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Pacific Harbor Seal *(Phoca vitulina richardii)*. Haul Out Impact on the Rocky Midtidal Zone

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ABSTRACT: A study of haul out and adjacent non-haul out rocks of the Pacific harbor seal *Phoca vitulina richardii* (Gray), Rice, on the Monterey Peninsula of California (USA), revealed significant differences in algal morphology and per cent composition, and in numbers of animals present. It is suggested that the mechanical and chemical impact imposed by the seals on the haul out sites are responsible for these differences.

INTRODUCTION

Previous studies on the environmental impact of the common harbor seal *Phoca vitulina* (Linnaeus) have focused on effects related to the fishing industry (Bonnot, 1932; Caldwell, 1972; Newby, 1978; Boulva, 1979). A review of the literature revealed no work on impact regarding any other aspect of the marine community. Paulbitsky (1975) reports that 50–200,000 seals are hauling out at regular sites of different kinds around the world. The study reported here was undertaken to determine if hauling out is affecting the rocky intertidal community. The report details the differences between the size and distribution of organisms within quadrates on existent haul out rocks and those on nearby control rocks picked to be as similar as possible to the haul out rocks. Since seals were neither excluded from an established haul out site, nor made to haul out in a new area, direct causality could not be demonstrated.

MATERIALS AND METHODS

Research was done between April and June and between August and October of 1979, on the Monterey Peninsula in California, USA. Three paired groups of haul out and control rocks were chosen, two paired groups at Hopkins Marine Station of Stanford University, and one paired group at Stillwater Cove, Pebble Beach. Each group of rocks was bordered by water at least 1 m deep at low tide. Rocks examined ranged in height from 0 to 2 m above mean lower low water.

The primary study area consisted of Seal Island (SI), a small rocky island about 50 m off Hopkins Marine Station shore where about 30 seals have been hauling out for over 5 years (Abbott and Baldridge, personal communication). The Island is also inhabited by birds, primarily seagulls and cormorants. It was arbitrarily divided into two sampling areas. Six clusters of control rocks along the nearby shore were chosen to be as much like the island as possible (Table 1).

A second sample area of haul out (HO) and non-haul out (NHO) rocks was located at Bird Island (BI), a rocky island just north of Seal Island. Part of this island was the occasional haul out site of about 6 seals. The control area for this haul out site was a group of rocks that appeared identical in all ways except that they were closer to the mainland and had less direct access to the open bay water.

The third comparison group of rocks was located at Stillwater Cove (SWC) where approximately 8 seals have hauled out regularly. Haul out rocks were those rocks not directly connected to the shore, plus a pair of large, sloping rocks jutting out into the cove. The non-haul out control sites chosen consisted of rocks that seemed different only in that they lay closer to the main shore.

Individual rocks within these areas were chosen by random number coordinate systems. Where the shore was more or less linear, the first random number coordinate determined the distance along the shore from some arbitrary point, and the second random number coordinate determined the distance in from the water, on an axis perpendicular to the shoreline. Where rocks lay in clusters, a different system was

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Table 1. Comparisons of haul out versus control non-haul out sites show few differences other than seal presence or absence and shore-land connection

	Site #	Direction of exposure	Direction area faces	Type of exposure	Rock size (diameter in m)	# Seals	Comments		Direction of exposure	Direction area faces	Type of exposure	Rock size (diameter in m)	Comments
SEAL ISLAND	1	NE	S, W	Indirect, moderate-light	0.3–1.5	31	Birds, 5 % of rocks have sandy bases	1	E	S, E	Direct, light	0.3–3.5	10 % sandy bases
	2	NE	W	Indirect, moderate-light	0.3–1.5		Birds, 5 % of rocks have sandy bases	2	N, E	N, E	Direct, light	0.3–2	15 % sandy bases
								3	N, E	E	Direct, moderate	0.3–1.5	30 % sandy bases
								4	E	E	Indirect, moderate	0.3–2.5	Birds, 20 % sandy bases
								5	S, N	SE	Indirect, light	0.3–3	Birds, 5 % sandy bases
								6	E	S	Indirect, moderate	0.3–2	Birds, 2 % sandy bases
BIRD ISLAND	1	NE	*	Indirect, moderate	0.4–3	6	Birds, *small islands	1	N (E)	*	Indirect, moderate	0.3–3	Birds, *small islands
STILL-WATER COVE	1	S	S	Direct, moderate-heavy	2–5	8	Top = gradual slope. Sides fall off sharply to deep water	1	S	SE	Indirect, moderate-heavy	1–6	Top = gradual slope. Sides fall off sharply to deep water
	2	S	E	Indirect, moderate-heavy	2–4		Top = moderate slope. Sides fall off sharply to deep water	2	S	E (S, N)	Direct, heavy-moderate	2–6	Top = moderate slope. Sides fall off sharply to deep water
	HAUL OUT SITES								NON-HAUL OUT SITES				

* Since these sites were on small islands, they faced all directions.

used. An arbitrary point at approximately the center of the cluster was chosen. Then, the first random number determined the angle from some arbitrary fixed point, and the second number, the distance from the point in that angular direction.

For the algal studies, 40 × 40 cm quadrates were used on the rock tops, and four 20 × 20 cm quadrates were used on the rock sides. Stillwater Cove is an exception to this; 40 × 20 cm quadrates were used for the rock sides, due to the very large rock sizes. Quadrates were subdivided into 4 × 4 cm squares, and the number of small squares a given type of algae occupied was converted to a percent cover of the total sampling area. Exceptions to this procedure are noted in the text.

For animal studies, the 40 × 40 cm rock top quadrates were also used. Animals on rock sides, however, were counted within a band of 5 cm on either side of four 50 cm transect lines running down the rock sides.

Fronds and holdfasts sampled were chosen by random number coordinates within the quadrates, and small animals were counted under a dissecting scope from 6.5 cm^2 holdfast samples.

RESULTS

Effects on Algae

Seventeen species of algae were studied for cover differences. Three were found to differ significantly between haul out and non-haul out sites.

Per cent cover of *Gigartina canaliculata* (Harvey) was found to be significantly greater on all areas of haul out rocks (Fig. 1). At Bird Island, the percent cover

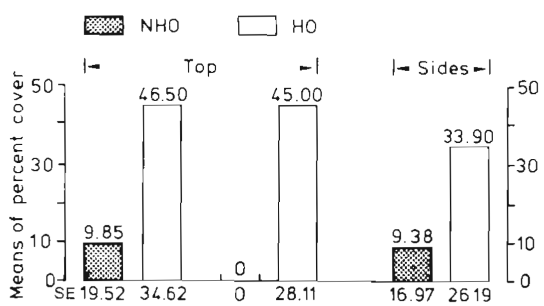

Fig. 1. *Gigartina canaliculata*. Percent cover differences are significant (Student's *t*-test). NHO: Non-haul out sites; HO: haul out sites. SI (Seal Island): $n_{NHO} = 65$, $n_{HO} = 26$, $t_{TOP} = 6.39$, $t_{SIDES} = 3.01$. BI (Bird Island): $n_{NHO} = 50$, $n_{HO} = 60$, $t = 11.31$. SE: standard error

was determined by random point identifications rather than simple percent cover, and was significantly different at haul out and non-haul out sites, with $p << 0.001$.

There was a significantly higher ($p << 0.001$) percent cover of *Ulva californica* on the tops of the haul out rocks at Stillwater Cove (Fig. 2). While the percent cover did not differ significantly elsewhere, there was an overall greater occurrence of *U. californica* on the tops of haul out rocks at Seal Island than the non-haul out rocks ($p < 0.005$) and also along the rock sides at Stillwater Cove ($p < 0.05$) ($R \times C$ contingency test; Fig. 2).

A reduction in cover of *Cladophora columbiana* (Collins) occurred where seals hauled out (Fig. 3). Per cent cover was significantly less at Stillwater Cove both for the rock tops ($p < 0.001$) and the rock sides ($p < 0.02$) (Student's *t*-test). And there was a reduction in overall occurrence on the haul out rocks compared to the non-haul out rocks of Seal Island ($p < 0.005$ for top and for sides, using $R \times C$ contingency test).

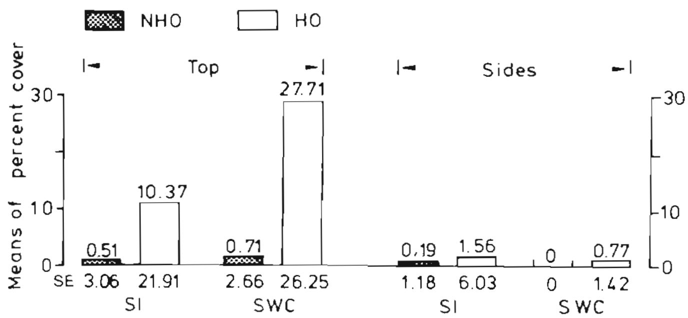

Fig. 2. *Ulva californica*. Percent cover differences on rock tops of Stillwater Cove. Student's *t*-test. Elsewhere, *t* was insignificant. $R \times C$ contingency tests were significant on rock tops of Seal Island and rock sides of Stillwater Cove. Seal Island rock sides *G* value was insignificant. SI: $n_{NHO} = 75$, $n_{HO} = 30$, $G_{TOP} = 12.788$, $G_{SIDES} = 0.848$. SWC (Stillwater Cove): top, $n_{NHO} = n_{HO} = 17$, $t = 4.22$; sides, $n_{NHO} = n_{HO} = 12$, $G = 4.588$

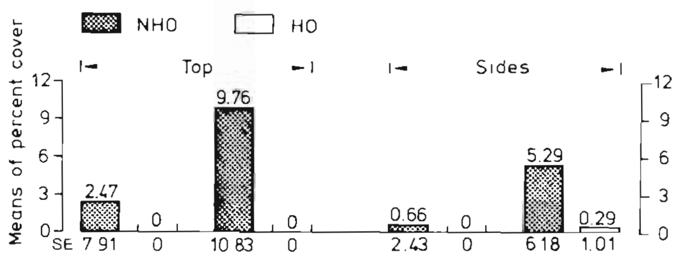

Fig. 3. *Cladophora columbiana*. Significant percent cover differences at Stillwater Cove only. Student's *t*-test. Significant differences using $R \times C$ contingency tests were found at Seal Island. SWC: top, $n_{NHO} = n_{HO} = 17$, $t = 3.72$; sides, $n_{NHO} = n_{HO} = 12$, $t = 2.77$. SI: $n_{NHO} = 75$, $n_{HO} = 30$, $G_{TOP} = 11.066$, $G_{SIDES} = 7.908$

Frond heights of algae in haul out and non-haul out areas were compared as an index to morphological differences. Significant differences were found in both *Gigartina canaliculata* and *Rhodoglossum affine* (Harvey), Kylin. *G. canaliculata* was nearly of the same height at both haul out and non-haul out sites on the rock tops. However, on the rock sides, the haul out site algae was significantly taller ($p < 0.001$) as shown in Figure 4. *R. affine* was found to be the same height in both areas on the rock sides. However, on top (Fig. 5), the haul out site algae was shorter ($p < 0.11$).

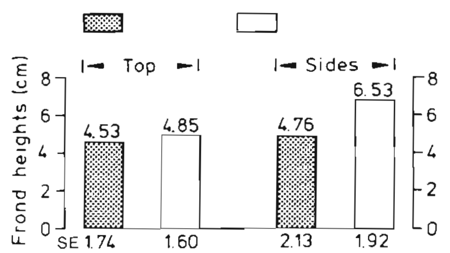

Fig. 4. *Gigartina canaliculata*. Percent cover differences are significant only on rock sides. Student's *t*-test. SI: top, $n_{NHO} = 58$, $n_{HO} = 48$, $t = 0.98$; sides, $n_{NHO} = 39$, $n_{HO} = 36$, $t = 3.77$

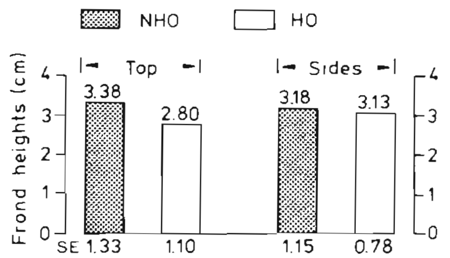

Fig. 5. *Rhodoglossum affine*. Percent cover differences are significant only on the rock tops. Student's *t*-test. SI: top, $n_{NHO} = 116$, $n_{HO} = 64$, $t = 2.97$; sides, $n_{NHO} = 86$, $n_{HO} = 42$, $t = 0.25$

Ten randomly selected rocks at each of three sites were studied for *Phyllospadix scoulteri* (Hooker) root exposure, as a possible indication of algal tearing (Table 2). Sample size was limited by the number of rocks suitable for haul out that had at least 80 % *P. scoulteri* cover. Once again, the 40 × 40 cm quadrate determined the rock area counted. Significantly more roots were found exposed at the haul out site ($p < 0.05$).

Table 2. *Phyllospadix scoulteri*. Many more roots are visible on rock tops at the haul out (HO) site than at non-haul out sites (NHO)

	Number of roots		
	NHO-2	NHO-6	HO
N	10	10	10
X	0.20	0.30	2.40
X	0.63	0.67	3.07
	NHO-2×HO		NHO-6×HO
	t = 2.22		t = 2.11
	p < 0.05		p < 0.05

Effects on Animals

The snails *Littorina scutulata* (Gould) and *Tegula funebralis* (Adams) were each found in significantly fewer numbers on the rock tops of haul out sites. *L. scutulata* numbers were too variable at the Seal Island area to show any statistical differences, but at Stillwater Cove, despite high non-haul out count variability, significantly fewer *L. scutulata* inhabited haul out sites ($X_{NHO} = 44.09$, $X_{HO} = 0.18$, $n = 11$, $t = 4.11$, $p < 0.001$). No *T. funebralis* at all were found at Stillwater Cove. However, at the Seal Island study area, significantly fewer *T. funebralis* occurred on the haul out rocks than at either control site ($X_{NHO-2} = 4.1$, $X_{NHO-6} = 3.3$, $X_{HO} = 0.0$, $n = 10$; control site one: $t = 2.97$, $p < 0.01$; control site two: $t = 3.59$, $p = 0.01$).

Of the smaller animals, *Barleeia haliotiphila* (Carpenter), *Lasea cistula* (Keen), and *Tricolia pulloides* (Carpenter) were all found in significantly greater numbers ($p < 0.005$) at the haul out site rock tops (Fig. 6).

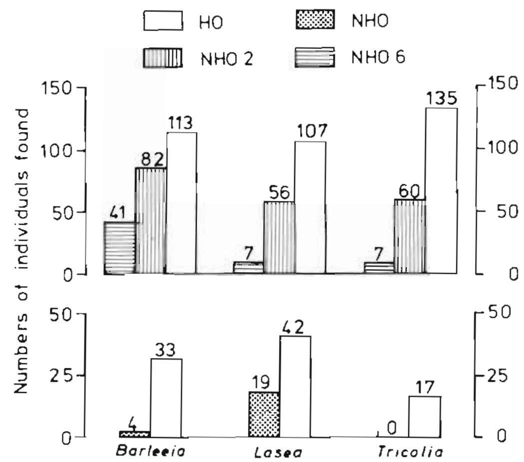

Fig. 6. Differences in animal presence at both Seal Island ($G = 37.628$) and Bird Island ($G = 129.82$) are found to be significant using $R \times C$ contingency tests

DISCUSSION AND CONCLUSIONS

Seals are placing two basic kinds of stress on the rock biota where they haul out: mechanical and chemical/environmental. Of the former, the actions of climbing on, around, and off the rocks may be responsible for knocking off the larger snails *Tegula funebralis* and *Littorina scutulata*. Also, tearing of algae may be occurring, as shown by *Phyllospadix scoulteri* root visibility and the slight cover of *Cladophora columbiana*, an easily dislodged alga. Another mechanical stress is simply the body weight (e.g. Newby, 1978) of seals resting on the rocks. Perhaps the short, compact *Vera* *californica* is able to compete well under this stress, and hence is more often found on haul out than non-haul out rock tops.

Chemical/environmental stresses include fecal and urinary fertilization (Johnson, 1979), warmth, humidity, and shade, all provided by the seals' bodies at what are normally the rocks' most exposed times of day. These factors may be having a strong effect on the microscopic biota present, which might explain the high numbers of grazing *Barleeia haliotiphila, Lasea cistula,* and *Tricolia pulloides* found. It is interesting to note that areas of Bird Island heavily fertilized by guano but not visited by seals did not show any of these haul out site differences in plants or animals.

Both *Gigartina canaliculta* and *Rhodoglossum affine* plants were found to be shorter on haul out rock tops than might be expected from heights elsewhere. This could be due to either the mechanical or the chemical/environmental stresses. However, since *G. canaliculata* is taller on the rock sides, it may be that it is benefiting from the fertilizing, but that one of the other factors is preventing tall growth on top. *R. affine* was not taller on the rock sides, nor did it show a greater per cent cover on the haul out rocks, as did *G. canaliculata.* Apparently, whether it is the fertilizing or some other factor that is benefiting *G. canaliculata, R. affine* is not being affected by it. More work is needed to sort out exact cause-effect relationships.

If the differences in organisms found in this study between haul out and non-haul out sites hold true throughout the harbor seal distribution range, their presence may be affecting the local distribution of plants and animals everywhere, and hence are a further factor to take into account when studying the intertidal zone. It seems desirable to critically examine whether other hauling out marine mammals are affecting the organisms in the area of their haul out, as well.

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