Ecological Indicators 81 (2017) 503–513

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Biomonitoring potential of a Caryophyllaeid tapeworm: Evaluation of *Adenoscolex oreini* infection level and health status in three fish species of the genus *Schizothorax* across eutrophication and pollution gradients

Ummer R. Zargar[a,*], Mohammad Z. Chishti[a], Mohmmad I. Rather[b], Musharaf Rehman[c], Nuzhat Zargar[d]

[a] Department of Zoology, Central University of Kashmir, Sonwar Campus, Srinagar, 190004, India
[b] P.G. Department of Environmental Sciences, University of Kashmir, 190006, India
[c] Centre of Research for Development, University of Kashmir, 190006, India
[d] Department of Veterinary Medicine, GADVASU, Ludhiana, Punjab, India

A R T I C L E I N F O

Keywords:
Biomonitoring
Caryophyllaeid tapeworm
Pollution gradient
Gonadosomatic index
Health attributes

A B S T R A C T

Endoparasitic infections vary significantly across altered aquatic ecosystems, making these organisms ideal for the biomonitoring of degraded environments. To assess the biomonitoring potential of the Caryophyllaeid tapeworm *Adenoscolex oreini* and the possible impact of water quality on fish species, a study was carried out in three lakes with marked eutrophication and pollution gradients. The *A. oreini* infection level in three host fish species of the genus *Schizothorax* and corresponding fish health status were determined. The pattern of cestode infection varied significantly in the three fish species across the pollution gradient. The prevalence of infection in two fish species (*Schizothorax esocinus* and *S. curvifrons*) was significantly greater ($P < 0.05$) in the eutrophic lake than in the reference lake, whereas in *S. niger*, the maximum was reached in the hypereutrophic lake. The estimated marginal mean intensity and other infection indices varied significantly ($P < 0.05$) across the inter- and intra-pollution gradients of lakes. Multivariate statistical analysis results revealed maximum cestode infection in the eutrophic lake. An altered seasonal pattern was observed in the highly stressed lake. The gonadosomatic index (GSI) and condition factor values were significantly greater in fish collected from the reference lake than in those collected from the other lakes. A significant negative relationship between GSI and cestode prevalence was observed in the hypereutrophic lake as compared to least eutrophic lake. These findings indicate that infection indices of the Caryophyllaeid tapeworm and health attributes of fish can act as surrogates for the environmental quality of deteriorated lentic water bodies of the north-western Himalayan region, which is currently undergoing environmental degradation.

1. Introduction

Stressed aquatic ecosystems pose a great danger to aquatic flora and fauna because of the presence of industrial, household, and other anthropogenic contaminants. The fish fauna, an important component of the aquatic food web, is directly or indirectly exposed to various stressful conditions, leading to the deterioration of its health status. Previous studies have shown that continuous exposure of fish to pollution may disrupt their reproductive potential and endocrine function, which can result in the decline of fish fauna (Kime, 1999; Kime and Nash, 1999). It has now been established that fish species are exposed to multiple stressors, which have different effects from those posed by a single stressor (Marcogliese and Pietroct, 2011). For example, Marcogliese and Pietroct (2011) showed that in conjunction with different natural and anthropogenic stresses, parasites can reduce the survival and health status of host organisms. Among aquatic fauna, the fish-parasite system is highly exposed to natural and human-induced pollutants, and it represents an ideal model that could be used to determine the effects of various factors on different biological and physiological attributes of hosts and their parasites (Kime, 1999). Recently, researchers have advocated the usefulness of parasites as ecosystem health indicators, especially in cases of metal contamination and cultural eutrophication (Shea et al., 2012; Shah et al., 2014). Therefore, it is important to understand the combined effects of parasitism and pollution in new host-parasite systems and to provide a better perspective of the relationship between hosts, parasites, and their

* Corresponding author.
E-mail addresses: uzssummer2@gmail.com, ummerzargar@yahoo.com (U.R. Zargar).

http://dx.doi.org/10.1016/j.ecolind.2017.06.025
Received 16 November 2016; Received in revised form 4 May 2017; Accepted 13 June 2017
1470-160X/

environment.

Parasites, hosts, and their environment interact with each other. For example, parasitism may increase or decrease when parasites and hosts interact in a contaminated environment. An increased level of parasitism may have further adverse effects on the health conditions of fish, which are already weakened through contaminant exposure. Therefore, complex interactions between parasites and host fish, associated with the health status of fish under polluted conditions, have great implications for the conservation of threatened fish fauna (Morley et al., 2010). Consequently, there is a need for an integrative research approach to understand the determinants of various factors that influence parasites and their hosts in ecosystems with multiple stressors.

In the past three decades, studies investigating the relationship between various pollutants and fish parasitism have conclusively shown the effectiveness of piscine parasites as indicators of contaminant effects and accumulation. As such, various environmental parasitologists have suggested the use of parasites in impact assessment studies (Chapman et al., 2015; Oluoch-Otiego et al., 2016). For example, Claxton and Laursen (2015) illustrated that endoparasites in sunfish varied considerably with the amount of coal mine effluent in southern Illinois, whereas Oluoch-Otiego et al. (2016) evaluated the potential of three cestode parasites of fish as bioindicators of polychlorinated biphenyls (PCBs) in Lake Victoria. The potential use of parasites as environmental indicators has been tested at various levels, especially under field conditions, and most studies have unequivocally advocated the use of parasites as environmental indicators (Blanar et al., 2009; Lafferty, 1997; Marcogliese, 2005; Marcogliese and Pietrock, 2011). However, a recent meta-analysis of the association between parasites and contamination, carried out by Vidal-Martínez and Wunderlich (2016) in Latin America, showed a significantly low negative effect, and the authors suggested an interdisciplinary approach to ascertain the possible response of parasites to environmental change. Additionally, there is still ambiguity with regard to various aspects of parasite-contaminant associations. Therefore, various researchers have highlighted the need to investigate new parasite sentinels in order to ascertain their responses to various environmental perturbations that are impossible to detect with existing indicators.

Endoparasites of fish, especially cestodes, have been a research focus in recent years, because their life cycle is simpler than that of other parasites. The seasonal dynamics and other ecological features of Caryophyllaeid tapeworms have been investigated by parasitologists (Williams and Jones, 1994). In addition, their importance lies in their colonization ability, and they have spread to new regions of the world where they are considered potential pathogens of both farmed and wild fish (Kennedy, 1994; Oros et al., 2004). Furthermore, cestode parasites of fish have been extensively used as bioindicators of heavy metal pollution and organic pollutants in various regions of world (Oyoo-Okoth et al., 2010; Yen Le et al., 2014; Yen Nhia et al., 2013). In a recent study conducted by Sánchez et al., (2016), cestode parasites in a multiple stress environment were shown to make *Artemia* (brine shrimp) more resistant to arsenic pollution. However, very few attempts have been made to elucidate the relationship among Caryophyllaeid tapeworm infections, water quality, and the health conditions of fish in stressed aquatic ecosystems. Considering the importance of fish cestodes in the ecological milieu, there is a dire need to investigate their potential as effective indicators under different stress conditions.

The main objectives of the present study were: (1) to investigate variation in the infection levels of Caryophyllaeid tapeworms *(A. oreini)* in three fish species of the genus *Schizothorax* across a eutrophic/pollution gradient (both inter- and intra-lake gradients); (2) to evaluate the effects of altered water quality on the seasonality of cestode infections across a pollution gradient; and (3) to elucidate the association between stressed aquatic conditions of lakes and the health traits of fish. Moreover, we sought to evaluate the biomonitoring potential of host-parasite systems (host-cestode sentinel systems) in altered lentic water systems of the north-western Himalayan region.

2. Methods

2.1. Study area

The Kashmir Valley is situated between the north-western and south-eastern Himalayas (33°01–35°00′N lat.; 73°48′–75°30′E long.) at an elevation of ≥1500 m above sea level. Three lakes were selected for the present investigation: Anchar, Dal, and Manasbal (Table 1 and Fig. 1). Anchar Lake (34°01′N, 74°02′E) is a hypereutrophic lentic water body located northwest of Srinagar city. This lake is subjected to montane valley climatic conditions, with severe cold from October to March (mean air temperature 7.5 °C) and warmer summer months (mean air temperature 19.8 °C). The temperature ranges in January (coldest month) and July (warmest month) are −2–3 °C and 34–35 °C, respectively. The lake is fed by the Sind River and by several springs present in its basin and along its periphery. A tertiary-care hospital (SKIMS) complex is situated northeast of this water-basin, and its toxic effluents are drained into the lake. The majority of the lake is occupied by different types of submerged and free-floating macrophytes. The area of the lake has been reduced not only by an influx of household waste from human habitation but also by illegal encroachments. The maximum length, breadth, and depth of the lake are 3.55 km, 0.65 km, and 3.5 m, respectively. Three sites were selected for the present study: a hypereutrophic site (A1H), a eutrophic site (A2E), and the least eutrophic site (A3LU). Dal Lake (34°07′N, 74°52′E) is located in the urban area of the summer capital (Srinagar) at the foot of the Zabarwan Hills, and it has an elevation of 1584 m above sea level. Three study sites were selected: a hypereutrophic site (D1H), a eutrophic site (D2E), and the least eutrophic site (D3LU). Manasbal Lake (34°15′N, 74°40′E) was the third lake selected for the investigation, and it is located 32 km from the capital city at an elevation of 1585 m above sea level. The lake is considered a warm monomictic lake, measuring approximately 3.2 km and 1 km in length and breadth, respectively. The lake has its own water source from underground springs that spread across all parts of the lake (Khanday et al., 2016a). Three study sites were selected in the lake: east (M1), centre (M2), and west (M3). M1 and M3 are situated in the peripheral zone, whereas M2 is located in the middle of the lake.

2.2. Hypothesis and study design

We predicted that altered eutrophic conditions might alter tapeworm infection incidence, with an increase in infection levels in fish across the eutrophic gradient (i.e. from the least eutrophic lake to the eutrophic lake). We further assumed that infection percentages and abundances might decrease when conditions changed from eutrophic to hypereutrophic (multiple-stressed conditions). In addition, we suspected that there would be either a synergistic or an antagonistic impact of multiple-stressed conditions on the health traits of fish (Fig. 2).

The three lakes selected for the current study showed well-marked changes in water quality, and were designated as follows:

Table 1
Brief description of investigated lakes of north-western Himalayan Region.

Characteristics	Anchar Lake	Dal Lake	Manasbal Lake
Latitude	34°14′N	34°07′N	34°15′N
Longitude	74°78′E	74°52′E	74°40′E
Elevation	1584 m amsl	1,58 4 m amsl	1585 m amsl
Total Surface Area	6.6 Km^{2*}	24 $Km^{2\$}$	2.81 km^{2*}
Maximum Depth	3m	6m	13 m
Lake type	Amictic shallow lake	Warm monomictic	Warm monomictic/ deepest monomicticˆ
Pollution status	Hypertrophic*ˆ+	Eutrophic*ˆ+	Least eutrophic*ˆ+

*Khanday et al. (2016b); ˆHumaira et al. (2013); +Zargar et al. (2012c), $Rashid et al. (2017).