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SKIPJACK MIGRATION, MORTALITY AND FISHERY INTERACTIONS

(Paper Prepared by the Skipjack Programme)

1.0 INTRODUCTION

At the Twelfth Regional Technical Meeting on Fisheries in November, 1980 results were presented of preliminary analyses of tag return data obtained by the Skipjack Survey and Assessment Programme. Since that time considerable progress has been made in the analysis of these data. This working paper will summarize the tag return data accumulated up to July, 1981 and the results of analyses carried out up to that time.

The analytical work has been hampered by two difficulties. One is the dynamic nature of the data set itself. Tag returns continue to come in to SPC headquarters, and this is likely to continue for several months to come. As a result, the data set considered in the analyses changes from day to day. As it is impossible to carry out all analyses in a single day, it was decided to accept the fact that the number of returns utilized in different analyses may vary somewhat simply because the analyses were carried out on different days.

The other more serious difficulty is that a complete set of catch statistics for the fisheries active in recapturing our tags is not available. These statistics are critical to most of the analyses. We have therefore had to forego some analyses or carry them out on a curtailed data set corresponding to the catch statistics available to us.

It is nonetheless possible to draw some important inferences from the data as they now stand. Results bearing on the migration, mortality and population size of skipjack will be presented along with the implications of these to interaction among fisheries in the region, both at their present levels and at possible expanded levels in the future. Analyses of these tagging data for the investigation of growth of skipjack and the investigation of skipjack school integrity are presented separately.

It is important to understand that the results discussed here are the results of tagging adult tuna which are vulnerable to pole-and-line fishing gear. Therefore the tagged fish are strictly representative only of that vulnerable fraction of the adult population and are unlikely to be representative at all of the pre-recruit portion of the population.

2.0 SUMMARY OF TAG RETURN DATA

2.1 Releases and Returns by Country and Month

Table 1 presents the details of the skipjack tag returns broken down by country-year-month of release and by country-year-month of recapture. Similar details for yellowfin are given in Table 2. Returns by the SPC tagging vessel are not included in Tables 1 and 2, nor are returns with imprecise[1] position or date of recapture information. To conserve space mnemonics for the various countries and areas within countries are used in these tables and elsewhere. Table 3 gives the meanings of these mnemonics. The areas defined in Table 3 will be called countries in this document even though many of them are actually subdivisions of countries.

2.2 Migration Arrows

In Figures 1 and 2 a selection of tag returns for skipjack and yellowfin are shown plotted as straight line arrows on a map. Returns were selected for skipjack by plotting no more than one example of a migration in each direction between any pair of ten degree squares and no more than one example of a migration wholly within any ten degree square. Yellowfin returns were selected in a similar fashion except that one degree squares were used as the returns were far less numerous than the skipjack returns.

2.3 Returns by Boat Type

Table 4 shows the tag returns broken down by country and vessel type. Note that the greatest proportion of returns is from regionally based commercial operations. The returns in this category are predominantly from the local pole-and-line operations in Papua New Guinea, Solomon Islands and Fiji, but they also include recoveries from pole-and-line boats based in Kiribati (Gilbert Islands), Palau and Tonga and bonitiers based in French Polynesia. Returns from the Japanese long distance pole-and-line fleet are the most extensive in terms of the area covered. Many areas would have no returns at all without the returns from this fleet. Unfortunately, we have been unable to obtain Japanese catch statistics as yet beyond 1978, which means that Japanese

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[1] Imprecision in this context is defined as follows: In cases where capture date is not known exactly but is known to be within a range of possible dates and the date range is less than half the span of time from the release date to the midpoint of the range, the return is accepted and the recapture date taken to be the midpoint of the range. If the range is longer than half the time from release to midpoint, the return is disregarded. Similar criteria are applied to the geographic recapture position, i.e. the distance to the midpoint of the range must be more than twice the maximum geographic extent of the range.

TABLE 1. SKIPJACK TAG RETURNS UP TO 21 JULY 1981

Release headings are listed giving the number of tags released for each country and year/month in which releases occurred. Each release heading is followed by capture country subheadings giving the countries from which one or more tags were returned from among the tags given in the main heading. Capture country subheadings are followed by the number of recoveries in that country for each year/month of recapture. A total of 5336 returns from 139961 tagged skipjack are included in the Table. Not included, are 280 recaptures by the SPC tagging vessel and 839 returns with missing or imprecise information on capture position or capture date.

AMS 78/06 : 74 released												
AMS 80/02 : 701 released												
	AMS returns:	80/02	3									
	WES returns:	80/04	1									
CAL 77/12 : 6572 released												
	CAL returns:	77/12	2	78/01	4	78/02	2					
	MAR returns:	79/03	1									
	PNG returns:	78/07	1									
	SOL returns:	78/07	1	80/01	1							
CAL 78/01 : 3622 released												
	CAL returns:	78/01	10									
	INT returns:	78/10	2									
	KIR returns:	79/08	1									
	PNG returns:	78/09	1									
	PON returns:	79/02	2									
	SOL returns:	78/04	1	78/06	1	78/07	1	78/08	1	78/09	2	78/10
		78/11	1									
	TRK returns:	79/01	1									
CAL 80/03 : 25 released												
FIJ 78/01 : 876 released												
	FIJ returns:	78/01	1	78/02	81	78/03	15	78/04	1	78/05	1	78/06
		79/02	1									
FIJ 78/02 : 3423 released												
	FIJ returns:	78/02	306	78/03	82	78/04	9	78/05	6	78/06	3	78/07
		80/05	2									
	TON returns:	78/07	1									
	TUV returns:	78/07	1	79/02	1							
	WAK returns:	79/10	1									
	ZEA returns:	79/03	1									
FIJ 78/03 : 2 released												
FIJ 78/04 : 3818 released												
	FIJ returns:	78/04	284	78/05	6	78/06	3	78/07	3	79/02	2	79/06
		81/03	1									
	INT returns:	78/09	1	80/02	1							
	NAU returns:	79/04	1									
	PHO returns:	78/09	1									
	SOC returns:	79/01	1									
	WAL returns:	80/05	1									
	WES returns:	78/08	1	79/02	1							
	ZEA returns:	78/11	1	79/01	1							
FIJ 80/04 :11646 released												
	CAL returns:	80/11	1									
	FIJ returns:	80/04	670	80/05	181	80/06	6	80/07	11	80/08	16	80/10
		80/11	2	80/12	9	81/01	27	81/02	40	81/03	35	81/04
		81/05	9	81/06	7	81/07	3					
	INT returns:	80/10	1	81/02	2							
	KIR returns:	81/04	1									
	PHO returns:	80/09	2	81/02	1							
	TUV returns:	80/07	1	80/08	1	80/10	1					
GAM 80/02 : 174 released												
JAP 78/10 : 108 released												
	IND returns:	79/03	1	79/05	1							
	INT returns:	79/03	1	79/04	1	79/06	1					
	JAP returns:	78/10	5	78/11	1	79/03	1					
	KIR returns:	80/03	1									
	MAR returns:	79/02	1									
	MAS returns:	79/12	1									

TABLE 1. (cont.) - <u>SKIPJACK TAG RETURNS UP TO 21 JULY 1981</u>

KIR 78/07 : 4403 released													
	AMS returns:	79/12	1										
	HOW returns:	79/08	6	79/09	3	79/10	9	80/03	1	80/04	1	80/07	1
		80/08	2	80/09	1								
	INT returns:	78/08	1	78/09	1	78/11	2	79/04	1	79/08	1	79/09	4
		79/10	3	79/11	2	79/12	3	80/02	3	80/03	2	80/04	2
		80/07	1	80/08	1	80/10	1	81/03	1				
	KIR returns:	78/07	37	78/08	161	78/09	92	78/10	82	78/11	3	78/12	3
		79/01	2	79/02	1	79/03	1	79/04	1	79/08	1	79/09	1
		80/10	1										
	KOS returns:	78/12	1										
	LIN returns:	79/09	1										
	MAS returns:	78/11	3	78/12	4	79/01	4	79/04	1	80/02	2		
	NAU returns:	78/09	1										
	PAM returns:	80/07	1										
	PHO returns:	79/10	1										
	PON returns:	78/10	1										
KIR 78/11 : 16 released													
KIR 79/11 : 150 released													
	INT returns:	80/04	1										
	PAM returns:	80/07	1										
KOS 78/11 : 135 released													
	INT returns:	79/04	1	79/08	1	80/02	1						
KOS 79/11 : 162 released													
	MAS returns:	80/02	2										
MAQ 79/01 : 1689 released													
	MAQ returns:	79/02	1										
MAQ 79/12 : 8137 released													
	INT returns:	80/09	2	81/02	1								
	KIR returns:	80/10	1										
	MAQ returns:	79/12	1	80/01	21								
MAQ 80/01 :10456 released													
	HOW returns:	81/03	1										
	INT returns:	81/03	1										
	MAQ returns:	80/01	14	80/02	3	80/05	1	80/09	1				
	PHO returns:	80/09	1										
	SOC returns:	80/12	1										
MAR 78/10 : 8 released													
MAR 79/11 : 187 released													
	INT returns:	80/04	1	80/08	1								
	JAP returns:	80/10	1										
	MAR returns:	80/06	1	80/07	1								
	MTS returns:	80/06	1										
	PON returns:	80/03	1										
	TRK returns:	80/02	1	80/04	1								
MAS 78/07 : 122 released													
MAS 78/11 : 164 released													
	INT returns:	79/10	1	80/02	1								
	MAS returns:	78/12	1										
	NAU returns:	79/04	1										
MAS 79/11 : 41 released													
NCK 78/11 : 163 released													
NCK 78/12 : 1066 released													
	NCK returns:	78/12	1										
NIU 80/02 : 91 released													
NOR 80/03 : 1113 released													
	CAL returns:	81/03	1										
	FIJ returns:	81/06	1										
	SOL returns:	80/12	1										

TABLE 1. (cont.) - SKIPJACK TAG RETURNS UP TO 21 JULY 1981

NSW 79/04 : 4322 released													
	AMS returns:	80/02	1										
	CAL returns:	79/11	1	79/12	3	80/01	1	80/02	1				
	FIJ returns:	81/02	1										
	INT returns:	80/07	1										
	NSW returns:	79/12	1	80/01	1								
	SOC returns:	80/01	1										
	SOL returns:	79/07	1	79/11	3	79/12	1	80/02	1	80/04	1	80/10	1
	WES returns:	80/01	1										
	ZEA returns:	80/01	4	80/02	4	80/03	1						
PAL 78/10 : 718 released													
	INT returns:	78/12	1	79/01	1	79/03	4	79/04	1				
	MAS returns:	80/02	1										
	PAL returns:	78/10	31										
	PHL returns:	79/08	1										
	PNG returns:	79/01	1										
	PON returns:	79/02	1										
	TRK returns:	79/02	1										
	YAP returns:	78/11	2	79/02	2	79/03	2						
PAL 80/08 : 6515 released													
	IND returns:	80/09	1	80/10	9	80/11	11	80/12	4	81/01	3		
	INT returns:	80/09	1	80/10	1	80/11	8	80/12	6	81/01	2	81/02	1
		81/03	6	81/04	8	81/05	5						
	KIR returns:	80/11	2	81/04	1								
	MAR returns:	81/02	1										
	MAS returns:	80/12	1	81/01	1								
	PAL returns:	80/08	5	80/09	7	80/10	48	80/11	7	81/02	3	81/04	1
		81/05	2										
	PNG returns:	80/09	3	80/10	4	80/11	7	80/12	21	81/01	4	81/02	7
		81/03	4	81/04	2	81/05	3						
	PON returns:	81/01	1	81/02	1	81/04	3						
	SOL returns:	81/05	1	81/06	1								
	TRK returns:	80/11	9	81/02	1	81/03	1	81/04	1				
	YAP returns:	80/10	4	80/11	1	81/01	3	81/02	1	81/03	4	81/04	1
PHO 79/12 : 367 released													
	KIR returns:	80/07	1										
PIT 80/02 : 59 released													
PNG 77/10 : 900 released													
	PNG returns:	77/10	1	78/06	1								
	SOL returns:	78/09	2	78/12	1								
PNG 79/05 : 3227 released													
	IND returns:	79/06	1	80/02	1								
	INT returns:	79/08	1	79/11	1	79/12	1	80/02	1	80/04	1	80/08	1
		80/10	1	81/04	1								
	KIR returns:	80/08	1										
	KOS returns:	80/02	1										
	MAS returns:	80/12	1										
	PAM returns:	80/08	1										
	PNG returns:	79/05	22	79/06	224	79/07	80	79/08	47	79/09	30	79/10	11
		79/11	5	79/12	1	80/04	4	80/06	2	80/07	1	80/08	2
		80/09	3										
	SOL returns:	79/07	1	79/08	1	79/10	4	80/01	2	80/07	3	80/08	1
		80/11	1	80/12	2								
	TRK returns:	80/03	1	80/04	2	80/08	1						
PNG 79/06 : 4401 released													
	HOW returns:	80/07	3	80/08	2								
	IND returns:	79/09	1	79/10	1	80/01	1	80/02	1	80/04	1		
	INT returns:	79/09	1	79/11	1	80/01	2	80/04	2	80/07	2	80/12	1
	MAS returns:	80/02	1	80/10	3	81/02	2						
	PAL returns:	79/09	1	80/10	1								
	PAM returns:	80/08	1										
	PNG returns:	79/06	173	79/07	130	79/08	56	79/09	28	79/10	16	79/11	2
		79/12	5	80/01	1	80/03	1	80/04	2	80/05	2	80/07	2
		80/08	4	80/09	3								
	PON returns:	80/03	2	80/04	1								
	SOL returns:	80/05	1	80/07	1	80/08	1	80/09	1	80/12	1	81/01	1
	TRK returns:	79/11	2	80/02	1	80/03	2	80/04	1	80/05	2		
	YAP returns:	79/09	2	79/10	1	80/03	1						

TABLE 1. (cont.) - SKIPJACK TAG RETURNS UP TO 21 JULY 1981

PON 78/08 : 428 released													
	INT returns:	79/04	1	79/06	1	79/10	1	79/12	1				
	KOS returns:	78/12	6										
	MAS returns:	78/11	1										
	PON returns:	78/08	1	78/09	1	78/10	1	78/12	2	79/02	1		
PON 78/10 : 317 released													
	HOW returns:	79/10	1										
	INT returns:	79/08	1										
	JAP returns:	79/05	1										
	KOS returns:	78/12	3	79/01	2	79/02	2						
	MAS returns:	79/05	1										
	PON returns:	78/12	5	79/01	1								
	TRK returns:	78/12	1										
	YAP returns:	79/02	1										
PON 78/11 : 163 released													
	KOS returns:	78/12	1										
	MAS returns:	78/11	1										
	PNG returns:	79/04	1										
	PON returns:	78/12	2	79/01	1								
PON 79/11 : 935 released													
	PON returns:	80/03	1										
	SOL returns:	80/10	1										
	TRK returns:	80/02	1										
PON 80/07 : 3650 released													
	INT returns:	80/12	2	81/01	1	81/04	3	81/05	2				
	KIR returns:	80/10	1										
	KOS returns:	80/10	3	80/11	2	81/03	1						
	MAR returns:	81/02	1										
	MAS returns:	80/10	6	80/11	5	80/12	2	81/01	2	81/02	2		
	PON returns:	80/07	1	80/08	5	80/09	6	80/10	8	80/11	3	81/01	4
		81/02	5	81/03	1								
	TRK returns:	80/11	3	81/02	2	81/03	3	81/04	1				
	YAP returns:	80/11	2	81/01	2	81/03	1	81/04	1				
QLD 79/05 : 2651 released													
	CAL returns:	79/11	1	79/12	2								
	QLD returns:	79/05	2										
	SOL returns:	79/07	2	79/10	3	79/11	7	79/12	6	80/02	1	80/06	1
		80/10	1	80/11	1	80/12	2						
	TRK returns:	80/05	1										
	VAN returns:	80/03	1	81/02	1								
SCK 79/02 : 9 released													
SCK 80/02 : 39 released													
SOC 78/12 : 828 released													
	SOC returns:	78/12	5	79/01	4	79/02	4	79/03	4	79/04	1	79/05	3
		79/06	2										
SOC 79/01 : 896 released													
	SOC returns:	79/01	8	79/02	2	79/03	1	79/12	1	80/07	1		
SOC 80/02 : 1 released													
SOL 77/10 : 268 released													
	SOL returns:	78/05	1	78/12	3								
SOL 77/11 : 1805 released													
	PNG returns:	78/05	1	78/06	3								
	SOL returns:	77/11	18	77/12	10	78/04	3	78/05	5	78/06	1	78/07	2
		78/08	3	78/09	4	78/10	7	78/11	4	78/12	5	79/01	1
		79/04	2										
SOL 77/12 : 417 released													
	KIR returns:	78/02	1										
	SOL returns:	78/11	1										
SOL 80/06 : 3731 released													
	FIJ returns:	80/11	1										
	IND returns:	80/12	1										
	PNG returns:	80/08	3	80/10	1	80/11	1	81/01	1	81/02	1	81/03	2
		81/06	1										
	SOL returns:	80/06	68	80/07	65	80/08	48	80/09	24	80/10	19	80/11	31
		80/12	35	81/01	44	81/02	4	81/03	2	81/04	10	81/05	8
		81/06	22										

TABLE 1. (cont.) - <u>SKIPJACK TAG RETURNS UP TO 21 JULY 1981</u>

TOK 78/11 : 64 released													
	TOK returns:	78/12	1										
TON 78/04 : 1402 released													
	PHO returns:	78/10	1										
	SOC returns:	79/04	1										
	TON returns:	78/05	9										
	WES returns:	78/06	1										
TON 80/03 : 567 released													
	TON returns:	80/04	1										
TRK 78/08 : 720 released													
	INT returns:	79/02	1	79/12	1								
	KOS returns:	78/12	4	79/01	1								
	MAS returns:	79/04	1	79/11	1								
	PON returns:	78/11	1	78/12	7	79/01	2	79/02	3	79/03	1		
	TRK returns:	78/08	6	78/10	2	78/11	1	78/12	2	79/02	1	79/03	1
	YAP returns:	79/01	1	79/03	1								
TRK 79/11 : 334 released													
	INT returns:	80/07	1										
	MAS returns:	80/02	1	80/10	2								
	PON returns:	80/03	3	80/04	2								
	TRK returns:	79/11	1	79/12	1	80/04	1						
TUA 78/12 : 2304 released													
	SOC returns:	79/02	1	79/06	1	79/07	1						
	TUA returns:	78/12	9	79/01	2	79/04	2						
TUA 79/01 : 2409 released													
	TUA returns:	79/01	1	79/04	10	80/03	1						
TUA 80/02 : 815 released													
	SOC returns:	80/09	1	80/11	1								
TUV 78/06 : 1766 released													
	FIJ returns:	79/02	1										
	INT returns:	80/07	1										
	KIR returns:	78/10	1										
	MAS returns:	80/01	1										
	PAM returns:	79/11	1										
	PNG returns:	79/10	1										
	SOL returns:	79/07	1	79/11	1								
	TUV returns:	78/07	1										
	WES returns:	78/08	1										
TUV 78/07 : 818 released													
	HAW returns:	80/05	1										
	HOW returns:	78/11	1										
	INT returns:	78/10	2	78/11	1	79/10	1	79/11	1				
	KIR returns:	79/02	1										
	KOS returns:	78/12	1										
	MAS returns:	80/02	1										
	NAU returns:	78/09	1										
	PHO returns:	78/10	1										
	TUV returns:	78/09	1										
	YAP returns:	80/03	1										
TUV 80/07 : 318 released													
	FIJ returns:	81/02	1										
	INT returns:	80/09	1										
	MAS returns:	80/11	1	81/02	1								
VAN 77/12 : 51 released													
	VAN returns:	78/01	1										
VAN 78/01 : 1099 released													
	PNG returns:	79/10	1										
	SOL returns:	78/10	3	79/11	1								
	VAN returns:	78/01	1										

TABLE 1. (cont.) - SKIPJACK TAG RETURNS UP TO 21 JULY 1981

WAL 78/05 :13513 released													
	CAL returns:	79/12	1										
	FIJ returns:	79/01	1	79/02	2	79/03	2	79/07	1	80/07	1		
	HOW returns:	79/08	1	80/04	1	80/06	1	80/07	1				
	INT returns:	78/10	2	78/11	1	79/10	3	80/04	1	80/08	1	81/02	1
	KIR returns:	78/09	2	78/10	1	79/02	1	80/01	1				
	MAS returns:	78/09	1	79/11	1	80/02	1						
	PHO returns:	78/08	1	78/09	4	78/10	15	78/11	1	80/09	1		
	PNG returns:	79/09	1										
	SOC returns:	79/02	1	79/07	1	79/08	1						
	TRK returns:	79/03	1										
	TUV returns:	79/01	1										
	WAL returns:	78/05	49										
	WES returns:	78/07	4	78/08	5	78/10	1						
	ZEA returns:	79/01	1	79/03	4	79/04	1						
WAL 80/05 : 2552 released													
	FIJ returns:	81/02	4	81/03	1								
	INT returns:	80/10	1										
	PHO returns:	80/09	1	81/03	1								
	WAL returns:	80/05	17										
	WES returns:	80/12	1										
WES 78/06 : 1767 released													
	AMS returns:	79/01	1										
	SOL returns:	80/05	1										
	WES returns:	78/06	10	78/07	1	78/10	2	78/11	1	79/05	1		
WES 80/02 : 159 released													
	SOC returns:	80/12	1										
	WES returns:	80/02	1	80/04	2	80/05	1						
YAP 78/10 : 778 released													
	IND returns:	79/01	2	79/02	1								
	INT returns:	79/01	2	79/03	2	79/04	2	80/04	1				
	JAP returns:	79/05	1										
	KIR returns:	79/08	1	80/03	1								
	MAR returns:	79/02	2	79/03	1								
	PAL returns:	79/02	1										
	PON returns:	79/02	1										
	TRK returns:	79/02	1	79/03	2								
	YAP returns:	79/02	1	79/03	4								
ZEA 79/02 : 2678 released													
	FIJ returns:	80/01	2	80/02	1	81/02	1						
	INT returns:	80/02	1										
	NSW returns:	79/11	1										
	WES returns:	79/12	1	80/01	1								
	ZEA returns:	79/02	2	79/03	215	79/04	1	79/05	1	80/01	6	80/02	4
ZEA 79/03 : 8945 released													
	CAL returns:	79/12	1	80/01	1	80/02	2	80/12	1				
	FIJ returns:	79/06	1	79/10	1	79/11	2	80/01	1	80/02	2	80/03	5
		80/04	1	80/07	1	80/08	1	81/02	2				
	INT returns:	80/02	1	81/02	1								
	NOR returns:	80/03	1										
	SOC returns:	80/01	1	80/02	1	80/05	1	80/10	1				
	TOK returns:	80/11	1										
	TON returns:	80/02	1										
	VAN returns:	80/03	1										
	WES returns:	79/12	1	80/01	1								
	ZEA returns:	79/03	318	79/04	3	79/05	2	80/01	23	80/02	8	80/03	4
		80/06	2										
ZEA 80/03 : 1111 released													
	FIJ returns:	81/01	2	81/02	2	81/06	2						
	NSW returns:	81/03	1										
	SOC returns:	81/02	1										
	WES returns:	81/02	1										
	ZEA returns:	80/06	1										

TABLE 2. YELLOWFIN TAG RETURNS UP TO 21 JULY 1981

Release headings are listed giving the number of tags released for each country and year/month in which releases occurred. Each release heading is followed by capture country subheadings giving the countries from which one or more tags were returned from among the tags given in the main heading. Capture country subheadings are followed by the number of recoveries in that country for each year/month of recapture. A total of 183 returns from 9338 tagged yellowfin are included in the Table. Not included, are 2 recaptures by the SPC tagging vessel and 23 returns with missing or imprecise information on capture position or capture date.

CAL 77/12 : 44 released													
CAL 78/01 : 12 released													
CAL 80/03 : 27 released													
FIJ 78/01 : 24 released													
	FIJ returns:	78/03	1										
FIJ 78/02 : 480 released													
	FIJ returns:	78/02	35	78/03	10	78/04	1	78/05	2	78/06	1	79/11	1
FIJ 78/04 : 332 released													
	FIJ returns:	78/04	26	78/06	1								
FIJ 80/04 : 1138 released													
	FIJ returns:	80/04	22	80/05	4	80/07	1	81/01	1	81/02	1	81/05	1
GAM 80/02 : 302 released													
KIR 78/07 : 44 released													
KIR 79/11 : 8 released													
KOS 78/11 : 1 released													
KOS 79/11 : 597 released													
MAQ 79/12 : 163 released													
MAQ 80/01 : 25 released													
MAS 78/07 : 6 released													
MAS 78/11 : 2 released													
MAS 79/11 : 86 released													
	KIR returns:	80/05	1										
NIU 80/02 : 31 released													
NOR 80/03 : 254 released													
	NOR returns:	81/02	1										
NSW 79/04 : 8 released													
PAL 80/08 : 1288 released													
	IND returns:	80/11	3										
	INT returns:	80/12	1	81/04	3	81/05	1						
	PAL returns:	80/10	2										
	PNG returns:	80/11	1	80/12	6	81/02	1	81/03	1	81/04	1		
	PON returns:	80/11	1										
	YAP returns:	80/10	1	81/01	1	81/04	1						
PHO 79/12 : 16 released													
PIT 80/02 : 290 released													
	INT returns:	80/12	1										
PNG 77/10 : 18 released													
PNG 79/05 : 199 released													
	PNG returns:	79/05	1	79/06	4	79/08	1						
PNG 79/06 : 583 released													
	IND returns:	79/09	2	79/10	1								
	INT returns:	79/09	1	79/11	1								
	PNG returns:	79/06	4	79/07	4	79/08	1	79/09	1	79/10	1		
	PON returns:	79/12	1										
	YAP returns:	79/09	1	79/11	1								

TABLE 2. (cont.) - YELLOWFIN TAG RETURNS UP TO 21 JULY 1981

PON 78/10 :	29 released										
	WAK returns:	79/10	1								
PON 78/11 :	31 released										
PON 79/11 :	146 released										
	TRK returns:	80/03	1								
PON 80/07 :	53 released										
	PON returns:	80/09	1								
QLD 79/05 :	54 released										
SOC 79/01 :	4 released										
SOC 80/02 :	33 released										
	SOC returns:	80/03	1	80/08	1						
SOL 77/11 :	118 released										
SOL 80/06 :	740 released										
	INT returns:	80/12	1								
	SOL returns:	80/08	2	80/09	2	80/11	1	81/02	1	81/06	3
TON 78/04 :	258 released										
	FIJ returns:	78/07	1								
TON 80/03 :	4 released										
TUA 78/12 :	62 released										
	SOC returns:	79/03	1								
TUA 79/01 :	32 released										
TUA 80/02 :	648 released										
	SOC returns:	80/10	1	80/12	1	81/03	1				
TUV 78/06 :	135 released										
VAN 78/01 :	191 released										
	SOL returns:	78/10	1								
WAL 78/05 :	213 released										
	WAL returns:	78/05	1								
WAL 80/05 :	521 released										
WES 78/06 :	78 released										
YAP 78/10 :	10 released										
	YAP returns:	79/01	1								

TABLE 3. COUNTRY MNEMONICS

AMS	American Samoa
CAL	New Caledonia
FIJ	Fiji
GAM	Gambier Islands (French Polynesia)
HAW	Hawaii
HOW	Howland and Baker Islands (U.S. Territory)
IND	Indonesia
INT	International waters
JAP	Japan
KIR	Kiribati
KOS	Kosrae (Federated States of Micronesia)
LIN	Line Islands (Kiribati)
MAQ	Marquesas Islands (French Polynesia)
MAR	Mariana Islands
MAS	Marshall Islands
MTS	Minami-tori shima (Japan)
NAU	Republic of Nauru
NCK	Northern Cook Islands
NIU	Niue
NOR	Norfolk Island
NSW	New South Wales (Australia)
PAL	Palau
PAM	Palmyra (U.S. Territory)
PHL	Philippines
PHO	Phoenix Islands (Kiribati)
PIT	Pitcairn Islands
PNG	Papua New Guinea
PON	Ponape (Federated States of Micronesia)
QLD	Queensland (Australia)
SCK	Southern Cook Islands
SOC	Society Islands (French Polynesia)
SOL	Solomon Islands
TOK	Tokelau
TON	Kingdom of Tonga
TRK	Truk (Federated States of Micronesia)
TUA	Tuamotu Islands (French Polynesia)
TUV	Tuvalu
VAN	Vanuatu
WAK	Wake Island (U.S. Territory)
WAL	Wallis and Futuna
WES	Western Samoa
YAP	Yap (Federated States of Micronesia)
ZEA	New Zealand

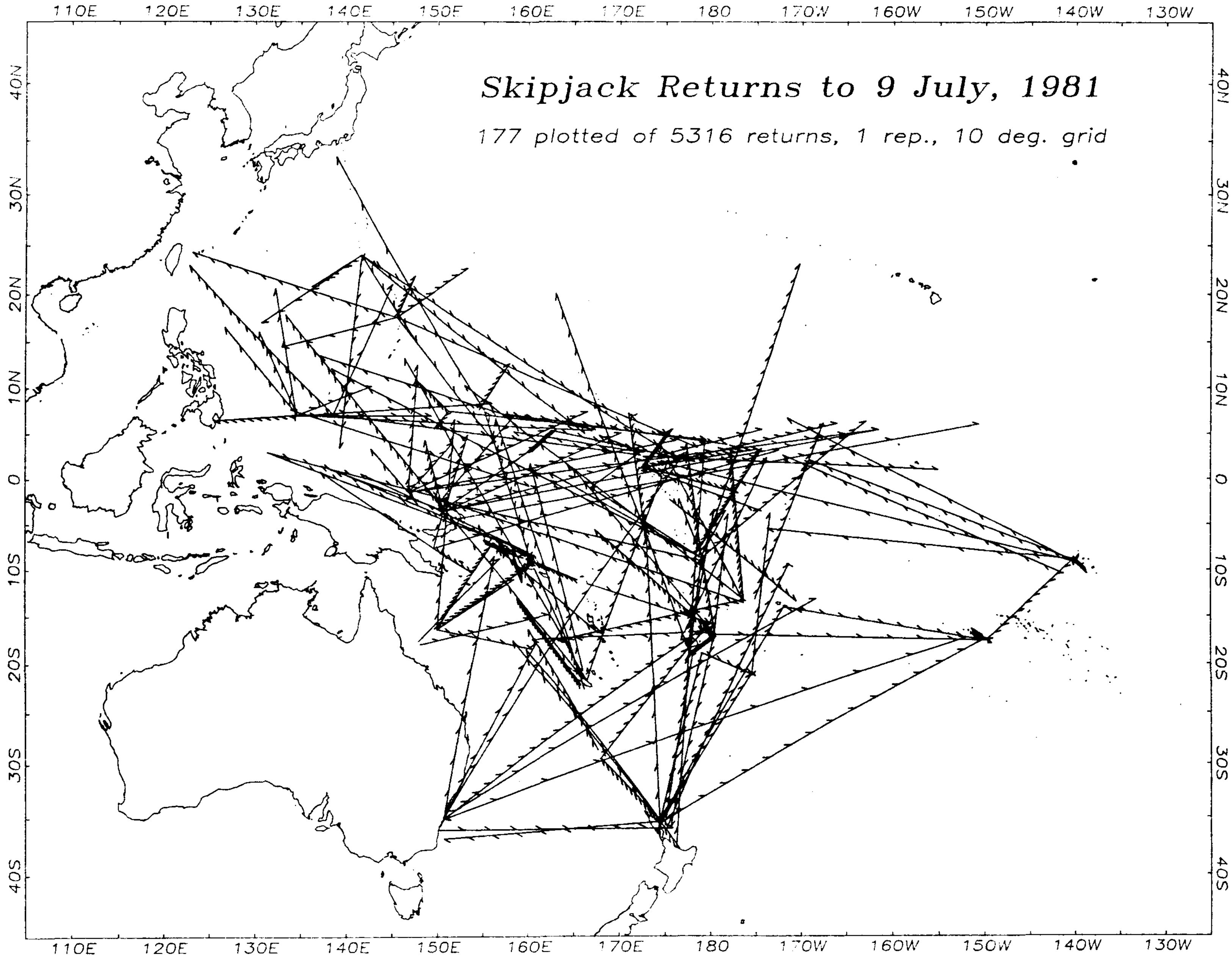

Figure 1. Skipjack migration arrows. The 177 returns plotted here were selected from among the 5,316 skipjack returns which had precise recapture data and position information and which were received by 9 July 1981. The selection procedure is given in the text.

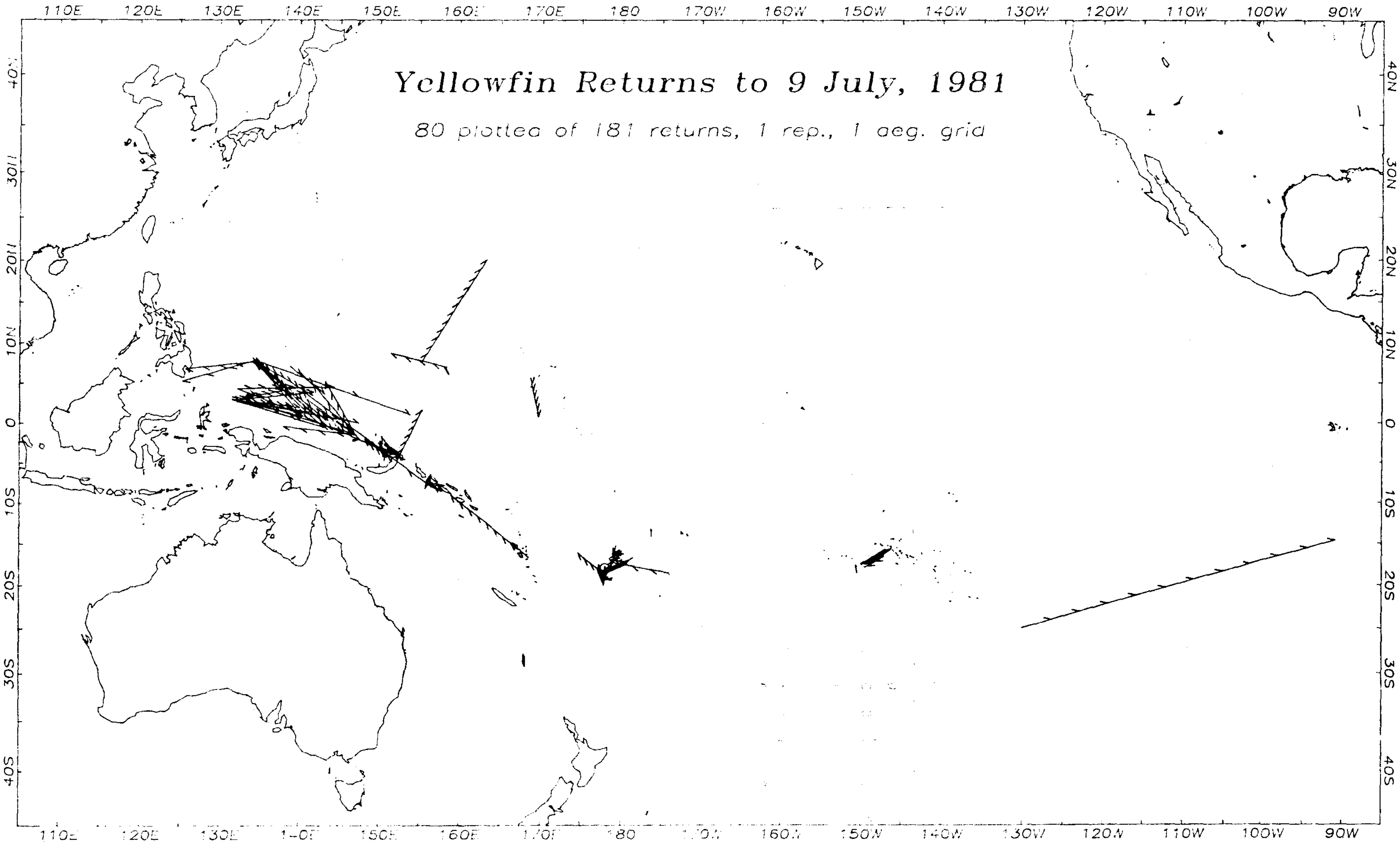

Figure 2. Yellowfin migration arrows. The 80 returns plotted here were selected from among the 181 yellowfin returns which had precise recapture data and position information and which were received by 9 July 1981. The selection procedure is given in the text.

TABLE 4. RETURNS BY COUNTRY AND BOAT TYPE UP TO 26 JULY 1981

Seven categories of recapture vessels are defined in the column headings. Regionally based commercial vessels include locally based pole-and-line operations in PNG, SOL, FIJ, KIR, TON and PAL as well as bonitiers operating in French Polynesia. Sub-columns represent species : SJ=skipjack, YF=yellowfin, OT=other. Interpretation of country mnemonics is given in Table 3.

Boat Type	Regionally Based			Artisanal Subsistence Recreational			SPC Tagging Vessel			Japanese Pole-and-line			Seiners			Longliners			Unknown		
Species	SJ	YF	OT	SJ	YF	OT	SJ	YF	OT	SJ	YF	OT	SJ	YF	OT	SJ	YF	OT	SJ	YF	OT
AMS	0	0	0	2	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CAL	4	0	0	1	0	0	13	0	0	17	0	0	0	0	0	0	0	0	0	0	0
FIJ	1878	110	43	1	1	0	93	1	0	2	0	0	0	0	0	0	1	0	0	0	0
HAW	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
HOW	0	0	0	0	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0
IND	5	0	0	1	1	0	0	0	0	1	0	0	34	5	0	0	0	0	0	0	0
INT	4	0	0	1	1	0	0	0	0	115	0	0	37	6	0	0	2	0	0	1	0
JAP	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	1	0	0
KIR	346	0	0	2	0	0	10	0	0	46	0	0	1	0	0	1	1	0	1	0	0
KOS	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0
LIN	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
MAQ	2	0	0	6	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAR	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
MAS	0	0	0	1	0	0	0	0	0	62	0	0	0	0	0	0	0	0	2	0	0
MTS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
NAU	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
NCK	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOR	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NSW	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
PAL	91	3	0	0	0	0	1	0	0	15	0	0	3	0	0	0	0	0	2	0	0
PAM	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
PHL	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHO	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0
PNG	964	20	6	7	0	0	5	0	0	5	0	0	55	9	0	0	0	0	13	0	0
PON	9	0	0	17	1	0	0	0	0	64	1	0	1	1	0	0	0	0	1	0	0
QLD	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOC	27	6	0	11	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOL	526	11	1	1	0	0	13	0	0	8	0	0	1	0	0	0	0	0	6	0	0
TOK	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TON	11	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
TRK	7	0	0	1	0	0	1	0	0	48	1	0	2	0	0	1	0	0	0	0	0
TUA	14	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TUV	2	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0
VAN	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0
WAK	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
WAL	0	0	0	0	0	0	67	1	0	0	0	0	0	0	0	0	0	0	0	0	0
WES	3	0	0	31	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YAP	0	0	0	0	0	0	0	0	0	23	1	0	16	5	0	0	0	0	2	0	0
ZEA	1	0	0	5	0	0	0	0	0	0	0	0	1013	0	0	0	0	0	3	0	0
???	23	0	0	0	0	0	0	0	0	12	1	0	19	0	0	0	1	0	109	12	0
TOTAL	3919	150	50	95	5	0	280	2	0	557	5	0	1183	26	0	2	5	0	142	13	0

long distance pole-and-line fleet returns from 1979 onwards, which account for 74% of the returns from this fleet, are not accompanied by catch or effort information. We also do not at this time have catch statistics for any of the purse seine fleets, except in the waters of New Zealand, nor do we have longline statistics beyond 1978.

3.0 ANALYTICAL RESULTS

The remainder of this presentation will be concerned only with skipjack since our skipjack results represent 90% of our data and catch and effort information is even less complete for yellowfin tuna.

3.1 Search for Migration Patterns

It is evident from Figure 1 that there are no apparent barriers to the movement of skipjack anywhere within the SPC area and beyond. The first impression is one of random or turbulent movement. Certainly it is to be expected that if a directional (ie. advective) migration pattern is discovered in the data this pattern can represent only an average tendency of skipjack migration as there are likely to be exceptions to any general trend. Still, it is of interest to search for general trends. Figure 1 is not ideal for this purpose. Because of the necessary selection of a subset of the tag migrations for plotting, there is built in bias against the more common migrations because several fish migrating between two particular ten degree squares will produce no more arrows in Figure 1 than would a single fish undertaking the same migration. There is also possible confusion due to the use of straight lines when the actual migraton pathways might be curved. Additional confusion could result from seasonal or longer term changes in the migration pathways. Finally, there is no correction in Figure 1 for the effect of non-uniform distribution of fishing intensity.

To try to alleviate some of the above difficulties, a different cartographical presentation of the results was made. The maps in Figures 3,4, and 5 show rosettes centered on the mean geographic position of the tag release positions in each country where we tagged skipjack. These rosettes depict the movement trends for tags originating in the area at which each rosette is plotted. The three figures represent three time-at-large categories, <50 days, 50-99 days, and >99 days. Within these categories, returns are further grouped according to distance from the point of release to the point of recapture. If a circle appears in a rosette, its radius is proportional to the number of tagged fish recaptured within 200 miles of the point of origin. In the ensuing discussion these fish shall be termed non-migrants although they may include fish that migrated long distances but returned to within the 200 miles boundary before being recaptured. Fish recaptured beyond 200 miles of the release point will be termed migrants for purpose of discussion. The migrants have been further categorized into 8 directional sectors. The arrows in the rosettes represent the numbers in these categories weighted for speed (distance from release to recapture points divided by time at large). The lengths of these arrows are proportional to the sum of the speeds of individual fish in the category. Thus each arrow represents the flux of skipjack heading in the direction of the arrow. The proportionality factors for the circle radii and for the arrow lengths are adjusted so that for an equal number of migrants and non-migrants in a given rosette, the radius of the circle would equal the sum of the arrow lengths. The rosette maps are not weighted for fishing activity because of lack of catch statistics.

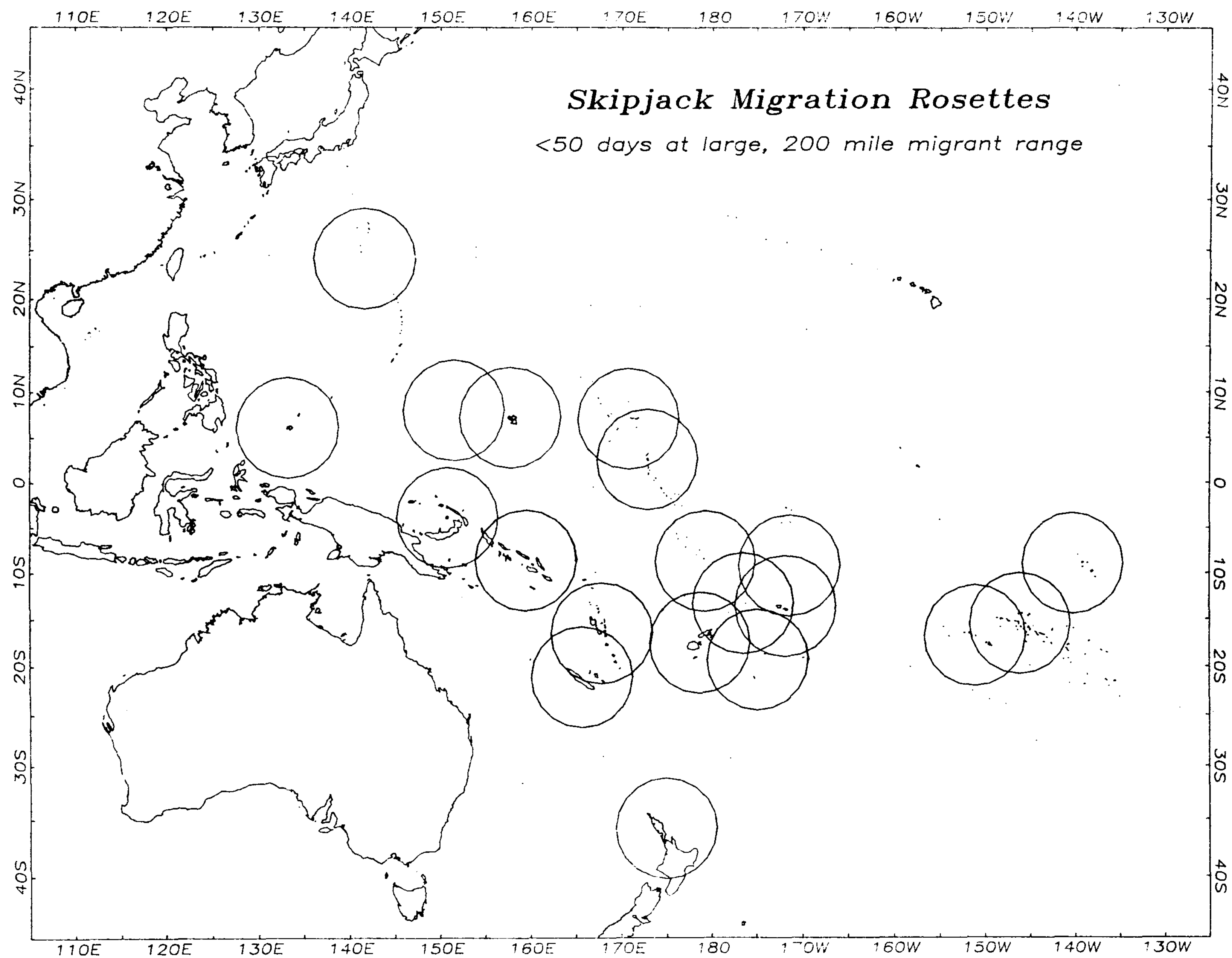

Figure 3. Skipjack migration rosettes for returns of fish recaptured <50 days following release, and received by 21 July 1981. Returns with imprecise recapture date or position were excluded. Arrows represent migrants (>200 miles from origin to recapture point). Circles represent non-migrants ($\leq$ 200 miles). Rosettes are further defined in the text.

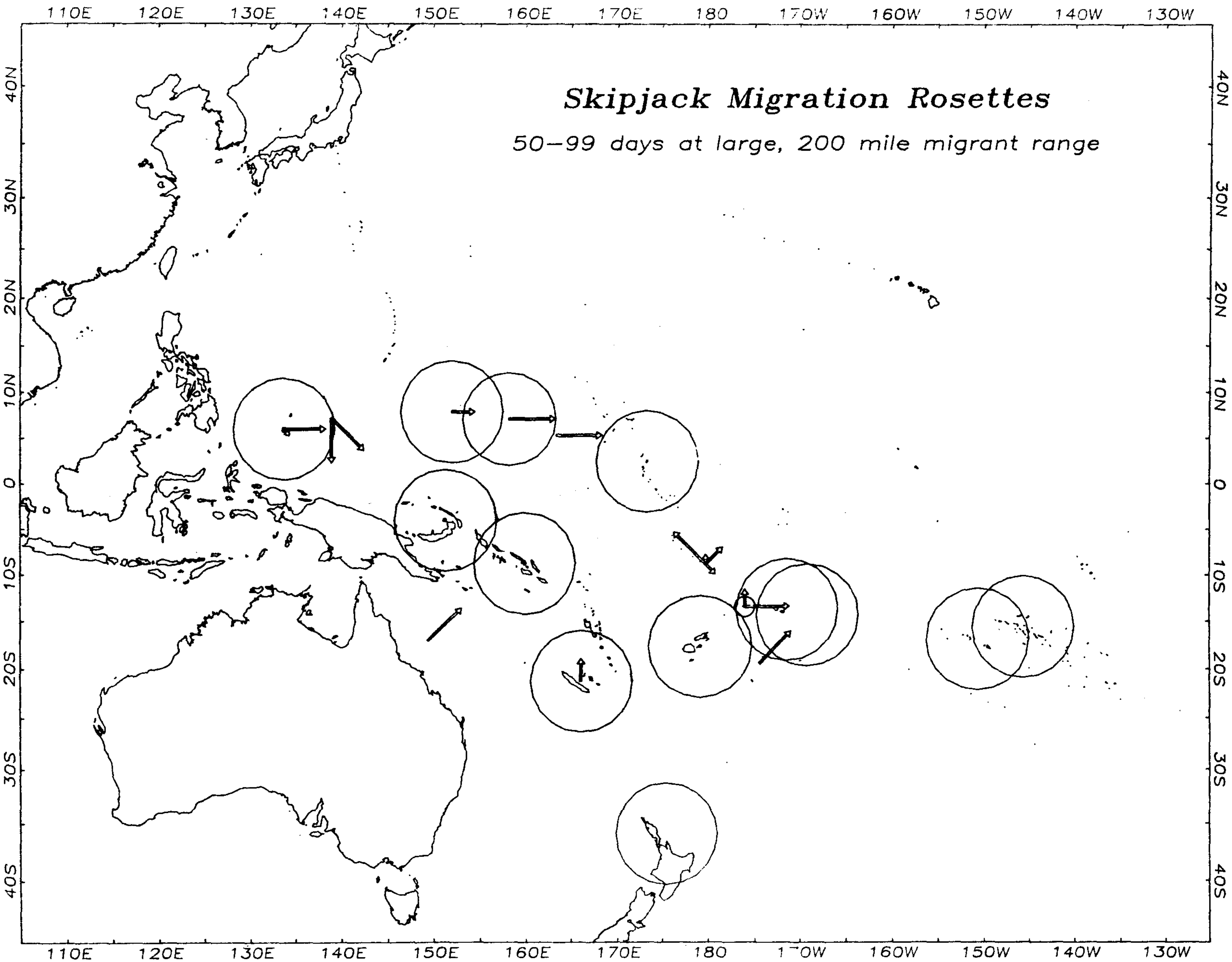

Figure 4. Skipjack migration rosettes for returns of fish recaptured 50 to 99 days following release, and received by 21 July 1981. Returns with imprecise recapture date or position were excluded. Arrows represent migrants (>200 miles from origin to recapture point). Circles represent non-migrants (≤ 200 miles). Rosettes are further defined in the text.

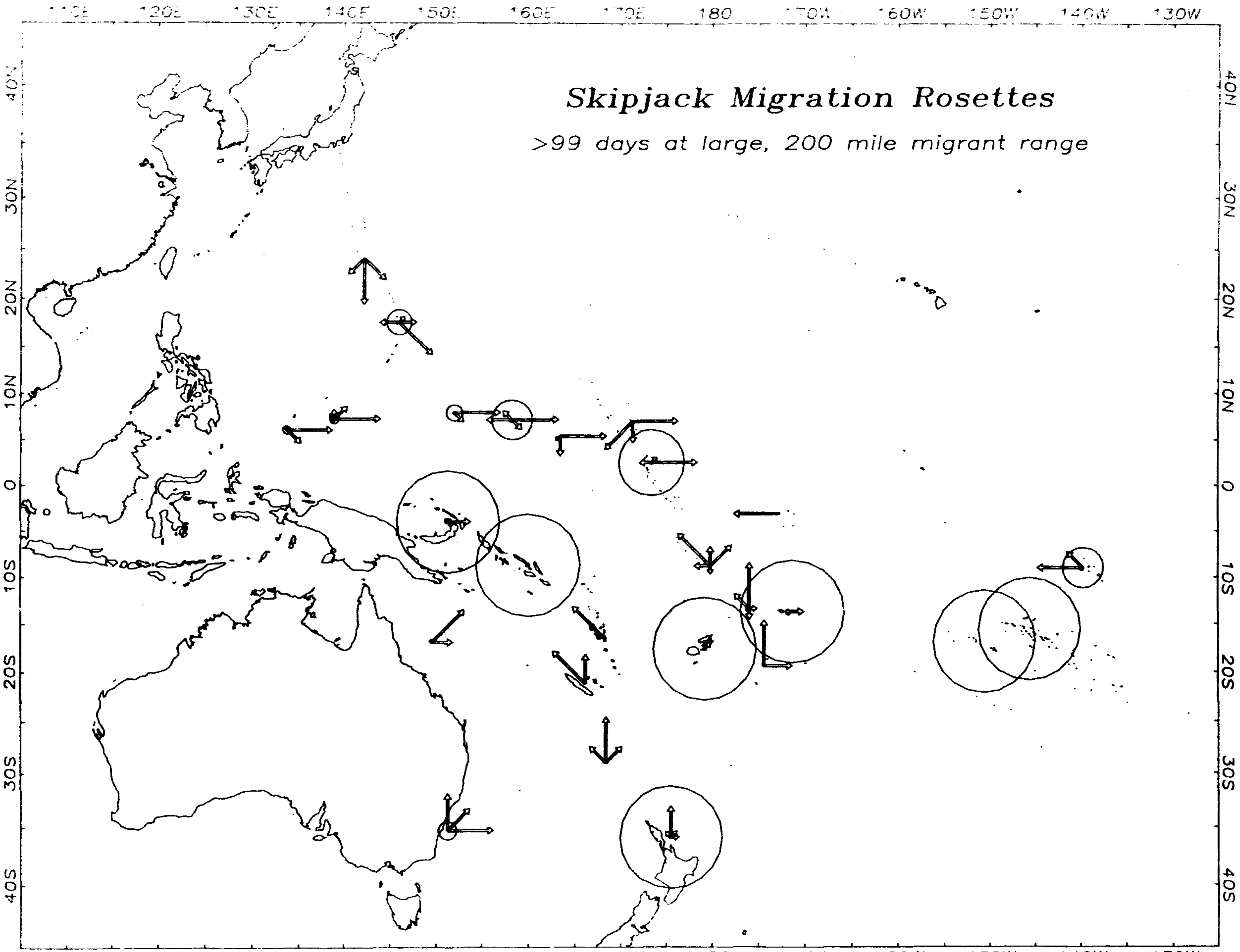

Figure 5. Skipjack migration rosettes for returns of fish recaptured >99 days following release, and received by 21 July 1981. Returns with imprecise recapture date or position were excluded. Arrows represent migrants (>200 miles from origin to recapture point). Circles represent non-migrants (≤ 200 miles). Rosettes are further defined in the text.

The prominence of the circles in Figure 3 indicates that few tagged fish show up as migrants in the first 50 days at large, but the increasing prominence of arrows in Figures 4 and 5 shows that with time migrants begin to appear and patterns to emerge. Around the periphery of the region the migration tendency is inward. This could be expected to the west of the region because of the geographic barrier of Australia and further north because the fisheries to the west concentrate on smaller skipjack than the ones we tagged. To the east in French Polynesia there may have been as much eastward migration as there is westward, but the fisheries in that direction are even more remote than the ones to the west. The prominent equatorial movement from the north and the south could be due to a tendency on our part to tag in the north in the northern summer and in the south in the southern summer. If there is a seasonal north-south migration pattern, then it is possible that we tended to tag in poleward areas in the time of year when the fish had reached the extreme of their poleward movement.

In the interior of the region, there is an apparent lack of a directional tendency, ie. arrows in the rosettes tend to fan out in many directions. This is most noticeable in Figure 5, which shows returns of greater than 99 days at large. It is thus quite possible that for many of the returns the direction from release point to recapture point is not the original direction of departure. If we could plot the original directions, it is possible that a much stronger advective pattern would emerge. Nonetheless a prominent eastward trend is apparent in Micronesian waters between 5 degrees and 10 degrees north. This impression is strengthened by the fact that it also appears in Figure 4 for intermediate times at large. The returns we have from this area are primarily from the Japanese pole-and-line fishery for which we unfortunately have incomplete catch data. For the limited data we do have covering only a part of the time of our tagging operations there is an eastward concentration of the Japanese pole-and-line fishery in Micronesia. Therefore this eastward migration trend may be an artifact.

Another feature that emerges from the rosette maps is the lack of movement out of certain areas, notably Papua New Guinea, Solomon Islands, Fiji, Western Samoa, Society Islands and Tuamotu Archipelago. For some of these areas this may be an artifact due to the lack of active fisheries in the neighbourhoods of these areas. Such is not likely the case for Papua New Guinea and Solomon Islands, which have important fisheries, neighbour each other and have extensive fishing activity in the area to the north of them. Of course there could be a significant number of undetected migrants from these areas going southwards where there is a lack of fisheries.

In considering these migration results, which only show up for fish that have been at large for some time, it is of interest to see what proportion of the original cohort of tagged fish is making the migrations. In Table 5 the returns in the two distance and three time-at-large categories are enumerated. It can be seen that only 902/5339 = 17% of the tagged fish were migrants. This would imply that the most important feature of adult skipjack migration is that on average they do not migrate very much. To put this statement in perspective, it can also be seen from Table 5 that there is a rapid attrition in the return rate (returns per unit time) with time. Only 1313/5339 = 25% of the returns were at large for more than 99 days. Of these, 764/1313 = 58% were migrants. Thus if most skipjack are not seen to migrate very far, it could be

TABLE 5. RETURNS BY TIME-AT-LARGE AND DISTANCE FROM RELEASE POINT

Skipjack returns up to 27 July, 1981 are included except for returns with imprecise recapture position or date.

		DISTANCE (MILES)		
		≤ 200	> 200	TOTAL
Time at	< 50	3416	22	3438
large	50 to 99	472	116	588
(days)	> 99	549	764	1313
	TOTAL	4437	902	5339

due to the high attrition rate and not through lack of trying. Either the fish do not live long enough to get very far, or a large proportion of the migrants go to areas of low fishing intensity, or a combination of these two effects may pertain. The attrition rate and its components are examined in detail in the next section.

3.2 Migration and Mortality

The number of tags returned per unit time is expected to decrease with time since the tag density in the fishery should decline due to mortality, emigration and other forms of attrition (eg. tag slippage). An important distinction between migratory and other types of attrition is that migratory loss from a given region depends not only on the underlying biological behaviour of the beast but also on the size and shape of the area under consideration. The migratory loss or exchange rate from an area the size of a football field would be much larger than from an area of the order of 200 miles in radius, or in turn from an area the size of the western Pacific. This is true even though the basic behaviour of the fish is the same in all cases. The effect of mortality and mortality-like processes on the other hand tends to be independent of the size and shape of the area of concern.

The total attrition rate and the relative contributions to it from migratory and other sorts of losses is of vital interest since these processes have an important bearing on the degree of interaction among neighbouring fisheries.

3.2.1 Aggregate data set

In order to estimate an average attrition rate for the whole region, the skipjack returns were examined in aggregate. Figure 6 gives the natural log (ln) of the number of returns received by monthly time-at-large categories plotted against time at large for all skipjack returns, exclusive of returns with imprecise date of recapture and recaptures by the SPC tagging vessel. The values represent the returns per month we would expect to see with time if we had released all our tags on the same day. As expected the return rate declines with time and follows a relatively straight line on the logarithmic plot. The dotted line shown is the result of fitting an exponential decay model to the observed results using a goodness-of-fit procedure and disregarding the initial high value for month zero. The best fitting attrition coefficient is .20 per month, which is the slope of the dotted line in Figure 6. This is the instantaneous attrition rate of a cohort of tagged fish, and to the extent that tagged fish behave like untagged ones, and to the extent that the adult population is at steady state, this attrition rate would also be the turnover rate of the population of adult skipjack. The extrapolated y-intercept has a value of 6.1 which is equivalent to an effective return rate at time zero of 466 returns per month. With 139961 skipjack released, this return rate implies an average harvest rate for the region of 0.003/p per month or .04/p on an annual basis. The coefficient, p, corrects for the recaptured tags that are not returned to us and for short term mortality due to tagging. It is a value between zero and one (ideally close to one).

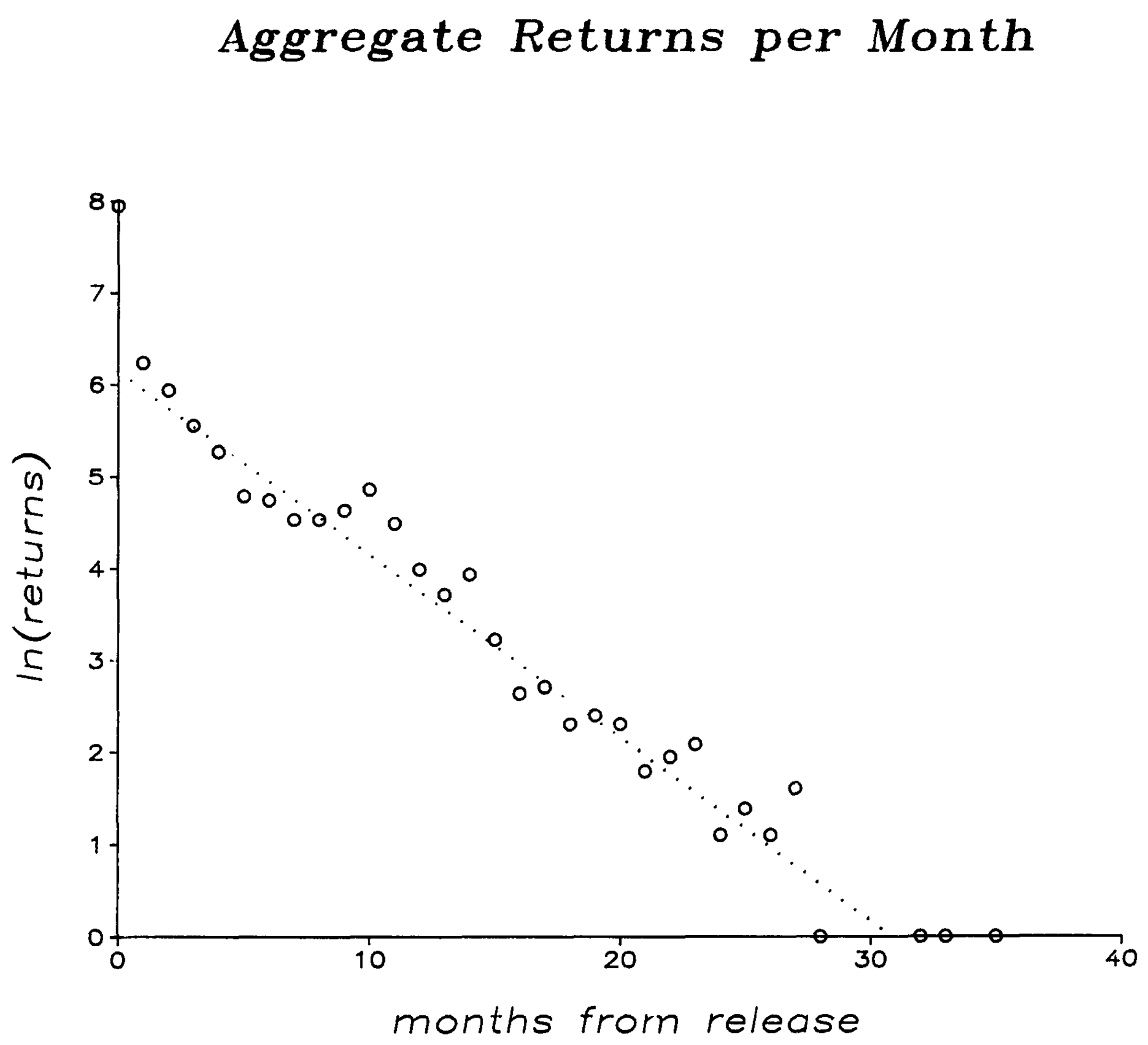

Figure 6. Logarithmic plot of skipjack returns by monthly time-at-large categories. Includes 5,442 returns received by 23 July 1981. Not included are 736 returns with imprecise date information and 280 recaptures by the SPC tagging vessel.

It must be remembered that the return rates shown in Figure 6 have not been corrected in any way for vagaries in fishing activity, which is known to be highly variable in space and time throughout the region. It is thus surprising that the results in Figure 6 look as good as they do. This might be ascribed to statistical smoothing resulting from aggregating a large number of data. Or it may be that as tagged fish become mixed in a population, non-uniformities in the sampling effort become less important.

A model consistent with the observed results is as follows: The fishery is clumped and covers only a portion of the skipjack habitat in the region. There is also a tendency for the tag release effort to occur in the same areas as the fishing effort, which would cause the initial observed displacement upwards. But the tagged fish within the fished areas can exchange with fish in the larger, unfished areas causing an extra high attrition in the return rate for a few months until an equilibrium between the fished and the unfished areas is established. Thereafter attrition occurs in both areas at approximately the same rate due to mortality and migratory losses out of the larger region as a whole. In this view the observed starting value of 7.9, which is equivalent to 2820 returns per month, can be taken to represent only the actively fished areas within the region. The resulting harvest rate within the fished areas is then .02/p per month or .24/p per year. The difference between the observed and extrapolated starting values implies that on average the fisheries in the region are directly exploiting only 466/2820 = 17% of the skipjack stocks, but the fast rate at which the return rate approaches the dotted line in Figure 6 implies that there is a rapid exchange between the directly exploited stocks and the rest of the adult population.

3.2.2 Individual countries

It should be emphasized that the above results for the aggregate data set represent averages over the whole region and are thus the expected results for a country with an average intensity and distribution of fishing activity in time and space. But the individual countries in the region are widely variable in the configuration of their fisheries. Therefore in considering the results for a particular country, it is necessary to take into account the particularities of the fishing activity in that country. To date, we have reasonably complete monthly catch information in only 6 countries: Fiji, Kiribati (Gilbert Islands), Papua New Guinea, Society Islands, Solomon Islands, and New Zealand. All of these countries have locally based fishing operations and they also all host foreign fishing vessels. With the exception of New Zealand, our catch information does not include these foreign vessels. Therefore, except for New Zealand only returns from locally based fisheries have been included in the individual country analyses.

Figures 7 through 12 show ln(returns/catch) for individual months (ten day periods for New Zealand) plotted against time for the 6 countries mentioned above. In general the data are not nearly as well behaved as they are in aggregate, which is as expected from a statistical point of view. No attempt has been made to mathematically fit an exponential (or other) model to these results, but values (or ranges of values) have been estimated by eye for the y-intercept, which is the natural log of the effective ratio of recaptured tags to total catch at the time of tagging, and the slope, which is the attrition rate. These estimated values are given in Table 6 along with various quantities derived therefrom.

FIJI

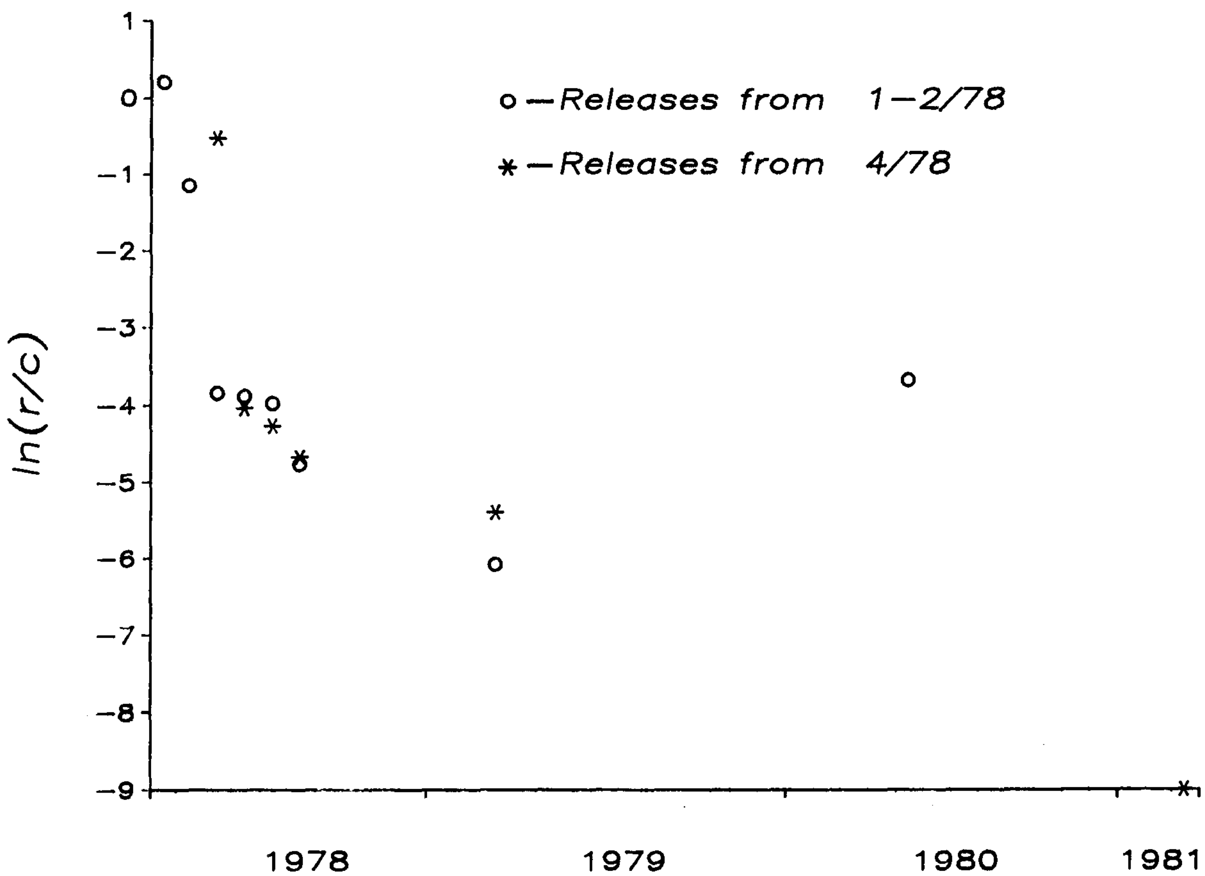

Figure 7. Monthly catch corrected returns of tags released in Fiji, recaptured in Fiji by the Fiji based pole-and-line fleet, and received by July 1981.

FIJI

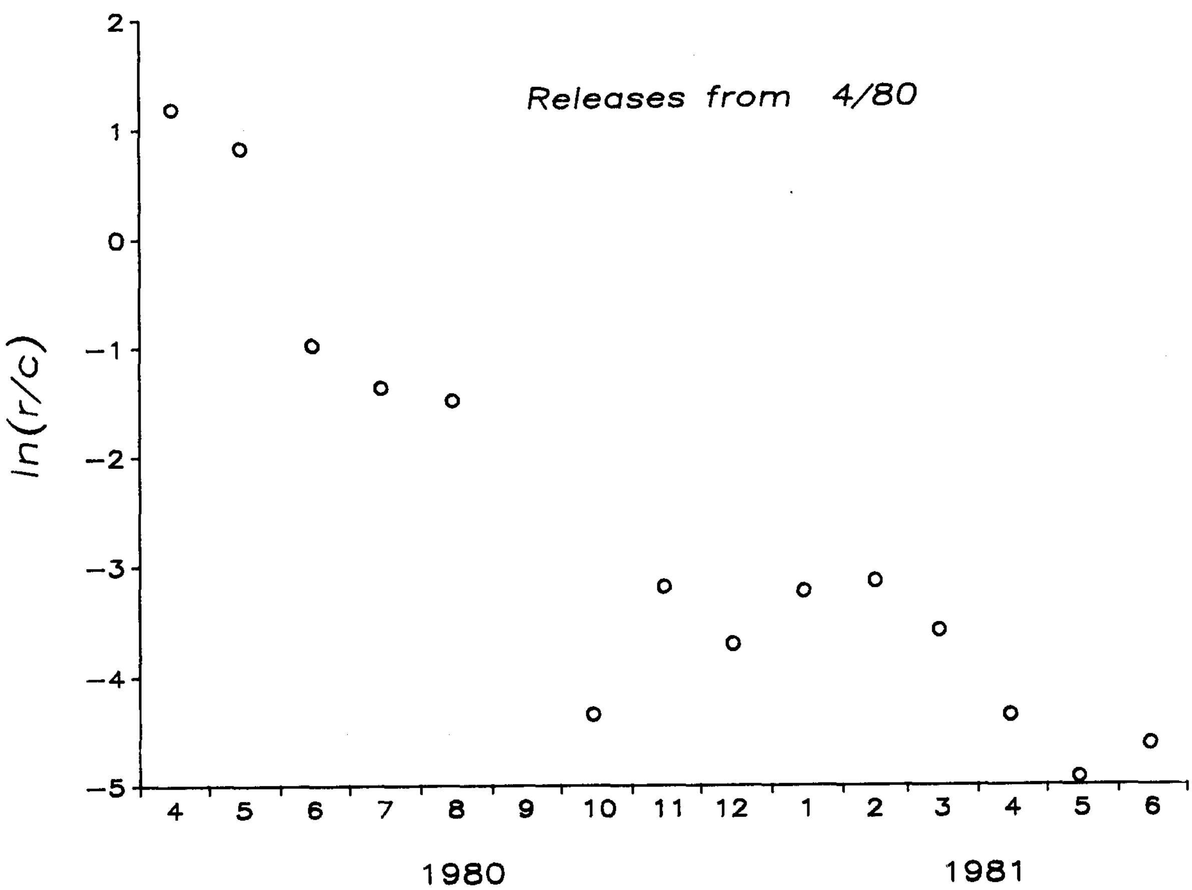

Figure 7. (cont.) Monthly catch corrected returns of tags released in Fiji, recaptured in Fiji by the Fiji based pole-and-line fleet, and received by July 1981.

KIRIBATI

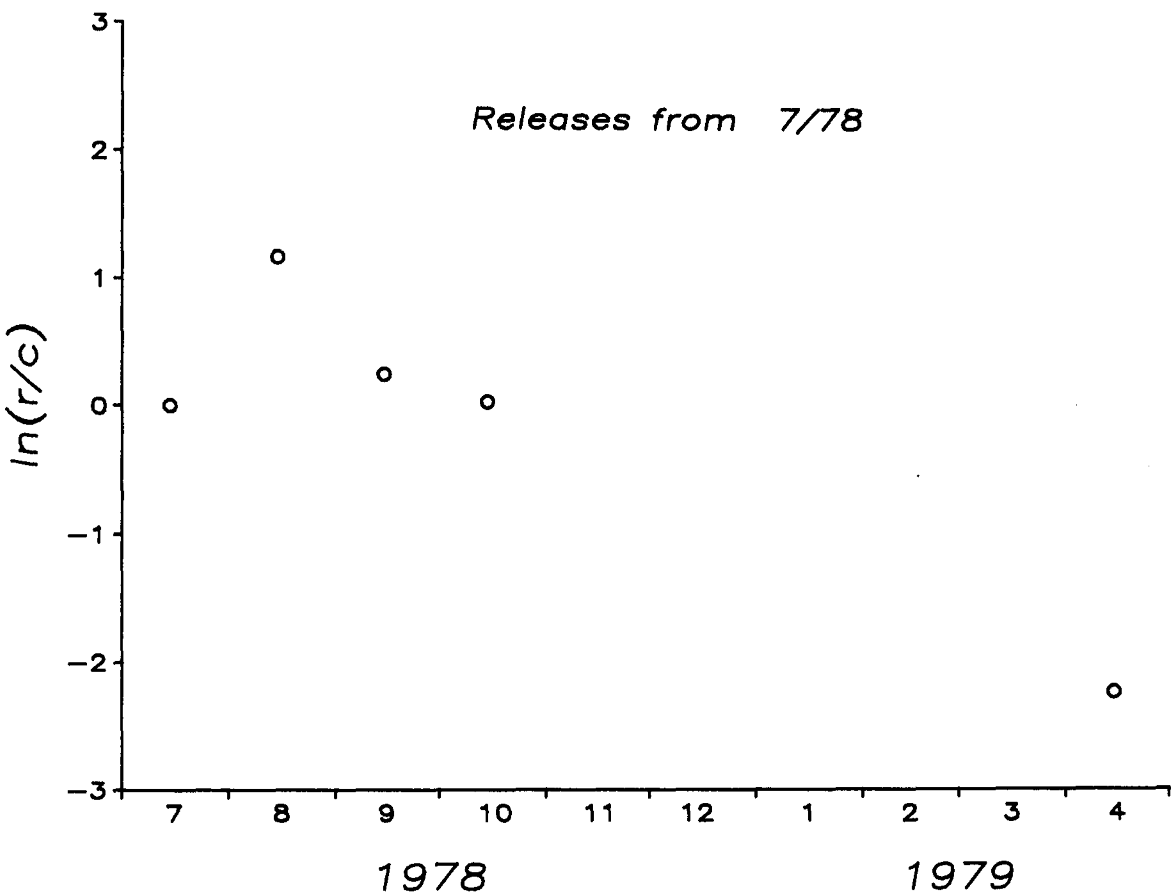

Figure 8. Monthly catch corrected returns of tags released in Kiribati (Gilbert Islands), recaptured by survey vessels operating in Kiribati (Gilbert Islands), and received by 22 July 1981.

PAPUA NEW GUINEA

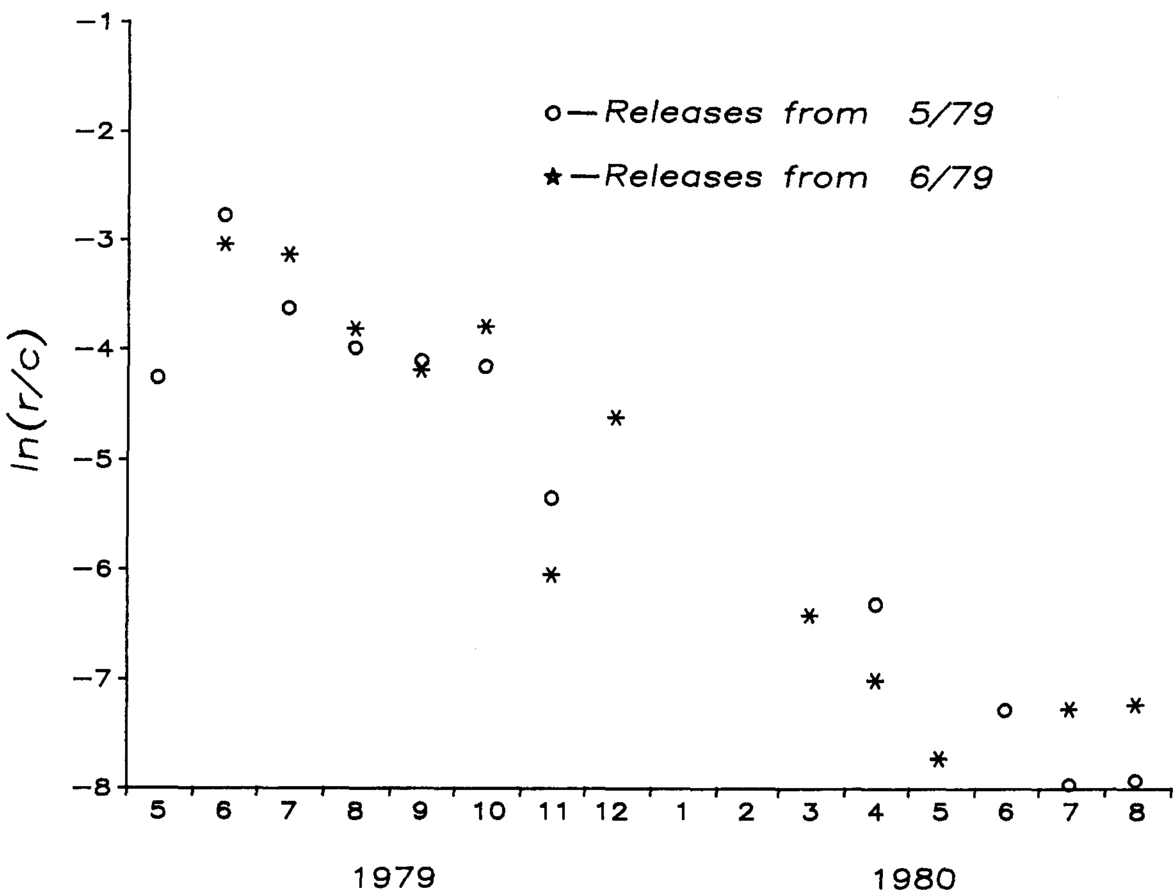

Figure 9. Monthly catch corrected returns of tags released in Papua New Guinea, and recaptured by the Papua New Guinea based pole-and-line fleet, and received by 2 July 1981.

SOCIETY ISLANDS

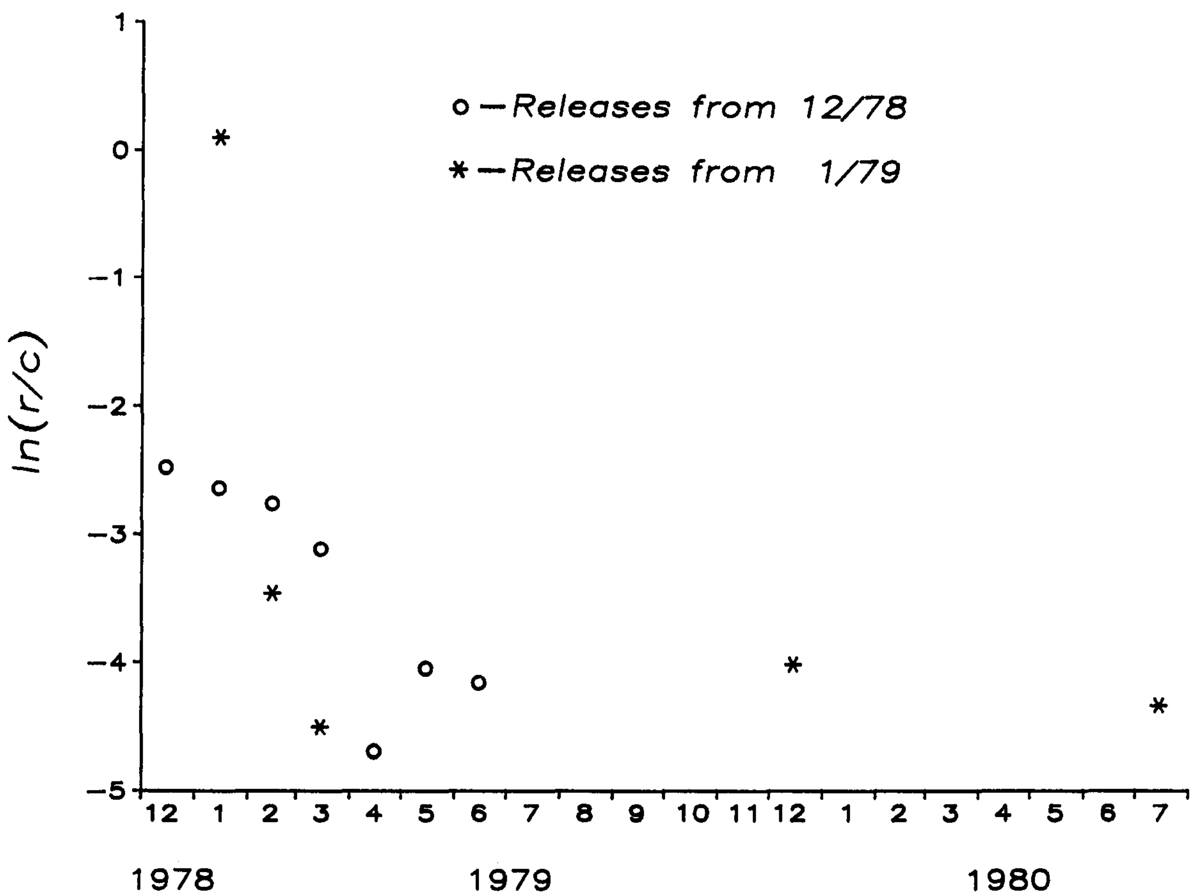

Figure 10. Monthly catch corrected returns of tags released in the Society Islands, recaptured by bonitiers operating in the Society Islands, and received by 21 July 1981.

SOLOMON ISLANDS

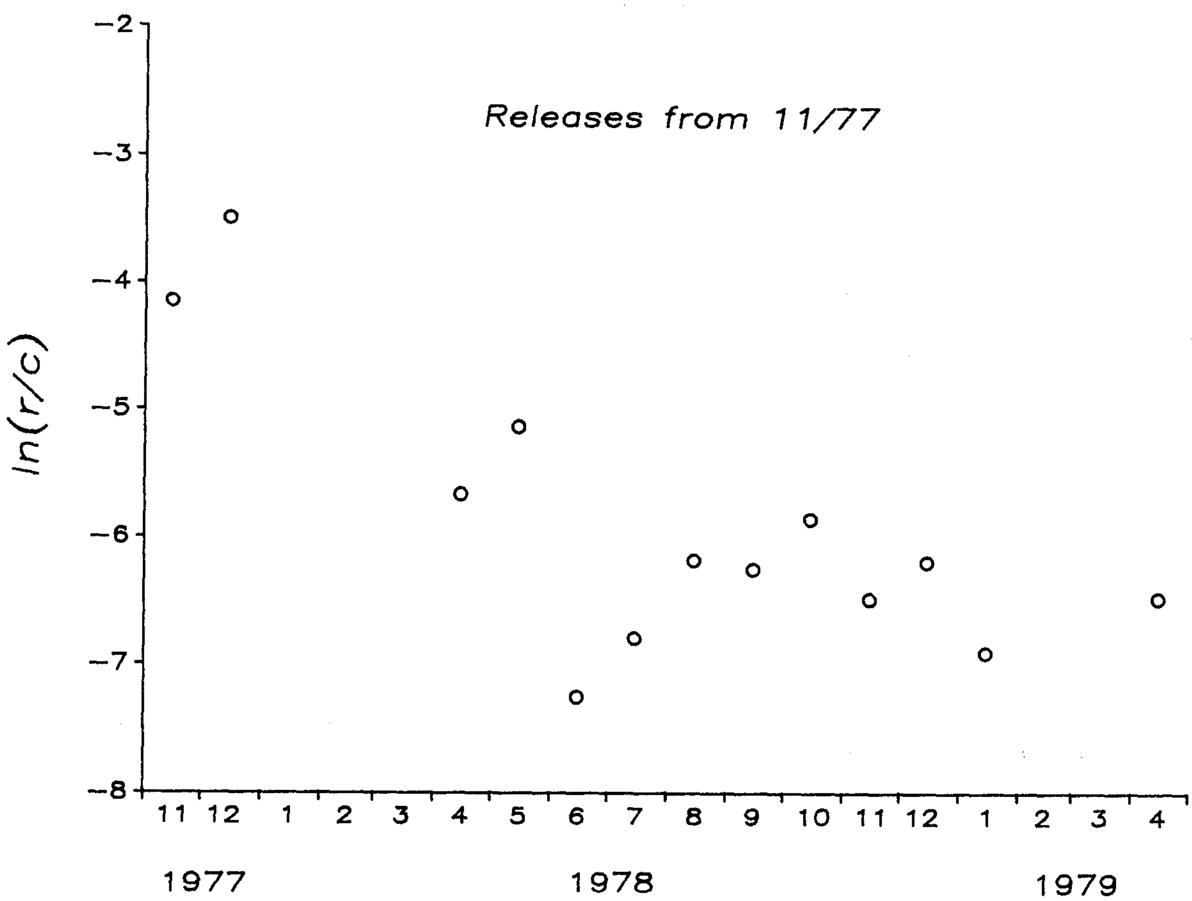

Figure 11. Monthly catch corrected returns of tags released in Solomon Islands, recaptured by the Solomon Islands based pole-and-line fleet, and received by 3 July 1981.

SOLOMON ISLANDS

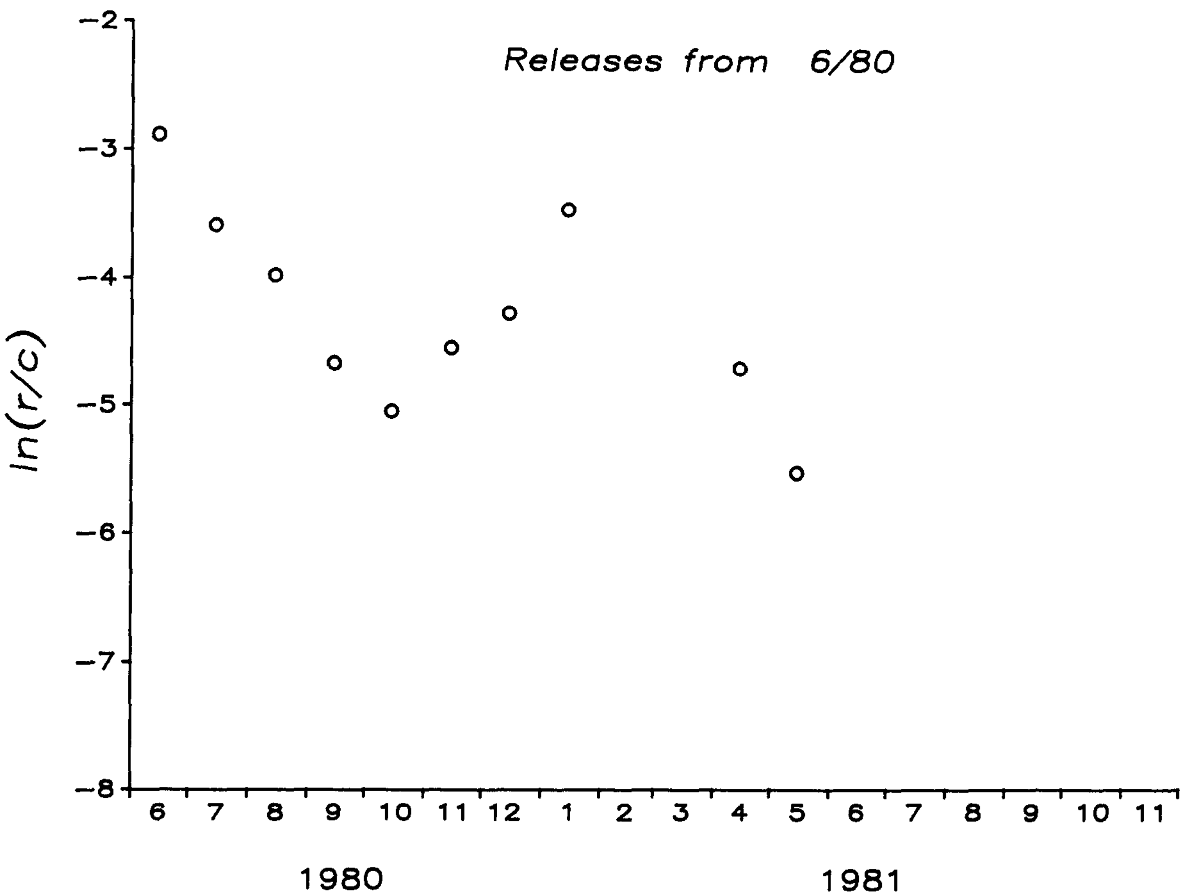

Figure 11. Monthly catch corrected returns of tags released in Solomon
(cont.) Islands, recaptured by the Solomon Islands based pole-and-line fleet, and received by 3 July 1981.

NEW ZEALAND

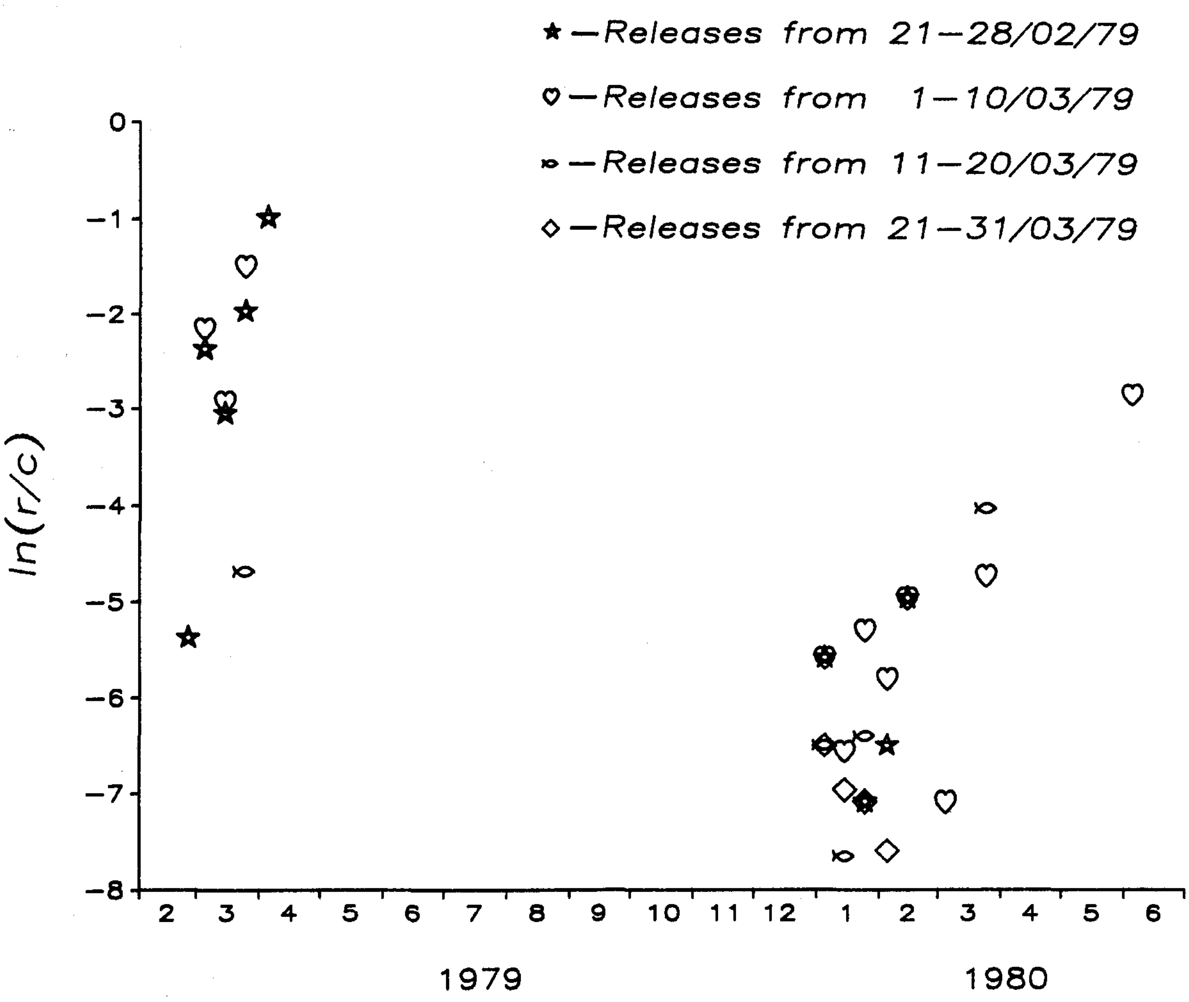

Figure 12. Catch corrected returns by 10-day period from tags released in New Zealand, recaptured by commercial vessels operating in New Zealand and received by 24 July 1981.

TABLE 6. TAG RETURN ANALYSES FOR INDIVIDUAL COUNTRIES

The variables in Columns 5 and 6 were estimated by eye from tags released within the range of dates given in Column 2 and plotted in the figures referenced in Column 3. Column 4 gives the number of tags released in the given country and time period. Column 9 gives a rough estimate of the average catch per month in the given country over the time the tags were being recaptured. Values in other columns are derived as follows:

Column(6) = EXP(-Column(4))

Column(8) = Column(7)·Column(4)

Column(10) = Column(9)/Column(8)

The factor, p, in columns 7, 8 and 10 is the correction for short term tagging mortality and non-reporting of recaptured tags.

Country (1)	Release period (2)	Tag recovery plot (3)	No. of tags released (4)	Intercept (5)	Slope (month^{-1}) (6)	Tonnes/tag at time of release (7)	Population (Tonnes) (8)	Catch (month^{-1}) (9)	Harvest rate (month^{-1}) (10)
FIJ	78/01-02	Fig. 7a o	4299	1 to -3.5	.18 to 1.14	1p to 33p	4000p to 140000p	300	.07/p to .002/p
FIJ	78/04	Fig. 7a *	3818	0 to -3.5	.18 to 1.14	1p to 33p	4000p to 130000p	300	.08/p to .002/p
FIJ	80/04	Fig. 7b o	11646	0 to 1.5	.34	1p to .02p	2600p to 12000p	300	.03/p to .12/p
KIR	78/07	Fig. 8 o	4403	1	.38	.04p	1600p	50	.03/p
PNG	79/05	Fig. 9 o	3227	-2.7	.36	15p	48000p	3000	.06/p
PNG	79/06	Fig. 9 *	4401	-2.7	.36	15p	65000p	3000	.05/p
SOC	78/12	Fig. 10 o	4823	-2.7	.38	7p	6000p	70	.01/p
SOL	77/11	Fig. 11a o	1805	-3.5	.35	33p	60000p	1000	.02/p
SOL	80/06	Fig. 11b o	3731	-3	.17 to .56	20p	75000p	2000	.03/p
ZEA	79/02/21-28	Fig. 12 ★	2678	0 to -3	.33	1p to 20p	2700p to 54000p	3000	.06/p to 1.1/p
ZEA	79/03/01-10	Fig. 12 ♡	6298	-2	.33	7p	47000p	3000	.06/p
ZEA	79/03/11-20	Fig. 12 ∞	2094	-4.5	.18	90p	188000p	3000	.02/p

With some exceptions, there is a tendency for the attrition rates (column 5, Table 6) in the individual countries to be higher than the .2 per month value derived from the aggregate data. This difference has not been subjected to statistical testing as yet. However, it should be noted that some difference is to be expected due to the fact that in the individual country plots, returns from other countries were not included, whereas returns from anywhere were included in the aggregate plot. As can be seen from Table 5 and from the rosette maps in Figures 3, 4 and 5, the effect of this difference should increase with time as a higher proportion of returns come from outside the country of origin. The result would be a steeper slope in the individual country plots. This is actually an example of the principle alluded to above wherein the contribution to attrition of population turnover due to migratory behaviour increases with decreasing territory size.

The harvest rates (column 9, Table 6) are for the most part closer to the harvest rate derived from the aggregate observed returns in the first month rather than from the value extrapolated from aggregate returns from subsequent time periods. Thus in terms of the discussion in section 3.2.2, it would appear that the individual country harvest rates (and hence the population estimates, column 7, Table 6) are more representative of the directly exploited stocks than of the population at large.

3.3 Fishery Interaction

Having estimated the attrition and harvest rates for local fisheries in individual countries it is now possible to draw inferences on interaction among these fisheries from the international tag migrations.

There are many types of interaction possible between fisheries. The present tagging results bear only on the concept of interaction due to the movement of post-recruits from one fishery to another. This type of interaction can be more precisely defined as follows: The exponential attrition rate, A1, for country 1 can be assumed to be the sum of a number of things among which is an emigration coefficient, which in turn is the sum of coefficients for migration to specific areas including $M_{1 \cdot 2}$, the coefficient of migration from country 1 to country 2. This coefficient is the proportion of the population in country 1 which migrates to country 2 per unit of time. The value of $M_{1 \cdot 2}$ would specify part of the interaction between countries 1 and 2, another part being the value of $M_{2 \cdot 1}$.

With a simple model based on the above concept the value of $M_{1 \cdot 2}$ can be derived from the number of fish tagged in country 1, the total returns of these tags from country 2, the harvest rate in country 2 and the total attrition rates in both countries.

3.3.1 Existing fisheries

Table 7 gives estimates of migration coefficients for a number of combinations of countries. Also estimated are the tonnes migrating per month implied by the migration coefficients. The migration coefficients are small compared to the overall population turnover in the present fisheries, which is here assumed to be .35 per month on average (Table 6, column 6). The tonnes migrating also seems small relative to the population sizes in origin and

TABLE 7. FISHERY INTERACTION RESULTS

Column 4 gives the number of returns in the destination country and only includes tagged fish which were recaptured in fisheries for which we have adequate catch statistics and which were released in one of the six countries given in Table 6. The values in Columns 5, 6 and 8 are obtained from Table 6. Column 7, migration coefficients, which are defined in the text, and Column 9, tonnes migrating per month from origin to destination, were calculated as follows :

$$\text{Column}(7) = A2.\text{Column}(4)/(\text{Column}(5).\text{Column}(6).p)$$

$$\text{Column}(9) = \text{Column}(7).\text{Column}(9)$$

where A is the total attrition rate (assumed to be .35 per month for all countries) and p is the correction for early tagging mortality and non-reporting of recaptured tags.

Origin	Destination	Period of release	No. of tags returned	No. of tags released	Harvest rate at destination (month^{-1})	Migration coefficient (month^{-1})	Population at origin (tonnes)	Tonnes per month migrating
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PNG	SOL	79/05	15	3227	.03/p	.01	43,000p	400p
PNG	SOL	79/06	6	4401	.03/p	.006	72,000p	400p
SOL	PNG	77/11	4	1805	.05/p	.005	60,000p	300p
SOL	PNG	80/06	7	3731	.05/p	.005	75,000p	400p
SOL	FIJ	80/06	1	3731	.03/p	.001	75,000p	80p
FIJ	ZEA	78/02	1	4299	.06/p	.0005	14,000p	7p
FIJ	ZEA	78/04	2	3818	.06/p	.001	12,000p	10p
ZEA	FIJ	79/02	20	11623	.03/p	.007	50,000p	400p
ZEA	SOC	79/02	4	11623	.01/p	.004	50,000p	200p

destination countries. However, it should not be inferred that migration is an insignificant component of the overall population turnover. The figures given apply only to migration between relatively small areas with a lot of space between and beyond that is not accounted for. The sum of migration coefficients to all areas to which it is possible to migrate might well be a sizable portion of the overall turnover.

3.3.2 Expanded fisheries

It should be understood that the above interactions between countries are dependent on the configuration in time and space of the fisheries as they existed while the tags were being recovered. If fishing activity increases in the future, particularly if the amount of territory covered within the countries increases, it is very likely that the degree of interaction will also increase. For individual cases, it is difficult to predict to what extent the interaction with neighbouring areas might increase without detailed knowledge of the underlying diffusional and advective migratory behaviour of the skipjack in the area in question.

This discussion has been concerned only with interaction in terms of exchange or movement of adult biomass from one fishery to another. It should be recognized that there could be other sorts of interaction, perhaps having to do with reproductive behaviour or with other phases of the recruitment process. Therefore expansion of fisheries, particularly expansion in the range of exploited size classes, might have consequences for other forms of fishery interaction.

4.0 CONCLUSIONS

The overall picture that is emerging is that the local fisheries in the region are directly exploiting only a portion of the skipjack resource in the various economic zones. The actively fished areas appear on average to be surrounded by buffer zones of diminished exploitation. Therefore interaction between fisheries is minimal at present. Obviously there are cases at present which deviate from this average situation. Furthermore the degree of fishery interaction could increase with increased utilization of the buffer zones. Elucidation of details of the present situation and quantitative prediction of the effects of expanded fisheries in the future requires a more intimate knowledge of diffusive and advective migratory behaviour and the balance between these and other forms of population turnover (eg. death and recruitment). Some contribution to this knowledge can be expected from further analysis of the tag results after more detailed and complete fishery statistics are available.

It should be reiterated that the present tag results are only indicative of post-recruit skipjack behaviour. The utility of these results for understanding fishery interaction is thus restricted to adult biomass exchange between fisheries. Understanding of the possibilities for and implications of other forms of interaction requires further study of skipjack ecology, particularly study that encompasses more than just the post-recruit life history stage.

ERRATA

WP9 - SKIPJACK MIGRATION, MORTALITY AND FISHERY INTERACTIONS

Page 32 - 6th line "Column(6) = EXP(-Column(4))"
should read "Column(7) = EXP(-Column(5))"

Page 33 - First paragraph, 2nd line "5, Table 6)"
should read "6, Table 6)"

Page 33 - Second paragraph, 1st line "...(column 9, Table 6)..."
should read "...(column 10, Table 6)..."

Page 33 - Second paragraph, 6th line "...column 7, Table 6)..."
should read "...column 8, Table 6)..."

Page 34 - Sixth line "...A2.Column(4)..."
should read "...$A^2 \cdot$Column(4)..."