An Introduction to the use of Geographical Information Systems and Remote Sensing in Fisheries Monitoring, Analysis and Management

FISH - GIS

A MANUAL

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Preface

This manual "An introduction in the use of Geographical Information Systems in fisheries monitoring, analysis and management", was made possible by the financial support of the Netherlands Government and the strong support and collaboration with the Environmental and GIS support for the water sector project (EGIS) in Bangladesh.

The idea of writing this introduction manual crystallised after applying GIS in a number of fisheries projects in Bangladesh and in a wetland restoration project in Rumania. As a fisheries biologist I had no formal training in GIS, and thanks to the assistance of a number of GIS experts and the consultation of reference books I slowly learned some techniques and started to appreciate GIS, especially its simplicity of use it and the extra information it provides compared to the traditional fisheries tools.

The intention of this is manual to provide some basic information on GIS to fisheries biologists and environmentalists who have no previous experience with GIS. It is more or less the manual I would have liked to receive a couple of years ago when I started to work with GIS.

The manual should not be considered as a complete training manual on GIS; for that it is incomplete as it covers only a small number of methods and does not provide the details and mathematical background of a number of analytical tools.

I realise that some of the methods presented and their application, especially "interpolation of surfaces", will draw some comments from GIS experts, and their first remark will most likely be, “you can-not do that in such a way”. However, it is my experience that you can use it as long as you keep in mind what your data set represents, and realise the biological or physical limits of the results. Then, in most cases the results of the analysis provide extra insight in the different processes.

This manual was written for the training of fisheries biologists in Bangladesh and on their request also basic information on fisheries management models (chapter 15) was provided, which is outside the scope of FISH-GIS.

I hope that this manual provides some basic understanding of GIS and will bring about the result that fisheries biologists, environmental specialists, etc, will overcome their general hesitations towards GIS and will at least learn to communicate with GIS experts so that their data can be analysed in GIS, according to their wishes.

August 2000, Dhaka, Bangladesh

Gertjan de Graaf
1 INTRODUCTION

The Bangladeshi expression “Mache Bathe Bengali” shows the importance of fisheries in their society. The importance can be found in the inland waters as well as in the coastal and marine waters. On a national level the formulation of a National Water Management Plan is going on at present and the development of an Integrated Coastal Management Programme is in preparation. Furthermore, the DFID-funded Fourth Fisheries Project and the Asian Development Bank-funded Sundarbans Biodiversity Conservation Project have recently begun. All these programmes deal with integrated planning of natural resources, whereby fisheries is a major component.

Within the last decade as part of the Master Plan Organisation (MPO) and the Flood Action Programme (FAP) studies, fisheries in relation to water management received more attention. Several studies were completed updating the knowledge on fisheries in Bangladesh. The first studies followed a more or less traditional approach. However, in recent years, through the improved availability of cheap and powerful computers and software, the incorporation of GIS, remote sensing and modelling in fisheries also began in Bangladesh; first in some FAP projects, such as the Compartmentalisation Pilot Project (CPP) in Tangail, and later at Environment and GIS Support Project for Water Sector Planning (EGIS) in Dhaka.

During the eight years of the Dutch-funded CPP project, a number of integrated tools related to fisheries, hydrological modelling and GIS have been developed in close cooperation with staff members of EGIS and SWMC. The developed tools are rather new for Bangladesh; therefore, EGIS and CPP decided to organise a training for the dissemination of these tools to Bangladeshi experts working in the field of fisheries and environment. The training could be realised thanks to funds of the Government of the Netherlands.

1.1 Set up of the training and the manual

As mentioned above, the main objective of the training is to train Bangladeshi fisheries and environmental experts in the application of tools developed in Geographical Information System (GIS) for monitoring and analysis of fisheries data and on decision making in fisheries management. Therefore the training is not a GIS training course, in which one learn the USE of GIS. It is realised, however that the majority of the trainees have no previous experience with GIS; therefore the basics of GIS are incorporated into the training course.

For trainees who want to learn more about GIS, it is strongly recommended to follow one of the regular training programmes on GIS provided by EGIS.

The training is organised in such a way that the participants will carry out a number of exercises to become familiar with GIS and the different tools. The manual and attached CD-ROM has been made in such a way that it can provide the information to those who do not attend the training course.

The training manual further includes two annexes where results are presented of an EGIS research project on the detecting of fish ponds with remote sensing techniques.

---

1 Fish and rice makes a Bengali
and where more details are provided on predictive multi-disciplinary modelling of different water management scenarios in the CPP project area.

1.2 The Training

During the training, exercises will be carried out on computers on which all the software has been installed and needed data have been copied to the Directory C:\nefisco-egis, the main directory for this training course/manual. The organisation of this directory is provided below. It is important to know that if in the future you want to repeat some of the exercises, you keep the exact structure of the directory and location of the files; otherwise you can-not open these "projects".

1. Arcview projects: all the GIS projects made in Arcview
2. Dbase files: all the raw data in Dbase IV format
3. DEM; the Digital Elevation Model of the CPP project in Grid form
4. Grid files: data in Grid format
5. Info: contains data linked to Grid files and is automatically generated for internal use.
6. MS Excel files: Needed files in MS Excel format
7. Radar: classified radar images of CPP
8. Reports contains technical reports of the CPP project
9. Results: the results of the exercises
10. Shape files: applications of GIS in "shape file" format used by Arcview.
11. Temp: the temporary directory where Arcview can automatically store all new files made during the training after you have set your working directory to this subdirectory.
NOTE

Installing the Data from the CD-ROM

If you want to carry out the exercises described in this manual, please copy the entire directory "Nefisco-Egis" from the CD-ROM to the C:\ drive of your computer.
Please check beforehand whether you have enough space on your hard disk. The files will take about 125 MB and to carry out the exercises at least an extra 100 MB is required.
After the data are copied all files become "read only". This is a characteristic of copying data from a CDROM. Before you can use the files and save changes you have to remove the "read only" indication of the files as follows;
1. Open Windows Explorer
2. Select C:\ nefisco-egis
3. Click in the menu "Tools" on "Find" and then "Find folders". In the windows that will pop up, type in the Name window " *. * " To select all files, and then click on "find now".
4. Once all files are displayed and the search is finished, click on "select all" in the "Edit menu".
5. Click on "Properties" in the "File" menu, delete the mark in the checkbox of "read only", click on "apply" and close the menu.
6. You are ready to start now.
2 WHAT IS GIS

People have made maps for thousands of years to present and analyse information. **Geographical Information Systems** or **GIS** is in principle nothing more than a very sophisticated mapping tool that allows one to visualise, explore, query and analyse data linked to any place on Earth.

Let's look at an example:

The Fisheries Resources Survey Systems (FRSS) collected data on the number of riverine fishermen in the districts of Bangladesh and published them in the form of tables such as that presented below.

**Table 1: Number of Riverine fishermen data of several districts in Bangladesh**

<table>
<thead>
<tr>
<th>DISTNAME</th>
<th>FISHERMEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAGERHAT</td>
<td>32974</td>
</tr>
<tr>
<td>BANDARBAN</td>
<td>80</td>
</tr>
<tr>
<td>BARGUNA</td>
<td>9548</td>
</tr>
<tr>
<td>BARISAL</td>
<td>34786</td>
</tr>
<tr>
<td>BHOLA</td>
<td>33400</td>
</tr>
<tr>
<td>BOGRA</td>
<td>1680</td>
</tr>
<tr>
<td>BRAHAMANBARIA</td>
<td>14800</td>
</tr>
<tr>
<td>CHANDPUR</td>
<td>15354</td>
</tr>
<tr>
<td>CHITTAGONG</td>
<td>13686</td>
</tr>
<tr>
<td>CHUADANGA</td>
<td>406</td>
</tr>
<tr>
<td>COMILLA</td>
<td>3900</td>
</tr>
</tbody>
</table>

The same information can be presented in the form of a map as presented in Figure 1.
In this case both the table and the map are easy to use but the situation changes if we want to present the data of all districts or all upazillas (sub-districts) of Bangladesh. We will get tables of several pages and it is clear that presenting the data in the form of a map then is more comprehensive.

In the example, the district population was presented in the form of a map, but of course any information obtained from a district can be visualised in such a way i.e. the number of fishing boats per district, literacy rate per district, the number of fish markets per district, the number of schools per district, etc.

The basic principle of mapping and GIS, which we have to keep always in mind, is:

"We join data stored in a table with a location on a map."

To do this GIS is nowadays the principle tool as it has the following advantages (Meaden and Chi, 1996):

- GIS allows for the display of spatially related data in a way that is easily comprehensible for most people;
- Once maps have been made in digital format, it is a simple task to update them, to change them, or to merge them with other maps in order to create new maps;
- GIS allows for the easy and immediate integration of other large data sets, i.e. enabling technologies of, for instance, GIS and remote sensing, or GIS and radar, to be readily combined;
- GIS allows for a regular flow of spatially related information in a standardised format. This might be for a given time series in which all maps are produced together, or it might mean that periodically a new version of the same map could be produced.
There are a number of different GIS software packages on the world market that will not be discussed further. In Bangladesh, Arcview, a product of Environment System Research Institute (ESRI), is the most commonly used.
3  A QUICK LOOK AT THE START-UP OF ARCVIEW

3.1  Starting Arcview

Arcview is installed on your computer and will start by "double click" on the "Arcview GIS version 3.0" icon located in the taskbar "Programs\ESRI\Arcview GIS version 3" see Figure 2.

Figure 2: How to start Arc View

Or we click on the "Quick start Icon" of Arcview visible on the monitor screen after you start the Computer.

When we start Arcview we will see the entry screen of Arcview which contains a common horizontal "tool bar" for opening and saving of projects, changing options in Arcview, etc, and a vertical "Project Window toolbar" which starts the different applications of Arcview. For our work the "View icon" and the "Table icon" are of importance (Figure 3). All the others we forget for the time being.
In "View" all the GIS spatial procedures, calculations, and analyses are carried out and data are displayed.

In "Table," all our data, which we want to join with a location on a map, are stored.

Example

Let's have a better look and familiarise ourselves with some features of Arcview by working with an example. All analyses carried out; and maps made in GIS are stored/saved in a project file with the extension "apr". We made a project with population data obtained from the Bangladesh Bureau of Statistics (BBS) and saved this "project" as 'BBS.apr'. Let's open it and see.

BBS.apr

Step 1
We start Arcview and open the project by selecting the file menu in the horizontal toolbar and choose "Open Project" (Figure 4).
Figure 4: Open a project

In the project dialogue box select drive c: in the drive combo box. Now double click on c:\ folder at the top of the directory list. Then move to Nefisco-Egis open it by double clicking, then move to Arcview-projects, Open it by double clicking and finally open the project by double-clicking bbs.apr in the left window (Figure 5) or by selecting bbs.apr and then click OK.

Figure 5: Opening bbs.apr.
Step 2
When the project opens you see a **Project Window** with a view named "**Population density**". Double click on Population Density (Figure 6) to open the view.

![Figure 6: Opening a View](image)

The view opens with a map of Bangladesh displaying the population density for each **upazilla** this map is called a "**Theme**" and this view contains only one Theme. In the View we see the map in the "**Map display**", the Theme title, the Legend and the Legend checkbox in the "**Table of contents**" and a large number of icons for different GIS application tools in the "**View tool bar**" (Figure 7).
3.1.1 **Structure of a Project, What is a project**

To understand better how Arcview works it is essential that we explain the structure of a Project and what it contains. In principle a "Project" is a file that contains exactly what you have done during an earlier Arcview session. Once you open the project again Arcview repeats the procedures exactly as you have carried them out before.

"An Arcview project does not contain data. It contains the information you need to find the data on your computer, and how to put them together again."

In Figure 8 an example is presented of a small part of a Project written by Arcview. In this case it searches for a polygon file giving the borders of Bangladesh called "country.shp" which is located in the subdirectory C:\nefisco-egis\shape files\.
The consequence of this is that when you change the location of your basic input data on your computer, Arcview can not find them again, and you will get all kinds of error messages after you open a Project. In such a case, i.e. when you put the "country.shp" of our example somewhere else, you will have a problem if you do not know where you have placed it.

3.1.2 Structure of a Project

As mentioned above, a project is a description of all the actions you have carried out before and contains a large number of instructions. It follows the principle of a tree, with a large number of "branches" (the information) and "leaves" (the files actually containing data) and all the information finally arrives in the stem, the project file (Figure 9).

![Figure 9: The structure of a project](image-url)
During the training you will be asked to open or add a number of different files and therefore some clear definitions:

A project encompasses one or more "Views" where a number of themes are displayed and where analysis carried out before with these themes are displayed again. Further, in a project, references will be made to "Data tables" that were needed in earlier actions.

A theme file is a file that contains geographical data in the form of Maps. It can be either location of places with further no data attached, or files with locations and data attached. Themes are Shape files, Grids, Images or Vector files.

A Table file: is a data Table often with one column where a reference is given to a certain location in one of the Theme files.

Let's go back to our opened View

3.2 Some Tools in View

- The "Theme" can be turned on or off by clicking on the checkbox
- By clicking on the Table of contents the "Theme" can be made active and appear raised in the table of contents.
- Once the "Theme" is active and we double click on the "Theme property" box the properties of the Theme are displayed (Figure 10)
From the theme properties we see the name of the theme and the data source, which is a "shape file" found in the subdirectory C:\nefisco-egis\shape files and called upazilla1.shp. In this tool we can manipulate how the original data are displayed. In the upper window the name is given of how this theme is displayed in the View. Here this name can be changed without changing the name that is saved in the computer.

**Try it out by changing the name of the file in this window.**

- With the "Zoom in Zoom out" icon in the toolbar we can make areas of interest larger by placing the cursor near the place of interest and dragging it till the area of interest is selected (Figure 11). After releasing the mouse button, the view will be redrawn in the magnified scale (Figure 12).
Figure 11: Selecting an area for enlarging

Figure 12: The result of zooming
Once you have zoomed in and you want to go to another location, you can move the map with the "Pan icon".

Try this out by zooming on Dhaka and "pan" then to Chittagong

"Identify", is a tool to get more information on the separate items displayed in the map. Once the tool is activated by clicking on the icon with your mouse, click on a item/location in the map, click the mouse and detailed information of the table attached to the map for this location is automatically provided (Figure 13).

Figure 13: Getting details from the map by using "identify".

By clicking with identify on an upazilla the data of this upazilla attached to this "Theme" automatically pops up. By doing it we see the name, the population density, etc.

We can use this tool to find an upazilla if we do not know exactly where it is, but this means that you have to click on a large number before you have found it. This can be
done much more easily with "autolabel". You can add the name of the upazillas by selecting “auto label” in the "Theme menu" and select "Upzname" in the "Auto-label" window (Figure 14).

![Figure 14: Auto labelling](image)

**Try it out:** Zoom in on Chittagong, Auto-Label the upazilla names and find the upazilla named “Ruma”.

### 3.3 Graphical displays in the Map View

For this chapter we open **BBS2.apr**

#### 3.3.1 Changing colours or the legend

Open the View "population density"

In the example on data of the Bangladesh Bureau of Statistics the data were presented in the map in the form of "gradual changing colours" whereby increasing red tones indicates a higher density. The number of classes of colour tones as well as the colour itself can be changed easily by double clicking on the "theme legend", after which the menu pops up (Figure 15).
Figure 15: The menu for changing the properties of the graphical display of a "Theme".

Click on the right downward arrow of the "colour ramp" window select "Yellow monochromatic". Click on "apply"; close the menu, and we see that all colours are changed, gradually changing Yellow (Figure 16).

Figure 16: Changed colours of the population density map
Try it out by changing the colours successively into: Yellow monochromatic; Blue monochromatic; and magenta monochromatic

3.3.2 Changing the number of classes in a legend

In the previous examples differences in the population for the different upazillas were visualised by using only five classes, and it could be the case that more details could become visible if a larger number of classes were used. Changing the number of classes over which the data are divided can be changed in a similar way as changing the colours, by double clicking on the "theme legend", after which the menu pops up (Figure 15). Click on "classify" after which the "classification menu" pops up; select 15 classes after opening the "number of classes" window with the small arrow on the right. Click OK, (Figure 17), apply, and close the menu. The new classification will be automatically displayed (Figure 18).

Figure 17: Changing the number of classes in a 'Theme'.

![Changing the number of classes in a 'Theme'.](image)
A little bit more detail is given in this view but the difference is not spectacular.

### 3.3.3 Selecting and applying bar or pie graphs

Till now the data in the maps were displayed with graduated colours filling the upazillas. But we could prefer a different graphic display, such as histograms or pie graphs or sometimes these displays are needed if we want to display two or more parameters in the maps.

Let’s look at an example. Open **BBS3.apr** and the population density view. You will see that the "Theme Total Population" exists three times. We copied them for you, and in one of them we will change the display into a "histogram" display while in the other we will change it into a "pie" display.

The type of graphical display can be changed in a similar way as changing the colours, by double clicking on the "theme legend" after which the menu pops up. In "legend type", open the window with the right arrow and select "chart" (Figure 19).
Now you see the "legend editor" and you have to select the "Field" or parameter you want to display which was the total population per upazilla so select in the "Fields window" Total_pop and click "ADD" (Figure 20).
After adding we see that the parameter "Totalpop" pops up in the right window, indicating a "symbol", which is the colour and the form of the displayed parameter, and a "field" indicating the name of the selected parameter. Finally we have to select if we want a "Pie" or a "histogram" which we do by clicking on the chart type.

If we select histogram and click "Apply" and close the menu automatically the data are displayed in the form of a histogram in Map View (Figure 21).
If you want to change the properties of the histogram, i.e. colour or size, you open the "legend editor" again by double clicking on the theme legend.

- For changing the colour after opening the "legend editor", double-click on "symbol" in the right window and the "Fill palette" menu pops up (Figure 22). Click on the "brush" and the "Colour palette" (Figure 22) pops up. Click a colour, click "apply", and close all menus.
3.3.4 Displaying two parameters in one theme

It can be the case that we want to display more parameters in one theme for example a set of different water-quality parameters or income figures of different social strata, etc. We can do this with histograms or pie charts. In BBS3.apr, we can make an example with the last not yet changed Theme. In the data set attached, we have data on the number of males and females in each upazilla, which we want to display in one theme.

- Double click on the “theme legend” to open the legend editor; Select "chart" in the window "legend type"; select in the "field" window "Male" and "Female", and "add" them. With the "colour palette" give males the colour blue and females the colour red. Click in "Chart type" on Bar, adjust when necessary the size in the properties menu in the palette located on the right side below, click "apply" and close the menu. The double histogram will automatically be displayed (Figure 23). In the view we see that there are more men than woman are living in Dhaka.
Another way to display the data is the "pie chart". The advantage of a Pie chart is that we can add one more parameter to the display of male and female population by relating the size of the pie to a third parameter in this case the total population.

Example in BBS3.apr
We click on the legend of the theme displaying the male and female population again and change the chart selection from histogram by clicking on the "pie icon"

Click on the "properties" button; the pie properties window will popup (Figure 24). Set the maximum and minimum size of the Pie to 4 and 26, respectively and select "Total_pop" in the size field window to relate the size of the pie to the total population in a Thana. Click "OK" and Apply and the pie chart will be displayed (Figure 25).
3.3.5 Exercise 1: Rural and urban population

Open BBS4.apr, which contains data from the Bangladesh Bureau of Statistics for the different upazillas in Bangladesh. The data joined to the Theme file is presented below in Table 2.
Table 2: BBS data, which are available in the Upazilla3 shape file.

<table>
<thead>
<tr>
<th>DISTRICT</th>
<th>UPZNAME</th>
<th>AREA</th>
<th>MALE</th>
<th>FEMALE</th>
<th>URBAN</th>
<th>RURAL</th>
<th>TOTAL_POP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARGUNA</td>
<td>AMTALI</td>
<td>721</td>
<td>123183</td>
<td>121255</td>
<td>12694</td>
<td>231744</td>
<td>244438</td>
</tr>
<tr>
<td>BARGUNA</td>
<td>BAMNA</td>
<td>101</td>
<td>32745</td>
<td>33220</td>
<td>6281</td>
<td>59684</td>
<td>65965</td>
</tr>
<tr>
<td>BARGUNA</td>
<td>BARGUNA S</td>
<td>454</td>
<td>111402</td>
<td>108327</td>
<td>22213</td>
<td>197516</td>
<td>219729</td>
</tr>
<tr>
<td>BARGUNA</td>
<td>BETAGI</td>
<td>168</td>
<td>55406</td>
<td>55520</td>
<td>9923</td>
<td>101003</td>
<td>110926</td>
</tr>
<tr>
<td>BARGUNA</td>
<td>PATHARGHA</td>
<td>387</td>
<td>68067</td>
<td>66568</td>
<td>16035</td>
<td>118600</td>
<td>134635</td>
</tr>
<tr>
<td>BARISAL</td>
<td>AGAILJHAR</td>
<td>162</td>
<td>75042</td>
<td>72301</td>
<td>8185</td>
<td>139158</td>
<td>147343</td>
</tr>
<tr>
<td>BARISAL</td>
<td>BABUGANJ</td>
<td>165</td>
<td>68739</td>
<td>67166</td>
<td>4789</td>
<td>131116</td>
<td>135905</td>
</tr>
<tr>
<td>BARISAL</td>
<td>BAKER GANJ</td>
<td>417</td>
<td>167154</td>
<td>169552</td>
<td>16050</td>
<td>320656</td>
<td>336706</td>
</tr>
<tr>
<td>BARISAL</td>
<td>BANARI PA</td>
<td>134</td>
<td>72869</td>
<td>70956</td>
<td>14325</td>
<td>129500</td>
<td>143825</td>
</tr>
<tr>
<td>BARISAL</td>
<td>GAURNADI</td>
<td>144</td>
<td>87721</td>
<td>83881</td>
<td>29365</td>
<td>142237</td>
<td>171602</td>
</tr>
</tbody>
</table>

1. Make a graduated colour map of the rural population (RURAL).
2. Make a graduated colour map of the population density urban population (URBAN) in blue gradients.
3. Make one map expressing both the urban population and the rural population in histograms.
4. Make the same map with a Pie chart whereby the size of the pie represents the total population.
5. Look at the graphs and draw conclusions.

3.3.6 Exercise 2: Riverine frame survey

Open Riverine Fisheries.apr

This project contains data of the riverine frame survey of 1984 and encompasses the number of small fishing boats, the number of large fishing boats, the total number of boats and the total number of fishermen per district.

1. Make a graduated colour map of the small boats
2. Make a graduated colour map of the large boats
3. Make a graduated colour map of all boats
4. Make a graduated colour map of the fishermen
5. Make a histogram displaying all boats and all fishermen
6. Make a pie displaying large and small boats, with pie size related to all boats
7. Draw conclusions from the graphs

3.4 Views and Themes: definitions and characteristics

In the previous chapters we have seen that views are interactive maps to show themes that represent real objects having a geographic location and a representative shape for example, a District, an Upazilla, Mauza, etc.

Arcview can work with three types of data sets:

- Shape files, which represent a geographical location, and data in the form of a table can be linked to them.
- Grid files, which already contain data in the form of a raster of "pixels" whereby each pixel represents a certain value the parameter represented by the Grid.
Images files. For images obtained from satellites

The different characteristics of the data sets determines the way they can be used in GIS and sets the limits of their use in different types of analyses. Therefore they are discussed more in detail in the next chapter.

There are in principle three different types of "Shape files".
- Polygon features, which are closed figures, enclosing a certain area and can represent a country, district, lake, forest, etc.
- Point features, indicate an exact location, i.e. tube wells, schools, villages, etc.
- Line features, which can represent, rivers, roads, canals, etc.

3.4.1 Polygons

In the previous chapters the different themes were "polygon files", representing the upazillas of Bangladesh. In Figure 26 three polygon themes are presented: Bangladesh, the districts of Bangladesh and the mauzas of Bangladesh. The principle of each polygon file is the same: they enclose a certain geographical area, and the only difference between the files is that the enclosed area becomes smaller.

Figure 26: Three polygon files of Bangladesh

As demonstrated in the previous chapters data obtained from the enclosed areas can be joined with each polygon and displayed either in a "graduated colour", a "histogram" or a "pie graph".

3.5 Joining data with location on a map

In chapter 2 of the basic principles we must keep always in mind was already given:

2 Not further discussed in this manual
"We join data stored in a table with a location on a map"  

In the examples/exercises given in the previous chapters, data were already joined to the different "Themes" used. In this chapter we explain how to join data in Arcview with locations in Maps or Themes.

The basic principle of joining is that the data obtained from a certain location is stored in a Table that contains a code number/name of the specific location. When the Theme file contains exactly the same code/name it is possible to join the two files through this code.

At EGIS coding of locations is done through official geocodes as used by the Bangladesh Bureau of Statistics. This is to build up a large uniform database for Bangladesh.

Let's look at an example, below in Figure 27: a table with data of different upazillas in the Bagherhat district is presented together with a polygon shape file of the same upazillas. In the polygon shape file as well as in the table we can see the geocodes through which the two can be joined.

Figure 27: Data table and map view of upazillas in the Bagherhat district, both indicating the geocodes used to join both in GIS.

Let's see how we can join the two in Arcview;

In Arcview there is a distinct difference between “Joining” and “Linking” please refer the Arcview guides on this subject.
We will start at the beginning with a blank Arcview project and will "add" the Upazilla map and the data table, after which we will join them and make a graphical display of the population density.

**Step 1: Adding a Theme**

Start Arcview, and open a new view. We can add a new Theme or the “upazilla.shp” polygon shape file by clicking the "add theme icon" or by selecting "add theme" from "view" in the tool bar (Figure 28).

"Add theme icon"

![Figure 28: Adding a theme to a view.](image)

The “Add theme menu” will open. Go to C:\nefisco-egis\shapefiles\, select "upazilla.shp" and click "OK" (Figure 29).
Open the Theme by clicking on the "View checkbox" and the upazilla shape file will open.

The "contents" of the shape file can be viewed by either clicking on the "view table" icon or by opening the "Theme menu" and selecting "Table" (Figure 30).

View table icon
The table will open, and we see that the theme only contains the needed “join item” in this case: the geocode and further, the names of the upazillas (Figure 31).

Figure 31: Geocodes in the “shape file” table

Close the table and close the View through "x" or through selecting "close" in the "file menu"

Step 2: Adding a Table

Click on the "Table " icon, and the menu will appear. Click on add and the "add" menu will appear. Select in the right window the Drive "C"; select C:\nefisco-egis\select Dbase files, and finally, select in the left window Upazilla.dbf and Click "OK" (Figure 32).

"Table " icon
The table will be added to the project and its content opens automatically, and we see the needed "geocode" in the table (Figure 33).
Step 3: the actual joining of the "table" with the "shape" file

Joining the "table" with the "theme file" is always carried out in the same three steps;

- **FIRST**, we activate the column in the "DATA Table" which contains the joining code, in our case "geocode" in the Upazilla.dbf table. **We do not close the table; we minimise it.**
- **SECONDLY**, we open the "Table of the Shape file" and activate the column which contains the same joining code as the "DATA table", in our case again the "geocode".
- **THIRDLY**, we join the "DATA table" with the "Shape file" by clicking on the "Join icon" which will automatically appear if everything is OK

**NOTE**

Try to remember the small phrase “DATA FIRST” You first click the code in the "source table" the table which contains the data you want to join.
Let's see how we join the table with the shape file in our example

**Step 3A**
The table is still open and we **click on the header of the column that contains the joining codes** in our case "geocode". After clicking on it, you see that this column header becomes light grey. After this, we **minimise the table**. (Figure 34).

![Figure 34: First step in joining a data table with a theme](image)

**Step 3B**
We open the View which contains the upazilla theme file again, activate the upazilla theme, **open the "Theme table" and click on the header of the column that contains the geocodes**. The header becomes dark grey and the "**Join Table Icon**" lights up. Click on this icon and automatically the data are joined with the Theme and appear in the window (Figure 35 & Figure 36).

![Join Table Icon](image)
Figure 35: Activating the data column for joining a table in the theme file

Figure 36: Results of joining data with the theme file
After closing the table we come back in the map view window and can start with displaying the data attached to the upazilla map.

Before continuing close the Theme and save the project as \texttt{C:\nefisco-egis\arcview projects\upazilla.apr}.

\begin{center}
\textbf{NOTE}
\end{center}

Sometimes you may think you did everything correctly and the join-icon does not appear. It could be that the joining codes do not have the same format. For example in your table file the code has a "text format", and in the shape file the code has a "numeric format", so joining is not possible. This can happen if your data were originally stored in an MS Excel file and saved to a Dbase file to allow joining in Arcview. The latter is often necessary, as amazingly Arcview can not join MS Excel, Lotus or other simple spreadsheet files.

\section*{3.6 Exercises: Joining Tables with Themes}

\subsection*{3.6.1 Exercise 1: Riverine catch data joining with a polygon shape file}

1. Open a new project, open view, add theme \texttt{"Country.shp"} and \texttt{"District.shp"} from \texttt{C:\nefisco-egis\shapefiles}, and close the view.
2. Click on the "Tables" icon.
3. Add the Table \texttt{"Riv84.dbf"} from \texttt{C:\nefisco-egis\dbase files} to the project. This Table contains district data on riverine fisheries of 1984.
4. Join the \texttt{"Riv84.dbf"} with the \texttt{"District.shp"} file by using the District code.
5. Make a pie display, which encompasses major carp, other carp, hilsa, small shrimp, and various, with total catch as properties for the pie size.
6. Repeat the exercise for \texttt{Riv97.dbf}, the riverine data for 1997.

\subsection*{3.6.2 Exercise 2: Making your own data table, joining and editing}

We have data on the total shrimp catch from Estuarine Set Bag nets (Behundi Jals) obtained in the different fishing zones in the Bay of Bengal (Table 3)

\textbf{Table 3: Total annual shrimp catch of set bag nets in different fishing zones in the Bay of Bengal}

\begin{tabular}{|l|c|c|}
\hline
Fishing Zone & Zone id & Annual catch \\
\hline
Cox's Bazar & 1 & 34000 \\
Chittagong & 2 & 2014 \\
Noakhali & 3 & 2425 \\
Pathuakhali & 4 & 11600 \\
Bagherat & 5 & 238000 \\
Satkhira & 6 & 1277 \\
\hline
\end{tabular}
1. Enter the data in a MsExcel spreadsheet, save the spreadsheet as a MsExcel file: C:\Nefisco-Egis\databases\ESBN.xls.
2. Arcview can not work with MsExcel files so convert the file to a Dbase file format; Click on File, select “Save as”, Select in the save as type window the DBF4 (dBase IV) format and click OK. When you close your file a window will pop up asking if you want to save the changes, click on No (Why ?).
3. Open Arcview,
4. Open a new View
5. Add the shape file Marine_Catchzone.shp from C:\Nefisco_Egis\Shape files, close the View
6. In project window, select table and click Add. Add the Table you just made before containing the data on ESBN catch in the Bay of Bengal
7. Join the Table with the Shape file

How to edit your Theme table ?

We would like to add a new column to the table containing monthly (January) catch data for each fishing zone as presented below in Table 4.

Table 4: Shrimp catch of setbag nets in the month of January for the different fishing zones in the Bay of Bengal

<table>
<thead>
<tr>
<th>Fishing zone</th>
<th>January catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cox’s Bazar</td>
<td>155</td>
</tr>
<tr>
<td>Chittagong</td>
<td>133</td>
</tr>
<tr>
<td>Noakhali</td>
<td>86</td>
</tr>
<tr>
<td>Pathuakhali</td>
<td>716</td>
</tr>
<tr>
<td>Bagherhat</td>
<td>17</td>
</tr>
<tr>
<td>Satkhira</td>
<td>63</td>
</tr>
</tbody>
</table>

1. Activate the Theme
2. Click on the table icon and select “Start editing”, click “add Field”
3. The Field definition window will pop up. Replace in the window “New Name” with “Catch January” in the same window we see “Type” where is written “Number” for our case this is OK as we want to enter numeric data. Further we see “Width” were “16” is given as default, This is the number of characters which can be entered, change this to “5”. Finally in the last box the number of decimal places can be indicated for us “0” is fine. Click OK.
4. Before entering the data in the new column you have to click on the “Edit icon” in the Tool bar
5. After the data entering data Go to “table” select “Stop editing” a window will pop up asking if you want to save the changes select “yes” and close the Table
6. Make a Histogram plot of the January catches
3.6.3 Exercise 3: Difference between polygon and point shape files

Step 1
1. Open a new View in the same project; add "district" shape file; add "distpoint" shape file. Remark the difference in the two different representations of districts.
2. Close View.

Step 2
1. Add "Riv92.dbf" to the project. This table contains data on the riverine catch per district obtained in 1992.
2. Join the Dbase table Riv92.dbf with the distpoint shape file.
3. Make a graduated colour display of “total catch”.
4. What do you see?
5. Save the project under a name of your own choice.

3.6.4 Exercise 4: Riverine frame survey data joining with point shape file

Open a new View.
Add the table "rivframe.dbf" from C:\Nefisco-Egis\dBase files.
Open a new View and add the "Distpoint" shape file.

6. Join the "rivFrame.dbf" with the "Distpoint" shapefile by using the "Distcode". The new table of district point shape file contains now data on the riverine frame survey of 1984.
7. Copy the "Distpoint" shape file two times so that you have three Distpoint shape files.

Step 4
1. Make a "graduated colour map" of the number of fishermen with the "distpoint shape file. Remark the results.
2. Make a "graduated symbol map" of the number of fishermen with the "distpoint" shape file. Remark the results.
3. Make a "Histogram map" of the number of fishermen with the "distpoint" shape file. Remark the results.
4. Repeat the exercise for the number of boats.
5. Make a double histogram with the number of boats and the number of fishermen.
6. Save the project as "Riverine fishermen frame".

3.6.5 Facultative Exercise 5: Repeat it with small and large boats.

With this exercise we have seen some characteristics of a shape file with POINT features, i.e. a shape file which is related to an exact location⁴ on the map.

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⁴ For this exercise we have chosen an arbitrary location in each district.
4 POINT SHAPE FILES

4.1 Characteristics of point shape files

The previous chapters used polygon files of districts, upazillas, etc., which are mostly made by specialised national institutes/agencies such as EGIS, or LGED, etc.

In more specialised institutes/agencies it happens often that data are collected on areas not directly covered by the National Agencies, especially if sampling of environmental and fisheries data is concerned and they have to make their own shape files of the sampling sites.

In point shape files we can make for each location an exact geographical location, which makes them extremely suitable for the use of indicating sampling sites on a map.

Let’s look at an example of a point shape file:

Open "Marine frame survey.apr", and open the View with the same name, which presents the location of the marine fishing villages as covered by the Frame survey of 1994.

If we click on the "identify icon" and move with the mouse over the screen we will see that in the upper right corner some numbers are changing rapidly (Figure 37). These numbers indicate the exact location on the viewed map or give the "georeference" of a location. If we go to some villages we find the following georeferences:

<table>
<thead>
<tr>
<th>Location</th>
<th>Geos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kat Ghar</td>
<td>672.394.52</td>
</tr>
<tr>
<td></td>
<td>498.466.27</td>
</tr>
<tr>
<td>South Salim</td>
<td>681.397.44</td>
</tr>
<tr>
<td></td>
<td>471.321.10</td>
</tr>
</tbody>
</table>
The geo-reference of the villages does not look like the normal references we are used to knowing from maps, which is expressed as

**Latitude:** °Degrees, 'Minutes," Seconds

**Longitude:** °Degrees, 'Minutes," Seconds

The geo-reference used in GIS for Bangladesh is obtained after projection of the coordinates (latitude and longitude) into a BTM\(^5\) or **Bangladesh Transverse Mercator** Georeference code. This projection is needed because the Longitude and Latitude values are related to a "globe", the Earth which is projected in GIS on a "flat surface", our screen or paper.

The projection from degrees, minutes, and seconds (longitude and latitude) is done\(^6\) with a small programme called "**Geowin"**

Let's look at the georeferences of the marine fishing villages, if you open the Table of the "**Fishing villages**" Theme you see two columns one with the header "**BTM-e**" and another with "**BTM-n**", the georeferences for respectively the X-axis (BTM-easting) and the Y-axis (BTM-northing) of the map (Figure 38)

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\(^5\) BTM is the standard georeference used by EGIS and WARPO

\(^6\) Before using this programme check with EGIS or SWMC the default setting needed for Bangladesh
4.1.1 How to get geo references

The geo-references, in longitude and latitude, can be determined nowadays easily with a Global Positioning System (GPS) available at a large number of institutes in Bangladesh. The price of the GPS reduced drastically in recent years and even the cheaper ones (300-400 US$) have an accuracy of 50-100 meters, which in most cases is sufficient for our work.

If a GPS is not available, then the geo-references can be taken from available maps. For example the references from the Marine fishing villages were taken from the LGED maps.

Example: Create a new point shape file

Open "Marine Framesurvey.apr"; open the View "Making Point Shape File". You see that a country shape file has already been added, and on top of it we want to place the marine fishing villages. The first step is to import the data table containing the georeferences/co-ordinates.

Step 1
Close the View. Click on "Table Icon". Add "Marine_villages_georef.dbf" to the project. The table appears, and you can see the BTM-E (X-axis) co-ordinate and the BTM-N (Y-axis) co-ordinate in the Table. Close the Table and open the View "Making Point Shape File" again.
Step 2
Open the "View menu". Click on "Add Event Theme" (Figure 39) after which the "Add Event Theme Menu" appears (Figure 40). The needed Table is of course "marine_villages_georef.dbf". For the X field we select BTM-e and for the Y field we select BTM-n, after which we click "OK" and the villages will appear once we have clicked the checkbox of the new created Theme. Save the file as "Marine Frame Survey exercises.apr"

Figure 39: Adding an event Theme
4.2 Exercises: Making point shape files

4.2.1 Exercise 1: Inland riverine fishing Villages in Bagherhat District

1) Open new Project.
2) Open new View.
3) Add "District" polygon shape file.
4) Add the Table Frame_Bagherhat.dbf, with the co-ordinates (BTM) of the riverine fishing villages of Bagherhat District, to the Project.
5) Create New Event Theme with BTM-e and BTM-n to get the villages.
6) Save the project as "Bagherhat."

4.2.2 Exercise 2: Sampling stations of salinity levels in the coastal area

The example contains data on salinity levels sampled in the coastal area of Bangladesh. The exact location of the sampling stations was determined with a GPS. Data on the salinity levels and the BTM co-ordinates are found in the file "salinity_coast_Bangladesh.dbf.

1. Open new project.
2. Add the data file with the geo-co-ordinates of the salinity sampling stations and data on salinity to the project (Salinity_coast_bangladesh.dbf).
3. Open a new View.
4. Add the "District" shape file.
5. Add the salinity sampling stations to the Map with Add event theme.
6. Make a histogram and a graduated symbol plot of the salinity levels.
7. Save the file as Salinity_coast_exercises 1.apr
4.2.3 Exercise 3: Adding the number of boats to the marine villages

To complete the handling of field data in Arcview we have to join to the just-created Theme with marine fishing villages the data on the number of boats found in each village.

1. Open the project "Marine Frame Survey exercises" again.
2. Click the "Table Icon".
3. Add the Table "Marine_villages_boats.dbf" which is found in C:\nefisco-egis\dbase files.
4. Join this table with the villages in View 1 by using "LGED_geoco".
5. Make a "graduated colour", a "graduated symbol" and a "histogram chart" display from the total boats in the villages.
6. Save the project again.

4.3 Graphical displays of point shape files and the creation of contour line plots.

In the previous and in exercise 3.3.6 we have seen how we can display data joined to a point shape file in the form of histograms or graduated colours and graduated symbols. The best plot is the "graduated symbol" (Figure 41) as it gives us in one view of the distribution of the fishing boats along the coast and allows us to identify quickly where the villages are with large numbers of boats. This is useful if we want to collect information on fisheries but have limited funds and are therefore not able to carry out an "at random" sampling program.

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7 When the marine fishing villages were geo-referenced by the Meghna Estuary Study in 1998, only the LGED geocodes were taken from the maps.
The different forms of displaying data in GIS discussed till now are difficult to use if we want to know why there is a large number of boats in a certain area or, if we want to know if there is a gradient in the density of boats and to which factors this gradient is related.

For this we have to interpolate between the numbers of boats in the different fishing villages, which is often done with a "contour plot" that connects data points with the same values.
5 DATA PLOTS AND GIS ANALYSIS

Two commonly known contour plots are the topographic map (Bangladesh Water Development Board, Finmap) presenting the land elevation (Figure 42) and the iso-hyaline maps of Surface Water Modelling Centre (SWMC) presenting salinity levels in the coastal surface water (Figure 43).

Figure 42: Contour line plot of land elevation in the north-western part of the CPP project area
“Contour line” plots can give more information on the data than "graduated symbol" plots. But still they are difficult to use in a further analysis in GIS, as will be explained in the next chapter.

5.1 Contours salinity lines versus surface plots

Let’s look at an example indicating why they are difficult to use

- Open the project "Salinity in the Coastal area".
- Open the View "Salinity contours".
- Activate the Theme "Salinity contour lines;" click "identify" and click with your mouse on the contour lines and in between the contour lines. As you will see "only the lines contain data". In between the lines there is no data attached to this Theme.
- Close the View.

- Open the other view in the project called "Salinity Grid",
- Activate the "Salinity Grid" Theme, click "identify" and click on the map again. Now you see that wherever you click there is data attached.
- If you "Zoom in" very large you see that this Theme consists of very tiny square blocks called "pixels". This theme is a "Grid file" where data is attached to each small block or pixel.

8 Use this file only for training purposes as the salinity levels are adapted for this training
This characteristic of Grid files, "Data attached to each pixel," makes them extremely useful for analysis in GIS.
6 GRID FILES

6.1 Grid file characteristics

As mentioned before, a Grid layer consists of a larger number of small squares (pixels) of equal size with certain criteria attached to them (see Figure 44).

**Figure 44: Examples of pixels in Grid Layers representing water depth and another representing a crop in the same location**

In the left grid, blue pixels represent water and green pixels represent dry area. In the right grid, Green represents a Rice crop, and Orange, no crop. From the example, it is concluded that rice in the observed area is grown in areas with a shallow water depth.

As always in GIS, a file or a Grid represents data linked to a certain location on a Map, which means that each pixel in a Grid represents a geographical location.

This also means that the size of the pixel or the resolution determines the degree or level of accuracy of the GIS grid layer.

This is well known from satellite images (which in principle are Grid files). The early images had a low resolution of 30-50 meters, or each pixel represented an area of 900-2500 m$^2$. Nowadays we have images with a high resolution with pixel sizes of 6x6 m (IRS) or a pixel size of 36 m$^2$ and lower.

Smaller pixel sizes also means increased number of pixels to store data, increased size of the files. Grid files of 1-2 megabytes are quite common in a GIS analysis and a fairly simple GIS analysis easily requires 200-300 megabytes of free hard disk space to store all the generated Grid files.

Grid files can be made in several ways

- The crop grid file presented was made by digitising the areas with crops from a satellite image after which the created "Polygon shape file" of the different crops was converted into a "Grid file".
- The water level Grid file was generated from water levels measured at a number of points in the area. A "point shape file" of the water reading stations was made. The data on water levels were joined and the Grid was generated through a
"Surface plot" which is in principle a contour plot only the data are presented with "pixels" instead of with contour lines.

To generate a surface plot you need besides Arcview, the software programme "Spatial Analyst"

6.2 Spatial Analyst

In the application of GIS in fisheries and environmental sciences the Point shape files are more important than polygon files. That is because they can give the exact location of sampling stations of fish, water quality parameters, water velocities, rainfall, water level, etc. The data on the different locations can be connected to generate data plots. We all know examples of such data plots from the pre-GIS period; contour lines made from topographic maps, salinity lines in the coastal areas, etc.

GIS has a number of powerful mathematical tools to create these data plots. Once a number of plots of different parameters are made for the same area, then GIS can look for interactions or relations between the different layers or parameters sets.

For example, GIS could be used to analyse whether in a certain area there is a relation between the occurrence of White Spot disease in shrimp farming and parameters such as water quality in the ponds or major canals, salinity level, feeding levels, stocking density of post larvae, etc (Figure 45).

Figure 45: Example of the use of different layers in analyses in GIS, with different colours indicating the individual pixels with different data attached

It can not be stated enough that GIS is much more than a sophisticated tool to make nice maps for reports. It is a tool for spatial analysis of data.

Unfortunately, for the complete spatial analysis of data not only Arcview is needed as mentioned before, but also the software programme "Spatial Analyst" from ESRI, which is often forgotten.

With Arcview you can only make nice maps and simple spatial analyses if Grid files are available. However you need Spatial Analyst to create grid files from your data and to carry out more complicated analyses.
6.3 How to set your defaults for the use of Spatial analyst

Once you have bought and installed Arcview and Spatial Analyst, it is important to set the defaults for the use of both programs after you start Arcview. After you have started Arcview, select "extensions" in the File menu, which opens the "Extensions menu," click all options, click "make default" and select "OK" (Figure 46 & Figure 47).
Figure 46: Selecting the 'File extension' menu

Figure 47: Setting the defaults for Arcview.
7 SURFACE PLOTS

Surface plots are important instruments in GIS, and a number of tools developed for fisheries is using them. Therefore more detailed information on how to make them is given in this chapter.

The basic characteristics of a surface plot or grid are similar to those of contour lines; it "connects data points with similar values". The large difference with contour lines is that the areas in between two points also have a value added to their pixels.

7.1 How the interpolation of the data works

In Figure 48 the salinity levels in the coastal area of Bangladesh are presented again, now with two extreme values highlighted one low value of 0.3 ppt in the north and one of 8 ppt in the south.

Figure 48: Two extreme salinity levels in the coastal area of Bangladesh used to interpolate the data in between.

In Figure 49 the way the "Theoretical salinity levels" of 12 areas between the two extreme points are calculated is that it is assumed that the salinity gradient is linear in relation to the distances between the two points.

---

9 Most interpolations in ArcView do not use a linear relation, (see Note)
The exact way Arcview interpolates is more complex as it interpolates between all data points or a selected number of data points simultaneously so that you get a kind of web of calculation. For more details on the exact mathematics, refer to the handbooks (see the note below).

7.2 How to make a surface plot

The best way to explain how to make a surface plot is to carry out an example, and for this we use water level readings in the CPP project area.

Within the CPP project area, a large number of gauges were placed in 1992 to measure the water level in the different parts of the project. An example of the water levels at the different stations is presented in Figure 50.

NOTE

The surface interpolators in Arcview make certain assumptions about how to determine the best estimated values. Based on the phenomena the values represent and on how the sample points are distributed, different interpolators will produce better estimates relative to the actual values. No matter which interpolator is selected, the more input points and the greater their distribution, the more reliable the results.

The Inverse Distance Weighted (IDW) interpolator assumes that each input point has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than it does those farther. A specified number of points, or optionally all points within a specified radius, can be used to determine the output value for each location.

The Spline interpolator is a general-purpose interpolation method that fits a minimum-curvature surface through the input points. Conceptually, it is like bending a sheet of rubber to pass through the points, while minimising the total curvature of the surface. It fits a mathematical function to a specified number of nearest input points, while passing through the sample points. This method is best for gently varying surfaces such as elevation, water table heights, or pollution concentrations. It is not appropriate if there are large changes in the surface within a short horizontal distance, because it can overshoot estimated values, and no barriers can be set.
Figure 50: Average water levels at the different gauge reading stations in CPP during September 1997\textsuperscript{10}.

We see immediately that the water levels in the Northwest are higher if compared with the South east of the CPP area, and we expect a gradient from high water levels in the Northwest to low levels in the Southeast. We will calculate this gradient with a surface plot, which will interpolate the values lying in between all the values provided by the gauges in the figure.

**NOTE**

By carrying analysis in GIS you create "new grid" files. They are automatically stored in the default temporary directory, often "C:\windows\temp" or "C:\temp". If you carry out a number of different analyses they are all stored there and are later difficult to separate. Therefore it is strongly recommended to make for each type of analysis a separate temporary directory, i.e. if you work with shrimp you make a temporary directory "C:\shrimp\temp" and set the "working directory" for each project you carry out for the shrimp analysis to this temporary directory.

Set the working directory in a project by opening "set working directory" in the "file menu" of the View of a project.

\textsuperscript{10} If you want to see this figure in Arcview, open CPP gauge readings graph.apr
7.2.1 CPP water level surface plot: An example

1. Start Arcview.
2. Start new project.
3. Make sure if Spatial Analyst is made default.
4. Open a new View; add the "CPPgauges.shp" to the view. This is a point shape file with the location of the water gauges within the CPP project. Add the shape file "CPPbound.shp" and the "District.shp" to the View.
5. Close View 1.
6. Click on the "Table" icon and add the data file "before9.dbf" to the project. The file contain data on average water levels in September in the CPP area.
7. Activate the column header "Gaugename", open View 1 again and join the data with the gauges.
8. Zoom in on the CPP area to see the gauges clearly.
9. Activate the "CPPgauges" theme.
10. Select "Interpolate surface" in the "Analysis menu". (Figure 51).

Figure 51: Start interpolate surface

11. The "Output Grid Specification" menu will pop up (Figure 52). In this menu we specify the characteristics of the new grid we are going to create. Select "Same as View" in the "Output Grid Extend" window, which means that the new grid will cover the whole View, including the areas at the moment not visible on the screen. If you select "as display" the grid will only be made visible for the area we see at the moment on the screen.
12. Enter "500" in the "Cell size" window, setting the pixel size at 500x500 meters. Observe that the "numbers of rows" and "number of columns" automatically change. Click "OK".

**Figure 52: Setting the output characteristics of the surface plot.**

13. The "Interpolate surface" window will pop up (Figure 53). We keep all the default settings of Arcview for the method (IDW see note) and only select "Water level" in the "Z-value" window. Click "OK". The window disappears and we can see that calculation is in progress by a horizontal blue bar appearing at the lower part of the screen indicating that the calculations of the interpolation have begun.\(^\text{11}\)

**Figure 53: Selecting the Z-value for interpolation of water levels in the CPP area**

14. After some time a new Theme called "Surface from CPPgauges" will appear. Activate the legend and change the colours in "blue monochromatic" and we have a nice plot of the calculated water gradient in CPP (Figure 54).

\(^{11}\) Do not worry if the interpolation takes some time.
15. Click on the "Identify Icon" and go with your mouse to the screen. Click on the different blue areas. Observe the values.

16. The surface plot shows a gradient with high water levels in the Northwest and lower water levels in the Southeast, so everything seems OK.

17. However, there is something fundamentally wrong, which becomes visible if we zoom out (Error! Reference source not found.)

We created a water level grid for the whole of Bangladesh, based on a number of water levels in the CPP project area. The example makes clear that for all analysis carried out in GIS we have to set the boundaries where the analysis takes place. In our example the boundary has to be set to within the CPP project boundary.

18. Close the View and save the project as Surface exercise 1.apr.
7.3 How to set the boundary or a mask in a GIS analysis

We will carry out the same exercise, but now with the CPP-boundary giving the borders of the analysis. First we have to know how to set the boundaries for a GIS analysis.

There are two ways to set the boundaries for an interpolation or analysis, and the way they work are fundamentally different.

- Making a boundary by setting a Mask; in principle, a mask delimits the area you will see after you have made the calculation or interpolation. The calculations are carried out beyond the boundaries of the mask. By putting a mask in our example, we still create water levels in the Chittagong hill tracts with data in CPP only we do not see them and they are not stored. Setting a mask is the easiest way to define a boundary for an analysis and provides reliable results as long as all data points that you want to interpolate are located within the boundary of the mask.

- The more correct way is to define the area where the interpolation takes place with "barriers". When you set a barrier, the calculation/interpolation will not carried out beyond it. In our example, it means that an interpolation is only carried out within the boundary set in the CPP area. Barriers are more difficult to apply as they work with line shape files only and are not further discussed in this manual.

Masks can only be set with "Grid files". In most cases, the boundaries are made in shape files such as the "Country.shp" or the "CPPbound.shp". We first have to convert them into a Grid File that will be shown in the next example.

7.3.1 CPP water level surface plot: An example with boundaries set

- Start Arcview.

NOTE
In the previous example you created a new Grid called "Surface from CPPgauges" it is stored as "C:\temp\sface1". The next interpolation you make will be saved as "C:sface2", etc. If you make a number of interpolations and you want to use one of them later in another project, you will have difficulties finding it again. You can, however, save the newly created surface grid under a name of your own choice just after you have made it by opening the "Theme menu" and clicking "save data set". If you forget this, it is not easy to change the names later.

This applies to all new grids made by "Map calculation", "Surface interpolation", "Queries" and "Reclassification".
♦ Open a new View; add the "CPPgauges.shp" to the view. This is a pointshape file with the location of the water gauges within the CPP project. Add the shape file "CPPbound.shp"
♦ Activate the Theme "CPPbound" and click in the "Theme menu" on "Convert to Grid".
♦ In the "Conversion Extent menu", that pops up, choose Same as View in the Output Grid Extent window. Enter "75" in the Output Grid Cell Size.
♦ The "Conversion field window" pops up; choose ID.
♦ After a while a menu pops up in which you are asked to enter a name. The default it gives is NWGRD1, (See Note) Change this in "CPPbound"; click "OK".
♦ Join feature attribute will appear; click Yes.
♦ Add View to Theme will appear; click Yes. Set the border for the analysis by selecting in the "properties" in the Analysis menu and selecting "CPPbound" in the "Analysis Mask" window. (Figure 56).

**Figure 56: Setting the boundary**

![Analysis Properties: View1](image)

♦ Close View 1.
♦ Click on the "Table" icon and add the data file "before9.dbf" to the project. The file contains data on average water levels in September in the CPP area.
♦ Activate the column header "Gaugename" and open View 1 again. Join the data with the gauges shape file.
♦ Zoom in on the CPP project area.

12 In the original analysis of CPP all grid sizes of 10x10 were used, as this is the pixel size of the DEM. In this manual for CPP 75x75 meters is always used as it takes less time to make the calculations.
♦ Select "Interpolate surface" in the "Analysis menu".
♦ The "Output Grid Specification" menu will pop up (Figure 52) In this menu we specify the characteristic of the new grid we are going to create. Select "Same as Display" in the "Output Grid Extend" window. That means that the new grid will cover only the visible area we see at the moment on the screen, or the CCP project area. If we choose here "CPP bound", we also limit the extend of the grid to the CPP project area.
♦ Enter "75" in the "Cell size" window, setting the pixel size at 75x75 meters. Observe that the "number of rows" and "number of columns" automatically change. Click "OK".
♦ The "Interpolate surface" window will pop up. We keep all the default setting of Arcview and only select "Water level" in the "Z-value" window. Click "OK". The window disappears and we can see that calculation is in progress by a horizontal blue bar appearing at the lower part of the screen indicating that the calculations of the interpolation have begun.
♦ After some time, a new theme called "Surface from CPPgauges" will appear. Activate the legend and change the colours to "blue monochromatic" and we have the correct plot of the calculated water gradient in CPP.
♦ Close the View and save the project as "Surface exercise 2.apr"

Figure 57: Water level surface plot of CPP generated with the CPP boundaries as a mask.
7.4.1 Riverine catch statistics

Open the project "Riverine catch 1993 exercise.apr". The project contains officially published (FRSS) catch statistics of riverine fisheries of the year 93/94. Make a surface plot of "total catch", "major carp", "Hilsa", and "Various" with Country as Boundary and pixel size 2000-m. For this convert the Country shape file into a grid and set the newly made grid as a mask.

There are two Views called "Riverine catch 1988" and "Riverine catch 1997" in which the Country Theme and the District Theme are already added. If you open the Table of the District Theme you will see that the catch data is absent. As a facultative exercise, add the Data tables; "Riv88.dbf" and "Riv97.dbf". Join them with the correct District shape files and make the same surface plots.

7.4.2 Salinity levels in the coastal areas

♦ Open the project "Salinity surface exercise".
♦ Open in the project the view with the same name.
♦ Check if the Mask is set on "Border".
♦ Make a surface plot for the salinity levels with a pixel size of 500x500 meters.
♦ Give the created "surface plot of sampling stations" a new name.
♦ Give the surface plot "orange monochromatic" colours.
♦ Save the file with the original name.
8 CALCULATION WITH GRIDS USING GIS

8.1 Map calculations

In a grid each pixel has a characteristic attached to it. This can be a code but also a number, as for example water level or topographic level. Once grids are compared in the same location, it becomes straightforward that you can make calculations between grids.

Let's look at an example. In Figure 58 a cross section is presented from the CPP project area with the red line representing the topography of the land and the blue line the water level.

![Figure 58: Cross section of the CPP project area](image)

In the previous chapter we made a surface plot of the water level. In the results, the plot made it appear that there was water everywhere. The reality is different. In our cross-section, the blue line is the surface plot we calculated and we see immediately that there is only water in places where the topo-level (red line) is lower than the surface plot.

Both grid files have values attached to each pixel. This allows us to calculate the water depth at each location presented by a pixel by simply subtracting the value of the topo-level from the water level.

Water depth = Water level - Topo level

An example of this calculation is presented in Figure 59 whereby for the topo level the values of the Digital Elevation Model (DEM, see chapter 8.3, page 76) are used and it is clear that once the value of the water depth becomes negative that the area is dry.
Figure 59: Schematic example of calculation of water level

<table>
<thead>
<tr>
<th>DEM</th>
<th>WL</th>
<th>Water depth =WL-DEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1350</td>
<td>1280</td>
<td>-20</td>
</tr>
<tr>
<td>1280</td>
<td>1310</td>
<td>30</td>
</tr>
<tr>
<td>1210</td>
<td>1310</td>
<td>100</td>
</tr>
<tr>
<td>1100</td>
<td>1310</td>
<td>210</td>
</tr>
<tr>
<td>1100</td>
<td>1360</td>
<td>260</td>
</tr>
<tr>
<td>1223</td>
<td>1380</td>
<td>157</td>
</tr>
<tr>
<td>1250</td>
<td>1300</td>
<td>50</td>
</tr>
<tr>
<td>1300</td>
<td>1290</td>
<td>-10</td>
</tr>
<tr>
<td>1300</td>
<td>1290</td>
<td>-10</td>
</tr>
<tr>
<td>1350</td>
<td>1280</td>
<td>-70</td>
</tr>
</tbody>
</table>

The same example in Arcview

1. Open the project "Calculate water depth in CPP exercise.apr" and its View with the same name. We see in the View the grids of the "water level" (the earlier created water level surface plot) and the "DEM" (the topo-level).
2. The water depth we calculate with: **Water depth = Water level - Topo level.** To do this we open "Map Calculator" in the "Analysis menu" (1).
3. After which the "Map calculation" window opens (Figure 61). In the window we see [Water level], [DEM] and [DEM .count]. The calculation we carry out with the first two and we simply enter the formula by clicking "water level", then "Minus", followed by clicking "DEM". Click on "evaluate " to start the calculation, and close the window after results called "Map calculation of..." appear.
4. **If you want to save this calculation under a new name at your temporary directory you must do it now (see note)**
5. Redo the colours of the calculation in such a way that water becomes various gradients of blue and dry land becomes one grade of yellow. You will see that the latter is not easy, as you have to think in negative values. It is easier to change the calculation to **Water depth = DEM - water level.** Positive values signify dry land, while negative values become water depth.
6. Save the project file with the original name.
NOTE
It is easier to calculate

Water depth = Topo level - Water level

This classifies nicer as dry areas will have positive values and flooded areas will get negative values and your first view of the results does not confuse you
Try this out
8.1.1 Reclassifying

The calculation of the water depth gives a large number of different water depths in the whole CPP area, which is the natural situation. However in some calculations we are not interested in the water depth but only whether a certain area is flooded or not. Working with all the different water levels makes further calculations unnecessary cumbersome. An easy way to overcome this problem is to reclassify the data i.e. we give a specific value to all pixels representing a dry (0) area and another specific value (1) to all pixels that are flooded (Figure 63).
**Figure 63: Schematic view of reclassification of flood depth into flooded and dry area**

<table>
<thead>
<tr>
<th>TOPO</th>
<th>WL</th>
<th>Water depth =WL-TOPO</th>
<th>Reclass Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300</td>
<td>1280</td>
<td>-20</td>
<td>Dry</td>
</tr>
<tr>
<td>1280</td>
<td>1310</td>
<td>30</td>
<td>Flooded</td>
</tr>
<tr>
<td>1210</td>
<td>1310</td>
<td>100</td>
<td>Flooded</td>
</tr>
<tr>
<td>1100</td>
<td>1310</td>
<td>210</td>
<td>Flooded</td>
</tr>
<tr>
<td>1100</td>
<td>1350</td>
<td>260</td>
<td>Flooded</td>
</tr>
<tr>
<td>1223</td>
<td>1350</td>
<td>157</td>
<td>Flooded</td>
</tr>
<tr>
<td>1250</td>
<td>1300</td>
<td>50</td>
<td>Flooded</td>
</tr>
<tr>
<td>1300</td>
<td>1290</td>
<td>-10</td>
<td>Dry</td>
</tr>
<tr>
<td>1300</td>
<td>1290</td>
<td>-10</td>
<td>Dry</td>
</tr>
<tr>
<td>1350</td>
<td>1280</td>
<td>-70</td>
<td>Dry</td>
</tr>
</tbody>
</table>

1. Open the project "**Calculate water depth in CPP exercise**" and its View again.
2. Activate the theme with the calculated water levels.
3. Open "**Reclassify**" in the Analysis menu; the "Reclassify values menu" will pop up and we see that the default setting is reclassification of the old data over 10 new classes (Figure 64). For our case this is too much as we want **ONLY 2 CLASSES; DRY and FLOODED**.
4. Click on 'Classify' and select 2 classes in the "**Classification window**" (Figure 65) and click "**OK**".

The "Reclassify Values window" appears again now with two classes. All negative calculated values were dry areas, so we use the values "**-1000 to 0**" for dry land and the values "**0 to 1000**" for flooded land (Figure 66). Click "**OK**" and after a while the new Map will appear (Figure 67).
Figure 64: Reclassification Menu

Figure 65: Select the number of classes
Figure 66: Enter the old and new Values

Figure 67: Calculated dry and flooded areas in the CPP project area
8.1.2 Querying

The last type of calculation discussed is querying. In a query, you try to find a location or area on a map that fulfils certain criteria. This can be done with two criteria using two GIS layers but it can also be a complicated query using a large number of layers.

Some examples:

- Find all the areas with a salinity level of 15 ppt and shrimp farming as a major crop, two GIS layers needed.
- Find all the areas with alluvial soils, medium rainfall and Borro as major crop, three layers needed.
- Find all the villages with more than 50% fishermen, more then 50% of Hindu households, average income of these households less then 8000 Tk/year and fishing in the river, four GIS layers.
- Calculate the area of F3, F2 and F1 land type inundated by flood, two layers needed.

The last query is an important component of "Habitat Oriented Fisheries Monitoring" and the principle is explained with an exercise.

8.2 Exercises

8.2.1 Exercise: Calculate the shrimp farming area in the different salinity zones without a computer

Below we have two grids, one representing

- land use in the coastal area, with red pixels representing shrimp farms and green pixels representing other crops.

- Salinity in the same area, with light yellow pixels representing 0-1 ppt; rose pixels; 1-2 ppt; dark yellow; 2-3 ppt, and brown pixels representing 3-4 ppt.

---

13 See next chapter
Each pixel covers an area of 5 hectares
Calculate the area covering shrimp farms in the different salinity zones by using the two transparencies on the next pages.
<table>
<thead>
<tr>
<th>0-1</th>
<th>0-1</th>
<th>0-1</th>
<th>0-1</th>
<th>1-2</th>
<th>1-2</th>
<th>2-3</th>
<th>2-3</th>
<th>2-3</th>
<th>2-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>1-2</td>
<td>1-2</td>
<td>1-2</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>0-1</td>
<td>0-1</td>
<td>1-2</td>
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<td>2-3</td>
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<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>3-4</td>
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<td>1-2</td>
<td>1-2</td>
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<td>1-2</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>3-4</td>
<td>3-4</td>
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<td>1-2</td>
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<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>3-4</td>
<td>3-4</td>
<td>3-4</td>
</tr>
</tbody>
</table>
8.2.2 Exercise 2: Calculate areas of shrimp farming in different salinity zones in Arcview.

Open the project "Querying Shrimp farms and salinity surface plot exercise.apr". This file contains the surface salinity plot made in a previous exercise and a Grid file of digitised Bagda Ghers in the same area.

We want to know how many hectares of shrimp are lying in the different salinity zones. So we query the "Shrimp farm grid" with the "Salinity grid", with the following basics

First we have to reclassify the "Salinity surface grid" with;

<table>
<thead>
<tr>
<th>PPT</th>
<th>New Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>1</td>
</tr>
<tr>
<td>1-2</td>
<td>2</td>
</tr>
<tr>
<td>2-3</td>
<td>3</td>
</tr>
<tr>
<td>3-4</td>
<td>4</td>
</tr>
<tr>
<td>4-5</td>
<td>5</td>
</tr>
<tr>
<td>5-6</td>
<td>6</td>
</tr>
<tr>
<td>6-7</td>
<td>7</td>
</tr>
<tr>
<td>7-8</td>
<td>8</td>
</tr>
</tbody>
</table>

So the basic queries will be:

Shrimp = 1 and salinity = 1
Shrimp = 1 and salinity = 2
Shrimp = 1 and salinity = 3
Shrimp = 1 and salinity = 4
Shrimp = 1 and salinity = 5
Shrimp = 1 and salinity = 6
Shrimp = 1 and salinity = 7
Shrimp = 1 and salinity = 8

Reclassify the "salinity surface grid" and carry out the analysis, then fill in the table below. Check the pixel size in the table format of the generated queries (100 ha);

<table>
<thead>
<tr>
<th>Salinity Zone</th>
<th>Area Shrimp farming (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>4-5</td>
<td></td>
</tr>
<tr>
<td>5-6</td>
<td></td>
</tr>
<tr>
<td>6-7</td>
<td></td>
</tr>
<tr>
<td>7-8</td>
<td></td>
</tr>
</tbody>
</table>

Zoom in after you have run the queries, and what do you see ?

14 For the exercise we made a salinity surface plot with a pixel size of 1000x1000 in order to save time. For this type of analysis, the grid should be much smaller.
8.3 Digital elevation model

Before continuing with the next chapters, we will first explain the Digital Elevation Model, as it the basis for a number of tools used in floodplain fisheries.

A Digital Elevation Model is a digitised topographic map of the area; it can be presented as a contour map (Figure 68) or in the form of a three-dimensional map (Figure 69).
For the CPP area, EGIS has made a new Digital Elevation Model from the FINMAP (1991, scale 1:20,000) with a 10-cm elevation level.

In the DEM a topographic level is attached to each pixel: that’s why we can use them in calculations as presented in the previous chapter.
Figure 70: The Digital elevation model of the CPP area
9 FLOODPLAIN FISHERIES MONITORING AND GIS

Fisheries are traditionally monitored through so-called “Catch and Effort” monitoring systems in which “effort” is the number of fishermen or devices operated in a water body and “catch” is the daily catch obtained by the fishermen or nets. The total catch is obtained by multiplying the catch per fishermen/net with the number of fishermen or gears. A prerequisite for a “Catch and Effort” monitoring system is that the total effort, the total number of fishermen or devices operated is known. For floodplain fisheries in Bangladesh it means that an incredibly large number of households has to be followed throughout the year, because of the large number of subsistence fishing households. If a traditional Catch and Effort monitoring program is used, practically speaking this is almost impossible.

The Compartmentalisation Pilot Project in Tangail developed a more practical monitoring system over the period 1992-2000. This “Habitat Fisheries Monitoring Program”, which is based on traditional Catch and Effort data recording, is combined with hydrological developments and the results are analysed in a Geographical Information Systems (GIS) environment.

In the next chapters the basic principles of habitat fisheries monitoring and GIS will be explained and several exercises will be carried out to help familiarise you with this new methodology.

9.1 Basic principles of habitat stratified floodplain fisheries monitoring

The principle of the Fisheries Monitoring Program used by CPP is a stratification of Catch and Effort Monitoring. Stratification along types of water bodies is needed to scale down the inputs/field staff for the monitoring program, while the results remain reliable and representative. This means that the monitoring program is divided into several representative smaller parts; for each one the fisheries are followed, and finally the overall picture is obtained by adding the results of all the small parts together. The estimation of the total catch follows three steps:

• First the Catch per Unit of Area (CPUA) for each type of water body is determined as accurately as possible with traditional Catch and Effort monitoring.
• Secondly, the total inundated area for each type of water body is determined as accurately as possible with GIS.
• The total catch per type of water body is determined by multiplying the catch per unit of area with the area.

9.2 Stratification or criteria and principles.

The types of water bodies in the floodplain of Bangladesh can be classified as:

Beels: These are the low-lying depressions in the floodplain (small lakes). They may have a permanent character, containing water throughout the year (perennial beels) or dry out completely during a part of the year, usually 4-5 months (seasonal beels).

15 Up to 70% of the rural population
16 Spatial and temporal
**Floodplains**: Land inundated during the monsoon as a result of rainwater congestion and river flooding.

**Rivers and canals**: Classification and selection of rivers and canals is straightforward, but the classification and selection of Beels/Floodplains is more complicated as they are hydrologically linked and highly dynamic. The National Water Development Plan (WARPO, 1999) states that water bodies can be classified according to flood extent, depth, duration, timing and connectivity within the water resource system. The number of parameters needed to classify indicates that classification is could be perplexing. The following statement can best describe this perplexity

“A floodplain or a beel does not have a specified area or water depth”

The latter can be explained as follows in Figure 71 Flood levels and the inundated area of a floodplain during the months April, June and September are presented.

**Figure 71: Water level and inundated area of a floodplain system at three moments during the year.**

In April there is no floodplain, and the water depth in the beel, which covers an area of 100 ha is 1 meter. Two months later, in June, later there is 0.3 meter of water in the floodplain which covers an area of 1200 ha, while the water depth in the beel...
increased to 2 meters and covers area of 150 ha. Another two-months later, in September, there is 0.3-1.5 meters of water in the floodplain, depending on where you are, and it covers an area of 2000 ha. In this example, we looked at water levels for dates that were rather far apart, but even within one month during the flood season the water level varies significantly. This phenomenon makes it difficult to use water level as selection criteria for habitat fisheries monitoring, as it would mean that these habitats are moving on the map.

In principle, criteria that can be quantified, can be replicated, can be used all over Bangladesh and are practical for implementation of fisheries monitoring programs must be used.

The land type classification as defined by the Master Plan Organisation fits the above mentioned criteria and was the best and most practical way to define fisheries habitats because of:

- The classification is well-known by large groups of planners, scientists, departments, etc, which is of utmost importance
- The classification is precisely defined and uniform for the whole of Bangladesh, with as a basic input a Digital Elevation Model (DEM) or topographic maps and a 1 in 2.3 years maximum water level.
- Land types have a fixed position and will only change due to water management interventions, such as the construction of embankments and regulators. So specific water areas can be selected, which represents a certain land type/habitat, and stratified monitoring can be applied, which reduces considerably the work-load of the field staff.
- The impact of water levels is incorporated as the classification works with maximum water levels.

The land type classification as defined by MPO is presented in Table 5 with other classification methods, such as the general water body classification and the classification of the farmer, which in general uses the terms: Tan Jomi (high land), Pachot Jomi (medium) and Dopa Jomi (low land) to indicate the suitability of the farmer’s land for different agriculture practices.

<table>
<thead>
<tr>
<th>Inundation depth (cm)</th>
<th>MPO Land type</th>
<th>Water Type</th>
<th>Farmers Classification</th>
<th>Land use during the monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>F0</td>
<td>Dry</td>
<td>Tan Jomi</td>
<td>Sugarcane, Vegetables, T Aman HYV</td>
</tr>
<tr>
<td>30-90</td>
<td>F1</td>
<td>Dry</td>
<td>Pachot Jomi</td>
<td>T. Aman, Local and T. Aman HYV</td>
</tr>
<tr>
<td>90-180</td>
<td>F2</td>
<td>Floodplain Seasonal Beel</td>
<td>Dopa Jomi</td>
<td>T. Aman, Local, DW Aman, Fish</td>
</tr>
<tr>
<td>&gt; 180</td>
<td>F3</td>
<td>Perennial Beel</td>
<td>Beel</td>
<td>DW Aman, Fish</td>
</tr>
</tbody>
</table>
Habitat stratified floodplain fisheries monitoring further uses the principle that fisheries data obtained from a site, within a certain land type, irrespective of the actual water level measured at the site, is representative of the total inundated area of this land type i.e. if the catch in 10 ha of F2 land is well monitored during a certain period, it is representative for the total area of inundated F2 land during this period.

This principle allows concentrating the monitoring program at fixed sites within a project area and even with a limited number of field staff a statistically sound analysis can be carried out.

9.2.1 Land types

In principle, the land type classification is a risk classification for flooding. It gives you the land that has a statistical risk of flooding every 2.3 years, for three consecutive days with the earlier mentioned water levels.

In principle, land types only change if the water management in an area is changed.

An example of CPP to explain:

- Before the 70's, the CPP area was more or less an open floodplain, not protected from flooding and water from the Lohajang over the whole area. And for this situation the water depth for the different areas can be calculated giving the land types for this situation.
- In the 70's the embankment was built but the Lohajang was not regulated, and for this situation, the water depth for the different areas can be calculated again, giving new land types with less F3 area.
- The embankments were rehabilitated by CPP, the Lohajang was regulated and a number of other sluices were constructed. For this, again, the water depth in the different areas can be calculated, giving again a new set of land types reducing the F3 land types even more.

Land types are made by a hydrologist and for the further exercises "the before CPP situation" and the "Drainage intervention in CPP", they are provided and not further discussed.

9.3 Habitat stratified monitoring

The actual monitoring consists of a catch assessment and frame survey within a fixed area at the selected sites:

Catch Assessment Survey: The daily catch of every individual fisherman is monitored regularly at each site. The numbers and weight of the dominant species in the catch are recorded. Furthermore, the gear-type, its mesh size, owner status and the number of units used per fisherman were recorded.

The Frame Survey: Regular standardised counting of the number of fishermen and the number of gears used at the different sampling sites.

Again, to keep the program practical, the habitat fisheries monitoring program of CPP followed only the most dominant species and the most common gears. In Table 6 and Table 7 the gears and species monitored by CPP are presented.
### Table 6: Gears monitored by CPP.

<table>
<thead>
<tr>
<th>Bengali name</th>
<th>English name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taki Jal</td>
<td>Cast Net</td>
</tr>
<tr>
<td>Thella Jal</td>
<td>Scoop Net</td>
</tr>
<tr>
<td>Dhorma Jal</td>
<td>Lift Net</td>
</tr>
<tr>
<td>Ber Jal</td>
<td>Seine Net</td>
</tr>
<tr>
<td>Kerrent Jal</td>
<td>Gill Net</td>
</tr>
<tr>
<td>Borshi</td>
<td>Lining</td>
</tr>
<tr>
<td>Darki</td>
<td>Traps</td>
</tr>
<tr>
<td>Others (Khata, De-watering, Hand-picking etc.)</td>
<td>Others (Khata, De-watering, Hand-picking etc.)</td>
</tr>
</tbody>
</table>

### Table 7: Specified fish species for fish catch monitoring in the CPP area

<table>
<thead>
<tr>
<th>Beel resident fish species</th>
<th>Scientific name</th>
<th>Riverine fish species</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common name</td>
<td></td>
<td>Common name</td>
<td></td>
</tr>
<tr>
<td>Baim</td>
<td>Mastacembelus pancalus</td>
<td>Baila</td>
<td>Glossogobius giurus</td>
</tr>
<tr>
<td>Gutum</td>
<td>Lepidocephalus guntea</td>
<td>Boal</td>
<td>Wallago attu</td>
</tr>
<tr>
<td>Kolisha</td>
<td>Colisha fasciatus</td>
<td>Catla</td>
<td>Catla catla</td>
</tr>
<tr>
<td>Puti</td>
<td>Puntius sophore</td>
<td>Mrigal</td>
<td>Cirrhinus mirgola</td>
</tr>
<tr>
<td>Shing</td>
<td>Heteropneustes fossilis</td>
<td>Rui</td>
<td>Labeo rohita</td>
</tr>
<tr>
<td>Koi</td>
<td>Anabas testudineus</td>
<td>Titputi</td>
<td>Puntius ticto</td>
</tr>
<tr>
<td>Taki</td>
<td>Channa punctatus</td>
<td>Ayre</td>
<td>Mystus aor</td>
</tr>
<tr>
<td>Others</td>
<td>Pisces anonymous</td>
<td>Others</td>
<td>Pisces anonymous</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9.4 Data analysis and estimation of annual catch

The principle of data analysis and estimation of annual catch of habitat fisheries monitoring and GIS is visualised in the relational diagram (Figure 72):

First, the Catch per Unit of Area (CPUA) for each type of water body is determined as accurately as possible on a monthly basis with traditional Catch and Effort monitoring.

Next, the total inundated area (A) for each type of water body is determined as accurately as possible with GIS on a monthly basis.

The total annual catch for the different land types is estimated by multiplying the monthly catch per unit of area with the monthly flooded area and summing them up for the whole year, or, in other words:

\[
\text{Annual Catch per site} = \sum_{i=1}^{n} \text{CPUA}_i \cdot \text{Area}_i
\]

The total annual catch for the monitored area is the sum of the annual catches of the different land types, or:

\[
\text{Total Catch} = \sum_{i=1}^{n} \text{Annual Catch per site}_i
\]
9.4.1 Determination of catch per unit of area

The catch assessment survey provides information on the average monthly catch per fishermen and per gear within a selected site. Differentiation between gears and fishermen is essential as professional fishermen catch more with a certain gear if compared with occasional or subsistence fishermen, because of their skills or because they fish longer.

The frame survey provides information on the average number of fishermen or gears operating within a selected site. By multiplying the two parameters for the different types of fishermen and types of gears and summing them, the monthly catch for each site is estimated, or:

\[
\text{Monthly Catch per site} = \sum_{i,j=1}^{n} \bar{f}_{i,j} \cdot \bar{cpue}_{i,j}
\]
**CPUA:** At each site monitoring was carried out within a well marked and fixed location with a known area or length, which allowed us to calculate the monthly fish Catch Per Unit of Area (CPUA) for F3, F2 and F1 or per unit of length for the khals and rivers by dividing the average total monthly catch with the fixed sample area or sample length:

\[
CPUA = \frac{\text{Monthly catch per site}}{\text{Sampled area}}
\]

**9.5 Exercises**

- Open the spreadsheet **CPUA exercises.xls.**
- The spreadsheet contains monthly average data from the sampling site Ghotokbari beel which is representative of F3 habitat.
- Calculate daily fish yield.
- Calculate monthly yield.
- Calculate the monthly catch per unit of area for F3 sites for this sampled year.
- Make a figure showing the CPUA, CPUE and the fishing effort over the different months.

The observed CPUA and measured water level over the period 1992-2000 in Ghotokbari Beel, a F3 habitat in the CPP project area is presented in Figure 73.

**Figure 73: CPUA and water levels as observed the last 7 years in Ghotokbari beel, a F3 habitat in the CPP project area.**
9.6 *Determination of monthly inundated areas or monthly flood maps*

From the stratified fisheries monitoring programme we obtained the quantity of fish per hectare (CPUA) caught from each land type per month in the CPP area.

We can calculate the total monthly catch per land type once we know the monthly flooded area for each land type.

In principle we do this by making an overlay of the "calculated monthly flood map" with the "land type map". Or we query our "dry" -"wet" grid with the "land type map", which is provided by a hydrologist.

All steps for the analysis to arrive at the monthly flooded areas of the different habitats are summarised in Figure 74.
Figure 74: Pathway of determination of monthly-inundated area per habitat in the CPP project area.
9.7  Exercises

For this exercise we use GIS files from the CPP project area. However, the data on water levels and the intervention are made in the computer especially for this manual and do not reflect in any way of what was done or happened in the CPP area. For the real data and events in CPP, please read the final reports of CPP.

9.7.1  Fish catch in the CPP for two scenarios

In Figure 75 average flooding during the month of September in the CPP project area during the period 1985-1992 is presented.

Figure 75: Average flooding during the month of September and drainage interventions in the CPP project area.

We see two large flooded areas in the Southwest and the Southeast of the project area. This situation is our "Before CPP scenario".

To improve the situation in this exercise, the following intervention will take place:
- A regulator will be build in the Lohajang River to control the water level downstream of the regulator.
- In the Southeast and Southwest the drainage system will be improved.

This is our "After CPP scenario"
For both scenarios we have average monthly water levels stored in C:\nefisco-egis\dbases.

**January before** is befor-1  
**February before** is Befor-2

**January after** is After-1  
**February after** is After-2  

**Step 1**

In the next exercise you only have to make the calculations for February and September for the two scenarios. The results for the other months are already provided in the Tables

**Before scenario**

1. Make a new project and save it as "CPP_Before.apr".
2. Check if your default settings of Arcview include "Spatial analyst".
3. Make for the two months a new View and rename each View to the name of the month.
4. Add to each View the Themes: CCPgauges.shp and the CPP boundary grid CPPbound.
5. Add the "Landtype map before" to be found in C:\Nefisco-egis\temp.
6. Add the CPP-Digital elevation model, "CPPin-10cg" to be found in C:\Nefisco-egis\DEM.
7. Add the water level tables for the two months of the CPP-before situation tables to the project.
8. Join for each month the Water level table with the Gauges theme.
9. Make for each month a surface grid of the water levels, with Grid extent "Same as View" and Grid Cell size 75 meters and with CPPbound set as a mask. A 10-meter Grid size is better as this is the grid size of the land type map. But this takes too much time for all surfaces to be made.
10. Calculate for each month the water depth.
11. Reclassify the water depth for "dry and "flooded" areas.
12. Add either the "land type map before" or the "land type map after".
13. Write down from the theme tables of land type before and after the total number of pixels for each land type and fill in Table 8.
14. Query the reclassified grid over the land type map to estimate the monthly flooded areas per land type and fill in Table 9 and Table 10. (C:\nefisco-egis\Msexcel files\Calculated areas.xls).
15. Save the project.
Table 8: Land type distribution before and after CPP

<table>
<thead>
<tr>
<th>Land type</th>
<th>Before CPP scenario (ha)</th>
<th>After CPP scenario (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0 and Settlements</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Calculated flooded areas per land type for the "Before" scenario

<table>
<thead>
<tr>
<th>Month</th>
<th>F3 pixels</th>
<th>F3 Ha</th>
<th>F2 Pixels</th>
<th>F2 Ha</th>
<th>F1 Pixels</th>
<th>F1 Ha</th>
<th>F0 ha</th>
<th>Settlements ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>655</td>
<td>369</td>
<td>134</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Feb</td>
<td>3057</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>556</td>
<td>313</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Apr</td>
<td>593</td>
<td>333</td>
<td>45</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>May</td>
<td>714</td>
<td>401</td>
<td>538</td>
<td>303</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>June</td>
<td>725</td>
<td>408</td>
<td>1394</td>
<td>784</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Jul</td>
<td>725</td>
<td>408</td>
<td>5066</td>
<td>2850</td>
<td>1996</td>
<td>1123</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Aug</td>
<td>725</td>
<td>408</td>
<td>5077</td>
<td>2856</td>
<td>2949</td>
<td>1659</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>723</td>
<td>407</td>
<td>1135</td>
<td>639</td>
<td>15</td>
<td>8</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Nov</td>
<td>712</td>
<td>400</td>
<td>1053</td>
<td>592</td>
<td>6</td>
<td>3</td>
<td>3057</td>
<td>3231</td>
</tr>
<tr>
<td>Dec</td>
<td>655</td>
<td>368</td>
<td>447</td>
<td>252</td>
<td>0</td>
<td>0</td>
<td>3057</td>
<td>3231</td>
</tr>
</tbody>
</table>

Table 10: Calculated flooded areas per land type for the "After" scenario

<table>
<thead>
<tr>
<th>Month</th>
<th>F3 pixels</th>
<th>F3 Ha</th>
<th>F2 Pixels</th>
<th>F2 Ha</th>
<th>F1 Pixels</th>
<th>F1 Ha</th>
<th>F0 ha</th>
<th>Settlements ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>389</td>
<td>219</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Feb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>370</td>
<td>208</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Apr</td>
<td>375</td>
<td>211</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>May</td>
<td>397</td>
<td>224</td>
<td>36</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>June</td>
<td>401</td>
<td>226</td>
<td>175</td>
<td>99</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Jul</td>
<td>401</td>
<td>226</td>
<td>2267</td>
<td>1275</td>
<td>1003</td>
<td>564</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Aug</td>
<td>401</td>
<td>226</td>
<td>2360</td>
<td>1328</td>
<td>1776</td>
<td>999</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>401</td>
<td>226</td>
<td>799</td>
<td>449</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Nov</td>
<td>399</td>
<td>225</td>
<td>95</td>
<td>53</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
<tr>
<td>Dec</td>
<td>396</td>
<td>223</td>
<td>26</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>5312</td>
<td>3231</td>
</tr>
</tbody>
</table>

17 is pixel number multiplied by pixel size
Interpret the two graphs that are automatically displayed in the spreadsheet (Figure 76 and Figure 77).

**Figure 76: Monthly dry and flooded areas of the different land types “before CPP”**

**Figure 77: Monthly dry and flooded areas for the different land types “After CPP”**
Calculate the fish production

In the CPUA exercise you learned how to calculate the CPUA over a one-year period and in the same chapter a figure was presented with the data over the last seven years (Figure 73).

The average CPUA over all the years and for the different land types are presented in Table 11 can be used to calculate the fish catch for both scenarios.

We calculated till now:

- The flooded areas for the different land types.
- The CPUA for the different land types.

So we can calculate the total annual fish catch for both cases below by using the spreadsheet: "Calculate fish before and after CPP.xls"

Table 11: Average catch per unit of area (CPUA) for the different land types/habitats in the CPP project area.

<table>
<thead>
<tr>
<th>Date</th>
<th>CPUA (kg/ha/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F3</td>
</tr>
<tr>
<td>Jan</td>
<td>22.3</td>
</tr>
<tr>
<td>Feb</td>
<td>29.2</td>
</tr>
<tr>
<td>Mar</td>
<td>29.4</td>
</tr>
<tr>
<td>Apr</td>
<td>8.4</td>
</tr>
<tr>
<td>May</td>
<td>15.9</td>
</tr>
<tr>
<td>Jun</td>
<td>22.3</td>
</tr>
<tr>
<td>Jul</td>
<td>29.2</td>
</tr>
<tr>
<td>Aug</td>
<td>29.4</td>
</tr>
<tr>
<td>Sep</td>
<td>29.0</td>
</tr>
<tr>
<td>Oct</td>
<td>88.5</td>
</tr>
<tr>
<td>Nov</td>
<td>32.5</td>
</tr>
<tr>
<td>Dec</td>
<td>21.0</td>
</tr>
</tbody>
</table>

Calculate the average Annual Catch

F3 habitat before:
F2 Habitat before:
F1 Habitat before:
Total CPP:
F3 habitat after:
F2 habitat after:
F1 habitat after:
Total CPP:

Calculate the average Annual Catch per ha

F3 habitat before:
F2 Habitat before:
F1 Habitat before:
F3 habitat after:  
F2 habitat after:  
F1 habitat after:
10 FURTHER APPLICATION OF HABITAT STRATIFIED MONITORING AND THE USE OF GIS IN BANGLADESH

10.1 Radar

Over the years developments in GIS and remote sensing were tremendous in the field of mapping technology. One of the most significant is the development of radar satellite imaging devices that can penetrate the clouds. The major advantage is that nowadays the real-time extent of flooding during the monsoon can be determined directly from radar images, which in principle is much easier than estimating this through measured water levels and GIS techniques. At the beginning of CPP, radar images were not available and the method of calculating the flood map through water levels was the only alternative.

One of the lessons we learned in CPP was that it is much easier to determine the flood maps directly from radar images. With this application we will miss the dry season catch, but the advantages of this rapid method outweighs the fact that we miss 5-10% of the total catch.

A comparison of the flood map as calculated with water levels in GIS and by direct application of radar images\textsuperscript{18} is presented in Figure 79.

\textbf{Figure 78: Comparison between calculated flooding and Radar application}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{comparison.png}
\caption{Comparison between calculated flooding and Radar application}
\end{figure}

10.1.1 Exercise: Radar Image flood mapping per Land type

\textsuperscript{18} The radar images were originally provided for a research programme of EGIS/CPP by the ARDO program of the Canadian Space Agency and Radarsat International and the permission to use the images also for this training course is greatly acknowledged.
- Open a **new project** and add the **CPP boundary grid** and the **CPP land type grid** from the “before interventions scenario”.
- Add the radar image from August 1998, "C:\nefisco-egis\radar\2cl_aug98". We see that in this grid file the **code 1 represents water and 0 is dry**.
- Query the radar grid with the land type grid and calculate the flooded areas for F3, F2 and F1\(^{19}\).
- Fill the Table 12 and compare with the earlier method.

### Table 12: Comparison of radar flood mapping and water level flood mapping

<table>
<thead>
<tr>
<th>Habitat Flooded (ha) in August 1998</th>
<th>Radar-GIS</th>
<th>Water levels-GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td></td>
<td>308</td>
</tr>
<tr>
<td>F2</td>
<td></td>
<td>2541</td>
</tr>
<tr>
<td>F1</td>
<td></td>
<td>3202</td>
</tr>
</tbody>
</table>

The difference in the F1 flooded areas is caused by the fact that the inundated area is calculated with water depth, and we classify everything as water when the depth is larger than 0 cm, larger than 0 cm does not exclude very shallow areas with inundated vegetation. The radar images only classify more or less open water and exclude these shallow areas, reducing the total flooded areas (Figure 79).

### Figure 79: Difference between the application of GIS and Radar

\[10.2\] Direct application of yields on land types

A very simple but statistically rough way calculate fish catch in a certain area, is to apply the **annual yields** for the land types directly to the total areas of the different land types in this area. This method requires a proper land type map, a topographic map or a DEM of the fixed sample sites and regular measured water levels. The topographic map and the water levels enables us to calculate the monthly CPUA and annual yield per site, after which they can be raised to the total annual, yield for the total area. For CPP, the estimation of the annual total catch for F3 land as estimated with this direct method is presented in Table 13 and compared with estimation through the GIS method.

\[19\] If you use Arcview 3.1 you can get an error messages as cell sizes in both grids are not the same. Set the cell size at 10 meter in the Analysis properties.
Table 13: Comparison of direct catch estimation and catch estimation by using GIS-
water levels for the whole area

<table>
<thead>
<tr>
<th>Year</th>
<th>Average yield F3 direct method (Kg/ha/yr.)</th>
<th>Annual catch direct method (Kg/yr.)</th>
<th>Average yield GIS method (Kg/ha/yr.)</th>
<th>Annual catch GIS method (Kg/yr.)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>92/93</td>
<td>102</td>
<td>31807</td>
<td>116</td>
<td>36352</td>
<td>-14%</td>
</tr>
<tr>
<td>93/94</td>
<td>318</td>
<td>99418</td>
<td>241</td>
<td>75508</td>
<td>24%</td>
</tr>
<tr>
<td>94/95</td>
<td>143</td>
<td>44608</td>
<td>137</td>
<td>42872</td>
<td>4%</td>
</tr>
<tr>
<td>95/96</td>
<td>141</td>
<td>44103</td>
<td>136</td>
<td>42681</td>
<td>3%</td>
</tr>
<tr>
<td>96/97</td>
<td>169</td>
<td>52906</td>
<td>155</td>
<td>48491</td>
<td>8%</td>
</tr>
<tr>
<td>97/98</td>
<td>278</td>
<td>86899</td>
<td>179</td>
<td>56002</td>
<td>36%</td>
</tr>
<tr>
<td>98/99</td>
<td>326</td>
<td>101885</td>
<td>311</td>
<td>97239</td>
<td>5%</td>
</tr>
</tbody>
</table>

The method seems rather simple and could be of interest at national level however the major hindrance is statistical. A very important factor is that the selected sites have to be representative for Catch and Effort patterns as well as for Hydrological Patterns, which is extremely difficult. Furthermore, extreme values within the sampling data set gain more importance as variations in the small sampling site are larger, and these extremes increase proportionally towards the total catch for the whole area.

10.2.1 Exercises: Direct application of annual yield on Tangail district

The land type map of Tangail district indicates the following distribution

\[ F3 = 13710 \text{ ha} \]
\[ F2 = 122631 \text{ ha} \]
\[ F1 = 136257 \text{ ha} \]

The annual fish catch for the different land types in the CPP project area in Tangail could be representative for the whole of the Tangail district and could be used to calculate the annual total catch of beels and floodplains.

The annual yields of CPP are presented in Table 14.

Table 14: Annual fish catch per ha for the different habitats as observed during 1992-1997.

<table>
<thead>
<tr>
<th>Year</th>
<th>F1 yield</th>
<th>F2 Yield</th>
<th>F3 Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>92/93</td>
<td>1.25</td>
<td>15.92</td>
<td>116.14</td>
</tr>
<tr>
<td>93/94</td>
<td>8.70</td>
<td>67.14</td>
<td>241.24</td>
</tr>
<tr>
<td>94/95</td>
<td>4.01</td>
<td>60.33</td>
<td>136.97</td>
</tr>
<tr>
<td>95/96</td>
<td>3.24</td>
<td>34.99</td>
<td>136.36</td>
</tr>
<tr>
<td>96/97</td>
<td>10.34</td>
<td>85.03</td>
<td>154.92</td>
</tr>
</tbody>
</table>

- Calculate the total annual catch for the Tangail districts with the Land type area and the annual yields and compare with published BFRSS\textsuperscript{20} statistics (Table 15).

\textsuperscript{20} Bangladesh Fisheries Resources Survey System.
Table 15: BFRSS Statistics for beel and floodplain catch in Tangail District

<table>
<thead>
<tr>
<th>Year</th>
<th>FRSS TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>92/93</td>
<td>5258</td>
</tr>
<tr>
<td>93/94</td>
<td>11779</td>
</tr>
<tr>
<td>94/95</td>
<td>4132</td>
</tr>
<tr>
<td>95/96</td>
<td>2647</td>
</tr>
<tr>
<td>96/97</td>
<td>4739</td>
</tr>
</tbody>
</table>

Figure 80: Comparison of annual floodplain catch as estimated by application of the direct GIS method and as calculated by BFRSS.
11 COMPARISON OF FISHERIES AND AGRICULTURE IN CPP, A MULTIDISCIPLINARY APPROACH.

11.1 Fish losses

In the previous chapters we calculated on a monthly bases the flooded areas of the different land types for the Before and After CPP scenario to estimate the fish yield for the two scenarios. We estimated the fish yield as:

- Before CPP: 349 mt/year
- After CPP training scenario: 179 mt/year

Or we would lose 170 mt/year if the scenario were implemented.

If we can calculate the monthly flooded areas for the different land types it is rather easy to calculate the monthly “dry areas” for the different land types also (Figure 76 and Figure 77).

We see that because of the intervention the non-flooded area increases substantially during the monsoon. This area become more suitable for agriculture and will result in an increased agriculture/paddy production.

11.2 Agricultural benefits

In principle, on each land type we find one major type of crop during the monsoon, each with its own crop budgets, net benefits and daily labour requirements, which are presented in Table 16.

Table 16: Characteristics of the different crops grown at the four land types during the monsoon.

<table>
<thead>
<tr>
<th>Land type</th>
<th>Crop</th>
<th>Yield/ha</th>
<th>Tk/kg/ha/crop</th>
<th>Daily labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>Broadcasted DW Aman</td>
<td>1523</td>
<td>9712</td>
<td>134</td>
</tr>
<tr>
<td>F2</td>
<td>Local DW Aman</td>
<td>1813</td>
<td>8484</td>
<td>113</td>
</tr>
<tr>
<td>F1</td>
<td>T. Aman local</td>
<td>2163</td>
<td>11955</td>
<td>172</td>
</tr>
<tr>
<td>F0</td>
<td>T. Aman HYV</td>
<td>3244</td>
<td>20559</td>
<td>168</td>
</tr>
</tbody>
</table>

If we know the dry cultivable area for each land type during the monsoon it is possible to calculate the agriculture production for the two scenarios. The dry cultivable area for each land type is the minimum dry season area for each land type found during the monsoon.

11.2.1 Exercise: Calculate the agriculture production for the two scenarios of CPP

Open the spread sheet “Agriculture”, fill in the table and calculate the total rice production, the net benefits in Taka and US$ and the total labour requirements for the two scenarios.

\[21 \text{ US$ } = 55 \text{ Taka}\]
Table 17: Agriculture “before CPP” scenario

<table>
<thead>
<tr>
<th>Land type</th>
<th>Ha</th>
<th>Yield MT</th>
<th>Tk Year</th>
<th>US$</th>
<th>Labour requirements (days per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14 169</td>
<td>86 349 449</td>
<td>1 693 126</td>
<td>851 647</td>
<td></td>
</tr>
</tbody>
</table>

Table 18: Agriculture “After CPP” scenario

<table>
<thead>
<tr>
<th>Land type</th>
<th>Ha</th>
<th>Yield MT</th>
<th>Tk Year</th>
<th>US$</th>
<th>Labour requirements (days per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0 dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21 791</td>
<td>134 401 944</td>
<td>2 635 332</td>
<td>1 254 996</td>
<td></td>
</tr>
</tbody>
</table>

11.3 Total losses and benefits of the two scenarios for CPP

The total losses and benefits of the two scenarios are summarised in Table 19.

Table 19: Summary of total annual benefit and losses in agriculture and fisheries for the two scenarios in CPP.

<table>
<thead>
<tr>
<th></th>
<th>Fish (mt/year)</th>
<th>Fish (US$/Year)</th>
<th>Rice (mt/year)</th>
<th>Rice (US$/year)</th>
<th>Labour requirement (Days/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>349</td>
<td>412455</td>
<td>14169</td>
<td>1569990</td>
<td>851647</td>
</tr>
<tr>
<td>After</td>
<td>179</td>
<td>211545</td>
<td>21791</td>
<td>2443672</td>
<td>1254996</td>
</tr>
<tr>
<td>Difference</td>
<td>-170</td>
<td>-200909</td>
<td>7621</td>
<td>873682</td>
<td>403349</td>
</tr>
</tbody>
</table>

The drainage scenario could generate a net profit of 670 000 US/year and an extra of 400 000 labour days will be needed for the different crops.

11.4 Who get the profits and who gets the losses

In the rural area of Bangladesh the possession of land is distributed highly unequal, with a large number of households possessing none and a few households possessing large areas. If an intervention aims at more than just increasing the rice production but also tries to take into account; poverty alleviation, environmental issues, etc, then justification of the intervention with a net profit of US$ 670 000 is not sufficient.

---

\(^{22}\) Investments not accounted for
It could be expected that as the profits are found mainly in agriculture that only the large farmers will gain an advantage from the intervention. Further, it is indicated that fisheries account for the major losses. Fish is a major source of protein for the rural poor and it can be expected that the rural poor mainly feel the losses.

However with “expectations” you cannot evaluate proposed interventions, and we have to try to quantify the benefits and losses for the different social strata. For CPP this can be done, as sufficient socio-economic data on agriculture and fisheries are available (Table 20)

**Table 20: Distribution of fisheries and agriculture activities over the different social strata in CPP (source: CPP Fisheries technical paper 2000/1)**

<table>
<thead>
<tr>
<th>Category</th>
<th>HH number</th>
<th>% of Net Cropped Area</th>
<th>% of Fish Catch</th>
<th>% Daily Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>19900</td>
<td>0</td>
<td>71</td>
<td>89</td>
</tr>
<tr>
<td>Marginal</td>
<td>2500</td>
<td>10</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Small</td>
<td>4600</td>
<td>44</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>1360</td>
<td>26</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Large farmers</td>
<td>475</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

With these data the earlier calculated profits and losses can be easily distributed among the different social strata in CPP.

**11.4.1 Exercise: Calculate distribution of losses and benefits over the different social strata in CPP**

Open the spreadsheet “Fish-Agrı Exercise” and calculate the distribution of losses and benefits

**Table 21: Distribution of agriculture, fisheries and daily labour over the different social strata for the “Before CPP” scenario.**

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>Agriculture (kg/HH/year)</th>
<th>Agriculture (Tk/HH/year)</th>
<th>Fish (kg/HH/year)</th>
<th>Fish (Tk/HH/year)</th>
<th>Labour (days/HH/year)</th>
<th>Labour (Tk/HH/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>809</td>
<td>38</td>
<td>2667</td>
</tr>
<tr>
<td>Marginal</td>
<td>568</td>
<td>3459</td>
<td>13</td>
<td>817</td>
<td>38</td>
<td>2667</td>
</tr>
<tr>
<td>Small</td>
<td>1358</td>
<td>8272</td>
<td>13</td>
<td>838</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>2714</td>
<td>16533</td>
<td>1</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large farmers</td>
<td>5976</td>
<td>36412</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 22: Distribution of agriculture, fisheries and daily labour over the different social strata for the “After CPP” scenario.

<table>
<thead>
<tr>
<th>AFTER</th>
<th>Agriculture (kg/HH/year)</th>
<th>Agriculture (Tk/HH/year)</th>
<th>Fish (kg/HH/year)</th>
<th>Fish (Tk/HH/year)</th>
<th>Labour (days/HH/year)</th>
<th>Labour (Tk/HH/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>413</td>
<td>56</td>
<td>3924</td>
</tr>
<tr>
<td>Marginal</td>
<td>872</td>
<td>5378</td>
<td>6</td>
<td>417</td>
<td>56</td>
<td>3924</td>
</tr>
<tr>
<td>Small</td>
<td>2085</td>
<td>12861</td>
<td>7</td>
<td>428</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>4168</td>
<td>25706</td>
<td>0</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large farmers</td>
<td>9179</td>
<td>56615</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 23: Comparison of the income obtained through agriculture, fisheries and daily labour for the two CPP scenarios.

<table>
<thead>
<tr>
<th></th>
<th>Before (Tk/HH)</th>
<th>After (Tk/HH)</th>
<th>Benefit (Tk/HH)</th>
<th>Average Income (Tk/HH)</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>3477</td>
<td>4337</td>
<td>860</td>
<td>15000</td>
<td>6%</td>
</tr>
<tr>
<td>Marginal</td>
<td>6943</td>
<td>9719</td>
<td>2776</td>
<td>19000</td>
<td>15%</td>
</tr>
<tr>
<td>Small</td>
<td>9110</td>
<td>13289</td>
<td>4179</td>
<td>31000</td>
<td>13%</td>
</tr>
<tr>
<td>Medium</td>
<td>16583</td>
<td>25731</td>
<td>9148</td>
<td>53000</td>
<td>17%</td>
</tr>
<tr>
<td>Large farmers</td>
<td>36412</td>
<td>56615</td>
<td>20203</td>
<td>80000</td>
<td>25%</td>
</tr>
</tbody>
</table>

From the comparison we see that the whole population is gaining from the intervention but as expected the large farmers are seeing the largest benefit.

Secondly, it should be noticed that the benefits for the landless and marginal farmers is mainly based on an increased daily labour demand. If this assumption is over estimated or if the labour demand is filled in on another way (mechanisation) the picture will change completely.

A very simple way to present differences of distribution of income, land ownership, fishing rights, fish ponds, etc, is the Lorenz curve.

In a Lorenz curve you plot the accumulative population against the accumulative benefits, and in our case we see that 26% of the total benefits is obtained by 69% of the population: or the other way around, the majority of the benefits; 74%, is received by a minority of the population; 31% (Figure 81, the straight line presents an equal distribution).
Figure 81: Lorenz curve of the distribution of benefits of the proposed CPP training scenario.
12 MARINE FISHERIES

12.1 Introduction

The continental shelf of Bangladesh from 10-200 m depth contours is about 24,000 km². The average depth of the Bay of Bengal within Bangladesh territorial limit is about 10 meter. There are three major demersal fishing grounds in the Bay of Bengal.

- South patches (6,200 km²) between 20° 50'N - 21° 40'N and 91° E - 91° 50' E.
- Middle ground (4,600 km²) between 20° 50'N - 21° 20' N and 90° E - 91° E.
- Swatch of No ground (3,800 km²) between 21° N - 21° 40'N and 89° E - 90° E.

Industrial marine fisheries is spread throughout the continental shelf of the Bay of Bengal and operates with Marine Setbag nets at 5-10 meters depth and with Trawls in the 30-80 meters depth range.

The artisanal fisheries sector, operated mainly in the nearshore waters with set bag nets, drift nets, fixed gill nets, longlines and beach seines.

The industrial catch remained more or less stable around 10,000 mt/year over the last decade and contribute for 5% of the total catch. Artisanal catch however increased from 150,000 mt/yr. in 1983/84 to 240,000 mt/yr. in 1993/94 (Figure 82).

Figure 82: The industrial and artisanal marine catch of Bangladesh since 1983/84 (BFRSS, 1983-95).
In Table 24 the annual catch for the different gears for the season 1994/95 is presented.

**Table 24: Annual catch for the different gears used in the coastal area of Bangladesh during the season 1993/94 (estuarine Hilsa catch excluded, BFRSS, 1983-95).**

<table>
<thead>
<tr>
<th>Gear</th>
<th>Annual catch (mt/yr.)</th>
<th>% of total catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnets mechanised</td>
<td>134308</td>
<td>51%</td>
</tr>
<tr>
<td>MSBN</td>
<td>51245</td>
<td>19%</td>
</tr>
<tr>
<td>ESBN</td>
<td>24665</td>
<td>9%</td>
</tr>
<tr>
<td>Gillnet non mechanised</td>
<td>19602</td>
<td>7%</td>
</tr>
<tr>
<td>Longline</td>
<td>10368</td>
<td>4%</td>
</tr>
<tr>
<td>Others</td>
<td>7435</td>
<td>3%</td>
</tr>
<tr>
<td>Shrimp trawlers</td>
<td>7247</td>
<td>3%</td>
</tr>
<tr>
<td>Trammel</td>
<td>5312</td>
<td>2%</td>
</tr>
<tr>
<td>Fish trawlers</td>
<td>4468</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>264650</td>
<td>100%</td>
</tr>
</tbody>
</table>

The majority of the catch (51%) is caught by gillnets operated from mechanised boats. These gears catch mainly Hilsa and it should be realised that the estuarine Hilsa catch is not included, which give an indication of the importance of the Hilsa catch in the Coastal area. The marine setbag nets contribute to 19% of the total catch followed by the Estuarine Setbagnets with 9%.

During the last decade no major changes were registered in the importance of the different gears as is indicated in Figure 83.

**Figure 83: Distribution of the marine catch among the different gears used in the Coastal area of Bangladesh (BFRSS, 1983-95).**

![Figure 83](image-url)
12.2 Marine fisheries and GIS

Over the years a number of fisheries surveys, especially trawl surveys, have been carried out in the Bay of Bengal. The data are very suitable for an analysis in GIS and are used in the next exercises.

12.2.1 Exercise 1; Shrimp fisheries by Estuarine Set Bag nets in the coastal zone

The data used in this exercise were collected by the marine wing of DoF in Chittagong during the period 1989-1991 and were analysed and published by Khan (1999).

1. Start Arcview
2. Open a new view
3. Add the shape file Coast.shp
4. Add the shape file Cpue_shrimps.shp
5. Add the shape file Esbn_shrimp_numbers.shp
6. Auto label the fishing zones
7. Make a pie histogrammes of *P. monodon*, *P indicus*, *M. monoceros* with the Total catch as indication for the Pie size from Cpue and catch number data.
8. Interpret the results

12.2.2 Exercise 2: Shrimp and fish trawling in the off shore waters of the Bay of Bengal

The data for this exercise has been collected in the mid 80’s by the Marine wing of DoF in Chittagong through the Marine Fisheries Survey Management and Development Project. They conducted exploratory demersal fishing surveys in the off shore and inshore waters of the Bay of Bengal. At a large number of station/sampling points in the BoB standard trawling was carried out and data on waterdepth and salinity was collected.

1. Start Arcview
2. Open a new view
3. Add the shape files Allfish_shrimp.shp, Allshrimp.shp, coast.shp and trawling_boundary.shp to the view
4. Convert the Trawling_boundary.shp file to a grid file with a cell size of 1000 meter
5. Set the mask with this new boundary grid
6. Make surface plot of Allfish_shrimp data with 500 meter cell size
7. Make surface plot of Allshrimp data with 500 meter cell size
8. Query the area where Shrimp and fish catch is larger then 300 kg/hr, Calculate the total area
9. Query the area where the shrimp catches are larger then 50 Kg/hr, Calculate the total area.
10. Trawling is only allowed in areas deeper as 30 meter include this in the analysis
11. Add the grid file Contour_grid to the view (to be found in C:\Nefisco_Egis\Marine\shapefiles). This file provides the water depth in the BoB
12. Indicate and calculate the area where Shrimp and fish catch is larger then 300 kg/hr and where the water depth is larger then 30 meter
13. Indicate and calculate the area where Shrimp catch is larger then 50 kg/hr and where the water depth is larger then 30 meter
14. Add the salinity grid file (C:\nefisco\egis\marine\salinity.grd
15. Investigate if the shrimp catch/density is related to salinity levels.
16. Save the project as BoB.apr

12.2.3 Exercise 3: Cephalopod catches

In the previous exercise we looked at the total catch for shrimp and fish. Data for individual species are also available for the different sampling stations and as an example we look at the catch of Cephalopods (squids)

1. Open a new View
2. Add the shape files Coast.shp, Squids.shp
3. Copy the Countour_grid and the Boundary grid file from the previous exercise to this view
4. Set the mask
5. Make a surface plot of the squid data with 500 meter cell size
6. Add the Turbidity shape file (C:\nefisco-egis\shapfiles\Secchi.shp)
7. Add a new boundary grid C:\nefisco-egis\marine\gridfiles\sal-bnd.grd
8. Set this grid as a new mask
9. Make a surface plot file from the turbidity data with a grid size 500 meter
10. Investigate if the distribution of squids is related to waterdepth or to turbidity or to both.

12.2.4 Facultative exercise 4: Fish biomass distribution in the BoB in relation to waterdepth

Trawling in the BoB has been carried out in a standard way and could provide preliminary information on standing fish stocks in the different parts of the BoB. Normally the trawl catches are converted into biomass parameters by taking the speed of the boat, the time of trawling and the opening of the trawl into account. This information is was not available so comparison of absolute values can not be made. But still the available data can be used to make a relative comparison and we can find out were the highest biomass can be found.

The basic assumption is that the CPUE or catch per hour of trawling reflects the abundance of the fish stock, which is the basic assumption behind holistic fisheries models.

Step 1

1. Open Arcview
2. Open the BoB.apr project
3. Open a new View
4. Copy the earlier made depth contour grid and the Fish & Shrimp distribution grid to this view
5. Add the Coast.shp shape file.
6. From the Fish & shrimp distribution grid we see the highest trawl catches or the highest standing stock near the coast around Chittagong.
7. We want to know if there is a relation between water depth and standing fish stocks.
8. For this we query the Fish&Shrimp distribution grid with the waterdepth grid.
9. Before we can do this we have to reclassify both grids into new grids with constant class sizes. Reclassify the water depth grid: We see that the maximum waterdepth in the BoB is 200 meter so we reclassify into 20 classes with an interval of 10 meter.
10. Activate the depth grid
11. Go to analysis and select “reclassify”. Click on classify, fill in 20 in the “number of classes window, this as the waterdepth ranges from 0 to 200 meter, click OK
12. Change the old values into 0-10, 10-20, 20-30, 30-40, etc, click OK.
13. The values in Fish & Shrimp grid varies from about 50 to 768 so we reclassify this grid into 32 classes with 25 kg/hr as interval.
14. Now we can query the to reclassified grids, we can do that manually with Analysis and the query command. But a much easier way is with the “tabulate areas” command in the analysis menu, which make a table of the combined grids. Go to analysis, select “tabulate areas” The tabulate areas windows pops up. In row theme we select “reclass fish” and in column theme we select reclass depth click OK. The form of the table, which will be generated, is presented below. For each combination of water depth class and fish trawling class the analysis counts the number of pixels that matches and calculates the total area covered by those pixels.
15. The generated table pops up, Go to file, select export and save the file as BoB.dbf file

<table>
<thead>
<tr>
<th>Class</th>
<th>0-10 m Class1</th>
<th>10-20 m Class 2</th>
<th>20-30 m Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25 kg/hr</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
</tr>
<tr>
<td>25-50 kg/hr</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
</tr>
<tr>
<td>50-75 kg/hr</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
<td>Area (m²)</td>
</tr>
</tbody>
</table>

**Step 2**

Now we can analyse the data further in MsExcel

1. Open MsExcel
2. Open the BoB.dbf file
3. We see that in the first column the fish trawl class starts a class 3. This means that there were no data with weight smaller then 50 kg/hr. In order to make a nice spread sheet we insert two rows for those missing classes.
4. Change the classes for fish from 1 into 0-25, 2 into 25-50, 3 into 50-75, etc.
5. In the first row we see Value 1, Value 2, Value 3, etc, change this in the depth classes Value 1 into 0-10, Value 2 into 10-20, etc.
6. The values in the table are in square meters by dividing them with 1 million we will get square kilometres as values and we get Table 25 below.
Table 25: Area distribution of experimental trawling in the BoB in relation to water depth and catch rates

<table>
<thead>
<tr>
<th>Catch rate (kg/hr)</th>
<th>Waterdepth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>0-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100 100-110 110-120 120-130 130-140 140-150 150-160 160-170 170-180 180-190 190-200</td>
</tr>
<tr>
<td>25-50</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>50-75</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>75-100</td>
<td>1 101 20 10 8 6 42 160 208 1093 642 752 773 826 906 941 988 1020 1052 1347</td>
</tr>
<tr>
<td>100-125</td>
<td>8 76 25 14 9 23 59 217 752 2182 308 218 206 165 101 93 72 70 45 33</td>
</tr>
<tr>
<td>125-150</td>
<td>0 97 43 29 23 97 120 260 1674 1123 44 35 38 45 33 27 25 26 14 8</td>
</tr>
<tr>
<td>150-175</td>
<td>17 563 270 347 240 218 152 277 982 718 41 50 63 61 70 54 33 9 1 1</td>
</tr>
<tr>
<td>175-200</td>
<td>1 299 233 150 94 117 137 326 888 335 60 39 14 8 0 2 3 0 0 0</td>
</tr>
<tr>
<td>200-225</td>
<td>0 490 177 109 160 168 306 394 336 225 1 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>225-250</td>
<td>5 668 147 129 144 164 120 231 296 43 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>250-275</td>
<td>149 786 106 137 119 159 106 172 173 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>275-300</td>
<td>126 457 143 133 125 143 142 308 71 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>300-325</td>
<td>596 511 140 126 196 159 257 163 1 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>325-350</td>
<td>240 661 128 157 237 180 146 35 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>350-375</td>
<td>12 423 216 388 148 125 76 4 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>375-400</td>
<td>15 479 139 109 151 39 7 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>400-425</td>
<td>0 94 36 36 15 23 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>425-450</td>
<td>0 22 33 22 10 18 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>450-475</td>
<td>0 0 14 24 9 13 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>475-500</td>
<td>0 0 7 21 7 11 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>500-525</td>
<td>0 0 6 16 10 10 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>525-550</td>
<td>0 0 4 14 20 9 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>550-575</td>
<td>0 0 3 11 15 5 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>575-600</td>
<td>0 0 2 13 10 6 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>600-625</td>
<td>0 0 0 13 10 4 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>625-650</td>
<td>0 0 0 13 8 5 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>650-675</td>
<td>0 0 0 9 5 5 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>675-700</td>
<td>0 0 0 9 5 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>700-725</td>
<td>0 0 0 8 4 5 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>725-750</td>
<td>0 0 0 7 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

The table presents an area distribution and is not yet indicative for biomass distribution. For example we have a large area of 1347 km² with a water depth of 190-200 meter were on the average 50-75 kg/hr is caught. However this area represents a much lower biomass as the area of 661 km² with a water depth of 10-20 meter where 300-325 kg/hr is caught. As indication of fish biomass we can use:

Relative Biomass = Area*average catch rate/total relative biomass

If we do this calculation in the spreadsheet we get
Table 26: Relative Fish and Shrimp biomass distribution in relation to water depth and experimental catch rates

<table>
<thead>
<tr>
<th>Catch rate (kg/hr)</th>
<th>Water depth</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>10-20</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>20-30</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>30-40</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>40-50</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>50-60</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>60-70</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>70-80</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>80-90</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>90-100</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>100-110</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>110-120</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>120-130</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>130-140</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>140-150</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>150-160</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>160-170</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>170-180</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>180-190</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>190-200</td>
<td>0.9</td>
<td>11.1</td>
</tr>
</tbody>
</table>

The table is difficult to interpret. Graphs are more clear.

So let’s look at the relative distribution of the biomass over the water depth.

1. Make a graph with on the X-axis the depth class and on the y-axis the relative distribution
2. Make a similar graph with on the X-axis the catch rate
Figure 84: Relative fish and shrimp biomass distribution in the BoB in relation to water depth

From the graphs we see that 20% of the fish and shrimp biomass is found in the shallow waters of 10-20 meters.

Further we see that the majority of the biomass is found in areas were a catch rate of 75-400 kg/hr can be obtained. The relative distribution of the fish in areas with a high catch rate is very low.

Both data sets can be combined in one ‘three dimensional graph’ (Figure 86) or in an ‘Isopleth graph’ (Figure 87) which are much easier to interpret.
Figure 86: Relative fish and shrimp biomass distribution in the BoB in relation to water depth and catch rates

Figure 87: Isopleth graph of relative fish and shrimp biomass distribution in the BoB in relation to water depth and catch rates
13 A RAPID FISH BIO-DIVERSITY APPRAISAL FOR FLOODPLAIN ECOSYSTEMS.

13.1 Changing species composition in Garinda and Ghotokbari Beel in the CPP project area

Garinda and Ghotokbari beel have been monitored since 1992 and in both beels the catch followed the seasonal patterns, with peak catches during the receding of the floodwaters in October and a high annual catch in years with high floods. However, in 1999, the catch in Garinda beel completely collapsed while the catch in Ghotokbari beel continued as normal.

In Garinda beel, since 1996 beel dependent fish species such as *Puti*, *Baim*, and *Kolisha* are gradually replaced by small prawns (*Icha* and *Chingri*) while the percentage of catfish and snakeheads remains more or less constant over this period (Figure 88). In Ghotokbari Beel the species composition remained more or less stable during the same period (Figure 89).

Figure 88: Species composition Garinda Beel, 1992-1999
A strong reduction of the dry season water level and over-exploitation were most likely responsible for the collapse of fisheries in Garinda beel. The water area covering a beel during April and May is the recruitment area for the fish. If this reduces to almost zero, recruitment will be zero and no fish will be found, even if the area gets flooded soon after. This phenomenon has been observed at Beel Dakatia just after implementation of the emergency dredging by the Bangladesh Water Development Board (Khulna Jessore Drainage Rehabilitation Project, 1995). This process gradually occurred at Garinda beel, as is indicated by the gradually reducing ratio between the water area in May and the water area in September of the same year (Figure 90) For Ghotokbari beel this ratio did not change over the years.
As a consequence of the reduced dry season water coverage, the fishing effort in Garinda Beel increased dramatically in May 1999 (Figure 91), finishing off the remaining fish.

![Figure 91: Fishing effort as observed at Garinda and Ghotokbari beel](image)

It was concluded that the collapse of fisheries and bio-diversity in Garinda Beel was caused by a gradual reduction in water level, followed by a rapid increase in fishing effort.

### 13.2 Changing fish species composition in Bangladesh in relation to water management

In general it can be stated that in over-exploited floodplains, with a high fishing pressure, the large, slow-growing species and the species that start to reproduce after two to three years are replaced by quick-growing and fast-reproducing species. This could be one of the reasons, next to the blockage of migration routes and the reduction spawning areas due to flood control projects, why the Indian carp disappeared from the floodplain catches in the last decades.

The results of the fisheries monitoring program at the Chandpur Irrigation Project indicated that a complete “cut off” of a floodplain system from annual flooding results in a species shift towards catfish (*Shing*), snakeheads (*Taki*) and small prawns (*Chingri* and *Ichta*).

The results of Garinda Beel in the CPP area and Beel Dakatia in the Khulna Jessore Drainage Irrigation Project area indicated that even if the floodplain is not “cut off” from annual flooding, a similar shift takes place if the spawning area becomes too small. The remaining species will be catfish, snakeheads, prawns and riverine species entering the floodplain with the annual flood.

In relation to floodplain fisheries and water-management the following successive phases in fish bio-diversity can be recognised:

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24 See final report CPP and fisheries annexes to the final report.
• **Phase I:** a healthy flood plain system with no over-exploitation. This situation existed some twenty years ago and maybe still exists in the large floodplains in the north of the country including Sylhet.

• **Phase II:** an over-exploited floodplain, due to the high fishing effort and small mesh-sizes used. The Indian carp stocks and other large fish come under pressure; they disappear as they reproduce only after several years, and are gradually replaced by fast-growing, small but quickly reproducing fish, the “miscellaneous” species.

• **Phase III:** controlled flooding and improved drainage is carried out; the total beel area reduces somewhat, but beel resident species are still abundant.

• **Phase IV:** controlled flooding and drainage is further improved; large extraction of groundwater for Borro irrigation begins and the area dries out. Spawning area in the pre-monsoon period is seriously reduced. Beel resident species such as *Puti*, *Baim*, and *Gutum* are under pressure and will disappear. Some riverine fish are still available because annual flooding still continues, and small prawns become the bulk of the biomass

• **Phase V:** Complete flood control. catfish, small prawns and snakeheads are the only survivors.

The different phases are visualised in Figure 92.

![Figure 92: Species composition and yields of floodplain fisheries (F3 land types) in relation to intensifying fisheries and flood control](image)

The mentioned species can be used as indicators for bio-diversity and health of a floodplain system. The method could be considered as a Rapid Fish Bio-diversity Appraisal, whereby the dominance of small prawns is used as a key indicator for the status of the system, and is most likely more practical and less time-consuming than trying to cover all species in a bio-diversity index.
The complete collapse of fisheries in Garinda beel and its shift in species composition toward small prawns led to the development of this Rapid Bio-diversity Appraisal, and in the final stage it was tested in and outside the CPP area.

All perennial beels were visited three times during the period December 1999 – March 2000; the catch was recorded from the fishermen and separated into the following groups/species:

**Prawns:** *Macrobrachium spp*

**Beel species:** Koi, Puti, Kolisha, and Baim

**Carps:** Catla, Rui, and Mrigal

**Catfish:** Taki (*Ophiocephalus punctatus*) and Shing (*Heteropneustes fossilis*)

**Others.**

"The data from the survey were analysed in GIS with a "surface plot" of the species composition in the area and the following conclusions were drawn: The beels south and southeastern part seem to be minimally affected. The beels in the north and central part of CPP and on the Northeast outside of the CPP seem to be deteriorating as the species composition changes from ‘beel residents” toward a more 'prawn dominant’ system. The difference could be caused by the fact that the southern part of the CPP is more flooded, or has a lower population density resulting in a lower fishing pressure. Another factor could be the construction of the railway and the by-pass road in the eastern part of the CPP project. In general it can be concluded that the change in species composition as observed in Garinda beel over recent years is part of a larger pattern in and outside the CPP area. The Bio-diversity Index and its use in a GIS environment visualises clearly the patterns, but it is realised that it visualises patterns after a change has been taken place and we are most likely too late to reverse the process. Definition of “clear criteria” i.e. what are the ranges for prawns to be accepted for a “healthy system”, will be needed in order to detect changes at an early phase.

It is realised that the results of this survey are very preliminary and that conclusions can not be drawn yet. However the combination of the “Rapid Fish Biodiversity Appraisal” and “GIS” could be a powerful tool for assessment of the status of water bodies, therefore as an example the results are presented in the next paragraphs and could serve as a basis for further developments” CPP final report, 2000.

### 13.3 **Exercise: Bio-diversity rapid appraisal**

Analyse the data as collected by the CPP on species composition in and outside the CPP project area by using a surface plot.

1. Open the project **CPP Biodiversity exercise. Apr.**
2. Open the View.
3. Convert the **Border.shp** shape file into a grid file (grid size 100 meter).
4. Use this **Border grid** file set the mask for the analysis.
5. Make a surface plot for **Beelfish 99**, with grid size 50 meter
6. Make a similar plot for **Shrimp 99** (grid size 50 meter).
7. Add some of the additional shape files such as roads, railways, embankments
8. Find the area where the % of Shrimps is larger then 25% and the % of Beel resident species is smaller then 20%.
9. Discuss/analyse the results.
10. Save the project.
14 LARVAL FISH DENSITIES IN THE MAJOR RIVERS

Tsai and Ali (1986) first studied hatchling densities in the major river systems of Bangladesh and found significant density differences as they looked at the catches of the Savar nets from the different locations in the Jamuna and Padma River.

Figure 93: The main locations of Savar nets for the catch of hatchlings in Bangladesh

They found that the catch of the hatchling nets (CPUE) in the Jamuna River gradually decreases the further they are located from the Indian border (Figure 94).

25 CPP, Fisheries Technical Paper No 2000/2, Larval fish drift and water management, Experiences with flood management and its impact on Riverine fish larvae in Bangladesh.

26 Special nets for fishing on carp larvae.
If the CPUE is a reflection of the density of larvae, which is one of the assumptions of holistic fisheries models, it would mean that the hatchling density in the river gradually decreases during the downward drift of the hatchlings.

In 1997 EGIS in co-operation with the Fisheries Research Institute studied this phenomena again and confirmed that the average hatchling density is significantly higher in the primary and secondary rivers if compared with the tertiary distributaries (Table 27).

<table>
<thead>
<tr>
<th>River Class</th>
<th>Average Total Hatchling Density (No. m$^{-3}$)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>$1.80 \pm 0.44^a$</td>
<td>46</td>
</tr>
<tr>
<td>Secondary</td>
<td>$1.94 \pm 0.43^a$</td>
<td>47</td>
</tr>
<tr>
<td>Tertiary</td>
<td>$0.45 \pm 0.43^b$</td>
<td>47</td>
</tr>
</tbody>
</table>

Table 27: The average total hatchling density ($\pm$sem) and average flow rate ($\pm$sem) as measured in primary, secondary and tertiary rivers. Parameters with a different superscript are significantly different ($P \leq 0.05$). 

Tsai and Ali (1986) applied, most likely for the first time analytical models on fisheries in Bangladesh and definitely for the first time in the world on drifting hatchlings. Their paper has not gotten the attention it should have had, considering its simplicity and the insights it provides on drifting hatchlings. Their concept provides the basis of how drifting of hatchlings in Bangladesh should be studied and analysed. They looked at the reduction of hatchling densities over time in the different rivers of Bangladesh, and was time-related to a location in the river system in relation to the Indian border that is located upstream. Their concept can be visualised nowadays in GIS which makes the practical implications of their findings more clear, therefore, in the next paragraphs, their concept and its application is discussed more in detail.

The basic analytical model used is the exponential decay model:
\[ N_t = N_0 \times e^{-Z(t_o-t)} \]

No = Initial number of larvae at location or time to
Nt = Number of larvae at time t or location t
Z = Mortality rate
To-T = time period or distance between to and t1

They used this to calculate the mortality rate (Z), for this a pair of estimates, \( n1, n2 \) of the number of larvae at two points in time \( t1 - t2 \) is required (Gulland, 1983). Then during the time interval the number will fall by a proportion:

\[ \frac{n2}{n1} = e^{-Z(t2-t1)} \]

And therefore Z can be estimated from the relation:

\[ Z = -\frac{1}{t2-t1} \ln \left( \frac{n2}{n1} \right) \]

They calculated the mortality rates for five sections of the Padma-Brahmaputra river systems and the results are presented in Table 28.

<table>
<thead>
<tr>
<th>River section</th>
<th>Fishing effort (nets/km)</th>
<th>Total mortality (Z)</th>
<th>Natural mortality (M)</th>
<th>Fishing mortality (F)</th>
<th>Exploitation rate (F/Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamuna-Brahmaputra River (west bank)</td>
<td>51.45</td>
<td>0.0123</td>
<td>0.0049</td>
<td>0.0074</td>
<td>0.60</td>
</tr>
<tr>
<td>Jamuna-Brahmaputra River (east bank)</td>
<td>20.72</td>
<td>0.0115</td>
<td>0.0049</td>
<td>0.0066</td>
<td>0.5739</td>
</tr>
<tr>
<td>Dhaleswari-Kaliganga River</td>
<td>23.18</td>
<td>0.0188</td>
<td>0.0049</td>
<td>0.0139</td>
<td>0.7394</td>
</tr>
<tr>
<td>Padma River</td>
<td>5.86</td>
<td>0.0050</td>
<td>0.0049</td>
<td>0.0001</td>
<td>0.0200</td>
</tr>
<tr>
<td>Gorai – Madhumati River</td>
<td>7.22</td>
<td>0.0007</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 28: Mortality rates and fishing effort for hatchling and Savar nets in the major river systems of Bangladesh

When the total mortality rate is plotted against the fishing effort, a positive linear relation ship is obtained (Figure 95). When the fishing intensity decreases to zero, the rate of reduction is equal to the natural mortality rate of the larvae. In this case the natural mortality equals 0.0049; in other words the larval abundance in the
Padma-Brahmaputra river system decreased at a rate of 0.49% per km. The fishing mortality (F) can be calculated by subtracting M from Z (F=Z-M).

**Figure 95: The relation between fishing effort and the total mortality rate of drifting fish larvae in the Padma-Brahmaputra river system (source: Tsai & Ali, 1986)**

\[ y = 0.0002x + 0.0049 \]

\[ R^2 = 0.3267 \]

Tsai and Ali concluded that the highest number of Savar nets are located at the west bank of the Jamuna River which results in a fishing mortality of 0.74% per km. The highest fishing mortality, i.e. 1.39% per km was found in the Daleswari-Kaliganga River system at a relatively low fishing effort of 23 net/km. This implies that the larvae are rather easy to catch in this river system if compared to the Jamuna River. The fishing pressure in the Padma and the Gorai River was low and resulted in low mortality rates.

### 14.1 GIS and hatchling distribution

The data set of Tsai and Ali can be easily analysed in GIS as we have data in a table that are related to a location in Bangladesh. Further the analysis carried out by Tsai and Ali indicates that there is clear Spatial differences in densities, fishing effort and mortality rates.

#### 14.1.1 Exercise: GIS-Hatchlings

1. Open a new project and open View.
2. Add the shape file "Hatch1.shp", "Hatchborder.shp" and "country.shp" to the view.
3. Convert the "hatchborder.shp" to a grid file (2000 meter, using "id" as cell values).
4. Use the created "hatchborder" grid file to set the mask for the analysis.
5. Create surface plot for "CPUE" and “Total mortality” (Z) with grid size of 500 meter

#### 14.1.2 Results of the exercise.
Figure 96: Savar net distribution

Figure 97: Hatchling density distribution
15 TOOLS FOR FISHERIES ANALYSIS AND MANAGEMENT

This part of the manual is more or less outside the scope of FISH-GIS, but it was felt that there was a need to provide some general basic information on Fish Stock Assessment Tools and therefore some very basic information on this subject is provided.

Floodplain fisheries systems consist in principle of three components; Fish-Habitat-Fishermen (Figure 98). CPP concentrated monitoring and analysis of data on the relationship "fishermen-fish" this in contrast with a number of other fisheries programs in Bangladesh that concentrate more on the relationship "Fish-Habitat".

![Figure 98: Principal components of floodplain fisheries systems](image)

For the development of a fisheries management strategy, fisheries scientists and policy makers want to know what the present status of their fish stock is and what the impact of fishing on their fish stocks will be. Within the last century a number of tools, fish stock assessment programs have been developed that can visualise the interactive processes between fishing and fish stocks. Fish stock assessment programs and their models can be grouped in:

- **Holistic models.** They use a limited number of parameters and consider the fish stock as a homogeneous biomass.

- **Analytical models.** They are based on a detailed description of the stock and take into account the length or age structure of the stock, mortality rates, growth rates etc.

15.1 **Holistic models**

15.1.1 **The basics**
The best-known holistic model is “the surplus production models”.

“Surplus production models” regard catch per unit of effort in relation to the fishing effort as basic input. The models are based on the assumption that the biomass in the sea is proportional to the catch per unit of effort.

The surplus production models work with catch, effort and CPUE and incorporates three closely related characteristics of fish stocks (Gulland, 1983), the quantity removed from it by fishing, "C": the rate at which fish are removed, or fishing mortality, "F"; and the abundance of the fish, "N". The relation connects these as instantaneous rates:

\[
\frac{dC}{dt} = F \times N
\]

Or, over a unit time period, say a year, by

\[
C = F \times \bar{N}
\]

Where \( \bar{N} \) is the average abundance during a year.

Normally the absolute values of neither the abundance nor the rate of fishing (the fishing mortality) are known, but estimates will be available of quantities that can be used as indices of these population characteristics. These are the fishing effort "f" and the "CPUE". These are related to mortality and abundance by the equations

\[
F = q \times f
\]

and

\[
\bar{N} = \left( \frac{1}{q} \right) \times CPUE
\]

where "q" is the catchability coefficient, which presumed to be constant.

The best-known surplus production models are the Schaefer and Fox models, which use catch per unit of effort in relation to the fishing effort as basic input. The models are based on the assumption that the biomass in the sea is proportional to the catch per unit of effort. Surplus production models use long-term data series as obtained from fisheries statistics, such as the BFRSS, but can only be used if substantial changes in the fishing effort have taken place over time. Surplus production models have been applied in Bangladesh for the estimation of the Maximum Sustainable Yield of shrimp trawlers.

15.1.2 A Schaefer curve for shrimp trawling in the Bay of Bengal

The traditional methods are the surplus production models of Schaefer\(^{27}\) (1954) and Fox\(^{28}\) (1970). Surplus production levels determine the optimum level of effort, that is the effort that produces the maximum yield that can be sustained without affecting

---

\(^{27}\) Schaefer, M. Some aspects of the dynamics of populations are important to the management of the commercial marine fisheries. Bull. 1-ATTC/Bol.CIAT. 1(2): 27-56.

long term productivity of the stock, the so-called maximum sustainable yield (MSY). The surplus production models can be applied when reasonable estimates are available by total catch (by species), the catch per unit of effort (CPUE) and the related fishing effort over a number of years. A prerequisite is that the effort must have undergone substantial changes over the period covered. This is the case for shrimp trawling in the coastal area of Bangladesh.

The Schaefer model plots the CPUE as a function of the fishing effort on a linear model with the form \( Y = a + bX \) or

\[
\text{CPUE} = a + b \times \text{fishing effort}
\]

This plot for shrimp trawling is presented in Figure 99.

**Figure 99: Schaefer curve for shrimp trawling in the coastal area of Bangladesh**

Yield and CPUE are expressed as

\[
\text{CPUE} = a + b \times (\text{fishing effort})
\]

And

\[
\text{Yield} = a \times (\text{fishing effort}) + b \times (\text{fishing effort})^2
\]

The maximum sustainable yield is then calculated with:

\[
\text{MSY} = -0.25 \frac{a^2}{b}
\]

A complete Schaefer plot with Yield and CPUE is shown in Figure 100.
The analysis indicates a MSY of about 3,960 mt of shrimp per year with a maximum fishing effort of 31 shrimp trawlers. Mustafa and Khan (1993) carried out a more sophisticated analysis based on trawling hours and boat days and arrived at MSY values for Penaeid shrimp of 4,145 Mt/yr. and 4,329 mt/yr. It would mean that the present number of shrimp trawlers can not be increased and that the maximum exploitation level is reached, or that fishing is already being carried out above the maximum level.

15.1.3 Modified surplus production models that could be used in Bangladesh

Surplus production models are usually applied to time series of CPUE and effort. A modification of the surplus production model is to apply the model to a data set collected in one year of different fishing grounds fished with different fishing levels (Munro and Thompson, 198329). For Bangladesh it should be studied if this adapted model can be applied for bagda fry catching, as the number of gears per km of shore length varies considerably.

15.1.4 Exercises: Schaefer curves

Shrimp trawling in the Bay of Bengal

Repeat the example given on shrimp trawling in the Bay of Bengal the basic data are presented in Table 1.

---

Table 29: Shrimp trawling data on the Bay of Bengal over a number of years

<table>
<thead>
<tr>
<th>No Trawlers</th>
<th>Shrimp catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>3716</td>
</tr>
<tr>
<td>31</td>
<td>4178</td>
</tr>
<tr>
<td>33</td>
<td>4239</td>
</tr>
<tr>
<td>33</td>
<td>3338</td>
</tr>
<tr>
<td>35</td>
<td>4661</td>
</tr>
<tr>
<td>37</td>
<td>2621</td>
</tr>
<tr>
<td>37</td>
<td>3903</td>
</tr>
<tr>
<td>40</td>
<td>3116</td>
</tr>
<tr>
<td>41</td>
<td>3650</td>
</tr>
<tr>
<td>41</td>
<td>3237</td>
</tr>
</tbody>
</table>

1) Open a new spreadsheet and enter the data.
2) Calculate the CPUE for each year.
3) Make a graph between the effort and CPUE.
4) Add a trend line and calculate the regression coefficient "a" and "b".
5) Make the Schaefer curve with \( \text{CPUE} = a + b \times (\text{fishing effort}) \)
   and \( \text{Yield} = a \times (\text{fishing effort}) + b \times (\text{fishing effort})^2 \)
6) Calculate the Maximum Sustainable Yield with: \( \text{MSY} = -\frac{0.25 \times a^3}{b} \)
Chaca Chaca Fish

Calculate MSY data in "Chaca Chaca fish.xls"

<table>
<thead>
<tr>
<th>Year</th>
<th>Total catch</th>
<th>CPUE</th>
<th>Population size</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926</td>
<td>4697</td>
<td>3.3</td>
<td>66000</td>
<td>1423</td>
</tr>
<tr>
<td>1927</td>
<td>6545</td>
<td>3.76</td>
<td>75200</td>
<td>1741</td>
</tr>
<tr>
<td>1928</td>
<td>8334</td>
<td>4.39</td>
<td>87800</td>
<td>1898</td>
</tr>
<tr>
<td>1929</td>
<td>12734</td>
<td>4.46</td>
<td>89200</td>
<td>2855</td>
</tr>
<tr>
<td>1930</td>
<td>17898</td>
<td>3.13</td>
<td>62600</td>
<td>5718</td>
</tr>
<tr>
<td>1931</td>
<td>29410</td>
<td>3.71</td>
<td>74200</td>
<td>7927</td>
</tr>
<tr>
<td>1932</td>
<td>6488</td>
<td>4.83</td>
<td>96600</td>
<td>1343</td>
</tr>
<tr>
<td>1933</td>
<td>18890</td>
<td>4.61</td>
<td>92200</td>
<td>4098</td>
</tr>
<tr>
<td>1934</td>
<td>17349</td>
<td>4.76</td>
<td>95200</td>
<td>3645</td>
</tr>
<tr>
<td>1935</td>
<td>16500</td>
<td>3.46</td>
<td>69200</td>
<td>4769</td>
</tr>
<tr>
<td>1936</td>
<td>17731</td>
<td>3.96</td>
<td>79200</td>
<td>4478</td>
</tr>
<tr>
<td>1937</td>
<td>14304</td>
<td>2.83</td>
<td>56600</td>
<td>5054</td>
</tr>
<tr>
<td>1938</td>
<td>14923</td>
<td>2.</td>
<td>40000</td>
<td>7462</td>
</tr>
<tr>
<td>1939</td>
<td>14081</td>
<td>1.77</td>
<td>35400</td>
<td>7955</td>
</tr>
<tr>
<td>1940</td>
<td>11480</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1941</td>
<td>4943</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1942</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1943</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1944</td>
<td>339</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1945</td>
<td>1042</td>
<td>1.36</td>
<td>27200</td>
<td>766</td>
</tr>
<tr>
<td>1946</td>
<td>3606</td>
<td>1.85</td>
<td>37000</td>
<td>1949</td>
</tr>
<tr>
<td>1947</td>
<td>9192</td>
<td>1.12</td>
<td>22400</td>
<td>8207</td>
</tr>
<tr>
<td>1948</td>
<td>6908</td>
<td>0.98</td>
<td>19600</td>
<td>7049</td>
</tr>
<tr>
<td>1949</td>
<td>7625</td>
<td>0.8</td>
<td>16000</td>
<td>9531</td>
</tr>
<tr>
<td>1950</td>
<td>6182</td>
<td>0.81</td>
<td>16200</td>
<td>7632</td>
</tr>
<tr>
<td>1951</td>
<td>7048</td>
<td>0.63</td>
<td>12600</td>
<td>11187</td>
</tr>
<tr>
<td>1952</td>
<td>5130</td>
<td>0.44</td>
<td>8800</td>
<td>11659</td>
</tr>
<tr>
<td>1953</td>
<td>3870</td>
<td>0.42</td>
<td>8400</td>
<td>9214</td>
</tr>
<tr>
<td>1954</td>
<td>2697</td>
<td>0.31</td>
<td>6200</td>
<td>8700</td>
</tr>
<tr>
<td>1955</td>
<td>2176</td>
<td>0.37</td>
<td>7400</td>
<td>5881</td>
</tr>
<tr>
<td>1956</td>
<td>1614</td>
<td>0.27</td>
<td>5400</td>
<td>5978</td>
</tr>
<tr>
<td>1957</td>
<td>1512</td>
<td>0.28</td>
<td>5600</td>
<td>5400</td>
</tr>
<tr>
<td>1958</td>
<td>1690</td>
<td>0.18</td>
<td>3600</td>
<td>9389</td>
</tr>
<tr>
<td>1959</td>
<td>1187</td>
<td>0.14</td>
<td>2800</td>
<td>8479</td>
</tr>
</tbody>
</table>

15.2 Analytical models

Analytical models have been used extensively in the Western Hemisphere, but their use in tropical waters was hampered due to the fact that most of the models were “age-based”. Age reading of fish is rather easy in the colder waters of the Western Hemisphere but it is difficult or impossible in the tropical waters. The development of “length-based” models and the growth of the computer industry since the early 80’s made these tools available for tropical fisheries.
Analytical models are based on a detailed description of the stock and require relatively more data and data of higher quality than holistic models, but it is believed that they produce more reliable predictions. Analytical models look at the structure of a certain fish stock and make an analysis with the following basic concepts:

- If there are too few old fish, the stock is overfished and the fishing pressure on the stock should be reduced.
- If there are many old fish the stock is underfished and more fish could be caught in order to maximise the yield.

In Bangladesh analytical models have been used for inland fisheries extensively by CPP from 1992-2000 and by a research project of BAU/MRAG in the early 90’s. For marine fisheries the marine wing of the department of fisheries in Chittagong applied models for the most important species in the Bay of Bengal and the fisheries research institute applied them for Hilsa fisheries.

15.2.1 Steps in length based stock assessment

The basic concept of Fish Stock Assessment can be described with the following relation.

\[
SS_2 = SS_1 + (R \times G) - (F + M)
\]

Where
- \(SS_2\) Standing fish stock in year 2
- \(SS_1\) Standing fish stock in year 1
- \(R\) Recruitment
- \(G\) Growth
- \(F\) Fishing mortality
- \(M\) Natural mortality

Proper fish stock management aims to keep \(SS_2\) and \(SS_1\) at the same level so that we can continue to harvest without destroying the resource.

For this a number of analytical mathematical models are used each describing a part of the above given relation.

An exponential decay model describes recruitment, natural mortality and fishing mortality:

\[
N_t = N_0 \times e^{- (F + M) t}
\]

Where
- \(N_0\) = Initial number of fish
- \(N_t\) = Number of fish at time \(t\)
- \(F\) = Fishing mortality
- \(M\) = Natural mortality
- \(T\) = Time interval

If we place this in the context of Bangladesh, the \(SS_2\) will reduce if the number of fishermen increases. The \(SS_2\) will further decrease if the natural mortality increases due to deteriorating habitats. The natural mortality also could be influenced by the
intensity of the flood, blockage of migration routes, mortality of hatchlings over regulators, etc

Further more the initial number\(^{30}\) of fish can be influenced by reduction of spawning area, blockage of migration routes and the size of the parent stock.

**Growth** of fish is the second important input for analytical models, as in our relation it has to replace the losses due to mortality.

Growth of fish species is mostly described with the Von Bertalanffy Growth Function (VBGF).

\[
L_t = L_\infty \times \left(1 - e^{-k(t-t_0)}\right)
\]

Where;

- \(L_\infty\) L infinitive or the asymptotic length, that is the mean length the fish of a given stock would reach if it were to grow indefinitely.
- \(K\) growth rate parameter or the rate at which \(L_\infty\) is approached.
- \(t_0\) t-zero or the "age of the fish at zero length" if they had always grown in a manner described by the equation.

Some basics and often-encountered problems of the model will be summarised in this chapter. There are two excellent handbooks on this subject *"An introduction to tropical fish stock assessment"* by Sparre and Venema (1992) and *"FAO-ICLARM stock assessment tools, reference manual"* by Gayanilo *et al.*, 1997.

**Steps in length-based fish stock assessment.**

A first step of the analysis is to determine growth and recruitment parameters of the selected species. The major parameters are \(L_\infty\) the maximum length of the fish, \(K\) the growth parameter and \(t_0\) the relative age at birth. The parameters are used in the von Bertalanffy growth curve. When growth of a species is considered in should cover the growth within the whole population. Here one of the major problems of length-based models is encountered how to estimate unbiased growth parameters. Fish samples are taken from gears in order to estimate the parameters, but most of the fishing gears are selective. **One of the most common errors in length-based fish stock assessment is that the growth parameters are estimated from catches obtained from selective gears**

Once the growth parameters for the entire unit of stock have been estimated the impact of the different gears on the structure of the stock is studied. Length data obtained from the different gears reflect the impact of the gear in terms of mortalities over the different length classes. For example in the catch of a large mesh size

\(^{30}\) However in practice most models work with constant recruitment as it is complicated to incorporate and quantify all the different factors involved
gillnet, the number of small bagda\(^{31}\) caught will be minimal as they swim through the gear, but the number of large bagda will be high, i.e. the mortality rate of this gear on small bagda is low and the mortality rate of this gear on large bagda is high. The second step is to determine the mortality rates of the different gears on the selected species. This is mostly done with a “length converted catch curve”. The input parameters are the unbiased growth parameters and the length frequency data from gear we are studying or of all gears combined. The length converted catch curves provides the total mortality rate (Z), the fishing mortality (F), the exploitation rate (E=F/Z) and information on first length at capture and on selectivity of the gear.

The data obtained in steps 1 and 2 can be used in to look at the Yield per Recruit Model of Beverton and Holt, obtained for the different gears at different theoretical exploitation rates. An essential input is the length of first maturity of the selected species. This type of analysis gives us a first insight at the exploitation levels of the different gears on the selected species.

A more sophisticated analysis is the Virtual Population Analysis (VPA) in combination with predictive Thompson and Bell models. Essential for this analysis is that the total catch of the selected species for each gear is known, as in the VPA the obtained length frequencies of a selected gear are raised by the total catch of the selected gear. A major problem with length-based VPA is that they can not be applied directly to fish with an oscillating growth, which is the case with most species in Bangladesh.

15.3 Examples of the CPP project\(^{32}\)

CPP applied holistic as well as analytical Tools to analyse the data obtained during its eight-year fisheries monitoring programme. Some examples and the results of the analysis are summarised in this chapter to give an example of how they can be applied and to provide more insight into the mechanisms behind floodplain fisheries in the CPP project area.

In Fig 101 the total fish catch over the years is presented for the different habitats.

\(^{31}\) P. monodon

The highest catches were always obtained during the receding of floodwater in the month of October and in most years a small peak appeared in May, when the water level in the beel was at its lowest level.

Secondly, it seems that the fish yields are related to the extend of flooding, i.e. in dry years such as 92/93 and 94/95, the yields were low if compared with yields obtained during the wet years 97/98 and 98/99 (Table 30).

<table>
<thead>
<tr>
<th>Year</th>
<th>Hydrology</th>
<th>Yield (kg/ha/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>92/93</td>
<td>Dry</td>
<td>65</td>
</tr>
<tr>
<td>93/94</td>
<td>Normal</td>
<td>198</td>
</tr>
<tr>
<td>94/95</td>
<td>Dry</td>
<td>142</td>
</tr>
<tr>
<td>95/96</td>
<td>Normal</td>
<td>141</td>
</tr>
<tr>
<td>96/97</td>
<td>Normal</td>
<td>85</td>
</tr>
<tr>
<td>97/98</td>
<td>Wet</td>
<td>201</td>
</tr>
<tr>
<td>98/99</td>
<td>Extremely wet</td>
<td>231</td>
</tr>
<tr>
<td>99/2000</td>
<td>Dry</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 30: Annual fish yields (kg/ha/year) of Ghotokbari Beel (F3 land type) in relation to hydrology

In Figure 102 this phenomena, which is called the “floodpulse”, is quantified for CPP by plotting the summed average weekly water level from July till October against the annual average yield of Ghotokbari beel.

Further this will be used as the Flood Index
The question was why do we have a high fish catch in years with high flood?

Analysing catch and effort data revealed that that 74% of the seasonal and inter-annual variance in observed yields can be explained by changes in fishing effort; 15% can be explained by changes in CPUE and only 11% of the variance is explained by changes in water level, and that the fish catch could be well described with the regression line (Figure 103) which included the major parameters

\[ 10 \log(\text{Yield}) = -10.26 + 1.64 \times 10^{\log(\text{CPUE})} + 2.73 \times 10^{\log(f)} + 10.91 \times 10^{\log(\text{WL})} \]

CPP concluded that the major driving force in floodplain fisheries in CPP and most likely also in the rest of Bangladesh is the fishing effort or the number of fishermen. During the high floods more people start fishing because more fish can be caught in one day. Another reason why large numbers of people go fishing during the flood could be that they have no income or employment opportunity. The fact that fishing effort is a major contributor to the catch is important as most of the fisheries
programs in Bangladesh and discussions about the reduction of the natural fisheries resources focus till present on mainly habitat restoration/preservation and maintaining flood levels.

15.3.1 Catch and Effort in CPP

Let’s have a closer look at Catch and Effort in the CPP project area. In Figure 104 we plotted the fishing effort against the CPUE, a Schaefer curve.

![Figure 104: The relation between fishing effort and CPUE in the CPP project area](image)

Surprisingly, a positive relation between CPUE and fishing effort emerges. At first glance it seems strange, as it is in conflict with the basics of “Surplus production models” such as the Schaefer and Fox models. They are based on the assumption that the biomass of fish in the water is proportional to the CPUE and that the biomass and consequently also the CPUE will decrease if the fishing effort increases: i.e. a negative relation between fishing effort and CPUE would be expected.

If further looked upon on an annual basis, there is a significant relation (P< 0.05) between the flood index and the average CPUE as observed during the flood (Figure 105).
In our case we have an “Inverse Schaefer or Fox curve”, and if the assumptions of Surplus Production Models are applied it means that the fish biomass during the flood season increases, which attracts large numbers of fishermen towards floodplain fisheries. This increase in biomass in this case should be related to increased fish growth or an increased number of fish in years of high floods.

It is known that the growth of floodplain fish is fast and strongly related to flood season (Bayley, 1988, Dudley 1972). Furthermore, the growth can vary significantly between years and has been correlated with flooding intensity and duration (Dudley, 1972, Kapetsky 1974, Welcomme, 1985).

The average length of the different species caught with “non-selective” gears such as scoop nets, seines, etc for different years in the whole of the CPP area during the months of October and November is presented in Table 31.

Table 31: Average length in Oct/Nov for the major species caught by non-selective gears in the CPP project area.

<table>
<thead>
<tr>
<th>Year</th>
<th>Puti</th>
<th>Shing</th>
<th>Taki</th>
<th>Koi</th>
<th>Gutum</th>
<th>Baim</th>
<th>Kolisha</th>
</tr>
</thead>
<tbody>
<tr>
<td>92</td>
<td>6.11</td>
<td>13.79</td>
<td>8.90</td>
<td>12.55</td>
<td>6.75</td>
<td>11.64</td>
<td>5.86</td>
</tr>
<tr>
<td>93</td>
<td>7.70</td>
<td>17.29</td>
<td>11.93</td>
<td>13.09</td>
<td>8.39</td>
<td>12.18</td>
<td>8.50</td>
</tr>
<tr>
<td>94</td>
<td>7.10</td>
<td>17.41</td>
<td>11.02</td>
<td>12.68</td>
<td>8.18</td>
<td>12.71</td>
<td>7.89</td>
</tr>
<tr>
<td>95</td>
<td>7.69</td>
<td>17.37</td>
<td>10.12</td>
<td>12.40</td>
<td>8.45</td>
<td>11.28</td>
<td>7.34</td>
</tr>
<tr>
<td>96</td>
<td>6.51</td>
<td>15.58</td>
<td>13.28</td>
<td>11.62</td>
<td>8.11</td>
<td>11.83</td>
<td>7.11</td>
</tr>
<tr>
<td>97</td>
<td>7.08</td>
<td>17.89</td>
<td>12.49</td>
<td>12.12</td>
<td>8.54</td>
<td>13.36</td>
<td>7.52</td>
</tr>
<tr>
<td>98</td>
<td>7.55</td>
<td>19.54</td>
<td>14.18</td>
<td>13.69</td>
<td>9.32</td>
<td>12.61</td>
<td>7.55</td>
</tr>
</tbody>
</table>
For most species the average length in 1992 (very dry) was significantly lower if compared with the other years and 1998 (very wet) was significantly higher.

It seems that growth is an important phenomenon in the floodpulse and data from the length-based stock assessment can provide more insight into the biological process behind it.

15.3.2 Growth from the length-based stock assessment programme of CPP

We use the data of Puntius sophore to explain the mechanisms

The parameters for the von Bertalanffy growth function and the corresponding phi-prime estimated for Puntius sophore over the years are presented in Table 32.

**Table 32: Growth parameters for Puntius sophore in the CPP project area**

<table>
<thead>
<tr>
<th>Year</th>
<th>L&lt;sub&gt;∞&lt;/sub&gt;</th>
<th>K</th>
<th>C</th>
<th>WP</th>
<th>Phi-prime</th>
</tr>
</thead>
<tbody>
<tr>
<td>92/93</td>
<td>13.1</td>
<td>0.8</td>
<td>0.3</td>
<td>1</td>
<td>2.14</td>
</tr>
<tr>
<td>93/94</td>
<td>13.0</td>
<td>1.3</td>
<td>0.8</td>
<td>1</td>
<td>2.34</td>
</tr>
<tr>
<td>94/95</td>
<td>12.9</td>
<td>0.6</td>
<td>1.0</td>
<td>1</td>
<td>2.00</td>
</tr>
<tr>
<td>95/96</td>
<td>13.0</td>
<td>0.7</td>
<td>0.8</td>
<td>1</td>
<td>2.07</td>
</tr>
<tr>
<td>96/97</td>
<td>13.0</td>
<td>1.3</td>
<td>0.6</td>
<td>1</td>
<td>2.32</td>
</tr>
<tr>
<td>97/98</td>
<td>13.0</td>
<td>1.3</td>
<td>0.9</td>
<td>1</td>
<td>2.34</td>
</tr>
<tr>
<td>98/99</td>
<td>13.0</td>
<td>0.7</td>
<td>0.7</td>
<td>1</td>
<td>2.07</td>
</tr>
<tr>
<td>99/2000</td>
<td>13.1</td>
<td>0.6</td>
<td>0.6</td>
<td>1</td>
<td>1.97</td>
</tr>
</tbody>
</table>
With an $L_\infty$ of 13 cm and a $K$ of 0.6-1 *Puntius sophore* is a fast growing species reaching its asymptotic length almost within one year. Further there is a strong trend indicating a higher growth in years with high flood and there is a significant ($P<0.05$) relation between the growth performance ($\Phi$-prime) and the flood-Index, if 1998 is excluded\(^{34}\) (Figure 106).

**Figure 106: the relation between the growth performance of Puntius sophore and the flood index as observed in the CPP project area during 1999-2000.**

The relation between growth and catch or the “floodpulse” becomes more clear if the individual growth of each cohort is plotted over time for the different years and looked upon in relation to $L_{25}$, the length at which 25% of the fish will be vulnerable to be captured. The plots for the individual cohorts are presented in Figure 107.

- 1992 was a dry year, resulting in a slow growth of Puti and the 1992 cohort is entering the catch somewhere in January 1993 when its length exceeds $L_{25}$ (solid black line).
- In contrast 1993 was a wet year resulting in a fast growth of Puti and the 1993 cohort enters the catch already during the flood of 1993. The catch during the 1993 flood thus consists of survivors of the 92 cohort and the newborn of the 1993 cohort.
- The flood of 1994 was relatively dry and Puti was growing slowly, consequently the catch during the flood of 1994 was comprised mainly of survivors of the 1993 cohort.
- 1995 was a year with a normal but short flood period. The growth of Puti was slow, and the 1995 cohort enters the catch after the flood was over. Consequently the catch during the flood of 1995 mainly consists of survivors of the 1994 cohort.
- 1996 was a normal flood year with high growth for Puti. Consequently the catch during the 1996 flood period consist of survivals of the 1995 cohort and the new 1996 cohort
- 1997 was a wet year and Puti grew fast, and the 1997 cohort entered the catch already during the flood of 1997. The catch was comprised of two cohorts, the survivors of the 1996 cohort and the new born of 1997.

The examples of *P. sophore* highlight two phenomena that are important for flood plain fisheries and the floodpulse:

---

\(^{34}\) 1998 was an extreme and dangerous flood year, which disrupted all normal activities in the CPP area.
• A fast growth results in new-borns entering already into the fisheries several months after they are born. In such a situation, the catch during the flood season comprises of two cohorts, the new cohort and the survivors of the previous cohort. This could be the mechanism behind the inverse “Schaefer curve”, as in this case large numbers of fish are available for the fisheries and the CPUE increases if compared with years where only one cohort from the previous year is available. The survival of the previous year’s cohort during the dry season, is then of utmost importance in terms of numbers and weight.

• Furthermore as *P. sophore* is a short-living species, its recruitment can be a critical factor. Low survival rates caused by a high fishing pressure during the dry season could reduce the needed spawning parent stock to an absolute minimum resulting in low catches in the following year, even if the hydrological conditions are optimal (high flood).
Figure 107: Growth of *Puntius sophore* in the CPP project area
15.3.3 Mortality rates from the length-based stock assessment program

We were interested in whether the increased fishing effort, which was observed in the Catch Assessment Survey during years of high flood, is also reflected in the Stock Assessment Data through the fishing mortality rate. Therefore, the estimated fishing mortality (F) and the exploitation rate (E) are plotted against the Flood Index in Figure 108 and Figure 109.

Figure 108: The fishing mortality (year\(^{-1}\)) of P. sophore in relation to the flood Index

\[ y = 29.513\ln(x) - 111.8 \]
\[ R^2 = 0.6073 \]

Figure 109: The exploitation rate (E=F/Z) for P. sophore in relation to the flood Index

\[ y = 2.1045\ln(x) - 7.4779 \]
\[ R^2 = 0.4408 \]

Both relations were highly significant (\(P<0.05\)). The fishing mortality and the exploitation rate increases in years with high floods and CPP concluded that the Stock Assessment Program confirms the findings from the Catch Assessment i.e.,
increased fishing effort is a major driving force behind increased yields in years of high floods, whereby the effort is stimulated by an increased growth rate of species during years of high flooding.
16 ANNEX 1: REMOTE SENSING TECHNIQUES FOR DETECTING AND MAPPING AQUACULTURE PONDS IN BANGLADESH

Gertjan de Graaf, Mohammad Mostafa Kamal, Timothy C. Martin and Menno Schepel

Abstract
This paper describes a remote sensing technique developed to detect and map fish ponds in Bangladesh. The method merges high-resolution Panchromatic IRS satellite images (6x6 with Multispectral SPOT images [20x20 m], resulting in detection of 65 percent of all ponds larger than 1000 m$^2$. Ponds larger than 1000 m$^2$ constitute about 70 percent of cultured fish in the study area. The cost of the remote sensing method is 9.45 US$/km$^2$ compared to 40 US$/km$^2$ for a traditional field survey, making the new method more cost effective.

16.1 Introduction

Being a country of rivers and floodplains, fish play an important role in the daily life of Bangladesh's. Inland capture fisheries and aquaculture are the main contributors to the 1.2 million metric tons of annual fish production in the country, 53 percent and 24 percent respectively. As the population of Bangladesh increases, the inland fisheries and floodplain catch decreases. This, in turn, spurs increased aquaculture production, and, from 1985 to 1994, aquaculture production increased from 144,700 Mt/year to 317,100 Mt/year. The development of proper husbandry techniques and the dissemination of these techniques through aquaculture extension programmes formed the basis for this increase. However, proper planning of aquaculture development is hampered by the fact that current information on the number of ponds and their distribution across Bangladesh is based on an inventory conducted in the mid-1980s by the Bangladesh Space Research and Remote Sensing Organisation (SPARRSO). Recent field surveys indicate that this inventory covered only 20 percent of the actual number of ponds (CPP, 1996).

Remote sensing techniques and geographical information systems (GIS) have long been used in the fisheries sector (Yamanaka, 1982; Mayer, 1984; Mooneyhan, 1985; Turgeon, 1986; Travaglia, 1989; Pramanik et al, 1990; Lily et al, 1994.). Further, Kapetsky et al (1987) and Kapetsky et al (1988) used satellite data to demonstrate the capabilities of a high-resolution sensor for aquaculture siting and planning. However, small water bodies such as ponds, tanks, and ditches were not visible because of the ground resolution of the images. Recent developments in merging high-resolution black and white images with the relatively lower resolution colour image (Chavez et al, 1991; Muralikrinsshnan, 1993) and the availability of satellite imagery with higher ground resolution could provide more accurate detection of small water bodies.

In response to the importance of aquaculture development in Bangladesh, the Environment and GIS Support Project for Water Sector Planning (EGIS) with assistance from Resource Analysis (the Netherlands) and Nefisco (the Netherlands) studied the application of new remote sensing techniques for detecting and mapping of aquaculture ponds in Bangladesh.

35 Submitted to NAGA in September 2000
16.2 Materials and Methods

16.2.1 Study Area and Field Survey

The study compared data from a complete field survey on fish ponds with data obtained from recent satellite images for the same area. The Compartmentalisation Pilot Project (CPP, Tangail) area (Figure 110) was selected to study because the CPP project had made a complete geographic informational inventory from 1992 to 1996 of all the area’s 3,000 ponds. To update the inventory, all ponds within three randomly selected blocks of 140 ha each were sited again in December 1999.

![Figure 110: Map showing the study area and the survey blocks](image)

16.2.2 Remote Sensing

The study merged satellite images and compared images obtained during various seasons to identify fish ponds from their surroundings.

Merging of satellite images

Two types of satellite images were available for the study:

- Panchromatic (IRS 1D), or black and white, images have a high-resolution (6x6 m) but do not easily distinguish water from vegetation.
- Multi-spectral (SPOT), or colour images, have a lower resolution (20x20 m) but do easily distinguish water from vegetation through multi-band properties.

When combined, the high-resolution characteristics of the black and white image and the multi-band properties of the colour images can increase accuracy.

Using different date images

It is difficult to use one image to separate water from other wet areas such as irrigated rice, moist soils, wetlands and canals. But cropping patterns have a distinct seasonal variation and by comparing two images of different dates, water can be separated from other wet areas as illustrated in Figure 2. The method is guided by the “two times hit” principle: All areas (or pixels in the images) that are classified as
“wet” in December images as well as in March images are considered to be “real water”. All other combinations are classified as floodplains that have dried, rice fields in which irrigation has started, or dry crops.

<table>
<thead>
<tr>
<th>Month</th>
<th>Pixel 1</th>
<th>Pixel 2</th>
<th>Pixel 3</th>
<th>Pixel 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>wet</td>
<td>wet</td>
<td>dry</td>
<td>dry</td>
</tr>
<tr>
<td>March</td>
<td>dry</td>
<td>wet</td>
<td>wet</td>
<td>dry</td>
</tr>
</tbody>
</table>

| Land cover | Floodplain | Water | rice | others |

Figure 2: Principles of how two satellite images of different dates are used to distinguish water from other wet areas.

The final step is to separate ponds from the other real water areas, such as water bodies, rivers and canals, by subtracting them from the data using GIS layers.

16.3 results

16.3.1 Field data on ponds

The CPP ground survey indicated that 3,100 ponds with a total water area of 249 ha, existed in the area. The average size of the ponds was 803 m² ± 22 m². The smallest pond was 20 m² and the largest 24,000 m². Distribution showed:

- 73 percent were ≤ 800 m²
- 13 percent were 800-1,500 m²
- 14 percent were 1,500 m² or more

Considering total pond area, the larger ponds constitute 58 percent of the area, medium-sized ponds, 19 percent; and small ponds, 23 percent. The cumulative distribution of total pond area in relation to pond size is presented in Figure 3.

Figure 3: The cumulative distribution of pond area to pond class size in the CPP area.

In the CPP area, it was found that about 74 percent of total fish production came from medium and large ponds, i.e., ponds larger than 800 m² (Figure 4).
From an aquaculture perspective it can be concluded that ponds larger than 800 m$^2$ are important as they produce the bulk of fish. The majority of the ponds in the area, however, are smaller than 800 m$^2$ and do not add significantly to fish production as they dry up quickly, are not stocked, and are not used for other purposes. In evaluating the remote sensing method, this conclusion involving large ponds is important as it provides the primary reason for determining such information.

### 16.3.2 Merging

Figure 5 presents a multi-spectral (A), a high-resolution black and white (B), and a merged image (C) of part of the study area. The advantage of merging two types of satellite images becomes clear when looking at the ponds. In the multi-spectra colour image (A) water is visible as bluish areas but no clear shapes are visible. In the high resolution black and white image (B), ponds are visible as deep black rectangular shapes. In the merged image (C) some of the ponds become red indicating that they are not ponds but agriculture plots.

### 16.3.3 Pond size detected with remote sensing

The remote sensing method easily detects large ponds. The distribution patterns of large ponds is similar to the original distribution of ponds larger than 2,000 m$^2$. Smaller ponds are more difficult to detect with the method; only 65 to 70 percent of ponds larger than 1,000 m$^2$ are detected (Figure 6). The method is difficult to apply to ponds of 800 m$^2$ or smaller and data becomes inaccurate. With ponds of 400 m$^2$ or smaller, the satellite images become too difficult to interpret.
16.3.4 Costs

To compare the costs of the remote sensing-based methodology with the cost of a traditional survey, a comparison was made on the cost per square kilometre (Table 1 and Table 2). The remote sensing method costs 9.45 US$/km$^2$ while a traditional survey costs 40 US$/km^2$.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per km$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field staff days</td>
<td>7</td>
</tr>
<tr>
<td>Transport</td>
<td>4</td>
</tr>
<tr>
<td>Small equipment</td>
<td>4</td>
</tr>
<tr>
<td>GPS hiring (days)</td>
<td>16$^{36}$</td>
</tr>
<tr>
<td>Co-ordination</td>
<td>5</td>
</tr>
<tr>
<td>Data entry</td>
<td>5</td>
</tr>
<tr>
<td>Total cost</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 1: Cost of a traditional pond survey

<table>
<thead>
<tr>
<th>Task</th>
<th>US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>13</td>
</tr>
<tr>
<td>Image Processing</td>
<td>42</td>
</tr>
<tr>
<td>Field Work</td>
<td>58</td>
</tr>
<tr>
<td>Analysis/Reporting</td>
<td>55</td>
</tr>
<tr>
<td>Image, optical</td>
<td>8100</td>
</tr>
<tr>
<td>Transportation and per diem</td>
<td>1740</td>
</tr>
<tr>
<td>GPS</td>
<td>928</td>
</tr>
<tr>
<td>Sub total</td>
<td>23633</td>
</tr>
<tr>
<td>Area of 1 image (km$^2$)</td>
<td>2500</td>
</tr>
<tr>
<td>Total cost in US$/km2</td>
<td>9.45</td>
</tr>
</tbody>
</table>

Table 2: Cost estimates for detecting ponds using six band composite satellite images

$^{36}$ When the survey was carried out a Global Positioning System was still expensive in Bangladesh. With the recent price drop the cost of GPS become negligible.
16.4 Conclusions

Merging high ground resolution black and white images with multi-band colour images improved pond detection capability significantly more than any single image. The use of multi-date images is essential for the proper separation of real water from ponds from other wet features.

Advantages of the remote sensing technique are the cost-effectiveness and the relatively short period in which results can become available. The disadvantage is that not all ponds can be detected. However, considering that the major fish production and fish production potential is found in larger ponds (>1000 m$^2$), of which approximately 70 percent can be detected, this becomes a reasonable compromise between costs and results.

The advantage of the traditional field survey method is that all ponds are detected and that more data, e.g., socio economics, can be collected. The disadvantages are the higher costs and complicated logistics in organising the survey. Also, field surveys would require substantially more time to cover the whole of Bangladesh, relative to remote sensing methods.

16.5 References


SPARRSO Inventory of Inland Waters and Landsat TM and SPOT HRV Data. SPARRSO.


16.6 Acknowledgements

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17.1 The Compartmentalisation Pilot Project

The floods in Bangladesh in 1987 and 1988 were catastrophic. Many people lost their lives, thousands became homeless, crops in the fields were destroyed and infrastructure was severely damaged all over Bangladesh including Tangail district. Immediately after the 1988 flood disaster, the Government of Bangladesh (GoB) carried out several studies and the international community resolved to find a lasting solution for the flood problem. In June 1989, the World Bank agreed with the GoB to co-ordinate the various flood control and related initiatives from which the Flood Action Plan (FAP) emerged.

The Compartmentalisation Pilot Project, (CPP, also called FAP 20) which started in 1991, is a water management project situated on the east bank of the Jamuna River, with Tangail Town in its centre (Figure 111).
The overall objective of the Compartmentalisation Pilot Project was to develop appropriate water management methods for protected areas so that criteria for design, implementation and operation can be made available for similar settings in floodplains in Bangladesh.

The project area is situated in the Young Brahmaputra Flood Plain. The natural drainage pattern is away from the Brahmaputra (Jamuna) and Dhaleswari rivers towards low-lying land in the Southeast. Land elevation varies between 14 and 7 m+PWD. Large depressions (beels) are found throughout the project area. Although the overall topography is rather flat, local landscapes are very diverse. Local differences are due to the following features:

- Floodwater courses of natural rivers
- Terraces and ridges of different levels, due to large extensions of the old and active floodplains
- Artificially levelled homesteads
- Roads, flood protection, embankments, etc
- Different levels of cropping fields, which is a sequence of small terraces built for water management.

A typical cross section profile of the study area from west to east is presented in Figure 112

Figure 112: A typical cross section of the CPP area from west to east.

The objectives of CPP were:

- To test the viability, sustainability and replicability of compartmentalisation as an approach for developing protected areas.
• To develop integrated water resource management options for different sections of the rural population, with specific attention to be paid to the needs of women, landless, farmers, fishermen and boatmen.
• To develop water management systems especially for agricultural production based on the total hydrological setting for maintaining the quality and quantity of water for domestic use and sanitation.
• To develop policies and guidelines for the development of integrated water resources management in protected areas.

The basic aim of CPP was to control the unpredictable and variable flooding patterns and improve the drainage congestion. In June 1992 the Flood Plan Co-ordination Organisation (FPCO) decided this was to be obtained through flood protection at the peripheral embankment. It was expected that fisheries would be affected by interventions such as construction of gated regulators in the main river and the peripheral embankment, improvement of drainage through excavation of khals and the construction of minor regulators within the project area. Fisheries aspects have therefore been included in the project since its start.

The objectives of the fisheries component of CPP were to increase the availability of fish by securing fisheries production and by improving aquaculture production by focussing on the following aspects:
• Determining the impact of CPP on natural fisheries production.
• Determining hatching migration patterns and incorporation of the results in water management options and design of water management structures.
• Development and implementation of mitigation measures to compensate eventual negative impacts of the implementation of CPP.
• Development of proper water management scenarios for fisheries production.

This Annex to the training manual presents the results and details of a model used to predict what will happen if the water level of the Lohajang River is kept at a certain level.

17.2 Modelling of fisheries in Bangladesh

One of the major questions during a number of studies related to flood control during the Flood Action Plan was “What will be the impact of the proposed interventions on fisheries?”. This was also the major objective of the initial fisheries study of CPP.

Reduction of the floodplain will result in direct and indirect losses. The direct loss is a result of the reduction in fishing area producing a certain quantity of fish per year. Indirect losses are the result of the reduction in spawning and nursing area impacting the whole fish community. In the past several methods were used to calculate the impact of flood control on fisheries:
• In the 80s, the average production of the floodplain was multiplied with the total floodplain area in order to estimate the floodplain fisheries production. Fisheries losses were estimated by multiplying the floodplain area lost with the average floodplain production.
• Water depth and water quality data were used in the Morpho Edaphic Index in order to predict/estimate fisheries production. However this method proved to be unreliable.
• In several FAP projects (FAP 12, FAP 5.2 & FAP 3) the methodology was improved and different habitats such as beel, floodplain, khals and rivers were
considered. The production levels in most cases were obtained from secondary data.

CPP 20 started to link habitat-related fish production figures with hydrological models in order to predict the fisheries production for different water management scenarios in 1992 (CPP, 1992). Over the years this methodology was improved through a rigorous habitat specific monitoring programme of FAP 17 (1992-1994) and CPP (1992-2000); development of hydrological models and the incorporation of Geographical Information Systems for the determination of the different habitat areas.

Over the years the model improved, became more accurate and more parameters were added, especially socio-economic ones. The model, little by little, evolved towards a decision support model or a preliminary stage of “blue accounting” (EGIS, 2000) for different water management options in CPP.

A multi-disciplinary and integrated approach to planning of natural resource use, for which such models are essential, is getting more attention in Bangladesh. Therefore in the next chapters, detailed information is provided on such a model made for CPP to explain the principles, and to provide the basis for further development and use of this method in Bangladesh.

To explain the principle and the inputs/outputs of the model it was applied to a water management scenario whereby the water level in the Lohajang River during the monsoon is maintained at a level in the range of 11.0 –10.5 m +PWD.

17.3 The CPP model

The CPP model works only with quantifiable parameters i.e. kg, Tk, labour days, ha, etc, and consists of the following five modules:

• A hydrological module, which translates target water levels into temporal and spatial flood patterns;
• A fisheries module, which calculates the fish catches for the different target levels;
• An agriculture module, which calculates the agricultural production for the different target levels;
• An economic module, which calculates the economic returns for the different target levels;
• A socio-economic module, which provides information on socio-economics and distribution of profits and losses.

The model works with the assumption of a constant fishing effort and does not take into account the impacts of over-fishing due to increased fishing effort or increased population growth. The rainfall and upstream hydrology of the season 1993/92 was chosen as a major input for the model, this as pre-project data on fisheries and agriculture were available for this year and the hydrology approaches a “normal” year. The analysis is carried out in five steps and the principal pathway is presented in Figure 113. The proceedings of each module are described below.
17.3.1 Hydrological module

The hydrological module is the Mike 11\(^{37}\) model of CPP, the gates of the main regulator are set in such a way that the preferred target water level in the Lohajang River is maintained throughout the monsoon. The model generates the average monthly water levels for 21 locations in the CPP area. For the dry season the water levels are reduced/increased at the same rate as was observed during the dry season of 93/94 where by for each target option the average water levels as obtained from the model served as a starting point.

For each target option a specific gate setting is needed to maintain the preferred target water level. For each option their specific gate setting is used to create a land type map according to the MPO specifications as discussed before.

The generated water levels and the land type maps are used as input for GIS modules.

17.3.2 GIS module

\(^{37}\) Mike 11 is hydrological software.
Within the GIS module the generated water levels for each option are used to calculate the monthly inundated areas for the F3, F2, F1 and F0 land types in a way as is described in Chapter 9.4. The generated flooded area serve as input for the fisheries and the agriculture modules.

17.3.3 Fisheries module

All options are compared with the situations of the season 93/94, which is considered to be a pre-project baseline situation. The monthly CPUA for the different land types for this year are used to calculate the annual fish catch for the different water target level options and are presented in Table 33.

<table>
<thead>
<tr>
<th>DATE</th>
<th>CPUA (kg/ha/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F3</td>
</tr>
<tr>
<td>May-93</td>
<td>1.83</td>
</tr>
<tr>
<td>Jun-93</td>
<td>3.47</td>
</tr>
<tr>
<td>Jul-93</td>
<td>3.03</td>
</tr>
<tr>
<td>Aug-93</td>
<td>15.02</td>
</tr>
<tr>
<td>Sep-93</td>
<td>84.01</td>
</tr>
<tr>
<td>Oct-93</td>
<td>64.52</td>
</tr>
<tr>
<td>Nov-93</td>
<td>46.51</td>
</tr>
<tr>
<td>Dec-93</td>
<td>25.39</td>
</tr>
<tr>
<td>Jan-94</td>
<td>20.64</td>
</tr>
<tr>
<td>Feb-94</td>
<td>42.68</td>
</tr>
<tr>
<td>Mar-94</td>
<td>6.41</td>
</tr>
<tr>
<td>Apr-94</td>
<td>4.80</td>
</tr>
</tbody>
</table>

Table 33: The monthly Catch Per Unit of Area used as input for the fisheries module

For the distribution of the catch over the different types of fishermen; professional, occasional and subsistence the distribution as observed during 1993/94 is used:

- Professional 19%
- Occasional 42%
- Subsistence 33 %

17.3.4 Agriculture module

Due to lowering of the water level in the Lohajang River drainage will improve and the different land types will become dryer and even shift from one type to another i.e. some of the F3 land will become F2, some of the F2 becomes F1 and some of the F1 becomes F0. During the monsoon each land type has its own cropping pattern or land use suitability. For the comparison of agriculture under the different target water level only the monsoon crop, i.e. Aman was used, as any water management scenario does not affect the dry season crop during the monsoon.

Cropping patterns, production and financial outputs for the different land types during the monsoon are presented in Table 34.
Table 34: Cropping pattern, production and financial outputs of agriculture on the different land types during the monsoon.

As suitable land types for DW Aman broadcasted the generated areas for F3-dry is used, as DW Aman is grown only at the edges of the beel or the higher located F3 land. This is also the case for the other crops where the F2-dry, F1-dry and F0-dry are used.

In the agriculture module the dry areas as estimated per land type for the month of September in the GIS module are considered to be the total area under agriculture. For each land type this area is multiplied with the production rate or financial output of the specific crop growing at that land type.

17.3.5 Economic module

In the economic module the annual production of fish and rice\textsuperscript{38} is translated into financial output. The financial output for agriculture was provided by the agriculture section of CPP and is presented in Table 34.

Details on the financial outputs used for fisheries are presented in Table 35, Table 36 and Table 37 and are based on CPP data.

\textsuperscript{38} Rice crop for the monsoon only
<table>
<thead>
<tr>
<th>OPERATIONAL COSTS PER UNIT OF GEAR</th>
<th>Cast</th>
<th>Seine</th>
<th>Liftnet</th>
<th>Scoops</th>
<th>Gill net</th>
<th>Traps</th>
<th>Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments Gear (Tk)</td>
<td>1500</td>
<td>30000</td>
<td>150</td>
<td>50</td>
<td>200</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Duration (years)</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Investment others (Tk)</td>
<td></td>
<td>15000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration others (Years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Investment per year (Tk)</td>
<td>375</td>
<td>4167</td>
<td>150</td>
<td>50</td>
<td>133</td>
<td>1500</td>
<td>200</td>
</tr>
<tr>
<td>Fishing Time (hours)</td>
<td>3</td>
<td>2.41</td>
<td>2.48</td>
<td>2.21</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Annual fishing hours</td>
<td>93</td>
<td>8</td>
<td>84</td>
<td>196</td>
<td>58</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Annual fishing days</td>
<td>9</td>
<td>1</td>
<td>8</td>
<td>20</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

GROSS PRODUCTION F3 WATER

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Production</td>
<td>22%</td>
<td>9%</td>
<td>10%</td>
<td>28%</td>
<td>15%</td>
<td>10%</td>
<td>6%</td>
</tr>
<tr>
<td>Annual yield per ha (181 kg/ha/yr.)</td>
<td>40</td>
<td>16</td>
<td>18</td>
<td>51</td>
<td>27</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>CPUE average kg/fishermen/day</td>
<td>1.29</td>
<td>5.16</td>
<td>0.54</td>
<td>0.57</td>
<td>0.94</td>
<td>1.37</td>
<td>1.03</td>
</tr>
<tr>
<td>No fishermen/ha/year to catch the total</td>
<td>31</td>
<td>3</td>
<td>34</td>
<td>89</td>
<td>29</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Relative fishing effort</td>
<td>0.19</td>
<td>0.07</td>
<td>0.31</td>
<td>0.42</td>
<td>0.11</td>
<td>0.33</td>
<td>0.16</td>
</tr>
</tbody>
</table>

INPUTS

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments per ha/year</td>
<td>71</td>
<td>292</td>
<td>47</td>
<td>21</td>
<td>14</td>
<td>491</td>
<td>32</td>
</tr>
<tr>
<td>Real Labour days * 50 Tk</td>
<td>463</td>
<td>38</td>
<td>419</td>
<td>982</td>
<td>289</td>
<td>132</td>
<td>132</td>
</tr>
<tr>
<td>Fish price Tk/kg</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OUTPUTS FINANCIAL

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Product Value per gear per ha (Tk)</td>
<td>2787</td>
<td>1140</td>
<td>1267</td>
<td>3548</td>
<td>1901</td>
<td>1267</td>
<td>760</td>
</tr>
<tr>
<td>Total Inputs per gear per ha financial (Tk)</td>
<td>71</td>
<td>292</td>
<td>47</td>
<td>21</td>
<td>14</td>
<td>491</td>
<td>32</td>
</tr>
<tr>
<td>Net Profit per gear per ha (Tk)</td>
<td>2716</td>
<td>849</td>
<td>1221</td>
<td>3527</td>
<td>1886</td>
<td>777</td>
<td>728</td>
</tr>
<tr>
<td>Total profit/ha Financial (Tk)</td>
<td>11703</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit/kg (Tk)</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 35: Details of financial analysis of fisheries at F3 land type
<table>
<thead>
<tr>
<th>OPERATIONAL COSTS PER UNIT OF GEAR</th>
<th>Cast</th>
<th>Seine</th>
<th>Liftnet</th>
<th>Scoop</th>
<th>Gill net</th>
<th>Traps</th>
<th>Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments Gear (Tk)</td>
<td>1500</td>
<td>33000</td>
<td>150</td>
<td>50</td>
<td>200</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Duration (year)</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Investment others (Tk)</td>
<td>15000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration others (year)</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment per year (Tk)</td>
<td>375</td>
<td>4500</td>
<td>150</td>
<td>50</td>
<td>133</td>
<td>1500</td>
<td>200</td>
</tr>
<tr>
<td>Fishing Time (hours)</td>
<td>3.19</td>
<td>2</td>
<td>0.9</td>
<td>2.04</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Annual fishing hours</td>
<td>49</td>
<td>3</td>
<td>11</td>
<td>105</td>
<td>32</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Annual fishing days</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

| GROSS PRODUCTION F2 WATER         |      |       |         |       |          |       |        |
| % of Production                   | 22%  | 9%    | 10%     | 28%   | 15%      | 10%   | 6%     |
| Annual yield per ha (82 kg/ha/yr.)| 18   | 7     | 8       | 23    | 12       | 8     | 5      |
| CPUE average kg/fishermen/day     | 1.18 | 5.65  | 0.69    | 0.45  | 0.77     | 1.70  | 0.89   |
| No fishermen/ha/year to catch the total | 15 | 1     | 12      | 51    | 16       | 5     | 6      |
| Relative fishing effort           | 0.08 | 0.03  | 0.34    | 0.39  | 0.18     | 0.16  | 0.05   |

| INPUTS                            |      |       |         |       |          |       |        |
| Investments Tk/ha/year            | 29   | 153   | 51      | 19    | 25       | 239   | 10     |
| Real Labour days * 50 Tk          | 244  | 13    | 53      | 525   | 160      | 48    | 69     |
| Fish price Tk/kg                  | 70   |       |         |       |          |       |        |

| OUTPUTS FINANCIAL                 |      |       |         |       |          |       |        |
| Gross Product Value per gear per ha (Tk) | 1263 | 517   | 574     | 1607  | 861      | 574   | 344    |
| Total Inputs per gear per ha financial (Tk) | 29  | 153   | 51      | 19    | 25       | 239   | 10     |
| Net Profit per gear per ha (Tk)   | 1234 | 364   | 523     | 1588  | 836      | 336   | 335    |
| Total profit/ha Financial Tk)     | 5215 |       |         |       |          |       |        |
| Profit Tk/kg                      | 64   |       |         |       |          |       |        |

Table 36: Details of financial analysis of fisheries at F2 land type.
### OPERATIONAL COSTS PER UNIT OF GEAR

<table>
<thead>
<tr>
<th></th>
<th>Cast</th>
<th>Seine</th>
<th>Liftnet</th>
<th>Scoop</th>
<th>Gill net</th>
<th>Traps</th>
<th>Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments Gear (Tk)</td>
<td>1500</td>
<td>33000</td>
<td>150</td>
<td>50</td>
<td>200</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Duration (year)</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Investment others (Tk)</td>
<td>15000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration others (year)</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment per year (Tk)</td>
<td>375</td>
<td>4500</td>
<td>150</td>
<td>50</td>
<td>133</td>
<td>1500</td>
<td>200</td>
</tr>
<tr>
<td>Fishing Time (hours)</td>
<td>3.19</td>
<td>2</td>
<td>0.9</td>
<td>2.04</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Annual fishing hours</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>13</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Annual fishing days</td>
<td>0.59</td>
<td>0.03</td>
<td>0.13</td>
<td>1.28</td>
<td>0.39</td>
<td>0.12</td>
<td>0.17</td>
</tr>
</tbody>
</table>

### GROSS PRODUCTION F1 WATER

- **% of Production**: 22% 9% 10% 28% 15% 10% 6%
- **Annual yield per ha (82 kg/ha/yr.)**: 2 1 1 3 2 1 1
- **CPUE average kg/fishermen/day**: 1.18 5.65 0.69 0.45 0.77 1.70 0.89
- **No fishermen/ha/year to catch the total**: 2 0 1 6 2 1 1
- **Relative fishing effort**: 0.01 0.00 0.03 0.04 0.02 0.02 0.01

### INPUTS

- **Investments Tk/ha/year**: 3 14 5 2 2 24 1
- **Real Labour days * 50 Tk**: 30 2 7 64 19 6 8
- **Fish price Tk/kg**: 70

### OUTPUTS FINANCIAL

- **Gross Product Value per gear per ha (Tk)**: 154 63 70 196 105 70 42
- **Total Inputs per gear per ha financial (Tk)**: 3 14 5 2 2 24 1
- **Net Profit per gear per ha (Tk)**: 151 50 65 194 103 46 41
- **Total profit/ha Financial (Tk)**: 649
- **Profit Tk/kg**: 65

---

**Table 37: Details of financial analysis of fisheries at F1 land type**

17.3.6 Socio-economic module.

The socio-economic module takes into account how the benefits and losses of the different options are distributed over the different social strata in the rural area of CPP. It considers the following social strata:

- Landless
- Marginal farmers
- Small farmers
- Medium farmers
- Large farmers

The combined results of the Household Survey and the Agriculture Monitoring Plot survey allowed us to estimate the land ownership of the Net Cropped Area and the beels\(^{39}\) in the CPP area which is presented in Table 38.

---

\(^{39}\) Beels should be included as the model works with shifting land types i.e. F3-wet (Beel) shifts to F3 dry (DW aman)
Table 38: Distributions of the Net Cropped Area (fishing area included) over the rural population in the CPP project area.

<table>
<thead>
<tr>
<th>Farmer Type</th>
<th>No HH</th>
<th>% of Rural HH</th>
<th>% of NCA</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>19890</td>
<td>69%</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Marginal</td>
<td>2509</td>
<td>9%</td>
<td>11%</td>
<td>1080</td>
</tr>
<tr>
<td>Small</td>
<td>4589</td>
<td>16%</td>
<td>44%</td>
<td>4341</td>
</tr>
<tr>
<td>Medium</td>
<td>1362</td>
<td>5%</td>
<td>26%</td>
<td>2539</td>
</tr>
<tr>
<td>Large</td>
<td>475</td>
<td>2%</td>
<td>20%</td>
<td>1991</td>
</tr>
<tr>
<td>Total</td>
<td>28825</td>
<td>100%</td>
<td>100%</td>
<td>9952</td>
</tr>
</tbody>
</table>

In Table 39 the distribution of the catch over the rural population in CPP is presented. The data are a combination of the Household Survey of CPP (1992) and the FAP 17 data for the North Central Region and it was assumed that all professional fishermen belong to the “landless” category.

Table 39: Distribution of the catch over the rural population in the CPP project area.

<table>
<thead>
<tr>
<th>HH Type</th>
<th>Occasional</th>
<th>Subsistence</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large farmers</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Medium farmers</td>
<td>2%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Small farmers</td>
<td>12%</td>
<td>21%</td>
<td>0%</td>
</tr>
<tr>
<td>Landless &amp; Marginal farmers</td>
<td>86%</td>
<td>76%</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The data in the two tables allows parcelling the agriculture benefits and the fisheries losses for the different target water level options over the different categories of the rural population in the CPP area. Within the analysis the professional fishermen and their catch and the rest of the rural population with its subsistence and occasional catch are treated separately.

In this module the following assumptions are used:

- The distribution of the NCA over the social strata is the same for the different land types (F3, F2, F1, and F0).
- Exclusively the landless and marginal farmers carry out the hired labour needed for the different crops.
- All calculations are on a household basis with 5.5 persons in a household.
- Annual income: large farmer, 80 000 Tk; medium farmer, 53 000 Tk; small farmer 31 000; marginal farmer 19 000 Tk; landless 15 000 Tk.
- Fish price 70 Tk/kg, Labour 50 Tk/day, 1 US$ = 50 Tk

The availability of protein for consumption is calculated with the subsistence catch only. For the transformation of “wet fish weight” to “dry protein” a conversion factor of 0.174 is used and the daily requirement of protein was set at 43 g/capita/day.

---

40 In reality this is not the case; medium and large farmers possess more F1 and F0 land (CPP Household Survey, 1992)
17.4 Results

17.4.1 Shift in water and land

Due to the lowering of the water level in the Lohajang River drainage is improved and the extent of flooding will be less i.e. the area becomes drier. In Figure 114 and Figure 115 for the two extreme options, without CPP and a 10.50 m + PWD target level the inundated and dry area per land type throughout the year is presented and it is clear that especially the area of dry-F0 increases substantially with a reduction of the flooded areas of F2 and F1.

Figure 114: Monthly flooded and dry areas for the different land types without CPP
17.4.2 Production and value

The reduction of dry F2 and F1 area and the increase in dry F0 area is also reflected in the rice production. By lowering the water level of the Lohajang River the production of DW transplanted Aman and T Aman local will be reduced while the production of DW Aman broad casted will increase slightly. The benefits are found in the large incremental production of T Aman HYV (Figure 116). The total rice production\(^{41}\) will increase with 5 300 Mt/year from 11 7000 Mt/year for the pre-project phase to 17 100 for the 10.50 meter water level.

\(^{41}\) During the kharif/monsoon season
Figure 116: Incremental rice production at different target water levels of the Lohajang River.

The consequence of a drier CPP area will be reduction of the fish catch there, especially from the F2 and F1 areas (Figure 117). The total fish catch will reduce by 41% from 285 mt/year for the pre-project situation to 168 mt/year for the 10.50 m water level.

Figure 117: Reduced fish catch in the CPP project area for the different water target levels
In financial terms the benefits obtained from agriculture outweigh the losses from fisheries and the value added increases with 0.5 million US/year, from 1.8 million US/year for the without CPP situation to 2.3 million US/year for the 10.50 meter water level (Figure 118).

![Graph showing value added for agriculture and fisheries](image)

**Figure 118**: The total “value added” for agriculture and fisheries as estimated by the model for the different water management options of CPP.

### 17.4.3 Socio-economics aspects

Increased financial outputs are not the only justification of an intervention it is the overall policy and the outputs of an intervention in relation to this overall policy which justify or negate an intervention. If the overall policy were to increase rice production, the results of the estimates would justify the implementation of the 10.50-meter target level. However if the overall policy includes poverty alleviation, then it has to be looked upon in terms of how much the rural poor are gaining from the intervention. Looking at the distribution of the benefits/losses over the different social strata does this. The model looks at professional fishing and subsistence combined with occasional separately.

**Agriculture**

The large farmers, because they own more land, get the highest incremental profit from the agriculture improvements, ranging 140–285 US/household/year, for respectively the 11.00-meter and the 10.50-meter scenario. This is in comparison with the marginal farmers, for whom the incremental profits are ranging from 14-29 US/household/year; and the landless, who have no direct incremental profit at all (Figure 119). In relation to the annual income, as well the large farmers will have the highest contribution as their income increases by 9-18%, this in comparison with the rate for marginal farmers, which is in the range of 4-8% (Table 40).
Figure 119: Distribution of the direct incremental benefits of agriculture for the different water target levels over the different social strata in CPP.

<table>
<thead>
<tr>
<th>Type</th>
<th>Water target levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1100</td>
</tr>
<tr>
<td>Landless</td>
<td>0%</td>
</tr>
<tr>
<td>Marginal</td>
<td>4%</td>
</tr>
<tr>
<td>Small</td>
<td>5%</td>
</tr>
<tr>
<td>Medium</td>
<td>6%</td>
</tr>
<tr>
<td>Large</td>
<td>9%</td>
</tr>
</tbody>
</table>

Table 40: Distribution of the incremental agriculture benefits for the different target water levels in terms of percentage of the average annual income of the different social strata in the CPP.

Fisheries

If the total annual catch of occasional and subsistence catch in CPP is analysed in relation to the total number of rural house-holds and their annual income from all economic activities (Table 41) we come to the same conclusions as FAP 17 (1995). Fishing is an economic activity, but the significance of fishing within the annual income should not be over-stressed. It is one of many sources, which becomes relatively more important during the flood season when all three of their main sources (agriculture labour, non-agriculture labour and self-employment) are at their annual low (FAP 17, 1995).
<table>
<thead>
<tr>
<th>HH type</th>
<th>No HH</th>
<th>Annual catch</th>
<th>Value annual catch</th>
<th>Value catch as % of annual income</th>
<th>% of required daily animal protein intake 42</th>
<th>Fishing days</th>
<th>Labour day equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large farmer</td>
<td>475</td>
<td>0.0</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium farmer</td>
<td>1362</td>
<td>4.3</td>
<td>300</td>
<td>0.57%</td>
<td>0.55%</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Small farmer</td>
<td>4589</td>
<td>8.7</td>
<td>608</td>
<td>1.96%</td>
<td>1.20%</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Land less &amp;</td>
<td>22399</td>
<td>8.3</td>
<td>580</td>
<td>3.05%</td>
<td>0.88%</td>
<td>13</td>
<td>12</td>
</tr>
</tbody>
</table>
| Marginal farmers

Table 41: Key parameters of the catch of non-professional fishermen in the CPP project area in relation to their land holdings (source CPP 2000).

Reduction in the floodplain area will cause losses in fisheries and for fisheries the picture is the inverse of agriculture; the large farmers have no losses as they do not fish, and the losses are mainly felt by the marginal farmers and landless, where 50-80 Mt/year is lost (Figure 120). Due to the large number of landless and marginal farmers (23,000 HH) on an individual household basis the loss becomes only 3-6 US/household/year (Figure 121), in terms of income this is equivalent to 1-1.5% of their annual income per year (Table 42).

Figure 120: Distribution of total annual fisheries losses over the different social strata of the rural population of CPP.

---

42 Calculated with subsistence catch only
Figure 121: Distribution of the fish losses for the different water target levels over the different social strata in CPP.

<table>
<thead>
<tr>
<th>HH type</th>
<th>Water target level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1100</td>
</tr>
<tr>
<td>Large</td>
<td>0.00%</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.15%</td>
</tr>
<tr>
<td>Small</td>
<td>-0.50%</td>
</tr>
<tr>
<td>Landless &amp; Marginal</td>
<td>-0.88%</td>
</tr>
</tbody>
</table>

Table 42: Distribution of the fish losses for the different target water level in percentage of the average annual income of the different social strata in CPP.

The combined impact on agriculture and fisheries

Combining the agriculture benefits and the fisheries losses indicates that all households except the landless will have a direct net profit (Figure 122). The landless, however, will lose 3-6 US/Household/year. Considering the fact that they form the majority of the rural households (68%) and they are the poorest and most vulnerable group this can-not be neglected.
Income generation as a spin-off agriculture developments

It is often stated that developments in agriculture will create income-generating activities for the landless and marginal farmers through daily labour. Estimates on the actual daily labour requirements for the different crops are obtained from the Agriculture Monitoring Plots of the CPP and were presented in Table 34. The differences in requirements seem to be small, but they become substantial if they are estimated for the whole of the CPP project area for the different scenarios (Figure 123).
Indeed it can be expected that in the long run the daily labour requirements will increase by 280 000 days/year with the 10.50 meter scenario (Table 43)

<table>
<thead>
<tr>
<th>Target level</th>
<th>Total Incremental days</th>
<th>Days/HH/year</th>
<th>Tk/HH/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>127597</td>
<td>6</td>
<td>285</td>
</tr>
<tr>
<td>1090</td>
<td>148367</td>
<td>7</td>
<td>331</td>
</tr>
<tr>
<td>1080</td>
<td>177876</td>
<td>8</td>
<td>397</td>
</tr>
<tr>
<td>1070</td>
<td>206386</td>
<td>9</td>
<td>461</td>
</tr>
<tr>
<td>1060</td>
<td>237775</td>
<td>11</td>
<td>531</td>
</tr>
<tr>
<td>1050</td>
<td>262662</td>
<td>12</td>
<td>586</td>
</tr>
</tbody>
</table>

Table 43: Incremental daily labour requirements for the different target water levels and their income generation for landless and marginal farmers in the CPP area.

This would mean that 6-12 labour days per year would be generated for the landless and marginal farmers if they were to provide daily labour exclusively\(^43\), and the overall impact of the different scenarios on the different groups in the rural area is presented in Table 44.

<table>
<thead>
<tr>
<th>HH type</th>
<th>Target water level</th>
<th>1100</th>
<th>1090</th>
<th>1080</th>
<th>1070</th>
<th>1060</th>
<th>1050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>138</td>
<td>163</td>
<td>194</td>
<td>224</td>
<td>259</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>60</td>
<td>71</td>
<td>84</td>
<td>97</td>
<td>113</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>28</td>
<td>33</td>
<td>40</td>
<td>46</td>
<td>54</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td>17</td>
<td>20</td>
<td>24</td>
<td>28</td>
<td>33</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Landless</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Table 44: Incremental annual income per household (US$/year) for the different social strata as estimated with the fisheries-agriculture model for the different target water levels.

From the exercise it could be concluded that the small, medium and large farmers will profit from the interventions and they will be better off. The marginal farmers and landless will have a slight benefit or will not lose from the interventions.

Daily animal protein intake

FAP 16 (1995) studied the fish consumption of the rural household in the CPP area and concluded that open water fisheries are a major source of animal protein consumption of the rural poor in the CPP area. The results were based on a household consumption survey in a small number of villages in the CPP area. From all four areas studied, the Tangail CPP area had the lowest average daily consumption of 11 gram fish/capita/day equivalent to 1.9 gram of fish protein per capita/day. The fish consumed is both caught and bought. Unfortunately in 1992 the results could not be compared with the catch statistics of CPP, as they were not available. Reliable catch statistics for CPP are now available.

\(^{43}\) It can be expected that the urban poor are also involved
and the role of subsistence fisheries with respect to animal protein consumption of
the rural population can be analysed and has been incorporated into the model. The
results are presented in Table 45 and Table 46.

<table>
<thead>
<tr>
<th>HH type</th>
<th>Water management scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without</td>
</tr>
<tr>
<td>Large</td>
<td>0.0</td>
</tr>
<tr>
<td>Medium</td>
<td>1.4</td>
</tr>
<tr>
<td>Small</td>
<td>3.0</td>
</tr>
<tr>
<td>Landless &amp; Marginal</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 45: Estimated daily per capita available fish for consumption from subsistence
fishing for the different water management scenarios in CPP.

The present availability of fish from subsistence fishing for daily consumption is low
and is in contrast with the general belief in Bangladesh that subsistence fishing is an
important source of protein but on the other hand it is consistent with the findings of
FAP 16 indicating that the average daily fish consumption in the CPP area was 50% below
the values as observed in the other studied areas (FAP 16, 1995).
Water management scenario

<table>
<thead>
<tr>
<th>HH type</th>
<th>Without</th>
<th>1100</th>
<th>1090</th>
<th>1080</th>
<th>1070</th>
<th>1060</th>
<th>1050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Medium</td>
<td>0.55%</td>
<td>0.41%</td>
<td>0.39%</td>
<td>0.37%</td>
<td>0.36%</td>
<td>0.34%</td>
<td>0.32%</td>
</tr>
<tr>
<td>Small</td>
<td>1.20%</td>
<td>0.89%</td>
<td>0.85%</td>
<td>0.82%</td>
<td>0.78%</td>
<td>0.74%</td>
<td>0.71%</td>
</tr>
<tr>
<td>Landless &amp; Marginal</td>
<td>0.88%</td>
<td>0.65%</td>
<td>0.62%</td>
<td>0.60%</td>
<td>0.57%</td>
<td>0.54%</td>
<td>0.52%</td>
</tr>
</tbody>
</table>

Table 46: Daily animal protein provided by subsistence fishing in percentage of the total required daily animal protein intake (43 g/capita/day).

At present about 0.88% of the daily required protein intake of the landless and marginal farmers could be provided through subsistence fishing of these households and this would decrease to 0.52% if CPP implements its 10.50 meter scenarios. The results could be the reflection of the importance of income for the rural poor, they will only fish if there is no other alternative, and they will buy the fish if they have money. This would mean that subsistence fisheries becomes less important in areas where alternative income is more easily available, and this phenomenon could be checked with the data on subsistence fishing and fish consumption of the Helen Keller Foundation in Bangladesh.

Professional fishermen

Key parameters of the catch and income of professional fishermen before CPP is presented in Table 47. With an annual income of about Tk 10,000 per year they can be grouped among the poorest of the inhabitants of CPP and changes in fisheries due to interventions of CPP will hit them harder than the other poor, as their income is mainly provided through fishing.

<table>
<thead>
<tr>
<th>Key parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No of fishermen</td>
<td>355</td>
</tr>
<tr>
<td>Annual catch (Mt/year)</td>
<td>54</td>
</tr>
<tr>
<td>Annual catch per HH (kg/HH/year)</td>
<td>153</td>
</tr>
<tr>
<td>Annual income (Tk/HH/year)</td>
<td>9931</td>
</tr>
</tbody>
</table>

Table 47: Key parameters of professional fishermen in the CPP area before the interventions of CCP.

The estimated impact of the different target water levels on the income of the professional fishermen is presented in Table 48. It can be concluded that the professional fishermen will always be impacted by CPP interventions, which is normal, as CPP becomes drier due to the interventions. The extent depends on the extent of the conversion of flooded area into agricultural land and ranges from a 26% to a 41% loss of annual income for the 11.00 and the 10.50 meter scenario respectively.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Without</th>
<th>1050</th>
<th>1060</th>
<th>1070</th>
<th>1080</th>
<th>1090</th>
<th>1100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual catch Kg/HH/YEAR</td>
<td>54</td>
<td>32</td>
<td>34</td>
<td>35</td>
<td>37</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Loss in income</td>
<td>9931</td>
<td>5853</td>
<td>6158</td>
<td>6464</td>
<td>6769</td>
<td>7075</td>
<td>7380</td>
</tr>
<tr>
<td>Annual income Kg/HH/YEAR</td>
<td>153</td>
<td>90</td>
<td>95</td>
<td>99</td>
<td>104</td>
<td>109</td>
<td>114</td>
</tr>
</tbody>
</table>

Table 48: Estimated loss of income of professional fisheries for the different water management scenarios of CPP.

17.5 Conclusions and recommendations for future developments

The model can predict future trends in developments based on shifting of land types under a more or less steady state condition i.e. no large changes in population structure, income generation activity or what is more important, fishing effort that takes place in the future. In principle, any scenarios can be predicted as long as the hydrological model can estimate shifting patterns in dry and flooded areas.

The model could be further improved by adding:

- population growth rate;
- more details on cropping patterns and inputs, i.e. the use of fertilisers or pesticides per crop could be added to have an idea of pesticide loads etc;
- the bio-diversity index;
- investment, operation and maintenance costs.

Fine-tuning of the model towards real developments in fisheries can only be done if it is linked with the output of “adapted dynamic fish stock assessment models” in which fishing effort and water management or its impact on the extent of flooding is related to fish production, species-wide, in a three dimensional way.
18 ACKNOWLEDGMENTS

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The support of the Mr. Frank Peacock (team leader of CPP) and Mr. Rob Koudstaal (team leader of EGIS-II) and the Royal Dutch Embassy were essential for the development of the Training.

Without all this support there would not have been a training course.
19 REFERENCES AND SUGGESTED FURTHER LITERATURE


FAP 16, Potential impacts of flood control on the biological diversity and nutritional value of subsistence fisheries in Bangladesh, ISPAN, Environmental Study, Dhaka, Bangladesh, 72 pp.


Bangladesh Water Development Board, DHV consultants & Kampsax, Dhaka, Bangladesh, 106 pp.


Pauly, D. and David, N., 1981. Elefan I, a basic program for the objective extraction of growth parameters from length frequencies data. Meeresforshung. 28 (4): 205-211.


Somers, I.F., 1988. On a seasonally oscillating growth function. ICLARM fishbyte 6 (1); 8-11.

