FISH GEOGRAPHY OF THE HIMALAYAS *

by A. G. K. MENON, *Assistant Zoologist, Zoological Survey of India, Calcutta*

(Communicated by S. L. Hora, F.N.I.)

(*Received April 15; read August 6, 1954*)

CONTENTS

INTRODUCTION

In 1937, Hora in two papers dealt with certain aspects of the zoogeography of the Himalayas and broadly discussed the distribution of torrential fishes on such data as were then available. It seems to be a well recognised fact concerning the distribution of all groups of animals that the fauna along the Himalayas becomes poorer and poorer as we go towards the west and the large assemblage of the so-called Malayan forms found in the Brahmaputra watershed and the Assam Hills reappears again in the hills of Peninsular India, but not to any appreciable extent to the west of the Brahmaputra drainage. As a result of extensive field surveys along the Vindhyas (Hora, 1949), the Satpuras (Hora and Nair, 1941), the Peninsular India (Hora, 1944) and the Orissa Hills and the Eastern Ghats (Menon, 1951), it has now been established that the route of migration of the Malayan elements in the freshwater fish fauna of India lay along the Assam Hills and the Vindhya-Satpura trend of mountains across the Garo-Rajmahal Gap during periods of Pleistocene glaciation when the sea-level fell by several hundred feet (Hora, 1951). The systematic studies of the Peninsular isolates *vis-à-vis* the Malayan forms have shown that this migration has been accomplished through four waves during the Pleistocene epoch (Silas, 1952). In this paper, an attempt has been made to analyse in detail the composition of the Himalayan fish fauna in order to demarcate the extent of penetration of the Malayan fauna † along the Himalayas, the barriers that obstructed its westward migration and the approximate age of such events.

---

* Published with the kind permission of the Director, Zoological Survey of India, Calcutta.

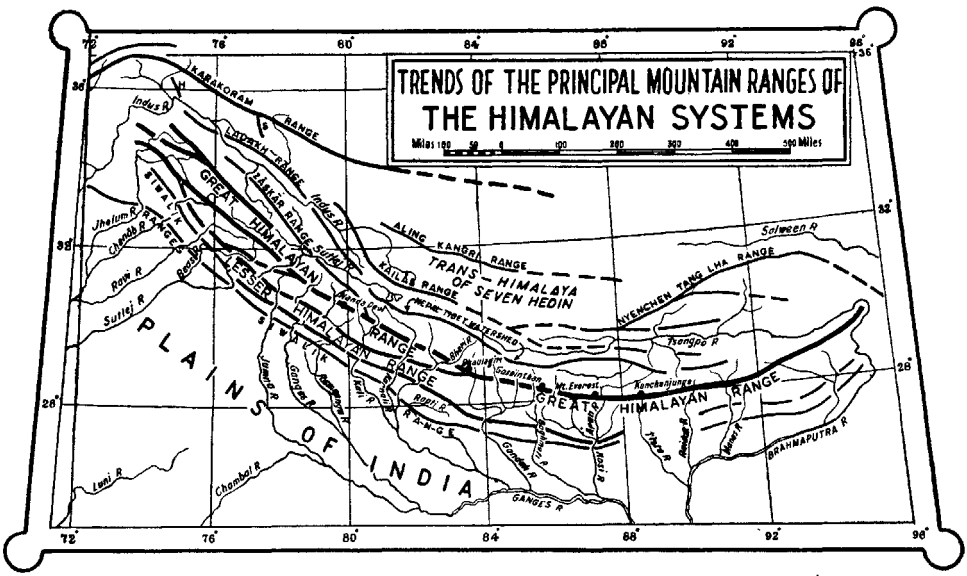
† As for palaeogeographical and zoogeographical studies, widely distributed species cannot be of any very great help, only fishes normally living in fast currents of rocky streams have been taken into consideration.

Physical features and Description of the Areas surveyed

(1) *Structural features.*—The Himalayas extend between latitudes 28° N. and 36° N. and longitudes 72° E. and 96° E. This segment is a complete mountain rampart, convex towards the south, the orientation of its western extremity being generally N.W.-S.E. and that of eastern extremity being W.S.W.-E.N.E. The great chain of Himalayas is 1,600 miles long and the total width varies between 90 miles and 250 miles. Geologists believe that greater part of this vast tract was under the waters which was the eastern extension of the Mediterranean sea—the Tethys—from the end of the Carboniferous period to the end of the Eocene *.

The Himalaya is the 'Youngest, largest and highest chain of mountains in the world, a chain that is probably still growing in altitude'. On the Himalayan region, 'overfolding, faulting, thrusting, contortion and recumbency'—all the accompaniments and causes of mountain building—are to be observed and date mostly from Tertiary or later times.

Himalayas comprise a series of parallel mountain ranges—the Himalaya proper and the Zanskar, Ladakh and Kailas ranges. The Aling Kangri and the Karakoram ranges lie further north.



Text-fig. 1. Trends of the Principal mountain ranges of the Himalayan systems. (After Burrard and Hayden, 1933.)

The Himalayan region may be divided into four zones on the basis of its geology and geography (Pascoe, *loc. cit.*, p. 14). These are longitudinal zones parallel to their length—from north to south: (1) the Tibetan Himalaya, (2) the Great Himalaya, (3) the Lesser Himalaya and (4) the Sub-Himalaya †. The outer

* Writing about the age of the Himalayas, Oldham observed that 'the occurrence of marine nummulitic beds at a height of many thousand feet on the northern face of the main snowy range in Hundes, and at a height of 20,000 feet in Zanskar, shows that the elevation of this part of Himalayas must have taken place entirely within the tertiary period'. Dr. Blanford also arrived at the same conclusion basing his arguments on geological and faunistic evidences (Pascoe, 1950).

† The three-fold division of the Himalayan system is also correct in which the Tibetan Himalaya is excluded. On this zone, *i.e.*, the Tibetan Himalaya, only the influence of the Himalayan movements can be detected (*vide* Krishnan, 1943, p. 142). Stratigraphically and

belt of the foot-hills, known by different names in different sections, as the Duars and the Siwaliks, is occupied by Tertiary sandstones and clays. The Great Himalayan zone is a complex of crystalline rocks—igneous rocks, granite and pegmatites. The foot-hill zone is about 25 to 30 miles wide with an average height of about 3,000 feet. The Lesser Himalayan zone, lying north of the foot-hill zone, has an average altitude of 10,000 feet and a width of 40 to 50 miles. The Great Himalayan zone consists of a great line of snow-clad peaks and the average height is about 20,000 ft.

From the geographer's point of view, both altitude and longitude (west to east) are significant as differences in both altitude and longitude can be correlated with differences in geographical landscapes. Altitudinally, 'temperate, but still evergreen forests' with oak as the prevailing tree are to be found above 5,000 feet, this succeeding the tropical forest below 5,000 ft.; coniferous forest dominates above 9,000 ft. while near about 12,000 feet lie the alpine meadows. Longitudinally, the Himalayan zone ean be divided into the drier west and the humid east. This west-east division is based on the differences in length and intensity of rainy season and natural vegetation. On the east are to be found dense jungles and humid forests with sal (*Shorea robusta*) while the west is characterised by 'dry monsoon type of forest—xerophytic—with the dhak replacing the sal. The zone between 78° and 82° longitudes is the transitional zone between the west and the east, but no detailed study of this zone has yet been carried out to draw the exact boundary between the two zones.

Biologically the limits of the Himalayas are governed by climatological considerations. Rainfall, temperature, humidity, etc. are important factors governing the distribution of plant life, and the dispersal of animal life is dependent on that of the flora. Thus the hills of Assam, though geologically much older as representing a part of Peninsular India, are climatically very similar to the Eastern Himalayas and would thus faunistically be included as parts of the Himalayas for the purpose of this paper.

In dealing with the distribution of fishes along the Himalayas some knowledge of the present-day watersheds is necessary as dispersal of torrential fishes can only take place if connections between watersheds take place at some period or another.

(2) *The Himalayan rivers and localities surveyed.*—The Himalayan region is drained by two principal river systems: the Indus and the Ganges. The Ganges is connected with the Brahmaputra and the Meghna; hence the Ganges system may be taken to include the rivers of Assam also.

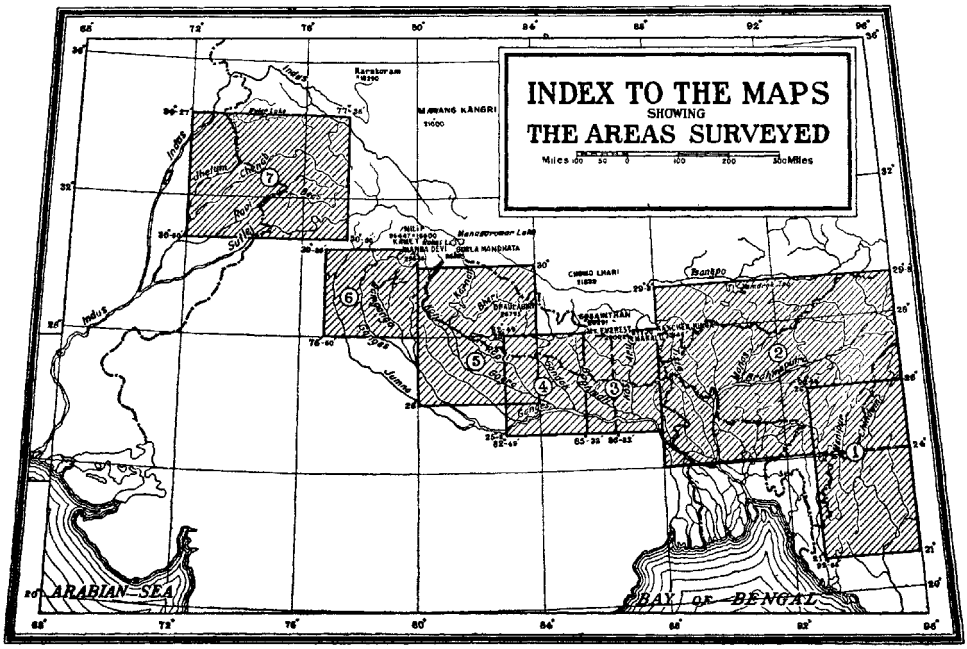
For descriptive purposes the Himalayan rivers can be divided into four groups. Burrard *et al.* (1933) have selected for the dividing lines of the Himalayan range the Tista, the Kali and the Sutlej. The rivers of the eastern section between Brahmaputra and Tista are grouped as the rivers of the Assam Himalayas, the next group between the Tista and the Kali, the Nepal Himalayas, the third between the Kali and Sutlej, the Kumaon and the last, west of the Sutlej, the Punjab Himalayan rivers.

In this classification the Tista has been considered as one of the Assam rivers although it does not drain the Assam Himalayan region. The Brahmaputra is the greatest river of Assam and since the Tista flows into it, as do all the other Assam rivers, it has been included among the rivers of the Assam Himalayas. Zoogeographically also the inclusion of Tista along with the Assam Himalayan rivers is sound as most of the Assam Himalayan forms, especially of the fish fauna, are found in the Tista drainage system. In the above classification, the Kali has been included with the rivers of the Kumaon Himalayas and the Sutlej with the Punjab.

---

orographically the Tibetan Himalaya may be included in the Himalayan group, but not geographically, *i.e.*, on the basis of climate, vegetation, altitude and human responses to environment.

(*a*) *The Brahmaputra and its tributaries.*—The Brahmaputra and its tributaries drain the southern face of the Himalayan area between longitudes 88° and 96° E. Its important tributaries from west to east are (1) the Tista, (2) the Raidak, (3) the Manas, (4) the Bhareli, (5) the Subansiri, (6) the Dibhang and (7) the Luhit. The Assam hill ranges south of the river Brahmaputra are drained by (1) the Kalang, (2) Dhansiri, (3) the Dikho and (4) the Burhi Dihing into the Brahmaputra, while the area below Kairong (lat. 25° 20′), which is the main water parting of the Naga hills, is drained into the Irrawaddy through the Chindwin (Hora, 1921, pp. 170-171).



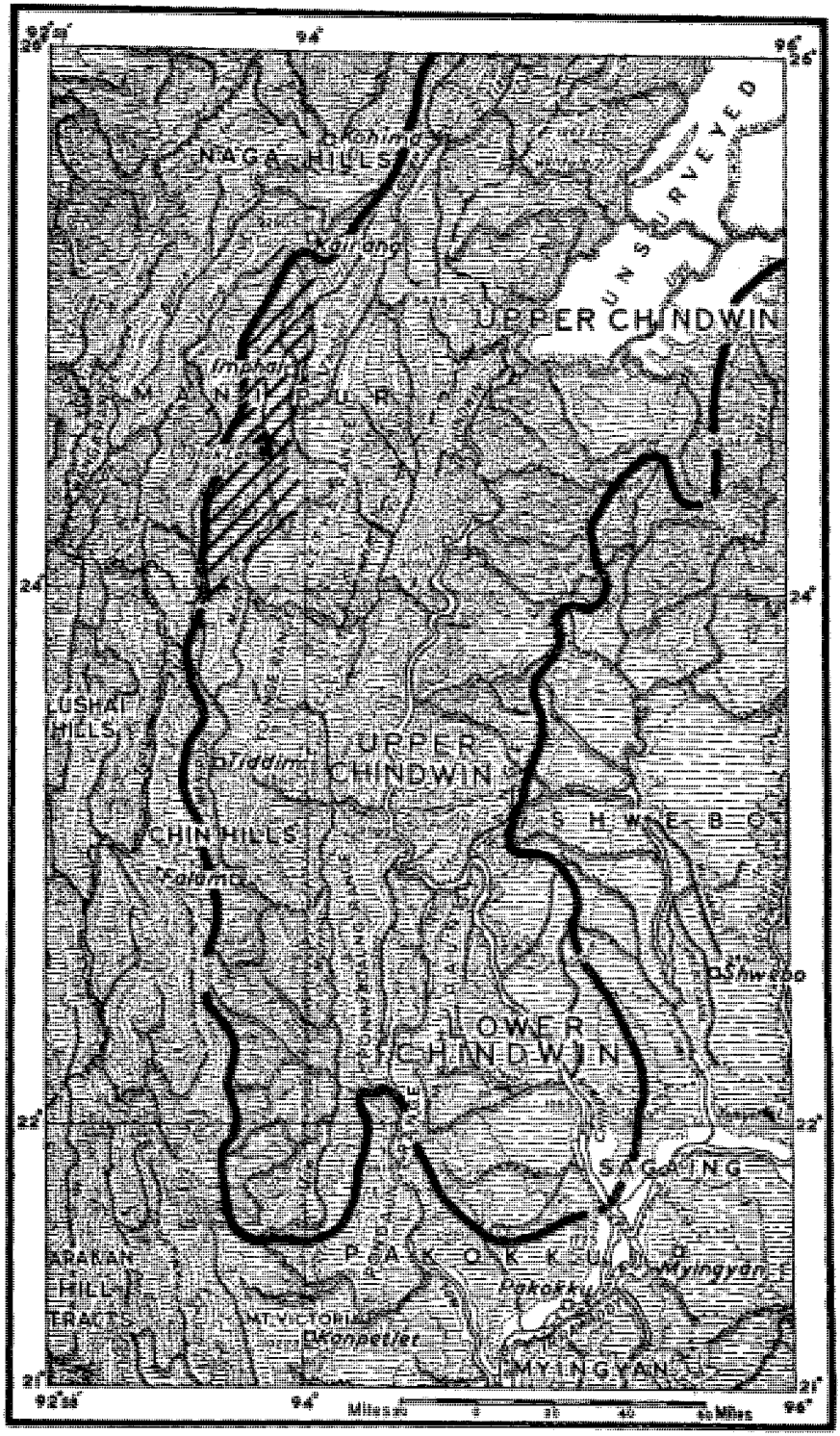
TEXT-FIG. 2. Index map of the Himalayas showing the areas surveyed.

Barely two centuries ago, the Brahmaputra and the Ganges were separate rivers, 150 miles apart. The Brahmaputra which now flows to the west of Dacca and the Madhupur jungle, then flowed considerable distance to the east and joined the Meghna river east of Dacca (Krishnan, *loc. cit.*, p. 25). This westward drift of the Brahmaputra during historic times is very remarkable and it is noteworthy that such a westward migration is indicated by the fish fauna of the Himalayas in the case of all the other Himalayan rivers.

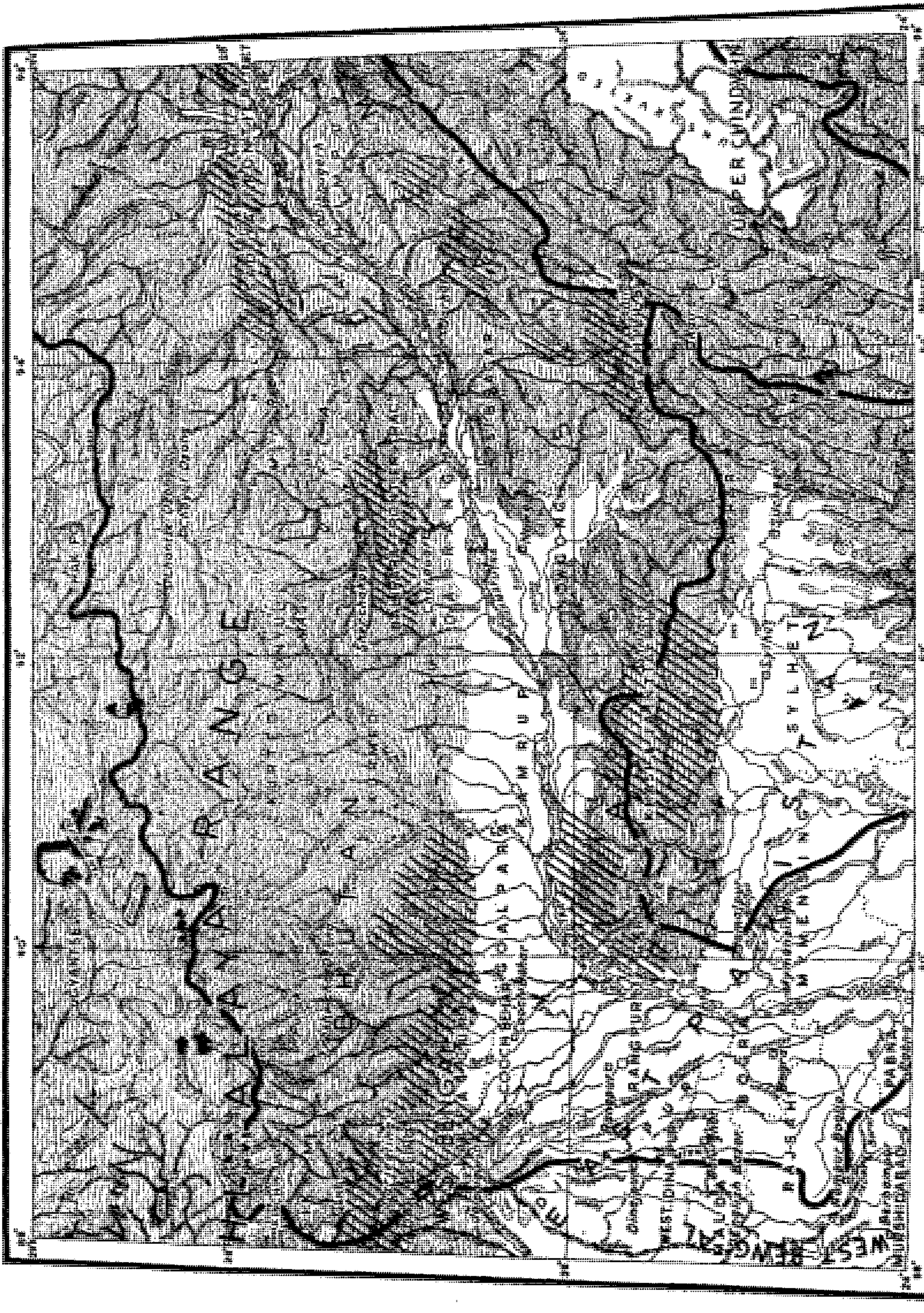
In Text-figures 3 and 4 are shown the Assam Himalayan and the contiguous mountain ranges south of the Brahmaputra drained by the rivers mentioned above and the localities from where fish collections have so far been made (Chaudhuri, 1912; Hora, *op. cit.*, 1921*a*, 1924, 1936; Hora and Mukerji, 1935, and Shaw and Shebbeare, 1937).

(*b*) *The Ganges and its tributaries.*—The Ganges and its tributaries, the Kosi, the Baghmati, the Gandak, the Rapti, the Karnali (Gogra), the Kali (Sarada) and the Jumna drain the Himalayan area between longitudes 77° and 88° E.

The Kosi (Text-fig. 5) drains the southern slopes of the Himalayas between longitudes 85° 32′ and 88° E. This area was extensively surveyed by a party of the



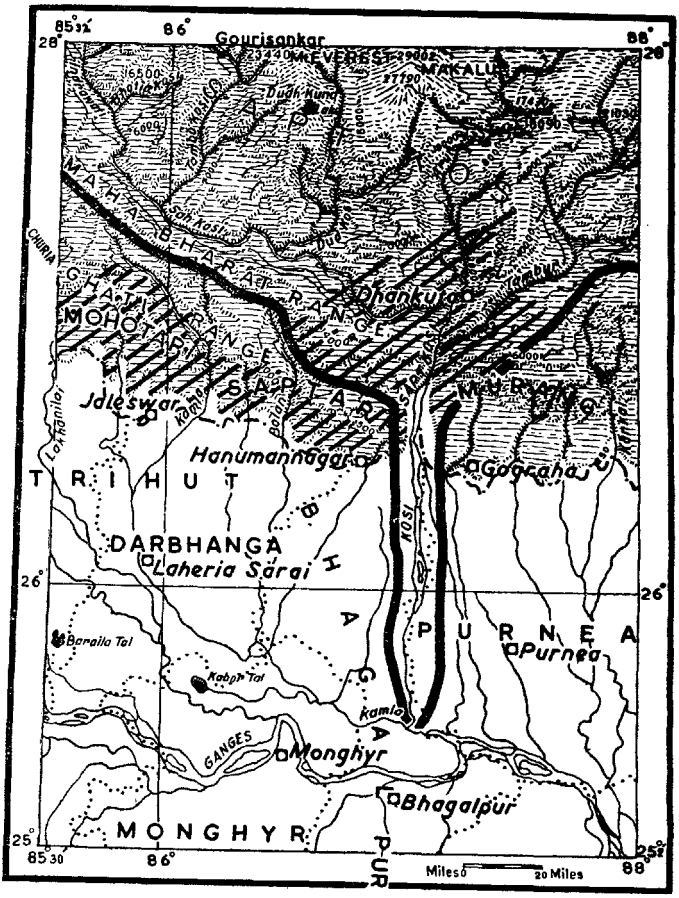
TEXT-FIG. 3. Map of the hill-ranges of Assam showing the localities in which the fishes were collected. The stripes represent the area surveyed. The area drained by the Chindwin is marked by thick black line.



TEXT-FIG. 4. Map of the Himalayan area drained by the Brahmaputra (indicated by thick black line) showing localities in which fishes were collected. The stripes represent the areas surveyed.

Zoological Survey of India in November, 1947, January-February, 1948 and April, 1948 (Menon, 1949).

The Kosi provides a typical example of the westward drift of the Himalayan rivers referred to earlier. It may be mentioned that in the early part of the 18th century, the Kosi flowed below the town of Purnea but it has gradually worked westwards across 75 miles of the country as is evidenced by its deserted channels (Chibber, 1949, pp. 4-5). The large commercial town of Nathpur, from where Hamilton collected several species of fish from the Kosi river, was several miles to the west of the river even up to 1850 but it has not only been washed away but the site of its ruins now lies many miles to the east of the river.

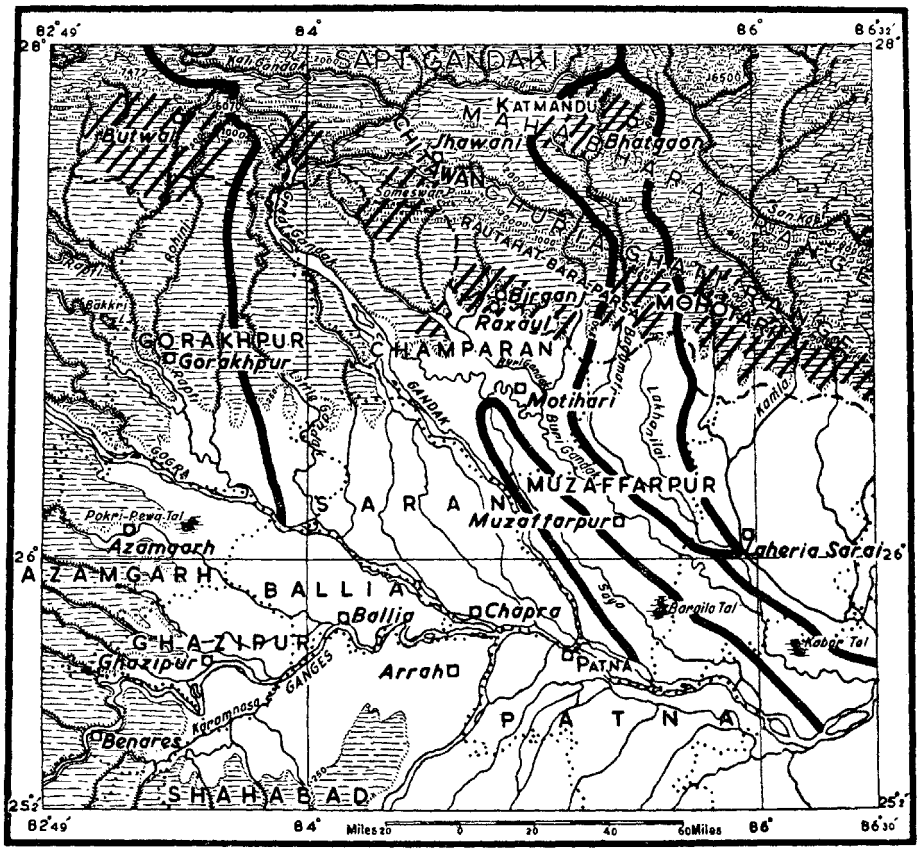


TEXT-FIG. 5. Map of the Himalayan area drained by the Kosi (indicated by thick black line) showing localities in which the fishes were collected. The stripes represent the areas surveyed.

This westward movement of the Kosi is also very strongly marked in its fish fauna as it shows a very close affinity to that of the Tista river, Eastern Himalayas and the Assam hills (Menon, *op. cit.*). This is suggestive of the fact that some of its earlier tributaries must have drained the region of the Darjeeling Himalayas and are now probably the feeder systems of the Tista river.

To the west of Kosi, the next important Himalayan river is the Gandak which drains the area between longitudes 83° 28′ and 85° 32′ E. It rises from the central

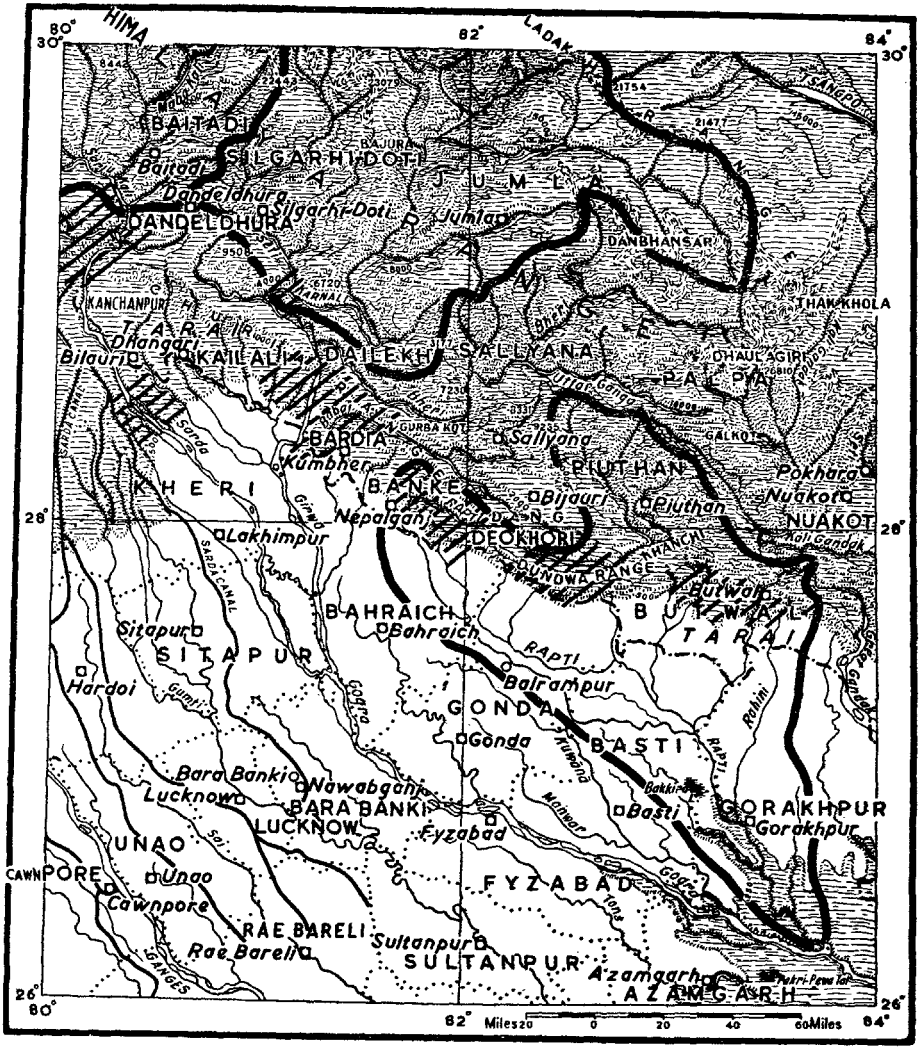
mountain basin of Nepal and flows southwards in a series of rapids, and finally leaves the mountain ranges at Tribeni, near Someswar hills, where it is joined by two of its major tributaries. On entering the plains, it flows for a short distance over a rocky bed between high banks covered with thick forests. The places from where fish collections were made by a party of officers of the Zoological Survey of India in January, 1948, by the author in February-March, 1949, and also places surveyed and recorded in literature (Hora, 1937*a*) are shown in Text-fig. 6. The fish fauna of the Gandak also shows a strong affinity to that of the Assam Himalayas thereby indicating that at some time or other there must have been some sort of intermingling of the drainage systems of the Gandak and that of the rivers to the east of it.



TEXT-FIG. 6. Map of the Himalayan area drained by the Baghmati and the Gandak (indicated by the thick black line) showing localities in which the fishes were collected. The stripes represent the areas surveyed.

The Rapti, the Karnali and the Kali (Text-fig. 7) are the next three important tributaries of the Ganges, west of the Gandak. They drain the Himalayan area between longitudes 80° and 83° 40′ E. The Rapti takes its origin in the lower ranges of the Himalayas in the Nepal territory and after flowing through Nepal for about a hundred miles enters the Bahraich district in U.P. It then flows in a sinuous course through the districts of Bahraich, Gonda, Basti and Gorakhpur, and finally joins the Gogra near the village Barhaj Bazar in Gorakhpur district. It

flows for the most part in a deep channel. Fish collections were made by the author at various places in February, 1949, camping at Gorakhpur in U.P. and Butwal and Nepalganj in the Nepal territory. The places of collection are marked in Text-fig. 7.



TEXT-FIG. 7. Map of the Himalayan area drained by the Rapti, Karnali and Kali (indicated by thick line) showing the localities in which fishes were collected. The stripes represent the areas surveyed.

The Karnali has a trans-Himalayan source and drains the trans-Himalayan trough of about 200 miles in length, between Gurla Mandhata and Diji pass, by two affluents, one flowing E.S.E. and the other W.N.W. The main river after receiving waters from all its tributaries runs due south and branches into the Kauriala and the Girwa in the plains. Both these branches are rapid flowing violent rivers with beds strewn with big boulders. After a course of about 30 miles, these rivers re-unite near village Birthapur in Bahraich district in U.P. to form the Gogra. Collections were made in the Girwa as well as the Kauriala at various localities by the author in March, 1949.

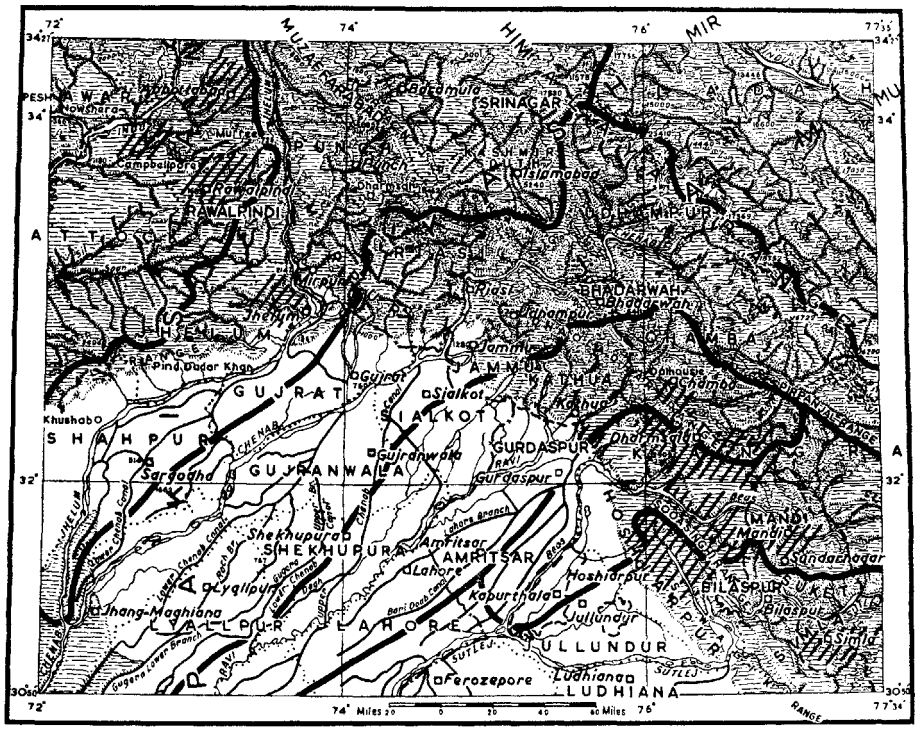
The Kali is formed by two main streams called the Mahakali and the Sarju Kali. The Mahakali originates in the high ridge that separates Almora and Nepal from Tibet, the Sarju rises on the eastern side of the Nandakot peak and flows south-eastwards through Almora to the Mahakali at Rameshwar (Nevilli, 1905). The joint stream which is generally known as Kali flows southwards and finally leaves the mountain ranges near Tanakpur under the name of Sarda. Like the Kauriala and the Girwa, the Sarda also is a very rapid flowing, violent river with its beds strewn with big boulders brought down from higher reaches in the Himalayas. The fish collections from the Kali river were made by the author at Tanakpur at a place where the river leaves the hills and enters the plains. At the time of the visit by the author there were a large number of rocky pools in the beds of the river from where good collections of fish could be easily made after treating the water with bleaching-powder. The fish fauna of the Rapti, Karnali and Kali also indicates a close relationship of these drainage systems to that of the rivers in the Eastern Himalayas and further east.

TEXT-FIG. 8. Map of the Himalayan area drained by Ramganga, Ganges and Jumna (indicated by thick line) showing the localities in which fish were collected. The stripes represent the areas surveyed.

The Ramganga, the Ganges and the Jumna (Text-fig. 8), the principal rivers of the Kumaon and Girhwal Himalayas, drain the Himalayan area between longitudes 78° 35′ and 80° E. The Ramganga is the smallest of these rivers draining the outer Himalayan range of Kumaon; its base is triangular in shape because the rivers on either side of it, the Ganges and the Kali have converged in all their branches in order to pierce the outer ranges and thus leaving only a small intermediate area undrained. The principal affluents of the river are the Kosi, Nandhapur and Kalaunia. These tributaries of the Ramganga drain the whole of the Nainital and Almora districts in U.P. from where extensive collections were made by

Messrs. E. O. Shebbeare and M. P. Bhola (Hora, 1937*b*, pp. 338–48) and by the author in May-June, 1948 (Menon, 1949*a*).

The name Ganges, regarded as a Himalayan river, is applied to the particular affluent that issues from the mountains at Hardwar. The two important Himalayan branches of the Ganges are the Alaknanda and the Bhagirathi. They drain the area lying between longitudes 78° and 80° E. The Alaknanda rises to the north of Badrinath and flows south-west to Nandaprayag and thence turns west as far as Rudraprayag where it receives one of its affluent, the Mandagiri. From the confluence of Mandagiri it turns south and flowing past Srinagar is joined by Bhagirathi at Deo-prayag to form the Ganges.



TEXT-FIG. 9. Map of the Himalayan area drained by the Indus (areas drained by the various tributaries, the Sutlej, the Beas, the Ravi, the Chenab and the Jhelum being marked by thick lines) showing the localities in which fish were collected. The stripes represent the areas surveyed.

The Alaknanda has an average breadth of about 35 to 40 yds., but at one place before its confluence with the Mandagiri it narrows down very much and rushes through a cut in the rocks which rise high up perpendicularly on either side (Walton, 1910). Here the river flows with very great force over a bed of big boulders. From this point the river again broadens out and flows over a succession of long reaches between it and Deo-prayag with intervening short rapids. At Deo-prayag the river again narrows down to almost half its proper breadth before it is joined by Bhagirathi. A representative collection of fish from the headwaters of the Ganges, especially from the narrowed down portion of the Alaknanda above Srinagar, was made by Babu Gonur Singh, Collection Tender of the Zoological Survey of India. The localities from where fish collections were either examined by the author or referred to earlier in literature are marked in Text-fig. 8.

The Jumna takes its origin in the south-western slopes of Bandarpunch which is the main watershed between Ganges and Jumna. Behind the Mussoorie hills, the Jumna is joined by its tributary, the Tons, which drains the area between Bandarpunch and Chor peak. It then pierces the Mussoorie range and a little further down is joined by the Giri river which drains the area between Simla and the Chor peak. The Jumna drains the Himalayan area between longitudes 77° 35′ and 78° 35′ E. from where extensive collections of fish were made by Hora and Mukerji in 1935 (Hora and Mukerji, 1936).

The Jumna is said to have flowed westwards from Karnal straight to sea in former days. In course of time, it took a more and more easterly course and ultimately merged into the Ganges at Prayag (Krishnan, *loc. cit.*, p. 25).

(*c*) *The Indus and its tributaries.*—The Indus and its tributaries drain the westernmost part of the Himalayas between longitudes 72° and 77° 35′ E. The Jhelum, Chenab, Ravi, Beas and Sutlej are the five great tributaries of the Indus; they take their origin in the Himalayas and after traversing the Punjab unite to form the Panjnad and falls into the Indus. Extensive collections of fish from the Punjab Himalayas were made at different times by the members of the Zoological Survey of India and the localities from where they were made are shown in Text-fig. 9.

The east-west movement of the Himalayan rivers referred to earlier is evident in the Punjab rivers also. There is evidence to show that during historic times, the Sutlej flowed through Rajputana into the sea independently of the Indus. In fact it was only during the 11th century that the Sutlej became confluent with the Beas and flowed the latter's channel deserting its own (Wadia, 1938, p. 391). All the other rivers also have repeatedly shifted their channels. The Chenab and the Jhelum joined the Indus at Uch in the 16th century; now the confluence is at Mithankot, 60 miles down-stream. Multan was then situated on the Ravi, but now it is 36 miles to the east of its combined waters with the Chenab. Likewise, there is also evidence to show that the Indus flowed more than 80 miles to the east of its present course into the Rann of Cutch which was then the gulf of the Arabian Sea (Wadia, *op. cit.*).

Evolution and Distribution of Torrential Fishes of the Himalayas

With the exception of the remains of a Schizothoracine fish, *Schizothorax* or *Oreinus*, described by Hora (1937*c*) from the Karewas of Kashmir, no other torrential fish is known in a fossil state from the Himalayas, though forms like *Silurus* and *Bagarius*, which live in somewhat deeper, clearer and cold waters at the bases of hills are known from the Upper Siwalik rocks (Hora and Menon, 1953). The Karewas of Kashmir are believed to be the Second Interglacial period, which lasted from approximately 440,000 to 250,000 years ago. It would thus appear that the typical torrential fauna of the Himalayas is not older than the Pleistocene. In this connection it is interesting to point out that one of the major upheavals of the Himalayas took place at the end of Pliocene or at the beginning of the Pleistocene (Krishnan, 1952, p. 46). This and the subsequent orogenic movements would seem to have been responsible for the evolution of the typical Himalayan fauna during the various stages according to the location and intensity of these movements.

Hora (1954) has explained that the evolution of the Schizothoracinae probably occurred during the First Interglacial period when, with the melting of the snow, turbulent streams must have been formed in Central Asia necessitating the reduction of scales characteristic of the Schizothoracinae. Since primitive forms of the sub-family occur today in South China (Hora, *op. cit.*), it is presumed that they originated there probably during the First Interglacial period. During the favourable ecological conditions of the Second Glacial period and east-west drainage they migrated westwards as far as Kashmir or even Seistan. The great proliferation of genera

and species of the Schizothoracinae probably occurred during the Second and subsequent Interglacial periods. Today the Schizothoracine fishes are mainly Central Asiatic in distribution though a few species are also known along the southern face of the Himalayas. One genus *Lepidopygopis* Raj has even gone as far afield as Peninsular India over the Assam Hills and Satpura trend of mountains (Silas, *loc. cit.*, p. 445). Since several Himalayan rivers have Trans-Himalayan sources, it is reasonable to presume that along these channels the Schizothoracine fishes may have come down to the Himalayan rivers and have now become distributed along the southern face (Hora, *loc. cit.*, p. 244).

From the earlier accounts (*op. cit.*) and also from my own extensive field-work along the foot of the Himalayas, I have been able to make out the following table (Table I) showing the distribution of torrential fishes in the various drainage systems of the Himalayas.

The most important and striking fact that is evident from the table (Table I) is the occurrence of a great variety of forms towards the east as compared with the west. In the Brahmaputra drainage system, for instance, forms like *Aborichthys*, *Acanthophthalmus*, *Batasio*, *Chaca*, *Conta*, *Erethistoides*, *Exostoma* and *Olyra* are present, whereas none of these genera extend along the Himalayas beyond the limits of the Brahmaputra System. *Lissocheilus* and *Pseudecheneis* extend up to the Kosi drainage, while *Balitora*, *Euchiloglanis*, *Myersglanis*, *Semiplotus* and *Somileptes* extend further as far as the Gandak system of drainage. *Laguvia* extends still further west to the Kali river, while the range of *Psilorhynchus* is up to the Jumna. Of the remaining twelve genera, eleven, namely *Amblyceps*, *Bagarius*, *Botia*, *Gagata*, *Garra*, *Glyptothorax*, *Nemachilus*, *Oreinus*, *Schizothorax*, *Sisor* and *Tor*, are distributed along the entire length of the Himalayas and in the case of *Garra*, *Glyptothorax*, *Nemachilus Oreinus*, *Schizothorax*, *Tor* and *Silurus* even beyond the Himalayas. While several forms of the Brahmaputra drainage and the Assam Hills do not occur in the western Himalayas, these very same genera or some closely allied forms are found in Burma, Southern China, Siam, the Malay Peninsula, the Archipelago and Indo-China on the one hand and the hills of Peninsular India on the other. It is very remarkable that the specialised forms of the Assam Hills and the Brahmaputra drainage, instead of spreading along the present-day ecologically and geomorphologically continuous Himalayan range towards the west, became deflected towards the south-west. The following chart of distribution (Table II) showing the relationships of the fish-fauna of the Himalayas with the neighbouring countries and the rest of the subcontinent of India will be helpful in bringing out this interesting zoogeographical point.

Of the 29 genera, *Garra*, *Nemachilus* and *Tor* are common to the countries towards the east as well as Africa in the west. *Aborichthys*, *Conta*, *Myersglanis* and *Somileptes* are endemic to the Eastern Himalayas. The remaining 22 genera are common to the Himalayas and the countries towards east and south-east. It has already been indicated that this fauna is again represented in the Western Ghats and the Satpura trend of mountains. Thus, the close relationship of the Himalayan fish-fauna to the South-East Asian and the Malay Archipelago can be clearly seen. Taking the endemic forms, the genera to which they belong are only those closely allied to South-East Asian forms (Hora, *op. cit.*). These facts prove that the Himalayas had undoubtedly derived its fish-fauna from the east, most probably from the Yunnan area (Hora, 1948, p. 306) and had spread to the west as far as Africa as and when the ecological conditions favoured their dispersal.

Factors governing dispersal of torrential fishes

The torrential fishes enumerated in Table II can be divided into six groups according to their habitats and consequently the degree of development of their adaptive characters for torrential environment.

TABLE 1

List of Torrential fishes known from the southern face of the Himalayas

	Chindwin.	Brahmaputra. 88° 96′ E.	Kosi. 85° 32′–88° E.	Baghmati.	Gandak.	Rapti.	Katnali.	Kali.	Ramganga. 78° 35′–80° E.	Ganges. 78°–80° E.	Jumna. 77° 35′–78° 35′ E.	Sutlej.	Beas.	Ravi.	Chenab.	Jhelum.	Indus.
				83° 28′–85° 32′		80°–83° 28′ E.						72°–77° 35′ E.					
Family CYPRINIDAE Subfamily CYPRININAE																	
1. *Barbus* (*Lissocheilus*) *hexagonolepsis* McClell. ..	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. *Barbus* (*Tor*) *progeneius* McClell. ..	?	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. *Barbus* (*Tor*) *putitora* Ham. ..	?	+	+	+	+	+	+	+	+	+	+	+	+	+	?	?	
4. *Barbus* (*Tor*) *tor* (Ham.)	+	+	?	+	+	?	?	?	—	+	+	?	?	?	?	?	?
5. *Garra abhoyai* Hora ..	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6. *Garra annandalei* Hora	?	+	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—
7. *Garra gotyla* (Gray) ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	?	+	+
8. *Garra kempi* Hora ..	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9. *Garra lamta* Ham. ..	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—
10. *Garra lissorhynchus* (McClell.) ..	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11. *Garra mullya* (Sykes)	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12. *Garra naganensis* Hora	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13. *Garra nasutus* (McClell.)	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14. *Garra prashadi* Hora	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—
15. *Garra rupeculus* (McClell.)	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16. *Semiplotus semiplotus* (McClell.)	?	+	?	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Subfam. SCHIZOTHORACINAE																	
17. *Oreinus molesworthi* Chaudhuri ..	?	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

18. *Oreinus plagiostomus* (Heckel) ..	?	+	–	–	–	–	–	+	+	+	+	+	+	+	+	?	+
19. *Oreinus richardsonii* Gray	?	+	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–
20. *Schizothorax annandalei* Regan	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–
21. *Schizothorax progastus* (McClell.) ..	?	+	–	–	–	–	–	–	–	–	–	–	–	–	?	?	?
Family PSILORHYNCHIDAE																		
22. *Psilorhynchus balitora* (Ham.) ..	?	+	–	–	–	+	+	+	–	–	+	–	–	–	–	–	–
23. *Psilorhynchus homaloptera* Hora and Mukerji	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24. *Psilorhynchus sucatio* (Ham.)	?	+	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–
Family HOMALOPTERIDAE																		
25. *Balitora brucei* Gray	?	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–
26. *Balitora maculata* Gray	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Family COBITIDAE																		
27. *Aborichthys elongatus* Hora	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28. *Aborichthys kempi* Chaudhuri ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29. *Acanthophthalmus pangia* (Ham.) ..	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30. *Botia almorhae* Day ..	–	–	–	–	–	+	+	+	+	–	–	–	–	–	–	–	–
31. *Botia berdmorei* Blyth	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32. *Botia dario* (Ham.) ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33. *Botia dayi* Hora ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34. *Botia histrionica* Blyth	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35. *Botia lohachata* Chaud.	–	–	+	+	+	–	–	–	–	–	–	–	+	–	–	–	–
36. *Botia nebulosa* Blyth	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37. *Nemachilus beavani* Gunther ..	–	+	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–
38. *Nemachilus botia* (Ham.) (Forma typica) ..	?	+	+	+	+	+	+	+	+	+	+	+	+	+	?	+	+

TABLE I.—*Contd.*

List of Torrential fishes known from the southern face of the Himalayas.

	Chindwin.	Brahmaputra. 88° 96′ E.	Kosi. 85° 32′–88° E.	Baghmati.	Gandak.	Rapti.	Karnali.	Kali.	Ramganga. 78° 35′–80° E.	Ganges. 78°–80° E.	Jumna. 77° 35′–78° 35′ E.	Sutlej.	Beas.	Ravi.	Chenab.	Jhelum.	Indus.
				83° 28′–85° 32′		80°–83° 28′ E.						72°–77° 35′ E.					
39. *Nemachilus carletoni* Fowler ..	–	–	–	–	–	–	–	–	–	–	–	+	+	+	?	?	?
40. *Nemachilus corica* (Ham.) ..	–	+	–	–	–	+	+	+	–	–	–	+	+	+	–	–	–
41. *Nemachilus devdevi* Hora	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42. *Nemachilus horai* Menon	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
43. *Nemachilus kangjupkhulensis* Hora ..	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
44. *Nemachilus kangrae* Menon ..	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
45. *Nemachilus manipurensis* Chaudhuri ..	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46. *Nemachilus montanus* McClell.	–	–	–	–	–	–	–	–	–	–	+	+	+	+	–	–	–
47. *Nemachilus multifasciatus* Day ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48. *Nemachilus prashadi* Hora	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49. *Nemachilus rupicola* (McClell.)	–	–	–	–	–	–	–	–	+	+	+	+	+	+	?	+	+
50. *Nemachilus rupicola* var. *inglisi* Hora ..	?	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–
51. *Nemachilus savona* (Ham.) ..	?	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–
52. *Nemachilus scaturigina* McClell. ..	?	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–
53. *Nemachilus shebbearei* Hora	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
54. *Nemachilus sikmaiensis* Hora	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

55. *Nemachilus subfusca* (McClell.) ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
56. *Nemachilus vinciguerrai* Hora	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
57. *Nemachilus zonalternans* (Blyth) ..	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
58. *Somileptes gongota* (Ham.) ..	?	+	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Family SILURIDAE																		
59. *Silurus cochinchinensis* C.V.	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Family BAGRIDAE.																		
60. *Batasio batasio*(Ham.)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
61. *Batasio tengara* (Ham.)	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
62. *Batasio merianiensis* Chaudhuri ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Family AMBLYCEPIDAE																		
63. *Amblyceps mangois* (Ham.) ..	?	+	?	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–
Family SISORIDAE																		
64. *Bagarius bagarius* (Ham.) ..	?	+	–	–	–	+	+	+	–	+	+	+	+	?	?	?	?	?
65. *Conta conta* (Ham.) ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
66. *Erethistoides montana* Hora	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
67. *Euchiloglanis hodgarti* (Hora) ..	?	+	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
68. *Euchiloglanis davidi* (Sauvage) ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
69. *Exostoma labiatum* (McClell.) ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
70. *Gagata cenia* (Ham.) ..	+	?	?	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–
71. *Gagata nangra* (Ham.)	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
72. *Gagata viridescens* (Ham.) ..	–	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE I.—*Contd.*

List of Torrential fishes known from the southern face of the Himalayas.

	Chindwin.	Brahmaputra. 88° 96′ E.	Kosi. 85° 32′–88° E.	Baghmati.	Gandak.	Rapti.	Karnali.	Kali.	Ramganga. 78° 35′–80° E.	Ganges. 78°–80° E.	Jumna. 77° 35′–78° 35′ E.	Sutlej	Beas.	Ravi.	Chenab.	Jhelum.	Indus.
				83° 28′–85° 32′		80°–83° 28′ E.						72°–77° 35′ E.					
73. *Glyptothorax annandalei* Hora	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
74. *Glyptothorax botia* (Ham.) ..	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
75. *Glyptothorax cavia* (Ham.) ..	−	−	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−
76. *Glyptothorax conirostris* (Steind) ..	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
77. *Glyptothorax platypogonoides* (Blkr.) ..	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
78. *Glyptothorax gracilis* (Gunther) ..	−	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−
79. *Glyptothorax horai* Shaw and Shebb. ..	−	+	+	−	−	+	+	+	−	−	−	−	−	−	−	−	−
80. *Glyptothorax lineatus* (Day)	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
81. *Glyptothorax minutus* Hora	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
82. *Glyptothorax pectinopterus* (Ham.) ..	−	−	−	−	−	−	−	−	+	+	+	+	+	−	−	−	−
83. *Glyptothorax striatus* McClell. ..	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
84. *Glyptothorax stoliczkae* (Steind) ..	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
85. *Glyptothorax telchitta* (Ham.) ..	?	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−
86. *Laguvia riberoi* Hora	?	+	?	+	+	+	+	+	−	−	−	−	−	−	−	−	−
87. *Laguvia shawi* Hora ..	?	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
88. *Myersglanis blythi* (Day)	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
89. *Pseudecheneis sulcatus* McClell. ..	?	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−

90. *Sisor rhabdophorus* Ham.	?	+	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–
Family CHACIDAE																		
91. *Chaca chaca* (Ham.) ..	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Family OLYRIDAE																		
92. *Olyra longicaudata* McClell. ..	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.

List of genera of Himalayan fishes to show the relations with those of the adjacent countries.

	Yunnan.	Burma.	Siam.	Indo-China.	Malay Peninsula.	Sumatra.	Java.	Borneo.	Assam Himalayas.	Nepal Himalayas.	Kumaon Himalayas.	Punjab Himalayas.	Afghanistan.	Persia.	Syria.	Africa.	Chota-Nagpur.	E. Ghats.	Vindhyas.	Satpuras.	W. Ghats.	Ceylon.
Family CYPRINIDAE																						
Subfamily CYPRININAE																						
1. *Garra*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2. *Lissocheilus*	+	+	+	+	+	+	?	?	+	+	—	—	—	—	—	—	—	—	—	—	—	—
3. *Semiplotus*	—	+	—	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
4. *Tor*	+	+	+	+	+	+	+	+	+	+	+	+	+	—	+	+	?	+	+	+	+	+
Subfamily SCHIZOTHORACINAE																						
5. *Oreinus*	+	—	—	—	—	—	—	—	+	+	+	+	+	—	—	—	—	—	—	—	—	—
6. *Schizothorax*	+	—	—	—	—	—	—	—	+	+	+	+	+	+	—	—	—	—	—	—	—	—
Family PSILORHYNCHIDAE																						
7. *Psilorhynchus*	?	+	—	—	—	—	—	—	+	+	—	+	—	—	—	—	+	—	—	—	—	—
Family HOMALOPTERIDAE																						
8. *Balitora*	?	+	+	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	—	+	—
Family COBITIDAE																						
9. *Aborichthys*	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—
10. *Acanthophthalmus*	?	+	+	?	+	+	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—
11. *Botia*	+	+	+	?	+	+	+	+	+	+	+	+	—	—	—	—	+	—	—	—	+	—
12. *Nemachilus*	+	+	+	+	+	+	+	+	+	+	+	+	+	?	+	+	+	+	+	+	+	+
13. *Somileptes*	?	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—

Family SILURIDAE																								
14. *Silurus*	+	+	+	+	+	?	?	+	+	−	−	−	−	−	+	−	−	−	−	−	+	−
Family BAGRIDAE																								
15. *Batasio*	?	+	+	?	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	+	−
Family AMBLYCEPIDAE																								
16. *Amblyceps*	?	+	+	?	+	−	−	−	+	+	+	+	−	−	−	−	+	+	+	+	−	−
Family SISORIDAE																								
17. *Bagarius*	?	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	+	+	+	−
18. *Conta*	?	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
19. *Erethistoides*	?	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	+	−	−	−
20. *Euchiloglanis*	+	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
21. *Exostoma*	+	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
22. *Gagata*	?	+	+	?	−	+	−	−	+	+	?	+	−	−	−	−	−	−	+	?	+	−
23. *Glyphothorax*	?	+	+	+	+	+	+	+	+	+	+	+	?	?	+	−	+	+	+	?	+	−
24. *Laguvia*	+	+	−	−	−	−	−	−	+	+	−	−	−	−	−	−	+	−	+	+	−	−
25. *Myersglanis*	?	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
26. *Pseudecheneis*	+	+	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−
27. *Sisor*	?	−	−	−	−	−	−	−	+	−	−	+	−	−	−	−	−	−	+	−	−	−
Family CHACIDAE																								
28. *Chaca*	+	+	−	−	+	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−
Family OLYRIDAE																								
29. *Olyra*	?	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−

It may, however, be understood that though according to similarities of habitat certain genera of fishes are put under a particular group, it need not necessarily mean that they all have a uniform distribution along the Himalayas. The distribution is governed both by their habitat conditions as well as their period of evolution. For instance, *Silurus* and *Bagarius*, though placed under the same group, have different evolutionary history and hence their range of distribution today along the Himalayas differs very much. *Silurus* is a very old fish with fossil representatives in the Eocene beds of Europe. It is distributed in Europe, northern Asia, the northern portion of South-East Asia, Burma, Thailand and Malaya. *Baragius*, on the other hand, is restricted in its distribution to South-East Asia and its fossils are known from the Siwalik beds of India and the Tertiary beds of the highlands of Pedong in Sumatra. Along the Himalayas *Silurus* is today known only from the Brahmaputra drainage, whereas *Bagarius* is seen all along the base of it.

It would appear from the distribution in time and space of *Silurus* that it had originated in Europe during the Eocene epoch and spread south and south-east and during the Pliocene colonised the Siwalik fore-deep of the Himalayas where it perished subsequently. On the other hand, *Bagarius* had originated somewhere in South-East Asia during the Tertiary period and began spreading along the Himalayas during the Pliocene epoch (*vide* infra, p. 489). Though its fossils are known from the Siwalik rocks of the Himalayas, the present-day distribution of *Bagarius* does not, however, indicate that the genus had entirely perished along the Himalayas then.

Again, the highly specialised genera of torrential fishes placed under *Group VI* below are distributed only along the Eastern Himalayas and do not extend westwards. This pattern of distribution can be attributed to the fact that their spread along the Himalayas was made possible only at a very late period and sufficient time had not probably lapsed for their colonisation of the whole of the Himalayan region (*vide* infra, p. 490).

Group I

This group consists of fishes which live in somewhat shallow, clear and cold waters at the base of hills and have, therefore, scarcely any striking adaptive characters. The genera coming under this group are: (1) *Silurus*, (2) *Bagarius*, (3) *Batasio*, (4) *Gagata* and (5) *Chaca*.

Group II

The following group consists of fishes living at the bottom of deep swift waters. The members of this group are cylindrical in form and possess a powerful muscular body. They are: (1) *Oreinus*, (2) *Schizothorax*, (3) *Tor*, (4) *Lissocheilus* and (5) *Semiplotus*.

Group III

Group III consists of fishes which are modified for a burrowing habit. They bury themselves in sand among pebbles and stones and thereby escape from the force of rushing water. They are: *Psilorhynchus* and *Sisor*.

Group IV

Fishes which live among pebbles and shingles at the bottom of shallow waters are grouped here; these fishes have to contend with a considerably less force of rushing water and, therefore, do not have any specially modified apparatus for adhesion, but are elongated and loach-like in form. They are: (1) *Amblyceps*, (2) *Nemachilus*, (3) *Somileptes*, (4) *Aborichthys*, (5) *Acanthophthalmus*, (6) *Olyra*, (7) *Conta* and (8) *Botia*.

Group V

This group consists of fishes which cling to exposed surface of bare rocks in comparatively slower waters. Since they have to bear a greater force of rushing water than the fishes in the preceding group, they have developed discs formed by the modification of the skin on the ventral surface by means of which they adhere to rocks. The fishes grouped here are: (1) *Glyptothorax*, (2) *Laguvia* and (3) *Garra*.

Group VI

Group VI consists of fishes which cling to exposed surface of bare rocks in swift waters. They have to bear the greatest force of rushing water than the fishes of the preceding group and hence they are very highly modified; in some the whole body is modified into a limpet-shape which helps the fish to adhere to stones in the rushing torrents, while others have developed adhesive discs (Hora, 1930, pp. 231–33). In these forms the mouth parts, the gills and the fins have all been modified in correlation with their habitat (Hora, 1947, p. 4). The genera coming under this group are: (1) *Balitora*, (2) *Erethistoides*, (3) *Pseudecheneis*, (4) *Euchiloglanis*, (5) *Myersglanis* and (6) *Exostoma*.

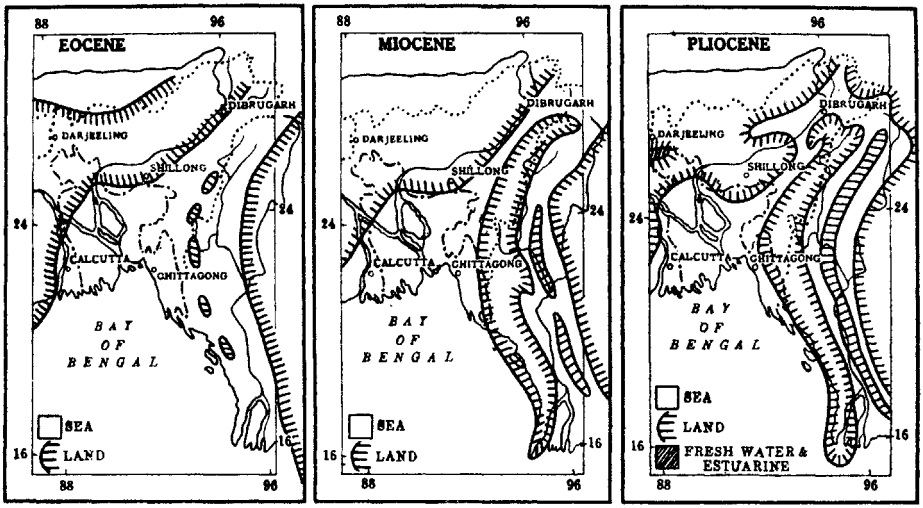
It will thus be seen from the above grouping of the Himalayan fishes that their migration would depend not only on the presence of continuous water courses, but also on the presence of their characteristic habitat conditions. It will now be possible to explain the distribution of torrential fishes along the Himalayas on certain palaeogeographical considerations.

Palaeogeography of the Himalayas as evidenced by the distribution of fishes

From stratigraphical and palaeontological evidences we know that from the Middle Eocene period an arm of the sea transgressed the Assam-Eastern Himalayan region and thus separated India from Burma (Hora, 1953; Menon, 1953). This condition seems to have lasted probably till the late Miocene period. The upheaval of the Himalayas during the Middle or Upper Miocene periods which is thought to have been the most violent of the movements (Krishnan, 1952, p. 45), probably made this arm of the sea recede southwards leaving at its head marshy conditions that allowed the invasion of the newly formed northern lands by those Chinese fishes capable of tolerating slightly brackish waters. The fossil records of *Clarias* and *Heterobranchus* from the early Pliocene deposits of the Siwalik support this view. Gradually with the rise of the Himalayas the marshy gap seems to have been replaced by low east-westward hills enabling such forms which normally live in somewhat deeper, clearer and colder waters at the base of hills to migrate from the east along the young Himalayas. Palaeontological records support this view, for fishes like *Bagarius* and *Silurus* are known from the later Siwalik beds of the Himalayas. Between the migration of the marsh-loving fauna during the early Pliocene and the hill-stream fauna during the late Pliocene, we have fossil records from the Siwalik beds of *Rita* and *Chrysichthys* which are pond-dwelling fishes capable of withstanding certain amount of salinity and foulness of water.

The Pleistocene orogenic movements of the Himalayas are stated by Geologists to have been of very great intensity and, as pointed out earlier, these intensive orogenic movements appear to have caused the evolution of the highly specialised torrential fishes in South-East Asia. But from the present-day distribution of torrential fishes along the Himalayas, it is evident that they did not spread westwards along the Himalayas till very recent times. It can be very reasonably inferred from this that the establishment of torrential ecological conditions in the region of the gap referred to earlier probably took place only recently, geologically

speaking. Till then most of the monsoon winds probably crossed over to the Central Asian region through this gap. According to Dr. S. K. Banerji, Retired Director-General of Meteorology of the Government of India, the 'south-west monsoon in its present form apparently commenced to be established at the close of the würm glaciation, that is about 20,000 years ago' (Hora, *loc. cit.*, p. 96). This means that the major upheaval of the Himalayas during the Pleistocene of Sub-Recent period (Krishnan, *op. cit.*) probably raised the low hills in the gap region high enough to obstruct the south-westerly winds and to produce torrential ecological conditions there. Consequently, the highly specialised torrential fishes would have been enabled to spread over gap portion of the Himalayas only during the Sub-Recent periods, probably roundabout 20,000 years ago.



TEXT-FIG. 10. Distribution of land and sea in the Bengal, Assam and Burma regions during the Eocene, Miocene and Pliocene periods (modified from Dr. M. S. Krishnan, *Bull. Nat. Inst. Sci. India*, **1**, pp. 26–28, 1952).

PROBABLE SEQUENCE OF MIGRATION ALONG THE HIMALAYAS

I have already pointed out that *Oreinus*, *Schizothorax*, *Bagarius* and *Silurus* had spread along the Himalayas earlier than the final upheaval of the Himalayas during the late Pleistocene times. *Nemachilus*, *Garra*, *Tor* and *Glyptothorax* also appear to have migrated along the Himalayas at a much earlier period than the other more specialised torrential fishes. It has been pointed out earlier that *Garra* and *Glyptothorax* generally live on exposed surface of bare rocks, *Nemachilus* among pebbles and shingle at the bottom of shallow waters and *Tor* at the bottom of swift, deeper waters. None of these show the highly specialised torrential adaptations characteristic of forms like *Balitora* and *Pseudecheneis*. From the ecological and distributional points of view, therefore, it can be safely concluded that these forms would have spread along the Himalayas, earlier than the upheaval of the Himalayas during the late Pleistocene when probably only low hills may have stretched in the region of the gap referred to earlier. This is further strengthened by the fact that *Balitora* and other Homalopterid fishes have migrated to Peninsular India and not to the Western Himalayas. This means that torrential ecological conditions existed over the Garo-Rajmahal gap area during the Pleistocene pluvial periods enabling the highly specialised torrential fishes to cross over to the Peninsula. It would further

appear from this that the monsoon-bearing winds at first struck the Garo-Rajmahal region during the pluvial periods of the Pleistocene when the sea-level fell by a few hundreds of feet and created torrential conditions there. From there as the winds rose up it would have probably passed through the gap to the Central Asian region, the mountain ranges in the gap area being too low to obstruct the monsoonic winds then and to make the Eastern Himalayas the recipient of heavy rainfall as at the present day.

Further, *Garra*, *Nemachilus* and *Tor* have great habitat tolerance having been found to live in mountainous lakes (Hora, 1921*b*, 1936*a*). It is, therefore, likely that *Garra*, *Tor* and *Nemachilus* had spread along the Himalayas and even further westwards as far as Africa during the early Pleistocene. During the pluvial periods of the Pleistocene when there was an uninterrupted greater flow of water in the streams at the base of the Himalayas these forms probably got dispersed. *Glyptothorax* had also probably spread likewise along the Himalayas during the early Pleistocene period for its present-day range extends as far as Syria. It could not extend its range as far as Africa owing to the fact that it is more specialised for torrential waters and has not so far been recorded from lakes, pools or other sluggish waters in the hills.

Silas (*op. cit.*) has shown that forms like *Botia*, *Gagata* and *Batasio* may have migrated south-westwards during the Second Glacial period of the Pleistocene. From a consideration of their habitat and range of distribution along the Himalayas, it would appear that the migration of these forms along the Himalayas may also have taken place during the Second Glacial period of the Pleistocene. Silas has also shown that *Balitora* may have spread south-westwards during the early 'Post-Tilt' period, *i.e.* probably during the Third Glacial period. Taking into consideration the ecological requirements of *Balitora* and its present-day range along the Himalayas, it can be concluded that the spread of *Balitora* along the Himalayas may have commenced only subsequent to the Sub-Recent upheaval of the Himalayas. *Amblyceps*, *Laguvia*, *Erethistoides*, *Psilorhynchus* and *Sisor* may have spread south-westwards during the last Glacial period of the Pleistocene (Silas, *op. cit.*). Along the Himalayas, however, they seem to have spread only during the Holocene Glacial period by which time the Himalayas would have sprung up to over 10,000 feet in the region of the gap referred to earlier and the south-west monsoon, as we know them in India today, had become established. All the other forms that are today found along the Himalayas should be considered to have either evolved in the Eastern Himalayas, or spread over there from the east during the last 10,000 years by which time the Holocene Glaciation ended and the Garo-Rajmahal gap became a barrier against their spread south-westwards.

Summary

A brief sketch of the physical features of the Himalayas, particularly the river system with special emphasis on the general drift of the rivers towards the west is given and the areas from where fish collections were either made by the author, or referred to in literature are indicated. Evolution and distribution of torrential fishes of the Himalayas are then discussed. With the exception of the remains of a Schizothoracine fish from the Kerewas of Kashmir (2nd interglacial period of the Pleistocene), no other torrential fish is known in a fossil state from the Himalayas indicating that the typical torrential fauna of the Himalayas is not older than the Pleistocene. The major upheaval of the Himalayas during the early Pleistocene period and the subsequent orogenic movements seem to have been responsible for the evolution of the typical Himalayan fauna during the various stages according to the location and intensity of the movements. Ninety-two species of torrential fishes found in the Himalayan rivers are tabulated according to their occurrence, or otherwise in the various drainage systems and the zoogeographical significance of the distribution of the various genera is then fully analysed. From such a critical analysis of the distribution of the torrential fishes it has been concluded that the Himalayas had derived its fauna from the east and that this fauna had moved westwards as far as Africa as and when ecological conditions favoured their dispersal.

The ecological factors governing the distribution of torrential fishes are then discussed. The torrential fish fauna of the Himalayas is divided into six groups according to their habitats and it has been pointed out that the range of distribution along the Himalayas of a fish is

dependent not only on its habitat, but also on the time of its evolution. Finally, the distribution of torrential fishes along the Himalayas is explained on certain palaeogeographical considerations.

During the Eocene-Miocene period an arm of the sea transgressed the Assam-Eastern Himalayan region and this separated India from Burma. The upper Miocene upheaval of the Himalayas made the arm of the sea recede southwards which enabled the marsh-loving forms to spread along the Himalayas. With the gradual rise of the Himalayas during the Pliocene this gap seems to have been replaced by low east-westward hills enabling the clear water forms to spread along the Himalayas. Thus during the Pliocene period forms like *Bagarius* and *Silurus* migrated along the Himalayas. Even fishes like *Nemachilus, Tor, Garra* and *Glyptothorax* appear to have migrated along the Himalayas during the early Pleistocene period. But the typical torrential fishes like *Balitora* and *Pseudecheneis* did not spread along the Himalayas till the major upheaval of the Himalayas during the Pleistocene of Sub-Recent period. This upheaval seems to have raised the low hills in the gap high enough to obstruct the monsoon winds and to produce torrential ecological conditions there. The spread of the torrential fishes along the Himalayas is, therefore, dated as subsequent to the late Pleistocene or Sub-Recent period.

The probable sequence of migration of torrential fishes along the Himalayas is also dealt with in the last section.

Acknowledgements

I am deeply indebted to Dr. S. L. Hora, Director, Zoological Survey of India, for his valuable suggestions, kind guidance and supervision in the preparation of this paper. I am also grateful to Dr. K. Jacob, Palaeontologist, Geological Survey of India, and through him to the Director, Geological Survey of India, for affording me facilities to examine the fossil fish collections of the Survey.

References

Burrard, S. C. and Hayden, H. H. (1933). *A sketch of the Geography and Geology of the Himalayan mountains and Tibet.* Revised by Burrard and Heron (Delhi).

Chaudhuri, B. L. (1912). Zoological results of the Abor expedition. XVIII. Fish. *Rec. Ind. Mus.*, **8**, 243–57.

Chhibber, H. L. (1949). Westward drift of the rivers in North India. *Bull. Nat. Geogr. Soc. India*, **12**, pp. 1–15.

Hora, S. L. (1921). Fish and Fisheries of Manipur with some observations on those of the Naga Hills. *Ibid.*, **22**, 166–214.

——— (1921*a*). On some new or rare species of fish from the Eastern Himalayas. *Ibid.*, **22**, 731–744.

——— (1921*b*). Indian Cyprinoid fishes belonging to the genus *Garra*, with notes on related species from other countries. *Ibid.*, **22**, 633–687.

——— (1924). Fish of the Siju cave, Garo Hills, Assam. *Ibid.*, **27**, 27–31.

——— (1930). Ecology, Bionomics and Evolution of the Torrential fauna with special reference to the organs of attachment. *Phil. Trans. Roy. Soc.*, London, **218**, 171–282.

——— (1934). The fishes of Chitral. *Rec. Ind. Mus.*, **36**, 279–319.

Hora, S. L. and Mukerji, D. D. (1935). Fishes of the Naga Hills, Assam. *Ibid.*, **37**, 381–404.

Hora, S. L. (1936). On a further collection of fish from the Naga Hills. *Ibid.*, **38**, 317–331.

——— (1936*a*). Report on fishes. Part I. Cobitidae. *Mem. Conn. Acad. Arts. Sci.*, **10**, 299–321.

Hora, S. L. and Mukerji, D. D. (1936). Fishes of the Eastern Doons. *Rec. Ind. Mus.*, **38**, 133–146.

Hora, S. L. (1937). Comparison of the Fish faunas of the Northern and the Southern faces of the Great Himalayan Range. *Ibid.*, **39**, 241–250.

——— (1937*a*). Distribution of Himalayan fishes and its bearing on certain Palaeogeographical problems. *Ibid.*, **39**, 251–259.

——— (1937*b*). Notes on Fishes in the Indian Museum. XXIX. On a collection of Fish from Nepal. *Ibid.*, **39**, 43–46.

——— (1937*c*). Notes on Fishes in the Indian Museum. XXXIII. On a collection of Fish from the Kumaon Himalayas. *Ibid.*, **39**, 338–348.

——— (1937*d*). On Fossil Fish remains from the Karewas of Kashmir. *Rec. Geo. Surv. India*, **72**, 178–187.

Hora, S. L. and Nair, K. K. (1941). Fishes of the Satpura Range, Hoshangabad district, Central Province. *Rec. Ind. Mus.*, **43**, 361–373.

Hora, S. L. (1944). On the Malayan affinities of the Freshwater Fish-fauna of Peninsular India and its bearing on the problem age of the Garo-Rajmahal gap. *Proc. Nat. Inst. Sci. India*, **10**, 432–39.

Hora, S. L. (1947). Torrential fishes and the significance of their distribution in zoogeographical studies. *Bull. Nat. Geogr. Soc. India*, **7**, 1–10.

——— (1948). The distribution of Crocodiles and Chelonians in Ceylon, India, Burma and further East. *Proc. Nat. Sci. India*, **15**, 285–310.

——— (1949). The Fish-fauna of the Rihand river and its zoogeographical significance. *Journ. Zool. Soc. India*, **1**, 1–7.

Hora, S. L. (1951). Some observations on the palaeogeography of the Garo-Rajmahal gap as evidenced by the distribution of Malayan fauna and flora to Peninsular India. *Proc. Nat. Inst. Sci. India*, **17**(6), 437–444.

——— (1953). Fish distribution and Central Asian Orography. *Curr. Sci.*, **22**, 93–97.

Hora, S. L. and Menon, A. G. K. (1953). Distribution of the fishes of the past and their bearing on the geography of India. 2. The extinct freshwater Teleostean fishes of India. *Everyday Science*, **2**, 105–113.

Hora, S. L. (1954). The evolution of the Indian torrential environment and its fishes. *Bull. Nat. Inst. Sci. India* (in Press).

Krishnan, M. S. (1943). *Geology of India and Burma.*

——— (1952). The Ganges, its geography and development. *Himalaya*, **1**(1), 35–49.

Menon, A. G. K. (1949). Fishes of the Kosi Himalayas, Nepal. *Rec. Ind. Mus.*, **47**, 1.

——— (1949*a*). Fishes of the Kumaon Himalayas. *Journ. Bomb. Nat. Hist. Soc.*, **48**, 535-542.

——— (1951). Rôle of the Eastern Ghats in the distribution of the Malayan flora and fauna to Peninsular India. *Proc. Nat. Inst. Sci. India*, **17**, 475–497.

——— (1953). Age of the transgression of the Bay of Bengal and its significance in the evolution of the freshwater fish fauna of India. *Bull. Nat. Inst. Soc. India* (in Press).

Nevilli, H. R. (1905). District Gazetteers of the U.P. **31**, 9–12.

Pascoe, E. H. (1950). A Manual of the Geology of India and Burma. (3rd Ed.)

Shaw, G. E. and Shebbeare, E. O. (1937). The Fishes of Northern Bengal. *Journ. Roy. As. Soc. Bengal, (Science)*, **3**, 1–137.

Silas, E. G. (1952). Taxonomic assessment and levels of evolutionary divergence of fishes with the so-called Malayan affinities in Peninsular India. *Proc. Nat. Inst. Sci. India*, **18**(5), 423–447.

Wadia, D. N. (1938). The Post-tertiary hydrography of Northern India and the changes in the courses of its rivers during the last glacial epoch. *Ibid.*, **4**, 387–394.

Walton, H. C. (1910). District Gazetteers of the U.P., **36**, 140-41.

Issued September 28, 1954.