SEAWEED FARMING IN PUGET SOUND

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Contents

There is already a small, but firmly established market for edible seaweeds in the United States that has good prospects for expansion. With the development of a system of offshore culture supported by spore hatcheries and a local processing capability, production of good quality nori in Puget Sound seems entirely feasible. Such a system should be able to satisfy current domestic consumption and produce a surplus that would be available for export to other countries.

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Seaweed Farming in Puget Sound

CHARLES J. HUNTER, National Marine Fisheries Service, Seattle, WA,
and CURTIS W. NYEGAARD, Kitsap County Extension Agent

The harvest of seaweeds in the Western world has varied with demand for such chemicals as soda and iodine. Each time a cheaper, more convenient source was discovered, the seaweed market collapsed.

During 1911 to 1914 when imports of potash into the United States were greatly reduced, seaweed was used as a source. Harvests along the Pacific coast during this period showed that estimates of yield from earlier surveys were overly optimistic (1), a point to be considered in estimating potential production from wild stands.

Now, seaweeds are used mostly for food, fertilizer, or as sources of agar, algin, and carrageenin.

In the Orient, where it is widely used as food, it is used as seasoning and as a supplement to other dishes rather than a staple. In Oriental communities throughout the world, the demand for edible seaweeds seems to be increasing as the standard of living rises.

In the United States edible seaweeds are marketed in Oriental communities in cites such as Los Angeles, Chicago, San Francisco, and Seattle. The sale of these seaweed products is expanding as Oriental foods work their way into gourmet markets. Most of the processed edible seaweeds are imported from Japan and retail as high as $56 per pound. However, home processing of seaweeds of good quality from the intertidal beaches is common among Oriental-Americans on the West Coast.

The three most common seaweeds used as food, both here and in the Orient, are kombu (*Laminaria*), nori (*Porphyra*), and wakame (*Undaria*). Kombu is used as soup stock and dried strips are eaten as snacks. When shredded and soaked in soy sauce, it is used as seasoning for rice dishes or it can be boiled and eaten as a vegetable.

Although those who eat seaweeds do so mainly for the taste, its nutritional benefits cannot be ignored (2). Kombu contains 6 per cent dry weight of protein, vitamins, and trace minerals, and nori (the Japanese term for laver) contains 30-50 per cent protein in addition to vitamins and minerals (3). Analysis of several species of nori that grow in Puget Sound showed similar ratios of protein (27 to 41 per cent).

Dried and pressed into sheets, nori is used to wrap rice rolls (Figure 1), which among Japanese are used somewhat as sandwiches are used in the West. Small flakes of nori are also used to flavor rice crackers, soups, and other dishes. Wakame is used as a vegetable in salads and soups.

In Japan, 65 per cent of the wakame and almost all of the nori production comes from areas set aside for seaweed farming. In contrast, only about 30 per cent of kombu comes from these farms.

Like other plants, seaweeds contain carbohydrates, fats, and proteins. The carbohydrates are not very sweet and do not significantly increase the blood sugar when eaten. The proteins, similar to those of land plants, are useful for human nutrition. Although they do not contain much fat, at least one unsaturated fatty acid necessary for good human health is usually present, along with vitamins (A, B-complex, and C) and minerals (sodium, iodine, and trace elements), which are important in human nutrition. Although syn-

Figure 1. Sushi, a Japanese dish made from rice and other foods such as fish, vegetables, and seaweed.

thetically iodized table salt is abundant and cheap, many people prefer natural combinations of these minerals as found in seaweeds.

According to Dr. Stanley Skoryna, of the Gastro-intestinal Laboratories of McGill University, the sodium alginate from ingested seaweeds assists the selective absorption of calcium over strontium so that calcium is absorbed through the intestinal wall while 50-80 per cent of the strontium (including the dangerous radio-active isotope Strontium-90) is bound by the alginate and is harmlessly passed out of the body (2). When a suitable binder such as alginate is not present, ingested Strontium-90 is absorbed along with calcium into the body where it accumulates in the bones where the radiation can damage the marrow.

A study of breast cancer in laboratory animals and humans shows that the higher the level of iodine in the body, the less chance of cancer (4). Adding seaweed products to the diet is a simple, effective way to provide iodine intake.

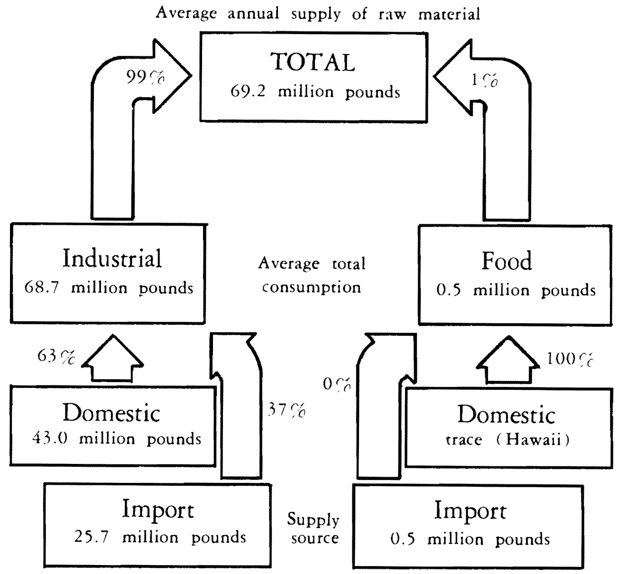

Figure 2. Average annual supply and source of seaweed (dry weight) in the U.S., 1962-71.

Harvests and Markets

World Production

In 1961 the world-wide harvest of wet seaweed amounted to 1.2 million metric tons and increased in 1970 to 1.7 million metric tons. For the 10-year period, harvest increased an average of 4.3 per cent per year. Silverthorne and Sorensen (3) estimated that Asia currently produces 72.3 per cent of the total world harvest with the People's Republic of China producing 35.8 per cent, Japan 29.5 per cent and the Republic of Korea 7.0 per cent. The United States produces only 7.5 per cent of the total world harvest.

United States Production

In the United States, seaweeds are used mainly for the production of agar, algin, and carrageenin. Smaller amounts are used for fertilizers and meal. The quantity, sources, and uses of seaweed in the United States are shown in Figure 2.

The Alaskan harvest of herring eggs on kelp (kazunoko-kombu), which is mostly exported to Japan, has not been included. This is classified in economic reports as fish eggs. For 1965-66 the value of this fishery was one-half million dollars (5).

The present U.S. production of edible seaweed is insignificant. Small amounts are harvested and sold fresh in Hawaii, some is processed for use by the health food industry, and the rest is gathered by individuals for personal use. Almost all of the edible seaweeds sold in the U.S. are imported.

Imports of Edible Seaweeds

Imports, which consist mostly of dried nori, wakame, and kombu, serve the needs of Oriental communities in the United States. In 1973 sample retail prices in Seattle for dried packaged seaweed products were:

(1) Nori—$10.31 to $56.00 per pound (average $34.39). A container of seasoned nori, weighing 0.6 ounce and cut into small sheets, sold for $1.75.

(2) Wakame—$9.55 to $31.04 per pound (average $17.01).

(3) Kombu, unprocessed, $2.08 to $6.36 per pound (average $5.00); sliced and processed, $4.52 to $34.06 per pound (average $17.10).

Increased interest in Oriental cookery by American housewives and the presence of large numbers of Japanese businessmen and tourists in the United States have substantially increased the market for these products (6).

Since Asian Americans and non-immigrant Asian visitors create most of the United States demand, areas where the incidence of people of

Asian descent is relatively high such as Hawaii, California, Washington, Oregon, New York, and Illinois, would be expected to be the main centers for marketing seaweed food products. Since there are over 600,000 persons of Japanese descent in the United States, the potential market for edible seaweeds of the kinds used in Japan would seem to be substantial.

Japanese Production of Edible Seaweeds

Japan is the largest producer and consumer of seaweed food products in the world (3). Landings of "tengusa" (*Gelidium*) for production of agar have been fairly constant at 10-20 thousand metric tons (wet weight) per year, whereas those of the other three seaweeds have fluctuated rather widely.

Wakame landings prior to 1965 came from natural production with an annual yield of 50-60 thousand metric tons (wet). Since 1965, the increased production (to 120,000 metric tons) resulted from the institution of culture methods. By 1970, cultured wakame made up 65 per cent of the total harvest of 122 thousand metric tons. The value of wakame landings during this period increased steadily from approximately $1 million in 1957 to $31 million in 1970 as did the bulk price—rising from 1.0 cent per pound in 1957 to 11.5 cents per pound in 1970.

Nori is harvested almost entirely from cultured crops. The harvest more than doubled in weight from 1957-1960, remained about level from 1961-1968, and then increased by about 5 per cent in 1970.

Although kombu has been harvested primarily from natural beds, increasing demand has stimulated the development of culture systems. In 1970, 284 metric tons were harvested from cultured beds.

The average value per pound (at primary processor level) of selected Japanese seaweed products is shown in Table 1.

Table 1. Average Annual Value per Pound of Selected Seaweed and Products in Japan for 1966-1970

Product	Landed Value (wet weight)	Processed Value (dry weight)
Kombu (Laminaria)	$.08	$.32
Wakame (Undaria)	.08	.85
Nori (Porphyra)		
Black sheet		.82
Mixed sheet		.71
Green sheet		.27
Pieces		.80
Nori seedlings	.28	

Potential Seaweed Industry in the United States

Growing shortages of food, fiber, and chemicals are forcing us to look more to the sea for new sources of these critical materials. The culture of seaweeds would seem to offer opportunities for increasing our resource base for all three. It also would offer the opportunity for making better use of our living marine resources in territorial waters that are protected from exploitation by other countries.

The market for industrial products from seaweed is well established in the United States, the raw material coming almost entirely from natural production of kelp and Irish moss. To be competitive, any system for culturing these seaweeds would have to produce a high-bulk, low-cost product. The price of raw kelp (*Macrocystis*) harvested from natural stands has been less than 1 cent per pound (3). For Irish moss it has been 3 cents per pound wet weight (5). At these prices the prospects for development of seaweed culture for industrial markets do not seem particularly attractive.

For high-priced edible seaweeds, however, the development of culture systems appears more attractive. Although the United States market for edible seaweeds is small compared with Japan's, the simplicity of processing edible seaweeds and the high prices that they command suggest that the prospects would be attractive for development of domestic culture and processing in the United States. If overhead costs could be kept low, as seems likely, the products should compete favorably with imports from Japan and Korea. Small, family-operated businesses in the Pacific Northwest should be able to meet much of the United States' demand for processed nori.

Culture Systems

Nori has been cultured in Japan since the 17th Century. Prior to that, it was gathered by fishermen from wild stands along the beach. In the earliest method of culture, spores from mature wild plants were caught by placing bundles of branches along the beach in early fall. After several weeks, when the young, leafy plants appeared, the bundles were moved inshore near the mouths of rivers where there was an abundance of nutrients. Several harvests were made throughout the winter (1).

Since the 1930's large mesh nets (hibi) or split bamboo blinds (saku) have been used (7). These usually measure 18.2 m x 1.2 m, but can vary from 18.0 to 45.5 m and in width from 1.2 to 1.8 m. The hibi are set out in stacks of five at the mean tide level in early fall to collect spores. After the spores are set, the stacks are separated and the hibi moved inshore. Harvesting begins about two months later. The largest plants are harvested first, allowing the small plants to continue growing. Usually three or four harvests may be made during winter and early spring (8).

The discovery by Drew (9) of the conchocelis stage in the life cycle of nori led to the development of new culture techniques. Under the proper temperature and light conditions, mature plants produce spores which attach to mollusk shells.

These spores develop into a filamentous (conchocelis) phase (Figure 3), which grows throughout the summer. When the temperature and light levels drop in the fall, spores are released from the conchocelis and attach to a suitable substrate to grow into leafy plants (Figure 4).

Figure 3. Intermediate stage in the life cycle of *Porphyra* (Conchocelis). The filaments usually grown on mollusk shells.

Figure 4. The mature stage of *Porphyra.*

This was the basis for the next step in nori culture in which bags of oyster shells were hung beneath the hibi (netting), for collecting spores. This led to the development of hatcheries, where it is now common practice to seed the hibi artificially (Figure 5). In early spring chopped leaves are placed in tanks containing strings of oyster shells.

Spores that set on the shells produce conchocelis which grow throughout the summer in the tanks. Very little care is required during this stage. In the fall, the water in the tanks is heated to forestall spore formation until the hibi are ready. When the water temperature is allowed to fall below 23°C, the hibi are placed in the

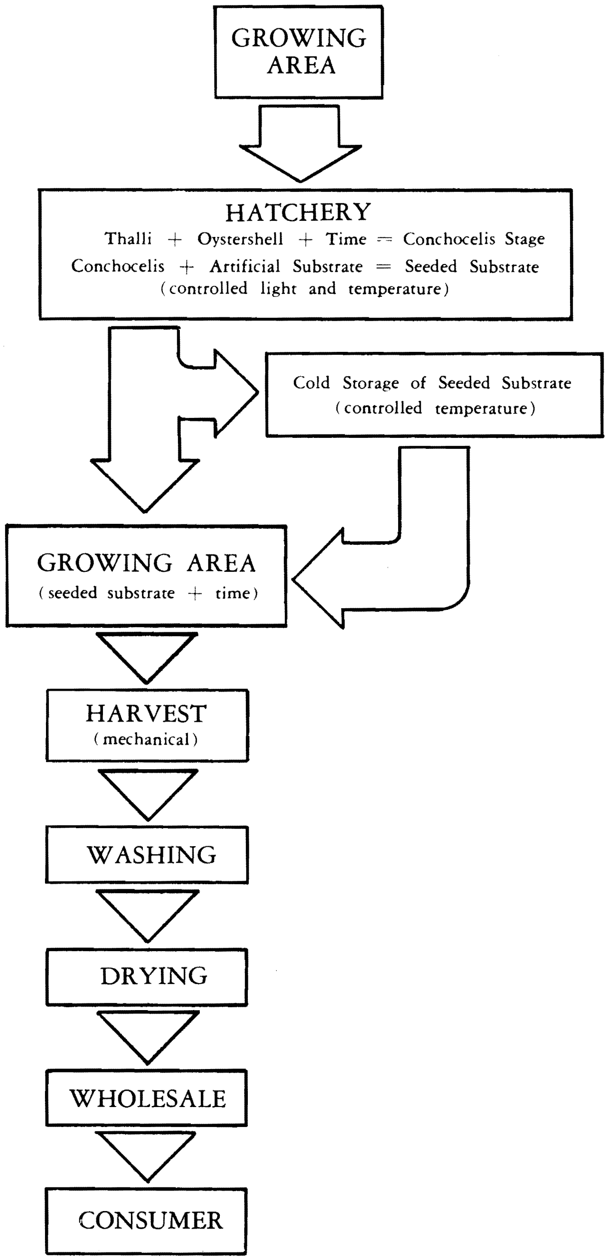

Figure 5. Culture and processing of *Porphyra*.

tanks for about 30 minutes, which is usually sufficient for a good set.

With the use of hatcheries, length of the growing season can be controlled by manipulating light and temperature, making it possible to spread the harvesting over several months. By keeping the spore tanks dark for over 12 hours each day and holding the water temperature to less than 23°C, sporulation can be speeded up to give an early start to the growing season. The growing season can be further extended by freezing the newly set spores at minus 20°C. These spores can be kept frozen for several months before setting them out. This technique also provides backup seed stock in the event of the failure of early crops from disease or storm damage.

Potential for Nori Culture in Puget Sound

Puget Sound seems well suited for the culture of nori. These plants require water temperatures in the winter ranging from 5° to 10°C for growing the species that can be processed into nori. For most of Puget Sound, winter temperatures range from 6° to 8°C and seldom go above 15°C in the summer (Figure 6). Sea ice rarely forms and only in the very shallow bays does the temperature of the water consistently exceed 15°C in the summer. Figure 7 shows the maximum and minimum temperatures for some representative sites. Fed by runoff from the nearby mountains, the rivers flowing into Puget Sound carry down nutrients needed by marine plants.

Currents in most areas are adequate for exchange of water and nutrients, but are not so strong as to cause damage or require extensive support structures (Figure 8). Although there is heavy cloud cover in the winter and spring, the light is sufficient for the growth of many species of *Porphyra*.

One limiting factor in the growth of large leafy marine algae is the amount of stable substrate in shallow water. This is due to the steeply sloping beaches and the depths of Puget Sound. The natural substrates suitable for growing seaweed are usually restricted to the narrow intertidal or upper subtidal strips on rocky shores. Therefore, in order to use this great body of water for seaweed production, an artificial substrate must be employed. Intensive, commercial culture of nori will require:

1. Artificial substrates that can be used offshore.
2. A mechanical harvesting system.
3. Local processing (for making nori sheets).

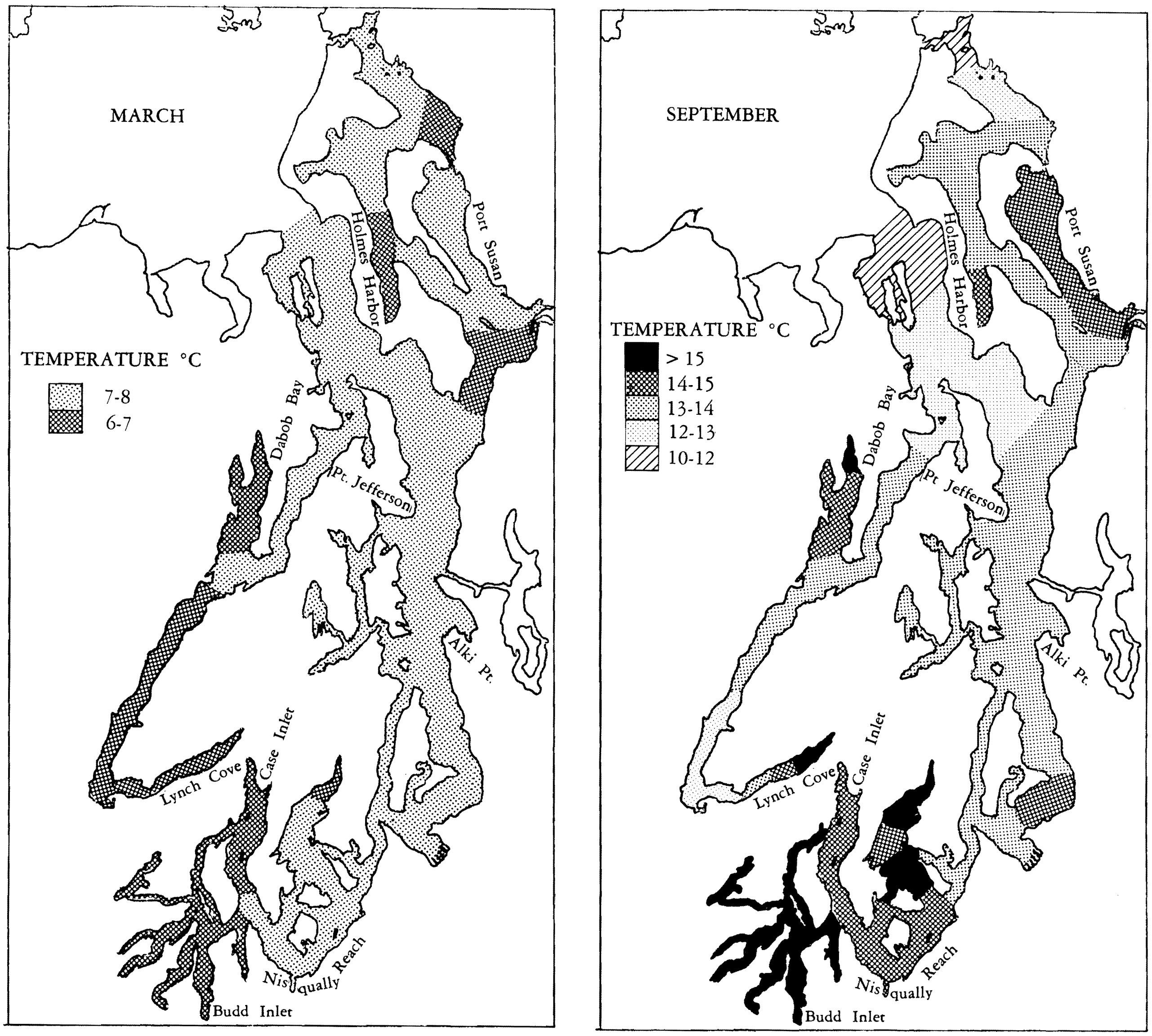

Figure 6. Puget Sound surface temperatures in March and September.

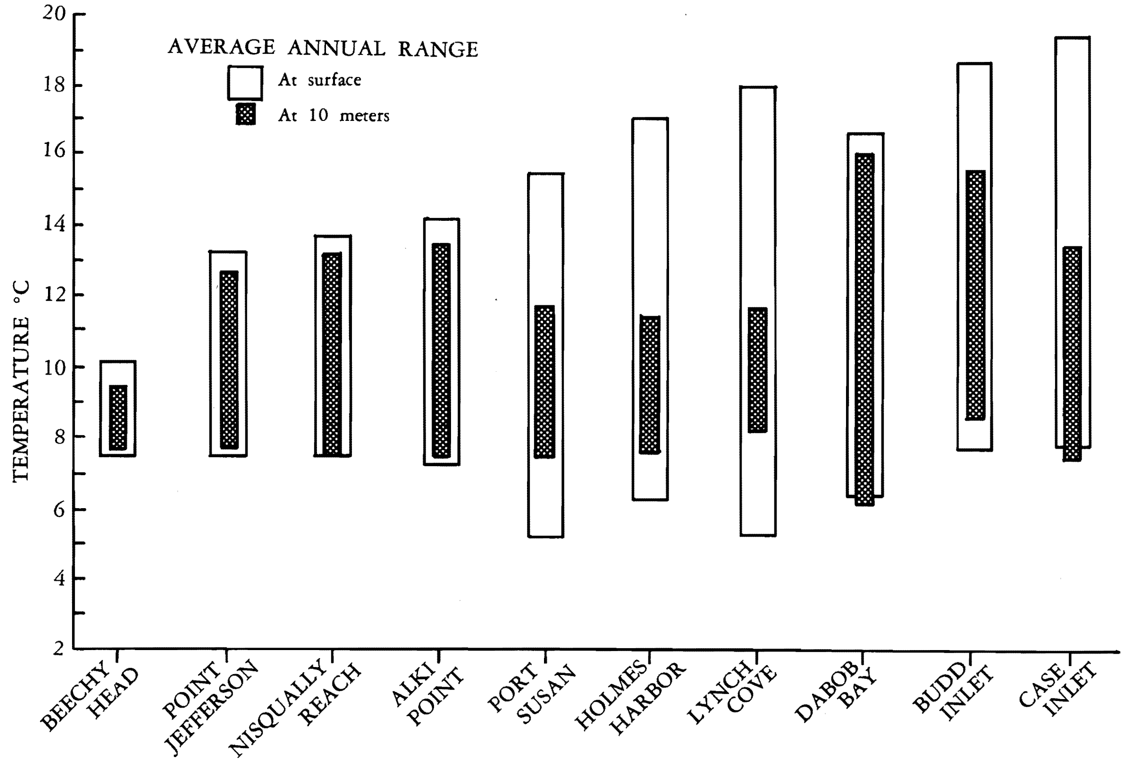

Figure 7. Ranges of temperature at some representative sites in Puget Sound.

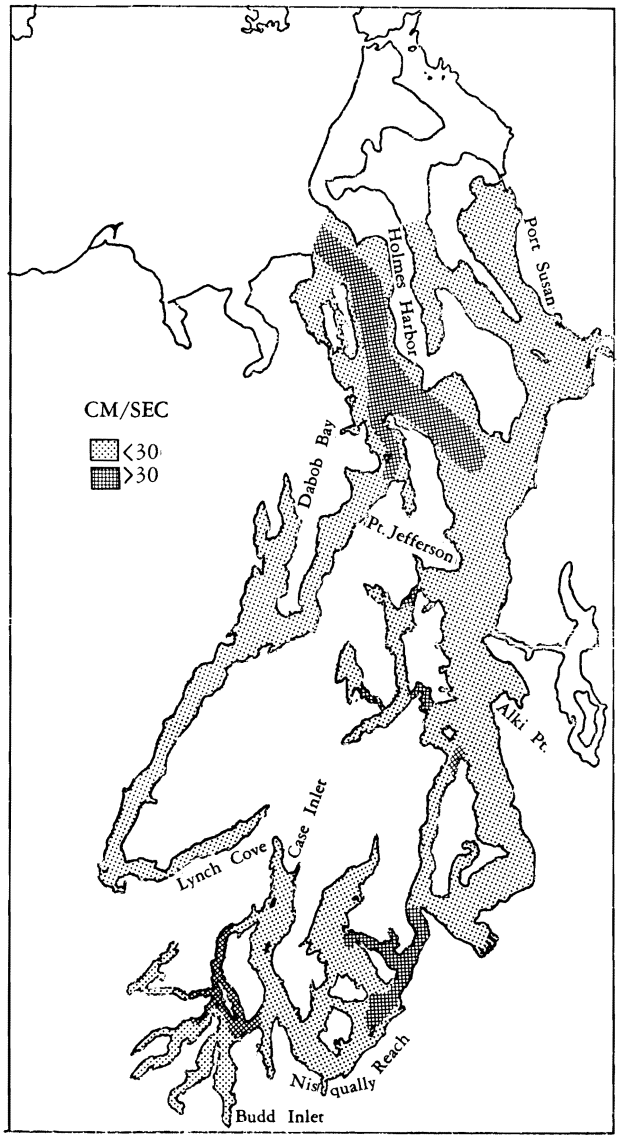

Figure 8. Puget Sound seawater current flows.

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