CALIFORNIA Sea Grant

Marine Advisory Publication

MARINE ALGAE

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All animal life in the ocean is dependent on marine algae. Algae are called *primary producers* because they are the first link in all oceanic food-chain systems. Like land plants, algae contain the green pigment, chlorophyll, that makes it possible for them to absorb the direct energy of the sun and convert it into organic starches and sugars by a chemical process called *photosynthesis*. Besides providing the sugars and starches necessary for life, algae produce oxygen and offer habitat and protection for many fish, invertebrates (*e.g.*, crabs, snails, and worms) and some marine mammals, such as the sea otter.

Marine algae constitute a large group of plants of varying sizes, shapes, and colors. One thousand of the smallest algae can fit on the head of a pin, whereas the largest alga is taller than the tallest redwood tree. Marine algae are used in many of man's processed food products and their nutritional value has been known for centuries in many Asian and South Pacific countries, where they are a staple food.

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Types of algae

Phytoplankton. Phytoplankton are free-floating, unattached, primarily microscopic, plant organisms of the sea, which account for 95 percent of the entire sea vegetation. Over 6,000 species of phytoplankton are known to man. Some of the more common phytoplankton include diatoms, dinoflagellates, silicoflagellates, coccolithophores, and a few blue-green algae (see fig. 1).

Diatoms are the most abundant of this group. They are encased in hard, silica shells (glass houses!) of various geometric shapes and beautiful microscopic markings. Frequently their shells are designed for flotation on the sea surface where they can receive maximum sunlight for photosynthesis. Some of the other tiny floating plants, such as the dinoflagellates and silicoflagellates, swim actively in the water with fine, waving tails called flagella.

Many dinoflagellates are luminescent and flash bright microscopic lights at night, often producing an eerie greenish "fire" when millions of organisms are present in the water mass. Some dinoflagellates produce a toxin poisonous to man for which there is no known antidote. The season for toxin production starts in May each year, in California, and causes mussels to be prohibited for food consumption through the summer. (See Sea Grant Marine Advisory Publication, Leaflet 21117, for further information.)

Seaweed. Macroscopic (large) marine algae are commonly known as "seaweed." The majority of seaweeds fall into three major groups, each classified by its dominant color pigment:

Chlorophyta —	green algae (1,000 marine species)
Phaeophyta —	brown algae (1,000 marine species)
Rhodophyta —	red algae (3,000 marine species)

Although all of these alga groups contain the green pigment, chlorophyll, the red and brown algae have other dominant pigments which mask the green.

Seaweeds are simple in structure when compared with land plants. Unlike land plants, they do not have different body tissues in their roots, stems, and leaves. However, the brown algae do have rootlike holdfasts, stemlike stipes, and leaflike blades. The complete body of a seaweed is called the thallus (see fig. 2).

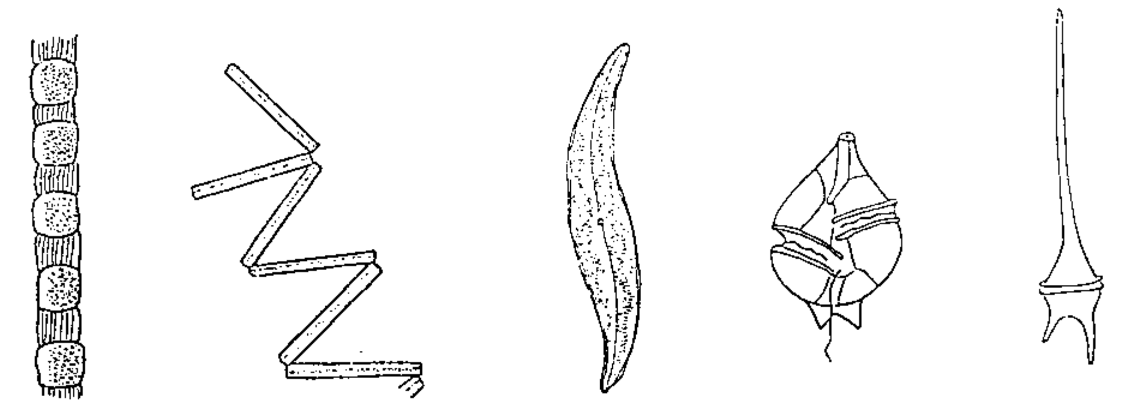


Fig. 1. Examples of phytoplankton (adapted from Newell and Newell, 1963).

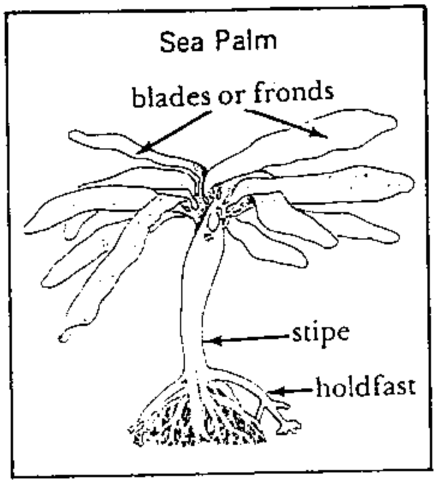
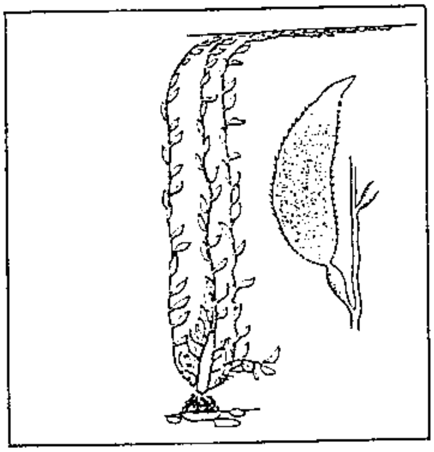


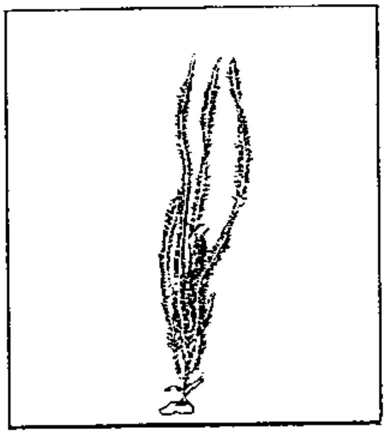
Fig. 2. Seaweed parts.

Marine algae can attach to the sea floor in two distinct ways. Some attach with a single disc holdfast while others have penetrating and entangling creeping holdfasts. Alga holdfasts are principally for anchorage and are not nutrient-gathering like the roots of land plants. The alga takes nourishment directly from the seawater through all exposed surfaces.

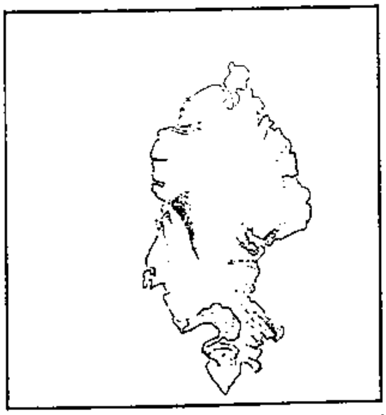
Unlike flowering plants, algae do not produce seeds for reproduction. Instead, microscopic cells known as spores are produced and germinate to form a new plant. Some seaweeds form miniature plantlets which grow to become new adult plants.



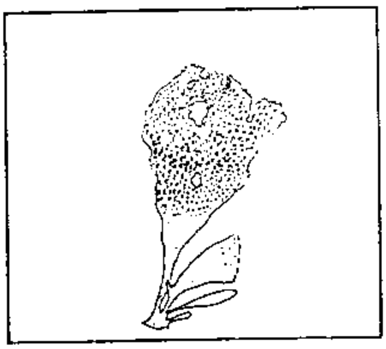
Giant kelp, *Macrocystis pyrifera*, a brown alga.



Feather boa kelp, *Egregia menziesii*, a brown alga.



Sea lettuce, *Ulva lactuca*, a green alga.



Gigartina papillata, a red alga.

Fig. 3. Some common marine algae.

Marine algae live close to the surface of the water because they must use the sun's energy to produce their food. Most seaweeds are attached to rocks, shells, or other plants in the intertidal region (that part of the shore that is covered and uncovered daily by the tides). Plants that live in the intertidal zone must be able to survive periods of drying out and changes in temperature, salt concentration, and tide levels.

The ability to resist periods of exposure varies with different seaweeds. One of the most abundant seaweeds of the intertidal area, a green alga, *Ulva lactuca* (sea lettuce), can lose up to 75 percent of its tissue water and suffer no ill effects once the water is replaced. Some brown algae, such as the common branched rockweed (*Fucus distichus*), can tolerate up to 48 hours of exposure without drying out. Most red algae are sensitive to heat and light and exist in the low intertidal zone because they cannot survive more than two or three hours of exposure.

Two marine flowering plants often mistaken as intertidal algae are *Zostera marina* (eelgrass) — common in bays and sheltered waters and often accompanied by various species of green algae — and *Phyllospadix* (surf grass) — commonly attached to rocks in intertidal zones.

Fig. 4. Surf grass—a flowering intertidal plant.

The large, treelike brown algae, called kelps, grow up to 150 to 200 feet and dominate much of the exposed California coast. They form large, tangled submarine forests, consisting of *Macrocystis* sp. (giant kelp), *Egregia* sp. (feather boa kelp), *Nereocystis* sp.(bull whip kelp) in northern California, and *Pelagophycus* sp. (elk kelp) in parts of southern California. All of these brown algae depend on gas-filled floats, called pneumatocysts, to buoy their long, swaying stipes and long blades. The stipes and blades are tough enough to survive the rigors of water and waves. Because kelps are so long, they can transfer photosynthesized material from the surface of their blades down to the holdfasts to support growth in the dim bottom environment. Kelp forests, often called kelp beds, are havens for many marine animals who depend on them for food and shelter.

Drift kelp

Large piles of loose kelp, washed up on the beach, are a common sight along the shore. "Drift kelp" plays an important part in the ecological cycles of the ocean. Kelps grow exceptionally fast and the towering, floating plants eventually become too large to be anchored by their holdfasts. During storms or times of large wave action (swells), the plants tear loose from the bottom and drift freely. Often these kelps float for days in the ocean, providing miniature habitats for small, free-swimming organisms and fish. Eventually winds and currents wash the drift kelp onto beaches where the plants begin to decay and return their nutrient value to the sea.

In the past, man has looked upon these massive piles of kelp (often 5 to 8 feet deep and many yards wide) as decaying, smelly nuisances to be hauled off to dumps as waste. However, research has indicated that drift kelp may be a useful resource. When processed properly kelp is an excellent fertilizer for agricultural crops. Further research may develop other uses for this resource.

If you are walking along the beach and see piles of drift kelp, stop for a while and examine them. Among the entangled fronds, and especially within the holdfast structure, you will find a myriad of small organisms (*i.e.*, crabs, worms, starfish, clams, and other invertebrates). These miniature habitats are exciting and interesting in themselves.

Alga aquaculture

Aquaculture — the farming of aquatic plants and animals — is fast becoming a widely accepted option for fisheries development. Plant aquaculture has been practiced in Japan and other oriental countries for many years, but is relatively new in the United States and is in the research and development stage.

Alga aquaculturists are looking at methods of growing various fast-growing brown alga species for food consumption. Alga geneticists are successfully cloning strains of algae to provide genetically desirable alga species. Red algae are being cultured to produce a desirable alga species which gives the carrageenan necessary for laboratory culture media.

Pacific herring spawn and deposit their eggs on marine algae in bays all along the Pacific coast. Egg-alga masses are harvested and sold to foreign markets (Japan) as a delicacy. The market value of this product is presently $20,000 per ton.Alga aquaculturists are looking at methods of culturing alga species on floating nets where eggs spawned by herring would be easy to harvest. The future of alga aquaculture is bright and holds potential for development and expansion.

Commercial uses of marine algae

Algin, a derivative of kelp, and agar and carrageenan, extracts of red algae, form the basis of a multi-million-dollar industry. These extracts are found in many prepared foods, including ice creams, puddings, salad dressings, cheeses, fruit juices, dehydrated mixes, and toppings. Alga derivatives provide a gel which is used to emulsify and stabilize foods.

Furthermore, algin is widely used in preparing dental molds and in brewing beer; it is commonly used in fertilizers, animal feed, and with dyes; and about 15 percent of the world's organic iodine supply is manufactured in Japan from kelp. The kelp beds off California are owned and leased by the State for harvesting *Macrocystis*.

Agar is used as a medium for growing laboratory cultures including animal cells. Medical laboratories grow out and identify on agar media the bacteria that cause many human illnesses. In recent years, the cost of agar has climbed so high that researchers are looking at carrageenan as a less expensive medium for laboratory culturing.

Marine algae can be used in decorative art work. Alga plants can be dried, pressed, and formed into many creative arts-and-crafts pieces. For details on how to dry and press marine algae, refer to Sea Grant Publication "Pressing Algae," Leaflet 2556.

Collecting seaweed on the California coast

Except in State parks and reserves, gathering algae for personal use, such as for pressing or eating, *does not* require a California fishing license or permit. However, collecting algae for commercial or scientific purposes requires a permit issued by the California Department of Fish and Game. Any person taking marine algae in a State park or reserve, for commercial *or* personal use, must obtain a permit from the State Department of Parks and Recreation.

While collecting algae in intertidal areas you will come across many invertebrates (crabs, clams, worms, and snails) living among the seaweeds. The animals are protected by the California Department of Fish and Game regulations and can be taken legally *only* by persons with valid California sport-fishing licenses and only when the animals are legally in season. Please check your local Fish and Game regulation booklet before taking marine animals.

A good bucket, knife, and some plastic bags are all that are needed to collect marine algae. A good field guide to marine algae identification is also useful. Books can be obtained at most book stores and marine science centers along the coast. It is also wise to wear sturdy gym shoes when collecting algae. Algae-covered rocks are very slippery and good shoes will prevent cut feet and frequent slips into the tidal water.

The greatest number of seaweeds are exposed at low tide. In California the tides reach high and low levels twice a day. Daily tide information can be found in local newspapers and long-range tide tables can be obtained at most sporting goods stores, surf shops, and bait and tackle shops.

A rocky shoreline is the best place to collect seaweeds because it supports the greatest variety of species. The vertical sides of the rocks are richer in plant life than the tops. Taking plants directly from their places of attachment is the best way to ensure freshness. (Seaweed drifted upon the beach is seldom fresh and is often full of debris.) Seaweeds can be cut off rocks with a knife, or some can be easily plucked. It is a good practice never to take more than you will use.

Seaweed smorgasbord, anyone?

Marine algae are primary foods in the daily diet of many people in Japan, China, Hawaii, the Philippines, and even the United States. Seaweeds are very nutritious and rich in vitamins A and E. The red, green, and brown algae are also very high in niacin and vitamin C. Concentrations of vitamins B-12, B-1, and folic acid are found in some green and red algae.

Marine algae contain highly digestible proteins which account for almost 25 percent of their dry weight. Red and green algae are the highest in protein content. Three ounces of the common red alga, *Gigartina papillata*, can supply one-half of the daily adult protein requirements. The most tender and nutritious part of some large seaweeds is the growth-producing tissue. With many of the red and green algae, the entire plant is edible and nutritious.

Fucus distichus, the branched rockweed, is one of the most common and nutritious seaweeds of the intertidal area. This brown alga is very high in protein, vitamin A, iodine, phosphorus, and vitamin C, and contains fair amounts of potassium, calcium, sodium, iron, and magnesium. The amount of vitamin A in *Fucus* is about 1,000 times higher than is contained in equal amounts of cod liver oil. It should be collected in early fall for high vitamin C content and in summer for high vitamin A content. *Fucus* adds a sweet taste to foods with which it is steamed or boiled. It is sold in health food stores as a bladder-wrack tea.

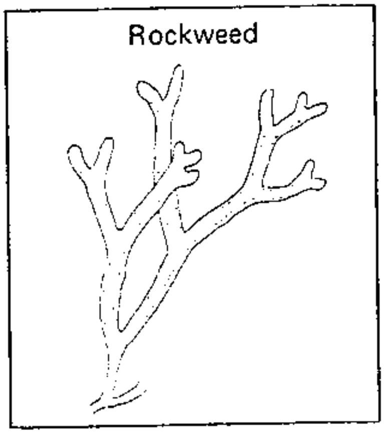


Fig. 5. The branched rockweed, *Fucus*.

Another common edible and nutritious seaweed in the intertidal region of the California coast is a green alga, *Ulva lactuca* (sea lettuce). It is very high in iron, protein, iodine, magnesium, vitamins A, B-1, and C, and sodium. The blades can be easily cut or plucked from the rocks at low tide and should be washed well and dried at room temperature before being used as a soup base.

Seaweed recipes

There are numerous ways to prepare seaweed and many are delicious raw or cooked. Some make nice additions to salads, especially when combined with cucumber and radish, all finely chopped.

KELP (NEREOCYSTIS) CAKE

- 3 eggs
- 2 c. sugar
- 1½ c. cooking oil
- 2½ c. flour
- 1 tsp. baking soda
- 1 tsp. baking powder
- 1 tsp. cinnamon
- ½ tsp. powdered ginger
- 1½ c. grated kelp
- 1 c. crushed pineapple, drained

Use portion of "head" or float of *Nereocystis*, the brown alga (kelp) frequently found on beaches in central and northern California. A float about 4 inches in diameter will not be too old or tough. Cut into pieces, peel with vegetable peeler, and grate or chop finely. Wash (to remove excess salt that is released in grating) and drain well in colander.

Beat eggs until thick and lemon colored, gradually adding sugar. When combined, add cooking oil and stir briefly. Stir together flour, baking soda, baking powder, cinnamon, and powdered ginger. Add to egg mixture, then fold in the finely-grated kelp and crushed pineapple. Bake at 350° F for 45 to 50 minutes in a greased and flour-dusted 10"×10" or 9"×12" pan.

Makes a moist spice cake which may be frosted with butter-lemon frosting or left unfrosted with powdered sugar sifted over the top, according to taste. (From I.A. Abbott.)

KIM CHEE

Based on the Korean method of preparing their famous pickled cabbages, using a red alga, *Gracilaria*.

- 2 lb. *Gracilaria* chopped into 2- to 3-inch pieces
- handful of coarse salt
- 2 cloves garlic chopped, per quart of wilted seaweed (or to taste)
- 1 to 2 chopped bulb onions, or ½ c. chopped green onions
- chili pepper, chopped, or ½ tsp. cayenne (or to taste—should be hot)
- ½ tsp. paprika

Wash and clean the *Gracilaria*. Salt and wilt by letting it stand overnight. Drain off liquid; add garlic, onions, chili pepper, and paprika. Pack tightly in jars, seal, and refrigerate. Let stand a few days before using. (From Abbott and Williamson, 1974.)

SEAWEED BREADS

Thoroughly rinse and dry seaweed, or use dried kelp. Using your favorite simple bread recipe, substitute water for milk, add extra tablespoon of butter to recipe, and omit salt. Grind or powder dried seaweed into a flour and substitute seaweed flour for half the amount of flour called for. Follow the rest of the recipe, experimenting with different seasonings. (From Coggins, 1975.)

Traditional "laver bread" is made from *Porphyra*, a red alga, used by the Welsh. The finished product is like a pudding. *Porphyra* is called "nori" by the Japanese. California species can be used to make sushi and Chinese seaweed soup.

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Glossary

Agar — an extract of marine algae which is used primarily as a medium for laboratory culture of bacteria.
Algae — a group of plants that have no true roots, stem, or leaf. Algae, often called seaweed, are found in both fresh and ocean water. (Singular: alga.)
Algin — a colloidal extract from brown algae. Used in industry in manufacturing rubber tires, paints, and so on.
Blade, or frond — The flattened, or leaflike, portion of marine algae.
Carrageenan — a colloid (similar to agar) extracted from certain red algae and widely used in prepared foods and to thicken, emulsify, and stabilize milk products.
Diatoms — algae with silicious cell walls fitting together like the halves of a pill box.
Flagella — microscopic, whiplike structures used for locomotion.
Holdfast — an organ of attachment which connects algae to the substrate.
Intertidal zone — area between the edges of the highest high tide and the lowest low tide.
Photosynthesis — the process in which plants use the sun's energy to combine carbon dioxide and water chemically to form carbohydrates.
Phytoplankton — mostly microscopic, passively floating or drifting algae.
Stipe — the stemlike region of marine algae.
Thallus — a plant body without true roots, stems or leaves.

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