METHODS USED BY THE SOUTH PACIFIC COMMISSION FOR THE SURVEY AND ASSESSMENT OF SKIPJACK AND BAITFISH RESOURCES

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Editor

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PREFACE

The Skipjack Survey and Assessment Programme, an externally funded part of the work programme of the South Pacific Commission, commenced in August 1977 and concluded on 30 September 1981. Funding for the Programme was obtained from the governments of Australia, France, Japan, New Zealand, United Kingdom and the United States of America.

The staff of the Programme during the preparation of this report comprised the Programme Co-ordinator, R.E. Kearney, Research Scientists, A.W. Argue, C.P. Ellway, R.D. Gillett, J.P. Hallier, J.N. Ianelli, P.M. Kleiber, T.A. Lawson and C.A. Maynard; Research Assistants, Susan Van Lopik and Veronica van Kouwen; and Programme Secretary, Carol Moulin.

As the Programme was the largest research undertaking in the world designed specifically to study skipjack and baitfish resources, and as it was destined to work over vast, relatively remote areas of the Pacific Ocean, many new research strategies and methods needed to be developed. Many of these were adopted or modified from existing commercial fishing or research techniques. As the Programme progressed, methods and techniques were evolved which in many cases changed accepted practices and in some fields revolutionised the state of the art. Therefore, in order to evaluate adequately the data generated by the Programme and to assess its conclusions, descriptions of the methods are essential. These descriptions have been compiled in one volume in order to provide a more comprehensive coverage for any organisation wishing to undertake similar studies.

The goals of the Programme were to produce skipjack and baitfish resource assessments and to use these assessments to provide development and management options for governments of the region. The work of the Programme was effectively divided into four major components: firstly, the study of skipjack resources through tagging; secondly, the collection of biological data on skipjack and other surface tunas; thirdly, the survey of baitfish resources; and fourthly, the in-depth analysis of resulting data. In this report the basic methods used by the Programme have been divided into chapters on each of these components, preceded by a chapter describing development of the Programme.

Many people, other than those listed as having worked for the Programme (Chapter I), provided assistance with the development of the Programme, or with the methods actually used. The advice and support of the late Dick Baird, Fisheries Adviser for the South Pacific Commission until his death in March 1976, was invaluable in the early days of the Programme's evolution. Most prominent in assisting with obtaining funding for the Programme were Dr Philip Helfrich (then Director of the International Center for Living Aquatic Resources Management), Dr James Joseph (Director of Investigations of the Inter-American Tropical Tuna Commission), Mr Richard Shomura (Director of the Honolulu Laboratory of the United States National Marine Fisheries Service) and Mr Duncan Waugh (Director of the Fisheries Research Division of the New Zealand Ministry of Agriculture and Fisheries). Fisheries officers in the countries and territories for which the South Pacific Commission works supported the Programme in many ways, most notably by facilitating the activities of the Programme's vessels and with the loan of technical equipment, particularly during the first few months of the Programme. In addition to the Director, Dr Joseph, many members of the Inter-American Tropical Tuna Commission, in particular Dr William Bayliff, provided valuable assistance with obtaining essential equipment.

Many staff members, other than the authors of the individual chapters, made major contributions to the development or implementation of the methods described. None moreso than Dr Tony Lewis whose efforts, particularly in the early days of the Programme, were critical to the smooth implementation of all field activities.

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R. E. Kearney

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CHAPTER I

DEVELOPMENT AND IMPLEMENTATION OF THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME

R.E. Kearney

1.0 INTRODUCTION

In the mid-1960s, Japan-based skipjack pole-and-line vessels began to extend their fishing operations into the tropical regions of the western Pacific. Shortly thereafter, Japanese companies commenced joint-venture fisheries in Palau (1966), Indonesia (1969), Papua New Guinea (1970), Solomon Islands (1971) and Fiji (1976). By 1974 total skipjack catches from the area of the South Pacific Commission (Figure 1) had risen to an impressive 188,000 tonnes (estimates from Kearney 1979) and were increasing. At that time Island countries in the South Pacific began to realise that skipjack fisheries offered tremendous potential for economic development. For many, they represented the only known avenue for economic self-sufficiency, particularly as catches by distant-water fishing nations within 200 miles of some Island states had a landed value in excess of the gross national product of those states. Further expansion of these fisheries was therefore planned, and increased involvement of Island states was anticipated.

Increased participation by Island states in the development and management of major new fisheries was enhanced by the ongoing United Nations Law of the Sea negotiations which were giving unprecedented credibility to the rights and responsibilities of coastal states to manage resources within 200-mile zones. A boom in skipjack fisheries development in the western and central Pacific, accompanied by greater participation by Island states, was therefore anticipated for the latter part of the 1970s and the early 1980s.

The rapid expansion in skipjack fisheries in the 1970s occurred without any significant knowledge of the resource of skipjack which would, it was hoped, yield catches to meet everybody's expectations. There were at the time no estimates of the distribution of the skipjack resources throughout the region, or even of the magnitude of the total resource and its ability to support sustainable catches. Island states therefore had inadequate technical information on which to base development alternatives or from which to formulate management strategies necessary to meet responsibilties under the emerging Law of the Sea. Therefore, in the mid-1970s the concept of a major skipjack resource survey and assessment programme was developed.

2.0 STAGES IN THE EVOLUTION OF THE PROGRAMME

2.1 Programme Conception and Development of Objectives

The increasing urgency for information on skipjack resources was stressed by the fisheries officers of the region at the South Pacific Commission's Sixth Technical Meeting on Fisheries in Suva, Fiji, in July 1973. In response to a recommendation from that meeting (SPC 1973), the Commission created the Expert Committee on Tropical Skipjack which met for the first time in Papeete, Tahiti, in February/March 1974. It was at this

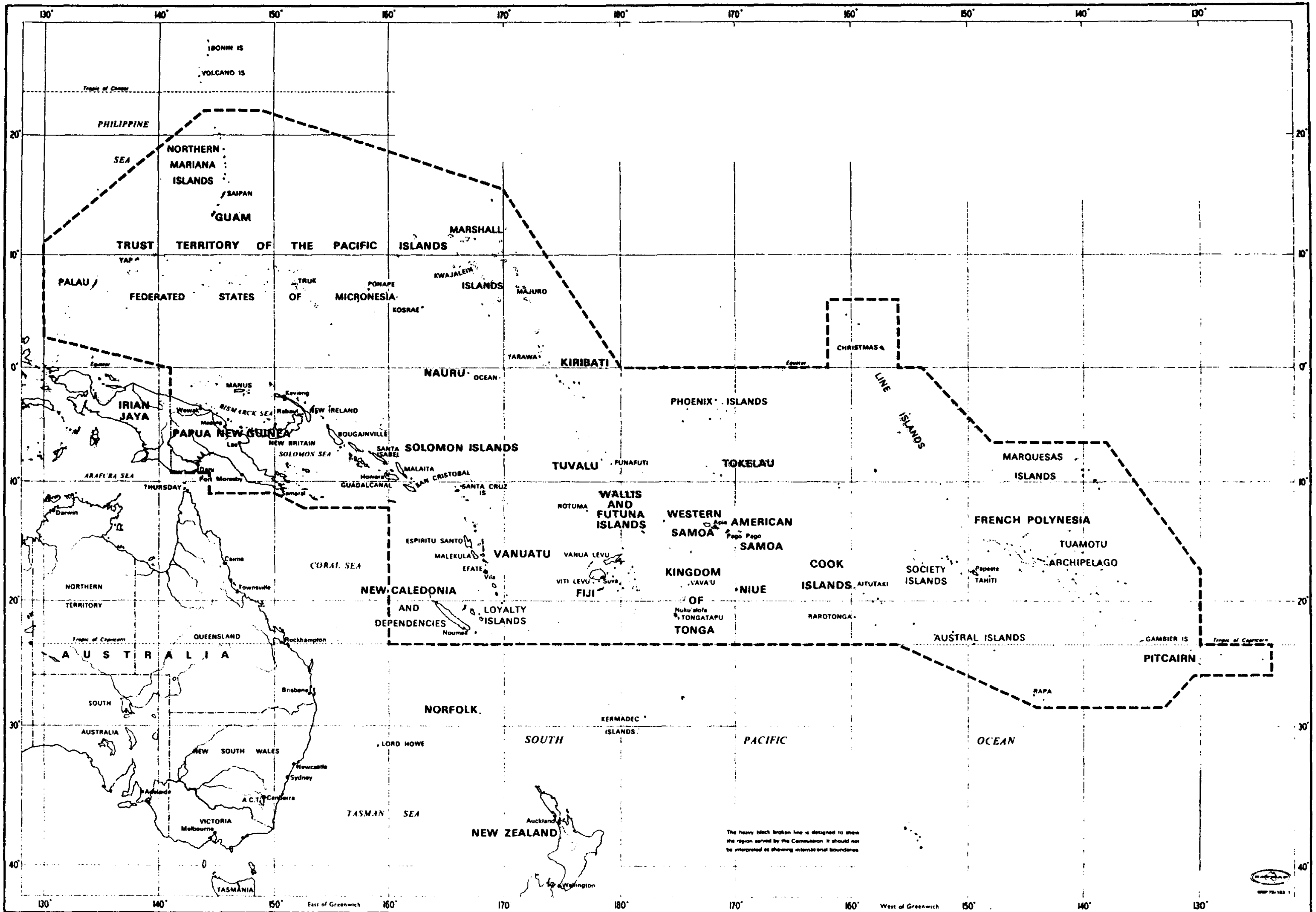


FIGURE 1. AREA OF THE SOUTH PACIFIC COMMISSION

meeting that the concept of a major regional skipjack research effort began to take form (SPC 1974). The second meeting of this Expert Committee in Noumea, New Caledonia, in October 1975, modified a draft proposal for a skipjack survey and assessment programme prepared for the South Pacific Commission and the Food and Agriculture Organization of the United Nations (Kearney 1975). The new proposal was then accepted as the plan for the Skipjack Programme (SPC 1975). It was then adopted by the Eighth Regional Technical Meeting on Fisheries (held in Noumea one week after the Expert Committee Meeting) and subsequently endorsed as part of the ongoing work programme of the Commission by the Sixteenth South Pacific Conference in Noumea in October 1976.

The agreed objectives of the Programme were to provide: (a) a better understanding of the migrations and stock structure of skipjack, thus determining the degree to which fisheries in different areas exploit the same stock, and hence interact with each other; (b) valuable survey information on the general distribution and availability of skipjack and baitfish as the basis for further development and management of these resources within the region; and (c) better knowledge of population parameters (growth, mortality, etc.) of each skipjack stock, thus enabling better assessment of the current status of these stocks and of the effect of fishing on them (SPC 1975). It was vital to the countries of the region that these objectives be fulfilled, for without this information they could not plan the development of skipjack fisheries in accordance with the abundance and distribution of the total available resource.

2.2 Budget and Funding

Initial "seed-money" for the establishment of the post of Programme Co-ordinator was made available in mid-1975 by the Rockefeller Foundation of New York, through the International Center for Living Aquatic Resource Management (ICLARM). This post was filled in September 1975. In order to implement the Programme it was first necessary for the Programme Co-ordinator to refine the budget and obtain commitments for the estimated annual budget of A$711,000 (SPC 1975), which was subsequently converted to U.S. dollars (Table 1) at the exchange rate at the time of A$1 = US$1.27. Eighteen months after adoption of the Programme proposal, funding for the Programme was secured with pledged contributions as outlined in Table 2 from Australia, France, Japan, New Zealand, United Kingdom and the United States of America.

3.0 STRUCTURE AND STAFFING OF THE PROGRAMME

In accordance with the agreed proposal the work of the Programme was centred on a three-year period of intensive fieldwork and an additional year of data analysis. The work was to be conducted by internationally recruited scientists. As soon as adequate funding for the Programme was assured, staff positions additional to that of Programme Co-ordinator were advertised. Two senior scientists, up to four research scientists, two experimental officers, a computer systems manager, up to three research assistants and a secretary were then recruited over a two-year period. Details of the period of employment of all staff, other than vessel crew, are given in Appendix A.

TABLE 1. ESTIMATED EXPENDITURE FOR EACH OF THE FIRST THREE YEARS OF THE SKIPJACK PROGRAMME (from Kearney 1978)

Item	Cost US$
Staff	275,000
Vessel charter costs including victualling of crew and scientists	537,534
Tagging equipment	27,765
Payment of tag rewards	10,160
Biological sampling, equipment and freight costs	11,430
Fishing nets	5,715
Experimental fishing gear	5,080
Travel	20,320
Data processing (computer) costs	10,500
TOTAL	903,504

TABLE 2. PLEDGED ANNUAL CONTRIBUTIONS FOR EACH OF THE FIRST THREE YEARS OF THE SKIPJACK PROGRAMME (from Kearney 1978)

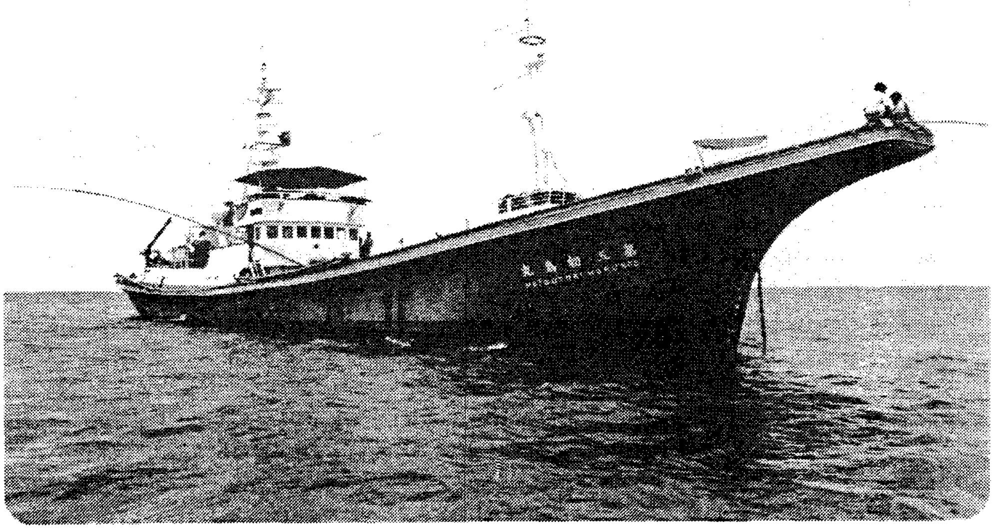
Country	Approximate US$ Equivalent
Australia (A$250,000)	275,000
France (FR.F 600,000)	122,474
Japan (Charter costs)	168,000
New Zealand (NZ$120,000)	114,624
United Kingdom (£stg. 70,000)	121,932
United States of America (US$150,000)	150,000
TOTAL	952,030

4.0 GENERAL PROCEDURES

The Programme was designed so that tagging, biological sampling and experimental fishing, combined with analyses of the available fishing effort and catch statistics, formed the basis of the survey and assessment of skipjack and other tuna resources in the region. Survey and assessment of baitfish resources were carried out primarily by experimental fishing, by night and by day, in each of the countries and territories visited by the Programme, and from biological analyses of baitfish captured in each area. Techniques for handling delicate, tropical baitfish species were also developed as part of the Programme's work on improving the usefulness of the available baitfish resources. An evaluation of the magnitude of the total available baitfishing grounds, estimated from examination of charts of all coastal areas, was incorporated into the final assessment of each country's total baitfish resources.

The data collection aspects of the Programme were dependent upon the use of chartered research vessels. Two vessels were used consecutively by the Programme; the first, the Hatsutori Maru No.1, a Japanese live-bait pole-and-line vessel in the 200-tonne class, and the second, the Hatsutori Maru No.5 (Figure 2), a similar vessel but approximately 50 tonnes larger. Specifications of both vessels and plans of the Hatsutori Maru No.1 appear in Appendices B and C. Charter of both vessels was negotiated by the Programme Co-ordinator with the owners, Hokoku Marine Products Company Limited of Tokyo, Japan.

FIGURE 2. THE HATSUTORI MARU NO.5



Vessels of this type have a proven commercial record and, in addition, are stable in rough weather, have ample work space and accommodation for a large crew and are readily adapted to tuna tagging. Furthermore, the fishing technique normally employed with this type of vessel involves stopping, or slowing almost to a standstill, immediately after a school has been successfully chummed; fishing and tagging is then possible from the bow, midships and stern. This procedure permitted the use of up to five large tagging cradles (two bow, one midships and two stern) on the chartered vessels while still providing space for several people to pole tuna into each cradle (see Chapter II). These vessels are also ideally suited for the use of a large "bouki-ami" bait net since there is ample space on the starboard side of the vessels for the stowage of nets of this type when not in use (Chapter III). Both vessels were specially equipped with a wet laboratory for routine examination and processing of biological and baitfish samples (Chapter IV).

Fieldwork for the Programme was divided into three survey periods, each of approximately 10 months' duration (October 1977 through August 1978, October 1978 through July 1979, November 1979 through August 1980). The research vessels travelled extensively between 130°E and 130°W, spending survey time in the waters of all 23 countries and territories of the South Pacific Commission area, as well as in the waters of New Zealand and Australia. The detailed survey schedule (Table 3) was drawn up after consultation with fisheries officers of all of the countries and territories of the region and took due account of national research requirements, seasonality of skipjack and baitfish, abundance and the need to distribute tagged skipjack throughout the region in such a way as to ensure comprehensive coverage of the resource. Particular care was given to plan the release of tagged fish in areas of high, intermediate and low fishing effort and to tag skipjack of all sizes vulnerable to the fisheries. Close liaison was maintained at all times with national fisheries officers, and official observers from each country were encouraged to take part in the Programme's fieldwork.

The original Programme budget made provision for the computerised processing of all data generated during the fieldwork of the Programme and it was always assumed that the most up-to-date data processing techniques would be used. The Programme purchased a Hewlett Packard 1000 computer with appropriate peripherals (Chapter V) during the second year.

The Programme's activities were given wide publicity throughout the region and beyond as part of the campaign to encourage the recovery and return of tags from skipjack recaptured by fishermen. A reward system for returned tags was based on a cash gift of $2 local currency or the equivalent of approximately US$2, or a T-shirt, for every recovery. In addition, an annual lottery was conducted (total prizes of approximately US$2,000 per annum), whereby prize-winning tag numbers were drawn at random from the total returns and from individual batches of returns from each country within the region.

Tag returns from all sources were carefully monitored to ensure reliability in recovery data and, as far as possible, consistency in the recovery procedures. Regular contact between Programme staff and fisheries personnel throughout the region and beyond helped in maintaining this consistency and in identifying any areas where irregularities occurred in the number of tags being returned or in the information that accompanied them. A system of computerised reliability codes for recovery information facilitated the exclusion of unreliable data from analyses in which they could lead to erroneous results. Monitoring of the proportions of tag recoveries coming from fishermen, unloading crews and cannery workers helped to evaluate tag recovery procedures.

TABLE 3. DETAILS OF TIMETABLE FOR THE TWO CRUISES (Nos.1 and 2) OF THE HATSUTORI MARU NO.1 AND ONE CRUISE (No.3) OF THE HATSUTORI MARU NO.5

CRUISE NO.1			CRUISE NO.2			CRUISE NO.3		
Country	Arrival	Departure	Country	Arrival	Departure	Country	Arrival	Departure
Papua New Guinea	5/10/77	31/10/77	Mariana Islands	6/10/78	8/10/78	Mariana Islands	6/11/79	8/11/79
Solomon Islands	1/11/77	4/12/77	Guam	9/10/78	11/10/78	Federated States of Micronesia	9/11/79	20/11/79
Vanuatu	5/12/77	12/12/77	Federated States of Micronesia	12/10/78	13/10/78	Marshall Islands	21/11/78	21/11/79
New Caledonia	13/12/77	19/01/78	Palau	14/10/78	21/10/78	Kiribati	21/11/79	5/12/79
Vanuatu	20/01/78	24/01/78	Federated States of Micronesia	22/10/78	5/11/78	International waters	6/11/79	7/11/79
Fiji	25/01/78	18/02/78	Marshall Islands	6/11/78	14/11/78	Cook Islands	8/12/79	11/12/79
Fiji	28/03/78	10/04/78	Kiribati	15/11/78	18/11/78	French Polynesia	12/12/79	2/02/80
Tonga	11/04/78	3/05/78	Tokelau	19/11/78	23/11/78	Pitcairn Islands	3/02/80	4/02/80
Wallis and Futuna	4/05/78	31/05/78	Cook Islands	24/11/78	5/12/78	French Polynesia	5/02/80	17/02/80
American Samoa	1/06/78	5/06/78	French Polynesia	6/12/78	4/02/79	Cook Islands	18/02/80	19/02/80
Western Samoa	6/06/78	14/06/78	Cook Islands	5/02/79	10/02/79	American Samoa	20/02/80	21/02/80
American Samoa	15/06/78	21/06/78	International waters	11/02/	14/02/79	Western Samoa	22/02/80	26/02/80
Western Samoa	22/06/78	22/06/78	New Zealand	15/02/79	28/02/79	Niue	27/02/80	1/03/80
Wallis and Futuna	24/06/78	24/06/78	International waters	29/02/79	31/02/79	Tonga	3/03/80	9/03/80
Tuvalu	25/06/78	4/07/78	Australia	1/04/79	13/05/79	New Zealand	10/03/80	25/03/80
Kiribati	5/07/78	25/07/78	Papua New Guinea	14/05/79	2/07/79	Norfolk Island	26/03/80	30/03/80
Marshall Islands	26/07/78	31/07/78	Indonesia	3/07/79	17/07/79	New Caledonia	31/03/80	31/03/80
Federated States of Micronesia	1/08/78	12/08/78	Federated States of Micronesia	18/07/79	19/07/79	Fiji	1/04/80	9/05/80
Guam	13/08/78	13/08/78	Guam	20/07/79	21/07/79	Wallis and Futuna	10/05/80	22/05/80
Mariana Islands	14/08/78	14/08/78				Fiji	23/05/80	24/05/80
						Solomon Islands	25/05/80	28/06/80
						International waters	29/05/80	29/06/80
						Tuvalu	30/06/80	8/07/80
						Kiribati	9/07/80	11/07/80
						Nauru	12/07/80	15/07/80
						Federated States of Micronesia	16/07/80	2/08/80
						Palau	3/08/80	20/08/80
						Federated States of Micronesia	21/08/80	22/08/80

Late in the Programme, a "tag-plant" experiment assisted in ascertaining the efficiency and reliability of unloading and cannery personnel in returning tags. In this experiment, dead skipjack were tagged and measured on board purse-seine vessels and, unbeknown to the crew, returned to the freezer wells. Subsequent tag returns were monitored and recovery rates were used as part of the evaluation of overall recovery patterns.

Throughout the Programme procedures for data analysis were constantly altered and improved in keeping with world-wide developments in analytical techniques. Only the more general methods are considered in this volume; detailed descriptions of specific analytical procedures are given in the numerous papers describing Programme results.

Numerous methods were adapted for reporting results to the countries and territories for which the Commission works. During the fieldwork in each country results were communicated personally by staff to the national fisheries officers or official observers. This was followed by presentation of a draft Preliminary Country Report, which, subject to the approval of the country for which it was prepared, was subsequently published as one of a series. Progress reports on the findings of the Programme were presented to the Commission's annual Regional Technical Meeting on Fisheries, to other international meetings, such as those of the South Pacific Forum Fisheries Committee, and by correspondence to the fisheries officers of the region and other interested parties. Final results on all aspects of the Programme's work, including individual assessments for each of the countries surveyed, are being published by the Commission. Papers on selected topics are also being published in other scientific series.

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APPENDIX A. STAFF, OTHER THAN VESSEL CREW, EMPLOYED IN THE PROGRAMME

Incumbent	Position	Period of Employment
Robert Kearney	Programme Co-ordinator	19/09/75 - 30/09/81
Alexander Argue	Senior Fisheries Scientist	9/03/79 - 30/09/81
Sam Bledsoe*	Senior Fisheries Scientist	19/03/79 - 29/08/79
Pierre Kleiber	Senior Fisheries Scientist	29/05/78 - 30/09/81
Antony Lewis*	Senior Fisheries Scientist	17/08/77 - 7/02/78
Charles Ellway	Fisheries Research Scientist	3/05/78 - 15/07/78
		4/12/78 - 30/09/81
Robert Gillett	Fisheries Research Scientist	17/08/77 - 30/09/81
Jean-Pierre Hallier	Fisheries Research Scientist	17/09/77 - 30/09/81
Timothy Lawson	Fisheries Research Scientist	9/06/80 - 30/09/81
Masakazu Yao*	Fisheries Research Scientist	20/10/77 - 23/01/78
Lionel Haeffner*	Fisheries Experimental Officer	16/01/78 - 18/02/78
		28/03/78 - 8/04/78
James Ianelli*	Fisheries Experimental Officer	3/07/78 - 2/08/78
		4/01/79 - 25/07/79
		29/10/79 - 28/02/80
		1/06/80 - 31/08/80
Christopher Thomas	Fisheries Experimental Officer	31/12/77 - 31/12/78
Desmond Whyman	Fisheries Experimental Officer	14/03/78 - 17/04/80
Conrad Hopman*	Computer Systems Manager	10/10/79 - 31/10/80
Clive Maynard	Computer Systems Manager	13/07/80 - 12/06/81
Veronica van Kouwen	Research/Administrative Assistant	29/05/78 - 15/01/81
		3/06/81 - 30/09/81
Susan Van Lopik	Research/Administrative Assistant	16/11/77 - 30/09/81
Louise El Kik	Research Assistant	2/02/81 - 15/07/81
Helyette Ventillon*	Research Assistant	5/05/79 - 17/11/79
Cecile Choukroun*	Data Entry Technician	11/02/80 - 10/03/80
Christine Guiffant*	Data Entry Technician	14/05/80 - 28/05/80
Al Collins	Consultant Systems Programmer	25/11/77 - 23/12/77
Richard Kinney	Consultant	28/03/78 - 7/04/78
Michael Rivkin	Consultant	4/06/80 - 31/07/80
Carol Moulin**	Secretary	1/08/77 - 30/09/81

* Temporary appointment.

** Mrs Moulin is paid from the SPC regular budget, but was attached full-time to the Skipjack Programme.

APPENDIX B. SPECIFICATIONS AND PLAN OF CHARTERED SURVEY VESSEL HATSUTORI MARU NO.1

Vessel number - 102653 Tokyo

Fishing vessel registered number - TK-1 813

Call sign - JRXK

Launched - 12 November 1967

GT - 192.36

Registered length - 34.5 metres, LOA - 42.2 metres

Beam - 6.7 metres

Draught - 3.18 metres

Speed - 11.837 knots (max.); - 10.5 cruising

Fuel capacity - 76.03 cubic metres

Range - 6,000 miles (-25 days)

Main engine - Akasaka TM6 SS; 820 ps, 360 rpm

Auxiliaries (2) - Niigata CNS 100; 130 ps, 1,200 rpm

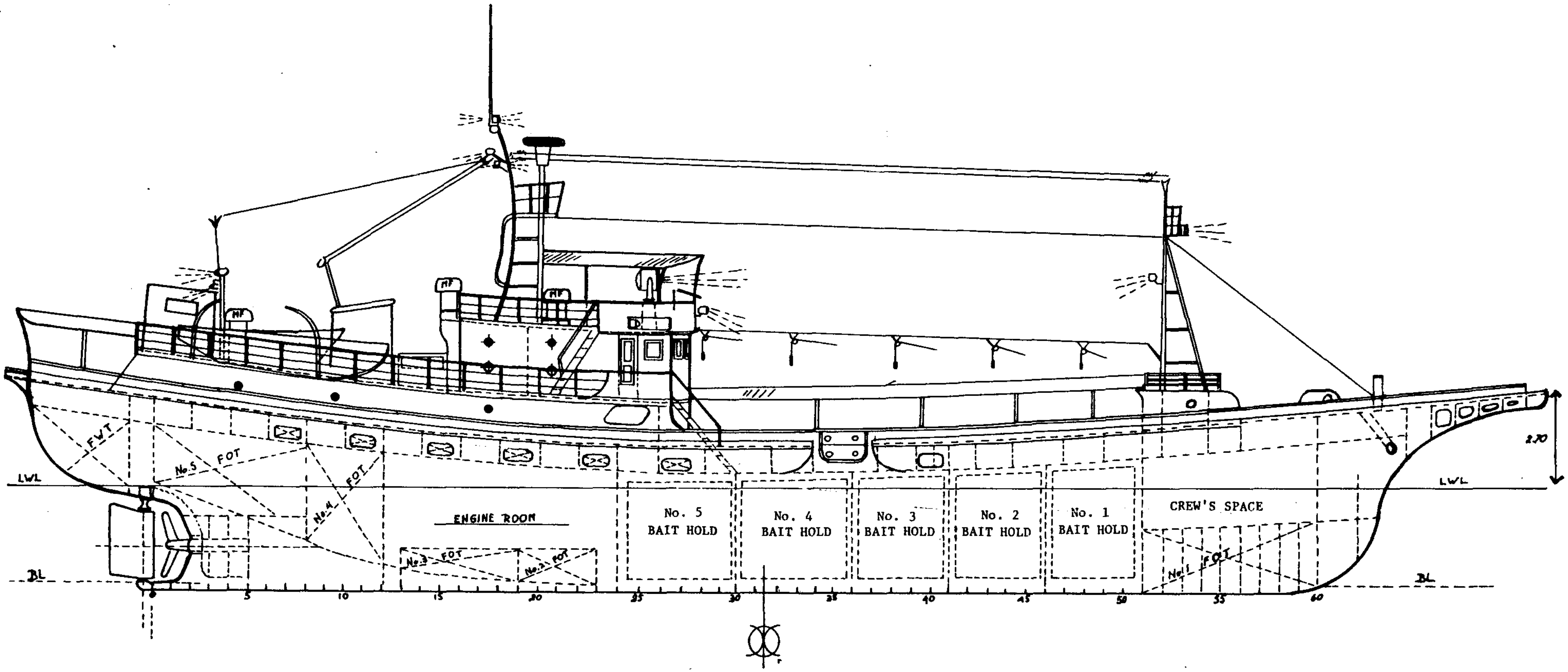
Generator (2) - Shinko-Denki 100 KVA, 3 phase, 230 v

Bait tank - stated capacity* (cubic metres)

No.1 - 13.879
No.2 - 14.052
No.3 - 13.702
No.4 - 16.842
No.5 - 16.134

* Actual volume slightly higher - 15-18 cubic metres

PLAN OF THE HATSUTORI MARU NO.1



APPENDIX C. SPECIFICATIONS OF CHARTERED SURVEY VESSEL *HATSUTORI MARU NO.5*

Vessel number - 1086823 Tokyo

Fishing vessel registered number - TK-1 970

Call sign - JNNN

Launched - 3 March 1970

GT - 254.41

Registered length - 39.80 metres, LOA - 46.75 metres

Beam - 7.30 metres

Draught - 3.15 metres

Speed - 13.95 knots (max.); - 11.50 cruising

Fuel capacity - 141 cubic metres

Range - 6,250 miles (-25 days)

Main engine - Hanshin Nainenki GLU32; 1,300 ps, 340 rpm

Auxiliaries (2) - Yanmar 6KL-HT; 200 ps
Yanmar 6KL-T; 160 ps

Generators (2) - Yanmar 160 KVA, 3 phase, 230 v
- Yanmar 130 KVA, 3 phase, 230 v

CHAPTER II

METHODS USED BY THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME FOR TAGGING SKIPJACK AND OTHER TUNA

R. E. Kearney and R. D. Gillett

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CHAPTER II

METHODS USED BY THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME FOR TAGGING SKIPJACK AND OTHER TUNA

R.E. Kearney and R.D. Gillett

1.0 INTRODUCTION

The Skipjack Survey and Assessment Programme commenced tagging tunas in October 1977. In three years of fieldwork more than 150,000 fish were tagged and released in 25 countries and territories in the central and western Pacific. The following is a description of the methods and materials used for tagging by the scientists involved in this Programme. The chapter concludes with data collection and transcription procedures.

2.0 THE VESSELS

The Skipjack Programme used two vessels for carrying out skipjack research, the *Hatsutori Maru No.1*, a Japanese live-bait pole-and-line boat in the 200-tonne class, and the *Hatsutori Maru No.5*, a similar vessel in the 250-tonne class. Specifications for both vessels and plans for the *Hatsutori Maru No.1* are given in Chapter I, Appendices B and C.

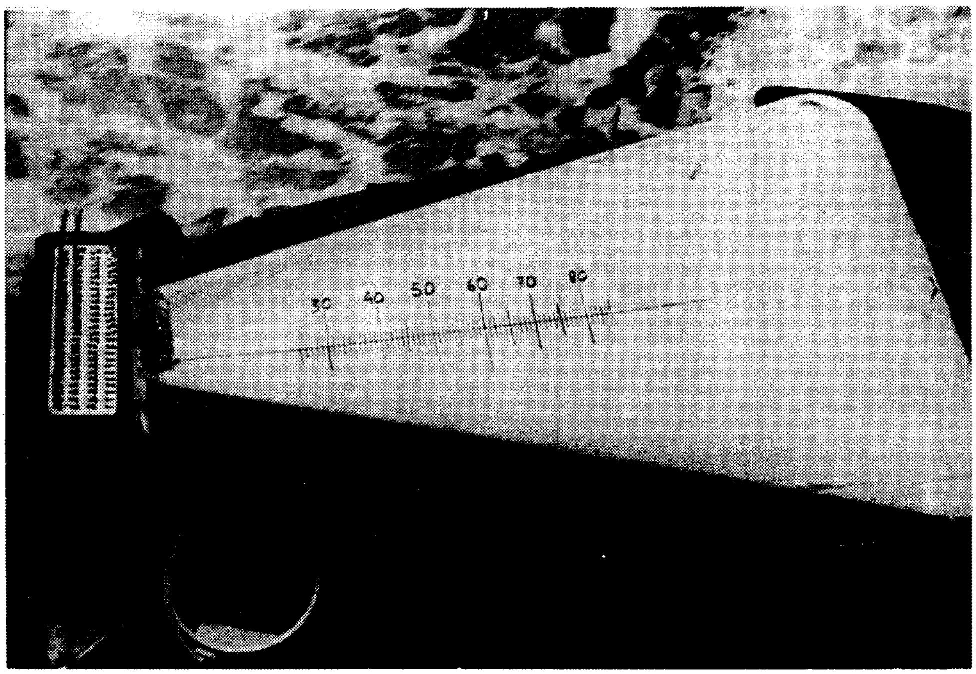
3.0 TAGGING CRADLES

Tagging cradles used by the Skipjack Programme were modified from the design of Kearney *et al*. (1972). The cradles used (Figure 1) were large enough so that one or two fish could be landed, unhooked and retained at one end by a tagging assistant while another was being examined, measured and tagged at the opposite end. Each cradle was on a slight incline so that fish would gently slide towards the narrow end. To prevent damage to the snout of the fish, the narrow end of the cradle (nose block) was padded with foam. Specifications of the tagging cradles are given in Appendix A.

The frames of the tagging cradles were made from galvanised steel pipe which was securely fastened to several points on the vessel. This was essential, as both the tagger and the assistant relied on the cradle for support in rough seas. A rectangular holder for the blocks of tagging needles was bolted to the narrow end of the cradle and a bucket for used needles was hung from this holder.

The cradle cover material was smooth to avoid abrasion of the fish, but tough enough to withstand some minor puncturing by the tagging needles. The cradle design allowed the cover, while out of use, to be rolled up and secured at the narrow end. This was useful in storm conditions. Cradle covers were usually replaced two or three times each cruise. The centre line of the cradle was graduated in one-centimetre increments from 30 to 90 cm, and the accuracy of these graduations was normally checked at least once each week. Adjustments were made by altering the tension on the lines holding the cradle cover, by adding or subtracting plywood shims behind the padded nose block, or by redrawing the graduations.

FIGURE 1. A TAGGING CRADLE SHOWING ONE-CENTIMETRE GRADUATIONS, A BLOCK OF TAGS, AND BUCKET FOR THE USED APPLICATING NEEDLES



4.0 TAGS AND APPLICATORS

4.1 Tags

Previous skipjack tagging experiments, particularly by the Inter-American Tropical Tuna Commission and the Department of Primary Industry, Papua New Guinea, had clearly demonstrated the utility of dart tags for this type of study. It was initially anticipated that tags consisting of yellow vinyl streamers and moulded nylon single-barb dart-heads, similar to those used in Papua New Guinea (Kearney et al. 1972), would be used throughout the Programme. However, following the discovery by Susume Kume of the Far Seas Fisheries Research Laboratory, Japan, that vinyl tag streamers break when frozen in tunas at very cold temperatures (Kume, personal communication), an attempt was made to obtain low-temperature-resistant streamer material. It was decided that, if possible, all tags used by the Programme should be resistant to temperatures as low as -50°C.

Unfortunately, a streamer material which met all of the Programme's specifications (i.e. resistant to breakage at low temperature, flexible, clearly visible, easily extruded and numbered) could not be found. It took much longer than anticipated to locate a streamer material even close to that required and, as a result, when the fieldwork of the Skipjack Programme commenced in October 1977, the first of numerous tag orders had not been filled. To enable the Programme to commence on schedule, tags were borrowed from the Fisheries Research Division of the Department of Primary Industry, Papua New Guinea. These Papua New Guinea tags consisted of vinyl streamers cut and numbered by Arthur E. King and Company of Newtown, Australia, fitted and glued to nylon dart-heads from the same manufacturer. A total of 1,422 blue and 4,593 yellow tags bearing the inscription DASF Port Moresby were used before the first of the fish with Skipjack Programme tags were released.

The first batches of Skipjack Programme tags were manufactured by Floy Tag and Manufacturing Company of Seattle, Washington, U.S.A. and consisted of 11 cm, yellow polyurethane streamers fitted and glued to nylon dart-heads manufactured for the Inter-American Tropical Tuna Commission, La Jolla, U.S.A. Unfortunately, there were many problems with the first batches of streamers; most notably: they were far stiffer than required; both internal and external diameters were variable, making it difficult to consistently accommodate the dart-heads or to fit the tags into the tagging applicators; the lacquer used to coat the streamers tended to crack and lift, removing the numbers; the lacquer on some batches did not dry and tags tended to stick together and to the applicators; the streamers were not particularly resistant to cold temperatures; and the numbering was not correct and did not meet the specifications for clarity and durability.

As a result of problems with the early batches of tags, additional combinations of streamers and heads were tried:

(1) Polyurethane streamers from Floy Tag and Manufacturing Company with heads from Arthur E. King and Company.

(2) Low-temperature vinyl streamers cut and numbered by Arthur E. King and Company with heads from the same company.

(3) Low-temperature vinyl streamers cut and numbered by Floy Tag and Manufacturing Company with heads from Arthur E. King and Company.

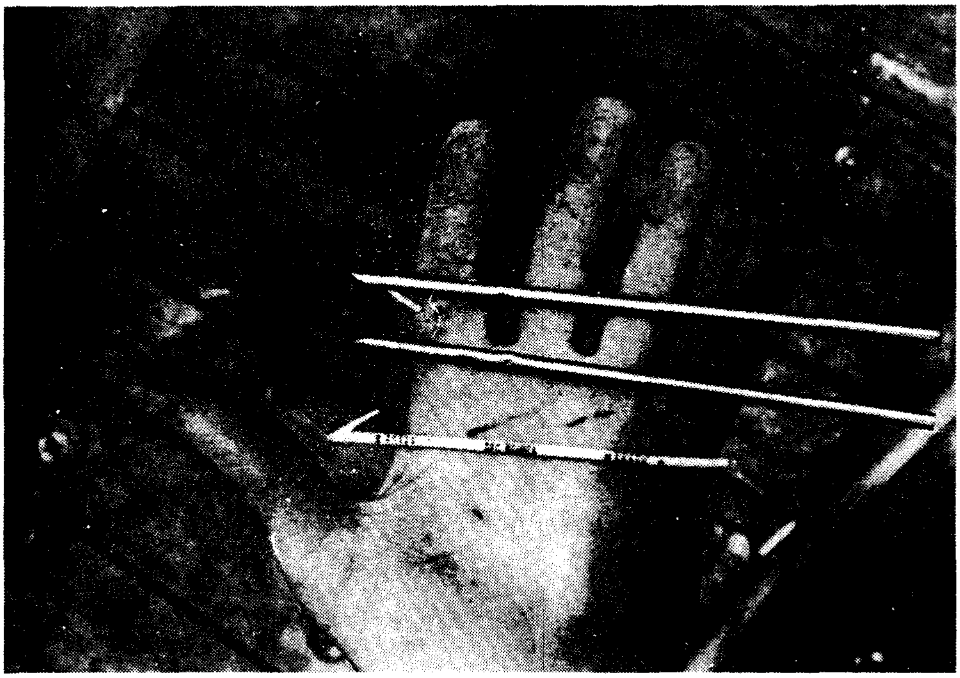
The use of polyurethane as a streamer material was finally abandoned because it tended to be too stiff and it was difficult to obtain polyurethane tubing extruded to consistent internal and external diameters.

It was not easy to obtain suitable vinyl streamer material. Eventually it was necessary to have vinyl extruded specifically for the Programme. This was done by Anjac Plastics Inc. of El Monte, California, U.S.A. The vinyl material selected had a guaranteed temperature tolerance to -65°C before extrusion. However, after extrusion this was greatly decreased, and the lower limit of the temperature tolerance of the streamers was estimated to be between -30°C and -40°C. Contrary to expectations, few, if any, fish carrying the Programme's tags were known to be frozen at temperatures as low as this, therefore this decreased temperature tolerance was not considered to be a major problem.

Even the vinyl tubing extruded specifically for the Programme showed some variability in internal and external diameter. This, coupled with variability of approximately eight per cent in the diameter of the shafts of the dart-heads, necessitated versatility in fixing the streamers to the dart-heads. Sometimes, immersion in alcohol for periods of up to 20 minutes was required to soften the streamers so the heads could be fitted; at the other extreme, application of large amounts of glue, provided by Arthur E. King and Company, was sometimes necessary.

The last 30,000 tags obtained by the Programme were of yellow, low-temperature vinyl of relatively uniform diameter extruded by Anjac. Tags were cut to 11 cm lengths and numbered by Floy, and were fitted and glued by Programme staff to single-barb dart-heads manufactured by King. A sample of these tags is shown in Figure 2. They were considered to be excellent tuna tags, far superior to those previously available.

FIGURE 2. A SAMPLE TAG, AN APPLICATING NEEDLE, AND A TAG INSERTED INTO A NEEDLE



During the Programme, several thousand tag streamers were cut to lengths of 7 cm and 8 cm for use when very small skipjack were tagged.

Tags used by the Programme were numbered either without a prefix, 00001 to 60000, or in smaller batches each preceded by one letter, for example, A00001 to A40000, or F00001 to F10000. In retrospect, it is considered inefficient to number each group of 100 tags beginning with the numeral 1; recording and processing of release and recovery data would have been much easier had each group of 100 tags been numbered 00 to 99.

4.2 Tag Applicators

Due to the variability in the external diameter of the numerous streamer materials tried, tag applicating needles of different sizes were necessary. All applicators were made from stainless steel, hypodermic tubing which was cut in 16 - 17 cm lengths and sharpened at one end (see Figure 2). In order to minimise trauma to the fish being tagged, and to keep tags from falling out of the applicators, all tags were applied using the smallest diameter tubing which would accommodate the tag. For the polyurethane tags, tubing with internal and external diameters of 3.84 mm and 4.82 mm respectively was used. For the smaller vinyl tags obtained from Papua New Guinea, applicator tubing of 3.32 mm internal and 4.20 mm external diameter was used. All of the last 100,000 vinyl tags were applied using tubing with an internal diameter of 3.72 mm and external diameter of 4.58 mm.

Applicating needles with an internal diameter slightly too large were crimped to prevent the tags from slipping out of the needles when held in an inverted position just prior to tag insertion.

5.0 TAGGING PROCEDURES

5.1 Preparation

Upon approaching a tuna school, one of the scientists recorded the time, sea surface temperature, school size and type, association and any notable behavioural characteristics of the school (see Chapter III). Each of the individuals doing the tagging was informed of the standardised time and this was recorded into tape recorders carried around the neck of each tagger, and was later used as an identification code for releases from individual schools. The complete serial number of the first tag to be used at each tagging station was recorded at the same time. This procedure served to identify the first batch of tags used by each tagger.

5.2 Tagging

When hooked, fish were carefully, but without delay, raised to the cradle level (Figure 3). An assistant standing next to the tagger (Figure 4) directed the fish gently into the cradle while holding the fishing line. The tuna frequently became unhooked by themselves, otherwise gentle twitching on the line was normally sufficient. If the fish was deeply hooked or obviously badly injured it was quickly rejected onto the deck by the fishermen. The tagging assistant made a preliminary assessment of more subtle damage to the fish and rejected those that appeared to be injured. Care was taken not to handle the fish by the relatively fragile caudal peduncle. The assistant then slid the fish (left side up, head towards narrow end of the cradle) to the tagger, who made a final evaluation of the condition of the fish. Criteria for rejection included bleeding, except for minor hook wounds, too long spent in the cradle (more than approximately 15 seconds), rough treatment by the assistant, or serious natural injuries. The tuna was gently pushed until its snout touched the padded block at the narrow end of the cradle. Fork length (tip of snout to caudal fork) was then measured to the nearest half centimetre from the calibrations on the cradle cover.

The tag was inserted level with, or just posterior to, the secondary dorsal fin (see Figure 5). Ideally it was positioned at an angle of 45°, or less, to the axis of the fish to minimise water resistance. Tags were inserted sufficiently deep so that the barb interlocked with the fin ray supports of the secondary dorsal fin or the neural spines, but not so deep as to cause unnecessary damage to underlying tissue. With experience the tagger could feel when the barb passed between the neural spines or fin ray supports (see Figure 6). An estimation of the quality of the insertion operation, together with any distinguishing characteristics of the fish, was tape recorded. Tagged fish were promptly returned to the water, head first if possible.

FIGURE 3. POLING A SKIPJACK INTO THE CRADLE AT THE BOW OF THE <u>HATSUTORI MARU NO.5</u>

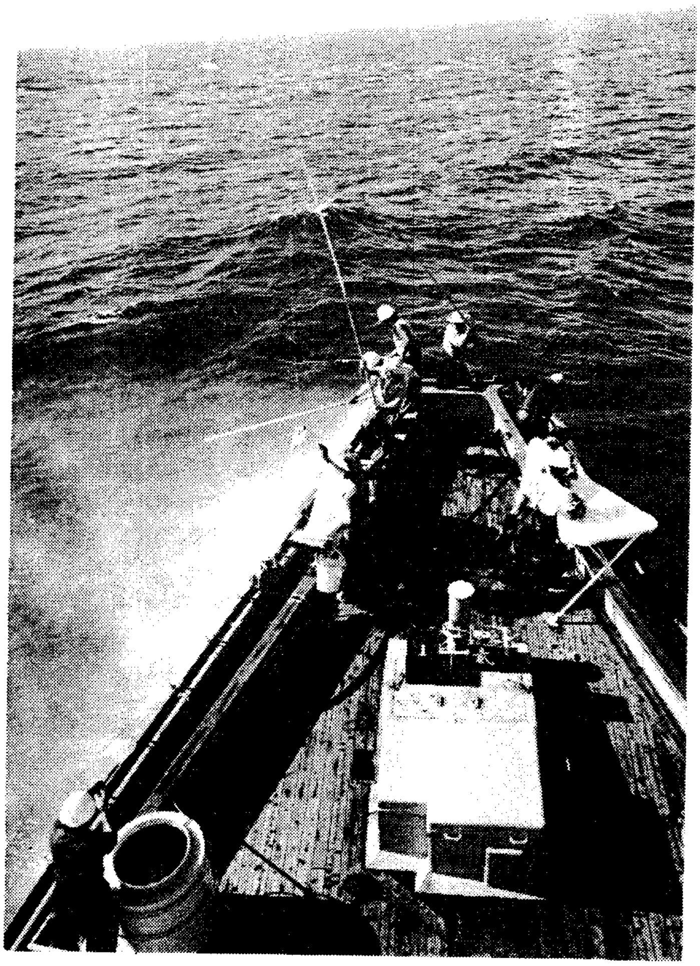


FIGURE 4. TAGGING ASSISTANT READY TO GUIDE A FISH INTO A STERN CRADLE. The person doing the tagging has just released a tagged skipjack.

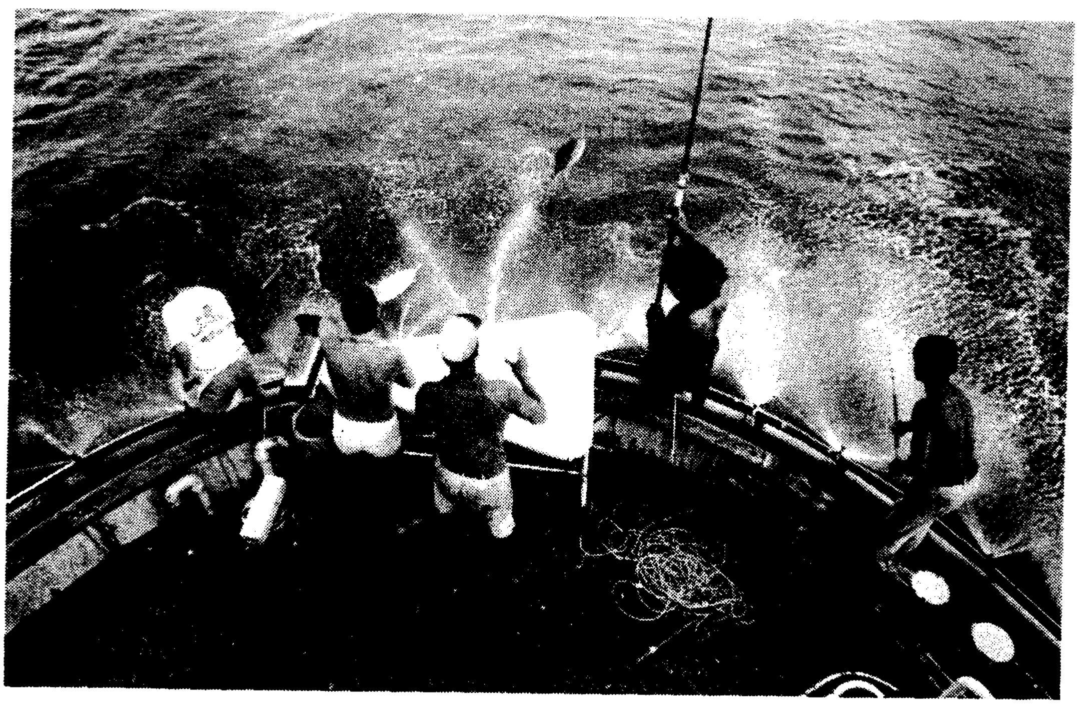


FIGURE 5. INSERTING A TAG INTO A SKIPJACK

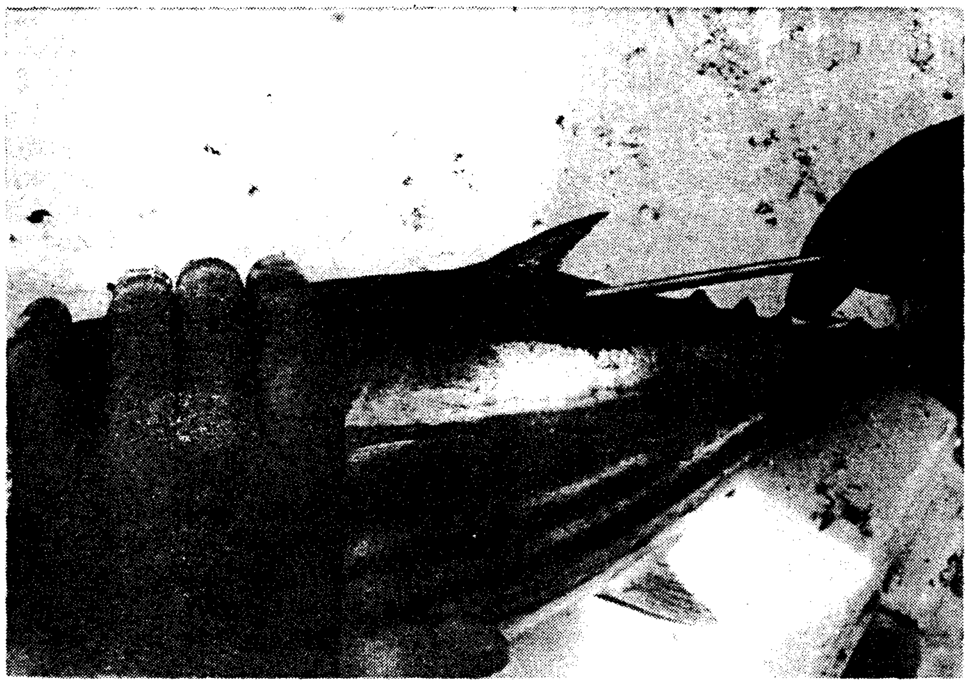
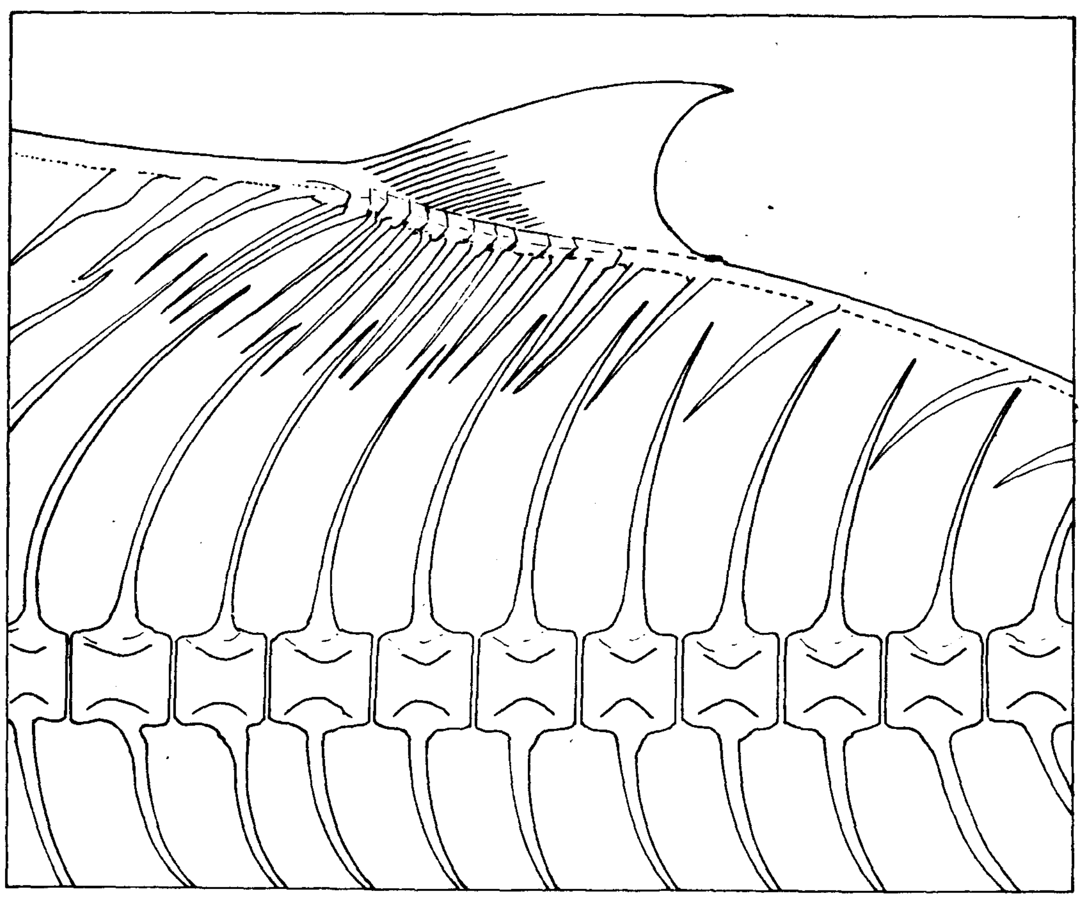


FIGURE 6. DIAGRAM OF SKIPJACK SKELETAL STRUCTURES IN THE AREA OF THE SECONDARY DORSAL FIN WHERE TAGS WERE INSERTED



It should be emphasised that every measure was taken to reduce trauma to the fish and to increase tagging speed. Fish that were out of the water for more than 15 seconds, or had struck part of the vessel, were normally rejected. When a scientist first began to tag tuna, his tagging rate was slow and the percentage of rejected fish was high because of problems meeting the strict quality standards. With experience, less fish were rejected and the tagging rate accelerated. Eventually, virtually all the fish were well tagged and the rate on occasions approached the maximum physically possible (approximately 20 fish per minute per tagger).

While very badly tagged or damaged fish were rejected, some fish in less than ideal condition were released. Such releases accounted for a small percentage (5.7%) of the total and in each case factors contributing to poor tagging quality or fish condition, such as incorrect tag placement or minor bleeding, were recorded. A list of such factors is given in Appendix B.

As previously mentioned, the entire identification number of the first tag was read into the tape recorder prior to the beginning of fishing each school. During periods of rapid tagging, only the numbers on the face of the needle blocks were recorded. These numbers corresponded to the last two digits of the full identification number on each tag. During lulls in tagging activity, a tag was removed from a needle and the entire number was tape recorded. This was particularly important each time a new block of 100 tags was being used.

Gloves were worn to protect the hands from hooks, tagging needles and fish spines, to facilitate handling of the fish and to reduce damage to the fish. Thick cotton gloves were used as most other materials were considered to be more damaging to fish than bare hands.

Goggles for eye protection were made available to the taggers for use on an optional basis. The danger of eye damage from flying hooks was considerable, especially when poling large fish; however, salt water spray, fish slime and blood often made vision through goggles or glasses nearly impossible; consequently they were not often worn. In spite of the hazards of tagging, common-sense precautions by taggers and fishermen prevented any serious injuries.

Several individual tuna out of every school were considerably livelier than the average. These "frisky" fish presented problems for both measuring and tagging. For example, small yellowfin often twisted in the cradle just before the tag was to be inserted. Covering the eyes with a gloved hand usually had a calming effect on these fish. Skipjack were not as easily pacified by this procedure. Fortunately, even the most active fish usually settled down for a brief instant while on the cradle and at this point the fish was tagged. As a fish could be measured while its tail was flapping, the tagger had the the option of measuring the fish before or after this calm period. In general, the tag tended to be inserted slightly more vertically in the friskier fish. During periods of brisk biting, rather than waste time with exceptionally lively tuna, it was often expedient to reject very active fish.

When a tuna school stopped biting, the time was tape recorded along with the full identification number of the last tag actually used. Used tagging needles were collected from each tagging station and counted. They were then sterilised for at least 20 minutes in a 10 per cent bleach solution to prevent possible contamination of fish being tagged. All tagging needles were rinsed in fresh water before re-use. All stray tags, and tags that had been inserted into rejected fish, were collected and recorded.

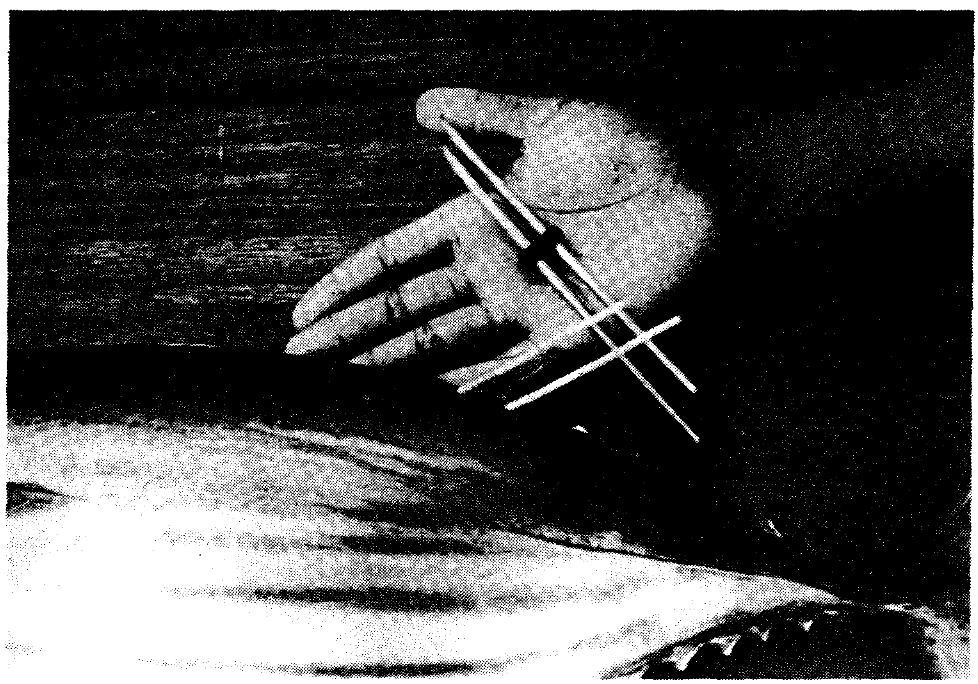
5.3 Double Tagging

Little is known of how well skipjack carry dart tags. Insertion of two tags into a single fish provides a means of estimating the rate of tag slippage. Double tagging, in conjunction with single tagging, can also indicate whether mortality due to tagging is significant, and allows estimation of how efficiently tags are returned.

Two techniques of double tagging were used. One method, conventional double tagging, involved inserting a single tag into the fin ray supports of the secondary dorsal fin on the left side of the fish, and immediately thereafter applying a second tag on the same side of the fish approximately one centimetre in front of the first.

In the second method, "rubber-double tagging", pieces of strong, stiff rubber (actually cut from an old conveyor belt) were used to join pairs of applicating needles together. One needle of each pair was approximately 1.5 cm higher than the other to permit simultaneous insertion of the two tags at the proper angle relative to the tuna body (see Figure 7). Using this technique, fish could be double tagged virtually as quickly as they could be single tagged.

FIGURE 7. A DOUBLE-TAGGED SKIPJACK AND TWO APPLICATING NEEDLES JOINED BY A PIECE OF RUBBER



In all cases, double tags were inserted on the same side of the fish. There were several reasons for this: (1) if both tags are inserted on the same side the risk of cutting off the first tag with the applicator used for inserting the second is minimised; (2) simultaneous insertion of two tags (rubber-double tagging) is next to impossible when both tags have to be inserted on opposite sides; (3) when two successive tags are inserted on the one side (conventional double tagging), there is considerable time saving because the fish does not have to be turned over; and (4) the negative hydrodynamic effects of carrying one tag are exaggerated by carrying two tags on the same side and it was hoped that recovery patterns would give some indication of the harmful effects of regular single tagging.

During the double tagging experiment, which was carried out in Fiji in April 1980, Skipjack Programme scientists double and single tagged alternate fish. Two scientists used the rubber-double method while one scientist used the conventional technique. Each day the taggers changed methods and rotated tagging stations on the research vessel to standardise the effect of individual tagging styles and tagging stations on recovery rates. Single tags were placed in 6,869 tuna, at the same time as 5,916 tuna were double tagged.

5.4 Data Collection and Transcription

5.4.1 Primary data collection

Tape recorders were considered indispensable for documenting tagging information. The scientists of the Skipjack Programme used several different models of cassette recorders with varying degrees of success. Initially, standard portable tape recorders (approximate size 13 x 6 x 24 cm) were carried in a back-pack. A wire around the neck supported a microphone a few centimetres from the tagger's mouth. Later in the Programme much smaller recorders (8 x 5 x 12 cm) were found to be superior and were then used exclusively. These mini-recorders were encased in a sealable plastic bag and suspended by a strap worn around the neck (see Figure 8). Advantages of using the mini-recorders were: (1) the recorder could be easily inspected while tagging to verify that it was functioning; (2) if the record button was inadvertently disengaged, the tape deck would audibly relay previous recordings, thus allowing instant correction; (3) the tagger had greater freedom of movement; (4) the quality of the recording was high; (5) the entire unit was easily made watertight; (6) batteries were rechargeable; (7) the recorder was more protected on the chest than on the back; and (8) the small recorders lasted, on average, at least twice as long as the larger models.

Ninety-minute cassette tapes were preferred. The sealable plastic bags protecting the recorders were discarded after each fishing day and the recording heads were cleaned with alcohol every few days to insure quality recording. Each evening the batteries were recharged.

5.4.2 Data transcription

At the completion of each fishing day, the time each school was encountered during the day was given to the navigation officer of the vessel, who assigned a position to the nearest minute of latitude and longitude to each school. This information was subsequently used by each tagger when entering data into the tagging log (Appendix C). Each tagger listened to his own cassette tape and recorded the data for each tagging station into a separate log-book. To avoid loss of data, it was mandatory that each tagger complete the transcription of all of his tagging data each fishing day. Tape-recorded remarks on individual fish condition and quality of the tag insertion were coded and entered. The identification number of rejected tags, and of tags inserted into fish that were subsequently not released, were noted in the tagging log-books. These tags were then destroyed to avoid possible confusion with tags still to be released.

FIGURE 8. PROGRAMME SCIENTIST WITH MINI-RECORDER AND COTTON GLOVES, CARRYING A BLOCK OF 100 TAGS

Problems in data recording arose if, in the course of rapid tagging, the entire identification number of at least one tag in each block of 100 had not been recorded. Problems were also caused by malfunction of tape recorders, either through mechanical or operator deficiencies. The impact of these problems was reduced by separate recording of the tag number series of each block of 100 tags before it was delivered to the individual tagging station.

6.0 CONCLUSIONS

The above methods were used by the Skipjack Programme to tag over 150,000 skipjack and other tuna. On numerous occasions more than a thousand fish were tagged in a single day. Greatest numbers of releases in different time periods were: 3,689 in one day (New Zealand), 9,089 in one week (Wallis and Futuna Islands) and 18,815 in one month (Marquesas Islands). Tagging rates as fast as 20 fish per minute per tagger were possible.

Every effort was made to minimise trauma to the fish. Preliminary results suggest that this effort was effective. Overall tag recovery rates, and those from double tagging experiments, suggest that tag slippage and tagging mortality were minimal (Skipjack Programme 1981). Numerous observations were made of fish captured shortly after release. For example, during the period spent in the Marquesas Islands, the crew of the research vessel recovered 34 tagged skipjack that had been at liberty up to 25 days. Twenty-five of these fish were examined by the scientists to see if any differences between tagged and untagged individuals could be detected. No differences in length, weight and general body condition were noted. Within a week of tagging a small depression, similar to that which streamlines pectoral and pelvic fins, had formed on the skipjack's dorsal surface underneath the tag. Perhaps this newly formed feature reduced detrimental hydrodynamic effects that may have been caused by the tag. It was also observed that scar tissue formed in a matter of a few days around the tag head. In a period from one week to 10 days, enough additional scar tissue had formed on the shaft of the tag to secure the tag into the body of the tuna, possibly without the aid of the barbed head.

The overall reported recovery rate for tagged fish to date (October 1982) is approximately 4.3 per cent and increasing slightly with time. Recovery rates vary greatly from area to area depending upon fishing effort. In Papua New Guinea the recovery rate shortly after completion of tagging was 14 per cent. In French Polynesia one year after tagging, it was 0.3 per cent. Skipjack tagged by the Programme have been recaptured up to 3,203 nautical miles away from the place of release and have been recaptured up to 1,070 days after release.

In summary, the tagging procedure followed by the Programme provided precise information on size, time and place of release, for large numbers of tag releases, and appear to have caused minimal disruption to the behaviour of the tagged fish.

REFERENCES

KEARNEY, R.E., A.D. LEWIS and B.R. SMITH (1972). Survey of skipjack tuna and bait resources in Papua New Guinea waters. Cruise Report Tagula 71-1. Department of Agriculture, Stock and Fisheries Research Bulletin 8.

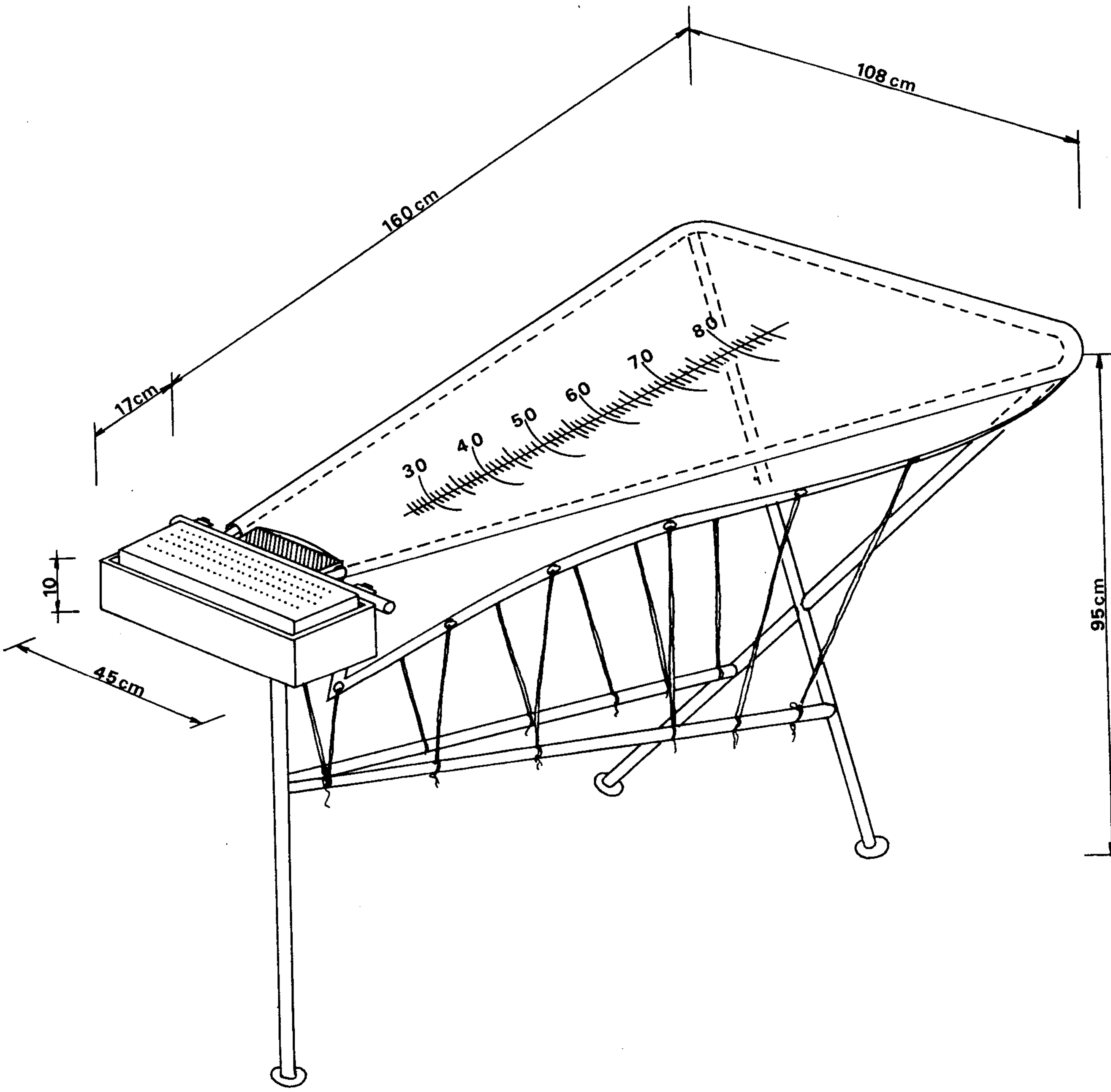
SKIPJACK PROGRAMME (1981). Effects of skipjack tagging procedures on subsequent tag recoveries. Regional Technical Meeting on Fisheries 1981, 13 : Working Paper No.8, South Pacific Commission, Noumea, New Caledonia.

APPENDIX A. TAGGING GEAR USED BY THE SKIPJACK PROGRAMME

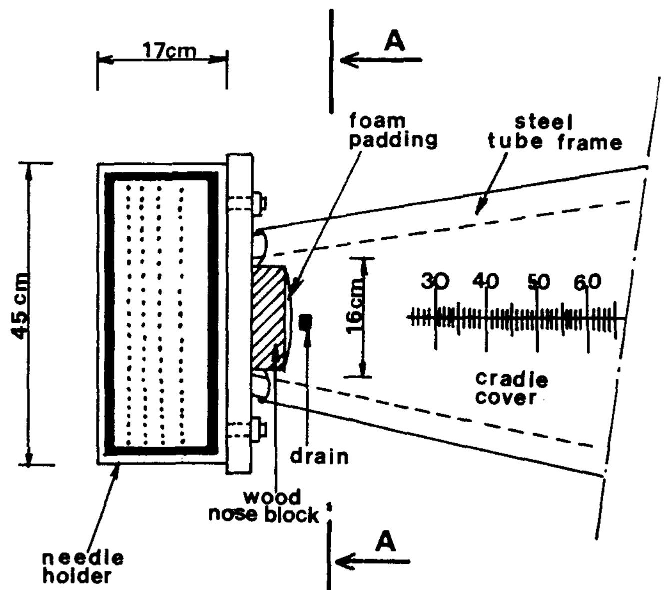
Tape Recorders:	Fairmate Super Mini-Recorder, C5,565 with Fairmate rechargeable batteries 565-833
Tags:	Manufacturer: Floy Tag and Manufacturing Inc. P.O. Box 5357 4616 Union Bay Place N.E. SEATTLE, Washington 98105, U.S.A. Arthur E. King and Co. Rear 135 King Street Newtown, SYDNEY, Australia Anjac Plastics Inc. 4466 N. Baldwin Avenue EL MONTE California 91731, U.S.A.
Cradle Frames:	Material: galvanised steel Tube size: O.D. 35 mm
Cradle Cover:	Material: Teska Fashionable Tent Material - .75 mm thick Manufactured by Kato Company Limited, Tokyo, Japan or Shelterite Manufactured by Marine Canvas Products, 3354 Kurtz Street, San Diego, California, U.S.A. Dimensions: Isosceles trapezoid shape, with equal sides of 166.2 cm and ends 148 cm and 83 cm
Tagging Needles:	Material: stainless steel ID - 4 mm Length - 170 mm
Connectors for rubber double tagging:	Material: conveyor belt rubber Size: 2 x 1 x 1/2 cm
Tagging blocks:	38 x 12 x 7 cm Wooden Painted white, numbered, varnished
Plastic bags for recorders:	15 x 50 cm

Cassette neckstrap:	75 cm
Gloves:	Material: soft cotton
Hooks:	Size: Nos. 2.0 to 3.5 Manufacturer: Kosak Sangyo Co. Ltd. Hamashima-cho Shima-gun Mie-ken, Japan
Poles:	Size: 3.30 to 3.75 metres Manufacturer: Hamaguchi Keiki Kogyo Co. Ltd. 1002-1 Matsuo-cho Toba-shi Mie-ken, Japan T 517-01

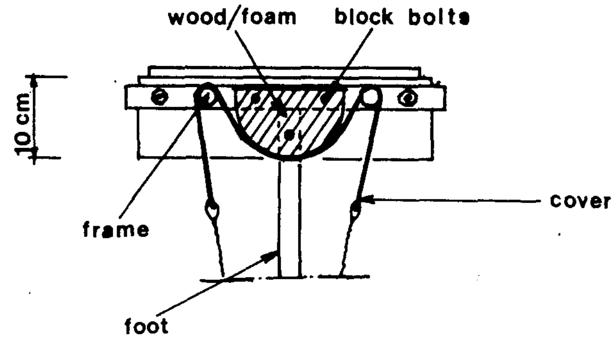
PLAN OF TAGGING CRADLE



ATTACHMENT OF TAG NEEDLE HOLDER TO CRADLE FRAME



TOP VIEW



CROSS SECTION A—A

THE BOW OF THE HATSUTORI MARU NO.5 ACCOMMODATING TWO TAGGING CRADLES

APPENDIX B. LIST OF TAGGING QUALITY CATEGORIES AND ASSOCIATED CODES FOR THE 5.7 PER CENT OF THE TAGGED SKIPJACK RELEASED IN LESS THAN OPTIMUM CONDITION

Badly tagged (poorly tagged, not good, etc.)	BT
Fish bleeding	BL
Badly tagged and bleeding	BZ
Tag too deep (too far in)	TD
Tag too shallow (not far enough)	TS
Fish dropped on deck after tagging	DD
Fish hit the side before landing in water	OS
Shark bite	SB
Bleeding and dropped on deck	BD
Shark bite and dropped on deck	SD
Shark bite and tag too deep	ST
Badly tagged and shark bite	BS
Tagged too far forward	TF
Bleeding and overside (hit side)	BO
Tail damaged	TA
Tagged too high	TH
Tagged too low	TL
Mouth injured	MI

APPENDIX C. TAGGING LOG-BOOK AS COMPLETED ON BOARD THE RESEARCH VESSELS

Date 28 / 12 / 79 (D M Y) Time 12.15 Tag Series C11901

Position Lat 8°53'S Lon 140°21'W School No. 1 Cruise No. ______

Temp. 28.8 Skipjack 100

Tagger JNI Cradle PS Yellowfin 0

No	LCF		No	LCF		No	LCF		No	LCF	
01	47		26	47		51	44		76	45	
02	46		27	47		52	47		77	50	
03	48		28	48		53	46		78	49	
04	45		29	48		54	46		79	47.5	
05	47		30	47		55	47		80	46	
06	44		31	49		56	47		81	47.5	
07	48.5		32	46		57	48		82	44	
08	46		33	46		58	47		83	46	
09	48		34	46		59	48	TS	84	47	
10	48		35	46		60	47		85	43	
11	45		36	45		61	49		86	49	
12	45.5		37	46		62	46.5		87	47.5	
13	45		38	47.5		63	48		88	47	
14	47		39	46		64	44.5		89	48	
15	48		40	45		65	47		90	46.5	
16	44		41	46		66	48		91	48	
17	46		42	46		67	48.5		92	48	
18	46		43	49		68	46		93	48	
19	47	TL	44	46		69	46	SB	94	46	
20	47		45	45		70	47		95	46.5	
21	46		46	45.5		71	47		96	46	
22	46		47	45		72	49	TL	97	45	
23	46		48	47		73	45.5		98	44	
24	48		49	45		74	43	TH	99	46	
25	48		50	47		75	46		00	48	

CHAPTER III

METHODS USED BY THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME FOR COLLECTING BIOLOGICAL, TUNA SCHOOL AND ANCILLARY DATA FROM A POLE-AND-LINE FISHING VESSEL

A. W. Argue

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CHAPTER III

METHODS USED BY THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME FOR COLLECTING BIOLOGICAL, TUNA SCHOOL AND ANCILLARY DATA FROM A POLE-AND-LINE FISHING VESSEL

A.W. Argue

1.0 INTRODUCTION

The Skipjack Programme provided a unique opportunity to obtain biological data and surface school observations for skipjack and other tunas over a broad area in the central and western Pacific Ocean. These data, when coupled with results from tagging, provided a significant increase to the data base on skipjack and other surface tuna species. During the course of the Programme, data was accumulated on 4,193 tuna schools, biological observations were made on more than 26,000 skipjack and other species (Table 1) and 58 skipjack blood samples were taken. This was additional to the release of 150,000 tagged skipjack and other tunas.

This chapter documents field methods used by the Programme to collect basic biological data, blood samples for genetic analyses of population structure, parasite samples, data on skipjack schools and various ancillary data.

2.0 BIOLOGICAL DATA

The basic unit sampled was a school, here defined as a body or aggregation of tunas that was spatially distinct at the time it was fished or sighted. Thus, all biological data were referenced to individual schools, as were all tagging data, and the schools were identified by a unique code, i.e. date, hour, minute in local time (Section 3 describes school identification procedures). Except where mentioned, sample sizes refer to the numbers of measurements per school.

Biological sampling was carried out on fish that had been rejected for tagging, or had fallen on deck during a "fast" biting school, and as skipjack and other tuna schools were often encountered and fished in rapid succession, sampling procedures were designed to enable data to be rapidly recorded. As sampling took place on the deck of the vessel under variable weather conditions, there was need to develop a durable and waterproof system for recording data. For these reasons scientists used 30 cm by 22 cm white plexiglass slates, similar to those used by scuba divers, and soft-lead pencils for data recording. All biological observations on specimens from each school were entered on these slates, together with the time identifying the school. At the end of each day, data were coded into log-books and slates were cleaned with soap and water ready for use the next day.

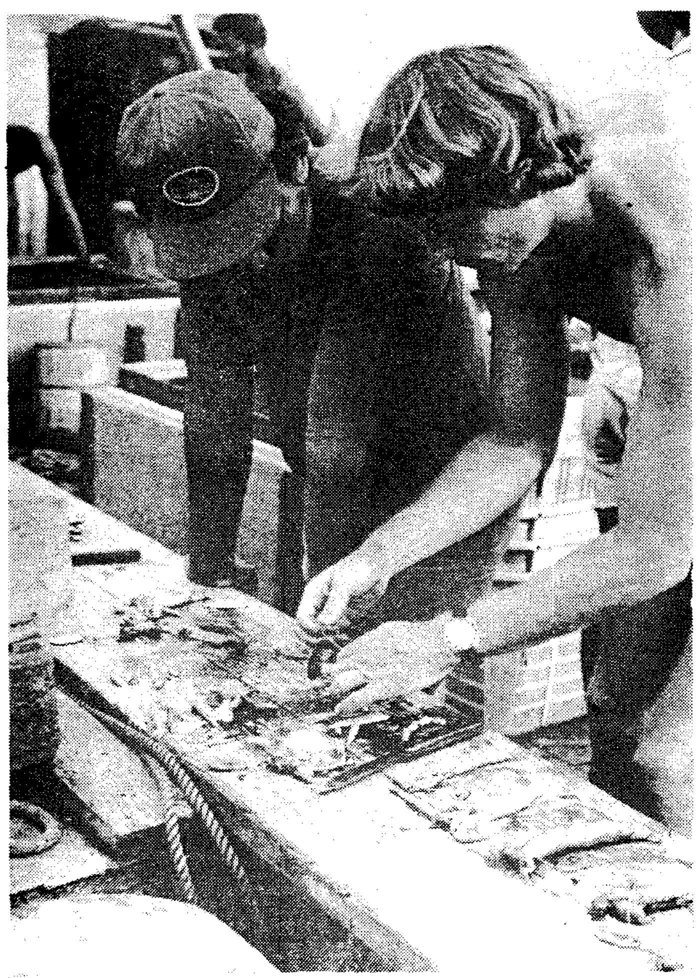
Once tagging ended, the crew quickly retrieved all pole-caught fish lying on the deck, sorted them by species, and placed them in plastic fish baskets on the midship deck, just aft of the forecastle, where all biological sampling took place. Numbered (1-20) plastic discs were attached to a random sample of 20 skipjack and 20 yellowfin. These round discs (approximately

TABLE 1. SUMMARY OF BIOLOGICAL DATA COLLECTED BY THE SKIPJACK PROGRAMME

Species	Total No. Measured	Total No. Weighed	Total No. Examined for Sex	Total No. Examined for Stomach Content	Total No. Examined for Tuna Juveniles
Skipjack *Katsuwonus pelamis*	21583	10285	10926	4621	9574
Yellowfin *Thunnus albacares*	3141	1852	1824	1035	1757
Mackerel Tuna *Euthynnus affinis*	495	219	223	145	223
Albacore *Thunnus alalunga*	67	67	67	51	67
Frigate Tuna *Auxis thazard*	213	168	169	99	158
Bigeye Tuna *Thunnus obesus*	18	12	12	13	17
Rainbow Runner *Elagatis bipinnulatus*	676	425	290	197	273
Dolphin Fish *Coryphaena hippurus*	77	61	37	35	37
Dogtooth Tuna *Gymnosarda unicolor*	9	9	9	9	9
Blue Mackerel *Scomber australasicus*	4	0	0	0	0
Spanish Mackerel *Scomberomorus commersoni*	3	3	3	3	3
Double Lined Mackerel *Grammatocynus bicarinatus*	22	22	22	7	7
Kingfish *Seriola lalandii*	3	3	0	3	3
Wahoo *Acanthocybium solandrii*	2	2	2	2	2
Little Dolphin Fish *Coryphaena equisetis*	1	1	0	0	0
White-spotted Triggerfish *Canthidermis rotundatus*	11	2	1	1	1
Shark *Carcharinus* sp.	1	1	1	1	1
Layang Scad *Decapterus macrosoma*	2	2	2	2	2
Barracuda *Sphyraena* sp.	1	1	1	1	1
TOTALS	26,329	13,135	13,589	6,225	12,135

2 mm thick and 2 cm in diameter), coloured green for skipjack and yellow for yellowfin, were wired to a large fish hook to facilitate attachment to the fish. Troll-caught fish were marked with white numbered plastic discs. Skipjack and yellowfin lengths, followed by weights, were then recorded by the scientists on the slates next to the fish's disc number. After size measurements were recorded, the crew removed viscera for later examination from the 20 measured fish of each species, and attached the numbered disc to the viscera which were later examined by scientists (Figure 1). If there were large numbers of other species on deck, processing of their biological data was left until skipjack and yellowfin were finished. Using this simple system, mix-ups with data records between individual fish or between schools were seldom encountered.

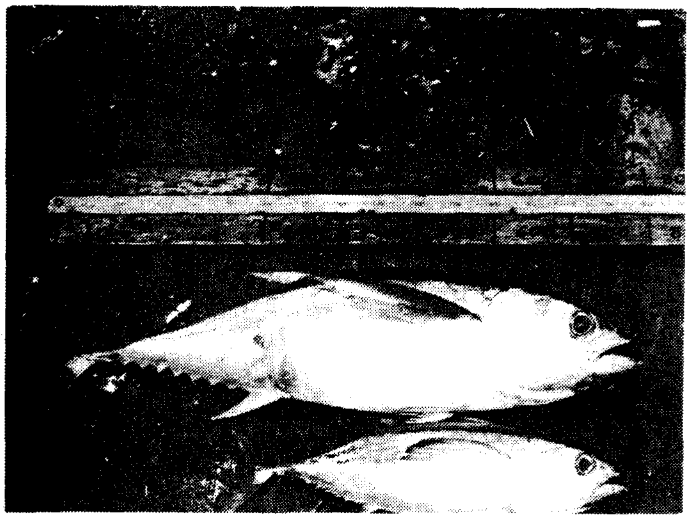
FIGURE 1. STOMACH CONTENT EXAMINATION ON BOARD THE RESEARCH VESSEL. Note numbered tags on stomachs used to assure that gonads and stomachs are associated and recorded with the proper fish length.



2.1 Length and Weight Measurements

Fork length measurements (to the nearest millimetre) were made on a maximum of 50 of each species (including the disc-numbered fish) that had accumulated on deck after a school had been fished. For this purpose, a measuring board consisting of a graduated 120 cm stainless steel rule, embedded in a wooden base and fitted with a header board was used (Figure 2). The 20 specimens of each species with numbered discs were weighed to the nearest 0.1 kg on spring scales. The range of individual fish weights necessitated the use of a range of scales (0-1 kg, 0-5 kg, 0-10 kg, 0-25 kg, 0-50 kg). Care had to be taken by the person weighing fish to allow for the ship's movement. With practice, discrepancies could be reduced, at least to within 0.1 kg on a 5 kg fish. Once or twice each week all scales were checked for accuracy with known weights of varying sizes. Each scale was tested against weights spanning its full range. When scales were no longer able to be adequately adjusted, they were discarded. At the end of each day one crew member washed the scales in fresh water; several times each week, scales were lubricated with light oil.

FIGURE 2. A MEASURING BOARD GRADUATED IN MILLIMETRES



2.2 Maturity and Sex

Next in the sequence of measurements on the 20 numbered fish of each species per school was determination of sex (male, female, or sex indeterminate - generally gonads less than about 1 g in weight); maturity stage (recorded for female skipjack and yellowfin only); and gonad weight. These data were recorded on the slate next to the fish's length and weight measurements. One of seven stages of sexual maturity was assigned to gonads from female skipjack and yellowfin, based on criteria described in Table 2 (adapted from various sources in the literature, e.g. Marr 1948; Schaefer and Orange 1956; Raju 1964). Starting with the third cruise in November 1979, the presence of running milt in the sperm ducts of male skipjack was recorded.

TABLE 2. FEMALE GONAD MATURITY STAGES

Female Gonad Stage	Description
1 Immature	Ovary small and slender. Cross-section round.
2 Early maturing	Enlarged, pale yellow ovaries. Ova not visible.
3 Late maturing	Enlarged, turgid, orange yellow ovaries. Ova opaque.
4 Mature	Enlarged, richly vascular, orange ovaries, losing turgidity. Ova translucent.
5 Ripe	Greatly enlarged ovaries, not turgid. Ova easily dislodged and extruded by pressure.
6 Spent	Flaccid, vascular ovaries. Most ova gone. Often dark orange-red coloration.
7 Recovering	Vascular ovaries. Next batch of ova developing.

Gonads were weighed to the nearest 5 g on spring scales of different ranges (0 to 50 g, 0 to 100 g, 0 to 500 g, 0 to 1,000 g).

2.3 Stomach Contents

2.3.1 Full examination

From the 20 fish of each species that had been measured, sexed and staged, a random sub-sample of 5 of each species was given a more detailed stomach examination. This entailed classification of fish diet items generally to the family level, and of invertebrate diet items generally to broader taxonomic levels. All identifications were based on visual characteristics, and therefore the partial digestion of organisms often made identification difficult. The Programme had, at all times, at least one scientist on board with extensive in-the-field experience in classification of stomach items, and this individual either carried out the on-deck identification work himself, or supervised the work of less experienced personnel. Difficult specimens were saved for later identification in the laboratory where time could be spent using the dissecting microscope, reference texts and field guides (e.g. Borradaile et al. 1961; Wickstead 1965; Munro 1967; Nelson 1976).

From November 1979 to the end of the survey, a visual system was used to estimate stomach volume. The categories recorded were empty, almost empty (contents less than approximately 1 cc), medium, and full (stomach walls stretched).

2.3.2 Tuna juveniles

Tunas, skipjack in particular, are suspected to prey heavily on their young, and those of other tuna species, and the incidence of juveniles in predator stomachs can be used to estimate apparent abundance (Yoshida 1971; Mori 1972). For these reasons data were collected on tuna juveniles in the stomachs of predators. From the stomachs of tuna and other species that were given a full examination, all individual fish, or portions of fish, that resembled tuna juveniles were retained. All specimens from a single predator were placed in individual "press-seal" plastic bags, which were punctured and placed in a plastic bottle containing 10 per cent formalin (from October 1978 in 80 per cent ethanol). A sequential tuna juvenile identification number and the number of juveniles in the stomach were entered on the recording slate next to the rest of the biological information for the predator. Later, in the ship's laboratory, the tuna juvenile number, the number of tuna juveniles in the stomach, and the time/date school code were written on waterproof paper which was inserted into the plastic bag. After the first cruise, stomachs from an additional 15 fish per species per school (disc-numbered fish only) were examined exclusively for tuna juveniles. On several occasions during each cruise the accumulated tuna juveniles were sent to Noumea, where they were identified to the species level and measured (standard length) as part of a joint study arrangement with the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM).

2.4 Skipjack Blood Sampling

Genetic analysis of blood samples from skipjack has been used to infer population structuring (Fujino 1970, 1976; Sharp 1978). Methods for preserving these samples are straightforward (Fujino 1966, Sharp 1969); however, at the time the Programme began there was some concern over the number of specimens to obtain per sample. This question was examined in detail during planning of the Programme. It was decided that the combination of tagging and blood sampling would be much more informative about skipjack population structuring than simply obtaining more large blood samples. In order to achieve a reasonable balance between tagging and blood sampling objectives, a blood sample size of at least 100 fish per sample from selected, individual skipjack schools was agreed upon, with all blood specimens coming from the dominant size class in the school. This allowed the combination of tagging and blood sampling such that hypotheses relating to skipjack movement and population structure could be tested with both sets of data.

Blood samples were taken after approximately 500 tagged skipjack had been released from a school. The decision to stop tagging and begin poling fish on deck for the blood sample was made by the chief scientist on board the vessel, and took into account his assessment of whether the school would continue biting long enough to obtain a sample of 100 fish from a relatively narrow size range, and his instructions to obtain blood samples from particular areas. Emphasis was placed on taking samples from areas that had not been covered during previous investigations. The strategy of tagging prior to blood sampling was followed because it was impossible to tell before fishing a school, whether it would bite well enough to produce sufficient catch for both tagging and blood sampling. Taking a blood sample before tagging commenced would have resulted in the sacrifice of many tag releases, and more often than not, there would still have been insufficient specimens for a blood sample.

When 100 or more fish had accumulated on deck, tagging recommenced until the school stopped biting. At this point, as many crew and scientific personnel as possible were involved in the taking of skipjack blood samples (Figure 3). This was done using disposable plastic syringes to obtain 4 to 5 ml of blood from each skipjack by direct heart puncture (Figure 4). The plastic syringes, minus needles, were then inserted into the skipjacks' mouths and the fish were passed to a scientist who measured each fish. A second scientist recorded this length on the syringe and on the slate. Immediately afterwards, in the ship's laboratory, preservative was added to each syringe. Syringes were placed in a labelled plastic bag and then into the ship's freezer at -20°C.

The complete blood sampling procedure generally took less than 45 minutes and did not seriously delay the completion of the routine biological sampling. At regular intervals the frozen blood samples were packaged in dry ice and air freighted to the Australian National University, Canberra, for electrophoretic analysis according to the methods described by Richardson (MS). Analytical procedures used by the Programme when considering electrophoretic results have been described in Anon (1980 and 1981).

2.5 Parasite Sampling

Internal and external parasites carried by skipjack from different parts of the Pacific may shed light on movement and population structuring of skipjack. In December 1979, the Programme began collection of viscera and gills from five skipjack per school, for a maximum of three schools per day. Samples were chosen at random from the fish on deck that were in excess of the standard biological sample of 20 fish. Viscera and gills were placed in plastic bags, one sample per bag, and then the five samples from a school were placed in a larger bag along with a label bearing the time/date school code and the modal length of skipjack in the school. Samples were frozen in the ship's freezer. At regular intervals they were air freighted on dry ice to the University of Queensland, Brisbane, where they were dissected and identified. In addition to the whole viscera samples, scientists counted the numbers of larval *Tentacularia coryphaenae* (a tapeworm common in skipjack) that were visible in the walls of the body cavity of the five skipjack from each school that were given a full stomach examination.

2.6 Data Transcription

Biological data were copied from the slates onto separate log forms for each school and species after the day's fishing had been completed. Appendix A presents a sample log-sheet and the coding instructions.

3.0 TUNA SCHOOL OBSERVATIONS

3.1 Spotting and Fishing

Searching for tuna schools began around 0600 hours, when six crew members began spotting from the upper deck. Each spotter used 7 x 50 mm Nikon marine binoculars which they rested on a wooden mount on the deck railing. The spotting height was approximately 7 m from the surface of the ocean. Depending on sea and weather conditions, visual coverage extended approximately five nautical miles from the vessel in the forward, port and starboard quarters (i.e. approximately 135° in either direction from the vessel's heading).

FIGURE 3. SCIENTIFIC AND FISHING CREW TAKING A BLOOD SAMPLE

FIGURE 4. TAKING BLOOD FROM A SKIPJACK BY DIRECT HEART PUNCTURE

Crew members rotated spotting duty throughout the day (normally 8 to 12 hours) and whenever the vessel was carrying sufficient bait for fishing at least one ship's officer was part of the spotting team. When the vessel was travelling without bait, or with bait and en route to distant fishing grounds, only two crewmen spotted.

Upon sighting a tuna school, usually indicated by a concentration of sea birds, the vessel began pursuit of the school. Once the school was at close range, the Captain decided whether to fish or abandon the school. This decision was taken considering factors such as amount of bait on board, size of the school, species composition, behaviour of the tuna, and weather conditions. Types of schools that were seldom fished included schools where the species were clearly other than skipjack or small yellowfin, or were schools in which large yellowfin ($\geq$10 kg average fish size) were dominant. The latter were avoided because large fish were difficult to pole into the tagging cradles.

A school was considered to have been fished if live bait (chum) was thrown by the chummers. A positive school was a school from which at least one fish was poled onto the deck of the research vessel.

3.2 Data Transcription

The time (local time) that chumming began was recorded by one of the scientists and if other schools were sighted in the vicinity, or were sighted as the vessel pursued a particular school, they were also noted. Schools sighted simultaneously were assigned slightly different times. Schools that were observed while the vessel was travelling were also assigned a time. Next to the time for each school were recorded: sea surface temperature; species composition when fish could be seen or had been caught; school association (birds, log, whale, etc.); school type, such as jumping, finning, no fish visible, etc.; a visual estimate of school size (small, medium, large); and chumming response.

In the evening, the Chief Officer estimated the ship's position, to the nearest minute, for each time entry, as well as the distance from land in nautical miles. Thus each school had a unique time, date and position, which was used in cross-referencing biological, tagging and sightings log records on individual fish. All school observations were recorded in the sightings log, along with counts of the numbers of each species that had been caught and tagged from the school. Appendix B presents detailed coding instructions and a sample sightings log.

4.0 GENERAL OBSERVATIONS

The daily log was a catch-all for recording noteworthy observations. The main activities of the day were noted, for example, fishing, in port, sighting, etc., as well as the hours spent fishing, the hours spent sighting without bait, and general observations on why fishing might have been better or worse than anticipated. Fishing hours included the time spent searching for schools and the time spent fishing schools (chumming and poling). Future investigators would be well advised to use some form of punch-in time-clock so that searching and fishing time could be easily separated.

Records were taken at 0900 and 1500 hours, of wind strength and direction (subjective estimates), sea surface temperature and sea condition

(Beaufort scale); and at 1200 hours the Chief Officer calculated the noon position of the vessel, to the nearest minute. The daily log also contained records of bait carried at the beginning of the day, its species composition, the amount of bait used for fishing during the day, the amount of bait that died during the previous day and overnight, the number of each tuna species that were tagged and sampled during the day, and miscellaneous sightings observations such as whales, other vessels, landmarks, etc. Finally, the remarks section was reserved for the Chief Scientist to comment generally on the day's activities. Appendix C presents coding instructions and a sample daily log.

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APPENDIX A. INSTRUCTIONS FOR COMPLETING THE BIOLOGICAL DATA LOG

Heading in Log	Column Number	Data Entered
COUNTRY	1-4	Three-letter country code plus visit number.
DATE	5-10	Date in year/month/day format.
TIME	11-14	Time school was spotted (taken from sightings log).
SPECIES	15-16	Two-letter code for species or fish examined, e.g. skipjack (SJ), yellowfin (YF). A separate log sheet was used for each species.
CAPT.METHOD	17	Fishing method used to capture, e.g. pole-and-line (P).
BLOOD SAMPLE	18-19	If blood sample was taken from school, a two-letter code identifying blood samples was entered.
lcf	20-23	Length of fish in millimetres measured from the tip of the snout to fork in tail.
wt	24-26	Weight of fish to one tenth of a kilogram.
sex	27	Male (M), female (F), or indeterminate (I).
	28	Stage of gonads: for female gonads see Table 2; for male gonads - ripe (R) or immature (blank).
g.wt	29-32	Gonad weight in grams.
v	33	Fullness of stomach, e.g. full (F).
sec	34	Stomach examination code. An "X" was entered if a complete examination of stomach contents was made. An "E" was entered if examination for only tuna juveniles was made.
stomach contents/ extra lengths	35-39 41-45 47-51	A five or ten letter abbreviation for stomach content items, e.g. <u>Acanthuridae</u> (ACANT). or Lengths of fish in millimetres measured from the tip of the snout to the fork in tail.
total	-	Total of lengths and weights of all fish sampled.
n	-	Number of fish measured.
mean	-	Mean size of fish measured.

school number	-	From sightings log.
total fish on deck	-	Total number of fish of species listed in column 15 remaining on research vessel after fishing school.

BIOLOGICAL DATA LOG

COUNTRY: FIJ2 (1) | DATE (yymmdd): 800416 (5) | TIME: 1410 (11) | SPECIES: SJ (15) | CAPT. METHOD: P (17) | BLOOD SAMPLE: (18)

lcf (20)	wt (24)	sex (27)	g. wt (29)	v (33)	sec	a (35)	b (41)	c (47)	d (53)	e (59)	f (65)	g (71)	h (77)	i (83)	j (89)	
539	3.2	MR	015	F	X	CHUM*	BLUEG	FISHR	TEN06							1
486	2.5	F2	015		E											2
487	2.3	F2	020	M	X	CHUM*	BLUEG	TEN26								3
486	2.4	F2	015		E											4
545	3.5	F2	040		E											5
482	2.5															6
492	2.6	F2	020		E											7
540	3.2	MR	015		E											8
484	2.3	F2	020	F	X	BLUEG	CHUM*	PLANT	TEN11							9
492	2.5	F2	020		E											10
549	3.6	MR	015		E								475	485	520	11
486	2.4	MR	010		E								473	500	550	12
530	3.0	MR	015		E								442	499	530	13
542	3.4	MR	015	M	X	FISHR	CHUM*	TEN02					478	533	476	14
495	2.4	F2	015		E								446	508	520	15
497	2.1	F2	025		E								503	420	510	16
469	2.1	MR	010	F	X	CHUM*	BLUEG	FISHR	TEN12				492	499	430	17
490	2.5	F3	020		E								485	483	496	18
496	2.6	M	005		E								555	531	532	19
536	3.2	MR	010		E								534	470	460	20

lcf	wt	
10123	54.3	total
20	20	n
506	2.7	mean

+ 19 unmeasured

7 school number

69 total fish on deck

recorder GLP

APPENDIX B. INSTRUCTIONS FOR COMPLETING THE SIGHTINGS LOG

Heading in Log	Column Number	Data Entered
COUNTRY	1-4	Three-letter country code plus visit number.
DATE	5-10	Date in year/month/day format.
AREA		A general description of the area.
RECORDER		Person doing recording.
TIME	11-14	Time school was sighted.
NO.	15-16	School number (numbered consecutively each day).
POSITION	17-20	Latitude in degrees and minutes.
	21	N or S indicating north or south latitude.
	22	Blank except when position was only rough estimate, in which case E was entered.
	23-27	Longitude in degrees and minutes.
	28	E or W indicating east or west longitude.
F	29	Spotting reliability - a single letter code used depending upon the experience of the crew spotting and whether or not aerial support was used.
DFL	30-33	Distance from land in nautical miles.
SST	34-36	Sea surface temperature to the nearest tenth of a degree centigrade.
TYP	37-39	Type of school, e.g. breezer (B), jumper (J).
SZ	40-41	Relative size of school (usually small, medium or large).
ASS	42-44	Association of the school with other items, e.g. birds (B), log (L), or tide or current line (T).
CH	45-46	Whether school was chummed and if not, why not, e.g. no bait (NN), or school too fast to chum (NS).
RS	47-48	Response to chumming. Positive or negative and relative response, e.g. positive and good (PG), or negative due to poor quality of bait (NB).
SP	49-50	Species in school. A separate line is used for each species.

TAGS	51-54	Number of fish of each species tagged as per columns 49-50.
POL	55-57	Number of fish of each species poled on deck but not tagged.
TR	58-59	Number of fish of each species trolled (trolled fish were not tagged).
TOTN	60-63	Total number of fish captured.
AWT	64-66	Average weight of each species to tenth of a kilogram as determined from biological sampling.
TOTL	67-70	Total weight in kilograms of all fish captured (the product of columns 60-63 and 64-66).
S	71-72	Number of strikes on trolling lines.
COMMENTS	73-90	General comments on fish behaviour or fishing performance, e.g. schools very flighty or poor approach to school.

SIGHTINGS LOG

COUNTRY CAR3 **DATE** (yymmdd) 800719 **AREA** PONAPE **RECORDER** RDG

TIME	NO	POSITION		F	DFL	SST	TYP	SZ	ASS	CH	RS	SP	TAGS	POL	TR	TOTN	AWT	TOTL	S	COMMENTS
0730	1	0704N	15819E		3.5	291	DS	S	B	P	NB	I								DOWN BEFORE ARRIVAL
0830	2	0759N	15824E		4.5	291	DS	M	B	P	PM	SJ	298	58		356	5.6	1994		BIG FISH
0930	3	0754N	15825E		3.5	292	DS	M	B	P	NB	SJ								
												4F								
1015	4	0751N	15824E		2.0	293	D	S	B	P	PG	SJ	515	90		605	2.4	1452		EXCITING BITING
												4F	6	2		8	3.7	30		
1235	5	0744N	15816E		2.5	298	D	S	B	P	PM	SJ	91	58		144	2.4	274		
												SJ	904	171		1075		3720		
												4F	6	2		8		30		
												Σ	910	173		1083		3750		

APPENDIX C. INSTRUCTIONS FOR COMPLETING THE DAILY LOG

Heading in Log	Data Entered
Six squares in upper left corner of log	Cumulative total. Number of fish tagged by species (skipjack, yellowfin, or other) and by tag type (single or double).
ACTIVITY	For example: fishing for skipjack; day baiting; in port.
DATE	Date in year/month/day format.
AREA	General area of operation, e.g. west of Yasawa Islands.
NOON POSITION	To nearest minute.
WIND	Wind direction and wind speed in knots at 0900 and 1500 hours.
SEA	Sea surface condition at 0900 and 1500 hours.
SST	Sea surface temperature to nearest tenth of a degree centigrade at 0900 and 1500 hours.
AIR TEMP.	Air temperature to nearest tenth of a degree centigrade at 0900 and 1500 hours.
CLOUD	Percentage of cloud cover at 0900 and 1500 hours.
BAIT CARRIED	Number of 1.5 kg buckets of bait carried on vessel.
SPP. COMP.	Code for main baitfish species carried on vessel, e.g. <u>Sardinella sirm</u> (SS1).
USED	Number of 1.5 kg buckets of bait used during the previous 24-hour period.
MORTALITY	Number of 1.5 kg buckets of bait which died during the previous 24-hour period.
RUNNING TIME	Start and finish times of vessel movement.
FISHING TIME	Amount of time spent searching, pursuing, chumming and poling tuna.

TAGS	Number of fish tagged during the day by species (skipjack, yellowfin, other) and by tag type (single or double).
OTHER SIGHTINGS	A one- or two-letter code describing items of interest spotted during the day, e.g. pilot whales (E), log (LL), fish aggregation device (FF).
BIOLOGICAL DATA	Number of specimens examined or collected during the day by species (skipjack, yellowfin, other).
REMARKS	A general description of the day's activities making special note of unusual occurrences.

DAILY LOG

B No. 545

	S	D	
SJ	8630	/	
YF	165	/	
	/	/	

ACTIVITY: Day baiting / Fishing for skipjack. DATE: 30 / 1 / 4

AREA: South of Nuku Hiva NOON POSITION: 9° 04' S 140° 04' W

	WIND	SEA	S.S.T.	AIR TEMP.	CLOUD
0900	E 10	3	28.0		
1500	E 15	3	28.0		

BAIT CARRIED: Night 22 + Day 38 bkts SPP.COMP: SM, USED: 59

MORTALITY: 1

RUNNING TIME: 1015 hrs to 1400 hrs FISHING TIME: 3 hours

TAGS	S	D	OTHER
SJ	468	/	
YF	/	/	

OTHER SIGHTINGS:

BIOLOGICAL DATA:	GONAD	STOMACH CONTENTS	BLOOD	OTHER
	21	6	/	
	/	/	/	
	/	/	/	

REMARKS:

Pulled net at 8.30. No bait appeared to follow the above water light from the bow to the net, however, 22 buckets were captured - even though the lights were on only two hours. At 4.10 a.m no bait around light - lots of moonlight and no cloud cover. Piled the troops into the skiffs at 5.45 for beach seining. Four sets were made. The cloudier the water, the better we did. The last set was an attempt to seine some sardine out of a rocky area into relatively deep water. The set yielded mostly hemirhamphids.

Departed at 10.15 for fishing. First school did not respond. Second was a very large school and we made four passes at it. It bit quite well. Upon examination, stomachs had lots of chum and some shrimp. Finished bait on third school.

Tonight to Tai-pi-vai for baiting.

CHAPTER IV

BAITFISHING METHODS USED BY THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME AND RECOMMENDATIONS ON BAITFISHING TECHNIQUES FOR THE TROPICAL PACIFIC

J.-P. Hallier, R. E. Kearney and R. D. Gillett

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1.0 INTRODUCTION

Most Japanese-style pole-and-line vessels based in the tropical western and central Pacific (Palau, Papua New Guinea, Solomon Islands, Fiji, etc.), and the two vessels chartered by the Skipjack Survey and Assessment Programme, use the same basic "bouki-ami" baitfishing technique. Though the net design is similar, dimensions vary considerably between vessels of different size, as does the use of bait attraction lights. From the commencement of the Programme, Commission scientists modified the conventional Japanese method on the basis of trials previously conducted by scientists from the Department of Agriculture and Fisheries in Papua New Guinea (Kearney *et al*. 1972).

In some fisheries, notably the Hawaiian pole-and-line fishery for skipjack, beach seines are the primary method used to capture baitfish. In April 1978, the Programme began using a beach seine to supplement bait catches made at night.

2.0 THE USE OF THE BOUKI-AMI

2.1 The Principle of Night Baiting

The principles of night baiting are the same for bouki-ami, lampara or purse-seine nets. Powerful lights are employed either above or under-water to attract fish. When sufficient fish have gathered close to the lights, a net is set to catch them. This net, when pulled, forms an enclosure or bag in which the fish are trapped. Different types of nets suit different fishing conditions and purposes, the end result being that baitfish are caught and loaded live into bait tanks.

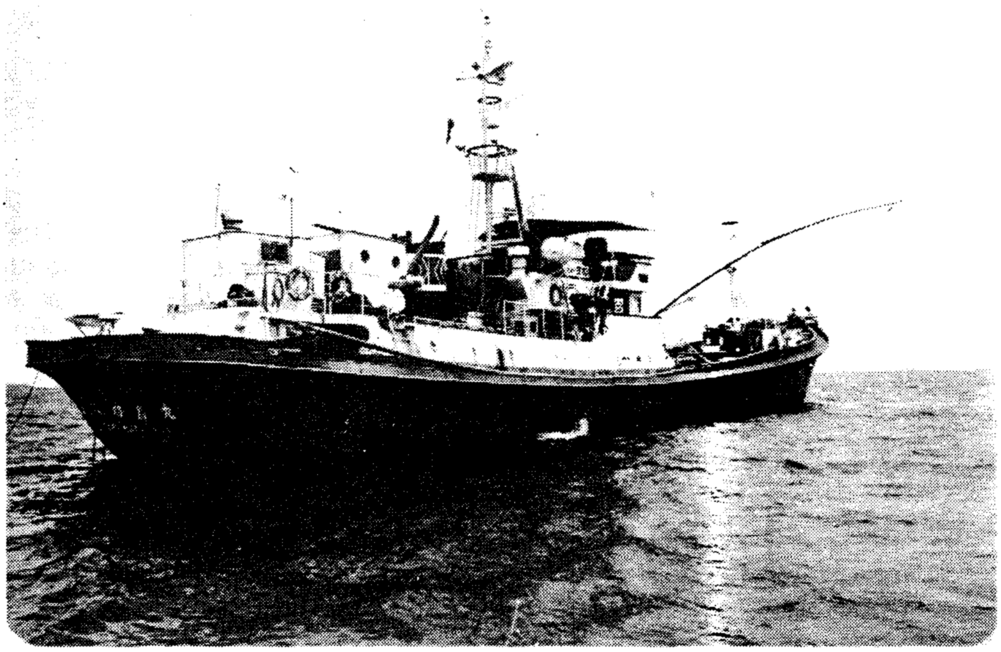
2.2 Fishing Gear

Basic gear involved in the bouki-ami fishing technique includes the vessel, the attraction lights, the net and the bait tanks. Appendix A contains technical specifications for baitfishing gear used by the Skipjack Programme.

2.2.1 The vessels

Two Japanese live-bait pole-and-line vessels, the 192-tonne *Hatsutori Maru No.1* (Figure 1) and the 254-tonne *Hatsutori Maru No.5*, were chartered by the Programme from Hokoku Marine Products Company Limited of Tokyo, Japan. Fieldwork for the Programme during the first two 10-month cruises from October 1977 was carried out using the *Hatsutori Maru No.1*. During the third 10-month cruise, November 1979 to August 1980, the *Hatsutori Maru No.5* was used.

FIGURE 1. THE STARBOARD SIDE OF THE Hatsutori Maru No.5. On this type of vessel most of the sponson along the starboard side is devoted to baitfishing. Note the bamboo net float which is lying on the sponson from the stern to the forecastle. Also visible is the pole for the net light extending over the water from the wheel house.



On standard Japanese pole-and-line vessels, most of the sponson (a ramp, 50 cm wide, that encircles the ship and is attached to the outboard and just below the ship's gunwhale) along the starboard side is devoted to baitfishing operations; the port-side sponson, as well as the bow and stern, are reserved for pole-and-line fishing (Figure 1).

2.2.2 Attraction lights

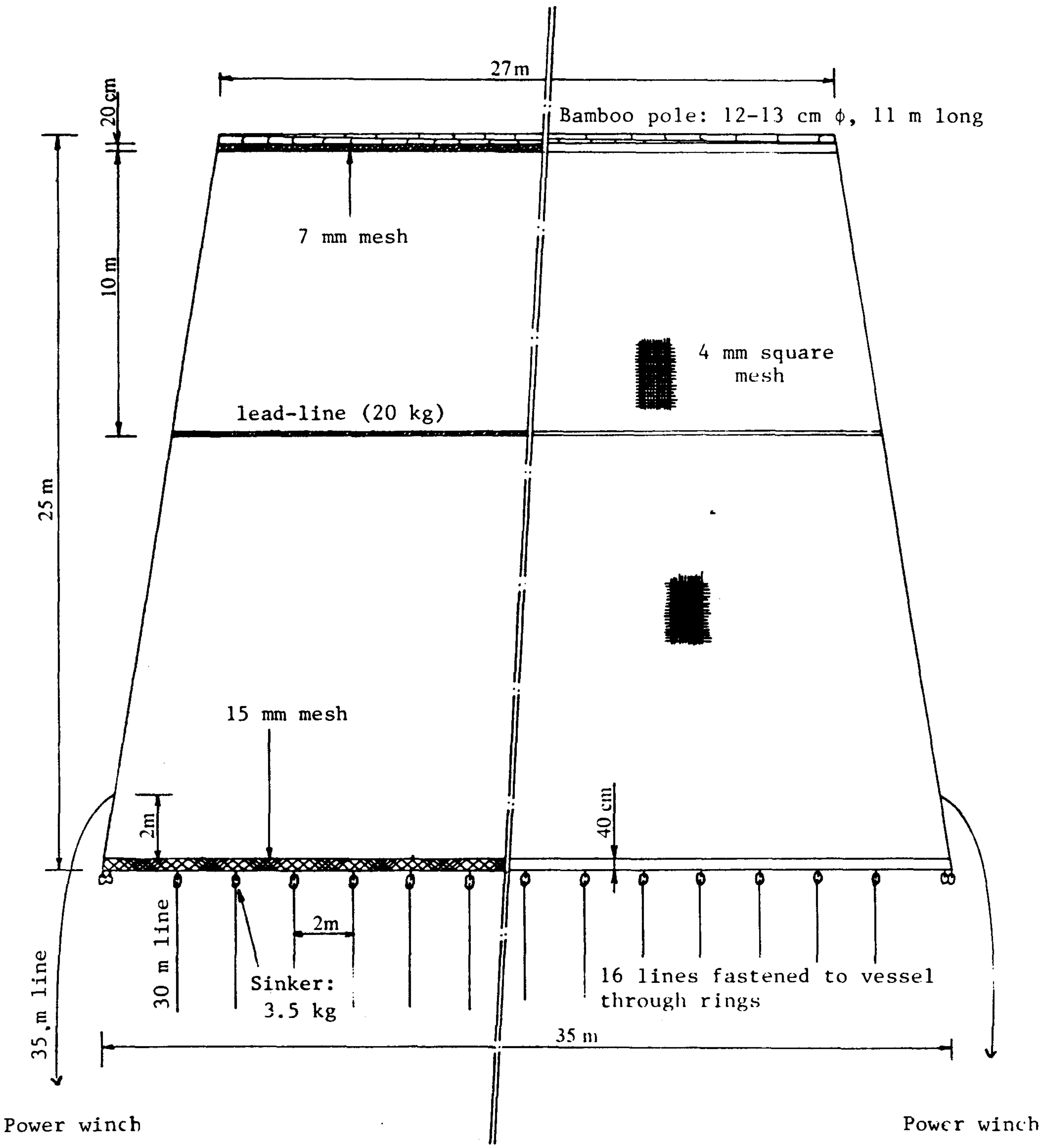
Most Japanese-style pole-and-line vessels operating in the central and western Pacific use underwater lights which are considered efficient in attracting most bait species. These lights are set between the surface and a normal maximum depth of 20 metres.

Bait lights are normally powered by AC current of 100 to 220 volts, according to availability. Power can be supplied either directly from the vessel's main electric system or from independent generators. The Programme initially used underwater lights of 1000 to 2000 watts and later added above-water lights of 100 to 1000 watts. During the transfer of bait from the bouki-ami net into the ship's bait tanks, one or more 40-watt above-water lamps were used to help control the behaviour of the bait within the net and to illuminate part of the deck.

2.2.3 The bouki-ami net

A bouki-ami consists of a sheet of fine mesh netting mounted on a bamboo frame (Figure 2). The net used on the Hatsutori Maru No.1 was 25 metres long at the top, 27 metres at the bottom and 23 metres deep, while the one used on

FIGURE 2. PLAN OF THE BOUKI-AMI USED ON THE HATSUTORI MARU NO.5



20 Sinkers: 16 single + 2 double
(i.e. 2 weights at each end)

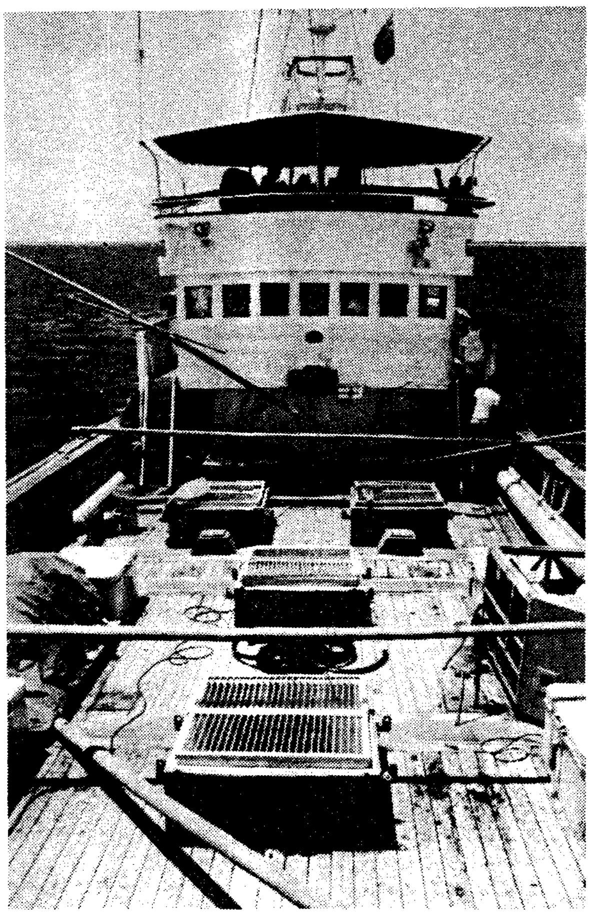
the Hatsutori Maru No.5 was larger, 27 x 35 x 25 metres. Both nets were made from 4 mm square mesh knotless netting made of brown polyamide nylon. Descriptions of the use of this type of net appear in many publications, one of the most recent by Ben Yami (1980). On the Hatsutori Maru No.1, the bottom edge of the net was weighted with 20 sinkers, of 3.5 kg each, placed 2 metres apart with two at each corner. A 20-kg lead-line was attached to the net a third of the distance from the top edge. This helped to keep the net vertical before hauling and prevented folds from forming in the bag while the net was being closed. Eighteen 30-metre lines attached from the sponson to the bottom lead-line allowed the net to be hauled. Two lines, attached on the fore and aft net sides, 2 metres from the bottom of the net, were hauled by power winches and ensured faster closure of the net.

The net, with its bamboo frame, weights and ropes, was assembled prior to the beginning of the vessel charter. The prepared net took up most of the starboard sponson, where it was securely fastened when the ship was not baitfishing.

2.2.4 Bait tanks

On Japanese pole-and-line vessels there are two types of bait tanks: large tanks on the main deck in which baitfish are kept after their capture, and small chumming tanks from which bait is thrown when fishing for skipjack and other tunas. On the Hatsutori Maru No.1, five large bait tanks held a total of 80 cubic metres of water; on the Hatsutori Maru No.5 (Figure 3), seven bait tanks contained 116 cubic metres. All tanks were rectangular in profile.

FIGURE 3. MIDDECK OF THE HATSUTORI MARU NO.5 SHOWING SIX OF THE SEVEN BAIT TANKS. Also visible on the right is the bait transporter (see Section 3.3)



Three types of water circulation systems were used:

(a) Bottom inflow and top outflow

In this type of tank the inflow pipe (20 to 30 cm in diameter) was fixed along three of the inside walls of the well, a few centimetres above the bottom. The pipe was drilled with approximately thirty holes (1.4 cm in diameter) that were regularly distributed along its length. Water was drained off at the top of the tank through an outlet which was covered by a grill to prevent bait from escaping.

(b) Top inflow and bottom outflow

In this tank, water inflow was through a pipe similar to that described in (a), but this pipe was set at the top of the tank just below the top of the walls. The water inflow was directed towards the bottom of the tank where the water was drained through a grill-covered outlet. There was an overflow at the top of the tank for the discharge of excess water, particularly when the bottom grill became blocked with dead bait.

(c) Lateral inflow and top outflow

Water inflow for this tank was through two vertical pipes placed at opposite corners of the tank; holes in these pipes were drilled in such a way that a circular, almost horizontal water movement was created. Outflow was from the standard grill-covered outlet at the top of the tank.

On the Hatsutori Maru No.1, three tanks had a bottom inflow system, one a top inflow system and one a lateral inflow system. All tanks, except one, had cooling coils on the bottom and sides in order to store frozen fish when the vessel was fishing commercially. Five centrifugal HITACHI 2.2 Kw pumps, operating at 1800 rpm, ensured complete water renewal in every tank within 20 to 30 minutes.

On the Hatsutori Maru No.5, three tanks had a bottom inflow system and four a top inflow system. Five of the tanks could be used as freezer holds. Five centrifugal NANIWA 3.7 Kw pumps operated at 1800 rpm and renewed the water in each tank in 15 to 30 minutes.

On both chartered vessels there were two chumming tanks, one at port-stern and the other at port-bow. These small round tanks (265 litres on the Hatsutori Maru No.1 and 375 litres on the No.5) had continuous water turnover approximately every 3 minutes.

2.3 The Bouki-Ami Fishing Technique

Night baitfishing with a bouki-ami is normally a labour-intensive technique requiring at least 20 crew on vessels the size of the Hatsutori Maru Nos. 1 or 5. The sequence for a normal operation can be summarised as follows.

2.3.1 Preparation of the net

Once the ship was anchored at a suitable baitfishing location, the crew untied the bouki-ami and readied the numerous lines. To position the net for fishing, bamboo poles, hereafter called cross-poles, were fastened at right angles to each end and to the middle of the bamboo float. This enabled the net to be moved seaward from the starboard side of the vessel. Prior to setting, the net rested on the starboard sponson with the cross-poles resting on the gunwhales (Figure 3). On both chartered vessels, 12 bamboo poles were needed: six as floats and six (three joined pairs) as cross-poles.

2.3.2 Setting the attraction lights (Step 1 of Figure 4)

Unless the Captain knew the baitfishing ground very well, and knew that it was clear of major obstacles, the vessel was generally anchored before dusk, after echo-sounding for a suitable bottom. An underwater light was then suspended from a skiff tethered at a distance of about 100 metres from the stern of the vessel. Sometimes a second light powered by a generator in another skiff was independently moored at some distance from the parent vessel.

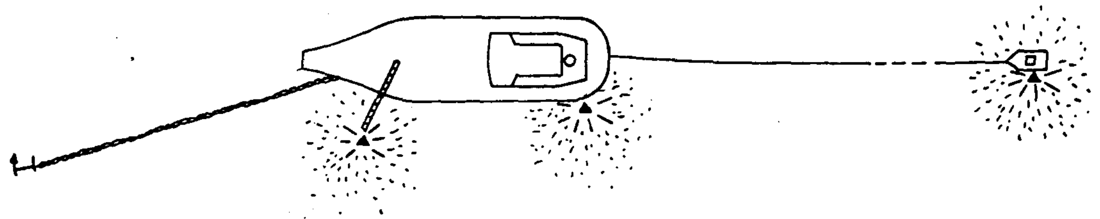
The Programme's research vessels each carried two sturdy fibreglass skiffs. These skiffs were 5.5 metres long and 1.5 metres wide and both were at times used to set underwater lights away from the main vessel. Both research vessels carried two 110-volt generators specifically to supply power for the underwater lights used from the skiffs; each generator provided power for one 1500-watt underwater light. Before nightfall, the 1500-watt light was immersed 10 metres under the skiff, the generator was started and the skiff allowed to drift away from the stern of the ship on its 100-metre-long towline. At the same time, on the port-side near the bow, a 2000-watt light was immersed to a depth of 15 metres. This light was suspended from a bamboo pole which extended about 5 metres from the port-side sponson. A third underwater light of between 1000 and 2000 watts was occasionally set 7 to 10 metres underwater at the stern. Rheostats enabled the light intensity to be varied as required. On the research vessels, two underwater lights, in addition to the skiff light, were controlled by rheostats.

2.3.3 Checking the quantity of bait (Step 2 of Figure 4)

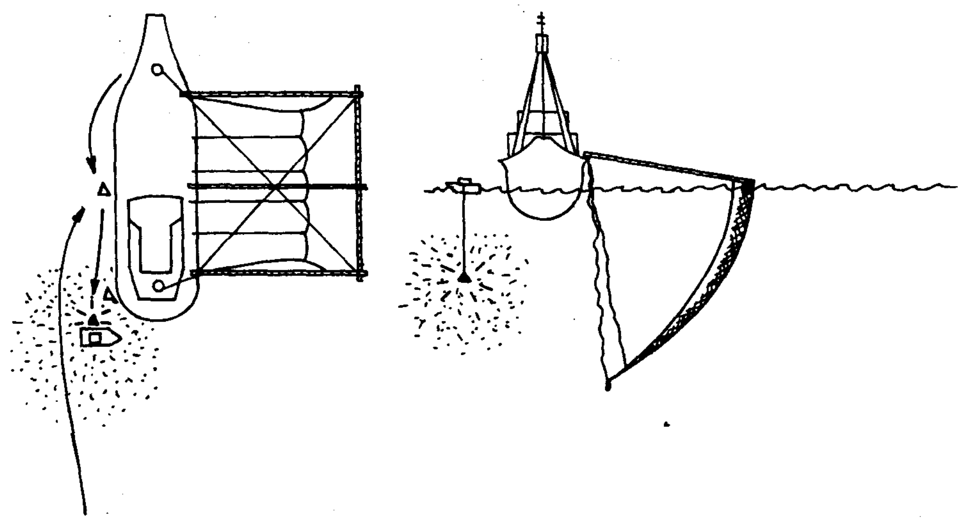
After the lights had been operating for four or five hours, a check for the presence of bait was made. The skiff light and the underwater bow light were moved along the port-side to midship. As the skiff was slowly drawn to the stern of the ship, and subsequently to midship, the stern light, if used, was gradually dimmed to zero, merging the two schools of bait. Simultaneously, the bow light was brought up from a depth of 15 metres to a depth of about 7 metres, and was moved from bow to port midship. The quantity of baitfish present was then checked with an underwater viewing glass from the skiff, and with an echo-sounder. If, on inspection, the quantity of bait was considered to be insufficient, then all lights were switched on again and moved back to their original positions. When sufficient bait had gathered, bait catching operations started.

FIGURE 4. THE DIFFERENT STEPS OF THE CONVENTIONAL BOUKI-AMI TECHNIQUE

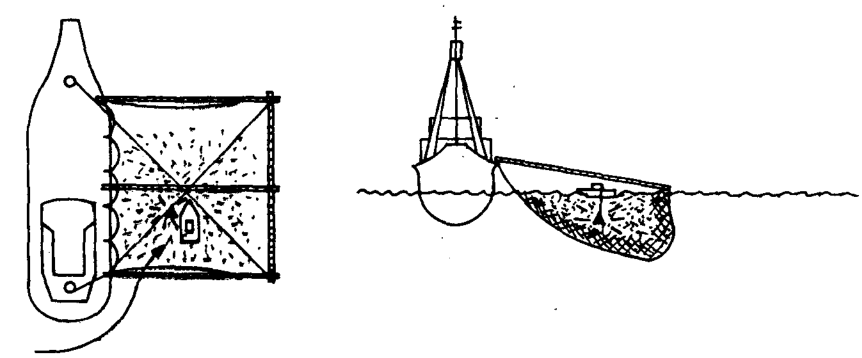
1. Attraction lights on



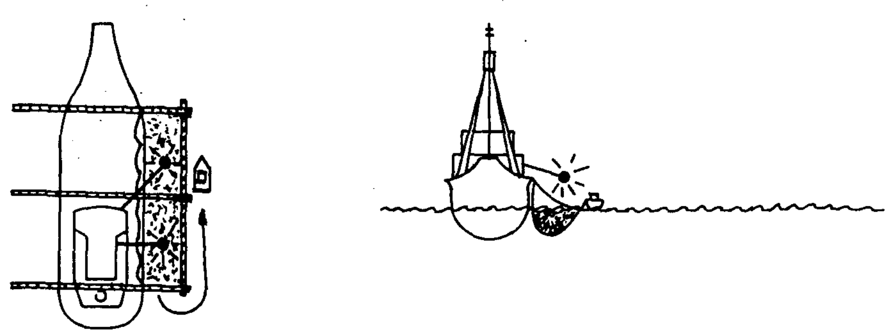
2. Checking the bait and setting the net



3. Concentrating the bait and hauling the net



4. Crowding the bait (see Figure 6)



2.3.4 Setting the net (Step 2 of Figure 4)

Available crew then took up positions on the starboard sponson and at the ends of the three cross-poles. The bamboo float was then lowered from the sponson into the water and gently pushed by the cross-poles away from the vessel. The net, which had been lying along the starboard sponson, then gradually spread out. When the bamboo float was about 18 metres from the side of the ship, the ends of the cross-poles were securely fastened to the ship's gunwhale and two spring lines were tied diagonally across the net to strengthen the framework. The bottom of the net, along with the sinkers and connecting lines, were then thrown overboard from their position on the sponson. While the net was sinking, the fishermen checked the tension on the lines to make sure that the net was spreading out evenly. The fishing master or the Captain also checked the position of the net from the upper deck. The area bound by the bamboo, the net and the vessel formed a box, which on the Hatsutori Maru Nos. 1 and 5 was approximately 26 metres long by 18 metres wide. The attracted bait had then to be drawn to a catching position between the net and the vessel before the net was raised from its vertical position under the bamboo float.

2.3.5 Concentration of the bait (Step 3 of Figure 4)

At this stage, under the conventional Japanese system, two men direct the skiff and its light, around which the bait has gathered, towards the starboard side of the ship. The skiff passes under the stern cross-pole and is moved forward to the middle of the rectangle formed by the bamboo frame and the ship. All movements of the skiff and the attached light must be very slow so that the baitfish follow the light and do not panic. When the skiff reaches the middle cross-pole, the light intensity is reduced. The degree of dimming depends upon the brightness of the moon, the water clarity and the species of bait present. In addition, the light is brought up slowly from a depth of 10 metres to within 1 metre of the surface. The purpose of these two simultaneous operations is to aggregate the baitfish and bring them close to the surface where they are more vulnerable to the net. Baitfish behaviour is monitored with an underwater viewing glass and an echo-sounder. If the bait does not gather satisfactorily around the light, further adjustments of the light are made. If all is well, the net is hauled.

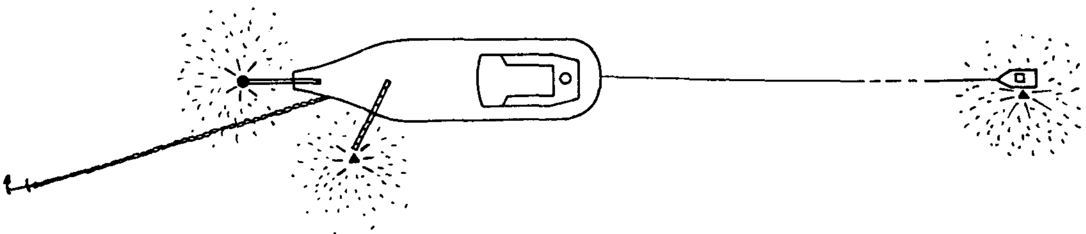
Scientists on board the survey vessels found that the cumbersome operation of bringing the skiff with the underwater light into the framework of the net could easily be replaced by suspending an underwater light in the centre of the net's frame. This modification was first made at the beginning of the Programme in October 1977, and was used with few exceptions during the three years of the Programme's fieldwork. A 2000-watt light was attached to a rope which slid on a pulley at the end of an 8-metre bamboo pole overhanging the bouki-ami. These fittings allowed both the depth of the light and its distance from the ship's side to be adjusted as required. The light was normally set about 6 metres below the surface. After the bait had been gathered around the underwater light at port midship (Section 2.3.2) and the net had been set, the 2000-watt underwater light between the net and the vessel was switched on, and the port light dimmed to effect transfer of bait to the light between the net and the vessel (step 3 of Figure 5).

2.3.6 Hauling of the net (Steps 3 and 4 of Figure 5)

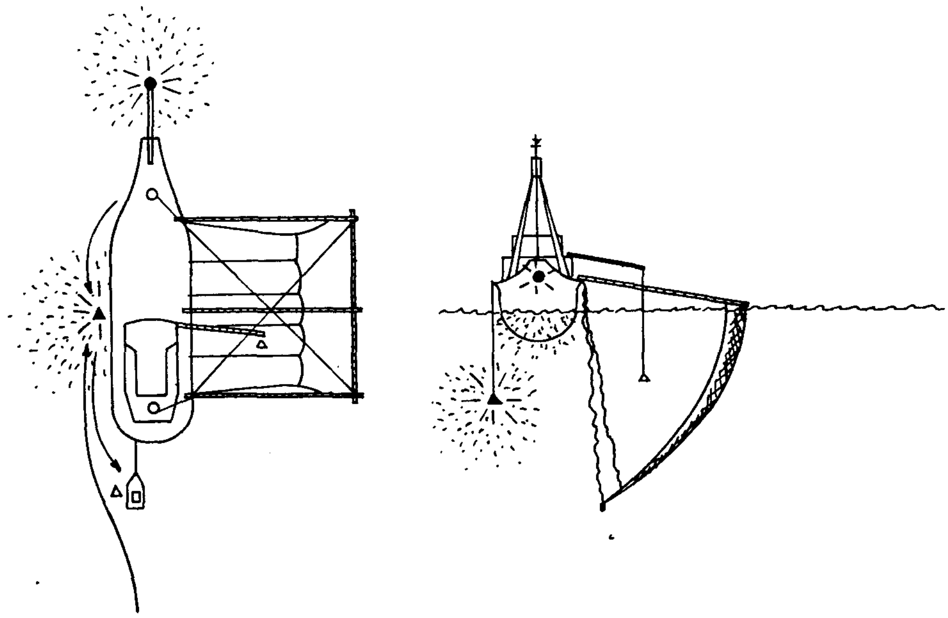
When the Captain and scientists agreed that the bait had concentrated around the light between the vessel and the bamboo float, the signal was

FIGURE 5. THE DIFFERENT STEPS OF THE BOUKI-AMI TECHNIQUE AS MODIFIED BY THE SCIENTISTS OF THE SKIPJACK PROGRAMME

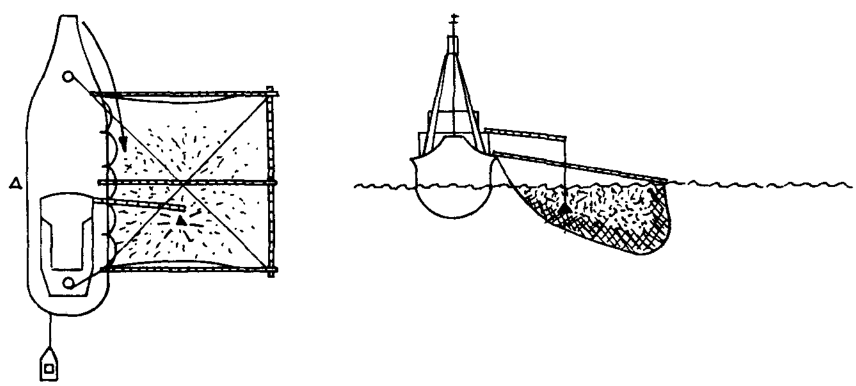
1. Attraction lights on



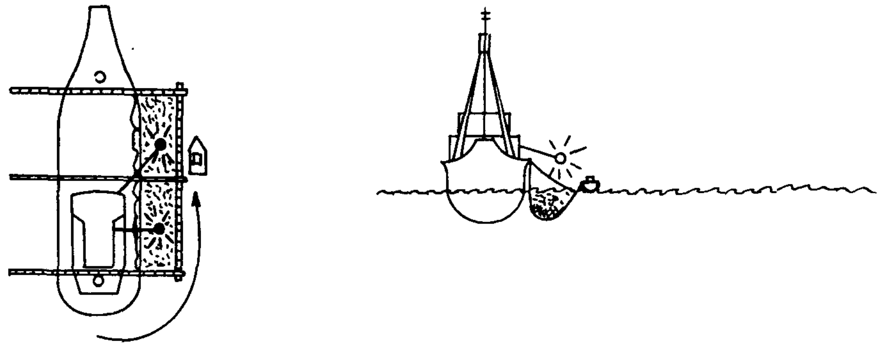
2. Checking the bait and setting the net



3. Concentrating the bait and hauling the net



4. Crowding the bait (see Figure 6)

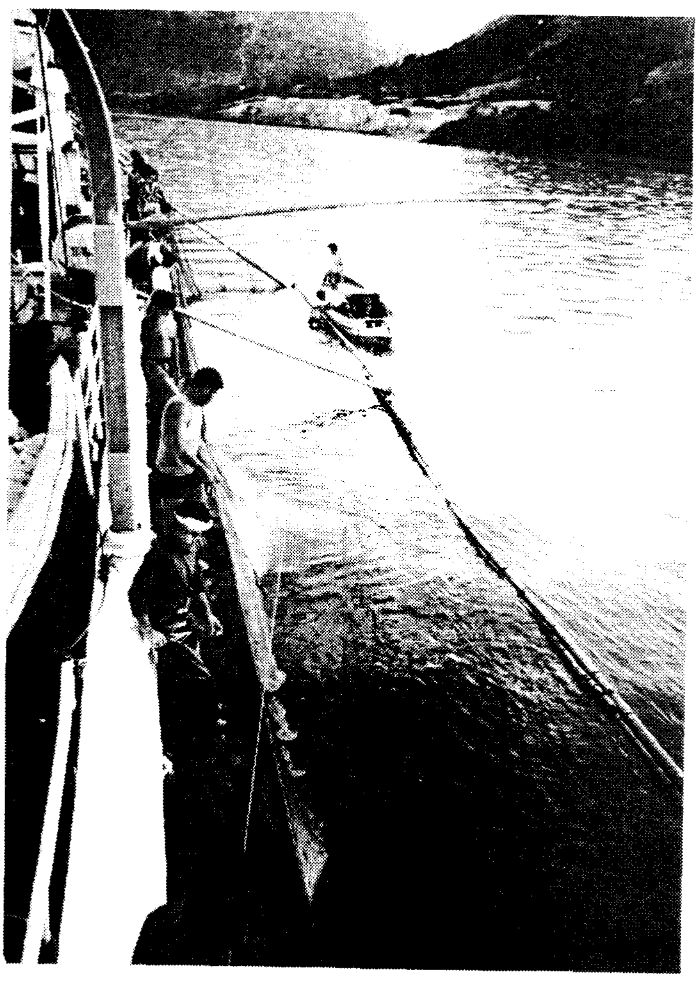


given for the crew to begin pulling the ropes. The two side ropes, which were under considerable tension, were hauled by power winches located at the bow and at the stern of the ship. These closed the fore and aft sides of the net while the ropes attached to the bottom of the net were pulled more slowly by hand.

With all net edges at the surface, the enclosure, or bag, thus formed trapped the bait. As soon as this bag was properly closed, the underwater light in the net was switched off and removed from the water. The skiff was then moved out of the net by the same route as it was entered.

The size of the bag was gradually reduced by hauling the net on board and pulling in the bamboo cross-poles. This work was carried out with the help of the two men in the skiff. During these operations, aimed at concentrating the baitfish, the lead-line incorporated into the mid-section of the net helps to keep folds from forming in the net, thereby preventing live bait from being trapped in small pockets. However, when currents or winds are strong, this lead-line is often not sufficient and additional weights, which are attached to lines connected in board of the sponson, are thrown into the bottom of the net. These weights are gradually removed as the size of the bag is reduced. The final size of the bag depends on the size of the catch, but generally the depth in the bag is kept to between 1 and 2 metres to assist loading, and the width is usually reduced to about 2.5 metres. At this stage, small deck lights are switched on over the net and on the deck to illuminate the loading operation, or the net is left as it is and the bait loaded after daybreak, as shown in Figure 6.

FIGURE 6. CROWDING THE BAIT (Step 4 of Figures 4 and 5)



2.3.7 Loading of bait

The final crowding of the bait in the net took place at the middle of the starboard side of the fishing vessel where the sponson is lowest; this made it easier to transfer the buckets of baitfish and water from the net to the bait tanks. When the bait was crowded into this restricted area, only limited effort was needed to continue adjusting the net, therefore most fishermen were free to assist with loading the bait into the bait tanks.

A plank was then placed across the net, one end resting on the skiff and the other suspended from a strong rope attached to the gunwhale. Two men were positioned on the plank; one guided or scooped the bait into buckets filled with water and the other lifted the full buckets and handed them to the fishermen standing on the ship's sponson, who then passed them from hand to hand (Figure 7) and emptied them gently into the bait tanks. The size of the bag formed by the net was reduced as the loading of bait proceeded.

FIGURE 7. BUCKETING BAIT FROM THE BOUKI-AMI TO THE BAIT TANKS

When all the bait had been transferred to the bait tanks, the last portion of the net and the bamboo float were pulled on to the sponson by means of the bamboo cross-poles. The net was left ready to be used again later the same night, or was tied up until the next baitfishing operation. In the latter case the cross-poles were removed and stored, and the remainder of the net and the bamboo floats simply fastened to the sponson.

Prior to loading bait onto the research vessels, an estimate was made of the amount of bait in the net bag. This estimate was used to decide which bait tanks to fill with water, and how to apportion bait amongst partially loaded and newly filled tanks. This estimate was made well before loading began so that sufficient tanks would be filled with water (15-30 minutes to with its underwater light is brought to midship on the port-side, the above-water light should be switched off. At this time the surface bait under the above-water light should move to the port-bow underwater light, which is then brought slowly towards the skiff and in turn switched off. All the bait, surface or otherwise, gathers around the skiff light. From this point, the conventional procedure continues as previously described.

When weather conditions are poor (rough seas, heavy rain), and/or when benthic or mid-water bait species are present, it is more efficient to use the fixed underwater light between the vessel and net.

At other times, and particularly during periods of full moon, the conventional method is recommended with the addition of an above-water light if surface bait species are present.

2.7 The Selection of Baitfishing Areas

The selection of a baitfishing ground is governed not only by abundance of the desired bait species, but also by physical limitations of the fishing gear. Major factors to be considered are:

2.7.1 Occurrence of desired baitfish species

Suitable bait species are mostly coastal. Populations may be resident or temporary. High abundance is often associated with presence of large shallow expanses of water, e.g. bays and lagoons, with depths ranging from a few metres to about 20 metres (Kearney *et al*. 1978). In the waters surrounding islands with mountainous topography, river sediments and extensive mangrove swamps help to provide a favourable environment for baitfish. For atolls, the size of the lagoon is often a good indicator, the larger lagoons being better.

Water clarity, which varies according to the proximity of rivers, mangrove swamps, currents, swell, etc., also affects bait abundance. For example, sprats are generally found in very clear waters, while anchovies are often associated with more cloudy waters.

2.7.2 Depth and bottom type

The depth of the net often limits the areas that can be fished. Nevertheless, if the bottom is sand or mud, and clear of obstructions, the net can be set in places where the water depth is less than the net fall. During the three years of Skipjack Programme fieldwork, the majority of baitfish hauls were made in waters between 25 and 35 metres deep; however, some sets were made in depths of 20 metres or less. On a few occasions the net was purposely set in shallow water to capture particular species such as Marquesan sardines (Gillett and Kearney 1980). Good quantities of bait are more often found on mud or muddy-sandy bottoms than in areas with pure sand.

2.7.3 Anchoring of vessel

When anchoring the ship, care must be taken to check that the area liable to be covered by the ship as it swings on its anchor is free of all obstacles such as large rock outcrops, coral patches, wrecks or sunken logs. The bottom should also be relatively flat as sudden variations in depth tend to make handling of the bouki-ami difficult, and can damage it.

On both Hatsutori Maru No.1 and No.5, limitations of the anchor windlass restricted the maximum depth for anchoring to about 45 metres.

2.7.4 Currents

Where currents are prevalent, it is sometimes effective for small vessels to anchor "across current" with bow and stern anchors so that the current will push the net away from the ship. This type of anchoring was not attempted with the large vessels chartered by the Programme. Consequently, there were instances where current decreased bait catches by causing the net to billow or fold and fish at a shallower depth than normal.

The bouki-ami, because of its fine mesh (4 mm) and its bamboo frame, is sensitive to even the weakest current. On several occasions, bamboo cross-poles were broken by strong currents. The effects of current could often be minimised by hauling the net during periods of slack tide.

2.7.5 Wind

If winds are strong at the time the haul is concluded, the forward (windward) end of the bouki-ami will occasionally catch the wind and billow like a sail. On the chartered vessels, at such times, 3.5-kg sinkers (the same as those tied along the bottom of the net) were pitched into the billowing net. When winds were exceptionally strong, a chain was attached between the forward end of the bamboo float nearest the bow cross-pole and the sponson. When the net was in position, this chain acted as a lead-line to prevent the net from billowing.

2.7.6 Swell and wind-chop

Rough seas hinder bouki-ami fishing; firstly, because of the very great strain placed on the bamboo poles and the ropes that hold the net in position; secondly, because the skiff becomes difficult to handle; and thirdly, because of injury to the baitfish during crowding and loading.

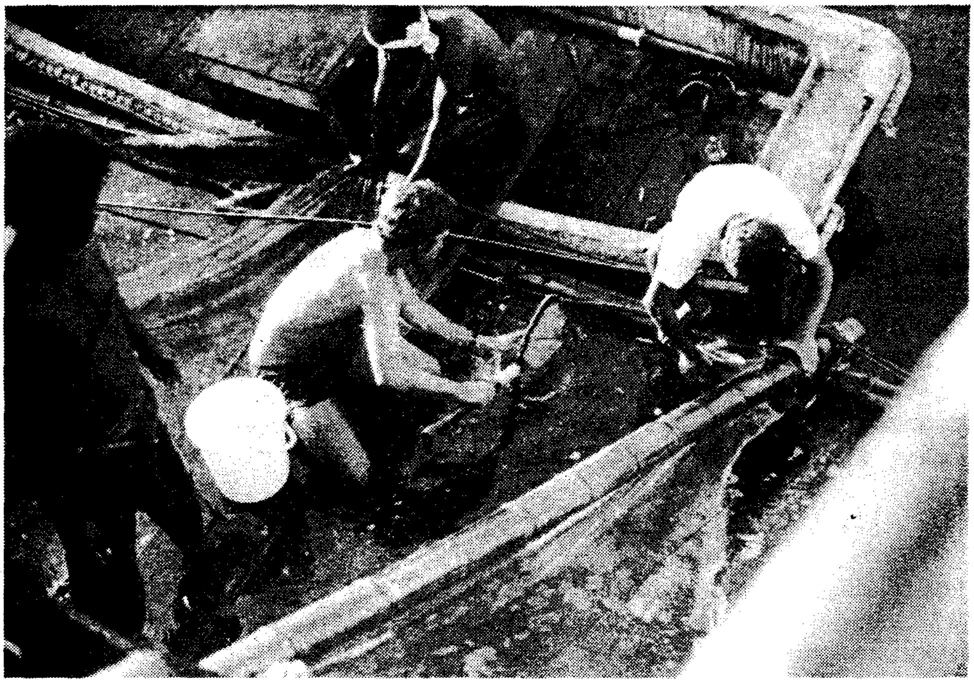
2.8 Recommended Procedures for Loading of Baitfish

Once baitfish are trapped in the net, they must be crowded together for bucketing and loading. Care must be taken during transfer to keep mortality to a minimum. In this respect time is a critical factor. When baitfish are severely crowded they can be loaded much faster, but some species tend to panic more and consequently mortality is higher. On the other hand, loading time increases as crowding decreases, and increased time in the net can also result in a high incidence of injuries.

Once the bait is adequately crowded, it is bucketed on board. Scoops are used to crowd bait into buckets filled with water (Figure 8). If flat scoops are used to fill the buckets, loading takes longer. If deep scoops are used, crowding in the bouki-ami can be less severe and loading time is kept short; however, such scoops result in more abrasion to the bait than the flat ones, which tend to direct the baitfish into the buckets, rather than force them in.

The Skipjack Programme used two scoops of different depths; a 40-cm diameter flat scoop with a stretched depth of 10 cm, and a 40-cm diameter scoop with a stretched depth of 25 cm. The netting in both scoops was of the same material and mesh size as the bouki-ami. Loading techniques were varied according to the bait species captured and the weather conditions at the time of capture. For example, in the lagoon at Wallis Island, the only accessible baitfishing ground for the Programme's vessel was open to strong south-east winds and sea conditions were often rough during loading. The dominant species, a delicate anchovy, Stolephorus devisi, would normally have been loaded in the most gentle manner possible. However, in this instance bad weather required rapid loading, hence the anchovies were tightly crowded and the deep scoop used.

FIGURE 8. GENTLY CROWDING BAIT INTO BUCKETS



2.9 Care of Baitfish Once Loaded

As bait captured by the Skipjack Programme was normally used within hours of capture, there was little need for baitfish husbandry, and consequently improvements to conventional bait handling techniques were few; there were some exceptions, however. Whenever the vessel travelled long distances between countries with bait on board, particularly cultured bait (Poecillia mexicana and Chanos chanos) or bait purchased in Japan (Engraulis japonicus and Sardinops melanosticta), a feeding regime was initiated. Either prepared fish food or finely ground skipjack gonads and flesh was offered several times daily. At times, an antibiotic (Furacin) was included with food, and in one instance a pre-treated fish food containing tetracycline was used to good effect.

The incidence of disease was found to increase when dead baitfish were allowed to accumulate in the tanks for long periods. Thus, as a matter of course, all crew members participated in removing accumulated dead bait from the grills over the surface outlets. This dead bait was either accumulated in plastic buckets placed beside the tanks, which were then periodically weighed before the bait was discarded, or, when mortality was low, the dead bait was simply allowed to pass through the drain by removing and shaking the grill. In this case, the scientist in charge of preparing the bait log made a subjective estimate of the amount of bait dying over a 24-hour period based on visual observations of dead bait on the grills. When dead bait accumulated on the bottom of the tanks, an electrical water pump was used to remove it and the bait so accumulated was weighed before being discarded.

3.0 BAITFISHING WITH A BEACH SEINE NET

Most of the skipjack fleets based in the islands of the central and western Pacific use the bouki-ami technique as the sole means of capturing baitfish. Skipjack Programme scientists appreciated the value of the bouki-ami technique, but felt that, as bait was frequently the limiting factor for skipjack fishing, increasing bait catches by utilising any alternative capture techniques would result in increased tuna catches. In March 1978, the Programme began using a beach seine to supplement bait catches made at night.

The basic principle of this method is to spot a baitfish school in shallow water during daylight hours and then encircle the school with a net set from a fast-moving skiff. Beach seining techniques used by the Programme were based on the Hawaiian anchovy (*Stolephorus purpureus*) fishery; however, in response to variable local conditions and the need to capture a variety of baitfish species, techniques evolved considerably.

3.1 Fishing Gear and Crew

Specifications for the rectangular 148 x 7-metre beach net, made of 4-mm knotless netting, and the 80-metre extension, together with a list of associated gear, appear in Appendix A. This relatively deep beach seine was used in conditions ranging from shallow atoll lagoons (Kiribati) to steep high islands without reefs (Marquesas Islands). It was found that, with experience, the 7-metre net was only a minor disadvantage in water shallower than one metre, and enabled many sets to be successful in deep water. Well over a half of all bait beach-seined by the Skipjack Programme came from sets where the water depth was greater than 4 metres.

The optimum length of the net should be determined according to the target species. For baitfish that are tightly schooled, such as hardyheads and goldspot herring, a short net may be an advantage as it can be set and hauled quickly. For fish that are dispersed or in several small schools strung out over a large area, a long net gives a better catch rate. Marquesas sardine, goatfish and mullet are examples of species which are frequently dispersed. As the Skipjack Programme frequently had to operate in areas of extreme bait scarcity, where these dispersed species were prevalent, an 80 x 2-metre extension was added to the larger net. This additional netting was set after the main net had been paid out, and then only on an optional basis when necessary to capture the remnants of a school or dispersed groups of fish. As it was only 2 metres deep, it was the last section set and the first section hauled, serving only to retain the fish for a few minutes until the school was securely surrounded by the deeper main net. The very light weight of the small section detracted little from the speed of the skiff while in the process of setting.

Additional gear used with the beach seine included a skiff large enough to hold the net and several fishermen, a 25-hp outboard engine, scuba gear for two divers, and a bait transporter. A second skiff was used but was not absolutely necessary. The net could be set with as few as 6 fishermen, but up to 14 were usually involved.

3.2 Fishing Operations

The net was stacked neatly into the outboard-powered skiff with the lead-line forward and the cork-line aft (Figure 9). Wetting the net with a deck hose while stacking proved useful as the wet net sank faster. Four to eight fishermen were involved in the search for bait from the net skiff (Figure 10).

FIGURE 9. THE BEACH SEINE STACKED IN THE 5.5 METRE SKIFF. The cork-line is stacked aft and the lead-line forward. In addition, the photograph shows bait being transferred from the bait-transporter to the survey vessel (see Section 3.3).

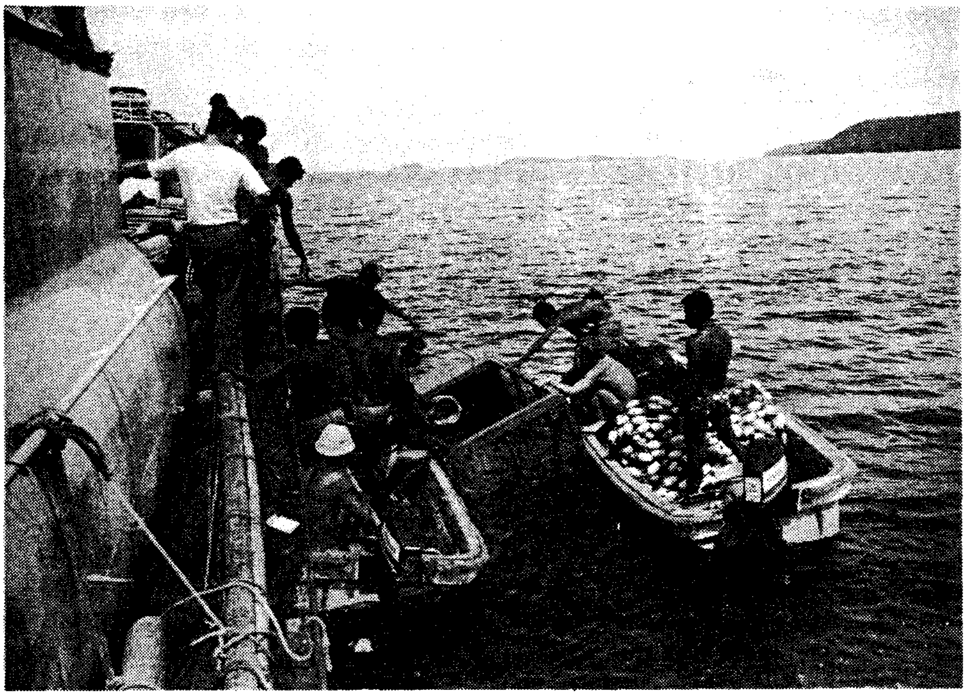
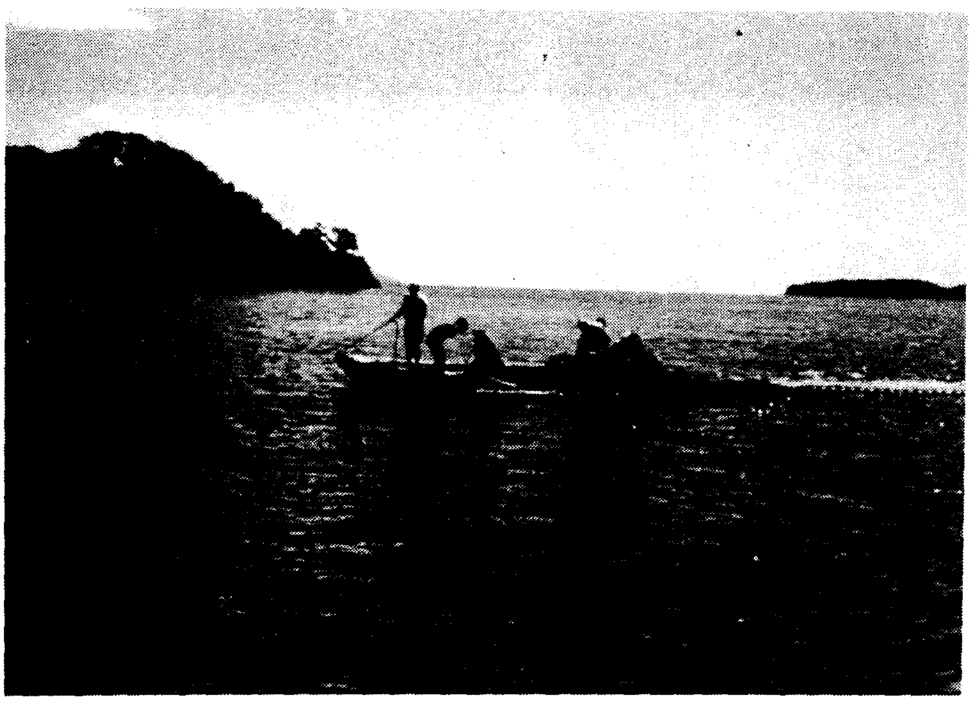


FIGURE 10. FISHING CREW IN SEARCH OF BAIT WITH BEACH SEINE. When the decision is made to set the net, all five of the crew who are standing will dive into the water.

Baitfish were found by looking for birds, spotting bubbles or ripples on the surface, direct observation (in which case polaroid sunglasses were helpful), or by diving with a face mask. After bait had been located, the decision to set the net was based on the absence of large quantities of coral, and the water being deep enough for the outboard but shallow enough for the net.

Immediately upon sighting baitfish that were judged to be vulnerable, one fisherman, holding the tow-line of the net, jumped into the water from the skiff as it was travelling at full speed. A second fisherman tossed the cork-line overboard in bunches of about 2 metres, while a third tossed the lead-line in a similar fashion (Figure 11). Others in the net skiff dived overboard ready to assist with hauling the net. This decreased the weight in the skiff and hence increased the setting speed. The skiff operator paid close attention to the movements of the baitfish, depth of the water, the speed at which the net was being thrown, the amount of net remaining on board, and any coral patches. Depending on underwater topography, distance from the beach, behaviour of the bait and surf conditions, the net was set either in a complete circle (Figure 12), or between two points on the beach. The encircling method resulted in a faster haul, while setting from beach to beach covered a greater length of beach. If the latter technique was used, the ends of the net were walked together along the beach. After the net formed a complete circle, hauling procedures for the two techniques were identical.

FIGURE 11. SETTING THE BEACH SEINE AT FULL SPEED



The cork-line from the section of the net first set was tied to the bow of the skiff. A diver, using scuba gear, was positioned directly under the skiff to hold the two sections of the lead-line together as the net was being hauled. Two to four men hauled and re-stacked the net in the skiff while other crew members constantly dived to clear the lead-line from any obstructions such as rocks or coral. An additional man, a second skiff, or an anchor was used to keep the net skiff in proper position with respect to the net for ease of hauling. During the final stages of the haul, the lead-line was brought together on the bottom and the net was pursed (Figure 13). Most of the remaining net was dried-up to crowd the bait together. Care was taken to eliminate folds in the net in which baitfish could be trapped. Figure 14 is a schematic representation of the setting and hauling process.

FIGURE 12. THE BEACH SEINE FULLY SET (Step 2 of Figure 13)

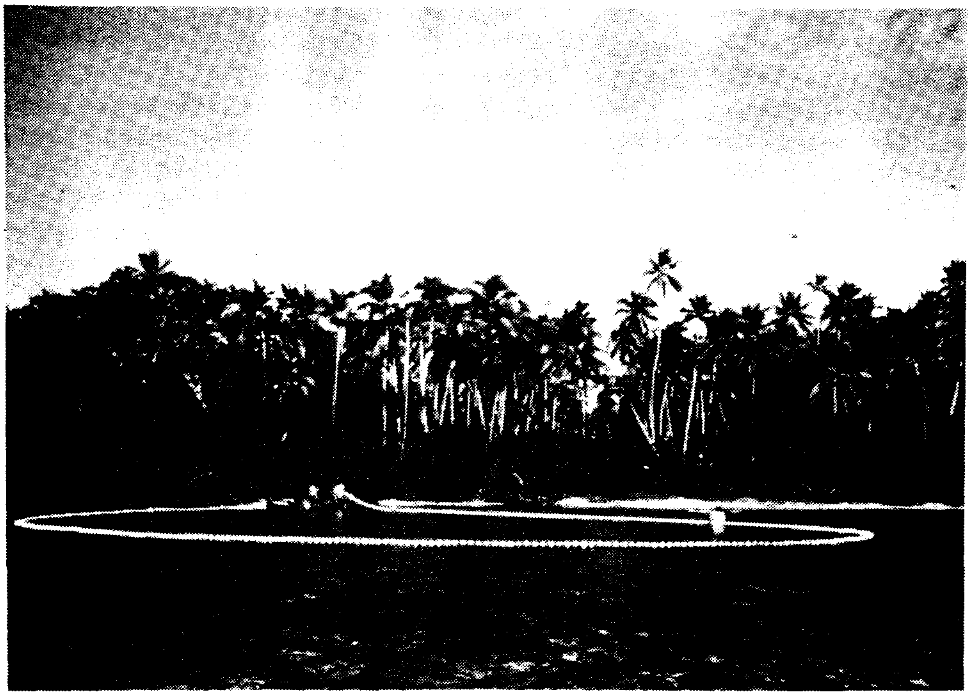
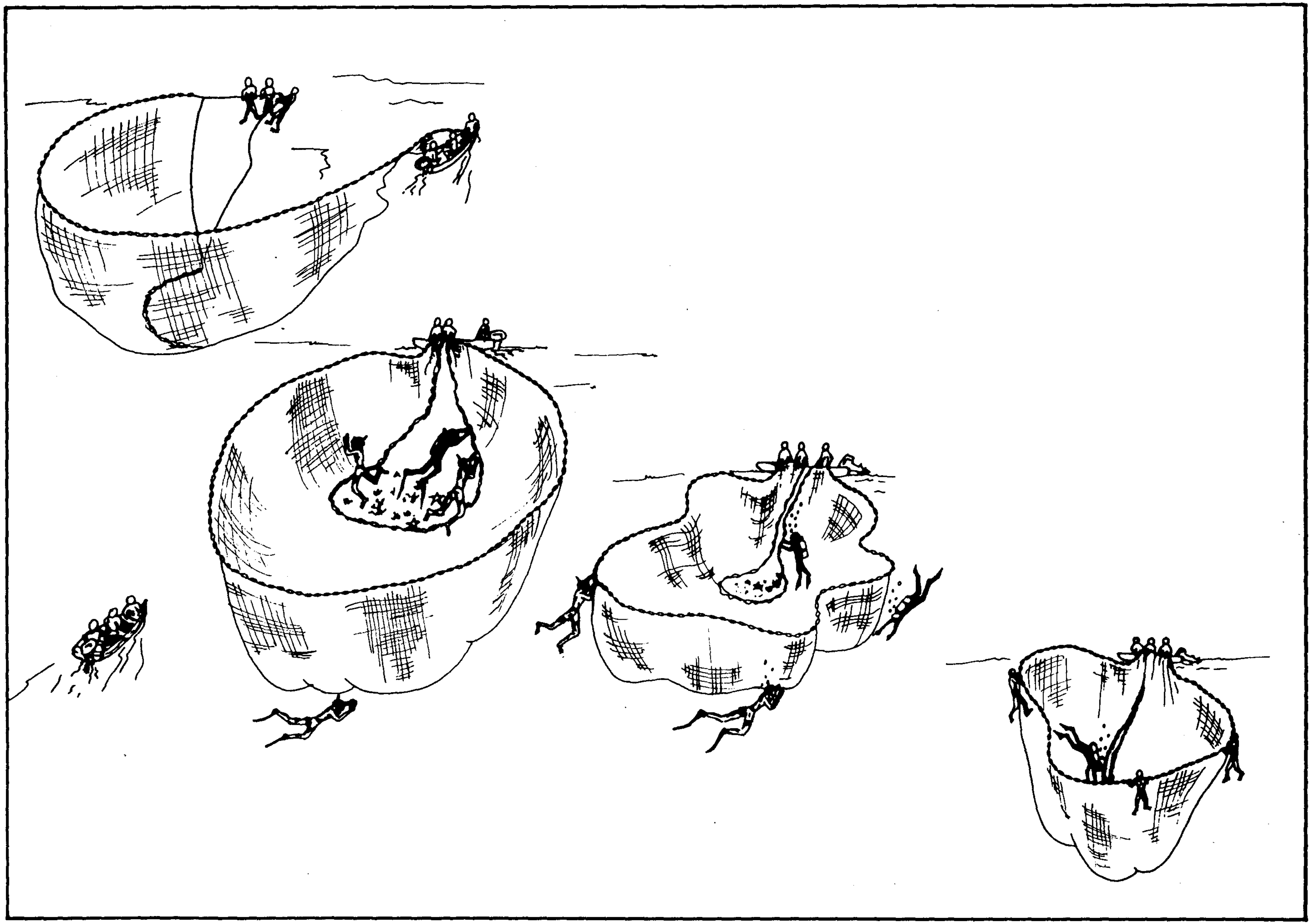


FIGURE 13. FINAL STAGES OF HAULING THE BEACH SEINE. At this stage the net has been pursed on the bottom by bringing the two sections of the lead-line together. Shortly hereafter, both sections of cork-line, both sections of lead-line and netting will be simultaneously hauled on board the skiff.

FIGURE 14. SCHEMATIC REPRESENTATION OF SETTING AND HAULING THE BEACH SEINE



3.3 The Transfer of Bait

As the research vessels drew nearly 4 metres of water, they often could not get close to the beach seining site, thus requiring the bait to be transported considerable distances. A box-type bait-transporter, as pictured in Figures 3 and 9 and described in Appendix A, was considered to be the most successful arrangement for bait transport. If the sea conditions were calm and the vessel was not too far from the baiting area, it was often more efficient to crowd the bait into a section of the net, and then sling this section between the two skiffs for transport to the fishing vessel.

3.4 Modifications

Numerous variations to the above techniques were carried out: (1) Valuable bait species were often found in and around large objects such as old wrecks. The seine was partially set adjacent to a wreck, or other obstacle, and bait scared into the net. (2) Setting the beach net at night in conjunction with an electical generator and underwater light was occasionally successful at the same location where regular day baiting had failed. (3) In shallow water, it was possible to set half of the net and then walk the remaining net several hundred metres parallel to the beach to increase the area of coverage (Figure 15). (4) When there was surf, the set was usually made in deeper water to avoid having the skiff in the impact zone.

FIGURE 15. THE BEACH SEINE PARTIALLY SET. The fishermen have walked several hundred metres along the shore to increase area of coverage.

3.5 Other Considerations

A scuba-equipped diver is considered helpful when water under the skiff is deeper than 1 metre, and necessary in water more than 2 metres deep. There were usually two divers using scuba, one directly under the skiff to haul the net and the other to swim the perimeter of the net in order to free the lead-line from obstructions and then to assist in hauling the net. The entire hauling operation was significantly faster using divers with scuba gear. On occasions, the entire 228-metre net was set and hauled in less than 22 minutes.

Net maintenance was very important. Only rarely was the beach net used without at least a few minor rips in the netting, usually caused by coral or rock obstructions. At the first opportunity after each beach seining operation, the net was inspected and repaired. As the mesh was of square knotless material, patches could be sewn over the holes, a procedure requiring little net-mending expertise.

The stage of the tide affected the success of beach seining in two ways. Firstly, in areas where the bottom was generally unfavourable, due to the presence of coral, seining was sometimes possible in the sandy inter-tidal area during periods of high tide. Tidal ranges are greatest during new moon and full moon periods and the area available for beach seining is then at a maximum. It is therefore convenient that during full moon, when night baiting is poor, opportunities for beach seining are greatest.

Tidal stage also affects vulnerability of certain species. For example, it was thought that the Marquesan sardine was most vulnerable to beach seining at low tide.

The effectiveness of the beach seine technique is greatly influenced by the habitat and behaviour of the species being pursued. Notes on the habitat, school type and behaviour of the most common species exploited by the Skipjack Programme are given in the Table. Despite the often rough beach seining conditions (wind chop, surf, etc.) and frequently long transport distances to the fishing vessel, baitfish mortality was surprisingly low. For instance, Spratelloides delicatulus, considered by some fishermen to be too fragile for use as bait, was beach seined and kept on board for five days during a trip from Truk Island to Saipan. In the Marquesas Islands, mortality for large quantities of beach-seined Marquesan sardine was no higher than that for the same species caught at night by bouki-ami.

3.6 Drawbacks of Beach Seining

A major problem with beach seining is that obstruction free, sandy areas, of proper depth, where baitfish species congregate are rare or non-existent around many islands. Another limitation is that the capture of quantities of fish close to shore during daylight hours could cause conflict with local traditional fishing rights. Furthermore, the efficiency of the beach seining technique in terms of catch per set or catch per unit of time was usually considerably less than for the bouki-ami. Over a period of three years, the Skipjack Programme caught an average of 45 kg of bait per haul of the beach net (74 hauls), compared to 122 kg per haul for the bouki-ami (561 hauls).

There are other disadvantages which are applicable only in certain situations. For instance, time spent in day baiting activities is normally time lost for tuna fishing. Beach seining is exhausting, physically demanding work that could be an additional hardship on the crew if other intense activities (night baiting, vessel maintenance, successful tuna fishing) are pursued during the same 24-hour period.

TABLE. BAIT SPECIES CAPTURED BY SKIPJACK PROGRAMME WITH BEACH SEINE

Species		Depth Captured	School Type	Behaviour and Comments
Hardy heads (Silversides)	Atherinidae: *Hypoatherina ovalaua* *Pranesus pinguis*	0.1 - 3 metres	Small to medium, dense close to beach.	Slow, easy to spot, easy to catch.
Gold spot herring	*Herklosichthys punctatus*	0.3 - 3 metres	Medium to very large, dense, close and far from shore. Frequently mixed with Atherinids.	Fast, if escape is found from net most bait will follow. Important to keep net on bottom. Difficult to estimate amount and overcrowd. Birds frequently indicate position.
Marquesan sardine	*Sardinella marquiensis*	0.8 - 7 metres	Small to medium, medium density, fairly close to beach. Frequently many small schools in one area.	Long net useful. Can be spotted by small bubbles on surface or by diving. Easily escape from net.
Blue sprat	*Spratelloides delicatulus*	1.5 - 10 metres	Dispersed school. Frequently on edge of drop off. Frequently around piers and wharfs.	Often in deep water adjacent to shallow area and may be scared to catchable location. Difficult to spot without diving. Leap when chased by predators.
Scad	*Selar crummenophthalmus*	2 - 5 metres	Dense, moving	Very fast, will try to outrace skiff, jumping in process.
Goatfish	*Mulloidichthys* sp.	1.3 - 3 metres	Very dispersed. Sandy area near beach. Small schools.	On bottom. Hard to see. Often in shade of overhanging trees.
Mullets	Muligidae	0.1 - 2 metres	Dispersed, near shore	Not usually found in concentrations. Net walked for several hundred metres to increase area of coverage.
Bone fish	*Albula vulpes*	0.3 - 4 metres	Dispersed, on bottom	

4.0 BAITFISH SAMPLING AND DATA COLLECTION

Detailed data on catches of all baitfish species, and their subsequent use, were collected and recorded regardless of which baitfishing technique was used.

4.1 Sampling Methods and Estimation of Total Catch

While the bait was being loaded into the bait tanks following each baitfish haul, a sample of one bucket was taken from approximately every 20 buckets of bait loaded. This sample ratio was reduced for very large hauls, and rarely were more than three buckets taken even when the total catch was more than 60 buckets. The wet weight of the baitfish in the samples was then taken to the nearest 1/10 kg using a spring balance. Total weight of bait loaded was then estimated from the product of average sample-weight and total catch in buckets. When the haul was less than 20 buckets, a sample was taken from several buckets with a small net scoop and the average weight of bait per bucket was estimated visually.

Sometimes the amount of bait caught exceeded the capacity of the bait tanks, and occasionally a significant amount of bait died in the net before loading. In both these situations the bait was discarded directly from the net and the amounts discarded alive or dead were estimated visually.

4.2 Sample Analysis and Estimation of Bait Usage

Baitfish species making up more than one per cent of the catch, or which had potential as tuna bait, were identified to the level of species; others were identified to family or genus. Percentage numerical abundance was determined from counts of each species making up more than five per cent of the sample. For each of these species, a subsample of 10 specimens was measured for standard length to the nearest millimetre with a stainless steel micrometre rule. During the course of the Programme, examples of the dominant species, species whose identification was difficult, and species of particular scientific interest were preserved in 10 per cent formalin or 80 per cent alcohol for the reference collection on board the vessel.

The weight of bait used for fishing each day was generally estimated from the number of buckets of bait taken from the tanks during fishing operations, and a visual estimate of the average weight of bait per bucket. In the middle of a "good biting" school, however, these estimates would often be inaccurate since the amount of bait per bucket was highly variable at such times, and the number of buckets used was sometimes misrecorded. Consequently, this estimate of the amount of bait used for fishing was cross-checked against the amount of bait estimated to have died during the day, and a visual estimate of the amount of bait remaining in the bait tanks at the end of the fishing day. Daily bait usage, in standard 1.5 kg buckets, was therefore monitored on the basis of four observations recorded in the daily log: (1) bait carried at the beginning of the day's fishing; (2) bait used during the day for fishing; (3) bait mortality during the 24-hour period prior to commencement of fishing (Section 2.9); and (4) a visual estimate of species composition of the bait on hand at commencement of fishing (only the dominant three or four species).

In addition to the above information, the following data were recorded for each baitfish haul: date, time and position of the haul, depth of water, type of bottom, and light combinations used. For most bouki-ami hauls, the trace obtained from the Programme's echo-sounder was attached to the log-sheet. Each day, data from individual bait hauls were entered onto the baitfish computer log-sheets, following the coding instructions listed in Appendix B.

4.3 Baitfish Identification

Identification of tropical bait fishes in the field is difficult. Separation of the more common species within the baitfish genera is particularly troublesome, often requiring the use of a dissecting microscope for careful anatomical examinations. The task is complicated because classifications of many baitfish are being revised as a result of current taxonomic studies, requiring constant up-dating of field keys. A draft field guide, prepared by scientists of the Programme, was used extensively by the Skipjack Programme to separate bait species in the families Engraulidae, Dussumeriidae, Clupeidae, Atherinidae, Carangidae, Leiognathidae, Caesiodidae, Apogonidae, and Scombridae. Keys in the guide were based on publications by Schultz et al. (1953), Chan (1965), Ronquillo (1965), Munroe (1967), Berry and Whitehead (1968), Paxton (1972), Whitehead (1972), and Fisher and Whitehead (1974). A revised key for Atherinids was supplied in September 1979 in pre-publication form by Dr W. Ivantsoff, Macquarie University, Australia. Throughout the Programme, field personnel maintained a baitfish reference collection and recorded visual features that assisted in rapid classification under field conditions. Specimens that could not be identified, but were common in the catch, were forwarded to specialist taxonomists for detailed examination.

The field guide, together with the baitfish reference collection accumulated during the survey, were invaluable aids to classification of baitfish species. An updated version of this field guide, including details on distribution and occurrence of the important baitfish species, is currently in pre-publication form (Lewis et al. MS).

5.0 SUMMARY AND CONCLUSIONS

During the three years of the Skipjack Programme, night baiting with the bouki-ami and day baiting with the beach seine led to a total catch of more than 68,000 kg of bait in the waters of 25 countries and territories. Catches with the bouki-ami exceed 65,000 kg, while day baiting with a beach seine in the waters of eight countries accounted for over 3,200 kg. These techniques produced large catches under a wide variety of conditions. Many bait species with different behaviour patterns were vulnerable to one or other, or both methods of capture.

Both techniques are labour intensive; however, this is not generally regarded as a handicap by most Pacific Island countries. The equipment is comparatively simple and resistant to the rough handling on board fishing vessels. Both techniques, when properly executed, are gentle on the baitfish, which is a valuable quality when handling the delicate species common in the South Pacific Commission area.

Trials conducted during the Programme showed that while underwater lights are generally more efficient, an above-water light can be more effective for attracting certain species of surface bait. The practicality of combining both types of lights was demonstrated.

When using the bouki-ami, replacement of the skiff and its underwater light by an underwater light controlled from the vessel's deck, improved flexibility of the fishing operations. Placement of an echo-sounder transducer between the net and the vessel enabled improved monitoring of the bait and the net at the final stage of the fishing operation.

In addition to work on bait capture, several methods of loading baitfish from the net to the bait tanks were tried, particularly techniques for scooping and bucketing live bait from the net. It was possible to improve survival considerably by gently scooping and bucketing bait into the bait tanks.

Details of results from these baitfish methods and resulting resource assessments for each of the 25 countries surveyed by the Skipjack Programme are presented in the Final Country Report series.

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APPENDIX A. SPECIFICATIONS OF GEAR USED FOR BAITFISHING BY THE SKIPJACK PROGRAMME

- Underwater lights :
  2000 watts - 200 volts
  1500 watts - 110 volts
  1000 watts - 110 volts

- Above-water lights :
  100 watts - 110 volts
  300 watts - 200 volts
  1000 watts - 200 volts

- Portable generator :
  YANMAR - 3000 watts - 100 volts

- Bouki-ami :
  Hatsutori Maru No.1 : 25 metres (float-line length)
  27 metres (lead-line length)
  23 metres (depth)

  Hatsutori Maru No.5 : 27 metres (float-line length)
  35 metres (lead-line length)
  25 metres (depth)

- Bamboo :
  Length : 11 metres
  Diameter : 12 cm

- Skiffs (two per vessel) :
  Length : 5.5 metres
  Width : 1.5 metres
  Material : fibre-glass
  Design : bottom flat

- Underwater viewing glass :
  Height : 42 cm
  Diameter at the bottom : 30.5 cm
  Diameter at the top : 26 cm

- Echo-sounders :
  Hatsutori Maru No.1 : SANKEN TS-16 0-1600 metres (4 scales - wet paper) Flying Bridge

  SANKEN NSS 1300 0-1320 metres (wet paper) Wheel House

  Hatsutori Maru No.5 : SANKEN TL-32 0-3200 metres (wet paper), 2 frequencies 28 KHz-200 KHz. Flying bridge.

  SANKEN NSS-1300 0-1320 metres (wet paper), frequency 28 KHz. Wheel house.

Portable echo-sounder : JAPAN MARINA, JMF-707AB-1.2 volts DC, frequency 50 KHz

- Scuba Gear :
  Air tank : 80 cubic foot aluminium SCUBA tanks - max. PSI 3000
  Double stage regulator : Sherwood
  Octopus pressure gauge : 0-3500 PSI, USD
  Backpack : U.S. Divers
  Air compressor : Luchard "Porpoise", 6.7 cubic metres per hour
  Weights : 2 lbs, 1.5 lbs, 0.75 lbs
  Weight belt : Sextec
  Diving masks, fins and snorkels

- Buckets :
  Volume : 13 and 15 litres
  Material : Blue plastic

- Scoops :

	Bait-loading scoops		Bait-chumming scoops
Diameter	40 cm	40 cm	24 cm
Depth	27 cm	12 cm	10 cm
Handle length	80 cm	41 cm	40 cm
Mesh size	4 mm	4 mm	4 mm

- Beach seine :
  Material supplier : K. Kida Fishing Supplies
  212 Kamani Street
  HONOLULU, Hawaii 96813

  Dimensions : 148 x 7 metres
  Type of mesh : 4 mm, square mesh knotless
  Floats : egg shaped, 12 x 6.5 cm, spaced every 24 cm

- Beach seine extension :
  Dimensions : 80 x 2 metres
  Mesh size : 5 mm (bar length) mycle knotless
  Floats : round, 3.5 x 5.5, spaced every 42 cm
  Leads : 4.5 x 2.0 cm, 100 g, spaced 1 metre apart
  Dry weight : 40 kg

- Bait transporter:
  Length : 2.45 metres
  Width : 1.22 metres
  Height : 1 metre

APPENDIX B. INSTRUCTIONS FOR COMPLETING THE BAITFISH LOG

Heading in Log	Column Number	Data Entered
AREA	-	General description of area
RECORDER	-	Person recording data
yymmdd	5-10	Date in year/month/day format
ht	11-14	Time of haul of bait net
ctry	15-18	Three-letter country code plus visit number
no	19-20	Sequential haul number for country
lat	22-27	Latitude of position of haul to 1/10 of minute
long	28-34	Longitude of position of haul to 1/10 of minute
s	38	Surface conditions, i.e. placid, rough
sst	41-44	Sea surface temperature
d	45-46	Depth of water in metres
b	47-48	Composition of bottom, e.g. sand, mud
l	51-52	Code number for location and number of bait attraction lights used
lt on	53-56	Time when lights switched on
n	57-58	Type of net used, e.g. bouki-ami, beach seine
bl	60-62	Number of buckets of bait loaded onto the research vessel
bw	63-54	Average dry weight of a bucket of bait
sbl	65-67	Number of standard (1.5 kg) buckets of bait loaded
bda	68-70	Number of standard buckets of bait discarded alive
bdd	71-73	Number of standard buckets of bait discarded dead
comment	15-80	Comment on unusual circumstances, e.g. moon very bright, strong current
f/gen	15-19	Five-letter abbreviations of family or genus of baitfish, e.g. Spratelloides (SPRAT)

Heading in Log	Column Number	Data Entered
sp	21-25	Five-letter abbreviation of species of baitfish, e.g. *Sardinella* (SARDI) (A separate line for each species)
%	26-28	Numerical percentage occurrence in net haul
lcf	30-68	Standard length to nearest millimetre of random sample of ten fish of each species

* Columns not listed were left blank.

BAITFISH LOG

AREA HELEN REEF 2 **RECORDER** JNI

	yymmdd	ht	ctry	no	lat	long	maosccsst	d	b	s	l	lt on	n	bl	bwsbl	bda	bdd	lt	pr
--H-	800808	0450	CAR3	21	0252•5N	131466•6E	R 29.136	55-					BK-	70221	03		1 20-		

comment

--C- DS SKIFF LT BROUGHT INTO NET

--S	f/gen	sp	%	lcf	lcf	lcf	lcf	lcf	lcf	lcf	lcf	lcf	lcf	m	low	high
1	SRRAT	DELIC	50	56	55	49	48	39	39	33	37	22	28	41	22	
2	DUSSU	ACUTA	21	158	162	160	157	162	152	158	142	160	159	157	142	
3	RHABD	CYPSE	11													
4	SPRAT	GRACI	6													
5	HYPOA	TEMMI	10	59	61	56	61	61	57	65	57	54	55	59	54	
6	ARCHA	LINEO	1													
7	PTERO	PISAN														
8	DIPTE	LEUCO														
9	PARAP	SP														
10	BLENN															
11	SYNOD															
12	SQUID															
13	SHRIM															
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CHAPTER V

DATA PROCESSING PROCEDURES OF THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME

P. Kleiber and C. A. Maynard

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CHAPTER V

DATA PROCESSING PROCEDURES OF THE SKIPJACK SURVEY AND ASSESSMENT PROGRAMME

P. Kleiber and C.A. Maynard

1.0 INTRODUCTION

The Skipjack Survey and Assessment Programme was notably successful in terms of the number of fish tagged, the amount of baitfish caught and the number of fish sampled for the collection of ancillary biological data. This very success brought with it considerable problems of data management, including initial recording of data in the field, transcription and entry of data into the computer, detection of errors, addition of new data as it was acquired, and finally access to the data by users.

Log-books containing data accumulated on board the survey vessel were sent to SPC headquarters, Noumea, at intervals of usually one to three months. It was necessary to assemble this information quickly in an easily accessible form so that incoming tag recapture information from fishermen and fishery officers could be matched with release information and appropriate replies prepared without delay. Another reason for the urgency in data processing was to allow the inevitable discrepancies in the data to be referred to the field personnel and hopefully resolved while the sampling period in question was still relatively fresh in mind.

A computer was acquired to facilitate timely and accurate data management. A considerable amount of effort on the part of the Skipjack Programme staff went into developing computer programs for the purpose of creating, maintaining and accessing data bases.

The purpose of this chapter is to document the data management methods used by the Skipjack Programme to process information gathered on board the Programme's research vessels (see Chapter I), in accordance with the methods described in Chapters II, III and IV. Methods of data analysis, e.g. for the purpose of determining mortality or growth, are detailed in other reports covering these specific subjects. It should be noted that the data management methods evolved considerably during the course of the Skipjack Programme.

2.0 DATA COLLECTION AND PROCESSING ON BOARD THE SURVEY VESSELS

The usefulness of a set of data depends ultimately on the accuracy and precision with which it was originally collected and recorded. Often the conditions during which fish were tagged were not conducive to careful data recording. The Programme quickly evolved a team approach to this problem. All new staff were carefully trained by experienced staff. Responsibility for different aspects of the data was rotated among staff to ensure that all those involved were intimately familiar with all aspects of the field programme. Finally, all activities were scrutinised by the chief scientist in charge of each period of the field programme.

Each evening on board the research vessel, the scientists routinely entered the day's data onto the data sheets. This was usually done as a group since all scientific crew were familiar with the day's collection of raw data and thus they could assist each other in rationalising difficult entries.

At the beginning of the Programme, the data sheets were in "field observation" format (Kearney and Lewis 1978), which proved unsuitable for computerised processing. Once computer files for each data set were designed, data sheets, except the daily log, were converted to a format more suitable for data entry (see Chapters II, III and IV). Field personnel were then provided with detailed instructions for coding data and filling in the forms. As a result, data could be entered on the computer with minimum interpretation and maximum speed.

3.0 DATA PROCESSING AT HEADQUARTERS

3.1 The Computer System

The computer system was based on a Hewlett-Packard 1000 computer configured as in Table 1. The operating system supplied with the computer was designed for real time applications as well as interactive, multi-terminal, time-shared data processing.

TABLE 1. CONFIGURATION OF THE PROGRAMME'S HEWLET PACKARD 1000 COMPUTER

Central processor	16 bit words, 630 nsec cycle time
Memory	384 K bytes
Disk	100 M bytes
Tape	1600 bpi, 9 track, phase encoded
Skipjack Programme Peripherals	
Terminals	5 screen terminals 1 screen terminal with graphics
Graphics	1 25 x 38 cm flat bed plotter 1 graphics terminal (mentioned above)
Printers	1 matrix printing terminal 1 impact printing terminal for high quality print

3.2 Computer Accessible Data Files

Information to which rapid access was required was maintained in files on the magnetic disk. Using the file management system, it was possible to manipulate information in the files by sequential or direct access.

For files with information that was regularly updated or corrected, it was desirable to keep the file size small enough to be handled by the file editor and in a printable character format (i.e. ASCII). For this reason most of the data sets, such as the tag data and the biological data, were maintained as sets of smaller files rather than one inconveniently large file.

3.2.1 Tag files

A set of files was designed to contain information about all tags used by the Skipjack Programme including the release date, time and position and the size of fish at release, and, in the event of recapture, the date and position of recapture and the size of the fish at recapture. Each tag required one or more variable length records. The use of variable length records allowed information to be added to specific records without the need to reserve sufficient space in all records to cover every contingency. Extra information might consist of comments at the end of a record or one or more additional records, as in the case of recapture information. Details of the information included in the tag file records and the record formats are given in the Appendix.

Tag entries were distributed among and located within files according to the tag number which consisted of seven characters, two alphanumeric, indicating the tag series, followed by five decimal digits. The file name of a particular tag entry was determined by the first three characters of the tag number, and the final four characters (digits) determined the position within a subfile. Each file was limited to 10,000 entries corresponding to the numbers 0000 to 9999.

Throughout the course of the Skipjack Programme it was often necessary to access the information for a single tag number, most often when recaptured tags were returned, but also when verifying or updating a particular tag entry. For this reason it was desirable to have direct access to the tag information by tag number. The address of an entry within a tag file could not be calculated directly because of the variable length of the tag entries. However, each tag file was accompanied by a directory file consisting of 10,000 fixed length records, each containing the address of the first record of the corresponding entry in the corresponding tag file. The directory file could be accessed directly using the last four digits of the tag number. The tag file address obtained from the directory file then allowed direct access to the first record of the tag entry in the tag file.

Throughout the analysis of the Skipjack Programme tagging results, it was necessary to access the information in other ways than by tag number. In particular, it was desirable to access all the information for tags released at a given date, time and position, i.e. all the tags released in a given school. Such tags did not necessarily constitute a contiguous series of tag numbers because of the way they were utilised during the tagging operation. Therefore a school directory file was created in which, for each school, there was a record containing a tag file address for each block of tags pertaining to that school. In this way it was possible to access all the tags in a given school directly or to read the tag information sequentially in chronological order of time of release, rather than in order by tag number. A similar directory exists to enable direct access to tags released during a particular visit to a country.

In all, tag release and recovery information occupied approximately 12 million bytes of disk storage with an additional 1.4 million bytes for the tag number directories and 0.2 million bytes for the school directory.

3.2.2 Other Skipjack Programme data files

In addition to the tag data, there were three other basic sets of data produced by the Skipjack Programme and stored on computer files. The biological data were collected from captured fish that were not tagged and released, and included data from genetic analysis of blood samples and data from parasitological analysis of viscera samples. The sightings data contained observations on each tuna school encountered, whether it was actually fished or whether it was just observed. The baitfish data included information on the results of the baitfish hauls and the baitfish samples taken therefrom.

As for the tag information, these data sets were also divided into sets of files composed of variable length records and a variable number of records per entry. Unlike the tag data, the sightings and biological information for a single school were arranged contiguously in the files. However, to facilitate cross-referencing between the sightings, biological and tag data, directory files similar to the tagging school directory file were constructed for the sightings and biological data.

The disk space required for these files was 1,430,000 bytes for the biological data, 534,000 bytes for the sightings data, and 436,000 bytes for the baitfish data. The biological and sightings directory files required an additional 32,300 bytes and 77,000 bytes respectively.

3.2.3 Catch and effort statistics

Catch and effort information was essential to many analyses involving tagging data. Several Pacific Island countries supplied catch and effort data for vessels which fished in the South Pacific Commission region. The largest data sets were those received from Papua New Guinea. Japanese, and some Korean and Taiwanese data were also received in computerised formats. All such data sets contained daily catch, effort and position information by vessel type and were received on magnetic tape. Since the formats of these detailed catch and effort statistics were not identical, different computer programs were written to extract summary information. Data sets from all other countries in the region were obtained only in summary form and were not computerised.

3.2.4 Cartographic data

It was often necessary to display the geographic distribution of Skipjack Programme results, in particular, to show the movements of tagged fish. In order to draw the necessary maps, a cartographic data set was obtained which contained geographic positions of points along coasts, rivers, reefs, etc. for the whole of Asia, Australia, the Americas and the islands of the Pacific. The resolution (i.e. the distance between points) was approximately 0.2 nautical miles. The points were organised into segments, a segment being a series of points which when connected would trace out a coast line, river, or other geographic feature.

A subset of these data, covering the whole of the Pacific Ocean and contiguous land masses from 45 degrees north to 45 degrees south, was maintained on the disk along with a directory file which contained a code indicating the type of geographic feature represented by each segment, the maximum geographic extent of the segment and a file address allowing direct access to the segment.

In order to draw boundaries of economic zones within the South Pacific Commission region, a digitised representaion of these boundaries was prepared by Skipjack Programme staff and appended to the cartographic data base. As these boundaries are not yet fixed by international agreement, this extra data set can be considered only an approximation of where the economic zone boundaries might eventually lie and is in no way intended to prejudice the outcome of any boundary negotiations. The data set can easily be edited to reflect any changes brought about by such negotiations. The cartographic data set maintained on disk occupies 7 million bytes.

3.3 Data Entry and Verification

3.3.1 Skipjack Programme tagging data

Tag release data, which were received from the research vessels in batches of up to 20,000 releases, were typed into temporary files using a special tag release entry program. The same information was then retyped under the mediation of a verification program which checked data fields within the records for reasonable values and verified that each newly typed version of a release record was the same as the original. The temporary files were then corrected and merged into a single temporary file which was subjected to another testing program which detected duplicate entries and produced a listing of all unique combinations of date, time, latitude and longitude found in the temporary file. This listing, sorted in chronological order, was then reconciled against the school sightings log for the same time period. Each item in the listing was matched with a corresponding sightings log entry having the same date, time, latitude and longitude. Most of the data errors were rectified by these procedures. Following correction, the temporary tag release file was merged into the permanent tag files using a program that distributed each tag entry to the appropriate file and assured that the files would maintain their order by tag number. Finally, programs were run to reconstruct the tag file directories.

A different procedure was required for entering tag recapture information. Recaptured tags were received at SPC headquarters at irregular intervals and in batches varying from one to several hundred. When the tags, together with a list of recapture information, was provided by the person returning the tags, the tag numbers on the list were first reconciled with the tag numbers on the actual tags. Input and verification of recapture information was then mediated by a special program. For each recovered tag, the release information was first recovered from the tag files and the operator was then required to verify this against the release information in the original handwritten tagging log. The program would then accept the recovery information and verify that all data fields were within reasonable bounds. For example, it would question recovery records that claimed that recovery occurred before the release date or after the date on which the recovery was being entered. Following a final verification by the operator, the relevant entry in the tag files was updated and the required changes made in the appropriate directory file. This instant updating of the directory files meant that user programs that access the tag files could operate simultaneously with the entry of recaptures.

Despite considerable care taken in entering data, the tag files inevitably contained some mistakes which needed to be corrected. Also new information concerning particular tags or blocks of tags would sometimes need to be entered, and occasionally major changes in codes or formats had to be made. Complete editing of the tag files, e.g. a change in country code, was usually accomplished by writing *ad hoc* programs for each specific instance. For simple changes, the Hewlett Packard file editor was used. In both these cases, programs had to be run afterwards to re-create the tag file directories. In the case of a small number of changes, a special interactive tag file editing program could be used which not only implemented desired changes, but also made the requisite changes to the directory files.

3.3.2 Skipjack Programme data other than tagging data

Upon receipt at headquarters, data generated by the Skipjack Programme had to be added to the appropriate files. For other than tagging information the data were typed into temporary files using the Hewlett Packard file editor. Listings of these files were then verified by eye against the original logs, after which the temporary files were corrected and merged into the permanent files, again using the file editor.

3.4 Directory File Maintenance

When data files are continually being updated, as is the case for the tag files, any associated directory files must be considered to be somewhat vulnerable. Even if the updating procedure includes the updating of the directories, the procedure is so complex that files are occasionally corrupted. Therefore it is important to have programs that can scan through the data base and refresh both the tag directories and the school directory. Since scanning the entire tag data base is a lengthy process, these programs were scheduled to run automatically every night as part of a general disk back-up and clean-up procedure. Similar programs were used periodically to update the biological and sightings data directories.

3.5 File Security

An important consideration in maintaining large quantities of valuable information on computer media is security of that information in case of natural disasters, machine breakdown, or human error. Two systems were used to minimise the possibility of losing Skipjack Programme data files and other files.

Using a program supplied by Hewlett Packard, those parts of the data critical to the success of the Skipjack Programme were stored on tape and immediately verified against the original. The magnetic tapes were then stored at the Australian Consulate in Noumea. At intervals of about three weeks new updated tapes were created and these replaced the oldest set at the Consulate on a cycle of five tape sets. These tapes provided a long-term back-up of approximately four months, and they guarded against serious disasters such as fire or flood that could have destroyed all information housed at South Pacific Commission headquarters.

In addition, a system was developed for convenient archiving of individual files on magnetic tape for later retrieval as part of the normal daily operations. This system included the ability to search a directory of the contents of the archive system to locate files and list descriptive comments about each file.

4.0 ACCESSING INFORMATION IN FILES

Access to the data files was accomplished by way of main programs and subprograms prepared by Skipjack Programme staff. A few main programs were developed for routine data processing. Most of the data processing and analysis, however, was not routine in nature and was carried out by *ad hoc*, user-written programs which accessed the data files by way of special subprograms. These subprograms were designed for ease of use, thus allowing the users to concentrate on the complexities of their particular data analysis task rather than the complexities of data base access.

4.1 Main programs

One of the most common problems, particularly while tags were being recovered, was to list all the information in the files for a particular tag. This was accomplished with a program which would solicit a tag number, locate the tag file entry for that tag, list all records in the entry, and display a summary of the information. In the case of returned tags, the summary also included the calculated days-at-large, and great circle distance and direction from release to recapture point. Table 2 gives an example run for one tag still at large and one returned tag.

TABLE 2. PORTION OF A TFIND RUN. Underlined part is typed by user.

```
TYPE IN TAG : SK12345
  SK12345  620M            78051314501328S17618WKKDOWPS01WAL1S289

                   DATE       LATITUDE      LONGITUDE      SIZE
  Release data:  78/05/13   13deg 28'S    176deg 18'W    62.0cm


TYPE IN TAG : AY06564
REAY06564+ 490M            77122215102142S16638EPYJPHPS01CAL1S273
CAAY06564  640W JAPPOL2    790305     1314N14636E          MAR

                   DATE       LATITUDE      LONGITUDE      SIZE
  Release data:  77/12/22   21deg 42'S    166deg 38'E    49.0cm
Recapture data:  79/03/05   13deg 14'N    146deg 36'E    64.0cm
Distance = 2405.1 naut. miles in direction 329.deg. true.
At large for  438  days.
```

It was sometimes necessary to list information for a series of tags. This was done routinely for sending tag information back to persons or institutions who had returned tags. For this task a program was prepared which obtained tag numbers from an input file containing a list of desired tag numbers. The printed output consisted of the same summary information as produced for a single tag.

In order to utilise the cartographic data base, a program solicited the boundaries of a desired map. It then extracted the relevant data from the data base, placing it into an output file. The output file could then be submitted to another program which plotted the map on a graphics device.

4.2 Subprograms

The large size of the data bases and the necessity of using directory files meant that the process of extracting data records was relatively complex. To simplify data base access, these complexities were embodied in a series of subprograms which would return data records to a calling program.

4.2.1 Accessing tagging data

The principle order of tag entries in the tag data base was by tag number. However, when analysing the data it was most often desirable to access all the entries for a school or group of schools. One subprogram used the school directory described in Section 3.2.1 to obtain tag records for a particular school or chronological series of schools. The most commonly desired grouping of schools was by visit, that is all schools tagged during a particular visit by the Skipjack Programme to a particular country. Another subprogram was designed to obtain tag records for a given visit. A single call to either subprogram returned a single record to the calling program or returned an indication of end of school, end of visit, or end of data. A third subprogram, which was useful in concert with the two previous programs, accepted a release record for a recaptured tag and identified the recapture record and range record, if any. If possible, it also calculated the distance and direction travelled and the time-at-large; otherwise it returned the fact that the calculation was impossible or inadvisable because of a large range in time-at-large or distance travelled.

4.2.2 Accessing other data bases

Analogous subprograms were designed for access to the biological data base, and the sightings data base. These facilitated cross-referencing between biological data and tagging data; that is, given a tagging record, it was possible to access the biological data records for the same school, and vice versa.

Catch and effort data could be accessed by a subprogram to return effort and catch of skipjack for any given one degree square and month. Another subprogram, which accessed the economic zone portion of the cartographic data, was designed not to plot maps but to take a latitude and longitude as input and return the country code of the economic zone containing that point. This was useful in verifying that the country codes in the various data records were consistent with the given geographic positions.

5.0 CONCLUSIONS

A large data base requires careful data management during all phases of data collection and analysis. The Skipjack Programme developed practical field methods to ensure that the data were accurately collected. Computer-mediated steps of verification and error detection facilitated development of a useful data base. This data base, coupled with a number of computer programs, for rapid and easy access to the data, formed a complete and useful data management system which was used by Skipjack Programme staff for all Programme reports and publications.

REFERENCE

KEARNEY, R.E. and A.D. LEWIS (1978). Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of the Solomon Islands (1 November - 4 December 1977). *Skipjack Survey and Assessment Programme Preliminary Country Report* No.2, South Pacific Commission, Noumea, New Caledonia.

APPENDIX. DETAILS OF INFORMATION LISTED IN TAG RECORD FILES

TAG RELEASE RECORD

Column Number	Data Entered
1-2	"RE" if tag has been recaptured, otherwise blank
3-9	Tag number
10	Blank
11	Tag code, e.g. reject (R), number questionable (Q)
12-14	Fish length in millimetres
15	Release length credibility, e.g. measured (M), estimated from biological data (B)
16-17	Tagging quality (see Chapter II)
18-24	Partner tag number if double tagged, otherwise blank
25	Anterior (A) or posterior (P) for double tags
26-28	Partner tag type if double tagged, otherwise blank
29-33	Date (Year, month, day)
34-37	Time (Hour, minutes)
38-48	Position (Degrees, minutes (N/S) - Degrees, minutes (E/W))
49-50	Tag type
51-53	Tagger
54-55	Position of cradle on vessel
56-57	Code for tagging boat (01 = <u>Hatsutori Maru</u>)
58-60	Country of release
61	Visit number
62	Species
63-65	Sea surface temperature

TAG RECAPTURE RECORD

Column Number	Data Entered
1-2	"CA" indicates recapture record
3-9	Tag number
10-11	Blank
12-14	Fish length at recapture
15	Credibility code for the reported length at recapture, e.g. measured by Programme staff (A), estimated from a given weight (J)
16	Blank
17-19	Nationality of recapture vessel
20-22	Type of recapture vessel, e.g. commercial pole-and-line (POL), subsistence (SUB)
23	How tag was found, e.g. found at sea (2), found in cannery (4)
24-26	City where found if found in a market or cannery