Bulletin of the Japanese Society of Scientific Fisheries 42 (11) 1229–1235 (1976)

Subpopulation Identification of Skipjack Tuna Specimens from the Southwestern Pacific Ocean*1

Kazuo FUJINO*2

(Received May 21, 1976)

A series of earlier genetic studies on blood groups and isozymes indicated the existence of at least two separate subpopulations of skipjack tuna, *Katsuwonus pelamis,* in the Pacific Ocean and that the boundary between ranges of the different subpopulations shifts east-westerly by season in the offshore waters of the east coast of Japan and in the waters between the Bonin-Mariana Chain and the international date line in the northwestern Pacific Ocean. Insufficient data, however, had made such description difficult for the southwestern Pacific Ocean. More recent genetic studies on blood specimens from the southwestern Pacific Ocean indicate that the boundary between ranges of the above two subpopulations stays within the Tasman Sea all the year round and suggest that the western limit of the range of the central-eastern Pacific subpopulation(s) extends to the west close to the east coast of New South Wales in early winter in the southern hemisphere. On the basis of genetic data accumulated for the last eleven years, rejection limits of frequencies of an allele, E^1_{SJ}, which determines the fastest band of serum esterase variants, were recalculated for the above two subpopulations.

On the basis of a series of genetic studies, FUJINO[1] concluded that there are at least two separate subpopulations of skipjack tuna, *Katsuwonus pelamis,* in the Pacific Ocean and that the boundary between migratory ranges of the different subpopulations shifts to the east in summer and to the west in fall and winter in the offshore waters of the east coast of Japan and in the waters between the Bonin-Mariana Chain and the international date line in the northwestern Pacific Ocean. With additional data on larval distribution and age composition of commercial catch, FUJINO[2] proposed a model of population structure and migration of the western Pacific subpopulation. Insufficient data, however, did not permit me to describe any further details on migratory pattern of fish from the different subpopulations in the southwestern Pacific Ocean. More recent collections of blood specimens from the areas make it possible to delineate more clearly the distribution of fish there.

Materials and Methods

Some 2,900 blood specimens (65 lots) were collected from skipjack tuna, *K. pelamis,* from the Pacific Ocean between 1971 and 1975 through the cooperation of many organizations (Table 1). In this table included are 4 lots of samples from Papua New Guinea

*1 Conducted in part at the National Marine Fisheries Service Southwest Fisheries Center, NOAA, Honolulu. Hawaii.

*2 Kitasato University School of Fisheries Sciences, Sanriku, Iwate Prefecture (藤野和男：北里大学水産学部).

Table 1. Skipjack tuna blood samples taken from the Pacific Ocean, 1971 to 1975*[1]

Area	Number of samples (lots)	Number of fish collected	Year
Japan	12	296	1973
Solomon Islands	12	264	1971
Papua New Guinea	9	177	1973, 1975
Papua New Guinea	4	631	1975*[2]
New Hebrides	7	139	1971
New Caledonia	2	98	1971
Australia	7	141	1975
Tasmania	1	25	1971
New Zealand	4	119	1971
Eastern Pacific	7	1,008	1975*[2]
Total	65	2,898	

*[1] Taken after the samples shown in FUJINO[2)] (Tables 1 and 2). *[2] By courtesy of Dr. G. SHARP, Inter-American Tropical Tuna Commission.

and 7 lots from the eastern Pacific, collected and analysed independently by the staff of the Inter-American Tropical Tuna Commission. Fish were captured by pole-and-line gears in the waters off Japan, Solomon Islands, and Papua New Guinea; by long-line primarily designed for large tunas in New Hebrides; by trolling in New Caledonia, Australia and Tasmania; by gillnetting in New Zealand; and by purse seining in the eastern Pacific. In the waters off New Hebrides, specimens, taken through a series of long-line operations during a single cruise, were pooled into one lot because of small numbers of fish caught. Blood specimen was taken by cardiac puncture with syringe from fish freshly caught, fish refrigerated for few days after being caught, or fish thawed after being kept frozen for up to several weeks as described in the earlier works[1)]. Blood specimen was added by an approximately equal amount of glycerol solution, kept frozen, and shipped with dry ice in an insulating container to laboratory for analysis as described before. After being analysed for genetic variations, frequency of gene E_{sj}^1 determining the fastest band of serum esterase was calculated for each lot and was used for subpopulation identification by comparing with rejection limits of the gene frequencies calculated for the two subpopulations. Phenotypes of serum esterases analysed by the staff of the Inter-American Tropical Tuna Commission were identified by comparing their incidences with those obtained by me.

Results

Fig. 1 shows locations where blood specimens were sampled from the southwestern Pacific Ocean. Results of subpopulation identification of specimens are summarized in Table 2 by geographical area. A good agreement in frequencies of phenotypes and gene E_{sj}^1 was seen between the results obtained by the staff of the Inter-American Tropical Tuna

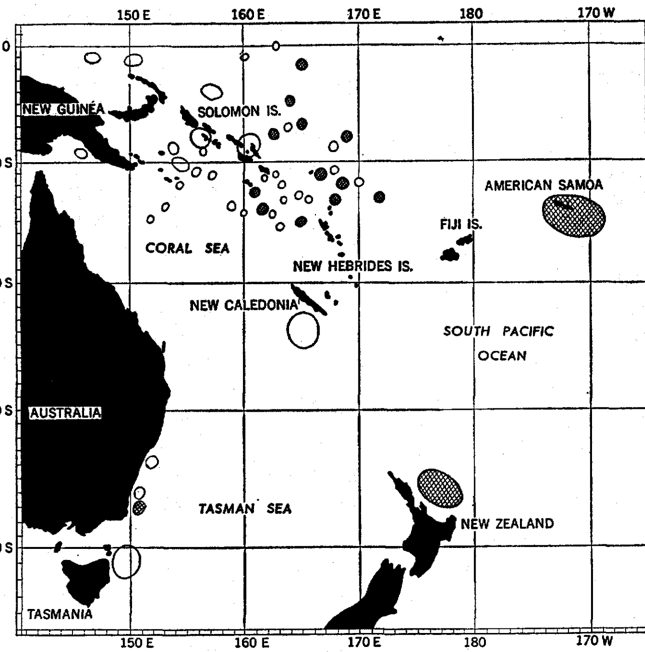

Fig. 1. Areas where blood specimens from skipjack tuna were sampled in the southwestern Pacific Ocean. Open areas show locations where fish of the western Pacific subpopulation were taken. Shaded areas show where fish of the central-eastern Pacific subpopulation(s) were taken.

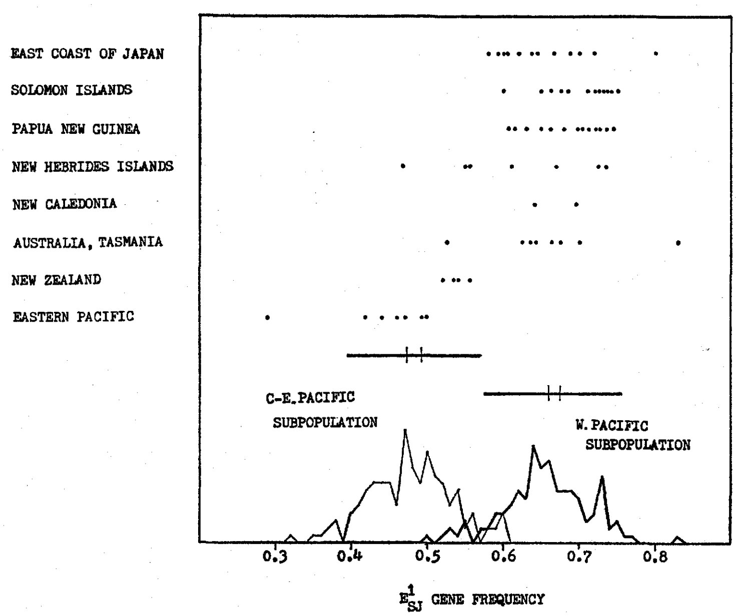

Fig. 2. Distribution of frequencies of an allele E^1_{SJ} of serum esterase system of skipjack tuna from the Pacific Ocean. Rejection limits in thick line with confidence limits are for the subpopulations indicated (at 5% significance level). Spotted are individual values representing samples shown in Table 2.

Table 2. Subpopulation Identification of Samples of Skipjack Tuna Taken from the Pacific Ocean, 1971–1975*1

Lot No	Number of fish examined	Month and year sampled	Locality: Latitude	Locality: Longitude	Freq. of gene E^1_{sj}	Fork length in cm	Subpopul. identif.
East coast of Japan							
90	24	Sep. 1973	41°N.	150°E.	0.667	N.D.*3	W. Pac. subpop.
91	25	Sep. 1973	41°N.	154°E.	0.600	N.D.	W. Pac. subpop.
92	25	Sep. 1973	40°N.	146°E.	0.800	N.D.	unidentified
93	25	Sep. 1973	37°N.	147°E.	0.700	N.D.	W. pac. subpop.
94	24	Sep. 1973	41°N.	146°E.	0.646	N.D.	W. Pac. subpop.
95	25	Sep. 1973	42°N.	146°E.	0.600	N.D.	W. Pac. subpop.
96	25	Sep. 1973	39°N.	147°E.	0.720	N.D.	W. Pac. subpop.
97	25	Sep. 1973	39°N.	147°E.	0.620	N.D.	W. Pac. subpop.
98	25	Oct. 1973	41°N.	147°E.	0.600	N.D.	W. Pac. subpop.
99	25	Oct. 1973	40°N.	146°E.	0.580	N.D.	W. Pac. subpop.
100	24	Oct. 1973	40°N.	146°E.	0.688	N.D.	W. Pac. subpop.
101	24	Oct. 1973	39°N.	146°E.	0.646	N.D.	W. Pac. supbop.
Solomon Islands							
1	45	Dec. 1971	Off Florida Is.		0.711	51–55	W. Pac. subpop.
2	15	Dec. 1971	Off Shortland Is.		0.667	52–54	W. Pac. subpop.
3	15	Dec. 1971	Off Shortland Is.		0.733	41–47	W. Pac. subpop.
4	15	Dec. 1971	Off Shortland Is.		0.600	52–54	W. Pac. subpop.
5	20	Dec. 1971	Off Shortland Is.		0.750	52–55	W. Pac. subpop.
6	15	Dec. 1971	Off Shortland Is.		0.733	50–60	W. Pac. subpop.
7	15	Dec. 1971	Off Shortland Is.		0.733	51–55	W. Pac. subpop.
8	20	Dec. 1971	Off Shortland Is.		0.650	50–60	W. Pac. subpop.
9	20	Dec. 1971	Off Shortland Is.		0.675	47–55	W. Pac. subpop.
10	15	Dec. 1971	Off Shortland Is.		0.733	46–52	W. Pac. subpop.
11	49	Jan. 1972	Off Florida Is.		0.735	51–64	W. Pac. subpop.
12	20	Feb. 1972	Off Florida Is.		0.675	50–60	W. Pac. subpop.
Papua New Guinea							
1	18	Nov. 1973	1° S.	150° E.	0.722	36–54	W. Pac. subpop.
2	8	Dec. 1973	1° S.	150° E.	0.688	52–57	W. Pac. subpop.
3	28	Dec. 1973	1° S	147° E.	0.696	52–60	W. Pac. supbop.
4	21	Jan.–Mar. 1975	Off Port Moresby		0.738	51–62	W. Pac. subpop.
5	18	Nov. 1975	9° S.	147° E.	0.722	55–58	W. Pac. subpop.
6	14	Nov. 1975	9° S.	153° E.	0.607	29–34	W. Pac. subpop.
7	30	Nov. 1975	9° S.	153° E.	0.617	27–36	W. Pac. subpop.
8	20	Dec. 1975	9° S.	153° E.	0.725	45–55	W. Pac. subpop.
9	20	Dec. 1975	9° S.	153° E.	0.700	29–69	W. Pac. subpop.
GS 1*2	146	Nov. 1975	10° S.	154° E.	0.664	49–63	W. Pac. subpop.
GS 2*2	162	Nov. 1975	10° S.	154° E.	0.633	49–63	W. Pac. subpop.
GS 3*2	144	Nov. 1975	10° S.	154° E.	0.653	43–50	W. Pac. subpop.
GS 4*2	179	Nov. 1975	11° S.	150° E.	0.746	47–60	W. Pac. subpop.
New Hebrides							
1	20	Mar.1971	11°–12°S.	167°–169°E.	0.550	48–65	C-E.Pac. subpop.
2	16	Jan.–Mar.1971	6°–14°S.	161°–168°E.	0.469	52–63	C-E.Pac. subpop.
3	18	Jan.–Apr.1971	0°–11°S.	157°–160°E.	0.611	47–66	W.Pac. subpop.
4	17	Jan.–Mar.1971	11°–15°S.	152°–166°E.	0.735	54–70	W.Pac. subpop.
5	15	Jan.–Apr.1971	12°–16°S.	160°–170°E.	0.733	49–66	W.Pac. subpop.
6	29	Mar.–May.1971	2°–15°S.	163°–172°E.	0.552	42–55	C-E.Pac. subpop.
7	24	Mar.–May.1971	11°–14°S.	154°–165°E.	0.667	48–68	W.Pac. subpop.

Continued from Table 2.

Lot No.	Number of fish examined	Month and year sampled	Locality Latitude	Longitude	Freq. of gene E^1_{ij}	Fork length in cm	Subpopul. identif.
New Caledomia							
1	52	Jan.1971	Off Noumea		0.644	43–48	W.Pac. subpop.
2	46	Feb.1971	Off Noumea		0.696	44–49	W.Pac. subpop.
Australia, east coast							
1	14	Mar.–Apr.1975	34°S.	151°E.	0.643	41–62	W.Pac. subpop.
2	40	Jun.1975	37°S.	150°E.	0.525	52–63	C-E.Pac. subpop.
3	17	Jun.1975	37°S.	150°E.	0.676	52–57	W.Pac. subpop.
4	9	Oct.1975	Off Sydney		0.833	42–46	unidentified
5	21	Oct.1975	Off Sydney		0.667	42–52	W.Pac. subpop.
6	32	Oct.1975	Off Sydney		0.641	42–46	W.Pac. subpop.
7	8	Nov.1975	Off Sydney		0.625	43–45	W.Pac. subpop.
Tasmania							
1	25	Mar.–Apr.1971	Off Tasmania Is.		0.700	49–59	W.Pac. subpop.
New Zealand							
4	23	Mar.1971	Off North Island		0.523	45–54	C-E.Pac. subpop.
5	53	Mar.1971	Off North Island		0.538	53–63	C-E.Pac. subpop.
6	18	Mar.1971	Off North Island		0.556	56–65	C-E.Pac. subpop.
7	25	Apr.1971	Off North Island		0.540	47–62	C-E.Pac. subpop.
Eastern Pacific*2							
GS 1	145	Jul.1975	23°S.	109°W.	0.493	44–58	C-E.Pac. subpop.
GS 2	198	Jul.1975	24°S.	113°W.	0.460	44–53	C-E.Pac. subpop.
GS 3	19	Jul.1975	24°S.	113°W.	0.289	55–68	unidentified
GS 4	199	Sep.1975	10°S.	81°W.	0.417	43–56	C-E.Pac. subpop.
GS 5	150	Oct.1975	24°S.	112°W.	0.497	41–62	C-E.Pac. subpop.
GS 6	161	Nov.1975	18°N.	112°W.	0.441	42–61	C-E.Pac. subpop.
GS 7	136	Nov.1975	18°N.	112°W.	0.471	40–56	C-E.Pac. subpop.

*1 Taken after the samples shown in Fujino[2]. *2 Four lots from Papua New Guinea and 7 lots from the eastern Pacific were collected and analysed by Dr. G. Sharp. *3 No available data.

Commission and those by *me*. The following statements can be drawn from this table: (1) Most samples from waters off east coast of Japan, Solomon Islands, Papua New Guinea, New Caledonia, east coast of Australia, and Tasmania were identified as fish from the western Pacific subpopulation. (2) Most samples from New Zealand and the eastern Pacific Ocean were identified as fish from the central-eastern Pacific subpopulation(s). (3) Four lots of samples from waters around New Hebrides were identified as fish from the western Pacific subpopulation and the other 3 lots from the central-eastern Pacific subpopulation(s); suggesting that fish both from different subpopulations migrate to the areas with time lag. (4) One sample (lot no. 2, 40 fish), taken from waters off east coast of Australia on June 18, 1975, was identified as fish from central-eastern Pacific subpopulation(s). The above observations support the proposed location of boundary between ranges of the different subpopulations (Fujino[2]) and suggest probable replacement of fish from one subpopulation by the other in the waters off east coast of New South

Wales in early southern winter.

On the basis of genetic data accumulated for the last eleven years, rejection limits (5% significance level) of frequency of gene E^1_{sj} were recalculated for the two subpopulations, giving figures of 0.394–0.570 for central-eastern Pacific subpopulation(s) and 0.578–0.758 for western Pacific subpopulation, in comparing with earlier figures of 0.379–0.587 and of 0.573–0.765 for the above subpopulations respectively. Disappearance of the overlapping portion of the two sets of figures after recalculation will reduce occasions in which sample be unidentified. Fig. 2 shows frequency distribution, rejection limits, and confidence limits of gene E^1_{sj} for two subpopulations together with the figures representing individual samples listed in Table 2.

Discussions

All available genetic data indicate that boundary between ranges of western Pacific subpopulation and central-eastern Pacific subpopulation(s) exists within the Tasman Sea all the year round, suggesting smaller extent of east-west shifts by season than those in the northern hemisphere. Occurrence of one sample (lot no. 2) suggests that western limit of range of the central-eastern Pacific subpopulation(s) extends to the west close to the east coast of New South Wales in early southern winter. A series of intensive collections of specimens, however, is badly needed from the areas as well as the neibouring waters before any conclusive statements on seasonal shifts of boundary of ranges between subpopulations. Since each sample from the waters off New Hebrides, as stated already, consists of specimens taken during several weeks by a series of long-line operations, intensive and extensive sampling is necessary to locate boundary of ranges in different seasons more accurately.

Acknowledgements

Mr. R. S. Shomura, Southwest Fisheries Center, Honolulu, Dr. H. Omura, the Whales Research Institute, Tokyo, and Dr. J. Joseph, Inter-American Tropical Tuna Commission, La Jolla gave me encouraging supports for continuing the present research. Drs. S. Hirao and A. Suzuki, Tokai Regional Fisheries Research Laboratory, Tokyo, kindly provided me laboratory facilities for analysing research materials. The cooperation of Dr. R. Kearney, South Pacific Commission, Noumea, Mr. A. D. Lewis, Department of Agriculture, Stock and Fisheries, Papua New Guinea, Dr. G. I. Murphy and Mr. K. Williams, C.S.I.R.O., Australia, Mr. J. F. Grant, Tasmanian Department of Agriculture, Tasmania, Dr. M. Legand and Mr. M. R. Grandperrin, O.R.S.T.O.M., Noumea, New Caledonia, Dr. D. Eggleston and Mr. A. G. York, Marine Department, New Zealand, Drs. S. Ueyanagi and S. Kikawa, Far Seas Fisheries Research Laboratory, Japan, Mr. T. Konagaya, Shizuoka Prefectural Fisheries Experimental Station, Japan, and staff of

Taiyo Fishing Company, Tokyo, in collecting research materials and careful technical assistance of Messrs. R. BIERMA and M. MUROFUSHI and Mrs. T. KANAMORI are greatly appreciated. Dr. G. SHARP generously provided me his unpublished data for comparisons.

References

1) K. FUJINO: *Trans. Amer. Fish. Soc.*, **99**, 152–178 (1970).
2) K. FUJINO: In "The KUROSHIO II, Proceedings of the Second Symposium on the Results of the Cooperative Study of the Kuroshio and Adjacent Regions" (ed. K. SUGAWARA), Saikon Publ. Co., Tokyo, 1972, pp. 373–384.