TABLE 3.—Estimates of ρ and L from 1971 U.S. east coast bluefin double tagging study.

Agency and tag type	lnρ	L on daily basis	ρ	L (on annual basis)
FRBC				
Plastic dart	-0.00102	0.0012195	0.999	0.44512
Metal dart	-0.03106	0.0011858	0.969	0.43282
WHOI				
Plastic dart	0.00426	0.0005922	1.004	0.21615
Metal dart	-0.10439	0.0007199	0.901	0.26278
Total				
Plastic dart	-0.01008	0.0007378	0.990	0.26929
Metal dart	-0.05532	0.0009835	0.946	0.35898
Total	-0.02787	0.0008504	0.973	0.31041

the estimates obtained from the combined data. These estimates of $\rho = 0.973$ and $L = 0.31041$ are close to the estimates of Bayliff and Mobrand (1972) of $\rho = 0.913$ and $L = 0.278$ for yellowfin tuna in the eastern Pacific.

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DISTRIBUTION AND ABUNDANCE OF THE SAND DOLLAR, *DENDRASTER EXCENTRICUS,* OFF THE COAST OF OREGON AND WASHINGTON

Dendraster excentricus is one of two known species of Clypeasteroid echinoids occurring along the Pacific coast of North America from British Columbia southward to Mexico. It lives on sandy bottoms from the low water zone to a depth of about 90 m[1] (Raup, 1956). Large beds of these animals have been reported in southern Puget Sound, Monterey Bay, Newport Bay, San Diego Bay, and El Estero de Punta Banda — just south of Ensenada, Mexico (Ricketts and Calvin, 1952). Merrill and Hobson (1970) made detailed observations on the behavior, distribution, and biotic relationships of *D. excentricus* along the Pacific coast of California and Baja California, Mexico. They remarked that relatively little was known about the populations of sand dollars along the exposed outer

[1] Richard J. Merrill, Department of Biological Sciences, University of California, believes this is too deep for *D. excentricus* and may refer to *D. laevis* (pers. comm.).

coast northward from Point Conception, Calif. The report presents new information on the distribution and abundance of sand dollars along the coast of Oregon and Washington.

Materials and Methods

The Seattle-based research vessel *John N. Cobb* of the National Marine Fisheries Service took large numbers of *D. excentricus* while dredging during two clam surveys along the Washington and Oregon coast in the summer of 1969. The dredge used during the surveys was an east coast type hydraulic clam dredge (Figure 1) which weighed approximately 1,021 kg (2,250 lb) and had a blade 91.4 cm (36 inches) wide with a maximum digging depth of 35.6 cm (14 inches). Each dredge haul was of 10 min duration, made from north to south, and covered an average distance of 0.56 km (0.3 nautical mile). The bottom area "swept" by each haul was approximately 508 m² (5,472 ft²). Hauls were made only on sandy bottom areas believed to be free of rocks.

The first survey was conducted in June along the Washington coast between Cape Flattery and the Columbia River. Forty-six hauls were made: 9 at 9-11 m, 15 at 13-15 m, 8 at 16-18 m,
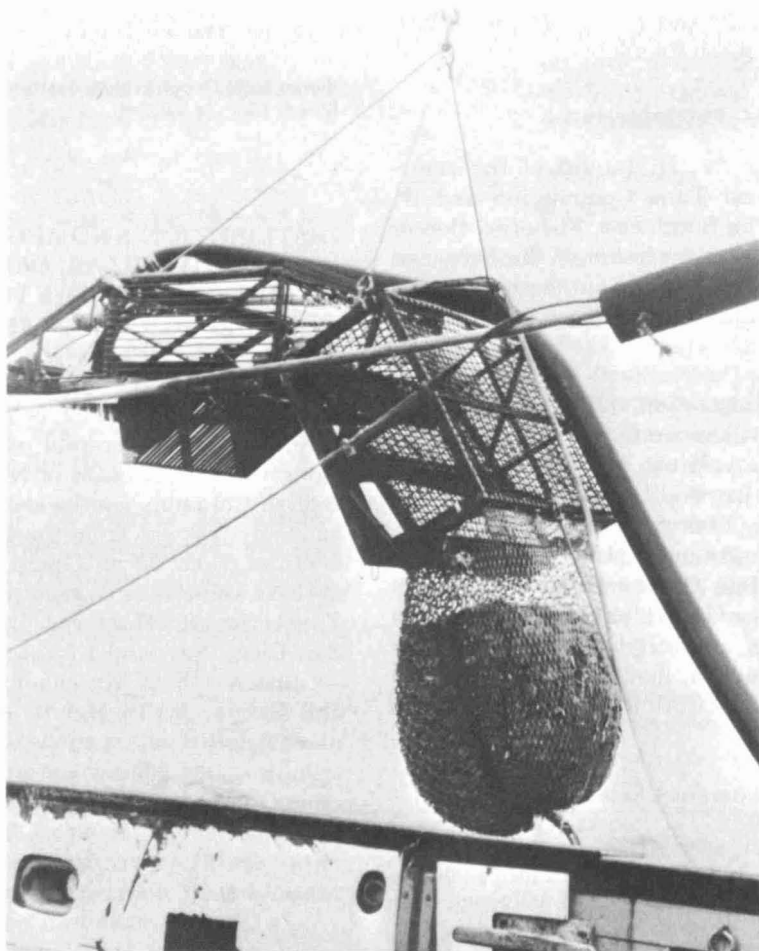

FIGURE 1.—A modified east coast type hydraulic clam dredge with a catch of over 1,000 lb of sand dollars being lifted board the RV *John N. Cobb*.

TABLE 1.—Average sand dollar catches off the Washington coast in kilograms per 10-min dredge haul and density (number of sand dollars) per square meter of bottom area. The catches are the total catch at each station, divided by the number of hauls shown in parentheses.

Sampling area (Lat)[1]	Catch, by sampling depth									
	9-11 m		13-15 m		16-18 m		24-27 m		29-37 m	
	Avg. catch (kg)	Avg. density (no./m²)	Avg. catch (kg)	Avg. density (no./m²)	Avg. catch (kg)	Avg. density (no./m²)	Avg. catch (kg)	Avg. density (no./m²)	Avg. catch (kg)	Avg. density (no./m²)
46°23.0'N	—[2]	—	0 (6)	0.0	0 (2)	0.0	—	—	—	—
46°34.5'N	408 (3)	26.7	11 (1)	0.7	0 (1)	0.0	—	—	—	—
46°51.0'N	—	—	95 (2)	6.2	—	—	—	—	—	—
47°00.0'N	121 (1)	7.9	—	—	0 (1)	0.0	0 (1)	0.0	0 (1)	0.0
47°05.0'N	378 (2)	24.8	404 (3)	26.4	<1 (1)	0.0	—	—	—	—
47°34.0'N	<1 (3)	0.0	0 (3)	0.0	0 (3)	0.0	—	—	—	—
47°45.0'N	—	—	—	—	—	—	0 (5)	0.0	—	—
48°15.5'N	—	—	—	—	—	—	—	—	0 (7)	0.0
Total averages	234 (9)	15.3	94 (15)	6.2	<1 (8)	0.0	0 (6)	0.0	0 (8)	0.0

[1]Approximate midpoint of hauls.
[2]Dashes (—) indicate that no haul was made at the station.

Table 2.—Sand dollar catches off the Oregon coast in kilograms per 10-min dredge haul and density (number of sand dollars) per square meter, September 1969.

Sampling area		Catch, by sampling depth									
		9 m		14 m		18 m		23 m		27 m	
Lattitude[1]	Coastal landmark	Catch (kg)	Density (no./m²)	Catch (kg)	Density (no./m²)	Catch (kg)	Density (no./m²)	Catch (kg)	Density (no./m²)	Catch (kg)	Density (no./m²)
43°25.7'N	Coos Bay	1,814[3][4]	118.9	603	39.6	363	23.8	0	0.0	0	0.0
43°27.3'N	—	0	0.0	0	0.0	499	32.7	0	0.0	0	0.0
43°31.1'N	—	—[2]	—	0	0.0	0	0.0	0	0.0	0	0.0
43°34.9'N	Ten Mile Cr.	102[3]	6.7	454[3]	29.8	454	29.8	907	59.4	0	0.0
43°37.9'N	—	0	0.0	91	5.9	0	0.0	1,179	77.3	680	44.6
43°42.9'N	Umpqua River	1,134[3]	74.3	1,270	83.2	14	0.9	4	0.3	0	0.0
43°47.0'N	Tahkenitch C.	113[3][4]	7.4	1	0.1	0	0.0	544	35.7	499	37.2
43°51.0'N	Siltcoos R.	567[3]	37.2	45	3.0	567	37.2	23	1.5	23	1.5
43°55.0'N	—	0	0.0	2	0.1	0	0.0	0	0.0	0	0.0
43°59.1'N	Siuslaw R.	1[3]	0.1	0	0.0	0	0.0	0	0.0	0	0.0
44°03.1'N	Sutton Cr.	1,134[3][4]	74.3	0	0.0	0	0.0	0	0.0	0	0.0
44°07.3'N	Hecata Hd.	—	—	—	—	0	0.0	0	0.0	0	0.0
44°11.3'N	Rocky Knoll	23[3]	1.5	<1	0.0	0	0.0	0	0.0	0	0.0
44°15.4'N	Gwynn Knoll	113[3][4]	7.4	2[3]	0.1	0	0.0	0	0.0	0	0.0
44°19.4'N	Yachats R.	363[3][4]	23.8	0	0.0	<1	0.0	<1	0.0	0	0.0
44°23.7'N	Alsea Bay	4[3]	0.3	2	0.1	1	0.1	0	0.0	0	0.0
44°27.7'N	Seal Rocks	—	—	0	0.0	—	—	0	0.0	0	0.0
Total averages		384	25.1	154	10.1	118	7.8	156	10.2	71	4.9

[1] Approximate midpoint of hauls.
[2] Dashes (—) indicate that no haul was made at the station.
[3] Live specimens, all others were dead (empty tests).
[4] Catches which were sampled for width measurements.

6 at 24-27 m, and 8 at 29-37 m. The second survey was conducted in September between Coos Bay and Newport, Oreg. Eighty hauls were made: 14 at 9 m, 16 at 14 m, 16 at 18 m, 17 at 23 m, and 17 at 27 m. The areas sampled were uniformly spaced along the coast, approximately 7.4 km (4 nautical miles) apart.

Sand dollar catches were weighed using a dynamometer on the first several hauls of each of the surveys. Weights of catches were estimated on the remaining hauls according to the portion of the cod end and dredge that was filled. During the Washington survey, which was largely involved with development of dredging techniques, no data were collected on the proportion of live and dead specimens. On the Oregon survey the incidence of live specimens and "empty tests" (dead specimens) in each haul was recorded. Also width measurements were made on five samples of live specimens taken at a depth of 9 m. Sample sizes varied from 136 to 310 individuals.

Results

Washington. — Nearly all the *D. excentricus* were taken in the two shallowest depth intervals — 9-10 and 13-15 m (Table 1). No sand dollars occurred in hauls made at depths greater than 18 m. The largest single catch, 1,209 kg (2,666 lb), occurred in a depth of 15 m off Ocean City (lat. 47°05.0'N), and catches of up to 454 kg (1,000 lb) were taken in 9-11 m just south of the Willapa Bay entrance (lat. 46°34.5'N). The average density in each of the above two sampling areas was over 26 sand dollars per m².[2]

Oregon. — There was a consistent pattern in the incidence of live and dead (empty test) sand dollars with increasing depth in Oregon waters — only live animals were taken in the shallower water and only dead animals were taken in the deeper water (Table 2). The largest catch

[2]All estimates of numbers of sand dollars from weight of specimens based on an average weight per specimen of 30 gm (15.1 specimens per lb).

(1,814 kg, or an estimated 60,400 specimens) was at 9 m and occurred near Coos Bay. The 14-m depth was an area of transition between living and dead sand dollars. Catches made at 18, 23, and 27 m were composed entirely of dead animals. At these depths, the largest catches along the coast occurred between Ten Mile Creek and Siltcoos River.

Mean widths of the five samples of live specimens ranged from 76.4 to 85.9 mm; the overall mean was 80.1 mm. The catches from which these samples were taken are marked with a footnote in Table 2.

Discussion

Merrill and Hobson (1970) reported that two types of distribution patterns occur in sand dollar populations along the protected outer coast. In one type, the populations run parallel to shore as dense bands and maintain a characteristic pattern that is reformed when disrupted by occasional heavy seas. The outer margin of these populations is well-defined in 4-12 m of water and here the largest individuals and greatest densities occur. The other type of distribution is similar, except that it extends into deeper water, below about 10-15 m; individuals become progressively smaller with depth.

These distribution patterns are apparently similar off the exposed outer coasts of Oregon and Washington. My findings off Oregon and Washington indicate well-defined seaward limits, as essentially no live *D. excentricus* were taken by the dredge at depths below 15 m.

McCauley and Carey (1967) collected *D. excentricus* off Oregon in depths of 8 to 56 m. They found the mean widths of specimens to be 78.2 mm at 8 to 13m, 35.8 mm at 22 m, and less than 10 mm at 50 m. They concluded that mean widths show a decrease in size with depth, suggesting that animals may move shoreward with increase in size or that in some way depth may influence growth. They apparently sampled both the near-shore and deeper water types of distribution patterns.

Merrill and Hobson (1970) speculated that available food for *D. excentricus* off the protected outer coast is most abundant just seaward of the breaker line, where the water is about 10 m deep,

and that beyond this depth available food decreases with depth. Our dredge catches of the species off Oregon and Washington support the hypothesis that optimum conditions for *D. excentricus* exist inside the 15-m depth interval.

It is difficult to explain why large numbers of dead sand dollars were found primarily in the deeper depths sampled during our surveys (18-27 m). Merrill and Hobson (1970) found that at Zuma Beach, Calif. (a protected outer coast area) much of the sand dollar population in shallow water is swept or carried seaward during heavy seas, but when the sea is calm individuals in the seaward part of the colony move shoreward. This seaward movement during heavy seas may be even more extensive in populations in exposed outer coast areas off Oregon and Washington where storms are often more frequent and severe. Empty tests would be even more subject to wave action and currents than live specimens. During heavy seas they may be swept seaward where they accumulate.

My findings support earlier observations that *D. excentricus* is widely distributed and, in addition, is abundant in many sandy bottom areas within a depth of 15 m off the coast of Oregon and Washington.

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