14. SUMMARY OF FISH STOCK ASSESSMENT

The introduction to this manual contains flow-charts for fish stock assessment (Fig. 1.3.0.1) and for the organization of the manual (Fig. 1.8.1). The beginner in fish stock assessment might have had some difficulties with the exact interpretation of parts of these figures. This chapter attempts to give a resumé of the methodology along the same lines as those of the introduction, but now assuming that the reader is familiar with the theory presented in the foregoing chapters.

The level of precision of fish stock assessments increases with the availability of data, which is usually positively correlated to the development of the fishery. In the case of unexploited stocks, assessments will have to be based on general ecological principles, or surveys with fishery research vessels. As soon as exploitation starts, the fishery itself can provide the data base for the application of more sophisticated assessments. In a very highly developed fishery a large portion of the stocks is landed and therefore accessable to sampling.

The methodology of fish stock assessment and prediction changes according to increasing availability of data. While preliminary assessments may be based on, for example, relationship between primary and secondary production or comparisons between unexploited areas and exploited areas with similar environmental characteristics, the first real assessments are usually derived from resource survey data obtained with a fishery research vessel. Assessments of the standing stocks of pelagic and demersal fish can be made by acoustic methods and by a bottom trawl. Although surveys with other types of gear/equipment, such as traps, gill nets and hooks yield data on catch rates, they can not be used directly for estimating the standing stock, because it is not known which area has been covered by the gear. The holistic model (Fig. 1.8.1B) most frequently used for assessment purposes at this stage, is the swept area method, which was discussed in Chapter 13.

An intermediate level of stock assessment can be reached when time series of catch and effort data are available from a developing fishery. Such data can be used in other holistic models, the so-called surplus production models (Fig. 1.8.1B and Chapter 9).

Once a fishery has developed and biological sampling schemes have been set up, it is possible to apply more sophisticated analytical models, which can be divided into two major categories, viz. age-based and length-based models (Fig. 1.8.1A).

In areas where it is possible to determine the age of a fish from otoliths or other hard parts, an age-length key can be established each year which can be used to assign ages to large length-frequency samples taken from the commercial fisheries. This data is then used to determine the number of fish in the sea per cohort or age group. Fairly reliable predictions can be made on that basis.

In areas where ages of fish cannot be determined on a routine basis from otoliths etc. or for resources which do not have structures that permit age-reading e.g. crustaceans, analyses have to be mainly based on length-frequencies. As long as the routine age-reading of tropical fish species is still under development most assessments in the tropical zone will depend on the interpretation of length-frequencies.

Unfortunately, length-frequency data are easily affected by biases caused by gear selectivity, migration and sampling errors, and this further complicates the assessment of tropical species. In this manual a lot of space has been dedicated to the analysis of length-frequency data. This does not mean, however, that the models used are fully length-based. In most of the methods given, the length-frequency data are used to separate presumed cohorts from each other, which are then assigned a relative age. The rest of the procedures is more age-based than length-based. It may be useful to point out here that the determination of growth parameters is only an intermediate step in assessments based on length-frequencies. The final objective is always to determine the amount of fish per cohort and the level of fishing mortalities it is subjected to. This is the basis for predictions of future yields and therefore the basis for future development or management measures.

14.1 GENERAL ASPECTS OF FISH STOCK ASSESSMENT

The main objective of fish stock assessment of exploited stocks is to predict what will happen in terms of future yields, biomass levels (sustainability) and value of the catch, if the level of fishing effort remains the same or if it is changed in one way or another.

Fig. 14.1.1 is an extended version of Fig. 1.3.0.1, giving a number of examples for each box. It shows both the final output of fish stock assessment and the methodology suggested in the present manual to obtain that output. The methodology can be divided into two parts: firstly the estimation of vital parameters, and secondly, the use of these parameters to predict future catches and stock biomasses under various assumptions about the development of the fishery.

Fig. 14.1.1, however, does not contain unquantifiable features of fish stock assessment, such as subjectivity of interpretation and bias in data. Essentially, the models by which historical data are analysed assume that data are random samples, that is, unbiased. If data were exactly as the models assume them to be, everything would be straightforward and any two persons would independently of each other come to the same result. The more biased data are, the more subjective is their interpretation.

Bias may have many causes, some of which can be eliminated, and some of which are very hard to tackle. Bias caused by badly planned and/or executed sampling programmes should be easy to overcome, while bias caused by migration and gear selectivity, may be difficult to handle. Often the technical solution to such biological bias problems is to expand and adjust the sampling programme, based on the first analyses. On top of the practical problems mentioned above, there are statistical (or theoretical) problems in sampling. For example: "How many fish should be sampled to secure a successful Bhattacharya analysis". There is probably no exact solution to this problem, but it is evident that analyses based on length-frequencies need a large amount of unbiased input data.

The prerequisites for any meaningful fish stock assessment are biological data on the resources and technical data on the fisheries. There are two main types of data, which in order of priority are:

1) Data sampled from the catches of commercial fisheries

2) Data from research vessel surveys

Essentially, fish stock assessments of exploited stocks can be made with data from the commercial fisheries only. In the case of unexploited resources, research vessel data are essential. However, the latter may also be very useful as a supplement to commercial fisheries data. Samples from commercial fisheries are usually much cheaper and much easier to obtain in large quantities than research vessel survey data, a feature that should be taken into account when planning fishery research.

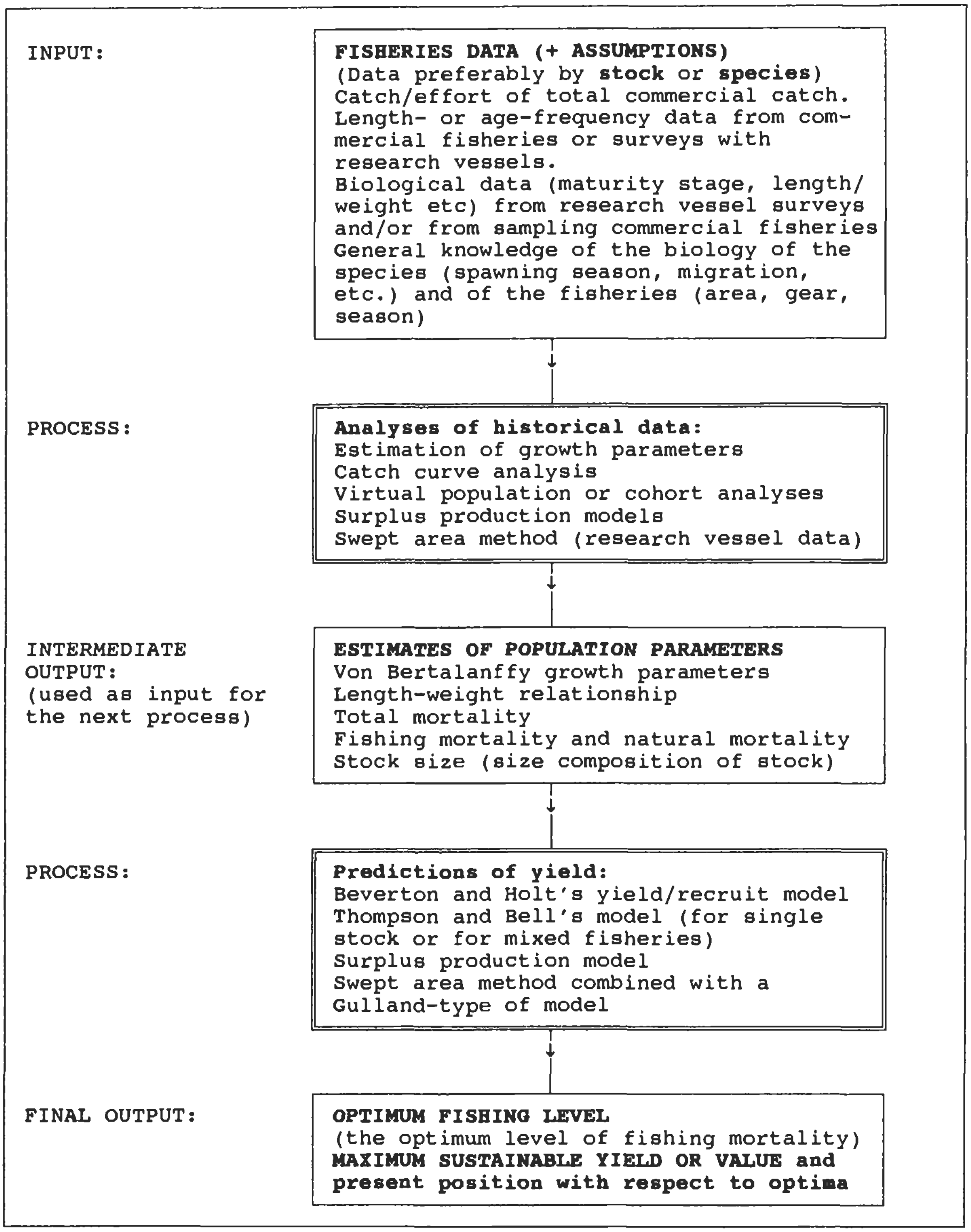

Fig. 14.1.1 General flow-chart for fish stock assessment (compare Fig. 1.3.0.1)

The two types of data essentially contain the following elements:

Commercial fishery data:
Total catch (by species, area and type of gear)
Effort (by area and type of gear)
Length-frequencies (by species and sex)
Age-frequencies (by species and sex)
Biological data (e.g. maturity stages, length/weight relationship)
Data on fishing gear (e.g. mesh size) and fishing operations

Research survey data:
Catch and effort (e.g. number caught per hour by species)
Catch per unit area (for swept area calculation)
Length-frequencies (by species and sex)
Age-frequencies (by species and sex)
Biological data (e.g. maturity stages, length/weight relationship)
Data on fishing gear (e.g. mesh size)

Some data are easy to define and record such as the length of a fish and the number of fish. Other data are more problematical to obtain, such as the age of a fish read from daily rings. Finally, there are data which are very problematical to define, such as a measure for effort that is proportional to fishing mortality. (This type of data problem may in certain cases never be solved, and perhaps the way out is to search for alternative models, which require a different type of input data.)

There is no systematic way to overcome the problems of defining data and the bias problems. The choice of an adequate methodology is to a certain degree a matter of personal judgement combined with skill and experience. This manual may appear as a kind of cookery-book with pre-determined recipes for each case, but unfortunately, it cannot be used as such. The most important background for a fish stock assessment worker is a profound knowledge of the biology of the living resources and the fisheries exploiting them gained through continuous sampling of as many (relevant) data as possible, year after year. A long time series, say several decades, of fisheries data may contain data reflecting extreme situations, and thus define the upper and lower limits for predictions of yield and stock size.

In some cases, only a part of the catch from a stock is covered by the sampling programme. That happens, for example, when several countries exploit a shared resource and do not exchange or pool their data, or when some countries do not collect data. In that case the catches should in one way or another be raised to account for the total. The raising would be based on certain assumptions, such as country B (which does not collect samples) has a fishery which corresponds to, say, 20% of that of country A (which collects samples). In such cases it is always better to make a qualified guess than to ignore an important component of the catch taken from a stock.

Often there are doubts about the stock definition. If that is the case, remember that it is better to make the mistake of pooling two small stocks than to make assessments of only a part of a stock. Because, even when two stocks have been wrongly pooled, the conclusions for the combined stocks may be correct also for each stock individually. If on the other hand, a stock is being exploited by more than one fleet, say from different countries, and the fishing mortality caused by the other fleet(s) is not taken into account when doing the assessments and making the predictions, the effect of manage-ment measures may not be as expected. For example, a decrease in fishing effort by one fleet may be offset by an increase in the other fleet. Then the total fishing pressure may remain the same or actually increase and the predicted improvements in yields may not occur.

Fisheries data may include other types of data than those dealt with in the present manual. Such data may concern economic, sociological and environmental aspects. Although a fishery biologist is concentrating on the biological/technical aspects of fisheries, she/he should also be aware of progress in these other research fields. This applies in particular to bio-economics, which is now developing rapidly (see Chapter 8).

14.2 REVIEW OF METHODS TO BE USED ACCORDING TO THE TYPE OF DATA AVAILABLE

One of the most difficult aspects of fish stock assessment is to decide which methods should be used to analyze a particular data set. In this section a series of data sets are presented in a systematic way, grouped at different levels of availability and quality. These sets will be discussed at a case-by-case basis.

In the following five main levels of availability of data are considered, namely:

Level A: When only survey data are available
Level B: When only catch or catch/effort data are available
Level C: When only length-frequencies are available
Level D: When both catch/effort data and length-frequencies are available. (One case with limited age-frequency data is also included.)
Level E: When all kinds of data are available, in particular time series of age-frequencies.

The review starts at the lowest level of data availability and gradually moves to the highest level. Within each main level, a number of cases is considered, which are categorized with the aid of a small table where the existence/non-existence of data from the commercial fishery and research survey data are indicated by the following:

-	:	No data collected
Single	:	A single or a few samples collected
Single time series	:	A time series for one year has been collected
Multiple time series	:	Time series for two or more years are available

Level A: When only survey data are available

Case A.1

A.1 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	-	-	-	-
Research survey	Single	-	-	-

This case and the following may apply to hitherto unexploited resources, or exploited resources which have never been investigated by fish stock assessment workers. Case A.1 deals with a virgin stock. Use the swept area method for analysis (see Chapter 13) and the Gulland formula for prediction of the potential yield (see Section 9.2). The result of this exercise gives only the order of magnitude of the sustainable potential yield (that is: 100 tonnes or 1,000 tonnes, or 10,000 tonnes, etc.).

Case A.2

A.2 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Single	-	-	-
Research survey	Single	-	-	-

In this case the resource is not a virgin stock, because there is a commercial fishery. Use the swept area method (see Chapter 13) for the historical analysis and the Garcia *et al.* formula for the catch prediction (see Section 9.4).

Level B: When only catch or catch/effort data are available

With this type of data only surplus production models can be used to predict the maximum sustainable yield. The models at hand are mathematically very simple, and therefore large deviations from the models can be expected.

Case B.1

B.1 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Single	-	-	-
Research survey	-	-	-	-

This is the lowest possible level allowing for a sort of fish stock assessment. The method suggested is the simplest possible one - it is so simple that it has not been mentioned earlier in the manual. Prediction for future years equals the catch observed. Effort is difficult to use, as nothing is known for sure about the state of exploitation. If only the catch is known (effort not known) for a series of years, use the average catch for prediction. There is no real historical analysis involved here.

Case B.2

B.2 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Multiple time series	-	-	-
Research survey	-	-	-	-

Use surplus production models (Schaefer or Fox models, see Chapter 9). If results of alternative methods deviate substantially, select the result giving the best fit to the data. If data are not by species, but by species group (family) the method may still be applied. The models are applied for the historical analysis as well as prediction. If data are by fishing grounds in the form of catch rates by area, for example in coral reef areas, the Munro and Thompson plot should be used (see Section 9.5).

Level C: When only length-frequencies are available

The methodology of length-frequency analysis is based on the assumption that recruitment is seasonal with one or at most two peaks per year (see Section 1.6). It assumes that samples cover the entire range of lengths. Often, there are problems with the smallest length classes due to gear selectivity and sometimes certain length groups are missing from the samples due to the migratory behaviour of the species in question.

The length-based methodology depends on the life span of the species under investigation. Naturally, only a short time series of data is needed for estimation of growth of a species with a short life span. On the other hand, frequent samples (say monthly) are needed for short-lived species like shrimps, while for long-lived species such as groupers one annual sample may be adequate.

As a matter of routine, try various forms of data-massage, that is, see what happens, for example, when doubling the size of the length class or when doubling the time period (see Section 3.4.2). Samples where bias problems can be demonstrated may be excluded. In cases of migration only data which are separated with a time period of one year should be used (see Section 11.3.1). There are many different ways of combining massaged data, so do not hesitate to try any sensible combination.

Be careful with computerized methods. Some computer programs give results irrespective of the degree to which the data conform to the underlying model. Choose the methods which provide a warning when data are in conflict with the model. Be critical of the results. Do not, for example, accept a growth curve fitting, unless a modal progression can already be seen in the original data. If the Bhattacharya and similar methods do not give convincing results even after all possible massaging, then the only solution is to try to read ages from hard parts.

The cases under C deal with situations where research on a resource has just been started.

Case C.1

In the first, most data-limited case (C.1), data do not include total catches and effort of the commercial fishery. Thus, no estimate of total catch is available, and all prediction results consequently become relative.

C.1 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	-	Single	-	Single
Research survey	-	-	-	-

C.1 Historical analysis

Growth parameters: Use length-frequency analysis for example, ELEFAN I or the Bhattacharya method (see Section 3.4.1) combined with (pseudo) modal progression analysis (see Section 3.4.2) or some more sophisticated maximum likelihood method, to estimate growth parameters from a single sample under the assumption that the normally distributed components correspond to one or two recruitments per year.

Mortality rates: Use the length-converted catch curve to estimate Z (see Section 4.4.5), under the assumption of constant recruitment and constant mortality. Use Pauly's formula for M (Eq. 4.7.2.1) and estimate F by subtracting M from Z. Estimate L50% from the catch curve and convert it to age (t50%) (see Section 6.5).

C.1 Catch prediction

Use Beverton and Holt's yield per recruit model (Sections 8.2 to 8.3). Use t50% as the "knife-edge-age". In cases where the length-weight relationship has an exponent significantly different from 3, or Z was found not to be constant after recruitment is completed, use the Thompson and Bell model (see Sections 8.6 to 8.7). If the fishery considered is a mixed fishery (most tropical fisheries are) then use the method for mixed fishery (see Section 10.4.2) for as many species as possible combined. Whenever possible, try to make the catch prediction for all fleets in one go (see Section 10.4.3) and calculate the value of all yields combined (value of landings in weight).

C.1 Comments

In theory this procedure is possible when only one single length-frequency sample is available. However, the results are subject to an unknown bias and uncertainty, and should always be followed up by further investigations. Length-frequency analysis may be dubious because the pseudo modal progression has to be based on the assumption that the single sample can be used as an estimate for the entire life span of the species. If the species is short-lived (for example shrimps) and therefore only shows one or at most two peaks, the method may not be applicable at all. In the latter case the sampling must be continued to obtain a time series (for example for each month of the year) before the estimation of growth parameters can be started.

Case C.2

C.2 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	-	Single	-	Single
Research survey	Single	Single	-	Single

C.2 Historical analysis

Growth parameters: Use length-frequency analysis on samples combined from research survey and from commercial fishery as under case C.1. The research survey data often provide a better coverage of the smaller length groups than the data from the commercial fishery.

Mortality rates: Use the length-converted catch curve based on the survey data to estimate Z, under the assumption of constant recruitment. The survey data are assumed to represent the entire stock better than the commercial fishery, which does not attempt to collect random samples. Use Pauly's formula for M and estimate F by subtracting M from Z. Do a length-based cohort analysis (see Section 5.3) and compare the average F for the fully-exploited age groups with the estimate obtained from the catch curve analysis. Estimate L50% from the catch curve and convert it to age (t50%).

C.2 Catch prediction

If estimates of stock size (or absolute recruitment) are available, use the Thompson and Bell model. The Beverton and Holt Y/R model can be used if the estimated F-array looks like knife-edged, and if the exponent in the length-weight relationship is not significantly different from 3. In all other cases it is better to use the Thompson and Bell model.

Level D: When size distributions and catch/effort data are available

In this case it is possible to raise the size-frequencies to the total catch taken from the stock in question. It is assumed that all major gear categories (fleets) have been sampled, and have been raised and summed to represent the total catch taken from the stock. If only part of the fishery is covered by the sampling programme, the estimate of total catch must be raised in one way or another to account for all catches. A skilled guess on the unknown catches will have to be used in the worst case.

Case D.1

D.1 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Single	Single	-	Single
Research survey	-	-	-	-

D.1 Historical analysis

Growth parameters: Use length-frequency analysis on samples from the commercial fishery as under case C.2.

Mortality rates: Use Pauly's formula for M and length-converted cohort analysis for the estimation of F and stock size by length group. Note that the recruitment number is also estimated.

D.1 Catch prediction

Use the length-based Thompson and Bell model. Use the recruitment estimated by cohort analysis as input to predict the absolute yield and stock biomass. Use the Thompson and Bell model for assessing the effect of changing the fishing pattern. Notice that in this case, the resultant selection parameters are not explicitly estimated - they are embedded in the F-by-length-class-array.

Case D.2

In case D.2 there is a time series over one year, for example, length-frequency samples each month of the year, for all major gear categories. In the case of short-lived species like shrimps the time series may cover the entire life span of the species.

D.2 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Single time series	Single time series	-	Single time series
Research survey	-	-	-	-

D.2 Historical analysis

Growth parameters: Use length-frequency analysis on samples from the commercial fishery. In this case it is possible to make a complete modal progression analysis for short-lived species, but for long-lived species (life span of two or more years) the modal progression becomes a mixture of pseudo and real cohorts.

Be critical of the results from growth curve fitting. If the time series contains parts with apparent negative growth (see Section 11.2) or periods of no growth, the possibility of bias in the data should be considered carefully, and perhaps a better way of sampling should be found. Do not ignore the parts of the time series which do not show modal progression, and do not use only those parts which show modal progression, unless there is a good rational justification for so doing. Be aware that bias caused by migration may appear as seasonality of the growth rate, and that it may be more or less impossible to separate the two phenomena.

Mortality rates: As for D.1. As input to the length-based cohort analysis, use all samples summed over the year (properly weighted). In the case of a short-lived species it is possible to make an age-based cohort analysis, if, for example, length-frequencies are available for each month which have been resolved into age-group components.

It is possible to do an age-based cohort analysis or a VPA (see Section 5.1), using the age groups estimated by the Bhattacharya analysis as input (see Fig. 7.6.5).

D.2 Catch prediction

Same as for D.1. For short-lived species the effect of a closed season can now also be assessed (see Section 8.6).

D.2 Comments

As the entire analysis is based on only one year's data, the results should be taken with reservation. Whether the year in question is an exceptional year or is close to the average year is not known. For example, there is no information on the variability in recruitment. It is of utmost importance to know if recruitment remains at a stable level or if it is highly variable.

Once length-frequency samples have been resolved it is possible to use only age-based methods, which have the advantage of being easier to work with, while the results are easier to interpret.

Case D.3

D.3 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Multiple time series	Multiple time series	-	Multiple time series
Research survey	-	-	-	-

In case D.3 there is a multiple time series, for example, length-frequency samples each month of the year, during, say, ten years, for all major gear categories. In the case of short-lived species like shrimps the time series may cover the life span of the species many times, and even for long-lived species some cohorts may be represented during their entire life span.

D.3 Historical analysis

Growth parameters: Use length-frequency analysis on samples from the commercial fishery. In this case it is possible to make a complete modal progression analysis for both short-lived and long-lived species.

Mortality rates: The average annual length composition may be used as input for a length-based cohort analysis, which would give the average fishing mortalities and stock size for the period covered. An age-based cohort analysis, with age groups from the Bhattacharya analysis as input may also be attempted. In the latter case the recruitment number will be estimated for each cohort, and some understanding of the variability of recruitment will be gained.

D.3 Catch prediction

Use the length-based and/or the age-based Thompson and Bell model, depending on the type(s) of cohort analysis made.

D.3 Comments

There may still be problems with the estimation of growth parameters, because certain length groups may be lacking, for example, because of gear selection and/or migration. The commercial fishery may not cover the entire distributional area of the resources, for example, the boats may only be able to fish to certain depths or their range may be limited.

Case D.4

D.4 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Multiple time series	Multiple time series	-	Multiple time series
Research survey	Single time series	Single time series	-	Single time series

D.4 Historical analysis

In this case there are two independent data collections and they may be used for mutual verification, or to disclose bias problems.

Growth parameters: It may be necessary to decide to use only the survey data for estimation of growth parameters, if the commercial data are suspected to be heavily biased. The two types of data may also be combined. Missing data from the commercial fishery may be filled in with research vessel data.

Mortality rates: Use cohort analysis or VPA. If the research vessel survey gave a swept area estimate of biomass, it may be possible to select a fishing mortality which produces a recruitment number which in the cohort analysis produces the same stock biomass as estimated from the survey. If this is not possible, then either the survey or the commercial sampling programme is biased. If both of them are biased it may not be possible to get agreement between the two methods. Z may be estimated from the catch curve analysis and be compared to the M plus the average F estimated from cohort analysis.

D.4 Catch prediction

Same as case D.3.

D.4 Comments

With the data of case D.4, there is no way to verify the estimates of growth parameters from length-frequencies.

In case D.5 a few age readings are available which can be used to verify the results based on length-frequency analysis.

Case D.5

D.5 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Multiple time series	Multiple time series	Single	Multiple time series
Research survey	Multiple time series	Multiple time series	Single	Multiple time series

D.5 Historical analysis

Growth parameters: Use the least squares method to estimate growth parameters from age/length data (see Section 3.3.4). If the results from the otolith data deviate from results from the length-frequency analysis, check the otolith readings carefully, for example, by comparison with other workers. If results still differ, use the otolith results rather than the length-based results, unless there are really good reasons to prefer the length-based methods, such as in the case where there are severe difficulties in reading the hard parts, while at the same time the length-frequency analysis shows a beautiful modal progression. For some small pelagic species it has proved to be very difficult to apply length-frequency analysis, and then the only solution seems to be age readings on hard parts.

Try to create an age/length key (see Section 3.2.1) and use it to convert length-frequencies into age-frequencies. This approach would replace the Bhattacharya method. However, as age/length keys may vary from year to year, otoliths should preferably be collected and read on a routine basis to apply this technique.

Mortality rates: Same as case D.4.

D.5 Catch prediction

Same as case D.4.

D.5 Comments

Some tropical fish deposit annual rings in otoliths or other hard parts, and for such species otoliths should be collected on a routine basis. For many tropical species, only the daily rings are useful for age determination, and then age reading becomes rather tedious and expensive. The results of age reading from daily rings may also depend on the equipment used. In some cases more rings can be observed when using a scanning electronic microscope than with a light microscope (see Morales-Nin, 1991).

Level E: When all kinds of data are available

This is the ideal case, where any kind of data you may think of is available. Forget all about von Bertalanffy growth curves, and do not use length-based methods. However, length-frequencies may be used in connection with an age/length key, and also for an assessment of gear selection. Mortality rates and stock sizes should be estimated with age-based methods.

If all these data are available several methods can be applied which are not described in the present manual, such as "tuning" of VPA and multi-species VPA. Tuning of VPA means that the VPA results are compared with independent observations which can be assumed to be proportional to the VPA results. For example, effort is supposed to be proportional to fishing mortality and catch per unit of effort (CPUE) from a research vessel survey is supposed to be proportional to the stock numbers estimated from VPA. For pelagic species estimates obtained by acoustic surveys may be useful for VPA tuning.

These are methods used in the North East Atlantic, where ICES (International Council for the Exploration of the Sea) is the scientific body that provides advice to the managers of fishery resources.

Case E.1

E.1 Data	Catch/Effort	Length-frequencies	Age-frequencies	Biological data
Commercial fishery	Multiple time series	Multiple time series	Multiple time series	Multiple time series
Research survey	Multiple time series	Multiple time series	Multiple time series	Multiple time series

E.1 Historical analysis

Growth parameters: Not really needed. The results of otolith readings provide a weight-at-age-array, which can be used as input to the Thompson and Bell model. Actually, any growth curve can be used. (The growth of some fish does not conform very well to the von Bertalanffy growth model.)

Mortality rates: Use VPA. If stomach content data are available then predation can be estimated and multispecies VPA be applied. If effort data are available then use VPA-tuning methods.

E.1 Catch prediction

Use the multispecies and multifleet Thompson and Bell model with all landings converted into value.

E.1 Comment

For some countries with large fisheries it is justifiable to organize expensive data collection programmes, while for countries with small fishery resources it may be difficult to justify large expenditures for fisheries research irrespective of the *per caput* income. For several reasons, the fishery researcher's dream of an ideal supply of data may never materialize, and that may not necessarily be a negative thing seen from the point of view of the entire society of the country. In that case the researcher will have to manage with a less demanding methodology.