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Ecology of the Asian tapeworm, *Bothriocephalus acheilognathi* Yamaguti, 1934 of fishes in the Dal lake of Srinagar, Kashmir

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Abstract
Seasonal surveys were conducted at the Dal Lake of Srinagar between April 2013 and January 2014. Twenty *Schizothorax niger* and 20 *Cyprinus carpio* were collected with the aid of gill nets. Surface water quality variables were included. The cestodes were identified as either *Bothriocephalus acheilognathi* Yamaguti, 1934 or "other cestode species." The majority (99.8%) of the cestodes found in both fish species were identified as *B. acheilognathi* (Asian tapeworm). The prevalence, mean intensity and abundance of *B. acheilognathi* in both fish species were calculated. Ecological parameters including species specificity, seasonality, gender specificity and relationships between fish size and the Asian tapeworm prevalence were also included. In this study, *B. acheilognathi* preferred *Schizothorax niger* over *Cyprinus carpio* although a low intensity was observed in *Cyprinus carpio*. Furthermore, the infection (in terms of prevalence, abundance and mean intensity) in *Schizothorax niger* was markedly higher. Seasonal patterns observed in the Asian tapeworm infection of *Cyprinus carpio* are attributed to breeding and subsequent feeding patterns of this fish species with relatively high infections recorded in winter and spring. In *Schizothorax niger* no explanation can be given regarding the seasonal patterns observed for the mean intensity and abundance of *B. acheilognathi*. The maximum and minimum mean intensity and abundance values in *Schizothorax niger* were recorded in autumn and spring, respectively. In addition, the prevalence of *B. acheilognathi* was consistently high in all four seasons.

Keywords: Asian tapeworm; *Bothriocephalus acheilognathi*; *Schizothorax niger*; *Cyprinus carpio*; seasonal prevalence.

1. Introduction
Surveys conducted by the fish parasitology group have shown unexpectedly high numbers of helminth parasites in fish species in the Dal Lake of Srinagar. The high number of helminth parasites can be attributed to *Bothriocephalus acheilognathi* which has been introduced with cyprinid fish into South Africa from Asia [3]. The Asian tapeworm, originally a parasite of the Chinese grass carp (*Ctenopharyngodon idella* Valenciennes, 1844*)* and the silver carp (*Hypothalmichthys molitrix* Valenciennes, 1844*)* in the Southern parts of China [2], have spread rapidly to other countries by means of infected fish [23] and has adapted itself successfully to the common carp (*Cyprinus carpio* Linnaeus, 1758) [2]. In South Africa, bothriocephalid parasites have been found in various dams and freshwater systems in Gauteng Province. Localities in South Africa, where *B. acheilognathi* has been found include the Komatipoort area (Mpumalanga Province) [2], Marble Hall (Mpumalanga Province) [3], Boskop Dam (KwaZulu-Natal Province) [27], Hartbeespoort Dam (North West Province), Piet Gouws Dam (Limpopo Province) [15], Olifants River (Limpopo Province) [15], Glen Alpine Dam (Limpopo Province) [15], and the Vaal Dam (Gauteng Province) [15]. The tapeworm's presence in most of the localities mentioned above can be attributed to the supply of common carp fry to commercial farmers [2]. However, according to [15] its presence in the Vaal Dam cannot be accounted for. [3] mentioned the possibility that this tapeworm was imported into South Africa with the common carp as long ago as 1859 or with the Dinkelsbuhl Aischgrund variety of the common carp in 1952. *Cyprinus carpio* has been found in the Dal Lake but its introduction date is uncertain.

Bothriocephalus acheilognathi was originally described as three different species of wild fish in Japan (as *B. acheilognathi* Yamaguti, 1934 and *Bothriocephalus opsariichthydis* Yamaguti, 1934) and from grass carp (*C. idella*) from South China (as *Bothriocephalus gowkongensis* Yeh, 1955) [20]. These three species were later recognized as being identical [11, 16] with the name *B. acheilognathi* taking priority. Pool DW [24] believes that the three species, *B. acheilognathi*, *Bothriocephalus kivuensis* and *Bothriocephalus aegyptiacus*, are identical, with *B. acheilognathi* having priority. Various authorities Pool DW [22, 24] noted that *Bothriocephalus opsariichthydis* Yamaguti, 1934, *Bothriocephalus fluviatilis* Yamaguti, 1952, *B. gowkongensis* Yeh, 1955, *Bothriocephalus phoxini* Molnár, 1968 and *Schyzocotyle fluviatilis* Akhmerov, 1960 are the same species as *B. acheilognathi* Yamaguti, 1934. Pool DW [22] concluded that there is only one *Bothriocephalus* species parasitizing cyprinid fish and suggested the continued use of the name *B. acheilognathi*. Cestodes in this study were identified as either *B. acheilognathi* or "other cestode spp.". The purpose of this article is to provide a brief description of the parasite infection, seasonality, gender specificity and species (host) specificity in the two fish species sampled. A comparison between the parasite infection in *Cyprinus carpio* and its infection in *Schizothorax niger* is also included.

2. Materials and methods

2.1 Study location

Four surveys were conducted in the Dal Lake of Srinagar on—one per season, namely in April 2013 (early spring), June 2013 (summer), October 2013 (late autumn) and January 2014 (winter).

2.2 Water quality

Water quality data for the duration of the project were obtained from the Water Board, and were collected during routine monitoring activities made by the Water Board. Standard techniques were used by the Water Board to analyse the water samples. In some months various parameters were not measured, the reasons being that sampling and/ or measuring instruments were either not in working order or being serviced. The following surface water variables were included: pH, temperature, electrical conductivity, dissolved oxygen and light penetration.

2.3 Collection of fish and cestodes

A field laboratory was set up for each survey. The fish species collected during the four surveys were *Cyprinus carpio* and *Schizothorax niger*. The fish was identified based on the size of the snout as suggested by [26]. Twenty *Cyprinus carpio* and 20 *Schizothorax niger* fishes per survey were collected using gill nets consisting of four sections with varying stretched mesh sizes of 90, 110 and 130 mm, respectively. They were weighed (in grams) and measured (fork length in millimeters). The fish were killed by severing the spinal cord behind the head and were subsequently dissected by making an insertion from the anus towards the head. Once they had been dissected, the intestines were removed and placed in a normal saline solution in petri dishes for examination. The methods described by [8] were used for processing the platyhelminth parasites found during the surveys. Parasites were collected as soon as possible after the death of the fish to prevent any deterioration. The intestines were pulled open carefully using two sharp tweezers to ensure that the cestodes were kept intact. Each cestode was carefully and slowly dislodged from the intestinal wall, ensuring that it remained intact. They were transferred to a clean sampling bottle containing normal saline solution, which was then shaken vigorously for a few minutes to dislodge debris and induce muscle fatigue in the helminths, which in turn, deters strong contraction of the scolices and relaxes them. While swirling the sampling bottle, an equal amount (equal to the amount of saline solution already present in the sampling bottle) of a hot alcohol-formaldehyde-acetic acid (AFA) solution was added to kill and fix the specimens. Specimens were then stored in 70% alcohol.

2.4 Identification of cestodes

The cestodes were stained with Grenacher's borax carmine stain [19] and identified.

2.5 Statistical analyses

All specimens were counted and the totals obtained were used for statistical analyses which were conducted by the University of Kashmir, Department of Statistics. Prevalence, abundance and mean intensity of *B. acheilognathi* were calculated per season for each fish species. Infection statistics were calculated by making use of the definitions set by [13, 4]. Data was analysed to determine the seasonality (using ANOVA and then Scheffe or Dunnet T3) and species and gender specificity (using Pearson Chisquare test and T-tests) of *B. acheilognathi*. A comparison between the infections in the two fish species was done (using the T-test). In addition, the infection of *B. acheilognathi* (intensity) in each fish species was compared to the size (fork length) of the fish sampled. Regression analysis was used to determine if any correlations existed. Digital micrographs of stained specimens were taken using a Zeiss Axioplan 2 Imaging microscope.

3. Results

3.1 Water quality

Surface water variables and data obtained in this study are presented in Table 1.

3.2 Identification of cestodes

According to [15], the classification of the bothriocephalid worms is based primarily on the shape of the scolex. Pool DW [21] concluded from his study on *B. acheilognathi* that the identification of adults should be based on the heart-shaped scolex and prominent square apical disc. The identification of the bothriocephalid cestodes in this study was therefore based on these characteristics. Specimens found in the current study were compared to sketches provided by various authorities [30, 31, 17, 15] as well as the diagnosis of *B. acheilognathi* (as *B. gowkongensis*) by [31], as cited by [20]. Micrographs and sketches of *B. acheilognathi* collected during the four surveys are presented in Fig. 1. When reviewing available sketches it is the authors' opinion that the scolex of specimens from the current study compared fairly well with many of the *Bothriocephalus* species that have a heart-shaped scolex (Fig. 1A). As mentioned in [20], the eggs are operculated (Fig. 1F) and the vitellaria laterally scattered (Fig. 1D). According to the diagnosis given in [20], mature and gravid segments vary in breadth and length. However, in this study this was not the case. Most segments were broader than they were long (Fig. 1B and C). We, however, disagree with the system of labelling the reproductive system as proposed by [30], and consider that, after reviewing the available literature; it should be as indicated in Fig. 1E.

Table 1: Summary of water quality variables recorded seasonally at the Dal Lake in Srinagar.

Survey	pH (pH units)	Temperature (°C)	Electrical conductivity (mS/m)	Dissolved oxygen (mg/l O_2)	Secchi disc readings (cm)
Autumn (April 2013)	7.60	__	17.00	__	__
Winter (June2013)	7.34	19.90	16.00	12.50	30.00
Spring (October 2013)	8.00	21.40	17.00	___	28.00
Summer (January 2014)	8.26	25.00	23.00	6.30	28.00

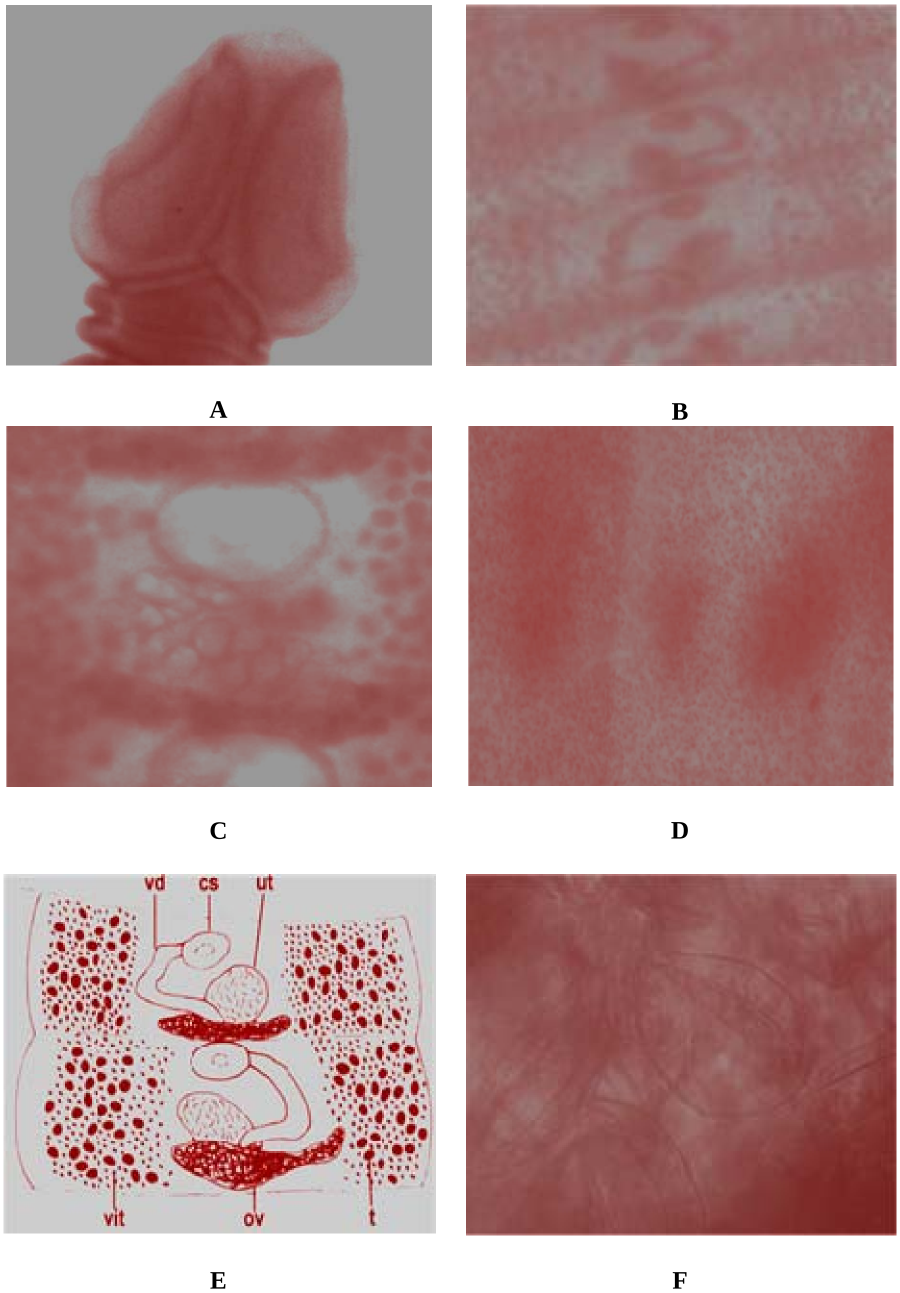

Fig 1: Micrographs and sketches of *Bothriocephalus acheilognathi* collected during the four seasons of the survey in the Dal Lake of Srinagar. A) Heart-shaped scolex with bothria. B) Mature proglottid with reproductive organs C) Young adult proglottid. D) Vitellaria scattered. E) Sketch of a young adult proglottid F) Operculated egg

Table 2: Number of cestodes collected from *Cyprinus carpio* and *Schizothorax niger* at the Dal Lake of Srinagar during the four seasons.

Survey	*Cyprinus carpio* (n=70)		*Schizothorax niger* (n=70)	
	B. acheilognathi	**Other cestode spp.**	***B. acheilognathi***	**Other cestode spp.**
Spring (April 2013)	4	0	417	4
Summer (June 2013)	298	0	651	0
Autumn (October 2013)	256	0	120	1
Winter (January 2014)	24	0	40	3
Total	582		132	8
Total cestodes	**582**		**1336**	

3.3 Parasite numbers
The tapeworms encountered in this study were grouped as either *B. acheilognathi* or "other cestode spp.". The number of *B. acheilognathi* and other cestode spp. collected during the four seasons of the survey is tabulated in Table 2. Of the 140 fish sampled, only 19 out of 80 *Cyprinus carpio* harboured *B. acheilognathi* while none harboured other cestode spp.; and 68 out of 80 *Schizothorax niger* harboured *B. acheilognathi* while only six harboured other cestode spp.

3.4 Infection statistics of *B. acheilognathi*
The percentage of hosts (prevalence) infected with *B. acheilognathi*, and its intensity (mean intensity) and abundance (relative density) in both *Cyprinus carpio* and *Schizothorax niger* are illustrated graphically in Fig. 2, 3 and 4, respectively. A statistical comparison (T-test) of the two fish species in terms of *B. acheilognathi* prevalence, abundance and mean intensity are also included to determine whether or not there are significant differences between fish species.

3.5 Prevalence
The prevalence of *B. acheilognathi* in *Schizothorax niger* was relatively constant over all seasons, ranging from 80–90 %, whereas the prevalence in *Cyprinus carpio* was fairly constant (10–15%) in autumn, spring and summer followed by a considerable increase in winter (55 %) (Fig. 2). When comparing its prevalence in the two fish species, that in *Schizothorax niger was* considerably higher. Statistical analyses indicate that, there was a significant difference (T-test, *P* = 0.001) in its prevalence in the two fish species.

3.6 Abundance (relative density)
During all surveys, the abundance of the Asian tapeworm was considerably higher in *Schizothorax niger* (Fig. 3). In this fish species, abundance values ranged from 55.0 (spring) to 170.9 (autumn) while in *Cyprinus carpio* these values ranged from 0.2 (autumn) to 14.9 (winter). The following seasonal trend was observed in *Schizothorax niger:* values decreased from autumn to winter and then again in spring. The latter was followed by an increase in summer. For *Cyprinus carpio* the opposite trend was observed. Values increased from autumn to winter and were followed by a decrease in spring and a further decrease in summer. Statistical analyses indicate that there was a significant difference (T-test, *P* = 0.011) between the relative densities of *B. acheilognathi* in the two fish species sampled.

3.7 Mean intensity
Excluding spring, the infection was considerably more intense in *Schizothorax niger (*Fig. 4). The highest value recorded in *Schizothorax niger* was 213.6 in autumn and the lowest value was 68.8 recorded in spring. During the remaining seasons the mean intensity decreased to 102.2 and 85.8 in summer and winter respectively. Similarly, the mean intensities in *Cyprinus carpio* differed considerably from 2.00 in autumn of 78.7 in spring. During winter and summer a mean intensity of 27.1 and 4.3, respectively, was recorded. Statistical analyses indicate that, there could be a significant difference between the mean intensities of *B. acheilognathi* in the two fish species (T-test, *P* value was slightly above 0.05 at 0.053) but due to either the sample size being too small or the variance being too big this cannot be said for certain.

3.8 Ecological parameters
3.8.1 Gender specificity
In both fish species, there were no significant differences (T-test, *P* values > 0.05) in the average number of *B. acheilognathi* found in males and females even though the average number of males and females differed. In *Cyprinus carpio* the average numbers of *B. acheilognathi* in male and in female fish were 12.85 and 2.70, respectively. In *Schizothorax niger* the average numbers were 91.43 and 107.42, respectively. In addition, the presence or absence of *B. acheilognathi* is not dependent on the gender of fish species (Pearson Chi-square test; *P* values for both fish species > 0.05). Similar numbers of male (7) and female (12) *Cyprinus carpio* and male (37) and female (31) *Schizothorax niger* were found to harbour *B. acheilognathi*. In *Cyprinus carpio*, the prevalence of *B. acheilognathi* in males and females was 0.21 and 0.26, respectively. Similarly, in *Schizothorax niger* the prevalence of *B. acheilognathi* was 0.84 in males and 0.86 in females.

3.8.2 Seasonality
In *Cyprinus carpio*, the highest number of *B. acheilognathi* was observed during the summer survey while in *Schizothorax niger* also the highest number was observed during the summer survey (Table 2). From the statistical analyses (Pearson Chi-square test) performed on the data, the presence/absence of *B. acheilognathi* in *Cyprinus carpio* was dependent on the season (*P* = 0.002) with the highest number of infected fish (11) being in those caught in winter and the lowest (2) being in autumn. This was not the case for *Schizothorax niger*. Similar numbers of *Schizothorax niger* (between 16 and 18) were infected with *B. acheilognathi* during all four seasons of the survey.
However, when conducting the ANOVA test to determine if there were significant differences between seasons, the results show that there were significant (*P* = 0.003) seasonal differences based on the number of *B. acheilognathi* found in *Schizothorax niger*. *Post hoc* tests were then undertaken to distinguish which of the seasons differed significantly. The results of the statistical analyses (Dunnet T3 test) showed that autumn and spring differed significantly with a *P* value of 0.011. No significant seasonal differences were determined by

the number of *B. acheilognathi* found in *Cyprinus carpio*.

3.8.3 Species specificity
When comparing fish species, *Schizothorax niger* harboured a higher number of *B. acheilognathi* than *Cyprinus carpio* (Table 2). The number of *B. acheilognathi* found in *Schizothorax niger* totalled 1328, while *Cyprinus carpio* only had a total of 582 *B. acheilognathi* in the same number of hosts (70). In addition, a higher number of *Schizothorax niger* (68) was infected with *B. acheilognathi* than *Cyprinus carpio* (19). From the statistical analyses (Pearson Chi-square) performed when data are pooled according to fish species, the presence/absence of *B. acheilognathi* was highly dependent on fish species, P values being 0.000.

3.8.4 Size specificity
No correlations were observed between the sizes (fork lengths) of fishes (both *Schizothorax niger* and *Cyprinus carpio*) sampled and the number of Asian tapeworms recorded.

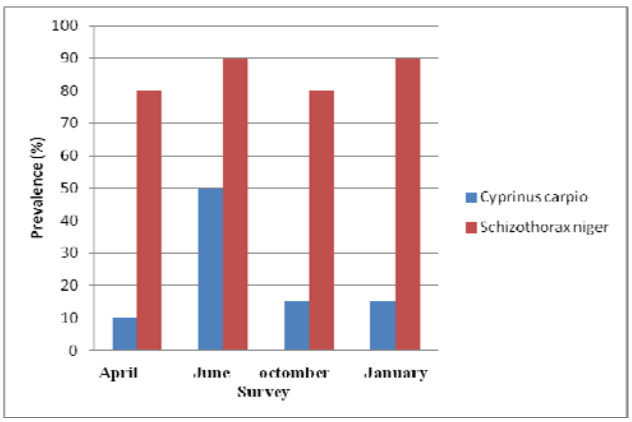

Fig 2: Graph depicting the prevalence of *Bothriocephalus acheilognathi* in *Cyprinus carpio* and *Schizothorax niger* during the four seasons

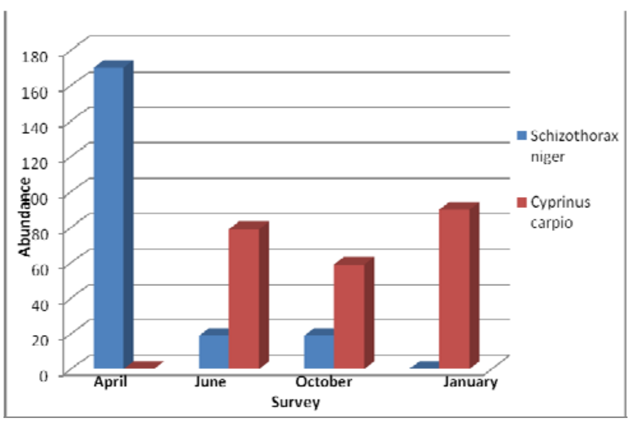

Fig 3: Graph depicting the abundance (relative density) of *Bothriocephalus acheilognathi* in *Cyprinus carpio* and *Schizothorax niger* during the four seasons of the survey

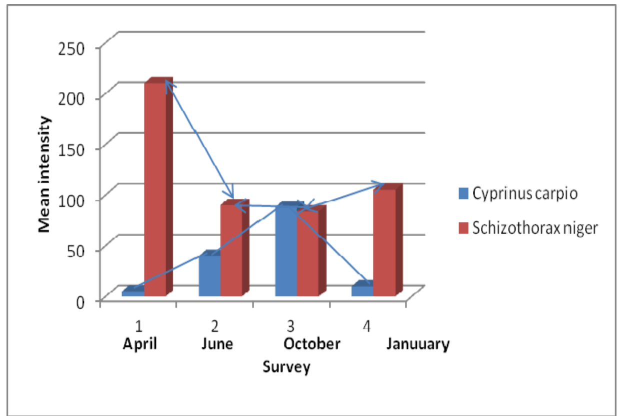

Fig 4: Graph depicting the mean intensity of *Bothriocephalus acheilognathi* in *Cyprinus carpio* and *Schizothorax niger* during the four seasons

4. Discussion
Exceptionally high numbers of *B. acheilognathi* and low numbers (an insignificant amount) of other cestode spp. were found in the fish sampled. As highlighted by [9], parasites are a natural part of the aquatic community and their distribution and abundance are potentially either directly or indirectly affected by a number of biotic and abiotic factors.

4.1 Infection
The infection of *B. acheilognathi* (in terms of prevalence, abundance and mean intensity) in *Schizothorax niger* was greater than that observed in *Cyprinus carpio*. Noticeably higher numbers of this tapeworm were observed in *Schizothorax niger* and a noticeably higher number of this fish species was infected. Similar prevalence and mean intensity values to those obtained in this study were recorded for *L. aeneus* and *L. kimberleyensis* in a separate preliminary study conducted by [18] in the Vaal Dam during 2001. The infection statistics indicate that both prevalence and abundance of *B. acheilognathi* differed significantly (statistically) between the fish species with *Schizothorax niger* exhibiting higher values. The mean intensity of *B. acheilognathi* was higher in *Schizothorax niger* for most seasons, except in spring when the opposite was the case. In spring a small number of *Cyprinus carpio* were infected with a relatively high number of tapeworms thereby increasing the mean intensity. It is possible that the mean intensities of the fish species differ significantly but this is uncertain in this study because either the sample size was too small or the variance was too big to distinguish between the fish species. It would be expected that the high numbers (and subsequently high prevalence, abundance and mean intensity) of *B. acheilognathi* found in *Schizothorax niger* in this study are linked to the life cycle of the tapeworm as the transmission of parasite to host is via an intermediate host eaten by the fish [20]. Korting W [11] mentioned that the intermediate host of the Asian tapeworm for carp is a crustacean and that a number of crustaceans can act as intermediate hosts. When considering the food preference of largemouth yellowfish, it is found that it initially feeds on insects and crustaceans, but once it reaches a fork length of more than 300 mm it feeds on other fish [26]. Although the majority of infected *Schizothorax niger* collected during the survey varied in fork length between 360 and 420 mm, it is possible that infected crustaceans are eaten occasionally, resulting in an infection in *Schizothorax niger*. It was unexpected, however, to find an infection as heavy as that obtained in this study. When considering the infection of *B.*

acheilognathi (in terms of prevalence, mean intensity and abundance) in relation to fish size (fork length), no correlations were recorded in *Schizothorax niger*. It is important to note that *L. kimberleyensis* was the first recorded host of *B. acheilognathi* (as *B. gowkongensis*) in South Africa in 1978 [3]. The type of crustacean or copepod acting as an intermediate host for *B. acheilognathi* for this fish species should be determined. This opportunistic tapeworm has already adapted successfully to the common carp, *Cyprinus carpio* [10, 2] in South African waters. This carp species feeds on a range of plant and animal matter [26] and, more specifically, carp fry, which tend to be more heavily infected with the tapeworm, feed on zooplankton [2]. A better understanding of the intermediate host could explain the high infection of *B. acheilognathi* in *Schizothorax niger*. Other authorities, such as [12, 29], mention that metacestodes use planktonic or benthic copepods as intermediate hosts. If this is the case, then *L. aeneus* should be the preferred host as this fish species is broadly omnivorous with zooplankton, benthic invertebrates, vegetation, algae and detritus forming the major food of the species [7, 26]. Although *L. aeneus* is not the preferred host [18], it still becomes infected (although low) with *B. acheilognathi*. [25] mentioned that parasites such as the Asian tapeworm that enter their host through ingestion cannot prevent non-host species from eating the infected intermediate hosts. This method of transmission (ingestion) enables more host species to become infected. Another reason why both fish species are infected with this tapeworm could be that the intermediate copepod host species can vary considerably. Various genera of copepods have been found to be compatible intermediate hosts [29, 20] and in this case it is possible that a larger crustacean, such as a crab, acts as a paratenic host-this would explain the enigma behind the higher infection observed in largemouth yellowfish. In a study conducted by [6] in Mexico it was found that helminth communities were generally more abundant in carnivorous fish species than in herbivores and detritivores. This matter needs to be researched further in order to gain a better understanding of infections by the Asian tapeworm.

4.2 Seasonal trends

In *Cyprinus carpio*, the prevalence of *B. acheilognathi* was fairly constant except in winter when noticeably higher numbers of *Cyprinus carpio* were infected. Prevalence values in winter were approximately four to five times higher than in the remaining seasons (Fig. 2). This could be due to a change in feeding regime, but during the four seasonal surveys it has been found that *Cyprinus carpio* fed well [1]. Korting W [10] indicated that early spring, when plankton grows, is likely to be a significant season in terms of seasonal incidence and infective period. This was not the case, however, in *Cyprinus carpio* in this study. In spring, the prevalence was fairly low. The reason could be that more infected food (copepods) was available in that particular winter than is usually the case. Temperature data recorded during the winter of this study (Table 1) were higher than in a previous separate study conducted in the Dal Lake [5]. In winter visibility (light penetration) in the Dal Lake was at its maximum, although in the remaining three seasons similar (slightly lower) values were exhibited (Table 1). It can be assumed that the finding of an increased prevalence in winter is exceptional and was caused by an external unknown factor. Statistical analyses indicated that, as a result of this high prevalence in winter, the presence of *B. acheilognathi* in *Cyprinus carpio* is dependent on the season. In *Schizothorax niger*, no trend was observed for prevalence of the Asian tapeworm throughout the four seasons (Fig. 2); a similar, very high number of fish being infected throughout the year. Abundance values in *Cyprinus carpio* exhibited a pattern similar to the prevalence values observed in the same fish species (Fig. 3). Values increased considerably from autumn to winter followed by a decline in spring and a further decline in summer. It is assumed that this seasonal trend is related to the breeding and subsequent feeding patterns of *Cyprinus carpio*. Feeding habits of the host account for a large percentage of the variation in the total number of parasites per host species [29]. The number of parasites in a host would depend on how much the host eats and whether the food is infected. In winter, the fish eat enough food to sustain them through the breeding season, which lasts from spring through to late summer [26] and explains the decrease in abundance recorded in spring and summer. As soon as the breeding season ends fish start eating again. This results in an increase in abundance from autumn to winter. In *Schizothorax nigeer*, the seasonal trend in abundance could not be attributed to the fish's breeding patterns. *Schizothorax nigeer* breed in mid to late summer [26] which would mean that abundance values should be higher in winter and spring, but nevertheless the opposite was observed (Fig. 3). A sharp decrease in abundance values was recorded from autumn to winter after which abundance values remained relatively constant decreasing slightly in spring but increasing again in summer. This seasonal trend could be related to changes in the amount of food and subsequently infected food available. In autumn the high abundance relative to the other three seasons was due to the considerably higher number of *B. acheilognathi* found in the *Schizothorax nigeer*, in the survey. A similar pattern to that recorded for the abundance of *B. acheilognathi* in *Schizothorax nigeer*, was recorded for the mean intensity (Fig. 4). This is due to the fact that most of the fish sampled during the four seasons were infected with *B. acheilognathi*. The mean intensity in *Cyprinus carpio* also exhibited a similar pattern to that of the abundance in *Cyprinus carpio*, except that the mean intensity peaked in spring rather than in winter (Fig. 4). Mean intensities in the *Cyprinus carpio* increased considerably from autumn to winter followed by a significant increase (three times that of winter) in spring after which the intensity decreased in summer to an intensity similar to that recorded in autumn. In spring, the mean intensity recorded in *Cyprinus carpio* was even higher than that recorded in *Schizothorax niger*. Opposite seasonal trends were recorded for the mean intensity of the two fish species. Statistical analysis indicates that the occurrence of *B. acheilognathi* in *Cyprinus carpio* is dependent on the season with the highest number of fish infected in winter. However, no statistically meaningful differences were observed in the intensity of *B. acheilognathi* found during each season. The opposite is true for the *Schizothorax niger* sampled in this study. Statistical analysis indicates that the occurrence of *B. acheilognathi* was not dependent on the season, even though there were significant statistical differences between the intensity of *B. acheilognathi* recorded in autumn and that recorded in spring.

4.3 Fish gender and species specificity

Statistical analysis indicates that the presence of *B. acheilognathi* is highly dependent on the species of fish with *Schizothorax niger*, as mentioned above, having the highest infection of the two fish species. [25] noted that high host specificity could be an artefact of inadequate sampling but in this study 20 fish per species per season were collected which cancels out this possibility. In addition, various studies conducted in the Dal Lake systems, in which cestode endoparasites have been incorporated, have revealed either an absence of cestodes or low infections of them in a range of fish species, namely *Clarias gariepinus* [14, 5, 28], *Labeobarbus marequensis* [28], *Oreochromis mossambicus* [28], *Labeo capensis* and *Labeo umbratus* [28]. When pooling the data according to the sex of the fish, the tapeworms exhibited no preference for male or female fish. Similar numbers of male and female *Schizothorax niger* were infected. Even though there were noticeably lower numbers of infected female *Cyprinus carpio* when compared to males there was no dependency (statistically) on fish gender.

4.4 Size specificity

In both fish species sampled no correlations were observed between fish size and Asian tapeworm infection. The statistical *P* values were closer to 0 than 1.

5. Conclusion

In this study, the majority of the tapeworms was identified as *B. acheilognathi* based in the heartshaped scolex and presence of bothria. This was achieved after comparing the specimens collected with the descriptions and sketches in the literature. *Bothriocephalus acheilognathi* in this study was species (host) specific with a considerably higher infection (in terms of prevalence, abundance and mean intensity) recorded in *Schizothorax nigeer*. The reason for this has still not been determined. The Asian tapeworm in this study was not fish-gender specific. Seasonal trends were observed in prevalence, abundance and mean intensity of the tapeworm in *Cyprinus carpio* although statistical analyses indicate that no significant differences existed between seasons. Seasonal trends in *Cyprinus carpio* were attributed to breeding and subsequent feeding patterns of the fish. In *Schizothorax nigeer*, no seasonal trend was recorded for prevalence. The abundance and mean intensities of *B. acheilognathi,* however, varied seasonally with the highest value being recorded in autumn and the lowest value in spring. Statistical analyses indicate that there was a significant difference between the presences of *B. acheilognathi* in these two seasons. The reason for the seasonal trends observed in *Schizothorax nigeer* cannot be explained. Further research on *Schizothorax nigeer* concentrating on factors such as post-spawning migrations of the host, schooling behaviour, age of host, reproductive behaviour, host feeding behaviour, host hormone levels/state of maturity, immunological response of host, availability of infected intermediate hosts as food, site of infection, negative interaction between parasites (as outlined by Williams & Jones 1994) should be conducted to provide an explanation as to why there are seasonal variations in *B. acheilognathi*'s infections in this fish species.

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