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OBSERVER COVERAGE RATES AND RELIABILITY OF CPUE ESTIMATES FOR PURSE SEINERS IN THE WESTERN AND CENTRAL PACIFIC OCEAN

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INTRODUCTION

This study examines the relationship between the coverage rate for observer programmes and the reliability of estimates of catch per unit of effort (CPUE) for six species caught by thirteen purse-seine fleets (China, Federated States of Micronesia, Japan, Kiribati, Republic of Korea, Marsha;ll Islands, Mexico, Papua New Guinea, Philippines, Solomon Islands, Chinese Taipei, United States of America and Vanuatu) that have fished in the Werstern and Central Pacific Ocean. The results are compared to similar studies done for offshore longline fleets (Lawson 2003, 2004).

SOURCE OF DATA

The observer data held by the OFP were either collected by SPC observers or provided by the national observer programmes of SPC member countries and territories.

The observer data for the covered 172 vessels, 525 trips and 17,272 days fished or searched (Tables 1 and 2). The observer data were collected from 1994 to 2003 and are distributed evenly across years, except for the first and the last years. The data are unequally distributed among fleets — the United States fleet accounts for 51.0% of trips; the Chinese Taipei and Republic of Korean fleets account for 14.7% and 10.1% respectively; and the ten other fleets account for the remaining 24.2%.

Table 3 presents summaries of the data for all 90 species and species groups reported by observers, sorted by CPUE, for all fleets and all years combined. CPUE ranges widely, from 17.7 and 6.6 tonnes per day for skipjack and yellowfin respectively, to less than 0.00005 tonnes per day for 42 species and species groups. Six species were chosen for the analysis based on their CPUE; the species and CPUE (tonnes per day) are given below:

COMMON NAME	SCIENTIFIC NAME	CPUE
Skipjack tuna	*Katsuwonus pelamis*	17.688359
Rainbow runner	*Elagatis bipinnulata*	0.065825
Silky shark	*Carcharhinus falciformis*	0.011997
Whale shark	*Rhincodon typus*	0.004317
Striped marlin	*Tetrapturus audax*	0.001076
Great white shark	*Carcharodon carcharias*	0.000003

METHOD

Sampling theory provides an analytical method of determining the variance of CPUE estimates. For estimates of a ratio, such as CPUE, it can be shown (Cochran 1977) that the variance is approximated by

$$V(\hat{U}) \cong \frac{1-r}{n\overline{E}^2} \cdot \frac{\sum_i^N (c_i - Ue_i)^2}{N-1}, \quad (1)$$

where U and $\hat{U}$ are the true CPUE and estimated CPUE; $\overline{E}$ is the true average effort per trip; c_i and e_i are the catch and effort for the i^th observed trip; N and n are the total number of trips and the number of observed trips; and r is the observer coverage rate, $\frac{n}{N}$. Assuming that the CPUE, average effort per trip and number of trips for all observed trips combined represent the 'true' population values, equation (1) can be used to examine the relationship between the coefficient of variation of the CPUE estimate and various factors.

Using equation (1), the coefficient of variation of the estimate of CPUE can be written as follows:

$$CV = \frac{\sqrt{V(\hat{U})}}{U} \cong \sqrt{\frac{1}{n} - \frac{1}{N}} \cdot \frac{\sqrt{\frac{\sum_i^N (c_i - Ue_i)^2}{N-1}}}{\overline{C}}, \quad (2)$$

where $\overline{C}$ is the true average catch per trip. The coefficient of variation thus depends on the number of trips observed and the total number of trips (i.e., the lefthand part of the formula) and a constant related to the ratio of the variation in the catch per trip to the average catch per trip (i.e., the righthand part of the formula).

It can be shown that the derivative of CV with respect to n is given by

$$\frac{dCV}{dn} = \frac{1}{2} \cdot n^{-3/2} \cdot \left(1 - \frac{n}{N}\right)^{-1/2}. \quad (3)$$

Figure 1 illustrates how the coefficient of variation depends on the coverage rate in a general case, with the constant on the righthand side of equation (2) assumed equal to 1 and the total number of trips scaled to 100. The coefficient of variation in Figure 1 decreases rapidly as the coverage rate increases to about 20%, then it decreases slowly until reaching zero at a coverage rate of 100%. The shape of the curve is the same as the shape of the curves presented in Lawson (2003, 2004), which present the relationship between the coefficient of variation and the coverage rate for various species caught by offshore longliners.

Figure 1 also shows how the slope of the curve, which is given by equation (3), depends on the coverage rate. The steep negative slope at very low coverage rates increases rapidly as the coverage rate approaches 20% and then it increases slowly while remaining slightly negative.

The relationship between the coefficient of variation of estimates of CPUE and the observer coverage rate for the six species listed above were examined for unstratified sampling using Equation (2).

The relationship for samples stratified on the basis of fleet and year were examined using sub-sampling. For coverage rates ranging from 1 percent to 100 percent in 1 percent intervals, 1000 random samples were drawn. The results for each coverage rate were summarised by calculating the standard deviation of the CPUE estimated from each of the 1000 samples. The number of sets in each sample was distributed among fleets and years in the same relative proportions as in the universe of observed sets; that is, the coverage rate was applied equally to each combination of fleet and year. The CPUE for each sample was then estimated by taking weighted averages of the CPUE estimated for each strata. The weights were equal to the ‘true’ ratio of the number of hooks in the strata to the total number of hooks, i.e. the ratio determined from the universe of observed sets.

RESULTS

Figures 2–7 show the relationship between the coefficient of variation of estimates of CPUE and the observer coverage rate, for unstratified sampling, for the six species listed above. As shown in the previous studies for offshore longliners, the value of the coefficients of variation depend strongly on the level of CPUE, with smaller coefficients of variation for higher levels of CPUE. Stratified sampling, which was examined using sub-sampling, resulted in only slightly lower coefficients of variation.

DISCUSSION

It can be seen in Figures 2–7 that the reliability of estimates of CPUE depend strongly on the level of CPUE. The following table gives the coverage rate (percent) required for a coefficient of variation of the estimate of CPUE of 10%, for unstratified sampling:

COMMON NAME	COVERAGE RATE
Skipjack tuna	8
Rainbow runner	64
Silky shark	65
Whale shark	92
Striped marlin	87
Great white shark	100

The required coverage rate increases from 8% for skipjack to 100% for great white sharks. If a coefficient of variation of 10% (which is approximately equivalent to a 95% confidence interval of plus or minus 20%) is an acceptable level of reliability for estimates of CPUE and, hence, catches (assuming fishing effort is known without error), then, for the target species, a moderate level of coverage is required, while for extremely rare species, full coverage will be required.

Figures 2–7 show that increases in the coverage rate beyond 20% to 30% result in smaller incremental improvements in the coefficient of variation of estimates of CPUE. If financial or other constraints limit the level of observer coverage, then the fact that the reliability of estimates of

CPUE improves less rapidly with increasing coverage, once coverage rates of 20% to 30% are achieved, will be an important consideration in setting the coverage rate.

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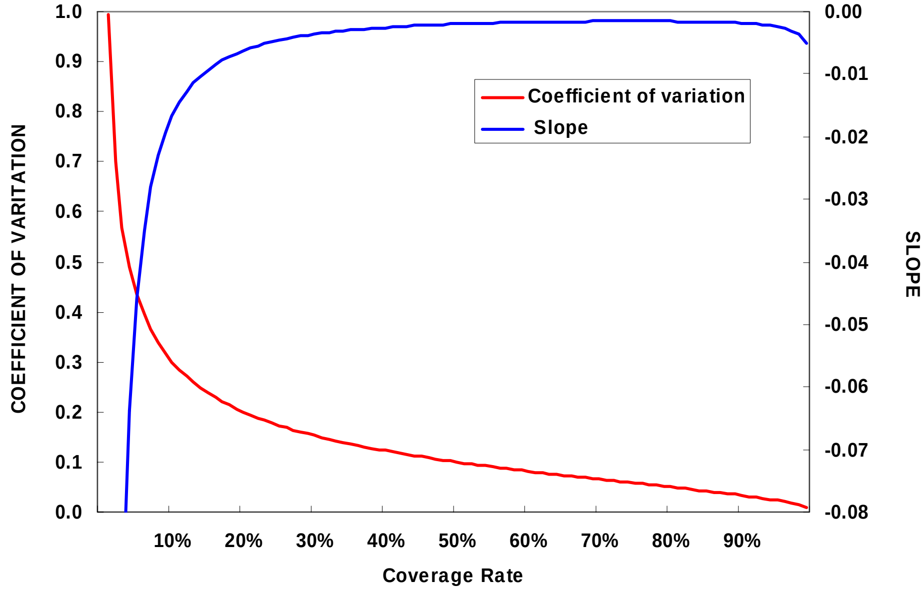

Figure 1. Relationship between the coefficient of variation and the observer coverage rate, based on equation (2) in the text

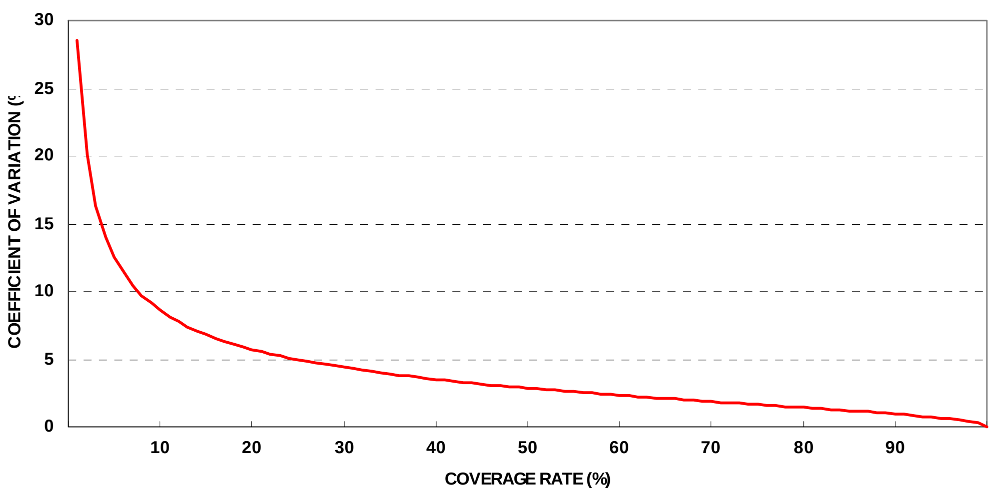

Figure 2. Relationship between the coefficient of variation of estimates of skipjack CPUE and the observer coverage rate

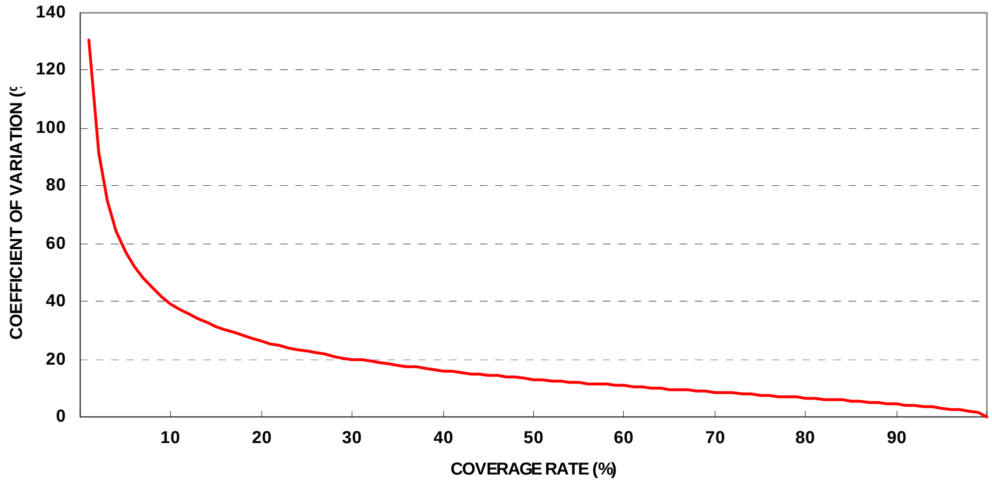

Figure 3. Relationship between the coefficient of variation of CPUE estimates for rainbow runner and the observer coverage rate

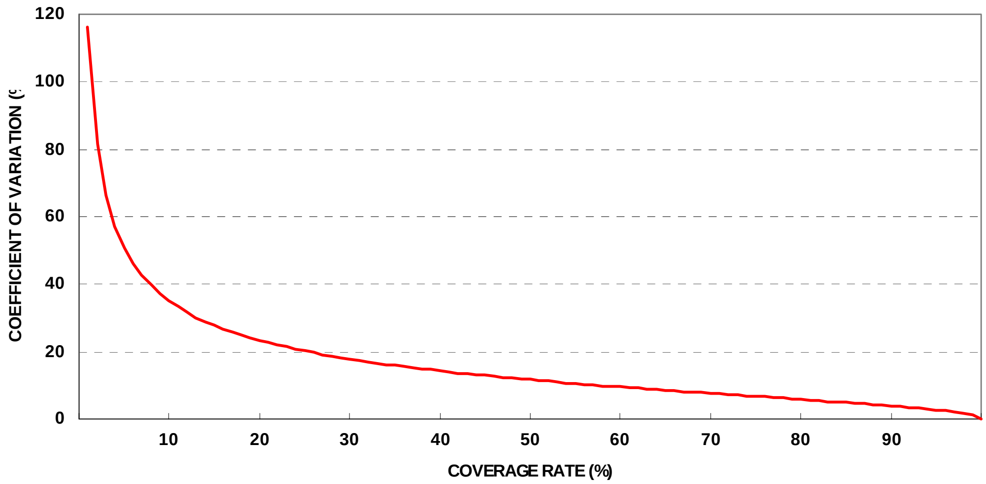

Figure 4. Relationship between the coefficient of variation of CPUE estimates for silky shark and the observer coverage rate

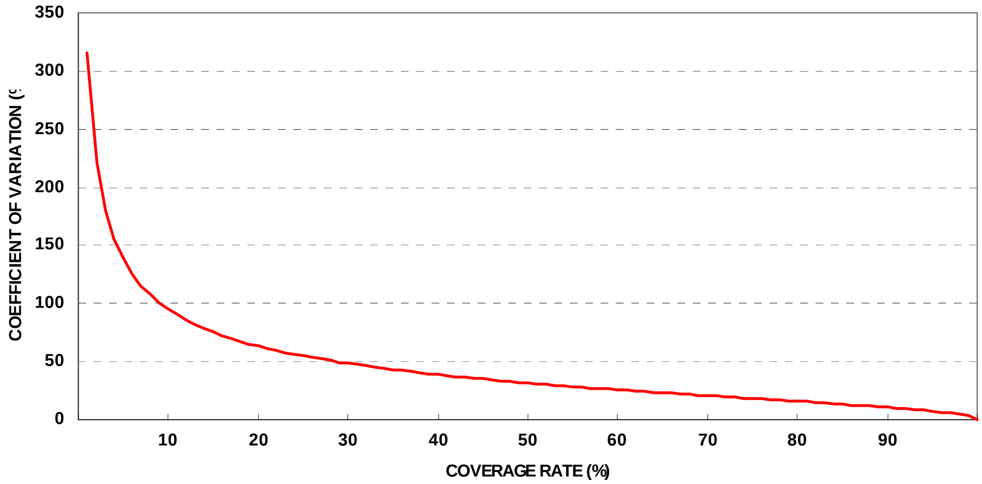

Figure 5. Relationship between the coefficient of variation of CPUE estimates for whale shark and the observer coverage rate

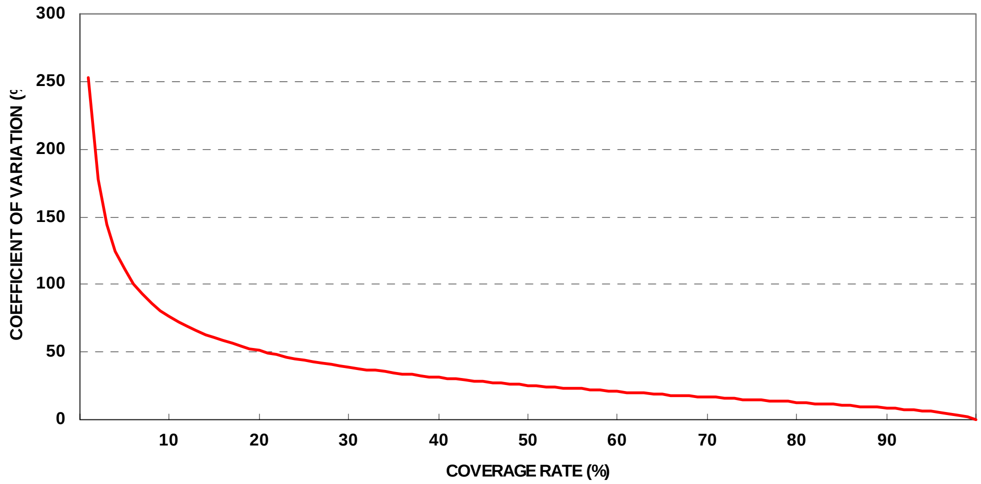

Figure 6. Relationship between the coefficient of variation of CPUE estimates for striped marlin and the observer coverage rate

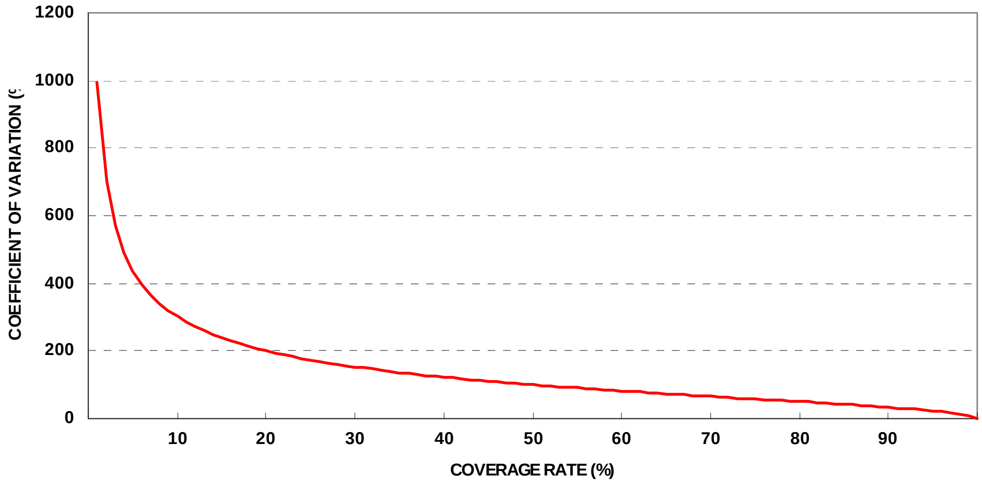

Figure 7. Relationship between the coefficient of variation of CPUE estimates for great white shark and the observer coverage rate

Table 1. Distribution of observer data held by the OFP covering purse seiners, by year

Year	Vessels	Trips	Days	Sets			Days Per Trip	Sets Per Trip
				Unassociated	Associated	Total		
1994	16	16	595	566	84	650	37.2	40.6
1995	33	35	1,273	738	382	1,120	36.4	32.0
1996	59	62	2,124	1,122	845	1,967	34.3	31.7
1997	61	65	2,407	790	1,180	1,970	37.0	30.3
1998	80	87	2,486	1,160	1,018	2,178	28.6	25.0
1999	47	57	1,253	277	772	1,049	22.0	18.4
2000	46	52	1,819	503	952	1,455	35.0	28.0
2001	63	71	2,298	1,093	968	2,061	32.4	29.0
2002	49	67	2,205	898	880	1,778	32.9	26.5
2003	12	13	812	197	219	416	62.5	32.0
TOTAL	172	525	17,272	7,344	7,300	14,644	32.9	27.9

Table 2. Distribution of observer data held by the OFP covering purse seiners, by fleet

Flag	Vessels	Trips	Days	Sets			Days Per Trip	Sets Per Trip
				Unassociated	Associated	Total		
China	2	2	71	29	19	48	35.5	24.0
Federated States of Micronesia	4	11	317	100	150	250	28.8	22.7
Japan	15	18	459	152	271	423	25.5	23.5
Kiribati	1	4	81	37	43	80	20.3	20.0
Republic of Korea	22	53	1,141	867	344	1,211	21.5	22.8
Marshall Islands	1	1	34	2	26	28	34.0	28.0
Mexico	1	2	40	6	8	14	20.0	7.0
Papua New Guinea	21	43	1,244	247	738	985	28.9	22.9
Philippines	10	24	648	70	415	485	27.0	20.2
Solomon Islands	6	17	262	19	158	177	15.4	10.4
Chinese Taipei	38	77	2,315	1,475	930	2,405	30.1	31.2
United States of America	49	268	10,527	4,264	4,166	8,430	39.3	31.5
Vanuatu	2	5	133	76	32	108	26.6	21.6
TOTAL	172	525	17,272	7,344	7,300	14,644	32.9	27.9

Table 3. Observed catch (tonnes) and CPUE (tonnes per day fished or searched) covering purse seiners, by school association

Species or Group	Unassociated		Associated		All Schools	
	Catch	CPUE	Catch	CPUE	Catch	CPUE
Skipjack tuna	110,006.750	14.2580	195,506.736	20.4579	305,513.486	17.6884
Yellowfin tuna	43,623.869	5.6541	69,598.416	7.2828	113,222.285	6.5552
Bigeye tuna	1,126.817	0.1460	20,780.026	2.1744	21,906.843	1.2683
Tunas nei	63.121	0.0082	1,772.835	0.1855	1,835.956	0.1063
Rainbow runner	29.651	0.0038	1,107.283	0.1159	1,136.934	0.0658
Sharks nei	107.490	0.0139	300.756	0.0315	408.246	0.0236
Triggerfishes, durgons nei	1.939	0.0003	233.716	0.0245	235.655	0.0136
Marine fishes nei	7.363	0.0010	209.793	0.0220	217.156	0.0126
Silky shark	17.734	0.0023	189.483	0.0198	207.217	0.0120
Mackerel scad	1.942	0.0003	174.858	0.0183	176.800	0.0102
Common dolphinfish	7.525	0.0010	160.657	0.0168	168.182	0.0097
Oceanic whitetip shark	9.277	0.0012	109.205	0.0114	118.482	0.0069
Blue marlin	32.444	0.0042	67.063	0.0070	99.507	0.0058
Albacore	15.488	0.0020	78.502	0.0082	93.990	0.0054
Black marlin	39.530	0.0051	51.530	0.0054	91.060	0.0053
Whale shark	16.800	0.0022	57.760	0.0060	74.560	0.0043
Wahoo	0.687	0.0001	69.142	0.0072	69.829	0.0040
Mackerels nei	1.402	0.0002	62.660	0.0066	64.062	0.0037
Yellowtail amberjack	0.000	0.0000	49.094	0.0051	49.094	0.0028
Frigate tuna	8.332	0.0011	22.652	0.0024	30.984	0.0018
Bullet tuna	2.663	0.0003	26.826	0.0028	29.489	0.0017
Mantas	18.941	0.0025	9.086	0.0010	28.027	0.0016
Barracudas nei	0.611	0.0001	23.557	0.0025	24.168	0.0014
Striped marlin	4.993	0.0006	13.593	0.0014	18.586	0.0011
Kawakawa	0.007	0.0000	10.659	0.0011	10.666	0.0006
Yellowtail scad	0.000	0.0000	10.526	0.0011	10.526	0.0006
Amberjacks nei	0.003	0.0000	8.665	0.0009	8.668	0.0005
Decapturus nei	0.800	0.0001	7.791	0.0008	8.591	0.0005
Black triggerfish	0.054	0.0000	7.085	0.0007	7.139	0.0004
Shortfin mako	0.513	0.0001	4.983	0.0005	5.496	0.0003
Batfishes	0.020	0.0000	5.119	0.0005	5.139	0.0003
Great barracuda	0.068	0.0000	4.880	0.0005	4.948	0.0003
Indo-Pacific sailfish	2.369	0.0003	2.496	0.0003	4.865	0.0003
Swordfish	1.634	0.0002	2.999	0.0003	4.633	0.0003
Silvertip shark	0.398	0.0001	3.420	0.0004	3.818	0.0002
Jacks, crevalles nei	0.000	0.0000	3.509	0.0004	3.509	0.0002
Ocean triggerfish	0.005	0.0000	3.159	0.0003	3.164	0.0002
Marlins,sailfishes,etc. nei	1.419	0.0002	1.278	0.0001	2.697	0.0002

Table 3 (continued)

Species or Group	Unassociated		Associated		All Schools	
	Catch	CPUE	Catch	CPUE	Catch	CPUE
Blue sea chub	0.005	0.0000	2.110	0.0002	2.115	0.0001
Ocean sunfish	1.315	0.0002	0.767	0.0001	2.082	0.0001
Filefishes nei	0.023	0.0000	1.971	0.0002	1.994	0.0001
Mako sharks	0.100	0.0000	1.630	0.0002	1.730	0.0001
Frigate and bullet tunas	0.002	0.0000	1.569	0.0002	1.571	0.0001
Bigeye trevally	0.009	0.0000	1.215	0.0001	1.224	0.0001
Pelagic stingray	1.067	0.0001	0.136	0.0000	1.203	0.0001
Pacific rudderfish	0.045	0.0000	1.149	0.0001	1.194	0.0001
Pomfrets, ocean breams nei	0.000	0.0000	1.140	0.0001	1.140	0.0001
Shortbill spearfish	0.175	0.0000	0.753	0.0001	0.928	0.0001
Blue shark	0.314	0.0000	0.437	0.0000	0.751	0.0000
Tripletail	0.041	0.0000	0.581	0.0001	0.622	0.0000
Sergeant-major	0.000	0.0000	0.489	0.0001	0.489	0.0000
Hammerhead sharks nei	0.015	0.0000	0.477	0.0001	0.492	0.0000
Longfin mako	0.000	0.0000	0.466	0.0000	0.466	0.0000
Batoid fishes nei	0.135	0.0000	0.120	0.0000	0.255	0.0000
Blacktip shark	0.010	0.0000	0.220	0.0000	0.230	0.0000
Tiger shark	0.000	0.0000	0.200	0.0000	0.200	0.0000
Malabar grouper	0.000	0.0000	0.164	0.0000	0.164	0.0000
Crocodile shark	0.000	0.0000	0.149	0.0000	0.149	0.0000
Greater amberjack	0.000	0.0000	0.131	0.0000	0.131	0.0000
Golden trevally	0.000	0.0000	0.128	0.0000	0.128	0.0000
Dogfish sharks nei	0.000	0.0000	0.100	0.0000	0.100	0.0000
Various squids nei	0.006	0.0000	0.084	0.0000	0.090	0.0000
Scribbled leatherjacket filefish	0.000	0.0000	0.093	0.0000	0.093	0.0000
Galapagos shark	0.090	0.0000	0.000	0.0000	0.090	0.0000
Unicorn leatherjacket filefish	0.000	0.0000	0.070	0.0000	0.070	0.0000
Thresher sharks nei	0.053	0.0000	0.015	0.0000	0.068	0.0000
Salmon shark	0.000	0.0000	0.064	0.0000	0.064	0.0000
Mango tilapia	0.000	0.0000	0.075	0.0000	0.075	0.0000
Japanese scad	0.000	0.0000	0.050	0.0000	0.050	0.0000
Great white shark	0.000	0.0000	0.060	0.0000	0.060	0.0000
Butterfly kingfish	0.050	0.0000	0.000	0.0000	0.050	0.0000
Longfin batfish	0.000	0.0000	0.041	0.0000	0.041	0.0000
Whip stingray	0.010	0.0000	0.008	0.0000	0.018	0.0000
Stingrays, butterfly rays nei	0.010	0.0000	0.000	0.0000	0.010	0.0000
Opah	0.000	0.0000	0.020	0.0000	0.020	0.0000
Milkfish	0.000	0.0000	0.020	0.0000	0.020	0.0000
Longfin yellowtail	0.000	0.0000	0.011	0.0000	0.011	0.0000

Table 3 (continued)

Species or Group	Unassociated		Associated		All Schools	
	Catch	CPUE	Catch	CPUE	Catch	CPUE
Bigeye thresher	0.000	0.0000	0.016	0.0000	0.016	0.0000
Atlantic pomfret	0.000	0.0000	0.015	0.0000	0.015	0.0000
White trevally	0.000	0.0000	0.000	0.0000	0.000	0.0000
Shark suckers	0.001	0.0000	0.005	0.0000	0.006	0.0000
Rudderfish	0.000	0.0000	0.005	0.0000	0.005	0.0000
Pilotfish	0.000	0.0000	0.002	0.0000	0.002	0.0000
Oilfish	0.000	0.0000	0.008	0.0000	0.008	0.0000
Lancetfishes nei	0.000	0.0000	0.001	0.0000	0.001	0.0000
Flyingfishes nei	0.005	0.0000	0.000	0.0000	0.005	0.0000
Dotted gizzard shad	0.001	0.0000	0.007	0.0000	0.008	0.0000
Bigeye scad	0.000	0.0000	0.001	0.0000	0.001	0.0000
Big-scale pomfret	0.000	0.0000	0.001	0.0000	0.001	0.0000
Batfish	0.000	0.0000	0.003	0.0000	0.003	0.0000
Total	155,156.141	20.1098	290,768.575	30.4261	445,924.716	25.8178