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Thesis Literature Review Synthesis Paper

**General Seaweed Aquaculture:**

History

The aquaculture of macroalgae has roots in Asia dating back centuries (Yang et al. 2016).

The macroalgae industry has taken off since the 1950s, with cultivation representing 97 percent of the industry, while wild collection has slowly begun to decline (Mancini).

Uses

Macroalgae has a wide range of uses in food, medical, X, and X industry. Besides having everyday uses, such as food—for humans and animals—shampoo, cosmetics, there are implications in biofuels (Green 2014, Sahoo & Yarish 2005, source).

IMTAS- bioremediation, inorganic compound sequestration

US

The US macroalgae industry is relatively small compared on the global scale. Out of the 35,762,504 tonnes of macroalgae cultivation and wild collection in 2019, the US was only responsible for 3,394 tonnes (Mancini). Of that 3,394 tonnes, 247 tonnes came from brown macroalgae, and 3,125 tonnes came from green macroalgae (Mancini).

The total US coastline is 95,471 miles (source). The current value of the global macroalgae industry is $XX (source). This industry is ever expanding, with the desire and demand increasing for more sustainable sources.

With the incredible range of uses macroalgae possess, the US is severely underusing these resources.

New England

Aquaculture in New England began in 2010, with the first kelp farm being developed in Casco Bay, ME (Grebe). The macroalgae industry has since budded into over 100 kelp farms in the Gulf of Maine in the last 13 years (Planet 2022). Of these 100+ farms, two species of kelp are grown—sugar kelp (Saccharina latissimi) and winged kelp (*Alaria esculenta*) (Grebe).

Growing interest in this field has fueled the desire for expansion, through the introduction of a new macroalgae.

**Nori:**

History

Before the life history of nori was understood, methods for wild harvest were cultivated in China and Japan (source). Early techniques for cultivation of nori species focused on lime washing rocks were nori was known to grow (source). This technique ensured an open substrate for the macroalgae to attach and grow on (source). Once British scientist Kathleen Drew-Baker discovered the conchocelis stage of nori, Japanese scientists were able to understand nori’s life history and build on this discovery. From that point on, larger scale aquaculture of nori species was accomplished and the industry was able to grow and spread (source).

Economics

The red algae within the foliose Bangiales order have become one of the most economically important seaweeds worldwide (Yang et al. 2017). They were responsible for 2,984,573 tonnes of cultivated and wild collection in 2019 globally, with 450 tonnes being from wild collection (Mancini). In Asia, China is responsible for 2,123,040 tonnes of cultivated or wild collected nori, with the Republic of Korea (606,913 tonnes), Japan (251,200 tonnes), and the Democratic People’s Republic of Korea (3,000) producing the rest (Mancini). The America’s are responsible for 294 tonnes, which is solely produced through wild collection in Chile (Mancini). Europe is responsible for 8 tonnes of nori cultivation and wild collection, solely from wild collection (Mancini).

Uses

Nori has been a staple in Asian diets for centuries (Kim, J.K. et al. 2019; Moreira et al. 2021); being a well-known source of the wrapper to sushi. This macroalgae contains high amounts of vitamins, minerals, and proteins (Chopin, Kim et al. 2007), can even stand as an alternative substitute in fishmeal (Redmond et al. 2014). Compounds derived from red macroalgae can be used as gelling agents, such as agar which can have a use in the food or science industry (Green 2014). Other uses in everyday life; shampoo, cosmetics; as well as in the biotechnological industry; with *Wildemania amplissima* being a source of taurine and r-phycoerythrin (Kim et al. 2007); have been identified for this macroalgae.

Species within the foliose Bangiales order have also been under review as the seaweed of choice for integrated multi-tropic aquaculture systems. Finfish aquaculture is a significant offloading source of phosphorus and nitrogen into an ecosystem, which can result in phytoplankton and harmful algal blooms (Kim et al. 2007). The development of polyculture systems would combat the ecological downsides of monocultured finfish, as well as provide other sources of revenue. Actions for bioremediation would mean finding native macroalgae that can manage the large inorganic waste outputs from these finfish farms, as well as having economic value (Kim et al. 2007). The foliose species within the Bangiales order are fast growing, economically valuable, needing constant high levels of nutrients in the water (Kim et al. 2009). Many foliose species within the order Bangiales are distromatic—two cell layers thick—meaning they have higher surface to volume ratio, making species capable of high nutrient absorption (Kim et al. 2007, Kim et al. 2009).

Taxonomy

The order Bangiales has been under constant taxonomic review. The constant review within the foliose species of the Bangiales has been due to misidentification, discovery of new species, and revisions of relationships between species (sources). Misidentification among the bladed Bangiales is considerably common due to extreme morphological similarities (sources), which has led to incorrect identifications and underrepresentation of the order (sources). With the development and use of molecular analysis, misidentifications have become less common (source). Even without misidentifications, revision of the foliose Bangiales species remains constant, with reworking relationships between genera and species.

The genus *Wildemania* was named by G.B. De Toni in 1897 and *Diploderma* by Kjellman in 1883, due to its distromatic thalli. These synonymous genera were later combined under the name *Diploderma*, and united by Rosenvinge in 1893 within the genus *Porphyra* due to discrepancies in consistent thalli stromatic layers. The genus *Porphyra* was named by C. Agardh in 1824, that incorporated distromatic and monostromatic thalli (Krishnamurthy 1972).

Species within *Wildemania* continued to stay within the genus *Porphyra* until *Wildemania* was resurrected in 2011. This taxonomic revision by Sutherland et al. resurrected two genera and named five new genera within the foliose species of the Bangiales order (Sutherland et al. 2011). The order Bangiales has continued to be revised, with the discovery of new species (Hasan et al. 2022), the resurrection of old genera (Sutherland et al. 2011, Yang et al. 2020), creation of new genera (Sutherland et al. 2011, Yang et al. 2020), and reorganization of relationships between genera (Yang et al. 2020).

Habitat

Nori species have a wide distribution worldwide (source).

Seven species can be found distributed throughout the Gulf of Maine (source),

Nori species can also vary vetically along the shoreline (Krishnamurthy 1972). *Wildemania amplissima* specifically is a cold-water species, found in the low intertidal region. This species is not adapted to desiccation events due to its location in the tidal region, but can be exposed to desiccation events during extreme low tides (sources, Redmond et al. 2014).

Coloration of the foliose Bangiales species can vary from X to X due to the ratio of phycobilins in the blades (Redmond et al. 2014).

Biology/ Life History

Nori has a heteromorphic life cycle, alternating between a gametophyte blade and microscopic filamentous sporophytes. Reproduction occurs when male gametes are released from the male thalli section of the blade and fertilize the egg in the female carpogonia. Once fertilized, mitosis occurs resulting in production of zygotospores which are then released into the environment. Once the zygotospores settle onto a substrate, typically shells, they germinate into microscopic filaments that bore into the shell surface and enter the conchocelis stage. The conchocelis grows in its vegetative form as ‘red fuzz’ on and in the shell surface. Under the right conditions, conchosporangial filaments form and meiosis occurs resulting in mature conchosporangia and forming four identical haploid spores. Conchospores are released and settled onto suitable substrate, typically shells, rocks, or other macroalgae, and grow into macroscopic haploid gametophyte blades (Redmond et al. 2014, other source).

Aquaculture

The aquaculture of nori was responsible for 2,984,573 tonnes of

**Kelp:**

Background

Kelp is a temperate to cold-water brown macroalgae that has increased popularity in European and North American countries (Grebe). Kelp has value beyond its range of economic purposes (source). This macroalgae is known for waste sequestration (nitrogen, carbon), bioremediation, nutrient cycling, and fisheries production (Grebe). Kelp forests are incredibly important to juvenile fish populations, by providing food, shelter, and protection from ocean currents and predators (source).

The aquaculture of kelp began in the US through the introducing and adaptation of Asian methods; this first US kelp farm was located in Casco Bay, ME in 2010 (Grebe). The US kelp aquaculture industry is centered around two species—sugar kelp (*Saccharina latissimi*) and winged kelp (*Alaria esculenta*), with farms located in seven states (Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, Washington, and Alaska) (Grebe).

Methodology

Kelp has a heteromorphic life history, transitioning between a gametophyte and sporophyte stage.

Technology

Longlines

References

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Grebe