Recovery Rate in Three Exploited Sea Urchin Populations From 1972 to 1977

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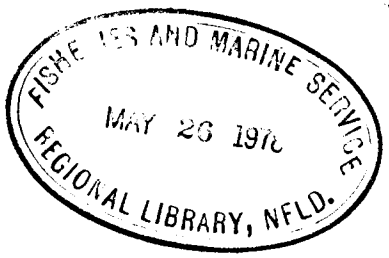

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RECOVERY RATE IN THREE EXPLOITED SEA URCHIN POPULATIONS FROM 1972 TO 1977

by

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ABSTRACT

Breen, P. A., B. E. Adkins, and D. C. Miller. 1978. Recovery rate in three exploited sea urchin populations from 1972 to 1977. Fish. Mar. Serv. MS Rep. 1446: 27 p.

Three sites near Tofino were examined in order to determine the rate of recovery of red sea urchin populations after harvesting. At all sites, harvesting had taken place in 1972. At two sites, the number now present is much less than the number that were removed in 1972. On the third site, the number removed is not known, but there are still large areas of empty sea urchin habitat. From size distributions observed in 1974, 1976, and 1977, we conclude that the number of juveniles recruited annually is only 5-10% of the present population.

The effect of harvesting on the algal communities is variable, depending on the area and the intensity of harvesting. At one site, harvesting appears to have had no effect, while at the other two sites Nereocystis and Pterygophora have increased in abundance. The effect on other invertebrates cannot be determined.

Key words: Fishery, sea urchins, kelp, Strongylocentrotus.

RÉSUMÉ

Breen, P. A., B. E. Adkins, and D. C. Miller. 1978. Recovery rate in three exploited sea urchin populations from 1972 to 1977. Fish. Mar. Serv. MS Rep. 1446: 27 p.

Près de Tufino, le fond marin a été examiné à trois endroits dragués en 1972, afin de déterminer à quelle vitesse se rétablissaient les populations d'oursins rouges. À deux des endroits, les effectifs sont très inférieurs à ceux des captures de 1972; au troisième, la quantité pêchée n'a pas été calculée, mais de grandes superficies propices demeurent inoccupées. D'après la répartition des tailles établie en 1974, en 1976 et en 1977, nous estimons que le nombre de jeunes prélevés annuellement ne représente que de 5 à 10 % de la population présente.

L'effet du dragage sur les populations d'algues a varié selon son intensité et l'endroit où il s'est fait. À l'un d'eux, le dragage semble avoir été sans conséquence, tandis que, aux deux autres, Nereocystis et Pterygophora se sont multipliés. Il a été impossible de mesurer l'effet de cette pêche sur les autres invertébrés.

Mots clés: Pêche, oursin, varech, Strongylocentrotus.

INTRODUCTION

A fishery for the red sea urchin (Strongylocentrotus franciscanus) took place in the Tofino area from 1970 through 1972. Descriptions of this fishery are provided by Hudnall (1970) and Bernard (1977), and an excellent description of a similar fishery in California can be found in Kato (1972).

The Tofino-based fishery ended after 1972, but red sea urchins remain a species with commercial potential in British Columbia. The Japanese market for sea urchin roe is large and strong (Mottet 1976). Many large unexploited populations remain on the B.C. coast, and there has been a fishery in Washington State for several years. The B.C. industry may be inhibited by the high cost of processing and the distances at which many of the dense sea urchin populations are removed from centres of human populations.

For management, it is necessary to know the rate at which harvested areas can recover. Previous surveys in B.C. (Bernard and Miller 1973; Miller 1976) showed that recruitment of juveniles to red sea urchin populations is slow and sporadic. The existing growth rate data for British Columbia populations (Bernard and Miller 1973) show a slow-growing species in which individuals may need 4 or 5 yr to reach the legal size of 102 mm test diameter. Thus relatively long periods may elapse before second harvesting can be carried out.

In 1977, we re-visited three sites that had been harvested in 1972. Two of these sites were examined in 1974 by DCM, and we examined all three in 1976 (Breen et al. 1976). Our purpose was to examine density, population structure, and total abundance of sea urchins at each site; and from this information to estimate recovery rate. We also examined the algal communities at each site, in order to determine whether kelpbed extended beyond its normal range, and whether the species composition had changed.

METHODS

The three sites were: (1) a barren islet just outside McIntosh Bay at the north end of Vargas Island (Fig. 1); (2) a small nameless bay on the south shore of Vargas Island (Fig. 2); and (3) a reef just north of Thorn Reef off Wickaninnish Island (Fig. 3). Sites 1 and 2 were visited in June 1977, sites 1 and 3 were visited in November 1977.

On each visit, 100 sea urchins or more were measured underwater with large calipers designed for that purpose. Care was taken to measure all the individuals in a randomly chosen group. Except site 1, where sea urchins were very sparse and irregularly clumped, sea urchins were counted by using a 1×1 m quadrat, which was placed at the top of the sea urchin zone and then turned end for end to obtain a series of counts along a transect. This information was plotted as shown in Fig. 4, and a smooth curve drawn by eye. Sea urchin density was usually some decreasing function of distance along the transect, as shown in Fig. 4. The smooth curve was then used to plot density contours on a map.

Algae were identified visually underwater. Depths were read from a diver's gauge and corrected to chart datum by subtracting the tidal height calculated from tables. All depths that follow are depths below datum.

SITE 1. MCINTOSH BAY

This site is a small barren islet, approximately 10 m × 15 m when fully exposed, rising 3 m above datum. Below the water, the islet is bedrock sloping at about 45° to soft substrate. The bottom of the islet lies in 4 m at the western end, in 12 m at the eastern end. The islet is smooth bedrock for about three-quarters of its circumference; the rest is broken and tumbled rock. From commercial divers we learned that 17,500 sea urchins were removed from around the islet in 1972.

In June 1976 we counted 735 sea urchins remaining on the rock, but a count made in November 1976, when visibility was much better, showed 1,700-1,800 sea urchins. Most of this difference comprised sea urchins in deep water which were not seen in June. In 1977, visibility was poor in both June and November, and an exact count could not be made. The areas occupied by sea urchins had remained the same, and the extensive areas without red sea urchins seen in 1976 were still present.

The sea urchins were found singly or in separated groups. Groups were found as shallow as 0.6 m below datum and as deep as 12 m. In general, those on the deep eastern end of the islet were found near the bottom and on small outlying rocks; while those at the shallow western end were found throughout the vertical range. Green sea urchins (S. droebachiensis), many of them 80-90 mm in test diameter, were abundant everywhere at densities averaging 1-3/m^2.

Sizes of S. franciscanus observed in November 1976, June and November 1977 are shown in Fig. 5. The modal size of large adults remained around 140 mm during the year. The proportion of juveniles (less than 50 mm) varied from 8 to 18% of the whole population. These were all found very close to adults, in fact adults often had to be moved aside so that the juveniles could be measured. We found no small sea urchins, except near adults.

The vertical distribution of algae followed this pattern: (1) In the intertidal zone, Fucus distichus dominated the upper part, and Alaria sp. the lower part. (2) Near datum was a narrow fringe of Egregia menziesii, tapering into (3) a zone with Macrocystis integrifolia (becoming less abundant with increased depth) and Nereocystis luetkaeana. These species form a dense canopy 2-10 m wide at the surface. Under the canopy grew a mixture of Alaria sp., Laminaria spp., Costaria costata, Pleurophycus gardneri, Desmarestia ligulata var. ligulata and Pterygophora californica. (4) Beginning at 2-4 m at the western end, a dense monoculture of Pterygophora extended to the bottom of the rock, where soft substrate dominated by beds of eelgrass (Zostera sp.) and sea pens (Ptilosarcus gurneyi) began. At the eastern end of

the rock, Pterygophora were absent from this zone, and Nereocystis were present as small (20-100 cm length) individuals to 5 m depth. Scattered small individuals of D. ligulata var. firma and Laminaria sp., with scattered small reds such as Rhodoptilum plumosum and Neoptilota ?californica, were the only algal cover in this zone. The rest of the cover was in the form of colonial ascidians, Sepula vermicularis, Spirorbis sp., Tealia crassicornis, Hinnites multirugosus, etc. On the soft bottom were Costaria and Laminaria.

SITE 2. SOUTH SHORE OF VARGAS ISLAND

This site is a small bay (Fig. 2) containing a shoal close to the northwest corner. On the shoal is a kelpbed, which forms the centre of the site. Sea urchins are present in a ring around the bed, and they continue onto the western shore of the bay. The smooth bedrock slopes gradually into soft sediment at 4 m. In 1972, 12,000-15,000 sea urchins were removed from this area.

We found the kelpbed to be the same size as in 1976, 24 × 24 m (Fig. 6). Sea urchins began at 0.0-0.3 m depth. Counts of sea urchins along transects are shown in Table 1. Mean sea urchin density around the shoal was 6.0/m^2 in a band of 7.8 m average width. Therefore we estimate that the shoal supported 5,500 sea urchins. Our estimate for 1976 was 3,500. In addition, we estimated another 1,500 on the shore of the bay adjacent to the shoal.

There was a band of purple sea urchins (S. purpuratus) sharing the first 1-2 m of the red sea urchin zone. Their abundance varied from zero to an estimated 50/m^2.

The sizes observed are shown in Fig. 7. There has been no change in the size of large adults since 1974. Juveniles formed 5-10% of the whole population.

The kelpbed ranged in depth from 1.3 m above datum to 0.3 m below datum, where sea urchins began. In the canopy were Egregia, Nereocystis, and Macrocystis. The undercanopy was variable. In some places a species of Laminaria formed a dense monoculture, in others, D. ligulata var. ligulata was the dominant. In other parts still, Gigartina sp. formed most of the undercover. Where the undercanopy was a mixture of species, all those just named were present, along with Rhodomela larix, Odonthalia floccosa, Porphyra sp., Codium fragile, Hedophyllum sessile, Iridaea sp., Pleurophycus gardneri and Costaria costata. An erect coralline (not identified) and Endocladia muricata formed a thick turf under parts of the undercanopy.

SITE 3. THORN REEF.

This site is a smooth bedrock reef, approximately 100 × 20 m, sloping to soft substrate 4-6 m deep. The northern end of this reef lies just awash at extreme LLW, and the rest of it is approximately 3 m below datum. Exact production from the reef is not known, but it was heavily harvested in 1972.

Transect observations are shown in Table 2, and sea urchin distribution on the reef is shown in Fig. 8. The patchiness of the population makes estimation of its size difficult. Our estimate for 1977 is 13,000-15,000, which is much greater than our 1976 estimate of 4,500. It is unlikely that there has been an actual increase of this size; rather, the sampling technique is not intensive enough, considering the distribution, to produce a precise estimate.

To obtain another measure of changes on the reef, we examined density data from the northern end only, where the population is most abundant and most continuous. In the first 10 m of the transects made in 1974 (Miller, unpublished data), 1976 and 1977, the mean densities and standard deviations were:

	1974	1976	1977
$\#/m^2$	4.8	5.6	9.6
S.D.	3.6	5.3	6.1

It appears from this that density has increased on this part of the reef.

The observed sizes are shown in Fig. 9. There is some apparent variation in the modal size of large adults, which probably reflects variation within sub-populations. Individuals less than 50 mm in diameter comprised 5-10% of the population at each sampling time.

In November 1977 the vegetated portion of the reef was dominated by Nereocystis, with some Macrocystis in the centre portion. This cover stopped where sea urchins began. In those parts of the reef that were free of sea urchins, Nereocystis gave way gradually to Pterygophora near the bottom of the reef. Both species grew on outlying boulders. There was no undercanopy, but widely scattered individuals of D. ligulata var. ligulata were seen. At the shallow north end of the reef, Nereocystis was replaced by Alaria sp. to 0.3 m depth.

DISCUSSION

The most intensely harvested site must have been the islet in McIntosh Bay, site 1. Because 17,500 sea urchins were taken, and now only about 2,000 can be found, the fishery took nearly all the adults. The remaining sea urchins have formed aggregations. It is only here that juveniles can be found, under or close to adults. This supports the observations of Low (1975) and Tegner and Dayton (1977), who also found newly-settled sea urchins only under the spines of adults. They suggested that if a fishery removed all the adults from an area, juveniles would have no place to settle successfully and re-colonization would be very slow. This is borne out at site 1.

Within the aggregations of adults at site 1, we found that juvenile abundance varied from about 5% to 18% of the whole population. This is similar to the observations made at the other sites described here, and at sites in Barkley Sound. Recruitment rate does not appear to increase in order to compensate for reduced population size.

Where harvesting was less intense, at sites 2 and 3, the populations are more continuously distributed, and thus there is a larger area for juveniles to settle into. Recovery rate is at least measurable: at site 2 we observed a change from 3,500 sea urchins in 1976 to 5,500 in 1977. However, the population at site 2 is still well below its original level, for at least 12,000 were taken in 1972. At site 3, density appears to have nearly doubled on one part of the site, since 1974.

The population size structure shows that recruitment varies within the range 0-18%, averaging about 7% per year. These values are in agreement with observations elsewhere, and they also conform with the slow rebounds in population size at harvested sites. The adult size modes at sites 1 and 2 are stationary, indicating an accumulation of individuals at final size. In turn, the low numbers of juveniles show that the average age of these must be high.

The biological information just presented: low recruitment, accumulation of old individuals, slow increases in populations of harvested populations, all lead to the conclusion that a sustained yield fishery for red sea urchins could take only a small part of the population each year. Because of the economic factors involved, fishermen must be able to remove a large number of individuals from a small area. Management on a sustained-yield basis thus seems to be impossible in this fishery.

Harvesting appears to have no effect on kelp communities unless it removes most of the sea urchins, as seen at site 1 and perhaps parts of site 3. At site 2, much of the population was removed, but there is no kelp except in very shallow water. At site 1, where no red sea urchins remain on many parts of the islet, Pterygophora and Nereocystis appear to have extended into deeper water than they would normally occupy. We also observed this at those parts of site 3 that have no red sea urchins. However, there was unfortunately no survey of algal zonation before harvesting, so analysis of present distributions is not useful.

Shephard (1973) found that sea urchins in Australia compete with abalone for space, and that abalone fishing allowed sea urchins to pre-empt habitat formerly used by abalone. We were interested in the reverse situation, namely abalone profiting from the removal of sea urchins, since the food requirements of these species are very similar. There was no evidence for this. Site 1 had only 46 abalone found during a careful count (Les Tulloch, personal communication) most of which were legal size; at site 2 abalone reached $1/m^2$ on one corner of the shoal, and all were close to legal size; and site 3 had no abalone at all. Thus we find no evidence of increased abalone settlement in these areas, nor of noticeably high densities of adults.

ACKNOWLEDGEMENTS

We are grateful to Les Tulloch for help in the field and for information from his work at McIntosh Bay; to Barb Bunting for algal identifications and helping with illustrations; to Rod Palm and Bob Crompton for information and interesting discussions; to Jim Arnett for lending us his engine when our water pump broke; and to the McLory family.

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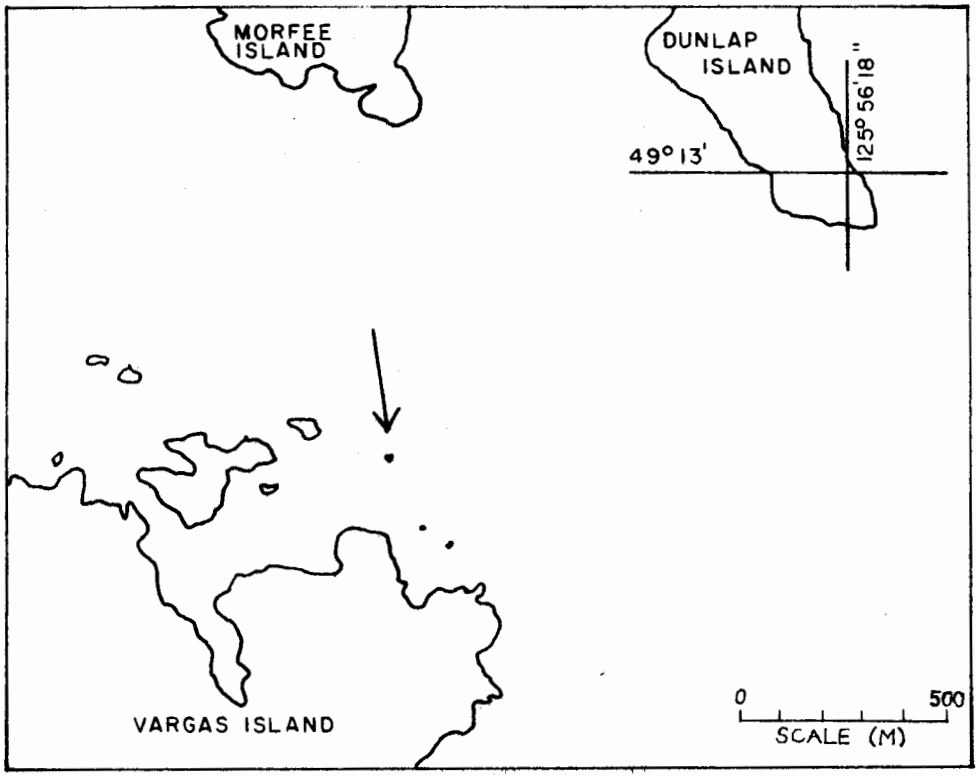

Fig. 1. Site 1, McIntosh Bay.

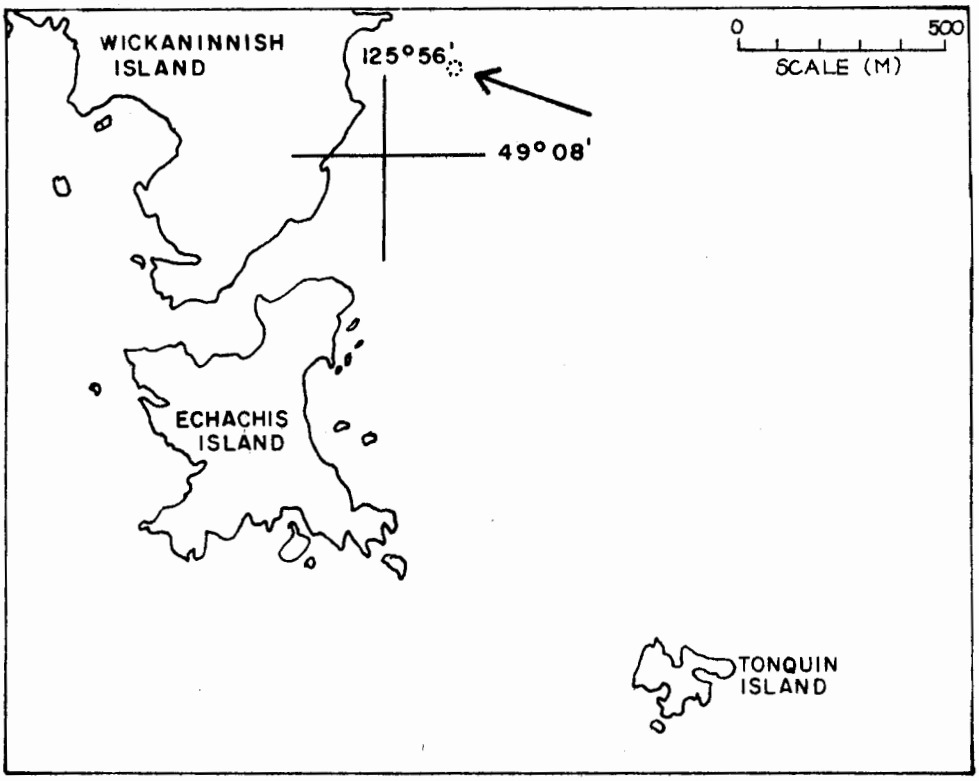

Fig. 2. Site 2, on the south shore of Vargas Island.

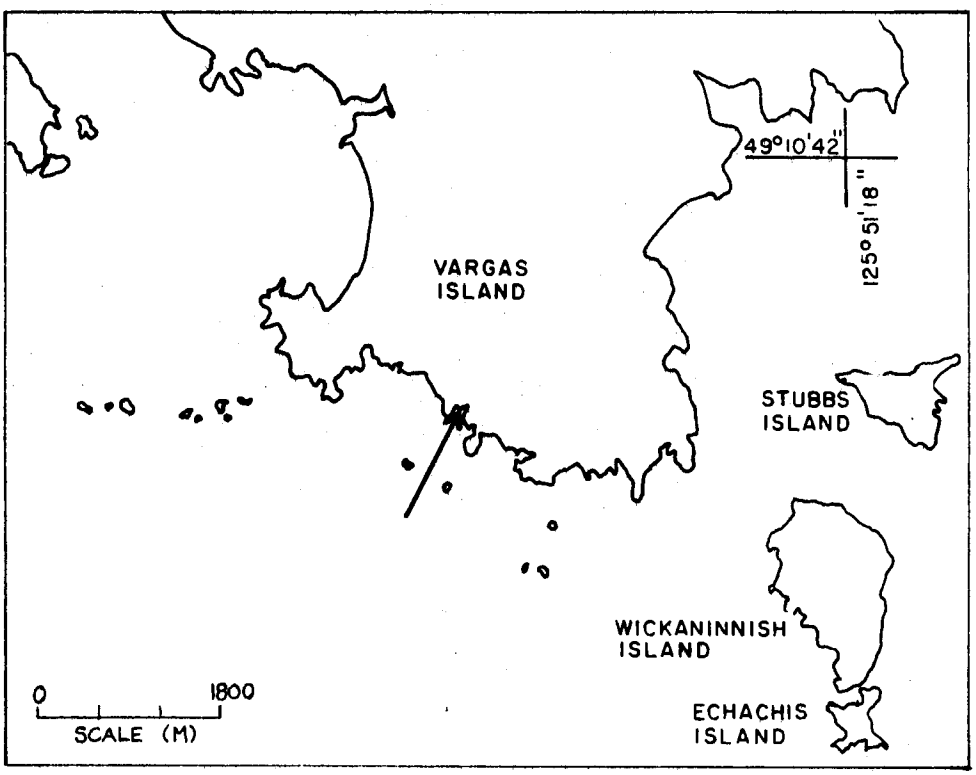

Fig. 3. Site 3, near Thorn Reef.

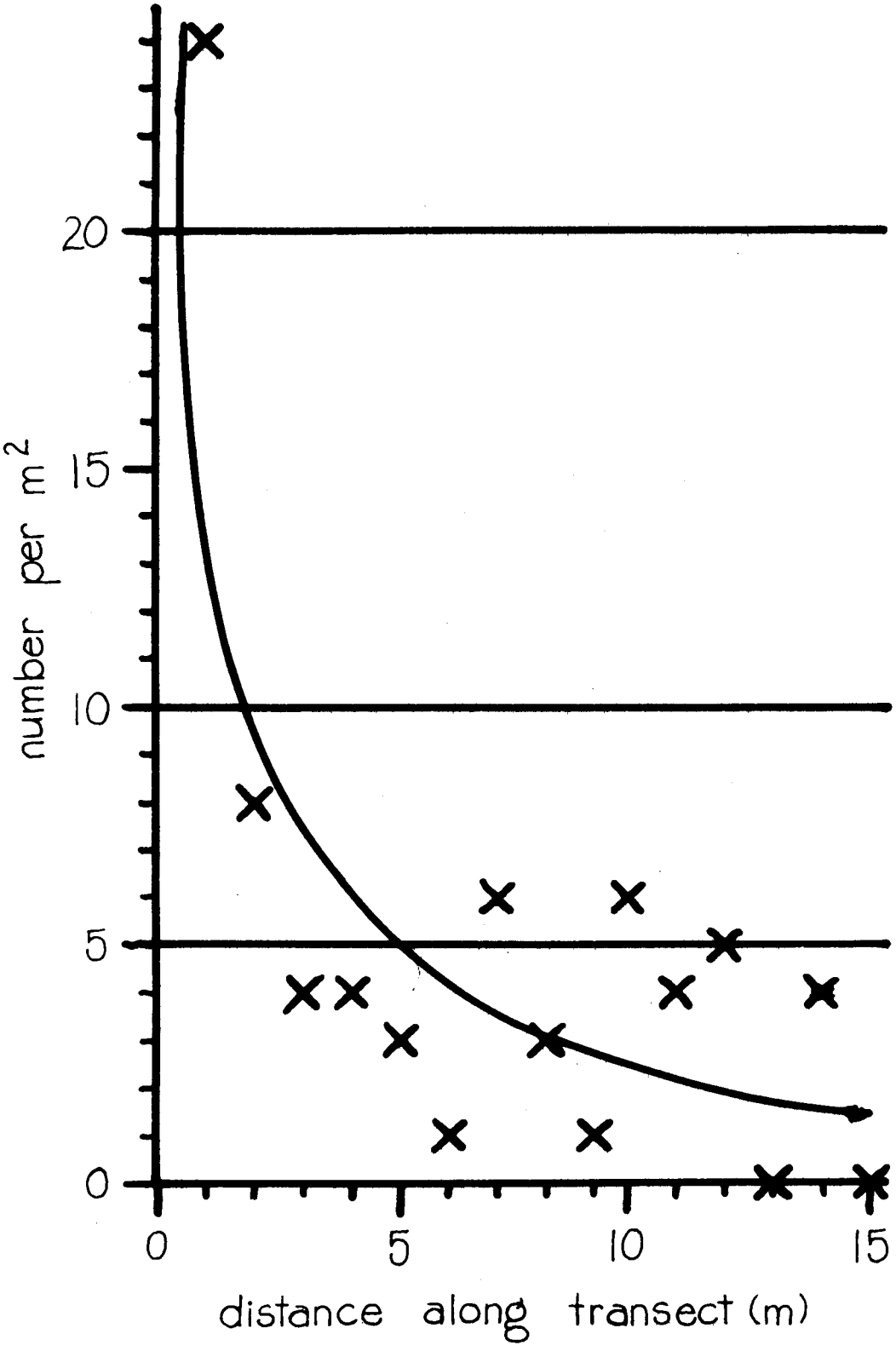

Fig. 4. A typical transect, showing the relation between sea urchin density and distance along the transect. The smooth curve was drawn by eye.

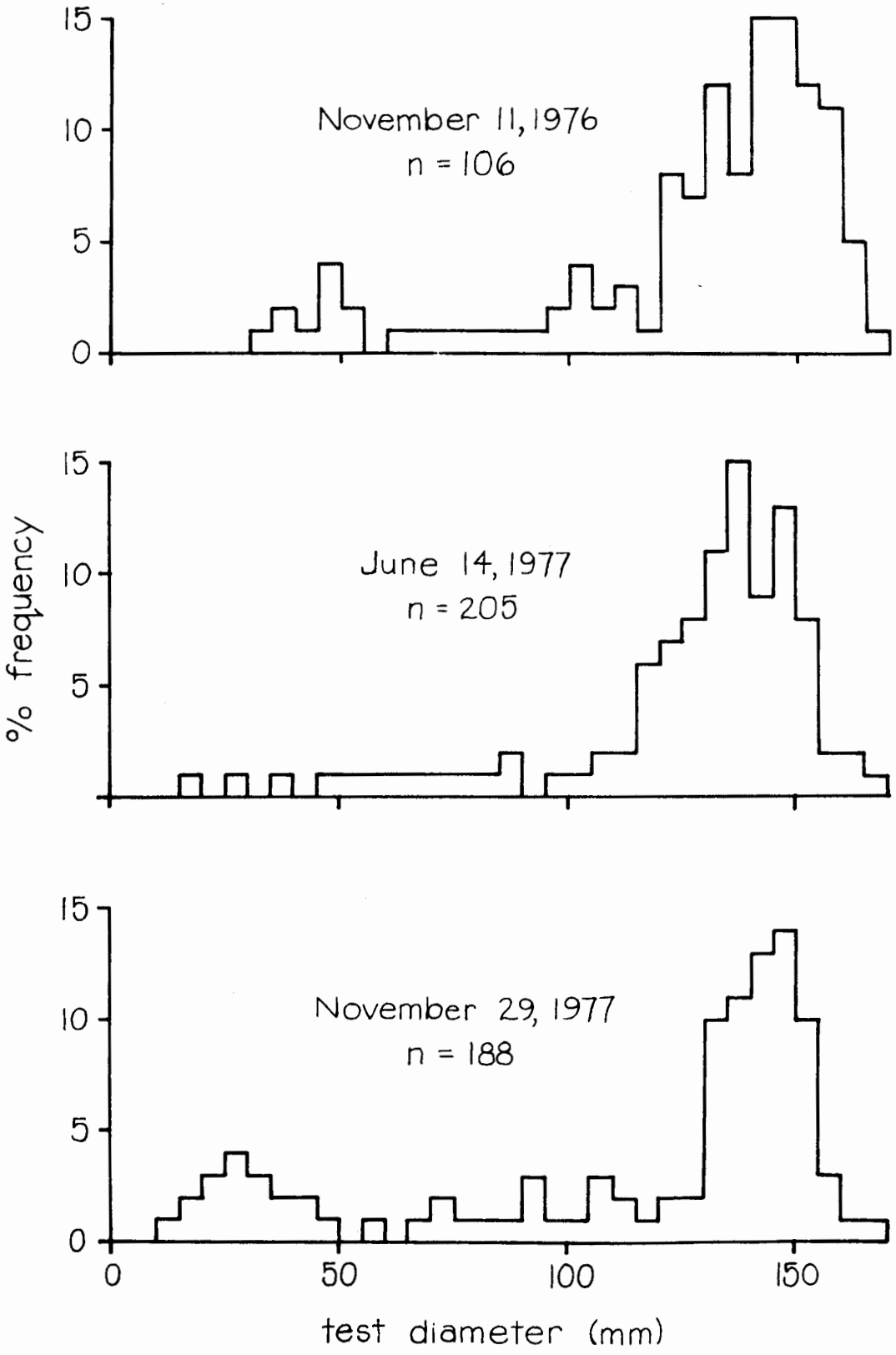

Fig. 5. Size frequencies of red sea urchins observed at Site 1.

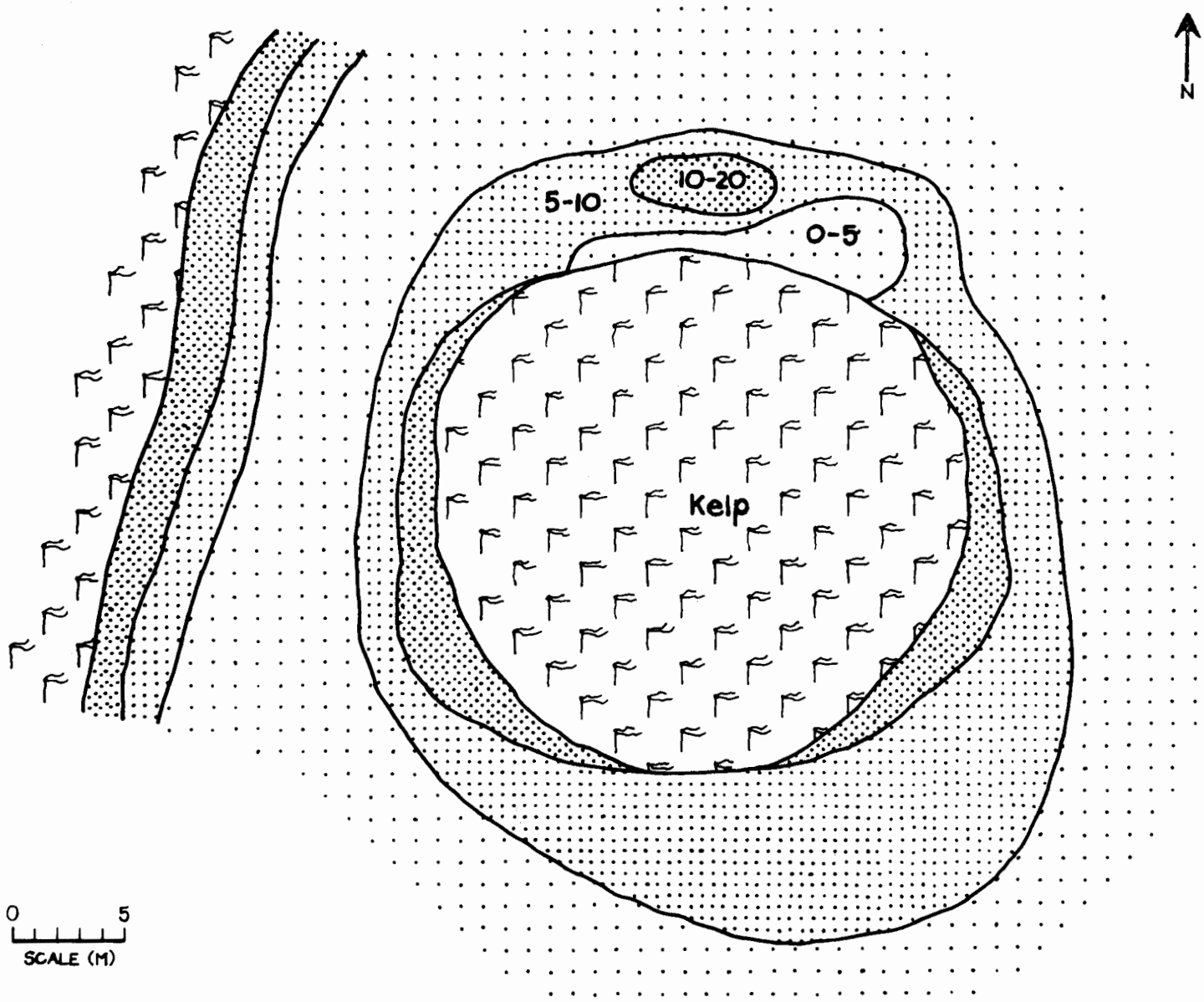

Fig. 6. Sea urchin density contours observed at Site 2 on June 15, 1977.

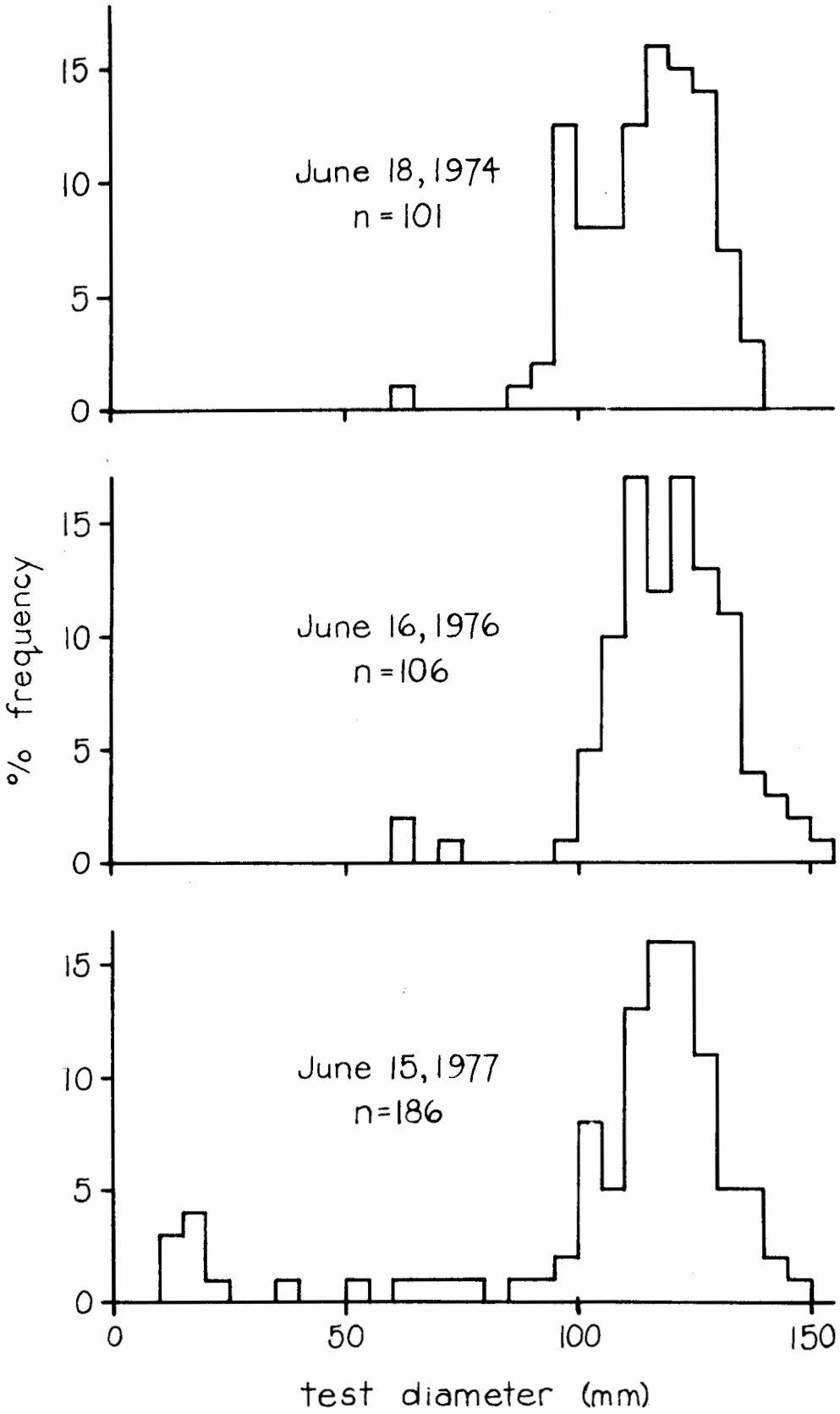

Fig. 7. Size frequencies observed at Site 2.

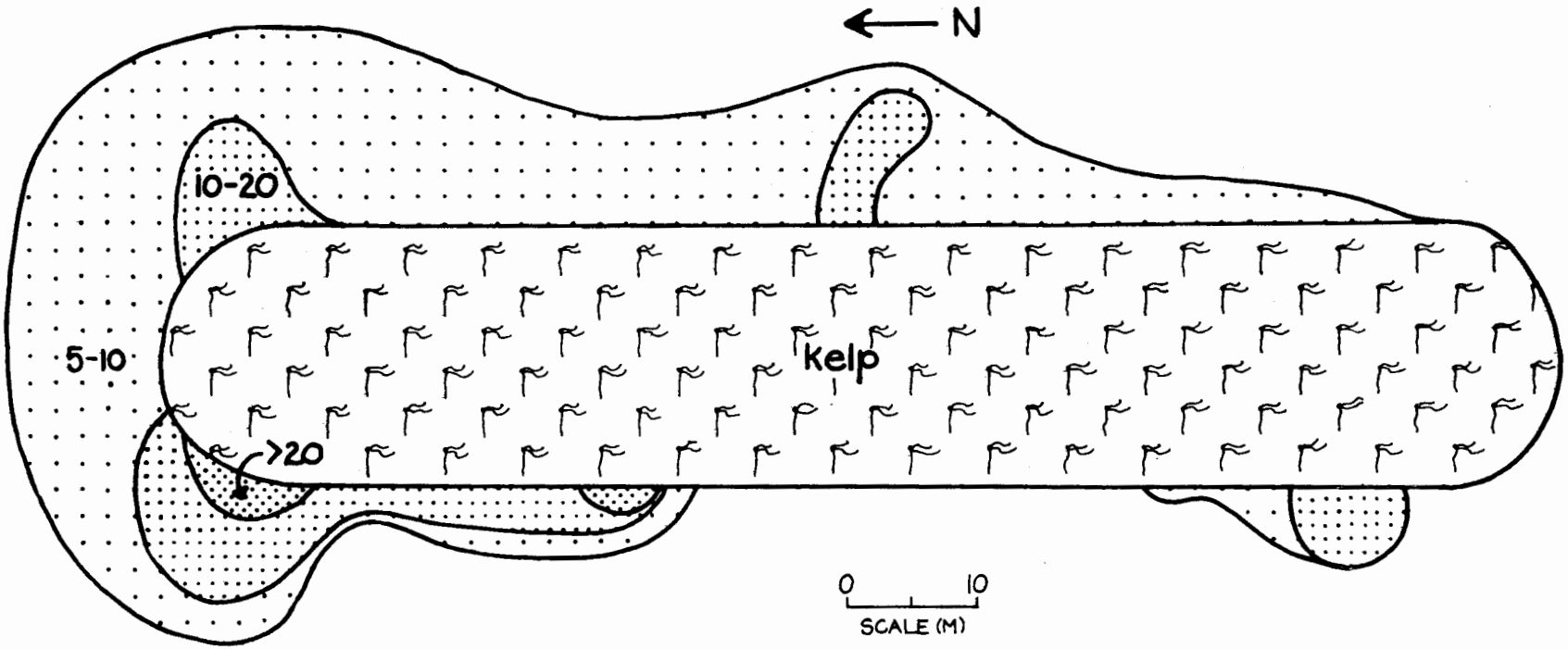

Fig. 8. Sea urchin density contours observed at Site 3 on November 30, 1977.

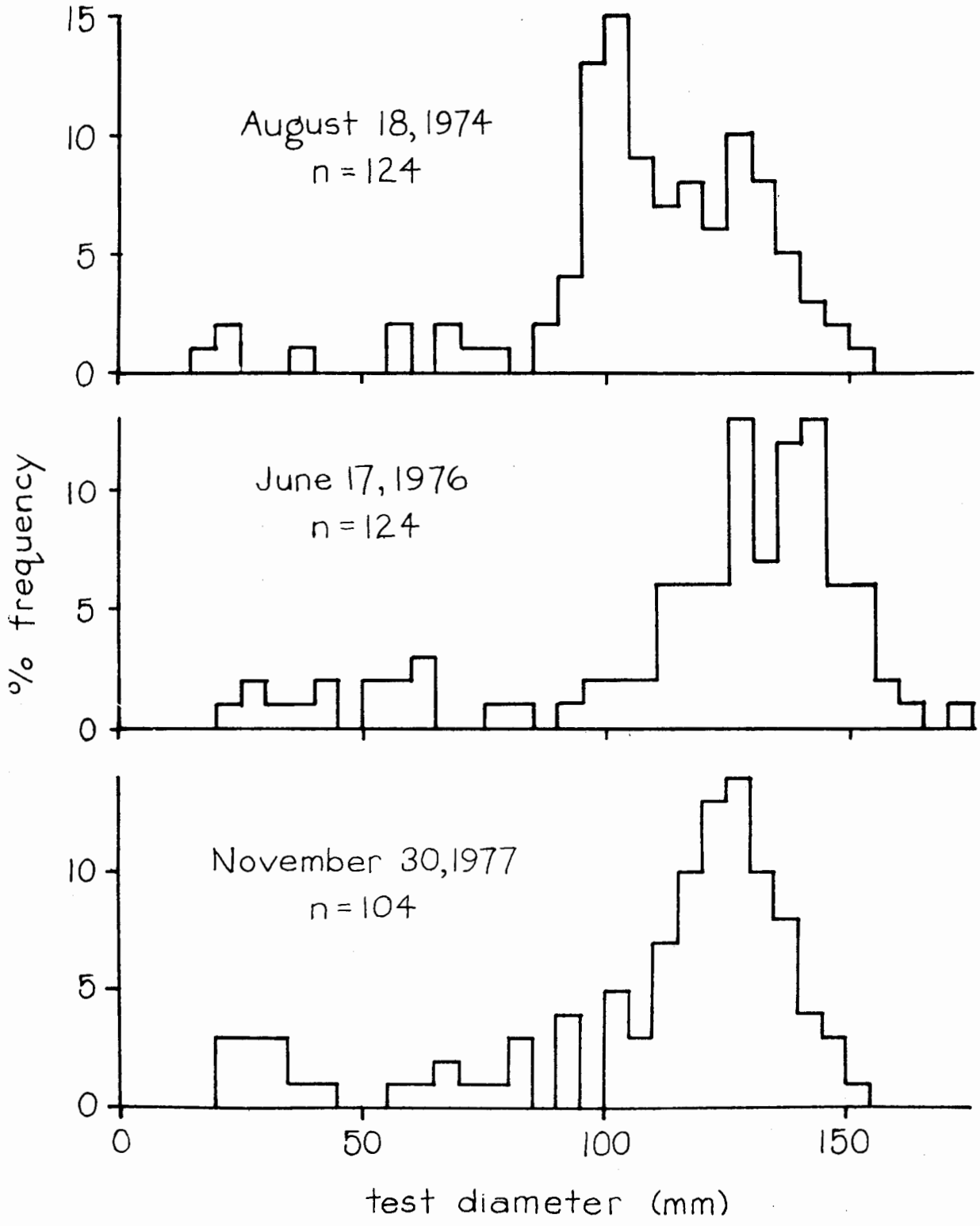

Fig. 9. Size frequencies of sea urchins observed at Site 3.

Table 1. Sea urchin density (no./m^2) along transects at Site 2. The shore is on the left, deep water on the right. Depths (m) are given beneath the density measurements.

Transect no.	Direction	Distance (m) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	N	2 0	7	17 0.3	7	1	4	0	0	0 2.5	4							
2	NW	5 0.6	6	9 0.6	4	0	3	0	2	1 1.6	3	2 2.0	1	1 1.3	17			
3	W	16 0.6	3	3 2.6	2	1	4	0 2.0	4	6 2.3	15	14 0.3						
4	W	27 0.6	8	7 2.3	4	5	2 2.3	2	3	0 2.3	5	2 2.3	6	3	4 2.0	4	13	15 0.3
5	SW	24 0.3	8	4	4	3 1.3	1	6	3	1 2.0	6	4	5 3.0	0	4	0 4.0		
6	SE	18 0	3	4	3	3	3	1 0.6	6	7 1.3	3	6	5	3 2.6	1			
7	E	20 0	36	16	9	8 2.0	6	5 3.0	5	2	4 4.3							
8	E	7 0.6	12 1.3	4	2 3.0	6	2	5 4.0	5	3	1							
9	NE	1 0.3	2	4 1.6	8	11 3.0												

Table 2. Sea urchin densities along transects at Site 3.

Transect no.	Direction	Distance (m)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	W	20 4.6	13	17	10	22 5.3								
2	W	9												
3	W	18 4.0	22	6	29	13	4 5.6							
4	W	16 4.0	20	18	5	6	 5.6							
5	W	20 4.6	18	1 5.3										
6	W	15 0.3	21	19	13	16	15 1.3	0	0	8	11	5	7 4.0	
7	N	7 0.3	7	8	1	4	8	5	15	8	10	17	3 3.0	
8	E	8 2.0	15	8	21	15	3	6 3.0	1	6	15	13	15	8 4.0
9	E	11 2.0	3	6	12	7	7	4	8	1	4	11	7	2 5.3
10	E	4 3.0	11	12	3	3 4.0	12	3	8 5.6					

Table 2 (cont'd)

Transect no.	Direction	Distance (m)									
		1	2	3	4	5	6	7	8	9	10
11	E	6 2.0	5	8	6	1	9	18 4.3	15	17	6 3.0
12	E	8 2.6	3	5 4.0							