Chapter 9C1. Focal Taxonomic Collections: Marine Plants in Prince William Sound, Alaska

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Background

Several NIS marine plants with potential for invasion of Alaskan waters have been reported on the west coast of North America. For example, the pervasive algae *Sargassum muticum, Lomentaria hakodatensis*, and the Japanese eelgrass *Zostera japonica* are thought to have been introduced with the aquaculture of oysters by the importation of spat from Japan. At least 5 oyster farms occur in Prince William Sound, and all have imported spat. For the herring-roe-on-kelp (HROK) pound fishery, the giant kelp *Macrocystis integrifolia* is transported to Prince William Sound via plane from southeast Alaska (the northern limit of this species) to be used as a substrate for herring roe. Although the giant kelp cannot recruit in Prince William Sound, it seems likely that other species, accidentally co-transported with *Macrocystis*, could become established. Our Pilot Study (Ruiz and Hines 1997) also considered several NIS algal species reported from Alaskan waters, including a report of a cosmopolitan species *Codium fragile tomentasoides* from Green Island.

Methods

Sample Period. Marine benthic algae, seagrasses, and intertidal lichens were sampled as a part of the cruise aboard the F/V Kristina during 20-28 June 1998, described above for invertebrates.

Site Information. A subset of 19 of the 46 sites selected for invertebrate sampling were chosen for the plant study, including 13 intertidal sites (4 within Port Valdez and 9 in Prince William Sound) and 6 off-shore float sites. Site abbreviations (for tables and figures to follow), coordinates, temperature, and salinity are given in Table 9C1.1. Please note that the site numbers in Table 9C1.1 for plants do not correspond to the site numbers on the map (Fig. 9A2) or Table 9A1 for invertebrates. The substratum types, listed for each site, are only those sampled for algae and seagrasses. For analysis and discussion, the 19 plant sites have been grouped into 5 basic habitat types: harbors, mud bays, rocky headlands and reefs, rocky bays, and floats. These will be discussed in greater detail in the Results section below.

Surveying Techniques. At each site, intertidal areas accessible by foot within the time period provided were sampled. Since introduced species could potentially occur in any of the marine plant taxonomic groups, it was important to sample the entire range of species present from as broad an area as possible. Marine algal populations are well-known for being extremely patchy in distribution, caused primarily by narrow species requirements (and tolerances) for substratum, tidal height (exposure), salinity, nutrients, and sunlight. Since the species were patchily distributed, they were encountered and collected sporadically, not uniformly over time. For this study, abundance was noted only when unusually large patches of a particular species were encountered; it was not documented uniformly for entire sites.

Time Allotment. As shown in Table 9C1.s, sampling times at major sites varied from 10 minutes to 2 hours. At low diversity sites, such as Cloudman Bay, the time provided was sufficient for complete algal collection; at other sites, such as Green Island, the time was often

TABLE 9C1.1. General Site Information, 1998 Collections*

ABBR.	DATE	LOCATION	LAT	LON	SUBSTR.	T (ºC)	SAL (0/00)
Port Valdez (Val)							
al-sbr	Jun 20	Alyeska, small boat ramp, Port Valdez	61º 05' 12"N	146º 23' 30"W	br, co	9	0
al-pil	Jun 20	Alyeska, small boat harbor, Port Valdez	61º 05' 10"N	146º 22' 28"W	pi	9	0
sough	Jun 20	Slough, near Alyeska gate, Port Valdez	61º 04' 54"N	146º 19' 00"W	mu	11	0
duckflat	Jun 28	Duckflat, Port Valdez	61º 07' 28"N	146º 18' 00"W	mf	17-22	0-4
Other Harbors							
Cor	Jun 23	Cordova, Orca Inlet	60º 32' 28"N	145º 46' 28"W	dm, mf	10-16	5-28
Whit	Jun 26	Whittier, Passage Canal	60º 46' 25"N	148º 40' 55"W	dm, bo, gr, mu	4-10	8-14
Mud/Cobble Bays							
CB	Jun 21	Cloudman Bay, Bligh I.	60º 50' 11"N	146º 43' 15"W	mu, co	10	3
SMB	Jun 22	Sawmill Bay, Valdez Arm	61º 03' 15"N	146º 47' 24"W	mu, co	8	5
Gro	Jun 27	Growler I.	60º 54' 15"N	147º 07' 48"W	mu, co	22	11
Rk Headlands and Reefs							
RP	Jun 22	Rocky Point, Valdez Arm	60º 57' 36"N	146º 45' 36"W	br, co	11	15
Bus	Jun 21	Busby I., south reef	60º 52' 55"N	146º 46' 29"W	br, co	11	23
Green	Jun 24	Green I., northwest reef	60º 18' 19"N	147º 23' 47"W	bo, br	11	30
Rk Bays							
NW	Jun 25	Northwest Bay, middle arm, Eleanor Island	60º 32' 57"N	147º 34' 48"W	gr, co	12	10-27
Floats and Buoys							
TAT	Jun 22	Tatitlek Narrows, Bligh I.	60º 52' 12"N	146º 43' 48"W	oy	12	26
WBF	Jun 23	Windy Bay, Hawkins I.	60º 33' 54"N	145º 58' 38"W	oy	14	28
MBF	Jun 25	Main Bay	60º 31' 58"N	148º 04' 41"W	bb	14	19-20
EIF	Jun 25	Lake Bay, Esther I.	60º 48' 00"N	148º 05' 24"W	bb	12	16
SBF	Jun 26	Squaw Bay	60º 50' 00"N	147º 49' 20"W	oy	14	24
EBF	Jun 26	Eaglek Bay	60º 51' 00"N	147º 45' 36"W	oy	14	24

Abbreviations:

*= coordinates, temperature, and salinity provided by T. Miller
abbr.=abbreviations
bb=barrier buoy
bo=boulders
br=bedrock
co=cobble
dm=docks/marina
gr=gravel
lat=latitude
lon=longitude
mf=mudflat
mu=mud
oy=oysterfloats
pi=wood pilings
rk=rocky
sal=salinity
subst=substratum
t=temperature

seriously inadequate to sample fully the algal diversity present. Differences among sites in amount of time for collecting were not factored out or corrected after sampling was completed; however, the sites which were judged to be undercollected are designated with an "*" in Table 9C1.2.

TABLE 9C1.2. Collection Efficiency Records

Data Type	Major Collection Sites (without off-shore floats)													
	Val	al-sbr	al-pil	slough	duckflat	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
New Records	5	1	1	1	4	5	2	2	5	4	2	2	6	1
Total Species	47	35	7	7	24	41	56	10	45	63	61	59	71	69
Collection Time	165	40*	10	15	100	120	120	30	45*	105	70*	75*	65*	136

Correlation	R	R^2
Total Species:Time**	0.896	43%
New Records:Time**	0.498	7%

*** = undercollected sites**
**** = both without Val (Total Valdez) included**

Field Sampling & Processing. All algal sampling was done by hand or with a chisel. Collected specimens were then placed in plastic bags for transport back to the boat for processing. On board, the samples were sorted to species and then either pressed in a plant press or preserved in 5% formalin/seawater. Site notes and preliminary species lists were made in the field, and some final identifications were done on board. However, for most species final determinations were not made until returning to the Hatfield Marine Science Center in Newport, Oregon, where compound microscopy was available. The smaller marine algae that require microscopic examination while still alive for identification were necessarily excluded from this study. After identification, both liquid and dried specimens were curated, labeled, and deposited in the herbarium at OSU/HMSC for reference in future Alaskan marine algal studies.

Identifications. Since no marine flora (identification guide) of Prince William Sound exists, the algae collected during this study were identified using a wide variety of literature. For common species, the most important references utilized were Abbott and Hollenberg (1976), Gabrielson et al. (1993), Perestenko (1994), and Sears (1998). For more obscure species, much of the world taxonomic literature on temperate/arctic marine algae was employed. To confirm the identification of particularly difficult or important species, some specimens were sent out to colleagues for identification using molecular techniques. These taxa are designated with a "#" in the species charts. Due to the costs of these tests, these results will not be presented here, but instead will be presented at a later date as part of the papers prepared by these experts.

Distributions, Residency Status, and New Records. In determining if species were introduced, the local and global distributions had to be determined from the literature. Some of the references used for this process were: Scagel et al. (1993), Sears et al.(1998), Selivanova and Zhigadlova (1997), Lee (1980), Guiry (1998), Rueness (1977), Phillips and Menez (1988), Yoshida et al. (1995), Adams (1983, 1994), Womersley (1984, 1987, 1994, 1996), Lindstrom (1977), Hansen et al. (1981), and Hansen (1997). These distributions, summarized in the abbreviated form explained below, are shown under range (Ra) in the first column of the species site lists (Tables 9C1.3 – 9C1.5). The ranges provided the basis for determining the Residency Status (St) of the species. Residency status rankings include the following 5 categories:

- E (Endemic) = species known only from Alaska
- N (Native) = species native to the North Pacific, including species with ranges limited to the northeast Pacific (nep) and those that occur in all other areas around the northern Pacific rim (np).
- C (Cryptogenic) = species with extremely broad distributions that occur circumboreally (cb) and/or extend to the southern hemisphere (ws).
- I? (Introduced?) = species that appear to have been introduced to the area.
- F (Failed Introduction) = deliberately introduced species that have failed to colonize the area

TABLE 9C1.3. Marine and Estuarine Plants Collected in Port Valdez, Alaska

NIS ANALYSIS				TAXA	PORT VALDEZ …………..June 1998 Collections………..					
Ra	**St**	**NR**	**So**		**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Total Checklist**
RHODOPHYTA, Rhodophyceae										
ws	C			*Ahnfeltia fastigiata*						O
nep	N			*Ahnfeltiopsis gigartinoides*						O
nep	N			*Antithamnionella pacifica*						O
ws	C			*Audouinella purpurea*						O
ws	C			*Bangia atropurpurea*	X		X			X
nep	N#			*Ceramium gardneri*						O
np	N			*Constantinea subulifera*						O
np	N			*Corallina frondescens*						O
np	N			*Corallina vancouveriensis*						O
np	N			*Cryptonemia borealis*						O
np	N			*Cryptonemia obovata*						O
nep	N			*Cryptosiphonia woodii*	X*	X*				O
cb	C			*Devaleraea ramentacea*	X				X	O
cb	C			*Dumontia contorta*						O
np	N			*Dumontia simplex*						O
nep	N			*Endocladia muricata*						O
ws	C			*Erythrotrichia carnea*						O
np	N			*Gloiopeltis furcata*	X*	X*				O
np,ar	N			*Halosaccion firmum*	X	X				O
np	N			*Halosaccion glandiforme*	X*	X*				O
ws	C			*Hildenbrandia rubra*						O
np	N			*Leachiella pacifica*						O
np	N			*Lithophyllum dispar*						O
nep	N			*Mastocarpus papillatus* complex	X*	X*				O
np	N			*Mastocarpus* cf. *pacificus* ?	X*	X*				X
nep	N			*Mazzaella heterocarpa*						O
np	N			*Mazzaella phyllocarpa*	X	X				X
nep	N			*Mazzaella splendens*						O
nep	N			*Microcladia borealis*						O
ws	C			*Nemalion helminthoides*						O
np	N			*Neorhodomela aculeata*	X	X				O
np	N			*Neorhodomela larix*	X	X				O
np	N			*Neorhodomela oregona*	X*	X*				O
nep	N			*Odonthalia floccosa*						O
np	N			*Odonthalia kamtschatica*						O
np	N			*Odonthalia setacea* (drift?)						O
nep	N			*Palmaria hecatensis*	X*	X*				O
cb	C			*Palmaria mollis/palmata*						O
np	N			*Phycodrys riggii*						O
ws	C			*Polysiphonia brodiaei*						O
nep	N			*Polysiphonia hendryi* v. *deliquescens*	X	X				O
nep	N			*Polysiphonia hendryi* v. *hendryi*						O
nep	N			*Polysiphonia hendryi* v. *luxurians*						O
nep	N			*Polysiphonia pacifica* v. *pacifica*						O
nep	N			*Porphyra cuneiformis*						O
nep	N			*Porphyra mumfordii*						O
np	N			*Porphyra perforata*						O
cb	C#	NR	NAT	*Porphyra purpureo-violacea ?*						O

Table 9C1.3. continued

nep	N	NR	Wa	*Porphyra rediviva*	X*				X*	X
np	N			*Pterosiphonia bipinnata*	X*	X*				O
np	N			*Ptilota filicina*						O
cb	C			*Ptilota serrata* (incl. *pectinata*)						O
cb	C			*Rhodomela lycopodioides*						O
cb	C			*Scagelia americana*						O
np	N			*Tokidadendron kurilensis*	X	X				O
nep	N			*Weeksia coccinea*	X*	X*				X
HETEROKONTOPHYTA, Phaeophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Agarum clathratum (cribrosum)*						O
cb	C			*Chordaria flagelliformis*	Xun				X un	O
np	N			*Chordaria gracilis*						O
cb	C			*Coilodesme bulligera*						O
np	N			*Costaria costata*						O
cb	C			*Desmarestia aculeata*						O
cb	C			*Desmarestia viridis*						O
cb	C			*Dictyosiphon foeniculaceus*	X*	X*			X un	O
nep	N			*Ectocarpus parvus*						O
ws	C			*Ectocarpus siliculosus*						O
nep	N			*Elachista lubrica*	X*	X*				O
cb	I ?	NR	NAT	*Fucus cottonii*	X*			X*		X
cb	C			*Fucus gardneri/distichus/evanescens*	X*	X*		X* un	X*	O
cb	C			*Fucus spiralis*	X	X			X	X
np, a	N			*Laminaria "groenlandica"/bongardiana*	X*		X*			O
cb	C			*Laminaria saccharina*	X*		X*		X	O
np	N			*Laminaria yezoensis*	X*		X*			O
ws	C			*Leathesia difformis*						O
cb	C			*Melanosiphon intestinalis*	X	X				O
ws	C			*Petalonia fascia*						O
ws	C			*Pilayella littoralis/washingtonensis*	X*	X*		X	X*	O
ws	C			*Scytosiphon simplicissimus*	X*	X*			X un	O
np	N			*Soranthera ulvoidea*	X*	X*				O
ws	C			*Sphacelaria rigidula*						O
cb	C			*Spongonema tomentosum*						O
HETEROKONTOPHYTA, Xanthophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
ws	C	NR	BC	*Vaucheria longicaulis* (?) mats	X*				X*	X
CHLOROPHYTA, Chlorophyceae					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Acrosiphonia arcta*	X*	X*			X*	O
nep	N			*Acrosiphonia coalita*						O
np	N			*Acrosiphonia saxatilis*						O
cb	C			*Blidingia chadefaudii*						O
ws	C	NR	BC	*Blidingia marginata*	X*		X*		X*	X
ws	C			*Blidingia minima*	X*	X*			X*	O
cb	C			*Blidingia subsalsa*	X*	X*	X*		X*	O
cb	C			*Chaetomorpha capillaris/cannabina*						O
nep	N	NR	Wa	*Chaetomorpha recurva*						O
ws	C			*Cladophora albida*						O
ws	C			*Cladophora sericea*						O
ws	C			*Enteromorpha clathrata*						O
ws	C			*Enteromorpha in compressa*						O
ws	C			*Enteromorpha intestinalis*	X*	X*			X*	O
ws	C			*Enteromorpha linza*						O
ws	C			*Enteromorpha prolifera/torta*	X*	X*		X*	X*	X

Table 9C1.3. continued

Ra	St	NR	So		Val	al-sbr	al-pil	slough	duckflat	Checklist
cb	C			*Gayralia oxyspermum*	X*				X*	X
cb	C	NR	BC	*Halochlorococcum moorei*	X*	X*			X*	X
cb	C			*Kornmannia zostericola* (epiphytic)						O
cb	C			*Monostroma grevillei/arcticum*						O
ws	C			*Rhizoclonium implexum*	X*	X*		X*	X*	O
ws	C			*Rhizoclonium riparium*	X*	X*		X*	X*	O
ws	C			*Rhizoclonium tortuosum*						O
ws	C			*Ulothrix implexa* (non *flacca*)	X*	X*	X*	X?	X*	O
np	C#			*Ulva fenestrata /expansa/lactuca*	X*	X*			X*	O
cb	C			*Ulvaria obscura*	X*	X*			X*	O
ws	C			*Urospora penicilliformis*?	X*	X*				X
SEAGRASSES					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Zostera marina*	X*				X*	O
LICHENS					**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
cb	C			*Verrucaria maura*						O
cb	C			*Verrucaria mucosa*						O
Ra	**St**	**NR**	**So**		**Val**	**al-sbr**	**al-pil**	**slough**	**duckflat**	**Checklist**
TOTALS:				**Species**	**47**	**35**	**7**	**7**	**24**	**112**
				New Records	**5**	**1**	**1**	**1**	**4**	**7**

Abbreviations:

! = abundant or common
= currently being examined with molecular techniques
?= uncertainty of identification
al-sbr=Alyeska boat ramp and vicinity
al-pil=Alyeska small boat harbor pilings
BC=British Columbia
C=cryptogenic
cb=circumboreal
Checklist=total records for Port Valdez including literature and the present study
duckflat=Mudflat east of the town of Valdez
N=native to North Pacific
NAT=North Atlantic
nep= northeast Pacific
np= North Pacific
NR = new record to Alaska
nr = northward range extension within Alaska
O= records from the literature and pilot study
slough=Slough about 1 mile from Alyeska gate
So=Closest source to PWS
Stat=NIS Status (native, cryptogenic, introduced, etc)
un= living unattached
Val=Total records for Port Valdez for the present study
Wa=Washington
ws= widespread, occurring in North Pacific, North Atlantic, and Australia or New Zealand
X*= current record noted with specimen
X= current record noted in the field

TABLE 9C1.4. Marine and Estuarine Plants Collected at Shore* Sites in Prince William Sound**

NIS ANALYSIS				TAXA	HARBORS			MUD BAYS			HEADLANDS AND REEFS			RK BAYS
Ra	St	NR	So		Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
RHODOPHYTA, Rhodophyceae														
ws	C			*Ahnfeltia fastigiata*								X*		X*!
nep	N			*Antithamnionella pacifica*							X*		X*	X*
ws	C			*Antithamnionella spirographidis*		X?	X?							
ws	C			*Audouinella purpurea*		X*							X*	
ws	C			*Bangia atropurpurea*	X	X*	X*							X*
np	N			*Bossiella cretacea*								X*		X*
nep	N			*Bossiella plumosa*									X*	
nep	N			*Callithamnion acutum*										X*
nep	N			*Callithamnion pikeanum* v. *laxum*									X*	
nep	N			*Callithamnion pikeanum* v. *pikeanum*										X*
cb	C#			*Ceramium cimbricum*		X*?				X*?				
nep	I?#	NR	Cal	*Ceramium sinicola?* (on *Codium*)									X*	
nep	N#			*Ceramium gardneri*			X*							
nep	N#			*Ceramium pacificum/washingtonensis*					X*	X*	X*	X*	X*?	X*!
ws	C#			*Ceramium rubrum/kondoi*			X*?						X*	
np	N			*Constantinea subulifera*					X*	X	X*		X*!	X*!
np	N			*Corallina frondescens*							X*	X*	X*	X
np,ch	N			*Corallina officinalis* v. *chilensis*							X*	X*	X*!	
nep	N			*Cryptosiphonia woodii*	X*		X*		X*	X*	X*	X*	X*!	X*
nep	N			*Delesseria decipiens*			X?							
cb	C			*Devaleraea ramentacea*	X		X*			X*				
cb	C			*Dumontia contorta*					X*	X*	X*	X*	X	X*
np	N			*Dumontia simplex*		X								
nep	N			*Endocladia muricata*							X*		X*	
ws	C			*Erythrotrichia carnea*			X*		X*			X*		X*
np	N			*Glioipeltis furcata*	X*	X	X*		X*		X*	X*	X*!	X*!
np,ar	N			*Halosaccion firmum*	X					X*	X?	X?	X?	
np	N			*Halosaccion glandiforme*	X*				X	X*	X	X*	X	X*
np	N			*Leachiella pacifica*			X*					X*	X*	X*
nep	N			*Mastocarpus papillatus* complex	X*					X*				
np	N			*Mastocarpus* cf. *pacificus*	X*	X				X*	X*		X	X*
np	N			*Mazzaella phyllocarpa*	X				X*	X*	X*!	X*	X*!	X!
nep	N			*Mazzaella splendens*			X							
nep	N			*Microcladia borealis*									X	
np	N			*Neorhodomela aculeata*	X		X		X*	X*	X*	X*!	X*!	X!
np	N			*Neorhodomela larix*	X					X*	X*		X*	
np	N			*Neorhodomela oregona*	X*		X*!	X	X*	X*	X	X*!	X*!	X*!
np	N			*Neoptilota asplenioides*						X*	X	X*	X!	X
nep	N			*Odonthalia floccosa*			X!		X		X*!	X*	X*!	X*!
np	N			*Odonthalia setacea* (drift?)			X*							
nep	N			*Opuntiella californica*									X*	
np	N			*Palmaria calophylloides/stenogona*			X		X	X			X**	X*!
nep	N			*Palmaria hecatensis*	X*		X*!			X*	X*			X
cb	C			*Palmaria mollis/palmata*		X*	X!			X*	X	X*	X*	X!
np	N			*Phycodrys riggii*					X	X*	X*			X*

Table 9C1.4. continued

nep	N			*Platythamnion pectinatum*			X?			X?				X*
np	N			*Pleonosporium* cf *vancouverianum*								X*		
nep	N			*Polysiphonia eastwoodae*								X*		
ws	C			*Polysiphonia brodiaei*									X?	
nep	N			*Polysiphonia hendryi* v. *deliquescens*	X				X					
nep	N			*Polysiphonia hendryi* v. *hendryi*								X*	X*	
nep	N			*Polysiphonia pacifica* v. *determinata?*						X*				
nep	N			*Polysiphonia pacifica* v. *pacifica*			X*				X*		X*	X*
np,nz	N	nr	SeA	*Polysiphonia senticulosa*		X*	X*				X*	X*	X*	X*
cb	C			*Polysiphonia stricta (urceolata)*								X*	X*	X*
nep	N			*Porphyra cuneiformis*		X*				X*				X?
cb	C	NR	Com	*Porphyra miniata*						X*				
nep	N			*Porphyra nereocystis*									X*	
nep	N	NR	Wa	*Porphyra rediviva*	X*									
np	N			*Porphyra torta/abbottae*										X*
np	N			*Pterosiphonia bipinnata*	X*	X*	X*			X*	X*	X*	X*	X*!
cb	C			*Ptilota serrata* (incl. *pectinata*)						X*	X*		X*	X*
np,ar	N			*Rhodymenia pertusa*					X		X*	X	X*	X!
cb	C			*Scagelia americana*		X*	X*			X*		X*	X*	X*
nep	N			*Smithora naiadum*								X*		
np	N			*Tokidadendron kurilensis*	X						X*		X*!	X*!
nep	N			*Weeksia coccinea*	X*								X?	X*
HETEROKONTOPHYTA, Phaeophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
np	N#			*Alaria taeniata/angusta/crispa*							X*	X	X	
np	N#			*Alaria tenuifolia/pylaii//membranacea*		X*								
np	N#			*Alaria praelonga/marginata*		X					X*	X*	X*!	
cb	C			*Agarum clathratum (cribrosum)*							X	X*		X*
np	N			*Analipus japonicus*			X		X*		X*	X*	X*	X
cb	C			*Chorda filum*		X*			X*	X*		X		
cb	C			*Chordaria flagelliformis*	Xun		X*!		X*	X*	X*	X*	X*	X*
cb	C			*Coilodesme bulligera*						X*				
ak	E	NR		*Coilodesme* n. sp.									X*	
np,nz	N			*Colpomenia bullosa*						X*				
ws	C			*Colpomenia peregrina*							X*	X*	X*	X*
np	N			*Costaria costata*							X*		X*	
np	N			*Cymanthera triplicata*						X*				
np	N			*Cystoseira geminata*									X*	
cb	C	NR	Com	*Delamarea attenuata*					X*			X*		
cb	C			*Desmarestia aculeata*			X		X	X	X	X*	X	
cb	C			*Desmarestia viridis*					X		X	X*		
cb	C			*Dictyosiphon foeniculaceus*	X*	X*!	X*!	X*	X*	X*	X*	X*	X*	X
ws	C			*Ectocarpus siliculosus*						X?				
cb	C			*Elachista fucicola*		X*	X			X	X*			
nep	N			*Elachista lubrica*	X*					X*				X*
cb	C			*Eudesme virescens*					X*	X*	X*	X*		
cb	I ?	NR	NAT	*Fucus cottonii*	X*			X*	X*	X*				
cb	C			*Fucus gardneri/distichus/evanescens*	X*	X*!	X*!	X	X	X* un	X*	X	X*!	X*
cb	C			*Fucus spiralis*	X			X*	X?	X	X		X!	X!
np,ar	N			*Laminaria "groenlandica"/bongardiana*	X*	X*	X*			X*	X*	X*	X*	X*!
cb	C			*Laminaria saccharina*	X*	X	X*!			X*				X!
np	N			*Laminaria yezoensis*	X*								X*!	X*

Table 9C1.4. continued

					Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
ws	C			*Leathesia difformis*					X		X	X*	X!	X
nep	N			*Leathesia nana*					X*		X*	X*	X*	
nep	F			*Macrocystis integrifolia*										X* drift
cb	C			*Melanosiphon intestinalis*	X		X*!		X*	X*	X*	X*	X*	X*
ws	C			*Pilayella littoralis/washingtonensis*	X*	X*	X*	X*	X*	X*	X	X		X*
ws	C	nr	SeA	*Punctaria latifolia*					X*		X*			
ak	E			*Punctaria lobata*		X*								
cb	C	NR	Jap	*Punctaria plantaginea**		X	X*		X?	X?			X*	
cb	C			*Punctaria tenuissima*										X*
cb	C			*Ralfsia fungiformis*			X*							X*
np	N			*Saundersella simplex*					X*		X*			
ws	C			*Scytosiphon simplicissimus*	X*		X*		X*	X*	X	X*	X*	X*
np	N			*Soranthera ulvoidea*	X*		X*		X?	X*	X	X*	X*	X*
np	N			*Soranthera ulvoidea* f. *difformis*						X*				X*
cb	C			*Sphacelaria racemosa*						X*				X*
ws	C			*Sphacelaria rigidula*						X?		X*	X*	X*
HETEROKONTOPHYTA, Xanthophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
ws	C	NR	BC	*Vaucheria longicaulis* (?)	X*	X*!								
CHLOROPHYTA, Chlorophyceae					**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C			*Acrosiphonia arcta*	X*	X*	X*!		X?	X*	X*	X*	X?	X*
np	N			*Acrosiphonia saxatilis*		X*	X*			X*				
ws	C	NR	BC	*Blidingia marginata*	X*									
ws	C			*Blidingia minima*	X*	X*	X*		X*	X	X*	X*		X*
cb	C			*Blidingia subsalsa*	X*	X*	X*							
cb	C	NR	BC	*Capsosiphon fulvescens*				X*						
ws	C			*Cladophora albida*		X*	X*		X*	X*	X		X*	X*
cb	C			*Cladophora hutchinsiae*		X*								
ws	C			*Cladophora sericea*		X	X*	X	X*	X*	X*	X*	X*	X*!
np	N			*Cladophora stimpsonii*			X*					X*		
nep	N	nr	SeA	*Codium fragile* subsp. *fragile*									X*	
ws	I?#	NR	Wa	*Codium fragile* subsp. *tomentosoides?*									X*	
ws	C			*Enteromorpha intestinalis*	X*	X*	X			X	X		X	X?
ws	C			*Enteromorpha linza*		X*!				X	X*	X*	X	
ws	C			*Enteromorpha prolifera/torta*	X*	X	X*	X*	X*	X				X*
cb	C			*Gayralia oxyspermum*	X*		X?				X?		X*	
cb	C	NR	BC	*Halochlorococcum moorei*	X*	X*								
cb	C			*Kornmannia zostericola* (epiphytic)			X*							
cb	C	NR	NAT	*Kornmannia leptoderma* (epilithic)		X*								
nep	N	NR	Wa	*Monostroma fractum*					X*	X*				
cb	C			*Monostroma grevillei/arcticum*			X?					X?	X*	X*
ws	C			*Percursaria percursa*		X*			X*					
ws	C			*Rhizoclonium implexum*	X*									
ws	C			*Rhizoclonium riparium*	X*									
ws	C			*Rhizoclonium tortuosum*		X*	X*			X*		X*	X	
ws	C			*Ulothrix implexa* (non *flacca*)	X*	X*	X							
ws	C#			*Ulva fenestrata /expansa/lactuca*	X*	X*	X		X*	X*	X*	X*		X*
cb	C			*Ulvaria obscura*	X*		X?			X*	X?			X*
np	N			*Ulvella setchellii*					X*					
ws	C			*Urospora penicilliformis*?	X*		X							

Table 9C1.4. Continued

			Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW
SPERMATOPHYTA, Seagrasses			**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C	*Zostera marina*	X*	X*	X*	X	X*	X		X*		
nep	N	*Phyllospadix scouleri*							X	X*		
nep	N	*Phyllospadix serrulatus*								X		
LICHENS			**Val**	**Cor**	**Whit**	**CB**	**SMB**	**Gro**	**RP**	**Bus**	**Green**	**NW**
cb	C	*Verrucaria maura*			X				X			X
			47	41	56							
TOTALS:		**Species (total =146)**	**47**	**41**	**56**	**10**	**45**	**63**	**61**	**59**	**71**	**69**
		New Records (total =17)	**5**	**5**	**2**	**2**	**5**	**4**	**2**	**2**	**6**	**1**
GROUP TOTALS (with overlap excluded)**:**			**Harbors**			**Mud Bays**			**Headlands**			**Rk Bays**
		Species in Merged Groups	87			78			96			69
		New Records in Merged Groups	8			7			8			1

Abbreviations:

! = abundant or common
= currently being examined with molecular techniques
***=shore sites include both shore and marina sites
?= uncertainty of identification
ak=Alaska
ar=arctic
BC=British Columbia
C=cryptogenic
Cal=California
cb=circumboreal
Ch=Chile
Com=Commander Islands, Russia
Cor=Cordova
drift= dying unattached
E=endemic to Alaska
F=failed introduction
I?=possible introduction
Jap=Japan
N=native to North Pacific
NAT=North Atlantic
nep= northeast Pacific
np=North Pacific
NR = new record to Alaska
nr = northward range extension within Alaska
nz=New Zealand
O=Presence known from the Pilot Study and literature
Ra=Distribution Range
RK=rocky
SEA=Southeast Alaska
So=Closest source to PWS
St=range status (see N, C, E, and I)
un= living unattached
Wa=Washington
ws= widespread, occurring in North Pacific, North Atlantic, and Australia or New Zealand
X*=Presence known from the current study; specimens available
X=Presence known from the current study; no specimen taken

Site Abbreviations and Dates:

Bus=Busby Island south reef, 21 June
CB=Cloudman Bay, East Bleigh I, 21 June
Cor=Cordova, 23 June
Green=Green Island, northwest point, 24 June
Gro=Growler Island, near resort, 27 June
NW=Northwest Bay, Knight Island, 25 June
RP=Rocky Point headland, 22 June
SMB=Saw Mill Bay, 22 June
V-Ck=Port Valdez checklist (all records known)
Val=all Port Valdez collections, June 1998
Whit=Whittier, 26 June

TABLE 9C1.5. Marine Algae Collected from Off-Shore* Floats in Prince William Sound, June 1998**

NIS ANALYSIS				TAXA	Float	FLOATS							Only
Range	Stat	NR	So		Cklist	TAT	WBF	MBF	EIF	SBF	EBF		on floats
CYANOPHYTA, Cyanophyceae													
ws	C			*Calothrix crustacea*	X	X*							**
ws	C			*Rivularia atra*	X	X*							**
RHODOPHYTA, Rhodophyceae													
nep	N			*Antithamnionella pacifica*	X				X*				
cb	I?	NR	SD	*Chroodactylon ramosum*	X	X*							**
nep	N	nr	SeAk	*Polysiphonia senticulosa*	X	X*							
ws	C			*Polysiphonia urceolata*	X	X*							**
cb	C			*Scagelia americana*	X						X*		
HETEROKONTOPHYTA, Phaeophyceae													
nep	N			*Coilodesme californica*	X	X*							**
ak	E	NR		*Coilodesme* n. sp.	X	X*							
np	N			*Cystoseira geminata*	X	X*							
cb	C	NR	Com	*Delamarea attenuata*	X						X*		
nep	N	nr	BC	*Ectocarpus acutus*	X			X*					**
nep	N	nr	BC	*Ectocarpus dimorpha*	X						X*		**
nep	N			*Ectocarpus parvus*	X	X*							**, V-CK
				Ectocarpus sp. (*Acinetospora*?)							X*		
				Giffordia sp.		X*							
np	N			*Laminaria groenlandica*	X					X*			
ws	C			*Laminaria saccharina*	X	X*					X*		
np	N			*Laminaria yezoensis*	X	X*							
cb	C			*Melanosiphon intestinalis*	X	X*							
cb	I?	NR	Jap	*Microspongium globosum*	X						X*		**
ws	C			*Pilayella littoralis*	X			X*					
				Pilayella sp. (elongate intercalary structures)						X*			
cb	C	NR	Jap	*Punctaria plantaginea*	X		X*						
cb	C	nr	SeAk	*Punctaria latifolia* (*Desmotrichum*)	X	X*							
ws	C			*Scytosiphon simplicissima*	X			X*					
CHLOROPHYTA, Chlorophyceae													
ws	C			*Cladophora albida*	X			X*		X*			
ws	C			*Cladophora sericea*	X	X*				X*	X*		
ws	C			*Enteromorpha prolifera/torta*	X	X*							
ws	C			*Percursaria percursa*	X	X*							
				TOTALS:	27	**17**	**1**	**4**	**1**	**4**	**7**		**9**
				New Records	9	**4**	**1**	**1**	**0**	**0**	**3**		**4**

Abbreviations:

*=Specimen available
**=Only on floats in this study
***=Sites accessed by boat
BC=British Columbia
C=cryptogenic
cb=circumboreal
Com=Commander Islands,
Jap=Japan

LJ=LaJolla, California
N=native
nep=northeast Pacific
np=North Pacific
nr=new record from neighboring area
NR=new record from remote area
SeAk=Southeast Alaska
V-Ck=also known from the Valdez Checklist
ws=widespread

Float Sites and Dates (Coord. with JC)
EBF=Eaglek Bay floats, 26 June
EIF=Ester Island float, 25 June
MBF=Main Bay barrier buoy, 25 June
SBF=Squaw Bay float, 26 June
TAT=Oyster floats near Tatilek, 21 & 22 June
WBF=Windy Bay floats, 23 June
Float Cklist=species used in this study

Species were then categorized as to whether they were new distribution records (NR) to the area. These included species that had never before been reported from Prince William Sound (nr) or Alaska (NR). In each of these cases, the closest known records to the area were given as the source (So). Since the new records seemed to be the most likely category in which to find recognizable NIS, they are highlighted in gray throughout the charts and tables.

This preliminary quantification of marine plant species and NIS in Prince William Sound required a number of lengthy, detailed steps. After gathering, identifying, and curating all of the species, site lists had to be prepared and both local and global biogeographic information compiled. Then, with this information in hand, the residency status and new distribution records of each species were determined. Only after all of this was completed could NIS begin to be recognized. Since many of the steps in this process revealed important data that characterized not only NIS but the marine flora in general, this report presents the site lists in their entirety and then summarizes the results for comparative purposes in tables and graphs. Since the results are lengthy, they have been organized into the following 7 major parts that are presented below:

- The Species Lists by Site, including Port Valdez, Shore, and Floats.
- The Total Species Numbers and Composition of the Individual Sites.
- Total Species Numbers and Composition in each Habitat Type.
- Native, Cryptogenic, and Introduced Species and their Taxonomic Composition.
- Native, Cryptogenic, and Introduced Species in the Habitat Types.
- New Species Records and Probable Introductions.
- Comments on the Five Probable Introductions and One Important Failed Introduction.

Results

During our 9-day search for NIS in Port Valdez and Prince William Sound, 489 plant samples were processed (Table 9C1.6). These samples contained 155 different species dominated by the red (Rhodophyceae), brown (Phaeophyceae), and green (Chlorophyceae) algae, in that order. Among these species, 21 were found to be new records to the area, and, of these, at least 5 appear to be introduced. In addition, 70 species were found to be cryptogenic, some of which have suspicious characteristics of NIS.

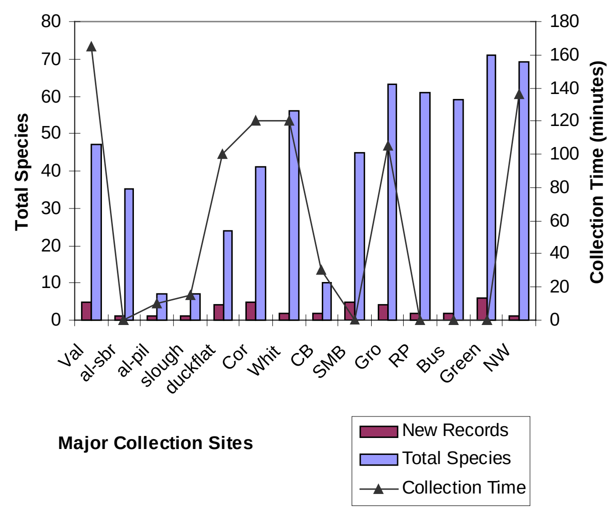
TABLE 9C1.6. Collection Data*

TAXONOMIC GROUP	SAMPLES			TOTAL SPECIES	NEW RECORDS
	Total	Herb.	Form.		
Rhodophyceae	199	135	64	69	5
Phaeophyceae	162	120	42	49	8
Chlorophyceae	117	99	18	30	7
Xanthophyceae	2	2	0	1	1
Seagrasses	7	4	3	3	0
Lichens	0	0	0	1	0
Cyanophyceae	2	1	1	2	0
Total, June 1998	489	361	128	155	21

Abbreviations:
* =Samples and species counts are only for the June 1998 trip.
Herb.=Pressed herbarium sheets
Form.=Bottles of preserved specimens

The total species and new species records/collecting site were correlated with collection time (Fig. 9C1.1). Longer collecting periods yielded more species at an R^2 value of 43%. New records, on the other hand, appear to be almost unaffected by collection time, showing an R^2 of only 7%.

FIG. 9C1.1. Collection Efficiency



The Site Species Lists. Species of marine and estuarine plants identified at all sites sampled during our June 1998 survey are listed in Tables 9C1.3, 9C1.4, and 9C1.5. The plants sampled were predominantly macrobenthic marine algae of the Rhodophyceae, Phaeophyceae, Chlorophyceae, Xanthophyceae, and Cyanophyceae along with several species of seagrasses and marine lichens. Species occurrence at the various sites is designated with an *X* in the lists. If samples were taken and curated for identification purposes, the species are listed with an *X**, indicating that vouchers are available in the OSU/HMSC herbarium for study. In addition, each species is categorized for several biogeographic features that are necessary for the NIS Analysis, explained in the Methods section above.

- <u>Species of Port Valdez.</u> Samples from 4 sampling sites in Port Valdez included 47 algal species and 5 new records (Table 9C1.3). The sites covering the largest areas (the Alyeska small boat ramp and the duckflat) contained the majority of the species. The highest species count occurred at the Alyeska boat ramp where the greatest amount of hard substratum was available for algal settlement. The highest number of new records occurred in the duckflat. A few of these species are good candidates for NIS status. However, their lack of earlier discovery may have an obvious explanation. Mudflats, like the duckflat, are not only notoriously poor habitats for most marine algae, but they can be dangerous in Alaska. Therefore, earlier phycologists avoided many of these areas. Knowing this to be true, it was possible to predict the occurrence of some new records (e.g., *Fucus cottonii* and *Vaucheria longicaulis*) in the mudflats and sloughs. Also shown in Table 9C1.3 is a Checklist of Algal Species for Port Valdez, which includes the species collected from the 1998 sampling, as well as those found previously during the 1997 Pilot Study (Ruiz & Hines, 1997) and the literature (Calvin and Lindstrom, 1980, and Weigers et al., 1997). In addition to our summer sampling, this list includes year-round collections taken by the earlier investigators. The total count for the entire Port Valdez area, including these earlier records, amounts to 112 species.

- Species of Shore Sites. Shore sites include all intertidal areas and marinas sampled during the June 1998 cruise, along with the combined records for Port Valdez (Table 9C1.4). These 10 sites covered a wide range of habitats, which were grouped into 4 major habitat types: Harbors, Mud Bays, Headlands and Reefs, and Rocky Bay (presented in more detail below). The overall species count for all of the shore areas was 146 species with 17 new records. The highest species diversity occurred at Green Island, Northwest Bay, and Growler Island, all of different habitat types; while the highest number of new records occurred at Green Island, Saw Mill Bay, Cordova, and Port Valdez, also a mixture of habitat types. Only two species (*Dictyosiphon foeniculaceus* and *Fucus gardneri*) were found at all shore sites sampled. Four others (*Cladophora sericea*, *Acrosiphonia arcta*, *Pilayella littoralis*, and *Neorhodomela oregona*) were found at all but one site (and were possibly overlooked there). Numerous species (31) were common to all of the habitat types, but there were also an extraordinary number of species that appeared to be limited to only 1 habitat type (17 were found only in harbors, 9 only in mud bays, 19 only on headlands and reefs, and 5 only in rocky bays). Two species restricted to harbors are new records to the area: *Porphyra rediviva*, a newly discovered free-floating marsh plant that could be easily transported by ships, and *Vaucheria longicaulis* , a species unique to high mudflats that is common to many southern west coast harbors. Although not a new record, another interesting harbor species is *Antithamnionella spirographidis*. This species is reported to be common to harbors in British Columbia and is thought to be introduced to that area (Lindstrom in DeWreede 1996). However, its circumboreal and Australian existence leads me to categorize it as cryptogenic in this paper.

- Species from Floats. Marine plants were sampled from five oyster floats and one barrier buoy (MBF) (Table 9C1.5). A total of 27 different algal species were identified from the floats. Of these, 9 were not collected at any of the other sites during our trip. Most of these unique species are small and could have been overlooked in other areas, but several are species that probably could only find suitable habitat on the floats. Over half the 27 species collected are well-known fouling organisms (e.g., *Cladophora sericea*, *Pilayella littoralis*, and *Polysiphonia urceolata*). Nine new species records, the highest habitat number in our survey, were also found on the floats. This may be related to the fact that most of the floats sampled are used in aquaculture, which could be a source of introductions. The highest counts for both species and new records occurred on the floats at Tatitlek Narrows (TAT) and Eaglek Bay (EBF) used in active oyster culture. Two of the new records found at these *sites (Chroodactylon ramosum* and *Microspongium globosum*) and possibly more are thought to be introduced. One species (*Polysiphonia senticulosa*) is considered to be a range extension from southeast Alaska, but it is already widespread in Prince William Sound. This species is presumably native in Washington to Southeast Alaska, and was recently reported to be introduced and pervasive in New Zealand (Nelson and Maggs, 1996).

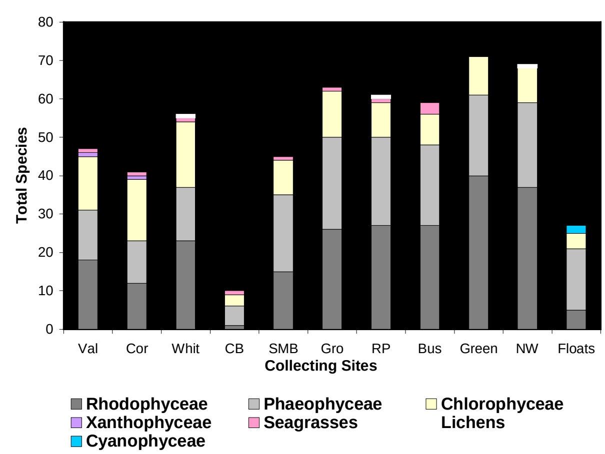
The Total Number of Species and Species Composition of the Individual Sites. The overall number of species was 155 for all sites, but the numbers of species per site ranged from only 10 to 71 species, indicating that there is considerable variation in species composition among habitats (Table 9C1.7, Fig. 9C1.1, 9C1.2). The 21 new records across all areas ranged from 1 to 9 at the individual sites and was highest on floats. The highest species count (71 species) occurred at Green Island, the most exposed and highly saline site. At this site, the proportion of red algal species was nearly 2 times that of the brown algae and 4 times that of the greens. The lowest species count (10 species) occurred at Cloudman Bay, a sheltered, estuarine mud bay. At this site there were almost no red algae, and the brown algae were more abundant than the greens.

Table 9C1.7. Total Species Numbers and Composition at Each Site, June 1998

Taxonomic Group	Val	Cor	Whit	CB	SMB	Gro	RP	Bus	Green	NW	Floats	Total*	V-Total**
Rhodophyceae	18	12	23	1	15	26	27	27	40	37	5	**69**	84
Phaeophyceae	13	11	14	5	20	24	23	21	21	22	16	**49**	52
Chlorophyceae	14	16	17	3	9	12	9	8	10	9	4	**30**	36
Xanthophyceae	1	1	0	0	0	0	0	0	0	0	0	**1**	1
Seagrasses	1	1	1	1	1	1	1	3	0	0	0	**3**	3
Lichens	0	0	1	0	0	0	1	0	0	1	0	**1**	2
Cyanophyceae	0	0	0	0	0	0	0	0	0	0	2	**2**	2
TOTALS	**47**	**41**	**56**	**10**	**45**	**63**	**61**	**59**	**71**	**69**	**27**	**155**	180
NEW RECORDS	**5**	**5**	**2**	**2**	**5**	**4**	**2**	**2**	**6**	**1**	**9**	**21**	23

Abbreviations: Sites as in Table 1; Val=the Port Valdez collections combined; Floats=the float collections combined; Total*=with overlap and earlier collections excluded; V-Total**=Total* with the Port Valdez Checklist species included.

Figure 9C1.2. Total Species Numbers and Composition at each Site, June 1998



Total Species Numbers and Composition in each Habitat Type. Since several sampling sites had mixed habitats, categorizing the sites into distinct habitat types had some weaknesses. However, it increased the number of species sampled for each category of habitat, providing more power to the data analysis (Table 9C1.8, Fig. 9C1.3a, b).

TABLE 9C1.8. Habitat Type and Species Composition

Taxonomic Group	Valdez	Harbors	Mud Bays	Rk Bays	Headlands	Floats	Total
Rhodophyceae	18	37	31	37	48	5	**69**
Phaeophyceae	13	22	31	22	30	16	**49**
Chlorophyceae	14	25	15	9	14	4	**30**
Xanthophyceae	1	1	0	0	0	0	**1**
Seagrasses	1	1	1	0	3	0	**3**
Lichens	0	1	0	1	1	0	**1**
Cyanophyceae	0	0	0	0	0	2	**2**
Total	**47**	**87**	**78**	**69**	**96**	**27**	**155**

Fig 3a. Habitat Type and Species Composition

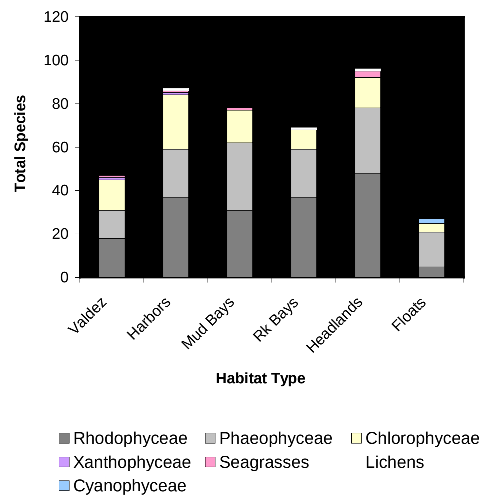
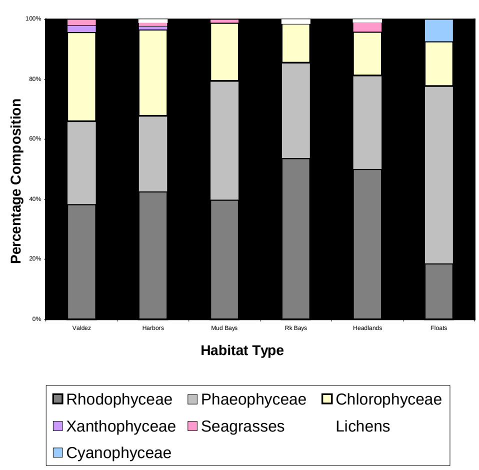


Fig. 3b. Habitat Type and Percentage Composition



The 5 habitat types with their features and included sites are:

- Harbors* (Val, Cor, and Whit). Sheltered areas with variable salinities (0-28 ppt) and variable substrates including mud, cobble, and wood (the pilings). Heavily influenced by boat traffic and other human activities. [* Note that Port Valdez (Val), also included in the Harbor group, is included separately in several of the tables to show the comparable diversity of this targeted site.]
- Mud Bays (CB, SMB, Gro). Sheltered bays with salinity ranges from 3-11 ppt with a substratum of primarily mud, although cobble and bedrock was often available.
- Rocky Bays (RB). One semi-sheltered bay with a salinity ranging from 10-27 ppt and a substratum varying from gravel to cobble to bedrock.
- Headlands and Reefs (RP, Bus, Green). Very exposed habitats with salinity ranges from 15-30 ppt and a substratum consisting almost totally of bedrock and cobble.
- Floats (TAT, WBF, MBF, EIF, SBF, EBF). Exposed to semi-sheltered off-shore habitats. Salinities ranged from 16-28 ppt and substrata included 5 plastic oyster floats and line and 1 cement buoy (MBF).

Headlands and reefs with high exposure and high salinity had the greatest species diversity. As would be expected for temperate zones, they are dominated in descending order by red, brown, and green algae. Surprisingly, the next largest diversity of species occurred in the harbors. Although the red algae also predominated there, harbors had a large number of green algae. In the mud bays and on off-shore floats, there was a tendency for increase in the percentage of brown algae. However, since total species number varies among habitat types, composition of algal groups may be partly an artifact of small number of species at the low diversity sites.

The numbers of new records among the various habitat types were fairly uniform except in rocky bays where the sample size (1 bay) was small (Table 9C1.9). The slight increase in numbers on floats may be significant, but overall, the data indicate that habitat type has little to do with the discovery of new species records.

TABLE 9C1.9. Habitat Type and New Species Records

TAXONOMIC	Valdez (mixed)		Harbors (mixed)		Mud Bays (mud/cob)		Headlands and Reefs		Rk Bays (gravel/cob)		Floats (pvc/ concrete)		Totals*		
GROUP	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	SP	NR	%
Rhodophyceae	18	1	37	2	31	1	48	2	37	1	5	2	**69**	**5**	**7**
Phaeophyceae	13	1	22	2	31	4	30	4	22	0	16	7	**49**	**8**	**16**
Chlorophyceae	14	2	25	3	15	2	14	2	9	0	4	0	**30**	**7**	**23**
Xanthophyceae	1	1	1	1	0	0	0	0	0	0	0	0	**1**	**1**	
Seagrasses	1	0	1	0	1	0	3	0	0	0	0	0	**3**	**0**	
Lichens	0	0	1	0	0	0	1	0	1	0	0	0	**1**	**0**	
Cyanophyceae	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**0**	
Total	47	**5**	87	**8**	78	**7**	96	**8**	69	**1**	27	**9**	**155**	**21**	
% Habitat Total		**11**		**9**		**9**		**8**		**1**		**33**		**14**	
% NR Total (21)		**24**		**38**		**33**		**38**		**5**		**43**		**100**	

* = excludes overlapping records
cob= cobble

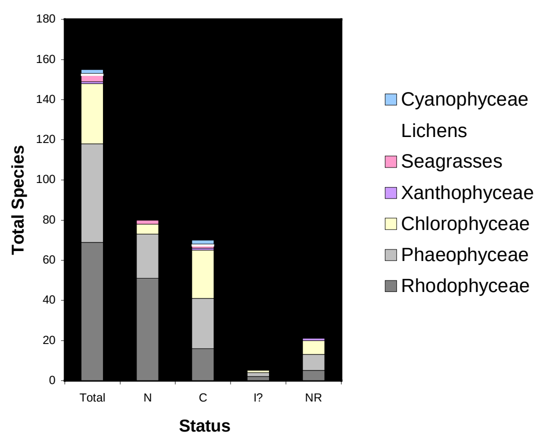
Native, Cryptogenic, and Introduced Species and their Taxonomic Composition. Of the 155 total algal species found, 52% are native, 45% are cryptogenic, and 3% (5 species) appear to be introduced (Table 9C1.10, Fig. 9C1.4). The taxonomic composition of these groups parallels the findings in the Pilot Study survey for Port Valdez. The native species contain a very large percentage of red algae, about 64% of the total. The brown algae make up 27% of the natives, and the greens only 6%. The composition of the cryptogenic forms is almost the reverse. The red algae are only about 23% of the total count, while the browns and the greens both average about 35%.

Table 9C1.10. Native, Cryptogenic, and Introduced Species and their Taxonomic Composition

Taxonomic Group	Total	Status**			NR
		N	C	I?	
Rhodophyceae	69	51	16	2	5
Phaeophyceae	49	22	25	2	8
Chlorophyceae	30	5	24	1	7
Xanthophyceae	1	0	1	0	1
Seagrasses	3	2	1	0	0
Lichens	1	0	1	0	0
Cyanophyceae	2	0	2	0	0
Totals	155	80	70	5	21
% of Total	100	52	45	3	14
NR	21	7	9	5	

** = For simplification, 2 endemics and 1 failed introduction are included with the natives.
N=native, C=cryptogenic, I?=potentially introduced, NR=new records

Fig. 9C1.4. Residency Status and Taxonomic Composition



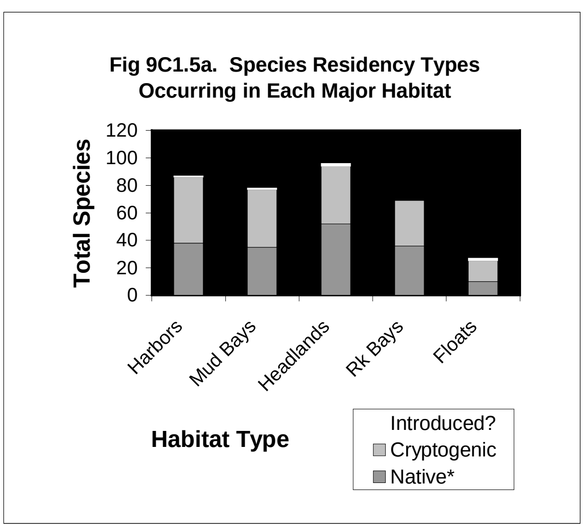
Of the 21 new species records across all habitats, 5 were red algae, 8 brown, 7 green, and 1 was a Xanthophyte (Table 9C1.9), reflecting a fairly uniform distribution of new records across at least the 3 major taxonomic groups. However, the percentage of new species records by group increased dramatically from red to brown to green algae. It is possible that this increase relates, in part, to our overall level of taxonomic understanding in each of these 3 major classes. Since stable morphological features usable in taxonomy decrease as one moves from the red to the brown to the green algae, ease of accurate identification likewise decreases. Hence, it is likely that our knowledge of the Alaskan flora is correspondingly most complete for the reds, then the browns, and lastly the greens.

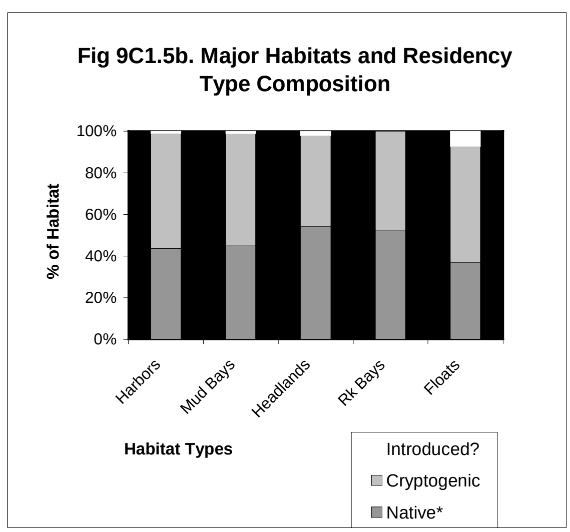
Native, Cryptogenic and Introduced Species by Habitat Types. In all habitat types except the floats, the native and cryptogenic species were fairly evenly distributed and ranged from 44 to 55% of the species (Table 9C1.11, Fig. 9C1.5a, b). However, there were some predictable reversals of dominance. In the harbors and mud bays and on the floats, the cryptogenic species were the most abundant, while on the headlands and reefs and in the rocky bays, the native species predominated. This reversal reflects the confounding effect of variation in groups among habitats (Figs. 9C1.3a, b). Since red algae predominated on the reefs and rocky bays (and green algae are relatively low in numbers), native species, consisting mostly of red algae, were also predominant there. On the other hand, in harbors and mud bays red algae were not as common (and green algae are more abundant); hence the numbers of native species were lower in those habitats. The reefs and rocky bays were under-collected in most cases, weakening the conclusions about algal species in these areas. On floats the cryptogenic forms consisted of 55% of the species while the native species consisted of only 37%. Since most of the floats sampled were from oyster farms, it is likely that they are periodically cleaned. Each cleaning of the floats would provide cleared primary substrata for ephemeral (opportunistic) species that are quick to colonize and reproduce. Since ephemeral species are most often cryptogenic, their higher percentage may be understandable.

Table 9C1.11. The Native, Cryptogenic, and Introduced Species Occurring in Each Major Habitat

Residency Status	Habitat Types					Totals
	Harbors	Mud Bays	Headlands	Rk Bays	Floats	
Native*	38	35	52	36	10	80
Cryptogenic	48	42	42	33	15	70
Introduced?	1	1	2	0	2	5
Totals	87	78	96	69	27	155
New Records	8	7	8	1	9	21

*2 endemics and 1 failed introduction (under rk bay browns) are included in natives.





New Species Records and Probable Introductions. The 21 new species records for the June 1998 trip are the most likely candidates to be NIS; however, several factors should be considered further before the status of the species can be determined definitively (Table 9C1.12). Since all of the new records appeared to have been overlooked for at least some period of time, the obvious questions related to why this oversight occurred are:

TABLE 9C1.12. New Records of Benthic Marine Algae to Prince William Sound
(species overlooked, misidentifications, range extensions, and possible introductions)

Justification	Stat	Taxon	Location	Type	Ra	So	C	Comments
		Rhodophyta, Rhodophyceae						
gi	I?	*Ceramium sinicola*?	Green	Exp	nep	Cal	3	epiphyte, MB in progress
gi, sol	I?	*Chroodactylon ramosum*	TAT	F	cb	S. Cal.	1	microscopic
rex	N	*Polysiphonia senticulosa*	RP, Cor, Whit, Bus, Green, NW, TAT	All ex M	np,nz	SeAk	1	easy to recognize invasive
mid	C	*Porphyra miniata*	Gro	M	cb	Com.	2	MB in progress
mid	N	*Porphyra redidiva*	Val (duckflat)	M	nep	Wa	1	recently described
		Heterokontophyta, Phaeophyceae						
mid	E	*Coilodesme* n. sp.	Green, TAT	Exp, F	ak		1	epiphyte, morph. needed
mid	C	*Delamaraea attenuata*	SMB, Bus, EBF	Exp, F	cb	Com	1	recently illustrated
rex	N	*Ectocarpus acutus*	MBF, EBF	F	nep	BC	1	
rex	N	*Ectocarpus dimorphus*	EBF	F	nep	BC	1	
gi	I?	*Fucus cottonii*	Val (slough), SMB, CB, Gro	M	cb	N. Atl	1	common in marshes MB in progress
gi, sol	I?	*Microspongium globosum*	EBF	F	cb	Jap, N. Atl	1	microscopic
rex	C	*Punctaria latifolia*	TAT, SMB, RP	Exp, F	cb	SeAk	1	
mid	C	*Punctaria plantaginea*	SMB, Cor, Whit, Green, Gro	All ex F	cb	N. Atl.	1	some think cold water form of latifolia
		Heterokontophyta, Xanthophyceae						
sol, rex	C	*Vaucheria longicaulis*?	Val, Cor	M, H	ws	BC	3	reproductive material needed to confirm sp.
		Chlorophyta, Chlorophyceae						
rex	C	*Blidingia marginata*	Val	M	ws	BC	1	
sol, rex	C	*Capsosiphon fulvescens*	CB	M	cb	BC	1	microscopic
rex	N	*Codium fragile** (NE Pacific form)	Green	Exp	nep	SeAk	1	epi=*C. sinicola*?
gi	I?	*Codium fragile* subsp. *tomentosoides*?	Green	Exp	ws	Wa.	2	MB needed for subsp.
sol, rex	C	*Halochlorococcum moorei*	Val, Cor	H	cb	BC	1	microscopic, endophytic
mid, sol	C	*Kornmannia leptoderma* non *zostericola* (epilithic) ?	Cor	H	cb	N. Atl.	2	Culture work needed
mid, sol	N	*Monostroma fractum*	Gro	M	nep	Wa.	2	Culture work needed

Abbreviations: (see earlier charts)

* = Recently also reported in O'Clair *et al.*, 1996, from my earlier EVOS collections
Category=preliminary decisions based on morphological and distributional features and the literature available
ex=except
Exp=exposed cobble
F=on floats
H=harbor, on cobble
gi=geographic isolation
I=likely introduction
ID=identification
M=mud
MB=molecular biological study
mid=earlier misidentification

morph.=morphological studies
rex=range extension
sol=species overlooked
Stat=residency status
Type=habitat type

C=Certainty of Idenfication
1=absolute certainty
2=Morphological identity but additional study (eg, MB or cultures) needed
3=Vegetative morphology similar, but reproductive or MB data needed for positive identification

- Are any of the species taxonomically problematic? Such problematic species often end up in new records lists; and, indeed, several of the new records are problematic species that require further study for positive identification. Investigations are currently in progress for 5 of these species.
- Could the species have been mistaken for other similar species in the past? Species that resemble one another can be confused easily. Often these mistakes are not revealed until a species is newly illustrated or described. In these cases, misidentifications and distributions could easily be corrected with herbarium searches. In the list, at least 6 species fall into this category, including at least 1 undescribed species.
- Has small size or habitat restriction influenced the species discovery? Microscopic species are frequently overlooked as are species from unusual habitats. On the list, 4 species are microscopic, and 1 occurs in the unlikely habitat of a high marsh.
- Is the species new to the area through range extension or through an actual introduction? For marine plants, historical (baseline and fossil) information, geographic isolation, and molecular data are appropriate for proving the latter.

The final justification for categorizing a species of marine plant as introduced (Table 9C1.12) was based on many of these factors, but remains tentative. All 5 species listed as introduced are geographically isolated. Nine other species are northward range extensions from southeast Alaska or British Columbia, and these species are tentatively identified as native. However, these range extensions could be caused by either natural dispersal, possibly caused by El Niño events of the past few years, or they could be introduced with aquaculture transports.

Of the 21 new records, at least 5 are at this time very strongly supported for NIS status based on their geographic isolation, and this is a very conservative estimate. To further confirm the status of these, molecular biological proof of identifications are currently in progress.

Comments on the 5 Probable Introductions and on 1 Important Failed Introduction. Additional description of each of the most probable introduced species and their habitats and distribution are provided below:

Chroodactylon ramosum. *Chroodactylon* is a microscopic primitive red alga that is typically bright bluegreen in color. Its uniseriate, dichotomously branched filaments are unmistakable under the microscope. Although common to the North Atlantic in both Europe and North America, in the Pacific it is only known from Japan, southern Australia, and southern California. Because this alga generally occurs in estuarine or freshwater habitats (Vis and Sheath 1993), its occurrence in the turf algae of the oyster floats at Tatitlek was a surprise, except that it could have been brought in with oysters. The lack of records for this species in the well-worked marine and estuarine environments of British Columbia and Washington indicates that it is truly an isolated population and in all likelihood introduced.

Codium fragile subsp. tomentosoides and the northeast Pacific complex*. The normal range of the native species complex of *Codium fragile* in the northeast Pacific is from Baja California to southeast Alaska. This complex appears to consist of several unnamed subspecies (C. Trowbridge, pers. comm.). Separate from this is an alien subspecies called *tomentosoides* that has been reported to occur in San Francisco Bay. This alien subspecies is differentiated from the native complex by having a different branching frequency and more rounded and mucronate utricle tips. At Green Island, two different subspecies of *Codium* appear to occur. The low intertidal form appears to be identical to the native complex. Its utricle tips are sharply pointed and it is fairly tightly branched. The second form occurs in the mid to upper intertidal and is more loosely branched with very short mucronate tips, nearly identical to subsp. *tomentosoides*. However, experts in the field (Silva and Max) have told me after considerable hesitancy, that neither are truly subsp. *tomentosoides*, and that both fall clearly within the native complex. This indicates that the Green Island *Codium* is probably a range extension or an introduction from southeast Alaska or from Washington, Oregon, or California. Perhaps studies on its epiphyte (discussed below) will enable us to detect its true source. (* Recently O'Clair et al., 1996, also noted that *Codium* occurs on Green Island. This record appears to be based on G.I. Hansen's earlier EVOS project collections, now located in Juneau.)

Ceramium sinicola. This *Ceramium* species was an epiphyte of *Codium fragile* at Green Island. The species, unlike *Ceramium codicola*, does not have bulbous rhizoids. It is completely corticated except for some slightly broken cortication near the tips like in the southern California species *Ceramium sinicola*. The morphology of the plants most closely matches the descriptions of Dawson (1950) and Setchell and Gardner (1924) for *C. sinicola*, and male, female, and tetrasporic specimens have all been observed. Its occurrence in Alaska is extremely unlikely unless it is a recent introduction. This past year I have been working with Mr. Tae Oh Cho, who is monographing the world species of *Ceramium* with both morphological and molecular techniques. He has agreed to look at this material for me and will also look at my Alaskan material of *Ceramium rubrum* which he feels may actually be *C. kondoi*, a Japanese/Korean species, and possibly another introduction to Alaska.

Fucus cottonii. This species is unrecorded for the North Pacific, and yet it occurred in nearly all of the high mudflat/marsh areas visited during the June 1998 cruise of Prince William Sound. The plant was first observed in unpublished notes by G.I. Hansen on Vancouver Island in 1981 and then at several Prince William Sound and Kenai sites during the EVOS studies. In some areas it dominated the supralittoral zone extending even into the terrestrial. At Cloudman Bay it occurred 100 meters away from the bay on stream banks intermixed with mosses and vascular plants. The plants in Alaska are mat-forming and either loose-lying on mud, entangled with other algae (such as *Fucus gardneri*), or intermixed with terrestrial plants. They range from 1-5 cm in height. The blades are dichotomously branched and often terete and only 1-3 mm in diameter. In some habitats, they become flattened, still without a visible midrib, and up to 5 mm in diameter. No receptacles were found during the June trip, but during the EVOS studies G.I. Hansen found a number of plants with relatively small (up to 2 cm long), elongate, somewhat pointed receptacles with conceptacles and oogonia bearing 8 eggs. In some areas, the extent of the mats of this small fucoid makes me question its form of reproduction. Since receptacles are so uncommon, propagation of the mats must be by fragmentation and vegetative growth, an advantageous feature for dispersal.

There is some question as to the use of *Fucus cottonii* (= *F. muscoides*) as a valid species. Fletcher (1987) considers the species as a high marsh ecad of *Fucus vesiculosis*, an Atlantic and Arctic species, but others have accepted *F. cottonii* as a distinct species (Guiry, 1998). To confirm the validity of the species and my designation of the Prince William Sound material, samples are being sent to Esther Serrao in Portugal, who is studying the phylogenetic relationships of the genus with molecular techniques.

Microspongium globosum. This tiny brown alga was found growing epiphytically on *Delamaraea attenuata* on the floats at Tatitlek. The thalli were abundant and bore plurilocular sporangia that clearly match the diagrams for this species in Fletcher (1987). Known only from the North Atlantic and Japan, the species makes a surprising appearance in Alaska. It also has not been reported from the well investigated areas to the south. Its occurrence on the oyster floats at Tatitlek as an epiphyte on another new record to Alaska indicates to me that this species, possibly along with its host, is another new introduction to the area. However, its vector could also have been oysters from Japan.

Macrocystis integrifolia. Since 1979 (Jay Johnson, Alaska Fish and Game, pers com.) *Macrocystis* has been imported (by plane) from southeast Alaska to Prince William Sound to be used as substrate for herring eggs in the lucrative Herring-Roe-On-Kelp (HROK) fishery. Normally only blades and fronds of the giant kelp are transported northward for the fishery. These are then placed in impoundment nets which house both the kelp and the fish. The egg-laden blades are then harvested and sold primarily to Japan as a gourmet food item. Theoretically, the blades that are brought up to the Sound are clean (the most desirable for HROK) and are all harvested for later sale. However, during our June trip and during many of Hansen's earlier trips to the area, blades and holdfasts of the kelp that had escaped were found adrift in Prince William Sound. Perhaps due to the climate, none of these plants appear to have propagated in the area since none have ever been found attached anywhere north of southeast Alaska. Hence, in the site list the species is listed as a failed introduction. However, even with the transport of "eye-clean" blades, it is likely that numerous small algal and animal species are co-transported accidentally from southeast Alaska to Prince William Sound every year with this kelp. This may account, as much as the current El Niño, for many of our new range extensions.

Discussion

During the search for marine plant NIS in Prince William Sound, it was important to characterize the flora at each of the sites so that the probable introduced species and their impacts on the community could be recognized. In addition, information on the taxonomic and residency status composition of these communities was absolutely essential to be able to determine vulnerable sites for future invasions. Although 155 species of plants collected during the 1998 cruise is probably only about half that of the actual flora of Prince William Sound, the data compiled reveal important trends in community composition. In addition, the final lists of new records and probable introductions give valuable insight into the difficulties of recognizing NIS.

Limitations of the data. Although 19 sites were visited during the June 1998 survey, the time allowed for sampling was inadequate at many of the beaches. This had a substantial impact on the overall data. Moreover, the lack of year-round collections for the area limits the results in ways that cannot even be predicted. In terms of numbers, this can be shown clearly by comparing the total count of 112 species shown for Port Valdez in the Checklist (which includes seasonal collections) with the count of 47 for the area obtained during this short trip.

Information derived from additional collections and herbarium specimens from our sites would help to overcome these difficulties and to improve the resolution of the data.

Although temperature and salinity influenced the total species counts for marine algal species, this could not be demonstrated clearly with the data on hand. Prince William Sound has regions heavily effected by rain, snow and ice melt, and marked changes in temperature and salinity occur throughout the year. During summers, salinity is the lowest as runoff produces a freshwater lens on the surface of many of the bays, including Port Valdez and Whittier. In these areas intertidal species are subjected to wide salinity fluctuations with the tidal cycle. Since these physical factors were measured only during the limited sampling periods, they do not reflect the range of conditions encountered over time by the intertidal species sampled.

Limited historical knowledge of the flora and new records. Only two floristic papers on the marine algae (and plants) of Prince William sound have ever been published (Calvin and Lindstrom, 1980; Wiegers et al., 1997). In addition, an overall identification guide to the marine algae does not exist for Prince William Sound or even for Alaska, and we are left with using an assortment of references from neighboring areas to identify species. This lack of both taxonomic information and baseline data for Prince William Sound is clearly evident in the discovery of 21 new records to the area amounting to 13.5% of the species collected during our short 9 day cruise. During our earlier Pilot Study, an additional 3 new records were found in Port Valdez alone. Though fairly evenly distributed among the 3 major taxonomic groups, there were a few more new records among brown and green algae than among the red, and the majority of the species appeared to be cryptogenic. In addition, new record species were slightly more abundant at certain sites. Green Island, the most diverse site in the study, bore 6 new records, while the float sites combined bore 9. Both of these areas (probably along with many others in Prince William Sound) appear to have been understudied in the past. Since, for this study, our probable NIS were derived from the new records, it is understandable that each of these 2 sites (or site types) also bore 2 of the 5 probable NIS designated in the study.

Taxonomic composition. In nearly all temperate outer-coastal habitats, the red algal species are the highest in numbers followed by the brown and then the green algae forming a R>B>G hierarchical pattern of dominance. Proceeding from open coasts into protected bays and estuaries, the ratio changes to reflect a reduction in the number of red algae. For instance, off the coast of Oregon, the R:B:G ratio is 61:22:17. In Prince William Sound, the overall ratio of R:B:G in the species surveyed was 47:33:20, a ratio probably indicating the influence of sheltered and less saline water. However, the overall composition pattern was still R>B>G (Table 9C1.13). The R>B>G dominance pattern in Prince William Sound occurred only at Rocky Headlands and Reefs and in Rocky Bays, all areas of moderate to high water movement (exposure) and relatively uniform salinity and temperature supporting established communities with numerous annuals and perennials. In Harbors, the proportion of green algae increased and the pattern became R>G>B, reflecting the tolerance of green algae for lower salinities found in this habitat. In addition, since many of the green and brown algae are ephemeral (opportunistic), they can survive the wide fluctuations in temperature and salinity. Moreover, since ephemeral forms are often fouling organisms, many are repeatedly brought in to seed these areas by boat traffic. In the mud bays and on the floats, the proportion of brown algae increased. In mud bays, the frequent shifts in mud level smothers many of the species, providing niches primarily for ephemerals and unattached forms. On the oyster floats, the early successional ephemeral forms are also encouraged due to the periodic cleaning of the habitat. The higher and generally more uniform salinity of both of these habitats appears to enable the ephemeral browns to outcompete the ephemeral greens.

Table 9C1.13. Summary of the Hierarchical Composition and Physical Features of each Habitat Type Observed during the June 1998 Survey

Composition	Habitat Types				
	Harbors	**Mud Bays**	**Rk Headlands and Reefs**	**Rk Bays**	**Floats**
Taxonomic*	R>G>B variable	B=R>G variable	R>B>G	R>B>G	B>R>G variable
Residency Status	C>N	C>N	N>C	N>C	C>N
Exposure	low	low	high	low	med-high
Salinity	variable	low-med	high	variable	high
Temperature	variable	variable	uniform	uniform	uniform
Substratum	variable	soft	hard	hard	hard

* = includes only the 3 major taxonomic groups sampled.

Resident type composition. Cryptogenic species predominated in the more disturbed and variable habitats of the Harbors, Mud Bays, and Floats, while the native species predominated in the less disturbed and more uniform habitats provided by Rocky Headlands and Reefs, and Rocky Bays. Cryptogenic algal species appear to contain a high percentage of ephemeral forms. Hence, their ability to survive in fluctuating environments and perhaps in ballast water and on ship bottoms is high.

Introduced species and their impact. The 5 probable plant NIS discovered during our survey are all isolated (and probably young) populations. Although four of these species do not appear to have wide distribution in Prince William Sound, *Fucus cottonii* does appear to have an expanding range. It was found at 4 of our sites and appears to be prevalent in the supra-littoral of all of these areas. Unique to sloughs and the marsh area of mudflats, this species does not seem to be replacing any of the known marine or estuarine species. However, in Cloudman Bay, it may actually be out-competing some terrestrial plants. Fortunately, none of the probable NIS plants found in Prince William Sound appear to be hazardous to the environment. None are as toxic or as invasive as the Mediterranean introduction *Caulerpa taxifolia* (Lemee et al., 1993; Verlaque and Fritayre, 1994).

The transport mechanisms of these introductions is only partially clear. The two species (*Chroodactylon ramosum, Microspongium globosum*) found on oyster floats could have been brought into the area with the transplantation of oysters for aquaculture purposes. The vector for *Codium* and its epiphyte *Ceramium* is more debatable. The subspecies *Codium fragile fragile* was potenitally transported up from southeast Alaska with *Macrocystis* for the HROK industry. But the only method of transport for the subspecies *Codium fragile tomentasoides* would have to be either ballast water or as fouling on the hulls of ships. The importation mechanism of *Fucus cottonii* is even less clear. Its relatively widespread occurrence in Prince William Sound (and in patchy spots along the west coast) indicates that it is probably not a recent introduction. However, since it is a predominantly unattached species, it is also an excellent candidate for transport by ballast water.

Other potential introductions and their significance. What of the other 70 cryptogenic species which are possibly introductions, but which have less obvious characteristics of invasion? These species are, by definition, wide-ranging and many are abundant, often heavily impacting the communities in which they occur. Proof of the NIS status of these prominent species is possible, but it will require detailed comparative morphological study and world-wide molecular biological tracking of their distributions. Furthermore, knowledge of the impacts of these species on community structure will demand complex physiological and ecological studies of the species in both their introduced and native habitats. These studies are important projects for future investigators who are concerned about the conservation of our native biodiversity.

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