MACROINVERTEBRATE DIVERSITY OF KAMAL LAKE, RUKUM EAST, NEPAL

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Institute of Science and Technology

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Nepal

May, 2023

DECLARATION

I hereby declare that the research work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All the sources of information have been specifically acknowledged by references to the authors(s) or institution(s).

Date...14 May 2023....

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RECOMMENDATION

This is to recommend that the thesis entitled "**Macroinvertebrate diversity of Kamal Lake, Rukum East, Nepal"** has been carried out by Ayuba Senchury for the partial fulfillment of Master's Degree of Science in Zoology with special paper Entomology. This is his original work and has been carried out under my supervision. To the best of our knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor Prof. Dr. Prem Bahadur Budha, this thesis submitted by Mr. Ayuba Senchury on "**Macroinvertebrate diversity of Kamal Lake, Rukum East, Nepal"** is approved for the examination and submitted to the Tribhuvan University in the partial fulfillment of the requirements for the Master's Degree of Science in Zoology with special paper Entomology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mr. Ayuba Senchury entitled **"Macroinvertebrate diversity of Kamal Lake, Rukum East, Nepal"** has been accepted as a partial fulfillment for the requirement of Master's Degree of Science in Zoology with special paper Entomology.

EVALUATION COMMITTEE

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
APHA	American Public Health Association
CDZ	Central Department of Zoology
DO	Dissolved Oxygen
EC	Electrical Conductivity
IUCN	International Union for Conservation of Nature
NLCDC	National Lake Conservation Development Committee
TDS	Total Dissolved Solids
TU	Tribhuvan University

ABSTRACT

The study of macroinvertebrate was carried out in unexplored mid hill lake 'Kamal lake' of Sisne Rural Municipality, Rukum, during September to December 2022. Altogether eight sampling sites were systematically selected at every 200 m distance apart from each other. Macroinvertebrates were collected for 30 minutes in each sampling site from the shoreline to two meter of peripheral zone by using a sweep method with a hand net and sieves (500 µm mesh size). The macroinvertebrates were collected from all possible substratums such as underside of stones, leaf litters, rotten stems, manures, muddy, grassy area and also measured physicochemical parameters such as pH, water temperature, dissolved oxygen, electrical conductivity and total dissolved solids using a handheld multi-parameter probe. A total of 3,467 individuals belonging to three phyla, 27 genera under 14 families and nine orders were identified including individuals of two unidentified species. The diversity index (2.40), species richness (27) and evenness (0.73) of the macroinvertebrate were recorded. The relation of diversity with physicochemical parameters was correlated by using Pearson Correlation Coefficient which shows positive relation with temperature (+0.6191), pH (+0.0658), TDS (+0.3825) and EC (+0.0432) but shows negative relation with DO (-0.0027). The analysis showed *Lymnaea* genus as the most abundant during the study period.

1. INTRODUCTION

1.1. Background of the Study

Macroinvertebrate are bottom-dwelling invertebrates that are widespread and common in rivers, streams, ponds, lakes and other bodies. They include a wide variety of taxa including arthropods, annelids, molluscs and worms such as leeches and oligochaetes (Heino, 2005; Hauer and Resh, 2017). They are mostly present in every type of aquatic habitats including lakes, streams, saline pools, coastal water, groundwater (Yule and Yong, 2004). The streams and rivers provide suitable microhabitats for the inauguration of macronvertebrates (Beisel *et al.,* 1998), are known to be representative of structure and functioning of freshwater ecosystems (Choudhary and Abhi, 2015).

Macroinvertebrate are the most universal and diverse organisms in freshwater (Strayer, 2006) that perform diverse and ecologically important role in the food chain of an aquatic ecosystem (Hynes, 1970; Allan, 1995). They are important freshwater heterotrophic groups acting as linkages between the producers and higher level consumers (Wallace and Webster, 1996). They act as predators, collectors and shredders on multiple trophic level. In addition to these, they serve as food sources for other organisms including fish, amphibians and snakes and contribute to nutrient cycling by breaking down organic matter and releasing nutrients back into the ecosystem.

Different group of macroinvertebrate shows different behavior as tolerable or nontolerable (Frey, 1975; Galay, 1987; Rosenberg and Resh, 1993; Hering *et al*., 2004), that is useful for assessing the health of freshwater ecosystem. They have significantly sensitive life stages that respond to stress and integrate effects of organic and thermal pollution, toxicity and substrate alterations (Sharma *et al*., 2008). Their presence or absence of certain taxa explains the level of pollution or environmental stress of an ecosystem. Therefore, they are considered the best biological indicators for freshwater quality due to their susceptibility to anthropogenic disturbances, their responses are used as indices worldwide (Kabore *et al*., 2016; Edegbene *et al*., 2021). They are considered as good bio-indicators of the health of aquatic ecosystem (Suren, 1994), as they have more resistivity to contamination with their high population structure, longevity, and comparatively affordable for assessment (Rosenberg, 1992;

Mo *et al*., 2020). They also reveal environmental changes such as eutrophication and several other mode of degradations by related changes in their abundance and composition (Solimini *et al*., 2006; Sharma and Rawat, 2009). In the modern perspectives, macroinvertebrates were used for studies of the impact of environmental perturbations on the aquatic ecosystem, as their presence, abundance and diversity can provide important information about the quality of the habitat they live in (Victor and Ogbeibu, 1985; Rosenberg and Resh, 1992).

Nepal covers 3% of total available inland water in the form of freshwater (Sharma, 1997), out of which 1% is in rivers, lakes and ground water. But the freshwater environment available for suitable habitat for aquatic macroinvertebrate is very tiny and patchy. The freshwater environment has been divided into two groups; lotic and lentic freshwater environment.

The Nepal's National wetlands Policy 2003 (amended in 2013) defines wetlands as naturally or artificially created areas, such as swamp, marsh, riverine floodplains, lake, water storage areas and agricultural lands containing water from underground water resources or atmospheric precipitations that may be permanent or temporary, static or flowing and freshwater or saline. This definition recognizes all lakes are wetlands but all wetlands are not necessarily lakes.

With regards to International Union for Conservation of Nature (IUCN), there are 133 wetlands in terai and 164 in the hills and mountains (Bhandari, 1998). Only nine wetlands in Nepal are globally recognized as Ramsar sites, with four in terai (Koshi Tappu Wildlife Reserve, Beeshazar Tal, Jagdishpur Reservoir and Ghodaghodi Tal), four in mountain (Gokyo lake, Phoksundo lake, Rara lake and Gosaikunda lake) and one (Mai Pokhari) in the mid hill region

Recognizing the diverse values of lakes, the government of Nepal established a separate entity; National Lake Conservation Development Committee (NLCDC) under the ministry of Culture, Tourism and Civil Aviation formed in 2007 with an aim to initiate an inventory of lakes in Nepal. After federal restructuring, it is now placed under the Ministry of Forest and Environment. According to NLCDC (2019), there are more than 6,000 rivers, 3,252 glaciers, 2,323 glacial lakes, 5,358 tectonic and ox-bow lakes in Nepal. Among them, Kamal lake is one of the important lake of mid hill of Nepal. It is situated nearby the village Rukumkot, Rukum East district of mid-western Nepal. This lake is famous having shaped in Nepal's map and well known for Lotus flowers (*Nelumbo nucifera*). From high hills to valleys, dense forest, natural vegetation, diverse culture, famous trekking routes, rich history, Rukum East has all of it. Rukum East is a new tourism destination located in the mid-western part of Nepal. It is in the Basin of Bheri river, a major tributary of the Karnali. Most of Rukum East is drained by west flowing tributaries such as Uttar Ganga draining Dhorpatan Valley and to the North of that the Sani Bheri draining southern slopes of the western Dhaulagiri Himalaya.

The study was carried out in Kamal lake, Rukumkot, Rukum East. This lake is a virgin area, so far no research work has been done yet. The lake has its own cultural significance. It carries a wide variety of flora and fauna. The research work has been done for the recognition of abundance and diversity of macroinvertebrates found in Kamal lake. This study will provide the baseline information and will fulfill the macroinvertebrate information gap of the lake.

1.2 Objectives

The general objective of this study is to explore macroinvertebrate diversity of Kamal lake in Rukum East, Nepal.

The specific objectives are:

i. To determine the species diversity in Kamal lake.

ii. To compare aquatic macroinvertebrate diversity with physicochemical parameters of water (pH, Temperature, DO, TDS and EC) of Kamal Lake.

1.3 Significance of the study

In context of Nepal, various research of the macroinvertebrate has been done and sufficient informations are available. But the informations are in the scattered form. The various researches has done more on the Terai and Himalayan regions. Therefore, it is very essential to study the macroinvertebrate from different parts of Nepal and that will help to know the health status of rivers, streams, ponds and lakes of our country. Macroinvertebrate serve as the indicator of water quality and bio-monitoring of human impact. They are also the source of food, bio-controls and bio-control agent in an aquatic ecosystem. The study area Kamal lake was not studied previously and the work is doing so far for the recognition of abundance of macroinvertebrates. This study will provide the checklists of macroinvertebrates fauna of Kamal Lake and intrepret the species diversity in relation with physicochemical parameters such as temperature, pH, Dissolved Oxygen (DO), Electrical Conductivity (EC) and Total Dissolved Solids (TDS). Furthermore, this study helps to evaluate the role of macroinvertebrates in freshwater ecosystems.

2. LITERATURE REVIEW

2.1 Studies in the Global context

Macroinvertebrate include a wide variety of taxa including arthropods, annelids, molluscs and worms such as leeches and oligochaetes that are almost found in every type of lotic and lentic aquatic habitats throughout the world (Yule and Yong, 2004). These are the most abundant and diverse group of organisms in freshwater habitats and often exhibit high diversity in freshwater ecosystem (Needam, 2000). Various works in the field of macroinvertebrate has been done by various researchers around the world.

Kalkman *et al*. (2020) prepared checklist of 559 species of dragonflies and damselflies covering from India, Bhutan, Bangladesh, Pakistan, Nepal and Sri Lanka. Belonging to the Indian Subcontinent only, it has 313 species in 59 genera and four subfamilies. Laidlaw (1917, 1920) and Fraser (1919b) studied on the naids of Odonata. From the Dehra Dun valley in Uttar Pradesh, Sagal and Kumar (1970a, 1970b) and Kumar (1973a, 1973b) provided descriptions of the final instar naids and remarks on biology of numerous species and published 46 species of naids in collaboration with other co-workers. Kumar and Khanna (1983) classified 102 species of which the naids were known. Out of which 10 species were identified only to generic level, 10 more were unpublished reports and six from Myanmar and Sri Lanka. While studying diversity and community structure of aquatic insects in a pond in Midnapore town, west bengal India, Jana *et al*. (2009) found 20 species from three orders and the most abundant order was Odonata.

Vazirani (1968) evaluated freshwater beetles of Noterinae, Laccophilinae, Dytiscinae and Hydroporinae from India sub-continent. Benamar *et al*. (2021) provided checklist of hydrophilidae including 52 species of 14 genera and five subfamilies and recorded *Peschetius* for the first time in Telangana, India. A total 10 species of *Peschetius*, Dytiscidae are found world wide of which two were found in Telangana India (Jaiswal *et al*., 2021).

Wahizatul *et al*. (2011) worked on the diversity of aquatic insects in relation to water parameters and reported 42 families of aquatic insects under nine orders from two freshwater streams of Terengganu. Similarly, Sharma and Agrawal (2012) identified

29 species of aquatic insects belonging to 14 families under four orders by studying the diversity of aquatic insects in Surha Tal of Ballia, India. In the same year 2012, Purkayastha and Gupta found five families under three orders from ponds of Chatla wetland, Assam. Furthermore, Gupta and Purkayastha (2013) studies health ecosystem of pond, Barak Valley, Assam. Three species from two families of the Hemiptera were recruited. Further, they also investigate aquatic insects from ponds around two cement companies of Assam and identified five families under Hemiptera and Odonata.

Abhijna *et al*. (2013) researched on the distribution and diversity of aquatic insects from Kerala's Vellayani lake. They identify 60 species under 37 families and eight orders of which Coeloptera was the most abundant order. In the same year, Majumder *et al*. (2013) examined aquatic insect fauna in Tripura, India and recorded 31 species belonging to 15 families under four orders. Hemiptera is the most abundant order in their study.

The abundance and diversity of aquatic insects from water bodies of Chittgong was studied by Nasiruddin *et al*. (2014) and reported 32 genera of belonging to 20 families under six orders with Hemiptera and Odonata as the most abundant. The role of macroinvertebrates in the Meenachil River's condition was investigated by Santhosh *et al*. (2014) and documented 36 genera from 31 families and nine orders during pre- and post-monsoon periods, with Ephemeroptera serving as the leading taxon. Dalal and Gupta (2014) assessed the aquatic insect diversity of ponds of Assam and identified 22 taxa of aquatic insects. In the same year, Vasantkumar and Roopa (2014) detected 15 species belonging to six orders, with the order Coleoptera being the most diverse, while researching the physicochemical and aquatic insect diversity of the pond, Karwar, India.

In 2013, Leelahakriengkrai gathered 46 families of aquatic insects under six orders from two streams of Thailand. Thereafter, Maneechan and Prommi (2015) studied the diversity of aquatic insects in streams of Mae Klong, Thailand and examined aquatic insects of 64 families under nine orders with Trichoptera order was more diverse during their study.

Choudhary and Gupta (2015) explored aquatic insects of Deepor beel, Assam. According to them, there was presence of 31 species under 18 families of five orders with the order Hemiptera being the most diverse.

Hossain *et al*. (2015) conducted research in the polluted rivers from Bangladesh's Sitalakkhya and Buriganga river and found Culicidae was the most dominant out of that 22 families under six orders were recorded.

Basoren and Kazanci (2020) reported 12 families and 16 taxa from total of 2,245 individuals at Yeslirmak River of Turkey. The diversity patterns of aquatic bugs were studied in North East Algeria. He enlisted 12 species of six genera and four families were recorded (Annani, 2020). In Turkey, 112 species from 37 genera and five Infraorders were evaluated as part of a study on the zoogeographic distribution of aquatic and semi-aquatic Hemiptera (Gulten, 2020).

During the taxonomic works, various researchers discovered new species from different parts of the world. Hayashi *et al*. (2020) reviewed distribution of Hemiptera and Coleoptera in Japan, in which Hemiptera included 118 species under 13 families, among which 22 species (18.6%) were endemic. A Chinese checklist enlists 1,267 described species in 116 genera and 30 families, in which added newly described species (Yang *et al*., 2016). Similarly, new genus of *Parisoperla* of family Perlodidae newly described including two new species in Guizhou Province of southwestern China (Huo and Du, 2020). *Anisops occipitalis* (Notonectidae), *Hydrometra okinawana* (Hydrometridae), *Neoalardus typicus (*Veliidae), and *Limno metraciliat* (Gerridae) are four aquatic and semi-aquatic Hemiptera species that were first recorded in Meghalaya, India (Jehamalar and Chandra, 2020). Four Pleidae species were exist in Colombia as Cook *et al*. (2020) discovered two new species, *Neoplea hyaloderma* and *N. melanosoma.* Cook (2020) reported two new species, *Heteroplea ornate* and *H. asperscyta* with which four species were recorded of *Heteroplea.*

A new species *Hydrovatus remotes* was discovered on Island of Iriomote, Okinawa Japan. All of these continents have *Hydrovatus* distribution range, however its main occurrence area is tropical and subtropical regions (Bistrom and Watanabe, 2017). In the oriental area, six *Nevromus* species have been identified and redescribed (Liu *et al*., 2012). Following this, two new species of genus *Amphinemura* (Plecoptera: Nemouridae: Amphinemurinae), *A. baumanni* and *S. siveci* were described from

Indian states of West Bengal's Darjeeling District and Maghalaya's West Garo Hills District respectively (Muranyi and Li, 2013). Two species of the genus *Nevromus*, *N. aspoeck* and *N. jeenthongi*, were discovered in Thailand from clear, flowing streams, with *N. jeenthongi* being the new species (Piraonapicha, 2021).

Barber *et al*. (2008) listed 20 families 84 genera and 390 species of Ephemeroptera from Oriental region in which 41 genera were endemic. Martynov *et al*. (2019) were reviewed and corrected to the original description and added new characteristics features of *Cincticostella insolta complex* (Ephemeroptera: Ephemerellidae) on the basis of latest field observations. *C. richardiand, C. ranga* were new from India and *C. sivaramakrishnani* was new from Nepal. Kaltenbach *et al*. (2021) newly discovered genus *Philibaetis* from Philippines and re-described two species, *B. aetisluzonensis* and *B. realonae*, and conclude that they do not belong to the genus *Baetis* but are instead a new genus.

Two new species of Chironominae, *Glyptotendip eshebetare* and *G. inflatum* were described on the basis of adult male, pupa and larva from West Bengal India (Konar and Majumdar, 2020).

Tu *et al*. (2019) gave a complete morphological description of *Anachauliodes laboissierei* along with the first time record of *Anachauliodes*.

Stylogomphus thongphaphumensis, a new species of Odonata from Thailand was described (Chainthong *et al*., 2020). *Indosialis bannaensis* and *Indosialissi amensi* of family Sialidae were identified from Thailand. A new species, *Indosialissi amensi* was discovered (Piraonapicha, 2020).

In addition, it may be said that the composition and distribution of aquatic insect is a reflection of the water health and thus can be used as robust bio-indicators. They are widely used as bio-indicators globally. Aquatic insects serve as the indicator of water quality and bio-monitoring of human impact. Aquatic insects were described by Gupta and Barman (2015) act as a bio-indicator of water quality in Bakuamari stream, Assam. The study described 21 species of aquatic insects of 14 families and seven orders and showed strong relationship between diversity and water quality parameters.

The abundance and distribution of aquatic insect species were varied and not constant due to biotic and abiotic factors (Mohd. Rasdi *et al*., 2012). In lotic ecosystem, aquatic insects are influenced by various ecological factors (physical or chemical) such as water temperature, Hydrogen ion concentration, dissolved oxygen, alkalinity and other factors. When changes occur in abiotic ecological factors that directly affect the distribution, abundance and diversity of aquatic insect fauna (Bream *et al*., 2017). Villamarin *et al*. (2021) illustrated that *Cricotopus, Rheotanytarsus, Tanytarsus*, and *Chironomus* were discovered in areas with high conductivity and low dissolved oxygen concentrations, while *Parametriocnemus, Cricotopus, Cricotopus* (Isocladius), *Oliveiriella, Onconeura, Alotanypus,* and *Pentaneura* were discovered in lower temperatures, high dissolved oxygen and low conductivity.

In the present scenario, the identification of aquatic insects was based on the molecular level. This technique has not been fully developed; still the work is going on molecular identification. Larva of *Agriocnemis* of family Coenagrionidae, collected from Thailand was described first time by using DNA barcording. According to barcoding, three species; *A. minima, A. femina,* and *A. pygmaea* were discovered by Saetung and Boonsoong (2019). New species of Nemourinae; *Sinonemura balangshana* was discovered based on morphology and molecular data from Balang Mountain, Sichuan, China (Mo *et al*., 2020). Two new species of chironomidae, *Limno phyesminimus* and *L. subtilus* from China (Liu *et al*., 2021a). By using DNA barcoding analysis, another new species of the Chironomidae family, *Polypedilum* (Cerobregma) *huapingensis* was discovered in the same year (Liu *et al*., 2021b).

2.2 Studies in context of Nepal

Most of the taxonomical researches on aquatic macroinvertebrates have been carried out by foreign scientists, mainly through the expeditions to Nepal during 19th century (Sharma *et al.,* 2008). The study of macroinvertebrates was started in the 1950s in Nepal but the extensive study was started in the 1990s by researchers from Nepal (Shah *et al.,* 2011). Various taxonomic works in the field of macroinvertebrates has been done by various researchers around the Nepal are reviewed.

The earliest contributions for insects from Nepal are as described by Hope in "Synopsis of Nepal Insects" published in 1831 (Atkinson, 1980). Thereafter, Mc.Donald (1976) made a short observation of aquatic insect along the foothills in Central Nepal and Everest region and reported seven orders of aquatic fauna from different altitude ranging from 915 m to 4,267 m above sea level.

Selys (1854) reported dragonflies, that is the earliest records from Nepal, published in Fauna of British India series. A number of Nepalese Odonata were recorded in Fraser's work "The Odonata in the Fauna of British Indian (3 volumes, 1933-36). Takgawadyl and Namikawa (1952-53) arrange the insect fauna systematically containing several species from different parts Himalayas of Nepal. Kimmins (1964) recorded 28 species of Tricoptera from Nepal in "Trichoptera from Nepal" publication. Miyamoto (1965) studied aquatic bugs of Rolwaling Himal Expedition in Nepal. The family Gyrinidae was recorded from East Nepal in 1966 (Och and Chui, 1966).

Similum indicum was first time recorded from Nepal (Lewis, 1972). *Protenemura* new genus collected by Canadian expedition of Himalayas and described (Harper, 1974). Mishra (1975) reported a short list of aquatic insects of Nepal at Natural Science Seminar, organized by Tribhuvan University.

Jewett (1975) described three new species *Capnia swani, C. triangulipennis* and *Nemoura unicornis* with other eight other species of stoneflies from North-West Himalayas from India and Mt. Makalu from Nepal. In same year 1976, many species of Caddisflies belonging families; Limnocentropidae, Limnephilidae, Rhyacophilidae, Hydropsychidae, Stenopsychidae, Glossosomatidae and Helicopsychidae were described (Botosaneanu, 1976). Ito (1986) described three Lepidostomatid Caddisflies from Nepal.

From families Capniidae, Leuctridae and Perlidae, 11 species of stoneflies with five new species were recognized from Nepal (Harper, 1977).

Malla *et al*. (1978) studied the aquatic insects of Kathmandu valley. He had collected altogether 61 species of insects were found from different water habitats of Kathmandu Valley where 37 were new generic and specific records. They recorded *Leptocerus* sp. (Leptoceridae) and *Psychomyia* sp. (Psychomyiidae) from Jawalakhel (military pond) and Sundarijal respectively. They also recorded *Tendes* sp., *Aedes* sp., *Anopheles* sp., *Culex* sp., *Pericoma* sp., *Tipula* sp., *Atherix* sp. from Kathmandu valley.

Yadav *et al*. (1980, 1981, 1983) carried out research on macroinvertebrates of Rajdal Pond, Godawari Khola (tributary of Manohara river) and Godawari fish pond, reported 25 taxa of macrofauna of which Oligochaetes and Molluscs were the dominant groups.

Five different species of Nemouridae larvae, *Indonemoura adunca*, *Indonemoura indica*, *Nemoura gosainkundensis*, *Mesomumoura funicular* and *Protonemura paraproctalis* were described (Sivec, 981a). Similarly, two new species *Amphinemura albifasciata* and *A. lebezi* were described. These species were collected from central Nepal (Sivec, 1981b).

Yadav and Rajbhandari (1982) carried out their study on benthic fauna of Bansbari Khola and Dhobi Khola (tributaries of the Bagmati River) in Kathmandu valley. The major groups of bottom fauna reported were Tubifera, Tipulidae, Dolichopidae and Chironomidae. Yadav and Shrestha (1982) recorded 11 genera of freshwater chironomid larvae collected from different lakes, ponds and rivers of Nepal. Of the 11 genera recorded, three species, *Tanytarsus* sp., *Chironomus* sp., and *Polypedilum* sp. were found in both lentic and lotic habitats whereas four species, *Tanytarsus* sp., *Endochironomus* sp., *Cardiocladius* sp., and *Orthocladius* sp. were restricted only in the lotic environment and the other four species *Pentaneura* sp., *Procladius* sp., and *Stictochironomus* sp. and *Dicrotendipes* sp. only in lentic environment.

Vick (1985) enlisted 66 spp. of Odonata from 23 localities in Shiplake College Trekking Society Expedition to Nepal. Vick (1989) published a list of dragonflies including 172 species with a summary of their altitudinal distribution recorded from Nepal. Mahato (1985) were added significant knowledge on Nepalese dragonflies and their distribution in Nepal.

Roback and Coffman (1987) marked out Chironomidae from Nepal. Manca *et al*. (1998) described three chironomid genera (*Pseudodiamesa*, *Orthocladius* and *Micropsectra*) from high mountain lakes in the Khumbu Valley of Nepalese Himalayas.

Takaoka and Shrestha (2010) and Takaoka *et al*. (2020) reported 16 new of described *Simulium* from different localities of Nepal. Four new species and three new recorded species from Nepal (Takaoka *et al*., 2020a, 2020b).

Kiss (2011) discovered *Himalopsyche* first time from Nepal. Similarly, the family Nymphomyiidae species were first time recorded in 2012 from central Asia (Hayford and Bauchard, 2012). Similarly, one new species of Rhyacophilidae family, *Rhyacophila biguensis* was discovered from Nepal (Kiss, 2017) and three new species of *Apsilochorema* was also described (Kiss, 2020).

Yadav (1987) reported 21 taxa of aquatic insects from Palung Khola. Similarly, Yadav (1994) reported 50 taxa of aquatic insects from feeding streams of the Kulekhani Reservoir. Suren (1994) studied about the macroinvertebrate communities from the streams of Western Nepal and listed 138 macroinvertebrates belonging to 53 families under eight orders among them order Ephemeroptera was most common especially family Baetidae from stream of western Nepal. Rajkarnikar (1998) carried out research on the biotic and abiotic components of Jagmuru pond and insect species collected belonged to 13 families under four orders. Sharma *et al*. (2005) studied about the impacts of dam on the macroinvertebrates in Tinau River and listed out 2,120 macroinvertebrates representing 22 families under ten 10 orders of which Chironomidae family was most abundant. Yadav (2006) carried survey on the aquatic insects of Palung Khola at Makwanpur district, 21 genera of aquatic insects belonging to 19 families of 7 orders were found and the most abundant order was Ephemeroptera. Niroula *et al*. (2010) studied about seasonal variations of biodiversity and physicochemical parameters in Betana pond and the parameters like pH, alkalinity was higher in summer whereas DO and temperature were recorded higher in winter and rainy season respectively.

Shah *et al*. (2011) researched on macroinvertebrates diversity and community assemblage of Jagadishpur Reservoir, enlisted total 50 taxa, belonging to 15 orders from littoral zone of the reservoir. The study described 50 taxa belonging to 15 orders and higher number of taxa belonged to order Heteroptera. According to his study, the diversity index was recorded higher in post monsoon compare to pre monsoon.

In Bagmati river, total 2,583 benthic macroinvertebrates were recorded representing 10 orders and 29 families. The EPT index and EPT to Chironomidae ratio showed that highly sensitive taxa were abundant in the upstream sites of the river whereas the pollution tolerant taxa were abundant at the downstream sites (Basnet, 2013).

Rana and Chhetri (2015) worked on the water quality assessment using macroinvertebrates as indicators in Bhalu Khola, Gorkha. The study revealed the presence of 103 macroinvertebrates distributed under 11 families with five orders. Maximum number of individuals was found from order Ephemeroptera.

Similar study was carried out in Bagmati river and its tributaries total identified taxa belonging to five invertebrates groups; Insects nymph/larva (18 taxa), Oligochaete worms (three taxa), Leech (three taxa), Snails (two taxa), and Bivalves (one taxon). Also analysed the river is highly polluted with bacteria, aquatic flora or fauna and with sewage (Mehta *et al*., 2016).

The field survey conducted in western part of Nepal, which revealed 61 Odonata species belonging 40 genera and 11 families. Family Libellulidae was dominant representing 28 species (Sharma *et al*., 2018).

A study on macroinvertebrate diversity and water quality parameters were conducted in Godawari river of Nepal. A total of one phylum, two classes, six orders, 25 families and 1,558 individuals were successfully recorded and Hydropsychidae, Baetidae, and Chironomidae were high abundance (Vaidya, 2019).

Twenty-eight species of 20 genera and six families were recorded from Debang Lake of Kaski District. Family Libellulidae was dominant representing 16 species *Aciagrion approximans* and *Ceriagrion cerinorubellum* were first time recorded in Nepal (Chettri and Gurung, 2020).

A study conducted in Sishaghat of Tanahun district showed the presence of 26 species 20 genera and seven families, with Shannon diversity index 2.25 (Miya *et al*., 2021).

Syangtan *et al*. (2022) studied on limnology of Thosne river, Lalitpur at which they have identified six different families of aquatic insects including Odonata, Plecoptera, Coeloptera, Ephemeroptera, Trichoptera and Lepidoptera. They also reported that all the water quality parameters were positively correlated with each other except dissolved oxygen and altitude which were negatively correlated.

Ghimire *et al. (*2022) studied benthic macroinvertebrates communities in upstream (Chitlang and Seti Streams) and downstream (spillway) of Kulekhani multipurpose reservoir, Makawanpur. They found 25 families and 8 orders including Diptera and Coleoptera orders are abundant whereas Oligochaeta and Odonata order are lowest.

Canonical Correspondence Analysis showed that pH, temperature, and dissolved oxygen have high influence in macroinvertebrate assemblages. The study reveals that the ecological health of downstream of the reservoir is disturbed with presence of tolerant macroinvertebrate assemblages.

Khatri *et al.* (2022) studied macroinvertebrates diversity from Bheri river and Babai river from western part of Nepal. They reported 38 families of insects in the Bheri river and 39 families of insects in Babai river. The non-insect fauna in the Babai river were represented by 10 families with four Mollusca taxa; one each of Malacostraca and Arachnida taxa and four Annelida taxa.

3. MATERIALS AND METHODS

3.1 Study Area

This study was carried out in Kamal lake, Rukum East, Nepal. Geographically, the area is located between 28° 29'–29° 0' N latitude and 82° 12'– 82° 53' E longitude on Rukumkot, Rukum East. It lies at an elevation range from 1,569–1,571 m above sea level. It has a circumference length of 1,600 m with an area of two km^2. The core area of Kamal lake is 8.5 hectare and basin area is 1,050 hectare. This lake is of freshwater, riverine and perennial type of lake.

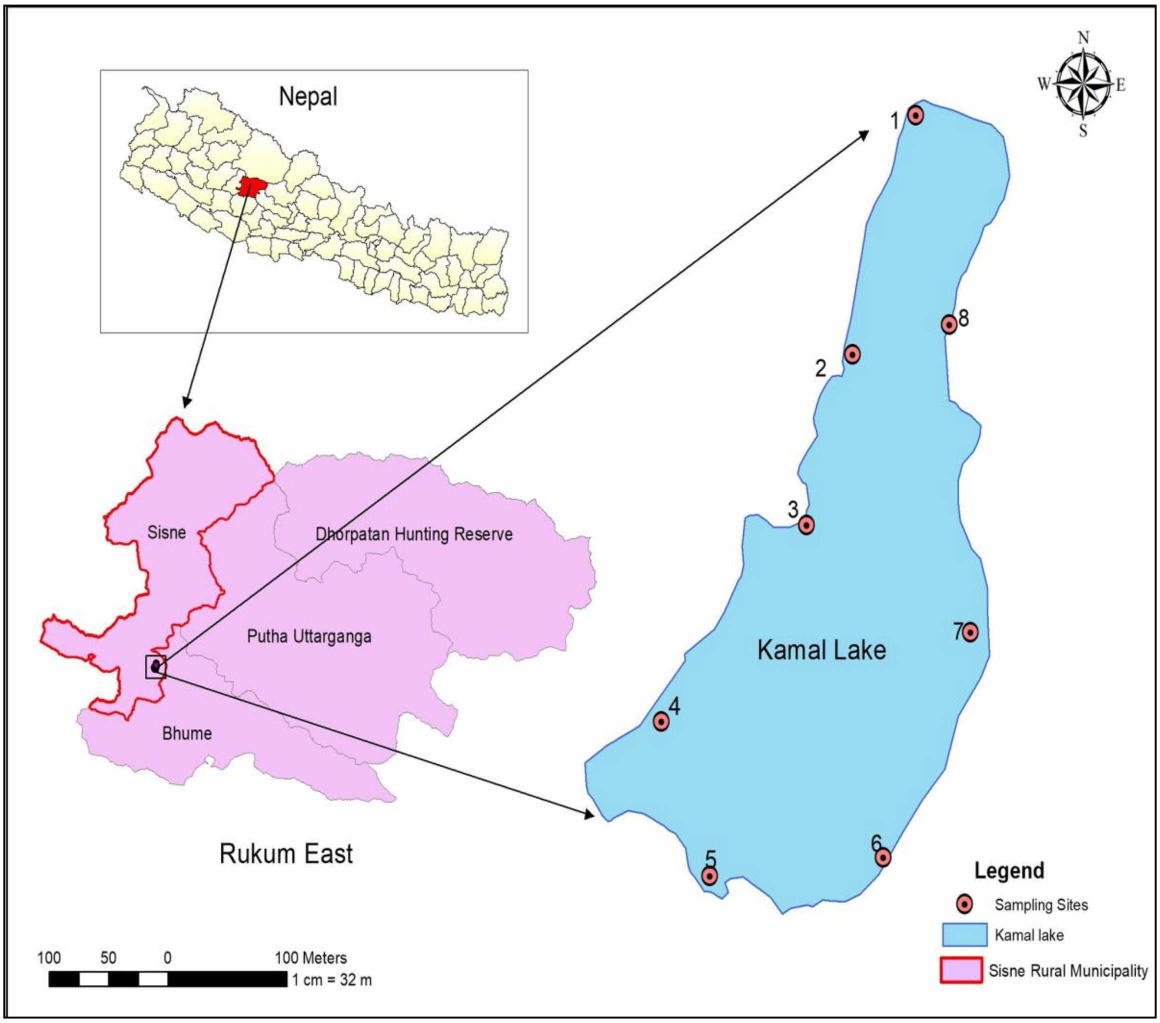

Figure 1: Map showing the Kamal Lake

3.2 Materials

The materials used during the field survey are as:

i. A hand net (mesh opening: 500 μm)
ii. Sieve (0.5 mm mesh size)
iii. 90% ethanol
iv. GPS (Global Positioning System: Garmin Etrex 10)
v. Field measuring tape
vi. Camel hair brush
vii. Forceps
viii. Enamel tray
ix. Bottle for collection of samples
x. DO meter
xi. pH meter
xii. EC and TDS meter

3.3 Sampling Design

Sampling was carried out from September to December 2022. The circumference length of Kamal lake is 1,600 m so that altogether eight sampling sites were systematically selected. Out of eight sampling site, first sampling site was selected at the entry point of lake and other sites were selected at every 200 m distance apart from each other.

The Description of the Sampling sites:

- **Sampling site I:** This site was located at the entry point of Kamal Lake. It was an open area. This site was influenced by human activities. There is a concrete ladder way to the shoreline. The average depth of this site was 80 cm. The site was muddy and grassy.
- **Sampling site II:** The average depth of this site was 110 cm. A Pipal tree (*Ficus religiosa*) is present. The site was grassy with small vegetations present near the tree.
- **Sampling site III:** The average depth of this site was 70 cm. The site is grassy and the small vegetation is present around the periphery of temple. The site was influenced by human activities such as plastic, bottles, fruits peel, incense sticks wastes was present. The water had smelly odour and also muddy.
- **Sampling site IV:** The average depth of site is 80 cm. The site is sandy. This site is used for the bathing, washing clothes.

- **Sampling site V:** The average depth of this site was 100 cm. The site was grassy with wide plain area. From this site, people extract root of Lotus plant (*Nelumbo nucifera*) that is used as food items.
- **Sampling site VI:** The average depth of this site was 115 cm. The site consists of big boulders. This site was muddy area. Bojho plant (*Acorus calamus*) was present. This site was very cold among the other sites.
- **Sampling site VII:** The average depth of this site was 150 cm. It is the deepest site among the others sites. This site was covered maximum with Bojho plants (*Acorus calamus*). This site was full of manures as there are lots of leaf litters, rotten stems, dead woods. Behind the site, there is a coniferous forest.
- **Sampling site VIII:** The average depth of this site was 130 cm. It consists of long grasses, boulders and dead roots. This site was very narrow and deep at periphery area.

Figure 2: Sampling sites

3.4 Macroinvertebrate Collection and Preservation

A plankton net of 500 µm mesh size was used for the collection of macroinvertebrates. At each site, macroinvertebrates were collected for 30 minutes from the shoreline to two meter of peripheral zone by using a sweep method with a hand net (mesh size of 500 µm). In addition to these, the sieves of size of 0.5 mm (500 µm mesh size) were used for collection from each sampling site. The macroinvertebrates were collected from all possible substratums such as underside of stones, leaf litters, rotten stems, manures, muddy and grassy area. All the collected macroinvertebrates from each sampling sites were preserved in 90% ethanol.

3.5 Macroinvertebrate Identification

The identification of macroinvertebrates up to the Genus level was done on the basis of morphology under stereo-microscope with the help of Nesemann *et al.* (2007), Nesemann *et al.* (2011), Sivaramakrishnan and Subramanian (2007), Morse *et al*. (1994) and Yoon (1995). The lists of identified fauna of macroinvertebrates were compared from the lists given by Thapa (2015).

3.6 Physicochemical Tests

The physicochemical parameters such as pH, temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were measured using a handheld multi-parameter probe through the Federation and APHA (2005) guidelines.

3.7 Data Analysis

All the collected data were analyzed by using statistical tools in Microsoft Office Excel 2007. The diversity and Species Evenness of macroinvertebrates were calculated by using Shannon Weiner Species Diversity Index (H'). Abundance (%) of macroinvertebrate was shown by graph. Species Richness was calculated by counting number of taxa present. The relationship between macroinvertebrates diversity and physicochemical variables were evaluated through Pearson Correlation Coefficient.

4. RESULTS

A total of 3,467 individuals belonging to three Phyla, 27 genera under 14 families and nine orders including individuals of two unidentified species were reported from Kamal Lake. The site specific macroinvertebrate fauna are given (Table 2).

Table 1. Representative number of macroinvertebrate in each identified taxonomical level

Taxonomical level	Representative number
Phylum	3
Class	4
Order	9
Family	14
Genus	27

Table 2. Identified Macroinvertebrates of Kamal lake

Macroinvertebrates	SiteI	SiteII	SiteIII	SiteIV	SiteV	SiteVI	SiteVII	SiteVIII
Platyhelminthes: Arhynchobdellida: Erpobdellidae								
Erpobdella sp.	-	-	-	++	-	-	-	-
Mollusca: Sphaeriida: Sphaeriidae								
Pisidium sp.	+++	-	+++	+++	+	-	-	-
Mollusca: Hygrophila; Lymnaeidae								
Lymnaea sp.	+++	+++	+++	+++	+++	+++	+++	+++
Mollusca:Hygrophila;Planorbidae								
Gyraulus sp.	+++	+++	+++	+++	+++	+++	+++	+++
Arthropoda:Insecta; Ephemeroptera: Baetidae								
Baetis spp.	+++	+++	+++	+++	+++	+++	+++	+++
Arthropoda:Insecta;Trichoptera: Leptoceridae								

Nectopsyche sp.	++	+++	-	+++	-	-	-	+++
Arthropoda:Insecta;Hemiptera: Notonectoidea								
Anisops sp.	+++	+++	+++	+++	++	+++	+++	+++
Arthropoda:Insecta;Hemiptera: Pleidae								
Neoplea sp.	+++	+++	+++	+++	+++	+++	+++	+++
Arthropoda:Insecta;Diptera: Culicidae								
Culex sp.	+	-	-	-	++	+++	+	-
Anopheles sp.	-	++	-	+	-	-	-	+
Arthropoda:Insecta;Diptera: Chironominae								
Chironomus sp.	++	+++	+++	+++	+++	+++	+++	+++
Arthropoda:Insecta:Coeloptera: Dytiscidae								
Hygrotus sp.	+++	-	+	-	-	-	-	-
Laccophilus sp.	+++	+++	+++	+	+	++	+++	+
Hydaticus sp.	-	+	-	-	-	-	+	-
Agabus sp.	+	+	+++	-	++	-	+++	+
Dytiscus sp.	+++	+++	+++	-	-	+++	+++	+++
Arthropoda:Insecta;Odonata: Libellulidae								
Sympetrum spp.	+	+++	+++	++	-	+++	-	+++
Acisoma spp.	+	++	+	-	-	-	+++	-
Othretrum spp.	+++	+++	+++	+++	+++	+++	+++	+++
Diplacodes sp.	+	+	-	+++	-	-	+++	-
Crocothemis spp.	+++	+++	+++	+++	+++	+++	+++	+++
Tramea sp.	+	-	-	-	-	++	-	++
Libellula sp.	+++	-	-	-	-	-	-	-
Arthropoda:Insecta;Odonata: Coenagrionidae								
Ischnura sp.	+++	+++	+++	+++	+++	+++	+	+++
Aciagrion sp.	+++	+++	+++	+++	+++	+++	+++	+++

Arthropoda:Insecta;Odonata: Aeshnidae								
Anax spp.	++	+	++	++	++	+++	+	+
Gynacantha sp.	+	-	+	-	-	-	-	-

Note: + indicates the taxa found once in the sampling periods, ++ indicates the taxa found twice in the sampling periods, +++ indicates the taxa found thrice or more times in the sampling periods.

A total of two individuals of leeches belonging to the family Erpobdellidae were found. *Erpobdella* sp. was collected from the site IV only. *Pisidium* sp. was reported belonging to the family Sphaeriidae. It was found in site I, III, IV, V. *Lymnaea* sp. belonging to the family Lymnaeidae was the most common genus to all the sampling sites. This was the most abundant genus during the study field. Similarly, *Gyraulus* sp. belonging to the family Planorbidae was also the most common genus to all the sites.

A total of 394 individuals of Ephemeroptera belonging to the family Baetidae were reported in the present study. Single species belonging to the genus *Baetis* spp. were reported and it is also present to all the sampling sites. Case building caddisfly genus *Nectopsyche* sp. belonging to the family Leptoceridae were reported from I, II, IV, and VIII sampling sites. A total of two genus of Hemiptera belonging to the family Notonectoidea and Pleidae were reported from the all sampling sites. *Anisops* sp. and *Neoplea* sp. both were maximum at all sampling sites. *Culex* sp. and *Anopheles* sp. genus belonging to the same family Culicidae were found. *Culex* sp. were more abundant than *Anopheles* sp. during the study field. *Chironomous* sp. belonging to the family Chironominae were reported from all the sampling sites.

Altogether five genus of Coeloptera belonging to the family Dytiscidae were reported. Hygrotus sp. were reported from I and III sampling sites only. *Laccophilus* sp. were common in I, II, III and VII sampling sites but lessly found in IV, V, VI and VIII sampling sites. *Hydaticus* sp. of Dytiscidae family was reported from II and VII sampling sites. The genus of *Agabus* sp. was more abundant at III and VII sampling sites than at I, II, V and VIII sampling sites. Dytiscus sp. was found common to I, II, III, VI, VII and VIII all these sampling sites.

Altogether 11 genus of Odonata belonging to the three families (Libellulidae, Coenagrionidae and Aeshnidae) were reported. Frequently reported genus were *Orthretrum* spp., *Crocothemis* spp., *Ischnura* sp. and *Aciagrion* sp. *Libellula* sp. was only reported from sampling site I only. A total of two individuals of *Gynacantha* sp. were found at sampling site I and III only. *Anax* spp. was found commonly from all the sampling sites. Two Individuals of Genus *Tramea* sp. was both separately reported from sampling site VI and VII and one individual was found at sampling site I. Genus *Acisoma* spp. were more abundant in sampling site VII than at sampling site I, II and III. Genus *Diplacodes* sp. were reported from I, II, IV and VII sampling sites. Genus *Sympetrum* spp. was reported from all sampling sites but absent at V and VII sampling sites.

4.1 Occurrence of Macroinvertebrate in the Study Area

Among nine orders of different macroinvertebrate were recorded in this study, the highest diversity was observed in the order Hygrophila (28.45%).

Hemiptera occupied the second position and occurrence of 28.38 percent, following the Odonata (21.11%). Ephemeroptera was noticed as 11.37 percent only. The presence of Diptera and Coeloptera were 6.11 and 3.37 percent only.

The Order Sphaeriida and Trichoptera were noticed equivalent numerical presence as 0.58 percent. The lowest percent 0.05 ranked for Arhychobdellida which consists of only two individuals.

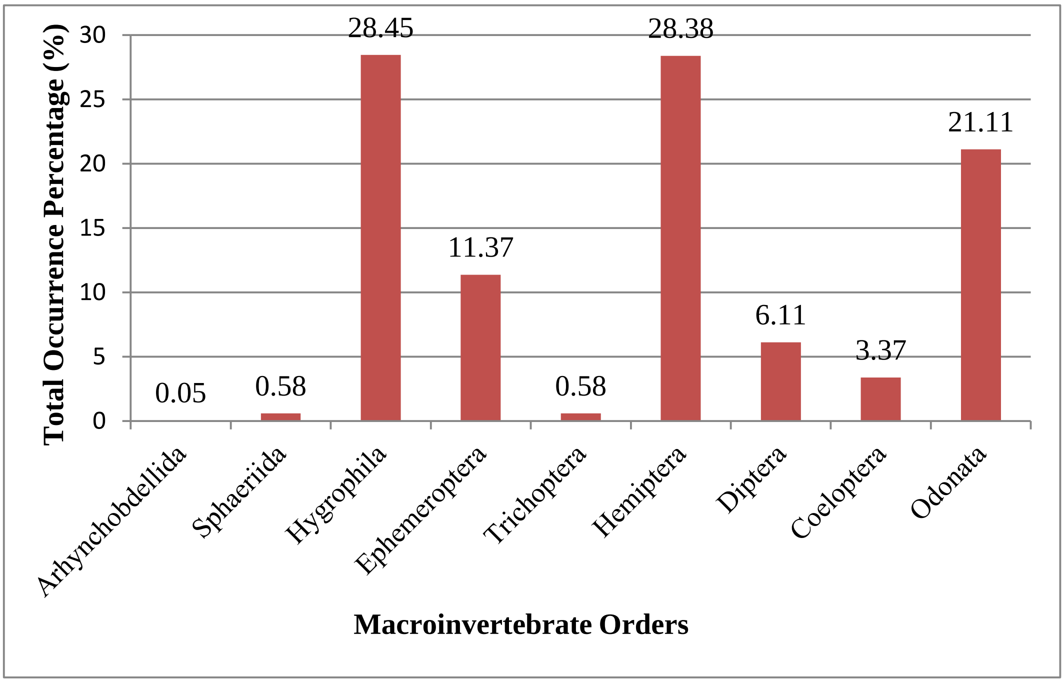

Figure 3. Total Occurrence of Macroinvertebrate Orders

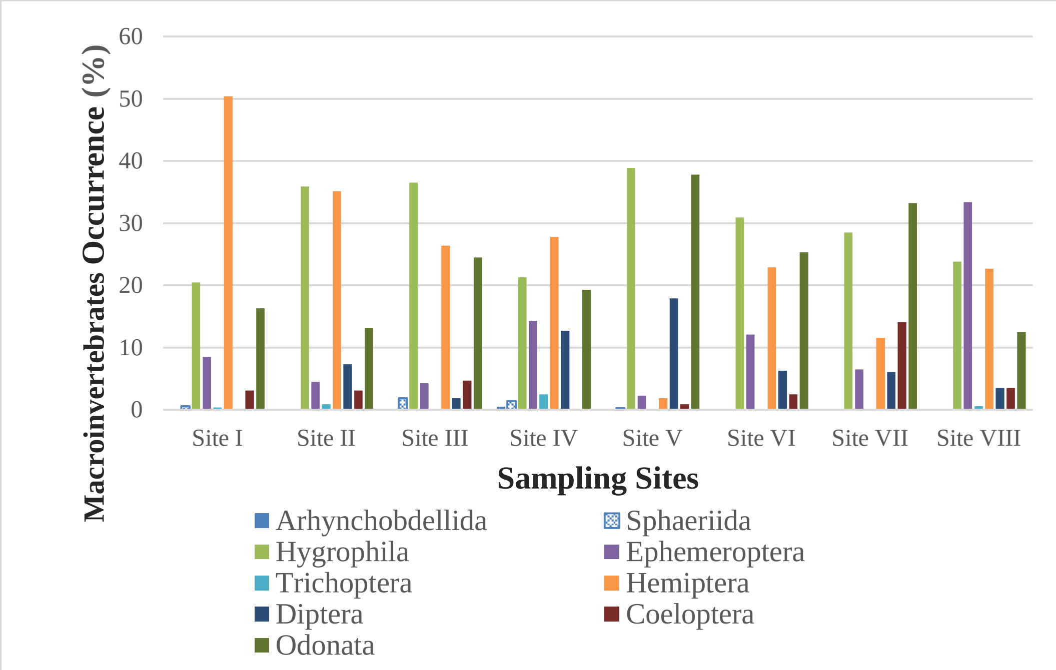

Figure 4. Macroinvertebrates Occurence at each Sampling sites

The diversity and richness of macroinvertbrates are shown in the Figure 4. The sampling site I covered 0 percent Arhynchobdellida, 0.6 percent Sphaeriida, 20.5 percent Hygrophila, 8.5 percent Ephemeroptera, 0.4 percent Trichoptera, 50.4 percent Hemiptera, 0.2 percent Diptera, 3.1 percent Coeloptera, 16.3 percent Odonata.The sampling site II covered 0 percent Arhynchobdellida, 0 percent Sphaeriida, 35.9 percent Hygrophila, 4.5 percent Ephemeroptera, 0.9 percent Trichoptera, 35.1 percent Hemiptera, 7.3 percent Diptera, 3.1 percent Coeloptera, 13.2 percent Odonata.The sampling site III covered 0 percent Arhynchobdellida, 1.9 percent Sphaeriida, 36.5 percent Hygrophila, 4.3 percent Ephemeroptera, 0 percent Trichoptera, 26.4 percent Hemiptera, 1.9 percent Diptera, 4.7 percent Coeloptera, 24.5 percent Odonata.The sampling site IV covered 0.5 percent Arhynchobdellida, 1.4 percent Sphaeriida, 21.3 percent Hygrophila, 14.3 percent Ephemeroptera, 2.5 percent Trichoptera, 27.8 percent Hemiptera, 12.7 percent Diptera, 0.2 percent Coeloptera, 19.3 percent Odonata.The sampling site V covered 0 percent Arhynchobdellida, 0.3 percent Sphaeriida, 38.9 percent Hygrophila, 2.3 percent Ephemeroptera, 0 percent Trichoptera, 1.9 percent Hemiptera, 17.9 percent Diptera, 0.9 percent Coeloptera, 37.8 percent Odonata.The sampling site VI covered 0 percent Arhynchobdellida, 0 percent Sphaeriida, 30.9 percent Hygrophila, 12.1 percent

Ephemeroptera, 0 percent Trichoptera, 22.9 percent Hemiptera, 6.3 percent Diptera, 2.5 percent Coeloptera, 25.3 percent Odonata.The sampling site VII covered 0 percent Arhynchobdellida, 0 percent Sphaeriida, 28.5 percent Hygrophila, 6.5 percent Ephemeroptera, 0 percent Trichoptera, 11.6 percent Hemiptera, 6.1 percent Diptera, 14.1 percent Coeloptera, 33.2 percent Odonata.The sampling site VIII covered 0 percent Arhynchobdellida, 0 percent Sphaeriida, 23.8 percent Hygrophila, 33.4 percent Ephemeroptera, 0.6 percent Trichoptera, 22.7 percent Hemiptera, 3.5 percent Diptera, 3.5 percent Coeloptera, 12.5 percent Odonata.

4.2 Abundance of Macroinvertebrate at different Sampling sites

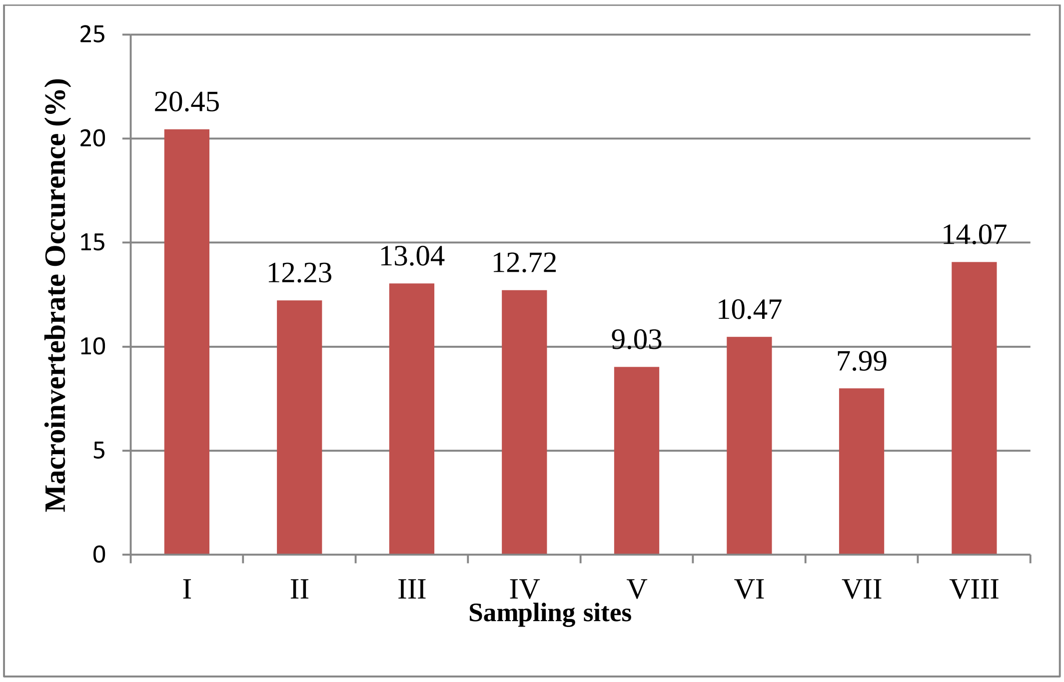

Figure 5. Abundance of Macroinvetebrate at different Sampling sites

Among all the study sites, the highest species richness (20.45%) of total recorded macroinvertebrates was found at sampling site I and least was found in sampling site VII. The macroinvertebrates slowly decreases from Site VIII (14.07%), Site III (13.04%), Site IV (12.72%), Site II (12.23%) , Site VI (10.47%), Site V (9.03%) and Site VII (7.99%) respectively.

4.3 Physicochemical Parameters of Water

The results of physicochemical parameters of water at different sites are given in the table below. The physicochemical parameters such as Temperature, DO, pH, TDS and EC were measured at eight different sampling sites. The average values of physicochemical parameters of water during the study period were calculated. The temperature of water was found was found 10.6–12.2 °C while DO was found 8.5–12.8 mg/l. The pH was almost equal in all sites. The TDS and EC were found at the range of 170.25–186 ppm and 325.5–392.5 µs/cm respectively.

Table 3. Average Values of Physicochemical Parameters of different Sampling sites

Parameters	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII
Temperature (°C)	11.7	12.1	11.9	11.1	10.6	11	12.2	11.1
DO (mg/l)	12.6	12.8	8.5	12.5	9.4	12.1	9.8	10.1
pH	8.3	8.7	8.4	8.3	8	7.9	8.01	8.02
TDS (ppm)	186	183.75	179.75	193.5	170.25	167.25	180.75	178
EC (µs/cm)	374	360	352.5	392.5	349	325.5	344.5	356.5

4.4. Coefficient of Pearson Correlation between Macroinvertebrates and Physicochemical Parameters

Pearson Correlation coefficient of different physicochemical parameters and number of macroinvertebrates at study sites were calculated and are shown (Table 4).

Table 4. Coefficient of Pearson Correlation between macroinvertebrates and physicochemical parameters

Physicochemical parameters	**Number of macroinvertebrates at sampling sites**
Temperature	+0.6191
DO	-0.0027
pH	+0.0658
TDS	+0.3825
EC	+0.0432

Assemblage of macroinvertebrate fauna showed negative correlation with DO which implies that slightly lowering the DO, increase the number of macroinvertebrate species. But the correlation with the temperature, pH, TDS and EC was positive that increase in the temperature favours the high diversity of macroinvertebrates.

5. DISCUSSION

The macroinvertebrates were collected monthly for three months from September to December 2022. A total of 3,467 individuals belonging to three phyla, 27 genera under 14 families and nine orders were identified including individuals of two unidentified species. The least abundant order Arhynchobdellida consists of family Erpobdellidae and genera *Erpobdella*. Sphaeridae consist of Sphaeridae family and genus *Pisidium*. The Hygrophila order consist of two families, Lymnaeidae and Planorbidae and two genus *Lymnaea* and *Gyraulus*. Ephemeroptera consist of family Baetidae that also consist of single genus *Baetis*. Trichoptera also consist of family Leptoceridae with a genus *Nectopsyche*. Hemiptera consist of two families Notonectoidea and Pleidae and two genus *Anisops* and *Neoplea*. Diptera consists of Culicidae family with genera *Culex* and *Anopheles*, family Chironomidae with genera *Chironomus.* Coeloptera consists of family Dytiscidae with five genera *Hygrotus, Laccophilus, Hydaticus, Agabus* and *Dytiscus.* Odonata consists of three families Libellulidae, Coenagrionidae and Aeshnidae and 11 genus, *Sympetrum, Acisoma, Othretrum, Diplacodes, Crocothemis, Tramea, Libellula, Ischnura, Aciagrion, Anax* and *Gynacantha.*

In this study, Molluscs have been seen to be highly abundant followed by Hemiptera. Subba (2003) reported 10 species of freshwater molluscs from Ghodaghodi lake. Subba (2003) reported *Lymnaea* sp. very common species in Ghodaghodi lake area. The present study also showed the highest diversity of the molluscs in Kamal lake. In the present study also, *Lymnaea* sp. belonging to family Lymnaeidae was seen to be highly abundant species. Similarly, Budha (2016) noted 32 species of freshwater molluscs from Kailali district, Nepal. *Lymnaea* sp., *Gyraulus* sp., small bivalve molluscs; *Pisidium* sp. were found abundant in Ghodaghodi lake. In present study, Molluscs were seen to be highly abundant in every sampling sites with different micro-habitats. *Lymnaea* sp. have been seen to be highly abundant followed by *Gyraulus* sp. and *Pisidium* sp.

The lake remains undisturbed due to protected by rod fencing around the lake, which restricts the exploitation of aquatic environment. Hence, high abundance of *Lymnaea, Gyraulus* and *Pisidium* species were highly associated with submerged and floating lotus plants which provides habitat and wide surface to these species. So, these species diversity increases with submerged and floating vegetation (Lodge and Kelly, 1985; Zealand and Jeffries, 2009). Krull (1970) noted that those communities with higher plant surface area tended to support larger insect populations. The surface area of the plant and the leaf morphology play an important role on a plant's ability to support aquatic fauna (McGaha, 1952). In the present study, Hemiptera shows the most abundance after Molluscs. Similar result was found by Nasiruddin *et al.* (2014). That might be because of the suitable habitat and water quality of Kamal lake. The diversity of snail population is influenced by the water parameters such as temperature, pH, depth, movement of water and aquatic vegetation (Garg *et al*., 2009) and are important for the composition, abundance and distribution of macroinvertebrates because the interaction of physicochemical parameters create either favorable or unfavorable environment conditions for faunal abundance and distribution (Dutta and Malhotra, 1986). Strzelec and Krölezyk (2004) indicated that many gastropods species tolerate to most physio-chemical parameters and their occurrence is affected by the quality of bottom sediments cover with thin layer of organic silt. Appleton (1978) and Sturrock (1993) suggested the temperature affects the abundance, distribution and spread of freshwater snail. In this present study, the positive correlation

(r= +0.61913) was found between temperature and mollusc species diversity. It means increasing temperature leads increasing molluscs species diversity. Similarly, Dutta and Malhotra (1986), Malhotra *et al*. (1996) and Garg *et al*. (2009) found the very similar results. Bath *et al*. (1999) revealed that higher abundance of molluscs can noticed with increased water temperature and decomposed organic matter. Similarly Michael (1968) suggested that high temperature, alkalinity and food were probable causes for the high in abundance of zoo-benthos.

Yadav *et al.* (1980) on similar kind of exploration reported 25 taxa of macrofauna from Godawari Khola of which Oligochaetes and Molluscs were the dominant groups. The reason for the abundance of Chironomiids has been due to enough organic matter present there. In my present study, Chironominae (*Chironomous* sp.) were recorded in all different sampling sites of lake. This might be due to high organic content of the lake as in the case of other tropical waters (Hansen *et al.*, 1997).

In the present study, the DO value of lake ranges 8.5–12.8 mg/l. DO below 5 mg/l is considered to be unsuitable for the life of many aquatic organisms (WHO, 1965). It means that Kamal lake supports wide variety of aquatic flora and fauna. In this present study, much less negative correlation (r= -0.0027) was found between DO and species diversity, indicates that there is a very weak positive relationship between species diversity and DO, meaning that as temperature decreases, there is a slight increase in the species diversity, but the relationship is not particularly strong. Garg *et al*. (2009) also reported the fluctuations in dissolved oxygen contents that do not have any effect on the mollusc populations. Cheatum (1934) and Sharma (1986) reported that some molluscs can even survive in very low oxygen condition. The value of dissolved oxygen was found decreased level in September, October and November during the study period indicates accumulation of organic materials in the lake, such type of relation was observed in the Beeshazar Tal (Jayana, 1997).

In the present study, the correlation coefficient values of pH (+0.065879), TDS (+0.38254) and EC (+0.043261) show weak positive relation with the species diversity. This means that if these variables increase, there is a tendency for species diversity to also increase. This also suggests that the variables may be related, it's possible that other factors could be driving both variables. Additionally, there could be confounding variables that influence the relationship between species diversity.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The present study on macroinvertebrates of Kamal lake in Rukum East reported three phyla, 27 genera under 14 families and nine orders. The diversity index (2.40), species richness (27) and evenness (0.73) of the macroinvertebrates were recorded during the study period. The analysis showed *Lymnaea* genus as most abundant during the study period. The relation of diversity with physicochemical parameters shows positive relation with temperature, pH, TDS and EC but shows negative relation with DO.

6.2. Recommendations

- There is a little information on the status of lakes in Nepal's mid hills. Therefore, it is very essential to make continuous investigation, census and research activities on the taxonomy and diversity of macroinvertebrate fauna, so that knowledge regarding this can be utilized by future researchers as baseline data for further research and conservation planning.
- According to the NLCDC (2021), the current status of the Kamal Lake is in degrading condition and it is currently facing some challenges related to conservation and environmental protection issues. So, there is a need for increased awareness and management of the lake to ensure its long-term preservation for future generations.
- It is necessary to do more research works related to macroinvertebrate such as identification up to species level should be encouraged that serve as a basis for ecosystem management and policy development.

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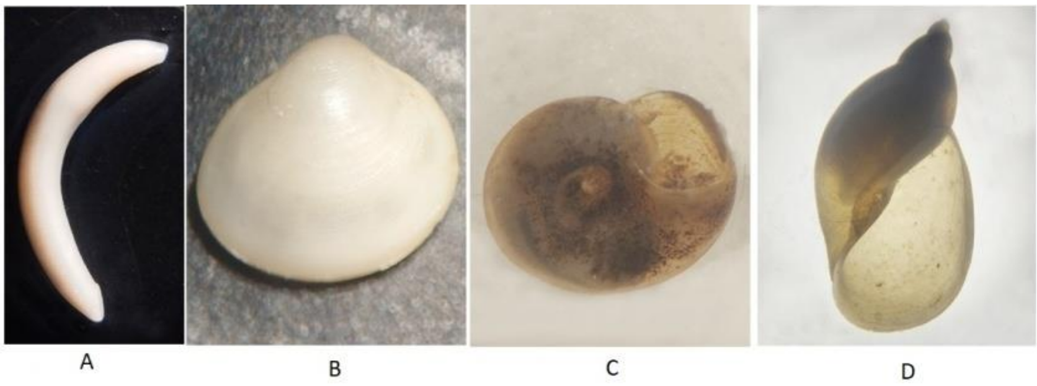
ANNEX

ANNEX 1. Identified Macroinvertebrates of Kamal lake at different Sampling sites

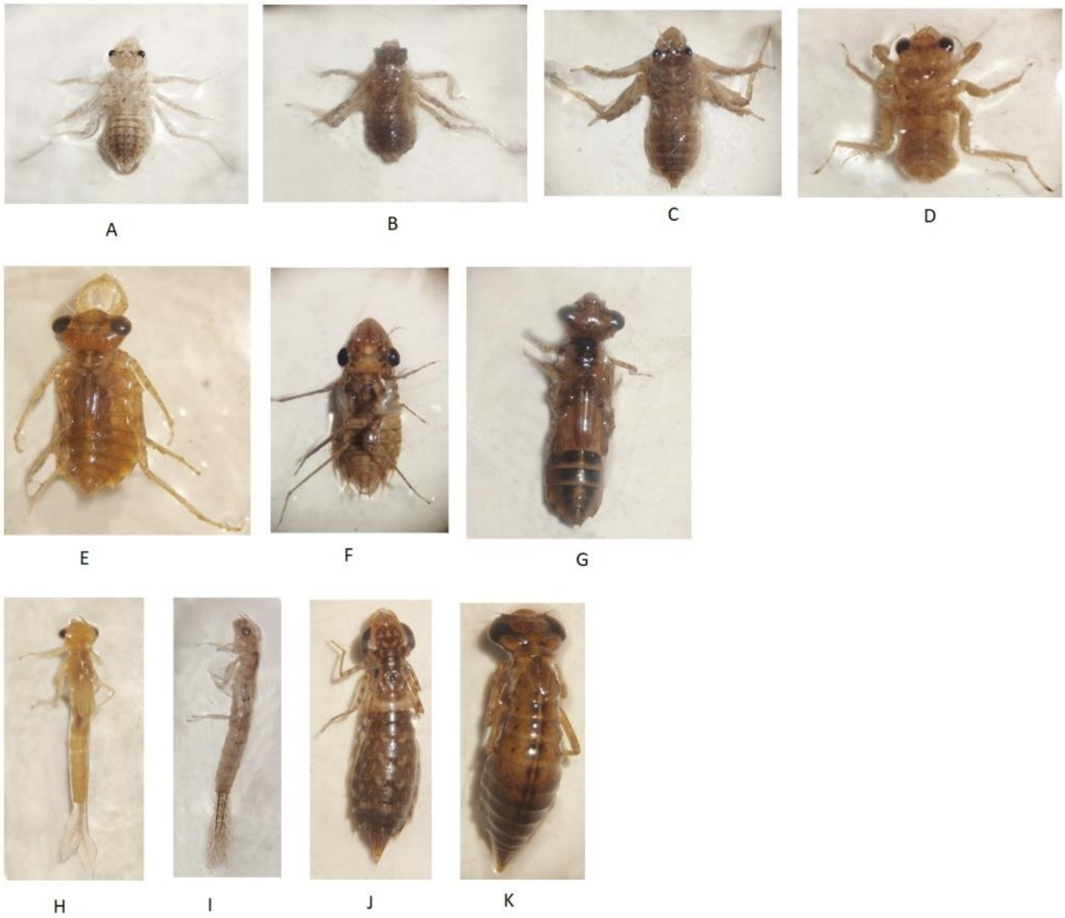
Order	**Family**	**Genus**	**SiteI**	**SiteII**	**SiteIII**	**SiteIV**	**SiteV**	**SiteVI**	**SiteVII**	**SiteVIII**
Arhynchobdellida	Erpobdellidae	*Erpobdella* sp.	0	0	0	2	0	0	0	0
Sphaeriida	Sphaeriidae	*Pisidium* sp.	4	0	9	6	1	0	0	0
Hygrophila	Lymnaeidae	*Lymnaea* sp.	95	113	60	83	102	100	52	88
	Planorbidae	*Gyraulus* sp.	52	39	104	11	20	12	27	28
Ephemeroptera	Baetidae	*Baetis* spp.	61	19	19	63	7	44	18	163
Trichoptera	Leptoceridae	*Nectopsyche* sp.	2	4	0	11	0	0	0	3
Hemiptera	Notonectoidea	*Anisops* sp.	111	107	43	61	2	71	3	30
	Pleidae	*Neoplea* sp.	250	42	76	62	4	12	29	81
Diptera	Culicidae	*Culex* sp.	1	0	0	0	2	7	1	0
		Anopheles sp.	0	2	0	1	0	0	0	1
	chironominae	*Chironomus* sp.	2	29	9	55	54	16	16	16
Coeloptera	Dytiscidae	*Hygrotus* sp.	9	0	1	0	0	0	0	0
		Laccophilus sp.	3	3	12	1	1	2	4	1
		Hydaticus sp.	0	1	0	0	0	0	1	0
		Agabus sp.	1	1	3	0	2	0	3	1
		Dytiscus sp.	9	8	5	0	0	7	31	15
Odonata	Libellulidae	*Sympetrum* spp.	1	8	6	2	0	7	0	6
		Acisoma spp.	1	2	1	0	0	0	5	0
		Othretrum spp.	17	6	10	19	7	5	22	5
		Diplacodes spp.	1	1	0	3	0	0	7	0
		Crocothemis spp.	20	19	45	25	45	22	47	13
		Tramea sp.	1	0	0	0	0	2	0	2
		Libellula sp.	3	0	0	0	0	0	0	0
	Coenagrionidae	*Ischnura* sp.	59	16	43	31	51	45	1	29
		Aciagrion sp.	11	3	3	3	13	8	9	5
	Aeshnidae	*Anax* spp.	2	1	2	2	2	3	1	1
		Gynacantha sp.	1	0	1	0	0	0	0	0

ANNEX 2. Photographs of Macroinvertebrates



Photograph 1. A-*Erpobdella* sp. B-*Pisidium* sp. C-*Gyraulus* sp. D-*Lymnaea* sp.

Photograph 2. A,B-*Baetis* spp. C-*Nectopsyche* sp. D-*Anisops* sp. E-*Neoplea* sp. F-*Culex* sp. G-*Anopheles* sp. H-*Chironomus* sp. I-*Agabus* sp. J-*Dytiscus* sp. K-*Hygrotus* sp. L-*Laccophilus* sp. M-*Hydaticus* sp.



Photograph 3. A-*Sympetrum* spp. B-*Acisoma* spp. C-*Othretrum* spp. D-*Diplacodes* spp. E-*Crocothemis* spp. F-*Tramea* sp. G-*Libellula* sp. H-*Ischnura* sp. I-*Aciagrion* sp. J-*Anax* spp. K-*Gynacantha* sp.

Other Photographs