The Community Ecology of the Sea Otter, (*Enhydra lutris*) in Checleset Bay, (Ecological Reserve 109).

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SUMMARY

Work conducted in 1987 and 1988 examined the community ecology of sea otters in Checleset Bay (Ecological Reserve 109).

SCUBA surveys of areas with and without sea otters indicated that in areas without sea otters the abundance and distribution of fleshy macrophytes is limited by grazing; urchin and grazer resistant crusts dominate the system. In otter dominated areas macro-invertebrates are absent and fleshy macrophytes are abundant and limited in distribution only by the physical environment.

Eight permanent sites were established along the west coast of Vancouver Island. Four of these sites were established peripheral to the present otter range. Changes in community structure will be monitored as otters move into these sites. The results of otter foraging at one of these sites is reported. Two sites were established within the present sea otter range to monitor the persistence and stability of otter dominated systems. Two sites were established well beyond the sea otters range and will monitor the stability and persistence of benthic communities in the absence of otter foraging.

Sea otter population surveys were conducted to determine the size and geographic extent of the population. Sea otters range from Quineex Reef to Thornton Island in Checleset Bay, and from north of Skuna Bay to Maquinna Point in Nootka Sound. Approximately 205 animals were counted in Checleset Bay and 156 in Nootka Sound.

The sites originally surveyed by Breen et. al. (1982) were resurveyed. Observations indicate that all of the nineteen sites are within the present sea otter range. Urchins are absent from all sites, including the nine sites previously otter free. Community changes observed at these sites are consistent with those inferred by Breen et. al. (1982).

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INTRODUCTION

From 1969 - 1972, 89 sea otters (*Enhydra lutris*) were reintroduced to Checleset Bay, on the west coast of Vancouver Island, after being hunted to near extinction in the previous two centuries. The population has grown to an estimated 350 animals and appears to be expanding southward down the west coast of Vancouver Island.

Sea otters are important predators of marine invertebrates, particularly sea urchins. By reducing the number of major herbivores, sea otters promote the growth of kelp which subsequently affects other invertebrates, fishes and higher trophic animals and moderates onshore wave action.

The effects of sea otters on nearshore communities have been studied to some extent in Alaska (Duggins 1980, Dayton 1975, Estes and Palmisano 1974, Estes et. al. 1978, Simenstad et. al 1978, Van Blaricom 1988, Kvitek and Oliver 1988) and to a lesser degree in California (Estes and Harrold 1988, Laur et. al. 1988, Foster and Schiel 1988). To date four population censuses (Bigg and MacAskie 1978, Farr 1980, MacAskie 1980, MacAskie and Bigg 1987 unpub.) and some early habitat data (Morris et. al. 1979, Stewart et. al. 1982, Breen et. al. 1982) are the only knowledge we have of the B.C. system.

Sea otters have been a source of controversy in many parts of the North East Pacific. Their voracious appetite for shellfish has created a conflict with fisherman, while their appealing nature and recent brush with extinction has endeared them to the public. Increasing interest in translocating sea otters to Hippa Island, Queen Charlotte Islands, and the inevitable expansion of sea otters from southeast Alaska into B.C. make it essential that data regarding the effects of sea otters on nearshore community structure in B.C. be collected

The presence of sea otters in Checleset Bay (Ecological Reserve 109) provides unique research opportunities, significant to both resource managers and academic science. Checleset Bay (Fig. 1) represents an ecosystem exposed to 20 years of sea otter foraging. Adjacent areas recently occupied and regions outside the present otter range present the opportunity to examine the dynamics of an otter dominated system in various stages of development, and to monitor the effects of sea otter foraging on benthic community structure as the population expands into new territory.

To fulfill the need for a quantitative description of this system, the following work was completed:

1.) Subtidal surveys were conducted to document benthic community structure within the otter dominated areas within Checleset Bay Ecological Reserve 109. These quantitative descriptions were compared to similar areas outside of the present otter range.

2.) Eight permanent sites were established along the west coast of Vancouver Island. Four of the sites are peripheral to the present otter range. Changes in community structure will be monitored as otters move into these sites. Two sites were established within the ecological reserve inside the present sea otter range, these sites will be used to monitor the persistence and stability of benthic communities already affected by otter foraging. Two permanent sites established in Barkley Sound beyond the sea otters range will be used to monitor the stability and persistence of benthic communities in the absence of otter foraging.

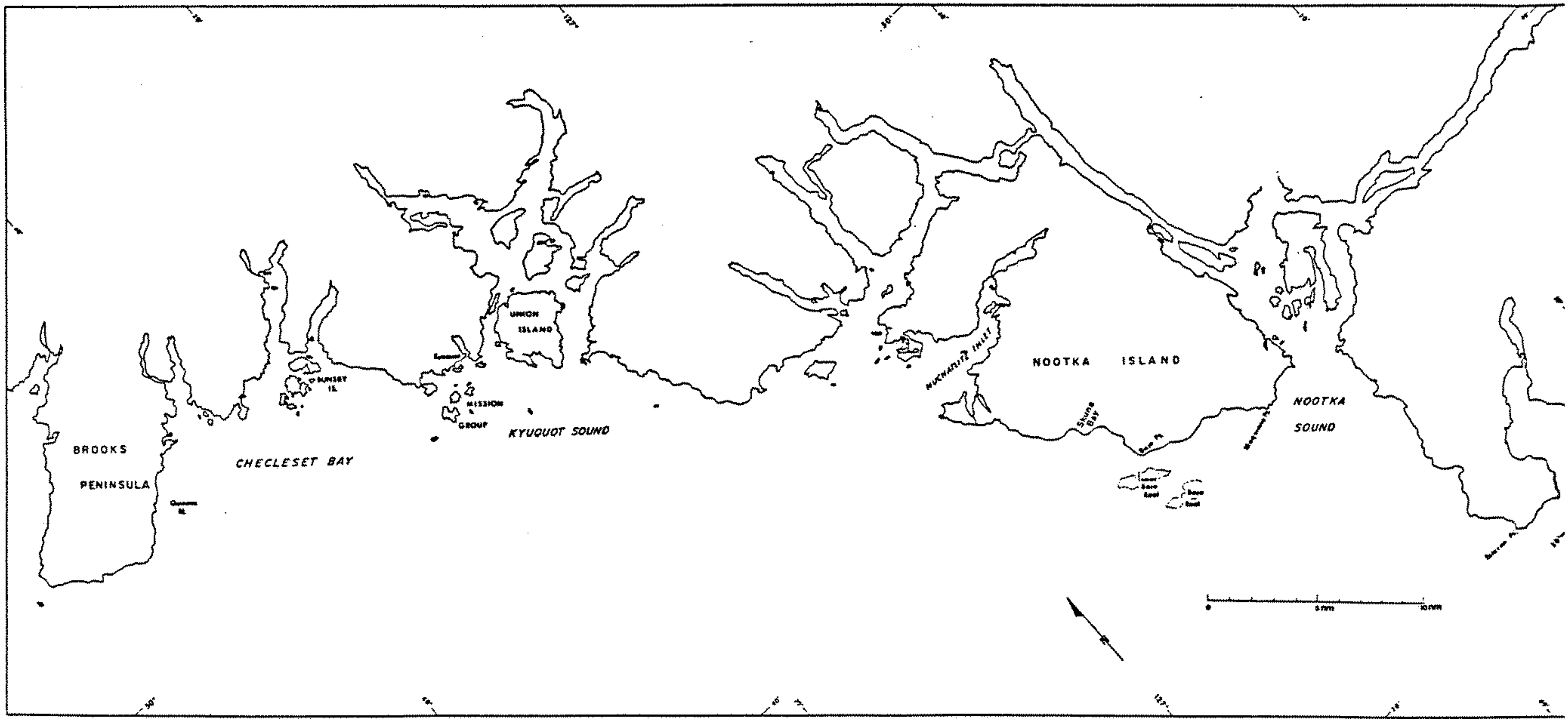


Figure 1. Detailed illustration of the study area.

3.) Sea otters within the Checleset Bay ecological reserve and surrounding area were censused. Particular attention was given to identifying areas dominated by specific groups of otters; females with pups, male groups and adult male territories.

4.) The sites surveyed by Breen et. al. (1982) were resurveyed to document changes in community structure as otters re-occupy these sites.

METHODS

Community surveys

Twenty sites within the area occupied by sea otters were compared to 20 sites located in adjacent areas, unoccupied by sea otters (Fig. 2 and 3). To avoid any bias in the choosing of sites a numbered grid (Fig. 4) was placed over a chart of the study area. Numbers were drawn from a table of random numbers until 20 sites with rock substrate were selected in each area. Twenty quadrats were sampled at each of the 20 sites, so that a total of 400 quadrats were examined in both the otter free and otter dominated areas

Divers worked in depths of 6-8 m. and for each quadrat swam a pre-determined random number of kicks and dropped a 1/2 square metre quadrat to the bottom. All major species of invertebrates and discrete species of algae were enumerated (Table 1).

Sample unit size and sampling effort were based on preliminary work conducted in September 1987. All urchins and abalone within each quadrat were measured in situ . A maximum of 20 quadrats or a minimum of 100 urchins were sampled, whichever was greater.

Fourteen sites in Bamfield, Barkley Sound, were also surveyed

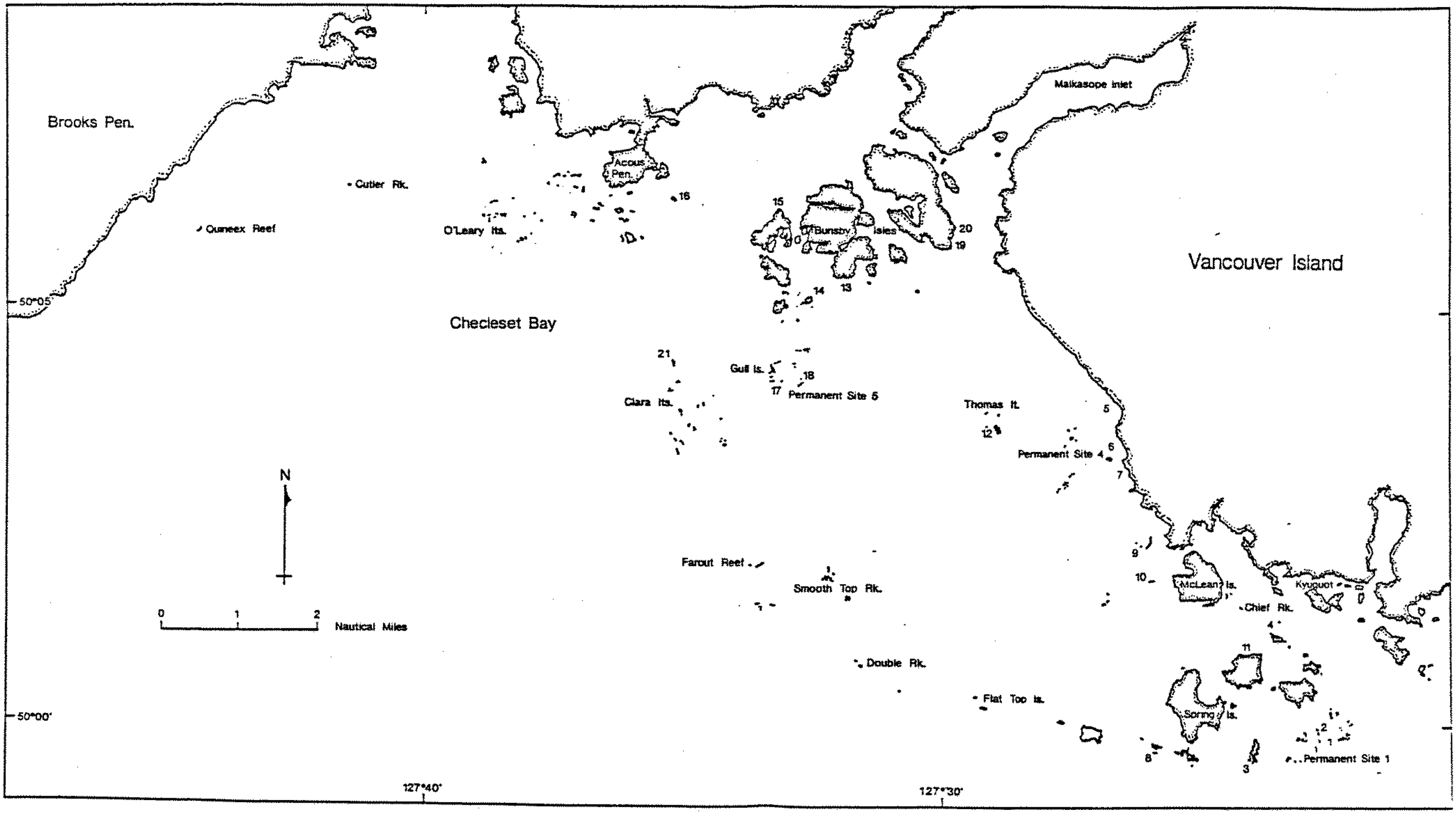


Figure 2. Location of otter dominated community survey sites and Permanent sites.

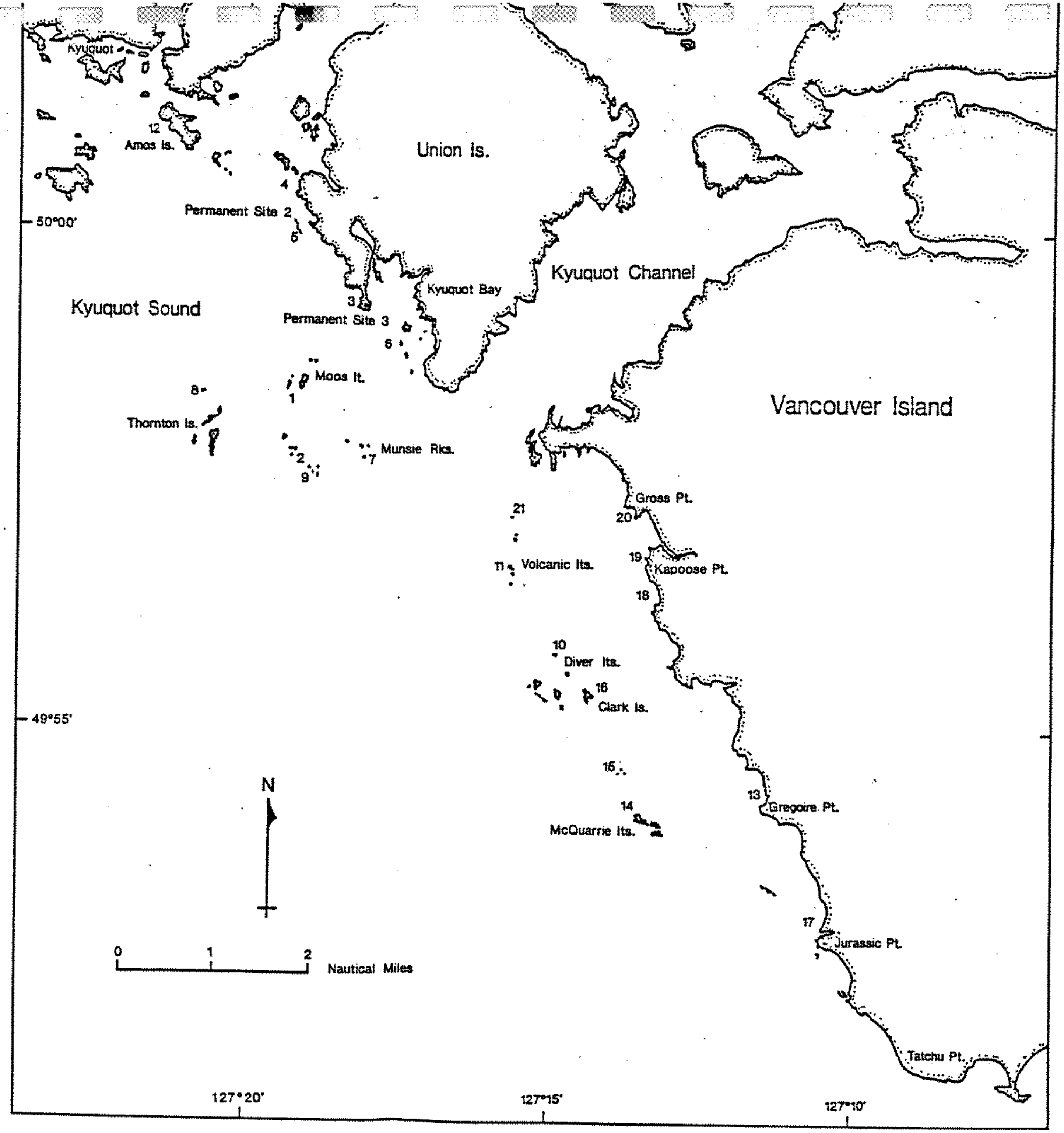


Figure 3. Location of otter free community survey sites and Perman...

SUBTIDAL SURVEY

STATION:____________ SWATHE NUMBER:__________ DATE:________

DIVER:____________ DEPTH:__________ BOTTOM TYPE:________

PLEUROPHYCUS	
NEREOCYSTIS	
MACROCYSTIS	
LAMINARIA SP	
YOUNG LAMIN.	
COSTARIA	
EISENIA	
PTERYGOPHORA	
DESMARESTIA	
ASTREA	
CRYPTOCHITON	
ABALONE	
PYCNOPODIA	
DERMASTERIAS	
HENRICIA	
ORTHASTERIAS	
PISASTER SP.	
PARASTICHOPUS	
S. FRANCISCANUS	
S. DROEBACHIENSIS	
S. PURPURATUS	
FILTER FEEDERS %	
CORALLINE ALGAE %	
RED ALGAE %	

Table 1. Species enumerated in all subtidal work conducted in this study.

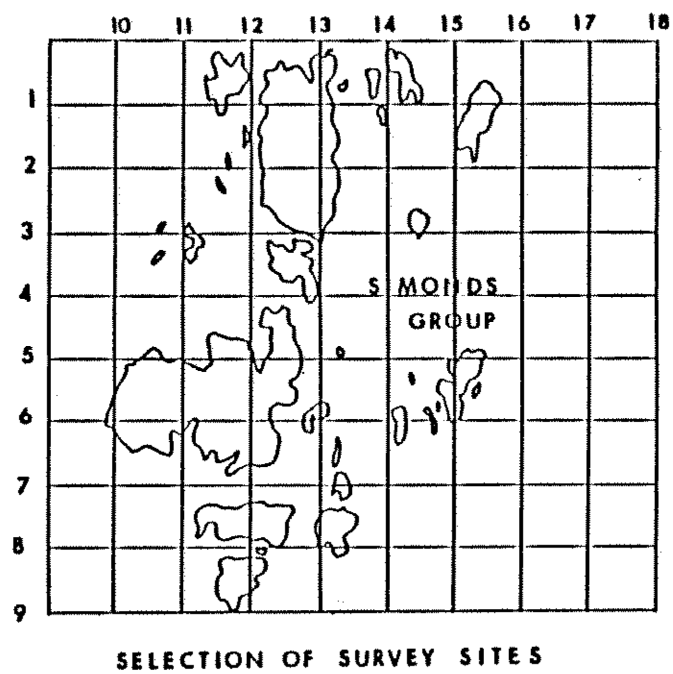


Figure 4. Method of site selection for random community surveys.

to determine if otter free sites in Kyuquot Sound were representative of otter free areas on the west coast of Vancouver Island.

Data analysis

Community data was plotted in histograms comparing mean species abundance at each site. Mean abundance across all sites in each treatment effect were then plotted to determine the differences between otter free and otter dominated areas. Mean values of each treatment effect were then compared in a pairwise fashion to determine if statistical differences occur between areas, and treatment effects.

Size frequency distributions of urchins were plotted cumulatively from all sites. The size frequency distribution of urchins in Kyuquot Sound was compared to that of Barkley Sound.

Permanent Sites

A total of eight permanent sites were established along the west coast of Vancouver Island in 1987 and 1988 (Figs. 2 and 3). Two sites were established in areas presently occupied by otters, within the ecological reserve. Two sites were established in Barkley Sound beyond the existing otter range. Four sites, (three in Checleset Bay, Kyuquot Sound and one in Nootka Sound, Fig. 5) on the edge of the sea otter range will be used to document changes in community structure as otters move into these areas. Sites established within otter dominated areas will monitor the persistence and stability of communities in areas occupied by otters. The two sites in Barkley Sound will monitor the

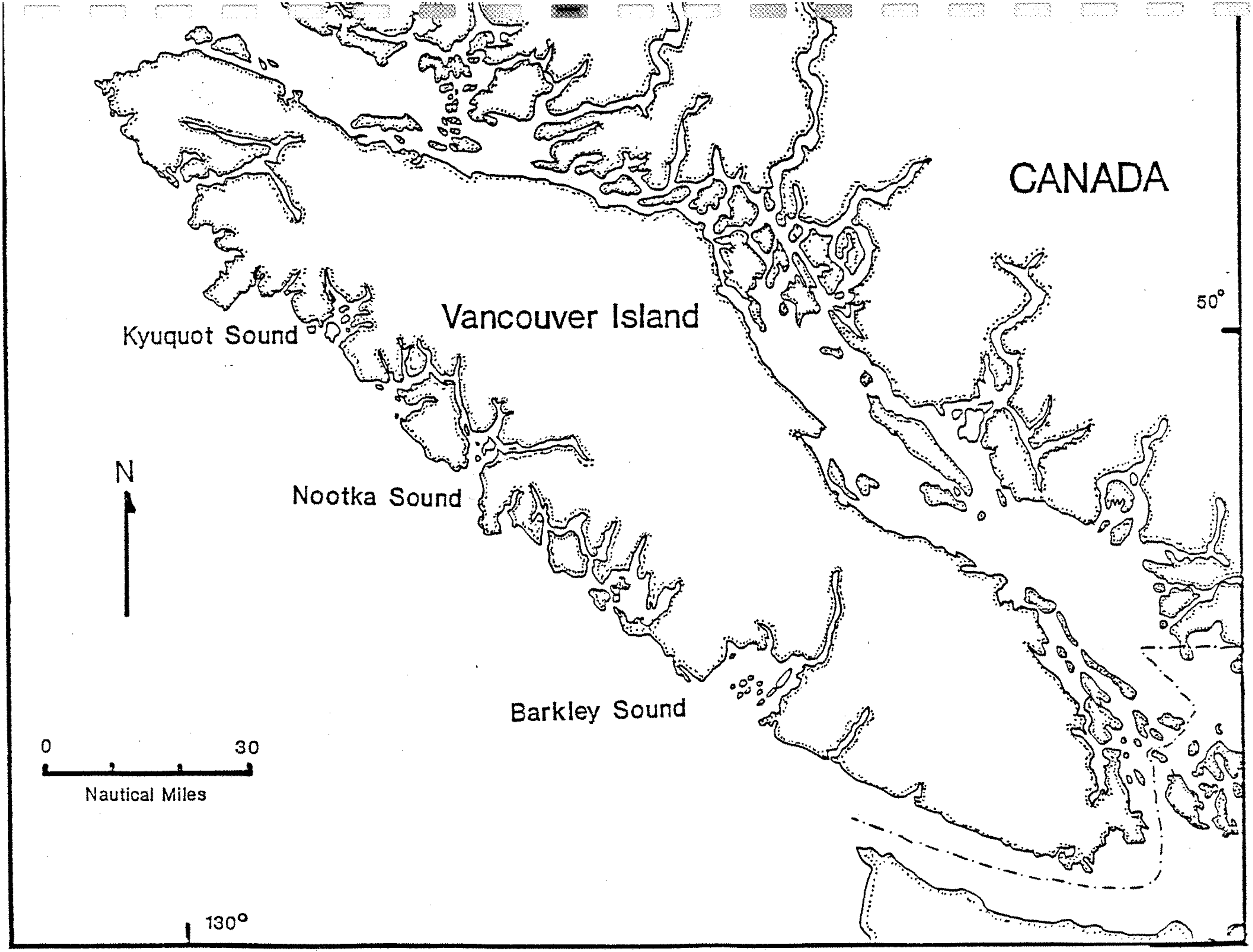


Figure 5. Location of the three areas where permanent sites are located

persistence and stability of communities in the absence of otter foraging. The use of permanent sites, monitored annually, allows the documentation of changes community structure without the confounding influence of spatial variation.

Each permanent site is composed of a 25 m. long central transect with five 10 by 2 m. swathes running perpendicular to the central line (Fig. 6). Stainless steel anchor bolts were placed at 5 m. intervals along the central line. Each of the perpendicular swathes was randomly located on the seaward or shoreward side of the central transect. Each swathe was marked by a stainless steel anchor bolt at each end. Predetermined algal and invertebrate species (Table 1) will be counted annually along each swathe to monitor temporal variability and to document changes resulting from sea otter foraging should any occur in the presently otter free study sites. Perennial algae in the sites occupied by otters were tagged to monitor algal persistence and recruitment.

Data analysis

These data will be analyzed to determine the persistence of otter free and otter dominated benthic communities and document the changes in community structure should presently otter free sites be exposed to otter foraging. The results of this latter analysis will depend upon the natural expansion of the sea otter population . Analyses presented in this report are preliminary.

Sea otter surveys

Sea otter surveys were conducted weekly for eight weeks

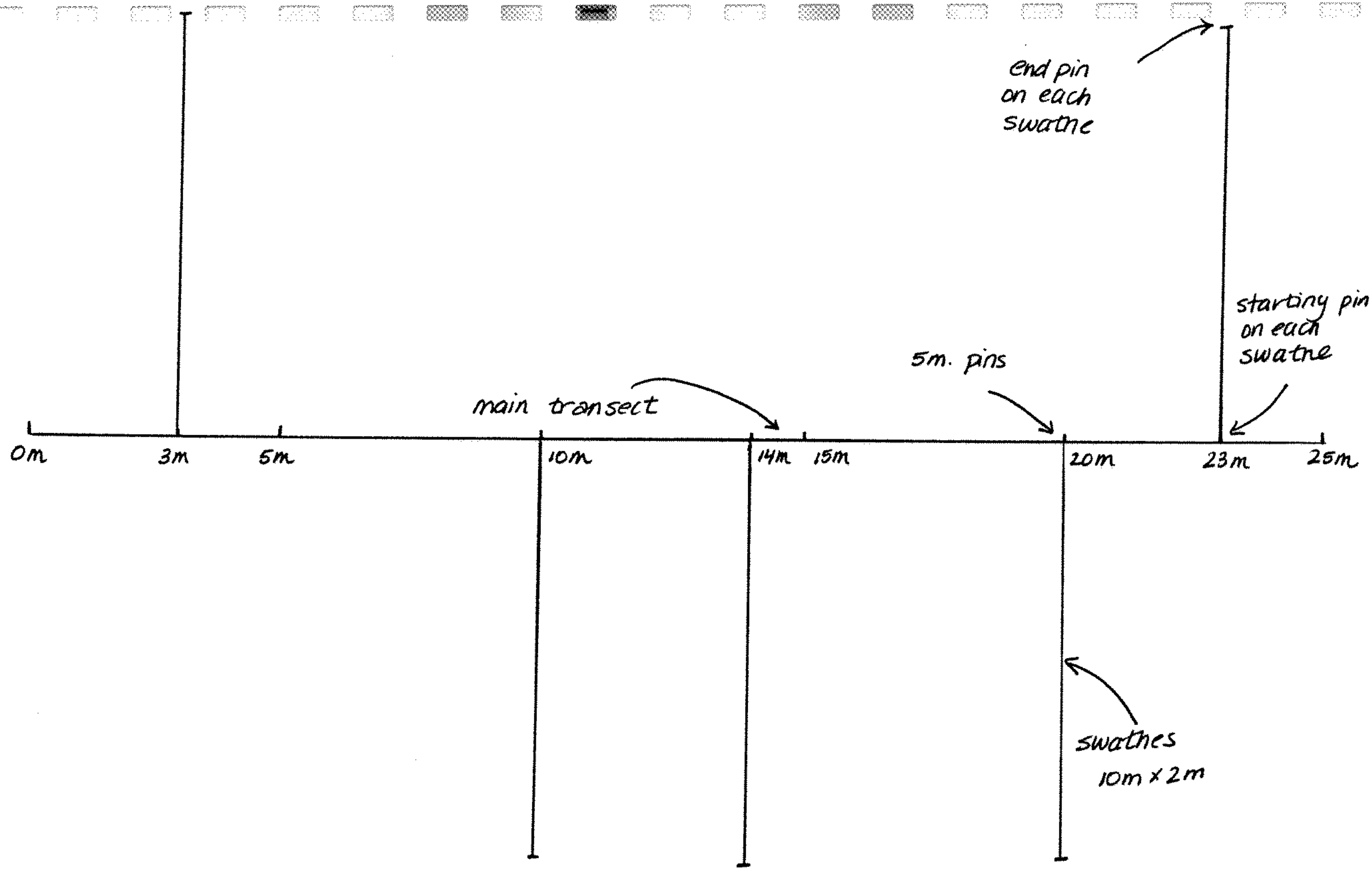


Figure 6. Configuration of the permanent sites.

throughout Checleset Bay. A specified route (Fig. 7), was followed to examine:

1.) The fidelity of otters to certain areas.
2.) Weekly movements of otters.
3.) Determine if animals segregated by age or sex.

Additional surveys were conducted in outlying areas to determine the geographic range of the otters.

To examine daily movements of otters, a double survey was conducted on September 17, 1988. Two boats were used to cover the survey route in both the morning and afternoon.

Surveys were conducted from inflatable boats with one operator and three observers. Otter sightings were recorded on a chart, with mothers and pups recorded separately.

Subtidal surveys of Breen et. al. (1982) sites.

Transects were run parallel to shore at 19 sites surveyed by Breen et. al. during 1979 (Breen et. al. 1982). A tape measure was run from 3.5 to 12.5 m. depth or unstable substrate, which ever occurred first. Where the shallow sublittoral shelf was wider than 50 m. the transects were run without a tape measure, using compass bearings.

At 1.5 m. depth intervals, from 10.8 to 3.0 m., two one half square metre quadrats were placed on the substrate and predetermined species of algae and invertebrates were counted (Table 1).

Data analysis

All data from these community surveys were compiled in

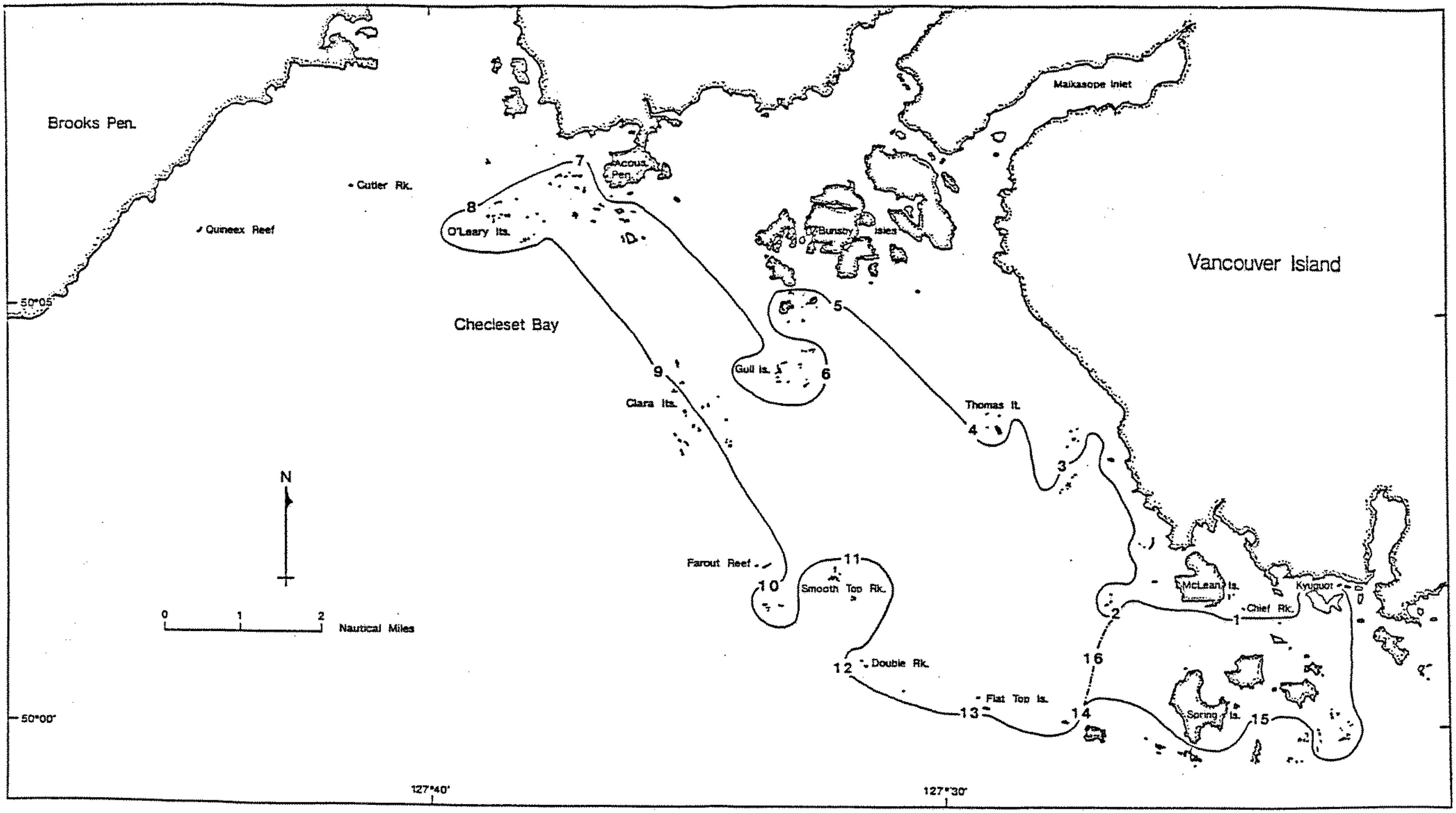


Figure 7. Sea otter survey route. Numbers represent areas of sea otter concentrations.

tabular form and compared to the qualitative observations reported by Breen et. al. 1982. Comparisons were made to determine how benthic community structure had changed at each of the sites, since the 1979 survey. Particular attention was given to sites which have been occupied by otters since 1979.

RESULTS AND DISCUSSION

Community surveys

In pairwise comparisons between areas, S. franciscanus was significantly more abundant at otter free sites than otter dominated sites (Table 2). No significant differences were observed between the two otter free sites. Urchins in all cases were almost absent from otter dominated sites and were very abundant (3.5 - 4.4 per 1/2 sq. m., Fig. 9) at otter free sites. Considerable variability in urchin abundances was observed between sites at both otter free sites (Fig. 8). The source of this variability is unclear, but may be a product of differential recruitment, or survivorship.

Abundance of all species of algae was significantly different between otter free and otter dominated sites (Table 2). No significant difference (Table 2) was found between the otter free sites in Checleset Bay and Bamfield, Barkley Sound.

Pterygophora californica (Fig. 10) and Laminaria spp. (Fig. 11) are stipitate (with a stipe, or stalk), subtidal kelps which form extensive subsurface forests beneath the more visible canopy forming kelps.

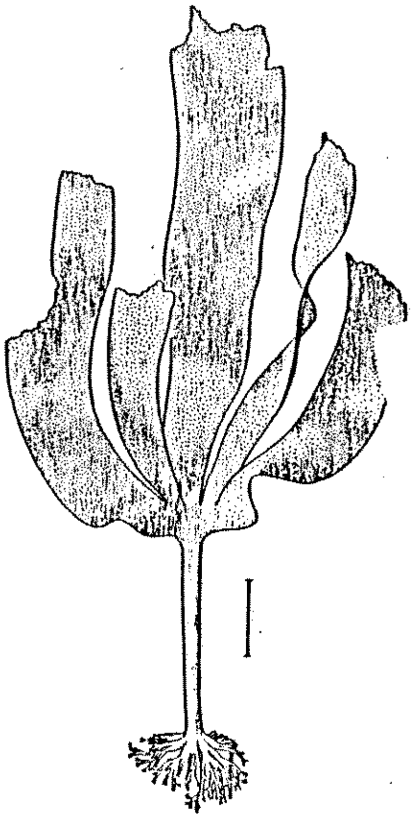
P. californica is the dominant kelp species in all moderately

Table 2. (b): t values for pairwise comparisons between areas. Significance is reported at p = .05.

	Checleset Bay Otter Free/ Checleset Bay Otter Dominated		Checleset Bay Otter Free/ Bamfield Otter Dominated		Bamfield Otter Free/ Checleset Bay Otter Dominated	
	t	Sig.	t	Sig.	t	Sig.
S. franciscanus	8.1	S	1.3	NS	9.1	S
H. kamchatkana	6.3	S	1.3	NS	6.4	S
P. californica	3.8	S	.67	NS	3.8	S
Laminaria spp.	2.6	S	1.4	NS	6.4	S
M. integrifolia	2.1	S	1.3	NS	2.1	S
N. luetkeana	3.1	S	1.3	NS	3.2	S
D. ligulata	2.6	S	1.1	NS	4.9	S
H. leviscula	2.0	NS	NA	NA	NA	NA

Table 2 (a): Mean density and variance per 1/2 sq. m. for selected species at each area.

	Checleset Bay Otter Dominated n=20		Checleset Bay Otter Free n=21		Bamfield Otter Free n=14	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
S. franciscanus	.10	.05	4.40	5.98	3.55	1.99
H. kamchatkana	.73	.98	.80	.01	.16	.02
P. californica	2.08	5.77	.02	.004	.04	.01
Laminaria spp.	1.62	3.17	.38	1.25	.08	.02
M. integrifolia	.85	3.21	.002	.0001	0	0
N. luetkeana	.73	.98	.08	.04	.02	.002
D. ligulata	3.11	6.79	.88	8.11	.21	.09
H. leviscula	.12	.01	.18	.04	0	0



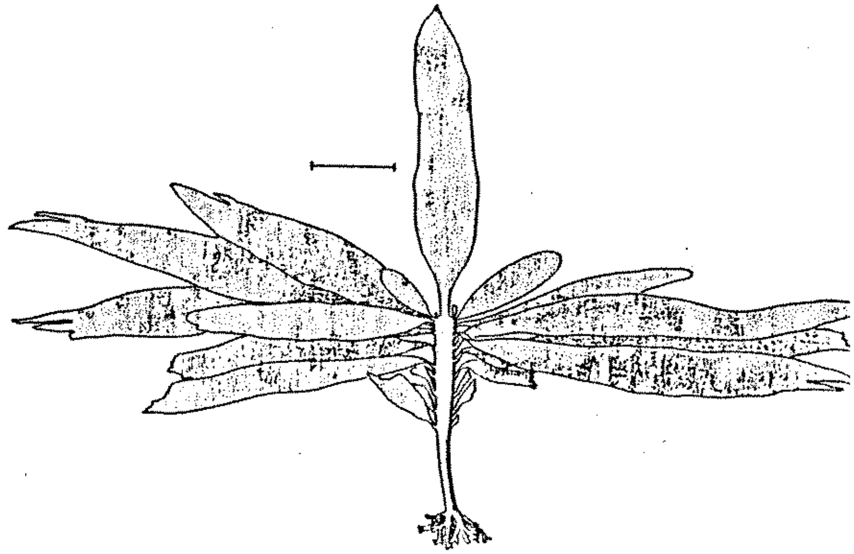


Figure 11. Pterygophora californica

Figure 10. Laminaria spp.

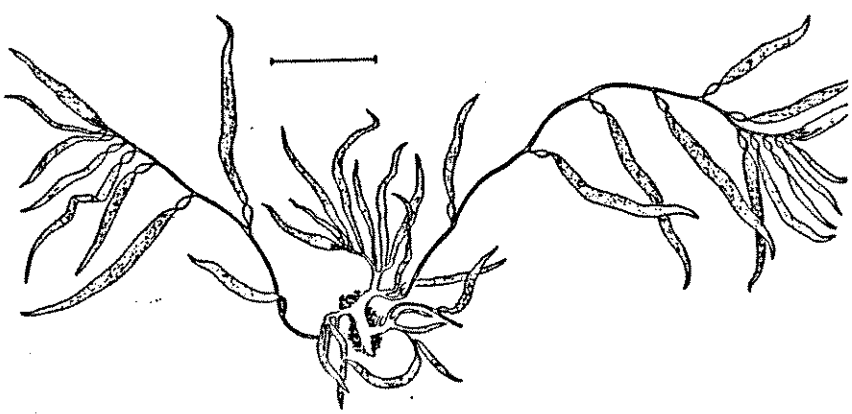


Figure 12. Macrocystis integrifolia

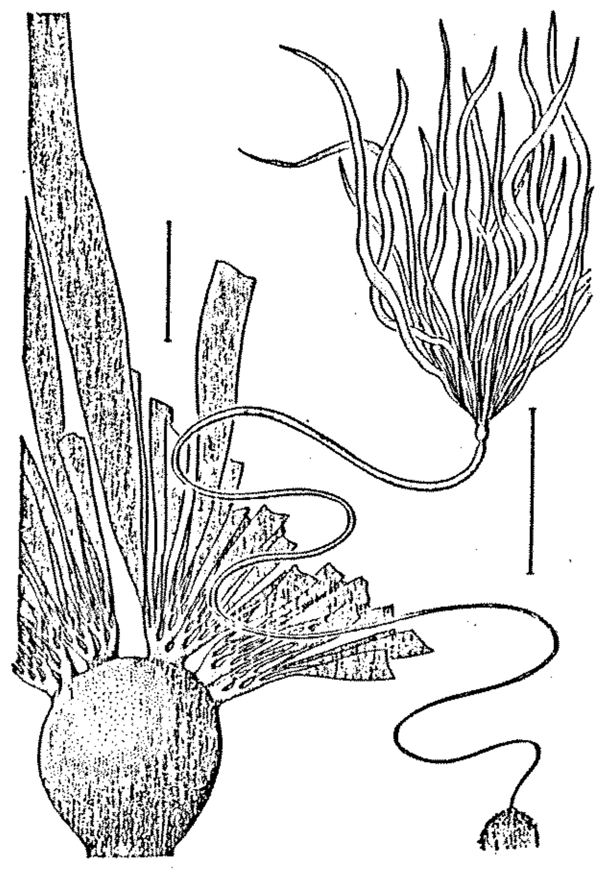


Figure 13. Nereocystis luetkean

exposed "well developed" otter dominated sites, in Checleset Bay (Fig. 14, Fig. 15). A long lived, perennial kelp, P. californica can live up to 24 years (R. Dewreede, pers. comm.). The abundance of P. californica appears to increase with the length of time individual sites have been subjected to otter foraging. Sites nearest the original translocation site (Chekalis Island) have higher abundances of P. californica than more distant, more recently foraged sites. The variability in P. californica abundance between sites, may be a product of the age of the community. In otter free areas, P. californica was restricted to the shallow sublittoral fringe by urchin grazing and was rarely found deeper than 5 m..

Laminaria spp. is characteristic of highly exposed shores, and may well compete for space with P. californica in moderately exposed areas. Laminaria spp. was significantly more abundant in areas with otters than in areas which were otter free, while otter free areas were not significantly different in Laminaria abundance (Table 2, Fig. 17). Variability in Laminaria abundance between sites (Fig. 16) probably reflects environmental gradients (wave exposure) and to some degree, competition for space with P. californica. Laminaria spp. was found down to 7 m. depth in some of the otter free sites, areas where water motion may exclude urchins and decrease grazing pressure. The abundance of Laminaria spp. at otter free sites 8 and 9 in Checleset Bay (Fig. 16) is a result of light otter foraging, undetected at the time of site selection.

Macrocystis integrifolia (Fig. 12) and Nereocystis luetkeana

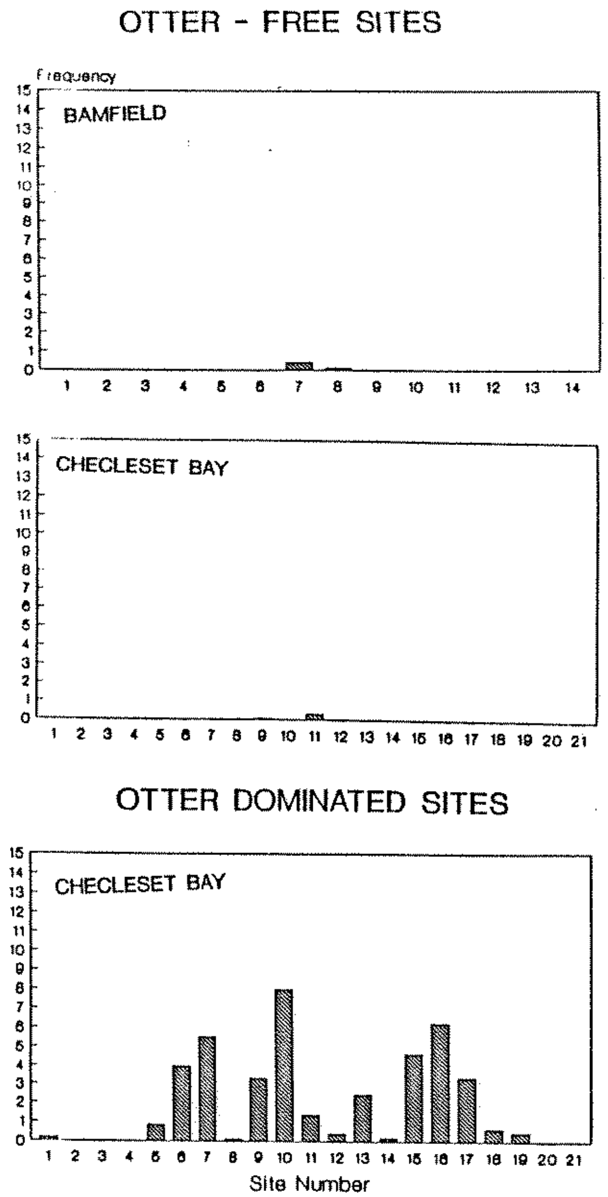


Figure 14. Mean (n=20) abundance of P. californica per 1/2 sq. m. at each site. Sites were sampled in Bamfield, Barkely Sound and Checleset Bay.

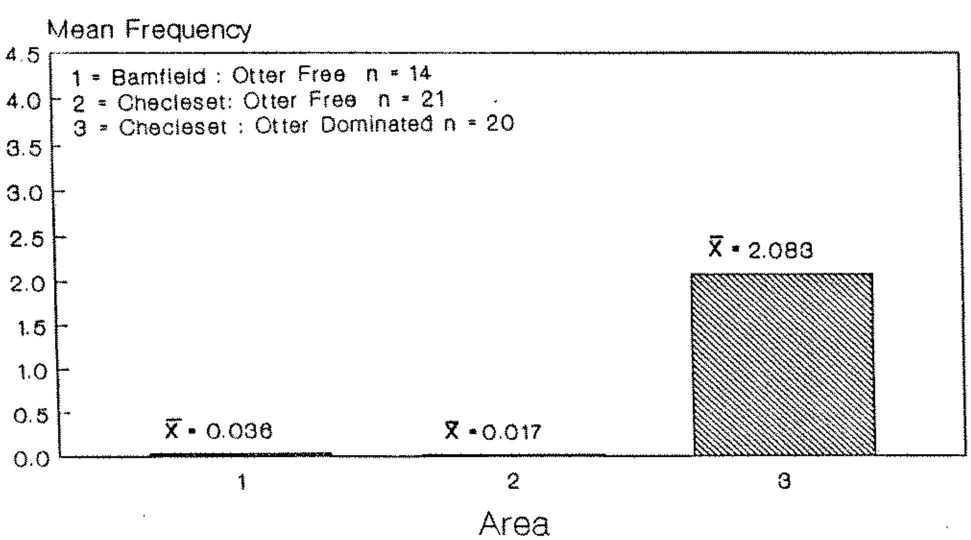


Figure 15.

Mean abundance of P. californica per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site. N = the number of sites sampled in each area

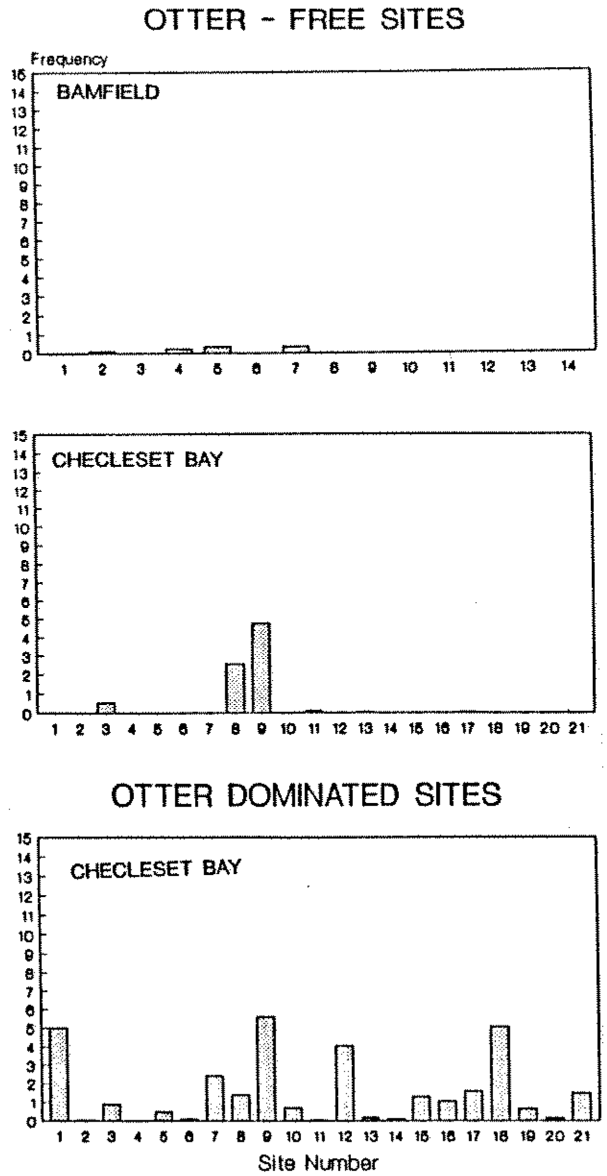


Figure 16. Mean (n=20) abundance of <u>Laminaria spp</u>. per 1/2 sq. m. at each site. Sites were sampled in Bamfield, Barkely Sound and Checleset Bay.

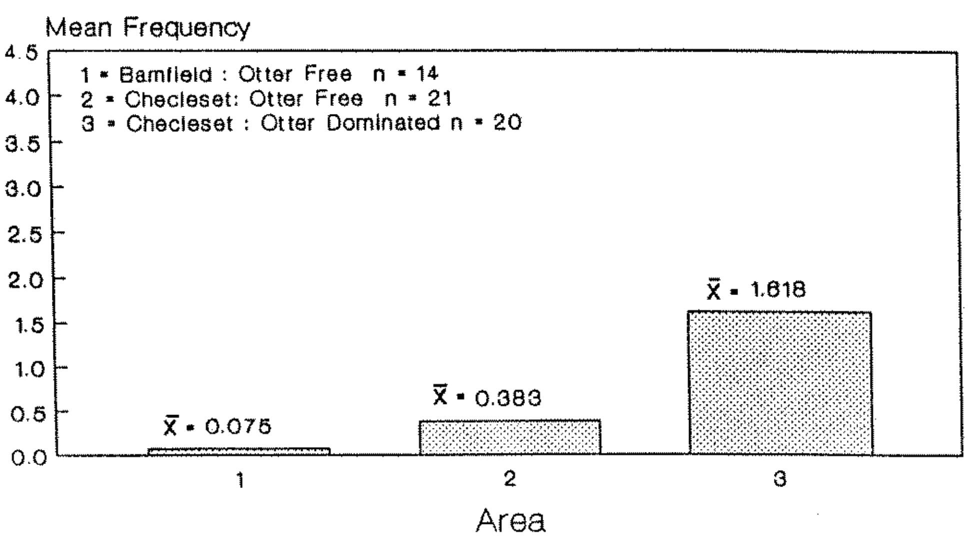


Figure 17.
Mean abundance of <u>Laminaria spp</u>. per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site.
N = the number of sites sampled in each area.

(Fig. 13) are both canopy forming kelps. Both species were significantly more abundant (Fig. 19, Fig. 21, Table 2) in areas with otters than in areas without otters. Abundances between the otter free areas were not significantly different (Table 2).

M. integrifolia is a perennial which does not tolerate high wave exposure. At sites without sea otters, M. integrifolia is restricted to the shallow sublittoral (depths less than 3 m.) by urchin grazing and forms a narrow band around most sheltered rocky shores. In otter dominated areas, M. integrifolia is limited only by exposure and stable substrate and forms extensive beds.

Nereocystis luetkeana is an annual kelp, tolerant to wave action. It has an opportunistic life history strategy, recruiting quickly to areas which have been biologically or physically perturbed. N. luetkeana was occasionally present at otter free sites, where wave action excluded urchins and reduced grazing. In general N. luetkeana formed the dominant canopy species at otter foraged sites which were exposed or recently disturbed, whereas, M. integrifolia formed the dominant canopy species at more sheltered sites. Abundances of canopy forming kelps varied considerably between sites (Fig. 18 and Fig. 20). This variability is probably largely a product of exposure gradients.

Desmarestia ligulata (Fig. 22) was significantly more abundant in areas dominated by otters than in otter free areas (Table 2, Fig. 24). There was no significant difference in D. ligulata abundance between the two otter free areas (Fig. 24, Table 2)

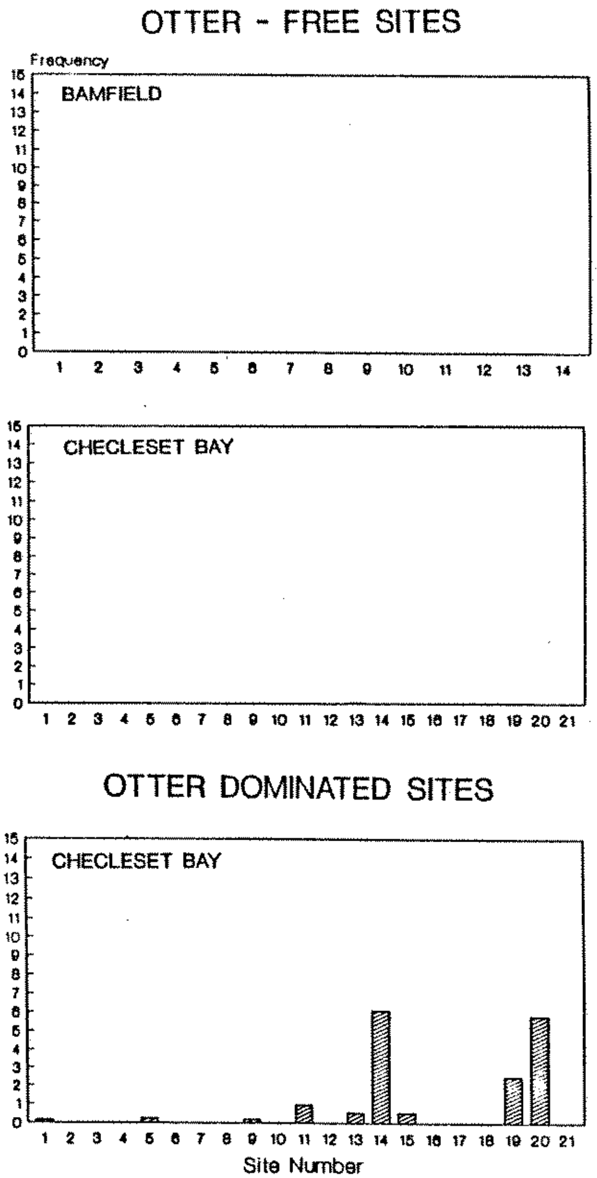


Figure 18. Mean (n=20) abundance of M. integrifolia per 1/2 sq. m. at each site. Sites were sampled in Bamfield, Barkely Sound and Checleset Bay.

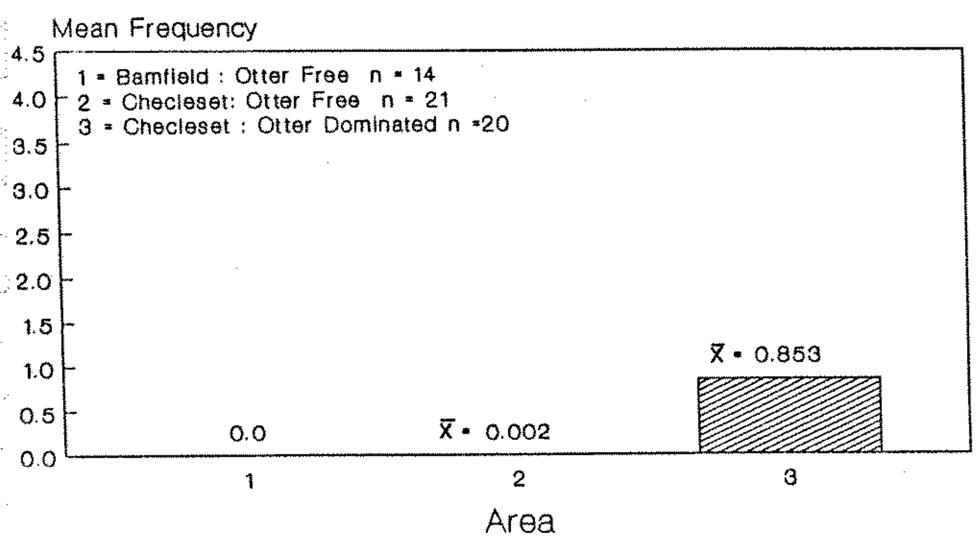


Figure 19.

Mean abundance of M. integrifolia per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site.
N = the number of sites sampled in each area.

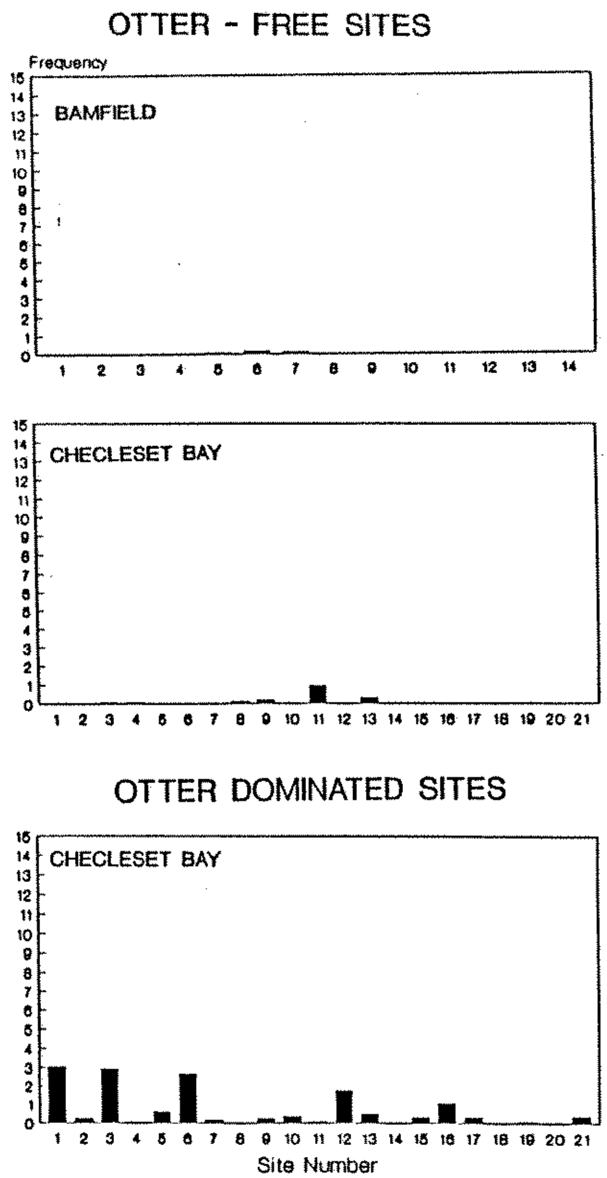


Figure 20.
Mean (n=20) abundance of <u>N. luetkeana</u> per 1/2 sq m. at each site. Sites were sampled in Bamfield, Barkley Sound and Checleset Bay.

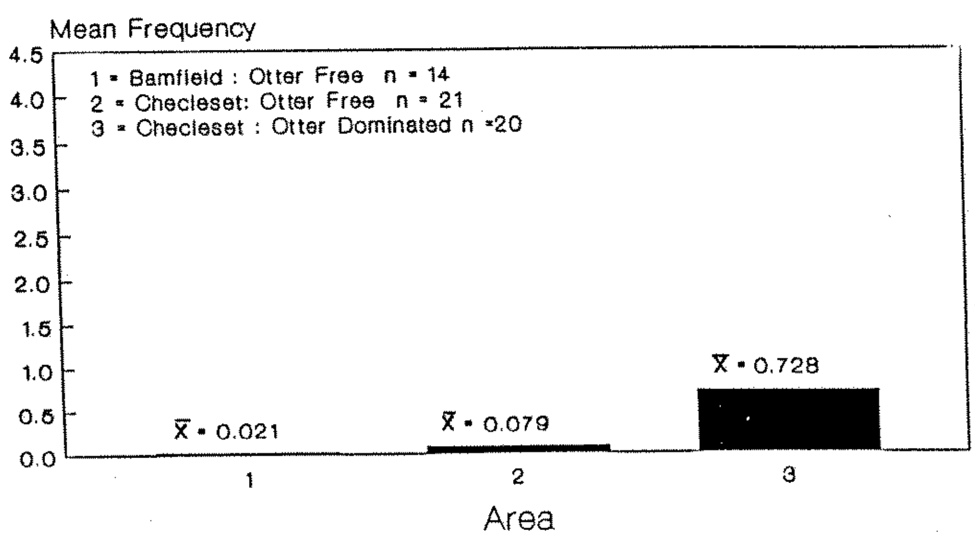


Figure 21.
Mean abundance of <u>N. luetkeana</u> per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site.
N = the number of sites sampled in each area.

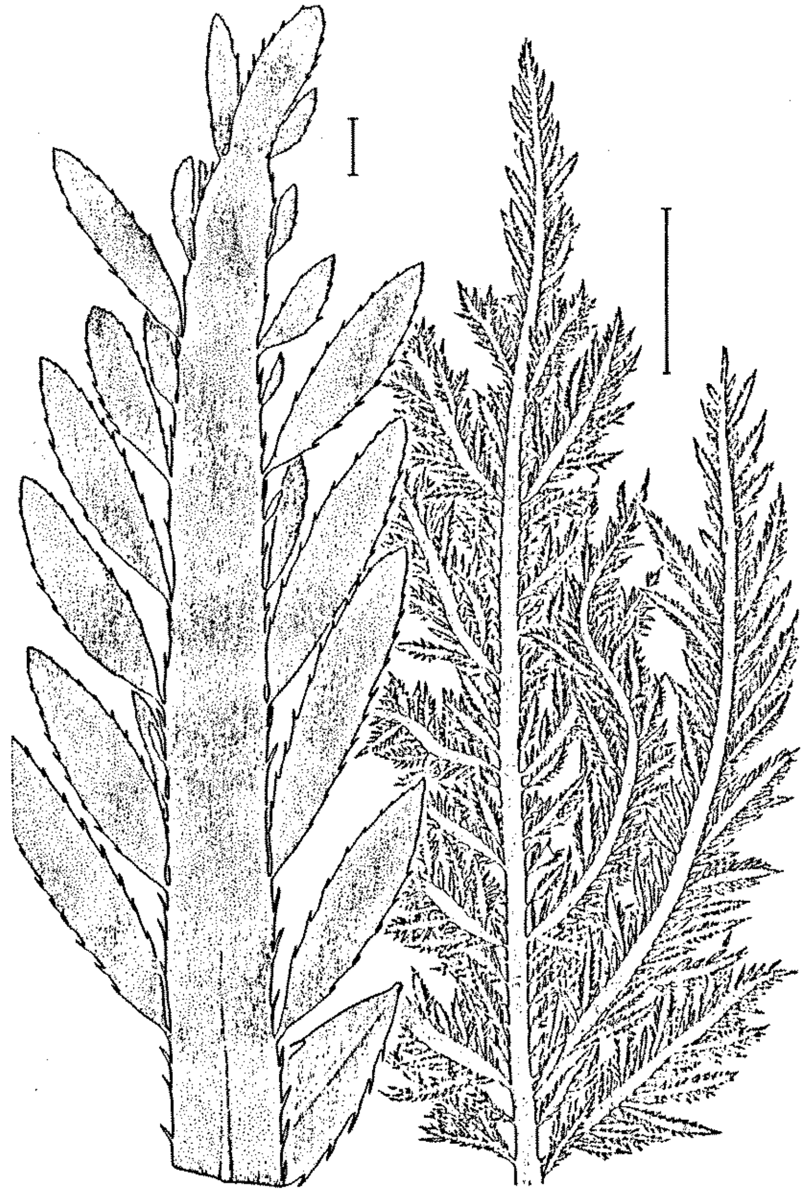


Figure 22. Desmarestia ligulata

Desmarestia ligulata is a weedy species recruiting quickly to disturbed areas, and areas recently freed from grazing pressure. The genus, *Desmarestia*, has sulfuric acid sequestered in vesicles within epidermal tissues (Abbott and Hollenberg 1982). This sulfuric acid acts as a chemical defence against herbivory.

Grazer resistance makes *Desmarestia* one of the most abundant algae in otter free areas. Moderately abundant in the presence of urchin grazing it recruits rapidly when urchins are removed. *D. ligulata* was very abundant at sites on the edge of the geographic range of the sea otter population, sites recently subjected to otter foraging (reduction in grazing pressure). *D. ligulata*, because of its ephemeral nature is able to recruit rapidly into physically disturbed patches in well developed kelp (otter dominated) communities. It is this ability that accounts for the variability of *D. ligulata* abundance between sites (Fig. 23).

Haliotis kamchatkana is commonly known as the Pinto abalone. *H. kamchatkana* was significantly more abundant in areas without otters than in areas with otters. No significant difference was observed in abalone abundance between the two otter free areas (Fig. 25, Fig. 26).

Henricia leviscula is a small common sea star found in most rocky subtidal communities. It is not a known prey item of sea otters and is probably unaffected by the large scale community changes associated with sea otter foraging. *H. leviscula* was not significantly different in abundance at otter free or otter dominated areas in Checleset Bay (Fig. 28, Table 2). It was not sampled in Barkley Sound. Since otters would have no predicted

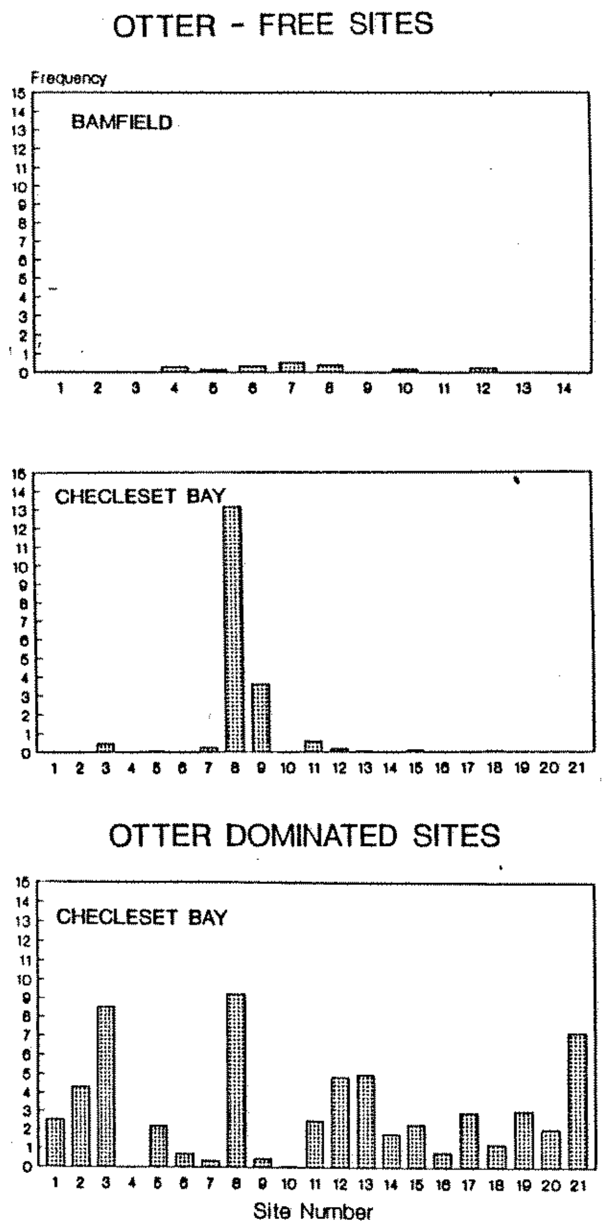


Figure 23.

Mean (n=20) abundance of D. ligulata per 1/2 sq. m. at each site. Sites were sampled in Bamfield, Barkley Sound and Checleset Bay.

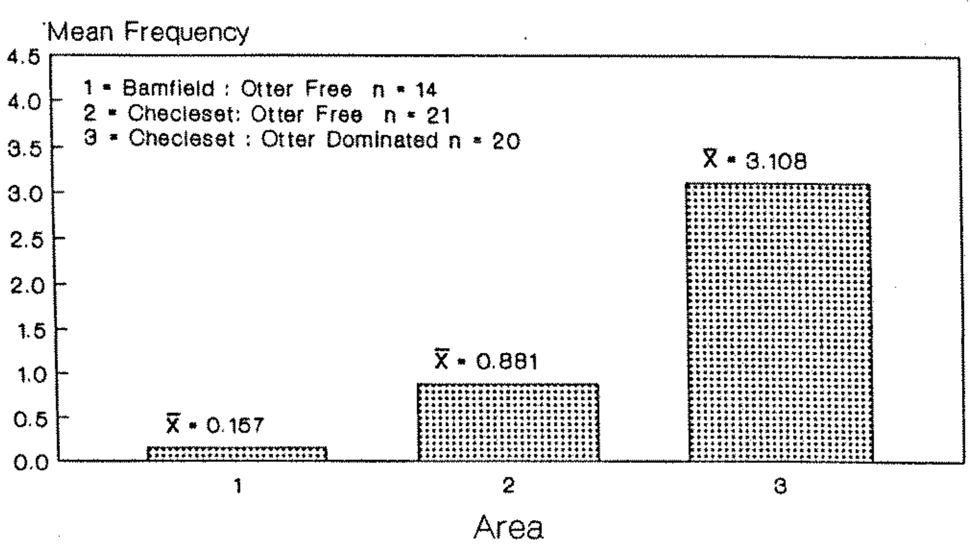


Figure 24.

Mean abundance of D. ligulata per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site. N = the number of sites sampled in each area.

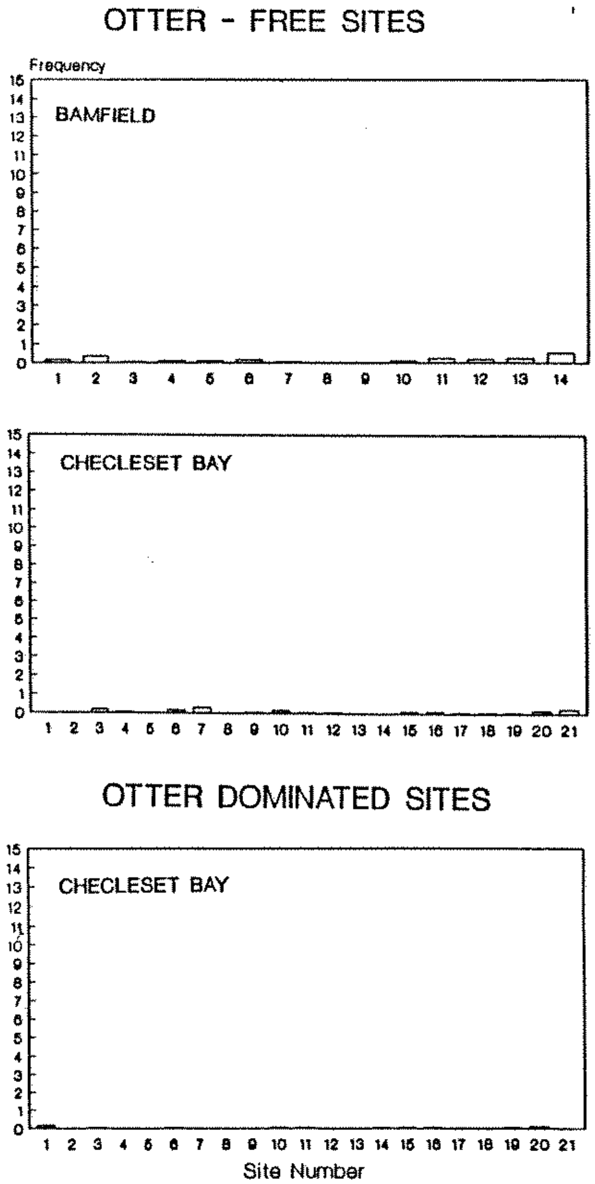


Figure 25.

Mean (n=20) abundance of H. kamchatkana per 1/2 sq. m. at each site. Sites were sampled in Bamfield, Barkley Sound and Checleset Bay.

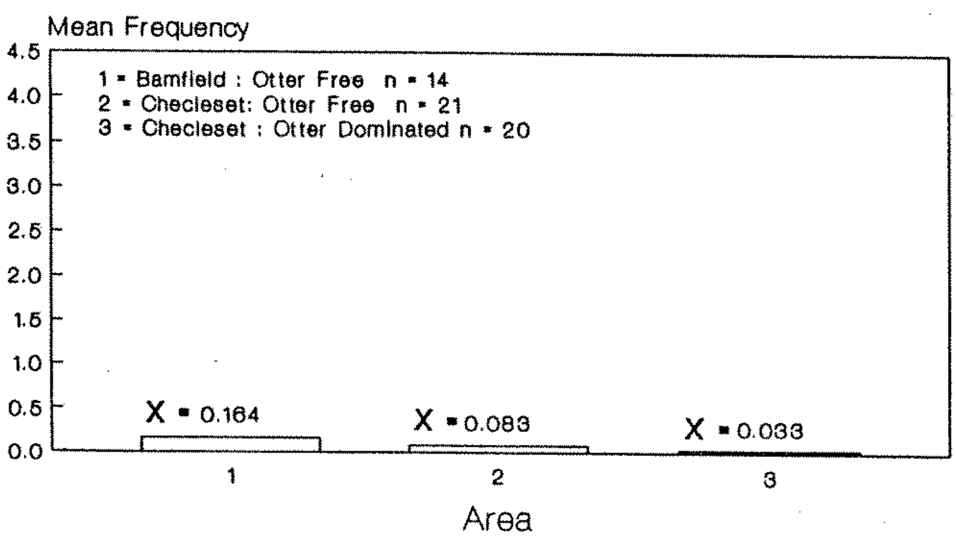


Figure 26.

Mean abundance of H. kamchatkana per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site. N = the number of sites sampled in each area.

OTTER - FREE SITES

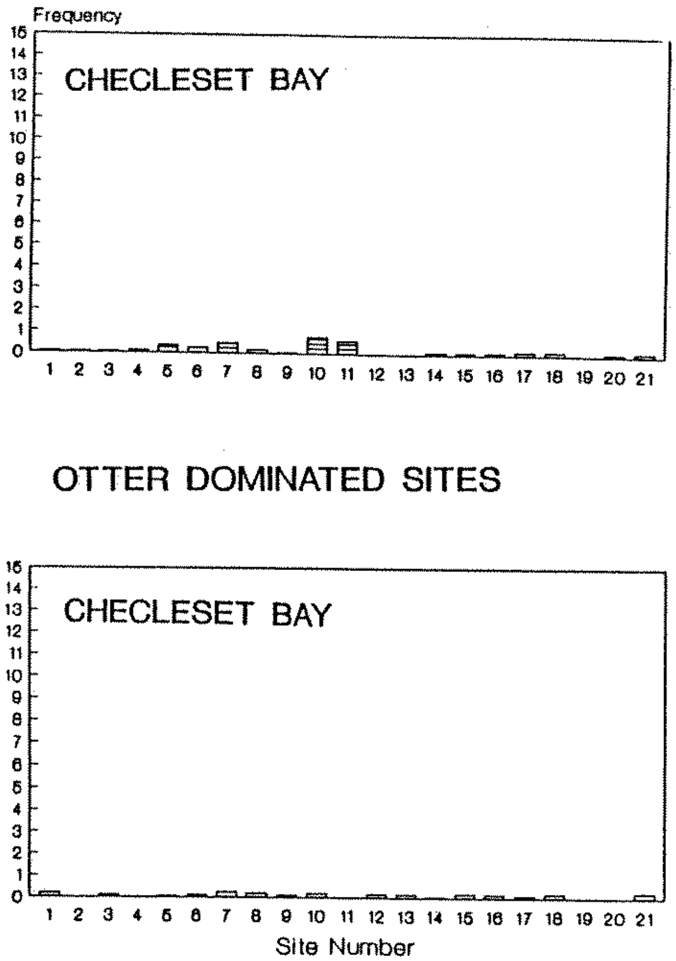


Figure 27.
Mean (n=20) abundance of H. leviscula per 1/2 sq. m. at each site.

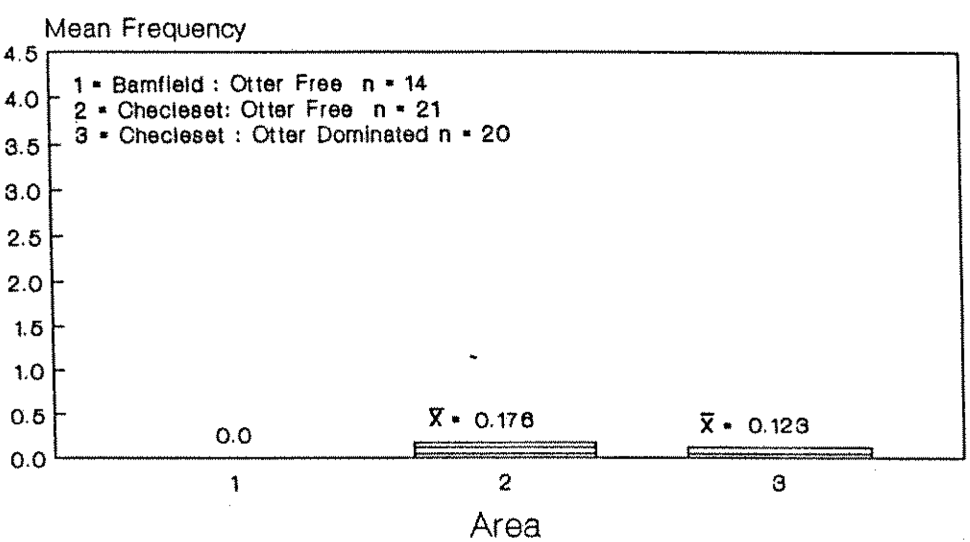


Figure 28.
Mean abundance of H. leviscula per area. Means are averages of all quads across all sites in each area. Twenty 1/2 Sq. m. quads were sampled at each site.
N = the number of sites sampled in each area.

effect on this species, this is an expected result.

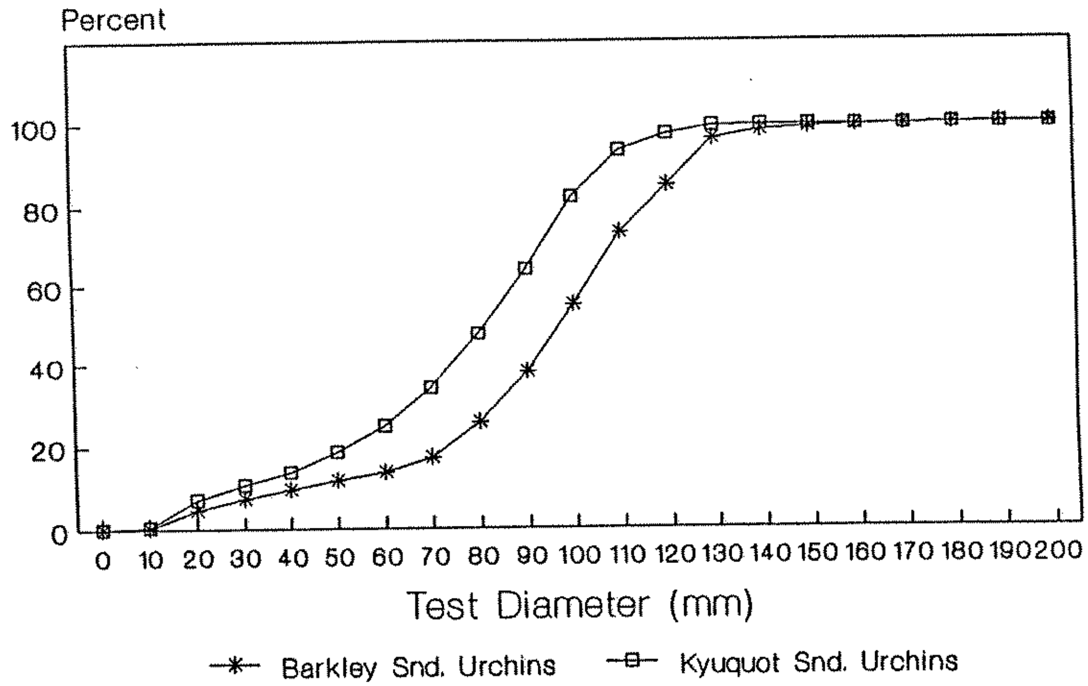
The community effects of otter foraging in British Columbia are similar to those observed in other areas (see VanBlaricom and Estes 1988 for an overview). The removal of major herbivores by foraging otters results in increased algal biomass. This reduction in grazing pressure alters the distribution of most fleshy subtidal macrophytes. In areas without otters, the seaward distribution of most subtidal algae appears to be restricted by herbivory and algae is found in the shallow sublittoral fringe, rarely deeper than 5 m. In areas dominated by otters, algae is abundant and is limited in distribution by exposure or stable substrate.

In this manner, otter foraging in Checleset Bay reduces the role of herbivory in structuring the nearshore community. Competitive interactions between algal species and the effect of the physical environment may structure communities dominated by sea otters.

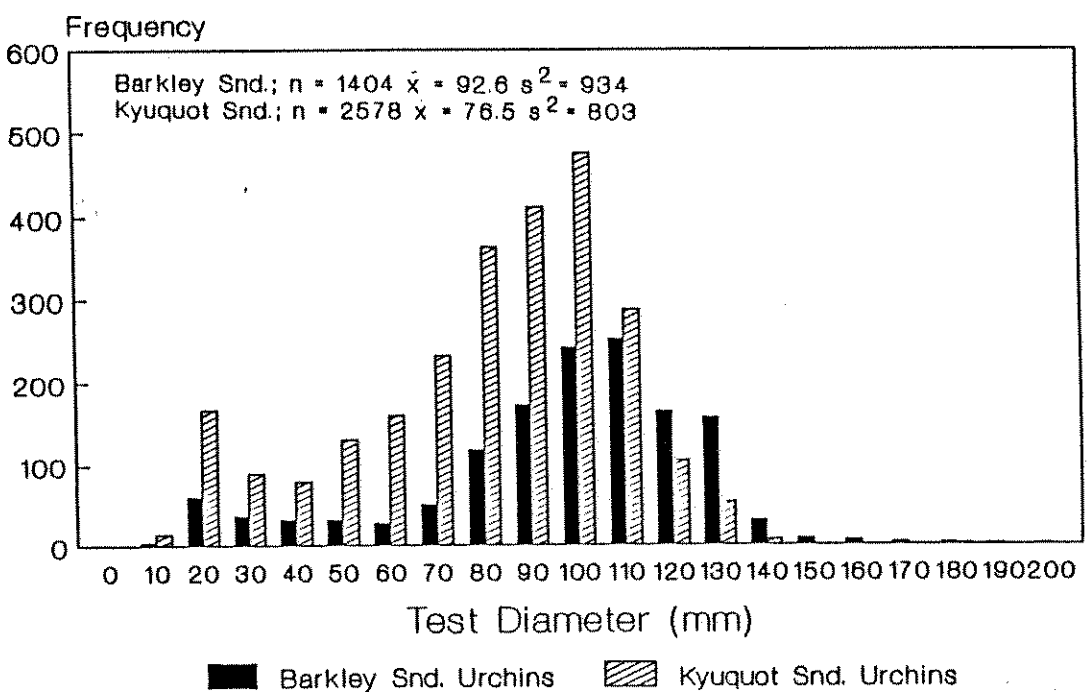
Size Frequency Distribution of *S. franciscanus*

Size frequencies were plotted for urchins at all sites sampled. Enormous variability was seen in size distributions between sites. In most cases this variability appeared to be the result of differential recruitment and/or survivorship.

Sea urchins at Bamfield, Barkley Sound, were significantly larger ($T=16.1$, $p \leq .05$) than urchins in Checleset Bay, suggesting differences in population dynamics between the two areas. This in part may be a result of differences in sample size. Recruitment



(a)



(b)

Figure 29. Cumulative (a) and actual abundances (b) of urchins by size at Kyuquot and Barkley Sounds.

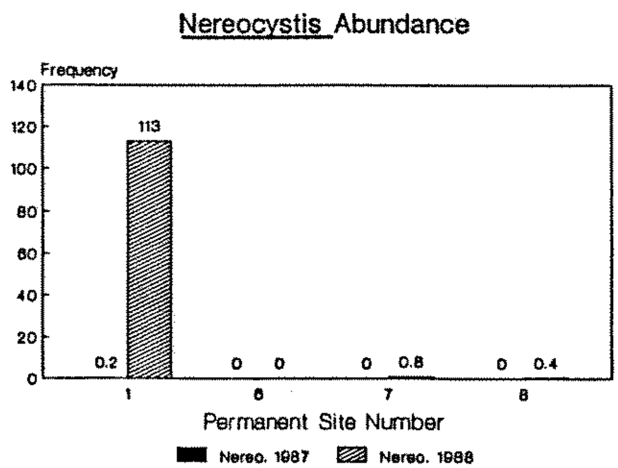
was common at many of the Checleset Bay sites and was not common at most of the Barkley Sound sites.

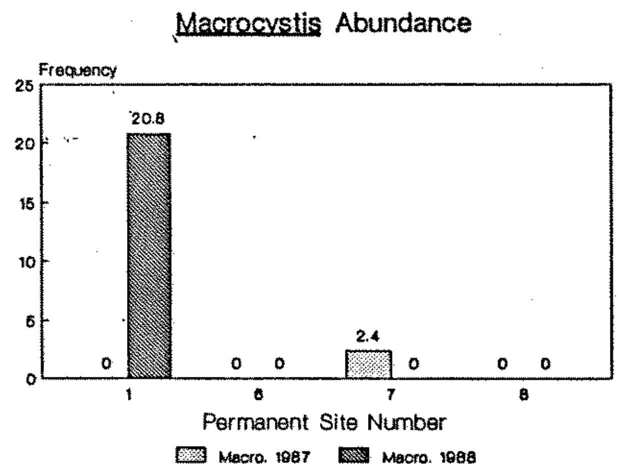
Permanent Sites.

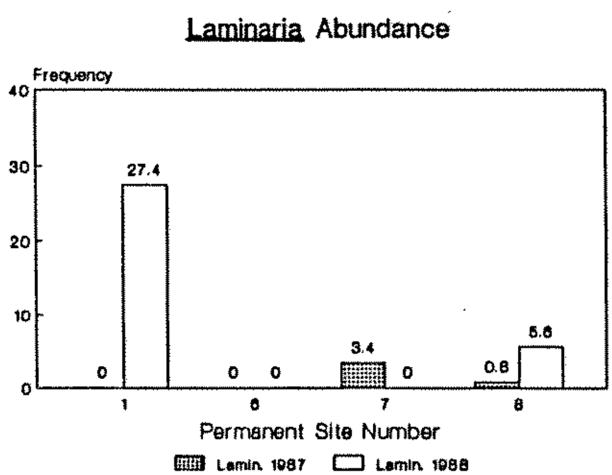
Four permanent sites established in 1987 were monitored to determine temporal variability at each site. At Permanent Site 1, located in the Mission Group, sea otter foraging occurred. The bottom was littered with broken sea urchin tests and a lush algal flora had developed. In 1987 algae was absent from Permanent Site 1 (Fig. 30) and the site was dominated by red urchins (Fig. 31) and an associated grazer resistant coralline crust. Otter foraging resulted in a significant decline in urchin abundance and an increase in algal biomass.

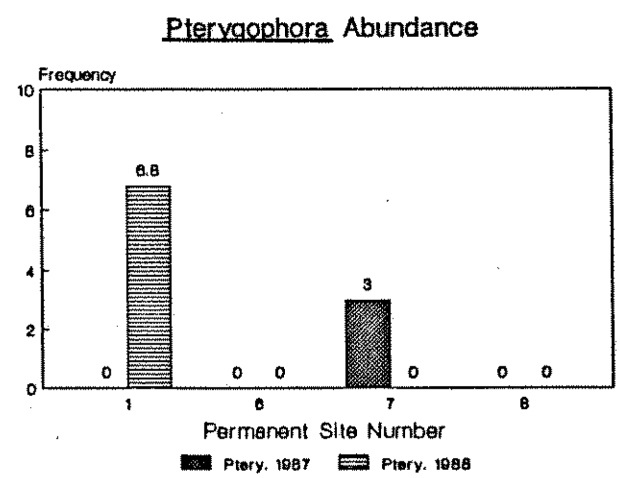
M. integrifolia, N. luetkeana, Laminaria spp., P. californica and D. ligulata all recruited to this site in 1988 (Fig. 30). Algae was most abundant on swathes where the greatest decline in urchin densities occurred (Fig. 31). M. integrifolia, N. luetkeana, and D. ligulata were the most abundant algal recruits.

From 1987 to 1988, S. franciscanus was eliminated from two of the five swathes at Permanent Site 1 (Fig.32). Urchin abundances at two of the three remaining swathes declined, while abundances in the third swathe almost doubled. Despite a relatively small (but significant) decline in mean urchin abundance (Fig. 31), a dramatic increase in algal biomass was observed. Algae was most abundant in swathes where urchins had been eradicated entirely (Fig. 33). In swathes where urchin density increased algal recruitment was not observed. This









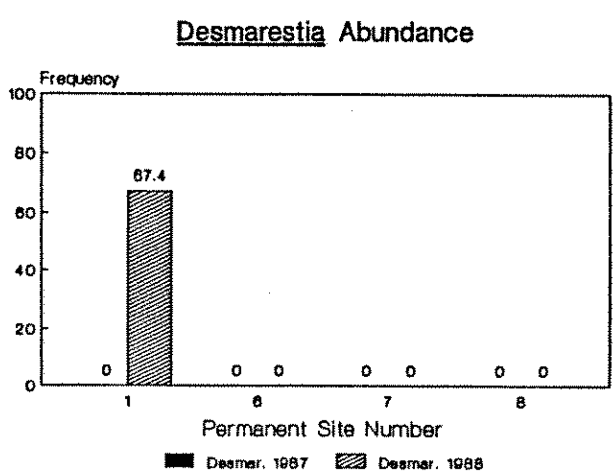


Figure 30. Mean abundance of algae (per 20 sq. m.) across all five swathes at the four otter free sites. Otter foraging occurred at site 1 between 1987 and 1988. Note the different scales.

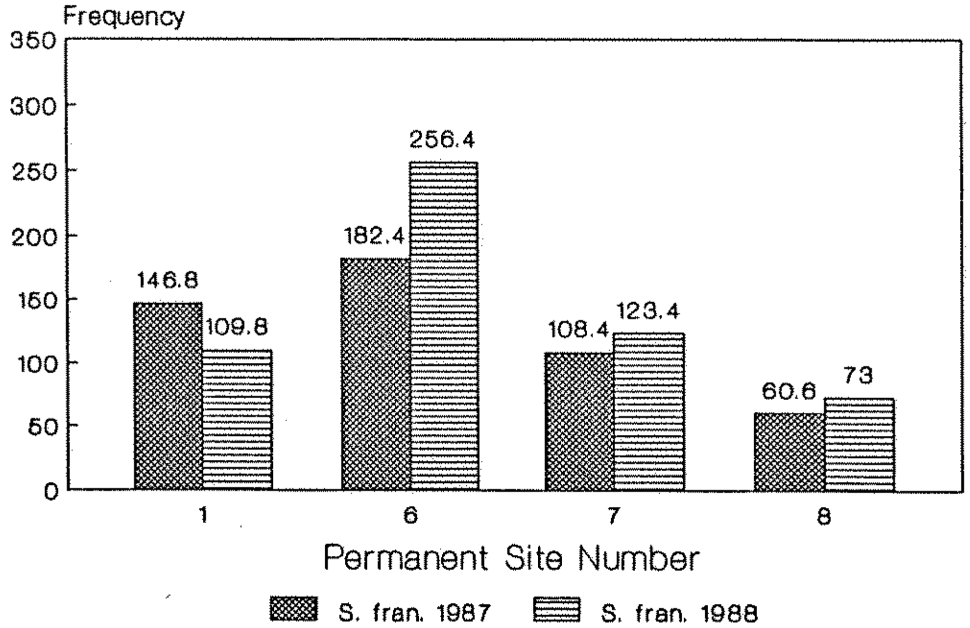


Figure 31. Mean abundance of urchins (per 20 sq. m..) at the four otter free permanent sites, in 1987 and 1988. Otter foraging occurred at site 1 between 1987 and 1988.

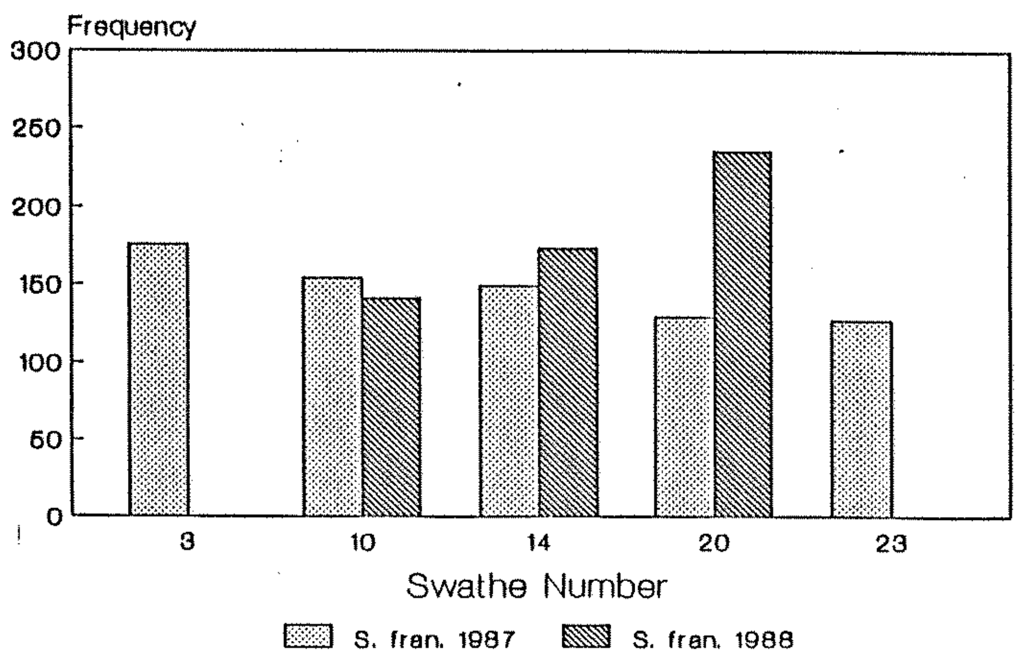
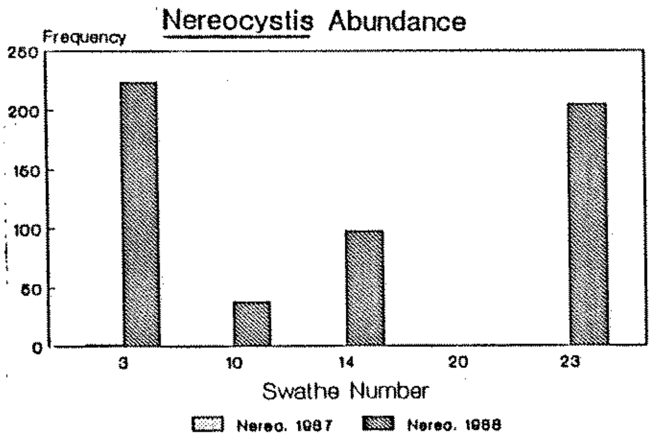
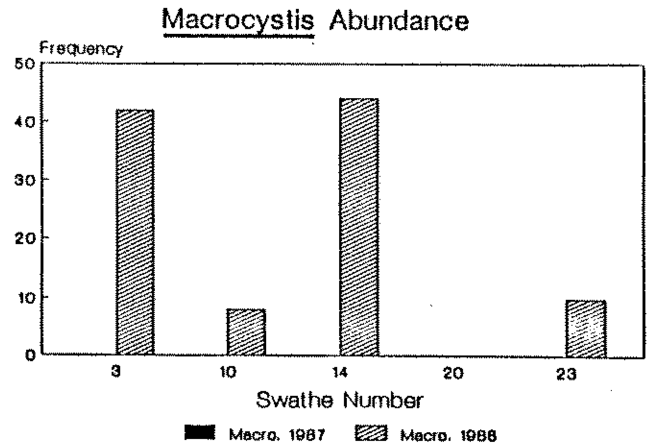
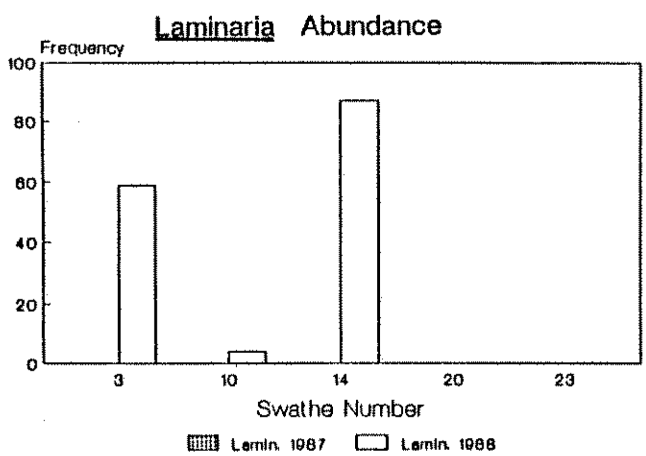
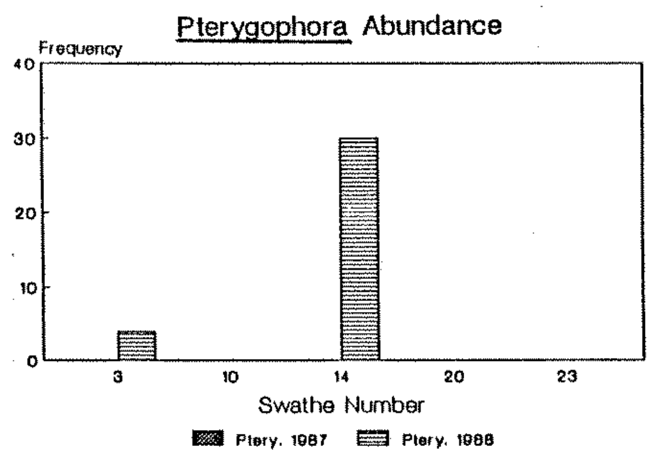


Figure 32. Urchin abundances (per 20 sq m.) on each swathe at permanent site 1 between 1987 and 1988. Urchins were removed by otter foraging.









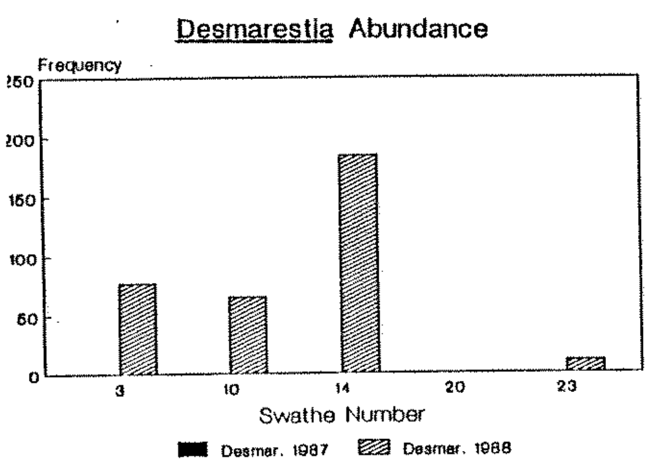


Figure 33. Abundance of algae (per 20 sq m.) on each swathe at permanent site 1 in 1987 and 1988. Otter foraging ocurred at Site 1 between 1987 and 1988. Note different scales.

pattern reflects the patchy nature of this system. At this site urchin distributions, after otter foraging, were contagious with areas of dense urchin concentrations and regions where urchins were absent. This aggregated distribution is probably a product of patchy otter foraging, and a behavioral response of the urchins to predation and changing availability of algal drift. This mosaic of urchins and algae may affect patterns of algae recruitment and subsequent community development.

Urchin densities at the remaining three permanent sites (established in 1987) increased significantly (Table 3). This increase indicates that temporal variability within the urchin dominated otter free system is high. The cause of this variability may be due to movement of urchins, or variable recruitment. Two sites were established in Bamfield, Barkley Sound, well beyond the immediately expected range of sea otters. These sites, Permanent Sites 7 and 8, will serve to monitor year to year variability in an otter free system.

In this study the response of the benthic community to otter foraging is rapid. In the Aleutians otters forage extensively on S. polycanthus, a small green urchin. While otter foraging has a profound effect upon the system (Estes et. al. 1978), the small size of the urchins makes it energetically impractical for otters to eat urchins below a minimum size. This selective foraging results in high densities of small urchins in the system, despite intense otter foraging. Small urchins do not have the grazing impact of larger conspecifics but their presence no doubt inhibits algae recruitment, and slows the rate of community

Table 3. (a) Mean abundance of urchins across all 5 swathes at each of the four otter free permanent sites in 1987 and 1988.

	PS1		PS6		PS7		PS8	
	$\bar{x}$	s^2	$\bar{x}$	s^2	$\bar{x}$	s^2	$\bar{x}$	s^2
S. franciscanus								
1987	146.8	19.7	182.8	50.0	60.6	27.6	108.4	51.6
1988	109.8	105.7	256.0	82.2	73.0	22.6	123.4	52.7

Table 3. (b) T values (p = .05) are reported from year to year comparisons at each site.

	PS1 1987/1988		PS6 1987/1988		PS7 1987/1988		PS8 1987/1988	
	t.	Sig	t	Sig.	t	Sig.	t	Sig.
S. franciscanus	7.4	S	14.2	S	4.3	S	2.3	S

response to reduced grazing pressure. Since S. franciscanus is much larger, sea otters remove all urchins, eliminating the major grazer. In California, otters are one of several important urchin predators. Fish and lobster (Cowen 1983, Tegner and Levin 1983) prey upon urchin recruits, affecting urchin abundance. Thus, in California, otters might be expected to have a less profound effect upon nearshore community ecology (see Foster and Schiel 1988 for a discussion).

Permanent sites established along the west coast of Vancouver Island will be monitored annually for the next three years. Data regarding spatial and temporal variability will be collected. The community effects of otter foraging will be documented as otters move into presently otter free sites.

Sea Otter Surveys.

The results of weekly sea otter surveys in Checleset Bay were extremely variable (Table 4), due to changing weather and sea conditions. The highest count of 203 animals was made on September 3. This represents a minimum estimate of sea otters in Checleset Bay, as boat surveys are conservative and animals outside of the survey area were missed.

Sea otters generally segregate by age and sex (Schneider 1978). Sex and age of sea otters is difficult to determine at a distance. In this study only the sex of animals with young was unquestionably determined.

The greatest concentrations of otters occurred at Chief Rock, the Clara Islets area (locations 9, 10, 11, 4, Fig. 7) and

Table 4. Numbers of single adults (A) mothers (M) and pups (P) seen at each location along the Checleset Bay Survey route (Figure 7) Survey route 1 followed the route in a counterclockwise direction. Survey route 2 followed the route in a clockwise direction.

	SURVEY ROUTE 1									SURVEY ROUTE 2											
Survey #	1			2			3			4			5			6			7		
Date	07/08/88			13/08/88			22/08/88			27/08/88			03/09/88			10/09/88			13/09/88		
Otter/Category	A	M	P	A	M	P	A	M	P	A	M	P	A	M	P	A	M	P	A	M	P
1. Entrance Kyoquot (Chief Rk)	17	10	10	9	0	0	33	2	2	17	2	2	46	8	8	30	4	4	49	9	9
2. Cole Rk.	2	0	0	1	0	0	0	0	0	6	0	0	7	0	0	7	1	1	7	0	0
3. Cole Rk. - Thomas It.	4	0	0	2	1	1	5	0	0	1	0	0	6	3	3	3	0	0	2	0	0
4. Thomas It.	2	9	9	2	2	2	7	8	8	8	3	3	7	2	2	1	0	0	0	0	0
5. Bunsby It.	1	0	0	5	0	0	3	0	0	1	0	0	0	0	0	0	1	1	3	0	0
6. Gull Island	0	0	0	1	0	0	1	1	1	3	1	1	3	1	1	1	0	0	1	0	0
7. Acous Peninsula	1	0	0	1	0	0	0	1	1	0	0	0	2	0	0	1	0	0	0	0	0
8. O'Leary Its.	3	12	12	0	0	0	4	13	13	15	22	22	5	6	6	7	14	14	25	8	8
9. Clara Its.	12	2	2	13	5	5	11	5	5	16	6	6	24	13	13	14	5	5	12	2	2
10. Farout Reefs	3	0	0	1	2	2	1	1	1	3	0	0	4	5	5	2	1	1	6	1	1
11. Smooth Top Rocks	21	13	13	20	7	7	2	0	0	12	3	3	8	4	4	3	0	0	5	1	1
12. Double Rocks	3	1	1	3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2	0	0
13. Flat Top Rocks	3	2	2	8	3	3	13	1	1	3	0	0	6	0	0	2	0	0	2	0	0
14. Lookout Island	2	1	1	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. Mission Group	2	0	0	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
16. Cole Rock - Flat Top	0	0	0	0	0	0	0	0	0	1	1	1	5	1	1	3	0	0	3	0	0
TOTAL	76	50	50	69	21	21	82	32	32	87	38	38	127	43	43	74	26	26	117	21	21
GRAND TOTAL	176			111			146			163			213			126			159		

O'Leary Islets (Fig. 7). Large rafts of single otters observed at Chief Rock were likely aggregations of males. In California concentrations of animals at the ends of the geographic range consist mostly of males (Vandevere 1970). Otters in the Clara Islets area and O'Leary Islets were predominantly females with dependent pups (Table 4). In California, groups of females generally occupy the best habitat and are comprised of females of all ages (Estes 1980). This pattern was apparent in Checleset Bay. Females with young were observed at most locations but consistently comprised the greatest percentage of animals in the centre of the geographic range, an area which is moderately sheltered.

Females with pups were cautious around boats and fled immediately when approached. Otters at Chief Rock were curious, porpoising or back paddling away, periodically stopping to watch. Otters at Chief Rock were the most easy to locate and count.

Large single, distinguishable animals were sighted regularly at predictable locations near female areas. These animals may be adult males with established territories. In Alaska and California, males occupy territories generally adjacent to female resting areas (Vandevere 1970, Loughlin 1977). Without marked animals distinguishing individuals is difficult.

A double survey was conducted on September 17, to examine daily movements of sea otters. The results were inconclusive, but indicate that otters move a great deal between areas. Otters rafting at Chief Rock consistently dispersed to surrounding areas by midmorning. By midafternoon otters were usually absent from

Chief Rock and the raft reformed just before sunset. Rafting at Chief Rock may well be a response to Northwest winds. Females with pups may travel considerable distance during the course of a day. During the morning 43.5 percent of the observed females were seen at the O' Leary Islets. In the afternoon only 6.8 percent of the female otters were present at the same location (Fig. 34, Table 5). More females with pups were seen on the afternoon trip, so some otters were missed on the earlier survey or may have been incorrectly identified as single otters. Since more females and pups were seen on the earlier survey it is unlikely that large groups were missed and females must have moved three nautical miles from the O'Learys, to the Clara Islets.

Weekly counts of sea otters in January and February of 1989, indicated that the location of otter rafts was determined by prevailing winds. Wind patterns in the summer are predictable. Mornings are windless, with northwest gales rising in the afternoon and dropping each evening. Choppy sea conditions often distress young otters and females may respond by swimming downwind or seeking shelter (Estes 1980). Afternoon movement of females southeast to the Clara Islets, may be a response to prevailing northwest winds.

The geographic range of sea otters in Checleset Bay is from Quineex Reef, south to Thornton Island in Kyuquot Sound. On September 26, a survey of the otter population in Nootka Sound counted 156 otters, north from Maquinna Point to one nautical mile north of Skuna Bay (Fig. 35).

The otter population in Checleset Bay appears to be expanding

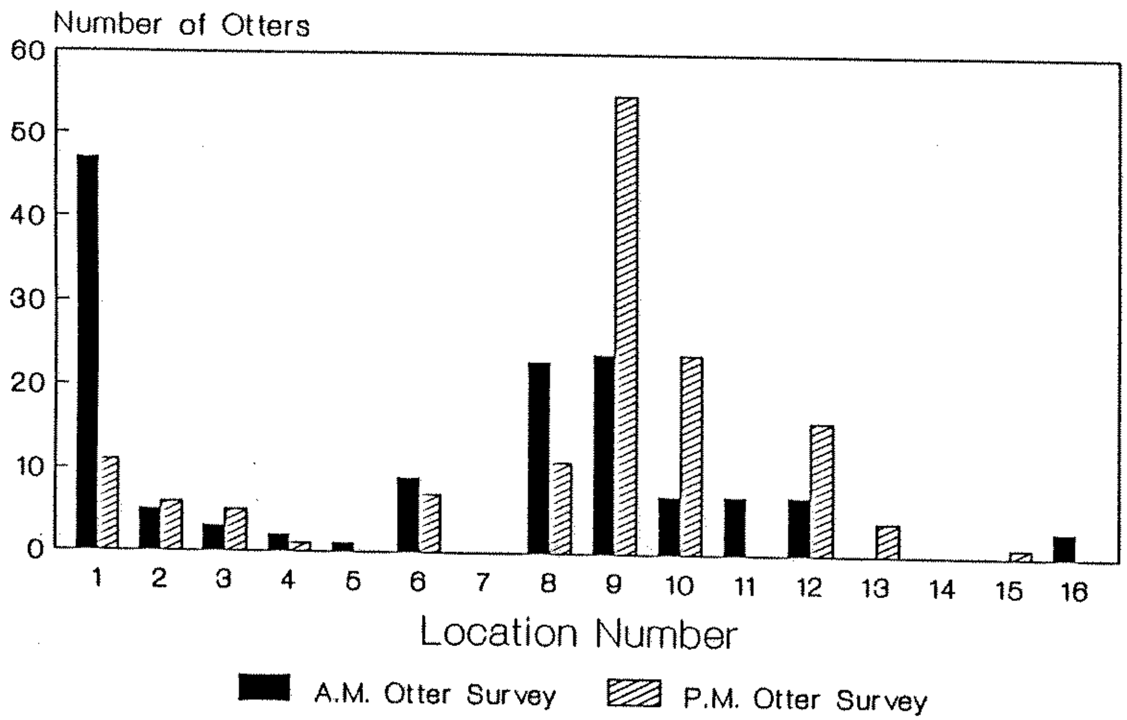


Figure 34. Histogram of daily changes in otter location on the double survey, September 17, 1988.

Table 5. Numbers of single adults (A), mothers (M) and Pups (P) seen at each location along the survey route on the double survey.

Time / Otter Category / Location	DOUBLE SURVEY 17/09/88 Morning A	M	P	Afternoon A	M	P
1. Entrance Kyoquot (Chief Rk)	43	2	2	7	2	2
2. Cole Rk.	5	0	0	6	0	0
3. Cole Rk. - Thomas It.	3	0	0	3	1	1
4. Thomas It.	0	1	1	1	0	0
5. Bunsby It.	1	0	0	0	0	0
6. Gull Island	7	1	1	5	1	1
7. Acous Peninsula	0	0	0	2	0	0
8. O'Leary Its.	13	10	10	5	3	3
9. Clara Its.	8	8	8	13	21	21
10. Farout Reefs	5	1	1	10	7	7
11. Smooth Top Rocks	7	0	0	0	0	0
12. Double Rocks	7	0	0	8	4	4
13. Flat Top Rocks	0	0	0	2	1	1
14. Lookout Island	0	0	0	0	0	0
15. Mission Group	0	0	0	1	0	0
16. Cole Rock - Flat Top	3	0	0	0	0	0
TOTAL	102	23	23	63	40	40
GRAND TOTAL		148			143	

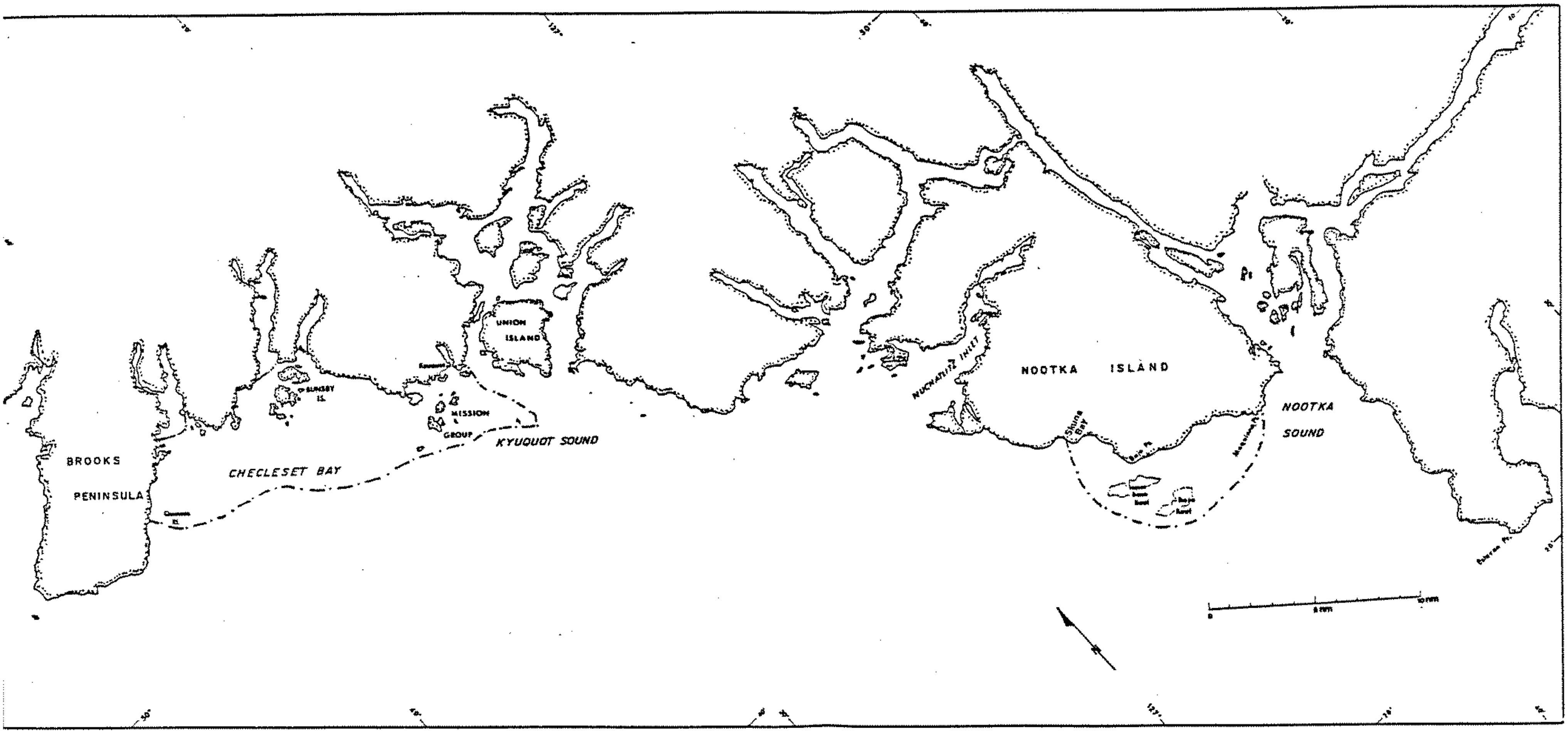


Figure 35. Geographic extent of the two otter populations in B.C.

in a southerly direction. Population growth is occurring at a rate of 17 percent per year (Estes in prep.). The sea otter population in Checleset Bay resembles populations below carrying capacity elsewhere in the northeast Pacific. Continued increase and expansion of both sea otter populations can be expected.

Resurvey of the Breen et. al. (1982) sites.

Observations indicate that sea otters now occupy all of the sites surveyed by Breen et. al. (1982) (Fig. 34). In 1979 ten of the nineteen sites were inferred or known sea otter feeding sites (Table 6). In the 1987-1988 survey, urchins were absent from all sites (Table 7). The nine sites previously unoccupied by otters were dominated by kelp and are encompassed by the present otter range. Otters were observed at all sites.

Nereocystis luetkeana formed the dominant canopy kelp at most sites. As suggested by Breen et. al. (1982) its' abundance at sites long occupied by otters is unexpected. *N. luetkeana* is ephemeral in nature and is out-competed by longer lived perennial species (see Dayton 1975, for a discussion).

While *N. luetkeana* forms the most obvious kelp species in many otter dominated areas, its dominance may be overestimated by visual estimates made at the surface. Extensive *N. luetkeana* canopies often occurred above dense sub-canopies of *Pterygophora californica* and *Laminaria spp.*. This was particularly true at sites 5, 3, 4, and 19 (Table 7). At these sites *N. luetkeana* canopies were extensive, but careful examination of the subtidal community indicated that *N. luetkeana* was limited to shallower

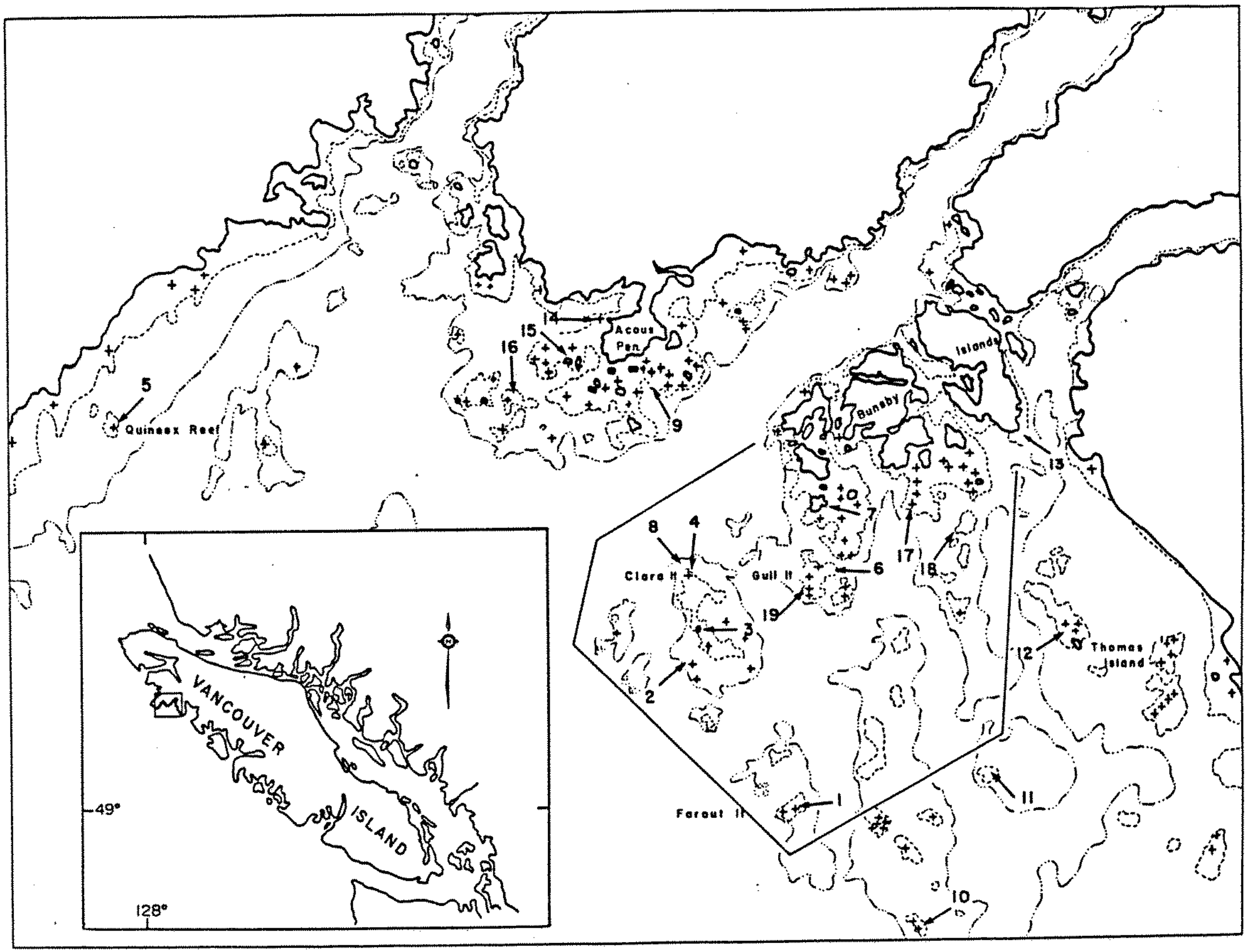


Figure 36. Sites of Breen et. al. (1982), sampled originally in 1979, and resampled in 1987 - 1988.

Site	Location	Invertebrates: Red sea urchins			Invertebrates: Abalone			Other	Kelp: Canopy		Kelp: Undercanopy		Comments
	Lat 50° Long 127°	Density (ind. m^{-2})	Size (mm)	Depth (m)	No. seen	Size (mm)	Depth (m)		Species	Range (m below datum)	Species	Range (m below datum)	
1	02' 00'' N 33' 25'' W	8 seen	30–80	6 in crevice	1	< 100	6	*Balanus nubilus* and *Pisaster ochraceus*	*Nereocystis*	1.5–9	*Pterygophora* *L. setchellii*	0–10	Kelp detritus abundant Known sea otter feeding site
2	03' 28'' N 34' 08'' W	None			< 10	< 100	6–9	Heavy encrusting fauna	*Nereocystis*	1–7.5	*L. setchellii* bladed reds (sparse)	1–7	Known sea otter feeding site
3	03' 48'' N 35' 00'' W	4 seen	30–80	3–6	None			*B. nubilus, P. ochraceus*, heavy encrusting fauna	*Nereocystis*	1–7	*L. setchellii* bladed reds	+ 1–7 7–9	Known sea otter feeding site
4	04' 20'' N 35' 08'' W	10 seen		4	5	20–70	4	*B. nubilus, P. ochraceus* heavy encrusting fauna	*Nereocystis*	1–7	*L. setchellii* *Dictyota* bladed reds	3–6.7 3–10	Known sea otter feeding site
5	06' 00'' N 44' 24'' W	10–15	20–150	5–13+	2	50	5.5	Heavy encrusting fauna 0–5 m deep	None		*L. setchellii* *Laminaria* sp. *Pterygophora* *Eisenia*	0–5	Not a feeding site Upper algal zone, lower sea urchin barrens
6	04' 30'' N 32' 48'' W	1 seen	20	7	Many	30–60	3–6	Abalone under stones in a fissure	*Nereocystis* *Macrocystis*	0–7 Near 0	*L. setchellii* *Laminaria* spp. *Pterygophora* *Costaria*	0–7	Known sea otter feeding site Shell bottom deeper than 7 m
7	05' 00'' N 32' 58'' W	None			6	1	0–4	*Tegula* extremely abundant	*Macrocystis*	0–3	*Laminaria* spp. *Pterygophora*	0–5	Inferred feeding site Most algae stopped at shell floor, 5 m
8	04' 28'' N 35' 16'' W	0–2 under boulders	20–120	10–15	1	50	8	Encrusting fauna heavy on vertical surfaces	*Nereocystis*	0–10	*L. setchellii* *Phyllospadix*	0–1.8	Known sea otter feeding site
9	06' 15'' N 35' 40'' W	10–15	20–100	1–8	To 1 ind. m^{-2}	< 100	0.5–2	*S. droebachiensis* to 1 ind. m^{-2}, *Astraea* to 0.1 ind. m^{-2}	None		*L. setchellii* *Phyllospadix*	0–1.2	Concluded to be a non-feeding site
10	00' 45'' N 31' 25'' W	None			None			Heavy encrusting fauna	*Nereocystis*	1–7+	*L. setchellii* *Pterygophora* *Phyllospadix*	1–7+	Very exposed site; only 1 depth examined
11	02' 16'' N 30' 18'' W	0–2	20–100	7–13	6	50	11	Sea urchins in crevices and small at top of range. *B. nubilus* to 80% cover	*Nereocystis*	1–10	*L. setchellii* *Pterygophora*	1–9	Inferred sea otter feeding site
12	03' 44'' N 29' 05'' W	10–20		5–6	To 0.2 ind. m^{-2}	30–80	3–6	Sea urchins in a narrow band below kelp	*Nereocystis*	3.5–5	*L. setchellii* *Desmarestia ligulata*	3.5–5	Concluded not to be a feeding site
13	05' 44'' N 29' 40'' W	0.5–1		3–8	To 10 ind. m^{-2}	50–130	+1–5		None		*L. setchellii* *Egregia* *Alaria* spp.	+ 1–1.5	Concluded not to be a feeding site. Algae only on reef tops and in very shallow water
14	06' 54'' N 36' 30'' W	5–10		0.5–1.5	None				*Macrocystis* (dense)	Disjunct 0–0.5 3.5–4.5	*Agarum* sp.	3.5–4.5	Concluded not to be a feeding site
15	08' 34'' N 37' 08'' W	10		0–3	To 2 ind. m^{-2}	50–135	4–6		*Nereocystis*	Boulder tops only	None		Concluded not to be a feeding site
16	06' 04'' N 37' 42'' W	10+		2–5	To 10 ind. m^{-2}	40–80	2–8		*Nereocystis*	Boulder tops only	*L. setchellii* *Phyllospadix*	0–2	Concluded not to be a feeding site
17	04' 58'' N 31' 36'' W	< 1		6–12	None			Sea urchins under boulders or in crevices only	*Nereocystis* (sparse)	7	*L. setchellii* *Costaria*	0–6	Concluded to be a feeding site
18	04' 45'' N 30' 52'' W	None			None			Dense *Metridium* on steep vertical surfaces	*Nereocystis*	6–8	None		Concluded to be a feeding site
19	04' 14'' N 33' 20'' W	1 seen	100	1	2	50–60	3–6	Encrusting fauna on verticals	*Nereocystis*	1.5–7	*L. setchellii* *Pterygophora*	1.5–7	Known sea otter feeding site

Table 6. Site description of the sites surveyed by Breen. et. al. 1982. (From Breen et. al. 1982).

Table 7. Site descriptions of the Breen et. al. sites (1982) resurveyed in 1987/1988.

PAB		JCW INTERTEBRATES							CANOPY		UNDERSTORY		
		RED SEA URCHINS			ABALONE								
Site	Location Lat 50 Long 127	Density (m²)	Size (mm)	Depth (m)	No. seen	Size (mm)	Depth (m)	OTHER	Species	Range (m. below) datum	Species	Range (m. below) datum	COMMENTS
1	02' 00" N 33' 25" W	None						Bryzoans common broken hinnites Balanus nubilus Pisaster ochraceus	Nereocystis	1.5-9	Desmarestia Laminaria Pterygophora	0-10	Previously an otter foraged site
2	03' 28" N 34' 08" W	None						Filter feeding community	Nereocystis	1-12	Laminaria Costaria Pterygophora Desmarestia	0-12	Previously an otter foraged site
3	03' 48" N 35' 00" W								Nereocystis	1-7	Pterygophora Laminaria Desmarestia	0-12	Previously an otter foraged site
4	04' 20" N 35' 08" W	1 seen	40	30' unadjusted	None			Lots of empty Mytilus Less encrusting fauna	Nereocystis (not thick)	5-8	Laminaria spp. Laminaria setch Pleurophycus Pterygophora	0-10	Previously not foraged Otters now present
5	06' 00" N 44' 24" W	None			None			Lots of urchin tests	Nereocystis	5-10	Pterygophora Eisenia L. setchellii	0-12	Previously not otter foraged Otters now present
6	04' 20" N 32' 48" W	3 seen	60 cm	35'	None			Bryzoans under Pterygophera canopy	Patchy Macrocystis Nereocystis not significant	3-10	Pterygophora L. setchellii Pleurophycus Phyllospadix	0-12	Dominated by Pterygophora
7	05' 00" N 32' 58" W	None			None			Patiria miniata common No fish	Macrocystis	3-10	L. groenlandica	5-8	No changes since 1979
8	04' 28" N 35' 16" W	None			None			Hinnites giganteus (1) Otters seen feeding Encrusting fauna	Nereocystis (not thick)	3-10	Desmarestia	3-14	No major changes
9	06' 15" N 35' 40" W	None			Broken shells only	80		Some S. drobrachiensis seen. Very small new recruits	Macrocystis	3-7	Laminaria Phyllospadix	0-10	Previously not otter foraged Otters now present
10	00' 45" N 31' 25" W	None			None			Mostly filter feeders Lots of Balanus nubilus Broken Hinnites	Nereocystis	-10	Laminaria Desmarestia Pterygophora	-10	Very exposed. No obvious changes
11	02' 16" N 30' 18" W	None			None			Found an eaten Cryptochiton	Nereocystis	-10	Laminaria Desmarestia	-9	Interrupted otter feeding here Females with pups
12	03' 44" N 29' 05" W	None			None			Broken Hinnites Lots of filter feeders Broken clams common Broken Astraea	Nereocystis	0-10	Laminaria Pterygophora Phyllospadix in shallow	0-10	Previously not otter foraged Otters now present
13	05' 44" N 29' 40" W	None			8	57-74	10-25'	One S. purpuratus seen Lots of urchin tests and empty abalone shells	Macrocystis	5-10	Pterygophora Laminaria setch.	3-11	Previously not otter foraged Nereocystis present in mixed Macrocystis canopy - in surrounding areas Lots of broken abalone shells
14	06' 54" N 36' 30" W	None			1	empty shell 56-64mm		Loads of Tegula with hermit crabs	Macrocystis	3-10	Phyllospadix Egregia Pterygophora Agarum	0-8	Previously not otter foraged Otters now present
15	06' 34" N 37' 08" W	1 seen	50 under rock	25'	Broken shells only	51-97mm		Absence of molluscs Lots of stars	Macrocystis	5-8	Egregia Phyllospadix L. setchellii no real understory	0-5	Previously not otter foraged Otters now present
16	06' 04" N 37' 42" W	Not Sampled											Otters seen foraging here in 1987/ Not sampled
17	04' 58" N 31' 36" W	None			None			Broken Astraea and clams	Macrocystis Nereocystis	4-10	Pterygophora Laminaria Eisenia Costaria	3-10	Very established kelp community Previously otter foraging site
18	04' 45" N 30' 52" W	None			Broken shells only			Lots of stars Dermastarias Pycnopodia Solaster	Macrocystis	5-12	Laminaria sp. Desmarestia Phyllospadix	0-12	Very thick Macrocystis canopy
19	04' 14" N 33' 20" W	None			None			P. ochraceus common, very big	None-Nereocystis Present		Desmarestia Costaria L. setchellii Alaria	0-12	exposed site

depths and recruited to disturbed patches within established perennial kelp beds. As suggested by Breen et. al. (1982) the abundance of N. luetkeana, at otter dominated sites is probably maintained by physical disturbance.

Macrocystis integrifolia dominated the canopy at sites 13, 14, 15, and 17 which are all relatively sheltered. Otters were rarely seen at these sites during the summer. The abundance of algae and the absence of urchins, in contrast to earlier observations, (Breen et. al. 1982, Table 6) suggested that otter foraging had occurred. Broken urchin tests and abalone shells were collected from sites 13 and 17. Observations made in January and February 1989, indicate that all of these sites are used extensively by otters during winter storms. These sites are sheltered and provide protection for rafting otters (particularly females with pups). The absence of physical disturbance may competitively favour M. integrifolia and prohibit the growth of N. luetkeana. Seasonal and weather related sea otter movements are difficult to infer by observations of the benthic community alone.

In Checleset Bay Desmarestia ligulata and N. luetkeana dominated sites at the edge of the otters' geographic range, while perennial kelps such as P. californica and Laminaria spp. were largely absent. The abundance of perennial species at all of the sites re-occupied by otters, since the 1979 survey, suggests these sites have all been exposed to otter foraging for some time.

Observations made by Breen et. al. (1982) are substantiated by this survey. Changes inferred to be a result of otter foraging have been documented by comparing the 1979 observations to the 1987 - 1988 observations of the same sites nine of which have since been occupied by sea otters. The geographic range of otters has expanded to include all of the previously unforaged sites. Differences due to the presence and absence of otters have been eliminated.

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