FISHERIES OF THE DAMODAR VALLEY IN RELATION TO CONSTRUCTION OF DAMS

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The paper critically examines the effects of the Damodar Valley dams on the fisheries of the river system as also of the Hooghly into which the Damodar drains. The species composition, their relative abundance and size structure of the catches from the reservoirs are compared and probable reasons for the observed differences explained. The weight-length relationship and relative condition of important species of fish in different reservoirs have been examined, on the basis of which conclusions are drawn regarding the environmental preference for different species. The influence of stocking rates of fish on fish production in the reservoirs has been examined in the light of probable productivity of the areas. The reduction in stocks of Hilsa and their migration into the Hooghly estuarine system is found to be a combined effect of the removal of essential directive factors for migration in the form of adequate velocities of flow and volumes of discharge and reduction in the spawning area of the fish in the residual Rupnarain and Damodar rivers due to considerable reduction in the wetted perimeter, resultant on dam construction. The need for rehabilitation of Hilsa stocks in the region is highlighted and probable measures suggested.

INTRODUCTION

It is generally known that the construction of barrages and dams for purposes of irrigation, flood control, navigation and hydro-electric power generation has far-reaching effects on the ecological conditions of harnessed rivers. These changes, in turn, affect the fish populations in the river stretches. The effects themselves could be beneficial, harmful or indifferent depending on the particular situation and the fish fauna obtaining in the rivers concerned. Fish, as all other poikilotherms, being highly susceptible to changes in environmental conditions, beyond rather narrow limits, are affected by the environmental changes forged in by the construction of dams. Effects of dams and other structures on fish populations can probably be divided into two categories, *viz.* obstructional and ecological. Obstructional effects, *viz.* effects due to dams becoming physical barriers to essential, genetic or trophic migration of fishes, naturally affect only such species which have to perform long- or short-range migrations for the completion of their normal life cycle. Ecological changes on the other hand can adversely affect both migratory and non-migratory species of fishes. Important among such ecological changes, brought about by construction of dams in the impounded areas, are changes in temperature regimen in the water, temperature stratification, changes in the salinity pattern in the brackishwater regions, altered conditions of current velocities and directions, inundation of spawning grounds and increase in depths in impounded areas which bring about changes both in the productivity pattern and the quality and quantity of plankton crop. Reduction of water levels in the residual rivers results in creation of shallow impassable areas for fish as also changes in temperature and salinity regimen. Drastic environmental changes in the impoundments can be expected to favour the growth of species capable of multiplying and thriving in the altered conditions and detrimental to rheophilic fishes which require conditions obtaining in the fast-flowing rivers for the adequate growth and reproduction of their populations.

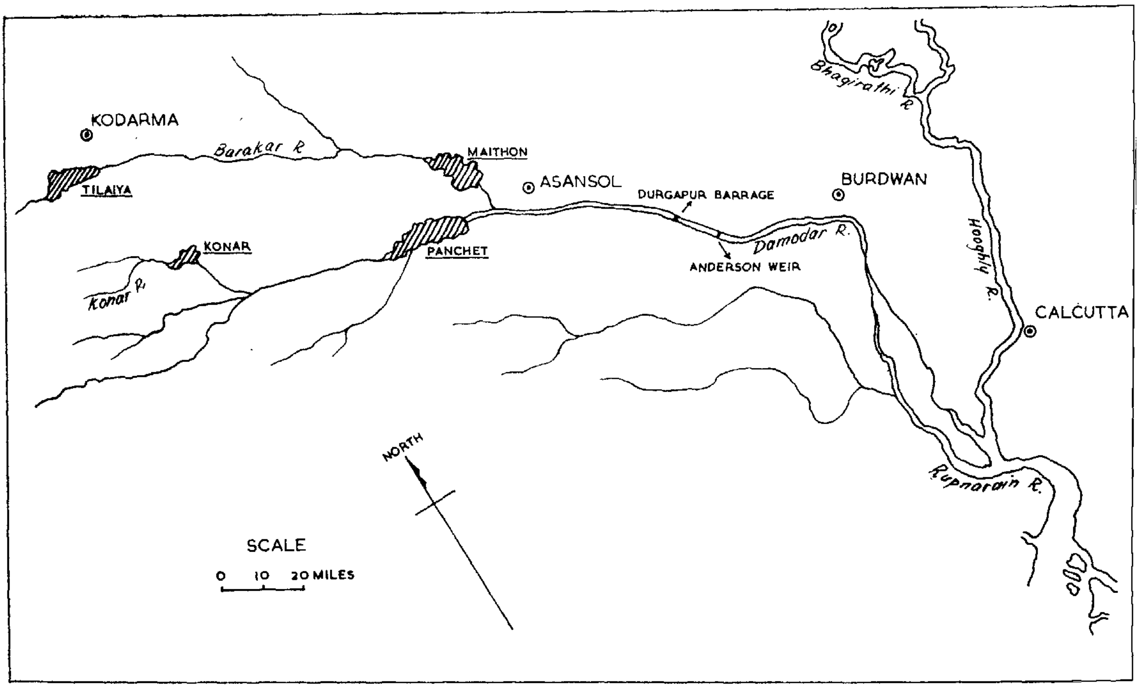

FIG. 1.

Considerable investigations on the effects of dams on fisheries have been made, particularly on the American continent in respect of the Pacific Salmon, *Onchorhinchus* spp, and the Atlantic Salmon, *Salmo* spp. The main philosophy underlying the provision of fish facilities in these cases has been that fish should have access to their parental spawning grounds where they have to return for successful spawning as they exhibit a strong homing tendency. In tropical countries like India, where such anadromous species occur, the effects of dams on fish populations (the fisheries problems involved and the management measures to be adopted) are likely to be identical. However, in most cases where dams are constructed beyond the range of migrations of such anadromous species and where the only species of commercial importance that inhabitate the river stretches are mainly cyprinids and siluroids, both the effects of dams on fisheries and protection facilities to be recommended have to be examined on an entirely different basis. Sunder Raj (1942) was probably the first to attempt an evaluation of the effects of Mettur dam on fisheries of that particular river system. He concluded that dams seriously affect fisheries otherwise than by obstructing free passage to fish. He and others (Hora and Nair 1940; Devanesen 1942; Chacko 1954; Day 1873) have opined that in case of Hilsa a few dams, particularly in the Madras Presidency, did affect Hilsa migration with drastic effects on their fisheries.

In this study an attempt has been made to examine the probable effects of dams constructed beyond the range of migrations of anadromous species on the fisheries of river systems, on the basis of data collected from the D.V.C. reservoirs on fish production and fish populations in the impoundments over a period of about four years. The data stem mainly from experimental nettings made in the reservoirs Maithon, Tilaiya, Panchet and Konar (Fig. 1) by the fisheries organization of the corporation. Lengths (in inches) and weights (in grams) of fishes and details regarding the gear employed were recorded. The data were analysed for the size frequency distributions (Fig. 2), for an estimation of growth rates, determination of size groups contributing to the fisheries, finding the relationship between weight and length and studies on catch per unit of effort.

The D.V.C. system of dams consists of two dams (Tilaiya and Maithon) on the Barakar river and one (Konar) on the Konar river and another (Panchet) on the main Damodar (Fig. 1). It may be mentioned that both the Barakar and the Konar are tributaries of the main Damodar which in turn is a tributary of the Hooghly river through which it drains into the sea (Fig. 1). Nearer to its confluence with the Hooghly are a barrage (Durgapur Barrage—104 miles from the confluence) and a weir (the Anderson Weir—93 miles from the confluence).

Preimpoundment Fauna

Prior to their development the Damodar and its tributaries were fast-flowing, torrential rivers, subjected to immense flooding during the monsoons. During drought conditions the rivers used to be more or less practically dry except in stretches where, by virtue of depressions, they used to retain some water. Similar conditions used to obtain during summer months also. The rivers thus used to sustain what may be termed as flood fisheries operated on species which used to perform local migrations during the flooded monsoon seasons and restrict themselves to the isolated stretches of deep-water pools during summer months. A list of the species that were encountered in this river system prior to the construction of the D.V.C. dams was given by Job *et al.* (1952). Since the present study is confined to commercially important species and not to the faunistic changes due to dams constructions, only the

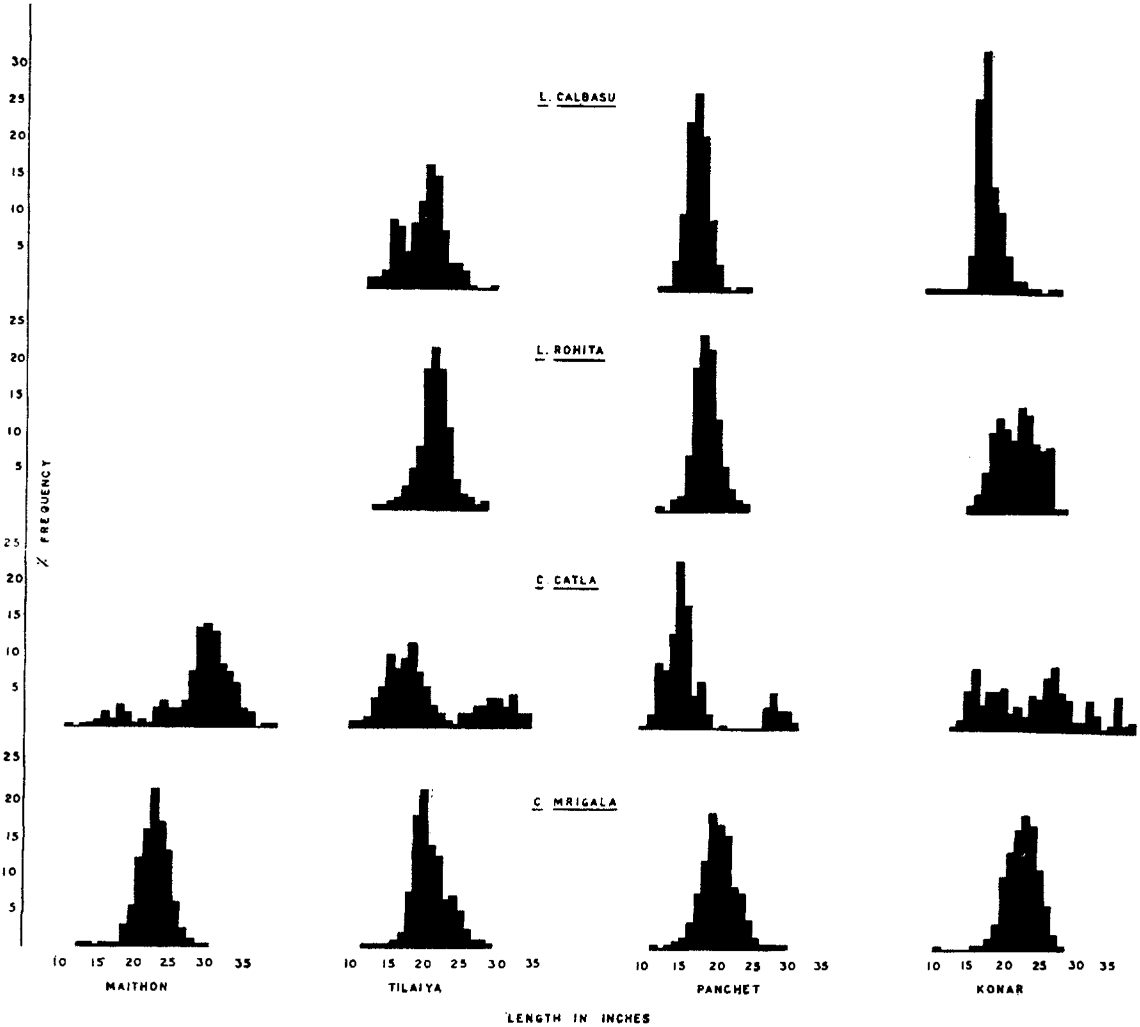

Fig. 2.

major carps, *viz.* Catla, Rohu, Mrigal and Calbasu, are being considered. Catla, Mrigal, Rohu and Calbasu were encountered both in the Barakar and Damodar rivers, whereas in Konar, above the Konar waterfalls, only Catla was recorded and not the other species. *H. ilisha* was recorded to be occurring up to the Anderson Weir. No accurate records about the physico-chemical conditions of water in these river systems prior to the construction of dams, nor any data to give an indication about the relative abundance of the different species of carps, are available. Hilsa was known to contribute considerably to the catches of both the Damodar and the Rupnarain (a distributary of the Damodar) prior to the construction of the D.V.C. dams.

The Tilaiya dam was filled in 1953, Konar in 1957 and Maithon and Panchet in 1958. After construction, these dams were stocked on an *ad hoc* basis with fingerlings of the major carps, *C. catla, L. rohita, C. mrigala* and *L. calbasu,* on the assumption that a stocking was necessary for proper rehabilitation of different species. Table I gives the pattern of stocking of fingerlings in different reservoirs up to 1960. Experimental fishing was started in the year 1956 in Tilaiya, in 1958 in Konar and in 1959 in both Maithon and Panchet.

TABLE I

Fingerlings liberated in the D.V.C. reservoirs up to 1960 (figures in lakhs)

Reservoirs	Fingerlings
Maithon	1·8
Tilaiya	36·6
Panchet	1·0
Konar	5·5
Total	44·9

COMPARATIVE ABUNDANCE OF DIFFERENT SPECIES IN DIFFERENT RESERVOIRS

Maithon

Analysis of catch statistics for the years 1961 and 1962 showed that Mrigal and Catla were by far the most dominant species in this reservoir (Fig. 3). In 1961 Mrigal was the most dominant species accounting for 52·1% of the total catches for a constant effort, followed by Catla 26·1%, Rohu 1·1% and Calbasu 0·4%. In 1962 Catla accounted for maximum landings by contributing 53·9%, followed by Mrigal 24·7%, Rohu 1·0% and Calbasu 0·8%. An examination of catch/effort (Fig. 4) for different months shows that Mrigal fishery was maximum and the fish contributed to the catches in large quantities during the months of March and August to October. Catla was landed in large quantities during January and May to July while Rohu and Calbasu, whose contribution to the fishery was negligible, were caught in relatively large quantities in the months of March and September and April and September, respectively. Size frequency distribution of the different species showed that two size groups of Catla having modal sizes of

18″ and 30″ contributed to the catches, whereas only one size group of Mrigal having a modal length of 23″ was reported (Fig. 2).

Tilaiya

Data on fish catches for the years 1960 and 1961 were analysed. In the year 1960 contribution from Mrigal catches topped the list, accounting for 50·2%, followed by Rohu 21·8%, Catla 20·4% and Calbasu 7·6%. But in the year 1961 catches of Catla contributed more than the other species, accounting for 48·1%. Second in order came the catches of Mrigal 28·8%, followed by

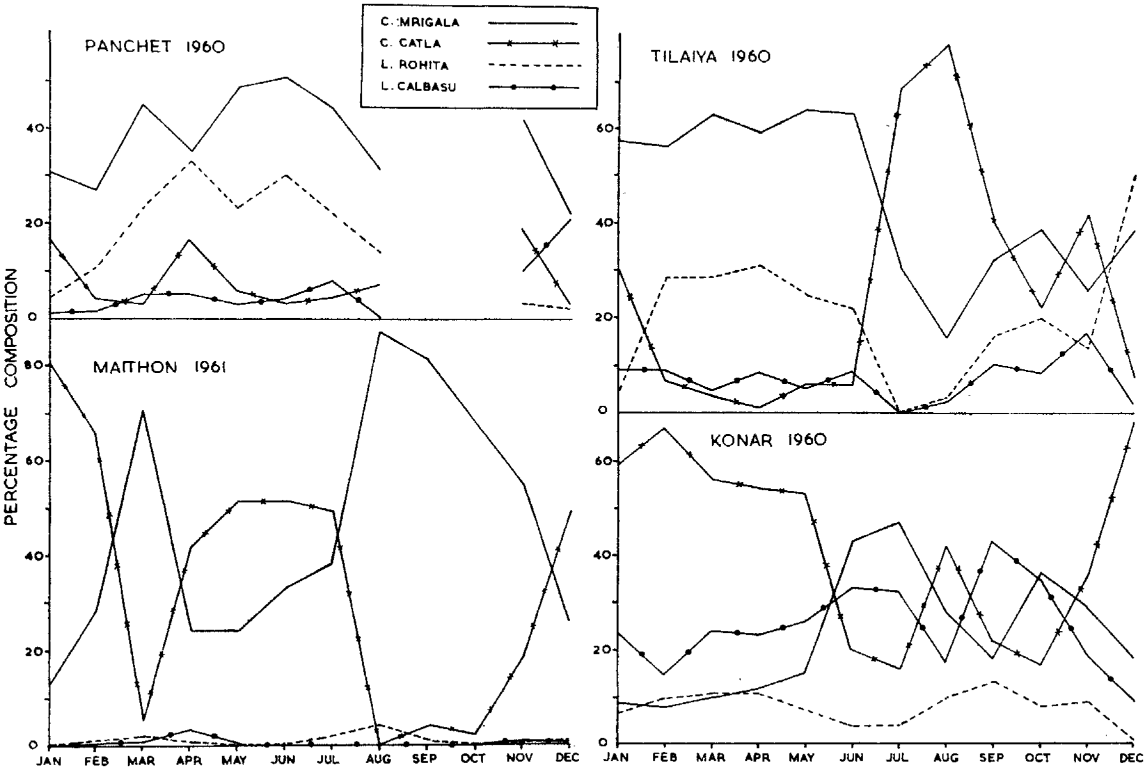

FIG. 3.

Rohu 15·0% and Calbasu 8·1%. Generally the catches of Mrigal were high during January to June and October to December, whereas good catches of Catla were caught during July to December. In the case of Rohu there was no such significant fluctuation in catches. A similar pattern was followed by the catches of Calbasu (Fig. 3). Length frequency analysis showed that the modal sizes of the dominant size groups that contributed to the catches were 20″ for Mrigal, 18″ and 30″ for Catla, 21″ for Rohu and 20″ for Calbasu (Fig. 2).

Panchet

From the analysis of fish catches for the year 1960 it was noticed that catches from Mrigal were dominant, followed by Rohu, Catla and Calbasu respectively, the contribution from these fishes being 40·4%, 19·3%, 8·0% and 5·8% respectively. Catches of Mrigal dominated throughout the year over other catches (Fig. 3). However, Rohu was landed in considerable

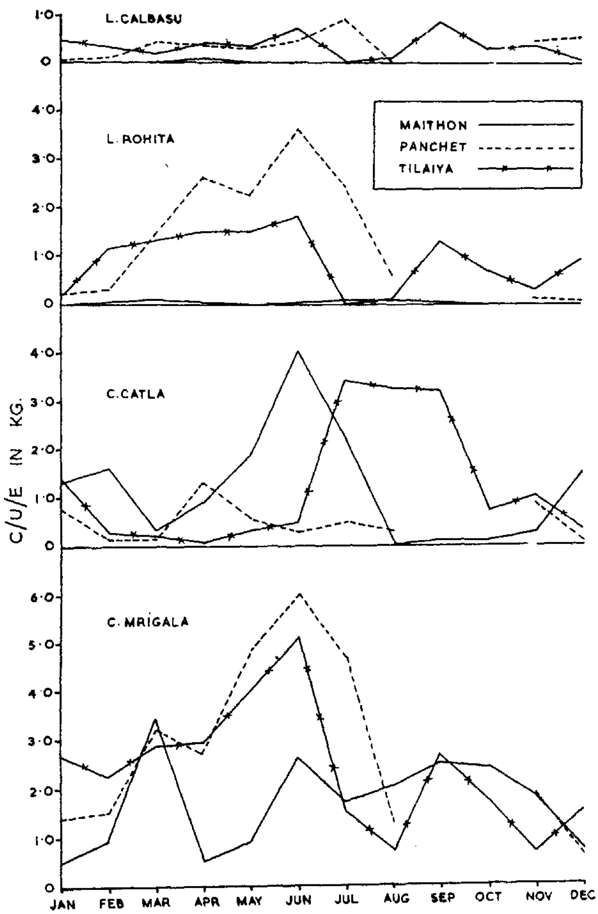

Fig. 4.

quantities during March to July. For both Catla and Calbasu, except for the comparatively good catches during the period November to January, the catches in other months were considerably less. From length frequency analysis it was found that there was a single mode for Mrigal at 20″, two modes for Catla at 15″ and 28″, a single mode for Rohu at 18″ and a single mode for Calbasu at 17″ (Fig. 2).

Konar

Analysis of catch statistics for the year 1959 showed that the major contribution to the total catches came from Catla, the contribution being 67·6%, whereas Calbasu contributed 23·3%, followed by Rohu 6·2% and Mrigal 2·3%. In the year 1960 also catches of Catla dominated though the contribution was comparatively less (35·6%) than the previous year. The catches of Mrigal amounted to 28·7%, followed by Calbasu 26·3% and Rohu 7·4%. As effort data were not available for this particular reservoir catch/effort was not calculated. Analysis of length frequencies showed single modes for both Mrigal and Calbasu, the modes being at 23" and 17" respectively. In the case of *L. rohita* there were two modes, one at 19" and another at 22". Maximum number of modes were found for Catla, the modes being at 16", 27", 32" and 36" (Fig. 2).

Comparison between Different Reservoirs

From the above account it is evident that a difference, in the relative abundance of the four species of cyprinids, exists between the different reservoirs under study. Since data on catch/effort are not available for Konar and as the catch/effort is taken as an index of abundance, in the following account a comparison of abundance of different species is made only between the reservoirs Maithon, Tilaiya and Panchet. While *Catla catla* appears to be the more dominant species in Maithon reservoir, *Labeo rohita* and *Cirrhina*

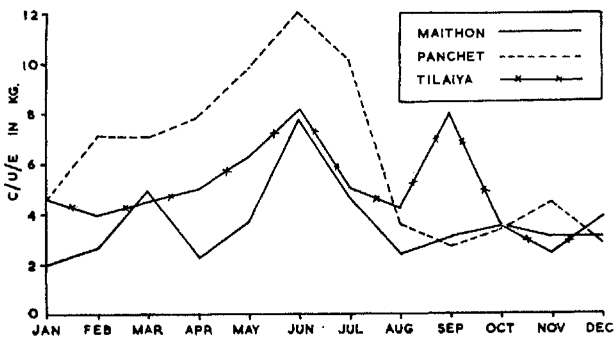

Fig. 5.

mrigala are comparatively more abundant in Panchet. There does not seem to be any remarkable difference in the abundance pattern of *Labeo calbasu*, which has a uniformly low abundance, between these three reservoirs. In this connection it is interesting to note that *L. calbasu* has contributed to the catches of Konar considerably. It is noteworthy that the abundance of *C. mrigala* and *L. rohita* is the least in Maithon where although Mrigal occurs fairly in good quantities the abundance of Rohu is practically negligible. In

Tilaiya on the other hand the abundance of all the three species, *i.e.* Catla, Rohu and Mrigal, is uniform. This tends to show that while the ecological conditions in Maithon are highly favourable for Catla and least favourable for Rohu, those in Panchet are most favourable for Rohu and least favourable for Catla. Unfortunately data on the ecological conditions in the reservoirs are not available to permit a critical examination of the particular factor or factors that are likely to be responsible for this situation. General trend in catch/effort showed that maximum catch/effort was available in Panchet (Fig. 5) indicating probably that this is the most productive of all reservoirs. Weight-length relationships of four species of carps in different reservoirs were estimated to ascertain whether any significant differences exist between them. Table II gives these relationships for the four species in different reservoirs. Though the relationships for different species of various reservoirs conform to general allometric formula, $w = al^n$, significant differences exist within each species between different reservoirs (Table II). Generally, differences in weight-length relationships, if significant, are attributed to racial differences within a given species. It can be seen from the table that the weight-length relationship only in respect of *C. catla* is not significantly different between different reservoirs, whereas for all the other three species the differences in the above relationships are significant. In the absence of other biometrical studies it is difficult to express any opinion as to whether these differences do reflect any differences in racial characters. The fact of the identical nature of weight-length relationship in respect of Catla also has to be left unexplained since the information regarding the sources from which the different reservoirs were stocked is not available.

The relative condition factor 'K_n', which is known to be a measure of well-being of a fish, has been estimated in all the cases. Table III gives the 'K_n' values of different species in various reservoirs. A critical examination of this table indicates that, generally, a direct correlation exists between the 'K_n' and abundance of a particular species in a given reservoir, 'K_n' being high in respect of species in reservoirs where they are relatively more abundant. Presumably, such a situation is to be expected, except where the population abundance has increased beyond a limit where density-dependent factors tend to come into play, since abundance may be related to favourable environmental conditions favouring the well-being of the fish. However, one important departure from the above trend has been observed in the case of Catla which is sparse in the Panchet reservoir though its relative condition in that particular reservoir is high. This may probably be taken to indicate that in this particular reservoir, despite the environmental conditions being favourable (as indicated by high 'K_n'), the abundance of the population of the species was low which may probably be attributable to other population-regulating mechanisms such as lack of suitable spawning grounds; the existence of other species which bring in the factor of inter-specific competition to the disadvantage of this particular species or even, presumably, lack of adequate

TABLE II

Weight-length relationship and regression analysis

Species	Reservoirs			
	Maithon*	Tilaiya	Panchet	Konar
C. mrigala	$w = 0{\cdot}0011771L^{3.2931}$	$w = 0{\cdot}0063183L^{2.7573}$	$w = 0{\cdot}0012362L^{2.6877}$	$w = 0{\cdot}0287010L^{2.2841}$
C. catla	$w = 0{\cdot}0014582L^{3.3692}$	$w = 0{\cdot}0023972L^{3.2028}$	$w = 0{\cdot}0033963L^{3.0761}$	$w = 0{\cdot}0022982L^{3.2075}$
L. rohita	—	$w = 0{\cdot}0083618L^{2.6977}$	$w = 0{\cdot}0136210L^{2.5326}$	$w = 0{\cdot}0062230L^{2.8079}$
L. calbasu	—	$w = 0{\cdot}0166640L^{2.4602}$	$w = 0{\cdot}0013412L^{3.3423}$	$w = 0{\cdot}0168420L^{2.4316}$

Tests in regression analysis

Species	The tests of calculated 'F'	
C. mrigala	Lines are identical	—53·98‡
	Slopes are equal	—75·23‡
C. catla	Lines are identical	— 2·08
	Slopes are equal	— 1·81
L. rohita	Lines are identical	— 4·55‡
	Slopes are equal	— 3·60†
L. calbasu	Lines are identical	—43·60‡
	Slopes are equal	—60·19‡

* As the catches of *L. rohita* and *L. calbasu* were very low no weight-length relationships were found.
† Significant at 5% level.
‡ Significant at 1% level.

spawning stock commensurate with the sustaining capacity of the reservoir. Hence, it would be interesting to study the entire species complex as well as their habits and habitats with a view to elucidating the interaction between the various populations.

TABLE III

Relative condition factors of different species in the D.V.C. reservoirs

Reservoirs	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						C. catla							
Maithon	1·00	1·03	1·00	1·06	0·87	1·08	1·02	—	1·05	0·96	0·95	0·98	1·00
Tilaiya	1·05	0·90	0·89	0·84	0·91	0·99	1·11	1·08	1·07	1·07	0·90	0·95	0·98
Konar	1·05	1·03	1·06	1·07	0·97	0·95	1·14	1·00	0·97	0·96	0·96	0·97	1·01
Panchet	1·14	1·03	0·88	0·99	1·00	0·86	0·87	—	—	—	1·06	1·22	1·01
						C. mrigala							
Maithon	1·12	1·12	0·99	1·00	1·01	1·01	0·97	1·03	1·05	0·98	1·04	1·09	1·03
Tilaiya	1·02	1·10	1·01	1·07	1·05	1·04	1·01	1·08	1·02	1·07	1·07	1·03	1·05
Konar	1·03	1·07	1·07	0·93	0·93	1·01	0·95	1·03	0·99	1·04	1·02	0·97	1·00
Panchet	1·00	1·03	1·04	1·10	0·98	1·03	0·94	—	—	—	0·97	1·05	1·02
						L. rohita							
Tilaiya	0·94	0·95	1·01	1·00	1·09	1·03	—	1·06	1·12	1·02	1·25	1·02	1·04
Konar	0·98	0·95	1·00	1·04	1·01	0·97	0·94	1·01	1·00	1·03	1·03	0·93	0·99
Panchet	1·11	1·14	0·96	1·01	0·95	0·98	0·91	—	—	—	1·06	—	1·02
						L. calbasu							
Tilaiya	0·97	0·95	0·94	0·99	0·96	0·99	—	1·12	1·02	1·09	1·08	0·91	1·00
Konar	1·04	1·12	1·08	1·07	1·07	0·97	1·00	0·97	1·02	0·99	1·05	0·92	1·03
Panchet	1·03	0·92	0·97	1·05	0·92	0·92	0·93	—	—	—	0·95	1·06	0·97

As mentioned earlier, fishing is generally done in the reservoirs by means of 'Rangoon' nets which are both entangling and gilling type of nets. The nets used in the reservoirs on which the present study is based have three different mesh sizes (2″ bar, $2\frac{1}{2}$″ bar and 5″ bar). The modal lengths of size distribution of different species of fish caught in these nets in the various reservoirs are given in Table IV. From an examination of these it is evident

TABLE IV

Modal lengths of four major carps in the D.V.C. reservoirs (in inches)

Species	Reservoirs			
	Maithon	Tilaiya	Panchet	Konar
C. mrigala	23″	20″	20″	23″
C. catla	18″ and 30″	18″ and 30″	15″ and 28″	16″, 27″, 32″ and 36″
L. rohita	—	21″	18″	19″ and 22″
L. calbasu	—	20″	17″	17″

that generally the size frequency distribution of most of the species in most of the reservoirs is unimodal except in case of Catla which is multimodal in all the reservoirs and in case of Rohu which is bimodal only in Konar. Normally, if the modes represent mesh selectivity modes, it is to be expected that the number of modes observed in the size frequency distribution should be identical to the number of sizes of mesh used in the exploitation. This observed dissimilarity is taken to indicate that the modes do not represent mesh selectivity modes but modal lengths of age groups represented in the catches, which is not unlikely considering the entangling nature of the nets. The fact that in most of the species except in Catla there is only one mode, indicates that a lower limit of selection of these nets is such that all except the largest available size groups escape. This explains the recruitment of only one size group in these species which obviously is the only vulnerable size beyond which the population has no presentatives. The fact that Rohu, Mrigal and Calbasu grow to maximum sizes of about 3′ only (Day 1889), corroborates this view, since the size represented in the catches is in the vicinity of maximum attainable size of the species. Based on this evidence a comparison of the earlier modal sizes represented in the catches can be taken to reflect the rate of growth of different species in these reservoirs. It appears that the growth of Catla is generally high in Maithon and Tilaiya; that of Mrigal is high in Maithon and Konar; the growth of Rohu is high in Konar and that of Calbasu is high in Tilaiya.

Population Abundance with Reference to Stocking

Conflicting opinions were expressed by different workers on the utility and desirability of stocking impoundments as a routine practice. Recent investigations on the morpho-ecological changes consequent on impoundment have thrown a new light on the subject. Studies in widely-separated regions of the world have revealed a constant pattern in the productivity cycle of reservoirs. Immediately after filling, there is an initial period of high productivity accompanied by a steep increase in fish food reserves, as a result of the fertilizing action of submerged vegetation, decay products and increased soil substratum. This initial spurt of high productivity lasts for a few years and is followed by a period of trophic depression and subsequent recovery (Lapitzky 1965). The only obvious way to take advantage of this initial phase of high productivity is to stock large quantities of fish of desirable varieties during the first year of filling, since the indigenous stocks present in the streams would not be numerically adequate to populate and exploit the food resources of the enormously-increased area. According to Lapitzky (1965) 'the survival rate of the generation of the first year of filling exceeds tenfold and sometimes hundredfold that of the fry of merging rivers and the generation of the first year forms a robust basis for fishing for many years to come'.

As mentioned earlier in this account, all the four reservoirs were stocked in different intensities. Table I gives the total number of fingerlings stocked up to 1960. From this it is evident that maximum stocking was done in the Tilaiya reservoir, Konar and Maithon ranking second and third, whereas in Panchet the stocking was practically nil. Compared to this, from the point of view of the abundance of fish Panchet ranks first with Konar a close second, Tilaiya and Maithon ranking third and fourth respectively. This fact apparently casts an element of doubt on the utility or necessity of indiscriminate stocking as a measure calculated to increase fish production and thus militates against established facts concerning reservoir management. However, the picture becomes clear when viewed in the light of productivity differences in different watersheds albeit in the same general drainage. Maithon and Tilaiya dams are located on the Barakar river, a tributary of the Damodar, whereas the Konar and Panchet dams are constructed on the Konar and the Damodar prior to the point of confluence of the Barakar and the main river (Fig. 1). The waters of Maithon and Tilaiya are generally turbid, whereas those of Panchet and Konar are clear. Thus, presumably it is factors associated with productivity pattern rather than with stocking rates that influenced the observed higher fish production in Panchet and Konar as compared to Maithon and Tilaiya. Probably, had Panchet and Konar been stocked more intensively, the returns in the form of fish production in these reservoirs would have been considerably higher.

Effects on the Residual Rivers

The results elaborated above had shown more or less conclusively that as far as cyprinid fishes are concerned, the effects of these impoundments on the fisheries of these species may be considered to be beneficial. Even with the limited intensity of experimental exploitation the departmental nets realize average annual landings of about four tonnes per reservoir, whereas prior to the construction of the dams these river stretches did not support commercial fisheries of any value (Table V). It may be mentioned that in addition to the

Table V

Reported annual catches from the D.V.C. reservoirs in 1960
(figures in kg.)

Species	Reservoirs			
	Maithon*	Tilaiya	Panchet	Konar
C. mrigala	1,821	2,314	1,982	1,355
C. catla	914	939	392	1,682
L. rohita	39	1,002	947	352
L. calbasu	15	349	284	1,246
Others	709	—	1,300	96
Total ..	3,498	4,604	4,905	4,731

* For Maithon catches for 1961 were taken.

departmental exploitation, commercial catches are being made in large quantities in these reservoirs, accurate statistics regarding which are not available.

While, thus, these impoundments do not appear to have adversely affected the fisheries in the river stretches above the dams there is considerable evidence to show that the effects of these dams on the fisheries of the residual rivers have been considerably deleterious, particularly to one of the most important fisheries of India, viz. *Hilsa ilisha* of the Hooghly estuarine system. Though the Hooghly is one of the distributaries of the main Ganga, it is well known that its connection with the parent river has silted up considerably, as a result of which the flow of water from the Ganga to the Hooghly is restricted in quantity and limited to the few monsoon months. Thus, the contribution of the Damodar river system to volume of water discharge from the Hooghly to the sea used to be significant and considerable. That dams affect fisheries of the residual rivers is also widely recognized. The D.V.C. dams were completed during the years 1953 (Tilaiya), 1955 (Konar), 1957 (Maithon) and 1958 (Panchet). It is a well-known fact that Hilsa fisheries in the Hooghly estuarine system, comprising of the main Hooghly and its tributaries, the Damodar and the Rupnarain, have registered a sudden steep decline in the year 1957, which is still continuing, except for minor spurts of increase in 1963 and 1964. Prior to this year, Hilsa used to contribute to over 60% of the total landings of fishes in this estuarine system, whereas afterwards its contribution fell to about 5%. This spectacular decline in catches, simultaneously as the completion of the Maithon dam, cannot be considered to be a mere coincidence in the light of known facts about fish behaviour. It is highly probable that a reduction in the volume of discharge from the main Hooghly, as a result of the reduced contribution from the Damodar, because of the impoundments at Tilaiya, Konar and Maithon, might have resulted in the removal of essential directive factors for the migration of the fish and consequently its availability. Prior to the construction of dams Hilsa used to migrate to a distance, about 90 miles, in the Damodar-Rupnarain system in fairly large numbers and used to breed in the freshwater stretches of these rivers, beyond the limits of tidal influence through the Hooghly. Thus, these two rivers used to provide about a 130-mile stretch of spawning ground for *Hilsa ilisha*. Subsequent to the construction of the D.V.C. dams the residual Damodar is practically non-existent in its original form and during the spawning season of this fish there is barely a trickle of water in this river which is unsuitable for migration of Hilsa. In the Rupnarain also the reduction of flow due to impoundments has reduced the effective part of the river into which Hilsa can migrate from 60 miles to only about 25 miles. Thus, an immediate effect of the impoundment has been the reduction of the total spawning stretch of the river by about 100 miles. It is well known that the abundance of stocks of anadromous species is largely a function of the spawning and rearing potential of its spawning grounds in the freshwater habitats. Thus this steep decline in the available spawning area might have been one of the major contributory factors for the decline of Hilsa fishery in the Hooghly estuarine system.

Though, unfortunately, no data on the temperature regimen of the residual Rupnarain and the Damodar prior to the construction of dams is available, the decreased volumes of flow after the dam construction must have contributed to a measurable increase in the temperature pattern of these rivers. In the main residual Damodar and in the Rupnarain above a point 60 miles from its confluence with the Hooghly there are innumerable stretches of difficult non-negotiable passages for Hilsa as a result of the reduction in the volume of the flow in these rivers due to impoundments. Hence, Hilsa does not, as mentioned earlier, migrate up the residual Damodar and in the Rupnarain it ascends only a 25-mile stretch of the river.

Essential directive factors for the migration of anadromous fishes up the estuaries are the velocities of the flow and the volumes of the discharge at the mouth of the estuary during periods of migration of these species. As a result of the construction of the D.V.C. dams the flow pattern in the main

Hooghly has considerably changed due to inadequate flushing of the rivers during the months of June to November. There are two waves of migration of Hilsa up the Hooghly estuary, one during the monsoon, July-September, and another during the winter months, mid-November to mid-January. The monsoon run has completely failed after the dam construction which is presumably attributable to the removal of cues for the migration in the form of the preferred volumes of discharge and velocities of flow which are specific requirements for migration of species. It is also significant to find that the winter runs continue subsequent to the construction of dams, though in considerably smaller numbers, which is to be expected in view of the fact that the interference in the volumes of the discharge and the velocities of flow in the residual river are not interfered with to the extent to which the flow and velocity during monsoons are, as the result of this impoundment. Thus, available evidence indicates that the drastic decline in Hilsa catches in the Hooghly estuarine system is a result of failure of migration due to the removal of essential directive factors for this species during monsoon months and due to a reduction in the abundance of stocks consequent on the reduction of total spawning and rearing areas, both for the monsoon and winter runs.

Since Hilsa fishery is of considerable importance to the economy of the country it would be worth while to investigate the possibility of rehabilitating runs of this species in these two rivers (the Rupnarain and the Damodar) by provision of suitable protection and, if necessary, passage facilities. Though the recommendation of actual measures should necessarily be preceded by a detailed study, the obvious measures that are likely to improve the position are:

(i) Releasing of adequate supplies of water from the dams during the period of migration, rearing and spawning of fishes, provided such a measure does not adversely affect the other functions of the dams such as irrigation and power generation;

(ii) channelization work in the upper stretches of the Rupnarain; and

(iii) if feasible, provision of passage facilities in the Anderson Weir and Durgapur Barrage to provide access to Hilsa to the stretches of rivers above these constructions with a view to making available larger spawning and rearing areas, provided the channelization work in the Rupnarain leads to the re-establishment of Hilsa runs in the main Damodar.

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