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Report on first half of the consultancy in fish population dynamics to the UNDP/FAO Marine Fisheries Resources Survey and Exploratory Fishing Project (BUR/77/003) in Burma

by

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1. Introduction

This consultancy of an expert in fish population dynamics to the "Marine Fisheries Resources Survey and exploratory Fishing Project" (BUR/77/003) was conceived between FAO and ICLARM as consisting of two elements (a) actual visits to the Project site (2 visits of two weeks each) and (b) report writing (2 periods of one week each). Consequently, the first half of this consultancy consisted of two weeks in Rangoon (from the 15th to the 27th of August), with one (the 29 August to 2 September) to complete (a) the present report (b) the first part of a manuscript to be published by the Project (see below), and (c) to perform various tasks described below under "miscellaneous items".

The second half of this consultancy will be executed in late November and December 1983.

The terms of reference for this consultancy are as follows:

a) to advise on analysis of current survey data;

b) to devise a long-range research program for all marine fisheries; and

c) to train Burmese scientists in fish population dynamics.

The data available to the consultant were:

a) the two reports and the raw data files of the R/V "Dr. Fridtjof Nansen" surveys off Burma, 1979 and 1980 (containing catch records and length-frequency data);

b) cruise survey reports 1 to 17 of the UNDP-FAP Marine Fisheries Resources Survey and Exploratory Fishing Project;

c) the raw data files upon which the reports in (b) were based, which included catch/effort data and length-frequency data.

2. Advice on analysis of current survey data

To date, the wealth of data obtained from the various surveys conducted since 1979 off Burma (and during earlier surveys as well) has been under-utilized in that use has been made of catch rates only. Thus, no attempts have been made to use the available length-frequency data for example to draw inferences on the age structure of the stock, and on its state of exploitation.

The consultant, therefore, strongly recommends that the data obtained during these surveys (particularly the L/F) data be analyzed as soon as possible. Also, it is suggested that any length-frequency data collected during surveys should be included in special data reports with each L/F sample kept separate and identified by species and station.

Length-frequency data collected now, in the early phase of the development of Burmese fisheries, will prove invaluable later and should therefore be reported in non-aggregated form, such that subsequent analysis, using more powerful methods than those presently available (in Burma) remain possible. An effort should be made to also include the L/F data collected by R/V Dr. Fridtjof Nansen in such data reports (these data are presently available as one set of photocopies which given the Burmese climate certainly won't last long!).

For the time being, advice was provided to the Burmese staff of the project on compilation, standardization and analysis of such data (see part 8 of this report). Also, it was agreed between the Project Team Leader, Dr. L. Rijavec and the consultant that the latter will, upon his return to ICLARM headquarters and in cooperation with Dr. Sann Aung, National Project Director, complete and submit for publication by the Project a manuscript giving a detailed example of the use for stock assessment of length-frequency data obtained during surveys using *Nemipterus japonicus* as an example.

3. First observations on a long-range research programme for all marine fisheries

The nature of Burmese resources makes it imperative to implement in this country as early as possible a scheme of data collection and analysis based predominantly on the analysis of length-frequency data.

Such a scheme has been outlined by Munro (1983a and see Fig. 1) and only its main features are restated here:

a) extensive collection of length-frequency data using standardized gears (e.g. trawls) similar to those used by the fleet;

b) standardization and compilation of the L/F and catch rate data, to obtain summary samples representative of single species populations at certain points in time and/or space;

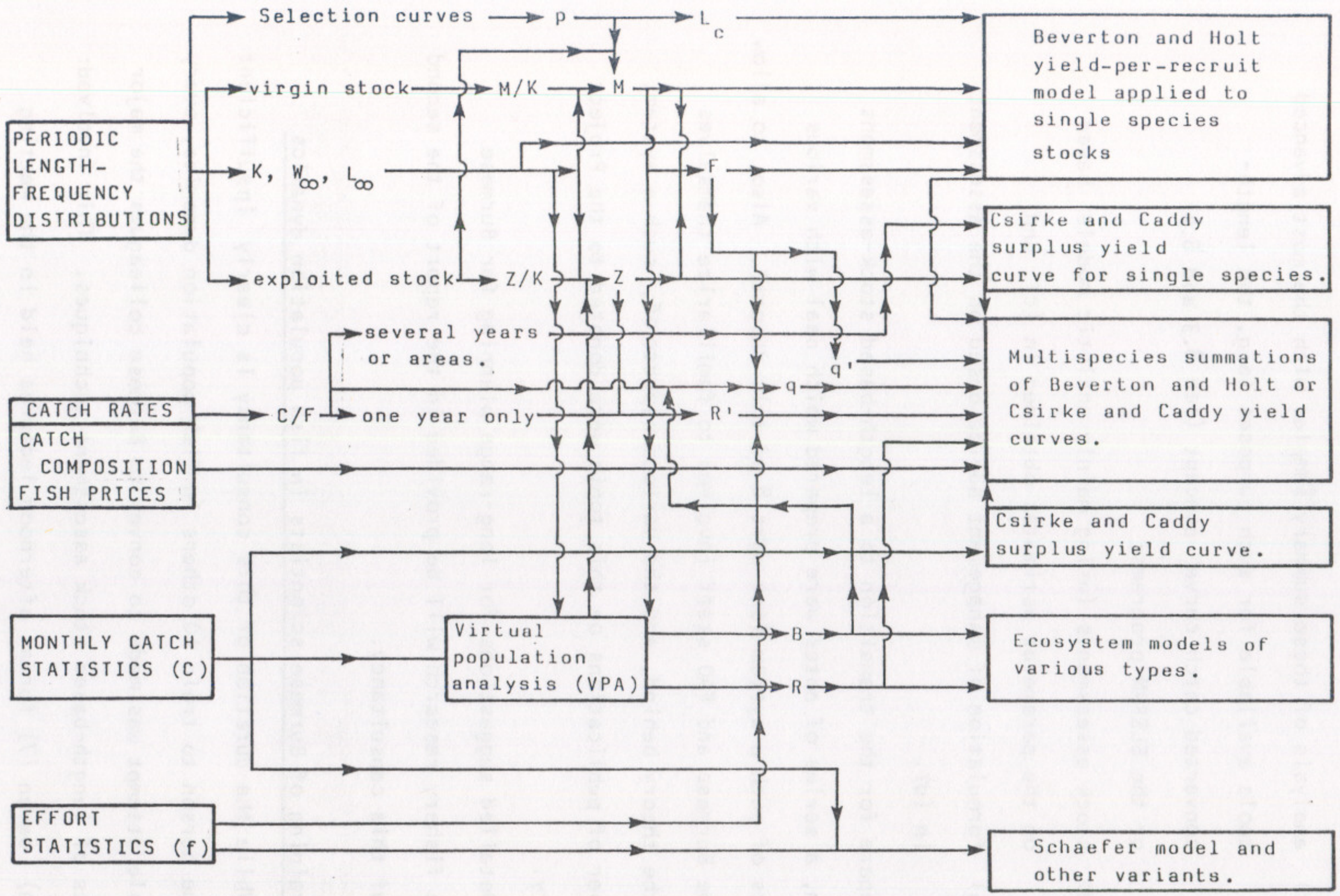

Fig. 1. Structure and components of a length-based stock assessment system. The left side of the graph gives the major type of data collected; the center of the graph gives intermediate computations or ancillary data needed; the right side of the graph represents inputs to and analyses by conventional or slightly modified stock assessment models (from Munro 1983a).

c) analysis of these summary samples with the most advanced tools available for such purposes (e.g. the length-converted catch curve" concept (see 8.3 and 8.4) or the ELEFAN programs;

d) stock assessments (using mainly analytic models) based on the parameter estimates obtained in (c), and

e) formulation of management advice based on the assessment in (d).

To prepare for the transition to a length-based stock-assessment system, a series of notes were prepared which deal with various aspects of such a system (see part 8 of this report). Also, to allow for the Burmese and FAO staff involved to familiarize themselves with the theory behind, and the various aspects of, such a system, a number of publications on this topic were donated to the Project Library.

Detailed suggestions for long-range planning for Burmese marine fishery research will be provided in the report of the second half of this consultancy.

4. Training of Burmese scientists in fish population dynamics

While the duration of this consultancy is clearly insufficient for one person to train 10 others in fish population dynamics, every possible attempt was made to convey to Burmese colleagues the major aspects of length-based stock assessment techniques. This involved:

a) seven (7) formal afternoon lectures held in the meeting room of the Project, each attended by at least 10 colleagues; and

b) informal instruction on data compilation and interpretation. Both media were used to convey the concepts outlined in part 8 of this report and in the FAO Manual related to these topics (Pauly 1983).

These training sessions made abundantly clear the need for a formal national training course of the type envisioned by FAO/DANIDA for late 1984.

5. Preliminary assessment of the Burmese stock of *Nemipterus japonicus*

Pending a more detailed treatment, to be written together with Dr. Sann Aung (see above), a preliminary analysis of a set of length-frequency data obtained during resource surveys is presented here. The data set pertain to the Japanese threadfin bream (*Nemipterus japonicus*), which is moderately abundant off the Burma coast. All data stem from the raw data files of four surveys conducted off Burma by R/V Fridtjof Nansen, in 1979 - 1980 (the data on *N. japonicus* obtained by the Project in 1981 - 1982 will be included in the final version of this note).

Following the method outlined in part 8.1 of this report, the 43 length-frequency samples of *N. japonicus* during the surveys of the R/V Dr. Fridtjof Nansen (which involve approx. 3200 fish actually measured) were grouped by surveys (two in Oct.-Nov. 1979 and one in Mar - April 1980) because no *N. japonicus* were measured in the 2nd 1980 survey), and by area (Rhakine Coast, Delta Area, Tenasserim Coast and Mergui Archipelago) by simply adding up the samples, previously raised to the catch.

Then, the combined samples for each area and survey were rendered equal by expressing them as percent samples, and added up for all areas and surveys to obtain an overall summary sample in which seasonal and area differences are ignored, yielding one overall summary sample representative of the average size composition of <u>N. japonicus</u> off the Burma coast (see Table 1) during the 1979/80 inter-monsoon period.

This sample was analyzed as outlined in part 8.3 of this report, with its y-axis changed from N to $\log_e N$, and its x-axis changed from length (L, in cm) to relative age through the conversion

$$\text{relative age} = -\left(\log_e\left(1 - \frac{L}{35}\right)\right)$$

where 35 (cm) is a preliminary estimate of asymptotic length, based on the largest fish recorded off Burma (see Table 1). The plot of $\log_e N$ values on the relative ages yielded a graph with a structure akin to that of a catch curve (Fig. 2) and whose slope (b) was converted to an estimate of Z/K through the conversion, fully derived in Pauly (in press):

$$-b + 1 = Z/K$$

This approach yielded a value of Z/K = 3.94, while using the mean length of 20.2 cm (computed from the length at full retention (16 cm) upward) yielded a slightly lower estimate of Z/K, i.e.

$$\frac{Z}{K} = \frac{35 - 20.2}{20.2 - 16} = 3.52$$

The value of K was computed using a method derived from that of Munro and Pauly (1983), where literature values for N. japonicus of L_∞ and K (29.5 cm and 0.458 resp., see Pauly 1980) are used to obtain a value of the growth performance index Ø from the equation

$$Ø'' = 2 \log_{10} 29.5 + \log_{10} 0.458 = 2.6$$

which was then used to generate the new value of K corresponding to $L_{(\infty)} = 35$, i.e.

$$\log_{10} K = 2.6 - 2 \log_{10} 35$$

which provided an estimate of K = 0.32. Applied to the values of Z/K given above, this value of K provides two estimates of Z, 1.13 and 1.26.

Using the growth parameter values of $L_{(\infty)} = 35$ and K = 0.32 an approximate value of M was obtained from the empirical equation of Pauly (1980), by using a temperature in the inshore waters off Burma of 29°C, valid for the period of the surveys. The estimated value of M was 0.83, which combined with the values of Z given above provides preliminary estimates of F = 0.29 to 0.45, as well as estimates of exploitation rate of E = F/Z = 0.26 to 0.36. This preliminary assessment thus supports the available evidence on the low state of exploitation of Burmese marine resources.

The length-weight relationship of N. japonicus was also estimated, using the data in Table 1; this relationship is summarized by the expression

$$W = 0.00943\ L^{3.1}$$

where weight is expressed in g and length in cm.

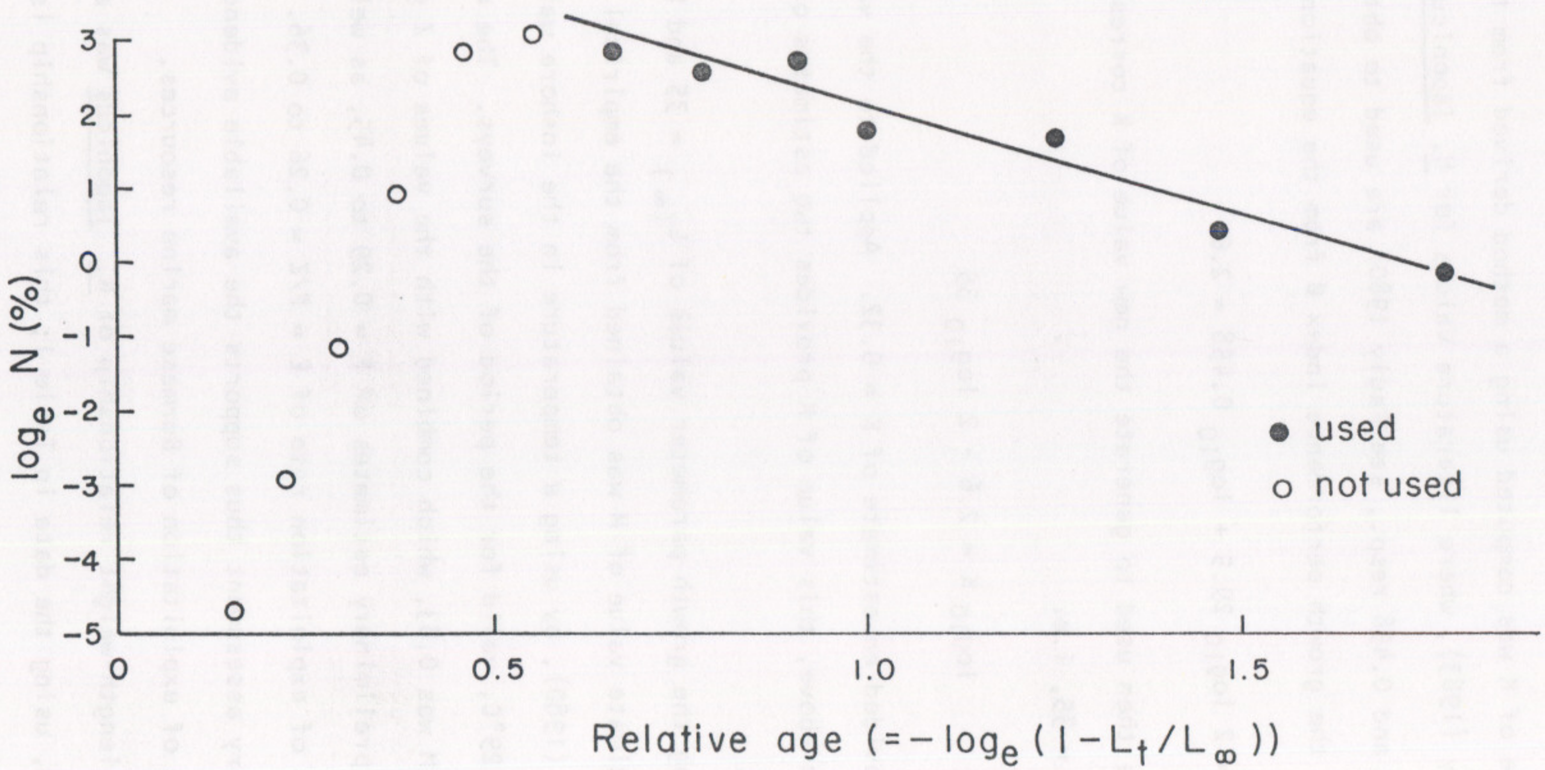

Fig. 2. Length-converted catch curve for *Nemipterus japonicus* off Burma, 1979-1980. See text (p. 6 and section 8.3) for interpretation.

Table 1. Summary of data used for the preliminary assessment of the stock of Nemipterus japonicus off the Burma Coast[a)]

$L^{b)}$	$N^{c)}$	$\log_e N$	Rel. age[d)]	$\overline{W}^{e)}$	W.f.[f)]
5	0.009	-4.739	0.154	-	-
7	0.053	-2.937	0.223	-	-
9	0.315	1.155	0.297	-	-
11	2.564	0.942	0.377	17.8	14
13	16.515	2.804	0.464	25.9	24
15	20.188	3.005	0.560	38.3	21
17	17.597	2.868	0.665	63.1	13
19	13.262	2.585	0.783	87.8	13
21	15.674	2.752	0.916	122	13
23	6.079	1.805	1.070	158	9
25	5.358	1.679	1.253	199	9
27	1.472	0.387	1.476	305	6
29	0.859	-0.152	1.764	295	4
31	-	-	-	-	-
33	0.035	-3.352	2.862	450	1
35	0.018	-4.017	(-)	550	1

a) compiled from the raw data files of the R/V Dr. Fridtjof Nansen surveys off Burma, 1979-1980.

b) mid-range of 2 cm classes (data regrouped from 1 cm classes).

c) summary sample obtained by weighing single samples to the catch, adding up samples by area and survey number and combining all intermediate samples (rendered equal by taking %) into a single sample, also expressed in %.

d) computed from $-\log_e(1 - L/L_{(\infty)})$, with $L_{(\infty)}$ set at 35 cm = L_{max}.

e) weighed mean computed from 19 different samples.

f) weighing factor computed as the integer closest to $\sqrt{n}$, where n is the number of fish involved in computing $\overline{w}$.

Another observation, to be documented later in detail, is that off the Burma coast, there seems to be no relationship between the size of N. japonicus and the depth of the water. Three causes - not mutually exclusive - may be listed to account for this apparent lack of a relationship that has been recorded elsewhere in a vast number of fishes, including N. japonicus:

- the data at hand (F. Nansen catch records) are not sufficient for the effect to be detected;
- the Burmese shelf is either too narrow (Rakhine coast) or too flat (Delta area) to allow for a clear size/depth gradient to emerge; and
- the lack of oxygen in the deeper, water layers and the occasional upwelling od deoxygenated waters off Burma might actually crowd most fishes in the upper part of the shelf, as was the case during the 1979/1980 pre-monsoon, when R/V Dr. F. Nansen conducted its surveys off the coast of Burma.

These various possibilities will be investigated in more detail in the final version of this note on N. japonicus. Indeed, a detailed analysis of the size/depth relationship of various species of marine fishes off Burma could help clarify a number of questions pertaining to the interactions between the inshore and offshore fisheries, as well as to the potential for a future extension of fishing into deeper waters.

6. Miscellaneous items

6.1. It was agreed between the Team Leader, Dr. L. Rijavec and the consultant that the latter would, upon his return to ICLARM headquarters in Manila send photocopies of a number of publications of relevance to the Project activities.

6.2. It was also agreed that the consultant would update the now outdated "Preliminary Bibliography of the Fish and Fisheries of Burma" (IPFC Occasional Papers No. 1, 1962) and that the updated version, which will cover marine resources only, will be included in the summary report of the Project.

6.3. The consultant also agreed to compile a list of books on fish and fisheries suggested for purchase by the Project library. (see Annex IV)

7. Recommendations

Given that the present document reports only on the first half of the consultancy, specific recommendations pertaining to long-range planning of marine fisheries research in Burma will not be given now - especially since a major decision pertaining to the continuation of this Project are still pending.

However, three points emerged clearly during this visit to Burma:

a) there is an urgent need to obtain a reliable estimate of the catch made by artisanal fishermen off the coast of Burma;

b) the present system for the collection of length-frequency data from commercial and survey vessels must be intensified;

c) every effort should be made to acquire a small computer for use by the research staff of the Project.

No country can manage its fishery, or even make rational decisions concerning the development of its aquatic resources in the absence of reliable catch data.

Such data are not available for the artisanal sector in Burma, which reportedly accounts for the overwhelming part of the total marine catch. Moreover, annual figures of catch and effort appear to be updated annually by application of constant multiplicative factors.

In light of this, it seems imperative to conduct, as early as possible, and on a national scale, an inventory of gears and a census of full and part time fishermen, and to obtain catch estimate by (subannual) time periods and species grouping, based on a sound sampling design.

A preliminary analysis of available length-frequency data collected by the Project revealed that, except in a very few species, sampling densities (both in terms of number of sample sizes) are too low for growth information to be extracted, or reliable mortality estimates to be obtained.

It is therefore recommended that a special effort be made to obtain additional length-frequency data from PPFC vessels.

Several of the methods discussed in this report including the ELEFAN programs, require the use of computers which are eminently suited for the analysis of length-frequency data. Also, a full extraction of the information embedded in the raw data files from the various surveys cannot be performed without at least a small computer. The consultant was informed that FAO would be willing to supply such a computer, given permission to import it into Burma. It is hoped that such permission will be granted, as it would allow for the Project personnel not only to interpret the data at hand, but also to acquaint themselves with modern data processing.

In this context, it should also be mentioned that the planned FAO-DANIDA training course will have computer data processing as one of its topics, and that therefore the previous availability of a computer at the Project, would help prepare the Project personnel for this course.

Computer programs for use by the Project would be immediately available, as Mr. Per Sparre (Danish Institute of Fisheries Research, Charlottenlund, Denmark) has already translated a number of them (including the ELEFAN I program) into a version that will run on the computer which FAO is offering.

Indeed, Mr. Sparre (who will incidentally be one of the lecturers in the planned FAO/DANIDA training course to be held in Burma) would be an excellent consultant in computer-aided stock assessment. He is qualified to train people in handling computers or writing programs and in performing actual assessments on both fish and shrimp resources.

8. Methodological notes

8.1. Compilation, standardizing and presentation of length-frequency data.

i) Area groupings: In view of the main structures of the Burma coast and of the sampling densities achieved (and expected in the future) 4 area groupings were proposed for the length-frequency data that have been, and will continue to be collected:

I. Rakhine Coast

II. Delta Area

III. Northern Tenasserim Coast

IV. Mergui Archipelago

All summary length-frequency sheet should therefore include these four designations, with boxes for marking the appropriate case, as in multiple choice tests (a form with these characteristics has been designed and is now being used at the Sea Fishery Survey and Research Unit).

ii) Temporal groupings: In order to capture the rapid changes in size occuring in small, fast-growing fishes, the level of aggregation for length-frequency samples shall be the calendar month. Hence, L/F data obtained during a given month shall always be lumped with other L/F data obtained during that same month (given the data stem from the same area as defined above). Before lumping, the various data set must be weighed by their catch (see (3) below).

iii) Weighing by the catch: In order to prevent single fish from unduly affecting the summary length-frequency samples should be (wherever possible) weighted by the catch they represent before they are combined with other samples.

For example, if two samples (1, 2) *N. japonicus* are to be combined, first determine the weight of each sample (Ws_1, Ws_2) and the weight of *N. japonicus* in each of the per hour catches (Wc_1, Wc_2). Then obtain raising factors (RF) as follows:
$Wc_1/Ws_1 = RF_1$; $Wc_2/Ws_1 = RF_2$. Then, multiply each frequency in the two samples by the corresponding raising factor (RF_1, RF_2). After the samples have been raised, they can be added. When the whole catch has been measured (i.e. when Ws = Wc) or when information are missing, simply add samples without weighing.

iv) Length classes: Fish should be measured in either 1/2, 1, 2 or 4 cm classes below, depending on the largest size they can reach (L_{max}). The appropriate class intervals are approximately as follows:

L_{max} (cm)	Class interval (cm)
12	1/2
25	1
50	2
100 and more	4

Since L/F samples will generally not cover the whole range of possible lenghts, these class intervals will ensure a number of size classes with non-zero frequencies generally ranging from 12 to 20, as is appropriate for most statistical analyses, including the ELEFAN programmes (see below).

v) Summary length-frequency data form should use "midlengths" (i.e. mid-point of length class, or midrange) to express the length of fish (as opposed to the forms used for field work, which give the lower class limit). This will help in preventing some of the errors associated with using lower class limits; also this is the format required by the ELEFAN programs and most other methods of analysis.

vi) Compiling of length-frequency data should be based on forms such as the one attached here (called "summary L/F data form"). Each form should contain the following:

a) a complete species name;

b) the year and mesh size used;

c) combined frequencies for the various months (omit month if no data are available), and

e) the year.

In the lower part of the form, the station numbers must be given from which the L/F data were obtained (this will allow for checking, and for dissagregation of data for specific uses).

vii) Prior to analysis with the ELEFAN programs - or using any other method - histograms should be prepared which depict the available length-frequency data, and upon which growth curves (traced by eye or as obtained by the ELEFAN I program) can be super-imposed. In the following, a procedure is given which, based on a number of graphing experiments, now appear optional:

a) convert all frequencies in the "Summary L/F data sheet" at hand in % frequencies.

b) use mm standard graphing paper, and the following scales:

<u>time scale:</u> 2 cm for one month (hence one year should take 24 cm, and start with January on top of sheet)

<u>frequency scale:</u> 10% = 1 cm; this scale will lead - especially when samples are graphed which have few modes - to a considerable amount of overlap between adjacent months. Such overlap is not detrimental, however, and suggests modal progression even better than when no overlap occurs.

<u>length scale:</u> must be selected such that as much as possible of sheet width is used; note, however, that length must begin with zero, and not with the smallest length sampled (L_{min}). Also, there should be space for at least 2-3 length classes beyond the largest fish sampled (L_{max}).

c) plot the data as histograms; draw only the outline of each histogram.

An example of such graph is attached (Annex II). One advantage of using one sheet per year is that it allows for pasting several graphs together, and hence to follow fish growth over 2 or more years (when only one year's worth of data is available "doubling up" still allows to better trace growth curves); it is also suggested here to make clean original graphs, and to use photocopies of the original for pasting up and tracing tentative growth curves.

viii) The following information can be derived from length-frequency data that have been suitable sampled and compiled:

a) growth parameters (L_∞ and K of the von Bertalanffy growth function, plus information on seasonal growth oscillations);

b) total mortality (Z) and hence - since natural mortality (M) can be roughly estimated from L_∞ and K - also fishing mortality, through $F = Z - M$;

c) selection curve and mean size at first capture by the sampling gear used (L_c, or L_{50});

d) recruitment pattern, i.e. a graph illustrating pulse of recruitment, and having one or two peaks, depending on whether the investigated fish (spawn and) recruit once or twice a year.

In principle, all the analyses in (a) to (d) can be performed with paper and pencil. However, the time involved can be considerable and it is suggested here that the ELEFAN package of program be used for the analyses (a microcomputer is required for implementation of these programs, which are supplied free by ICLARM).

8.2 Remarks on field sampling of length-frequency data

Given the usefulness of length-frequency data for stock assessment, care should be taken to ensure representativeness of the length-frequency samples obtained from systematic surveys, exploratory fishing or the commercial fishery. Thus, in addition to considering the items listed in the previous note (2.1), the following items should be considered:

i) When conditions allow - i.e. during all systematic surveys, and all exploratory fishing trips - the same species should be measured every time they occur in the catch, irrespective of their number. Thus, if say Lutjanus sanguineus is selected as species to be monitored, then Lutjanus sanguineus must be measured every time it occurs (and the sample raised to the catch), even if it occurs with only one fish.

ii) In view of the point raised in (i), it becomes essential to define, ahead of any further cruise a list of say 16 species of fish and invertebrates which should fulfill at least two of the three following criteria:

- the species should be abundant (i.e. occur in many hauls);
- the species should be commercially valuable (e.g. shrimps);
- the species should be representative of a trophic level, area, or broad ecological group (e.g. large piscivore (i.e. apex predator), planktivore, benthivore, (macro and/or meiobenthos), estuarine fishes, etc.

The reason for the first two of these criteria should be obvious. The third criterion refers to the definite need to collect data which can be used to model the multi-species stock off Burma, using one of the simplified methods that have or will become available (e.g. Pauly 1982, in SCS/GEN/82/41, Manila, or J. Polovina, NMFS, Honolulu, in prep.). An example of a list of selected along the criteria listed here is attached, as Annex III.

iii) In view of the need to collect more, and better length-frequency data, weighing of fish at sea (to eventually obtain data, e.g. for the establishment of length-weight relationships) should be reduced, if not dropped entirely. Collection of samples for biological studies (e.g. stomach and gonad analyses, aging based on annual or daily structures on otoliths) should be reduced to 1 species (or genus) per investigator; this species or genus should not change between cruises (selection of that group should follow the same criterion as in (ii).

iv) Detailed selection experiments (using a doubled cod end) should be performed such that the selective characteristics of the cod-end material used by the majority of the PPFC trawler fleet can be determined, for all species listed in Annex III. Such selection experiments are essential in interpreting L/F data from the commercial fleet, and will also allow for the estimation of natural mortality in a number of fish species, based on the method of Munro (in press).

8.3. Estimation Z/K from length-frequency data

An important parameter for stock assessment is Z/K, a ratio which can be easily determined from a length-frequency sample, representative of a population.

The steps involved are as follows:

i) Obtain a length-frequency sample representative of the population (this can be achieved by (a) combining several samples obtained during a survey in a certain area, as shown in 8.1, (b) adding up several of the combined samples obtained in (a); samples to be added up should be given the same weight, e.g. by expressing them as % samples prior to adding up.

ii) Plot the natural logarithm ($\log_e$, or l_n) of the frequency values of the sample obtained in (i) against the relative age (t') corresponding to the mid-length of each length class (L^*). The relative age is obtained, for a given length class by computing

$$t' = -\log_e \left(1 - \frac{L^*}{L_{(\infty)}}\right)$$

where $L_{(\infty)}$ is a preliminary estimate of the asymptotic length of the fish, obtained from the maximum length observed (L_{max}) through

$$L_{max}/0.95 = L_{(\infty)}$$

iii) Identify points to be used for regression, as follows:

a) do not include points from the left, ascending side of the curve. The first point to be included (P_1) should generally be the one immediately to the <u>right</u> of the highest point;

b) do not include last point if it is based on less than 5 fish and/or if it is based on a value of L^* within 5% of $L_{(\infty)}$.

iv) Calculate, using the linear regression technique the values of r^2, $\underline{a}$ and $\underline{b}$ pertaining to the points included, and test significance of correlation. The value of r should be negative, and lower than the critical value ($P = 0.01$) [caution: statistical tables include only absolute values]

v) The value of b (which will be negative) will provide an estimate of Z/K through the transformation

$$-b + 1 = Z/K$$

vi) The value of Z/K obtained should be somewhere between 1 and 10.

For precise definitions of Z, K and related parameters, see documents in Project Library (e.g. Munro (1982) or Pauly (1982).

8.4 <u>Preliminary assessment of the status of a stock from length-frequency data and published growth parameters</u>

The value of Z/K obtained from length-frequency frequency data can be used for assessing the status of a stock when the growth of the fish in question has been studied somehwere, such that estimates of K and L_∞ are available. In such cases, a growth performance index ($0''$) characteristical of a given species can be computed from the relationship

$$0'' = 2 \log_{10} L_\infty + \log_{10} K$$

which can be used to estimate a new value of K (K_{new}), pertaining to a value of L_∞ different from the one from which $\emptyset''$ was estimated.

Thus, once $\emptyset''$ has been estimated, one estimates a value of K compatible with a given value of $L_{(\infty)}$ (see 8.3) from

$$\log_{10} K_{new} = \emptyset'' - 2 \log L_{(\infty)}$$

Then estimate Z from the values of Z/K (see 8.3) and K_{new}, using

$$(Z/K) \cdot K_{new} = Z$$

An estimate of natural mortality can then be obtained from the empirical relationship (Pauly 1980):

$$\log_{10} M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

where L_∞ is expressed in cm, K is expressed on an annual basis is the mean annual habitat temperature.

Once an approximate value of M has been obtained, estimate fishing mortality (F) through

$$Z - M = F$$

and compute the exploitation rate $E = \frac{F}{Z} = \frac{F}{M + F}$

The value of E, for most fishes off the Burma coast should be markedly less than 0.5; it will increase as fishing effort increases, and E > 0.5 effort should not increase beyond values which generate a value of E > 0.5.

The work outlined in part 8 of this report should be repeated, for each important species (see suggested list of 16 species, Annex III) at least annually, and a status report on each species prepared and made widely available. Growth studies should be conducted which will allow for direct computation of K and L_∞ (rather than relying on literature values and/or approximations); also the values of Z obtained annually should be plotted against some measure of trawler effort (e.g. aggregated horsepower of trawler fleet) to obtain independent estimates of natural mortality (see Pauly 1982 for an example of this method as applied to Gulf of Thailand data).

9. References

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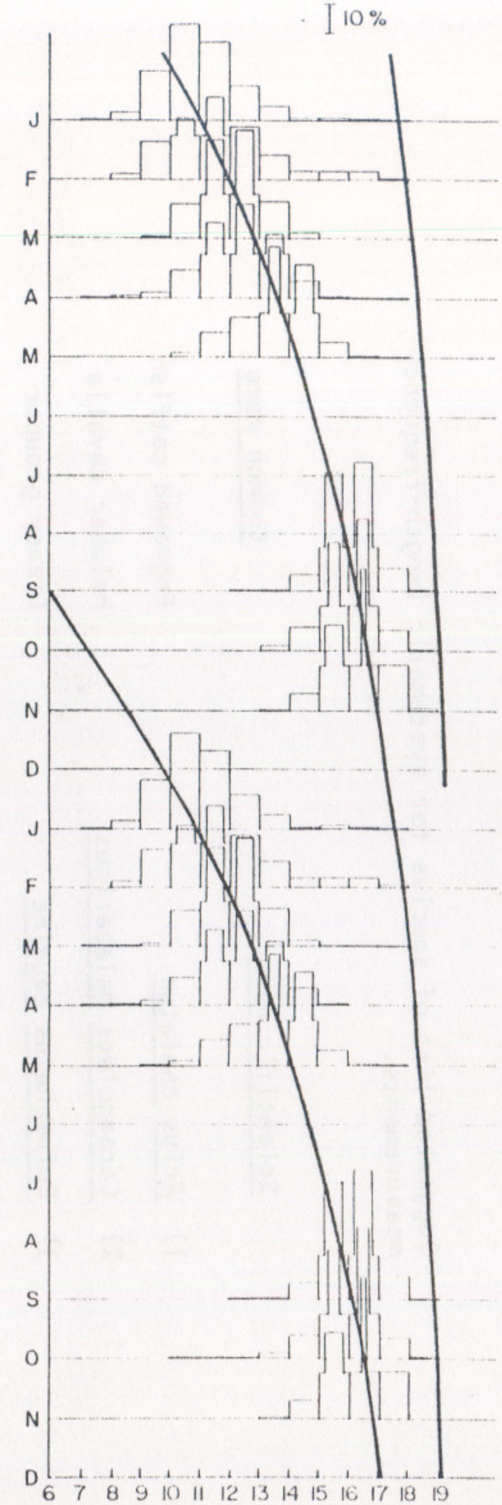
Species: ______ Year: ______ Location: ______

Midlength (cm)	J	F	M	A	M	J	J	A	S	O	N	D
Σ												

Notes: ______ Source: ______

ANNEX II

Example of length-frequency data plotted using 2 cm per month for the time scale, 1 cm per 10% for the % frequency scale and 1 cm of graphing paper for 4 cm total length of fish. Note that data (which pertain to Peruvian anchovy caught in 1978) are plotted twice along the time axis to allow for longer growth curve to be drawn (the parameters of the growth curve were here estimated by means of the ELEFAN I computer program).



ANNEX III

Suggested list of species for systematic length-frequency measurements.

	Scientific name	Common name
1)	*Arius caelatus*	Engraved catfish
2)	*Carangoides malabaricus*	Malabar cavalla
3)	*Epinephelus tauvina*	Greasy grouper
4)	*Leiognathus splendens*	Splendid ponyfish
5)	*Lepturacanthus savalla*	Smallhead hair tail
6)	*Lutjanus sanguineus*	Blood snapper
7)	*Nemipterus japonicus*	Japanese threadfin bream
8)	*Pennahia macrocephalus*	Big-head pennahia croaker
9)	*Polynemus indicus*	Indian threadfin
10)	*Pomadasys hasta*	Lined silver grunt
11)	*Scomberomorus guttatus*	Spanish mackerel
12)	*Saurida tumbil*	Greater lizardfish
13)	*Puerulus sewelli*	Deep sea lobster
14)	*Penaeus merguensis*	White shrimp
15)	*Penaeus monodon*	Tiger shrimp
16)	*Loligo* (species to be identified)	Squid

ANNEX IV

List of fishery and stock assessment-related books recommended for acquisition by the Project.

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Gulland, J.A. (ed.) 1971. The Fish Resources of the Ocean. Fishing News (Books Ltd., London. 255 p.

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