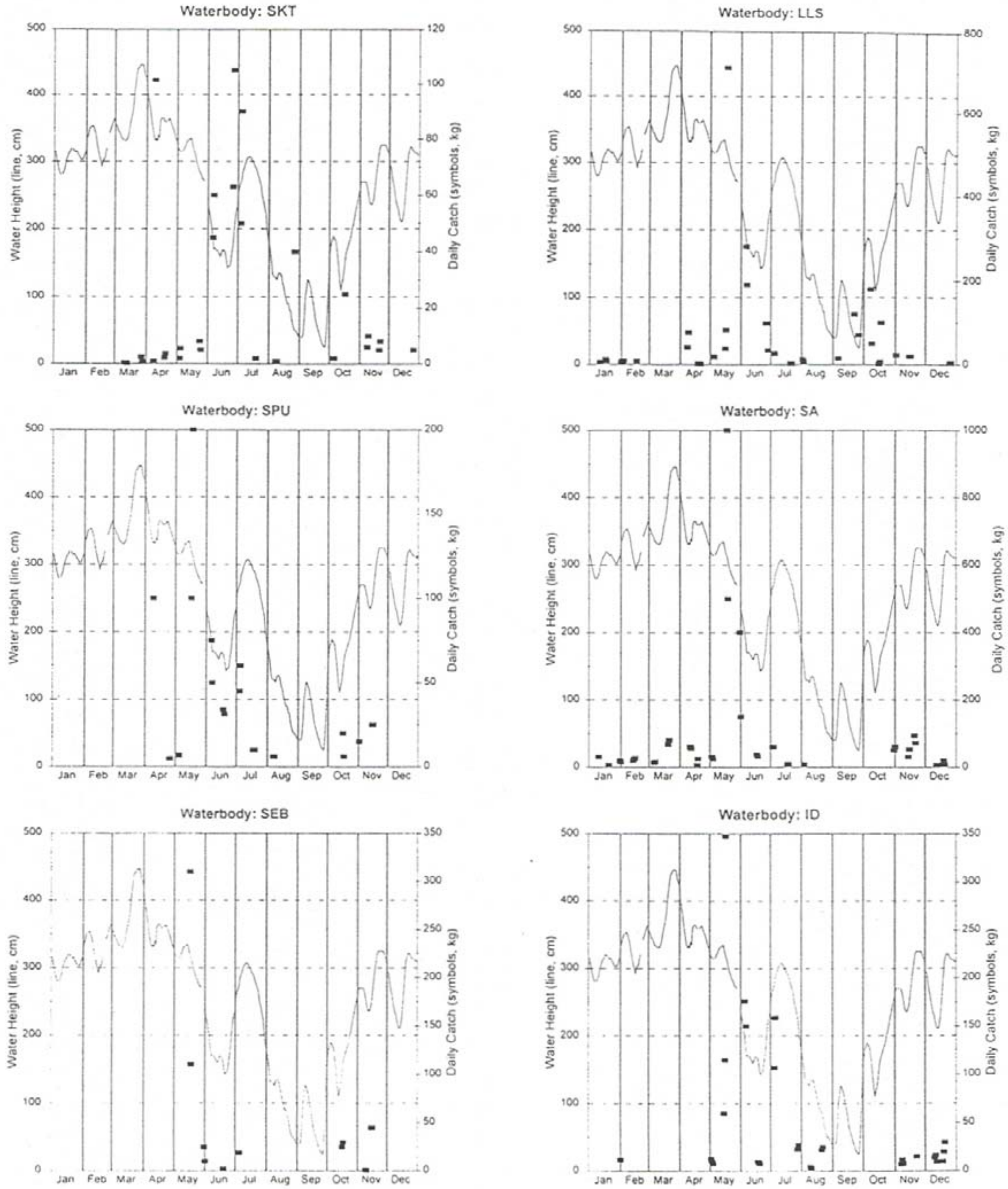

Figure 5.47 Daily fish catches of *tuguk* and *corong* riverine barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region (left graphs) and the downstream Savanna river region (right graphs) in 1995. Water height shown in Lubuk Lampam guage.

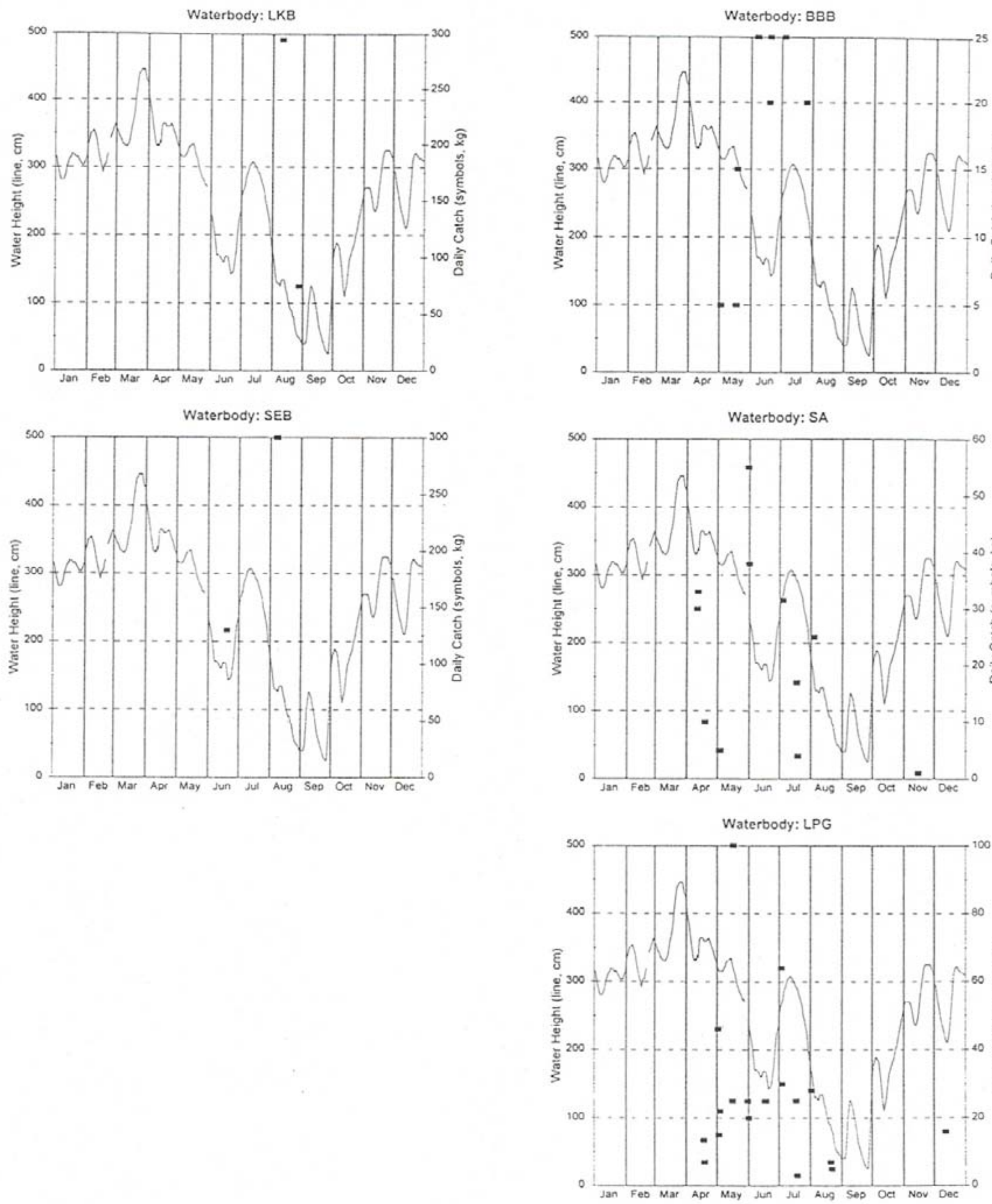

Figure 5.48 Daily fish catches of *kilung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region (left graphs) and the downstream Savanna river region (right graphs) in 1995. Water height shown in Lubuk Lampam guage.

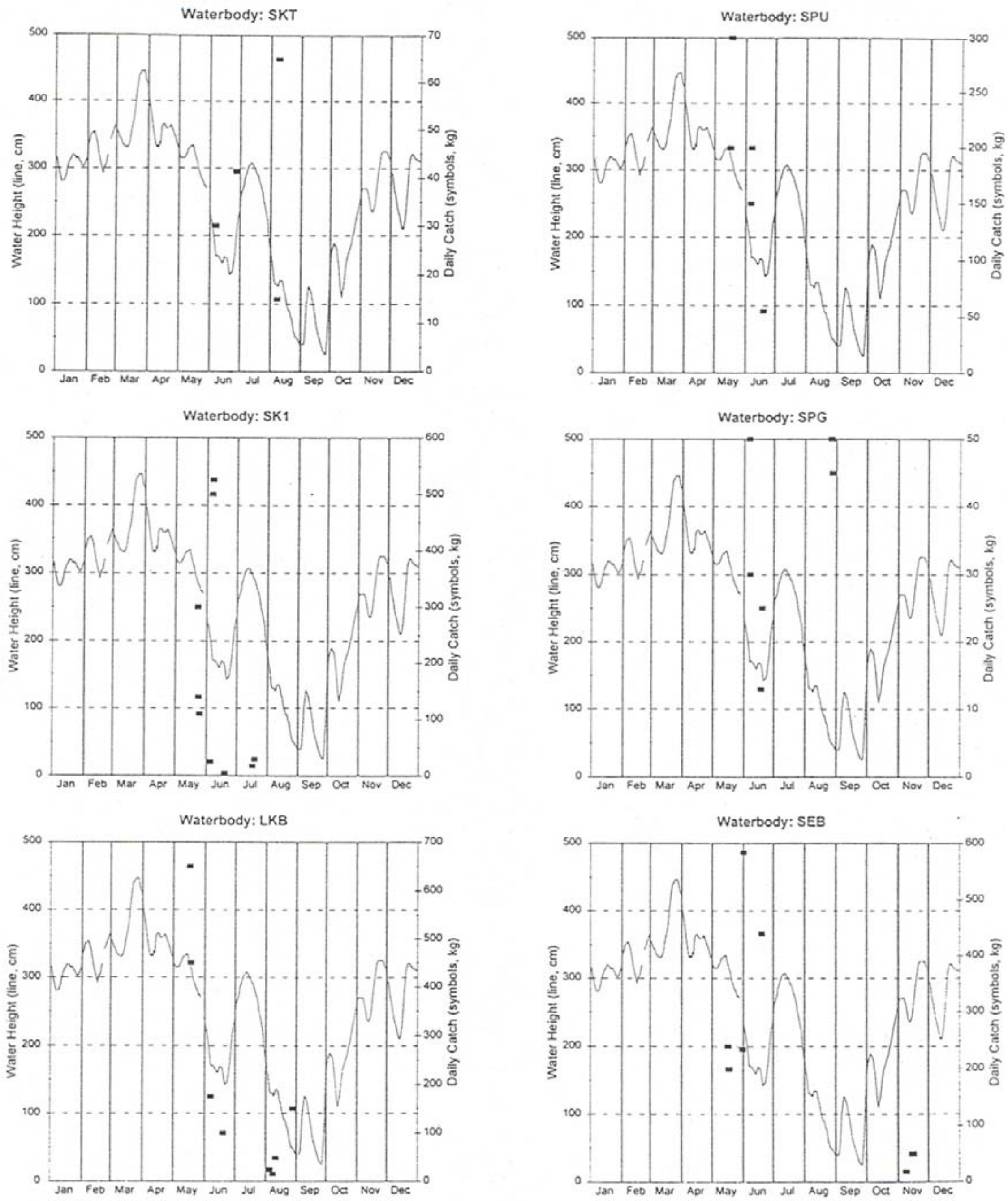

Figure 5.49 Daily fish catches of *empang lalung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region in 1995. Water height shown in Lubuk Lampam guage.

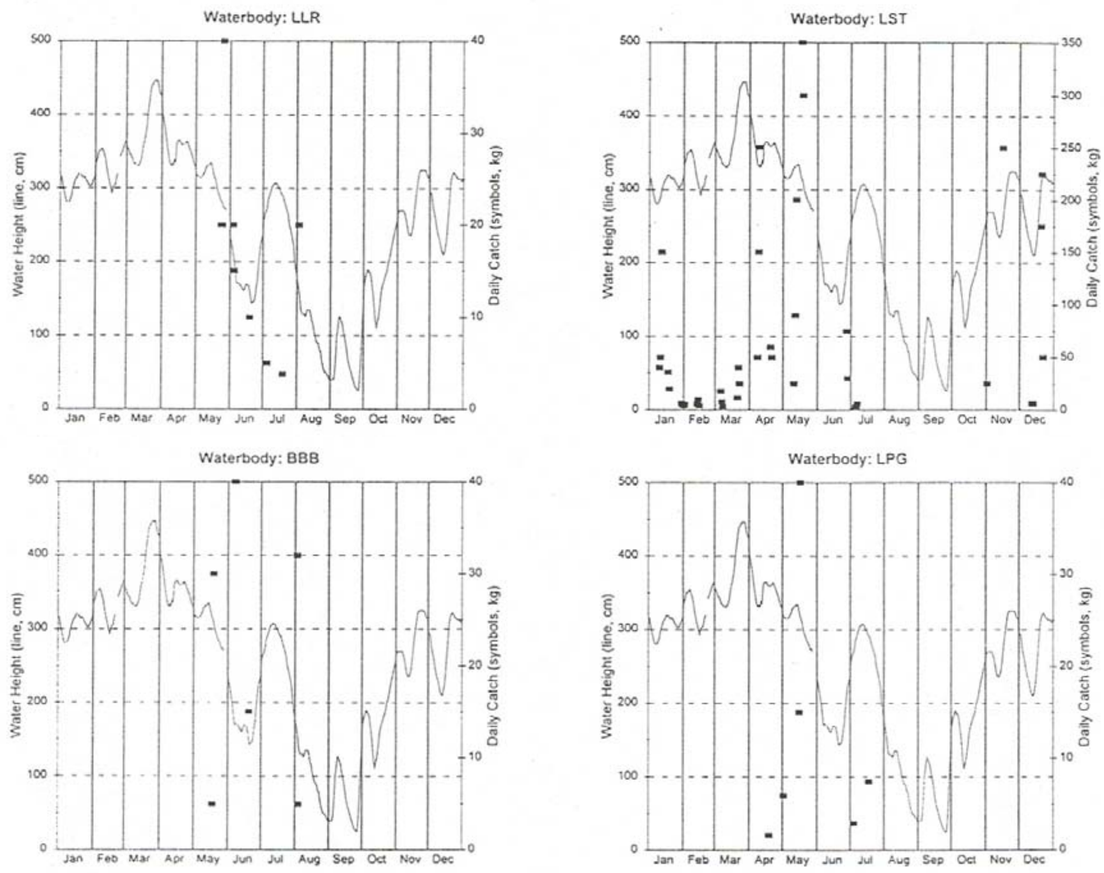

Figure 5.50 Daily fish catches of *empang lalung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the Lake region (LST waterbody) and the Savanna river region (other graphs) in 1995. Water height shown in Lubuk Lampam guage.

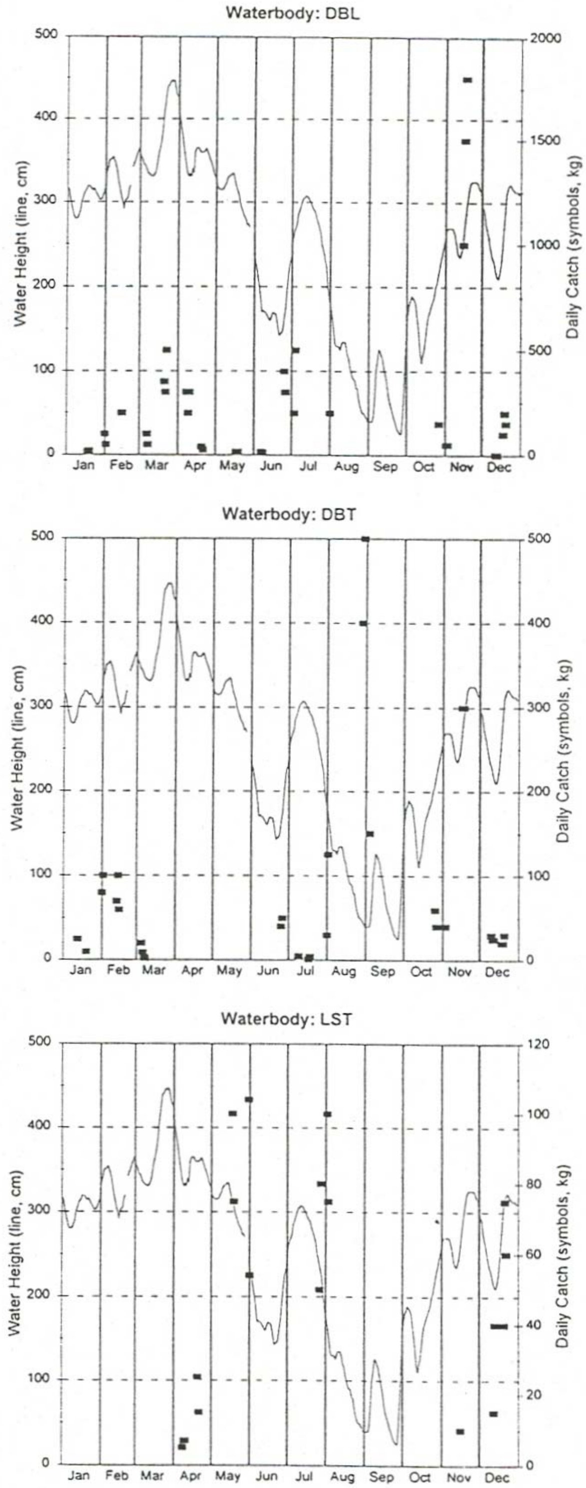

Figure 5.51 Daily fish catches of *kilung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the Lake region in 1995. Water height shown in Lubuk Lampam guage.

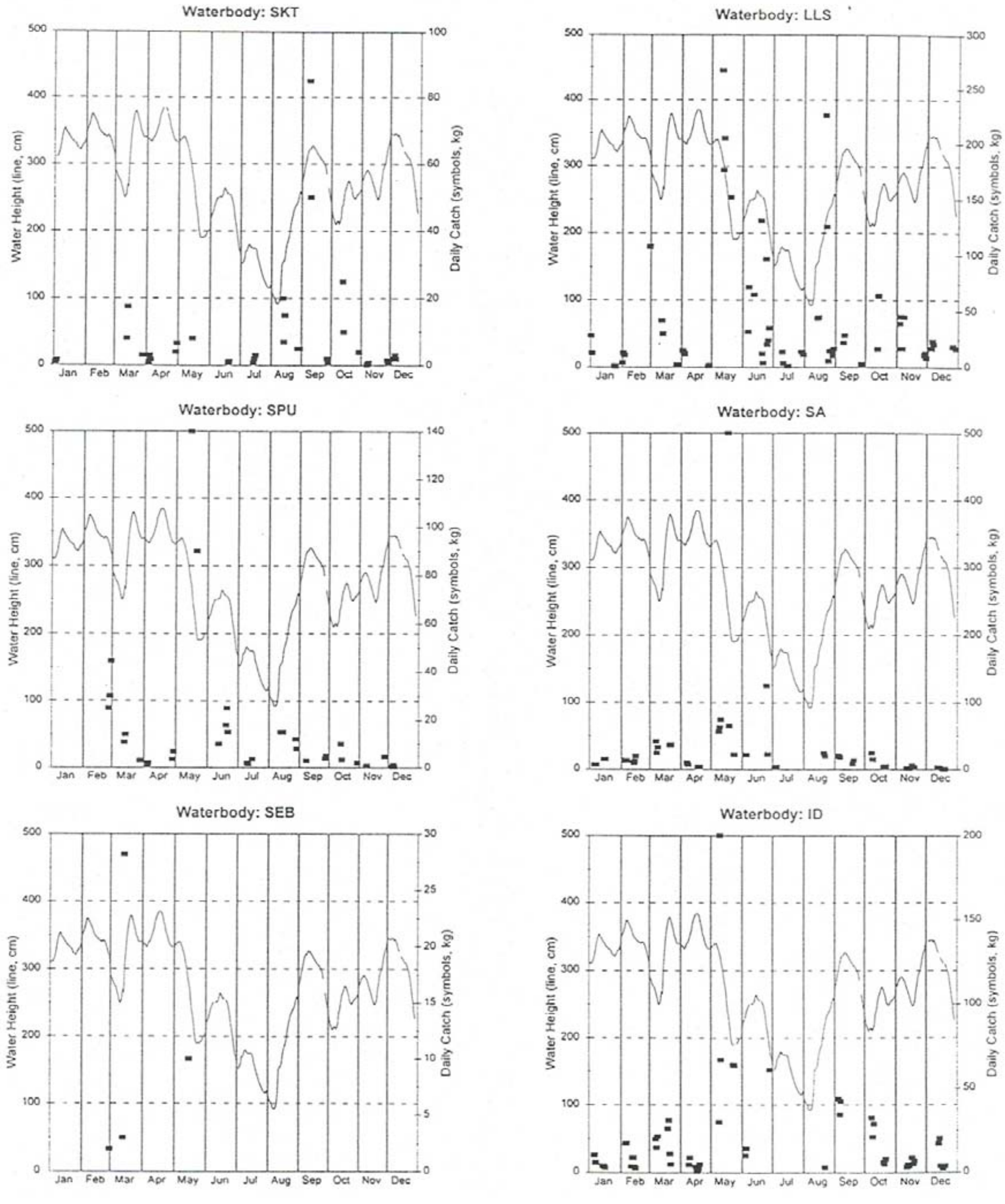

Figure 5.52 Daily fish catches of *tuguk* and *corong* riverine barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region (left graphs) and the downstream Savanna river region (right graphs) in 1996. Water height shown in Lubuk Lampam guage.

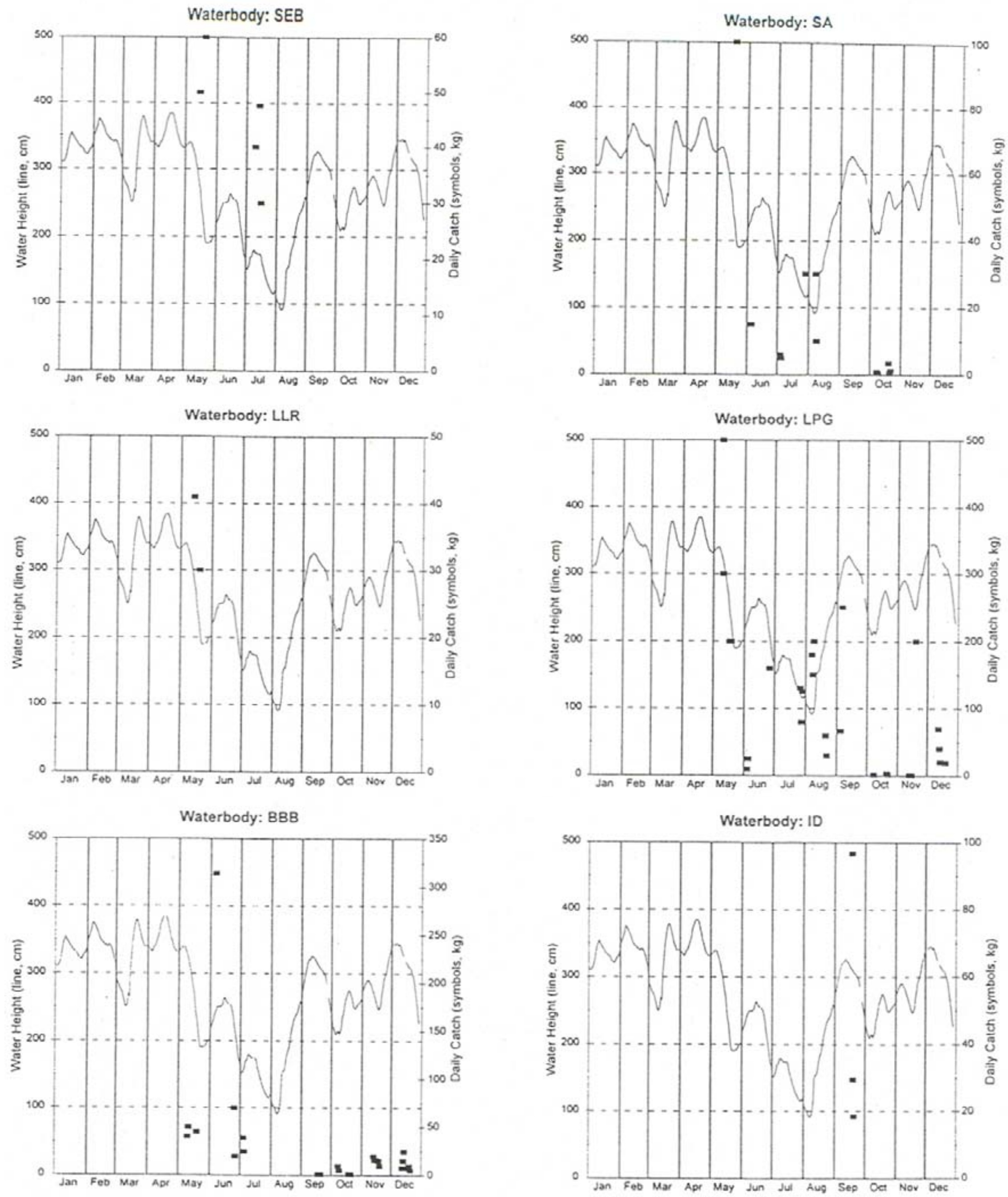

Figure 5.53 Daily fish catches of *kilung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region (SEB waterbody) and the downstream Savanna river region (other graphs) in 1996. Water height shown in Lubuk Lampam guage.

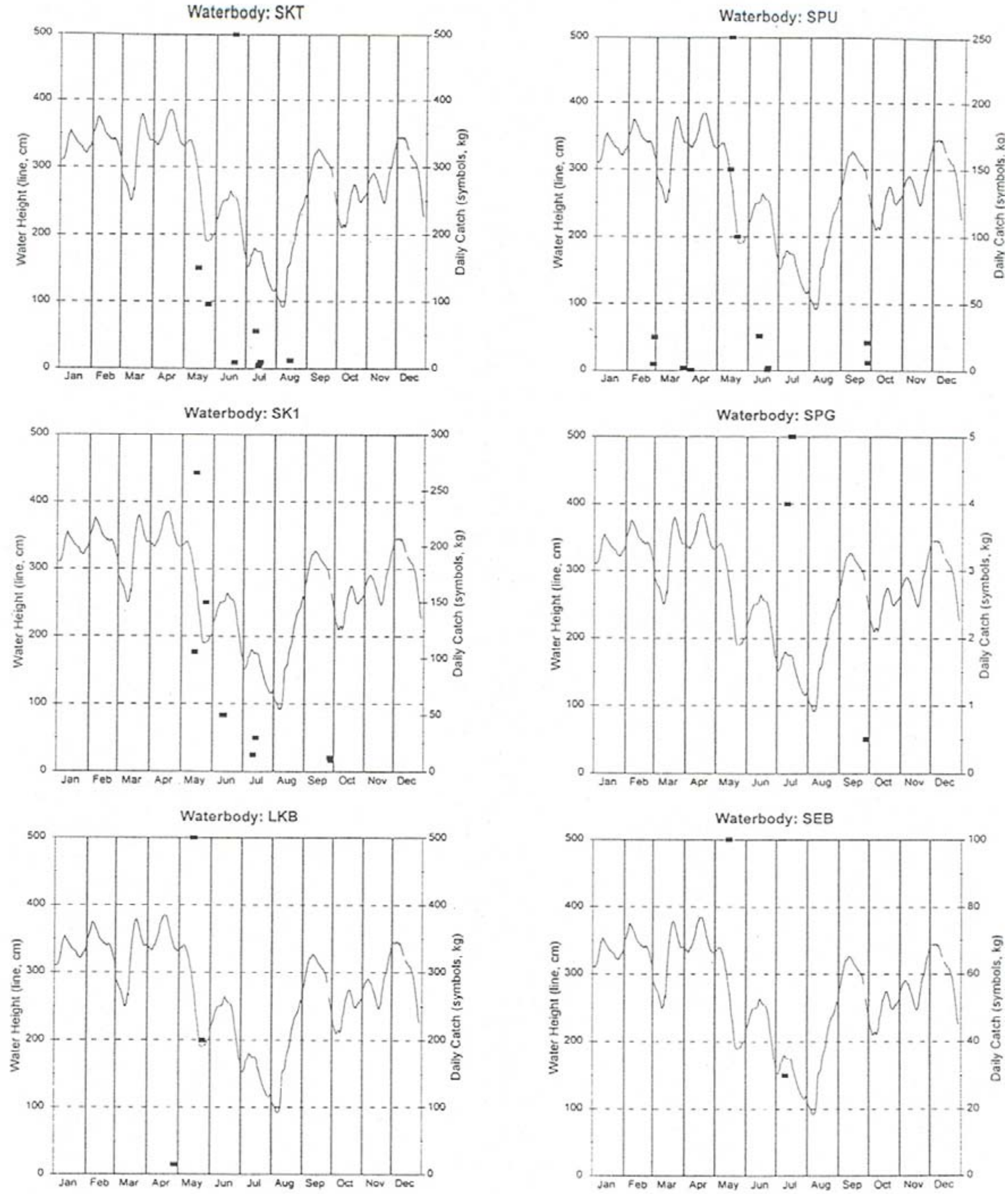

Figure 5.54 Daily fish catches of *empang lalung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the upstream Forest river region in 1996. Water height shown in Lubuk Lampam guage.

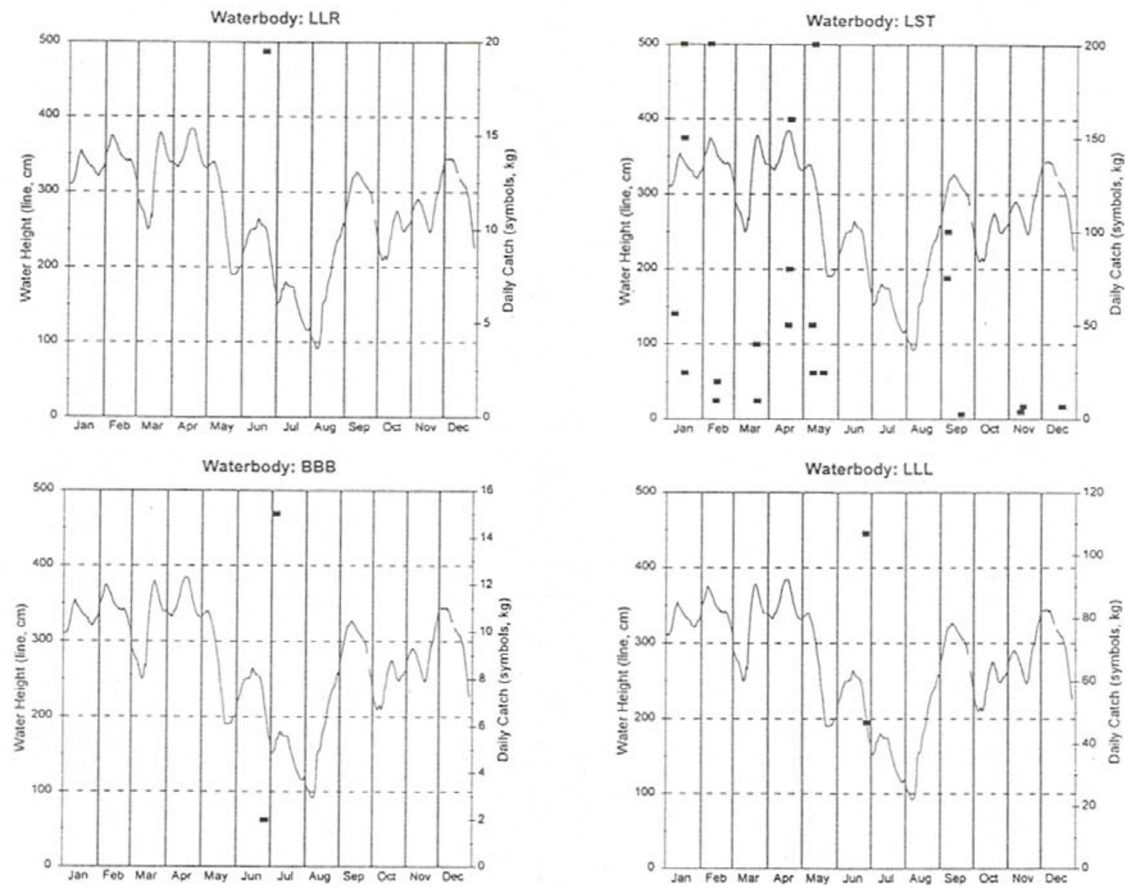

Figure 5.55 Daily fish catches of *empang lalung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the Lake region (LST waterbody) and the Savanna river region (other graphs) in 1996. Water height shown in Lubuk Lampam guage.

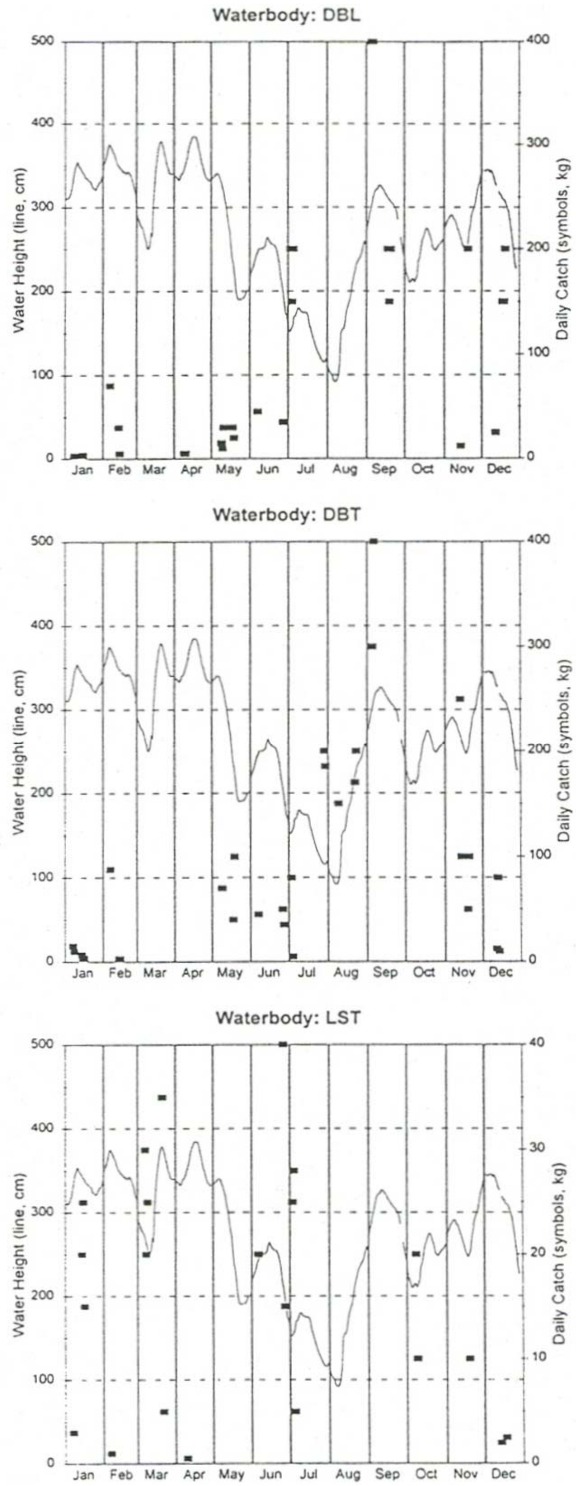

Figure 5.56 Daily fish catches of *kilung* floodplain barrier gears of respondent fishing groups (see Figure 3.5 for waterbody locations) in the Lake region in 1996. Water height shown in Lubuk Lampam guage.

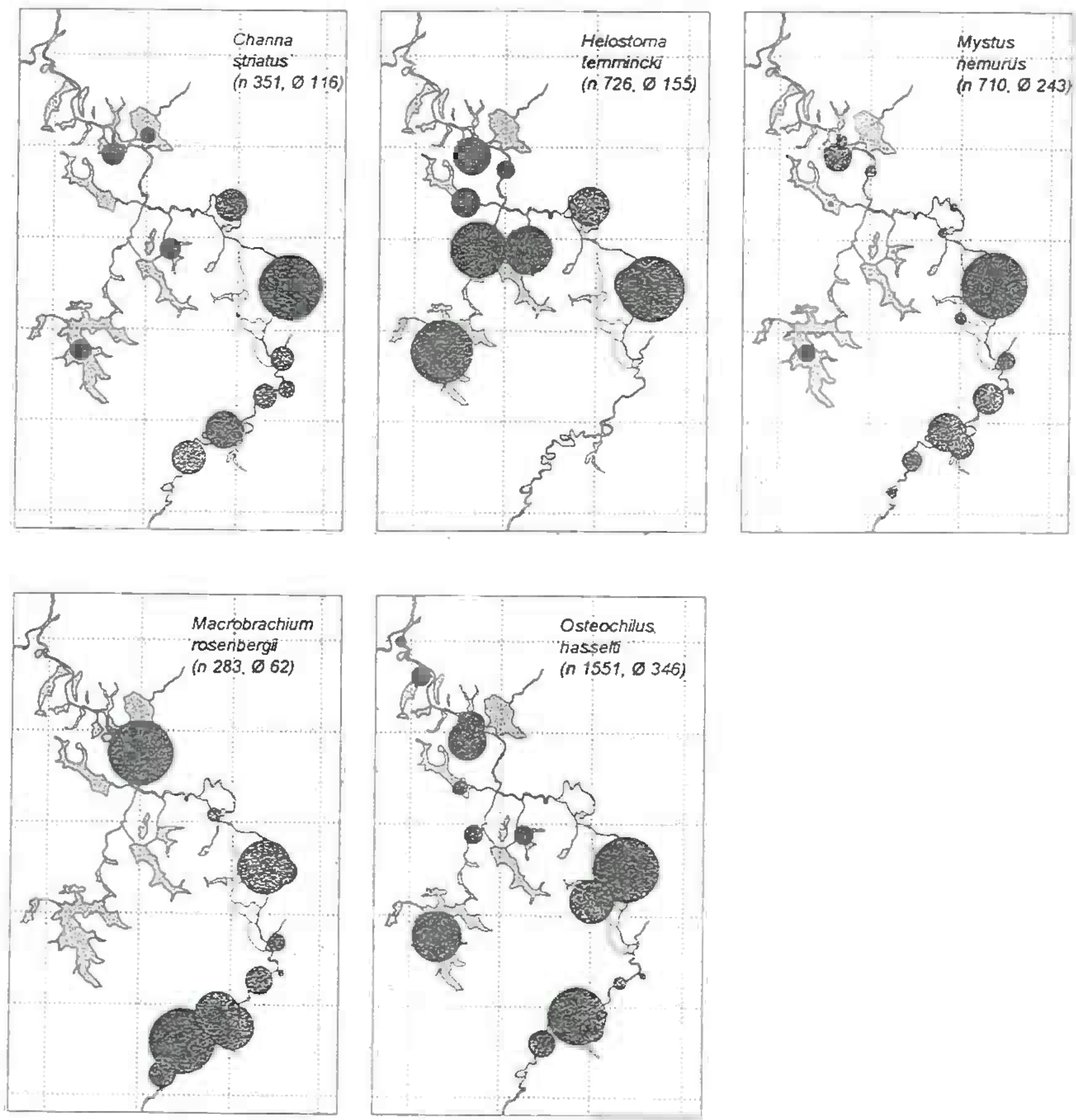

Figure 5.57 Total numbers of fish (*n*) tagged and released at the Indonesian River Lempuing study site, by species and location (ø indicates the number of fish represented by the largest diameter circle).

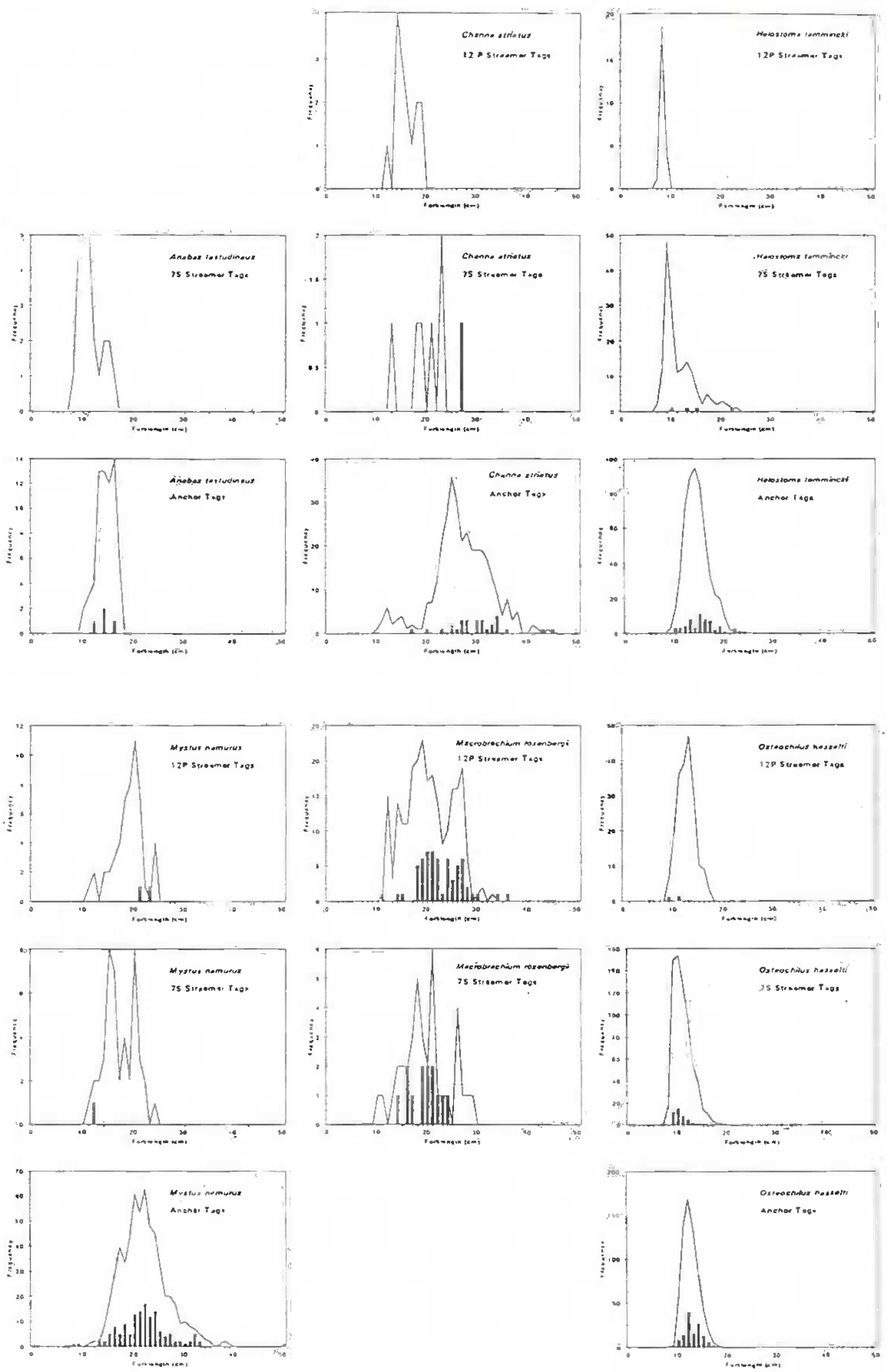

Figure 5.58 Overall fork length frequencies of fish tagged (lines) and recaptured (bars) at the Indonesian River Lempuing study site, by species and tag type.

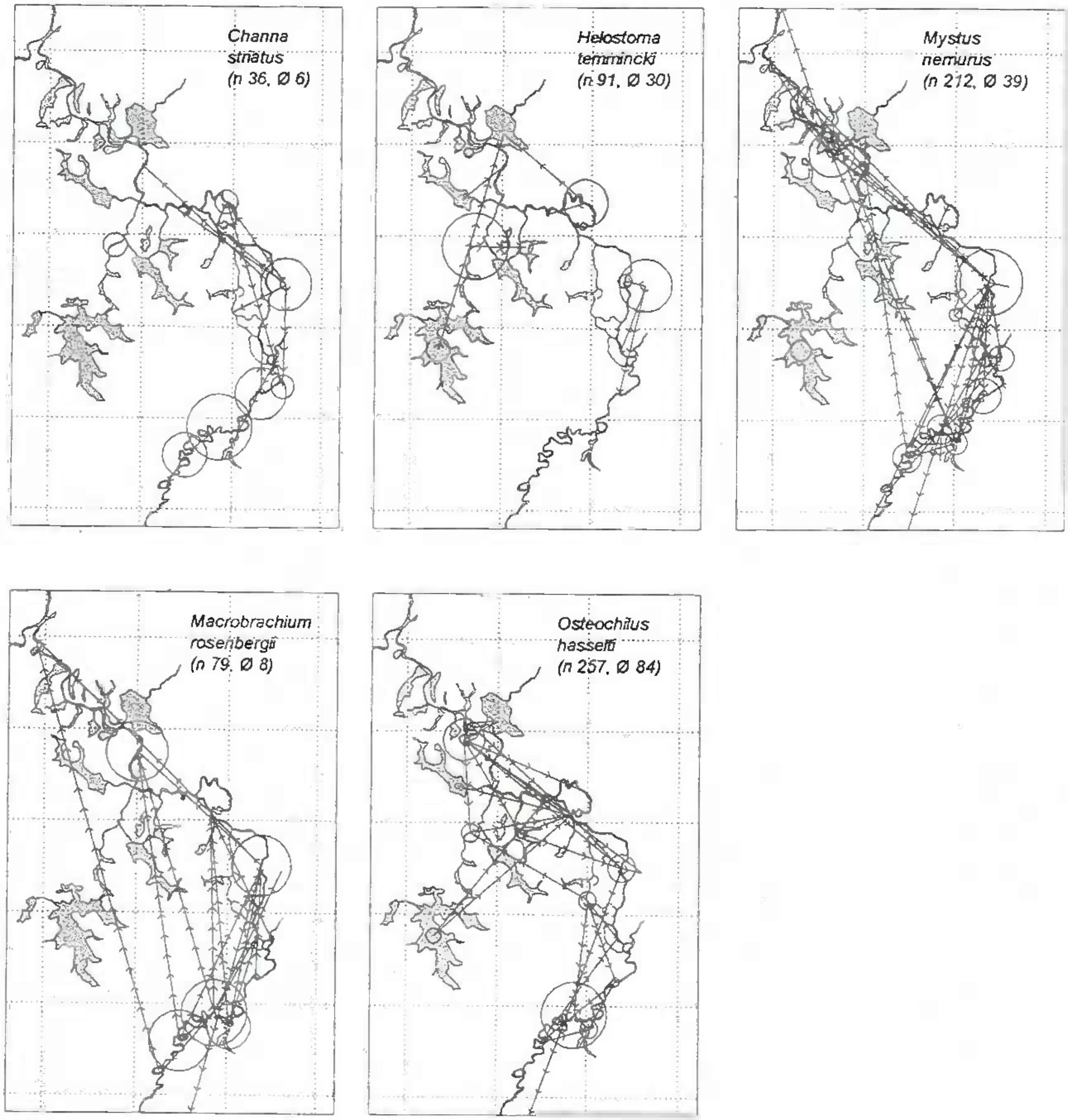

Figure 5.59 Total numbers (*n*) of each species of tagged fish recaptured at the Indonesian River Lempuing study site, at the same location (circles, with ø indicating the number of fish represented by the largest diameter circle), or at a new location (lines, with arrows indicating the direction of movement).

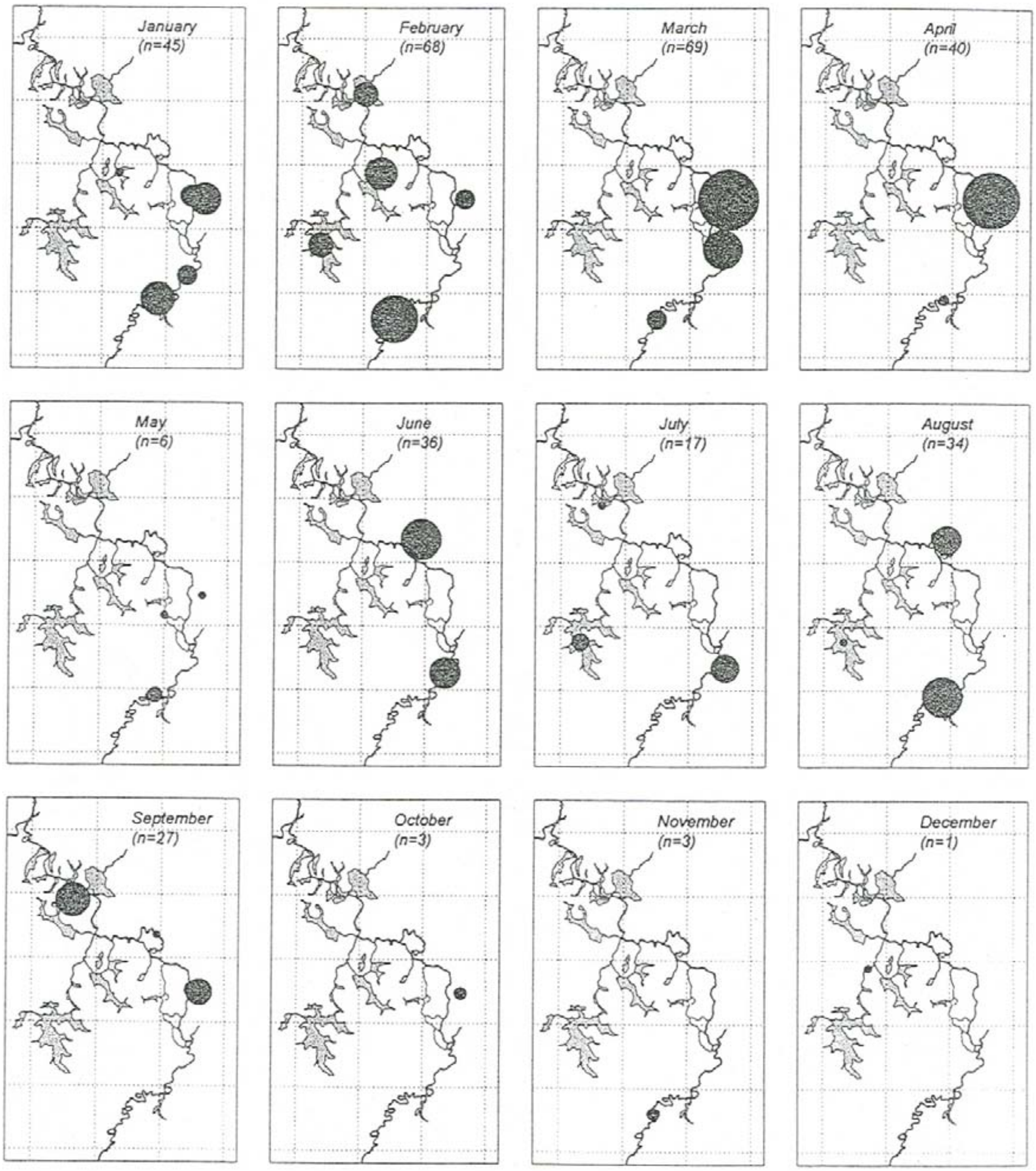

Figure 5.60 Numbers of *Channa striatus* (*n*) tagged and released at the Indonesian River Lempuing study site, by location and month (1995 and '96 combined). The largest diameter circle represents 43 fish.

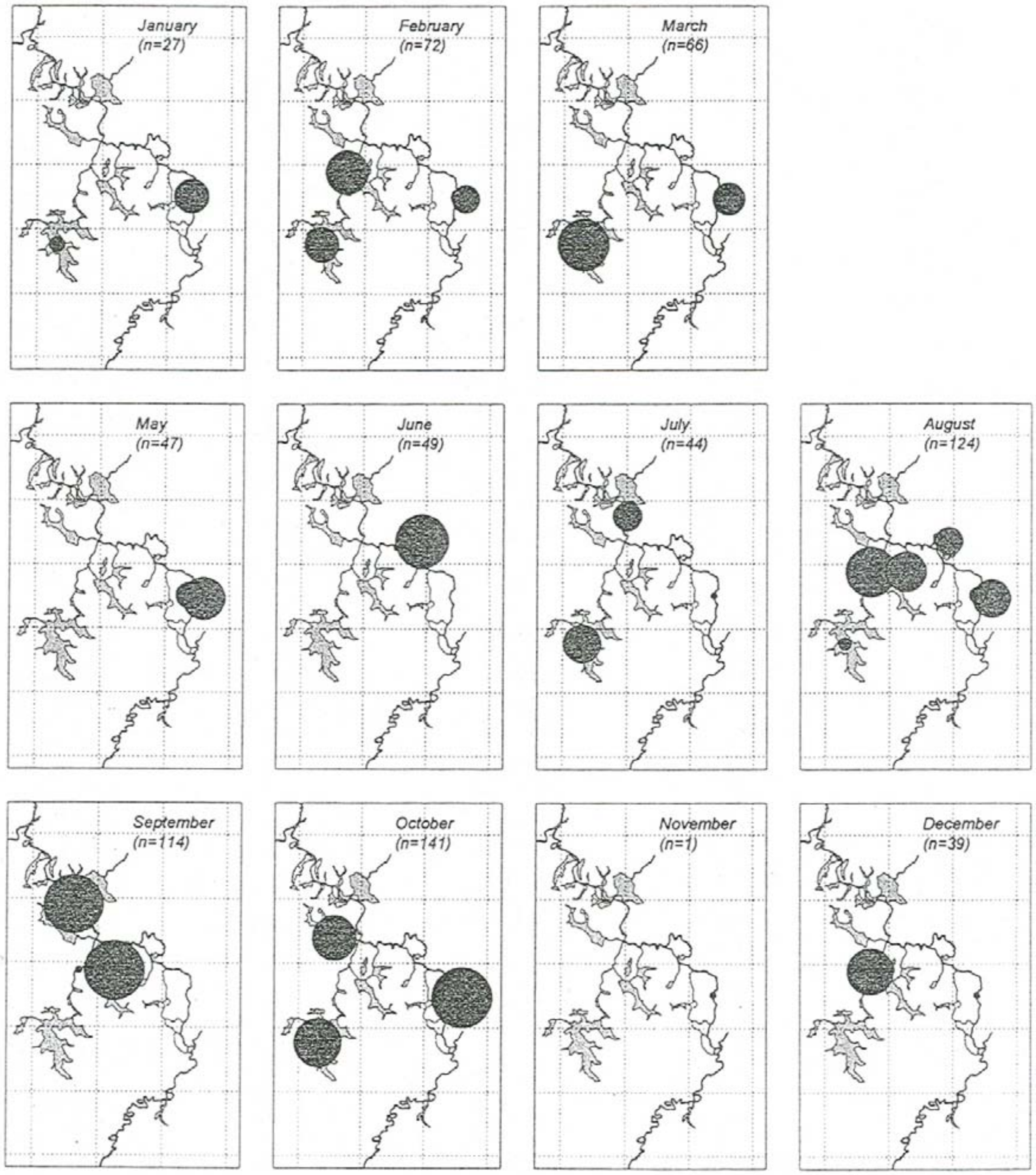

Figure 5.61 Numbers of *Helostoma temmincki* (*n*) tagged and released at the Indonesian River Lempuing study site, by location and month (1995 and '96 combined). The largest diameter circle represents 60 fish.

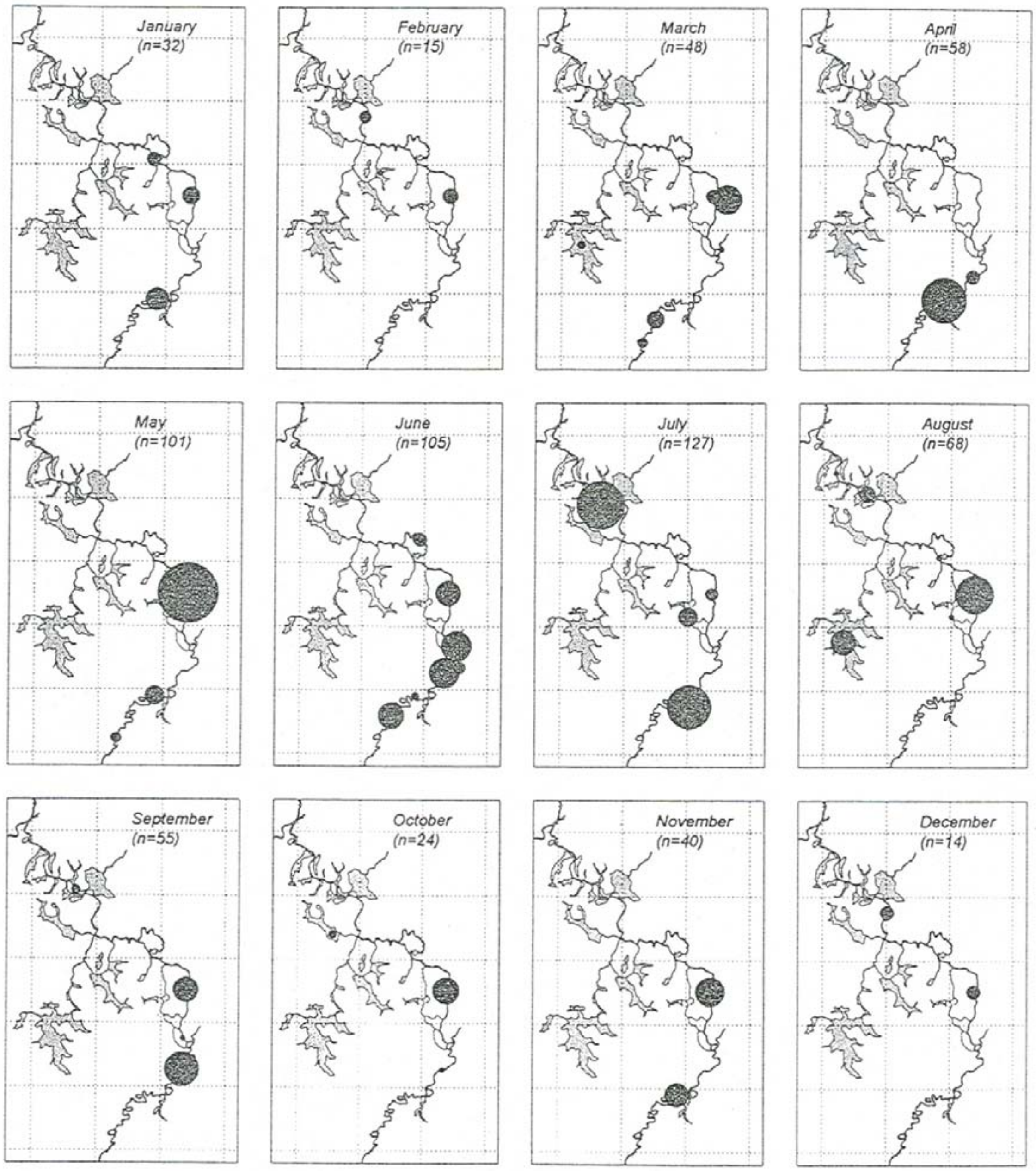

Figure 5.62 Numbers of *Mystus nemurus* (*n*) tagged and released at the Indonesian River Lempuing study site, by location and month (1995 and '96 combined). The largest diameter circle represents 86 fish.

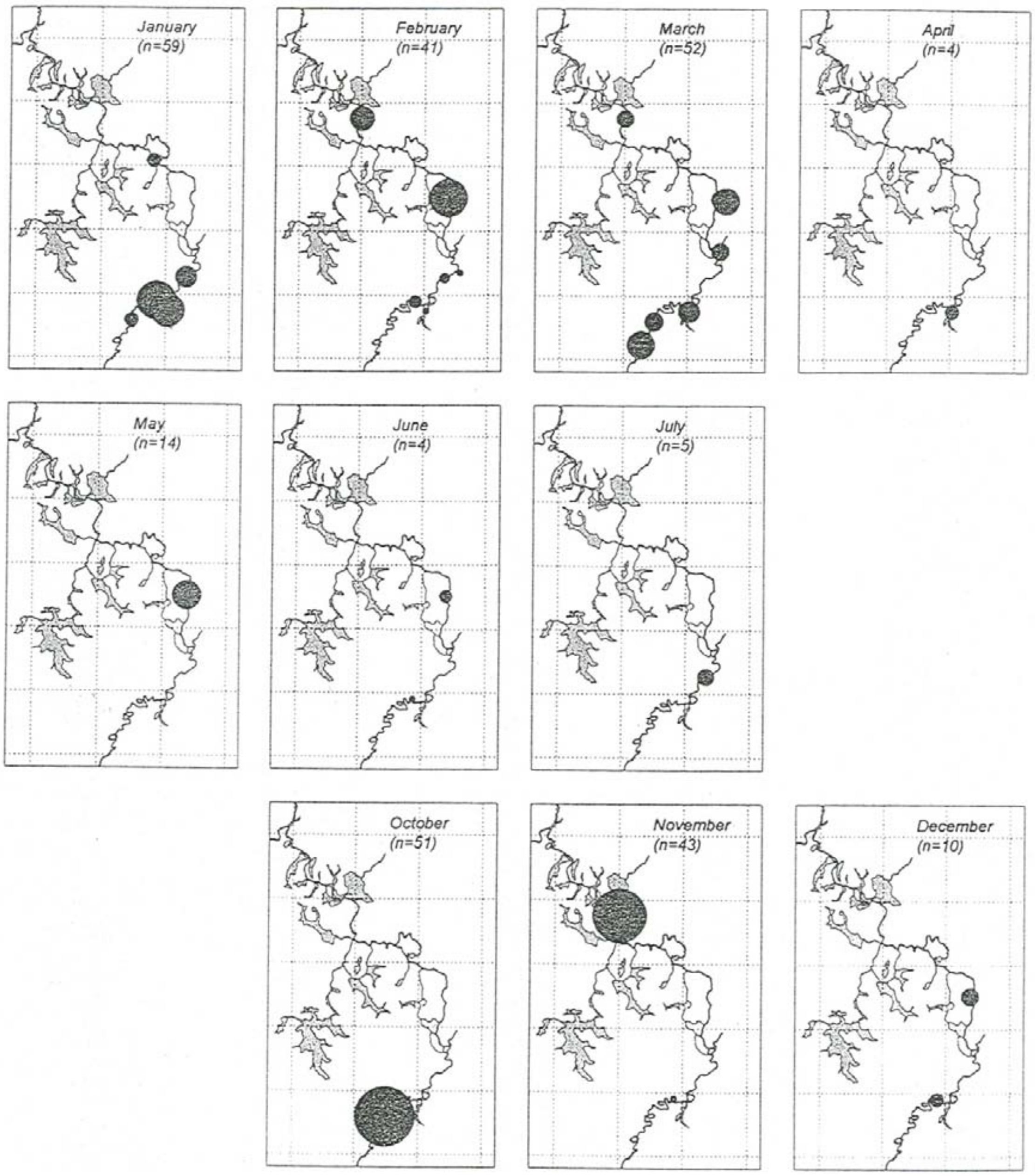

Figure 5.63 Numbers of *Macrobrachium rosenbergii* (*n*) tagged and released at the Indonesian River Lempuing study site, by location and month (1995 and '96 combined). The largest diameter circle represents 51 fish.

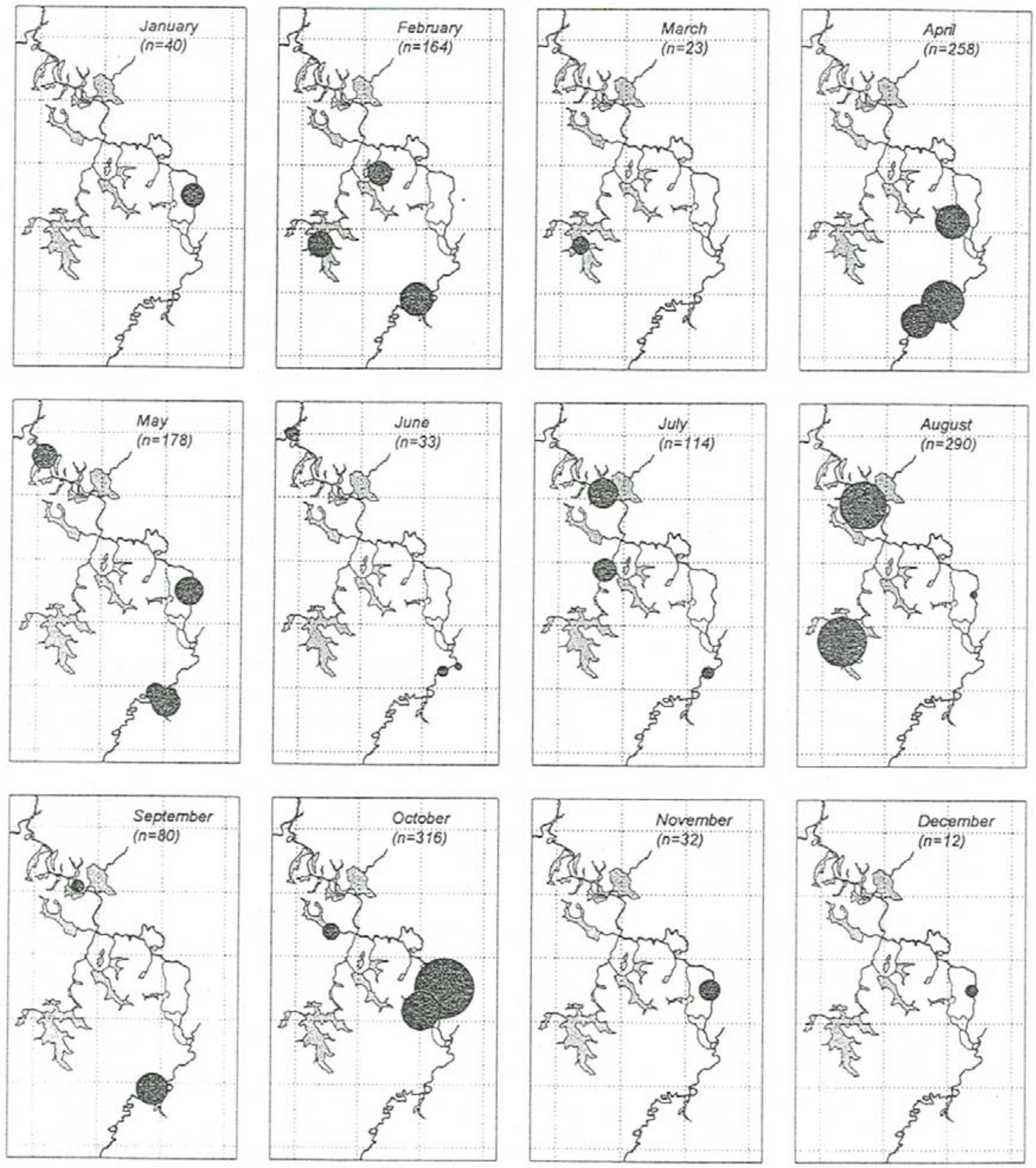

Figure 5.64 Numbers of *Osteochilus hasselti* (*n*) tagged and released at the Indonesian River Lempuing study site, by location and month (1995 and '96 combined). The largest diameter circle represents 201 fish.

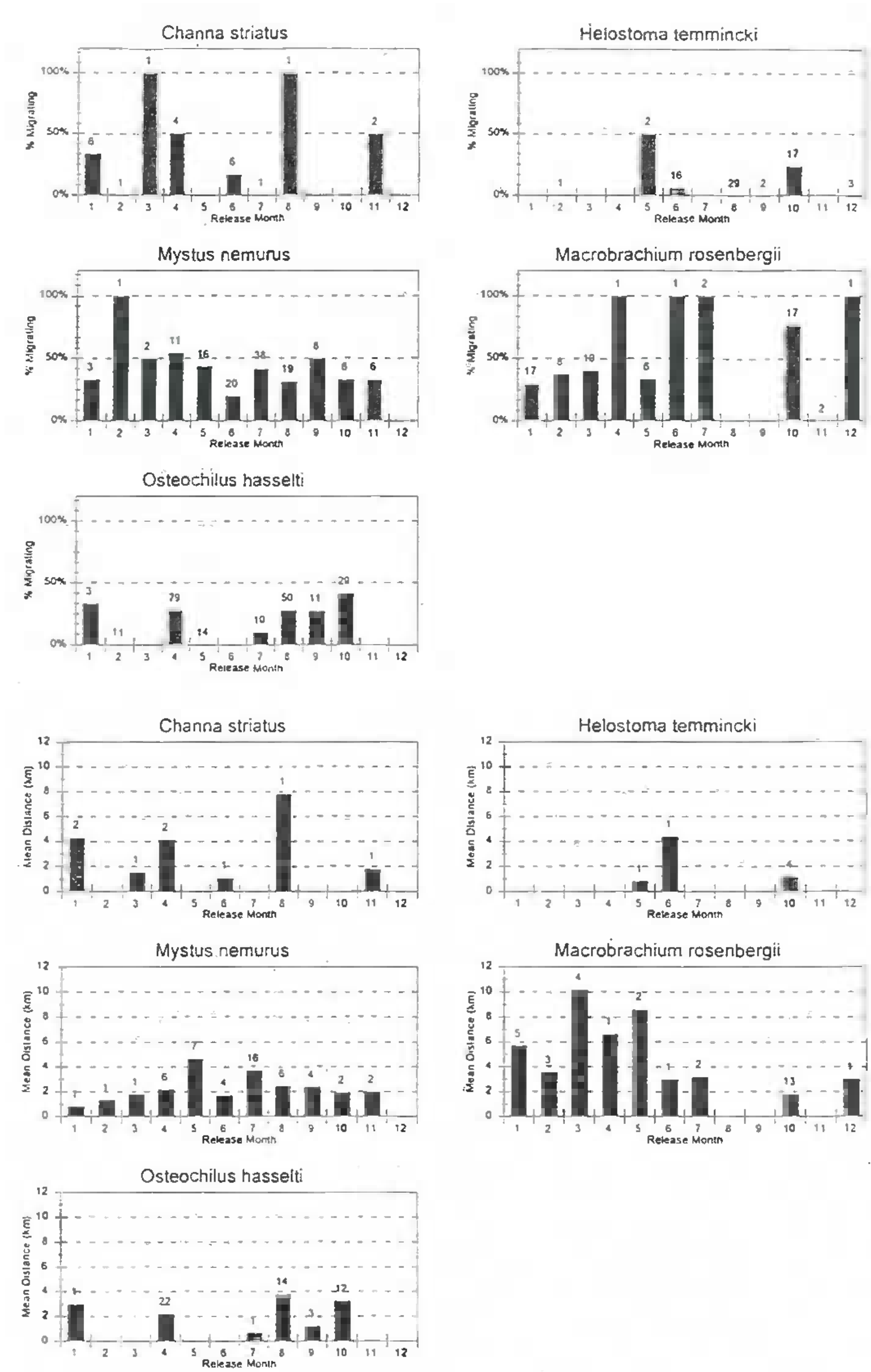

Figure 5.65 Monthly percentages of those tagged fish recaptured within one calendar month of release which had migrated from their release locations (upper series), and the mean distances migrated (km) of the fish which had moved (lower series) at the Indonesian River Lempuing study site. Numbers over bars indicate the sample sizes.

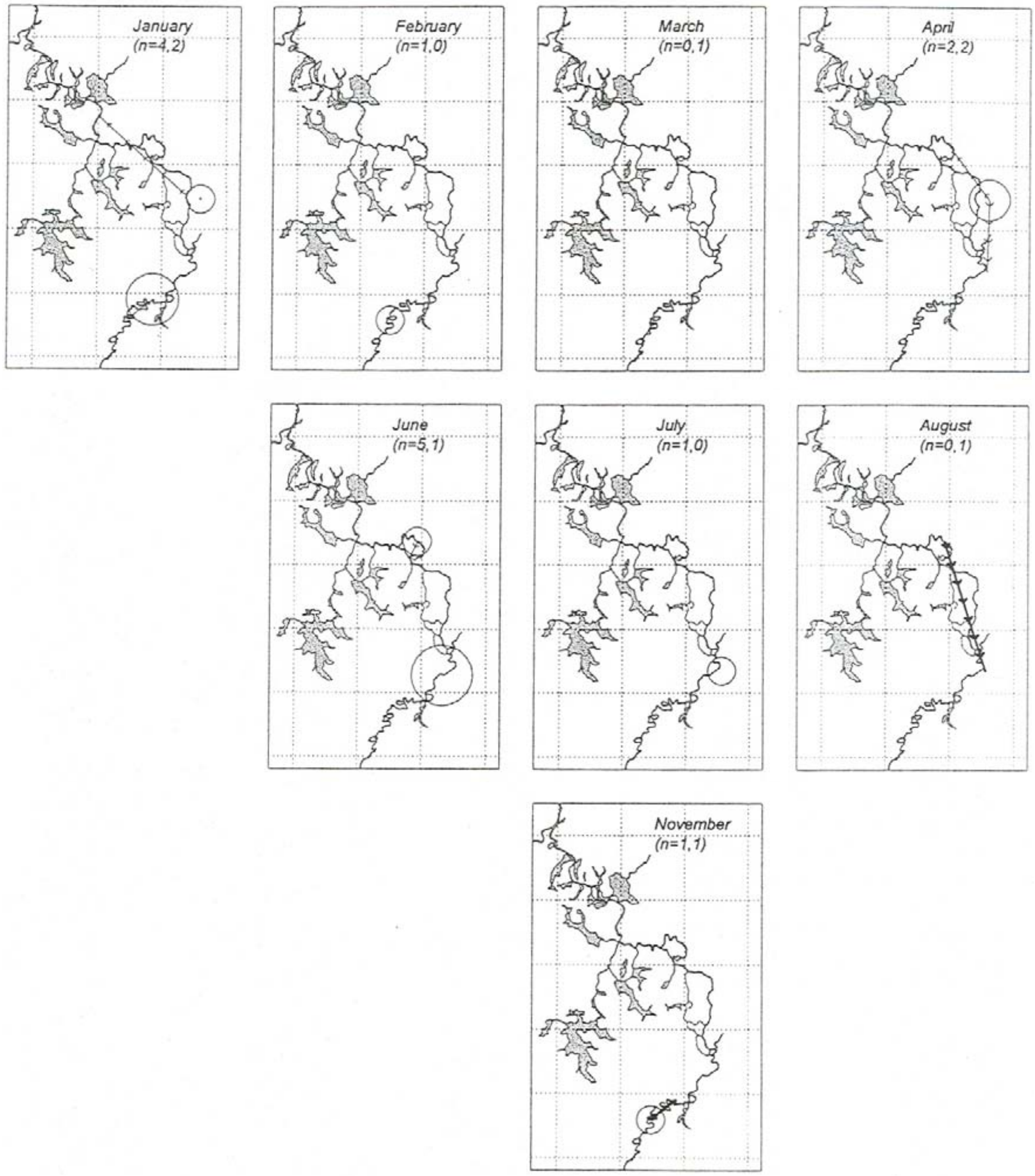

Figure 5.66 Monthly numbers of tagged *Channa striatus* recaptured at the Indonesian River Lempuing study site within the same or next calendar month, at the same location (first *n*, and circles, with the largest diameter circle representing 4 fish), or at a new location (second *n*, and lines, with arrows showing the direction of movement), in 1995 (thin lines) and '96 (bold lines).

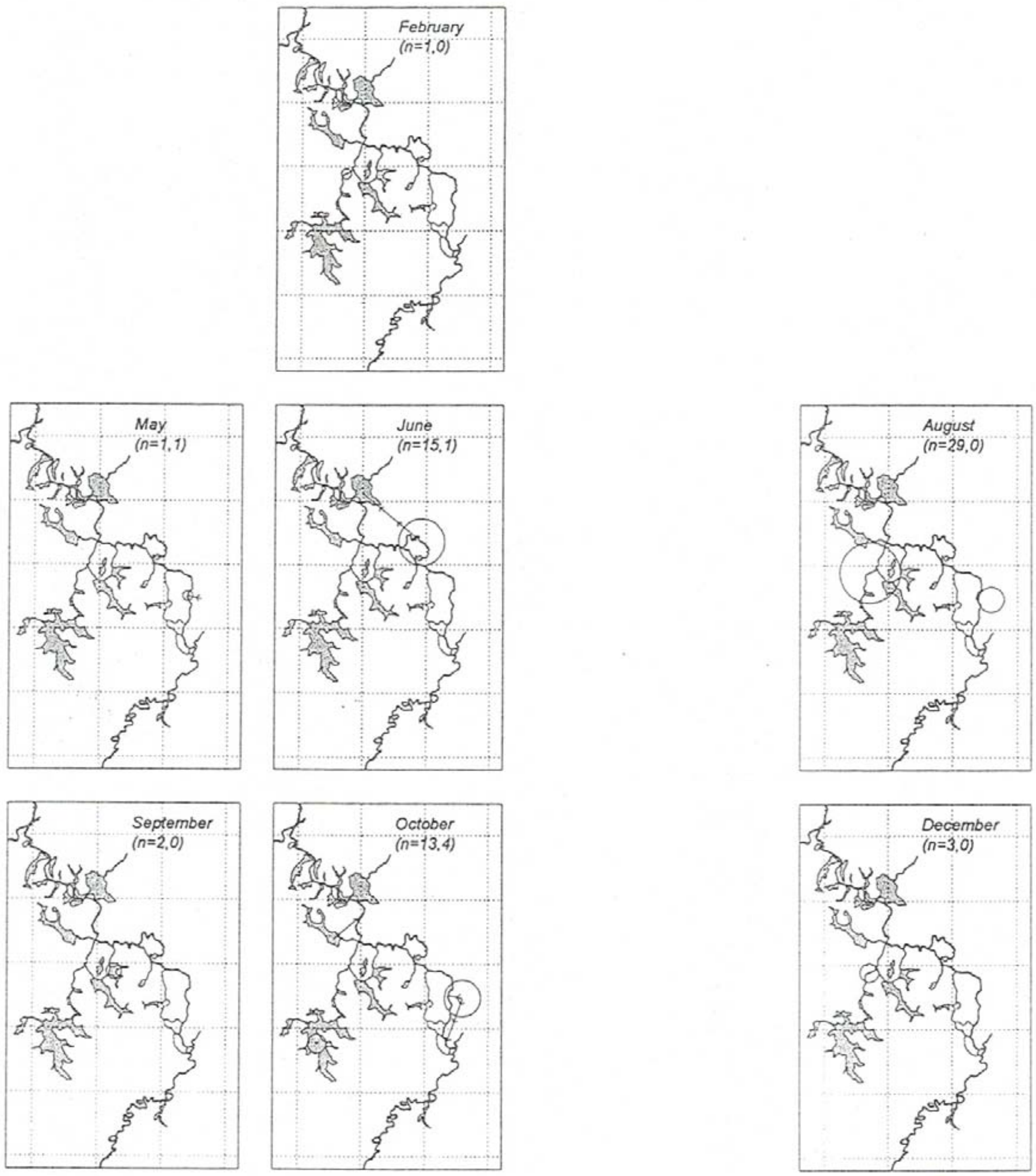

Figure 5.67 Monthly numbers of tagged *Helostoma temmincki* recaptured at the Indonesian River Lempuing study site within the same or next calendar month, at the same location (first *n*, and circles, with the largest diameter circle representing 24 fish), or at a new location (second *n*, and lines, with arrows showing the direction of movement), in 1995 (thin lines) and '96 (bold lines).

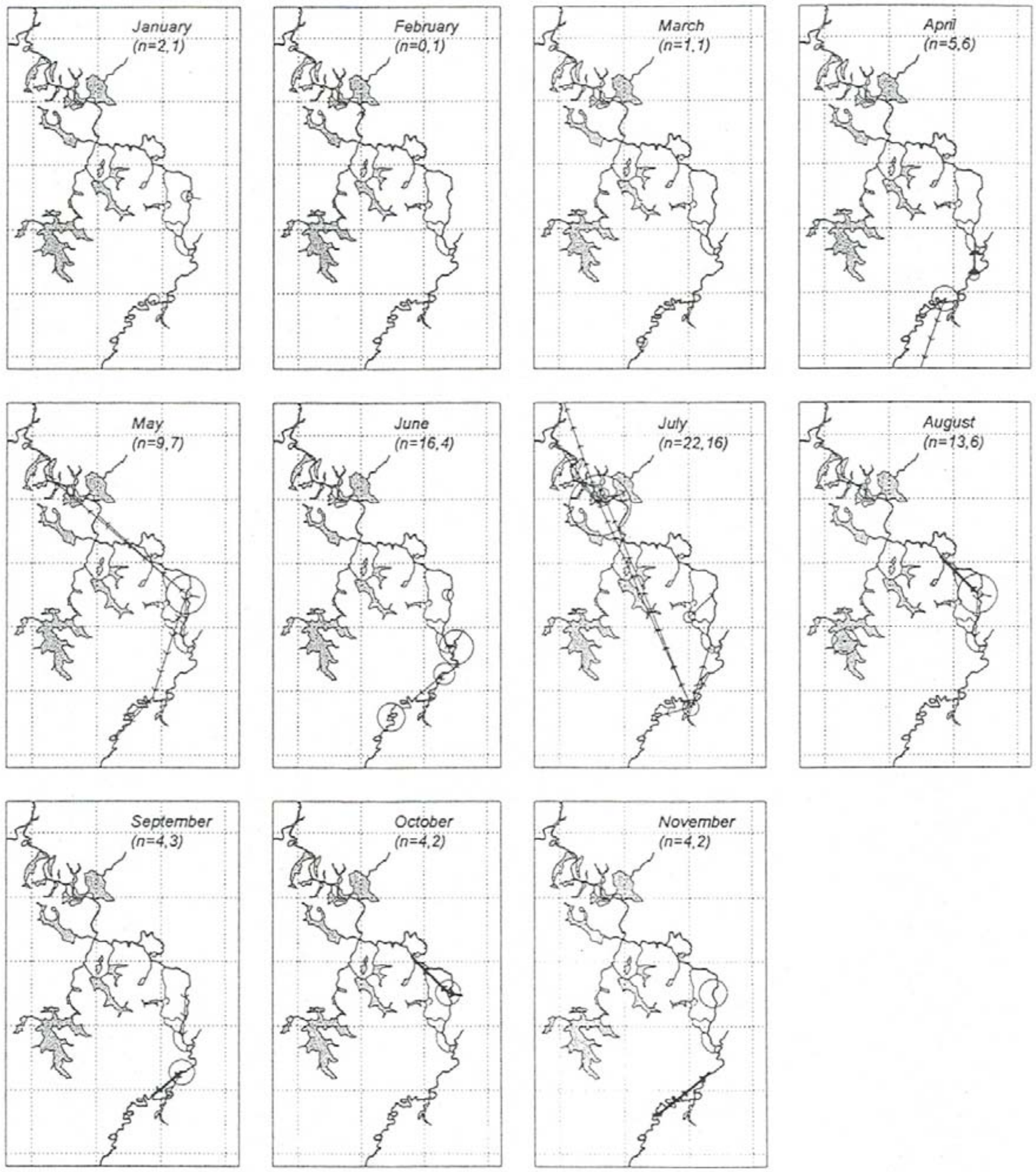

Figure 5.68 Monthly numbers of tagged *Mystus nemurus* recaptured at the Indonesian River Lempuing study site within the same or next calendar month, at the same location (first *n*, and circles, with the largest diameter circle representing 19 fish), or at a new location (second *n*, and lines, with arrows showing the direction of movement), in 1995 (thin lines) and '96 (bold lines).

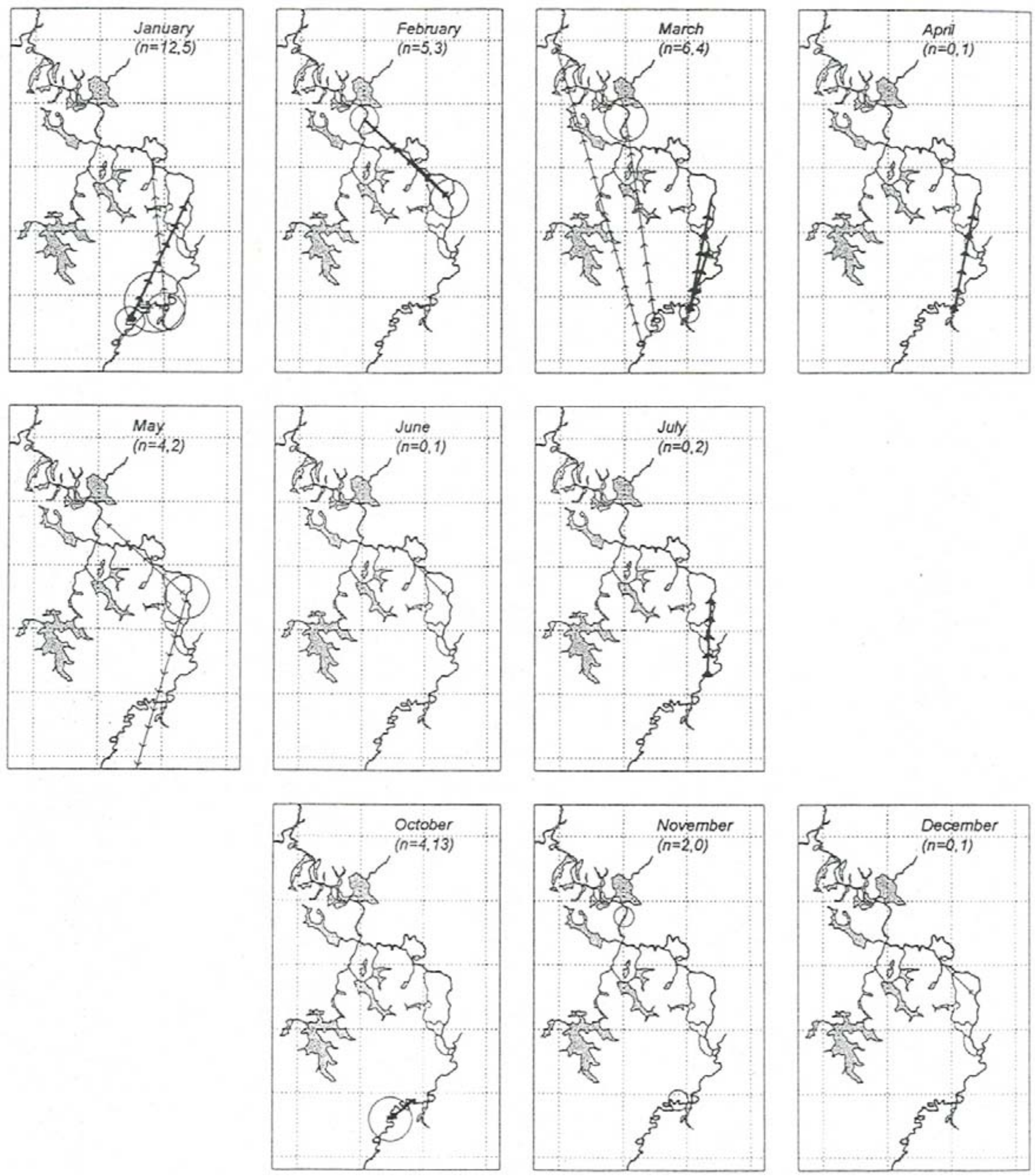

Figure 5.69 Monthly numbers of tagged *Macrobrachium rosenbergii* recaptured at the Indonesian River Lempuing study site within the same or next calendar month, at the same location (first *n*, and circles, with the largest diameter circle representing 7 fish), or at a new location (second *n*, and lines, with arrows showing the direction of movement), in 1995 (thin lines) and '96 (bold lines).

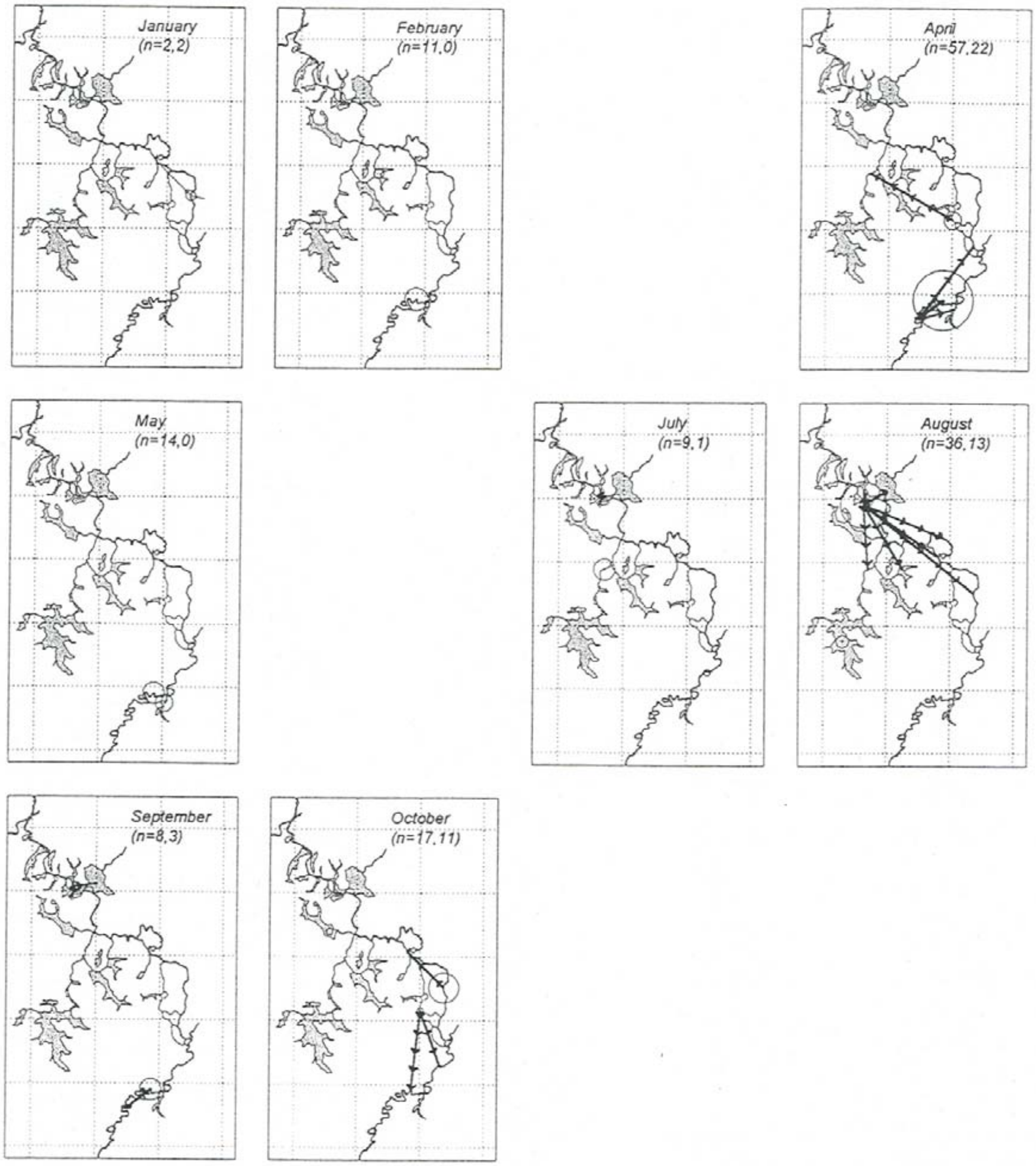

Figure 5.69 Monthly numbers of tagged *Osteochilus hasselti* recaptured at the Indonesian River Lempuing study site within the same or next calendar month, at the same location (first *n*, and circles, with the largest diameter circle representing 51 fish), or at a new location (second *n*, and lines, with arrows showing the direction of movement), in 1995 (thin lines) and '96 (bold lines).

6 Dynamics of the Fisheries

6.1 Introduction

This section describes the technical aspects of the two fisheries, with some brief consideration of social factors as important for management considerations. Particular attention is given to the spatio-temporal points at which the fisheries most heavily target any important key life-history stages. The understanding of such factors is now much enhanced by the biological insights on the fish stocks outlined in the last chapter. New insights on the spatial technical interactions of the different fishing gears are also considered, following the thorough covering of these factors by ODA Project R4791 (see also Hoggarth & Kirkwood, 1996). As will be shown, such interactions result from the spatial behaviour patterns of both the fish, and the fishermen.

6.2 Fishing Gear Use

The types of fishing gears used in floodplain fisheries has been well described in general terms by Welcomme (1985) and by the previous ODA project R4791 (MRAG, 1994a; see also Hoggarth and Utomo, 1994 for a description of the Indonesian fishing activities). Broadly similar fishing gears are used at both sites, but with significantly different overall approaches. As will be shown in the following brief summaries of fishing gear use, the exclusively licensed Indonesian fishermen catch fish mainly in barrier traps while the more competitive Bangladeshi fishermen use far more active chasing gears.

6.2.1 Description of fishing gears - Bangladesh

In Bangladesh, both the Inside and Outside regions were fished with broadly similar fishing gears in both 1995 (Figure 6.1) and '96 (Figure 6.2), particularly by katha, seine nets, lift nets, cast nets, fixed gill nets, passive traps and long lines (see Table 6.1 for brief gear descriptions). Significantly more spears were used in the Inside region in both years, reflecting the higher water clarity inside the embankment. The dry season katha and dewatering were particularly successful in the 1996 dry season, following the strong '95 flood.

Gear use in the Adjacent and Main River habitats differed significantly from the two main study regions. In the Adjacent region, catches were dominated by fixed gill nets and dewatering (both by hand and pumped, as kua, Figures 6.1, 6.2). In the Main River region, 1995 catches were strongly dominated by the bag net (winged fyke trap), not used in any other region. In 1996, Main River catches were mainly taken by both the bag net and by katha and seine nets.

Particular consideration is given to the gears used in dry season waterbodies and around sluice gates at the PIRDP in Appendices C and E respectively.

6.2.2 Description of fishing gears – Indonesia

In Indonesia, catches are dominated by 15 main gear types, with 12 other gears occasionally used (Table 6.2). The main catches in all three regions are taken by the riverine and floodplain barrier gears (gears KL, EL, TU and CO in Figures 6.3 and 6.4), and by the dry season active seine methods (gears NK, NR, NP and NL). All such gears are owned and used by the license-holding group fishermen (see Section 3.7.1). Other gears used by individual fishermen include gill nets, traps and hooks, usually fished in a passive way, unattended by the fishermen (Figures 6.3 and 6.4).

The langgian dip net previously much used to catch prawns at night in the River Lempuing (as reported in 1994 by project R4791), was not reported during the 1995 and '96 study years reflecting a decline in prawn populations. Similar dip nets (known as cerok, Table 6.2, Figure 6.4) are now sometimes used in association with poison to catch stunned fish.

6.2.3 Comparison of gear use

As shown below, the Indonesian fishermen, who hold exclusive rights to fish in their waterbodies (see Section 7.2.2, 7.2.3) use far more barrier traps, and individual gears fished in an unattended 'set and wait' manner. Only the 25% of catches from the dry season seine gears, which 'hoover' fish from drying waterbodies were taken by fishing in an active way.

Relative catches from different types of fishing gears

Fishing Gear Class	Bangladesh Catch	Indonesia Catch
Full Barrier Gears	11%	49%
Partial Barrier Gears	10%	0%
Set and Wait Gears	32%	26%
Chasing Gears 26%	1%	
Dry Season Hoovering	21%	25%

In comparison to this relatively relaxed and efficient exploitation in Indonesia, the Bangladeshi fishermen only took 43% of their catches from barrier gears and unattended 'set and wait' gears. The majority of the catch was taken by fishermen actively competing with each other using partial barriers and chasing gears such as cast nets, drag nets, push nets, and attended gill nets and hooks.

6.3 Spatio-Temporal Dynamics

The spatio-temporal dynamics of the fisheries are compared in this section. Fishing effort levels are first compared, particularly inside and outside the FCD/I scheme in Bangladesh (where study site areas were available) to support the productivity comparison of the preceding chapter. The seasonality of catches are then described to demonstrate the points in the fishes' life cycles most harvested by fishermen, particularly in relation to their dry season survival strategies.

6.3.1 Fishing Effort - Bangladesh

The relative amounts of fishing effort inside and outside the FCD/I scheme were compared as effort-per-unit-area (EPUA) figures in units/ha/year (Figure 6.5). Relative fishing effort varied between the different gears: in 1995, 8 of the 14 recorded gears were used more outside the FCDI scheme and 6 used more inside; in 1996, 9 of the 17 gears were used more outside the FCDI scheme and 8 used more inside. All of the 13 gears recorded in both sampling years had the same in/out prevalence in both years. The gears used more inside the FCDI included lift nets, spears and jumping traps, all commonly used in riverine waters. Those gears used more in the Outside region included gill nets, passive traps, long lines and dewatering, all commonly used in beel and floodplain waters. These differences in gear use largely reflect the availability of different habitats (see following section).

Comparing the overall intensity of fishing effort between regions is complicated for such a multigear fishery due to the different units used for each gear (see Survey Methodologies Appendix A and Chapter 3, Table 6.1). Since the fishing efforts of each geartype cannot be simply added to give a meaningful total, the ratios of fishing efforts inside/outside were calculated for the comparison[8]. The average ratio of In/Out EPUAs for the gears with non-zero efforts in both regions was 0.65 (CI 0.19 to 2.29, n=12 gears) in 1995 and 0.85 (CI 0.25-2.84, n = 10 gears) in 1996. These ratios indicate an overall 53% and 18% greater fishing effort outside the FCDI scheme in 1995 and '96 respectively. The lack of precision in these estimates partially reflects the small sampling ratios leading to incomplete coverage of the full fishing season for each gear. The influence of seasonality on this comparison was removed for the 1995 data by estimating the average ratio of In/Out EPUAs for each gear, for only those months with data available for both regions. This approach gave a more precise but still similar In/Out EPUA ratio of 0.62 (CI 0.35 to 1.12, n=27 gear-months), mostly based on the more commonly used gear types CN, FG, LL, LN, and SN. These more complete data indicate that overall fishing effort was approximately 61% greater in the Outside region than the Inside one in 1995.

[8] Average calculated on log-transformed data, with approximate 95% confidence interval (CI) calculated as +/- 2*SE, before back-transformation.

6.3.2 Fishing effort - Indonesia

At the Indonesian study site, absolute fishing efforts have not been formally compared as above for Bangladesh. The overall numbers of fishermen have, however, been seen to decline in recent years from 587 in the 1994 season, to only 356 and 324 in 1995 and '96 respectively (Table 3.2). It is possible that fishermen opted to leave the fishery in 1995 after the high exploitation rates achieved in the driest ever dry season of 1994, or that numbers were controlled by leaseholders.

6.3.3 Catch seasonality by habitat - Bangladesh

In broad terms, catches on the floodplains and their associated waterbodies in Bangladesh are taken over virtually the whole year, with catches only declining towards the end of the dry season, and during the early flooding season (Figure 6.6). In contrast, catches in the main river have a complementary seasonality, being greatest exactly when floodplain catches are reduced.

Considering habitats, in 1995, catches in the Outside region were taken equally from all four habitat types, beels, floodplains, canals and (secondary) rivers; while those in the Inside and Adjacent regions were taken mostly from beel (88%) and river (87%) habitats respectively (Figure 6.7). The difference between the Adjacent and Inside regions reflects the presence of the substantial and permanent Gajnar/Gandahasti Beel within the Adjacent region.

Considering both the Adjacent and Inside regions together as areas inside the FCDI scheme, fish catches were taken from both the beel and riverine habitats over the flood and drawdown months, but fell to zero in all habitats except the secondary river by the end of the dry season in May. Notably, the greatest catches in the Inside riverine habitat were taken later (March) than those in the Adjacent beel habitat (January), suggesting that the Inside rivers (the Atrai and Badai) may provide the habitats with the greatest potential for survival over the dry season in this locality (Figure 6.7).

In the Outside region, catches were maintained throughout the dry season in both beel and riverine habitats, though not in the shallower canals, confirming the existence of good permanent dry season survival habitats outside the FCDI scheme in both beel and rivers.

In the Main River, in contrast, the greatest catches were taken at the time of the dry season, with a secondary peak during the drawdown months. Comparing the riverine catches between the Inside, Outside and Main River regions (the lower, right three plots in Figure 6.7), suggests that the both the Inside and Main River fish are strongly targeted over the dry season, when the Outside river fish are less heavily exploited. Field staff observed that the Hilsa run in the Main River and the lack of free fishing places in the dry season encouraged fishermen to go and fish in the Main River at this time (see section 6.4.1).

In broad terms, the 1996 catches showed remarkably similar distributions across regions, habitats and seasons (Figure 6.8) to those seen in 1995 (Figure 6.7). Outside river and beel catches were again sustained throughout the dry season, though inside river catches were not in this year. Outside catches in both floodplains and rivers were particularly high in the early months of 1996 following the large 1995 flood season.

These results confirm the conclusions on the dry season survival strategies of fish drawn in the previous chapter, but also demonstrate that fishermen do currently continue fishing such stocks over the dry season as much as they are able.

6.3.4 Catch seasonality by habitat - Indonesia

In Indonesia, catches are more strongly correlated with flood events, both during the drawdown and reflooding, and also occur over the dry season (Figure 5.2). Compared to Bangladesh, very little fishing is done in the Indonesian river regions over the high water season, when fish are growing and least vulnerable to passive gears. This catch seasonality reflects the stronger use of barrier gears in Indonesia (relative total catches in Figures 6.3 and 6.4, and gear seasonalities in Figures 6.9 and 6.10), and also the lower mortality rates at this site (Chapter 5), such that more fish remain available for capture during reflooding after the dry season. The catch data confirm that both the riverine and floodplain barrier traps do catch fish during both the drawdown and reflooding seasons. Catches of fish migrating upstream to spawn were taken most strongly in 1996, after the short dry season (compare Figures 6.9 and 6.10).

Compared to the riverine regions, the seasonality of catches in the Lake District included much greater catches over the flood season (Figure 5.2). These included year-round catches in both the kilung and empang barriers, and also gill nets and wire traps (Figures 6.9 and 6.10).

Catches in the Forest river region were the most seasonal of all three of the regions studied. The very high catches in the empang barriers in this region in May 1996 (Figures 5.2 and 6.10) reflect the sudden drawdown at that time (Figure 4.4), and demonstrate the urgency with which fish then attempt to emigrate from floodplain waterbodies in this highest mortality region.

6.4 Fishermen Behaviour

This section briefly discusses certain aspects of the behaviour patterns of fishermen at the two study sites which have implications for their management. These include the mobility of fishermen and their fishing strategies and relative catches. Further information is given on the licensing and wider management of fishermen at the study sites in Chapter 7.

6.4.1 Fisherman mobility

The spatial behaviour of fishermen throughout the seasons shows the accessibility of different fishing grounds to fishermen, and the importance of those fishing zones to them.

In Indonesia, fishermen pay for licenses to fish in discrete and defined waterbodies and river sections, with the River Lempuing having 35 such fishing units (see Section 7.1, 7.1). These waterbody units, or perairan are sometimes further divided into sub-units for fishing by separate groups of fishermen. As discussed in Section 3.1, individual fishermen are then sometimes sub-licensed by the groups to fish with certain small gears. Most importantly, all these fishermen then fish almost exclusively within their own waterbodies (some free fishing is available in January of each year and in the unlicensed section of the River Lempuing flowing through the main town Pedamaran). As a result of this restriction, the incomes of Indonesian fishermen are strongly seasonal, particularly those of the group fishermen who take most of their catches in the drawdown and dry seasons. The catches of group fishermen are also particularly vulnerable to unfavourable water levels: the total catches of group fishermen in the short dry season of 1996 were thus reduced to 55% of their 1995 levels, compared to only 75% for individuals. For this reason, it is concluded that the less variable barrier gears are vitally important as a guaranteed source of income for group fishermen.

Though Indonesian fishermen thus hold exclusive rights for fishing within their licensed waterbodies, the behaviour and mobility of fish - as discussed in the last section - is such that they do not hold exclusive rights to the fish within their waterbodies. In competition with fishermen in adjacent and more remote waterbodies, fishermen clearly perceive a strong incentive to catch as much as possible from their waters each year. No evidence was observed in the River Lempuing waterbodies of any form of restraint over the dry season period (though this is observed in other regions in Indonesia, as shown in Sub-Project 6, Appendix G).

The situation in Bangladesh is in complete contrast to that in Indonesia. Though the larger waterbodies have traditionally been licensed for restricted fishing (see Section 7.2.1), many waters, especially over the flood season, are freely available to all. At the PIRDP site, in each of the Adjacent, Inside and Outside regions, the greatest catches were then usually taken by respondents fishing within their own region (Figures 6.11, 6.12; the Inside region in 1996 was the only exception). Such localised fishing was concentrated during the drawdown and early dry seasons when fish are most easily caught. Fishermen did, however, also fish outside their own localities: in all four fishing regions in both years, at least some of the catch was taken by fishermen from all three of the other regions of residence (Figures 6.11, 6.12). Fishermen from both the Inside and Outside regions took significant portions of their catches (26% to 46%) from the Main River habitat, especially over the dry season. At this time, both fish and fishing places are scarce on the floodplain, and many Hilsa are available outside. In 1995, fishermen from the Adjacent region took only negligible catches from the Main River, reportedly preferring to farm or labour during the dry season. In 1996, however, Adjacent fishermen took 23% of their catch from the Main River, and 26% from the outside region, especially over the dry season.

Comparing only the floodplain regions across the FCDI embankment, fishermen from both the inside regions took substantial catches from the Outside region in both 1995 and 1996 (Figures 6.11, 6.12). Respondents living outside, however, took only very small catches from the two inside regions, lending further support to the view that fishing outside is better than fishing inside the FCDI scheme.

The above results indicate a significant mobility of fishing labour among the four fishing zones in Bangladesh. This mobility can be roughly measured in terms of the number of 'location' codes fished by the respondents. Such location codes were defined for over 300 small areas of the floodplain, categorised by habitat type as floodplain, river, canal and beel (Section 3.4). Individual 'locations' represented an average 1.13km2 for floodplain and beel waters, and an average 1.18km for sections of secondary rivers and canals in Bangladesh. During 1995 and '96 the 40 CE respondents each fished an average 7.8 and 6.4 different 'locations' respectively; the most mobile respondents fished up to 20 different locations! On this basis, fishermen in Bangladesh are far more mobile than those in Indonesia, who, as noted above, fish only in their own licensed waters (average 2.55km length for riverine license units).

6.4.2 Fishing hours

In addition to the active nature of their fishing gears, fishermen in Bangladesh work significantly longer hours than those in Indonesia (Table 6.3). For those respondent fishermen actively engaged in fishing in each month, daily fishing hours were almost three times longer in Bangladesh (11.1 hours) than in Indonesia (4.0 hours)! Taking non-fishing respondents into account, average fishing hours in Bangladesh (4.7) were still almost twice those Indonesia (2.7).

The seasonality of fishing hours, varied significantly over the year, particularly for the overall average figures, suggesting that participation in fishing was highest in Bangladesh over the drawdown period, and highest in Indonesia in the dry season for the hoovering gears (Table 6.3). Relatively few fishermen in Bangladesh participated in the dry season fisheries when the accessibility of resources is reduced, and more farming occupations are available.

6.4.3 Fishermen densities and individual fishing catches

Fishermen densities at the project sites are approximately an order of magnitude greater at the Bangladesh site than in Indonesia. Fishermen densities in Bangladesh were estimated at 47 and 36/km2 (high water flooded areas) respectively in the Inside and Outside regions, not including subsistence fishermen (Section 3.8.3). Fishermen densities in Indonesia can not be accurately estimated due to the unknown high water flooded area of the study site. Assuming that flood waters cover approximately 100km2 within the River Lempuing study area (Figure 2.2), the group and individual fishermen (Table 3.2) were at densities of approximately 3.5 and 3.2/km2 in 1995 and '96 respectively, well below those in Bangladesh. This conclusion roughly supports the comparison made in 1993 by ODA Project R4791 (MRAG, 1994a).

With ten times as many fishermen in Bangladesh, each of them working significantly longer hours than in Indonesia, the total annual fish catches per individual fishermen in Bangladesh are 6-16 times lower than in Indonesia, as shown below:

Fishermen numbers and individual annual catches

	Bangladesh Inside	Bangladesh Outside	Indonesia
Total number of fishermen			
1995	1947	2433	355
1996	1947	2433	324
Total catches (tonnes)			
1995	444.35	766.24	1,183.79
1996	403.17	858.97	717.73
Catch per fisherman (tonnes)			
1995	0.23	0.32	3.34
1996	0.21	0.35	2.22

Allowing for the differences in fishing practices in the two countries, and the relative daily hours of active work, fishing in Bangladesh is between 11 and 28 times less productive per hour than in Indonesia! In comparison to these strong differences due to employment levels and fishing practices, the two fisheries produced similar catches per unit area (51-130kg/ha/yr in Bangladesh, and approximately 72-118kg/ha/yr in Indonesia).

6.5 Gear Selectivity

As mentioned in the previous chapter, fishing gears in Bangladesh are generally much smaller meshed than in Indonesia (compare the mesh sizes quoted in Tables 6.1 and 6.2), resulting in much smaller fish being caught in Bangladesh (see Hoggarth and Kirkwood, 1996). This relative selectivity towards small fish in Bangladesh reflects its high mortality rates, and the overexploitation of many of the larger species. It may, however, be justified in that country due to the high demand for nutritious, inexpensive fish from the multitudes of relatively poor people.

In Indonesia, mesh sizes are lowest for the barrier and hoovering seine gears (Table 6.2) of the group fishermen, who may need to achieve the highest returns from the relatively large investments in gear costs, and who usually operate on-site fish processing (salting or smoking) to enable them to handle seasonally large catch volumes. The Indonesian group fishermen take great care in the construction of these barrier traps in order to maximise their catches and prevent the escape of fish to adjacent waterbodies. Since some tagged fish were observed to migrate through several floodplain and riverine barriers before recapture, it is clear, however, that such structures are not completely impassable to fish.

6.6 Technical Interactions

Technical interactions exist where two or more species compete for one or more species of fish, either at the same time, or sequentially (Hoggarth & Kirkwood, 1996). Such interactions were investigated in depth in ODA Project R4791, and are only briefly considered here.

6.6.1 Competition between gears

Competition between gear types is strong at both the study sites. All the common fish species are taken by several different gear types, and conversely, most gears take several different fish. Within this generalisation, some gears are more species specific than others, however. In Bangladesh, for example, the main river clap nets are used exclusively to catch the migratory Hilsa shad (Table 6.4). Also in the main river, the savar seine nets are used primarily to catch the fry of the major carps C. catla and L. rohita. Other gears, such as lift nets, seine nets, fixed gill nets, passive traps and katha brushpile traps are potentially able to catch virtually every species common in the fishery! As discussed in Appendix E, lift nets and bag nets compete with each other to catch fish passively migrating through the sluice gates in Bangladesh, though the jump traps used at such sites generally catch fish moving in different directions.

In Indonesia, the barrier and seine gears of the group fishermen are the least species specific, along with the gill nets (J.) of the individual fishermen (Table 6.5). The most targeted gears include the group fishermen's ngubek lubuk cast netting in deep river pools (NL), particularly used to catch riverine catfish, and the individual's seruo baitfish traps (SE) and both longlines (RA) and single hooks (TL).

6.6.2 Competition between license units

In addition to the strong competition between gears and fishermen observed within waterbody license units, the fish migration patterns have now confirmed that fishermen in different license units also compete with each other for the stocks of fish moving between and among them. In Bangladesh, competition is further enhanced by the mobile behaviour of fishermen themselves, moving apparently in response to seasonal changes in fish abundances and fishing opportunities and accessibilities.

6.7 Overall Comparison of the Study Site Fisheries

This section has shown that the high productivity seen at the two study site fisheries is achieved in very different ways.

In terms of their seasonality, both fisheries clearly target fish during their migration periods and on pre-spawning fish over the high mortality dry season period. The Bangladeshi fishery also targets younger fish earlier in the high water season, due to the smaller mesh sizes of its gears, the great abundance of its fishermen and the freely accessible fishing at that time. In contrast, only the individual fishermen fish in Indonesia during the high water season and more fish are caught during the reflooding seasons, reflecting the lower total mortality rates at this site.

Fishing practices vary significantly between the sites, largely it seems due to the differences in their management and licensing (see next chapter also). In Indonesia, fishing rights are completely allocated to licensees and their sub-groups, within one year periods, by the annual auction system. The abundant use of expensive, but productive barrier traps at that site may then be seen as a way of catching many fish with little effort, for group fishermen who are confident that their fish stocks are not accessible to outsider fishermen once the waters start to decline (see Appendix G). Due to the incomplete selectivity of the barrier gears, some fish do clearly escape though. The sub-licensing of individual fishermen is permitted as a means of sharing the license fees and ensuring some income in early months before the drawdown begins. This approach to fishing generates very high catches per fisherman in Indonesia for relatively little daily effort.

In Bangladesh, in contrast, fishing rights are only incompletely allocated to the largest waterbodies and river channels, and only for the dry season period. The much more abundant fishermen in Bangladesh then begin fishing as soon as the fish start to grow on the floodplain, and use many more active and competitive 'chasing' gear types with which to catch fish. When the dry season arrives, fewer fishermen are able to work in the fishery, presumably due to the reduced numbers of fish and also the restrictions placed on licensed waterbodies, but many fishermen are also able to fish in the main river system over the dry season.

The exploitation pattern in Bangladesh thus generates much lower catches per fisherman, and even lower catches per fishing hour compared to Indonesia. Due to the high demand for employment and incomes spread among such an abundant population, this highly accessible system is in accord with the needs of the country. The lack of a complete spatial licensing system in Bangladesh may also possibly be explained by the lack of clear boundaries on its floodplains compared to the Indonesian site, which is more sub-divided by various levees and high ground areas between waterbody license units.

6.8 Summary - Dynamics of the Fisheries

- This section describes the technical aspects of the two fisheries, including the gears used, and their seasonality, selectivity and interactions, and briefly considers some social factors as important for management considerations.

- Significant differences were seen in gear use between the two sites. Both fisheries used some small 'set and wait' gear types, such as hooks and portable traps, and also some active 'hoovering' gears in the dry season including the kathas and kuas in Bangladesh. In addition to these gears, 49% of the total catches at the Indonesian site were taken by barrier traps, compared to only 11% in Bangladesh. In contrast, 26% of the Bangladesh catches were taken by active 'chasing' gear types, including cast nets, push nets and attended gill nets etc, compared to only 1% in Indonesia.

- Fishing effort on floodplains and in associated waterbodies was roughly 53-61% greater outside the FCDI scheme than inside in 1995, and 18% greater outside in 1996. The numbers of fishermen at the Indonesian were similar between years, though they had declined dramatically from the 1994 season. Roughly ten times as many fishermen fished at the Bangladesh site than at the Indonesian site (not including subsistence fishermen).

- In Bangladesh, catches were taken throughout the dry season in both rivers and beels of the Inside and Outside regions, confirming that fish use these habitats to survive over the dry season, and also that fishermen do continue to fish for them at this pre-spawning time. Canal habitats did not support fish catches throughout the dry season. Large catches were taken in the main river habitat during the dry season, but these were of mainly riverine species, especially Hilsa ilisha, not the escapees from the floodplain.

- In Indonesia, with its many barrier traps, catches are more strongly correlated with flood events and fish migrations, both during the drawdown and the reflooding season when fish migrate to spawn. Large catches were also taken over the dry season, but much less so over the high water period. The relatively high catches during the flood reflect the lower mortality rates at this site, and the high numbers of fish still alive after the dry season.

- Fisherman mobility is much higher at the Bangladesh study site than at the Lempuing site. In Indonesia, almost the whole river system is sub-divided into license units, and fishermen only fish within their own licensed waters. Fish movements between waterbodies, however, mean that this licensing does not allocate exclusive rights to the fish contained in them. In Bangladesh, only part of the river system is licensed, and only over the dry season, and fishermen are free to fish many waters. Local waters are fished during the drawdown and early dry season, and the main river is particularly fished during the dry season. Fishermen from inside the FCDI scheme regularly fish outside, but fishermen outside the FCD/I scheme rarely fish inside.

- Reflecting the active nature of their fishing gears, fishermen in Bangladesh attend their gears for 2-3 times longer each day than in Indonesia. With similar productivities, but around ten times as many fishermen in Bangladesh, the catches per fisherman are approximately 6-16 times lower than in Indonesia. Allowing for their long hours and active fishery, the Bangladeshi catches per fishermen per hour are approximately 11-28 times lower than in Indonesia!

- Fishing gears in Bangladesh are much smaller meshed than in Indonesia, and catch correspondingly smaller fish earlier in the season. The capture of small fish may be justified by the high demand for nutritious, cheap fish for poor people. In Indonesia, mesh sizes are lowest for the barrier and hoovering seine gears of the group fishermen, who may need to achieve the highest returns from their relatively large investments in gear costs.

- Both fisheries show strong technical interactions, both between different fishing gear types, and between different license units due to the mobility of fish.

- This section concludes that the fishing practices at each site are largely due to the variable accessibility of the fishing waterbodies - restricted in Indonesia by complete licensing, and more open in Bangladesh. The high employment generated by the fishery in Bangladesh and the higher individual catches achieved in Indonesia are in accord with the relative needs of the two countries.

Table 6.1 Brief descriptions of the fishing gears used at the Bangladesh PIRDP study site, with gear reference codes, positions fished and mesh sizes

Classes of fishing gears, local names and descriptions	Gear Code	Position1	Mesh2(mm)
Static Filtering Nets (full channel barriers)			
Suti jal Large bag net, suspended in high flows, eg outside sluices	BN	Sluice gates	3 - 7
Ucha bandh Small bag net, suspended in channels in floodplain	UC	F	2 - 7
Bandh veshal Bamboo/net barrier with two lift nets at river margins	—	S	5 - 10
Static Interceptory Nets (not full channel barriers)			
Shangla jal Bivalve-shaped clap net, bottom fished from boat	CL	M (deep part)	25 - 35
Urani Flat net, suspended above swirling waters below sluices	JT	Sluice gates	1 - 10
Veshal jal Large triangular lift net, mounted on pivot (with barriers)	LN	All areas	5 - 10
Dharma jal Small square lift net, with/without pivot	LN	C, S, M	5 - 10
Saver jal Funnel shaped carp hatchling fyke net	SV	M (shallows)	1
Bandh jal Net fyke with bag nets suspended at intervals	—	M	25 - 40
Active Seine Nets			
Kachal jal Large, common seine net, fished by 1-2 boats	SN	F, B, S, M	1 - 5
Katha jal Small seine with poles on end, fished by children	SN	F	2 - 7
Dora jal Large seine with poles on ends, fished by adults	SN	B, C, F	10 - 30
Chabi jal Encircling seine, fished with polo traps	SN	M (shallows)	25 - 40
Drag/Push nets			
Moi jal Small drag net, fished from boat or shore	DN	B, C, S, M	4 - 7
Ucha jal Small triangular net, fished by children	PN	B, F	2 - 4
Cast Nets			
Jhaki/kheo jal Fished in open water/brushpiles from canoes/bank	CN	All areas	5-10
Gill Nets			
Fashi jal Fixed multifilament, parachute thread, unattended	FG	B, S	6 - 50
Current jal Fixed monofilament nylon thread, unattended	FG	B, S, F	30 - 50
Bogi jal Drifting monofilament, floating, attended from boat	DG	M	20 - 40
Shandi jal Drifting multifilament, bottom-set, attended from boat	DG	M	35 - 75
Portable Traps (all constructed of split bamboo & synthetic twine)			
Polo Basket trap, rammed down into mud, emptied by hand	AT	B, C, F, M	15 x 60
Labani Box shaped passive trap, fished in fences	PT	F, B	4 x 40
Doair Round shaped, fished with bamboo sheet fykes	PT	S, M	10 x 120
Hooks (mostly baited with worms, fish, or small frogs)		All areas	hook gape
Tona borshi Rod & line, single hook, attended	HA/HK	B, S, M	3 - 12
Tana borshi Hook & line, single hook, attended	HA/HK	Rice fields	3 - 12
Borsha borshi Hook & line, single hook with float, unattended	HU/HK	B, S, C, M	2 - 5
Sita borshi Rod & line, single hook, live baited, surface, unattended	HU/HK	B, S	5 - 12
Mati daun Long-lines, 20-600 hooks, bottom fished, unattended	LL	B, F, S, M	3 - 7
Ziala daun Long-line, 3-10 hooks, live baited, surface, attended	LL		5 - 12
Spears			
Foxa/tetra Cluster of 7-20 fine metal rods attached to bamboo pole	SP	Sluice gates	
Konch/juti Split bamboo pole, with 7-20 points tipped with metal	SP	B, F, S	
Akra Metal gaff, fished from boat in soft mud	SP	C, S	
Dewatering			
Kua Large depressions dewatered by diesel pump in dry season	KU	B , S, C, F	
Hatano Individual man fishing by hand with/without dewatering	HF	All areas	
Fish Attracting Devices (FADs)			
Katha Brushpiles surrounded by large ber jal seine nets	KT	B, S, M	1
Boat Katha Sunken boat brushpile, surrounded by seine nets	KT	C, B, F	1
Hogra Triangular frame with brushpile inside	KT	C, B, S, M	1

1 B= beel, C= canal, F=Floodplain, M=Main River, S=Secondary River
1 Where only one dimension or a range is given, it represents one edge of a single mesh of net.

Table 6.2 Brief descriptions of the fishing gears used at the Indonesian River Lempuing Study site, with gear reference codes, positions fished and mesh sizes

Classes of fishing gears, local names and descriptions		Gear Code	Position1	Mesh2(mm)
Static Filtering Barriers/Fykes				
Suspended nets:				
Kilung	Wide shallow barriers with net flumes to strand fish	KL	lebak > river	9
Tuguk	Stationary trawl net, mounted in wooden penetak frame in strong flows	TU	main river	7
Bamboo barriers (made of split bamboo tied into panels or 'empang'):				
Empang	Large fykes, with trap chambers (lulung)	EL	lebak > river	10 x 200
Corong	Stationary flumes, mounted in wooden penetak frame in strong flows (often associated with tuguk)	CO	main river	25 x 200
Active Seine Nets/Barriers				
Ngesek	Fish driven by empang barriers, without FADs	NK	lebung pools	10 x 100
Ngesek pinggiran	Kerakat seine-netting of uprooted water hyacinth beds	NP	river margins	9 - 13
Ngubek lubuk	Cast netting of empang-enclosed fish in lubuk deep pools, with sunken trees as FADs	NL	river deeps along river	10 x 100
Ngesar	Fish driven by noise and kerakat seines, without FADs	NR		9 - 13
Scoop Nets				
Cerok	Large scoop net, fished with poison to stun fish	CR	main river	?
Sekap	Small scoop net, used in dry season	SK	lebak	?
Cast Nets				
Jala	Fished from canoes, at end of NK/NL fish drives	JL	all areas	17
Gill Nets				
Jaring	Fished in open water or channels, usually demersally	JR	all areas	19 - 40
Roket	Short, scattered in rice paddy shallows	RK	rice paddies	19 - 40
Portable Traps (mostly surface fished without bait in fish migration routes)				
Pengilar rotan	Rattan fish trap, ~60x40x35cm	PR	lebak/lebung	32 x 40
Bengkirai bilah	Bamboo fish trap, ~60x40x20cm	BB	lebak/lebung	24 x 100
Bengkirai kawat	Chicken wire fish trap, ~50x40x30cm	BK	lebak/lebung	22 x 22
Lapun	Wire predator trap, ~80x50x40cm	LP	river margins	80
Menteban	Bamboo baited trapdoor trap, ~60x30x30cm	ME	river deeps	60
Seruo	Bamboo, bullet-shaped 'baitfish trap', ~30x15cm	SE	lebak/lebung	12
Bubu	Bamboo, large cylindrical predator trap	BU	river margins	20 - 25
Karaman	Bamboo, rice-bran baited trap	KM	?	?
Hooks (bait usually whole small fish, initially alive)				hook gape
Rawai	Long lines of ~100 hooks, fished demersally	RA	main river	10 - 12
Tajur cogak	Single hook, fished from rod in bank, on water surface	TC	river margins	10 - 12
Tajur luyuk	Single hook, fished from floating stick, among weeds	TL/TB	river margins	10 - 12
Pancing	Rod & line, fished by hand, for small fish	PA	lebak/lebung	7
Dewatering				
?	Catching fish by hand in muddy shallows	TN	lebak/lebung	

1 '>' indicates a boundary position and the main direction of fish movement during capture.
2 Where only one dimension or a range is given, it represents one edge of a single mesh of net.

Table 6.3 Average numbers of hours spent actively fishing per catch/effort respondent (CER) per day, subdivided by monthat the Bangladeshi and Indonesian study sites

Month	Bangladesh, PIRDP		Indonesia, River Lempuing	
	All CERs	Fishing CERs	All CERs	Fishing CERs
January	4.1	11.7	1.1	3.0
February	3.1	9.8	2.1	3.9
March	3.1	10.5	1.7	2.9
April	3.5	11.1	1.9	3.2
May	3.5	13.9	3.2	4.3
June	4.8	14.3	3.1	3.8
July	4.2	9.0	3.2	4.0
August	4.8	9.2	3.5	4.4
September	7.6	12.1	3.0	4.3
October	7.3	11.3	3.5	4.9
November	5.4	10.7	3.3	4.6
December	4.8	12.4	2.1	3.7
Average	4.7	11.1	2.7	4.0

Table 6.4 Estimated total catches in 1995 and '96 (kg), subdivided by gear type (gear code names in Table 6.1) abd soecies (species code names in Table 5.1), at the Bangladesh study site.

Species	Full Barriers		Interceptory Nets				Seines	Drag/Push Nets		Cast Net	Gill Nets		Traps		Hooks/lines		Spears	Dewatering			FADs
	BN	UC	CL	JT	LN	SV	SN	DN	PN	CN	DG	FG	AT	PT	HK	LL	SP	DW	HF	KU	KT
AC	0	0	0	0	4886	0	55312	32	0	365	0	584	0	182	189	0	0	0	0	0	240
AM	0	47	0	0	331	0	808	0	6	2	0	0	0	466	0	0	0	1113	0	114	298
AMR	0	0	0	0	9671	0	5496	0	0	131	0	32483	0	0	0	0	0	0	0	0	251
AP	0	0	0	0	25	0	0	0	0	0	0	0	0	140	0	0	0	556	68	0	576
AT	0	0	0	0	435	0	532	35	0	10803	0	32022	47	372	94	108	0	2664	1162	1471	218
BB	0	0	0	0	130	0	575	10	102	11	0	0	0	777	0	0	0	650	0	275	2907
BBS	2038	0	0	0	0	0	0	0	0	0	0	0	0	0	0	658	0	0	0	0	0
BD	0	0	0	0	2792	0	1145	0	0	72	0	85	0	270	0	0	0	0	0	0	1143
BN	0	0	0	0	0	0	447	0	0	0	0	405	0	617	0	0	0	0	0	0	0
CA	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0
CB	0	0	0	0	88	0	0	4	173	0	0	377	0	34	0	1822	0	0	85	0	132
CBS	0	47	0	0	1704	0	3802	15	18	2129	17	11	0	10476	0	0	0	866	0	548	7698
CC	0	0	0	0	63594	589	21805	0	0	1455	0	6864	0	339	13	4843	8477	0	0	1244	7956
CCA	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
CCO	0	0	0	0	0	0	0	0	0	114	0	0	0	0	0	0	9807	0	0	0	809
CCS	0	0	0	0	25	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	517
CF	0	851	0	0	6663	0	3490	95	2085	10418	0	56049	3	27906	0	0	0	3351	546	513	4236
CG	639	0	0	0	4892	0	656	0	0	70	1429	94	0	12	754	1719	0	0	2	0	125
CGA	0	0	0	0	3	0	0	0	0	0	0	5990	0	349	0	987	0	0	0	0	0
CI	0	0	0	0	166	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	185
CL	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	284
CLA	0	0	0	0	179	0	289	0	66	0	0	17	0	59	0	0	0	0	0	0	0
CLS	0	0	0	0	2569	0	309	3	173	31	0	17	0	258	0	0	0	0	0	0	382
CM	0	945	0	0	3979	0	231	25	0	642	0	719	20	672	36	12343	15751	189	0	1008	12495
CMA	97	567	0	0	23450	0	1029	99	0	52	0	1643	0	1060	0	0	0	0	0	539	9884
CN	0	425	0	0	5354	0	17275	8	140	585	0	451	0	2828	0	376	0	745	0	888	17550
CP	0	19852	0	0	3427	0	22872	5991	926	21743	0	68543	994	5954	591	109659	1639	79911	8049	7103	4159
CR	0	378	0	0	17740	0	39084	26	0	775	0	17560	0	1647	0	0	0	0	0	881	5235
CRA	0	284	0	0	8376	0	16151	0	284	89	0	0	0	7068	0	0	0	498	0	995	6416
CS	0	4821	0	419	5298	0	2504	27	0	9368	0	3836	288	5552	78	39543	24871	2190	86	4361	6345
CSA	0	0	0	0	1347	0	2319	0	121	0	0	0	0	10	0	0	0	798	0	0	128
CSN	0	0	0	0	187	0	5013	0	0	0	0	0	0	18	0	0	0	0	0	0	0
DR	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ED	0	0	0	0	1039	0	2126	20	157	0	0	6	0	2815	0	0	0	3024	71	220	2763
EV	0	0	0	0	154	0	1381	0	0	0	0	204	0	0	0	0	0	0	0	0	0
GC	0	0	0	0	5590	0	109940	0	0	303	411	6120	0	195	0	0	0	0	0	0	563
GG	0	473	0	0	12516	0	18252	1435	253	5788	4377	54377	0	42228	1669	10557	0	2381	3263	888	4902
GN	0	0	0	0	9	0	274	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GV	0	0	0	0	0	0	0	94	0	0	0	0	0	0	0	0	0	0	0	0	0
GY	0	0	0	0	398	0	1422	43	0	20	592	0	0	39	0	0	0	0	0	0	0
HF	0	284	0	0	107	0	27	15	128	611	0	10816	0	282	10	206	0	94	58	987	650
HI	349671	0	12282	0	1282	0	10612	0	0	823	37364	2005	0	0	0	0	0	0	0	0	0
HM	0	0	0	0	11106	0	3939	0	0	209	0	377	0	0	0	0	0	0	0	0	0
LB	0	0	0	0	5500	0	3802	0	0	15	0	1827	0	6483	0	0	0	0	0	0	278
LC	48	0	0	0	3935	0	1213	0	0	5	0	3052	0	311	0	0	0	189	0	0	13868
LG	0	331	0	0	1586	0	2148	100	191	1360	0	356	0	4807	0	0	0	866	330	662	1501
LGS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127
LR	0	1323	0	0	44785	1177	21941	0	0	3390	0	16143	0	13131	0	2114	4579	189	0	2653	55906
MA	4223	0	0	0	18	0	14837	0	0	7	0	7287	0	1443	1	4596	298	0	0	0	20686
MAR	0	0	0	0	325	0	2581	140	60	2655	0	4765	0	5482	195	20113	969	189	57	0	8641
MAS	0	0	0	0	466	0	3550	32	25	52	0	17037	0	3117	422	482	3804	0	28	658	149
MB	0	95	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	127
MC	0	47	0	0	2331	0	5955	1782	0	2373	297	3890	0	3714	4356	1569	113	0	3223	0	62173
MCA	0	0	0	0	62	0	475	0	0	0	0	0	0	57	0	0	0	0	0	0	125
MP	0	5814	0	0	5038	0	11951	738	1449	2546	32	2604	0	16873	0	233	491	1115	7389	995	9104
MR	0	0	0	0	0	0	43	0	0	0	0	16	0	71	0	0	0	0	0	0	712
MS	0	0	0	0	0	0	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MT	0	0	0	0	292	0	2687	304	98	297	0	16	0	2682	4	0	0	377	0	433	3121
MV	0	238	0	0	2423	0	7912	2566	363	5869	0	23025	0	5250	2938	368	15	2664	1994	1889	25199
NB	0	0	0	0	15	0	899	0	0	0	0	6	0	0	0	0	0	0	0	0	91
NC	0	0	0	0	740	0	108	0	0	0	0	5472	0	0	0	0	9159	0	0	0	6362
NN	0	0	0	0	0	0	0	0	0	0	0	143	0	0	0	0	0	0	0	0	427
OBR	0	0	0	0	166	0	26	0	0	0	0	0	0	7	0	0	0	0	0	0	88
OBS	0	0	0	0	0	0	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OM	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OP	0	47	0	0	390	0	576	0	0	3	0	400	0	0	0	9	0	0	0	0	5939
OT	0	0	0	0	2882	589	3573	4928	3	3459	296	347	0	516	0	59	0	0	0	1141	3233
PA	0	0	0	0	1861	0	1784	4	0	239	0	69	0	814	0	0	0	0	0	0	35390
PC	0	95	0	0	33573	0	8364	117	179	3998	0	3805	0	3401	971	0	0	2177	15	1967	3704
PG	0	0	0	0	19	0	733	0	133	0	0	35	0	486	0	0	0	0	0	0	802
PGO	0	0	0	0	0	0	0	0	0	0	0	108	0	0	0	0	4579	0	0	0	0
PP	36887	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PPA	0	0	0	0	11	0	1831	0	0	17	60	61	0	105	0	0	0	0	0	0	0
PPO	0	189	0	0	19	0	1805	0	113	2	0	0	0	308	0	0	0	0	0	0	3
PS	0	16070	0	0	26369	0	45816	8045	3564	33779	296	264074	0	26295	425	0	16	22585	12352	48767	14280
PT	0	47	0	0	368	0	2206	20	339	796	0	0	0	2318	0	0	0	0	0	108	2841
RC	0	0	0	0	5383	0	1612	0	116	430	0	3460	0	204	0	232	0	0	0	0	111
RCO	0	0	0	0	3	0	32	0	0	11	0	47	0	0	0	0	0	0	0	0	443
RR	250	0	0	0	22	0	891	0	0	0	0	0	0	110	0	1076	0	0	0	0	0
SA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SB	0	0	0	0	269	0	1272	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF	0	47	0	0	633	0	12826	0	12	50	0	61	0	459	0	0	0	0	0	0	3332
SG	0	0	0	0	243	0	896	0	0	1	0	558	0	7	0	0	0	0	0	0	155
SGN	0	0	0	0	0	0	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SH	0	804	0	0	22170	0	40495	18555	1878	11927	5223	856	0	73824	0	0	0	2746	459	1843	53267
SP	0	0	0	0	269	0	1146	0	0	28	66	83	0	0	0	0	0	0	0	0	125
SS	0	0	0	0	6372	0	2893	0	0	13	1673	0	0	0	0	0	0	0	0	0	0
TC	0	1087	0	0	728	0	569	0	76	174	0	0	0	2014	0	0	0	155	0	161	1098
WA	0	567	0	0	25631	0	72404	418	0	238	0	13648	0	113	109	114792	19192	3772	0	3210	184826
XC	0	945	0	0	4674	0	6567	0	0	1883	0	1743	0	169	0	0	0	155	0	106	2850
Total	393853	56718	12282	419	399124	2355	637960	45726	13231	142226	52133	676649	1352	287258	12855	328464	103751	136209	39237	86628	620111

Table 6.5 Estimated total catches in 1995 and '96 (kg), subdivided by gear type (gear code names in Table 6.2) abd soecies (species code names in Table 5.2), at the Indonesian River Lempuing study site.

Species	Group Barrier Gears				Group Seine Gears				Individual's Gears						
	KL	EL	TU	CO	NK	NR	NP	NL	JR	PR	BB	BK	SE	RA	TL
AT	1941	0	166	0	5274	0	0	0	1099	0	507	2609	0	0	1724
BB	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	0	293	0	0	0	0	0	0	0	0	0	0	0	0
BM	0	0	607	0	0	0	0	0	0	0	0	0	0	0	0
BS	1036	8482	456	15	0	0	0	0	2204	89	46	0	0	0	0
C	27752	13444	38952	13656	2459	8686	2297	20194	245	0	0	0	0	516	688
CA	10180	11285	166	544	8197	737	3511	0	548	0	0	0	0	0	0
CB	0	291	285	0	0	0	0	0	674	0	703	0	0	0	506
CD	420	0	0	0	0	232	0	0	48	269	812	1203	0	0	0
CK	0	0	0	0	0	5259	0	0	0	0	0	0	0	0	0
CL	0	0	48	0	0	0	0	0	0	0	2025	0	0	0	0
CM	2720	615	53	0	166	0	4161	0	189	423	0	0	0	60	0
CN	0	0	223	0	0	0	0	0	0	0	0	114	0	0	0
CO	12439	248	1164	1819	0	2895	0	0	0	0	0	0	0	0	0
CS	1385	6210	315	1214	32731	851	15426	0	475	5156	36222	4717	0	4726	121090
DO	1090	15594	2585	949	0	0	0	0	1914	0	0	0	0	0	0
HA	0	0	0	0	0	2320	0	0	404	0	0	0	0	0	0
HM	1752	0	0	0	0	0	0	0	1318	0	0	0	0	0	0
HT	50082	3774	823	1132	60550	11027	22365	0	44213	12590	2665	10986	0	0	0
L	15469	23695	11303	3399	11091	3982	2591	0	967	45	474	229	0	0	0
LH	601	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA	0	59	0	18	0	0	0	0	0	0	0	14669	0	0	0
MN	11340	7201	58934	14693	2153	0	7663	0	3687	0	0	0	0	18457	2559
MR	330	294	4286	2223	0	0	0	0	0	0	2112	0	0	0	0
MU	0	0	148	0	0	0	0	0	46	0	0	0	0	0	0
MV	43194	36620	24410	5442	133	4613	0	0	26	0	0	0	0	0	0
NN	1889	4463	1195	190	1280	0	12916	0	1057	368	0	0	0	0	0
O	279	778	401	24	886	4873	0	0	4	0	0	0	0	0	0
OH	28568	146115	12535	2080	5687	18665	11320	0	11442	34	0	134	33380	0	0
OM	0	95	0	0	0	0	0	0	508	0	141	0	0	0	757
OV	629	0	4764	0	0	0	0	0	4	0	0	0	0	0	0
P	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PF	177	4091	4912	0	12851	147	0	0	4	292	0	0	0	0	0
PG	0	1857	0	0	0	0	0	0	2780	0	0	0	0	0	0
PH	0	0	0	0	0	0	0	0	0	0	0	134	0	0	0
PM	29416	3835	1672	2469	0	0	0	0	0	0	0	0	0	0	0
PP	0	0	3824	0	0	0	0	0	0	0	0	0	0	0	0
PS	463	471	231	0	0	0	0	0	0	0	0	0	0	0	0
PT	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R	4360	782	8202	1067	0	0	3372	0	0	255	0	0	0	0	0
RA	10283	1195	4290	1063	25701	0	0	0	0	0	0	0	0	0	0
S	2354	2187	2775	0	5407	0	4577	0	473	0	0	0	0	0	0
SL	0	0	1454	0	0	0	0	0	0	0	0	0	0	0	0
TP	43955	22758	3206	0	12272	5975	0	0	1884	0	0	17762	0	0	0
TR	37885	3101	0	0	32530	1160	21475	0	17002	1614	1083	55510	0	0	0
TT	11134	1621	0	297	5539	0	5583	0	0	0	0	1832	0	0	0
WL	0	0	3207	579	884	0	4602	5049	595	197	0	0	0	585	412
Total	353130	321161	197927	52873	225791	71422	121859	25243	93810	21332	46790	109899	33380	24344	127736

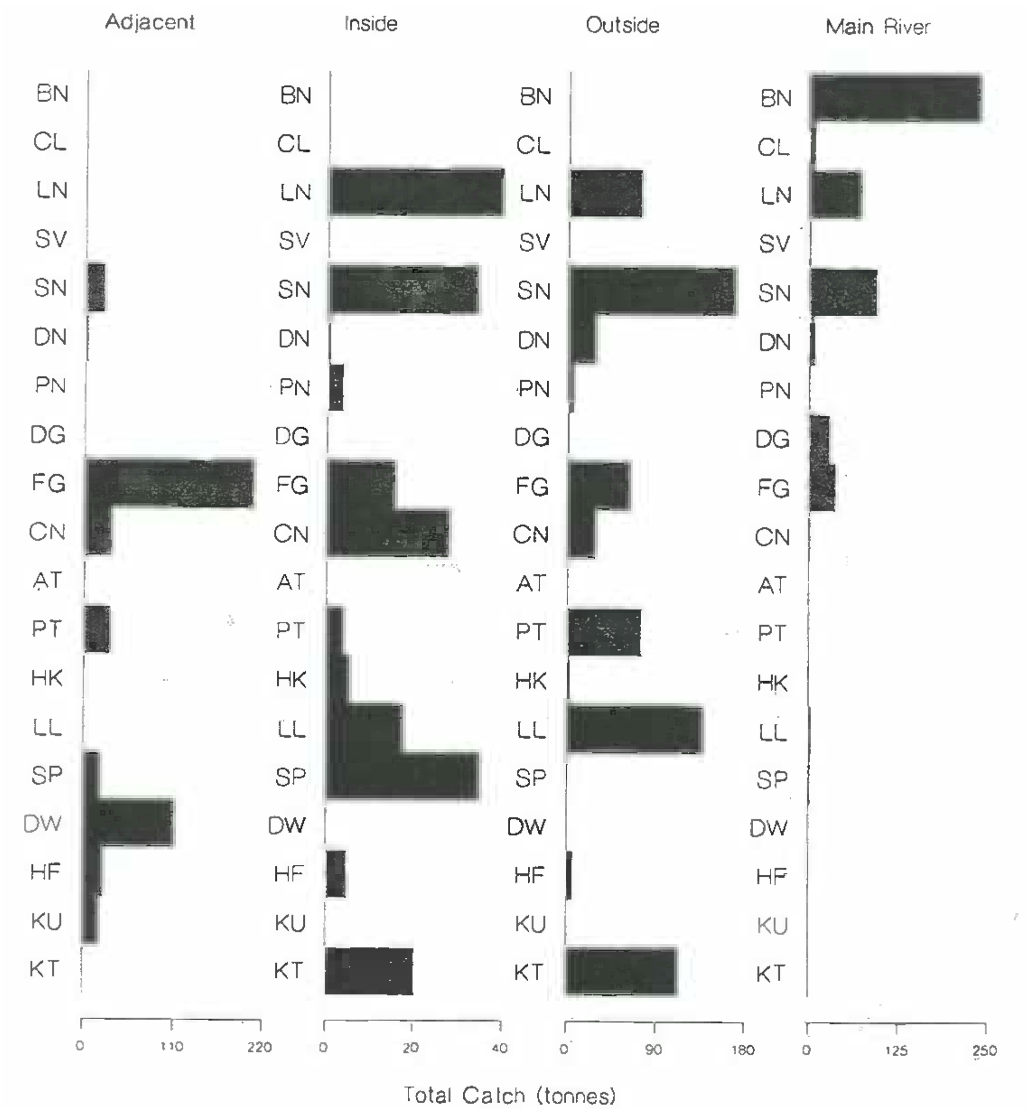

Figure 6.1 Estimated 1995 total catches (tonnes), subdivided by gear type (gear code names in Table 6.1) and study region, at the Bangladesh study site.

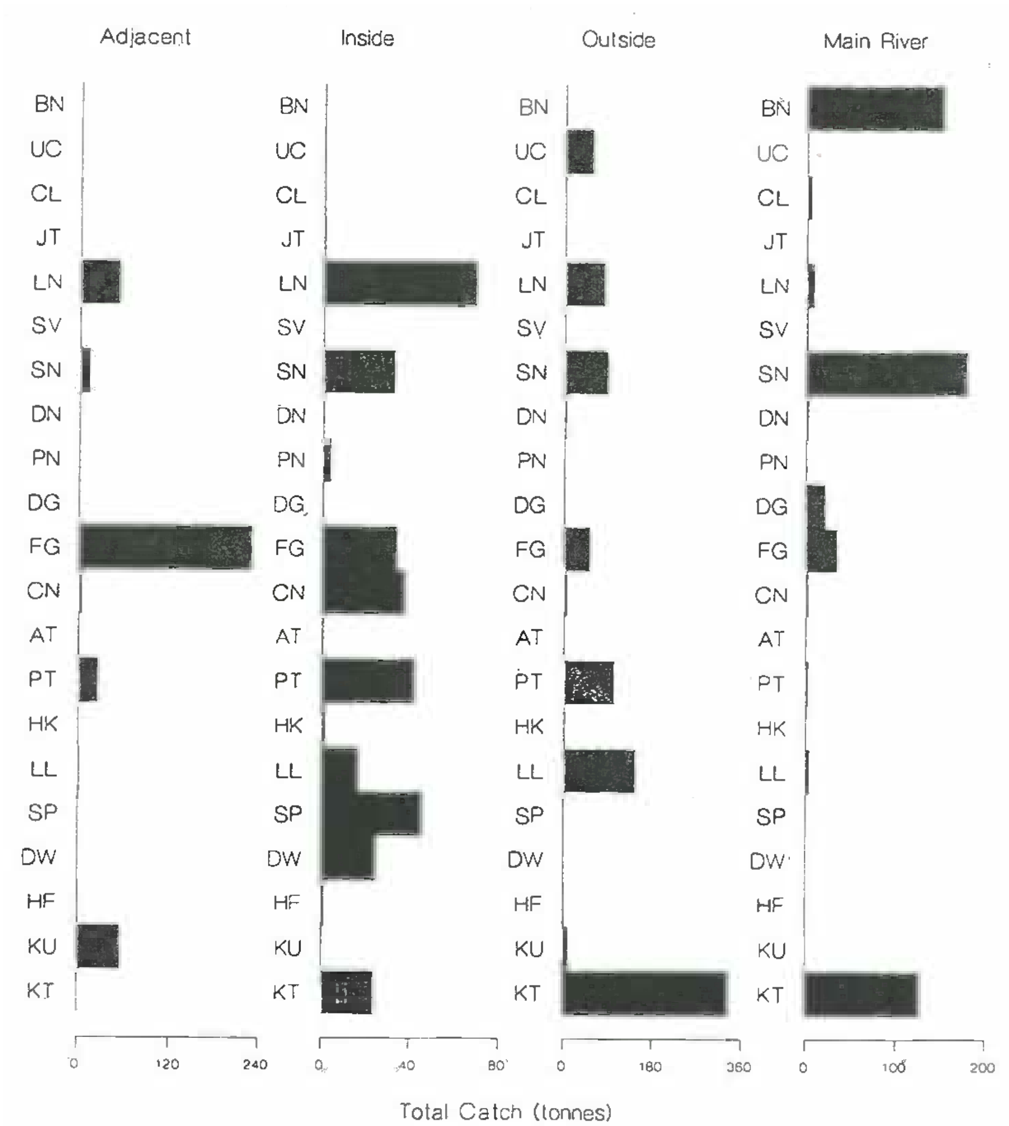

Figure 6.2 Estimated 1996 total catches (tonnes), subdivided by gear type (gear code names in Table 6.1) and study region, at the Bangladesh study site.

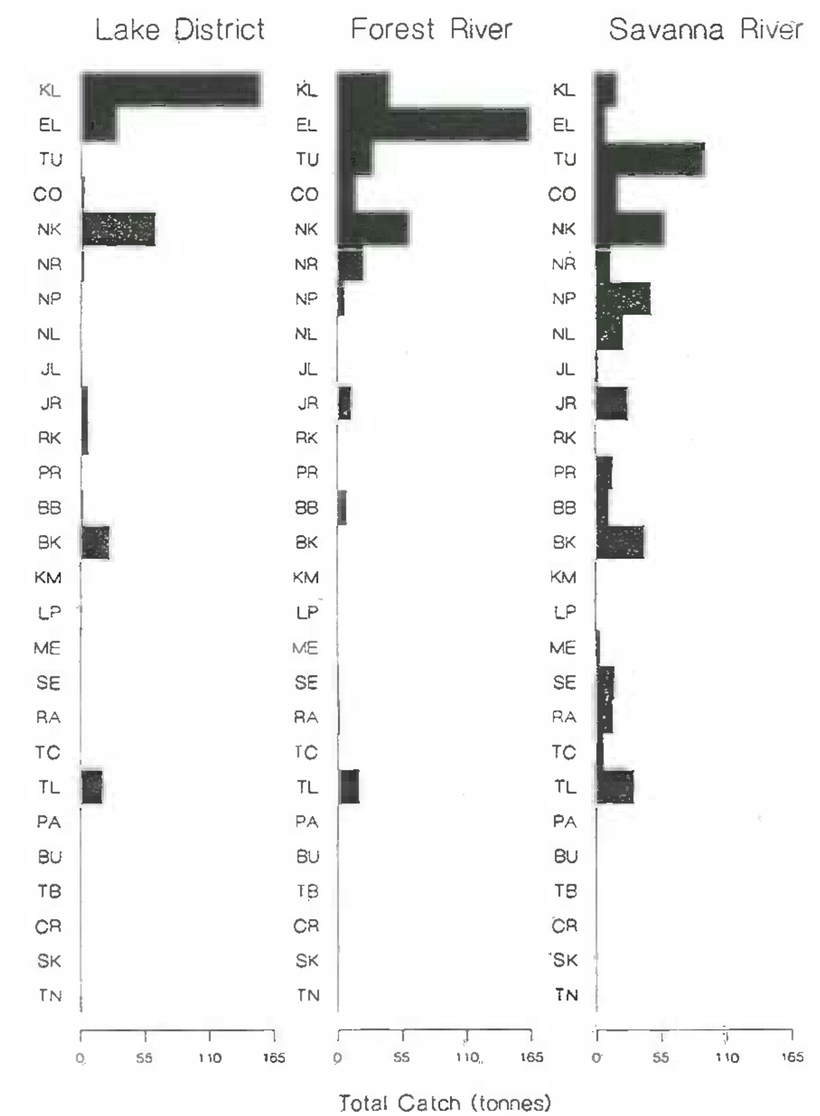

Figure 6.3 Estimated 1995 total catches (tonnes), subdivided by gear type (gear code names in Table 6.2) and study region, at the Indonesian study site study site.

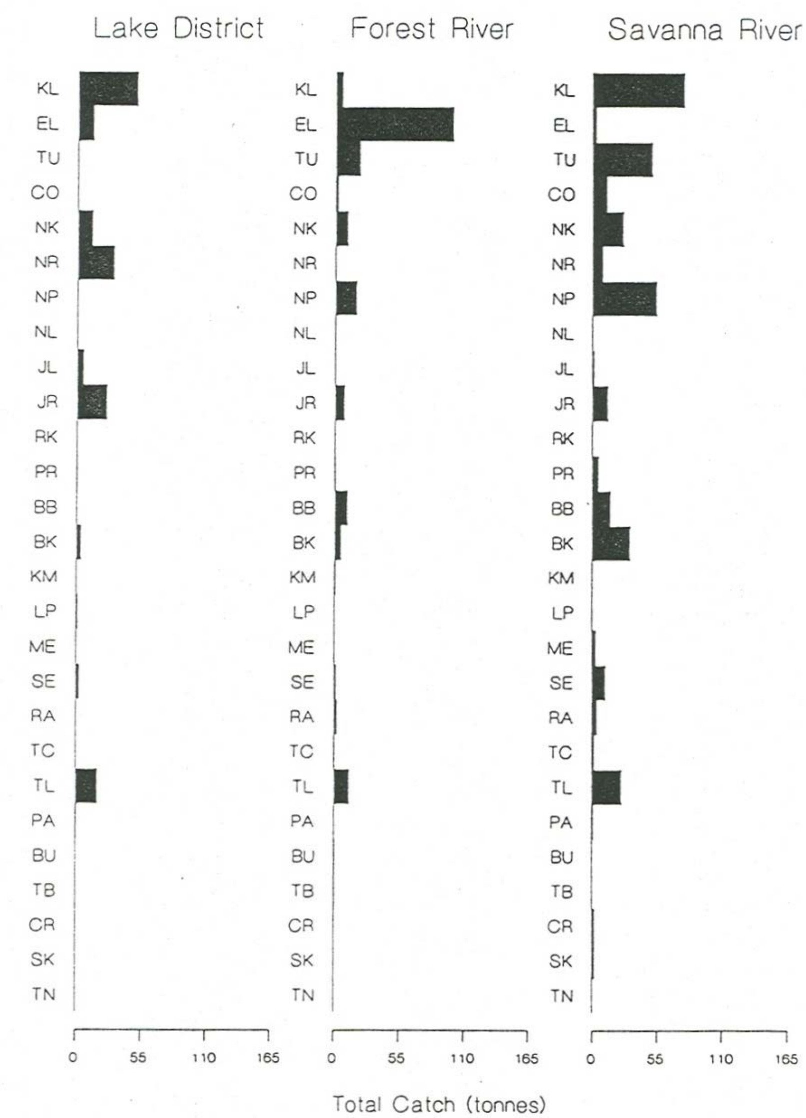

Figure 6.4 Estimated 1996 total catches (tonnes), subdivided by gear type (gear code names in Table 6.2) and study region, at the Indonesian study site study site.

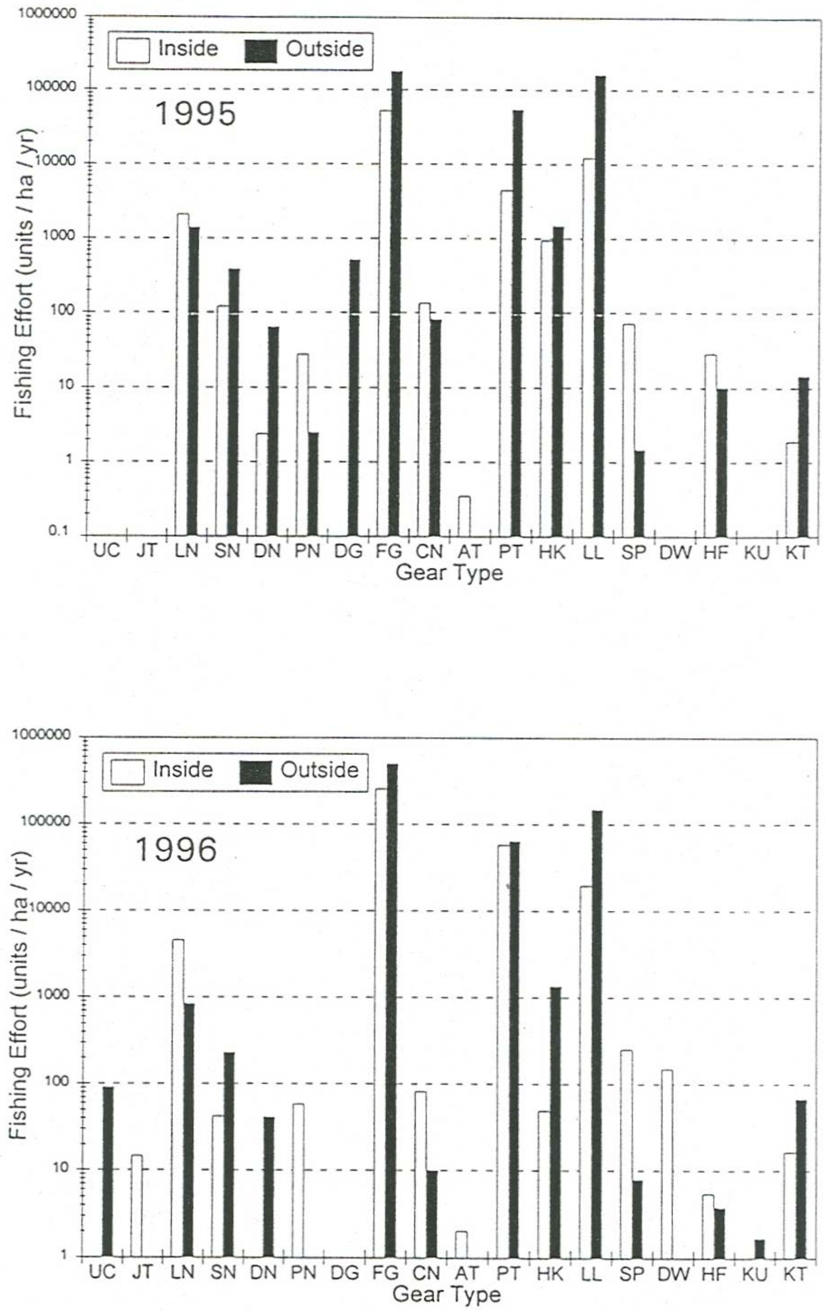

Figure 6.5 Estimated fishing efforts-per-unit-area (EPUA, gear unites / ha / year) for 1995 and 1996, subdivided by gear type (gear code names in Table 6.1), for the Insode and Outside regions of the Bangladesh study site.

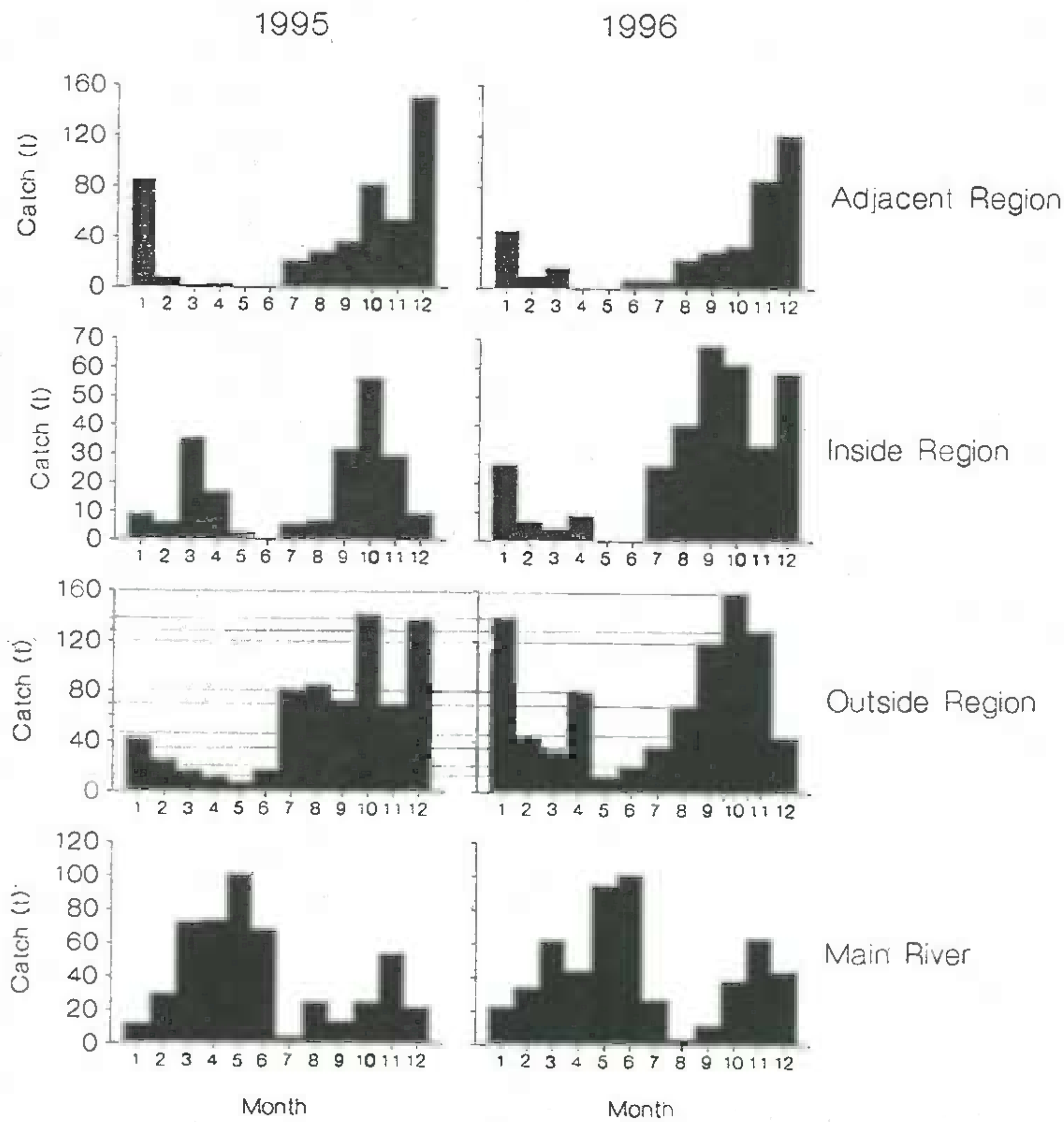

Figure 6.6 Estimated monthly catches (tonnes) during 1995 AND '96, subdivided by study region, at the Bangladesh study site.

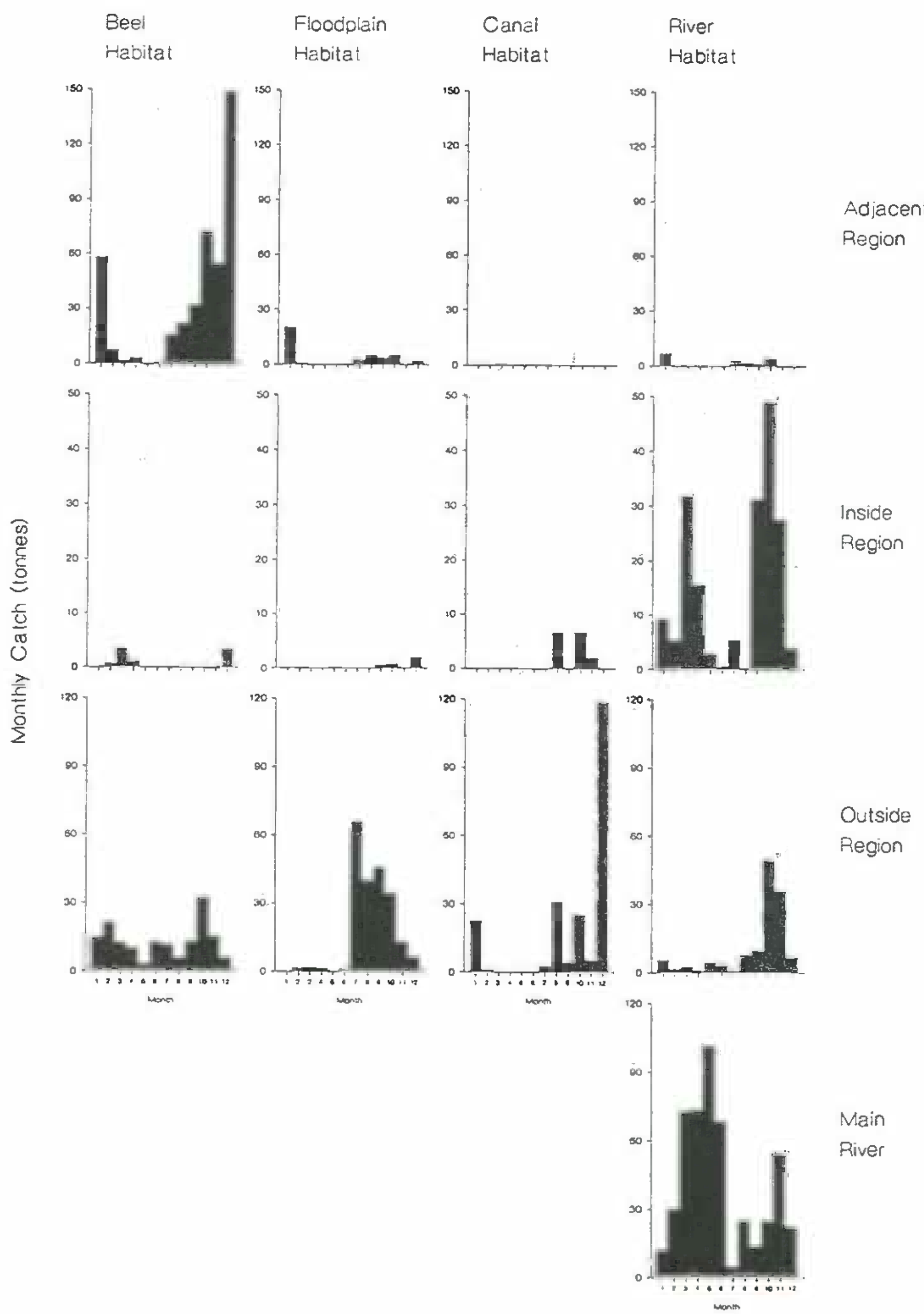

Figure 6.7 Estimated monthly catches (tonnes) during 1995, subdivided by habitat type and study region, at the Bangladesh study site.

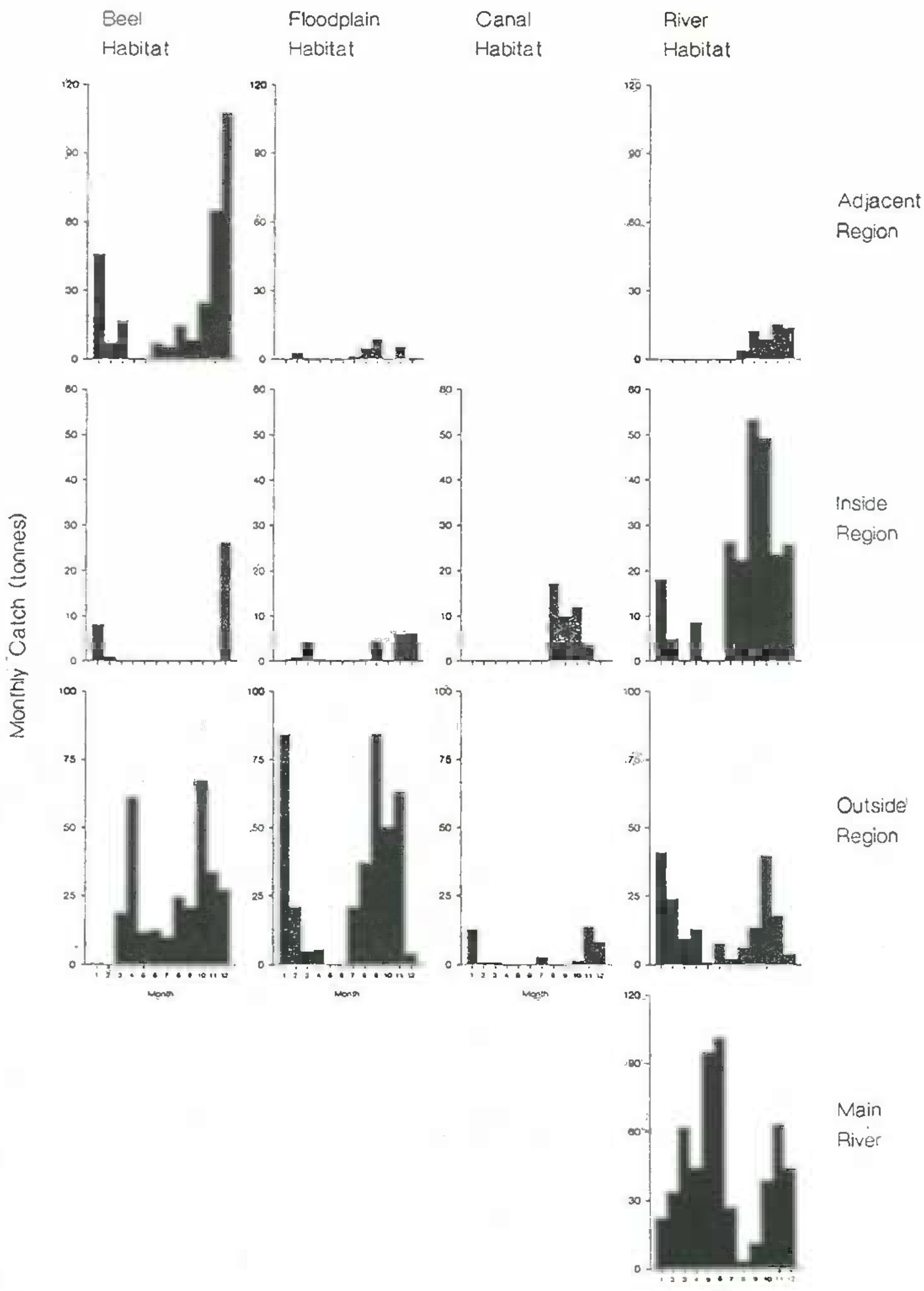

Figure 6.8 Estimated monthly catches (tonnes) during 1996, subdivided by habitat type and study region, at the Bangladesh study site.

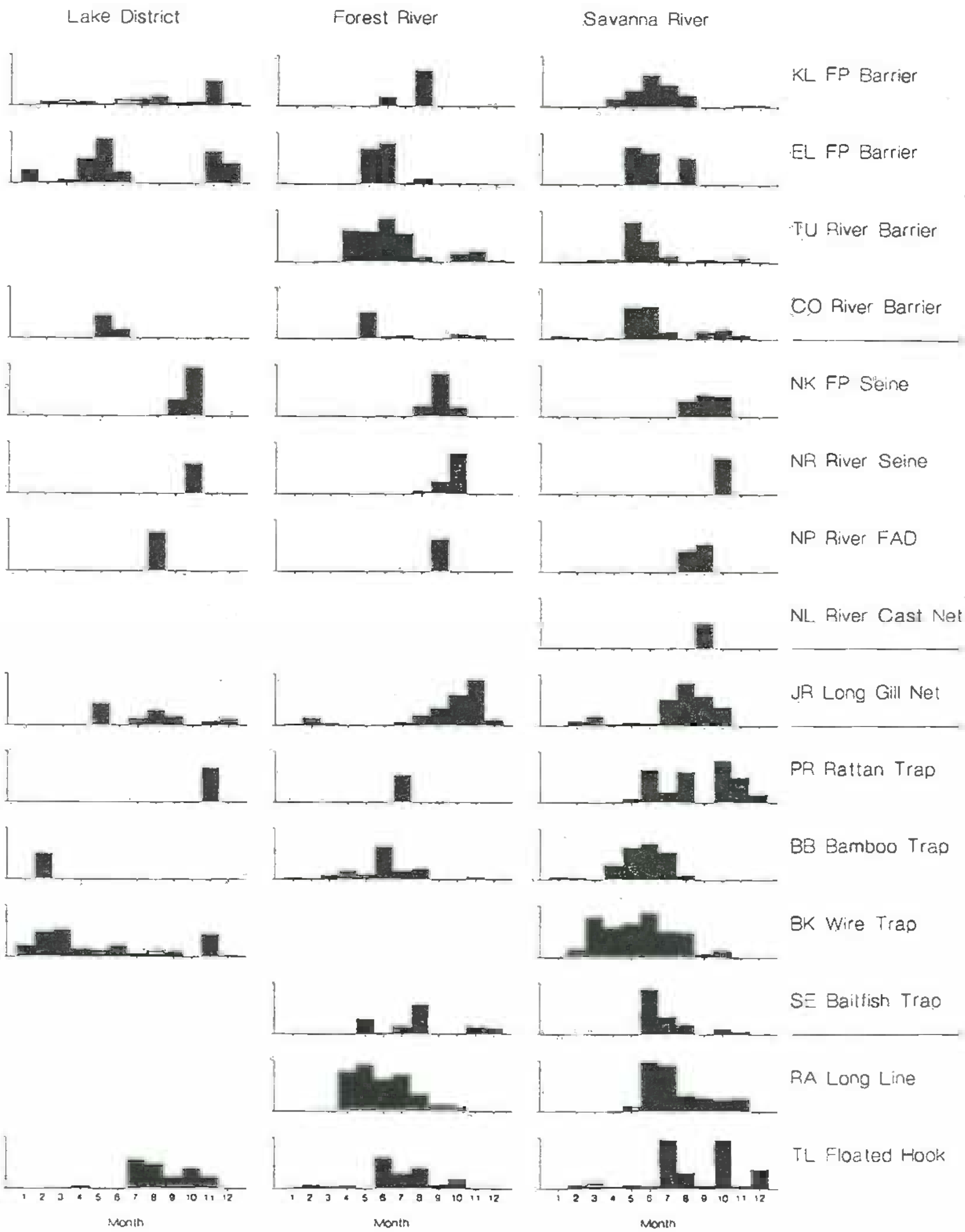

Figure 6.9 Estimated monthly catch (tonnes) during 1995, subdivided by study region habitat types and gear types (codes given in Table 6.2) at the Indonesian River Lempuing study site.

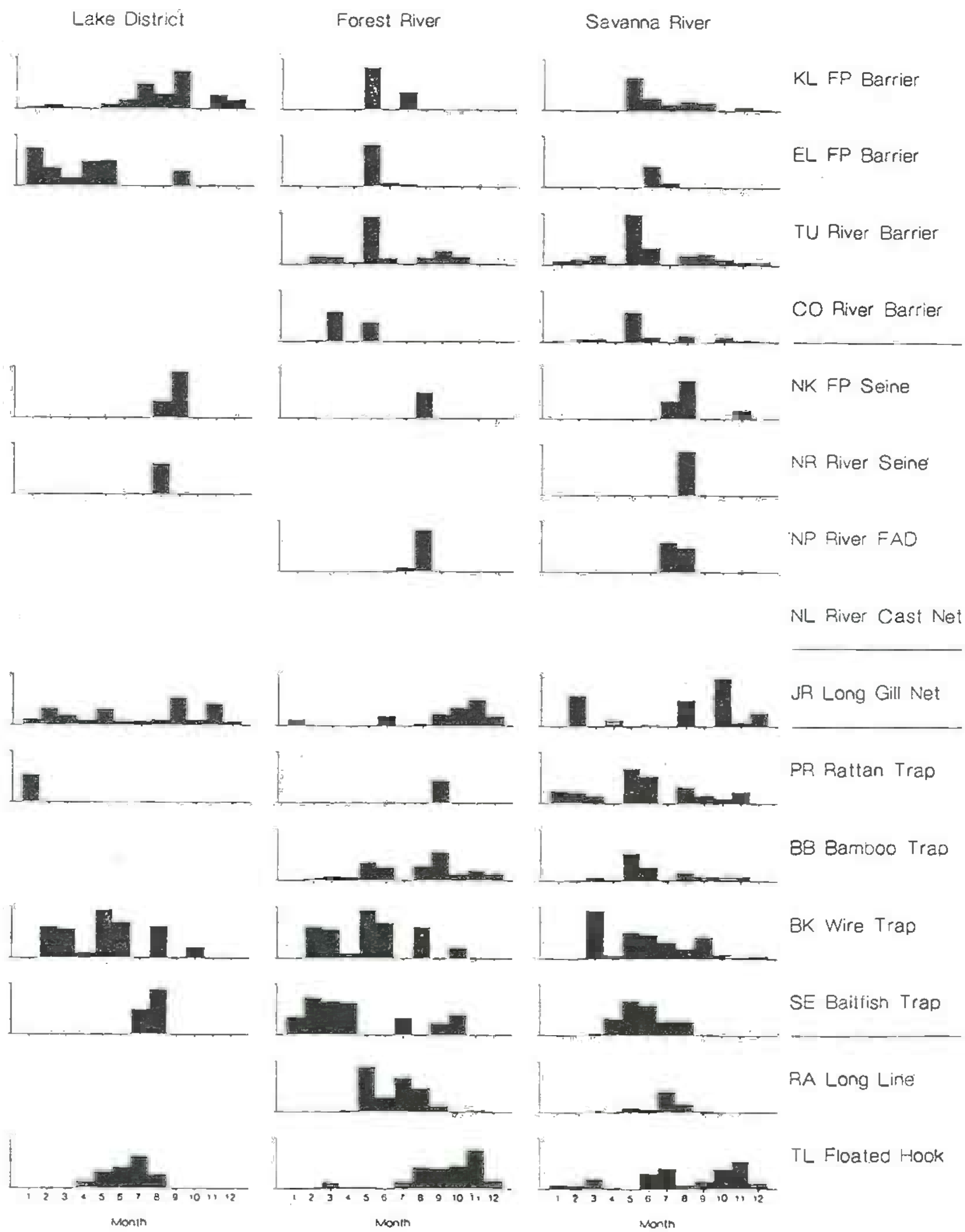

Figure 6.10 Estimated monthly catch (tonnes) during 1996, subdivided by study region habitat types and gear types (codes given in Table 6.2) at the Indonesian River Lempuing study site.

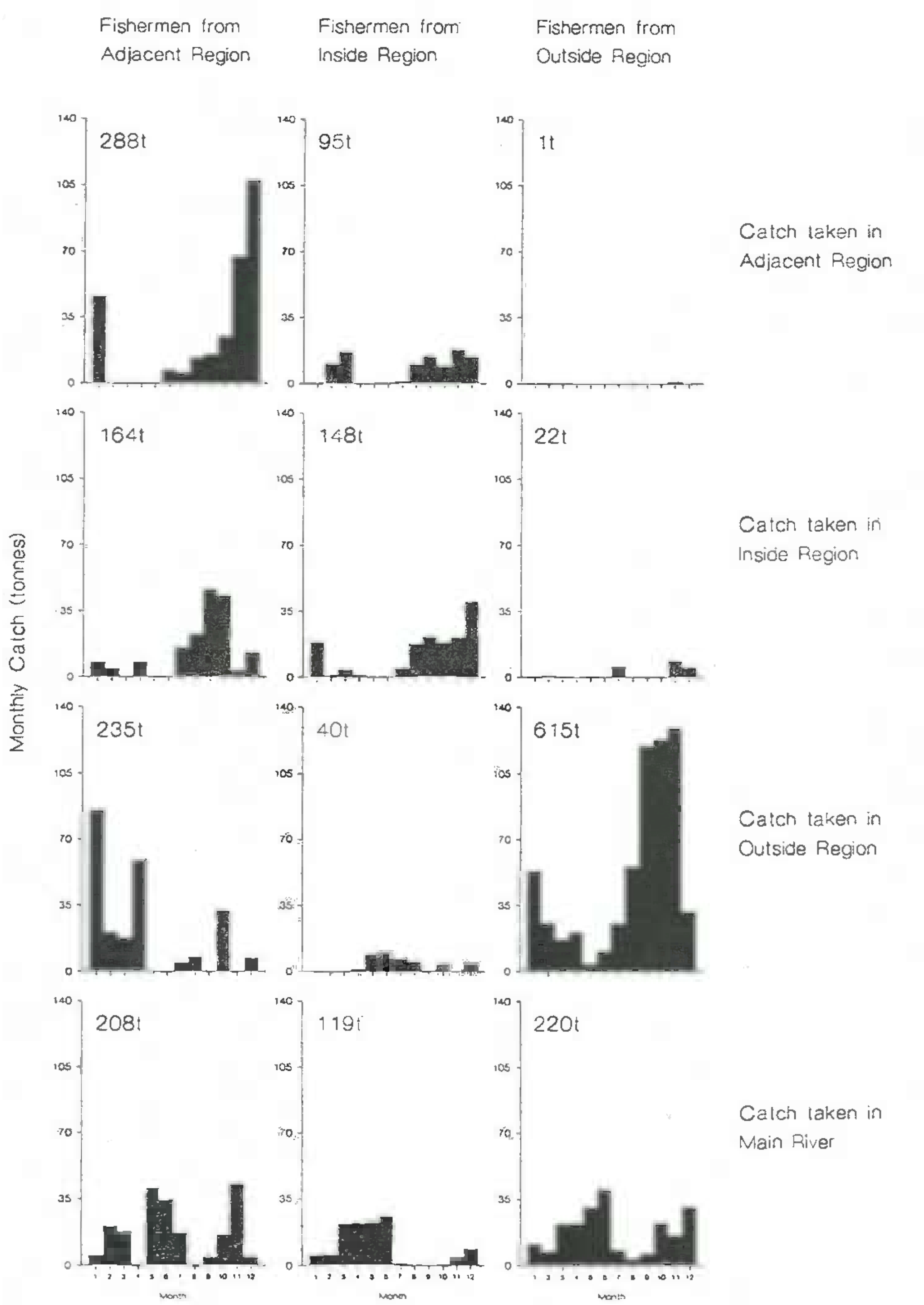

Figure 6.11 Estimated monthly catches (tonnes) during 1995, taken in the four capture regions by fishermen from the three residence regions, at the Bangladesh study site.

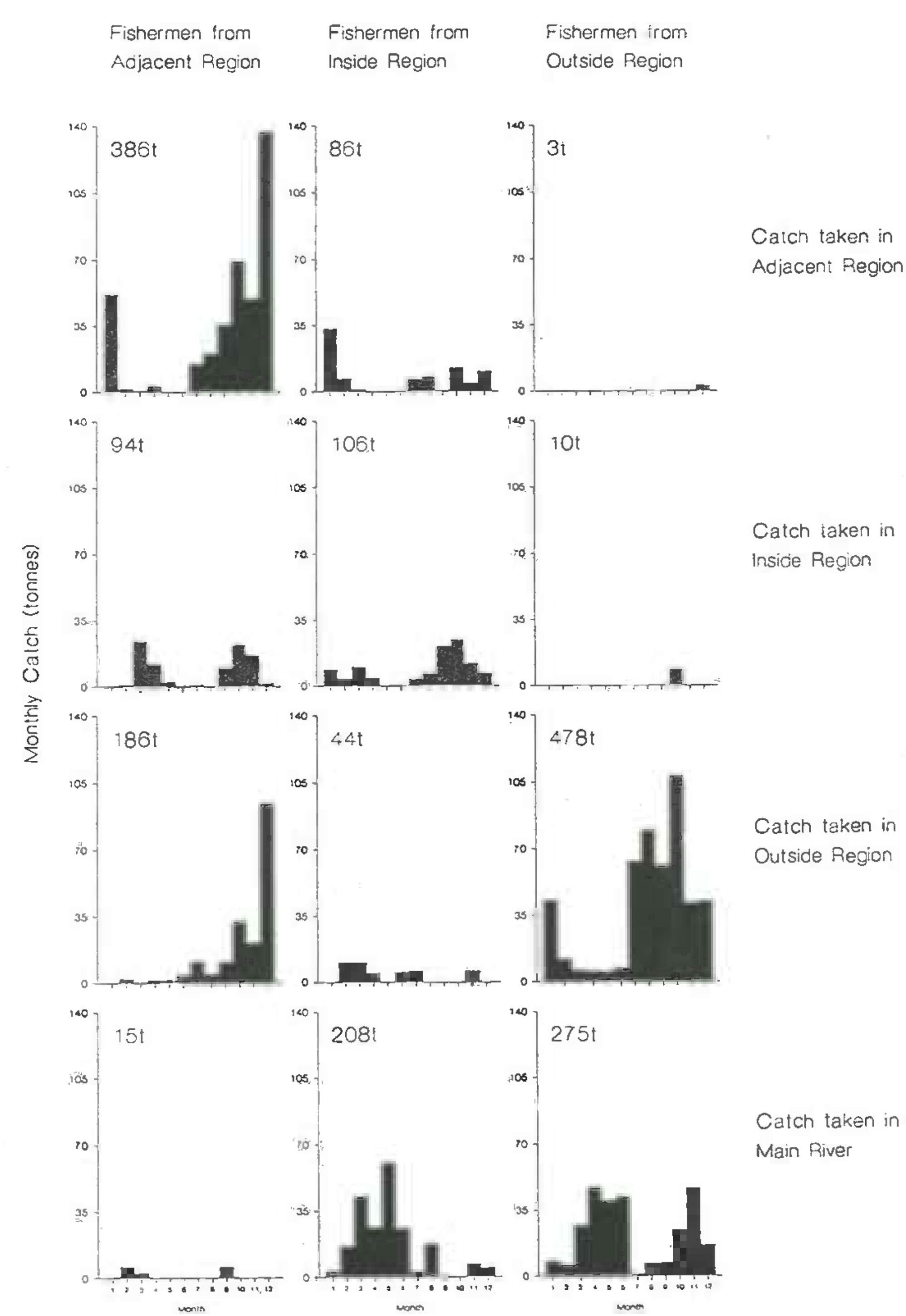

Figure 6.12 Estimated monthly catches (tonnes) during 1996, taken in th four capture regions by fishermen from the three residence regions, at the Bangladesh study site.

7 Floodplain River Fisheries Management

7.1 Introduction

This section reports the management approaches presently used at the two study sites, and then discusses the management implications of the results arising from this project.

Management strategies presently used for floodplain fisheries in Asian rivers are mainly based on spatial licensing systems, with some technical regulations, many of which are ignored and/or effectively un-enforced. The effect of fishing in Asian inland fisheries is not well understood by local management agencies. Kottelat et al (1993), for example, list fishing as a threat to the stocks of the W. Indonesian region (along with deforestation, pollution and other factors), but mention only that the use of explosives and poisons are the main threats. This impression has clearly followed through to the fishery management agencies with only these concerns addressed in the fisheries legislature.

An earlier ODA Project R4791 'Poverty and Sustainability in the Management of Inland Capture Fisheries in S. and SE. Asia' demonstrated that even more restrictive technical measures - such as overall reductions in fishing effort, gear bans, mesh size changes or fish size limits, and high water closed seasons - would produce little overall gain in productivity, but would instead cause strong reallocations of catches between different gear types. With different gears often owned by different sectors of the fishing community, such technical measures were largely seen as a potential source of dispute among fishing communities for little real benefit (MRAG, 1994a; Hoggarth and Kirkwood, 1996; Hoggarth 1994).

Following such previous conclusions, this project has sought to find simple management recommendations, with strong potential gains for the fisheries that are easily demonstrable, acceptable and enforceable. A common sense approach is taken, aimed largely at increasing recruitment levels in floodplain fisheries rather than changing the exploitation patterns of the existing fisheries in major ways. Due to the almost annual fish stock dynamics described in Chapter 5, a precautionary approach is also recommended for the conservation of these fisheries, already experiencing losses of some valuable fish species due to 'ecosystem overfishing' (Pauly et al, 1989).

Approaches are currently being tested in many countries for the 'enhancement' of inland fisheries, mainly using habitat restorations (see Cowx, 1994) and fish stocking (MRAG, 1997). Such measures are, however, usually prohibitively expensive to apply on a large scale for poor developing countries, unless supported by external funding. This project therefore concentrates on management measures which may provide stock conservation and enhancement at minimal costs, by simple changes in local practices. As described later in this section, such measures will require the strong cooperation of fishing communities.

In Bangladesh, hydrological modifications carried out under the Flood Action Plan have been shown in Chapter 5 to reduce the productivity of impounded floodplains, by reductions in their accessibility. Their inherent capacity for production has, however, been shown to be undiminished. Measures are therefore also discussed in this chapter by which fish recruitment may be further enhanced in modified floodplains, by hydrological management at the existing sluice gates.

7.2 Spatial Licensing

The spatial licensing of fisheries is used in many Asian waters, including both the study sites. Previous chapters have shown that such licensing has little conservation value, due to the competitive nature of the fisheries, enhanced by the mobility of the fish. This section describes the licensing systems in the study sites, with brief reference to those elsewhere, to determine their utility in these fisheries.

7.2.1 Fishing in licensed jalkars - Bangladesh

In Bangladesh, many natural waterbodies are leased as 'jalkars' by the Ministry of Land's Revenue

Section 9. Larger waterbodies (>8ha) are administered by the district level offices, and smaller waterbodies by the thana or union level offices. Man-made canals, in contrast, may be leased more informally by their builders, including the Water Development Board and the Roads and Highways Department of the Ministry of Communication. Some small waterbodies are privately owned, following historical claims, and either leased or fished by their owners. Jalkar and other leases usually run for one year, starting on the 15th April (in Baishak, the first month of the Bangladeshi calendar). Waterbody auctions take place at the end of the year, during the month of Chatra. Some waterbodies are occasionally leased for three year periods.

In leased waterbodies, the leaseholder either fishes the most effective gears himself or sub-leases the rights to fish these gears to other (usually professional) fishermen. Gears in this category may include the stationary lift nets, bag nets and katha, and mobile drag nets and seine nets. For gears taking relatively small catches, fishing in the Pabna region is generally free, reflecting the generosity of the leaseholders towards community members operating on low profits margins. Free fishing may also be had on virtually all floodplain waters over the flood season, including lands privately owned for farming during the dry season. This accessibility has resulted in the strong mobility of Bangladeshi fishermen, discussed in the last chapter.

In the Pabna study site, 14 defined waterbodies are leased as jalkars (Figure 7.1). These jalkar waters include three long sections of the main rivers, 66% of all the location codes in secondary rivers, 15% of the beels (especially the deeper, perennial beels), and 10% of the canal locations. Floodplain waters are not included in any jalkars. Of the 14 jalkars, 10 were fished at some time during 1995 by the 40 project catch/effort respondents. On average, the respondents fished in 2.1 different jalkars each (range 0-7) over the year. Fishing in jalkars was at its highest during the dry season months February to June (71% of the gear-days fished by respondents at this time), particularly within the main river jalkars. Other jalkars in home regions were fished during the drawdown months. Jalkars were least fished during the high flood season (25% of the gear days fished from July to September 1995), when more fishing is done on the unlicensed floodplains. All of the fishing gear categories recorded in 1995 were used both in jalkar waterbodies and in unleased waters, indicating the relatively open access of Bangladeshi leasing units to all types of fishermen. The license fees for Bangladeshi jalkars in the project area range from only Tk725 to over Tk150,000 for the largest jalkar in the main river. Total license fees collected at the PIRDP site were Tk201,000 and Tk374,800 respectively in 1995 and '96. Based on a low-season, mean, wholesale fish price of Tk50/kg[10], the total fish catches at the PIRDP study site were estimated to have first sale values of approximately Tk95m and Tk108m in 1995 and 1996 respectively. Total government jalkar license fees at the PIRDP site then amount to only 0.21 and 0.35% of total catch values in 1995 and '96 respectively.

7.2.2 Indonesian waterbody licensing systems

- **The River Lempuing auction system**

A waterbody licensing system was established in the Lempuing River system by the leaders of the Palembang kingdom in 1822, to avoid conflicts developing among fishermen (Depati H. Muh. Rawas, ex-head of Kayuagung marga administration, personal communication, 21 May 1996). In the Lempuing area, the current Indonesian administrative system was introduced in 1983, with the old marga being replaced by a more hierarchical government system. The Lempuing waterbodies defined in 1822 were maintained, however, for licensing by the new administrators, and are still used in today's auctions.

The waterbody auctions, or lelang, are now held on an annual basis and conducted by the head of

[9] The *jalkar* licensing system was abolished on 16 Aug 1995, by the then BNP government, in addition to the New Fisheries Management Plan introduced by the Fisheries Department in 1988 for licensing directly to 'real' fishermen. Confusion now exists, however, over which *jalkars* have been abolished, and the present Awami League government have yet to clarify the situation. During 1996 at the Pabna site, the 1995 *jalkar* owners continued to exert control, and charged sub-lease fees at the 1995 prices, even though they paid no license fees themselves!

[10] The use of a low-season mean price, compared to means of Tk68 and Tk96 in the early and late dry seasons, is approximately balanced by the lack of weighting towards the lower values of the more common smaller fish species.

each administrative district (kecamatan) under the supervision of Department of Fisheries regional (kabupaten) staff. The Indonesian auctions now appear to be viewed by local administrators mainly as a means of raising revenues. In 1983, the new administrators thus introduced a 'commodity flow' tax (usually applied for cars / toll roads) of 15%, on top of the auction fees. Minimum sale prices are also raised deliberately by administrators in some years by a standard percentage, often of 10-15% (data not presented). Substantial revenues are then raised in the productive Lempuing auctions, and up to 50% of kabupaten incomes may be derived from the licensing of these fisheries.

The Lempuing auctions are open to any bidders, including outside investors, and demand for licenses has traditionally been high. Fishery license fees for Kabupaten Ogan Komering Ilir (which includes the Lempuing River) rose dramatically by 290% from 1992 to 1996, having shown only gradual increases before that time (Dinas Perikanan OKI annual reports, data not presented). Based on a very rough calculation, using an average fish price of Rp1,500/kg, total license fees for Lempuing waterbodies in 1995 and 1996 were estimated to be 8.6 and 15.3% respectively of the total catches in those years. As described in Section 3.7.3, both the numbers of waterbodies licensed and the numbers of fishermen in them have declined in the most recent years. Total license fees for the Lempuing also peaked in 1996 at Rp164.9m (approx. £47,000), and declined in 1997 to Rp156.1m

Against this background, the Indonesian auction system in South Sumatra is now threatened by recent central government regulations. In 1992, Regulation 15 on fisheries stated that only 2.5% of the income from commercial fishing should be taken as tax, for distribution between central government (70%), and the provinces (30%). With no allocation to the kabupaten regencies (some of whom currently receive more than 50% of their income from licensing in South Sumatra), this regulation and the management strategies for these fisheries are now under dispute. There is also much confusion among Indonesian fisheries agencies about how a 2.5% tax on catches (as compared to a license for fishing) could actually be collected in these artisanal and dispersed fisheries. With these disputes and uncertainties, it seems likely that the auction will continue for the present time.

- **Other traditional Indonesian management systems**

In other localities in Indonesia, different systems exist for the management of floodplain river resources, usually well adapted to local conditions. Such systems have been studied in depth during Sub-Project 5, written up as Appendix G.

Spatial licensing was also found in the other localities, but usually at a village level, and undertaken with clearer understanding of local resource potentials, partly achieved by the representation of fishermen on licensing committees. In localities with smaller floodplain resources, closely associated with particular villages, some local communities had also developed additional management approaches designed for the long-term sustainability of the resources, and for social gains. Some villages restricted bidding at auctions to village members only, preferring local social benefits over maximum revenues. Other villages used 'sacred' reserve waterbodies, sometimes associated with traditional, ceremonial fishing days. Main river habitats were not protected in any way, though, and local communities clearly perceived their actions as benefiting local resources, especially of blackfish species, rather than the more shared riverine whitefish species (Appendix G).

In contrast, licensing systems in some other South Sumatran regencies have now collapsed, increasing fishing opportunities in the open access conditions, but reportedly decreasing the overall health of the fisheries. In kabupaten Ogan Komering Ulu, the waterbody auction system was suspended some time ago due to complaints by poor fishermen that the system benefited only the rich license holders. Regulations introduced on mesh sizes and closed seasons were inadequately enforced, and the open access conditions then reportedly led to stock declines and conflicts (including one murder), and of course, to no government income from licensing (Mat. Asim Makuddin, ex-head of OKU Dinas Perikanan, personal communication, 21 May 1996).

7.2.3 Duration of licensing

Most waterbodies in both Indonesia and Bangladesh are licensed for only one year periods, as preferred by fishermen due to the uncertain profitability of future seasons. Longer licensing periods have been considered for these fisheries to give fishermen a greater incentive to manage their own resources and achieve conservation goals. While such approaches may be useful for self-contained waterbodies such as ox-bow lakes (Middendorp et al, 1996), it is now seen that they would provide little benefit for the more interactive floodplain waterbodies due to the strong migratory behaviour of floodplain fish species.

7.2.4 Comparison of licensing systems

Spatial licensing systems are used as the main current management tool at both study sites, though with subtle local differences. In comparison to floodplain fisheries in both Bangladesh and other Indonesian catchments, the River Lempuing fishery may be seen as strongly commercially oriented, both from the view of fishermen and the licensing authority. The complete licensing system used in this catchment thus creates opportunities for very high catch rates per fisherman, by keeping the numbers of fishermen low, which in return allow much higher percentages of the catch values to be taken by administrators as licence fees. Such a system may be justified for the extensive River Lempuing catchment, where catches are large and the deeply flooded 'marga danau' is not associated with any single village. The high licence fees may also be seen as a fair way of distributing resource benefits more widely around the community from a relatively small group of licensed fishermen.

Alternative licensing systems are seen in other Indonesian localities. Where waterbodies were closely associated with villages, auctions were still used but steps were taken to ensure that license fees did not become excessive, and reserves and other measures were used to ensure the sustainability of the resources for future users. In Bangladesh, waterbodies appear to be less clearly associated with particular villages and only partial licensing is used for the largest waterbodies. Fishing is then much more freely available, especially over the high water period, and for the poorest fishermen using low-catchability gears at all times. License fees in Bangladesh are then a small component of the total catch values reflecting the lower marginal benefit of having a license when many opportunities are also available for free fishing. Lower license fees may also be seen as fair in such a fishery, in which the benefits are already widely distributed among the population.

With clear benefits to both fishermen and licensing authorities, it is interesting that the licensing systems are currently under dispute in both countries. Since both systems may be seen as fair, given the variable demands of the two countries, and since they also prevent conflicts between resource users and generate income, it is recommended that the license systems should be maintained at both sites. However, since neither of the two main license systems provide any conservation incentives, it is also recommended that they should be supported with additional measures, as traditionally used in other localities (Appendix G), and discussed in the following sections.

7.3 Reserves

Fishing reserves or refuges are increasingly being used throughout different regions of the world, particularly in the marine zone, both in open oceans (Shackell and Willison, 1995), and coastal areas (Polunin et al, 1983; Roberts and Polunin, 1991; Dugan & Davis, 1993). Reserves are more rarely used in river systems, but are becoming more common (Pinedo-Vasquez et al, 1992; McGrath et al, 1993). Reserves are particularly useful as a highly visible, easily understandable and enforceable means of controlling fishing effort, and may be applied in river fisheries in various ways.

Some river reserves are now established on vast scales, such as the 11,000km2 Projeto Mamiraua national park reserve in central Amazonia, and the 800km2 Danau Sentarum forest reserve on the River Kapuas lake district in West Kalimantan, both supported by ODA funding. Such approaches are expensive but provide the maximum conservation value to the most threatened species within a single catchment area. At both sites, traditional fishermen are encouraged to continue exploitation at sustainable rates, while acting as guardians of the resource.

Reserves may also be used on a much smaller scale, and for the deliberate purpose of enhancing fisheries. Enhancement may either be achieved by increasing the production of larvae and recruits, or by optimising exploitation rates on the overall stocks. In theory, little overall gains are possible in 'yield-per-recruit', but substantial gains may be achieved in 'spawning-stock-biomass-per-recruit', with potential increases in recruitment and stock stability (Polacheck, 1990).

To protect spawning capacity and maximise recruitment, reserves should be located in areas of critical life cycle phases, especially over the high-mortality dry season period, when fish are maturing in advance of flood season spawning. It is with this objective that reserves are recommended by this research within dry season waterbodies of floodplain habitats. It has been demonstrated in Chapter 5 that restraints on fishing activities towards the end of the dry season, which would reduce catches by only a few tonnes, could potentially increase recruitment levels substantially for the forthcoming season. Furthermore, since dry season restraint and year-round reserves are already used as traditional management measures in some Indonesian communities, it is evident that reserves are an acceptable means of management in these societies, which would not have persisted without some benefits. In Bangladesh, the use of dry-season dewatering is also reported to have been banned (equivalent to a dry-season reserve), though its use remains widespread in practice.

7.3.1 Year-round reserves

The empirical benefits of year-round reserves have been reviewed for relatively simple coastal areas by both Roberts and Polunin (1991) and Dugan & Davis (1993): gains due to reserves have been observed in some cases in both fish abundances and sizes. The potential of reserves for fish catches (allowing that some fish become unaccessible to the fishery in the reserve) depend on the reproductive output of the protected stock and the resulting recruitment to surrounding areas. The potential benefits to outside fisheries depend largely on the 'transport rates' of fish between the reserve and the fishery (Polacheck, 1990; Carr and Reed, 1993; DeMartini, 1993). Fish with minimal transport rates (mobility) are thus likely to be highly protected by a reserve, but to provide no benefits to outside fishermen. Conversely, fish with high mobilities may not be protected by small reserves because their migrations take them too frequently into exploited areas. Fish with intermediate mobilities show the greatest potential to produce benefits for fisheries outside.

At the project sites, fish have been observed with low, medium and high levels of mobility. It is clear that year-round reserves would do little to conserve floodplain fisheries, except for the most resident blackfish species, unless applied on a large scale (as for example at Mamiraua and Danau Sentarum) to provide full protection to all life history stages (McDowall, 1984). Many floodplain fish are, however, clearly well adapted to survive very high levels of mortality, and the high demand for fish catches and employment justifies continued exploitation wherever possible.

7.3.2 Dry season reserves

While year-round reserves may not be justifiable in fishing areas, temporary restrictions over the dry season may be recommended both to ensure that some fish do survive, and to enhance the next year's catches. The potential increases in reproductive output of fish in reserved dry season waterbodies has been shown to be high in Bangladesh floodplains from the ratio of natural and fishing mortality rates. The distribution of new recruits from such waterbodies is also a natural process following the waters of the new flood. At an intuitive level, reserves are therefore recommended for dry season waterbodies of floodplain rivers both to protect spawning stocks for precautionary conservation, and potentially to enhance floodplain catches due to increases in recruitment.

Since fishing mortality levels are lower in Indonesia than in Bangladesh, dry season reserves may provide less benefits in that fishery. Some implementation of reserves is, nevertheless, recommended on precautionary grounds, due to the declining water levels seen at that site, and the strong variability of dry season depths (Chapter 4).

7.3.3 Numbers of dry season reserves

The absolute numbers or areas of reserves required for floodplain resources has not been investigated in this project, nor by other workers, reflecting the complexities of the multispecies, multi-habitat floodplain resources.

In general terms, however, the optimum designs of reserves again depend on transport rates and the objectives of the reserve. For recruitment enhancement of fish with relatively low mobility, many small reserves are recommended by Polacheck (1990) for their high boundary to area ratios, giving the maximum possible output. For the same reasons, when conservation is the objective, one large reserve may give better protection than many small ones (Diamond, 1975; Picket and Thompson, 1978; Shafer, 1990). For practical and social reasons in floodplain resources, it is recommended that many small dry season reserves would be most likely to produce significant enhancements of fish stocks. Since the fisheries are strongly interceptory, and mobilities were usually not observed over a few kilometres, it is concluded that reserves would only 'seed' surrounding areas up to a small distance away from them. As an initial recommendation, reserves at least every 5km or so would probably be worthwhile.

For social reasons, since both fish and fishermen are mobile on floodplain waters of Bangladesh, it would also be most equitable for all communities to contribute in some way to the reserved dry season stock. With a recognised programme of 'local action for national benefits', more communities would be likely to consider sacrificing some of their dry season catches (knowing that some of their fish would migrate to adjacent villages next year), if they knew that their actions were being complemented by equivalent actions (and return recruitments next year) from other nearby villages. Unilateral declaration of reserves would provide some benefits to local fishermen but would, no doubt, also attract fishermen in from other surrounding areas, if catches were seen to be improved.

7.3.4 Locations of dry season reserves

The optimum locations for dry season reserves are obviously in waterbodies where fish are known to survive over the dry season, and also from which fish subsequently distribute into the exploited stock in the following year. In Bangladesh, the larger perennial beels and river sections have been identified as key survival habitats, both inside and outside the FCD/I embankment. In Indonesia, the wider downstream Savanna river sections provide higher survival than the upstream Forest river: the large waterbodies in the Lake district also allow good survival. Interaction between the lake and river habitats is limited to a subset of the fish community, however. The existing DOF year-round reserve at Teluk Rasau in the Lake region (Figure 3.2) may thus provide conservation and enhancement of species such as H. temmincki and O. hasselti, but probably gives little gains for other species. Additional reserve waterbodies are thus also recommended in riverine habitats, particularly in the downstream areas. In general, due to the habitat preferences of different species, and their variable migrations and distributions across catchments, dry season reserves should be implemented in several different perennial waterbodies throughout the catchment. A catchment with only a single reserve waterbody - even a large one - is unlikely to achieve benefits across its full area.

7.3.5 Implementation of dry season reserves

Dry season reserves could be implemented in various ways, including (1) a specified closed season period, (2) a flexible closed season period depending on water levels or (3) bans on the most exploitative dry season gears, such as dewatering and fish drives. Partial restrictions could also either be placed on all waterbodies, or full restrictions be placed on only a few waterbodies. The types of management strategies appropriate for a given area depend strongly on its hydrological characteristics, and the distribution of the stock during the dry season. Due to seasonal variations in drought conditions, encouragement of end-of-season restraint in one large waterbody may provide more escapement than complete closure of several smaller waterbodies, if these subsequently dried out in some years.

On the social side, since the early dry season usually provides a strong catch opportunity in floodplain fisheries, for license-paying fishermen in both countries, closure of the full dry season fishery would be both unacceptable and probably unnecessary. Due to the diversity of resources and the demands of the fisheries, the traditional knowledge and participation of local fishing communities should thus be fully utilised in both the selection and implementation of reserve waters in their local areas (Section 7.7). Starting with a low number of reserves, and monitoring the catches from them, would enable communities to adapt their selections to provide maximum gains, after confirming the benefits they received.

In summary, this project recommends the more extensive use of dry season reserves as a conservation and enhancement measure, based on their theoretical potential gains and minimal costs to the fishery during the end-of-drought period. The actual benefits available to these fisheries from reserve waterbodies will be investigated in future FMSP research projects. Approaches for the implementation of reserves will also be investigated in future research, in collaboration with target institutes and fishing communities.

7.4 Closed Seasons

Previous research (MRAG, 1994a) has investigated the benefits of closed seasons over the high water period, intended to reduce growth overfishing, and improve the yield-per-recruit from floodplain fisheries. Over the high water period, a closed season was shown to give some benefits in size of fish, but little benefits in overall catches. Strong and socially unacceptable catch reallocations were also seen, predictably from those fishermen currently active in the high water season, to those currently active during the drought (Hoggarth and Kirkwood, 1996).

The current research project has investigated the possible benefits of partial closed seasons in the form of dry season reserves. The benefits of this type of closed season are anticipated mainly in the form of increased recruitment from the extra spawning stock available at the end of the dry season. Such benefits are far more difficult to predict due to the uncertainties in the stock-recruit relationships, and density dependent mortalities of the many fish species. This research has, however, indicated that very large gains are potentially available.

Like a high water closed season, dry season reserves would also have some allocative implications for the fishery. The licensed fishermen usually active over the dry season would need to make the main sacrifices. However, with a sacrifice of only a few tonnes in the dry season, catches in following years could potentially be, for example, doubled for all fishermen from the extra recruitments. Since licensees are generally the richer members and leaders of the fishing communities, it may be possible to encourage some restraint towards the end of the dry season, for the improved status and regard this would generate for them among poorer community members.

7.5 Management of Barrier Traps and Accessibility

While dry season reserves are strongly recommended by this research, it has also been shown that reserves do not protect all species, with species compositions being most depleted towards the end of the dry season. It has also been concluded that the biodiversity of modified FCD/I schemes in Bangladesh is maintained by their partial accessibility to outside fish through the sluice gates. Measures to protect the accessibility of modified floodplains are therefore recommended wherever practical (Rahman et al, 1996).

In addition to the management of sluice gates themselves (Section 7.6), restraint should also be encouraged on fishing activities wherever the stock is constrained to pass through a very narrow channel (especially at the sluice gates). Sacrifices of flood season lift nets at the sluice gates, taking small fry entering the FCD/I scheme, could thus benefit many more fishermen over a much wider area once inside, particularly if allowed to grow before capture. The largest catches of the bag net fishermen during the drawdown season probably could not be restricted.

As a general principle, it also seems sensible to protect the movements of those fish migrating towards their spawning grounds, especially in floodplain fisheries when such pre-spawners may be very low in numbers. The increasing use of barrier traps in Indonesia has thus been raised as a source of concern, given the declines in certain riverine species (Hoggarth & Utomo, 1994). This project's information on the riverine barrier traps, corong and tuguk, in the River Lempuing has confirmed that these gears are mainly responsible for the catches of pre-spawning fish, certainly more so than the traditional, lateral kilung and empang traps between the rivers and the floodplains. The most migratory Indonesian fish have been shown in Chapter 5 to suffer the highest levels of fishing mortality, largely from these gears, though stock structures are still healthier than in Bangladesh. Given the declines in prawn stocks and other riverine species in Indonesia, some degree of control may be required in the future.

To ensure the successful migration of pre-spawning fish to their spawning grounds in the River Lempuing, it could thus be recommended that some restrictions be placed on penetak barrier traps, particularly during the rising water period, perhaps from August to December. Such regulations would enable river barrier fishermen to continue to take their main catches during the drawdown season, but would emphasise the protection of the spawning stocks. Regulations of this sort would however be difficult to achieve as the penetak barriers are usually left in place over the whole year ready for the next season. Dismantling the penetaks for only a few months would therefore introduce significant extra costs for fishermen, while non-permanent closure of the gears (eg removing the nets and flume traps only) would require continual inspections and be much more difficult to enforce. Since barrier traps are the main fishing gear of the primary licensing groups in Indonesia, practical and acceptable measures for the control of barrier traps should be discussed directly with these members of the fishing community (Section 7.7).

7.6 Hydrological Management

7.6.1 The Flood Action Plan

From the broad perspective of the Flood Action Plan in Bangladesh, this project recognises the strong social and agricultural gains achieved by the PIRDP FCD/I scheme. Though only a very minor focus of the project, agricultural production has been reported by Pabna farmer/fishermen, to be significantly greater and more reliable inside the embankment.

This project has, however, also shown that the PIRDP has reduced fish productivies inside the scheme, due to reductions in recruitment due to accessibility, and to reductions in fishing effort due to allocation of floodplain land for farming. Though fish numbers are reduced, the inherent capacity of floodplains inside the FCD/I scheme remains high for those fish actually present. Measures are therefore recommended in this section to maximise the recruitment of fish inside FCD/I schemes to make best use of their productive potential. Such measures would support (not replace) the use of dry season reserves for modified floodplains.

7.6.2 Implications of fish migrations

It has been shown that fish have strong migratory tendencies to enter the PIRDP, and are able to pass through both large and small sluice gates in the Talimnagar sector of the PIRDP. The biodiversity of fish stocks inside the PIRDP has also been presumed to be largely maintained by the entry of fish from outside waters. Many fish species have been shown to enter the PIRDP passively at the start of the flood; major carps and catfish also migrate actively in to the PIRDP at the start of the ebb season. The latter fish were presumed to be mistakenly entering flood control schemes due to their positive attraction for flowing waters, while attempting to migrate upstream towards spawning grounds further up the catchment. Such migratory behaviour creates opportunities for the natural enhancement of modified floodplain fisheries by appropriate sluice gate management procedures. Maximising the entry of major carps during the early ebb active immigration phase would increase the unit value of the Inside fish community. Allowing additional fish to enter FCD/I schemes should also be supported by additional survival locations inside, in the form of dry season reserves.

7.6.3 Management of sluice gates

The tendencies of fish to enter the PIRDP could presumably be encouraged by particular modes of operation of the sluice gates to allow fish entry. Such modes have not been determined by this project beyond the obvious conclusion that fish only enter when the gates are open rather than closed. Catches in 1996 were thus raised in the PIRDP when the sluice gates were open. Fish larvae and fry were shown by FAP 17 (1994b) to be available in main rivers outside the PIRDP at highest densities just below the water surface. Since both the large and small sluice gates at Talimnagar are of 'undershot' design, this may restrict the entry of some fry. Other fish, including some of the larger tagged specimens are clearly able to penetrate such sluice gates. Further studies are recommended on optimum strategies for the management of sluice gates for fish accessibility (see also FDL, 1992).

The PIRDP sluice gates are currently managed purely for the purpose of maintaining water levels for agricultural production. Sluice gate management committees do not include any voice from the fishing communities, but sluice gates are sometimes opened unofficially with or without the permission of the Water Development Board, in response to requests from fishermen. At the study site, the unattended Baulikhola sluice gate was also opened by fishermen in 1995, without the knowledge of the WDB. To improve this situation, the placement of a representative of the fishing community in the management committee for the sluice gates would be a significant first step to recognising their additional potential for fishery enhancement.

While significant gains may be achieved, it is also recognised that sluice gates could not be opened permanently due to their function as flood protection devices. During the 1995 flood, the sluice gates were mostly kept shut because local rainfall had already raised inside water levels to a point where extra waters from outside could have threatened rice production. Within such restraints, requests could be made by the fishermen's representative to open the sluice gates, particularly at times when maximum fry numbers were observed in outside waters, in the catches of lift nets and savar nets.

7.7 Co-Management of Floodplain Fisheries

The above management recommendations on reserves, barrier traps and sluice gates could not be achieved without the active involvement of fishing community members. With low levels of enforcement available in developing countries, it is recommended that changes to the management of floodplain fisheries should be undertaken as much as possible by the participatory co-management of both regulatory institutes and fishing communities (Chambers, 1992). To achieve this objective, both the Bangladeshi and Indonesian governments would need to adopt the broad management approaches of NGOs, by recognising both the deep local knowledge of fishing communities, and also their right to participate in the management process.

7.7.1 Contribution of fishing communities

The 'traditional ecological knowledge' of resource users is particularly required for floodplain resources due to their dramatic variability in catchment morphology and the behaviour of their multispecies fish stocks. With regard to reserves, for example, local people are best placed to say where most fish survive over the dry season, and reserve sites should always be selected by fishers, and defined with reference to recognised local ecological features, rather than abstract measures such as grid references (Neis, 1995).

While strongly recommending community management approaches, it is also recognised that they are neither simple to apply nor suitable for all situations. A wide range of preconditions have been identified where community management has been successful (Pinkerton, 1989; Ostrom, 1990; Pomeroy & Williams, 1994). Such preconditions include clearly defined boundaries around resource management units, recognition and respect by fishers for management institutions (either community or government), strong monitoring and conflict-resolution systems, and legal support for local participation in management. Some preconditions are better met in some floodplain locations than in others. In Indonesia, the strongly hierarchical administration and the low traditional mobility give good prospects for floodplain fishery co-management, as is indeed already practised in some villages and districts (Appendix G). In Bangladesh, in contrast, the lack of traditional self-management systems, and the high mobility of fishermen will require that particularly innovative solutions are sought.

The high recapture rates of fish tags in both countries do, however, indicate the potentially high cooperation of fishing communities at both sites, when they perceive the benefits of their involvement (received as cash rewards for the tagging programme, but as social or sustainability benefits in co-management). In Bangladesh, recent approaches encouraging the wide participation of all stakeholders in the fishery have already shown significant benefits in fishery productivity (Middendorp et al, 1996; Rahman et al, 1996).

Finally, it should be emphasised that local community management may only be successful when legislative support is provided such that fishermen have clear rights to participate in the management process and to benefit from such participation. Fishing communities must also be given rights to develop joint rules for the management of their resources, and the rights to enforce those rules in their area. Significant changes would be required in national fisheries legislature, particularly in Indonesia, to achieve the appropriate conditions for such community management (Bailey & Zerner, 1992).

7.7.2 Contribution of fishery management agencies

Community management is likely to hold the greatest potential for blackfish resources, due to their low mobility. Traditional Indonesian fishing communities were thus observed to conserve local blackfish resources, even when they fully exploited the migrant whitefish species shared with neighbouring fishing communities. The high mobilities of whitefish clearly reduce the incentives for the unilateral restraint of individual fishing communities.

The full catchment management of highly migratory whitefish species would require the more active participation of broader management agencies and the recognition by all communities of a 'local action for catchment benefits' approach. The co-management of full floodplain river catchments thus poses a far greater challenge, particularly until strong communication and transport systems are developed across whole catchments, and fishing communities come to know and trust each other. Until this time, it is recommended that fishery management agencies concentrate on encouraging the local participatory co-management of floodplain resources to develop management experience and protect local stocks.

Due to the poor knowledge of floodplain resources, it is also recommended that regional management agencies take responsibility for improved monitoring of the overall state of these river fisheries, including their whitefish species. When new co-management approaches are implemented, their success may then be detected quantitatively at both local and catchment scales. To aid the monitoring process, catch/effort data may be simply collected for these licensed fisheries by requesting annual (or quarterly) returns from fishermen as a condition of their license. Information collected in this way could include the numbers of fishermen in licensed waterbodies, the gears they used, and the total weights and ranked presence of different species in the catches. Such simple information, collected across several different catchments would soon develop a strong database for the improved adaptive management of floodplain resources.

7.8 Summary - Floodplain River Fisheries Management

- Following earlier work on technical management strategies, showing little potential gains in multispecies yield-per-recruit from effort reductions, gear bans, mesh size changes or high water closed seasons, this research has sought simple management tools, with strong potential gains for the fisheries, that are cheap to apply, easily demonstrable, acceptable and enforceable.

- Management strategies presently used for floodplain fisheries in Asian rivers are mainly based on spatial licensing systems. The details of the licensing system, and the fees charged varied between the sites. The completely licensed Lempuing River fishery employed relatively few fishermen but generated high individual incomes, with up 15% of them taken as license fees. The partially licensed Bangladeshi fishery employed 10 times as many people per unit area, but generated much lower incomes and license fees. The high license income from the Lempuing fishery was maintained by an open auction system and additional taxes. In other Indonesian regions, where smaller waterbodies were associated with villages, auction bidding was restricted to village members, and the sustainability of their local resources was protected by traditional reserves and ceremonies.

- The licensing systems at both the main study sites may be seen as fair, given the variable demands of the two countries, and they prevent conflicts between resource users and generate income. It is therefore recommended that the license systems should be maintained at both sites. However, since neither licensing system provides any conservation incentives, it is also recommended that they should be supported with additional precautionary measures.

- Dry season reserves are recommended as the main management tool for floodplain fisheries, as they are highly visible, easily understandable and enforceable. Year-round reserves are predicted to have little benefits for floodplain fisheries, unless applied on very large scales, due to the high mobility of their fish stocks. Dry season reserves or partial restraints are recommended instead for their minimal cost to the fisheries, and high potential benefits for stock conservation and recruitment enhancement. Dry season reserves would be best located in several deep, perennial waterbodies spread across each river catchment, including both river sections and beels/lebungs, ideally with each village offering some restraint on its dry season fishing. Further work is planned to determine the actual benefits available from reserves, and to develop participatory approaches for their implementation.

- Dry season reserves would not conserve or enhance all species in floodplain fisheries, and restrictions on the use of riverine barrier traps may also be considered to ensure the accessibility of fish to their upstream spawning grounds.

- The PIRDP sluice gates have been shown to allow some passage of fish into the FCD/I scheme, and the biodiversity of inside stocks is thought to be partly maintained by such migrations. Some floodplain fish - particularly the major carps and large catfish - have strong migratory tendencies which cause them to enter the PIRDP both during the flood, and the early ebb season. Such migratory behaviour may create opportunities for the natural enhancement of modified floodplain fisheries by appropriate sluice gate management procedures. Further studies are recommended on this subject. Sluice gates are currently managed only to optimise water levels for agricultural production. It is recommended that fishermen be represented on sluice gate management committees, and that sluice gates be opened whenever possible at times of high external fish fry production.

- It is recommended that the future management of floodplain fisheries should be undertaken as much as possible by the participatory co-operation of both regulatory institutes and fishing communities. Managers should take advantage of the traditional ecological knowledge of rural resource users for the selection of reserve sites, and the enforcement of agreed rules. The high mobility of Bangladeshi fishermen may increase the difficulties of community management in Pabna, due to the traditional access rights of outsider fishermen. With adequate consideration of social factors, and inclusion of all stakeholders, significant gains in production have, however, already been demonstrated in other parts of Bangladesh.

- Dry season reserves and community management both have the greatest potential to conserve and enhance blackfish stocks. Management of migratory whitefish stocks would require a broader catchment approach, posing a much greater challenge for management agencies. For the present time, it is recommended that co-management systems are first developed for local blackfish stocks, and that catch returns are implemented as a condition of licensing to provide data for monitoring the fisheries and developing future adaptive management strategies.

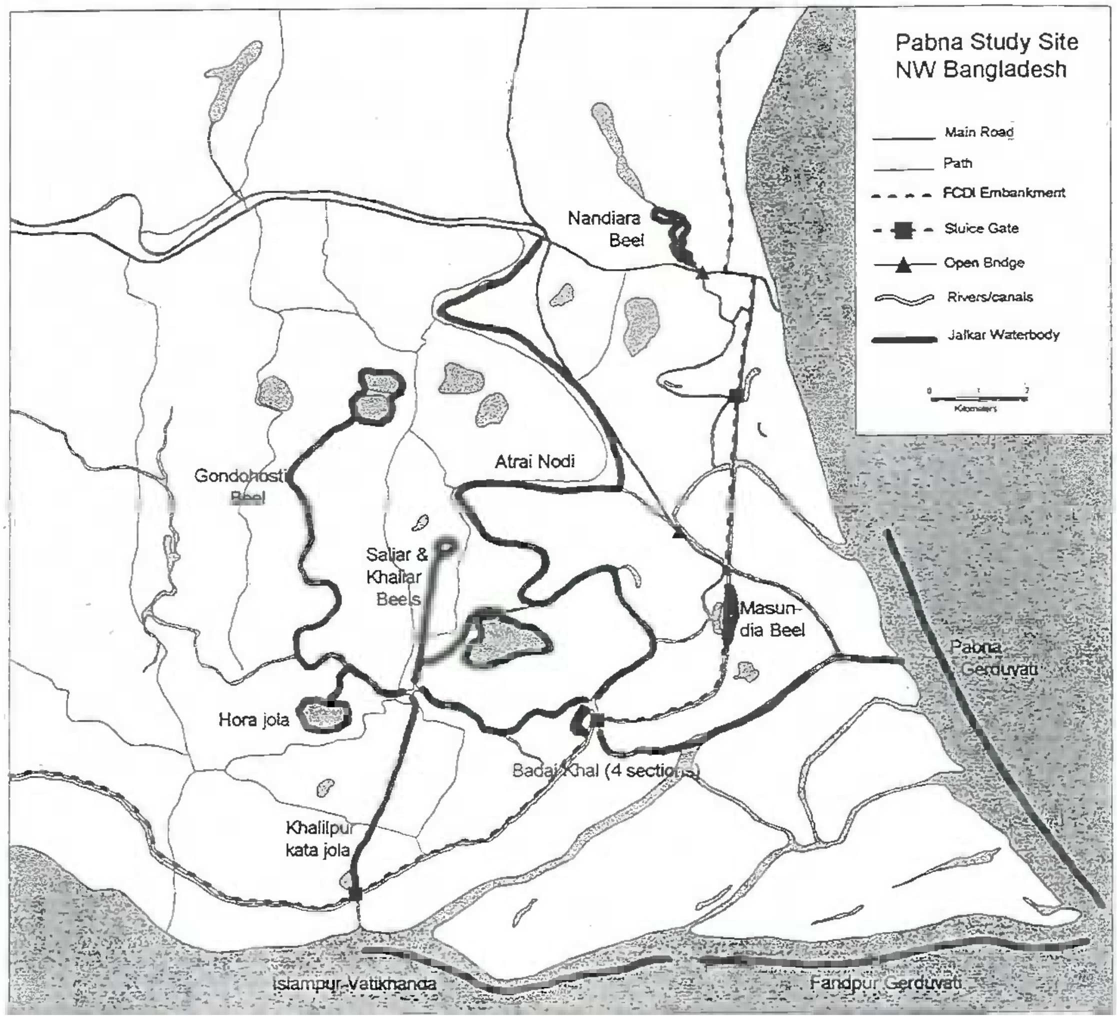

Figure 7.1 Locations of the fourteen *'jalkar'* waterbodies at the Bangladeshh study site, licensed for fishing by the Bangladesh Government's Ministry of Land.

8 References

Ahmad, M. 1989. Deluge in the Delta. In: Ahmad M (ed) Flood in Bangladesh, First edn. Community Development Library, Dhaka.

Bagenal T.B., 1978. Aspects of fish fecundity. In: Gerking SD (ed) Ecology of freshwater fish production. Blackwell Scientific Publications, Oxford

Bailey, C. and C. Zerner. 1992. Local management of fisheries resources in Indonesia: opportunities and constraints. p. 38-56 In Pollnac, R.B., C. Bailey and A. Poernomo, Contributions to Fishery Development Policy in Indonesia, Central Research Institute for Fisheries, Jakarta, Indonesia.

Bayley P.B., 1988. Factors affecting growth rates of young tropical floodplain fishes: seasonality and density-dependence. Environmental Biology of Fishes 21:127-142

Beddington, J.R., A.A. Rosenberg, J.A. Crombie & G.P. Kirkwood, 1990. Stock assessment and the provision of management advice for the short fin squid fishery in Falkland Island waters. Fisheries Research, 8: 351-365.

Begon, M. & M. Mortimer, 1986. Population Ecology. A Unified Study of Animals and Plants, Second edn. Blackwell Scientific Publications, Oxford.

Belk, M.C., 1993. Growth and mortality of juvenile sunfishes (Lepomis sp.) under heavy predation. Ecology of Freshwater Fish 2:91-98.

Brown D. & P. Rothery, 1993. Models in Biology: Mathematics, statistics and computing, First edn. John Wiley and Sons, Chichester.

Bryant, H.E., M.R. Dewey, N.A. Funicelli, G.M. Ludwig, D.A. Meineke & J. Mengel, 1989. Movement of five selected species of fish in Everglades National Park. Abstract. Bull. Mar. Sci. 44: 515.

Buxton, C.D. & J.A. Allen, 1989. Mark and recapture studies of two reef sparids in the Tsitsikamma Coastal National Park. Koedoe 32: 39-45.

Carr, M.H. & D.C. Reed, 1993. Conceptual issues relevant to marine harvest refuges: examples from temperate reef fishes. Can. J. Fish. Aquat. Sci. 50: 2019-2028.

Chambers, R., 1992. Rural Appraisal: Rapid, Relaxed, Participatory. IDS Discussion paper 311. Institute for Development Studies, Brighton, UK.

Clarke KR, Warwick RM (1994) Change in Marine Communities. An Approach to Statistical Analysis. Natural Environment Research Council, UK, 144pp.

Cowx, I.G. (ed), 1994. Rehabilitation of Freshwater Fisheries. Fishing News Books.

DeMartini, E.E., 1993. Modeling the potential of fishery reserves for managing Pacific coral reef fishes. Fish. Bull. 91: 414-427.

Diamond, J.M., 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7: 129-146

Dudley, R.G., 1972. Growth of Tilapia of the Kafue Floodplain, Zambia: Predicted effects of the Kafue Gorge Dam. Trans.Amer.Fish.Soc. 2:281-291

Dudley, R.G., 1996. The fishery of the Danau Sentarum wildlife reserve, West Kalimantan, Indonesia: management considerations. Wetlands International - Indonesia Programme.

Dugan, J.E. & G.E. Davis, 1993. Applications of marine refugia to coastal fisheries management. Can. J. Fish. Aquat. Sci. 50: 2029-2042.

FAP 17, 1994a. Fisheries Studies and Pilot Project. Final Report (Draft). Main Report. Government of the Peoples Republic of Bangladesh, Flood Action Plan, ODA, UK.

FAP 17, 1994b. Fisheries Studies and Pilot Project. Final Report (Draft). Supporting Volume Number 11, Fisheries Study, Movements of Fish Hatchlings. Government of the Peoples Republic of Bangladesh, Flood Action Plan, ODA, UK.

FAP 20, 1994. Compartmentalization Pilot Project (FAP 20). Final Report Special Fisheries Study (Draft). Technical Note TN 94/10.

FDL, 1992. FAP17 Migration and Fish Pass Study. Fisheries Development Ltd, report to ODA.

Funicelli, N.A., D.A. Meineke, H.E. Bryant, M.R. Dewey, G.M. Ludwig & L.S. Mengel, 1989. Movements of striped mullet, Mugil cephalus, tagged in Everglades National Park, Florida. Bull. Mar. Sci. 44: 171-8

Gamba, A.L., 1982. Macrobrachium: its presence in estuaries of the northern Venezualan coast (Decapoda, Palaemonidae). Carib. J. Sci. 18: 23-4, 135-6.

Garrod D.J. & B.J. Knights, 1979. Fish stocks: their life-history characteristics and response to exploitation. Symp.zool.Soc.Lond. 44:361-382

Gayanilo F.C., P. Sparre & D. Pauly, 1994. The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. Food and Agriculture Organisation of the United Nations, Rome, 1994.

Gulland, J.A., 1982. Fish stock assessment, a manual of basic methods. Wiley-Interscience. 223pp.

Gulland, J.A. & A.A. Rosenberg, 1992. A review of length-based approaches to assessing fish stocks. FAO Fisheries Technical Paper 323. Food and Agriculture Organisation of the United Nations, Rome. 100pp.

Hasselblad, V., 1966. Estimation of parameters for a mixture of normal distributions. Technometrics 8:431-444

Hoggarth, D.D., 1994. Management strategies and their sensitivity to parameter uncertainties in a model of artisanal river fisheries. ICES C.M 1994/T:30.

Hoggarth, D.D. and A.D. Utomo. 1994. The fisheries ecology of the Lubuk Lampam river floodplain in south Sumatra, Indonesia. Fisheries Research 20: 191-213.

Hoggarth, D.D. and G.P. Kirkwood. 1996. Technical interactions in floodplain fisheries of south and south-east Asia. p.280-292 In Cowx, I.G. (ed.) Stock Assessment in Inland Fisheries, Fishing News Books, UK.

Holden, S., G.P. Kirkwood & M.V. Bravington, 1995. LFDA Version 4.01 User Manual. MRAG Ltd.

Hyslop, E.J., 1980. Stomach contents analysis; a review of methods and their application. J.Fish.Biol. 17:411-429.

ISPAN, 1993. Nutritional consequences of fisheries biodiversity. Environmental Study (FAP16).

Ivlev, V.S., 1966. The biological productivity of waters. J. Fish. Res. Bd. Canada 23: 1727-1759.

Kapetsky, J.M., 1974. Growth Mortality and Production of Five Fish Species of the Kafue River Floodplain, Zambia. Doctor of Philosophy (Fisheries) Thesis, University of Michigan.

Kottelat, M., A.J. Whitten, S.N. Kartikasari & S. Wirjatmodjo, 1993. Freshwater Fishes of Western Indonesia and Sulawesi. Periplus Editions (HK) Ltd.

Lowe-McConnell, R.H., 1987. Ecological studies in tropical fish communities. Cambridge University Press, Cambridge.

Matin M.A. & A.M. Hussain, 1989. Hydrological aspects of 1988 flood. In: Ahmad M (ed) Flood in Bangladesh, First edn. Community Development Library, Dhaka

McDowall, R.M., 1984. Designing reserves for freshwater fish in New Zealand. J. R. Soc. N.Z., 14(1): 17-27.

McGrath, D.G., F. deCastro, C. Futemma, B.D. de Amaral & J. Calabria, 1993. Fisheries and the evolution of resource management on the lower Amazon floodplain. Human Ecology, 21: 167-195.

Middendorp, H.A.J., Md. Rezual Hasan & Niaz Ahmed Apu, 1996. Community fisheries management of freshwater lakes in Bangladesh. NAGA 19(2): 4-8.

MRAG, 1994a. Floodplain Fisheries Project, Poverty, Equity and Sustainability in the Management of Inland Capture Fisheries in South and South-East Asia, Biological Assessment of the Fisheries. ODA Project R4791.

MRAG, 1994b. Potential Yield of South Asian Small Reservoir Fisheries. Final Report. Fisheries Management Science Programme. ODA.

MRAG, 1997. An Evaluation of Floodplain Stock Enhancement. Draft Final Report. Fisheries Management Science Programme, ODA.

Neis, B., 1995. Fishers ecological knowledge and marine protected areas. pp 265-272 in Shackell, N.L. and J.H.M. Willison (eds) 1995. Marine Protected Areas and Sustainable Fisheries. Proceedings of the symposium on marine protected areas and sustainable fisheries conducted at the second international conference on Science and the Management of Protected Areas, held at Dalhousie University, Halifax, Nova Scotia, Canada, 16-20 May 1994. Science and Management of Protected Areas Assoc., Wolfville, Canada.

Ostrom, E., 1990. Governing the Commons. The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge. 280pp.

Pauly, D. & N. David, 1981. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequency data. Meeresforschung 28(4): 205-211.

Pauly, D., G. Silvestre & I.R. Smith, 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Nat. Resour. Model. 3: 307-329.

Pickett, S.T.A., & J.N. Thompson, 1978. Patch dynamics and the design of nature reserves. Biol. Conserv. 13: 27-37.

Pinedo-Vasquez, M., D. Zarin & P. Jipp, 1992. Community forest and lake reserves in the Peruvian Amazon: a local alternative for sustainable use of tropical forests. Advances in Economic Botany, 9: 79-86.

Pinkerton, E., 1989. Co-operative Management of Local Fisheries. New Directions for Improved Management and Community Development. University of British Columbia Press, Vancouver, 299pp

Pitcher T.J. & P.J.B. Hart, 1982. Fisheries Ecology, First edn. Chapman & Hall, London.

Pitcher, T.J. & P.D.M. MacDonald, 1973. Two models for seasonal growth in fishes. J. Appl. Ecol. 10: 597-606.

Polacheck, T., 1990. Year-round closed areas as a management tool. Nat. Resour. Model. 4: 327-354.

Polunin, N.V.C., M.K. Halim & K. Kvalvaguaes, 1983. Bali Barat: an Indonesian marine protected area and its resources. Biol. Conserv. 25: 171-191.

Pomeroy, R.S. & M.J. Williams, 1994. Fisheries co-management and small-scale fisheries: a policy brief. ICLARM, Manila, 15pp.

Pramanik, M.A.H., 1994. Natural disasters. In: Rahman AA, Huq S, Haider R, Jansen EG (eds) Environment and development in Bangladesh, First edn, vol 1. University Press, Dhaka.

Rahman, A.K.A., 1989. Freshwater fishes of Bangladesh. Zoological Society of Bangladesh, Dhaka.

Rahman, M., S. Halder & D. Capistrano, 1996. Community-based wetland habitat restoration and management: experiences and insights from Bangladesh. Paper presented at the 6th Annual Conference of the International Association for the study of Common Property, 5-8 June 1996, Berkeley, California, USA.

Regier, H.A., R.L.Welcomme, R.J. Steedman & H.F. Henderson, 1989. Rehabilitation of degraded river ecosystems. In: Dodge, D.P. (ed) Proceedings of the large river symposium. Can. Spec. Publ. Fish. Aquat. Sci. vol 106.,

Ricker, W.E., 1954. Stock and recruitment. J. Fish. Res. Board. Can., 11: 559-623.

Roberts, C.M., & N.V.C. Polunin, 1991. Are marine reserves effective in management of reef fisheries? Rev. Fish Biol. Fish. 1: 65-91.

Seber, G.A.F., 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin & Co, Ltd, London.

Shackell, N.L. and J.H.M. Willison (eds) 1995. Marine Protected Areas and Sustainable Fisheries. Proceedings of the symposium on marine protected areas and sustainable fisheries conducted at the second international conference on Science and the Management of Protected Areas, held at Dalhousie University, Halifax, Nova Scotia, Canada, 16-20 May 1994. Science and Management of Protected Areas Assoc., Wolfville, Canada.

Shafer, C. 1990. Island biogeography and the design of nature reserves. Smithsonian Institution Press, Washington, D.C.

Shepherd, J.G., 1987. Towards a method for short term forcasting of catch rates based on length-compositions. In: Pauly D, Morgan GR (eds) Length based methods in fisheries research. ICLARM Conf.Proc., vol 13.

SWMC, 1994. Pabna Irrigation Project, Mathematical Model Investigation for Impact Assessment. River Research Institute, Surface Water Modelling Centre Report to Bangladesh Flood Action Plan 17 Fisheries Study.

Temple, S.A. & A.I. Payne, 1995. The Ganges Basin: An overview for Fisheries (Project R5485). Fisheries Management Science Programme, Overseas Development Administration.

Tesch, F.W., 1971. Age and Growth. In: Ricker W.E. (ed), Fish production in Freshwaters. Blackwell, Oxford.

Ward, J.V. & J.A. Stanford, 1989. Riverine Ecosystems: the influence of man on catchment dynamics and fish ecology. In: Dodge JP (ed) Proceedings of the international large river symposium. Can.Spec.Publ.Fish.Aquat.Sci, vol 106.

Welcomme, R.L., 1979. Fisheries Ecology of Floodplain Rivers, First edn. Longman, London and New York.

Welcomme, R.L., 1985. River Fisheries. FAO Fish. Tech. Pap. 262. 330pp.

Welcomme, R.L., 1989. Review of the present state of knowledge of fish stocks and fisheries of African rivers. In: Dodge DP (ed) Proceedings of the large river symposium. Can.Spec.Publ.Fish.Aquat.Sci., vol 106.

Wootton, R.J., 1990. Ecology of teleost fishes, First edn. Champman & Hall, London.

Zar, J.H., 1984. Biostatistical Analysis, Second edn. Prentice Hall, New Jersey.