Prevalence and intensity of *Cornudiscoides agarwali* (Monogenoidea) on the gills of Day's mystus (*Mystus bleekeri*) in relation to some ecological and biological factors from Arunachal Pradesh, India

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Article info

Summary

This work investigated the relationship of host size, seasons, and water quality parameters with the prevalence and intensity of *Cornudiscoides agarwali* on *Mystus bleekeri* collected from the Dikrong River in Arunachal Pradesh, India from February 2016 to January 2017. A total of 2760 specimens of *C. agarwali* were recovered from 114 individuals of *M. bleekeri*. The levels of mean intensity, but not the prevalence, of infection of *C. agarwali* were positively correlated with fish host size, peaking in the largest size class (45.20 ± 5.69 parasites/fish). The prevalence values had a statistically significant seasonal trend, reaching highest (100 %) during the pre-monsoon season, followed by 91.8% during the post-monsoon period and 87.5 % during the monsoon season. The levels of mean intensity of infection were also dependent on the seasons, reaching significantly higher levels during the pre-monsoon season (42.75 ± 4.18 parasites/fish). All water quality parameters measured were within the safety value recommended for freshwater aquaculture. *Cornudiscoides agarwali* maintained its prevalence above 87.5 % throughout the annual cycle, which means it was able to reproduce year-round in a non-polluted river. This could be an indication of monogenoidean community and population dynamics thriving best under optimum water quality parameters. Also, this article draws the attention of parasitologists and ichthyologists to a taxonomic problem of the misidentification of *Mystus* spp., and therefore, possibly of their parasitic monogenoids.
Keywords: Monogenoidea; *Mystus bleekeri*; *Cornudiscoides agarwali*; season; host size; 28S rRNA

Introduction

Fish diseases, especially those caused by parasitic monogenoids (Platyhelminthes), are one of the most important factors that threaten fish culture and fish farming globally (Thoney & Hargis, 1991). Monogenoids are very diverse ectoparasites, with more than 10,000 extant species distributed across the globe (as cited in Tripathi, 2014) and about 300 from India (Pandey & Agrawal, 2008). Arunachal Pradesh, located in the extreme northeast corner of India, has been identified as a major hotspot for freshwater fish biodiversity in the world (Kottelat & Whitten, 1996), boasting no fewer than 213 recorded species of fish (Bagra *et al*., 2009). Although only eight monogenoid species have been described/recorded from Arunachal Pradesh to date (Wangchu *et al*., 2017), more than 128 species have been identified from 55 species of sampled fish, giving an average infection of 2.32 monogenoids per infected host fish species (Tripathi: unpublished data).

Day's mystus (*Mystus bleekeri*) (Siluriformes: Bagridae) is a commercially important indigenous freshwater potamodromous fish species, which commonly inhabits the rivers and lakes of several

Asian countries, including Bangladesh, Bhutan, India, Indonesia, Myanmar, Nepal, and Pakistan (Froese & Pauly, 2018). In India, this species is known from the Brahmaputra-Ganges system and Indus and Mahanadi River drainages, where it is targeted as a food fish besides being exported as an ornamental fish (Ng, 2010). Despite the known importance of *M. bleekeri*, there is insufficient information regarding the distribution, biology, and potential threats for this species, including parasites (see Froese & Pauly, 2018). Only three species of helminth parasites (all monogenoids) have been recorded from *M. bleekeri*: *Cornudiscoides bleekerai* Agrawal and Vishwakarma, 1996, *C. gussevi* Agrawal and Vishwakarma, 1996, and *C. susanae* Agrawal and Vishwakarma, 1996 (Lim *et al*., 2001). Moreover, there is a complete lack of epidemiological data on the prevalence and intensity of parasites of *M. bleekeri* in relation to ecological and biological factors, which may hamper control interventions. Thus, we aimed to fill these knowledge gaps by determining the prevalence and intensity of monogenoids from *M. bleekeri* in relation to host size, season, and water quality parameters of the Dikrong River in Arunachal Pradesh, India.

Materials and Methods

Study area and host sampling
This study was conducted from February 2016 to January 2017 in the Dikrong River, a perennial tributary of the Brahmaputra River in western Arunachal Pradesh, India (27°6'N; 93°37'E) (Fig. 1). This river is approximately 145 km long (Huda, 2017) and has a catchment area of about 1,556 sq. km (Pandey *et al*., 2008). A total of 114 live specimens of *M. bleekeri* were collected using various local fishing nets and gears (see Chetry *et al*., 2012 for details) at monthly intervals from a single site to control for climatological conditions. Identification of fish specimens as *M. bleekeri* followed the taxonomic keys recommended by FishBase (Froese and Pauly 2017) and Jayaram (1999). They were immediately transferred to the research laboratory at Rajiv Gandhi University, Itanagar, where they were maintained in glass aquaria conditions, unless sacrificed, usually within 24 hours of collection, by anaesthetizing and then *pithing*. All fish specimens were measured (fork length, in cm) and classed into three length classes: 4.1 – 6 cm, 6.1 – 8 cm, and 8.1 – 10 cm to determine whether a correlation existed between fish length and infection level.

Water sampling and laboratory analysis
Water samples were collected monthly at the same time and place as host fish and were analysed according to American Public Health Association standards (APHA, 1998) for dissolved oxygen, Free CO2, Alkalinity, and pH. The surface water temperature was measured using an infrared thermometer (Mextex DT-8811). A one-year cycle was divided into three seasons (modified from Deka *et al*., 2015) – namely, pre-monsoon (February to May), monsoon (June to September), and post-monsoon (October to January).

Parasite sampling
Gills were dissected out and placed in petri dishes and examined for the presence and quantification of monogenoids under a dissecting microscope (Leica© EZ 4HD). Worms were picked off the gills using fine needles and then identified by a light microscope equipped with phase contrast optics using identification keys provided by Gussev (1976). After identification, some of the worms were fixed in 4 % formalin (for morphological studies) and others in absolute ethanol (for molecular studies). Temporary mounts were prepared by clearing and mounting the worms in glycerin for studying their sclerotized body parts; permanent mounts were made by staining and mounting the worms in Canada balsam according to the procedures recommended by Kritsky *et al*. (1986) for studying the soft body parts. The mounted parasites were photographed with a digital camera (Leica DFC450 C) attached to a Leica DM3000 light microscope. Voucher specimens were deposited in the British Natural History Museum, UK (NHMUK 2018.12.18.1).

DNA extraction, PCR, and sequencing
For molecular identification of parasite species, genomic DNA was extracted (from 52 adult worms fixed in 100 % ethanol) and 28S rDNA sequence was amplified following recent useful protocols (Tripathi *et al*. 2014; Choudhary *et al*. 2017). Sequencing was carried out by the commercial sequencing company (Xcelris Labs Limited, India) using the primers applied for PCR. The generated sequence (GenBank accession number MG832102.1) was subjected to BLAST (Basic Local Alignment Search Tool) analysis for homology search.

Table 1. Prevalence and mean intensity of infection of *Cornudiscoides agarwali* from *Mystus bleekeri* in relation to host size.

Size class	I	II	III
Length (cm)	4.1-6	6.1-8	8.1-10
Fish screened	29	54	31
Fish find infected	27	50	29
No. of parasites recovered	481	968	1311
Prevalence (%)	93.10%	92.59%	93.54%
Mean intensity (SE)	17.81 (3.02)	19.36 (2.42)	45.20 (5.69)

Table 2. Infection indices (in relation to three seasons and water quality parameters) of *Cornudiscoides agarwali* on *Mystus beleekri* from the Dikrong River, Arunachal Pradesh during 2016-2017 [DO= dissolved oxygen, Alk=Alkalinity, SWT=surface water temperature, FS=fish sampled, FI=fish infected, PR=parasites recovered, P=prevalence, MI=mean intensity].

| Seasons	Water quality parameters					Host size classes			
Pre Monsoon	DO	Alk	pH	SWT		CL-I	CL-II	CL-III	Total
Feb	7.5	47.13	7.1	22.7	FS	8	18	7	33
March	6.2	52	7.2	25.2	FI	8	18	7	33
April	6.2	27.3	6.4	21	PR	254	690	467	1411
May	6.5	35.33	6.8	22	P (%)	100	100	100	100
Mean	6.6	40.44	6.87	22.72	MI	31.75	38.33	77.83	42.75
Monsoon									
June	6.8	27.6	7.2	24	FS	10	14	8	32
July	7.7	31.66	7	28	FI	8	12	8	28
August	8.2	32	7.1	28.8	PR	92	76	292	460
Sept	7.8	43.33	7.4	25.7	P (%)	80	85.71	100	87.50
Mean	7.6	33.68	7.17	26.62	MI	11.5	6.3	36.5	16.42
Post Monsoon									
Oct	6.9	33.66	6.6	21.3	FS	11	22	16	49
Nov	6	31.33	7.4	15.8	FI	11	20	14	45
Dec	6.2	22.33	7.9	16.8	PR	135	202	552	889
Jan	6.2	30.5	7.2	18	P (%)	100	90.90	87.5	91.8
Mean	6.2	29.45	7.27	17.85	MI	12.27	10.1	39.42	19.75
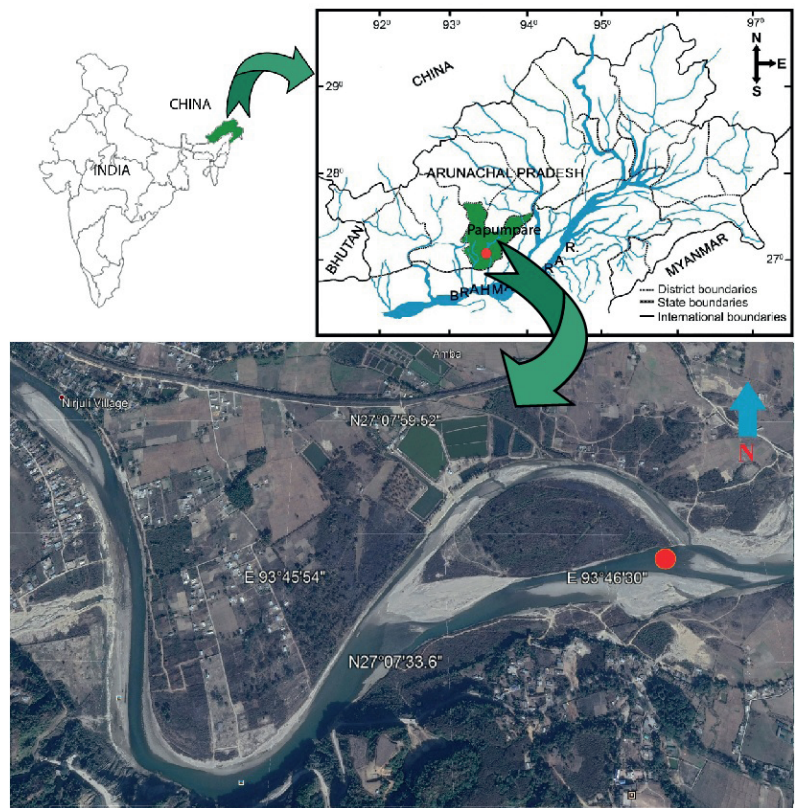
Fig. 1. The map of collection site of *Mystus bleekeri* in Arunachal Pradesh, India (satellite image from Google Earth™).

Fig. 2. Photomicrograph of an individual of *Mystus bleekeri* (not drawn to scale). Photo by Leki Wangchu.

Statistical analysis

The infection variables studied were prevalence (percentage of infected hosts in a sample) and mean intensity (mean number of parasites per infected host in a sample), which were calculated according to Bush *et al*. (1997). The standard deviation was calculated using Microsoft Excel (Office 2010). Fisher exact test was used for testing differences in prevalence values between the seasons. Kruskal-Wallis (K-W) ANOVA test was used for comparing the variations in the mean intensity of parasites for the seasons and host fish size. Pearson's correlation test was used to measure the correlation between mean intensity of infection and host fish size. All statistical calculations and graphs were made in the GraphPad Prism software (version 6). Confidence limits (P –values) were set at 95 %.

Ethical Approval and/or Informed Consent

The research related to animal use has been complied with all the relevant institutional policies for the care and use of animals.

Results

114 individuals of *M. bleekeri* (Fig. 2) were collected from February 2016 to January 2017 in the Dikrong River in western Arunachal Pradesh, northeast India. Upon the parasitological analysis of collected samples, two monogenoid species were found and identified using morphological characters: *Cornudiscoides agarwali*
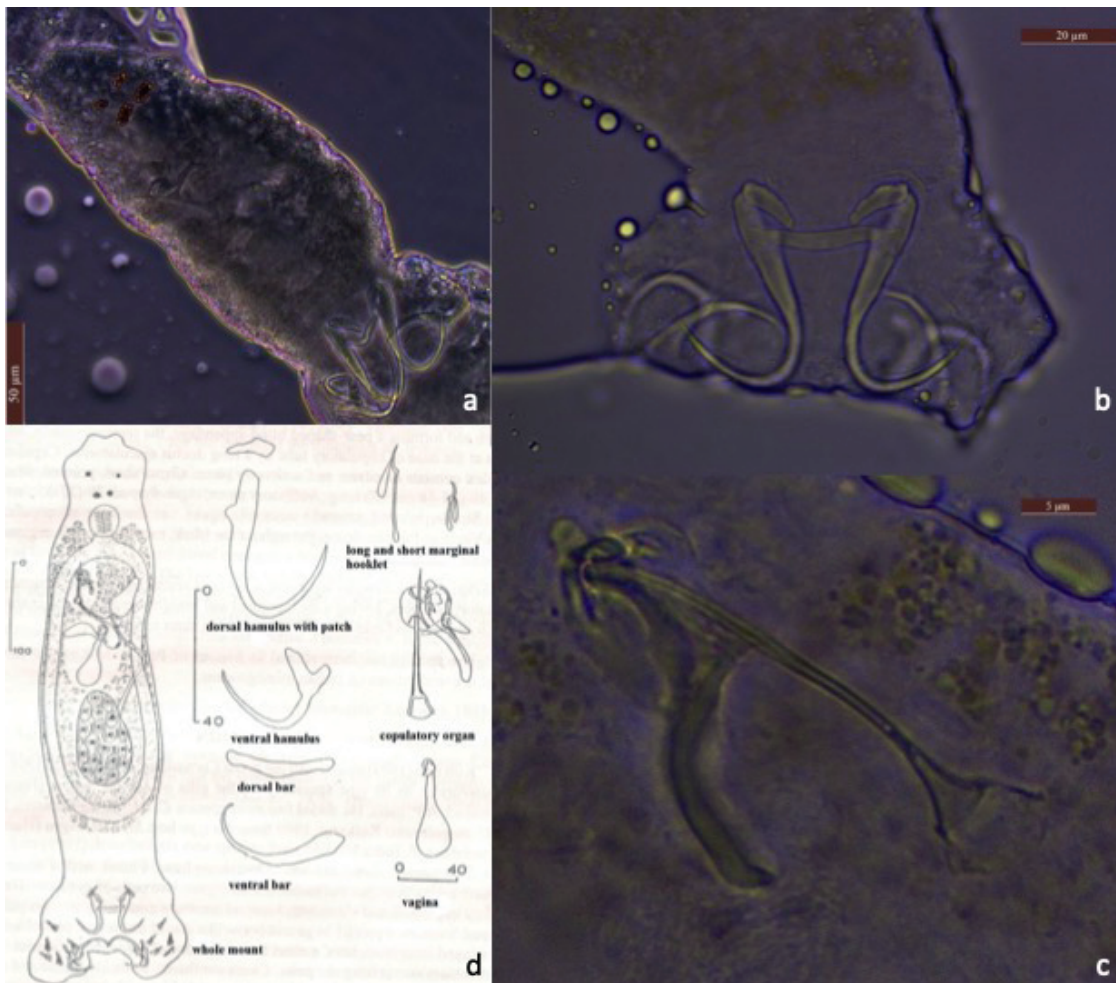

Fig. 3. Montage of *Cornudiscoides agarwali* recovered from *Mystus bleekeri*. (a) An individual worm, dorsal view. (b) Haptor armed with sclerotized structures: anchors, bars and hooks. (c) Copulatory complex. (d) Original figures of *Cornudiscoides agarwali* by Agrawal and Vishwakarma (1996). Scale bar: 100 µm for 3a, 20 µm for 3b and 5 µm for 3c. Photo (a, b, and c) by Amit Tripathi.
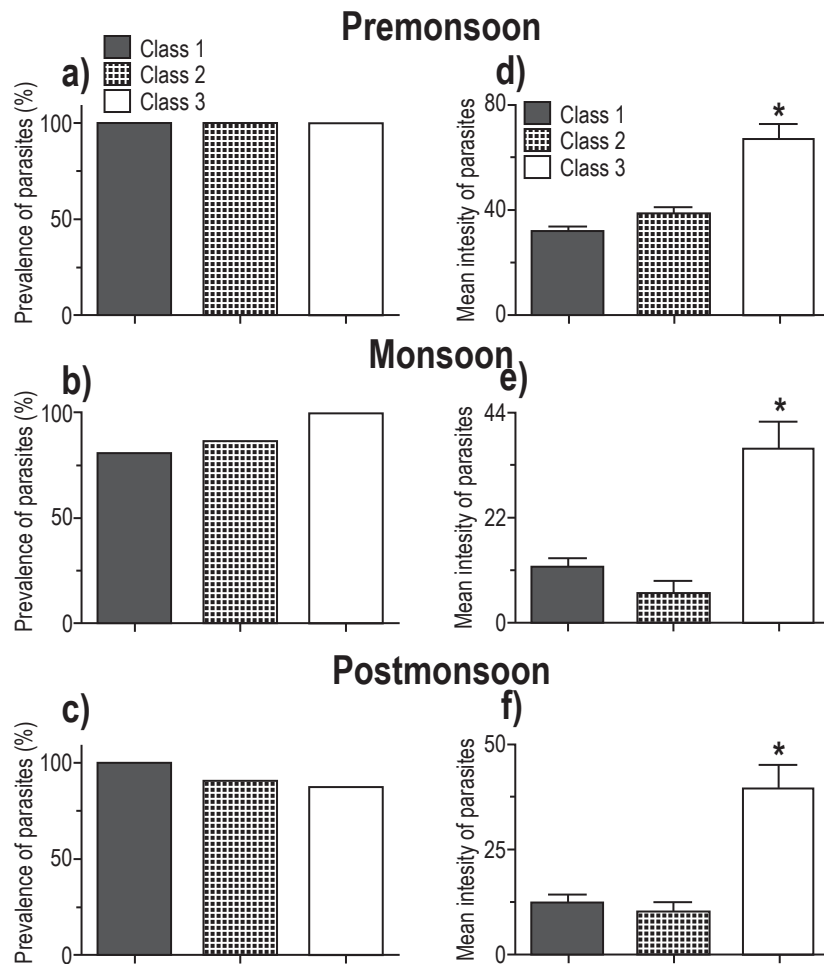
Figure 4. Left hand panel shows prevalence of parasites (a, b, c) and right hand panel shows mean intensity of parasites (d, e, f) during different seasons. Top panel shows prevalence and mean intensity during pre-monsoon (a, d), middle panel shows prevalence and mean intensity during monsoon (b, e), and bottom panel shows the prevalence and mean intensity during the post-monsoon season (c, f). * indicates significant difference (P < 0.05).

Agrawal and Vishwakarma, 1996 (Fig. 3) and *Cornudiscoides* n. sp. Of these two species, only *C. agarwali* was found infesting throughout the investigation period covering all host sizes and seasons, and hence, it was the subject of the current investigation. Of the 114 specimens of *M. bleekeri* examined, 106 were found to be infested with 2760 individuals of *C. agarwali* with overall prevalence and mean intensity values of 92.98 % and 26.03 ± 4.43, respectively. The results of molecular analysis showed that the 28S rRNA gene sequence for *C. agarwali* from the present study (accession MG832102.1) was most closely related to *C. agarwali* from northern India (query cover 95 %, E value 0, max identity 92 %, accession KU208071.1, and query cover 25 %, E value 5e-84, max identity 98 %, accession KU208072.1).

Size classes of the host fish and the distribution of population of C. agarwali
The prevalence levels of *C. agarwali* were almost similar, at 93.10 %, 92.59 %, and 93.54 % in the three host fish size classes

of 4.1 – 6 cm, 6.1 – 8 cm, and 8.1 – 10 cm, respectively (Table 1). The mean intensity was, however, highest in the fish of class III (8.1 – 10 cm) (45.20 ± 5.69 parasites/fish), followed by class II (6.1 – 8 cm) (19.36 ± 2.42 parasites/fish) and class I (4.1 – 6 cm) (17.81 ± 3.02 parasites/fish) (Table 1). The Kruskal-Wallis test revealed a significant variance in the mean intensity of infection between class I (4.1 – 6 cm) and class III (8.1 – 10 cm) (P<0.0001) and between class II (6.1 – 8 cm) and class III (8.1 – 10 cm) (P<0.0001); there was no difference between class I (4.1 – 6 cm) and class II (6.1 – 8 cm). Bonferroni post hoc test indicated that the mean intensity was significantly higher (P<0.05) in class III in comparison to class I and II. Pearson's correlation also suggested a positive correlation (r=0.12, P=0.0002; n=114) between mean intensity of parasite infection and host size.

Seasonal distribution of population of C. agarwali
The infestation of *M. bleekeri* with *C. agarwali* was found throughout the year though, with a definite seasonal effect. The prevalence
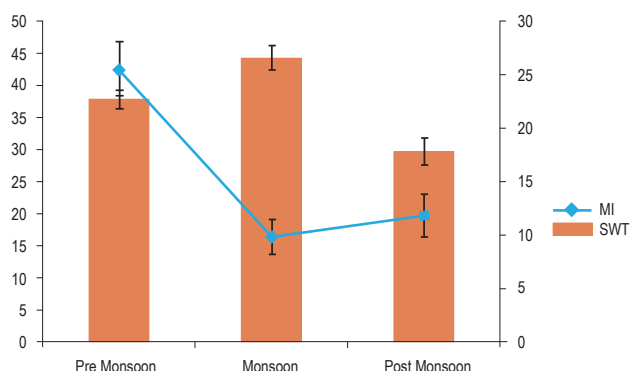
Fig. 5. Seasonal changes in the mean intensity of *Cornudiscoides agarwali* on the gills of *Mystus bleekeri* in relation to surface water temperature.

was highest (100 %) during the pre-monsoon season, followed by 91.8 % during the post-monsoon period and 87.5 % during the monsoon season (Table 2). A Fisher's exact test revealed that the differences in the prevalence of the monogenoids among the different seasons were significant (P<0.0001) (Fig. 4). Seasonal changes in the mean intensity also showed significant variations [$F_{2,104}$=14.2, P<0.0001 (one way analysis of variance]. For all three class sizes, the mean intensity was lowest (16.42 ± 2.90 parasites/fish) during the monsoon season, followed by an increase (19.75 ± 3.32 parasites/fish) in the post-monsoon season, and the highest (42.75 ± 4.18 parasites/fish) during the pre-monsoon season (Table 2).

Water quality parameters and the seasonal distribution of population of C. agarwali

Surface-water temperature
Surface-water temperature (°C) in the sampling area had a mean (± SE) of 22.4 ± 1.22 °C. The highest mean temperature was recorded in August (28.8 ± 0.38 °C) and the lowest in November (15.8 ± 0.07 °C). The highest mean intensity of *C. agarwali* was recorded during the pre-monsoon period (42.75 parasites/fish) when the surface-water temperature was 22.72 °C. Then, it rapidly declined during the monsoon period (16.42 parasites/fish) when
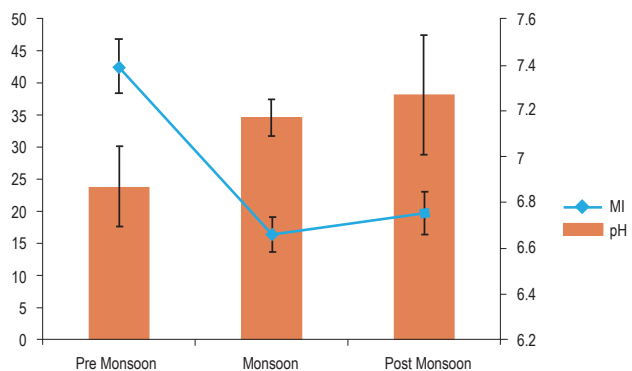
the surface-water temperature increased to 26.62 °C. It increased slightly during the post-monsoon period (19.75 parasites/fish) when the surface-water temperature decreased to 17.85 °C (Fig. 5).

Dissolved oxygen
Dissolved oxygen (DO) (mg/L) in the sampling area showed a mean (± SE) of 6.83 ± 0.22 mg/L. The highest DO mean value was recorded in August (8.2 ± 0.11) and lowest in October (6 ± 0.11). The mean intensity of infection was highest during the pre-monsoon period (42.75 parasites/fish) when the mean DO was 6.6 mg/L. It was followed by a rapid decline during the monsoon period (16.42 parasites/fish) when the mean DO increased to 7.62 mg/L. Then, it increased slightly during the post-monsoon period (19.75 parasites/fish) when the mean DO decreased to 6.27 mg/L (Fig. 6).

Water pH
The pH in the sampling area showed a mean (± SE) of 7.10 ± 0.11. The highest pH mean value was recorded in December (7.9 ± 0.05), and lowest in April (6.4 ± 0.12). The mean intensity of infection was highest during the pre-monsoon period (42.75 para_sites/fish) when the mean pH as 6.87. It was followed by a rapid
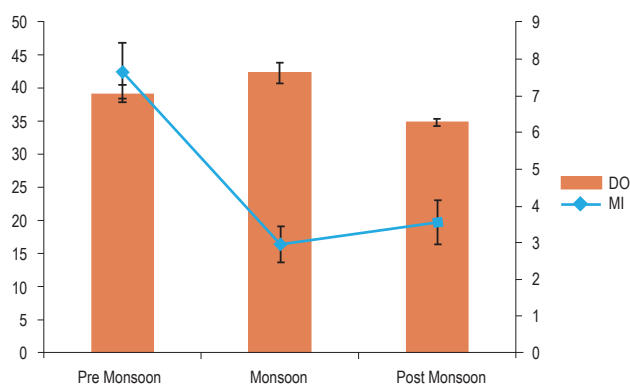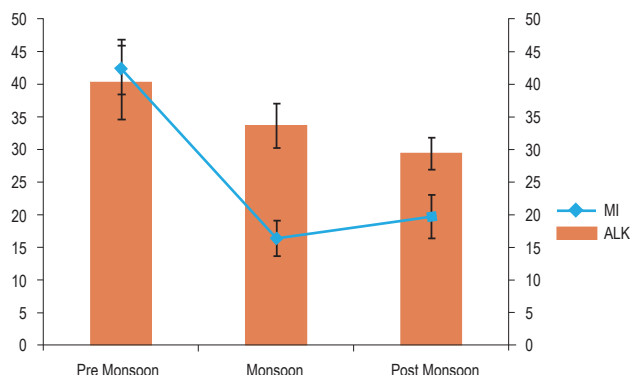

Fig. 6. Seasonal changes in the mean intensity of *Cornudiscoides agarwali* on the gills of *Mystus bleekeri* in relation to dissolved oxygen.

Fig. 7. Seasonal changes in the mean intensity of *Cornudiscoides agarwali* on the gills of *Mystus bleekeri* in relation to pH.

Fig. 8. Seasonal changes in the mean intensity of *Cornudiscoides agarwali* on the gills of *Mystus bleekeri* in relation to alkalinity.

decline during the monsoon period (16.42 parasites/fish) when the mean pH increased to 7.17. The mean intensity of infection then increased slightly (19.75 parasites/fish) during the post-monsoon period when the mean water pH also slightly increased to 7.27 (Fig. 7).

Water alkalinity

Alkalinity (mg/L) in the area showed a mean (± SE) of 34.51 ± 2.51 mg/L. The highest mean alkalinity was recorded in February (52 ± 1.99) and the lowest in December (22.33 ± 0.95). The mean intensity of infection was highest during the pre-monsoon period (42.75 parasites/fish) when the mean alkalinity was around 40.44 mg/L. This was followed by a rapid decline during the monsoon period (16.42 parasites/fish) when the mean alkalinity decreased to 33.64 mg/L. However, the mean intensity of infection increased slightly during the post-monsoon period (19.75 parasites/fish) when the mean alkalinity further decreased to 29.45 mg/L (Fig. 8).

Discussion

Given the high host specificity of monogenoids (Desdevises *et al*., 2002) it was highly improbable, though not impossible, that *C. agarwali* originally described from *M. vittatus* in northern India would infect specimens of *M. bleekeri* in Arunachal Pradesh in extreme northeast India. While the near identical morphometry of *C. agarwali* from Lucknow (1996) and Itanagar (this study) (Fig. 3) strongly suggested that they are one and the same species, we were also sure that our identification of *M. bleekeri* was correct. We then attempted, therefore, to identify parasite species via PCR and DNA sequencing. The partial nucleotide sequence (892 bps) of the 28S rRNA gene of *C. agarwali* from the present study (accession MG832102.1) was characterized and compared with previously available *Cornudiscoides* species. The BLASTn search showed two entries that returned the same species name for 28S rRNA gene: accession KU208071.1 (query cover 95 %, E value 0, max identity 92 %) and accession KU208072.1 (query cover 25 %, E value 5e-84, max identity 98 %). On balance, these are inconclusive BLASTn results as to whether the worms in question are of same species-level taxon.

A thorough search of the literature on the taxonomy and distribution of *Mystus* spp. suggests that this problem could be due to the misidentification of the Indian species of *Mystus* and, thus, their monogenoids. For example, despite the fact that *M. tengara* is a north Indian species (Jayaram & Sanyal 2003), Kulkarni (1969) described *Cornudiscoides heterotylus*, the type species of the genus, from *M. tengara* in Hyderabad (south India). Similarly, Agrawal and Vishwakarma (1996) described *C. agarwali* from *M. vittatus* in Lucknow (north India), although *M. vittatus* is a south Indian species. Likewise, *Mystus keletius* is confined to southern India, and possibly Sri Lanka, only (Dahanukar, 2011), yet *M. keletius* has been found in Bengal and north India (Johal & Tandon 1979; Jayaram & Sanyal 2003 and references therein). These tax-

onomic errors can be appreciated in the background of the fact that the identification of many species within the genus *Mystus*, which has traditionally been based on morphological features, is very difficult and confusing (Jayaram & Sanyal 2003; Singh *et al*.; 2013; Plamoottil, 2017) and their phylogeny is also unclear (Singh *et al*., 2013). For example, Jayaram and Sanyal (2003) noted that '*M. vittatus* and *M. tengara* are closely related and their exact identity has been in confusion'. Darshan *et al*. (2010) also pointed out that 'several records of *M. vittatus* from northeast India and Gangetic basin (in northern India) were misidentifications of *M. tengara*'. In fact, *M. vittatus* may have been confused with many other *Mystus* species (Froese & Pauly 2018; Hossain, 2014). Similarly, the identity of *Mystus nigriceps* Valenciennes has also been the subject of much confusion among ichthyologists (Ng, 2002).

In view of the high host specificity of monogenoids combined with the widespread confusion over the identity of *Mystus* spp., and the identical morphometry of *C. agarwali* from Lucknow (1996) and Itanagar (this study), we believe that Agrawal and Vishwakarma (1996) might have confused *M. bleekeri* with (and misidentified it as) *M. vittatus*. This explains the occurrence of *C. agarwali* in *M. bleekeri* in Arunachal Pradesh. However, examination of additional genes, probably more rapidly evolving markers such as *Cox1*, are necessary to confirm the validity of recognizing *C. agarwali* from northeast India and northern India. This is beyond the scope of this paper.

With respect to host size, the prevalence levels of *C. agarwali* were 93.10 % in class I (4.1 – 6), 92.59 % in class II (6.1 – 8), and 93.54 % in class III (8.1 – 10). Clearly, prevalence values were not dependent on host size. The mean intensity levels, however, generally increased with host size and peaked in the largest class size (8.1 – 10), indicating that the size of the host fish is important in determining the parasitic load. Statistically, this trend was more distinct between sizes classes I (4.1 – 6) and III (8.1 – 10) and between size classes II (6.1 – 8) and III (8.1 – 10). Our findings are similar to those reported by Tombi *et al*. (2014), who found the highest mean intensity of *Dactylogyrus amieti* and *Dogielius njinei* in larger fish (> 7.5 cm). These results could well be a reflection of any one or even a combination of the following factors: (i) that larger host species live longer, and thus, represent a more predictable resource for a parasite (Peters, 1983); (ii) that the larger-bodied hosts may be easier to colonize because of their larger roaming ranges, or (being older), their longer time to have accumulated parasites (Poulin, 1998), and (iii) that larger hosts offer more vacant niches for greater abundance of parasitic monogenoids (Guegan *et al* 1992; Sasal *et al*., 1999).

Cornudiscoides agarwali showed a seasonal variation in terms of prevalence, though the values remained above 87.5 % throughout the year, of course suggesting that the parasite reproduced around the year. On the other hand, the mean intensity values fluctuated for all the three class sizes from low (during the monsoon), to moderate (in the post-monsoon period), to high (in pre-monsoon period), generating a statistically significant seasonal cycle.

We investigated the physical (temperature) and chemical (DO, pH, and alkalinity) properties of the river water with respect to the mean intensity values of *C. agarwali* to understand the seasonal relationship between the infestation of monogenoids and the water quality parameters. With respect to water temperature, the results indicated an inverse relationship between mean intensity and water temperature during monsoon and post-monsoon seasons, and a direct relationship during the pre-monsoon season. Many studies have indicated that high water temperature often increases monogenoids' growth, reproduction, and egg hatching, facilitating the build-up of large populations (e.g., Hooglund & Thulin, 1989; Gannicott & Tinsley, 1998; Kim *et al*., 2001; Silan & Maillard, 1989). The direct relationship between mean intensity of infestation and the water temperature during the pre-monsoon season in this study supports this assumption, as did the findings of Anderson (1974) and Simkova *et al*. (2000). However, the inverse relationship found during the monsoon and post-monsoon seasons suggests that temperature alone may not be the only controlling factor in the population dynamics of *C. agarwali*. According to Marcogliese (2001) the low water levels and the subsequent low flow rates of water may promote the retention of free-swimming infective stages of complex life-cycle parasites. We suggest that the inverse relationship between *C. agarwali* and water temperature during the monsoon and post-monsoon seasons is actually a function of higher stream velocity, which may have swept away larvae (oncomiracidia) resulting in low recruitment. It is worth noting that an increase in velocity of Indian rivers due to heavy rainfall during the monsoon season is well documented (see Soni *et al*., 2014). This velocity increases even further in hill streams of Arunachal Pradesh (Mahanta *et al*., 2012) due to presence of steep slopes and the obstructions within the river beds.

With respect to the dissolved oxygen, the results indicated an inverse relationship between mean intensity and dissolved oxygen during the monsoon and post-monsoon seasons but a direct relation during the pre-monsoon season. It is important to note that, throughout the year of investigation, the concentrations of dissolved oxygen were found to be within the recommended range for freshwater fish in the tropics (desired values of DO>5 mg/L) (Boyd, 1982; Wetzel, 1983). Seemingly, the dissolved oxygen, when present in its optimum value, had little or no significant influence over the monogenoids' proliferation. The decrease in mean intensity of infestations during the monsoon and post-monsoon seasons was probably related to the higher stream velocity discussed above, and not to the dissolved oxygen.

With respect to the pH, the results indicated an inverse relationship for the pre-monsoon and monsoon seasons but a direct relation for the post-monsoon season. In this study, the seasonal range of pH (from 6.8 to 7.2) remained within a narrow range, making it difficult to understand or predict its effect on the seasonal dynamics of *C. agarwali*. Moreover, the pH values observed were close to recommended values (7 – 8) (Boyd, 1982; Wetzel, 1983)

for tropical aquaculture. From these facts one would expect that *C. agarwali* survives and reproduces best in water with a near-neutral pH value.

With respect to water alkalinity, the results indicated a direct relationship between mean intensity and water alkalinity during the pre-monsoon and monsoon seasons but an inverse relationship during the post-monsoon season. The alkalinity is interdependent with other water quality parameters, especially pH. Since the observed pH values staryed within a narrow range across seasons, alkalinty did not seem to have any significant impact on the mean intensity of infection of *C. agarwali*. Moreover, the values of alkalinity were found to stay within the recommended range for freshwater catfish (>20 mg/l) throughout the annual cycle (Swann, 1997). Considerable work has been done on the interaction between water quality parameters and parasitism, concluding with three major and often contradictory predictions. The first conclusion is that pollutants may increase parasitism by reducing the immunological response of hosts (McDowell *et al*., 1999), including fish (Jokinen *et al*., 1995; Siddall *et al*., 1996), thus rendering them more susceptible to some parasites. The second conclusion is that pollutants can decrease parasitism by killing the parasites directly or by reducing the host density by causing differential mortality in infected hosts but not in uninfected fish (reviewed by Sures 2004). The third conclusion is that eutrophication may increase parasitism by increasing the abundance of their hosts (Beer & German, 1993) including fish (Valtonen *et al*., 1997) through nutrients-associated productivity. The river water in the Indian Himalayan region, spread across 11 states including Arunachal Pradesh, is generally free from pollution, since the industrial and domestic pollutants are minimal in this region (Semwal *et al*., 2006; National Commission on Farmers 2004). This is justified by the fact that mean values – as well as extreme values – of water quality parameters tested in this study were all within the desired values for tropical aquaculture (see above). Therefore, the fact that *C. agarwali* was found reproducing throughout the year (since it maintained its prevalence above 87.5 % throughout the year) in a non-polluted Dikrong River site indicates that the monogenoidean community and population dynamics thrives best under optimum water quality parameters. To confirm this, however, laboratory-based experimental studies are necessary to determine the tolerance of *C. agarwali* to pollutants.

Conflict of Interest

Authors state no conflict of interest.

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