# PART 2:
# TECHNICAL GUIDELINES

# Summary

It is necessary to define management objectives so that if these objectives are met, the CITES goal will automatically follow. The CITES objective will be to control exports so that the stock remains in a state sufficiently close to its unexploited state so that it will not become endangered. Whether this objective is met should be verifiable through various government reports and export monitoring.

Fisheries management objectives should be to:

- Maintain the conch population above the overfished level.
- Maintain fishing effort below level that would lead to overfishing.
- Maintain the reproductive capacity of the stock.
- Maintain socio-economic returns as close to the desired optimum as possible.

Note that these objectives are not limited to exports, but may encompass wider controls and concerns of which CITES objectives are a part.

These objectives are met by achieving management and scientific outputs. Management is required to set and enforce the controls that change the state of the fishery so that the:

- Current stock state is above its limit.
- Current mortality rate is below its limit.
- Reproductive state is above its limit.
- Socio-economic returns are closer to the optimum.

The outputs from the scientific authority include indicators and reference points for the current stock state, fishing mortality, reproductive capacity and socioeconomic performance. These are use as feedback to the management controls.

This manual provides advice on how management and scientific authorities might achieve these outputs. This is largely through implementing a data collection programme and then basing advice upon the data collected.

Data is converted to simplified indicators and reference points which measure the state of the fishery and the stock. While difficult to estimate statistically, chosen indicators should be simple to understand and capture all relevant important information about the fishery.

Definitions of such states as “overfished” should be agreed based on indicator values. For example, if the catch per boat day is an indicator, overfishing could be defined as a point when this indicator is too low. Management actions already agreed among stakeholders should be associated with all such points. In this example, a rebuilding plan would automatically be applied.

It is important that the decision-making is transparent and based upon objective assessments of the fishery. It will be necessary for all stakeholders to identify the current state of the fishery and verify that agreed measures have been implemented.

# 5. General approach

The initial aim of any management planning is to define a minimum set of objectives covering conservation/sustainability, catch rates and other key social and economic concerns. As well as general principles usually expressed in the policy, the management will also require explicit operational objectives. Operational objectives should represent the policy, but be more clearly defined in terms of what practically they mean in day-to-day running of the fishery.

The management plan should include documentation of the:

- policy and goals on which decisions should be based;
- operational objectives defining practical achievable management aims and reconciling as far as possible conflicts within the fishery;
- indicators and reference points that will be used to quantify the objectives;
- controls which will be applied to achieve the objectives by among other things altering the indicators;
- plan of actions when indicators pass reference points;
- technical information on the assessments conducted and the default operational model on which management decisions are taken.

## 5.1 DEVELOPING MANAGEMENT OBJECTIVES

The management objectives should consider all major issues pertaining to the fishery and the way it operates. These issues can be divided broadly into four types:

- Biological: The stock needs to have sufficient numbers of animals remaining in the sea after fishing so that it is able to replenish itself. The biological objectives set for conch usually refer to controlling the total catch to be commensurate with the growth of the stock maximum sustainable yield (MSY), and leaving sufficient spawning stock (mature females) for breeding purposes. It may be possible for management to undertake stock enhancement. This has not been shown to be successful for conch to date, but introducing adults to severely depleted resources could be found to be beneficial in future.
- Ecological and environmental: Conch are not an isolated species, but live with other species in a shallow water tropical ecosystem. Fishing can affect this ecosystem in many ways. However, unlike other fisheries, conch fishing is not associated with habitat damage or significant by-catch. It is possible conch fishers will take other species opportunistically, but in general conch does not form part of a multispecies commercial fishery. Conch can, however, form part of the incidental catch for other directed fisheries.
- Social, cultural and economic: Cultural and economic concerns may encourage high profits for fishers, keeping fish prices low in markets to provide food security for consumers, maintaining employment. Social and cultural issues are often the most difficult to change. Where, for example, people believe everyone has a right to fish; it may be difficult to protect individual fisher livelihoods against opportunistic fishing. Stopping people fishing altogether when it is part of their culture may neither be possible or desirable, and therefore some middle way may be necessary.
- Externalities: There are usually other stakeholders apart from fishers, such as those involved in tourism, who have an interest in the conch and other fished resources.

Operational objectives often depend upon giving precise meanings to words, such as "sustainable", "optimal", and "benefits" used in the policy and goals statements. Optimal implies some beneficiaries who need to be made explicit, whether they are fishers or the general public who buy fish. Benefits may refer to income, economic rent, industrial profits, foreign exchange or local protein and food.

Statements may appear to be conflicting, and therefore may need rewording or restructuring. A strategy is required to deal with conflicting interests. Conflicting quantitative requirements can be converted explicitly or implicitly into a single variable using an exchange rate, for example, one job is worth US$10 000 profits. This works well if they are not mutually exclusive. If they conflict, it can become very contentious as to what an appropriate exchange is. For example, an extra US$10 000 profit for some investors is unlikely to be acceptable to another who loses his job as a result. More often, the general objective is surrounded by constraints representing acceptable losses. So, for example, the aim might be to maximize industrial vessel profits, subject to maintaining a minimum employment of 500 fishers in the artisanal fishery. In general, only one objective can be maximized (optimized), although this objective may cover a combination of mutual considerations, but any number of factors can be considered in the form of constraints.

Consultation and joint decision-making are essential in determining the objectives. The objectives should reflect the reasonable desires of interest groups within the constraints imposed by ecological limits and overriding objectives of national planning. Identifying the various interest groups and encouraging them into partnership with the management authority will often form an initial objective in itself.

Most controls are secondary compared to controlling overall fishing mortality and fishing capacity (including processing capacity). If fishing mortality is controlled to the appropriate level, other requirements will very likely be met. Fleet capacity should be reduced to be commensurate that required to produce the maximum sustainable yield or lower. If there is excessive capacity, experience has shown that economic and social pressures will make it very difficult to control the amount of fishing.

## 5.2 STOCK IDENTIFICATION AND MANAGEMENT UNITS

With a pelagic larval stage, conch stocks may recruit individuals from many surrounding populations. In the strict sense of stocks being completely isolated, it is quite possible that several fisheries will share a single conch population. Although this should lead to calls for greater cooperation, it should not lead to inaction on the part of individual fisheries for two reasons.

Firstly, joint actions are likely to be close to the sum of individual fishery actions taken as though they are exploiting isolated stocks. Therefore it does not take cooperation to know what to do. A fishery should undertake action immediately and then seek adjoining fisheries to do likewise.

Secondly, recruitment links between populations may not be strong. Conch has only a short three-week pelagic larval stage. It is therefore unlikely they travel far and the majority of recruits are probably derived locally. In this case, running a country's fishery as a separate management unit is appropriate.

## 5.3 FROM POLICY TO DATA COLLECTION

To apply policy in fisheries, it is necessary to obtain information on the state of the fishery. This is achieved by routine data collection which allows scientists to estimate variables which measure different aspects of the state of the fishery (FAO, 1999).

Fisheries are general too complex to manage without some simplification. This can be achieved by reducing the description of change in the fishery to a small set of indicators representing the fishery's performance.

Interpretation of indicators may be difficult. It is achieved by decision rules usually defined by boundaries, called reference points, where the fishery is deemed to change from one state to another. Each policy needs to be represented by a set of indicators and reference points.

For example, overfishing is often talked about but rarely defined. Application of the policy to avoid overfishing needs a precise definition of what overfishing is. A common interpretation is the point where biomass has fallen below 50 percent of its unexploited state.

Policy usually requires two types of reference points:

- Limit and precautionary reference points define when the fishery might close and when rebuilding programmes might be instituted.
- Target reference points define the optimum point towards which managers are trying to move the fishery.

It is important that both types of reference points are defined for each fishery.

As well as providing an objective way to summarize the state of a fishery, indicators and reference points allow easier communication between scientists and managers and others within the fishery. Although there is considerably more to managing a fishery than simply defining indicators and reference points they can be used to plan for important changes in management actions and allow easier communication between stakeholders.

Data collection must provide information for the estimation of indicators and reference points. Regular data collection forms the foundation for providing independent advice and arbitration between different interest groups.

Controls that can have a demonstrable effect on the indicators need to be defined for the fishery. Controls on catch and effort should allow managers to change the indicators, demonstrably improving the performance of the fishery.

Indicators must not only accurately represent the state of the fishery; they must be independent of the controls. A control that affects an indicator directly makes the indicator invalid. For example, if CPUE is being used as an indicator, a control affecting the gear efficiency may change CPUE even if biomass does not change. If this is the case, an alternative, possibly more costly indicator, may have to be developed to bridge this change.

All these issues must be addressed in the management plan. The management plan should encapsulate not just the general policy, but the framework through which it will be applied.

## 5.4 MANAGEMENT LOGIC AND MEANS OF VERIFICATION

It is necessary to define a logical system that will achieve CITES overall goal: to avoid endangering *Strombus gigas*. This is achieved by preventing the various stocks of conch from becoming endangered, which in turn is achieved by meeting various fisheries management objectives (Figure 1 and Table 2).

Objectives should be defined not only for the direct avoidance of particular fishery states, such as overfishing, but to achieve socio-economic conditions which will encourage a sustainable fishery. In particular, avoiding overcapacity is necessary to achieve a sustainable fishery.

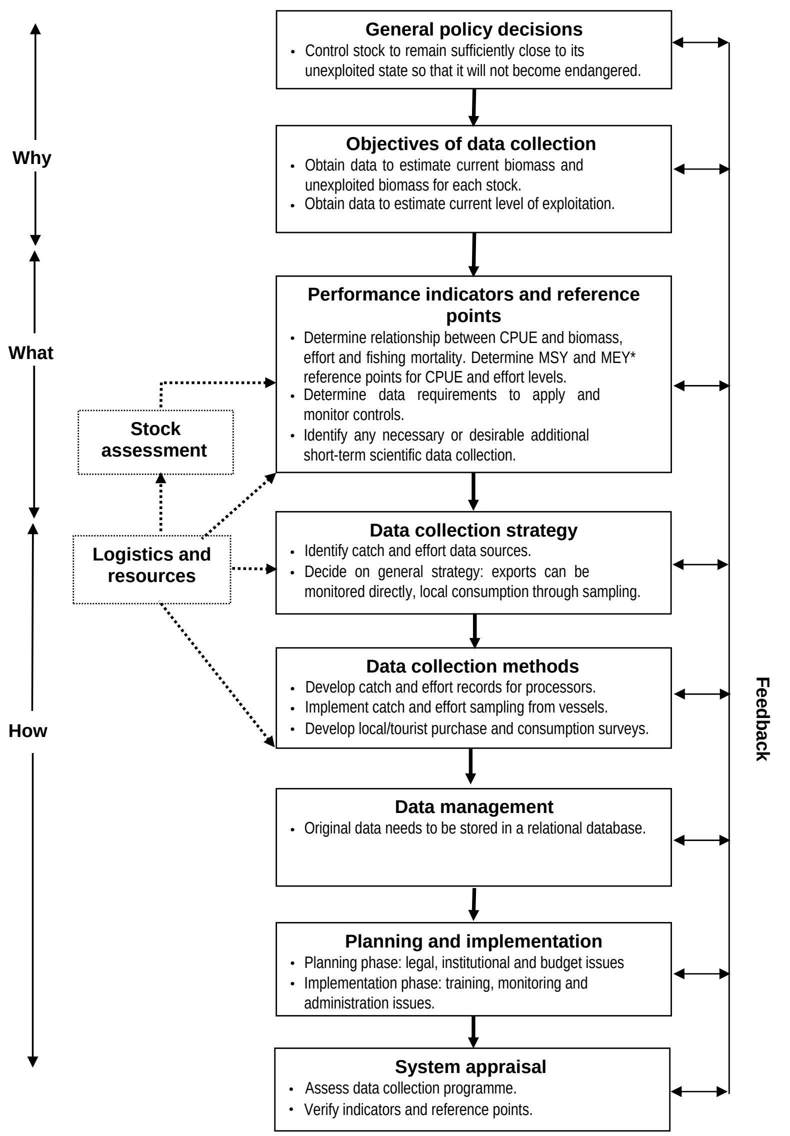
The system can be defined by a hierarchical set of objectives. Meeting the lowest set of objectives should automatically achieve the highest goal. Each fishery should set out such a plan. This need not necessarily follow the specific recommendations in this manual, but must apply some logic that guarantees CITES objectives are met.

There is an international standard against which a fishery can be measured represented by the FAO Code of Conduct for Responsible Fisheries. There is no perfect management regime. Management is always limited by resources and various social constraints. A checklist given in the Appendix (Fishery checklist) can be used to assess a fishery's management regime.

As well as defining the logic showing that the management objectives will be achieved if the various activities are completed satisfactorily, a management plan will need to identify how the various activities and outcomes will be verified. Verification is necessary both for managers to assess the effectiveness of the system and for external reviewers to make sure that management claims are justified. The monitoring information, including such sources as the vessel register, purchase receipts, export inspection reports, and scientific sampling system should ideally be used to generate an annual report on the performance of the management system.

FIGURE 1

**An illustration of the relationship between the policy and a data collection programme. In this case, catch and effort data are collected to estimate the state of the stock and the exploitation rate. It will be necessary to check that the data collection programme gives reasonably precise estimates of the indicators and that the indicators are truly related to the state of the fishery. For example, applying a reduced catch quota should eventually lead to a demonstrable increase in the CPUE and immediately reduce effort indicators (adapted from FAO, 1999).**




*MEY: maximum economic yield

TABLE 2

**A logical framework for a conch fishery management system. Management should be focused on the means of fishery control and level of control to achieve objectives. Objectives are translated into suitable indicators and reference points. If these objectives are met, the CITES goal will automatically follow**

| Narrative summary | Means of verification |
|---|---|
| **Goal** | |
| Article II paragraph 3. …[exports] should be limited in order to maintain that species throughout its range at a level consistent with its role in the ecosystems in which it occurs and well above the level at which that species might become eligible for inclusion in Appendix I … | |
| **CITES objectives** | |
| Control exports subject to a stock remaining in a state sufficiently close to its unexploited state so that it will not become endangered. | Science reports<br>Working Group Report<br>Export monitoring |
| **Fisheries management objectives** | |
| Maintain population above the overfished level<br>Maintain fishing capacity below overfishing level<br>Maintain fishing effort below level that would lead to overfishing<br>Maintain reproductive capacity of the stock<br>Maintain socio-economic returns as close to the desired optimum as possible | Government Policy Statement<br>Fishery Management Plan |
| **Management outputs** | |
| Set annual controls to move:<br>current stock state above limit<br>current mortality rate below limit<br>reproductive state above limit<br>socio-economic returns closer to the optimum | Annual Management Report<br>Demonstrable correlation between control and indicator from time series |
| **Science outputs** | |
| Define indicators and reference points proxies for:<br>current stock state<br>fishing mortality<br>reproductive capacity<br>socio-economic performance | Independent Annual Science Report<br>Scientific reports and papers justifying measures chosen |
| **MANAGEMENT ACTIVITIES** | |
| Landings, effort, vessel, fisher and gear monitoring<br>Fishery area and seasonal closures<br>Prosecutions applied | Database records<br>Data sheets<br>Internal reports |
| **Science activities** | |
| Catch sampling and monitoring<br>Fishery independent surveys<br>Models and analysis<br>Assess by-catch and environmental impacts | Database<br>Data sheets<br>Scientific papers and reports |

## 5.5 STANDARD INDICATORS AND REFERENCE POINTS

The fundamental indicators are the proportion of the stock that is being removed by fishing (fishing mortality) and the remaining biomass of mature females upon which recruitment ultimately depends.

These variables can be estimated directed or monitored through the use of proxies (Table 3). Proxy variables ideally should be approximately proportional to, rather equal to, the variable of interest. Even if a stock assessment model cannot be fitted, these variables can be plotted to monitor trends in the fishery.

Particular types of data need to be collected to estimate indicators and reference points (Table 4). Interpretation of indicators may require research (Table 5), or at the very least a decision on the default growth and mortality models to apply. These types of data either are used for monitoring (collected continuously) or as single research programmes. Information from research programmes can be shared within the region, thereby reducing costs.

Indicators are statistics calculated from the available data. Like any statistic, they are associated with some error. So, for example, the indicator could be an estimate of the biomass. The biomass estimate will be uncertain, and that uncertainty will need to be taken into account in decision-making.

Density could be used as an indicator (as opposed to population biomass) but establishing a reference point could be problematic and density will be sensitive to sample design, types of habitat present and their extent.

Reference points require an application of some principle (Table 6) Reference points should define boundaries where fisheries management takes actions or changes a control following some predefined agreement (Figure 2). These points need to be decided by management in consultation with stakeholders.

Other measures of the fisheries state are also required, particularly fleet capacity and vessel fishing power. This can be achieved through a vessel register. Most countries already operate vessel registers and a licensing system.

TABLE 3
**Proxy variables which should be related to standard fisheries indicators. The relationship should ideally be verified. The proxies can be used to monitor the fishery without carrying out a full stock assessment**

| Proxy | Variable of interest |
|---|---|
| Effort | Fishing mortality (F) |
| CPUE | Biomass |
| Survey density | Biomass and spawning stock biomass |
| Mean meat weight* | Fishing mortality |

*Mean meat weight indicates the average size of the conch. The statistic can be obtained by weighing an d then counting a number of individuals. It is important that processing is taken into account as this will lower the weight. Mean weight should indicate the age and hence maturity of the conch in the landings, and may be used to monitor which parts of the conch population the fishery is exploiting.

TABLE 4
**The main data types and the indicators or models they may be used to estimate or research**

| Data type | Estimates |
|---|---|
| Catch and effort | Biomass |
| Survey density | Biomass and spawning stock biomass |
| Size frequency data (meat weight, shell morphometrics) | F and spawning stock biomass<br>Conversion functions |
| Tagging data | Growth and mortality parameters, including F |

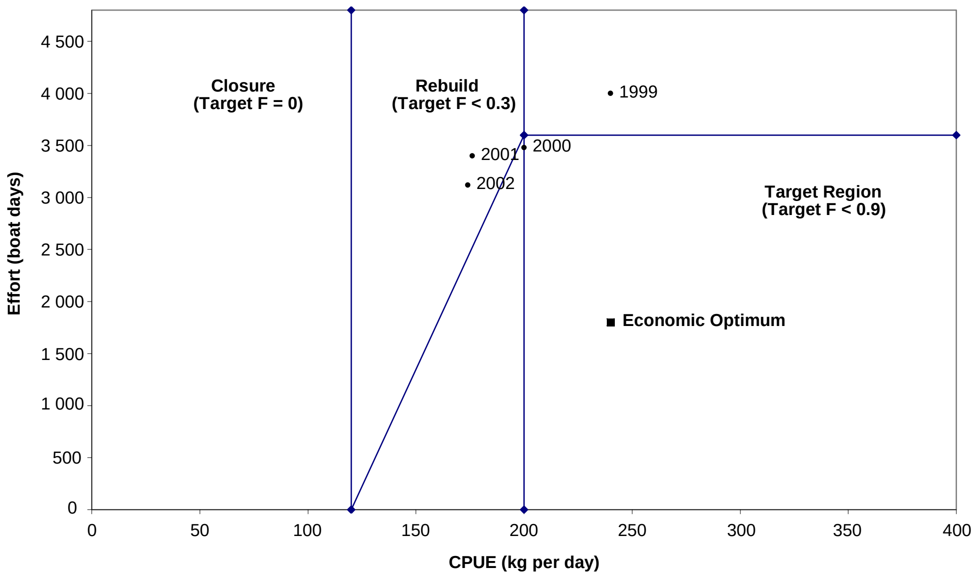
TABLE 5
**Priority research to enable interpretation of routinely collected data**

| Research | Use |
|---|---|
| Growth model | Conversion between size and age necessary for all catch-at-age assessment approaches. |
| Morphometric conversion | Conversion between measurements particularly processed and unprocessed meat weights. |
| Population parameters | Where there are few data, parameters can be estimated independently. Catchability, recovery rates and unexploited density may be obtainable from fishing experiments, for example. |

TABLE 6
**Basic reference points and their principles**

| Reference point | Principle |
|---|---|
| MSY | Maximum sustainable yield. When effort is at the point at which MSY is obtained, any further increase in effort will lead to a decrease in long-tern yield. |
| $F_{SPR}$ | Fishing mortality allowing adequate escapement to replenish the spawning stock (spawners per recruit). |
| MEY | Maximum (discounted) economic yield, the same as MSY but for maximising the economic value after allowing for costs. It is always less than the MSY point and should be a suitable target. |
| $F_{opt}$ | Optimum fishing mortality could be defined in a number of ways, as it should address socio-economic returns and improving utility-per-recruit, for example. |

FIGURE 2
**Example fishery-state diagram of the two main indicator variables and the harvest control rule. The diagram shows the effort in this hypothetical example that could be allowed at different observed catches per unit effort. The reference points are marked as boundaries. The best estimate for the fisheries state (measured as CPUE) is plotted for each year (1999–2002). In this example, there has been excessive effort and the fishery has entered its rebuilding programme. The main current aim would be to reduce fishing effort below 2 500 boat days until CPUE has risen to above 200 kg day-1**




Vessel fishing power is of particular concern in many fisheries as on-going improvements in fishing power of vessels may invalidate CPUE indicators. Fortunately in conch fisheries, fishing power is likely to remain stable and easy to monitor if it does change. Critical change would be between free diving and use of scuba or hookah allowing deeper populations to be exploited. Otherwise vessel length and engine power could indicate fishing power and be monitored through a vessel registration system. Vessel characteristics will not only affect the numbers of divers a vessel might carry, but also will affect the fishing grounds used.

Controlling fleet capacity so that it is appropriate to the potential yield of the fishery is an important aim of management. Excessive fleet capacity is one of the biggest underlying causes for overfishing. For commercial conch fishing, a vessel register is necessary for all vessels exploiting conch. A register should allow managers to control the number and type of vessels which have access to the resource. This in turn limits potential fishing mortality and reduces risks of overfishing.

## 5.6 EMPIRICAL OR NON-PARAMETRIC INDICATORS

While focus has been on interpreting standard indicators such as spawning stock biomass or fishing mortality, in many cases indicators can be developed which are less dependent on model assumptions, but try to apply controls through decision rules and empirical measures of performance.

While such measures would be more robust where information is limited, they will still be founded upon some underlying models of the fishery or stock. These models still need to be researched, verified and improved. However, day to day management can be made a great deal easier through development of simple rules using indicators which are easy for non-technical staff to understand.

## 5.7 PROBABILISTIC INDICATORS

Indicators based on probability explicitly take into account risk. That is, the reference points are defined to take account of the risk decision-makers are prepared to accept and the uncertainties in the observed indicators. Decision analysis can be used to define target reference points. Probabilities defining acceptable risk can be used to define limit reference points.

For example, instead of defining a reference point as the biomass being 50 percent of the unexploited biomass, it can be defined as a 10 percent probability that the current biomass is below 50 percent of the unexploited biomass. This is more realistic than fixed points as the current state of the stock can never be defined precisely.

Approaches based on probability are more sophisticated than classical stock assessment and require some expertise particularly where software is unavailable. Methods are generally based on decision analysis which provides powerful methods for assessments.

Probabilistic approaches are most useful where data are poor and uncertainty is a significant component of decision-making. Under these circumstances reducing risks of overfishing may form the central policy. If data collection is expensive, probabilistic approaches allow a balance between the cost of overfishing and costs of increased data collection.

A policy is required to define how much risk to take. The risk in this case would be defined as the probability of the stock falling below the limit reference point for stock size, or fishing effort being above its limit reference point. While the “precautionary approach” is often put forward as the desirable risk-averse option, it would have to be quantified as specific probabilities.

# 6. Queen conch biology[6]

## 6.1 REPRODUCTION AND RECRUITMENT

Queen conch have been reported as spawning through much of the year, but most spawning is reported between April and September. The season can be variable depending on temperature, turbulence (winter storms) and perhaps density.

Conch begin to mature when the flared lip starts to form, which occurs between 2 and 4 years old and mature conch will usually have a lip thickness of greater than 4 mm. Queen conch females produce demersal eggs, usually in areas of clean sand and will repeatedly deposit egg masses over the course of the spawning season. The number of eggs/egg mass is variable and ranges for 0.3 to 1.5 million depending on age, temperature, weather, condition of the conch and genotype among others.

Females can store eggs for several weeks prior to spawning, and since many males can copulate with one female, sperm from several males can fertilize a single egg mass. Because physical contact with females is necessary for copulation and hence egg production, and because conch are slow moving, it is thought that high density of spawners may be necessary for successful reproduction. In some places, reproductive activity has been observed to decline at relatively low density.

The demersal eggs of queen conch hatch in approximately 5 days, releasing planktonic veliger larvae. The exact length of larval life is not well known, but from mariculture and experiments an expected larval life is 14 to 21 days. Observations suggest that the average extent of larval dispersal is up to a few hundred kilometres, although some long-distance dispersal is possible. Despite this potential, it is likely that dispersal is limited within sub-regions, and therefore populations within different countries should be managed as separate stocks.

## 6.2 ADULT MOVEMENT

Conch settle in areas of soft sand and remain buried during their first year. At this time they are unavailable for assessment. At shell lengths ranging from 50 to 100 mm young juveniles begin to emerge and live on the sand surface. Emergence may be protracted and may accompany a change of habitat. General movement rates are low, but larger conch move further.

There is an ontogenetic migration into deeper water, which becomes more pronounced in large juveniles, which leave nursery areas. A second migration is related to spawning. Conch may move inshore to spawn as temperatures start to increase in spring, but still remaining deep relative to juveniles, and return to deeper water in autumn.

## 6.3 GROWTH

The most unusual aspect of queen conch biology is that growth in shell length ceases at the time of sexual maturity. At this time the shell lip of the adults flares and thickens.

[6] The information presented here is a brief summary, with emphasis on information directly relevant to stock assessment. For more detail and source references see: R.S. Appeldoorn and B. Rodriguez (eds.). 1994. Queen conch biology, fisheries and management. Fundación Científica Los Roques, Caracas, Venezuela. CFMC/CFRAMP. 1999. Report on the Queen Conch Stock Assessment and Management Workshop. Belize City, Belize, 15–22 March 1999. Section 2. (available from http://www.strombusgigas.com/workshops.htm)

This makes it difficult to estimate age, growth and mortality using size-based methods, as the size and age at which the switch occurs between the two growth forms varies. It is therefore recommended that size frequency sampling does not form the only method of stock assessment that is applied. On average, female conch are slightly larger than males.

Growth in lip-thickness cannot be used to age very old conch, because growth is offset by the rate of shell erosion, which is dependent upon the type of substratum the conch occupies, being least in soft sand and greatest on hard or rocky bottom. As a consequence, it is impossible to precisely age conch greater that about 10 years using shell measurements, about half or less of the maximum life span. At best, one can assign individuals to different age-categories based on a combination of shell thickness, color and degree of erosion. These population categories are useful for obtaining some idea of age structure from abundance surveys.

Meat weight varies with age, but does not only increase, but may also decrease with very old conch. Meat weight also can vary depending on the level of processing, which may change over time, reflecting changes in age structure and the increasing skill of workers in processing. Using meat weight data for indicators or as a control is highly uncertain.

Growth related relationships developed for one specific area may not be representative of conch over a broader area. Conch morphology is largely controlled by habitat characteristics, operating directly or mediated through control of growth rate. Factors such as depth, substrate type, food quality and quantity, and density are known to affect growth and morphology.

## 6.4 NATURAL MORTALITY

Conch have a maximum longevity of 20 to 30 years, which suggests adult natural is between 0.28 and 0.20 $year^{-1}$, respectively. Mortality is thought to be very low in conch once they have matured and thickened the shell, but could be very much higher for juvenile conch. Estimates of mortality on juveniles have shown that mortality decreases significantly with increasing size. Mortality can also vary widely due to season, habitat and other factors.

## 6.5 CONCLUSION

The biological characteristics of queen conch make biomass dynamics approaches adequate methods for quantitative stock assessment as they do not require detailed life history information. These methods rely on total catch data (meat weight) and measures of abundance such as catch and effort and surveys. These types of information can be collected, although catch and effort data require some degree of cooperation from the fishing industry. Furthermore, these methods generally require a time series of information and contrast in the data (i.e. catches have changed during the period of monitoring). Single surveys can give estimates of appropriate quotas, but they are not as reliable as dynamic assessment methods.

Methods which attempt to model life history require the ability, at the very least, to link size to age. Shell size data as an indicator of age is most useful during approximately the first seven years of life. Thereafter ageing is difficult due to the split pattern of growth (before/after lip flaring). The degree of general shell erosion is a further indicator of age, but cannot be interpreted accurately. Meat weight may increase in young adults, but declines in older, thick-shelled conch, making meat weight alone a difficult statistic to use.

# 7. Data collection

## 7.1 INTRODUCTION

Data collection forms the foundation for all management decision-making. Data provide independent assessment on the real state of the fishery (see Table 7). It is important that data collection is founded on good statistical principles. However, for data which will be used for long-term monitoring, the collection system must be sustainable and therefore not be too logistically or financially demanding.

Indicators are calculated from data on the basis of scientific research into the appropriate models and supporting information required. These scientific activities are usually reported through a stock assessment which should be carried out regularly. In particular, stock assessment is required to estimate current biomass and unexploited biomass of the stock (see Chapter 8).

Data collection needs to be efficient. There are a number of ways to reduce costs: co-management and participation makes data collection less expensive, more accurate and generally easier to conduct.

There are a number of statistical sampling methods which can be used to improve sampling efficiency including stratification/unequal probability design and cluster sampling. These more complex designs reduce cost but require specialist knowledge.

Use of subjective opinion as well as objective scientific data collection reduces costs. While expert opinion can never truly replace empirical data, it is never possible to do research on all management questions, and assumptions have to be made. Obtaining wide agreement among experts on assumptions through interviews and meetings not only increases the reliability of final results, but also makes the process more transparent and acceptable to stakeholders and reviewers.

It is also important to note that conch data will probably be collected alongside catch statistics for other species. It may therefore not be possible to separate data collection for conch from other data collection activities. However, many of the issues discussed here apply to all fisheries.

TABLE 7
**The main indicators and the data and underlying research required for them**

| Indicator | Data collection | Supporting research |
|---|---|---|
| Biomass | Catch-effort.<br>Stock surveys.<br>Consumption surveys | Estimate expected unexploited CPUE.<br>Unexploited biomass. |
| Fishing Effort | Catch-effort surveys.<br>Effort frame survey.<br>Licensing. | Catchability by gear.<br>Effort limit and target by gear.<br>Capacity limit and target. |
| Spawning stock status/biomass | Catch composition. | Size-maturity ogive. |
| Shell lip thickness | Monitor lip thickness of landed shells. | Develop shell growth model and natural and fishing mortality models. |
| Mean meat weight | Total weight and pieces. | Develop limit and target points from growth and mortality models. |
| Illegal, unreported and unregulated (IUU) fishing | Patrol reports, fisher reports. | Develop IUU index as a relative rate and estimate total IUU catch. |

## 7.2 CATCH AND EFFORT

### 7.2.1 Overview

The fishery will commonly consist of two parts: commercial and non-commercial. The commercial fishery, supplying conch for export and local tourist consumption through restaurants, should be able to supply total catches with high accuracy, and effort for the majority of the fishery. The non-commercial fishery, including traditional subsistence, is more difficult to monitor and it would be advisable to use methods based on sampling.

### 7.2.2 Commercial landings monitoring

Processors should report all the catches they purchase from fishers. This information should be maintained for their own financial records anyway. The requirement is only to copy this information to the management authority.

Receipts should be obtained for all transactions. This is particularly important if the fishery is controlled through catch quotas. If quotas are operating, reported catches will need to be verified by inspection.

Data should be kept as simple as possible. Given a vessel register, only an identifier for the vessel is required (e.g. licence number or captain's name). For daily trips, only the catch landed on each day is required. If possible the time of departure and return is useful, but not necessary. The fishing times are valuable only where there is significant variation in the number of hours in a trip. In many fisheries the trip time does not vary much.

It is not reasonable to expect a commercial company or cooperative to supply much more data than they record anyway as part of their normal operations. Clearly, the quantity of catch purchased falls into this category, but much beyond this would require another approach.

### 7.2.3 Commercial logbooks

Commercial vessels going out for more than one day, perhaps carrying out processing on board, should be required to complete log-books. For larger vessels, this is not particularly onerous as such vessels keep their own private fishing logs.

Log-books should record on each day the date, location and amount of fishing (some measure of effort depending on gear – in this case hours fishing times the number of fishers), and catch weight.

### 7.2.4 Exports

Commercial catches for export can be obtained from two main sources. Actual exports should be reported to the Government Customs Department. As exports require CITES certification by the scientific authority, it should be relative straightforward to measure all exported landings.

Processed weight needs to be linked to landings through a statistical model. This requires good estimates of the conversion parameter(s) based upon large sample from the landings.

### 7.2.5 Commercial purchase receipts

All local restaurant purchases could be monitored through purchase receipts. Restaurants should supply copies each month to the management authority of purchase receipts with the date, fisher's identity, amount bought and value of the conch. Receipts should be simple to complete. It may be necessary to carry out spot checks on quantities in storage to verify receipts, particularly if such purchases cover a significant proportion of the catches.

With growth in tourism, restaurant purchase may be one of the largest changes in local consumption. It is important to monitor changes in catches as these have a direct impact on the exploitation level. Therefore, if tourism is changing or fluctuates, monitoring tourist consumption will be an important component of the data collection system.

### 7.2.6 Obtaining non-commercial catch and effort

Stamatopoulos (2002) describes the sample-based fishery survey method in detail. This method is appropriate to non-commercial conch fishing where there is no easy way to institute or enforce fishers to keep records. Sample-based fishery monitoring requires three components.

Firstly, a sampling frame is required. This usually consists of a complete enumeration of all landing sites and vessels which will land there. Up-to-date information should be available through a vessel register. If no register exists, a frame survey will be required every few years until a register is developed.

Secondly, fisheries staff must visit landing sites and measure the vessel activity. Sites can be chosen at random if there are more sites than staff available. If staff know how many vessels could land at a site from the vessel register, it could be checked which of these vessels have left to fish and are expected back. They need to visit as frequently as possible in a month. If visits must be limited, they should be made at random times during a month.

Finally, vessel trips need to be sampled to obtain estimates of mean catch-per-unit effort. This will require staff to choose vessels randomly when they land if staff cannot measure all vessel catches. Vessels must let them measure their landings. At this point, size frequencies and other data may also be collected through a trip interview.

These data can be combined to estimate total fishing effort and total catch, which can be added to the commercial fishery. Estimation methods also allow the statistical uncertainty to be evaluated and included in assessments. This makes the approach potentially very efficient in collecting information cheaply.

### 7.2.7 Consumption interview data

Where a substantial subsistence fishery exists with no set landing sites, consumption surveys may give some estimate of the quantity of catch taken. This would sample the local population and ask how much and how often people eat conch. Given a total population census, it is possible to raise this estimate to obtain the amount of the total catch that was consumed by local inhabitants which will need to be added into any assessment if not already included elsewhere.

## 7.3 CATCH SIZE FREQUENCY SAMPLING

Catches can be sampled at landing sites. Possible measurements will depend on what is being landed. It is recommended that the following are obtained through sampling landings:

- Shell length and lip thickness (where the shell is landed)
- Unprocessed meat weight
- Sex
- Maturity
- Processed meat weight

For size catch frequencies, a random sample is required. For conversion relationships, a wide range of weights are required. Therefore not all measurements are required for all animals. It is recommended that unprocessed meat weight, sex and maturity be measured for a random sample of landings (around 300 conch should be adequate in the first instance). Of these, a smaller selection taken from the largest, smallest and medium size individuals can be weighed before and after processing. The same process would apply to shell length, lip thickness, (un)processed meat weight, maturity and sex. Any control would have to be consistent so that fishers could avoid discarding dead conch and instead apply selection towards flared lipped conch. This may involve employing fishers to land shells to allow sampling.

There are no commercial size categories that can be used. However, if a minimum weight limit is applied, it is possible animals below this limit will be sold locally. This may still achieve the conservation objective if the price is reduced, but would have to be monitored and assessed.

## 7.4 FISHERY INDEPENDENT SURVEYS

### 7.4.1 Objectives

Surveys are particularly useful in providing a baseline where no previous data has been collected. For many countries surveys are seen as good start point for developing a data collection system. Fishery independent surveys are widely used in many fisheries to estimate abundance. They are particularly appropriate for conch as adult conch can be easily seen and counted and occupy a relatively well defined habitat.

A conch survey will generally have three objectives;

- estimate population densities (number per hectare);
- estimate overall abundance and abundance by age/size and maturity;
- estimate maximum sustainable yield.

While surveys are useful, they are also expensive. They may therefore not form part of a long-term monitoring even if used to initiate a management plan and set management controls. Alternative less expensive methods can be set up which provides similar information at lower cost. However, where financial resources can be found, surveys will always prove a useful source of information and increase confidence in results. It is up to the local managers to assess whether survey costs are justified in each case.

Likewise fishing experiments may estimate biomass in particular areas and can also be used to estimate fishing mortality. Fishing experiments use intensive fishing in a monitored area, effectively closed to immigration and emigration of conch, to link the decline in density to the catch. Coupled with a survey, they would be particularly useful and provide rapid information, but again, may be prohibitively expensive for some fisheries.

### 7.4.2 Sample sites

Survey design is a specialist activity requiring particular expertise. However, the basic method will follow common design needs outlined below. Thompson (1992) can be consulted for more details.

In designing the survey, you will first need to define what you will sample from. For conch surveys, this will be a map of the area where conch are found. Since the conch population rapidly declines below 30-metre depth, minimum information would be a bathymetric map of the bank or shelf which is being exploited. If you lack anything better, a fairly coarse bathymetric map can be obtained from the internet. If you have a habitat map, you can use this to improve your survey even further. You should include areas which are not fished as well as fished areas.

A GPS unit will be needed to locate each sample site. In general, the survey will be conducted from a vessel which can be anchored at an exact location using a global positioning system (GPS).

You will need to know the total sample area, and the area of each stratum, if you are using them. These can be obtained most easily from geographic information system (GIS).

Based on the map, you will need to sample random points within the conch habitat area. In those areas where you do not sample, you will have to assume the density is zero (or some other value). The easiest way to sample points randomly is to use a GIS. The simplest procedure is to choose grid points randomly within the map area, keeping those within the designated boundaries and rejecting the rest. This is continued until the requisite number of random sites within the area is obtained. It is also possible to do this manually using spreadsheet functions, but this is much slower than a GIS.

You can stratify your sample based on the expected abundances and degree of aggregation. You should focus your sampling on the largest areas, the areas that you expect would have the highest conch density and those areas where you suspect conch are more aggregated (in spawning groups for example).

Given that you have a bathymetric map; it makes sense to apply a depth stratification. The bathymetry should have contours marking the depths 0–10 m, 10–20 m, 20–30 m, >30 m. You will need to sample random points within each of the depth ranges using the contours.

If you have a habitat map you can use this to focus your survey on good conch habitat (e.g. seagrass beds, high algal abundance, shallow coarse sand areas). The amount of fishing can also be used, with classifications from high, medium, low and "marine protected areas" (MPA). If in doubt, use only depth for stratification as this captures most of the habitat and fishing intensity variation. If you have MPAs, however, these will need to be sampled as a separate stratum.

If you plan to have the amount of sampling only proportional to the areas being sampled from, the stratification will essentially serve little statistical purpose, but may be useful for logistical purposes. The main gain will be from setting the amount of sampling proportional to the area multiplied by the expected density, the expected variance (clustering) and cost of the survey. However, until you have estimates of density and variance from at least one survey, you should probably sample based on area in each strata and the cost. Deeper strata are generally more expensive to sample, and therefore would have fewer sample sites.

Once a stratum has been defined, some sampling must be carried out within it, or you must assume a density of some value. If you fail to sample in a stratum, you will severely limit the accuracy of the results.

### 7.4.3 Transects

There are, broadly, two types of transect. The most common and easiest to use is the band transect, which has a defined length and width, and all animals within the band are counted. The main assumption is that no conchs within this band are missed. As long as densities are high enough, this method is adequate for conch. However, at low densities this method may become difficult to apply as the sample area becomes too small to get adequate numbers of conch in the sample. The sample area can be increased, by increasing the length of transect or increase its width. The length of transect is limited for operational reasons and should be set at the maximum anyway; its width is limited by how far divers can see underwater while being sure no conch are missed. Employing more divers can increase the transect width, although logistics may become more difficult.

A tape can be used to lay the appropriate transect length underwater. Transect width can then either be estimated by trained divers, identified by divers using a rod (widths up to 5 m) or using a line (e.g. stretched between a pair of divers). Accurate width measurement is important because there is often a tendency to include or exclude conch close to the boundary which can bias the results.

You can vary transect length from site to site, bearing in mind that this will reduce the total sample area. However, shortening transect length may be necessary for deeper ones as the bottom time is limited. Varying the transect line length makes the analysis a little more complicated.

The alternative approach is to count all conch that are seen, but also measure their perpendicular distance from the transect line. This is then used to estimate how detection falls off with distance from the line. While the perpendicular distance should ideally be measured using a tape, it is quite possible for divers to be trained to estimate distances under water quite accurately, at least to the nearest metre. This procedure is more complicated both for data collection and analysis, and probably only advisable when densities are low. For example, if band transects are undertaken and many have zero counts, but divers report that they do see conch outside the transect quite often, this alternative method can be considered. If this approach is adopted, more specific help might be required.

If there is considerable area of greater than 40-m depth where suspected significant conch populations reside, an alternative approach to implement transects may be required. The safe bottom time available to compressed air scuba diving is too short at this depth to make diver transects viable, but remote operated vehicles (ROVs) can easily run transects from a small research vessel. The ROV transect widths are relatively narrow, but they can move more rapidly covering the same or greater areas, and as conch are relatively easy to see, the approach should be very accurate. A ROV and operator would probably need to be hired and brought out for the duration of the survey.

### 7.4.4 Example methodology

A live-aboard vessel with four divers and a vessel captain is provided with a list of survey points. The captain and divers work out the best order in which to do the sites based on safety and logistics. Depending on water depth, it should be possible to do up to four sites a day.

At each sample site, the vessel anchors and four hundred metres transects in each of the four cardinal compass directions (north, south, east, west) are conducted by two groups of two divers. Each transect is laid using a 100-metre length of weighted rope) off a hand-held roller, one by each pair of divers. The rope must be denser than water – nylon rope with small lead weights attached at five metres should be adequate. The width may depend on water clarity (which should be measured using a Secchi disk), but it should usually be possible to cover 5m on either side of the transect line. The total area covered at each site is 100 x 4 x 10 = 4 000 $m^2$ (0.4 ha).

The total area is about 1 000 $km^2$ which 250 000 site areas (4 000 $m^2$). A target sample size of 125 sites is considered possible in 40 days sea time, which should cover 0.05 percent of the area. Although this is only a small part of the area, as long as the population is not too clumped it should be adequate. As this is the first survey, it is decided to divide up the samples among three depth strata approximately according to area. This can be adjusted in future surveys based on the results of this first survey.

### 7.4.5 Data recorded

When a conch is counted, it is useful to place it in a size/maturity category. Divers can be easily trained to recognize broader categories on sight (Table 8). The survey should be able to provide the density and population size for each category. Divers could also take shell measurements (shell length and lip thickness) underwater if densities are very low. To aid conversion from numbers to biomass, it would be wise to collect a random sample of conch in each category and stratum for processing. Additional quantitative information on sex, maturity and meat weight can then be obtained. It is important the sample is random and not all collected from the same area. Although the higher the numbers the more accurate the estimates, 50–100 conch in each category should be adequate, with highest samples for the juveniles.

As well as information on the conch, the divers should record various attributes of the site itself. The date, location and observed depth at the site should clearly be recorded related to the counts. In addition, sea-state, water clarity and wind speed can be used to check for variations in counts not due to density changes. The other important information is the habitat which the transect line covers. This can be categorized into general types (e.g. seagrass, sand, hard bottom, coral reef), or types of habitat can be estimated as a proportion of the transect area to obtain semi-quantitative information. The latter is recommended if an ecologist is present on the survey.

TABLE 8
**Definition of size/age categories for queen conch**

| Category | Description |
|---|---|
| Small juvenile | < 150 mm shell length. |
| Medium juvenile | 151–200 mm shell length. |
| Large juvenile | > 200 mm shell length, but without flared shell lip. |
| Sub adult | Flared lip starting to grow, but not fully developed (lip < 4 mm thick). |
| Adult | Flared lip is fully formed, with minimal to moderate shell erosion. |
| Stoned conch | Shell characterized by heavy to serious erosion and heavy fouling (coral, sponges, bryozoans, algae, etc.). Shell lip thick and worn. |

### 7.4.6 Estimation

The population density for a particular stratum and population category can be calculated for each sample location *i*:

$$d_i = \frac{x_i}{a_i}$$

$$D = \frac{\sum_{i=1}^{n} a_i \, d_i}{\sum_{i=1}^{n} a_i}$$

where $d_i$ = the required density estimate at sample site $i$, $D$ = overall density for a particular population category in a particular stratum, $a_i$ = each location sample area, and the observed number of conch in the relevant stratum and population category is $x_i$. The sample variance for the density estimate is:

$$s^2 = \frac{\sum_{i=1}^{n} a_i^2 (d_i - D)^2}{\sum_{i=1}^{n} a_i^2}$$

The variance of $D$ is estimated as:

$$Var(D) = \frac{\left(A - \sum_{i=1}^{n} a_i\right)}{A\,n} s^2$$

where $n$ = number of sample sites in the particular stratum. To calculate the population category totals across all strata, the estimated densities are multiplied by the relevant area in each stratum:

$$P = \sum_{j=1}^{m} A_j D_j$$

$$Var(P) = \sum_{j=1}^{m} A_j^{\,2}\ Var(D_j)$$

where $P$ = total number of conch in a particular population category in a particular stratum, and $A_j$ = the total area of stratum $j$. The biomass is calculated as population categories summed by their mean meat weight:

$$B = \sum_{j=1}^{m} w_k P_k$$

$$Var(B) = \sum_{j=1}^{m} w_k^{\,2}\ Var(P_k)$$

where $B$ = the total biomass across all strata and categories, $w_k$ = the average meat weight of an animal in population category $k$. Note that the mean meat weight is assumed to be known exactly. The variance calculation is more complex if you also wish to account for uncertainty in the meat weight.

More complex approaches can be used to estimate the various statistics. In particular, if the sample size is thought to be too small to guarantee normality of the means, other procedures, such as the robust bootstrap can be used in constructing confidence intervals rather than relying on the sample error. To conduct more complex analyses may require specialist help. If you think that there will be difficulties, you should consult a statistician before designing the sampling programme. However, the basic method described here is reasonably robust, and should give a good working estimate of population abundance if the sample size is adequate (at least 50 sites per main stratum 0–20 m).

### 7.4.7 Safety and logistics

If you are doing any counts at depths greater than 10 m, you will need to use scuba. If all counts are in less than 3-m depth, you can use snorkel only. Between three and ten metres, the choice is up to the survey design. Scuba will tend to be more accurate as continuous resurfacing is not necessary and depth off the bottom can be standardized. Scuba, however, is more logistically onerous, more expensive and requires more training. In almost all surveys, scuba will be required.

Scuba diving to conduct transects requires a minimum training to a sports diving level. Diving should take place from an appropriate vessel. All the usual dive and boat safety rules should be applied. In particular, adequate contingency needs to be given to the overall survey time to allow for days lost due to bad weather and breakdown.

A minimum of two divers is required in each count team. All dives should be planned, keeping strictly to dive tables or using dive computers. To maximize the number of dives and underwater times, dive computers are strongly recommended. Decompression dives should not be necessary for conch surveys and generally avoided. In any case, the survey will require a plan should any of the team develop decompression sickness (i.e. how to get to the nearest decompression chamber).

If work is offshore, a live-aboard vessel with a compressor will be required. Inshore work can be done using smaller dive boats, but boat cover is always recommended. The boat operator/vessel captain should be familiar with small boat handling and diving.

### 7.5 TAGGING

Tagging could form an important source of information on conch. Many of the problems associated with tagging other species do not occur with conch. The tag is placed on the shell, so it is fast, relatively cheap and tag loss is negligible. The main problem is ensuring tagged conch are returned by fishers to the scientists.

Conch can be tagged by wire and numbered plastic disks. The sex, maturity, shell length, weight, flared lip thickness are recorded. These data, with meat weight, should be recorded again when the tagged conch is returned. This allows growth and mortality to be estimated. Where possible, tagging should concentrate on smaller, younger conch.

The main problem is getting fishers to return tagged conch to the scientists. Even where fishers agree to cooperate, the tags will be overgrown by algae over time and therefore difficult to spot. Ensuring fishers check for tags during the experiment would be important. While statistical analysis can be used to correct for fishers failing to spot a tag, if this failure rate is high, the data will become relatively uninformative.

As tagging can provide considerable information quickly on the current state of the resource and fishery, it is always worth reviewing whether a tagging experiment would be feasible in each fishery Gulland (1969) provides an introduction to the way tagging data can be used in stock assessment.

### 7.6 INTERVIEWS

Interviews form an important data gathering tool in fisheries, social and economic research. Not only is this often the only way to obtain economic and social data, but interviews also allow direct interaction between fisheries staff and fishers. Interviews can be used as a tool to improve understanding between government and the fishing community, providing education and awareness for both sides.

Interviews broadly fall into two types. Open-ended unstructured interviews are usually an exploratory tool for getting information from stakeholders where very little is assumed beforehand. For example, open-ended unstructured interviews could be used to identify what stakeholders concerns are. On the other hand, structured interviews are used to gather specific information where it is known what is required. Interviews are often used to get quantitative information on activities within fishing trips for example. Structured interviews in particular are important for getting quantitative estimates, such as fishers perceptions on the current state of the resource, their alternative livelihood opportunities and food consumption information, such the how much conch is consumed in an average household.

Structured interview surveys are carried out in much the same way as other surveys. The first task is to define the "population" from which the interview sample will be drawn. Fisher licence and registration, population census and electoral registers can provide a useful frame for sample surveys. The sample unit may be active fishers, fishing community households (for economic surveys), or all households (for consumption surveys. The surveys themselves should consist of questions which the respondent (fisher or head of household) can reasonably answer. The questionnaire will require test and refinement, sometimes several times, before providing satisfactory information within a reasonable time. Moser and Kalton (1971) provide an overview of the design and use of household and other surveys.

### 7.7 OTHER INFORMATION

Beyond researching specific parameters, biological research can be carried out on life history, ecology and habitat use. This information is valuable in management as well as for developing new improved models for assessments. Such research is not a priority however, but should follow basic stock assessment activities and implementation of appropriate fishery controls. For most scientific authorities, monitoring the scientific literature and attending appropriate workshops and conferences will be adequate to obtain and use this information.

# 8. Assessments linking data to indicators

## 8.1 INTRODUCTION

In order to assess any fishery, an operational model of the fishery is required. The aim is to estimate the parameters for the model chosen. The model parameters will then define the appropriate reference points for the indicator. Various assessments are possible, but two approaches are highlighted here.

## 8.2 BIOMASS DYNAMICS ASSESSMENT

### 8.2.1 Indicators and reference points

An assessment of biomass should be able to use all indicators and estimates of biomass, including surveys and CPUE. The assessment aims to construct a history of biomass change, and the potential and safe yields from the population. Indicators can be simple (e.g. CPUE, catch, effort) or based on model variables (e.g. biomass, spawning stock biomass or fishing mortality). The former has the advantage that it is more easily understood by managers.

The key reference points are the biomass and fishing mortality at maximum sustainable yields (MSY; Figure 3). If biomass falls below the biomass at MSY, a rebuilding programme should be applied. Target reference points can be developed based on economics and fisher's requirements.

### 8.2.2 Data sources

The primary data source for estimating biomass will be catch and effort. These data are important not only to estimate biomass, but to estimate appropriate catch and effort controls.

Survey density can also be used to estimate biomass either as an index or in absolute terms. An index would require less data to get a reasonable result and hence is less costly. The same survey must be repeated annually or every few years and may be included in the stock assessment. Absolute abundance estimates require more sampling, but do not require, in theory, an extra scaling parameter in the stock assessment model and therefore the first estimate can be used immediately. A compromise for monitoring could be to apply many transects to obtain an absolute abundance estimate at the start of the time series and thereafter to revisit a smaller proportion of the original transects, perhaps stratified[7] by the observed conch density.

Short-term research may provide estimates of potential biomass growth. For example, monitoring recovery within closed areas may indicate the potential productivity rate. Such experiments could be designed and implemented with fisher cooperation.

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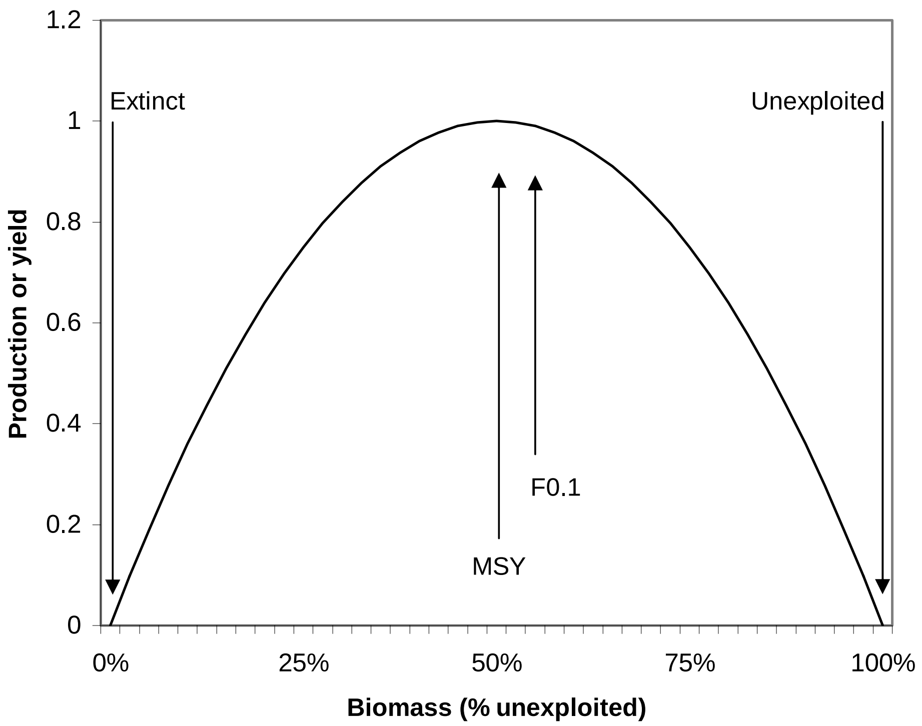
[7] Stratification groups the prospective sample so that the "population" in each group are as similar as possible. This allows more efficient sampling in the sense that a lower variance for the same sample size is possible.

FIGURE 3

**The diagram illustrates stock biomass growth described by the logistic model. The stock produces no surplus production (that is, it does not change its size) when it is unexploited and when it is extinct (population is zero). When unexploited, the stock reaches its carrying capacity for the environment and only reproduces enough young to replace those which die. When the population is reduced in size, it will produce more biomass than is lost through natural causes, so that the population grows. This excess production is shown in the curve. Production is zero at extinction and at the unexploited size, but there is some maximum in between, labelled as the maximum sustainable yield (MSY) and often used as a reference point. Maximum sustainable yield is too risky for management to aim for as it is right on the edge of overfishing. Alternative target reference points have been proposed to reduce the chance of overfishing. F0.1 (illustrated) identifies a point before the maximum yield is reached, but still allows most economic benefits to be obtained from the fishery. Similar definitions can be made for reference points in other models**




### 8.2.3 Assessment model

The simplest and most appropriate operational model would be a biomass dynamics model. The logistic model is used in the Turks and Caicos Islands (Medley and Ninnes, 1999). Other models might be used, but the logistic ("Schaefer") population model seems most applicable without evidence for alternatives.

The model can be fitted to catch and effort time series as well as any other appropriate index of population size, such as those based on fishery-independent surveys. With enough contrast in the catches, it can be fitted in a spreadsheet (e.g. Punt and Hilborn, 1996; 2001).

### 8.2.4 Getting started

If a fishery has no time series of catch and effort, or the time series does not include both depletion and recovery periods, it will not be possible to apply classical stock assessment methods. Alternative methods must be used.

If survey estimates of biomass are available, potential yield can be estimated assuming that the survey estimates the unexploited stock. If fishing is already occurring, such potential yield calculations are likely to underestimate the actual yield possible from the stock.

The growth rate parameter estimates (*K*) for conch vary from 0.2 to 0.7 year$^{-1}$ (CFMC, 1999), with the most reliable estimates for recruited conch being towards the lower end of this range. Assuming recruitment at around two years old, and post-recruitment natural mortality and growth rates being about 0.3 and 0.2 year$^{-1}$ respectively, the MSY would be around 8 percent of the unexploited biomass (Beddington and Cooke, 1983). Sustainable catches therefore need to be maintained at somewhat less than this amount.

If biomass is estimated from a survey with a mature fishery already operating, the survey will estimate current biomass not unexploited biomass. The MSY estimated from Beddington and Cooke in such cases would therefore be lower than the true MSY. The estimate can still be used in a biomass dynamics model or to estimate fishing mortality directly (fishing mortality is approximately the catch as a proportion of the stock biomass).

A more general approach which can make use of all information (including a survey if available) is to apply decision analysis. The method uses available information more efficiently and explicitly takes into account risks. For this reason, this approach is recommended.

The biomass dynamics stock assessment model is relatively simple, requiring only a few parameters. This makes it particularly appropriate when time series data are lacking. Decision analysis needs or may use the following information:

- Size of fishery: An estimate of the current effort and catch in the fishery is required to provide the relevant scale.
- Any catch effort data series: Even a short series without contrast can provide useful information.
- Fisher interviews: Fishers can be interviewed to obtain their view on the productivity of the resource. While fishers may tend to be optimistic, they may be the only source of time series data and in particular the only source on information on what the unexploited state of the resource was (PFSA, 2003).
- Current biomass from a resource survey: The current biomass can be incorporated with its uncertainty.
- Other data from other fisheries: Traditionally parameter point values from other fisheries are used in stock assessments, but this will underestimate the uncertainty in the results. Decision analysis allows information to be shared as probability distributions which include uncertainty.
- Measures of cost of actions and outcomes: It is often the case that a review of the potential costs and benefits will allow a decision to be made even if information of the likelihood of outcomes is lacking.

Bayesian statistical software exists allowing various numerical techniques to be applied to model probability distributions, such as Bayes SA (Punt and Hilborn, 2001) which applies a Bayesian approach to fitting stock assessment models. These require some expertise in using and developing models and data sources.

One way that these data and model results can be combined is to use the new software, PFSA (2003). The software requires that parameter estimates be represented by frequencies, which can be derived from various sources and techniques. The parameter frequencies are used to model the parameter probability distributions which can then be used in decision analysis. Data types the software can use include interviews and catch and effort data, for example, as well as output from other software, which can draw parameter frequencies from likelihoods.

Decision analysis will initiate the management process with clearly defined reference points from the beginning. It will not be necessary to wait for scientific research to be complete and the information can be updated smoothly as more data from adaptive management becomes available. However, the Bayesian approach is potentially sophisticated and may require some expert help.

### 8.2.5 Using biomass survey data

The biomass can be estimated using the techniques described in Section 8.4. This estimate can be used in a number of ways. If confident that the survey covers the entire area of the stock, it can be used in any stock assessment as an estimate of the absolute abundance and can be very useful even if there is only a single survey. If the absolute measure is not thought reliable (significant areas are missed by the survey due to, for example, depth), the survey can still be used as a relative index although at least two surveys in different years will need to be conducted before the survey becomes useful. In all cases, the longer the time series of surveys the better is.

If the survey is the only data you have to set a quota, some care needs to be taken. First and foremost, any estimate of maximum sustainable yield and potential yield will be highly uncertain, although the best you will have at this stage. It needs to be understood that, as more data become available, this estimate may change significantly.

Maximum sustainable yield has been estimated by the formula:

$$MSY = 0.5\ M\ B_0$$

Where $M$ = natural mortality, which, from estimates of longevity (for adult conch) of 20–30 years, suggest $M \cong 0.2\ yr^{-1}$. This in turn suggests that quotas should be limited to ten percent or less of the current biomass.

The estimate assumes that the current biomass is the unexploited biomass ($B_0$). If the fishery has already matured, this will not be the case, and this estimate will underestimate MSY. However, this method has been generally criticized for overestimating MSY, so using current biomass should be more precautionary.

It is not possible currently to estimate the state of the stock from surveys. Some densities have been proposed as "healthy" and a minimum density has been proposed as necessary for successful reproduction. These proposals need testing, particularly taking into account variation across habitat and the ability of conch to form spawning aggregations. It is important however, to further research, for any and all density estimates to be made available. If you have conducted a survey, it would be very useful to publish the density (and standard error) for each stratum.

### 8.2.6 Recommendations

The requirement for only a few parameters makes the biomass dynamics model the recommended approach. It has been shown to fit long-term time series data from at least one conch fishery (Medley and Ninnes, 1999). The assessment model, in the absence of proving a better alternative, should be the logistic population model. Even where no historical information exists, sharing information among countries may allow an initial stock assessment to be conducted and then updated as information becomes available.

Where a suitable time series of catch and effort is not available, the Beddington and Cooke (1983) approach combined with an estimate of current biomass and, if available, an estimate of unexploited or lightly exploited biomass can provide useful information on potential yield until sufficient data exist for more reliable analyses.

It is recommended that decision analysis is used. This not only allows assessment when data is lacking, but is transparent and allows explicit application of the precautionary approach.

## 8.3 PER-RECRUIT ASSESSMENT

### 8.3.1 Indicators and reference points

Per-recruit assessments focus on fishing mortality as the main indicator and control variable. Spawners-per-recruit measures the rate at which the spawning stock is replenished. In yield-per-recruit, the aim is to find a fishing mortality level to achieve a particular level of yield for each conch recruited to the fishery. The yield can be adapted to convert to processed meat yield or value. Per-recruit measures can also be used monitor and interpret mean meat weight.

The method will also allow size selectivity to be addressed. For example, the impact of a minimum size or flared lip only control can be assessed using yield-per-recruit.

In general, estimates of current fishing mortality and the size at first capture (or a full selectivity function) are required. Initial size is easy to obtain, but generally fishing mortality and selectivity can be difficult. Fishing mortality is usually related to fishing effort.

Reference points are heavily dependent on the growth model and natural mortality estimates. Work has been conducted on this, but wider agreement is required on standard default models and parameters to use. If agreement could be reached by scientists on these models, the way would be paved for regional agreement on harmonized controls such as minimum size.

A limit reference would be $F_{MSY}$, although this does not always exist in yield-per-recruit models. Yield begins to fall after this point, so there is absolutely no reason for fishing mortality to exceed it. Although $F_{MSY}$ is often at a higher level than desirable for economic benefits or to protect the spawning stock, it may still be used as a limit reference point. $F_{0.1}$ always exists and, in the absence of economic information, can be used as a target reference point. It has often been found to be close to the economic optimum when more data becomes available.

It will be necessary for a spawners-per-recruit analysis to be conducted as well as yield-per-recruit to manage the fisheries properly. There is currently no standard spawners-per-recruit reference point for conch. One will need to be developed based on the conch life history and biology, and based upon experience in other fisheries (see Mace and Sissenwine, 1993).

### 8.3.2 Data sources

The main data source for conch would be catch-at-size composition which can be collected rapidly. Rapid collection is an important advantage of this assessment approach. To estimate mortality, however, size must be converted to age. As there is no way to age conch directly, it will be important to have a good growth model.

Catch size composition will depend on two factors:

- Size composition of the population will depend on age composition and growth variation. In its turn, age composition will depend on the recruitment history of the stock and history of mortality.
- Selectivity of the fishing method will decide which sized conch are more likely to be caught. As collection methods are basically the same, selectivity will depend on the distribution of the population by size and the distribution of fishing effort.

Supporting scientific research should produce information important to interpreting size frequency data. Research is needed to estimate growth model parameters and selectivity and to link yield-per-recruit fishing mortality to the chosen indicator (e.g. effort). Data may include more complex expensive methods, such as tagging, in the short-term, as well as standard monitoring data.

An important but relatively simple requirement in fisheries is the ability to convert between different measures. For example, conversions will be required between shell length and weight, lip thickness, sex, maturity, processed and unprocessed meat weights. Conversion parameters can be estimated using generalized linear models.

### 8.3.3 Estimation of indicators and reference points

Reference points require growth and natural mortality models. Either previous published models and parameters can be used (CFMC, 1999), or special scientific research can be conducted to estimate them for each fishery. Also, these two sources of information could be combined, using decision analysis.

Fishing mortality must be estimated for each fishery. Proxy variables, such as fishing effort, can be used but will need to be converted to fishing mortality for interpretation in a yield-per-recruit context. Inaccurate selectivity models are perhaps the greatest weakness of the classical method.

An alternative, still based on yield-per-recruit, would depend on developing appropriate statistics for applying harvest control rules. These approaches can bypass critical dubious assumptions, but ultimately still depend on growth and mortality models.

### 8.3.4 Getting started

Length and weight compositions can be obtained immediately. As long as growth and mortality models are available, these can be interpreted.

Although they can be obtained immediately, mortality estimates from length or weight converted catch curves are probably unreliable. They do not take into account growth variability and require most of the catch to be young animals. It is also necessary to know the size/age selectivity of the method used in the collection of the sample (e.g. the fishery) in order to be able to estimate the true length or weight distribution from the sample.

The harvest control (decision) rule described based on an observed catch composition could be used to provide immediate management advice. Clearly, immediate monitoring of the proportion of mature animals being landed could also be used to apply a harvest control rule. Such rules would at least indicate the appropriate level of control to apply initially while monitoring continues.

Preliminary analysis suggests a decision rule could be developed for interpreting meat weights. Two rules are possible:

- A rule based on the optimal size to prevent growth overfishing. The rule would apply to controlling gross landings, fishing effort and other fishing mortality related controls. The rule would also allow management to evaluate controls in relation to selectivity.
- A rule based on only landing conch with flared lip. The rule would apply to enforce selectivity by fishers to only take mature conch. It needs to be verified that a meat weight control can be used to enforce this.

It should be noted that prescriptive regional controls could have a detrimental effect on some fisheries. In particular, different selectivity among fisheries remains a problem. Where free diving is the sole gear, mature conch that have escaped the fishery can be found in deeper water in abundance. A policy shifting emphasis to large conch could encourage exploitation of the spawning stock which is probably best left alone in these fisheries. There should therefore be scope for some flexibility in controls at the national level and possibly even at the local level.

### 8.3.5 Recommendations

A good growth model is required for yield-per-recruit assessment. A number of growth models and parameter estimates exist. These need to be assessed and a final acceptable method for modelling meat weight growth proposed. Results are sensitive to parameter values, so precision and uncertainty would have to be considered.

Estimation is a significant problem for yield-per-recruit approaches. Conversion of size to age is problematic and may prove impossible. As conch cannot be aged directly, it is necessary to rely on conversion using a growth model. Such models are not necessarily reliable for individual animals as variation in individual growth may be high and size does not increase perceptibly with age beyond maturity.

Use of meat weight should revolve around a decision rule rather than absolute reference points. This allows greater flexibility as well as dealing effectively with uncertainty. Decision rules could be developed for rejecting or allowing exports based on samples, for example, as well as applying management controls. While developing a decision rule may be sophisticated, applying it should be very straightforward.

Yield-per-recruit and spawner biomass per recruit require more information than biomass dynamics model. However, their ability to use size frequencies which can be collected quickly makes the per-recruit methods useful at least as a comparison to the results from the biomass dynamics model. Ultimately they may replace biomass models as the primary source of management advice as they allow assessment of selectivity which may prove important.

### 8.4 OTHER ASSESSMENTS

The natural extension to these assessment approaches would combine the dynamic aspects of the biomass dynamics model with the growth and mortality models. Such age structured dynamic models allow recruitment to be monitored and ultimately modelled. However, they have a very high demand for data, including a time series of catches, effort and size frequencies as well as reliable growth to age conversion. It is not possible to apply this approach at this time (Lassen and Medley, 2001). Haddon (2001) gives a practical introduction to this and other quantitative approaches to stock assessment.

# 9. Controls and monitoring

## 9.1 INTRODUCTION

Stock assessments are only useful where they lead to some control on the level of fishing. Management authorities must be prepared to limit and reduce fishing activity to protect the resource.

Any control aiming to improve the stock state, must reduce catches at least in the short-term. If they are not reducing catches, they are not being effective. For example, putting marine reserves where fishers do not fish will have no positive effect (although it may reduce problems later). Reducing catches can make controls unpopular with fishers, but it is up to management to minimize problems through consultation and joint decision-making, and to demonstrate the advantages of the control to fishers through emphasis on longer term benefits.

Experience has shown that it is always necessary to consider the socio-economic effects of controls. Enforcement will, at best, be difficult if the needs of industry and fisher communities are not taken into account. Every effort should be made to apply controls which not only achieve biological objectives, but socio-economic ones as well. As overfishing is the worst socio-economic outcome for a conch fishery, it should be possible to find some level of control that satisfies most objectives. It is possible, however, that socio-economic needs can only be met by external intervention, either by providing short-term support during restructuring or by assisting them to find alternative livelihoods.

Controls need to be consistent, so that they do not make legal fishing impossible. For example, a size limit preventing catching small animals in shallow water coupled with a gear restriction preventing exploitation of larger animals in deeper water could result in catch rates too low to make fishing a viable livelihood.

## 9.2 FLEET CAPACITY AND EFFORT

All commercial vessels should only be allowed to fish if they are registered and licensed by the management authority. The number of licences issued for conch should be commensurate with the number of vessels needed to harvest the resource.

If fleet capacity is much greater than the allowable effort, there will be tremendous economic and political pressure to allow greater fishing activity. Fleet capacity in commercial fisheries must therefore be controlled. Both numbers and sizes (fishing power) of vessels can be controlled by limiting registration.

Effort and fishing mortality may be controlled by limiting the number of days that the registered, and hence legal, vessels spend at sea. Closed seasons may allow this, but specific effort controls are often difficult to administer. Enforced closure of processing plants may also allow some control.

## 9.3 CATCH QUOTAS

Catch quotas will control fishing and at least exports can be enforced. However, they require careful monitoring of the stock and can easily allow overfishing. For example, setting the quota to the maximum sustainable yield is inherently unstable and will always lead to overfishing the resource. It is recommended catch quotas are used alongside other controls.

To be applied, it will be necessary to be able to convert catch quotas to export quotas accurately. All exports need to have a CITES certification so quotas will be enforced at this point. Conversion needs to be monitored as meat yield may change with the size composition of the catch.

Fishing mortality can be related to catch in the form of a feedback system. Lowering catch quotas will lower *F*, but setting the precise quota to achieve a particular fishing mortality will be difficult. Using biomass dynamics models will allow direct estimation of appropriate quotas.

Catch limits can be enforced through export quotas and trade controls (as implemented by CITES, for example). Trade controls can be used to help the enforcement within both the exporting and importing countries. For catch quotas to be enforced as export quotas, exports need to take up a significant proportion of the catch, so that catches for local consumption and illegal catches are controlled and accounted for or they are negligible. Examples where such controls have been successful are Turks and Caicos Islands and Jamaica.

## 9.4 MINIMUM SIZE AND MATURITY

Minimum size should be related to growth and size at maturity. In general, unless the shell is landed, an effective minimum size control is difficult to apply. While there is a significant problem trying to relate meat weight to maturity and to age, meat weight has some value for yield-per-recruit approaches and it is still possible to monitor the proportional juveniles in the unprocessed catch. Other measures besides minimum size are needed to ensure fishery sustainable.

Meat weight is not effective because weight does not increase and may decrease with age, and may be affected by sexual dimorphism and stunting. If the minimum meat is set small enough to allow older animals to be caught, it becomes ineffective at protecting younger conch. It is also difficult for fishers to see how much the meat might weigh without killing the conch, and discarding is not desirable. However, the flared lip thickens with age, making lip thickness a good theoretical measure for ensuring only older animals are caught. However, lip thickness is not easy to measure accurately for enforcement purposes, and would require all shells are landed. Furthermore, a lip thickness control does not allow checks during and after processing or export.

A control requiring fishers to only take conch with a flared lip or applying a minimum lip-thickness would require cooperation from fishers. It would be possible to prevent immature conch from being landed, and this may be a useful control in the non-commercial sector. It would require a fairly sophisticated education awareness campaign, however.

## 9.5 CLOSED AREAS AND MARINE PROTECTED AREAS

There may be effective closed areas already present in some countries through gear controls. Fisheries which only allow free-diving (e.g. Turks and Caicos Islands) have *de facto* protected deep-water populations. Otherwise, properly designed closed areas could be useful for reducing risks of overfishing.

The biology of conch suggests that area controls are a useful fishery management tool:

- Adult conch show limited movement, so a reasonable area can directly protect a proportion of the stock.
- Areas can be used to target habitat specific life stages.
- Areas can be used to help maintain spawning stocks at high density to aid reproduction.

While stock assessments can result in more effective and flexible management strategies, there exists significant information on the biology and ecology of queen conch, as well as the consequences of overfishing, to enact effective management in the absence of quantitative assessments on local stocks.

Marine protected areas (MPA) or no-take zones can form an important part of an ecosystem approach to management (FAO, 2003). MPA may not deal with other concerns such as pollution, damage from other activities such as tourism. Costs of MPA enforcement can also be high and need to be considered prior to setting up. However experience of MPAs in the Caribbean region is generally positive, although at least one country has found maintenance of its conch closed area onerous compared to other controls. A general discussion of the issues and considerations in implementing MPAs can be found in FAO (2007).

## 9.6 CLOSED SEASON

In general, closed seasons can be used for four purposes.

- To protect the stock during critical periods, such as spawning.
- To gain from growth by delaying recruitment to the fishery. This would require a discrete recruitment period
- To reduce effective fishing mortality. This would be the most likely use of a closed season as a biological control.
- To achieve socio-economic alternatives. For example, a closed season may allow a quota to be spread more evenly through the year.

Whether closed seasons are used would be up to managers, stakeholders and scientists in local fisheries.

## 9.7 TAXATION

Taxation on exports might be used to raise revenue to pay for fisheries management. Management costs governments money, yet fishers should gain significant benefits from good management. Export taxes are one means to help pay for this management.

Importantly, taxation also discourages overfishing by lowering the effective price paid for conch. Regional cooperation on setting taxation levels would reduce problems in terms of competitiveness and thereby help to protect the regional resource.

## 9.8 COMPLIANCE TO FISHERY MANAGEMENT MEASURES

### 9.8.1 Objectives

Monitoring, control and surveillance (MCS) makes an important contribution towards good fishery management through ensuring that appropriate controls are set, monitored and complied with. MCS plays no role in setting overall goals and objectives, but is central to management strategies applied to achieve these goals.

Developing an MCS system requires considering four broad activities:

- **Management measures**: Help choose the measures which will achieve overall goals and objectives. MCS is mainly concerned with the practicality of implementing measures, whereas fisheries managers and scientists will be concerned with the effectiveness of these measures, once properly implemented, in achieving overall objectives.
- **Efficiency**: Plan what needs to be done to implement the measures most efficiently. While cost-efficiency will form part of deciding which measures will be adopted, costs become most important in implementing the measures.
- **Activities**: Develop and plan MCS activities to fit in with fishing activities. What is done, where, when, how?
- **Evaluation**: Set realistic targets for activities and levels of compliance, and evaluate the MCS implementation.

International cooperation is an important consideration. As with many other fisheries, illegal, unreported and unregulated (IUU) fishing is a problem and international cooperation is likely to be necessary to deal with this and other shared stock issues. Conch may suffer less than other species in terms of being a shared stock. Its relatively short pelagic larval stage and slow movement make it less likely to be shared between different jurisdictions, even where there is a shared shallow platform. However, this does not stop fishers being highly mobile and control of foreign fishing is a problem for a number of countries.

In general MCS terms, conch is not different to other fisheries. There are, however, specific problems and aspects to each conch fishery which need to be addressed or can be used to make MCS more effective and efficient in each case. Although these characteristics will need to be taken into account in MCS, it is also worth noting that it is unlikely an MCS system will be tailored only to a conch fishery, but will need to cover a number of fisheries simultaneously for practical and efficiency reasons.

### 9.8.2 Management measures

In choosing management measures, MCS will comment on practicality, cost and likely compliance with the various control options. At this level, the overall MCS strategy will be decided and it is likely that the strategy will not be species or stock specific. Typical questions that the MCS plan attempts to answer include:

- What are the practical requirements needed to implement the proposed management measures?
- What factors will encourage compliance rather than demanding enforcement and can they be developed?
- What happens if controls are not complied with and what level of non-compliance might be acceptable? How much non-compliance is there currently?
- What are the costs of management measures and how are they met and who bears them?

The two core MCS responsibilities are policing and deterrence, and monitoring and compliance. Activities are required in both areas for fisheries management to function. While larger fisheries may be able to allocate staff to separate these areas, small-scale fisheries are rarely able to do so. There are advantages to separating the responsibilities, since monitoring and education requires a good rapport with the fishing community which can sometimes be difficult to maintain when the staff are seen as policemen.

Policing and deterrence consists of activities which directly enforce controls. Even in co-management situations, some policing is inevitable to prevent anti-social behaviour by a few fishers. Deterrence comes about from visible policing activities and publicizing successful captures and prosecutions.

Monitoring and compliance activities focus on improving information flow to and from the fishing community. Monitoring generally consists of finding out what fishers are actually doing, what they are catching, where they go and so on. Compliance can be improved by making sure fishers understand regulations, explaining the rationale behind regulations so that they can see the benefits, holding meetings to discuss acceptable ways to implement measures and so on. MCS also should obtain monitoring information on non-compliance so that the scientific assessment can be adjusted accordingly. A well-designed strategy will include evaluation of the performance of the MCS system against targets.

As a first step, it is important to establish what is feasible under the legal framework, the available resources and the cultural/political situation. The legal framework establishes who can fish, where, which species, how much, with what gear and where fish must be landed. If legislation does need updating, it is important this happens quickly. There are a number of cases in the Caribbean where drafted legislation has remained in limbo, probably primarily because the fisheries do not have an agreed management plan. In general, legislation should be one of the tools developed to implement the management plan.

MCS forms part of the design and evaluation of management plans, with monitoring being particularly important for adaptive management. Monitoring allows an evaluation of past management measures so that lessons can be learnt. A management plan improperly implemented undermines the credibility of the management authority.

A foundation for all MCS systems is the access rights. It will be necessary to establish access rights, which requires that poaching is minimized. If poaching is significant, limited access rights are undermined, and users are encouraged to go for short-term profits as opposed to long-term sustainability.

MCS must be designed to cover a fishery, not a stock or species. It may not be efficient or feasible to treat conch separately from other fisheries. For many artisanal fisheries, conch will be one of a number of species landed. The MCS approach will have to deal all species and fisheries in an integrated manner, and conch will only form a part of the overall strategy.

Once MCS activities are decided, an assessment needs to be made of staff skills. An important part of improving MCS is staff training. It will be necessary to consider whether a smaller better trained work force is better than a larger less well trained work force. To maintain motivation of the work force, training should be recognized through, for example, promotion or increased pay.

Lower level jobs require vocational modular training based on adult learning principles. Such training (e.g. observers, inspectors, clerks, data entry and basic reporting) can often be conducted by senior personnel and developed for local situations. A minimum quality needs to be assured, particularly if local training is undertaken, which can be best achieved trough an external review of the training programme.

### 9.8.3 Specific measures for conch

It is difficult to make any firm recommendations for fisheries controls for conch that could be applied in all cases, as all fisheries are different. However, the following list should at least be considered, as they cover the common controls used by at least one country with success.

**Vessel register**: All vessels should be registered and marked with the register number that can be seen clearly, including from the air.

**Inspection**: Vessels should be inspected once per year for all licensed vessels as well as random inspections on landing from beach patrols, for example. Industrial vessels can also be inspected before departure and on landing after long trips.

**Licensing**: The number of vessels should be controlled through licensing. For larger vessels, licences should be able to limit the species being caught. Licences for smaller vessels may only limit engine size, gear and so on, but allow a range of species to be landed.

**Closed/protected area and zoning**: It may be wise to protect sections of the conch population, such as mature breeding conch or undersize juveniles, which can often most easily be achieved through implementing a closed area. Vessel monitoring systems are fundamental tools for enforcing compliance with this particular control.

**Closed seasons**: Closed seasons can be used to reduce effort on conch or spread a catch quota more evenly through the year. In general, they are easy to administrate and for fishers to understand. If the closed season stops all fishing for an extended period, fishers may find a closed season difficult if there is no alternative employment.

**Total allowable catch**: Where the total catch can be monitored and controlled reliably, a TAC can be implemented. A related control would be a total export quota, which may be easier to enforce. An export quota, combined with a closed season and other controls, could be very effective in controlling a mixed subsistence-artisanal fishery.

**Shell size**: It is possible to monitor shell size at landing if they are being landed. Whether the lip is flared is monitored in some countries. This sort of control is appropriate for small-scale fisheries where only a few conch are being landed. It is likely that an additional regulation requiring that the meat be landed in the shell would be required. Furthermore, it would have to be clear to the fishers and enforcement officers exactly how this measurement would be taken, as the lip varies in thickness depending on the way it is measured. Based on simulations models, shell lip thickness is the most promising measure, since shell length does not increase after maturity (FAO, 2007b).

### 9.8.4 Efficiency

Enforcement can represent the most significant management cost. It is therefore important to keep costs to a minimum and consider how income will be generated to pay for MCS activities. The scale and type of MCS adopted should be commensurate with the level of income from the fisheries sector. A cost benefit analysis will help ensure that the best is being made of the available resources.

An important principle to minimizing costs is that the user (fishing industry) should pay. Not only does this ensure that management costs are kept to a level lower than earnings from the industry, but encourages greater efficiency. If the fishing sector is paying the MCS costs, it will have a greater incentive to cooperate and keep costs to a minimum. The fishing industry may contribute to MCS either financially or by carrying out some activities such as collecting monitoring data. Industry can conduct many activities more cheaply than government departments.

It is not necessary to achieve 100 percent compliance in all cases. Costs need to be considered in setting acceptable levels of non-compliance. Total compliance may often only be achieved at too high a cost.

User participation is important to increase compliance without significant additional cost. Trying to enforce unpopular decisions can be expensive and ineffective. For this reason, simple awareness and "outreach" programmes should form the first MCS activity in implementing a new fisheries measure.

While finance might be obtained for capital assets such as patrol vessels, running costs need to be taken into account. Fuel and general maintenance costs are very high for a high policing approach and the decision to operate patrol vessel should only be taken after realistic operational cost assessment.

Privatizing non-core MCS operations should be considered. For example, small planes can be chartered, with a fisheries officer aboard, to patrol areas. This allows activities to vary in intensity to focus at key times (e.g. beginning of the fishing season or with the introduction of a new fishing control) or in response to budget changes, and avoids capital and recurrent costs which may become unsustainable.

The MCS system will cover the fishery, not the stock. As a result, a policy of international cooperation may be necessary where stocks may be shared. Ideally surveillance activities will cover several fisheries to allow cross checking of information and increase the chance of identifying non-compliance.

If enforcement needs to cover a large area, a surveillance plan following a random sampling design that aims to maximize the chance of observing non-compliance should be implemented. Surveillance can legitimately focus on fleets and individuals that offer the biggest threat.

Adaptive operations can be based on monitoring information from the fishing community. This requires that the community believe breaking the rules, whether by foreign fishers or their own people, infringes on their rights and enforcement officers are on their side.

Some controls may be required less for enforcement per se, than for simplifying enforcement and reduce costs. For example, limiting the locations where fishers can land fish to allow easier control and monitoring is a common requirement for industrial and artisanal fleets. This is often a requirement in any case for exports to meet minimum product quality and safety controls, and therefore may not be onerous to the fishery. However, it is clearly not appropriate for subsistence and many local artisanal fisheries.

The possibility of sharing costs with other sectors should always be considered. For example, coastguard patrols may be searching for various illegal activities, and expanding their scope to include illegal fishing may well be both cost effective and mutually beneficial. Joint committees can be convened to increase efficiency and effectiveness of activities. Other departments such as customs and coast guard may be active in many sea areas and be able to report information on fishing activities.

### 9.8.5 MCS activities

MCS activities can be divided up according to when they are conducted in relation to fishing trips. The MCS authority needs to have a good understanding of when and where fishing takes place. This will allow MCS activities to be harmonized with fishing activities and ensure MCS is effective.

As part of the general management of MCS, the system will need to be periodically evaluated. In evaluating MCS, example critical questions would include:

- Are all MCS strategies implemented in an effective and efficient way?
- Are staff performing as expected?
- Are there changes in the fishing fleet or within certain fisheries that are not covered under the present MCS operations?
- Find out if, and if not why, fishers agree with the current policy and legislation?

Based on the evaluation, MCS should be improved and might be changed. Some change in MCS is almost always necessary as fisheries are dynamic and the some fishers will probably be discovering new ways to circumvent controls.

The types of MCS activities according to the timing of fishing activities are described below and summarized in Table 9.

TABLE 9
**Types of MCS activity in relation to the fishing activities**

| Timing | Types of activity |
|---|---|
| Before fishing | Vessel inspection for licence. |
| During fishing | Observers, log-books, radio reports, vessel inspection at sea. |
| On landing | Beach patrols and trip interviews. |
| After landing | Processing plant inspection, quota control and chain of custody, mean meat weight of export. |

#### BEFORE FISHING

Each vessel should be inspected, before an annual licence is issued for example, or each time an industrial vessel departs on a trip. It should be ensured vessels meet minimum standards for maintaining product quality, safety, and appropriate marking.

Gear and vessel inspection can be executed at licence issue. As conch is a diving fishery, diver safety should be an important issue as well as general safety at sea. Licensing is an important opportunity to talk to all fishers, explain the regulations and any changes, give information on how they can report any information useful to the management authority and record any concerns they may have, etc.

#### DURING FISHING

Cost is often the most important consideration for surveillance and monitoring. Vessel patrols tend to be expensive. A clear vessel marking system, so that vessels can be identified from the air, should be a requirement as aerial surveillance is often the cheapest option.

A wide range of requirements can be placed on larger, industrial vessels, including a requirement to maintain a logbook, a satellite-based vessel monitoring system and observer coverage. Of these, logbooks are a basic requirement of most industrial fisheries. While these clearly cannot be used for enforcement as they are filled out by the vessel captain, they are critical for monitoring activities, catch rates and other indicators used to assess the stock and management system. For many countries, most of these requirements would probably be inappropriate for conch fisheries as the vessels tend to be too small.

#### DURING LANDING

The critical problem for activities related to non-industrial vessels is knowing when and where they will land. The smallest vessels can and do often land anywhere on a large number of beaches. Meeting these vessels as they land may require work outside normal office hours. Surveillance can be conducted through beach patrols and monitoring fishing activities through trip interviews

Landing sites for exported conch should be limited to a few designated sites, but this should not apply to artisanal landing for local consumption. It may also be wise to ban any trans-shipment at sea, as trans-shipment makes it difficult to trace from where catches were taken.

Where the landed catch is to be used for commercial purposes, such as export, it can be monitored by requiring the buyers to keep and submit copies of purchase receipts. While these data cannot be directly used for enforcement, they can be used for scientific purposes and to cross check against export quotas, which can be enforced at point of export.

#### AFTER LANDING

Processing plant monitoring can be combined with product quality control. USA and Europe require various health controls on products (Hazard Analysis and Critical Control Point - HACCP), which itself requires a monitoring system. Extending these systems to link landed catch to export for MCS purposes requires very little adaptation.

Meat weight can be monitored after landing by weighing a fixed number of conch. Falling meat weight may be a good indicator of overfishing, but only after the fact. It is therefore a poor control, unless there are specific attributes of the fishery it can be related to. For example, minimum meat weight might effectively enforce a no-take zone of areas where predominantly small conch are found, and could aid recovery of an overfished stock.

### 9.8.6 International cooperation

A common policy towards MCS has already been suggested by some Caribbean Community (CARICOM) Member States by the signing of the Organization of Eastern Caribbean States (OECS) Common Fisheries Surveillance Zones Agreement (CFSZ). This gives powers to officers authorized under the agreement broader than those accorded to national authorized officers under individual national fisheries laws. Given that many of the targeted species are usually within the boundaries of the territorial sea, enforcement and other provisions of an arrangement similar to the OECS/CFSZ Agreement may be pertinent to the management of most of the fisheries of CARICOM Member States.

There is also need to consider the development of standard operational procedures (SOPs) for fisheries enforcement similar to those developed by and for OECS Member States, geared toward the enforcement aspects of their fisheries acts, as well as harmonization of sanctions. Such SOPs would need to be adapted based on the requirements of the international fisheries environment.

Sharing information among countries on registered vessels can be an important control on highly mobile fleets. Under high levels of cooperation, it may be possible to develop a shared vessel register. The regional vessel register of the South Pacific Forum Fisheries Agency is used very effectively for enforcement (www.ffa.int). The register grants "good standing" for vessels dependent on their compliance. Lack of this good standing prevents vessels operating in the region. A similar system could be developed within the Caribbean, adapted to the regions needs and based on the degree of cooperation available among the highly diverse states which would be involved.

Where possible and relevant, harmonized legislation can help ensure better cooperation and reduce enforcement costs. For example, a common registration could ensure the vessel marking system is consistent and applied to all vessels. Any vessel fishing not appropriately marked can be identified immediately as an illegal vessel and/or illegal activities can be followed up with the relevant states.

Illegal, unreported and unregulated (IUU) fishing is a regional problem and requires a regional international solution. A similar problem, albeit more significant, occurs in high seas areas being addressed by the High Seas Task Force. The High Seas Task Force has made several proposals, some of which are equally relevant for problems of illegal fishing of conch in national waters where nations have difficulty enforcing controls on illegal fishing.

- Strengthen the international MCS network and establish a regional information system on vessels operating in the region. This involves improving information sharing about vessels and illegal activity and passing this information between authorities.
- Promote broader participation in United Nations Fish Stocks Agreement and the FAO Compliance Agreement. Improve cooperation between countries and organizations.
- Develop the Regional Fisheries Management Organization (RFMO) that covers the conch fisheries and countries involved in conch fishing. RFMOs should apply the same management cycle and self assessment procedures as national management organizations. There are a number of RFMOs which can be used as a blueprint to develop procedures (reference or link).
- Develop methods to improve estimates of IUU catches. Estimates of IUU catches are not only important to improve estimates of total catches, and therefore improve assessments of the total allowable legal catch, but also allow monitoring of the effectiveness of controls designed to decrease the amount of IUU fishing.
- Promote vessel monitoring systems (VMS) for industrial vessels. VMS allows automatic monitoring and reporting of some vessel activities.
- Adopt and promote guidelines on flag state performance.
- Develop and support port and trade measures. In this case, CITES can be used to help support national initiatives to protect local conch stocks.

# 10. Adaptive management

## 10.1 MANAGEMENT CYCLE

Management should follow a basic cycle. Once the policy and objectives for the fishery have been developed and interpreted in the form of indicators and reference points, the monitoring and assessment cycle can start.

1. Data should be collected for estimating indicators and monitoring the fishery.
2. Indicators should be updated and stock assessments conducted, if necessary.
3. The effectiveness of previous fishing controls should be evaluated.
4. Based on these results, scientists should provide advice to the managers.
5. Based on the scientific advice, fishing controls should be updated and applied.
6. Policy and objectives should be reviewed and updated.

These steps should be repeated indefinitely, although they may not all be conducted in every year. There should also be close consultation with stakeholders during this cycle, for example at steps 3, 5 and 6.

The stock assessment should undertake to update indicators and reference points with new data, as appropriate. All technical aspects of the stock assessment should be fully documented, including a description of the data used, method applied and assumptions made. Models and data should be stored for future reference. This makes updating the assessment much more rapid.

The assessment should report separately to managers the stock status and then supply management advice. Full technical information on the stock assessment will not be required, but a non-technical summary should be submitted to decision-makers. This should make clear the uncertainties in the assessments.

For discrete changes of state, from fully exploited to stock rebuilding, for example, it is recommended that decision rules are used. Decision rules should already be agreed by decision-makers, so the scientist's job should be to evaluate the rule and report back the evaluation. This should make communication of results more straightforward.

It is recommended that the rules applied should follow a system similar to that shown in Figure 2. If the stock is already low or the stock size falls below a particular, pre-specified level, a rebuilding plan should apply. This will lead to setting lower effort (or quota) than the sustainable yield, allowing the stock to grow. A principle is needed, such as the time to rebuild, to set a particular level of fishing. Hence the exact plan would have to be developed through consultation between scientists, managers and stakeholders.

Adaptive management actively applies management to gain information about the resource. The main problem with many stock assessments is that they require contrast in the catch time series. Ideally, the time series should include periods of both depletion and recovery. If this information is not available, it is quite possible for a fishery to remain in a chronically overfished (or underutilized) state indefinitely without the potential for recovery and higher yields being known. Carefully reducing and increasing controls within the overfishing limits is quite legitimate, and is the final test of other scientific results. Other management actions, such as setting up temporary closed areas, may also form part of these adaptive management actions.

## 10.2 VERIFICATION AND TRANSPARENCY

The management plan and assessments should be subject to periodic review. This will ensure that the assumptions and advice are reasonable and based on the available evidence. The reviewer can be internal, but should not have been involved in preparing the plan or in the assessments so as to ensure objectivity. Comments of the reviewer should be addressed, and comments themselves incorporated in the plan where appropriate.

A checklist for testing a management regime has been proposed for fishery certification (see Appendix I). This can be applied to conch fisheries in exactly the same way to provide an independent assessment of how well management is doing against the best practice. The tests go well beyond CITES requirements, but recognize the wider benefits of good management as contained in the FAO Code of Conduct, of which the CITES requirements represent a part.

## 10.3 CO-MANAGEMENT AND PARTICIPATION

Participation will always be necessary at some level. If industry is not consulted or kept informed, the fishery will become considerably harder to manage. Co-management is where fishers are involved in direct management and are responsible for at least some management decisions. Co-management is particularly appropriate for small-scale fisheries where top-down government-led management is too expensive and impractical.

Co-management requires that fishers understand how to manage the resource. This means that government's main function is one of education and facilitation. Government can facilitate local management by supporting development of local management institutions, providing information, training and so on.

Participation involves fishers and other stakeholders not just in decision-making, but also in enforcement, administration and data collection roles (see Halls *et al.,* 2005). While it may be dangerous to let fishers get involved in policing, they can carry out surveillance and monitoring activities, reporting data back to government who can act as appropriate. It can be useful to supply or require vessels to possess VHF radios both for their own safety and to report observations at sea. For monitoring, it is not necessary that every vessel cooperate, as long as a representative section of the fleet supplies relevant information.

Participation is achieved primarily through fisheries meetings. Exactly how these are conducted and how decisions are reached will depend upon the local culture. However, interviews may help inform such meetings, and give a voice to shyer members of the community who otherwise might not give their views. Gathering information through interviews and small focus groups also should help keep meetings short. It should be remembered that fishers meetings, once the novelty has worn off, will be work, and must be made as efficient and productive as possible.

# 11. Potential regional management regime

Cooperation between countries on many issues will be difficult. Data and information sharing is one area which should not be contentious and is in the best interests of all. Scientific workshops focused on conducting assessments using shared research and data could produce significant insight into how to manage this resource.

Further cooperation would have to be founded on developing commonly accepted models for fisheries and conch biology. Common biological models will form the basis for choosing common reference points. Common indicator and reference points would then allow different countries to apply the same management rules. Regionally accepted and applied growth and mortality rates would be necessary to identify a single optimum minimum meat weight for example.

Although common indicators, reference points and controls should make enforcement easier, there may well be a cost to individual fisheries. A common minimum size policy will assume a particular growth model applies to all stocks. Conch which grow more or less that this model implies will result in an inefficient choice of size, either ineffective or too restrictive.

The most likely areas of immediate concern across the region should probably be a minimum mean meat weight, closed season and export tax level. It is suggested that these issues be considered by scientists first in assessments and then advice passed on to managers to see whether and how much cooperation is advisable.

Controlling poaching is difficult for many countries, and improved international cooperation is likely to be the only method to reduce illegal, unreported and unregulated fishing activities. CITES may provide a means to help reduce illegal catches by trade controls. The requirement that catches are documented will make it increasingly difficult for illegal catches to enter the mainstream market, depressing the demand for illegal, unreported and unregulated catches.