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COMPILATION OF PUBLISHED ESTIMATES OF TUNA LIFE HISTORY AND POPULATION DYNAMICS PARAMETERS

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This working paper was prepared solely for discussions at the Workshop on the Assessment of Selected Tuna and Billfish Stocks in the Indian and Pacific Oceans (Shimizu, Japan, 13-22 June 1979) and is subject to revision. Its contents should not be cited without consent of the author.

Stock assessment studies require estimates of (1) certain factors that cause changes to the stock and (2) other life history parameters. The purpose of this paper is to compile such data, specifically, published estimates of von Bertalanffy growth parameters, instantaneous mortality coefficients, length-weight relations, fecundity, and size at sexual maturity of tunas including albacore, *Thunnus alalunga*; bigeye tuna, *T. obesus*; northern bluefin tuna, *T. thynnus*; southern bluefin tuna, *T. maccoyii*; and yellowfin tuna, *T. albacares*.

Because of the commercial importance of tunas, there is now a large accumulation of information on the biology of these species; however, the data available on each individual species were not equal in volume and information on some species were not as plentiful. Although a rigid set of criteria was not followed in compiling the data, generally, more recent data and those data that appeared "reasonable," in light of available biological information on the various species, were selected for inclusion.

LENGTH-WEIGHT RELATIONS

Numerous length-weight relations of albacore, bigeye, northern bluefin, southern bluefin, and yellowfin tunas in the form, $W = aL^b$, where W is weight in kilograms, L is length in centimeters, and a and b are estimated parameters are available (Tables 1-5). In many of the equations computed by the various authors, the length and weight units used varied. For ease of comparison, all the equations that required it were recomputed in terms of kilograms and centimeters.

Tables 1-5

Many of the predictive regressions that have traditionally been used to relate length and weight in fishes are in some degree inherently biased (Beauchamp and Olson 1973; Ricker 1973). Ricker (1973) pointed out that a functional regression is more appropriate even for the purpose of prediction and Beauchamp and Olson (1973) noted that the logarithmic transformation to linearize data used by many investigators introduces an inherent bias. As far as I know all the length-weight relations in Tables 1-5 are uncorrected predictive regressions except that for the South Pacific albacore computed by Yong.[1]

Footnote 1

VON BERTALANFFY GROWTH PARAMETERS

Tables 6-10

Estimates of von Bertalanffy growth parameters for the five species of tunas reported on here are numerous in the literature (Tables 6-10). These estimates are available from growth studies based on scale, otolith, and vertebra reading methods, tagging experiments, size-frequency analyses, and varying combinations of the different methods. The growth parameters were either estimated by the original author or by other investigators using data available in the literature (e.g. Shomura 1966).

L_∞ estimates for albacore (Table 6) range from 104.8 to 146.3 cm. These estimates can be compared to the observed maximum size of albacore, 120-124 cm reported in the literature (Otsu 1960; Miyake and Hayasi 1978). Murphy (1977) stated that L_∞ is an estimate of the mean maximum size and that "therefore the largest observed fish should be at least slightly larger than the estimated mean maximum size, if the growth equation is to be regarded as realistic." Using this criterion of the reasonableness of the L_∞ estimates, any estimate greater than about 124 cm for albacore would be unreasonable or unrealistic.

Estimates of L_∞ for bigeye tuna range from 183.0 to 338.53 cm (Table 7) as compared to observed maximum sizes of 190-198 cm (Shomura 1966; Miyake and Hayasi 1978). For northern bluefin tuna L_∞ estimates range from 277.3 to 437.46 (Table 8); the observed maximum size is over 300 cm (Miyake and Hayasi 1978). The L_∞ estimates for southern bluefin tuna are 180.8 to 222.5 cm and the maximum observed size 188 to 230 cm (Murphy 1977; Miyake and Hayasi 1978), and for yellowfin tuna, 150-307.9 cm (Table 10) and 190 cm (Miyake and Hayasi 1978), respectively.

INSTANTANEOUS MORTALITY COEFFICIENTS

Estimates of instantaneous mortality coefficients (M = natural, F = fishing, Z = total) are available in varying numbers for all the tuna species under

Table 11 consideration (Table 11). It appears that more estimates of mortality rates are available for albacore and yellowfin tuna than for other tunas. However, some available estimates in the literature may have been overlooked.

Murphy and Sakagawa (1977) made a review and evaluation of available estimates of tuna natural mortality rates. The two criteria they used to make their evaluations were (1) how closely the assumptions needed to derive the estimates were met and (2) whether the estimates agreed with other estimates available for the same species. When comparable mortality estimates were unavailable or few, they used the axiom that long-lived species have low natural mortality rates and short-lived species relatively high mortality rates in making their evaluation. They concluded that the most reasonable estimates of M for albacore were between 0.2 and 0.4; for bigeye tuna, in the lower portion of the range 0.35 to 0.73; northern bluefin tuna, 0.1 and 0.2; and yellowfin tuna around 0.8.

FECUNDITY AND SEXUAL MATURITY

Estimates of fecundity are available for all the tunas under consideration

Table 12 (Table 12). However, as far as I could determine, size at first spawning information for northern bluefin and southern bluefin tunas was unavailable in the literature. Baglin (1976) indicated that there still are questions on the actual age of maturity of northern bluefin tuna in the Atlantic.

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TEXT FOOTNOTE

1. M. Y. Y. Yong. Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812. Pers. commun., May 1979.

Table 1.--Length-weight relations ($W = aL^b$) of albacore. Length (L) is in centimeters and weight (W) in kilograms.

Area	Size range (cm)	a	b	Source	Comments
Eastern Pacific	50.0-85.0	1.225×10^{-5}	3.13	Partlo (1955)	
	38.0-100.0	2.188×10^{-5}	2.99	Clemens (1961)	
Hawaii and North Pacific	49.6-127.6	2.5955×10^{-5}	2.9495	Nakamura and Uchiyama (1966)	
American Samoa (landed)	78.0-108.0	8.8406×10^{-5}	2.6822	Nakamura and Uchiyama (1966)	
North Atlantic	44.0-112.0	6.303×10^{-6}	3.2825	Beardsley (1971)	
South Pacific	--	1.7401×10^{-5}	3.0521	Yong[1]	Males. Functional regression (see Ricker 1973).
	--	1.4168×10^{-5}	3.0967	Yong[1]	Females. Functional regression (see Ricker 1973).
South Africa	--	2.3079×10^{-5}	2.98	de Jaeger (1963)	Males.
	--	1.40343×10^{-5}	3.09	de Jaeger (1963)	Females.
Western North Pacific	45-85	1.781×10^{-5}	3.053	Lee et al. (1978)	

[1]See text footnote 1.

Table 2.--Length-weight relations ($W = aL^b$) of bigeye tuna. Length (L) is in centimeters and weight (W) in kilograms.

Area	Size range (cm)	a	b	Source	Comments
Central Pacific	80.0-190.0	3.661×10^{-5}	2.90182	Nakamura and Uchiyama (1966)	
West Africa	41.0-132.0	1.2494×10^{-5}	3.12082	Lenarz (1974)	
South Africa	--	8.24277×10^{-5}	2.72	de Jaeger (1963)	Males.
	--	5.8106×10^{-5}	2.79	de Jaeger (1963)	Females.
Eastern Atlantic (off Ivory Coast)	86.2-179.2	4.454×10^{-6}	3.31768	Choo (1976)	
Western North Pacific	45.5-163.8	1.97308×10^{-5}	3.024669	Morita (1973)	
Central and eastern Pacific	65.5-173.0	1.97927×10^{-5}	3.021632	Morita (1973)	
Atlantic Ocean	50.2-175.5	2.50577×10^{-5}	2.973242	Morita (1973)	
Indian Ocean	73.5-166.5	4.92194×10^{-5}	2.832860	Morita (1973)	

Table 3.--Length-weight relations ($W = aL^b$) of northern bluefin tuna. Length (L) is in centimeters and weight (W) in kilograms.

Area	Size range (cm)	a	b	Source	Comments
Western Atlantic	--	3.17×10^{-5}	2.90444	Sakagawa and Coan (1974)	
Eastern Atlantic	25.0-279.5	1.9×10^{-5}	3.0	Rodríguez-Roda (1964)	May-June 1956-59.
	130.0-249.5	5.3×10^{-5}	2.8	Rodríguez-Roda (1964)	July-August 1956-59.
Eastern Pacific	55.8-178.4	5.686×10^{-5}	2.79012	Bell (1964)	
Western North Pacific	171.0-219.0	2.977×10^{-5}	2.910	Shingu et al. (1974)	
Western South Pacific	171.0-225.0	2.503×10^{-5}	2.9249	Shingu et al. (1974)	

Table 4.--Length-weight relations ($W = aL^b$) of southern bluefin tuna.

Length (L) is in centimeters and weight (W) in kilograms.

Area	Size range (cm)	a	b	Source
Australia	--	3.13087×10^{-5}	2.9058	Robins (1963)
Southeastern Indian Ocean	--	1.01625×10^{-5}	3.115	Shingu (1970)
Southwestern Pacific Ocean	--	9.4624×10^{-6}	3.120	Shingu (1970)

Table 5.--Length-weight relations ($W = aL^b$) of yellowfin tuna. Length (L) is in centimeters and weight (W) in kilograms.

Area	Size range (cm)	a	b	Source	Comments
Pacific coast of Costa Rica	54.2-157.1	2.3864×10^{-5}	2.940	Schaefer (1948)	
Eastern tropical Pacific	47.6-114.9	1.8496×10^{-5}	3.020	Chatwin (1959)	
Hawaii	--	2.8522×10^{-5}	2.9045	Tester and Nakamura (1957)	
Japan	--	6.64×10^{-6}	3.1878	Kamimura and Honma (1959)	Dressed weights of fish used.
Central Pacific	70.0-180.0	1.4769×10^{-5}	3.05834	Nakamura and Uchiyama (1966)	
West Africa	40.0-170.0	2.1804×10^{-5}	2.96989	Lenarz (1974)	
South Africa	--	8.1466×10^{-6}	3.18	de Jaeger (1963)	
	--	3.99165×10^{-5}	2.85	de Jaeger (1963)	
Eastern Atlantic (off Ivory Coast)	104.5-163.0	3.5133×10^{-6}	3.3432	Choo (1976)	
Western South Pacific	26.0-157.0	2.51211×10^{-5}	2.939597	Morita (1973)	
Eastern and central Pacific	63.4-148.0	3.49515×10^{-5}	2.868069	Morita (1973)	
Atlantic Ocean	46.9-169.5	1.6612×10^{-5}	3.026546	Morita (1973)	
Indian Ocean	79.5-162.5	6.5874×10^{-5}	2.750437	Morita (1973)	

Table 6.--Von Bertalanffy growth parameter estimates for albacore. K and t_o are in years.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_o	Comments
Pacific coast of Japan	Uno (1936)	Vertebra reading	104.8	0.431	1.504	Growth parameters computed by Shomura (1966).
North Pacific	Nose et al. (1957)	Scale reading (1952-53 samples)	114.4	0.308	0.818	Do.
	Nose et al. (1957)	Scale reading (1953-54 samples)	145.3	0.159	-0.056	Do.
Eastern North Pacific; troll	Bell (1962)	Scale reading	108.8	0.2247	-2.2728	Growth parameters computed by author.
Western North Pacific	Yabuta and Yukinawa (1963)	Scale reading	146.3	0.150	-0.396	Growth parameters computed by Shomura (1966).
North Pacific; longline, pole and line, troll	Otsu (1960)	Tagging	118.8	0.250	1.999	Do.
North Pacific; troll, pole and line, rod and reel, longline	Clemens (1961)	Tagging	135.6	0.17	1.87	Growth parameters computed by author.
Atlantic; longline and surface	Beardsley (1971)	Length-frequency analysis	140.0	0.141	-1.63	Do.
Atlantic	Yang (1970)	--	135.0	0.19	--	Do.
North Atlantic; troll	Bard (1974)	Scale reading, length-frequency analysis	134.4	0.183	-0.35	Do.

Table 7.--Von Bertalanffy growth parameter estimates for bigeye tuna. K and t_0 are in years.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_0	Comments
Western North Pacific (north of lat. 25°N, west of 180°)	Yukinawa and Yabuta (1963)	Length-frequency analysis	257.5	0.156	-0.107	Growth parameters computed by Shomura (1966).
Pacific (north of lat. 10°S)	Yukinawa and Yabuta (1963)	Scale reading	215	0.208	0.00055	Growth parameters computed by authors.
	Yukinawa and Yabuta (1963)	Scale reading	213.1	0.212	0.017	Growth parameters computed by Shomura (1966).
Central Pacific (Hawaii); longline	Shomura and Keala (1963)	Length-frequency analysis (males)	196.7	0.267	-0.929	Growth parameters computed by authors.
	Shomura and Keala (1963)	Length-frequency analysis (females)	183.0	0.316	0.718	Do.
Eastern Pacific (east of long. 130°W, lat. 10°N-25°S)	Kume and Joseph (1966)	Length-frequency analysis	186.95	0.38	0.528	Do.
Pacific (north of lat. 10°S)	Nose et al. (1957)	Scale reading	195.2	0.16	-1.128	Growth parameters computed by Shomura (1966).
Eastern Atlantic (Dakar-Pointe-Noire)	Champagnat and Pianet (1974)	Length-frequency analysis	338.53	0.104	-0.542	Growth parameters computed by authors.

Table 8.--Von Bertalanffy growth parameter estimates for northern bluefin tuna. K and t_0 are in years.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_0	Comments
Southern Spain; traps	Rodríguez-Roda (1971)	Vertebra reading	355.84	0.09	0.89	Growth parameters computed by author.
Western North Atlantic	Mather and Jones[1]	--	447.88	0.053	-1.592	Growth parameters computed by Sakagawa and Coan (1974).
	Butler et al. (1977)	Otolith reading	286.64	0.134	0.3278	Males. Growth parameters computed by authors.
	Butler et al. (1977)	Otolith reading	277.315	0.116	0.7999	Females. Growth parameters computed by authors.
Western North Atlantic; pound nets, hook and line	Mather and Schuck (1960)	Length-frequency scale-vertebra reading	437.46	0.055	-1.489	Growth parameters computed by Sakagawa and Coan (1974).
Western Pacific	Yukinawa and Yabuta (1967)	Scale reading and length-frequency analysis	320.5	0.1035	-0.7034	Growth parameters computed by authors.

[1]Mather, F. J. III, and A. C. Jones. 1972. A preliminary review of the stock structure of bluefin tuna in the Atlantic Ocean. Unpubl. manuscr., 18 p. Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

Table 9.--Von Bertalanffy growth parameter estimates for southern bluefin tuna. K and t_o are in years.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_o	Comments
Southwest Pacific-Southeast Indian Ocean; longline and pole and line	Yukinawa (1970)	Scale reading	219.7	0.135	0.04	Growth parameters computed by author.
South Australia; pole and line	Murphy (1977)	Tagging	180.84	0.146	-0.011	Do.
Australian waters; pole and line and trolling	Shingu (1970)	Length-frequency analysis	222.5	0.14	0.011	Growth parameters computed by author based on data from Robins (1963).
Southwest Pacific-Southeast Indian Ocean; pole and line, trolling, longline	Shingu (1970)	Tagging	187.4	0.149	0.021	Growth parameters computed by author based on Australian and Japanese tagging data.

Table 10.--Von Bertalanffy growth parameter estimates for yellowfin tuna. K and t_o are in years.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_o	Comments
Pacific coast of Japan; longline and pole and line	Yabuta and Yukinawa (1957)	Length-frequency analysis	168.9, 168	0.564; 0.55	0.368, 0.35	Growth parameters computed by Shomura (1966) and Suzuki (1971), respectively.
Western Pacific (lat. 12°N-5°S, long. 130°E-180°); longline	Yabuta et al. (1960)	Scale reading	197.5, 190; 188.4	0.312, 0.33, 0.32	-1.030, 0	Growth parameters computed by Shomura (1966), Suzuki (1971), and Le Guen and Sakagawa (1973), respectively.
	Yabuta et al. (1960)	Scale reading	191.1	0.327	-1.020	Growth parameters computed by Shomura (1966) using estimated lengths derived from Walford transformation of scale data.
Central Pacific (Hawaii); mainly longline	Moore (1951)	Weight-frequency analysis	190.2, 192, 191.9	0.454, 0.44, 0.43	0.267, 0.22	Growth parameters computed by Shomura (1966), Suzuki (1971), and Le Guen and Sakagawa (1973), respectively.
Western Pacific (lat. 12°N-5°S, long. 130°E-180°); longline	Yabuta and Yukinawa (1957)	Length-frequency analysis	151.6, 150	0.663, 0.66	-0.620, 0.40	Growth parameters computed by Shomura (1966) and Suzuki (1971).
Eastern Pacific; mainly pole and line	Hennemuth (1961)	Length-frequency analysis (1953-55 year classes)	169, 200.3	0.60, 0.36	0.83, 0.47	Growth parameters computed by author and Le Guen and Sakagawa (1973), respectively.
Eastern Pacific; pole and line and purse seine	Davidoff (1963)	Length-frequency analysis	167, 200.3	0.60, 0.36	0.83	Do.
Eastern Pacific (north of lat. 10°N); pole and line	Diaz (1963)	Extended year class	165.6	0.71	—	Growth parameters computed by author.
	Diaz (1963)	Atelic	214.3	0.36	—	Do.
Eastern Pacific; pole-and-line	Diaz (1963)	Extended year class	167.2	0.65	—	Do.
	Diaz (1963)	Atelic	179.8	0.49	—	Do.
Western Pacific (0° to lat. 10°N, long. 155°-175°E); longline	Yang et al. (1969)	Scale reading	195.2	0.36	—	Do.

Table 10.--Continued.

Area and fishing gear	Investigator(s)	Method	Growth parameters L_∞ (cm)	K	t_0	Comments
Atlantic (lat. 39.5°N-6°S, long. 83°W-6°E); longline	Yang et al. (1969)	Scale reading	222.8, 223.0	0.28, 0.28	--	Growth parameters computed by author and Le Guen and Sakagawa (1973), respectively.
Eastern Atlantic						
Dakar	Le Guen et al. (1969)	Length-frequency analysis	206.6	0.3144	0.45	Growth parameters computed by authors.
Pointe-Noire	Le Guen et al. (1969)	Length-frequency analysis	182.4	0.4428	0.54	Do.
All areas	Le Guen et al. (1969)	Length-frequency analysis	191.7	0.3828	0.52	Do.
Eastern Atlantic; pole and line and purse seine						
Abidjan	Le Guen and Sakagawa (1973)	Length-frequency analysis (age unknown)	185.0	0.52	--	Do.
Dakar	Le Guen and Sakagawa (1973)	Length-frequency analysis (age unknown)	307.9	0.20	--	Do.
Gulf of Guinea	Le Guen and Sakagawa (1973)	Length-frequency analysis (age unknown)	185.0	0.49	--	Do.
Pointe-Noire	Le Guen and Sakagawa (1973)	Length-frequency analysis (age unknown)	210.1	0.32	--	Do.
All areas	Le Guen and Sakagawa (1973)	Length-frequency analysis (age unknown)	194.8	0.42	0.62	Do.
Eastern Atlantic (São Tomé-Angola); pole and line and purse seine	Le Guen and Sakagawa (1973)	Length-frequency analysis (age known)	175.2	0.53	0.80	Do.
Eastern Atlantic; pole and line	Baudin-Laurencin (1968)	Length-frequency analysis	218.5	0.2952	--	Do.
Eastern Atlantic (Pointe-Noire)	Le Guen and Champagnat (1968)	Length-frequency analysis	165.8, 166.5	0.5568, 0.5418	--	Do.
Eastern Atlantic (Dakar)	Le Guen and Champagnat (1968)	Length-frequency analysis	182.3	0.4308	--	Do.

Table 11.--Estimates of instantaneous mortality coefficients for tunas.

M = natural, F = fishing, and Z = total.

Species	Area	Instantaneous mortality coefficient M	F	Z	Source
Albacore	Atlantic Ocean	0-0.30	--	--	Bard (1974)
	Atlantic Ocean	0.20, 0.32	--	0.96, 0.50, 0.79	Beardsley (1971)
	Pacific Ocean	--	--	0.4	Suda (1963)
	Pacific Ocean	0.2	--	--	Suda (1966)
	South Atlantic Ocean	0.475	--	0.805	Morita (1977)
	Indian Ocean	0.4-0.6	--	--	Suda (1974)
	Atlantic Ocean	0.23	--	--	Murphy and Sakagawa (1977)
Bigeye tuna	Indian Ocean	0.7268	--	1.130	Suda (1970)
	Pacific Ocean	0.349, 0.350, 0.5630	--	--	Ishii (1968)
	Pacific Ocean	0.10	--	0.4	Silliman (1966)
	Pacific Ocean	0.361	--	--	Suda and Kume (1967)
Bluefin tuna	Atlantic Ocean	0.10-0.20	0.28-1.00	0.59-1.75	Mather et al. (1974)
	Atlantic Ocean	0.1-0.2	--	0.48-2.96	Sakagawa and Coan (1974)
	Atlantic Ocean	0.10	--	--	Murphy and Sakagawa (1977)

Table 11.--Continued.

Species	Area	Instantaneous mortality coefficient M	F	Z	Source
Southern bluefin tuna	Indian-Pacific Oceans	0.2	--	--	Murphy (1977)
	Indian-Pacific Oceans	0.2-1.0	0+-2.61	1.15-1.84	Hayasi et al. (1972)
	Indian-Pacific Oceans	0.15, 0.16, 0.18	--	--	Suda (1971)
Yellowfin tuna	Atlantic Ocean	1.58, 2.61	--	--	Pianet and LeHir (1971)
	Pacific Ocean	0.11-4.57	0.56-2.02	0.77-5.17	Fink (1965)
	Pacific Ocean	0.64-0.90	0.82-1.08	1.60-1.85	Hennemuth (1961)
	Pacific Ocean	1.1, 2.5	--	--	Honma et al. (1971)
	Pacific Ocean	0.34, 0.44, 0.91	--	--	Ishii (1969)
	Pacific Ocean	0.55-1.05	0.69-1.20	--	Schaefer (1967)
	Pacific Ocean	0.3-0.8	--	--	Hayasi and Honma (1971)
	Indian Ocean	0.35-0.44	--	--	Kawakami and Kitahara (1964) as cited by Suda (1971)
	Atlantic Ocean	0.80	--	--	Murphy and Sakagawa (1977)

Table 12.--Estimates of tuna fecundity and size at first spawning.

Species	Area	Size at first spawning	Number of ova per spawning	Source
Albacore	Central Pacific Ocean	90 cm (33 lb)	1-2 million	Otsu and Uchida (1959)
	Central South Pacific Ocean	86 cm	--	Otsu and Hansen (1962)
	Indian Ocean	--	1.8-1.9 million	Ueyanagi (1955)
	Western Pacific	90 cm	0.8-2.6 million	Ueyanagi (1957)
Yellowfin tuna	Central equatorial Pacific Ocean	70 cm	--	Yuen and June (1957)
	Hawaii	--	2-8 million	June (1953)
	Eastern Pacific Ocean	--	0.6-5.5 million	Joseph (1963)
	Eastern Pacific Ocean	50-60 cm	--	Schaefer and Orange (1956)
Bigeye tuna	Pacific Ocean	14-20 kg	2.9-6.3 million	Yuen (1955)
	Western Pacific	90-100 cm	--	Kikawa (1953)
	Indian Ocean	92 cm	--	Kume (1962)
Northern bluefin tuna	Western Atlantic	--	16.7-33.0 million	Baglin (1976)
Southern bluefin tuna	Indian Ocean	--	14.0-15.0 million	Kikawa (1964)