OPEN ACCESS

Journal of Life Sciences

Journal of Life Sciences

(A Quarterly, Refereed, & Peer Reviewed Journal of Life Sciences)
Published by: AAASSHER, Mumbai, (MS) India
Journal homepage: https://jls.aaassher.org/
ISSN (Online): xxxx-xxxx
Volume 1, Issue 1, December 2025; Pages 1 – 11
DOI: 10.5281/zenodo.17457694

A study comparing the growth of *Clarias batrachus* in cage culture using natural and artificial feed at Dhangar Takli on the River Godavari, Maharashtra, India

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Article history:

Received 12 July 2025
Received in revised form
22 September 2025
Accepted 26 September 2025
Available online 01 October 2025

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Abstract

This pioneering study in Marathwada demonstrates the region's potential for cage aquaculture. Over the course of 180 days, *Clarias batrachus* (walking catfish) showed substantial growth in both natural and supplementary feeding cages.

In natural feeding conditions, the average weights were: 5.48 ± 1.69 grams during the first month, 6.71 ± 2.17 grams during the second month, 11.60 ± 7.19 grams during the third month, 19.57 ± 12.32 grams during the fourth month, 45.80 ± 17.58 grams during the fifth month, 97.27 ± 24.59 grams at the end of six months.In cages with additional supplemental feed, the average weights recorded were: 7.20 ± 0.84 grams in the first month, 14.05 ± 3.82 grams in the second month, 24.61 ± 4.69 grams in the third month, 51.01 ± 14.12 grams in the fourth month, 91.22 ± 14.11 grams in the fifth month, 156.40 ± 10.85 grams after six months.

By the conclusion of the culture period, fish in the supplemented feeding cages reached an average weight of around 156.40 grams, notably higher than the 97.27 grams in natural feeding cages, underscoring the effectiveness of supplemental feeding for promoting growth.

Keywords: Blue Revolution, Cage Culture, *Clarias baratchus*, Nanded

Introduction

The precise origins of cage culture are not definitively known, but it is generally accepted that the practice initially emerged as a means for fishermen to temporarily store live fish prior to sale. The deliberate use of cages for aquaculture is believed to have developed in Southeast Asia during the late 19th century. Early cage systems were typically constructed from locally available materials such as bamboo and wood, and the fish were commonly fed with low-value bycatch and household food waste. The advent of modern cage aquaculture can be traced to the 1950s, coinciding with the availability of synthetic materials that allowed for more durable and efficient cage designs. Today, cage culture is a widely adopted method of fish production in several Central and Southeast Asian nations, including China, the Philippines, Indonesia, and Thailand **(Beveridge, 1983; Beveridge, 1987; Beveridge, 1996; Beveridge & Stewart, 1998).**

Cage aquaculture has become an increasingly prominent method of fish farming, exhibiting substantial growth over the past two decades. Its development continues to accelerate in response to the dynamics of globalization and the escalating global demand for aquatic products. The transition toward more intensive cage farming systems is influenced by several interrelated factors, including constraints on access to natural resources, the pursuit of economies of scale, and the imperative to maximize production efficiency per unit area.One of the key benefits of cage culture is its efficient use of existing water bodies, allowing farmers to avoid the costs associated with water storage or construction. This makes it particularly appealing to rural and landless communities, offering them a viable and cost-effective livelihood option. In India, cage aquaculture was first introduced using air-breathing fish species such as *Heteropneustes fossilis* and *Anabas testudineus* in swampy regions **(Dahadrai et al., 1974).**

Cage aquaculture in India remains underdeveloped, with efforts so far limited to isolated pilot projects, mainly undertaken in MP and Karnataka. Although it is recognized globally as the second-largest inland fish producer after China, India has yet to establish a significant presence in cage aquaculture, especially when compared to countries like China, Vietnam, Indonesia, the Philippines, and others.In this context, it is crucial to initiate a comprehensive project or research program that leverages the country's potential for developing cage farming. Such initiatives would contribute significantly to increasing fish production while also creating employment opportunities across both the public and private sectors. **(Fishing Chimes, 2008).**

Cage culture activities have not yet been initiated in the Marathwada region. If cage-based fish farming proves successful, it could greatly benefit local fishermen and pave the way for a new era in Maharashtra's fisheries development. Consequently, this study was conducted with the goal of supporting the **"BLUE"** revolution and promoting sustainable aquaculture progress in the region.

Reasons for Implementing Cage Technology in Marathwada

Marathwada, a significant region in the state of Maharashtra, is endowed with extensive freshwater resources, including lakes, ponds, rivers, and reservoirs. Among its major river systems, the Godavari River is the most prominent, serving as a lifeline for numerous water-related initiatives across the region. Several major water infrastructure projects are situated along the Godavari basin and its tributaries. These multipurpose water projects play a crucial role in sustaining a wide array of activities, including agriculture, irrigation, domestic water supply, industrial operations, and aquaculture development. According to Balkhande (2014), the Shankar Sagar Reservoir, part of the Vishnupuri Project in Nanded district, has successfully supported the culture of Indian major carps—*Catla* and *Rohu*—alongside the Asian catfish *Clarias batrachus* and the prolific breeder *Oreochromis mossambicus*. The selection of these species reflects both ecological suitability and market demand in the region. Indian major carps, such as *Catla* and *Rohu*, are well-adapted to the lentic water conditions of reservoirs and are widely preferred for their fast growth and commercial value. *Clarias batrachus*, known for its hardiness and ability to tolerate low dissolved oxygen levels, is particularly suited for culture in environments with fluctuating water quality. Meanwhile, *Oreochromis mossambicus*, a prolific breeder, has demonstrated adaptability across varied water bodies and is capable of thriving under minimal management. The successful cultivation of these species underscores the untapped aquaculture potential of reservoir systems in Marathwada. With strategic planning, improved management practices, and policy support, such water bodies could be effectively harnessed to enhance rural livelihoods, promote food security, and contribute to the region's blue economy.

Materials and Methods

Study Area

The study was conducted in the backwaters of the Asarjan Lift Irrigation Project, situated on the Godavari River in Nanded district, Maharashtra. Commissioned in 1988, the Asarjan project is one of the largest lift irrigation schemes in Asia, primarily developed for irrigation and domestic water supply. The specific research site is located at Dhangar Takli (19°7'12"N, 77°3'28"E), a small riverside village approximately 8 kilometers from Purna in Parbhani district, accessible via the Nanded–Purna road. The site was selected based on favorable physico-environmental conditions for cage aquaculture, including adequate water depth, efficient water exchange, and minimal sediment deposition, all of which contribute to an optimal aquatic environment for fish culture.

Criteria for Site Selection

Potential sites for cage culture include lakes, reservoirs, ponds, quarries, rivers, and streams, provided they meet certain conditions:

- Adequate water volume with sufficient depth to accommodate cages.
- Sediment-free water to prevent damage and fish health issues.
- The cage units were structurally engineered to withstand the hydrodynamic forces associated with local wind and wave conditions, thereby maintaining stability and operational integrity.
- Adequate water exchange was maintained to facilitate continuous oxygen replenishment and efficient removal of metabolic waste. A survey covering approximately 40 km of backwater area was conducted, leading to the selection of Dhangar Takli based on these criteria.

Structural Design of Cage Units

Iron materials that are strong, durable, and non-toxic were employed in the construction of the cages to guarantee safety, stability, and extended service life. The design included appropriate mesh sizes that allow maximum water flow, facilitating oxygenation and waste dispersal, which are vital for fish health. The cages were built to withstand environmental conditions such as wind and waves.

Selection of Fish Species

The species selected for culture was *Clarias batrachus* (air-breathing catfish), a bottom feeder and carnivorous fish known for its adaptability to low-oxygen environments and suitability for cage culture.

Stocking of Fish

Fingerlings of *Clarias batrachus* were procured from the College of Fishery Science, Maharashtra Animal and Fishery University, Telangkhedi, Nagpur. Following procurement, the fingerlings were transported to the study site in Air-inflated transport pouches to minimize stress and ensure high survival rates during transit.

Prior to stocking, the individual length and weight of each fingerling were recorded to establish baseline data. The trial was conducted using two separate cages: one stocked with fish provided with artificial feed, and the other without, relying solely on natural food sources. A stocking density of 100 fingerlings per 72 cubic feet of water was maintained in both cages.

Feeding Regime

Fish stocked in the experimental cages were administered a commercial pelleted diet, sourced from KVK, Karda, Risod, in Washim district, to ensure consistent and nutritionally balanced feeding throughout the culture period. Feeding was carried out daily at 7:00 a.m., with the feed quantity calculated at 5% of the total body weight of the fish to ensure adequate nutrition.

The initial weights of the fingerlings were used to determine feed quantities, which were adjusted as the fish grew. This methodology aimed to evaluate the feasibility and productivity of cage culture of *Clarias batrachus* in the backwaters of the Asarjan project, considering environmental conditions, cage design, and feeding practices.

Table 1. Ingredients and Percentage Composition of Artificial Feed for Caged Fish

Sr. No	Ingredients	Inclusion level (%)
1	Rice bran and peanut oil cake	25
2	Soy cake	25
3	Corn flour	40
4	Low-value fish meal	09
5	Mineral supplement	01

Cage maintenance practices

The cage units were systematically managed to maintain optimal environmental conditions for the cultured fish. Scheduled cleaning was conducted before feeding sessions to eliminate mortalities, residual feed, and organic detritus. These measures helped reduce waste accumulation and safeguarded water quality from potential degradation.

Table 2. Shows the stocking densities used in the study along with their corresponding feed dosages.

Particulars	Experimental Cage	Control Cage
Stocking Density	100 fingerlings / 72 cubic feet	100 fingerlings / 72 cubic feet
Mean Fingerling Length	2 cm	2 cm
Fingerlings per Cubic Foot	1.3 fingerlings / cubic foot	1.3 fingerlings / cubic foot
Feeding Frequency	Once daily at 5% of total body weight	-
Feed Type	Pelleted commercial feed	Natural food only

Additionally, every 8 days, the cages were partially lifted from the water to inspect for structural damage and to control algal blooms, ensuring the integrity of the cages and maintaining optimal conditions for fish growth.

Checking and Measurement of Fish

At regular intervals throughout the culture period, fishes were harvested using hand nets to monitor their growth. The length of individual fish was measured in centimeters, and their body weight was recorded in grams. These measurements helped assess growth rates and overall health of the fish during the 180-day culture period.

Culture Period

The fingerlings of *Clarias batrachus* were cultured in the cages for a duration of 180 days, allowing sufficient time for growth and development before harvest.

Limnological Parameters

Throughout the duration of the study, critical water quality parameters were routinely assessed to determine the aquatic environment's suitability for fish rearing. Monitored variables included water temperature, hydrogen ion concentration (pH), water transparency, total alkalinity, dissolved oxygen (DO), free carbon dioxide (CO_2), total hardness, calcium, magnesium, and biological productivity. These parameters were analyzed using standardized methodologies prescribed by the American Public Health Association (APHA, 2000), ensuring precision and consistency in data collection for evaluating environmental factors affecting fish performance and the effectiveness of cage aquaculture practices.

Results & Discussion

Growth Dynamics and Production Efficiency of *Clarias batrachus* Cultured in Cages.

The results indicate that *Clarias batrachus* provided with supplementary (artificial) feed showed significantly superior growth compared to those fed naturally within the cages. This underscores the beneficial impact of supplemental feeding on the growth and overall yield of the fish.

Progression of Length and Weight

In Natural Feeding Cage: Initial lengths (cm): 1.5, 6.3, 7.3, 9.6, 11.6, 14.9 (from 1st to 6th month), Final lengths (cm): 6.3 ± 1.70, 7.3 ± 1.65, 9.6 ± 2.43, 11.6 ± 2.04, 14.9 ± 1.91, 21.9 ± 2.14. Final weights (g): 5.48 ± 1.69, 6.71 ± 2.17, 11.60 ± 7.19, 19.57 ± 12.32, 45.80 ± 17.58, 97.27 ± 24.59.

In Supplementary (Artificial) Feeding Cage: Initial lengths (cm): 1.8, 7.4, 9.2, 13.0, 14.9, 19.0. Final lengths (cm): 7.4 ± 0.55, 9.2 ± 1.01, 13.0 ± 0.89, 14.9 ± 0.94, 19.0 ± 1.03, 24.2 ± 1.09. Final weights (g): 7.2 ± 0.84, 14.05 ± 3.82, 24.61 ± 4.69, 51.01 ± 14.12, 91.22 ± 14.11, 156.40 ± 10.85

At the conclusion of the 180-day culture period, fish in the supplementary feeding cage achieved an average weight of approximately 156.40 g, notably higher than the 97.27 g recorded in the natural feeding cage.

Summary of Growth Performance

Fish receiving supplemental feed demonstrated faster growth rates, with marked increases in both length and weight over the study period. These findings clearly show that providing artificial feed enhances growth performance, leading to increased biomass and potential productivity.

Implications

Adopting supplementary feeding practices can significantly improve the efficiency and profitability of cage aquaculture systems. The data suggest that such strategies can lead to larger fish and higher overall yields, making the culture of Clarias batrachus more sustainable and economically viable.

Weight Gain Percentage

During the 180-day culture period, the fish in natural feeding cages exhibited weight gains of 204.4%, 22.44%, 72.87%, 68.70%, 134%, and 112.3% across months I to VI. In comparison, fish in supplementary feeding cages showed higher weight gains of 300%, 95.13%, 75.16%, 107.2%, 78.82%, and 71.45% during the same months, indicating improved growth with additional feed.

Specific Growth Rate (SGR)

The SGR values, detailed in Tables 5 and 6, revealed that fish without supplementary feeding had lower average SGRs: 12.26%, 4.1%, 16.3%, 26.56%, 87.43%, and 171.5% per day for months I to VI. Conversely, fish in the supplementary feeding cages exhibited significantly higher SGRs: 18%, 22.83%, 35.2%, 88%, 134%, and 217.6% per day across the respective months.

Daily Growth Rate (DGR)

The mean daily growth rates further supported these findings. Fish in natural feeding cages grew at rates of 0.12 g/day, 0.04 g/day, 0.16 g/day, 0.26 g/day, 0.87 g/day, and 1.7 g/day. In contrast, fish in supplementary feeding cages showed higher DGRs of 0.18 g/day, 0.22 g/day, 0.35 g/day, 0.88 g/day, 1.3 g/day, and 2.1 g/day.

Mortality and Survival Rate

In the supplementary feeding cages, 19 fish died during the study, but no further mortality was observed after that. In the natural feeding cages, slightly higher mortality was recorded, with 21 fish dying within the first 15 days post-stocking. Overall, survival rates were comparable: 79% in natural feeding cages and 81% in supplementary feeding cages, with most deaths occurring within the initial two weeks.

Total Yield / Total Production

The total biomass produced over the 180 days was significantly higher in the supplemented cages, amounting to 12.6 kg, compared to 7.6 kg in the natural feeding cages. This clearly demonstrates that supplemental feeding markedly enhances the growth and overall productivity of Clarias batrachus in cage culture systems.

In the case of Clarias batrachus (magur), the mean final length of fish in both natural and artificial feeding cages was found to be significantly different at the 5% level of significance ($P < 0.05$), as illustrated in Figures 1 and 1.1. The statistical analysis was conducted using Welch's corrected t-test, performed with GraphPad Prism 6 software. The results showed a minimal difference between the mean values and their corresponding differences, with a 95% confidence interval ranging from 1.746 to 2.833.

An F-test was conducted to compare the variances between the two groups. The calculated F-value was 3.847, with degrees of freedom for the numerator (DFn) = 78 and for the denominator (DFd) = 80. The analysis revealed a statistically significant difference in variance between the two groups. The Welch's t-test yielded a t-value of 19.59 with approximately 106.7 degrees of freedom, demonstrating a highly significant difference between the mean final lengths of fish in natural versus artificial feeding conditions. Similarly, the F-test results ($F = 5.134$, DFn = 78, Dfd = 80) were also statistically significant.

Overall, these findings confirm that the differences observed in the final lengths of Clarias batrachus in natural and artificial feeding cages are statistically significant, with P-values less than 0.05.

Borthakur and Goswami (2007) carried out a comprehensive study on the cage culture of Clarias batrachus (Linnaeus) in a floodplain wetland ecosystem in Assam. This study aimed to assess the growth and production performance of the species under selected non-conventional diets. The researchers formulated and tested alternative feed ingredients sourced locally, aiming to reduce dependence on commercial feeds and improve the cost-efficiency of cage-based aquaculture practices. Their findings demonstrated that Clarias batrachus could effectively utilize non-conventional feeds without compromising growth, thereby highlighting the viability of low-cost, sustainable feed strategies for small-scale fish farmers in similar wetland environments. During a 120-day rearing period, they observed variations in average weight gain depending on the diet provided. The highest average weight gain was recorded in fish fed a diet comprising blood meal mixed with papaya peels, reaching 75.00 ± 2.18 grams. In contrast, fish fed blood meal alone showed the lowest average weight gain of 66.53 ± 4.04 grams. These results underline the significant influence of diet composition on the growth performance of Clarias batrachus in cage culture systems. Similar results were observed in our study, where the average weight of Clarias batrachus reared with artificial feeding was 156.40 ± 10.85 grams, compared to 97.27 ± 24.59 grams for fish in natural feed cages after 180 days of culture. This suggests that cage-based cultivation of Clarias batrachus has the potential to enhance socioeconomic sustainability for rural populations, as successful cultivation can improve income and food security.

The increasing popularity of Clarias batrachus in intensive cage culture systems is primarily due to its ease of cultivation; unlike many other aquaculture species, it does not require additional conditioning or growth supplements. To establish a sustainable culture system, it is essential to raise fry to fingerlings within cages before stocking them into the main culture ponds. Consequently, extensive testing and validation of this cage culture technology are necessary to optimize practices and ensure its viability for broader adoption.

Water Quality

To evaluate the potential influence of cage culture on the surrounding aquatic environment, key water quality parameters were monitored on a monthly basis throughout the experimental period. The assessment encompassed physical variables such as water temperature, pH, and transparency, as well as chemical parameters including dissolved oxygen (DO), free carbon dioxide (CO_2), chloride, total alkalinity, total hardness, calcium, and magnesium concentrations. All measured parameters remained within the optimal ranges recommended for sustainable fish culture. The mean values along with their corresponding standard deviations (±SD) for each treatment group are detailed in Table 3.

Conclusion

The results of this research indicate that Marathwada possesses promising potential for establishing cage culture, representing the first initiative of its kind in the state. Conducting training sessions and workshops on fabricating cage structures from locally sourced materials can help lower construction costs and generate employment opportunities. To encourage wider acceptance of cage culture practices, it is important to implement more grassroots extension programs, as many fishermen and local entrepreneurs in the area are currently unfamiliar with this concept. Additionally, water bodies in Marathwada could be effectively utilized to expand and promote cage culture activities, supporting sustainable aquaculture growth in the region.

Acknowledgement

Author extends sincere thanks to the UGC, New Delhi, for the financial support received through the RGNF, which was instrumental in facilitating this research. The author also wishes to express profound gratitude to Dr. A.N. Kulkarni, Ex. Head of the Department of Fishery Science and Principal of N.E.S. Science College, Nanded, for his expert guidance, steadfast support, and the provision of necessary research facilities throughout the duration of the study.

Fig. Clarias batrachus after harvesting from cage culture.

Table Analyzed	One-way ANOVA data
Column B	Artificial Feed
vs.	vs.
Column A	Natural Feed
Unpaired t test with Welch's correction	
P value	< 0.0001
P value summary	****
Significantly different? (P < 0.05)	Yes
One- or two-tailed P value?	Two-tailed
Welch-corrected t, df	t=8.523 df=115.3
How big is the difference?	
Mean ± SEM of column A	21.96 ± 0.2409, n=79
Mean ± SEM of column B	24.26 ± 0.1213, n=81
Difference between means	2.299 ± 0.2697
95% confidence interval	1.764 to 2.833
R squared	0.3864
F test to compare variances	
F,DFn, Dfd	3.847, 78, 80
P value	< 0.0001
P value summary	****
Significantly different? (P < 0.05)	Yes

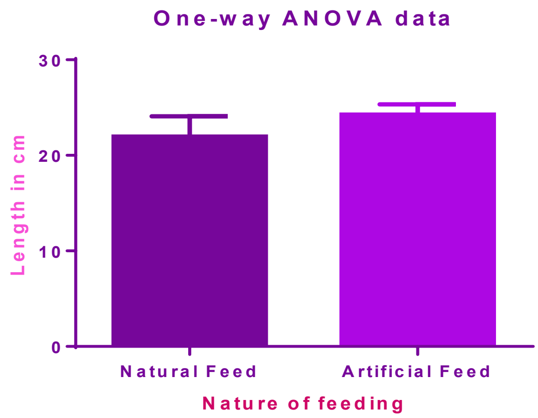

Fig. 1 t test with Welch's correction for Length of *Clarias batrachus* (Cage culture)

Table Analyzed	One-way ANOVA data
Column B	Artificial Feed
vs.	vs.
Column A	Natural Feed
Unpaired t test with Welch's correction	
P value	< 0.0001
P value summary	****
Significantly different? (P < 0.05)	Yes
One- or two-tailed P value?	Two-tailed
Welch-corrected t, df	t=19.59 df=106.7
How big is the difference?	
Mean ± SEM of column A	97.28 ± 2.767, n=79
Mean ± SEM of column B	156.4 ± 1.206, n=81
Difference between means	59.13 ± 3.019
95% confidence interval	53.14 to 65.11
R squared	0.7824
F test to compare variances	
F,DFn, Dfd	5.134, 78, 80
P value	< 0.0001
P value summary	****
Significantly different? (P < 0.05)	Yes

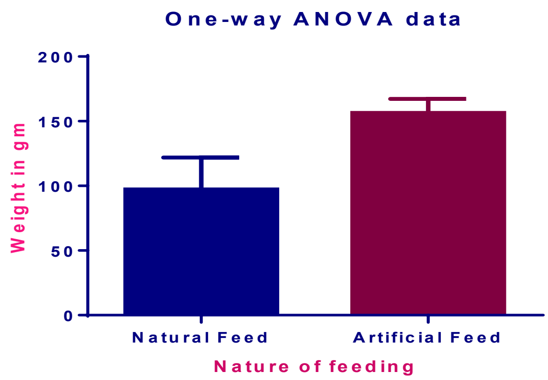

Fig. 1.1 t test with Welch's correction for Weight of *Clarias batrachus* (Cage culture)

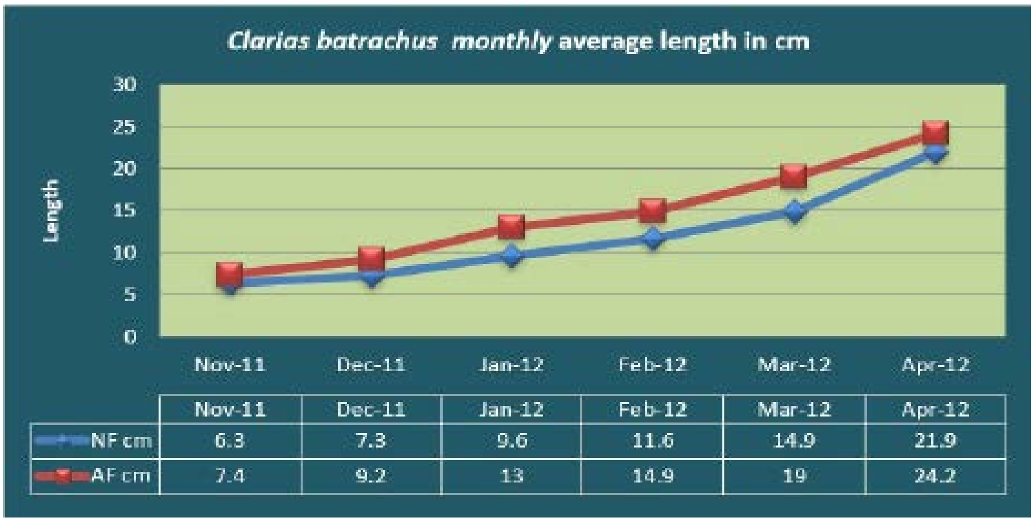

Fig. 2. Monthly Mean Length of Clarias batrachus Cultured in Cages

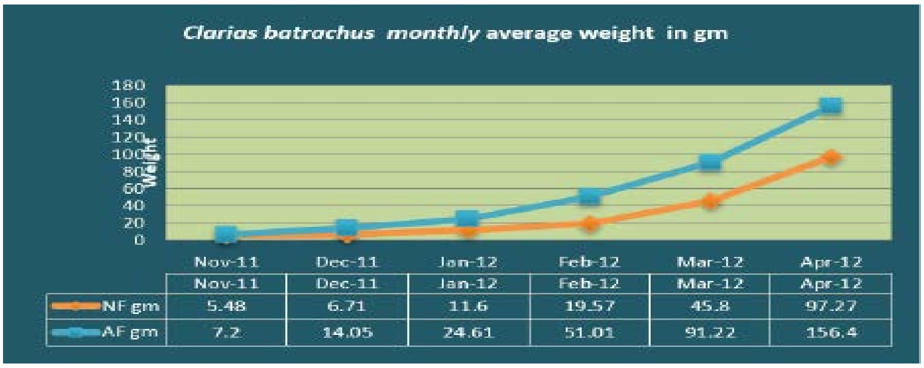

Fig. 2.1. Monthly Mean weight of Clarias batrachus Cultured in Cage.

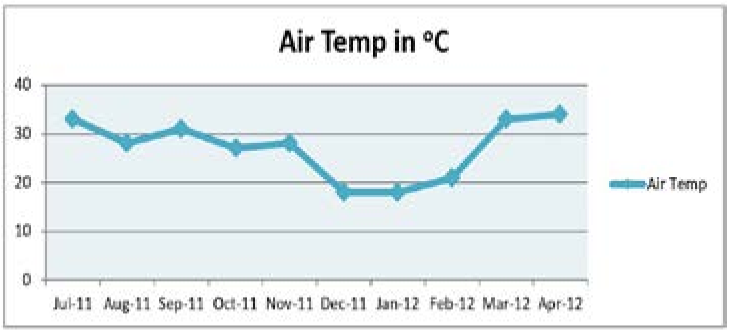

Fig. 3. pH of river Godavari at Dhangar Takli from July 2011 - April 2012.

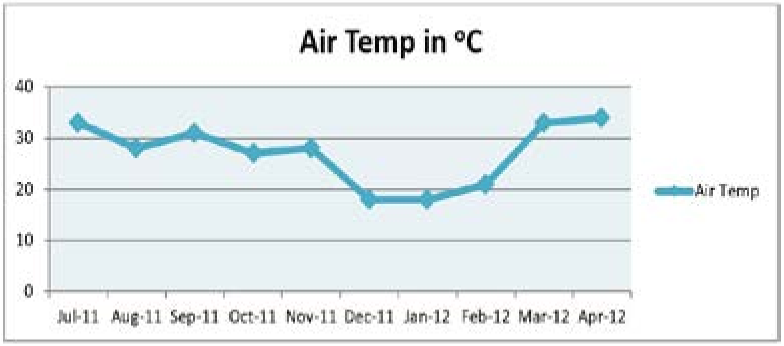

Fig. 4. Air Temperature of river Godavari at Dhangar Takli from July 2011 - April-2012.

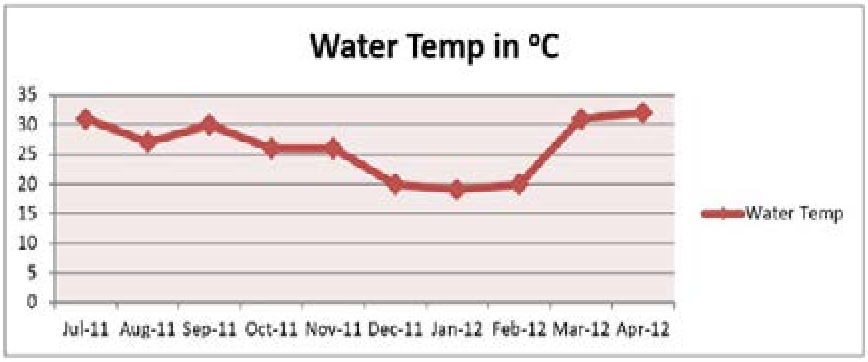

Fig. 4.1. Water Temperature of river Godavari at Dhangar Takli form July 2011- April 2012.

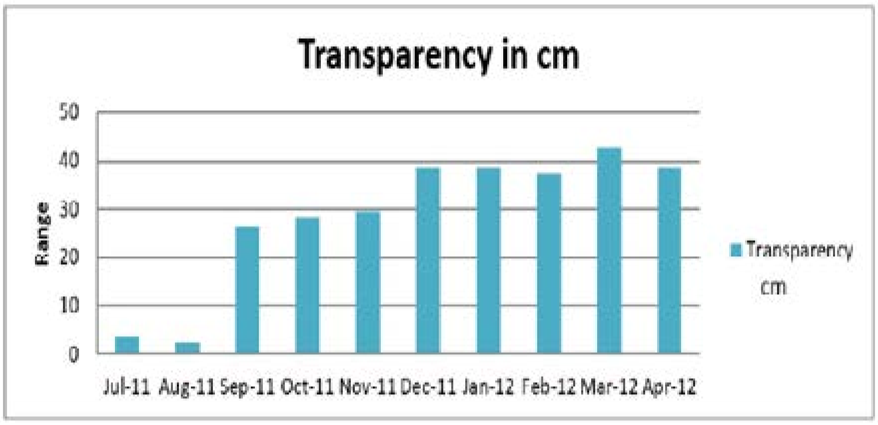

Fig. 5. Transparency (cm) of river Godavari at Dhangar Takli from July 2011 - April 2012.

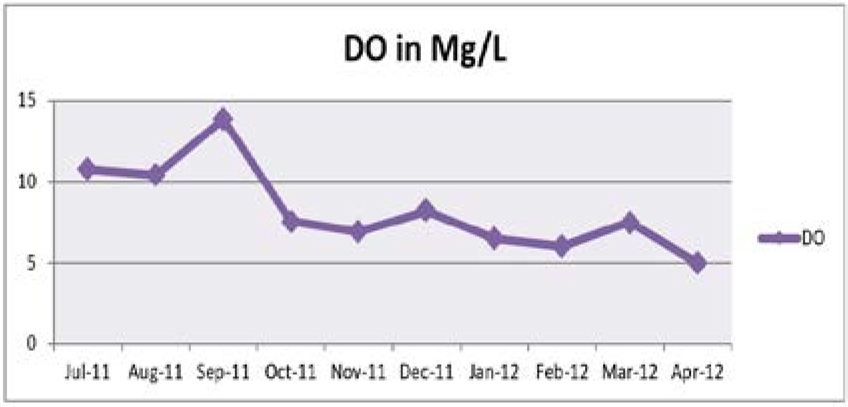

Fig 6. DO (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

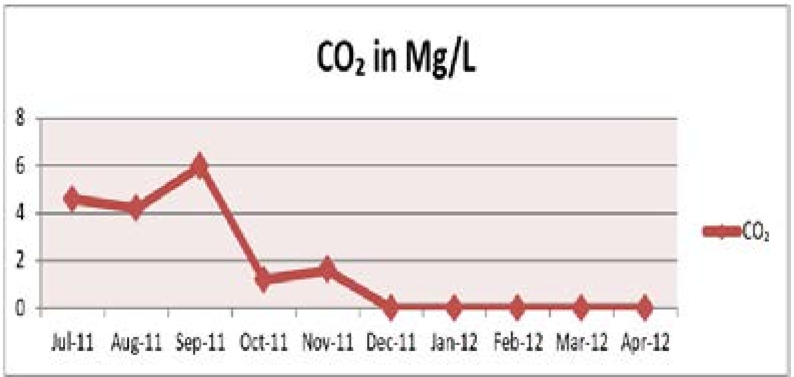

Fig 7. CO_2 (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

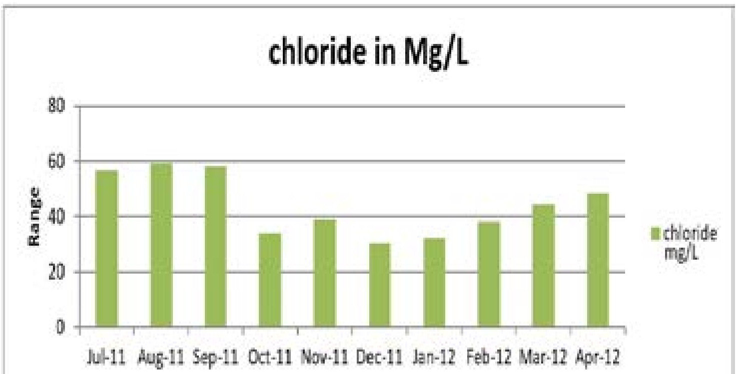

Fig. 8. Chloride (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

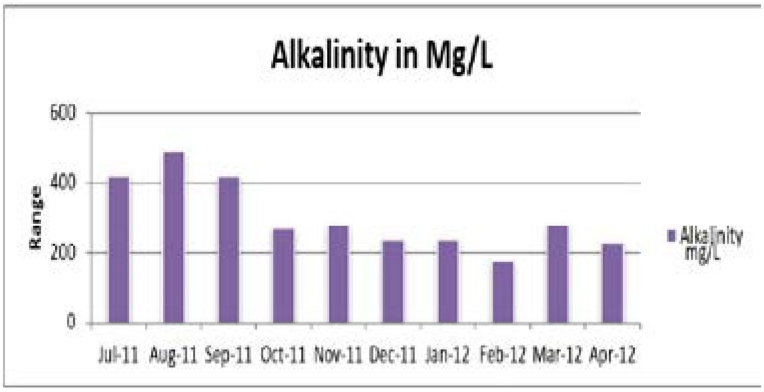

Fig 9. Alkalinity (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

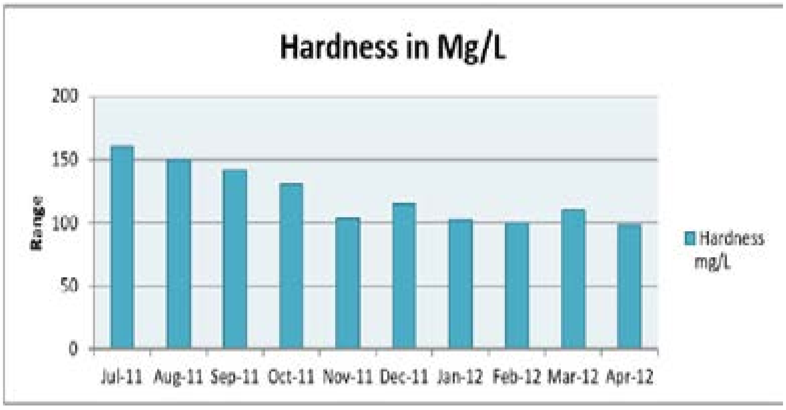

Fig 10. Hardness (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

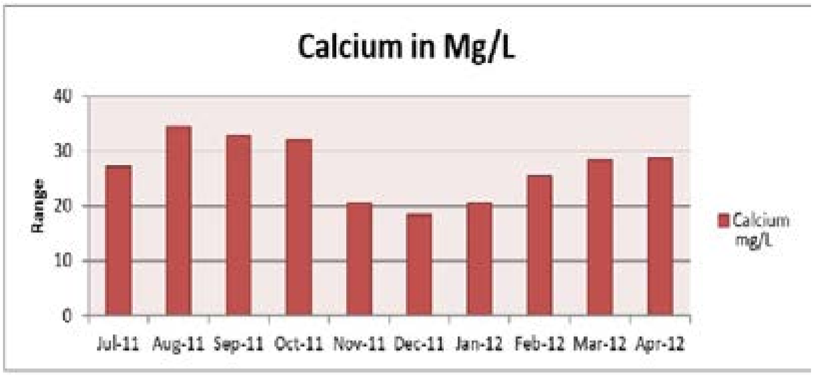

Fig 11. Calcium (mg/L) of river Godavari at Dhangar Takli from July 2011- April – 2012.

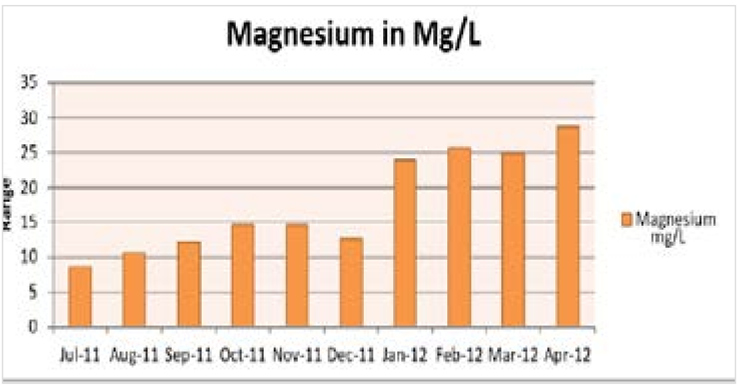

Fig 12. Magnesium (mg/L) of river Godavari at Dhangar Takli from July 2011-April 2012.

Fig 13. Productivity (mg/L/hr) of river Godavari at Dhangar Takli from July 2011- April 2012.

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