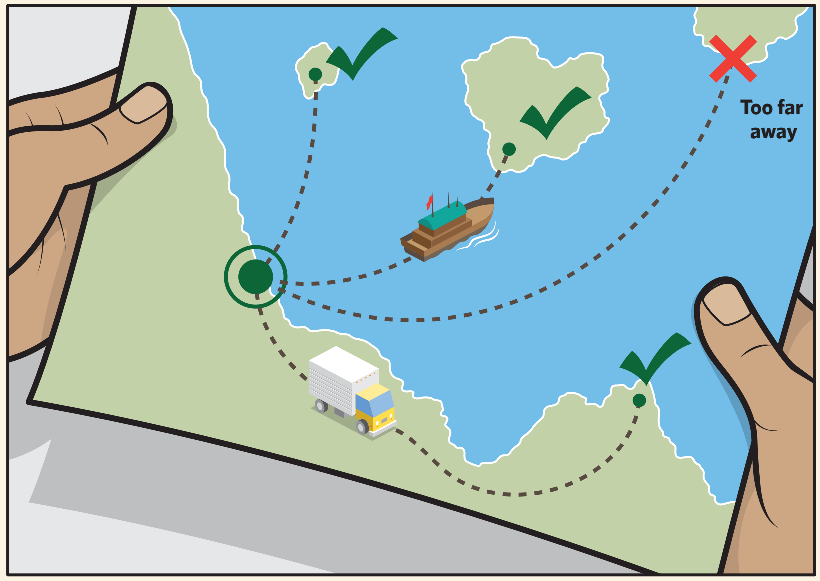
Higher quality plastics for floats should be used whenever possible. Floats and ropes made of long-lasting, but biodegradeable materials are preferable to plastics.

Mangroves:

Mangroves are a protected species important for fish habitat and ecosystem health. Do not cut down mangroves for use as stakes. Use other shrubs like Bunga Kuning.

Obtaining and Transporting Seed

In order to have resilient seed for the local area, it is important to source seed locally. If harvesting seed from own farm or seaweed nursery, then harvest seed after 25-30 days of growth.

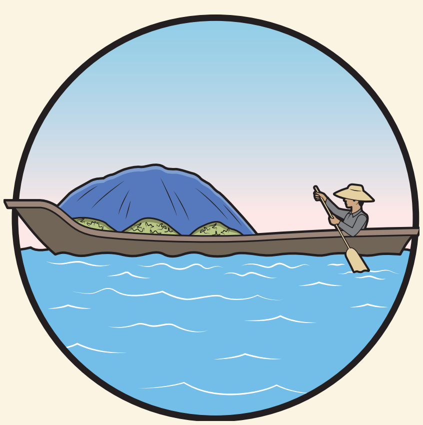


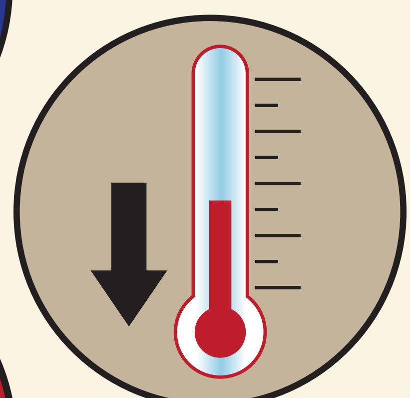
Transporting and covering seed:

Local seed can generally result in the most resilient seed for your area and a good rule of thumb is to obtain seed from nearby locations. When transporting seed, it is important to cover it and keep it dry, protected from the sun and rain.

Weather and time:

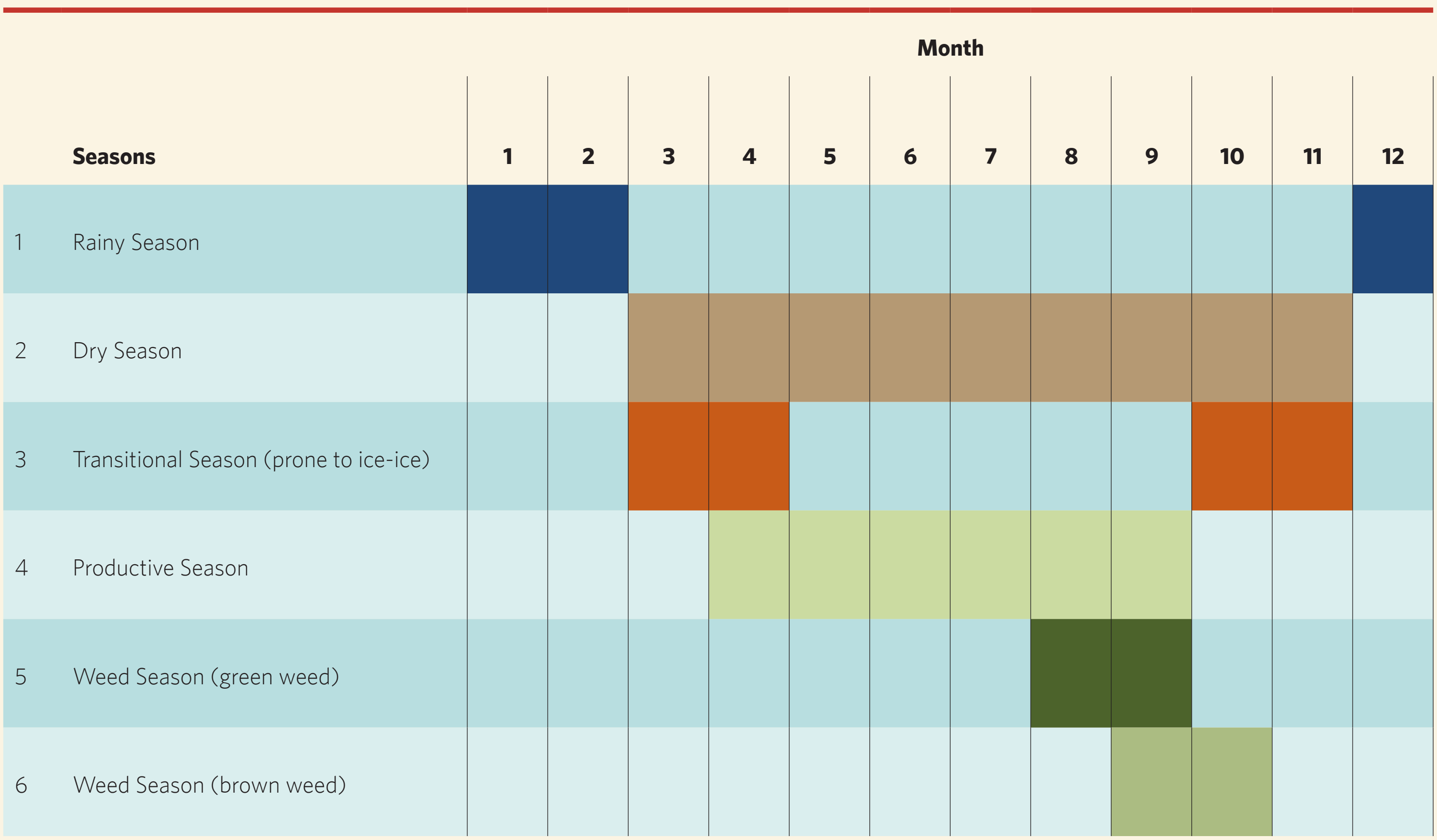
The best time to transport seed is in the early morning or evening when it is cooler. Do not transport during periods of heavy rain.





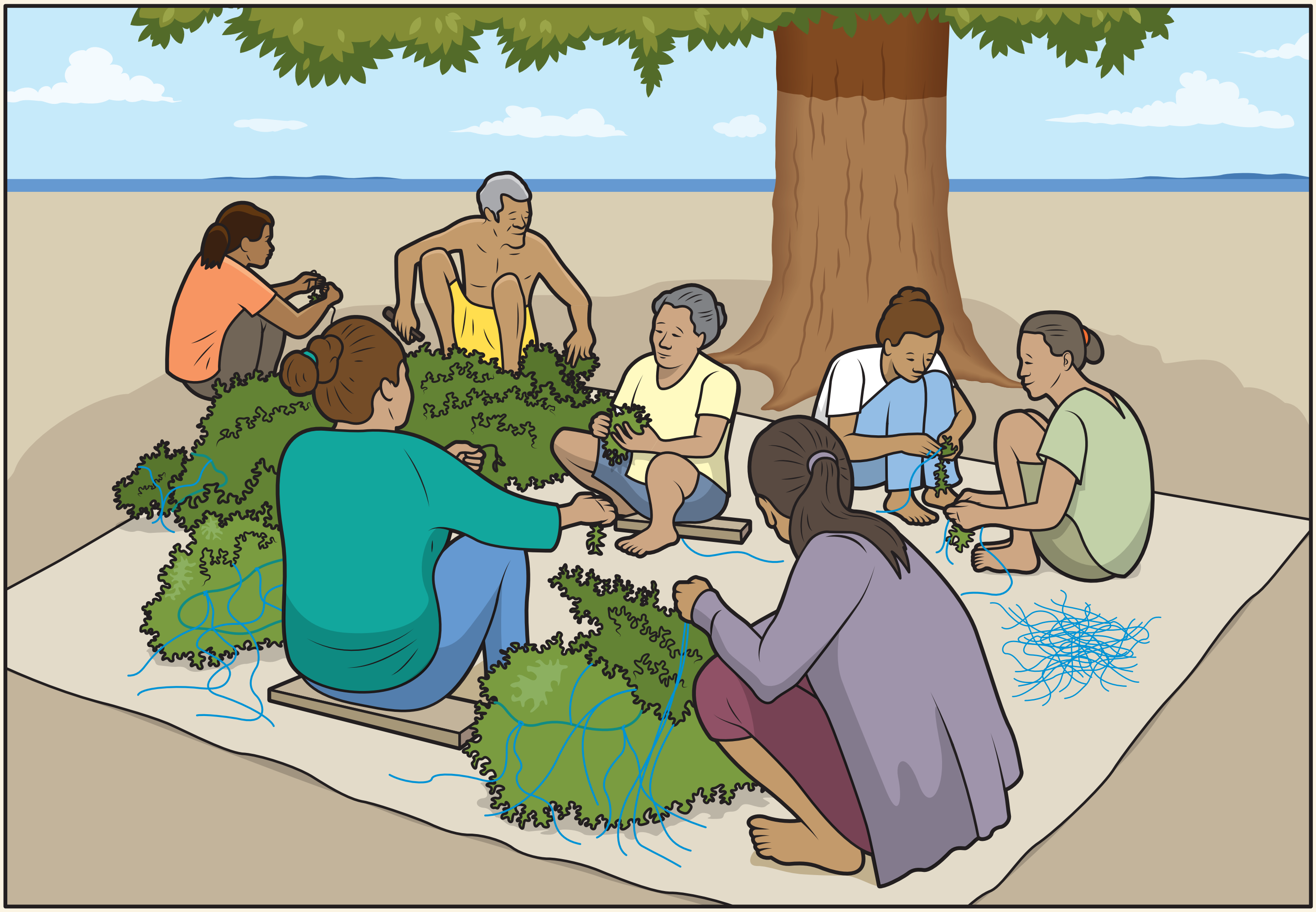
Example Seasonal Calendar

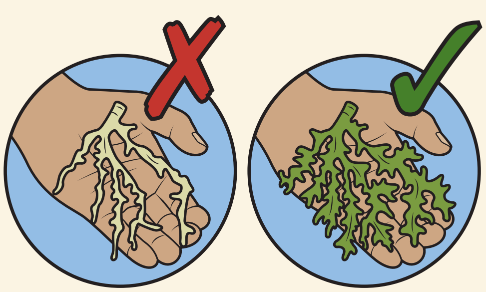
Creating a seasonal calendar for the specific location conditions is very important for overall seaweed farming success. Understanding the times of the year when the seaweed can be vulnerable to disease, weeds, and weather events will help the farmer to be more resilient to these issues.



Seed Selection and Tying

Seed selection is a very important part of seaweed farming, as picking high quality resilient seed will help keep disease away. Cutting and tying the seed correctly will allow the seed to grow and succeed.





Bad vs. good seed:

Poor quality seed is white in color or turning white, and has few branches. Good seed has vibrant color, is dense with many branches, and is not infected with disease.

How to cut:

It is important to use a sharp knife to cut seed, in order to not break or damage the seaweed. All seed should be of equal size, roughly between 50-200 gram range.

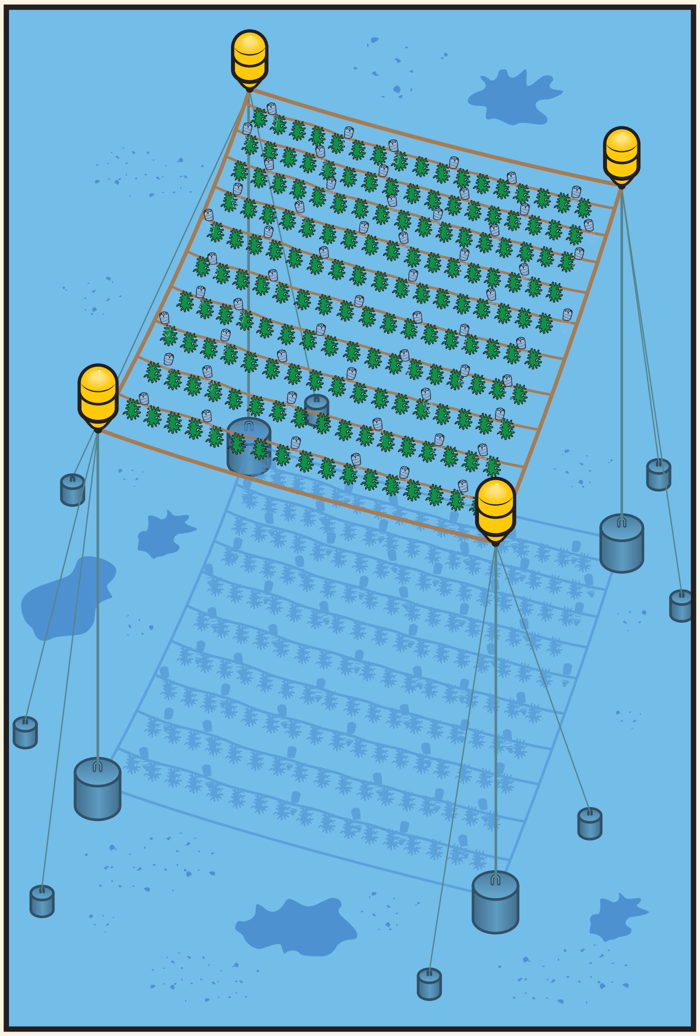
Tying seaweed:

In tying the seed to rope, the knot should not be too loose as the seed will fall out. The knot should also not be too tight as this will not allow room for growth and the thallus can break.

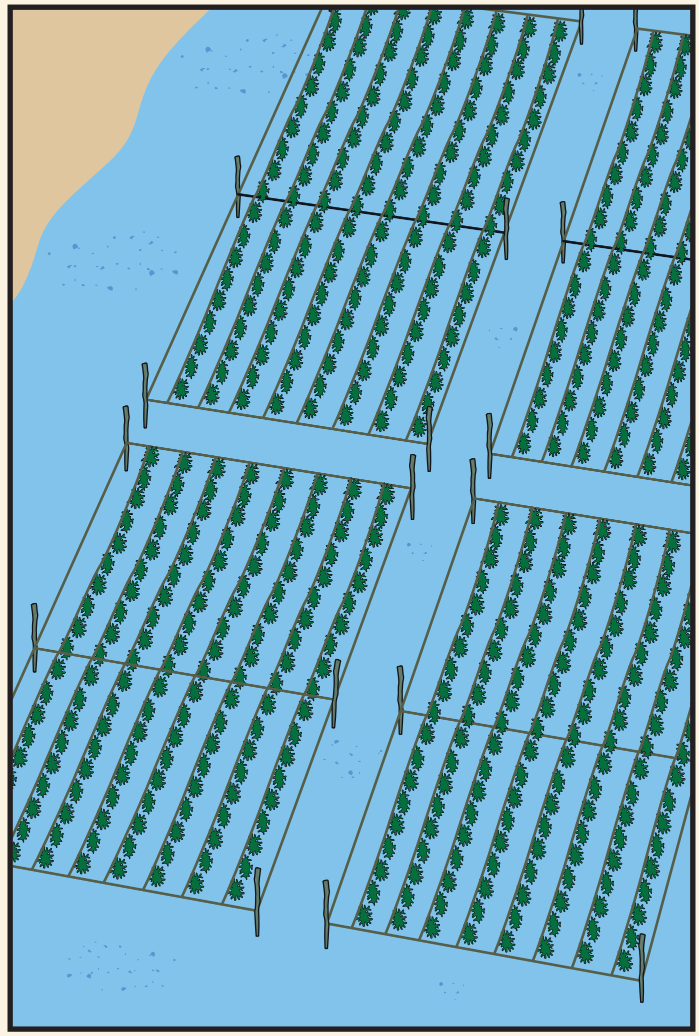
Off-bottom and Floating Long-line Farm Construction

Two ways to farm seaweed are the long-line floating and the off-bottom methods shown below. Farmers should not remove seagrasses and coral reefs in placing seaweed lines as these are important habitat for fish and the health of the oceans. When corals and seagrasses are present, the floating long-line method is best.

Floating Long-Line (deep water)

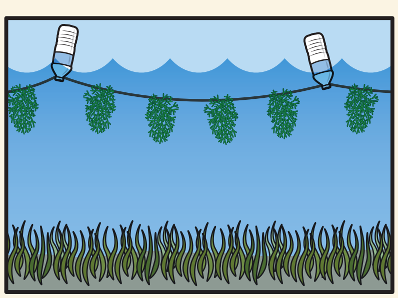


Off-Bottom (shallow water)



Depth over seagrasses:

When placing floating long lines over seagrasses, the depth at low tide should be a minimum of 2 to 3 meters at low tide.



Do not tie seaweed to corals:

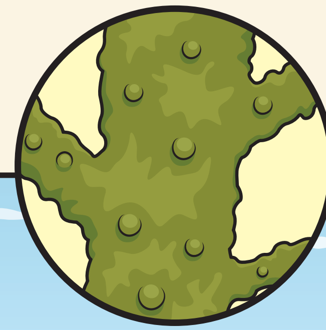
Do not tie seaweed anchor lines to coral reefs - this will cause damage to a key habitat. Use concrete blocks or bags to anchor lines.

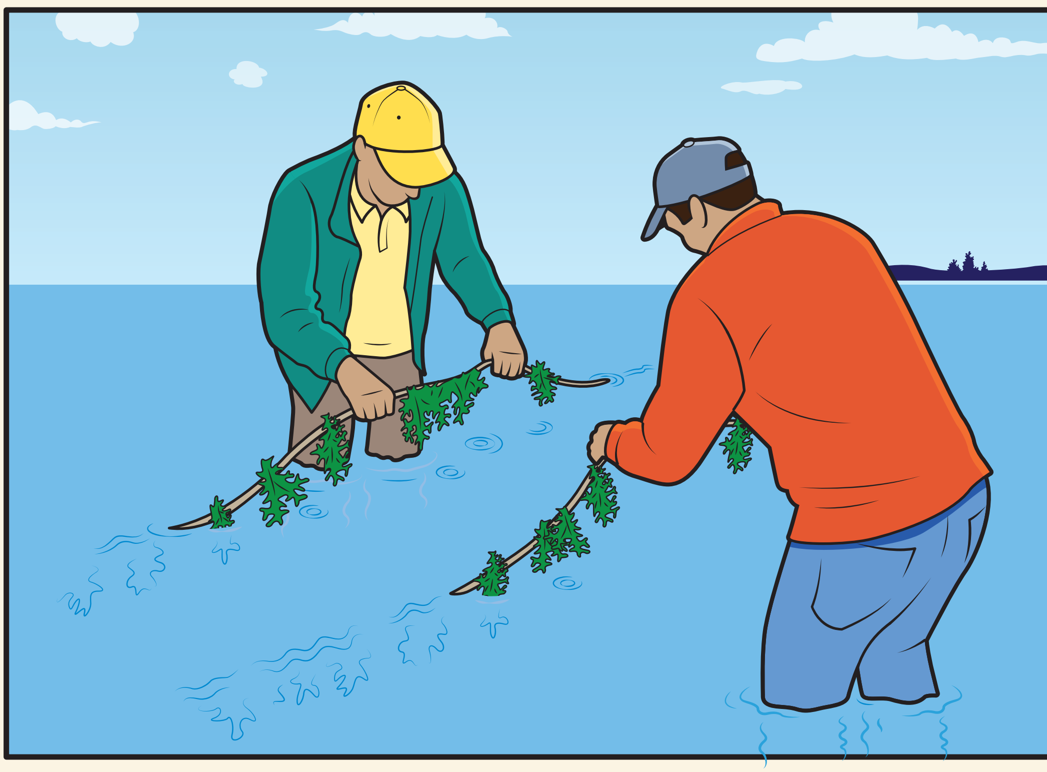
Farm Maintenance and Disease Prevention

For healthy and productive seaweed, maintenance must occur at least three times per week. More maintenance will be needed before and after storms to make sure the lines are secure, and during bigger tides (half-moon tides). Check to make sure the seaweed is tight on the ropes and, for the long lines, that the seaweed is always below the water. Shake the seaweed and manually remove epiphytes and other seaweeds from the lines.

Epiphytes:

Examples of epiphytes that can affect seaweed. Maintaining seaweed lines and removing these is important for the highest quality seaweed. Remove and dispose of on land.





Fertilizer and green tonic:

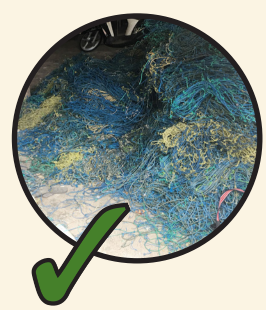
Do not use fertilizer or green tonic on seaweed lines - this will damage the habitat and not increase productivity.

Remove plastic water bottles:

Check to ensure that all water bottles are properly attached to lines. Plastic water bottles should be removed from the water when they are no longer tied to seaweed lines.

Seaweed with ice-ice:

If ice-ice occurs – harvest immediately. Stop farming in the area temporarily and farm in other area until disease is gone. The best way to recover from ice-ice is to use seed from a nursery that is located away from pollution or nutrient runoff.

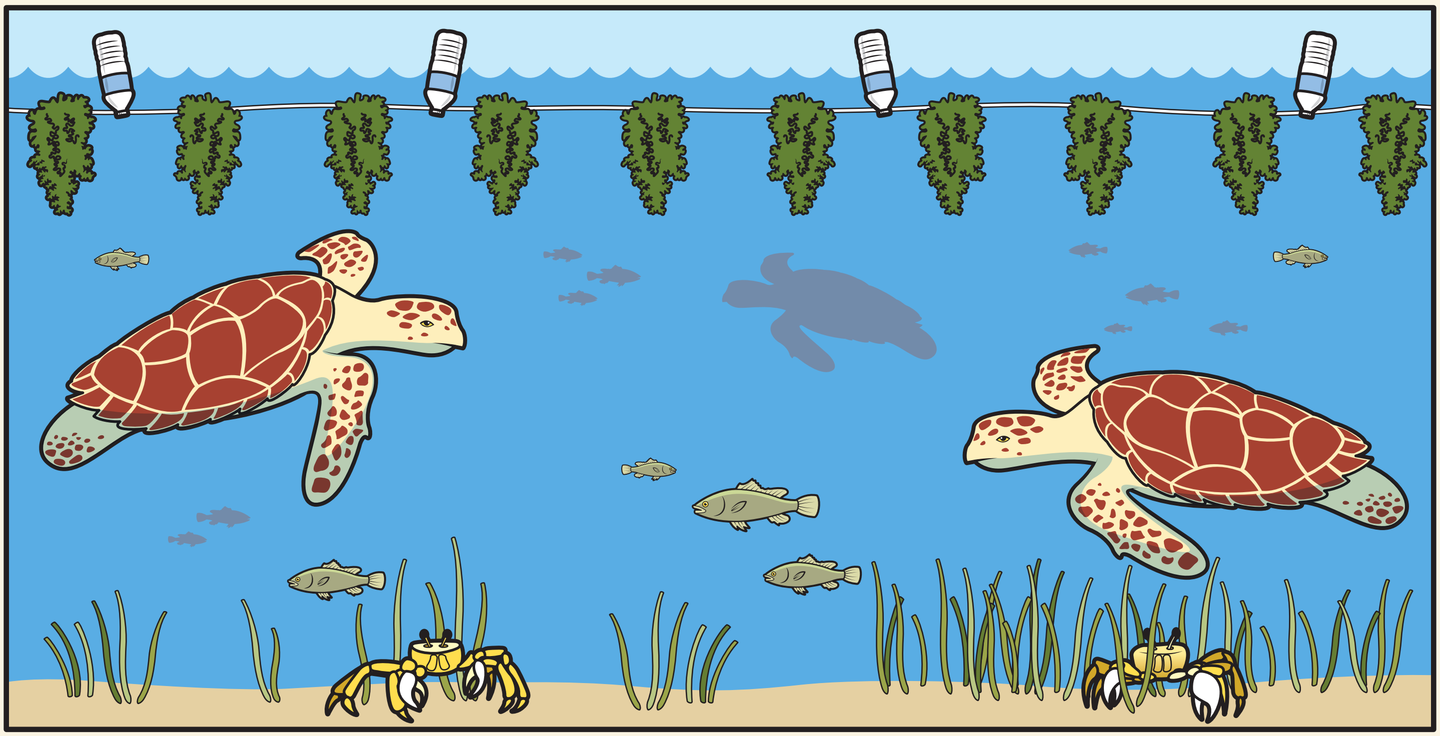


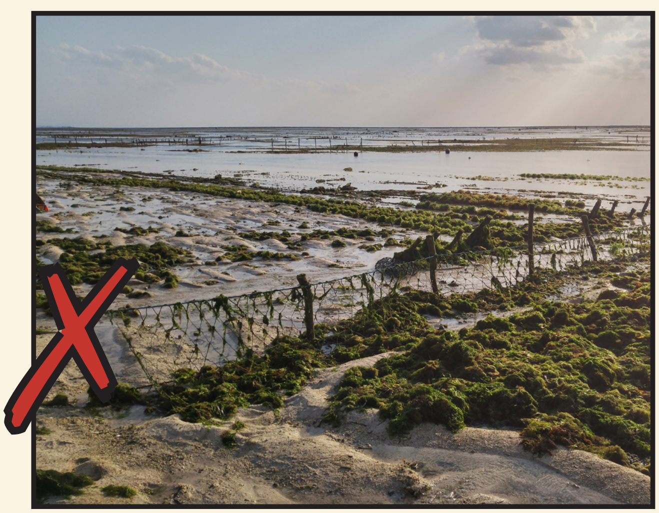
Seaweed line rope:

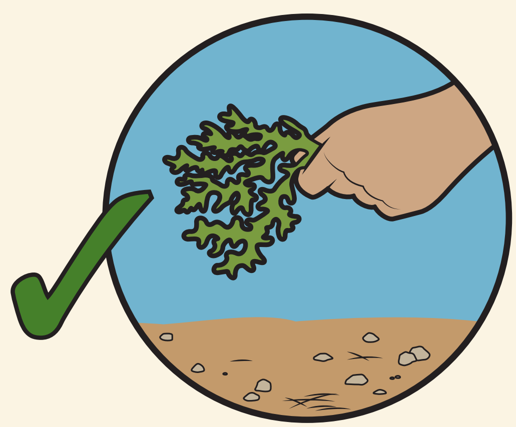
Rope should be removed from the beach and stored away from the water.

Animal Management and Preventing Grazing

Farming in an area with many fish and animals is positive as this means the farm has good habitat and water quality. However, turtles, fish, dugong, and other animals can graze on the seaweed. If there are turtles and other animals eating the seaweed, do not kill – catch and remove them.







Seaweed farm with fence:

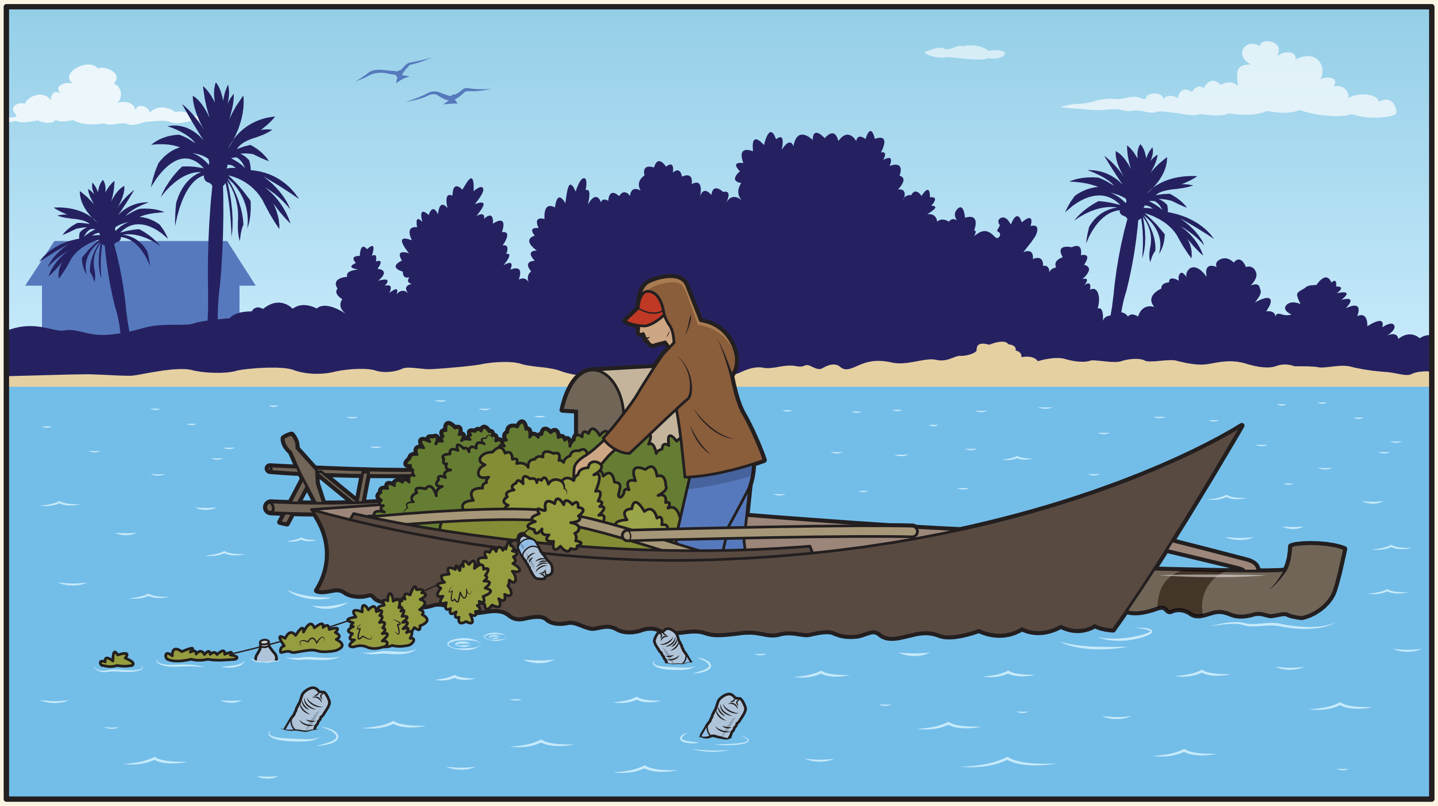
Do not use gillnet fencing to mark seaweed farm - this will entangle turtles and other sea life.

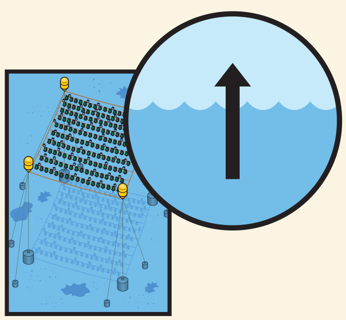
Picking seaweed up from ground:

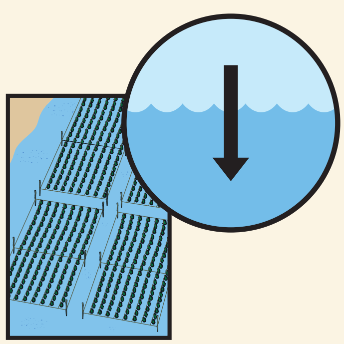
By picking up seaweed from the sea floor that has dropped off the lines, fewer animals will graze on the seaweed as they will not be attracted to the seaweed on the sea floor.

Harvesting Procedures

After the seaweed has been growing for ~45 days (can be ~30 days for spinosum), this is the best time to harvest for the highest quality seaweed and price. Harvest should occur in the morning in order to allow enough time in the day to remove the seaweed from the lines and begin drying. For floating long-lines, harvest during high tide; for off-bottom lines, harvest during low tide. Once on land, shake the seaweed and strip it off by hand.





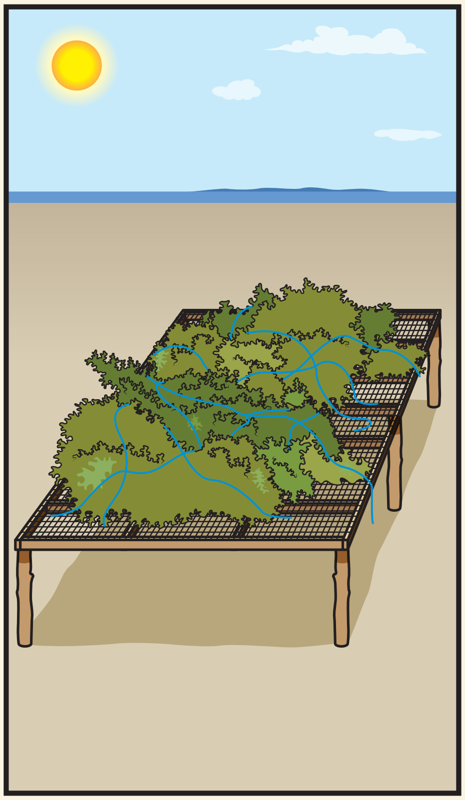


Seaweed transport:

When transporting the seaweed from water to land, it is important to keep the seaweed away from the sand and ground as it will pick up impurities.

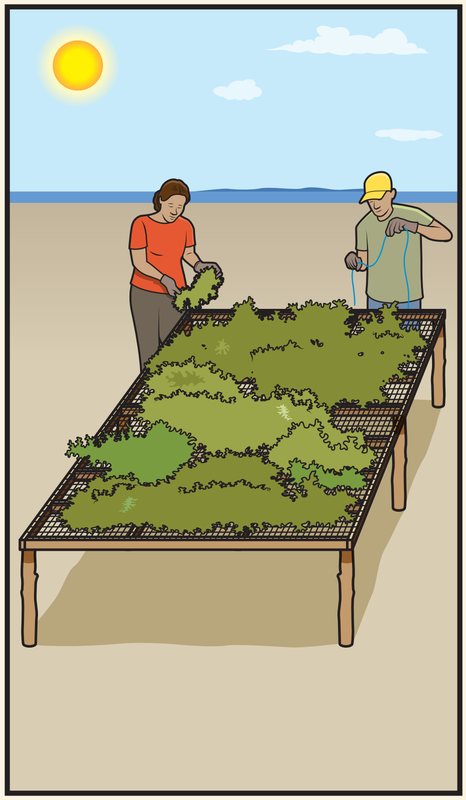
Post-harvest Handling, Drying, and Packing

After removing the seaweed from the lines, place the seaweed on the drying rack. The ideal drying duration is more than ~3 days in order to achieve moisture content below 35% - so that it is crunchy in one's hand. Drying the seaweed on racks will reduce impurities and increase the price of the seaweed. Keep different seaweed types separate so that the best price for each can be obtained.



Place seaweed on racks:

After removing seaweed from lines, place seaweed on drying racks that are located in an open area for maximum sun.

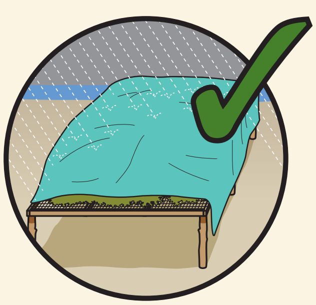


Flip seaweed and remove lines:

As seaweed dries, it will need to be flipped so that the seaweed dries evenly. Remove any remaining ropes, ties, or pests from the seaweed.

Package seaweed after drying:

After ~ 3 days, the seaweed should be dry and ready to be packed into bags. Keep different seaweed species separate so that the highest prices for each can be obtained.

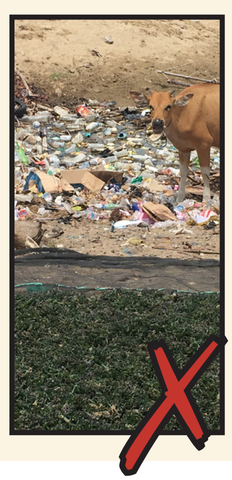


Use tarp during rain:

When it rains or during the morning times when there is mist/dew, cover the seaweed with a tarp.

Do not place on sand or directly on ground:

Drying seaweed on the sand/ground will encourage animals to eat and/or walk on the seaweed. The sand will also add impurities, lowering the price.



Keep beach clean:

It is important to remove trash, ropes, bottles, and debris from beach. Bring these to the shore to recycle, take-a-way for trash, or to burn.

Conclusion

Seaweed aquaculture in Indonesia, as an important industry for over one million coastal Indonesians, has substantial potential to be managed in a more sustainable way. The Conservancy's goal in compiling this guide for seaweed purchasers, organizations working in seaweed for conservation gain, and seaweed farmers, is to provide information to encourage increased economic, social, and environmental sustainability throughout the seaweed supply chain for improved seaweed production, increased livelihoods for farmers, and protection of coastal areas and oceans. Some key takeaways from this guide include:

- Reliable sources of seaweed that are farmed in environmentally better ways are not only of interest and benefit to coastal communities and environments, but to seaweed purchasers who are interested in securing stable and traceable sources of seaweed for their industries, in mitigating business reputational risks, and/or seeking to obtain market advantage.
- For seaweed purchasers interested in improving the sustainability of their supply chains, several third-party certifications exist and should be considered, although many have not been tailored to the unique circumstances of Indonesia's seaweed industry. In some cases, internal buying and traceability standards, vetted and audited by an independent third party, may be appropriate.
- There are significant challenges in Indonesia supply chain traceability, including a large number of small farmers that are located in geographically remote areas; a significant number of collectors and distributors that bloat the chain through side-selling; re-drying, co-mingling, and re-packing of product at multiple stages of the supply chain; and lack of general record keeping. Due to these complexities, a mass balance approach may be the most suitable traceability scheme for many parts of Indonesia at this time, but book and claim methods also show promise.
- Seaweed farming has great potential for use as a tool for conservation due to the economic, social, and environmental benefits it can provide when farmed in an environmentally and socially sound way.
- To reach its potential as a tool for conservation and community empowerment, seaweed farming must address a number of key challenges, including: habitat degradation from destructive farming practices, marine debris associated with farming activities, lack of technical knowledge on farming activities, a lack of regulatory controls and spatial planning for seaweed farming, a bloated supply chain and lack of farmer financing, climate change, and crop disease.
- Many challenges can be overcome by improving farmer knowledge through trainings on farming practices and making farmer information resources more readily available. Incorporating sustainable practices into village development plans, the development of cooperatively managed-nurseries, and working with financial institutions to provide access to capital and incentivize environmental practices are also critical steps to ensure the sustainability of farming activities.
- Asset-based community development, wherein local communities are committed to investing in themselves and their resources, is a model that NGOs and government can employ to work hand-in-hand with villages to improve seaweed farming practices, empower communities, and increase livelihoods. The Conservancy's "SIGAP" approach to asset-based

Seaweed farm near Kupang; © Tiffany Waters community management can be applied to seaweed farming communities throughout Indonesia.

The Conservancy is actively working in Indonesia to expand SIGAP and seaweed trainings to additional village sites in East Nusa Tenggara, including the potential of incorporating seaweed trainings into the SIGAP mobile app for greater reach to other Indonesian villages. This guide is intended to be a living document and will be revisited as our community-based seaweed work continues and evolves. We also see this three-part guide structure as replicable for other countries and communities, wherein local issues, knowledge, and market data can be analyzed and incorporated for purchasers, conservation practitioners, and farmers.

In communication with stakeholders throughout the process of developing this report, we have identified several additional areas of needed research and development activities to ensure the long-term sustainability and resilience of seaweed farming in Indonesia. While research needs were largely beyond the scope of this report, we feel they are important to acknowledge. Future research and development efforts on the Indonesia seaweed industry should consider:

- An evaluation of the impacts of climate change on farming activities and farming communities and strategies to address/mitigate potential impacts;
- Developing methods to increase the genetic diversity of popularly cultivated seaweeds to improve crop resilience and improve yields;
- Exploring the development of other seaweed species for commercial cultivation to increase crop diversity;
- Market research and connectivity of sustainably grown seaweed to non-carrageenan markets, such as the emerging technology and demand for seaweed biopolymers and animal feeds.

This report marks a first attempt to guide seaweed buyers, conservation organizations, and seaweed farming communities towards a joint vision of a more sustainable future for Indonesia's seaweed farming industry. To achieve this vision, it will take a collaborative effort and commitment on the part of all interested parties going forward. Only by working together with a broad range of stakeholders and maintaining a strong-community orientation, can conservation organizations help ensure seaweed aquaculture grows in harmony with coastal environments to generate consistent livelihoods and empower communities.

Wa Nuri harvesting and preparing seaweed at the docks of Liya village on the island of Wangi Wangi in Wakatobi National Park, Indonesia. Credit: Bridget Besaw

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Yayasan TAHIJA

The Nature Conservancy