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CSIRO Data Base for Southern Bluefin Tuna (*Thunnus maccoyii* (Castlenau))

Edited by Jacek Majkowski

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CSIRO DATA BASE FOR SOUTHERN BLUEFIN TUNA (*THUNNUS MACCOYII* (CASTLENAU))

Edited by *Jacek Majkowski*

Contributions by *John Hampton, William Hearn, Kevin Williams*

Division of Fisheries Research, CSIRO Marine Laboratories
P.O. Box 21, Cronulla, NSW 2230, Australia

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Abstract

Southern bluefin tuna (*Thunnus maccoyii* (Castlenau)) has been exploited on a commercial scale since the early 1950's. During this time, a large amount of data has been accumulated by research agencies of countries involved in the fishery (Australia and Japan). These data are gross catch and fishing effort statistics (effort data are available for the Japanese fishery only), length distributions of caught fish and tagging data. This report provides details of the southern bluefin tuna data holdings at the CSIRO Marine Laboratories and reviews the methods of their collection, processing, editing and storage. Access to data stored on a computer system is explained. A list of recommendations provides guidelines for the future efficient organization of the system of data collection, processing, editing and storage.

CONTENTS

1. INTRODUCTION

Southern bluefin tuna (*Thunnus maccoyii* (Castlenau)) fishing in Australia and tuna research by CSIRO date back to 1938 (Murphy 1979). In the early years of the fishery, trolling was the only method used, and catches were very small. Pole and live bait fishing was introduced in 1951 but it was not until 1962 that it gained popularity and catches began to increase rapidly. Purse seining was introduced in 1974. The Australian catch increased from a few thousand tonnes in the early 1960's to about 10 000 t in the late 1970's (Majkowski *et al.* 1981).

The Japanese fishery (longlining) for southern bluefin tuna started in the early 1950's (Shingu 1978). Even during its initial stages this fishery was much more productive (in terms of catch weight) than the Australian fishery. The Japanese catch reached about 70 000 t in 1961 and then started to decline, falling to below 30 000 t in the second half of the 1970's.

The Australian fishing effort is directed upon younger fish than the Japanese effort. This is reflected in comparisons of relative weights and numbers of fish caught by the two fisheries (Murphy 1977). New Zealand is presently interested in entering the southern bluefin tuna fishery, and would probably exploit fish of similar maturity to those caught by the Japanese.

Southern bluefin tuna is an economically valuable resource. Prices around $A1 000 per tonne are presently paid to Australian operators by processing companies for canning-quality product. However, the price of sashimi-quality fish in Japan paid to fishermen is over ten times as high. Such high prices provide a stimulus for rapid development of the fishery which can lead to heavy overfishing of the species. Therefore, considerable research on an international scale is required to support the management of southern bluefin tuna. Present management is based on commercial (catch and fishing effort data), length-frequency and tagging data. These data have been collected by Australia and Japan over the past 30 years.

This report reviews the methods of collecting, processing, editing and storing the routine data. It explains in detail the access to the data which are of interest not only to CSIRO but also to the Australian Federal Government, State Governments, research and fisheries agencies as well as to Japanese and New Zealand authorities and research institutes. The report will highlight shortcomings in the present system and indicate areas where improvements need to be made.

2. CATCHES AND FISHING EFFORT

2.1. *Australian catches*

2.1.1. *Data collection method*

Information on catches made by Australian boats is gathered from processing companies by contractors employed by CSIRO, directly by CSIRO staff or by agencies co-operating with CSIRO. Catches are normally weighed on truck weigh-bridges. The landed biomass rounded to the nearest kilogram is logged by boat, date of landing, port of landing and catch destination (company which buys the fish). Catch weights recorded are the actual amounts weighed in at unloading (any losses occurring after this point are not subtracted) and so catch weights, not processed weights, are recorded.

Small amounts of southern bluefin tuna sold on fresh fish markets (estimated at less than 20 t per year) are not included in the catch totals but the fraction of these fish which is sent back from the markets (due to low marked prices) to the processing establishments (canneries) is included. Any fish exported (e.g. to Italian or

Japanese markets) are also included. These catches are accredited to the boat that caught the fish on the appropriate landing date. All individual boat catch totals are confidential to CSIRO and the Department of Primary Industry.

Length-frequency sampling is carried out by contractors employed by CSIRO, directly by CSIRO staff or by agencies co-operating with CSIRO. The sampling has taken place at many of the processing establishments over the years, but is currently limited to Eden (NSW), Port Lincoln (SA) and Perth (WA). There are at present other canneries in Albany (WA) and Melbourne (Vic). Sampling operations are restricted to these places because of the ease of sampling there and the ease of identifying the date of landing and boat involved. These establishments process about 50% of the Australian catch of southern bluefin tuna.

Under ideal conditions, measuring occurs daily and the sample size is usually 200 fish per day. The fish are measured after thawing or removal from a brine tank before they go to the butchering table. The 200 fish are selected at random from the first batch (or batches) to be processed for the day, or the first 200 to be processed are measured depending on circumstances. Fish are measured from the tip of the snout to the fork in the caudal fin. Lengths are measured to the nearest centimetre on wooden measuring boards marked off in centimetres. The scale is offset 0.5 cm and, therefore, the whole number read off gives the length to the nearest centimetre e.g. 64 cm means 63.5 - 64.5 cm.

The number of fish in the batch from which the subsample of 200 fish was taken is recorded along with the total weight of the batch. The number of fish is measured by a digital counter rigged on the processing line in such a way that every fish that passes down the line trips the counter. When numbers are not available in this way (processing not going on) the total weight of fish unloaded by the boat from which the subsample was taken is noted.

2.1.2. *Data processing and storage*

Daily records of landings and length-frequency are received by CSIRO from Eden (NSW) and Port Lincoln (SA) at approximately half-monthly intervals throughout the respective fishing seasons. Monthly landing data are received throughout the year from Albany and Esperance (WA), but the receipt of length-frequency data from Western Australia has been sporadic. All landing data are recorded manually (by vessel and date of landing) to give running totals of catch weight throughout the year.

Length-frequency samples and landing data for each locality are matched by date and grouped by time periods of, ideally, a half-month. Sometimes (particularly near the beginning or end of fishing seasons when catches are relatively small) sample numbers are too small to give a representative length distribution for the catch over one half-month. In such cases, data are grouped by periods longer than a half-month (the period used depends on the number of samples and landed catch weight).

These data are punched on computer cards and input to the length-frequency computer program MGDØ3 (for a listing of this program see Appendix I), which provides estimates of the length compositions by 1 cm length classes, time period and locality. It should be noted that each length distribution is multiplied within the program by the ratio of the actual or estimated number of fish in the batch from which the sample was taken to the number of fish in the sample. So that the length composition may be given in absolute numbers, each frequency is raised by the ratio of the total landed weight to the estimated weight from which samples were taken for that period.

To facilitate their use in various analyses, these outputs are coded and punched in the following format:

Column	Item recorded	Format	Example
1 - 2	Year (last two digits only)	I2	79
3 - 4	Half-month number (1-24)*	I2	09
5 - 7	State (left justified)**	A3	NSW
8 - 10	First length class (cm)	I3	053
11 - 17	Number of fish within the first length class	F7.1	bbb1124
18 - 77	Up to 6 further length classes and frequencies may be specified	6(I3,F7.1)	

* Where time periods greater than a half-month are used, the number of the first half-month in the longer period is assigned and taken to represent that period.

** ALB or ESP are coded for Western Australian samples if the catch location of the fish measured in Perth is known.

If more than seven length classes are to be recorded for a particular period (usually the case), a new record is punched with the information in columns 1-7 duplicated. This is repeated until all length classes and their associated frequencies for that period have been recorded.

Updated annually, the file is stored in a partition of a magnetic tape with the following identification parameters:

Magnetic tape label:	AUSTJPNLFDATA
Magnetic tape VSN:	Variable
Filename:	AUSTLFDATA
File ID:	CFOXJH

2.2. *Japanese catches and fishing effort (entire fishery)*

2.2.1. *Data collection method*

Japanese longline catch and fishing effort data are collected by the Research Department of the Fisheries Agency of Japan (Shimizu, Japan). Fishing effort is measured by the number of longline hooks set. Catches are recorded in numbers of each species of tuna caught. These data are compiled from log books filled out by the skipper and/or fishing master of each longliner operating out of Japan.

The basic unit of data in the log book system is a longline set. The structure of a typical tuna longline is shown in Fig. 1. When setting the line, the main line is paid out over the stern of the vessel at about 7 - 10 knots with the baited branch lines being clipped on just prior to being set. When fishing for southern bluefin tuna, usually five hooks per basket are used. A basket comprises the line between two successive float buoys. Hauling takes place from near the starboard bow. All fish are removed from the lines as soon as they are on board

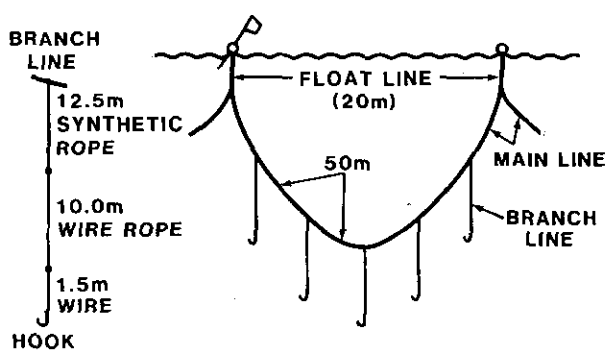

Figure I. Structure of a typical tuna longline (five hooks per basket).

and all lines transported to the stern ready for shooting the next day. One operation, i.e. setting, soaking time and hauling takes about 24 hours. Usually 2000-3000 hooks per set are used.

The Far Seas Fisheries Laboratory (Shimizu, Japan) organizes the length-frequency sampling of the Japanese longline catch. Ten to twenty longline vessels are selected each year and almost all the southern bluefin tuna caught by these boats are measured. Each boat trip (one trip per year) covers two or three major fishing areas (Fig. 2) and 10-20 boats is regarded as providing an adequate coverage of all areas for each year.

The fish are measured by calipers as soon as they are pulled from the water and killed. The gilled and gutted body weight is recorded along with the length in special logs issued to the selected vessels.

2.2.2. *Form of data presentation and storage*

Japanese catch and fishing effort data are presented in a series entitled "Annual Report of Effort

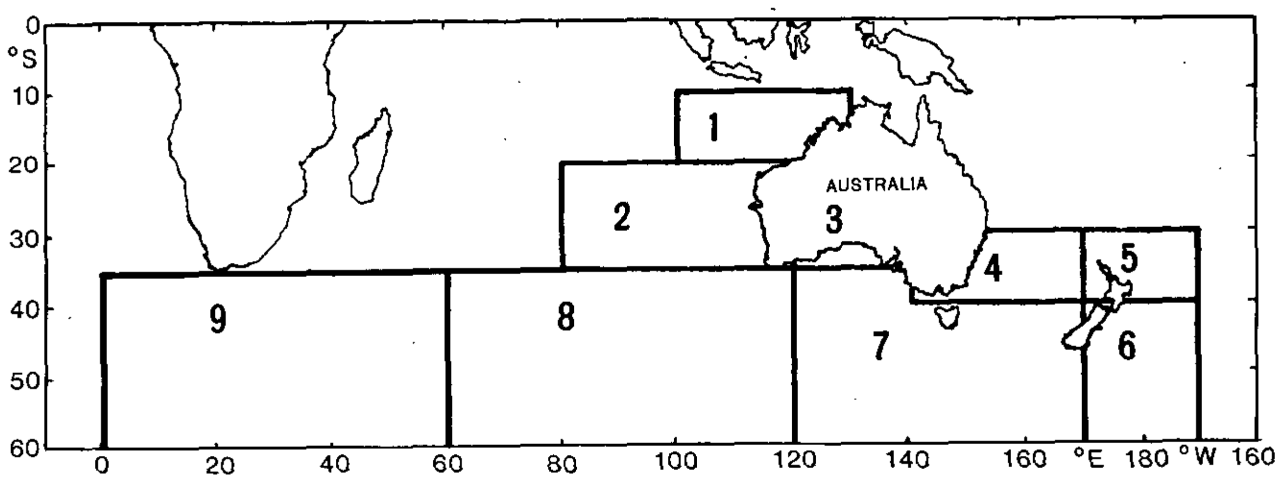

Figure 2. Areas representing major fishing grounds for southern bluefin tuna. 1. "Oka" fishing ground 2. "Oki" fishing ground 3. Fishing ground along South Australia 4. Fishing ground along New South Wales 5. Fishing ground off north New Zealand 6. Fishing ground off south New Zealand 7. Fishing ground around Tasmania 8. Fishing ground in south-central Indian Ocean 9. Fishing ground south of Africa

and Catch Statistics by Area of the Japanese Tuna Longline Fishery 19.." published by the Research Department of the Fisheries Agency of Japan. The Marine Laboratories Library at Cronulla, currently holds these publications for the years 1962-1979.

The data consist of monthly estimates of fishing effort (in sets and hooks) and catch (in numbers) by tuna species. These data are tabulated by 5° grid squares, type of operation (individual vessel or mothership plus catcher boats), size of vessel (20-50 tonne class, 50-100, 100-200, >200) and type of bait (squid, saury, livebait or other). Finer scale data (e.g. daily catch and effort for 1° squares) are available on request from the Far Seas Fisheries Research Laboratory. In each publication, the data are summed to give yearly estimates of fishing effort and catch, tabulated in the same way.

It should be noted that the fishing effort statistics refer to the entire Japanese longline fishery (i.e. for all species of exploited tuna), so some selection is necessary when analysing fishing effort statistics for the southern bluefin tuna fishery.

Computer listings of length-frequency tables are received annually from the Far Seas Fisheries Research Laboratory detailing catches in 2 cm size classes, by quarter of the calendar year and Japanese statistical area (see Fig. 2). This information is not published, but can be obtained on request from the Far Seas Fisheries Research Laboratory. Receipt of length-frequency tables is currently about two years in arrears. All tables are held at the Marine Laboratories Library, Cronulla. Data from the tables are coded and punched on to computer cards. For each length class and area in that year, the following card image is recorded:

Column	Item recorded	Format	Example
1 - 2	Year (last two digits only)	I2	52
3 - 4	Area (see Fig. 2)	I2	03
5 - 7	Lower length of size class (cm)	I3	131
8 - 10	Upper length of size class (cm)	I3	132
11 - 20	Number of fish caught in year quarter 1	I10	16
21 - 30	" " " " " " " 2	"	5
31 - 40	" " " " " " " 3	"	52
41 - 50	" " " " " " " 4	"	17381
51 - 60	Total number of fish caught in this year and area, from the length class specified above	I10	17454

Data in this format are stored using PFBACKUP on the CSIRONET computer system as a file in a partition of a magnetic tape within the following identification parameters:

Magnetic tape label:	AUSTJPNLFDATA
Magnetic tape VSN:	Variable
Filename:	JPNLFDATA
File ID:	CFOXJH

2.3 *Japanese catches and fishing effort in the Australian Fishing Zone (AFZ)*

2.3.1. *Data collection method*

Data have been collected since the proclamation of the AFZ on 1 November 1979. These data are received in the form of radio reports and log books.

(a) *Radio reports*

Japanese longline vessels fishing in the AFZ are obliged, under the conditions of their licence, to radio details of total catch, species composition of catches and fishing effort every six days, and to state their position at the time the message is sent. All catches are given in weight (kg) and number of fish. Fishing effort is reported as number of hooks set. The radio messages are received in telex form by the Australian Coastal Surveillance Centre (ACSC) in Canberra.

(b) *Log books*

Logs are issued to vessels with their licence before they commence fishing in the AFZ. The log is of a fixed format type with respect to species catches, and has a provision for the specification of size gradings for southern bluefin tuna. Other information provided by this system include the GMT noon position in degrees and minutes, number of baskets of gear, and number of hooks set. Completed log sheets are forwarded to the Department of Primary Industry (DPI), Canberra.

2.3.2. *Data processing and storage*

(a) *Radio reports*

Telexed data are keyed directly to disc by operators at ACSC, with summary information being copied to the CSIRONET computer system daily. Each week, the accumulated data are edited and stored in a FORDATA data base by staff of DPI. For details of the editing and storage process see Morris (1980).

Radio report data are not usually more than ten days old so they provide a good indication of year-to-date catch and effort for the fishery. For details of the method of retrieval and output options consult Morris (1980).

(b) *Log books*

The editing and storage of log book data are undertaken by DPI staff and involves the use of the software developed by Morris (1980). Updates to this data set are recorded on a data base status report which is held on the CSIRONET computer system as a partition called DBSTAT of the FLASHBL ED library of user ID CFOXGB.

3. FISH TAGGING

3.1. *Tagging method*

Almost all tagging of southern bluefin tuna was carried out by CSIRO staff on commercial or charter live bait and pole fishing vessels. Fish were caught on a barbless hook attached to a feathered lure on the end of a short line held by a stout bamboo pole. After a fish had been hooked it was hauled aboard the vessel where it was measured, tagged and quickly returned to the water (usually within 30 seconds). Records were kept of the date, geographical position, tag numbers and lengths of the tagged fish.

The dart tags used were made of 12-15 cm lengths of 3 mm O.D. polypropylene tubing fitted with moulded nylon dart heads glued into one end. Tags were fitted into stainless steel tubing applicators, approximately 13 cm long and 3.5 mm I.D. sharpened at one end. Using the applicator, the tag was inserted into the musculature of fish approximately 35-40 mm below the second dorsal fin at an angle of 45° to the body and pointing towards the head of the fish. The dart head was buried about 25 mm into the muscle and the applicator removed. Ideally the tag barb should then have been anchored in or around the basal bone elements of the fin rays. The procedure was repeated on the other side of the fish for double tagging.

Fish were double tagged initially to estimate the rate of tag shedding. Also, fish tagged during the early 1960's were injected with an antibiotic to help combat tag shock, handling and infection. This practice was later discontinued on a regular basis and used only in special cases, and then for the purposes of marking the calcareous tissues in the tagged fish. Oxytetracyline (the antibiotic) effectively marks the hard parts (e.g. ear bones) of the fish and enables growth during the period from tagging to recapture to be evaluated.

Information sought on the recapture of a tagged fish is date and geographical position of recapture, length of fish, gilled and gutted weight of fish, and in the specialized experiments the otoliths (ear bones) are required. This information along with the tags is usually forwarded by fishermen to CSIRO or its contractors and a reward paid. An example of a CSIRO reward poster is shown in Fig. 3.

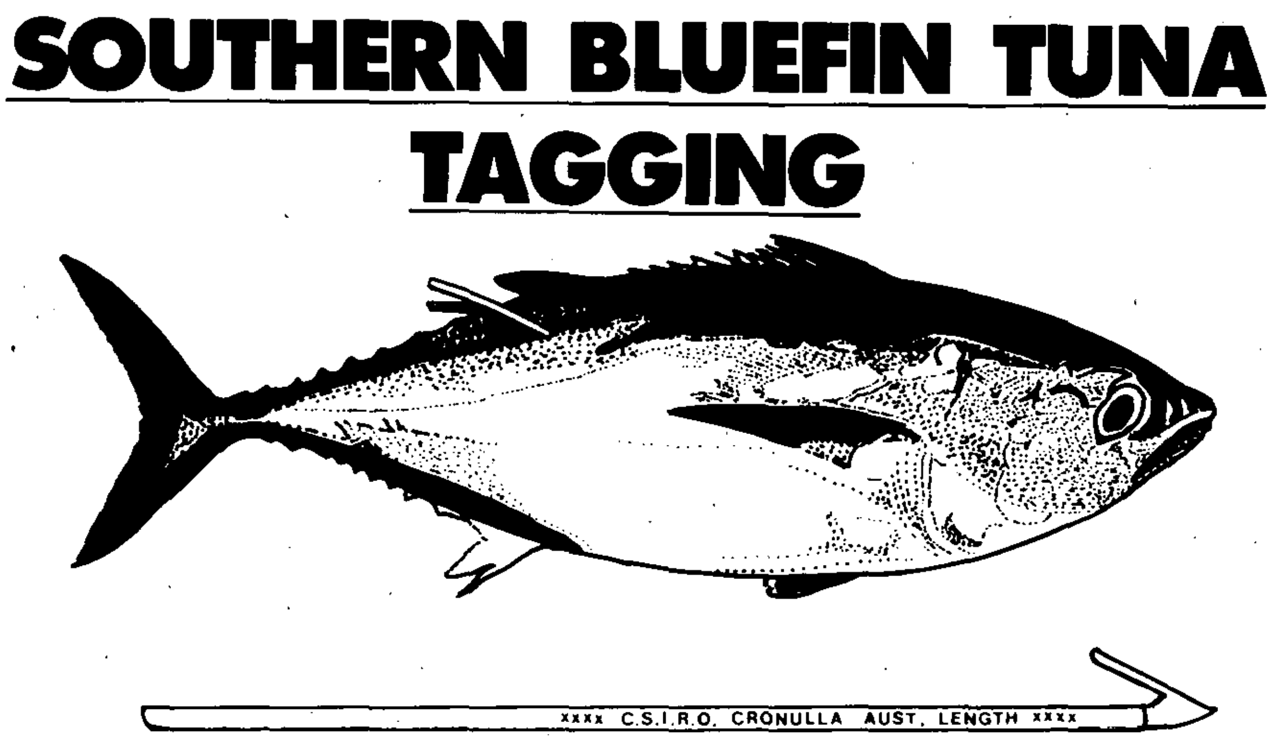

Figure 3. Southern bluefin tuna tag reward poster.

3.2. *Data processing, editing and storage*

3.2.1. *Data documentation*

The tagging data and background information are recorded in various files, original letters associated with recovered tags, published material and computer tapes. Table 1 describes manual documentation of tagging data, gives details of the data items recorded, and indicates the degree of data completeness.

A computer card image record is made for each tagged tuna. These are sorted by date of release, vessel code and tag number (in that order), and contain tag release and recapture (if the tag(s) have been returned) information. The format of computer storage of the data is described in Tables II-IV. All data records associated with the tags returned up to December 1978 have been edited by the author by comparing them with the available written documents and checking their internal consistency. The editing procedure and the resultant data are described below.

3.2.2. *Data editing*

All documents concerning individual tag returns were examined for comments or manifest inconsistencies indicating data of doubtful accuracy. Codes corresponding to these doubtful data were added to the computer tape records in previously blank fields (see Table II). In addition, written records associated with tags returned from the Japanese longline fishery were compared with the computer tape records; errors and omissions were corrected.

Release and recapture vessel codes were compared, by computer, with a master list of codes. Errors were noted and corrected. Locations of recaptures were compared manually and by computer with known fishing ground locations. Errors were detected and corrected.

The internal consistency of the tag recapture data was checked by comparing the data with (i) a least squares fit of the von Bertalanffy growth equation to the length increment during liberty, using the method of Fabens (1965) and (ii) the weight-length relationship developed by Warashina and Hisada (1970) (only for tags returned from the Japanese longline fishery where the weights of the recaptured fish are known).

A preliminary least squares fit of the von Bertalanffy growth equation was made to selected tag-recapture data. The data used had dates and lengths associated with release and recapture but did not have doubtful data codes Z, D, M, Y, N and except for tags returned from the Japanese longline fishery L (see Table II). The selected data also had periods of freedom not less than 250 days. This minimized any possible seasonal growth effects on growth parameter estimates.

The first fit to these data (1854 tag returns) gave estimates of L_∞ = 170.8 cm and K = 0.1633 $year^{-1}$. Outliers, defined as tag returns with reported length increments which differed from those predicted by the growth equation by more than two standard deviations, were listed. Documents corresponding to these outliers were carefully scrutinized for overlooked errors or explanatory comments on the data quality. Corrections were made and doubtful data codes i.e. Z, D, M, Y, N or L assigned as appropriate (see Table II).

After the exclusion of additional data identified as doubtful, a refit of the growth equation to the data yielded estimates of L_∞ = 177.5 cm and K = 0.1526 $year^{-1}$. Outliers were again listed and the relevant documents rechecked.

It was noticed that Australian recoveries from the tagging operation (carried out without direct supervision by CSIRO staff) from the vessels *Nadgee* 1 (coded as 7N) and *Silver Cloud* (coded as 2S) had large numbers of negative outliers with respect to the growth equation. *Silver Cloud* and *Nadgee 1* were trolling vessels whereas the other vessels (excluding *Marelda*) were substantially polers. It is presumed that fish were treated more harshly with trolling than with poling and that this had affected the growth rate after tagging. Murphy and Hearn (in prep.) observed that even southern bluefin tuna caught by poling suffer a weight loss of at least 10% within two or three weeks of tagging. Data associated with fish tagged by

Silver Cloud and *Nadgee 1* and recaptured in the Australian fishery were thus regarded as unsuitable for the purposes of estimating growth curves.

Outliers with respect to the growth curve for tag returns from the Japanese longline fishery were examined separately. It was observed that fish with lengths at recapture smaller by more than 3.5 standard deviations from the expected length increment values were associated with weights recorded at recapture higher (50% or more) than those predicted from the lengths at recapture on the basis of the weight-length relationship (Warashina and Hisada 1970):

$$W = \begin{cases} 0.00004159L^{2.8160} & \text{for } L<130 \text{ cm} \\ 0.000002178L^{3.4229} & \text{for } L\geq 130 \text{ cm} \end{cases}$$

where W is gilled and gutted weight (kg), and L is the length from the nose tip to the caudal fork (cm). It is thought, therefore, that these fish were measured after removal of their heads or tails. This is consistent with the hypothesis of Lucas (1974).

If the ratio of the recorded length at recapture to that estimated from the weight recorded at recapture was less than 0.88 (18 cases identified), the recorded length was regarded as being doubtful and an "R" was added in column 65, 66 or 67 of the card image for that tag return. The von Bertalanffy growth equation was fitted to the tag-recapture data after additional elimination of data from fish tagged by *Silver Cloud* and *Nadgee 1*, data coded with an "R" and data relating to fish recaptured by Japanese longlines which had reported lengths at recapture smaller by more than 3.5 standard deviations from the expected length increment values. This yielded estimates of $L_\infty = 185.1$ cm and $K = 0.1540$ year^{-1}. If no weight was recorded, and the ratio of the reported length at recapture to that predicted by this growth equation was less than 0.88 (10 cases identified), an "S" was coded in column 65, 66 or 67 of the card image. This procedure should ensure that data on fish measured without heads or tails are readily identifiable.

All records which were added to or altered during the editing process are listed on computer paper and held at this laboratory. In these lists the nature of alterations and their reasons are noted. Microfiche copies of the fully edited data set have been created and the data set is also stored on magnetic tape.

4. SUMMARY OF RECOMMENDATIONS

(i) The length-frequency sampling and catch landing data collection for the Australian fishery should be continuously monitored. The methods used should be reviewed in the event of any operational changes at the Eden, Port Lincoln or Perth processing establishments.

(ii) The length-frequency sampling of catches off Western Australia should be extended in terms of its intensity, coverage and regularity. This is currently being organized by this Division.

(iii) Data processing and storage of the Australian length-frequencies and catch landing data should be rationalized. A redesigned system which eliminates the necessity to code the estimated length composition of half-monthly catches (see section 2.1.2) and is compatible with the existing AFZ Fisheries Information System would provide the most efficient processing and long term storage of the Australian length-frequency and catch landing data.

(iv) The establishment of an effective log book system within the Australian fishery is essential for a rational management of the fishery. Such a system should provide data not presently available, such as catch at geographical position and fishing effort.

(v) The establishment of an aircraft observation log book system would provide additional information on the relative abundance, school sizes and the temporal and spatial distribution of surface schools of southern bluefin tuna.

(vi) Complete data regarding Japanese catch and effort (1962-1979) are presently available in a hard copy form only (see sections 2.2.2. and 2.3.2.). To enable analyses of these data to be performed, it is essential that they first be punched and stored (preferably in AFZ Fisheries Information System compatible format) in a form accessable through the CSIRONET computer system.

(vii) The processing and storage of estimates of the length composition of the Japanese southern bluefin tuna catch should be redesigned in line with recommendation (iii).

(viii) Rationalization of the editing of tagging data is necessary. The large number of tests presently performed during editing would suggest that a computer based editing system would be the most efficient and objective means of identifying inconsistencies in the data.

(ix) A reappraisal of the method of storage of tagging data is necessary. The size of the data file and its high frequency of use for a variety of purposes demands a more efficient form of storage than that which presently exists. The revised form of storage should cater for efficiency in terms of disc space (if appropriate), ease of updating, the facility to retrieve data quickly and easily based, if necessary, on one or more sampling constraints, and data security. For these reasons, storage in a structured data base (such as FORDATA) seems appropriate.

(x) An orderly and systematic back-up system of the entire data set for southern bluefin tuna needs to be established. This system should encompass the storage of original documents, punched computer cards and computer back-up on magnetic tape. At least three copies (of varying currency) of computer-stored material should be in existence at any given time.

5. ACKNOWLEDGMENTS

The authors would like to express their thanks to the scientists of the Far Seas Fisheries Research Laboratory (Shimizu, Japan) for the supply of data over many years and especially to Dr. C. Shingu for information on methods of collecting the data from the Japanese fishery.

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Table 1. Manual documentation of southern bluefin tuna tag data.

Type of documentation	General description of information source	Information contained	Degree of data completeness
FAB series folders	Original handwritten field data sheets for released fish with attached tags	Colour(s) and number(s) of tags, date of tagging, geographical position of release, vessel code, fish length, treatment (if any) at time of tagging, time out of water, species of tagged fish, fishing method used.	All data sheets are complete
	Information transferred from the original letters sent with recovered tags (see below)	see below	see below
Original letters sent with recovered tags	Handwritten recapture information	Colour(s) and number(s) of tags, date of recapture, geographical position of recapture, name of vessel, fish length and weight, comments concerning data quality	Few letters associated with tag returns from the Australian fishery remain. Most letters regarding Japanese fishery recaptures are available, except those for the period mid 1967 to early 1970. Various data items are often omitted e.g. weights for fish recaptured in the Australian fishery.
Fisheries field bulletins (prepared by the CSIRO Division of Fisheries Research and distributed to the Australian fishing industry and other interested bodies)	Release and recapture data for tag returns processed by CSIRO in the period to which the bulletin refers (usually monthly)	Colour(s) and number(s) of tags, date of tagging, geographical position of tagging, fish length when tagged, date of recapture, fish length when recaptured, tag finder	Release and recapture fish lengths are not reported before Bulletin No. 14 (16-31 October 1964). A number of complete sets of bulletins is held by this Division
Tuna tag catalogs	Release and recapture data for southern bluefin tuna	Colour and number of each tag, date of tagging, geographical position of tagging, tagging vessel name, fish length when tagged. If recaptured, date of recapture, geographical position of recapture, fish length and weight (if known) when recaptured, tag finder	Information is recorded and is available for every southern bluefin tuna tagged by the CSIRO Division of Fisheries Research. Various items of recapture data are frequently not available.

Table 11. Format of computer records for tagging data.
Notation: Zero and blank are denoted by Ø and b, respectively.

Columns	Item recorded	Comments
1	Colour of primary tag	1 is coded for red. 2 " " " yellow. 3 " " " yellow with an X prefix. 4 " " " blue.
2 - 6	Tag number	Right justified number with leading zeros. Example: tag number 85 is coded as ØØØ85.
7 - 8	Colour of companion tag, if used.	bR is coded for red. bY " " " yellow. YX " " " yellow with an X prefix. bB " " " blue.
9 - 13	Number of companion tag, if used.	Right justified number with leading zeros. This field is blank if no companion tag used.
14-15	Day of release date	Right justified numbers with leading zeros. Example: 8 September 1968 is coded as Ø8Ø968.
16-17	Month of release date	
18-19	Year of release date	
20-21	Vessel involved during releasing	Alpha-numerical code (see Table III for a list of vessels and their codes).
22-23	Latitude of release position (degrees south)	Right justified number with leading zeros.
24	Latitude of release position (minutes)	Ø is coded for 00' to 05' 1 " " " 06' to 10' etc.
25-26	Longitude of release position (degrees east)	Last two digits only. Right justified number with leading zeros.
27	Longitude of release position (minutes)	Coding the same as for column 24. Example: 35°08'S, 117°55'E is coded to 351179.
28-30	Length at release (cm).	Right justified number with leading zeros. Field is blank if no measurement.
31-32	Day of recapture date.	Right justified numbers with leading zeros.
33-34	Month of recapture date.	If day is unknown, it is coded as 15.
35-36	Year of recapture date.	If month is unknown, the middle of the season (i.e. March 1, for SA, November 15 for NSW, and June 1 for WA) or the middle of a specified period is used. Examples: Dec. 1968 is coded as 151268; SA 1969 is coded as Ø1Ø369; 1-8 Dec. 1964 is coded as Ø51264.
37-39	Latitude of recapture position	Same coding as for release position. If location is not given, for NSW grounds code 37Ø49Ø, for SA grounds code 34Ø36Ø and for WA grounds code 35Ø18Ø(Albany) or 339219 (Esperance). See also column 74.
40-42	Longitude of recapture position	
43-45	Length at recapture (cm)	Right justified number with leading zeros. Field is blank if no measurement.
46-47	Vessel involved at recapture	Alpha-numeric code (see Table IV for a list of vessels and their codes).
48	Primary tag recovery indicator	+ is coded to indicate tag presence.
49	Companion tag recovery indicator	- " " " " " absence. These fields are blank if fish was single tagged.
50-51	Treatment applied during tagging (1963-1964)	Ab for tag soaked in antiseptic and no OTC injection, Cb or bb for no treatment, ØA for tag soaked in antiseptic and OTC injection, ØØ OTC injection and no antiseptic.

Table 11. (contd.)

Columns	Item recorded	Comments
52-54	Length of time the fish was out of water (seconds)	Right justified number with leading zeros.
55	Was tagged fish rereleased after recapture?	* if yes b if no
56	Had tagged fish been recaptured previously?	* if yes b if no
57	Blank field	
58	Species tagged	b is coded for southern bluefin tuna 1 " " " yellowfin tuna 2 " " " albacore 3 " " " skipjack tuna
59-60	Blank fields	
61-64	Weight at recapture (kg x 10)	Right justified number with leading zeros. Field is blank if no measurement.
65-67	Indication of doubtful information	Up to 3 of the following codes can be used per tagged fish. D recapture day is uncertain M recapture month is uncertain. Y recapture year is uncertain L length at release is uncertain N length at recapture is uncertain W weight at recapture is uncertain Z tag number is uncertain R weight and length data are inconsistent, i.e. reported length at recapture is less than 88% of that predicted from the reported weight. S outlier in growth equation, i.e. reported recapture length is less than 88% of that predicted from the growth curve. A release position is uncertain P recapture fishing ground is uncertain
68-73	Blank field	
74	Recapture longitude code	b is coded for longitude between 100° and 180°E 1 is coded for longitude between 0° and 99°E 2 is coded for longitude between 100° and 180°W 3 is coded for longitude between 0° and 99°W
75-76	Tag catalog book number	(see codes below)
77-80	Page number in tag catalog book	Right justified number with leading zeros.

Tag catalog book number (columns 75-76):

Code	Primary tag colour	Tag numbers
Ø1	red	1 - 1000
Ø2	yellow	10001 - 20000
Ø3	yellow	20001 - 27000
Ø4	blue	1 - 10000
Ø5	yellow X	X1 - X10000
Ø6	blue	10001 - 20000
Ø7	yellow X	X10001 - X20000
Ø8	blue	20001 - 30000
Ø9	yellow X	X20001 - X30000
1Ø	red	27001 - 37000
11	yellow	27001 - 37000
12	red	40001

Table 111. Tagging vessels and their associated codes

Vessel name	Code	Vessel name	Code
Aquarius	Z3	Mameena	U1
		Marauder	3M
Bintang Terang	U9	Marelda	38
Carolyn Star	Y7	Nadgee 1	7N
Cape Byron	T9	Nadgee 11	N2
Catriona B	T8		
		Pelamis	45
Degei	T2	Peter's Hope	6P
Derwent Hunter	1Ø		
		Robyn Julie	T4
Eden Star	W2	Rosebud	U3
Estelle Star	17		
		St Michael	U8
Favourite	T1	Silver Cloud	2S
Fearnot	Y6	Southern Bluefin	U4
Fortescue	F1	Sundowner A	S6
Hermay	T5	Tacoma	T7
Huon	T3	Torbay	5T
		Two Freddies	T6
Imlay	W4	Tuna Club of Tasmania	3T
Karina G	2K	Vessel Unknown	9Z
		Vida	U6
Lady Merle	6L	Viking Queen	2V
Leah	L4		
Loch Lomond	U2	Weeruta-Investigator	76

Table IV. Australian southern bluefin tuna vessels and their codes

Vessel name	Code	Vessel name	Code
Archenar	6A	Eagle	2E
Agnes James	X3	Eden Star	W2
Ajax 1	31	Eklata	3E
Ajax	X5	Elizabeth Star	4E
Albatross	ØØ	Enfield	X1
Allanwood	Y3	Enterprise	6E
Alan	32	Ern Jay	5E
Almonta	2A	Espirito Santo	Y9
Ana Star	9A	Estelle Star	17
Angelica	A2	Fair Venture	X8
Anchovette	7A	Favourite	T1
Anne Marie	8A	Fearnot	Y6
Aquarius	Z3	Fortescue	F1
Arbrooka	5A	Fortuna	11
Arcadia Star	3A		
Atlanta	33	Geoffrey H	5G
Australia Star	4A	Gipsy	Y2
		Gladiator	X9
BMB	5B	Good Intent	4Ø
Bergmagui Star	2B	Golub	2G
Bertha M	6B	Gracie P	3G
Bintang Terang	U9	Grozdana A	41
Boorowa	7B	Gulf	4G
Bosna	34		
Boston Bay	9B	Hermay	T5
Bronwyn	8B	Hunter	Y1
Bronzewing	4B	Huon	T3
Camalla T	35	Ibex	W1
Canberra	4C	Imlay	W4
Carol S	6C	Income	8J
Caroline Star	Y7	Invader	2H
Cape Byron	T9	Irene M	3H
Cape Baron	W7	Isobel Star	7J
Catriona B	T8		
Challenge	W9	Jadran	3J
Charissa	36	Janet D	J2
Cindy Joan	5C	Jay Dee	4J
Co-Re 11	37	Jillian Sandra	6J
Coral Queen	3C	Jo Ana	J4
Crested Turn	56	John Dory	42
Crusader	2C	Joan Marie Star	5J
		Judith Anne	43
Daisy Bell	4D	Julie Anne	2J
Dageraad	39		
Day	3D	Kali	7K
Dee Jay	7D	Kaloona	4K
Degei	T2	Karina G	2K
Delcara	6D	Kathy O	6K
Dell R.	5D	Kendon B	3K
Derwent Hunter	1Ø	Kerry Anne	5Z
Dinjerra	2D	Kiama	K2
Dragon	8Ø	Kimbla	X4

Table IV. (contd.)

Vessel name	Code
Kolega	9K
L.C.W.	8L
Lady Christina	44
Lady Merle	6L
Lauken	L2
Leah	L4
Leonie Star	2L
Leonard Star	57
Letiva	4L
Liawaner	5L
Lincoln	3L
Linda	9L
Lismore Star	W6
Loch Lomond	U2
Lucy Anne	7L
Maas Banker	7M
Mameena	U1
Marauder	3M
Marconis Cross	W3
Marelda	38
Maria Luisa	8M
Marina Star	M2
Mary Ann Simms	W8
Melport	4M
Mirrabooka	U5
Mirrumbeena	2M
Monaro	5M
Moriah	9M
Moya Ann	6M
Nadgee 1	7N
Nadgee 11	N2
Naomi B	9N
Naracoopa	5N
Naranga	3N
Nautilis	N1
Nenad	4N
New Dolphin	2N
Noosa Star	8N
Ocean Raider	02
Orao	01
Palamuna	4P
Peggy May	5P
Pelagic	7P
Pelamis	45
Pelican	8P
Peter's Hope	6P
Petoni	X7
Porto Salvo	3P
Richard Allen	X2
Robyn Julie	T4
Robyn 11	46
Roma Star	3R
Rosa S	R3
Rosalind Star	Y8
Rosebud	U3
Rose Marie	2R
Roza Star	47
Salvatore	S2
Santa Lucia	48
San Christophano	6S
San Rocco	49
Santa Maria Star	S1
Santa Rosa	S5
Sartuna	7S
Savar	12
Shirley Marie	4Z
Shanidar	5Ø
Sirenia Pearl	8S
Southern Condor	51
St Joseph Star	5S
St Michael	U8
St Omer	52
Sensation	4S
Seabelle	53
Silver Cloud	2S
Smada	W5
Southern Gull	54
Southern Bluefin	U4
Sundowner A	S6
Tacoma	T7
Tammy	4T
Torbay	5T
Torpedo	55
Tun	2T
Two Freddies	T6
Una Voce	X6
Urania	2U
Valentina	5V
Velebit	4V
Venture	3V
Vida	U6
Viking Queen	2V
Vis	6V
Weeruta-Investigator	76
Wendy Belle	2W

Table IV. (contd.)

Vessel name	Code	Other tag finders	Code
Zadar	Z4	Safcol, Eden	3Z
Zora	Z1	Safcol, Melbourne	3S
		Safcol, Portland	2Z
Other tag finders	Code	Safcol, Port Lincoln	9S
		Sports fishing vessels	8Z
Heinz, Eden	5K	Tuna Club of Tasmania	3T
Heinz, Narooma	6N	Ulladulla Fishermen's Cooperative	3U
Heinz, Port Lincoln	8K	Unknown finder	9Z
Hunt's, Albany	4H	West Ocean Canning, Experance	Z6
Japanese longliners	9J	West Ocean Canning, Perth	Z2
Lakes Entrance Processors	L3	Pt Lincoln Processors	9P
Peck's	2P		

```
MGD03.
NDFILE(2)
REQUEST(TAPE3,*PF)
ATTACH(TAPE1,TUNSA78,ID=CFOXGA)
FTN(SL)
MODE,1.
LGO.
REWIND(TAPE2)
COPY(TAPE2,OUTPUT)
REWIND(TAPE3)
COPYSP(TAPE3,OUTPUT)
REWIND(TAPE3)
*EOS
      PROGRAM MGD03(INPUT,OUTPUT,TAPE1       ,TAPE2,TAPE3)
C     PROGRAM TO CARRY OUT ROUTINE ANALYSIS OF THE LENGTH-FREQUENCY
C     DISTRIBUTION OF SOUTHERN BLUEFIN TUNA FROM THE COMMERCIAL CATCH.
C     MEASUREMENTS ARE READ IN UNSORTED IN GROUPS OF BATCHES. EACH GROUP
C     BEGINS WITH A HEADING CARD AND ENDS WITH TWO BLANK CARDS. BATCHES
C     ARE SEPARATED WITH SINGLE BLANK CARDS. THE FIRST CARD OF EACH
C     BATCH MUST CONTAIN EITHER NO.OR WT SAMPLED.
      DIMENSION FHAT(170),FREQ(170),LTH(20),IWORD(5)
     1,VEC(200),NUM(20),INUM(8),JCNT(8)
      DIMENSION IGRAPH(121)
      IGRAPH(1)=1H.
      DO 65 IP=2,121
   65 IGRAPH(IP)=1H
      LU=1
      INDIC=2
    1 FORMAT(30X,50H C.S.I.R.O. DIVISION OF FISHERIES AND OCEANOGRAPHY)
    2 FORMAT(38X,36H MARINE LABORATORY, CRONULLA, N.S.W./)
      XLINF=176.38
      XKAY=0.00483725
      IDENT=6HNS702-
      DO 19 IP=1,8
      JCNT(IP)=0
   19 INUM(IP)=0
      READ(LU,57)XYZK,NTOT,IOPT
      IF(IOPT.EQ.0)IOPT=1
   57 FORMAT(A10,I7,3X,I1)
      WRITE(2,67) XYZK
   67 FORMAT(1H1,//, * LENGTH */* IN CMS   HISTOGRAM OF PERCENTAGES     -
     1*A10,/ *           0.0    0.5    1.0    1.5    2.0    2.5    3.0    3.5    4.
     20    4.5    5.0    5.5    6.0    6.5    7.0    7.5    8.0    8.5    9.0    9.
     35   10.0*)
    3 FORMAT(32X,44H COMMERCIAL FISHERIES CATCH SAMPLING PROGRAM ///)
      DO 444 I=1,200
  444 VEC(I)=0.0
    4 FORMAT(20X,32H ESTIMATED LENGTH COMPOSITION OF/23X,27HSOUTHERN BLU
     1EFIN TUNA CATCH//)
      PRINT 8
    8 FORMAT(1H1)
      PRINT 1
      PRINT 2
      PRINT 3
      PRINT 4
    5 FORMAT(80H1          PERIOD                AREA           LANDED CATC
     1H WEIGHT(METRIC TONS)          )
C     HEADING CARD-PERIOD CAUGHT,COLS 5-23,AREA,COLS 30-40,
C                     LANDED CATCH WT(M/T),COLS 48-56
    6 FORMAT(4A10,A6,F9.3)
  201 PRINT 5
      READ(LU,6)(IWORD(IP),IP=1,5),CWT
      IF(EOF(LU   ))99,402
```

```
 402 DECODE(20,1001,IWORD(3))TIME
     CWT=CWT
     PRINT 6,(IWORD(IP),IP=1,5),CWT
1001 FORMAT(8X,F4.0,8X)
401  PRINT 15
 15  FORMAT(//22H FIRST RAISING FACTORS/)
     FMHAT=0.
     TOTAL=0.
     SUM=0.
     PCENT=0.
     SWT=0.
     N=0
     DO 101 I=1,150
     FHAT(I)=0.
101  FREQ(I)=0.
     LEAST=100
     MOST=100
     MMOST=60
     LLEAST=60
     READ(LU,7)BWT,BNO
     BWT=BWT
  7  FORMAT(9X,F6.0,F4.0)
     LTH(12)=0
     GO TO (28,18) IOPT
 28  READ(LU,27)((LTH(IP),NUM(IP)),IP=1,11)
 27  FORMAT(22I3)
     GO TO 29
 17  FORMAT(24I3)
 18  READ(LU,17)((LTH(IP),NUM(IP)),IP=1,12)
  29 IF(LTH(1 ).EQ.0) GO TO 203
     IPP=10+IOPT
     DO 111 K=1,IPP
     IF(LTH(K ).EQ.0) GO TO 203
     LGTH=LTH(K)
202  IF(LGTH-30)104,104,105
105  IF(LGTH-200)106,106,104
104  PRINT 14,LGTH
 14  FORMAT(/8H LENGTH=I3,19HCMS., OUTSIDE RANGE)
     GO TO 111
106  IF(LGTH-LEAST)107,108,108
107  LEAST=LGTH
108  IF(LGTH-MOST)109,109,110
110  MOST=LGTH
109  I=LGTH-30
     FREQ(I)=FREQ(I)+NUM(K)
111  SUM=SUM+NUM(K)
     IF(IAST.EQ.1H*) GO TO 203
     GO TO (28,18)IOPT
203  LEAST=LEAST-30
     MOST=MOST-30
     DO 207 J=LEAST,MOST
     FJ=J+30
207  SWT=SWT+FREQ(J)*2.704E-5*FJ**2.94
     IF(BNO)204,204,205
204  BIUPK=BWT/SWT
     BNO=BIUPK * SUM
     GO TO 206
205  BIUPK=BNO/SUM
206  N=N+1
     PRINT 9,N,BIUPK,BWT,SWT,BNO,SUM
  9  FORMAT(7H BATCH ,I3,19H, WEIGHTING FACTOR=,F6.2/14H WT. OF BATCH=,
    1F8.0,17H   WT. OF SAMPLE=,F7.0,16H   NO. IN BATCH=,F6.0,17H   NO.
    2IN SAMPLE=,F5.0//)
     DO 208 J=LEAST,MOST
208  FHAT(J)=FHAT(J)+FREQ(J)*BIUPK
     TOTAL=TOTAL+BNO
```

```
      IF(LLEAST-LEAST)113,113,114
  114 LLEAST=LEAST
  113 IF(MMOST-MOST)115,116,116
  115 MMOST=MOST
  116 READ(LU,7) BWT,BNO
      BWT=BWT
      SWT=0.
      IF(BWT)310,310,209
  310 IF(BNO)210,210,209
  209 DO 117 I=1,150
  117 FREQ(I)=0.
      SUM=0.
      LEAST=100
      MOST=100
      GO TO (28,18)IOPT
  210 DO 216 J=LLEAST,MMOST
      FJ=J+30
  216 SWT=SWT+FHAT(J)*FJ**2.94
      SWT=SWT*2.704E-8
      BIUPK=CWT/SWT
      PRINT 16,BIUPK,SWT
   16 FORMAT(/23H SECOND RAISING FACTOR=F6.2,5X,26H ESTIMATED WEIGHT SAM
     1PLED=F8.1,12H METRIC TONS//)
      PRINT 10
   10 FORMAT(  *   LENGTH IN CMS.  FREQUENCY   PERCENTAGE   CUMULATIVE P
     1ERCENTAGE.*/)
      DO 211 J=LLEAST,MMOST
      PCENT=PCENT+100.0*FHAT(J)/TOTAL
      PPCENT=100.0*FHAT(J)/TOTAL
      IYJ=J+30
      PFHAT=FHAT(J)*BIUPK
      YJ2= IYJ+0.5
      YJ1= IYJ-0.5
      XY1= YJ1+(1-EXP(-XKAY*TIME/10.0))*(XLINF -YJ1)
      XY2= YJ2+(1-EXP(-XKAY*TIME/10.0))*(XLINF-YJ2)
      NXY1=XY1+0.5
      NXY2=XY2+0.5
      IF(NXY1.EQ.NXY2) 20,21
   20 VEC(NXY1)=VEC(NXY1) +PFHAT
      GO TO 30
   21 IF(NXY1.EQ.NXY2-1)22,23
   22 D1 =NXY1+0.5 -XY1
      D2 = XY2-NXY2+0.5
      VEC(NXY1)= VEC(NXY1) +(D1/(D1+D2))*PFHAT
      VEC(NXY2)= VEC(NXY2) +(D2/(D1+D2))*PFHAT
      GO TO 30
   23 D1= NXY1 +0.5 -XY1
      D2= XY2-NXY2+0.5
      VEC(NXY1)= VEC(NXY1)+ (D1/(D1+1.0+D2))*PFHAT
      VEC(NXY1+1)= VEC(NXY1+1)+ (1.0/(D1+1.0+D2))*PFHAT
      VEC(NXY2)= VEC(NXY2)+(D2/(D1+1.0+D2))*PFHAT
   30 FMHAT=FMHAT+PFHAT
  211 PRINT 11,IYJ,PFHAT,PPCENT,PCENT
   11 FORMAT(6X,I4,7X,F8.1,7X,F6.2,9X,F6.1)
      TOTAL=TOTAL*BIUPK
      IF(TOTAL-FMHAT+2.0)212,214,214
  214 IF(TOTAL-FMHAT-2.0)213,213,212
  212 PRINT 13,TOTAL,FMHAT
   13 FORMAT(28H  ERROR IN FREQUENCY TOTALS ,2F9.1 ///)
      GO TO 201
  213 PRINT 12 ,TOTAL
   12 FORMAT(12X,4HSUM=F9.1 ///)
      GO TO 201
   99 PRINT 40
   40 FORMAT(1H1)
      TX=0.0
```

```
      DO 411 I=1,200
  411 TX=TX+VEC(I)
      PRINT 56,XYZK
   56 FORMAT(  *    LENGTH IN CMS.  FREQUENCY          PERCENTAGE*13X*CUMUL
     1. FREQ.   -*A10)
      IVSUM=0
      SL=0
      IC=0
      DO701 I =1,200
      IF(VEC(I).EQ.0) GO TO 701
      IC=IC+1
      IF(NTOT.EQ.0)INUM(IC)=VEC(I)+0.5
      IF(NTOT.NE.0)INUM(IC)=VEC(I)*NTOT/TX+0.5
      JCNT(IC)=I
      IF(IC.NE.8) GO TO 701
      IC=0
      WRITE(3,1002)IDENT,((JCNT(IP),INUM(IP)),IP=1,8)
 1002 FORMAT(A6,8(I3,I6),2HBF)
      DO 24 IP=1,8
      JCNT(IP)=0
   24 INUM(IP)=0
  701 CONTINUE
      IF(INUM(1).NE.0)
     1WRITE(3,1002)IDENT,((JCNT(IP),INUM(IP)),IP=1,8)
      DO 311 J=1,200
      IGRAPH(INDIC)=1H
      IF(TX.NE.0.0)  TY=(VEC(J)/TX)*100.0
      INDIC=TY*12+0.5 +1
      IF(INDIC.GT.121) GO TO 58
      IF(INDIC.LT.2) GO TO 66
      IGRAPH(INDIC)=1H*
   62 WRITE(2,60) J,(IGRAPH(IP),IP=1,121)
   60 FORMAT(3X,I4,3X,121A1)
      GO TO 61
   58 INDIC=121
      IGRAPH(INDIC)=1HO
      GO TO 62
   66 INDIC=2
      GO TO 62
   61 IF(VEC(J).EQ.0.0)  GO TO 311
      IF(NTOT.NE.0)  IV=VEC(J)*NTOT/TX + 0.5
      IF(NTOT.EQ.0)  IV=VEC(J) +0.5
      IVSUM=IVSUM+IV
      SL=SL+J*VEC(J)
      PRINT 511,J,IV,TY,IVSUM
  511 FORMAT(6X,I4,7X,I8,7X,F7.2,16X,I10)
  311 CONTINUE
      AVL=SL/TX
      IF(NTOT.EQ.0) NTOT=IVSUM
      PRINT 812,NTOT
  812 FORMAT(12X,4HSUM=,I9)
      PRINT 1065, AVL
 1065 FORMAT(/ 4X*MEAN LENGTH =*F7.2 *CMS*)
      PRINT 40
      STOP
      END
*EOS
*EOP
```

CSIRO
Marine Laboratories

comprises

Division of Fisheries Research
Division of Oceanography
Central Services Group

HEADQUARTERS
202 Nicholson Parade, Cronulla, NSW
P.O. Box 21, Cronulla, NSW 2230, Australia

QUEENSLAND LABORATORY
233 Middle Street, Cleveland, Qld
P.O. Box 120, Cleveland, Qld 4163

WESTERN AUSTRALIAN LABORATORY
Leach Street, Marmion, WA
P.O. Box 20, North Beach, WA 6020