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Monitoring and managing queen conch fisheries

A manual

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Abstract

This publication presents guidelines on the requirements for responsible management of the fisheries exploiting Caribbean queen conch (*Strombus gigas*), with particular emphasis on the requirements to comply with the relevant regulations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Caribbean queen conch is listed on Appendix II of the CITES, which requires that any specimen of the species can only be exported if a permit has been issued to allow the export. Further, CITES states that export permits should only be issued when the responsible authority has deemed that the export will not be detrimental to the survival of that species. This manual describes the basic fisheries management cycle which includes: development and interpretation of policy; the need for management controls to regulate fishing activities; data collection and analysis; decision-making; enforcement of and compliance with the management controls; and regular feedback and review of the management system. It provides general guidance on each of those steps for the queen conch fisheries of the Caribbean. It also provides three examples of management systems for industrial, artisanal and non-directed fisheries. Part 1 covers the main issues and examples in a relatively non-technical manner and Part 2 explains similar issues in a more technical manner.

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Introduction

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is concerned with preventing conch from becoming an endangered species. Governments which have a conch resource are concerned with the sustainable development of their fisheries. However, CITES and government policy should have considerable common ground. Managing a fishery to maximize sustainable economic benefits and protect the ecosystem are compatible. This indicates that good management practice should meet CITES requirements as well as improve economic returns from these fisheries.

The main issue should not be what fisheries are setting out to achieve, but whether these objectives can be met with available technical and logistical resources. Achieving optimal sustainable economic returns from a fishery is far from simple, mainly due to the lack of the necessary information to define where the optimum is and how to get there. To define the optimum and then enforce the conditions to ensure this is reached requires considerable scientific and management expertise and resources. However, once set up, monitoring and maintaining the fishery should be simple and well within the capability of most governments.

Good management requires political choices, which is why emphasis is placed here on easier communication, by reducing complex fisheries to a set of simpler performance indicators, and planning ahead. Planning ahead means gaining agreement on appropriate actions before they need to be applied. Prior agreements not only allow government to plan ahead, but industry too. This should lead to smoother changes and greater stability in the long term.

This manual is focused on Caribbean queen conch *Strombus gigas* and the requirements for responsible management of the fisheries exploiting this important resource, with particular emphasis on the requirements to comply with CITES regulations and requirements for the Appendix II listing.

This manual presents guidelines only. The large differences between fisheries make it impossible to prescribe exactly what must be done in all fisheries. However, it is possible to make two general requirements that will need to be met by any conch fishery:

- The processing and catching capacity needs to be on the same scale as the productivity of the resource. Where there is overcapacity, political and economic pressures will often lead to short-term planning meeting immediate demands of the processing and catching capacity, which in turn will lead to overfishing. A stock assessment should provide advice on the appropriate capacity.
- It should be possible to show that the policy and the fishery management system are effective. For this, you have to monitor the resource state and the fishery. When a control is applied, you need to be able to demonstrate that the control affects the monitoring variables in the manner expected. For example, if the average vessel catch rate is used to monitor stock size, when you apply a control, such as reducing the number of vessels allowed fish so as to increase stock size, you need to see a corresponding increase in catch rate. This implies that the control has increased the stock as intended. Similarly, it should be possible to show that a stock increases once a “no-take zone” has been established. There are many reasons why controls may be ineffective. If you do not have effective controls, you are not managing the fishery and not meeting CITES requirements.

The level of management, control and monitoring needs to be appropriate for the size of the fishery. There is often concern that the management required will be too expensive. It need not be, and should not be, expensive relative to the size of the fishery. Importantly, the more certain you wish to be as to the state of the fishery, and you will need to be certain if you wish to exploit the resource at close to the maximum level, the better information and enforcement will be required, and the higher the cost of management. Lower management costs generally mean lower levels of exploitation, but should not prevent you from exploiting the resource efficiently and optimally.

There are two ways to deal with uncertainty. The first, and perhaps most important, is to obtain more and better information about your fishery. The second is to keep fishing pressure low. This decreases the chance of overfishing even if you are uncertain exactly when overfishing will occur.

It is quite possible, where a management regime is not well developed, that you will start with little information on which to base decisions. It is quite reasonable to develop a programme which will bring the management system up to the required standard without closing the fishery. To meet international standards, however, the development would need to follow a predetermined time table.

This document is divided in two parts. In Part 1, Chapters 1 to 4 cover the main issues and examples in a relatively non-technical manner. This section is suitable for decision-makers and persons not familiar with fisheries methods. In Part 2, Chapters 5 to 11 cover similar issues but in a more technical manner.

Further information on fisheries management in general can be obtained from the publications listed at the end of this manual under the heading "References and further reading". These include the FAO Technical Guidelines for Responsible Fisheries No. 4 and No. 4, Suppl. 2, the FAO Fisheries Technical Paper No. 424 "*A fishery manager's guidebook*" (Cochrane, 2002) and the book "*Managing small-scale fisheries*" (Berkes *et al*., 2001).

PART 1:
GENERAL GUIDELINES

1. CITES and the FAO Code of Conduct for Responsible Fisheries

1.1 THE CONVENTION

CITES is an agreement to control the exports and imports of species listed in its appendices. Most importers, such as the European Union and United States of America, are bound by the agreement. Conch is listed under Appendix II. The most relevant part of the convention for Appendix II species are:

"2. The export of any specimen of a species included in Appendix II shall require the prior grant and presentation of an export permit. An export permit shall only be granted when the following conditions have been met:

(a) a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species; …", and

"3. …[Appendix II species 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."

Appendix I listed species are banned from international trade. If conch were listed under Appendix I, the export trade in conch would essentially cease.

One of the central goals of fishery management is to prevent overfishing. The FAO Code of Conduct for Responsible Fisheries (hereafter referred as the Code) sets out the principles which need to be applied to achieve this. We can reinterpret CITES convention in the terms of the Code. While the Code covers considerably more issues than CITES, CITES requirements fall well within its scope. In fact, perhaps the most important aim of good fisheries management is to maintain the abundance of the stock above the state where it would be considered depleted or have a negative impact on the ecosystem. This should still be above the endangered state, where the species would be included in Appendix I. So, if we apply good management as defined under the Code. CITES conditions are met, the productivity of the resource is maintained and its function in the ecosystem is not impaired.

However, "overfished" and "overfishing" still need to be defined. Typically, a stock is considered "overfished" when exploited beyond an explicit abundance limit considered too low to ensure safe reproduction (FAO Fisheries Glossary[1]). The decision that a fishery is overfished needs to be based on more than opinion. It needs to have a sound basis in science, which depends on data collection and research. It is also critical that a fishery can be clearly seen to be not overfished by people not involved in the fishery.

1.2 NATIONAL CITES AUTHORITIES

Each State signatory to CITES needs to appoint both a Scientific Authority and Management Authority. It is the Management Authority's task to issue and enforce the export permits for all species listed on CITES appendices. The Scientific Authority monitors both the overall exports granted by the State for any quantities of species included in Appendix II and the actual exports of such quantities. Whenever a Scientific

[1] FAO Fisheries Glossary: www.fao.org/fishery/collection/glossary_fishery/1/en

Authority determines that the export of any such species 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”, the Scientific Authority should advise the appropriate Management Authority of suitable measures to be taken.

The primary responsibility of the CITES Authorities is the implementation of the export permit system. Any export requires an export permit, which can only be granted when meeting three conditions. The Scientific Authority of the State of export must advise that such export will not be detrimental to the survival of that species. The Management Authority of the State of export must be satisfied that the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora, and that any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment. The last issue only applies if live conch is being exported. It is the responsibility of these authorities to ensure that exports are from legal catches and those catches do not endanger the conch resource.

As CITES Authorities may deal with many non-fished species, authorities may well be composed predominantly of non-fisheries staff. It is important that the Fisheries Department has representation in each such authority. Misunderstanding the way fisheries work can make it difficult for the authorities to implement appropriate export controls. For small states, it may be necessary to combine the management and scientific roles into a single authority.

2. Fishery biology

Fish stocks have much in common with other exploited living resources, such as goats. Managing fisheries is like managing a goat herd where you must maintain the herd with its own offspring. If you sell too many female goats[2], you will not be able to produce enough young goats in future years to support the herd's productivity and eventually you will have to reduce the number sold. Conversely, if you allow the goat population to increase, they will consume all the available grass and forage and will become thinner, produce fewer kids and will be more likely to die from disease until the herd balances out with births and deaths, reaching its "carrying capacity". Usually farmers prefer to maintain the herd at its optimum size, the size when its productivity is at its maximum, the "maximum sustainable yield". If you replace "goats" with "conch", you have a description of conch fisheries management.

However, there are two important differences between farming and fishing.

You will be uncertain exactly how many conch remain in the sea. Whereas a farmer can count his stock, you can only make an estimate of how many conch you have remaining to ensure the stock can replenish itself. To ensure the estimate is as good as possible, and to make it acceptable to all parties (including CITES), you must use good statistical and scientific methods.

The stock is held in common with all fishers. Where, as sole owner, a farmer can take decisions in his own best long-term interest, fishers can not unless they cooperate. If fishers believe that any conch they leave will be taken by others, from their point of view there is no benefit in leaving enough conch in the sea to replenish the stock. They are therefore encouraged to take as much as they can before the stock is depleted by others.[3] It is management's task to create the circumstance where it is in fishers' best long-term interest to cooperate. This will require setting up a suitable system of access rights, effort control or both as well as an effective management system. A part of that management system must be to ensure the regulations are obeyed because illegal fishing (poaching) may not only directly cause overfishing, but may also undermine the degree to which fishers will cooperate with management.

[2] One male goat can fertilize many females. It is the number of females which control the herd's productivity and growth.

[3] Also known as the tragedy of the commons (*sensu* Hardin). Co-management and individual transferable quotas are fisheries management techniques that try to recreate a sense of sole ownership of the resource.

3. The fisheries management cycle

Fisheries management, like driving a car, should be a “feedback control system”. Driving a car consists of the controls (accelerator, brakes, gears and steering wheel) and monitoring (the driver’s eyes and ears). When you are driving, you are constantly monitoring the progress and position of your car and taking appropriate action by slowing down, speeding up or changing the direction in which the car is moving. Few people drive without moving the steering wheel or with their eyes shut. Fisheries management also needs controls. In the case of queen conch fisheries, the controls are usually in the form of effort limits, catch quotas, minimum size and closed areas; and eyes and ears in the form of a monitoring programme.

The monitoring programme should do more than simply report on the state of the fishery. It also needs to measure the effectiveness of the controls, to make sure that they are working, and help decision-makers ensure that they are implementing the policy correctly.

3.1 POLICY

Policies set out the principles on which decisions are made. Most policies state that a fishery should be exploited optimally and sustainably. All policies should include an intention for sustainable exploitation and to apply the precautionary approach be applied in making decisions, if the policy is to be consistent with the Code.

To be meaningful, a policy will need to define “optimal”, “sustainable” and “precautionary”. “Optimal” will need policy to provide further details on what management should aim to maximize, subject to which constraints. For example, the policy may be to maximize fisher income, while not allowing employment to fall below the current level. It will be necessary for the policy to recognize that it is not possible to maximize everything, and “optimal” implies the best that can be done under various constraints. “Sustainable” generally means “catches can be maintained at the desired level for the foreseeable future”. The precautionary principle is much more difficult to interpret.[4] Generally, decision-makers should avoid unnecessary risks and irreversible actions, and support research and data collection which will reduce uncertainty. In fisheries this generally also means reducing the amount of fishing.

A clear link needs to exist between the policy and management actions. Practical implementation of a policy is usually achieved by agreeing what indicators and reference points will be used. Indicators are numbers representing whatever it is that policy is interested in. If employment is important the policy, an indicator could be the number of full time fishers. Any indicator should be straightforward to calculate, reliable and easy to understand. Reference points are values of the indicator which guide management actions. For example, a reference point for the number of full time fishers. Reference points may require more sophisticated analysis to define, but should be based on simple, agreed principles. Reference points generally define conditions in the fishery when some management action will be taken.

Policies should also cover economic and other incentives that encourage overfishing. For example, subsidies for fishing should generally be avoided except where they are applied on a short-term basis. Policies should not encourage rapid investment. Excessive fishing and processing capacity can be very difficult to reduce once it occurs.

[4] For a detailed discussion, see FAO (1996) Precautionary approach to capture fisheries and species introductions. FAO Technical Guidelines for Responsible Fisheries. No. 2. Rome, FAO. 54p.

It is better to avoid overcapacity, as the economic losses associated with too much capital investment can be very high and overfishing is strongly encouraged as investors try to recover their capital. Unfortunately most overcapacity disincentives, such as higher taxes, also tend to be unpopular and may require considerable political acumen to implement.

Some fisheries operate forms of subsidies to achieve the management objective of preventing fishers' incomes from falling below the minimum wage. Many of these subsidies currently encourage overfishing. Management should consider diverting subsidies through means that encourage meeting the requirement for sustainability.

3.2 CONTROLS

Legislation should allow the means to control the exploitation rate of the resource and various other protective measures which reduce the chance of overfishing. It is best to use a variety of controls and not just depend upon one. Controls should always include some limit on fishing effort, or, at the very least, a limit on fishing capacity.

Fishing effort is the work done by fishers to catch fish (days fishing, amount of gear set, etc.). Fishing capacity is the limit on what effort (work) could be applied in the short term. For example, capacity could be the number of vessels available for fishing. The limit on effort (i.e. capacity) would be reached if all these vessels fished all the time that they possible could. Effort controls might force days fishing to be reduced below this limit: vessels could be laid up, for example. However, the capital cost of the vessels (e.g. interest on loans used to purchase the vessels) strongly encourages their use. Therefore trying to maintain effort far below the potential effort capacity becomes very difficult to enforce and represents a significant cost to both industry and management.

3.3 DATA COLLECTION

Data will be needed to monitor the fishery. Data must be collected for objective assessment of the state of the fishery and is necessary for rational, informed decision-making. An efficient and effective data collection system will also be necessary to convince outside observers that the fishery is meeting international standards.

Data are best collected from critical monitoring and control points during catching and processing, which will vary from fishery to fishery. Identifying these critical points forms an important part of an effective management system. Critical points can be identified as being "bottle-necks" in the fishery, where costs of monitoring are low and monitoring can be enforced. Such critical points are often at points of landing and export.

Low-cost approaches fit the data collection system to the fishing industry practices. For example, it is natural for processors to provide purchase receipts to fishers, and routine data collection can include getting copies of such receipts. Getting copies of such transactions need not be onerous to industry, and accuracy is enforced by the businesses involved.

There are four types of monitoring data which can be collected, in order of importance:

- Fishery based indices will monitor the inputs to and outputs from the fishery. Indices usually include catches and fishing effort.
- Abundance based indices will monitor the changes in the population size. A commonly used index is catch-per-unit-effort, but some fisheries are monitored using abundance surveys.
- Biological indices monitor specific aspects of the fish population. An important statistic is the number or weight of females in the population at spawning time. As one male should be able to fertilize the eggs of many females, the ability of the population to replenish itself is usually thought to depend on the number of

females. However, this also depends on the species, and in the case of queen conch, scientists may decide to assume an equal sex ratio between males and females is desirable.
- Socio-economic and other indices are important to monitor the fishery in relation to policies required to meet economic objectives. The simplest indices would be the price of the product, which multiplied by the landings give the revenue from the fishery. Other indices of interest could include the number of employees (licensed fishers and numbers involved in processing, etc.) and costs of the industry.

3.4 DATA ANALYSIS
Raw data needs to be interpreted using models of the fishery. Models are just simple versions of how scientists think the fishery behaves and should capture the most important behaviour of the fishery in relation to management decisions. Because models are only approximations of reality, the advice obtained from them needs careful consideration.

The analysis should produce simple indices, which indicate how well the fishery is doing. Appropriate indices include average vessel catch rates, fishing mortality and the spawning stock biomass. These can be used to indicate the economic efficiency of the fishery, whether the fishery is sustainable and whether the stock is overfished.

3.5 DECISION-MAKING
The decision-making authority needs to be defined. That is, the people responsible for the decisions need to be clearly identified. Decisions need to be documented and transparent, so that how and why particular decisions have been made are clear.

Decision-making must be consistent with CITES and the Code of Conduct. The easiest way to implement these policies is to apply decision rules. Decision rules are management actions which are planned to be applied in response to key changes in indicators. For example, a simple decision rule could be a twenty percent reduction in quota when catch rates fall below some critical level. The difference between decision rules and any other sort of decision making is that the rules are planned in advance. They should be simple and transparent, so that their implications to the fishing industry can be discussed before they have to be applied.

3.6 ENFORCEMENT AND COMPLIANCE
While decisions can be easily made, ensuring they are carried out can be difficult. Enforcement usually consists of direct methods and auditing methods. Direct methods include patrolling by enforcement vessels and spot checks at landing points by fisheries officers. These methods can be expensive, but at least some direct policing at landing sites is recommended. A complementary method creates audit trails, by using documentation and comparing information obtained at different points during the catch to export process. This is a powerful method to enforce rules and regulations set by decision-makers and audit-like documentation is increasingly required for international export by many countries and international organizations, such as CITES.

Enforcing unpopular decisions can be expensive or impossible. Improving the effectiveness of decision-making requires two actions:
- Consultation with stakeholders and participation in decision-making makes decisions better as the concerns of stakeholders are taken into account. Also, if stakeholders understand the problems, they may be more ready to accept decisions resulting in short-term hardship in exchange for long-term sustainable benefits. Co-management is a term implying fisher (and others) participation in management and encourages much of the decision-making to be devolved to the fishers themselves.

- Enforcement is always necessary. Once a few fishers get away with ignoring controls, other law-abiding fishers will see less reason for themselves to follow regulations and controls, and management can break down. Similarly, poaching undermines the management process unless poaching can be suppressed by enforcement activities.

CITES has proved useful in helping countries enforce decisions. However, this is a two-way process and in return managers have to accept interference in policy and the requirement for transparency in decision-making. One complaint against CITES has been the lack of involvement of stakeholders in making CITES policy. CITES regulations have been thrust upon many Caribbean countries who are signatories of the Convention which may make enforcement in some cases more difficult.

3.7 FEEDBACK AND REVIEW

It is important that decision-making undergoes some sort of feedback, whereby the process can suggest improvements, adapt to new situations and learn from its mistakes. Feedback should not just consult with the management authority, government officials and the like, but should include industry and other stakeholders. Reacting to their concerns and including them in the management process should improve management, making it more cost-effective and better enforced.

Independent reviews, particularly of the technical parts of the decision-making process (i.e. the science), will add significantly to the credibility of the decisions. It is rarely possible for international institutions to study a fisheries management system in depth. Confidence in the management system can come from independent experts who do have the time and local knowledge to study decisions and be satisfied, perhaps through discussion with decision-makers, that the process has met international standards. Local scientists, for example, might be easily recruited from the region's academic institutions.

A useful review system requires independent, reliable information. A fishery monitoring system is required to assess whether management objectives are being achieved. For example, if the management objective is to reduce fishing capacity, fishing capacity will need to be monitored to see how well management is doing.

4. Example of management systems

The following general examples follow implementation of some of the ideas in the manual in four types of fishery: industrial, artisanal, mixed artisanal/subsistence and incidental. These examples have been simplified to illustrate the approach. The reality of day-to-day management needs to consider many details of administration not covered here.

One of the aims of these examples is to promote the idea that good management need not be expensive or complex. Fairly simple procedures may be applied and provide adequate management for smale-scale fisheries, as long as they are well adapted to local conditions.

In looking at the examples, use the background to match most closely with your local fishery. However, all these fisheries have a lot of issues in common, as does conch with other fisheries. Real fisheries will often be a mixture of these different types, or be developing from one type to another. For example, an artisanal fishery may become more industrial as a country's economy develops. It is therefore still worth looking through all these examples even if they do not apply.

4.1 CHECKLIST

Table 1 is a simple checklist of the issues that should be considered when managing a conch fishery (see also Appendix: Fishery checklist). You can check how well the fishery addresses each criterion. This will help to decide which actions might need to be taken to strengthen fishery management. These issues should be covered in the management plan.

4.2 INDUSTRIAL FISHERY

4.2.1 Background

The conch fishery operates mainly on an offshore bank where vessels spend considerable time before returning to land their catch. Vessels are large mother boats each having several catching vessels. The conch are partially processed and frozen at sea. As most harvesting is at depths greater than 10 m, divers use both scuba and hookah gear.

4.2.2 Policy and legislation

The policy is bound by CITES requirements, and the stock is managed so as not to impair the ability of the conch population to replenish itself. This, in practice, means maintaining the population above some level (e.g. 50 percent) of its unexploited size. When the population is at 50 percent of its unexploited size, it is presumed to be at the point of maximum sustainable yield. Once below this point, the stock is considered overfished.

The objective has been to move the fishery to a sustainable exploitation level. In the early years of the fishery, landings were very high and uncontrolled. Rather than change the quota immediately to the lower long-term level, a step-wise quota reduction was agreed with industry to give them time to adjust their capacity and fishing activities.

TABLE 1
Checklist of issues to consider in managing a conch fishery

Checklist	Comment
The fishery is clearly defined	The fishery and management unit need to be clearly identified. A conch stock as a management unit should be defined relatively easily using depth contours. Adult stocks are not thought to migrate through deep water. The fishery includes fleets, gear and "best guess" illegal, unregulated and unreported fishing (i.e. poaching).
An effective monitoring system is in place	Reliable monitoring indices should be available. Monitoring should include indicators and reference points/decision rules for: quantity of conch remaining: biomass and/or spawning stock index; quantity of conch being caught: fishing mortality; economic: revenue, costs and profits from fishing.
The effects on the ecosystem have been considered	The stock needs to be maintained at a level where it will not adversely affect the ecosystem. There is very little information to decide what level this should be. Usual definitions of overfishing have to suffice. Other ecosystem effects could include indirect damage to habitat and environment, although they are likely to be minor. Habitat damage from gears, discarded shells and disposal of conch processing waste are the main potential problems that need to be considered.
Uncertainty has been characterized	Uncertainty needs to be taken into account in decision-making. Decision-makers need to apply the precautionary approach. They need to consider possible bad outcomes from their decisions; whether decisions are reversible should they prove inappropriate and so on. The only effective way to reduce uncertainty is through an active research programme, which includes routine data collection as well as appropriate research projects.
A harvest strategy and decision rules exist	Decision rules refer to specific plans of what to do when the state of the resource and fishery change. Based on the monitoring programme, it should be possible to decide when the fishery changes from a normal to overfished state. Management's focus should reflect the state the fishery is in: Normal phase • The capacity limit and how it will be monitored and adjusted from time to time. • How selectivity might be adjusted to improve yields and protect the spawning stock. • Rebuilding phase • How a temporary reduction in fishing mortality will be achieved. • For how long it will be necessary to maintain the reduction in catches. • Whether and how compensation may be given to fishers and/or the industry.
Independent reviews are undertaken	The stock assessment and management system should meet acceptable international standards and independent reviews should ensure this is the case.
An adequate legal basis exists	Check if the legal basis provides for monitoring, control and enforcement. Laws implementing policy not only exist but are being applied. There also needs to be a method to resolve conflicts and disputes.
There is an effective management system	Clear lines of responsibility exist from political levels which define policy down to technical and enforcement levels where day-to-day management is undertaken. The management structure must be documented in the management plan. Such documentation improves the transparency of the system and allows external review. Co-management is desirable, where stakeholders are actively involved in decision-making and management. Co-management generally improves the effectiveness of management actions.

The fisheries legislation needs to make provision for fishing licensing and registration (local and foreign); fisheries research; fish processing and export licensing; the establishment of a broad array of conservation measures and regulations, such as minimum sizes, close seasons, gear restrictions and marine reserves; and the enforcement of regulations and conservation measures.

The conch fishery is large enough to require a fishing permit specific to conch. Individual quotas (and variants) could be used to avoid overcapacity and encourage sustainability. The fishing industry is vertically integrated, with processors owning or having part ownership in the majority of fishing vessels, which makes the allocation of quotas among processors more likely to improve the economics of the fishery.

As well as covering the objectives and controls above, a good fisheries plan should consider how to help the stock recover if it is designated as being overfished. This should include ensuring that too much capacity for processing and fishing is not overbuilt. As well, management resources should include a contingency put aside by the fishery to cover periods of reduced fishing. Other policies address improving health and safety for fishers and increasing awareness of marine resources in all sectors of society starting from primary school.

A major concern has been to look at ways to reduce poaching. Illegal fishing is seen as a significant problem. An estimate of all illegal catches must be subtracted from the total quota, which is based on the biological productivity of the stock, before the remainder can be allocated to the legal fishery. Clearly there is a direct significant advantage in reducing illegal fishing. Direct enforcement is too expensive, so there is an increasing need to promote international cooperation, perhaps through a regional fisheries management organization as well as participation in regional and international fisheries management initiatives. For example, to facilitate enforcement and to avoid illegal catches being laundered through neighbouring countries, a harmonized closed season should be implemented consistent with other countries with conch fisheries.

4.2.3 Controls and interventions

The fishery is primarily controlled through licensing and an export quota. The export quota is set by the government. Fishers are allowed to use breathing apparatus as the exploited area is in relatively deep water. The number of licences issued and the vessel quota allocation is agreed with the processors, who own the vessels. There is a closed season for conch (August-October) when all catch and trade in conch is prohibited (including importation). Management costs can be recovered using a tax on exports as a percentage of its value. This sort of tax benefits the fishery as it also reduces the incentive to overfish.

Control over the quota has been helped by the monitoring which is necessary for the sanitary standards required for export to Europe and the United States (Hazard Analysis Critical Control Point). Combining monitoring systems has helped implement the conch quota efficiently.

A vessel register and licensing system should be applied to maintain or reduce fishing capacity to the appropriate level. The register will cover all fishing vessels, but licences are issued specific to the industrial conch fishery. All fishing vessels should be required to register and the register needs to be maintained and kept up-to-date.

Licence allocation for conch fishing is conditional upon meeting various requirements. These are clearly printed on the back of the licence. The conditions are designed to make monitoring and enforcement much easier. Adding them explicitly to the issued licence document helps ensure that fishers are fully aware of their obligations.

A future control which could be introduced would be a vessel monitoring system (VMS). This consists of units aboard the mother vessels which record the time and location while the vessel is at sea. These units, with supporting legislation to avoid tampering, can allow implementation of closed areas without expensive enforcement. Implementation would depend upon obtaining reasonable support across industry and the availability of reliable cheap VMS units.

An important concern has been poaching. While direct enforcement, through patrol vessels for example, has not been undertaken because of the expense, control through trade (i.e. CITES) has been used to apply pressure to reduce illegal fishing. Nevertheless, improved international cooperation will be required to eliminate this problem.

Any management actions aiming to promote less efficient gears are likely to be strongly resisted by the fishing industry. Gear controls often increase industry costs and therefore gears are difficult to ban once they have been adopted by industry. As most depths fished are below ten metres, banning compressed air diving is not possible in this fishery. Other depth limits are not currently enforceable.

Health and safety standards for fishers[5] may justify various controls which also happen to increase costs or decrease fishing efficiency. The most important requirement for any diving fishery is a minimum level of training amongst divers. Divers need to be aware of the potential problems associated with diving, particularly long-term health problems associated with poor diving practices. Industry should be able to organize fishing activities efficiently to minimize bottom-times for divers with little increase in costs. Trying to enforce controls at sea is difficult, but government can help through supporting fisher organizations which support divers through education and other benefits.

It is not possible to enforce shell-based size limits, but meat weight limits could be applied, although meat weight controls would protect the fishery to only a limited degree (see Section 9.4). If a minimum meat weight size limit is being applied, the level of processing needs to be taken into account. This requires precise definitions of processed categories and conversion factors, which may need a special research programme to estimate. Exporting of "chopped or diced" conch should be prohibited without written permission from the management authority.

In general, controls should be chosen so that they are enforceable and can be shown to have the desired effect on the fishery. An effort control should be applied to cap the maximum effort which can be applied in any year. A quota control should ideally be set on total catch rather than on exports and additional controls, such as marine reserves, can be used to reduce the risk of overfishing.

4.2.4 Indicators and reference points

The stock has been monitored primarily through biomass surveys. These surveys have been conducted by divers swimming fixed distances over the bank counting and measuring conch (see Section 8.4). By conducting a large number of such transects, the total biomass of conch has been estimated.

An alternative index is being developed using catch and effort data to decrease dependence on expensive surveys. Collecting catch and effort data can be difficult to start where industry is not used to providing such information. Once started, however, it can be the least onerous and least expensive source of information on stock size. Once data on catch per unit of effort (CPUE) has been established as an accurate index, the frequency of surveys can be reduced or could be conducted on an ad hoc basis, decreasing management costs.

The survey data can be used in three ways:

1. The biomass can be monitored directly. Decreases in quota (or illegal fishing) should produce higher estimates of biomass in the medium term. Conversely increases in the quota should decrease the biomass. This allows management to set controls and then check they are achieving their objective in terms of stock size.
2. A model has been applied to interpret the survey data and estimate the maximum sustainable yield (see Section 8.2.5). This sets the maximum quota that could be allocated. Applying the precautionary approach, and allowing for illegal fishing, has meant that the quota is set below this figure.

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[5] See the International Labour Organization Sub-Regional Office for the Caribbean (www. ilocarib. org. tt) for general information on health and safety issues and worker representation.

3. Another way to assess the state of the stock has been to compare two survey areas, one fished at the current average rate and the other not fished (because it is inaccessible or protected). The assumption is that the areas not fished have the same density of conch as the whole area would if unexploited. This assumption needs careful review, but nevertheless such comparisons can give general indications as to the state of the stock.

The density estimates can also be used to identify potential areas for closure. Information from surveys are more likely to influence closures for industrial fisheries, as it is possible to enforce closed areas based on depth or habitat or observed conch density using vessel monitoring systems. Additional sampling might be suggested for the proposed closed area to verify that it will achieve management objectives, such as protecting 5 percent of the spawning stock.

All commercial catches should be recorded through purchase receipts and processor records. Logbooks can be required for commercial vessels at sea for more than one day. This allows more accurate recording of both catch and effort, but requires the cooperation of the fishing industry. Catch size composition can be obtained through random sampling of all the landings. Other non-industrial catch and effort data should be estimated through sampling programmes.

Population size structure data collected from the processing plants and survey could prove useful in future, in particular for estimating the illegal catch, but is difficult to interpret (see Chapter 7) and therefore is not currently used. Scientific research will be required to make effective use of these data.

Where meat weight is being used as a control or indicator, random samples will be needed from processors. It is recommended that measurements are taken before processing and with only the digestive glands removed. This allows the maturity and sex also to be recorded. The proportion of meat weights below any regulation will also be obtained from these data to indicate compliance. While as has been noted, a meat weight control is of limited use for this species, monitoring meat weight is still useful for assessing the effectiveness of other controls. For example, a marine reserve designed to protect undersize conch should raise the average conch size if effectively enforced.

A biomass dynamics model will be used to set limit, precautionary and target reference points for total catch and effort. The default population model should be the logistic unless another can be shown to fit the available data better.

Regular assessments of the data should be carried out. It is not necessary, or even desirable, that assessments be carried out every year. It is however necessary that monitoring of indicators be continuous. A fall in indicators should initiate an assessment.

It will be necessary to demonstrate that the chosen management controls can affect the fishery. For example, reducing quotas should result in increases in the CPUE index. This can and should be verified by management.

Longer-term research should be coordinated in the region. Models for growth and mortality are a priority. Not only do estimates for parameters need to be refined, but explicit measures of uncertainty are also required. Ideally, a default growth and mortality model paradigm should be agreed among scientists.

4.2.5 Decision-making

The primary control, the total allowable catch (TAC), has been arranged between government and industry and is based on scientific advice. Ultimate authority rests with the Minister for Fisheries, although decisions have been made on the advice of the fisheries department. The TAC is allocated to the different parts of industry through a committee. Industry takes a significant role in management decisions which encourages industry to abide by them.

Due to their size, industrial fisheries are involved in decision-making through representation rather than participation. This requires organization of industry at the different levels of government, fishing and processing to ensure all interests are represented and that representatives have a mandate. Setting up organizations may require government support. Representation is most easily achieved by establishing a fishery advisory council that can discuss and recommend actions to government.

4.2.6 Enforcement and compliance

Exporters must possess a licence issued from the relevant government department, not necessarily the fisheries department, although fisheries should be consulted. Exporters also require a CITES permit for each export consignment. The CITES permit should always be approved by the fisheries department whether the fisheries department is the designated scientific authority or not.

It is important that all products are inspected before export. Inspection covers health as well as conservation requirements. The primary aim of the conservation requirement is to makes sure the various information on the permit application matches the shipment, including: (1) the total weight of product being exported; (2) the level of processing of the meat ; and (3) the average meat weight compared to the minimum meat weight for the level of processing, if this control is applied. Random sampling of the frozen product is difficult, however, and most meat weight sampling should be conducted during processing.

The fisheries department issues both the CITES permit and the health certificate, after the shipment has been inspected by an authorized officer. It is from these various forms that the export data are collected. Hazard Analysis and Critical Control Point (HACCP) and conservation monitoring are combined as much as possible to minimize red tape and make controls as efficient as possible.

Enforcement at sea is more problematic. The only realistic option is to incorporate random checks with other coastguard activities, notably drug interdiction. Mostly this depends on the enforcement officers at sea simply understanding the fishery and fishery regulations and developing greater cooperation between the fisheries department and the enforcement agency. This can be achieved most easily by convening a joint committee between fisheries and all other parties interested in marine enforcement. This will allow fisheries officers to be taken on patrols, ensure enforcement officers know what to look for in relation to the fisheries regulations, and so on.

An important component of enforcement against poaching is to negotiate the requirement that all fishing vessels are clearly marked so that they can be identified from the air as well as from sea. Infringements can then be reported to the flag state. The policy aim of increasing international cooperation will make this information gathering more effective.

4.2.7 Feedback and review

A national CITES scientific committee is responsible for reviewing CITES issues, of which conch is one concern. The committee, made up of independent scientists and people from institutions interested in conservation, has reviewed both the science and decision-making. It reports directly to CITES on its findings. The reviews have included interviews with government staff.

4.3 ARTISANAL FISHERY

4.3.1 Background

Most fishing occurs on wide shallow banks of sand, seagrass, algae and reef habitat suitable for conch. There is sufficient area to support a commercial fishery employing a significant number of fishers with their own vessels exploiting conch, landing around

200 kilos whole meat each fishing day. They depart in the morning and return mid to late afternoon, usually landing at one of several processing plants that purchase, clean and pack the conch for export. Shells are usually removed and discarded at sea. There is local consumption of conch, but it is thought to be low compared to the quantity caught for export.

4.3.2 Policy and legislation

The policy for an artisanal fishery is broadly the same as that for the industrial fishery. This means maintaining the stock above 50 percent of its unexploited state is the primary objective. More generally, it is the policy to apply regulations consistent with maintaining or restoring populations of marine species to levels that can provide the maximum sustainable yield. However, because employment tends to be a more important consideration in artisanal fisheries, other policies may be developed which are more orientated to maintaining and extending livelihood opportunities.

An obvious way to increase employment is to make better use of the resource locally rather than allow increases in fishing effort. Therefore the policy includes encouraging all meat processing to be local, developing uses for the conch meat waste (process into protein for animal feed, for example), and developing uses for the shells. This last includes procedures for obtaining the meat which avoids damaging the shell, as well as encouraging local artists to create jewellery and curios from shells.

Given that information on artisanal fisheries will be harder to obtain than for industrial fisheries due to economies of scale, management of risk needs to be considered. This will need implementation of a precautionary approach based on the available information and analysis. As a result the TAC is always set such that it is very unlikely to exceed the maximum sustainable yield in any one year. In addition, a closed area (or appropriate gear controls) can be useful in guaranteeing the protection of a proportion of the stock.

A desirable aim would be to maintain current fisher earnings. This is a difficult policy to implement however, as any reduction in catches to protect the stock implies a reduction in fisher income. It should be noted that any control that conserves the stock, such as TAC, marine reserves or closed seasons, by necessity must reduce catches to be effective unless they are being used to prevent future threats to the resource. One way to protect fisher income is to apply a limited entry policy, where only professional fishers are allowed to fish conch for export. This, unfortunately, is directly opposed to the need to provide employment as it would prevent new entrants to the fishery. The policy needs to balance the need to protect earnings and the employment that the fishery provides.

4.3.3 Controls and management interventions

The fishery is primarily controlled through licensing and an export quota, which is calculated based on a target TAC. There is also a small area closed to fishing, a closed season to spread the catches more evenly through the year, and fishers are not allowed to use breathing apparatus, but must free dive.

The export TAC was set up largely as a result of CITES requirements. The export TAC is controlled both locally and internationally through customs. Most exports go through Miami, the United States of America, where they must be accompanied by a CITES form issued by the government indicating the part of the TAC which the export constitutes. Quotas as parts of the TAC are allocated to the processors.

The number of licences are limited, but are not controlled by management. While any national can get a licence, the number of eligible people in the population is small, making numbers of full-time licensed fishers limited. The processing sector is similarly licensed, although they do not only process conch; they also buy lobster and scale fish from fishers.

Various management controls might be considered for increasing local employment. For example, an export tax based on the exported weight would encourage 100 percent local processing rather than processing abroad. More innovative interventions could be to develop a market and methods to give greater value to landing the shell, which are currently discarded. This could allow better enforcement of shell based controls as well as improve returns to the fishery.

4.3.4 Indicators and reference points

All fishing vessels should be registered. A survey may need to be conducted to initiate a register if none already exists. Registration of artisanal vessels is more difficult than industrial vessels, because the vessels are usually more dispersed and there are more of them.

If catch is not available, a vessel survey should be undertaken to estimate current total catch. The survey would cover vessel activity and catch per unit effort.

Size composition sampling should be carried out on the landed catch. Catches should be chosen at random and size recorded for all samples (e.g. meat weight). A sub-sample should be selected ensuring it covers the widest range of catch size to estimate conversion parameters between various measures, such as processed and unprocessed meat weight.

Fisher interviews can be conducted to obtain fishers' views on the productivity of the stock. This is not only useful in estimating the current state of the stock, but also is a useful move towards co-management, which should improve enforcement.

Data can and should be shared between countries to enable those with little information to develop a monitoring programme immediately. Setting up such a system could form one of the tasks undertaken by a regional fisheries management organization.

Data collection for long-term monitoring purposes relies mainly on the processing industry. Every processor must complete forms indicating the daily landings from each vessel. At the end of each month the processor sends the completed form to the fisheries department where the data is entered into a database.

The data reported by industry is used to calculate the total landed catch, by adding up all the reported daily landings, and the total effort, by counting all the landings that have been made. Each landing reported for a boat represents a day's fishing for a boat, the fishing effort.

A standard fishery model is used to interpret the catch and effort data. By analysing past behaviour of the fishery, it is possible to estimate the abundance of conch relative to the unexploited stock size and estimate the current productivity of the stock. It is necessary to know both to set an appropriate quota.

If an insufficient catch-effort time series is available, the process can be initiated with a conch survey in much the same way as that suggested for the industrial fishery. The survey scale should be commensurate with the size of the fishery, and therefore require fewer samples sites than for an industrial fishery.

The primary indicator for this fishery is CPUE and estimated biomass relative to the unexploited biomass. Biomass is estimated using the catch and effort time series, any survey biomass estimate and a biomass dynamics model (see Section 8.2). The analysis is not difficult, and can be repeated each year to assess how well the fishery is doing. The model provides an expected CPUE at the MSY point, so that the observed CPUE (catch per day) can be directly compared to this value. If the CPUE falls below this figure for a number of years, action can be taken to raise it by reducing the quota.

Long-term monitoring would depend on being able to generate annual CPUE by fishing ground. CPUE is the indicator of choice to monitor biomass as it is usually the cheapest method and can be maintained over a long time period. Short breaks in the series do create a problem, but total catch time series must be complete. Total catches measure the impact of the fishery on the stock and must be recorded and be available.

It is important that the catch and effort monitoring be robust to changes in available capacity. Such monitoring should form a core activity of the management and scientific authorities. Much of the monitoring of commercial catches should use records completed by processors and other purchasers. The scientific authority only needs the ability to collect, check and store these data.

If possible, stock surveys can be conducted to provide a fishery independent assessment of biomass. Such surveys are valuable as they provide a check on CPUE as well as providing an independent assessment on the scale of the fishery, and are often used to improve assessments. If CPUE is being monitored, however, they need not be frequent.

The main concern with using CPUE is that there will be changes in catchability. Catchability is the scaling parameter between biomass and the CPUE variable. It can change if vessels become more efficient, for example, or if management controls the way vessels fish (e.g. introducing a minimum size control). Stock surveys can be used to bridge such changes. Vessel register data can be used to standardize CPUE for many changes in fishing power.

Stock assessments require contrasts in the data in terms of population depletion and growth to allow accurate estimates of appropriate controls. Periods of depletion, in particular, may not be considered desirable. However, if it is to be verified that chronic overfishing is not taking place, a period of reduced fishing mortality after monitoring is in place should be applied to estimate the rate at which the population increases in response.

The state of the stock should be maintained above the overfishing point. Standardized CPUE as a proportion of the estimated unexploited CPUE can be used as the biomass indicator. There are two reference points:

- 50 percent unexploited CPUE precautionary: the indicator falls below this point a rebuilding programme is implemented (CPUE should be monitored during rebuilding or a set recovery period applied).
- 30 percent unexploited CPUE limit: a fishery falls below this point, the fishery should close.
- The secondary aim is to maintain the fishing mortality below levels which could drive the fishery into an overfished state.
- f_{MSY} limit: effort should be reduced to be below this level where yield is maximized. f_{MSY} (effort at the maximum sustainable yield) is the fishing effort which theoretically maximizes the total catch from the fishery.
- f_{TEY} target: this is the fishing effort required to move the stock to some optimum level which can be defined using socio-economic indicators. f_{TEY} (effort at the target economic yield) should be adjusted to approach the target level as quickly as possible. A socio-economic target should be developed immediately and can be based on average costs, conch price and/or on fisher interviews. It can be refined through further socio-economic research.

4.3.5 Decision-making

Ultimate authority and therefore decisions, rest with the fisheries authority. However, the authority takes advice from a scientific committee and decisions going against this advice would have to be justified.

The scientific committee assesses evidence based on a stock assessment. The stock assessment mainly assesses the impact of management actions on the catch rate of fishers. Setting a reduced TAC should increase the average catch taken on a vessel fishing day. Conversely, higher TACs will decrease the catch taken on a day's fishing. The limit reference point, the level that management aims to maintain the catch rate above, is around 200 kilos per day, as this is estimated to be the maximum sustainable yield point. In addition, the scientific committee needs to apply the precautionary approach, so higher catch rates are preferable.

There is no formal review process for the assessments or management. However, the scientific committee is made up of local experts as well as government scientists, so that the advice is independent. Local scientists also take part in regional fisheries workshops where informal reviews can also take place.

4.3.6 Enforcement and compliance

Although the TAC is set based on landings, the landings are controlled through export quotas allocated to each processor and not enforced directly. The yield from processing is 40 percent of the TAC. Once the export quotas are met by processors, the fishery is closed and no further landings undertaken. Stockpiling conch for the following season was a problem, but has been discouraged and is not permitted.

Other controls are enforced directly by fishery department patrols. In particular, poaching vessels from other states have been caught and prosecuted. The information required to catch such poachers has usually been based on information from fishers or police surveillance. Regular fishery patrols have proved difficult and costly to maintain.

4.4 ARTISANAL/SUBSISTENCE FISHERY

4.4.1 Background

The fishery is very similar to the artisanal fishery described above, with individual small vessels collecting and landing conch within each day. The catch is used for local consumption, including tourist outlets, as well as sold for export.

Unlike the previous examples, catches may be landed at numerous sites and over a number of islands. Catches then may be consolidated for processing and export, or distributed locally for subsistence or commercial purposes. The more diffuse nature of the fishery makes monitoring difficult, which needs to be taken into account in the fisheries management.

4.4.2 Policy and legislation

The policy is bound by CITES requirements, and the stock is managed so as not to impair the ability of the conch population to replenish itself. However, direct control over the subsistence fishing is not possible and subsistence fishing is more difficult to monitor. Only a proportion of the catches can be recorded.

The primary objective is to maintain the stock for local consumption. The amount of fishing that goes on for local consumption is related to the islands' population size and the alternative employment opportunities that exist. Any yield beyond that used locally can be exported. Hence, the exported catch provides a buffer protecting the local market and subsistence. This policy will clearly only work if the local demand is less than the maximum sustainable yield.

Implementing this policy is not easy as the total catch and state of the resource is largely unknown. An initial operational objective would be to maintain the CPUE at a level that is not significantly different from the previous 10 year average until further scientific information is available. If this objective is met, it would suggest that at least the situation has not worsened and the current fishery is sustainable. Similarly, if there has been no overall decline in CPUE over the last 5–10 years, the total export quota could be set to the average exports over the same period.

Another indicator of overfishing is for divers to dive to greater depths as they deplete shallow water resources. Enforcing a maximum depth is difficult, but depths can be monitored by, for example, recording maximum depth recorded on dive depth metres or dive computers. This can be compared with the bathymetry of the shelf to indicate where most exploitation is occurring. At the same time, the risk of decompression sickness associated with scuba diving can be reduced through requiring certification of all divers, perhaps introduced over a five year time frame.

While it will not be possible to control the number of subsistence fishers, artisanal fishers might be controlled through licensing. Only licensed fishers might be allowed to sell to processors for export, for example. However, the policy will need to balance the needs for employment and earnings.

There is also a policy to protect critical habitats for conch from exploitation and degradation. This is most easily done by declaring marine reserves and applying protective legislation to prevent any practices, including fishing, which threaten the reserve ecology. However, marine reserves on shallow water banks may be less easy to define and patrol than other habitats such as coral reefs or mangrove.

Another conservation objective would be to maintain the average marketable meat weight at a level that is not significantly different than the previous 10-year average and maintain non-compliance levels with respect to the marketable meat weight at or below the current level. As meat weight does not increase beyond maturity, this is a crude control and cannot be relied upon to prevent overfishing. Meat weight is still worth monitoring as it should indicate changes in the population or fishing practices, but should have lower priority compared to other activities.

4.4.3 Controls and interventions

One of the most important interventions will be an education and awareness programme. For any subsistence fishery, there will be a reliance on self-enforcement. It is therefore important that the fishing community and the public understand why there is concern for conch, so that they understand what controls there are and why they are being applied. Most people are, on the whole, law-abiding, and will not flout regulations when they are understood and they agree with them. It is also important that not just fishers are targeted. Fishers are often influenced by the wider community, so the whole community needs to be in broad agreement with government interventions for them to be successful.

Direct controls will mostly target the export fishery. An export quota can be applied and adjusted in response to the monitoring programme. In addition, licensing might be used to control fishing effort for export. It is usually difficult to control local subsistence fishing through licensing, as this is seen as an infringement of the right to collect food, so full effort control will not be possible.

Other controls might be applied to the gear and fishing activities themselves. An education programme together with a progressive requirement for scuba certification should reduce health risks. Hookah (direct feed from a compressor) may be banned and the number of compressed air tanks taken aboard per diver can be limited. It also may be wise to require that a spare scuba rig is hung from the boat at a depth just below three metres to avoid rapid ascents. Finally, decompression treatment should be available to divers, and, if necessary, a tax levied to ensure this is available to all fishers.

The distributed nature of the fishery makes closed areas or marine reserves a useful tool to reduce risks of overfishing, but implementation and in particular enforcement may be difficult unless the fishers themselves support the initiative.

4.4.4 Indicators and reference points

The diffuse nature of the landings makes monitoring catches (and effort) difficult, but not impossible. Landings can be sampled using trip interviews, which provide an estimate of average CPUE. This can be raised by the total effort to obtain total catch, using, among others, fishing activity and a frame survey or vessel register.

Unfortunately sampling can be so low, and frame surveys out of date, making these estimates of catch and effort very poor. If no reliable catch and effort information is available, other methods need to be used.

Trip interviews can be used to draw out more detailed information on fishing activities. Number of air tanks used with average and maximum dive depth can not only give a better estimate of effort, but can be used to estimate the annual mean depth dived by all divers. Compared to a bathymetric map, this can give some indication of where divers are operating, and whether they might, for example, be depleting the shallow water resources.

Even if catch and effort information can be obtained, it may difficult to interpret until a reasonable length time series has been built up (at least 10 years). Hence reference points may be difficult to propose. Initially CPUE can be compared to an historical reference point (e.g. last 5 years average) to identify trends.

Export quotas should be recorded, so it will only be the subsistence catch and catch sold through local outlets which will not be covered. Landings sold through local restaurants and stores can be monitored through purchase receipts. However, while main restaurants can be monitored this way, temporary stores and markets often do not produce reliable data. The most reliable way in terms of estimating all catches is through a consumption survey. This involves asking various households and groups (e.g. tourists) what they have eaten over a fixed time period. As conch will be only one product, it makes sense for a consumption survey to cover everything that people eat, including other types of fish and food stuffs. This makes the survey much more efficient as information is valuable to agriculture, tourism and health as well as fisheries departments, so costs can be shared. The sample from the survey can be raised to totals using population census surveys.

A biomass survey will make interpretation of catch and effort easier as well as providing estimates of an indicator, reference point and controls itself. Total catch divided by total biomass gives some indication of the exploitation rate. A level below ten percent indicates fishing is at a safe level. An average density of conch well above 50 per hectare would also suggest a safe population, but densities below 50 do not automatically imply overfishing as density will be habitat dependent.

If earnings are an indicator, current earnings will need to be assessed from this fishery. A simple indicator is the catch per fisher, which can be estimated from trip interviews and can be used to detect trends. If a comparison is required between the fisher earnings and a national minimum wage, the absolute earnings will be required from revenue and costs which is a much more difficult task, but again can only be obtained from interviews and gathering price information.

Indicators for marine reserves would include the proportion of conch biomass protected (from a biomass survey), and the proportion of the various types of habitat within the area, which would require a habitat map of the fished area. Water quality and pollution could also be monitored within the marine reserve, although control of these indicators would be beyond the control of fisheries management alone. The number of infringements (fishing activity within the reserve) per year would give some indication of compliance. Repeated mapping, using remote sensing for example, could be undertaken to monitor change in habitat quality and area, although this would form a wider activity than just dealing with the conch fishery.

For health and safety objectives, the relevant indicators would be the proportion of divers holding a diver certification (e.g. PADI) and the number of fishers reporting with decompression sickness per year. There are no acceptable levels except zero percent decompression sickness rates and one hundred percent diver certification.

4.4.5 Decision-making

Participation of fishing communities directly in management decision making becomes more important as fisheries become smaller and more diffuse. This particularly applies to the location and extent of closed areas and closed seasons. Whether these initiatives are a success or not very much depends on the level of consultation which has taken place.

The level of consultation will largely depend on the size of the fishery. Larger fisheries are likely to be limited to representation through a fisheries advisory committee or similar institution. For small fisheries, decisions might be made directly by meetings of fishers. Representation may still play a role where fishing communities are spread out among islands. Representatives can take individual community decisions and concerns to higher level meetings.

The more participatory management decisions are the more important education in fisheries management becomes. In all cases, it is important the decision-makers understand the issues they are dealing with. Many decisions are difficult to make, implying a loss of income in the short term, with the hope of greater income in the future. Rational decision-making requires a good understanding of the outcomes and risks resulting from management actions.

An annual quota will need to be set. It is recommended that this is not subject to arbitrary decisions, but a simple decision rule should be decided upon which can be applied over a number of years. For example, a consumption survey together with a population census can estimate the total catch for local use. The population and tourist census should also be able to estimate trends, which should allow an export quota to be adjusted automatically each year to maintain the current catch until the next consumption survey. This would set a reasonable control on catches until further information becomes available.

4.4.6 Enforcement and compliance

Compliance will depend to a large extent on getting the fishing community to agree with the policy being implemented. This involves not only winning the "hearts and minds" of the community, but conducting a consultation where the management listens and reacts to community's views. This may mean rejecting controls even where there is strong outside pressure to implement them. On the other hand, poaching undermines the community-based compliance, and rigorous enforcement is required to prevent local fishers feeling that they are not in control of the amount of fishing going on.

Direct enforcement through policing activities has only a limited role in these sorts of fisheries. It is nevertheless important that antisocial behaviour is curtailed and policing supports the community's decisions. Education of fishers is particularly important to improve compliance in these types of fisheries.

Some regulations, such as minimum size can be enforced on land through beach patrols at landing times. Most likely this would have to be combined with data collection activities. Separating enforcement from monitoring is often not possible, but may compromise the monitoring data.

Effective minimum size enforcement would require shells to be landed. In commercial fisheries, where catches are large and the shells need to be removed at sea, a minimum size control is not likely to be enforceable unless there are very frequent inspections at sea.

The level of non-compliance can be monitored with respect to minimum size regulations. By random sampling at landing or during processing, the proportion of the catch below the minimum size (or that breaks other regulations) can be estimated. This can be used in scientific assessment as well as monitoring the effectiveness of enforcement activities.

4.5 NON-DIRECTED FISHERY

4.5.1 Background

There is no commercial conch fishery. Conch are harvested mainly opportunistically, rather than through a directed fishery, such as bycatch in a fishery directed at spiny lobster. Anecdotal information and local knowledge suggest that only small quantities are harvested mainly for shells, which are polished and sold as curios to tourists; and/or the meat is usually consumed by the harvester or sold privately and not openly at markets.

Both established souvenir retail stores and itinerant salesman are involved in the sale of conch shells. A significant number of shells are imported. Local conch populations are believed to be typically much smaller that those of neighbouring islands.

Since there is no commercial conch fishery, no resources have been allocated to the assessment of this resource in the past. The status of the resource is therefore unknown.

4.5.2 Policy and legislation

The general policy of maximizing economic benefits while conserving the resource applies to conch even though it is not a targeted species. However, in economic terms conch may not be significant, and therefore the primary objective may simply be conservation.

It may be decided that there is insufficient information on conch to develop any operational management objectives. Therefore, a first objective would be to determine the status of the fishery and begin consultation to develop reasonable objectives. Information on conch could include location of resources, the level of fishing effort, market demand, export and imports.

If it is determined that there is no significant fishery for conch (for example, catch: biomass < 5 percent only a minimum level of management will be required. This would consist of continued monitoring of imports and exports, and the fishery so that action can be taken if conch exploitation increases. Otherwise conch should be explicitly included in any ecosystem management initiatives (e.g. marine protected areas).

Alternatively, if it is determined that conch is being heavily fished (i.e. the resource size is very small), the most cost-effective option may be to discourage fishing of conch. It may be not be possible to eliminate fishing altogether.

This is the type of fishery where "passive management" may be most appropriate. Passive management sets up controls such as minimum size and closed areas, but does little, if any, monitoring of the day to day activities of the fishery. The controls need to be stringent enough that they ensure the resource is conserved, but need only be reassessed and changed infrequently.

A permit should be required for import and export of all conch shells whether to or from CITES member countries or not. For meaningful management, all exploited conch needs to be monitored. It is possible to operate a personal limit on exports as long as this remains small. This avoids unnecessary red tape on trivial quantities, as long as the managers remain sure that these quantities are trivial.

Fisheries management policy may apply an ecosystem approach, where conch is one component. Within the shallow water tropical ecosystem, conch have an important niche, and juvenile conch in particular contributes to the diet of many predators. An ecosystem approach should guarantee conch and their habitat are protected, along side other species which share their habitat.

4.5.3 Controls and interventions

With the exception of an export control (e.g. a personal limit on shells or meat carried), trip limit (bag limits) and size limits, controls and interventions should probably not be limited to conch, but conch should be covered by the fishery controls that exist. As part of fisheries management, government should probably have several controls and interventions in fisheries, and each of these should consider conch as one of the species covered. These should include, for example, overall effort and fishing capacity controls and gear restrictions such as a requirement for scuba training certification.

It is not recommended that a no-take zone specific to conch is implemented, but marine protected areas which contain significant conch biomass are recommended. These should provide protection for the conch within these areas as well as other species and the habitat.

All imports and exports should be controlled. If conch is not thought to be threatened, a personal export limit can be applied of a few shells or pounds of meat which does not require an export permit. If the resource is thought to be threatened, all exports should require a permit and the personal limit essentially set to zero.

Where landings are monitored and the shell is landed, a minimum shell/lip size can be enforced. Enforcing meat weight is not recommended if it is not already done, although meat weight might still be useful as a monitoring indicator.

Other more expensive options such as directed controls on conch will not be cost effective. Any regulations on conch should be enforced while conducting other activities. Minimum size regulations and bag limits for conch, together with other species, can be checked during beach patrols. By combining activities, the efficiency will be increased and some direct enforcement might be possible. What will be possible will depend upon what other activities are being undertaken, which will therefore have a bearing on the controls applied.

4.5.4 Indicators and reference points

For this sort of fishery, the critical indicator is the catch to biomass ratio. If the catch is only a very small proportion of the biomass, management only has to maintain the *status quo*. If catches are a high proportion of the biomass, further action might be needed.

Catches can be obtained from trip interviews and consumption surveys, in the same way as for other fisheries. With catch and effort monitoring, catches of conch can be obtained in the normal way as long as conch, where it is caught, is recorded. Without catch and effort monitoring (for example, where subsistence and recreational fisheries are not surveyed), a consumption survey and/or curio survey can be conducted. As all imports of conch should be recorded, these can be taken from the estimates obtained from consumption and shells. Where conch is taken as bycatch, the effort recorded by the directed fishery can be used.

Conch should only be a small part of any data collection. Any data collection exercises, such as trip interviews, need to ensure that conch are included. This might be done by having conch as an explicit item in interviews, catch measurements and so on. For an incidental fishery, data collection should not be conducted on conch alone, as this is not only inefficient, but understanding conch catches may require knowing what other species were caught on a trip.

As with any fishery, surveys can be undertaken to identify and map conch grounds, determine stock densities, identify stakeholders and fishing effort. As conch is not a directed fishery, any survey should set out to cover conch as only one component. For all data collection activities, efficiency is an important consideration. It is not appropriate to take limited resources away from other species which are more heavily exploited or more threatened.

Simple, easy to collect indicators should be chosen to monitor whether management needs to carry out any interventions. Once it has been determined that the stock is only lightly fished, for example, the main aim would be to have an indicator of a change in circumstances that would warrant either a reassessment or immediate intervention. For example, at each trip interview, the interviewee could be asked whether they have caught any conch today, the last trip, and/or this month as a qualitative indicator. An indicator might then be the proportion of trips in which conch are caught in a year. If this proportion changes +/- 20 percent a reassessment might be considered necessary, so that the original biomass surveys would be re-conducted. Standard indicators as described for other fisheries, such as CPUE, can be also used, but may not be appropriate. Where a species is only taken infrequently, CPUE can be a poor indicator of stock size.

4.5.5 Decision-making

Conch in this fishery would require no special decision making mechanisms. Fisheries advisory committee, government departments, community managers, CITES and other decision-making authorities would also deal with conch. The most appropriate management options for an incidental species like conch are either to discourage fishing or maintain the *status quo*. In either case, the systems in place should be able to deal with the decisions required.

4.5.6 Enforcement and compliance

There would be two key enforcement activities: public awareness and controls on exports. Any other enforcement activities for the fisheries where conch occurs as an incidental catch, such as effort controls and marine reserves, would also cover conch by default.

It is important that the public are aware as to the state of the conch resource and are discouraged from catching it, if it is suspected that it is overfished. A moratorium on fishing may be the best way to rebuild an economically minor resource, and may be acceptable to the fishing community if they understand why the moratorium is in place. Alternatively, a bag limit can be applied, so only a maximum of one or two conch per day per person might be landed. This would allow incidental fishing, but keep exploitation to a very low level. It may appear to be easier enforcing a complete ban on fishing conch, but if this would be very unpopular, a bag limit may be the most effective overall control.

The most likely controls on exports would be an overall quota, a personal export limit and/or a minimum meat weight. The overall export quota is an important tool for controlling exploitation and may need to be reduced or reduced to zero if overfishing is detected. Imports can still be used to supply the local trade. If designated as overfished, the export personal-limit should probably be reduced or set to zero. Imported conch shells and curios could still be exported, but would require an accompanying certificate issued to the shop selling the curios. This can be enforced by customs, but most tourists would automatically comply with a conservation export requirement once made aware of it.

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.

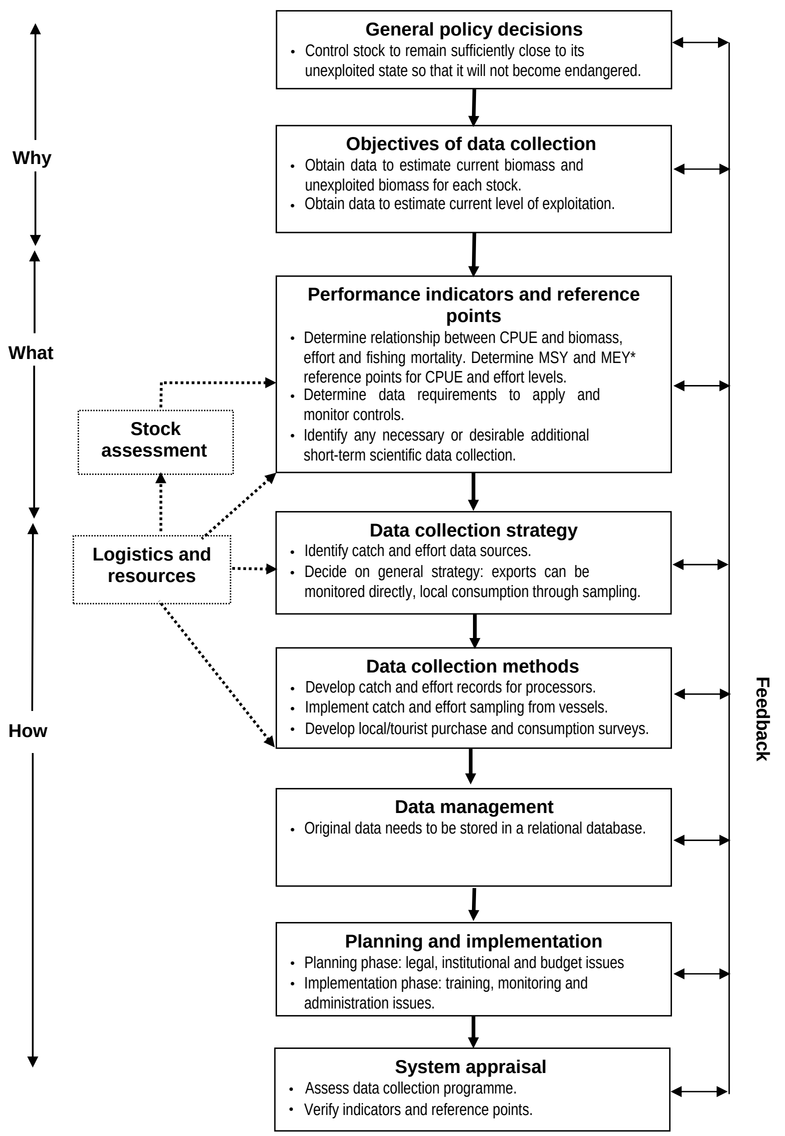
The system can be defined by a hierarchical set of objectives. Meeting the lowest set of objectives should automatically achieve the highest goal. Each fishery should set out such a plan. This need not necessarily follow the specific recommendations in this manual, but must apply some logic that guarantees 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 Working Group Report Export monitoring
Fisheries management objectives	
Maintain population above the overfished level Maintain fishing capacity below overfishing level Maintain fishing effort below level that would lead to overfishing Maintain reproductive capacity of the stock Maintain socio-economic returns as close to the desired optimum as possible	Government Policy Statement Fishery Management Plan
Management outputs	
Set annual controls to move: current stock state above limit current mortality rate below limit reproductive state above limit socio-economic returns closer to the optimum	Annual Management Report Demonstrable correlation between control and indicator from time series
Science outputs	
Define indicators and reference points proxies for: current stock state fishing mortality reproductive capacity socio-economic performance	Independent Annual Science Report Scientific reports and papers justifying measures chosen
MANAGEMENT ACTIVITIES	
Landings, effort, vessel, fisher and gear monitoring Fishery area and seasonal closures Prosecutions applied	Database records Data sheets Internal reports
Science activities	
Catch sampling and monitoring Fishery independent surveys Models and analysis Assess by-catch and environmental impacts	Database Data sheets 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 Conversion functions
Tagging data	Growth and mortality parameters, including F

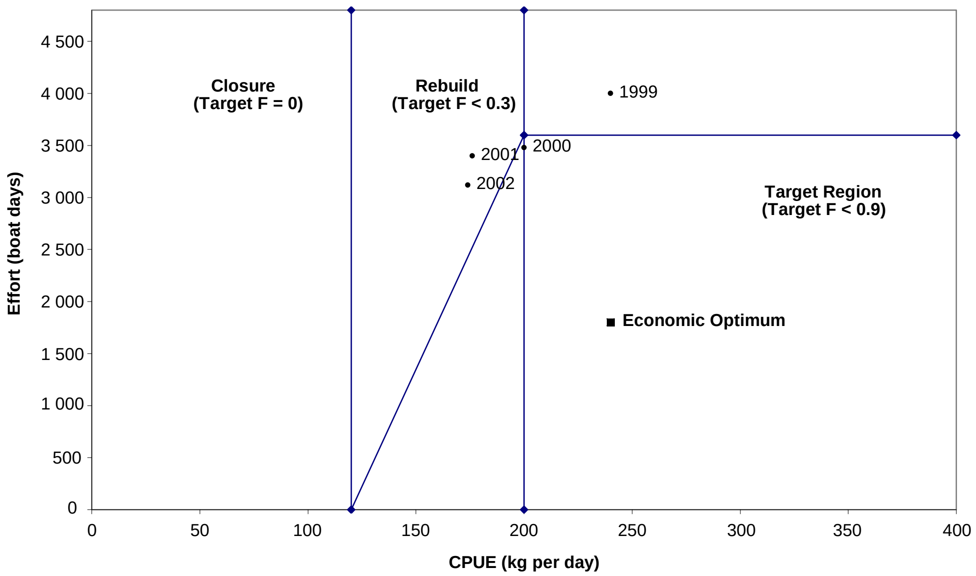
TABLE 5
Priority research to enable interpretation of routinely collected data

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. Stock surveys. Consumption surveys	Estimate expected unexploited CPUE. Unexploited biomass.
Fishing Effort	Catch-effort surveys. Effort frame survey. Licensing.	Catchability by gear. Effort limit and target by gear. 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.

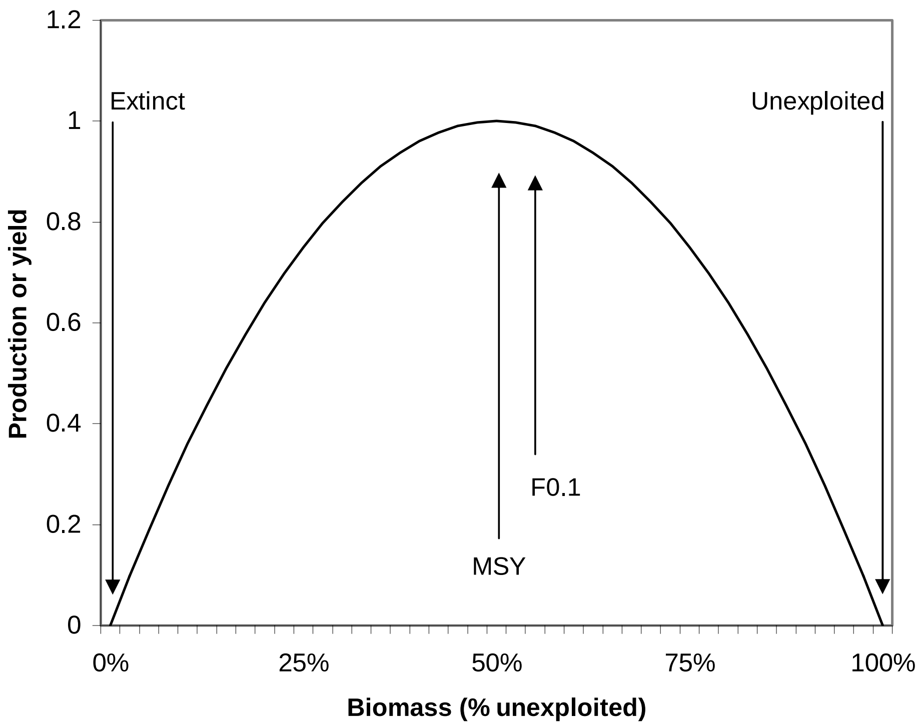
Survey density can also be used to estimate biomass either as an index or in absolute terms. An index would require less data to get a reasonable result and hence is less costly. The same survey must be repeated annually or every few years and may be included in the stock assessment. Absolute abundance 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.

[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.

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APPENDIX

Fishery checklist

The Marine Stewardship Council (www.MSC.org) has developed a series of principles and criteria which allow the fishery management to be measured against the FAO Code of Conduct for Responsible Fisheries. By applying good management defined by the Code of Conduct, not only will CITES requirements be immediately met, but various pressures leading to overfishing will be removed.

The following checklist outlines the issues to be considered for any fishery, although the commentary refers to typical conch fisheries. Some fishery management issues present more of a problem for conch, in particular choosing the right level of management monitoring and control commensurate with the size of the fishery. On Principle 2, which is concerned with bycatch and ecosystem sustainability, most issues may not be a problem and conch fisheries should perform well.

The checklist indicates the various areas which will need to be addressed if the fishery is to be considered well managed and certified under the MSC scheme. In all cases, the management authority needs to put together an argument as to why the fishery meets the required standard. If it does not meet the standard, the management authority will need to plan the activities that will address this aspect of the fisheries management.

The fisheries management objectives and procedures and the logic documenting how the procedures will achieve the objectives should be set out in the fisheries management plan. It is important to note that there is no prescriptive approach, but the plan needs to be convincing if it has not yet been implemented, or shown to be working if it has been implemented for some time.

PRINCIPLE 1	A fishery must be conducted in a manner that does not lead to overfishing or depletion of the exploited populations and, for those populations that are depleted, the fishery must be conducted in a manner that demonstrably leads to their recovery.

1.1	**Outcomes**
Reference points	Limit and target reference points need to be defined so that the status of the stock can be determined. The reference points need to be based on a biological model describing how the population responds to fishing. Until there is a reliable growth model for conch, yield-per-recruit based reference points are probably not available. Reference points based on biomass (B_{MSY}) are most likely.
Stock status	The stock needs to be at a level that maintains high productivity (around the target reference point) and has a low probability of being below the limit reference point. Information needs to be sufficient to show this is the case. If the stock is only lightly fished, then the information and evaluation need only show this. For heavily fished stocks, high precision is required.
1.2	**Harvest strategy/management**
Overall harvest strategy	There should be a robust and precautionary harvest strategy in place. The harvest strategy lays down the principles which achieve the management goals. Specifically, the strategy should set out: • how much fishing which can be carried out which is sustainable for the stock, • how catches should be restrained, • what will be done if stock falls to a low level. The harvest strategy should be appropriate for the size of the fishery.
Harvest control rule	The harvest control rule is the part of the management strategy which sets out a quantitative control describing what management will do in response to the scientific advice. Harvest control rules can be very simple, but should revolve around a target proportion of the stock which is taken when the stock is not overfished, and separate lower amounts (which could be none) taken when the stock is overfished.
Stock assessment	There should an adequate assessment of the stock which is reliable enough for the harvest control rule. The harvest control rule requires an estimate of the state of the stock and the exploitation rate, which can be provided by data collection and assessment. For very simple robust decision rules, simple assessments may be adequate, such as calculating the number of days fishing summed over all vessels and the average catch per day. Commercial fisheries require more precision and more extensive data collection.
Information/monitoring	Information gathering should be adequate for the stock assessment and other uses within the management strategy. Again, this can be simple, based on vessel reports or logbooks, beach sampling or other records suitable for the assessment.

PRINCIPLE 2	Fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends

2.1	**Retained species**
Management strategy	Retained species include all catch which is not the target of the fisheries. The retained catch could include lobster and finfish, or conch if it was being taken while fishers were searching for lobster or other species. (In this last case, conch would not be dealt with under Principle 1.) The management strategy for retained species is usually either the catches are accounted for within a full stock assessment under a directed fishery, or catches are low enough for the management authority to demonstrate low risk to the stock. The retained species could include other species of conch besides *Strombus gigas*.
2.2	**Bycatch**
Management strategy	Bycatch is not an issue in diving fisheries where fishers can select the species. All directed conch fisheries are through diving, and conch are only caught very rarely using other means. Unless dropped in deep water, non-retained adult conch are very likely to survive.
2.3	**ETP (endangered, threatened, protected) species**
Management strategy	The only other ETP species likely to be caught by conch fishers are small turtles (mainly green or hawksbills). Turtles are listed in the IUCN Red Data books. If turtles are taken, it will have to be demonstrated that this does not threaten the local population. For example, catches might be negligible compared to local natural mortality or significant proportion might be returned tagged and protected. Raising the minimum size or banning taking turtles altogether and enforcing the control can eliminate the risk to turtle populations.
2.4	**Habitat**
Management strategy	Conch fisheries should not have much impact on habitat. Conch are usually found on sand or seagrass and can be picked up without impact on the substrate. Discarded shells are unlikely to have any more impact than shells left conch dying from natural causes. If vessels anchor on reefs (while knocking the conch for example) they may damage coral.
2.5	**Ecosystem**
Management strategy	Conch are not thought to be a keystone species in the ecosystem. They graze algae, but there is little evidence that their absence has a significant effect on algae or seagrass populations. Conch are important prey for some species (rays, crabs, lobsters), but mostly as juveniles. Adult conch, which are targeted by the fishery, are difficult for predators to attack because of the thick shell. Therefore, the fishery should have a low effect on the ecosystem as long as recruitment is not compromised (Principle 1).

PRINCIPLE 3	The fishery is subject to an effective management system that respects local, national and international laws and standards and incorporates institutional and operational frameworks that require use of the resource to be responsible and sustainable.

3.1	**Governance and policy**
Legal and customary framework	The management system requires an appropriate and effective legal and/or customary framework that meets the requirements of the various management strategies, observes the legal rights created explicitly or by custom of people dependent on fishing for food and livelihood, and incorporates an appropriate way to resolve disputes.
Consultation, roles and responsibilities	The roles and responsibilities of organizations and individuals who are involved in the management process need to be clear. The management system should have effective, open consultation processes.
Long-term objectives	The management policy should include clear long-term objectives to guide decision-making incorporating the precautionary approach. Policy documents should state clearly that the resource is to be managed for sustainability and long-term economic benefit, and outline how these goals are to be achieved.
Incentives for sustainable fishing	The management system should provide economic and social incentives for sustainable fishing and should not operate with subsidies that contribute to unsustainable fishing. For example, gear, boat or fuel subsidy provided by the government may be considered an incentive for unsustainable fishing. Conversely, social and economic support which controls or limits fishing effort may be considered positively.
3.2	**Fishery specific management system**
Fishery specific objectives	The fishery should have clear, specific objectives designed to achieve sustainability. Fishery objectives are usually described in a fisheries management plan, which also sets out the management procedures and logic as to why these procedures should achieve the objectives.
Decision-making processes	The fishery-specific management system should include effective decision-making processes that result in measures and strategies to achieve the objectives. It should be possible to review the decisions which have been made about the fishery, and have evidence that the decisions are being effectively implemented. The decision-making should be shown to be linked to meeting the objectives.
Compliance and enforcement	Monitoring, control and surveillance mechanisms ensure the fishery's management measures are enforced and complied with. Evidence of compliance should be kept.
Research plan	The fishery needs to have a research plan that addresses the information needs of management. This may be no more than a brief review identifying local knowledge gaps, if any. On-going research may not be necessary beyond the analysis of monitoring data for small fisheries and cooperation with regional research initiatives.
Monitoring and evaluation	There needs to be a system for monitoring and evaluating the performance of the fishery-specific management system against its objectives. The monitoring and surveillance forms part of the feedback for the fishery, confirming that the current management system is working, or identifying problems that need to be addressed.

This manual presents guidelines on the requirements for responsible management of the fisheries exploiting Caribbean queen conch (*Strombus gigas*), with particular emphasis on the conditions necessary to comply with the relevant regulations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It provides general guidance on each step of a basic fisheries management cycle and examples of management systems for industrial, artisanal and non-directed fisheries for queen conch in the Caribbean.

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