Survey of Abalone Populations at Stryker Island, Tribal Group and Simonds Group, Central Coast of British Columbia, May, 1997

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SURVEY OF ABALONE POPULATIONS AT STRYKER ISLAND, TRIBAL GROUP AND SIMONDS GROUP, CENTRAL COAST OF BRITISH COLUMBIA, MAY, 1997

by

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ABSTRACT

Campbell, A., and K. Cripps. 1998. Survey of abalone populations at Stryker Island, Tribal Group and Simonds Group, central coast of British Columbia, May, 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2451: 21 p.

Transect surveys were conducted to determine the density of the northern abalone, *Haliotis kamtschatkana*, from intertidal to approximate 8m depths, in the Tribal and Simonds, Stryker group of islands of the central coast of British Columbia during May, 1997. Most (>96 %) adult abalone ($\geq$ 70 mm shell length SL) were exposed or emergent (visible on rocks). Mean abalone sizes were generally largest in the -1-3 m depth range and smallest in > 7 m depths. Adult abalone were more abundant < 5 m depths, whereas small juveniles (<50 mm SL) were found at all depths, but less frequently in the intertidal. Mean densities for all sizes of abalone were similar (0.47, 0.47 and 0.53 per m^2) between areas. Abalone densities were highest in the 0 - 1 m depth range, with fewer abalone found in the intertidal areas and to depths >4 m.

RESUME

Campbell, A., and K. Cripps. 1998. Survey of abalone populations at Stryker Island, Tribal Group and Simonds Group, central coast of British Columbia, May, 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2451: 21 p.

Nous avons effectué en mai 1997 des relevés sur transects pour déterminer la densité de l'ormeau nordique (*Haliotis kamtschatkana*), de la zone intertidale à une profondeur d'environ 8 m, dans les îles Tribal et Simonds, du groupe Stryker, dans la zone centrale de la côte de Colombie-Britannique. La plupart (> 96 %) des ormeaux adultes ($\geq$ 70 mm, LS de la coquille) étaient exondés ou émergents (visibles sur les rochers). La taille moyenne des ormeaux était généralement au maximum dans la zone de profondeur de 1-3 m et au minimum à des profondeurs de plus de 7 m. Les adultes étaient plus abondants à des profondeurs de moins de 5 m, tandis que les petits juvéniles (< 50 mm LS) se retrouvaient à toutes les profondeurs, mais moins fréquemment dans la zone intertidale. Les densités moyennes étaient semblables pour toutes les tailles (0,47, 0,47 et 0,53 au m^2) d'une zone à l'autre. Les densités des ormeaux étaient au plus haut dans la plage de profondeur de 0-1 m, et les ormeaux étaient moins nombreux dans les zones intertidales et à des profondeurs de plus de 4 m.

INTRODUCTION

The ‘northern’ or ‘pinto’ abalone, *Haliotis kamtschatkana*, generally occurs in patchy distribution on exposed and semi-exposed coasts from Sitka Island, Alaska to Baja California, including British Columbia (B.C.) (Sloan and Breen 1988). Northern abalone were harvested by first nations and in commercial, and recreational fisheries in B.C. until 1990. Previous surveys at index sites in southeastern Queen Charlotte Islands and the north central coast of B.C. indicated that the abundance of northern abalone had declined more than 75% between the period of 1978-84 and remained low until 1994 (Winther *et al.* 1995; Thomas and Campbell 1996). Faced with the possibility of abalone population collapse the northern abalone fishery has remained closed since 1990 due to conservation concerns. The standard broad-scale survey design has remained essentially the same since 1978 (Breen and Adkins 1979) and consisted of counting and measuring abalone in 16 alternate 1 m^2 quadrats per index site. Apart from a few samples made by Breen and Adkins (1982) of abalone densities at Spider Island, Triquet Island and the Goose Group during 1980, little was known of the status of abalone stocks in the Heiltsuk First Nations traditional fishing area. Consequently, the traditional broad-scale survey of the Central coast of B.C. (Thomas and Campbell 1996) was extended to include sample sites in the Stryker, Simonds and Breadner group of islands (Campbell *et al.* 1998). The objectives of the present paper were to estimate the density of abalone using a random transect method (Cripps and Campbell 1998) and to determine whether there was a relation between depth and abalone size and density at the Tribal, Simonds and Stryker islands (Fig. 1).

METHODS

Transects were randomly placed on a nautical chart by positioning a metric ruler, marked in mm, along the length of shoreline to be surveyed. A random numbers table was used to select the position along the ruler where survey transects were to be placed. The survey method was the same as that described by Cripps and Campbell (1998). The primary sampling unit was a “transect”, made up of a cluster or variable number of secondary units. Each transect was one meter wide and variable in length depending on the slope of the substrate within the depth range of 0 to 8m. The secondary sampling unit consisted of a 1 m^2 quadrat that was placed on the right side of the transect line. Lead line was deployed perpendicular to the isolepths to a depth of approximately 10 meters below chart datum. Transect origin was determined by indescriminantly throwing a lead cannon ball into the intertidal zone. Divers, equipped with a 1m x 1m quadrat, flipped the quadrat parallel to the transect line, from deep to shallow, and the number of “emergent” or “exposed” (visible on rocks) abalone, shell length (SL in mm) of each abalone, depth, substrate type, and dominant algal cover was recorded for each quadrat. All kelp, sea urchins and starfish were removed from the quadrat to ensure abalone were easily detectable, however, boulders were not rolled to examine for cryptic abalone. Caution was exercised to ensure that abalone in upcoming quadrats were not disturbed. Sampling only exposed abalone is an efficient sampling strategy, since the majority of mature abalone (e.g., ≥70 mm SL) of interest to the survey are exposed (Campbell 1996).

All depth recordings were converted to depth at datum. The surveys were conducted from the intertidal zone to about 8 m below chart datum. Surveying deeper would have greatly reduce the number of transects that could be safely completed in a day.

To determine the detectability of exposed animals and the cryptic proportion of the population, a few transects in each area were randomly chosen and subjected to more intensive sampling protocol. The number of transects intensively surveyed at the Tribal group was 4, Simonds group was 6, and Stryker Island was 3. The intensive survey protocol involved examining each quadrat three times before moving onto subsequent quadrats. Depth, substrate, dominant algal cover, number of exposed (emergent) abalone on first examination, number of emergent abalone on second examination, and number of cryptic abalone were recorded for each quadrat. The first examination involved identifying and harvesting all the exposed animals. Sampled abalone were placed in a marked collection bag. The quadrat was then more closely examined to see if any exposed abalone were missed during the first pass. If an abalone was missed on the first pass the animal was removed and placed in a separate labeled collection bag. On the third examination, the cryptic component of the population was sampled by removing and inspecting all of the moveable material within the quadrat. The cryptic abalone were also removed and placed in a labeled collection bag. The shell length (mm) was recorded for each abalone in each collection bag. Once the abalone were measured they were returned to the area from where they were sampled.

The mean density, d (number / m^2), was calculated as

$$d = \frac{\sum_i c_i}{\sum_i a_i} \tag{1}$$

The standard error of the mean density, se (d), was calculated as

$$se(d) = \sqrt{1 - n/N}\sqrt{\frac{\sum_i (c_i - da_i)^2}{n(n-1)a^2}} \tag{2}$$

where for each ith transect, c_i = the number of abalone observed in a transect, a_i = the area of transect surveyed in square metres, a = the mean transect area for all transects, n is the number of transects sampled, and N is the total population of possible transects. Adjusting densities for detectability was calculated by substituting c_i with c_i / e, where e = mean proportion of total population estimated to be detectable (exposed abalone / (exposed + cryptic abalone)). This method accounted for the variable length of transects. Mean and standard error of densities by depth range and abalone size class was also calculated by subsampling each transect. The depth ranges were (1) <0 m, (2) 0 - 1.5 m, (3) 1.51 - 3.0 m, (4).3.01 - 4.50 m, (5) 4.51 - 6.00 m, (6) 6.01 - 7.50 m, (7) >7.50 m. The size classes were "mature" ≥ 70 m SL [i.e., about 100 % of abalone would be mature (Campbell *et al.* 1992)], "prerecruit" 92-99 mm SL, "legal" ≥ 100 mm SL, "new recruit" 100-106 mm SL and "total" which included all size classes. Although some of the size categories, overlap they were included in the analyses so that the results could be compared with those from previous surveys of abalone from other areas. The "immature" <70 mm SL size class was not included in the density estimates (except as part of the "total") because of the difficulty of finding small abalone.

RESULTS

SURVEY LOGISTICS SUMMARY

The number of transects surveyed off the Tribal Group was 29, the Simonds Group was 32, and Stryker Island was 20 (Table 1, 2). The mean length of transect was 12.0 m for the Tribal Group, 13.3 m for Simonds Group, and 12.7 m for the Stryker Group.

POPULATION SIZE STRUCTURE

Juvenile exposed abalone (< 50 mm SL) made up 22.5 %, 20.3 % and 23.3 % of the population for the Tribal, Simonds, and Stryker group, respectively. The length frequency distribution of exposed abalone indicated that the majority of the animals sampled at both locations were less than 100 mm SL, with most abalone between 70 and 100 mm SL (Fig. 2, Table 3). Abalone ≥ 70 mm SL were 43.2 %, 55.4 and 55.1 % of the population for the Tribal, Simonds, and Stryker group, respectively. The percentage of legal abalone (≥ 100 mm SL) was greater for the Simonds (18 %) than for those for Stryker (5 %) and Tribal group (2 %).

Detectability expressed as a percent of exposed compared to total (exposed + cryptic) abalone was higher for sizes ≥ 70 mm SL than smaller abalone (Table 4, Fig. 3). Most cryptic animals were < 70 mm SL. These results were similar to those reported for other surveys (Campbell 1996; Cripps and Campbell 1998). These detectability factors were used to estimate the combined cryptic and exposed abalone densities (Table 5).

Size frequencies and mean SL of exposed abalone generally decreased as depth increased (Fig. 4, 5). Adult abalone were more abundant < 5 m depths, whereas small juveniles (<50 mm SL) were found at all depths, but less frequently in the intertidal (Fig. 4A, 4 B, 4C).

DENSITY ESTIMATES

Mean densities per transect ranged from 0 to 2.72 total exposed abalone per m^2 (Fig. 6). Total mean densities of exposed, and adjusted for detectability, were similar for each area (Table 5). Abalone densities were generally highest in the 1-3 m depth range, although abalone were found at all depths surveyed (Fig. 7).

DISCUSSION

This study showed that there were differences in mean size and density of abalone with increases in mean depth. Abalone were most abundant between 1 to 3 m depth, and both density and mean abalone size declined with increasing depth in all three study areas. Reduced density and size with increasing depth has been reported previously for *H. kamtschatkana* (Sloan and Breen 1988; Cripps and Campbell 1998). All abalone were found on firm substrates in this survey, although northen abalone are reported to be capable of moving across sand or gravel (Sloan and Breen 1988). The decrease in mean length with depth was probably due to adult abalone preferentially inhabiting shallow water habitats for spawning (Breen and Adkins 1980) with juveniles found throughout the 1 - 7 m depths in this study. Breen and Adkins (1979, 1982) found juvenile northern abalone were generally distributed deeper (5 - 15 m) than adults (Sloan and Breen 1988).

In general, the estimated mean total densities of abalone (adjusted for detectability) found in this study appear to be similar to the densities found in previous surveys of abalone in the central coast. Using the same transect method, Cripps and Campbell (1998) estimated similar abalone densities in east Higgins Pass compared to those found in the present study. Thomas and Campbell (1996) reported slightly higher densities from a survey of abalone at 25 sites further north along the central coast of B.C. conducted during 1993 (in this survey, the mean density of the total was 0.53, legals was 0.09). The differences in mean density were probably a result of differences between the depth ranges sampled by the index site 16-quadrat method (1 - 4 m) (Thomas and Campbell 1996; Campbell *et al.* 1998) and the present transect survey method (intertidal to 8 m). After standardizing the data to similar depth ranges, Campbell *et al.* (1998) found abalone densities, estimated by the two survey methods at Simonds and Stryker Islands, during May, 1997, to be similar. The results of the present survey and those of Campbell *et al* (1998) indicated that northern abalone densities in southern areas of the central coast of B.C. were at density levels when the fishery was closed in 1990, and were well below those reported by Breen and Adkins (1982) in a few samples during 1980.

Studies suggest that abalone growth and recruitment can differ dramatically from one small area to another depending on local conditions, such as habitat type, food availability, substrate type, and exposure to wave action (Sloan and Breen 1988). Future surveys and studies of abalone in these areas should involve estimates of growth, mortality and recruitment rates so that the productivity and surplus abalone production for possible exploitation can be determined. Due to uncertainties about abalone productivity and ability of abalone populations to recover from previous exploitation there still remains conservation concerns for *H. kamtschatkana* along the central coast of B.C.

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Table 1. Dive survey summary for abalone transects surveyed in the Tribal, Simonds and Stryker groups, May 1997.

		Time		Bottom	Depth (m)		Number of	Total #	Density
Transect	Date	Start	Finish	Time	Min	Max	Quadrats	of Abalone	(No./m^2)
Tribal Group									
101	May 21	14:35	14:50	0:15	0.12	7.86	7	0	0.000
102	May 21	15:00	15:45	0:45	-2.74	8.38	17	18	1.059
103	May 22	9:14	9:34	0:20	-0.76	7.68	9	9	1.000
104	May 21	11:20	11:33	0:13	-2.07	7.86	9	2	0.222
105	May 22	11:40	11:57	0:17	-2.77	5.70	15	12	0.800
106	May 22	9:50	10:03	0:13	-1.13	6.98	10	2	0.200
107	May 22	14:50	15:32	0:42	-1.28	6.00	21	17	0.810
108	May 22	11:40	11:57	0:17	-2.77	6.31	11	0	0.000
109	May 22	11:10	11:30	0:20	-2.41	7.04	10	13	1.300
110	May 22	13:42	14:37	0:55	-2.62	7.19	20	19	0.950
111	May 21	10:29	10:48	0:19	-1.46	7.35	15	2	0.133
112	May 21	11:00	11:15	0:15	-1.52	6.89	11	0	0.000
113	May 21	11:20	11:33	0:13	-1.46	7.25	11	0	0.000
114	May 21	13:15	13:30	0:15	-2.26	7.22	8	16	2.000
115	May 21	14:00	14:12	0:12	-2.50	7.62	8	8	1.000
116	May 21	11:43	11:58	0:15	-2.65	6.34	8	6	0.750
117	May 21	10:01	10:16	0:15	-1.92	8.66	11	3	0.273
118	May 22	15:47	16:00	0:13	-1.80	7.77	9	1	0.111
119	May 22	16:12	16:25	0:13	-1.55	6.83	10	2	0.200
121	May 23	15:16	15:28	0:12	-2.29	5.70	12	1	0.083
122	May 23	14:43	15:05	0:22	-2.62	5.61	11	4	0.364
123	May 23	14:15	14:45	0:30	-2.01	6.31	12	4	0.333
124	May 23	12:45	13:15	0:30	-1.74	6.25	26	1	0.038
125	May 23	12:17	12:34	0:17	-1.83	7.89	10	4	0.400
126	May 23	11:41	12:06	0:25	-1.71	7.22	14	2	0.143
127	May 23	11:00	11:25	0:25	-1.68	8.44	14	7	0.500
128	May 23	10:23	10:51	0:28	-1.49	8.35	17	19	1.118
129	May 23	16:06	16:15	0:09	-1.07	5.70	6	0	0.000
130	May 23	16:24	16:34	0:10	-2.13	6.19	6	0	0.000
Simonds Group									
201	May 25	14:10	14:30	0:20	-2.16	7.53	16	0	0.000
202	May 25	9:16	9:44	0:28	0.40	8.41	20	14	0.700
203	May 25	14:46	15:29	0:43	-3.63	7.10	39	11	0.282
204	May 25	10:29	10:47	0:18	1.86	10.18	21	22	1.048
205	May 26	11:04	11:28	0:24	0.24	9.17	13	3	0.231
206	May 26	10:40	10:57	0:17	-0.27	9.20	11	4	0.364
207	May 26	12:45	13:11	0:26	-1.10	8.99	12	14	1.167
208	May 25	11:19	11:32	0:13	-0.67	8.32	10	4	0.400
209	May 25	10:50	11:11	0:21	-0.46	8.26	8	10	1.250
210	May 25	10:29	10:47	0:18	-0.27	8.35	11	9	0.818
211	May 25	9:51	10:21	0:30	0.46	9.02	16	17	1.063
212	May 25	9:16	9:44	0:28	-0.21	9.94	15	10	0.667
213	May 25	9:00	9:09	0:09	-0.34	7.96	7	0	0.000
214	May 25	11:40	12:14	0:34	-1.19	7.77	17	26	1.529
215	May 26	9:52	10:05	0:13	-0.12	9.11	8	1	0.125

Table 1 (cont'd).

Transect	Date	Time Start	Time Finish	Bottom Time	Depth (m) Min	Depth (m) Max	Number of Quadrats	Total # of Abalone	Density (No./m^2)
Simonds Group (cont'd)									
216	May 26	9:28	9:47	0:19	-0.61	9.91	10	1	0.100
217	May 26	8:47	9:18	0:31	-0.73	8.75	14	2	0.143
218	May 24	15:18	15:38	0:20	-2.90	6.86	14	1	0.071
219	May 24	14:58	15:10	0:12	-2.87	7.22	8	4	0.500
220	May 24	14:31	14:46	0:15	-2.77	6.80	12	7	0.583
221	May 24	14:07	14:19	0:12	-2.26	7.01	9	0	0.000
222	May 24	13:40	13:57	0:17	-2.32	7.62	11	6	0.545
223	May 24	13:07	13:32	0:25	-2.62	7.77	17	25	1.471
224	May 24	11:07	11:38	0:31	-1.25	8.93	20	12	0.600
225	May 24	10:12	10:55	0:43	-0.98	8.87	21	4	0.190
226	May 24	9:56	10:07	0:11	1.62	8.69	9	1	0.111
227	May 24	9:41	9:50	0:09	1.10	8.14	6	0	0.000
228	May 24	9:26	9:35	0:09	0.55	8.17	5	0	0.000
229	May 24	9:06	9:20	0:14	0.24	8.20	8	0	0.000
230	May 26	12:45	13:11	0:26	-1.40	8.99	18	11	0.611
231	May 26	13:20	13:32	0:12	-1.98	7.92	10	1	0.100
232	May 26	13:39	13:59	0:20	-2.07	8.90	11	9	0.818
Stryker Island									
301	May 29	11:40	11:55	0:15	-1.10	7.56	8	4	0.500
302	May 29	11:13	11:31	0:18	-1.34	7.96	21	3	0.143
303	May 29	10:37	10:47	0:10	-1.40	8.44	6	2	0.333
304	May 29	10:55	11:05	0:10	-0.30	7.10	14	0	0.000
305	May 29	9:48	10:30	0:42	-2.23	7.96	14	16	1.143
306	May 29	9:17	9:39	0:22	-3.14	8.35	14	3	0.214
311	May 28	8:38	9:09	0:31	-1.71	8.11	16	10	0.625
312	May 28	9:19	9:36	0:17	-1.52	8.44	9	0	0.000
314	May 28	10:24	10:47	0:23	-0.79	8.29	11	10	0.909
316	May 28	11:33	11:58	0:25	-1.16	8.72	13	16	1.231
317	May 28	11:01	11:21	0:20	-1.07	7.01	29	4	0.138
318	May 28	12:08	12:20	0:12	-0.70	8.14	7	7	1.000
319	May 28	12:26	12:36	0:10	0.55	8.17	7	1	0.143
320	May 28	12:46	12:57	0:11	-1.04	9.05	10	1	0.100
321	May 28	13:04	13:14	0:10	-1.10	9.33	8	0	0.000
322	May 28	13:20	13:40	0:20	-1.22	7.41	16	20	1.250
323	May 28	13:47	14:00	0:13	-0.76	7.86	12	2	0.167
324	May 28	14:10	14:32	0:22	-1.07	8.90	12	33	2.750
325	May 28	14:43	15:02	0:19	-1.10	6.43	18	2	0.111
326	May 28	9:44	10:10	0:26	-0.61	8.84	9	2	0.222

Table 2. Summary statistics of transect survey of exposed abalone from the Tribal, Simonds and Stryker groups, May, 1997. Values in brackets are standard errors.

Details per transect	Tribal Group	Simonds Group	Stryker Group
Dates	21-24 May	24-26 May	28-29 May
Number of tansects	29	32	20
Mean Depth (m)	2.41 (0.09)	3.75 (0.09)	3.21 (0.12)
Mean quadrats or length (m)	12.0 (0.9)	13.3 (1.2)	12.7 (1.2)
Mean minutes	20.5 (2.0)	20.9 (1.6)	18.8 (1.8)
Mean minutes/quadrat	1.59 (0.14)	1.60 (0.07)	1.69 (0.08)

Table 3. Mean shell length (mm SL) of exposed abalone of different size groups for all transect surveys of the Tribal, Simonds and Stryker Island groups, May, 1997. N = number of abalone. Values in brackets are standard errors.

Size group	(mm SL)	N	% of total	Shell Length
Tribal Group				
Mature	≥ 70	73	43.20	83.6 (1.1)
Pre Recruit	92 - 99	13	7.69	94.8 (0.5)
New Recruit	100 - 106	2	1.18	102.5 (2.5)
Legal	≥ 100	4	2.37	106.3 (2.7)
Total	all sizes	169	100.00	64.4 (1.6)
Simonds Group				
Mature	≥ 70	123	55.41	92.5 (1.2)
Pre Recruit	92 - 99	24	10.81	95.5 (0.4)
New Recruit	100 - 106	17	7.66	102.5 (0.5)
Legal	≥ 100	40	18.02	108.3 (1.0)
Total	all sizes	222	100.00	71.3 (2.0)
Stryker Group				
Mature	≥ 70	66	51.16	83.4 (1.3)
Pre Recruit	92 - 99	8	6.20	95.8 (0.9)
New Recruit	100 - 106	6	4.65	103.5 (0.9)
Legal	≥ 100	7	5.43	105.0 (1.7)
Total	all sizes	129	100.00	66.6 (2.1)

Table 4. Detectability as a percent of total abalone by size category for cryptic and exposed abalone from intensive samples at all depths from the Tribal (4 transects), Simonds (6 transects) and Stryker (3 transects) groups of islands, May, 1997.

	Tribal Group		Simonds Group		Stryker Group		Total of Three areas	
Details	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Immature Abalone < 70 mm SL								
Cryptic	6	20.00	1	11.11	10	33.33	17	24.64
Exposed	24	80.00	8	88.89	20	66.67	52	75.36
Total	30		9		30		69	
Mature Abalone ≥ 70 mm SL								
Cryptic	0	0.00	1	6.67	1	7.69	2	3.57
Exposed	28	100.00	14	93.33	12	92.31	54	96.43
Total	28		15		13		56	
All sizes of Abalone								
Cryptic	6	10.34	2	8.33	11	25.58	19	15.20
Exposed	52	89.66	22	91.67	32	74.42	106	84.80
Total	58		24		43		125	

Table 5. Mean density (number/m^2) of exposed abalone of different size groups for all depths from Tribal, Simonds and Stryker group of islands, May, 1997. Means unadjusted and adjusted for detectability. Values in brackets are standard errors.

Size group	mm SL	Tribal	Simonds	Stryker
Unadjusted				
Mature	≥ 70	0.188 (0.053)	0.231 (0.068)	0.255 (0.099)
Pre Recruit	92 - 99	0.039 (0.014)	0.049 (0.017)	0.030 (0.014)
New Recruit	100 - 106	0.008 (0.005)	0.028 (0.014)	0.018 (0.009)
Legal	≥ 100	0.013 (0.008)	0.064 (0.032)	0.022 (0.012)
Total	all sizes	0.468 (0.094)	0.468 (0.081)	0.526 (0.149)
Adjusted for detectability				
Mature	≥ 70	0.188 (0.053)	0.248 (0.072)	0.276 (0.108)
Pre Recruit	92 - 99	0.039 (0.014)	0.052 (0.018)	0.032 (0.015)
New Recruit	100 - 106	0.008 (0.005)	0.030 (0.015)	0.020 (0.010)
Legal	≥ 100	0.013 (0.008)	0.069 (0.034)	0.024 (0.013)
Total	all sizes	0.522 (0.105)	0.510 (0.088)	0.707 (0.200)
Number of transects		29	32	20

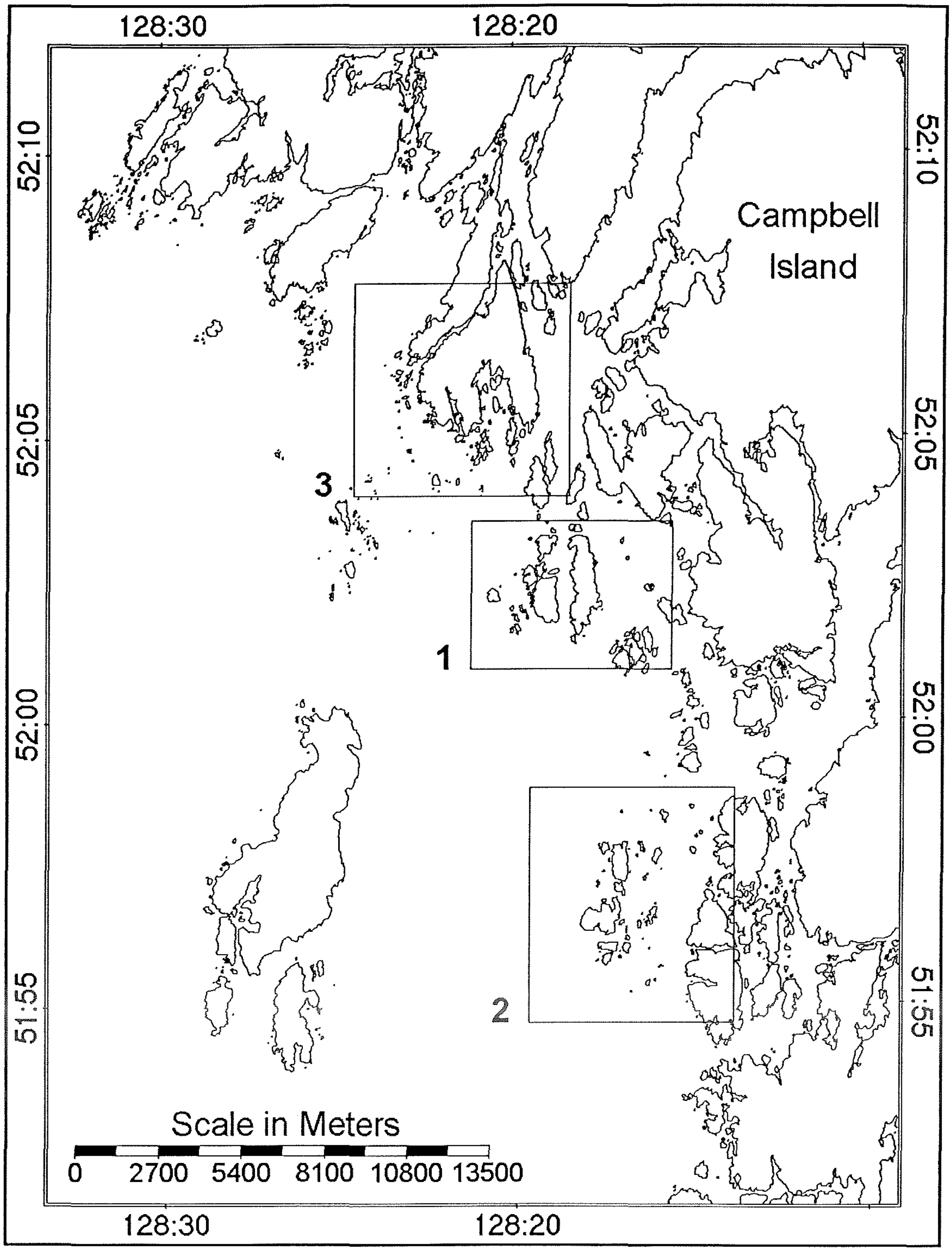

Fig. 1. General location of study areas (1) Tribal (in statistical area 7 -18), (2) Simonds (in statistical area 7 -25),, and (3) Stryker group of islands (in statistical areas 7 -18, 7 - 19), in the central coast of British Columbia surveyed for abalone during May, 1997.

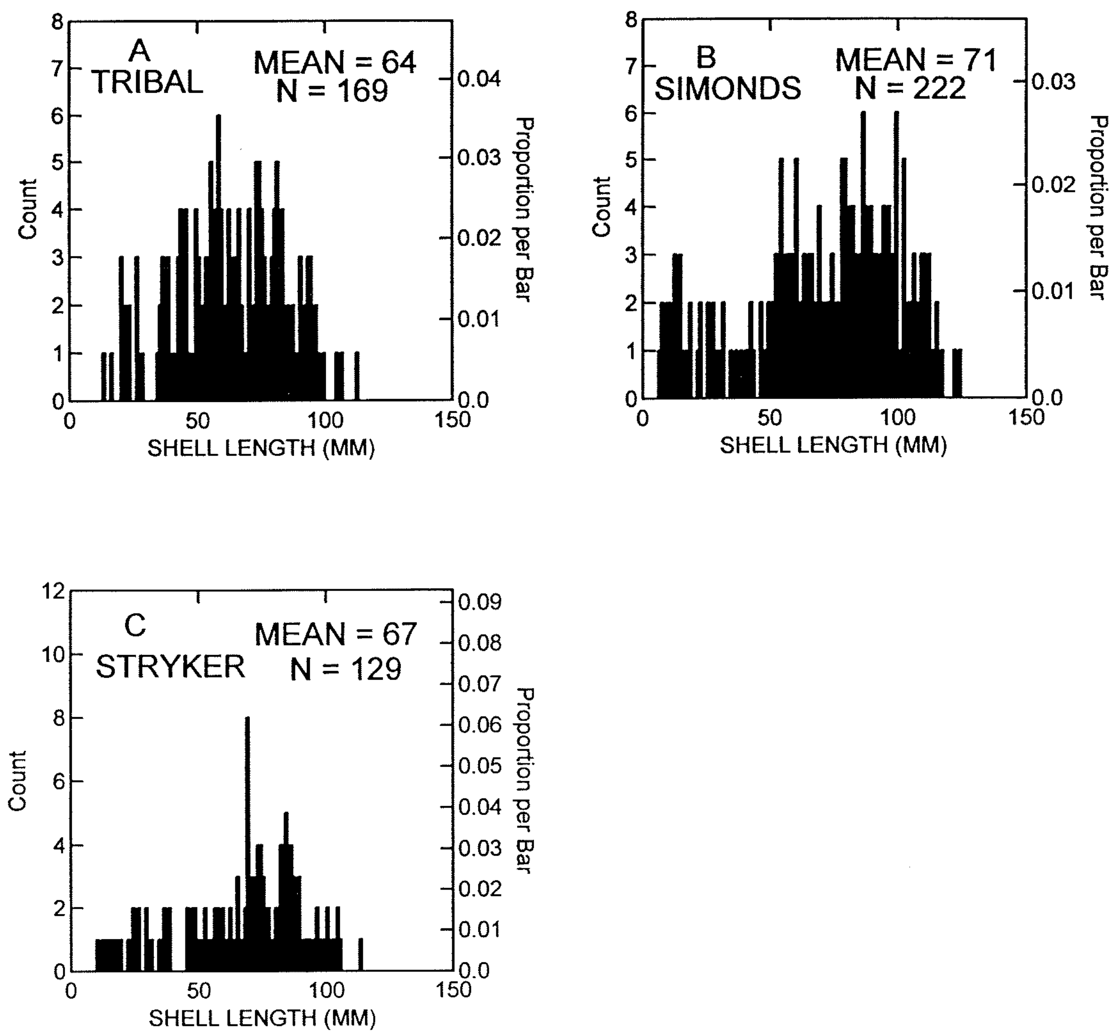

Fig. 2. Size frequencies of exposed abalone from the (A) Tribal, (B) Simonds, and (C) Stryker group of islands surveyed May, 1997.

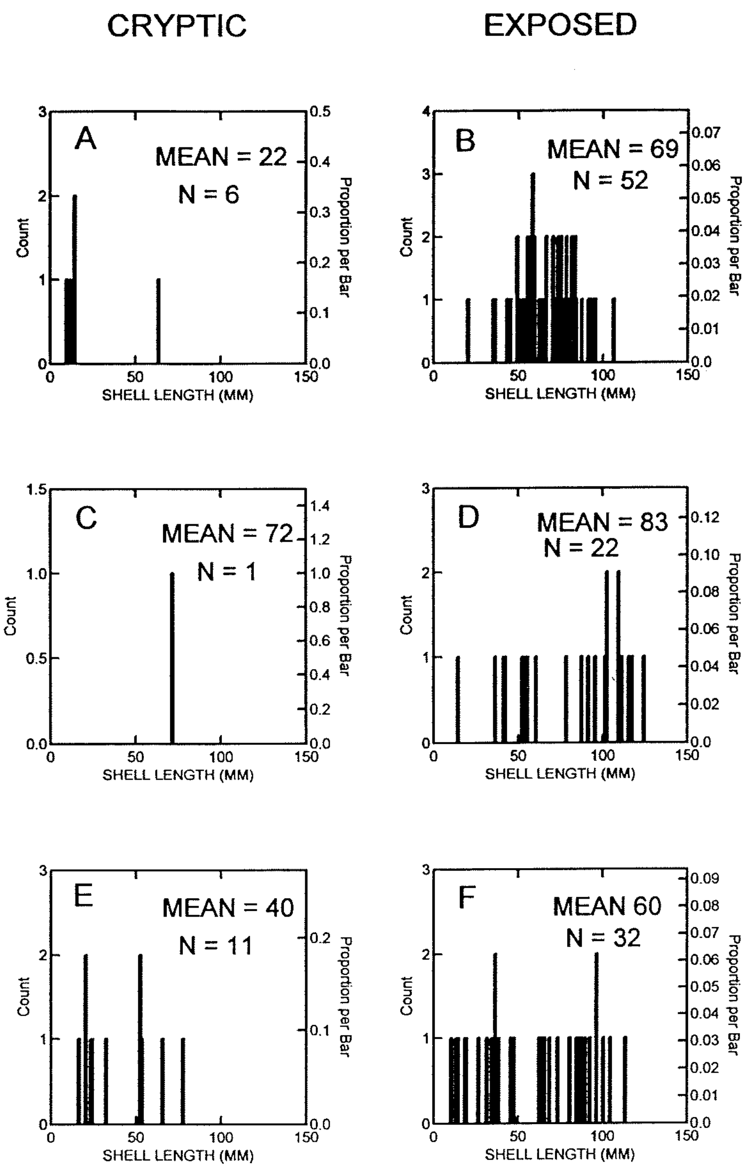

Fig. 3. Size frequencies of cryptic and exposed abalone, respectively, (A) and (B) Tribal Group, (C) and (D) Simonds Group, and (E) and (F) Stryker Group from intensive survey samples May, 1997.

TRIBAL GROUP

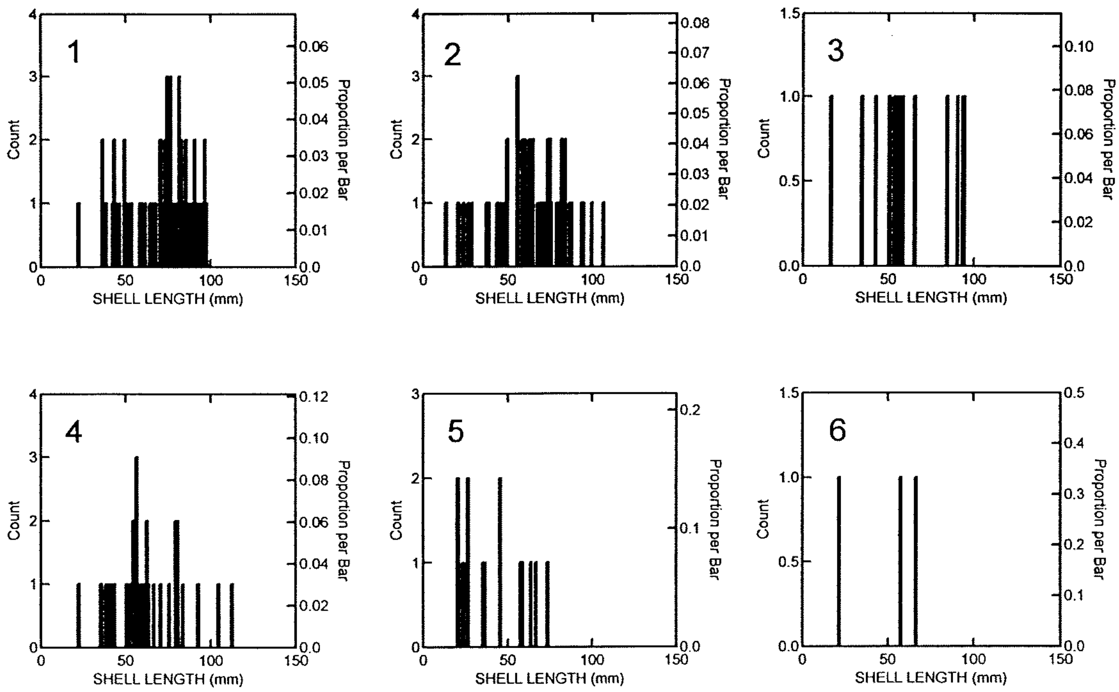

Fig. 4A. Size frequencies by depth category of exposed abalone from the Tribal Group, surveyed May, 1997. Depth category (1) < 0 m, (2) 0 - 1.50 m, (3) 1.51 - 3.00 m, (4) 3.01 - 4.50 m, (5) 4.51 - 6.00 m, (6) 6.01 - 7.50 m.

SIMONDS GROUP

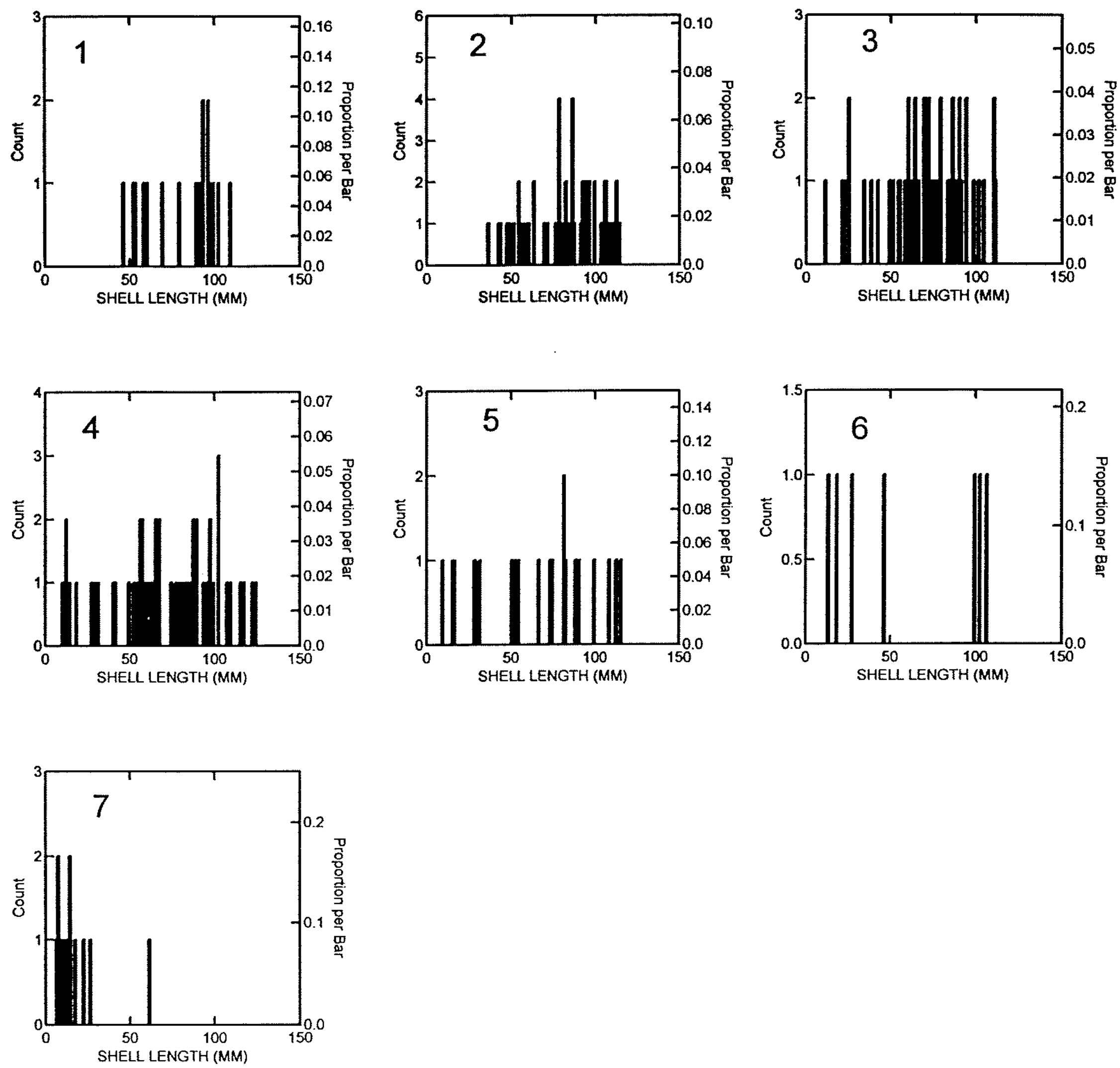

Fig. 4B. Size frequencies by depth category of exposed abalone from the Simonds Group, surveyed May, 1997. Depth category (1) < 0 m, (2) 0 - 1.50 m, (3) 1.51 - 3.00 m, (4) 3.01 - 4.50 m, (5) 4.51 - 6.00 m, (6) 6.01 - 7.50 m, (7) >7.50 m.

STRYKER GROUP

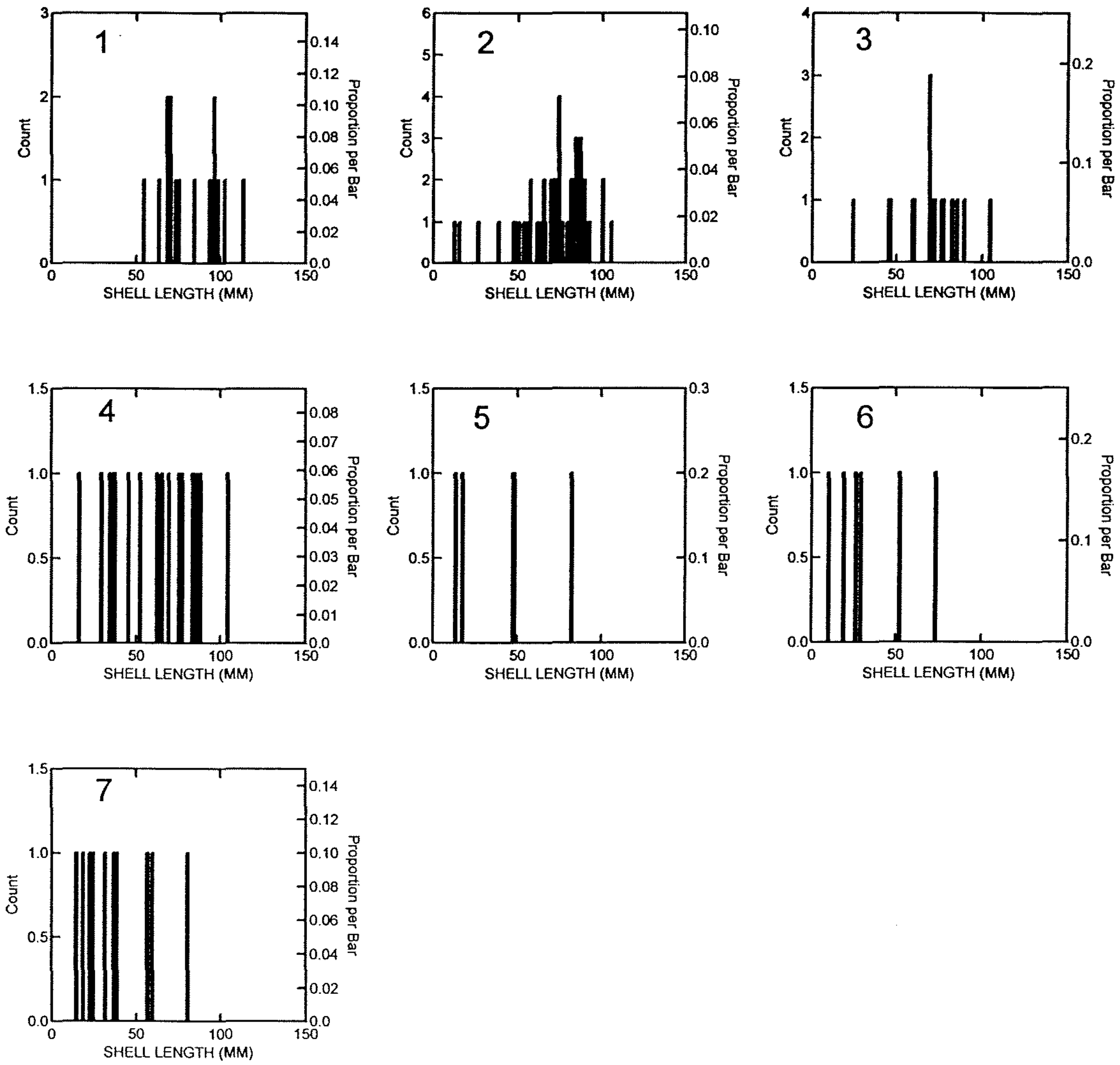

Fig. 4C. Size frequencies by depth category of exposed abalone from the Stryker Group, surveyed May, 1997. Depth category (1) < 0 m, (2) 0 - 1.50 m, (3) 1.51 - 3.00 m, (4) 3.01 - 4.50 m, (5) 4.51 - 6.00 m, (6) 6.01 - 7.50 m, (7) >7.50 m.

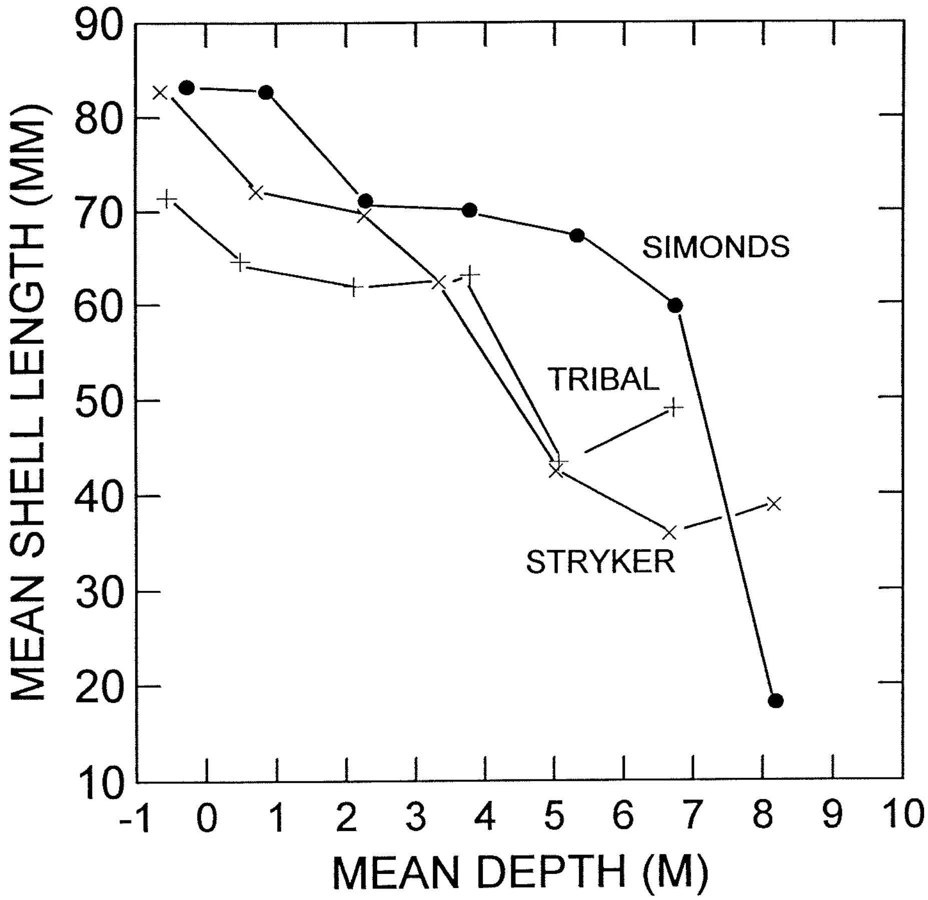

Fig. 5. Mean shell length of exposed abalone by mean depth in the Tribal, Simonds, and Stryker groups of islands during May, 1997.

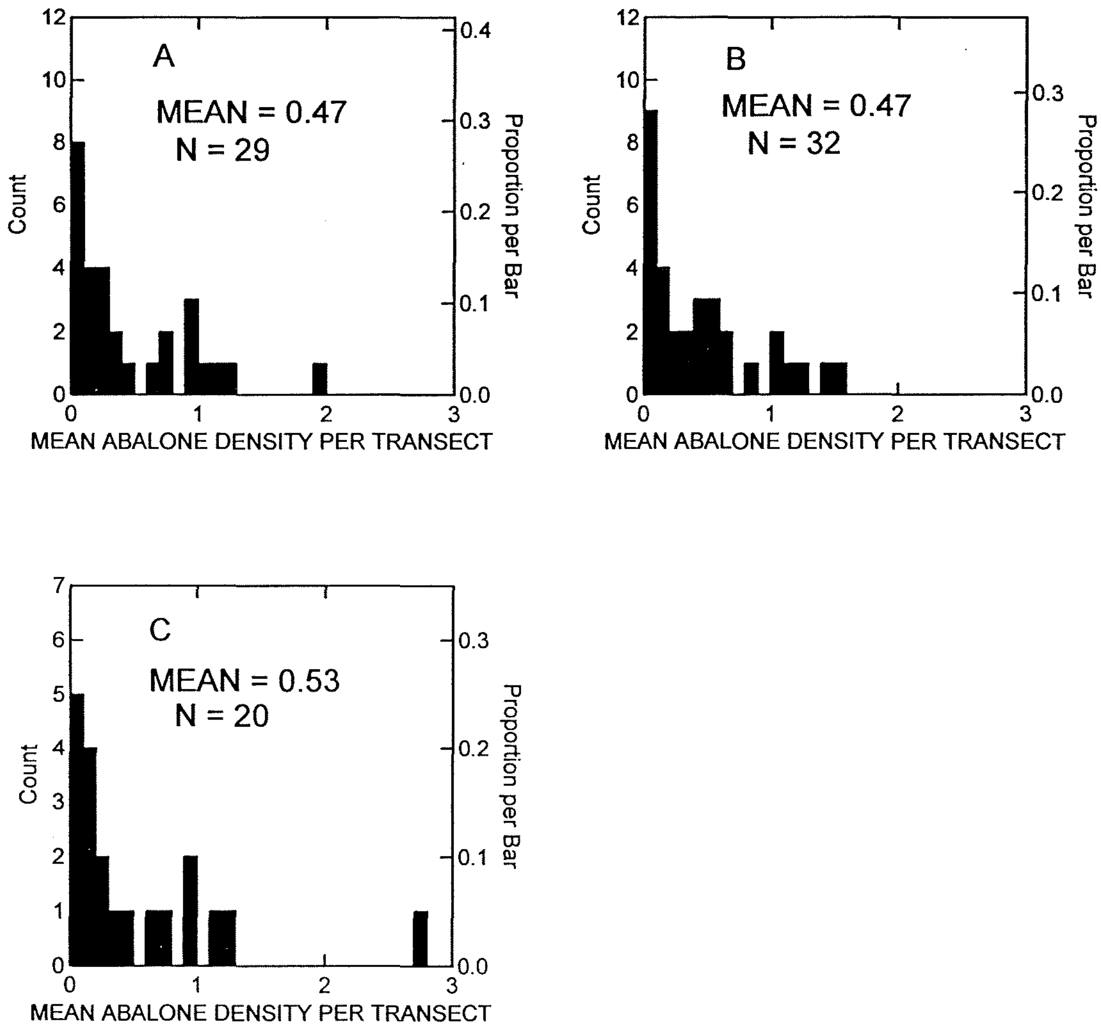

Fig. 6. Frequency distribution of mean densities (number per m^2) of exposed abalone per transect for all depths combined from the (A) Tribal, (B) Simonds, and (C) Stryker group of islands surveyed during May, 1997.

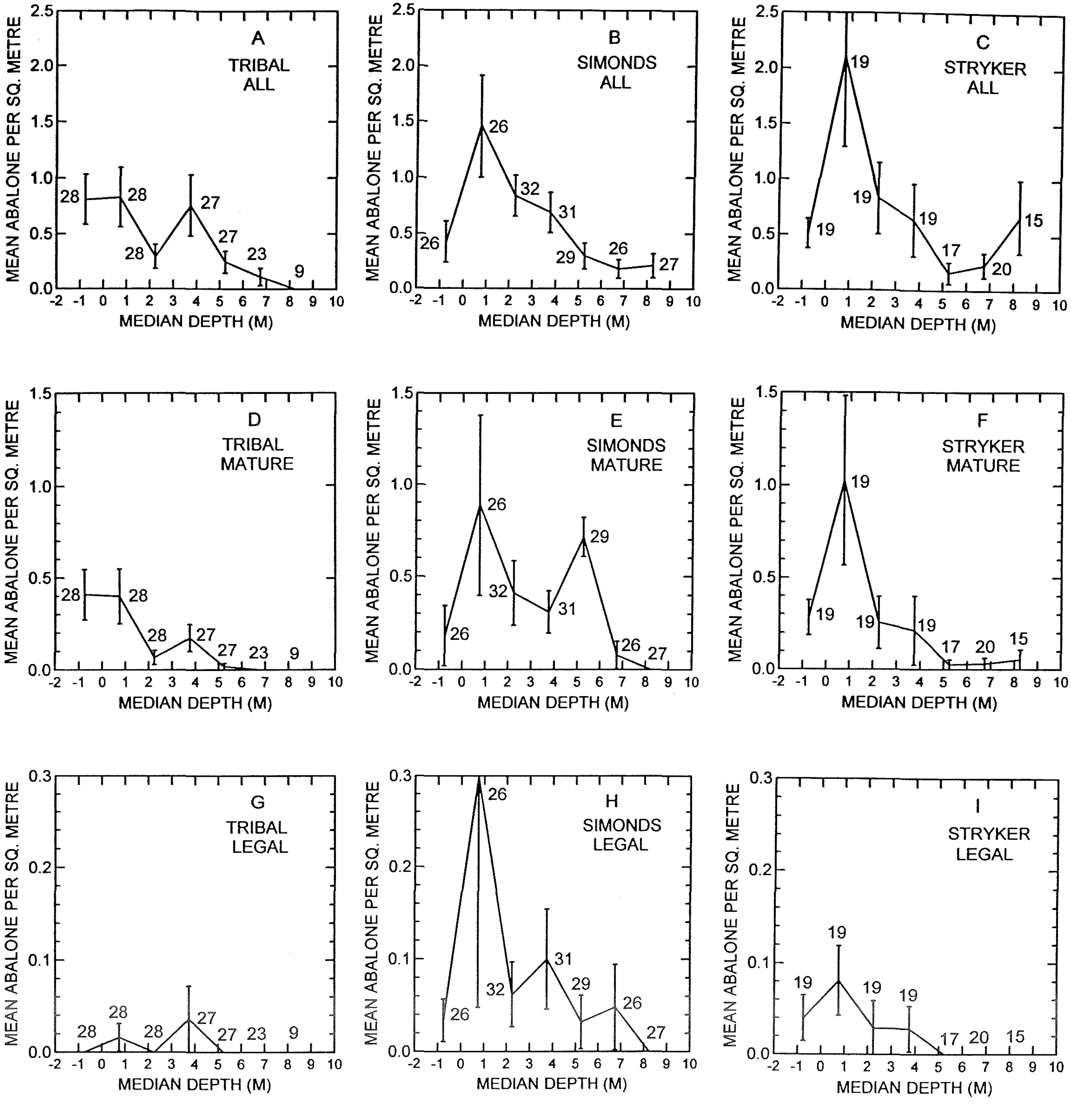

Fig. 7. Mean densities of abalone (adjusted for detectability, to include exposed and cryptic) by size group and depth from the Tribal, Simonds, and Stryker group of islands, respectively for (A, B, C) all sizes, (D, E, F) mature sizes (≥ 70 mm SL), and (G, H, I) legal sizes (≥ 100 mm SL) surveyed during May, 1997. Vertical lines are ± 1 standard error. Numbers represent number of transects.