Morphometric Characters of Yellowfin Tuna, *Neothunnus albacora* (LOWE), in the Southwestern Waters of the Indian Ocean (off the Southwest of the Madagascar Island)※

By

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Introduction

Our previous reports[1,2] were concerned with the morphometric features of yellowfin tuna caught in the eastern and northwestern waters of the Indian Ocean. Present report presents the results of our research in series on yellowfin tuna samples obtained in the southwestern waters of the Indian Ocean (off the southwest of the Madagascar Island), in an attempt to clarify their morphometric characters.

Identification of the species by a statistical study of morphometric characters was initiated by FISHER (1930). This method has been applied by many other workers to ichthyology. The results of their researches have led to the belief that the yellowfin tuna migrates only in limited ranges, and that no major intermigration occurs among their schools. SCHAEFER[3] (unpublished) has pointed out that a superior method is required for statistical analyses. However, to those whose objective is to compare tuna caught in the waters widely apart from each other, it seems impractical to conduct any more accurate analyses. I have endeavoured at collection of samples in an effort to gain measurement values identical with that of our large samples, yet I have still to find a method with which to determine whether our collections are of the typical species or not. Provided that our present samples are of the typical species, I must first give descriptions of yellowfin tuna schools in the waters and at the time when our samples were collected. This, at once, is the purpose of our present study.

Data and Method

Present sample was obtained from among yellowfin tuna caught with tuna longline by the crew of the fisheries training ship, *Koyo-Maru*, of the Shimonoseki College

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of Fisheries during the period from January 1st to 13th, 1961, in the southwestern waters of the Indian Ocean (position approximately 31°—46° E long., 29°—39° S lat.; see Fig. 1). After removing those in postmortum rigor I have got 78 samples. The external morphometric characters were estimated by the usual method. Data are shown in Table 1. I should hereby like to extend my sincerest appreciation to all crews and cadets of the *Koyo-Maru* for their willing cooperation in morphometric measurements carried out this work.

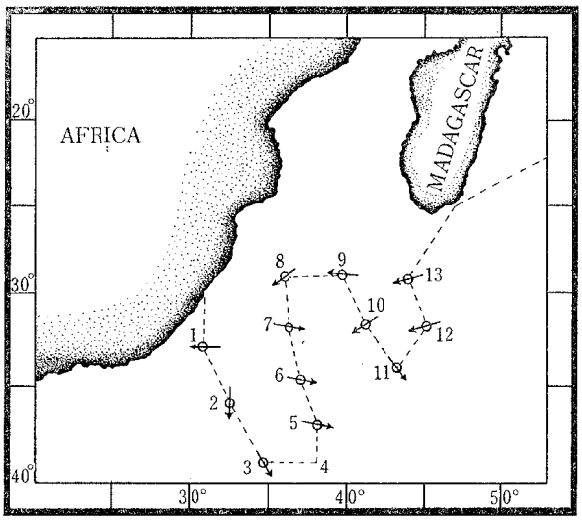

Fig. 1. Tuna longline fishing ground; operational course line, 12 setting positions and direction and date (Jan. 1~13 in 1961).

Table 1. Morphometric measurements of yellowfin tuna from the southwestern waters of the Indian Ocean, Jan. 1~13, 1961.

Body length	Head length	Insertion I.D.F.	Insertion II.D.F.	Insertion A.F.	Height of II.D.F.	Length of P. F.	Height of A. F.	Greatest body depth	Greatest body width	Body weight	Sex
cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	lbs	
78	22	23	44	45	13	21	14	19	15	24	M
79	22	23	42	47	13	23	13	19	13	22	M
81	23	23	43	48	11	21	13	20	14	22	M
82	23	24	45	48	13	22	14	21	17	31	M
115	31	34	62	70	28	33	27	24	——	90	F
117	32	34	63	71	25	31	27	28	——	77	F
119	31	30	58	70	22	27	23	29	22	75	F
120	32	33	67	68	24	29	29	31	23	84	M
121	32	36	66	72	26	30	28	31	25	84	M
121	34	34	66	74	31	32	33	32	26	101	F

121	33	34	64	71	26	29	27	33	——	90	M
121	32	34	64	72	26	28	27	32	23	88	F
121	31	32	64	71	27	32	32	32	25	95	F
122	33	32	62	72	34	32	39	32	——	90	M
122	33	34	65	70	32	32	34	31	24	90	F
123	33	36	63	72	34	32	35	32	——	106	F
123	31	33	64	70	26	30	32	30	——	84	M
124	33	33	64	73	30	31	35	32	25	95	M
124	33	35	64	73	26	23	30	33	——	97	F
124	33	35	66	72	23	30	27	31	24	93	F
125	33	36	64	77	28	29	30	33	24	94	M
125	32	36	67	73	29	29	31	32	24	93	M
125	34	37	66	73	29	28	27	28	22	85	F
125	32	37	66	74	31	31	34	34	——	94	F
125	34	37	67	76	28	34	27	33	26	104	M
125	33	35	63	71	27	30	34	34	25	99	F
125	32	34	65	70	33	30	34	32	26	97	F
126	33	36	65	73	31	31	32	31	25	90	F
126	32	37	67	75	28	29	30	32	25	99	F
126	33	34	64	71	28	31	29	33	25	93	F
126	32	34	65	72	26	28	25	31	24	95	F
126	33	35	67	72	31	31	29	33	23	99	F
127	34	33	65	74	33	33	35	32	23	99	M
127	33	32	64	73	29	31	32	31	25	99	F
128	32	34	67	72	30	33	32	32	26	97	F
128	34	34	67	73	30	32	33	33	25	99	M
129	34	34	67	73	29	31	27	33	——	103	F
129	34	37	71	74	26	30	27	34	——	110	M
129	33	35	69	74	30	30	31	34	27	106	M
129	33	35	67	74	25	32	28	31	28	96	F
129	33	34	67	73	34	32	36	34	27	112	M
130	33	36	66	72	33	32	37	31	——	101	F
130	34	37	67	73	30	32	23	33	——	101	M
130	33	36	67	74	24	29	27	32	——	93	M
131	35	39	71	76	33	30	36	30	——	76	F
131	34	34	68	78	28	29	28	33	25	112	M
131	34	38	69	75	36	36	37	32	28	104	F
131	33	33	66	73	35	35	37	31	25	101	F
132	33	39	68	77	31	33	33	35	27	115	F
133	34	37	69	75	34	31	36	35	27	115	M

133	35	35	68	77	40	35	43	32	26	119	F
134	35	38	71	77	42	32	35	33	26	114	F
135	34	37	67	75	38	33	43	34	21	108	F
135	36	35	67	75	41	34	41	35	27	115	M
136	36	35	69	80	41	33	46	36	——	99	F
136	36	40	72	79	44	31	49	36	——	119	F
138	34	39	70	77	39	30	42	35	——	115	F
138	35	40	68	77	30	31	29	36	27	119	M
138	36	38	71	76	65	33	52	37	——	135	F
138	35	35	69	78	38	32	41	35	28	124	F
139	35	38	70	79	35	34	48	32	——	119	F
139	34	37	72	79	37	32	40	35	——	119	F
139	34	37	69	77	45	32	47	35	28	126	F
140	34	38	73	81	71	32	71	37	30	141	F
141	37	39	72	82	40	35	51	35	26	124	F
141	37	37	74	81	44	33	49	37	——	141	F
141	36	37	72	79	47	35	54	33	27	124	F
142	38	42	76	82	52	34	62	33	——	111	F
142	35	38	71	78	41	33	37	35	19	115	M
143	37	39	76	79	45	34	51	35	27	137	F
143	39	39	72	90	35	31	44	37	27	137	F
144	37	37	73	82	44	34	50	33	25	130	F
145	38	35	72	80	67	33	67	40	——	154	F
147	40	40	76	82	49	32	57	39	——	130	M
147	37	39	74	82	51	34	45	39	28	154	M
150	37	40	78	84	45	35	53	36	27	148	F
151	38	39	75	83	36	35	55	40	——	161	M
155	40	42	81	86	54	33	34	40	29	174	M

Growth-rate of Yellowfin Tuna in the Southwestern Waters of the Indian Ocean

From Table 1, we obtained data as in Table 2, by the usual statistical calculation method.

The rate of growth of yellowfin tuna in various parts of the waters in discussion from the stage when the body length is 100 cm to the stage when it has grown to 150 cm is, as shown below, much the same as with yellowfin tuna in the other waters, being the greatest in the height-increment on the second dorsal fin and anal fin, and the smallest in the length on the pectoral fin.

1. Head length: 36.2 % (276 mm—386 mm)
2. Distance from tip of snout to insertion of first dorsal fin: 41.5 % (282 mm—399 mm)
3. Distance from tip of snout to insertion of second dorsal fin: 35.0 % (557 mm—752 mm)

Table 2. Statistics of linear regression of measurements of yellowfin tuna, *Neothunnus albacora* in the southwestern waters of the Indian Ocean (Jan. 1—13, 1961).

Independent variable (x)	Dependent variable (y)	N	$\overline{x}$	$\overline{y}$	Sx^2
Total length	Head length (cm)	78	129	34	15,759
Do.	Insertion of Ⅰ. D. F. (cm)	78	129	35	15,759
Do.	Insertion of Ⅱ. D. F. (cm)	78	129	67	15,759
Do.	Insertion of A. F. (cm)	78	129	74	15,759
Do.	Greatest body depth (cm)	78	129	33	15,759
log Total length	Length of P. F. (cm)	78	2.1105897	31	0.2878738
Do.	*log* Height of Ⅱ. D. F. (cm)	78	2.1105897	1.5314789	0.2878738
Do.	*log* Height of A. F. (cm)	78	2.1105897	1.5563025	0.2878738
Do.	*log* Body weight lbs.	78	2.1105897	2.0086002	0.2878738

Sy^2	Sxy	b	a	s
852	3,486	0.221207	5.46	1.020
1,078	3,698	0.234660	4.73	1.663
3,570	6,155	0.390572	16.62	3.918
4,454	8,072	0.512215	7.92	2.053
1,190	4,125	0.261755	− 0.77	1.204
7.3	12.076947	41.952222	−57.54	1.648
1.6533089	0.576251	2.001749	− 2.6933913	0.08108
1.6789392	0.574203	1.994634	− 2.6535506	0.08378
1.9891603	0.688868	2.392951	− 3.0499369	0.06696

4. Distance from tip of snout to insertion of anal fin: 43.5 % (591 mm—848 mm)
5. Greatest body depth: 51.6 % (254 mm—385 mm)
6. Height of second dorsal fin: 125.5 % (204 mm—460 mm)
7. Length of pectoral fin: 28.0 % (264 mm—338 mm)
8. Height of anal fin: 124.0% (217 mm—486 mm)
9. Body weight: 164.2 % (55.4 lbs—143.7 lbs)
10. Ratio of sexes: male 37.2 %, female 62.8 %

Equations of regression needed for the above calculations were obtained from Table 2 and are shown below:

1. Head length y on total length x : $y=0.221207\ x+5.46$
2. Snout to insertion of first dorsal fin y on total length x : $y=0.234660\ x+4.73$
3. Snout to insertion of second dorsal fin y on total length x : $y=0.390572\ x+16.62$
4. Snout to insertion of anal fin y on total length x : $y=0.512215\ x+7.92$
5. Greatest body depth y on total length x : $y=0.261755\ x-0.77$
6. Length of pectoral fin y on total length x : $y=41.952222\ x-57.54$
7. Height of second dorsal fin y on total length x : $y=0.00202586\ x^{2.001749}$
8. Height of anal fin y on total length x : $y=0.00222049\ x^{1.994634}$
9. Body weight y on total length x : $y=0.000891381\ x^{2.392951}$

Comparison

1. Head length

The samples with body length of about 100 cm measure 276 mm in the head length, which is longer than yellowfin tuna's of corresponding sizes in any other waters. The length indicates the greatest difference when compared with the Hawaiian sample and the mid-Indian Ocean sample, being 18 mm larger than that of the former and 7 mm than that of the latter, respectively. Little differences are noted from samples of the other waters. The samples with body length of 150 cm measure 386 mm in the head length, which is 15 mm longer than that of the Hawaiian's but much the same as that of the samples of the other waters. However, the rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of the other waters, being a little over 36 percent. It may be said that head length is, in general, relatively small in large samples. Table 3 shows these computed values.

2. Distance from tip of snout to fin insertions

(1) **Distance from tip of snout to insertion of first dorsal fin** : The samples with body length of 100 cm and 150 cm measure 282 mm and 399 mm in the distance respectively, which is both shorter than that of any other waters; and this is 24 mm shorter with the 100 cm sample and 37 mm shorter with the 150 cm one than that of the mid-Indian Ocean samples, and also is 17 and 38 mm shorter than that of the southwest of the Greater Sunda Islands one. The great differences also indicate in this distance from samples of the other waters than in the case of the head length. The rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 41 percent, which is greater than the southwest Pacific's, but a little smaller than that of the other waters. Table 3 shows these computed values.

(2) **Distance from tip of snout to insertion of second dorsal fin** : The samples with body length of 100 cm measure 557 mm in the distance, which is longer than that of any other waters ; and this is 43 mm longer than that of the Hawaiian's. The samples with body length of 150 cm measure 752 mm in the distance which is a little longer than that of the southwest Pacific and the Hawaiian's, but shorter than that of the other waters, and this is 23 mm shorter than that of the mid-Indian Ocean's. It may be said, therefore, with the small specimens in this water, the distance between the first and second dorsal fins is longer than that of the other waters. However, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 35 percent. This, as in the case of the head length, is smaller than that of any other waters. Table 3 shows these computed values.

(3) **Distance from tip of snout to insertion of anal fin** : The samples with body length of 100 cm measure 591 mm in the distance, which is 21 mm shorter than that of the southwest Pacific's, but longer than that of the other waters, which is 22 mm longer in the distance than the Hawaiian's and 19 mm longer than the

samples of the southwestern waters of the Greater Sunda Islands. With the 150 cm sample, this measures 848 mm in the distance, which is 8 mm shorter than that of the Costa Rican's, but longer than that of the other waters, and also which is 22 - 25 mm longer in the distance than that of the samples of the southwest Pacific, Hawaii and the southwestern waters of the Greater Sunda Islands. The rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 43 percent. This, as in the case of 2 (1), above, is greater than that of the southwest Pacific's, but slightly smaller than that of the other waters. Table 3 shows these computed values.

3. Greatest body depth

The samples with body length of 100 cm measure 254 mm in the depth, which is 26 mm and 17 mm larger than that of the southeast Arabian Sea and the mid-Indian Ocean's, respectively, but smaller than that of the other waters, and in comparison with the southwest Pacific's, which is 17 mm smaller. With the 150 cm sample, this measures 385 mm in the depth, which is 10 mm smaller than that of the Angola's, but 24 mm and 13 mm larger than that of the southwest Pacific and southeast Arabian Sea's, respectively. The rate of the depth-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 51 percent, which is smaller than that of the southeast Arabian Sea and the mid-Indian Ocean's, but greater than that of the other waters. Table 3 shows these computed values.

4. Height and length of fins

(1) **Height of second dorsal fin** : The samples with body length of 100 cm measure 204 mm in the height, which is 84 mm lower than that of the southwest Pacific's, but 46 mm greater than that of the Costa Rica's. With the 150 cm sample, this measures 460 mm in the height, which is 95 mm lower than that of the sample of the southwestern waters of the Greater Sunda Islands and 88 mm smaller than that of the southwest Pacific sample, but 145 mm greater than that of the Costa Rica's. The rate of the height-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 125 percent, which is smaller than that of the samples of the southwestern waters of the Greater Sunda Islands, Hawaii and the southeast Arabian Sea, but greater than that of the other waters. Table 3 shows these computed values.

(2) **Length of pectoral fin** : The samples with body length of 100 cm measure 264 mm in the length, which is considerably shorter than that of any other waters, but is 54 mm shorter in length than the southwest Pacific's. With the 150 cm sample, this measures 338 mm in the length, which is shorter, as in the case of the 100 cm sample, than that of any other waters, but 41 mm and 36 mm shorter in length, respectively, than that of the Hawaiian and Angola's. The rate of the length-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 28 percent, which is smaller than that of the Angola and Costa Rican samples, but greater than that of the other waters. This rate of the length-increment is approximately twice as large as that of the southwest Pacific and

the mid-Indian Ocean's. Table 3 shows these computed values.

(3) Height of anal fin : The samples with body length of 100 cm measure 217 mm in the height, which is 81 mm lower than that of the southwest Pacific's and 7 mm lower than that of the sample of the southwestern waters of the Greater Sunda Islands, but 46 mm higher than that of the Costa Rican's. With the 150 cm sample, this measures 486 mm in the height, which is 129 mm and 58 mm higher than that of the Costa Rican and Angola's, respectively, but 161 mm lower than that of the southwest Pacifc's. The rate of the height-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 124 percent, which is greater than that of the Costa Rican and the southwest Pacific's, but considerably smaller than that of the samples of the southwestern waters of the Greater Sunda Islands and the mid-Indian Ocean. Table 3 shows these computed values.

5. Body weight

The samples with body length of 100 cm measure 54.4 lbs in the body weight, which is heavier than that of any other waters, but 14.4 lbs heavier than the Costa Rican's. With the 150 cm sample, this measures 143.7 lbs, which is slightly lighter than that of the southeast Arabian Sea's and much same as the Hawaiian's, but the weight is approximately 12 lbs heavier than that of the Costa Rican and the mid-Indian Ocean samples. The rate of the weight-increment of the samples in the range from 100 cm to 150 cm in body lengfh is a little over 164 percent, which is slightly smaller than that of the southwest Pacific and the mid-Indian Ocean's, and considerably smaller than that of the other waters. Table 3 shows these computed values.

Table 3. Comparison of morphometric characters between the SW of the Indian Ocean samples and those of samples from the other waters at each 100 cm and 150 cm in body length.

Item \ Locality		SW of the Indian Ocean	Middle of the Indian Ocean	SE of the Arabian Sea	SW of the Greater Sunda Is.	SW of the Pacific Ocean	Hawaiian waters	Costa Rica	Angola
Head length	A	276 mm	− 7 mm	—· mm	− 3 mm	− 2 mm	−18mm	− 3 mm	− 4 mm
	B	386 mm	− 1 mm	—mm	+ 4 mm	− 6 mm	−15mm	+ 4 mm	− 2 mm
	C	36.2 %	43.1 %	—· %	42.9 %	38.7 %	43.8 %	42.9 %	41.2 %
Snout to insertion of 1st dorsal fin	A	282	+24	+18	+17	+17	+ 6	+13	+13
	B	399	+37	+29	+38	+ 5	+13	+28	+17
	C	41.5	42.5	42.7	46.2	35.5	43.1	44.7	41.0
Snout to insertion of 2 nd dorsal fin	A	557	−28	−31	−22	−16	−43	−31	−28
	B	752	+23	+15	+ 3	− 9	− 4	+13	+ 6
	C	35.0	46.5	45.8	41.1	37.3	45.5	45.4	43.3
Snout to insertion of anal fin	A	591	− 6	——	−19	+21	−22	− 2	− 9
	B	848	−10	——	−22	−25	−24	+ 8	−16
	C	43.1	43.2	——	44.4	34.5	44.8	45.3	43.0

Greatest body depth	A	254	−17	−26	+ 3	+17	0	+ 1	+ 7
	B	385	− 7	−13	− 2	−24	− 4	− 2	+10
	C	51.6	59.5	63.2	49.0	33.2	50.0	50.2	51.3
Height of 2nd dorsal fin	A	204	——	−29	− 3	+84	−28	−46	−28
	B	460	——	−38	+95	+88	−23	−145	−81
	C	125.5	——	141.1	176.1	90.3	142.6	100.1	116.4
Length of pectoral fin	A	264	+39	——	+30	+54	+28	+ 6	+15
	B	338	+11	——	+21	+25	+41	+10	+36
	C	28.0	15.2	——	22.1	14.2	26.4	28.9	34.1
Height of anal fin	A	217	−34	——	+ 7	+ 81	−20	− 46	−27
	B	486	+16	——	+155	+161	+13	−129	−58
	C	124.0	174.3	——	186.2	117.1	153.3	108.8	125.3
Body weight	A	lbs 54.5	lbs −8.6	lbs −9.1	lbs −11.4	lbs −4.4	lbs −11.4	lbs −14.4	lbs ——
	B	lbs 143.7	lbs −11.6	lbs +6.5	lbs −5.6	lbs −9.4	lbs +0.2	lbs −11.7	lbs ——
	C	164.2%	188.4%	231.6%	220.9%	168.0%	234.9%	230.0%	——%

Note : A and B are body length 100 cm and 150 cm but C is growth rate (%).

6. Ratio of sexes and morphometric differences

(1) **Ratio of sexes** : According to sexes, sorting was made of the 98 yellowfin tuna without 13 failed to the measure and 5 dameged by sharks in a total catch of 116; and among these, 38 (39%) were male and 60 (61%) female. However, of those caught in the southern waters (near 37° E long., 34° S lat.), almost all were female. As we proceeded northward, the number of males increased, but the majority were still ocupied by females. The most samples occured with gonads of the earliest stage, but a few females were seemed to be the second stage.

(2) **Morphometric differences between male and female** : The following differences among male and female were detected from Table 1 by the same calculation method applied as to produce Table 2. HIRANO and TAGAWA[4] reported that no external differences are noted between male and female, and that the male is a little larger than the female only in the average greatest body depth. This is also the case of our samples, but we have also noted some other differences.

1) **Head length** : The 100 cm samples measure 274 mm in the head length both for male and female. The 150 cm samples do 387 mm in the head length, which is 7 mm longer than that for female. Therefore, the rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than female, being about 41 percent for the former and about 39 percent the latter. Equations of regression are given below and Table 4 showing these computed values.

$y=0.226011\ x+4.75$ ·····Male

$y=0.211134\ x+6.34$ ·····Female

2) Distance from tip of snout to fin insertions:

(i) Distance from tip of snout to insertion of first dorsal fin : The 100 cm samples measure 280 mm in the distance for male, which is 22 mm shorter than that for female. On the contrary, the 150 cm samples do 401 mm in the distance for male, which is 5 mm longer than that for female. Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than for female, being about 43 percent for male and about 31 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.242039\ x+3.75$ ·····Male
$y=0.187741\ x+11.41$ ·····Female

(ii) Distance from tip of snout to insertion of second dorsal fin : The 100 cm samples measure 545 mm in the distance for male, which is 4 mm longer than that for female. On the contrary, the 150 cm samples do 754 mm in the distance for male, which is 11 mm shorter than that for female. This is the very reverse of (i). Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is greater for female than that for male, being about 41 percent for female and about 38 percent for male. It may be said, therefore, that the distance between the first and second dorsal fins is longer for male than for female with small samples, and that the exact reverse is the case with large samples. Equations of regression are given below and Table 4 showing these computed values.

$y=0.414999\ x+13.13$ ·····Male
$y=0.446550\ x+9.50$ ·····Female

(iii) Distance from tip of snout to insertion of anal fin : The 100 cm samples measure 581 mm in the distance for male, which is 38 mm shorter than that for female. The 150 cm samples do 839 mm in the distance for male, which is 7 mm shorter than that for female, too. Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is, as in the case of (i), greater for male than for female, being about 44 percent for male and about 37 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.517922\ x+6.26$ ····· Male
$y=0.455108\ x+16.38$ ·····Female

3) Greatest body depth : The 100 cm samples measure 251 mm in the depth for male, which is 23 mm smaller than that for female. On the contrary, the 150 cm samples do 389 mm in the depth for male, which is 8 mm larger than that for female. Therefore, the rate of the depth-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than for female, being about 55 percent for male and about 39 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.276144\ x-2.52$ ·····Male
$y=0.214391\ x+5.92$ ·····Female

Table 4. Comparison of some morphometric characters with sexes at each stage of 100 cm and 150 cm in body length.

Item \ Sex		Male	Female
Head length	A	274mm	274mm
	B	387mm	380mm
	C	41.2 %	38.7 %
Snout to insertion of 1st dorsal fin	A	280	302
	B	401	396
	C	43.2	31.2
Snout to insertion of 2nd dorsal fin	A	546	542
	B	754	765
	C	38.1	41.0
Snout to insertion of anal fin	A	581	619
	B	839	846
	C	44.4	36.7
Greatest body depth	A	251	274
	B	389	381
	C	55.0	39.1

Note : A and B are body length 100 cm and 150 cm but C is growth rate (%).

4) Composition of body length and body weight : Body length of males ranges from 78—155 cm and about 52 percent have body lengths ranging from 121—130 cm, constituting of one major mode. Of females this ranges from 115—150 cm and about 43 percent have body lengths ranging from 121—130 cm and about 33 percent from 131—140 cm, thus constituting of two major modes. Of the total number of males and females, about a half have body lengths ranging from 121—130 cm and about a quarter from 131—140 cm. Table 5 shows these composition of body length.

Table 5. Comparison of composition of body length with sexes.

Body length	Composition of body length					
	Male		Female		Total	
70—100 cm	4	13.8 %	0	0 %	4	5.1 %
101—110	0	0	0	0	0	0
111—120	1	3.5	3	6.1	4	5.1
121—130	15	51.7	21	42.8	36	46.2
131—140	4	13.8	16	32.7	20	25.6
141—150	3	10.3	9	18.4	12	15.4
151—160	2	6.9	0	0	2	2.6
Total	29		49		78	

Body weight of males ranges from 24—174 lbs and about 38 percent have body weights ranging 81—100 lbs and another 38 percent from 101—130 lbs, thus constituting of two major modes. Of females this ranges from 75—154 lbs, about 39 percent have body weights ranging from 81—100 lbs and 41 percent from 101—130 lbs, thus, like males in the same weight bracket, constituting of two major modes. However, the ratio of females weighing more than 100 lbs is slightly greater than that of males in the corresponding weight bracket. Table 6 shows these composition of body weight.

Table 6. Comparison of composition of body weight with sexes.

Body weight	Composition of body weight					
	Male		Female		Total	
20～ 40 lbs	4	13.8 %	0	0 %	4	5.1 %
71～ 80	0	0	3	6.3	3	3.8
81～100	11	37.9	19	38.8	30	38.6
101～130	11	37.9	20	40.8	31	39.7
131～150	0	0	7	14.1	7	9.0
151～180	3	10.4	0	0	3	3.8
Total	29		49		78	

7. Fishing and oceanographic conditions

Fishing operations were conducted on 12 occasions during the period from January 1st to 13th, 1961 (operations suspended on Jan. 4th due to rough sea). A total of 1,495 baskets (7,475 hooks) is used, and the catch of 299 consisted of yellowfin tunas, albacores and other fishes, and the average angling rate was 4.0 percent. The greater part of the catch was comprised of yellowfin tuna and albacore, the former numbering 116 (38.8 %) and the latter 114 (38.1 %), followed by 41 bigeyed tuna (13.7 %) and 18 marlins (6.0 %).

As for areas of operations, yellowfin tuna were mainly caught in the waters north of 35° S lat., albacore were caught in all the waters that we covered. These waters, therefore, may be regarded as an albacore fishing ground. Bigeyed tuna and sharks were caught from the most part in the southwestern waters where the thermocline is great, while marlins were caught in the middle of the waters (38°—41° E long., 32°—37° S lat.) with a high-temperature water mass at the bottom.

The surface water temperature was the lowest on the southwestern waters (operated on Jan. 3), being 17.7°C, and the highest on mid-northern waters (operated on Jan. 9), being 25.3° C. The distribution of surface water temperature was 25° C in the northern waters, became lower as we proceeded southward, and was 18° C in southern waters. At the 50 m depth, the water temperature generally follow suit after the surface water temperature, being high in the north and low in the south. At the 100 m depth, an 18° C water mass extends generally along 40° E long. to the vicinity of 37° S lat. At the depth of more than 100 m, changes in the water tempe-

rature show a generally similar tendency. At the 500 m depth, the water temperature is low in the southwestern waters, and in its center, as in the case of the 100 m depth, a tongue-shaped 16° C water mass extends from north toward south.

Since no tuna fishing has ever been carried out in these waters, I hesitate in examination making any further criticism of a fishing and oceanogrophic conditions. Details of those fishing operations are given in Table 7.

Table 7. Details of the tuna longline fishing in the southwestern waters of the Indian Ocean (Jan. 1—13, 1961).

Dates	Locations		Weather and sea water temperature					
	E long.	S lat.	Weather	Wind		Atmos. press.		
				Direction	Force		0	50
Jan.						mb.	°C	°C
1	30°——59′	33°——05′	b	N E	1	1,031	22.0	——
2	32 ——38	35 ——46	b c	N N E	1	1,024	19.0	18.0
3	34 ——56	38 ——56	c	N	3	1,014	17.7	18.3
5	38 ——30	36 ——58	c	N W	3	1,004	21.0	19.1
6	37 ——11	34 ——27	b c	W	4	1,010	21.8	22.4
7	36 ——26	32 ——01	b c	W	3	1,014	23.2	23.5
8	36 ——11	29 ——06	b c	E	1	1,016	24.2	22.7
9	39 ——45	28 ——57	c	E	2	1,013	25.3	25.5
10	41 ——13	31 ——46	c	S S E	1	1,016	25.0	23.0
11	43 ——23	34 ——09	c	N	2	1,019	22.8	20.6
12	45 ——17	31 ——47	b c	N N E	1	1,019	23.5	22.6
13	44 ——00	29 ——17	b c	N E	2	1,018	24.3	23.8

Depth (m)			G E K records		Operations		Yellowfin	Albacore
100	200	500	Direction	Speed	Number of hooks	Soaking time		
°C	°C	°C		Knots		h m h m		
——	——	——	294°	1.4	490	3 —30→12—10	22(3)	——
15.9	13.4	9.8	133	1.9	490	3 —20→12—05	1	1(1)
15.6	13.0	10.7	72	1.3	745	3 —15→14—10	——	11
19.3	17.9	——	25	0.2	495	3 —20→12—00	——	38
19.7	19.4	16.4	60	0.9	745	3 —30→14—00	12	11
16.2	17.2	——	350	0.6	745	3 —30→14—10	24(1)	21
16.8	17.2	13.3	230	0.7	495	3 —30→12—00	14	4
21.7	20.2	16.3	200	0.9	495	3 —30→11—55	12	4
20.0	17.5	——	162	0.4	750	3 —30→14—00	8	13
17.3	16.2	13.5	330	0.6	750	3 —30→13—20	——	——
17.2	16.2	16.6	160	0.8	750	3 —30→13—15	6	1
17.8	17.7	14.5	243	0.8	525	3 —30→11—55	12(1)	9
				Total	7,475	113—35	111(5)	113(1)

Captured fishes							Angling rate per 100 hooks
Bigeye	Marlins			Sharks	Others	Total	
	Black	Broadbill	Shortnose				
——	2	——	——	1	——	25(3)	5.7%
——	——	——	——	1	——	3(1)	0.8
29(1)	——	——	——	1	——	41(1)	5.6
——	——	——	1	1	Opah— 1 Dorado— 1	42	8.5
3	——	1	1	——	Dorado— 1	29	3.9
3	2	1	1	——	Skipjack— 1	53(1)	7.2
——	——	——	1	——	——	19	3.9
——	——	——	——	——	——	16	3.2
5	1	——	4	——	——	31	4.1
——	——	——	——	2	——	2	0.3
——	3	——	——	——	——	10	1.3
——	——	——	——	——	——	21(1)	4.2
40(1)	8	2	8	6	4	292(7)	(Average) 4.0

Note : Weather and sea water temperature observed in 5h～7h a. m.
G E K : Geomagnetic Electro-Kinetograph (used occasionally).
Number in brackets is injured fishes.
Jan. 4th, no fished due to rough sea.

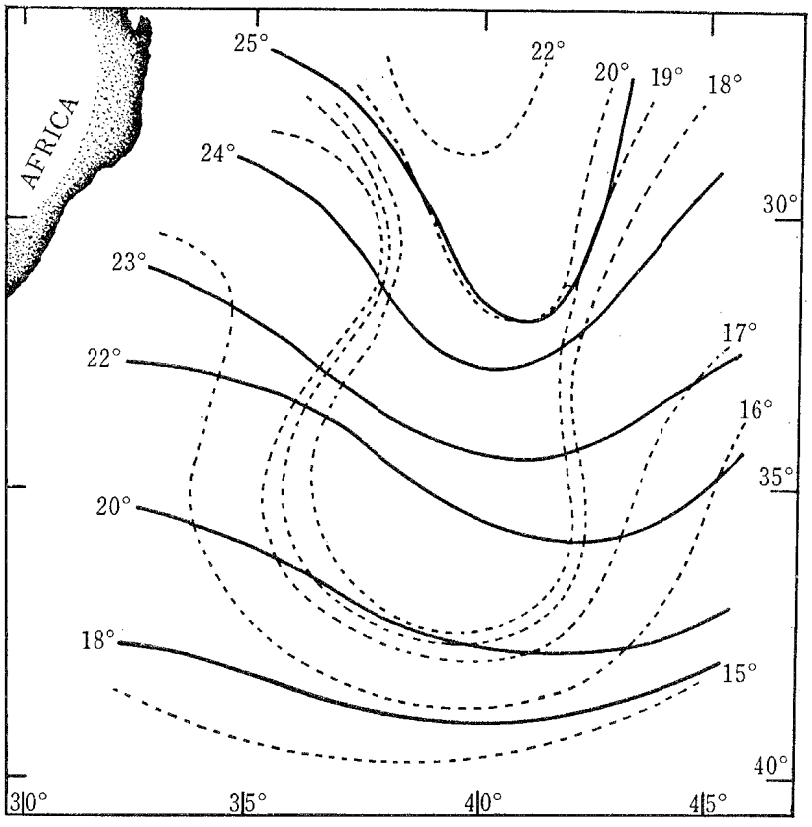

Fig. 2. Thermocline topography (Jan. 1～13, 1961). Note : —— 0 m, ·····100 m cepth.

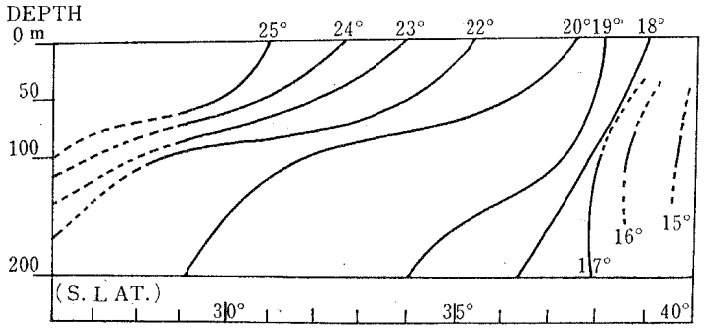

Fig. 3. Vertical distribution of water temperature at 40° E long.

Discussion

With our yellowfin tuna samples obtained in the southwest of the Indian Ocean, the rate of growth of various parts is as much the greatest at the second dorsal fin and anal fin, and the smallest at the pectoral fin as in the case of samples of the other waters.

1. External morphometric characters

1) Head length : With the 100 cm sample, head length is longer than that of the samples of any other waters. With 150 cm sample, head length is longer than that of the Hawaiian counterpart, but shows little difference when compared with samples of the other waters. The rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of the samples of any other waters. In this regard, our samples, it may be said, therefore, compared with samples of corresponding body lengths obtained in the other waters, head length is longer in small specimens (body length under 100 cm), and, on the contrary, shorter in large specimens (body length above 150 cm).

2) Distance from tip of snout to insertion of first dorsal fin : Regardless of body length, the distance of this is shorter than that of of any other waters. The rate of this distance-increment is, like that of head length, low.

3) Distance from tip of snout to insertion of second dorsal fin : With the 100 cm sample, the distance is, contrary to 2), longer than the samples' of any other waters. With the 150 cm sample, the distance sampleis a little longer than that of the west of the mid-Pacific Ocean's, but shorter than that of the other waters'. The rate of this distance-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of any other waters. It may be said, therefore, that the distance between the first and second dorsal fins of this sample is longer in small specimens than those of corresponding size in the other waters.

4) Distance from tip of snout to insertion of anal fin : Regardless of body length, this distance of this sample is generally longer than that of the other waters. The rate of this distance-increment, however, is smaller than the that of other waters.

5) Height of second dorsal fin : The height is, in general, shorter than that of the east Indian Ocean and the southwest Pacifics', but longer than that of the samples of the other waters.

6) Length of pectoral fin : Regardless of body length, the length of the pectoral fin is, as in the case of 2), shorter than that of any other waters. The rate of this length-increment is smaller than that of Angola and Hawaiian's, but greater than that of the other waters.

7) Height of anal fin : With the 100 cm sample, this height is lower than that of the east Indian Ocean and southwest Pacific's, but higher than that of the other waters. With the 150 cm sample, the height indicates genarally greater differences from that of the other waters. The rate of this height-increment of the samples in the range from 100 cm to 150 cm in body length is greater than that of the east Pacific's, and generally smaller than that of the other waters.

8) Greatest body depth: With the 100 cm sample, this depth is larger than that of the north of the mid-Indian Ocean's, but smaller than that of the other waters. With the 150 cm sample, the depth is generally larger than that of the other waters.

Table 8. Regression coefficients for various dimensions on total length, for samples from off the SW of the Madagascar I., Indian Ocean, Pacific Ocean and Angola.

Locals	Head length	Insertion I.D.F.	Insertion II.D.F.	Insertion A. F.	Height of I.D.F.	Length of P. F.	Height of A.F.	Greatest body depth	Body weight
SW of the Madagascar I.	0.22121	0.23466	0.39057	0.51222	2.00175	41.952	1.99463	0.26176	2.39295
Middle of the Indian Ocean	0.23234	0.26052	0.49268	0.50906	——	25.873	2.48733	0.28115	2.61155
SE of the Arabian Sea	——	0.25571	0.48074	——	2.17188	——	——	0.28303	2.95796
SW of the Greater Sunda Is.	0.23417	0.27687	0.43915	0.50854	2.51378	36.943	2.58067	0.25091	2.88983
SW of the Pacific Ocean	0.21202	0.20971	0.40469	0.42184	1.58926	25.284	1.90955	0.18083	2.43006
Hawaiian waters	0.22567	0.24821	0.46914	0.51941	2.21305	49.193	2.28934	0.25469	2.99587
W coast of America	0.24356	0.26148	0.48358	0.54383	——	——	——	——	——
Costa Rica	0.23504	0.26346	0.47675	0.53508	——	——	1.81538	0.25550	2.94457
Angola	0.22380	0.24190	0.45840	0.50210	1.89473	53.741	2.00815	0.26775	——

9) **Body weight** : With the 100 cm sample, this weight is heavier than that of any other waters. With the 150 cm sample, the weight is lighter than that of the east Arabian Sea's, but generally heavier than that of the other waters. Table 8 gives coefficients for x in equations of regression indicating the foregoing characteristics of the samples in various waters.

2. Ratio of sexes and morphometric differences

1) **Ratio of sexes** : According to our previous data, the male-female ratio of yellowfin tuna in the Indian Ocean increases, as we proceed northward or eastward, in favor of males. The data also show that in the eastern waters the majority are male. Our study on the samples of the waters covered by present report, however, has revealed that above 30° S lat. the majority are female, and that under this latitude the number of males increases as we proceed northward, but females are still predominant in number. It may be assumed, therefore, that in the Indian Ocean of January males constitute of the majority in the northeastern waters, while females are predominant in number in the southwestern waters.

2) **Morphometric differences** :

(1) **Head length** : With the 100 cm sample, no difference is noted among male and female. With the 150 cm sample, this length is slightly longer for male. From this, the rate of the head length-increment is larger for male, and that difference grows wider according to the body length increases.

(2) **Distance from tip of snout to insertion of first dorsal fin** : With the 100 cm sample, this distance is longer for female. On the contrary, with the 150 cm sample, the distance is longer for male. From this, it is understood that the rate of the distance-increment is larger for male, and that difference grows wider according to the body length increases or decreases.

(3) **Distance from tip of snout to insertion of second dorsal fin** : With the 100 cm sample, this distance is a little longer for male. On the contrary, with the 150 cm sample, the distance is longer for female. It may be said, therefore, that the rate of the distance-increment is, contrary to (2), larger for female, and that the distance between the first and second dorsal fins is longer for male in small specimens and longer for female in large ones.

(4) **Distance from tip of snout to insertion of anal fin** : With the both 100 cm and 150 cm samples, this distance is longer for female. The rate of the distance-increment, however, is larger for male, and that difference, therefore, became smaller according to the body length increases.

(5) **Greatest body depth** : With the 100 cm sample, this body depth is larger for female. On the contrary, with the 150 cm sample, the depth is larger for male. It is understood, that the rate of the depth-increment is greater for male, and that difference grows wider according to the body length increases or decreases.

3) **Composition of body length and body weight :**

(1) **Composition of body length :** The majority have body lengths ranging from 121—140 cm. Both sexes, those in the 121—130 cm bracket constitute of the major group, but females constitute of the second major group in the 131—140 cm bracket.

(2) **Composition of body weight:** The majority have body weights ranging from 81—130 lbs (37—59 kg). Both sexes, those in the 81—100 lbs (37—45 kg) bracket and in the 101—130 lbs (46—59 kg) bracket each constitute of two modes. The number of females in the latter bracket is slightly larger than that of males.

Conclusion

As the result of comparison between our yellowfin tuna samples caught in the southwestern of the Indian Ocean and those of the other waters, it may be summarized as follows :

1. **Head length:** The length is larger in small specimens (body length under 100 cm), and smaller in large specimens (body length above 150 cm).

2. **Distance from tip of snout to insertion of first dorsal fin :** The distance is shorter regardless of body length.

3. **Distance from tip of snout to insertion of second dorsal fin :** The distance is longer in small specimens, and generally shorter in large specimens. It may be said, therefore, that the distance between the first and second dorsal fins is longer in small specimens.

4. **Distance from tip of snout to insertion of anal fin :** The distance may be said to be generally longer regardless of body length.

5. **Height of second dorsal fin :** The height may be said to be generally higher regardless of body length.

6. **Length of pectoral fin:** The length is shorter regardless of body length.

7. **Height of anal fin:** The height, although higher than the east Pacific and Angola samples, may be said to be generally lower.

8. **Greatest body depth:** With small specimens, excluding mid-Indian Ocean's, the depth is generally smaller than that of the other samples, but large specimens, excluding Angola's, the depth is larger than that of the other samples.

9. **Body weight:** The weight is generally heavier regardless of body length. This tendency, however, turns downward according to the body length increases, since the rate of the body weight-increment is low.

10. **Differences between male and female :**

(1) **Head length:** Little difference is detected in small specimens, but in large ones the length is longer for male.

(2) **Distance from tip of snout to insertion of first dorsal fin:** The distance is longer for female in small specimens, and longer male in large ones.

(3) **Distance from tip of snout to insertion of second dorsal fin:** The distance is longer for male in small specimens, and longer female in large ones. The distance between the first and second dorsal fins, therefore, is longer for male in small specimens, and longer female in large ones.

(4) **Distance from tip of snout to insertion of anal fin:** The distance is longer for female regardless of body length. The difference, however, becomes smaller according to the body length increases, since the rate of the distance-increment is larger for male.

(5) **Greatest body depth:** The depth is larger for female in small specimens, and larger male in large ones.

As is apparent from the foregoing, many unique characteristics and some similarity to other samples are noted. The most notable discovery is that, as is clear from Tables 3 and 8, our samples present much resemblance to the Angola's than the any other waters', in the rate of growth of fin insertion, greatest body depth and height of anal fin, when their body length has grown from 100 cm to 150 cm. The Angola waters are on the other side of the African continent, and those waters that we covered are presumed to be partitioned with each other by the *West Wind Drift* which surrounds the Antarctica. However, NAKAMURA and YAMANAKA[5] have reported that in the Indian Ocean tunas have a property of distributing themselves according to systematic ocean currents.

The Atlantic tuna form has those characters found among Pacific tuna form, the so that the Pacific fishes are atmost identical with the Atlantic fishes, again the Atlantic fishes are similar to those of the Indian Ocean as reported by BEEBE and TEE-Van (1936), on these facts that our samples bear more resemblance to the samples of farther waters than to those of near waters, i.e. the Indian Ocean, provide grounds for the assumption that the yellowfin tuna, too, forming partly independent stocks all over the world but probably referable to a single species.

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