Bulletin of Pure and Applied Sciences
Vol.39A (Zoology), No.2,
July -December 2020: P.379-386
Original Research Article

Print version ISSN 0970 0765
Online version ISSN 2320 3188
DOI 10.5958/2320-3188.2020.00042.X
Available online at www.bpasjournals.com

Population Ecology of Parasitic Helminthes *Oncodiscus* Yamaguti, 1934 (Cestoda: Bothriocephalidae) in Greater Lizardfish *Saurida tumbil* Bloch (Aulopiformes: Synodontidae) from the Coast of Visakhapatnam, Bay of Bengal

[1]Sushil Kumar Upadhyay*
[2]Raj Singh
[3]Babita
[4]Priya Panwar
[5]Dheer Pal Singh
[6]Kavita Rani
[7]Deepak Yadav

Author's Affiliation:
[1,2,3,4]Department of Biotechnology, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, Haryana-133207, India
[5]Department of Zoology, K.V. Subharti College of Science, Swami Vivekanand Subharti University, Meerut- 250005, UP., India
[6]Department of Biotechnology, Meerut College, Meerut- 250003, UP., India
[7]Department of Zoology, Miranda House, Delhi University, New Delhi -110021, India

***Corresponding Author:**
Dr. Sushil Kumar Upadhyay,
Assistant Professor, Department of Biotechnology, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala (Haryana) - 133207, India.

E-mail: upadhyay.k.sushil@gmail.com

*ORCID:
https://orcid.org/0000-0002-1229-4275

Received on 13.07.2020
Accepted on 22.10.2020

Abstract:
The present study was undertaken to determine the parasitic helminthes infection prevalence and mean intensity in marine greater lizardfish *Saurida tumbil* Bloch (Aulopiformes: Synodontidae) with special reference to hosts size, weight and marine hydrobiological parameters in the Coast of Visakhapatnam, Bay of Bengal. The sample water, host fish and parasites were collected from R.K. beach Visakhapatnam coast, Andhra Pradesh during January to June, 2014. The sample water processed for physicochemical attributes showed month wise and seasonal oscillations in hydrobiological parameters. During parasitological investigation intestinal tapeworms *Oncodiscus* sp. Yamaguti, 1934 (Cestoda: Bothriocephalidae) were recovered in variable number. The sex, size and weight biased parasitic load was well marked during the study. The peak infection prevalence 92% and mean intensity 7.0 recorded during summer showed parasitic infections were more prevalent in male compared to female fish. The study also showed that some physicochemical features of the marine body including water temperature, salinity, alkalinity and hardness played significant positive correlation with the cestodes prevalence.

Keywords: *Oncodiscus* sp., *Saurida tumbil,* Population ecology, Visakhapatnam coast, Hydrobiological attributes, Infection prevalence, Mean intensity.

INTRODUCTION

Parasites in fish are natural, ubiquitous, rich and common in occurrence (Madhavi and Lakshmi, 2012; Jaiswal et al., 2013). Parasites can provide information about host population ecology and help to correlate varieties of specialized traits and life-history strategies for aquaculture management (Iwanowicz, 2011; Upadhyay, 2012, Jaiswal et al., 2014a, Upadhyay et al., 2015a). Small numbers of cestodes often occur in healthy fish, but high numbers cause illness or even death in turn

reproductive capacity of aquaculture systems (Overstreet and Hawkins, 2017; Upadhyay, 2020a,b). The zoonoses encompassed the preparation methods of traditional fish dishes, being prepared in society for centuries, are instrumental in transmission of food-borne pathogens from fish to human beings (Upadhyay et al., 2015b; Babita et al., 2019; Upadhyay et al., 2019a,b). All the parasites, their developmental stages, population biology and transmission dynamics governed by the intrinsic environment of host and extrinsic habitat environment in which hosts are living (Malhotra et al., 2009; Jaiswal et al., 2014b; Upadhyay, 2017; Nanware et al., 2019). The close proximity or contact among host individuals positively correlated to parasite transmission. Therefore, greater host sociality or gregariousness should translate to higher parasite prevalence and diversity for directly transmitted species (Jaiswal et al., 2014b; Upadhyay and Singh, 2018; Upadhyay et al., 2019b). Increased prevalence and intensity may result directly from social contacts, foraging behavior, whereas the parasite species richness may increase because of aggregated hosts provide a larger habitat for parasites through effects analogous to island biogeography (Morand, 2000; Altizer et al., 2003; Britton et al., 2011; Upadhyay et al., 2013). A large number of epidemiological models, supported by data from several empirical and comparative studies, point to stronger links between host density or local group size and the spread and diversity of directly transmitted parasites (Upadhyay, 2017; Upadhyay, 2018; Upadhyay et al., 2019a).

The survival establishment and transmission dynamics of parasites in hosts are influenced by climate change short term or long term alike (Wali et al., 2016). Since primary and intermediate consumers of aquatic food web play a very significant role in transferring the developmental stage of parasite from one host to other (Frantz et al., 2018). Thus available faunal diversity may also responsible for seasonal transmission dynamics of parasites in aquatic to terrestrial hosts or vice versa (Upadhyay, 2020c; Upadhyay and Nanware, 2020). The characteristics changes in the aquatics body such as fluctuations in abiotic conditions, chemical and physical buffering capacity along other biotic interactions have the potential to reflect out in life cycle, and maturity cycle of adult worm or in body of host as well (Jones, 2013; Cable et al., 2017). The attributes of sex of fish that enhanced host susceptibility to helminthes infections, were analyzed by a large number of investigators (Jaiswal, 2006; Kumar, 2012; Upadhyay, 2012; Upadhyay, 2020b). Adult fish harbor more parasites of a more diverse fauna than pre-adults are generally more heavily parasitized than male (Puniyabati et al., 2010; Upadhyay et al., 2013; Jaiswal et al., 2014b).

The parasite–mix is affected by seasonal change only if the abundance of an obligatory intermediate host varies seasonally (Jaiswal et al., 2014a,b; Babita et al., 2019). As depth increases, seasonal effect declines because of migration and predation by epipelagic fish (Turner et al., 2012; Murphy et al., 2013). The effect of temperature dependent host–parasite rejection response was established in earlier literature and showed variability in response of life cycle stages to sudden changes in ambient temperature (Macnab and Barber, 2012; Paul et al., 2012; Cornet et al., 2014; Barber et al., 2016; Upadhyay, 2018). As a consequence, structure of parasitic communities in an aquatic ecosystem is the function to influence host characteristics such as body size, weight, sex, diet, social contact, swimming behavior and host phylogeny (Iwanowicz, 2011; Giannetto et al., 2012). Therefore, the current investigation was planned to work out the trends of cestodes infection and their correlation to intrinsic factors of fish host and extrinsic hydrobiological environment of the marine ecosystem.

MATERIALS AND METHODS

The investigations were conducted for six months during January to June, 2014, to work out environmental influence on infectivity patterns of cestode *Oncodiscus* Yamaguti, 1934 (Cestoda: Bothriocephalidae) in marine Greater lizardfish *Saurida tumbil* Bloch (Aulopiformes: Synodontidae). The collections of sea fish *S. tumbil* were made at R.K. beach Visakhapatnam coast, Bay of Bengal ($83^0$19'12.08"E (Lon), ($17^0$42'41.96"N (Lat), 11m (Alt)), Andhra Pradesh. The hosts were brought to Parasitology Laboratory of Zoology Department, Andhra University, Visakhapatnam, and separated on the basis of sex, size and weight of hosts for further parasitological study (Upadhyay, 2012). The worms were recovered kept in lukewarm water, and their number was recorded carefully based on individual host. These were further processed for correct taxonomic identification after Yamaguti

(1959). The isolated cestodes were fixed in 4% of hot formaldehyde, stained in aqueous solution of Mayer's Haemalum (HiMedia), dehydrated in graded ethanol, cleared in xylene and finally mounted using Canada balsam (Malhotra, 1985; Kumar, 2012). The qualitative estimation of hydrobiological parameters was performed by titrimetric/ volumetric analysis after manual of American Public Health Association (APHA, 1998). However, the salinity was enumerated through digital Salinometer (ERMA hand refractometer, Tokyo). The modern numerical tool was applied for the analysis of hydrobiological effects on the infectivity patterns of cestodes in the selected hosts through software SYSTAT11. The infection prevalence percent (IP%) and mean intensity (MI) of helminthes in hosts was calculated after Malhotra and Chauhan (1981); Malhotra (1982); Malhotra and Nanda (1989).

RESULTS

The tapeworms isolated from the intestine of *Saurida tumbil* were characterized and identified as *Oncodiscus* sp. (Yamaguti, 1934; Yamaguti, 1959; Kuchta et al., 2009). The hydrobiological estimation based on titrimetric analysis reflected that the hardness of the R.K. beach coastal area ranged between 27900-32670 (29000±1570) mg/l; however the alkalinity was recorded 3600-6300 (4550±790) mg/l. The water temperature of selected coast was recorded between 26.9-28.5 (27.5±0.5) ^{o}C. However, salinity ranged between 31-34 (32.5±1.0) ppm. The parasitological investigation showed that total 45-80 (69±11) % fish found to be infected (35-92 IP % in male fish and 65.5-75 IP % in female fish). The mean intensity (MI) of cestodes in total fish was recorded between 2-7 (4±1) during investigation (MI in male fish, 3-7; MI in female fish, 2-5). The male fish were comparatively more prone to cestodes infection with peak infection prevalence 92% and mean intensity 7.0 than female fish (IP %, 75.0 and MI, 5.0). All the collected host fish from marine coast at Visakhapatnam were grouped in three different size (cm) and weight (g) classes. The association of size and weight of hosts to parasitic infection reflected that larger and heavier the fish greater the infection prevalence (IP%) and mean intensity (Table 1). The effect of hydrobiological parameters was also remarkable throughout the investigation assessed by linear regression analysis. It reflected that the water temperature (Fig. 1) salinity (Fig. 1), alkalinity (Fig. 2) and hardness (Fig. 2) of marine water body were positively correlated to *Oncodiscus* sp. infection in Greater lizardfish *S. tumbil*.

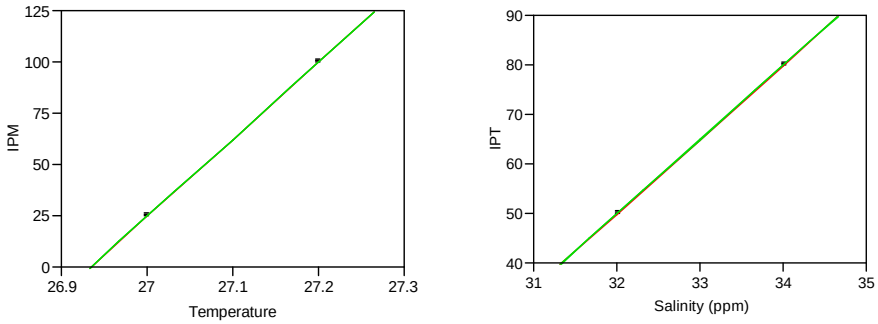

Figure 1: Correlation of infection prevalence (IP%) of *Oncodiscus* sp. in *S. tumbil* with water temperature (^{o}C) and salinity. *Where: IPM, IP% in male fish; IPT, IP% in total fish.*

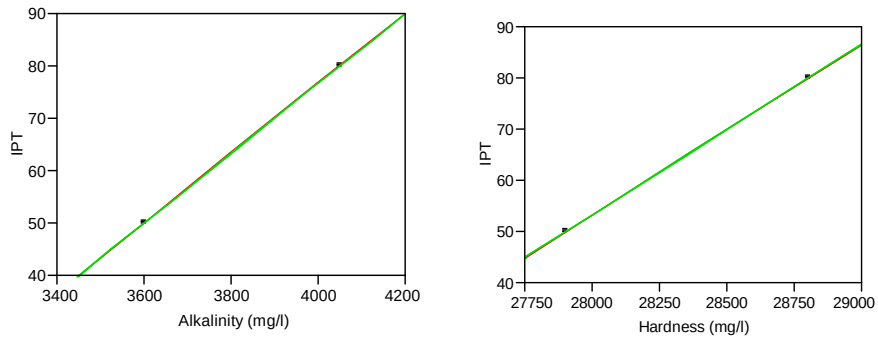

Figure 2: Correlation of infection prevalence (IP%) by *Oncodiscus* sp. in *S. tumbil* with alkalinity (mg/l) and hardness (mg/l). *Where: IPT, IP% in total fish.*

DISCUSSION

The distinct correlation in month wise variations of cestodes infection was recorded during investigation reflected higher parasitic incidence during summer with peak mean intensity in late summer (Wali et al., 2016). The scanty cestodes infection during January and early February corroborated to seasonality influence on developmental cycle and restricted release of eggs as emphasized by Kumar (2012); Hoberg and Brooks (2015). The invasion of cestodes infection in fish hosts by procercoid larval stages through intermediate hosts were reported and found to be either low or be undetectable during winter (Jaiswal, 2006; Mangal et al., 2008; Paul et al., 2012). The study peculiarly depicted strong association of parasitic incidence (IP% and MI) in fish with aquatic attributes like salinity, alkalinity and hardness, and found to be statistically significant (Jaiswal et al., 2013). The increase in infection prevalence was positively correlated with augmented water temperature (Jaiswal et al., 2014b; Barber et al., 2016; Upadhyay, 2017; Upadhyay, 2020b). The overall interaction of all hydrobiological parameters like alkalinity and salinity were found to be corroborated significantly to earlier parasitic infection investigations (Kumar, 2012; Upadhyay, 2012; Jaiswal et al., 2013; Jones, 2013). The findings, therefore, associated to generally higher prevalence of tapeworm infection during the period of enhanced alkalinity and salinity under natural conditions (Turner et al., 2012; Cizauskas et al., 2017). The strong association of fluctuation in monthly and seasonal cycle of tapeworms' with salinity and alkalinity has been confirmed as highlighted in earlier studies also (Macnab and Barber, 2012; Turner et al., 2012).

Table 1: Correlation of *Oncodiscus* sp. to size and weight of *Saurida tumbil* from R.K. beach at Visakhapatnam coast, Bay of Bengal.

Hosts' body parameter	Measurement classes	Mean IP % in hosts			Mean intensity in hosts		
		Male	Female	Total	Male	Female	Total
Body size (cm)	0<15.0	0.0	0.0	0.0	0.0	0.0	0.0
	15.1-20.0	35.0	25.0	30.0	3.0	2.0	2.5
	20.1-25.0	95.0	75.0	85.0	6.0	4.0	5.0
Body weight (g)	0<50.0	10.0	15.0	12.5	1.0	1.0	0.5
	50.1-100.0	25.0	35.0	30.0	2.5	3.5	3.0
	>100.1	85.0	95.0	90.0	5.0	4.0	4.5

Larger female fish heavily infected than the male fish during the investigations that was supported by the findings of Akinsanya et al. (2008). Similar investigation on rainbow trout for the parasitic disease severity recorded that had long been known to be dependent on the size of host (Thompson et al., 1999; Genc et al., 2005). During the spawning or breeding period, male fish moved faster than female therefore, the possibility of contact with parasites was higher; hence male had higher infection prevalence and mean intensity by *Oncodiscus* sp. (Jaiswal et al., 2013; Jaiswal et al., 2014b; Wali et al., 2016; Upadhyay, 2017). Larger and older fish were more infected than the smaller fish as supported by the earlier findings because small fish can serve as a paratenic hosts for various parasitic fauna and thus representing a source of infection for larger fish (Scholz, 1997; Jaiswal et al., 2014b; Upadhyay et al., 2015b; Upadhyay, 2020b).

Peak infection prevalence in *S. tumbil* by *Oncodiscus* sp. was reported in medium weight class during the period of investigation; however, infestation was higher in heavier fish (Madhavi and Lakshmi, 2012; Gudivada, 2014; Upadhyay, 2019b). The increase in weight due to resultant increase in gonads size and dietary habit during the breeding season was one of the major determinant factors as mentioned by earlier worker (Genc et al., 2005; Upadhyay et al., 2015b; Mignatti et al., 2016). It means during that time the heavier fish were more susceptible to helminthes infection and resultantly higher establishment of *Oncodiscus* was recorded. The findings of overall intensity and prevalence of infection being higher in the fish with heavier body mass were also supported by the earlier studies (Upadhyay, 2012).

CONCLUSIONS

The parasitic investigation on *Oncodiscus* sp. in fish (*Saurida tubil*) of marine habitat was conducted. The period of highest infection prevalence was recorded during summer with peak mean intensity in late summer period. The sex biased cestodes prevalence was well marked and statistically found to be significant. Older and larger female fish heavily infected than the male fish during the investigation at marine coast of Visakhapatnam, Andhra Pradesh. On contrary, the infection prevalence and mean intensity of cestodes being absent or rare in smaller and lighter weight fish. The author wish to recommend the awareness about parasitic helminthes among societies based on aquaculture system for health, economy and sustainable management of fish and fisheries culture.

Funding Support

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgements

SKU is thankful to Head Dept. of Zoology, Andhra University, Visakhapatnam (AP) for laboratory facility during investigation. SKU is also grateful to Prof. S.K. Malhotra, Fmr Head of Zoology Department, University of Allahabad, Prayagraj (UP) for able guidance in parasitic identification. Authors are extremely appreciative to HOD Biotechnology, MMDU, Mullana-Ambala (HR), India for his kind acquiescence and unremitting encouragement to interuniversity mutual research work.

REFERENCES

1. A.P.H.A. (1998). Standard method for the examination of water and waste water. 20th ed. *Amer. Wat. Works. Asso. Wat. Poll. Cont. Fed. Wash. D.C.* 1085p.
2. Akinsanya, B., Hassan, A.A. and Adeogun, A.O. (2008). Gastrointestinal helminth parasites of the fish *Synodontis clarias* (Siluriformes: Mochokidae) from Lekki lagoon, lagos, Nigeria. *Rev. Biol. Trop.* 56: 2021–2026.
3. Altizer, S., Nunn, C.L. and Thrall, P.H. (2003). Social organization and parasite risk in mammals: Integrating theory and empirical studies. *Ann. Rev. Ecol. Syst.* 34: 517–547.
4. Babita, Panwar, P. and Upadhyay, S.K. (2019). A review on ecosegregation and parasitocoenosis of helminthes: Perspective to health and sustainability. *Bull. Pure Appl. Sci. (Zool.)* 38 A(1): 40–51.
5. Barber I., Berkhout, B.W. and Ismail, Z. (2016). Thermal change and the dynamics of multi-host parasite life cycles in aquatic ecosystems. *Integr. Comp. Biol.* 56(4): 561–572.
6. Britton, J.R., Pegg, J. and Williams, C.F. (2011). Pathological and ecological host consequences of infection by an introduced fish parasite. *PLoS One* 6(10): e26365.
7. Cable, J., Barber, I., Boag, B., Ellison, A.R., Morgan, E.R., Murray, K., Pascoe, E.L., Sail, S.M., Wilson, A.J. and Booth, M. (2017). Global change, parasite transmission and disease control: Lessons from ecology. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 372(1719): 20160088.
8. Cizauskas, C.A., Carlson, C.J., Burgio, K.R., Clements, C.F., Dougherty, E.R., Harris, N.C. and Phillips, A.J. (2017). Parasite vulnerability to climate change: An evidence-based functional trait approach. *R. Soc. Open Sci.* 4(1): 160535.
9. Cornet, S., Bichet, C., Larcombe, S., Faivre, B. and Sorci, G. (2014). Impact of host nutritional status on infection dynamics and parasite virulence in a bird-malaria system. *J. Anim. Ecol.* 83: 256–265.

10. Frantz, A., Perga, M.E. and Guillard, J. (2018). Parasitic versus nutritional regulation of natural fish populations. *Ecol. Evol.* 8(17): 8713–8725.
11. Genc, E., Genc, M.A., Genc, E, Cengizler, I. and Can M.F. (2005). Seasonal variation and pathology associated with helminthes infecting two serranids (Teleostei) of Iskenderun Bay (North-East Mediterranean Sea), Turkey. *Turk. J. Fish. Aquacult. Sci*. 5: 29–33.
12. Giannetto, D., Carosi, A., Franchi, E., La Porta, G. and Lorenzoni, M. (2012). Proposed standard weight (Ws) equation for European perch (*Perca fluviatilis* Linnaeus, 1758). *J. Appl. Ichthyol.* 28: 34–39.
13. Gudivada, M., Vankara, A. Hemalatha, M. and Vijayalaksmi, C. (2014). Ecology of metazoan parasite community of marine threadfin fish, *Polydactylus sextarius* (Bloch and Schneider, 1801) from Visakhapatnam coast, Bay of Bengal. *Asian J. Anim. Sci*. 8(2):47–55.
14. Hoberg, E.P. and Brooks, D.R. (2015). Evolution in action: Climate change, biodiversity dynamics and emerging infectious disease. *Phil. Trans. R. Soc. B. Biol. Sci.* 370(1665): 20130553.
15. Iwanowicz, D.D. (2011). Overview on the effects of parasites on fish health. *Proc. 3rd Bilat. Conf. Russia United States* 3: 1–10
16. Jaiswal, N. (2006). Spectral signatures in ichthyophthiraisis and co-occuring parasitic infracomminity variations in freshwater and marine habitats. Unpubl. D.Phil. Thesis, Univ. Allahabad. p387.
17. Jaiswal, N., Upadhyay, S.K., Malhotra, A. and Malhotra, S.K. (2013). Multifactorial etiology of infections by larvae of *Eustrongylides tubifex* (Nematoda: Dioctophymidae) in silver whiting of the central west coast of India at Goa. *Asian J. Biol. Sci.* 6(1): 21–39.
18. Jaiswal, N., Upadhyay, S.K., Malhotra, A. and Malhotra, S.K. (2014b). Ecological morphotaxometry of trematodes of garfish (Teleostomi: Belonidae) from Gangetic riverine ecosystem in India. III. Principal Component Analysis for hydrobiological correlates to dynamics of infections by *Cephalogonimus yamunii* (Upadhyay et al., 2012). *J. Parasit. Dis.* 38(2): 153–162.
19. Jaiswal, N., Upadhyay, S.K., Malhotra, A., Blend, C.K., Dronen, N.O. and Malhotra, S.K. (2014a). A new species of *Neolebouria* Gibson, 1976 (Opecoelidae: Plagioporinae) from the whitecheek monocle bream, *Scolopsis vosmeri* (Perciformes: Nemipteridae), from the Panjim coast at Goa, with a checklist of parasites previously reported from this fish. *Zootaxa* 3802(1): 098–108.
20. Jones, I. (2013). The impact of extreme events on freshwater ecosystems. In: Ecological issues. *British Ecol. Soc.* pp. 1–68.
21. Kuchta, R., Scholz, T., Vickova, R.R., Milan, W., Thorsten, Y., Asri, T., Palm and Harry, W. (2009): Revision of tapeworms (Cestoda: Bothriocephalidea) from lizardfish (Saurida: Synodontidae) from the Indo-Pacific region. *Zootaxa*. 1977: 55–67.
22. Kumar, S. (2012). Ecological attributes and biochemical variants in the dynamics of infections of vertebrates. Unpubl. D.Phil Thesis, Univ. Allahabad, India. p310.
23. Macnab, V. and Barber, I. (2012). Some (worms) like it hot: Fish parasites grow faster in warmer water, and alter host thermal preferences. *Glob. Change Biol.* 18(5):1540–1548
24. Madhavi R. and Lakshmi L.T. (2012). Community ecology of the metazoan parasites of the Indian mackerel *Rastrelliger kanagurta* (Scombridae) from the coast of Visakhapatnam, Bay of Bengal. *J. Parasit. Dis.* 36: 165–170.
25. Malhotra, A., Jaiswal, N., Upadhyay, S.K., Kumar, S. and Malhotra, S.K. (2009). Parasite stress response in zoonoses of *Cephalogonimus* sp. *Indian J. Helminthol. (N.S.).* 27: 73–80.
26. Malhotra, S.K. (1982). Bionomics of hill-stream cyprinids. III. Food parasites and length weight relationship of Garhwal mahaseer, *Tor tor* (Ham.). *Ind. Acad. Sci.* 91:493-499.
27. Malhotra, S.K. (1985). Ecophysiology and taxometry of cestodes from fish, reptiles, aves, and mammalian hosts of Garhwal Himalayas. Unpubl. D.Sc. Thesis, Univ. Allahabad, India. p350.
28. Malhotra, S.K. and Chauhan, R.S. (1981). Temperature variations on abundance of cestodes in hill-stream fishes. *Geobios*. 8:260–263.
29. Malhotra, S.K. and Nanda, S. (1989). Parasitological and hydrobiological interactions in high altitude aquatic environment. *Strat. Biosci*. 135–150.

30. Mangal, T.D., Paterson, S. and Fenton, A. (2008). Predicting the impact of long-term temperature changes on the epidemiology and control of schistosomiasis: A mechanistic model. *PLoS One* 3(1): e1438.
31. Mignatti, A., Boag, B. and Cattadori, IM. (2016). Host immunity shapes the impact of climate changes on the dynamics of parasite infections. Proc. *Natl. Acad. Sci.* 113(11): 2970–2975.
32. Morand, S. (2000). Wormy world: comparative tests of theoretical hypotheses on parasite species mortality in African lions. *J. Anim. Ecol.* 68: 1161–1178.
33. Murphy, E.J., Hofman, E.E., Watkins, J.L., Johnston, N.M., Pinones, A., Ballerini, T., Hill, S.L., Trathan, P.N., Tarling, G.A., Cavanagh, R.A., Young, E.F., Thorper, S.E. and Fretwell, P. (2013). Comparison of the structure and function of Southern Ocean regional ecosystems: The Antarctic Peninsula and South Georgia. *J. Marine Syst.* 109–110: 22-42.
34. Nanware, S.S., Bhure, D.B. and Upadhyay, S.K. (2019). Diversity of tapeworms from piscean, avian and mammalian hosts from Marathwada region (M.S.) India. *Bull. Pure Appl. Sci. (Zool.).* 38A(2): 120-125.
35. Overstreet, R.M. and Hawkins W.E. (2017). Diseases and mortalities of fishes and other animals in the Gulf of Mexico. In: Habits and Biota of the Gulf of Mexico: Before the deep water horizon oil spill (ed., Ward, C.). *Springer, New York.* pp. 1589–1738.
36. Paull, S.H., LaFonte, B.E. and Johnson, P.T.J. (2012). Temperature-driven shifts in a host parasite interaction drive nonlinear changes in disease risk. *Glob. Change Biol.* 18(12): 3558–3567
37. Puniyabati, H., Shomorendra, M. and Kar, D. (2010). Infection of helminth parasites in relation to the length of fish host. *Nat. J. Life Sci.* 7: 49–50.
38. Scholz, T. (1997). Life cycle of *Bothriocephalus claviceps*, a specific parasite of eels. *J. Helminthol.* 71: 240–248.
39. Thompson, K.G., Nehring, R.B., Bowden, D.C. and Wygant, T. (1999). Field exposures of seven species or subspecies of salmonids to *Myxobolus cerebralis* in the Colorado river, Middle Park, Colorado. *J. Aquat. Anim. Health.* 11: 312–329.
40. Turner, W.C., Versfeld, W.D., Kilian, J.W. and Getz, W.M. (2012). Synergistic effects of seasonal rainfall, parasites and demography on fluctuations in springbok body condition. *J. Anim. Ecol.* 81(1): 58–69.
41. Upadhyay, S.K. (2012). Transmission dynamics and environmental influence on food borne parasitic helminthes of the Gangetic plains and central west coast of India. Unpubl. D.Phil. Thesis. Univ. Allahabad. pp. 1–400.
42. Upadhyay, S.K. **(**2017). Environmental impact on helminth parasites of fresh water garfish from river Yamuna at Allahabad, Uttar Pradesh, India. *Proc. Zool. Soc. India.* 16(02): 63–75.
43. Upadhyay, S.K. (2018). Morphotaxonomy, histopathology and population dynamics of natural enoplid infections in wild rat, *Rattus rattus* of eastern Uttar Pradesh, India. AASCIT *J. Biosci.* 4(3): 22–27.
44. Upadhyay, S.K. **(**2020a). Biodiversity of parasites and parasitoses: Perspective to health and sustainability**.** In: Biodiversity and Development Challenges of 21st Century (eds. Prakash, S., Ranjan, R., Pandey, R.K.). *Swaranjali Publ. Pvt. Ltd. U.P.* pp. 162–192.
45. Upadhyay, S.K. (2020b). Parasitology: Taxonomy and bioecology. *Write and Print Publ., New Delhi*. pp 1–209.
46. Upadhyay, S.K. **(**2020c). Autogenicity and precocious development of *Sturdynema multiembryonata* in *Xenentodon cancila* (Osteichthyes: Belonidae) from the Gangetic ecosystem. *Bull. Pure Appl. Sci. (Zool.).* 39A(1): 36-45.
47. Upadhyay, S.K. and Nanware, S.S. (2020). Parasitoses and histological consequences of *Trichuris trichiura* (Nematoda: Enoplida) in rodents, *Rattus rattus* (Mammalia: Rodentia). *Asian J. Biol. Life Sci.* 9(1): 74–78.
48. Upadhyay, S.K. and Singh, R. (2018). Polyfactorial etiology on demography of parasitic allocreodoidean trematodes in the Gangetic ecosystem. *Amer. J. Biomed. Sci. Engin.* 04(02): 17–23.
49. Upadhyay, S.K., Babita and Singh, R. (2019). The diversity and bioecology of cestodes in freshwater snakehead fish *Channa* sp. (Bloch) with a checklist of tapeworms previously

reported from this fish in India. In: Parasitology: Taxonomy and bioecology (ed. Upadhyay, S.K.). *Write and Print Publ., New Delhi.* pp. 17–37.

50. Upadhyay, S.K., Babita, Panwar, P., Kumar, S. and Nanware, S.S. (2019). Parasite-host interactions: A negative symbiotic association between organisms' perspective to health and sustainability. In: Parasitology: Taxonomy and bioecology (ed. Upadhyay, S.K.). *Write and Print Publ., New Delhi.* pp. 164–183.
51. Upadhyay, S.K., Jaiswal, N., Malhotra, A. and Malhotra, S.K. (2013). Ecological morphotaxometry of trematodes of garfish (Teleostomi: Belonidae) from Gangetic riverine ecosystem in India. II. Correlation of seasonality and host biology with distribution pattern of *Cephalogonimus yamunii* n.sp. *J. Parasit. Dis.* 37(2): 211–217.
52. Upadhyay, S.K., Yadav, D. and Pathak, R.K. (2015). The impact of water quality on the population distribution pattern of cephalogonimid trematodes *Cephalogonimus yamunii* in fresh water fish *Heteropneustes fossilis* at Allahabad, Uttar Pradesh. *J. Kal. Sci.* 3(2): 11–17.
53. Upadhyay, S.K., Yadav, D. and Tripathi, A. (2015). A redescription and report of *Eustrongylides tubifex* Nitzsch, 1819 (Dioctophymoidea: Dioctophymidae) larvae in deep sea fish *Sillago sihama* off central west coast of India at Goa. *Natl. J. Life Sci.* 12(2): 161–164.
54. Wali, A., Balkhi, M.H., Maqbool, R., Darzi, M.M., Shah, F.A., Bhat, F.A. and Bhat, B.A. (2016). Distribution of helminth parasites in intestines and their seasonal rate of infestation in three freshwater fishes of Kashmir. *J. Parasitol. Res.* https://doi.org/10.1155/2016/8901518.
55. Yamaguti, S. (1934). Studies on the helminth fauna of Japan. Part 4. Cestodes of fishes. *Jpn. J. Zool.* 6(1): 1–112.
56. Yamaguti, S. (1959). Systema Helminthum. Volume II. The Cestodes of Vetebrates. (Part II). *Intersci. Publ. Inc. NY.* 1265p.