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AN OVERVIEW OF RESULTS FROM ANALYSES OF DATA ON GROWTH OF SKIPJACK

(Paper Prepared by the Skipjack Programme)

1.0 INTRODUCTION

In 1977 the South Pacific Commission established the Skipjack Survey and Assessment Programme to study, among other things, skipjack population dynamics and subpopulation structure. From October 1977 to August 1980, the Programme tagged over 150,000 tuna throughout the western and central Pacific, of which over 6,000 have been recovered to date. This document presents some of the results from a study whose object was to examine patterns of regional variation in the growth rates of tagged skipjack. It was hoped that an analysis of geographic variation in growth rates would shed some light on the extent to which skipjack population dynamics as a whole varies across the region.

2.0 DIFFERENCES IN GROWTH BETWEEN THE EASTERN AND WESTERN PACIFIC

In preliminary growth results presented to the Twelfth Regional Technical Meeting on Fisheries in November 1980 (Skipjack Programme 1980), there was an emphasis on the comparison of von Bertalanffy growth curves fitted to data from the eastern Pacific (Joseph and Calkins 1969) and from several Island States in the western Pacific. These initial results suggested that the mean length at age of young fish in the western Pacific is substantially higher than for the eastern Pacific, and that the average assymptotic size is lower, about 60 cm compared to about 85 cm.

Subsequently, however, it was felt that these comparisons were not entirely valid, since the growth curves for the western Pacific were based on data for quite a different distribution of sizes of fish and times at large than for the data used to fit the eastern Pacific growth curve. To check this, a data set was constructed which more evenly matched that of the eastern Pacific.

In so doing, data from fish tagged in Papua New Guinea, Solomon Islands and Fiji were aggregated. From this large set, a smaller set was taken which matched almost point for point the distribution of release lengths and times at large of the eastern Pacific data set. Data were selected in such a way that no bias was introduced into the growth increments. Unmatched data in both the eastern Pacific data set and the aggregated western Pacific set were rejected, leaving 361 matched data points in each of the two sets. As can be seen in Figures 1 and 2, the growth curves fitted to the matched data sets are quite similar compared to curves fitted to the unmatched sets.

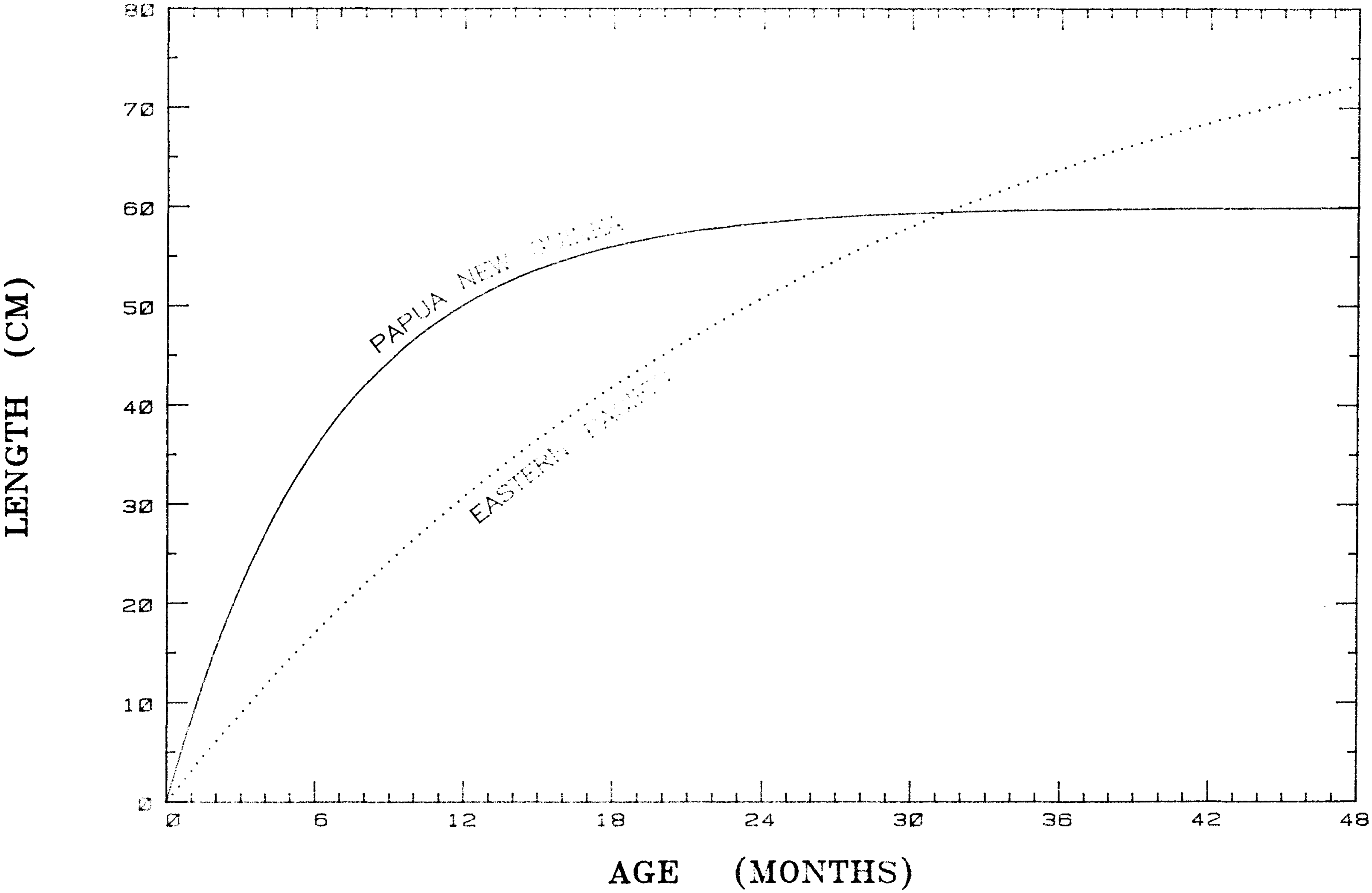

Figure 1. Skipjack growth curves for the Papua New Guinea and eastern Pacific data sets. Von Bertalanffy parameters K and L-infinity are 1.81 years^{-1} and 60.0 cm (n=343) respectively for Papua New Guinea, and 0.43 years^{-1} and 88.1 cm (n=67 averaged from 438) for the eastern Pacific (Joseph and Calkins 1969).

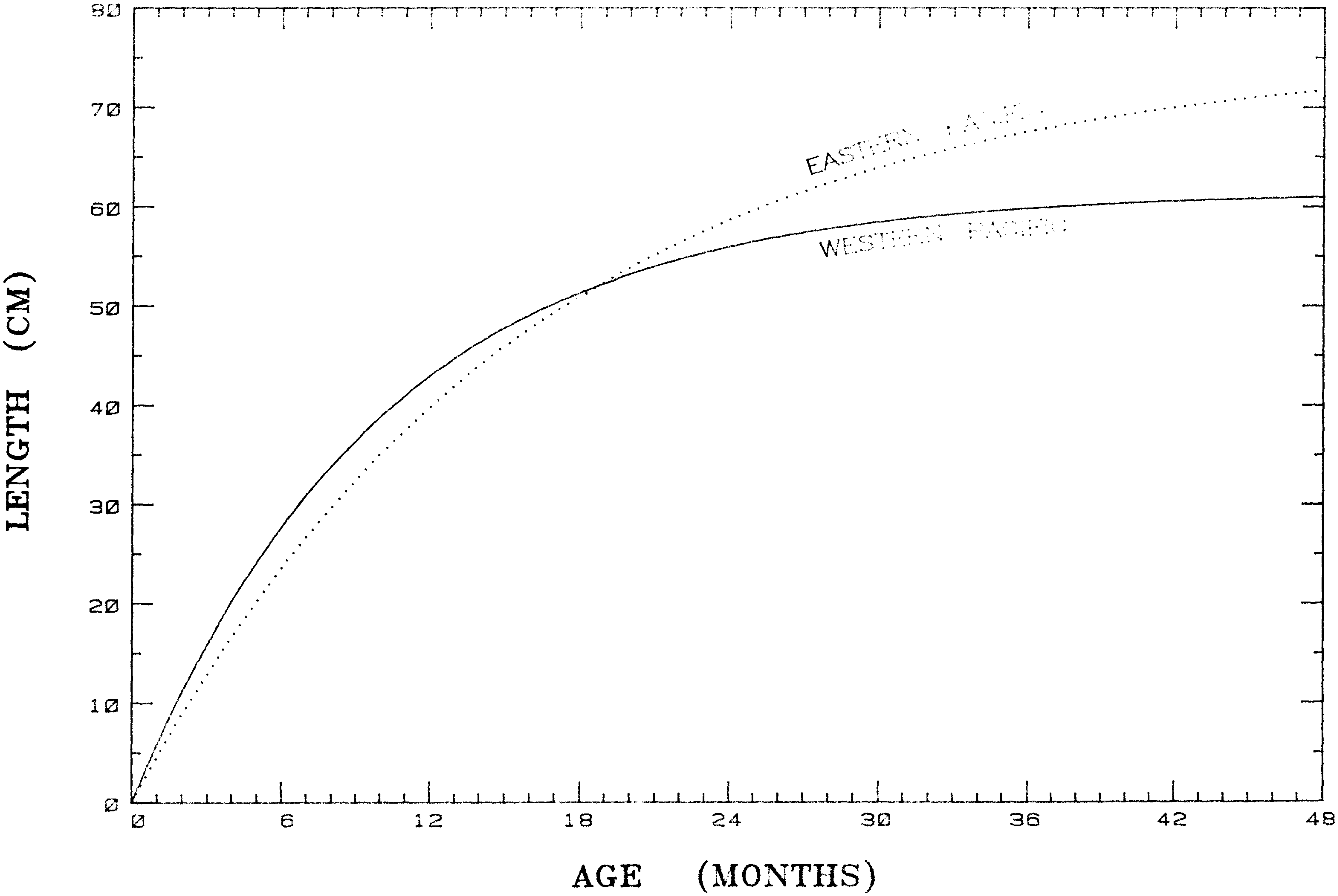

Figure 2. Skipjack growth curves for the western Pacific and eastern Pacific <u>matched</u> data sets. Von Bertalanffy parameters K and L-infinity are 1.20 years^{-1} and 61.5 cm (n=361) respectively for the western Pacific, and 0.75 years^{-1} and 75.5 cm (n=361) for the eastern Pacific.

The discrepancy between the two outcomes is due in part, of course, to changes in the distribution of the data, but it is also due to the manner in which we interpret growth curves. In Figures 1 and 2, the results are extrapolated back to length zero, beyond the range represented by the data. This is legitimate if we have evidence that growth is adequately represented by the von Bertalanffy model over the whole of the fish's life. But if we have no such evidence, we ought to view the growth curves starting at the length at which our data begins. Figure 3 shows the growth curves for the eastern and western Pacific presented in Figure 1 truncated at 45 cm. Beyond 45 cm, the growth curves are not as different as they appear to be when extrapolated to length zero. This observation corroborates the results from the matched data sets, and altogether the data suggest that growth rates for 45 cm skipjack in the eastern and western Pacific are roughly the same, and that growth rates for 50-60 cm fish in the eastern Pacific are faster than for 50-60 cm fish in the western Pacific.

Another method of comparing growth between regions is to examine average growth rates directly, rather than fitting the data to a growth model. The problems with each method are similar. A growth model makes an assumption on how the growth rate changes with size of fish and allows, in theory, data for any size fish to be used in estimating the model parameters. In practice, however, as pointed out above, different results are obtained from data for different sized fish. On the other hand, unless growth rates are constant over size of fish and time at large, average growth rates calculated for different areas will be comparable only when the distributions of both size and time at large are similar. This is rarely the case for whole data sets, but usually there is a subset of the data that satisfies these conditions.

Recently, the Inter-American Tropical Tuna Commission has published some comparisons of average growth rates between eastern and western Pacific skipjack. Those results also suggest that growth rates for fish over 50 cm in the eastern Pacific are faster than for the western Pacific. For fish at large two to five months, it was found that growth of 50-55 cm and 55-60 cm eastern Pacific skipjack were 21.74 and 16.57 cm/yr respectively (IATTC 1981), compared to 7.65 and 7.20 for Papua New Guinea fish (Josse _et al_ 1979).

In sum, it appears that larger skipjack grow faster in the eastern Pacific than in the western Pacific. Data for smaller fish are sparse and inconclusive.

3.0 GEOGRAPHIC VARIATION IN GROWTH OF SKIPJACK WITHIN THE SPC REGION

Average growth rates of skipjack tagged within the 200-mile economic zones of those countries for which adequate data were available (Papua New Guinea, Solomon Islands, Kiribati, Fiji, New Zealand, and a similar zone for Ponape) were examined in detail. Only data for fish tagged _and recaptured_ within a given area were used, though whether fish were resident between tagging and recapture can only be surmised. At the least, fish were present during two periods of their lives, supporting the assumption that growth rates were representative of the area during the time of study.

Two size classes were examined, 40-49 cm and 50-59 cm. Data for fish less than 40 cm or greater than 60 cm were too few to include in the analysis. Shorter length intervals were not used since sample sizes for some of the countries were too small. Two classes of time at large were used, 31-180 days and 181-450 days. Data for fish at large 0-30 days were considered relatively uninformative of growth and were not used to estimate growth rates.

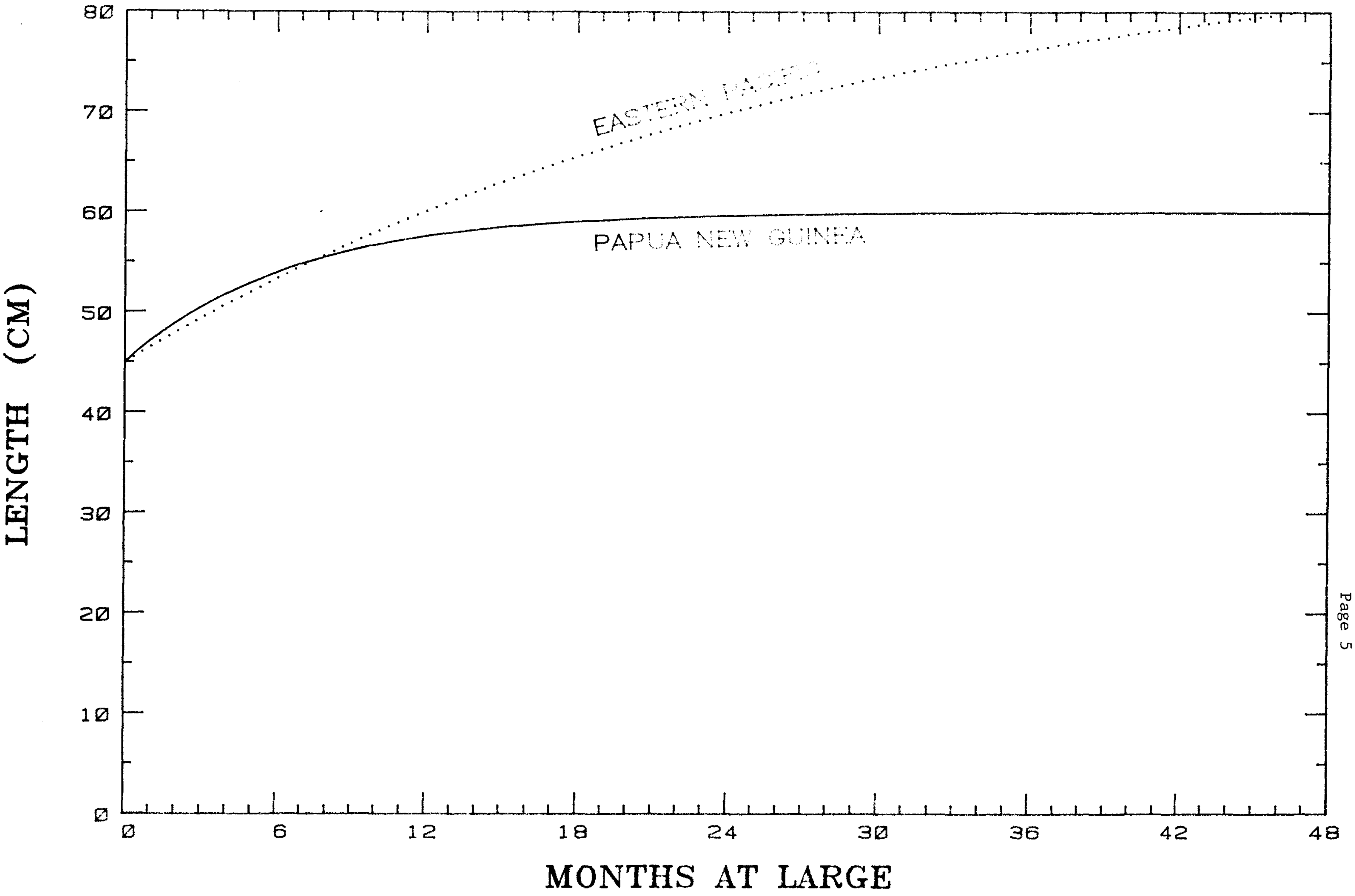

Figure 3. Truncated skipjack growth curves for the Papua New Guinea and eastern Pacific data sets. Von Bertalanffy parameters are as for Figure 1.

The results in Table 1 show average growth rates for data corrected for length measurement bias. Some sample sizes are very small and some estimates of growth rate are very unreliable, therefore caution must be exercised in interpreting these results. (In Table 1, growth rates with standard errors greater than 4.0 cm or from samples of five observations or less were marked "unreliable".) Three features, however, stand out clearly from the reliable estimates of growth rate. First, there is a consistent decrease in growth rate with size. Second, except for one country, there is a consistent decrease in growth rate with time at large. Third, there is substantial variation in growth rates among areas.

Fiji appeared to have relatively fast growing fish in both size classes, while Kiribati fish were relatively slow growing. Solomon Islands fish were intermediate. Smaller Papua New Guinea skipjack appeared to be growing very fast, whereas larger fish were intermediate. On the other hand, smaller fish in Ponape were intermediate, while larger fish were growing relatively fast.

The results for New Zealand are curious. Apparently smaller fish, during the time of the study, were growing slower than large fish, in contrast to the pattern observed for all other countries. Seasonal immigration of distinct size classes are suspected to occur for this fishery, hence slower growth for small fish may reflect differences in nutritional state or potential for growth between fish migrating from distinct environmental conditions. All but one of the New Zealand growth rates were considered unreliable, however, and this result may have been a statistical artifact.

4.0 TEMPORAL VARIATION IN GROWTH RATES

It is important to determine whether the geographic differences in growth rates observed above are stable over time. If growth rates within a given area are temporally invariant, this suggests that either the fish inhabiting the area or the environmental conditions or both are relatively constant. If, on the other hand, growth rates are seen to vary through time, either the fish or the environment or both are presumably in a state of flux.

The SPC research vessel made two (sometimes three) tagging trips, usually separated by about a year, to most island groups in the region. Even so, the data available to make comparisons of growth rates between visits are few. Usually only one trip was successful in tagging enough fish to estimate growth rates. Moreover, in the case of Fiji, where two trips were successful, recoveries from the first visit (at large for more than 30 days) were predominantly from fish at large for two to three months, while fish for the second visit were mostly at large for about ten months, hence the data are not really comparable.

Adequate growth data does exist, however, from two visits to Solomon Islands, and our data for Papua New Guinea can be compared to data from tagging studies carried out in 1972-1974 by Papua New Guinea´s Department of Primary Industry (data published in Josse _et al_ 1979).

Table 2 shows growth rates estimated for Papua New Guinea fish at large 31-180 days and 181-450 days, and for Solomon Islands fish at large for 181-450 days. For the 31-180 day Papua New Guinea fish, the differences in growth rates between 1972-1974 and 1979 are not statistically significant.

TABLE 1. AVERAGE GROWTH RATES FOR VARIOUS AREAS WITHIN THE SPC REGION

Unreliable estimates are marked by an X.

Fish at large 31-180 days

	40-49 cm at release							50-59 cm at release						
Area	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)
Ponape	X	1	48.0	170	21.06	-	-		9	52.6	100	13.67	2.05	6.15
Papua New Guinea		16	46.7	68	20.85	3.62	14.47		292	55.0	65	5.40	0.69	11.75
Solomon Islands		87	44.9	104	12.72	1.20	11.23		42	53.2	96	5.75	2.84	18.43
Kiribati		180	47.6	65	9.46	0.74	9.96		39	51.6	65	1.42	2.05	12.78
Fiji		38	46.0	67	17.23	2.42	14.89	X	12	52.4	66	11.95	6.00	20.79
New Zealand	X	2	45.0	52	-6.75	6.92	9.78	X	3	53.5	62	14.55	1.88	3.26

Fish at large 181-450 days

	40-49 cm at release							50-59 cm at release						
Area	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)
Ponape	X	3	48.5	196	13.78	1.76	3.06	X	4	50.9	217	12.89	1.57	3.13
Papua New Guinea	X	3	44.2	271	19.38	4.44	7.70		15	53.8	368	8.23	0.63	2.45
Solomon Islands		77	45.3	267	11.37	0.90	7.90		50	53.2	303	4.08	0.90	6.35
Kiribati	X	1	46.0	408	5.43	-	-		0	-	-	-	-	-
Fiji		20	46.7	316	16.16	0.87	3.91		10	53.0	316	7.01	1.93	6.10
New Zealand		11	46.4	330	8.41	0.86	2.85	X	3	50.8	322	13.44	0.55	0.95

TABLE 2. AVERAGE GROWTH RATES FOR PAPUA NEW GUINEA AND SOLOMON ISLANDS BY VISIT

Unreliable data are marked by an X.

		40-49 cm at release							50-59 cm at release						
Area	Year of release	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)	Reliability	Sample size	Average release length (cm)	Average days at large	Average growth rate (cm/yr)	Standard error (cm)	Standard deviation (cm)
Papua New Guinea 31-180 days	1972-74	X	5	47.2	128	14.18	3.60	8.05		76	54.8	107	6.75	0.75	6.52
	1979		16	46.7	68	20.85	3.62	14.47		292	55.0	65	5.40	0.69	11.75
Papua New Guinea 181-450 days	1972-74		7	47.3	295	7.09	1.72	4.55		64	54.9	314	5.33	0.52	4.16
	1979	X	3	44.2	271	19.38	4.44	7.70		15	53.8	366	8.23	0.63	2.45
Solomon Islands 181-450 days	1977	X	5	49.0	317	6.46	1.37	3.06		26	53.1	334	5.44	0.83	4.22
	1980		72	44.8	252	12.54	0.97	8.27		24	53.3	270	1.08	2.00	9.81

For the 181-450 day Papua New Guinea fish, however, the differences are significant. Altogether, the Papua New Guinea data suggests that growth rates have increased considerably for 40-49 cm skipjack, though growth rates for 50-59 cm fish in 1979 were much the same as in 1972-1974. The Solomon Islands data shows significant changes in growth rates between 1977 and 1980 for 40-49 cm fish, which were apparently growing slower in 1977.

To try and describe temporal variation in growth from this limited data set would be dangerous, yet one feature is clear: growth rates do vary through time. It appears that variation is greater for smaller fish and that the degree of temporal variation is similar to the degree of geographic variation noted above.

5.0 A MULTIVARIATE ANALYSIS OF SKIPJACK GROWTH

In an attempt to account for observed regional variation in growth rates, several variables for which data were available were examined using multivariate statistics. Average instantaneous growth in weight for fish at large 31-90 days was found to be correlated with size of fish, skipjack abundance as measured by the average number of skipjack schools sighted per hour fishing, sea surface temperature, and predicted skipjack serum esterase gene frequency. Presumably predicted esterase gene frequency is some measure of population structuring (Skipjack Programme 1981), and is possibly a surrogate variable for some environmental factor or group of factors that condition growth processes.

The four-variable model accounted for 51% of the variation about the mean and the root residual mean square was 0.343 kg/year. Partial F values showed that all variables were statistically significant at $P<.05$, except esterase gene frequency, which was significant at $P<.10$.

These results suggest that growth rates are sensitive to environmental variables, and both confirm and help to explain the geographic and temporal variation in growth discussed in sections 3.0 and 4.0 above.

6.0 DISCUSSION: SKIPJACK GROWTH AND THE CHANGING ENVIRONMENT

In the past, growth rates for skipjack have been determined from growth marks laid down on vertebral centra, dorsal spines, otiliths, and scales, from temporal progressions in length frequency modes, and from tag-recapture data. Reviews of these studies (Joseph and Calkins 1969, Matsumoto and Skillman 1975, and Josse *et al* 1979) point out wide variation in estimates of growth rates and von Bertanlanffy growth parameters. In retrospect, this is not surprising; though much of the variation has been due to differences in methodology and distributions of size of fish examined, it has long been known that growth of fish is related to many environmental variables, including abundance of food, stock density, competitor density, temperature, and other biotic and abiotic factors. This is particularly relevant to studies of skipjack growth since, with few exceptions, conclusions have been based on small samples taken from very small geographic areas. Hence many of the growth models reported in the literature have likely reflected the response to ephemeral local conditions, rather than the average growth behaviour over broader environments that the models are often meant to convey.

On a local scale, it appears that growth of skipjack is quite responsive to their environment. This contrasts with the notion of deterministic growth within a homogeneous environment invoked by the von Bertalanffy model. If local conditions are changing, or if fish move from one area to another, growth is probably a more discontinuous process. This implies that the von Bertalanffy model, or any other model in which growth rates depend only on size of fish, is valid only over an aggregation of localities or time periods.

The data presented here are consistent with Kearney´s (1978) suppositions, and with Josse _et al_´s (1979) hypothesis of "ecological compartments". Simply stated, certain configurations of various environmental conditions are conducive to rapid growth, whereas others are not.

While our picture of skipjack growth responses is becoming more detailed, there are still, however, many unanswered questions.

First, how stable are conditions within a given locality? Though results presented in section 4.0 suggest that conditions vary, the data is as yet too sparse to draw any firm conclusions. The question remains as to the magnitude of temporal variation relative to geographic variation.

Second, what environmental variables are responsible for observed variation in growth rates? Section 5.0 indicated that growth may be strongly temperature and density-dependent, but the quality of environmental indices, especially for skipjack abundance, was poor, and only half of the variability was accounted for. Future tagging studies would benefit from development of improved abundance indices for skipjack, and their food and competitor densities in this regard.

Third, how sensitive are other population parameters to environmental heterogeneity? Growth rates reflect the quality of the fish´s habitat, its "well-being". Natural mortality rates, which also reflect habitat quality, probably respond to environmental changes as well. Moreover, rates of movement may be a function of habitat and "well-being", and therefore responsive to environmental flux. Clearly, there is a possibility that skipjack population parameters are very dynamic, but as yet neither the degree of environmental heterogeneity, nor the effect on skipjack populations are well understood.

LITERATURE CITED

IATTC (1981). Bi-monthly Report. January-February 1981. Inter-American Tropical Tuna Commission, La Jolla, California.

JOSEPH, J. and T.P. CALKINS (1969). Population dynamics of the skipjack tuna, *Katsuwonus pelamis*, of the eastern Pacific Ocean. IATTC Bulletin 13(1): 273p.

JOSSE, E., J.C. LE GUEN, R.E. KEARNEY, A.D. LEWIS, B.R. SMITH, L. MAREC, and P.K. TOMLINSON (1979). Growth of skipjack. Occasional Paper No.11, South Pacific Commission, Noumea, New Caledonia.

KEARNEY, R.E. (1978). Some hypotheses on skipjack (*Katsuwonus pelamis*) in the Pacific Ocean. Occasional Paper No.7, South Pacific Commission, Noumea, New Caledonia.

MATSUMOTO, W.M., and R.A. SKILLMAN (1975). The biology, ecology, and resource of the skipjack tuna, *Katsuwonus pelamis*. Southwest Fisheries Centre Administrative Report No.12H, National Marine Fisheries Service, Honolulu, Hawaii.

SKIPJACK PROGRAMME (1980). Summary of Skipjack Survey and Assessment Programme Preliminary Growth Data. SPC/Fisheries 12/WP.19, South Pacific Commission, Noumea, New Caledonia.

SKIPJACK PROGRAMME (1981). An appraisal of the genetic analysis of skipjack blood samples. SPC/Fisheries 13/WP.10, South Pacific Commission, Noumea, New Caledonia.