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Trends in interannual yield variation of reservoir fisheries in Bangladesh, with special reference to Indian major carps

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Abstract

Interannual variation in yield per species from a freshwater reservoir in Bangladesh was analysed by using long-term landing data. Each species was categorized according to characteristics in interannual yield variation. The characteristics were defined with respect to size of the interannual variation in terms of absolute and relative variation around the mean yield and long-term trends in catch levels. Annual variation was directly ($t_{18} = 7.84$; $P < 0.01$) related to the yield and can serve as a good indication of the status of the fishery when catches are low. The target fish, Indian major carps (IMC) *Labeo rohita*, *Labeo calbasu*, *Catla catla* and *Cirrhinus mrigala*, showed large variation in annual yield. This might have occurred because of variation in annual recruitment. Illegal use of gears is mostly related to variation in year class strength, and is assumed to be the most important source of change of stock variation. An increase in catch rate was recorded for *Corica soborna*. Such a stable combination may only be possible for a certain period without a long-term trend. Trends in the yield rate of the major fish category for three decades reveal a sharp decline in the catch of IMC. In contrast, small clupeid-like *C. soborna* have the highest yield rate. Fishing gears can play a crucial role in this fishery. Fisheries managers must always be alert when issuing fishing licenses and on the control on gears. The conclusion is that the IMC fishery of Kaptai Reservoir is an overexploited fish stock. In this fishery, the same gears are usually employed indiscriminately for different species and size classes. To stabilize the fishery, the existing policy needs to be strengthened and more effectively implemented. Also, some fishing gears and traps need to be restricted. An effective stock protection policy is suggested. Further study on catch size of individual species is essential prior to the development and implementation of any management scheme.

Key words

Bangladesh, interannual yield variation, reservoir fishery.

INTRODUCTION

Capture fishery is considered to be an important fishery resource in Bangladesh and contributes approximately 52.2% of the total fish production in the country (Ahmed *et al.* 1997). Kaptai reservoir, one of the largest man-made freshwater lakes in the world (BLP/IDRC 1980) and the largest in South-east Asia (Fernando 1980), covers a surface area of $68.8 \times 10^6\,m^2$ at full supply level (FSL) (Ali 1985). It is a significant component of inland water resources, occupying 46.8% of the total pond area of Bangladesh, and offers a huge potential for fisheries development and enhancement of fish production. At present, Kaptai reservoir supports small-scale fisheries and is rich in fish species diversity, contributing approximately 6×10^6 kg of freshwater fish annually.

The fish production of this reservoir is primarily dependent on the previous riverine stock that dates back to 37 years of impoundment. As such, the present fish fauna shows a strong resemblance to those of rivers, haors (low lying natural depressions) and beels (deeper portion of a low lying natural depression) of Bangladesh. Changes in fish community structure, with respect to resistance, abundance and shifting habitat, took place as the environment changed from riverine to lacustrine following the construction of the dam. Additionally, some species survived the closure of the River Karnafully and adapted to the new ecosystem; they, too,

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currently contribute substantially to total landings. And some new species appeared and now play a significant role in total landings.

The variability of annual landings for each species with one or more peaks is common. Buijse *et al.* (1991) noted that the reasons for variability in yield may be caused by fluctuations in recruitment, growth rate, survival and, more indirectly, alterations in mesh size and fishing effort. For intensively exploited fish stocks, annual variation in yield is mainly caused by variation in recruitment (Hennemuth *et al.* 1980). Successful exploitation of a fishery depends not only on the quantity of fish caught, but also on the stability of supply (Silvert 1982; MacLennan & Shepherd 1988; Buijse *et al.* 1994). The advantages of a stable yield can be observed from marketing and fishermens' incomes. The effects of management are also more obvious. Variation in yield increases with increasing effort, particularly when the level of effort exceeds the level required for maximum sustainable yield (Beddington & May 1977; May *et al.* 1978; Buijse *et al.* 1994).

The variable yield of a fishery has direct consequences on the economic status of the fishers. Steadily increasing catches often stimulate investment, which in turn can lead to increased fishing efforts. Steadily falling catches respond to total yield less markedly than the actual decrease in stock size. Fish traders and processors are also sensitive to this variability. Categorizing species and situations by characterizing the interannual variation in yield might help the fishery manager in embedding management advice in the context of inevitable uncertainty generated by the environment (Buijse *et al.* 1994). Coupling biological models of the fish stock, which describes its variability with socioeconomic models, might help reveal suitable management strategies (Silvert 1982).

In this study, data from a long-time series (32-year period: 1966–1997), are reported for the first time from Bangladesh, and used to analyse the variability in annual yield of a number of freshwater fish inhabiting this man-made reservoir. Annual yield variation of each species is considered on a long-term and short-term basis. Finally, the usefulness of the findings for developing a sound fisheries management policy is discussed.

METHODS

Analysis of interannual yield variation of some commercially exploited freshwater fish

Annual catches of commercially important fish for a period of 32 years were taken from the landing records of the Bangladesh Fisheries Development Corporation (BFDC), Kaptai Lake projects, Rangamati, Bangladesh. An analysis of the coefficient of variation (CV) is carried out for annual catches of IMC species and other commercially important fish to determine the extent of variation in yield. The long-term variation in catches experienced by the fishers is expressed by the CV in annual yield. In the short term, fishers relate their catches (y_i) in a given year to that in the previous year (y_{i-1}). In a long-term data series, the mean of the absolute differences in the annual catch between successive years can be related to the mean catch according to the model developed by Buijse *et al.* (1991):

$$U_a = \frac{|dy|}{y} = 100 * \frac{mean|y_i - y_{i-1}|}{y} \ (\%)$$

where, U_a = index of absolute variation; y = mean of long-term catch; y_i = catches in a given year; y_{i-1} = catches in the previous year.

Because the fishermen generally experience short-term variation in their catch as a percentile change, the relative variation (U_r) was calculated from the mean of the absolute difference of log transformed catches (r) as:

$$r = \sum_{i=2}^{n} |\log_{10}(y_i/y_{i-1})| / (n-1)$$

where n = length of the time series (1–32 years) and:

$$U_r = 100*2\ ((1 - 1/10^r)/(1 + 1/10^r))\ (\%)$$

If $U_r > U_a$, variation is inversely related to yield, but if $U_r < U_a$, relative variation is directly related to yield. Part of the variation in annual yield might come from a long-term downward or upward trend in catches. To investigate whether catches follow trends, linear trends of first- and second-order polynomials were fitted to the data by using time (32 years) as the independent variable and catch as the dependent variable. The estimated coefficients of variation were named CV0, CV1 and CV2, respectively. The number indicates the order of polynomial fitted to the data.

Trend in fish yield

Trends in annual fish landing of Kaptai Reservoir were estimated by using a standard semilog trend function within exponential growth rate. The model is given by:

$$\ln Y = \alpha + \beta t$$

where, Y = annual fish catch (MT); t = time series (t = one for 1965–1966, two for 1966–1967 ... 32 for 1996–1997); α and β are parameters to be estimated where β is the exponential growth rate and ln = the natural log.

RESULTS AND DISCUSSION

Annual variation in the yield of the commercially important fishery

A total of 19 commercially important fish were selected for examination (Table 1). The length of annual data of fish

Table 1. Coefficient of variation for zero, first and second order polynomials (%), the indices (%) for absolute (U_a) and relative (U_r) short-time variation and the index (dy/y) for long-term trends (%) of historical yield (MT) of some commercially important species of Kaptai Reservoir

Species	*n*	Year range	Yield (MT)	CV0	CV_1	CV_2	U_a	U_r	dy/y
Labeo rohita	32	1966–97	125	88	31	53	67	10	3
Catla catla	32	1966–97	295	80	23	18	34	12	−3
Cirrhinus mrigala	32	1966–97	129	104	101	117	51	12	−8
Labeo calbasu	32	1966–97	147	96	101	116	40	12	−0.2
Tor tor	32	1966–97	22	74	53	54	66	5	−0.3
Notopterus chitala	32	1966–97	137	61	7	46	45	12	3
Notopterus notopterus	32	1966–97	66	71	39	32	51	11	2
Aorichthys aor	32	1966–97	89	63	21	96	38	12	1
Mystus cavasius	16	1982–97	13	41	10	10	50	6	−0.4
Wallago attu	32	1966–97	70	68	2	44	54	10	2
Eutropiichthys vacha	32	1966–97	35	86	1	57	51	6	1
Gudusia spp.	32	1966–97	722	72	57	53	39	11	22
Corica soborna	9	1989–97	350	48	51	44	35	9	103
Oreochromis niloticus	11	1987–97	9	102	129	80	75	9	2
Channa marulius	16	1982–97	23	35	11	16	37	20	2
Channa striates	14	1984–97	5	171	6	21	130	2	0.1
Ailia coila	13	1984–97	8	82	100	68	91	8	1
Puntius spp.	32	1966–97	52	108	176	107	61	7	1
Labeo gonius	32	1966–97	227	80	69	69	55	12	5

CV0, Coefficient of variation; CV1, linear trends; CV2, second order polynomials.

landing varies between 9 and 32 years. A total of 13 species (68% of the total) have data for the entire 32-year period under investigation. Over the period from 1966–1997, the long-term coefficient of variation (CV0) was found to vary between 61 and 108%, while the absolute variation (U_a) ranged from 34 to 67%. For species with a time series between 9 and 16 years, the CV0 varied between 35 and 171%. The highest variation was observed for *Channa striatus* (171%) followed by *Puntius* spp. (102%). Absolute variation for this type of series was found to be highest for *Channa striatus* followed by *Ailia coilia*. The frequency distribution for overall U_a was positively skewed with a mode value approximately 30–60%. The frequency distribution for CVs had a higher mode for the second-order polynomials than the first-order polynomials (Table 1).

In general, fishers experience a variation in the catch of different species from one year to the next. The mean U_a and U_r were 56 and 9%, respectively. Note that U_a was significantly larger ($t_{18} = 7.84$; $P < 0.01$) than U_r, indicating that variation was directly related to yield. This can serve as a good indication of the status of the fishery when catches are low.

Table 1 shows that the major carps have high long-term CVs (80–104%). Compared to 19 commercially exploited fish species (average CV0 = 80% and U_a = 56%), IMC (*Labeo rohita, Catla catla, Cirrhinus mrigala, Labeo calbasu*), have higher long-term CVs and moderate ones for absolute variation (Fig. 1). Both *C. mrigala and L. calbasu* exhibited a large and highly comparable variation for CV0, CV1 and CV2. Among the IMC, *C. catla* showed higher average yield, but lower values for all comparable CVs. The large variation in IMC yield occurs because of the large variation in the annual recruitment pattern.

In Kaptai Reservoir, there are no data on the extent of stocking success. During the inception period of the reservoir, stocking of IMC fingerlings was sporadic and did not follow any particular number or species composition. And later, over the past 10 years, a given stocking programme by using a certain number of self-sustainable sized (9–13 cm) fingerlings with certain species composition was implemented without undertaking any initiative to evaluate the success of this stocking programme. Furthermore, BFDC officials and Fisheries scientists were unaware whether the existing brood stocks of IMC played any significant role in the recruitment pattern through auto-stocking in the fishery. Results from Table 1 reveal that in spite of auto- and artificial stocking, successful recruitment did not happen because of higher exploitation before harvestable size was attained.

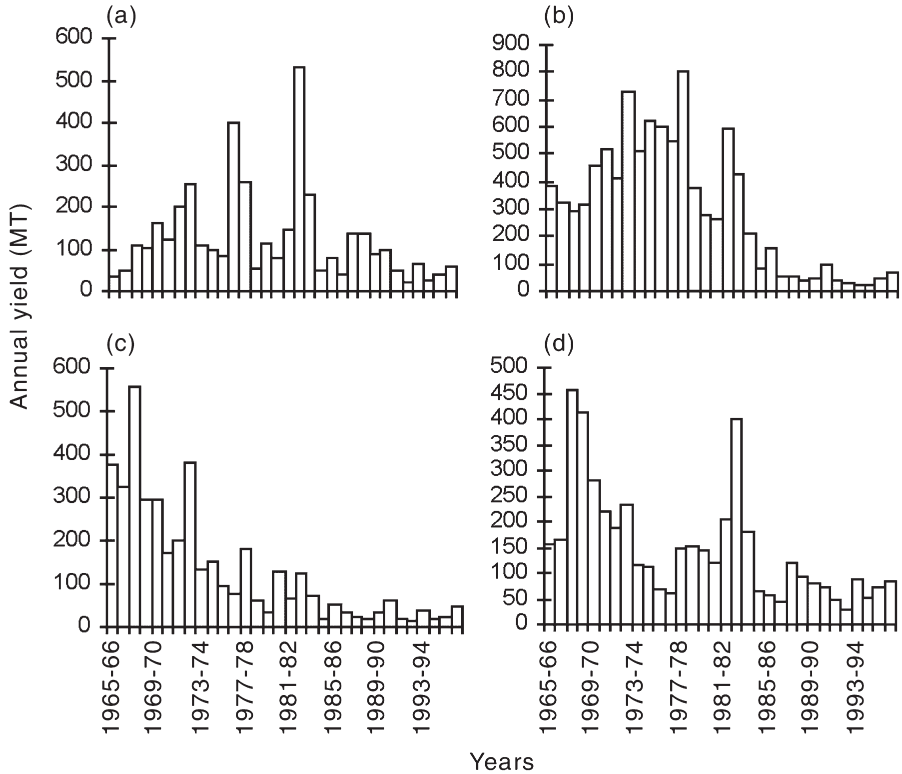

Fig. 1. Annual yield and coefficient of variations of (a) *Labeo rohita*: CVO = 88%, U_a = 67%; (b) *Catla catla*: CVO = 80%, U_a = 34%; (c) *Cirrhinus mrigala*: CVO = 104%, U_a = 40% and (d) *Labeo calbasu*: CVO = 96%, U_a = 40% from Kaptai Reservoir from 1965 to 1994. U_a, index of absolute variation; CVO, long-term coefficient of variation.

Stocking as a management option, and as undertaken in Kaptai Reservoir, has failed in most Indian reservoirs. Indeed, after 50 years Sugunan (1997) acknowledged that the stocking strategy by using IMC in Peninsular India has failed. In Bhavanisagar, Tungabhadra, Krishnagiri, Malampuzha, Peechi and Nagarjunasagar Reservoir, stocked IMC fingerlings have had little impact on catch, as none of the stocked fish was reported to breed and contribute to auto-recruitment. Sreenivasan (1984) reviewed the impact of stocking in 10 reservoirs of Tamil Nadu. Stocked *C. catla* was found to build up a naturalized population in the Mettur Reservoir; however, this fishery suffered periodic setbacks because of breeding failure. *Labeo calbasu,* another transplant (which have replantation capacity), found the environment suitable for breeding and has provided support for a viable fishery over the last few decades. *Labeo calbasu* has never been stocked in the Kaptai Reservoir, but it too has become established there and has contributed to the total yield since the inception of harvesting.

Stocking has been much more effective in improving the yield from small reservoirs than from large and medium sized reservoirs in India. This is because success in the management of small reservoirs depends more on recapturing stocked fish than on breeding success. Stocking programmes in medium sized and large reservoirs are successful only when stocked fish breed and contribute to auto-stocking. So far, funds spent on stocking for Kaptai Reservoir have been much higher than the cost of recaptured fish. Carp stocking in reservoirs has not been cost effective in Thailand (Bhukeswan & Chookajorn 1988) or in southern India (Sugunan 1997), and has been a complete failure in Sri Lanka (Fernando 1993).

Whether the long-term trend in catches is negative or positive can be determined by investigating dy/y (Table 1). A negative sign indicates a decline of the catch rates during the period of investigation, whereas a positive one indicates an increase. Table 1 shows that, except for *L. rohita*, the catch rates of all species of IMC have declined by 0.2% to 0.8%. Kaptai Reservoir presumably has a major impact in decreasing IMC after physical changes in the original river Karnafuli channel, where the presence of barrage resulted in a major habitat alternation. Most of the gears used in this fishery, including brush shelters, are non-selective and harvest more than one species. Irrespective of size classes, fishing is carried out daily without any regulation on gears, so that the recruitment pattern of the IMC fishery has been affected from the beginning of impoundment. Nevertheless, fishers claim that from the 1990s the number of monofilamentous gill nets used for harvesting *Gudusia* spp. have increased progressively, although mesh size has not been regulated to ensure legal size catches. Thus, the same small-meshed gear also catches IMC fingerlings before they

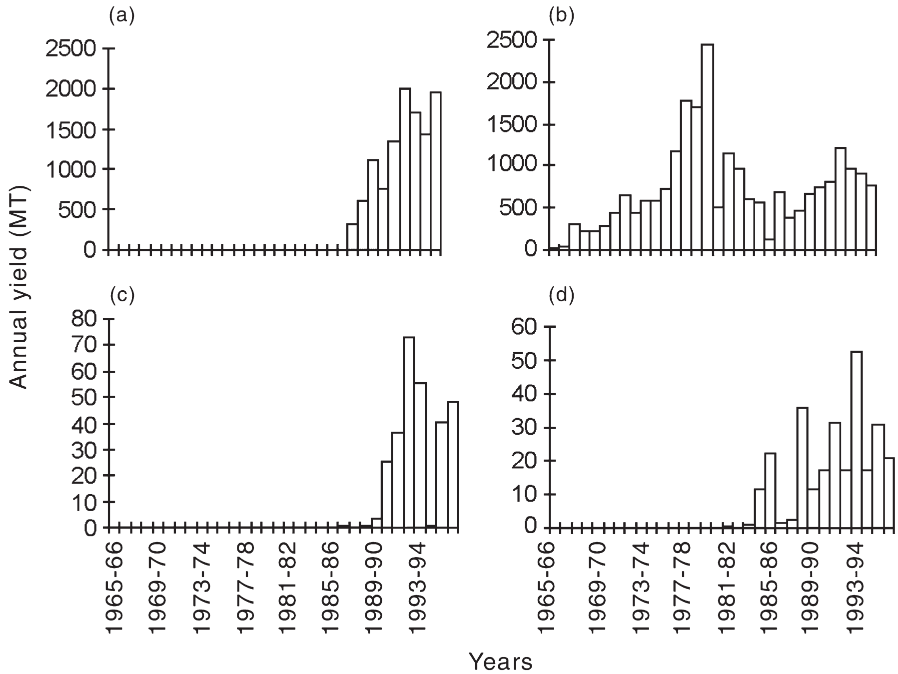

Fig. 2. Annual yield and coefficient of variations of (a) *Corica soborna*: CVO = 48%, U_a = 35%; (b) *Gudusia* spp.: CVO = 72%, U_a = 37%; (c) *Oreochromis niloticus*: CVO = 102%, U_a = 75%; and (d) *Ailia coilia*: CVO = 82%, U_a = 91% from Kaptai Reservoir from 1965 to 1994. U_a, index of absolute variation; CVO, long-term coefficient of variation.

attain legal capture size. Limitation on fishing efforts is attempted by the imposition of a closed season (June–August), but some resource-poor fishers who live on the shore ignore this. This happens often during the post-stocking period when IMC form schools and move around shallow areas. Two types of gears, the mosquito seine net and the monofilamentous gill net are mainly responsible for harvesting such fingerlings. This sort of fishing occurs mostly at night near the Rangamati district town. The same mature stocked IMC are also attracted by fish lure or attractants from indigenous ingredients administered before employing baited hooks, and in brush shelters. Every year, hooks and lines and brush shelters catch a significant percentage of fingerlings during the poststocking period because they lack any protection mechanisms. Ahmed and Hambrey (1999) noted the potentially deleterious effects of brush shelters on the Kaptai Reservoir as this technique involves the complete harvesting of all brood fish with progeny. Unplanned and unregulated use of this type of fishing poses a serious threat both to natural stocks and the effectiveness of stock enhancement as mostly small fish are harvested.

Since its first appearance in 1988/1989, *Corica soborna* has showed a stable yield over a 9-year period (Fig. 2a). The CV0 of this pelagic fish was found to have lower than moderate variation (48%) and small interannual differences (35%). This stable combination may only be able to exist for a certain period without a change in trend. The periodicity encompasses time intervals of approximately one decade or more of steadily rising or declining catches. Relative variation of this category of fish seems to be directly related to yield ($U_a < U_r$), and hence the noticeable increasing trend of catch rate recorded. One hundred and three percent was the highest value among the species considered. A remarkable production of this short-lived fish species is reported at peak water-level with transparent water. The ratio of the annual water-level manipulation is also considered as a prime factor for varying production from one year to another. At present, the most dominant fish in Kaptai Reservoir is lacustrine marine derived fish, the Clupeidae. They account for more than half (approximately 64%) of the total catch, and their contribution and importance is apparently increasing day by day. Fernando and Holcik (1991), and Fernando *et al.* (1998) noted that in addition to lacustrine fish, recent lakes are colonized by marine-derived fish-like clupeids, osmerids and some other families. Generally, fish with marine antecedents that are more likely to be lacustrine adapted, were found to dominate in lacustrine conditions in lakes and reservoirs. Petrere (1996) showed that marine-derived species dominate in large reservoirs in South America. In shallow lakes and reservoirs of the tropics, tilapias are the most productive fish. In deeper lakes, clupeids play a significant role (Sirimongkonthaworn & Fernando 1994). Recent yield rate of clupeids in Kaptai Reservoir is comparable to the yield levels of African clupeids in Lake Tanganiyaka or Kariba Reservoir. It is the introduction of lacustrine and self-propagating fish species that lead to spectacular increases in fish yields in reservoirs in Cuba, Sri Lanka, North-East Brazil and elsewhere (Fernando & Holcik 1991).

Table 1 shows a long-term upward trend in the CV for *Gudusia* spp. Although U_a is low, the uncertainty is high, and the trend is characterized with an initial sharp increase and low stabilization after peak catches (Fig. 2b). This pattern is seen regularly in the annual yield of reservoir fisheries. A continuous higher value of annual catch indicates a positive increasing trend of long-term catch. It is assumed that as the annual juvenile recruitment is higher for *C. soborna* than those of *Gudusia* spp., rational exploitation of *C. soborna* results in an even distribution of fish landings.

The yield of *Oreochromis niloticus,* after its accidental introduction into the Kaptai Reservoir fishery, showed a sharp initial increase, reaching the peak within 5–6 years and thereafter recorded a drastic decline. Later, in the following years, consistent catches were observed (Fig. 2c). In this case, all CVs showed higher values with high U_a, while the interannual variation is found to be lower than the long-term variation. However, the case of *O. niloticus* it is not well defined by either the first- or second-order polynomial, although their values were observed to be higher in both cases (Table 1). The introduction of exotic fish to open waters is still a subject of controversy in India and also in Bangladesh because of the potentially deleterious effects on indigenous populations. With the exception of very few reservoirs in India, tilapia (*O. mossambicus*) dominated fishing invariably leads to low yields. In the Krishnagiri and Vaigai reservoirs, production has been erratic because of the unpredictable behaviour of tilapia owing to competition with other fish. *Oreochromis niloticus* has not yet been introduced to the reservoir ecosystem in India. Confined to the estuarine and freshwater wetlands of eastern India, this species is not reported to have problems of stunted growth and prolific breeding (Sugunan 1997). The remarkable performance of *O. mossambicus* in the Sri Lankan reservoirs is attributed to shallow margins, which facilitate nest building activities and frequent water level fluctuations. But, it is interesting to note that India with almost identical situations, failed to produce high production rates. The increasing importance of the lacustrine cichlids (*O. niloticus*) in Kaptai reservoir seems to be consistent with the findings of Fernando and Holcik (1991).

Ailia coilia, one of the recently appeared species in the Kaptai reservoir fishery and the only member of schilbeids, showed a special characteristic. Its interannual variation is rather higher than the long-term variation (Fig. 2d). In spite of higher CV1, values of other CVs are relatively higher and the fishery seems to be stable within that range (Table 1).

The long-term coefficient of variation for carnivorous fish such as *Notopterus chitala* (Fig. 3a), *Wallago attu* (Fig. 3b) and *Aorichthys aor* (Fig. 3c) were found to be more or less similar, and varied between 60 and 70%. First-order polynomials exhibit lower values for these carnivores than the second-order polynomials (Table 1). The interannual differences were also lower in comparison to long-term variation. Such short-term variation can only exist when some periodicity occurs. This periodicity encompasses time intervals

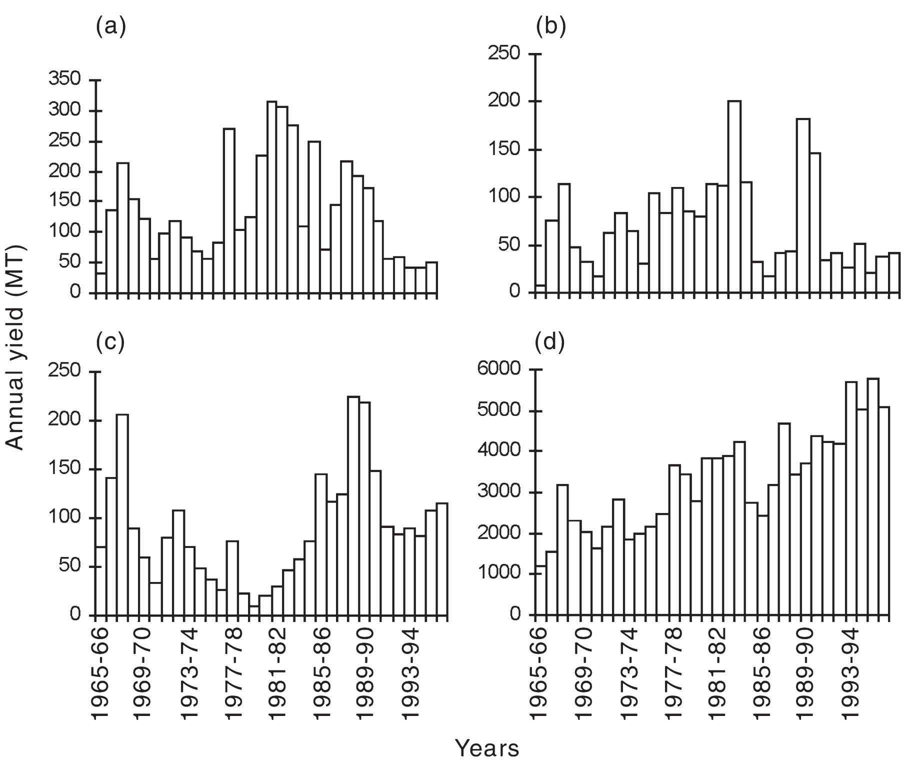

Fig. 3. Annual yield and coefficient of variations of (a) *Notoplerus chitala*: CVO = 6.1%, U_a = 45%; (b) *Wallago atlu*: CVO = 68%, U_a = 54%; (c) *Aorichthys aor*: CVO = 63%, U_a = 38%; and (d) total landings: CVO = 37%. U_a, index of absolute variation; CVO, long-term coefficient of variation.

of 10 years or more of steadily rising and declining catches. The long-term coefficient of variation for total landings was only 37% (Fig. 3d).

Determination of yield rate

Trends in yield rate of major fish categories for the last three decades reveals the sharp declining rate of IMC (Table 2). The average annual declining rate was approximately 8%. The yield rates of exotic species declined at a faster rate (11%). The highest rate of declining trend was found in *Puntius* spp. (21%), which is alarming. Yields of snakehead and clupeids were increasing at a higher rate of 19 and 9%, respectively. Dried fish, which is mainly composed of two species of clupeid (70% of total) and fingerlings of IMC, snakehead and miscellaneous small fish recorded the highest growth rate of 33%. The miscellaneous species are also growing at a similar rate (34%). As a whole, all species considered together, the fish production in the Kaptai reservoir is increasing at an annual rate of approximately 3.4%.

Among individual species, *Tor tor*, a member of the Cyprinidae, recorded the highest rate of declining trend at 25%. The four species of IMC declined sharply. *C. mrigala* and *C. catla* rates declined at an annual rate of 10%, while the decline in the yield rate of *L. calbasu and L. rohita* was moderate (Fig. 4). It is noted that Cyprinidae was found to predominate at the advent of postimpoundment condition that has been shifted to Clupeidae as the reservoir became older. Fernando and Holcik (1991) reported the predominance of Cyprinidae in lakes with low yields, and proposed that high fish yields in reservoirs (and lakes) are linked to the presence of indigenous or introduced lacustrine adapted fishes worldwide. Traditional stocking of fish into reservoirs, where it cannot self-propagate like tilapias, result in low fish

Table 2. Determination of the yield rate of different categories of commercially important fish harvested during 1965–1966 to 1996–1997 from the Kaptai reservoir

Category of fish	Yield rate (%)	*t*-Value	Adjusted r^2	*F*-value
Species				
Labeo rohita	–2.84	–2.03b	0.092	$F_{(1,30)}$ 4.13b
Catla catla	–10.35	–8.26a	0.684	$F_{(1,30)}$ 68.15a
Cirrhinus mrigala	–10.00	–10.35a	0.774	$F_{(1,30)}$ 107.15a
Labeo calbasu	–4.92	–5.05a	0.441	$F_{(1,30)}$ 25.47a
Tor tor	–25.09	–10.05a	0.763	$F_{(1,30)}$ 101.01a
Gudusia chapra	5.29	3.32a	0.245	$F_{(1,30)}$ 11.05a
Corica soborna	26.94	7.01a	0.608	$F_{(1,30)}$ 49.11a
Oreochromis niloticus	1.50	7.77a	0.657	$F_{(1,30)}$ 60.39a
Notopterus chitala	–0.64	–0.51	–0.024	$F_{(1,30)}$ 0.26
Aorichthys aor	1.88	1.36	0.03	$F_{(1,30)}$ 1.85
Wallago attu	–0.019	–0.13	–0.033	$F_{(1,30)}$ 0.017
Eutropiichthys vacha	–0.11	–0.07	–0.033	$F_{(1,30)}$ 0.005
Mystus cavasius	15.25	9.51a	0.742	$F_{(1,30)}$ 90.37a
Group				
Indian major carps	–7.77	–8.85a	0.714	$F_{(1,30)}$ 78.40a
Catfish	2.07	2.66b	0.164	$F_{(1,30)}$ 7.09b
Clupeid	8.91	5.93a	0.523	$F_{(1,30)}$ 35.11a
Snakehead	18.71	9.58a	0.745	$F_{(1,30)}$ 91.72a
Featherback	1.00	0.91	–0.006	$F_{(1,30)}$ 0.83
Minor carp	–0.88	–0.67	–0.018	$F_{(1,30)}$ 0.45
Exotic spp.	–10.53	–3.95a	0.320	$F_{(1,30)}$ 15.62a
Puntius spp.	–21.23	–6.06a	0.535	$F_{(1,30)}$ 36.68a
Miscellaneous spp.	33.68	7.17a	0.619	$F_{(1,30)}$ 51.35a
Dried fish	33.42	9.29a	0.733	$F_{(1,30)}$ 86.38a
Total fish	3.42	8.58a	0.700	$F_{(1,30)}$ 73.59a

Yield rates are computed by fitting semilog trend function $\ln Y = \alpha + \beta t$, where Y = yield, α and β are parameters and t is time (t = 1,2,3–32); α and β indicate the significance level at 1 and 5% levels, respectively. F-values, F-ratio of analysis of variance; adjusted r^2, proportion of variation in the dependent variable y, explained by the relationship between y and x expressed in the regression line.

yields. It is also evident that old lakes in general have higher fish yields than younger lakes (Fernando 1998).

Among the carnivorous fish, *N. chitala* and *W. attu* are declining at a very negligible rate (< 1%). The production of *Eutropiichthys vacha*, an important catfish, is also declining slightly (0.11%). Pelagic species like *C. soborna* recorded the highest growth rate (27%) among the species examined, followed by *Mystus cavasius* (15%), a small sized, but very popular and tasty catfish. The growth rate of *Gudusia* spp. was moderate (5%). An increasing trend in the growth rate of *A. aor* (2%) was also noticed.

There is ample evidence on the prevalence of short-term and long-term annual variations in fish yield from different categories of water-body throughout the world (Schlick 1978; Hatch *et al.* 1990; Buijse *et al.* 1991; Buijse *et al.* 1994). Various reasons are involved in causing variations in yield. In many cases, however, the causes remain unidentified. In some occasions, human induced factors serve as the main causes (Hatch *et al.* 1990; Schlick 1978). However, in most of the cases, principle reasons for variability in yield are: fluctuations in recruitment, growth and survival rate, alterations in mesh sizes and fishing effort (Buijse *et al.* 1991). In the history of Kaptai reservoir, no effort has been taken to examine fish catch effort, stocking success and recruitment pattern. At the start of the postimpoundment period few studies confirmed the natural spawning of IMC (Azadi 1985; Hye & Alamgir 1992; ARG 1986). At present, the occurrence of successful natural spawning of *L. rohita*, *C. catla* and *C. mrigala* is doubtful because of several causes such as, siltation owing to shifting cultivation (*jhum* cultivation or slash and burn agriculture), water level fluctuation, lack of rainfall at the proper time and ultimate current velocity.

From the above discussion, it can be concluded that the IMC fishery of Kaptai reservoir seems to be an overexploited fish stock where a presumed increase in yield was initiated through different fishing methods and ultimately preceded by a decline in yield. In spite of recent improvement of the stocking policy, production of the mentioned species is not at all promising, and the mean total length of all IMC is decreasing gradually. The recruitment variation was largely responsible for the subsequent variation in yield rather than the variation in annual stocking rate. The impact of IMC fingerling stocking has not proved feasible. Ahmed *et al.* (1999) found a negative correlation ($r = -0.68$; $P < 0.05$) between stocking and corresponding yield of IMC in the Kaptai Reservoir. Such negative correlation increases further ($r = -0.85$; $P < 0.05$) when moving average for yield of stocked fingerlings is used.

Caddy and Gulland (1983) categorized the natural variation in fish stocks into steady, cyclical, irregular, spasmodic and stressed variation while developing management strategies for fishery stability. A high variation in recruitment and high fishing effort has resulted in a high uncertainty. Therefore, as recruitment is often difficult to manage for a certain water-body, because of uncertainty between stocking and recruitment relationships, the stabilizing management strategy should be mainly to reduce the fishing effort. As fishing in the reservoir Kaptai is multigear and

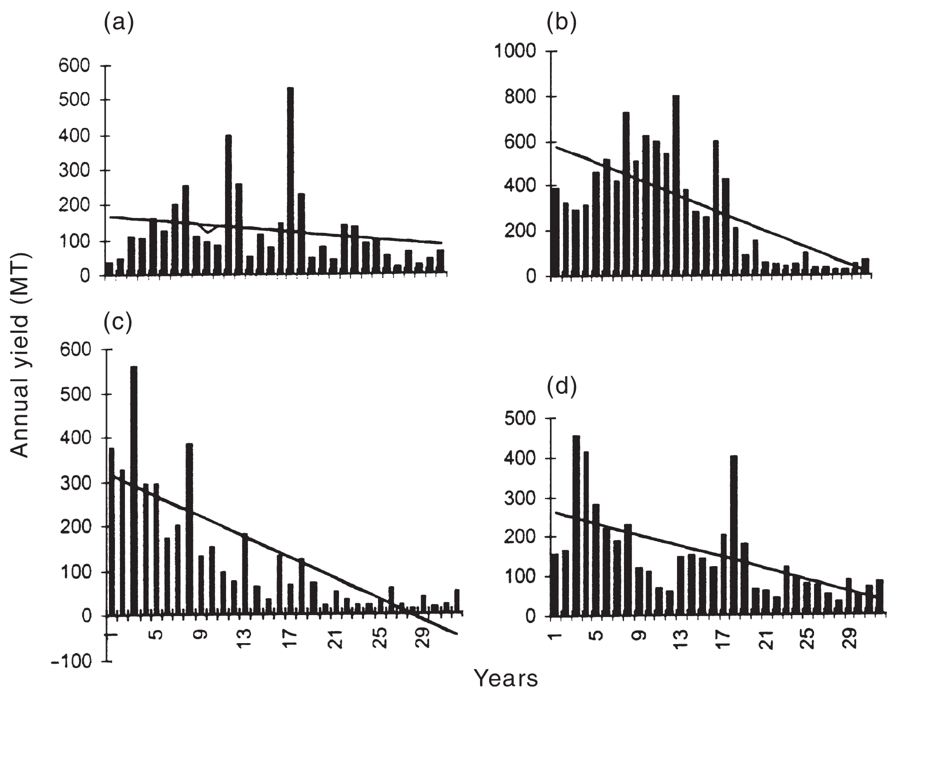

Fig. 4. Annual landings and predicted yield trend of (a) *Labeo rohita*, $y = -2.713x + 170.66$, $r^2 = 0.05$; (b) *Catla catla*, $y = -18.189x + 594.49$, $r^2 = 0.52$; (c) *Cirrhinus mrigala*, $y = -11.684x + 325.2$, $r^2 = 0.62$; (d) *Labeo calbasu*, $y = -7.1986x + 267.82$, $r^2 = 0.36$. During 1965–1966 to 1996–1997 from Kaptai Reservoir. (■) y, (—) predicted y.

multispecies in nature, that is, the same gears are usually used not only for different species but also for different size classes, studying the catch of individual gears is an essential task prior to developing any management policy. In cases of very high variation in yield, fishers may be willing to communicate with the fisheries managers and accept suggestions regarding the stabilization of the catch by lowering fishing efforts. But the only drawback in this case is that most of the artisanal fishers are illiterate. It is believed that specialists have more difficulty in coping with natural variability than the fishing community (Smith & McKelvey 1986). When the variation is high, but trends are less easily detected and are clear only after a very long period is passed, the fishers' experience and ideas in such cases might be an asset for fisheries managers. It can be cited that, in case of sauger in Lake Eries, fishers were less likely to be cooperative (Buijse *et al.* 1994).

A constant catch quota policy could stabilize variation in the yield, but is regarded as less successful than a constant effort policy (Jacobson & Taylor 1985). A simulation of harvest strategies for whitefish in Lake Michigan showed that a constant effort policy produced relatively larger sustainable yields (Jacobson & Taylor 1985). In this context, no in-depth study has been initiated so far in Kaptai Reservoir, which can play a significant role to help develop a suitable management policy. Studies on catch-effort and fish population dynamics are conducted exclusively at a preliminary level. As such, any of the mentioned strategies cannot be initiated without intensive study in this respect.

Fishing gear, that is more size selective, such as gill nets, hooks and lines, will result in a catch that consists of fewer age groups and sizes than the catches made with seines and lift nets, and will thus it would be more difficult to stabilize variations. Evidence shows that in different water-bodies worldwide, more than one species is caught with the same gear. A recruitment pattern of IMC fishery may be evolved in the Kaptai Reservoir fishery, because the type and number of gears appropriate for harvesting IMC of all size classes with respect to the area is assumed to be much lower than the expected level. Large-sized seine nets are such gears that are decreasing gradually because of constant declining of the catch per unit effort (CPUE). Presently, the fishing community tends to shift from reservoir to other inland fishing and sea fishing activities.

Therefore, to stabilize the fishery, the existing policy needs to be strengthened urgently and should be implemented properly so that the stocking success of both autostocking (natural spawning source) and artificial stocking (yearly stocking programme). Some fishing gears and traps should be restricted for a given area either for the whole season or limited time period. Also, an effective stock protection policy can be initiated for this fishery. Swartzman *et al.* (1983) reported that a constant quota regime will lead to a stock collapse after a number of consecutive unfavourable years, whereas this will not occur in the case of a constant effort policy or an effective stock protection policy. With respect to the exploitation rate, constant quota policies might be more conservative than other policies. Therefore, fisheries managers must be prepared to make a trade-off between maximizing the yield and minimizing the variation in yield.

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