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EFFECTS OF SKIPJACK TAGGING PROCEDURES ON SUBSEQUENT TAG RECOVERIES

(Paper Prepared by the Skipjack Programme)

1.0 INTRODUCTION

The Skipjack Survey and Assessment Programme tagged 139,961 skipjack during a three year period from October 1977 to August 1980. At the time of writing over 6,000 of these tags had been returned to the South Pacific Commission (SPC) headquarters in Noumea. These returns afford an excellent opportunity to study the effects of certain tagging procedures and to improve tagging techniques for future tuna research. In addition, the data give some insight into the assumption that tagging does not alter certain aspects of skipjack behaviour.

Data from a double tagging experiment were analyzed to estimate tag shedding rates, and comparisons were made concerning return rates, growth, and migration between single and double tagged fish. An additional five factors were examined for their effect on subsequent tag recovery rates: length of tags, size of fish, condition of the fish at time of release, and tagger/cradle position.

2.0 METHODS

All tagging techniques mentioned in this report are described in detail in "Methods Used By the South Pacific Commission for Tagging Skipjack and Other Tunas" (Gillett and Kearney, MS).

In summary, the tagging procedures consisted of hooking a skipjack with a barbless lure and carefully raising the fish to the tagging cradle level. An assistant standing next to the tagger directed the fish gently into the cradle by grabbing the fishing line. The tuna frequently became unhooked by itself; otherwise twitching on the line was normally sufficient. If the fish was deeply hooked, it was discarded. The tagging assistant made a preliminary assessment of any damage to the fish and rejected those that appeared injured. Care was taken not to handle the fish by the relatively fragile tail. The assistant then slid the tuna, the left side up, head towards narrow end of the cradle, to the tagger. The tagger made a final evaluation of the condition of the fish. Criteria for rejection included bleeding anywhere, except for minor hook wounds, slime oozing from the mouth or eye, or rough treatment by the assistant. The tuna was carefully pushed until its nose touched the padded block at the narrow end of the cradle and was measured to the fork length of the tail against the calibration on the cradle cover. The dart tag was inserted just posterior to the insertion of the secondary dorsal fin and sufficiently deep so that the barb interlocked behind or below the fin ray supports of the secondary dorsal fin, but not so deep as to cause unnecessary damage to underlying tissue. The quality of the insertion operation, together with any distinguishing characteristics of the fish, was tape recorded. Tagged fish were promptly returned to the water, head first if possible.

3.0 RESULTS

The following analyses were performed between May and August 1981. As tag returns were still being received at the time of writing, the results could change slightly with time. However, general conclusions are not expected to change with additional returns.

3.1 Double Tagging

During April 1980 a double tagging experiment was carried out in Fiji. Fish were tagged alternately singly and doubly from every school by three SPC scientists who rotated their tagging station every day. In addition, two visiting scientists exclusively single tagged fish. The present analysis includes only those skipjack tagged by SPC personnel in April 1980. Two methods of double tagging fish were used and evaluated, rubber double tagging and conventional double tagging. A total of 5,399 skipjack were double tagged and 5,625 were single tagged.

3.1.1 Tag shedding rates

Of the 481 returns of double tagged fish, 467 pairs of tags were intact, and 14 pairs were missing a partner. No pattern was apparent for the unpartnered tags with respect to size class, tagger, rubber/conventional double tagging, cradle, or area of release.

Factors responsible for the double tags being returned as singles included:

1) The shedding of one of the two tags after the fish had been released and before recapture.

2) The loss of one of the two tags by the finder(s) of the tags.

3) Loss of one tag by abrasion due to handling after capture.

It is known that item 2 above has occurred as there have been several situations in which this irregularity was discovered and subsequently rectified. For example, tag no. C22480 was returned by the captain of a fishing vessel on February 6, 1981 and its partner, C22479, was assumed to have been shed. However, a crew member on the same vessel apparently took one of the two tags (presumably to guarantee himself a T-shirt reward), and returned it on March 28, 1981. This has been known to occur with five different pairs of tags. Because the captains of the fishing vessels are more conscientious concerning the return of tags, there is a much higher chance that the crew member will fail to return his half of the tag through loss or lack of interest.

Therefore, the 14 non-intact tag pairs returned to SPC are a maximum estimate of shedding with the actual value probably being less. Nevertheless, the following analysis assumes that these non-intact pairs were all due to shedding.

The distribution with respect to time of fish double tagged and returned with a single tag (NDS) and fish double tagged and returned with both tags (NDD) is as follows:

Days at liberty	NDS*	NDD*	NDS/NDD
0-10	3	302	.0099
11-30	3	68	.0441
31-180	0	19	.0000
181-360	5	53	.1132
361-450	2	10	.2000
	13	452	

* Only includes returns for which days at liberty is known (one unpartnered pair returned without date of recapture).

Using the Gulland method (Gulland, 1963) the annual instantaneous tag shedding rate was estimated to be .0759. Immediate tag shedding appears to be quite low as shown by the small NDS/NDD value for the recoveries in the first 10 days. Analysis by other methods is currently in progress and results will appear in a future publication. Results of previous double tagging studies on tuna analyzed, by a variety of techniques, are as follows:

Study	Area/Species	Shedding Result
Baglin et al. (1980)	Atlantic Bluefin	.04 immediate .205 annual instantaneous
Bayliff and Mobrand (1972)	Eastern Pacific Yellowfin	(approx.) .087 immediate .278 annual instantaneous
Chapman et al. (1965)	Eastern Pacific Yellowfin	.814 annual instantaneous (assumed no immediate shedding)
Kirkwood (1979)	Australia Southern Bluefin	.19 to .38 annual instantaneous (one of several models used)
Laurs et al. (1976)	Northern Pacific Albacore	.12 immediate .086 to .098 annual instantaneous
Lewis (1980)	Western Pacific Skipjack	2 out of 29 double tag returns were unpaired in an unspecified time over 390 days

The difference between the low rate obtained by SPC for skipjack and the rates by other organisations involved in tagging tunas could be accounted for by a number of factors, including differences in tag inserting techniques, type of tag, fishing technique used for the recovery, and species of tuna being tagged.

3.1.2 Comparison of single tag and double tag return rates

Single tag recovery rate (adjusted for shedding) $= \frac{527}{5,625} = .094$

Double tag recovery rate $= \frac{481}{5,399} = .089$

A T-test on these two rates failed to show a significant difference (P=.36).

To investigate the influence of time at liberty on recovery rates recoveries were broken down into time periods and T-tests were performed on each interval, and no significant differences were found:

Time at liberty	Single returns in period	Double returns in period	Single rate	Double rate	P value
0-5 days	157	121	.028	.022	.07
6-10 days	158	184	.028	.034	.07
11-30 days	94	71	.017	.013	.16
31-180 days	23	18	.004	.003	.50
>180 days	55	49	.010	.009	.70

(Data as of June, 1981)

Combining the probabilities from these independent tests likewise reveals no significant difference overall (P=.0877). Figure 1 depicts these results.

The smallest size class for which sufficient data was available in the double tagging experiment (401-450mm), was analyzed for single versus double tag return rate differences. A T-test for the differences between proportions reveals a significant difference. All other size categories were then tested similarly. However, they failed to show a significant difference.

Size	Double releases	No. of doubles returned	Single releases	No. of singles returned	Return rate double	Return rate single	P value
401-450	851	15	874	34	.018	.039	.01
451-500	2,146	161	2,436	200	.075	.082	.37
501-550	1,800	205	1,958	238	.114	.123	.47
551-600	281	36	277	36	.128	.130	.94

Figure 2 shows the return rates for single versus double tags for the different size classes.

The only significant difference between the return rate of single and double tags was noted at the smallest size class. The additional lethal effects of double tagging in this case presumably have resulted in a lower return rate for double tagged fish relative to single tagged fish of the same size class, so it is reasonable to believe that for ordinary single tagging, tagging mortality is higher in this size class than for the other size classes.

3.1.3 Conventional rubber tagging versus rubber double tagging

Two techniques of double tagging were used. One method termed conventional double tagging, involves inserting a single tag into the fin ray supports or neural spines of the secondary dorsal fin on the left side of the fish, and immediately thereafter applying a second tag on the same side of the fish approximately one centimetre in front of the first. The other method, "rubber double tagging", uses a piece of conveyor belt rubber to join two applicating needles together. One needle of each pair was approximately 1.5 cm higher than the other to permit simultaneous insertion of the two tags at the proper angle relative to the tuna body. Results show:

Rubber double return rate $\frac{316}{3,882} = .081$

Conventional double return rate $\frac{143}{1,517} = .094$

A T-test on these rates failed to show a significant difference (P=.13).

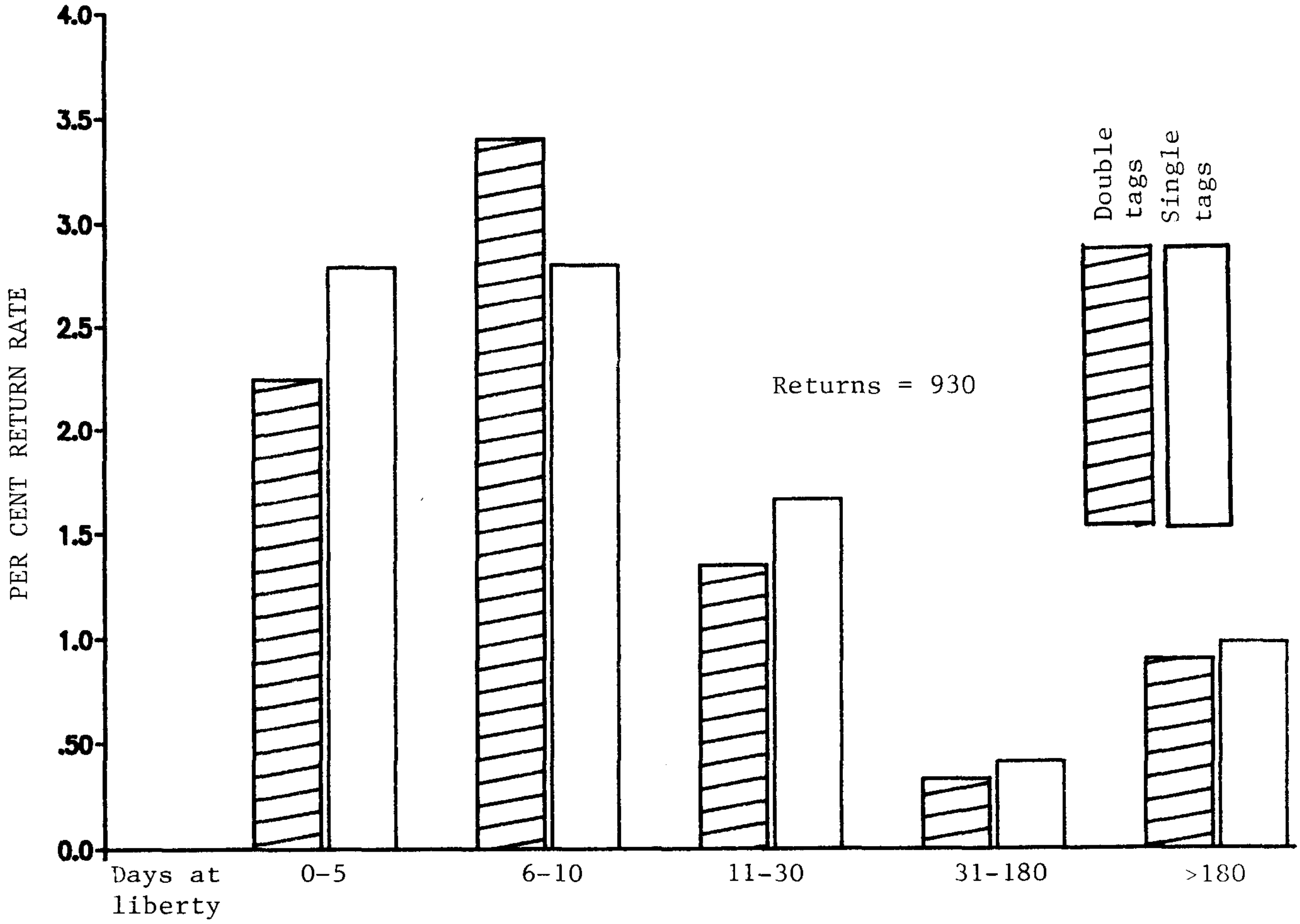

FIGURE 1 - RETURN RATES OF SINGLE AND DOUBLE TAGGED FISH WITH RESPECT TO DAYS AT LIBERTY

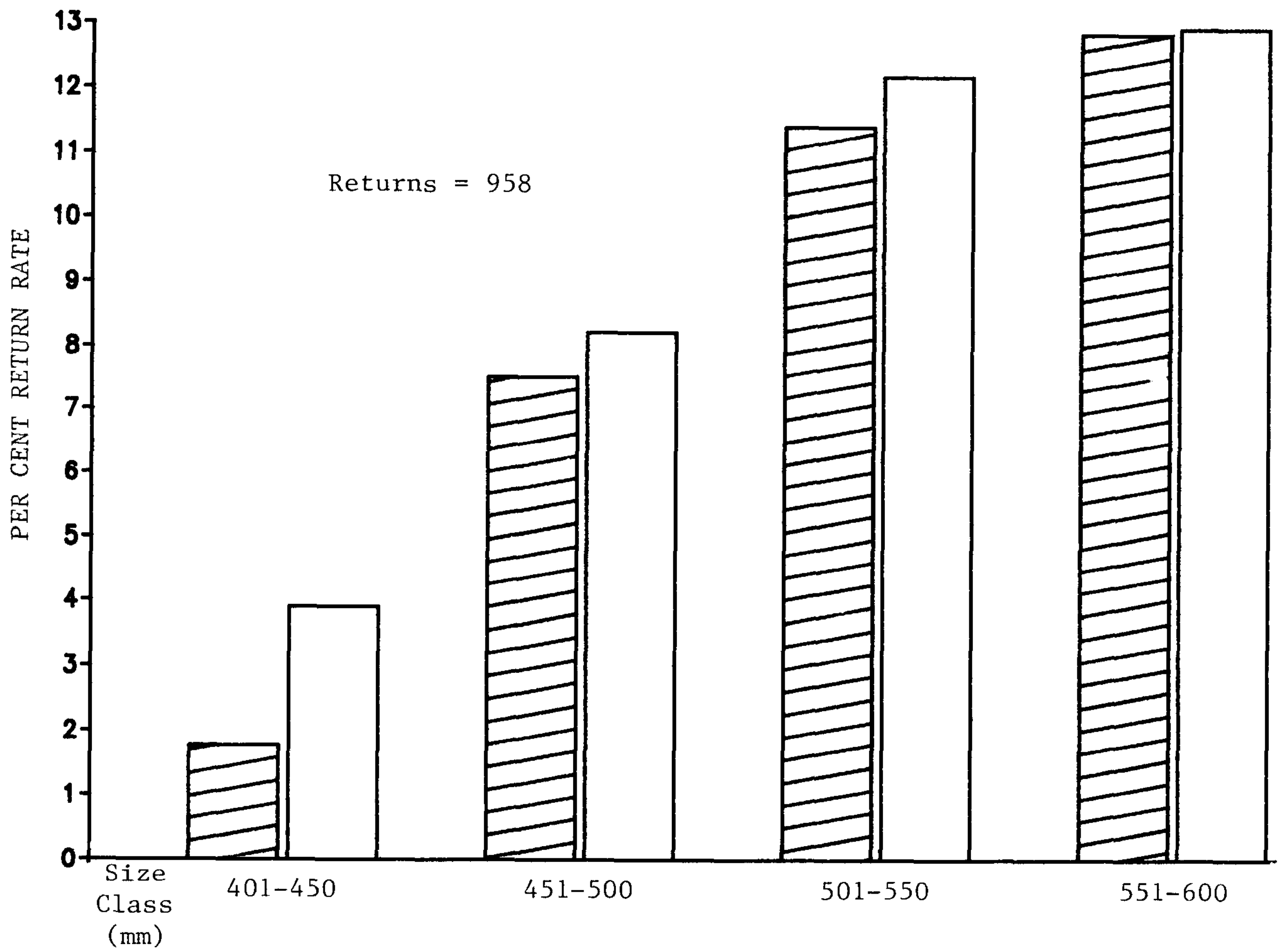

FIGURE 2 - RETURN RATES OF SINGLE AND DOUBLE TAGGED FISH WITH RESPECT TO SIZE

3.1.4 Effect of double tagging on growth

Growth rates were compared between single and double tagged fish. Fish which had been at large for less than 30 days were excluded from this study as well as fish whose annual growth rates were less than 48 mm or greater than 400 mm (obvious outliers). Results are -

	Single tagged fish	Double tagged fish
No. of fish recovered	53	46
Av. size on release	502.1 mm	517.5 mm
Av. size on recapture	594.9 mm	601.0 mm
Av. time at large	275.3 days	282.5 days
Av. yearly growth rate	134.9 mm/yr	111.2 mm/yr
Standard deviation of av. yearly growth rate	85.4 mm/yr	65.8 mm/yr

A T-test on the difference in average growth rates failed to find a difference between the two groups (P=.12).

3.1.5 Effect of double tagging on movement

As a further test of the effect of tagging on skipjack behaviour, a comparison was made on rates of movement for single and double tagged fish. Rate of movement was calculated as the great circle distance from the point of release to point of recapture divided by the time at large.

Fish at liberty 30 days or less :

	Single tagged fish	Double tagged fish	P value (of single vs double comparison)
No. of fish in sample	401	369	
Miles travelled per day	4.03	3.88	.62
Standard deviation of miles per day	4.41	4.07	

Fish at liberty for more than 30 days :

	Single tagged fish	Double tagged fish	P value (of single vs double comparison)
No. of fish in sample	97	90	
Miles travelled per day	.87	.63	.12
Standard deviation of miles per day	1.23	.89	

T-tests failed to reveal a difference between single and double tagged fish with respect to rates of movement for fish at liberty for either less than or more than a month.

3.2 Investigations Based on Single Tagging

3.2.1 Long versus short tags

Most of the tags used by SPC were between 110 and 120 mm long. However, 2,826 skipjack (2% of total) were tagged with a cut-down version of the same tag measuring between 70 and 80 mm. Short tags were used on most occasions where fish under 450 mm were a major component of the catch. It was thought that the shorter tag might cause less drag in the water. Disadvantages of the shorter tags are that they are less visible to the recapturing fishermen, they have only one set of identification numbers versus two sets on the standard length tag, and there is a chance that the tag could become completely buried in tissue of the fish with growth. To test the difference between return rates of the two types of tags, it was necessary to have tagged simultaneously in the same area with long and short tags, preferably over a number of size classes and to have received a large number of returns from these fish. The only country/visit to fulfill these requirements was PAL3. More returns are expected from this area and results may change slightly. 5,531 skipjack under 450 mm were tagged in this area; 4,669 with regular tags, 862 with short tags. A T-test was carried out on the differences in the ratios between normal and short tags for four size classes :

Size Class	Normal releases	Normal returns	Short releases	Short returns	Short tag return rate	Normal tag return rate	P value
< 351	317	7	506	5	.010	.022	.15
351-400	3,376	109	215	3	.014	.032	.14
401-450	976	40	141	7	.049	.041	.66
451-500	528	18	125	5	.040	.034	.75

None of the size classes revealed a difference between short and normal tags, and likewise did not reveal a significant effect of tag length.

The data can also be analyzed on a school by school basis. During the three year tagging period there were 17 schools in which both short and normal tags were used and from which there was at least one tag return. No significant differences could be demonstrated between the return rates for any of the 17 schools. Considering the effort needed to cut the tags off, the confusion over when to use the short tags, the fact that the numbers are not consecutive with the single tags, and the extra tagging equipment and storage space needed, the use of short tags is not recommended for further tagging projects on skipjack.

3.2.2 Size of fish

The lengths of all skipjack at time of release were grouped into eight size classes and recovery rates were analyzed:

Class	Size	No. of releases	No. of returns	Return rate
1	< 351	2,967	15	.005
2	351-400	4,882	136	.028
3	401-450	17,925	909	.051
4	451-500	47,785	2,290	.048
5	501-550	46,297	1,862	.040
6	551-600	12,404	596	.048
7	601-650	6,455	123	.019
8	> 650	959	11	.011

A G test of the hypothesis that no difference exists between the return rate of the eight size classes listed above gives a P value less than .0001; therefore there are significant differences in recovery rates among the size classes for the combined data set.

There are disadvantages in aggregating the data as was done above. Chiefly, high or low effort in a country/visit with a single size class is a problem (e.g. over 18,000 SJ were tagged in MAQ2, most of them were in size class 4, and there were very few returns). Also, the largest number of very small fish was tagged during the last country/visit of the survey, eight months prior to the present analysis. Recaptures of these small fish will undoubtedly continue for several months. Bearing in mind these limitations, results for the aggregated data are presented in Figure 3. The recoveries from each size class are divided into three periods of time at large. It can be seen from the graph that much of the variation in recovery rates is due to the number of short-term recoveries (less than 22 days). Notable is the fact that the percentage of long-term recoveries does not vary a great deal between the size classes.

The data were broken down by country to attempt to eliminate large variations in fishing effort. ZEA "B" was eliminated because tagging was done in two different areas which had distinctive size classes and large differences in effort. Only country/visits with at least 500 fish tagged in two or more size classes and with an overall recovery rate of at least four per cent were considered. Country/visits in this category were : ZEA "A", FIJ "A", PNG 2, SOL2, FIJ2. For each country/visit, return rates for size classes were computed and a chi-square test was performed to determine if the observed differences within each country visit were significant. Figure 4 depicts three examples of these country/visit comparisons. Probabilities for the five country/visit chi-square tests were combined and results showed there was a significant difference between size classes (P less than .0001).

3.2.3 Tagging quality and condition at time of release

A total of 20 codes were used to describe the quality of the tagging operation and/or condition of fish at release. The bleeding fish category has the lowest return rate, approximately 66 per cent lower than that of a normal release. However, a G test of the return rates of each of the code categories and the category in which no code was used (presumably a normal release), failed to show differences among the code categories (P=.9359).

Of the 20 tagging codes, nine were used frequently.

Code	Description	No. Released	No. Recaptured	Recovery Rate
BL	Bleeding	1,413	38	.027
TD	Tagged too deep	220	13	.059
TS	Tagged too shallow	197	9	.046
OS	Skipjack hit side of vessel on release	375	14	.037
TF	Tagged too far forward	744	30	.040
TH	Tagged too high	526	18	.034
TL	Tagged too low	1,640	59	.036
SB	Shark bite on skipjack side	921	44	.048
BT	Poorly tagged (not otherwise specified)	1,093	46	.042
Without code	Normal release	132,074	5,416	.041

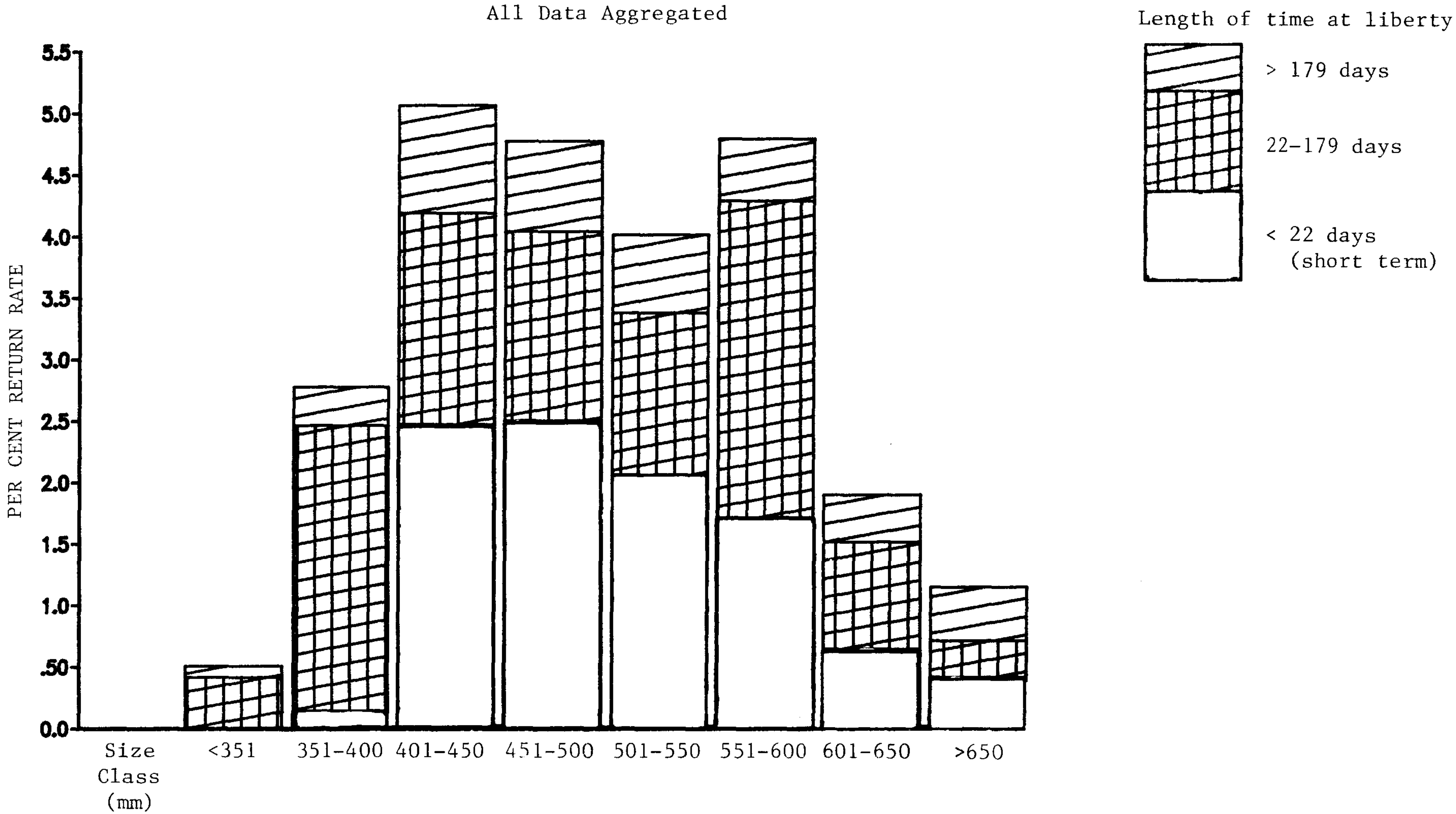

FIGURE 3 - RETURN RATES BY SIZE CLASS

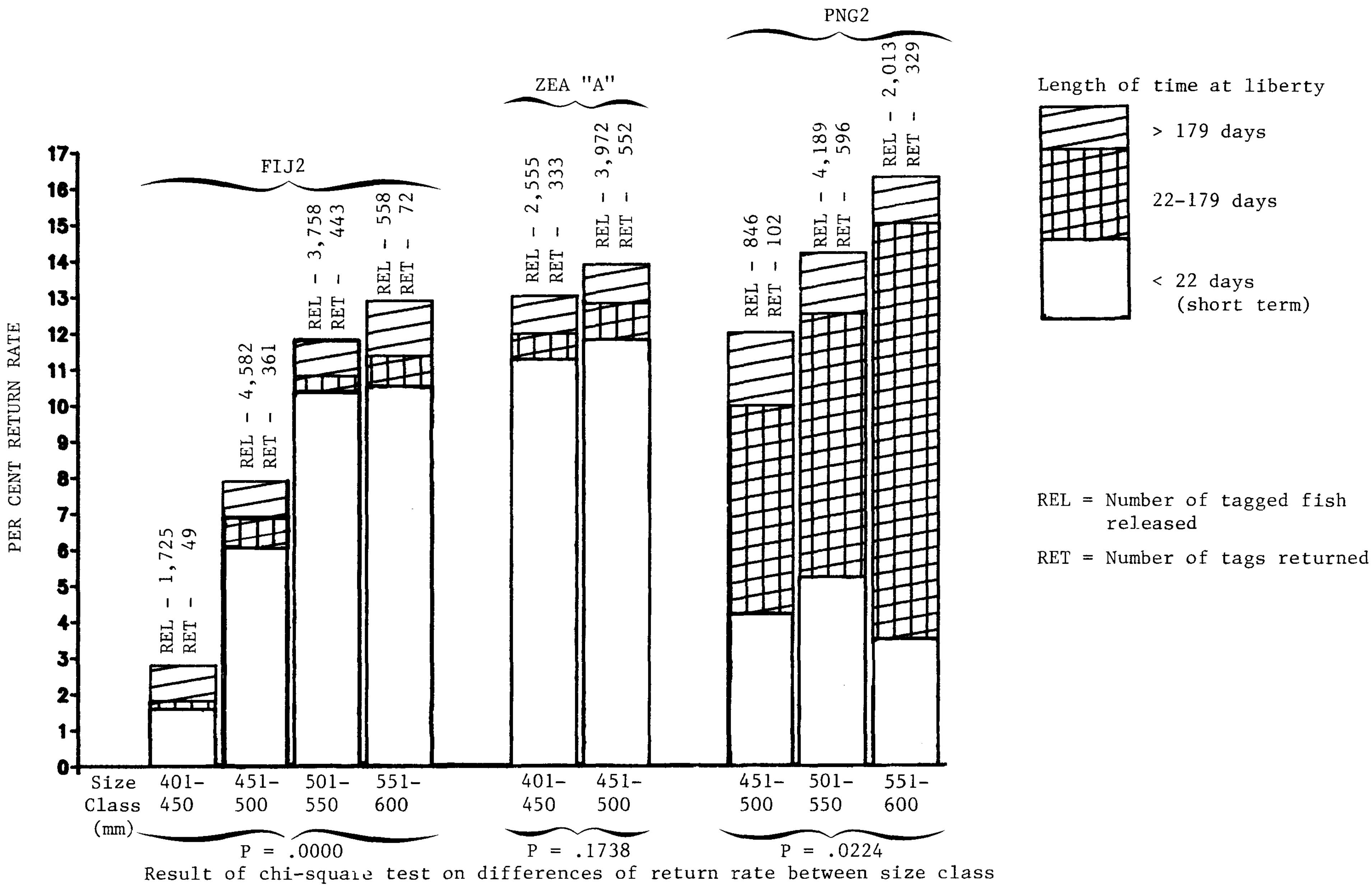

FIGURE 4 - RETURN RATES BY SIZE CLASS GROUPED BY COUNTRY/VISIT

3.2.4 The tagger/cradle position effect

Five different cradle positions were at various times used on the research vessel and skipjack were tagged at these positions by several different scientists. Seven of these scientists tagged more than 4,000 skipjack each. Release and recapture data are summarized as follows:

Tagger		CRADLE POSITION: Starboard Bow	Port Bow	Port Middeck	Port Stern	Starboard Stern
	RELS	2,779	21,621	356	4,892	100
A	CAPS	254	1,330	37	124	1
	RATE	.091	.062	.104	.025	.010
	RELS	804	16,648	136	5,912	124
B	CAPS	103	432	3	121	8
	RATE	.128	.026	.022	.020	.065
	RELS	2,722	3,724	5,832	10,891	451
C	CAPS	196	165	427	312	11
	RATE	.072	.044	.073	.029	.024
	RELS	1,372	3,323	5,280	7,808	0
D	CAPS	56	277	59	378	0
	RATE	.041	.083	.011	.048	0
	RELS	0	3,344	973	7,469	0
E	CAPS	0	126	12	394	0
	RATE	0	.038	.012	.053	0
	RELS	1,408	1,415	1,094	487	2
F	CAPS	13	146	114	33	0
	RATE	.009	.103	.104	.068	0
	RELS	0	2,854	148	2,032	0
G	CAPS	0	314	1	9	0
	RATE	0	.110	.007	.004	0
	RELS	3,844	2,702	6,947	6,035	4,234
VVV	CAPS	14	48	306	297	78
	RATE	.004	.018	.044	.049	.018

RELS = No. of tag releases CAPS = No. of tag returns

VVV is a composite category consisting of 18 individuals who tagged fewer than 4,000 skipjack each. The above table must be corrected for variations in fishing effort as certain tagger/cradle combinations were employed only in areas of high or low fishing effort. For each school from which there were 10 or more tag returns, the observed number of tag releases and returns for each tagger/cradle position were noted. Expected numbers of tag returns were computed by partitioning all returns from each school among tagger/cradle positions proportional to the releases from the particular tagger/cradle positions for the school. These expected and observed figures were summed for all schools and a G test (Sokal and Rohlf, 1969) was performed.

CRADLE POSITION

Tagger		Starboard Bow	Port Bow	Port Middeck	Port Stern	Starboard Stern
	RELS	2,144	9,316	227	1,828	71
A	OCAPS	*234.0*	*1,184.0*	*36.0*	*93.0*	1.0
	ECAPS	*223.1*	*1,069.9*	*35.5*	*87.4*	3.2
	# SCH	10	53	5	9	1
	G	.58	13.33	.01	.38	2.21
	RELS	566	4,553	0	952	52
	OCAPS	*98.0*	*234.0*	0.0	88.0	*5.0*
B	ECAPS	*85.0*	*237.5*	0.0	92.5	*2.9*
	# SCH	3	23	0	10	1
	G	2.24	.20	0.00	.25	1.30
	RELS	1,316	2,235	3,612	3,043	246
	OCAPS	*158.0*	*119.0*	393.0	272.0	*9.0*
C	ECAPS	*156.9*	*116.0*	419.8	279.7	*3.8*
	# SCH	17	9	28	13	1
	G	.01	.08	1.97	.23	5.14
	RELS	1,055	2,657	1,357	3,641	0
	OCAPS	46.0	*261.0*	26.0	313.0	0.0
D	ECAPS	52.2	*256.8*	29.8	370.0	0.0
	# SCH	7	11	8	31	0
	G	.80	.07	.52	10.26	0.00
	RELS	0	752	0	4,240	0
	OCAPS	0.0	*42.0*	0.0	329.0	0.0
E	ECAPS	0.0	*38.1*	0.0	329.2	0.0
	# SCH	0	4	0	29	0
	G	0.00	.40	0.00	.00	0.00
	RELS	801	849	842	234	0
	OCAPS	7.0	143.0	104.0	20.0	0.0
F	ECAPS	10.6	150.8	108.8	28.2	0.0
	# SCH	2	6	14	5	0
	G	1.41	.50	.25	2.96	0.00
	RELS	0	1,943	0	0	0
	OCAPS	0.0	*279.0*	0.0	0.0	0.0
G	ECAPS	0.0	*249.0*	0.0	0.0	0.0
	# SCH	0	12	0	0	0
	G	0.00	4.01	0.00	0.00	0.00
	RELS	0	90	2,071	2,096	616
	OCAPS	0.0	12.0	188.0	195.0	68.0
VVV	ECAPS	0.0	12.0	211.4	232.1	74.8
	# SCH	0	2	28	23	12
	G	0.00	.00	2.98	7.00	.71

RELS = No. of tags released
OCAPS = Observed number of returns
ECAPS = Expected number of recaptures
# SCH = No. of schools

G = Contribution to G value obtained
* = see text

The G value obtained, 59.796, suggests that there is a significant tagger/cradle position effect on return rates (P<.001). In the above table, in cases where the observed values exceed the expected, these figures are flagged with asterisks. It is not possible to separate the tagger effect from the cradle position effect because an unequal number of fish were tagged by each tagger in each position. Nevertheless, some patterns are suggested by the table. As the taggers are listed in order of decreasing number of fish tagged, it appears as though the return rates are influenced by the experience of the tagger as more asterisks appear at the top of the table. This notion is reinforced by the fact that the VVV category has less returns than expected for each cradle position. The bow cradles, and especially the port bow, seem to have higher return rates than the stern. At the extreme, the expected to observed ratio for the best tagger/cradle position combination is 1.325 times that of the worst.

In order to further investigate tagger/cradle effects on tag recoveries, an experiment was carried out during the second visit of the Programme's research vessel to Fiji and the third visits to Palau and Ponape (FIJ2, PON3, PAL3; country visit codes are given in the Appendix). During these periods, the three Programme scientists on board rotated daily between the three main tagging positions. This data set was analyzed using the same method as for the table on page 12. Results are:

Tagger		CRADLE POSITION		
		Starboard bow	Port bow	Port stern
A	RELS	2,144	1,063	1,389
	OCAPS	*239.0*	*136.0*	*67.0*
	ECAPS	*231.8*	*121.8*	*65.9*
	# SCH	10	8	6
	G	.25	1.81	.02
B	RELS	894	1,931	2,368
	OCAPS	103.0	*95.0*	215.0
	ECAPS	104.3	*91.9*	220.6
	# SCH	8	6	10
	G	.02	.11	.16
C	RELS	947	2,453	795
	OCAPS	43.5	246.0	75.0
	ECAPS	47.7	247.6	87.9
	# SCH	5	10	8
	G	.41	.01	2.24

The G value obtained was 5.023. Although this shows that tagger/cradle position did not have a significant effect when comparing only experienced personnel and when tagging positions were rotated (P=.7551), for all three taggers the stern position was worse than the bow as is the case in the table on page 12. The difference between the previous two tables and the associated results shows that experience of taggers is an important factor in the tagger/cradle position effect on recovery rates for the aggregated data set. Some aspect associated with cradle position also appears to have an effect.

4.0 SUMMARY

The results of the double tagging experiment showed that tags were shed from skipjack at a very low rate. The increased trauma of double tagging relative to single tagging appears to have had an impact on only very small fish. No difference in growth or movement could be detected between single or double tagged skipjack.

Tagger/cradle positions and fish size have some effect on return rates, whereas no effect of tagging quality/condition at release or size of tag was demonstrated.

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APPENDIX

COUNTRY VISIT CODES

Codes	Country	Period of Visit
FIJ "A"	Fiji	February-March 1978
WAL1	Wallis and Futuna	June 1978
ZEA "A"	New Zealand	February-March 1979
ZEA "B"	New Zealand	March-April 1979
PNG "A"	Papua New Guinea	May-June 1979
PNG "B"	Papua New Guinea	June 1979
PNG2	Papua New Guinea (PNG "A" and PNG "B")	May-June 1979
MAQ2	French Polynesia (Marquesas Islands)	December 1979-January 1980
FIJ2	Fiji	April-May 1980
SOL2	Solomon Islands	May-June 1980
PON3	Ponape	July 1980
PAL3	Palau	August 1980