Length-Weight Relationship and Condition Factor of a Threatened Climbing Perch (*Anabas testudineus*) from Arrah (Bihar), India during Non-Breeding Season

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Abstract
The purpose of this study was to calculate the length-weight relationship as well as the condition factor of a threatened freshwater climbing perch, *Anabas testudineus* (total length: 5-18cm; body weight: 12-58g) from Arrah (Bihar), India to assess the importance of allometric factor and well-being. From September 2022 to March 2023, a total of 458 fish specimens were collected for this purpose. For the total fish, the length-weight relationship was calculated as y = 3.610x - 5.619 (logy = 1.836 logx - 0.430) with coefficient determination = 0.914. This indicates that the species' growth is negative allometric and a statistically significant correlation (r) was calculated between the length and weight of the sampled fish. The coefficient determination (R^2) ranges from 24-97% (r= 0.488-0.986) indicating a proper growth pattern. Fulton's condition factor values ranged from 1.346 to 3.613 indicating that the fish was in good health. The average values of condition factor (K) of 2.00 and relative condition factor (K') of 0.999 indicate that its habitat is in good condition. This study is useful in providing pertinent information for understanding fish biology, estimating fish conditions in its environment and assessing population dynamic parameters.

Keywords: *Anabas testudineus*, Length-weight relationship, Condition factor, Relative condition factor, Arrah (Bihar), India.

INTRODUCTION

The relationship between fish length and weight is a useful index for understanding growth, survival, maturity, reproduction and general well-being.It allows for the conversion of one variable to another, which is critical in fish culture (Le-Cren 1951, Primavera *et al.*, 1998). It can change as a result of life events like metamorphosis, growth and the onset of maturity.

Knowing the length-weight relationship in fishery science reveals the poundage of fish caught and the measure of produce from data on the number and size of fish, as well as assisting in the easy assessment of growth rate, the appearance of first maturity, time of spawning, stock variation status, growth dynamics, the general well-being of fishes etc. (Beverton and Holt 1957).

The condition of a fish reflects the most recent biological and physical circumstances, and it varies as feeding conditions, pathogen infestations, body physiology, and other environmental factors change. The condition factor (K) indicates the population's well-being at various life cycle stages, and assessments of fish condition based on weight at a given length are thought to be reliable indicators of energetic condition or energy reservesof fish (Lambert and Dutil, 1997).

'Condition', 'fatness' or relative condition factor of fish expressed by K_n, is an index used to monitor feeding intensity and growth rate (Oni et al., 1983) and is based on the hypothesis that heavier fish for a given length are in better condition (Bagenal and Tesch, 1978). A 'K_n' value of more than one indicates that the fish is in better health condition (Le Cren 1951).

Several researchers have investigated the length-weight relationship in various fish species from various habitats (Subba and Ghosh, 2000; Muchlisin *et al.*, 2010; Rahaman *et al.*, 2015; Guilin *et al.*,2019; Augustina *et al.*, 2022). Though many freshwater fish species have been studied in terms of length-weight relationship, there is a lack of recent information on air-breathing fishes from Bihar (Devraj 1973)

Anabas testudineus (Bloch 1792), also known as the omnivorous obligate air-breathing threatened climbing perch (Kumar *et al.*, 2013; Ndobe *et al.*, 2019), is a popular freshwater fish in South and Southeast Asia. Because of its high levels of DHA and EPA (Mohanty *et al.*, 2016), high protein content, high ω-3 content, and high ω-3/ ω-6 ratio (Mohanty *et al.*, 2019), it is becoming more widely recognised as a species with neutraceutical potential. In addition, as predators of mosquito larvae, climbing perch can be effective in mosquito control (Bhattacharjee *et al.*, 2009).

MATERIALS AND METHODS

Fortnightly, specimens of *Anabas testudineus* (body weight: 10-60g; total length: 6-16cm) of various age groups were randomly collected were collected from the local markets of Arrah (N 25° 35' 0.096", E 84° 7' 47.5212") from September 2022 to March 2023. The total length of the fish nearest to 0.1mm was measured using a scale (cm), while weight was determined as total weight (W) using a digital balance.

The length-weight (log-transformed) relationship of the fish (n = 458, female = 227, male = 221) was worked out as per the cube law given by Le-Cren (1951). Length-weight relationships were calculated after separating the male and female.

$$W = aL^b$$

$$\text{Or, } \log W = \log a + b \log L$$

Where, W = the weight of the fish, L = observed total length of the fish, *a* = the normalization constant, initial growth index or intercept and *b* = the growth coefficient, scaling exponent or slope.

L_{max}, the length of the longest specimen within the total sample was also measured.

The coefficient of determination (r^2) indicates the validity or goodness of fit of the analysed data and explains the proper fit of the growth model. Covariance analysis was applied to determine variation in 'b' for each species. A function was used to assess the statistical significance of the isometric exponent (b): $t = \frac{b-3}{S_b}$ (Sokal and Rofal 1987), where S_b = the standard error of 'b'. The comparison of the obtained t-test values and the respective critical values allowed the statistically significant 'b' values to be determined and their inclusion in the scaling is isometric (b=3) or allometric (negative allometric; b<3 or positive allometric; b>3).

Fulton's condition factor (K) was calculated using the equation:

$$K = 100 \times \left(\frac{W}{L^3}\right)$$

The relative condition factor (K_n) was estimated by using the following formula:

$$K_n = \frac{\text{Observed weight}}{\text{Caluclated wright}} \text{ or } \frac{W'}{W}$$

The total weight and length of the fish were plotted on scatter plot diagrams. Excel and SPSS will be used for statistical analysis.

RESULTS AND DISCUSSION

Fish length is considered more important than fish age because many ecological and physiological factors are more dependent on length than age. *Anabas testudineus* generally showed negative allometric growth and very rarely isometric or positive allometric growth (Table 4).

The total length (L) of the climbing perches used in this study (n = 458) ranged from 5.0 to 18.0 cm and the body weight (W) ranged from 12.0 to 58.0 g (Table 3). L_{max} was 18.0 cm in the longest specimen (female, weight 57.0 g) (Table 1). The largest male specimen weighed 56.2 g and measured 17.4 cm (Table 2). L_{max} exceeds but falls short of the maximum lengths reported by Shafi and Quddus (1982) and Talwar and Jhingran (2001), which are 22.00 cm and 25.00 cm, respectively. Maximum length is useful for estimating growth parameters, which are required for capital planning and sustainable management in fisheries (Ahmad *et al.*, 2012).

Table 1: Length, weight and regression equation for female *Anabas testudienus* at Arrah (Bihar), India

Sl. No.	Month	No. of specimen (n)	Total length (cm) and its log value	Total weight (g) And its log value	Regression equation	K	K'
1.	September, 2022	33	8.95±2.39 (0.952±0.378)	25.90±9.00 (1.413±0.954)	y = 3.717x –7.353 (R^2 = 0.973)	3.613	0.999
2.	October, 2022	32	11.47±3.61 (1.060±0.557)	27.36±8.54 (1.437±0.931)	y = 5.477x–35.46 (R^2 = 0.946)	1.813	1.000
3.	November, 2022	30	12.78±1.72 (1.106±0.235)	43.92±3.15 (1.642±0.498)	y = 1.711x+22.12 (R^2 = 0.933)	2.104	0.998
4.	December, 2022	32	12.83±2.23 (1.108±0.348)	44.28±3.22 (1.646±0.508)	y = 1.419x+26.07 (R^2 = 0.969)	2.097	1.000
5.	January, 2023	32	14.43±1.03 (1.159±0.013)	50.89±2.39 (1.707±0.378)	y = 2.182x+19.38 (R^2 = 0.876)	1.694	1.000
6.	February, 2023	32	14.49±1.45 (1.161±0.161)	49.92±3.95 (1.698±0.596)	y = 2.472x+14.08 (R^2 = 0.926)	1.641	1.000
7.	March, 2023	30	15.98±1.27 (1.204±0.104)	54.92±1.93 (1.740±0.285)	y = 1.458x+31.61 (R^2 = 0.916)	1.346	1.000
		221	12.86±2.74 (1.110 ±0.438)	42.07±12.07 (1.624±1.082)	y = 3.987x–9.221 (R^2 = 0.819)	1.978	0.999

					logy=1.480logx–0.027 (R^2 = 0.860) (t = 5.20)		

Table 2: Length, weight and regression equation for male *Anabas testudienus* at Arrah (Bihar), India

Sl. No.	Month	Number of specimens (n)	Total length (cm) and its log value	Total weight (g) and its log value	Regression equation	K	K'
1.	September, 2022	31	8.46±2.12 (0.927±0.326)	18.36±5.35 (1.264±0.728)	y = 2.474x – 2.569 (R^2 = 0.962)	3.032	1.000
2.	October, 2022	32	10.13±3.07 (1.001±0.487)	20.00±7.75 (1.301±0.889)	y = 2.462x –4.935 (R^2 = 0.954)	1.923	1.021
3.	November, 2022	28	12.50±1.47 (1.097±0.167)	34.90±1.19 (1.543±0.076)	y = 0.779x+25.22 (R^2 = 0.921)	1.787	1.001
4.	December, 2022	34	12.74±1.82 (1.105±0.260)	41.24±1.20 (1.615±0.079)	y = 2.660x+9.493 (R^2 = 0.956)	1.994	1.052
5.	January, 2023	35	13.62±2.08 (1.134±0.318)	43.38±4.94 (1.637±0.694)	y = 0.616x+46.12 (R^2 = 0.962)	1.644	1.257
6.	February, 2023	32	13.83±1.70 (1.141±0.230)	47.21±4.21 (1.674±0.624)	y = 2.325x+15.03 (R^2 = 0.882)	1.785	0.999
7.	March, 2023	35	14.09±3.58 (1.489±0.554)	54.52±1.45 (1.737±0.161)	y = 0.310x+36.86 (R^2 = 0.866)	1.949	0.756
	Total	237	12.25±3.07 (1.088±0.487)	37.55±13.37 (1.575±1.126)	y = 3.231x–2.046 (R^2 = 0.551) logy=0.835logx+0.597 (R^2 = 0.641) (t = 7.732)	2.043	0.999

A linear relationship between total length and body weight revealed that the fish's weight was directly related to length. The logarithmic transformation of total length and body weight yielded the same result.

Table 3: Length, weight and regression equation for pooled *Anabas testudienus* at Arrah (Bihar), India

Sl. No.	Month	Number of specimens (n)	Total length (cm) and its log value	Total weight (g) and its log value	Regression equation	K	K'
1.	September, 2022	64	8.71±2.26 (0.940±0.354)	22.25±8.32 (1.347±0.920)	y = 3.333x–5.787 (R^2 = 0.819)	3.366	1.045
2.	October, 2022	64	10.80±2.50 (1.033±0.398)	23.68±8.90 (1.374±0.949)	y = 3.231x–11.21 (R^2 = 0.822)	1.879	1.000
3.	November, 2022	58	12.48±1.49 (1.096±0.173)	39.08±4.82 (1.592±0.683)	y = 1.299x+22.85 (R^2 = 0.161)	2.010	0.999
4.	December, 2022	66	13.36±3.07 (1.126±0.487)	42.38±2.46 (1.627±0.391)	y = 0.391x+37.15 (R^2 = 0.238)	1.777	1.281
5.	January, 2023	67	13.56±1.71 (1.132±0.233)	47.03±5.43 (1.672±0.735)	y = 3.019x+6.071 (R^2 = 0.903)	1.886	0.999
6.	February, 2023	64	14.16±1.60 (1.151±0.204)	48.56±4.27 (1.686±0.630)	y = 2.461x+13.70 (R^2 = 0.852)	1.710	0.998
7.	March, 2023	65	14.78±2.04 (1.170±0.310)	54.74±1.67 (1.738±0.223)	y = 0.618x+45.60 (R^2 = 0.866)	1.695	0.999
	Total	458	12.55±2.93 (1.099±0.467)	39.72±12.94 (1.599±1.112)	y = 3.610x–5.619 (R^2 = 0.668) logy=1.836logx-0.430 (R^2 = 0.914) (t = 4.62)	2.009	0.999

Female *Anabas testudineus* mean length and weight were highly correlated and significantly higher (r = 0.9633, p<0.001; t = 30.71, p<0.001) than males. The length-weight relationship equations were obtained through linear regression (Tables 1 and 2):

(A) Simple linear regression equation:
Females (*n* = 237): y = 3.987x–9.221
Males (*n* = 221): y = 3.231x–2.046
Pooled (*n* = 458): y = 3.610x–5.619
(B) Logarithmic linear regression equation:
Females: logy = 1.480logx – 0.026 (t = 5.20; p<0.01) (Table 1; Figure 1)
Males: logy = 0.835logx +0.597 (t = 7.73; p<0.001) (Table 2; Figure 2)
Pooled: logy = 1.836logx – 0.430 (t = 4.62; p<0.01) (Table 3; Figure 3)

The current study's findings are consistent with those reported for *Pampus argenteus* (Rahman *et al.,* 2004) and *Catlacatla* (Zafar *et al.,* 2003).

The allometric co-efficient, b value, in our current study, ranged from 0.835 to 1.836.*Anabas testudineus* exhibited a negative allometric growth pattern, with length growth outpacing weight growth, based on the value of b. Several researchers have reported negative allometric growth patterns of *Anabas testudineus* (Kumar *et al.,* 2013; Mustakim *et al.,* 2019) The work is within the limits reported by Mawa *et al.,* (2021) (2.62-3.34), Froese (2006) (2.50-3.50), and Carlender (1969) (2.00-4.00). Hile (1936) and Martin (1949) discovered that the regression coefficient 'b' typically ranges between 2.5 and 4.0, with an ideal fish maintaining its shape at b = 3.

The presence of mature fish may have influenced the relatively high values of b in this study, particularly for females. Environmental factors can influence *Anabas testudineus* growth patterns (Ernawati *et al.,* 2009, Kumar *et al.,* 2013). The value of b is affected by physiological and environmental conditions such as temperature, pH, salinity, geographical location, and sampling techniques (Jennings *et al.,* 2001), as well as biological conditions such as growth phase, season, abdominal fullness, gonadal maturity, gender, measurement range, and disease (Le Cren 1951; Froese 2006). Other populations have reported higher b values for females than males (Ernawati *et al.,* 2009) and a tendency for adult female *Anabas testudineus* to become both longer and heavier than adult males (Jacob, 2005). Males are heavier than females at first, and reach maturity at slightly shorter lengths, according to the length/weight regression models for males and females; however, once most fish are mature (around 9-10 cm total length), females are heavier than males and grow faster.

The values of the length-weight relation parameters b and L_{max} for *Anabas testudineus* in this and other studies are within the range reported for *Anabas testudineus* populations from other sites and countries (Table 4). However, higher values of b indicating isometric growth patterns have been reported from wild populations in Indonesia (Ernawati *et al.,* 2009) and Thailand (Sidthimunka 1973), as well as cultured climbing perch in Bangladesh (Begum and Minar 2012). In contrast, the observed L_{max} for the Sigi District *A. testudineus* population is low (Table 4). Such a condition may be indicative of a stressed-out population (Lambert 2008). Similar to those reported in (Ndobe *et al.,* 2014), threats observed during sampling included wetland habitat conversion (rice paddies and aquaculture ponds), competition from alien species (introduced as aquaculture commodities), and high fishing pressure (including illegal electric fishing).

Table 4: Reported values of the length-weight parameters and L_{max} for *A. testudineus*at Arrah (Bihar), India and other places

Country	No. of specimens (n)	L_{max} (cm)	$\log_a$	b	R^2	Growth pattern	References
Bangladesh	72	-	-	1.5-3.1	>0.9	A^- to A^+	Begum & Minar, 2012
	-	-	-	2.7- 2.8	-	A^-	Shafi & Mustafa, 1976
Fishbase				2.77		A^-	Froese & Pauly, 2019
India	149 (Cage)			2.621	0.76	A^-	Kumar *et al.,* 2013
	257 (Tank)			2.769	0.95	A^-	,,
	238 (Pond)			2.770	0.87	A^-	,,
	-	18.2		-	-	-	Ramaseshaiah, 1985
	319	19.0		-	-	-	Jacob, 2005
	221 (female)	19.2	-0.026	1.480	0.860	A^-	Present work
	237 (male)		0.597	0.835	0.641	A^-	,,
	458 (pooled)		-0.430	1.836	0.914	A^-	,,
Indonesia	71 (female)	16.3		3.055	0.967	I	Noble *et al.,* 2019
	69 (male)			2.878	0.983	A^-	,,
	265			2.997	0.993	A^-	,,
Thailand	155	-		3.015	0.998	I	Sidthimunka, 1973

In this study, the coefficient determination (R^2) of *Anabas testudienus* females ranges from 87-97% (r= 0.936-0.986), males from 86-96% (r= 0.931-0.981), and in poled conditions from 24-90% (r= 0.488-0.950). Mustakim *et al.,* (2019) discovered that the R^2 of male *Anabas testudienus* in swamp habitats in Indonesia is 76-94% (r-value= 0.87-0.97), females are 78-98% (r-value: 0.889-0.99), and the coefficient determination value on males in lake habitat is 77-93% (r-value: 0.877-0.96), and females are 75-92% (r-value: 0.866-0.959).

With a correlation coefficient (r) close to 1, it can be stated that the relationship between *Anabas testudineus* length and weight has a positive correlation, with each length increase followed by weight. Several studies found coefficient determination value (R^2) and correlation value (r) close to one in *Anabas testdineus* (Alam *et al.,* 2007; Mustakim *et al.,* 2009; Satrawaha & Pilasamorn 2009; Begum & Minar 2012; Kumar *et al.,* 2013; Rahman *et al.,* 2015; Kumary & Raj

2016). The coefficient of determination was close to 100% in general, indicating that the diversity influenced by other factors (sex, disease, and food availability) is small and the relationship between the total length and total weight of *Anabas testdineus* is very tight.

Figure 1. Length-weight relationship of female *Anabas testudineus at* Arrah (Bihar), India

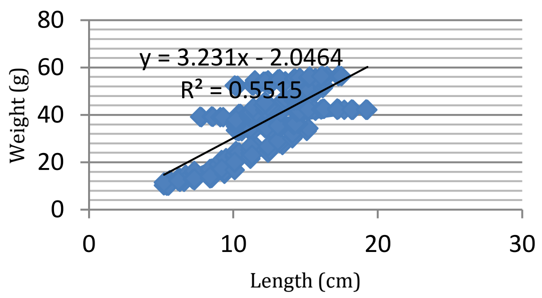


Figure 2. Length-weight relationship of male *Anabas testudineus* at Arrah (Bihar), India

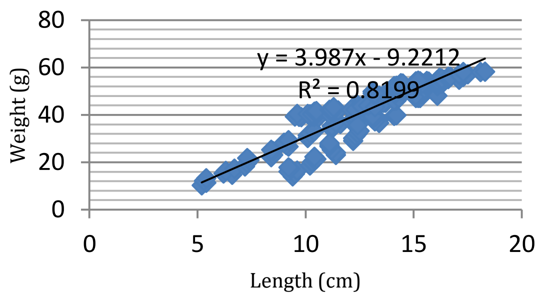


Figure 3. Length-weight relationship of *Anabas testudienus (both sexes pooled)* at Arrah (Bihar), India

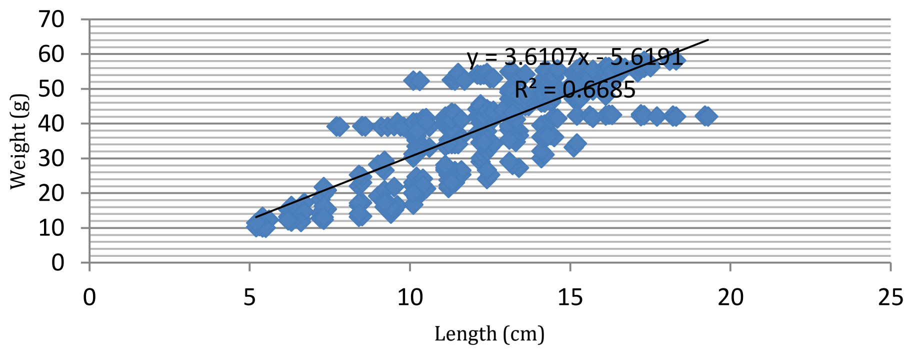


Figure 4: Relationship between relative condition factor and total lenght of female *Anabas testudienus*

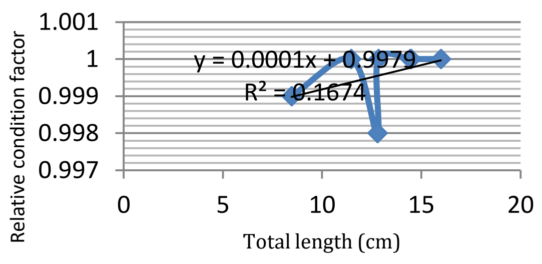


Figure 5: Relationship between relative condition factor and total length of male *Anabas testudineus*

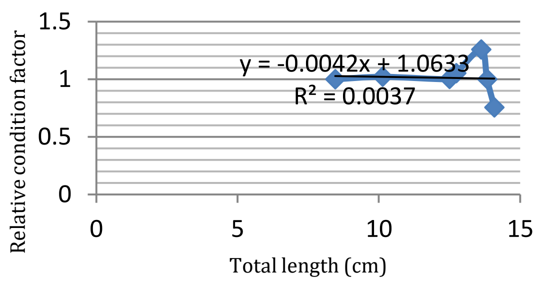
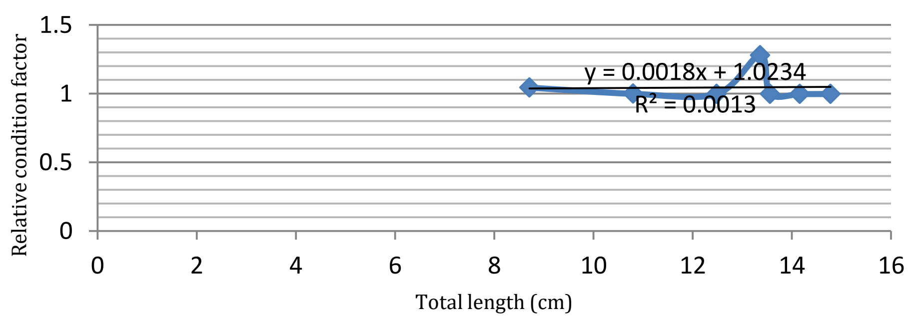


Figure 6: Relationship between relative condition factor and total length of pooled *Anabas testudienus*



In the current study, the K value in *Anabas testudineus* (female) ranges from 1.346-3.613, in males from 1.644-3.032, and pooled condition from 1.695-3.366, indicating that the experimental fish is in better condition (Table 1). The condition factor had the highest value in the shorter-length classes. In general, females have a higher condition factor than males. The sexes account for the difference in the value of this condition factor (Lorenzoni *et al.,* 2015). Previously, Mostafa *et al.,* (2008) calculated a K range of 18.913-21.051 in *Anabas testudineus* of various lengths. The variation could be due to the smaller sample size, different stages of maturity, spawning variation, or the weight of food in the stomach. Islam et al. (1999), Karim *et al.,* (1988) and Mia (1984) all reported similar fluctuating trends in the condition factor in the case of other fishes.

In the current study, the K_n value in *Anabas testudineus* (female) ranges from 0.998-1.000, in males from 0.756-1.257, and pooled condition from 0.998-1.281, indicating that the experimental fish is in better condition (Table 1; Figures 4-6). The relative condition factor in males increases from lighter to heavier fish, indicating that the general well-being and growth are good in heavier fish. K_n values were not stable across length classes. The highest K_n values were found in the middle length classes, and they gradually decreased from left to right as length increased. Yousuf and Khurshid (2008) also observe an increase in K_n value with increasing length.Mostafa *et al.,* (2008) previously calculated a range of 0.956-1.032 in *Anabas testudineus* of various lengths. Rahman *et al.,* (2015) found K_n values ranging from 0.79 to 1.42 in male *Anabas testudineus* and 0.71 to 1.29 in females.

In terms of potential competition and predation by alien species, introduced species observed during this study included carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus* and *O. mossambicus*), catfish (*Clarias* sp.) and a voracious fast-growing fish from South America, most likely pacu (*Piaractus*). All are known or suspected to be invasive and to have negative effects on native fish and invertebrate communities, primarily through competition (Cagauan, 2007).

CONCLUSION

Anabas testudineus grew at a negative allometric rate. Low maximum size is consistent with other indicators of a stressed population, such as reports of native fish population declines due to habitat conversion and increased fishing pressure, reinforcing the need for holistic wetland management in India. This could be due to genetic diversity and/or plasticity, and it could indicate the possibility of selective breeding as part of domestication efforts. More research is needed to look into possible links between genetic diversity and life history traits important in aquaculture.

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