Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2013 | 5(11): 4562–4568

CRITICAL ECOSYSTEM PARTNERSHIP FUND

Western Ghats Special Series

ISSN
Online 0974–7907
Print 0974–7893

OPEN ACCESS

Population dynamics of the Hill Stream Loach *Acanthocobitis mooreh* (Sykes, 1839) (Cypriniformes: Nemacheilidae) from northern Western Ghats of India

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Abstract: We have studied the sex ratio, length-weight relationship, growth pattern and mortality of a hill stream loach, *Acanthocobitis mooreh* (Sykes, 1839), from its type locality in northern Western Ghats of India. The sex ratio of *A. mooreh* was unbiased and did not deviate from the expected 1:1 ratio. The power of the length-weight relationship of *A. mooreh* for both males and females and for the combined population was significantly lesser than the cubic value expected by isometry. Von Bertalanffy Growth Function fitted to the length frequency data suggested that the asymptotic length of the fish is 6.04cm while the growth constant is $0.79y^{-1}$. Total mortality of the fish is $2.05y^{-1}$ and the young are more prone to mortality. Both, the high growth rate and high mortality at younger ages indicates that the fish is 'r' selected.

Keywords: Growth function, length-weight relationship, sex ratio.

Acanthocobitis mooreh was originally described as *Cobitis mooreh* by Sykes (1839) from Mula-Mutha River of Pune. Because of its remarkable similarity with *Acanthocobitis botia*, *A. mooreh* has often been confused as its junior synonym. However, *A. mooreh* can be distinguished from *A. botia* by incomplete lateral line as opposed to complete lateral line in *A. botia* (Menon, 1987). There is some debate regarding the correct generic status of this species and it has often been put under *Noemacheilus* (Menon, 1987), *Nemacheilus* (Talwar & Jhingran, 1991) and *Acanthocobitis* (Jayaram, 2010). Currently, the species is recognized as *Acanthocobitis mooreh* in Eschmeyer (2013).

Acanthocobitis mooreh is endemic to peninsular India (Jayaram 2010) and is common in the upper reaches of the Krishna River system. Some information on the reproductive biology and allometric relationships between different growth and reproduction related

DOI: http://dx.doi.org/10.11609/JoTT.o3301.4562-8 | **ZooBank:** urn:lsid:zoobank.org:pub:22FE53F0-A8A1-453E-BE19-09EDCBEC0E8E

Editor: Davor Zanella, University of Zagreb, Zagreb, Croatia. **Date of publication:** 26 July 2013 (online & print)

Manuscript details: Ms # o3301 | Received 11 August 2012 | Final received 25 April 2013 | Finally accepted 29 June 2013

Citation: Kharat, S.S. & N. Dahanukar (2013). Population dynamics of the Hill Stream Loach *Acanthocobitis mooreh* (Sykes, 1839) (Cypriniformes: Nemacheilidae) from northern Western Ghats of India. *Journal of Threatened Taxa* 5(11): 4562–4568; http://dx.doi.org/10.11609/JoTT.o3301.4562-8

Funding: None.

Competing Interest: None.

Acknowledgements: We are thankful to an anonymous reviewer for critical comments on the earlier draft of the manuscript.

The publication of this article is supported by the Critical Ecosystem Partnership Fund (CEPF), a joint initiative of l'Agence Française de Développement, Conservation International, the European Commission, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank.

body parameters of *A. mooreh* is available (Kharat 2001; Kharat et al. 2008). However, not much information is available on the population dynamics of this species. Such information is also relatively rare on loaches, especially from India. Since the information on the population dynamics can aid in understanding the basic ecology of the species and also help in the conservation action (Raghavan et al. 2011; Prasad et al. 2012), in the present study we document the population dynamics, including sex ratio, length-weight relationship and growth and mortality patterns in *A. mooreh* collected from its type locality in Pune, northern Western Ghats of India.

Methods

Specimens of *Acanthocobitis mooreh* were collected from Mula-Mutha River, a tributary of Krishna River system, in Pune (18.521^{0}N & 73.857^{0}E, elevation 557m), Maharashtra, India (Image 1) from local fishermen and fish markets. The fish were collected as target fish by the fishermen using dragnet in shallow to waist deep waters with muddy, sandy or pebbly river bed, which is the habitat of the fish. The fish were collected each month for a period of one year and were preserved in 4% formaldehyde. Number of male and female individuals collected every month are given in Table 1.

The standard length of the fish was measured using dial calipers with a least count of 0.1mm. The weight of each individual was measured on an electronic weighing balance with a least count of 0.01g. The sex of the fish was determined by dissecting the fish and identifying the gonads. We used chi-square test to test the null hypothesis that the sex ratio is 1:1. Bonferroni correction was used when applying chi-square test for

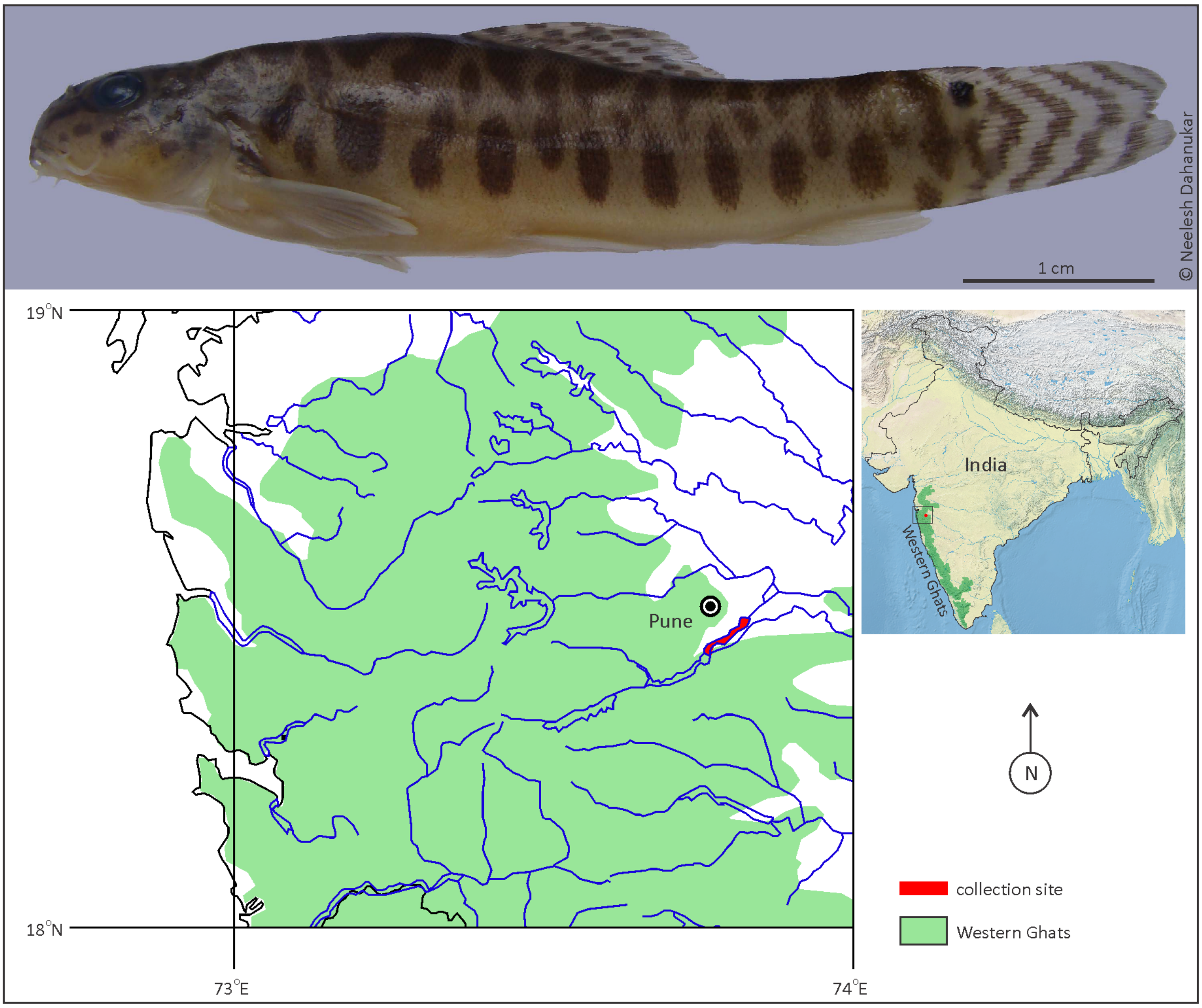

Image 1. *Acanthocobitis mooreh* lateral view and collection site in the northern Western Ghats.

multiple comparisons. We plotted length and weight of the fish to determine the power of the length-weight relationship $W = aL^b$, where W is the weight, a is the normalization constant, L is the length and b is the scaling power. The null hypothesis that $b = 3$ was tested using t test as described by Zar (1999, pp. 342). To test whether the power b, calculated as a slope of the log-log plot for weight and length, was different for males and females, we used *t* test as described by Zar (1999, pp. 362).

Data were arranged in a length frequency table with 0.25cm as the smallest midlength and 0.5cm class interval. A contour plot was prepared to understand the distribution of length classes in relation to different months. Growth and mortality parameters, as well as exploitation levels were estimated from the length frequency data using FAO–ICLARM Stock Assessment Tools II (FiSAT II) software (Gayanilo et al. 2005). Asymptotic length (L_∞) and growth constant (K) of von Bertalanffy Growth Formula (VBGF) were estimated using ELEFAN 1 method (Pauly 1984). Based on L_∞ and K values, the growth performance index ($ø' = 2 * \log L_\infty + \log K$) and potential longevity ($3/K$) of fish were estimated for different sites (Pauly & Munro 1984). Total mortality (Z) was estimated from length converted catch curve. Natural mortality (M) was determined using Pauly's M equation, which works well, especially for tropical fish, $\ln(M) = -0.0152–0.279 \ln(L_\alpha) + 0.6543 \ln(K) + 0.463 \ln(T)$, where, T is the average annual temperature, which is 26^0C. Fishing mortality (F) was calculated as $F = Z\text{-}M$ and the current exploitation level (E) was calculated as $E = F/Z$ (Pauly 1984).

Result and Discussion

Sex ratio

We collected 373 individuals of *Acanthocobitis mooreh* out of which 185 were males and 188 were females. The male to female sex ratio was 1:1.02 (Table 1) and it was not significantly different from 1:1 ($\chi^2 = 0.02$, $P = 0.8766$). The monthly sex ratio, except for January and October, did not differ significantly from 1:1 (Table 1). Female bias in October was not significantly different from the expected 1:1 ratio when Bonferroni correction was applied and significance was tested at a=0.004167. Bias towards the male individuals in January, however, was significant even after Bonferroni correction and is likely to be a sampling bias rather than a true skew. Thus, we suggest that the sex ratio of *Acanthocobitis mooreh* does not deviate much from the expected 1:1 ratio.

Even though 1:1 sex ratio has also been observed in some other loaches such as *Sabanejewia balcanica* (Zanella et al. 2008) and *Cobitis simplicispina* (Ekmekçi & Akan 2003) in many other loach species such as *Cobitis* sp. (Kostrzewa et al. 2003), *Cobitis calderoni* (Valladolid & Przybylski 2008), *Cobitis ohridana* (Bohlen et al. 2003), *Cobitis narentana* (Zanella et al. 2003) and *Cobitis tanenia* (Marconato & Rasotto 1989; Boroń et al. 2008) the sex ratio is often biased towards more female dominated populations. In fact, in *Cobitis tanenia* the male:female sex ratio can sometimes escalate up to 1:22 (Bohlen & Ritterbusch 2000). Many factors including temperature dependent sex determination, presence of hormone analogue in the environment, sex selected mortality due to predation, intersexual differences in life span or behavior, evolution of hermaphrodism and polyploidy sperm parasitism (Bohlen & Ritterbusch 2000 and references mentioned within) have been suggested as driving forces for the biased sex ratio. Since *Acanthocobitis mooreh* showed more or less consistent unbiased sex ratio throughout the year, it is possible that no such external factors affect the *A. mooreh* population in the study area.

Table 1. Monthly gender wise frequency of individuals and the chi-square test for expected 1:1 sex ratio. (P values in bold are significant.)

Month	Female	Male	Chi-square value	P
January	8	29	11.92	**0.0006**
February	19	18	0.03	0.8694
March	19	18	0.03	0.8694
April	13	9	0.73	0.3938
May	23	12	3.46	0.0630
June	13	12	0.04	0.8415
July	10	10	0.00	1.0000
August	9	9	0.00	1.0000
September	22	33	2.20	0.1380
October	28	12	6.40	***0.0114**
November	11	13	0.17	0.6831
December	13	10	0.39	0.5316
Total	188	185	0.02	0.8766

* not significant after Bonferroni correction

Length-weight relationship

Power b of the length-weight relationship of *Acanthocobitis mooreh* for the pooled data was 2.8143 (SE = 0.0539) while for males and females it was 2.8135 (SE = 0.0718) and 2.7899 (SE = 0.0808) respectively (Fig. 1). In all the cases the observed values of power b was significantly different than cubic value expected by isometry (pooled: $t = -3.4418$, $df = 371$, $P = 0.0006$; male: $t = -2.5970$, $df = 176$, $P = 0.0102$; female: $t = -2.6021$, $df =$

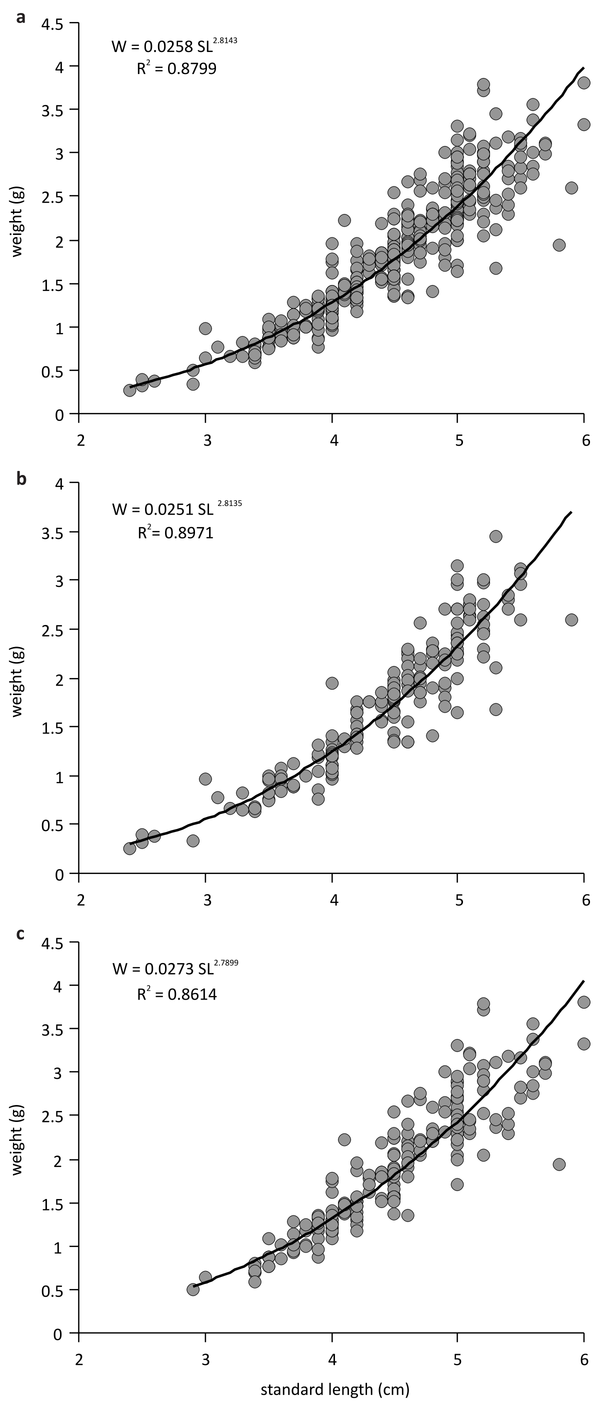

Figure 1. Length-weight relationships for (a) pooled data, (b) males and (c) females. All regressions are significant at P<0.001.

192, P = 0.01). Thus, the null hypothesis of an isometric relationship was rejected and it can be said that the power of the length-weight relationship in *A. mooreh* is significantly lesser than an isometric cubic value. Further, the value of *b* was not significantly different for males and females (t = 0.2185, df = 368, P = 0.8272).

Our value of *b* for the pooled data is slightly higher than the value determined by Kharat et al. (2008) for *Acanthocobitis mooreh*. However, in both the cases it could be established that the power *b* in *A. mooreh* is significantly lesser than 3. In the case of other loaches it is shown that the value of power *b* for the pooled data is either close to 3 (Ekmekçi & Akan 2003; Sánchez-Carmona et al. 2008; Valladolid & Przybylski 2008) or often more than 3 (Rita Kumari & Nair 1978; Marconato & Rasotto 1989, Harka et al. 2002; Dhakal & Subba 2003; Sánchez–Carmona et al. 2008). It is suggested that the power *b* in length-weight relationship of fish differ according to the species, sex, age, season, ontogenic changes, fish feeding, number of specimens examined, differences in the observed length ranges of the specimens caught and additive effect of variation in gonad weight during various stages of sexual maturity (Türkmen et al. 2001; Moutopoulos & Stergiou 2002; Peck et al. 2005; Froese 2006; Kharat et al. 2008). Less than cubic value of the power in the case of *A. mooreh* could also be an effect of stress response as a part of habitat decline in this area.

Growth

Distribution of length frequencies across the months are shown in Fig. 2a. Most of the population was observed between 3–6 cm standard length and the length rarely exceeded 6cm standard length. Highest frequency of large-sized specimens was observed during February and September (Fig. 2a). This coincides with the spawning period of *Acanthocobitis mooreh* (Kharat 2001; Kharat et al. 2008). It has been shown that *A. mooreh* spawns twice in a year, once between February/March and again between August/September (Kharat 2001; Kharat et al. 2008). We fitted the von Bertalanffy Growth Formula to the length frequency data (Fig. 2b) and the *Rn* values depicting goodness of fit for the growth curve was 0.359. Asymptotic length approached about 6cm standard length (Table 2), which is consistent with our observations where the large-sized fish only seldom crossed 6cm standard length.

In all the loaches studied so far, including *Sabanejewia*

Table 2. Growth related parameters of *Acanthocobitis mooreh*.

Parameter	Value
Asymptotic length (L_∞)	6.04 cm
VBGF growth constant (K)	0.79 y^{-1}
Growth performance index (ø′)	1.46
Potential longevity (3/K)	3.79 y
Power of the length-weight relationship (b)	2.81

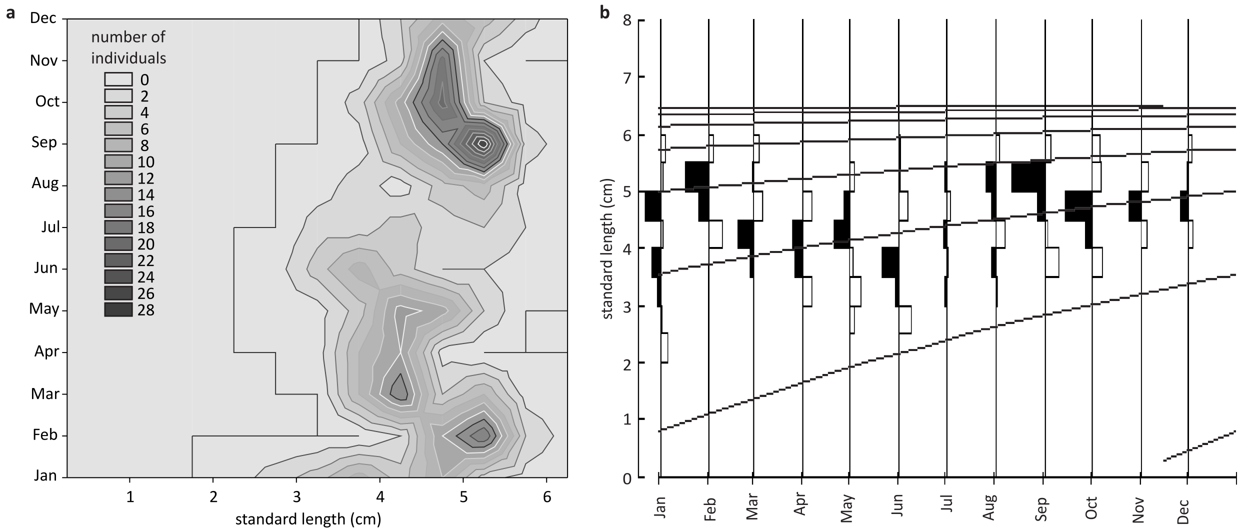

Figure 2. Distribution of standard lengths across months (a) and von Bertalanffy growth function (b).

balcanica (Zanella et al. 2008), *S. aurata* (Harka et al. 2002), *Cobitis* sp. (Kostrzewa et al. 2003), *C. ohridana* (Bohlen et al. 2003), *C. simplicispina* (Ekmekçi & Akan 2003) and *Barbatula zetensis* (Bohlen et al. 2003), the growth constant (K) is much lower than that for *A. mooreh*. Coupled with the fact that *A. mooreh* also has a much smaller asymptotic length, it can be said that *A. mooreh* grows very rapidly towards maturity.

Mortality

We used length converted catch curve (Fig. 3a) to determine various mortality related parameters (Table 3) and plotting of length structured virtual population analysis (Fig. 3b). *A. mooreh* has a very high natural mortality rate of 2.05y^{-1} and with the fishing mortality of 0.26y^{-1} the total mortality (Z) of *A. mooreh* is 2.31y^{-1} (Table 2). This is much higher than that reported for another loach *Sabanejewia aurata* (Harka et al. 2002). For *A. mooreh*, natural mortality was higher during the early age groups and it decreased with the size of the fish while the fishing mortality increased with the size (Fig. 3b). *A. mooreh* is often caught by tribal people in this area and are sold in local fish markets. The fishing mortality of the

Table 3. Mortality related parameters for the population of *Acanthocobitis mooreh*.

Parameter	Value
Length at first capture (Lc)	4.51 cm
Natural mortality (M)	2.05 y^{-1}
Fishing mortality (F)	0.26 y^{-1}
Total mortality (Z)	2.31 y^{-1}
Exploitation rate (E)	0.13

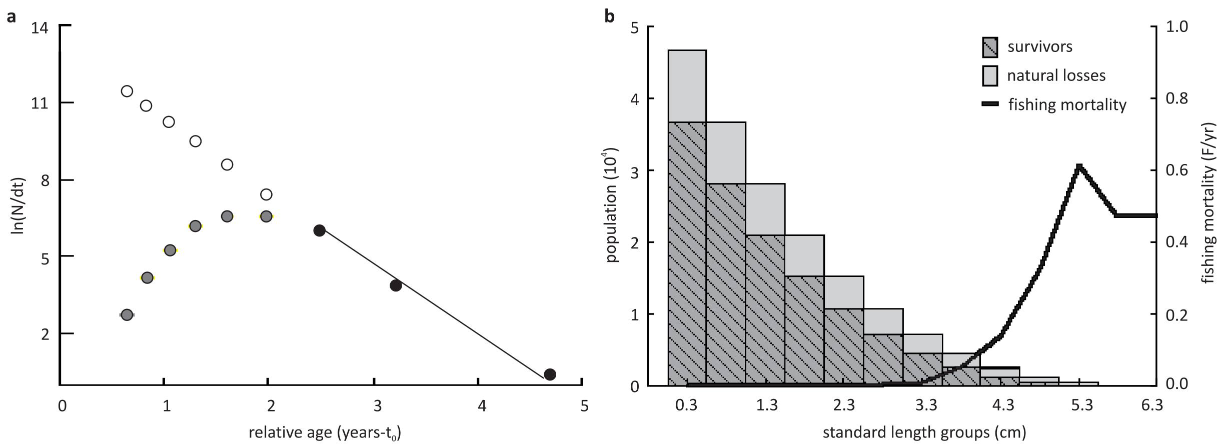

Figure 3. Mortality parameters for the population. (a) Length converted catch curve and (b) length structured virtual population analysis.

fish is very low at $0.26y^{-1}$ with the exploitation rate of 0.13 indicating that fishing is not a threat to the populations of *A. mooreh*. The fact that A. mooreh has a high growth rate (Table 2) and high mortality in the young age (Fig. 3b), indicates that the species is 'r' selected.

Conclusion

Even though *Acanthocobitis mooreh* has been assessed as Least Concern species in IUCN Redlist, owing to its wide distribution and absence of any recognizable wide spread threat to the species, it has been pointed out that some of the populations of the species are facing threats because of pollution of water bodies and loss of habitat (Raghavan & Ali 2011). Especially in the current study area increase in the extent of urbanization has severely threatened the population of the species. The population of the species, which was once considered as abundant in Pune urban area (Kharat et al. 2001), has declined drastically in the recent past and has become fragmented because of habitat modifications, recreational activities and levels of pollution in different stretches of the river. Such threats are known for other populations of *A. mooreh* as well (Dahanukar et al. 2012; Kharat et al. 2012). Since, any conservation action plan targeted towards the species could be a futile exercise in the absence of knowledge about the ecology of the species, we believe that the current study will contribute significantly to our knowledge about the ecology of *A. mooreh* and may also provide insights about the ecology of loaches of the Western Ghats in general.

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