# Chapter 4.

## COASTAL ECOSYSTEM MANAGEMENT

### Introduction:

Coral reefs, seagrass beds and mangals are the characteristic ecosystems of tropical island coastlines. They are associated with rocky headlands, bays, beaches, lagoons, and sometimes estuaries and deltas on the larger islands. Each has its characteristic plant and animal components, and the structure and productivity are regulated by a range of physico-chemical and biotic processes. In most coastal ecosystems, both terrestrial and marine influences are important, and variations in local conditions of climate, geomorphology and oceanography can affect the way the systems develop and function.

The plants and animals forming, and contained in, the major ecosystem types are of considerable value to the economy of most tropical islands. It is important, therefore, to sustain these ecosystems and their resources by appropriate management. Biological resources are generally "renewable", and management will seek to ensure the wise use of these resources by as many people as possible over the longest possible time period (managers may wish to plan for a 25-30 year period). In other words, management should aim at " the conservation of coastal ecosystems at the highest achievable carrying capacity" (Clark 1977).

As with any type of resource management, the first step is to identify the resource and assess the nature of resource use. Its location, composition and condition are investigated and documented. Condition or **status** is assessed relative either to its condition in the past or to the desired condition according to national coastal zone management goals. If the status differs from what is expected or desired appropriate management strategies can be formulated to alter the status; these may require manipulation of the ecosystem or regulation of human impacts, or both.

One of the greatest problems encountered in coastal ecosystem management is the natural variability in ecosystem structure and processes in different parts of most island states. This means that management interventions may work better in some habitats than others, or that development impacts might be more severe on an ecosystem at one site than on an apparently similar ecosystem at another. Over and above the preliminary inventory and status assessment, individual natural habitats must be **evaluated** for their ecological and economic roles with regard to conservation and development of the coastal zone. To do this the coastal manager must understand the methods and data assembled by ecologists, if these are to be used in ecosystem management decision making. Of critical importance is data which will be used to calculate the **yield** of products from reefs, mangrove swamps, and other coastal ecosystems, because this will influence regulatory policies to control resource exploitation.

In many islands, where natural resource utilization has not been based on wise traditional or scientific principles, overexploitation of resources has resulted, with consequent ecosystem damage and loss of income. Before the damage can be reduced or further prevented the manager must determine why it occurred, by investigating the way in which ecosystem function has been perturbed. Further ecological research may be required to determine what the carrying capacity for the system under exploitation should be, so that renewed resource use can be encouraged on a sustainable basis. Where depletion or ecosystem damage are severe, a determined effort may be needed to **resuscitate** the resource. This will require, again, an understanding of the way the particular species population or ecosystem responds to manipulation, and of the techniques available for natural resource recovery.

This Chapter guides the student through a series of exercises designed to give experience in coastal ecosystem management and exposure to some of the problem areas in tropical island situations. The emphasis is on biological aspects, but it must be remembered that resource use has socio-cultural, economic and institutional aspects also. All these aspects must be understood to some degree if good management decisions are to be made that have a chance of being implemented. Exercises 4.3 and 4.4 introduce these non-biological aspects of resource management in a general way, and trainees should refer to concepts developed in Chapter 3 above.

## Exercise 4.1 ASSESSING THE STATUS OF COASTAL ECOSYSTEMS

**Background:**

Natural coastal communities are an important part of the economic **resource base** of most islands. Coral reefs, mangroves, and seagrass-algal beds make a significant contribution to food and materials production, tourism, employment, and coastal protection. The majority of these systems have been exploited for long periods and are subjected to pollution and development stress. As a consequence, sustainable exploitation is a priority concern for many environmentally aware governments.

Prior to taking any management decision with respect to natural communities, it is essential to evaluate their **status**. This evaluation builds on the baseline ecological description of the system, by considering how much the system deviates from pristine natural conditions as a result of human impact. General categories that can be used to describe an ecosystem are listed in Table 4.1.

**Table 4.1 Categories for describing status of coastal ecosystems.**

1. Pristine
2. Impacted
   - slightly modified
   - moderately modified
   - greatly modified, but apparently healthy
   - greatly modified, and showing sign of damage
   - severely damaged
3. Destroyed

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In most cases, the status designation will determine the available management options. For example, if the ecosystem is "severely damaged", the best option would be either total protection to permit natural recovery or a programme of active resuscitation (see also Ex. 4.4). If an ecosystem has been "destroyed", as through land reclamation or timber removal in a mangrove swamp, a decision must be made as to whether or not it is desirable ecologically, feasible technically, or advisable economically to attempt to rebuild it.

Options would be selected also in terms of the island's coastal management goals (see also Ex. 3.1). For example, if a Nature Reserve for scientific or educational purposes is required, it would be best to select a "pristine" or "slightly modified" ecosystem. Alternatively, if the ecosystem selected as a Reserve for some special attribute is found to be "greatly modified, and showing signs of damage" the proposed management strategy would have to include removal of the factors causing damage or siting the reserve elsewhere. A status assessment is of great socioeconomic importance where large numbers of people derive livelihood from a system's resources, as it might indicate that present impact is threatening future utilization, with potential economic losses.

Data concerning the nature of the particular ecosystem in the past is required as the baseline for assessing present status. Where published scientific data is not available the manager may have to rely on popular knowledge. Good knowledge and experience of the structure and functioning of that type of ecosystem is essential also, because of the natural variability of coastal ecosystems. For example, not only do coral reefs and mangrove swamps show a spatial zonation of the species as a reflection of localised environmental differences, but also temporal successional changes, responses to episodic events like hurricanes, differences on windward and leeward shores of islands and latitudinal variations between islands (Milliman, 1973; Bacon, 1987b). Furthermore, there are likely to be a variety of types of human impact, both presently and in the past, and variations in the intensity of those impacts. Damage may not become apparent until a particular threshold of impact has been reached; or only as a synergistic effect of two or more human activities, or human activities and unusual natural events, in combination.

An illustrative **case study** is the management plan developed for the Caroni Swamp by the Forest Division, Government of Trinidad & Tobago, which had regulatory responsibilty for this coastal mangrove area (Thalen & Faizool, 1979). Figure 4.1 shows the within-system variability in vegetation, and effects of attempted reclamation in the 1920's (Bacon, 1975); and Figure 4.2 shows the zoned management plan for the swamp which was based on status assessments of its sub-regions in 1974. The least impacted area with most diverse fauna was designated as the "Scientific Zone", to be used for research and monitoring purposes only. Whereas the area to the north and west of the swamp was considered to be badly degraded and designated as "Recuperative Zone - not

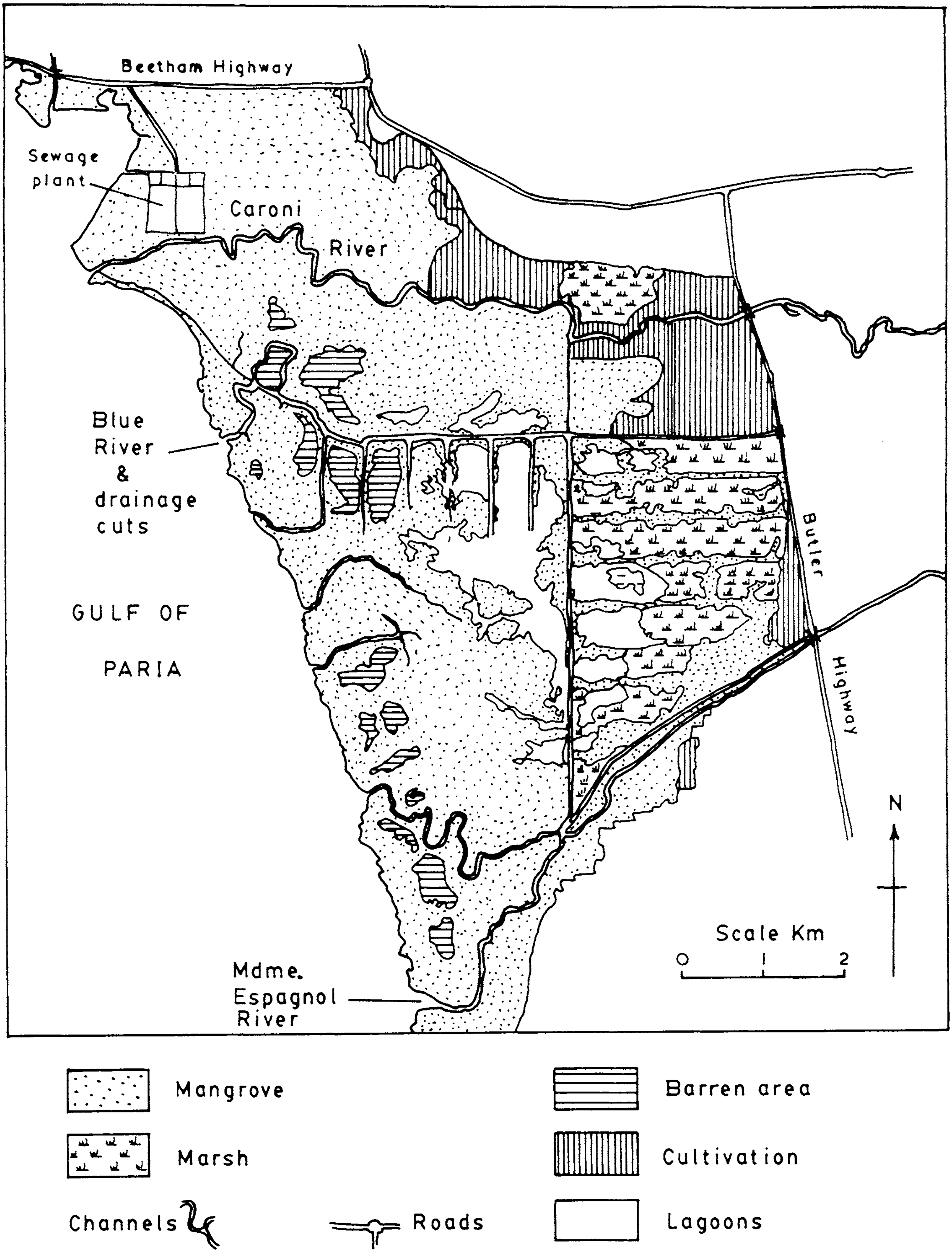


FIGURE 4.1 EXISTING CONDITIONS - CARONI SWAMP, TRINIDAD

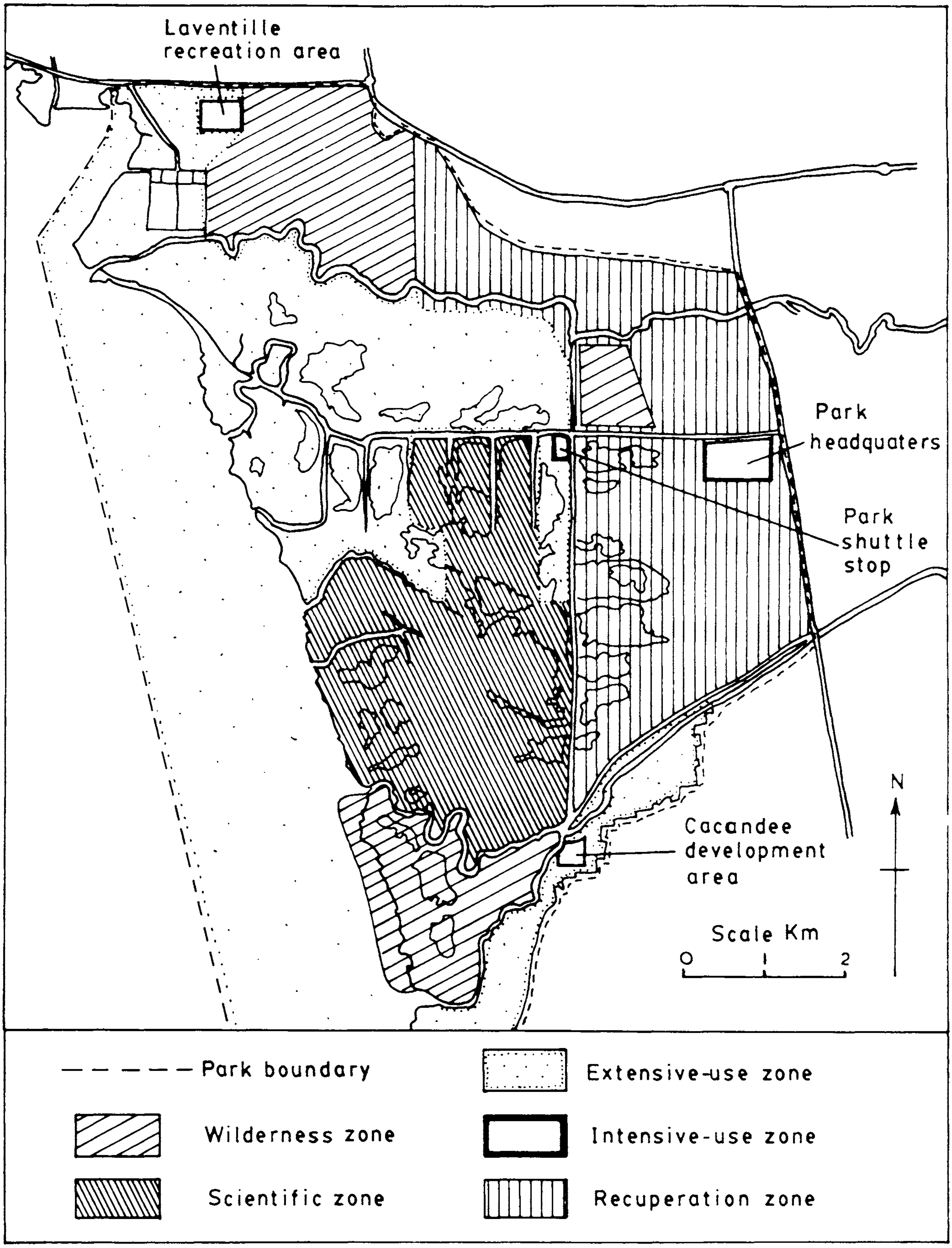


FIGURE 4.2 ZONING PLAN - CARONI SWAMP NATIONAL PARK

to be utilized until its natural biota had re-established".

Status assessments for selecting management options are appropriate for small areas of island coasts, as well as large complex areas like Caroni Swamp. Status assessments can be used to compare all patches of one ecosystem type throughout an entire island, for example when developing a National Coral Reef Management Plan. In all these cases, the management process depends on the accuracy of the status assessment.

This exercise is concerned with a common, and economically significant coastal ecosystem, the coral reef. Suggestions follow for alternative exercises which concentrate on other tropical island ecosystems.

The ability of a reef to provide goods and services is related directly to the presence or absence of certain organisms, most of which are readily recognisable by the non-specialist. A fisherman wants to catch fish, and knows that a healthy, productive reef shows a certain balance between living corals and seaweed cover; a tourist wants to see a variety of live animals, so his or her satisfaction during a tour relates largely to reef species diversity; while a hotelier wants the beach protected by the reef and replenished with particles from the reef, so also needs to be assured that the neighbouring reef is a living, actively growing, coral-animal dominated structure. Each of these user groups, and others, may be responsible for reducing the value of the reef resources by perturbation of the ecological balance, through overfishing, through walking on and breaking off coral heads, or discharging sewage. The effects of such impacts are recognisable in changes of biota over time, i.e. the reef does not contain the normal range of organisms; or the relative abundance of organisms differs from what is expected (see Porter, 1972; Dahl, 1981). Even where prior data are not available, present community gross composition gives a useful preliminary indication of reef status; Archer (1985), for example, reported that live coral cover in Barbados ranged between 20 - 37 % whereas it had normally been greater than 50 - 60% in the Western Caribbean. Even when it is remembered that reef species diversity and abundance vary with depth, aspect and locations, such departures from the expected norm can help to focus the natural resource manager's attention.

**Aim:**

To make a preliminary assessment of the status of a coral reef.

**Duration:**

One day (depending on the availability of historical or other baseline data).

**Suitable Location:**

An area of fringing reefs, small patch reefs, or coral cays, preferably within the main barrier on the island shelf. Selection should be made (a) bearing in mind the swimming/diving competence of the trainees, and (b) in order to examine a gradient of conditions, from areas known to be heavily impacted by human activities to those thought not to be. An area used by tourists, where trampling and/or intensive spear fishing have taken place, makes a suitable "impacted" site. Sites should be at least 1 km apart, but preferably on the same side of the island (so that results are not biased by windward/leeward coastal variations in reef structure). Choosing areas that have been described at an earlier date can assist interpretation of the data collected.

**Materials Required:**

Per group (3 - 4 persons)

Transect line, that should not float, marked at 1 m intervals.
A weighted line marked at 0.5 m intervals to be used for depth measurements.
Underwater writing slate (three to four clipboard or smaller size sheets of white formica tied loosely together).
Waterproof Identification Guides, if available.
Compass

Personal

Face mask, snorkel, fins
(life support vest; SCUBA gear, as appropriate)

**Instructions**

Field Methods

Measurements can be made in the more accessible, shallow reef flat area by inexpert swimmers; or on the reef slope if SCUBA is to be used. The instructor must ensure that measurements are made in similar depths in all comparative sites. A plotless line transect method will be employed, as follows:

1. Place the transect line parallel to the shore (Figure 4.3) and anchor it so it is relatively taut.

2. Record the site and depth on the underwater slate which has been prepared in advance as shown in Table 4.2.

3. Investigate the line over a distance of 10 m and record -

   (a) any organism which intercepts the line, and
   (b) the proportion of the line intercepted by each organism.

   For example, a brain coral, Diploria, is located and intercepts the line between 1.25 and 1.48 cm from the start, i.e. it intercepts along 23 cm of the transect.

   For this introductory exercise, algae can be recorded as colonies, rather than trying to count individual plants; and where layered organisms occur or one organism is seen below another, only the surface in contact with or directly below the line should be measured.

   As far as possible, identify and record all sessile macroalgae and macro invertebrates intercepting the transect.

4. Move the transect line to a new location 1 m deeper than the first, but still parallel to the shore, and repeat the measurements and record keeping.

5. Repeat with further transects at 1 m deeper intervals, to a total of at least five transects.

6. Each sub-group should record a replicate set of transects nearby, but at least 10 m away from the first set (Figure 4.3).

   If more than one group of trainees is running transects, these could be treated as replicate samples and analysed for intra-site variability. As there may be differences in the field competence of the sub-groups, this might introduce a source of error. Sub-group compatibility can be tested by all sub-groups working over the same transect and comparing results at the start of the exercise.

7. Repeat the transect measurements at the other location/s being used in this comparative study.

**Table 4.2 Sample Data Recording Format for Coral Reef Survey**

| Species | Total linear cover (cm) | % cover | No. of colonies | % colonies |
|---|---|---|---|---|
| Corals | | | | |
| species A | | | | |
| species B | | | | |
| species C | | | | |
| etc | | | | |
| Total corals | | | | |
| Algae | | | | |
| species A | | | | |
| species B | | | | |
| species C | | | | |
| etc | | | | |
| Total algae | | | | |
| Seagrass | | | | |
| Bare sand | | | | |
| Other biota | | | | |
| species a | | | | |
| species b | | | | |
| etc. | | | | |
| Total non-coral/algal | | | | |

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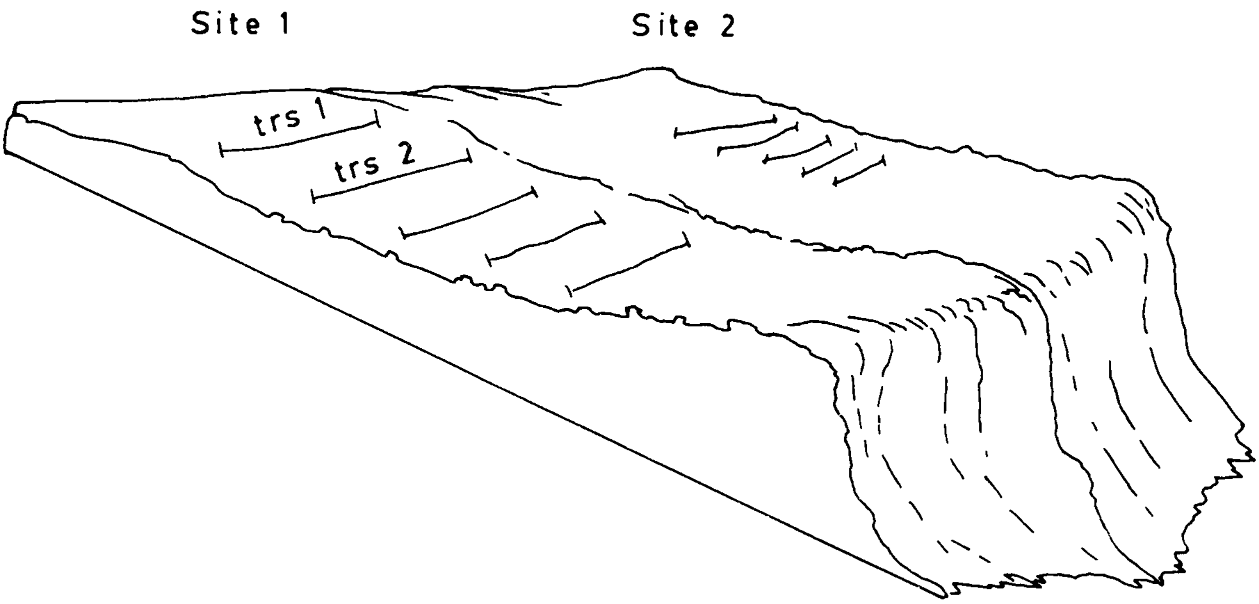


FIGURE 4.3 LINE TRANSECT POSITIONS

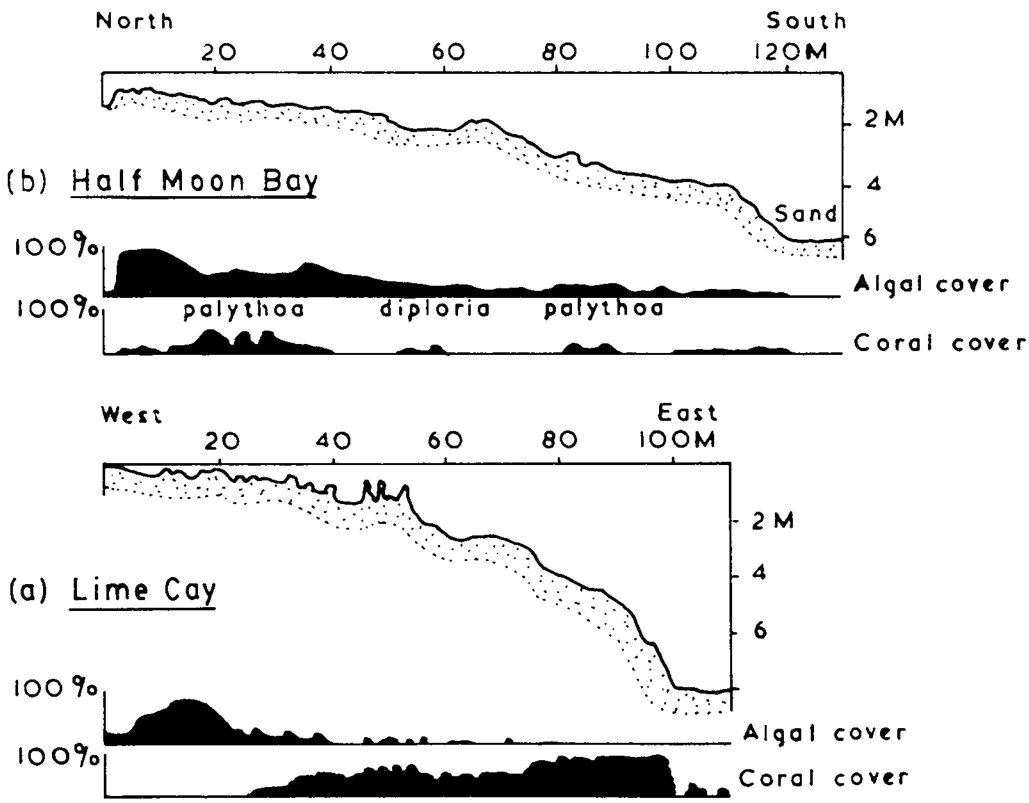


FIGURE 4.4 PROFILES COMPARING TWO JAMAICAN REEFS

## Laboratory Methods

8. Transfer all data to data sheets, using a format similar to that shown in Table 4.2.

9. Draw profile diagrams of the transects using depth measurements (see Figure 1.7). This will allow visual comparison of replicate sites and different locations.

10. For each transect calculate and record -

    (a) % cover for each species, and
    (b) % of total number of colonies occupied by colonies of each species.

11. Using data from all replicate samples at each site, calculate means and standard deviations for all data.

## Analytical procedures

12. Status at the single location can be assessed by listing in order of importance dominant organism groups, from % cover estimates. This list is compared with historical data or expert opinion on what a healthy reef in the island should be like. For example, J. Woodley (personal communication 1987) suggested that most Caribbean reefs had 60% or more living coral, with good development of staghorn coral, Acropora cervicornis, and coralline algae widespread with fleshy algae occupying less than 10% cover. The occurrence of dead coral showing white skeletons without algae growing on them was evidence of recent death of the coral. Recent events in the Caribbean, such as coral diseases, have altered these cover estimates. In any island where this analysis is attempted up to date information should be consulted. Does the survey data suggest deviation from the norm at this location ?

13. As there is likely to be considerable localised variation in complex coral reef communities, you should test your series of transect data for within system and between system variability by ANOVA or other appropriate statistical test.

14. Plot the relationship between total coral cover (hard corals and soft corals) and total algal cover at each location.

15. Draw a histogram which shows number of species and % cover at each site, under different categories of

organisms, such as "corals", "algae", "other biota".

16. Compare the mean % cover of corals and algae at the different sites.

17. Give a brief narrative description of any marked differences between study locations. Note which location appears to have the highest coral cover and the greatest coral species diversity (for purposes of this exercise these features are taken to indicate healthy reef environments, as suggested in the literature referred to above).

18. Assuming that significant differences between reef locations are demonstrated, arrange your reef locations in order of deteriorating status.

19. Discuss the results of your preliminary status assessment. Remember that alteration of the natural balance of a reef community could be the result of pollution, overfishing or natural phenomena like hurricanes.

**Product:**

Data can be presented in tabular form, as indicated, or as figures and species list as shown in the following **Case Study**:

Two reef areas studied by Head and Hendry (1985) are illustrated by the profile, Figure 4. 4. The more pristine site at Lime Cay showed initially high algal cover which declined as nearly 80% coral cover was found on the reef crest and forereef. Half Moon Bay showed coral cover much lower with heavy mats of macro-algae throughout the transects. Lime Cay showed a much more diverse coral fauna and greater numbers of sea fan species (Table 4.3). The suggestion was made that the Half Moon Bay reefs showed evidence of disturbance, due possibly to sewage pollution.

Assessment of status does not necessarily answer many questions, but is more likely to point to the need for further research. It does help to focus attention on potential problem areas, by indicating that something is not as expected (see Table 4.1). A status assessment can indicate the nature of a problem; for example, increased seaweed growth on a coral reef suggests some degree of nutrient enrichment (eutrophication) which, if not explainable by natural causes, might be related to nearby sewage discharge. On the other hand, an assessment which showed low levels of commonly expected reef fishes would suggest that the problem is more likely related to the fishing pressure than to pollution, and the manager would

**Table 4.3 Anthozoan and hydrozoan 'coral' species present on the Lime Cay and Half Moon Bay traverses.** For abundance, 1 = single specimen, 2 = uncommon, 3 = common, 4 = abundant, 5 = locally dominant.

| | LIME CAY | HELLSHIRE |
|---|---|---|
| Stephanocoenia michelinii | 1 | |
| Acropora palmata | 5 | 1 |
| A. cervicornis | 3 | |
| Siderastrea radians | 4 | 3 |
| S. siderea | 2 | 3 |
| Agaricia agaricites | 2 | |
| Porites porites | 5 | |
| P. astreoides | 4 | 3 |
| P. branneri | | 3 |
| Montastrea annularis | 4 | 2 |
| M. cavernosa | 3 | 1 |
| Diploria clivosa | 5 | 3 |
| D. strigosa | 5 | 3 |
| Colpophyllia natans | 1 | |
| Isophyllia sinuosa | 2 | 3 |
| Isophyllastrea rigida | 2 | |
| Rhodactis sanctithomae | 2 | |
| Ricordea florida | 2 | |
| Zoanthus sociatus | 4 | 4 |
| Zoanthus sp. | 2 | |
| Palythoa caribbea | 5 | 5 |
| Erythropodium caribaeorum | 2 | |
| Plexaura flexuosa | 3 | |
| Pseudoplexaura porosa | 3 | |
| P. flagellosa | 3 | |
| Eunicea tourneforti | 3 | |
| Muricea atlantica | 3 | |
| M. pinnata | 3 | |
| Pseudopterogorgia acerosa | 4 | 1 |
| P. americana | 5 | |
| Gorgonia flabellum | | 2 |
| G. ventalina | 4 | |
| Millepora alcicornis | 4 | 2 |
| M. complanata | 2 | 3 |
| TOTAL SPECIES NUMBER | 32 | 16 |
| TOTAL ABUNDANCE SCORES | 100 | 39 |

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be aided in deploying scarce resources in an appropriate direction. Although the coastal manager might be more concerned with pressing and vocal demands from the resource users, his primary task is to maintain in a viable form the resources on which those user groups depend. Although the problem might be seen as reduced incomes by fishermen, the cause probably lies in the condition (status) of the reef which they are working; and the resource users' problem is unlikely to be solved while the resource is in a less than optimally productive state. Continued economic development of natural resources in the coastal zone is dependent on regular checks on the "environmental bank balance".

**Alternative Exercises:**

1. Reef status assessment by fish counts

   Considerable information is available on the composition and abundance of coral reef fish populations in tropical islands (Munroe & Williams, 1985). Perturbation of reef condition will be reflected in changes in the fish community, particularly lowering of diversity.

   One simple technique for estimating the diversity is the Stationery Visual Census Technique described by Bohnsack and Bannerot (1986). This is best done using SCUBA, but can be adapted for snorkel surveys from the surface.

   At randomly selected points, all species of fish are recorded which are observed within an imaginary cylinder extending from the surface to the seabed, with a radius of 24 ft (7.5 m) during a five minute interval. Further points are selected, based on a number of swimming kicks determined from random number tables. Additional information on fish fork-lengths, size of schools, or other parameters, can be recorded as appropriate.

2. Assessment of the legal status of coral reefs.

   For management purposes, the legal status of a natural resource is as important as its ecological status. As a desk exercise, or through visits to relevant government agencies, legislation can be examined.

   It is important to decide what type of legal protection is required (a) for the reef itself, (b) to control use of reef resources, (c) to buffer the reef from adverse external impacts, such as water-borne pollutants or excessive land run-off, or (d) to remove already existing adverse human impacts.

The adequacy of existing legislation can be assessed and preliminary drafts can be prepared of any new legislation which may be required (see Chapter 3). Emphasis should be placed on provision for enforcement of legislation, bearing in mind the particular difficulties of managing coral reef environments.

3. Reliability of sampling procedures in highly variable natural environments.

As mentioned, differences between sample sites are frequently obscured by ecosystem variation along transects or between neighbouring plots. A coral reef is an ideal place for demonstrating the importance of an appropriate sampling method, including replication and inter-investigator compatibility.

Coral species diversity and cover estimates can be compared using 2 - 3 methods described in the UNESCO Coral Reef Research Methods handbook. A comparison should be made of the results obtained using different methods and by different groups of trainees using the same method. The accuracy of a sampling method should be related to the number of replicate samples taken. Standard statistical or biological methods texts should be consulted.

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**Further Reading:**

Banner, A. H. 1974. Kaneohe Bay, Hawaii: urban pollution and a coral reef ecosystem. Proceedings of the 2nd International Symposium on Coral Reefs, 2; 685 - 702.

Beller, W.S. (Ed). 1979. Transactions at the Conference on Environmental Management and Economic Growth in the Smaller Caribbean Islands, St. Michael, Barbados, Sept. 1979; 103 pages.

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Smith, S.V., Kimmerer, W.J., Law, E.A., Brock, R.E. & Walsh, T.W. 1981. Kaneohe Bay Sewage dispersion experiment: perspectives on ecosystem responses to nutritional perturbation. Pacific Science 35; 279-402.

Stoddart, D.R. & Johannes, R.E.(Eds.) 1978. Coral Reef Research Methods. UNESCO Monographs on Oceanographic methodology No. 5; 581 pages.

UNESCO 1984. Comparing Coral Reef Survey Methods. UNESCO Reports in Marine Science, 21; 170 pages.

UNESCO (In press) Caribbean Coastal Marine Productivity: Manual of Methods, UNESCO Reports in Marine Science.

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## Exercise 4.2 CONDUCTING HABITAT EVALUATION

**Background:**

Coastal ecosystems are complex, and understanding how they function or what organisms they support requires specialist knowledge and long periods of research. The coastal manager is concerned rarely with biological intricacies, such as taxonomic composition, diversity indices, food webs or productivity estimates, and is more likely to want to know why and how ecosystems should be managed. A further problem faces the manager where island coasts contain several, apparently diverse, areas of any ecosystem type, e.g. lagoons of different shapes and sizes or swamps dominated by different mangrove species. In these cases, should there be a common management strategy for each ecosystem type or should there be a ranking in order of their ecological importance? If the latter, how should the several areas of an ecosystem type be ranked to show priority order for exploitation ?

Exercise 3.3 considered criteria for selecting natural areas, in terms of their general value to society. This included criteria for "biological value" (Table 3.5), although no attempt was made to quantify that value. The exercise selected for areas "important" to commercial species or wildlife, but did not discuss how to decide whether one habitat was more important than another on economic or aesthetic grounds. Every coastal ecosystem, be it seagrass bed or salina, has **ecological value**, and, ideally, these values should be sustained. But the development situation in most islands dictates that only some coastal areas can be retained in their natural state. Areas with **commercial** species or those considered **unique** or **representative** (Table 3.5) are identified readily and their preservation easily justified during coastal zone management planning. When the management objective is conservation of a particular wildlife species, selecting its most important habitat is problematic, but critical to the survival of that species.

The evaluation of wildlife habitats is important for several reasons;

(a) It assists the manager to concentrate scarce resources on protecting the areas of greatest importance to the target wildlife species.
(b) It helps locate development activities, particularly those likely to impact on commercially or aesthetically important species, in the less valuable areas of habitat.
(c) It permits the manipulation of habitats to produce

optimal conditions for the target wildlife, as when previously impacted sites are being returned to productive status.

Many techniques have been devised for habitat evaluation. One evaluation model, reviewed by Golet (1978), used maximum wildlife diversity and production as the standard against which a series of wetland habitats could be evaluated. Criteria used under the Ramsar Convention to select wetlands of international importance (Table 4.4) stress the numbers of waterfowl supported by particular sites.

**Table 4.4. Criteria for Identifying Wetlands of International Importance. (Source: The Ramsar Convention 1971)**

1. Quantitative criteria for identifying wetlands of importance to waterfowl

    (a) Regularly supports either 10,000 ducks, geese or swans; or 10,000 coots; or 20,000 waders; or
    (b) Regularly supports one percent of the individuals in a population of one species or subspecies of waterfowl; or
    (c) Regularly supports one percent of the breeding pairs in a population of one species or subspecies of waterfowl.

2. General criteria for identifying wetlands of importance to plants or animals

    (a) Supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal.
    (b) Is of special value for maintaining the genetic and ecological diversity of a region because of the quality or peculiarities of its flora and fauna.
    (c) Is of special value as the habitat of plants or animals at a critical stage of their biological cycles.
    (d) Is of special value for its endemic plant or animal species or communities.

3. Criteria for assessing the value of representative or unique wetlands.

    (a) Is a particularly good example of a specific type of wetland characteristic of its region.

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However, wildlife diversity and abundance of individuals are rarely characteristic of small island habitats, so a suitable technique would evaluate habitat in terms of one or a few target species. The following exercise is based on Habitat Suitability Index models (Schamberger & Far (HEP) formulated by the US Fish and Wildlife Service (see Schamberger & Kumpf, 1980; USFWS, 1985).

**Aim:**

To evaluate the quantity and quality of habitat available to a selected species in an island or region of an island.

To rank the areas of available habitat in order of importance for the conservation of the target species.

**Duration:**

Minimum 1 day ( depending on the quality of ecological data available and the location of sites used by the target animals).

**Suitable Location:**

Laboratory or drawing office work, supported by field work in two or three local sites. Preferably the study sites should be of different sizes and one should either be impacted by human activity or scheduled for development.

**Materials Required:**

Topographic maps of island or region.
Aerial photographs of the study sites.
Narrative summary of biology of the selected animal species, including information on food requirements, reproductive habitat requirements, migratory movements or territorial behaviour, as appropriate.
Drawing materials.

**Instructions:**

Preliminary Study

1. Select a species of animal for study. Preferably, this should be a resident species with some recognised commercial or aesthetic value, e.g. a national symbol, a game or food species, or an endangered species. Choice of a bird might be advisible, particularly one of the coastal waterfowl, because the biological data base is often better in tropical islands than for other animal groups.

2. Study the literature and summary report provided, and list key biological requirements of the target species, e.g.

   - food type
   - foraging habitat type
   - cover, e.g. preferred roosting site
     preferred nesting site
     means of protection from predators
   - special factors, e.g. site tenacity (e.g. use of traditional nesting sites) or response to human disturbance
   - interspersion, i.e. distances travelled between roosting sites and foraging areas

3. On the maps provided, locate areas of apparently suitable habitat. Take into account portions of habitat used for all life history requirements, e.g. feeding areas, roosting areas, migratory routes. Use aerial photographs to supplement this activity.

4. Estimate the size of all areas of apparently suitable habitat in the island or region. Sum these and record the total. This gives an indication of the <u>quantity of available habitat</u>.

Field Study

5. Select at least three sites from the above list (preferably sites which can be visited on the same day) and confirm their use by the target species.

6. Make field measurements which permit comparison of the suitability of these sites for the target species. This measure of the <u>quality of the available habitat</u> should be made as follows:

   - select some of the more easily measured habitat variables, such as distance between roosting and foraging areas, distance between cover and sources of human disturbance, area of vegetation stands used for nesting.
   - Quantify these values, and compare between sites. If three sites are being assessed, assign values on a relative scale from 1 - 3 for each variable; sum these and record the totals for each site.
   - If the optimum habitat conditions are known (from available literature or from a local expert), establish a Habitat Suitability model format. This model should be in index format, i.e. a ratio between the value under investigation and a

standard of comparison, as follows:

$$HSI = \frac{\text{Site habitat condition}}{\text{Optimum condition}}$$

As shown in Figure 4.5, assign habitat variables to a scale of (unsuitable)0 - 1(optimum). Sum these values and record them.

7. Calculate Habitat Units for each site, as the product of the HSI (quality) and total site area available (quantity), from the above estimates. The Habitat Units can be used for inter-site comparisons, as indicated below.

Habitat Assessment

8. Existing conditions in the study sites should be compared. Identify the site with greatest capability for supporting the target wildlife species, and rank others in order of decreasing capability. Discuss the implications of this rank order for conservation of the target species.

9. Assuming that one of the study sites is being impacted by human activity, and that this impact is likely to continue, calculate Habitat Units at fixed periods in the future for that site, i.e. estimate remaining area and/or habitat condition after one year, two years or 5 years. Compare the future condition of all sites and discuss the implications.

10. Assuming that one site is earmarked for development, predict Habitat Units on completion of the development. Discuss how the development might be modified to maintain Habitat Units as close to existing conditions as possible.

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**Alternative Exercises:**

1. Habitat assessment can be made using a range of species. In this case, habitat suitability indices must be calculated for all species and then combined to produce HU's. This can be complex and will require considerably more information on the

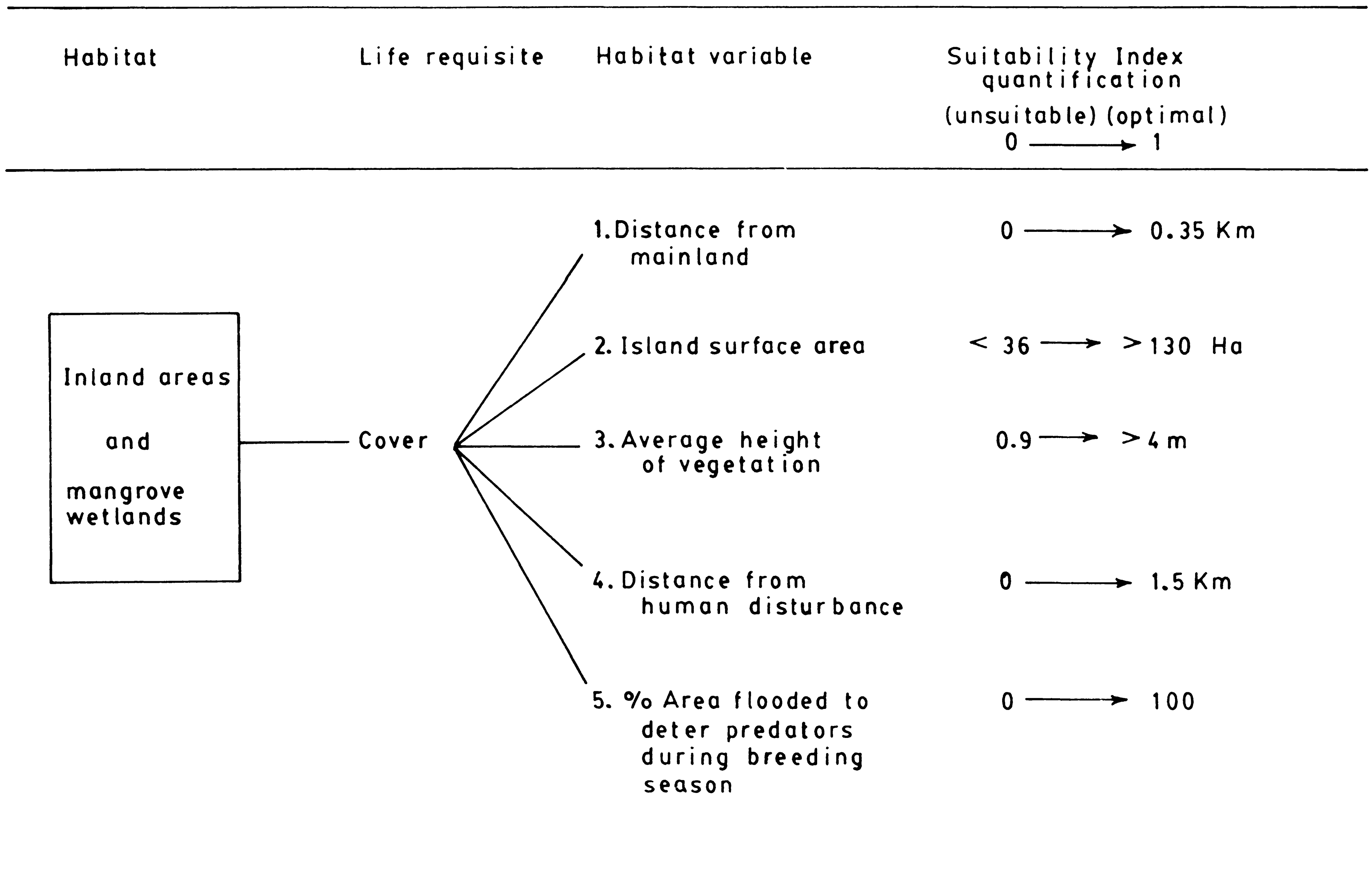


FIGURE 4.5 SAMPLE HABITAT SUITABILITY INDEX CHART: BASED ON A SINGLE LIFE REQUISITE "COVER" FOR WHITE IBIS (Data after USFWS, 1985)

ecology of the sites. A broader treatment of this nature will produce a more accurate assessment of habitat value, however.

2. One of the sites studied in the main exercise which had a low habitat value could be reinvestigated with a view to improving its value. This extension of the main exercise could be used to suggest how the site or ecosystem could be manipulated in order to remove negative features. For example, the removal of sources of human disturbance or the planting of more trees might make the site a more suitable breeding area for the target species.

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**Further Reading:**


Gleeson, P.E., Clark, J.R. & Clark, J.E. (Eds). 1979. Wetland Functions and Values: the State of our Understanding. Proceedings of the National Symposium on Wetlands, American Water Resources Association, Mineapolis, USA, 674 pages.

Tihansky, D.P. & Meade, N.F. 1976. Economic contribution of commercial fisheries in valuing U.S. estuaries. Coastal Zone Management Journal, 2; 411 - 421.

USFWS 1980. Habitat Evaluation Procedures (HEP). Division of Ecological Services, U.S. Fish & Wildlife Service, Washington; 143 pages.


* * *

## Exercise 4.3 CALCULATING OPTIMUM SUSTAINABLE YIELDS FOR COASTAL RESOURCES

**Background:**

There is a wide range of directly harvestable natural resources in the coastal zones of tropical islands. Primarily these are fin-fish, but other edible species such as sea-mosses, conch, shrimp, lobsters and sea turtles are of economic importance in many areas. Stony corals, sea fans, black coral and sea shells have minor, but widespread use in the tourism and handicraft sectors, both locally and in international trade; while renewable non-biological resources include beach sand and salt.

Theoretically, the supply of sea salt is unlimited. Beach sand in tropical islands can be mined rarely in large quantity or for long periods without causing environmental disturbance (Cintron, 1981). Some very slow growing organisms, like black coral (Antipatharians), can be eradicated easily by over-enthusiastic harvesting (Mailer, 1982); sea turtle populations decline rapidly if too many nesting females are killed on beaches or too many eggs are taken (Carr & Schroeder, 1967; Carr, 1980); and overexploitation of mangrove timber may lead to habitat alteration that prevents natural regrowth of the forest (Hamilton & Snedaker, 1984). The removal of coastal resources at levels beyond the capacity of the population or ecosystem to restore them, not only reduces the size of available resources, but has serious socioeconomic consequences (Snedaker & Getter, 1985). In small tropical islands resources are characteristically limited and ecosystems fragile (Towle, 1971; McEachern & Towle, 1972), so that the effects of careless utilization or overexploitation may be extreme.

In order that loss of resources (and income and jobs) and consequent environmental deterioration in the coastal zone be prevented, exploitation rates must be regulated. There are several approaches to this very important aspect of coastal zone management, some of which stress the technical aspects of establishing permitted **yields**, while others concentrate on legal or institutional measures for regulating user-group activity. Both are important, but the second approach depends also on an understanding of the **potential yield** or **carrying capacity** of the resource being studied. Methods of predicting yield are summarized in Appendix 6. One of these, Optimum Sustainable Yield (OSY), forms the subject of this exercise and, as its name suggests, is a measure that has direct management implications. Theoretically it can be applied to any coastal or marine resource which is renewable. It accommodates within the calculations effects on the user-groups of managing the resources which they are exploiting.

The most advanced work on predicting yields has been concerned with marine fish populations (Cushing, 1975; Gulland, 1977). Data requirements and statistical treatments are necessarily complex because of serious restraints on obtaining accurate estimates of fish stocks. It is virtually impossible to study an entire population of a fish species in any area of the coast, because most catch methods are 'blind', fish move in and out of the area, and fishing gear is selective for particular size/age classes of fish. Long periods of research producing long series of fisheries statistics are necessary for yield prediction. This is because fluctuations in marine environmental conditions, sometimes due to events in far distant parts of the oceans, affect rates of recruitment, growth and mortality in fish populations. Coral reef fisheries, which are typical of so many tropical islands, are based on multi-species stocks (Munro & Williams, 1985), the analysis of which requires specialist knowledge outside the scope of this Workbook.

To simplify the OSY calculation, this exercise deals with an easily accessible, fixed-size coastal resource which can be sampled in its entirety, namely mangrove trees for use as timber or charcoal. The principles of yield prediction can be illustrated through hands-on experience in most tropical islands without the need for costly or complex equipment. Furthermore, no capture or destruction of resources is actually required for this training activity. The exercise assumes that the study area is pristine and not presently used by anybody. This is probably unrealistic for most mangrove areas, so some of the socioeconomic aspects of management are raised at the end of the section.

**Aim:**

To calculate the Optimum Sustainable Yield of timber from a mangrove stand.

**Duration:**

One day (depending on location and data availability).

**Suitable Location:**

A small (about 4-5 ha) mangrove area, preferably accessible from the land or by a small boat, close to the laboratory or training centre.

**Materials Required:**

50 m long rope, marked in 1 m, intervals.
Tape measure, marked in cms.
Compass.
Map of site (or aerial photograph).
A simple field key to local mangrove species.
Data sheet giving local market prices of mangrove timber and/or charcoal.

**Instructions:**

Field methods

1. Select an area of mangrove forest using the map or aerial photograph. This should be a clearly defined area, or part of a larger area, of mangrove which can be studied in the available time frame.

2. Estimate the gross areal coverage of this 'stand' of mangroves in hectares, and record this.

3. In the field, set out a quadrat 10 x 10 m (0.1 ha) in size using the marked rope. Tie the rope to suitably placed trees or use stakes to mark the boundary. Set the boundary marker line at a fixed orientation using the compass to ensure regular quadrat placing. Mark the quadrat position on the map.

4. Systematically study each tree and record the species and the diameter of the trunk, as follows:

   - Mangrove species are identified using a simple key provided by the instructor.
   - Diameter of the trunk is most easily calculated by measuring circumference (c) with a flexible tape measure. This is done at breast height or above prop roots as appropriate. Diameter at breast height equivalent is dbh = $c/\pi$ , recorded in cm.

5. Count the number of established (growing) seedlings in the quadrat.

6. Measure trees in a second quadrat, and repeat this until about 25% of the total area has been sampled. With small areas, use quadrat sampling to measure all trees.

Preliminary calculations

7. Parameters for mangrove growth rates and biomass (timber) production rates will vary with different species and different geographic locations. If rates for mangroves in the island being studied are known these should be utilised, otherwise, for purposes of this exercise, general conversion factors modified from Lugo and Snedaker (1975) can be applied (Table 4.5, Figure 4.6). (These make several assumptions and generalisations, which could be refined if time permits to give more accurate estimates, by reference to the mangrove literature).

**Table 4.5 Conversion factors and measurements - mangroves**

1. Mean increase in dbh = $0.33\ cm\ yr^{-1}$
2. Mean weight increase per tree (above 10 cm dbh) = $1\ kg\ yr^{-1}$
3. Seedling initial mean weight = 6.3 g
4. Mean weight increase per seedling = $0.4\ g\ yr^{-1}$

..................................................

Enter your data for the measured area on the Table provided. A separate table could be completed for each species of mangrove in the stand (cf. the example Table 4.6).

8. Calculate the standing crop of timber (kg) for each dbh class of trees;

crop = no. of trees x dbh to weight conversion factor

**Table 4.6 Sample Field Data Format - Mangrove yield survey**

---

Location name: Observers:

Date: Time: from to

---

| Quadrat No: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| <u>Species No. 1. Rhizophora</u> | | | | | | | | | | |
| Tree No. | | | | | circumference or dbh | | | | | |
| 1 | . | . | . | . | . | . | | | | |
| 2 | . | . | . | . | | | | | | |
| 3 | . | . | | | | | | | | |
| 4 | . | . | | | | | | | | |
| etc.. | | | | | | | | | | |
| Mean | | | | | | | | | | |
| No.seedlings | . | . | . | . | | | | | | |
| Species No. 2 <u>Avicennia</u> | | | | | | | | | | |
| Tree No. | | | | | Circumference or dbh | | | | | |
| 1 | . | . | . | . | . | . | . | . | | |
| 2 | . | . | | | | | | | | |
| Mean | | | | | | | | | | |
| No. seedlings | . | . | . | | | | | | | |
| etc. ........... | | | | | | | | | | |

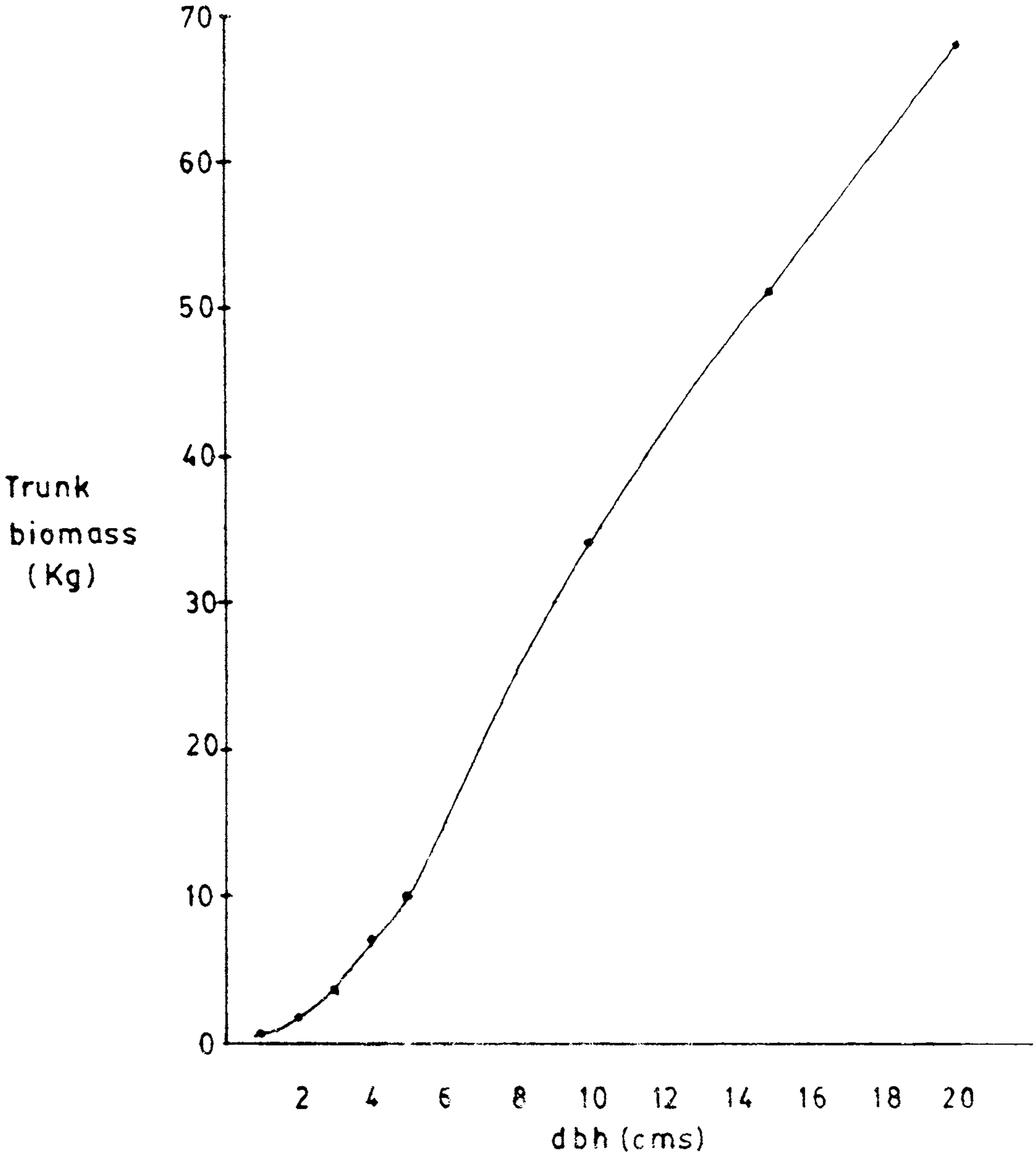


FIGURE 4.6 GENERAL RELATIONSHIP BETWEEN dbh AND BIOMASS OF RED MANGROVE TREES (modified from Golley *et al*, 1962 and various other authors)

9. Calculate the mean weight of the timber stocks for each dbh class in the measured mangrove sample plots (see example, Table 4.7).

10. Calculate the total timber stock for the whole mangrove stand:

= mean for sample plots (kg $m^{-2}$) x no. of $m^2$ in stand.

## Management options

11. The total timber stock (10 above) is available for exploitation, management decisions must be made concerning method of harvesting. The main options (see also Ex. 3.1) are as follows:-

a. Clear fell the mangrove forest to remove all timber; the harvest will be equivalent to the total timber stock/standing crop (as estimated in 10 above).

Note: With mangroves growing at a mean rate of 0.33 cm $yr^{-1}$, it will be necessary to wait approximately 35 years before any further crop is ready for harvesting. This has economic implications for resource users.

b. Selective harvesting is an option if large sized timber or wood for charcoal is required. One could harvest only trees with greater than 10 cm dbh, for example. Calculate what proportion of the total stock is available under this restriction. The yield is smaller, of course.

Note: Trees in dbh class 7-9 cm will reach harvest size in about three year's time. It will be necessary to wait several years for other size classes to reach harvestable size. This method forces resource users into an irregular exploitation cycle.

c. Continuous or regular harvesting

The two previous options give sustainable yields of timber/charcoal over long periods of time but at irregular intervals, so are not optimal for the user group. It should be possible to calculate a smaller, but continuous mangrove crop which would support permanent industries; for example a small regular amount of timber cut and prepared as charcoal for the the weekly market.

Table 4.7 Survey of Mangrove Timber Stocks - L'Anse Paletuvier, September, 1987.

(a) Trees

| | | A | | B | C |
|---|---|---|---|---|---|
| dbh class (cm) | No. trees in sample plot(500m ) | Timber in sample plot (kg) | Timber wgt per $m^2$ (kg) | Total timber in stand (5.6ha) (kg) | Expected total timber in stand after 1 year (kg) |
| > 15 | 1 | 60 | 0.12 | 6,720 | 6,832 |
| 15 | 5 | 255 | 0.51 | 28,560 | 29,120 |
| 14 | 2 | 96 | 0.19 | 10,752 | 10,976 |
| 13 | 0 | - | - | - | - |
| 12 | 12 | 492 | 0.98 | 55,104 | 56,448 |
| 11 | 10 | 380 | 0.76 | 42,560 | 43,680 |
| 10 | 22 | 748 | 1.49 | 83,776 | 86,240 |
| 6 - 9 | 24 | 528 | 1.06 | 59,136 | 60,480 |
| 1 - 5 | 57 | 262 | 0.52 | 29,344 | 30,940 |

Total A = 2,821 kg

Mean = 0.63 kg $m^{-2}$

Total B = 315,952 kg

Total C = 324,716 kg

Increment C - B = 8,764 kg

(b) Seedlings

| | D | | E | F |
|---|---|---|---|---|
| No. in sample plot | Biomass in sample plot (kg) | Seedling biomass (g $m^{-2}$) | Total biomass in stand (kg) | Expected total biomass after 1 year (kg) |
| 4,500 | 28.35 | 56.7 | 3,175 | 3,377 |

Total B + E = 319,127 kg

Total C + F = 328,093 kg

Stand Increment (C + F) - (B + E) = 8,966 kg

Further calculations

12 . Continue to fill in the data table as follows:

- Assume the annual weight increase per tree over 10 cm dbh is 1 kg. For smaller trees read weight increases from Fig 4.6. Calculate the increase in timber weight (G - for growth) for the whole stand for the next year.
- Assuming the mean weight of established seedlings to be 3.6 g, calculate the total weight of seedlings per $m^2$. Calculate the total weight of seedlings in the stand (R - for recruitment).
- Assume a weight increase per seedling of 0.4 g $yr^{-1}$. Calculate the biomass of seedlings (recruitment) in the whole stand at the end of Year 1.
- Sum the total timber weight and seedling weight at end of Year 1 (G + R).
- Assuming a 30% mortality (M) for seedlings and trees, calculate the annual increment in timber weight as;

$$\text{Annual increment (yr 1)} = R + G - M$$

Management decisions and further calculations

13. Theoretically, an amount equivalent to the annual increment of mangrove biomass could be removed without altering stand integrity. This is essentially the <u>Surplus Yield Model</u> (Appendix 6). The question is, how should this yield be removed ?

- Compare the 'surplus yield' figure with that for the total timber weight of trees over 10 cm dbh. How similar are these figures ? Could the yield be taken by removing only the larger trees ?
- Compare the expected yields for trees over 10 cm dbh for each species of mangrove. Could any one species supply the surplus yield ?
- In order to sustain seedling recruitment, it would be advisable to leave occasional mature trees in the stand. Reduce the yield of mature trees by 10% to take this into account.
- Make a final calculation for the (much reduced) amount of 'surplus yield' available for <u>annual</u> harvesting from the stand.
- Calculate the amount of timber which could be harvested;

(a) monthly
(b) weekly

- Calculate the area of the stand that must be cleared to supply the timber;

  (a) each month
  (b) each week.

14. Refer to the data sheet giving local market prices for mangrove timber. Calculate the market value of the following:-

    (a) total stand timber crop
    (b) annual (surplus yield) crop
    (c) monthly harvest quota
    (d) weekly harvest quota

15. Discuss the socioeconomic implications of these different yields. What number of persons would be required to cut timber in these various ways and what income could each expect ? Pay special attention to manpower requirements and income for cutting the most restricted amount on a weekly basis.

    Note: Your calculation has probably shown that regulation of mangrove cutting to 'surplus yield' amounts severely limits its direct economic value, and employment generation prospects. There are those who would argue that, with such low economic returns, it would be better not to cut, but preserve mangrove stands for their wildlife and fisheries values. This is probably true for clear felling as this causes reduction in forest cover, frequently leading to adverse alteration of swamp sediments and production rates. These changes can be avoided to a large extent if mature trees are left at regular intervals (the shelterwood system in forestry practice); which as mentioned above also aids seedling recruitment and juvenile growth.

    Selective removal of large trees can be beneficial to stand productivity, as it gives opportunity for increased growth by young trees. It can improve the economic value of the stand also, if the less desirable species are removed to encourage growth of the better timber or charcoal species (e.g. <u>Rhizophora</u> in the Caribbean islands).

## Planning for OSY

16. Finally, plan the harvesting strategy for this mangrove stand.

mangrove stand.

- Formulate a scheme for regular cutting of trees of a particular dbh that will ensure sustainable timber yield.
- Determine manpower needs for

  (a) cutting timber
  (b) marketing timber
  (c) replanting seedlings
  (d) husbanding young trees and cleaning the stand

17. Prepare draft regulations for management of the stand.

This exercise was designed to expose trainees to the principles and implications of yield estimation, and for simplicity used a "natural" mangrove stand. However, there are few cases in tropical islands where mangroves are in their natural state and are not used by somebody. If management options are to be determined in the real-life situation, there must first be an assessment of current resource use and its rationale. Socio-cultural, economic, and institutional components of this rationale must be understood before realistic options can be considered. Determining OSY (for mangrove timber for example) may be a theoretical starting point, but just as important are overall questions, such as who uses the mangrove and for what? What are the current rates of each type of use and how do they relate to one another ? Are there compatible or competative uses ? Which uses or combination of uses produce the greatest net benefit, and is timber harvest one of them? If so, are the current harvest rates above or below the theoretical OSY (for timber)? If above, what alternatives are there to continuing harvesting at current levels and what incentives might be used? Which user groups can best afford to reduce harvest rates? Given the institutional set-up and user groups involved, what management measures might be most effective in achieving the target harvest levels? Students should keep in mind the management planning concepts generated in Chapter 3 while considering the implications of OSY assessments.

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Alternative Exercises

Yield estimation may be conducted on virtually any coastal resource, provided either that catch data are available or it is accessible for research purposes. Basically one wishes to know:

- How much of the resource is there, per unit area ?
- How much can be taken annually ?
- What harvest technique should be used ?
- How can requirements of the user groups be accommodated ?
- What regulatory and enforcement measures are needed to ensure sustainable yield ?

Suitable field oriented study examples are as follows:

(a) Yield of oysters from mangrove roots.
Estimate stock by counting numbers of oysters per linear metre of channel margin, or per root and number of roots per linear metre. Obtain growth rate to market size for the species. Assume year-round spawning in most tropical oyster species, giving continuous recruitment.

Yield calculated for whole mangrove area, assuming harvest method is removal of individual oysters. If harvest involves cutting of whole roots, recruitment rate calculations must involve growth rates of mangrove roots (see for example, Gill & Tomlinson, 1977). Continuous spawning means that closed seasons for regulation of stocks have little meaning. A better regulatory mechanism might be rotational harvesting from the margins of different channels of the swamp in successive years.

(b) Yield of brackish water crabs
Several species of large crabs are collected in swamps and estuarine environments, particularly on the drier marginal areas, such as Cardisoma guanhumi and Ucides cordatus in many Caribbean islands. Crabs are caught in or at their burrows using hooks or traps.

Stock assessment is made by counting burrows per unit area, catching crabs and calculating % burrows occupied by market-sized crabs. Growth rates are obtained from the literature; recruitment is assumed to be continuous.

(c) Yields of marine conch
Several species of large marine gastropods are harvested for food (e.g. Strombus gigas) or the shell trade (e.g. Charonia variegata). In coastal areas of the Caribbean conch are found in seagrass beds and shallow lagoonal environments.

Stock assessment is made by snorkel or SCUBA surveys, estimating number seen either per unit area or per time period. Growth rates, spawning season and recruitment rates are obtained from the literature, Most conch are easily tagged, so that stock size observational estimates can be cross- checked by mark - release - recapture techniques.

For a - c above, an estimate of current fishing pressure (fishing mortality) should be obtained before calculating potential yield.

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**Further Reading:**

Clark, J.R. 1983. Coastal Ecosystem Management. Krieger Publishing Co. Inc., Florida, USA; 940 pages.

Cushing, D. H. 1981. Fisheries Biology: a Study in Population Dynamics. University of Wisconsin Press; 295 pages.

Dammann, A.E. 1986. Assessment of fish and shellfish stocks produced in the Biosphere Reserve. Virgin Islands Resource Management Cooperative, Biosphere Research Report No. 10, 30 pages.

Hamilton, L.S. & Snedaker, S.C. 1984. Handbook of Mangrove Area Management. East-West Center, Hawaii, IUCN & UNESCO, 123 pages.

Lugo, A.E. & Snedaker, S.C. 1974. Ecology of Mangroves. Annual Review of Ecology and Systematics, 5; 39 - 54.

Odum, W.E. 1976. Ecological Guidelines for Tropical Coastal Development. IUCN Publications New Series, No. 42; 60 pages.

Pauly, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. FAO Fisheries Circular. No. 729; 54 pages.

USDC 1987. Caribbean Marine Resources, Opportunities for Economic Development and Management. US Department of Commerce, Washington, D.C.; 91 pages.

Walsh, G.E. 1977. Exploitation of mangal, pages 347 - 362 in Chapman, V.J. (Ed) Wet Coastal Ecosystems, Elsevier Publishing Co., Amsterdam; 428 pages.

* * *

## Exercise 4.4 PLANNING THE RECOVERY OF DAMAGED COASTAL ECOSYSTEM RESOURCES

**Background:**

Tropical coastal ecosystems are subjected to varied and often severe human impacts. **Overexploitation** of extractable products can lead to damage or even loss of resources, as has happened with many populations of sea turtles (Hopkins & Richardson, 1984), and manatees (Bertram, 1974). Intense fishing pressure on reef fishes can upset the ecological balance leading to deterioration of reef building coral populations (Munro & Williams, 1985) and loss of protective reef structures. Although their importance to coastal stability and productivity is widely acknowledged (Hamilton & Snedaker, 1984), mangroves have been cleared extensively to make room for coastal development and agriculture (Hudson, 1983). Dredging activity in the coast zone is implicated in the loss of coral reefs (Grigg, 1970) , while coastal pollution and eutrophication have done considerable damage to seagrass beds (Thorhaug et al, 1985), with their attendant fish nursery and sediment stabilising properties.

As mentioned in the discussion on status assessments (see Ex. 4.1), coastal managers in almost every tropical island will be faced with stressed, damaged or severely diminished natural resources. A very important management option, therefore, is the **recovery** of such resources to the condition where controlled utilization could take place once more. Clear decisions must be made concerning the rationale for attempting resource recovery and the objective of a recovery plan. After this several key factors must be investigated before deciding how recovery will be achieved, and the time period involved. The recovery plan must be placed in an appropriate economic and social context in all phases of the planning. A recent, ongoing recovery plan can be used to illustrate these points:

**Case study:** The U.S. Sea Turtle Recovery Plan (After Hopkins & Richardson, 1984)

a. Rationale

The following six species of sea turtle occur in coastal regions of the southern U.S.A. and associated states and, under the Endangered Species Act 1973, are listed and considered to have the following status:

| | | | |
|---|---|---|---|
| 1. | Loggerhead | - Caretta caretta | T |
| 2. | Green turtle | - Chelonia midas | T |
| 3. | Kemp's Ridley | - Lepidochelys kempi | E |
| 4. | Olive Ridley | - L. olivacea | T |
| 5. | Hawksbill | - Eretmochelys imbricata | E |
| 6. | Leatherback | - Dermochelys coriacea | E |

E = Endangered species - a species in danger of extinction throughout all or a significant portion of its range.

T = Threatened species - a species likely to become endangered in the forseeable future.

b. Objectives

i - The survival and eventual recovery of listed species or populations, so that they may be removed from the endangered or threatened list.
ii - The conservation of sea turtle habitat as an aid to recovery of the species.
iii - The protection of the species after delisting.

c. The recovery procedure (for each species)

c.1 Collection of baseline data on population status.
c.2 Identification of the causes of decline in the stocks.

Five factors identified:

i. Destruction and modification of habitat
 - Pollutants from industrial and residential development
 - Exploratory oil and gas drilling
 - Disposal of garbage at sea
 - Dredge and fill operators
 - Power boats
ii. Overutilization for commercial purposes
iii. Inadequate regulatory mechanisms
iv. Disease and/or predation
v. Incidental catch

c.3 Designing appropriate research for describing desired population numbers and habitat characteristics.

c.4 Developing management recommendations.

i. Reduction of turtle mortality on land
 - Protection of nests in situ

- Predator reduction
- Increased law enforcement

ii. Reduction of turtle mortality at sea
- Prevention of incidental catch (e.g. by shrimp trawlers)
- Increased law enforcement

iii. Enhancement of production from nesting beaches
- Rearing eggs in hatcheries
- Headstarting (keeping young turtles in captivity until large enough to have a better chance of survival when released)

c.5 Monitoring populations.

c.6 Assessing success or failure of management techniques applied.

c.7 Recommending changes in management strategy.

c.8 Updating the plan as new information becomes available.

The U.S. Sea Turtle Recovery Plan is based on the biology of the target species, but one obvious weakness is its lack of attention to the socioeconomic aspects of sea turtle utilization, other than recommending improved enforcement of regulations banning such use. In small tropical islands where dependency on coastal resources is likely to be greater at subsistence level, a recovery plan would need to take cognisance of these aspects.

The exercise which follows considers the **basic biology** of another damaged resource, but stresses **cost factors** and suggests opportunities for **community participation** in the recovery process.

**Aim:**

To prepare a plan for the recovery of damaged seagrass beds.

**Duration:**

1 day (6 hours)

**Suitable Location:**

Laboratory/drawing office exercise using an hypothetical case-study. This should be supported by field observations in similar environments where students are not familiar with seagrass beds.

**Materials Provided:**

(a) An Executive Summary from a consultant's report (page 220).

(b) The following accompanying maps and data tables:

| | |
|---|---|
| Fig. 4.7 | Physical features of Green Turtle Bay. |
| Fig. 4.8 | a. Mooring sites (Nov. 1986) |
| | b. Extent of seagrass beds 1985-1987 |
| Table 4.8 | Fishery Catch Statistics, Green Turtle Bay 1983 -1987 |
| Table 4.9 | Visitor boat moorings 1983 -1987 |

(c) Summary of seagrass replanting methodology (Appendix 7).

**Instructions:**

1. Study the Executive Summary taken from a report by a consultant ecologist under Government Contract BWI - 19A/1987.

2. Study the accompanying maps and data tables; Figures 4.7 - 4.8 and Tables 4.8 - 4.9.

3. Discuss the issue and decide on the following:-

   - What is the nature of the problem ?
   - What is the extent of the problem ?
   - What is the cause (or causes) of the problem ?

4. You are faced with two options, as manager of this coastal area, either ignore the problem or attempt to correct it.

   - What are the likely economic and social costs of ignoring the problem ? Attempt to express these at today's currency value and identify who will bear these costs.
   - Make a list of all actions necessary to correct the problem.
     This should be subdivided as follows:-

     (a) Reduction of impacts by fishing industry.
     (b) Reduction of impacts by yachting interests.
     (c) Reduction of impacts from other sources.
     (Remember that fishing and yachting make significant contributions to the economy, so you wish to sustain these activities in Green Turtle Bay while controlling adverse impacts.)

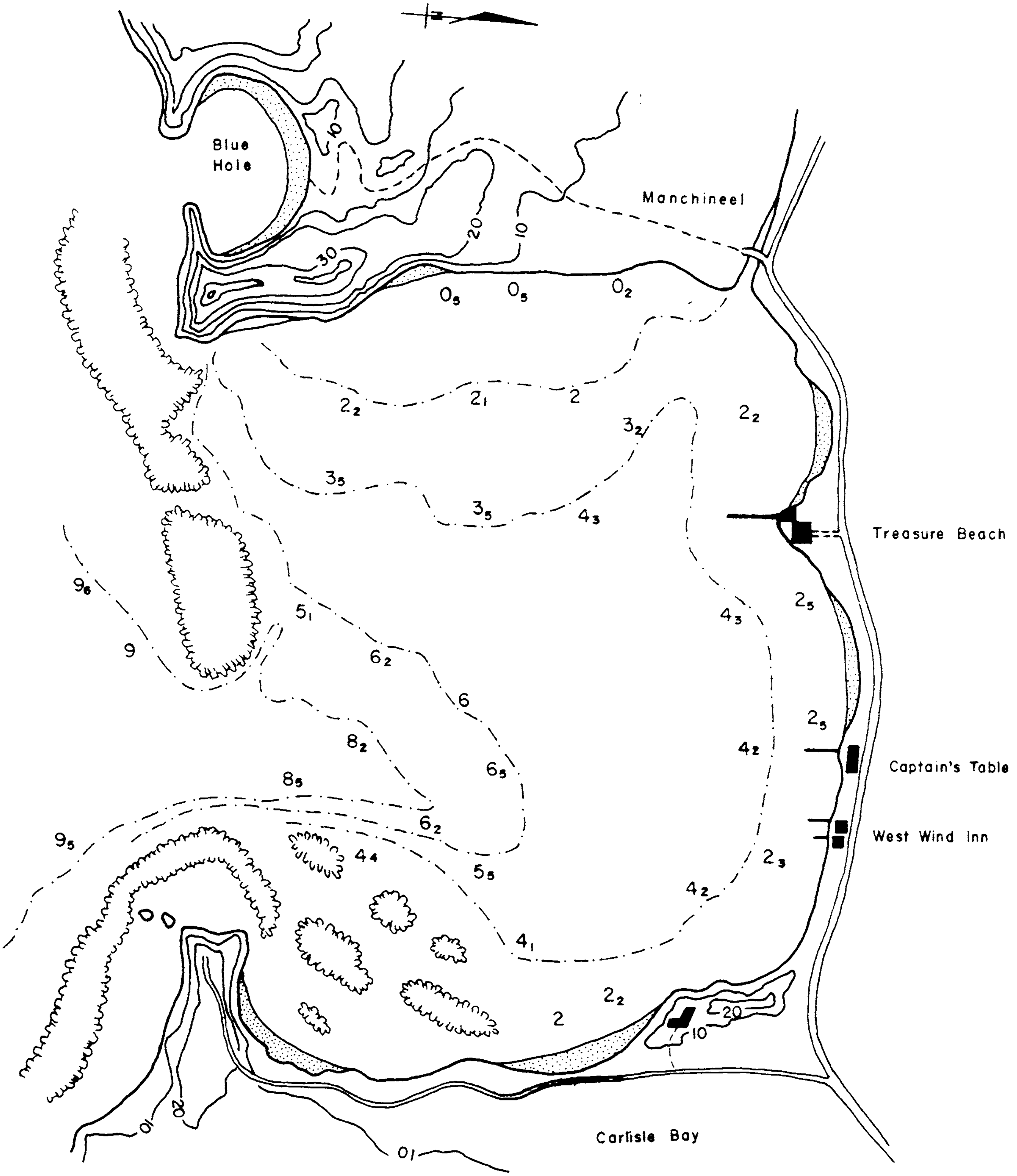


FIGURE 4.7 PHYSICAL FEATURES - GREEN TURTLE BAY

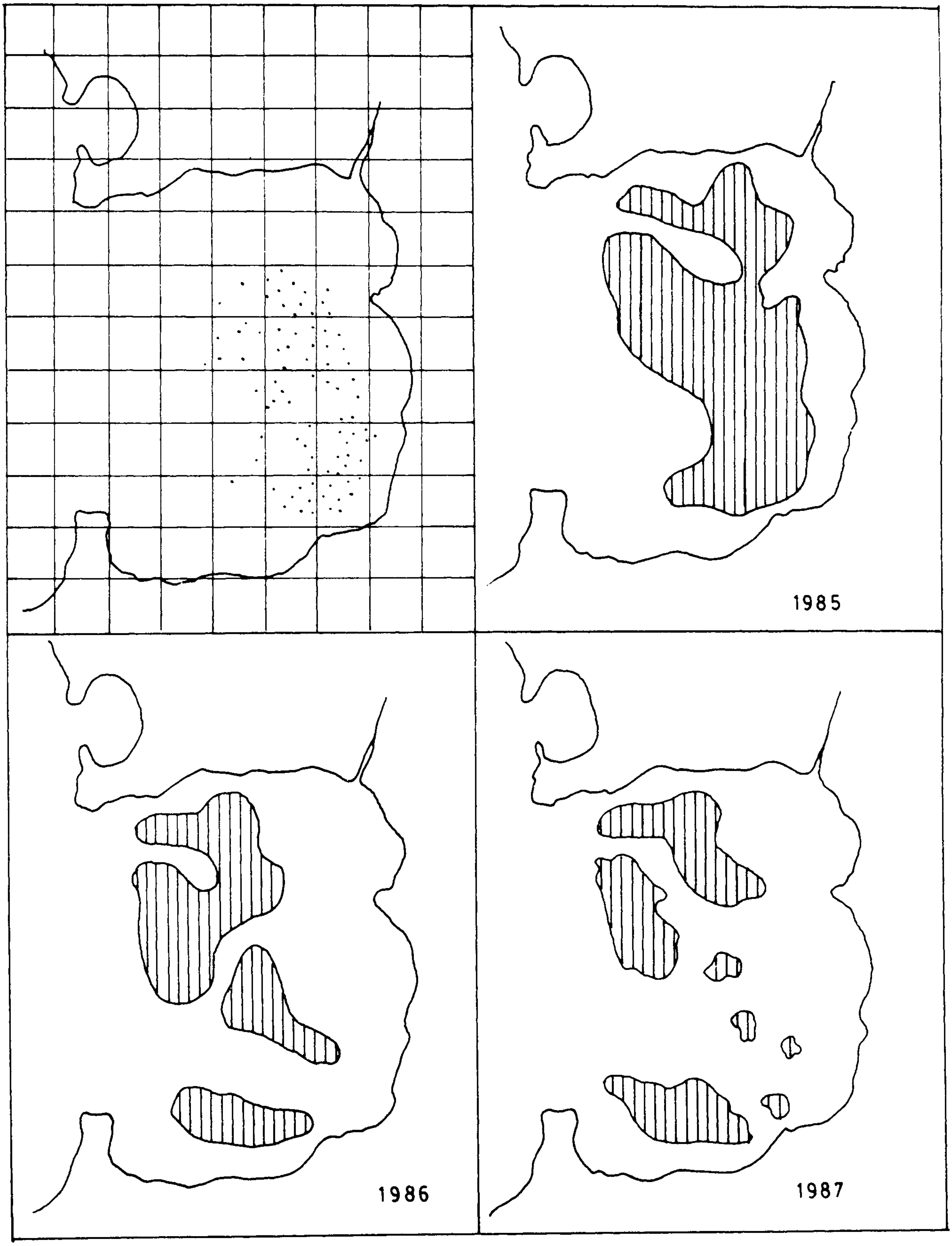


FIGURE 4.8 GREEN TURTLE BAY - BOATS MOORED DURING TWO DAYS AIR SURVEY (top left), AND SEAGRASS DISTRIBUTION 1985 TO 1987

**Table 4.8 Catch statistics: Green Turtle Bay, 1983 -1987**

| Year | No. Active fishermen by method of catch | | | | Annual catch kg | | | | Approx Total income US$ |
|---|---|---|---|---|---|---|---|---|---|
| | Seine | Trawl | Line | Spear gun | Fish | Shrimp | Conch | Total | |
| 1983 | 15 | 0 | 8 | 4 | 86,000 | 5,660 | 8,424 | 100,088 | 128,34 |
| 1984 | 12 | 0 | 9 | 5 | 92,050 | 6,480 | 7,860 | 106,390 | 137,99 |
| 1985 | 6 | 12 | 6 | 6 | 104,500 | 84,600 | 8,800 | 197,900 | 419,20 |
| 1986 | 4 | 17 | 4 | 3 | 72,224 | 12,026 | 6,320 | 90,570 | 131,97 |
| 1987 | 5 | 10 | 15 | 2 | 8,160 | 2,320 | 162 | 10,642 | 17,79 |

Source: Western Region Fisheries Center, Annual Report 1987.

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**Table 4.9 Visitor boat moorings: Green Turtle Bay, 1983 - 1987.**

| Year | Annual boat moorings (all foreign craft) | | | | |
|---|---|---|---|---|---|
| | Treasure | Captain's Table | West Wind Inn | Total | Mooring fees US$ |
| 1983 | 82 | 21 | 6 | 109 | 216 |
| 1984 | 78 | 22 | 82 | 182 | 364 |
| 1985 | 410 | 141 | 185 | 736 | 3,680 |
| 1986 | 482 | 152 | 322 | 956 | 9,560 |
| 1987 | 960 | 740 | 820 | 2,520 | 70,600 |

Source: National Yachting Association, Annual Report, December 1987.

- Put a dollar cost on the actions suggested, and compare this with possible losses estimated above. Your calculations should include costs of materials and labour, as appropriate.
- Plan a chronogram for mitigation activity, i.e. a timetable for the corrective actions listed above.

5. Once plans are finalised for removing adverse impacts on the seagrass beds, prepare a plan for recovery of damaged areas of seagrass. You have two options, viz., (a) rely on natural recovery and spread of seagrass which may take several years, or (b) assist recovery by replanting.

   - Examine figure 4.8 and assess the technical feasibility of replanting all damaged areas in Green Turtle Bay. Study some of the scientific literature relating to seagrass replanting in your region and note that some authors, such as Fonseca 1987, consider that replanting schemes have a low chance of success.
   - Estimate how many transplants you will need and the cost of obtaining these (refer to Appendix 7).

     Transplants can be removed from areas of healthy seagrass, taking care not to uproot or denude too much of these areas. Select areas likely to be a source of plants for transplanting.

     Estimate the cost of other materials used in replanting.

     Estimate manpower needs and labour costs to complete replanting in 2 - 3 months.

6. Draw up a budget for the total costs of adverse impact mitigation and seagrass bed recovery.

   Compare with socioeconomic costs of ignoring the problem, noting who will bear these costs, and decide on the most appropriate management options.

7. If you decide on the option of taking corrective action, plan a resource recovery strategy for Green Turtle Bay.

8. The success of your recovery strategy will depend heavily on cooperation from the fishing community and yachting interests; hopefully, it will be seen as a benefit to both, plus local recreationers in the long-term. There are advantages, therefore, in "community participation" in the seagrass restoration project.

- List ways in which the community can assist, e.g. collecting transplants; preparing sprigs for planting out.
- Calculate cost savings at all levels of the project through the use of voluntary labour or other forms of local assistance.
- Budget funding and time for creating community awareness of the restoration project.

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**Supporting Document**

**Executive Summary: Report on the Destruction of Seagrass Beds in Green Turtle Bay.**

1. Factors leading to deterioration of water clarity, increased accumulation of weed on beaches, and reduced fishing yields in Green Turtle Bay, were investigated over the three month period March through May, 1987.

2. All human activities dependent on the bay were documented. Three main categories of activity were observed: fishing, yachting and recreational beach use.

3. Fishing was conducted from the fishing depot at Manchineel (Figure 4.7). There were 32 fishermen in full-time employment, showing preferences for different gear. Fishermen all confirmed serious reduction in catch rates since 1985, especially for fin fish with turtles (<u>Chelonia mydas</u>) and conch (<u>Strombus</u> spp.) rarely obtained nowadays (Table 4.7).

4. Previous productive fishing areas had been largely in the eastern and south eastern sections of the bay.

5. Three bayside hotels had become popular with foreign yachtsmen in recent years. Sail and motorised craft anchor in the bay near to Treasure Beach, Captains Table and West Wind Inn while patrons enjoy the facilities (Figures 4.7 & 4.8). Records of the National Yachting Association show an over 2,000% increase in small craft stopovers in the last five years; and collection of mooring fees now exceeds US$70,000 per annum (Table 4.8).

6. Green Turtle Bay is rarely used by local boats.

7. The Carlisle Bay beach is used by local families for

recreation, largely at weekends. The maximum number of persons on the beach at any one time during the survey was 106.

8. Residents and recreationers confirm that Carlisle Bay has been fouled by weed much more than usual during late 1986 and early 1987. Collections of weed made at weekly intervals throughout the survey were 86% Thalassia, 10% algae and 4% Syringodium.

9. Deterioration in water quality was confirmed using a Secchi disc. The disc was visible only to the depth of 1.0 m at any point in the south eastern half of the bay, and only during calm weather. At most times visibility was less than 0.5 m. Visibility for divers underwater in this sector was rarely greater than 1.0 m. - Pilkington & Haynes mapped seagrass distribution in 1985 along transects while snorkelling at the surface, indicating that visibility was much greater at that time.

   - One hotelier reported decreasing use of the sea by guests for bathing, and frequent complaints of poor water quality.

10. The floor of the entire bay was surveyed by a team of biologists and experienced SCUBA divers, using a grid of parallel transects marked at 2 m intervals. Bottom substrate type and plant community composition was mapped for the area 1 m wide on each side of the line.

11. The seagrass, Thalassia testudinum, was the dominant marine plant. Fleshy algae were the next most abundant group.

12. The distribution of seagrass was compared with maps produced in a previous study in 1985 by Pilkington & Haynes (Figure 4.8). It was found that a 48% reduction had occurred in the area covered by seagrasses since 1985.

13. Detailed observations over a three month period indicate that seagrass beds are being damaged by two principal activities:

   (a) use of otter trawls by fishermen damages seagrass blades and disturbs sediment.
   (b) boats pulling up anchors, and occasionally dragging anchors, uproot seagrasses.

14. These causes of damage are quantified and (b) is shown to cause greatest mortality to the plants.

15. It is recommended that the use of otter trawls be

banned with immediate effect.

It is recommended that adequate mooring facilities be provided for small craft and that yachting regulations be formulated to discourage bottom anchoring in Green Turtle Bay.

(Note: Figure and Table numbers refer to the preceeding exercise, not to those used in the original consultant's report)

End of Summary

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**Alternative Exercises**

Actual recovery of damaged biological resources or ecosystems is normally a lengthy process, so that for training course purposes it may not be possible. However, with prior planning and laboratory support the feasibility and some of the problems associated with recovery can be demonstrated, as follows:

1. Survival of Seagrass Transplants

   Three to four permanent plots 5 x 5 m can be established and marked with lines or blocks. Seagrass plugs, sprigs or seeds can be planted, using techniques of Appendix 7. This will require at least one day's work. The plots should be inspected at intervals of one week to monitor replanting success, for as many weeks as possible. The following can be measured (1) Amount of growth, (2) relative growth of plugs, sprigs and seeds, (3) % mortality or loss of transplants.

2. Effects on a donor bed of removing seagrass transplants

   Transplant plugs should be removed from a donor bed according to a regular grid pattern. The site can be revisited at intervals to study (1) if removal has led to erosion of the bed, or (2) the rate of filling up of patches from which seagrasses were removed.

3. Reseeding an overexploited conch population

Juvenile conch can be reared in the laboratory in advance, or collected from areas of high population density. They can be released into a marked section of the depleted area (provided that suitable habitat conditions are present, according to the literature). For this exercise, the site should be revisited at intervals of two to three days to study (1) dispersal of the released stock and (2) % loss (assumed natural mortality).

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**Further Reading:**


Bacon, P.R., Berry, F.D., Bjorndal, K. et al. (Eds). 1984. Proceedings of the Western Atlantic Turtle Symposium, San Jose, Costa Rica, July 1983, Center for Environmental Education, Washington, D.C.;1138 pages.

FIU 1984. Seagrass Restoration in Caribbean Nearshore Areas. Florida International University and the United States Agency for International Development; 70 pages.

Lewis, R.R. 1982. Creation and Restoration of Coastal Plant Communities. CRC Press, Inc., Florida; 219 pages.


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