DATA REQUIREMENTS FOR CONVERSION OF LENGTHS AND WEIGHTS OF CENTRAL AND WESTERN PACIFIC TUNA AND BILLFISH

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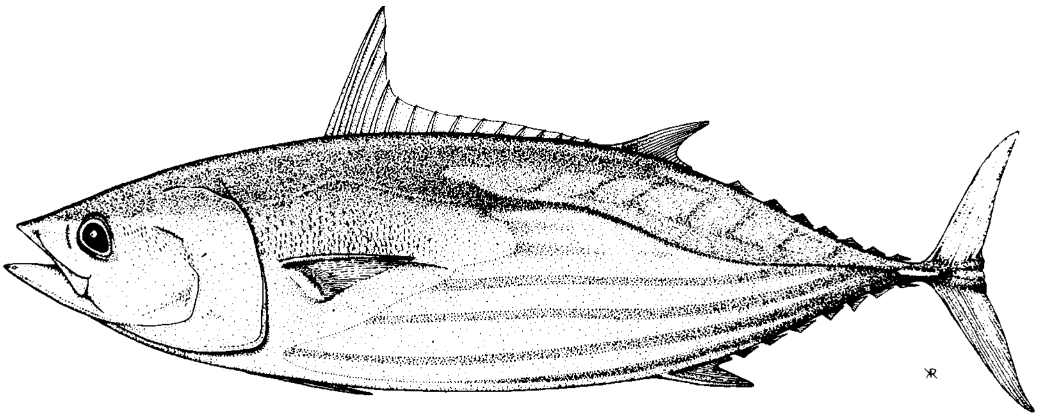

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INTRODUCTION

Length and weight measurements of tuna and billfish in the western and central Pacific Ocean have been collected through port sampling programmes in South Pacific Commission (SPC) member countries and territories and through the observer programmes of SPC members and the SPC Oceanic Fisheries Programme (OFP). This paper summarises the types of length and weight data currently held by the OFP, reviews the need for conversions of length and weight data, and examines the effects of various factors on the relationship between yellowfin weight and length. The implications for sampling programmes supported by the OFP are drawn at several points in the discussion.

THE NEED FOR CONVERSIONS OF LENGTH AND WEIGHT DATA

The OFP collects length and weight measurements for tuna and by-catch species from port sampling, observer programmes, and tagging programmes. The standard measurements collected include:

Length measurements: all species, except billfish

- tip of upper jaw to caudal fork (if whole)
- tip of upper jaw to anterior insertion of second dorsal (if tailed)
- anterior insertion of pectoral to anterior insertion of second dorsal (if headed and tailed)

Length measurements, billfish

- tip of lower jaw to caudal fork (if whole)
- anterior insertion of pectoral to caudal fork (if headed)
- anterior insertion of pectoral to anterior insertion of second dorsal (if headed and tailed)

Weight measurements; all species except billfish

- whole weight
- gilled and gutted
- gilled, gutted and tailed
- headed, gutted and tailed

Weight measurements; billfish

- headed and gutted
- headed, gutted and tailed

As length-based methods of stock assessment are increasingly applied to tuna, there will be a need to convert length measurements to a standard measure. Most tuna lengths are measured from the upper jaw to the caudal fork. However, many large, longline-caught bigeye and yellowfin, which have been headed and tailed, are measured from the pectoral fin to the second dorsal. In order to use these data in a length-based assessment, they will have to be converted to the upper jaw to caudal fork length.

Billfish measured during port sampling are usually headed, and often headed and tailed. In order to construct length frequencies from these data, all lengths will have to be converted to the lower jaw to caudal fork length.

Of even greater importance is the need to convert the various tuna length and weight measurements taken during port sampling to whole weights, for use in monitoring longline catches. (The exception is for albacore, which are usually landed whole.) Port samplers typically sample the length, and often the weight, of fish as the vessel unloads. Total unloadings for a given trip are usually reported in numbers of fish and in processed weight, rather than in whole weight. In order to estimate the total catch of whole fish, the sampled lengths or processed weights must be converted to whole weights.

There is therefore a need for converting lengths of processed fish to a standard length, weights of processed fish to whole weight, and lengths to whole weight.

Conversion factors for estimating the whole weight from the processed weight have been published by the Food and Agriculture Organization of the United Nations (FAO 1992) and the International Commission for the Conservation of Atlantic Tunas (ICCAT 1990). Table 2 summarises conversion factors for tuna and billfish from these two sources, and from the Australian Bureau of Resources Sciences. These conversion factors would appear to vary depending on geographic area and possibly year, but little information has been provided regarding the size ranges of fish examined or sample size.

Table 2 shows the various conversions that are required by the OFP for tuna and billfish, and summarises the amount of data currently available to examine conversions. (Data for which the time-area stratum cannot be assigned have not been included in Table 2.) The data have been collected primarily during the Skipjack Survey and Assessment Programme (1977–1981), the Regional Tuna Tagging Project (1989–1992), and the South Pacific Albacore Research Project (1990–1992); a considerable amount of data has been provided by the Australian Fisheries Management Authority.

The OFP holds extensive fork length and whole weight data for albacore, bigeye, skipjack and yellowfin, and a moderate amount of fork length and whole weight data for certain by-catch species. A large amount of whole weight and gilled-and-gutted weight data are held for bigeye and yellowfin, and a moderate amount of whole weight and gutted-headed-and-tailed weight data are held for shortbill spearfish and swordfish. The data held for many conversions listed in Table 2 are insufficient or totally lacking.

Due to the lack of data for many of the conversions listed in Table 2, OFP observers have recently been instructed to collect such data, as a matter of priority. OFP observers have usually been placed aboard fishing vessels on an opportunistic basis, such that the fleets, geographic areas and time periods covered have not been based on an experimental design.[1] The question arises as to whether opportunistic sampling will result in the type of data required for conversions.

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[1] An exception has been the simultaneous placement of observers on four longliners based in Noumea, New Caledonia, in October 1996, to examine variation among vessels of catch, by-catch and discards.

YELLOWFIN LENGTH–WEIGHT CONVERSIONS

In a review of length–weight curves for yellowfin, Ward & Ramirez (1992) stated that the relationship between length and weight depended on geographic area, year, season, gender and fishing method. They based their claims partly on the results of Student's *t* tests of the hypothesis that the data used to estimate length–weight regression coefficients represented different populations, and partly on a simulation study of the effect of length–weight parameters on the estimation of population size. They also presented yellowfin length–weight parameters from the literature, which suggests that there is considerable variation. This result has implications for the data required for length–weight conversions, and for conversions in general. Therefore, it was decided to examine these claims in detail using yellowfin fork length and whole weight data held by SPC.

The yellowfin fork length and whole weight data were used to estimate the parameters of a length–weight curve. Given fork length, L, and whole weight, W, we have

$$W = a \cdot L^b \cdot e^{\varepsilon} \quad \text{where } \varepsilon \sim N(0,\sigma^2). \tag{1}$$

Noting that our model assumes lognormal errors, and taking logarithms, we obtain

$$\ln W = \ln a + b \cdot \ln L + \varepsilon. \tag{2}$$

[Equation (1) can be used to estimate the whole weight given a value of the fork length. Usually $a \cdot L^b$ is used as the estimate of the whole weight. However, this is not exact, since, in general, the expected value of a function of a random variable is not a function of the expected value of the random variable. In our case, the expected value of e^{ε} is not $e^0 = 1$, but $e^{\frac{\sigma^2}{2}}$ (see Appendix). However, the value of $e^{\frac{\sigma^2}{2}}$ for the data considered here is about 1.003, and therefore it can be ignored.]

Results of the regression using the entire sample of 7,124 fish indicated the presence of outliers (Figure 1); therefore, all standardised residuals greater than 2.0 were removed. There were 220 outliers, which accounted for 3.1 per cent of the original sample. The results with the outliers removed indicate that the residuals are normally distributed (Figure 2). The estimated values of the parameters *a* and *b*, with outliers removed, were 2.5937 x 10^{-5} and 2.9164 respectively. R^2 was 0.998 and the residual mean square was 0.00610.

The 6,904 fish comprising the SPC sample, with outliers removed, include 5,059 fish (73 per cent) sampled from longliners and 1,845 fish (27 per cent) sampled from pole-and-line vessels. The frequency of fork lengths in the sample (with outliers removed) is shown in Figure 3. Unlike previous studies of the yellowfin length–weight relationship, there are ample data over a wide range of sizes. Previous studies have examined primarily longline–caught yellowfin, which tend to be larger than surface–caught yellowfin, whereas the present study includes a large number of both longline– and surface–caught fish.

A scatter plot of lengths and weights is shown in Figure 4 and a plot of the residuals against fork length is shown in Figure 5. The residuals are evenly distributed with regard to fork length, and the regression line in Figure 5 indicates that the residuals do not depend on fork length; there is therefore no lack of fit..

The results were compared with those from Nakamura & Uchiyama (1966) and Morita (1973) (Table 3 and Figure 6). For the model based on the SPC data, for fork lengths above 50 cm, the predicted whole weights, given the fork length, are somewhat smaller than those for the other two models.

In order to see if this effect might be related to the greater proportion of smaller fish represented in the SPC data, the regression was repeated using SPC data with fork lengths greater than 70 cm. The predicted weights were different from those based on the whole data set; predicted weights at fork lengths less than 130 cm were smaller than those based on data for the full range of fork lengths, while the predicted weights at fork lengths greater than 130 cm were greater. The effect was more pronounced when SPC data with fork lengths greater than 100 cm were used. The estimates of length–weight parameters thus depend on the size–frequency of the data, and this might explain, at least in part, the differences between the predicted weights based on the SPC data and those from Nakamura & Uchiyama (1966) and Morita (1973).

It should also be noted that Nakamura & Uchiyama used logarithms to the base 10, rather than natural logarithms, to transform the data used in their linear regression. A regression of the SPC data, transformed with logarithms to the base 10, was done for comparison. The resulting estimates of the weight–length parameters were identical to four significant figures to those from the regression based on data transformed with natural logarithms, indicating no effect related to the transformation.

The differences between the predicted weights among the three studies reported in Table 3 might also be the result of several factors, in addition to the size–frequency of the data, as suggested by Ward & Ramirez (1992). In order to examine the effect of year, quarter, latitude, longitude, and gender, an analysis of variance was conducted on the residuals from the regression. If there are significant differences in the relationship between length and weight due to these factors, then this information should be contained in the residuals.

The categories in the analysis of variance include seven years, four quarters, six bands of 10° of latitude, and five bands of 20° of longitude, and two genders. The results of the analysis of variance are presented below:

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	265.808	19	13.990	14.291	.000
Quarter	88.153	3	29.384	30.018	.00
Year	118.596	6	19.766	20.192	.000
Latitude	86.116	5	17.223	17.594	.00
Longitude	55.900	4	13.975	14.276	.00
Gender	1.059	1	1.059	1.082	.298
Explained	265.808	19	13.990	14.291	.000
Residual	4719.283	4821	.979		
Total	4985.092	4840	1.030		

All of the effects are statistically significant, except gender, and the most important effect is quarter.

While four of the effects are statistically significant, the question remains whether the effects are significant in a practical sense. The sample size is sufficiently large to allow the analysis of variance to reject the null hypothesis of no differences among categories of an effect, due to only small differences among the categories. In order to examine the practical significance of the effects, length–weight curves were estimated for each category of quarter, and the predicted weights for each category were compared. The results are shown in Table 4 and Figure 7. The predicted weights for the first quarter are larger, while those for the fourth quarter are smaller.

Table 4 also presents the "maximum error" which is defined as the maximum difference among quarters between the predicted fork length by quarter and the predicted fork length based on the curve for all SPC data (Table 3), as a fraction of the predicted fork length by quarter. That is, the "maximum error" measures the error incurred by using the length–weight curve for all quarters combined, rather than a length–weight curve for a specific quarter. This statistic ranges from 1 to 7 per cent.

The interpretation of the results of the comparison by quarter is confounded by differences in the size–frequency of the data for each quarter. The differences in size–frequency are greatest for the first and fourth quarters (Figure 7), which, as noted above, are the quarters for which the predicted weights are largest and smallest respectively. For the two quarters for which the size–frequencies are representative of the whole data set, the second and third quarters, the maximum error statistic is only 1 per cent for all predicted weights (Table 4).

The problem of interpretation also arises for the factors of year, latitudinal band and longitudinal band. For the categories of year, only data for 1991 and 1992 have a size–frequency that is representative of the whole data set (Figure 9). For latitudinal band, no specific category has a representative size–frequency (Figure 10), while for longitudinal band, only 140°E–160°E and 160°E–180° have representational size–frequencies (Figure 11).

The estimated parameters of length–weight curves and predicted weights for the two categories of year and the two categories of longitudinal band with representational size–frequencies are presented in Tables 5 and 6 respectively. For both factors, the maximum error statistic is small, ranging from 1 to 3 per cent for year and from 1 to 4 per cent for longitudinal band.

DISCUSSION

This study of yellowfin length–weight data held by SPC indicates that while the effects of various factors on the length–weight relationship are statistically significant, they may not be of great practical significance. For each category of an effect for which the data were representational of the whole data set, the predicted weights differed by only a few percentage points from those based on the whole data set.

This is in contrast to Ward & Ramirez (1992), who concluded that the weight–length relationship for yellowfin is far from constant. However, the following should be noted with regard to their study.

Ward & Ramirez (1992) present the estimated parameters of ten yellowfin weight–length curves from various studies. The estimated parameters are considerably different, but so are the size ranges of the data; for example, one curve is based on fish from 15 to 65 cm in fork length and another based on fish from 100 to 155 cm. It should also be noted that the sample size for four of the curves are less than 100 fish. As Ward & Ramirez point out, and as noted above, the size–frequency is important in determining length–weight parameters, therefore few of the ten curves are comparable.

It would appear that in the original publication, the estimated length–weight parameters from Nakamura & Uchiyama (1966) are for the weight in pounds, rather than kilograms, as they were presented in Ward & Ramirez (1992). This might explain why Ward & Ramirez's simulation study of the effect of length–weight curves on the estimation of population size, and their examination of the effect of sample size on the estimate of the length frequency, gave poor results for the curve presented in Nakamura & Uchiyama (1966).[2]

CONCLUSION

The placement of OFP observers, and hence the collection of data that can be used for conversions, has so far been done on an opportunistic basis. The present study suggests that sampling stratified by year, quarter, longitude and latitude may be not be as important as sampling a wide range of sizes. However, this conclusion may be valid only for length–weight conversions for yellowfin. Data for other species and conversions should also be examined.

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Ward, P.J. & C.M. Ramirez. 1992. Length and weight relationships for yellowfin tuna in the western Pacific. Working Paper 14. Second Meeting of the Western Pacific Yellowfin Research Group, Honolulu, Hawaii, 22–24 June 1992. Bureau of Rural Resources, Department of Primary Industries & Energy, Canberra, Australia. 9 pp.

[2] It should also be noted that the length–weight parameter, *a*, of Nakamura & Uchiyama (1966) for the weight in pounds, 3.256×10^{-5}, was mistakenly reported as being for kilograms in SPC (1992, p. 18); it would appear that this relationship was incorrectly used to estimate the yellowfin catch in numbers of fish by length class in the study reported therein.

APPENDIX

DERIVATION OF EXPECTED VALUE OF WHOLE WEIGHT GIVEN FORK LENGTH

Let $W(x)$ be the whole weight, given the fork length L, the length–weight parameters a and b, and the normal random variable x, such that

$$W(x) = a \cdot L^b \cdot e^x \text{, where } x \sim N(0, \sigma^2) \text{.} \qquad \text{(A1)}$$

The expected value of $W(x)$ is given by

$$E[W(x)] = \int_{-\infty}^{\infty} W(x) f(x) dx \qquad \text{(A2)}$$

where $f(x)$ is the probability density function for the normal random variable, x. We have

$$E[W(x)] = \int_{-\infty}^{\infty} a \cdot L^b \cdot e^x \cdot \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{-x^2}{2\sigma^2}} \cdot dx \qquad \text{(A3)}$$

$$= a \cdot L^b \cdot e^{\frac{\sigma^2}{2}} \int_{-\infty}^{\infty} \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{-1}{2\sigma^2}\left(x^2 - 2\sigma^2 x + \sigma^4\right)} \cdot dx \qquad \text{(A4)}$$

$$= a \cdot L^b \cdot e^{\frac{\sigma^2}{2}} \int_{-\infty}^{\infty} \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{-\left(x-\sigma^2\right)^2}{2\sigma^2}} \cdot dx \qquad \text{(A5)}$$

$$= a \cdot L^b \cdot e^{\frac{\sigma^2}{2}} \int_{-\infty}^{\infty} f'(x) \cdot dx \qquad \text{(A6)}$$

Since $f'(x)$ is the probability density function for a normal random variable, with mean σ^2 and variance σ^2, the integral in equation (A6) is equal to 1, and we have

$$E[W(x)] = a \cdot L^b \cdot e^{\frac{\sigma^2}{2}} \text{.} \qquad \text{(A7)}$$

The above assumes that the true values of a, b and σ^2 are known. Beauchamp & Olson (1973) derive an approximation to an unbiased estmator of $E[W(x)]$ when a, b and σ^2 are unknown. However, substituting least-squares estimates of a, b and σ^2 in equation (A7) is close to the unbiased estimator, unless σ^2 is large.

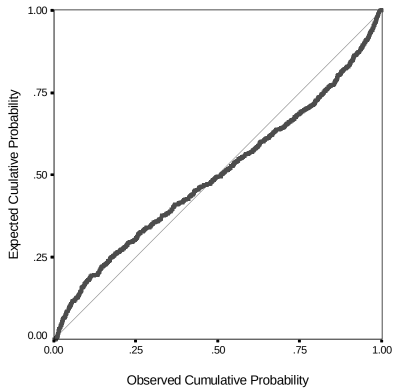


Figure 1. Normal probability plot for regression of logarithm of yellowfin fork length on logarithm of whole weight, with presence of outliers

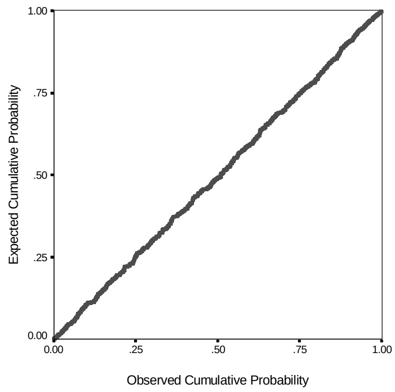


Figure 2. Normal probability plot for regression of logarithm of yellowfin fork length on logarithm of whole weight, with outliers removed

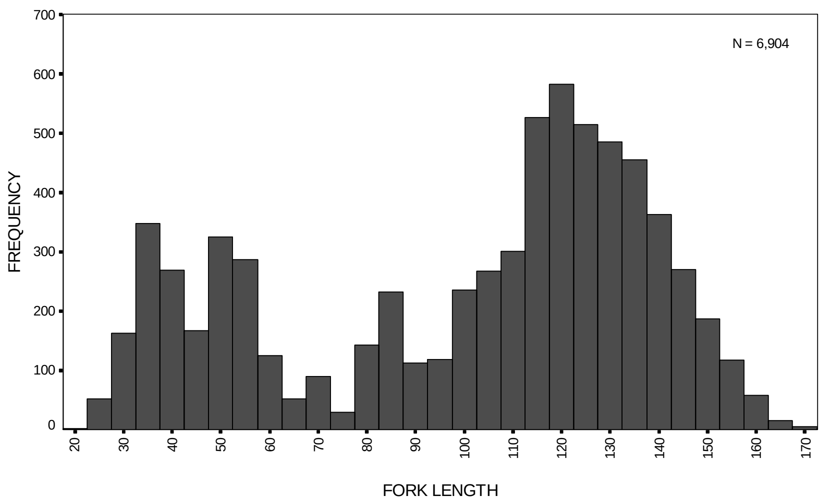


Figure 3. Frequency of upper jaw to caudal fork length (cm) for yellowfin length-weight data

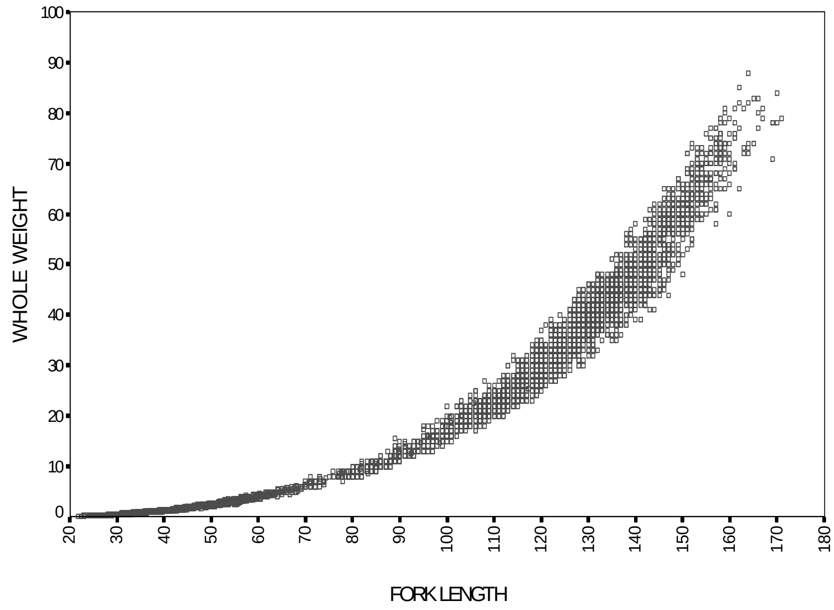


Figure 4. Yellowfin whole weight (kg) vs upper jaw to caudal fork length (cm) for yellowfin, with outliers removed

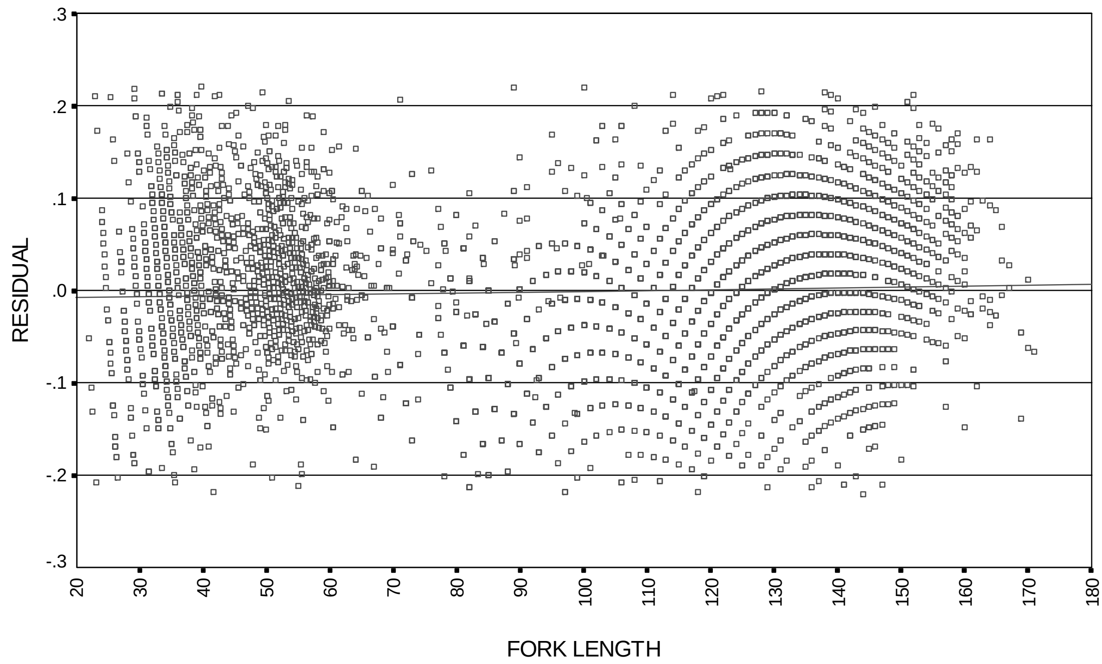


Figure 5. Standardised residuals from yellowfin length–weight regression vs upper jaw to caudal fork length (cm). The linear regression of residual on fork length is also shown. Striations are due to rounding of whole weight measurements to tenths of a kilogram for small fish and kilograms for large fish.

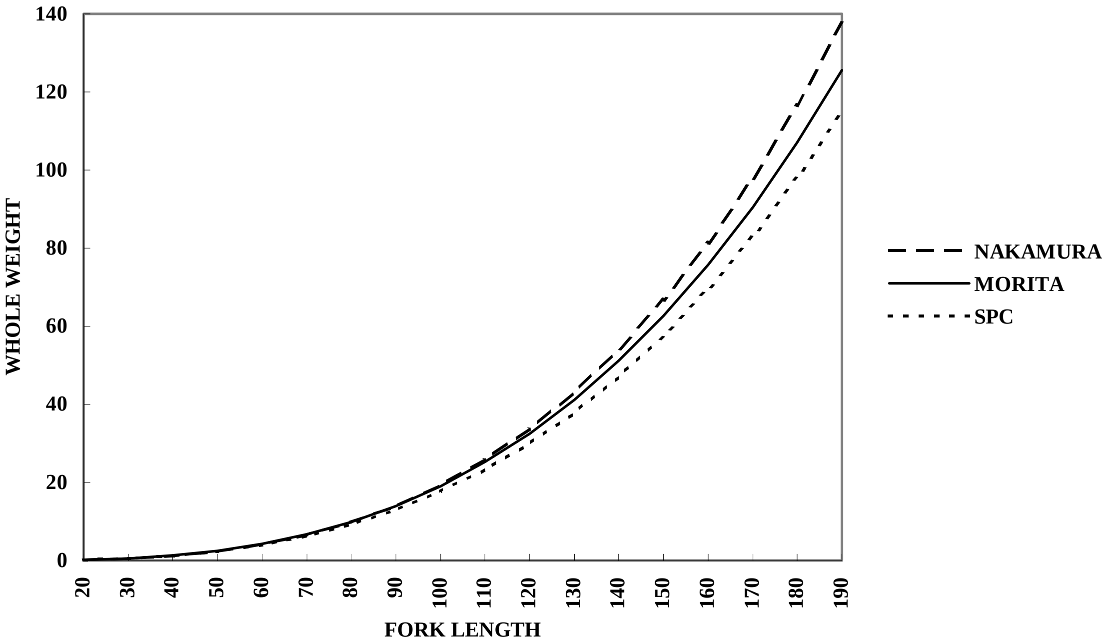


Figure 6. Fitted yellowfin whole weight (kg) – fork length (cm) curves from Nakamura & Uchiyama (1966), Morita (1973), and SPC data

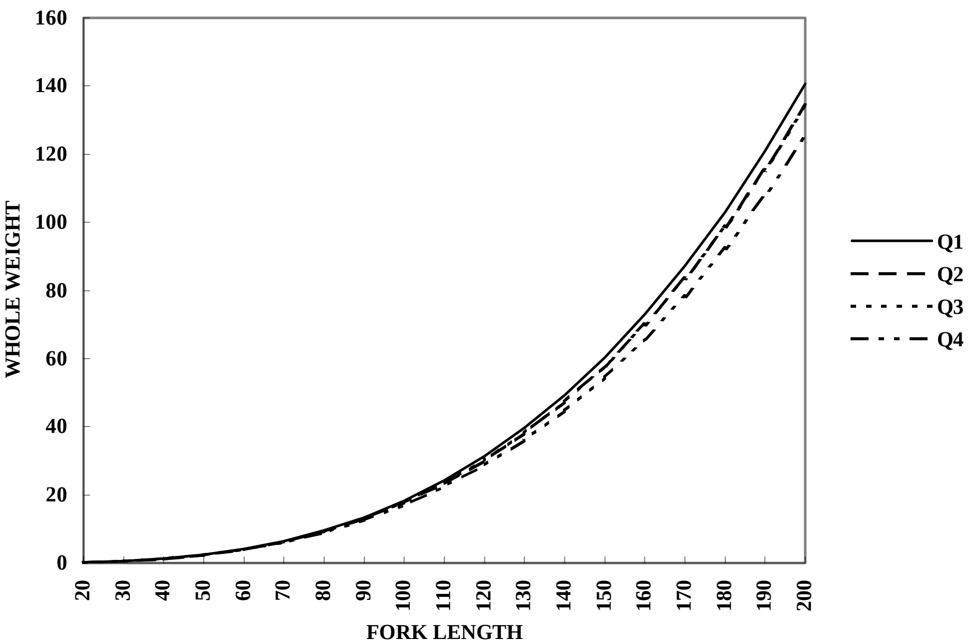
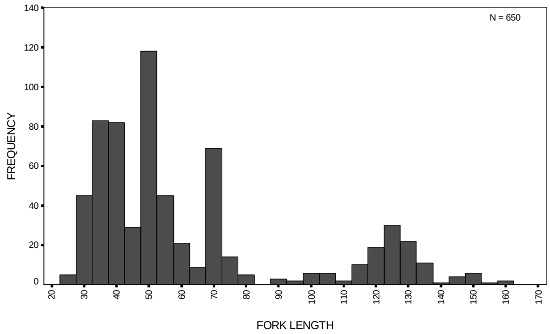
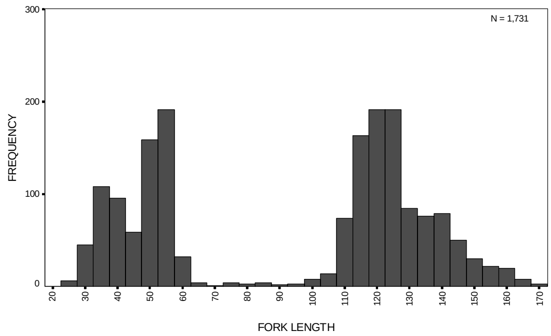


Figure 7. Fitted yellowfin length (cm) – weight (kg) curves by quarter

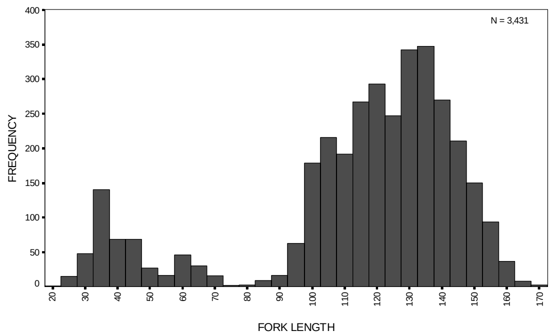
Figure 8. Frequency of yellowfin fork length (cm) by quarter



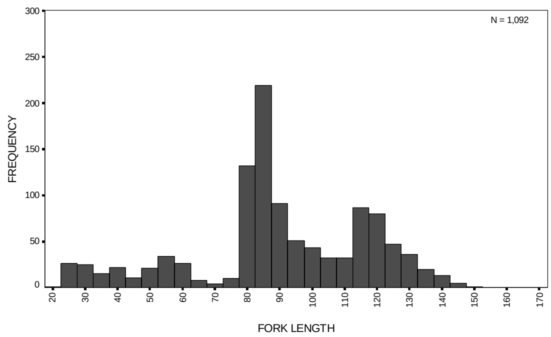
First quarter



Second quarter

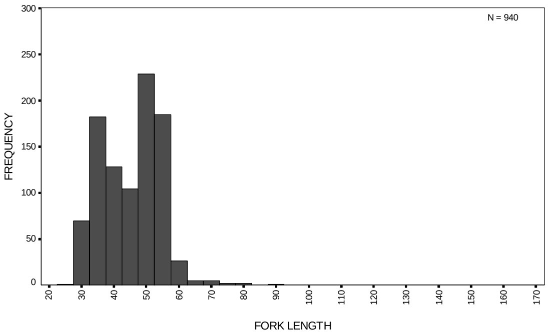


Third quarter

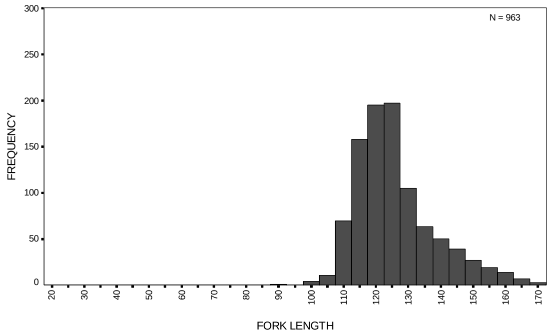


Fourth quarter

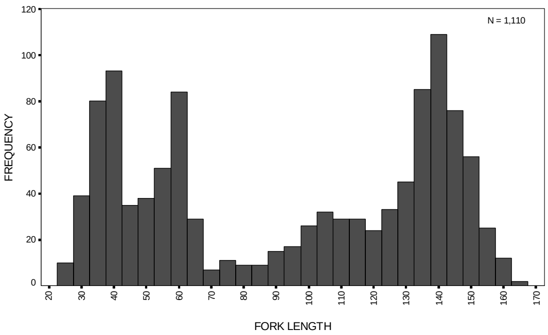
Figure 9. Frequency of yellowfin fork length (cm) by year



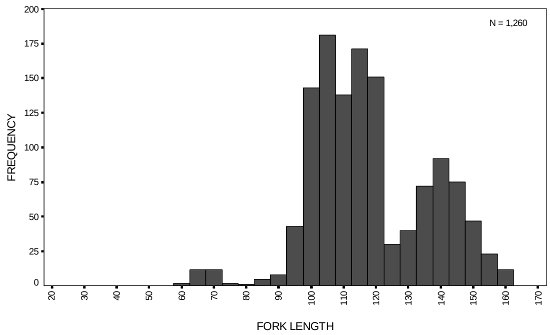
1990



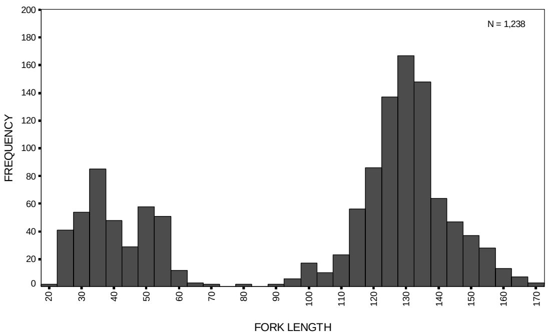
1994



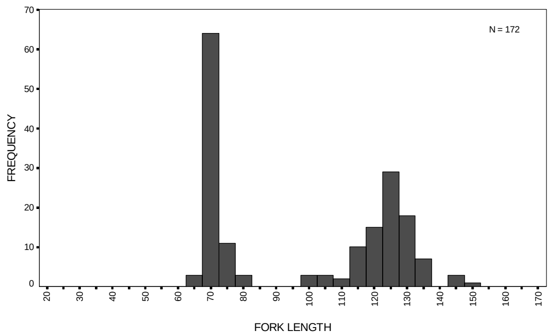
1991



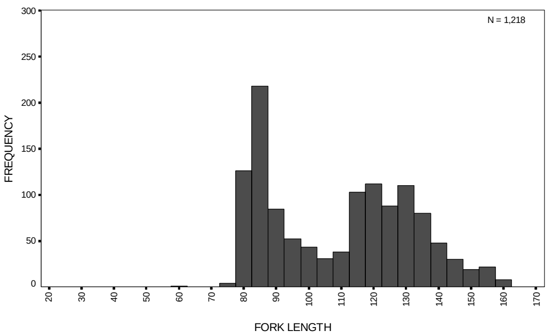
1995



1992

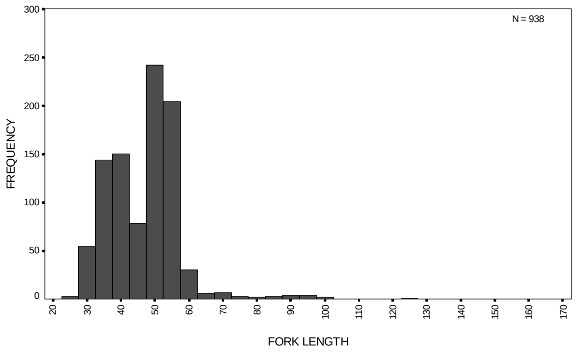


1996

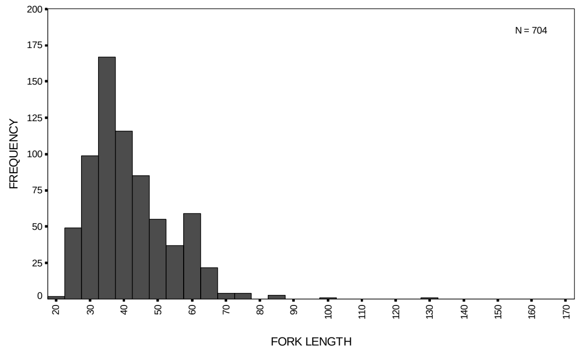


1993

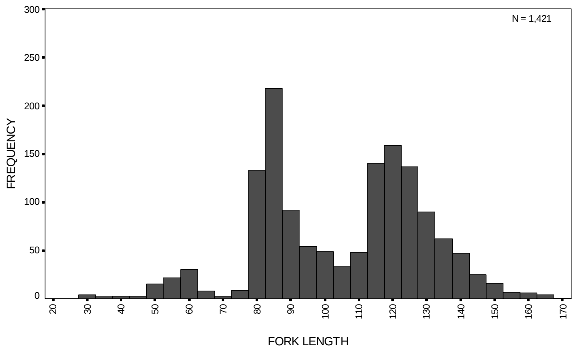
Figure 10. Frequency of yellowfin fork length (cm) by latitude band



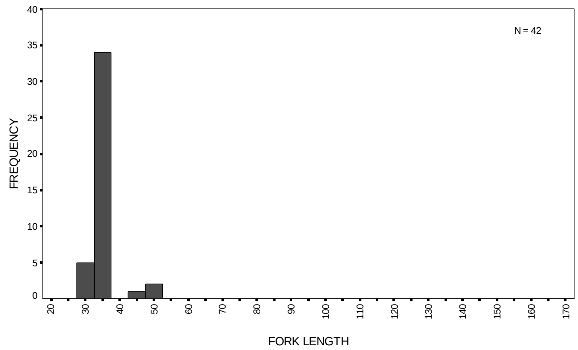
10S – EQ



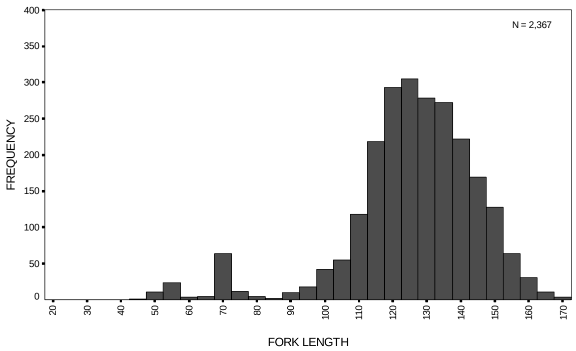
EQ – 10°N



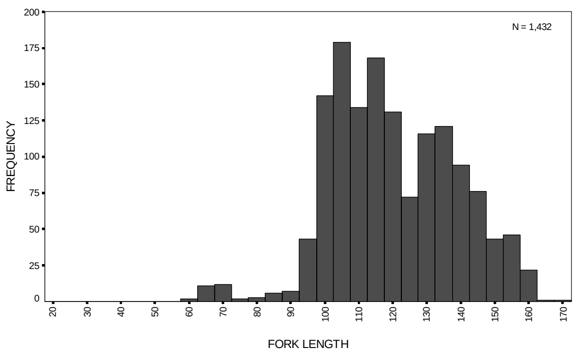
20°S – 10°S



10°N – 20°N

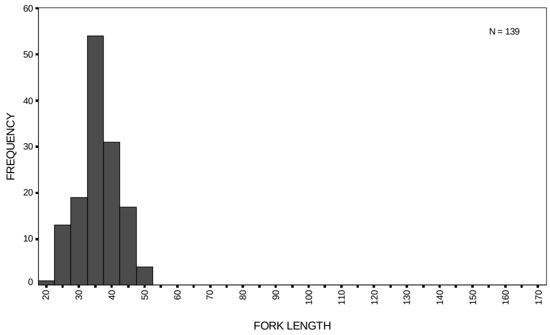


30°S – 20°S

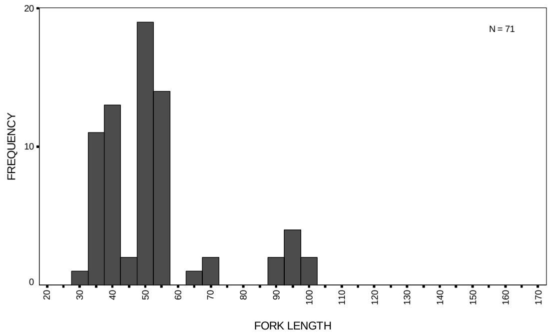


40°S – 30°S

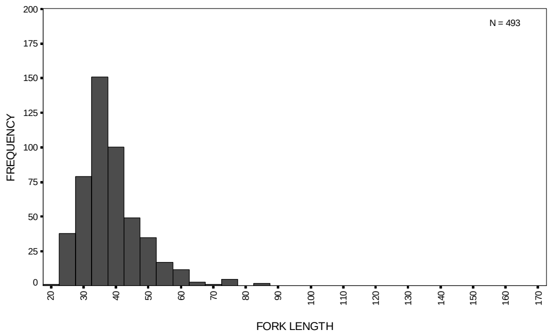
Figure 11. Frequency of yellowfin fork length (cm) by longitude band



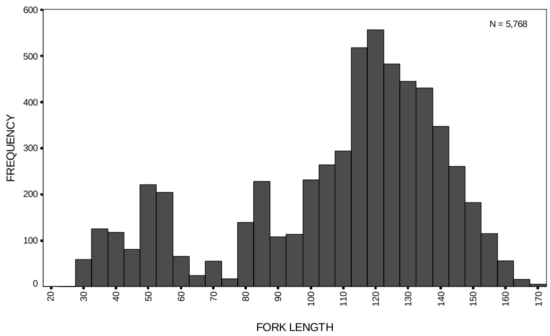
100°E – 120°E



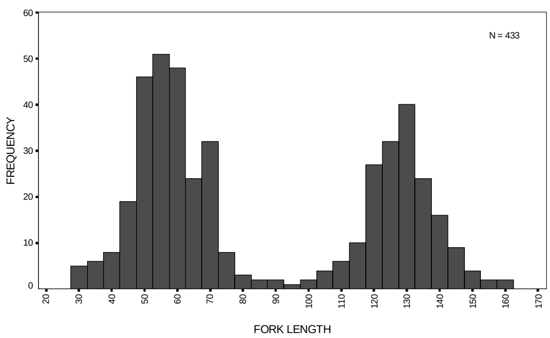
180° – 170°W



120°E – 140°E



140°E – 160°E



160°E – 180°

Table 1. Counts of length and weight data held by SPC, for tuna and certain by-catch species, that can be used to construct conversion equations. **Key: US = length from upper jaw to second dorsal; UF = upper jaw to caudal fork; PF = pectoral to caudal fork; LF = lower jaw to caudal fork; GG = gilled and gutted weight; WW = whole; GH = gutted and headed; GT = gilled, gutted and tailed; GX = gutted, headed and tailed**

			LENGTH TO LENGTH				WEIGHT TO WEIGHT				LENGTH TO WEIGHT				
COMMON NAME	SPECIES	CODE	US-UF	PS-UF	PF-LF	PS-LF	GG-WW	GH-WW	GT-WW	GX-WW	UF-WW	US-WW	LF-WW	PF-WW	PS-WW
Bigeye	*Thunnus obesus*	BET					1,004			3	1,302				
Yellowfin	*Thunnus albacares*	YFT					4,340			3	7,106				
Black marlin	*Makaira indica*	BLM								2					
Indo-Pacific blue marlin	*Makaira mazara*	BLZ								2			1		
Indo-Pacific sailfish	*Istiophorus platypterus*	SAI								18					
Shortbill spearfish	*Tetrapterus angustirostris*	SBS								189			28		
Striped marlin	*Tetrapterus audax*	MLS								10					
Swordfish	*Xiphias gladius*	SWO								159			11		
Albacore	*Thunnus alalunga*	ALB									33,820				
Skipjack	*Katsuwonus pelamis*	SKJ									14,124				
Spanish mackerel	*Scomberomorus commerson*	COM									3				
Mahi mahi	*Coryphaena hippurus*	DOL									62				
Dogtooth tuna	*Gymnosarda unicolor*	DOT									9				
Frigate tuna	*Auxis thazard*	FRZ									168				
Kawakawa	*Euthynnus affinis*	KAW													
Longtail tuna	*Thunnus tonggol*	LOT									10				
Rainbow runner	*Elagatis bipinnulata*	RRU									426				
Wahoo	*Acanthocybium solandri*	WAH									47				

Table 2. Conversion factors for estimating live weight from landed weight, for tuna, billfish and tuna-like species. The sources of the conversion factors include the Bureau of Resource Sciences (BRS) of Australia (Ward, personal communication, November 1995) and the International Commission for the Conservation of Atlantic Tunas (ICCAT 1990); conversion factors from other sources have been compiled by the Food and Agriculture Organization (FAO 1992). The numeric codes listed under 'areas' refer to FAO areas. The treatment 'Gutted' refers to gilled-and-gutted fish.

SPECIES	COMMON NAME	TREATMENT	SOURCE	AREA	YEAR	FACTOR
TUNA						
Euthynnus alletteratus	Atlantic black skipjack	Frozen. Gutted. Headed. Tailed.	Romania	34	1988	1.400
Katsuwonus pelamis	Skipjack tuna	Frozen.	Indonesia	57,71	1985	1.000
Katsuwonus pelamis	Skipjack tuna	Frozen.	Maldives	51	1985	1.020
Katsuwonus pelamis	Skipjack tuna	Gutted.	Mexico	31,77,87	1988	1.100
Katsuwonus pelamis	Skipjack tuna	Gutted. Frozen.	Mexico	31,77,87	1985	1.100
Thunnus alalunga	Albacore	Frozen.	Ecuador	77	1985	1.000
Thunnus alalunga	Albacore	Gutted. Headed. Tailed.	St Helena	47	1988	1.430
Thunnus albacares	Yellowfin tuna	Gutted.	ICCAT	Atlantic	1990	1.130
Thunnus albacares	Yellowfin tuna	Gutted.	Mexico	31,77,87	1985	1.100
Thunnus albacares	Yellowfin tuna	Gutted.	BRS	Australia	1996	1.166
Thunnus albacares	Yellowfin tuna	Gutted. Frozen.	Mexico	31,77,87	1988	1.100
Thunnus albacares	Yellowfin tuna	Gutted. Headed.	Mexico	31,77,87	1985	1.250
Thunnus albacares	Yellowfin tuna	Gutted. Headed. Tailed.	St Helena	47	1988	1.430
Thunnus obesus	Bigeye tuna	Gutted.	ICCAT	Atlantic	1990	1.130
Thunnus obesus	Bigeye tuna	Gutted.	BRS	Australia	1996	1.131
Thunnus obesus	Bigeye tuna	Gutted. Headed. Tailed.	St Helena	47	1988	1.430
Thunnus thynnus	Northern bluefin tuna	Gutted.	ICCAT	Atlantic	1990	1.160
Thunnus thynnus	Northern bluefin tuna	Gutted. Headed.	Norway	27	1988	1.280
Thunnus maccoyii	Southern bluefin tuna	Gutted.	BRS	Australia	1995	1.324
BILLFISH						
Istiophoridae	Marlins, sailfish, spearfish	Frozen.	Ecuador	77	1985	1.000
Istiophoridae	Marlins, sailfish, spearfish	Frozen. Gutted.	Ecuador	77	1988	1.100
Istiophoridae	Marlins, sailfish, spearfish	Gutted. Partly headed. Finned.	ICCAT	Atlantic	1990	1.200
Tetrapturus audax	Striped marlin	Gutted. Partly headed. Finned.	BRS	Australia	1995	1.357
Xiphias gladius	Swordfish	Gutted.	Norway	27	1988	1.150
Xiphias gladius	Swordfish	Gutted. Tailed. Finned.	Cyprus	37	1988	1.140
Xiphias gladius	Swordfish	Headed. Tailed. Frozen.	USSR	34,47	1988	1.390
Xiphias gladius	Swordfish	Headed. Tailed. Frozen.	USSR	51	1988	1.550
Xiphias gladius	Swordfish	Gutted. Headed.	Canada	21	1985	1.300
Xiphias gladius	Swordfish	Gutted. Headed. Frozen.	USSR	34,47	1988	1.310
Xiphias gladius	Swordfish	Gutted. Headed. Frozen.	USSR	51	1988	1.390
Xiphias gladius	Swordfish	Gutted. Partly headed. Finned.	ICCAT	NW Atlantic	1990	1.333
Xiphias gladius	Swordfish	Gutted. Partly headed. Finned.	ICCAT	CE Atlantic	1990	1.316
TUNA-LIKE SPECIES						
Acanthocybium solandri	Wahoo	Gutted. Headed. Tailed.	St Helena	47	1988	1.300
Sarda sarda	Atlantic bonito	Gutted. Headed. Frozen.	Bulgaria	34	1985	1.320
Sarda sarda	Atlantic bonito	Gutted. Headed. Tailed. Frozen.	Romania	34	1988	1.700
Sarda chiliensis	Eastern Pacific bonito	Gutted. Headed. Tailed.	Mexico	77	1988	1.100
Sarda chiliensis	Eastern Pacific bonito	Gutted. Headed. Frozen.	Mexico	77	1985	1.250
Scomberomorus maculatus	Atlantic Spanish makerel	Gutted.	El Salvador	77	1988	1.104
Scomberomorus maculatus	Atlantic Spanish makerel	Gutted. Dry-light salted.	El Salvador	77	1988	2.150
Scomberomorus sierra	Pacific sierra	Gutted.	Mexico	77	1988	1.100
Scomberomorus spp	Seerfishes	Gutted. Headed. Boned. Smoked.	New Caledonia	71	1988	2.300

Table 3. Fitted whole weight (kg) – fork length (cm) curves for yellowfin from SPC data, Nakamura & Uchiyama (1966), and Morita (1973). N = sample size; LL = longline; PL = pole-and-line. Area refers to the Pacific Ocean. "a" and "b" are parameters of the weight–length curve.

	SPC	**NAKAMURA**	**MORITA**
N	6,904	4,822	2,043
Lengths	21 - 171	70 - 180	26 - 157
Gear	LL and PL	LL	Mainly LL
Area	West-Central	Central	West
Year	1989-1996	Pre-1966	Pre-1973
a	2.5937E-05	1.4769E-05	2.5121E-05
b	2.9164	3.0583	2.9396
FORK LENGTH	**WHOLE WEIGHTS**		
20	0.16	0.14	0.17
30	0.53	0.49	0.55
40	1.22	1.17	1.29
50	2.34	2.32	2.48
60	3.98	4.05	4.24
70	6.24	6.49	6.67
80	9.21	9.76	9.87
90	12.98	14.00	13.95
100	17.65	19.32	19.02
110	23.31	25.86	25.17
120	30.04	33.74	32.51
130	37.94	43.10	41.13
140	47.09	54.07	51.14
150	57.59	66.77	62.64
160	69.52	81.34	75.73
170	82.96	97.91	90.50
180	98.01	116.61	107.06
190	114.75	137.58	125.50
200	133.27	160.95	145.93

Table 4. Fitted fork length (cm) – whole weight (kg) curves for yellowfin by quarter. N = sample size; "a" and "b" are parameters of the weight–length curve. "Maximum error" is the maximum difference among quarters between the predicted fork length by quarter and the predicted fork length based on the curve for all SPC data in Table 3, as a fraction of the predicted fork length by quarter.

	Q1	Q2	Q3	Q4	MAXIMUM ERROR Q1-Q2-Q3-Q4	MAXIMUM ERROR Q2-Q3
N	650	1,731	3,431	1,092		
a	2.4137E-05	2.4810E-05	2.6387E-05	2.9407E-05		
b	2.9401	2.9263	2.9141	2.8807		
FORK LENGTH	WHOLE WEIGHT					
20	0.16	0.16	0.16	0.16	0.02	0.01
30	0.53	0.52	0.53	0.53	0.01	0.01
40	1.24	1.21	1.23	1.21	0.02	0.01
50	2.39	2.32	2.36	2.31	0.02	0.01
60	4.08	3.96	4.01	3.90	0.02	0.01
70	6.42	6.22	6.28	6.08	0.03	0.01
80	9.50	9.20	9.27	8.93	0.03	0.01
90	13.44	12.98	13.07	12.53	0.04	0.01
100	18.32	17.67	17.77	16.98	0.04	0.01
110	24.24	23.36	23.46	22.34	0.04	0.01
120	31.31	30.13	30.23	28.70	0.05	0.01
130	39.61	38.08	38.17	36.15	0.05	0.01
140	49.26	47.30	47.37	44.75	0.05	0.01
150	60.33	57.88	57.92	54.59	0.05	0.01
160	72.94	69.92	69.90	65.75	0.06	0.01
170	87.17	83.49	83.41	78.29	0.06	0.01
180	103.12	98.69	98.53	92.30	0.06	0.01
190	120.89	115.60	115.34	107.86	0.06	0.01
200	140.56	134.33	133.94	125.04	0.07	0.01

Table 5. Fitted fork length (cm) – whole weight (kg) curves for yellowfin by year. N = sample size; "a" and "b" are parameters of the weight–length curve. "Maximum error" is the maximum difference among quarters between the predicted fork length by year and the predicted fork length based on the curve for all SPC data in Table 3, as a fraction of the predicted fork length by year.

	1991	1992	
N	1,110	1,238	
a	2.5883E-05	2.5912E-05	
b	2.9160	2.9214	
FORK LENGTH	**WHOLE WEIGHT**		**MAXIMUM ERROR**
20	0.16	0.16	0.01
30	0.53	0.54	0.02
40	1.22	1.24	0.02
50	2.33	2.38	0.02
60	3.96	4.06	0.02
70	6.21	6.36	0.02
80	9.17	9.40	0.02
90	12.93	13.26	0.02
100	17.58	18.04	0.02
110	23.21	23.84	0.02
120	29.92	30.74	0.02
130	37.78	38.83	0.02
140	46.90	48.22	0.02
150	57.35	58.99	0.02
160	69.22	71.23	0.02
170	82.61	85.03	0.02
180	97.59	100.48	0.02
190	114.25	117.67	0.02
200	132.69	136.70	0.03

Table 6. Fitted fork length (cm) – whole weight (kg) curves for yellowfin by longitudinal band. N = sample size; "a" and "b" are parameters of the weight–length curve. "Maximum error" is the maximum difference among quarters between the predicted fork length by longitudinal band and the predicted fork length based on the curve for all SPC data in Table 3, as a fraction of the predicted fork length by longitudinal band.

	140E-160E	160E-180	
N	5,768	433	
a	2.4370E-05	2.4390E-05	
b	2.9291	2.9354	
FORK LENGTH	WHOLE WEIGHT		MAXIMUM ERROR
20	0.16	0.16	0.02
30	0.52	0.53	0.02
40	1.20	1.23	0.02
50	2.31	2.37	0.01
60	3.94	4.04	0.02
70	6.18	6.36	0.02
80	9.14	9.41	0.02
90	12.91	13.29	0.02
100	17.58	18.11	0.03
110	23.24	23.96	0.03
120	29.99	30.93	0.03
130	37.91	39.12	0.03
140	47.10	48.63	0.03
150	57.65	59.54	0.03
160	69.65	71.96	0.03
170	83.18	85.98	0.04
180	98.34	101.68	0.04
190	115.22	119.17	0.04
200	133.90	138.53	0.04