Indian Fisheries Association

Journal of Indian Fisheries Association

Analysing Stability and Shifts in Marine Fish Production of Maharashtra, India

Akilandeshwari, A., Shivaji Argade*, Ananthan, P. S., Ankush Kamble

Fisheries Economics, Extension and Statistics Division, ICAR-Central Institute of Fisheries Education, Mumbai, India

Abstract

The study investigates the dynamics of marine fish production in Maharashtra, India, spanning four decades (1981- 2020) at the district level. It utilises metrics such as Compound Annual Growth Rate and instability measures- Coefficient of Variation and Cuddy Della Valle Instability Index to analyse and explore the factors influencing marine fish production trends. The study reveals positve growth in marine fish production until 2010, after which the state recorded a negative CAGR of -0.43% from 2011 to 2020. Greater Mumbai consistently exhibited low instability in the last two decades, while Sindhudurg displayed the highest instability in the 1991–2000 period. Greater Mumbai consistently dominated marine fish production in Maharashtra, contributing nearly 40% to the state's production in the last decade. However, Sindhudurg experienced a decline in its contribution over the years. The classification of districts into categories based on growth rate and instability provides insights into the factors influencing fish production. The study highlights the transition from non-mechanised to mechanised fishing boats, with over 80% of boats being mechanised in recent years, positively impacting production. Additionally, the development of fishing ports and financial assistance in the form of fishing gear have influenced marine fish production. The findings are crucial for policy formulation, sustainable fisheries management, and the well-being of the state's coastal communities. They underscore the need for continued monitoring and strategic interventions to ensure the long-term sustainability of marine fishery resources in Maharashtra.

Keywords:
Compound Annual Growth Rate, Instability, Marine Fish Production, Maharashtra

***Corresponding author:**
shivaji@cife.edu.in

Received : 24 March 2023
Accepted : 15 September 2023

Introduction

In the fiscal year 2021-2022, India produced 4.127 million metric tons of marine fish, with Maharashtra contributing 4.33 lakh metric tons, making up 10.5% of the national marine fish production. The Indian marine fisheries supported 2.65 million fishermen and 2.29 million fisherwomen, with 7.46% of fishermen and 8.22% of fisherwomen earning their livelihood through marine fisheries in Maharashtra (Handbook on Fisheries Statistics, 2022). The state had a continental shelf of 89,096 sq. km., providing rich potential for marine fisheries. Fishing grounds in depths of 0-50m and 50-200m were estimated at 2.55 and 10.48 million hectares, respectively. From the early 1960s, the state's marine fish landings consistently progressed due to increased mechanized fishing, stabilizing at 2.57 lakh tons in 1975 and reaching 3.06 lakh tons in 1984. (Srinath *et al*., 1987). The total marine fish production in India during 1980 was 12.49 lakh tons, with the state of Kerala as the highest contributor at 22.37% (2.8 lakh tons), followed by the state of Maharashtra with 2.32 lakh tons (18.54%). Kerala

accounted for the highest catch in pelagic and demersal fin fishes, followed by Maharashtra (CMFRI, 1981).

During 1986-87, mechanized fishing boats contributed to 70-75% of marine fish production in Maharashtra, leading to increased landings and a decline in landings by non-mechanized boats. Resource exploitation analysis suggested no further increase in the intensity of dol net fishing, while a marginal increase in gill net and trawl net efforts could yield additional production. Maharashtra was a prominent prawn-producing state in India, contributing 75% of non-penaeid and 34% of penaeid prawn landings nationwide (CMFRI, 1988). From the 1960s to 1990, Maharashtra was the second-largest contributor to marine fish production in India. However, in 1991, Gujarat surpassed Maharashtra, driven by an increased catch of Bombay duck, croaker, and other pelagic fishes (CMFRI, 1995). From 1999 to 2013, Maharashtra consistently held the third position in marine fish production, maintaining a production share ranging from 12% to 16% (Handbook on Fisheries Statistics, 2011 & 2014). However, in 2014, the state slipped to the fourth position, trailing behind Gujarat, Kerala, and Andhra Pradesh. This decline continued, and by 2015-2020, Maharashtra had fallen to the fifth position, with its production share fluctuating between 11% and 13% (Handbook on Fisheries Statistics, 2018 & 2020). The trend persisted in 2021-22, with Maharashtra dropping to the sixth position, even falling behind Karnataka, contributing 10.49% to the overall marine fish production in India (Handbook on Fisheries Statistics, 2022).

Adiga *et al*. (2016) utilized RAPFISH analysis to evaluate the sustainability of Maharashtra's marine fisheries. Results indicated that the management and technology dimensions exhibited notable sustainability, with influencing attributes including vessel registration, mesh size regulation and the monsoon fishing ban. However, the economy, ecology, and social dimensions showed relatively lesser sustainability. Among the 18 fish species studied, only 10 (60%) were considered quite sustainable, with golden anchovy, carangids, and seer fish identified as the most sustainable fisheries in Maharashtra. Singh *et al*. (2020) stated that the mechanization of fishing fleets in Maharashtra had resulted in increased fishing efforts, led to overfishing, mainly by trawlers, resulting in declines in various stocks such as Penaeid and non-penaeid prawns, Indian mackerel, horse mackerel, Bombay duck, and red snapper. From 2000 to 2016, most marine groups experienced declining year-on-year growth, except for molluscs, which showed promising growth at 54.82%. Crustaceans, including the top export commodity shrimp, declined by -30.27%, pelagic finfishes by -19.64%, and demersal finfishes by -4.3%.

Presently, the state's fishery potential was estimated at 6.0 lakh tons, and it harnessed 72.17% of this potential in 2021-22. Trawlers were responsible for 39.08% of the marine fish harvest, followed by bag nets at 27.12%, purse seine at 25.21%, gill nets at 7.61%, and other methods accounting for 0.99% in the year 2021-22 (Fish Production Report, DoF, Maharashtra, 2021-22). Out of 28 fish species assessed along the Maharashtra coast, five were sustainable, nine were recovering, and 13 were overfished, including black pomfret, catfishes, crabs, Indian mackerel, little tunny, lizard fishes, oil sardine, other clupeids, perches, penaeid prawns, scads, soles, and Thryssa. The five major fishing fleets in Maharashtra, namely mechanized multiday trawlnets, mechanized gillnets, mechanized purse seines, outboard gillnets, and mechanized dol nets, collectively harvested 85-99.6% of the overfished stocks. To restore the biomass of overfished stocks in Maharashtra, it was necessary to implement a 50% reduction in total annual fishing hours for mechanized multiday trawlers and a 7% reduction for mechanized dolnetters (Sathianandan *et al.,* 2021). Capture fisheries in Maharashtra have been stagnant for years, with a significant concern being competition from fishermen in Gujarat, Goa, and Kerala operating in Maharashtra waters. Challenges include inadequate infrastructure at landing centres, declining catch and fish size, use of unauthorized mesh-size nets, overfishing, juvenile fishing, bottom trawling, fishing during banned periods, rising costs for diesel and labour, and environmental issues like pollution and frequent cyclones due to climate change (Lakra *et al*., 2021).

The provided facts highlight the significant role of Maharashtra in India's marine fish production and the evolving dynamics in the state's fisheries sector. Nonetheless, it prompts several vital inquiries that require in-depth exploration. Therefore, the research problem in this study revolves around understanding the dynamics of marine fish production in Maharashtra, India. It addresses the growth, trends, and factors influencing marine fish production in Palghar-Thane, Greater Mumbai, Raigad, Ratnagiri, and Sindhudurg coastal districts. The research objectives are to analyse the historical trends in marine fish production in Maharashtra's coastal districts during the four decades from 1981 to 2020, to assess the impact of various fishing gears and methods on

marine fish production in Palghar-Thane, Greater Mumbai, Raigad, Ratnagiri, and Sindhudurg, and to categorise the districts based on their growth rates and instability in marine fish production. These objectives provide a structured approach to investigating the multifaceted issue of marine fish production in Maharashtra and its coastal districts. They guide the study in examining historical trends and factors affecting production and are useful to formulate potential policy implications for sustainable fisheries management.

Methodology

Maharashtra boasts a 720-km coastline, the fifth longest coastline in India, with a continental shelf area of up to 40 fathoms, i.e., 55,529 sq. km (50% of the total continental shelf) is being exploited. The state has three major fish landing centres: Sassoon Dock, New Ferry Wharf in Mumbai, and Mirkarwada in Ratnagiri. Fig. 1 shows the study area map. Marine fish harvested in the state consists of about 49 commercially important species. Important marine fishes in the state are Mackerels, Non-Penaeid Prawns, *Harpodon nehereus*, Penaeid Prawns, Pomfret, Seer fishes, Black pomfret, etc. Table 1 showcased the marine fishery status of Maharashtra. This research utilised secondary data, specifically time series datasets detailing marine fish production at the district and state levels. The data source was the Annual Fish Production Reports provided by the Commissionerate of Fisheries, Maharashtra, spanning from 1981 to 2020. To facilitate analysis, this 40-year duration was segmented into four distinct decades: Decade I (1981-1990), Decade II (1991-2000), Decade III (2001-2010), and Decade IV (2011-2020), and the complete 40-year timeframe (1981-2020). The analysis involved employing percentage analysis to assess the contribution of each district to marine fish production within the state. Trend analysis was conducted to gain insights into the factors driving changes in marine fish production across all five coastal districts and the state over time.

Table. 1. Marine fishery status of Maharashtra

Length of Coastline (km)	720
Fishing villages (nos.)	526
Fisherfolk population (lakhs)	3.65 (3,64,899)
Male (nos. & %)	**1,85,622 (50.87%)**
a) Adult	1,30,830 (35.85%)
b) Children	54,792 (15.02%)
Female (nos. & %)	**1,79,277 (49.13%)**
a) Adult	1,30,547 (35.78%)
b) Children	48730 (13.35%)
Fishermen family (nos.)	**87,717**
a) Pucca house	79,880 (91.07%)
b) Kutcha house	7837 (8.93%)
Active Fishermen (nos.)	**76,928**
a) Full-time actual fishing	60,258 (78.33%)
b) Part-time actual fishing	15,515 (20.17%)
Landing centres (nos.)	173
Ice Factories (nos.)	107
Operating Fishing Boats (nos.)	**15,524**
a) Mechanised	13,172 (84.85%)
b) Non- mechanised	2352 (15.15%)
Education status (%)	**70.5% formally educated (2,56,722 fisherfolk)**
a) Primary Education	39.57%
b) Secondary Education	48.29%
c) Higher Secondary Education	8.5%
d) Graduation & above	3.64%

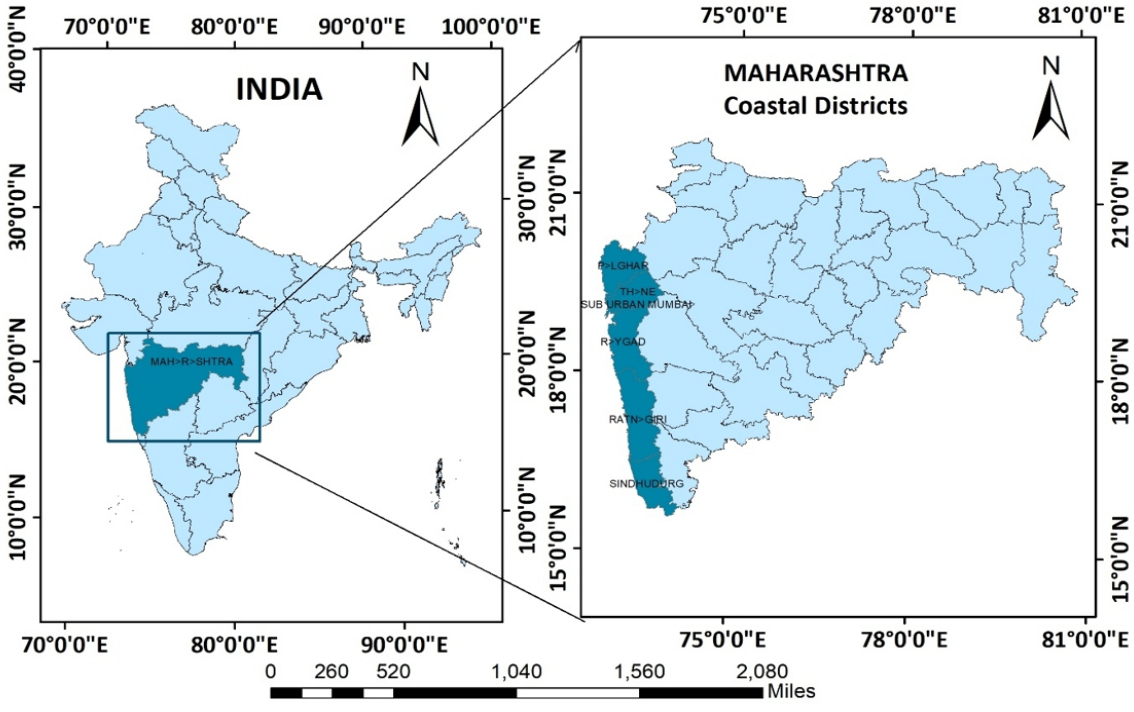

Fig. 1 Study area

CAGR, or Compound Annual Growth Rate, calculates the average annual growth rate of something over a specified period, considering the compounding effect. CAGR was employed to ascertain the annual growth rate of marine fish production across coastal districts and states. CAGR was computed for the duration spanning from 1981-82 to 2020-21, factoring in year-to-year fluctuations in fish catch. CAGR was calculated at decadal and quinquennial intervals during this 40-year timeframe, offering insights into the cumulative variations in fish production growth over the specified duration.

$$Compound\ Annual\ Growth\ Rate\ (CAGR) = \left|Logest\ (X_{ij}\ total) - 1\right| * 100$$

where X_{ij} = values of marine fish production over a period.

Instability was assessed using various measures, including the Coefficient of Variance (CV), Cuddy-Della Valle Index (CDVI), Ray Instability Index (RII), and Coppock Instability Index (CII). The Coefficient of Variance (CV) is a standard indicator of variability (Wasim, 2007). The present study evaluated the instability of marine fish production through metrics such as the Coefficient of Variation (CV) and Cuddy Della Valle Instability Index (CDVII). Cuddy and Della Valle developed the Cuddy Della Valle Instability Index in 1978, which is regarded for its accuracy. CDVI is a refined version of the coefficient of variation used to

Table. 2 Percentage share of marine fish production in coastal districts

Years/ Districts	Thane	Greater Mumbai	Raigad	Ratnagiri	Sindhudurg	State's Marine Fish Production
1981-1985	30.71% (2nd)	**38.35% (1st)**	11.84% (3rd)	10.55% (4th)	8.55% (5th)	**3,23,951**
1986-1990	25.81% (2nd)	**36.16% (1st)**	13.06% (4th)	16.44% (3rd)	8.54% (5th)	**3,43,348**
1991-1995	25.78% (2nd)	**40.25% (1st)**	11.11% (4th)	15.67% (3rd)	7.19% (5th)	**3,74,992**
1996-2000	22.66% (2nd)	**36.85% (1st)**	11.78% (4th)	19.69% (3rd)	9.03% (5th)	**4,26,044**
2001-2005	18.94% (2nd)	**40.22% (1st)**	9.96% (4th)	26.35% (3rd)	4.52% (5th)	**4,16,844**
2006-2010	26.91% (2nd)	**38.83% (1st)**	8.94% (4th)	20.41% (3rd)	4.91% (5th)	**4,28,468**
2011-2015	25.22% (2nd)	**38.52% (1st)**	9.43% (4th)	21.58% (3rd)	5.24% (5th)	**4,49,551**
2016-2020	20.71% (2nd)	**47.44% (1st)**	10.39% (4th)	17.09% (3rd)	4.36% (5th)	**4,49,415**

State's marine fish production figures are the average values during that period and the unit of marine fish production- *Metric Tons*.

Table. 3 Decadal percentage share of marine fish production in coastal districts

Decade/ Districts	Thane	Greater Mumbai	Raigad	Ratnagiri	Sindhudurg	State's Marine Fish Production
1981-1990	28.19% (2nd)	**37.22% (1st)**	12.46% (4th)	13.58% (3rd)	**8.54% (5th)**	**3,33,650**
1991-2000	24.12% (2nd)	**38.44% (1st)** ↑	11.47% (4th)	17.80% (3rd)	**8.17% (5th)** ↓	**4,00,518**
2001-2010	22.98% (2nd)	**39.52% (1st)** ↑	9.44% (4th)	23.34% (3rd)	**4.72% (5th)** ↓	**4,22,656**
2011-2020	22.97% (2nd)	**42.98% (1st)** ↑	9.91% (4th)	19.34% (3rd)	**4.80% (5th)** ↓	**4,49,483**
1981-2020	24.34% (2nd)	**39.74%** (1st)	10.71%	18.81%	**6.40%**	**4,01,577**

State's marine fish production figures are the average values during that decade and the unit of marine fish production- Metric Tons.

measure the instability in the area and production of major crops. Instability categories were defined as follows: 0 to 15 indicated low instability, 15 to 30 represented medium instability, and above 30 indicated high instability.

$$Coefficient\ of\ Variation\ CV = Standard\ Deviation/Mean * 100$$

$$CDVII = CV * \sqrt{(1 - R^2)}$$

CV is Coefficient of Variation in %, and R^2 is the coefficient of determination from a time trend regression adjusted for its degree of freedom.

A bivariate relationship was established between the growth rate and instability index to classify the districts into four groups: High growth and low instability (HGLI), High growth and high instability (HGHI), Low growth and low instability (LGLI), Low growth and high instability (LGHI).

Results and discussion

Percentage contribution of districts:

In the continuous sequence of five-year periods, Greater Mumbai consistently holds the top position, with Palghar-Thane and Sindhudurg securing the second and fifth ranks, respectively. Except for the period from 1981-1985, Ratnagiri and Raigad districts maintain the third and fourth positions throughout these five years. In 2021-2022, marine fish production in Maharashtra is dominated by Greater Mumbai, contributing 51.41% of the total, followed by Ratnagiri at 23.39%. Table 2 presents the breakdown of marine fish production percentages across districts in Maharashtra in quinquennial intervals.

Greater Mumbai has maintained its leading position in Maharashtra for the past four decades, consistently contributing the highest percentage to marine fish production. Specifically, it accounted for 42.98% from 2011 to 2020. Palghar-Thane district, encompassing Palghar, closely trailed in second place, with Ratnagiri and Raigad districts also making noteworthy contributions. In contrast, Sindhudurg district exhibited a comparatively lower marine fish production over these four decades, and its contribution further declined in the last two decades, reaching just 4.80% during 2011-2020. Table 3 showcases the percentage-wise contribution of districts to marine fish production over a decade-by-decade timeframe.

Trend Analysis of Marine Fish Production

Palghar-Thane district's marine fish production experienced a notable shift over the years. It amounted to 4.97 lakh MT in the period 1981-1985 but saw a decrease to 3.95 lakh MT during 2001-2005. Subsequently, it exhibited an upturn in production, reaching 5.76 lakh MT in 2006-2010. However, from 2016 to 2020, The district's marine fish production declined to 4.65 lakh MT. The data demonstrates fluctuations resembling peaks and troughs, and it conforms to a polynomial trendline of the sixth order

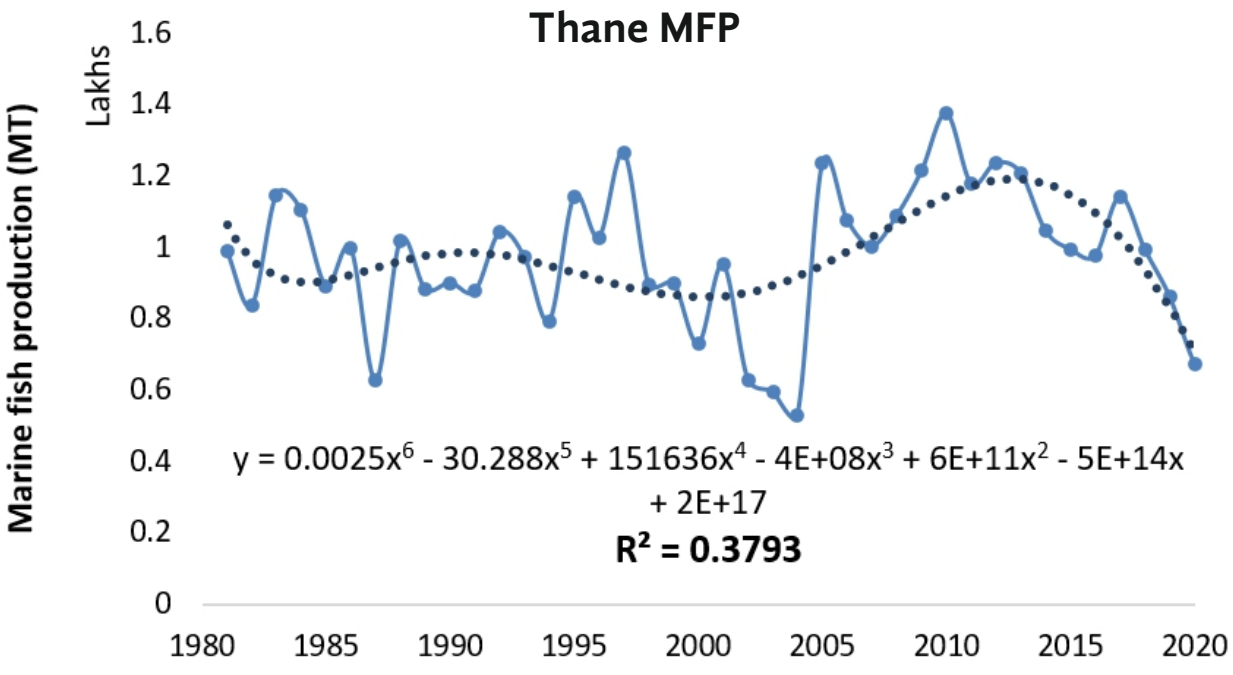

Fig. 2 Trend in marine fish production of Thane district

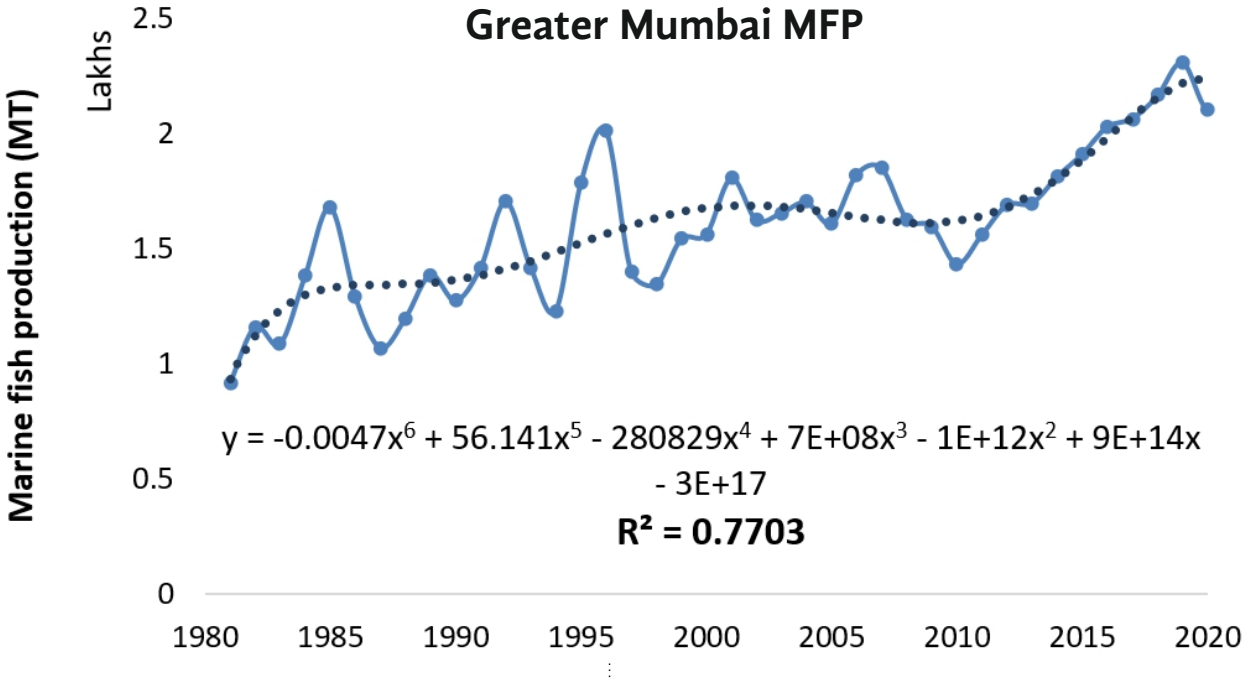

Fig. 3 Trend in marine fish production of Greater Mumbai district

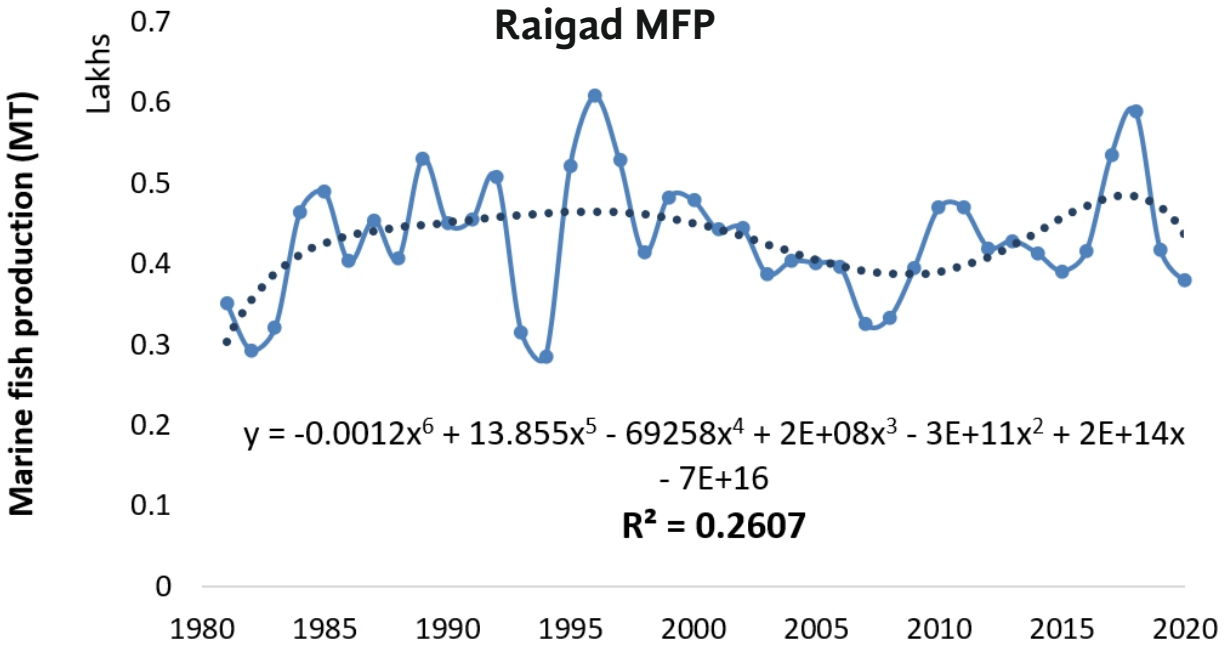

Fig. 4 Trend in marine fish production of Raigad district

with an R^2 value of 0.3793. Marine fish production in the Greater Mumbai district grew significantly over the years. It stood at 6.21 lakh MT during 1981-1985, experienced a substantial increase to 7.85 lakh MT in the period from 1996-2000, and maintained a consistent upward trajectory, reaching 10.66 lakh MT in 2016-2020. The data aligns with a polynomial trend and has a strong fit, as evidenced by an R^2 value of 0.7703, making it the most suitable model. Nabi *et al.* (2019) noted a fluctuating pattern in marine fish production in Greater Mumbai. They observed a decline from 2007 to 2009, followed by an upward trend after 2013-14. To illustrate this trend, they applied a polynomial trendline with an R-squared value of 0.76 to 20 years of fish landing data. The results align with the findings of the present study. Marine fish production in Raigad district displayed distinct trends over the years. It started at 1.92 lakh MT during 1981-1985, significantly rose to 2.51 lakh MT in the period from 1996-2000, experienced a sudden drop to 1.92 lakh MT during 2006-2010, and then witnessed a substantial increase, reaching 2.34 lakh MT in 2016-

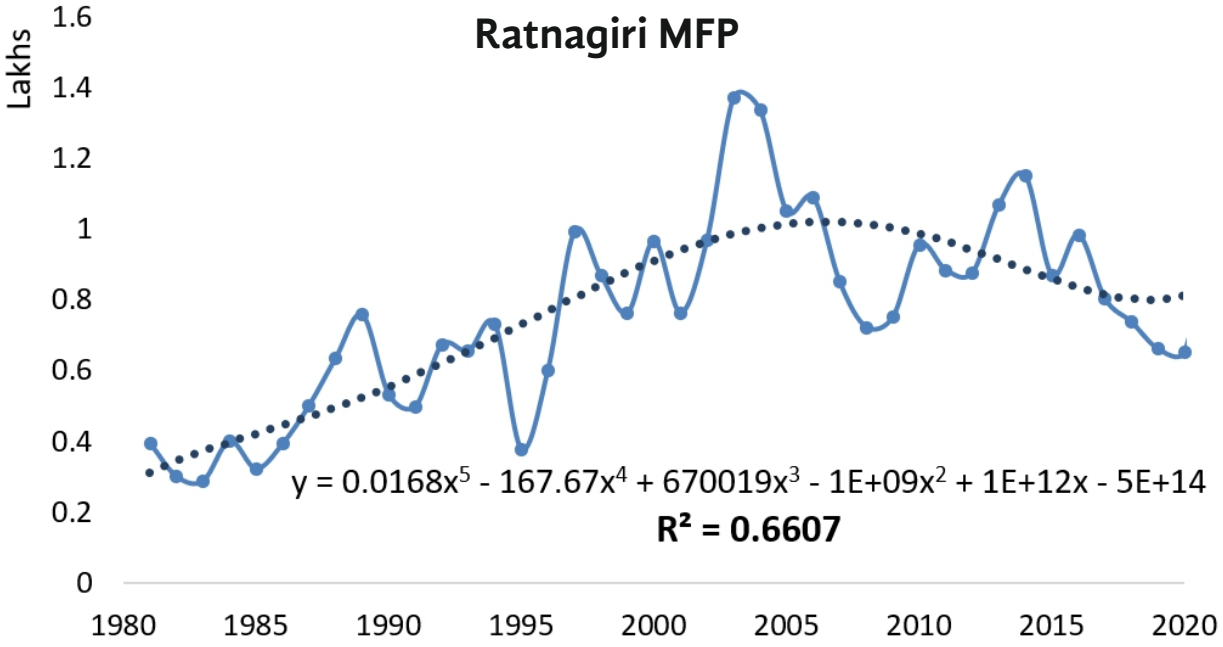

Fig. 5 Trend in marine fish production of Ratnagiri district

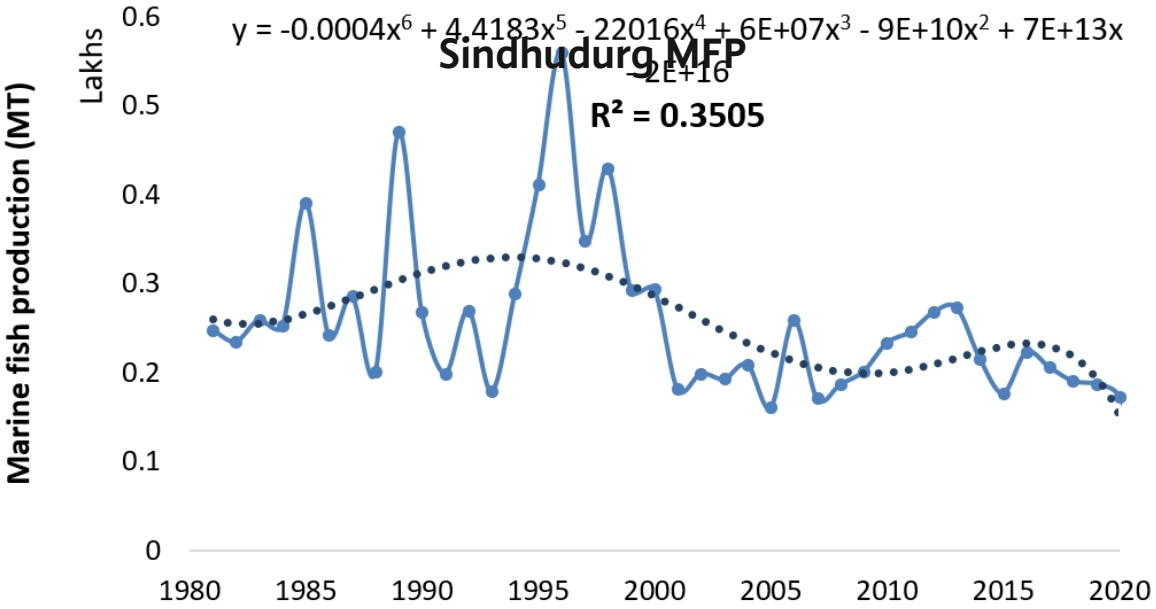

Fig. 6 Trend in marine fish production of Sindhudurg district

2020. The data exhibited fluctuations characterized by two peaks and two troughs, and it conformed to a polynomial trendline of the sixth order with a lower R^2 value of 0.2607. Ratnagiri district's marine fish production began at 1.71 lakh MT during 1981-1985 and exhibited a continuous growth, peaking at 5.49 lakh MT in 2001-2005. However, it subsequently experienced a decline, reaching 3.84 lakh MT during 2016-2020. The data displayed fluctuations marked by peaks and troughs, fitting well with a polynomial trendline of the fifth order and possessing an R^2 value of 0.6607

Sindhudurg district's marine fish production started at 1.39 lakh MT during 1981-1985, saw a significant boost to 1.92 lakh MT in 1996-2000, but experienced a drop to 0.94 lakh MT during 2001-2005. Subsequently, the marine fish production in the district remained relatively stable, recording 0.98 lakh MT during 2016-2020. The data exhibited fluctuations, characterized by one peak and two troughs, indicating a fit with a polynomial trendline of the fourth order, albeit with a lower R^2 value of 0.3505. Marine fish

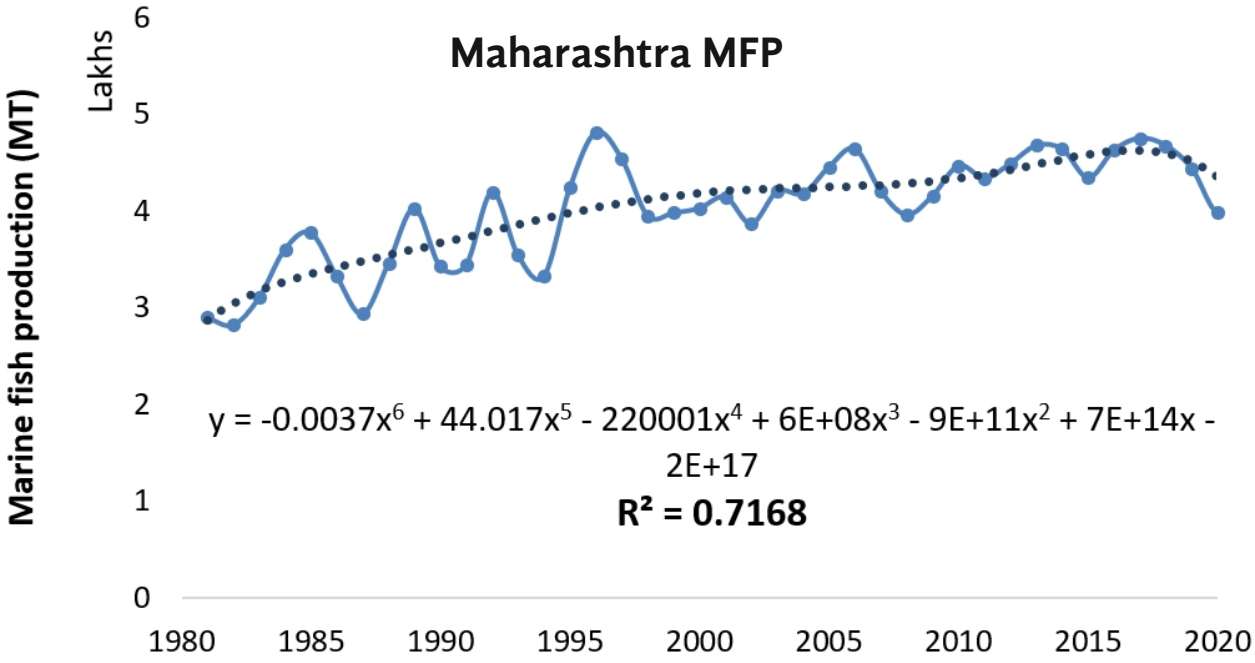

Fig. 7 Trend in marine fish production of Maharashtra state

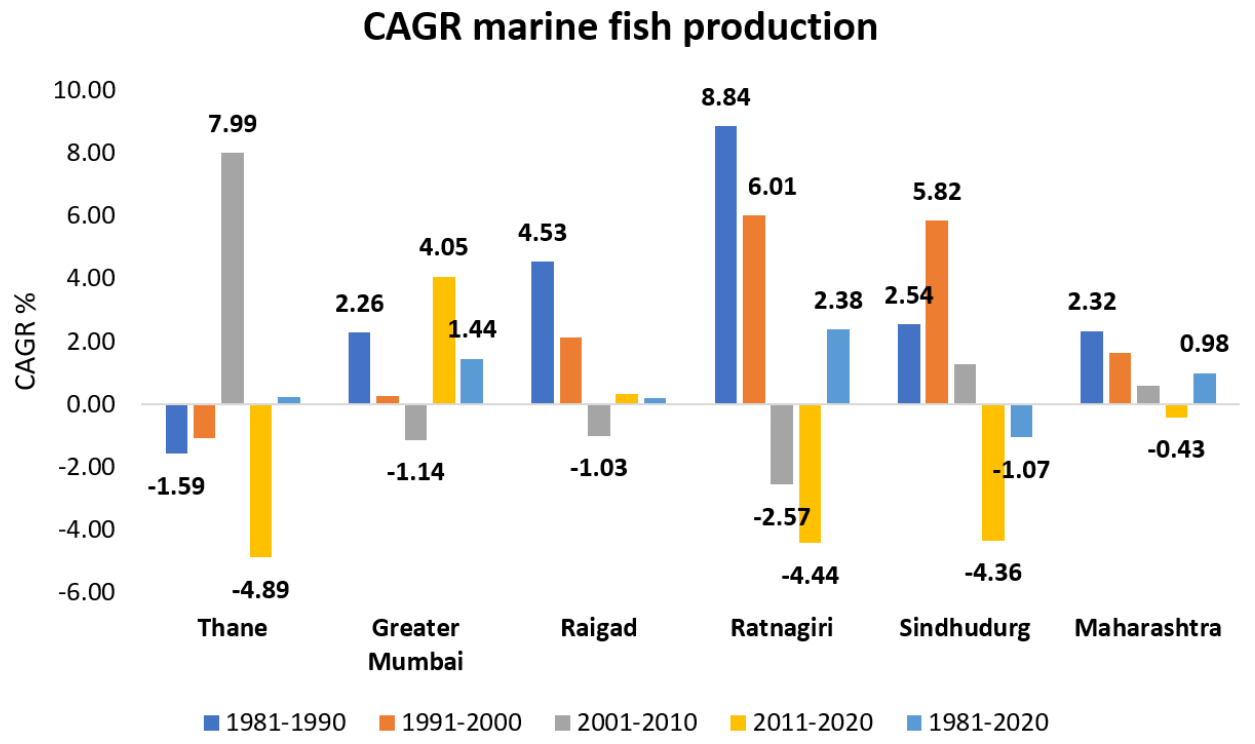

Fig. 8 CAGR of marine fish production in Maharashtra

production in Maharashtra was 16.2 lakh MT during 1981-1985, rose significantly to 21.3 lakh MT in 1996-2000, but then declined to 20.84 lakh MT during 2001-2005. Post-2011, the state's marine fish production remained stable at approximately 22.4 lakh MT. The data displayed fluctuations, showing peaks, and it was best represented by a polynomial trendline of the sixth order, with a strong fit indicated by an R^2 value of 0.7168. The trends of marine fish production in all coastal districts and the state are depicted in Fig. 2.

Compound Annual Growth Rate of Marine Fish Production

The marine fish production in Maharashtra exhibited a compound annual growth rate of 0.98% over 40 years, from 1981 to 2020. Notably, during the decade I (1981-1990), decade II (1991-2000), and decade III (2001-2010), marine fish production experienced positive CAGRs of 2.32%, 1.61%, and 0.57%, respectively. However, during decade IV (2011-2020), the state recorded a negative growth rate of -0.43%. The CAGR of marine fish production in Maharashtra

Table. 4 CAGR of marine fish production in coastal districts of Maharashtra

Years/ Districts	Thane	Greater Mumbai	Raigad	Ratnagiri	Sindhudurg	Maharashtra
1981-1985	0.69	14.95	11.88	**-1.13**	10.31	8.02
1986-1990	1.43	2.36	3.86	10.68	7.26	3.82
1991-1995	2.61	1.37	**-2.93**	**-4.57**	16.47	1.85
1996-2000	**-9.76**	**-4.07**	**-5.52**	7.07	**-13.61**	**-4.74**
2001-2005	3.57	**-1.84**	**-2.91**	10.04	**-1.90**	2.25
2006-2010	7.04	**-6.06**	5.52	**-3.81**	**-0.43**	**-0.86**
2011-2015	**-4.95**	4.88	**-3.77**	2.42	**-8.34**	0.34
2016-2020	**-9.72**	1.87	**-4.11**	**-9.63**	**-5.84**	**-3.61**

Table. 5 CAGR of marine fish production in Maharashtra and India

Decades	1981-1990	1991-2000	2001-2010	2011-2020
Maharashtra	2.32	1.61	0.57	-0.43
India	5.14	1.47	1.09	1.10

Table. 6 Instability Measure of Marine Fish Production

Decades	1981-1990		1991-2000		2001-2010		2011-2020		1981-2020	
Districts	**CV**	**CDVII**	**CV**	**CDVII**	**CV**	**CDVII**	**CV**	**CDVII**	**CV**	**CDVII**
Thane	15.78	**15.95**	16.67	**17.46**	30.12	**21.84**	16.78	**9.54**	20.18	**20.19**
Greater Mumbai	17.08	**16.97**	15.23	**16.14**	7.54	**7.19**	12.44	**4.10**	20.15	**12.29**
Raigad	18.29	**14.05**	21.43	**22.00**	11.47	**11.80**	14.91	**15.73**	17.48	**17.62**
Ratnagiri	33.84	**22.32**	27.45	**22.16**	23.39	**23.19**	18.93	**14.58**	35.93	**28.38**
Sindhudurg	28.75	**28.78**	34.96	**33.71**	14.66	**14.94**	16.75	**10.23**	34.42	**32.26**
State - Maharashtra	11.95	**10.38**	11.81	**11.55**	5.56	**5.60**	5.13	**5.29**	13.68	**8.59**

over the four decades is summarized and visually represented in Fig. 3 and Table 4, 5.

In Palghar-Thane, marine fish production showed a negative Compound Annual Growth Rate during decades I, II, and IV, but it had a positive CAGR during decade III and the overall 40-year span (0.23%). In Greater Mumbai, marine fish production experienced a negative CAGR during Decade III, while it had positive CAGRs during decades I, II, IV, and over the 40 years (1.44%). Raigad had a negative CAGR during decade III, with positive CAGRs during decades I, II, IV, and the entire 40-year duration (0.19%). Ratnagiri exhibited a negative CAGR during decades III and IV but had positive CAGRs during decades I and II and over the entire 40-year span (2.38%). In Sindhudurg, marine fish production had a negative CAGR during decade IV and over the 40 years (-1.07%), but it showed positive CAGRs during decades I, II, and III. The growth rate in the Ratnagiri district was consistently decreasing at all landing centres- Burundi, Mirkarwada, and Ratnagiri- except for Dabhol. This decline aligned with the trends observed in Maharashtra over the past two decades. Among marine fish species, Caranx, Sardines, and Cuttlefish exhibited growth potential, whereas Tunnies, Non-penaeid prawns, and other clupeids had been over-exploited in the Ratnagiri district. This conclusion was drawn from an analysis of fish varieties' rankings based on total marine landings from 1982 to 2012 (Prabhu *et al*., 2021). Sali *et al.* (2023) revealed that the growth rate of marine fish production in Kerala from 1981 to 2020 was 0.82%, which was relatively less than in Maharashtra. Palghar-Thane district experienced negative growth in marine fish production during 1996-2000, 2011-2015, and 2016-2020, while it saw positive growth during other quintennial intervals. Greater Mumbai had negative growth rates during three periods: 1996-2000, 2001-2005, and 2006-2010. Raigad had more negative growth rates,

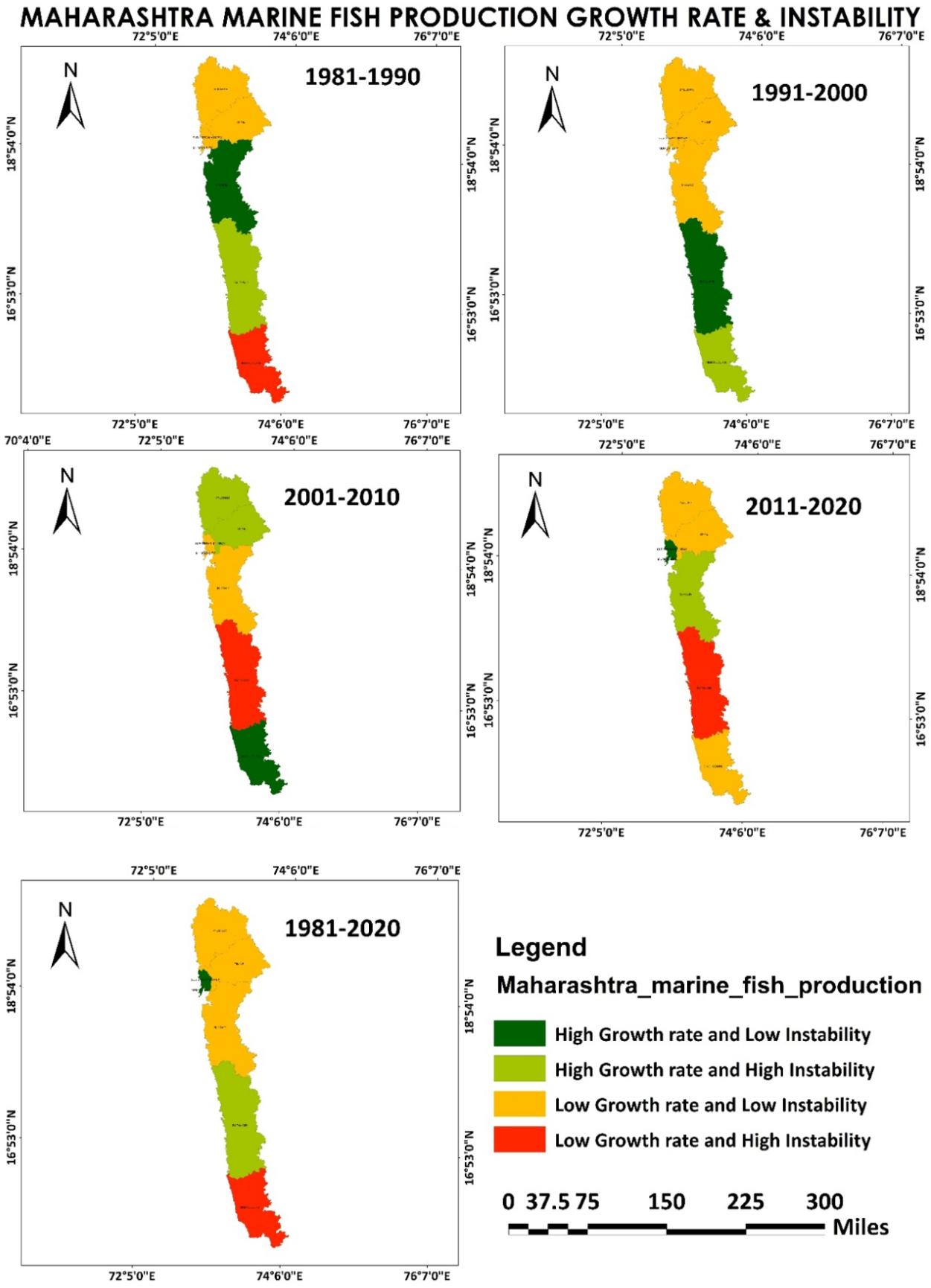

Fig. 9 Marine fish production growth rate and instability across districts of Maharashtra

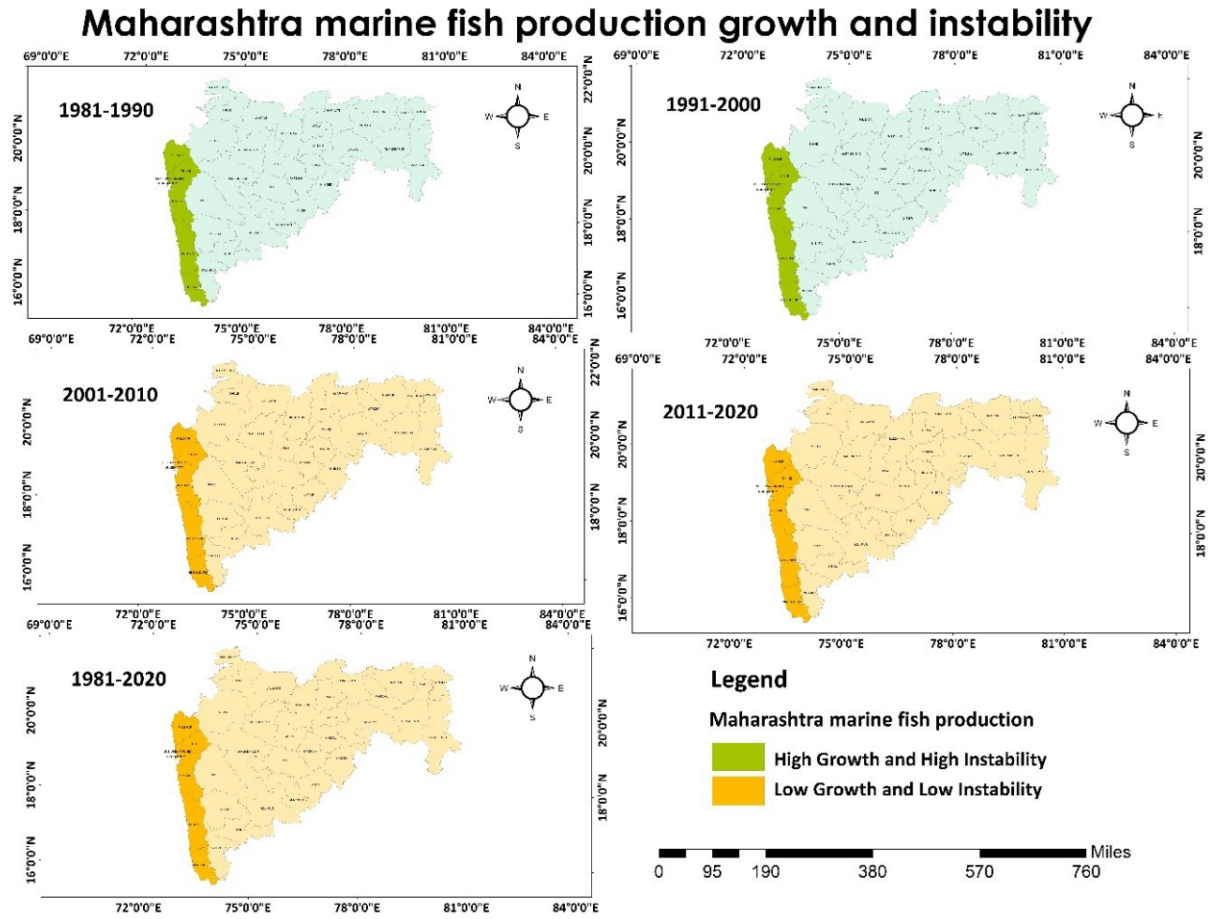

Fig. 10 Maharashtra state marine fish production growth rate and instability

specifically during 1991-1995, 1996-2000, 2001-2005, 2011-2015, and 2016-2020. On the other hand, Ratnagiri exhibited negative growth rates during 1981-1985, 1991-1995, 2006-2010, and 2016-2020. Meanwhile, Sindhudurg had the most significant negative growth rate of 13.61% from 1996 to 2000 and continued to experience negative growth rates in subsequent periods. Maharashtra recorded negative growth rates in 1996-2000, 2006-2010, and 2016-2020 while experiencing positive growth rates in all other time frames.

Maharashtra's marine fish production growth rate lagged behind the national growth rate in decades I, III and IV (1981-90, 2001-10, 2011-20). However, in the second decade (1991-2000), Maharashtra slightly outperformed the nation's growth rate in marine fish production, as shown in Table. 5.

Instability measure for marine fish production

Table 6 presents the Coefficient of Variation (CV) and Cuddy Della Valley Instability Index (CDVII) for marine fish production in Maharashtra. Greater Mumbai exhibited low instability, with CDVII values of 7.19 and 4.1 in the last two decades, namely 2001-2010 and 2011-2020, respectively. In contrast, Sindhudurg district recorded the highest CDVII of 33.71 during 1991-2000, followed by a moderate CDVII of 28.78 during 1981-1990. During the most recent two decades, 2001-2010 and 2011-2020, CDVII indicates that marine fish production in the district experienced gradual and consistent growth, falling within the low instability category with values of 14.94% and 10.23%, respectively. CDVII, as a measure of instability, was highest during 1991-2000, ranging from 16.14% to 33.71% (Greater Mumbai and Sindhudurg), while it was at its lowest during 2011-2020, ranging from 4.1% to 15.73% (Greater Mumbai and Raigad). Over the 40 years (1981-2020), Sindhudurg district displayed the highest overall CDVII at 32.26%. Greater Mumbai showed a low instability measure with 12.29%, while Raigad, Palghar-Thane, and Ratnagiri exhibited medium instability. The overall CDVII for Maharashtra during the 40 years (1981-2020) fell within the low instability category at 8.59%. Sali *et al.* 2023 calculated the instability index for 40 years of marine fish production in Kerala, resulting in a CDVI value of 17.77%, indicating a moderate level of instability. Similarly, a study by Shwetha *et al.* (2023) explored the instability in marine fish production in Tamil Nadu and

found low instability in marine fish production for 40 years.

A bivariate relationship between CAGR and CDVI was examined, leading to the classification of districts into four distinct categories: low growth rate and low instability (LGLI), low growth rate and high instability (LGHI), high growth rate and low instability (HGLI), and high growth rate and high instability (HGHI). These categories were visually depicted in Figures 4 and 5. In the first decade (1981-1990), Palghar-Thane fell into the LGLI category, Greater Mumbai into LGHI, Sindhudurg into HGLI, and Raigad and Ratnagiri into HGHI. During the second decade (1991-2000), Palghar-Thane and Greater Mumbai were in the LGLI category, Raigad was classified as LGHI, and Ratnagiri and Sindhudurg as HGHI. In the third decade (2001-2010), Greater Mumbai and Raigad were categorized as LGLI, Ratnagiri as LGHI, Sindhudurg as HGLI, and Palghar-Thane as HGHI. In the fourth decade (2011-2020), Palghar-Thane and Sindhudurg were classified as LGLI, Ratnagiri as LGHI, Greater Mumbai as HGLI, and Raigad as HGHI. Over the entire 40-year period (1981-2020), Palghar-Thane and Raigad were in the LGLI category, Sindhudurg was in LGHI, Greater Mumbai was in HGLI, and Ratnagiri was in HGHI.

Maharashtra experienced high growth and high instability in the first decade, contrasting with the low growth and low instability observed in the third decade. These findings align with the study by Lingamurthy *et al.* (2015), which analyzed India's marine fish production along the east and west coasts. During 1978-87, India's marine fish production exhibited high growth and high instability. Notably, the west coast, including states like Gujarat, Goa, and Kerala, and union territories, exhibited greater instability than the east coast. However, Karnataka and Maharashtra showed relatively lower instability than other states during 1999-2010. Lakra *et al.* (2021) reviewed the status, challenges and opportunities of marine fisheries in Maharashtra. It was suggested that an ecosystem-based management approach be adopted to enhance and improve marine fisheries. Upgrading landing centres for better hygiene and efficiency was seen as essential. Enhancing deep-sea fisheries through modern vessels and technology, along with capacity building, was recommended. Strengthening the value chain along the coastline was emphasized to improve the efficiency and sustainability of harvesting, post-harvesting, and processing in the state.

Factors shaping the ebb and flow of marine fish production in districts

1) **Diverse fishing methods: efforts and harvests**

a) **Palghar-Thane:** The district achieved its peak fish production of 5.76 lakh tons during 2006-2010, showing a positive Compound Annual Growth Rate (CAGR) of 7.99% from 2001-2010. Conversely, the lowest fish production of 3.95 lakh tons was recorded during 2001-2005. During the 2001-2005 period, the fish catch from mechanized bag nets, gill nets, and other fishing gears gradually increased from 3.5 lakh tons, 43,783 tons, and 512 tons to 4.9 lakh tons, 80,997 tons, and 1646 tons, respectively, during 2006-2010. The fish caught from gill nets and other gear nearly doubled during 2006-2010. This increase was attributed to the positive CAGR of 7.99% during 2001-2010, which resulted from heightened fish production using various fishing gears. In contrast, fish catch from mechanized bag nets, gill nets, and other fishing gears gradually declined from 4.6 lakh tons, 1.02 lakh tons, and 855 tons during 2011-2015 to 3.7 lakh tons, 90,746 tons, and 140 tons, respectively, during 2016-2020. The negative CAGR of -4.89% during 2011-2020 was attributed to the reduced fish catch from various fishing gear employed in the Palghar-Thane district.

b) **Greater Mumbai**: The negative CAGR of marine fish production at -1.14% in Greater Mumbai during 2001-2010 resulted from reduced per-unit-effort production in various fishing methods. For instance, the production from trawl nets dropped from 2808 kgs in 1991-2000 to 2368 kgs in 2001-2010, purse seine net production decreased from 46,634 kgs to 38,417 kgs, and gill net production fell from 61,442 tons to 47,409 tons during the same period. Conversely, Greater Mumbai achieved its highest fish production of 10.66 lakh tons in 2016-2020, showing a positive CAGR of 4.05% from 2011-2020. This growth was attributed to increased fishing efforts and greater fish production across various fishing methods, including trawl nets, bag nets, gill nets, and purse seines. In particular, the per-unit effort production from mechanized trawlers significantly increased to 56,680 kgs during 2011-2020, three times higher than the previous decade (18,821 kgs). Similarly, per-unit-effort production from mechanized bag nets reached 6,218 kgs during 2011-2020, which was 2.6 times higher than the previous decade (2,368 kgs), while mechanized gill net production also improved, with per-unit-effort production at

3,251 kgs during 2011-2020, compared to 2,598 kgs in the previous decade.

c) **Raigad:** Raigad district witnessed its highest fish production of 2.51 lakh tons and the lowest production of 1.92 lakh tons during the periods 1996-2000 and 2006-2010, respectively. The surge in production was linked to increased yields from mechanized bag nets and trawl nets, accounting for 20,208 tons and 1.93 lakh tons, respectively. Conversely, the decline in fish production during the low period was due to reduced yields from mechanized bag nets, trawl nets, and purse seiners, with figures of 11,925 tons, 11,821 tons, and 20,182 tons, respectively. The negative CAGR of -1.03% during 2001-2010 was primarily attributed to the decreased fish yields from mechanized bag nets and trawl nets.

d) **Ratnagiri:** Over the past two decades, the trend analysis and CAGR of marine fish production in Ratnagiri district have revealed a significant and continuous decline, resulting in a negative growth rate. This decline can be attributed to a marked decrease in total fish production (in tons) and the per-unit effort production (in kgs) across various fishing methods. Specifically, the per-unit-effort production from bag nets, gill nets, trawl nets, and purse seines during 2011-2020 was notably lower, standing at 50 kgs, 976 kgs, 4,837 kgs, and 25,021 kgs, respectively. These figures represent a decline compared to the 2001-2010 period, where the respective production values were 367 kgs, 1,039 kgs, 4,725 kgs, and 28,111 kgs. The total catch per trip from mechanized bag netters experienced a considerable decrease, with figures of 1,571 kgs per trip, 367 kgs per trip, and 50 kgs per trip during 1992-2000, 2001-2010, and 2011-2020, respectively. Similarly, mechanized gill netters showed a drop in their total catch per trip, with 1,041 kgs per trip during 2001-2010 and 976 kgs per trip during 2011-2020. The total yield per trip among bag netters rapidly declined over the decades.

e) **Sindhudurg:** Sindhudurg district experienced its most substantial positive CAGR for marine fish production at 5.82% during 1991-2000. This growth was primarily attributed to the impressive production of 52,412 tons of fish from Rampan boats. During this period, the total catch per trip from Rampan boats was robust at 8,050 kgs per trip, which exceeded the figures seen in the subsequent 2001-2010 period. However, during the decade spanning 2011-2020, Sindhudurg district encountered a negative CAGR of -4.36% in marine fish production. This decline was due to reduced fish production of 4,238 tons from Rampan boats, while the 2001-2010 period saw a production of 18,274 tons from the same source. Notably, Sindhudurg district achieved its highest fish production, totaling 1.92 lakh tons, during 1996-2000, primarily resulting from an increased catch from Rampan boats, which yielded a total catch of 3,534 kgs per trip. Conversely, the lowest fish production, at 0.94 lakh tons, was recorded during 2001-2005 due to a decreased yield from Rampan boats, with a total catch of 1,745 kgs per trip for those five years. Edwin *et al.* (2020) in their study reported that the beach seines are operated at a depth of 8-10m for 3-4 hours with 30-100 crew members. The peak seasons of Rampani operation are monsoon with CPUE 70-80kg/ operation and post-monsoon with CPUE 2000-6000kg/ operation.

2) **Legacy of the sea: Koli community's enduring love for fishing:** As stated in the study by Mathews (2005), the Kolis of the Bombay Presidency, originally a traditional fishing community, underwent a significant transformation in the mid-18th century with the arrival of the British. During this period, they transitioned into palanquin bearers, restricting their fishing activities. During the 1790s, Bombay Island was home to 2046 Kolis, among whom 1064 were engaged in fishing and possessed a fleet of 130 boats. The British introduced a "*work for fishing*" program in response to these changes. Under this program, when not engaged in fishing, the Kolis would provide ballast for incoming ships, utilizing their boats for this purpose. In return, the Kolis were granted the right to fish within their territories, exempting all associated rents (Town and Statistical Account, Bombay 1894). In the Bombay Presidency, 109,688 active fishers in 1901 grew to 147,162 by 1931. In contrast, Bombay City had 4,302 active fishers in 1901, and this count decreased to 2,451 by 1931. In 1965, there were 32,073 active fishers in Maharashtra, which increased to 75,773 by 2020, according to CMFRI-FSI-DoF data. Specifically for Greater Mumbai, the number of active fishers was 2,826 in 1965, which rose to 4,857 by 2020. Over the years, the increase in active fishers might have a

role in contributing to the growth of fish production in the state.

3) **Mechanization of fishing boats:** Traditional fishing methods thrived in the state until the early 1980s; however, the landscape transformed with the introduction of intensive shrimp trawling, a surge in purse seine fleets, and a significant increase in fishing efforts (CMFRI, 2011). In 1961-62, 15.62% of boats were mechanized (1,414 boats), while 84.38% were non-mechanized (7,637 boats). By 1981-82, mechanized boats increased to 36.65% (4,532), with non-mechanized boats at 63.35% (7,835). In 2001-02, mechanized boats rose to 83.70% (10,733), and non-mechanized boats dropped to 16.30% (2,089). Fast forward to 2021-22, 84.85% of boats were mechanized (13,172), and 15.15% were non-mechanized (2,352). In the 1960s, non-mechanized boats dominated the state, accounting for over 80% of the total. However, this trend has been notably reversed in the past two decades, with more than 80% of boats now being mechanized. This shift towards an increased number of mechanized boats in Maharashtra has played a pivotal role in driving the growth of marine fish production in the state. (Census of Fishermen, Boats and Nets, Maharashtra, 1972 to 2016). Between 1975 and 1984, there was a substantial increase in marine fish catch from mechanized fishing boats, rising from 1.48 lakh tons (57.6%) to 2.87 lakh tons (93.6%). This surge significantly reduced landings from non-mechanized fishing boats, dropping from 10.87 lakh tons to 1.94 lakh tons. Mechanized crafts, utilizing dol nets, trawl nets, and gill nets, targeted Bombay duck, non-penaeid and penaeid prawns, while purse seiners in the Ratnagiri coast focused on pelagic fishes such as mackerel and oil sardine. (Srinath *et al*., 1987). The substantial proportion (54.2%) of overexploited fish stocks in the northwest coastal region can be attributed to the large number of fishing vessels in states such as Gujarat, Daman Diu, and Maharashtra, leading to intense fishing pressure on the available resources. This region houses almost half (49.7%) of the country's total mechanized fishing vessels, as reported by CMFRI-FSI-DoF in 2020 (Sathianandan *et al.,* 2021).

4) **Development of fishing ports:** From 2001 to 2005, a total expenditure of ₹1,953.46 lahks was incurred within the framework of the Fishery Ports Development scheme, with the state's contribution amounting to ₹1,236.41 lahks, inclusive of the Konkan Development Programme funds (₹234 lahks in 2002-03 and 2003-04). For establishing essential amenities at fish landing centres in coastal districts, the government allocated expenditures of ₹82.58 lakhs and ₹69.49 lakhs during the 8th and 9th Five Year Plans. These funds were used to construct fish drying sheds, open shelters, and install guide lights (Annual Development Program Report, 2008-09, Department of Fisheries, Maharashtra).

5) **Financial assistance on purchasing fishing gear:** Within the special central assistance scheme, the government procured fishing gear and distributed it to economically weaker tribal fishers in Raigad and Palghar-Thane districts. Notably, a sum of ₹145.51 lakhs was utilized to acquire 12,522 fishing gears, distributed among 6,725 tribal fishermen between 1996 and 2000. The upsurge in fish production in Raigad and Palghar-Thane during this period was attributed to the increased number of beneficiaries through this program (Annual Development Program Report, 2008-09, Department of Fisheries, Maharashtra).

The increase in fish landings in the state of Maharashtra can be attributed to several factors, including the diverse fishing efforts using different types of gear, the number of active fishers in the district, the use of mechanized fishing crafts, the development of fishing ports, and financial assistance for purchasing fishing equipment.

Conclusion

In Maharashtra's marine fish production context, this study comprehensively analyses the dynamics, trends, and contributing factors, helping us understand the complex interplay of variables that shape the state's marine fisheries. With a coastline spanning 720 km and six coastal districts, Maharashtra plays a significant role in India's marine fish production. The study analyses data from four decades (1981-2020) to explore the temporal shifts, growth patterns, and instability in marine fish production at the district and state levels. Greater Mumbai consistently emerged as the leading contributor to Maharashtra's marine fish production. The findings highlight the importance of mechanized boats, with their share significantly increasing in recent decades. This shift, from predominantly non-mechanized to mechanized boats, played a pivotal role in boosting marine fish production in the state. The Compound Annual Growth Rate (CAGR) analysis reveals notable variations in the production trends. Palghar-Thane and Raigad districts have experienced positive and negative growth, while Greater Mumbai has steadily grown. Ratnagiri's fish

production exhibited remarkable growth in the past but declined more recently. Sindhudurg, on the other hand, faced a prolonged period of declining production. Furthermore, examining the instability measures using the Coefficient of Variation (CV) and Cuddy Della Valle Instability Index (CDVII) reveals varying degrees of stability and instability across districts and periods. Greater Mumbai exhibited low instability, while Sindhudurg experienced the highest instability during the 1990s. Over the 40 years, Sindhudurg maintained the highest overall instability, while Greater Mumbai remained stable. The interplay between CAGR and CDVI categorizes districts into groups, considering growth rate and instability. This classification provides valuable insights into the unique challenges faced by different districts and can guide policy and resource allocation. Factors shaping fish production variability include the shift towards mechanized boats and fluctuations in production across various fishing methods. Palghar-Thane, for instance, demonstrated a significant change in production patterns due to fluctuations in different fishing gears. Greater Mumbai's growth was attributed to increased efforts in various fishing methods. In conclusion, this study comprehensively examines the dynamics of marine fish production in Maharashtra, offering insights into the factors influencing production trends, the significance of mechanized boats, and variations in district-level contributions. It also highlights the importance of categorizing districts based on growth and instability, providing a holistic view of the challenges and opportunities within Maharashtra's marine fisheries sector. This knowledge can be a foundation for targeted policies and initiatives for sustainable growth and stability in the state's marine fish production.

Note: Greater Mumbai's marine fish production includes both Mumbai City and Mumbai Suburban. The marine fish production of Thane district encompasses both Palghar and Thane district.

MFP - Marine Fish Production.

Acknowledgement

I am grateful to ICAR-CIFE, Mumbai, for the financial support and facilities. Special thanks to the Department of Fisheries, Maharashtra, for their invaluable contribution to my research. Their generous provision of data has enhanced the depth and quality of my study.

Conflict of interest- We declare that there are no conflicts of interest that could affect the fairness or objectivity of this research. There are no financial, personal, or professional ties that might sway the interpretation or presentation of the study's results.

References

Adiga, M.S., Ananthan, P.S., Kumari, H.D. and Ramasubramanian, V. 2016. Multidimensional analysis of marine fishery resources of Maharashtra, India. *Ocean and Coastal Management*, *130*: 13-20.

Annual Development Programme Reports (2008-09 and 2022-23), Department of Fisheries, Government of Maharashtra, India.

Annual Fish Production Reports (yearly reports from 1981-82 to 2021-22), Department of Fisheries, Government of Maharashtra, India.

Census of Fishermen, Boats and Nets, 1972. Department of Fisheries, Government of Maharashtra.

Census of Fishermen, Boats and Nets, 1977. Department of Fisheries, Government of Maharashtra.

Census of Fishermen, Boats and Nets, 1982. Department of Fisheries, Government of Maharashtra.

Census of Fishermen, Boats and Nets, 1988. Department of Fisheries, Government of Maharashtra.

Census of Fishermen, Boats and Nets, 1992. Department of Fisheries, Government of Maharashtra.

Census of Marine Fishermen, Boats and Nets, 1997. Department of Fisheries, Government of Maharashtra.

CMFRI, 1981. Trend in Total Marine Fish Production in India-1980. *Marine Fisheries Information Service, Technical and Extension Series,* 32: 1-6.

CMFRI, 1989. Proceedings of the Workshop on Fisheries Research and Development in Maharashtra Held at Bombay on 25th and 26th May 1988. *Marine Fisheries Information Service, Technical and Extension Series,* 93: 1-6.

CMFRI, 1995. Marine fish landings in India during 1985-93. *Marine Fisheries Information Service, Technical and Extension Series*, 136: 1-28.

CMFRI, DoF, 2006. Marine Fisheries Census 2005 Part III (9) Maharashtra. Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. 330p.

CMFRI, DoF, 2010. Marine Fisheries Census 2010 Part II (9) Maharashtra. Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. 336p.

CMFRI-DoF, 2020. Marine Fisheries Census 2016 Maharashtra. Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare; Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. 264p.

Cuddy, J.D. and Valle, P.D. 1978. Measuring the instability of time series data. *Oxford bulletin of economics and statistics*, 40(1): 79-85.

Department of Fisheries, Government of Maharashtra, India website https://fisheries.maharashtra.gov.in/ accessed on 21-09-2023.

Edwin, L., Lekshmi, N.M., Yasmi, V.S. and Jha, P.N. 2020. Beach seine fishery of India–A Review. *Fishery Technology*, 57: 225-233.

Handbook on Fisheries Statistics, 2011. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. October, 2012. 145 p.

Handbook on Fisheries Statistics, 2014. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. August, 2014. 166 p.

Handbook on Fisheries Statistics, 2018. Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. 175p.

Handbook on Fisheries Statistics, 2020. Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. November, 2020. 176 p.

Handbook on Fisheries Statistics, 2022. Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. November, 2022. 198p.

Lakra, W.S., Ramkumar, S. and Gopalakrishnan, A. 2021. Marine fisheries and biodiversity management in Maharashtra: Status, challenges and opportunities. *Indian Journal of Animal Sciences*, 91(2): 91-95.

Lingamurthy, S.S. 2015. Growth, productivity and instability of fish production in India: A special reference to marine sector by east and west coast. *International Journal of Development and Sustainability*, 10(4): 1016-1029.

Mathews, R.D. 2005. Indian Fisheries: A Historical Alternative. Centre for Civil Society.

Nabi, S. 2019. Scoping Doubling Income of Fishers of Mumbai, Maharashtra. *M. F. Sc.* Dissertation. ICAR- Central Institute of Fisheries Education, Mumbai, India.

Prabhu, N., Zodape, G. and Sharma, A. 2021. A Novel Analytical Procedure for Sustainability Assessment for Marine Fisheries: A Case Study of Ratnagiri District, Maharashtra State, India. *Uttar Pradesh Journal of Zoology,* 42(24): 532-543.

Sali, A., 2023. Fisheries Development in Kerala: Contours of Growth and Discontent. *M. F. Sc.* Dissertation. ICAR- Central Institute of Fisheries Education, Mumbai, India.

Sathianandan, T.V., Mohamed, K.S., Jayasankar, J., Kuriakose, S., Mini, K.G., Varghese, E., Zacharia, P.U., Kaladharan, P., Najmudeen, T.M., Koya, M.K. and Sasikumar, G. 2021. Status of Indian marine fish stocks: modelling stock biomass dynamics in multi-gear fisheries. *ICES Journal of Marine Science*, 78(5): 1744-1757.

Sharma, S., Bellmann, C., Beaton, C., and Pant, A., 2021. Supporting Marine Fishing Sustainably: A review of central and state government support for marine fisheries in India.

Shwetha, T. A., 2023. Fisheries Development in Tamil Nadu: Contours of Growth and Discontent. *M. F. Sc.* Dissertation. ICAR- Central Institute of Fisheries Education, Mumbai, India.

Singh, N.D., Pawar, N., Kiresur, V.R., Sivaramane, N., Ramasubramanian, V. and Krishnan, M. 2020. Surge Pricing and Catch-Income Sustainability Paradox in Marine Fisheries in Maharashtra. *Indian Journal of Agricultural Economics*, 75(3): 290-304.

Srinath, M., Jacob, V., Kanakkan, A., Mani, P.T. and Karbhari, J.P., 1987. Appraisal of the Marine Fisheries of Maharashtra. *CMFRI Special Publication*, 37: 1-46.