

## New species of *Pseudothysanoes* Blackman, and *Sphaerotrypes* Blandford (Coleoptera: Curculionidae: Scolytinae) from Jammu and Kashmir, with biological observations, and a key to South Asian species of *Sphaerotrypes*

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### Abstract

Two new species of Scolytinae (Coleoptera: Curculionidae) are described from Jammu and Kashmir, *Pseudothysanoes kashmirica* sp. nov. and *Sphaerotrypes montanus* sp. nov. These discoveries mark the first records of the genera *Pseudothysanoes* Blackman, 1920 from South Asia and *Sphaerotrypes* Blandford, 1894 from the Northwestern Himalayan region. A discussion on the biology of the new species together with a complete key to the known species of *Sphaerotrypes* from South Asia are provided.

**Key words:** Himalayan fauna, new species, taxonomic key, bark beetles

### Introduction

The Jammu and Kashmir is the Northwestern region of the Indian subcontinent between the Palaearctic and Oriental biogeographic realms, and is rather rich in species diversity (Mittermeier *et al.* 2004). The valley of Kashmir is bounded on the southwest by the Pir Panjal range and on the northeast by the main Himalayan range and owing to its high altitude (1620 m), it has a temperate climate. Among the temperate fruit trees, apple (*Malus domestica*), pear (*Pyrus communis*), peach (*Prunus persica*), cherry (*Prunus avium*), walnut (*Juglans regia*) and almond (*Prunus dulcis*), along with a few other tree species, are grown in the valley of Kashmir and mountainous areas of Pir Panjal range. Cherry bark elm (*Ulmus villosa*), poplar (*Populus deltoides*) and willow (*Salix alba*) are also commonly cultivated as social forestry plantations in the region. All trees are vulnerable to damage by bark beetles and other pests, thus adding to management issues of the growers. Older, taller trees in poor physiological conditions are preferred for feeding by bark beetles and, therefore, much more likely to become diseased compared with younger trees (Ryan *et al.* 2015).

The species diversity in the Himalayan region is likely much higher than currently recognized mainly due to large regions of conifer habitat and extensive mountain ranges (Critchfield & Little 1966). The species composition of Scolytinae (Coleoptera: Curculionidae) is also determined by the distribution and abundance of their host tree species and climate (Lekander *et al.* 1977) and consequently additional research is needed to increase the knowl-



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# Morpho-molecular identification of the bark beetle *Hylesinus macmahoni* (Stebbing, 1909) (Coleoptera: Curculionidae: Scolytinae) infesting *Olea europaea* subsp. *cuspidata* (Wall. & G.Don) Cif., along with a brief biological synopsis

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## ABSTRACT

In Jammu and Kashmir's Govindpora (Ramban) and Salamabad (Baramulla), horticultural nurseries with a majority of *Olea europaea* subsp. *cuspidata* (Wall. & G.Don) Cif. plantings were examined for possible bark beetle attacks. These olive tree plantations are infested with a variety of insect pests, but the bark beetle *Hylesinus macmahoni* (Stebbing, 1909) did significant harm to the olive trees that carry fruit. The beetle attacks and consumes the phloem tissues of the plant during its development, causing the afflicted trees to become weak and eventually die. At both sites, infestations of *H. macmahoni* were discovered. The cytochrome oxidase subunit I (COI) gene was used to validate the species' diagnosis, and its morphological characteristics were re-described. The species has a polygynous mating system (one male and two females), producing two full and a third partial generation annually in Kashmir.

## KEY WORDS

bark beetle, diagnosis, *COX-1* gene, phylogenetic assessment, biology

## INTRODUCTION

The olive tree, *Olea europaea* subsp. *cuspidata* (Wall. & G.Don) Cif. is a species of small, evergreen tree that belongs to the family Oleaceae and is native to the coastal areas of the Eastern Mediterranean region, from Lebanon and the maritime parts of Asia Minor to northern Iran at the southern end of the Caspian Sea

Mediterranean-type climates as a source of olive oil and table olives. The olive trees are mainly grown in two semi-temperate regions of Jammu and Kashmir viz. Govindpora (Ramban) and Salamabad (Baramulla) (Shant 1999). Many diseases and insect pests are known to damage olive trees (Borg 1932; Mifsud 1997; Porta-Puglia and Mifsud 2005; Lozano et al. 2009). Bark beetles utilise a wide variety of hosts including living, dam-



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## RESEARCH ARTICLE

## First Record of Genus *Blascoa* (Pteromalidae) from Asia and Discovery of Its Novel Phytophagous Interaction with *Ephedra*

Zubair Ahmad Rather<sup>1</sup> · Abdul Ahad Buhroo<sup>2</sup> · Sajad Hussain Parey<sup>3</sup> · Anzar Ahmad Khuroo<sup>1</sup> Received: 26 June 2021 / Revised: 26 June 2021 / Accepted: 17 January 2024  
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**Abstract** This paper reports *Blascoa ephedrae* Askew, 1997, from Kashmir Himalaya, which is first record of this insect species from Asia. To validate this new record, a brief diagnosis, photographic illustrations and distributional map of the species are provided. In addition, the present study first time describes a novel interaction between *B. ephedrae* and a gymnosperm plant *Ephedra intermedia*, wherein the insect forages the female cones and completes life cycle by overwintering within the seeds of this plant species. Such a phytophagous behavior suggests the role of *B. ephedrae* in retarding the reproductive potential of *E. intermedia* in Kashmir Himalaya.

**Keywords** *Blascoa ephedrae* · Seed herbivory · *Ephedra intermedia* · Himalaya

**Significance statement:** The present study reports *Blascoa ephedrae* Askew as first record from Asia with a brief diagnosis, photographic illustrations and distributional map. It also describes a novel interaction between *B. ephedrae* and a gymnosperm plant *Ephedra intermedia* for the first time. These findings have implications for taxonomy, biogeography, ecology, behaviour and plant-insect interactions of the investigated taxa.

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### Introduction

*Blascoa* is a monotypic genus belonging to family Pteromalidae of order Hymenoptera with only single species *Blascoa ephedrae* Askew, 1997, reported from Zaragoza in the world [1]. This genus resembles with *Seladerma* and *Ormocerus* genera, but markedly differs from both in clypeus and scutellum characters. While as in *Blascoa* clypeus has a small median tooth on the anterior margin, it is tridentate and truncate in *Seladerma* and *Ormocerus*, respectively. Further, *Blascoa* has relatively a broader base of the scutellum [1]. *Blascoa* shows resemblance with other two genera of tribe Miscogasterini (i.e., *Ksenoplata* and *Susteraia*) in having a single clypeal tooth and broader scutellum, but in *Ksenoplata* its anterior corners are almost rectangular and the mesonotum dorsally flat and *Susteraia* differs in having a narrow, laterally compressed female gaster which is longer than the rest of the body [1].

While studying the genus *Ephedra* (a gymnosperm plant) in India, we collected hitherto unknown insect specimens from the seeds of *E. intermedia* in the Kashmir Himalaya. On detailed investigation of macro- and micro-morphological characters and perusal of relevant literature [1], the insect specimens collected have been scientifically identified as *B. ephedrae* Askew. Until now, globally, there has been only a single report of *B. ephedrae* from Zaragoza, Spain, on the host plant, *Ephedra nebrodensis* [1]. Thus, the present record of *B. ephedrae* from Kashmir Himalaya, India represents its first report from the Asian continent and the second report from the entire world. In Kashmir Himalaya, *B. ephedrae* has been reported on a new host plant, *E. intermedia*.

In fact, during the last two decades, about 20 parasitoid insect species belonging to 9 different families have been reported to have novel interactions with 4 different *Ephedra* species. These insects of hymenopteran parasitic wasps



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## A review of the Indian species of genus *Polygraphus* Erichson, 1836 (Coleoptera: Curculionidae: Scolytinae) with bio-ecological notes on *P. major*, a pest of *Pinus wallichiana* A. B. Jacks (Pinaceae) in Kashmir, India

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### ABSTRACT

The Indian species of the genus *Polygraphus* Erichson, 1836 (Coleoptera: Curculionidae: Scolytinae) collected from various localities of the Western Himalayan region and the species available at the National Forest Insect Collection (NFIC), Forest Research Institute, Dehradun (India) were studied and are reviewed herewith. A key to Indian species of *Polygraphus* is provided. Detailed bioecological field and laboratory observations of *P. major* including mating behaviour, gallery pattern, life cycle and seasonal history are reported.

### KEY WORDS

bark beetles, *Polygraphus*, bioecology, Kashmir

### INTRODUCTION

Bark beetles (Coleoptera: Curculionidae: Scolytinae) are among the most economically important pests of the world's forests. Most of the 6000 described species

of healthy trees (Kirkendall et al. 2015). The majority of species occur in tropical and subtropical regions (Knížek and Beaver 2004). Raffa et al. (2015) and Kirkendall et al. (2015) provide useful reviews of their biology, and Hulcr et al. (2015) of their morphology, tax-



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# Breeding Biology of Ibisbill (*Ibidorhyncha struthersii*) in the Kashmir Himalayan Region of India

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**Abstract.**—This study aims to describe the breeding biology of Ibisbill (*Ibidorhyncha struthersii*), a poorly studied wader nesting on the River Sindh in Kashmir Himalayan region of India. A total of 16 nests were monitored during the breeding seasons (late February to late July) of Ibisbill in 2018 and 2019. Nest building was completed in 21–28 days on bare ground by tossing small pebbles into a shallow depression that had no special markings to the human eye (mean pebble size =  $4.09 \text{ mm} \pm 1.26 \text{ SD} \times 6.23 \pm 3.71 \text{ mm}$ ,  $n = 42$ ). Nests measured  $28.45 \pm 1.75 \text{ cm} \times 18.91 \pm 0.99 \text{ cm}$  ( $n = 12$ ). Eggs were laid in the first week of April with clutch size ranging from 2 to 4 eggs. Eggs were  $50.58 \pm 1.07 \text{ mm}$  in length and  $36.77 \pm 0.85 \text{ mm}$  in breadth ( $n = 5$ ), with egg shape index of  $72.23 \pm 2.58$  (range: 69.23 to 76.42). Incubation lasted 28–32 days, with 3 out of 19 observable eggs successfully hatched (15.79% hatching success). Fledging success was zero due to predation. Defensive behavior was directly observed for 16 nesting pairs during two breeding seasons. A total of 407 defensive incidents were recorded during incubation and chick stage, with both parents engaging in defense together and individually. Received 20 February 2021, accepted 7 August 2021.

**Key words.**—hatching success, Himalayas, *Ibidorhyncha struthersii*, Ibisbill, incubation period, Kashmir, nest success, nesting biology, fledging success, River Sindh.

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Ibisbill (*Ibidorhyncha struthersii*) is a little known species of shorebird, belonging to the order Charadriiformes and the only extant species in the family Ibidorhynchidae (Stepanjan 1979). Ibisbill inhabits river beds comprised of cobble and boulders at high altitudes in Central Asia (Ali and Ripley 1969).

Kovsar 1980; Ye *et al.* 2013). Given the rarity of information, we attempted to study multiple aspects of breeding biology including nest characteristics, courtship, incubation, defense, and breeding success in the River Sindh of the Kashmir Himalayan region of India.



RESEARCH ARTICLE



## Efficacy of entomopathogenic fungi against codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae)

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### ABSTRACT

*Cydia pomonella* L. is a highly destructive pest inflicting substantial damage on pome fruits globally. Resistance to chemical pesticides by *C. pomonella* poses a significant challenge to the effective management strategies. Utilising entomopathogenic fungi (EPF) for the management of insect pests has emerged as one of the promising and environmentally friendly alternatives. Against this backdrop, we conducted laboratory bioassays to assess the efficacy of three EPF, namely *Beauveria bassiana* (Bals.-Criv.) Vuill., *Cordyceps fumosorosea* (Wize) and *Metarhizium anisopliae* (Metschn.) Sorokin against *C. pomonella* using three effective concentrations ( $1 \times 10^4$ ,  $1 \times 10^5$ , and  $1 \times 10^6$  conidia/ml). Highest larval ( $98.62 \pm 10.00\%$ ) and pupal ( $37.35 \pm 2.15\%$ ) mortality was observed when treated with *B. bassiana* while lowest larval ( $51.55 \pm 6.30\%$ ) and pupal ( $17.83 \pm 7.28\%$ ) mortality was seen in *C. fumosorosea*. Maximum adult emergence ( $16.26 \pm 3.24$ ) was recorded in *C. fumosorosea* and the minimum ( $5.72 \pm 0.09$ ) in *B. bassiana*.  $LC_{50}$  values of *C. fumosorosea*, *M. anisopliae* and *B. bassiana* were 5.482, 2.683 and 1.891 conidia/ml, respectively. All three tested EPF were effective against *C. pomonella* under controlled laboratory conditions.

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Insecticide resistance;  
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## Introduction

The codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae) is one of the most devastating pests (Isci and Ay 2017; Zhang et al. 2023) of pome fruits and walnuts around the world (Yang and Zhang 2015; Yang et al. 2016). Over the past two centuries, *C. pomonella* has spread across the entire world (Hu et al. 2020; Ju et al. 2022), including Australia, China, Europe, North America and South Africa (Jiang et al. 2018). Larvae of the pest alter the shape of the fruit (Eliceche et al. 2023) by digging galleries and feeding on seeds (Husain et al. 2018), which results in its early fall (Danelski et al. 2017). A fruit infected with *C. pomonella* can be easily identified by the frass (Ju et al. 2022) that is pushed out of the entrance hole during feeding (Witzgall et al. 2007; Willett et al. 2009). At the fifth instar, the larvae leave the fruit and pupate beneath the bark of a tree trunk or in other safe areas

## Review

# An Insight into the Global Problem of Gastrointestinal Helminth Infections amongst Livestock: Does Nanotechnology Provide an Alternative?

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**Abstract:** Helminth parasitic infections are a considerable constraint to the livestock industries worldwide. Nematode parasites cause the major proportion of harm to livestock. The infections caused are accountable for severe economic losses in cattle, goat and sheep farming industries. Morbidity and mortality in livestock due to parasitic diseases are increasing alarmingly. Also, their zoonotic influence on human health is considered significant. Anthelmintic drugs have been developed occasionally to curb this disease and prevent major losses. But the development of resistance against these drugs has put another constraint on this flourishing industry. Helminth parasites have developed resistance against three main classes of anthelmintics: benzimidazoles, macrocyclic lactones and nicotinic agonists. With the intensification of resistance, various screening and confirmatory tests have been developed for the speedy introduction of newer drugs in the livestock industry. At the same time, designing and launching novel anthelmintics is time-consuming and economically restrained. Phytochemicals attract much attention because of their pharmacotherapeutic potential, least toxic profile and low environmental hazards. A lot of work is going on plant-based anthelmintic drugs throughout the world. Plants possessing anthelmintic activity have been found efficacious against gastrointestinal parasites. Nevertheless, these herbal medicines have various drawbacks, which include poor efficacy and the absence of target selectivity. These problems are now being taken care of with the help of nanotechnology. Nanoparticles improve the drug's effectiveness, enhance drug delivery, and target selectivity at specific sites. A comprehensive literature survey was carried out via electronic searches of Google Scholar, PubMed, MEDLINE, Science Direct, Scopus and Cochrane Library databases and based on inclusion and exclusion criteria; articles were selected for this review. The review aims at providing a comprehensive overview of plant-based nanoparticles as therapeutic alternatives over conventional synthetic anthelmintic drugs. It also encompasses the methods of detection of resistance and the ways to overcome this menace. The effectiveness of various organic and inorganic nanoparticles against helminthes is also discussed in this review.

**Keywords:** nematode parasites; livestock; zoonosis; anthelmintic resistance; phytochemicals; nanoparticles



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# Plant Defense and Insect Adaptation with Reference to Secondary Metabolites

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Abdul Rasheed War, Abdul Ahad Buhroo, Barkat Hussain,  
Tariq Ahmad, Ramakrishnan M. Nair, and Hari C. Sharma

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## Abstract

Insects pose a great threat to plants, and plants, in turn, withstand to insect attack through various morphological and biochemical traits. Among the plant defensive traits, secondary metabolites play a major role against insect herbivory as they are highly dynamic. They either occur constitutively in plants or are induced in response to insect herbivory. These metabolites include sulfur- (terpenes and flavonoids) and nitrogen-containing metabolites (alkaloids, cyanogenic glucosides, and nonprotein amino acids), which are being implicated by plants against insect pests. Plant secondary metabolites either are directly toxic to insect pests or mediate signaling pathways that produce plant toxins. Further, some of the plant secondary metabolites act through antixenosis mode by developing non-preference in host plant to the insect pests. However, some plant secondary metabolites recruit natural enemies of the insect pests, thus indirectly defending plants against insect pests. However, insects have developed adaptations to these plant secondary metabolites. In this chapter, important plant secondary metabolites, their mechanism of action against insect pests, counter-adaptation by insects, and promising advances and challenges are discussed.

## Keywords

Plant-insect interactions · Plant secondary metabolites · Insect adaptation · Sequestration · Induced resistance





SHORT COMMUNICATION

## *Bactrocera invadens* Drew, Tsuruta & White (Diptera: Tephritidae), a Fruit Fly Pest Newly Recorded from Kashmir, India and New Host Plant Records

Rayees Ahmad<sup>1</sup> · Tariq Ahmad<sup>1</sup> · Barkat Hussain<sup>2</sup> · David L. Hancock<sup>3</sup>

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**Abstract** *Bactrocera invadens* Drew, Tsuruta & White is newly recorded from temperate climatic conditions of Kashmir Valley, northern India, coinciding with the fruiting season of common host plants such as *Cucumis sativus*, *Lagenaria siceraria*, *Cucurbita maxima*, *Momordica charantia*, *Luffa acutangula*, *Citrullus vulgaris* (Cucurbitaceae), *Lycopersicon esculantum* (Solanaceae), *Malus domestica*, *Prunus armeniaca*, *Prunus persica*, *Pyrus communis*, *Prunus domestica*, *Cydonia oblonga* (Rosaceae). Methyl eugenol-baited traps revealed a relative abundance of 44% compared with other species, with maximum trap catches in Srinagar and Kupwara. In field-collected infested fruits and vegetables, *B. invadens* was highly polyphagous, showing a distinct preference for cucurbit vegetables. The presence of *B. invadens* poses a severe threat to agriculture and horticulture in temperate climatic conditions of Kashmir and its presence is a cause of concern to both fruit and vegetable growers.

**Keywords** *Bactrocera invadens* · Kashmir valley · Host plants

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Agriculture and horticulture are the major industries of Kashmir, where climatic conditions are very different from the rest of India. Globally, climate change and non-native or alien invasive insect pests are considered the main drivers for biodiversity loss. If these pests cannot be controlled, huge economic losses are likely in both horticulture and agriculture, which are the backbone of Kashmir.

There are more than 4600 species of Tephritidae known, several of which cause economic damage to a wide variety of crops [1]. *Bactrocera* spp. are the most significant fruit and vegetable pests worldwide [2], facilitated by their polyphagous and invasive nature, spread through fruit trade, urbanization and poor quarantine infrastructure in developing countries. Their immature stages are readily transported to new places via fruit shipment or transportation within the country or from abroad. In Kashmir, *Bactrocera cucurbitae* (Coquillett) *B. tau* (Walker) and *B. scutellaris* Bezzi [3, 4] infest cucurbits, while *B. invadens* Drew, Tsuruta & White (previously incorrectly recorded as *B. dorsalis* (Hendel)) and *Bactrocera zonata* (Saunders) [5] infest fleshy fruits. In India, the highly polyphagous pest *Bactrocera invadens* has not been reported on any crop, due to its previous confusion with *B. dorsalis*. Many authors consider it to be a synonym of *B. dorsalis* but its specific status was demonstrated by Drew et al. (2005), Maneesh et al. (2022) and Drew & Hancock (2022) on morphological grounds, with differences in characters of the wing, aedeagus and thorax [6]. *Bactrocera cucurbitae*, *B. tau* and *B. scutellaris* are often placed in a separate genus, *Zeugodacus* Hendel, but that is based solely on molecular data known to be unreliable at that level and not supported by morphology, biology or molecular clock dating [7, 8].

The resemblance of *B. invadens* to *B. dorsalis* has led to its occurrence in Kashmir being overlooked previously. We report its presence for the first time as a new emerging pest

# Morphological and molecular characterization and new distributional record of *Tetrastichus miser* (Nees, 1834) (Hymenoptera: Chalcidoidea: Eulophidae) from Kashmir

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**Morphological and molecular characterization and new distributional record of *Tetrastichus miser* (Nees, 1834) (Hymenoptera: Chalcidoidea: Eulophidae) from Kashmir**

**Abstract:** *Tetrastichus miser* (Nees, 1834) (Hymenoptera: Eulophidae: Tetrastichinae) is a parasitoid of Curculioninae and Scolytinae infesting various trees of economic importance. In the present study, it was collected from dried *Cedrus deodara* (Roxb.) G. Don (Pinaceae) infested with *Scolytus* beetles using sweep net and aspirator. The species is reported first time from Kashmir valley. Identification of a parasitoid is of paramount significance for studying its behavior, ecology, life cycle and usage in various biological control programmes. In addition to morphological description, molecular analysis using Cytochrome C Oxidase Subunit I was carried out to complement morphotaxonomy and to facilitate its easier identification for future studies. Phylogenetic analysis by Bayesian inference (BI) and Maximum Likelihood (ML) method showed Isolates of *Tetrastichus miser* species clustering in same clade and separated from its closest match Tetrastichinae sp. Inter-specific divergence between *Tetrastichus miser* and Tetrastichinae sp. was evident and ranged from 0.09 to 0.10 % (0.05 % mean). No overlap was observed between maximum distance within species and minimum distance between species.

**Key words:** *Tetrastichus miser*; *Cedrus deodara*; beetle; Cytochrome C Oxidase Subunit I; Clade; morphotaxonomy; molecular analysis

**Morfološka in molekularna določitev ter novi podatki o razširjenosti vrste *Tetrastichus miser* (Nees, 1834) (Hymenoptera: Chalcidoidea: Eulophidae) v Kašmirju**

**Izvleček:** Vrsta *Tetrastichus miser* (Nees) (Hymenoptera: Eulophidae: Tetrastichinae) je parazitoid hroščev iz podružin Curculioninae in Scolytinae, ki napadajo različne gospodarsko pomembne drevesne vrste. V raziskavi je bil parazitoid nabran s stresalnimi mrežami in aspiratorjem na posušenih himalajskih cipresah, *Cedrus deodara* (Roxb.) G. Don (Pinaceae), ki so bile napadene s hrošči iz rodu *Scolytus*. O vrsti poročajo prvič iz doline Kashmir. Določitev parazitoida je zelo pomembna za preučevanje njegovega obnašanja, ekologije, življenjskega kroga in pri njegovi uporabi v različnih programih biotičnega zatiranja škodljivcev. Poleg morfološkega opisa je bila za lažjo določitev v bodočih raziskavah uporabljena molekularna analiza na osnovi podenote I citohrom C oksidaze. Filogenetska analiza z metodama Bayezinove inference (Bayesian inference, BI) in največje verjetnostni (Maximum Likelihood, ML) je pokazala, da so se izolati vrste *Tetrastichus miser* združevali v istem kladu, ločeno od najbližjih, ki se ujemajo s predstavniki podružine *Tetrastichinae*. Ločitev vrste *Tetrastichus miser* in predstavnikov podružine *Tetrastichinae* je bila očitna in je znašala od 0,09 do 0,10 % (v povprečju 0,05 %). Opaženega ni bilo nobenega prekrivanja med maksimalno razdaljo znotraj vrste in minimalno razdaljo med vrstami.

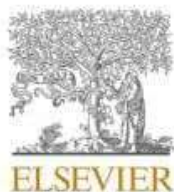
**Ključne besede:** *Tetrastichus miser*; *Cedrus deodara*; hrošč; podenota I citohrom C oksidaze; klad; morfotaksonomija; molekularna analiza

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## Review

# The evolution of integrated multi-trophic aquaculture in context of its design and components paving way to valorization via optimization and diversification

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## ARTICLE INFO

**Keywords:**  
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## ABSTRACT

The plummeting productivity of marine resources complemented by a growing demand for fish and its products makes the intensification of aquaculture systems inevitable. Such intensification breeds the predicament of nutrient loading which eventually hampers the smooth functioning of an aquatic ecosystem. Ecological engineering, working in tandem with aquaculture has evolved a system under the backdrop of Integrated multi-trophic aquaculture (IMTA) which facilitates such intensification. IMTA involves simulating a co-culture system that mimics a natural aquatic ecosystem, entailing multiple trophic levels arranged in a way to harness the potential of by-products and thereby minimize waste production. IMTA offers a sustainable approach to aquaculture development with a two-component stock configuration of fed aquaculture species (fish or shrimp) and extractive species (seaweeds, molluscs, echinoderms etc). The theme of the setup is to feed the fed component and utilize their waste for the culture of the extractive species. Since its inception, the IMTA has evolved in every aspect ranging from diversification of its components to its expansion to open waters, providing avenues that support its emergence as the aquaculture of the future. The following paper reviews the evolution of IMTA in the context of its need, components and design, besides providing ways to valorize the system via diversification and optimization.

## 1. Introduction

Fish is commonly referred to as “rich food for impoverished people” because it is inexpensive and supplies important nutrients, particularly high biological value proteins, lipids, a variety of minerals (especially magnesium, phosphorus), and vitamins (particularly A and D) (Sujatha et al., 2013; Mohanty et al., 2019; Ali et al., 2020). A 140 g of fish can offer roughly 50–60% of an adult human's daily protein requirements (FAO, 2010). Micronutrients found in fish are more readily available than those found in plant meals (Lilly et al., 2017). Fish contain a high proportion of omega-3 long-chain polyunsaturated fatty acids granting them a nutritious advantage over land animals (Tacon and Metian, 2013). Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), well-known types of omega-3 fatty acids from fish and fish oil are crucial for amelioration and the prevention of many common human ailments (Connor, 2000).

Aquaculture entails farming (enhancing production via rearing process intervention) of aquatic organisms (fish, molluscs, crustaceans, and aquatic plants) (FAO, 1988). Its inception is shrouded in mystery, albeit the consensus of most workers points out China, for its origin, with the kickstart being speculated to be as far back as 3500–4000 years (Rabanal, 1988; Bardach et al., 1972; Ling, 1977). However, an agreement on the first published report on aquaculture dates to 475 BPE (Borgese, 1980). The aquatic counterpart of agriculture, aquaculture has grown rapidly in the recent past and has eventually equated its production of fish and shellfish with fisheries. In 2020, fisheries and aquaculture production reached a record 214 million tonnes, with aquaculture alone contributing approximately 122.6 million tonnes in 2020, having a total value of US\$ 281.5 billion. Approximately 600 million livelihoods depend on aquaculture and fisheries, with 58.5 million being directly employed in the primary sector. In 2020 the consumption of aquatic food, on per capita basis grew from 9.9 kg in

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# Chapter 9

## Plastic Pollution and Its Impact on Aquatic Fauna

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### ABSTRACT

*Plastic pollution is the buildup of unwanted plastic products in the environment by its abundant and limitless use by a greedy human population in various ways. Plastics are usually made of chains of monomer units of ethylene and propylene linked together. Plastics are durable and resistant to degradation and tend to accumulate where they are disposed. One more disaster this material causes is the release of toxic chemicals with time which badly affects the ecosystem where it is dumped. Same is the case with aquatic ecosystem, because tons of plastic wastes are dumped into it in one way or the other. The major threats of this menace on aquatic ecosystem include ocean acidification, degradation of water quality, increase in number of invasive species, overfishing, pollution and choking of water bodies, habitat degradation, loss of aesthetic value, blocking of sea routes, and above all, it badly affects plant and animal life there.*

### INTRODUCTION

Pollution can simply be defined as the introduction of contaminants into the natural environment that causes adverse changes. It is the addition of any unwanted substances to the environment at a faster rate than it can be dispersed, diluted, decomposed or recycled. Pollution is known to be there with the humankind ever since groups of people first congregated and remained for a long time in any one place, but present situation is worse as it has grown to unprecedented levels due to rapid industrialization and

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# Comparison of the Growth Potential of *Macrobrachium rosenbergii* in Mono and Polyculture Conditions in Earthen Culture Ponds of Jammu, India

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## Abstract

The study was conducted to assess the growth and survival of *Macrobrachium rosenbergii* in earthen culture ponds in order to know about the growth potential of *M. rosenbergii* in mono as well as polyculture conditions in Jammu. Polyculture experiments of prawn with some selected carps Indian Major Carps (*Cirrhinus mrigala* and *Labeo rohita*) and Exotic Carps (*Cyprinus carpio*) were undertaken in 3 freshwater ponds for duration of 4 months. Under the monoculture conditions, prawns attained an average size of  $10.40 \pm 0.17$  cm weighing  $23.84 \pm 0.32$  g in 4 months and the survival rate was found to be more than 75%. The growth rate of prawns was found to increase steadily during the first half (upto mid-October) after which a decline in the growth rate was evident as the mean temperature reached below 18°C. In the polyculture ponds the prawns attained an average size of  $10.10 \pm 0.03$  cm weighing  $18.39 \pm 0.89$ g (without *C. carpio*) and  $8.4 \pm 0.36$  cm weighing  $15.23 \pm 0.36$  g (with *C. carpio*) in 4 months and their survival rate was less than 70%. Prawns being benthic feeders utilized the leftover food (of the fishes) that settled at the bottom, therefore, saving the feed cost. It was observed that mean size of the fish attained in the polyculture practice was almost similar to that obtained in the monoculture. The ideal prawn polyculture should be practiced with fast growing compatible carps such as Rohu and grass carp. Bottom feeder carps such as Mrigal (*C. mrigala*) should be avoided in prawn polyculture practice as they compete with prawns in feeding.

**Keywords:** Indian Major Carps and Growth, Monoculture, *M. rosenbergii*, Polyculture

**Abbreviations used:** (T<sub>1</sub>- Only *M. rosenbergii*), (T<sub>2</sub>- *M. rosenbergii*, *C. mrigala* and *L. rohita*), and (T<sub>3</sub>- *M. rosenbergii*, *C. mrigala*, *L. rohita* and *C. carpio*). (MR-I) Monoculture and (MR-II) in Polyculture with two carps and (MR-III) with three carps. (MR) *M. rosenbergii*, (CM) *C. mrigala*, (LR) *L. rohita* and (CC) *C. carpio*.

## 1. Introduction

*Macrobrachium rosenbergii* (de Man, 1879)<sup>1</sup> is a freshwater prawn, commonly known as 'Scampi' or 'giant freshwater prawn' commonly distributed in fresh as well as in brackish water and estuaries<sup>2</sup>. The production of freshwater prawn *M. rosenbergii* gained popularity since 1995 and China is the topmost producer followed by India, Thailand and Bangladesh<sup>3</sup>. India being the second largest contributor of freshwater prawns to the world market has undergone a phenomenal growth in the past two decades. Freshwater

prawns are important in the capture and culture fisheries and are extensively distributed in freshwater and estuaries of the world mostly in tropical and subtropical areas. Freshwater prawn culture is an aquaculture business designed to raise and produce freshwater prawn for human consumption<sup>4</sup>.

Out of 125 species of *Macrobrachium*, only a small number (*M. rosenbergii*, *M. malcolmsonii*, *M. birmanicum*, *M. choprai* etc.) have been exploited from the culture point of view. The giant freshwater prawn *M. rosenbergii* dominates the shell fish production currently because of its faster growth and adaptation to the environment and acceptance of artificial feed. The desire to culture *M. rosenbergii* has persisted since the first success at controlled production of juveniles of this prawn was achieved<sup>5</sup>. Minimizawa and Morizane (1970)<sup>6</sup> successfully cultured all larval stages using newly hatched nauplii of brine shrimp. Later, monoculture<sup>7</sup> and polyculture with a

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## Paradigm of Climate Change and its Influence on Zooplankton

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Zooplankton are the precious elements of aquatic ecosphere playing a significant role in some ecological phenomena viz., biomonitoring, ecological indication, link between primary producers and higher trophic levels, aquaculture, and maintenance of balance in aquatic food webs. The climate, being a dynamic abiotic entity, changed many times during the history of earth particularly before and after the industrial revolution. The unending materialistic benefits of human beings have been increasing the concentration of greenhouse gases such as carbon dioxide, methane, nitrous oxide, and fluorinated gases since the last few decades that is enough to raise the global temperature. It is a fact that both biotic and abiotic factors affect the dynamics of aquatic biota due to which the aquatic ecosystems and the organisms inhabiting them such as zooplankton are becoming the worst targets of the climate change phenomenon. Some of the significant consequences of climate change posing threats for the zooplankton community include increased temperature, acidification, nutrient enrichment, and increasing ultraviolet (UV) environment of the aquatic ecosystem that significantly affect their survival, behaviour, nutritional procurement, reproduction, and their overall population dynamics. Due to the profound effects of climate change on the zooplankton community, the entire aquatic food web gets crushed away leading to more severe concerns about the higher trophic levels and overall dynamics of the aquatic biota. Thus, unending loss in the dynamics of the aquatic ecosystem could prevail and will go on expanding if the causal factors of climate change continue to operate beyond their limits unless a strong scientific policy and framework in contrary to climate change are reinforced with the key focus on aquatic biota especially zooplankton.

**Keywords:** Aquaculture, Biomonitoring, Climate change, Food web, Greenhouse gases, Zooplankton.

Weather across the entire planet over time has always varied and is still varying because of the interactions between the components in the climate system (atmosphere, oceans, ice sheets, etc.). Climate change is a long-term swing in the weather statistics such as temperature, precipitation, or wind<sup>1</sup> and is considered the major significant environmental issue for the current generation<sup>2</sup>. The

amount of energy in the entire climatic system is changing due to change in energy received from the sun and the amount of greenhouse gases in the atmosphere, which in turn affect every module in the system leading to Climate change. The results of climate change are havoc ranging from melting of glaciers resulting in extreme floods up to the change in species distribution<sup>3,4</sup>. Climate is changing due

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# Chapter 10

## Zooplankton: The Significant Ecosystem Service Provider in Aquatic Environment



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and Hamid Iqbal Tak

### 10.1 Introduction

Zooplankton comprise very small organisms but the valuable assets of the aquatic biota with size ranging from few microns to few millimetres or more, which are actually representatives of almost every taxon of the animal world (Goswami 2004). Among zooplankton, some spend their whole life as plankton (holoplankton) or some part of their life as plankton (mesoplankton) (Lindeque et al. 2013). In general, zooplankton represents the organisms living in the water column and are collected with plankton net (the so-called as net zooplankton). Zooplankton community may be non-motile or weak swimmers which drift in water bodies via water currents and are correlated with respect to changes in the phytoplankton communities (Zannatul and Muktadir 2009; Perbiche-Neves et al. 2016). Since they feed on either phytoplanktons or other members of zooplankton species, they play an important role in food web (Ward et al. 2012) and also act as a means to transfer energy between phytoplankton and fish (Telesh 2004). Zooplankton community is affected by both biotic and abiotic components of an aquatic ecosystem. Among the biotic components, food quality and predation (Danielsdottir et al. 2007) and among the abiotic components temperature, pH, turbidity, conductivity, biological oxygen demand (BOD), chemical oxygen demand (COD), etc. alter or affect the distribution, abundance and seasonal variation of zooplankton community (Sebastian and Yamakanamardi 2014; Raut and Shembekar 2015; Das and Kar 2016). Some of the other important ecological factors viz., dispersal through atmospheric wind and water flow regulate zooplankton distribution (Havel and Shurin 2004). The main

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# Effects of Dietary Phenylalanine: Tyrosine Ratio on Growth, DNA/RNA, Serum Biochemistry, Digestive Enzyme Activities and Physiological Responses of *Heteropneustes fossilis*

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## Keywords

Nutrition

Optimum ratio of phe:tyr

Protein deposition

Physiological response

Stinging catfish

## Abstract

Stinging catfish (*Heteropneustes fossilis*) has high consumer demand due to its high iron and calcium contents. Also, being a lean fish, it is very suitable for people who do not prefer to consume animal fats. In view of its nutritional and therapeutic significance and lack of data on dietary phenylalanine: tyrosine ratio, a dose-response experiment was conducted to determine phe: tyr ratio for *H. fossilis* fry (4.1±0.3g). Six isonitrogenous (380 g/kg crude protein) and isocaloric (15.3 kJ/g digestible energy) amino acid test diets were prepared by adjusting 26.6 g/kg of total phenylalanine and tyrosine in varying ratios of phenylalanine/tyrosine (30:70, 40:60, 50:50, 60:40, 70:30, 80:20) on molar basis. Quadruplicate groups of fishes were fed with diets indicated for 12-weeks to apparent satiation, thrice daily. Mathematical analyses of Daily Growth Coefficient (DGC%), Specific Growth Rate (SGR%/day), Feed Conversion Ratio (FCR) and Erythrocyte Osmotic Fragility (EOF) as quadratic-broken line regression analyses, exhibited optimum dietary phenylalanine: tyrosine ratio of 64.94: 35.06 corresponding to 15.83 g/kg: 8.55 g/kg on equimolar basis. Data of this study would be of high significance to ensure that optimum phenylalanine and tyrosine ratio of fish is met while using a greater variety of cost-effective dietary protein feedstuffs for sustainable aquafarming of this fish.

## Introduction

Fish consumption has more than doubled from 9.6 kg/capita in 1961 to 20.5 kg/capita in 2018 (FAO, 2020). In present pandemic situation, global appetite for fish is expected to increase further due to its superior nutritional profile of high biological value. With the fall in capture fisheries, aquaculture has been the only alternate to fill the gap between supply and demand of quality protein diet as fish.

Amino acids (AA) are vital molecules in the metabolism of all living organisms and are the building blocks of enzymes (Yaghoubi *et al.*, 2018). Essential amino acids are key molecules for building proteins, as

well as important regulators of key metabolic pathways including cell signaling, appetite stimulation, growth and development, energy utilization, immunity, osmoregulation, ammonia detoxification, antioxidative defense, metamorphosis, pigmentation, gut and neuronal development, stress responses, reproduction, normal pancreatic and liver function, and for suppression of aggressive behavior in aquatic animals (Wu *et al.*, 2013, 2014; Yaghoubi *et al.*, 2018). Aromatic properties of fish meat partly depend up on amino acid distribution (Hall & Ahmad, 1992). Since most alternative protein sources are deficient in point of including all essential amino acid, it is crucial to establish essential amino acid requirements for various cultivable



RESEARCH ARTICLE

Open Access



# Effect of water temperature on protein requirement of *Heteropneustes fossilis* (Bloch) fry as determined by nutrient deposition, hemato-biochemical parameters and stress resistance response

Shabihul Fatma<sup>1\*</sup>  and Imtiaz Ahmed<sup>2</sup>

## Abstract

**Background:** Dietary protein requirements are dependent on a variety of factors and water temperature is one of the most important abiotic factors affecting protein requirement of fish. This study was, therefore, conducted to investigate effects of water temperature on dietary protein requirement of fry *Heteropneustes fossilis* which has high demand in most of the Asian markets.

**Methods:** Quadruplicate groups of 30 fish per treatment ( $2.97 \pm 0.65$  cm;  $5.11 \pm 0.34$  g) were fed seven isoenergetic diets ( $17.9$  kJ g<sup>-1</sup> gross energy;  $14.99$  kJ g<sup>-1</sup> digestible energy) containing dietary protein levels ranging from 28 to 52% at two water temperatures (18 and 26 °C). Experimental diets were fed to apparent satiation as semi-moist cakes thrice daily at 17:00, 12:00, and 17:30 h for 12 weeks. For precise information, various growth parameters, protein deposition, hematological parameters, metabolic enzymes, and stress response were analyzed, and effects of water temperature on dietary protein requirement was recommended on the basis of response from above parameters.

**Results:** Groups held at 26°C attained best growth, feed conversion, and protein deposition at 44% dietary protein indicating that temperature affected dietary protein requirement for optimum growth of *H. fossilis* fry and protein requirement seems to be satisfied with 44% dietary protein. Interestingly, interactive effects of both dietary protein levels and temperature were not found ( $P > 0.05$ ). Fish reared at 18 °C had comparatively higher values for aspartate and alanine transferases than those reared at 26 °C water temperature which exhibited normal physiological value for these enzymes indicating that body metabolism was normal at this temperature. Hematological parameters also followed same pattern. Furthermore, fish reared at 26 °C water temperature exhibited more resistant to thermal stress ( $P < 0.05$ ). The 95% maximum plateau of protein deposition data using second-degree polynomial regression analyses exhibited dietary protein requirement of fry *H. fossilis* between 40.8 and 41.8% of diet at 26 °C water temperature. The recommended range of dietary protein level and protein/digestible energy ratio for fry *H. fossilis* is 40.8–41.8% and 27.21–27.88 mg protein kJ<sup>-1</sup> digestible energy, respectively.

**Conclusions:** Information developed is of high significance for optimizing growth potential by making better utilization of nutrient at 26 °C and, to develop effective management strategies for mass culture of this highly preferred fish species.

**Keywords:** Temperature, *Heteropneustes fossilis*, Growth, Metabolic enzymes, Hematological parameters

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Amino acids (AA) are vital molecules in the metabolism of all living organisms and are the building blocks of enzymes (Yaghoubi *et al.*, 2018). Essential amino acids are key molecules for building proteins, as

well as important regulators of key metabolic pathways including cell signaling, appetite stimulation, growth and development, energy utilization, immunity, osmoregulation, ammonia detoxification, antioxidative defense, metamorphosis, pigmentation, gut and neuronal development, stress responses, reproduction, normal pancreatic and liver function, and for suppression of aggressive behavior in aquatic animals (Wu *et al.*, 2013, 2014; Yaghoubi *et al.*, 2018). Aromatic properties of fish meat partly depend up on amino acid distribution (Hall & Ahmad, 1992). Since most alternative protein sources are deficient in point of including all essential amino acid, it is crucial to establish essential amino acid requirements for various cultivable



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## An updated checklist of non-marine molluscs of the western Himalaya

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**Abstract:** This paper presents the first comprehensive checklist of the non-marine molluscs from the western Himalaya, a region of high biodiversity and endemism. Based on faunistic surveys during 2019–2023 and published records, the paper reports 242 species belonging to 101 genera and 45 families of gastropods and bivalves, of which 168 species are endemic to the region. The paper also provides new distribution records and taxonomic notes for some species. Among the notable findings are the first records of *Limax mayae*, *Oxyloma* sp., *Odhneripisidium kuiperi*, *Thiara aspera* from India, and *Bensonies jamuensis*, *Euaustenia cassida*, *Stagnicola* sp. from the western Himalaya. The paper presents some species with substitutional illustrations and literature from the region for the past two centuries. Additionally, the paper also discusses the threats that non-marine molluscs face in the western Himalaya and suggests some conservation measures to protect them. The authors hope this paper will serve as a baseline for future studies on the diversity, distribution, ecology, and conservation of non-marine molluscs in the western Himalaya.

**Keywords:** Biodiversity, conservation, endemic, gastropods, India, *Limax mayae*, malacofauna, non-marine, Pir Panjal range.

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**Author contributions:** HA led the entire field sampling, data collection and preparation of the manuscript. IA and NAA gave study conceptualization, design, manuscript review, editing and supervision. Their significant contributions were crucial for the improvement of the overall quality of the manuscript.

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# New record of gill hemorrhagic parasite *Myxobolus richardsonii* n. sp. (Cnidaria: Myxozoa) infecting *Schizothorax richardsonii* in Kashmir Himalayas

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## Abstract

Myxozoans are highly specialized metazoan parasites with a very diverse host range that live on aquatic hosts. In both wild and farm-raised fish, myxozoans are the most frequent parasites. The aim of the current study was to evaluate any myxozoan parasite found in different organs of *Schizothorax richardsonii*. Live fish were transported with artificial aeration to the University of Kashmir. Thirty-five fish specimens were examined during the study period, and only gills of 6 fish were determined to be infected. Taxonomic study was carried out with the help of different keys, and histopathological study was assayed in order to study the diseased organs of the fish. Besides, characterization of partial 18S rDNA gene was also done in the present study as per the standard procedures. The findings showed that the plasmodia were big, oval shaped, and white in color, measuring  $1.5 \times 2.0$  mm. They were referred to as intralamellar vascular-type plasmodia (LV<sub>3</sub>). Histological changes in the gills included inflammation, gill epithelium lifting, hypertrophy of lamellar cells, and fusion of nearby gill lamellae. The myxospore body had a tiny ICP at the anterior end and was spherical to ovoidal in form, measuring  $11.19 \times 7.66$   $\mu$ m. Polar tubules were pyriform in shape and measuring  $6.12 \times 1.95$   $\mu$ m, having coils up to 7 in number. The gill plasmodium index showed a moderate level of infection (GPI 2). According to their phylogenetic relationships, *M. richardsonii* n. sp. was sister species to *Myxobolus* sp. KLT and *Myxobolus dermiscalis*—infecting scales of *Labeo rohita* from Myanmar and India, respectively. The novel sequence KU885918 and 30 additional sequences from closely related sequences showed 97% homogeneity or above in NCBI GenBank database. Moreover, the tree showed grouping based on the tissue tropism, host, and geographical location of the infected host. Morphological, histological, and molecular characterizations were used to identify a novel myxosporean parasite, *Myxobolus richardsonii* n. sp. in cold water fish, *Schizothorax richardsonii* (Heckel), obtained from Wullar Lake in Kashmir Himalayas, India.

**Keywords** *Myxobolus* · 18S rDNA · Wullar Lake · Pathogenicity

## Introduction

The most prevalent parasites that fish encounter both in natural and farmed habitats are myxozoans (Ahmad and Kaur 2017, 2018). Several species have reportedly posed a serious threat to economically significant freshwater fish in the past (Kaur and Ahmad 2016, 2017). These parasites are distinguished by having multicellular myxospores and making up roughly 18% of the cnidarian species diversity (Lom and Dykova 2006). Most abundant among the myxozoans are species belonging to the genus *Myxobolus*, with approximately 905 species (Eiras et al. 2014; Mathews et al. 2020). Emerging diseases that are related to environmental change are caused by specific myxozoans. Some of our most recognizable fish, like salmon and trout, are affected by these new diseases in the wild. Whirling disease and proliferative kidney disease are

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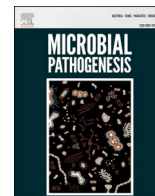
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## Strategies for describing myxozoan pathogens, dreadful fish diseases in aquaculture

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### ABSTRACT

Myxozoans are obligate endoparasites, cosmopolitan in distribution with both vertebrate and invertebrate hosts. Their myxospores consist of shell valves, polar capsules with coiled polar tubules that are extrudible, and infective amoeboid germs. Myxozoan parasites are most abundant, and due to their increasing number in recent years, they can pose an emerging threat to the fish industry worldwide. Hence, the immediate need is to devise a strategy to understand and detect parasites and parasitism. They may proliferate to different organs with the advancement of infection. This all warrants the development/devising of strategies and results of integrative studies in order to identify these dreadful parasites and resolve taxonomic issues. Different methods whether classical methods including gross morphology or advanced methods such as electron microscopy (SEM, TEM, STEM), Confocal laser scanning microscopy (CLSM), histopathological studies, site preference, host and tissue specificity, a molecular approach using new markers can be clubbed for identification because these parasites are hidden and are difficult to recognize. This group was earlier classified only on the basis of myxospores morphology, but due to the high structural variability of this group advanced methods and approaches have to be implied which can minimize the problems in assigning new species.

### 1. Introduction

Members of Phylum Cnidaria (Hatschek, 1888) are in most cases free-living organisms. Of them, members of the subphylum Myxozoa Grassé, 1970, Myxozoa have a parasitic way of life, because of their worldwide ecological and economic importance. Myxozoans have diverged from their free-living ancestors and during the process of divergence, they became miniaturized and thus evolved a complex life cycle [1,2]. Myxozoan is of great evolutionary interest and is an important component of ecosystems. According to Zhang [3], 2400 described myxozoan species exist and the life cycles of only 50 species have been resolved [4]. Among the important diseases of myxozoan, whirling disease and proliferative kidney disease are the emerging diseases affecting the wild populations of trout and salmon. Due to the diversified nature of myxozoan, they have exploited amphibians, reptiles, and waterfowl besides freshwater and marine fish hosts, mammals

[5,6] and birds [7]. An increase in fish aquaculture practices and pathological/pathophysiological studies have advanced our understanding of Myxozoa and thus led to increasing in research efforts [8]. Diversification of myxozoan reveals well-supported lineages including a marine lineage that utilizes polychaetes as final hosts, a freshwater lineage that utilizes oligochaetes as invertebrate hosts, and sphaerosporids whose invertebrate host remains unknown [9,10]. Myxospores have developed hard walls which extend viability in the environment for long periods depending on the temperature [11]. There are two classes of Myxozoa: Malacosporea and Myxosporea [12]. With a total of five described species, Malacosporea includes only two genera (*Buddenbrockia* and *Tetracapsuloides*). Myxosporea includes about 2400 species in 62 genera [13]. These myxozoans have enormous diversity, with nearly 20 % of described cnidarian species greater than the combined species richness of cubozoans, staurozoans, and scyphozoans. Due to their high diversity, abundance in nature, and economic importance

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