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Impact of Flood on Freshwater Fish Biodiversity of North East region of India: with Special Reference to Assam

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Abstract: Flood is among the most common natural disasters of the world. According to the National Flood Commission (1980), 12% land of Indian subcontinent is prone to flood. Among the regions of the India that are most vulnerable to water induced disasters, the North East Region is the one that experiences devastating flood every year. Every state of the NE region is prone to flood with variable extent, frequency and intensity. The state of Assam is the highest flood affected in the region and is one of the top five flood affected states of the country. The impact of flood is mediated by the magnitude, frequency, duration, timing and rate of change of water levels. Depending on these factors, flood may have both negative and positive impacts on the inundated area. The nature, extent and gravity of the mayhem of flood may vary according to the nature of the resources (culture or capture fisheries), intensity and duration of flood along with many other factors and have tremendous impact on the indigenous fish biodiversity. The NE region of India is known as one of the 'Hot spot' for Freshwater Fish Biodiversity of the world. The conservation status revealed that out of the 422 fish species available in the region 48 are endangered, 69 near threatened, 103 vulnerable, 153 least concerned 23 data deficient and 26 not evaluated. The paper reviews the impact of flood on fish biodiversity of the region with special reference to Assam and way ahead for mitigation and restoration.

Keywords: North East region of India, Biodiversity, Hotspot, Flood, Impact on fish biodiversity, Conservation status, Mitigation

1. Introduction

The North East Region of India comprised of eight land locked states viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim is the eastern most region of the country representing a geographic and political administrative division of the country. Situated in the eastern Himalayan Region between longitude 21º57′ to 29º30′ N and latitude 84º46′ to 97º30′ E,

the region covers a geographical area of 2.62 lakh sq.km, which is around 7.97% of the total geographical area of the country (32.87 lakh sq. km). The region is connected to the rest of the country, through a narrow corridor called the "Chicken's neck" and differs significantly from other parts of the country in physiographic, agro-climatic, demography and socio- economic features. The region is characterised by unique, drastically varied microclimates, representing tropical, sub-tropical, temperate and alpine zones in different locations. Being situated in one of the highest precipitated zones of the planet, the states of the region receive a very high rainfall with annual precipitation ranging from1577 mm to 6002 mm (average 2068 mm) in different places [56]. Acidic soil and water (pH 4.0-6.0), spectacular seasonal variation in environmental temperature (sub-zero to 39ºC) are characteristic features of the region along with diverse topography ranging from vast plains of Assam and Tripura, upland flat valley of Manipur to predominantly hilly and mountainous regions of Arunachal Pradesh, Mizoram and Sikkim. The region shares an international border of 5182 kilometres, which is around 99% of its total geographical boundary, as it is bordered by six Asian countries, Tibet autonomous region, Bhutan, China, Myanmar, Nepal and Bangladesh (Fig 1)

Fig.1. NE Region of India

2. Fisheries resources and fish biodiversity of NE Region of India:

The region of lies in two of the 34 mega biodiversity hotspots of the world listed by Biodiversity International, the Indo Burma Hot spot and the Himalayan Hot spot [51] .The Indo Burma hotspot that includes parts or whole of six NE states viz. Assam (southern part of Brahmaputra), Mizoram, Meghalaya, Nagaland, Manipur and Tripura represents a wide diversity of ecosystems and remarkable freshwater fish fauna [51]. The states of Sikkim, Arunachal Pradesh and Assam (Northern part of the Brahmaputra) lie in the Himalayan Hot spot (Fig 2). The region is bestowed with vast and varied aquatic resources in the form of rivers, streams, lakes, reservoirs, flood plain wetlands, ponds, low lying paddy fields and a variety of aquatic micro habitats. The major natural fishery resources of the region are comprised of 20050 km of rivers that includes two major rivers

systems Brahmaputra and Barak and myriads of flood plain wetlands and lakes covering around 143740 ha area [81] The Brahmaputra is a transboundary river flowing through different countries of Asia, viz. Tibet (China), Bhutan, India and Bangladesh. The Brahmaputra basin spreads over five different states in the NE Region viz. Assam, Arunachal Pradesh, Meghalaya, Sikkim and Nagaland. The Barak valley spreads over the states of Assam, Meghalaya, Manipur, Mizoram, Tripura and Nagaland [76].Three other notable rivers viz the Chindwin river system flowing through the eastern part of Manipur and Nagaland, the Koladyne river system flowing through the southern part of Mizoram and the Teesta river rising from the eastern Himalayas and flowing through the state of Sikkim add to the vast river resources of the region.

The fishery resources of the region experience three types of environments i.e. tropical, subtropical and temperate and harbour a remarkably rich and diversified fish fauna. Drastic variation is observed in available fish biodiversity, from warm water species to cold water species and from torrential species to species inhabiting marshes. Vast and varied aquatic resources along with other biotic and abiotic components and suitable climatic condition have attributed to create one of the richest 'Hot spots' for freshwater fish biodiversity of the world [43]. Although there are different schools of opinion regarding the number of fish species available in the NE region [74] [84] [69], a more recent report enlisted 422 fish species from the region belonging to 133 genera and 38 families [28],that accounts for about 62.81% of total fish species inhabiting the fresh water resources of India.

The state wise fish biodiversity [28] revealed that the state of Manipur (325 nos) has the highest number of fish species followed by Assam (Fig 3). Recently ICAR- Directorate of Cold-Water Fisheries Research, Bhimtal, Uttarakhand has recorded the occurrence of 138 fish species endemic to this region. Out of these the maximum endemism was recorded in Manipur (91species), followed by Assam (29species), Arunachal Pradesh (26 species), Meghalaya (23 species), Nagaland (14 species), Mizoram (8 species), Tripura (7species) and Sikkim (5 species) (Newsletter, ICAR-DCFR, 2016-17).

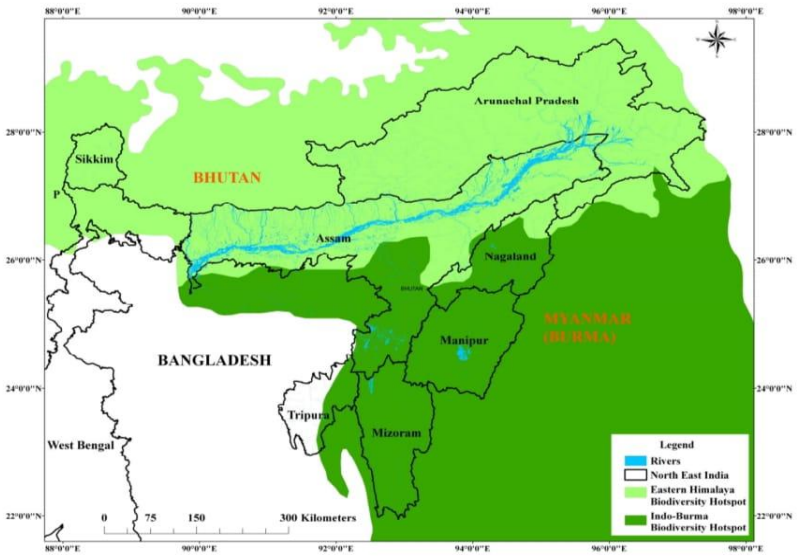

Fig.2. Parts of the states of NE Region of India in Himalayan and Indo Burma Hot spot Zones

Around 250 indigenous fish species of the NE region are recognised as potential ornamental fish species due to their ornamental characteristics [48]. Although there are different opinions about the

number of available ornamental fish species in the NE Region, [28] recorded 98 to183 ornamental fish species in different states of the region, out of which highest number has been recorded from the state of Manipur (183), followed by Assam (180) and Arunachal Pradesh (159). However, the ornamental fish biodiversity of the region has been degraded at an alarming rate due to over exploitation and improper conservation measures. In addition, indigenous sport fish species biodiversity including golden mahseer (*Tor putitora*) is another significantly potential area of the Region that is often linked with developing recreation-based ecotourism [63].

It has been observed that the fish biodiversity hotspot of the NE Region of India has been facing serious threats due to a variety of anthropogenic and natural reasons resulting in catastrophic loss of the rich diversity. Catch statistics reports indicate that there has been a drastic reduction in the abundance and distribution range of fish species of the NE region of India, due to habitat modification, over exploitation, climate change, natural calamities and other anthropogenic causes [6] [13] [65] [30]. The conservation status revealed that out of the 422 fish species available in the region, 48 are endangered, 69 near threatened, 103 vulnerable, 153 least concerned, 23 data deficient and 26 not evaluated [28]. Nine endemic fish species of the region viz. *Ompokpabda*, *Ompokpabo*, *Labeodyocheilus*, *Semiplotussemiplotus*, *Olyralongicuudata*, *Psilorhynchushiomalopters*, *Noemacheilus elongates*, *Balitorabrucci*and *Barbusdukai*, were identified as most threatened by National Bureau of Fish Genetic Resources, India [46]. Several measures for conservation of the rich freshwater fish biodiversity has been taken by different agencies of the region. Majority of the states of the region declared a fish species endemic to the state as 'State fish species' as a conservation measure. The Indian Fisheries Act 1897 has been in vogue in all the states of the region with location specific improvisation for protection of fishery resources and biodiversity with varying level of implementation. In spite of that there is alarming rate of depletion of the fish biodiversity in the region as stated due to various natural and manmade reasons[29] [30]. Annual flood is one of the factors which has major impact on fish biodiversity of the region.

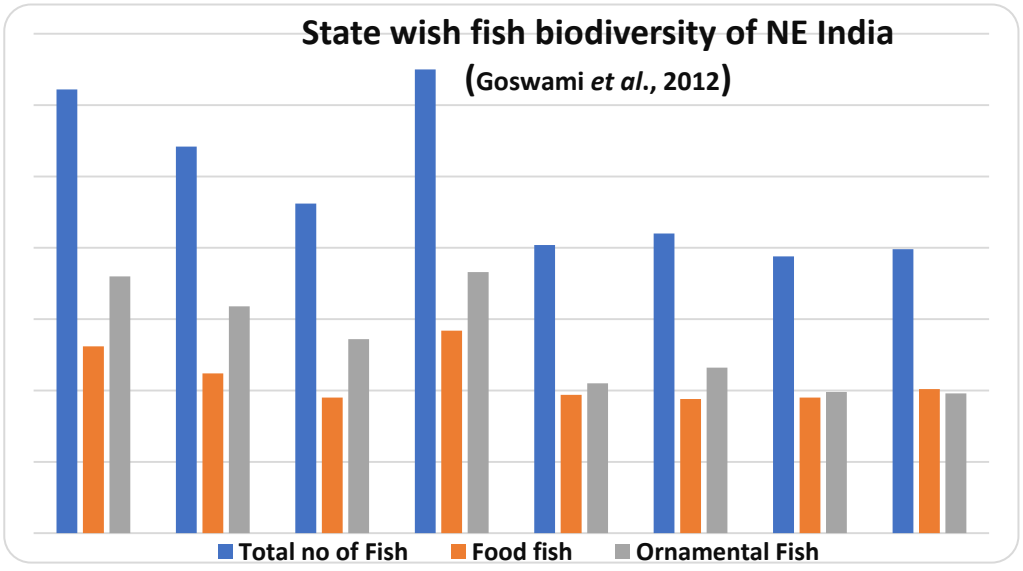

Fig. 3. State wise fish biodiversity of NE Region of India [29]

3. Impact of flood on fish biodiversity in the NE Region:

Flood, defined as an overflow of large quantity of water that submerges a normally dry area, is among the most common natural disasters of the world, having tremendous impact on the socio economic condition, life and livelihood of people of the affected region. The impact of flood is mediated by the magnitude, frequency, duration, timing and rate of change of water levels [61]. Depending on these factors, flood may have both negative and positive impacts on the inundated area. Regular annual flood rhythm is recognised as a natural phenomenon of a river ecosystem that maintains productivity and ecosystem harmony [38]. In addition to the impact on the inundated areas, the inbuilt overflowing condition of the water body has a variety of effects on different components of the aquatic ecosystem either directly or indirectly. India is one of the worst flood affected countries of the globe. Specific geographical structures along with other inherent factors induce flood vulnerability in many parts of the subcontinent. The snow clad Himalayan range to the north encompassing one of the largest glaciers of the world, is the origin of several perennial river systems flowing through the subcontinent.

Fig. 4. Map of India showing the flood prone regions

The Vulnerability Atlas of flood zone of India published by Central water Commission (CWC) revealed that the flood prone areas of India are mainly distributed in the Indo-Ganga-Brahmaputra plains and in the Eastern and Western Coastal regions. According to the report of National Flood Commission (1980), 12% land of Indian subcontinent (nearly 40 million ha) is prone to flood. However the area affected by flood has been reported to be on an increasing trend as per data base maintained by CWC during 1953-2010 (Report on Working Group on Flood Management and Region Specific Issues for XII Plan, 2011). Available data on flood related damage in India indicates

that recurrence and intensity of flood has amplified to a great extent over the years making it one of the biggest disasters in the country taking lives of thousands of people, affecting millions of people, causing loss of crops, livestock and other property worth huge amount of money thus affecting the socio economic growth of the country. Among the regions of the Indian subcontinent that are most vulnerable to water induced disasters, the North East Region is the one that experiences devastating flood every year. Each and every state of the NE region is prone to flood with variable extent, frequency and intensity. The state of Assam is the highest flood affected in the region and is one of the top five flood affected states of the country (Fig.4).

Assam, the second largest and most populous state of the North Eastern Region of India is situated in between latitude 24º0′ and 28º18′ N and longitude 89º50′ and 97º40′ E. The state covers a geographical area of 78,438 sq km that forms around 2.4 percent of the country's total. With 'tropical monsoon rain forest climate', the state experiences maximum 35-39°C temperature in summer and minimum 6-8°C temperature in winter and very heavy rainfall and high humidity. Major occupation of the population of the state is agriculture and allied activities including fisheries. Around 95% of the population is non-vegetarian with particular preference for fish. Fish has been an indispensable part not only of their diet, but also a variety of traditions and customs of their society and for that reason a very high demand for fish prevails in the state.

The state is bestowed with vast and diverse fishery resources (total around 5.5 lakh ha) comprising of two major river systems the Brahmaputra and the Barak, myriads of flood plain wetlands, reservoirs, ponds, low lying paddy field etc. and abundant freshwater fish biodiversity. In addition to that, other factors like sub tropical climate, scope for vertical development of culture sector through available technology back up, direct linkage with rest part of the country, export potentiality and available human resource support a congenial background for revamping fishery sector as a flourishing fishery based industry in the state [15]. Earlier it was reported that the fish biodiversity of Assam, comprising of 216 fish species belonging to 104 genera under 37 families and 10 orders was the richest among the fish biodiversity of all the states of the North East Region of India [6]. However, recent study revealed that the state is the second richest in fish biodiversity in the region with 311 fish species next to Manipur [29].

4. Major Factors causing flood in NE Region of India:

Devastating flood in the region is caused by the combined effects of a variety of natural and manmade reasons as summarized in Table 1 [13]. Overflow of the major river systems and their tributaries for different reasons is the primary source of flood in the NE states causing loss of life, damage of agricultural and allied crops, infrastructure and other properties. Being situated in one of the highest precipitated zones of the planet, the states of the North East Region of India receive a very high rainfall with annual precipitation ranging from 1577mm to 6002mm (average of 2068mm) in different places [56]. The South West monsoon is responsible for major share of annual rainfall in the Region. Although trend analysis data of rainfall during 1871-2008 did not show any clear trend of rainfall in the region as a whole [35], very high rainfall during monsoon (June- September) is recorded over the region (around 1513mm, much higher than all India average 865mm)[56], which is one of the major reasons for flood during that season. Over the North East region as a whole,

highest rainfall events has been recorded in the month of July followed by June and August [47]. The Barak valley also receives 2000-3900 mm precipitation with maximum during monsoon which along with other factors resulting in high intensity flood during that period. Erratic rainfall during different seasons also gives rise to untimely and unprecedented flood creating havoc in different states of the region. An all time higher intensity flood has been recorded in different states like Assam, Manipur, Mizoram and Tripura in recent years as a result of heavy shower causing landslides, erosion and geo morphological changes in addition to impact on life and livelihood of people.

Flood in Assam is characterised by extremely high magnitude, frequency of occurrences and extensive devastation. The state witnesses fury of flood every year with multiple instances (2-5 waves) extending from pre monsoon to post monsoon months (May to October), resulting in huge loss of life and property and making coping and mitigation mechanism difficult. A perusal of available literature on flood intensity in the state of Assam indicates an increasing trend from the year 1950 to 2000 in terms of area affected (from 8.85% to 40%) with substantial increase in loss of crop and property due to flood (from Rs. 58.6 Million to 1451.7 Million) during this period [9] The year 2012 has experienced unprecedented mayhem of flood in the state inundating 9.35 lakh hacter area, affecting 20 lakh of people of 27 districts and causing death of 126 people [9]. The recently updated flood hazard atlas for the state of Assam prepared by National Remote Sensing Centre (NRSC), ISRO, Hyderabad, indicated that 28.75% (22.54 lakh ha) of land of the state was affected by flood during the period 1998-2015. During the recent years (2016-18), the state has been experiencing unprecedented mayhem of flood, crossing the all time highest record of flood in the year 2018. The mayhem of devastating flood in Assam is not only due to high precipitation, but also due to the geographical position that allows the state to be influenced by the runoff from the plateaus and hills of the surrounding states [9]. The Brahmaputra valley covers about 56000 Sq km of alluvial plains and is fed by 34 tributaries of both the bank. The river Brahmaputra has the highest specific yield (with an annual runoff of 537.2cukm) in the world and that flows through a very narrow valley of hardly 40-50km width in Assam [76]. The breach in embankments along the mighty river Brahmaputra and its various tributaries crisscrossing the valley are the causes of increasing incidences of flooding in the region.

Climate change has been identified as one of the major reasons for increase in frequency and intensity of flood [62]. Study on change in climatic factors indicates global warming to the range of 0.69 to 1.08°C over the period of 1901-2012, with a projection of increase of global mean surface temperature by 0.3°C to 1.7°C, (IPCC 2013). Climate change has been recognized as a major threat to the existence of global biodiversity and integrity of ecosystems worldwide [34].A study on the river Brahmaputra basin of India indicated that impact of climate change manifested by increased temperature may have profound impact, as the rising temperature may trigger melting of glaciers in the Himalayas, which along with rising actual evapo-transpiration and erratic rainfall pattern may cause repercussions on the river hydrology leading to intense flood and also draughts in Assam [76] .The state level climate change trends in India [59] indicated that, there is significant increase in Annual mean temperature in several states of NE India like Arunachal Pradesh, Assam, Manipur and Tripura as well as significant change in annual rainfall pattern in different seasons in recent years, which along with other reasons may induce untimely, intense and unpredictable flood in these states. The high vulnerability of the Himalayan Region to climate change effects is likely to

further exacerbate the hydrological regime of the Brahmaputra fluvial system with resultant adverse impact on the Brahmaputra valley [76].

A case study on flood in the Brahmaputra valley indicated that loss and shrinkage of wetlands resulted in floods with higher intensity in recent years [76]. Absence of proper boundary demarcation in most of the flood plain wetlands leading to human encroachments, transformation of wetland and surrounding land for urban development are the major reasons which along with other factors like weed infestation, siltation and climate change related impacts have led to shrinkage of flood plain wetlands. As per report, over 4500 wetlands in the Brahmaputra valley are rapidly degrading due to wanton encroachment, weed infestation and siltation resulting in decrease in flood absorption capacity [76]. As for example, there was an overall decline in the area of an important wetland, the Deepor Beel of Brahmaputra valley (the only Ramsar site of Assam declared by Ramsar Convention in 2002), upto14.1% during the period from 1990 to 2007 [76]. The flood control measures like erection of embankment as well as sluice-gate near the feeding river or along the wetland area the affect productivity of wetland by way of preventing or limiting auto-stocking and annual flushing. Rapid urbanization in the region has led to conversion of many wetlands inducing impending danger of unprecedented devastating flood in new and flood free areas (not declared as flood prone). Instances of draining out of wetlands and converting them for other purposes in several developed countries has led to undesirable consequences like loss of ground water level, unpredictable flash floods, erosion and draught like situations leading to ecological disasters[76]. Reclamation and restoration of the water holding capacity of the flood plain wetlands therefore offers tremendous scope for reducing flood intensity and frequencies in the river valleys [6].

Erosion and siltation caused by action of flood is another significant factor that leads to reduction in area and depth in most of the river systems as well as flood plain wetlands of NE India. This problem is registered to be particularly severe in the Brahmaputra basin. Because of its erosive nature and high voltage flowing force, the river Brahmaputra carry very high quantity of silt which is deposited in the river bed, wetlands and other areas during inundation by flood. Annual sediment volume carried by the river Brahmaputra is around 800 million tonnes which is one of the highest in the world [76]. Due to constant silt deposition process in the Brahmaputra and its tributaries, the sizes of the river channels are progressively getting reduced over the years making them inadequate to carry the huge flow volume (around 429.76cukm during four monsoon months) resulting in widespread flooding due to excess water spill from the siltation impaired river channels [76].

Sudden release of huge volume of water without any precaution or warning from the Hydro electric power plants under the North Eastern Electric Power Corporation Limited (NEEPCO, a Central public Sector enterprise owned by the Government of India), situated in different parts of NE Region of India often results in devastating flood in the downstream areas. Huge volume of water released from the Ranganadi Hydro Electric Project under NEEPCO, situated in Arunachal Pradesh often creates havoc in the Dhemaji Lakhimpur area of Assam resulting in loss of life and livelihood of people [12]. Likewise water rush from the Doyang Hydroelectric project under NEEPCO, situated in Nagaland has been the cause of intensive flood in Golaghat district of Assam in the downstream.

Table 1: Major causes of Flood in states of NE Region of India [13].

Sl. No.	Natural	Anthropogenic
1.	Geography and geomorphology of the region	Drainage blockage due to construction of bridge, culverts, sluice gate etc. and congestion due to plastic and garbage pollution
2.	Siltation and rising of river bed	Human encroachment in riverine catchment area.
3.	Seismic activity	Deforestation
4.	Excessive rainfall	Shrinkage of floodplain wetlands due to human encroachment and conversion
5.	Siltation & weed infestation/ shrinkage of flood plain wetlands	Unscientific construction of dams/bundhs in river drainage system
6.	Blockage in the drainage due to landslide, erosion	Sudden release of huge volume of water from hydroelectric power projects(NEEPCO)

5. Impacts of flood on Fish Biodiversity:

The impact of flood is mediated by the magnitude, frequency, duration, timing and rate of change of water levels [76]. Depending on these factors, flood may have both negative and positive impacts on the inundated area. Regular annual flood rhythm is recognised as a natural phenomenon of a river ecosystem that maintains productivity and ecosystem harmony. In addition to the impact on the inundated areas, the inbuilt overflowing condition of the water body has a variety of effects on different components of the aquatic ecosystem either directly or indirectly. Although the impact of flood on the agriculture sector in North East India is assessed every year, similar assessment on the fishery sector is not carried out properly. It is obvious that flood related mayhem has tremendous impact on the life and livelihood of the fishers of the natural resources as well as on the socio economic condition of the fish farmers and other stake holders. The nature, extent and gravity of the mayhem of flood may vary according to the nature of the resources (culture or capture fisheries), intensity and duration of flood along with many other factors [13]. Review of works done elsewhere indicated that flood has multifaceted impact on the fish biodiversity and fish population of natural fishery resources.

A. **Changes in habitat characteristics and population structure**: Review of works done elsewhere on impact of flood in natural fishery resources has indicated that floods induce changes in aquatic environment in the form of widening / extension of habitat and enhancing resource availability that can stimulate fish productivity, increase species abundance, richness, diversity and evenness compared to an ecosystem with stable flow regime [38]. Study on impact of long term flooding on fishes and aquatic habitat in riverine deltas indicated overall decrease in species richness and diversity with decline in structural indices, while there was higher relative abundance of some species during post flood period [2]. As such, flood has tremendous impact on the structure and abundance of resident fish population. Earlier studies indicated that flood may have positive impact on population of some fish species through production enhancement by promoting recruitment, whereas negative impact on some other species resulting in decline in population size

due to abrupt change in the habitat[7], [2]. Although lotic fish communities have evolved with dynamic geo-morphological conditions and are relatively resilient to extreme hydrologic events [45], high intensity flood may reduce fish density and biomass and influence community composition of the resident population [90] [49]. The magnitude of flood, availability of suitable refuge (floodplains and backwaters) and flood timings have tremendous impact on the resident fish population in relation to the life history of the species [37] [24] [40] and may vary according to the fish species, age, size, health, morphology, physiology (tolerance to turbidity, strength to swim in turbulence intensive water etc), behaviour (movement, habitat use) and community composition (species abundance, diversity etc.).

Fig. 5. Erosion by the bank of River Brahmaputra in Assam

B. Impact on reproduction of fish: Floods generally create connection of rivers with the flood plains and supply nutrients to aquatic terrestrial transition zones stimulating biological productivity and habitat heterogeneity *vis* a *vis* benefit the resident fish population by inducing breeding and enhancing recruitment [83], [80]. Seasonal fluctuation of water level, known as 'flood pulse' influence the population dynamics of river fisheries [38], but the extent and mechanisms through which the flood pulses affect the productivity has not been established. Rising water levels trigger fish production, as many fish species migrate to spawn naturally in freshly flooded floodplains when water level rises. However, the impact is species specific and varies according to the biological and physiological characteristics of the fish species. Direct effects involve displacement of eggs, destruction of incubating eggs, developing embryos and newly hatched out juveniles, while indirect effects may include reduction in carrying capacity and change in population composition due to habitat alteration [22]. Beside leading to shrinkage in depth and area of water body, flood induced erosion and siltation also damage the ecological niche for certain fish species, destroy breeding and feeding ground and bring about changes in the natural habitat system , which ultimately have impact on the reproduction of resident fish population. The flood control measures like erection of embankment as well as sluice-gate near the feeding river or along the wetland area affect productivity of wetland by way of preventing or limiting auto-stocking, spawning migration and annual flushing leading to negative impact on fish biodiversity. Generally fish fauna of lotic environment are adapted to regular annual flood pulse that gives them ample opportunities for breeding and grazing in wider area in fresh flood water. It has been observed that along with

overflowing of the water bodies during monsoon, the gravid and mature fishes of different species use to come out from their natural habitats and escape to the adjoining areas filled with fresh rain water for breeding. However, with the increasing intensity of flood they get dispersed to the neighbouring areas, where most of them are caught by the local population or fall prey to other untoward situations resulting in tremendous impact on the natural population of different fish species. There is need for location specific study and proper assessment of the impact, so as to draw a road map to cope up with the mayhem of flood and address necessary mitigation measures.

Table: 2. Impacts of flood on fisheries of NE Region (Chetia Borah, 2019)

Sl. No.	Capture fishery	Culture fishery
1.	Impact on environmental parameters	Damage of pond infrastructure
2.	Changes in ecosystem balance	Changes of ecosystem balance
3.	Impacts of infrastructures (Dam, Bridge, Bundh etc.)	Pollution through flood
4.	Siltation and erosion, weed infestation	Weed infestation (specifically floating weeds)
5.	Pollution from catchment area	Impact on farming operation
6.	Impacts on fishing operation	Loss of fish through migration/mortality
7.	Impacts on fish assemblage	Water and soil quality deterioration
8.	Impact on fish population structure	Change in primary productivity/ food chain
9.	Enhancement of fish productivity by autostocking , recruitment.	Entry of alien/ wild carnivorous fish species
10	Loss of fish through destruction of eggs/juveniles, migration, mortality.	Disease outbreak
11.	Invasion of alien species.	Siltation/ sand deposit

C. Impact of flood on resources under protected area: The North East Region of the country is bestowed with a good number of forests designated as the National parks and Wild life sanctuaries for their importance as wild life habitats as well as biodiversity repository. Out of the total 103 National Parks of India, 16 nos are situated in the states of the North Eastern Region covering around 2.57% total geographical areas of the region. Majority of the protected forest areas of NE India encompass a variety of natural water bodies including parts of the major river systems of the region and their tributaries, flood plain wetlands, swamps etc. that are abode of indigenous as well as endemic fish fauna. Studies conducted on the fishery resources of the protected areas of the NE region [21], [73], [87], [64], indicated potentiality of these resources in protection and conservation of indigenous fish biodiversity. The Dibru Saikhowa National park of Assam, for example, is endowed with vast and varied water bodies that encompasses 51 sqkm of flood plain wetlands, several rivers, rivulets, swamps etc. harbouring rich aquatic biodiversity including 108 fish species representing 64 genera and 27 families [3]. The residential population of the freshwater River Dolphin, *Platanista gangetica* in the Dibru Saikhowa National park water resources, is reportedly the most dense and prominent population in the entire North Brahmaputra Basin of Assam [87]. The Kaziranga National Park, which hosts two thirds of world's one horned Rhinoceros, is a World Heritage Site, declared as a Tiger Reserve in 2006 for its unique Royal Bengal Tiger population and

as an important Bird Area for conservation of avifaunal species by Bird life International. The Park is criss-crossed by four major rivers including the mighty river Brahmaputra and is endowed with myriads of flood plain wetlands, swamps, rivulets and canals that act as habitat and breeding ground for diverse indigenous and endemic fish fauna. Although scientific information and documentation on the fish fauna of the water resources of the Kaziranga National Park is scanty, promotion of these water resources as aquatic Sanctuary would gear up conservation of the rich fish biodiversity of the region and would add to the fish biodiversity based ecotourism sector of the country (Fig 6).

Most of the National parks and Wild Life Sanctuaries of this region experiences flood every year causing threat to the wild life. For example, the Dibru Saikhowa National park of Assam has been under continuous threat of flood, as it is situated in the flood prone areas of the flood plains of the river Brahmaputra and rivulets Debang, Lohit, Dibru in the tropical monsoon belt with high annual rainfall. The park has been subjected to geo-morphological changes in recent years due to widening and changing of river courses and high amount of siltation during flood [75].This along with increasing anthropogenic pressure from the neighbouring areas has led to shrinkage of the ecosystem and depletion of the biodiversity [89]. Likewise, the Kaziranga National Park situated in the flood plain of the mighty River Brahmaputra experiences devastating flood every year causing loss of valuable wild life including the one horned Rhino. During flood the aquatic lives of the natural water bodies under these protected areas including the rich wild fish fauna also get affected severely. As such, although the creation of Freshwater Aquatic Sanctuary (FAS) within protected forest area network has been recommended as one of the effective strategies for protecting biodiversity from different threats [70], [64], intensive flood likely to hamper achieving this goal

Fig .6. Flood in the Kaziranga National Park, Assam

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D. Flood induced invasion of alien fish species: Besides impact on the resident population, flood facilitates invasion of alien fish species in to the natural resources, creating another threat for the native fish biodiversity and natural habitat [36]. Quite a few alien fishes were introduced to NE Region of India for improving local fishery potential and broadening species diversity in aquaculture programme. The Chinese carps Silver carp (*Hypophthalmichthys molitrix*), Grass carp

(*Ctenopharyngodon idella*) and Common carp (*Cyprinus carpio*)are some of the species that were already established themselves in the culture fishery sector of the state. Some other species like *Clarias gariepinus* (Thiland magur), *Arichthys nobilis* (Big head), *Oreochromis nilotica,* etc. introduced to the state clandestinely have been causing severe problems in ecosystem balance. Recent introduction & popularization of other alien species like African Pangas (*Pangassius sutchi*) and Amazon Piranha (Pacu) locally called as Rupchanda (*Piaractus brachypomus*) as well as reporting of some of the species in natural waters like *beels* and rivers, has indicated an alarmingly grave situation of invasion and establishment of these alien species in natural resources [8]. Reported invasion of alien ornamental species like Sucker mouth armoured catfish of Loricariidae family in natural water resources like flood plain wetland, rivers etc. has been creating havoc in the region [77]. There are reports that floods may exert differential effects on introduced and native species by increasing reproduction, recruitment and population growth to a greater extent than the native species [71], [79], [4]. As such, there is need for immediate action to check entry and culture of alien fish species, particularly in the flood affected areas of the region, where there is every risk of escaping of the alien species from the culture ponds along with flood water and invade the natural resources resulting in negative impact on indigenous fish population.

E. Flood induced pollution :Pollution of water bodies during flood : During flood many water bodies, specifically the flood plain wetlands are subjected to pollution through surface runoff from paddy field, tea gardens or other agricultural activities where a variety of pesticides are commonly used for pest management. Effect of pesticides on non-target aquatic organisms including fish has been a major threat for fish biodiversity. Studies on impact of commonly used pesticides on commercially important food fish species like *Monopterus cuchia*, *Anabas testudineus*, *Channa punctatus, Heteropneustes fossilis* etc. support this view [5]. [32]. [19]. [33]. In addition to that, pollution from domestic and industrial wastes, crude oil pollution of natural water bodies during flood due to oil exploration activities of Oil and Natural Gas Commission are specific issues that need to be addressed for protection of the aquatic biodiversity of the region[30].

F.Flood induced water quality deterioration: Extensive growth of weed, particularly the Water hyacinth infestation brought in by flood water is a menace to flood plain wetland fisheries. This fast expanding weed leads to faster eutrophication in the wetlands by slowing down water current and depositing debris and silt at the bottom which is one of the causes of degradation of the wetland ecosystem and shrinkage of water spread area and depletion of fish biodiversity.

6. The Way ahead:

Since most of the climate change models predict increased frequency of extreme hydrologic events [62], a better understanding of the impact of flood related disturbances on the aquatic biota and habitat is the need of the hour for proper management of water resources as well as for developing coping up strategies and mitigation measures to combat impact of flood on the fish biodiversity of the region. In addition the high vulnerability of the Himalayan Region to climate change effects is likely to further exacerbate the hydrological regime of the Brahmaputra fluvial system with resultant adverse impact on the Brahmaputra valley [76].

For conservation of fish biodiversity in flood prone areas some basic points need to be addressed:

1. Proper assessment of impact of flood including loss of fish stock, change in community size and structure, deterioration of ecosystem, change in water quality, pollution, damage of infrastructures and implements, disease outbreak, invasion of alien species and mortality of fish.
2. Record on statistical data of highest flood level, frequency of flood and number of waves every year in the flood prone areas need to be collected Early warning system, Disaster management system need to be strengthened.
3. Eco friendly, Sustainable road map should be chalked out to control flood as well as to mitigate impact of flood on fish biodiversity.
4. Use of modern technology like Drone (Unmanned Aerial vehicle, UAV), Global Positioning System (GPS), Geospatial technology etc. for efficient assessment and management of flood related challenges.
5. Revisiting and refinement of technologies for creation of bundh, dam, sluice gate, drainage system etc. befitting the specific environmental, geographical and hydrological conditions as well as biological need of the resident aquatic species at particular locations and water bodies.
6. Reclamation of flood plain wetlands that have been facing the problem of shrinkage to restore its original size and depth, so as to enhance their water holding capacity for retaining more flood water from the overflowing rivers and thus reducing the intensity of flood considerably [12].
7. Proper sustainable measures including planting indigenous suitable plant species along the bank of river to control erosion of bank.
8. Integrated approach for sustainable and productive management of flood plain wetlands with community participation [11].
9. Creation of aquatic sanctuary in flood secured areas to conserve and restore the fish germplasm of the region.
10. Development of technology for breeding and creation of infrastructures like hatchery for fish seed production for ranching in the natural resources after flood to mitigate loss due to flood.
11. Awareness and preparedness to address the flood induced challenges, availability of day to day meteorological data, early warning system and coping up strategies among the aboriginal fisherman communities and other stakeholders, particularly before release of sudden flash of water from hydroelectric project.
12. Suitable alternative livelihood option during the flood period along with specific skill development programme for the fishers and other stakeholders that depend on the flood affected water bodies for their livelihood.
13. Improvisation of fishing gears, crafts and tools for better efficiency and for responsible harnessing of productivity of the flood prone natural resources
14. Strengthening transport and communication facility, power supply system, disaster management, health care and maintaining hygiene in the flood prone areas.

15. Provisioning specific policy support for coping up and mitigation strategies for the flood affected fisher population including insurance and financial support.
16. Specific policy support for conservation and restoration of indigenous biodiversity through checking invasion of alien species in the natural resources through flood as well as addressing and mitigating the impact of flood on the natural fishery resources in eco-friendly way.

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