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ALLOMETRY STUDY OF EIGHT FISH SPECIES OF ANAND AND KHEDA DISTRICTS OF GUJARAT IN INDIA DURING SUMMER SEASON

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ABSTRACT
The allometry study of eight fish species available in the districts of Anand and Kheda of the state of Gujarat in India are carried out during the summer season. The eight fish species are *Barbus stigma*, *Cirrhinus mrigala*, *Labio rohita*, *Ophiocephalus punctatus*, *Amblypharyngodan mola*, *Oreochomis mossambicus*, *Thryssa setirostris* and *Harpadon nehereus*. The months covered for the summer season are March, April and May. The four years, 2014 to 2017, data collection was done for the study. Along with allometry study, physico-chemical parameters like pH, dissolved oxygen, total dissolved solid and water temperature of the waters are measured. The study showed that *Oreochomis mossambicus* is the fish species to have good yield and wellness during the summer season of the region.

KEYWORDS: Allometry, eight fish species, Anand and Kheda districts, physico-chemical parameters.

INTRODUCTION

The countries having natural water resources can foster up their economy with contribution from the fish farming or pisciculture. The farming involves raising fish commercially in enclosures or tanks for food. The demand for fish and fish protein is increasing with each passing days. The 2016 Report of the Food and Agriculture Organization (FAO) of the United Nations, states that China contributes nearly 62% of the world's farmed fish. In this context it becomes very imperative to know the best means of fish farming. One of the techniques to assess the wellbeing of live fish and to estimate the yield is the method of allometry (Moslen *et al*., 2018). This method can also be used to provide the best capture time for maximum biomass yield of a particular species in its life span in the existing habitat.

The allometric length-weight relation (LWR) in fisheries helps in yield assessment (Gracia *et al.*, 1998) as well as in predicting the biomass of the livestock (Martin-Smith, 1996). The LWR information can provide stock estimation as well as in system modeling of ecology for yield maximization (Christensen *et al.*, 2004). The observational enumeration of underwater fish length is easy through moving boat leading to the estimation of the weight based on LWR thus realizing the fish harvest. The conversion of the length-weight parameters using LWR helps in estimating reap for a specific fish species. This estimation can help in morphometric comparison between species and their populations thus helping in selection of best yield giving species (Goncalves *et al.*, 1997; King, 1996). The length (L) and weight (W) of a fish is related by an expression $W = aL^b$.

The magnitude of the exponent *b* provides the information of the fish growth. When *b* is equal to 3 the relationship is said to be isometric and the two parameters, length (L) and weight (W) of fish, scale proportionately with each other without depending on absolute size. If *b* is other than 3 the relationship between length (L) and weight (W) of fish is said to be allometric and the parameters scales non-linearly with one another. If the value of *b* is greater than 3 it is known as positive allometry and if the value of *b* is less than 3 it is known as negative allometry. In positive allometry the parameters scale non-linearly, one parameter's growth is more compared to another. The negative allometry also has non-linear parameter scaling with one of the parameter growth is less compared to another (Evagelopoulos *et al.*, 2017). The other parameter *a* in the equation is the coefficient term.

The authors did study of LWR of eight fish species available in the central region of the western Indian state of Gujarat. The study covered two mid of Gujarat state located districts, Anand and Kheda. Both the districts have natural water resources in the form of rivers, ponds, lakes, sea coastline, etc. as well as man-made canals and artificial fishing ponds. These water resources provide sufficient opportunity for fish farming. Also the water adequacy in these water bodies remains sufficient all throughout the year making it possible the supply of fish without any hindrance all the year around. The eight fish species studied were collected during the summer months of March, April and May. The

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duration of the study was from 2014 to 2017 meaning four consecutive years. The authors aim is to determine the allometry parameters of the common fish species available in the two districts during the summer season. This allometry study leads to decide the best fish species suitable for rearing during the summer season in the two districts. The four years recorded allometry data have been mixed and the most scattered data are discarded from the study.

MATERIALS AND METHODS

The samples belonging to the eight fish species are collected from the sellers of the local markets of the Anand and Kheda districts, **Figure 1**. The fish supply to the local markets are from the native fresh water lakes and ponds situated in the villages like Samarkha, Bakrol, Jhol, Napa, Sarsa, Karamsad, Porda, etc. The catchment area also covers the Mahi, Vatrak, Khari, etc. rivers and its irrigation canals. In the present study, samples are also collected from Khambat coastline (coastal fish landing zone), Gujarat. The fish samples are collected at the catch sites (water sources) to make the authors convenient to record on-the-spot physico-chemical water data. The fish catch are done by cast nets and trap nets in the fresh water bodies, whereas shore seines stake technique are employed at the sea coast. The authors tried to collect fish species samples of length less than 25 cm, though this selection criterion was not rigid. This criterion was followed for the ease of sample handling and data collection.

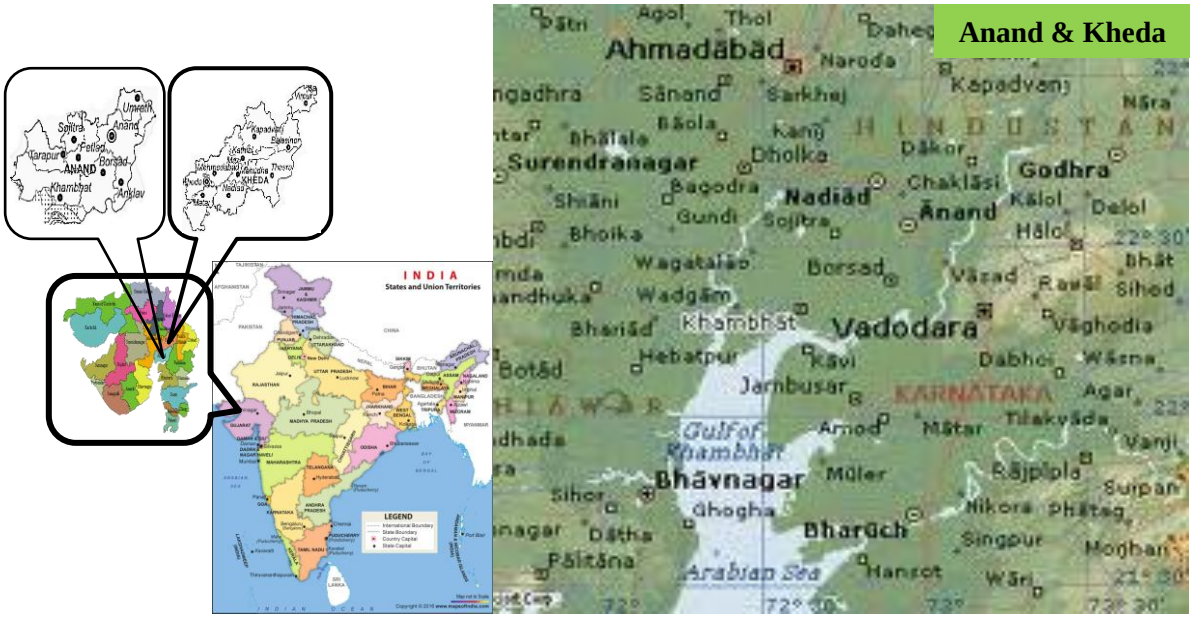

Figure 1 TheAnand and Kheda districts in the state of Gujarat in western India.

At the fish collection sites the physico-chemical water parameters like pH, dissolved oxygen (DO), total dissolved solid (TDS) and water temperature are measured. The pH, DO and TDS measurements are done employing handy Deluxe Water and Soil Analysis Kit, Model: LT – 60 [Labtronics, Panchkula, Haryana, India]. The water temperature measurement is done by employing 1.5V battery operated LCD portable digital Multi-Stem thermometer with external sensing probe [Model: ST-9283B, Resolution: 0.1°C, Accuracy: ±1°C].

The raw data for allometry study of the fishes are taken by measuring the lengths and weights of each sample. The least count of the measuring geometric ruler used for length measurement is 0.5 mm. The weight is measured employing two electronic weighing machines. Small fishes having weight below 50 gm are weighed by Reptech Weighing Machine, Model: RA – 50 (Weighing Capacity: Maximum – 50 gm; Minimum – 0.1 gm; Error – 0.001 gm). The fishes having weight above 50 gm are weighed by using Scale Tec (Make: Citizen Weighing System; Capacity: Maximum – 5 Kg, Minimum – 10 gm; Error – 0.5 gm) weighing machine.

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The relationship between length L- weight W is estimated by using the expression of power law equation (Jin *et al.*, 2015);

$$W = aL^b \quad (1)$$

The variation of measured L and W being large and to express the above equation in the straight line form so that solving the equation becomes easy is to take logarithm of the equation. Taking natural logarithm of the above expression gives the form;

$$\log W = \log a + b\log L \quad (2)$$

Here W is the total body weight, L is the standard length of the fish specimens, *a* is the intercept and *b* is the slope (power coefficient of weight dependent on length function). The equation (2) is intrinsically linear of the straight line form.

The graphs of logL versus logW are plotted for each fish species to determine its corresponding allometric parameters *a* and *b* values. The accuracy of the determined parameters *a* and *b* depends on the linear regression analysis (least square method) on log transformed data. Effort is made to make the values of the regression (r^2) near to unity so that the determined parameters are to the optimum accurate values.

The authors also determined the predicted weights (PW) of each individual fish samples. This PW calculation for each samples of different species are done by utilizing the determined parameters *a* and *b* of that respective species. The PW of the individual fish samples are estimated using the formulas;

$$a + b\times\log L = \log W \quad (3)$$

$$10^{\log W} = \text{Predicted weight} \quad (4)$$

Here L is the actual measured length of the fish whose predicted weight is to be determined and is denoted by PW. The predicted weights (PW) are then compared with the actual weights (AW) of the respective species. This comparison of the AW with PW is done to substantiate the author's correctness of the existing allometry analysis.

The condition factor which gives the degree of well-being of the fish in their existing habitat is determined by the equation (Gomeiro *et al.*, 2005).

$$K = 100W/L^b \quad (5)$$

Where K is the condition factor, W is the actual weight of the fish in gm, L is the standard length of the fish in cm and *b* is the exponential value obtained from the plot of equation (2). The exponent *b* value that is equal to 3 was not used to calculate the K value. Bolger and Connolly (1998) claimed that for *b* equal to 3 is not a real representation of length-weight relationship for greater majority of fish species, thus K is not determined for the value equal to 3 (Lima-Junior *et al.*, 2002). The value of K greater than unity states good wellness, less than unity states poor health.

In the present study all the allometry analysis of the fish samples are done by using the raw data employing computer programming. Firstly all the fish raw data are entered into the computer and transformed into its logarithm values by Microsoft Excel software. Using the logarithmic values of the different lengths and their corresponding weight the Log-Log graphs are drawn by employing Microsoft Origin version 6.0. The values of parameters *a*, *b* and r^2 are determined. The PW of each fish samples are determined in Excel using the obtained allometry parameters. Using Microsoft Origin software version 6.0 the graphs of length L versus actual (AW) - predicted weight (PW) plots are drawn.

RESULTS AND DISCUSSION:

In total 319 fish samples belonging to eight fish species from two different water bodies, fresh water and estuarine water, are sampled for the present study. Local limitations of obtaining adequate number of fish samples forced the authors to study only those fish species easily available in the local markets. The present study is conducted for four

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consecutive years, thus the samples that are uninterruptedly available in the studied period of 2014 to 2017 during the summer seasons are covered. The graphs of Log-Log values of L-W relationship are shown in the **Figures 2(a–h)**. The regression values of r^2 are tried to be kept near to unity to obtain the accurate *a* and *b* values.

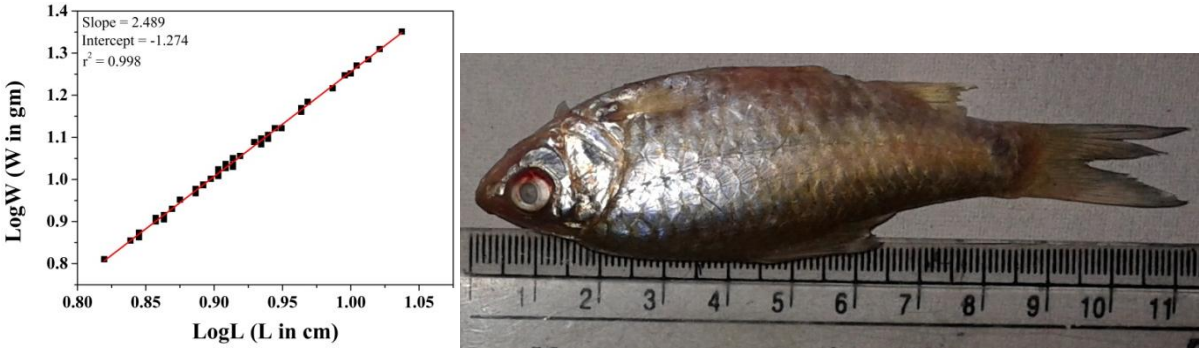

Figure 2(a) The plot of LogL versus LogW and photograph of *Barbus stigma*.

Figure 2(b) The plot of LogL versus LogW and photograph of *Cirrhinus mrigala*.

Figure 2(c) The plot of LogL versus LogW and photograph of *Labio rohita*.

Figure 2(d) The plot of LogL versus LogW and photograph of *Ophiocephalus punctatus*.

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Figure 2(e) The plot of LogL versus LogW and photograph of *Amblypharyngodan mola*.

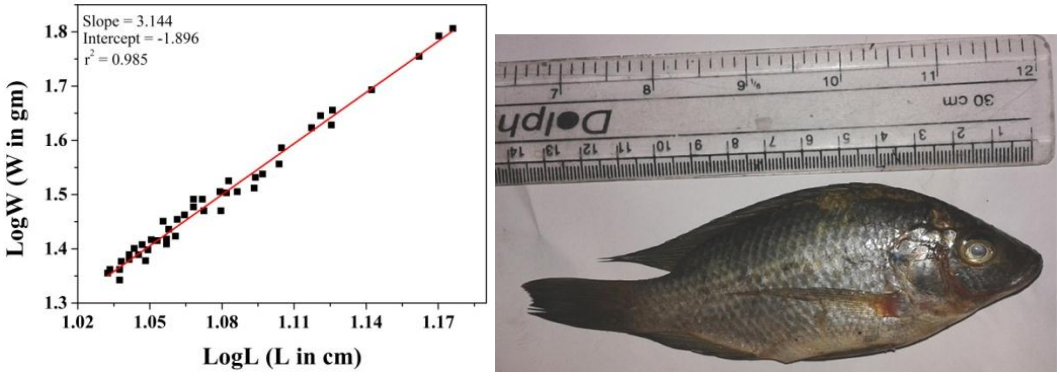

Figure 2(f) The plot of LogL versus LogW and photograph of *Oreochomis mossambicus*.

Figure 2(g) The plot of LogL versus LogW and photograph of *Thryssa setiroshtris*.

Figure 2(h) The plot of LogL versus LogW and photograph of *Harpadon nehereus*.

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The obtained regression data from the plots are tabulated in Table – 1. Based on the values of the parameters *b*, the growth types G of fish species are determined [7]. The growth types G is also tabulated in the Table – 1.

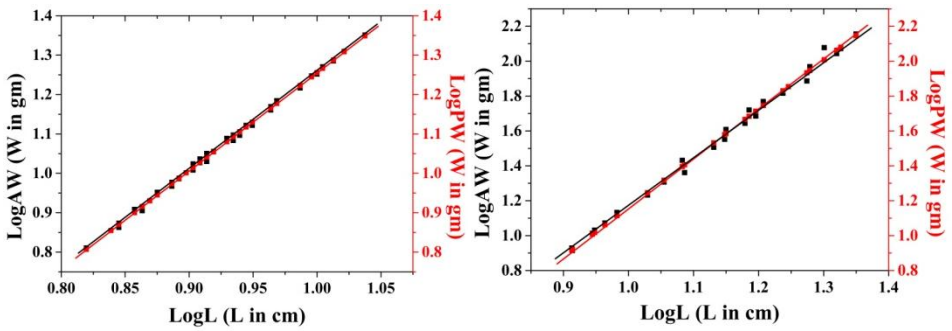
Table – 1 The standard length-weight (LWR) data for evaluated eight fish species of Anand and Kheda districts of Gujarat. Here n is the sample size; *a* and *b* are the parameters of the LWR; S.E. is the standard error of *b*; r^2 is the regression coefficient; G is the type of growth (I - Isometry, P - Positive allometry, N - Negative allometry).

Sr. No.	Species	Samples size (n)	Parameters of the relationship				Growth G	K
			a	*b*	r^2	S.E. in b		
1	*Barbus stigma*	46	-1.274	2.489	0.951	0.0016	N	0.88
2	*Cirrhinus mrigala*	36	-1.644	2.807	0.995	0.039	N	0.24
3	*Labio rohita*	43	-1.792	2.794	0.998	0.164	N	1.68
4	*Ophiocephalus punctatus*	39	-2.169	2.899	0.999	0.050	I	1
5	*Amblypharyngodan mola*	33	-1.831	2.006	0.997	0.048	N	1.21
6	*Oreochomis mossambicus*	44	-1.896	3.144	0.985	0.061	P	1.21
7	*Thryssa setirostris*	35	-2.003	2.981	0.991	0.047	I	1
8	*Harpadon nehereus*	43	-3.129	3.655	0.993	0.097	P	0.38

The analysis of data of Table – 1 show that out of eight fish species studied in the summer season of the months of March, April and May of the years 2014 to 2017; two fish species follow positive allometry; two species showed isometry and remaining four species showed negative allometry. The positive allometry showing fish species are *Oreochomis mossambicus* and *Harpadon nehereus*. The isometry showing fishes are *Ophiocephalus punctatus* and *Thryssa setirostris*.

***Comparison of actual weight (AW) and statistically derived predicted weight (PW)*:**

The graphs of standard length L versus actual weight (AW) and predicted weight (PW) of each studied fishes are shown in **Figure 3(a – h)**. The PW of each fish samples belonging to eight species are determined using equation (4). In the PW determination the respective species parameters, *a* and *b* values, obtained from the Log-Log LWR graphs of the respective species are used.



(a) *Barbus stigma* **(b)** *Cirrhinus mrigala*

Figure 3(a, b) The plots of length (L) versus actual weight (AW) and predicted weight (PW) of (a) *Barbus stigma* and (b) *Cirrhinus mrigala*.

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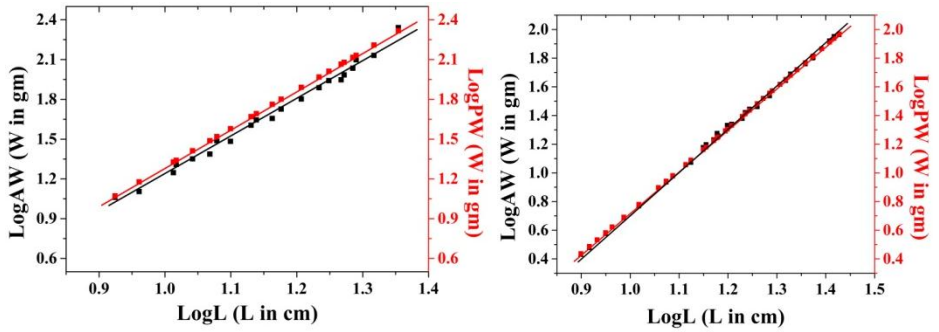
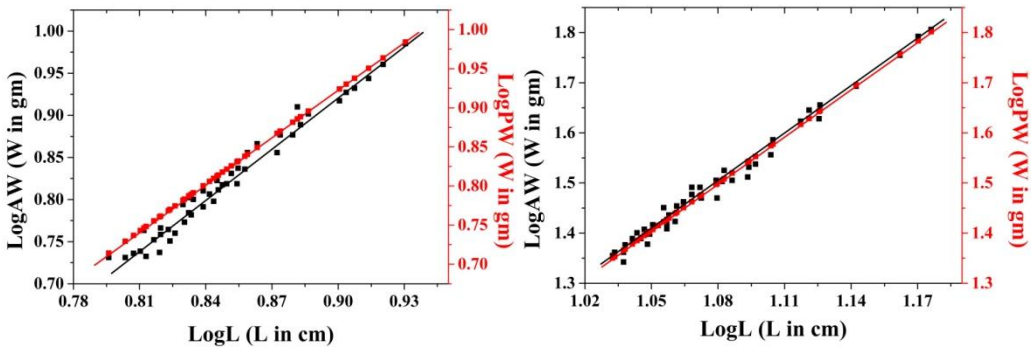


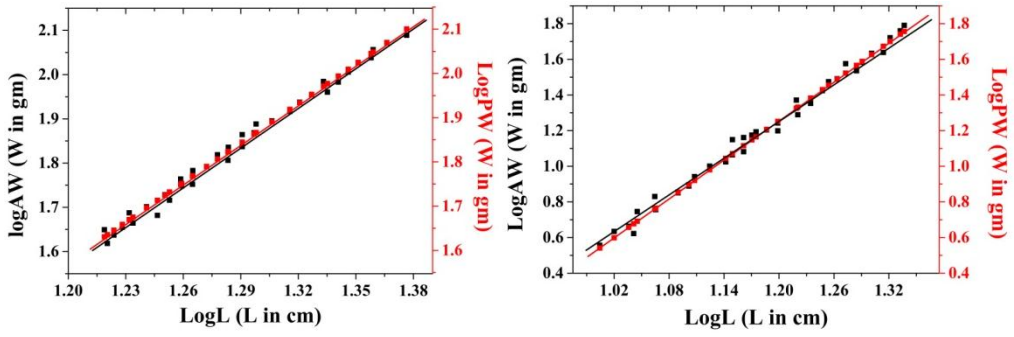
(c) *Labio rohita* **(d)** *Ophiocephalus punctatus*

Figure 3(c, d) The plots of length (L) versus actual weight (AW) and predicted weight (PW) of (c) *Labio rohita* and (d) *Ophiocephalus punctatus*.



(e) *Amblypharyngodan mola* **(f)** *Oreochomis mossambicus*

Figure 3(e, f) The plots of length (L) versus actual weight (AW) and predicted weight (PW) of (e) *Amblypharyngodon mola* and (f) *Oreochomis mossambicus*.



(g) *Thryssa setirostris* **(h)** *Harpadon nehereus*

Figure 3(g, h) The plots of length (L) versus actual weight (AW) and predicted weight (PW) of (g) *Thryssa setirostris* and (h) *Harpadon nehereus*.

The standard length L versus actual weight AW-predicted weight PW for *Barbus stigma* [**Figure 3(a)**], *Cirrhinus mrigala* [**Figure 3(b)**], *Ophiocephalus punctatus* [**Figure 3(d)**], *Oreochomis mossambicus* [**Figure 3(f)**] and *Thryssa setirostris* [**Figure 3(g)**] showed that both the weights are in good match with each other. Similarly the L versus AW-PW plots for fish species *Labio rohita* [**Figure 3(c)**], *Amblypharyngodan mola* [**Figure 3(e)**] and *Harpadon nehereus* [**Figure 3(h)**] showed slight deviations between the AWs and PWs, the variation being minor states both the values are in near agreement with each others. These observations of good match and near agreement with each other states that

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the allometry data, Table 1, determined from the Log-Log LWR plots are accurate for the eight fish species. These further states that the determined parameters like the types of growth and condition factors are also perfect.

The condition factor K values of each fish species are determined using equation (5). The determined K values are tabulated in Table – 1. Literature states K value greater than unity assert good health and less than unity affirms bad health. The K values of the studied eight fish species states that the wellness is best in case of *Labio rohita* followed by good wellness in case of *Amblypharngodan mola* and *Oreochomis mossambicus*. The two species of *Ophiocephalus punctatus* and *Thryssa setirostris* showed isometric growth and thus have unit value of K. The other species like *Barbus stigma*, *Cirrhinus mrigala* and *Harpadon nehereus* showed appalling wellness. Thus from the K values it can be concluded that summer season of Anand and Kheda districts are best suited for *Labio rohita* followed by *Amblypharngodan mola* and *Oreochomis mossambicus*. But along with K value if allometry growth is taken into consideration than *Oreochomis mossambicus* showed positive allometry also, thus is the best species for cultivation and getting best yield during summer season condition.

***Physico-chemical analysis of water samples*:**
The physico-chemical analysis of the water samples are carried out at the spot of fish catching sites. The obtained data are tabulated in Table 2. Each parameter is shown by a variation range. The range means data variations observed at different sites as well as variation of data for the four years, 2014 to 2017.

Table – 2 The physico-chemical data of water samples during summer season.

Water bodies	pH	Dissolved oxygen (DO)	Total dissolved solid (TDS)	Temperature
Fresh water	7.2 – 8.3	6.4 – 7.7 mg/l	88 – 220 mg/l	28.3 – 34.2°C
Estuarine	7.9 – 8.7	6.6 – 8.1 mg/l	109 – 370 mg/l	27.2 – 32.1°C

The analysis of the physico-chemical data recorded for the districts of Anand and Kheda of the state of Gujarat during the summer season, Table – 1, shows that the pH values are in alkaline range for both the types of water bodies, fresh and estuarine. The value is a little more in case of estuarine (Gulf of Khambat) compared to fresh water stating alkalinity is more of estuarine water; this may be due to salty water from the sea making it more alkaline. Literature states the alkaline water condition is always favorable for growth of life (Shinde *et al.*, 2007). Thus based on pH values both the waters of the two districts are favorable for fish growth during the summer season.

The data of DO level showed estuarine water has a little more dispersed oxygen compared to fresh water in the season of summer. The more DO in estuarine (Gulf of Khambat) may be due to wind waves leading to natural churning and aeration. Also due to meeting of two major rivers of the state of Gujarat, Sabarmati and Mahi, at the Gulf of Khambat increases dynamics and thus enhances DO level. The minimum required DO for fish survival is 5 mg/l [Svobodova *et al.* 1993; Verheyen *et al.*, 1994). In the present study involving two districts of Anand and Kheda of the Gujarat state, the fresh and estuarine water bodies possesses the DO values well above the minimum stating good for fish growth during the summer season.

The TDS meaning dissolved content of the organic and inorganic matters in the analyzed water, either in its molecular, ionized or suspended colloidal forms. Literature states the standard limit of TDS acceptable by fish fauna is 500 mg/l (Boyd 1999; Suman *et al.*, 2017). The observed data of TDS for the two types of water bodies of the districts of Anand and Kheda in the state of Gujarat, Table – 1, is well below the limit thus suiting the growth of fish during summer season.

The measured temperature values showed that the fresh water bodies have more temperature than the estuarine water. This may be due to dynamic condition of estuarine water compared to still condition in fresh water. The measured temperature data of the fresh water flowing in canal had less temperatures compared to the fresh still waters of lakes, ponds, etc. The average temperature data of fresh water is than too greater than estuarine water. The ideal temperature

range reported for wellness of fishes is 20 to 30°C (Azevedo *et al.*, 1998). In present study the temperatures are found to be much more than the ideal values. Fishes are cold blooded vertebrates and can adjust to ecological temperature. Thus the present temperature ranges recorded for fresh and estuarine waters are suitable for the fishes during summer season.

CONCLUSIONS

The allometry study of the fish species found in Anand and Kheda districts of Gujarat are carried out. The eight fish species studied are *Barbus stigma*, *Cirrhinus mrigala*, *Labio rohita*, *Ophiocephalus punctatus*, *Amblypharyngodan mola*, *Oreochomis mossambicus*, *Thryssa setirostris* and *Harpadon nehereus*. The study was carried out during the months of summer season comprising of months of March, April and May. The duration of the study was four years during 2014 to 2017.

The allometry study showed two fish species, *Oreochomis mossambicus* and *Harpadon nehereus* showed positive allometry, whereas two species *Ophiocephalus punctatus* and *Thryssa setirostris* showed isometry. Other species like *Barbus stigma*, *Cirrhinus mrigala*, *Ophiocephalus punctatus* and *Amplypharyngodan mola* showed negative allometry. The predicted weight nearly matched with the actual weight in case of all studied fish species substantiating the obtained allometry data is accurate. The condition factor K values of the eight fish species showed that the wellness is best in case of *Labio rohita* followed by good wellness in case of *Amblypharngodan mola* and *Oreochomis mossambicus*. Along with K value, if allometry growth is taken into consideration than only *Oreochomis mossambicus* showed positive allometry and good wellness. Thus the best species for cultivation and getting best biomass yield during summer season condition is *Oreochomis mossambicus* in the eco condition of districts of Anand and Kheda.

The physico-chemical parameters of the water sample of the two districts of the fish catch water bodies during summer season showed pH to be alkaline in nature as well as the DO and the TDS ranges favorable for the studied fish species growth. The water temperature range was a little on higher side, but fishes being cold blooded can adjust to temperature variation. The general conclusion drawn from the study of the allometry and the physico-chemical parameters of the fish catch water bodies of the districts of Anand and Kheda in Gujarat is that the fish species *Oreochomis mossambicus* possess positive allometry and good wellness, thus making the species suitable for harvesting during the summer season.

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