Depth and Habitat Distribution of *Parastichopus californicus* Near Sitka, Alaska

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Abstract: The depth distribution of sea cucumbers *Parastichopus californicus* was investigated in the vicinity of Sitka Sound, Alaska, to evaluate the proportion of the emergent population available to commercial dive harvesters. A submersible was used to census 20 transects to 118 m. Observations above 10-m depth were made by scuba on 10 transects. Sea cucumber densities were greatest in shallow waters, with approximately 60% of the sea cucumbers observed above 15 m and 70% above 20 m. Average densities were $0.03 \cdot m^{-2}$ on the submersible transects and $0.30 \cdot m^{-2}$ on the scuba transects. The deepest sea cucumber observed was at 87 m. Sea cucumber densities were highest on shell debris and gravel (pebbles), and lowest on mud and silt bottoms. Tests for substrate distribution generally indicated a nonrandom affinity for harder substrates, except bedrock and boulders. The mostly shallow distribution of *P. californicus* near Sitka exposes approximately two-thirds of the surveyed population to exploitation by commercial divers, who commonly descend to 15- or 20-m depth. The large fraction of the population in deeper water is not included in estimating the harvestable surplus, and because this leads to an underestimate of the population size, this approach provides a conservative safeguard against overexploitation.

INTRODUCTION

Sustainable development of invertebrate fisheries is often hampered by a scarcity of stock assessment information (Caddy 1986). A reasonable response to this problem is to compensate with conservative management measures that are expected to provide for a sustainable harvest. This is the approach taken in the commercial fishery for the sea cucumber *Parastichopus californicus* (Stimpson 1857) in Alaska's southeastern panhandle, where a suite of conservative safeguards is imposed.

Parastichopus californicus is a commercially important species common to the west coast of North America from Baja California to the Gulf of Alaska (Lambert 1986). They are harvested to obtain their skin and their muscles, which occur in 5 longitudinal bands. Large individuals may exceed 500 g when drained of fluids. Sexes are similar. Maturity is estimated to occur between 4 and 8 years of age, and the maximum age is estimated as 12 years in British Columbia (Cameron and Fankboner 1989). This species is an epifaunal deposit feeder, acting as a "bioturbator" that reworks and redistributes sediment in the process of feeding (Brenchley 1981).

In southeastern Alaska the sea cucumber fishery is managed by the Alaska Department of Fish and Game using a surplus production model (Woodby et al. 1993). Application of this model requires an estimate of population size to which a harvest rate of approximately 5% per year is applied. Two conservative measures are incorporated into the development of the harvest rate: (1) a 50% reduction to account for the possibility the model assumptions are incorrect, and (2) an approximate 30% reduction to account for sampling errors in the assessment survey. A third safeguard is a restriction that only those sea cucumbers above 15-m depth (below mean lower low water, MLLW) are included in estimates of population size. This restriction is imposed because stock assessment surveys are conducted by Alaska Department of Fish and Game divers using scuba gear, and frequent dives to greater depths would pose unacceptable risks to the survey divers.

Prior observations from a submersible and statements by commercial divers indicated that significant

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Authors: Doug Woodby is a fisheries biologist for the Alaska Department of Fish and Game, Commercial Fisheries Division, Box 240020, Douglas, Alaska 99824-0020, email: doug_woodby@fishgame.state.ak.us. Scott Smiley is the director of the University of Alaska - Fisheries Industrial Technology Center, 118 Trident Way, Kodiak, Alaska 99615-7401. Robert Larson is a fisheries biologist for the Alaska Department of Fish and Game, Commercial Fisheries Division, Box 667, Petersburg, Alaska 99833-0667.

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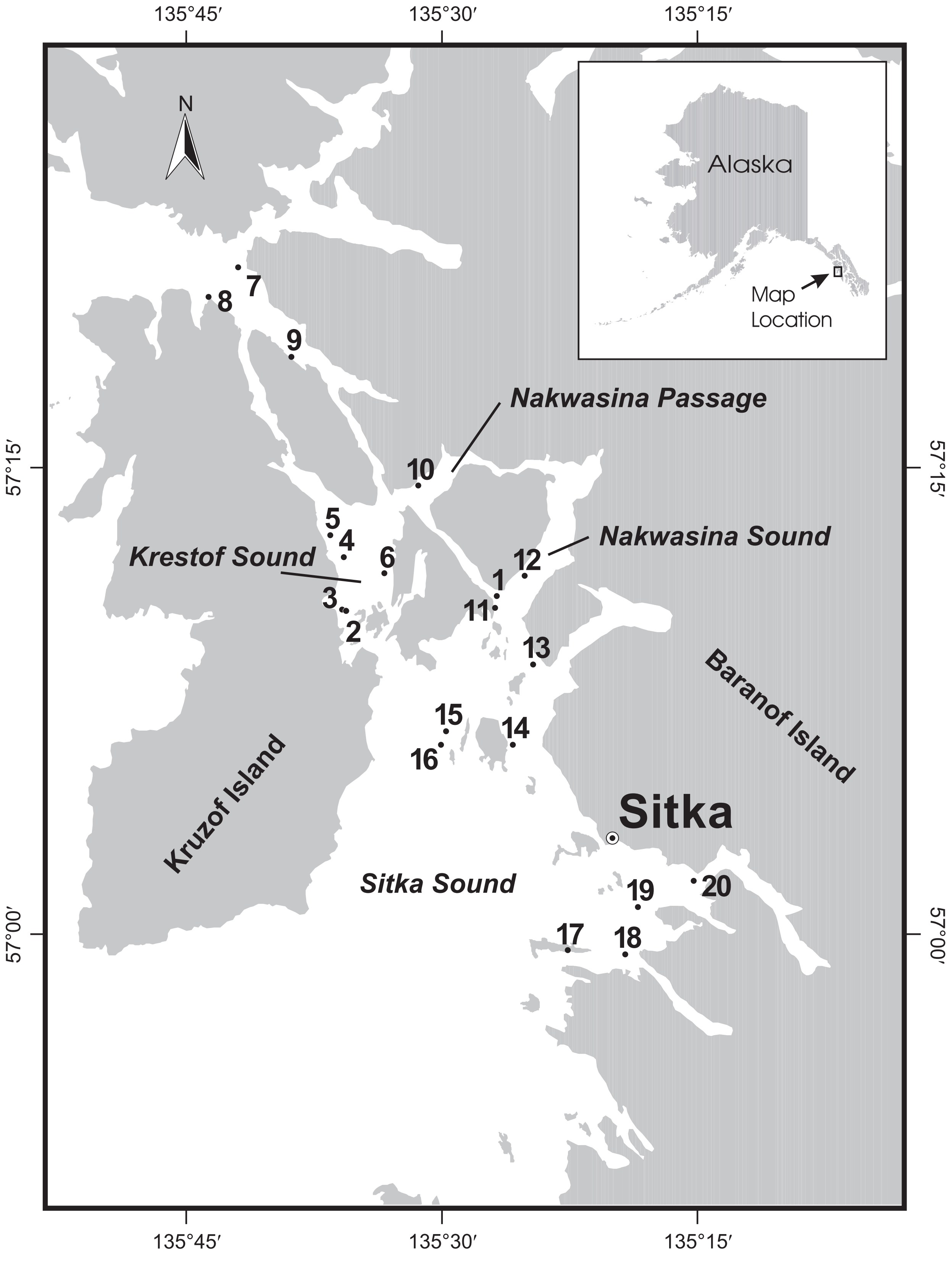

Figure 1. Map of study area showing dive locations near Sitka, Alaska.

numbers of *P. californicus* occur below 15-m depth in Southeast Alaska, suggesting the management program may be overly conservative. This paper describes research with the *Delta* submersible and with scuba to estimate the densities and proportion of the population that occur below depths of the scuba surveys. The distribution of sea cucumbers by substrate types and the relationships between the substrate and depth distributions are also reported. A prior study at Barlow Cove, Alaska, provided information of this type, but shallow-water densities were likely underestimated due to algal cover, and overall densities there were well below those considered minimal for commercial harvest activities (Zhou and Shirley 1996). Conclusions from that study are not applicable to the question of densities in relation to depth limits of the stock-assessment surveys conducted in commercial harvest areas.

METHODS

The 2-person submersible *Delta* was used to survey 20 strip transects from 21 to 29 April 1992 in northern Sitka Sound and nearby areas (Figure 1). The bottom topography of this area includes several troughlike fjords and embayments, with depositional basins bordered by steep rocky slopes. Transects were perpendicular to depth contours from the basin edges up the steep slopes to the shoreline. Maximum dive depths ranged from 37 to 118 m and averaged 80 m.

Transects were systematically distributed to sites in Krestof Sound, Salisbury Sound, Nakwasina Sound, Nakwasina Passage, and Sitka Sound. The first 4 transects were spaced at intervals of approximately 5 km along the shoreline beginning from a random start in southern Krestof Sound. These first transects began approximately 620 m from shore. We found poor visibility in the northern, shallow end of Krestof Sound and modified subsequent transect locations to avoid the inner ends of embayments where visibility was expected to be poor due to reduced water flow. Transects 5 to 20 were located near mouths of embayments and in passages and were spaced at intervals of approximately 5 km. The resulting set of transects provided a sample of sea cucumber habitats in areas where visibility was sufficient to obtain observations (Table 1). Transects 5 to 20 were begun closer to shore (approximately 460 m) to reduce time surveying the bottom of muddy basins where virtually no sea cucumbers were observed on 2 preliminary transects on 21 April and on transects 2 to 4 on 27 April.

The beginning point as well as occasional waypoints for each transect were plotted using the global positioning system of the support ship. These geographic points were recorded when the ship was positioned over the submersible using a Trak-Point navigation system. Endpoints were plotted visually where the *Delta* surfaced at or near the shoreline. Transect lengths were estimated as the sum of track-line distances between points plotted on a 1:40,000 nautical chart.

An externally mounted video camera was used to create a continuous record of each transect, including an audio record of observations by the scientific observer and submersible pilot. The camera was equipped with a wide-angle lens and was mounted on the starboard side looking down and out from the submersible. The field of view was illuminated by 2 external lamps. Transects were 2-m wide with the starboard edge of the submersible acting as the inner transect boundary. The outer transect boundary was marked by a weight suspended from a stout fishing pole, which was mounted on top of the submersible and extended 2 m horizontally to starboard. The weight was a 10-cm length of white, 19-mm outside diameter, polyvinyl chloride (PVC) tubing with a steel bolt inside. The line attached to the weight ran through the guides on the fishing pole and onto a reel that could be wound in or let out by the pilot in the submersible. At typical speeds of 0.3 $m \cdot s^{-1}$ the weight was heavy enough to remain visible in the video field of view without being swept backwards out of sight. The video camera was mounted sideways, permitting the field of view to include the entire 2-m transect width. The observer counted the sea cucumbers seen from the lower and middle starboard view ports for comparison with the video record. A Pisces Box recorded depth, height off the bottom, and time on the video tape at 1-s intervals.

Time, depth, and substrate data were transcribed from the video tape for each sea cucumber observed. Time and depth were also recorded whenever the substrate type changed. As many as 3 substrates were identified for each sea cucumber observation, with the primary substrate listed first. Substrates were categorized as rock, boulders, cobbles, gravel, mud, sand, silt, or shell debris. Rock was defined as bedrock surface at least several meters in extent and was characterized by jagged edges and fissures. Boulders, cobble, gravel, sand, and silt were qualitatively identified from the video tapes to fall roughly within size categories based on the Wentworth–Udden scale (Pettijohn 1975): boulders were individual rocks larger than 26-cm diameter, cobble ranged from 6 to 26 cm, gravel (pebbles in the Wentworth-Udden scale) ranged from 2 mm to

Table 1. Summary of transect data collected from the *Delta* submersible near Sitka, Alaska.

					Transect			Sea Cucumbers	
Transect	Delta Dive	Time	Latitude (N)	Longitude (W)	Time Elapsed (min)	Length (m)	Maximum Depth (m)	*n*	Density (m^{-2})
21 April 1992									
1	2,710	14:10:26	57°10′53″	135°26′42″	10	172	58	8	0.023
27 April 1992									
2	2,734	10:33:50	57°10′25″	135°35′32″	22	440	85	26	0.030
3	2,735	12:02:23	57°10′28″	135°35′47″	23	432	74	6	0.007
4	2,736	14:02:10	57°12′08″	135°35′41″	49	552	61	44	0.040
5	2,737	15:28:00	57°12′50″	135°36′27″	35	484	47	38	0.039
6	2,738	16:49:46	57°11′36″	135°33′16″	33	524	104	55	0.052
28 April 1992									
7	2,739	09:18:29	57°21′21″	135°41′54″	20	364	113	23	0.032
8	2,740	10:25:12	57°20′24″	135°43′36″	9	244	47	11	0.023
9	2,741	11:33:26	57°18′30″	135°38′44″	17	360	73	31	0.043
10	2,742	13:40:43	57°14′24″	135°31′17″	19	440	37	25	0.028
11	2,743	15:04:49	57°10′30″	135°26′47″	19	360	65	26	0.036
12	2,744	16:13:50	57°11′32″	135°25′02″	17	352	118	1	0.001
13	2,745	17:26:31	57°08′43″	135°24′31″	14	260	67	28	0.054
29 April 1992									
14	2,746	08:05:35	57°06′09″	135°25′45″	21	460	88	22	0.024
15	2,748	10:08:35	57°06′35″	135°29′40″	33	532	116	61	0.057
16	2,749	12:14:26	57°06′08″	135°29′56″	27	476	92	51	0.054
17	2,751	14:05:42	56°59′34″	135°22′29″	20	388	84	5	0.006
18	2,752	15:04:11	56°59′27″	135°19′08″	26	540	44	23	0.021
19	2,753	16:23:43	57°00′58″	135°18′24″	23	400	96	3	0.004
20	2,754	17:23:45	57°01′47″	135°15′06″	31	305	97	0	0.000
Total					471	8,086		487	0.029[a]

[a] Average of transect densities.

Table 2. Summary of transect data collected by scuba methods near Sitka, Alaska. All data were collected on 30 April 1992. Maximum depth was 10 m.

Associated Submersible Dive Number	Time	Elapsed Time (min)	Transect Length (m)	Sea Cucumbers n	Sea Cucumbers Density (m^{-2})
1	13:25	7	21	18	0.429
2	09:55	9	41	21	0.256
3	10:13	9	49	3	0.031
4	10:42	8	25	9	0.180
5	11:23	7	40	3	0.038
6	09:30	10	35	24	0.343
10	11:53	12	36	49	0.681
11	14:05	20	62	49	0.395
12	13:42	10	26	18	0.346
13				20	
Total				214	0.300[a]

[a] Average of transect densities for 9 transects with transect length data.

6 cm, and sand from 0.06 to 2 mm. Silt was defined as a thin layer of sediment finer than sand, usually no more than a few centimeters thick overlying other substrates, whereas mud was sediment typically more than 5 cm thick.

Kelp at depths less than 10 m (usually *Laminaria* spp.) sometimes obscured the view from the submersible, making counts of sea cucumbers unreliable at those depths. This problem was addressed by resurveying the upper 10 m of 10 transects with scuba gear on 30 April. These transects were positioned within 50 m of the submersible transects by reference to marked locations on a nautical chart. Each transect began at the shoreline, and was sampled by a team of 2 divers. On each transect a diver swam downslope holding a 2-m rod (2.1-cm diameter white PVC tube) in a horizontal position perpendicular to the census path. Transect direction was maintained by reference to a compass mounted on the rod. The diver carrying the rod counted the number of sea cucumbers in the census path and relayed the data to the second diver using hand signals. The second diver recorded the count, depth, the 2 most common substrate types, the percentage vegetative cover, and the 2 most common vegetation types. Beginning and ending times for each transect were also recorded.

Depths recorded on each transect were standardized to depths below MLLW by subtracting the tidal height. Tidal height for a central location (Dog Point on the Lisianski Peninsula, 57°10′N, 135°25′W) was estimated for the midpoint in time of each transect using TIDE.1 computer software (Micronautics 1992). All depths reported here are relative to MLLW.

The proportion of sea cucumbers above 10- and 18-m depths was estimated by treating the scuba transects as shoreward extensions of the submersible transects with which they were paired. That is, the 2- to 3-day lag (9 days in the case of dive 2,710) between submersible- and scuba-transect dates was ignored, and each pair of transects was assumed to be collinear. The count of sea cucumbers above 18 m was the taken as the sum of those seen above 10 m by scuba plus those seen from 10 to 18 m from the submersible.

The relationship between sea cucumber counts and substrate type was examined with the following protocol. First, each observation of sea cucumbers and substrate was assigned to one of a series of adjacent 2 x 3-m quadrats on each transect. The number of quadrats n_j in each transect j is equal to the integer part of the total transect length l_j (in meters) divided by 3. Boundaries between quadrats do not correspond to a photographic frame or other physical features; rather, they were imposed on the transcribed data with equal intervals of elapsed time from the beginning of each transect. This method assumes that the submersible traveled at a constant speed.

The correlation ρ_{XY} between the count of sea cucumbers X_i and substrate type Y_i (one for the substrate of interest and zero otherwise) was estimated as a Pearson product-moment correlation coefficient for $i = 1$ to N ($=\Sigma n_j$). The significance of the correlation for each substrate type was tested using a randomization procedure (Malatesta et al. 1992) to overcome the statistical difficulty that observations on nearby quadrats were not independent. Quadrat counts of sea cucumbers were randomly permuted, and the correlation coefficient for all quadrats was recalculated for each substrate type (substrate types were not permuted). The randomization was repeated 1,000 times.

For each substrate type, the hypothesis H_0 that $\rho_{XY} = 0$ was rejected in favor of the hypothesis H_1 that $\rho_{XY} \neq 0$ at significance level $1-\alpha$ if the observed correlation was greater in absolute magnitude than the randomized correlation coefficients in at least $1-\alpha$ proportion of cases. Significance is a direct measure of the proportion of random results less extreme than the observed value, but is not an exact measure when multiple tests are made.

RESULTS

Sea cucumbers were seen on all but one of the transects (Tables 1 and 2). Virtually all of the individuals seen

Table 3. Sea cucumber counts, area, average densities, and Pearson product-moment correlation coefficients (ρ_{XY}) for each substrate type as observed from the *Delta* submersible. Probability values are the proportion of more extreme events in each randomization test.

		Sea Cucumbers			
Substrate	Area (m^2)	*n*	Density (m^{-2})	ρ_{XY}	*P* value
Boulder	34	3	0.084	0.023	0.165
Cobble	902	59	0.069	0.084	<0.001
Gravel	421	38	0.085	0.079	0.001
Mud	5,875	35	0.009	-0.164	<0.001
Rock	3,974	127	0.038	0.008	0.345
Sand	2,787	142	0.068	0.089	<0.001
Shell debris	795	69	0.093	0.114	<0.001
Silt	1,385	14	0.012	-0.054	<0.001
Total	16,173	487			

were identified as *P. californicus*, and all further references to sea cucumbers are for this species. Counts ranged from 0 to 61 on the submersible transects (Table 1) and from 3 to 49 on the scuba transects (Table 2). Average densities were 0.029·m^{-2} on the submersible transects and 0.30·m^{-2} on the scuba transects (for the 9 transects with length data).

Distribution by Depth

Sea cucumber counts on the 10 scuba transects, coupled with deeper observations from the adjacent *Delta* transects, indicated densities were greatest in shallow water and decreased rapidly with depth (Figure 2). About 60% of the sea cucumbers were shallower than

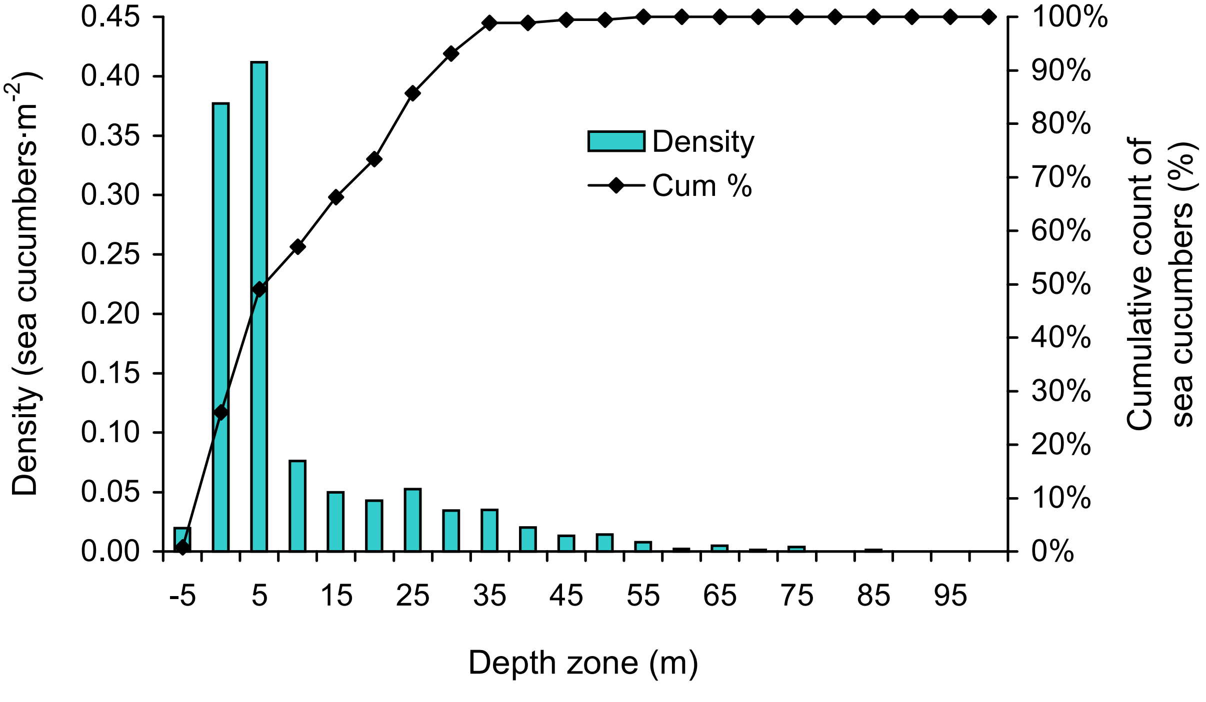

Figure 2. Density (bars) and cumulative percent frequency (line) of *P. californicus* in 5-m depth zones. Depth labels are shallow end of 5-m depth intervals. Density data are from 9 scuba transects for depths less than 10 m and from 20 submersible transects for depths greater than 10 m. Count data are from the 9 scuba transects and the 9 associated submersible transects.

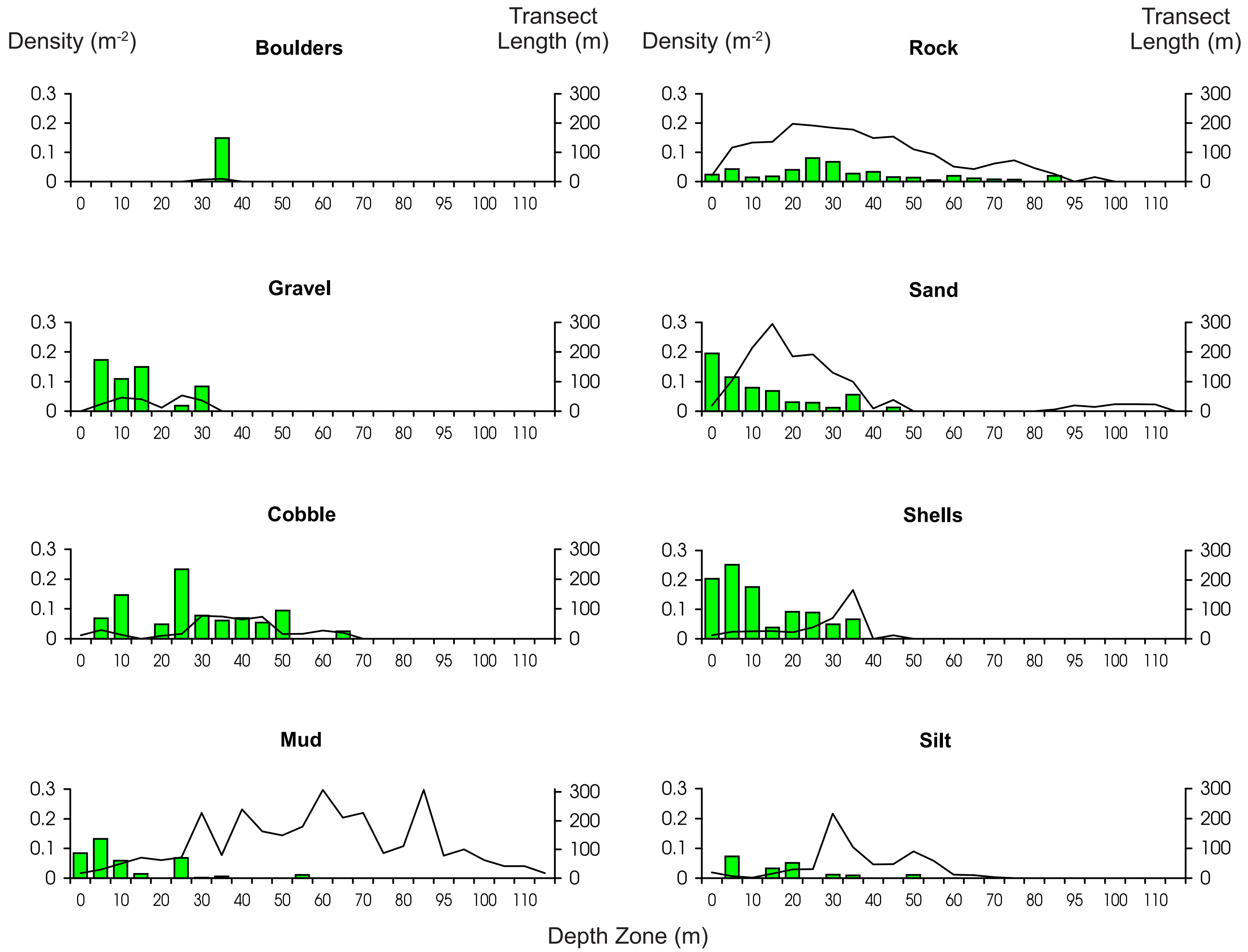

Figure 3. Density of *P. californicus* (bars) and transect lengths (lines) in 5-m depth zones for each of 8 substrate types. Transect lengths are the total of lengths of the survey paths in each of the substrate types.

Table 4. Correlations between sea cucumber counts and substrate types for shallow (0–19 m) and deep (20–118 m) samples as observed from the *Delta* submersible. Correlations are the Pearson product-moment correlation coefficients (ρ_{XY}). Probability values are the proportion of more extreme events in each randomization test.

Substrate	Shallow (0–19 m)		Deep (20–118 m)	
	ρ_{XY}	*P* value	ρ_{XY}	*P* value
Boulder			0.035	0.095
Cobble	-0.009	0.415	0.115	<0.001
Gravel	0.111	0.019	0.026	0.134
Mud	-0.004	0.464	-0.160	<0.001
Rock	-0.179	0.000	0.076	<0.001
Sand	0.049	0.148	0.012	0.298
Shell Debris	0.155	0.004	0.099	0.002
Silt	-0.055	0.080	-0.038	0.018

15 m and about 70% were shallower than 20 m. The deepest sea cucumber was observed at 87 m on transect 15 in Sitka Sound where one sea cucumber was seen on rock substrate.

Distribution by Substrate

Sea cucumber densities were highest on shell debris, gravel, and boulders, and lowest on mud and silt bottoms (Table 3). In shallow waters where sea cucumbers were most common, densities were highest on gravel, sand, and shell debris (Figure 3).

Coefficients of correlation between counts and substrate types were mostly near zero (Table 3), a result of the high frequency (90%) of quadrats without sea cucumbers. The difficulty of interpreting those results is overcome in part by the randomization tests, which are robust with respect to zero counts. These tests indicated sea cucumbers were more commonly seen on cobble, gravel, sand, and shell debris than would be expected if sea cucumbers were randomly distributed by substrate type (Table 3; individual correlation coefficients were positive and significant at $P < 0.001$). Far fewer sea cucumbers were seen on mud and silt substrates than expected (negative correlations were significant at $P < 0.001$), and the number of sea cucumbers seen on boulders and rock substrates was not significantly different than would be expected to occur at random.

Availability of substrates varied with depth, as did sea cucumber densities on the various substrates (Figure 3), suggesting that relationships between sea cucumber densities and substrates may be dependent on depth. For example, mud substrates were typically deeper than all other substrates. The negative correlation between counts and mud substrate may simply reflect a biological preference for shallow waters rather than an avoidance of mud.

Depth dependence in substrate use was tested by applying the randomization method to substrate and count data from the submersible at 2 depth intervals from 0 to 19 m and from 20 to 118 m (the deepest quadrat). Sea cucumber counts were negatively correlated with mud substrates below 20 m (Table 4), but were random with respect to mud substrates above 20 m. Results for silt substrates were similar but not as significant. Counts were negatively correlated with rock substrates above 20 m and positively correlated below 20 m. The correlation for cobble was also positive below 20 m with no significant association in shallower waters. The results for gravel were positive in shallow waters with no significant relationship in deeper waters. Shell debris was the only substrate with a significant positive correlation in both depth zones, and sand was the only substrate with no significant relationship in either zone. In effect *P. californicus* selected hard substrates in preference to soft substrates, including mud and silt, at least below 20 m. Distribution on substrates in the upper 20 m, where *P. californicus* was most common, showed selection for shell debris and for gravel only.

DISCUSSION

Parastichopus californicus appears to have a substrate preference. We found this species less frequently on softer substrates, including mud and silt, and more frequently on harder substrates including sand, shell debris, cobble, and rock. Our data are generally consistent with those published recently for the same species in Barlow Cove, Alaska (Zhou and Shirley 1996), even though substrates were defined differently in the 2 studies. The apparent preference for harder substrates may be due in part to the method of locomotion used by this holothurian. Locomotion in sea cucumbers is largely effected by tube feet, although some sea cucumbers swim (Pawson 1966). Tube feet are fleshy protrusions of the body wall that contain a central coelomic cavity that is part of the ambulacral or water-vascular system (Smiley 1994). Extension and retraction of tube feet are controlled hydrostatically by the water-vascular system, but the tube feet adhere to the substrate in locomotion. In other echinoderms tube feet also adhere to the substrate and leave "tracks" of their presence after they have released. The consensus is that these tracks represent protein and the adhesion of tube feet to the substrate is controlled via a duo-gland system (Hermans 1983), but this hypothesis is not without controversy (Smiley 1994). Local ecological factors such as current velocity may also be required to explain the substrate preference of *P. californicus*. At relatively high velocities, sea cucumbers may need more solid footing to keep from drifting away.

Silt may also pose another problem for *P. californicus*. Respiration in sea cucumbers is carried out by inflating water lungs, also called the respiratory trees. These remarkably extensible structures are diverticula of the hindgut. Sea cucumbers rhythmically inflate and deflate these by sucking and expelling water through their anus (Smiley 1994). The force of water expelled during holothurian respiration can easily disturb fine silt. This sea cucumber may avoid silty habitat to reduce potential contamination of its respiratory surfaces.

Parastichopus californicus is known to have a wide depth distribution (Lambert 1986). The species is generally subtidal and has been found at depths ranging from the intertidal in British Columbia (Cameron and Fankboner 1986) to 249 m in the Gulf of Alaska, southwest of Kodiak Island at 56°01′N, 154°28′W (Lambert 1984, 1986). They are "usually subtidal" at Monterey, California (Ricketts and Calvin 1968), and occur below 30 m south of Pt. Conception in southern California where they are replaced in more shallow waters by the congener *P. parvimensis* (Deichmann 1937; Yingst 1982).

In a prior submersible study in Barlow Cove, Alaska, *P. californicus* were observed at depths to 183 m and were densest between 10 and 20 m and between 110 and 120 m (Zhou and Shirley 1996). The shallower depth distribution observed in this study, relative to the Barlow Cove study, can only be partially explained. Zhou and Shirley note they underestimated densities where there was algal cover, which is common in the shallow waters. Further, the submersible becomes more buoyant in shallow depths and is therefore less well-suited to census work near the surface. Our study included scuba transects to more completely census depths above 10 m. Sea cucumbers may be sensitive to low salinities. A more complete explanation for differences in densities and depth distributions between areas in Southeast Alaska may require an analysis of salinity, which decreases markedly in the vicinity of mainland rivers. Several large rivers are within 20 km of Barlow Cove.

The mostly shallow distribution of *P. californicus* near Sitka exposes the majority of the commercial-sized population to exploitation by commercial divers who commonly descend to 15- or 20-m depth to find concentrations of sea cucumbers. However, the commercial fishery in Southeast Alaska begins October 1, and the depth distribution could change from spring to fall. For example, observations of spawning adults suggest sea cucumbers may migrate to shallow waters to spawn in the spring (Courtney 1927; Cameron and Fankboner 1986; Smiley et al. 1991). The means by which sea cucumbers migrate are slow, at best. *Parastichopus californicus* may migrate by a variety of locomotory behaviors, including swimming and a bounding crawl, in addition to their routine sluggish crawl (Reese 1966; Margolin 1976; Smiley 1994).

In a study of sea cucumber food habits Yingst (1982) found *P. parvimensis* are most abundant where the organic content of the substrate is highest, and the species ingests the top few centimeters of sediment irrespective of particle size. *Parastichopus californicus* may exhibit similar behavior to its congener *P. parvimensis*, which is similar in form. The mostly shallow distribution of *P. californicus* may reflect a higher organic content of the top centimeters of substrates in the euphotic zone compared to deeper zones. Sea cucumbers may occupy shallower regions in spring and early summer because of increased food availability, which is driven by increased shallow primary production. The seasonal changes in the distribution of *P. californicus* are not known well for any region. Anecdotal reports of spawning aggregations (Smiley et al. 1991) indicate that individuals in a population probably can aggregate. Although we did not observe spawning aggregations in this study, available evidence on this species suggests spawning probably occurs near the time of reliable algal blooms in early summer.

Size of sea cucumbers may affect distribution by substrate types. Near Santa Catalina Island in southern California larger *P. parvimensis* on average were found on granular substrates (sand and calcareous algae fragments) than on rock (Yingst 1982). Smiley (personal observation) found juvenile *P. californicus* (3 cm and smaller) tended to aggregate in cobble "nursery" areas with lower wave action. These small sea cucumbers were most frequently found under medium-sized cobbles averaging about 10–30 cm in diameter. Sea cucumbers were not measured in our study; however, the vast majority of *P. californicus* seen were of the mature sizes harvested in the commercial fishery.

SUMMARY AND CONCLUSIONS

The Sitka area was chosen for this study because it was known to have relatively dense, commercially viable concentrations of *P. californicus*, such that results from this study would be meaningful in the context of other commercially viable areas in Southeast Alaska. Most of the shoreline in Southeast Alaska with commercially viable sea cucumber populations has been censused by the Alaska Department of Fish and Game. Prior to this study, the population segment below survey depths was unknown. This segment was not included in estimates of the population available for harvest as a deliberately conservative method of underestimating the population size on which harvest quotas are based (Woodby et al. 1993). Recent analyses of trends in population size and in biomass for the harvested areas (unpublished data) indicate this fishery has been operating sustainably on a regional basis since the current management plan was put into effect 10 years ago. The fishery management program has additional conservative features (halving of the model harvest rate and discounting biomass estimates to account for sampling error), and it is therefore difficult to know the importance of underestimating abundance due to depth limits in the apparent success of the program. Given that the program appears to meet objectives for sustainable fishing, we do not recommend any corrections to population estimates to account for the unsurveyed population segment below survey depths.

The extent and mode of interchange between shallow segments of the population and deeper segments is unknown. Interchange might occur by adult migration, juvenile dispersal, or larval dispersal. If interchange is infrequent, and if there are differences between shallow- and deepwater population segments in characteristics such as sex or growth rates, then harvest of mostly shallow animals could have important implications for management.

The potential for seasonal differences in the depth distribution of *P. californicus* may bias results of surveys conducted at different times of the year. We are most concerned with differences that may occur between spring (June) and late summer (August and September), the 2 periods when the Alaskan surveys have been conducted historically, and fall (October and November) when the fishery occurs. We recommend a sampling program be conducted to examine seasonal depth changes, sited on hard bottom substrates where sea cucumber densities are highest.

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