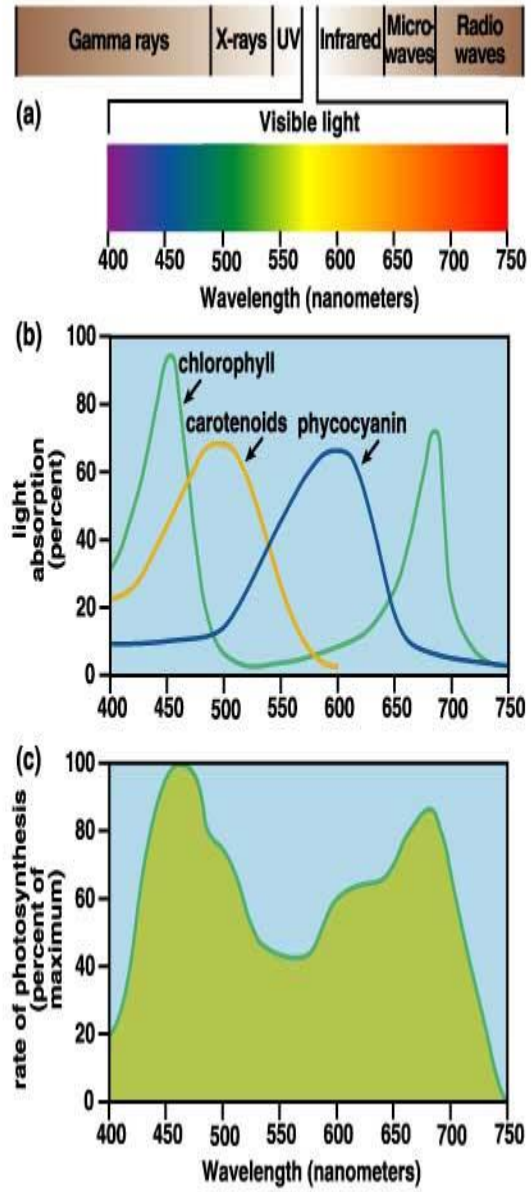
Biology of Seaweeds

The first step of photosynthesis involves using pigments to capture light.



The range of visible light used for photosynthesis is from about 400 to 750 nanometer wavelengths of electromagnetic radiation… this range is referred to as PAR – Photosynthetically Active Radiation.

Although chlorophyll is the primary pigment used by green platns, accessory pigments (carotenoids , phycocyanin etc.)are also used Why may this be of particular interest in algal systems?

Species Name	Japanese name	Harvest preparation	Food use	Remarks
Chlorophyta				
Monostroma complex	Hetoegusa	f, d	miso soup, nori-jam	*M. nitidum*
Enteromorpha complex	Aonori	d	seaweed powder for various foods	*E. prolifera* *E. intestinales*
Caulerpa racemosa	Kubirezuta	f	seaweed salad	only found in Okinawa coral reef area
Phaeophyta				
Cladosiphon okamuranus	Okinawamozuku	s	with soy sauce and vinegar	commonly called Mozuku
Nemacystis decipiens	Mozuku	s	with soy sauce and vinegar	commonly called Mozuku
Ecklonia cava	Arame	d	boiled with soy sauce	health food
Undaria pinnatifida	Wakame	d, s	soup boiled seaweed salad	
Laminaria japonica	Kombu	d, s	boiled with soy sauce in many kinds of soup	
Hizikia fusiformis	Hiziki	d	boiled with soy sauce	
Rhodophyta				
Porphyra complex	Nori	d	rolled with rice	*P. tenera* *P. yezoensis*
Grateloupia filicina	Mukadenori	s	seaweed salad	
Eucheuma gelatinae	Kirinsai	s	seaweed salad	local
Meristotheca papulosa	Tosakanori	s	seaweed salad	
Gracilaria complex	Ogunori	s	seaweed salad	*G. verrucosa* *G. lemaneiformis* *G. bursa-pastoris*

fresh, d: dried, s: salted

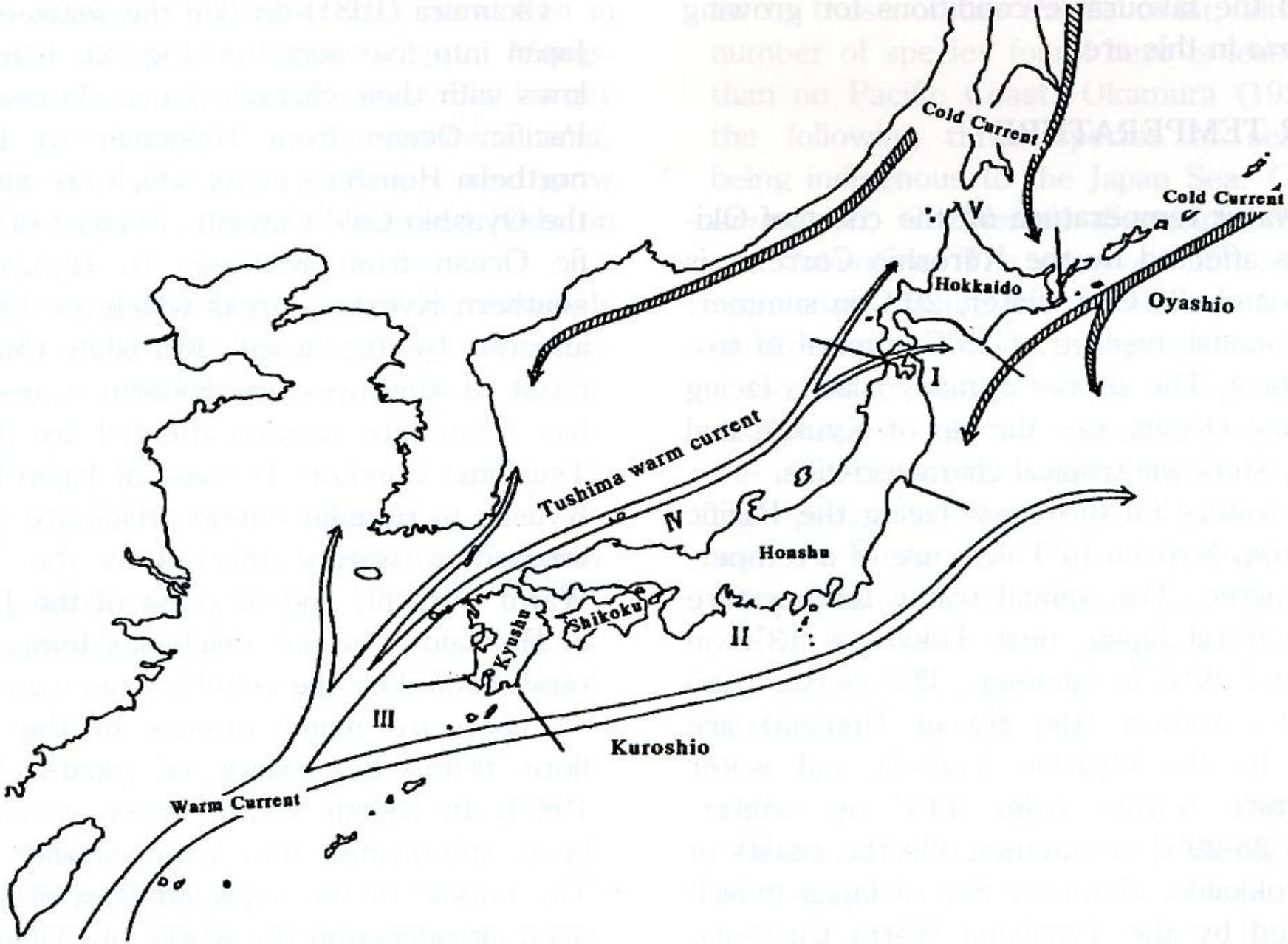


Figure 1. Map showing drifts of ocean currents and five regions of marine algal floras in

Economic Implications

Seaweeds have a wide range of potential uses:

Food – The most obvious use of seaweeds is in form of various foods prepared directly or indirectly from algae or algal products…

Phycocolloids – used in food processing, they have the ability to form viscous suspensions and gels…

Algin and carrageenen for example are often used as a stabilizers and emulsifiers in dairy products, the baking industry, and for making of shampoos and toothpastes, etc.

Agar, another phycocolloid, is used in canning of hams, fish, meats, etc., because of its ability to form jellies… this helps with protecting the canned material… Other uses of agar include production of various forms of pharmaceuticals, and even research media…

Seaweeds may also be used as a source of fertilizer, food additives in animal feeds, etc., etc., etc.,… Big industry!!!!!

Green Seaweed

Division Chlorophyta – Green algae

Photosynthetic pigments: Chlorophyll a, b; Carotenioids
Major storage products: starch
Major cell wall component: Cellulose

The similarity of photosynthetic pigments, storage products, and cell wall components of green algae with higher plants suggest that higher land plants probably evolved from a green algal type ancestor…

Useful Seaweed: ***Monostroma***
Enteromorpha

Ulva fenestrata, the perforated form

Codium fragile

Ulva pertusa

Codium fragile

Monostroma

The fronds growing on the high tidal zonn

Green seaweeds that emits fluorresence

Acetabularia ryukyuensis

Caulerpha fronds growing the warm waters

Brown Seaweed

Division Phaeophyta —Brown algae

Photosynthetic pigments: Chlorophyll a, c ; Carotenioids (including <u>fucoxanthin</u> which give the brown coloration)
Major storage products: Laminarin, Alginic acid
Major cell wall component: Cellulose

Useful Seaweed:

***Laminaria*（ Konbu)**
***Undaria* (Wakame)**
***Laminaria*（ Konbu)**
***Undaria* (Wakame)**
Ecklonia
Lessonia
Macrocystis

Giant kelp *Macrocystis pylifera*

Ecklonia cava

Eadible brown seaweed

***Sargassum* bed**

Sargassum plycystum

Lessonia flaviacans and
brown seaweed bed in Chili

Kelp bed in Canada, Cold watets

***Laminaria* bed**

Soft eadible seaweed MOZUKU

Sargassum fronds growing on the intertidal zone

KOMBU fronds appeared in the low tides

Red Seaweed

Division Rhodophyta – Red algae

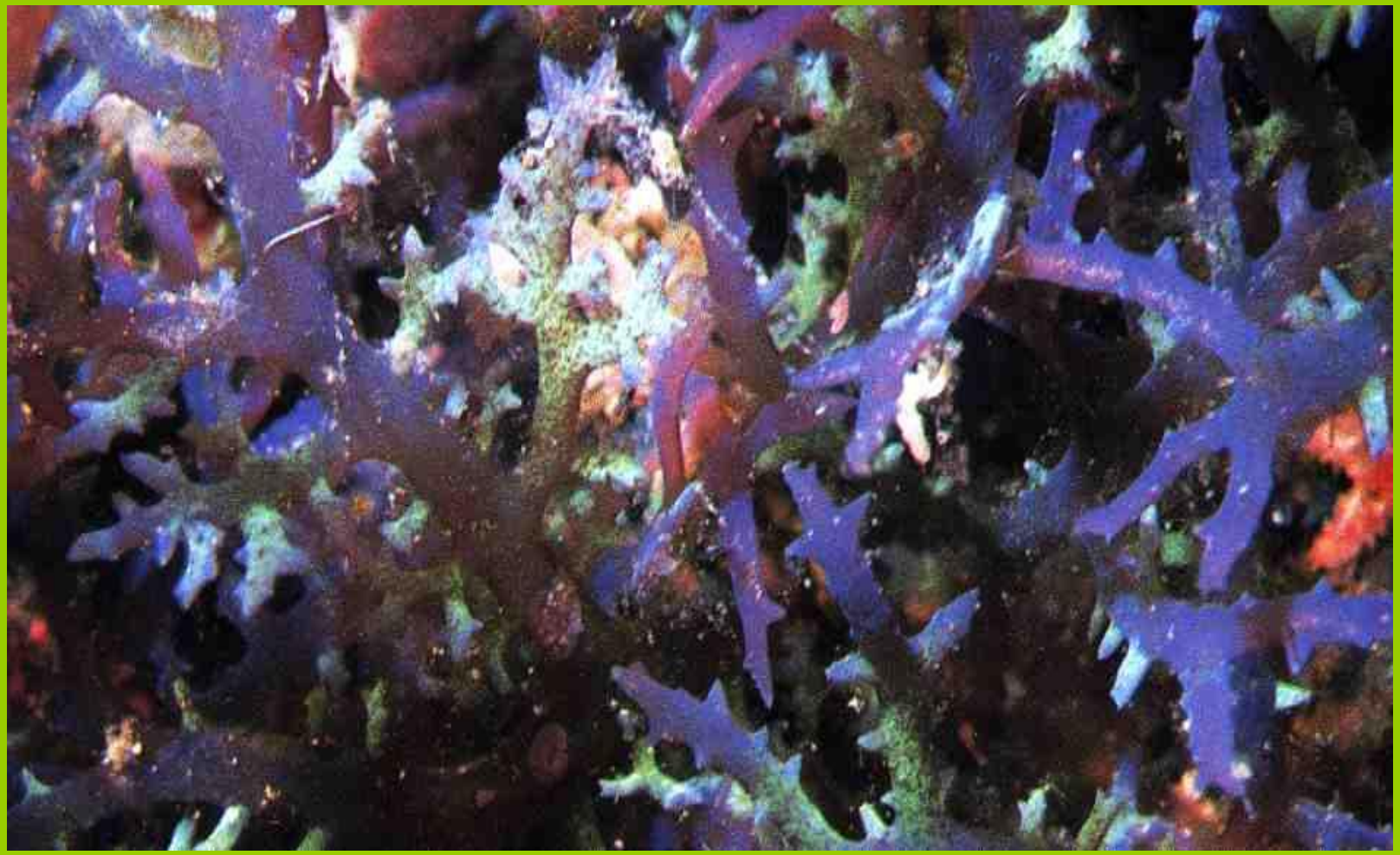
Photosynthetic pigments: Chlorophyll a; Phycobilins [including phycoerythrin (red in color) and phycocyanin (blue in color)]
Major storage products: Starch
Major cell wall component: Cellulose, Agar, Carrageenan and in case of coralline algae, Carbonates

Useful Seaweed:
***Porphyra*（Nori)**
Gracilaria
Gelidium
Euchuema
Kapppaphycus

Gelidium amansii

Gelidium amansii TENGUS天草

Kappaphycus alvarezii



Chondracanthus tenellus
shown flourecence

***Corallina* sp.**
in the tropical waters

Seaweeds containing line ,
石灰成分

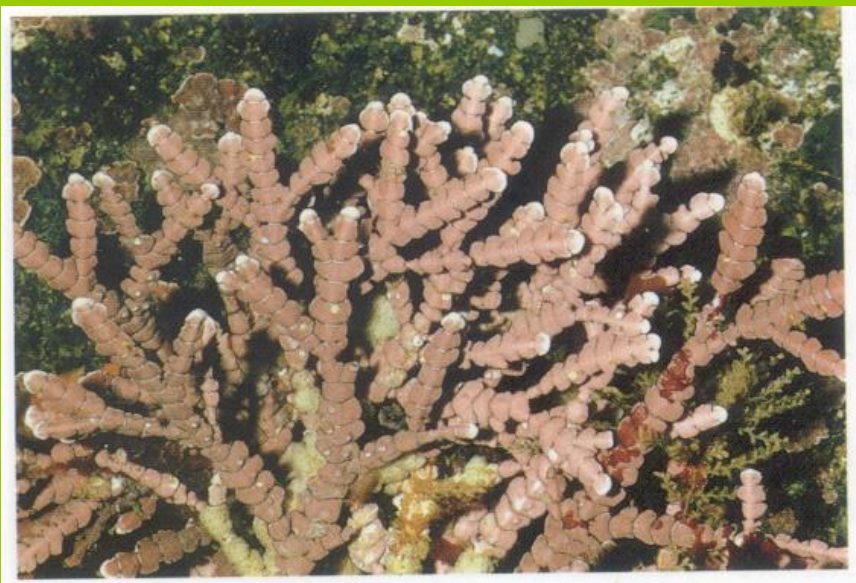
Lime(coral) seaweed

Chnodurus fronds with dark red

Nori (紫菜）growing of high tidal zone

Amphiron fragilissim

***Amphiron* sp.**



Bossiella orbigniana

Lithothrix aspergillum

Coral seaweeds

Sea Grasses

Tracheophyta – Vascular plants

(The classification of tracheophyts will vary depending on whom you talk to… many researchers cannot even agree on if algae and vascular plants should be in the same kingdom or not… same issues need to be considered when studying cyanobacteria)

Photosynthetic pigments: Chlorophyll a, b ; Carotenioids [including Carotene (orange in color), and Xanthophyll (yellow in color)]

Major storage products: Starch

Major cell wall component: Cellulose

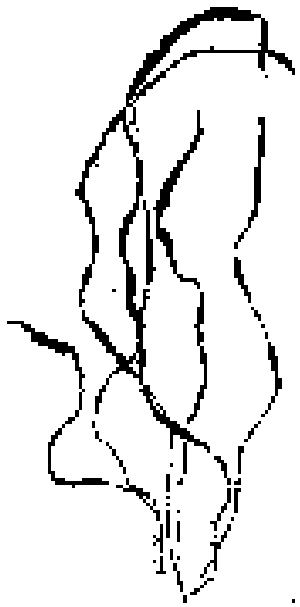


Fig. 3 *Enteromorpha compressa* Japan, Worldwide habitats

Fig. 4 *Enteromorpha intestinalis* Japan, Europe, So. America

Fig. 5 *Enteromorpha linza* Japan & Worldwide Habitats

Green laver (*Monostroma nitidum*) (Fig. 6)

Monostroma is used in much the same way as sea lettuce. This green alga has a similar taste to nori but is much less expensive to manufacture. Therefore it is being cultivated on a large scale in several districts in Japan. It is processed as a preserved

Fig. 6 *Monostroma nitidum*

Fig. 7 *Caulerpa racemosa*

food by being boiled in soy sauce to a concentrated form, and used as a substitute of the same type of Nori-food.

Sea grapes, Iwazuta (*Caulerpa racemosa and C. lentilifera.*) (Fig. 7)

Known as "Arancip" in Philippines. It is widely distributes over middle and south coasts of the Pacific Ocean, Malay Islands and Philippines etc. It is widely used as food and it began to cultivate recently in this country (*C. racemosa.*) and in Okinawa (*C. lentilifera*). However, some of *Caulerpa* produce anesthetic toxins such as caulerpin and caulerpicin, but they are destroyed on boiling.

Sea lettuce (*Ulva sp*) (Fig. 8)

There are many species Of *Ulva*. *Ulva* is used in soups, salads or dried, made into powder and sprinkled on foods. Besides in warm Japanese coasts, widely distribute in Malaysia Islands, Polynesia, Australia, West coasts of North America and Indian Ocean etc.

Fig. 8 *Ulva pertusa*

Fig. 9 *Codium fragile*

Seongetang, miru or 'chongak' in Korean (*Codium fragile*) (Fig. 9)

In Korea, *Codium* is sun dried and used as tea. In the Philippines, it is processed for soup stock or used as a salad.

Habitat: Japan, Malaysia, Australia, Pacific Coast of No. America, Atlantic Ocean, Indian Ocean and Bering Sea.

Phaeophyta: Brown algae

Brown Algae are characterized by having large amounts of a brownish carotenoid called fucoxanthin besides alginates and fucoidans. They have chlorophylles a and c but not b. However, they do have some carotenoids similar to those of green algae and terrestrial plants. The dietary importance of fucoxanthin will be discussed in connection with β-carotene. Some brown algae form a very large group, both in species and size. The giant kelps belong to this group. Bathed in seawater, kelps (Laminariales) contain all of the essential minerals our bodies need, along with varying amounts of the essential vitamins. The significance of these pigments, alginates, fucoidans and minerals will be discussed in the section on the pharmaceutical and nutritional properties of marine algae. Brown algae are a very important source for alginates which are used in very large quantities in a variety of commercial products.

Konbu or kelp (*Laminaria* or "sea tangle") (Fig. 10)

There are about ten species of *Laminaria* used as food. Some common ones are as follows: *L. japonica* (makonbu), *L. angustata* (mitsuishi konbu), *L. religiosa* (hosome konbu) *L. saccharina*. Some kelp such as *L. japonica* are cultivated in Japan, Korea and on a much larger scale, in China. In China, roughly 35% of this kelp is used for the manufacturing of alginates. The kelp synthesizes particularly abundant mucilaginous acid polysaccharides such as alginates and fucoidans, those of which are much effective as water-soluble dietary fibers when taken the blades as food.

Fig 10 *Laminaria japonica*
Japan (Hokkaido) cultured,
China (all cultured)
Korea (mostly cultured)

Kelp is sundried on graveled ground near the beach and made into commerical products. All of these dried products are reconstituted in water before using. Konbu (kelp) is also made into a powder. Before it is made into powder, it is boiled to remove the excess iodine. Excessive iodine leads to the same condition as too little iodine. It is important to soak konbu, if large quantities are consumed because of its high iodine content. This probably is a cause for alarm in the U.S. where konbu will not be eaten to the extent that it is in Japan. If seaweeds are included in the diet, it is probably not necessary to use iodized salt. The mature blades of European *Laminaria* are tough and difficult to eat but the juvenile blades are soft and can be used as food. Most of them are used as fodder and manure. Tororo konbu: Dried sheets of konbu are shaved into very thin sheets which are 'ecru' in color. This product can be found in oriental groceries. It can be eaten as is, added to soups, etc.

Wakame (*Undaria pinnatifida*) (Fig. 11)

Wakame is widely used as food in Japan, Korea and China especially for soup and in salads. Some of them are cultivated. Large quantity of wakame are exported from China and Korea to Japan. Wakame in China and Korea are often cooked in oil. Recently, there has been mass production of an instant convenience food called "cut wakame". This product can be added to any prepared soup or salad. Wakame contains, like konbu, abundant acidic polysaccharides effective as watersoluble dietary fibers.

Alaria crassifonia (honeyware, wina kelp, Ainu wakame) (Fig. 12)

Alaria wakame has a softer blade and is used in products such as instant soup, etc. This algp distributes in Bering Sea, and North Pacific coasts of North America and some are in the coast of Hokkaido.

Bladder wrack or yellow tang (*Ascophyllum nodosum*) (Fig. 13)

Large size and perennial alga. Distributes widely in the coasts of the North Pacific Ocean. An algiophyte, and often utilized as fodder for domestic animals. Fresh algal

Fig. 11 *Undaria pinnatifida* (Wakame) Japan, China, Korea

Fig. 12 *Alaria crassifolia* (Chigaiso) Japan, Pacific coast of Noth America

it is a good idea to cook it for 10 to 20 minutes, however, some of the beautiful green color and crispness may be lost. This large alga may reach for 50 to 70 feet from the end of the stipe to the tip of the blades.

Fig. 16 *Postelsia palmeformis* (Abbott & Hollenberg 1976)

Sea Palm (*Postelsia palmaeformis*) (Fig. 16)

Olive brown stipe which can grow up to one to two feet long. While it can be used in touch the same way as wakame, alaria or bull whip kelp, at this writing it is illegal for amateurs to collect it. It can be purchased in select stores in dried form. It can be found from the coast of Vancouver Island to central California. The mature stipe grows to about 2 feet in length.

Bull kelp (*Durvillea* sp.)

Bull kelp (*Durvillea*, Fig. 18) is one of the largest of the marine algae besides *Lessonia* (Fig. 17) and is found in the Southern Hemisphere. It is used as food in Chile, Australia and New Zealand. They are rich in alginate. Bull kelp is used in soups and is also processed as a salted vegetable in Chile. Bull kelp, along with another brown alga, *Lessonia*, is imported to Japan from Chile for the industrial processing of alginates. *Lessonia* is not generally used as food. Bull kelp is used as common food widely in Chile with the name of "Cochayuyo"(Fig. 18).

Fig. 17 *Lessonia flavicans* (Hoffmann & Santelices 1997)

Fig. 18 *Durvillea antarctica* (Hoffmann & Santelices, 1997)

Fig. 19 *Macrocystis pyrifera* (Tereca, Y)

Fig. 20 *Nemacystus decipiens* (Okamura, 1936)

Fig. 21 *Cladosiphon okamuranus* (Okamura, 1936)

Macrocystis pyrifera (Giant kelp) (Fig. 19)

A perennial kelp with world wide distribution and it is also an alginophyte. It can grow up to more than 45m long and usually makes large kelp forests. Yong blades of this kelp are often used for sprinkling on foods.

Fig. 22 *Analipus japonica*

Mozuku (*Nemacystis decipiens*) (Fig. 20)

Habitat is coast of Japan, particularly in Okinawa (Okinawa mozuku, *Cladosiphon okamuranus*) (Fig. 21). These brown algae contain fucoidans in higher contents. These brown algae are cooked as a salted with ginger.

Fig. 23 *Fucus evanescens* (Terada, Y)

Fir needle or matsumo (*Analipus japonica*) (Fig. 22)

Habitat is Sakhalin, Kurile Islands, the West coast of North America and the west coast of north parts of Japan Sea. Mainly used for soup. Usually, the alga is sold as a air-dried net like sheet in Japan.

Bladderwrack, swine tang, hibamata (*Fucus evanescens*) (Fig. 23)

Found in Hokkaido and the Pacific Coast of No. America and in most rocky coasts of the Northern Atlantic and Pacific Oceans. Although this brown alga has not used as human food in countries while some species, e.g. *F. aestoulosus* is used as fod-

4: Rhodophyta: Red algae

Red algae are characterized by having a red pigment, phycoerythrin (phycobillins). The color is not always an indication for the phycoerythrin because it can be masked by other pigments especially if found along the intertidal zones. Algae belonging to this group are found in the various depths of the oceans. A large group of red algae is either the source of agar (agarophyte) or the source of carrageenan (carrageenophyte). The algae of both groups are generally suitable for additive food. Moreover, they are also suitable to use as a source of many other kinds of food products. Most notable, perhaps is *Porphyra* (*P. tenera* (Fig. 24), *P. umbilicaris* and *P. yezoensis* etc.) (the nori in Japanese) which are mainly made into sheets as is used as its self or an enveloping cover of rice ball (Sushi). *P. yezoensis* occupies most of it in present Japan.

Fig. 24 *Porphyra tenera* (nori) Japan, Korea and China (Mostly cultured in these countries)

Nori (*Porphyra tenera* and *P. yezoensis*) (Fig. 25)

P. yezoensis is widely cultivated today in Japan, China and Korea on a very large scale. The culture of nori began in 17th Century in Japan. The fronds are chopped, boiled and reconstituted into sheets. By the early 900's cultivation techniques spread to China and Korea and continues to expand. In Hawaii in 1986 more than a ton of nori was cultured and manufactured in a land based tank. Sea water from the surface (temperature of 22-25℃) was mixed with water from a depth of 870 meters (tem. 10℃). In both quality and flavor, this product almost equaled the Japanese product. Every indication points to a continuing cultivation of *Porphyra* worldwide. In Wales, red laver (*Porphyra umbilicalis*) is mashed into a paste to make laver bread. This laver bread is used in cooking with vegetables and fish or as a gelatin.

Fig. 25 *Porphyra yezoensis* (nori) Japan, Korea, and China. (Mostly cultured in these countries)

Stone flower, tengusa, cowhair (*Gelidium amansii*) (Fig. 26)

Gelidium is a typical agarophyte. It was one time between 1955-1959 when the master of an inn at Kyoto, Japan found that mucous extract from Japanese agar-agar was changed to an elastic jelly (agar) suitable for a food upon exposing the extract had been put out of door. This was the first finding of "agar". Most agarophytes are found at the coasts of all around Malay Islands, the Indian Ocean and the Atlantic Ocean. Most members of agarophytes are edible, particularly as salad.

Fig. 26 *Gelidium amansii*

Tosakanori (*Meristotheca papulosa*) (Fig. 27)

Found in the middle and southern districts of Japan, Hachijio Island, Taiwan, Polynesia, Indian Ocean. It is used in soups and salads.

Fig. 27 *Meristotheca papulosa*

Irish Moss or carrageenan moss (Also: sea pearl moss, white wrack) *Chondrus crispus*: *Ch. ocellatus*. (Fig. 28)

It is found everywhere in Japan and the North Temperate Zone of the Atlantic. This red alga is one of the best carrageenophytes. Carrageenan is one of the complex galactan as agar and has a long history of researches and utilization. Ireland is the pioneer country and its mother alga is the best known as the name of Irish Moss or carrageenan Moss.The alga has been used in the dessert like the blank mange.

Fig. 28 *Chondrus ocellatus*: Habitat: everywhere in Japan
C.crispus (Irish Moss): No temperate zone of Atlantic carragaenophyte

Sea noodle or ogonori (*Gracilaria verrucosophylla*) (Fig. 29)

Found everywhere in Japan, Sakhalin, Chishima, Korea, Taiwan: in worldwide habitats. This red alga has recently occupied an important part as a source of agar, and has been used as fixing with "Sashimi" in Japan.

Fig. 29 *Gracilaria vermiculophylla*

Fig. 30 *Palmaria palmata* (darusu) (Okamura, 1936)

Dulse : Neptunes girdle, darusu. (*Palmaria palmata*) (Fig. 30)

Habitat: Northern Pacific cost of Japan, Hokkaido, Korea, Sakhalin, Kurile Islands, West Cost of No. America, Australia, Polynesia and Atlantic waters. Dulse has a long history of use as food in Scotland and Ireland.

Fig. 31 *Kappaphycus alvarezii* cultivated type

Kirinsai-zoku (*Eucheuma*), *Kappaphycus alvarezii*. (Fig. 31)

The genus *Eucheuma* is important algal group for carrageenan of various types. These galactans are as with agalose are used for making foods in an industrial scale as sizing or stabilizing material. In the Philippines, these carrageenophytes are cultivated on the largest scale in the world. Grow in Malaysia and Philippines.

Fig. 32 *Bonnemaisonia hamifera*

Kagikenori or limu (*Bonnemaisonia hamifera*) (Fig. 32)

Habitat: Everywhere in Japan, Korea, Pacific Coast of North America, Atlantic waters. The alga has antiiniotic properties, and may be edible as salad.

zone. Since this red alga is one of the agalophytes and very soft, it has been used particularly as thickening and flavoring for meat dishes etc.

Suginori (*Chondracanthus tenellus*) (Fig. 35)

An agarophyte. Distributes over most coasts of Japan, south-west islands of Japan and most coasts of Korea. Other several species grow in the USA coasts, mainly in the Pacific side.

Fig. 33 *Gloiopeltis furcata*

Fig. 34 *Ahnfeltia pilosa* (Abott & Hollenberg, 1976)

Fig. 35 *Chondracanthus tenellus*