THE RESEARCH METHODS EMPLOYED IN THE STUDY OF THE PAPUA NEW GUINEA SKIPJACK FISHERY

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ABSTRACT

The major research techniques employed in the study of the rapidly expanding Papua New Guinea skipjack Katsuwonus pelamis *fishery are detailed. The objectives of the total research effort and aims of the individual strategies are briefly discussed. A brief summary of the results of each aspect is presented.*

IN March, 1971, one year after the commencement of commercial skipjack fishing in Papua New Guinea, a research programme was initiated to investigate the stocks of skipjack and tuna and to study the factors affecting the catch of each species. American (Anon. 1971) researchers had suggested that the skipjack resource in the south-western Pacific Ocean was of the order of several hundred thousand tonnes but little information was available to support such claims. The expanding influence of foreign skipjack and tuna fishing vessels in the waters surrounding Papua New Guinea stressed the urgency for the accumulation of sufficient knowledge to facilitate the formulation of management policies for the utilization of resources available to Papua New Guinea. The research programme was therefore geared towards a three year intensive field work and data collection phase from which preliminary resource estimates could be made along with recommended development policies. Following this phase it was intended that catch-effort data and selected biological information would continue to be collected to be used for reviewing resource descriptions at a later date.

To achieve these aims four major research strategies were employed—

(1) Investigation of the migration and biology of skipjack and other commercially important tuna species. Tagging was used as the fundamental research technique.

(2) Analysis of the bait-fish resources and evaluation of the dependency of skipjack and tuna catches on them.

(3) Aerial surveys of all surface schooling tunas.

(4) Collection and analysis of catch and effort data.

(1) *Tagging and Biological Studies*

The original aims and methods of the skipjack tagging programme have been detailed by Kearney *et al.* (1972), and any modifications in technique subsequently developed, will be covered in the report of the 1972 voyages of the F.R.V. *Tagula* (Lewis *et al.*, in prep.).

Skipjack tagging carried out to date has been almost exclusively from the F.R.V. *Tagula*, and small numbers of yellowfin tuna (*Thunnus albacares*) and bluefin tuna (*Thunnus tonggol*) have been marked and released from the F.R.V. *Rossel*. All tags used were of the standard dart type (see Akyuz 1970, page 1) manufactured by Arthur E. King and Co., Sydney, and consisted of a moulded nylon single barb head, fitted and glued into an 11 cm length of vinyl tubing, bearing the inscription "D.A.S.F. PORT MORESBY", bracketed by duplicate numbers printed at each end of the shaft. Although yellow tags were mostly used, smaller numbers of fish were released which carried either red or blue tags.

A cradle was used for all skipjack tagging (see Kearney *et al.* 1972) but many of the yellowfin and bluefin were merely poled and/or hand-lined onto a foam rubber mattress, tagged and released.

In 1971 no tagged fish were measured; rather, an estimate of length was obtained by sampling fish caught from the same school, but not released. This method proved unsatisfactory for fish taken from schools consisting

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of individuals of greatly varying length. In late 1972 the tagging cradle was graduated to allow an estimate of the length of every tagged fish to be made to the nearest centimetre.

Preliminary experiments to evaluate the comparative advantages in using different coloured tags were carried out, but these experiments were largely unsuccessful, due to technical problems with the manufacture of the red tags.

Table 1 gives the number of releases and re-captures by species in each year since tagging commenced. Most of the releases were from the F.R.V. *Tagula*, but 77 skipjack, 168 yellowfin tuna and all bluefin tuna were released from the research vessel F.R.V. *Rossel*.

The information gained from the 496 skipjack returns has greatly increased the understanding of the movements of this species in the general vicinity of Papua New Guinea, and has allowed the first estimates of skipjack growth rates in the region to be made. Because of the complexity of movements of skipjack and the varying fishing pressure in different areas, accurate estimates of tagging, fishing and natural mortalities have yet to be derived, however the returns received are indicators of fishing pressure and represent a foundation upon which future mortality experiments can be based.

Numbers of the other tuna species tagged have been insufficient to enable any meaningful conclusions to be drawn.

Numerous techniques were employed for the accumulation of other biological data on skipjack and tuna and research efforts were concentrated on the following factors:

(1) Reproductive bioligy, oriented towards determining seasons and areas of possible spawning, and size at first maturity.

(2) Length frequency distribution of the catch and length/weight relationships.

(3) Stomach contents and feeding behaviour.

Specimens were analysed from the catches of both research and commercial vessels and the techniques used were as described by Kearney *et al.* (1972).

(2) *The Bait Fishery*

Late in 1972 several of the fishing masters of the joint-venture fleets fishing in Papua New Guinea claimed that the availability of suitable bait-fish had had more influence on skipjack catches than the abundance of skipjack itself. And indeed, there appears little doubt that as long as the skipjack industry continues to be based on live bait and pole vessels, gross fluctuations in the abundance of suitable bait-fish will be reflected to some extent in the catches of skipjack and other tuna. As a result a considerable portion of the research effort given to pelagic fisheries has been devoted to bait research, with particular emphasis on identification, distribution and measurement of abundance of all bait-fishes and on the biology of the most important species.

Most of the species distribution data has been collected on voyages of the research vessel F.R.V. *Tagula*, and a detailed presentation of the methods and preliminary findings has been previously given (Kearney *et al.* 1972). To date, 206 bait collection stations have been investigated from the F.R.V. *Tagula*. In addition, from February, 1972, until September, 1973, each of the four fishing companies was requested to forward bait samples to the fisheries research laboratory fortnightly.

The following information was obtained from each sample:

(1) Species present in the sample.

(2) Numerical abundance and size range of all species present.

Table 1—**Releases and re-captures of tuna species in Papua New Guinea**

Year	Number Tagged			Number of Recorded Re-captures		
	Skipjack	Yellowfin Tuna	Bluefin Tuna	Skipjack	Yellowfin Tuna	Bluefin Tuna
1971	74	—	—	1	—	—
1972	3459	113	37	249	1	—
1973	4388	389	114	246	—	—
TOTAL	7921	502	151	496	1	—

(3) Length frequency histograms of the numerically dominant species.

(4) Sex composition and reproductive state of the populations of the dominant species.

Examination of all samples has lead to the identification of more than 300 different species, approximately 10 of which appear suitable and are sufficiently abundant to be used as live bait for skipjack and other tuna. Research into the biology of the more important bait-fish has given some indications of the reproductive behaviour of these species and has permitted preliminary estimates of growth rates to be made for a few of them.

A third major phase of bait research was undertaken on samples regularly taken from selected sites near Port Moresby. These stations were maintained primarily to facilitate a more detailed study of the *Stolephorus* spp., which have proved to be the most important bait species in Papua New Guinea. It was hoped that growth rates and reproductive development could be better observed in serial samples taken from the one discrete area. In all, 61 samples from the area have been analysed.

Experimentation with bait handling resulted in improved techniques: it was found that bait mortality was greatly reduced if bait-fish captured at night were held in the net until daylight and then transferred into the bait tanks.

In general, research findings from bait research to the end of 1973 have been most encouraging. While there does not appear to be any single bait species possessing all the attributes of an ideal bait-fish, the species and resources present appear adequate to allow considerable expansion in the skipjack fishery. The major problems appear to be in the management of existing known resources and improvement of handling techniques currently in use.

(3) *Aerial Surveys*

In June, 1972, an aerial survey of skipjack, tuna and other pelagic fish resources in the waters adjacent to Papua New Guinea was proposed, and budget approval for the expenditure of $60,000 was given in September of the same year. The aims and methods of the survey as given by Kearney *et al.* (1973) were:

(1) to investigate the distribution and abundance of surface schools of skipjack tuna species in the waters adjacent to Papua New Guinea;

(2) to derive an estimate of the percentage of the resource occurring within 12 miles of a recognized land mass;

(3) to follow, if possible, any large scale seasonal movements of fish concentrations to complement other facets of the general research programme;

(4) using an infra-red radiation thermometer, to investigate possible relationships between thermal discontinuities at the sea surface and pelagic fish concentrations.

Tenders were called for the charter and the contract was awarded to Territory Airlines Pty Ltd for the supply of a Cessna 336. Although this aircraft had many deficiencies, it was the best available in Papua New Guinea at the time. A professional spotter with considerable experience in Australian pelagic fisheries was employed for the entire survey.

Normally, spotting was carried out at altitudes between 800 feet and 1,400 feet, depending on weather and sea conditions, but after a school had been sighted, the aircraft was often flown much lower to facilitate species identification. The spotter maintained accurate daily flight logs, giving relevant details of time, weather and sea conditions and position and description of every fish school observed.

An infra-red radiation thermometer was hired for use in the survey but, unfortunately, its poor mechanical condition prevented it from being of any value.

The preliminary findings of the survey have been presented (Kearney *et al.* 1973) and a final report is in preparation. In all, a total of 491 hours was flown, and an estimated 36,489 tonnes of pelagic fish (excluding bait-fish) were observed. The survey was most useful in detecting possible new fishing areas by locating good concentrations of fish other than those at present being fished. Under-exploited species, other than skipjack, were also shown to be in good concentration in some areas.

At the completion of the survey it was concluded that the joint-venture fishing companies operating in Papua New Guinea would profit by using light aircraft for fish detection, at least on a part-time basis.

(4) *Catch and Effort Data*

Appreciating the need for accurate description of the catch, a daily catch record form suitable for distribution to the live bait and pole boats was devised. Several modifications to the form were required until the format depicted in *Figure* 1 was accepted and exclusively used in the skipjack and tuna fishery. Some difficulty was encountered in obtaining correctly completed catch returns from all four fishing companies, but with the signing of a fisheries agreement with each company, the Administration* was empowered to suspend any boat or company not complying with reasonable requests for scientific information. Three of the four companies now supply all data required, and most catch returns are submitted within thirty days of the end of each calendar month.

The primary data on the catch returns is coded into a format acceptable to an I.C.L. 1903A computer, and after punching and verifying is sorted and stored on master files by an edit and up-date system coded LE-3 at the Computer Centre, Waigani, Port Moresby.

The programme LE-4 is employed to produce the required reports from the updated master file. Such reports are available in several forms, but for routine analysis a report is given for each moon phase period, each month and each year for every boat, each company and every one degree grid square (*Figure* 2) in which some fishing has taken place in the prescribed period. These reports present the results of only basic data collation and processing (e.g., means for all effects), and no sophisticated statistical procedures are used in the programmes LE-3 and LE-4.

Although values for water temperature and wind and sea condition for each entry are punched and stored on master file, they are not incorporated into the routine reports; it is necessary to store these records for the operation of other statistical programmes, e.g., the stepwise multiple linear regression (see later) which extract appropriate data direct from the records held.

Use of LE-4 allows the monitoring of monthly, seasonal and yearly fluctuations in catch per unit effort, total catch and catch composition. From this information studies of monthly, seasonal and yearly changes in each of the areas fished, and of migration of fish of different sizes throughout the fishing grounds, have been made. In addition, the data is converted to a convenient form for hypothesis testing of the fishery.

At the same time as the completed data sheets are returned, each company is required to submit a summary of the fishing master's monthly report to the company. These reports facilitate evaluation of variations in catch, and are particularly valuable where, despite the abundance of skipjack, catches are poor. Such discrepancies are usually the result of poor response of skipjack to chum, and unless such phenomena are reported separately they may not be detected by examination of the daily catch returns.

Any observed activities by fishing vessels, other than those registered in Papua New Guinea, in the area are also reported in the monthly bulletins.

In addition to the computed monthly summaries of the catch per effort data described above, several other programmes have been used to assist in the investigation of numerous topics of specific importance. These programmes had to be adapted for use on the available computers, the I.C.L. 1903A—the only computer available in Papua New Guinea, and later the C.D.C. 7600 in Canberra. They can briefly be described as follows:

(1) Generation of curvilinear length-weight regression equations—

This programme was adapted from WTLN (Abramson 1971), written by Norman J. Abramson and modified by Patrick K. Tomlinson and Catherine L. Berude. About it Abramson writes: "Fits a curve giving weight as a function of length, produces a table of fitted weights and lengths and provides various related statistics".

(2) The fitting of the von Bertalanfly growth equation to tag return date—

This programme was an adaptation of Patrick K. Tomlinson's original programme, BLG4 (Abramson 1971), which was defined as follows—"Estimates the parameters K and $L\alpha$ of the von Bertalanfly growth-in-length curve, when only the lengths of individual

* Papua New Guinea achieved self-government on 1st December, 1973.

FIG. 1. CATCH STATISTICS FORM USED FOR ALL SKIPJACK AND TUNA LANDINGS.

DAILY TUNA CATCH RECORD

Boat Type	Form Type	Month	Year	Comp	Boat	Crew	No.of Days	Av.
1	2	3 4	5 6	7	8 9	10 11	12 13	14

COMPANY ______________________

NAME OF BOAT ______________________

LICENCE NO. ______________________

TYPE OF GEAR ______________________
(e. g. Pole, long-line or purse seine) ______________________

NUMBER OF CREW ______________________

MONTH ________

						CATCH BY SPECIES WEIGHT IN KG.														
					bait (buckets or hooks x 100)	SKIPJACK		YELLOW FIN		BIGEYE		BILLFISH		MACK TUNA		SHARKS	OTHER SPECIES			TOTAL
day	grid ref.	water temp.	wind vel.	sea cond		Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Species	Number	Weight	Weight
1 2	3 4 5	6 7 8	9	10	11 12 13	14 18	19 24	25 29	30 35	36 40	41 46	47 50	51 55	56 59	60 64	65 68	69	70 73	74 78	
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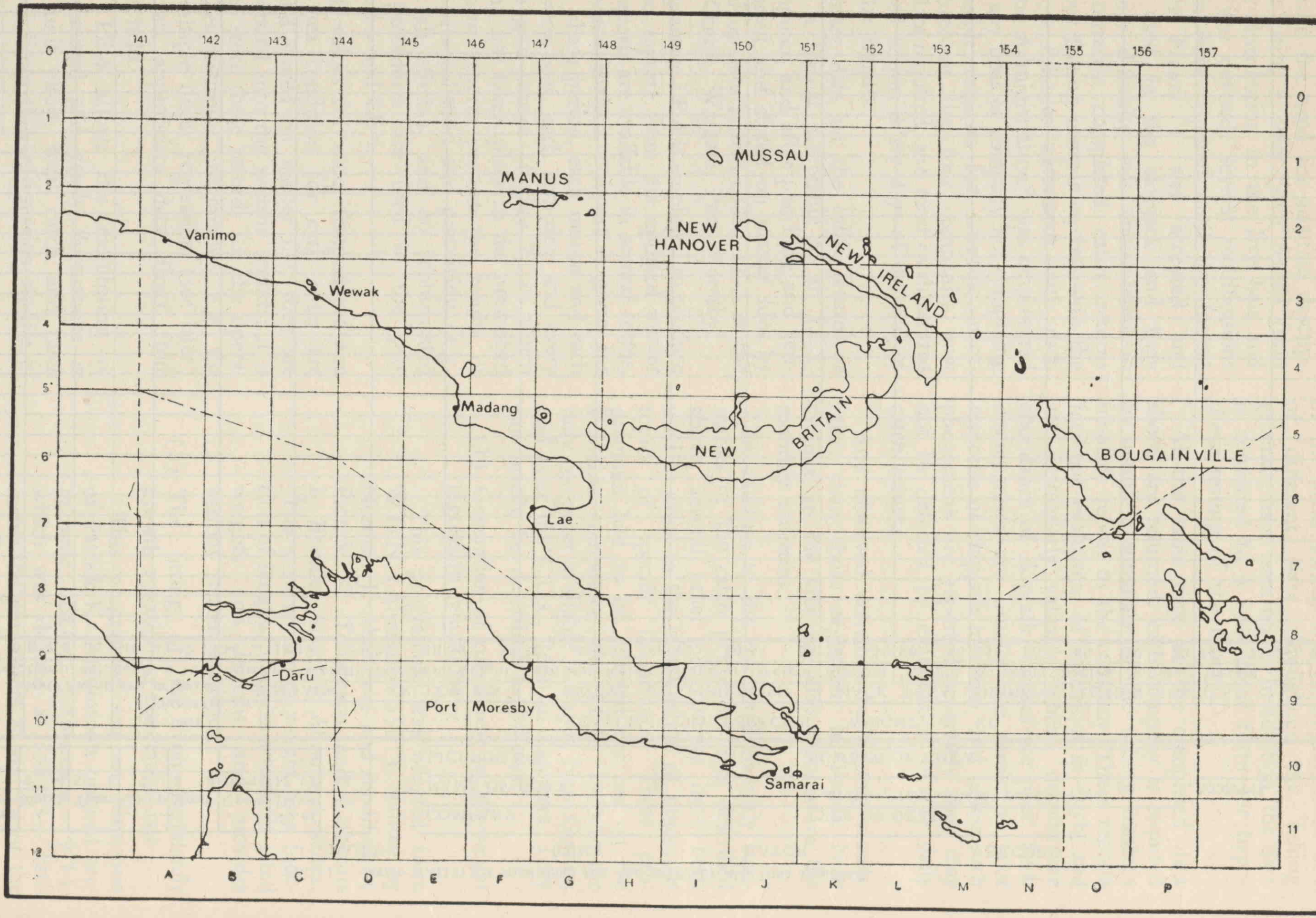
30																				
31																				
TOTAL																				

FIGURE 2 PAPUA NEW GUINEA DIVIDED BY ONE DEGREE SQUARES



fish at two points in time are known. This allows the curve to be fitted to tag release and recovery data".

(3) Normal distribution separator—

A programme was adapted from NORMSEP (Abramson 1971), which was a modified (Patrick K. Tomlinson) version of the original, by Victor Hasselblad. This programme "separates length frequency sampling distributions into component normal distributions. Used to estimate age group relative abundance in length samples of unageable species". In this work it was used for skipjack data, and also for the analysis of data on the most important bait species.

(4) Double or triple classification analysis of variance—

This was an adaptation of the Veldman (1967) programme AVAR 23, which was selected because of its ability to handle unequal sample sizes, and to treat zeros as either missing values or valid numbers, as indicated. The programme was used for routine statistical analysis, involving comparisons of results achieved during fishing periods described by variant parameters, particularly for comparing catch per unit effort variations with season, moon phase and the availability of bait.

(5) Stepwise multiple linear regression—

A programme based on REGRAN (Veldman 1967), selected because of its ability to handle up to 50 variables, and to supply tests of significance of the models selected. The programme was used exclusively on data taken directly from the LE master file, with all variables (e.g., weather, water temperature and bait) being included. Models for the description of skipjack catch were obtained for each year of the fishery, and for each individual company. Correlation co-efficients for every pair combination of variables were determined. The dependence of the skipjack fishery on the availability of bait was highlighted.

(6) Fishing Power—

The programme FPOW (Abramson 1971), written by Catherine L. Berude, was used and run on the C.D.C. 7600 computer in Canberra, Australia. Abramson (1971) states the purposes of the programme as "estimating the fishing powers of individual vessels relative to a standard vessel, and estimating the densities of fish in time-area strata, relative to a standard time-area stratum". Use of this programme enabled catch per effort data to be more accurately presented, and also gave more valuable estimates of the relative densities (actually presented as "catch-abilities") of skipjack in each of the one degree squares fished.

The six programmes listed have already been used for numerous data sets and, in addition, two more programmes are being developed, one for the estimation of tagging, fishing and natural mortalities based on tag release and recapture data, and the other for the study of community structure in the species composition of bait stations.

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