

## CHAPTER 5

### RISK ASSESSMENT AND CONTINGENCY PLANNING

#### Introduction:

Island coasts are exposed frequently to extreme forces generated by tropical storms. The damage caused by hurricanes (typhoons or cyclones) may be from direct effects of the strong winds or indirect effects such as flooding. Direct and indirect damage to coastal areas occurs also from the tsunamis which may be generated by other events such as earthquakes.

While they cannot be prevented, these events can be predicted with increasing accuracy, so that steps can be taken to remove people from danger areas and secure property against possible damage. However, **Disaster Preparedness** should not be solely an emergency procedure in response to immediate perceived danger, but part of long-term national planning (Schnabel, 1972). It should include the following:

- (a) **Risk Assessment** - in which the coastal areas most likely to be subjected to hurricane, storm surge or flooding are identified; or alternatively, the areas likely to suffer the greatest economic losses should a natural disaster occur.
- (b) **Contingency Planning** - in which a strategy is devised for dealing with the disaster should it occur, or, preferably, when it is forecast. To be most effective, the Contingency Plan should be prepared well in advance and, if possible, rehearsed.

Both aspects of Disaster Preparedness carry the implication that human settlement and economic activity should be reduced in, or removed from, the areas of greatest risk from natural disasters. This concept is important in coastal development planning; it raises the whole question of set-back lines, and the location of industries and tourism infrastructure at the land-sea interface (United Nations, 1982; Deane, 1987).

In addition to the possible impacts of the sea on human activities, there are potential ecological and economic disasters associated with man's impact on coastal areas. Chief among these are accidental spillages of oil and toxic substances in ports and harbours. The agency responsible for Disaster Preparedness would need to assess the risks involved in the transport and use of these

substances, locate critical areas, strengthen preventative measures and prepare Contingency Plans. Each aspect would require detailed and accurate knowledge of coastal structure and processes, of socioeconomic conditions and development activities in the coastal zone. There would also need to be coordination of responsible agencies and their enabling legislation, as there would be for dealing with natural disasters. Risk Assessment and Contingency Planning thus form an important component of the coastal zone management process; and the exercises which follow are designed to illustrate some practical approaches to this complex topic.

## Exercise 5.1 PREDICTING COASTAL FLOOD HAZARD

### Background:

Among the many effects of tropical storms on island coasts, the greatest damage is probably caused by the **storm surge**. This is "an abnormal rise in water generated by a tropical storm along coastal regions. A storm in a sea or ocean creates a circulating mound of water, of small surface elevation, which follows the storm's core. On its approach to shallow waters, the mound of water feels the bottom and begins to elevate; on striking the coast it is further amplified by coastal barriers before receding seaward. The length of the coast affected by a surge averages about 100 miles and the surge may last for a period of several hours" (WMO, 1981).

It is possible to **predict** which sections of an island's coast are most likely to experience storm surges. This is being done by studying coastal geomorphology and prevailing wind patterns (Deane, 1987) supported by analysis of historical records (Naughton, 1984) (see also Exercise 2.2. & Appendix 3). However, the actual location of maximum storm surge is dependent on the track of the hurricane itself, which is less easily predicted.

For Risk assessment purposes, the degree of **vulnerability** of the coast may be a more practical criterion, i.e. if a storm surge should occur there, which parts of the coast are likely to suffer the greatest damage? This will depend on observable, and measureable, characteristics of the coastal zone, including natural features and human settlement patterns (Table 5.1), rather than predictions. An analysis of these characteristics, and planned changes to sections of the coastal zone, can be prepared in the form of maps or tables which highlight the most vulnerable areas. This exercise deals with one likely effect of storm surge, **flooding of low-lying areas** of the coast as a result of abnormal rise in sea level. (Flooding could occur also as a result of rainfall associated with the hurricane storm, and the effects are likely to be most severe in the same areas identified as being vulnerable to flooding with seawater). **Flood Hazard Prediction** can be carried out rapidly and with reasonable accuracy in most tropical islands because it relies almost entirely on the fixed locations of land-based features on available topographic map sheets.

### Aim:

To prepare a map showing coastal areas most likely to be flooded by hurricane storm surge.

**Duration:**

One Day (minimum).

**Table 5.1. Characteristics of a coast which might contribute to damaging effects of hurricane storm surge.**

a. Physical characters:

- topography (sea level to 10 m contour)
- bathymetry
- nature of the island shelf
- presence of reefs, and other inshore features
- presence of mangrove swamps, or lagoons
- natural drainage pattern
- reclamation works
- extent of fill
- modification of drainage channels

b. Settlement characters:

- location of settlements
- number of settlement units
- size/extent of settlements
- types of structures used
- range of activities in the settlement (residential, commercial, industries & specialised sites, recreation, farming)
- nature of connecting infrastructure

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**Suitable Locations:**

Drawing Office/Laboratory exercise.

**Materials Required:**

Topographic map sheets of island, or portion of island coast. These will need to be large scale maps, showing fine contour detail.

Descriptive information or data on the nature of settlements in the target coastal area (population density, types of housing, types of industries).

Summary of scheduled developments for the target coastal area.

Drawing materials.

Map making materials (see Chapter 3).

**Instructions:**

Map Work and Preliminary Analysis

1. On the topographic maps provided, distinguish low-lying coastal areas. Assume that a storm surge causes a rise in sea level of one metre; mark or shade all areas up to one metre above sea level. Trace this onto a clear acetate sheet.
2. Repeat the above step for storm surges up to 5 m and 10 m.
3. Overlay the acetate sheets, and trace onto a fourth sheet to show the vulnerability of the target coastal area to flooding by storm surge waves of different heights.
4. On a further overlay sheet, trace the locations of settlements and their supporting infrastructure. Distinguish, by means of symbols, between residential, commercial, agricultural and industrial features.
5. Overlay the settlement pattern map with the flood level maps and produce a summary narrative description of the extent of damage that could be expected with storm surge waves of different height.
6. Return to the settlement map (stage 4 above), and distinguish as far as possible between different types of developments, i.e. use symbols to distinguish between villages dominated by wooden houses as opposed to concrete/brick houses; or industries and activities that might create special problems if flooded, such as sewage treatment plants or solid waste dumps. Modify the narrative description if any of these features might lead to increase in economic losses or environmental problems.
7. Continue the analysis of the possible effects of flooding by considering whether it would be advisable to relocate any part of existing settlements or their infrastructure. (Bear in mind that "risk" is being considered, and willingness to risk damage must be weighed against costs of relocation. In some cases the benefits of being sited close to the coast, for certain industries and tourism facilities, become part of the equation for

risk assessment).

8. Examine the summary of development plans for the target coastal area. In the light of the mapping and analysis conducted above, recommend any changes or relocations that might avoid losses due to flood damage in the future.

#### Final Analysis

9. Represent the information and concepts generated above in the following way:
  - (a) **Risk Intensity Maps** - as drawn above to show risk in terms of relative height above sea level and degree of socioeconomic losses.
  - (b) **Best Use Maps** - which show recommended categories of land-use in the relative risk zones; i.e. land below 1 m a.s.l. which has a high risk of storm surge flooding could be earmarked for wildlife conservation or wilderness type recreation; housing could be restricted to land with relatively low risk, and certain sensitive industries removed to sites with extremely low risk.

Support this final analysis with a narrative summary of the relative area available for each designated activity.

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#### Alternative Exercises:

1. Factors which modify effects of hurricane storm surge on coastal areas can be examined, provided good topographic maps and bathymetric charts of the island are available. Inshore features are known to affect storm waves; barrier beaches, coral reefs and mangrove swamps can dampen their height and energy, whereas certain patterns of sea bottom contour (Bathymetry) can increase them (see also Exercise 2.2). Maps of an island can be examined and coastal features of this type identified.
2. Analysis of historical records of storm surge damage can be carried out and an attempt made to explain why the intensity of damage varied in different parts of

the affected coastal area. This depends on the availability and accuracy of the historical records. Damage data should be compared with risk intensity maps based on elevation and settlement patterns, as prepared above.

3. Human activity in the coastal zone is imperilled by global changes in sea level. Some two thirds of the population of most tropical islands and the major part of their economic activity is centred at, or very close to, sea level; including capital cities, ports, mariculture facilities and tourism infrastructure. In recent years, good evidence has accumulated of a slow but continuous rise in mean sea level of from 10 - 20 mm annually. Initially this does not appear to be of great significance for coastal zone management, but if students calculate the possible change in water level after 10 or 15 years a different picture emerges. Students could discuss the long-term implications of sea level rise on (a) subtidal systems, such as coral reefs (b) intertidal systems, such as mangrove swamps, (c) rates of erosion and sedimentation, (d) the horizontal displacement of the shoreline, (e) human settlement in supratidal situations, and (f) economic activities in the coastal zone. If detailed contour maps of one economically significant coastal area are available, a prediction could be made of the extent of coastal flooding and resulting economic losses after several years, presuming that the rate of sea level rise remains constant. A further calculation could be of the cost of improving coastal defences to prevent flooding or erosion.

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**Further Reading:**

Pirazzoli, P.A. 1985. Sea level change. Nature and Resources, 21 (4); 2 - 9.

Schnabel, R.E. 1972. Disaster Preparedness. Office of Emergency Preparedness, Washington, D.C.; 364 pages.

United Nations 1982. Coastal Area Management and Development. United Nations Department of International Economic & Social Affairs, Ocean Economics & Technology Branch, Pergamon Press; 188 pages.

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## Exercise 5.2 OIL SPILL CONTINGENCY PLANNING

### Background

Oil spilt into the marine environment is known to cause serious ecological damage and economic losses. Technology is available for containment and clean-up of spilt oil, but its effectiveness depends on rapid deployment of appropriate gear or dispersants by trained personnel. Successful deployment depends also on accessibility to the site of the spill and the sea conditions following the spill.

Because of the serious damage that might result from a spill, no country can afford to wait for an accident and then start to work out what to do about it. A more sensible approach is to prepare a "Contingency Plan" in advance, so the responsible authorities are ready should a spill occur. For this, the planners try to predict:

- (a) where a spill might occur,
- (b) what is likely to happen when the spilt oil spreads in the sea, and
- (c) how to protect those coastal areas which are likely to be affected.

Even on a small island it would be difficult and costly to protect the whole coastline, so a decision must be made concerning which coastal ecosystems or economic activities get priority for protection. Other aspects that must be planned are:

- (a) who will take responsibility for organising the clean-up operation,
- (b) who will actually do the work,
- (c) what equipment will they use,
- (d) where will that equipment be stored,
- (e) how will the equipment and personnel be transported to the site of the spill,
- (f) how will orders and instructions be communicated and the clean-up operation coordinated.

### Aim:

To produce the outline for an Oil Spill Contingency Plan for the island.

### Duration:

3 - 4 hrs

**Suitable location:**

Drawing Office/Laboratory

**Materials required:**

- a. Topographic map (large scale) of the whole island and surrounding seas.
- b. Topographic maps (1:50,000 or smaller scale) of sub-regions of the whole island.
- c. Bathymetric charts of inshore areas and harbours.
- d. Wind rose diagrams, January through December (obtained from the main airport or other meteorological station)
- e. Sea surface current diagrams, for all coasts, January through December.
- f. Data sheets and/or diagrams showing distribution of major fishing grounds and fishing communities; hotels and major tourist beaches; important coastal ecosystems (eg. mangrove areas) or marine species (eg. sea turtle nesting beaches); ports and petroleum product handling sites; air fields; mooring locations of marine police launches or coastguard boats.

**Instructions:**

1. Locate high-risk oil spill areas around the island
  - for tanker accidents at sea
  - for tanker accidents when entering or leaving port
  - for spills during loading or off-loading.
2. Chart the likely directions of movement of spilt oil in the sea in order to identify areas of possible impact on the coastline. These are predicted from wind and surface current data. Take note of any seasonal changes in these factors. For example, reference to streamline flow patterns around the island of Tobago resulting from wind-driven currents (Figures 2.14 & 2.15) show a likely impact on eastern but not western coasts. Prevailing winds around Jamaica (Figure 5.1c) suggest likely movement of spilled oil alongshore from east to west, with marine currents showing a strong onshore component on both northern and southern coasts. Inshore eddy currents and tidal effects will further modify the actual path of an oil spill, and the likelihood of a tanker accident is increased during storm or other "abnormal" weather conditions.

Although the main movement of oil will be due to movements of the water mass (i.e. currents), the major part of a spill will be floating at the surface and therefore affected by wind direction. Seasonal

changes in strength and direction of winds and currents (Figure 2.14 & 2.15) will affect the general pattern of drift.

The accuracy of prediction depends on the accuracy of available wind and current data, both recorded and forecast, particularly for inshore areas. Current speed, and therefore likely travel time of spilled oil, is an important consideration in planning the response time of clean-up crews.

3. Map the distribution of the different coastal ecosystems and identify priority areas for protection. Coastal ecosystems will be affected by spilled oil in different ways. Some will be more **vulnerable** than others; for example floating oil is more likely to strand on intertidal rocky shores than on submerged seagrass beds, or alternatively, is more likely to persist on sheltered mangrove roots than on exposed wave-washed rocky cliffs. (Use of a Vulnerability Index is discussed in Alternative Exercise 2 below). Some ecosystems will be more **sensitive** to petroleum hydrocarbon residues than others; for example, oil might destroy a population of rocky shore biota but recolonisation will be rapid once the oil disperses, whereas if oil kills red mangroves the resulting habitat damage will reduce the likelihood of population re-establishment. In the case study presented below, coral reefs and mangrove swamps are identified as "key ecosystems" because of their vulnerability and sensitivity (Figure 5.2a). These common tropical island ecosystems are priority areas for protection also in terms of their **importance** for coastal protection, marine foodchain support and commercially exploitable resources.

The group should identify the types of ecosystem present in the coastal zone of the study island and discuss their priority ranking, using the above criteria.

In some cases, in addition to ecosystems, there might be resource organisms under threat from an oil spill; for example, nesting sea turtles, migratory or resident wading birds or marine mammals. Habitat used by these organisms might need to be included in any maps showing priority areas for protection.

4. Map the distribution of economic activities in coastal areas and identify priority areas for protection.
5. Use a table or diagram to show clearly areas of highest priority for protection (combine 3 & 4 above).
6. Map areas of the coastline which might be inaccessible

to the clean-up crew, from both/either land or sea.

7. Prepare a diagram showing a suggested "command structure" and lines of communication for operation of the plan.
8. Map the main routes for transporting clean-up equipment from its storage site to priority areas of the coast. Consider land, sea or air routes.

The plan should be presented in the form of annotated maps and/or diagrams, so that a reader can grasp quickly the objectives of the plan and the suggested logistics of the clean-up operation.

You may assume that a set of clean-up equipment is stored at the Harbour Master's office in the main port. The equipment is ready on the dock side and consists of a boom, barrels of chemical dispersants, a work boat, a hand-operated pump and a small winch.

#### **Product expected**

The Contingency Plan will be a series of "visual aids" suitable for notice board display at a training course. Examples of maps and diagrams which form part of a similar plan for the coast of Jamaica are shown in Tables 5.2 & 5.3 and Figures 5.1 & 5.2; and interpreted as follows: Oil tanker routes (Figure 5.1a) show that accidental spillage is most likely off the east or southeast coasts, while six areas are identified with off-loading ports (Figure 5.1b & Table 5.3). Likely directions of movement of spilled oil are, on average, from east to west (Figure 5.1c). The distribution of coastal ecosystem types (Figure 5.2a) and economic activities (Figure 5.2b & Table 5.2) indicates that five areas of the coast should be considered priority for protection (Figure 5.2c). The chain of command for plan operation would include the Jamaica Office of Disaster Preparedness and the Office of the Prime Minister making the decision to launch clean-up operations, under coordination by the Defence Force/Coast Guard using funds and labour provided by the Parish or District Councils. The Natural Resources Conservation Department would advise on environmental protection and monitor the operation (see also Table 1.3).

Table 5.2. Annual catch and landings on Jamaican fishing grounds

	FISHING GROUND				TOTAL/ AVERAGE
	NORTH SHELF	SOUTH SHELF	PEDRO BANK	OTHER BANK	
Annual catch	1107.95	3610.19	1590.70	896.63	7205.37
No. of landings	119.64	173.15	7.53	27.71	328.63
Catch per landing	20	46	466	71	4

(Various sources)

Table 5.3. Petroleum and petroleum products - outports 1981.

Port	Petroleum products in tons (1 ton = 1016 kg)					
	Total	Fuel	Gas oil	Bunker C	Marine diesel	Auto diesel
Montego Bay	120,045	120,045	-	-	-	-
Ocho rios	13,609	13,568	-	41	-	-
Port Esquivel	631,246	547,347	-	83,899	-	-
Port Kaiser	635,650	619,381	16,269	-	-	-
Port Rhodes	30,611	6,440	-	16,042	3,543	4,586
Rocky Point	162,749	162,749	-	-	-	-
Total	1,593,910	1,469,530	16,269	99,982	3,543	4,586

(Various sources)

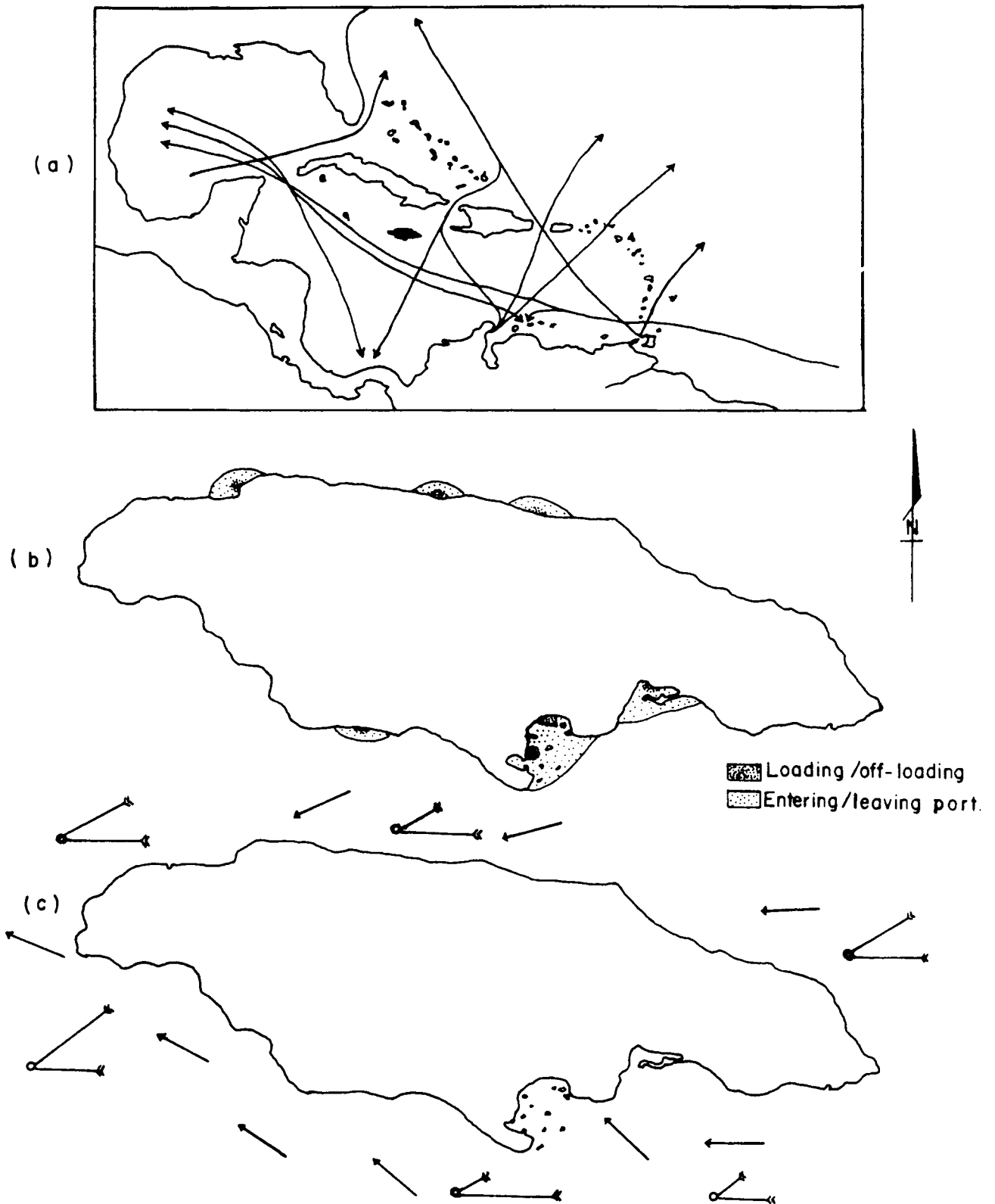


FIGURE 5.1 (a) MAJOR OIL TANKER ROUTES, (b) INSHORE HIGH RISK SPILL AREAS, (c) WINDS AND CURRENTS

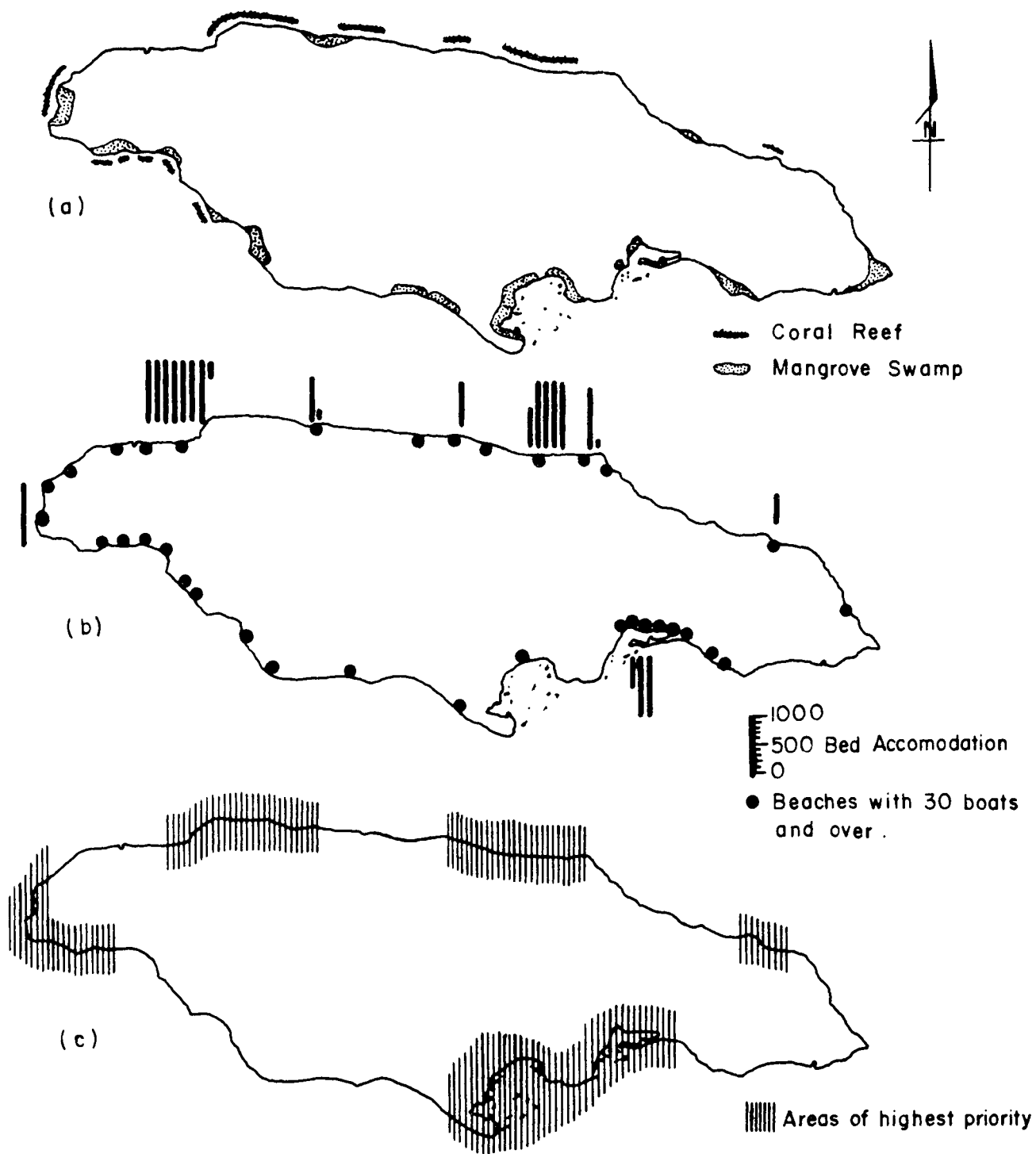


FIGURE 5.2 (a) KEY ECOSYSTEMS, (b) CENTRES OF ECONOMIC ACTIVITY - TOURISM AND FISHING, (c) AREAS OF HIGHEST PRIORITY FOR PROTECTION

**Alternative Exercises:**

1. Oil spill control in a harbour.

Oil Spill Contingency Plan could be prepared for a smaller section of island coast, such as the main harbour. The principles will be the same, but finer detail will be required and more precise data handouts supplied.

Oil may be spilled from loading and offloading at storage tanks or a refinery, or from shipping, or from a land-based source. Likely wind or current-driven movements of the oil can be estimated by techniques given in Chapter 2, or can be measured in the field.

2. Preparation of an Oil Spill Vulnerability Index.

As an extension of the main exercise above, or as a preliminary to it, an Oil spill Vulnerability Index can be prepared for the whole island coast. This is based on the physical longevity of oil in each type of coastal environment in the absence of clean-up attempts. It produces a classification similar to that shown in Table 5.4. The use of vulnerability indices is described by Gundlach and Hayes (1978) and Owens and Robilliard (1980). (see also Exercise 5.1)

3. Identification of sources of spilled oil.

Samples of existing petroleum hydrocarbon residues can be collected and the possible sources identified (see also Exercise 2.4). If suitable laboratory apparatus is available, such as a spectrofluorometer or a gas chromatograph, the type of oil (actual source) can be identified with considerable accuracy. This is important not only for providing opportunities to control oil pollution at source, but also in obtaining compensation from the polluter.

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**Further Reading:**

Wardley-Smith, J. 1983. The Control of Oil Pollution.  
Graham & Trotman, London; 285 pages.


IMO 1987. Practical information on means of dealing  
with oil spillages. Manual on oil Pollution

section IV (Revised). International Maritime  
Organisation, London; 143 pages.

International Tanker Owners Pollution Federation. 1987.  
Response to marine oil spills.

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**Table 5.4 A Suggested Coastal Classification For Trinidad Based On Its Vulnerability to Potential Oil Spill Damage (Source: Georges, 1982)**

	Vulnerability Index	Coastal Environment	Comments	Examples
LOW  HIGH	1	Exposed, steeply dipping, cliffed rocky headland.	High energy little oil would strand, little clean up needed.	N & N.E coasts.
	2	Eroding wave cut platform.	Most oil removed by natural processes in a few weeks.	La Fillette Point Radix, S. coast.
	3	Flat, fine-medium grained sand beach (0.0625-0.25mm).	Close packed sediment resists penetration, oil may persist for many months.	Cocos Bay, Irois Bay.
	4	Steeper, medium-coarse sand beach (0.25-2.0mm).	Oil may sink 20mm into sand, clean up difficult	Maracas, Cumana, Icacos, Cedros.
	5	Exposed compacted sandy mudflats.	Oil does not penetrate can persist for one year.	Erin, Moruga, off Roussillac.
	6	Mixed sand & gravel beach.	Oil penetration rapid, clean up difficult.	Chaguaramas.
	7	Gravel-boulder beach.	Similar to above.	Cyrils' & Damien Bays.
	8	Sheltered rocky coasts.	Oil may persist for may years.	S. shores of offshore islands.
	9	Wetland.	Oil may persist for more than 10 years impact severe.	Caroni Swamp.