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IMPACT OF TEMPERATURE AND RAINFALL ALTERATIONS ON SPAWNING BEHAVIOUR OF INDIAN MAJOR CARPS AND CONSEQUENCE ON FISHERS' INCOME IN ODISHA

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The present communication assessed the impact of the changes in climatic variables, *viz.* temperature and rainfall on the spawning of Indian Major Carps (IMC) in the river Mahanadi, in the fish hatcheries in its plains and on the fishers' income in five districts of Odisha. The average minimum and maximum temperature throughout the state has increased in the range of 0.1 °C to 0.9 ºC. The annual rainfall in Cuttack and Puri districts have increased by 27.78 mm and 13.20 mm respectively and decreased by 18.73 mm, 16.25 mm, 7.4 mm, 86.88 mm and 11.25 mm in Angul, Balasore, Khurda, Sambalpur and Bolangir districts, respectively during 1981-2010. The fish spawn availability has decreased drastically in river Mahanadi in three decades from 30-43 ml $net^{-1}day^{-1}$ to the present level of 6 ml $net^{-1}day^{-1}$. The study revealed that the onset of the breeding period of the Indian major carps has advanced by one month in the hatcheries, compared to the previous two decades. The advancement in breeding period of IMC in the fish seed hatcheries in Balasore, Khordha, Puri and Mayurbhanj districts can be attributed primarily to the effect of increased water temperature and shifting of the rainfall pattern facilitating early maturation and spawning. The respondents in the fish seed hatcheries surveyed also perceived temperature and rainfall as the most important factors responsible for advancement of the onset of breeding of IMC.

Key words : Climate change, breeding season, Indian major carps, hatchery, Mahanadi river basin, Odisha, India

Introduction

In recent years the climate is showing perceptible changes on a regional scale in India. In the state of Odisha the average temperature is on the rise over the last 30 years. The average minimum and maximum temperature throughout the state has increased in the range of 0.1 °C to 0.9 ºC (IMD, 2010). The average rainfall has decreased with a shift in the seasonal pattern. With this background, investigation was conducted to assess the impact of the alteration in the climatic variables on the breeding of Indian major carps in the river Mahanadi and Brahmani and in the fish hatcheries in its plains and on the fishers in five districts of Odisha.

Materials and methods

Study area

Study was undertaken in five districts of Odissa in the Mahanadi river basin, *viz.* Puri, Khorda, Balasore, Cuttack and Angul. (Fig. 1)

Meteorological data analysis

Rainfall

The rainfall pattern of the districts in the Mahanadi basin of Odisha were analysed from data available with Indian Meteorological Department (IMD), Pune. The Annual rainfall data were clubbed into three blocks of pre 90's (1981-90), 90's (1991-2000) and post 90's (2001-2010) since most of the fish seed hatcheries came up during

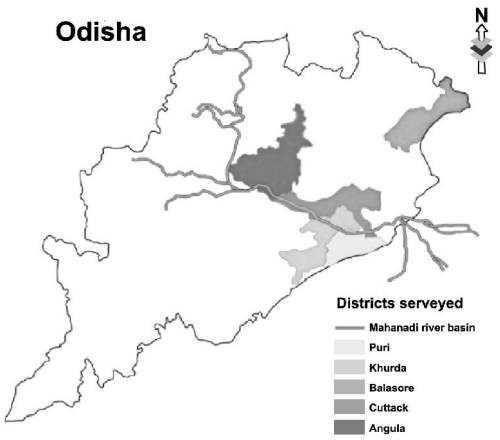

Fig. 1. Map of Odisha showing five districts under study

this period in the state of Odisha. The months were clubbed into January-April, May-August, September-December blocks and the variation in annual rainfall during the two time periods were analysed.

Temperature

Annual maximum and minimum air temperature data during the breeding period of March to September for the years 1979-2008 in the six districts of Odisha, *viz*. Angul, Balasore, Bolangir, Cuttack, Puri and Mayurbhanj were analysed using exponential moving average (EMA) method.

Relation between air and water temperature

Based on the established relation between air and water temperature, the equation $y = -0.006x^2 + 1.510x - 8.821$ $R^2 = 0.964$ was put into the recorded air temperature in breeding season months of March-September of the study area.

Impact studies on breeding and fishers

Sixteen fish seed hatcheries were surveyed in the above-mentioned districts. A list of fish seed hatchery owners was prepared based on their performance and sustainability during the last two decades. A list of fishers containing both the hatchery owner, as well as, the salaried workers was prepared. Two questionnaires (for hatcheries and fishers) were prepared based on the preliminary survey of the hatcheries. The questionnaires were pre-tested and finalized for data collection and a total of 100 fishers from 16 small and large scale hatcheries selected at random constituted the study. Data on fish species, breeding technique, onset of breeding season, end of breeding season, initial brooders quantity per set, first spawn, number of times brooders set, total spawn produced during full season, price (Rs. in lakh) during various periods in a season, onset period of favourable temperature for breeding, in the two time periods, *viz*. prior to 1990 and 1990-2007 were collected from recorded data available as well as through personal interview. The data was collected by participatory rapid appraisal (PRA) through the standardized questionnaire interacting with hatcheries owners and operatives. PRA was chosen for this study because it provides guidelines for the fast appraisal of a real situation in the field with in a relatively short time.

The information has been analyzed through simple tabular analysis to cater to the need of the objectives. The purpose of the study was to derive information on the changing scenarios of climate change and its impact on fish breeding and ultimate affect on the fishers economic status.

The fishers' response towards the changing scenario in river Mahanadi and Brahmani was carried out along the stretches of river Mahanadi at Naraj, Munduli in Cuttack district, Tikarpara in Angul district, Kantilo in Nayagarh district and Jenapur and Sialia in Jajpur district on River Brahmani. Fishermen were interviewed regarding spawn availability, spawn collection from river done by operating fixed filtration /trap nets with

cloth netting as lead and a napkin acting as pot for collection of spawn fixed in marginal areas of flooded rivers during monsoon months, fish catch, species availability, fishing techniques, marketing and income in pre and post 1990's.

Results

Trend of temperature alteration

The air temperature pattern analysed during the period 1979 to 2008 exhibited a distinct change. During this period, the maximum temperature has decreased by 1.24% (0.73°C) whereas the minimum temperature has increased by 0.86% (0.19°C) compared to 1979 in this state. The average yearly rainfall variation in the state is about 667 mm among the districts (Fig. 2).

Seasonal air temperature alterations

The mean minimum air temperature at Bhubaneshwar in the district of Khordha during the months (March to September) shows an increase by 0.17 ºC and the mean maximum temperature has increased by 0.11ºC (Fig. 3 and 4).

The mean maximum and minimum air temperature in Puri during March to September during 1980-2008 increased by 0.56 ºC and increased by 0.33 ºC respectively (Fig. 5).

The mean minimum air temperature in Balasore during March to September during 1980-2008 has increased by 0.15 ºC and mean maximum air temperature decreased by 0.23 ºC (Fig. 6).

The mean maximum temperature at Cuttack district has increased by 0.05 ºC and minimum has decrease by 0.40 ºC during the last three decades (Fig. 7).

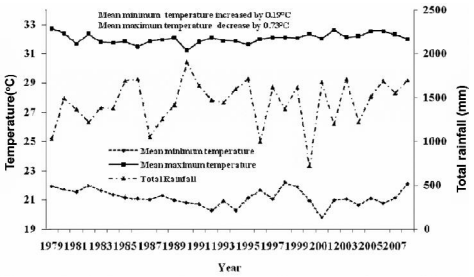

Fig 2. Minimum, maximum air temperature and rainfall trend of Odisha state during 1979-2008

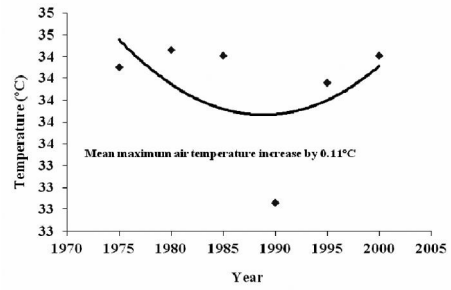

Fig. 3. Mean maximum air temperature at Bhuwaneswar during March to September (1975-2005)

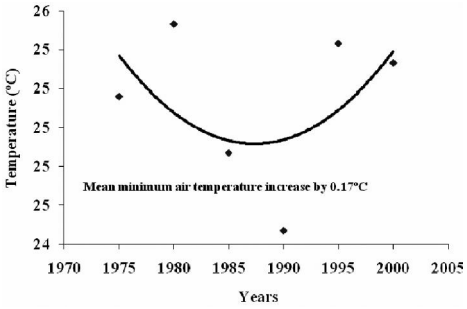

Fig. 4. Mean minimum air temperature at Bhuwaneswar during March to September (1975-2005)

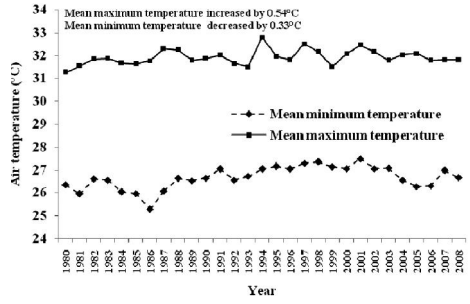

Fig. 5. Mean maximum and minimum air temperature at Puri during March to September (1980-2008)

Angul: The mean maximum temperature at Angul district has increased by 0.54 ºC and the minimum has decrease by 0.24 ºC during last three decades (Fig. 8).

Water temperature alterations

The water temperature is particularly important for maturation and breeding of the fish. Ground water temperatures integrate annual temperature conditions and are usually within 1-2 ºC of the mean annual temperature (Meisner, 1990). The data of air and water temperature for three years from the study area was analysed.

During the last three decades and the mean minimum water temperature during 1980-2008 has increased by 0.18 ºC and mean maximum water temperature has increase by 0.28 ºC at Balasore (Fig. 9).

Changes in rainfall pattern

The rainfall pattern of the surveyed districts of Odisha recorded the following variations in the districts.

There is a distinct shift in rainfall pattern in Khordha during 1981-1990 to 2001-2010 with increase in September-December (from 26% to 34.21%) and decrease in Jan-April months from 7.10% to 4.28% during 2001-2010 (Fig 10).

In Balasore district during (1981-1990 to 2001-2010) September-December months the percentage rainfall has increased from 26.46% to 36.77% and decreased from 61.34% to 57.03% during May-August months (Fig. 11).

In Puri district the rainfall has increased from 32.31% to 34.53% in the September-December during time period 1981-90 to 2001-2010 and

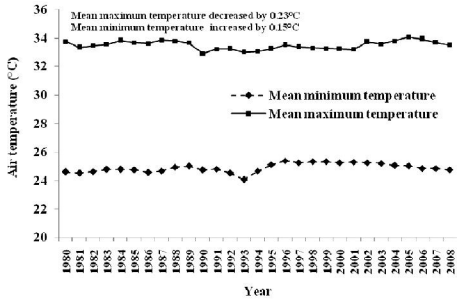

Fig. 6. Mean maximum and minimum air temperature at Balasore during March to September (1980-2008)

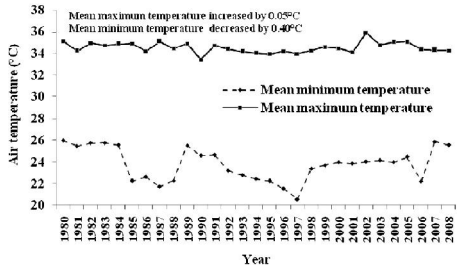

Fig. 7. Mean minimum and mean maximum air temperature at Cuttack during March to September (1980-2008)

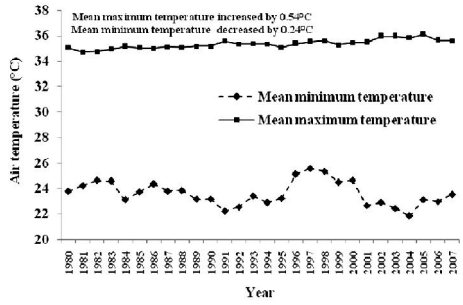

Fig. 8. Mean minimum and mean maximum air temperature at Angul during March to September (1980-2008)

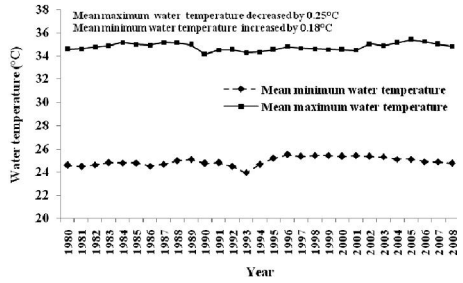

Fig. 9. Mean minimum and maximum water temperature at Balasore from March to September (1975-2005)

decreased from 66.1% to 61.48% during May to August of 1991-2000 to 2001-2010 (Fig. 12).

The seasonal pattern at Cuttack also shows changes in rainfall with decrease from 8.27% to 4.73% in the January- April months, increase from 64.94% to 67.80% during May-August and 26.79% to 27.47% during September to December, in the last three decades 1981-2010 (Fig. 13).

In Angul district the rainfall has decreased from 9.78% to 5.47% during January to April and from 25.91% to 25.59% during September - December months, whereas it has increased from 64.31% to 68.94% in May to August months. Since the months January- April is considered as maturing period of fishes, any alteration might disturb the normal breeding and spawning in natural systems (Fig. 14).

Impact on aquaculture

Advancement of breeding period of the Indian major carps

In Odisha the Indian major carps, *Catla catla, Labeo rohita* and *Cirrhinus mrigala* are bred in captivity by hypophysation and their spawning occurs during the monsoon season (June-July) and extends till September. However, in recent years IMC are maturing and spawning as early as March in the fish hatcheries in four districts of Odisha. Investigations conducted in the fish hatcheries in four districts of Odisha revealed that in Mayurbhanj district the breeding period of IMC in the hatcheries has advanced by over 60 days during the last decade. Presently breeding season starts by 15-20th April, as against 15-20th June earlier (Fig. 15).

In Balasore district, the season starts with first breeding by 15-20th May, while during pre- 2000

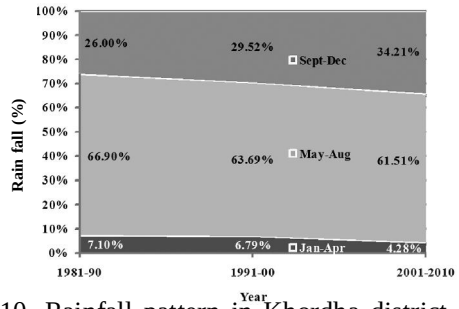

Fig. 10. Rainfall pattern in Khordha district during 1981-2010

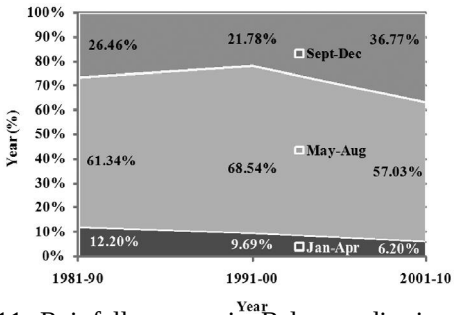

Fig. 11. Rainfall pattern in Balasore district during 1981-2010

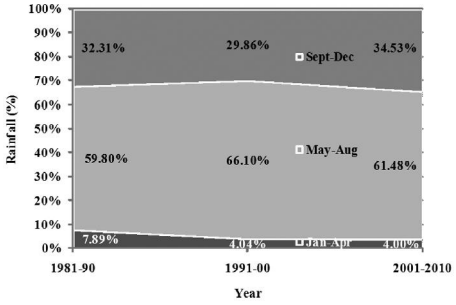

Fig. 12. Rainfall pattern in Puri district during 1981-2010

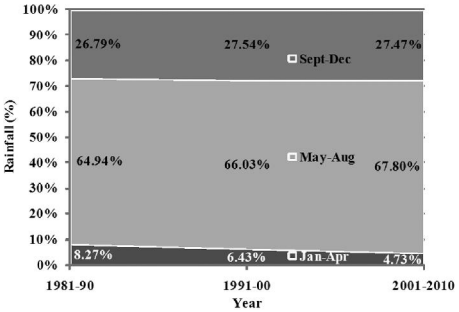

Fig. 13. Rainfall pattern changes in district Cuttack during 1981-2010

breeding of IMC started during 3rd week of June thus showing an advancement by over a month (Fig. 16).

In Puri district breeding of IMC showed an advancement by a month with breeding commencing by 21st June during 2007, as against 2nd week of July during pre-2000 (Fig. 17).

In Khurda district the present breeding period of IMC is 75 days while it lasted 30-40 days earlier (Fig. 18).

Alteration in breeding behaviour of Indian major carps and fishers income

Data on the various parameters of hatcheries and fishers collected from operative persons in hatcheries are presented in Table 1. Participatory Rural Appraisal (PRA) with hatchery operatives revealed that 85-90% fishers prereceieved temperature rise to be the main factor for advancement of the breeding period while 80-90% reasoned it to demand and high sell price (Table 2). The increase in income is attributed to good quantity of spawn by 90-95% respondents. The study also indicated that in majority of the fish seed hatcheries the breeding period of the major carps has advanced in all the districts by 1-2 months since the last twenty years. However, all the districts surveyed have shown decline in the spawn production from each set of brooders in all the districts, but the price per measure (cup) have increased two folds in the last decade. The increase is noteworthy in the initial months, (March-April), where the price is almost two times more than during the end of the breeding season of September.

Spawn production

The spawn production from one kg of brooder

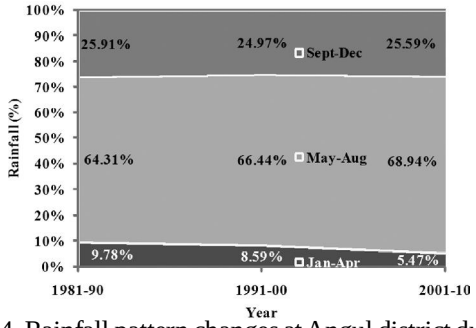

Fig. 14. Rainfall pattern changes at Angul district during 1981-2010

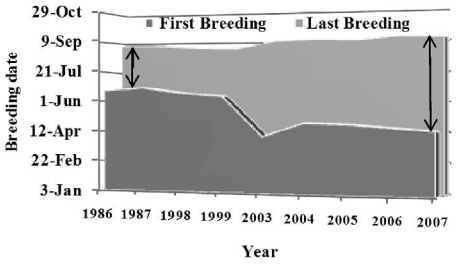

Fig. 15. Advancement in Indian major carps breeding period in Mayurbhanj district

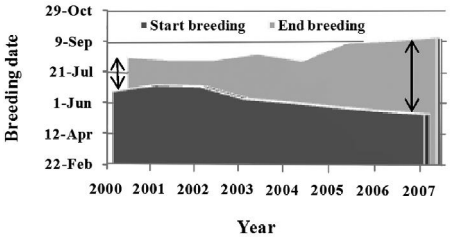

Fig. 16. Advancement in Indian major carps breeding period in Balasore district

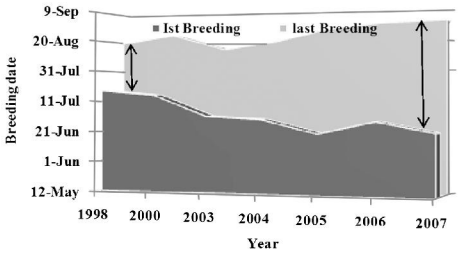

Fig. 17. Advancement in Indian major carps breeding period in Puri district

set was 1 lakh during 1990-2000; whereas during 2000-2008 one kg of brooders could produce only 40,000-50,000. Certain factors like brooder maturity, brooder management and breeding skill played a role in spawn quality and quantity. Although the spawn production varied between hatcheries the overall trend of 1/3 rd production during advancement period was distinct in all the districts covered. Previously, fish brooders were set twice to thrice in a season. At present with the extended breeding season, brooders are set three to four times in a season. Thus in spite of less quantity of spawn from the initial set of brooders an extended breeding period allows the hatchery owners to produce more quantity of spawn in a season.

Alteration in price and income of fishers: The price of spawn varied during the season. During 1990-2000 the price per lakh of spawn was Rs. 250-300 in July that decreased to Rs. 200-250 in August, while during 2000-08 the initial price per lakh was Rs. 500-600 in April - May, which comes down to Rs. 500-400 in August - September (Figs. 19 and 20; Table 1).

In all the hatcheries surveyed the low production of spawn at present due to advancement of the breeding season is compensated by two fold increase in sell price during the season opening months and an extended season of sale. Although the cost of production has increased in the last two decades, the high price initially with extended season of sale has raised the income per season of the fish seed hatcheries.

Impact on riverine fisheries

River Mahanadi: The fish spawn availability in river Mahanadi has decreased drastically over the years. Earlier investigations during the years 1954, 1962, 1963 recorded average total spawn availability of 30-43 ml $net^{-1}day^{-1}$, whereas during the study (2007) it recorded only 6ml $net^{-1}day^{-1}$ (Fig. 21).

The PRA responses of fishers analysed (Table 3) revealed that at present the major change that has occurred in river Mahanadi and Brahmani in relation to inland fisheries had been the decline in fish spawn availability and fish catch. The prime factor assigned by the respondents for this decline has been primarily elevated temperature (75-90%), decrease in rainfall (90-95 %), siltation (70-95%), floods (60-80%) decline in water level (70-80%)

Discussion

The present study revealed that the onset of the breeding period of the Indian major carps has advanced in the hatcheries compared to two decade earlier. It is established that temperature and rainfall are the most important climate variables influencing the breeding of IMC in India (Hora, 1945; Khan, 1945; Das and Das Gupta, 1945; Smith, 1945; Dey *et al.*, 2007; Vass *et al.*, 2009). Maturation process of gonad of the IMC commence during January -February when temperature gradually increases and completes prior to onset of monsoon (May-June). During these five months (February-June) temperature in India gradually increases and reaches the maximum in mid June. In these months there is also a greater variation in the daily maximum and minimum temperatures (Qasim and Qayyum 1962; Das *et al.*, 1945). Effect of environmental temperature on the sexual maturation and breeding of fish has been studied by several workers (Chaudhuri, 1960; Alikunhi *et al.*, 1963; Ahsan 1966; Ibrahim 1961; Dey *et al.*, 2007). Their observations indicate optimum temperature ranges for breeding of Indian major carps. Enhanced temperature of water plays a significant role in stimulating the maturation of the gonads in fishes and also accelerates spermiation (Ashan, 1966).

Table 1. Change in breeding behaviour of IMC and exotic carps in Odisha along with fisher's income

Changes		Time period
Parameter	Before 1990s	After' 90s
Fish species	*C. catla* *L. rohita* *C. mrigala*	*C. catla, L. rohita, C. mrigala, Labeo bata,* Exotic species *(Ctenopharyngodon idella, Hypophthalmichthys molitrix, Cyprinus carpio), Puntius gonionotus*
Breeding technique	Hypophysation, Natural spawning	Hypophysation, stripping method in the initial months and natural spawning later. Use of pituitary gland for IMC and ovaprim for exotic carps.
Start of breeding season	June-July with onset of monsoon.	1st week of April
End of breeding season	4th week of September	2nd week of September.
Initial brooders quantity set. Big capacity 50-70 kg Big capacity 50-90 kg	Small capacity 40-50 kg Small capacity 15-25 kg	
Ist spawn	100000-120,000 nos kg^{-1}	40000-60,000nos kg^{-1}
No .of times brooders set	Twice in a season	3-4 times a season
Total spawn produced during full season.	Khorda - 5 crore Puri - 2 crore Balasore - 666 lakhs Mayurbhanj - 1.5 crore	Khorda - 10 crore Puri - 5 crore Balasore - 1 crore Mayurbhanj - 2.5 crore
Price (Rs/- per lakh of spawn) during various periods in a season	June: 200-250 July: 250-300 August: 200-250 September: 250-300	April:500-600 May: 500-600 June: 300-350 July: 350-400 August: 400-500 September: 400-500
Onset of favourable temperature for breeding	June - July	April - May

*Each cup is a measure of 50,000 nos. of spawn.

* Aged brooders respond well to advanced breeding as they mature earlier

Table 2. Response of fish operatives and fishers of hatcheries surveyed

Reason	Response (%)			
	Khorda	Puri	Balasore	Mayurbhanj
Advancement in breeding period				
Increase in temperature	85	90	90	85
Improved brooder care	95	80	85	75
Improved strain of brooders	65	50	55	60
Better management techniques	85	75	80	85
Demand and high sell price	90	90	80	90
Improved breeding technique after training	55	50	65	65
Increase in income				
Improved spawn quality	75	80	70	70
More quantity spawn	80	75	80	85
Better marketing	70	85	85	80

Table 3. Fishers Response towards changing scenario

Criteria / Scenario	Response %				
	River Mahanadi			River Brahmani	
	Naraj	Mundali	Tikarpara	Sialia	Jenapur
Decrease in spawn availability	99	95	95	95	95
Decrease in fish catch	90	95	90	95	95
High cost and maintenance of crafts and gears	80	80	75	90	90
Low sell price	80	80	90	75	75
Inadequate marketing and storage facilities	95	95	95	95	95
Decrease in man hr/day	60	70	30	80	60
Migration to other profession Reason	20	20	10	40	20
Rise in temperature	75	75	80	90	90
Decrease and shift in rainfall	95	95	90	95	95
Siltation	90	90	70	90	95
Floods	80	75	60	75	75
Decrease in water level	80	80	80	70	70

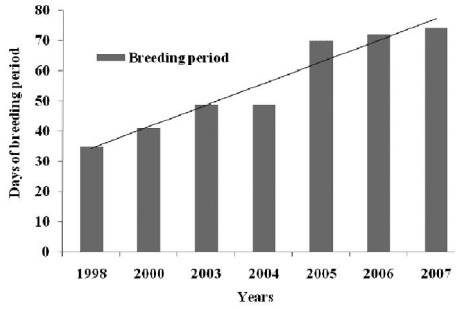

Fig. 18. Advancement in Indian major carps breeding period in Khurda district

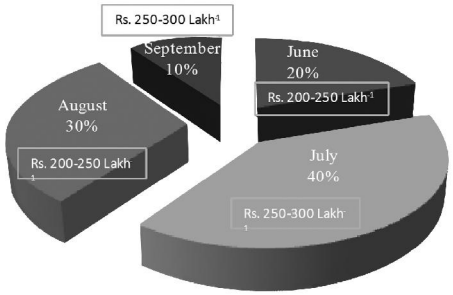

Fig. 19. Percentage of spawning and its rate (1990-2000)

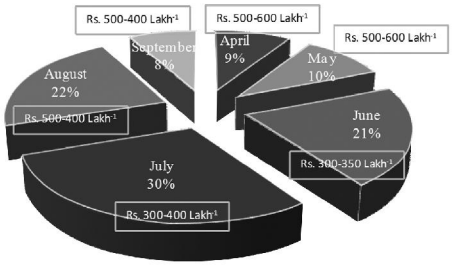

Fig. 20. Percentage of spawning and its rate (2000 - 2008)

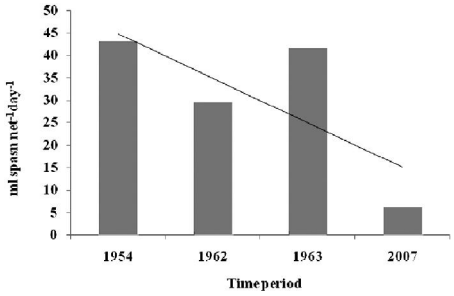

Fig. 21. Spawn quantity of Mahanadi river during 1954-2007 (Source: Mitra 1972)

Thus, temperature affects the gonads firstly by regulating their ability to respond to pituatory stimulation and secondly on pituitary synthesis and release of gonadotropins (Lofts *et al*., 1968; Mookherjee 1945; Ganapati and Thivy 1995; Alikunhi *et al*., 1964; Chaudhuri *et al*., 1957). Apart from light and temperature, rainfall is an important factor for induced breeding of fish. Successful spawning in majority of the fishes has been induced in rainy days especially after heavy

showers (Chaudhuri, 1960). Sinha *et al*. (1971) suggested that sudden drop in the electrolyte level in the environment caused by rainfall induces hydration in the fish and gonads resulting in natural spawning. Two decades earlier fish spawning season in the fish seed hatcheries surveyed used to start with the onset of monsoon in the months of June-July and extended till the end of September with the fish brooders spawning once or twice in a season. Bhowmick *et al*. (1977) reported spawning by hypophsation at an interval of 36-77days after first spawning. At present, however, hatcheries practice multiple breeding where brooders are bred more than two times a year by hypophysation.

It is evident from the findings that the increase in air and water temperature and alteration in the rainfall pattern in the districts are the most significant attributes for the advancement of the breeding period of IMC in the fish hatcheries of Odisha. The present observation is in agreement to the findings of Dey *et al.* (2007) in the fish hatcheries of West Bengal. However, the respondents in the fish seed hatcheries surveyed also indicated that besides temperature other factors such as better brooder management, improved fish health management, early demand and high price of fish spawn are the other factors responsible for advancement of the breeding season of IMC.

In case of riverine fishes, which breed naturally in rivers, erratic rainfall during the breeding season hampering inundation of the floodplains of the river hamper breeding (Das, 2007; Vass *et al.,* 2009). In river Mahanadi basin a decrease in rainfall was evident in majority of the districts during the monsoon months and an increase in rainfall in the post monsoon period when resorption of the gonads of IMC sets in has hampered the spawning of IMC in river Mahanadi as indicated by drastic decrease in spawn availability and decrease in fish catch.

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