

TUNA TAGGING ACTIVITIES IN THE MALDIVES, 1993-95

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ABSTRACT

Between September 1993 and August 1995 a total of 7777 tunas were tagged, comprising 6474 skipjack (83%) and 1303 (17%) yellowfin. Tetracycline injection of skipjack was carried out in 1994, and of yellowfin in 1995. To the end of August 1995 a total of 557 recoveries had been received, which was 7.2% of releases. There were 540 skipjack recoveries (8.3% of releases) and 17 yellowfin recoveries (1.3% of releases). The majority of tags were recovered within the Maldives. No difference in migratory behaviour of 'inshore' and 'offshore' skipjack was found. An alternative hypothesis of skipjack migration is proposed. Further analysis of recovery data is planned

INTRODUCTION

The tuna fishery is one of the pillars of the Maldivian economy. It provides a major source of employment, of food and of export earnings for the Maldivian people. The tuna fishery is a traditional one which has been in existence for centuries. Despite economic diversification in recent years, tuna fishing continues to be of major importance to the Maldives, with record catches in 1994. The main fishing technique used is live-bait pole and line, and the main species caught are skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*). 1994 catches of these two species amounted to 82,500 t (Anon, 1995) which was 79% of the total Maldivian fish catch.

In view of the vital importance of the tuna fishery to the country, the Government of Maldives is committed to carrying out tuna research in order to enhance the rational management and sustainable utilization of the resource. Towards this ultimate end, two tagging programmes have been carried out in Maldives, in 1990 and in 1993-95.

First Tagging Programme - Results and Recommendations

During 1990 the Marine Research Section (MRS) of the Maldivian Ministry of Fisheries and Agriculture (MOFA) carried out a tuna-tagging programme, with assistance from the Indo-Pacific Tuna Programme (IPTP). Nearly 10,000 tunas were tagged, of which 81% were skipjack and 19% were yellowfin tuna (Yesaki and Waheed, 1992). Recoveries amounted to 17.8% for skipjack and 7.0% for yellowfin (Waheed and Anderson, 1994).

Analysis of returns from the first tagging programme gave insights into the migrations and growth of both skipjack and yellowfin tuna (Yesaki and Waheed, 1991 & 1992) as well as into some aspects of the population dynamics of skipjack in Maldivian waters (Bertignac, Kleiber and Waheed, 1994; Bertignac, 1994). That tagging programme

successfully fulfilled all of its stated aims (Yesaki and Waheed, 1992; Lewis, 1992). It also raised a number of new questions. In order to address these questions, several recommendations were made for future tagging activities, and are summarized below (after Waheed and Anderson, 1994):

1. The results of the first tagging programme suggested that skipjack tagged 'offshore' moved further than those tagged 'inshore.' Yesaki and Waheed (1992) and Bertignac *et al.* (1994) recommended that future tagging experiments should tag more offshore skipjack in order to obtain better estimates of movements from the Maldives, and of the relationship between 'resident and migratory stocks.'
2. The results of the first tagging programme suggested that yellowfin tuna are more wide-ranging than skipjack. Yellowfin might therefore be more vulnerable to interactions with other fisheries. They might also potentially be more vulnerable to over-exploitation because of their longer life cycle. Yesaki and Waheed (1992) therefore recommended that future tagging experiments should concentrate on tagging yellowfin, and include both juveniles and adults.

Table 1. Summary of tag releases by trip and by species, 1993-95.

<i>Trip No.</i>	<i>Date</i>	<i>No. Days Tagging</i>	<i>Location</i>		<i>No. Tunas Tagged</i>		
			<i>Atoll</i>	<i>Island</i>	<i>Skipjack</i>	<i>Yellowfin</i>	<i>Total</i>
1	9/93	12	L.	Maamendhoo	643	369	1,012
2	11/93	4	Gn.	Fuvah Mulaku	-	31	31
3	1-2/94	13	G.A.	Villingili	2,082	46	2,128
4	4/94	13	L.	Maamendhoo	1,317	-	1,317
5	8/94	18	G.A.	Kolamaafushi	2,432	84	2,516
6	4/95	19	Gn.	Fuvah Mulaku	-	36	36
7	8/95	9	B.	Thulaadhoo	-	737	737
Total	-	88			6,474	1303	7,777

3. In order to better understand seasonal movements of tunas, Yesaki and Waheed (1992) recommended that tagging should ideally be carried out in each target area during both seasons.
4. Although tag returns from tunas recaptured in the Maldives during the first tagging programme were believed to have been very good, information supplied with the tags was often lacking or of dubious quality. It was recommended that more effort be spent obtaining more accurate tag return information, particularly length-at-recapture information for growth estimates (Yesaki and Waheed, 1992; Lewis, 1992). The value of injecting tagged tunas with tetracycline to mark their otoliths for aging studies was also recognized.
5. Several recommendations were made for the improvement of tag return data, to facilitate future attrition model analysis (Bertignac *et al.*, 1994). These included tagging in discrete 'pulses,' double tagging, and tag seeding.
6. Yesaki and Waheed (1992) recommended that more effort be expended on obtaining better information on the bait fishery.

Second Tagging Programme - Aims

The recommendations of the first tagging programme were used as the basis for planning the second tagging programme, which was carried out during 1993-95. However, a number of other considerations had also to be taken into account. First, with a budget allowing for approximately 7000 releases it was not practical to address all of these recommendations. Furthermore, although Yesaki and Waheed (1992) had recommended concentrating on yellowfin tuna, skipjack is by far the most important fish species for the Maldives. Skipjack

catches averaged 68% of the total recorded national fish catch in 1992-94. Therefore emphasis was placed on tagging skipjack rather than yellowfin.

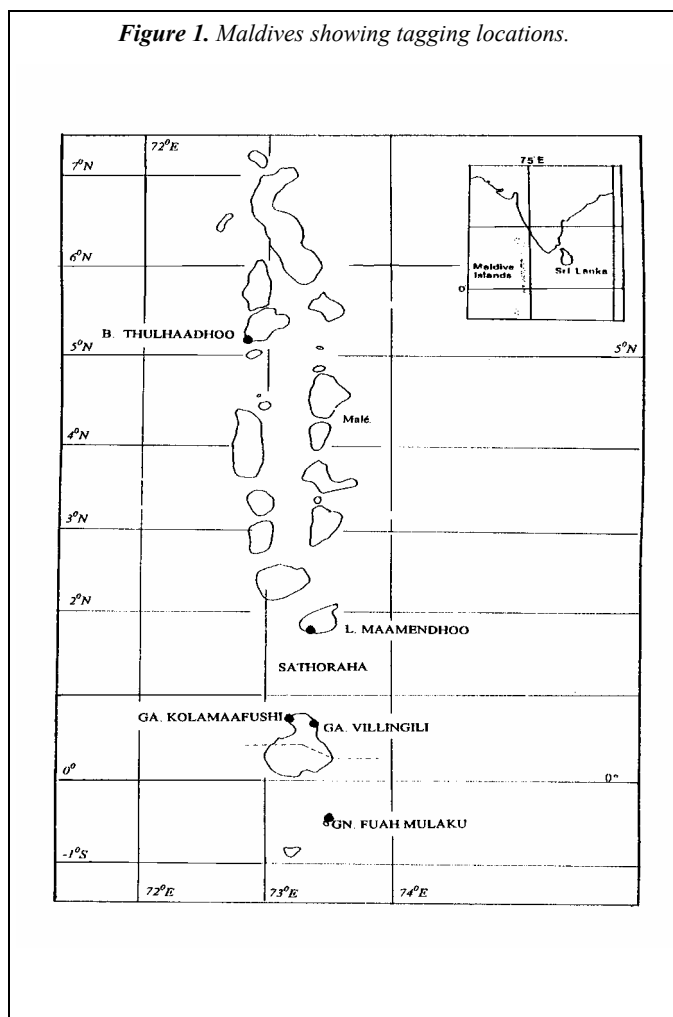
Tagging of skipjack was concentrated in the south of Maldives. From the results of the first tagging experiment, skipjack in this area were believed to be the most likely to show interactions with the western Indian Ocean purse-seine fleet. In addition, there is a highly productive 'offshore' fishing ground in the southern Maldives, in which it was believed large numbers of skipjack could be tagged. This is actually a seamount, known locally as *Satoraha*. It should be noted that it was impractical to tag near Malé because the high prices usually paid at Malé market make releasing tagged fish an unattractive proposition for fishermen there.

Only limited tagging of yellowfin could be carried out. It was therefore planned to concentrate on large individuals (>80cm FL) which show marked, but poorly understood, migrations in Maldivian waters, and are likely to show interactions with high-seas longline and purse-seine fleets.

The specific aims of the second Maldivian tagging programme were:

1. To tag at least 6000 skipjack tuna, divided as evenly as practical between inshore/offshore and northeast monsoon/southwest monsoon, in order to study their migrations.
2. To double-tag 500 skipjack, in order to obtain a first estimate of tag shedding rates.
3. To inject 500 skipjack with tetracycline prior to tagging and release, in order to validate otolith aging, and to test procedures for returning recaptured fish, for future experiments.

Figure 1. Maldives showing tagging locations.



4. To obtain estimates of skipjack growth rates from tag recovery data.
5. To tag up to 500 large yellowfin tunas (>80cm FL), in order to study their migrations. This was to be carried out both opportunistically on tagging trips mainly targeting skipjack, and on specific trips targeting

known concentrations of large yellowfin. This objective proved impossible to achieve. It was therefore changed to the tagging and tetracycline injecting of 1000 juvenile yellowfin tunas, in order to validate otolith aging.

6. An additional non-tagging objective was to obtain information on the quantities of live bait used during pole-and-line fishing, in order to estimate total live bait utilization in the Maldives.

It was decided not to carry out tag seeding, for two reasons. First, because of the practical difficulties of doing so unobserved on a small open boat. Secondly, because every tuna caught in Maldives is individually handled about 2-5 times between capture and sale/processing/consumption, so non-reporting is believed to be minimal.

The aims of this report are to present a description of the tuna-tagging activities undertaken in the Maldives during 1993-95, together with a preliminary analysis of returns. Analysis of otoliths of tetracycline-marked skipjack is reported elsewhere (Adam, Stéguert and Anderson, 1995). Analysis and reporting of skipjack returns using attrition models will be carried out and reported later. Analysis of otoliths of tetracycline-marked yellowfin will be carried out once sufficient returns have been received.

METHODS

Tagging Strategy

Tagging strategy and methodology generally followed that established during the first Maldivian tuna-tagging programme (Yesaki and Waheed, 1992). Tagging was carried out on board mechanized Maldivian pole-and-line vessels (*masdhoni*). These vessels are about 12-15m LOA and of traditional wooden construction. Fishing is carried out from a stern platform by 2-6 polers. *Masdhonis* typically leave from their home islands before dawn to collect live bait from nearby reefs. Baiting, with a simple

Figure 2. Length-frequency distribution of skipjack tuna releases.

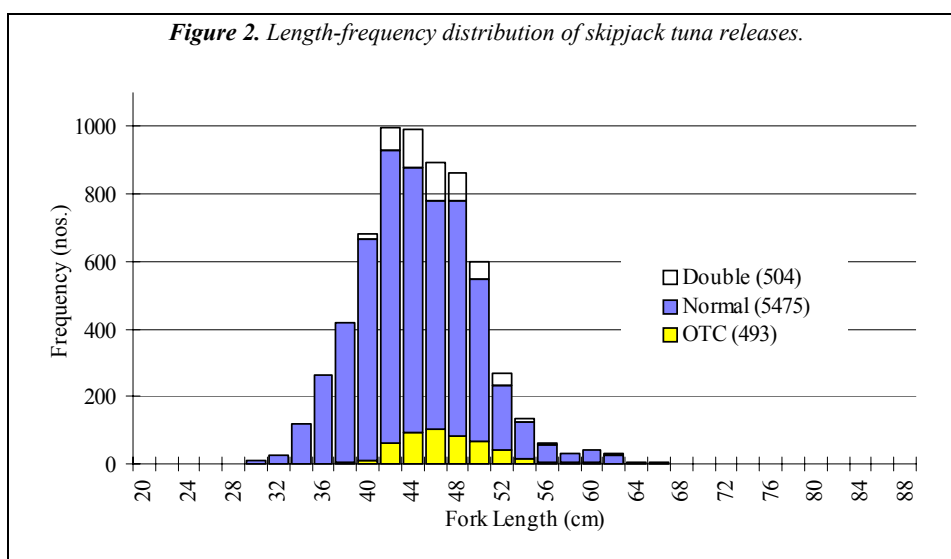


Table 2. Annual Maldivian catches (t) of frigate tuna by vessel type, 1970-94. Source: MOFA. Note: minor catches by other categories are included under trolling.

Trip	Date	Season	Location		No. Skipjack Tagged			Total
No.			Atoll	Island	Normal	Double	OTC	
1	9/93	SW	L.	Maamendhoo	643	-	-	643
3	1-2/94	NE	G.A.	Villingili	2,075	5	2	2,082
4	4/94	NE	L.	Maamendhoo	1,263	22	32	1,317
5	8/94	SW	G.A.	Kolamaafushi	1,495	477	460	2,432
Total	-	-	-	-	5,476	504	494	6,474

Table 3. Number of Skipjack tag releases by grid area of release, 1993-94.

Grid No.	Location	Survey (No. and Atoll)				Total
		1. Laamu	3. Gaafu Alifu	4. Laamu	5. Gaafu Alifu	
+01734	SE of Laamu	-	-	1,021	-	1,021
+01733	S of Laamu	635	-	57	-	692
+01724	SW of Laamu	8	-	-	-	8
+01731	'Satoraha'	-	1,853	239	2,312	4,404
+00724	NW of G.A.	-	-	-	2	2
+00733	N of G.A.	-	34	-	118	152
+00734	NE of G.A.	-	195	-	-	195
Total		643	2,082	1,317	2,432	6,474

lift net, may take 1-8 hours, although 3 hours would be typical. Once sufficient bait has been collected the fishermen move offshore in search of tuna schools. They return to their islands in the late afternoon or evening. Fishermen sometimes collect bait on one day for use on the next.

Tagging took place during normal *masdhoni* day trips. The ideal strategy would have been to select the best *masdhonis* on the chosen island, and for each tagging team (there were normally two) to go out every day on the same boats. However, in order to ensure the cooperation of the entire fishing community it was necessary to carry out tagging from as many *masdhonis* as possible. Therefore it was normal practice to use a different fishing boat every day. Although the start of a day's tagging was often rather slow, the skill of the Maldivian pole-and-line fishermen meant that they very quickly adjusted their technique to the requirements of the tagging teams. As a result the need to use many different vessels did not prove to be a constraint.

Vessels were not chartered. Rather, fishermen were paid a premium rate for every tuna tagged and released from their vessel. The rates paid were 3-4 times market value, which was normally sufficient to ensure the fishermen's full cooperation. The rates paid were initially set at:

MRf 50	(about US\$4.20)	for skipjack and yellowfin < 80cm FL
MRf 100	(about US\$8.40)	for yellowfin 80-100cm FL
MRf 150	(about US\$12.70)	for yellowfin >100cm FL

These rates were paid during tagging trips 1, 2 and 3. However, during trip 3 (at G.A. Villingili) problems arose as a result of arguments between those fishermen who had achieved high tag releases (and hence high financial

rewards) and those who had achieved none. Subsequently, the payments for the release of skipjack and small yellowfin were reduced to MRf 40 per fish. During trip 6 (Fuvah Mulaku) fishing was poor, and the price available for large yellowfin on the island was high. In this case it was necessary to increase the price paid for releases to MRf 175 for yellowfin of 80-100cm FL and to MRf 250 for yellowfin greater than 100cm FL.

It was decided not to tag near FADs (of which there were 14 deployed in Maldivian waters in September 1993, and 28 in August 1995). To do so might have added a complicating factor to the analysis of attrition rates. An exception was made in the case of yellowfin injected with tetracycline during the tagging trip in August 1995. The main aim of that tagging exercise was the determination of growth rates, not the study of movements or attrition rates.

Tagging Methodology

Tagging was normally carried out by a team of three: a fish holder, a tagger, and a recorder. In addition, a member of the crew was often enlisted to help pass tunas to the fish holder. The tagging team sat on one side of the fishing vessel, just forward of the stern fishing platform. The crew fish from both sides of the fishing platform. They were instructed to fish as normal from one side. On the side with the tagging team the fishermen were asked to pole any tunas caught directly to the fish holder. The captured tunas were held on a 1-m wooden measuring board on the deck while being tagged. When tagging juvenile yellowfin care was taken to avoid tagging any bigeye tuna (*Thunnus obesus*), but it is possible that a few individuals of this species may have been tagged by mistake. Plastic dart tags

manufactured by Hallprint of Australia were used, in three varieties:

1. For skipjack and small yellowfin:

Tag type: PDT (Yellow 10cm x 1.5mm)
 Tag numbers: MDV1201 - MDV8200
 Legend: No. MDV....MIN. FISH. & AGRI. MALDIVES.
 FAX(960)326558 No. MDV.
 SEND LENGTH, LOCATION, DATE, SPECIES

2. For large yellowfin:

Tag type: PDA-T (Yellow 12.5cm x 2.0mm)
 Tag numbers: MDV0001 - MDV0650
 Legend: No. MDV....MIN. FISH. & AGRI. MALDIVES.
 FAX(960)326558 No. MDV.

MDV.

SEND LENGTH, LOCATION, DATE, SPECIES

3. For tetracycline injected fish:

Tag type: PDT (Orange 10cm x 1.5mm)
 Tag numbers: MDV0651 - MDV1200 (For skipjack)
 MDV8201 - MDV9300 (For yellowfin)
 Legend: No. MDV....MIN. FISH. & AGRI. MALDIVES.

FAX(960)326558 No. MDV. COLLECT OTOLITH, LENGTH, LOCATION, DATE, SPECIES

Stainless steel applicators of 140mm x 3mm were used for PDT tags (*i.e.* for skipjack and small yellowfin) and of 135mm x 4mm for PDA-T tags (*i.e.* for large yellowfin). Tags in their applicators were set out in plastic-impregnated canvas aprons prior to each day's tagging. Each apron was stitched with two rows of 50 pockets, enabling it to hold 100 applicators; the aprons could be folded and rolled into compact bundles when not in use.

Tags were inserted dorsally, adjacent to the second dorsal fin in such a way that the tag barb became caught under the fin ray extensions or the neural spines

Whenever possible fish were returned to the water in a slightly head-down attitude and facing the fishing vessel's bows. In this position the tagged tunas tended to swim down and forward, away from the feeding school at the stern. Tagging times (from first hooking to release) were of the order of 12-16 seconds at the beginning of tagging trips with inexperienced tagging teams, and of the order of 7-10 seconds with experienced teams. Tetracycline injecting was only carried out by experienced teams, but still increased tagging times by 2-5 seconds.

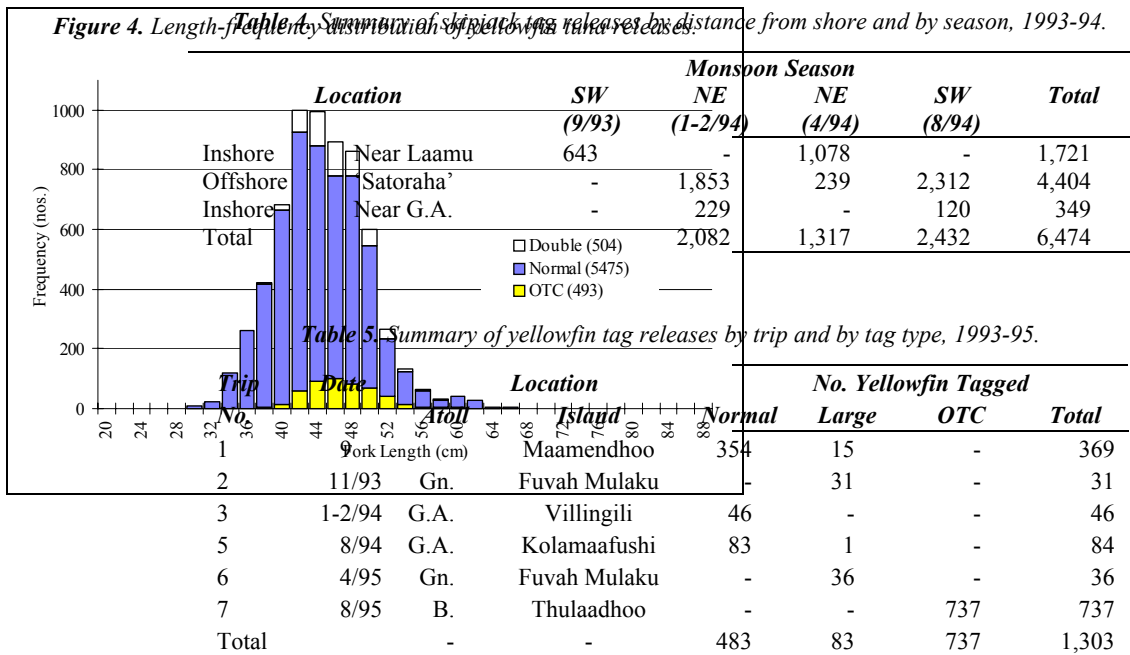
Large Yellowfin

Large yellowfin were caught by handline or troll, not by pole and line. A few were caught with handlines from pole

Figure 3. Skipjack tuna releases and recoveries by grid reference (Note: recoveries are to end August 1995)

SKIPJACK RELEASES					SKIPJACK RECOVERIES*				
+7N					+7N	2			
							3		
+6N					+6N	1	6		
						5	1	7	
+5N					+5N	2	1		
						1	5		
+4N					+4N	2		14	
							1	18	
+3N					+3N	3	1	8	
						9	6	3	
+2N					+2N	5	8	10	
		8	692	1021			18	6	
+1N			4404		+1N		137	64	
		2	152	195		56	18	32	
0					0	10	6	9	
							6		
-1S					-1S	1	24		
	72°E	73°E		74°E		72°E	73°E		74°E

*Excludes 12 with unknown location of recovery and 18 made which were from overseas.



and line vessels (*masdhonis*) near Laamu and Gaafu Alifu Atolls during breaks in pole-and-line fishing. Most were tagged near Fuvah Mulaku from the small (5-9m LOA) local *dhonis*. During the first trip in November 1993 the large yellowfin were caught with short handlines; cut pieces of skipjack and/or other tunas were used as chum. Fishing times were of the order of 5-10 minutes, and tagging times were of the order of 1 minute or less. During the second trip to Fuvah Mulaku in April 1994 trolling was used to catch large yellowfin. Fishing times were of the order of 3-5 minutes, and tagging times were about 1 minute or less. A brief description of the Fuvah Mulaku yellowfin fishery is given by Anderson, Adam and Waheed (1993). Both trips made to Fuvah Mulaku were hampered by bad weather; another trip planned for November 1994 had to be cancelled because of bad weather.

Double Tagging

A total of 504 skipjack were double-tagged in order to provide an estimate of tag shedding rates. One tag was placed in the normal position, adjacent to the second dorsal fin on the left side of the fish. The second tag was inserted about 1-2 cm posterior to the first on the right side of the fish. Consecutively-numbered tag pairs were used.

'Dummy Tagging'

During the course of tagging operations it was noticed that live tunas are highly tensed during handling. Dead tunas when measured are (except during *rigor*) rather flaccid. It is therefore possible that one potential source of discrepancy between length at release and length at

recapture, even for fish recaptured on the day of release, may be loss of tone following death. To quantify this possible source of error a small number of fish were tagged in the normal way, but then 'released' to the fish hold instead of the sea. Later, when dead, these fish were re-measured.

Tetracycline Injection

494 skipjack (out of a planned total of 500) were injected with tetracycline prior to tagging and release. Most skipjack were injected and tagged by a team of three: a fish holder, an injector, and a tagger/recorder. The dose injected was about 1 ml of 100 mg/ml oxytetracycline (OTC) for an average-size skipjack (*i.e.* nominally about 50 mg/kg). Minor seepage of oxytetracycline was often observed from the injection site, so the effective dose injected would often have been less than this. It was not practical to adjust dosage for individual fish, although the largest skipjack were injected with 2 ml of 100 mg/ml oxytetracycline (again nominally about 50 mg/kg). Injections were made intramuscularly, just below the first dorsal fin origin, using a continuous pipetting syringe dispenser. Care was taken to avoid injecting in the region of the lateral line. Tetracycline-injected skipjack were tagged with orange tags to differentiate them from 'normal' tagged skipjack (Anderson, 1995). The results of this experiment are reported separately (Adam, Stéquent and Anderson, 1995) and are not dealt with further here.

737 juvenile yellowfin tuna were injected with tetracycline prior to tagging and release during a trip to Baa Atoll in August 1995. More juvenile yellowfin may be tetracycline-injected in December 1995, to bring the total number of releases up to the planned total of 1000. Yellowfin were injected and tagged by a team of four: a

fish holder, an injector, a tagger, and a recorder. The dose injected was about 0.7 ml of 200 mg/ml oxytetracycline for an average-size yellowfin (*i.e.* nominally about 100 mg/kg). Minor seepage of oxytetracycline was often observed from the injection site, so the effective dose injected would often have been less than this. It was not practical to adjust dosage for individual fish, although the largest yellowfin were injected twice (nominally about 80 mg/kg). A higher dose of tetracycline was injected than had been used for skipjack because several otoliths from recaptured skipjack did not show a tetracycline mark (Adam, Stéquent and Anderson, 1995). As in the case of skipjack, injections were made intramuscularly, below the first dorsal fin origin, using a continuous pipetting syringe dispenser. Tetracycline-injected yellowfin were tagged with orange tags to differentiate them from 'normal' tagged tunas. The results of this experiment will be reported separately, and are not dealt with further here.

Publicity, Recoveries and Rewards

Tuna tagging activities have received considerable publicity within the Maldives. Each of the seven tagging trips undertaken received national radio news coverage. In addition, there have been periodic informative broadcasts on radio and TV, and occasional articles in local newspapers. Posters printed in the local language (Dhivehi) were distributed to each of the 202 inhabited islands and to every tuna collector and freezer vessel.

It was noted during the first tagging programme (Yesaki and Waheed, 1992) that recapture information, and in particular information on length at recapture, was often of poor quality. To try to improve recapture information, printed recapture forms and tailors' tape measures were distributed to the government offices on each inhabited island and to every collector/freezer vessel. Conversion factors for tape length to board length were prepared by MRS. Measuring boards were available on 16 islands with MOFA/MRS field officers.

Rewards for tags recovered in the Maldives were paid in cash, as recommended by Yesaki and Waheed (1992), at the following rates:

Tag without full information	MRf 25 (about US\$ 2.10)
Tag with full information	MRf 50 (about US\$ 4.20)
Orange tag plus OTC injected fish	MRf 200 (about US\$17.00)

In addition to the cash rewards paid for every recovery, a 'lucky dip' was held on Fishermen's Day (10 December) 1994 in which every tag number returned during the previous two years was entered. A total of ten tag numbers were drawn, each receiving a cash prize of MRf 1000 (about US\$ 85). This 'lucky dip' received advance radio publicity, and the actual draw received live national radio coverage. A second 'lucky dip' is planned for Fishermen's Day 1995.

Internationally, the second Maldivian tuna-tagging programme was announced at the fifth IPTP Expert

Figure 5. Attrition rates of skipjack tuna tag recoveries by position of release (inshore and offshore), up to end August 1995.

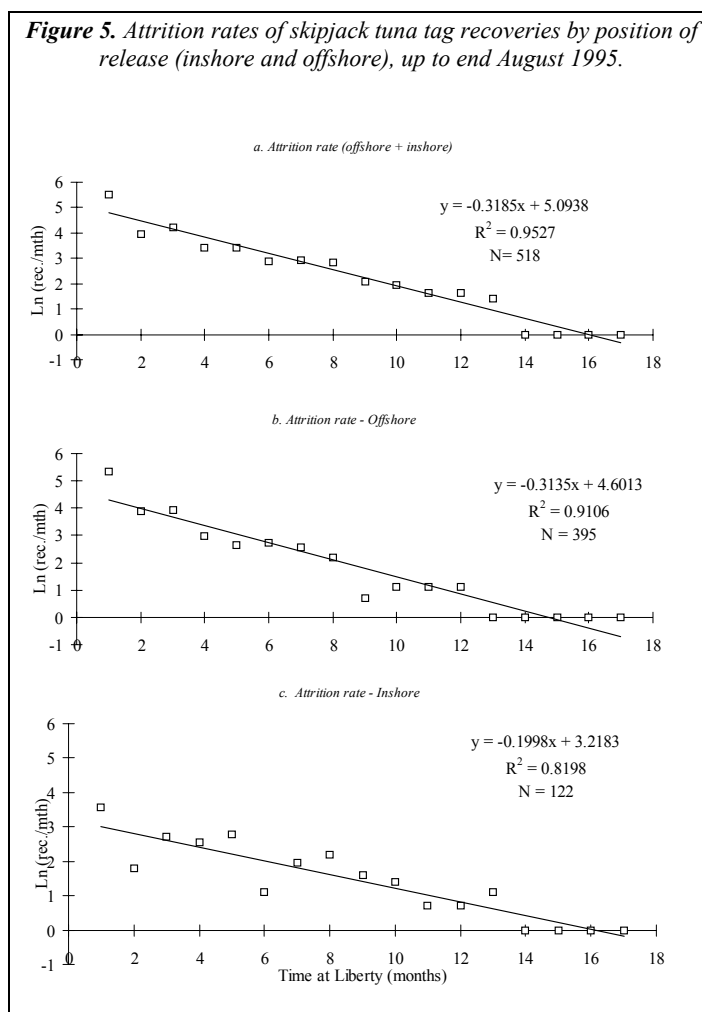


Table 6. Summary of skipjack recoveries up to end August 1995, by tag type and date of release.

Trip No.	Date	Numbers recovered			Total	Percentage recovered			
		Normal	Double	OTC		Normal	Double	OTC	Total
1	9/93	17	-	-	17	2.6	-	-	2.6
3	1-2/93	125	0	0	125	6.0	0	0	6.0
4	4/94	89	2	0	91	7.0	9.1	0	6.9
5	8/94	203	46	58	307	13.6	9.6	12.6	12.6
Total		434	48	58	540	7.9	9.5	11.7	8.3

Consultation on Indian Ocean Tunas, held in Seychelles in October 1993 (Waheed and Anderson, 1994). English-language posters were distributed to selected delegates at that meeting. Subsequently, more English-language posters were sent to interested parties. Dhivehi posters were sent to Minicoy (the southernmost island in the Indian Lakshadweep Islands, where the inhabitants speak the same language as in the Maldives). IPTP printed a Sinhalese language poster for distribution in Sri Lanka. A number of announcements about the tagging programme were published in regional fisheries newsletters (Adam, 1994; Anon., 1993a, 1993b & 1994; Anderson, 1995). T-shirts printed with information about the tagging programme were given as rewards for international tag recoveries.

Live-bait weighing

Tagging teams usually requested fishermen to collect bait on the day before tagging took place, in order to maximize time spent tuna fishing. As a result relatively few baiting operations were observed. Despite this it was possible to weigh the total morning live-bait catch of six *masdhonis*. Every haul of live bait (average 12 hauls per operation) was weighed in a large plastic container with several centimetres of water in the bottom, using a large pan balance. The average weight of live bait caught before each of the six days' tuna fishing was 46.7 kg. From these data it was roughly estimated that the total quantity of live bait caught in the Maldives was 11,100 ± 2800 t in 1993. The details of this study have been published elsewhere (Anderson, 1994) and are not considered further here.

Observers

During trip 3 (G.A. Villingili) two observers from the Indo-Pacific Tuna Programme, Colombo, participated in several tagging day trips. During trip 4 (L. Maamendhoo) two observers from the Fisheries Survey of India participated in several tagging day trips.

RESULTS

Tag Releases

Seven tagging cruises were carried out between September 1993 and August 1995, during which a total of 7777 tunas were tagged and released (Table 1). A location map

showing tagging areas is given in Figure 1. The releases comprised 6474 skipjack (83%) and 1303 yellowfin (17%). In addition, a single frigate tuna (*Auxis thazard*) was tagged and released during trip no.3 (January 1994); it has not been recovered to date (August 1995) and is not included in any tables or totals in this report.

The 6474 skipjack were released during the course of 4 tagging trips between September 1993 and August 1994 (Table 2). The 6474 skipjack releases included 504 double-tagged fish and 494 which were injected with tetracycline. The length-frequency distribution of all the skipjack released (excluding a few for which release length was not recorded) is presented in Figure 2. The location of skipjack releases, by $\frac{1}{2}^{\circ} \times \frac{1}{2}^{\circ}$ square, is given in Table 3 and Figure 3. The numbering of the grid of $\frac{1}{2}^{\circ} \times \frac{1}{2}^{\circ}$ squares used in Table 3 follows that of Waheed and Yesaki (1992). The sign indicates position relative to the equator (+ve is N; -ve is S). The first two digits indicate latitude, the next two digits indicate longitude, and the final digit indicates one of four $\frac{1}{2}^{\circ} \times \frac{1}{2}^{\circ}$ squares within the $1^{\circ} \times 1^{\circ}$ grid.

Table 4 summarizes skipjack releases by position (*i.e.* inshore/offshore) and by season. Although it had been planned to release roughly equal numbers of skipjack inshore and offshore on each trip and in each season, this proved impossible because of the vagaries of weather and fishing. Despite this, roughly equal numbers were released in the two seasons: 3399 (53%) during the northeast monsoon and 3075 during the southwest monsoon. The division of skipjack releases between inshore and offshore was less equitable, reflecting the generally better fishing offshore. Offshore fishing was carried out in the vicinity of a seamount, known locally as *Satoraha*, which is about 6 hours by fishing vessel south of Laamu and 4 hours north of Gaafu Alifu. 4404 (68%) skipjack were released offshore, and 2070 inshore. Inshore fishing was generally within sight, or only just out of sight, of either Laamu or Gaafu Alifu Atolls.

1303 yellowfin were released during the course of 6 tagging trips between September 1993 and August 1995 (Table 5). Yellowfin releases included 83 large fish (*i.e.* FL > 80cm). Catch rates for large yellowfin were very low, so it was not possible to meet the target of 500 releases. Therefore the new objective of tetracycline injection was introduced. 737 juvenile yellowfin were tetracycline injected during August 1995, and there are plans to mark another 300+ in December 1995. The length-frequency

Table 7: Summary of Skipjack recoveries up to end August 1995, by tagging trip/season and by distance from shore at release.

Location		Recoveries by monsoon season				Total
		SW (9/93)	NE (1-2/94)	NE (4/94)	SW (8/94)	
Inshore	Near Laamu	17 (2.6%)	-	69 (6.4%)	-	86 (5.0%)
Offshore	'Satoraha'	-	105 (5.7%)	22 (9.2%)	283 (12.2%)	410 (9.3%)
Inshore	Near G.A.	-	20 (8.7%)	-	24 (20.0%)	44 (12.6%)
Total	-	17 (2.6%)	125 (6.0%)	91 (6.9%)	307 (12.6%)	540 (8.3%)

distribution of all the yellowfin released (excluding a few for which release length was not recorded) is presented in Figure 4

Tag Recoveries

To the end of August 1995 a total of 559 recoveries had been received, which was 7.2% of releases. There were 540 skipjack recoveries (8.3% of skipjack releases) and 17 yellowfin recoveries (1.3% of yellowfin releases). For skipjack, tag recoveries by tag type and release date are summarized in Table 6, and recoveries by release season and location are summarized in Table 7. For yellowfin, tag recoveries by tag type and release date are summarized in Table 8.

There was considerable variation between skipjack tag recovery rates according to release trip, season and position inshore or offshore. Overall recovery rates for skipjack released during the southwest monsoon were higher than those for skipjack released during the northeast monsoon (10.5% vs. 6.4%). However, the variation in recovery rates between the two tagging trips conducted during the southwest monsoon (2.6% v 12.6%) was greater than that between the two seasons. Similarly, overall recovery rates for skipjack released offshore were higher than those for skipjack released inshore (9.3% vs. 6.3%). Again, however, the variation in recovery rates between the two inshore tagging areas (5.0% vs. 12.6%) was greater than that between inshore and offshore.

Times of Recovery and Attrition Rates (Skipjack)

Of 540 skipjack recoveries, 18 did not have date of recapture information and 4 had suspect dates of recapture (*i.e.* date of recapture recorded as being before the date of release). Of the remaining 518 skipjack, 10 were caught on the day of release or the following day, and 250 (48%) were recovered during the first month after release. Thereafter skipjack recoveries declined exponentially (Figure 5), with the longest time at liberty being 518 days.

The attrition rate of all tagged skipjack returns was estimated at 27% per month (Figure 5a). The attrition rate

of tag recoveries for skipjack tagged offshore was estimated at 27% per month (Figure 5b). For skipjack tagged inshore the tag attrition rate was estimated at 18% per month (Figure 5c).

Tag Shedding (Skipjack)

From 504 releases of double-tagged skipjack, 48 recoveries (9.5%) were received by the end of August 1995. The majority of double-tagged skipjack were released during trip 5 (G.A. Kolamaafushi, August 1994). 46 recoveries (9.6%) were made from the 477 double-tagged skipjack releases made during that trip. Of the total of 48 recoveries, 45 were of skipjack with both tags still in place, and 3 were of skipjack with only a single tag in place. Thus, 93 out of 96 tags were recovered, *i.e.* 96.8%. Date of recapture was reported for 45 of the double-tagged skipjack.

Times at liberty for these fish, from which tag shedding rates might be estimated, are summarized in the following list:

<i>Time at Liberty (months)</i>	<i>Recaptured with two tags</i>	<i>Recaptured with one tag</i>
0-1	20	2
1-2	6	1
2-3	8	0
3-4	1	0
4-5	1	0
5-6	1	0
7-9	4	0
10-12	1	0
Total	42	3

Skipjack Growth

Of 540 skipjack recoveries, 22 had no information on date of recapture, a further 20 had no information on length at recapture, and one was recorded as having an unreliable release length. Of the remaining 497 skipjack recoveries, 210 were recorded as being measured at recapture with a tape. The lengths at recovery of these fish were converted to board lengths using a board length-tape length regression for skipjack (MRS, unpublished data). Skipjack recoveries that had been at liberty for less than 30 days, and those reportedly showing negative growth were then removed. The remaining 219 skipjack recoveries were further screened following the procedure used by Yesaki and Waheed (1992): they were first segregated by length at release into 5-cm intervals (39 cm and below, 40-44 cm, 45-49 cm, and 50 cm and above). These four subsets were then further divided into recoveries that had been at liberty for less than 120 days and those at liberty for more than 120 days. The means and standard deviations of the monthly growth rates were calculated for each of the 8 length/time groupings. Values beyond one standard deviation from the mean were deleted.

A Gulland and Holt plot of the remaining 192 screened skipjack recoveries is presented in Figure 6. There is clearly considerable variation in the estimated growth rates of individual recaptured skipjack, despite the rigorous screening. The average predicted growth rates are:

1.4 ± 0.2 cm/month at 40cm,

1.1 ± 0.1 cm/month at 50cm,

0.9 ± 0.3 cm/month at 60cm.

During the course of trip 5 (8/94) a total of 54 tunas of three species were ‘dummy tagged.’ They were measured and tagged but not released, and at the end of the day’s fishing they were measured again

The numbers of fish measured and the differences in length between the two measurements are summarized below:

	<i>Differences in length</i>				<i>Total number</i>	<i>Mean diff (cm)</i>	<i>SD</i>
	<i>-2cm</i>	<i>-1cm</i>	<i>0cm</i>	<i>+1cm</i>			
Skipjack	3	8	5	0	16	-0.88	0.72
Yellowfin	0	7	19	3	29	-0.14	0.58
Bigeye	0	4	5	0	9	-0.44	0.53
Total	3	19	29	3	54	-0.41	0.69

These figures suggest that a tuna is on average about 0.4cm shorter alive than dead. This difference was not corrected for in calculating the growth rate estimates presented here, in part because of the relatively small numbers of tuna ‘dummy tagged,’ and uncertainty over the significance of apparent interspecific differences. Nevertheless, this is a source of error that could be taken into account in future, particularly if dealing with tunas that have been at liberty for short periods.

Skipjack Movements

Of 540 skipjack recoveries, 522 (96.7%) were from within the Maldives. Of these, recovery locations were reported for 510 skipjack, and are illustrated in Figure 3. Skipjack recoveries by season and position inshore/offshore at releases are summarized in Table 7. A detailed study of recaptures within the Maldives is planned for later, so this aspect of the study will not be considered further here.

18 skipjack recoveries (3.3% of releases) were made overseas. Of these, 10 (1.9% of releases) were made by purse seiners operating in the western Indian Ocean to the west and southwest of Maldives. The remaining 8 overseas skipjack recoveries (1.5% of releases) were made by Sri Lankan vessels operating to the east and northeast of Maldives.

Yesaki and Waheed (1992) suggested that skipjack tagged offshore were more migratory than those tagged inshore. They based this idea on their observation that skipjack tagged offshore had a lower recovery rate within the Maldives, but a higher recovery rate overseas, than skipjack tagged inshore. Our findings are the exact opposite, and do not support this hypothesis. During this programme, tag recovery rates from within Maldives were higher for skipjack tagged offshore than for those tagged inshore (9.1% v 5.8%). Tag recovery rates from outside the Maldives were lower for skipjack tagged offshore than for those tagged inshore (0.2% vs. 0.4%).

Quality of Tagging (Skipjack)

During tagging operations, efforts were made to ensure that only tunas in good condition and with well-placed tags were released. However, in some cases fish in slightly sub-

optimal condition were released, in which case records of their condition and tag placement were kept.

370 skipjack were released in sub optimal condition (5.7% of all releases). There were 509 recoveries of skipjack released in good condition (8.3% of such releases), and 31 recoveries (8.4%) of skipjack released in sub optimal condition. Thus there is no difference in recovery rates between the two subsets which suggests that the criteria for rejecting tuna were adequate.

177 skipjack were released with their tags sub optimally positioned (2.7% of all releases). There were 536 recoveries of skipjack released with well-placed tags (8.5% of such releases), but only 4 recoveries (2.3%) of skipjack released with poorly placed tags. The difference between observed and expected recoveries for the two subsets is significant (chi squared = 8.1, df=1, p<0.01). This suggests that in future tunas which have their tags inserted poorly should not be released, or if released that they should be excluded from most analyses.

Recoveries by School Type/Association (Skipjack)

On the tag recovery forms distributed to every fishing island, fishermen were asked to note the type of school (of which four categories were listed) from which their recapture had been made. This information was supplied for 509 of the 540 skipjack recoveries, as follows:

Reef-associated	9	(1.8%)
Free-swimming	263	(51.7%)
Flotsam-associated	15	(2.9%)
FAD-associated	222	(43.6%)

Yellowfin

To the end of August 1995 a total of 17 yellowfin tag recoveries had been received (Table 8). This is only 1.3% of releases. However, over half of all releases were made in August 1995, from which only 1 recovery had been made by the end of that month. For the 566 yellowfin tagged earlier there had been 16 recoveries (2.8%). Recovery rates were low for all trips except one. In November 1993, 31 large yellowfin were tagged near Fuvah Mulaku in the south of Maldives. 7 of these (22.6%) were recaptured, all close to Fuvah Mulaku and all within two months of release. A second trip to Fuvah Mulaku in April 1994 resulted in 36 more releases of large yellowfin, but no recaptures. Two of the 17 yellowfin recoveries were from overseas, one from a Sri Lankan vessel, the other without precise information but probably from the western Indian Ocean purse-seine fishery (transshipped in Reunion).

DISCUSSION

Skipjack Growth

Because of the enormous variability in apparent growth of individual recaptured skipjack, the growth rates estimated during this programme might best be treated as unreliable.

Yesaki and Waheed (1992) also concluded that their estimates of skipjack growth rates from Maldivian tagging returns were unreliable, because of inaccuracies in lengths at both release and recapture. The results of the two programs are summarized for comparison:

Yesaki and Waheed (1992)	2.4 cm/month at 40 cm	1.8 cm/month at 60 cm
This study	1.4 cm/month at 40 cm	0.9 cm/month at 60 cm

The differences between the results of the two studies are in part due to the correction of lengths at recapture measured with tapes in this study, but not in that of Yesaki and Waheed (1992). This will tend to reduce the growth rates estimated in this study. However, it did little to improve the precision of the growth estimates in this study. In neither study was correction made for fish tensing during tagging.

Skipjack Movements

Yesaki and Waheed (1992) suggested that skipjack tagged offshore were more migratory than those tagged inshore, but our findings suggest the opposite. There are at least three possible explanations for this difference in findings.

First, account should be taken of the great variation in recapture rates between individual tagging trips, within seasons, and within release areas. As an example, the two skipjack-tagging trips conducted during the southwest monsoon season (trips 1 and 5) had overall recovery rates of 2.6% and 12.6% (Table 7). Much of this variation can be explained by differences in recaptures during the first month at liberty. As noted above, skipjack recaptures during the first month amounted to 48% of the total. During and after trip 1 the weather was very bad, and fishing activity was presumably limited. Only 14% of all recaptures from this trip were made in the first month (2 out of 14 recoveries with recapture dates). In contrast, during and after trip 5 the weather was very good, and fishing activity was presumably high. 52% of all recaptures from this trip were made in the first month (155 out of 300 recoveries with recapture dates). Substituting first-month recapture rates gives estimated total recapture rates of 5.5% of skipjack released during trip 1, and 7.1% for trip 5.

A second possible reason for the difference in findings on migration of inshore vs. offshore skipjack relates to the definition of 'offshore'. Yesaki and Waheed (1992) defined 'offshore skipjack' as any skipjack tagged in a ½°x½° square without land. The offshore area fished during this programme (grid area +01731, Satoraha) was specifically included in their definition (Yesaki and Waheed, 1992, p. 8). However, this fishing area includes a seamant with a general depth of about 300m, on the line of the Laccadives-Chagos Ridge. It might be argued that from a skipjack's perspective this is not an offshore area.

Table 8. Summary of yellowfin recoveries up to end August 1995, by tag type and date of release.

Trip No.	Date	Numbers recovered			Total	Percentage recovered			
		Normal	Large	OTC		Normal	Large	OTC	Total
1	9/93	6	1	-	7	1.7	6.7	-	1.9
2	11/93	-	7	-	7	-	22.6	-	22.6
3	1-2/93	1	-	-	1	2.2	-	-	2.2
5	8/94	1	0	-	1	1.2	0	-	1.2
6	4/95	-	0	-	0	-	0	-	0
7	8/95	-	-	1	1	-	-	0.1	0.1
Total		8	8	1	17	1.7	9.6	0.1	1.3

The second area cited by Yesaki and Waheed (1992) as an offshore one was to the west of Raa Atoll, off the northwest Maldives, where there are no known seamounts. In general, though, the Maldives is a country of oceanic islands and the distinction between 'inshore' and 'offshore' is far from clear.

A third possible explanation relates to the size of fish tagged. Yesaki and Waheed (1992, p. 8) specifically note relatively low recapture rates within Maldives of skipjack tagged offshore from Raa Atoll during their tagging trip 7. Their Figure 3 (Yesaki and Waheed, 1992, p. 6) shows that a large proportion of those skipjack were within the size range of 50-55cm. It is possible that the 'migratory skipjack' referred to by Yesaki and Waheed (1992) may have been '50-cm size class fish' rather than 'offshore' fish as such.

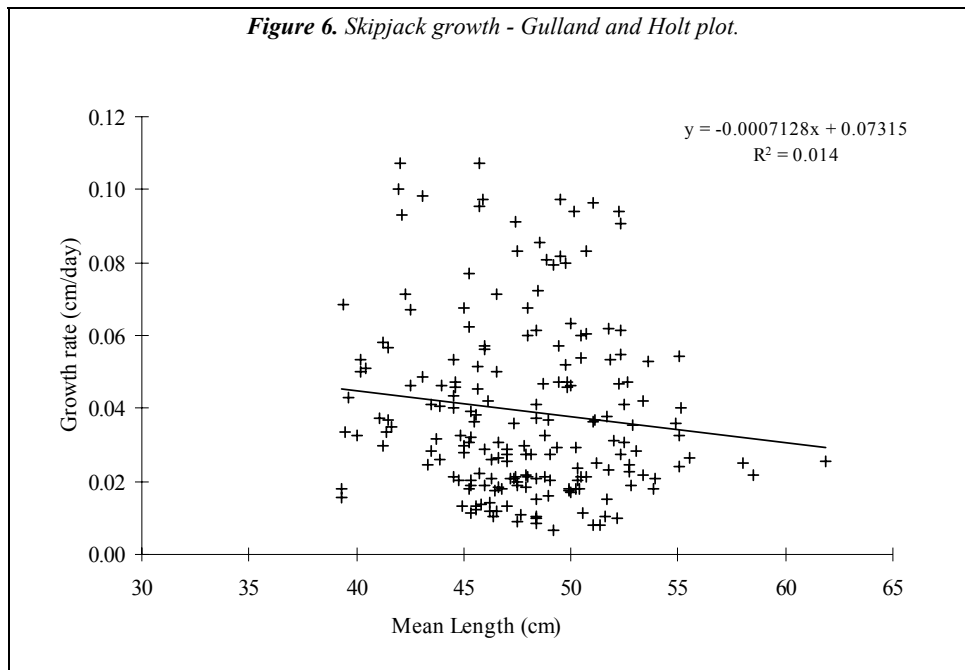
50-60 cm skipjack are known to be relatively under-represented in Maldivian catches (Anderson and Waheed, 1990; Adam and Anderson, 1995; see also Figure 2). Skipjack in Maldives mature at about 45-50 cm, and skipjack sex ratios are biased towards males (Hafiz, 1985; Anderson and Waheed, 1990).

50-60 cm skipjack are relatively common in Sri Lankan catches (Amarasiri and Joseph, 1985; Maldeniya and Suraweera, 1991; Maldeniya and Dayaratne, 1994). Within Sri Lankan waters peak catches of skipjack are made off the southwest coast during the southwest monsoon (Maldeniya and Suraweera, 1991; Maldeniya and Dayaratne, 1994), *i.e.* off the coast facing Maldives when the current is from Maldives. Furthermore, Maldeniya and Suraweera (1991) note that female skipjack are unusually abundant at this time. Yesaki and Waheed (1992, p. 14) note that Sri Lankan recoveries of skipjack tagged in Maldives occurred predominantly during the southwest

monsoon season (21 out of 23 recoveries), when prevailing currents are from west to east. Our results confirm this finding, with all 8 recoveries of skipjack from Sri Lanka being made during the southwest monsoon season.

Yesaki and Waheed (1992) note that skipjack recoveries from the western Indian Ocean purse-seine fishery were not so clearly current-related as those from Sri Lanka. Nevertheless, they report that most recoveries were made after the northeast monsoon when the prevailing current is to the west. Again, our results confirm this finding, with 6 out of 8 recoveries with known recapture dates being during the northeast monsoon. The other 2 recoveries were released in January and February 1994 and recaptured in June 1994.

On the basis of this information a provisional hypothesis of skipjack tuna migration in the waters around Maldives is proposed. Skipjack of 40-50 cm are abundant in Maldivian waters. After reaching sexual maturity these fish migrate offshore, moving with the prevailing currents. It is possible that females have a greater tendency to migrate than males. During the southwest monsoon season the prevailing current carries the skipjack into Sri Lankan waters. During the northeast monsoon the skipjack are carried towards the western Indian Ocean purse-seine fishing area. At least some of these fish may return to Maldivian waters at a later date, since 60+cm skipjack are relatively well represented in Maldivian catches (Hafiz, 1985; Anderson and Waheed, 1990; Adam and Anderson, 1995). It is not known at this stage to what extent the immature 40-50-cm skipjack in Maldives are essentially resident. However, the high recapture rates of such fish within Maldives (Yesaki and Waheed, 1992; this study) and the low skipjack diffusion rates within Maldives estimated by attrition model analysis (Bertignac, 1994) suggest that this is a possibility.



Yellowfin

With only 17 yellowfin recoveries to date there is limited analysis that can be carried out. It is hoped that more recoveries will be received from yellowfin tagged in August 1995, and that a more detailed analysis of all yellowfin recoveries from both tagging programmes will be possible in the future.

It is remarkable that 7 out of 31 (22.6%) large yellowfin released near Fuvah Mulaku in November 1993 were recaptured there within two months. There is a distinct seasonal fishery for large yellowfin at Fuvah Mulaku every November-December (Anderson and Hafiz, 1986; Anderson, Adam and Waheed, 1993). There is also a less marked fishery in April-May. From analysis of longline data, Morita and Koto (1971) suggested that there is a movement of adult yellowfin from the equatorial western Indian Ocean, through the southern Maldives and up past Sri Lanka into the Bay of Bengal every year between October and March. It is possible that the yellowfin tagged at Fuvah Mulaku in November 1993 were part of this migration. Unfortunately, there have been no overseas recoveries of these fish so far.

Of 17 yellowfin recoveries made by August 1995, two (11.8%) were made outside of the Maldives. This compares with 3.7% of skipjack recoveries from overseas. Similar results were obtained from the first Maldivian tagging programme, with overseas recoveries amounting to 17.9% for yellowfin and 3.3% for skipjack (Waheed and Anderson, 1994). Thus, skipjack tagged in the Maldives appear to be 'less migratory' than yellowfin (Yesaki and Waheed, 1992).

Of the two overseas yellowfin recoveries, one was actually reported as a bigeye tuna. As noted above, a very few bigeye may have been released by mistake and recorded as yellowfin. The specific identity of this individual is therefore in question.

Quality of Recovery Information

Yesaki and Waheed (1992) recommended that more effort should be given to obtaining more accurate tag return information in future Maldivian tagging experiments. To this end tag return forms were printed and distributed to every inhabited island and all collector/freezer vessels, together with instructions and measuring tapes. MOFA/MRS field officers on 16 islands were given measuring boards and instructions on how to deal with recoveries. As a result of these efforts more information and more consistent information was received with recovered tags. As an example, Yesaki and Waheed were able to use information from only 192 out of 1407 skipjack recoveries in their estimation of skipjack growth rates. In this study it was possible to use information from exactly the same number of recoveries to estimate growth rates, but from a total of only 540 skipjack recoveries. Furthermore, because the recovery forms requested information on the measuring tool used, it was possible to correct for the use of tape measures.

Another useful insight provided by information on the tag recovery forms was the percentage of fish caught from different school types. Of particular interest is the observation that nearly 44% of skipjack recoveries were reportedly made close to FADs. There are a number of sources of error associated with this estimate (*e.g.*

difficulty of assigning fish caught to specific schools, misreporting, and possible regional biases). Nevertheless, it does provide the first estimate of the magnitude of the catch currently being taken near FADs in the Maldives.

RECOMMENDATIONS

1. The results presented here are from preliminary analyses only. Further analysis should be carried out, including the recoveries from the first Maldivian tagging programme wherever possible. Attrition-model analysis of skipjack returns is to be carried out. A detailed analysis of the accuracy of recaptured tuna length measurements from both Maldivian tagging programmes may allow growth estimates to be refined, and indicate means by which length at recapture information might be improved in any future study.
2. Further tetracycline marking and tagging of juvenile yellowfin tuna should be carried out as already planned. Analysis of the tetracycline-marked yellowfin otoliths is to be carried out once sufficient returns have been received.
3. The one recommendation of Yesaki and Waheed (1992) that could not be addressed was to concentrate tagging on yellowfin tuna. Further tagging of yellowfin tunas, with the principal aim of studying their movements and interactions with other fisheries should be carried out in the future, ideally as part of a wider Indian Ocean study.
4. Other questions that could be addressed by tagging in Maldivian waters include aging frigate tuna and kawakawa (*Euthynnus affinis*) using tetracycline injections.

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5. More accurate recapture information might be obtained in future if, in addition to any types of publicity already undertaken, MRS staff visited the 20 or so most important fishing islands in the country to brief fishermen and island officials on the proposed activities prior to any major tagging experiment.
6. The use of cash rewards for tag recoveries within the Maldives has proved successful. On balance, though, the amounts paid for tag releases seemed a little high, while those paid for rewards seemed a little low. They should be adjusted in any future tagging exercise.
7. Fishermen are not normally keen to have their live-bait catches weighed. However, on tagging trips, with the prospect of a large financial reward for tag releases, they are normally very amenable. During future tagging exercises full use should be made of this cooperation to weigh live-bait catches.

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