doi:10.21077/ijf.2025.72.1.152167-01

Available online at: epubs.icar.org.in/index.php/IJF

Delineating impact of climatic variable(s) on commercial fish landings in a tropical river through multi-species modelling

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Abstract

For effective fisheries management and sustainable development of fisheries in the Indian segment of the Brahmaputra River, it is crucial to examine how fish landing patterns have been influenced by climatic factors over recent years. In this context, this study aimed to assess the impact of climatic variables, specifically precipitation, on commercial fisheries in the Brahmaputra River at Uzanbazar (Guwahati) using a multi-species modelling approach. The annual data from 1987 to 2017, encompassing precipitation and multi-species fish landings, including Indian major carps (IMC), catfishes, minor carps, featherbacks, miscellaneous fishes and hilsa was utilised for the study. To analyse this, the Dynamic Factor Analysis (DFA) technique was employed to identify common trends and quantify the effects of precipitation on the different fish groups/species. Based on the model selection criterion, the optimal DFA model revealed three distinct common trends with an unconstrained covariance matrix. Trend-1 primarily represented the landings of minor carps, catfishes, and IMC; Trend-2 was associated with miscellaneous fishes and featherbacks and Trend-3 corresponded to hilsa landings. Precipitation was incorporated as an explanatory variable in the optimally selected DFA model to characterise the relationship between fish landings and climatic factors. The results indicated that annual precipitation significantly influenced the landings of catfishes, hilsa, featherbacks and miscellaneous fishes. Specifically, a significant positive regression coefficient was observed for miscellaneous fish landings, whereas significant negative regression coefficients were found for hilsa, catfishes and featherbacks. The comparison between the standardised empirical fish landings and the predicted landings from the DFA model showed a good agreement. This study represents the first application of the DFA approach to explore common trends in commercial fish landings and the influence of precipitation on these landings in the Brahmaputra River. The findings can inform the development of sustainable management strategies for multispecies commercial fisheries in riverine ecosystem.

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Keywords:
Brahmaputra, Dynamic factor analysis, Fish landings, Precipitation, Sustainable fisheries

Received : 29.05.2024
Accepted : 25.03.2025

Introduction

Rivers provide essential services supporting agriculture, water transport, industry and hydropower generation, forming a critical part of India's open-water resources. India's riverine fisheries are divided into two main groups: Himalayan rivers (Ganges, Indus, Brahmaputra) and Peninsular rivers (Narmada, Tapti, Mahanadi, Godavari, Krishna, Cauvery). These rivers, including their tributaries, span approximately 45,000 km with a catchment area of 3.12 million km² across 113 basins (Vass and Moza, 2011). These systems support both warm-water species in plains and cold-water species at higher altitudes. The north-eastern state of Assam, rich in riverine resources, relies heavily on natural riverine fisheries, where species propagate naturally and humans harvest without intervention. The conservation of native fish populations is critical for sustainable fisheries (Joshi *et al*., 2018), as environmental factors such as rising temperatures, precipitation changes, altered runoff and water quality degradation threaten fish diversity (Das *et al*., 2020; 2022).

The Brahmaputra River, with a drainage area of 580,000 km², flows through China (50.5%), India (33.6%), Bangladesh (8.1%) and Bhutan (7.8%). In India, its basin spans Arunachal Pradesh (41.9%), Assam (36.3%), Meghalaya (6.1%), Nagaland (5.6%), Sikkim (3.8%) and West Bengal (6.3%). The Brahmaputra's Assam stretch supports 126 fish species across 26 families, with 41 species forming the commercial fishery (Motwani *et al*., 1962). These species span torrential, plain and cold-water forms (Bhattacharjya *et al*., 2017). Riverine fisheries provide both food security and livelihoods to local populations.

In Assam, there are 42 fish landing centers along the Brahmaputra, with major centers in Uzanbazar (Guwahati), Nimatighat (Jorhat), Dhubri, Goalpara, Jogighopa, Dhekiajuli, Tezpur, Biswanathghat, Dibrugarh and Chaikhowaghat. The ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore, monitors fish landings, which have shown a declining trend, especially for important species such as Indian major carps (IMC) and Hilsa. The fishery composition varies between the river's upper stretch, dominated by species like *Labeo gonius, L. bata, Wollago attu, Notopterus notopterus, Chitala chitala* along with major carps, and the lower stretch, which features IMC, catfishes and Hilsa (Bhattacharjya *et al*., 2017). While studies on fish yield patterns are limited (Choudhury *et al*., 1980; Yadava and Sugunan, 1992; Vass and Moza, 2011; Bhattacharjya *et al*., 2017; Yadav, 2022; Yadav *et al*., 2022a,b), no research has explored the impact of meteorological variability on commercial fish landings in the Brahmaputra. Understanding these patterns is crucial for developing sustainable management strategies for the multispecies fishery.

Previous research has primarily used univariate time series models, which link individual species' catches to climatic and hydrological variables (Box *et al*., 1994; Raman *et al*., 2018). However, to better understand the multispecies fishery, it is important to model the relationship between fish landings and climatic/hydrological factors. Dynamic Factor Analysis (DFA) is a robust method for modelling multivariate time series data, revealing common trends in multispecies landings and estimating the impact of multiple factors on fish yield (Zuur *et al*., 2003). While DFA has been widely applied in marine systems (Zuur *et al*., 2003; Chen *et al*., 2006; Sathianandan *et al*., 2016), its use in river ecosystems, particularly in India, remains underexplored.

Against this background, this study aims to identify common trends in commercial fish landings and to assess the impact of precipitation on fish landings in Brahmaputra river system. It identifies common trends, evaluates species contributions, and highlights climatic variable(s), particularly rainfall, influencing catch dynamics. The findings will inform effective multispecies fisheries management strategies for riverine ecosystems.

Materials and methods

Study area and data collection

The major fish landing centres in the lower stretch of the river Brahmaputra are shown in Fig. 1. The present study is based on primary as well as secondary data on fish landings (in tons, t) at Uzanbazar (Guwahati) (26°11'44.3"N and 91°45'23.94"E) landing centre of the river Brahmaputra for the period from 1987 to 2017. The commercially important fish groups/species of the river Brahmaputra is given in Table 1. Secondary data on landings for commercial fish groups/species at this landing centre was collected from the field books and annual reports of ICAR-CIFRI (1987-2014). Primary data for the estimation of fish landings at Uzanbazar

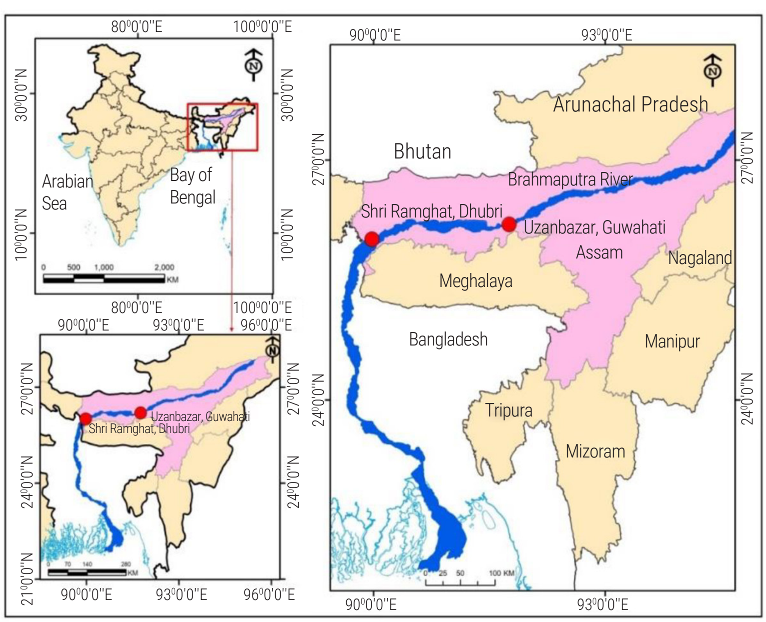

Fig. 1. Map showing major landing centers in the lower stretch of the river Brahmaputra, Assam

Table 1. Commercial fish groups/ species of the river Brahmaputra at Guwahati, Assam, India

Groups	Species
Indian major carps (IMCs)	*Labeo rohita, L. catla, Cirrhinus mrigala*, *L. calbasu*
Minor carps	*L. gonius, L. bata, L. dero* and *C. reba*
Catfishes	*Wollago attu, Mystus seenghala, M. aor, Rita rita, Pangasius pangasius, Bagarius bagarius, B. yarelli, Eutropiichthys vacha, Ompok pabda, Clupisoma garua, Ailia coila, Setipinna phasa, M. tengera, M. cavasius*
Featherbacks	*Chitala chitala, Notopterus notopterus*
Miscellaneous fishes (including freshwater prawns)	*Cabido morar, Gudusia chapra, Barilius barilius, Puntius* spp., *Colisa* spp., *Macrobrachium* spp.
Hilsa	*Tenualosa ilisha*

was generated using the stratified random sampling techniques described by Tyagi and Mandal (2008). Data on annual precipitation in and around Guwahati for the same period was collected from Regional Meteorological Station, Guwahati, Assam.

Statistical analysis

Based on the temporal pattern of fish landings, long-term fish landing data from the Brahmaputra River at Uzanbazar (Guwahati) were categorised into three decadal intervals *viz.,* 1987-1997, 1998-2007 and 2008-2017. A one-way analysis of variance (ANOVA) was conducted to test for significant differences in landings (tons, t) and the contribution of fish groups/species across the decades. Prior to performing the ANOVA, the data were assessed for normality (using Kolmogorov-Smirnov test) and homoscedasticity (using Levene's test) following Das *et al*. (2023). The fish landing data were log-transformed before applying ANOVA, as the variances within the landings of commercial fish groups/species differed significantly. Duncan's Multiple Range Test (DMRT) (Duncan, 1995) was used for *post-hoc* analysis, revealing that the average fish landings across decades were significantly different ($p<0.05$).

DFA technique to characterise common trends

DFA is a method employed to identify the latent common patterns across multiple time series data. The DFA model consists of four key components: a linear combination of common trends, explanatory variables, a level parameter and a noise component (Zuur *et al*., 2003). Mathematically, the DFA model with P common trends and error is represented as follows:

$$y_t = Z\alpha_t + \epsilon_t$$

where y_t is a vector of dimension N × 1 containing the values of N time series at time t, α_t , is a vector of dimension P × 1 representing the P common trends at time t and ϵ_t is a vector of dimension N × 1 representing the error component, where $\epsilon_t \sim N(0,R)$ and R is the covariance matrix. The matrix Z is of dimension N × P and contains the factor loadings, which determine the linear combinations of the common trends.

The common trends, which are important for a particular time series as well as for groups of time series related to the same common trend, can be inferred by comparing the factor loadings. The trends are modelled as underlying common patterns over time, described by the equation:

$$\alpha_t = \alpha_{t-1} + g_t,$$

where $g_t \sim N(0, Q)$, Q is a diagonal covariance matrix of error, with g_t and ϵ_t being independent. The contribution of the error component is expected to be small for all *t* if the corresponding diagonal element of Q is small, resulting in smoother trends. Conversely, a larger diagonal element of Q leads to greater fluctuations in the trend. Therefore, the trends are considered smoothing functions over time and are mutually independent.

To allow each linear combination of common trends to move up or down, a constant parameter vector c of dimension N × 1 is included, so that the model becomes:

$$y_t = z\alpha_t + c + e_t$$

To incorporate predictor or independent variables into the DFA model, suppose the values of the M predictor variables at time t are represented by a vector x_t and D is an N × M matrix containing regression coefficients. The effects of the predictor variables are modelled as in linear regression:

$$y_t = Z\alpha_t + c + Dx_t + e_t$$

where α_t represents the latent variables and x_t represents the observed variables. Therefore, α_t contains the information shared by the dependent variables that cannot be explained by the independent variables.

Standardised data of the variables under study were used to build the DFA model and draw inferences. A model with only explanatory variables and no latent variables is preferred for easier interpretation. The optimal model for the 'multispecies-precipitation' relationship and the number of common trends was selected based on the smallest Akaike Information Criterion (AIC) value, a standard measure of model selection. The Multivariate Autoregressive State-Space Modelling (MARSS) package was used to fit the DFA model using R software (v 3.5.2).

Results and discussion

Total fish landings

A comparative analysis on patterns of average fish landings at the Brahmaputra River landing centre in Uzanbazar (Guwahati) over the period from 1987 to 2017 was performed. Based on an initial assessment of the chronological patterns in fish landings, the time period was divided into three decadal intervals: 1987-1997 (Period-1), 1998-2007 (Period-2) and 2008-2017 (Period-3) to examine variations in fish landings over the decades. The total fish landed at this centre averaged 198.5±100.1 t per year during the study period. The total landings showed an overall upward trend from 1987, reaching peak landings of 471.8 t in 2002, followed by a consistent decline to the lowest level of 84.6 t in 2016 (Fig. 2). The average fish landing was 195.5±50.4 t per year during Period-1,

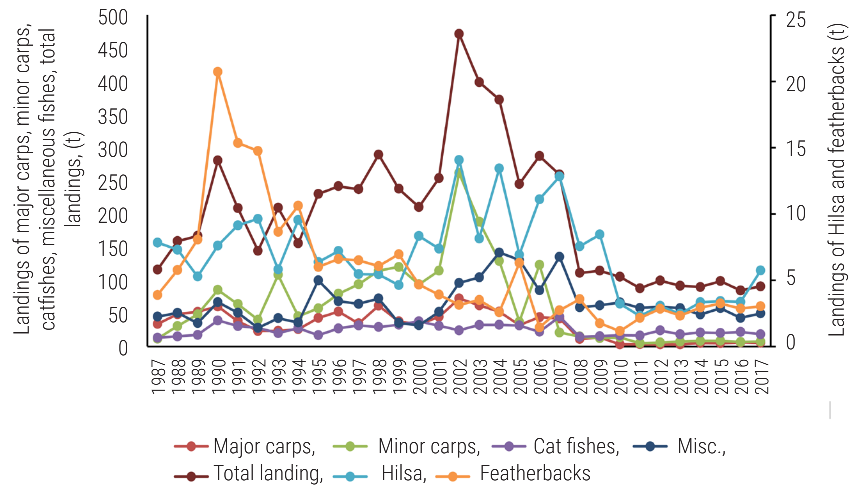

Fig. 2. Landings (t) of six commercial fish group/species of Brahmaputra River at Uzanbazar (Guwahati), for the period 1987-2017

which significantly increased to 302.8±83.9 t per year during Period-2, representing a 55% increase over the decade. However, average fish landings decreased significantly in Period-3 compared to the previous periods. The average landing during Period-3 was 97.4±10.2 t per year, showing a 60% decline compared to the average landings of the earlier decades.

Landings by commercial fish groups/species

The landings of commercial fish groups/species exhibited notable temporal variations (Fig. 2). The landing of IMCs decreased from 34.1 t in 1987 to 5.7 t in 2017, despite exhibiting year-to-year fluctuations. The IMC landings peaked at 72.5 t in 2002 and were at their lowest in 2013 (3.1 t) (Fig. 2). The average IMC landing was 31.7±21.2 t per year over the study period. The average IMC landings increased from 39.9±12.7 t per year during Period-1 to 48.4±13.4 t per year during Period-2, although this increase was not statistically significant. In contrast, the average IMC landing during Period-3 was significantly lower than in the previous periods, with a decline of 86%, averaging 6.1±3.7 t per year compared to the earlier decades (1987-2007). The average contribution of IMC landings decreased from 21.0% during Period-1 to only 6.1% during Period-3. Previous studies also noted a decline in IMC catches, from 7.7 t (13.7%) in 1975 to 4.0 t (3.9%) in 2010 (Debnath *et al*., 2015) at this landing centre. Boruah and Biswas (2002a, b) also reported a drastic reduction of IMC landings in the upper reaches of the Brahmaputra River in the last decade. Similar declines in IMC landings have been reported from the Ganga River (Vass *et al*., 2009; Joshi *et al*., 2014; Jha *et al*., 2017, 2020). For instance, the contribution of IMC in the Ganga River at Prayagraj declined from 90.8 t (38.1%) during 1956-1967 to 25.6 t (15.0%) during 2005-2018 (Jha *et al*., 2020). Vass *et al*. (2009) also documented a decline in the contribution of IMC from 41.4% to 8.3% over the past two decades.

The landing of minor carps in the Brahmaputra River system at Guwahati exhibited fluctuations since 1987 (Fig. 2). Initially, there was an increasing trend up to 2002, followed by a subsequent decline. Minor carps peaked in 2002 with 261.7 t and reached their lowest point in 2011 with 5.0 t. The average minor carp landings were significantly higher during Period-2 (120.4±-68.4 t per year) compared to Period-1 (60.5±29.0 t per year). However, average landings during Period-3 (9.2±3.4 t per year) were significantly lower than the previous periods, with a sharp decline of 85 and 92% compared to Period-1 and Period-2, respectively (Table 2). The average contribution of minor carp landings decreased from 29.6% in Period-1 to 9.3% in Period-3.

Catfish landings averaged 25.1±8.2 t per year over the period 1987-2017, with peak landings recorded in 2007 (45.2 t) and the lowest in 1987 (13.4 t) (Fig. 2). There was no significant difference in the average landings of catfish between Period-1 (24.5±8.3 t per year) and Period-3 (18.9±3.1 t per year). However, the average landings during Period-2 (32.1±6.4 t per year) were significantly higher than those during Period-1 and Period-3 (Table 2). The average contribution of catfish landings increased from 12.7% in Period-1 to 19.7% in Period-3.

Featherbacks landings averaged 5.6±4.3 t per year during the study period, with the highest recorded landing of 20.7 t in 1990 and the lowest of 1.2 t in 2010. The featherbacks landings exhibited a declining trend following the peak in 1990 (Fig. 2). Featherbacks landings were highest during Period-1, with an average of 9.7±5.2 t per year, and declined significantly by 58% to an average of 4.1±1.8 t per year during Period-2. During Period-3, featherbacks

Table 2. Average landings (t yr^{-1}) of commercial fish groups/species of the river Brahmaputra at Uzanbazar (Guwahati)

Groups	Average landings (t yr^{-1})		
	Period-1 (1987/1997)	Period-2 (1998/2007)	Period-3 (2008/2017)
Indian major carps (IMCs)	39.9±12.7^{a}	48.4±13.4^{a}	6.1±3.7^{b}
Minor carps	60.5±29.0^{b}	120.4±68.4.0^{a}	9.2±3.4^{c}
Catfishes	24.5±8.3^{b}	32.1±6.4^{a}	18.9±3.1^{b}
Hilsa	7.4±1.6^{a}	9.2±3.4^{a}	4.3±2.2^{b}
Featherbacks	9.7±5.2^{a}	4.1±1.8^{b}	2.6±0.7^{b}
Miscellaneous fishes	53.6±20.4^{b}	88.5±40.4^{a}	56.4±7.0^{b}
Total	195.5±50.4^{b}	302±83.9^{a}	97.4±10.2^{c}

Data expressed as mean±SD. Means bearing the same supescripts are not significantly different at p≤0.05.

landings stabilised at 2.6±0.7 t per year, representing a 73% decline compared to Period-1 (Table 2). The average contribution of featherbacks landings decreased from 5.1% during Period-1 to 2.7% during Period-3.

Hilsa landings averaged 7.0±3.1 t per year over 1987-2017, with a maximum landing of 14.1 t in 2002 and a minimum of 2.3 t in 2010. There was no significant difference in Hilsa landings between Period-1 (7.4±1.6 t per year) and Period-2 (9.2±3.4 t per year). However, landings during Period-3 (4.3±2.2 t per year) were significantly lower compared to previous periods (Table 2). The average landings of Hilsa during Period-3 were nearly 48% lower compared to the earlier decades (1987-2007). The contribution of Hilsa landings remained almost constant over the three decadal periods.

Miscellaneous fish landings peaked in 2004 at 141.8 t and were at their lowest in 1992 (28.2 mt). Following the peak in 2004, landings exhibited a declining trend (Fig. 2). The average miscellaneous fish landings were 53.6±20.4 t per year during Period-1, which increased significantly to 88.5±40.4 t per year during Period-2, reflecting a 65% increase over the decade. The average landing during Period-3 was 56.4±7.0 t per year, representing a 40% decrease compared to Period-2 (Table 2). The average contribution of miscellaneous fish landings increased from 27.5% during Period-1 to 57.9% during Period-3. Previous studies have noted an increase in the dominance of miscellaneous fishes, with contributions ranging from 40 to 50% (Vass and Moza, 2011). Additionally, the small-sized cyprinid species *Cabido morar* has become the most dominant fish species in all major landing centers in recent years (Borah *et al*., 2014; Bhattacharjya *et al*., 2017). Similar increases in the landings of miscellaneous fish and catfish have been reported in the middle stretch of the Ganga River (Vass *et al*., 2009). Such changes in the fish landings and composition in the Brahmaputra River may be partly attributed to habitat modifications, over-exploitation, climate change, and anthropogenic factors (Debnath *et al*., 2015). The process of "fishing down the food-web", where large predatory fish are over-exploited, may have led to an expansion and dominance of smaller miscellaneous fish groups due to reduced predation pressure. Furthermore, the expansion of minnows, which are climate-resilient (Sarkar *et al*., 2019), could also contribute to their population growth in the Brahmaputra River.

Precipitation

The average annual precipitation in and around Guwahati was 1751.2±259.1 mm over the period 1987-2017, with maximum precipitation recorded in 2008 (2253.3 mm) and the minimum in 2011 (1296.7 mm). The year-to-year variation in precipitation is shown in Fig. 3. The average precipitation significantly decreased from 1872.0±288.2 mm per year during 1987-1997 to 1628.6±241.7 mm per year during 2008-2017.

Development of model to characterise common trends

We made three choices for the R matrix *viz.,* diagonal and equal, diagonal and unequal, and unconstrained, for the development of the model. Additionally, different DFA models were fitted for the P (1 ≤ P < N, the number of time series) common trends. A total of nine DFA models corresponding to the paired combinations of R matrix and M (1, 2 and 3) were fitted. Based on the lower AIC values presented in Table 3, the optimal DFA model with an unconstrained covariance matrix identified three common trends (AIC = 450.07). Canonical correlations were then computed to quantify the contribution of the 'landing series' to the 'common trend'.

Table 3. AIC value estimated from DFA modelling approach on five commercial fish landing time-series from 1987-2017

Type	Model		
	Catch series = Constant + P common trends + Noise		
	P	R matrix	AIC
1a	1	Diagonal and equal	468.0979
1b	2	Diagonal and equal	450.9076
1c	3	Diagonal and equal	453.0457
2a	1	Diagonal and unequal	475.3004
2b	2	Diagonal and unequal	452.8685
2c	3	Diagonal and unequal	456.0773
3a	1	Unconstrained	465.8151
3b	2	Unconstrained	452.3629
3c	3	Unconstrained	450.0666

P is the number of common trends; here a, b, c letters denote the fitting of 1, 2 and 3 common trends, respectively.

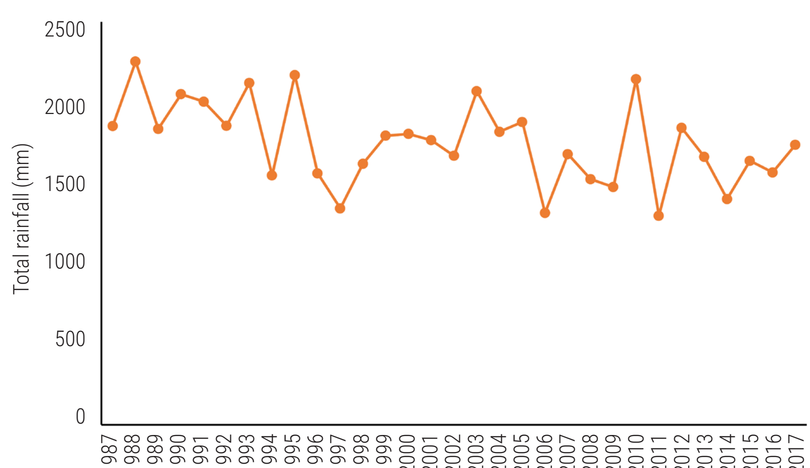

Fig. 3. Precipitation (mm) for the period 1987-2017 in and around Guwahati, India

The patterns of the three common trends, estimated by the selected DFA model for six commercial fish groups/species, along with their corresponding factor loadings, are presented in Fig. 4. Trend-1 exhibited irregular fluctuations from 1987 to 2002, followed by a sharp decline until 2008, after which it stabilised. Trend-2 showed a decreasing trend from 1987 to 1990, followed by a more or less increasing trend until 2002 and a subsequent decreasing trend from 2013. Trend-3 displayed a decreasing trend until 1999, followed by a rapid increase, reaching its maximum in 2004, after which it decreased sharply.

Among the landings of the six commercial fish groups/species, minor carp landings showed a high positive canonical correlation loading with Trend-1, followed by landings of catfishes and IMCs (Fig. 4). Featherbacks landings had a low, statistically insignificant influence on Trend-1. Catches of miscellaneous fishes and Hilsa showed no correlation with Trend-1. Trend-2 exhibited a high negative correlation for featherbacks landings, while miscellaneous fish landings showed a positive correlation (Fig. 4). IMC and catfish landings showed an insignificant negative influence, and Hilsa landings exhibited a positive but insignificant influence with Trend-2. Minor carps had no correlation with Trend-2. Hilsa landings exhibited a high positive correlation loading with Trend-3 (Fig. 4). Major carps showed a low influence on Trend-3. Catfishes and featherbacks had a negative but statistically insignificant contribution to Trend-3. Minor carps showed no influence on Trend-3.

Thus, Trend-1 represents the landings of minor carps, catfishes, and major carps; Trend-2 represents the landings of featherbacks and miscellaneous fishes and Trend-3 represents the landings of Hilsa.

The standardised empirical fish landings of the six commercial fish groups/species and the predicted landings (represented by lines) from the DFA model demonstrated a good agreement (Fig. 5).

Influence of climatic factor(s) on the commercial fish landings

To assess the influence of climatic factors on fish landings, precipitation was included as an explanatory variable in the optimally selectedDFA model with three trends (P=3). The estimated regression coefficients and their significance are presented in Table 4. Precipitation showed a significant negative regression coefficient on the landings of featherbacks (−0.05, $p<0.05$), catfishes (−0.09, $p<0.05$) and Hilsa (−0.19, $p<0.05$) and a significant positive regression coefficient on the landings of miscellaneous fishes (0.10, $p<0.05$). Das *et al*. (1992) observed a direct relationship between total precipitation and Hilsa landings in its spawning areas, noting a significant negative correlation between Hilsa landings and local precipitation at lag 2, which was observed in both the Bangladesh section of the Ganges River and the Pakistan section of the Indus River. This mechanism may be related to the fact that heavy precipitation can wash away eggs and larvae and since Hilsa are typically 1+ years old when recruited to the fisheries, their recruitment may be negatively affected by such environmental changes (Sarker *et al*., 2019).

Climatic variability and hydrology significantly influence fish landings in both inland and marine ecosystems. Existing literature has documented such influences using various statistical

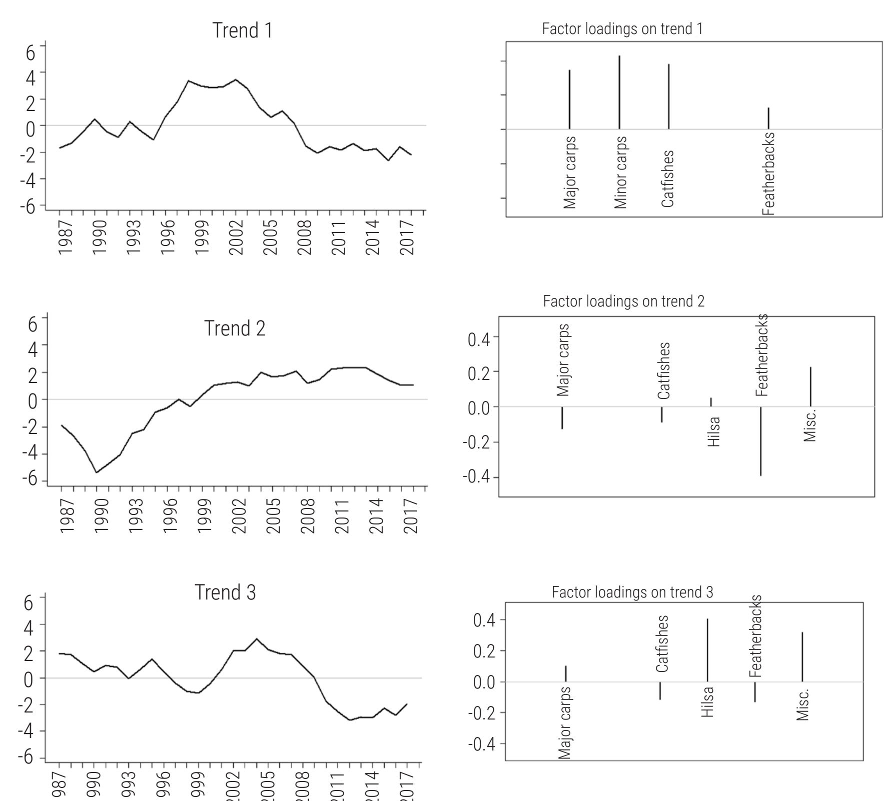

Fig. 4. Estimated three common trends and correlation loadings of six commercial fish groups/species in Indian part of the river Brahmaputra

Table 4. Impact of annual precipitation on fisheries of Brahmaputra River during 1987 to 2017

Group	ML.Est	Std. Err	Low CI	Up. CI	t-stat	Significance
Indian major carps	0.009	0.13	-0.24	0.26	0.07	NS
Minor carps	-0.020	0.12	-0.26	0.22	-0.17	NS
Catfishes	-0.096	0.16	-0.42	0.22	-0.59	Sig.
Hilsa	-0.192	0.14	-0.47	0.09	-1.34	Sig.
Featherbacks	-0.055	0.12	-0.28	0.17	-0.47	Sig.
Miscellaneous fishes	0.102	0.16	-0.22	0.42	0.63	Sig.

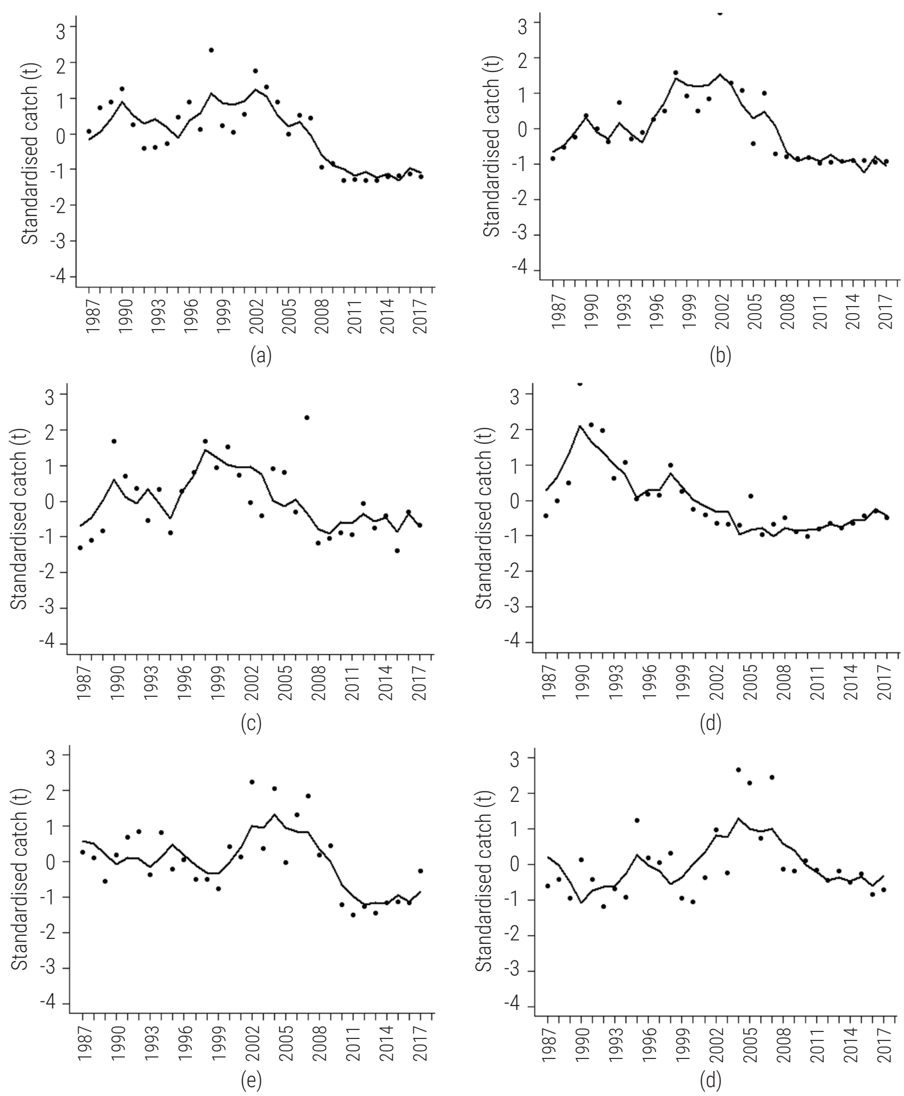

Fig. 5. Standardised empirical landings and predicted values by fitted DFA model for six commercial fish groups/species in the river Brahmaputra at Guwahati during 1987 to 2017. (a) Major carps, (b) Minor carps, (c) Catfishes, (d) Featherbacks, (e) Hilsa, (f) Miscellaneous

techniques, such as Canonical Correspondence Analysis (CCA), Non-metric Multidimensional Scaling (NMDS), and others, to assess the effect of hydrology on fish diversity and assemblage (Grubh and Winemiller, 2018; Abrial *et al*., 2019; Bower *et al*., 2019) and Multivariate Analysis of Variance (MANOVA) for describing the effects of floods and droughts on multispecies landings (Gillson *et al*., 2012). However, these techniques do not provide quantitative estimates of the effects or their statistical significance. In contrast, species-specific time series regression models, such as Autoregressive Integrated Moving Average with Exogenous Variables (ARIMAX) and Nonlinear Autoregressive Networks with Exogenous Inputs (NARX), have been applied to compute these effects. Nevertheless, these methods fail to reveal hidden common trends (Naskar *et al*., 2017; Raman *et al*., 2018; Yadav *et al*., 2020). The present study overcomes these limitations by applying DFA, which not only identifies common trends but also estimates the 'multispecies-precipitation' interaction and their statistical significance.

In a review of relevant studies, Sathianandan *et al.* (2016) explored common trends in the abundance of marine fishery resources in India without incorporating explanatory variables, while Raman *et al*. (2020) examined common trends in commercial catches in a tropical river-estuary system with flood and sediment load using DFA. This study extends the application of DFA by analysing multispecies fish catch in relation to the meteorological regime of the riverine system, using the Brahmaputra River in Assam as a case study. The study establishes two key relationships: the common trends among multispecies landings and the 'multispecies-precipitation' association. The proposed modelling approach is general and applicable to region-specific multispecies fisheries in riverine ecosystems. However, the study is limited to exploring the influence of natural factors, such as rainfall, on fish landings in the Brahmaputra River, without considering the impact of anthropogenic stressors such as fishing pressure, habitat degradation and pollution. Future studies should integrate both natural and anthropogenic factors to study changes in fish diversity and abundance patterns in the Brahmaputra River.

The study revealed a significant decline in fish landings at the Uzanbazar (Guwahati) landing centre of the Brahmaputra River over the past decade, with notable changes in both landings and fish composition from 1987 to 2017. The once-abundant IMCs and minor carps in the Brahmaputra River system have been increasingly replaced by catfishes and other small fish species of lesser economic value. DFA analysis revealed a good fit between observed and predicted landings, with precipitation showing a significant positive influence on miscellaneous fish landings but a negative effect on landings of Hilsa, catfishes, and featherbacks. However, the DFA model could be further refined by including hydrological variables (*e.g.,* flow/discharge, flood levels, sediment load) and seasonal patterns. The study highlights the need for the propagation and conservation of depleting fish stocks in the Brahmaputra River. Given the high demand and market value of riverine fishes, maintaining a substantial population in the river would enhance the livelihood security of the fishing communities living along its banks.

Acknowledgements

The authors express thanks to the Director, ICAR-CIFRI, Barrackpore, for providing the necessary facilities and encouragement for carrying out this study. The research forms part of the Institutional Research Project (FREM/2017-20/15) and the NEH Component of ICAR-CIFRI.

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