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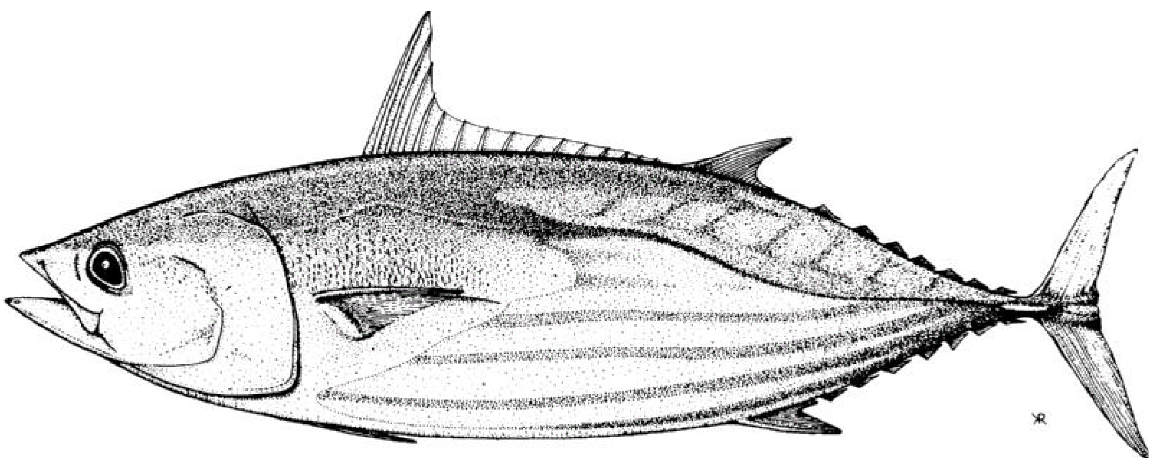

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Sampling design and variability associated with estimates of species composition of tuna landings for the U.S. purse seine fishery in the central-western Pacific Ocean (1997-2001)[1]

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INTRODUCTION

The U.S. purse seine fleet has fished in the central-western Pacific Ocean since 1974. In 1988, U.S. vessels started fishing under the South Pacific Regional Tuna Treaty (SPTT). As part of the SPTT, vessels are required to submit their total landings of yellowfin, bigeye, and skipjack tunas at the end of each fishing trip. It is typical for vessel captains to simply obtain these estimates from the canneries. However, since the price paid for 'small' (roughly, <9 kg fish) yellowfin and bigeye tunas is generally similar and given the two species are difficult to identify at this size, landings of these tunas are usually combined and reported nominally as yellowfin tuna. Also, landings of small yellowfin and bigeye tunas are sometimes combined in skipjack tuna landings as well, particularly, when landings compose fish <1.8 kg in size. In 1988, the National Marine Fisheries Service (NMFS) developed a port sampling program to determine species-composition estimates of each of these landing categories, i.e., the 'yellowfin tuna' and 'skipjack tuna' landing categories—henceforth, quotations are used to differentiate landing categories from actual species contained within them.

Although the original sampling design was stratified by set type ('associated' sets on fish schools using logs, FADs, etc. and 'unassociated' sets on free-swimming schools) and size group ('small,' <9 kg fish and 'large,' >9 kg fish), sample data were commonly pooled to generate only annual estimates (in mt) of species composition, i.e., the catch time series of interest in assessment models. However, due to increased fishing on fish aggregation devices (FADs) during the mid 1990s, which resulted in significant changes to the species compositions, further examination of the stratified sampling design was undertaken to ensure final results were appropriately derived.

Landing estimates of individual species are critical sources of data for conducting stock assessments and generally considered one of the most important time series for evaluating the status of a fish population. The purpose of this study was to evaluate the current species-composition sampling program for U.S. purse seine landed tunas in the central-western Pacific Ocean and in particular, to determine the quality (i.e., sampling error or precision) of the sample estimates of species composition (1997-2001).

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METHODS

Species-composition sampling program

The original sampling design primarily focused on determining the amount of bigeye tuna in the ‘yellowfin tuna’ landing category on a yearly basis. The design incorporated biological sampling objectives as well, e.g., collection of size (length) data along with species-composition information. Port biologists selected 50 fish from vessel wells that contained catches made in individual months and NMFS sampling areas (Figure 1). Biologists were instructed to collect a species-composition sample whenever they encountered a species other than the species targeted for the biological sample (i.e., 50-fish length sample). As soon as another species was encountered, the biologists increased the number of fish selected to 100. They then identified and measured each species in the 100-fish sample. If after drawing a length sample from a landing category (i.e., ‘yellowfin tuna’ or ‘skipjack tuna’ landing categories) no other species were encountered, then the sample was considered a ‘pure’ sample composed entirely of the targeted species within the landing category, e.g., the ‘yellowfin tuna’ landing category was assumed to be comprised of only yellowfin tunas. Finally, for each species, a weight-length relationship was used to convert number of fish into weight of fish and thus, each species-composition sample reflected a total weight (kg) of each species contained within the sample. This data collection approach is considered a stratified, multistage sampling design combined with poststratification, where vessels (i.e., wells within vessels) are treated as primary sampling units, landing categories are treated as poststratification units or the actual ‘domains of study,’ and 50-100 fish samples from landing categories within vessel wells represent the secondary sampling units.

Beginning in 1996, the purse seine fleet began fishing more regularly with FADs (an ‘associated’ set), which dramatically influenced the biological attributes of the purse seine catches (Figure 2). Anecdotal observations from the ‘associated’ sets indicated that they generally attracted: (1) smaller fish than ‘unassociated’ sets; and (2) greater numbers of bigeye tuna than ‘unassociated’ sets. The dramatic shift from ‘unassociated’ sets to ‘associated’ (FAD) sets during the mid-1990s was the motivation for the analysis presented here, i.e., it became evident that sample estimates of species composition could vary substantially across different strata. Currently, for each domain of study (landing category), biologists are instructed to collect samples from vessel wells based on month, NMFS sampling area, set type, and size group. For purposes of this study, sample data were combined over months and NMFS sampling areas and evaluated within the following strata: year, all sampling areas, set type, and size group. A species-composition sample is defined here as a collection of 50-100 fish from a vessel well based on the strata defined above. The number of samples collected per strata varied considerably, ranging from 3 to 450 for the period 1997-2001 (Table 1).

Species–composition estimation

Given the overall objective of determining annual estimates of species composition (in mt) for the U.S. purse seine fishery of the central-western Pacific Ocean based on a stratified sampling design, it was necessary to first partition the total landings of each category (i.e., ‘yellowfin tuna’ and ‘skipjack tuna’ landing categories) by the appropriate strata (year/set type/size group). This exercise was straightforward when stratification ignored set type and size group, but somewhat problematic if finer level strata needed to be accommodated, i.e., total catches by set type and size group are not maintained by the canneries. Total catches of each category within the strata defined above were estimated using both logbook and biological (length data) sample information. Catch records from logbooks were used to apportion the vessel’s catch by set type and length samples were used to further partition the total catch by set type into size groups (Table 1). Ultimately, we feel the stratified estimates of total landings within each category can be accurately determined using the auxiliary information from logbook and length sample data; however, we did not evaluate the error associated with these calculations and strictly speaking, treated the derived values as known, i.e., our assumption is that the variability associated with such estimation is negligible and not likely to influence conclusions drawn from the analysis conducted in this study.

For each landing category, annual estimates of species composition (in proportion) were derived for each strata (year/all sampling areas/set type/size group) based on the following procedures: (1) the species composition of each sample (in weight) was converted to proportions; (2) estimators treated each sample equally, i.e., each sample was assumed to be equally informative in terms of the species composition of a landing within a stratum of interest; (3) mean estimates of species composition (in proportion) and associated sampling error were calculated; and (4) mean estimated species compositions (in proportion) were multiplied by the estimates of total landings of each category to generate landing estimates of individual species in weight. Finally, for each year (1997-2001), landing estimates of individual species were summed across applicable strata (i.e., for each category, combinations of set type and size group) to obtain annual landing estimates of each species. All calculations followed straightforward estimation methods applicable to multistage sampling designs commonly used to monitor landings from commercial fisheries. Estimated sampling error associated with estimates of species composition (in proportion) within each stratum are presented as coefficients of variation of the mean (CVs) and variability associated with annual landing estimates (in mt) calculated across strata is presented as both CVs and 95% confidence intervals (CIs).

RESULTS AND DISCUSSION

In general, the mean estimates of species composition (in proportion) for each stratum were relatively precise, particularly, for species encountered more frequently. That is, for the most part, estimates for species that composed larger proportions (>25%) of the mean estimated compositions had associated CVs <10% (Table 1). Whereas, species that composed smaller proportions of the overall compositions had moderately to highly variable landing estimates (i.e., CVs generally >20%). In each stratum, skipjack tuna dominated the 'skipjack tuna' landing category, where estimates ranged from 82 to over 99% of the total landings and were very precise (CVs <10%). Yellowfin tuna composed the majority of the 'yellowfin tuna' landing category for 'unassociated' sets in each of the strata (at least 76%), but 'associated' sets generally comprised substantial amounts of bigeye tuna (in some cases, 50% of the total landings). Skipjack tuna were never observed in the 'yellowfin tuna' landing category. Species-composition estimates in the 'yellowfin tuna' landing category were largely precise; however, in some cases, infrequently sampled strata did result in relatively variable estimates (e.g., 1998/ 'unassociated' sets/'small' size group).

The annual-based time series of estimated species compositions (in mt), summed across strata, were very precise, with CVs <6% for skipjack and yellowfin tuna landing estimates and CVs <13% for bigeye tuna landing estimates (Table 2). To summarize, results presented here indicate that the catch time series for these species are reliable sources of data and thus, are not likely to introduce substantial amounts of variability in assessment models used for these fisheries.

It is important to note that this study examined the sampling error associated with species-composition data and did not formally evaluate potential non-sampling error (e.g., bias from non-random sampling techniques, incomplete statistical population coverage, etc.) associated with the sampling design described above. That is, we assumed that species were identified correctly and that samples were collected randomly across the entire statistical population of interest (i.e., the total landings made in a spatial/temporal stratum of interest). In this regard, the following issues represent areas of concern that would benefit from further scrutiny:

(1) Accurate identification of species in the field is difficult in some cases, particularly, differentiating small-size yellowfin and bigeye tunas. Plans are underway to evaluate this potential bias through controlled experiments in the field.

(2) Determination of total landings for each landing category is problematic for some strata. Logbook coverage of the fleet is 100% and thus, we feel that partitioning total catches into set types is likely accurate; however, length-composition data, used to further separate the landings by size group, may be limited to 1-2 wells from a vessel's trip, which could potentially bias final estimates of total landings by size group. In the future, the representativeness of the ancillary length data will be evaluated, as well as documenting the precision of this sample information in a similar manner as was done for species-composition sample estimates presented here.

(3) As fishery operations change over time, there is a tendency to construct more and more strata to effectively monitor the landings; however, over-stratification can often lead to less precision associated with the overall estimates of interest, as well as introduce bias that may go unnoticed for long periods of time.

(A) We strongly recommend that species-composition estimation be fully conducted in each stratum, given total landings in each landing category can vary widely between strata and pooling sample data across strata, before converting estimated proportions to landing values (in mt), could lead to misleading annual-based estimates of landings for one or more of the species.

ACKNOWLEDGEMENTS

We would like to thank Gordon Yamasaki and his staff of biological technicians at the Pacific Islands Area Office of the Southwest Region in Pago Pago, American Samoa for providing sample data that were analyzed in this study. We also thank the vessel captains of the U.S. purse seine fishery in the central-western Pacific Ocean for their cooperation during sampling efforts.

Table 1. Estimates of species composition (in proportion) and associated coefficients of variation of the mean (CVs) for landing categories ('skipjack tuna'and 'yellowfin tuna') within strata (year/set type/size group) for the U.S. purse seine fishery operating in the central-western Pacific Ocean (1997-2001). Total landings (in mt) for each landing category and estimated landings (in mt) for each species are also presented. Set types are denoted as 'associated' sets (ASSOC) and 'unassociated' sets (UNASSOC). Size groups are denoted as 'small' (SML) and 'large' (LRG). Species are denoted as skipjack tuna (SKJ), yellowfin tuna (YFT), and bigeye tuna (BET). Sample sizes (wells within vessels) are denoted as n.

Year	Landing category	Set type	Size group	Total landings (mt)	n	Species	Estimate (proportion)	CV	Estimate (mt)
1997	'Skipjack'	ASSOC	SML	52,739	304	SKJ	0.9722	0.01	51,271
						YFT	0.0186	0.21	981
						BET	0.0092	0.24	487
1997	'Skipjack'	UNASSOC	SML	26,647	131	SKJ	0.9996	<0.01	26,636
						YFT	0.0004	1.00	11
						BET	0.0000	na	0
1997	'Yellowfin'	ASSOC	LRG	21,150	113	SKJ	0.0000	na	0
						YFT	0.8375	0.03	17,712
						BET	0.1625	0.18	3,437
1997	'Yellowfin'	ASSOC	SML	15,066	170	SKJ	0.0000	na	0
						YFT	0.6028	0.04	9,081
						BET	0.3972	0.05	5,984
1997	'Yellowfin'	UNASSOC	LRG	27,603	122	SKJ	0.0000	na	0
						YFT	0.9786	0.01	27,012
						BET	0.0214	0.56	591
1997	'Yellowfin'	UNASSOC	SML	878	6	SKJ	0.0000	na	0
						YFT	0.9298	0.04	816
						BET	0.0702	0.48	62
1998	'Skipjack'	ASSOC	SML	103,230	326	SKJ	0.9808	<0.01	101,243
						YFT	0.0133	0.27	1,371
						BET	0.0060	0.36	616
1998	'Skipjack'	UNASSOC	SML	28,343	115	SKJ	0.9991	<0.01	28,318
						YFT	0.0007	1.00	18
						BET	0.0002	1.00	7
1998	'Yellowfin'	ASSOC	LRG	4,552	67	SKJ	0.0000	na	0
						YFT	0.9330	0.03	4,247
						BET	0.0670	0.39	305
1998	'Yellowfin'	ASSOC	SML	9,444	161	SKJ	0.0000	na	0
						YFT	0.5145	0.03	4,858
						BET	0.4855	0.03	4,585
1998	'Yellowfin'	UNASSOC	LRG	28,602	67	SKJ	0.0000	na	0
						YFT	1.0000	0.00	28,602
						BET	0.0000	na	0
1998	'Yellowfin'	UNASSOC	SML	277	3	SKJ	0.0000	na	0
						YFT	0.6682	0.25	185
						BET	0.3318	0.50	92
1999	'Skipjack'	ASSOC	SML	126,218	450	SKJ	0.9276	0.01	117,079
						YFT	0.0487	0.12	6,147
						BET	0.0237	0.15	2,993
1999	'Skipjack'	UNASSOC	SML	3,044	8	SKJ	0.8209	0.09	2,499
						YFT	0.1528	0.45	465
						BET	0.0262	0.59	80
1999	'Yellowfin'	ASSOC	LRG	30,882	199	SKJ	0.0000	na	0
						YFT	0.6966	0.04	21,511
						BET	0.3035	0.09	9,371
1999	'Yellowfin'	ASSOC	SML	21,237	139	SKJ	0.0000	na	0
						YFT	0.5670	0.04	12,042
						BET	0.4330	0.05	9,195
1999	'Yellowfin'	UNASSOC	LRG	1,103	4	SKJ	0.0000	na	0
						YFT	1.0000	0.00	1,103
						BET	0.0000	na	0

Table 1. Continued.

Year	Landing category	Set type	Size group	Total landings (mt)	n	Species	Estimate (proportion)	CV	Estimate (mt)
2000	'Skipjack'	ASSOC	SML	56,144	314	SKJ	0.8179	0.02	45,918
						YFT	0.0934	0.09	5,246
						BET	0.0887	0.08	4,980
2000	'Skipjack'	UNASSOC	SML	24,128	119	SKJ	0.9782	0.01	23,601
						YFT	0.0143	0.45	346
						BET	0.0075	0.52	181
2000	'Yellowfin'	ASSOC	LRG	28,320	240	SKJ	0.0000	na	0
						YFT	0.8223	0.03	23,289
						BET	0.1777	0.13	5,031
2000	'Yellowfin'	ASSOC	SML	7,605	109	SKJ	0.0000	na	0
						YFT	0.5079	0.04	3,862
						BET	0.4921	0.04	3,742
2000	'Yellowfin'	UNASSOC	LRG	8,443	49	SKJ	0.0000	na	0
						YFT	0.9800	0.02	8,274
						BET	0.0200	1.00	169
2000	'Yellowfin'	UNASSOC	SML	711	9	SKJ	0.0000	na	0
						YFT	0.7613	0.10	541
						BET	0.2387	0.32	170
2001	'Skipjack'	ASSOC	SML	48,396	280	SKJ	0.9786	0.01	47,359
						YFT	0.0115	0.34	556
						BET	0.0099	0.30	481
2001	'Skipjack'	UNASSOC	SML	37,040	187	SKJ	0.9879	0.01	36,592
						YFT	0.0120	0.58	443
						BET	0.0001	1.00	5
2001	'Yellowfin'	ASSOC	LRG	5,366	89	SKJ	0.0000	na	0
						YFT	0.9270	0.02	4,975
						BET	0.0730	0.22	392
2001	'Yellowfin'	ASSOC	SML	10,941	179	SKJ	0.0000	na	0
						YFT	0.4914	0.03	5,376
						BET	0.5086	0.03	5,565
2001	'Yellowfin'	UNASSOC	LRG	12,952	90	SKJ	0.0000	na	0
						YFT	0.9977	<0.01	12,922
						BET	0.0023	0.68	30
2001	'Yellowfin'	UNASSOC	SML	829	18	SKJ	0.0000	na	0
						YFT	0.8135	0.06	674
						BET	0.1865	0.27	155

Table 2. Annual estimates of species composition (in mt) and associated coefficients of variation of the mean (CVs) and 95% confidence intervals (CIs) across strata (set type/size group) for the U.S. purse seine fishery operating in the central-western Pacific Ocean (1997-2001). Species are denoted as skipjack tuna (SKJ), yellowfin tuna (YFT), and bigeye tuna (BET). Sample sizes (wells within vessels) are denoted as n.

Year	n	Species	Estimate (mt)	CV	95% CI (lower)	95% CI (upper)
1997	846	SKJ	77,907	<0.01	77,301	78,513
		YFT	55,615	0.03	52,612	58,618
		BET	10,561	0.13	7,750	13,373
1998	739	SKJ	129,560	<0.01	128,507	130,613
		YFT	39,282	0.02	37,905	40,659
		BET	5,605	0.09	4,545	6,666
1999	800	SKJ	119,578	0.01	117,088	122,067
		YFT	41,268	0.06	36,624	45,911
		BET	21,639	0.09	17,945	25,333
2000	840	SKJ	69,519	0.01	67,656	71,382
		YFT	41,558	0.04	38,261	44,856
		BET	14,274	0.11	11,255	17,293
2001	843	SKJ	83,951	0.01	82,815	85,088
		YFT	24,945	0.03	23,442	26,449
		BET	6,627	0.07	5,711	7,544

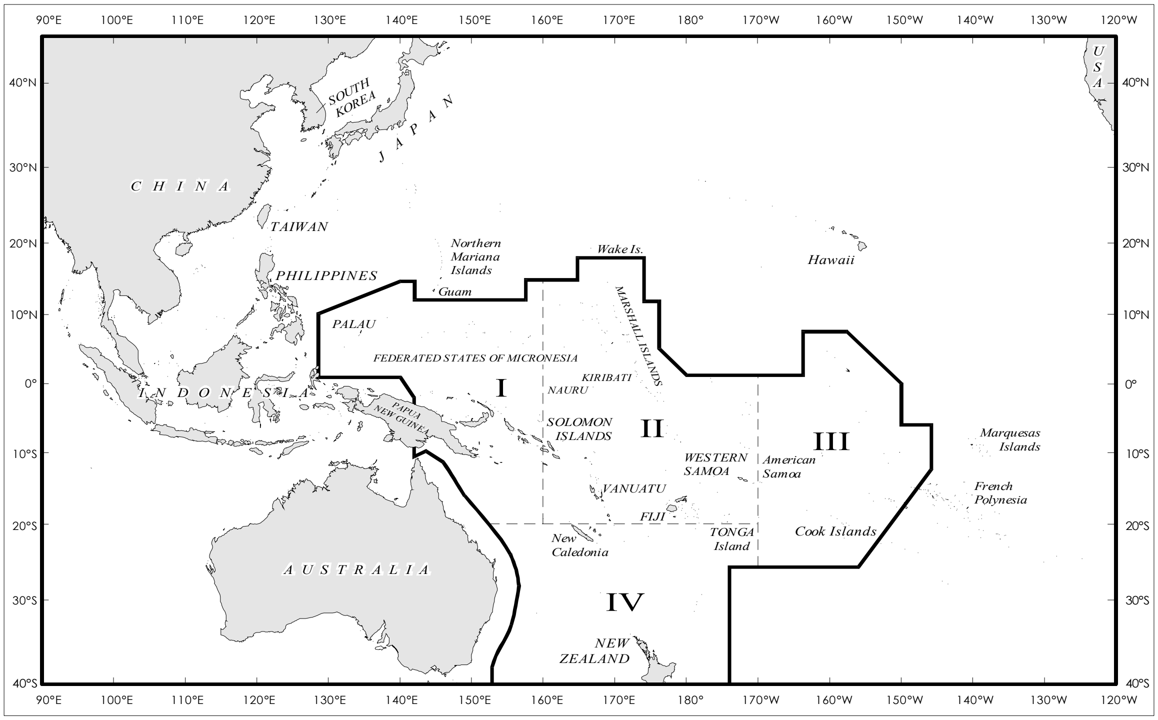

Figure 1. National Marine Fisheries Service areas used to sample U.S. purse seine catches in the central-western Pacific for length and species composition.

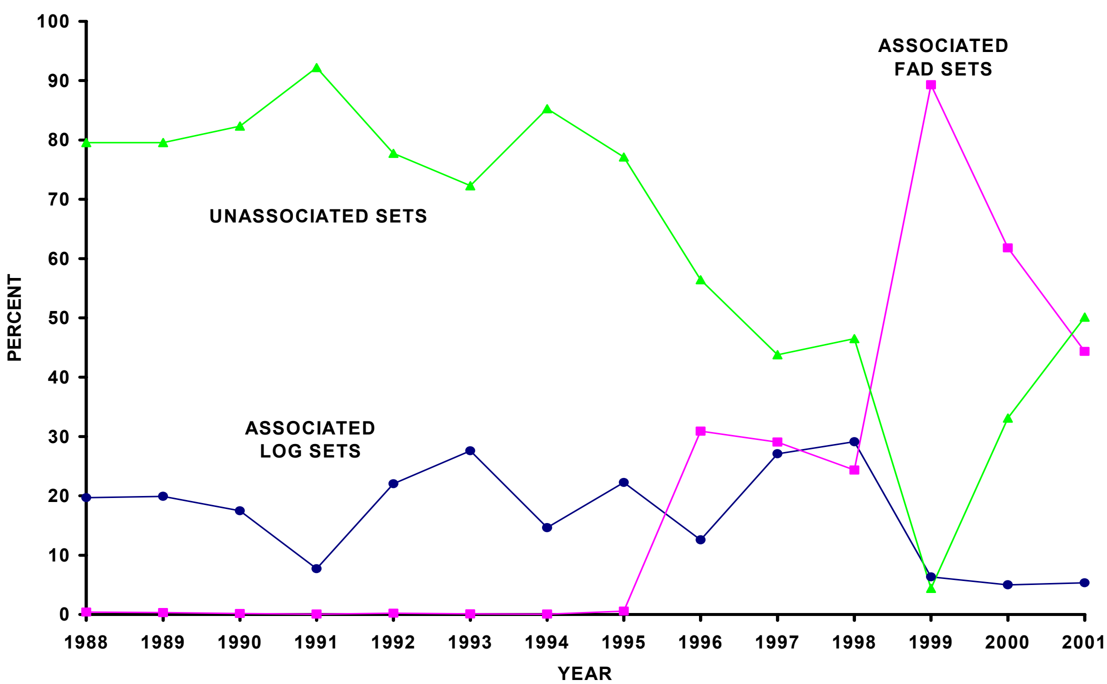

Figure 2. Set types used by U.S. purse seiners fishing in the central-western Pacific.