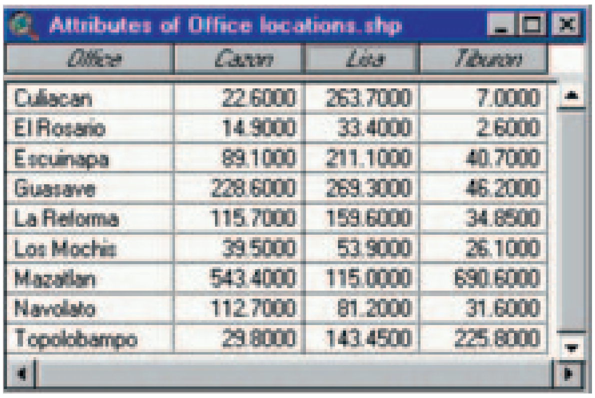
FIGURE 17.23
The Attributes of office locations



Attributes of Office locations.shp

Office	Cazon	Lisa	Tiburon
Culiacan	22.6000	263.7000	7.0000
El Rosario	14.9000	33.4000	2.6000
Escuinapa	89.1000	211.1000	40.7000
Guasave	228.6000	269.3000	46.2000
La Reforma	115.7000	159.6000	34.8500
Los Mochis	39.5000	53.9000	26.1000
Mazatlan	543.4000	115.0000	690.6000
Navolato	112.7000	81.2000	31.6000
Topolobampo	29.8000	143.4500	225.8000

The data for 'Lisa', 'Cazon' and 'Tiburon' can now be plotted on the map of office locations (Figure 17.24).

FIGURE 17.24
The data of different fish species per fisheries office

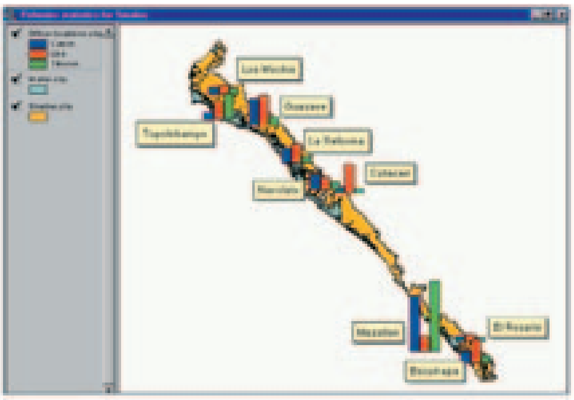


TABLE 17.2
Spanish, Scientific and English fish species names

Spanish name	Scientific name	English Name
Bandera	*Bagre Panamensis*	Chilhuil sea catfish
Baqueta	*Epinephelus acanthistus*	Rooster hind
Berrugata	*Menticirrhus panamensis*	Panama king kroaker
Cabrilla	*Myctoperca rosacea*	Leopard grouper
Cazon	*Nasolamia velox*	Whitenose shark
Corvina	*Cynoscion nebulosus*	Spotted weakfish
Guachinango	*Lutjanus spp*	Snapper
Jurel	*Caranx latus agassiz*	Horse-eye jack
Lenguado	*Hippoglossina tetropthalma*	Fourspot flounder
Lisa	*Mugil cephalus*	Flathead mullet
Mero	*Enicephalus itajara*	Itajara
Pampano	*Trachinotus carolinus*	Florida pompano
Pargo	*Lutjanus argentiventris*	Yellow snapper
Pierna	*Caulolatilus princeps*	Ocean whitefish
Rayas	NA	NA
Robalo	*Centropomus undecimalis*	Common snook
Ronco	*Pomadasys panamensis*	Panama grunt
Rubia	*Lutjanus inermis*	Golden snapper
Sierra	*Scomberomorus sierra*	Pacific sierra
Tiburon	*Echeneis naucrates*	Live shark sucker

17.1.4 Floodplain fisheries monitoring and GIS, an example from Bangladesh

Fisheries in Bangladesh[31]

Fish plays an important role in the daily life of many people in Bangladesh, as it is a country of rivers and floodplains, with a high potential of aquatic resources. The Bengali expression 'Mache bhate Bengali', or 'Fish and rice make a Bengali', expresses this importance. Bangladesh produces 1 500 000 tonnes of fish annually (FAO, 2000). Inland capture fisheries and aquaculture are the main contributors to this production. About 12 millions people depend on fisheries, of which 1.2 millions are fulltime dependent on fish and fishing activities (de Graaf *et al.*, 2001).

Fish production in Bangladesh, as in other floodplain areas in the world, cannot be properly considered without knowing the specific characteristics. Reproduction and growth of fish and prawn in Bangladesh are strongly related to the sequence of flooding (Junk, Bayley and Sparks, 1989). The floodplains, which are inundated during the monsoon season, are nutrient and food rich and play a significant role for 4–5 months of the year. Larvae, juveniles and adults grow in this habitat, after which they migrate back to rivers or depressions at the end of the monsoon, when waters recede. In this period the fish are more vulnerable to fishing.

Habitat stratified fisheries monitoring

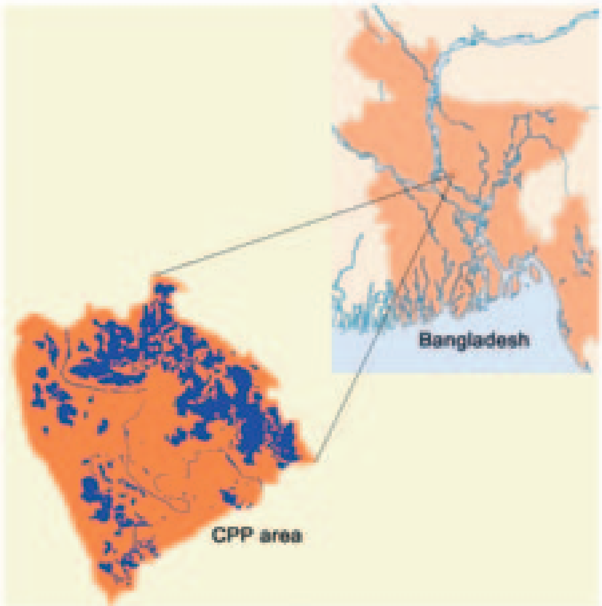
Inland fisheries are traditionally monitored through so-called catch and effort monitoring systems. Where effort (F) is the number of fishers, or the number of gears, operated in a waterbody, and catch (CPUE) is the daily catch harvested per fisherman, or gear. The total catch (C) is obtained by multiplying the catch per fishers (or gear) (CPUE) with the total number of fishers (or gears) (F). A prerequisite for a catch and effort monitoring system is that the total effort (F, the total number of fishers (or gears) operated) is known.

This would mean for floodplain fisheries monitoring that an incredibly large number of households would have to be followed throughout the year, because most of the catch is not landed centrally, but is taken home and consumed (as for instance 60–70 percent of the rural population on the floodplains of Bangladesh is engaged in 'subsistence fishing[32]). This large household survey would be very costly, making a traditional catch and effort monitoring system not an attractive option.

The Compartmentalization Pilot Project (CPP), a water management project in Bangladesh (Figure 17.25), developed a more practical monitoring system over the period 1992–2000. This habitat fisheries monitoring programme was based on traditional catch and effort data recording, and was combined with hydrological modelling developments[33], resulting in a final analysis in a GIS environment.

[31] The exercise is based on work of de Graaf, Born, Uddin, and Marttin (2001) in the Compartmentalization Pilot Project implemented from 1991 – 2001 in Tangail, Bangladesh.
[32] Fishing for their daily consumption.
[33] Spatial and temporal.

FIGURE 17.25
The CPP project in Bangladesh



Basic principles of habitat stratified floodplain fisheries monitoring

The principle of the fisheries monitoring programme developed by CPP is a stratification of catch and effort monitoring. Stratification means that the area to be monitored is divided into different habitat-types. Of each different habitat type a small part was selected, becoming a representation for the habitat type. These standard sites were monitored closely with a normal catch and effort monitoring programme. The results of these small monitoring programmes were extrapolated, per habitat type, over the whole project area.

The estimation of the total catch followed three steps:

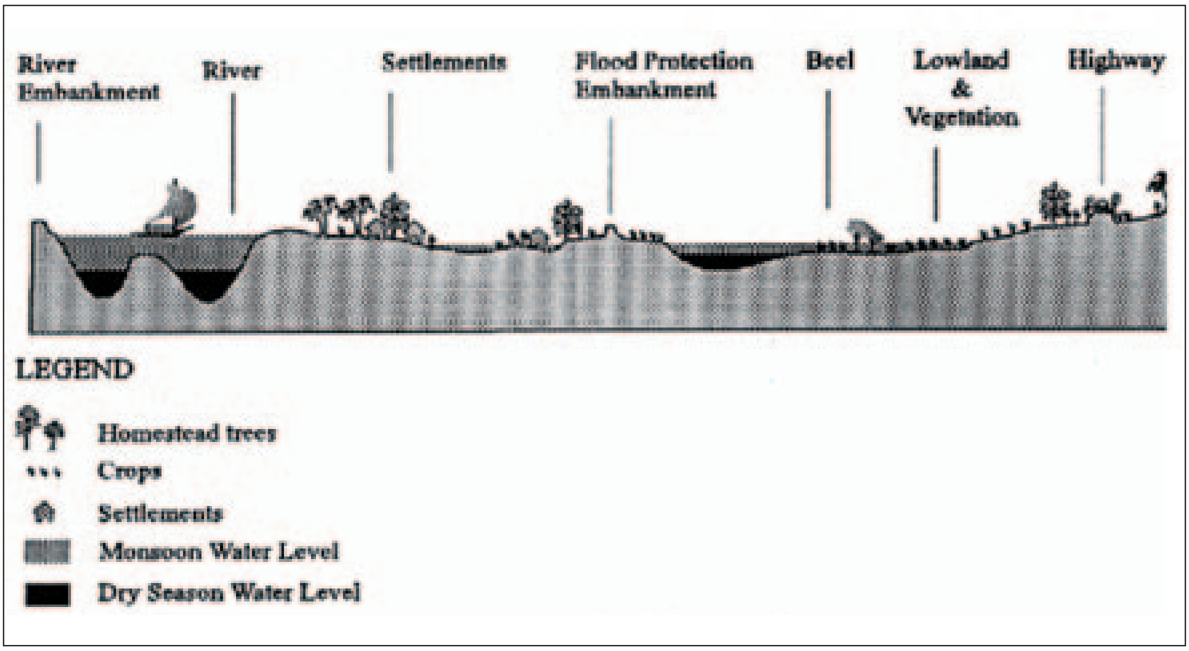
- The Catch per Unit of Area (CPUA) for each type of habitat was determined as accurately as possible with traditional catch and effort monitoring.
- The total flooded area (A) for each type of waterbody (or habitat type) was determined as accurately as possible with GIS.
- The total catch per type of waterbody (or habitat type) was determined by multiplying the catch per unit of area with the actual area. (CPUA * A = total catch).

Stratification of the CPP area, or criteria and principles

The waterbodies/habitat types (Figure 17.25) in the floodplains of Bangladesh can be classified as:

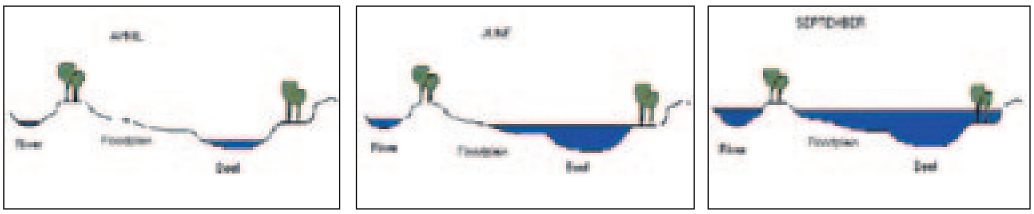
- **Beels**: These are the low-lying depressions in the floodplain (small lakes). They may have a permanent character, containing water throughout the year (permanent waterbodies) or dry out completely in the dry season, usually for a period of 4–5 months (seasonal waterbodies).
- **Floodplains**: Land inundated during the monsoon because of rainwater congestion and river flooding.
- **Rivers and canals**.

FIGURE 17.26
Cross-section of a typical floodplain system in Bangladesh



Classification and selection of rivers and canals is straightforward, but the classification and selection of beels and floodplains is more complicated, as they are hydrologically linked and very dynamic. The following figure shows this extremely dynamic character, where the floodlevels and the inundated area of the floodplain in the CPP area during the months April, June and September are presented.

FIGURE 17.27
Water level and inundated area of a floodplain system at three moments during the year



In April, there is no inundated floodplain, and the average water depth in the beel, which covers an area of 100 ha, is 1 metre.

Two months later, in June, there is on average 0.3 metres of water in the floodplain, which at this time covers an area of 1 200 ha, while the average water depth in the beel has increased to 2 metres and the beel covers an area of 150 ha.

Another two months later, in September, there is on average 0.3–1.5 metres of water in the floodplain, depending on where you are, and an area of 2 000 ha of floodplain is inundated.

The time intervals in this illustration are quite big (two months), but even within one month during the flood season water levels may vary significantly. This phenomenon makes it difficult to use water levels as selection criteria for habitat fisheries monitoring, as it would mean that these habitats would not be fixed in one place. This was the reason why the fisheries team of the CPP project looked for other criteria to classify habitats. These criteria needed to be quantifiable, replicable, usable all over Bangladesh, and practical.

In Bangladesh all land is classified (by the Master Planning Organization, MPO) for suitability of agriculture practices. This MPO classification is well known by large groups of planners, scientists, departments, farmers, and could be described as a flooding risk classification of land. After careful consideration it was concluded that this system could be used for the habitat fisheries monitoring programme in the CPP project. The MPO classification classifies land according to the risk of flooding for three consecutive days with a certain maximum water level. This risk of flooding determines which type of crops can be grown during the monsoon season. The different classes with their criteria are in Table 17.3, you see that fishing is carried out mainly in the F3 and the F2 lands.

TABLE 17.3
Land classification according to the Master Planning Organization, Bangladesh

Maximum flooding depth for three days *(cm)*	Landtype	Risk of flooding	Land use during the monsoon
0–30	F0	Very low risk of flooding	sugarcane, vegetables, rice
30–90	F1	Low risk of flooding	rice
90–180	F2	High risk of flooding	rice, floating rice, fish
>180	F3	Certainly flooded	floating rice, fish

The landtypes in a certain area only change if the water management in that area is changed. This happened for instance with the CPP area. Before the 1970s, the CPP area was more or less an unprotected floodplain. Large areas were flooded annually, and large areas were classified as F3 and F2. An embankment around the area was built in the 1970s, which highly reduced the risk of flooding, resulting in a reclassification of a large area of land previously classified as F3/F2 into F2/F1.

The developers of the habitat-stratified floodplain fisheries monitoring programme assumed that data obtained from a landtype site was representative for the total flooded area of this landtype, irrespective of the actual water level measured at that site. For instance, if the catch in 10 ha of flooded F3 land was well monitored during a certain period, it was considered representative for the total area of flooded F3 land during this period. This assumption allowed concentrating on the fixed sites within the project area. As a result a sound analysis was possible, considering even the limited amount of resources.

The monitoring programme

The goal of the stratified monitoring programme was to estimate the monthly CPUA of the different habitat types (in this exercise the different landtypes, F2 and F3), and to estimate monthly what the flooded area was of the different habitat types (F2 and F3). With these figures it was possible to estimate the monthly catch per habitat type ($CPUA_{Fx}$ * $Area_{Fx}$ = Catch of the habitat type Fx). Adding the results of the different habitat types resulted in the total catch from the floodplains of the project area ($Catch_{F2}$ + $Catch_{F3}$ = Total catch).

To be able to establish the monthly CPUA per landtype (F2 and F3) several sites were selected that were representative for all other sites with the same landtype. The area of these sites was measured accurately, so that after establishing the monthly catch per site, the monthly CPUA per landtype was easy to establish ([Monthly catch]/[Area] = CPUA).

Two surveys were done at the selected sites:

- **Catch assessment survey:** provided information on the average monthly catch per fishers (CPUE) at a selected site. The daily catch of every individual fisherman was monitored regularly at each site. The numbers and weight of the dominant species in the catch were recorded. Furthermore, the gear-type, its mesh size, owner status and the number of units used per fisherman were recorded.
- **Frame survey**: provided information on the average number of fishers (F) operating at a selected site. It consisted of regular standardized counting of the number of fishers, and gears used.

From these two surveys the average monthly catch could be established per site (CPUE * F = Catch), after which the CPUA of the landtype the site represented could be established ([Catch] / [Area] = $CPUA_{Fx}$).

Using GIS, the total inundated area per landtype was determined, after which it was possible to estimate the total catch ([$CPUA_{F2}$ * $Area_{F2}$] + [$CPUA_{F3}$ * $Area_{F3}$] = Total Catch).

Figure 17.28 shows the sites which were monitored for eight years in the CPP area. Data from the sampled sites you can find in Table 17.4 and Table 17.5.

FIGURE 17.28
Sampling sites of the fisheries monitoring programme in the CPP project area

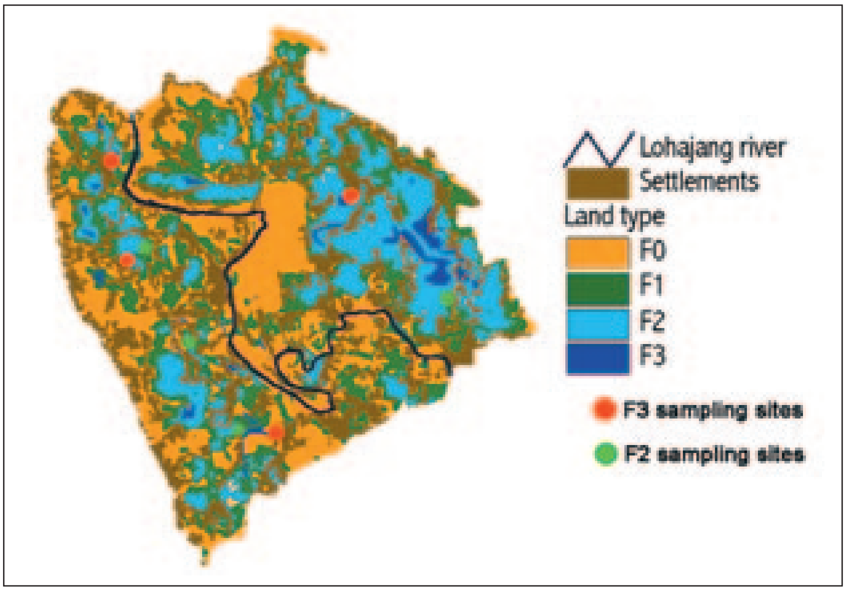


TABLE 17.4
Fisheries data (1997) from F3 sampling sites

Month	Number fishers per day (F)	Catch per fishers per day (CPUE) *(kg/day)*	Daily Yield in sampled Area (CPUE * F = Catch) *(kg/day)*	Monthly yield (Catch*days) *(kg/month)*	Sampled **Area** *(ha)*	**CPUA** (Catch/Area) *(kg/ha/month)*
January	3	0.68	2.04	63.24	4.22	**14.99**
February	3	1.07	3.21	89.88	3.60	**24.75**
March	3	0.87	2.61	80.91	3.77	**21.46**
April	3	1.06	3.18	95.40	7.19	**13.27**
May	6	1.13	6.78	210.18	8.90	**23.62**
June	6	1.41	8.46	253.80	10.01	**25.35**
July	8	0.63	5.04	156.24	17.10	**9.14**
August	5	0.75	3.75	116.25	17.80	**6.53**
September	11	1.28	14.08	422.40	17.80	**23.73**
October	15	3.06	45.90	1 422.90	12.23	**116.35**
November	8	0.96	7.68	230.40	6.52	**35.34**
December	4	0.91	3.64	112.84	5.63	**20.04**

TABLE 17.5
Fisheries data (1997) from F2 sampling sites

Month	Number fishers per day (F)	Catch per fishers per day (CPUE) *(kg/day)*	Daily Yield in sampled Area (CPUE * F = Catch) *(kg/day)*	Monthly yield (Catch*days) *(kg/month)*	Sampled **Area** **Area** *(ha)*	**CPUA** (Catch/Area) *(kg/ha/month)*
January	9	0.74	6.66	206.46	11	**18.77**
February	0	0.00	0	0	11	**0**
March	0	0.00	0	0	11	**0**
April	0	0.00	0	0	11	**0**
May	0	0.00	0	0	11	**0**
June	0	0.00	0	0	11	**0**
July	5	0.56	3	86.80	11	**7.89**
August	15	0.72	11	334.80	11	**30.44**
September	13	1.25	16	487.50	11	**44.32**
October	9	2.57	23	717.03	11	**65.18**
November	15	0.85	13	382.50	11	**34.77**
December	3	1.50	5	139.50	11	**12.68**

The data show that floodplain fisheries in the project area are highly seasonal with peak yields in October (Figure 17.29). This strong seasonality makes it essential that analysis of data and estimation of total catch is carried out on a monthly basis.

FIGURE 17.29
Seasonal variation in fishing effort and CPUE in the floodplain (F3) of Bangladesh

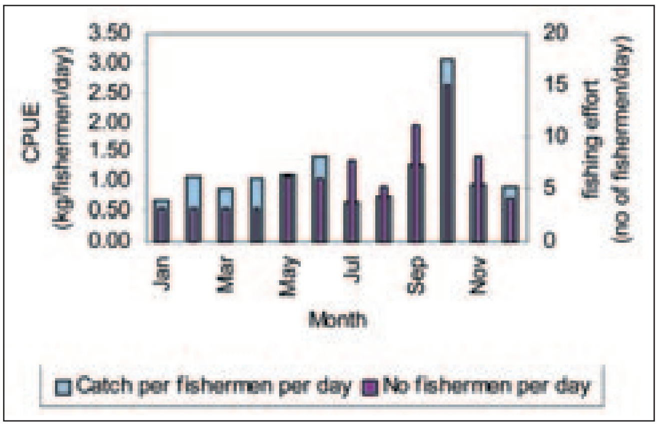


Table 17.4 and Table 17.5 show monthly Catch per Unit of Area (CPUA) for F3 and F2 landtypes, respectively. To calculate the total catch from these landtypes in the project area, you need to know the flooded areas of these landtypes in the project area. When you have these, the total monthly catch in the floodplains of the project area can be calculated by filling in Table 17.6.

TABLE 17.6
Frame for the estimation of the monthly floodplain catch in the CPP project

Month	$CPUA_{F3}$	Area $_{F3}$ flooded	Total Catch $_{F3}$ CPUA $_{F3}$*Area $_{F3}$ flooded	CPUA $_{F2}$	Area $_{F2}$ flooded	Total catch $_{F2}$ $CPUA_{F2}$*Area $_{F2}$ flooded
January	14.99			18.77		
February	24.75			0	0	0
March	21.46			0	0	0
April	13.27			0	0	0
May	23.62			0	0	0
June	25.35			0	0	0
July	9.14			7.89		
August	6.53			30.44		
September	23.73			44.32		
October	116.35			65.18		
November	35.34			34.77		
December	20.04			12.68		

Determination of monthly inundated areas or monthly flood maps

Previously you made a flood map of Pais Pesca through interpolation of measured water levels, calculation of the water level by subtracting the generated grid from the available topographic level and finally you made the flood map by reclassifying the dry and flooded areas. This method was used to make floodmaps of the CPP area.

Next to fisheries data, water levels were measured weekly in a large number of sites throughout the project area. These waterlevels were used in a hydrological model to make a waterlevel map. A reliable topographic map or a Digital Elevation Model (DEM) was subtracted from this water level map to make monthly flood maps. Open the presentation (by double clicking the file in MS Explorer) 'flood maps 92–99.pps' in the 'RW_03_Floodplain' folder on the CD. Let it run and pay attention specifically to the change in water levels during the years (blue is water, yellow is land) to get an idea of the extend and the seasonality of flooding in the CPP project area.

Land in the CPP area was classified according to the MPO classifications (see Table 16.3 for the criteria) With the flood maps and the landtype map you can calculate the monthly flooded area per landtype by querying (Figure 17.30) the two with the criteria:

- Give all areas with water in the flood map grid and which are F3 in the Landtype grid; and
- Give all areas with water in the flood map grid and which are F2 in the Landtype grid.

All steps for the analysis to arrive at the monthly flooded areas of the different habitats are summarized in Figure 17.31.

FIGURE 17.30
The principle of querying the floodmap with the landtype map

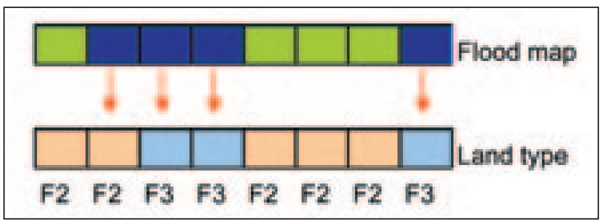
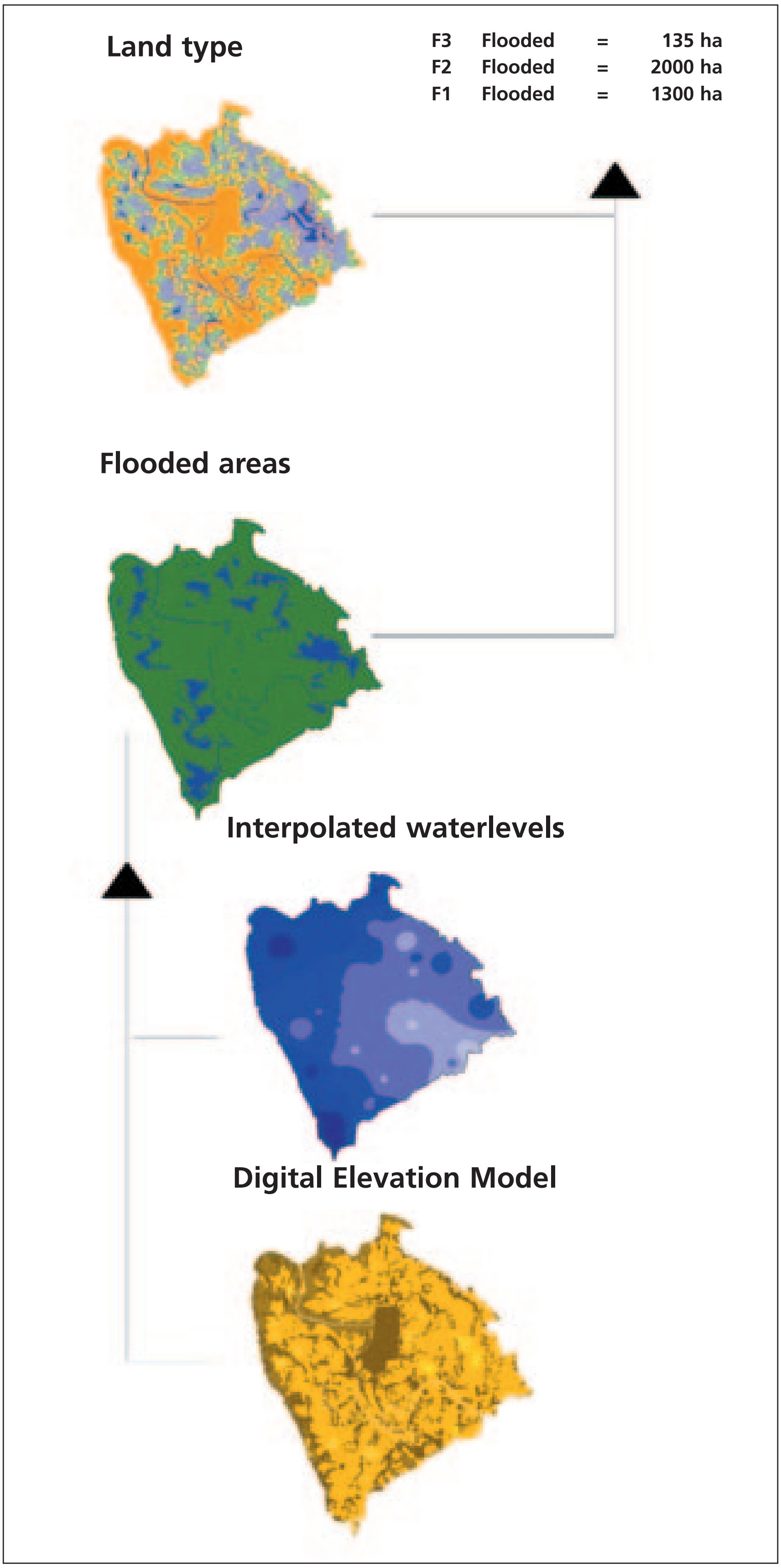


FIGURE 17.31
Pathway of determination of monthly flooded area per habitat in the CPP project area



Estimation of floodplain fish catch in the CPP project area

The objective of this exercise is to estimate the annual catch in the floodplains of the CPP project area. For this you will calculate with GIS the missing data in Table 17.6 on page 114.

Making floodmaps

This exercise is similar to the exercise starting on page 70. You will have to make floodmaps of the CPP area showing dry and flooded land.

1. Start ArcView, New project, New View. Add from the folder rw_03_floodplain from CD2 the Feature Data Source Themes 'Bangladesh.shp', 'CPP_outline.shp', 'Waterlevels.shp', and the Grid Data Source Theme 'Topography' to the View. Make sure to load the legend of 'Topography'.
2. Set the working directory to a directory of your choice (for instance D:\Bangladesh\temp\). Do not set the projection, but set the map units and distance units to meters.
3. Make a mask for the analysis from the 'CPP_outline.shp' Theme by converting it into a grid (menu bar: **Theme/Convert to Grid...**) (Output Grid Extent: Same As Display, Cell size: 10 metres).
4. Set the 'CPP_outline' grid Theme as a mask (menu bar: **Analysis/Properties...**)

Now you are ready to do a complete analysis, but for this exercise you will only do the month of January.

5. Interpolate the waterlevels for the month January (**Surface/Interpolate Grid...**, Output Grid Extent: Same as Display, Cell Size: 10 metres, Method: IDW, Z Value field: January). You can get the same legend as in Figure 17.32 by loading the legend: **Theme/Edit Legend,** press **Load**, locate the file 'waterlevels.avl' in the RW_03_floodplain directory.

FIGURE 17.32
Interpolated waterlevels for January in the CPP project

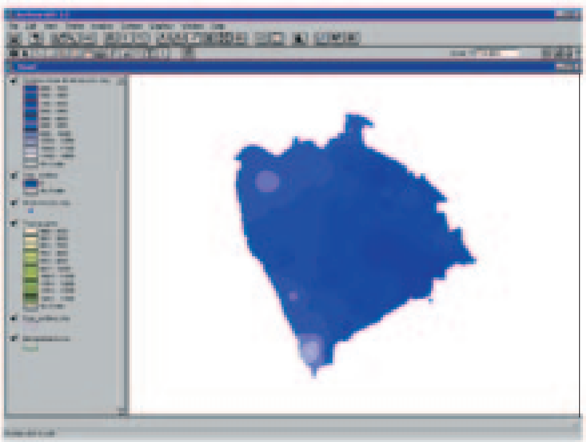
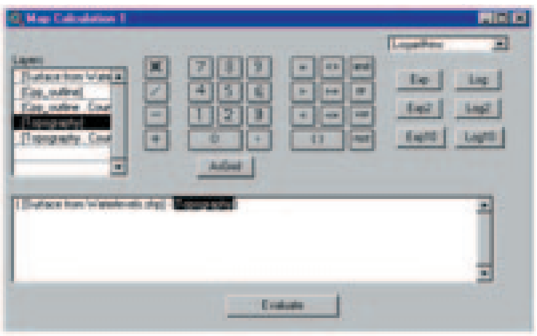


FIGURE 17.33
Calculating the waterdepth

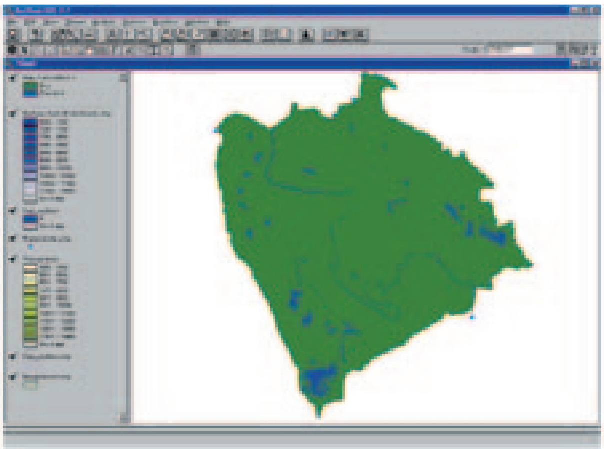


6. Calculate the water depth using the map calculator, calculating Water depth = Surface from Waterlevel.shp - Topography (Figure 17.33).

Make a flood map of the project area in January, showing dry and flooded land (negative values are dry land, positive values are flooded) by reclassifying the calculated grid, either via reclassifying the analysis (menu bar: **Analysis/Reclassify...**), or via the legend editor (**Theme/Edit Legend...**).

If you did everything correct you have made the grids as presented in Figure 17.34.

FIGURE 17.34
Calculated water depth for January in the CPP project area

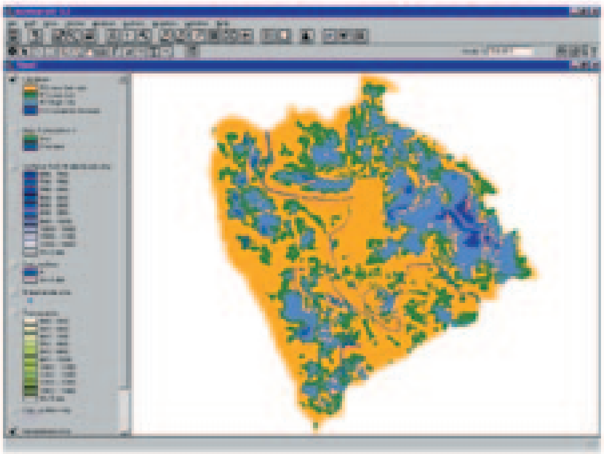


Monthly flooded area calculation

You need to calculate the monthly flooded areas of the different landtypes (F2 and F3) in the project area. This can be done by querying the flood maps with the landtype map.

7. Add the Theme 'Landtype' (from the folder 'RW_03_floodplain' on the CD) to the View. Load via the Legend editor (menu bar: **Theme/Edit Legend...**) the Legend 'Landtype.avl' from the RW_03_floodplain folder on the CD (Figure 17.35).

FIGURE 17.35
Landtypes in the CPP project area



This landtype Theme you have to query with the monthly flood maps. You just made the flood map for the month January. the floodmaps for the other months are already made and are called 'DWJAN' for January, 'DWFEB' for February, 'DWMAR' for March, 'DWAPR' for April, etc.

8. Add the flood map for January ('DWJAN') to the View.

9. Query the 'Landtype' with the flood map of January ('DWJAN') for F3 Landtype (via **Analysis/Map Query...**, Figure 17.36). Open the Theme Table of 'Map Query 1' and you will see that there are 25 286 pixels fitting the criteria 'F3 landtype' and 'flooded' (Figure 17.37).

FIGURE 17.36
Querying the Floodmap of January and the Landtype Theme

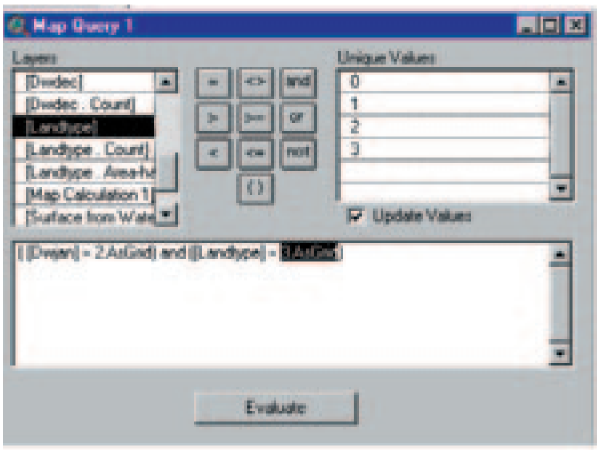
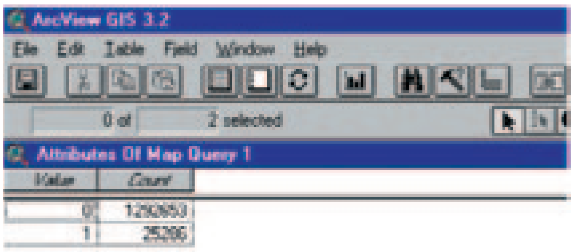


FIGURE 17.37
Number of pixels representing flooded F3 Land



How many hectares of F3 are flooded with a grid size of 10 metres?[34]

10. Save the query Theme as 'F3jan' (menu bar: **Theme/Save Data Set...**).
11. Query the 'Landtype' with the 'flood map of January' for F2 Landtype. Open the Theme Table of this query and you will see that there are 17243 pixels fitting the criteria 'F2 landtype' and 'flooded'. How many hectares F2 are flooded? Save the query as 'F2jan'.
12. Add the flood map for February ('DWFEB') to the View. Query the 'Landtype' with the 'flood map of February' for F3 Landtype. Open the Theme Table of this query and you will see that there are 22958 pixels fitting the criteria 'F3 landtype' and 'flooded'. How many hectares of F3 are flooded with a grid size of 10 metres? Save the query as 'F3feb'.
13. Query the 'Landtype' with the 'flood map of February' for F2 Landtype. Open the Theme Table of this query and you will see that there are 12 115 pixels fitting the criteria 'F2 landtype' and 'flooded'. How many hectares F2 are flooded? Save the query as 'F2feb'.
14. Continue the exercise for all months and fill in Table 17.6.

Tabulate Areas

Querying this way can be done quicker with Tabulate Areas which is in principle a cross-table query:

1. Make sure you have all flood maps added to the View (DWJAN, DWFEB, DWMAR, etc.). Go via the menu bar to: **Analysis/Tabulate Areas...**. The Tabulate Areas window will pop-up (Figure 17.38).
2. Select as Row Theme 'landtype' and as Column Theme the floodmap of the month you want to analyse, starting with January (Dwjan). Click **OK**.

[34] 252 ha, 1 pixel is 10 x 10= 100 m^2, 1 hectare is 10 000 m^2, or I pixel = 0.01 ha.

3. The calculated Table will pop-up (this table is saved automatically in the Tables part of the project). The areas are calculated in m^2 as the property settings of the view were in meters, so dividing by 10 000 will give you the hectares.

FIGURE 17.38
The Tabulate Areas window

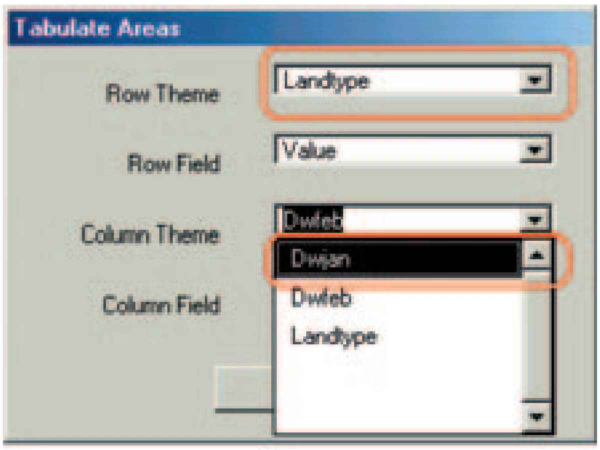
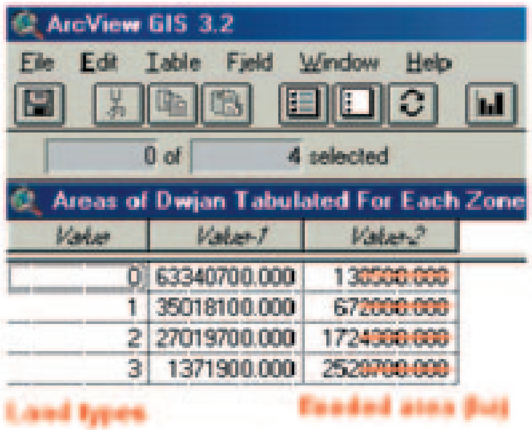


FIGURE 17.39
Calculated area in hectares



If you carried out the exercise properly you will find the areas as presented in Table 17.7. Using these data and the data in Table 17.6, the result will be an estimated catch of 111 metric tonnes/year for landtype F3 and 349 metric tonns/year for landtype F2.

TABLE 17.7
Estimated monthly flooded area for F3 and F2 landtypes in the CPP project area

Month	F3 (ha)	F2 (ha)
January	252	172
February	229	121
March	227	99
April	236	123
May	324	254
June	360	658
July	375	2 576
August	378	2 793
September	379	2 828
October	370	1 410
November	358	563
December	302	259