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By

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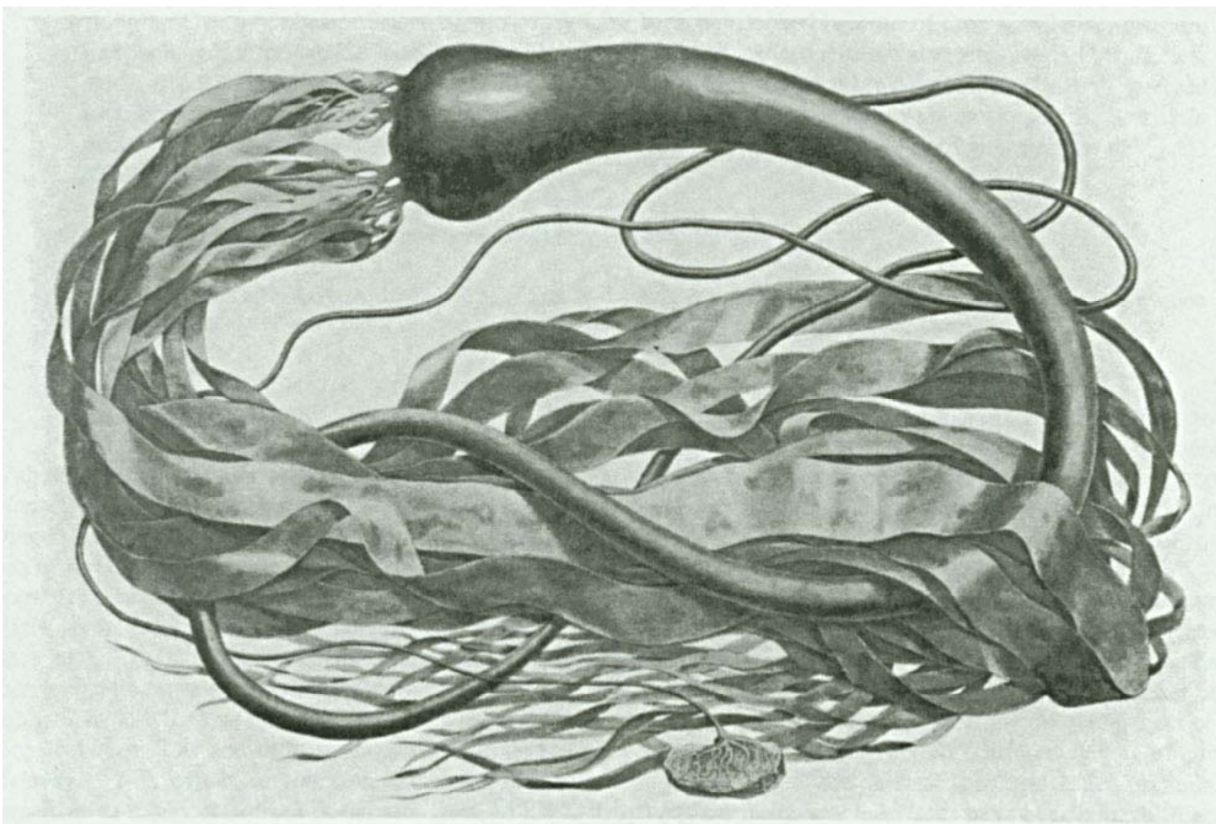

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Frontispiece
Postels, A., and F. Ruprecht. 1840. *Illustrationes algarum*…Petropoli [St. Petersberg]
Pl. 9. *Nereocystis luetkeana*, adult.

Figures, Tables, Appendices and a 2003 Addendum

A REVISED CHECKLIST AND PRELIMINARY ASSESSMENT OF THE MACROBENTHIC MARINE ALGAE AND SEAGRASSES OF OREGON

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ABSTRACT

A new checklist of the macrobenthic marine algae of Oregon is presented. The new list includes 50 new records and 90 new names, providing an overall nomenclatural change in the recorded flora of 36 percent since the earlier list of Phinney (1977). Of the 387 taxa reported, 20 percent have distributional boundaries within the state, indicating that Oregon is an area of relatively minor floristic change. Species overlap analyses with the floras of SE Alaska-Washington and California show that the Oregon flora is closer in composition to its northern neighbor than to its southern (Jaccard Coefficients of 54 and 44 respectively). Species richness is surprisingly low: Oregon has 227 fewer taxa than SE Alaska-Washington and 336 fewer than California. The depauperate nature of the flora has been proposed to be caused by latitudinal range and temperature differences, lack of sheltered habitats, sand domination, seasonal upwelling, and human disturbance. Some of these factors are influential. However, an analysis of taxa with west-coast distributions skipping Oregon indicates that many taxa may have been overlooked because of their small size, crustose morphology, and/or subtidal location. The lack of species richness is therefore also attributed to insufficient study. Additional surveys concentrating on the cryptic taxa will be necessary to determine if Oregon's seaweed flora is truly species-poor. Within the checklist, the following new binomials have been proposed: *Botrytella pacifica* (Hollenberg) comb nov., *Cryptopleura farlowiana* (J. Agardh) ver Steeg *et* Josslyn comb. nov., and *Kallymeniopsis oblongifructa* (Setchell) comb. nov.

Key Words: marine algae, seagrasses, checklist, Oregon, biogeography

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INTRODUCTION

With the recent publication and adoption of the *Territorial Sea Plan* (Ocean Policy Advisory Council, 1994), the state of Oregon has outlined new management policies for the protection of its coastal marine flora and fauna. The intertidal and nearshore conservation problems faced by this state are particularly great due, in part, to regulations that were imposed historically. Oregonians have long been concerned that the shoreline in this state should remain open and available to the public. In 1913, Gov. Oswald West designated the ocean shore between "low and ordinary high tide" to be a public highway. This official designation prevented the private ownership of most ocean-front tidelands. Then, in 1967, the Oregon legislature passed the "Beach Bill", sponsored by Gov. Tom McCall. This bill created a public recreation easement across dry sand beaches, extending the legal public use area on both public and private property from the intertidal to the 4.9-meter (16-foot) elevation line or the "line of vegetation". These regulations together with the 1936 completion of the Roosevelt highway (Route 101) have made the coast of Oregon one of the most publicly available and accessible in North America. In addition to the problems of pollution and development, the fragile marine biota in this state must endure the pressures of trampling, collecting, and handling imposed by masses of year-round public visitors (Brosnan and Crumrine, 1994).

In order to first develop management programs for coastal areas with high species diversity, the state selected rocky shores and reefs for their first area of study. The *Territorial Sea Plan* designated 29 rocky-shore site-complexes or "cells" along the coast that the state is now in the process of investigating and categorizing for different levels of protection. Inventories of the physical, geological, and preliminary biological features of these sites have been completed and tallies have been made of their use by humans (Fox *et al*., 1994). Counts of bird and marine mammal colonies are also complete, but the much more difficult task of surveying the intertidal and subtidal marine biota has just begun.

In order for the names of organisms to be consistent in these surveys as well as in other investigations, it is important that taxonomically and nomenclaturally up-to-date checklists of the marine flora and fauna of Oregon be available for reference. The primary purpose of this study was to provide such a list for the macrobenthic marine algae and seagrasses.

HISTORY OF FLORISTIC INVESTIGATIONS

The Northeast Pacific is well known for having a rich diversity and biomass of macrobenthic marine algae. Although early collections of marine algae were described by naturalists accompanying the explorers in the late 1700's and 1800's (see Scagel *et al*., 1989), it wasn't until the 1900's that comprehensive floristic treatments of the area were published. The first of these was produced by Setchell and Gardner (1903) and covered the flora from Cape Flattery in northwestern Washington to Kotzebue Sound near the Bering Strait. A few years later, these same authors published illustrated accounts for the entire Pacific coast, expanding their range from the Arctic through Mexico. These studies were divided into three parts: the first was on the “Myxophyceae” or blue-green algae (1919), the second on the “Chlorophyceae” or green algae (1920), and the third on the “Melanophyceae” or brown algae (1925). Their final comprehensive account was to be on the red algae. Although by far the most speciose group, it was never completed.

Later floristic accounts and checklists concentrated on narrower geographic areas. In California, Smith (1944) wrote a beautifully illustrated account of the marine algae of the Monterey Peninsula. After his death, Abbott and Hollenberg (1966) prepared a supplement that updated this volume, and later these authors (1976) revised and expanded the text to include all of California. The *Marine Algae of California* is still one of the most widely used identification guides on the west coast. In Oregon, the first floristic studies were done in the southern portion of the state: Sanborn and Doty (1944) completed a checklist of the Coos Bay to Cape Arago region, and then Doty (1947a, 1947b) completed an illustrated flora of the area from Coos Bay to the California border. These studies remained the only published references for Oregon until Phinney (1977) updated and expanded the checklist to include all of the state. In British Columbia, Scagel (1957) prepared an annotated checklist and keys to the marine algae of British Columbia and northern Washington, as far south as Cape Flattery. After monographing many of the taxa, Scagel *et al*. (1986) expanded the list to include southeast Alaska, and the most recent edition (1989, reprinted in 1993) includes both southern Washington and all of Oregon. Keys to the taxa have been written to accompany these volumes by Gabrielson *et al*. (1987, 1989). The geographic regions covered by the most recent accounts above are shown in Fig. 1.

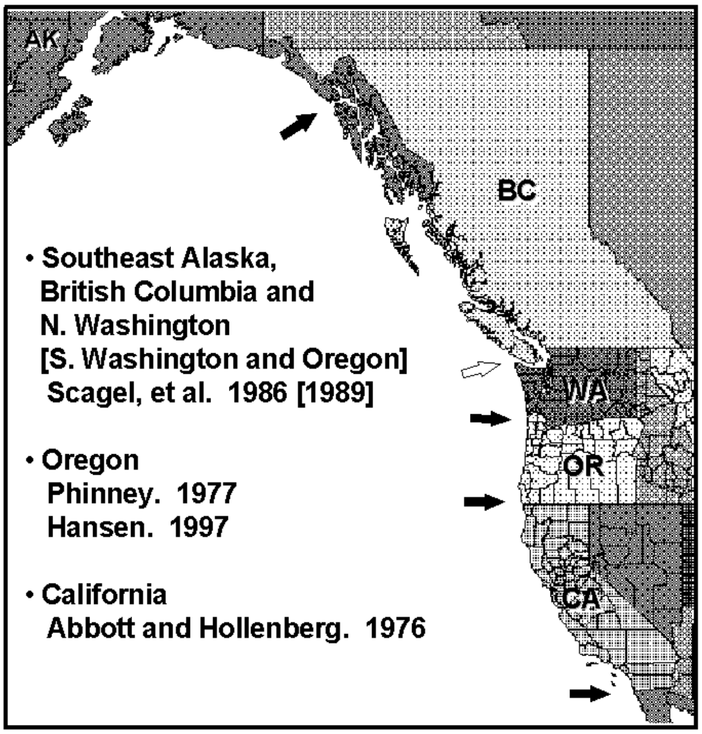

Fig. 1. Map of the west coast of North America showing the areas covered by the three most recent floristic treatments.

THE NEW FLORISTIC LISTS AND TABLES FOR OREGON AND THEIR PREPARATION

The Checklist

A new checklist of the macrobenthic marine algae and seagrasses of Oregon is presented in Appendix A. It is intended to be an updated version of the checklist prepared by Phinney (1977), which is now nearly 20-years old and out-of-date. The new list has been prepared primarily from the literature, but some new records of algae are included from collections made by Henry, Kawai, students at the Hatfield Marine Science Center, and the author. In addition, new records are included from Markham and Celestino (1976). Although some of these latter records were noted as an addendum in Phinney (1977), none were incorporated into his main list due to the near concurrent publication of the papers. Therefore, they have been added here. Seagrass records, not included in Phinney, were taken from Bayer (1979) and Phillips and Menez (1988). All new records are coded with an "R" in the list, and the collecting information for each is given in brackets after the name.

The most recent edition of the *Synopsis of Benthic Marine Algae* by Scagel *et al*. (1989) at the University of British Columbia has greatly simplified updating the taxonomy and nomenclature of the Oregon species. For the most part, the names utilized by these authors have been followed, and the reader is referred to this volume for the literature on name changes up to 1989. The synonymies and mistaken identities carefully detailed in the *Synopsis* have also been incorporated except in cases where additional studies appear to be necessary for the Oregon species. These and other problematic taxa have been given the notation "needs reinvestigation" in the Oregon list.

A number of new names have been used in the checklist that were either not used in the *Synopsis* or were established or re-established since 1989. These include the following genera: *Ahnfeltiopsis* (Silva and DeCew, 1992), *Botrytella* (Kornmann and Sahling, 1988), *Chondracanthus* and *Mazzaella* (Hommersand *et al*., 1993, 1994), *Norrissia* (Balakrishnan, 1980; but see notation in the list), *Osmundea* (Nam *et al*., 1994), *Petrospongium* (Womersley, 1987), *Pterothamnion* (Anasthasiadis and Kraft, 1994), and *Sahlingia* (Kornmann, 1989). The new combinations for the Oregon species of these genera are included in the list as are additional new species names derived from the literature. The reference for each of these is given in brackets after the name.

Three new combinations have been made in the list. *Botrytella pacifica* incorporates an older generic name for *Sorocarpus* (Kornmann and Sahling, 1988). *Cryptopleura violacea* is a name used in an earlier publication by ver Steeg and Josselyn (1984); with permission of the authors, it is validated in this paper by including the basionym. *Kallymeniopsis oblongifructa* is based on my personal observations of the type of this species and of reproductive material gathered in Oregon and Washington; this study will be published in a later paper.

In the Oregon list, all new names since Phinney (1977) are coded with an "N". Both synonyms and incorrect names, including those from Phinney, are listed in brackets after the taxon. It is important to recognize that the names that are indicated as incorrect here may still be valid in other geographic regions. For example, *Hedophyllum subsessile* is listed in brackets after *H. sessile*; although *H. subsessile* was misidentified in Oregon, it is still a valid species in Alaska (Hansen, in prep.). *Iridaea cordata* var. *cordata* is listed in brackets after *Mazzaella splendens*; it is not a valid species in Oregon, but it does occur in the Falkland Islands (Hommersand *et al*., 1993).

The Classification System

The classification system adopted for the checklist is that of van den Hoek *et al*., 1995. This system incorporates much of our new understanding of phylogeny based on molecular and ultrastructural data. In addition, it is now being followed by Guiry (1996) in his WWW version of the *Checklist of the Seaweeds of Britain, Ireland, and northern*

Europe. It is a system that is easy to adapt to floristic studies such as this, because only a few changes have been made in the higher classification categories. In traditional systems, the Chlorophyta (green algae), Chrysophyta (golden algae), Phaeophyta (brown algae), and Rhodophyta (red algae) were used for the major divisions. In the new system, the Chlorophyta, Heterokontophyta, and Rhodophyta are used. The Heterokontophyta encompasses the Phaeophyta, most of the Chrysophyta and the Oomycetes of the lower fungi. In this treatment of macrobenthic marine algae, it will include only the Chrysophyceae, Xanthophyceae (Tribophyceae), and Phaeophyceae. For comparative purposes, the Heterokonotophyta (Chrysophyceae and Xanthophyceae) will be kept separate from the Heterokontophyta (Phaeophyceae) as was done in the *Marine Algae of California* and in the *Synopsis.*

The Distribution Lists

By utilizing records from Abbott and Hollenberg (1976) and Scagel *et al*., (1989) in combination with data derived from the new Oregon list, it has been possible to prepare two additional lists on the distribution of the taxa. These are presented in Appendices B and C. Appendix B lists taxa that are reported to have distribution limits within Oregon, including those whose ranges extend to the north, to the south, and those that are limited to Oregon. Appendix C lists those taxa with disjunct west-coast distributions skipping Oregon; these are the taxa that occur from north to south along the west coast of North America, but, for reasons discussed below, they have not yet been found in Oregon. In the context of this paper, the term “west coast” refers to the west coast of North America or to the limited region of the Northeast Pacific covered by this paper.

Comparison Tables

Since the data provided by all three Appendices are whole-area and not site-specific information, the methods available for assessing the flora are limited. However, some broad-scale comparisons can be made between Oregon and its neighboring floras. For these comparisons, counts of the taxa in Oregon were derived from the Appendices. However, additional checklists had to be prepared in order to obtain comparable counts of the taxa from Cross Sound, Alaska, to Washington (SE Alaska-Washington) and from California. The new checklists for each of these areas were compiled primarily from Scagel *et al*. (1989). Abbott and Hollenberg (1976), Silva (1979), Stewart (1991), and Phillips and Menez (1988) and from shorter papers in the literature, many of which were used for the Oregon checklist. In order to be certain that the taxon names were comparable between areas, a spreadsheet was prepared correlating the names and distributions of all taxa in the three regions. Since the lists (and counts) were limited to multicellular algae, unicellular algae were excluded except for the tide-pool species of *Tetraselmis* capable of making pseudofilaments and the endophytic genus *Halochlorococcum*, which, in the past, has been grouped with species now known to be stages in the life histories of multicellular algae. The crustose alternate phases of a few red and brown algae were also included in order to illustrate the fact that they have not yet been reported from Oregon. All of the lists were also adjusted to include all taxa-of-lowest-rank (species, subspecies, varieties, and formas). Since the genetic distance between species in the algae is highly variable, this seemed to be the most logical approach to use. However, this did increase the taxon counts for SE Alaska-Washington by 16, for Oregon by 12, for California by 21, and for the overall area by 25, adding some additional weight to the richer floras.

RESULTS AND PRELIMINARY ASSESSMENT OF THE FLORA

The new checklist of Oregon's macrobenthic marine algae and seagrasses includes a total of 387 taxa, including all taxa of lowest rank. Of these taxa, 50 or 13 percent are new records to Oregon since Phinney (1977) and 90 or 23 percent have new names, making a total of 140 taxa different from the initial list and an overall change of 36 percent in the recorded flora.

Floristic Affinities

The reported distribution of Oregon taxa, extracted from Appendix A and the supplementary checklists and spreadsheet, is shown in Table 1. Of the 387 taxa in the flora, 78 or 20.2 percent have distributional boundaries within Oregon. Of these, only 6 or 1.5 percent are unique to the state. Of the remaining 72 taxa, 42 or 10.9 percent reach their southern limit in this state (occurring from Oregon and north) and 30 or 7.8 percent reach their northern limit (occurring from Oregon and south). The names of these northern, southern, and unique taxa are listed in Appendix B. Table 1 also shows that 96 west-coast taxa are reported to have distributions that skip Oregon. These taxa, possibly overlooked in Oregon, are listed in Appendix C and discussed more thoroughly in the section on “Lack of Study” below.

DISTRIBUTION OF TAXA	# TAXA	% TOTAL
Oregon only	6	1.5
Oregon and North	42	10.9
Oregon and South	30	7.8
North to South through Oregon	309	79.8
Total Oregon Taxa	**387**	**100.0**
North and South skipping Oregon	96	--

Table 1. Distributional ranges of west-coast taxa in relation to Oregon.

From the data provided above, it can be seen that the affinity of the Oregon flora is slightly closer to the flora of SE Alaska-Washington than it is to California. This is illustrated clearly in Table 2 which shows the similarity of the floras using two simple methods of comparison: percentage species (or taxa) overlap and Jaccard’s coefficient of community (Jaccard, 1908; Barbour *et al*., 1980). These analyses can be calculated from the data given in Table 1 by employing the formulae given in the ledgend of Table 2. As would be expected, Oregon has an huge amount of species overlap: 90.7 percent of its taxa also occur in SE Alaska-Washington and 87.6 percent also occur in California. On the other hand, only 57.2 percent of the taxa of SE Alaska-Washington also occur in Oregon, and only 47 percent of California’s taxa also occur in Oregon. In order to factor out these differences caused by the direction of association and by total count differences, Jaccard's coefficient, one of the most widely used methods for analyzing plant community similarity, was determined. Via this method, Oregon and SE Alaska-Washington are related by a coefficient of 54 and Oregon and California by one of 44.

AREAS		*B* SE Alaska-Washington	*B* Oregon	*B* California	Total Taxa
A	**SE Alaska-Washington**	100.0%	57.2%	66.0%	614
A	**Oregon**	90.7%	100.0%	87.6%	387
A	**California**	56.0%	47.0%	100.0%	723
A	**Jaccard's Coef. (for Oregon)**	**54.0**	**100.0**	**44.0**	

Table 2. Similarity of the floras. Percentage taxa overlap is calculated using the formula C/A x 100. Jaccard's coefficient of community is calculated using the formula C/[(A+B)-C] x 100. [A=total taxa in area A; B=total taxa in area B; C=shared taxa of A and B].

Comparisons were also done between the floras of SE Alaska and California. The overlap percentages between these floras are surprisingly high as is the Jaccard coefficient of 44. However, even though the areas are not adjacent to one another, these numbers are strongly influenced by the uniformity of the entire west-coast flora and by the taxa that skip Oregon in their distributions.

Floristic Barriers

Although site data were not compiled for this project, my personal collecting records indicate that the most obvious area for a floristic break in Oregon occurs between Coos Bay-Cape Arago and Heceta Head-Sea Lion Point, just north of Florence. This 88 km (55-mile) stretch of coastline is the longest in the state dominated entirely by sand. In this area, stable habitats for marine algae are rare. The larger and more obvious southern taxa like *Cystoseira osmundaceae* and *Chondracanthus canaliculatus* appear to be restricted to points south of this barrier. However, the southern limits of the northern taxa are less obvious: many, like *Rhodymenia pertusa*, *Dictyosiphon foeniculaceous*, and *Palmaria hecatensis* occur all the way south through Cape Blanco. By far the majority of Oregon's flora, 309 taxa, extend throughout the state from the north to the south. If Oregon is considered to have a floristic break between Florence and Coos Bay, it is only a minor one. The transition of species is mostly a gradual change as predicted by Scagel (1963) for the Northeast Pacific north of Point Conception. However, additional specimen data are necessary to verify this conclusion.

Species Richness

The total counts for taxa-of-lowest-rank and for genera in Oregon and in the neighboring areas of SE Alaska-Washington and California are shown in Table 3. In addition, the counts for the Chlorophyta, Heterokontophyta (Chrysophyceae and Xanthophyceae), Heterokontophyta (Phaeophyceae), Rhodophyta, and Spermatophyta (seagrasses) are listed independently. The total counts of 614 taxa for SE Alaska-Washington and 723 for California indicate that the Northeast Pacific contains a fairly rich algal flora. However, it is immediately apparent that the total count of only 387 taxa for Oregon is very low: Oregon's flora (with 227 fewer taxa) is only 63 percent as rich as the SE Alaska-Washington flora, and (with 336 fewer taxa) it is only 54 percent as rich as the California flora.

AREA	CL	HK-Cr+X	HK-Ph	RD	SP-Sg	TL
SE Alaska-Washington	103 (47)	6 (3)	135 (67)	365 (164)	5 (2)	**614 (283)**
Oregon	62 (27)	2 (1)	85 (52)	233 (107)	5 (2)	**387 (189)**
California	80 (35)	1 (1)	148 (72)	490 (188)	4 (2)	**723 (298)**
Total Area	125 (50)	6 (3)	207 (89)	595 (219)	5 (2)	**938 (363)**

Table 3. Numbers of taxa (of lowest rank) reported to occur in each area. [CL=Chlorophyta, HK=Heterokontophyta, Cr=Chrysophyceae, X=Xanthophyceae, Ph=Phaeophyceae, RD=Rhodophyta, SP=Spermatophyta, Sg=Seagrasses, TL=Total; genera are listed in parentheses]

Why is Oregon's flora so depauperate?

The low number of algal species in Oregon was first pointed out and discussed by Phinney (1977) and then later by other authors. Their explanations are based primarily on the geographic and environmental features of the coast including latitudinal range and temperature, wave exposure, sand domination, and upwelling; and, partly on anthropogenic factors such as pollution and disturbance. In addition, inadequate sampling and study has also been mentioned. The role of each of these factors in limiting diversity (in the sense of species richness) is briefly discussed and evaluated below.

Latitudinal Range--The latitudinal range and span of each of the three floristic areas is shown in Table 4. The Oregon coast spans a much narrower range than either of the neighboring areas and, on this basis alone, could be presumed to have fewer species. However, if species richness increases with latitudinal span, one would expect to get proportionally higher species numbers in the latitudinally wider regions. The fact that this does not occur can be clearly demonstrated by calculating the relative number of taxa/degree of latitude span (*B/A*). The results, shown in the last column, are just the opposite of what would be expected. Latitudinally narrower states have higher counts. This data is heavily influenced by the degree of taxa overlap along the west coast.

AREA	LAT. RANGE	° LAT. SPAN *A*	TOTAL TAXA *B*	TL TAXA/ ° LAT. SPAN *B/A*
SE Alaska-Washington	58° 15' - 41° 15'	**17.0**	614 (283)	36.1 (16.6)
Oregon	46° 17' - 42° 00'	**4.3**	387 (189)	90.0 (44.0)
California	42° 00' - 32° 36'	**9.4**	723 (298)	76.9 (31.7)

Table 4. Latitudinal range and total taxa. [LAT=Latitude; TL=Total; genera are listed in parentheses]

However, it is exceedingly clear that the low species richness in Oregon is not attributable to its narrow latitudinal span.

Temperature-- Temperature is well-known to be the major factor influencing algal distributions (Setchell, 1915; Scagel, 1963; Murray *et al*., 1980; Murray and Littler, 1981; Lüning, 1990; Lüning and Freshwater, 1988). Along the west coast of North America from SE Alaska to Point Conception, the California and Alaska currents combined with coastal upwelling, cause nearshore surface-water temperatures to be fairly uniform, varying only 11° C from north to south along the open coast. South of Point Conception, the Southern California countercurrent warms the surface waters another 7° C. Annual surface-water temperature ranges for the three floristic areas are shown in Table 5.

AREA	T RANGE °C	T SPAN °C *A*	TOTAL TAXA *B*	TL TAXA/ °T SPAN *B/A*
SE Alaska-Washington	4-14	**10**	614 (283)	61.4 (28.3)
Oregon	9-15	**6**	387 (189)	64.5 (31.5)
California	10-21	**11**	723 (298)	65.7 (27.1)
N of Pt Conception	10-15	5		
S of Pt Conception	14-21	7		

Table 5. Temperature range and total taxa. [T=Temperature; TL=Total; genera are listed in parentheses; temperature ranges are derived from ≥30-year averages of mean-monthly, outer-coast, near-shore, surface-water temperatures in each floristic area; see the text for further detail]

These ranges are derived from ≥30-year averages of mean-monthly temperatures reported by Cayun *et al*. (1991) for Alaska, British Columbia, Washington, and California. The Oregon data are from Landry *et al*. (1989). The ranges represent the highest and lowest mean-monthly temperatures of all available outer-coast, near-shore sites in each area. They do not include data from inner harbors or bays where extreme fluctuations in temperature can occur.

When the temperature spans in each area are calculated from the ranges, they can be seen to vary from each other by only 4 or 5° C. When the relative number of taxa/degree of temperature span (*B/A*) is calculated, the resulting numbers for the three floristic areas are surprisingly similar. This suggests a close relationship between temperature span and species richness in this area, and it indicates that the narrow temperature range in Oregon could indeed account, at least partially, for the low number of species.

Although species richness in marine algae does not necessarily increase as one goes southward to more tropical and warmer water (Bolton, 1994), floristic composition does change. Ratios involving counts of Rhodophyta, Phaeophyta, and Chlorophyta have been devised by Feldmann (1937) and Cheney (1977) to show how tropical, temperate, or polar a flora might be. These ratios, modified to incorporate the newer use of the Heterokontophyta for the Phaeophyta, are shown in Table 6 for our west-coast floras. Both ratios indicate that all three floras are temperate in their composition with California being, by far, the most tropical.

FLORISTIC AREA	R/H *	(R+C)/H **
SE Alaska-Washington	2.6	3.3
Oregon	2.7	3.4
California	3.3	3.8

Table 6. The Feldmann* and Cheney** ratios of floristic composition modified to fit the classification scheme of van den Hoek *et al*. (1995) and calculated for the west-coast floras. [R=Rhodophyta, H=Heterokontophyta (Chrysophyceae, Xanthophyceae, and Phaeophyceae), C=Chlorophyta]

Wave Exposure--Some of the low species richness in Oregon has been attributed to the lack of protected, fully saline habitats for sheltered-water species. Sheltered-water habitats are rare in this state. The outer coast is almost entirely exposed to strong wave action. Offshore rocks and subtidal reefs, such as those around Cape Arago, Port Orford, and Brookings, offer only a small amount of protected habitat, as do the leeward areas around headlands and, on a smaller scale, bedrock outcroppings and boulders. Except for the small inlets of Netarts Bay and Whale Cove, sheltered-water bays do not exist unless they are part of an estuary.

Some sheltered habitats for marine algae do occur at the entrances to estuaries. However, the heavy rainfall along the coast (183 centimeters or 72 inches/year in Newport) causes large volumes of fresh-water to flush the estuaries during the winter and early spring. Low-tide salinities of 10-20 ppt are not uncommon, and high turbidity and limited light penetration is the norm. These factors along with heavy siltation and lack of suitable substratum make major portions of the estuaries inhospitable to macrobenthic marine algae.

Even with the scarcity of protected marine habitats, 20 taxa are reported from Oregon that are noted in Abbott and Hollenberg (1976) as occurring only in sheltered water.

These taxa (noted with an “sh” in the checklist) are mostly estuarine and/or ephemeral species that take advantage of the short periods of high salinity in the estuaries. However, several are relatively high salinity taxa that survive in the few quiet water areas along the outer coast. These taxa often have extremely limited ranges (e.g., *Macrocystis integrifolia* occurs only at Simpson's reef at Cape Arago). The lack of appropriate habitat clearly influences the overall abundance of sheltered-water species, but it appears to have little impact on their presence or absence in Oregon.

Sand Domination--The coast of Oregon is 636 kilometers (395 miles) long and consists of a series of rocky headlands interspersed with numerous short and long pocket beaches. According to a recent survey by the Oregon Department of Fish and Wildlife (Fox *et al*., 1994), only 130 kilometers (81 miles) or 20 percent is considered to be "rocky intertidal habitat". The remaining 506 kilometers (314 miles) or 80 percent of the coastline consists almost entirely of sand.

The rocky intertidal habitats that do exist often consist of a mixture of bedrock and cobble intermixed with sand, and the algal species surviving in these areas endure heavy sand scour. Many filamentous and/or delicate species, often epiphytes on coarser marine algae, cannot tolerate these conditions and are rare or absent in these habitats. The detrimental effects of sand scour on the epiphytes of *Neorhodomela larix* were reported by D'Antonio (1986). However, a number of coarser algal species are known to thrive in these conditions. Phinney (1977) lists 34 of these species that are common in sandy areas, and many more could be added to his list.

In addition to sand-scour and increased turbidity due to wave and current action along the coast, the algae that survive in these habitats frequently must also endure sand burial for months. Although sand build-up is temporally and spatially quite variable at specific sites (Trowbridge, pers. comm.), sand transport along the Oregon coast is generally off-shore in the winter during heavy storms and on-shore in the summer when the storms subside, upwelling occurs, and algal growth is often at its maximum (Markham and Celestino, 1976). Phinney (1977) reported a sand build-up of up to 3.6 meters (12 feet) over algal-inhabited rocks at Otter Crest and 2.4 meters (8 feet) at Seal Rock during the late summers of 1974 and 1975. Some of the algae that survive in these heavily sanded habitats have been well-studied. *Ahnfeltiopsis linearis* (Markham and Newroth, 1971), *Phaeostrophion irregulare* (Mathieson, 1982), and *Neorhodomela larix* (D'Antonio, 1986) were reported to have maximum growth in the spring and early summer before burial and then to withstand burial for several months in the late summer and fall. Mathieson found that *Phaeostrophion* could endure 4 to 6 months of burial with little impact on its survival. D'Antonio reports that the plants in these areas profit from the lack of epiphytes and competitors for space and from the lack of large herbivores.

Not all rocky habitats along the coast are influenced by sand, but, in those that are, changes occur in the floristic composition and species richness is reduced.

Upwelling--Along the Oregon coast upwelling is seasonal and sporadic. Generally upwelling episodes begin in early May and extend throughout the summer, ending with the first storms of the fall (Hermann, *et al*., 1989). Downwelling occurs in the winter. Upwelling brings cold nutrient-rich water to the nearshore areas, and phytoplankton blooms are common. Studies of intertidal seaweeds (Fujita *et al*., 1989) have shown that a few species are N-limited in April and May before upwelling begins and that they then appear to take advantage of the replenished nutrient supply. In some areas, however, seaweeds appear to be put at a disadvantage by upwelling. Local enhanced upwelling occurs around many of the headlands along the coast, and, in the adjacent intertidal areas, seaweed diversity and cover can be puzzlingly low. Menge, who is interested in the effects of nutrients on community structure (Menge, 1992), is investigating Strawberry Hill and Bob Creek where sessile invertebrates (mussels, barnacles, tunicates, and sponges) dominate the low intertidal and algal species richness is low at all tide levels. He hypothesizes that the invertebrate larvae and adults, well-nourished by the phytoplankton blooms, preempt seaweeds for space in these areas.

Bolton (1994) in his study of global seaweed diversity reported that major upwelling regions have low diversity because of the erratic and unpredictable environmental conditions. High fluctuations of within and between-year nutrient concentrations and temperature are not optimal for many benthic marine algae, because, along with daylength and irradiance, these factors control their growth and reproduction. One example of the impact of between-year variations can readily be seen along the Oregon coast: El Niño events in this area cause a decrease in upwelling, a corresponding increase in water temperature, and a predictable decrease the size of the off-shore beds of *Nereocystis leutkeana*.

Anthropogenic Factors--Pollution and disturbance have both been suggested as additional factors limiting species richness. These seem unlikely to be significant in Oregon, since the coast is not highly populated and much of it is still pristine. Along the outer coast, strong wave action and currents rapidly mix any non point-source runoff that does occur, and regulations prevent the point-source dumping of untreated wastes. In the estuaries, where pollution should be most noticeable, there are fewer and less diverse industrial sites than in either of the neighboring states. The industries that do exist include marinas, boat-building-and repair shops, fish-processing companies, pulp-and-paper mills, and sewage-treatment plants. These industries have caused some problems, but few studies have been published on them, partially because most appear to have minor long-term effects. Logging is common near the coast and has caused increased siltation in the estuaries, but little of this has been formally documented. Commercial shellfish farming, a clean-water industry, is prominent in the estuaries, and the few pollution studies that have been published have been directed at environmental monitoring in support of this industry; these include papers on the levels and impact of coliform bacteria, heavy metals, and hydrocarbons (benzo(a)pyrene) on clams and oysters (Arnold *et al*., 1992; Caldwell and Buhler, 1983; Mix and Schaffer, 1983). On the whole, the estuaries in this state appear to be relatively clean.

Activities associated with shellfish farming have created one real threat to biodiversity in the Northeast Pacific. Early in this century, due to the failing commercial success of the native oyster, the Pacific oyster, *Crassostrea gigas* Thunberg, was brought in yearly from Japan to use as "seed" for commercial shellfish farms. The importation of these Japanese oysters is thought to have caused the introduction into the estuaries of a number of taxa including *Sargassum muticum* (Scagel, 1956) and *Zostera japonica* (Harrison and Bigley, 1982). Each of these plants was first reported to have occurred in Washington or British Columbia and then to have spread rapidly southward along the coast. *S. muticum* was first noticed in British Columbia before 1940, then it appeared in Coos Bay in 1947, in Humboldt County in 1965, and in San Diego in 1973 (Phinney, 1977). *Z. japonica* is thought to have been introduced in the early part of the century, and at least two introductions are thought to have taken place. The speculated sites are Willapa Bay and northern Puget Sound where the largest beds now occur. In Oregon, *Z. japonica* was first noticed in Coos Bay in the 1940's and in Yaquina Bay only in the 1990's. Carleton and Geller (1993) have recently reported introductions of over 367 taxa of invertebrates and microalgae from ballast water into Coos Bay, Oregon.

Oregonians are "beach people": they love visiting the shore. Recent counts by Oregon Department of Fish and Wildlife showed that 13 million visits to the areas adjacent to rocky shores occurred in 1991-1992 and that each year the counts are increasing (Fox *et al*., 1994). Visitor traffic to the intertidal can also be intense. The affect of trampling on algae and invertebrates in the mid-to-upper intertidal zones was recently studied by Brosnan and Crumrine (1994). They found that trampling damaged the holdfasts and thalli of foliose algae, such as *Mazzaella cornucopiae* and *Mastocarpus papillatus*, and increased their vulnerability to dislodgement by waves. Turf-forming algae, such as *Endocladia muricata*, seemed unaffected and increased in abundance. Hence, trampling lowered the species richness and changed the community structure to one dominated by turf algae rather than foliose forms. In heavily visited areas, this could be a problem. However, since much of the rocky intertidal in Oregon consists of steep cliffs and inaccessible beaches, these areas may serve as refuges for species that are inadvertently eliminated in the popular "marine garden" reserves along the coast.

Lack of Study--Numerous investigators have worked on different aspects of Oregon's macroscopic marine algae. Approximately 200 publications and theses have been produced, mainly by faculty and students at Oregon's three major universities: Oregon State (OSU), Portland State (PSU), and the University of Oregon (UO). Although these papers are too numerous to cite, the main professors and their areas of research can be briefly mentioned. The Gerwick lab at OSU has published extensively on the pharmaceutically useful chemicals from marine algae, particularly the oxylipins. To compliment this research, Rorrer (OSU) has developed methods to commercially cultivate these algae for chemical extraction in bioreactors. Menge and Lubchenco (OSU) and their students have worked on the community ecology, competition, and herbivory of many members of Oregon's intertidal flora. Through detailed developmental studies, Quatrano (OSU, UNC) has made Oregon's *Fucus gardneri* a model alga for the laboratory teaching of developmental biology. Wheeler (OSU), Reuter (PSU), Tocher (PSU), Castenholz (UO), McIntire (OSU), and Phinney (OSU) and/or their students have all published on the physiology of some of the macroscopic marine algae in Oregon, and Kentula (EPA) has worked on the production dynamics of

Zostera marina. Finally, though fewer in number, taxonomic, floristic and life history studies have been done on the seaweeds by Phinney (OSU) and his students and by the authors mentioned earlier in the text.

Of the 200 papers on Oregon's seaweeds summarized above, nearly 100 pertain to the biochemistry of certain algal species, around 60 concern marine algal ecology, about 30 are on physiology and/or developmental biology, and 10 are on the taxonomy, life histories, and distribution of the flora. Of these 10, only 5 are floristic lists and descriptions. With the large amount of related research occurring in Oregon, it is surprising that there are so few floristic studies. The low species richness in Oregon could partially be an artifact of insufficient taxonomic investigation.

In order to examine this problem more closely, I analyzed those taxa that are unknown in Oregon but that are reported from both SE Alaska-Washington and California. These taxa that skip Oregon in their distributions are the species most likely to have been overlooked in this state. Appendix C provides a list of 96 of these species, keyed for features of size and habitat that might make them difficult to find or collect. In order to compare these taxa with the species known in Oregon, the main checklist in Appendix A has also been keyed. The results are shown in Table 7. Two groups of features have been tallied: "Concealing features", including small size, crustose form, and subtidal habitat; and and "limiting features",

FEATURES	OCCURRENCE IN: TAXA PRESENT IN OREGON		TAXA SKIPPING OREGON		RATIO OF % OCCUR-RENCE
	# Taxa	% Total Taxa (A)	# Taxa	% Total Taxa (B)	(B/A)
Concealing features:					
Small thalli	71	18	52	54	3.0
< 0.5 cm (size 1)	48	12	36	37	3.1
> 0.5-2 cm (size 2)	23	6	16	17	2.8
Crustose (c, c+e, c+)	23	6	14	15	2.5
Subtidal (sub)	48	12	32	33	2.8
Total (removing overlap)	**130**	**34**	**76**	**79**	**2.3**
Limiting features:					
"Parasitic" (p)	6	2	3	3	1.5
Epi or endobiotic (ep/ez)	78	20	43	45	2.3
Sheltered water (sh)	20	5	2	2	0.4
Total (removing overlap)	**108**	**28**	**47**	**49**	**1.8**
TOTAL TAXA	**387**	**100**	**96**	**100**	

Table 7. The occurrence of concealing or limiting features in taxa with west-coast distributions present in or skipping Oregon. The data and abbreviations are taken from Appendices A and C.

including parasitic and epi/endobiotic associations and a preference for sheltered water. Since many taxa had several of these features, there was overlap within and between the groups. Therefore, in the total group counts, the overlap was eliminated. The percentage occurrence ratios, shown in the last column, summarize the results.

“Concealing features” were found to be 2.3 to 3.1 times more common in taxa skipping Oregon than they were in the resident flora. Small size and subtidal habitat were particularly prevalent. “Limiting features” were 1.8 times more common in the missing taxa, but the results for the individual features were less uniform. Parasitic and epi/endobiotic associations were 1.5 to 2.3 times more frequent in the missing taxa. Although categorized as limiting (since they often require specific hosts), these associations could also have been considered concealing because many of the taxa are small and hidden on their hosts. Sheltered-water preference was a surprise because it was just the opposite of the other features. It was 2.5 times more common in the Oregon flora than it was in the missing taxa. This further supports the discussion on “Wave exposure” above, but it also demonstrates the fact that sheltered-water species are relatively easy to find and that they have been taxonomically well-studied in Oregon. With this exception, all of the concealing and limiting features investigated have a higher occurrence in taxa skipping Oregon than they do in the resident flora. This strongly suggests that many species have been overlooked in Oregon and that the current low counts could be substantially increased by future surveys and careful taxonomic study.

CONCLUSIONS

Oregon's marine algal flora is still not well understood. Although intermediate in location between the rich floras of SE Alaska-Washington and California, the flora is comparatively depauperate with only a little more than half as many taxa. Part of the reason for the low species richness appears to be the lack of adequate floristic investigation, as shown by the cryptic morphology and habitats of those west-coast species that skip Oregon in their distributions. However, a number of environmental features of the Oregon coast also contribute to the low taxon counts. These include the comparatively narrow temperature range of the near-shore water, heavy sand domination, and sporadic seasonal upwelling. Other factors, such as the narrow latitudinal range, limited sheltered-water habitat, and human disturbance, are secondary in their impact on algal species diversity in this area. A more complete knowledge of the flora is necessary if we are to more accurately assess the impact of all of these factors on marine species richness in Oregon.

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APPENDICES ARE ON WEBPAGE #2