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manuscript
Running head: Subtidal communities and sea otters

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Changes in subtidal community structure resulting from
the British Columbia sea otter transplants

by

Paul A. Breen¹, Trudy A. Carson², J. Bristol Foster², & E. Anne Stewart^{3,4}

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¹Department of Fisheries and Oceans

Resource Services Branch

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

²Ecological Reserves Unit, Ministry of Lands, Parks & Housing, Victoria, B.C.

³Box 26, Bamfield, B.C.

⁴Priority of authorship is alphabetical.

Abstract

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Sea otters (Enhydra lutris) were introduced to B.C. in 1969-1972, after being hunted to extinction in the previous two centuries. In 1979, we visited the area known to be occupied by 55 animals in 1978, and made subtidal observations of the abundance and distribution of red sea urchins, other grazers, and kelps. Where sea otters were known to have fed, red sea urchins (Stongylocentrotus franciscanus) were scarce and restricted to crevices or the areas beneath boulders; other grazers were scarce, and kelps colonized the bottom to as deep as 10 m. Where sea otters had not fed, kelps were limited to shallow water by abundant sea urchins. The algal communities in sea otter grazed areas appear to be simple downward extensions of the previous sublittoral fringe communities.

Observations made in the feeding range prior to the introduction of sea otters confirm that changes in subtidal communities have taken place since the introduction. These changes are probably caused by early decimation of sea urchins by sea otters, as has been reported from Alaska and California. From the pattern of sea urchin abundance in the area, we were able to delineate roughly the range now used by this small population of sea otters.

Introduction

Sea otters (Enhydra lutris) were once abundant along the outer coast of British Columbia. They were hunted intensely after Cook's third voyage, which touched at Nootka Sound in 1778. By 1900 they were scarce (Moon 1978), and the last confirmed record of a live specimen was made in 1929 (Cowan and Guiguet 1965).

Sea otters are a voracious predator of fish and a wide range of benthic invertebrates (Kenyon 1969), and their impact on the structure of subtidal communities is dramatic and well described. In the Aleutian Islands, islands with sea otters have only low numbers of sea urchins (Strongylocentrotus polyacanthus), which are small and restricted to crevices or deep water (Estes and Palmisano 1974; Estes et al. 1978). Islands without sea otters have numerous large and exposed sea urchins, which occur in shallow water. At islands without sea otters, sea urchin grazing prevents the development of subtidal macrophytes; but where sea otters are present kelp associations grow to at least 24 m below MLLW. Other invertebrates such as mussels and chitons show clear differences in distribution, abundance and size as a result of sea otter predation. In areas populated by sea otters, increased kelp abundance and primary productivity has also led to increased fish and harbour seal abundance.

In California, the expanding sea otter population has had a similar impact on the sea urchins S. franciscanus and S. purpuratus. McLean (1962) and Ebert (1968) reported large decreases in sea urchin

abundance after sea otters migrated into new feeding areas. In an area occupied by sea otters since the early 1960's, Lowry and Pearse (1973) found that both sea urchins and abalone (Haliotis spp.) were small, reduced in abundance from previous levels, and restricted to crevices. Cooper et al. (1977) repeated the observations on abalone, and found that abalone size and abundance remained low. Since abalone are important to both commercial and recreational harvests, changes in abalone abundance caused by sea otters have become an important and controversial problem (Bissell and Hubbard 1968; Cicin-Sain et al. 1977).

Sea otters were re-introduced into British Columbia in three separate transplants from 1969 to 1972 (Bigg and MacAskie 1978). Eighty-nine individuals were moved from Amchitka Island and Prince William Sound, Alaska, to the Bunsby Islands (Fig. 1) near Kyuquot. An aerial survey made in 1977 (Bigg and MacAskie 1978) found a population of 55 animals remaining in the area, and a separate colony of 15 individuals near Nootka Sound. Another aerial survey made in 1978 confirmed these numbers (Michael Bigg and Graeme Ellis; personal communication).

Sea otters observed in the Bunsby Islands group during the summer of 1978 (Morris et al. in prep.) fed mostly on unidentified clams, and also on red and purple sea urchins (S. franciscanus and S. purpuratus). The red sea urchin limits the vertical distribution of kelp on the outer British Columbia coast (Pace 1975; Low 1975; Druehl 1978); and, as in many systems worldwide, large shallow

Kelp harvesting for direct use and red sea urchin harvesting for export of their gonads to Japan are both being investigated as sources of resource revenue in B.C. The commercial abalone fishery (Haliotis kamtschatkana) is currently valued at over \$1 million (landed value, 1979). An understanding of the impact of sea otters on these elements of the subtidal community is essential, especially if the transplanted colony expands from its present range or if further transplants are proposed.

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Study Site and Methods

The transplant site and surrounding area are shown in Figure 1. The otters were released within the Bunsby Islands, and

ve since been observed at the southernmost edge of the Bunsby Island group, at the Clara Islet complex of rocks, at Gull Islet, and at the Farout Rocks (Morris et al. in prep; our observations).

Within the area shown in Figure 1, there is a wide range of wave exposure conditions. The inshore area among the Bunsby Islands is very sheltered and supports soft bottom communities; the Farout Rocks are directly exposed to oceanic swells. The complex of reefs and rocks frequented by the present population of sea otters is formed by solid, jagged rock masses projecting through the flat sand or shell bottom. The reefs vary considerably in individual depth and topography.

During the period September 21-24, 1979, underwater observations were made with SCUBA at the 19 sites shown on Figure 1. These are described in Table 1. At each site, two divers made notes on substrate type and slope at various depths; dominant algae in the overhead canopy, the understory, the turf and on the rock itself; the estimated percent cover of algal dominants; depths at which major algal changes occurred; the estimated density and size ranges of red sea urchins and abalone; the estimated density or percent cover of the most abundant invertebrates; and the presence of abundant fishes were identified visually as far as possible. Algal species were collected and preserved for further identification by EAS.

Depths were read from divers' depth gauges, and were later corrected from tide tables to depths below chart datum (at this location, chart datum is 0.77 m below MLLW). Depths reported here are

1 given as meters below chart datum unless otherwise indicated. Because
2 of the strong surge at most sites, the intertidal zone could not
3 always be examined systematically.

4 Notes were also made on the location and number of sea
5 otters seen during diving trips. No serious attempt was made to count
6 the sea otters in the area as a whole, as a proper count can be made
7 only from the air; or to establish from sightings where the sea otters
8 were feeding, as this had been done extensively the previous summer.

9 At the surface, underwater notes were transcribed into
0 summary observations. The divers present on each dive consulted each
1 others' notes to resolve differences. Although we tried to be as
2 objective and quantitative as possible, these observations are not
3 entirely objective, and our numerical results might be difficult to
4 compare statistically. The method used can be justified on two
5 grounds: first, the only choice was between doing the study in this
6 way and not doing it at all; second, the changes observed are obvious
7 enough that they are easily demonstrated by descriptive observations.

9 Results

1 For brevity, only a summary of observations will be
2 presented here (Table 1). Detailed observations are presented
3 elsewhere (Stewart et al. 1980).
4

a otter observations

Several groups of sea otters were seen, but only in the areas listed by Morris et al. (in prep.). One group contained at least 11 individuals, other groups were smaller. The animals were retiring and could not be approached within 50 m.

Subtidal observations

Our observations are divided into three groups of sites: known sea otter feeding sites, sites where sea otters have not been seen and presumably had not fed; and sites with unknown status.

1. Known sea otter feeding sites

As indicated in Table 1, we dove at 7 locations (sites 1-4, 6, 8, and 19) where sea otter feeding had been observed. Red sea urchins were extremely scarce. Less than a dozen were seen at each of 6 sites, mostly in crevices or under overhangs. At the remaining site their density reached 2/m², but all were in deep fissures or under boulders in relatively deep water (10-15 m). Sea urchins seen under boulders ranged to an estimated 150 mm in test diameter, but all those seen in crevices were less than 100 mm.

Kelp was extensive at these feeding sites, and the increased biomass was apparent even from an aircraft. The major algal dominants and their distribution were similar at all 7 sites. In every case Nereocystis luetkeana formed a dense surface canopy, and the understory contained Pterygophora californica, Laminaria setchellii,

1 Cinararia spp., or a mixture of these. These algae began in shallow
2 water, usually below a band of the basket grass Phyllospadix scouleri
3 near datum. The kelp community continued deeper until either the
4 bottom changed to shell (at 3 sites) or depth reached 7-10 m on
5 continuing substrate.

6 There was a characteristic turf of bladed red algae with a
7 high percent cover underneath the kelps. The most important and
8 consistent species were Constantinea subulifera and C. simplex
9 (forming 10-75% cover); Gigartina spp.; Botryoglossum farlowianum;
0 Opuntiella californica; Iridaea spp. and Laurencia spectabilis. Large
1 quantities of algal drift and detritus were found trapped in crevices
2 and depressions.

3 Cover of the rock surface itself was variable. Foliose
4 coralline algae and Codium setchellii were often important but equally
5 often absent. At some sites, large barnacles (Balanus nubilus)
6 covered much of the primary space, and were being eaten by dense
7 aggregations of the starfish Pisaster ochraceus. Along with these
8 barnacles, the rock surface was richly encrusted with bryozoans,
9 hydroids, sponges, colonial ascidians, tunicates (especially Styela
0 montereyensis) and sea anemones (especially Metridium senile, Tealia
1 piscivora, T. crassicornis and Epiactis prolifera).

2 Abalone were abundant only at one site, where all were under
3 rocks in broad fissures. At the six remaining sites, no more than 18
4 abalone were seen in all. Only one abalone over 100 mm length was
5 seen; the remainder ranged from 20-80 mm.

Potential food items for sea otters seemed scarce. In the 7 feeding sites, we saw only one red turban snail (Astraea gibberosa) and one sea mussel (Mytilus californianus), although the latter were numerous in the intertidal zone at these sites. No more than 6 keyhole limpets (Diodora aspera), rock scallops (Hinnites giganteus), green sea urchins (S. droebachiensis), or purple sea urchins were seen at any of these sites. Crabs were mostly lithode species, small and hidden. The small snails Ceratostoma foliatum, Amphissa columbiana, Collisella ochracea, and Acmaea mitra reached densities of 1-5/m² at all these sites. Tegula pulligo was very dense (up to 50/m²) in and near the kelp, and hermit crabs inhabiting Tegula shells reached even greater densities.

2. Non-feeding sites

From the observations made during the summer of 1978 (Morris et al. in prep.), sea otters had apparently not fed at sites 9, 14, 15 and 16; nor did they range as far west as site 5.

The distribution and abundance of red sea urchins at each of these 5 sites was very different from the 7 sites just described. Estimated density reached at least 5-10/m². Sea urchins formed a distinct and usually barren zone with an upper limit at 0.5-2.0 m; except that this boundary was at 5 m at the more exposed site 5. Most of these individuals were found crowded on the open rock faces and boulder faces. At several sites, the majority were greater than 100 mm diameter. Green sea urchins reached 4/m² in the sublittoral fringe at one site, but were only sporadic elsewhere.

1 The dominant kelps at these sites were essentially the same
2 species as in sea otter feeding areas, but their distribution was
3 markedly different. Nereocystis was the canopy species at three
4 sites; Laminaria setchellii was the major undercanopy dominant at all
5 five sites; Pterygophora and Eisenia were present at one site.

6 At sites 5, 9, and 14, kelp extended down to the top of the
7 sea urchin zone, then stopped abruptly, and sea urchins continued
8 deeper. At sites 15 and 16, most kelps stopped where sea urchins
9 began, but Nereocystis was found growing from the tops of high
0 boulders in the otherwise barren areas dominated by sea urchins. At
1 both places, sea urchins were found grazing on these plants.

2 Bladed red algae in the dense turf were again dominated by
3 Gigartina spp., Botryoglossum farlowianum, Iridaea spp. and
4 Constantinea spp. These red algae were absent from sea urchin
5 barrens. The rock surface under the kelps was covered with encrusting
6 organisms, as described for the feeding areas, but large numbers of
7 Balanus nubilus were not observed, and Pisaster ochraceus was
8 restricted to the upper subtidal and intertidal zones.

9 Within the sea urchin barrens, encrusting fauna were not
0 abundant except on vertical surfaces. Encrusting coralline algae
1 (Lithothamnion and related genera) and the colonial polychaete
2 Dodecaceria fewkesi dominated nearly all primary space. Chitons
3 (Tonicella lineata) and limpets (Acmaea mitra and Collisella
4 ochracea) were numerous in the barrens.

Abalone were scarce or absent at two sites, but reached densities of 1-10/m² at three sites. They were mostly exposed, and at one site reached 135 mm in length.

Astraea were noted in densities up to 0.5/m² at 2 sites. Except for this species, no species had obviously greater abundance at non-feeding than at feeding sites. Tegula were much less abundant at these sites, and were found only in association with kelps.

3. Other sites

At sites 7, 10-13, 17 and 18, we had no information as to whether sea otters had fed there or not. Based on the observations just reported, red sea urchin distributions seem useful in determining whether otters have fed at a site. At site 7, no sea urchins were seen, and dense Nereocystis and Laminaria covered the rocks to 5 m, where a flat shell floor began. From the complete absence of sea urchins, we inferred that this site must have been foraged by sea otters. Site 10 comprised a group of boulders on a flat shell floor 7 m below datum. There were no sea urchins, but the effects of surge even at this depth (8.5 m below the surface) were pronounced even on a calm day. The absence of sea urchins could be explained by the extreme exposure.

At site 11, red sea urchins were present at 7 m (the shallowest part of the reef where we dove) but were rare and restricted to crevices. They became more exposed and numerous with increasing depth. At 13 m they reached local maxima of 2/m², but were

very irregularly distributed. Nereocystis extended to 10 m as in sea otter feeding areas. We found one broken test, with irregular edges, that may have been broken by a sea otter. We considered this to be a sea otter feeding site.

Site 12 was clearly not a place where sea otters had fed. Nereocystis extended only to 5 m, and red sea urchins were abundant both within the kelp and below it. Site 13 was also not a feeding site. It was dominated by sea urchins below 2 m, and kelps were restricted to the upper subtidal zone. Abalone were abundant from +0.5-5 m. This was one of only three sites at which abalone greater than 100 mm were found.

At site 17, red sea urchins were present at low densities from 6-12 m, allowing only sparse canopy species to grow there. They were found only under boulders and in crevices, however, indicating that sea otters may have fed here. The complete absence of sea urchins at site 18, where kelps extended to 6-8 m, indicated that sea otters had probably fed there.

Further observations

Our notes on fishes were not systematic enough to permit a comparison of feeding and non-feeding areas. We noted large schools of black rockfish (Sebastes melanops) and juvenile rockfish (Sebastes sp. or spp.) in the kelp at sea otter feeding sites and at site 13.

Harbour seals (Phoca vitulina richardi) were seen in small numbers both within and without the feeding range of sea otters; and sea lions were seen at two places outside the range. These observations were too sparse to support any generalization.

Discussion

The pattern made by these observations is clear; and it is consistent with the ecology of sea otters, sea urchins and kelps in other parts of the northeast Pacific. Where sea otters are known to feed, sea urchins are rare and algae are extensive. Elsewhere, red sea urchins dominate the subtidal zone except for a shallow fringe to which kelps are restricted.

Observations were made in this area by fishermen before the transplant (Kayra, personal communication), and in 1972 in association with the last transplant (Miller, unpublished MS [contained in Stewart et al. 1980]; Quayle, unpublished obs.). These sources are consistent in reporting that, at Clara and Gull islets and in the southern edge of the Bunsby Islands, red sea urchins were dense and obvious from the surface, and kelp was correspondingly restricted to shallow water. From this previous evidence, it seems certain that the present absence of sea urchins has resulted from sea otter predation. Abalone and turban snails were also present in lower numbers and smaller sizes where sea otters had fed.

In the absence of sea otters, the role of red sea urchins in preventing the downward extension of kelps has been well documented by experimental removals and descriptive observation (Pace 1975; Low 1975; Druehl 1978). The boundary between deeper sea urchins and shallower kelps is essentially stable but varies in depth from place to place. Depth of the boundary is determined by factors associated

1 with water mixing and movement, substrate type, and slope (Pace 1975;
2 Breen in prep.). Since the extinction of sea otters, kelp has existed
3 in shallow refuges whose size is determined by local hydrography and
4 topography.

5 The algal communities observed by Estes et al. (1978) on
6 Aleutian Islands with sea otters were structured by competitive
7 relations among the algae, which were elucidated by Dayton (1978).
8 Competitive relations among the algae we observed have not been
9 studied; and even systematic descriptions of distribution or
0 succession in B.C. kelps are rare. However, it appears that the
1 communities observed are probably not structured entirely by
2 interspecific competition. The major canopy species is not a
3 successional dominant, and the other kelps frequently occurred in
4 mixed stands. Within the areas inhabited by sea otters, we observed
5 canopies of Nereocystis with mixtures of Pterygophora and
6 Laminaria spp. underneath. We concluded that these communities can be
7 interpreted as downward extensions of the associations in refuges. In
8 experimental (Vadas 1968) and descriptive (Foreman 1977) studies of
9 the effect of sea urchin grazing on algal communities, the annual kelp
0 Nereocystis was found to be a temporary successional form later
1 out-competed by Laminaria; and the presence of Nereocystis may
2 indicate disturbance. The presence of mixed stands of Pterygophora
3 and Laminaria in the undercanopy also show that competition between
4 species has not reached an end point in competitive dominance.
5 Nereocystis is commonly ripped up from the bottom by fall and winter

1 storms, and this may clear enough space for sporophytes to colonize in
2 the following spring. Another alternative is that grazing by chitons
3 and limpets is a sufficient disturbance to allow the persistence of
4 competitively inferior kelps.

5 If we have interpreted all the sites correctly, sea otters
6 seem to be restricted to a discrete area that is easily characterized
7 by the absence of sea urchins, even though areas nearby have abundant
8 sea urchins. We conclude that sea otters have fed in an area roughly
9 26 km², part of which may be too deep for efficient feeding. The
0 carrying capacity of sea otter habitat is reported to be 4-30/km²
1 (Kenyon 1969; Estes et al. 1978, respectively).

2 We used the absence of red sea urchins to determine the
3 feeding range of this population of sea otters. Observers in
4 California (McLean 1962; Ebert 1968; Kenyon 1969) report that sea
5 urchins disappear rapidly when sea otters first occupy a new area, and
6 that other species are eaten after sea urchins have disappeared. In
7 finding that Bunsby Island sea otters ate mostly clams in 1978, Morris
8 et al. (in prep.) confirm this observation. These clams presumably
9 exist at depths which we were unable to explore. In addition, the
0 existence of abundant less preferred (hence unexploited) food items
1 such as Tegula and intertidal sea mussels indicates that the present
2 range is still able to support the sea otter population. Against
3 this, the partly exploited sea urchins at site 12 indicate a recent
4 feeding range expansion.

1 In November 1977 an Ecological Reserve was proposed in
2 Checleset Bay for protection of sea otter habitat (Krajina et al.
3 1978). The area of the proposed reserve is approximately 10 times the
4 feeding range of sea otters inferred from this study, leaving plenty
5 of space for future increases in this population.

6 7 Acknowledgments

8
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TABLE 1

Site #		INVERTEBRATES					
		Red sea urchins			Abalone		Other
Lat 50° Long 127°		Density (#/m ²)	Size (mm)	Depth (m)	# seen	Size (mm)	
1							
02' 00" N 33' 25" W		only 8 seen	30-80	6 in crevice	1	<100	6 <u>Balanus nubilus</u> and <u>Pisaster ochraceus</u> to 9
2							
03' 28" N 34' 08" W		none			<10	<100	6-9 heavy encrusting fauna
3							
03' 48" N 35' 00" W		only 4 seen	30-80	3-6	none		<u>B. nubilus</u> , <u>P. ochraceus</u> , heavy encrusting fauna
4							
04' 20" N 35' 08" W		only 10 seen		4	5	20-70	4 <u>B. nubilus</u> , <u>P. ochraceus</u> heavy encrusting fauna
5							
06' 00" N 44' 24" W		10-15	20-150	5-13+	2	50	5.5 heavy encrusting fauna 0-5 m deep
6							
04' 20" N 32' 48" W		only 1 seen	20	7	many	30-60	3-6 Abalone under stones in a fissure
7							
05' 00" N 32' 58" W		none			6	?	0-4 <u>Tegula</u> extremely abundant
8							
04' 28" N 35' 16" W		0-2 under boulders	20-120	10-15	1	50	8 encrusting fauna heavy on vertical surfaces
9							
06' 15" N 35' 40" W		10-15	20-100	1-8	to 1/m ²	<100	0.5-2 <u>S. droebachiensis</u> to 1/m ² , <u>Astraea</u> to 0.1/m ²
10							
00' 45" N 31' 25" W		none			none		heavy encrusting fauna
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. <u>B. nubilus</u> to 80% cover
12							
03' 44" N 29' 05" W		10-20		5-6	to 0.2/m ²	30-80	3-6 Sea urchins in a narrow band below kelp
13							
05' 44" N 29' 40" W		0.5-1		3-8	to 10/m ²	50-130	+1-5
14							
06' 54" N 36' 30" W		5-10		0.5-1.5	none		
15							
06' 34" N 37' 08" W		10		0-3	to 2/m ²	50-135	4-6
16							
06' 04" N 37' 42" W		10+		2-5	to 10/m ²	40-80	2-8
17							
04' 58" N 31' 36" W		<1		6-12	none		Sea urchins under boulders or in crevices only
18							
04' 45" N 30' 52" W		none			none		dense <u>Metridium</u> on steep vertical surfaces
19							
04' 14" N 33' 20" W		only 1 seen	100	1	2	50-60	3-6 encrusting fauna on verticals

KELP

Canopy		Undercanopy	
Species	Range (m below datum)	Species	Range (m below datum)
<u>Nereocystis</u>	1.5-9	<u>Pterygophora</u> <u>L. setchellii</u>	0-10
<u>Nereocystis</u>	?-7.5	sparse: <u>L. setchellii</u> bladed reds	?-7
<u>Nereocystis</u>	1-7	<u>L. setchellii</u> bladed reds	+1-7 7-9
<u>Nereocystis</u>	?-7	<u>L. setchellii</u> <u>Dictyota</u> bladed reds	3-6.7 3-10
none		<u>L. setchellii</u> <u>Laminaria</u> sp. <u>Pterygophora</u> <u>Eisenia</u>	0-5
<u>Nereocystis</u> <u>Macrocystis</u>	0-7 near 0	<u>L. setchellii</u> <u>Laminaria</u> spp. <u>Pterygophora</u> <u>Costaria</u>	0-7
<u>Macrocystis</u>	0-3	<u>Laminaria</u> spp. <u>Pterygophora</u>	0-5
<u>Nereocystis</u>	0-10	<u>L. setchellii</u> <u>Phyllospadix</u>	0-1.8
none		<u>L. setchellii</u> <u>Phyllospadix</u>	0-1.2
<u>Nereocystis</u>	?-7+	<u>L. setchellii</u> <u>Pterygophora</u> <u>Phyllospadix</u>	?-7+
<u>Nereocystis</u>	?-10	<u>L. setchellii</u> <u>Pterygophora</u>	?-9
<u>Nereocystis</u>	3.5-5	<u>L. setchellii</u> <u>Desmarestia</u> <u>Ligulata</u>	3.5-5
none		<u>L. setchellii</u> <u>Egria</u> <u>Alaria</u> spp.	+1-1.5
<u>Macrocystis</u> (dense)	disjunct 0-0.5 3.5-4.5	<u>Agarum</u> sp.	3.5-4.5
<u>Nereocystis</u>	boulder tops only	none	
<u>Nereocystis</u>	boulder tops only	<u>L. setchellii</u> <u>Phyllospadix</u>	0-2
<u>Nereocystis</u> (sparse)	7	<u>L. setchellii</u> <u>Costaria</u>	0-6
<u>Nereocystis</u>	6-8	none	
<u>Nereocystis</u>	1.5-7	<u>L. setchellii</u> <u>Pterygophora</u>	1.5-7

KELP

Canopy		Undercanopy	
Species	Range (m below datum)	Species	Range (m below datum)
<u>Nereocystis</u>	1.5-9	<u>Pterygophora</u> <u>L. setchellii</u>	0-10
<u>Nereocystis</u>	?-7.5	sparse: <u>L. setchellii</u> bladed reds	?-7
<u>Nereocystis</u>	1-7	<u>L. setchellii</u> bladed reds	+1-7 7-9
<u>Nereocystis</u>	?-7	<u>L. setchellii</u> <u>Dictyota</u> bladed reds	3-6.7 3-10
none		<u>L. setchellii</u> <u>Laminaria</u> sp. <u>Pterygophora</u> <u>Eisenia</u>	0-5
<u>Nereocystis</u> <u>Macrocystis</u>	0-7 near 0	<u>L. setchellii</u> <u>Laminaria</u> spp. <u>Pterygophora</u> <u>Costaria</u>	0-7
<u>Macrocystis</u>	0-3	<u>Laminaria</u> spp. <u>Pterygophora</u>	0-5
<u>Nereocystis</u>	0-10	<u>L. setchellii</u> <u>Phyllospadix</u>	0-1.8
none		<u>L. setchellii</u> <u>Phyllospadix</u>	0-1.2
<u>Nereocystis</u>	?-7+	<u>L. setchellii</u> <u>Pterygophora</u> <u>Phyllospadix</u>	?-7+
<u>Nereocystis</u>	?-10	<u>L. setchellii</u> <u>Pterygophora</u>	?-9
<u>Nereocystis</u>	3.5-5	<u>L. setchellii</u> <u>Desmarestia</u> <u>Ligulata</u>	3.5-5
none		<u>L. setchellii</u> <u>Egregia</u> <u>Alaria</u> spp.	+1-1.5
<u>Macrocystis</u> (dense)	disjunct 0-0.5 3.5-4.5	<u>Agarum</u> sp.	3.5-4.5
<u>Nereocystis</u>	boulder tops only	none	
<u>Nereocystis</u>	boulder tops only	<u>L. setchellii</u> <u>Phyllospadix</u>	0-2
<u>Nereocystis</u> (sparse)	7	<u>L. setchellii</u> <u>Costaria</u>	0-6
<u>Nereocystis</u>	6-8	none	
<u>Nereocystis</u>	1.5-7	<u>L. setchellii</u> <u>Pterygophora</u>	1.5-7

Comments

Kelp detritus abundant
Known sea otter feeding site

Known sea otter feeding site

Known sea otter feeding site

Known sea otter feeding site

Not a feeding site.
Upper algal zone, lower sea urchin barrens

Known sea otter feeding site.
Shell bottom deeper than 7 m

Inferred feeding site.
Most algae stopped at shell floor, 5 m

Known sea otter feeding site

Concluded to be a non-feeding site

Very exposed site; only 1 depth examined

Inferred sea otter feeding site

Concluded not to be a feeding site

Concluded not to be a feeding site. Algae
only on reef tops and very shallow water

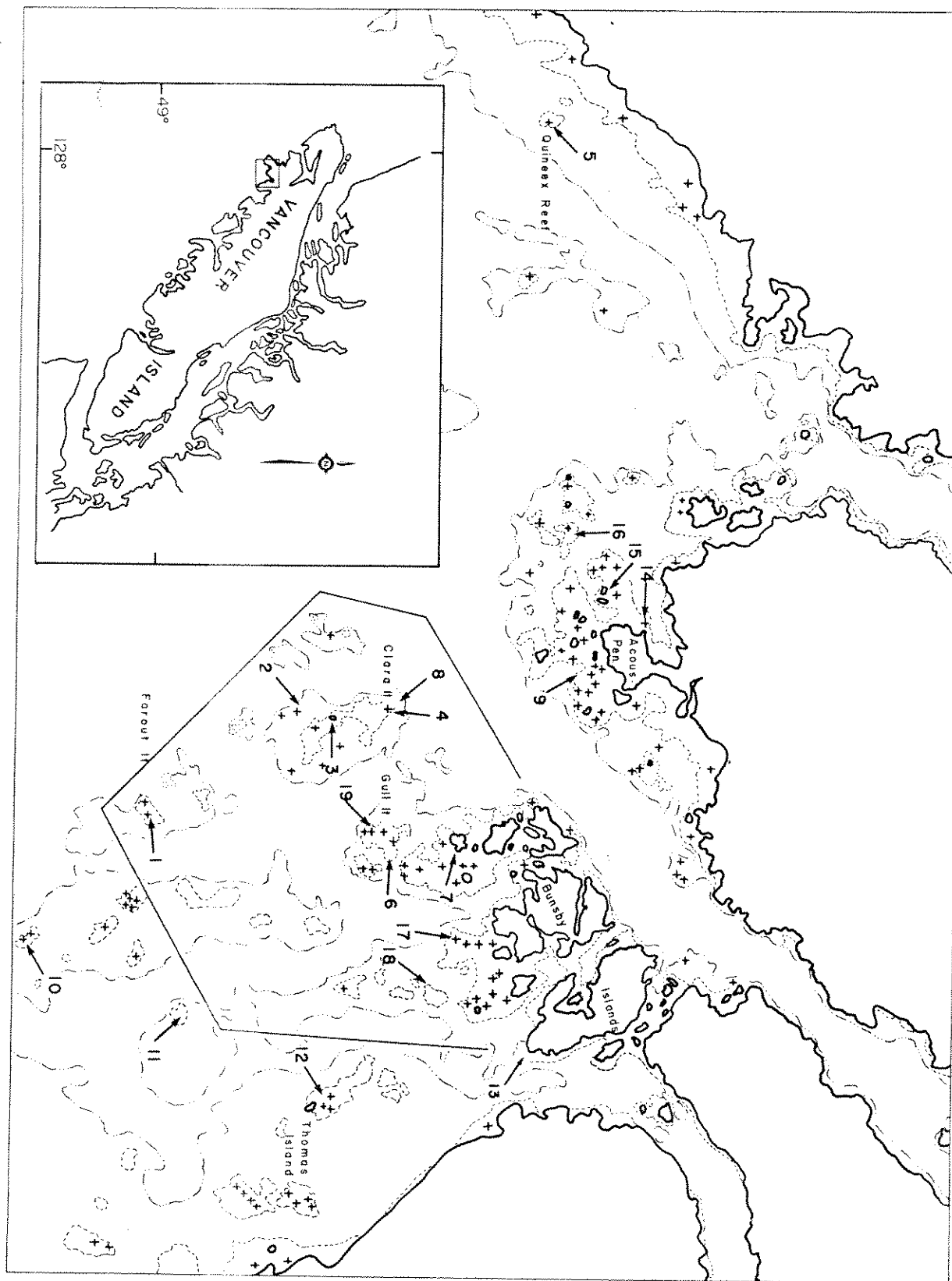
Concluded not to be a feeding site

Concluded not to be a feeding site

Concluded not to be a feeding site

Concluded to be a feeding site

Concluded to be a feeding site



CAPTIONS FOR ILLUSTRATIONS

Fig. 1. The solid line encloses the area occupied by sea otters.