TAGGING OF SKIPJACK TUNA (*Katsuwonus pelamis*) IN PAPUA NEW GUINEA WATERS, 1973–1974

A. D. LEWIS

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DEPARTMENT OF PRIMARY INDUSTRY
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ERRATA

Tagging of Skipjack Tuna (KATSUWONUS PELAMIS) in PNG WATERS - 1973-1974

PAGE 8. 1.17, 1973-3 should read 1973-1974.

PAGE 19. Fig 10, R. should read N

same lines across should read r^2.

PAGE 26. 1.17 & 25, 35% should read 35%o

1.36, should read Zooplankton (spelling)

1.48, of should read or (first word in line).

1.27, nomads (spelling).

PAGE 27. 1.16, Fig 7 should read Fig. 8.

PAGE 28. 1.3, South of 5^o should be underlined.

1.4, immigration (spelling).

1.9, Fig. 11 should read Fig. 12.

PAGE 29. 1.1, Fig 11 should read Fig. 12.

PAGE 30. Donguy *et al* (3-3) should read (3).

PAGE 31. Thynnus (spelling).

APPENDIX TABLE 3. (a) (b1. values left off bottom;

(They are in text p. 24 1.11-12)

(a) x^2=19.67, df. 10, P<.05

(b) x^2=15.09, df. 10, P>.05.

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ACKNOWLEDGEMENTS

The tagging experiments were carried out by a team comprising my colleagues Bob Kearney, Barney Smith, Marc Wilson, Grant West, Reg Eginton, the crew of the *FRV Tagula* and myself. Other releases were made from the Shizuoka Prefecture's vessel, the *RV Fuji Maru,* and the *MV Daidô Maru,* chartered from Gollin Kyokuyo (Niugini) Pty. Ltd. The paper has benefited from discussion with Bob Kearney and Barry Richardson, Joanne Daly and John Oakeshott made useful comments on the manuscript and Jacek Wanowski expedited its publication. The South Pacific Commission provided some unpublished tagging data. For the assistance freely given by these people and agencies, I am extremely grateful.

ABSTRACT

Returns (450 or 7.5%) from the 6005 skipjack tagged and released in Papua New Guinea waters during 1973-74 confirmed the cyclical nature of skipjack movements in the area. Between-year differences in these movements were found to be slight, with the proportion of fish respectively remaining within the Bismarck Sea and environs for lengthy periods or emigrating soon after release showing some variation. The net distance travelled was small. An hypothesis accounting for these movements is proposed and recognizes resident and nomadic components of the resource. The occurrence of the latter is linked to the periodic large scale oceanographic events which lead to increased forage production and supplement the background productivity which retains residents in the area.

Relationships with surrounding areas and their fisheries remain unclear, due to the constraints imposed by the patchy distribution of effort. Skipjack movements seem relatively limited in extent and interchange with areas to the south appears more extensive than with areas to the north.

Estimates of survival, derived from "total mortalities" (loss rates) indicate high turnover in productive sectors of the fishery. Non-reporting and tag slippage were investigated, but were not felt to be major sources of information loss.

INTRODUCTION

Tagging experiments with skipjack tuna (*Katsuwonus pelamis*) in the Papua New Guinea area were undertaken as part of a wider research programme accompanying the development of a large scale tuna fishery in the early 1970's. During 1971-72, 3542 skipjack were tagged and released, mostly in the centrally located Cape Lambert sector of the fishery, (Lewis, 1980). Of the 277 returns (7.8%) received, over 50% were after 200 days at liberty, clearly demonstrating the effectiveness of the techniques developed. Analysis of these returns indicated that skipjack movements were directed rather than random, with movement into the Solomon Sea occurring during the November 1972 - April 1973 period, followed by return movement into the Bismarck Sea in mid-1973. The small net distance moved was a feature of the returns. Only 9.8% of returns had moved beyond 200 nautical miles of the release point, and 1.4% beyond 1,000 nautical miles. It was surmised that recruitment occurs in part through the New Hanover sector, with some of these recruits possibly originating north of the Equator.

The experiments were continued as planned during 1973-74 with the following objectives:

(i) to provide data for between-year comparisons of skipjack movements by continuing releases in the Cape Lambert sector during 1973

(ii) to extend the spatial coverage of releases to include other sectors of the Papua-New Guinea fishery, especially the productive New Hanover sector.

(iii) to obtain preliminary mortality estimates from the tagging data and assess sources of tag loss.

(iv) to define as far as possible, relationships with fisheries in adjoining areas.

The paper describes the results of the 1973-74 tagging experiments relative to these objectives, and integrates where possible the 1971-72 results.

METHODS

Tagging Technique

Minor improvements were continually effected to the tagging cradle with the result that the one in use by the end of 1974 differed substantially from the original model (Lewis, 1980 - Figure 1). A tripod frame of 2.5 cm water pipe was substituted for the collapsible wooden frame, the canvas sling with its vinyl cover replaced by a durable cloth-backed plastic cover, the cumbersome protective pad around the cradle head discarded as the crew achieved finer control over poled fish, and the drop along the length of the cradle reduced from 22.5 cm. to 10 cm., giving the tagger easier access to the confined fish. Other aspects of the tagging procedure remained unchanged.

Despite possible shortcomings of the tag material at low temperature, it did not prove possible to develop a suitable alternative in time for use during 1973-74. Tags of two different colours (red, blue) were used in addition to the yellow tags for some of the 1973 releases, but this practice was discontinued when production flaws were discovered in the red and blue tags. As equivalent return rates were achieved, tags of different colours have not been considered separately in the analysis.

Individual size estimates (LCF* to the nearest cm.) were obtained routinely, as were biological data from fish in each school.

Collection of Supplementary Data

Catch and effort data, with the fishing day and the one degree square as the basic units of effort and area respectively were available for all vessels of the joint venture companies operating in Papua New Guinea. Figure 1 illustrates the division of the fishery into sectors and the coding of the one degree squares. Appendix Table 1 lists monthly effort (fishing days) and catch per unit effort (tonnes/day) by sector for the years 1973, 1974 and 1975.

Data from the Japanese bait boat fishery (effort and catch per one degree square for 10-day, monthly and yearly periods) for the same years were obtained (Anon., 1977a, 1977b, 1977c). These large data sets have recently been summarised in more convenient form (Kasahara, 1978). Yearly catch, effort (unadjusted and effective) and density indices have been calculated for 5° (latitude) by 10° (longitude) quadrangles south of 20°N, and for six sub-areas north of 20°N. Quadrangles between 20°N and 20°S are shown in Figure 9.

The best available figures on total catch and effort were also obtained from the Solomon Islands and Palau fisheries.

Mortality Estimates

Mortality estimates are frequently derived from rates of decrease with time in the numbers of tagged fish returned. Using the notation of Bayliff and Mobrand (1972) the number of tags remaining on skipjack after time t is given by:

$$N_t = N_o \Pi \rho e^{-zt}$$

where N_t = number of tags remaining on skipjack after time t

N_o = number of tags released

Π = proportion of skipjack alive after immediate tagging mortality

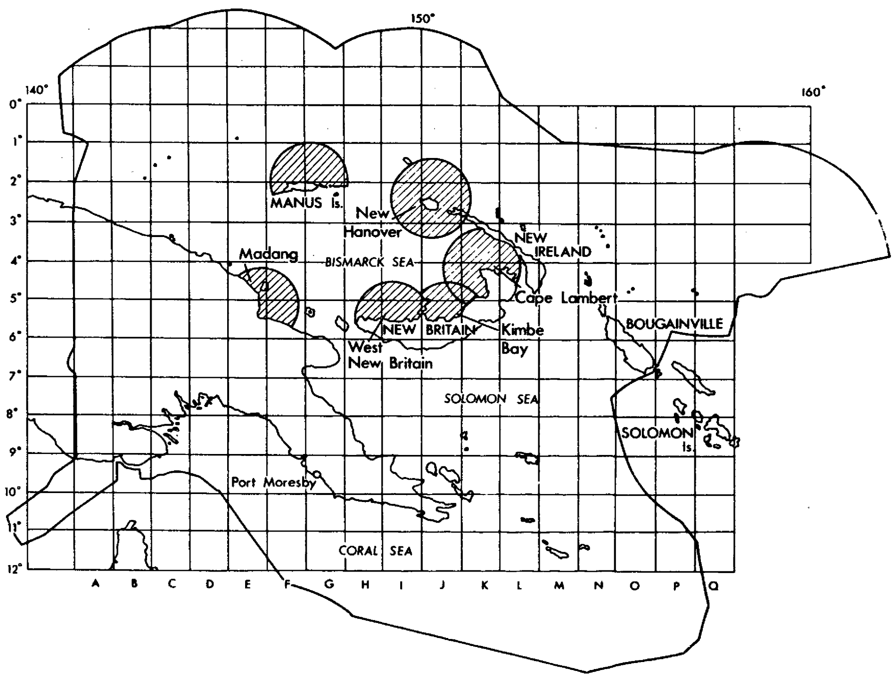
ρ = portion of tags retained after immediate shedding

---

* Length to caudal fork.

Figure 1. The waters of Papua New Guinea

The boundary of the declared Offshore Seas is shown as a solid line and the various sectors of the fishery shaded. One degree grid squares are coded by a combination of a longitudinal letter (A-Q) and a latitudinal number (00-12) as defined below. Sectors are shown as a 100 km radius from the central point of the baiting grounds.



Z = instantaneous total losses

More specifically, Z = F + M + G + L + E

where F = instantaneous fishing mortality

M = instantaneous natural mortality

G = instantaneous tag-induced mortality

L = instantaneous tag shedding

E = instantaneous emigration.

The proportion of tags returned will be influenced not only by these immediate and instantaneous coefficients of tag loss, but also by incomplete reporting of recaptures, by unequal vulnerability of tagged and untagged fish and by tagged fish not mixing uniformly with the untagged population.

Attempts were made to estimate L and ρ by double tagging skipjack from three release sets in the Cape Lambert area, and possible non-reporting was examined indirectly by comparing return rates per unit catch and effort both between companies operating in the same area and amongst vessels.

Total mortality estimates (Z) were made by the regression method (e.g. Fink, 1965; Mather *et al.*, 1974). Estimates were restricted to release sets in the Cape Lambert sector where emigration to the north-west and south-west could be detected. To make some allowance for this detected emigration, effort was defined as days' fishing summed over those Bismarck Sea sectors where returns were made during that month, i.e. the area over which effort was summed widened as dispersal proceeded.

RELEASES

During five cruises in the July-September period, 1973, 2928 skipjack were tagged and released in the Cape Lambert sector (release sets 10, 11, 12, 14 and 15) to enable the comparison to be made with the 3454 releases in the same area during 1972.

To examine movement into the Bismarck Sea through the New Hanover sector, tagging activities in that sector were accorded high priority. With skipjack concentrations frequently 100-150 km from baiting grounds, the research vessel's relatively slow speed (8-9 kts.) and small bait carrying capacity made it difficult to operate effectively in the area and other alternatives were pursued. Releases were made during a joint Papua New Guinea-Japan tagging cruise with a large well equipped vessel in October 1973 (release set 20; other releases also in the Solomon Sea - release set 21). By chartering a commercial vessel for several weeks, a further 1066 releases were made in June 1974 (release set 22).

Additional geographical coverage was given by releases from *FRV Tagula* in the southern and western Bismarck Sea (sets 16, 17), the

TABLE 1

Releases of tagged skipjack during 1973-74

Release Set	Dates	Locality	Number	Vessel
9	17-23/4/73	Solomon Sea (I06, J06)	34	FRV Tagula
10	5-14/6/73	Cape Lambert (K04)	805	"
11	23/6-5/7/73	Cape Lambert (K04)	1252	"
12	11-12/7/73	Cape Lambert (L04)	400	"
13	5-8/8/73	New Hanover (I01, J02)	84	"
14	28-30/8/73	Cape Lambert (L04)	471	"
15	5/9/73	Cape Lambert (L04)	212	"
16	19-28/9/73	New Britain - various (K04→F05)	388	"
17	21/10-8/11/73	Madang (E04, C03)	326	"
18	2-12/12/73	Nth. Coral Sea (I10, G09)	300	"
19	16/2-4/4/73	Port Moresby (G09)	62	FRV Rossel
20	11-21/10/73	New Hanover (J01, L02, L03)	240	RV Fuji Maru
21	29/10/73	Solomon Sea (I06, J07)	143	RV Fuji Maru
22	11/6-28/6/74	New Hanover (J01, J02) (I01, I02)	1066	MV Daido Maru
23	16/1-18/4/74	Port Moresby (G09)	222	FRV Rossel
			6005	

Solomon Sea (set 9), and the Coral Sea (set 18). Releases in the Coral Sea were supplemented by tagging activities on day trips out of Port Moresby from a 10 m. research vessel in the January-March period in 1973-1974 (sets 19 & 23); although most of these fish were poled, short troll lines were also used to catch skipjack for tagging.

RESULTS

Size of Tagged Fish

As agreement between estimated individual lengths (ℓ_1) and measured mean lengths within schools ($\bar{\ell}_1$) was good, and as estimated lengths (ℓ_1) have been shown to agree closely with measured lengths of tagged fish captured within ten days of release (Josse *et al.*, 1979), the ℓ_1 estimates have been used for length frequency analyses. Appendix Table 2 summarizes this data by release set. Skipjack 50-60 cm. in LCF accounted for 85.7% of releases, with 95.4% of fish between 45 and 60 cm. LCF.

In contrast to the 1972 releases, when it was possible to discern three distinct size groups of skipjack, the size composition of the 1973-73 releases generally showed greater complexity. As 1973 was a much more productive year for the fishery (over twice the 1972 catch) this may reflect a more diverse recruitment base. In any event it was not possible to separate and follow particular size groups between release sets.

Total Returns

Table 2 lists the sources of the 450 skipjack tags returned. The higher proportion of returns from processing facilities (44 or 9.8% as against 4 or 1.4% from 1971-72 releases) was probably a function of the larger catches during both years, when tagged fish were presumably more likely to be overlooked on board the fishing vessels.

The overall return rate (7.5%) approximated that of the 1971-72 releases (7.8%). Return rates and times at liberty stratified by 50 day intervals are given by release set in Table 3. Only 20.2% (91) of the 1973-74 returns were at liberty for more than 200 days, compared with 50% of 1971-72 releases, and 52.2% (235) of returns were from skipjack at liberty 50 days or less, compared with 28.2% (78) of 1971-72 releases.

TABLE 2

Sources of Returns of Tagged Skipjack

Local join-venture vessels	351
Local mother ships and shore bases	11
Foreign join-venture vessels	6
Long range pole boats	45
Indigenous fishermen	1
Canneries	33
Research vessel	3

TABLE 3

Returns of tagged skipjack from the 1973-74 release sets by 50-day strata

Releases are grouped geographically

	CAPE LAMBERT					NEW HANOVER			SOUTHERN BISMARCK SEA		SOLOMON SEA		CORAL SEA			
Release set	10	11	12	14	15	13	20	22	16	17	9	21	18	19	23	**Total**
0- 50	35	50	42	54	8	4	4	36	2	-		-				**235**
51-100	26	19	13	1	2	-	-	18	1	1		1				**82**
101-150	-	3	-	2	-	-	1	11	2	3		2				**24**
151-200	2	-	1	2	-	1	-	7	3	2						**18**
201-250	-	1	-	-	-	2	1	1	3	5						**13**
251-300	2	-	1	1	1	-	-	2	6	4		1				**18**
301-350	2	-	1	3	4	1	1	2	1	1	1					**17**
351-400	1	6	2	-	-		1	4	2	2						**18**
401-450	1	2	3	2	1		-	-	1	1						**11**
451-500	2	-	1	1			-	1	1							**6**
501-550	1	-					1							1		**3**
551-600													1			**1**
Other								1*			1†		2*			**4**
TOTAL	72	81	64	66	16	8	9	83	22	19	2	4	3	1	0	**450**
No. released	805	1252	400	471	212	84	240	1066	388	326	34	143	300	62	222	**6005**
return	9.0	6.5	16.0	14.0	7.5	9.5	3.8	7.8	5.6	5.8	5.8	2.8	1.0	1.6	0	**7.5**

* Incomplete recapture data

† 789 days at liberty

Recapture localities within the Papua New Guinea area have been plotted on Figures 2, 3, 5, 6 and 7. Calculation of net distance moved (nautical miles) where adequate recapture data were available, showed only 16.5% of these returns to have moved further than 200 nautical miles (360 kms.) from the release point and only one (<1%) further than 1000 nautical miles (1800 kms.). Corresponding figures for the 1971-72 releases were 10% and 1.4% respectively.

Movements within the Bismarck Sea

Cape Lambert sector

Returns from the 1971-72 releases in the Cape Lambert sector showed skipjack movements to be directed rather than random. Although some tagged fish remained in the vicinity of the release point or moved northwards soon after release, most moved to the southwest, apparently to enter the Solomon Sea for some months before reappearing in the southern Bismarck Sea in mid-1973. This pattern of limited northerly movement through the New Hanover sector and oscillation between the Bismarck and Solomon Sea was repeated in approximately the same time frame during the latter half of 1973 and during 1974, i.e. one year later.

The geographical distribution within the Papua New Guinea area of returns from the 1973 Cape Lambert releases (sets 10, 11 - Figure 2; sets 12, 14 and 15 - Figure 3) parallels that of the 1972 releases. Examination of the adjusted numbers of returns by sector by month (N_{ij} - Lewis, 1980) shown in Table 5, shows the pattern of returns from the 1973 releases to differ in three respects from the 1972 data set.

(i) initial returns rates were higher,

(ii) movements out of the release area to northwest and southwest appeared stronger and weaker respectively relative to the 1972 figures,

(iii) the attrition in return rates with time was significantly greater (Figure 4), and returns ceased after 550 days cf. 750 days for 1972 returns.

With the dearth of returns in each case for the November-April period after release, when it is presumed that many tagged fish moved into the Solomon Sea and local returns virtually ceased, regression lines have accordingly been fitted for two time periods.

In the case of sets 14 and 15 no southwesterly movement immediately following release was detected, although returns were received from West New Britain and Madang sectors during 1974.

The Madang sector was again the site of many long term (> one year) returns; returns from the New Hanover sector in the year after release (1974) were virtually restricted to the July-November period, as had been the case with returns in 1973 and 1974 from the 1972 releases, emphasizing the cyclic nature of these northerly movements leading to wider dispersal.

Figure 2. Location of returns within the Papua New Guinea area from release sets 10 and 11.

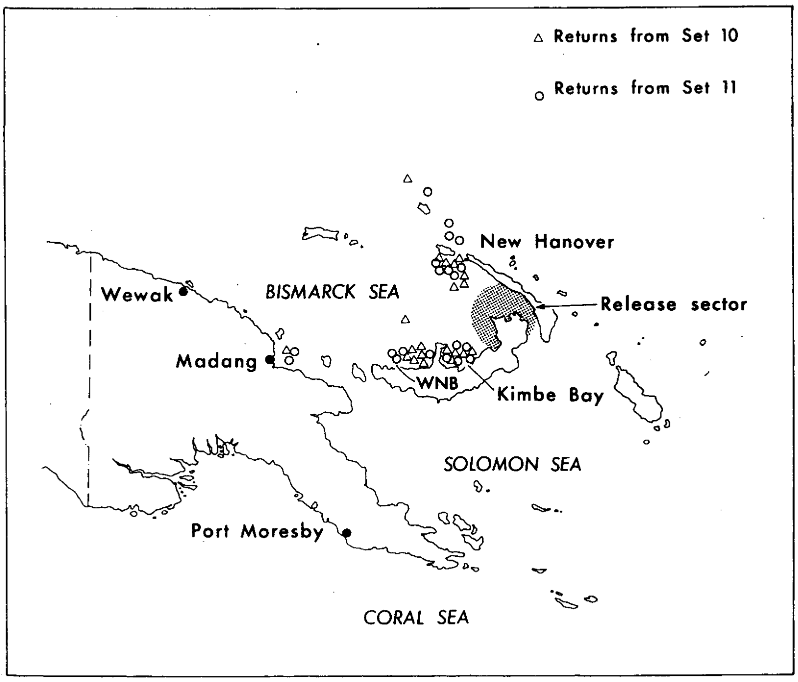


Figure 3. Location of returns within the Papua New Guinea area from release sets 12, 14 and 15.

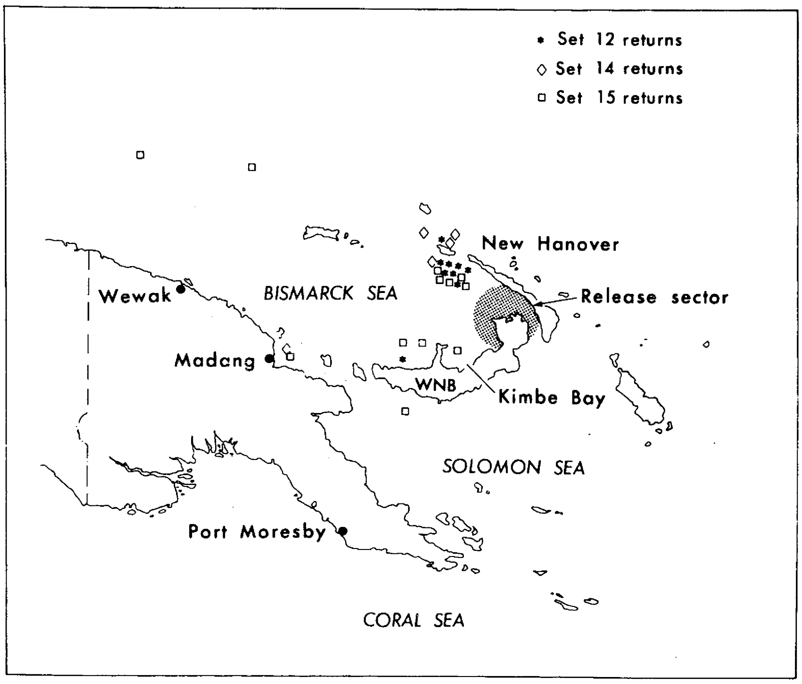


TABLE 4

Adjusted number of returns (Nij) by month for each sector
All releases were in the Cape Lambert sector

NH: New Hanover; CL: Cape Lambert; KB: Kimbe Bay; WNB: West New Britain; MD: Madang

Symbols: *, <10 days effort; -, no returns

SET 10 5-14/6/1973

	1973							1974			
Month/ Sector	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND
NH	-	-	3.0	6.9	-	-	-	-	0.9	-	-
CL	13.5	7.5	5.1	1.5	-	-	-	-	0.6	-	-
KB	*	6.0	3.6	-	-	-	-	*	-	*	*
WNB	4.8	-	6.3	4.2	*	*	-	-	*	2.2	-
MD	-	*	*	*	*	*	*	-	2.8	3.0	2.4

SET 11 23/6-5/7/1973

Month/ Sector	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND
NH	-	-	0.3	3.6	4.5	2.7	-	-	-	2.0	-
CL	0.6	13.2	16.1	3.6	-	-	-	-	-	0.7	-
KB	-	5.7	5.4	-	-	-	-	*	-	*	*
WNB	-	-	6.0	2.1	*	*	-	-	-	-	-
MD	-	*	*	*	*	*	*	-	2.8	3.0	-

SET 12 11-12/7/1973

Month/ Sector	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND
NH		-	3.0	6.9	1.8	-	-	-	-	2.0	-
CL		21.2	8.7	3.9	-	-	-	-	0.6	0.7	0.7
KB		-	-	-	-	-	-	*	-	*	*
WNB		-	2.1	-	*	*	-	-	-	-	-
MD		*	*	*	*	*	*	-	-	-	-

SET 14 28-30/8/1973

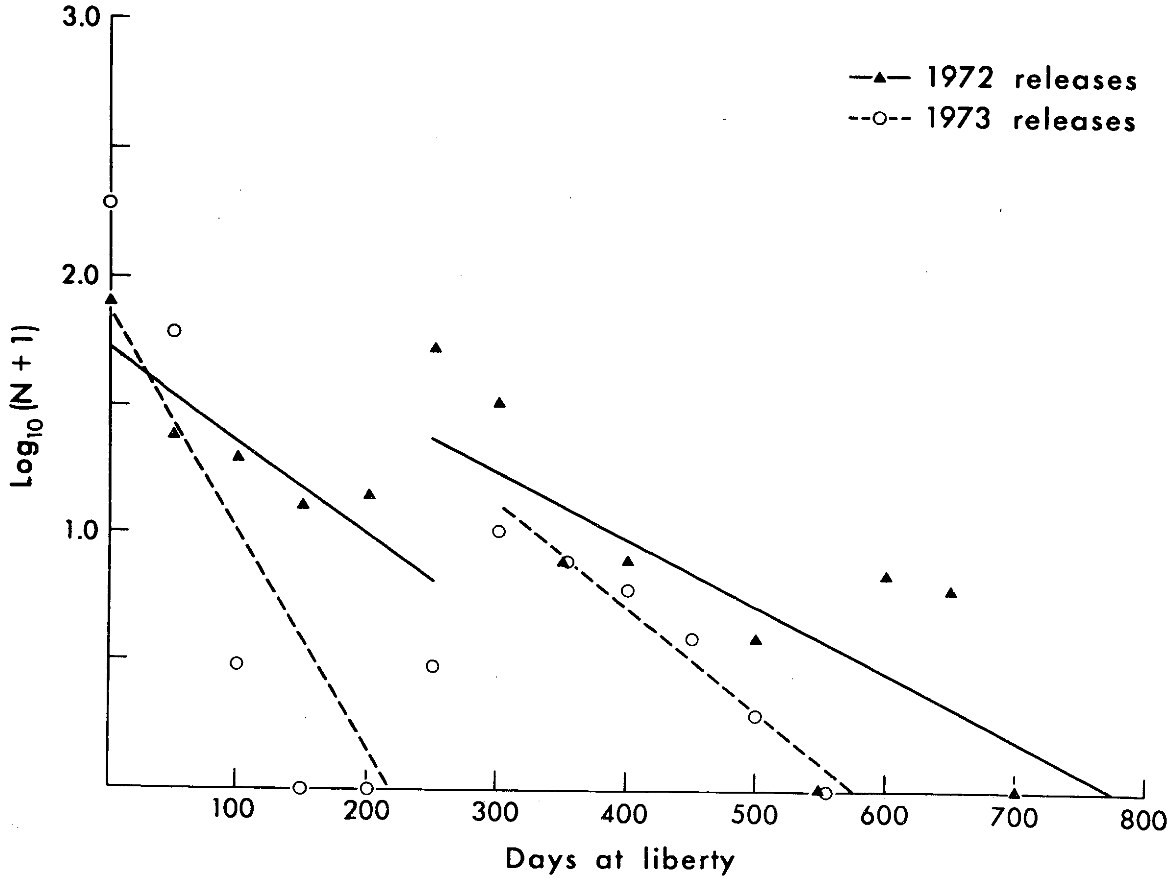
Month/ Sector	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND
NH			-	3.6	4.5	-	-	-	-	-	-
CL			1.8	34.8	2.4	-	-	-	-	0.7	1.4
KB			-	-	-	-	-	*	-	*	*
WNB			-	-	*	*	-	-	-	-	-
MD			*	*	*	*	*	-	-	4.2	-

SET 15 5/9/1973

Month/ Sector	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND
NH				-	-	1.5	-	-	-	4.0	-
CL				5.4	-	-	-	-	0.9	-	-
KB				-	-	-	-	*	-	*	*
WNB				-	*	*	-	-	-	-	-
MD				*	*	*	*	-	-	-	2.4

Figure 4. The attrition with time in number of local returns received from 1972 and 1973 releases in the Cape Lambert sector.

As the relationship is usually exponential and as no returns were received for some 50-day periods, regressions of log (N + 1), where N = number of returns, against the number of days representing the beginning of each 50-day time period, have been fitted for two time periods in each case. Seasonal movement into the Solomon Sea, with resultant lack of returns, engenders this subdivision (see text).



New Hanover Sector

Adjusted number of returns (N_{ij}) from the 1066 set 22 releases (June 1974) are given in Table 5, and location of returns from release sets 22, 13 and 20 plotted in Figure 5.

Figure 5. Location of returns from releases in or adjacent to the New Hanover sector, sets 22, 20 and 13.

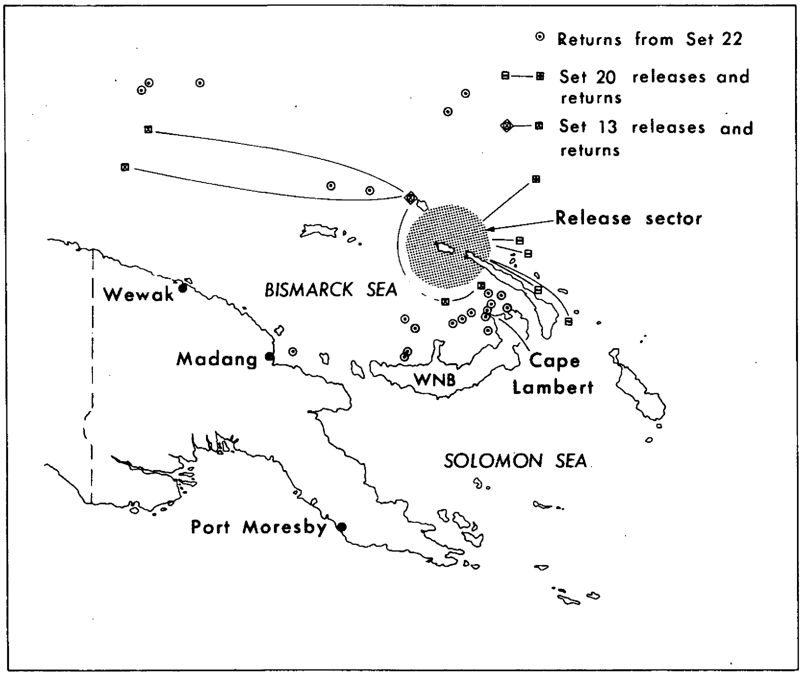


TABLE 5

Adjusted number of returns (N_{ij}) by month for New Hanover set 22 releases, 11-28/6/1974

	1974							1975		
	J	J	A	S	O	N	D	JFM	AMJ	JAS
New Hanover	7.01	22.3	8.5	4.3	4.0	3.0	-	*	-	-
Cape Lambert	-	-	1.2	0.6	0.6	1.2	-	5.9	1.8	-
Kimbe Bay	*	-	*	*	*	*	*	*	*	*
W. New Britain	-	-	1.8	2.7	-	*	-	-	-	*
Madang	-	-	-	-	-	-	-	-	-	1.8

* <10 days effort
\- no returns

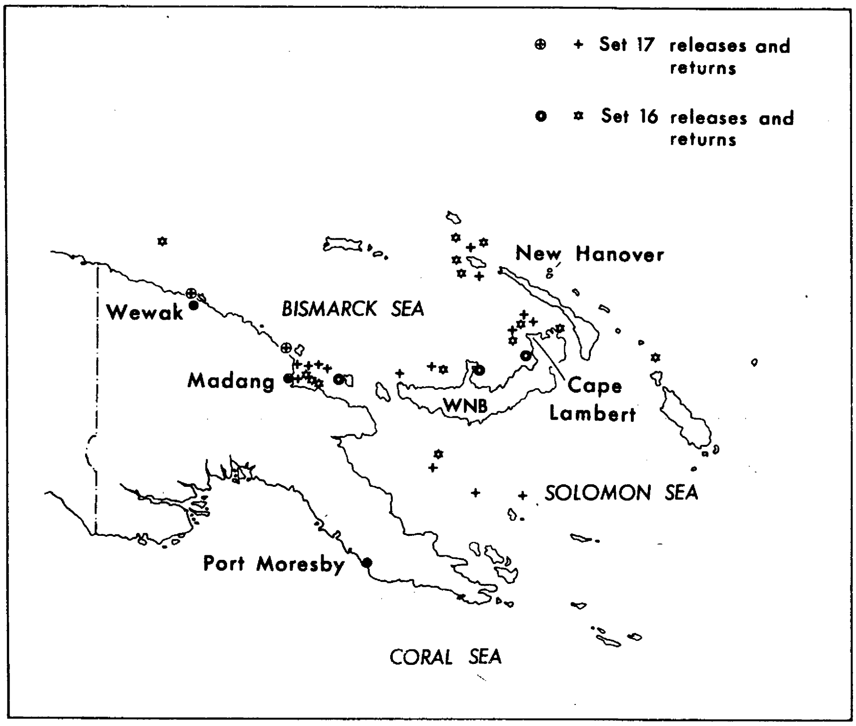
Most returns were made locally in the five months following release, after which time (November 1974) they ceased abruptly despite continuing effort and good catches (Appendix Table 1), indicating probable emigration out of the area. Returns from the Cape Lambert and West New Britain sectors indicate that some southwards movement occurred, establishing a link between the New Hanover sector and those further south. Returns to the north and northwest, including six within the five months following release, demonstrate that movement out of the Bismarck Sea also occurred.

The smaller release set 13 produced similar results: three returns within the New Hanover sector, one to the south and the remainder over a wide area to the north.

Set 20 releases (October 1973) were made both in the New Hanover sector (n = 110) and at several points to the south, off the New Ireland east coast (n = 130). The former produced one local return, one cannery return likely to have originated from the Cape Lambert sector and two some distance to the north; the latter (130) resulted in three returns soon after in the New Hanover sector, one there during 1975 and one in the Solomon Islands.

<u>Southern and Western Bismarck Sea</u>

<u>Figure 6.</u> Location of returns from releases in the southern and western Bismarck Sea, sets 16 and 17.



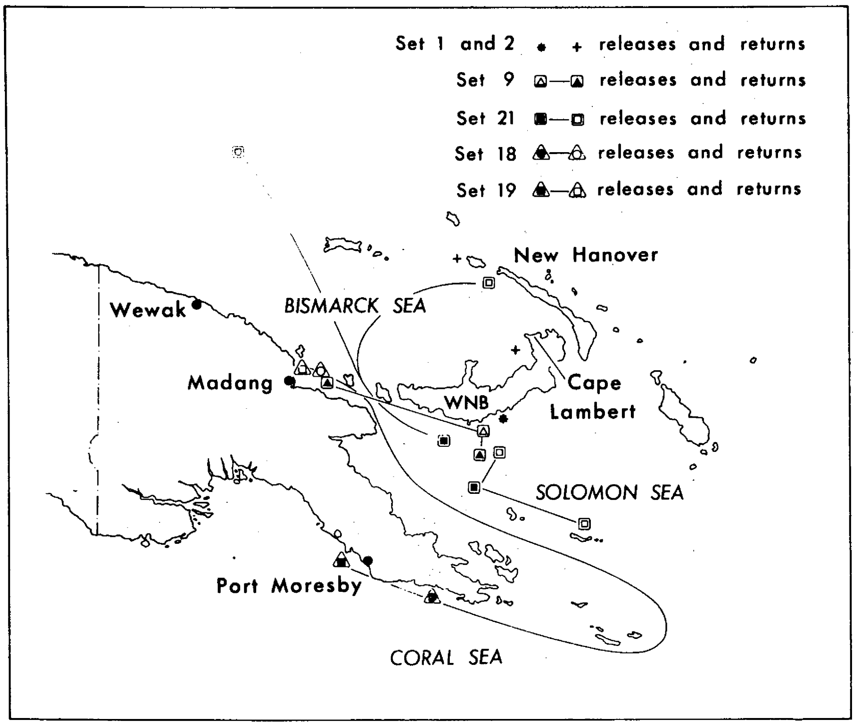
Returns from the heterogeneous release set 16, spread over several one degree squares along the north coast of New Britain, and release set 17, in the Madang sector and near Wewak, are shown in Figure 6. They occur at various points along the movement sequences described previously. Set 17 returns from skipjack larger than 58 cm. (4 kg) in estimated length were nearly all (7 out of 8) within the Madang sector and western Solomon Sea, whereas returns (11) from those less than 58 cm. at release were made in other sectors of the Bismarck Sea.

Solomon and Coral Sea releases

Releases from sets 9 and 21 (1973) and 1 and 2 (1971-72) in the Solomon Sea total 265 for 8 returns (3.0%) (Figure 7). These consist of four in various Bismarck Sea sectors, one north of the Bismarck Sea and three in the Solomon Sea.

The 584 Coral Sea releases (sets 18, 19 and 23) produced only 4 (0.7%) returns. Two of these were in the Madang sector, and thus link the northern Coral and Bismarck Seas. The remaining two could not be traced.

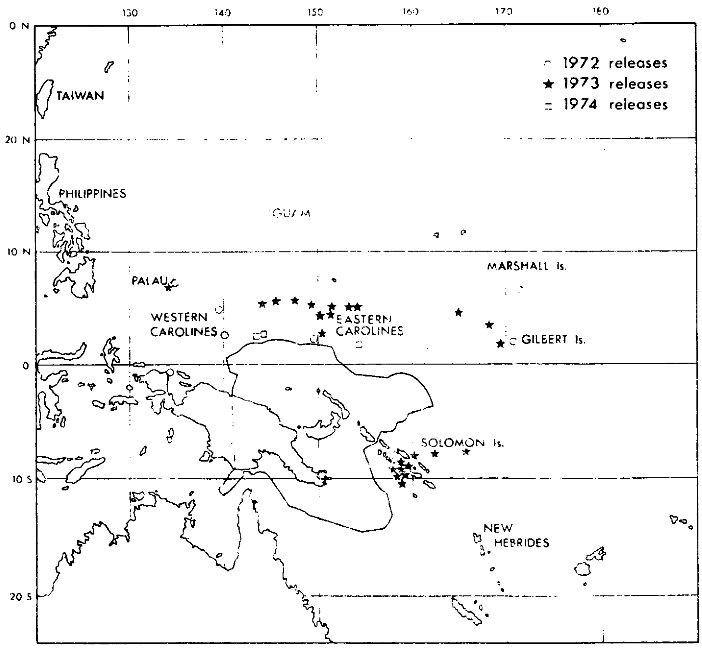
Figure 7. Location of returns from releases in the Coral and Solomon Seas, sets 1, 2, 18, 19 and 21.



Movements beyond the Papua New Guinea fishery

Fifty three returns from the 1973-74 releases revealed movement beyond the various sectors of the Papua New Guinea fishery. Twenty eight of these returns were outside the boundaries of the Papua New Guinea offshore seas as defined in Figure 1. Their locations plus those of the 9 such returns from the 1972 releases are shown in Figure 8.

Figure 8. Location of returns of tagged skipjack from outside the Papua New Guinea area.



Relative to distribution of effort

Returns beyond the Papua New Guinea fishery (69 in total, when 1971-72 data is included) need to be related to the geographical distribution of effort by the Japanese long range pole fishery, and joint venture operations in neighbouring countries, since those fisheries accounted for all but one of the returns. As a first step, 1974 returns (51 out of 69) from each of the 17 areas in the region bounded by 10°N-10°S, 125°E-175°E (see earlier) have been compared with the unadjusted days effort (fishing days) per area during 1974 (Figure 9). In addition, equivalent unadjusted effort figures for the Solomon Islands and Palau fisheries were obtained using the long range vessel average catch per day in that area for 1974 as the standard daily catch rate and dividing the total catch by this figure.

<u>Figure 9.</u> Tag returns received during 1974 outside sectors of the Papua New Guinea fishery, relative to distribution of effort and catch. For each 5° x 10° quadrangle, the number of returns is indicated in bold type, and from top to bottom on the right hand side, unadjusted days effort, effective days effort and catch ('000 tonnes) during 1974. Analagous data for the Solomon Islands and Palau fisheries is also given. Each quadrangle can be coded by longitudinal letter (A-G) and latitudinal number (1-8).

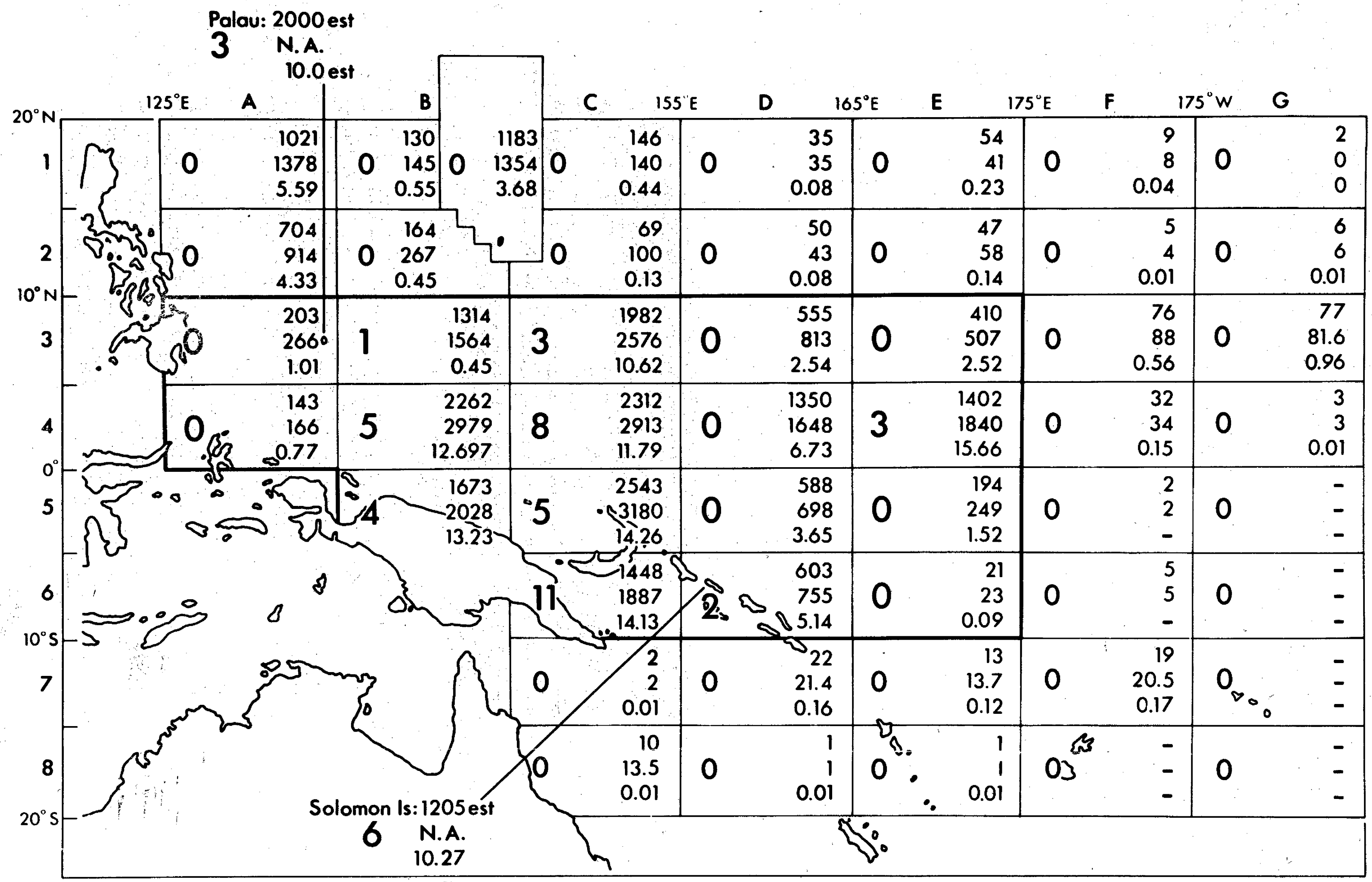
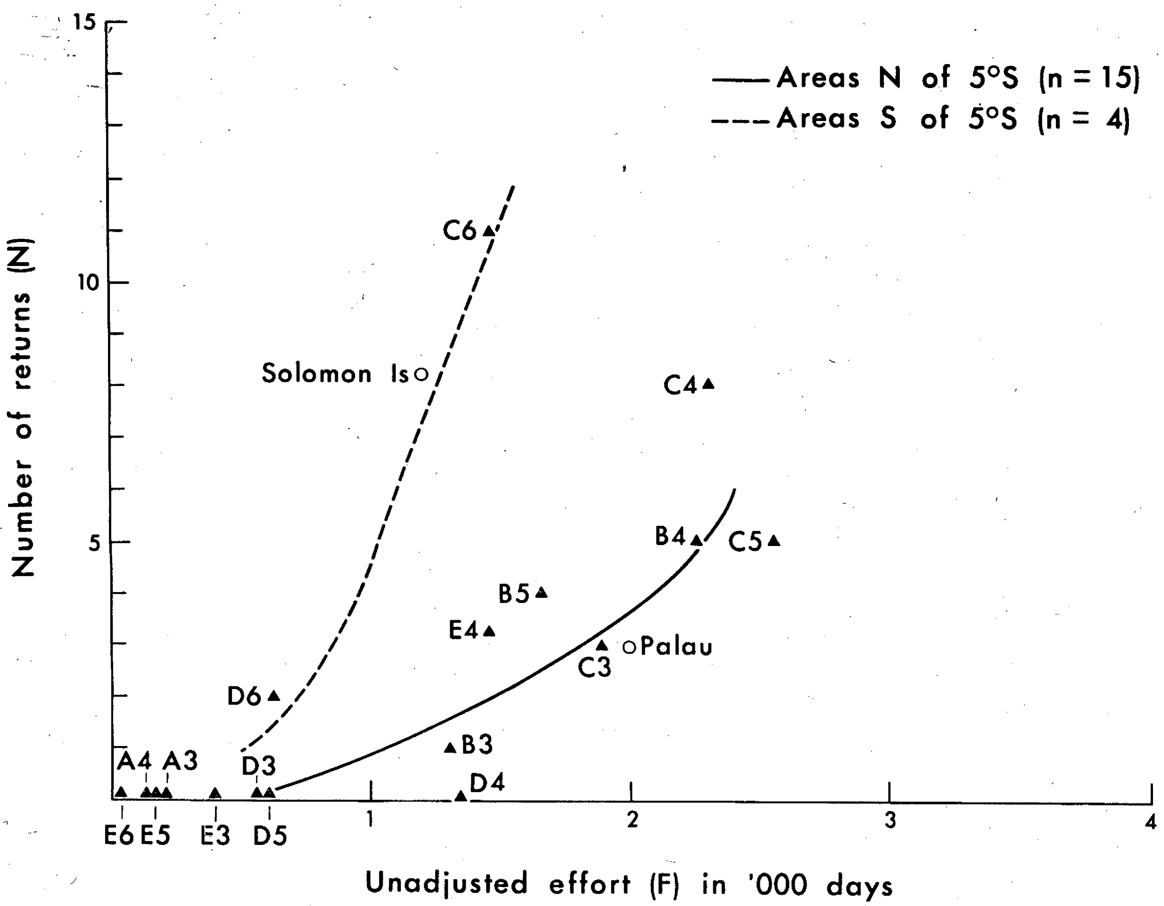


Figure 10. The relationship between number of returns (N) and in unadjusted days effort (F) during 1974 for areas north and south of 5°S respectively.



N of 5°S

(1) R = -.07316 + .03427 F + .97996 F^2 (^{2} = .77)

(2) R = -.21033 + .09434 F_e + 61917 F_e^2 (^{2}= .81) where F_e = effective effort

(3) R = -1.06978 + 0.5134C - .00781 C^2 (^{2}= .69) where C = catch in '000 tonnes.

S of 5°S

As only four points were available, the relationship was not quantified.

Data for areas north of 5°S (14 quadrangles plus the Palau fishery) show a reasonably good fit to the second degree polynomial (non-linear) function (Figure 10). The goodness of fit improves slightly if effective effort figures are used, but deteriorates when catch is used as the independent variable. The three areas south of 5°S show much higher return rates by comparison. Examination of effort figures in the adjoining blocks 10°-20°N, 125°-175°E to 20°N-10°S, 175°E-165°W (Figure 9) show effort in only two areas (2/23) to exceed 1000 days; effort south of 10°S does not exceed 100 days in any square other than the three considered. The observed distribution of returns in 1974 thus mirrors the distribution of effort. The significance of differences in return rates between areas north and south of 5°S will be discussed later. Returns received during 1973 (13) and 1975 (5) were considered too few to lend themselves to the above analyses.

Relative to size at release

The total length frequency data (Appendix Table 2) and the estimated size of release for the 69 returns beyond the Papua New Guinea fishery were subdivided into 4 size groups, <50 cm. LCF, 51-55 cm., 56-60 cm. and > 60 cm. Differences in the number of these longer distance recoveries amongst the size classes were not significant (homogeneity $\chi^2 = 2.09$, df = 3, P > .05) when averaged over all release sets. Thus, changes in mobility with size, as measured by number of recaptures beyond the Papua New Guinea fishery, were not apparent over the total 1973-74 data set. This is in contrast to the greater mobility of smaller (β) fish noted in the 1972 releases (Lewis, 1980). Within individual release sets, however, differences were noted in the amount and type of net movement according to size and the situation will probably vary from release set to release set according to a complex set of environmental and biological factors. It seems likely that no simple size dependent relationship exists for adult skipjack 45-60 cm. in LCF in the Papua New Guinea area.

A related phenomenon is the apparent size stability by area within the Bismarck Sea as reported by Kearney (1977), particularly the predominance of skipjack 5 kg. and above in the Madang sector. Average length and weight of skipjack recaptured in this area, typically after long periods at liberty, were respectively 62.26 $\pm$ 2.94 cm. and 5.23 $\pm$ 0.44 kgs., consistent with the above observation. Given the environmental restrictions hypothesized to apply on fish of this size (Barkley *et al.*, 1978), it would be interesting to examine data on vertical temperature profiles and dissolved oxygen levels for the southwestern Bismarck Sea.

Mortality Estimates

Estimates of total mortality (Z) for release sets 10, 11, 12, 14 and 22 were obtained by the regression method as described previously. Those for sets 10, 11 and 12 and set 14 are taken to the end of September and October respectively as release sector returns ceased at that time (Table 5). The estimate for the set 22 releases was based on the five month period after release. The calculated values of Z and S (survival), where $S = e^{-zt}$, are given in Table 6. As it is not possible to account

TABLE 6

Total Mortality Estimates

Legends as follows: R = number of returns; R^1 = No. of returns/100 days' effort;
Zm = calculated monthly total mortality
Zf = total mortality during months (f) exposed to the fishery

Sectors: CL = Cape Lambert; KB = Kimbe Bay; WNB = West New Britain;
NH = New Holland

Release Set 10

Month	Sector	Effort (days)	R	R^1	log R^1
June	CL	488	23	4.71	0.673
July	CL, KB	573	14	2.44	0.387
August	CL, KB, WNB, NH	933	14	1.50	0.176
Sept.	CL, NH, WNB	707	8	1.13	0.054

Zm = 0.200

Zf = 0.800 S = 0.45

Release Set 11

Month	Sector	Effort (days)	R	R^1	log R^1
July	CL, KB	573	24	4.12	0.622
August	CL, KB, WNB, NH	933	30	3.22	0.507
Sept.	CL, NH, WNB	707	9	1.27	0.104

Zm = 0.259

Zf = 0.777 S = 0.46

Release Set 12

Month	Sector	Effort (days)	R	R^1	log R^1
July 12-31	CL	295	27	9.15	0.96
August	CL, NH, WNB	762	14	1.6	0.20

Zm = 0.433

Zf = 1.299 S = 0.27

Release Set 14

Month	Sector	Effort (days)	R	R^1	log R^1
Sept.	CL, KB, NH	756	49	6.4	0.805
Oct.	CL, NH	463	5	1.1	0.04

Zm = 0.765

Zf = 1.530 S = 0.22

Release Set 22

Month	Sector	Effort (days)	R	R^1	log R^1
July	NH	304	27	8.88	0.948
August	NH, CL	928	11	1.18	0.073
Set.	NH, CL, WNB	840	8	0.95	$\bar{0}$.021
Oct	NH, CL	891	5	0.63	$\bar{0}$.199
Nov.	NH, CL	777	5	0.64	$\bar{0}$.191

Zm = 0.257

Zf = 1.285 S = 0.28

for emigration beyond the Bismarck Sea, Z in this situation is effectively an estimate of loss rates from the fishery with emigration (E), natural (M) and fishing (F) mortality being the major contributors. In an open system such as this, and with fluctuating levels of effort in surrounding areas, the difficulties of partitioning Z into F, M and E components are formidable, and the most useful estimate may be that of S, the proportion of the release set remaining in the area at the end of the initial exploitation period for which the Z estimates were derived. This ranges from .21 to .46, i.e. less than half of the releases remaining in the fishery, and indicates rapid turnover in the productive Cape Lambert and New Hanover sectors.

Table 7 lists release and return details of double tagged skipjack. Of the 28 returns received, only two were as single tags. Both were from outside the Papua New Guinea area, one from a cannery and the other from a long range pole vessel. With only one return from greater than 365 days, the logical division of the data set for the purposes of estimating ρ (portion of tags returned after immediate shedding) and L (instantaneous tag shedding) would be by six monthly periods. With 25 of the 28 returns in the first 6 month period, and 22 within the first 60 days however, this is clearly of limited value. Inspection of comparable data sets (Laurs *et al.*, 1976; Bayliff and Mobrand, 1971; Lenarz *et al.*, 1973 suggests that values of ρ and L (on an annual basis) might lie within the approximate ranges of .98-1.00 and .10-.01 respectively.

A crude assessment of the importance of G (instantaneous mortality attributable to carriage of the tag) might be obtained by comparing the overall return rates of single and double tagged fish. These did not differ significantly ($\chi^2 = 0.42$, $P > 0.5$). As the data set is very small, this result needs further confirmation. The high proportion of returns from 1971-72 releases at liberty for more than 200 days (Lewis, 1980) had previously suggested that G might be small. Given the good condition of tagged skipjack at the time of release and the return rates achieved, Π (the proportion alive after immediate tag-induced mortality) is believed to approach unity.

Non-reporting of Recaptures

Individual vessel performance in returning tags was investigated in three cases where the number of tags returned during a given period was relatively large.

(a) Fourteen vessels of company B fishing in the Cape Lambert sector during the June-September period, 1973. Sets 10, 11, 12, 14 and 15 releases were made during this period and the vessels accounted for 165 returns excluding cannery returns, i.e. 55% of all returns from these sets.

TABLE 7

Results of double tagging experiments

η_{dd} = number of returns with both tags

η_{ds} = number of returns with a single tag

Release set		10		11		14		23	
Number released		37		257		54		10	
		η_{dd}	η_{ds}	η_{dd}	η_{ds}	η_{dd}	η_{ds}	η_{dd}	η_{ds}
	1-30	-	-	2	-	10	-	1	
	31-60	-	-	8	-	1	-		
	61-90	-	-	1	-	-	-		
	91-120	1	-	1	-	-	-		
Period at liberty (days)	∿								
	211-240	-	-	1	-	-	-		
	∿								
	331-360	-	-	-	-	1	-		
	361-390	1	-	-	-	-	-		
	390+	-	-	-	1	-	-		
		2	0	12	2	12	0	1	0

TOTAL η_{dd} 27

η_{ds} 2

(b) Four vessels of company C fishing in the West New Britain sector during June-September 1973, and accounting for 79 returns.

(c) Eleven vessels of company A fishing in the New Hanover sector during July-November 1974, and accounting for 52 returns.

This was done by relating the number of tags returned by each vessel to that vessel's effort and catch respectively during the period. (Appendix Table 3).

In case (a), amongst-vessel effects were significant for both effort (χ^2 = 45.44, df. 13, P < .005) and catch (χ^2 - 32.45, df. 13, P < .005); in case (c) for effort (χ^2 = 19.67, df. 10, P < .05) but not catch (χ^2 = 15.09, df. 10, P > .05) and in case (b) effects relative to neither effort (χ^2 = 2.85, df. 3, P > .05) nor catch (χ^2 = 0.20, df. 3 P > .05) were significant. This suggests that some vessels were probably less dilligent in detecting and/or returning tags. In cases (a) and (c), 19 and 10 tags respectively were returned from canneries and traced to this period, and could have evened out discrepancies in the number of recaptures per vessel. If this was the case, the recovery process was breaking down on particular vessels through failure to detect tagged fish, rather than failure to report recaptured fish.

Few opportunities arose to compare company performance in the same area, given the geographical structuring of the fishery by company, but one such occasion arose during a two month period in the Cape Lambert sector (Table 8) and significant differences in the numbers of tags returned were observed with respect to effort (χ^2 = 12.88, df.1, P < .005) and catch (χ^2 = 6.6, df. 1, P < .025). This was reinforced by the fact that one of the apparently defaulting company's vessels accounted for half that company's returns during the June-September period whilst expending 14.6% of the effort and providing 14.9% of the catch. However, companies operating alongside each other tend to minimize contact during fishing operations and the difference could reflect unequal distribution of the tagged population through the sector in question.

It is more difficult to assess non-reporting of recaptures from sources other than Papua New Guinea fishery. The good correlation obtained between levels of effort and number of tags returned by long range pole boats (Figure 10) suggests however levels of any non-reporting were probably constant.

In summary, there is little evidence that non-reporting of tags has introduced any systematic bias to the interpretation of results.

TABLE 8

Comparison of tag returns with catch and effort between two companies, June-July 1973

Part of the Company D fleet was operating in the Kimbe Bay sector during June-July, and the entire fleet operated there during August-September.

Company	Days fished	Catch (tonnes)	Tags returned
B	693	2199	81
D	265	593	9

DISCUSSION

The cyclical nature of skipjack movements within the Bismarck Sea, inferred from returns of skipjack released in the Cape Lambert sector during 1972 (Lewis, 1980), was confirmed by returns from the 1973 releases in the same sector. Despite the marked difference in fishing conditions and annual catch rates between the two years, the essential features of the movements - the interchange between Bismarck and Solomon Seas during November-April and northerly movement through the New Hanover sector in the July-October period - were again observed. Returns from releases in the southern and western Bismarck Sea provided further supporting data and returns in the Bismarck Sea from Solomon Sea releases reaffirmed that two-way movement does occur between these areas, presumably through the Vitiaz Straits but possibly also between New Ireland and New Britain (St. Georges Channel) or via the New Hanover sector. Returns in the Bismarck Sea from Coral Sea releases link these areas and suggest that the seasonal movement into the Solomon Sea may extend to the Coral Sea.

The 1973 releases however produced higher initial return rates, more pronounced movement to the northwest (after which most skipjack are presumed lost to the fishery) and an earlier cessation in returns relative to the 1972 releases. This indicates that although patterns of movement may be similar from year to year, the proportions of fish which respectively remain within the Bismarck Sea for lengthy periods, or emigrate soon after release, may show considerable variation. Periods of greater abundance appear to be associated with the latter.

Returns from the New Hanover releases produced analogous results, with northwestward movement soon after release and southwards movement into the Bismarck Sea sectors being observed. Again the relative strength of these movements will conceivably vary amongst groups of fish between and within years.

Adequate explanation of these complex movements and factors regulating them awaits improved understanding of the species biology and determinants of distribution and abundance. The following hypothesis however accords well with available data. Skipjack present in the area at any given time are believed to comprise two groups, residents and nomads. Residents are retained in the area by the generally increased productivity of waters adjacent to islands due to island mass effects (Gilmartin and Revelante, 1973; Doty and Oguri, 1956), food concentrating mechanisms (Murphy and Shomura, 1972) and 'leakage' of micronekton and zooplankton from coastal ecosystems. Such fish may be of local origin, could be expected to remain in the area for lengthy periods and may spawn within the area. Their density will be related to the average productivity over a preceding time period; they provide baseline levels of production and in 'bad' years, e.g. 1972, probably comprise the majority of the catch. Nomadic elements appear in the area during periods when local productivity is enhanced by oceanographic events on a larger scale. Donguy *et al.*, (1978), using the 35% isohaline as a marker for productive convergences on either side of the seasonal nutrient-rich equatorial upwelling, obtain a good correlation between this parameter and catches by Japanese long range pole vessels in the equatorial western Pacific. Annual fluctuations in the Papua New Guinea fishery also appear to fit the pattern described by them, (Lewis, unpublished). Monthly average catches for the years 1971-77 peak during May-October when the equatorial upwelling should be strongest; fluctuations throughout the year are not marked however, and the 35% isohaline is often favourably located in other months.

The numbers of residents are thus supplemented by episodic influxes of nomands, primarily through the New Hanover sector, but possibly also through the St. George Channel, Vitiaz Strait and Western Bismarck Sea. Losses or emigration, mostly of nomads, occur through these areas, possibly mediated by density-dependent factors, and a variable but much reduced portion of fish originally recruited into the New Hanover sector moves into the southern Bismarck Sea.

During the November-April period, with the change in wind direction and current reversal through the Vitiaz Straits (Yamanaka, 1973; Wyrtki, 1960), nutrient enrichment in the western Bismarck Sea (Donguy *et al.*, 1980) produces displaced zooplanckton and micronekton concentrations in the Solomon Sea, facilitating movement of skipjack, including many residents, into this area. With the advent of the southeast trade winds in April-May, this process is reversed and resident skipjack re-enter the Bismarck Sea.

Added to this, local environmental characteristics favour residents of particular sizes, and thus exert a sieving effect. Other variables such as year class strengths can also be expected to contribute to the complexity of this scheme.

Such an hypothesis has considerable implications for the fishery. The New Hanover sector, benefiting both from a large resident component accruing from its position at an island point rather than on the leeward of windward side (Grandperrin, 1978) and from large scale influxes of nomads, should have the most stable resource base. Operations in the west New Britain and Madang sectors would, on the other hand, rely essentially on residents. Since mid-1975, effort in the Papua New

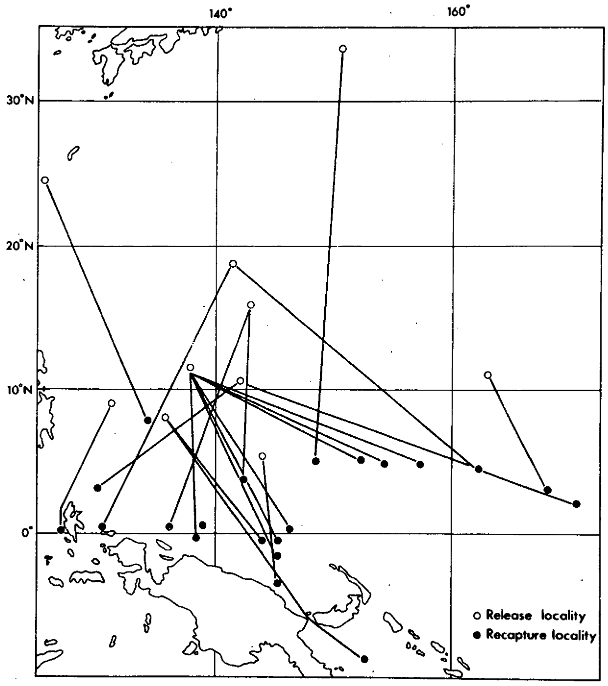
Guinea fishery has focussed not surprisingly on the New Hanover, Manus and Cape Lambert sectors almost exclusively.

The hypothesis, which has been given brief mention in similar form by other authors (e.g. Kawasaki, 1965; Sharp and Dizon, 1978) has not been fully developed here and is being refined as additional data come to hand (Lewis, unpublished). It has the advantage of being amenable to test. Given knowledge of an area's productivity and the timing of environmental processes inducing higher productivity and resultant influxes of nomads, the pattern of tag returns against distribution of catch and effort should be predictable, at least within the local area.

Relationships with adjoining areas and their fisheries, or the geographical extent of nomadic movements into and out of the Papua New Guinea area, remain unclear, largely due to the constraints imposed on the experiments by the variable levels of fishing effort in these areas.

Returns from beyond the Papua New Guinea fishery cover a wide area (Figure 7). North of 5°S, they parallel the distribution of effort, at least within the area considered, i.e. 20°N-5°S, 125°E-165°W. Large fisheries in the western Pacific outside this area (e.g. the Japanese homewater, Philippine and Indonesian fisheries) produced no returns and assuming equal likelihood of recaptures in these fisheries being returned, the extent of migration obviously has finite limits. The relatively high level of annual effort (approximately 1000 days) required to produce a return in a 5 x10 quadrangle indicates either that northward movement of tagged skipjack beyond the Papua New Guinea fishery was a rare event, or more likely, that tagged fish underwent considerable mixing and comprised a very small proportion of the exploited stocks north of 5°S during 1974. The nature of the second degree polynomial function which best describes the relationship between returns and effort and the weaker fit between returns and catch, possibly reflect the non-random distribution of effort by the mobile long range pole and line fishery, i.e. effort is concentrated in productive areas where stock mixing is probably maximized. The negative value of the constant also suggests that effort figures are not additive with respect to tag return probability. Figure 11, reproduced from Lewis (1980), shows notable returns from 8003 releases by Japanese research organizations in an area bounded by 5° and 20°N, and 135° to 165°E, between 1972 and 1976. Six returns were received south of the Equator, but none actually in the Papua New Guinea fishery. This would seem to indicate limited immigration into the area from north of 5°N. Releases between 0° and 5°N would be useful in clarifying this point.

Figure 11. Returns in the western equatorial Pacific from releases north of the Equator.

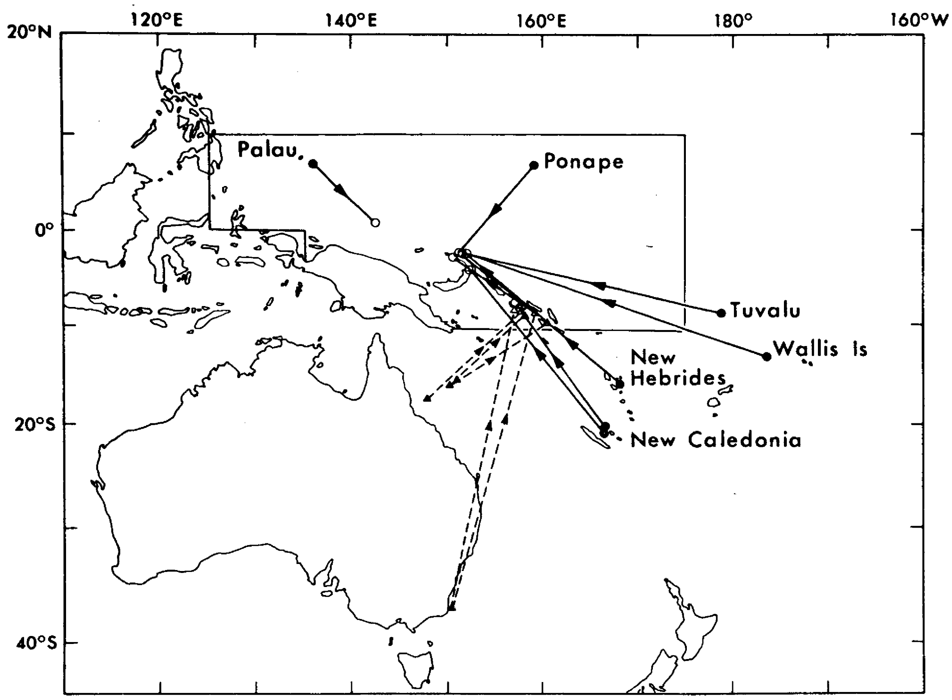


Return rates south of 5°S were considerably higher, indicating that emigration southwards may be relatively more important. The general lack of effort south of 10°S precludes more detailed investigation at this stage. Recent returns from the South Pacific Commission's tagging programme have however provided evidence of the complementary relationship, i.e. immigation into the Papua New Guinea area from areas to the south and east (Figure 11).

Genetic analyses of skipjack blood samples (e.g. Fujino, 1970, 1972, 1976; Sharp and Dizon, 1978) have indicated that this technique may be useful in improving our understanding of inter-areal relationships and population structure, particularly as it is less subject to constraints imposed by distribution of effort and other fishery related factors. To this end, sequential blood sampling was initiated in the New Hanover sector during 1978 (replicate samples at 3 week intervals) in conjunction with collection of length frequency data, with the aim of identifying and monitoring the periodic influxes of groups of skipjack which are so important to the fishery. At the same time, sampling over a much wider area was undertaken by the South Pacific Commission (Anon, 1980). This should enable the time series analysis to be placed in a wider perspective, and add considerably to the results of these tagging experiments. These genetic data should also provide an independent test of aspects of the resident-nomad hypothesis.

Figure 11. Returns in the Papua New Guinea area from releases made elsewhere by the South Pacific Commission.

Returns made in the Solomon Islands are shown with broken lines. The area covered by returns from Papua New Guinea releases is also shown.



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Appendix Table 1. Monthly Effort (fishing days) and catch per unit effort (tonnes/day) by sector for the years 1973, 1974 and 1975.

1973	J	F	M	A	M	J	J	A	S	O	N	D
New Hanover	24(0.4)	8(0.1)	90(1.1)	182(1.4)	195(4.1)	196(6.5)	204(8.4)	208(4.5)	173(6.9)	203(4.6)	194(5.7)	105(5.6)
Cape Lambert	237(1.2)	116(1.6)	241(1.7(	228(2.0)	479(3.9)	488(2.5)	473(3.3)	408(5.8)	389(4.9)	260(2.3)	15(0.6)	199(6.5)
Kimbe Bay	64(0.9)	4(0.2)	51(0.3)	15(0.1)	1(0.1)	2(1.5)	103(4.0)	171(3.3)	190(4.4)	151(0.7)	158(1.3)	162(3.7)
West New Britain	-	-	8(1.0)	7(0.5)	1(0.1)	60(5.3)	116(2.1)	145(2.8)	145(4.4)	-	-	11(1.4)
Madang	30(0.2)	126(0.1)	22(0.3)	110(0.8)	135(1.2)	61(1.2)	1(0.5)	-	-	-	2(1.0)	10(1.1)
Manus	3(0)	-	-	26(0.2)	-	14(1.9)	-	-	-	12(5.5)	200(5.4)	39(2.9)

1974	J	F	M	A	M	J	J	A	S	O	N	D
New Hanover	-	-	38(8.5)	247(4.4)	386(9.0)	340(8.3)	327(6.4)	282(3.9)	284(3.7)	305(5.6)	310(6.0)	243(4.5)
Cape Lambert	162(6.6)	175(8.3)	276(3.9)	338(4.2)	468(3.2)	438(3.8)	378(3.6)	478(4.6)	450(4.2)	475(3.2)	467(2.1)	292(1.8)
Kimbe Bay	-	-	1(0.7)	16(1.4)	47(2.2)	-	144(3.3)	-	-	-	-	-
West New Britain	59(3.2)	56(6.0)	87(0.8)	18(5.0)	4(3.4)	45(4.9)	138(4.0)	168(3.3)	106(1.0)	12(1.0)	7(0.2)	29(2.3)
Madang	5(0.6)	4(0.3)	66(2.1)	90(5.9)	124(3.4)	121(3.8)	99(4.2)	86(4.6)	103(2.7)	170(2.0)	123(2.2)	89(2.0)
Manus	7(2.2)	-	-	-	-	-	-	-	-	23(2.5)	15(4.1)	-

1975	J	F	M	A	M	J	J	A	S	O	N	D
New Hanover	6(0.8)	9(4.4)	6(5.7)	71(4.2)	224(2.8)	229(3.4)	236(3.7)	224(3.6)	279(3.1)	402(1.7)	226(2.3)	235(1.6)
Cape Lambert	109(2.6)	79(3.4)	130(3.8)	163(4.3)	383(1.6)	467(2.9)	462(1.9)	440(1.7)	265(1.9)	338(2.2)	231(1.0)	313(2.2)
Kimbe Bay	-	-	-	-	-	-	-	-	-	-	-	-
West New Britain	19(0.7)	14(0.5)	23(1.3)	-	1(5.2)	3(1.9)	2(0)	-	-	-	-	-
Madang	60(0.9)	16(0)	6(1.9)	9(1.1)	-	80(3.0)	171(1.1)	-	-	-	-	-
Manus	-	-	-	-	-	-	-	-	-	-	-	-
Solomon Sea	97(2.0)	128(1.6)	130(1.4)	29(1.3)	-	-	-	-	-	-	-	-

APPENDIX TABLE 2

Frequency of estimated length at release for skipjack tagged during 1973-74

Est LCF \ Release Set	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	% of Total
< 40	1										5			2		8	0.1
40	4							1			2			2		9	0.1
41	3							-		2	-			-		5	0.1
42	2							-		-	1	2	3	-		8	0.1
43	2							-		-	1	1	5	1		10	0.2
44	1					1		-		-	-	8	6	1		17	0.3
45	3		2	1		5		1		-	1	9	17	6	1	46	0.8
46	1	1	-	-		-		-		3	4	4	8	5	9	35	0.6
47	-	1	1	1	2	-		4		12	4	8	10	16	31	90	1.6
48	1	-	-	3	5	5	1	5		16	3	9	7	18	25	97	1.7
49	-	5	3	4	7	7	-	20		23	2	16	9	15	23	134	2.3
50	-	34	12	5	12	10	1	34		48	4	19	1	25	34	239	4.1
51	3	28	20	7	21	12	1	51		20	3	12	2	24	28	232	4.0
52	3	62	52	57	9	34	-	44	2	36	4	24	5	15	58	405	7.0
53	2	57	198	108	17	38	6	35	7	30	1	33	2	7	49	590	10.2
54	1	90	154	80	8	49	19	22	8	30	1	17	11	9	70	569	9.8
55	3	113	290	66	0	76	45	19	33	35	1	42	20	9	150	902	15.6
56	1	127	251	49	1	97	46	33	49	12	1	15	10	11	165	868	15.0
57	-	104	123	7		88	49	13	66	6	1	10	14	7	182	670	11.6
58	1	71	62	4		20	30	23	48	1		4	7	5	114	390	6.7
59	-	59	11	1		5	9	24	39	2		1	1	1	67	220	3.8
60	-	25	6			1	2	8	35	2	1	-	3		38	121	2.1
61	-	9	-			1	1	4	19	-		1	-		15	50	0.9
62	1	4	2			-		6	5	2			1		3	24	0.4
63		1				-		7	7	2					2	19	0.3
64		-				-		10	3	1						14	0.2
65		1				-		6	1	4						12	0.2
66								2		2						4	0.1
67						1		2								3	0.1
68								1		1						2	0.1
69																	
70																	
	33	792	1187	393	82	450	210	375	322	290	40	235	142	179	1064	5794	

APPENDIX TABLE 3

Comparison amongst vessels of numbers of tags returneo, effort (fishing days) and catch (tonnes)
(a) & (b) are χ^2 homogeneity values for tag/effort and tag/catch comparisons respectively.

Boat	Time period	Days fished	Catch (tonnes	Tags returned
B01	June-Sept. 1973	76	594.6	16
B03	Cape Lambert	75	352.0	7
B05	"	89	455.7	4
B06	"	84	608.6	31
B08	"	84	502.0	14
B11	"	79	339.7	10
B12	"	84	513.6	14
B13	"	84	525.0	18
B14	"	78	460.8	8
B15	"	84	441.1	11
B16	"	51	182.3	0
B22	"	85	522.0	16
B23	"	90	592.9	8
B24	"	86	414.4	8
	(a) χ^2 =	45.44, df. 13;	$\rho <$ ·005	
	(b) χ^2 =	32.45, df. 13;	$\rho <$ ·005	
C02	June-Sept. 1973	103	493.4	27
C05	West New Britain	98	337.3	16
C06	"	96	404.3	21
C11	"	93	285.1	15
	(a) χ^2 =	2.85 df.2	; $\rho >$ .05 (NS)	
	(b) χ^2 =	0.20 df.2	; $\rho >$ .05 (NS)	
A09	July-Nov, 1974	132	862.8	10
A06	New Hanover	129	659.0	8
A10	"	129	622.7	4
A18	"	129	625.9	5
A16	"	120	622.4	2
A11	"	131	536.2	6
A05	"	133	638.1	5
A13	"	132	944.6	9
A01	"	111	461.8	1
A17	"	103	267.3	2