

4. HABITAT MAPS

4.1. INTRODUCTION

The purpose of creating habitat maps is to supply basic visual information to the Saudi Arabian authorities for the establishment of a system of conservation and appropriate management of the natural environment and biological diversity in the northern part of the Red Sea coast.

All habitats of the marine and coastal areas in the Study Area are identified and categorised into simplified habitat types. They are represented in different colours so that it is easy to understand how each habitat type is distributed and exactly where it is. This provides NCWCD with a very clear idea of the marine environment of the Study Area.

4.2. METHODS

4.2.1. AERIAL SURVEYS

The mosaic habitat zones in the Duba - Tiran area and the Al-Wajh - Al-Wajh Bank area were selected to interpret zonation patterns and to make a visual estimation of benthic attributes and cover categories from their different colours, for which information from the ground truth surveys were utilised. These areas were selected on the basis of information from existing literature and maps.

Aerial surveys were undertaken on 12 and 13 (Duba - Tiran area), and the 16 (Al-Wajh - Al-Wajh Bank) February 1998. For aerial surveys in the Duba - Tiran area, a single-engined aircraft was provided by NCWCD, and in the Al-Wajh - Al-Wajh Bank area, a helicopter was provided by the Ministry of Defence and Aviation. Flying altitude ranged from 150-600 feet above sea level.

The main objective of the aerial surveys was to compare colours and coverage of the habitats. In order to do so, the member of the Aerial Photograph Analysis Team flew with the Coral and Seagrasses / Algae Team members to observe the actual habitats and to understand

their colours and coverage. Video camera and still camera were used to record all these habitats and colours.

4.2.2. AERIAL PHOTOGRAPHS

A series of aerial photographs (164 lines, 3,347 prints) was taken during 3 June to 12 July 1998 (Table 136) covering the entire Study Area except for the Gulf of Aqaba and south of Rabigh.

The photographs covered the area between latitudes 23°N and 28°15'N. The marine area of 0-20 m depth was analysed for mapping, while the coastal belt area on the land 1-2 km wide was taken for the maps.

Habitat maps of 1:10,000 scale were prepared through a careful analysis of the aerial colour photographs. Further information obtained by the ground truth surveys was added to finalise the maps.

The list of aerial photographs is given in Appendix 23.

Table 136. Schedule of aerial photography.

Date of flight	Line and area
3 June 1998	Line 150, 152, 156 South of Yanbu'
	Line 158-163 Masturah
7 June 1998	Line 145-148, 151 Yanbu'
	Line 154-155 Shi'bal Sab'ah off Yanbu'
8 June 1998	Line 50 Al-Wajh
9 June 1998	Line 87-94, 101-104 South of Al-Wajh Bank
10 June 1998	Line 77-86, 109 South of Al-Wajh Bank
14 June 1998	Line 29-46 Duba
29 June 1998	Line 139-144 Yanbu'
30 June 1998	Line 115-131 Umluj
	Line 75-76 Al-Wajh Bank
4 July 1998	Line 105-108, 111-114 Umluj
	Line 130-139A North of Yanbu'
7 July 1998	Line 68-74 Al-Wajh Bank
	Line 106,110 Umluj
8 July 1998	Line 10-14, 19-24 Entrance to the Gulf of Aqaba
	Line 47-50 Duba
11 July 1998	Line 57-63 Al-Wajh Bank
	Line 2-4, 6-9, 15-18, 25-28 Entrance to the Gulf of Aqaba
12 July 1998	Line 51-56 Al-Wajh
	Line 149, 153, 157 Yanbu'
	Line 160-164 North of Masturah

4.2.3. CATEGORISATION OF HABITATS

All aerial photographs were examined individually to establish the discrepancy levels in such aspects as colour shifts until they could be satisfactorily printed as 1:10,000 scale aerial photographs. These were carefully analysed, and the habitats in the Study Area were classified into the categories shown in Table 137 and Photographs 10-1 – 8.

The habitat maps include important data on the social environment, such as factories, farms and fishing ports.

Table 137. Classification of habitat categories and their characteristics of colour and pattern.

Terrestrial Habitats		Marine Habitats	
D	Desert (yellow, orange, brown systems)	S	Sand (pale ocher, white, pale yellow)
Is	Island (yellow, orange, brown systems)	Md	Mud (brownish gray)
Tf	Tidal flat (brown, dark brown, moss green)	Rp	Sand with Reef Patches (Coral less than 10%) (scattered gray, brown)
Ro	Emerged rock (dark orange, dark brown)	C-1	Coral (coverage 11-30%) (white, gray, brown)
M	Mangrove (dark green, brown)	C-2	Coral (coverage 31-50%) (white, gray, brown)
V	Coastal vegetation (brown, greenish brown)	C-3	Coral (coverage 51-75%) (white, gray, brown)
Sk	Sabkhah (with Cyanophyceae and Salt marsh) (black, brown, gray)	C-4	Coral (coverage 76-100%) (white, gray, brown)
Sm	Salt marsh (scattered brownish green based Sabkhah)	T/Sa	Turf/Small algae (scattered pale or dark brown, black)
Fm	Farm (confirmed by forms)	Ma	Macro algae (patched pale or dark brown, black)
Lv	Fence of livestock (confirmed by forms)	Sg	Seagrass (patched dark bluish greenish black)
Fp	Fishing port (confirmed by forms)	Cy	Cyanophyceae (blue-green algae) (patched dark brown or true black)
Tw	Town area (confirmed by forms)	Se	Sea (blue, green)
Fc	Factory (confirmed by forms)		

N.B.: Colours of habitats in the marine environment appear bluer when they are deeper in the sea because of the colour of the seawater.

4.2.4. UTILISATION OF THE RESULTS OF THE GROUND TRUTH SURVEYS

Information from the ground truth surveys throughout the Study Area and in the Model Area was used to verify the categories and the coverage of coral.

4.2.5. AERIAL VERIFICATION

In order to verify and revise the categories of the habitat maps, aerial surveys flying at altitudes of 500 to 1,000 feet covering the Model Area were conducted on 15 and 16

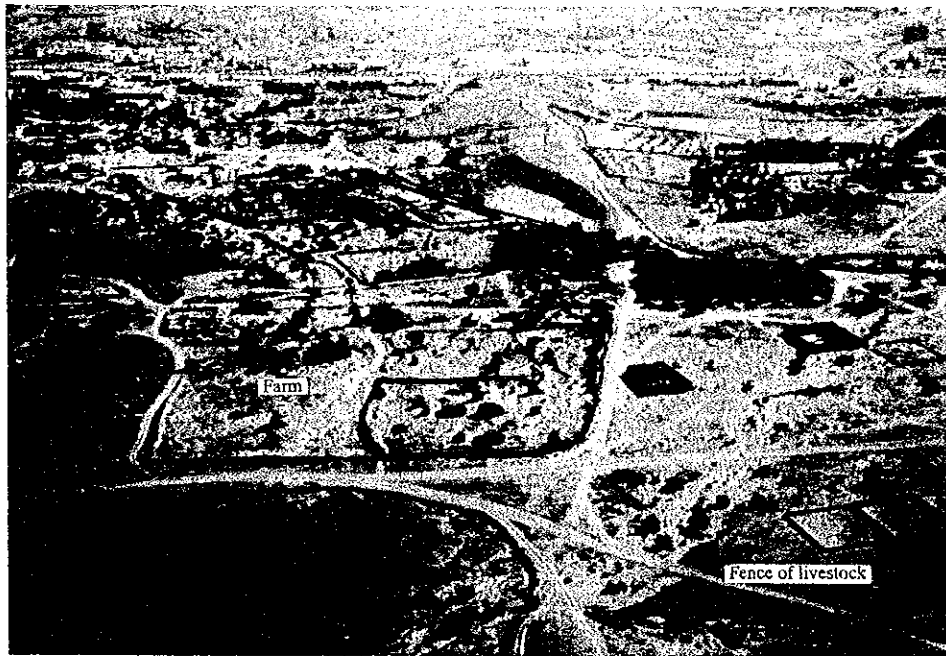
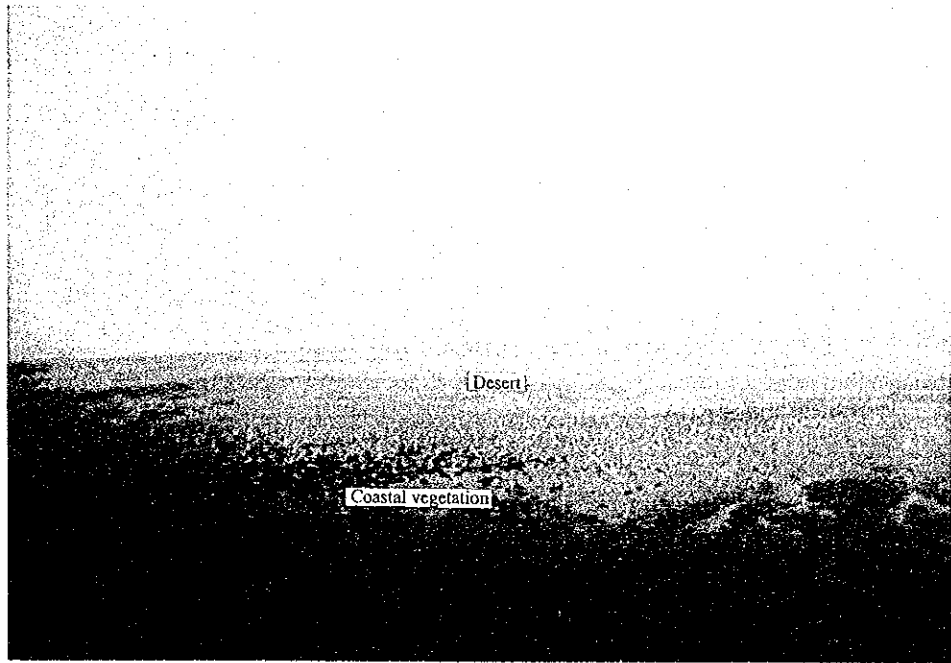


Photo. 11-1. Examples of habitat categories in photographs taken in the aerial survey.



Photo. 11-2. Examples of habitat categories in photographs taken in the aerial survey.

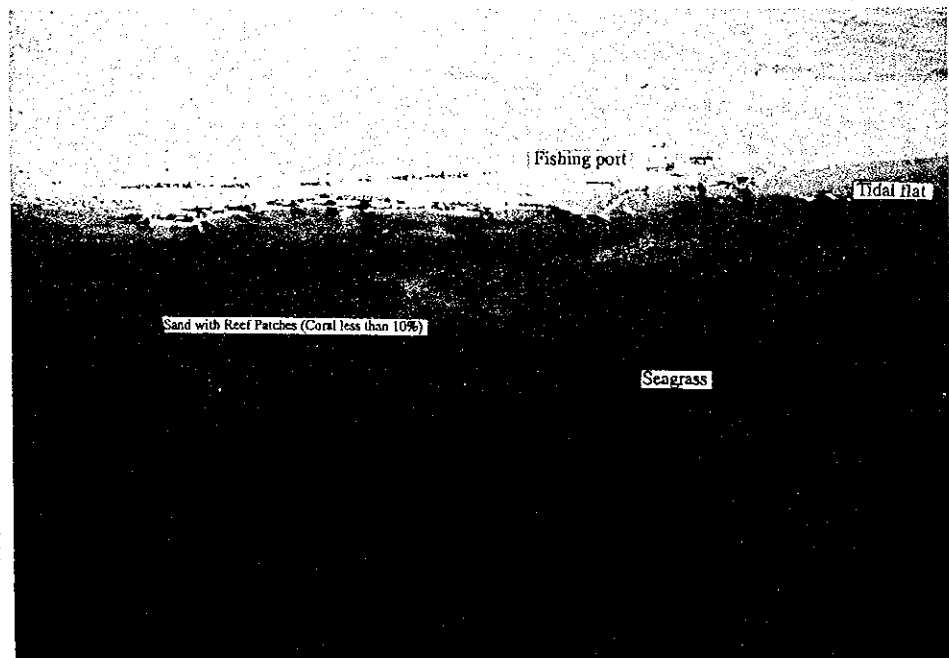
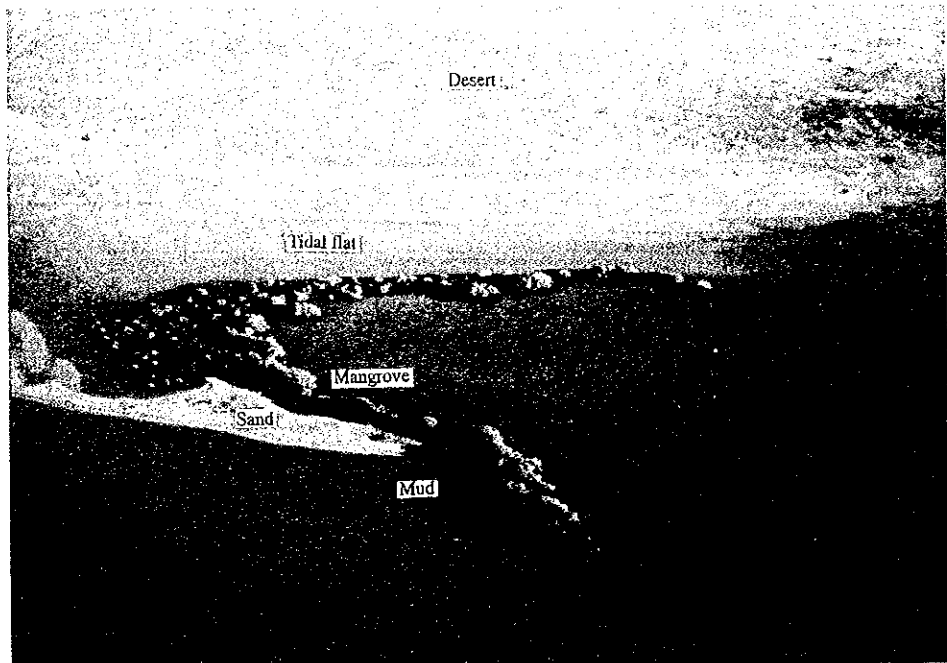


Photo. 11-3. Examples of habitat categories in photographs taken in the aerial survey.

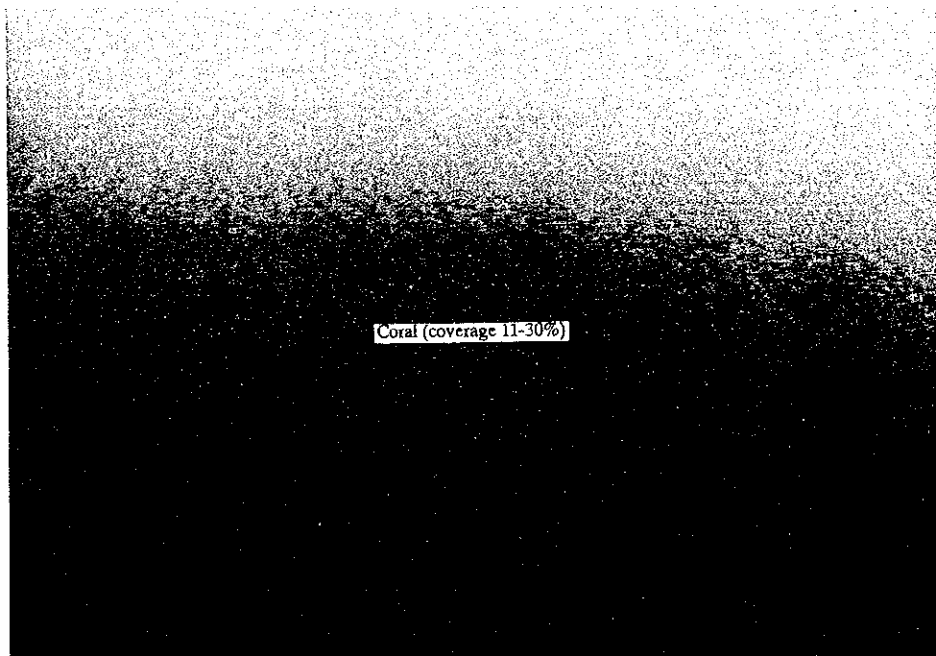


Photo. 11-4. Examples of habitat categories in photographs taken in the aerial survey.

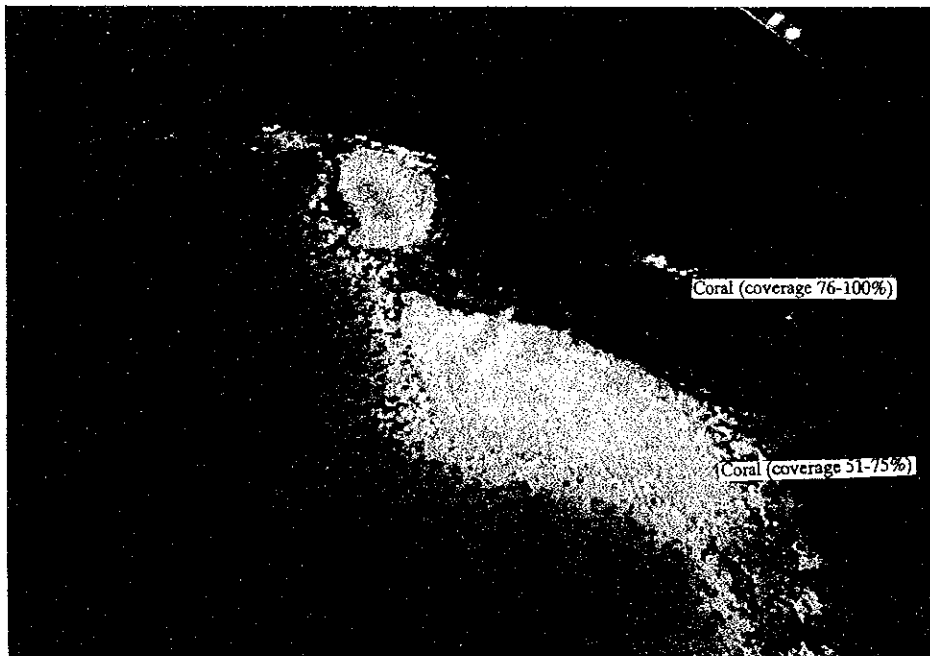
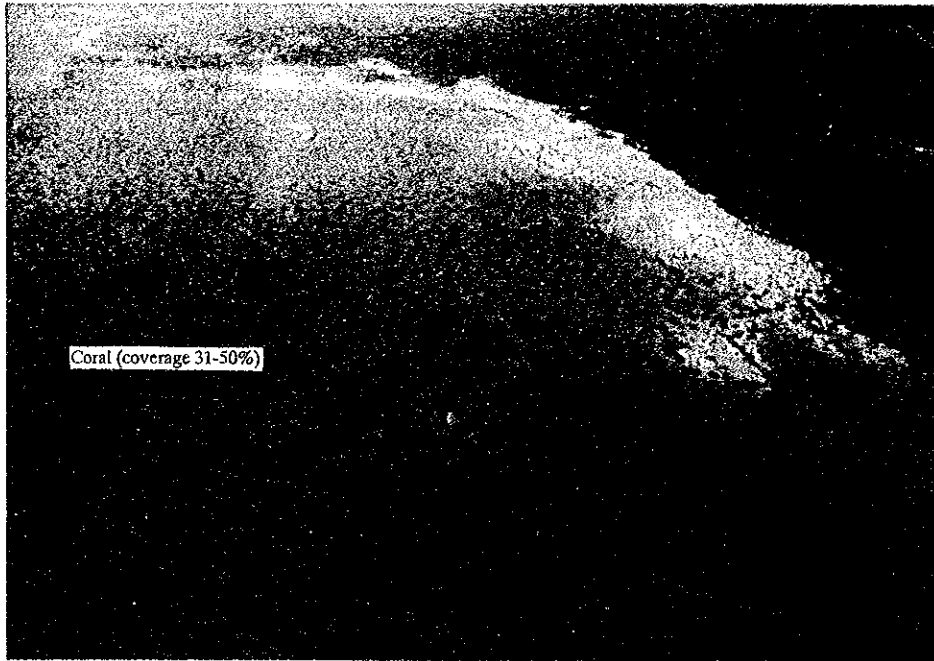


Photo. 11-5. Examples of habitat categories in photographs taken in the aerial survey.

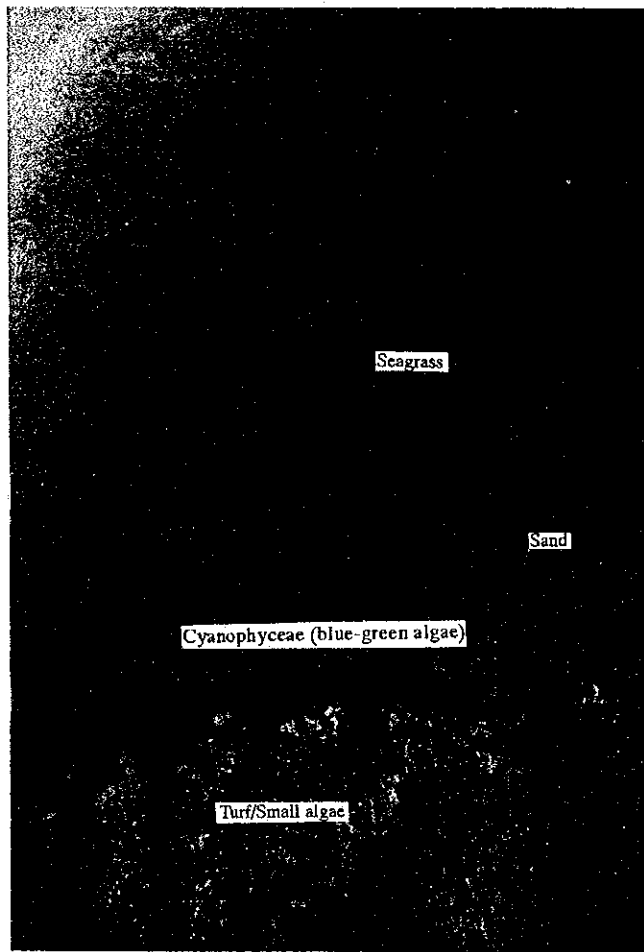
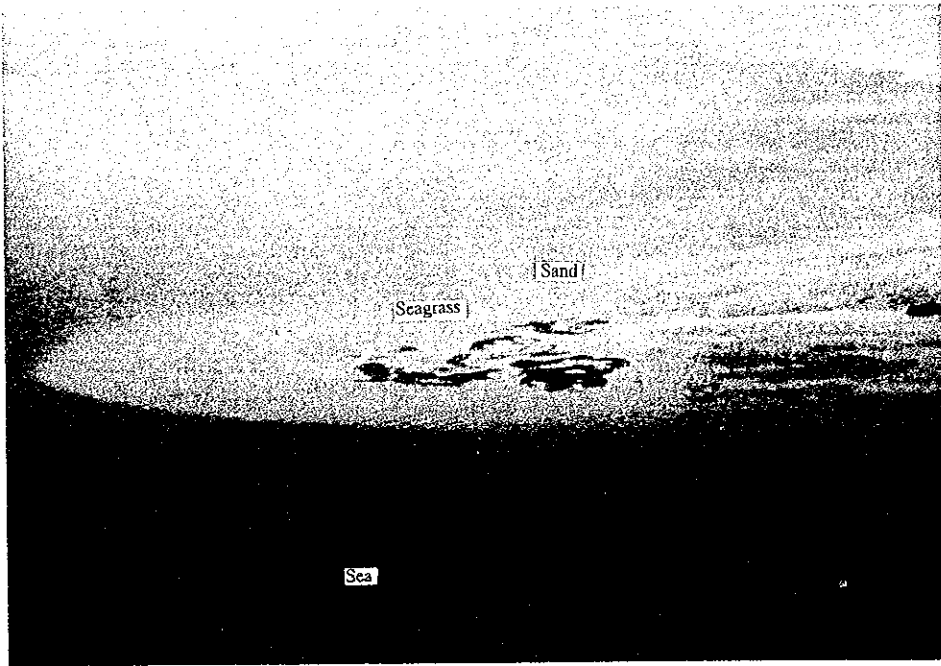


Photo. 11-6. Examples of habitat categories in photographs taken in the aerial survey.

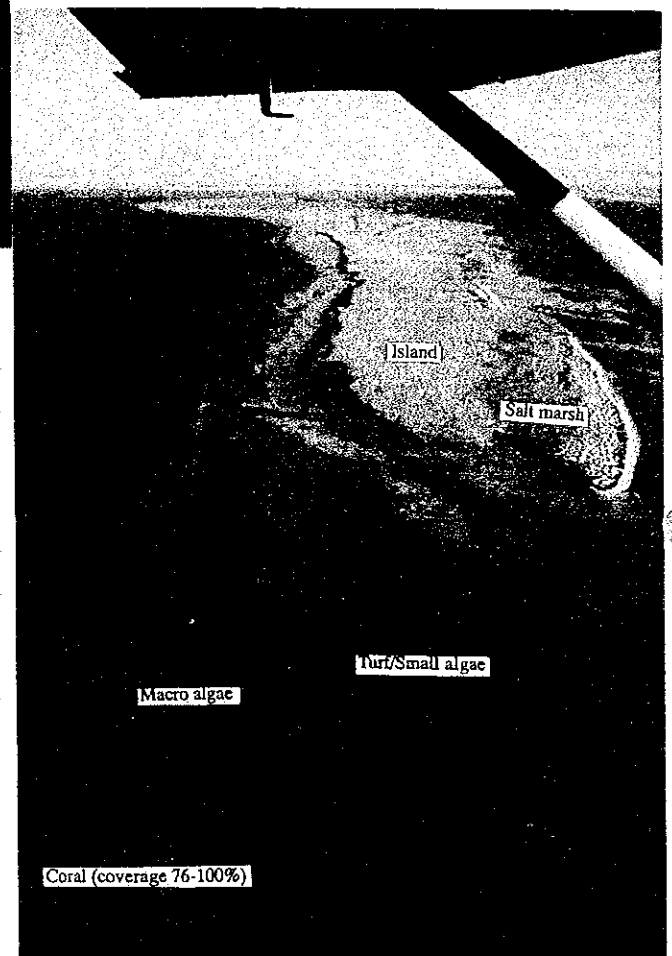
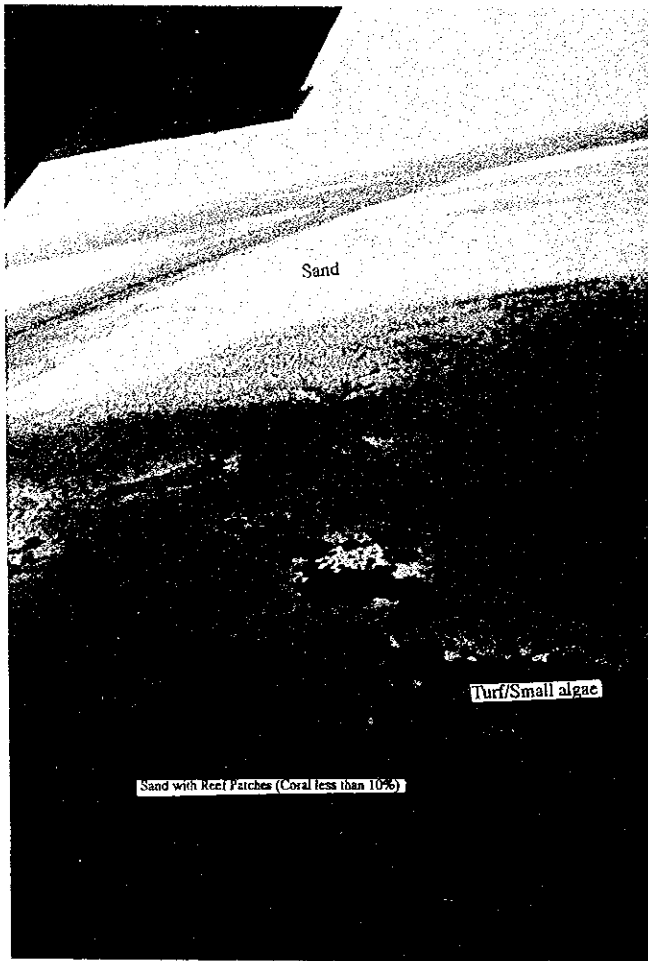


Photo. 11-7. Examples of habitat categories in photographs taken in the aerial survey.

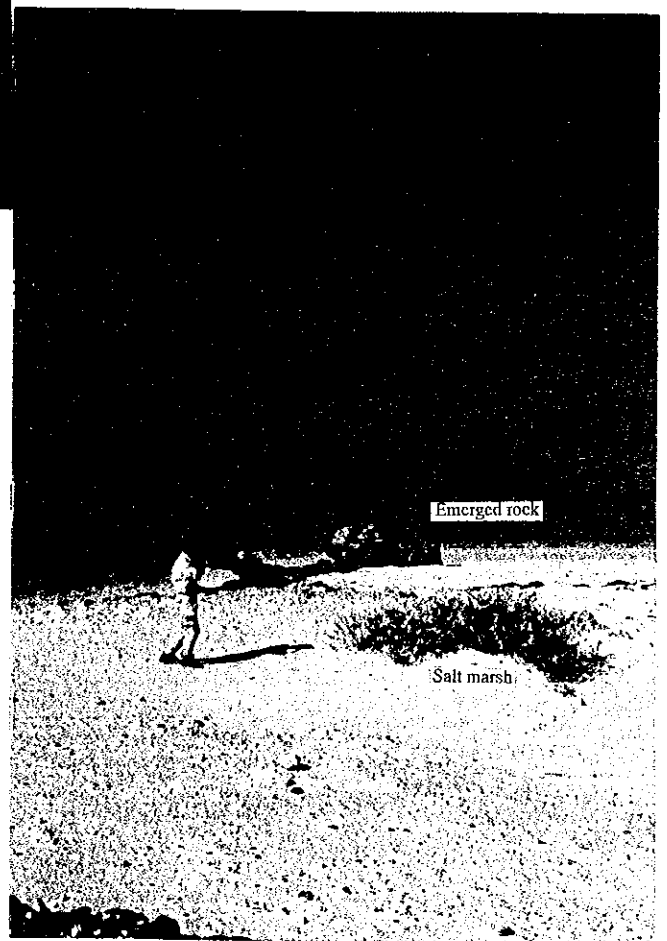
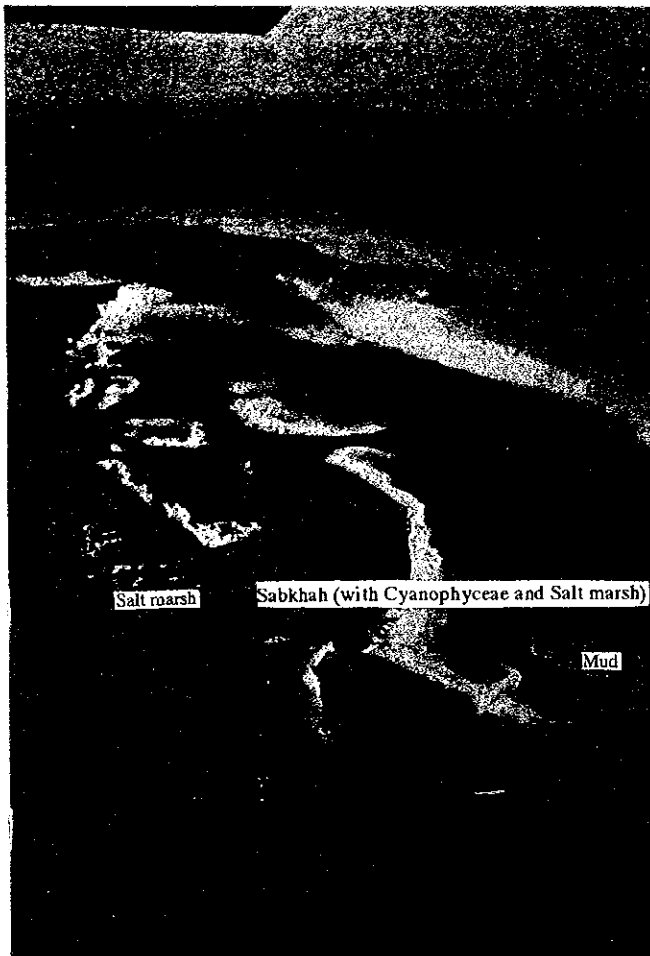


Photo. 11-8. Examples of habitat categories in photographs taken in the aerial survey and ground truth surveys.

February 1999. The main habitats of the Model Area were recorded on video tape and photographs were taken. An aircraft of NCWCD was utilised.

4.2.6. SATELLITE IMAGERIES

Aerial photographs were not taken in the areas of the Gulf of Aqaba and south of Rabigh because these areas are restricted for national security reasons. Habitat maps of both areas were completed by utilising satellite imageries taken by "JERS-1: OPS" on 31 July 1996 and 6 and 7 April 1994. JERS-1 is operated by the National Space Development Agency of Japan.

4.2.7. SUMMARY OF THE PROCESS

The entire process of drawing the habitat maps was summarised as follows, and a flow chart is shown in Fig.81.

- 1) An index list of the photographs was made in order to find in the most efficient and easiest way whichever photograph was needed for analysis (Appendix 24).
- 2) Coverage of each habitat zone was hand-traced onto tracing paper.
- 3) The traced habitat map was reduced to a scale of 1:50,000, and then traced onto a topographical map of the same scale.
- 4) Supplemental data and information from the ground truth surveys and the aerial verifications were used to improve the precision of the aerial photograph analyses.

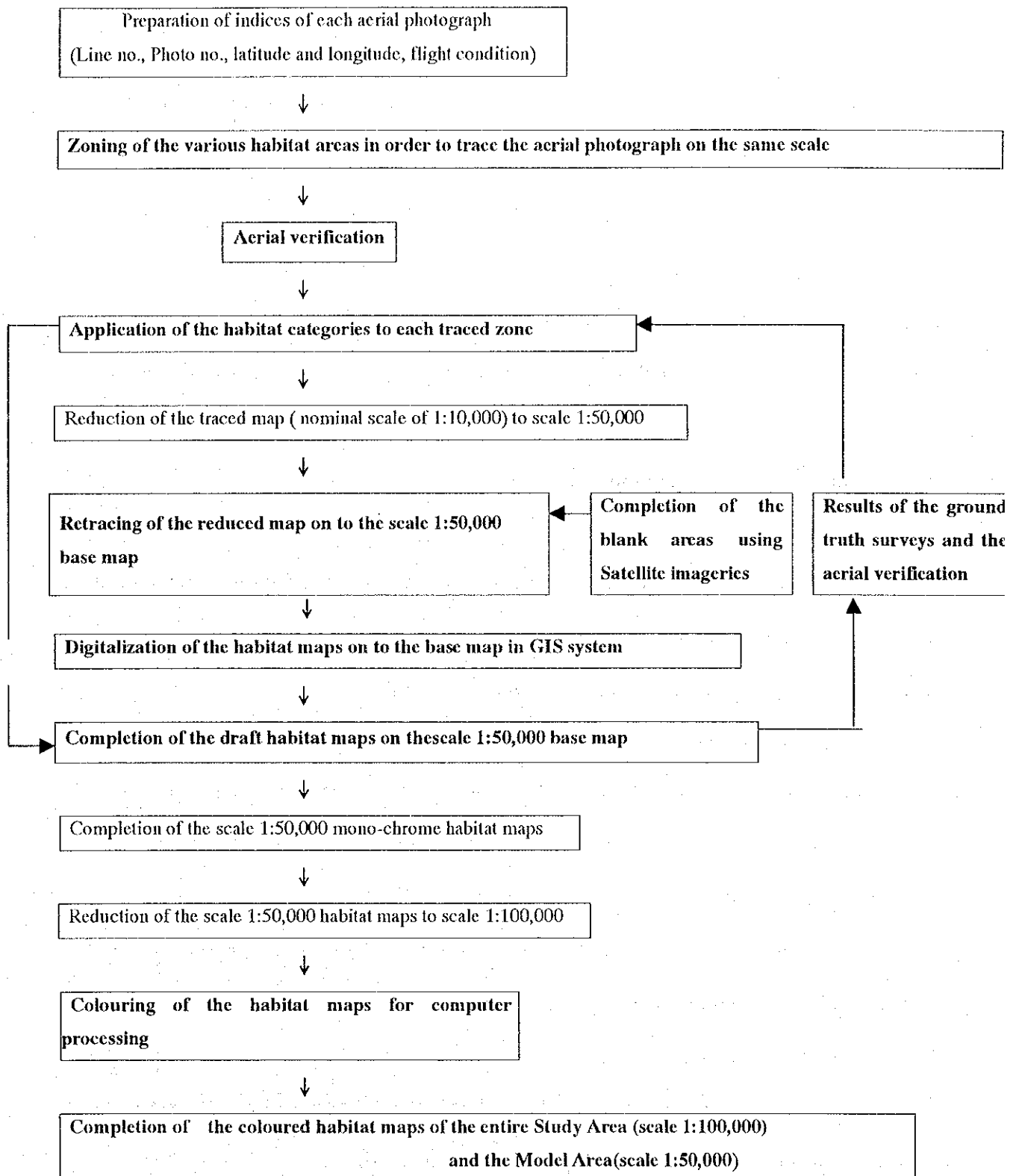


Fig. 81 Flow chart of process for drawing up the habitat maps (cells in bold letters are important steps).

4.3. RESULTS

4.3.1. HABITAT MAPS

The habitat maps of the Study Area (1:100,000) and the Model Area (1:50,000) are presented in Separate Volume 2 and 3, respectively.

In the areas of the Gulf of Aqaba and south of Rabigh habitat maps of which were completed using satellite imageries, the coral is represented in only one category as it was not possible to analyse the coral coverage in detail from prints of the satellite imageries. This is because the resolution of the satellite imagery was too lower to be able to recognise the details of the habitats.

Distribution of habitats in the Study Area

Varied, large expanses of habitats are found at the entrance to the Gulf of Aqaba, in the area from Al-Wajh Bank to Jazirat Jabal Hassan and the area from Masurah and Rabigh.

At the entrance to the Gulf of Aqaba, the variety and extent of habitats are ranked at the middle level because of the absence of a mangrove habitat.

In the northern part of Al-Wajh Bank, the variety of habitats is ranked the same as that at the entrance to the Gulf of Aqaba. There are mangrove habitats, and the coverage of coral is monotonous compared with that of the southern part. The extent of habitats is ranked high in the northern part.

In the southern part of Al-Wajh Bank, the variety of habitats is ranked at the highest level because of the complex geomorphic features. The extent of habitats in this area is ranked higher than in the northern part.

In terms of both variety and extent of habitats, the southern part of Al-Wajh Bank is evaluated as the most important and interesting site in the Study Area.

The rest of the Study Area does not have habitats that are as varied and / or extensive.

4.3.2. GROUND TRUTH SURVEYS AND RE-CATEGORISATION OF HABITATS

Supplemental data and information from the ground truth surveys were utilised for the revision of categories on aerial photographs in order to draw up the draft habitat maps. Habitat information on coral came from 109 spots, on seagrass / algae from 108 spots, on fish from 45 spots, on benthos from 61 spots and on mangrove / coastal vegetation from 70 spots in the Study Area.

In addition to consideration of seasonal fluctuations in biota, the habitat maps were improved (re-categorised) using the results of the ground truth surveys throughout the Study Area and in the Model Area.

The re-categorisations and revisions as the followings were made.

1. "Seagrass" and "Cyanophyceae" categories

The colours of "Seagrass" and "Cyanophyceae (blue-green algae)" were the same on the aerial photographs, but it was clarified from the ground truth surveys that Cyanophyceae forms colonies on silt (mud) substrate where water flow is slow due to topographic features, while colonies of seagrass appear on sand substrate where the topographic features generate moderate water flow to sweep the silt (mud) out. Therefore, the colour on the silt (mud) substrate was re-categorised as "Cyanophyceae (blue-green algae)" and the colour on the sand substrate was categorised as "Seagrass".

2. "Turf / Small Algae" and "Macro Algae" categories

The colour of "Turf / Small Algae" and "Macro Algae" were the same on the aerial photographs. It was clarified from the ground truth surveys that colonies of macro algae grow on the edge of the barrier reef facing towards the open sea, directly affected by strong wave energy. Although the reef flat is predominated by colonies of turf / small algae, colonies of macro algae also develop at the end of the reef flat where the waves strike directly on the hard

substrate.

Therefore, the colour on areas exposed to strong wave action was categorised as “Macro Algae” and the rest as “Turf / Small Algae”.

3. “Coral” categories

At the beginning hard coral coverage was ranked into five grades in the habitat maps, such as “Hard Coral 1-10%”. There is one more category related to coral habitat: “Reef Patches”.

The name “Hard” is misleading. This is because there are generally two types of coral: hard coral and soft coral. Soft coral does not appear on the aerial photographs at all. Therefore, the category “Hard Coral” was changed to “Coral”.

It is difficult to distinguish “Reef Patches” and “Hard Coral coverage 1-10%”. One new category of “Sand with Reef Patches / Coral less than 10%” was created to include both of the above two categories.

4.3.2. IMPROVEMENT OF THE HABITAT MAPS

The habitat maps made in this study were based mainly on the aerial photographs taken in summer from 3 June to 12 July 1998, at an altitude of about 5,000 feet. The information from the ground truth surveys in winter (February 1999) and early summer (June 1999) in the Model Area was also incorporated into the habitat maps to improve the precision of the aerial photograph analyses. As the information from the ground truth surveys was limited because of the lack of time, only two seasons and several parts of the Study Area were covered, hurriedly; complementary studies will be needed covering the entire Study Area in the future to up-grade the precision of the habitat maps.

The habitats gradually change in quality and quantity. Habitats of seagrass, algae and coastal vegetation growing on the inter-tidal zone in particular, change rapidly in comparison

with coral in the water. After large-scale flooding, the organisms in the inter-tidal zone and the shallow water area will be strongly affected by large amounts of soil sedimentation and freshwater discharged from the land; consequently, it is expected that the habitats of these organisms will change. Therefore, aerial surveys and ground truth surveys should be conducted at least once every 5 years, or immediately after only large scale flooding.

5. GEOGRAPHICAL INFORMATION SYSTEM

(GIS) / DATABASE

5.1. INTRODUCTION

5.1.1. GEOGRAPHICAL INFORMATION SYSTEM

By collecting, analysing and managing data on the natural resources of an area, we are able to understand the current status of those natural resources. In order to do this smoothly and effectively, the Geographical Information System (GIS) is employed. Data from dozens of sources can be consolidated on GIS overlays and the relationships between various factors such as social environment and biological resources can be examined. It is also possible to monitor changes in these factors over time. This enables us to understand environmental issues affecting the target area.

Another advantage of using GIS is that it can present very complex and technical data visually, making it very easy for not only professionals but also non specialists to understand.

The key components of a successful GIS operation are as follows:

- Vision to use GIS; leadership and management support;
- Data maintenance; and
- User training

5.1.2. PREPARATION OF GIS

For the preparation of the GIS, the hardware and software listed below was purchased.

Hardware

Materials purchased in the Kingdom of Saudi Arabia

A0 Colour Plotter

CALCOMP A0 Size Plotter

Materials purchased in Japan

Computer

COMPAC Desktop Pro 4000X

223MHz Pentium Processor with MMX

	3.2GB Hard Disk Drive
	1.44MB Diskette Drive
	CD-ROM Drive
17 inch Colour Monitor	COMPAQ 17inch Colour Monitor
32MB RAM	COMPAQ 32MB RAM for Upgrade
MO Disk Drive	LOGETEC LMO640F/P
A4 Laser Printer	EPSON LP-1800
A2 Colour InkJet Printer	EPSON MJ-6000C

Software (materials purchased in the Kingdom of Saudi Arabia)

ArcView Ver.3.0	ESRI (GIS Software)
Windows95	Microsoft (English with Arabic language support)
MS Word	Microsoft (English with Arabic language support)
Access	Microsoft (English with Arabic language support)

5.2. STRUCTURE OF THE DATABASE

5.2.1. PREPARATION OF GIS DATABASE (digitising of base maps)

Preparation of the base maps for the GIS database was arranged by digitising the 1/150,000 scale maritime charts. The area covered is from Jeddah to the Gulf of Aqaba near the border with Jordan. Fig. 82 shows the output of digitised maritime charts. The base maps were digitised in vector format for storage. Data are recorded as distinct points, lines or areas (polygons). Information on points, lines and areas is encoded and stored as collections of x-y coordinates. Point features represent the locations. Cities are examples of point features.

Roads are examples of line features. Area features are delineated by closed boundaries, such as islands. Fig. 83 shows the flow of work in digitising for the GIS.

5.2.2. DATA CONVERSION

The data conversion process is carried out to collect, coordinate and clean up the data before it is converted to a digital format. Therefore, the first step in data conversion is to compile all data from the field survey, check them for completeness and gather in missing information.

When the data are compiled and all source records are completed, these data will be attached to the corresponding graphic data features (Fig. 84). The graphic data and the attribute data are then explicitly linked, so that there are 1 to 1 correspondences between map features and attribute data records. After this process has been completed, GIS can quickly search through the map data, looking for features with certain characteristics or inspecting spatial relationships between features. These data are digitised and stored as a collection of x-y coordinates which is organised in map features separately by layer.

The Meteorology & Environmental Protection Administration (MEPA) provided NCWCD with digital maps which include the coastal area of the Red Sea. Marine charts of scale 1:50,000 were mainly used for digitising. 5 m, 10 m and 15 m sea depth data provided by MEPA was used in this project.

5.2.3. Structure of the database

For GIS to be practicable, the database must be structured. The database format is shown in Fig. 85.

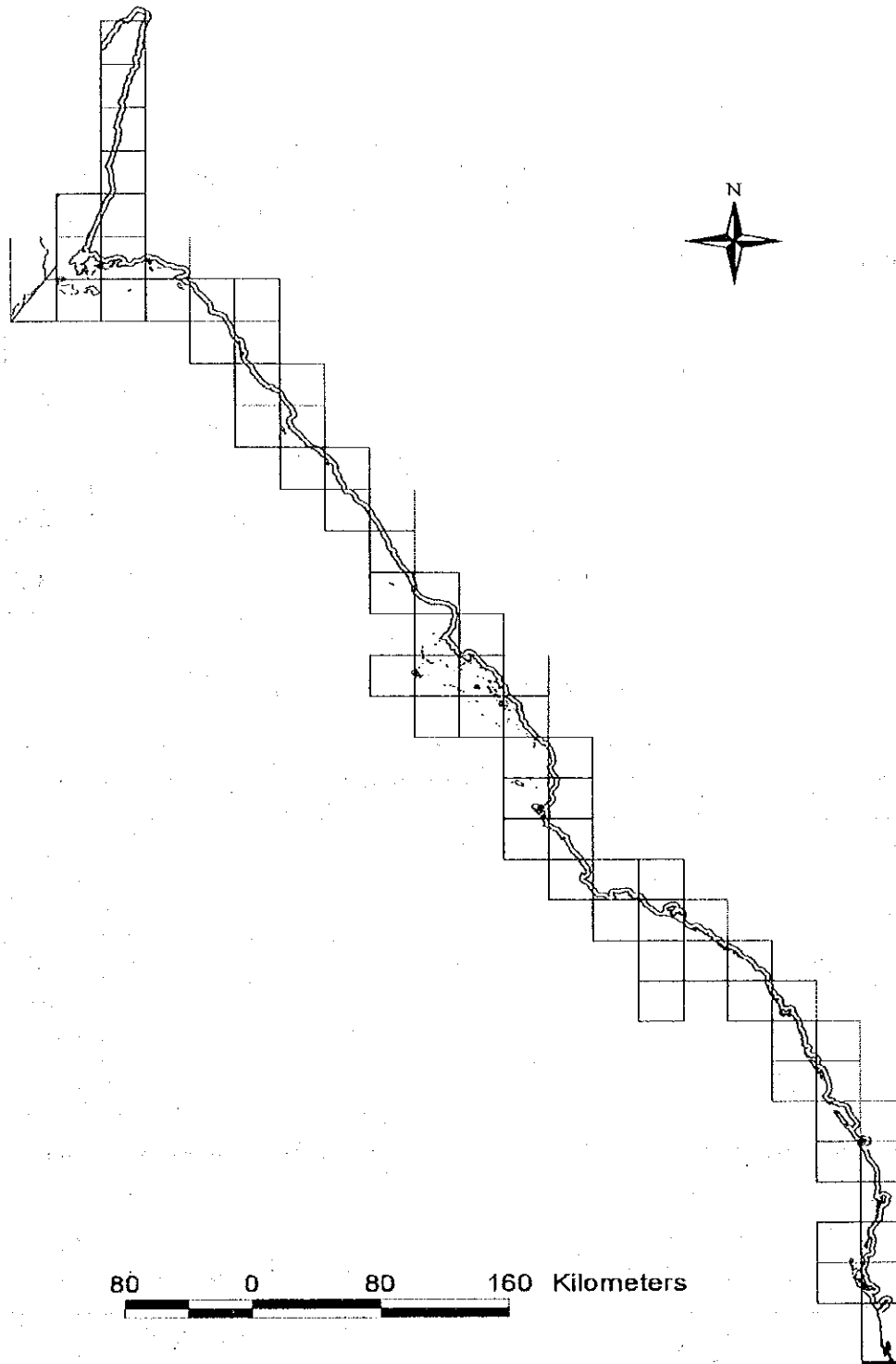


Fig. 82. Output of the digitised maritime charts.

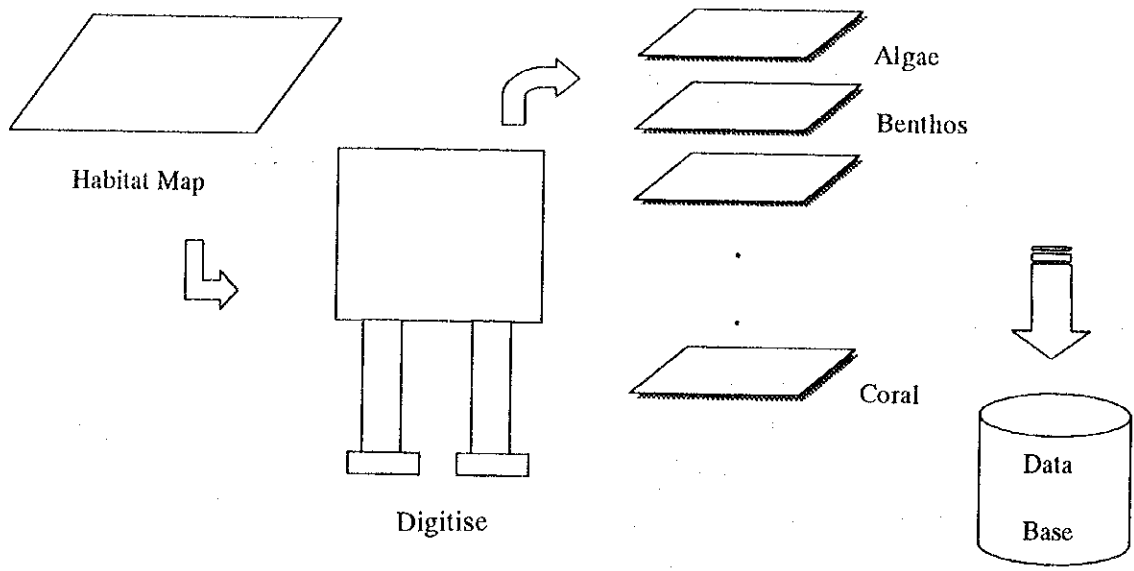


Fig. 83. Digitising data for GIS.

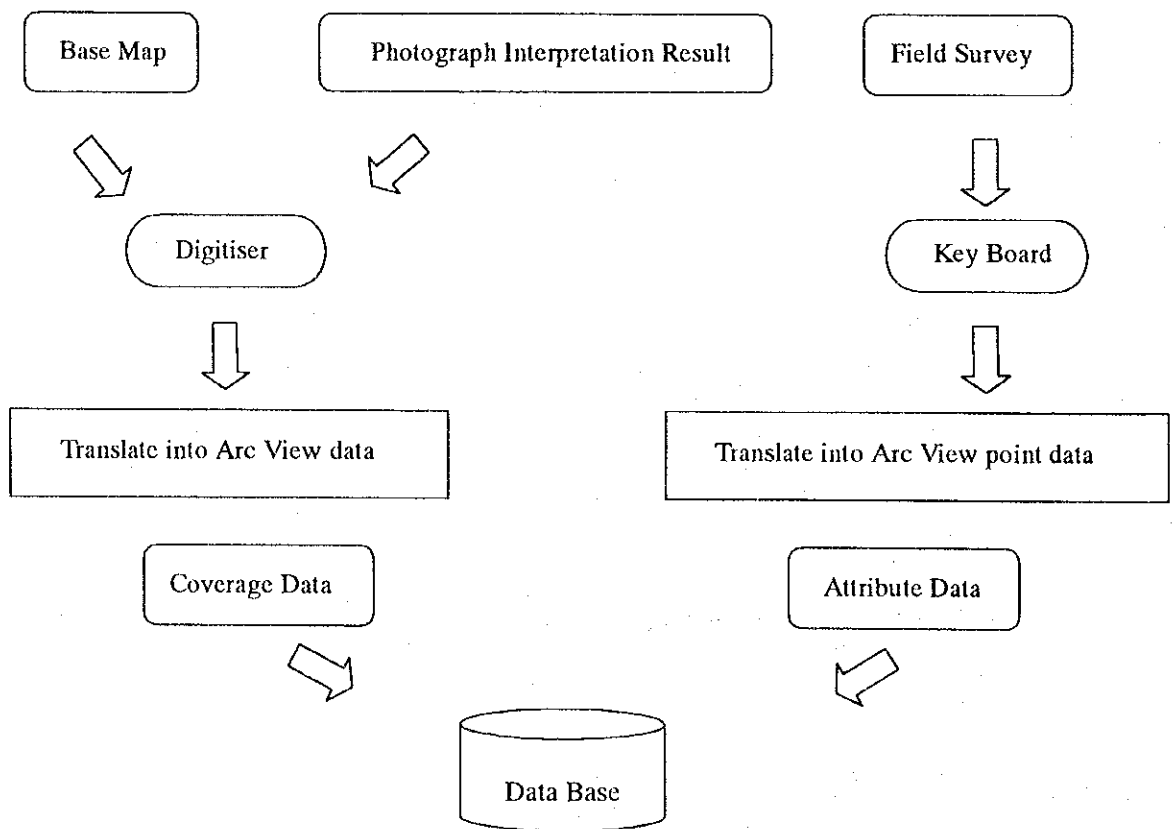


Fig. 84. Data conversion flow.

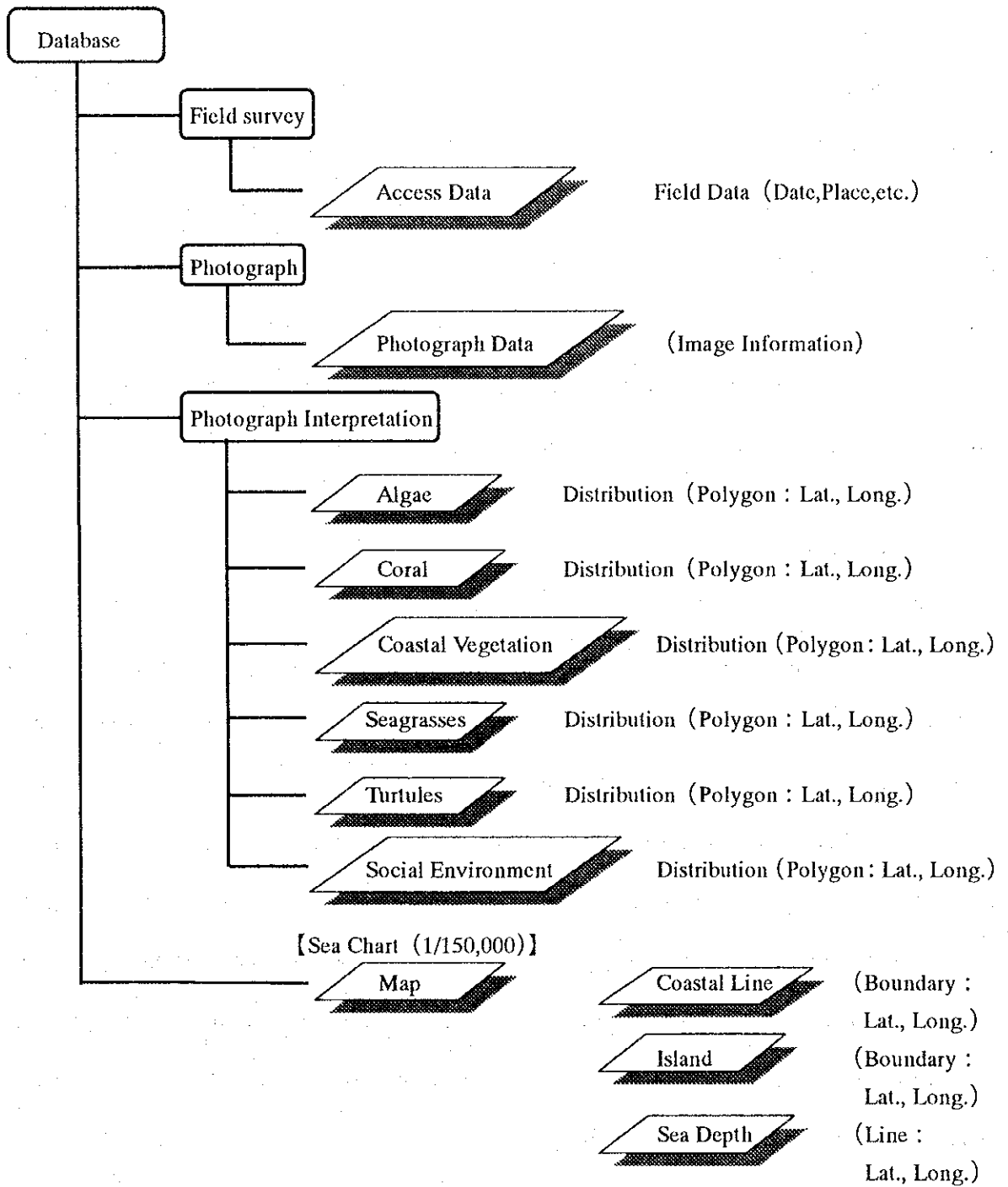


Fig. 85. Database structure.

5.3. GIS SOFTWARE

5.3.1. ArcView 3

For this project, a GIS software package, ArcView (Ver.3.0), was used. ArcView is a desktop geographic information system created by Environmental Systems Research Institute, Inc. (ESRI). With ArcView, any data linked to geographic locations can be loaded and displayed graphically as maps, charts and tables. ArcView uses five types of component to organise information, views, tables, charts, layouts and scripts. Each component displays data differently and has its own related menus, buttons and tools organised in a unique interface. An manual how to operate the software is attached as Appendix 26.

5.3.2. Customisation

(1) Customisation of the software

User-friendliness is one of the most important factors in computer software. If the software is user-friendly and easily accessible for use by persons with little programming experience, users will gain maximum advantage from GIS.

ArcView is designed to meet the needs of the largest possible number of users for many purposes, and it has capabilities for many types of application. In order to obtain the maximum capability for use with GIS, it was necessary to customise the software is necessary. Customisation allows the user to operate GIS using single easy command. Examples of customisation include an interactive front-end driver programme, which uses a menu type system to control each programme module.

The items customised were as follows (Fig. 86).

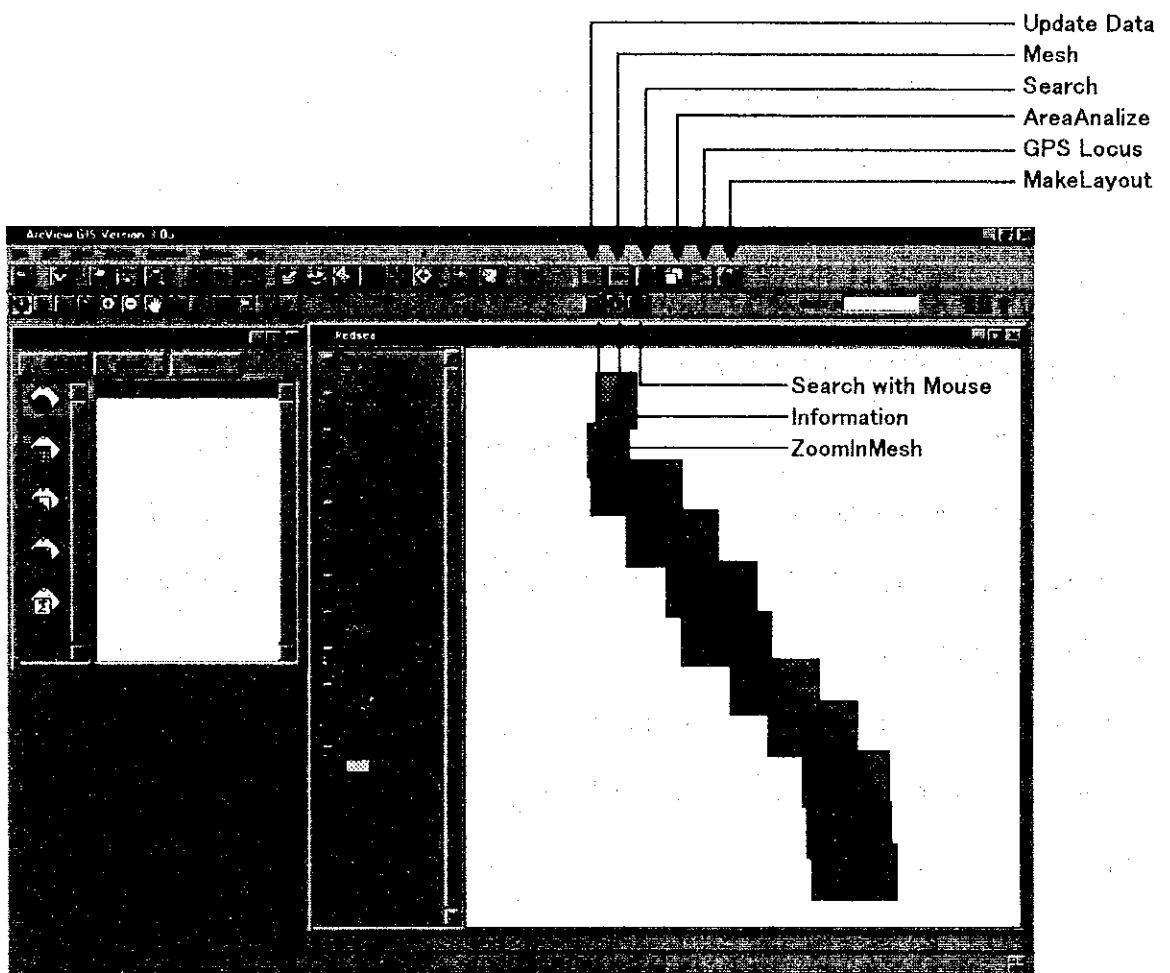


Fig. 86. A window customised for a special application.

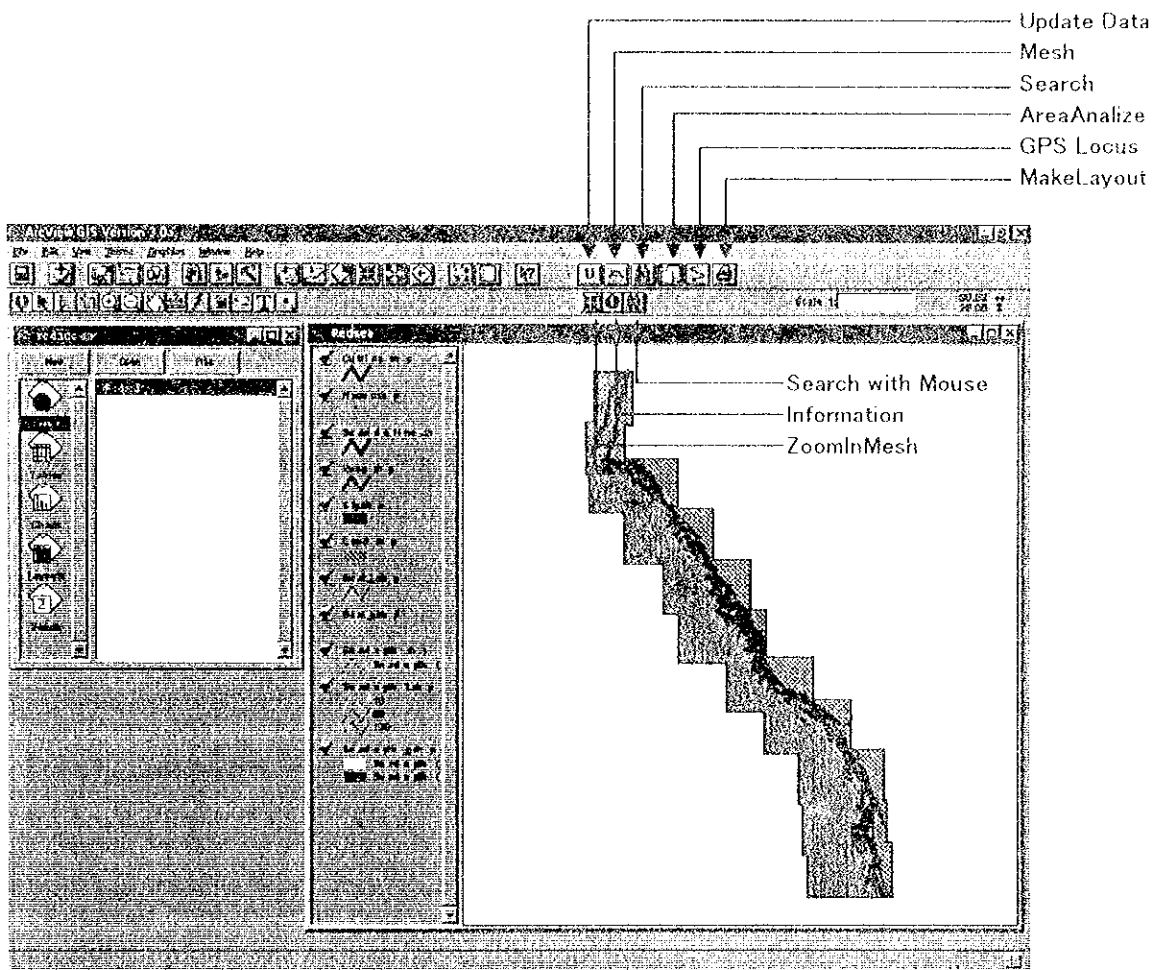


Fig. 86. A window customised for a special application.

Update Data: Icon to update data.

- Grid: Icon to overlay mesh on the map.
- Search: Icon to search inventory data (using inventory code, classified name, scientific name, observed date and location).
- Area Analyse: Icon for estimating area.
- GPS locus (location): Icon to draw a line using GPS data.
- MakeLayout: Icon for making automatic layout.
- ZoominMesh: Icon to zoom.
- Information: Icon to show inventory information.
- Search with Mouse: Icon to search for items using the mouse.

5.4. COUNTERPART TRAINING

5.4.1. TRAINING IN SAUDI ARABIA

GIS is a new technology which represents different way of manipulating geographic information. The introduction of GIS has created a need for users of geographic information to become knowledgeable about this technology. Even people who are familiar with computer commands and keyboard instructions may be very unfamiliar with computer mapping concepts and computer-based geographic information handling. Therefore, a series of GIS counterpart training sessions was conducted to improve counterparts' skills and allow them to make better use of this system.

Major exercises conducted are listed below.

1. Classifying features based on their attributes

The counterparts learned how to use tools in ArcView to classifying and presenting information.

2. Measuring distance and area in a view

The counterparts learned the advantages of GIS in measuring distance and area on the surface of the earth directly from the computer.

3. Managing scale

The counterparts learned how to set a scale for a view and how to set scale thresholds for themes.

4. Managing tabular data

The counterparts learned how to use the hot-link function, which is operated by a set of commands to link a feature in a theme to a text file, an image or other ArcView project.

5. Analysing spatial relationships

ArcView uses theme-on-theme selection to analyse the locations of features in relation to other features, whether in the same theme or in different themes. The counterparts focused on the analysis of proximity and adjacency relationships.

6. Presenting information

The counterparts created a chart then modified its characteristics, and used it to access information and edited its source table.

5.4.2. TRAINING IN JAPAN.

GIS training for a duration of six weeks was held twice (1998 and 1999) in Japan. The key goal of the training was to understand techniques in making a database for GIS and to learn how to use the GIS software. This was an initial user training. The items learned were as follows.

1. Creating maps

Learning how to create a new map using some of the spatial data.

2. Adding tabular data about features to a map

Learning how to add data to the attribute table.

3. Symbolising data

Learning how to symbolise data. Also, grouping or classifying features according to attribute values.

4. Layout and printing of maps

Learning how to produce presentation-quality maps.

When the basic training is finished, it is also important to offer advanced training, to provide counterparts with the opportunity to improve their skills and to make better use of the GIS. The key goals of the advanced training are as follows.

- Understanding techniques in making a database for GIS.
- Learning how to use GIS in various fields.
- Learning how to use GIS software, especially ArcView.

6. EVALUATION OF THE STUDY RESULTS

6.1. INTRODUCTION

The Study Area is extended 1,000 km long and has a width of 1 km from shoreline to land and up to 15 m depth in the marine environment. The present data are limited within this area. Species identification is conducted by conventional techniques within the Study time frame. New scientific classification technology using genetic analysis might produce different results in the future. The Study primarily aimed at an understanding of the structure of the ecosystems, not of their functions and linkages as these may be done in future. The habitat maps show a mosaic of habitats covering land and sea in the Study Area. Interaction and / or intervention between the habitats could not be evaluated because of the lack of physical data, such as oceanographical data, which could make a simulation of natural and human activities possible. Thus, the Study results are evaluated within these limitations.

6.2. SUMMARY MAP

6.2.1. INTRODUCTION

In order to programme appropriate and effective conservation management of the natural environment in the Study Area, a precise understanding of the current status of the area and a categorisation of the natural and social environments into appropriate zones are essential. The compilation of appropriate data from the Study into one map is the easiest way for decision makers or protected area planners to gain a visual understanding of the current status of the natural environment.

With regard to the natural environment, data on important taxa is given a score to indicate the current status in each area. With regard to the social environment, current and planned human activities (e.g. industry, agriculture, tourism) in the environment are listed and mapped. The data are compiled into one for the integration with natural and social environment indices to produce one summary map.

6.2.2. METHODS

In order to make preliminary site assessment using the Study results, a series of habitat map data were integrated for preparation of a summary map. On the summary map, areas of special interest in terms of conservation of the natural environment are to be identified. The entire Study Area, except for the Gulf of Aqaba and the southern area of Rabigh where the essential aerial photos are lacking, is marked off for every 15 minutes of latitude and longitude on the summary map. The data from the habitat maps are converted to indices in the following groups. Each group is presented as a map.

1. Extent of marine areas shallower than 20 m (index rank 1-5): Map 1 (Fig. 87)

Marine habitats up to about 20 m in depth can be analyzed from aerial photographs. These shallow areas are basically the most productive habitats. Large shallow areas indicate large productive areas in the Study Area.

2. Numbers of habitat categories (index rank 1-5): Map 2 (Fig. 88)

Habitats each have their own ecological structure and functions. Each habitat requires other habitats for its survival. A complex of habitats is important to species and this ecosystems as well as functional diversity. An area which has more habitat categories has greater diversity of species, ecosystems and ecological functions.

3. Extent of habitat {(Extent of marine areas shallower than 20m) × (Numbers of Habitat categories)} (index rank 1-5): Map 3 (Fig. 89)

The extensiveness and the diversity of habitats per unit area are mutually contrary categories. The extensiveness of habitats is as equally important as the diversity. ①

indicates the extensiveness of productive areas and ② indicates the diversity of species, ecosystems and functions. The two are integrated into one index which takes extensiveness into account.

4. Extent of coral { Σ (Coral coverage, rank (1-5) \times (Coral extent, rank 1-5)) (index rank 1-5): Map 4 (Fig. 90)

Coral reefs are an important habitat, providing areas for fish and shellfish to live and shelter in. Five categories of coral coverage were analysed on the aerial photographs. Coverage and surface area of the habitat are equally important. Coverage rank multiplied by surface area was used to calculate the abundance of coral reefs in an area to give the index ranks

5. Extent of seagrass colonies (index rank 1-5): Map 5 (Fig. 91)

Seagrass beds are an important habitat as a primary producer; a spawning ground for fish and shellfish, a living area for fish fry, an area of shelter for fish and a feeding ground for Dugong and Green Turtle. Seagrass beds are highly divergent because of their complex ecosystems. The extent of seagrass beds is contrary to the extent of coral reef, but equally important in an assessment of the area.

6. Extent of algae colonies (index rank 1-5): Map 6 (Fig. 92)

Colonies of algae are also important as a primary producer; supplying spawning, growing and hiding grounds for fish and shellfish just like seagrass beds. Colonies of algae are also highly divergent. The extent of algae colonies is contrary to the extent of coral reef, but equally important in an assesemnt of the area.

7. Extent of mangrove communities (index rank 1-5): Map 7 (Fig. 93)

The extent of mangrove communities in the Study Area is important for their greenery, because the hinterland is mainly desert. The nutrients originating from the mangrove habitats are diffused in to the ocean by flooding and support many other species. Mangrove communities play a vital role in providing nutrients to tidal zones. Birds live in mangrove communities; benthos living under the mangroves feed on the decomposed fallen leaves. Therefore, mangrove communities play an important ecological function in supporting other species and their productivity.

8. Extent of colonies of Cyanophyceae (index rank 1-5): Map 8 (Fig. 94)

Cyanophyceae thrive even in a severe environment such as the Sabkhah, in which other plants can hardly grow. Colonies of Cyanophyceae are found on silt (mud) substrate where coral, seagrass and algae have difficulty growing. These colonies however provide primary production areas which support other species.

9. Extent of tidal flat (index rank 1-5): Map 9 (Fig. 95)

Tidal flat are periodically exposed and covered by sea water. The tidal flat provides special space for species adapted to this physical environment. The tidal flat is an important living space for benthos such as shrimps, crabs, shells and worms. It is also important as a feeding ground for waterbirds.

10. Existence of industrial plants (index rank 0 or -5): Map 10 (Fig. 96)

Large industrial plants such as desalination, power or oil refinery plants built on the coastal areas have an adverse impact on the coastal and marine environment through the discharge of exhaust water, oil sludge and other pollutants. Each grid with land area is

given an index rank of 0 or 5 depending on whether or not it contains one of these plants.

11. Number of fishing boats (index rank -1~-5): Map 11 (Fig. 97)

The number of fishing boats is indicative of human pressure on the marine environment. A negative index is given for the number of fishing boats, to evaluate human pressure on the area.

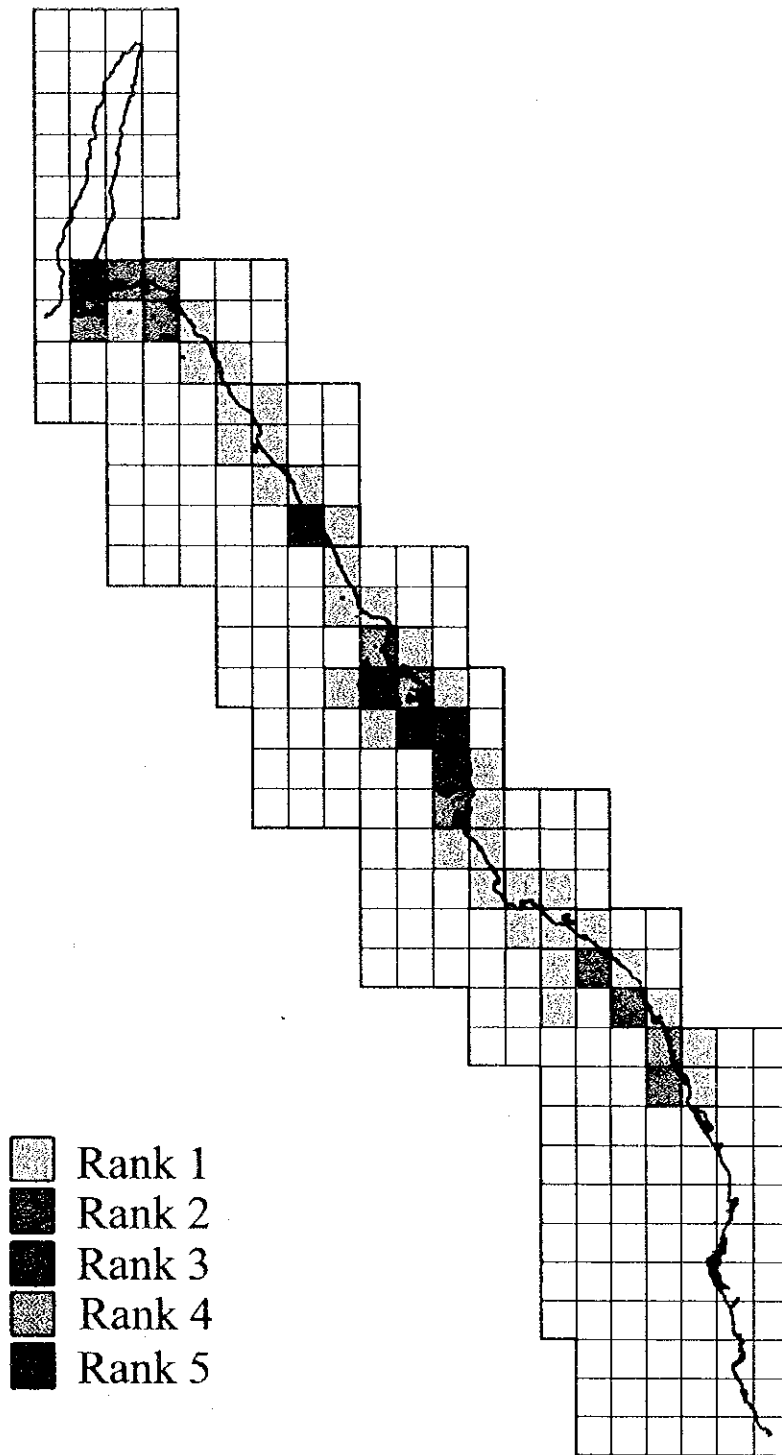
12. A summary map summing up the indices of maps ①~⑪ (Fig. 98)






A summary map prepared by summing up all the indices ①~⑪ provides integrated information of their relative importance for coastal and marine environment conservation.

Data on Dugong, marine turtles and the endemic or newly recorded species are important and should be incorporated into the summary map. Not enough data on these items were obtained from the Study for an appropriate ranking to be made.

6.2.3. RESULTS

The natural environment of the Study Area is ranked on five level in the summary map. The mouth of the Gulf of Aqaba, Al-Khuraybah, the Al-Wajh Bank, Umluj to Sharm Shabaan and Al-Hajir (north of Ra's Masturah) areas are evaluated as high ranking (3-5) areas.

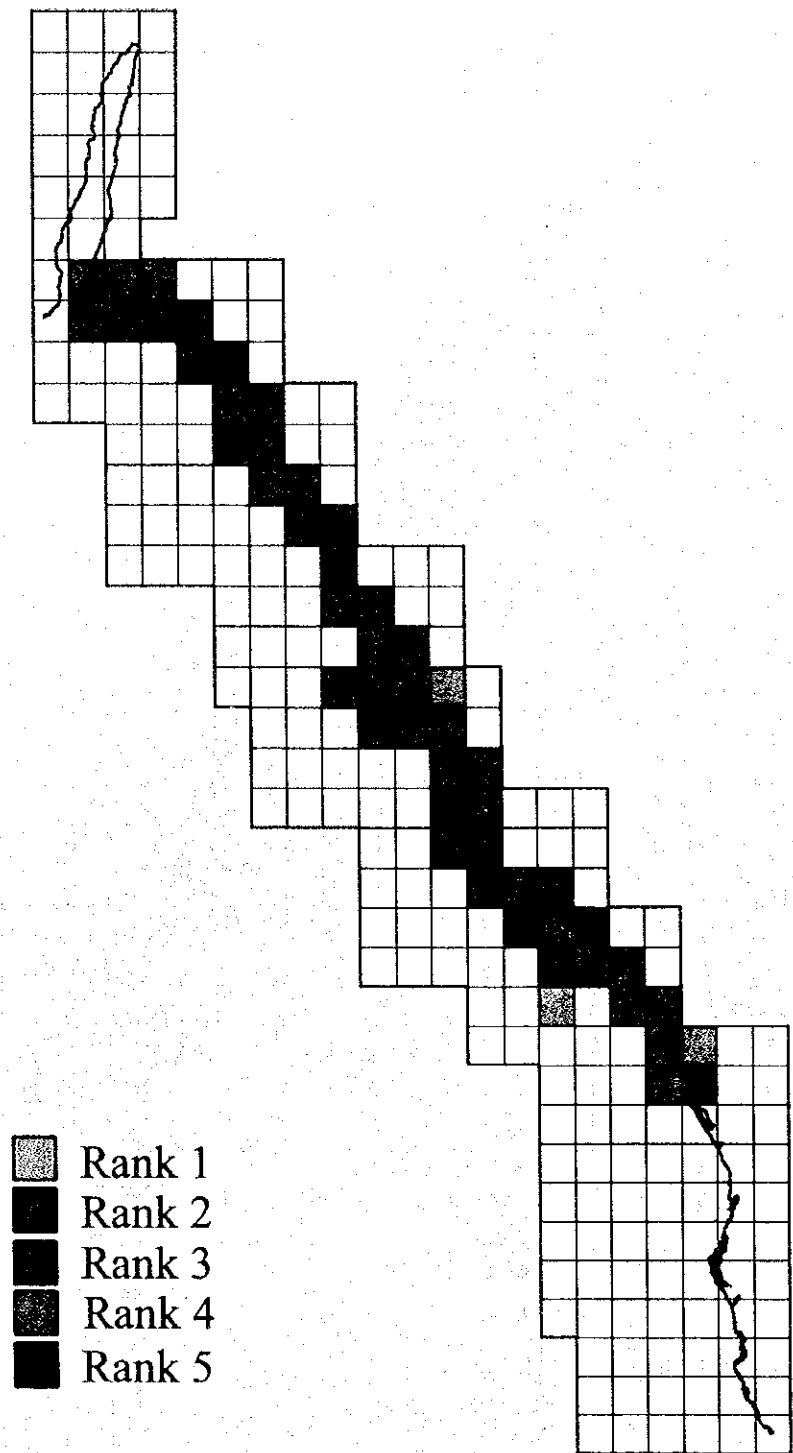







-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers




Fig 87. Extent of marine areas shallower than 20 m depth: Map 1.

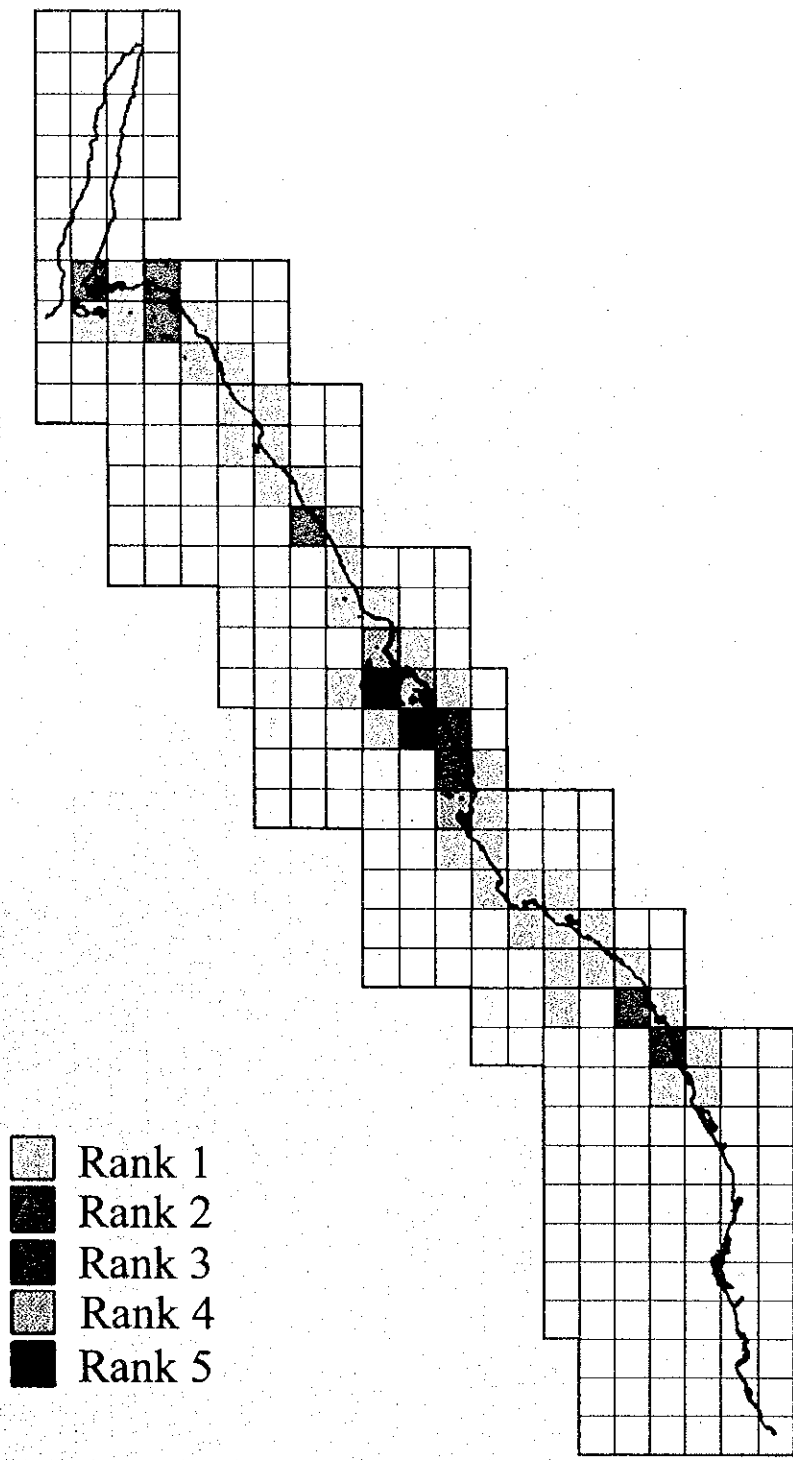


-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers




Fig. 88. Numbers of habitat categories: Map 2.

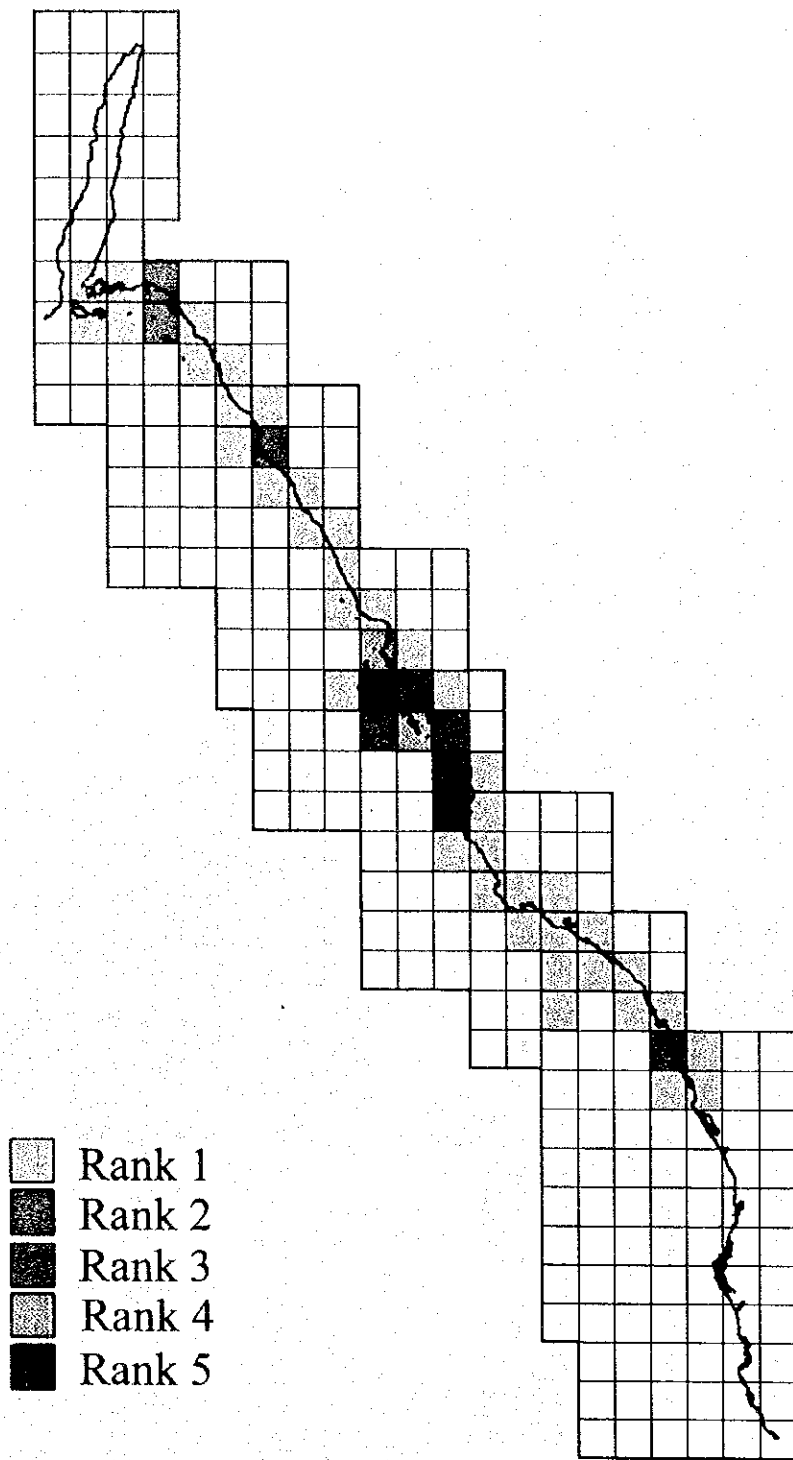







- Rank 1
- Rank 2
- Rank 3
- Rank 4
- Rank 5

100 0 100 200 Kilometers



Fig. 89. Extent of habitat: Map 3.



-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers


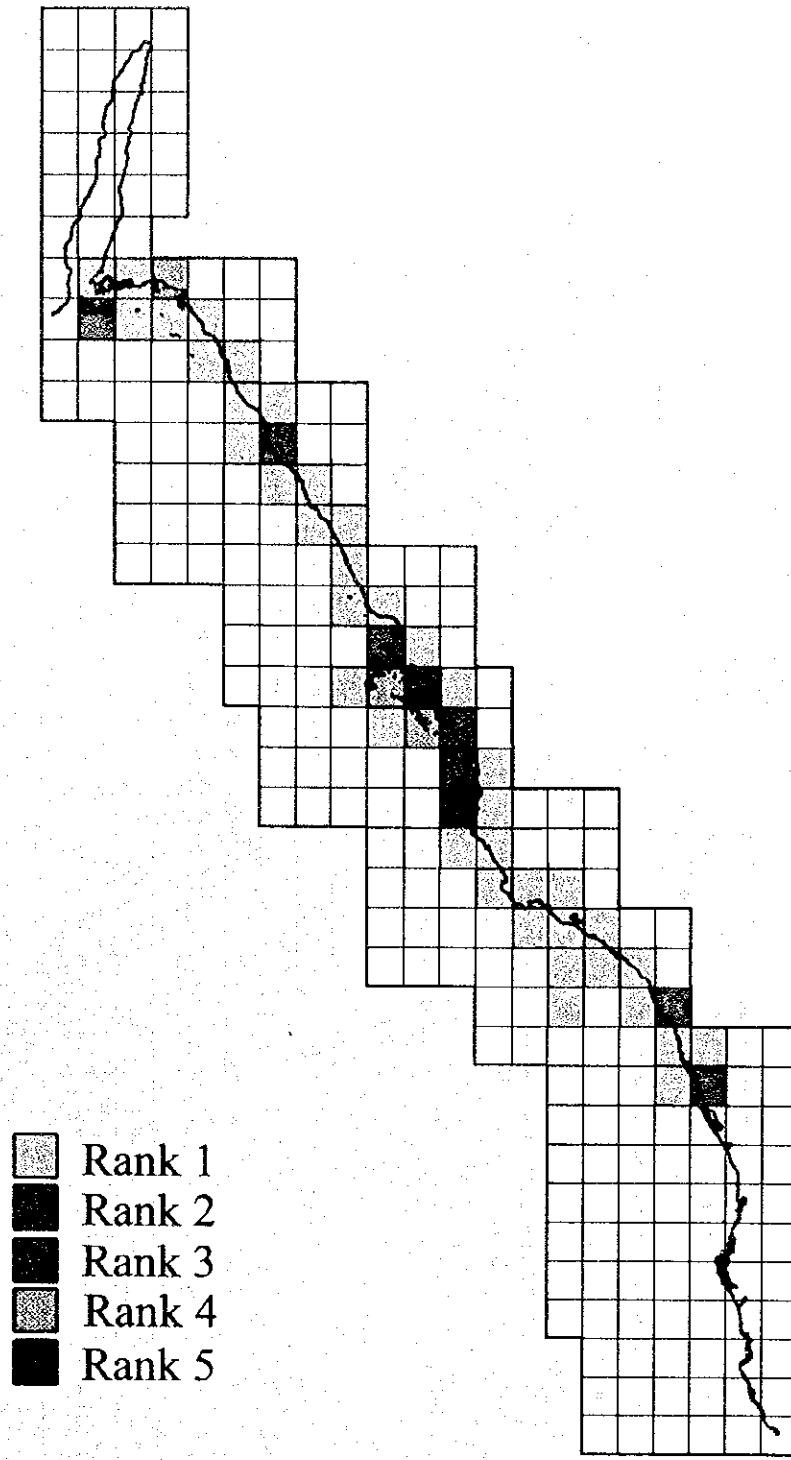


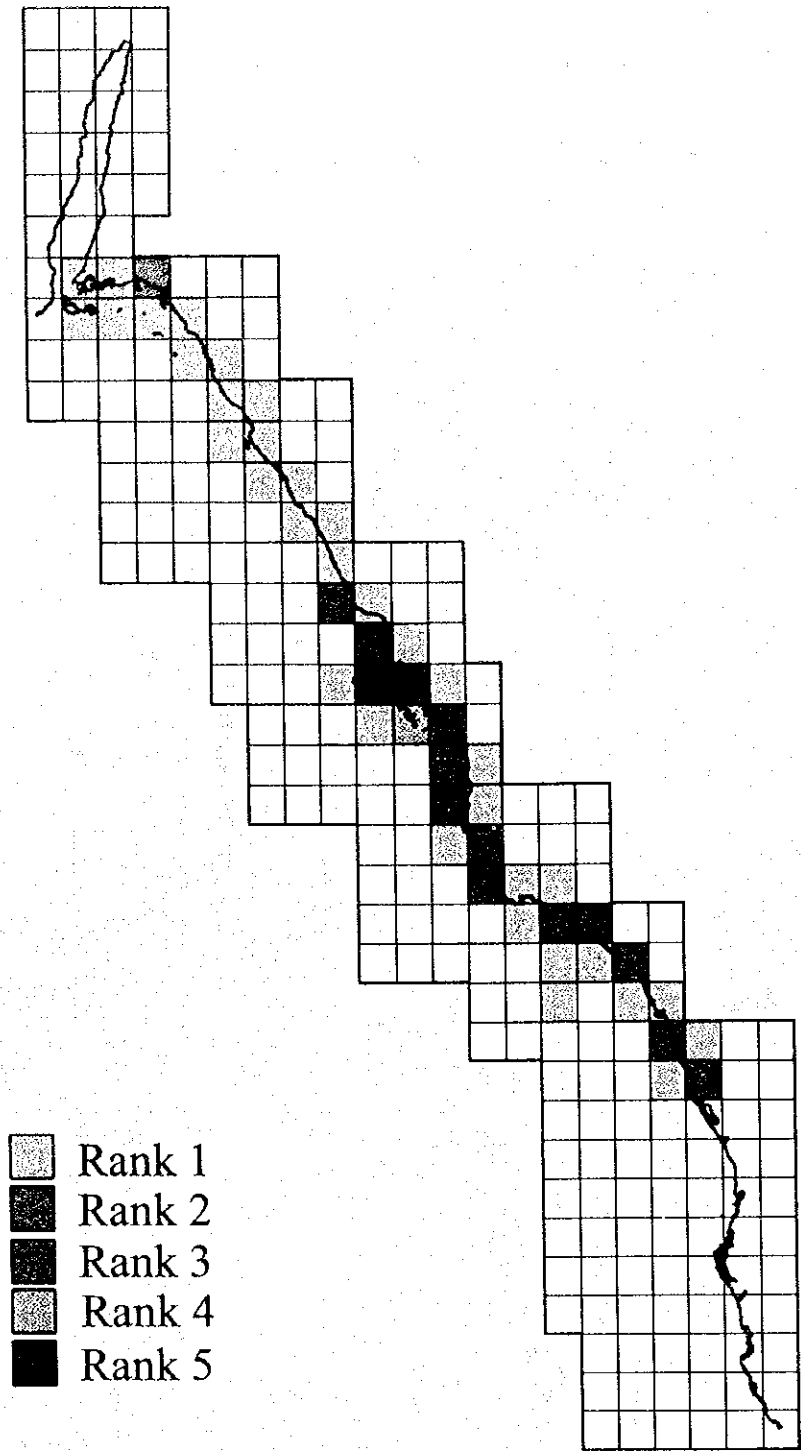

Fig. 90. Extent of coral: Map 4.








100 0 100 200 Kilometers



Fig. 91. Extent of seagrass colonies: Map 5.

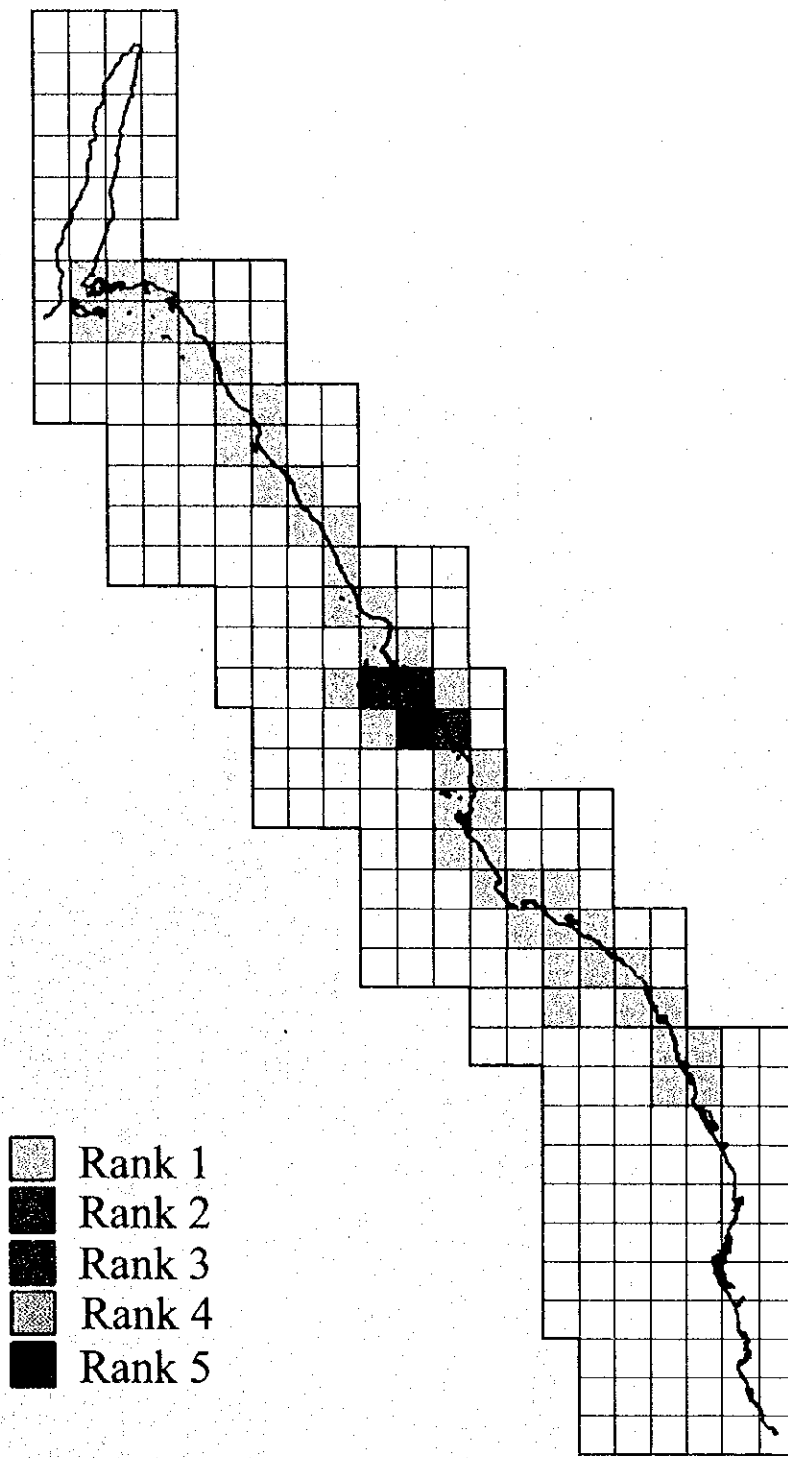







-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers



Fig. 92. Extent of algae colonies: Map 6.



-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers


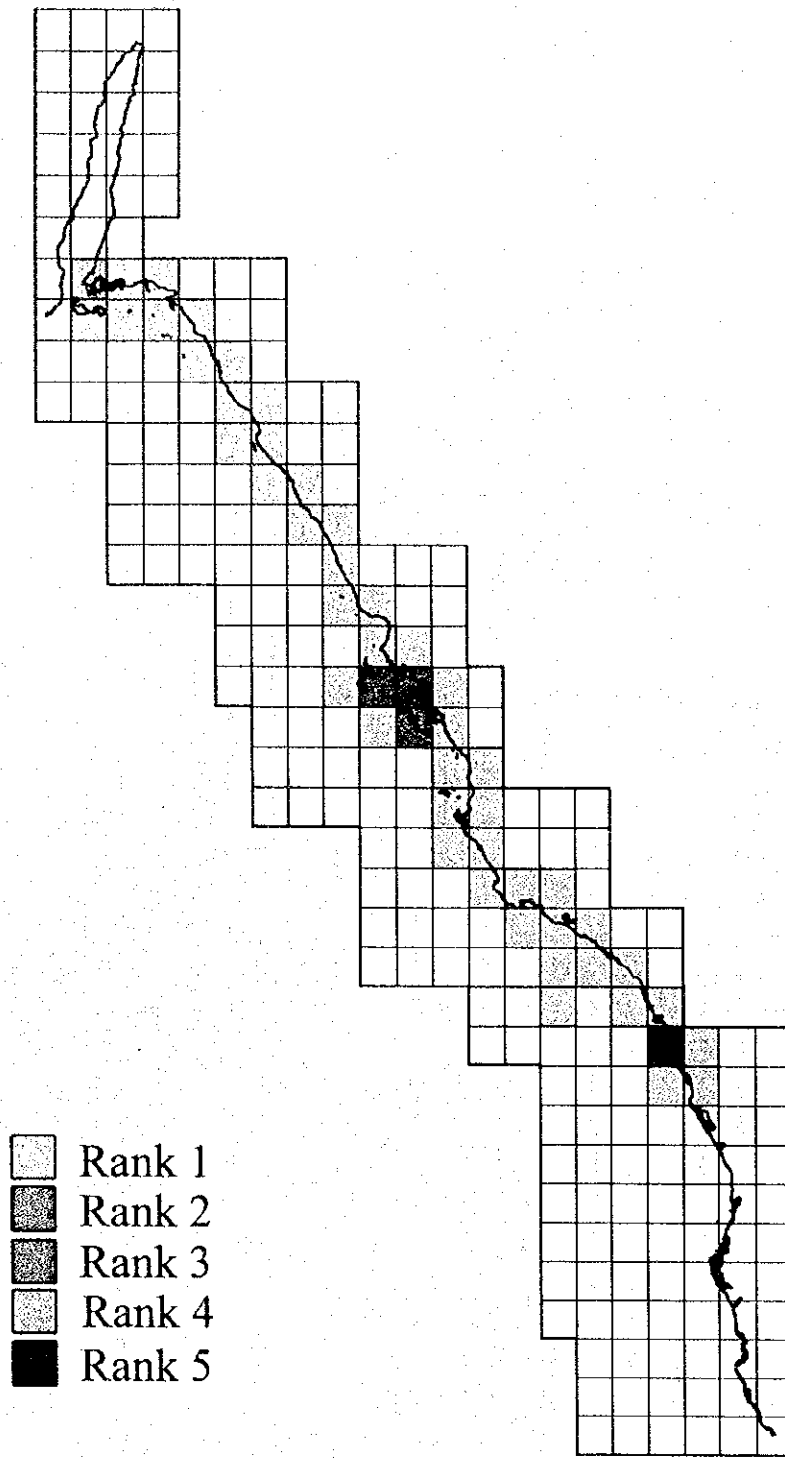



Fig. 93. Extent of mangrove communities: Map 7.

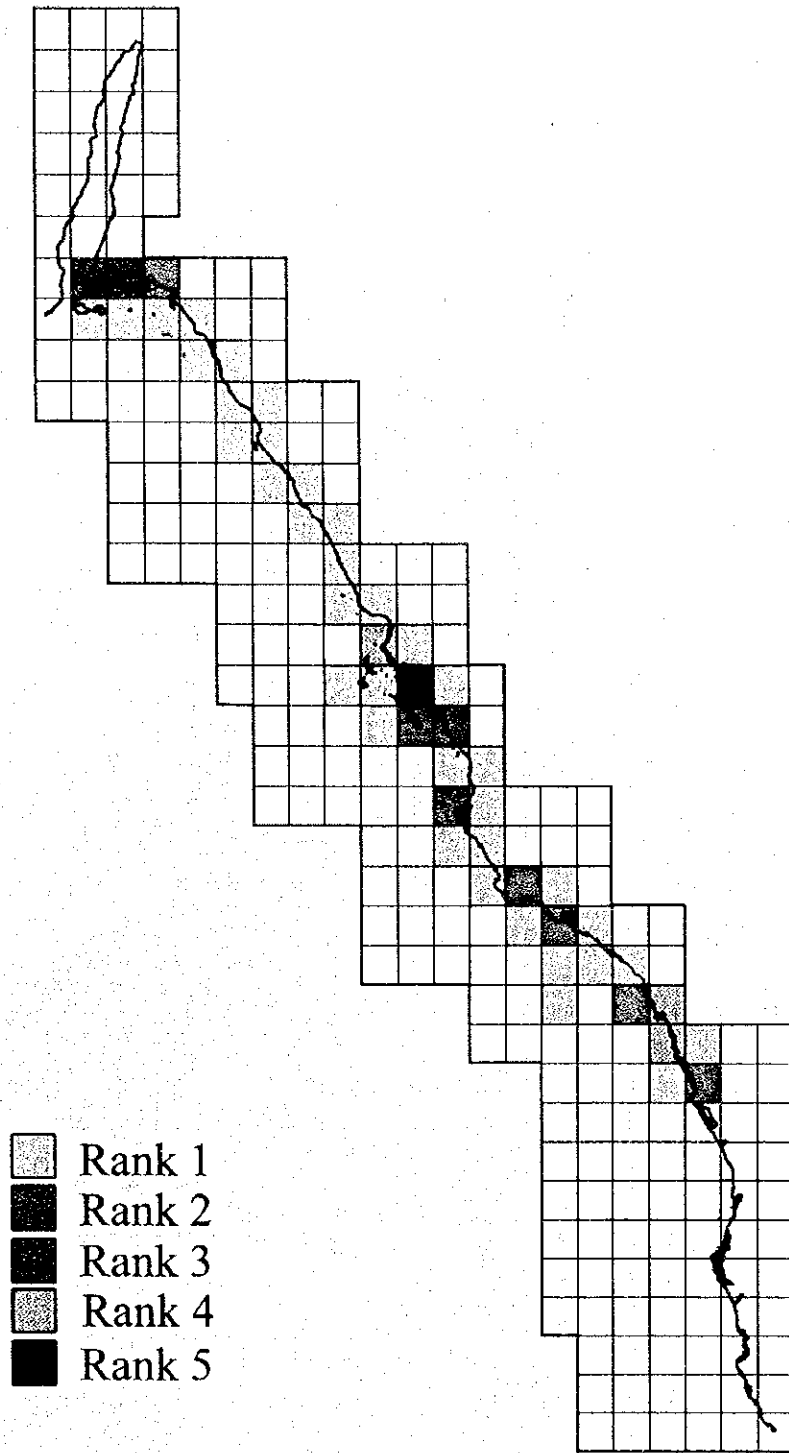


- Rank 1
- Rank 2
- Rank 3
- Rank 4
- Rank 5

100 0 100 200 Kilometers



Fig. 94. Extent of Cyanophyceae colonies: Map 8.



100 0 100 200 Kilometers



Fig. 95. Extent of tidal flat: Map 9.

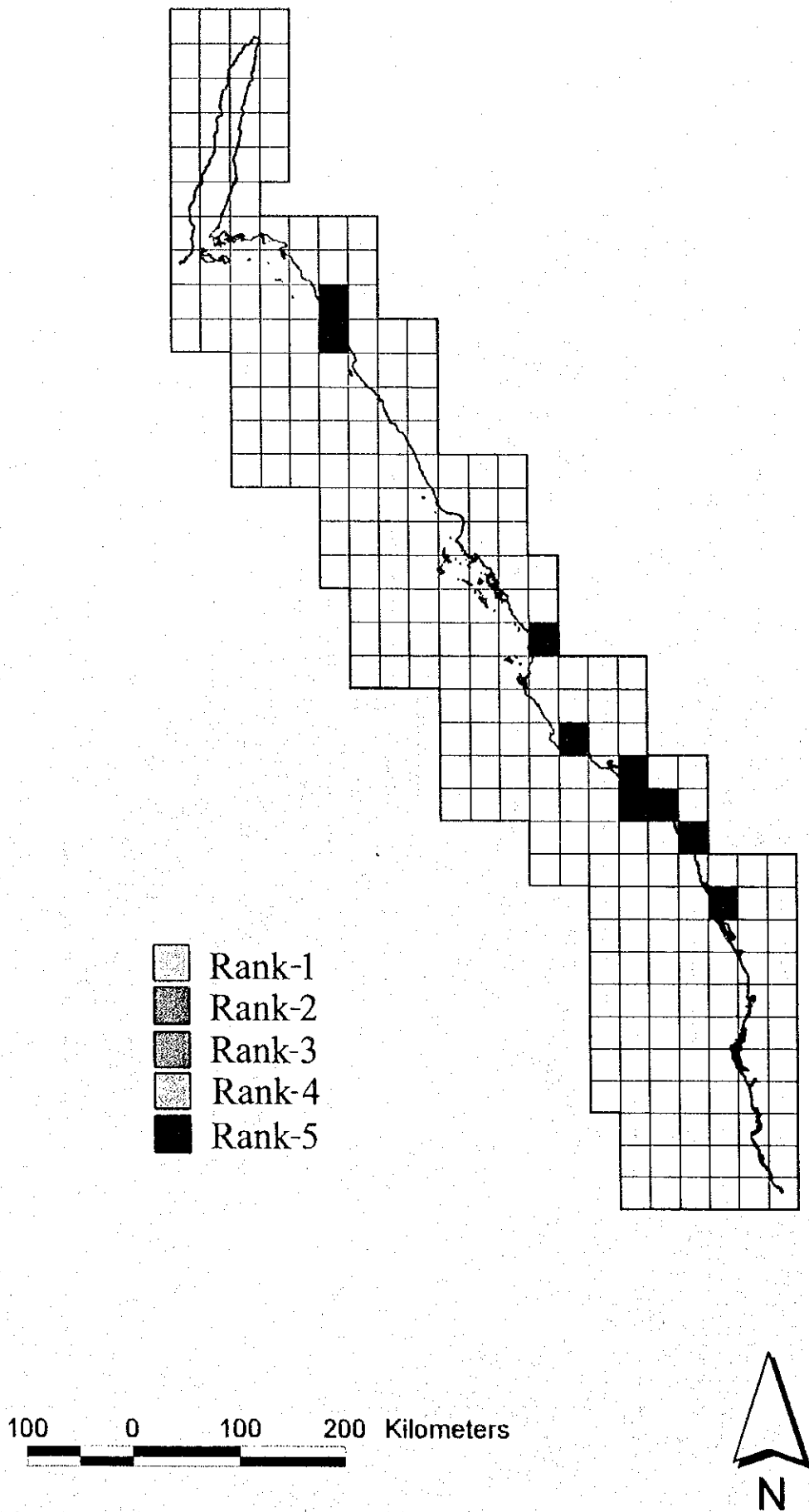
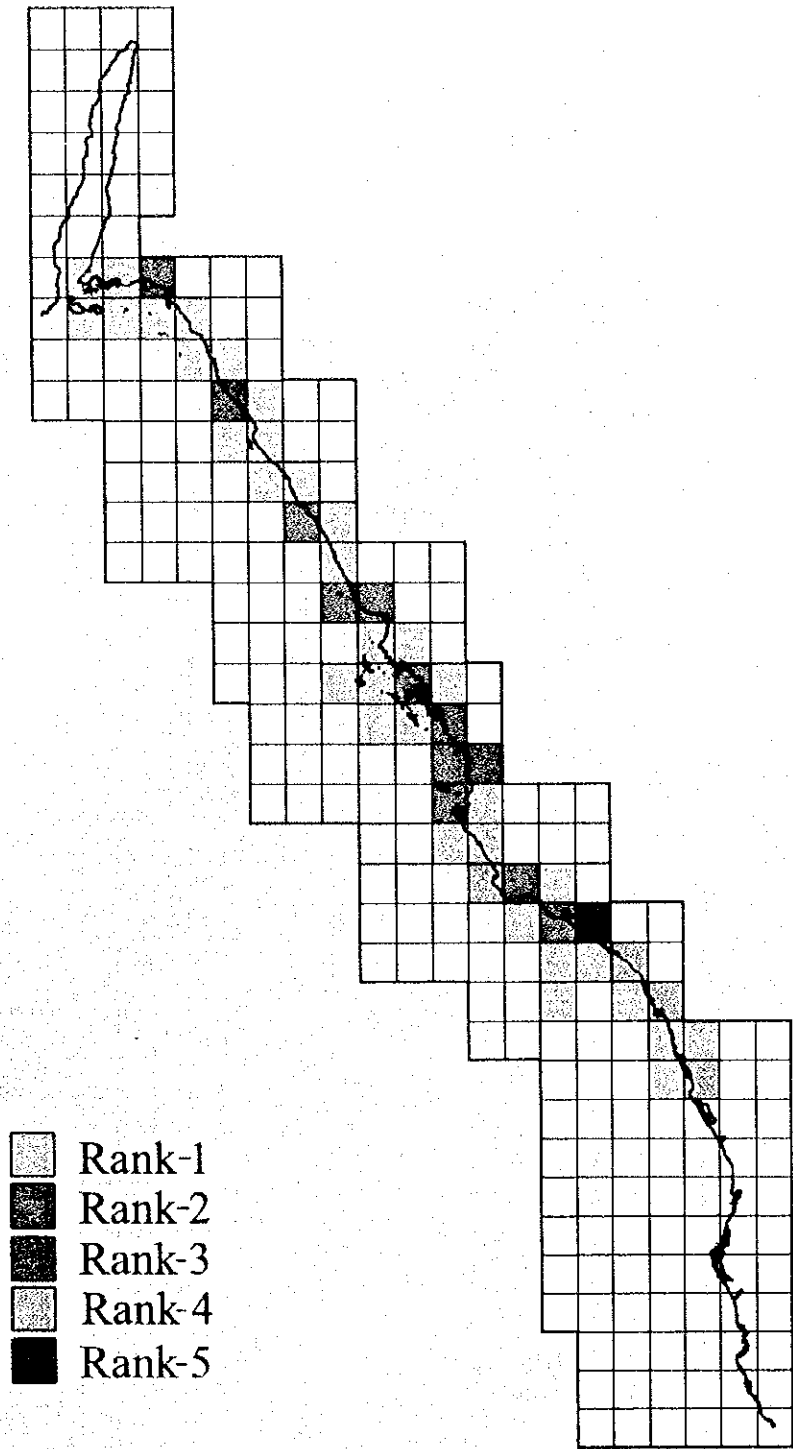







Fig. 96. Existence of industrial plants: Map 10.



-  Rank-1
-  Rank-2
-  Rank-3
-  Rank-4
-  Rank-5

100 0 100 200 Kilometers


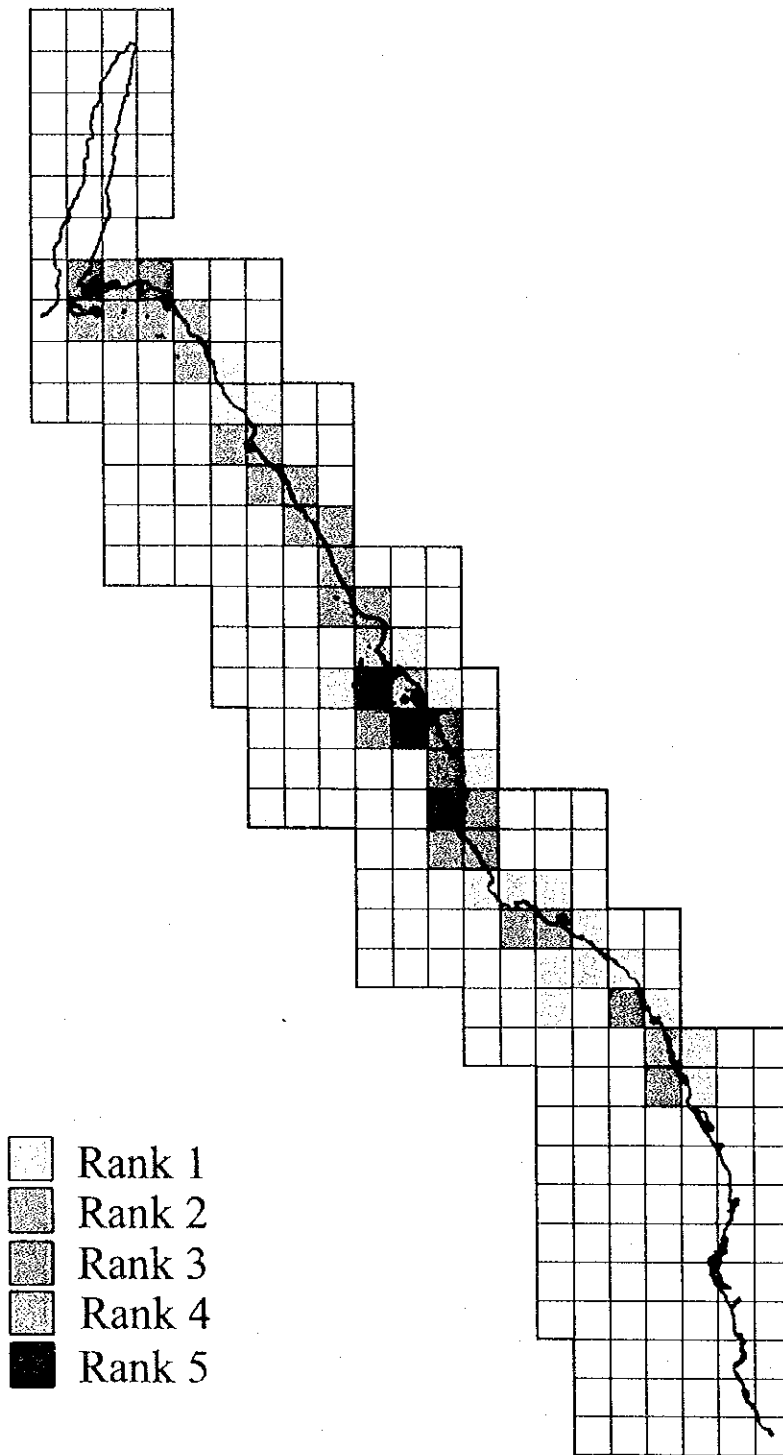








Fig. 97. Number of fishing boats: Map 11.



-  Rank 1
-  Rank 2
-  Rank 3
-  Rank 4
-  Rank 5

100 0 100 200 Kilometers





Fig. 98. Summary map.

The following three types of status can be considered from a management point of view.:

1. Priority conservation area (Rank 3-5);
2. Strategic environment management area (Rank 2); and
3. Multiple use area (Rank 1).

On the basis of these rankings, comprehensive regional marine resource and environmental management policies and plans could be drawn up. A comprehensive approach to the regional environment can assure a healthy regional ecosystem and continuation of its productivity. Regional environment management is to be assured by the establishment of marine protected areas.

6.3. PRIORITY CONSERVATION AREAS

The Study results provide sufficient understanding of the current status and characteristics of the environment using the latest scientific technology. Priority areas representative of the Study Area are identified by the summary map which combines the data on each taxon, the extensiveness of the habitats and social parameters. Consideration of the continuity of areas suggests three priority conservation areas; 1) Tiran area (the mouth of the Gulf of Aqaba – Al-Khuraybah), 2) Al-Wajh Bank plus surrounding area (Sharm Habban – Sharm Shabaan), 3) Al-Hajir (north of Ra's Masturah). There are some areas of Rank 2 between the mouth of the Gulf of Aqaba and Al-Khuraybah, the areas being closely linked together.

These three priority conservation areas have significance and potential for the establishment of marine protected areas. A network of marine protected areas in the northern part of the Red Sea will be the key component in comprehensive coastal and marine

environment management programmes.

The principle objectives of a marine protected area are:

1. to maintain essential ecological processes and life support systems;
2. to ensure the sustainable utilisation of species and ecosystems; and
3. to protect and conserve biodiversity.

1. Delineation

The Study provides information on the ecosystem structure but not on the functions and their linkages (eco-physiology). The delineation of the marine protected area needs to be based on true ecological boundaries with regard to the structure and functions of the ecosystem. Therefore, in order to make precise delineation for marine protected areas, key function areas and linkages must be identified. Areas needing to be identified, for example include, courtship or spawning grounds; nutrient loading; specialised feeding and breeding areas; migratory corridors, stopover points; nursery areas; habitats important for keystone or other controlling species, areas which support a population of grazers. Seasonal variations (the time component of the functions) in these areas are also to be evaluated. With this information, precise ecological boundaries will be drawn for the delineation of marine protected areas.

In the sea, currents carry sediments, nutrients, pollutants and organisms through an area. Wind and tide generated currents mix water masses. Thus, events originating outside the boundaries of a protected area will affect its populations. Because of this open nature of the marine environment, protected areas need to be large enough that any human induced or natural impact is buffered or diluted, and critical habitats and communities can be conserved relatively undisturbed.

2. Objectives and zoning

The objectives and goal of conservation management need to be determined by the

Kingdom as part of the process of the establishment of marine protected areas. Clear objectives are the basis for clear management zoning. In zoning plans for marine protected areas, core areas are to have the strongest protection. The core areas are to be designated in order to protect critical structural and functional areas. When ecosystem functions are properly evaluated, core areas which restrict human activities need not be too large. However, in order to conserve important ecosystem functions, a multiple core area system is usually applied.

3. Management implications

Science-harnessed management plans are the most effective and efficient. However, science in this field is developing quite quickly and might bring different results. Results from the monitoring survey might require different management programmes. The Study Area was found to be rather ecologically isolated from other seas. This means its habitats are unique and rather sensitive. No other country has experienced research and conservation management of such unique, and sensitive habitats. Therefore, the important feature of conservation management must be for both research and management programmes to have enough flexibility to be able to accommodate new findings, survey results and information on the habitats.

The supply of nutrients to primary biological producers namely algae and seagrasses, is limited because of the nature of the environment. Limited productivity by many species is speculated on in the Study. The ecosystems in priority areas have evolved in a very delicate natural balance with little human impact. This balance is the key for survival of many species in the harsh natural environment, terrestrial as well as marine. This sensitivity of species and habitats in the priority areas should be given full consideration development of effective management programmes.

Natural succession of habitats and species have also been taking place under the

limited human impact. Additional human pressure on the habitats would accelerate the natural succession and /or lead it in different directions. Coral bleaching has occurred from time to time in the past, but, the frequency of the recent massive bleaching might be due to human activities. The accretion of events might cause alteration of the natural succession. Thus, programmes to monitor critical habitats and species need to be carefully planned.

Monitoring programmes need to be carried out in a systematic manner. Monitoring methodology must be simple, practical and applicable in local condition . Apart from ecological monitoring programmes, human activities such as fishing, livestock grazing and coastal development are to be monitored.

Endemic species in the Red Sea have been found in the Study. However, there are many more species that appear to be distinctively different from their closest species. It is suggested that this is mainly due to the ecological isolation. The isolation level of a species is an important key factor in biodiversity conservation and should be specially focused on in conservation management programmes.

Information gathering is one of the key elements for conservation management programmes. Because the area is scarcely populated, information gathering is very difficult. Systems to gather information on the natural environment, especially from fishermen, herders and local municipalities need to be established.

Co-operation between the authorities and local communities is essential for effective conservation management. The coast guards are stationed to control human activities in coastal and marine areas. Fishing and nomadic communities exist in the priority areas. Co-operation between the regulatory authorities and the communities needs to be established for the sake of effective conservation management.

6.4. STRATEGIC ENVIRONMENT MANAGEMENT AREAS

A strategic environment management area is essentially the area surrounding a priority conservation area excluding cities / towns. The area basically includes coastal shelf and deep sea with scattered open and enclosed bays and small shallow areas. The important habitats are benthic communities in enclosed or open bays which are more vulnerable than other areas. Offshore pinnacles and bed rock areas sometimes perform key ecological functions such as providing breeding and courtship areas for many animals. These scattered important habitats should be focused on within the strategic environment management areas since their ecological functions are not clearly understood in the Study. The environmental management of these areas will harness more effective conservation activities in the priority areas.

1. Delineation

Delineation of the strategic environment management area also needs to be based on its structure and functions. The area basically surrounds the priority area.

2. Objectives and zoning

Objectives of the area are to manage scattered important and vulnerable habitats, especially open and enclosed bays, and to provide supportive functions for the priority conservation area. Management zoning will be set to fulfil these objectives.

3. Management implications

Open and enclosed bays and other habitats with critical ecological functions are to be identified for management. The identified habitats are to be given special attention in management. Fishing activities are to be closely monitored, especially trawling, netting, collecting (shells, aquarium fish) and spear fishing.

6.5. MULTIPLE USE AREAS

Multiple use areas are basically the vicinities of cities or towns where coastal development takes place. Linkages between terrestrial and marine habitats in the Study Area are weaker than in tropical and subtropical areas because of the low precipitation. However, the impact from cities, such as coastal developments, desalination plants, sewage and solid waste, does effect the marine environment. In order to provide a healthy living environment for the city dweller and to control human impact on the priority conservation and strategic environment areas, the impact from human activities should be monitored and managed.

6.6. RECOMMENDATIONS

1. Establishment of marine protected areas in the priority conservation areas identified.

The Study provides sufficient information on the habitat structure with precise maps. All information is integrated into GIS database for efficient conservation management. Three priority conservation areas are identified; Tiran, Al-Wajh Bank and its surroundings, and the Al-Hajir area. In order to establish marine protected areas, the critical and important ecological functions and linkages are to be identified in the priority conservation areas. The delineation of marine protected areas is to be drawn up from the identification of these. Feasibility of establishment of marine protected areas is assessed in the social conditions of the Kingdom.

2. Establishment of management programmes, including management zoning and guidelines for marine protected areas in the priority conservation areas

First define objectives and goal of a marine protected area. A zoning plan with guidelines is the primary document that defines the strategic framework for management. Management programmes need to contain the following items;

- Objectives of management
- Boundary and area description
- Resource description (area and location, geographic and habitat classification, conservation status, access and regional context, history and development)
- Physical and biological features (landforms, bathymetry, tide, salinity and turbidity, geology, currents, precipitation, temperature, wind, terrestrial and marine fauna and flora)
- Management issues (conflict, pollution and future demand)
- Management policies (objectives, zoning and guidelines)
- Biological, environmental and usage monitoring
- Education and information
- Enforcement
- Maintenance and administration (budget and staffing)
- Plant species, animal species, special features, past, present and proposed use.
- Zoning map

3. Establishment of management programmes of strategic environment management areas

It is important to identify habitats which have important ecological functions and linkages such as open and enclosed bays and offshore pinnacles. Focusing on the conservation of the functions of these habitats, management programmes of the strategic environment management areas are to be prepared and established.

4. Further studies and monitoring surveys

- Monitoring survey of coral habitat with methodology in Reef Check and Global Coral Reef Monitoring Programmes.

- Study on predator-prey relationship with coral habitats (fish, coral and crown-of-thorns starfish) in Al-Wajh Bank especially in the south.
- Study on macro benthos such as Polychaeta or Amphipoda for precise understanding of the ecosystems of Al-Wajh Bank.
- Genetic or DNA study on Hawksbill Turtle in Al-Wajh Bank to understand isolation level from the Indian Ocean population.
- Study on distribution and abundance of sponges as a primary food source for Hawksbill Turtle in Al-Wajh Bank.
- Study on migration route of Green Turtle nesting population in Al-Wajh Bank.
- Study on reproduction status of Dugong population in Al-Wajh Bank
- Survey on the permanent quadrats for vegetation dynamics and/or succession.
- Survey on seasonal changes of avifauna.
- Survey on interactions between the mangroves in Al-Wajh Bank and their fauna including birds.
- Evaluation of the habitat changes by comparison with existing previous aerial photos.
- Monitoring survey on fishing (fishermen, boats, fishing yield, sampling data of monitoring species)
- Monitoring survey on fish in Al-Wajh Bank with Reef Check methodology.
- Monitoring survey on grazing (number of livestock, herders, production and others).

5. International cooperation for coral reef monitoring

The Red Sea is becoming of more and more international interest in the global coral reef conservation. International monitoring programmes have been implemented with participation of many countries. The monitoring data of coral reef in the Red Sea have an international significance. An important aspect of the monitoring survey is the continuity and

the systematism. The results of coral reef monitoring surveys will provide significant information for global monitoring and the international linkage will bring up-to-date knowledge and skills for effective coral reef conservation in the Red Sea. Therefore, international cooperation of coral reef monitoring for marine environment conservation in the Red Sea should be established.

6. Education and public awareness programme

Nature conservation can only be achieved with public participation, especially community support. The success of marine protected areas is largely dependant on participation of local communities. The Study provides sufficient knowledge of habitat structure (what biological resources they have) and the specimens of their inhabitants. Two books targeted at public awareness are produced by the Study. Many photographs on the biological resources were taken in the Study. These outputs are an ideal tool for public education and awareness. In order to promote public understanding and support for coastal and marine environmental conservation through establishment of marine protected areas in the northern part of the Red Sea, educational and awareness programmes should be established and implemented centrally and locally. These programmes will harness the public and governmental support on coastal and marine environment conservation programmes.

