SCTB17 Working Paper

SWG–4

OBSERVER COVERAGE RATES AND RELIABILITY OF CPUE ESTIMATES FOR OFFSHORE LONGLINERS IN TROPICAL WATERS OF THE WESTERN AND CENTRAL PACIFIC OCEAN

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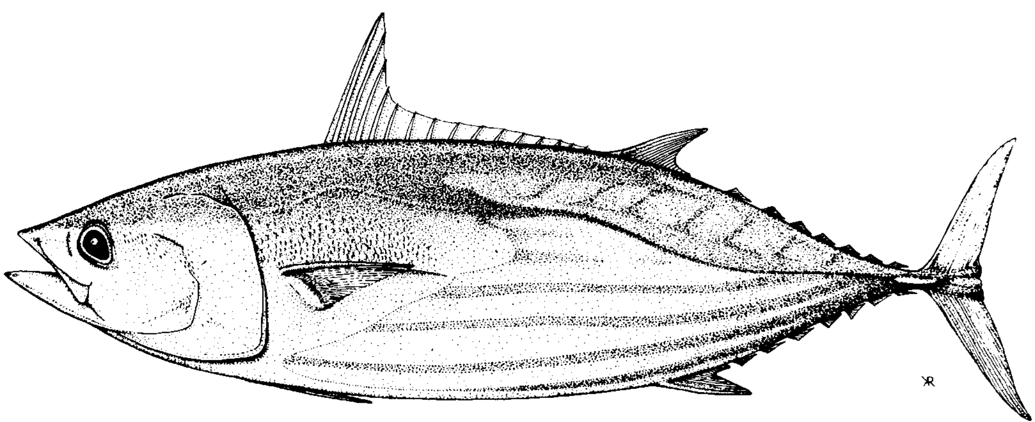

Oceanic Fisheries Programme
Secretariat of the Pacific Community
Noumea, New Caledonia

June 2004

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 eight species caught by six offshore longline fleets (China, Federated States of Micronesia, Japan, Papua New Guinea, Taiwan and the United States of America) targeting yellowfin and bigeye in tropical waters. The results are compared to a similar study done for seven offshore longline fleets targeting South Pacific albacore (Lawson 2003).

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 six offshore longline fleets targeting bigeye and yellowfin covered 165 vessels, 191 trips, 1,634 days fished, 1,643 sets and 2,091,041 hooks (Tables 1 and 2). The observer data were collected from 1993 to 2002; 87.3 percent of the data cover 1994–2000, while the remaining 12.7 percent cover 1993 and 2000–2001. The data are also unequally distributed among fleets; 81.9 percent of the data cover China, Japan and Taiwan, while 18.1 percent cover the Federated States of Micronesia, Papua New Guinea and the United States.

Table 3 presents summaries of the data for all 88 species and species groups reported by observers, sorted by CPUE, for all fleets and all years combined. CPUE ranges widely, from 0.72 and 0.42 fish per 100 hooks for yellowfin and bigeye respectively, to 0.00005 fish per 100 hooks for 12 species for which only one fish was observed. Eight species were chosen for the analysis based on their CPUE; the species and CPUE (number of fish per 100 hooks) are given below:

COMMON NAME	SCIENTIFIC NAME	POOLED CPUE
Yellowfin	*Thunnus albacares*	0.71750
Bigeye	*Thunnus obesus*	0.41940
Blue shark	*Prionace glauca*	0.17590
Blue marlin	*Makaira nigricans*	0.06480
Wahoo	*Acanthocybium solandri*	0.03240
Mahi mahi / dolphinfish	*Coryphaena hippurus*	0.02920
Opah	*Lampris guttatus*	0.00550
Leatherback turtle	*Dermochelys coriacea*	0.00005

METHOD

Sub-sampling

Lawson (2003) examined the relationship between the coverage rate and the accuracy and reliability of estimates of CPUE for offshore longliners targeting South Pacific albacore by conducting sub-sampling of observed sets at coverage rates ranging from 2 to 100 percent in 2 percent intervals. For each coverage rate, 300 random samples were drawn without replacement and, for each sample, CPUE was estimated. For each of the eight species examined, the coefficient of variation of the CPUE estimates was found to decline steeply as coverage increased from 2% to 20%. Above 20%

coverage, the coefficient of variation decreased at a slower rate, gradually declining to zero at 100% coverage. Stratifying sampling by fleet and year improved the coefficients of variation by small to moderate amounts.

Sampling theory

Sampling theory provides an analytical method of determining the variance of CPUE estimates, which is computationally much more efficient than sub-sampling. For estimates of a ratio, such as CPUE, it can be shown (Cochran 1977) that the variance is approximated by

$$V(\hat{U}) \approx \frac{1-r}{n\overline{E}^2} \bullet \frac{\sum_i^N (c_i - Ue_i)^2}{N-1}, \tag{1}$$

where U and $\hat{U}$ are the true CPUE and estimated CPUE; $\overline{E}$ is the true average effort per set; c_i and e_i are the catch and effort for the ith observed set; N and n are the total number of sets and the number of observed sets; and r is the observer coverage rate, $\frac{n}{N}$. Assuming that the CPUE, average effort and number of sets for all observed sets 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.

Coefficient of variation of estimates of CPUE

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

$$CV = \frac{\sqrt{V(\hat{U})}}{U} \approx \frac{\sqrt{1-r}}{\sqrt{n}} \bullet \frac{\sqrt{\frac{\sum_i^N (c_i - Ue_i)^2}{N-1}}}{\overline{C}}, \tag{2}$$

where $\overline{C}$ is the true average catch per set. It can be seen from equation (2) that the coefficient of variation depends on four factors.

The first and second factors, $\sqrt{1-r}$ and $\frac{1}{\sqrt{n}}$, depend on the observer coverage rate and the absolute number of observed sets respectively. If the coverage rate is large, then $\sqrt{1-r}$ and, hence, the coefficient of variation, will be small. If the coverage rate is small, $\sqrt{1-r}$ will be close to 1 and the coefficient of variation will be more dependent on the absolute number of observed sets than the coverage rate. This implies that even when the observer coverage rate is small, the coefficient of variation can still be reduced by half with every fourfold increase in the number of observed sets.

The third factor, $\sqrt{\frac{\sum_i^N (c_i - Ue_i)^2}{N-1}}$, is the standard deviation of the difference between the observed catch per set and the catch per set predicted by the product of the observed effort per set and the true CPUE. When the observed catch per set varies considerably from the predicted catch per set, i.e.

when the variation in CPUE among sets is high, then this factor, and hence the coefficient of variation, will be large.

The fourth factor, $\overline{C}$, is the true average catch per set. For species with a relatively high average catch per set, the coefficient of variation will be relatively small. For species with a relatively low average catch per set, such as species of special interest (i.e., marine turtles, sea birds and marine mammals), the coefficient of variation will be relatively large.

Sampling theory for stratified sampling

Equations (1) and (2) apply to an unstratified sampling design. The variance of estimates of CPUE determined from a stratified sampling design, $V(\hat{U}_{st})$, can be approximated as a linear function of the variances of the estimates of CPUE for individual strata, assuming that the CPUE for individual strata are independent, as follows:

$$V(\hat{U}_{st}) \approx \sum_{j} W_j^2 V\left(\hat{U}_j\right) \qquad (3)$$

where W_j is the proportion (or 'weight') of the jth strata in the total, $\frac{N_j}{N}$.

Comparison of sub-sampling to sampling theory

The coefficients of variation of CPUE determined from sub-sampling were compared to those based on sampling theory, i.e. equation (2). For unstratified sampling, the coefficients of variation for yellowfin (Figure 1) are identical over all coverage rates, indicating that those based on sampling theory are unbiased. Similar results were obtained for the other seven species examined.

For unstratified sampling, therefore, equation (2) was used to determine coefficients of variation of CPUE for coverage rates ranging from 1 percent to 100 percent in 1 percent intervals.

For stratified sampling, the results of the comparison depend on the species examined. For yellowfin (Figure 2), the coefficients of variation are identical. However, for leatherback turtles (Figure 3), the coefficients of variation determined from sub-sampling are much greater than those based on sampling theory. Differences were also obtained for other species, with the magnitude of the differences increasing with decreasing CPUE. Recalling that equation (3) assumes that the CPUE for individual strata are independent, the differences in the results for sub-sampling and sampling theory can be attributed to covariation among strata.

For stratified sampling, therefore, sub-sampling was used to determine coefficients of variation of CPUE. 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 4–11 compare the results for unstratified and stratified sampling for each species. The following points are of interest:

- The value of the coefficients of variation depend strongly on the level of CPUE, with smaller coefficients of variation for higher levels of CPUE.
- The shape of the relationship between the coefficients of variation and the coverage rate is similar among species, with a steep decline in the coefficients of variation from 1 percent coverage to about 20–30 percent coverage, followed by a gradual decline to a coefficient of variation of zero at 100 percent coverage.
- Stratified sampling reduces the coefficients of variation by small amounts.

DISCUSSION

Dependence of coefficient of variation on CPUE

It can be seen in Figures 4–11 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 percent, for both stratified and unstratified sampling:

COMMON NAME	COVERAGE RATE	
	UNSTRAT	STRAT
Yellowfin	11	10
Bigeye	6	6
Blue shark	17	14
Blue marlin	20	16
Wahoo	25	22
Mahi mahi / dolphinfish	43	42
Opah	64	60
Leatherback turtle	100	100

For both unstratified and stratified sampling, the required coverage rate increases from 6 percent for bigeye to 100 percent for leatherback turtles. If a coefficient of variation of 10 percent (which is approximately equivalent to a 95% confidence interval of plus or minus 20 percent) 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.

Stratified versus unstratified sampling

The unstratified sampling conducted in this study is equivalent to allocating sampling effort across the region and through time, without regard to the coverage rates for individual fleets and years. This is more or less how the opportunistic sampling of these fleets has actually occurred. When sampling is stratified by fleet and year, the coverage rate is applied to each fleet-year stratum. Figures 4–11, and the table above, indicate that only small improvements in the coefficients of variation of estimates of CPUE are achieved by stratifying the sampling.

Rate of decline of coefficient of variation

Figures 4–11 show that increases in the coverage rate beyond 20–30 percent 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 20–30 percent are achieved, will be an important consideration in setting the coverage rate.

Comparison to offshore longliners targeting South Pacific albacore

The results presented above are similar to those for offshore longliners targeting South Pacific albacore presented in Lawson (2003), with the exception that stratified sampling for the offshore longliners in tropical waters results in only small improvements in the coefficients of variation of estimates of CPUE, whereas for the offshore longliners targeting South Pacific albacore, the improvements are small to moderate. This suggests that CPUE is more strongly related to fleets and time-area strata for the offshore longliners targeting South Pacific albacore than for the offshore longliners targeting yellowfin and bigeye in tropical waters.

REFERENCES

Cochran, W.G. 1977. Sampling Techniques, Third Edition. John Wiley & Sons, New York, New York.

Lawson, T. 2003. Observer coverage rates and the accuracy and reliability of estimates of CPUE for offshore longline fleets targeting South Pacific albacore. Working Paper SWG–4. Sixteenth Meeting of the Standing Committee on Tuna and Billifsh, 9–16 July 2003, Mooloolaba, Queensland, Australia. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

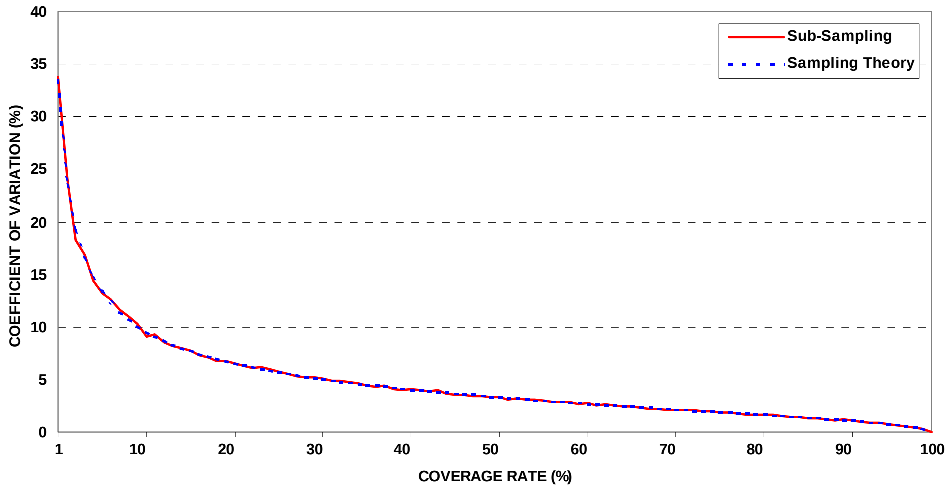

Figure 1. Comparison of coefficients of variation for yellowfin CPUE determined from sub-sampling and sampling theory, for unstratified sampling

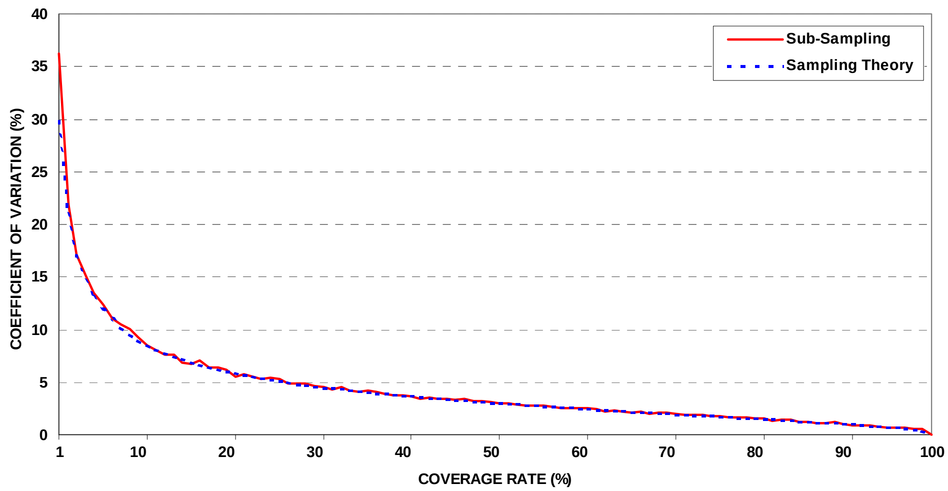

Figure 2. Comparison of coefficients of variation for yellowfin CPUE determined from sub-sampling and sampling theory, for stratified sampling

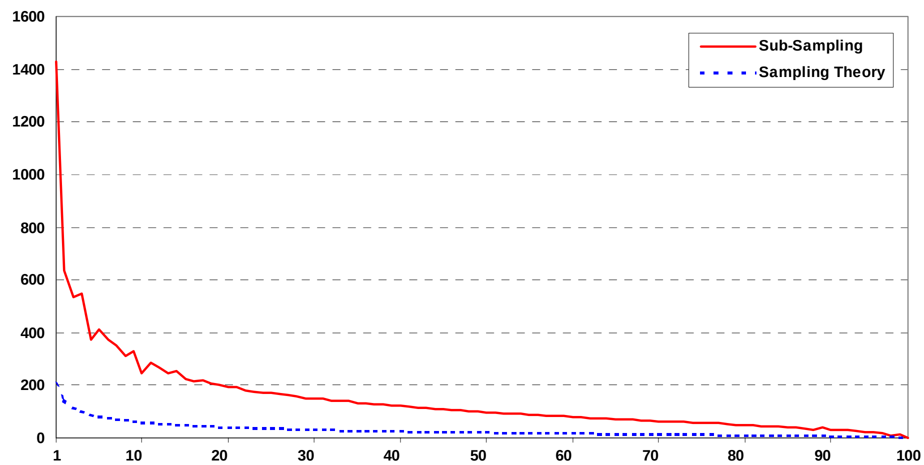

Figure 3. Comparison of coefficients of variation for leatherback turtle CPUE determined from sub-sampling and sampling theory, for stratified sampling

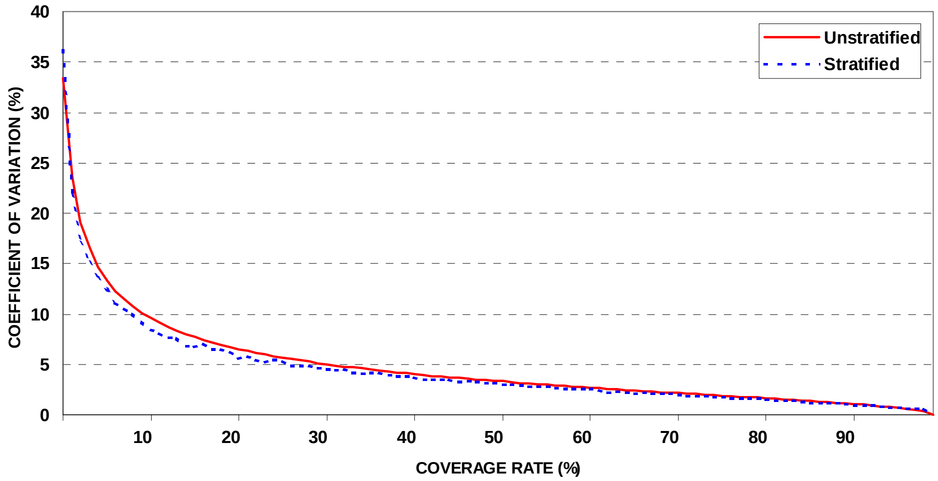

Figure 4. Coefficients of variation of estimates of yellowfin CPUE

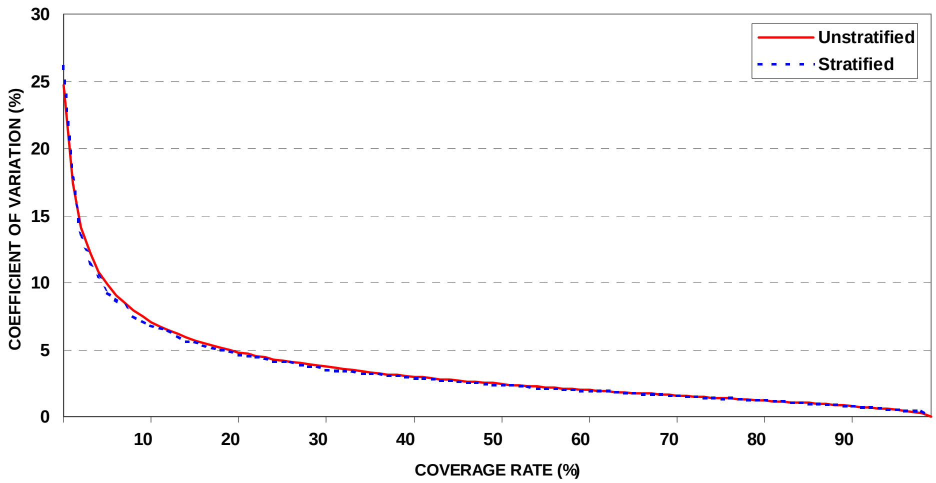

Figure 5. Coefficients of variation for estimates of bigeye CPUE

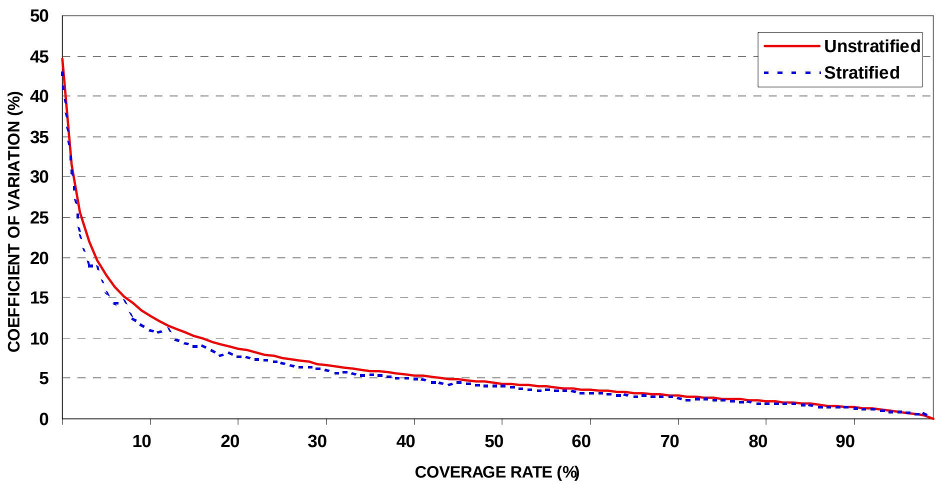

Figure 6. Coefficients of variation of estimates of blue shark CPUE

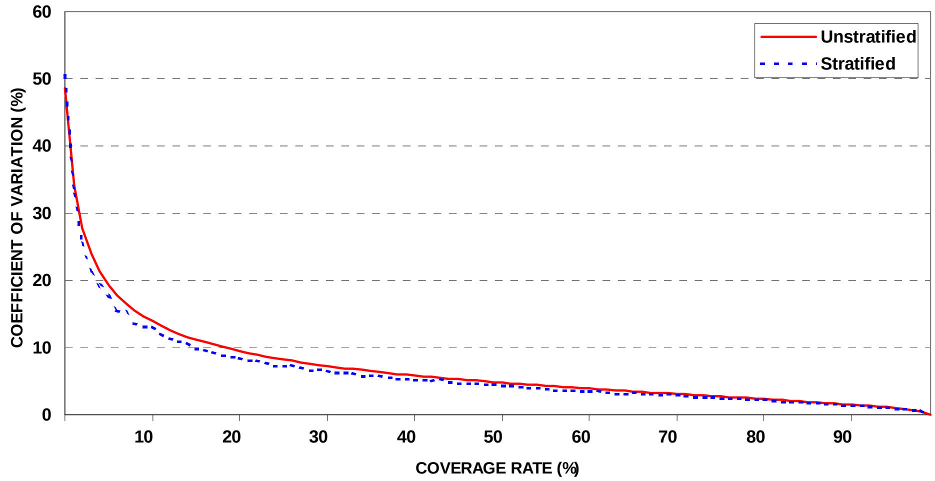

Figure 7. Coefficients of variation of estimates of blue marlin CPUE

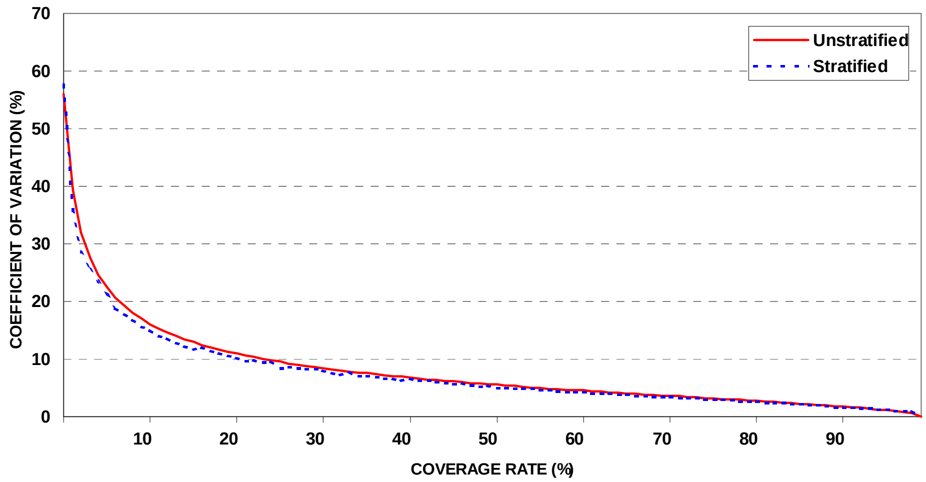

Figure 8. Coefficients of variation of estimates of wahoo CPUE

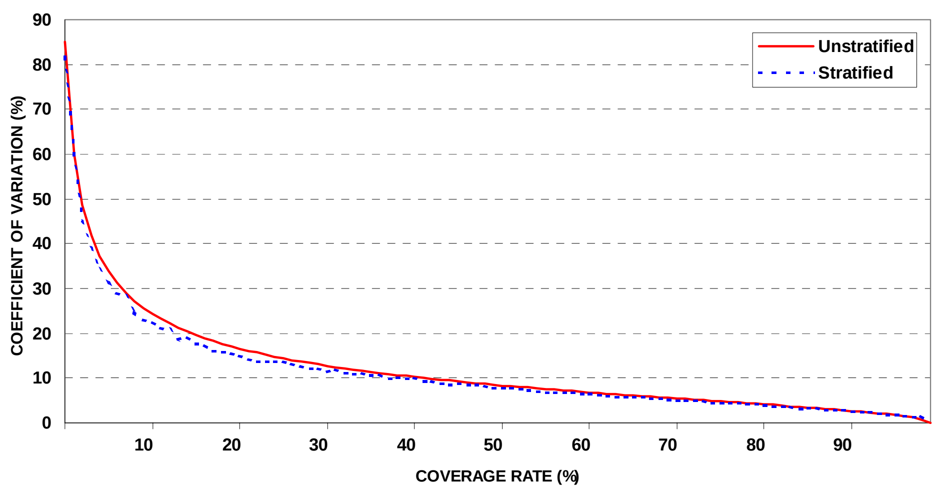

Figure 9. Coefficients of variation of estimates of mahi mahi CPUE

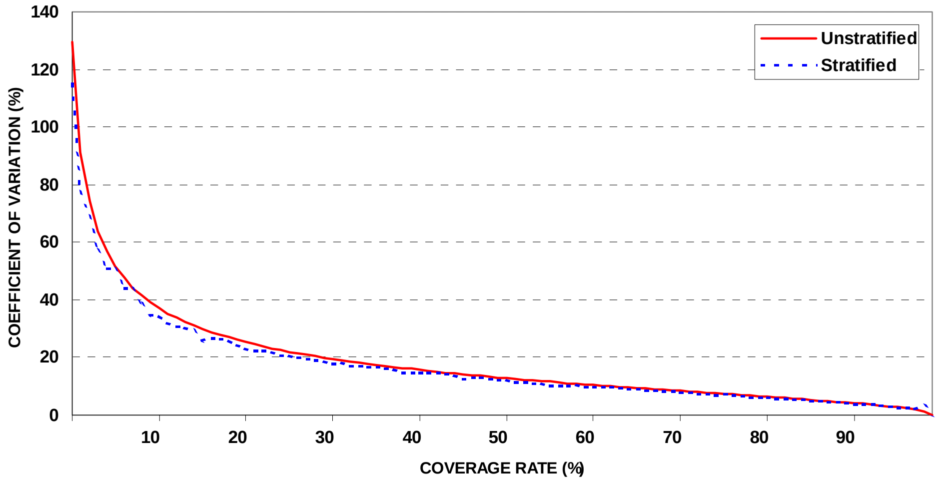

Figure 10. Coefficients of variation of estimates of opah CPUE

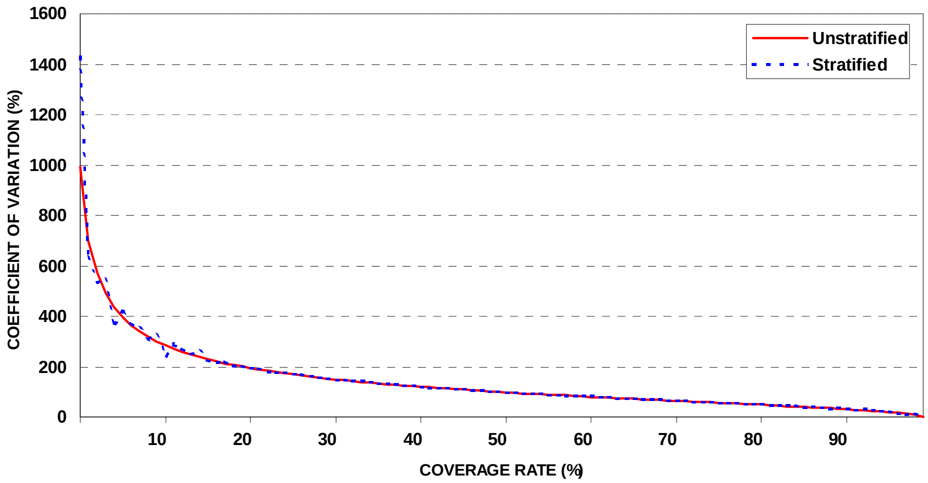

Figure 11. Coefficients of variation of estimates of leatherback turtle CPUE

Table 1. Distribution of observer data held by the OFP covering offshore longline fleets targeting yellowfin and bigeye in tropical waters, by year

YEAR	VESSELS	TRIPS	DAYS	SETS	HOOKS		DAYS PER TRIP	HOOKS PER SET
					NO.	%		
1993	7	7	68	68	99,873	4.8	9.7	1,469
1994	21	21	182	182	229,559	11.0	8.7	1,261
1995	24	26	213	213	262,842	12.6	8.2	1,234
1996	18	19	135	136	159,564	7.6	7.1	1,173
1997	31	32	259	261	324,072	15.5	8.1	1,242
1998	28	30	236	238	279,614	13.4	7.9	1,175
1999	18	19	201	201	319,278	15.3	10.6	1,588
2000	24	24	201	204	250,602	12.0	8.4	1,228
2001	6	6	69	69	96,516	4.6	11.5	1,399
2002	7	8	70	71	69,121	3.3	8.8	974
TOTAL	165	191	1,634	1,643	2,091,041	100.0	8.6	1,273

Table 2. Distribution of observer data held by the OFP covering offshore longline fleets targeting yellowfin and bigeye in tropical waters, by fleet

FLEET	VESSELS	TRIPS	DAYS	SETS	HOOKS		DAYS PER TRIP	HOOKS PER SET
					NO.	%		
China	62	71	532	534	406,722	19.5	7.5	762
FSM	15	21	132	132	148,819	7.1	6.3	1,127
Japan	26	31	389	389	853,055	40.8	12.5	2,193
Papua New Guinea	14	16	142	143	172,912	8.3	8.9	1,209
Taiwan	45	48	408	412	453,333	21.7	8.5	1,100
United States	4	4	31	33	56,200	2.7	7.8	1,703
TOTAL	165	191	1,634	1,643	2,091,041	100.0	8.6	1,273

Table 3. Pooled CPUE (number of fish per 100 hooks), standard deviation of CPUE (number of fish per 100 hooks and percentage of mean CPUE), number of positive sets, and total number of fish caught from observer data covering offshore longliners targeting yellowfin and bigeye in tropical waters

SPECIES	POOLED CPUE	POS SETS	NO CAUGHT
YELLOWFIN	0.71749	1,433	15,003
BIGEYE	0.41936	1,375	8,769
BLUE SHARK	0.17594	931	3,679
SILKY SHARK	0.08771	546	1,834
BLUE MARLIN	0.06475	595	1,354
SWORDFISH	0.05724	646	1,197
PELAGIC STING-RAY	0.05021	423	1,050
SKIPJACK	0.04141	353	866
OCEANIC WHITE-TIP SHARK	0.03419	366	715
ALBACORE	0.03271	161	684
WAHOO	0.03242	377	678
LANCETFISHES	0.03190	161	667
SHARKS (UNIDENTIFIED)	0.03065	208	641
MAHI MAHI / DOLPHINFISH / DORADO	0.02922	283	611
SAILFISH (INDO-PACIFIC)	0.02855	302	597
POMFRETS AND OCEAN BREAMS	0.02692	226	563
ESCOLAR	0.02611	211	546
BARRACUDAS (UNIDENTIFIED)	0.01832	260	383
UNSPECIFIED	0.01640	211	343
THRESHER SHARKS	0.01597	139	334
BLACK MARLIN	0.01416	196	296
OILFISH	0.01310	177	274
GREY REEF SHARK	0.01105	57	231
STRIPED MARLIN	0.01052	174	220
SNAKE MACKERELS AND ESCOLARS	0.00933	105	195
SHORT FINNED MAKO SHARK	0.00909	97	190
GREAT BARRACUDA	0.00890	56	186
OTHER FISH	0.00861	28	180
BIGEYE THRESHER SHARK	0.00818	109	171
SNAKE MACKEREL	0.00780	95	163
SHORTSNOUTED LANCETFISH	0.00765	29	160
SHORT-BILLED SPEARFISH	0.00679	108	142
CROCODILE SHARK	0.00622	84	130
MOONFISH / OPAH	0.00555	80	116
MARLINS, SAILFISHES, SPEARFISHES (UNIDENTIFIED)	0.00521	55	109
SILVER-TIP SHARK	0.00478	32	100
LONG FINNED MAKO SHARK	0.00454	50	95
PELAGIC THRESHER SHARK	0.00440	65	92
WHIP STINGRAY	0.00373	43	78
TUNA (UNIDENTIFIED)	0.00311	40	65
LONGSNOUTED LANCETFISH	0.00239	23	50
OCEAN SUNFISH	0.00206	37	43
MARINE TURTLE (UNIDENTIFIED)	0.00187	37	39

Table 3 (continued)

SPECIES	POOLED CPUE	POS SETS	NO CAUGHT
DOGTOOTH TUNA	0.00167	21	35
MAKO SHARKS	0.00139	20	29
GEMFISH (SOUTHERN OR SILVER KINGFISH)	0.00120	17	25
RAYS, SKATES AND MANTAS	0.00115	15	24
GALAPAGOS SHARK	0.00110	12	22
MANTA RAYS (UNIDENTIFIED)	0.00110	19	23
HAMMERHEAD SHARKS	0.00105	16	23
OLIVE RIDLEY TURTLE	0.00091	18	18
WHITE-TIP REEF SHARK	0.00086	7	19
RAINBOW RUNNER	0.00081	16	16
TIGER SHARK	0.00077	13	17
BARRACUDA (S. JELLO)	0.00062	8	13
BLACKTIP REEF SHARK	0.00057	6	12
BLACKTIP SHARK	0.00057	7	12
ATLANTIC MACKEREL	0.00057	9	12
GREEN TURTLE	0.00057	11	12
THRESHER SHARK (VULPINAS)	0.00053	6	11
SICKLE POMFRET	0.00048	8	10
BIRD (UNIDENTIFIED)	0.00043	5	8
RAYS (DASYATIDIDAE)	0.00038	6	9
HAWKSBILL TURTLE	0.00038	6	8
YELLOW-BELLIED SEA SNAKE	0.00033	3	7
BIG-SCALED POMFRET	0.00033	7	7
MARINE MAMMAL (UNIDENTIFIED)	0.00019	4	4
RAY'S BREAM / ATLANTIC POMFRET	0.00019	4	4
BLACKFIN BARRACUDA	0.00014	2	2
BARRACUDA (S. PUTNAMIAE)	0.00014	2	2
DOG FISHES	0.00014	2	3
DOLPHINS / PORPOISES (UNIDENTIFIED)	0.00014	2	2
DEEPWATER RED SNAPPER	0.00010	2	3
BARRACUDINAS (FAMILY)	0.00010	2	3
LONGTAIL TUNA	0.00010	2	2
SHORT-TAILED BLACK RAY	0.00010	1	3
BATFISHES	0.00005	1	1
ATLANTIC BLUEFIN TUNA	0.00005	1	1
SPANISH MACKEREL (NARROW-BARRED)	0.00005	1	1
FLYING FISHES	0.00005	1	1
FRIGATE TUNA	0.00005	1	1
LEATHERBACK TURTLE	0.00005	1	1
PILOT FISH	0.00005	1	1
BIGEYE SAND SHARK	0.00005	1	1
SOUTHERN BLUEFIN TUNA	0.00005	1	1
BARRACOUTA (SNOEK)	0.00005	1	1
TREVALLIES (UNIDENTIFIED - JACKS)	0.00005	1	1
LOGGERHEAD TURTLE	0.00005	1	1