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INTRODUCTION

Purse seine catches of the U.S. tropical tuna fishery in the central-western Pacific are typically landed as skipjack tuna, *Katsuwonus pelamis*, and "yellowfin tuna." This latter category is a mixture of mostly yellowfin tuna, *Thunnus albacares*, and some bigeye tuna, *T. obesus*. Catches of these species are not recorded separately primarily because the prices paid by canneries to fishermen are the same for both species and yellowfin tuna is the predominant species in the landings. To date, yellowfin tuna statistics reported for this fishery has, therefore, included catches of bigeye tuna (Coan et al. 1995; Coan 1994). In other words, the yellowfin tuna statistics are unadjusted statistics.

Beginning in 1988, the National Marine Fisheries Service (NMFS), Southwest Region has maintained a port sampling program to measure the species composition of tuna in the unadjusted yellowfin tuna landings by U.S. purse seiners in the central-western Pacific. The data collected for the period 1989-1994 were analyzed and the results used to estimate catches of bigeye tuna in the unadjusted yellowfin tuna statistics. The results of this investigation is reported here.

SAMPLES

Species composition samples are collected during off-loading of U.S. purse seiners in Pago Pago, American Samoa to cannery facilities. The sampling is conducted by random drawing of fish from storage wells, unloading buckets, or containers. The primary purpose is to draw samples and measure each fish for fork length (FL) with a target of 50-fish/sample. If in the course of this activity a mixture of species is encountered, a total of 100-fish is drawn for length measurement and species composition. Recorded for each sample is ancillary information such as date of catch, place of catch, sizes of fish and set type (log or school-fish), which are obtained from fishing logbooks.

Species identification of especially small bigeye tuna from yellowfin tuna was once difficult and required dissection and examination of internal organs, e.g. the liver. In the late 1980s, a simple method using external characteristics was discovered (Yamasaki 1993). The method relies on characteristics of the caudal keel and fin. That is, a well-defined keel and a pronounced v-shaped indentation in the center of the trailing edge of the caudal fin are characteristics of yellowfin tuna. Bigeye tuna, by contrast, has a less developed keel and no indentation or notch in the central leading edge of the caudal fin.

This species identification method is used in Pago Pago. Furthermore, the sampling procedure require that whenever a fish drawn had a broken or missing tail, it is replaced with another fish with a tail. In this way, all fish in a sample can be identified to species using this method.

STRATIFICATION

Species composition samples were stratified by year, size of fish (large fish—LG (>9 kg) and small fish—SM (<9 kg)) and type of set (log set—LOG and school-fish set—SCH). Fishing logbook records were used to obtain type of set information and, FL measurements were used for size of fish information.

From 1988 through 1994, the NMFS program collected 1,474 samples with a mixture of yellowfin tuna and bigeye tuna (mixed samples), 2,027 samples containing only yellowfin tuna (pure yellowfin samples) and 8 samples containing only bigeye tuna (pure bigeye samples) (Table 1). The largest number of samples was collected in 1989 (645 samples), followed by the next largest in 1992 (637 samples). The largest number of pure yellowfin samples was collected in 1989 (375) and the smallest, in 1988 (153). The fewest samples (250) was collected in 1988, the year sampling began in mid year. Samples for 1988 were not used in our analysis because they did not span the entire year.

The number of pure samples far exceed the number of mixed samples, indicating that mixed condition is exceptional. The samples were weighted by the sampled catch and pooled to obtain the percentage of bigeye tuna by weight for each stratum. Conversion of the sampled catch to weight of fish by species was done following the procedure described in WPYRG (1993) and using a bigeye tuna length-weight equation of,

$$\text{Weight (in lb.)} = 0.00008071 \text{ FL (in cm)}^{2.90182}$$

(Nakamura & Uchiyama 1966). The results indicate that the highest percentage of bigeye tuna was 27% in LOG-SM samples in 1994 and the lowest, 0.05% in SCH-LG samples in 1989 (Table 2). Averaging over the period 1989-94, the highest percentage of bigeye tuna was 20.52% in LOG-SM samples and lowest, 0.25% in SCH-LG samples.

The unadjusted yellowfin tuna catch for each year was similarly stratified by type of set and size of fish (Table 3). For each year, the highest catch was always in the SCH-LG stratum (average 30,955 t or 64%), followed by the LOG-SM stratum (average 8,482 t or 17%).

ANALYSIS AND RESULTS

Chi-square analysis was used to statistically evaluate the effect of the stratification design (Table 2). The first test used the hypothesis that the proportion of yellowfin tuna and bigeye tuna in the unstratified samples (all samples combined) by year is the same as in the stratified samples. The results (Table 4) show rejection of this hypothesis for all LOG-SM and SCH-LG samples and for one year each for LOG-LG (1989) and SCH-SM (1994) samples.

A second test involved the hypothesis that the proportion of yellowfin tuna and bigeye tuna within a size-of-fish stratum is the same between log set and school-fish set samples. The results (Table 5) show strong rejection of this hypothesis for each year.

We conclude from these results that the proportion of bigeye in the stratified samples is significant different from the proportion in the unstratified samples. For the SCH-LG stratum, the proportion of bigeye tuna is significantly lower (0.05% to 0.51%) than in the unstratified samples (4.30% to 8.36 %); whereas for the LOG-SM stratum, the proportion of bigeye tuna is significantly higher (14.52% to 27.20%) than in the unstratified samples. Furthermore, type of set appears to have a major effect on the proportion of bigeye tuna in the catch when comparing samples with identical sizes of fish; the proportion is higher in log sets.

The stratified samples were used with the stratified unadjusted catches (Table 3) to estimate the amount of bigeye tuna caught each year by the U.S. purse seine fishery. The estimates range from 1,763 t in 1990 to 3,823 t in 1993 and average 2,507 t (Table 6).

DISCUSSION

Surface fisheries for tropical tunas typically underreport or don't report catches of bigeye tuna. The fisheries often catch bigeye tuna along with yellowfin tuna, but because bigeye tuna make up a small fraction of the catch and is priced the same as yellowfin tuna, it is mislabeled and included in the yellowfin tuna statistics. This has created complications for accurate assessment of the effects of surface fishing on the bigeye tuna stock and for administrating regulations that affect one species and not the other. The solution adopted by ICCAT for the Atlantic Ocean fisheries has been an area-wide sampling of surface fisheries catches for estimating the bigeye tuna catch and adoption of common regulations for both yellowfin and bigeye tunas (ICCAT 1980).

For Pacific fisheries, no solution has yet been implemented and studies are underway to evaluate the extent of the underreporting. For the U.S. tropical tuna purse seine fishery, port sampling was initiated in 1988 to gather data for determining the amount of bigeye tuna in the unadjusted statistics. Data from the sampling reveal that the amount of bigeye tuna caught depends on the type of set and size of fish in the catch. Log sets which usually contain mostly small fish, had a high percentage (average 21%) of bigeye tuna. School-fish sets, on the other hand, which contain mostly large fish, had a low percentage (average 0.25%) of bigeye tuna.

The data also revealed that the probability of a purse seine set being a mixed species (bigeye tuna and yellowfin tuna) catch is much greater in log sets than in school-fish sets

(Table 1). In successful log sets, about 66% of the sets have mixed catches. Whereas in successful school-fish sets, only 13% have mixed catches.

The stratified data were used to adjust the U.S. fishery statistics. The estimated catch of bigeye tuna in weight is small. However, in terms of numbers of fish caught annually, the amount is substantial (5.6 million fish in 1994) because the catch is primarily of juvenile fish less than 100 cm FL.

Our results cannot be directly applied to catches of other purse seine fleets because the U.S. fleet operates over a wider area and has a higher proportion of school-fish sets than other purse seine fleets fishing for tropical tunas in the central-western Pacific (WPYRG 1993). However, we can draw three general conclusions from our results that are applicable to the international purse seine fishery as a whole. First, a mixture of yellowfin tuna-bigeye tuna are more often encountered in log sets than in school-fish sets and the fish are mostly juveniles. Second, the amount of bigeye tuna mislabeled and reported as yellowfin tuna catches by the purse seine fleets is probably between 5% and 20% of the yellowfin tuna catch. Third, the catch of bigeye tuna in weight is small compared to the yellowfin tuna catch, but it is substantial in terms of numbers of fish, because it is composed of mostly juveniles.

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Table 1: Number of species composition samples collected by the NMFS and stratified by set type (log set and school-fish set), and size of fish (<9 kg, small and >9 kg, large). PURE YFT are samples with only yellowfin tuna; PURE BET are samples with only bigeye tuna; and MIXED are samples with a mixture of yellowfin tuna and bigeye tuna.

YEAR	ALL SAMPLES (TOTAL)				SMALL FISH (SM)			LARGE FISH (LG)			SCHOOL SETS (SCH)			LOG SETS (LOG)		
	MIXED	PURE YFT	PURE BET	TOTAL	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL
1988	97	153	0	250	77	29	106	10	120	130	12	56	68	67	76	143
1989	267	375	3	645	174	78	252	45	286	331	26	242	268	189	75	264
1990	190	327	0	517	145	20	165	27	305	332	25	253	278	149	65	214
1991	190	326	0	516	97	39	136	31	258	289	63	258	321	118	57	175
1992	336	299	2	637	230	38	268	72	247	319	36	155	191	291	128	419
1993	247	334	3	584	176	65	241	46	265	311	15	178	193	219	127	346
1994	147	213	0	360	105	7	112	15	201	216	15	151	166	129	60	189
TOTAL	1474	2027	8	3509	1004	276	1280	246	1682	1928	192	1293	1485	1162	588	1750

YEAR	SCHOOL-FISH SETS						LOG SETS					
	SMALL FISH (SCH-SM)			LARGE FISH (SCH-LG)			SMALL FISH (LOG-SM)			LARGE FISH (LOG-LG)		
	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL	MIXED	PURE	TOTAL
1988	8	14	22	2	39	41	54	15	69	5	60	65
1989	19	39	58	5	201	206	122	27	149	29	40	69
1990	16	10	26	6	241	247	116	9	125	19	56	75
1991	41	25	66	12	215	227	53	12	65	16	35	51
1992	25	12	37	9	134	143	201	21	222	62	102	164
1993	11	26	37	4	150	154	156	30	186	39	95	134
1994	11	3	14	1	147	148	93	4	97	13	53	66
TOTAL	131	129	260	39	1127	1166	795	109	904	183	441	624

Table 2. Percentage of bigeye tuna in unstratified (total) and stratified samples. Stratification is for type of set (log set and school-fish set) and size of fish (<9 kg, small and >9 kg, large).

YEAR	TOTAL	SCHOOL-FISH SETS		LOG SETS	
		SMALL FISH (SCH-SM)	LARGE FISH (SCH-LG)	SMALL FISH (LOG-SM)	LARGE FISH (LOG-LG)
1989	5.72	4.37	0.05	17.70	14.10
1990	4.30	8.17	0.16	20.28	7.34
1991	4.63	7.17	0.18	14.52	6.23
1992	8.36	6.51	0.39	22.59	10.09
1993	7.78	5.24	0.51	19.84	7.79
1994	4.72	14.54	0.18	27.20	2.59
AVERAGE	5.92	7.67	0.25	20.52	8.02

Table 3. Unadjusted yellowfin tuna catches (mt) for the U.S. purse seine fishery stratified by set type (log set and school-fish set) and size of fish (<9 kg, small and >9 kg, large).

YEAR	TOTAL	SCHOOL-FISH SETS		LOG SETS	
		SMALL FISH (SCH-SM)	LARGE FISH (SCH-LG)	SMALL FISH (LOG-SM)	LARGE FISH (LOG-LG)
1989	45,160	5,020	26,770	9,401	3,970
1990	53,419	1,317	41,855	6,462	3,786
1991	38,835	5,869	22,636	6,458	3,872
1992	47,044	1,446	24,099	9,270	12,228
1993	49,624	3,366	22,484	13,939	9,835
1994	57,169	1,619	47,888	5,361	2,301
AVERAGE	48,542	3,106	30,955	8,482	5,999

Table 4: Chi-square values for comparison of proportion of yellowfin tuna and bigeye tuna in stratified versus unstratified samples. An asterisk indicates that the chi-square value is statistically significant at the 95% level with d.f. = 1.

YEAR	SCHOOL-FISH SETS		LOG SETS	
	SMALL FISH (SCH-SM)	LARGE FISH (SCH-LG)	SMALL FISH (LOG-SM)	LARGE FISH (LOG-LG)
1989	0.13	4.96*	24.44*	11.51*
1990	0.71	4.75*	36.66*	0.23
1991	0.17	4.71*	12.77*	0.00
1992	0.02	4.33*	49.69*	2.78
1993	0.00	4.11*	34.40*	0.46
1994	12.84*	4.71*	81.62*	1.28

Table 5: Chi-square values for comparison of proportion of yellowfin tuna and bigeye tuna within size-of-fish stratum between log set and school-fish set. An asterisk indicates that the chi-square value is statistically significant at the 95% level with d.f. = 1.

YEAR	SMALL FISH	LARGE FISH
1989	39.39*	3673.89*
1990	17.97*	279.34*
1991	7.05*	171.43*
1992	39.88*	217.88*
1993	40.04*	90.66*
1994	11.90*	11.90*

Table 6: Adjusted catches (t) of yellowfin and bigeye tunas for the U.S. purse seine fishery of the central-western Pacific Ocean.

YEAR	YELLOWFIN TUNA	BIGEYE TUNA
1989	42,703	2,456
1990	51,657	1,763
1991	37,194	1,641
1992	43,528	3,516
1993	45,801	3,823
1994	55,329	1,840
AVERAGE	46,035	2,507