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MIGRATORY BEHAVIOUR OF SKIPJACK AND YELLOWFIN IN THE WESTERN AND CENTRAL PACIFIC:

A PRELIMINARY SUMMARY OF TAGGING RESULTS OF THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME

(Paper Prepared by the Skipjack Programme)

1.0 INTRODUCTION

For cosmopolitan species such as skipjack and yellowfin, a pertinent question to the process of fisheries development is the extent to which neighbouring fisheries might interact. Thus it is important to investigate the migratory behaviour of these animals. On initial inspection of tag returns, skipjack movement appears to have a random component, and some individuals cover great distances, so it is perhaps useful to borrow some of the concepts of fluid mechanics and break fish movement down into advective or directed motion and diffusional or random motion. There might be advective migratory patterns analogous to ocean currents. But superimposed on this there is certain to be some amount of diffusional motion analogous to fluid turbulence. There may also be more complex biological phenomena such as subgroups of the population with different migratory behaviour. Lewis (1980), for example, postulates the presence of resident and nomadic skipjack subgroups. Subgroupings based on size, geographic location or other factors might show differences in migratory behaviour. The main objective of an analysis of skipjack and yellowfin migrations would be to describe any advective or directed migratory patterns and measure the degree of diffusional activity for any identifiable subgroupings that show distinct differences in migratory behaviour.

The present working paper is a preliminary review of Skipjack Survey and Assessment Programme tagging data relevant to migration behaviour.

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2.0 THE DATA SET

Of the approximately 150,170 tagged fish released by the Skipjack Survey and Assessment Programme 5,750 were returned to the SPC headquarters by the end of October, 1980. Of these, 4,741 had complete information pertinent to an analysis of fish movement; that is, the species, the date and positon of release and recapture were all known to a reasonable degree of accuracy. These are the recoveries included in this preliminary summary. They comprise 4,599 skipjack and 142 yellowfin tuna.

2.1 Selection of Pertinent Recoveries

Of the array of information normally recorded for each released and subsequently recaptured tag, some items are sometimes missing for a variety of reasons. When precise information is not known, an attempt is made to establish a range of possible values. For example, the exact date of recovery might not be known but the date might be known to be sometime in June or July because that was the extent of the fishing cruise during which the tag was recovered by a particular boat. This would establish a date range from 1 June to 31 July. Similar ranges occur geographically for recovery positions. Recoveries with missing date or position information were not used in these analyses, nor were recoveries with date or position ranges if the extent of the range was greater than half of that from the point or time of release to the midpoint or median time of the range.

3.0 MIGRATION MAPS

3.1 Skipjack Total

Figure 1 is a map showing a selection of the skipjack recoveries plotted as direct trajectories from the point of release to the point of recapture. Tick marks on the lines indicate the direction and time of movement, one tick being plotted for every 30 days that a fish is at large. Not all pertinent migrations could be included on this map with our pen plotter because in some places the density of lines is so great that the individual migrations become confused, and in extreme cases, the build up of ink dissolves the chart paper. Returns were selected for plotting firstly by choosing only those at large for more than 30 days. This eliminated 66 percent of the skipjack returns. The remaining recoveries were further selected by plotting a maximum of two examples of movement in each direction between any two 5° squares. For example, say 50 returns originated in the 5° square bounded by 175°E, 180°, 5°S, 0° and terminated in the 5° square bounded by 170°E, 175°E, 0°, 5°N, and 10 migrations occurred in the opposite direction, then, of these, only four arrows would be plotted in Figure 1, two in each direction. Migrations originating and terminating in the same 5° square were limited to two arrows on the map.

Because of the high density of arrows and the obvious limitation of assuming straight line migrations, Figure 1 is a difficult picture from which to draw generalizations about skipjack migratory behaviour. A break down by season or month might allow some pattern to emerge. Another analytical tactic along these same lines would be to prepare an animated film showing motion along hypothesized migration trajectories.

It should be noted that Figure 1 is biased because of the way the data is treated, that is, the selection of a maximum of two arrows per pair of 5° squares causes rare movements to be weighted almost the same as common ones. A second bias is inherent in the data because the distribution of fishing activity is by no means uniformly distributed across the region; hence neither is the probability of recovering a tagged fish. Our future analyses will account for these biases.

3.2 Skipjack by Country

To assist in considering tag movements pertinent to individual countries a number of maps have been prepared, each of which includes only migration arrows originating or terminating in the waters of a particular country. These maps are shown in Figures 2 to 23 in the order given in Table 1. Tags were selected by the same 5° square principle as for Figure 1; and of course, biases noted above apply as well to these figures. Table 2 is a country to country migration matrix which shows the total number of skipjack recoveries originating and terminating in any pair of countries.

3.3 Yellowfin Migrations

Yellowfin recoveries were selected for plotting in the same way as for skipjack except that recoveries shorter than 30 days were allowed because of the limited data set. The resulting map is shown in Figure 24. This map is not black with arrows as for skipjack, but it does suffer from the same limitations and biases as in the skipjack maps. Generalizations drawn from such a low number of recoveries would be highly suspect. Therefore the remainder of this working paper will deal only with skipjack movements.

4.0 MOVEMENT DISTRIBUTIONS

Another way to picture the tagging results is to consider the joint distribution of recoveries over distance from point of origin, and from time at large. This would be the numbers or frequency of occurrence of recoveries as a function of migration distance and time at large.

4.1 All Skipjack Data Combined

Figure 25 shows the movement distribution for all recovered skipjack in the data set at four different time periods after release. The distributions at each time period are scaled to sum up to 100, thus compensating for mortality which can be seen by the diminishing numbers of tag recoveries (N in the graphs), with increasing time.

As would be expected, for short times the fish are clustered close to their release points, but with time they range farther and farther away. Within thirty days of release most of the recoveries occur within 100 miles of the release points. However, by 150 days 35 percent of the tagged fish appear to have ranged more than 500 miles from their release point.

If the migratory behaviour was simply a diffusive phenomenon, this spreading would be expected to continue. But as can be seen after approximately one year, only 36 percent of the fish have strayed more than 500 miles. Figure 26 is a plot of this percentage versus time at large. It is tempting to ascribe the peak at one year to a cyclical, seasonal migratory pattern. It must be remembered, however, that the data have not been corrected for the effect of non-uniform distribution of fishing activity over space and time, and it is possible that the results in Figure 26 could have been caused by seasonal patterns in the fishery.

4.2 Effect of Size at Release

Figures 27 and 28 are a break down of the skipjack movement distribution by length at release. In this case recoveries without accurate release length measurements were eliminated. There appears to be little influence of size on migratory behaviour within the size range covered by the present data.

5.0 RESUME

It is evident that to properly elucidate migration behaviour from the tagging results, it is necessary to deal with the effect of the distribution of fishing activity. To this end data on catch and effort throughout the region for the relevant years are being collected. When this data set is complete it will be possible to correct for the effects of the fishery either by the method of Bayliff (1979) or by the more ambitious tactic of Ishii (1979), who made a comprehensive model of yellowfin migration, mortality, fishing activity and tag recoveries for the Eastern Pacific. Such a model could incorporate biological complexities of migration behaviour as well as diffusional and advective motion patterns. A model such as this would constitute a satisfactory analysis of the tagging results, and it would also be an excellent medium for explaining the implications of those results to persons involved in the development of fisheries in the South Pacific Commission region.

6.0 REFERENCES

BAYLIFF, W.H. (1979). Migration of yellowfin tuna in the eastern Pacific Ocean as determined from tagging experiments initiated during 1968-1974. Inter-Amer. Trop. Tuna Comm. Bull. 17(6):447-506.

ISHII, TAKEO (1979). Attempt to estimate migration of fish population with survival parameters from tagging experiment data by the simulation method. Invest. Pesq. 43(1):301-317.

LEWIS, A.D.L. (1980). Tagging of skipjack tuna (*Katsuwonus pelamis*) in Papua New Guinea waters, 1973-1974. 34 pp. (in press)

TABLE 1 - ORDER OF FIGURES

Figure No.	Country	Page No.
2	Papua New Guinea	13
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13	Marshall Islands	35
14	Federated States of Micronesia	37
15	Republic of Palau	39
16	Northern Marianas	41
17	Bonin Islands	43
18	French Polynesia	45
19	New Zealand	47
20	Australia	49
21	Norfolk Island	51
22	Nauru	53
23	Minor U.S. Possessions	55

TABLE 2 - TOTAL NUMBER OF SKIPJACK RECOVERIES ORIGINATING (VERTICAL AXIS) AND TERMINATING (HORIZONTAL AXIS) IN ANY PAIR OF COUNTRIES

	AMS	CAL	FIJ	FSM	GUM	KIR	POL	MAR	MAS	NAU	NCK	NOR	PAL	PNG	SOL	TOK	TON	TUV	VAN	WAL	WES	AUS	IND	INT	JAP	PHL	TAI	USP	ZEA
AMS	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CAL	0	18	0	3	0	1	0	1	0	0	0	0	0	2	10	0	0	0	0	0	0	0	0	2	0	0	0	0	0
FIJ	0	0	1703	0	0	3	1	0	0	1	0	0	0	0	0	0	1	2	0	1	2	0	0	1	0	0	0	1	3
FSM	0	0	0	84	0	2	0	3	7	0	0	0	1	1	1	0	0	0	0	0	0	0	0	20	1	0	2	2	0
GUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KIR	0	0	0	3	0	389	0	0	13	1	0	0	0	0	0	0	0	0	0	0	1	0	0	27	0	0	0	24	0
POL	0	0	0	0	0	0	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAR	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
MAS	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
NAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NCK	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAL	0	0	0	8	0	0	0	0	1	0	0	0	32	1	0	0	0	0	0	0	0	0	0	6	0	2	0	0	0
PNG	0	0	0	18	0	1	0	0	1	0	0	0	1	854	22	0	0	0	0	0	0	0	0	19	0	0	0	7	0
SOL	0	0	0	0	0	1	0	0	0	0	0	0	0	5	265	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TON	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	10	0	0	0	1	0	0	0	0	0	0	0	0
TUV	0	0	1	2	0	4	0	0	0	1	0	0	0	1	2	0	0	2	0	0	1	0	0	5	0	0	0	4	0
VAN	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0
WAL	0	1	7	1	0	26	3	0	3	0	0	0	0	1	0	0	0	2	0	66	10	0	0	8	0	0	0	4	4
WES	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	19	0	0	0	0	0	0	0	0
AUS	1	9	0	1	0	1	1	0	0	0	0	0	0	0	28	0	0	0	0	0	1	2	0	3	0	0	0	0	9
IND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JAP	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0
PHL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TAI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZEA	0	4	18	0	0	0	3	0	0	0	0	1	0	0	0	0	1	2	1	0	4	1	0	0	0	0	0	0	590

AMS	AMERICAN SAMOA	TOK	TOKELAU
CAL	NEW CALEDONIA	TON	TONGA
FIJ	FIJI	TUV	TUVALU
FSM	FEDERATED STATES OF MICRONESIA	VAN	VANUATU
GUM	GUAM	WAL	WALLIS AND FUTUNA
KIR	KIRIBATI	WES	WESTERN SAMOA
POL	FRENCH POLYNESIA	AUS	AUSTRALIA
MAR	NORTHERN MARIANAS	IND	INDONESIA
MAS	MARSHALL ISLANDS	INT	INTERNATIONAL WATERS
NAU	NAURU	JAP	JAPAN
NCK	NORTHERN COOK ISLANDS	PHL	PHILIPPINES
NOR	NORFOLK	TAI	TAIWAN
PAL	PALAU	USP	U.S. POSSESSIONS (WAKE, HOWLAND, JARVIS, PALMYRA, LEEWARD - HAWAII)
PNG	PAPUA NEW GUINEA	ZEA	NEW ZEALAND
SOL	SOLOMON ISLANDS		

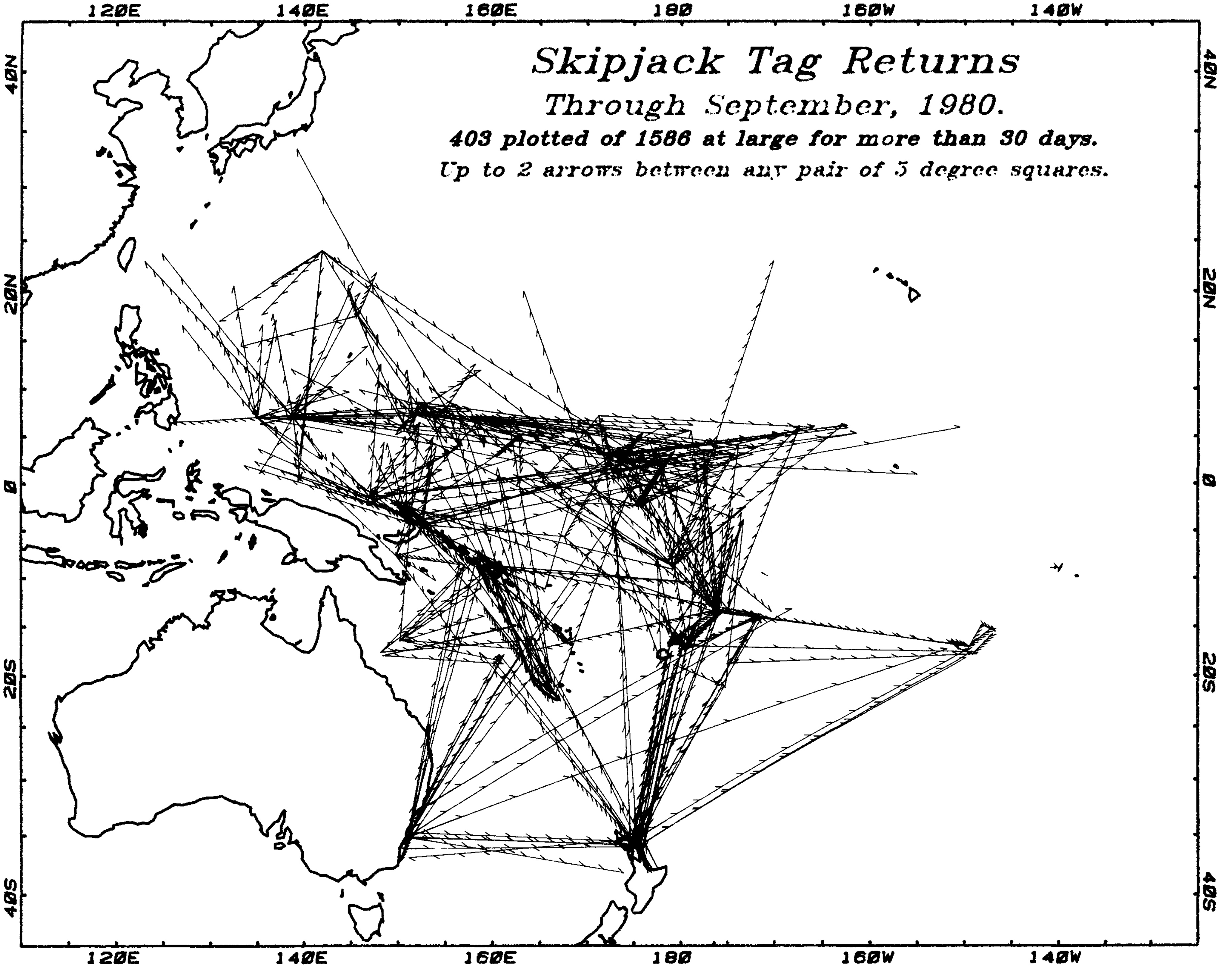

Skipjack Tag Returns
Through September, 1980.
403 plotted of 1586 at large for more than 30 days.
Up to 2 arrows between any pair of 5 degree squares.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 1

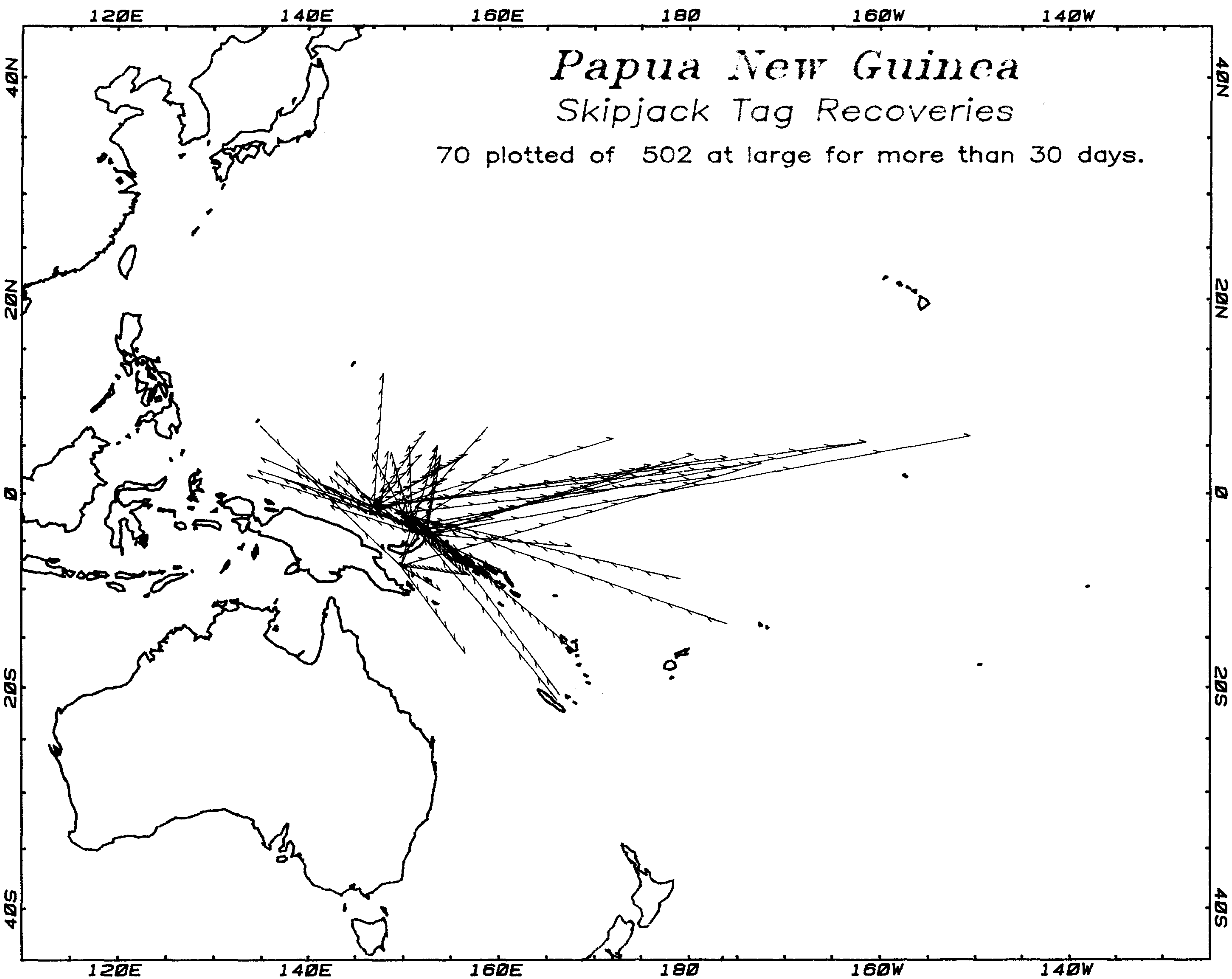

Papua New Guinea
Skipjack Tag Recoveries
70 plotted of 502 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 2

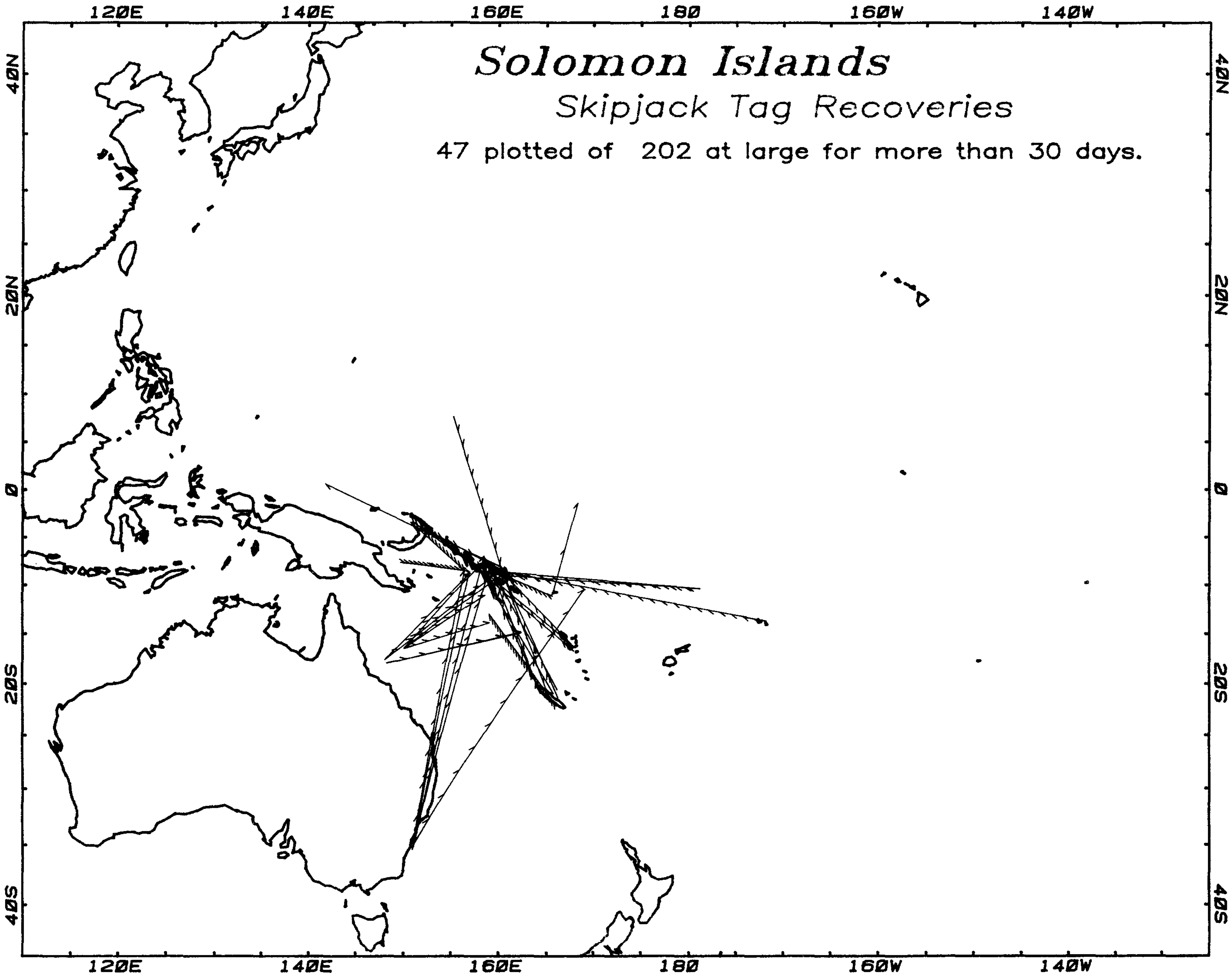

Solomon Islands
Skipjack Tag Recoveries
47 plotted of 202 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 3

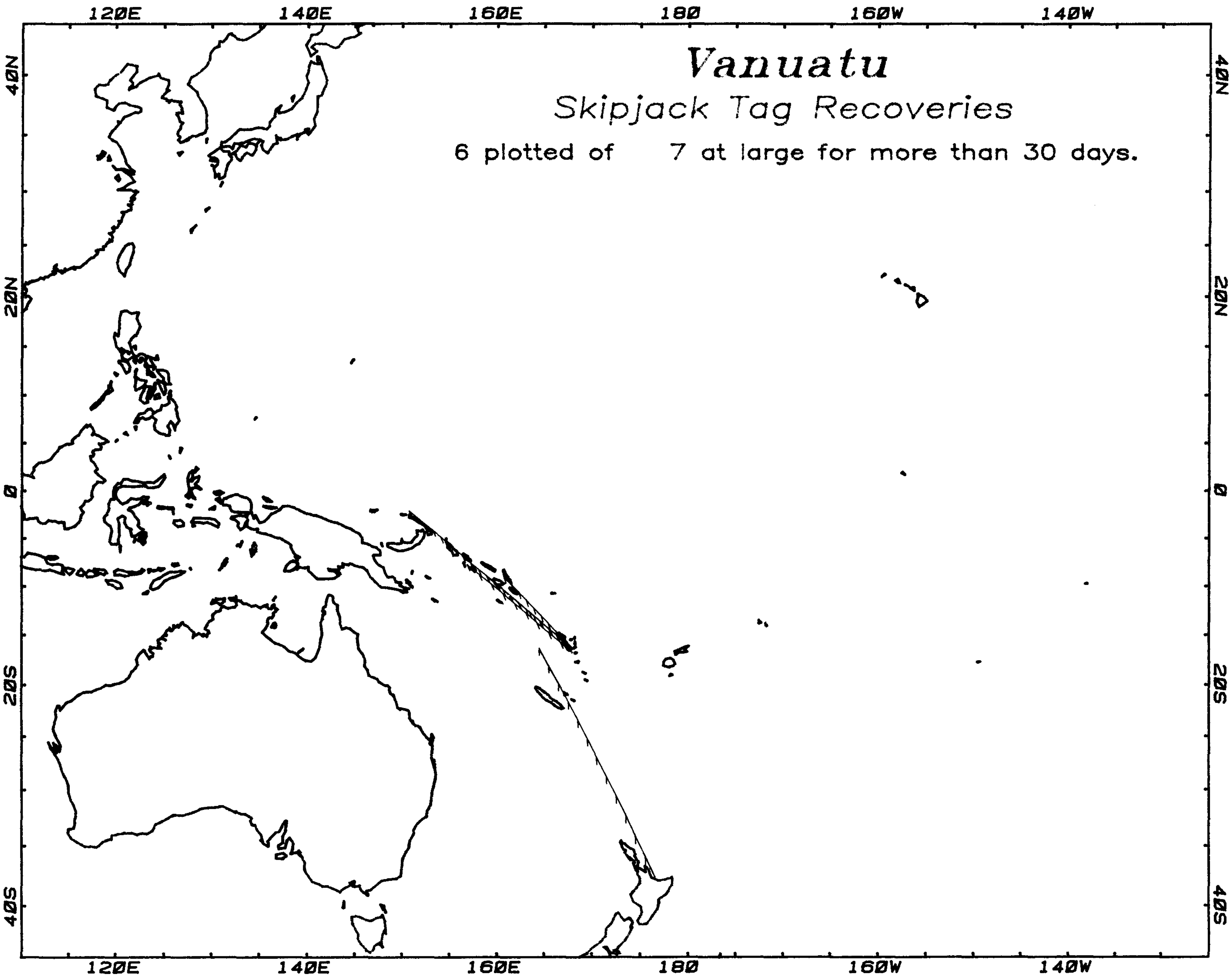

Vanuatu
Skipjack Tag Recoveries
6 plotted of 7 at large for more than 30 days.
120ØE
140ØE
160ØE
180
160ØW
140ØW
40N
20N
Ø
20S
40S

Figure 4

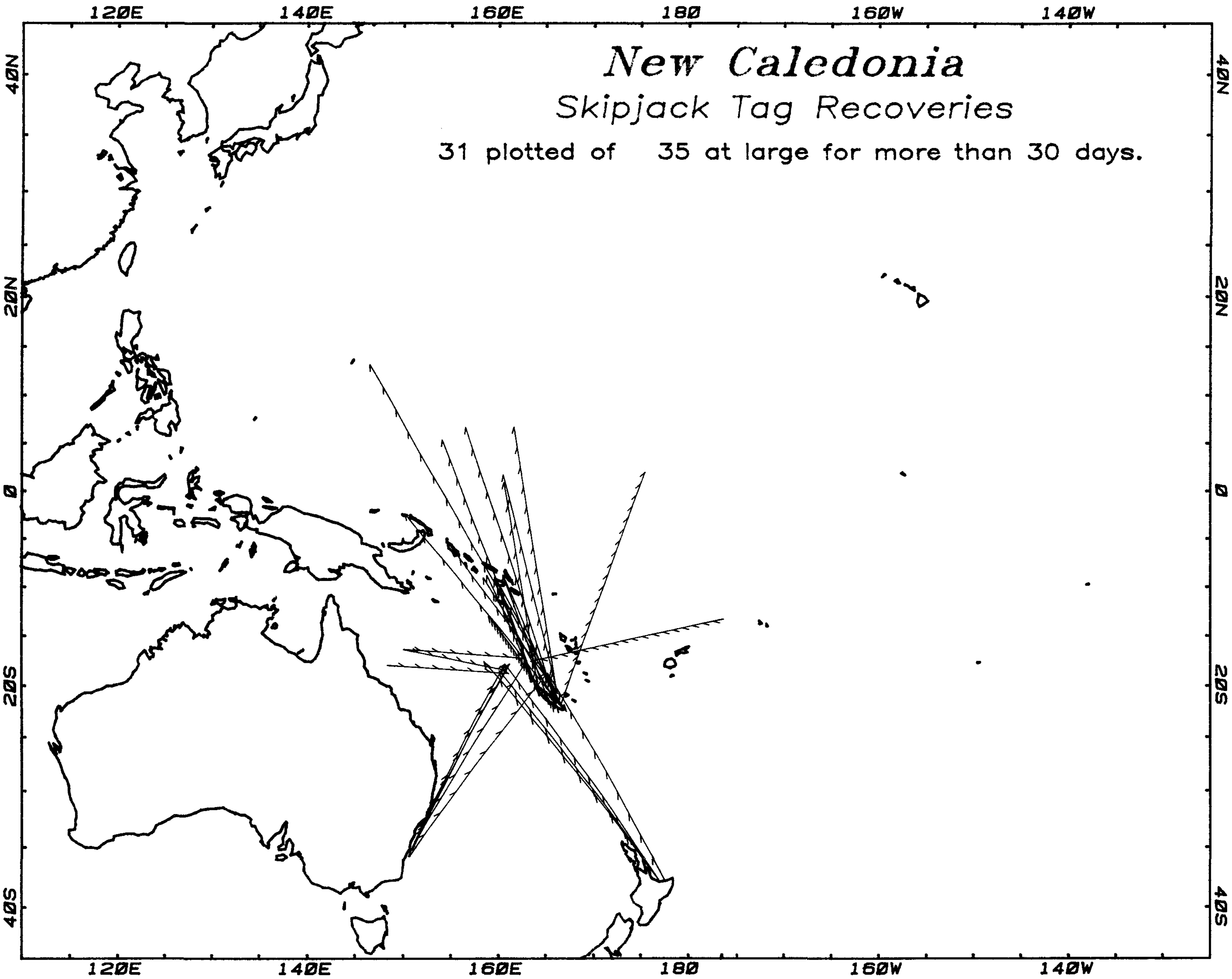

New Caledonia
Skipjack Tag Recoveries
31 plotted of 35 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 5

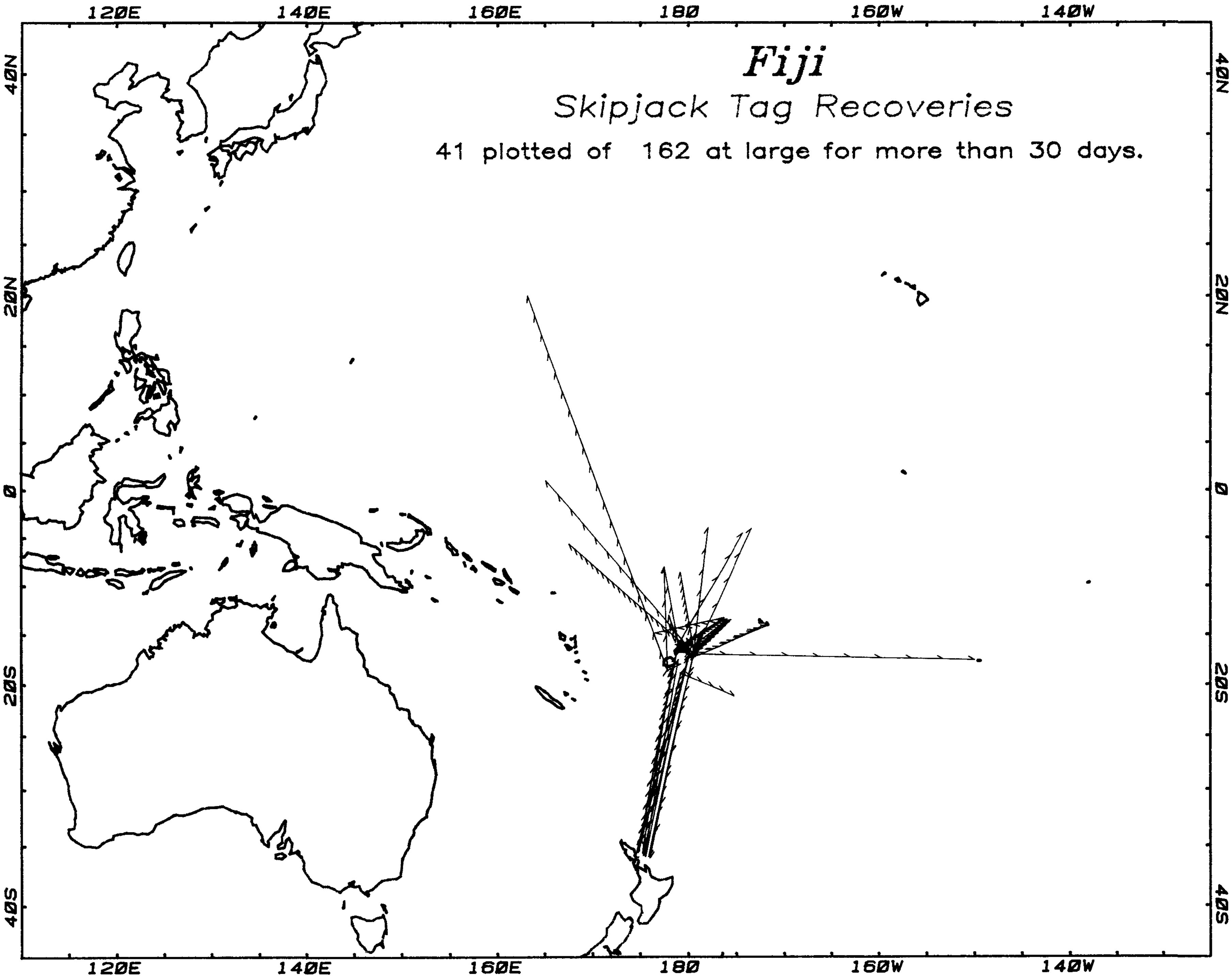
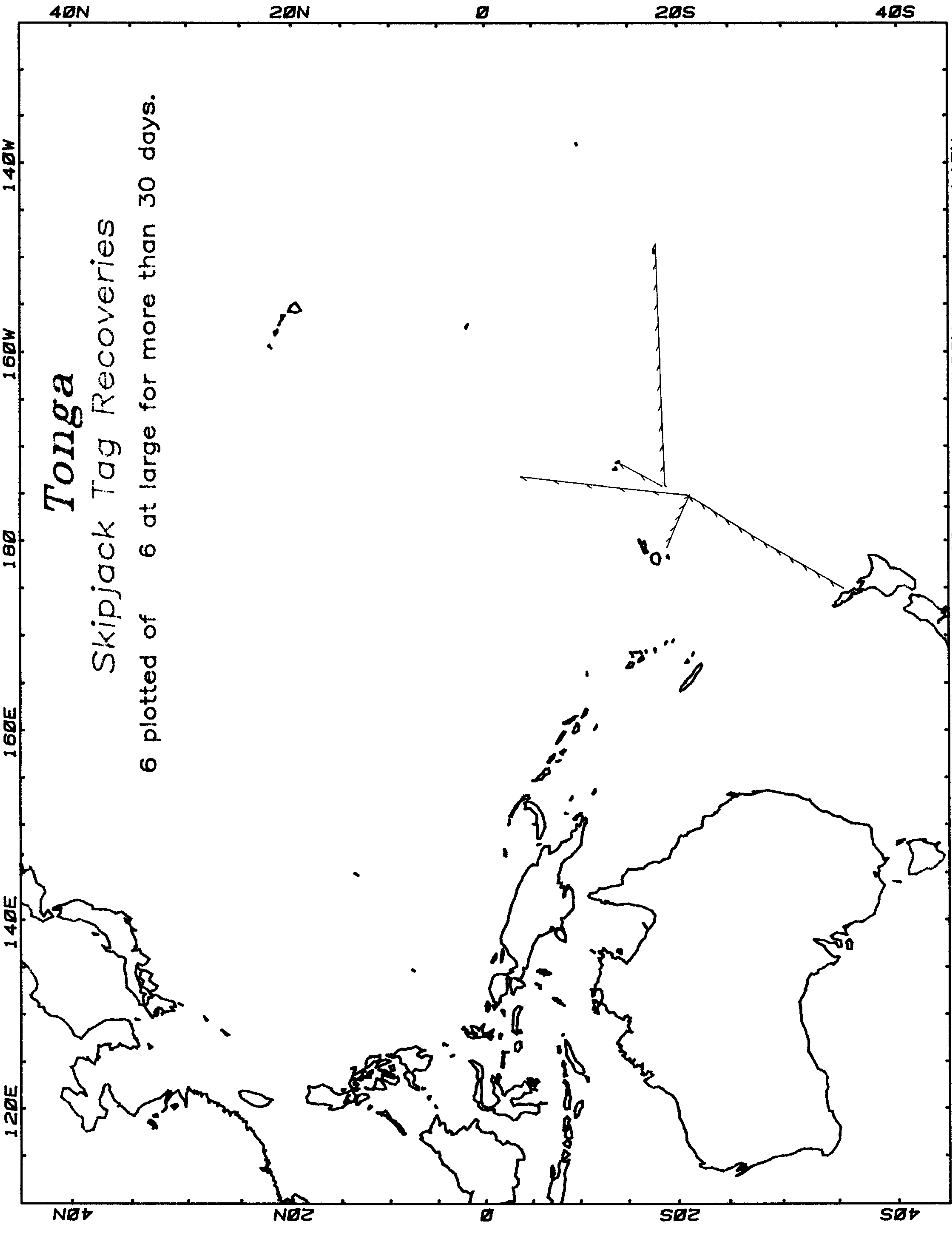

Fiji
Skipjack Tag Recoveries
41 plotted of 162 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 7


Tonga
Skipjack Tag Recoveries
6 plotted of 6 at large for more than 30 days.
40N
20N
0
20S
40S
140W
160W
180
160E
140E
120E

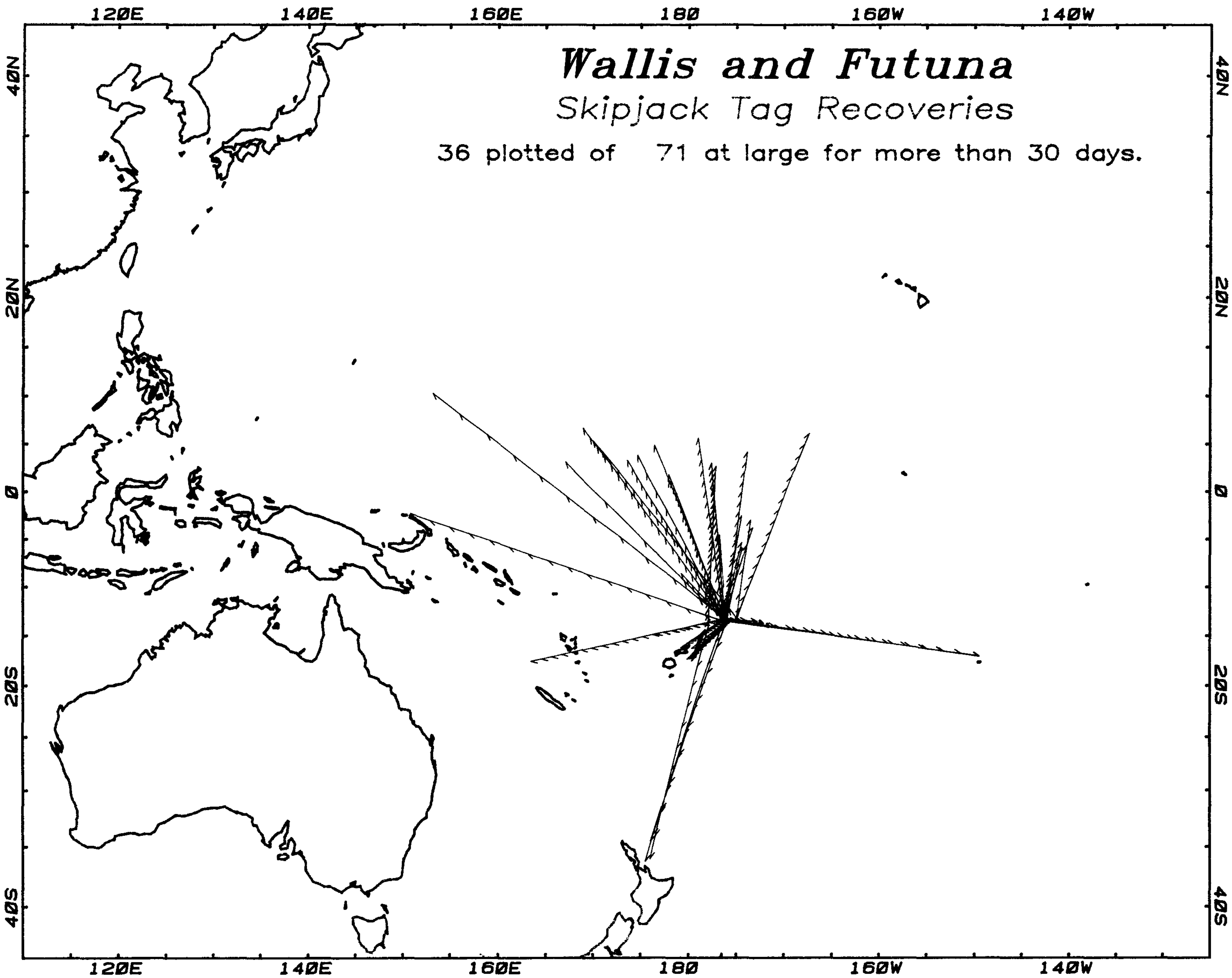


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Figure 8

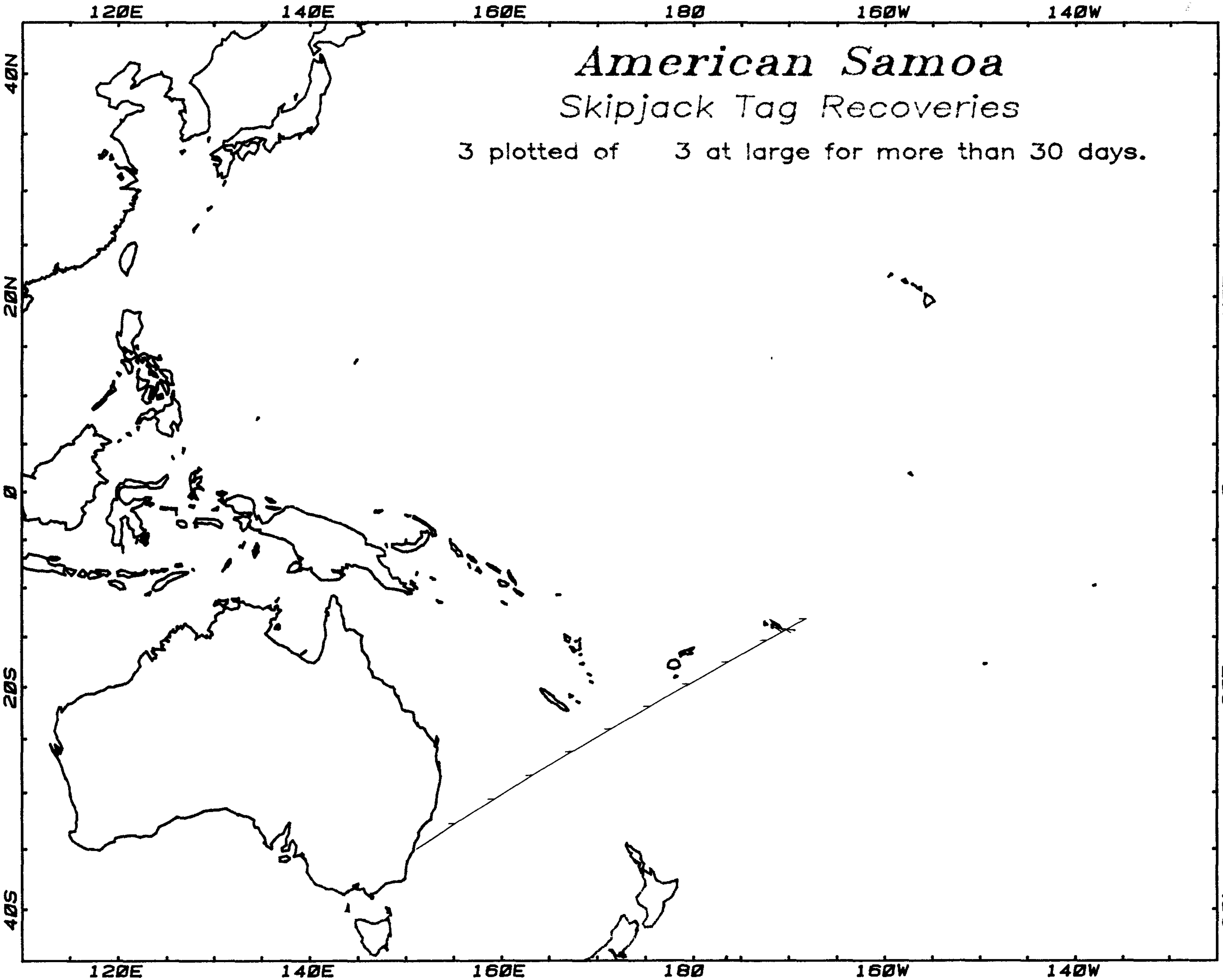
American Samoa
Skipjack Tag Recoveries
3 plotted of 3 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 9

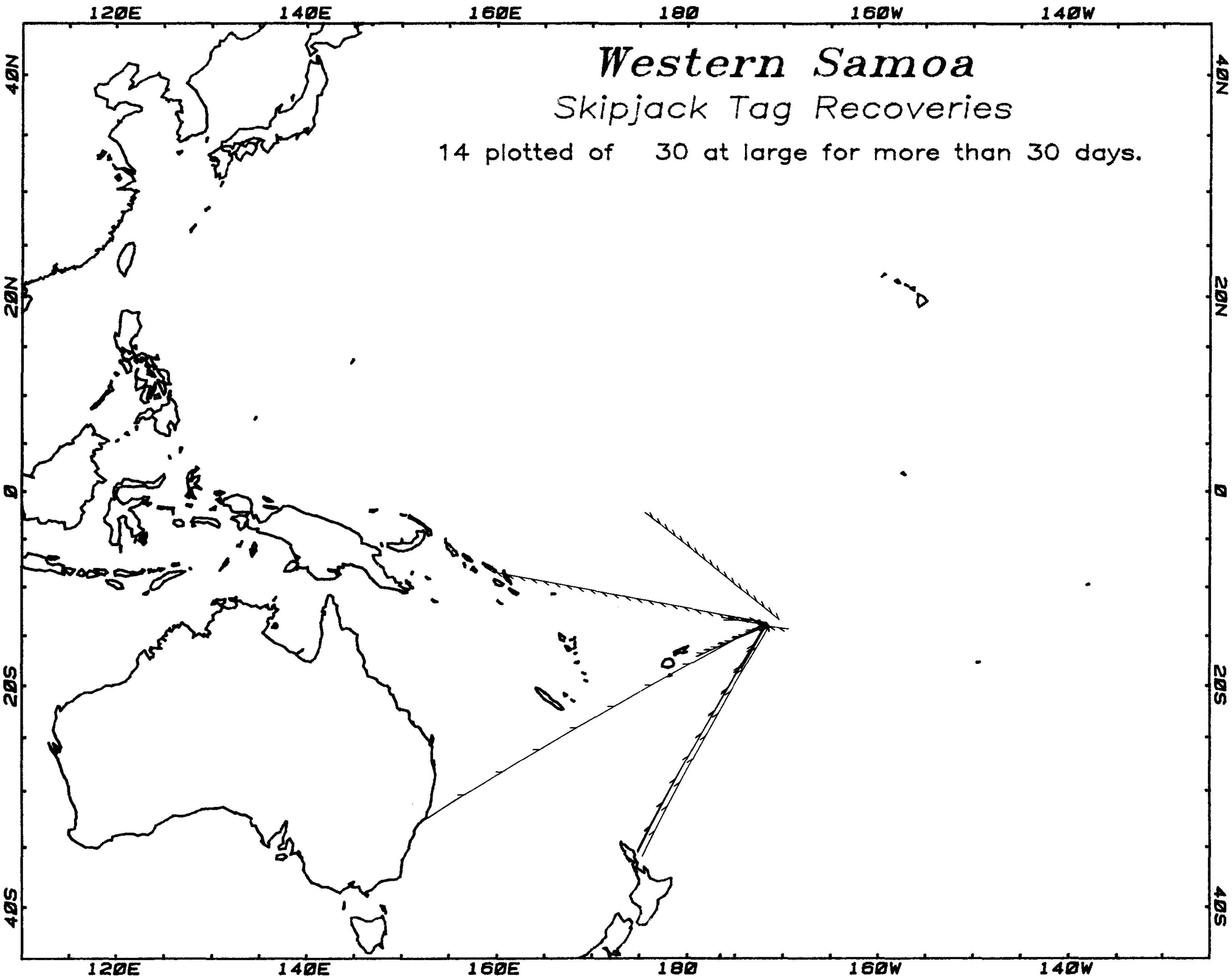
Western Samoa
Skipjack Tag Recoveries
14 plotted of 30 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 10

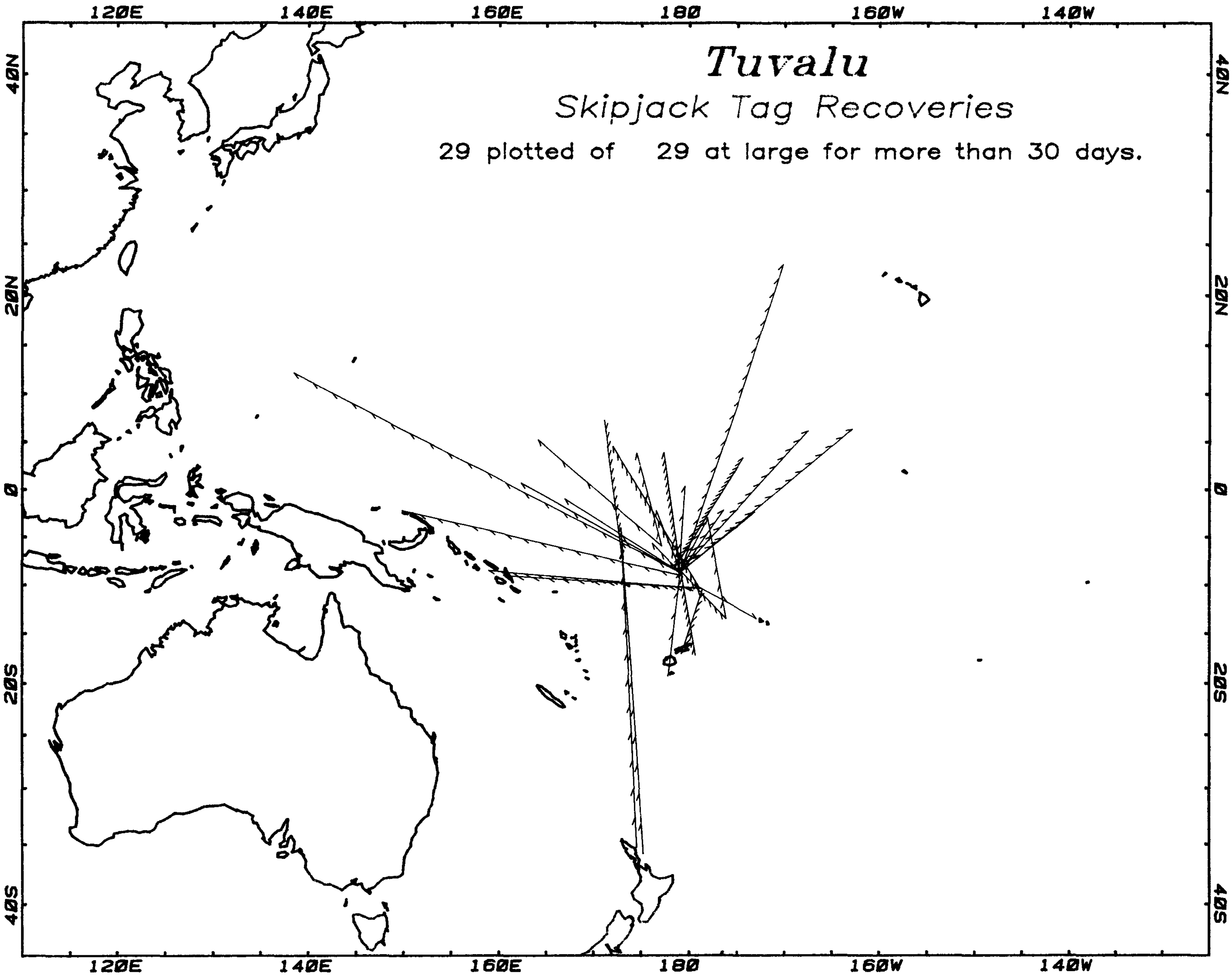
Tuvalu
Skipjack Tag Recoveries
29 plotted of 29 at large for more than 30 days.
120ØE
140ØE
160ØE
180
160ØW
140ØW
40N
20N
0
20S
40S

Figure 11

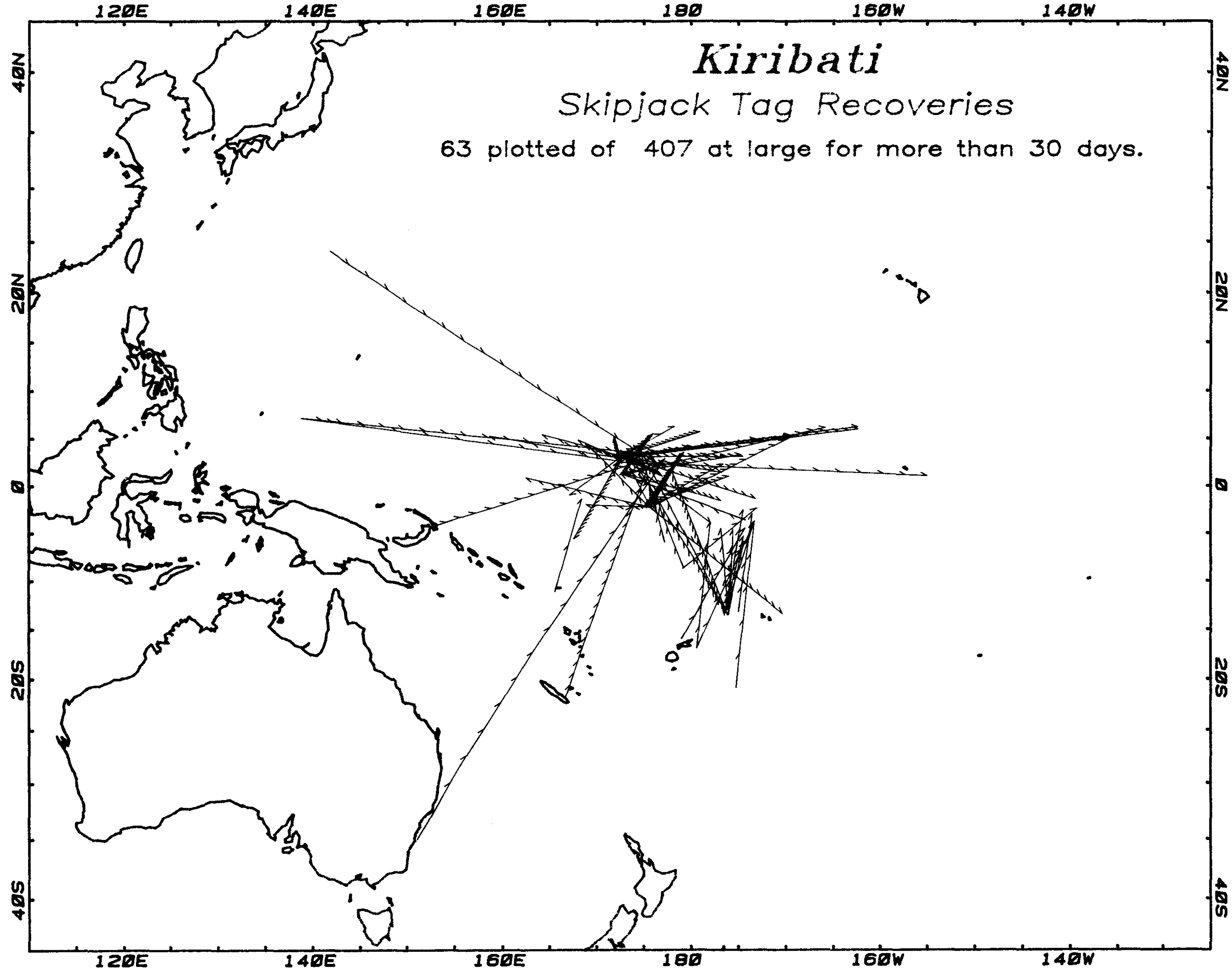
Kiribati
Skipjack Tag Recoveries
63 plotted of 407 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 12

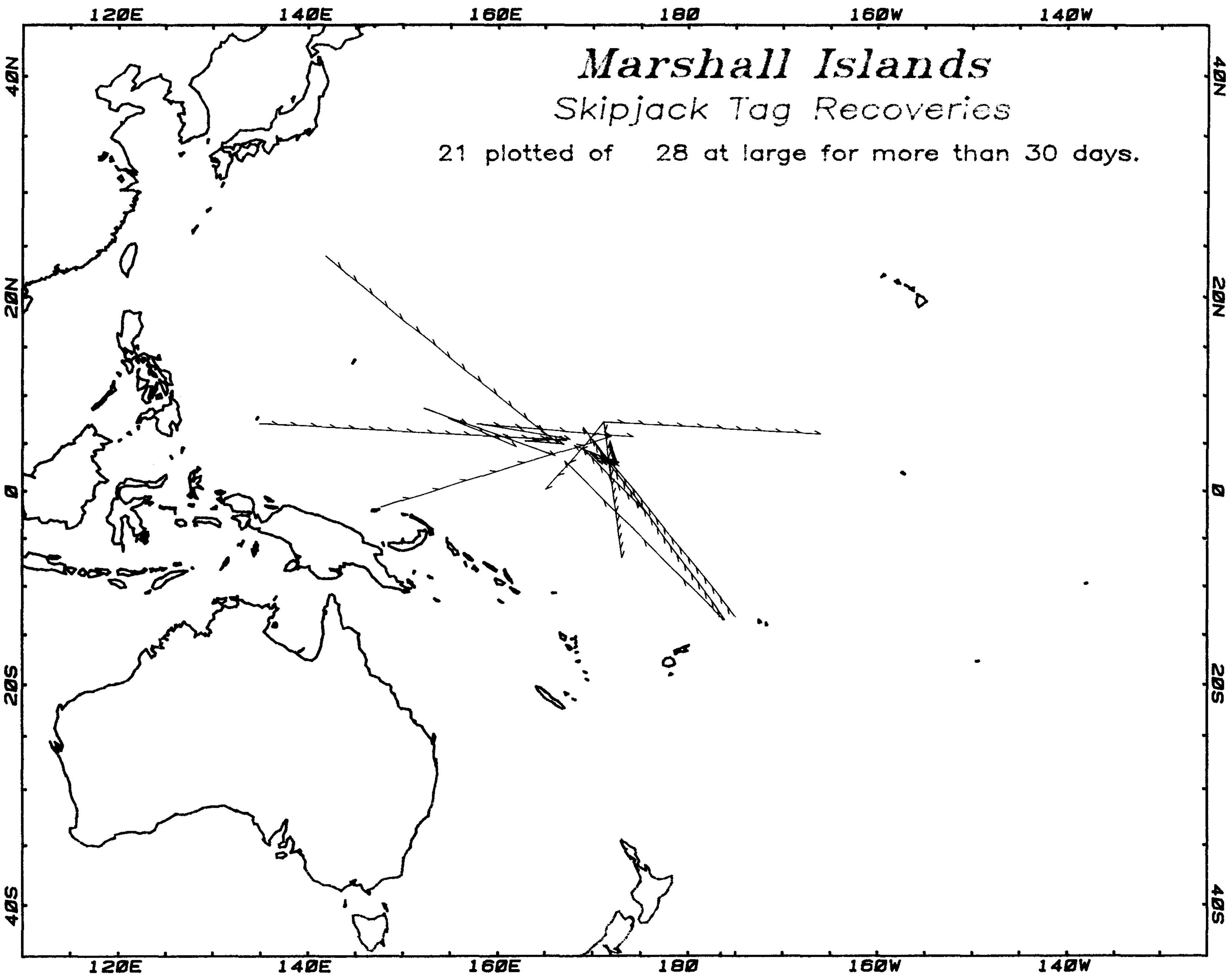

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Figure 13

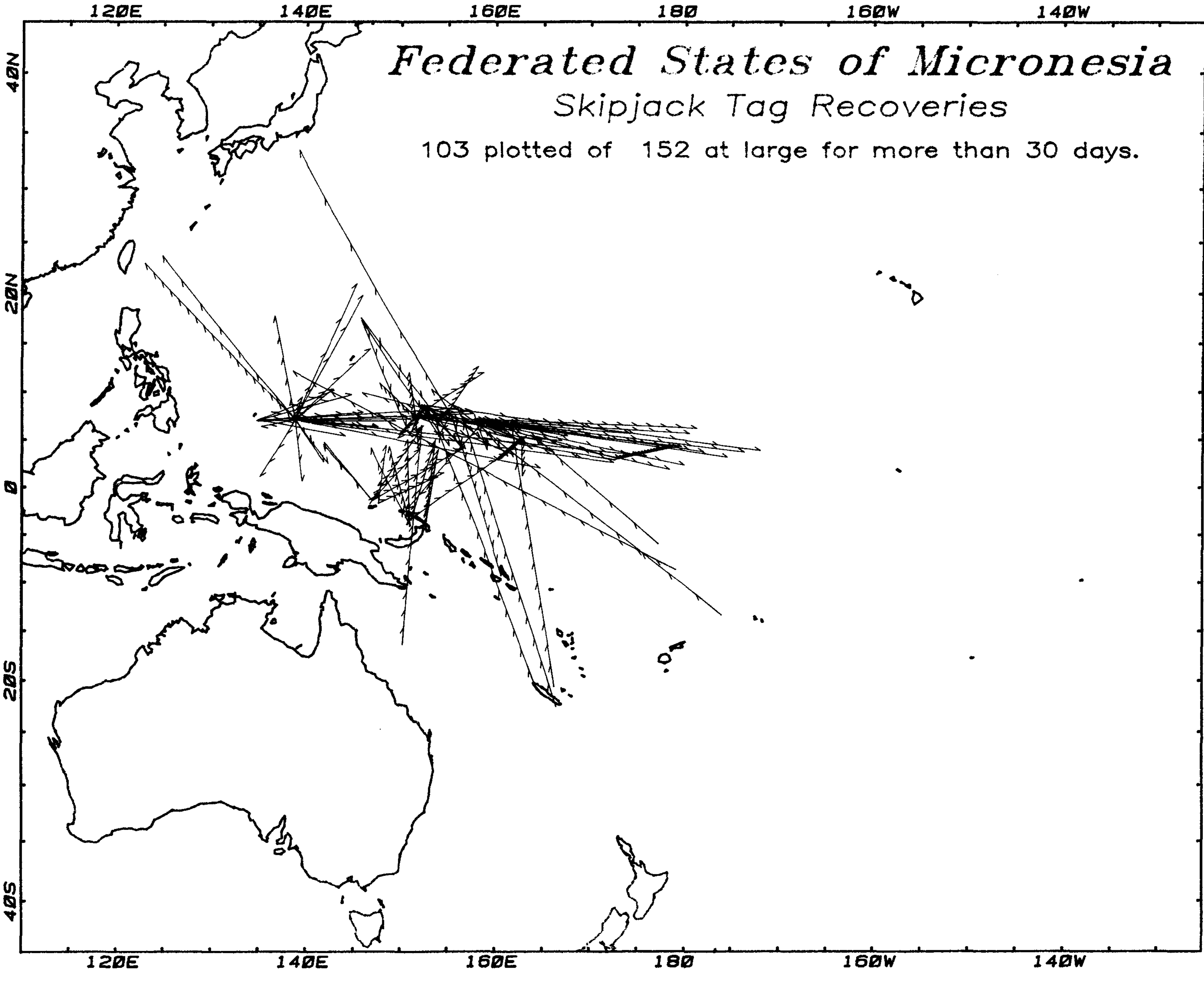
Federated States of Micronesia
Skipjack Tag Recoveries
103 plotted of 152 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 14

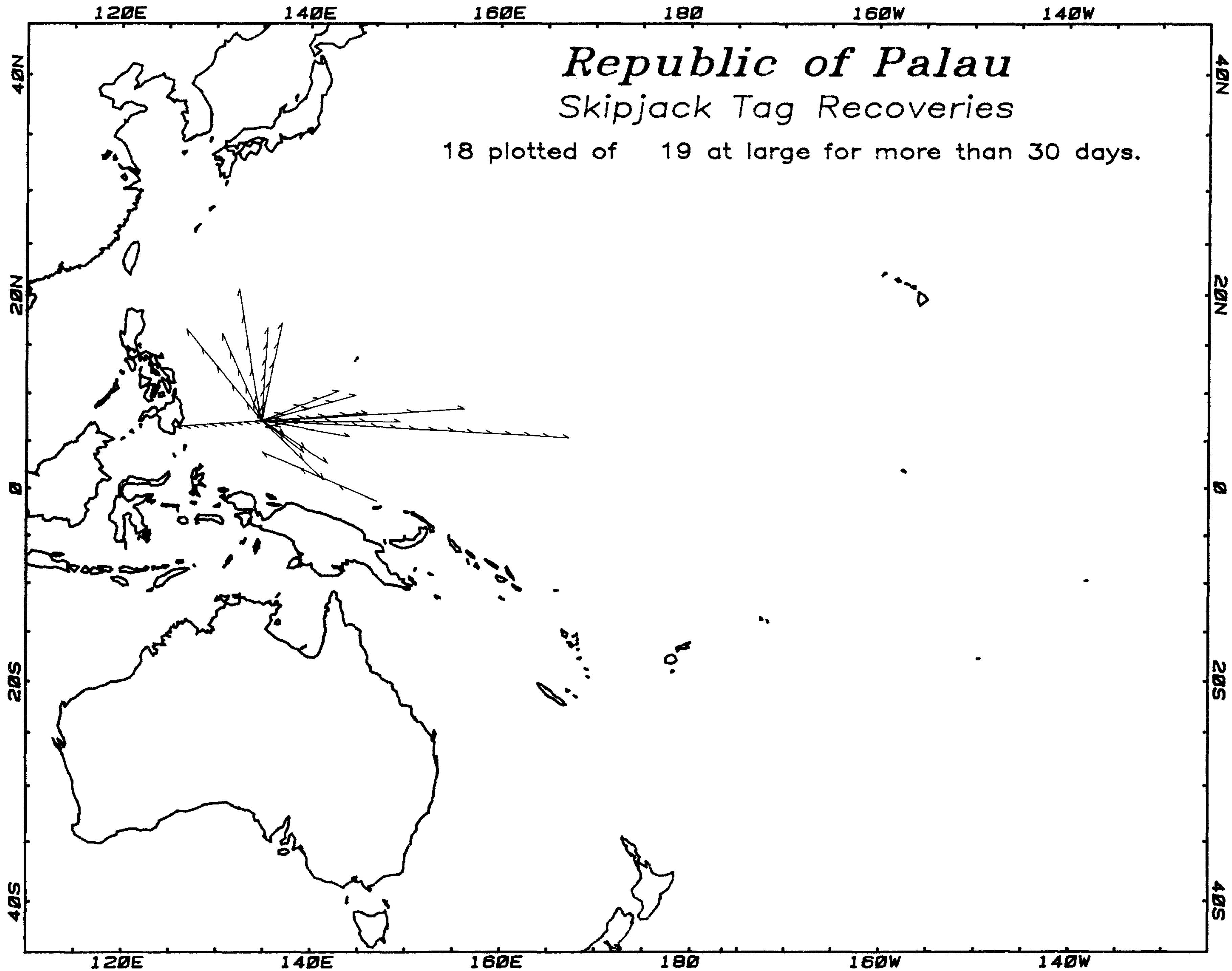
Republic of Palau
Skipjack Tag Recoveries
18 plotted of 19 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 15

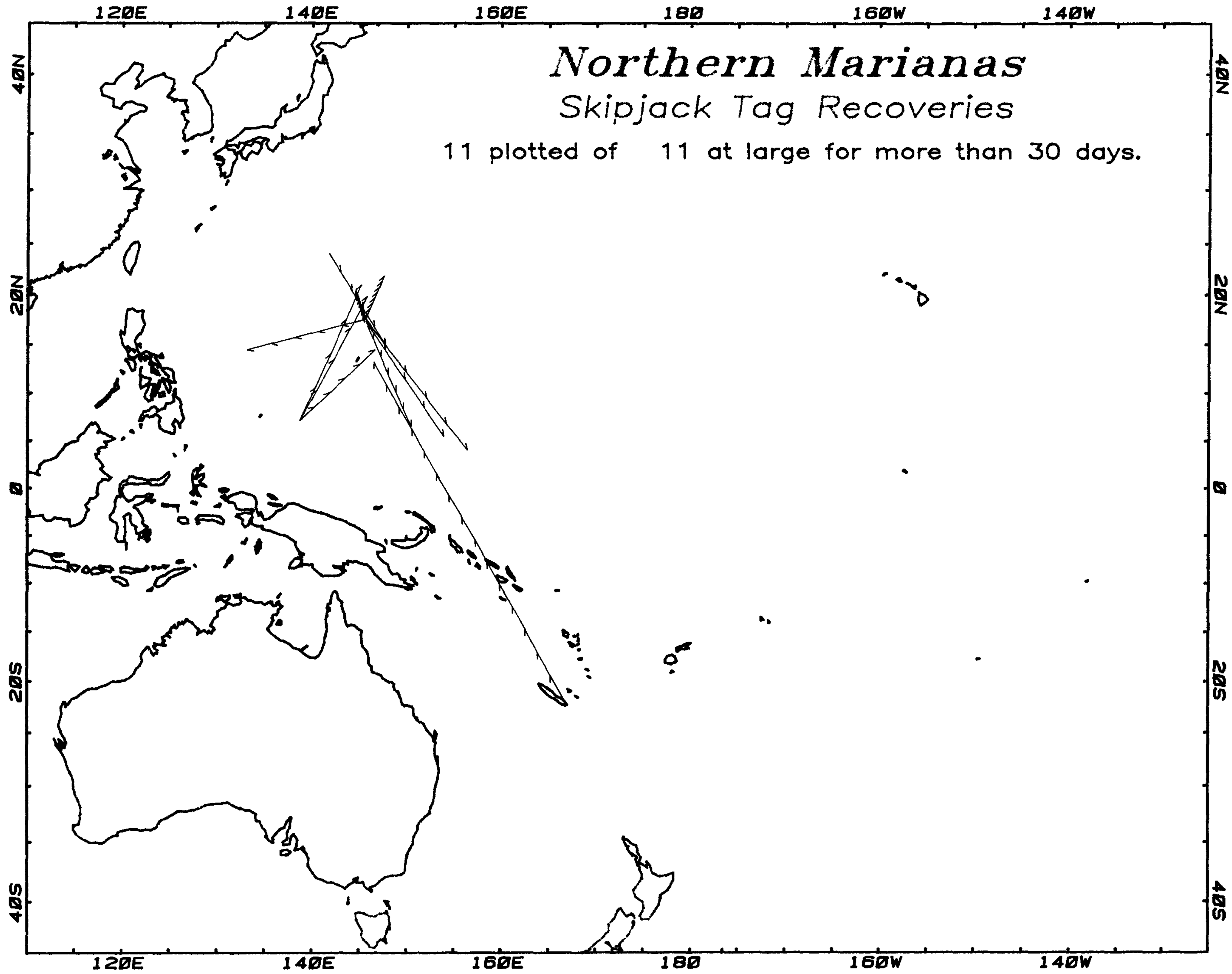

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Figure 16

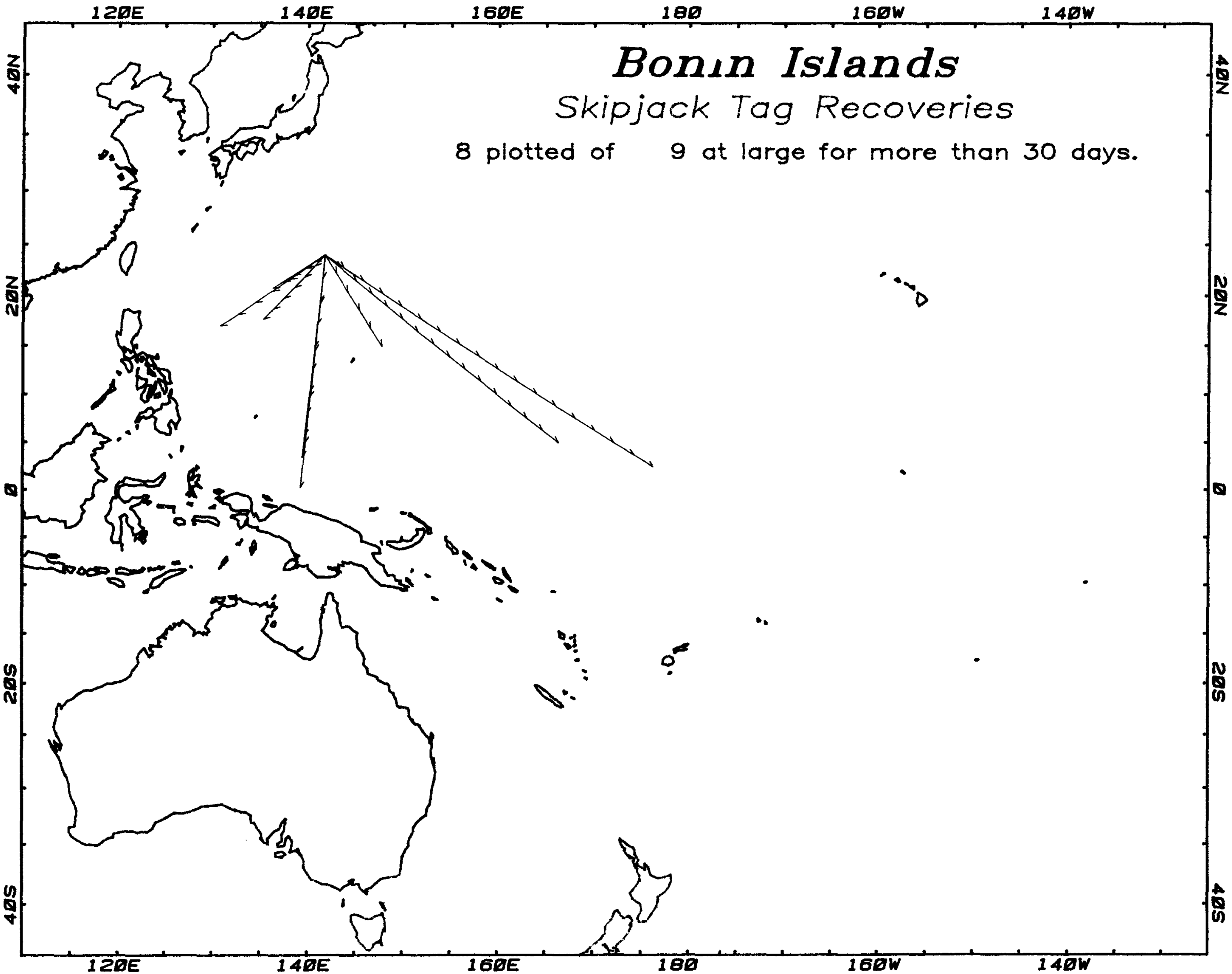
Bonin Islands
Skipjack Tag Recoveries
8 plotted of 9 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 17

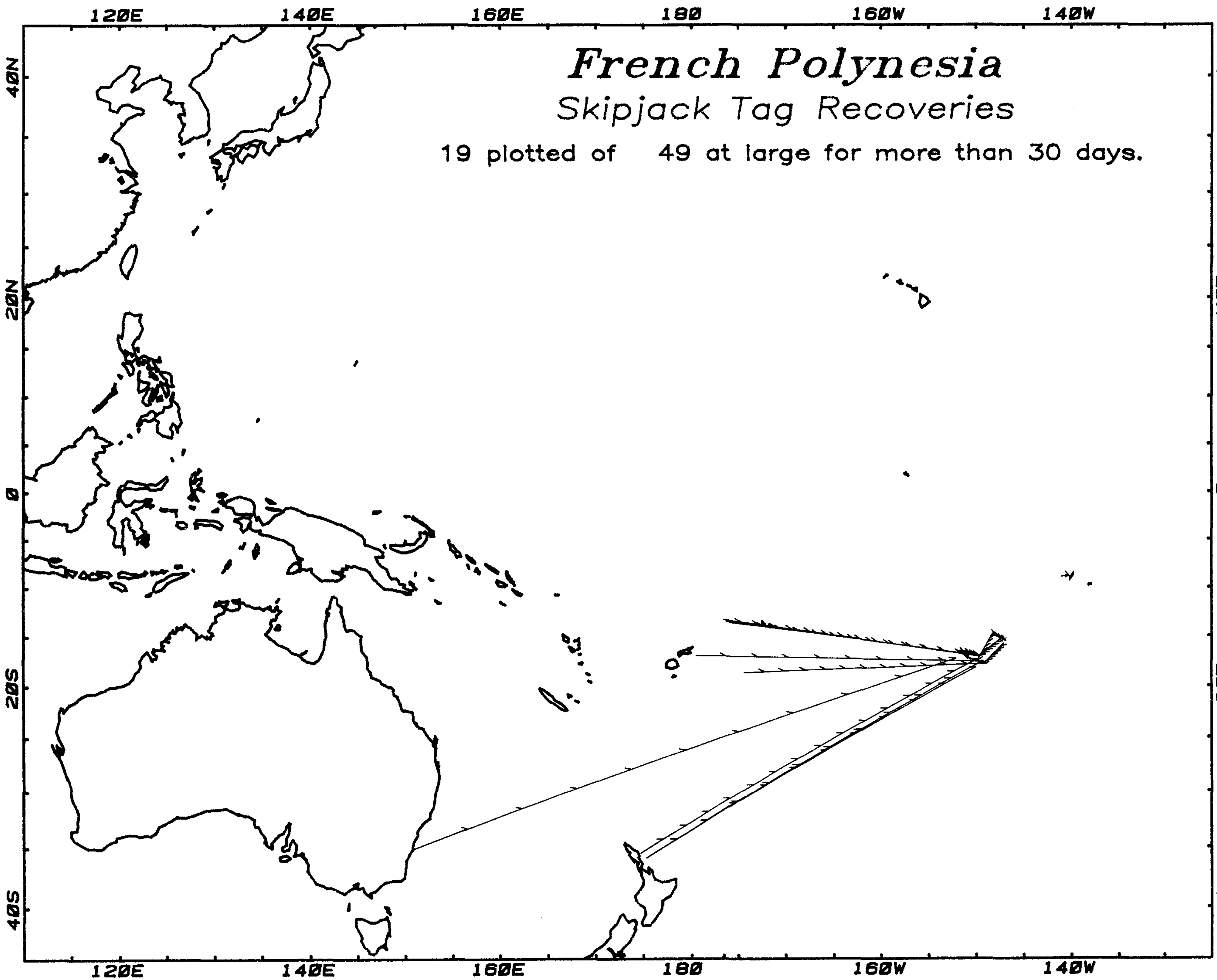
French Polynesia
Skipjack Tag Recoveries
19 plotted of 49 at large for more than 30 days.
120ØE
140ØE
160ØE
180
160ØW
140ØW
40ØN
20ØN
Ø
20ØS
40ØS

Figure 18

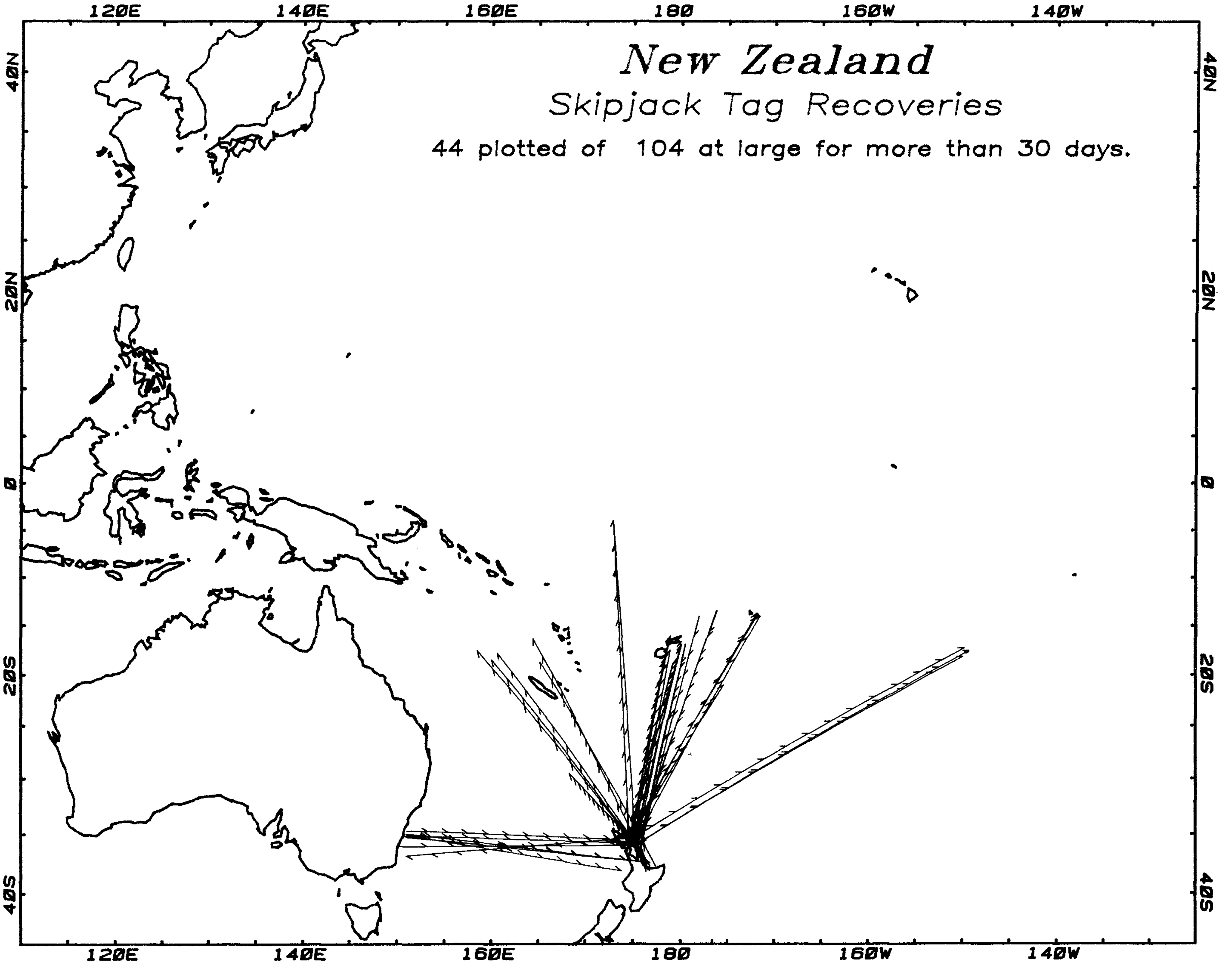
New Zealand
Skipjack Tag Recoveries
44 plotted of 104 at large for more than 30 days.
120ØE
140ØE
160ØE
180
160ØW
140ØW
40N
20N
0
20S
40S

Figure 19

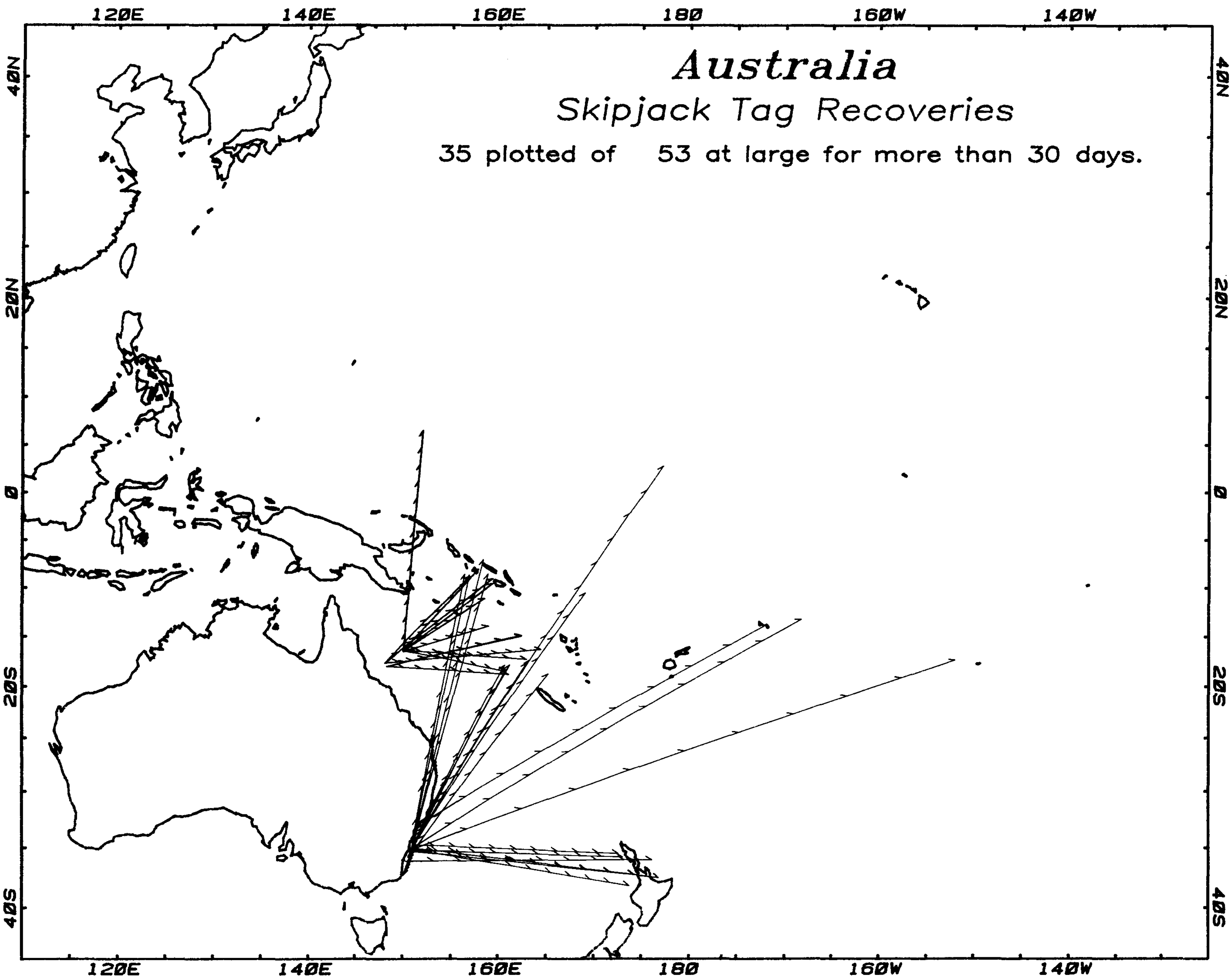

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Figure 20

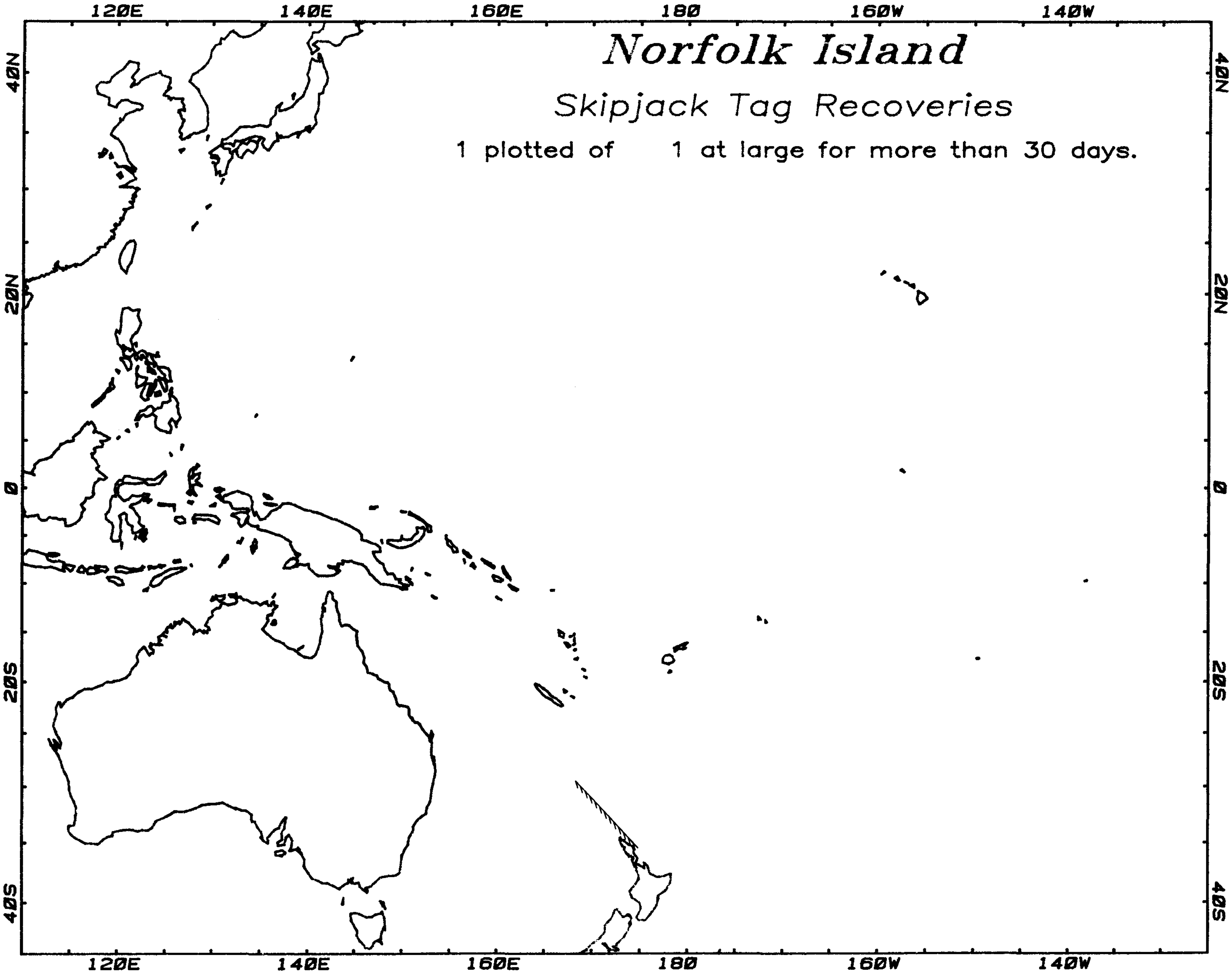
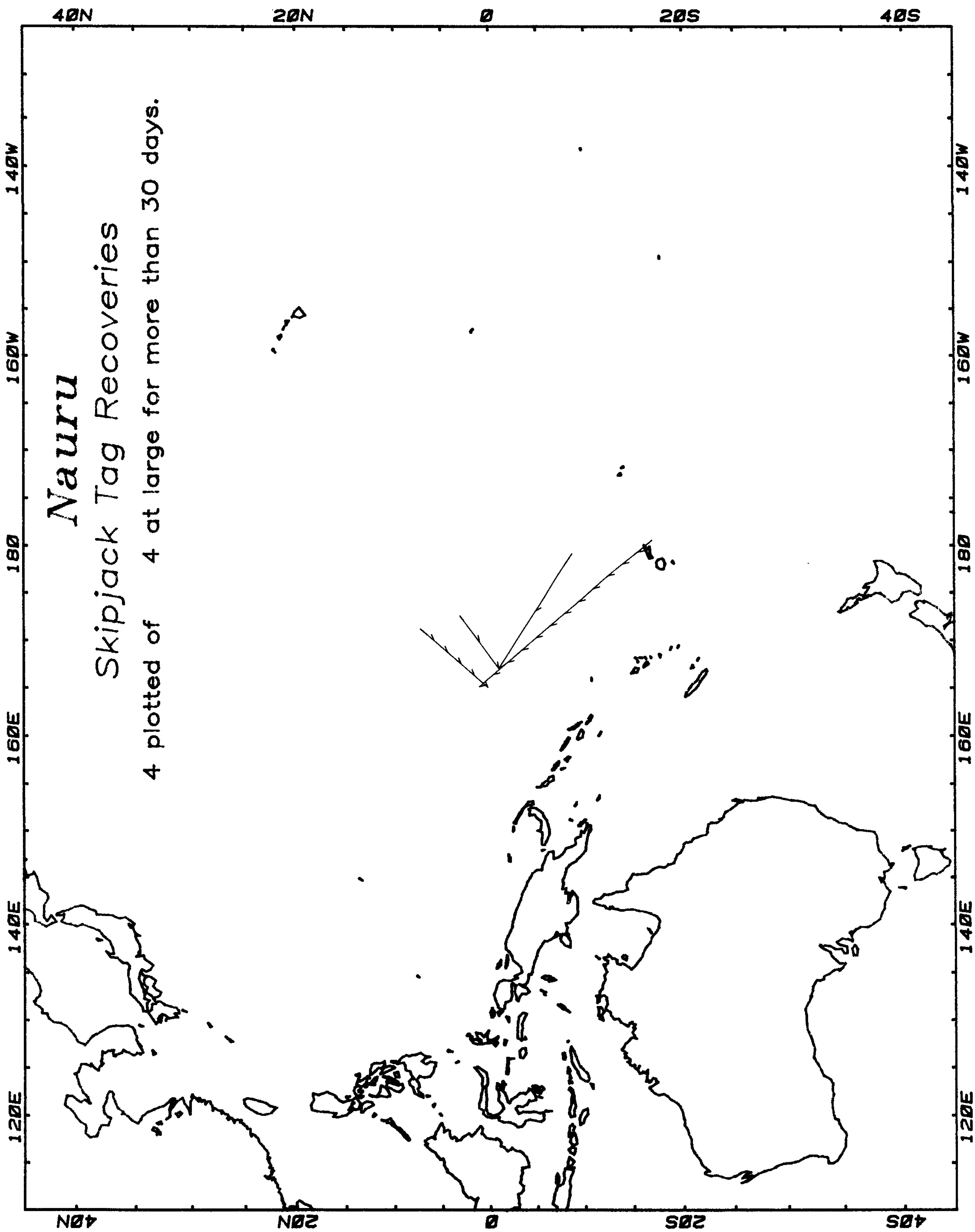

Norfolk Island
Skipjack Tag Recoveries
1 plotted of 1 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 21


Nauru
Skipjack Tag Recoveries
4 plotted of 4 at large for more than 30 days.
40N
20N
0
20S
40S
140W
160W
180
160E
140E
120E

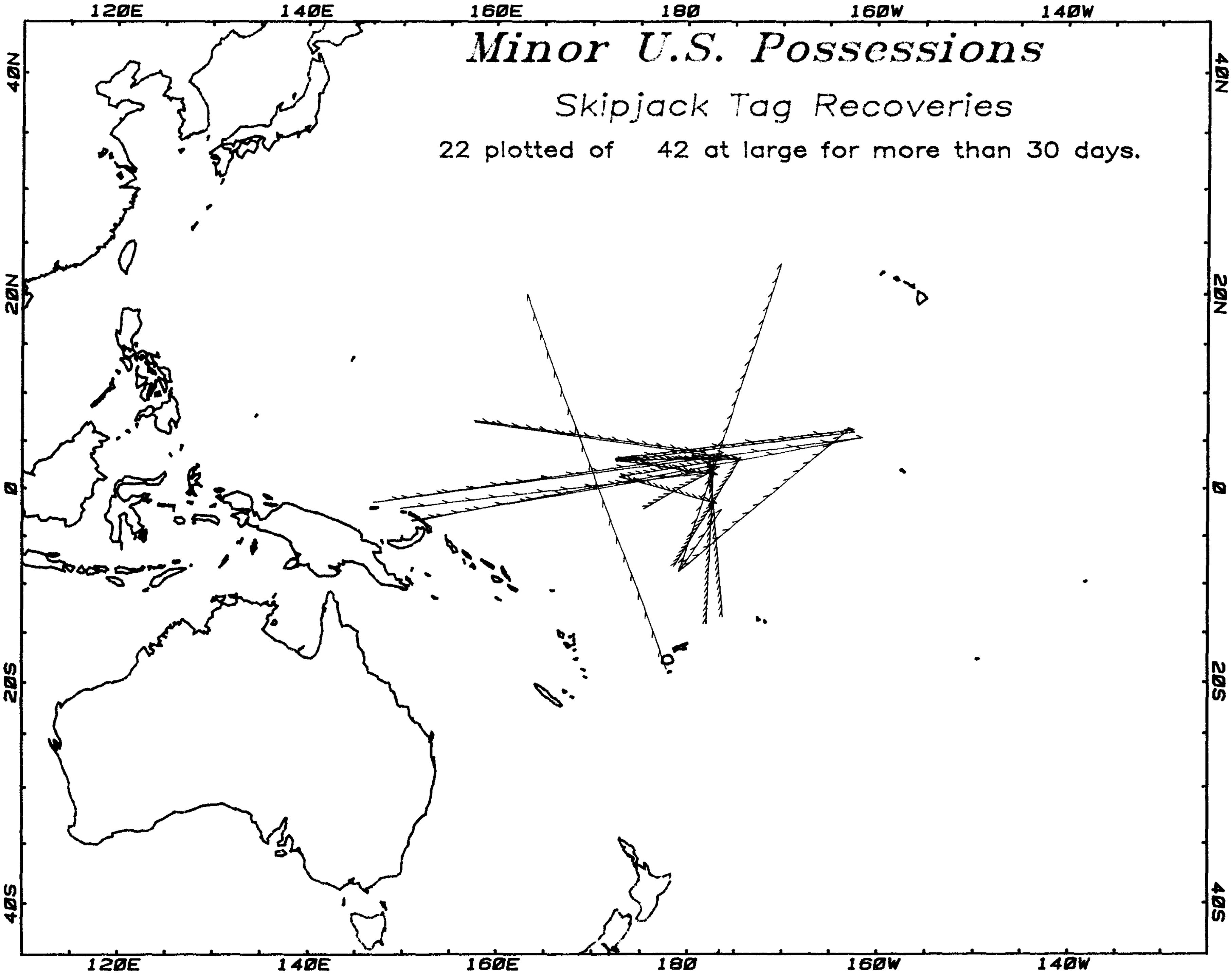

Minor U.S. Possessions
Skipjack Tag Recoveries
22 plotted of 42 at large for more than 30 days.
120E
140E
160E
180
160W
140W
40N
20N
0
20S
40S

Figure 23

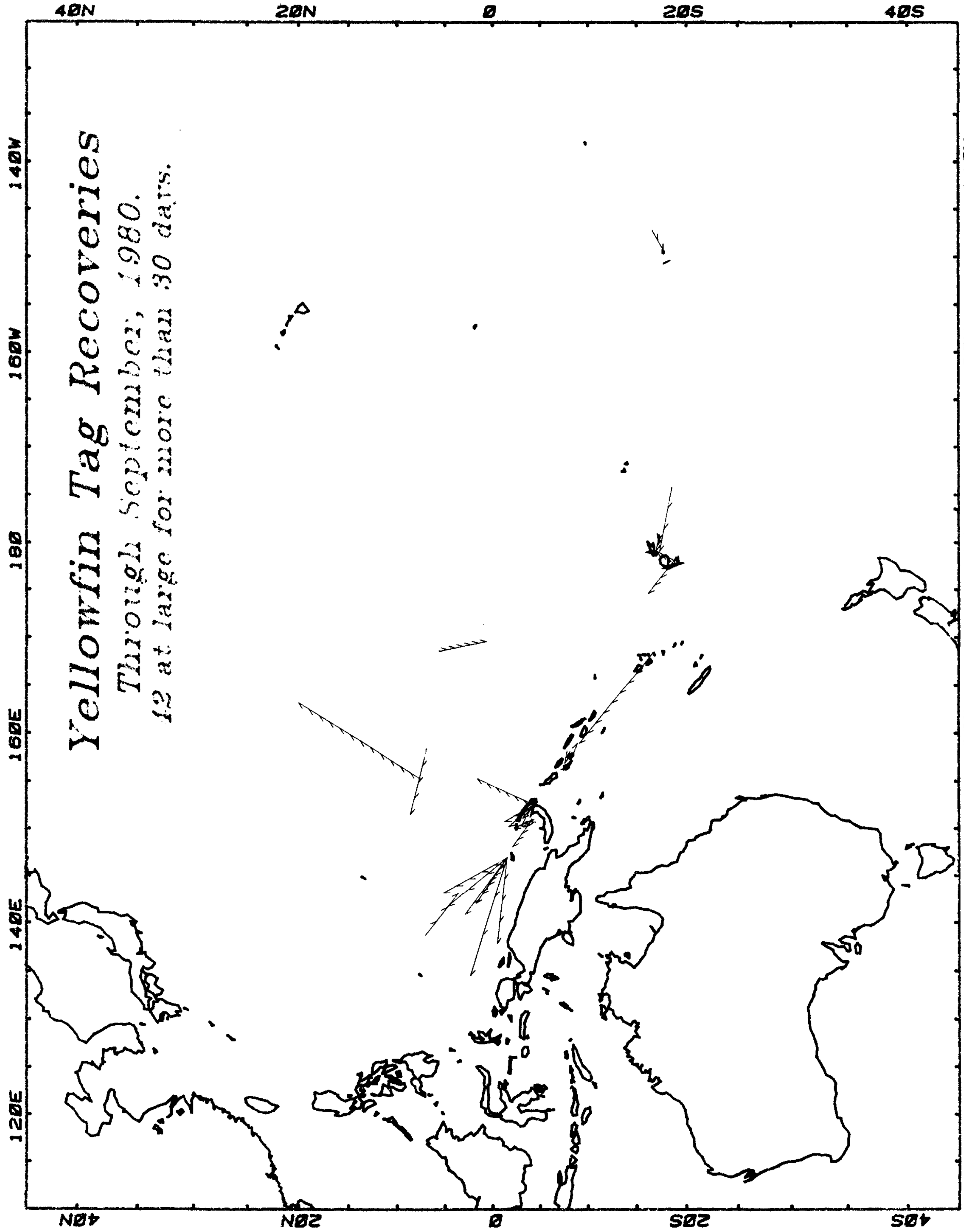
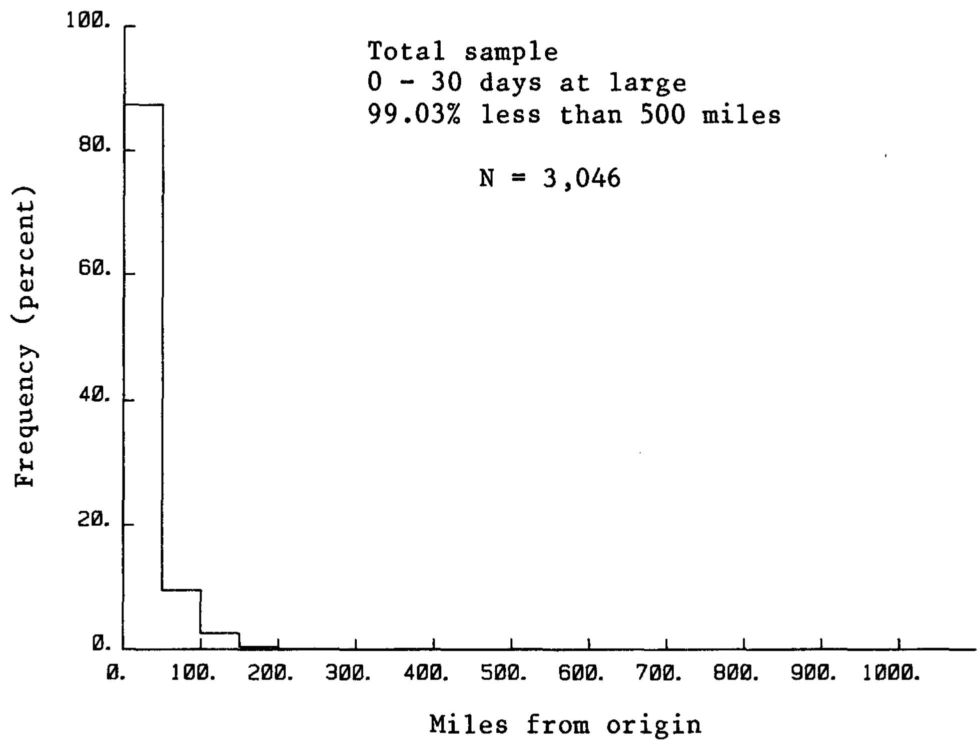

Yellowfin Tag Recoveries
Through September, 1980.
42 at large for more than 30 days.
4ØN
2ØN
Ø
2ØS
4ØS
14ØW
16ØW
18Ø
16ØE
14ØE
12ØE

FIGURE 25 - Movement distributions for all skipjack tag recoveries at large during four different time periods.



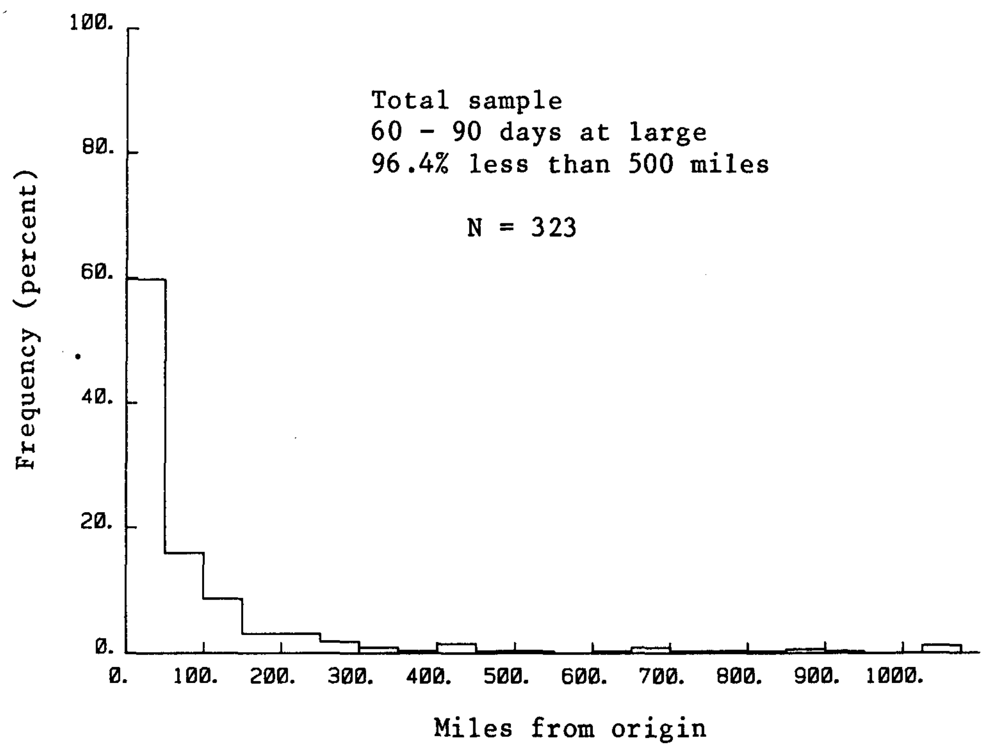
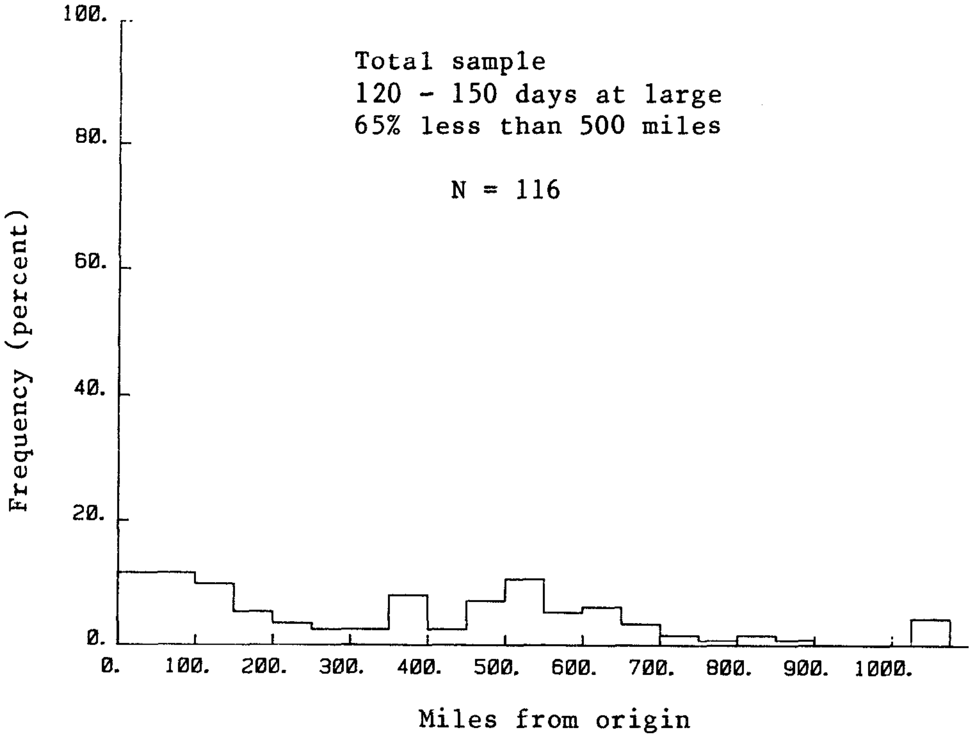


FIGURE 25 - Movement distributions for all skipjack
cont. tag recoveries at large during four different
time periods.



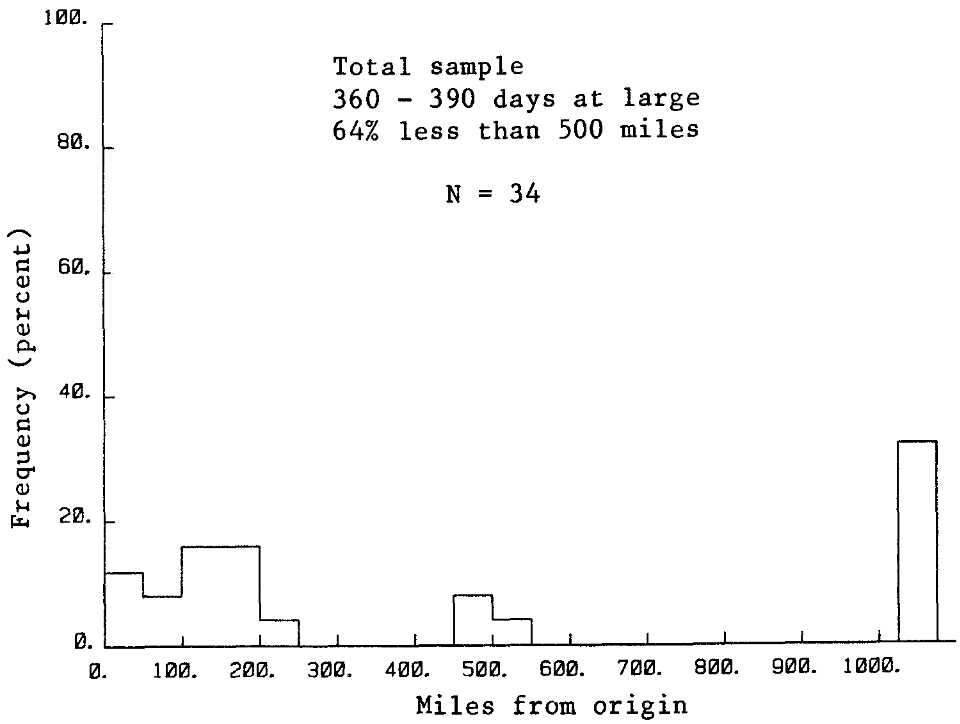


FIGURE 26 - Distribution of time at large for fish captured within 500 miles of their point of release (i.e. local recoveries).

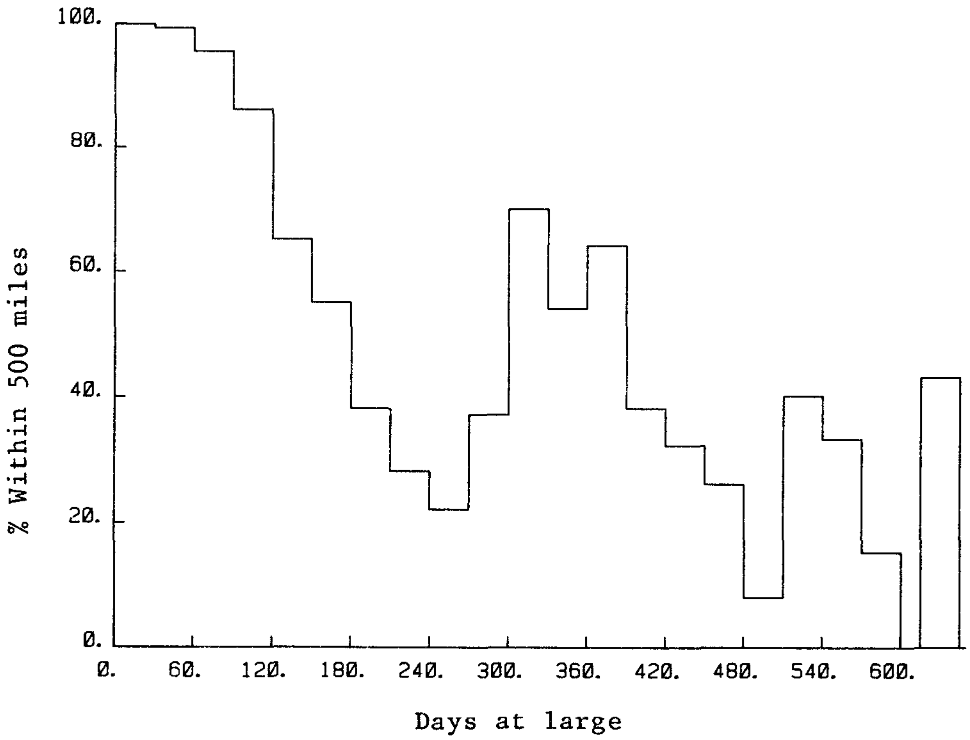
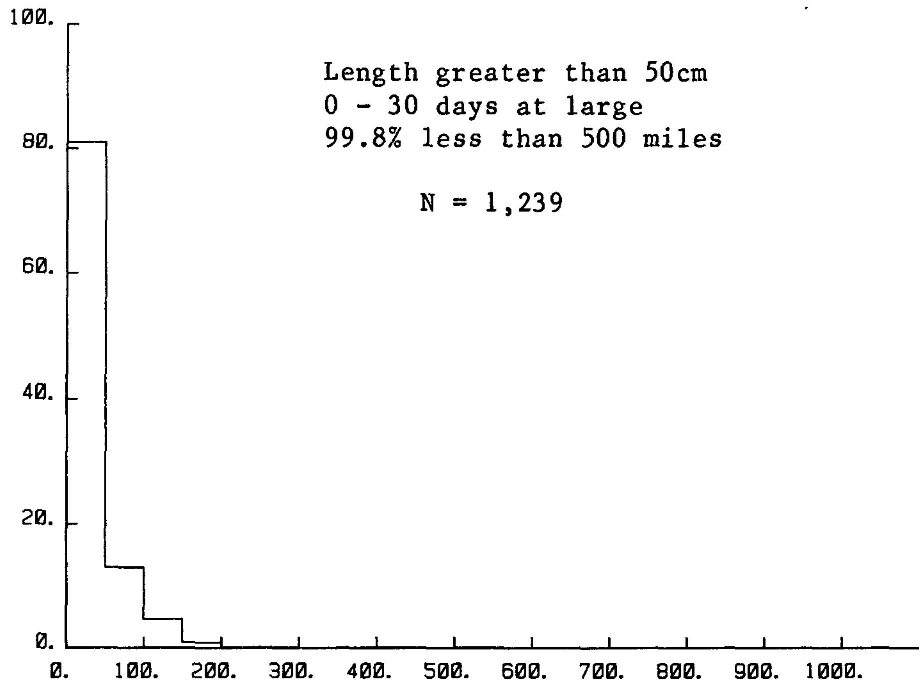


FIGURE 27 - Movement distributions for all skipjack tag recoveries that were greater than 50cm in length at time of release. Four different recovery time periods are indicated.



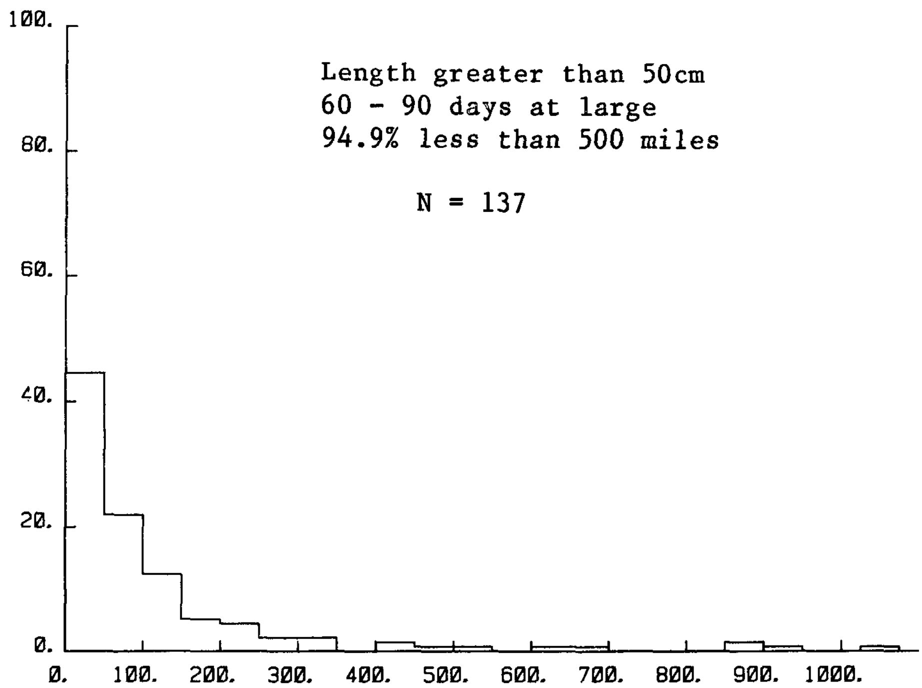
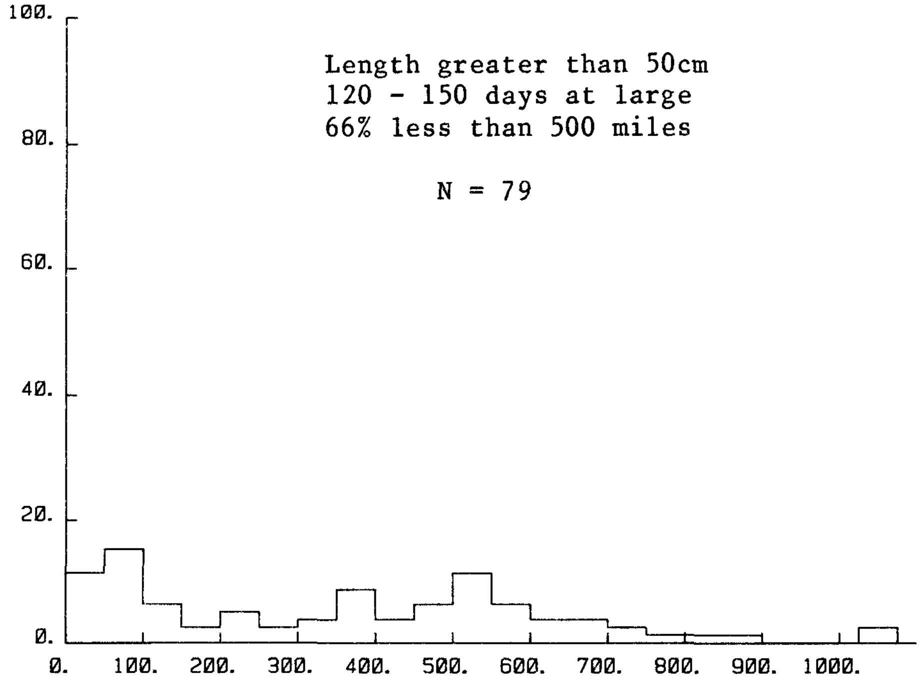


FIGURE 27 - Movement distributions for all skipjack
cont. tag recoveries that were greater than 50cm in length at time of release. Four different recovery time periods are indicated.



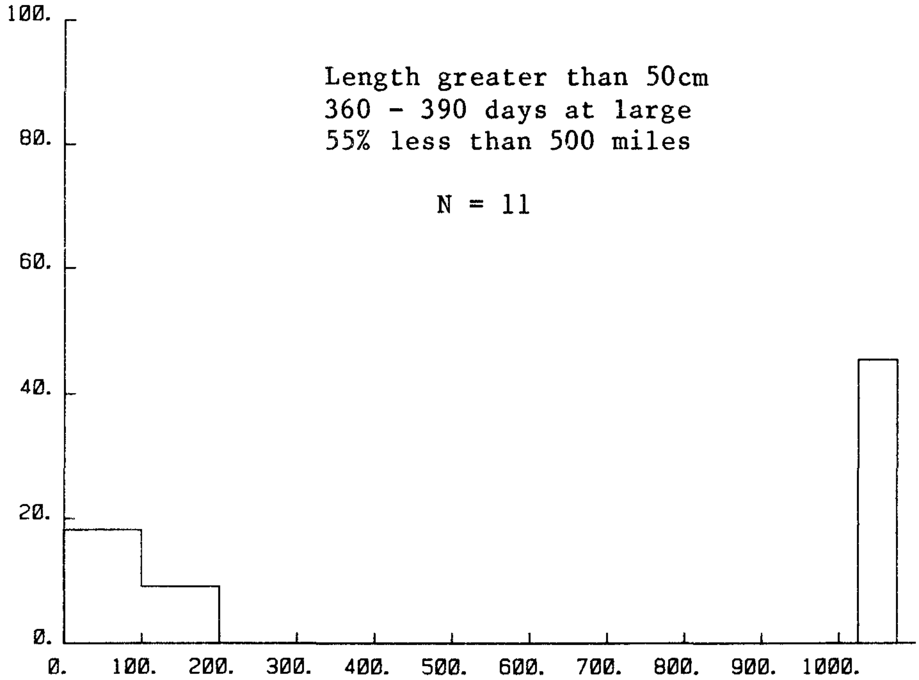
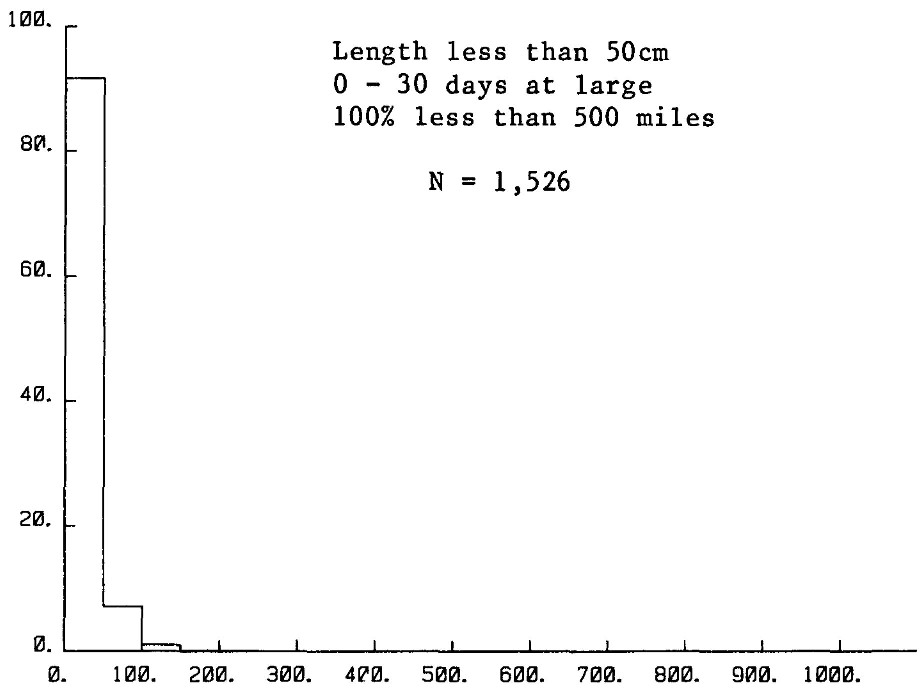


FIGURE 28 - Movement distributions for all skipjack tag recoveries that were less than 50cm in length at time of release. Four different recovery time periods are indicated.



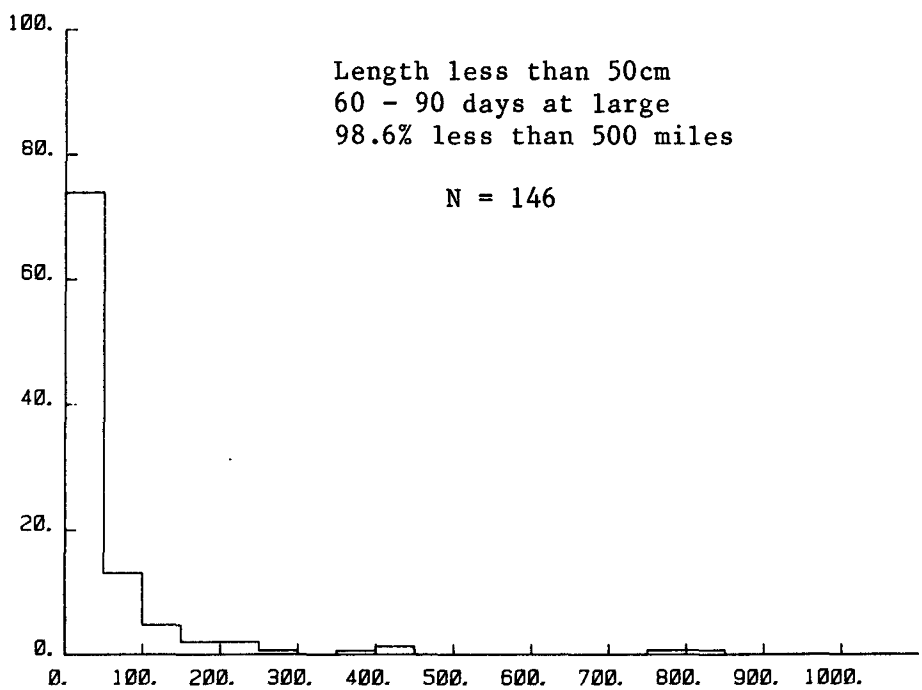


FIGURE 28 - Movement distributions for all skipjack
cont. tag recoveries that were less than 50cm in length at time of release. Four different recovery time periods are indicated.